

Post-Wildfire Debris Flows in Southern British Columbia

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Post-wildfire Natural Hazards in BC

Most wildfires in British Columbia have only minor effects on hydrology and geomorphology.

However, in a few cases, significant landslide events have followed wildfire – most of these are debris flows.

Why? What makes these few wildfires hazardous?

Before 2003, post-wildfire landslides or floods were very rarely reported in British Columbia.

Since 2003, there have been several significant incidents, which have resulted in destroyed houses, damaged highways, and one fatality.

The BC Forest Service developed a risk analysis procedure (based loosely on the BAER program in the US) to identify and help manage these risks.

Risks to public safety and infrastructure are the focus. Soil erosion and water quality have not been identified as important concerns.



Kuskonook fire, August 2004



Cedar Hills fire, June 2004



Springer fire, May 2008



The 2003 fire season ...

On 22-23 August 2003, the Okanagan Mountain Park fire burned into the city of Kelowna. 33,000 people were evacuated, and 238 homes burned.

The 2003 fire season was the worst in British Columbia's history. Record-breaking drought in July and August resulted in fires which burned 266,000 ha (10 times the long-term average).

These included 15 interface fires, from 1000 to 30,000 ha in size, which burned 334 homes (including in Kelowna), as well as industrial infrastructure.

