The hydrological effects of wildfire

David Scott

The University of British Columbia, Kelowna, BC

Effects of fire on hydrology

- Scientific literature is full of contrasting reports
- **Fires**: little effect *or* dramatic effects (peak flow & total flow increases; sediment yield increases as high as 800% higher)
- Two main sources of variation

1. Fires vary in their severity
2. Random effect of weather after fire

- Will try to explain reasons behind this

Outline

- Effects of wildfire on soils
- Effects on surface processes
- Effects on streamflow

What determines fire severity? I

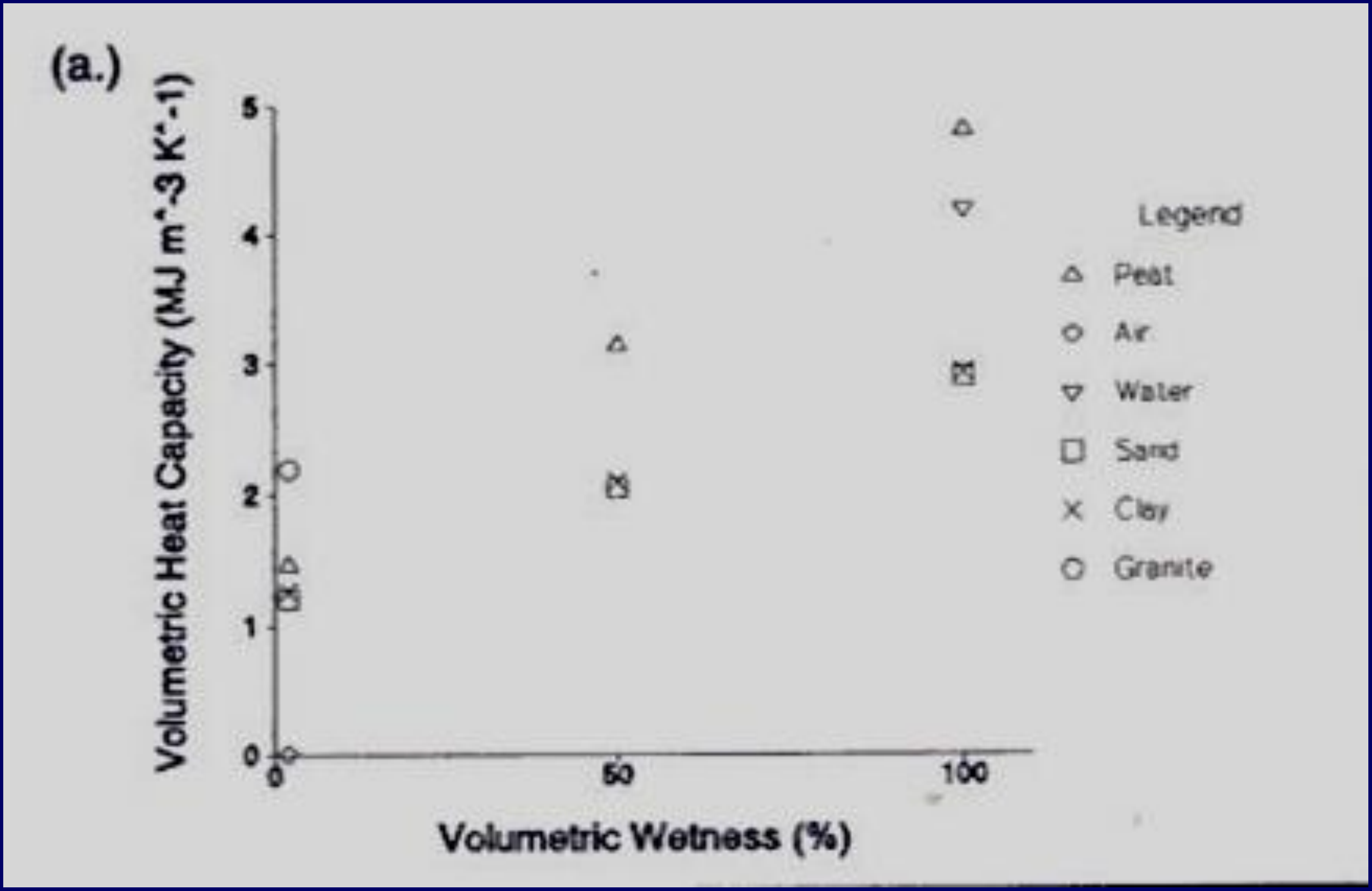
- Size of fuel load (potential energy)
- Fuel type, wetness → proportion consumed
- Litter/duff all consumed?
  - *No*, then soil insulated from heating during fire
  - *Yes*, then soil exposed to greater energy during fire

