

Rural Roads: Hydrologic and Water Quality Impacts

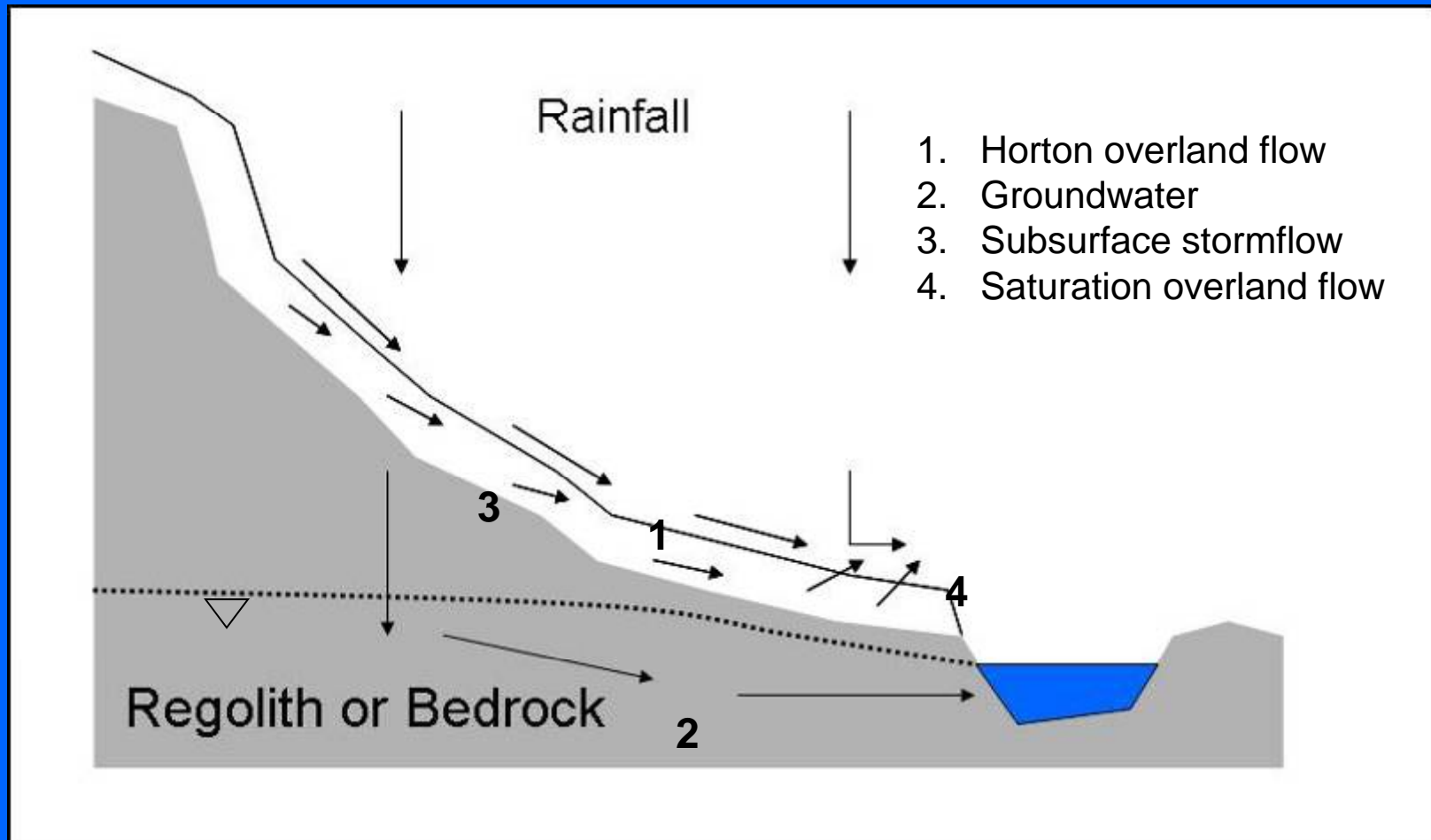


Drew Coe – Central Valley Regional Water Quality Control Board

Overview:

- What are the hydrological processes and pathways affected by rural roads?
- How is water quality affected by rural roads?
- Reducing hydrogeomorphic impacts from roads

Hillslope Runoff Processes



(Dunne and Leopold, 1978)

Horton Overland Flow (HOF)



- Infiltration rate \ll Rainfall rate
- Common in arid to subhumid climates
- Thin vegetation
- Soil disturbance (e.g. compaction)
- **NOT COMMON IN UNDISTURBED FORESTED AREAS**

Subsurface Stormflow (SSF)



(Hillslope trench; McDonnell, 2005)

- Steep hillslopes
- Permeable soils overlying relatively impermeable bedrock or regolith
- Humid climate w/ abundant vegetation
- **COMMON IN FORESTED WATERSHEDS**