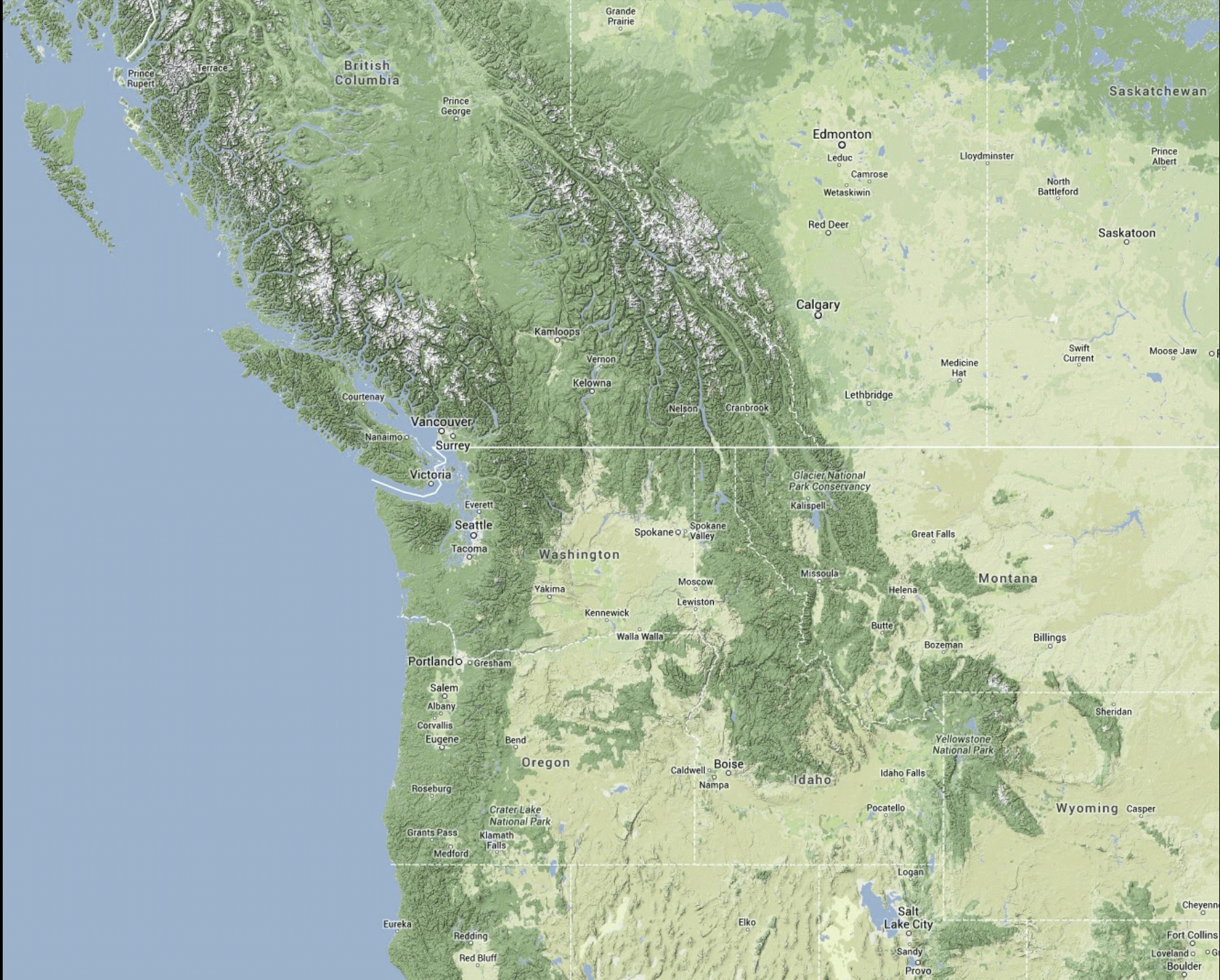


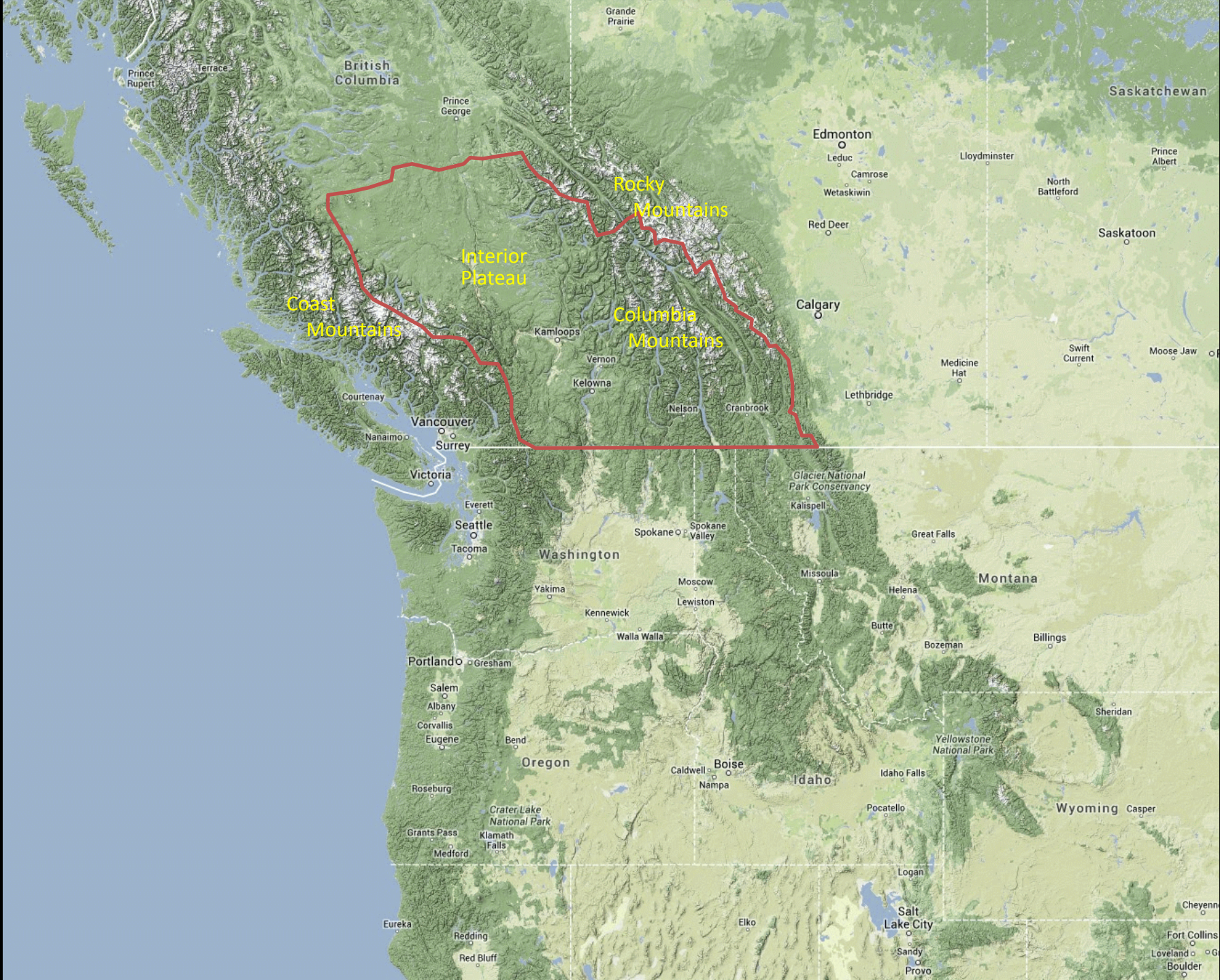
Shortly after the fire was out in October 2003, an unusually intense rainstorm caused debris floods on two streams on the southern edge of Kelowna, damaging homes, streets, and drainage structures.