Fire severity, from a soil's point of view? II

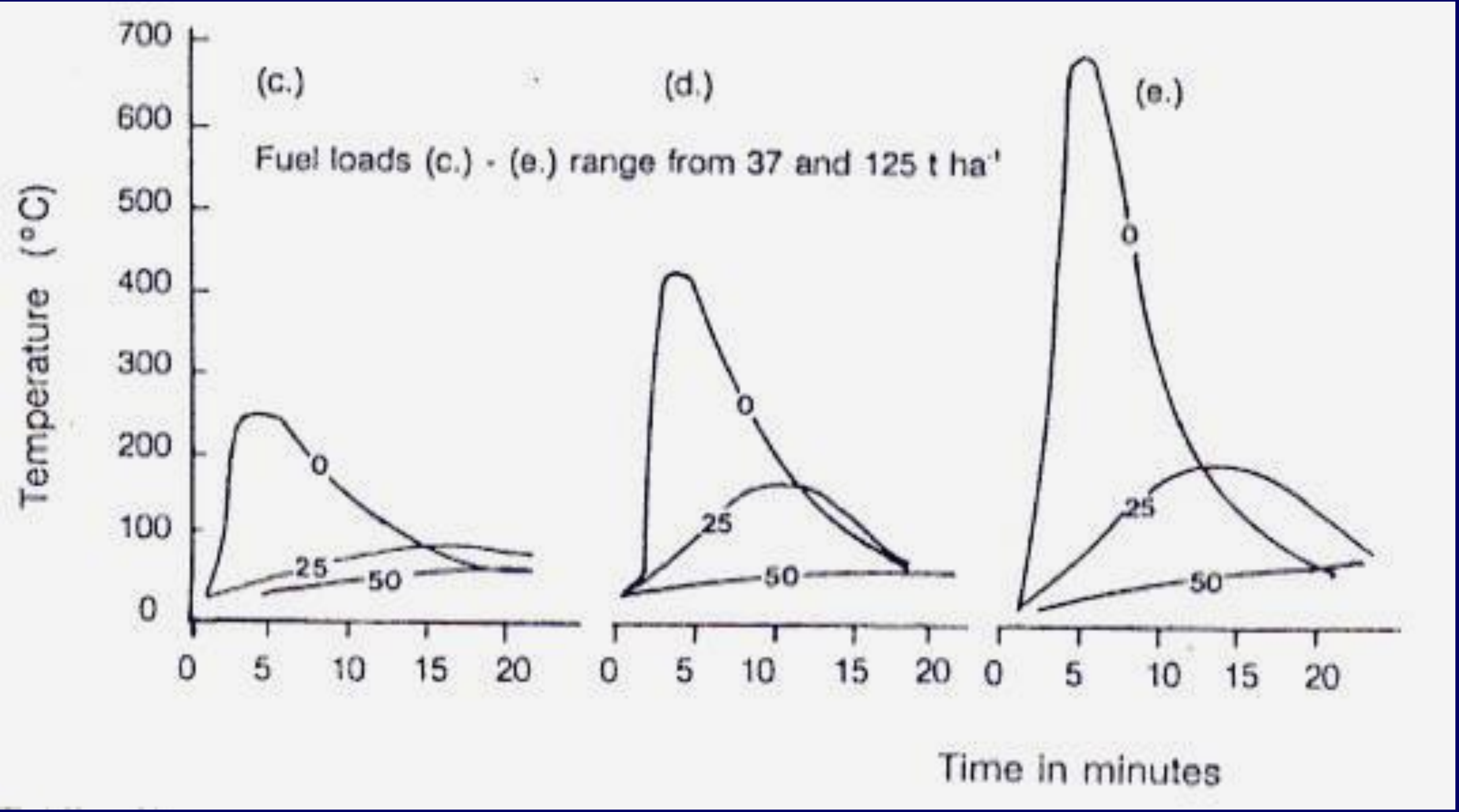
- Soil water content
  - **Moist**: energy to vaporisation; thermal capacity & conductivity increased
  - **Dry**: all energy into heating soil & heating concentrated near surface
- If soil temperatures >250° C
  - Soil organic matter combusted (ashed)
    - ➔ loss of soil aggregation
    - ➔ increased soil erodibility