Road Surface Hydrology

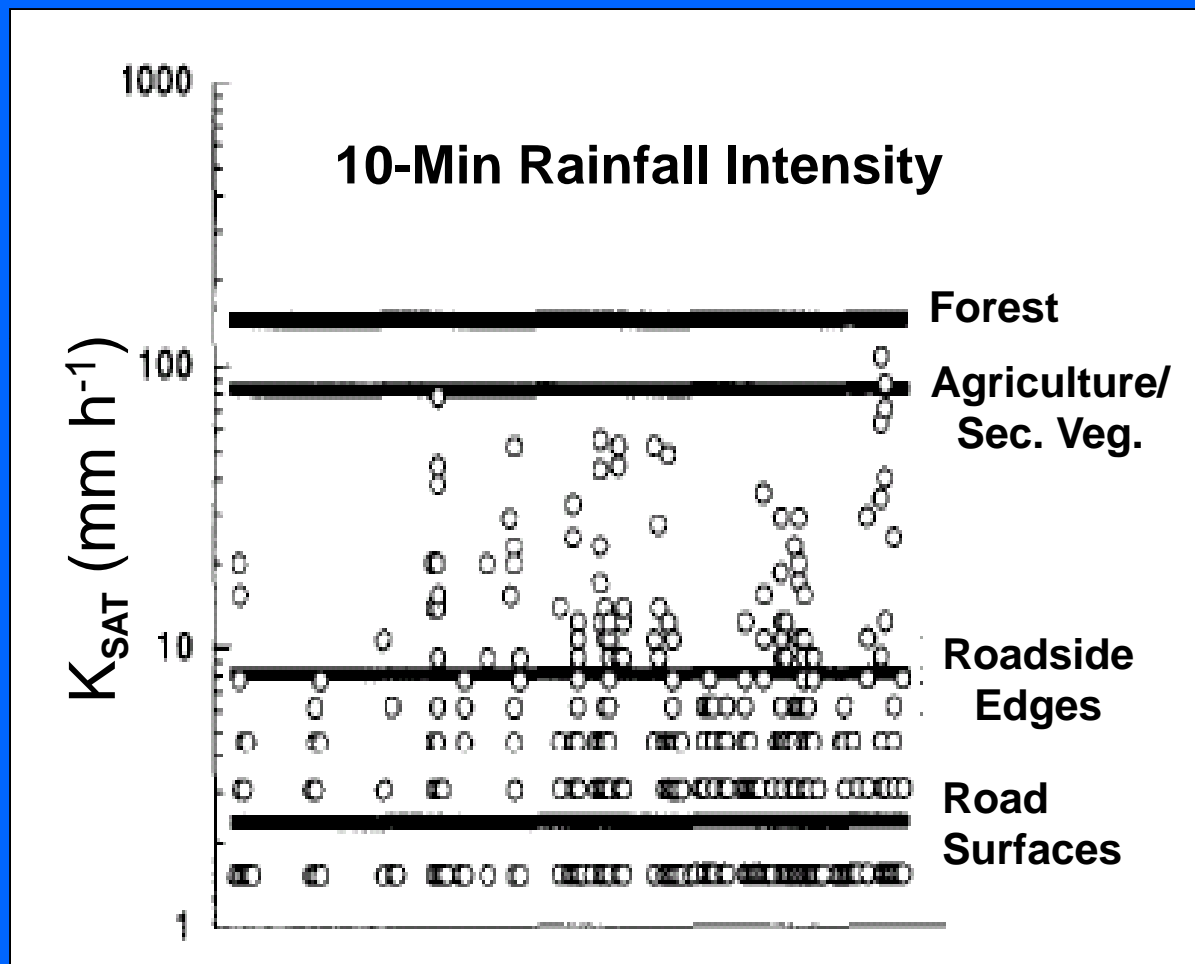


- Highly compacted
- High bulk densities
- Little or no pore space

Road Surface Hydrology - K_{SAT}

K_{SAT} (in hr^{-1})	Location	Reference
0.0001	Oregon C.R.	Loague and Kyriakidis, 1997
0.004	N. Rockies	Luce and Cundy, 1994
0.01	NW. Washington	Reid and Dunne, 1984
0.09	Thailand	Ziegler and Giambelluca, 1997
0.1	Idaho	Luce, 1997
1.4	SE. Australia	Lane and Sheridan, 2002

Road Surface Hydrology



- Have the potential to produce runoff during small storms
- Abundance of HOF on road surfaces

(Ziegler and Giambelluca, 1997)

Cutslope Hydrology



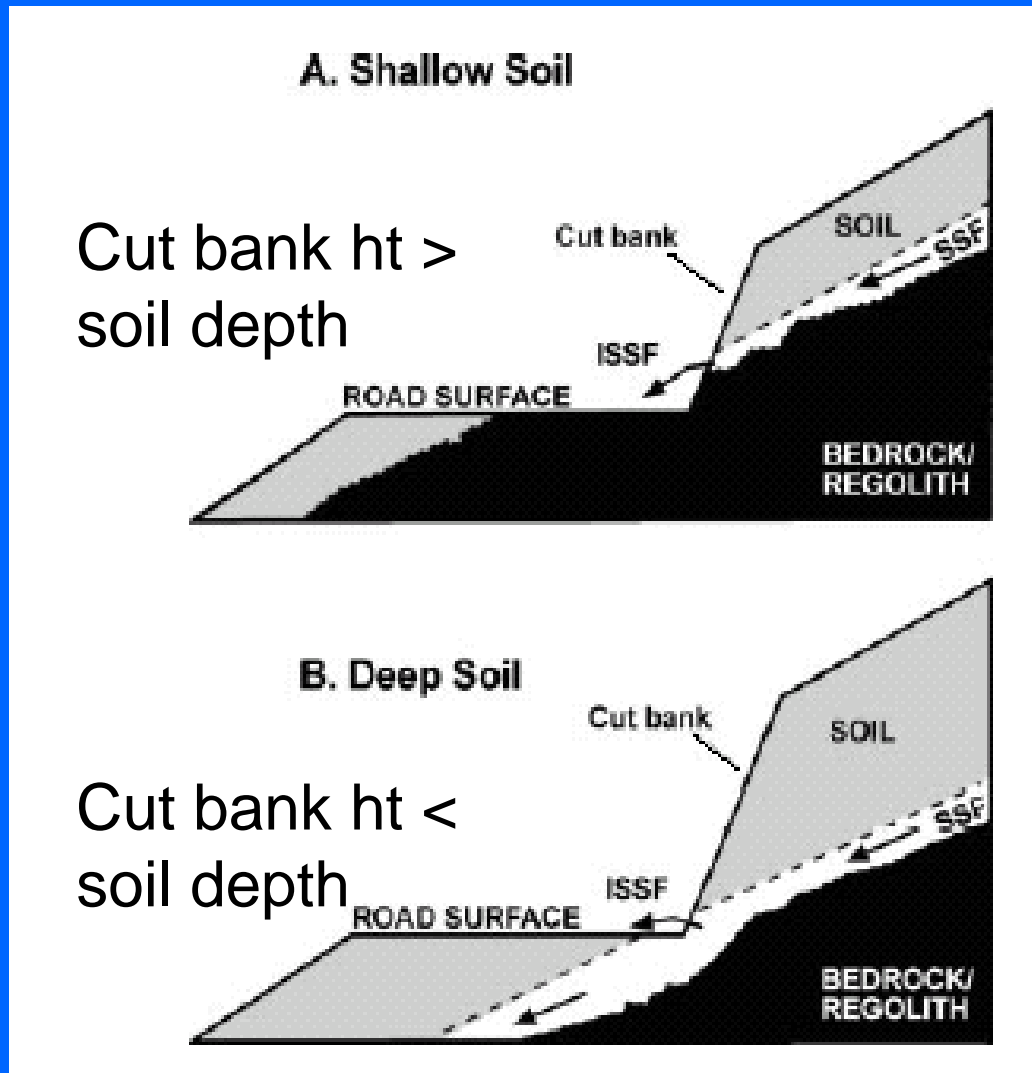
- Road cuts can expose soil/regolith interface
- Intercepts subsurface stormflow
- Responsible for up to 95% of total road runoff for PNW (Wemple and Jones, 2003)

Cutslope Hydrology – Impacts on Runoff Timing



- Velocity of overland flow is 10-10000 time greater than SSF (Dunne, 1978)
- Increases rising limb of hydrograph