This was a relatively minor event, but in the following two years, much larger debris flow and flood events occurred in four other 2003 fires.

These incidents led to development of the BC Forest Service's risk analysis procedure, and the funding of a research program to study post-wildfire natural hazards.







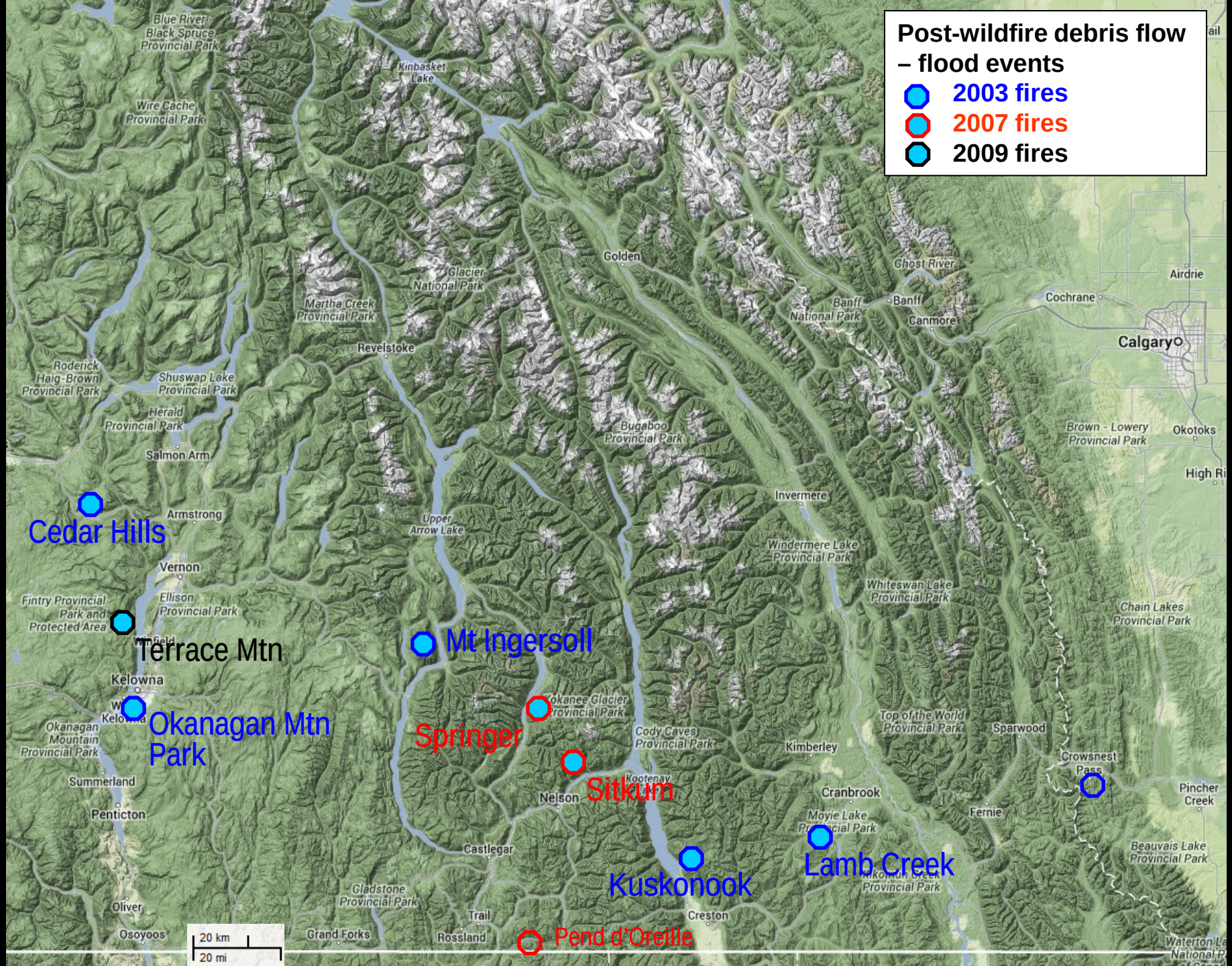
Post-wildfire debris flow