- Hence, wildfires differ from prescribed burns

Soil thermal capacity & thermal conductivity are functions of water content

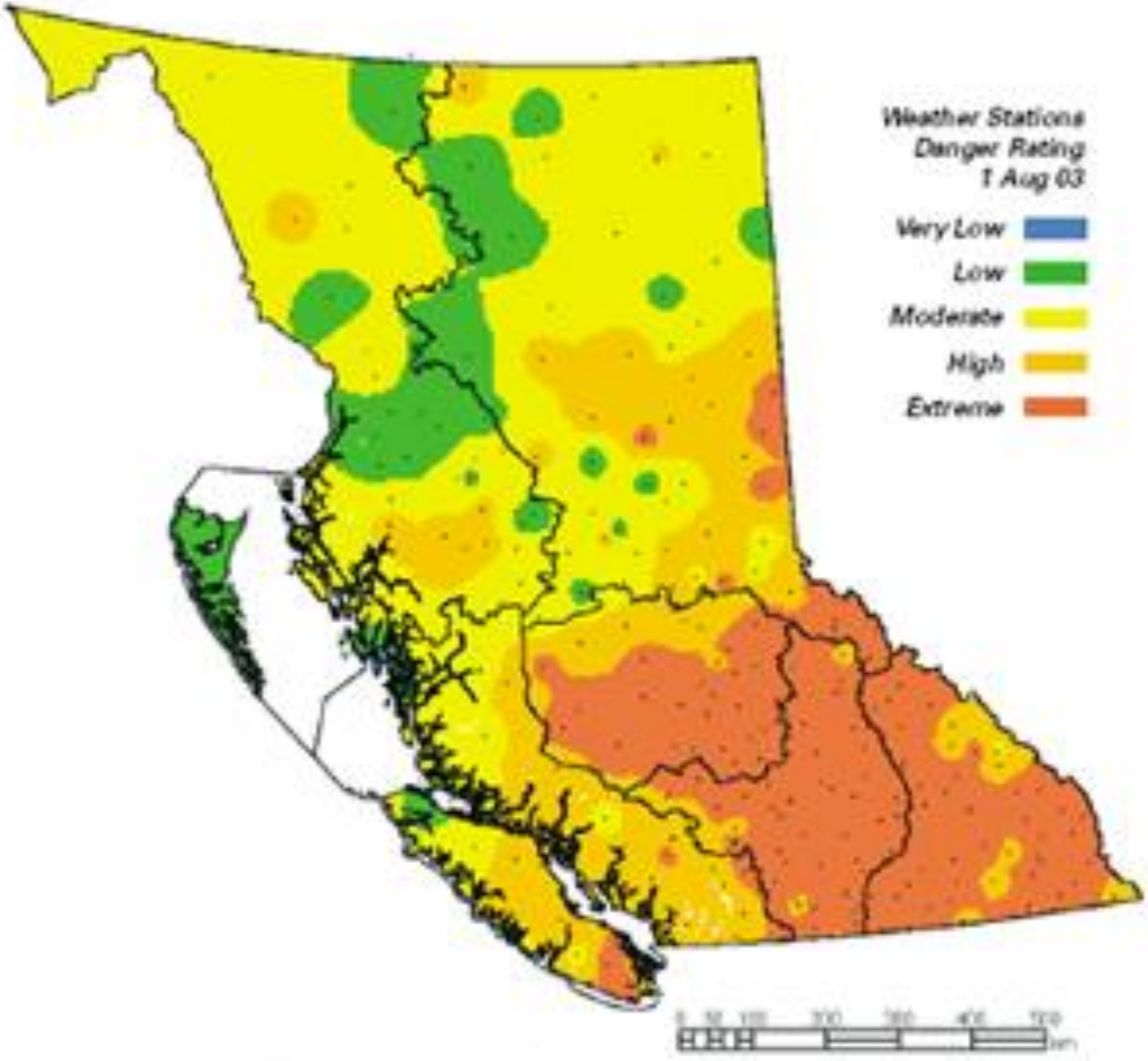


Soil temperature during a fire is a function of depth & fuel load (DeBano 1981)