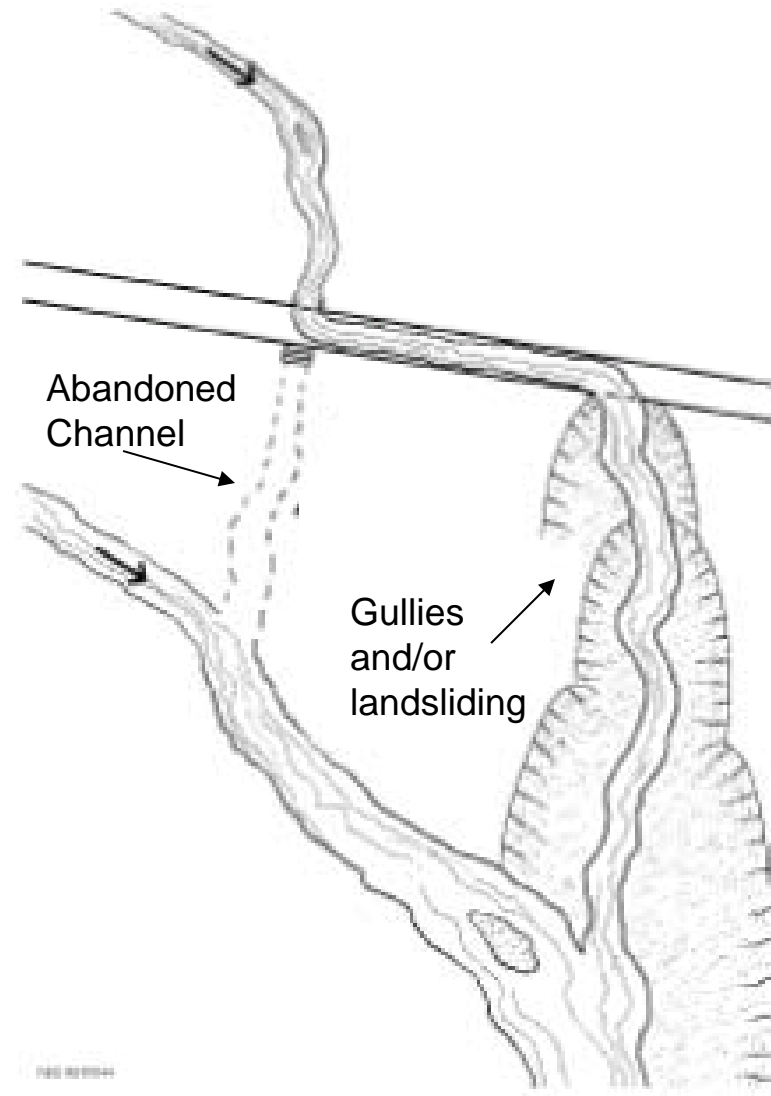
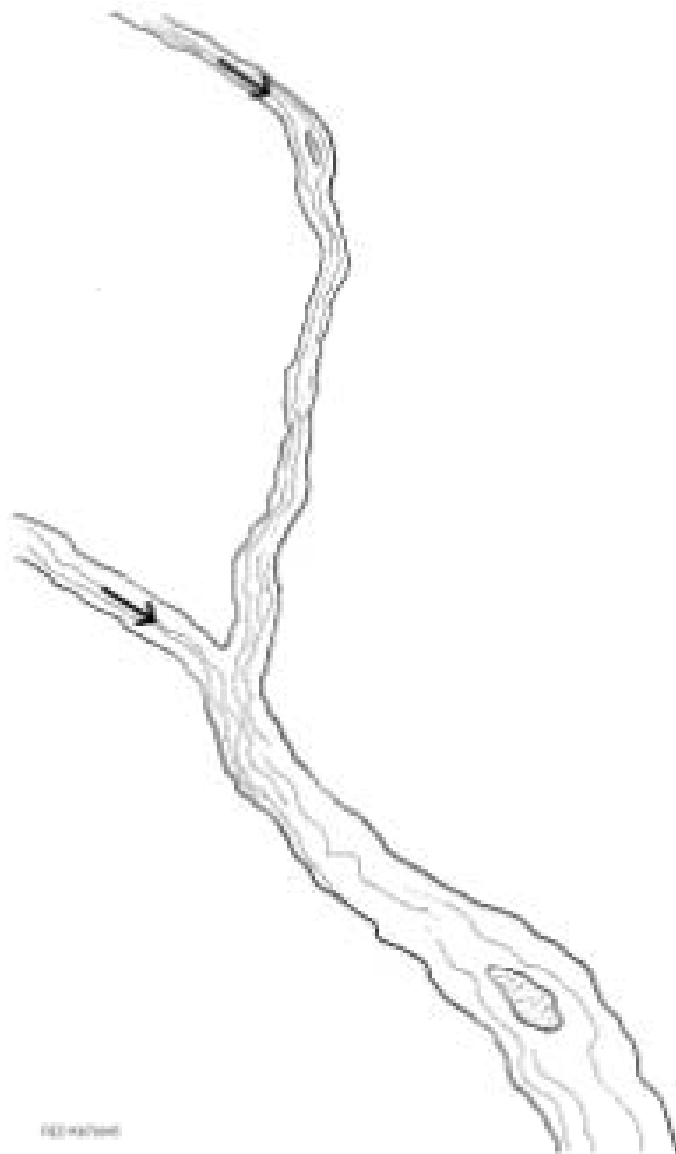
Cutslope Hydrology



- Cut banks intercept SSF (ISSF) when the cutslope height > soil depth
- ISSF is less likely on deeper soils, lower slopes, and ridgetops

(Ziegler et al., 2002)

Road Segment Hydrology – Stream Diversion



(Furniss et al., 1997)

Road Segment Hydrology



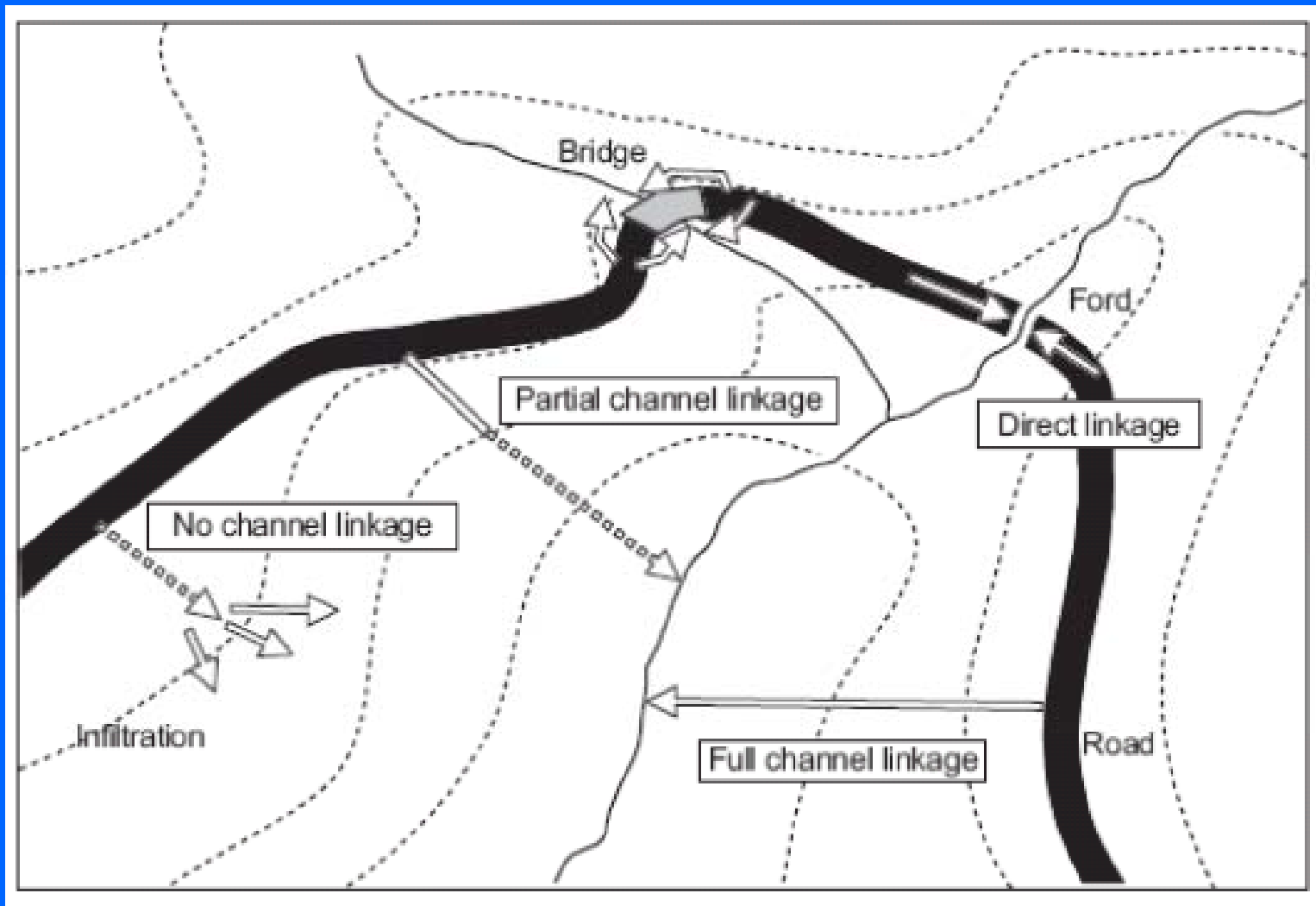
- Combination of HOF, ISSF, and/or stream diversion can increase the likelihood of gully and landslide initiation