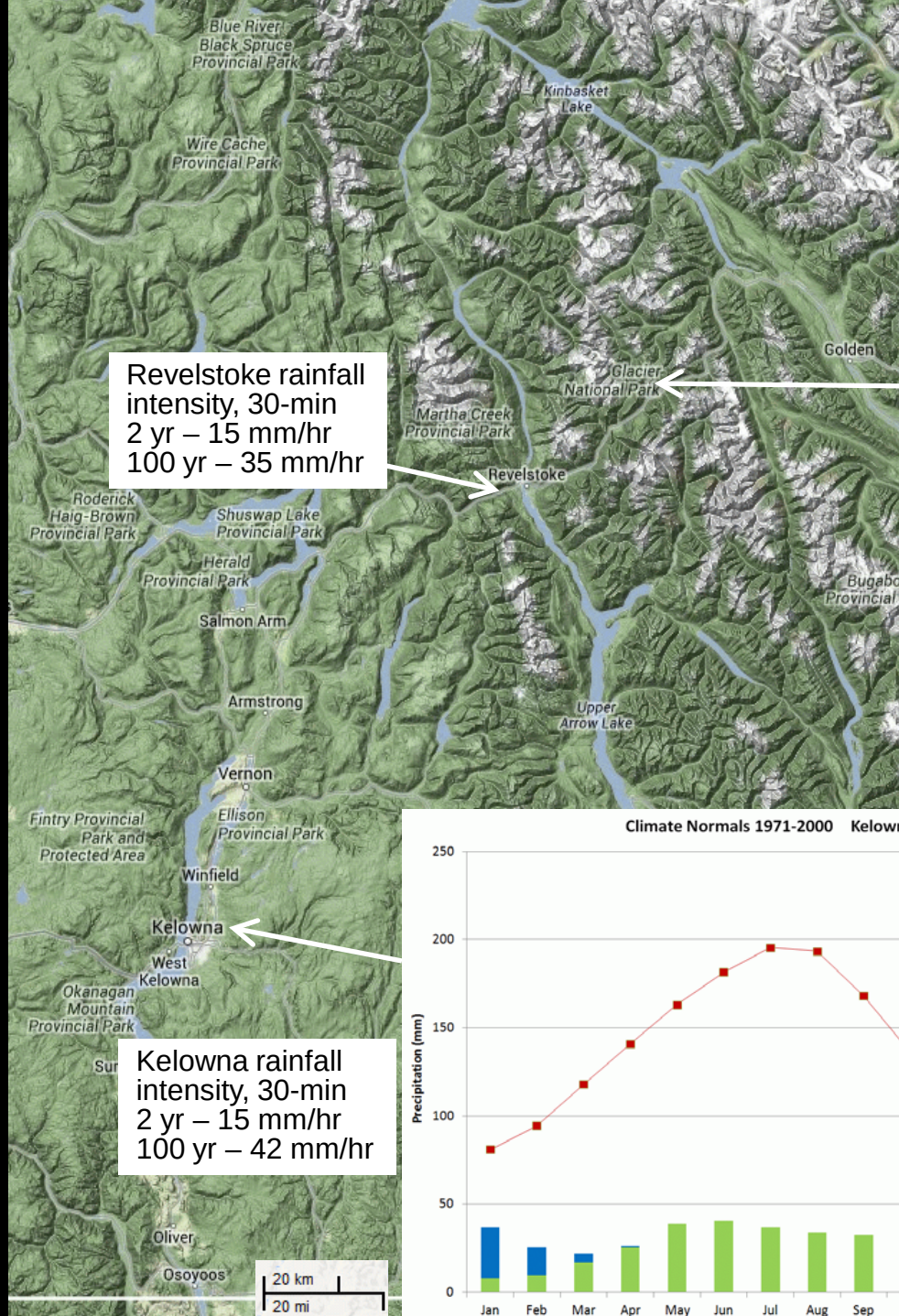
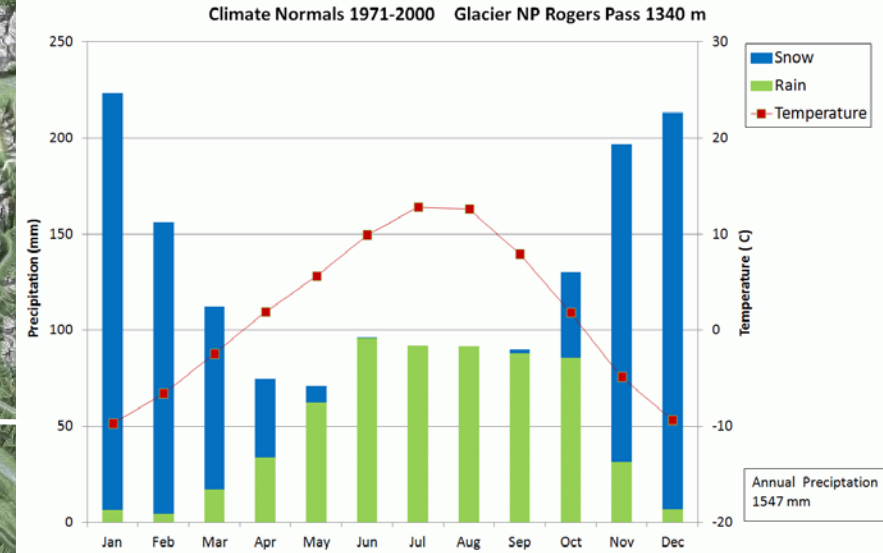
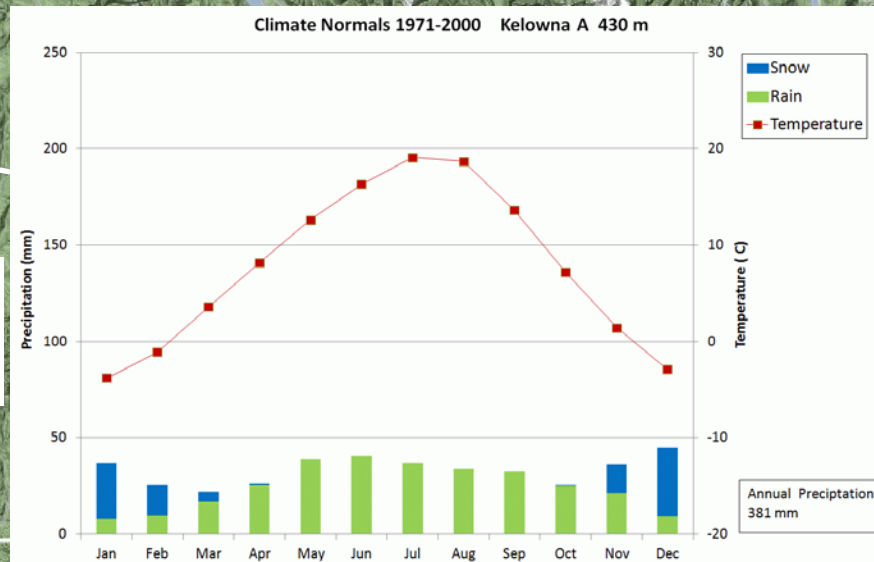
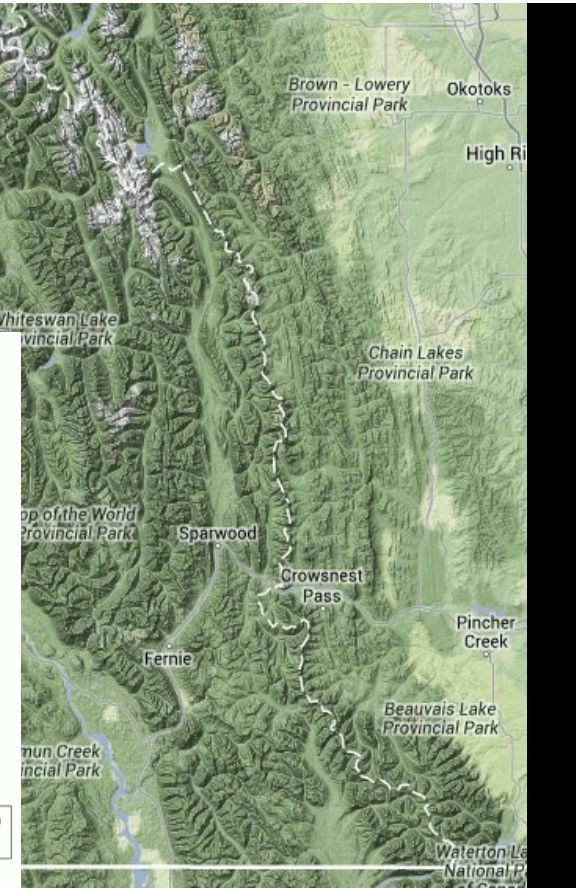
– flood events