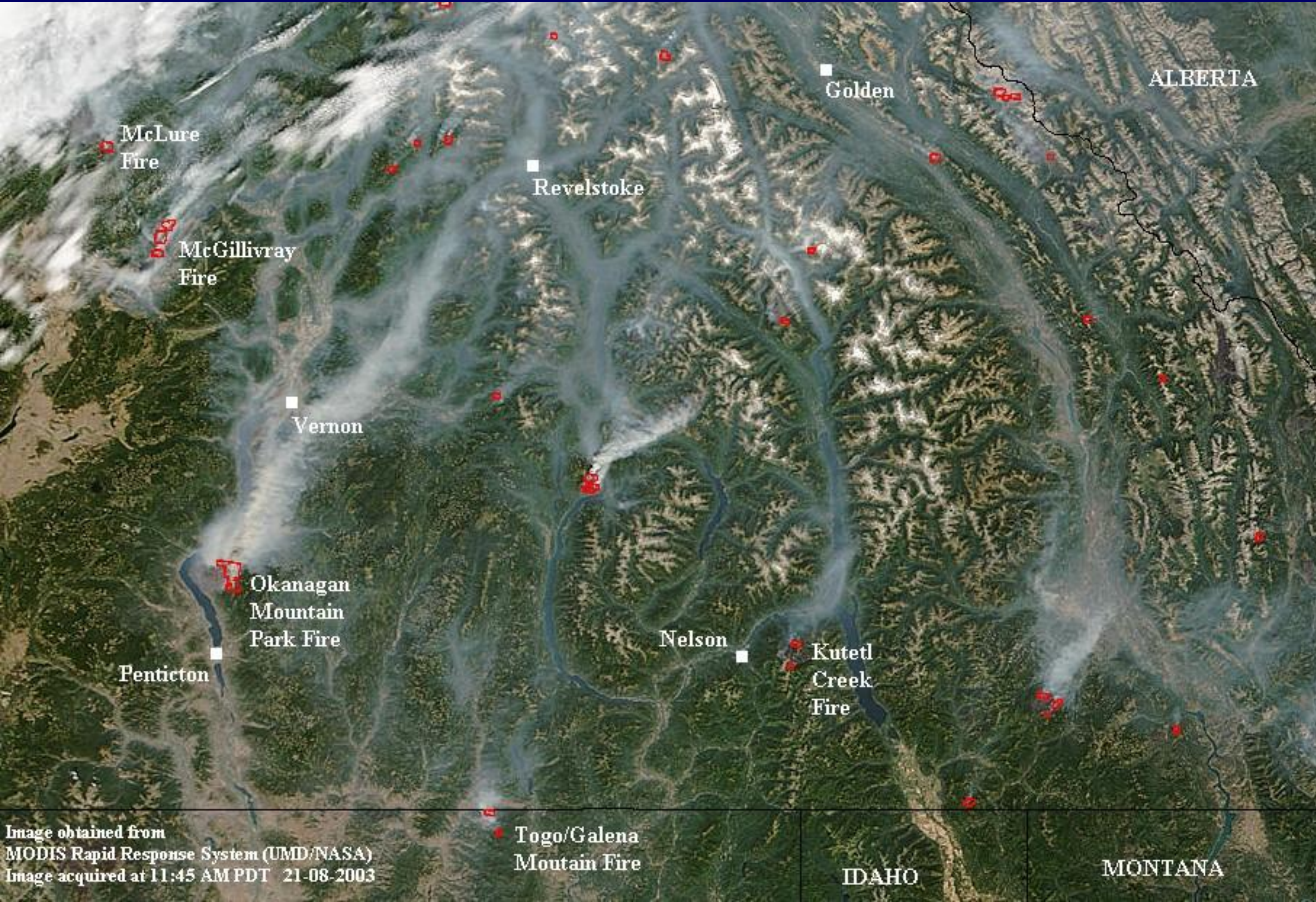


Soil aggregates: good example (right) & bad

Danger Rating August 1, 2003



Active fires in southern British Columbia on 21 August 2003



Wildfire enters Kelowna, BC, in August 2003, burning 215 homes in one night

Indicators of fire severity