Road Segment Hydrology



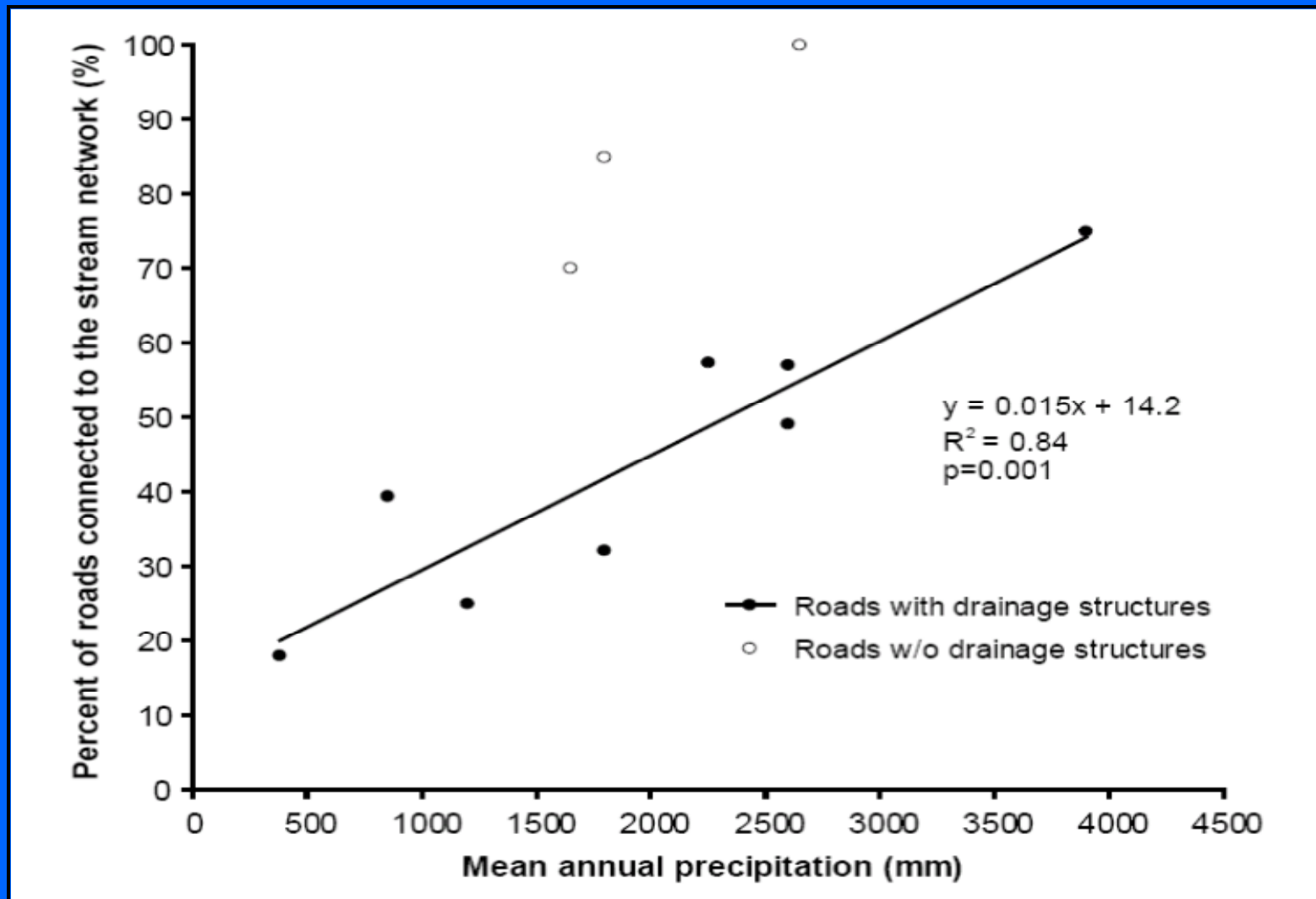
- Road segments can potentially deliver excess runoff to channel network at stream crossings

Road Segment Hydrology – Connectivity to Surface Water



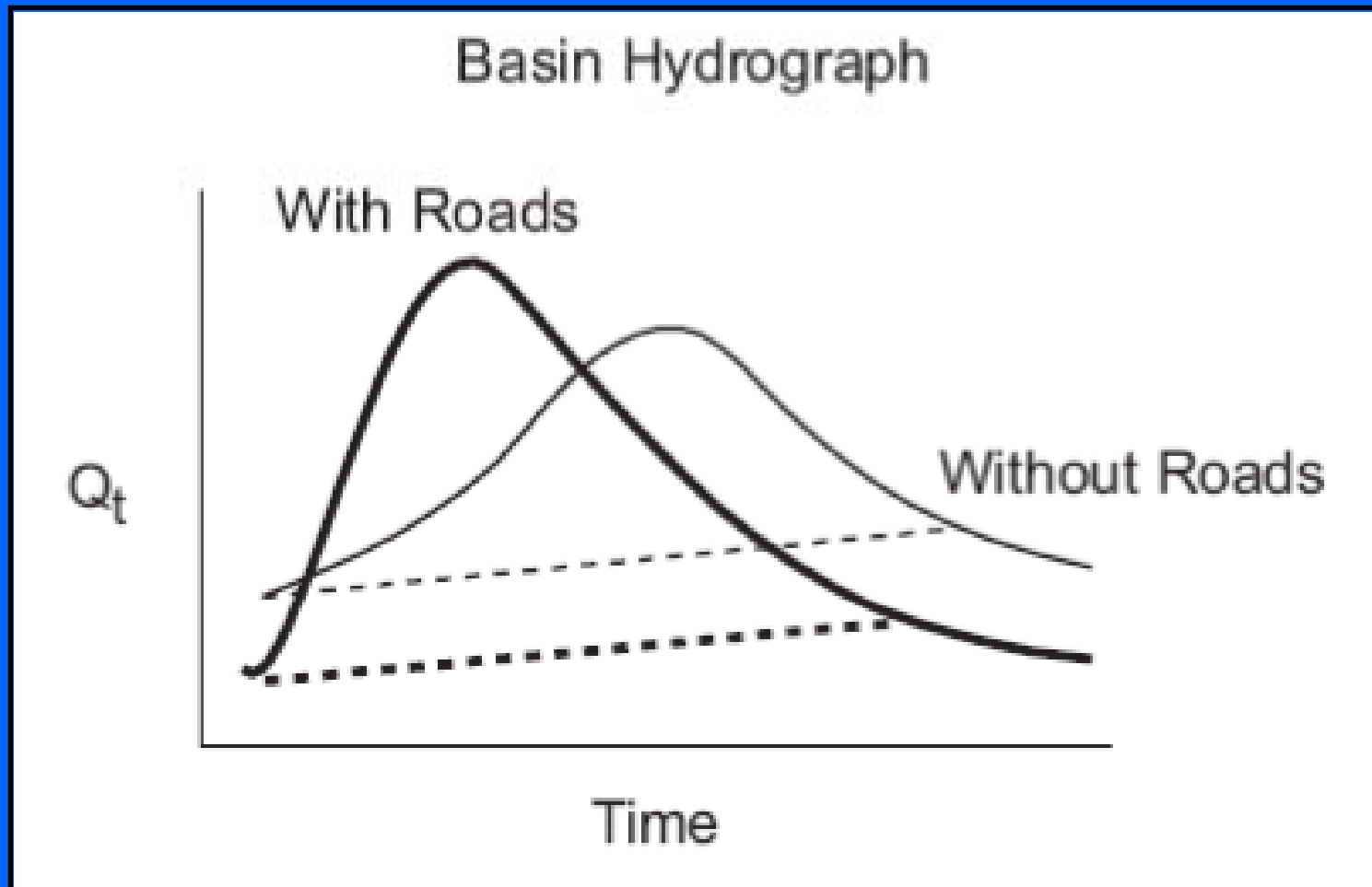
(Croke and Mockler, 2005)

Road Segment Hydrology – Connectivity



(MacDonald and Coe, 2007)

Watershed Impacts – Do the Hydrologic Impact of Roads Translate or Disperse Downstream?