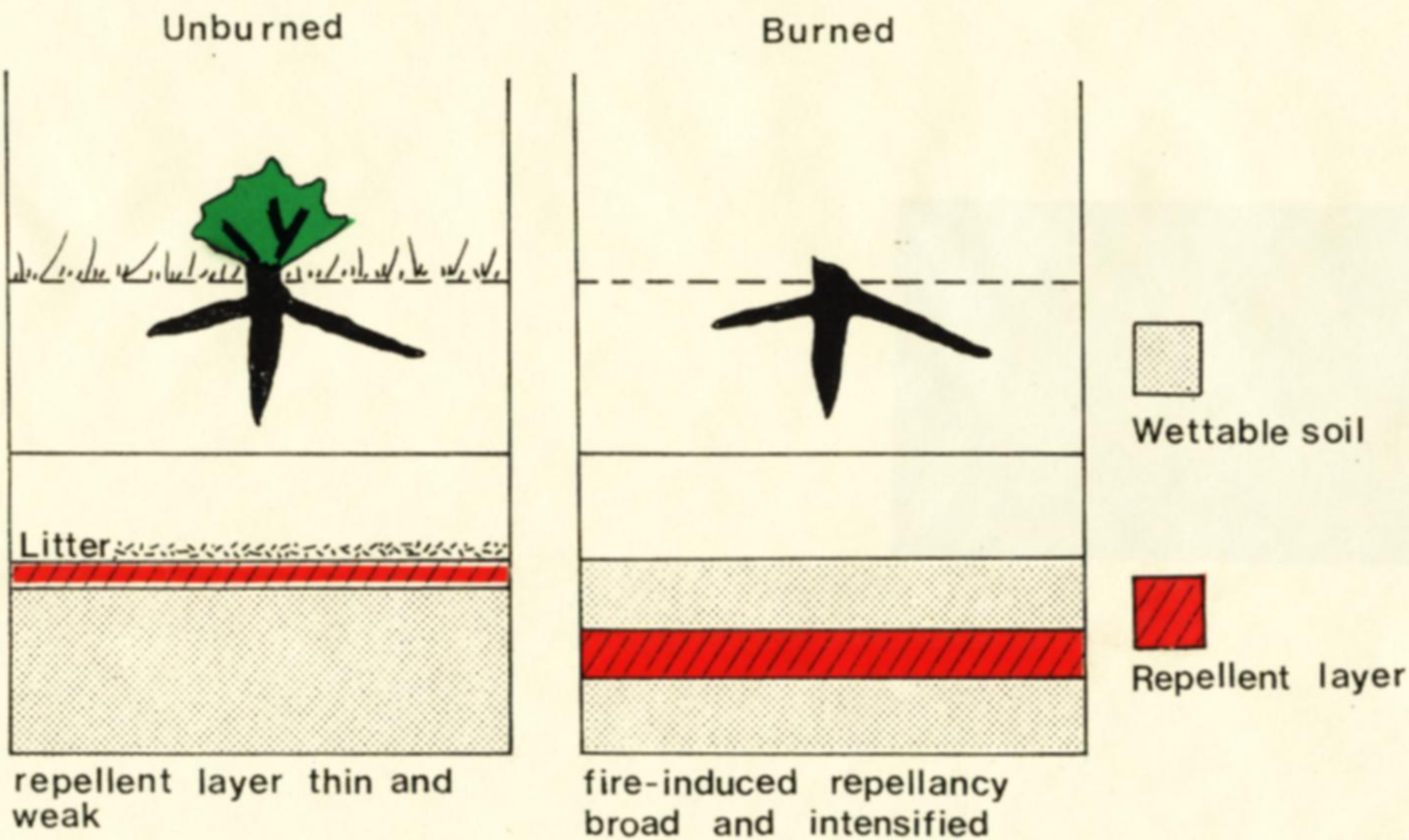

Indicators of fire severity

Soil heating indicated by coloured layers

Direct effects on soils: severe burn

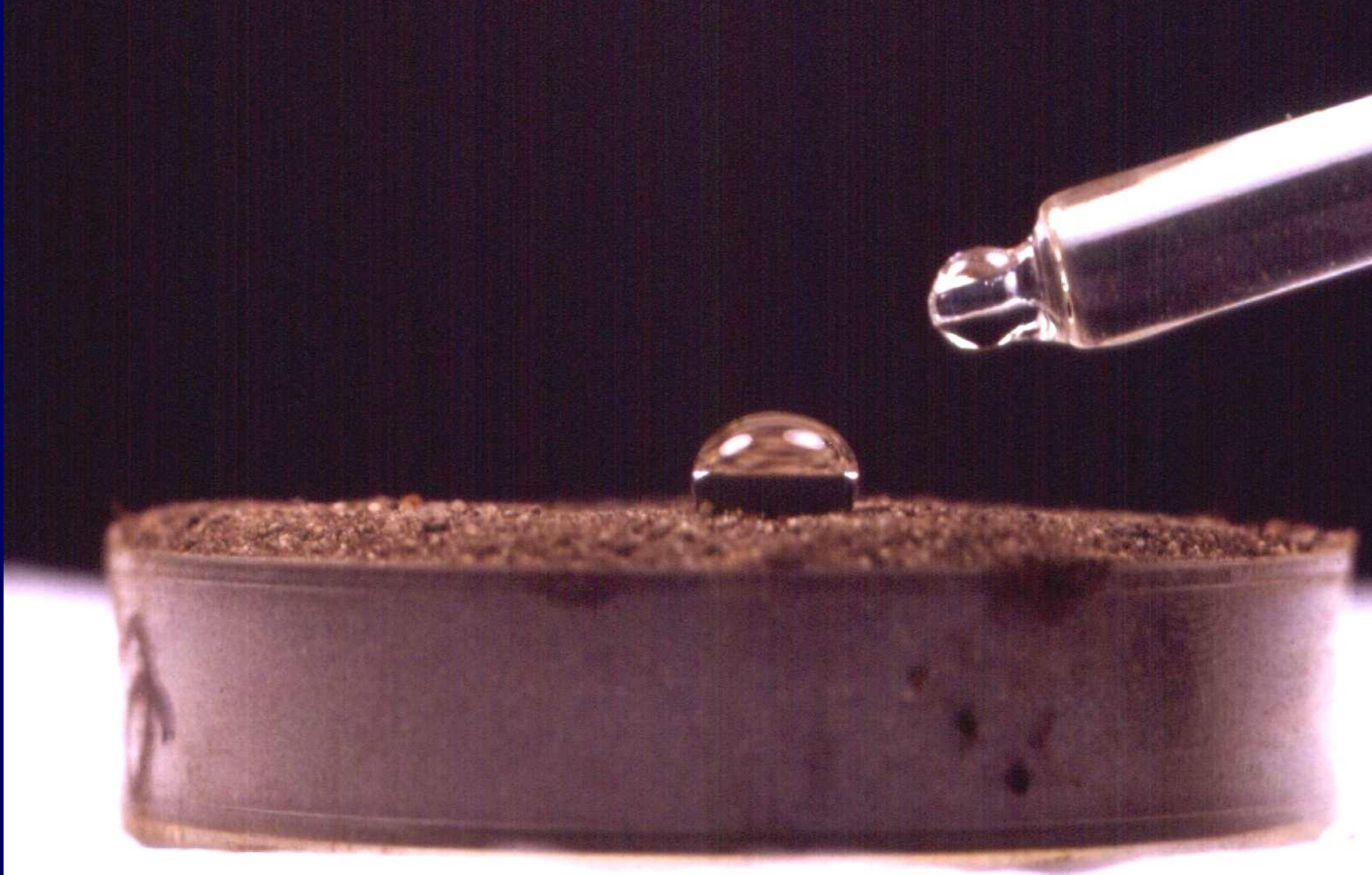
1) Litter cover removed
   - No protection from erosive forces after fire
2) Increased erodibility of soils
   - Have consistency of powder
3) Fire-induced water repellency in sub-surface soils
   - Organic compounds volatilized out of litter during fire, distil onto cooler soil at depth

Fire-induced water repellancy (De Bano 1969)



Water repellent soil resists wetting:

Solid-liquid contact angle > 90 degrees

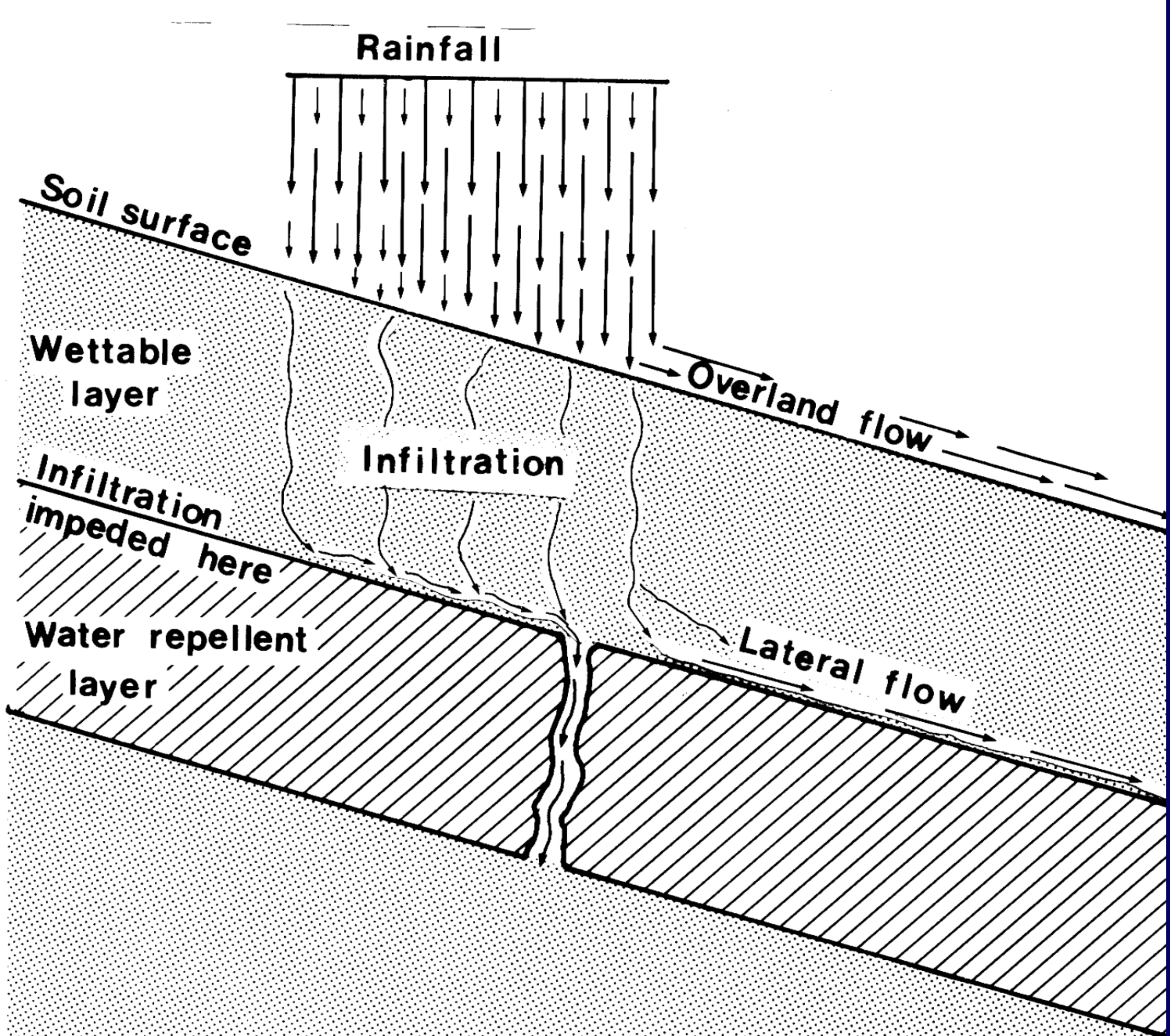


Saturated surface soils, OMP, October 2003

“Dusty footprint in the mud”, OMP, Oct `03

Dusty footprints in the mud, OMP, Oct ‘03

Rainfall on a "burnt" soil.



DeBano
1969

Ponded stemflow, Okanagan Mountain Park, October 2003

Tin roof effect: "Waterproofing by water repellent soils", OMP, Oct.03

Post-fire surface processes

- Repellency → Increased risk of overland flow
- Risk a function of: *rainfall characteristics, available storage on-site, gaps in water repellent "layer", slopes*
- Overland flow erodes ash & soils
- Flow concentrates in rills on hillslopes
- Rills deliver water & soil, ash & debris to streams
- Overland flow shortens concentration times & increases peak discharge
- Bulking causes debris floods

Sheet & rill erosion on severely burned & repellent slopes, shortens concentration times