(Wemple et al., 1996)

Hydrologic Effects of Roads at the Small Watershed Scale for Paired Watershed Studies in CA & PNW

- Watershed areas ranged from 61-759 acres
- Data from the HJ Andrews and Caspar Creek showed no increases in mean annual peak flow due to roads (Rothacher, 1973; Ziemer, 1981)

Small Watershed Scale: Forestry Effects on Peak Flows



- No detectable effects of roads except when roads occupied more than 12% of watershed area (Harr et al., 1975)
- Typical area occupied by roads in industrial forestland is 2-4%

Watershed Scale: Modeling Studies (DHVSM)

- **Effects of forest roads on peak flows equivalent to harvest**
- **11-12% increase per 2% of area disturbed by roads**
- **When roads are combined with harvest, effects are additive rather than synergistic**
- **Models may not accurately represent true processes (Surfleet et al., 2010)**

WATER QUALITY IMPACTS FROM RURAL ROADS



Water-Quality Impacts

=

Erosion

+

Delivery to a Waterbody

Surface Erosion:



- Amount and energy of surface runoff applied to road prism

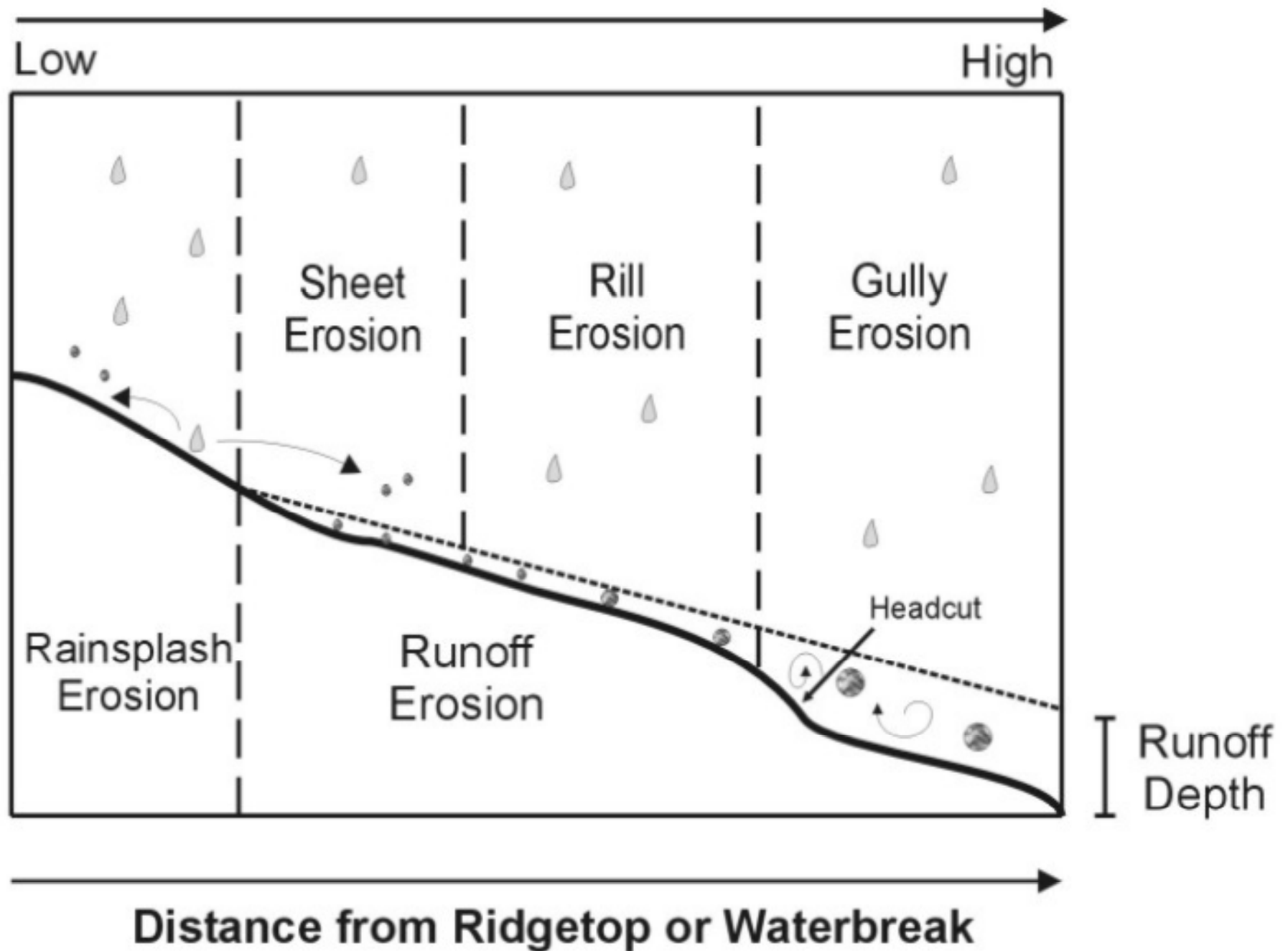
- Erodibility of road prism

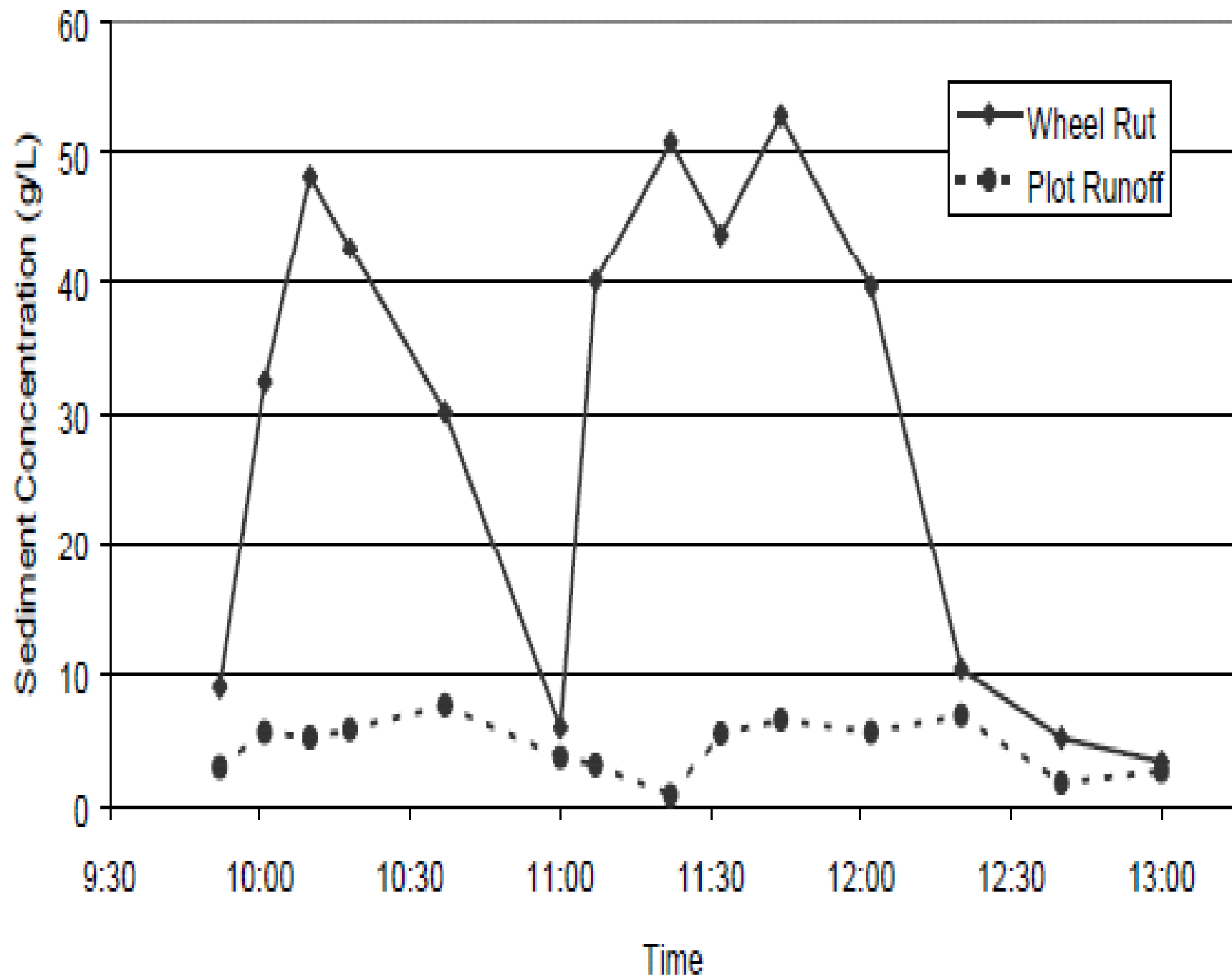
Erosive Power



- Runoff depth and slope of the flowpath dictate erosive force (depth x slope)
- Runoff depth controlled by environmental factors, distance between waterbreaks, and degree of runoff concentration

Erosion Severity





Erodibility



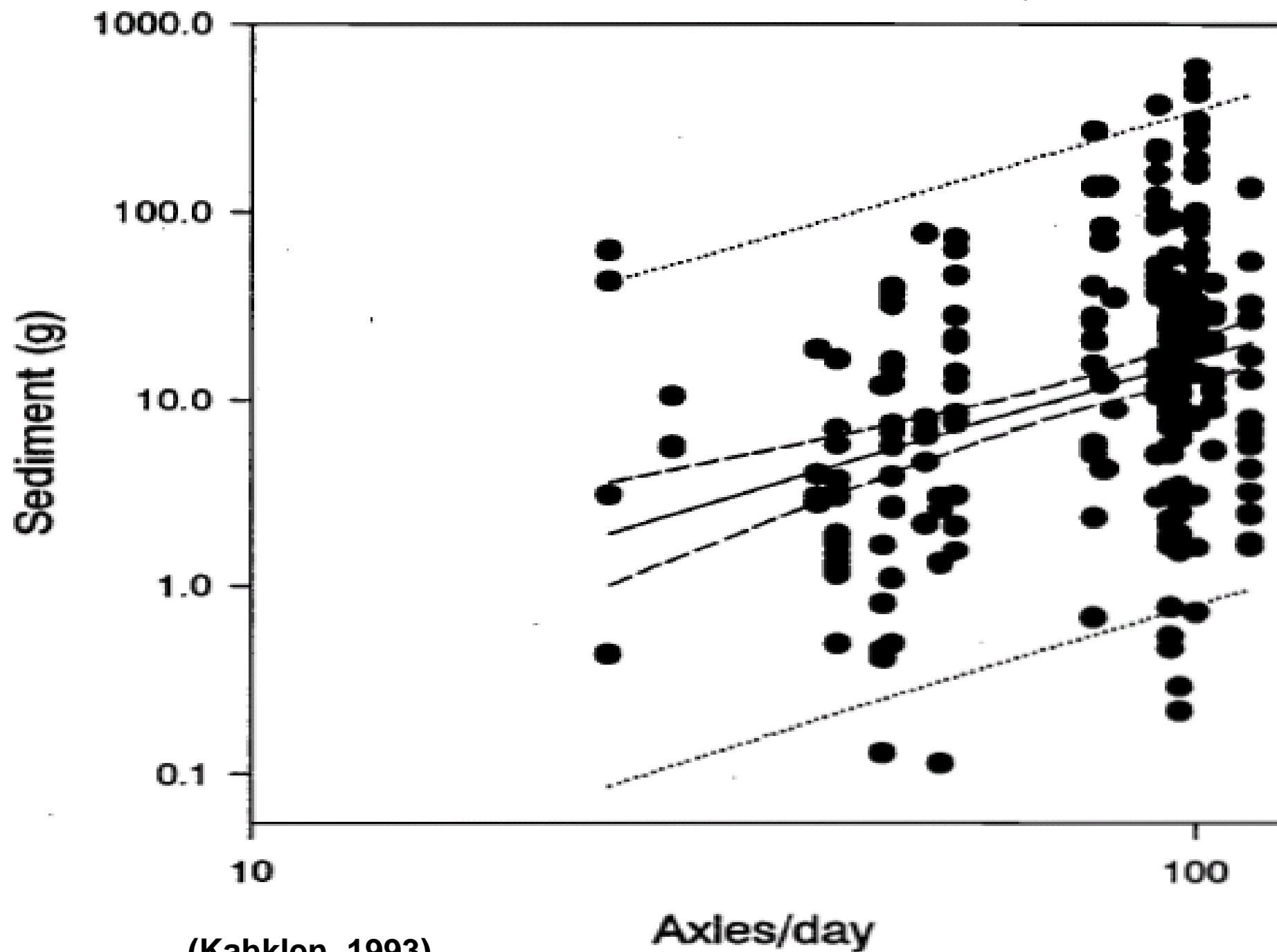
Loose material on road

- Erodibility a function of:
 - **Geology**
 - Soil properties
 - **Traffic**
 - **Maintenance**
 - **Age of road**