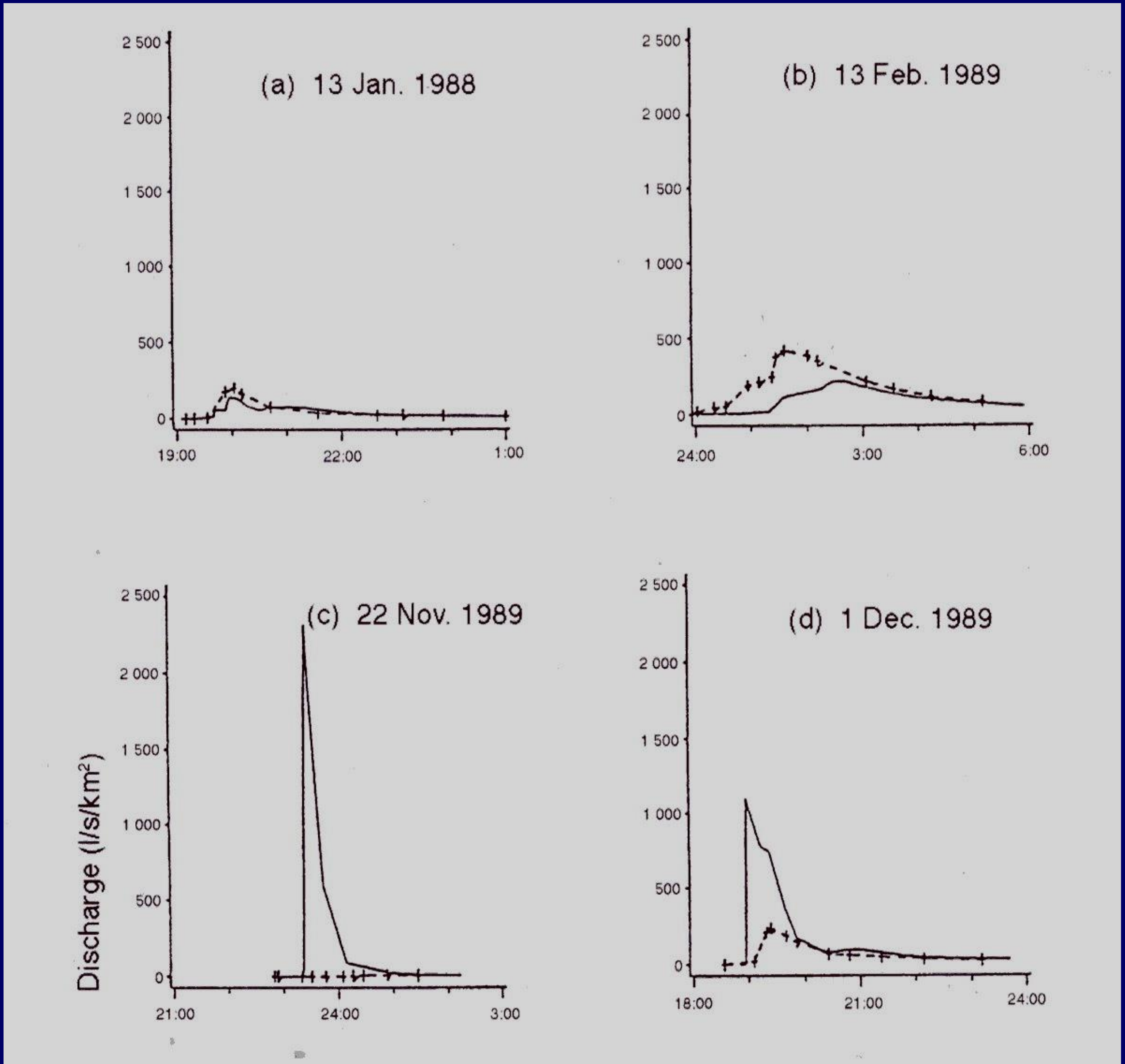
Aerial view, Cedar Hills flood: most channels did not coalesce.

Larger peak discharge erodes drainage channel, Kelowna, Oct.03

Deposition of eroded material in surface runoff, Kelowna, Oct.03

Photo courtesy of Dobson Engineering

Effect of fire on streamflow at catchment scale: Ntabamhlope



Before fire

After fire

Channel scour, Colorado.

Photo: Deborah Martin, USGS

Debris flow path, Colorado.

Photo: Deborah Martin, USGS

Alluvial fan deposit, Colorado. Photo: USGS

Debris washed into reservoir below burned watershed, Colorado. Photo: USGS

Economic effects of fire's effects on hydrology (Denver Water)

Following the Hayman Fire, SE of Denver, 2002

- 26 Water treatment plants were closed
- Water treatment costs: up by $250 million
- Plus costs of watershed rehabilitation

Vaseux Lake, July `04: Ephemeral channel scoured in single flood, “Extreme” rain event

Kuskanook, Aug `04: partially burned catchment, overland flow in upper catchment, channels coalesce

Kuskanook channel scoured out by debris flow;

Storm of unknown size – nearest station ~10 mm

Deposition of eroded debris on alluvial fan, Kuskanook, BC, 07/04

Close-up of debris deposit - >10 000 cu.m; 3 homes destroyed overnight

CONCLUSIONS

- Conditions at time of fire are critical
- Okanagan:
  - Fuel loads large, dry
  - Soils dry
  - High energy release & severe soil heating
- Vulnerability to flooding & erosion increased
- Rate of consumption (intensity) is not critical
- Wildfires *vs* Prescribed burning

CONCLUSIONS, II

- Nature of storms following fire is critical
  - Risk exists, but outcome is uncertain
  - No large storms in first 3 years ➔ "dodged the bullet"