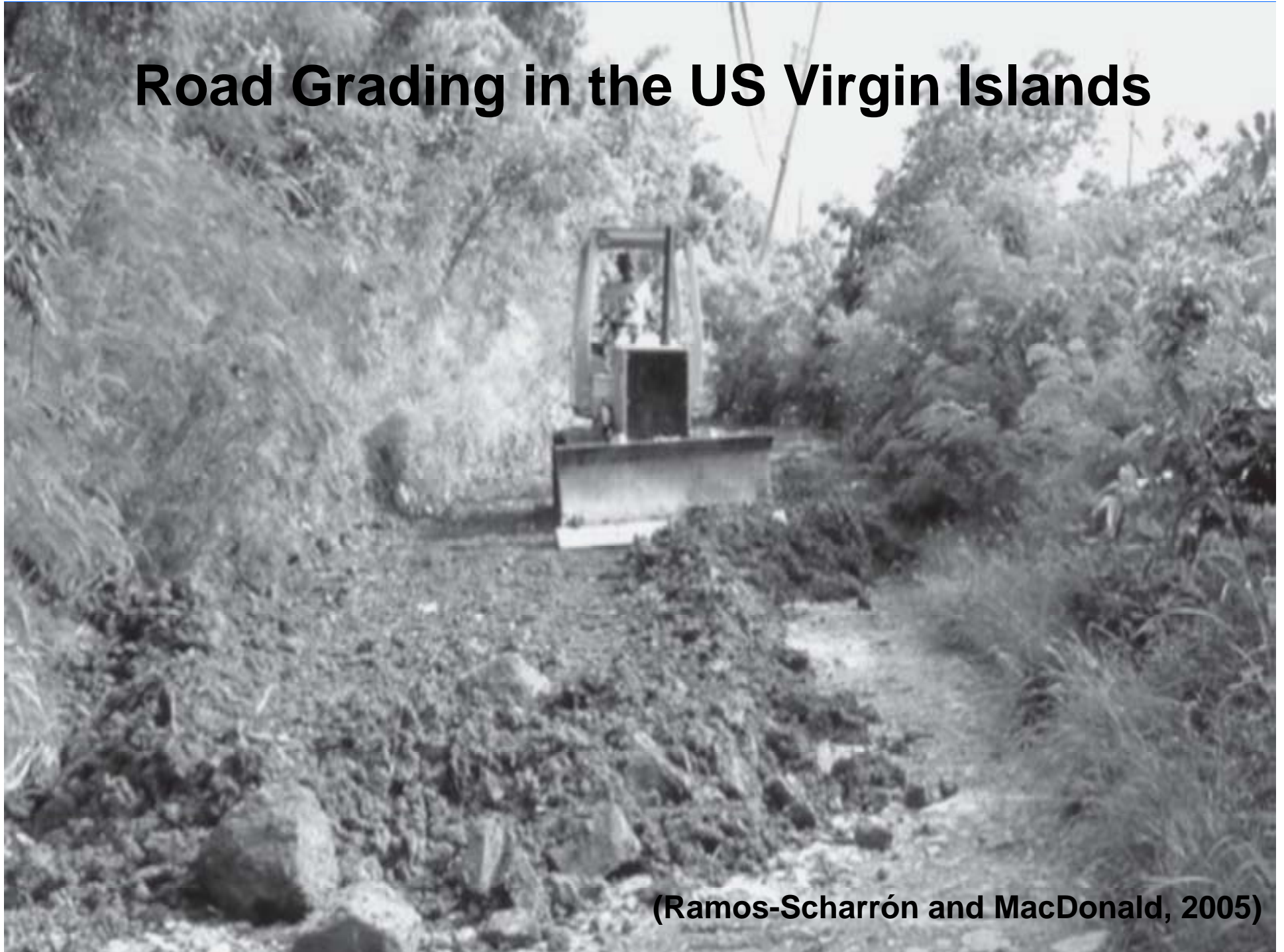
5.19.2006





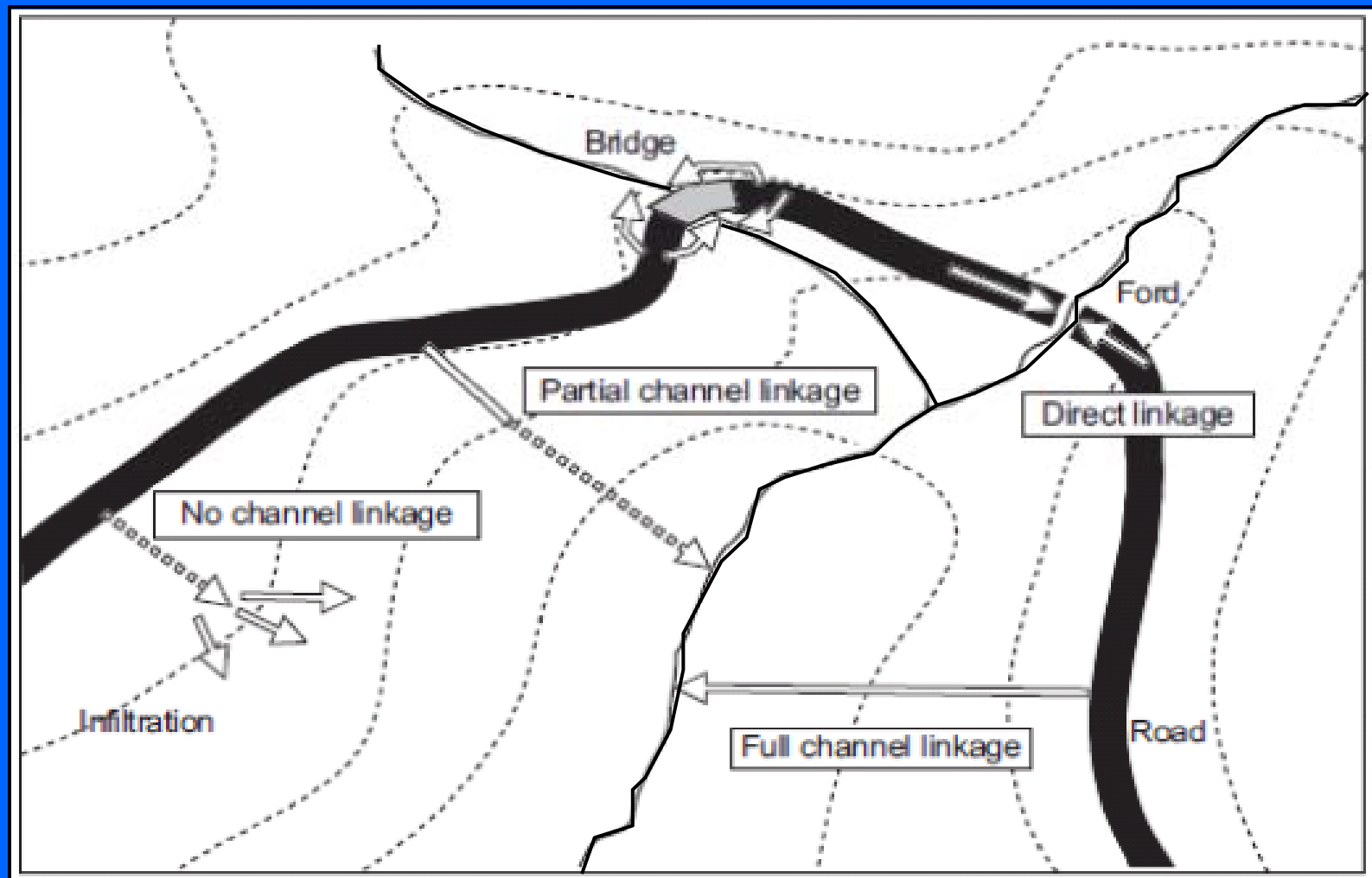
(Kahklen, 1993)

Road Grading in the US Virgin Islands



(Ramos-Scharrón and MacDonald, 2005)

Impacts Depend on Degree of Linkage



(Croke and Mockler, 2005)



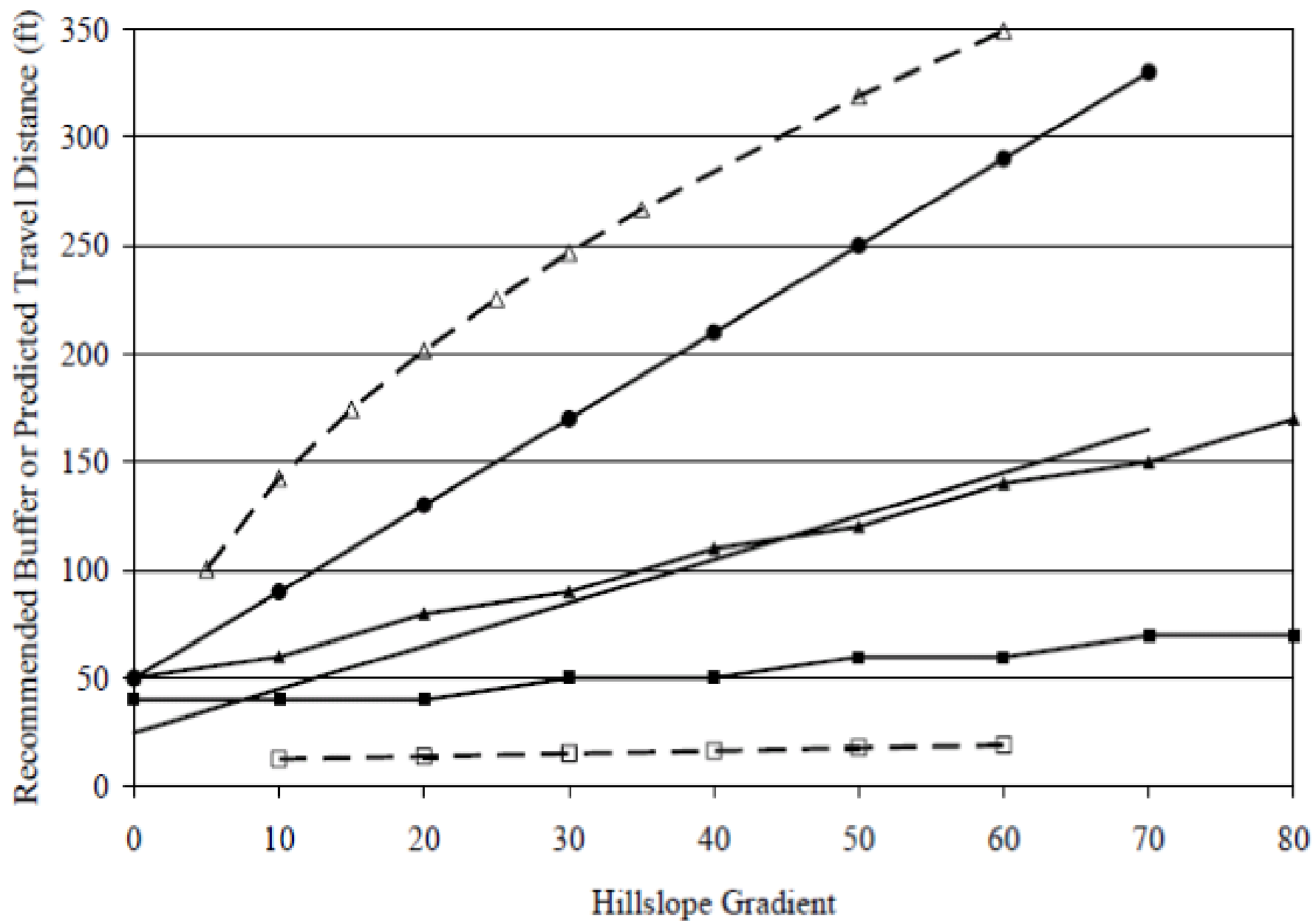
- Linkage most common at road-stream crossings
- Water quality impacts are typically chronic
- Sediment is fine grained



- **Sediment breakthroughs can happen when:**
 - Roads are close to streams
 - When roads discharge large volumes of runoff and sediment
 - Gully or landslide initiation at discharge points

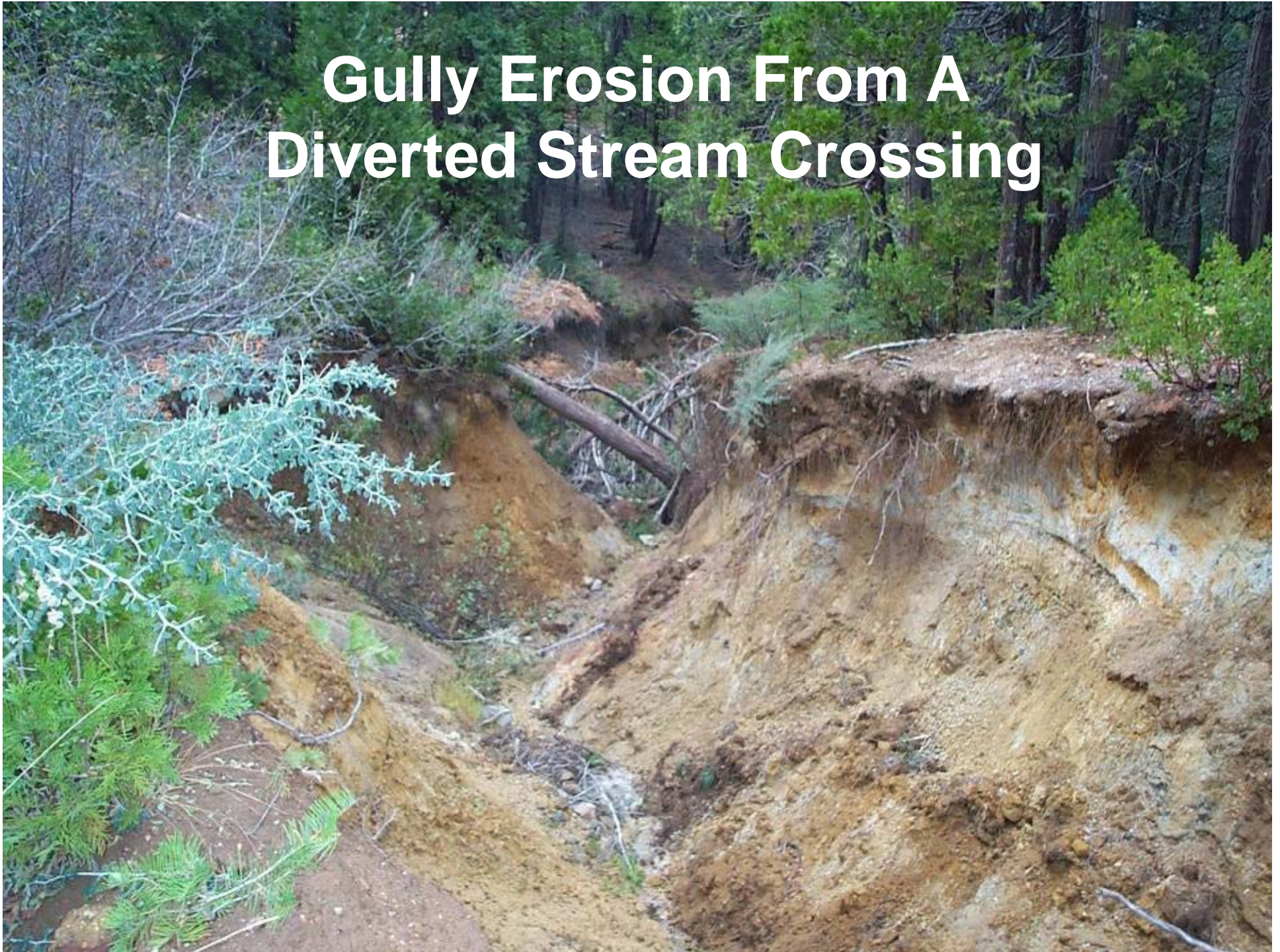
Gully Initiation Via Road Drainage





—▲— Swift	—■— Swift w/brush barriers	— Trimble&Sartz
—●— Trimble&Sartz total protection	—△— Meghan & Ketcheson	—□— Brake

Gully Erosion From A Diverted Stream Crossing



Linkage Via Mass Wasting



(WA DNR, 2004)

Water Quality Impacts



- Fine sediment increases suspended sediment concentrations and turbidity.

Increased Settleable Materials



(Sari Sommarstrom)

Incision Through Debris Flow Deposits



(Miller and Benda, 2000)

How Do We Mitigate the Water Quality Impacts of Roads?



(Wemple, 2005)

Mitigation



Road ditch with intercepted groundwater

- Drain roads frequently
- Disperse, rather than concentrate, runoff
- Avoid excess stream crossings
- Disconnect road runoff from stream crossings
- Minimize cutslope/flowpath interaction

Mitigation

- **Harden running surfaces with linkage to surface waters**
 - Heavily trafficked roads and new road construction the highest priority
- **Avoid unnecessary grading of hydrologically connected road segments**
- **Prevent rutting of road surface**
 - Wet weather restrictions
 - Adequate rocking

Mitigation

- **Decrease stream crossing diversion potential by:**
 - **Oversizing culverts to pass flow, sediment, and debris**
 - **Construct critical dips (DPDs)**
- **Anticipate crossing failure**
- **Prevent gullying and/or mass-wasting below roads by:**
 - **Decreasing runoff at discharge point**
 - **Draining to planar or convex slopes**
 - **Providing energy dissipation at the outlet**

Monitor, Learn, and Adjust





Any Questions?