 2003 fires

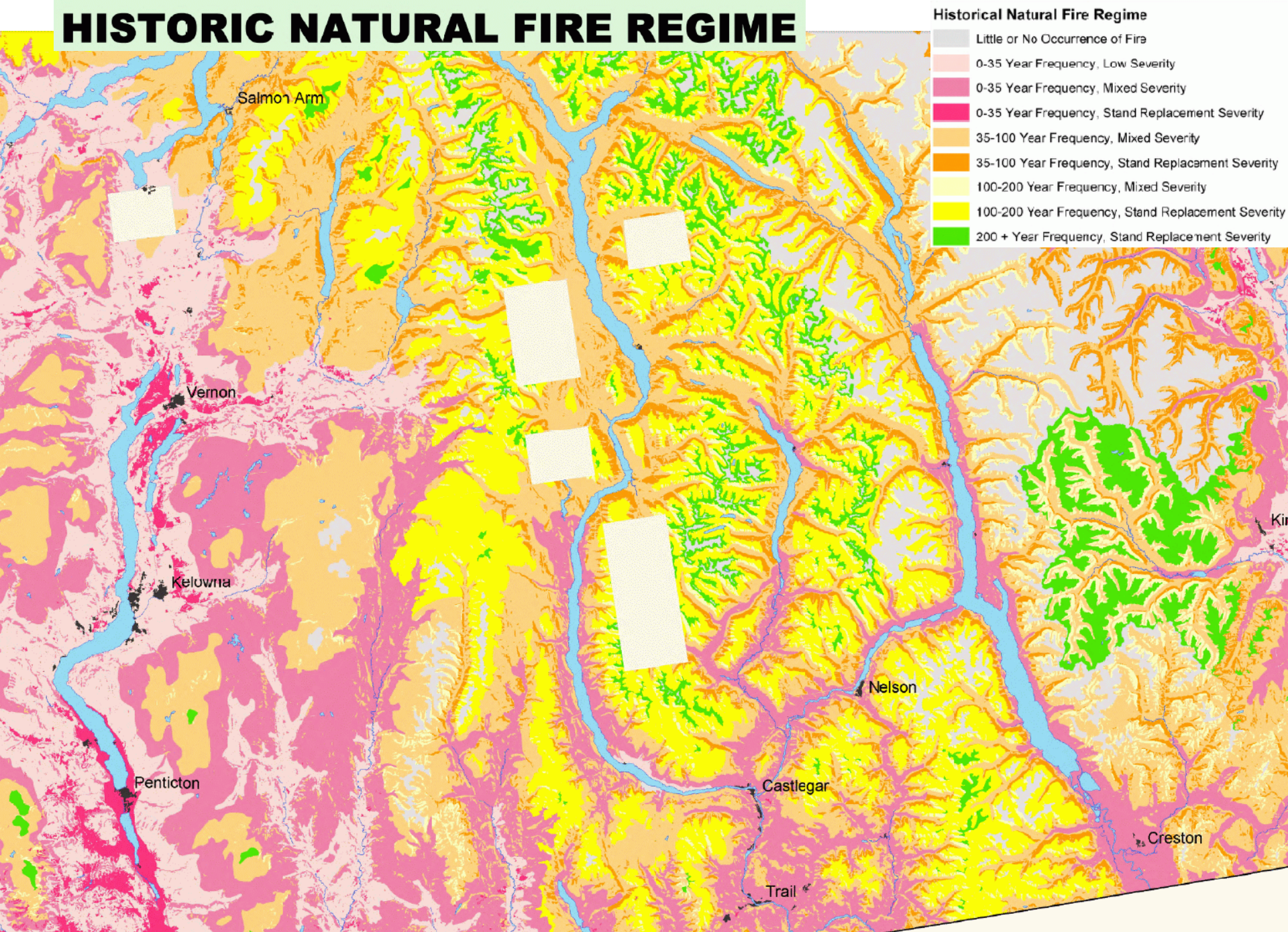
 2007 fires

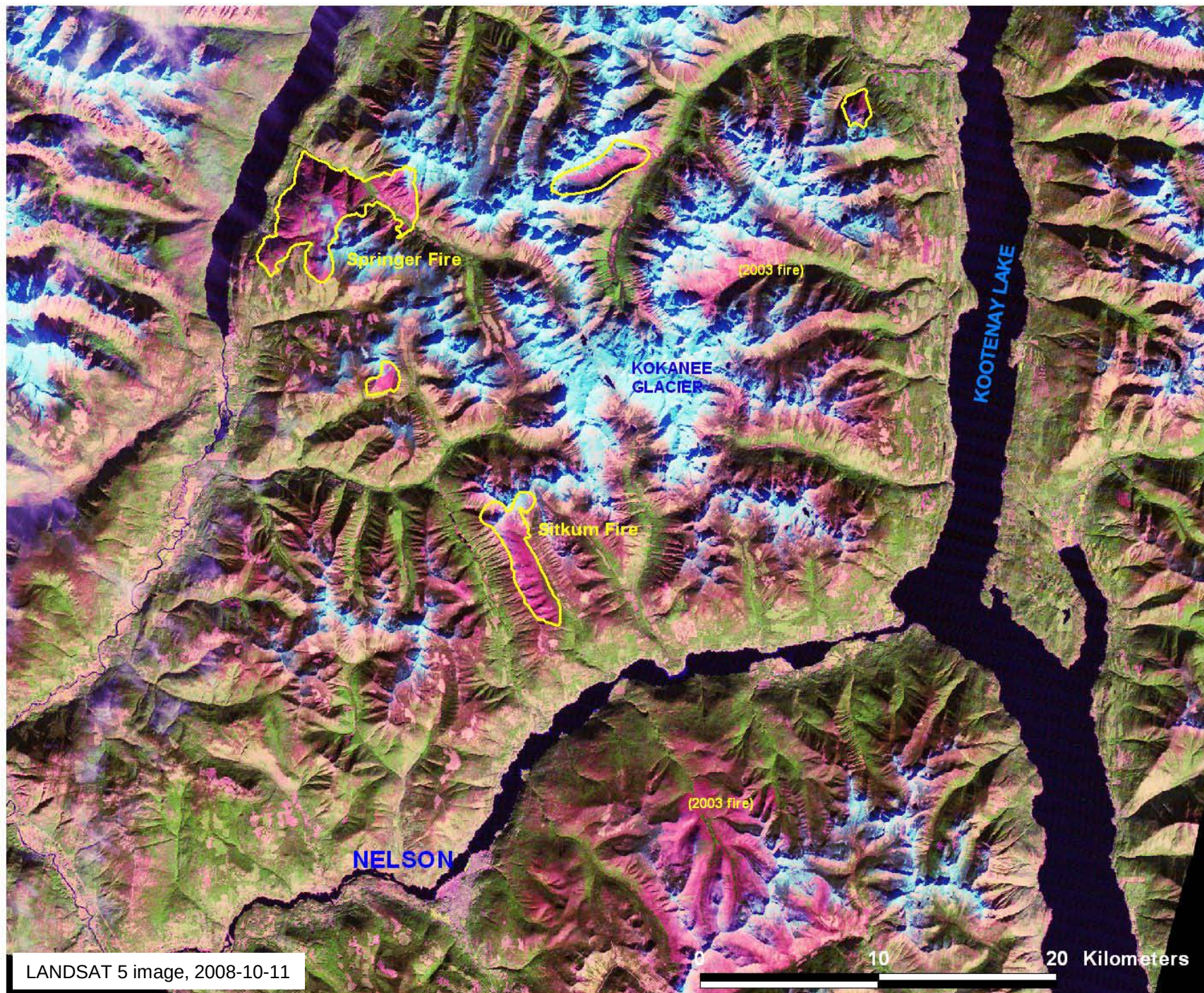
 2009 fires





HISTORIC NATURAL FIRE REGIME







Typical landscapes: Columbia Mountains, Kootenay Lake near Nelson



Okanagan-Thompson Plateau: Okanagan Lake



Events following the 2003 wildfires: Cedar Hills fire, June 2004 rainstorm

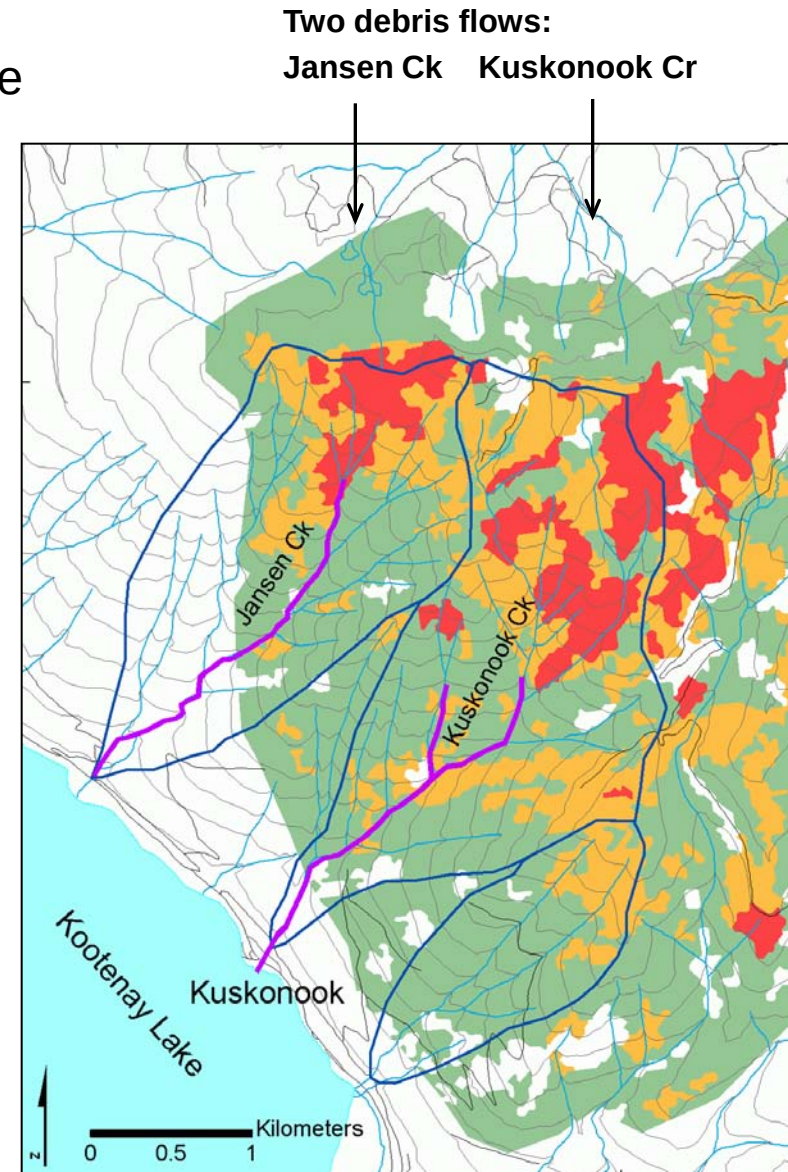


Events following the 2003 wildfires:

- Kuskonook debris flow, August 2004:
- Two houses destroyed, other buildings damaged, Highway 3A closed for several days.
- Water repellent soil in headwaters area, severely burned by 2003 fire, was identified as the main cause of the event.
- A high intensity rainstorm was the trigger.



- About 17% of the Kuskonook drainage, and 10% of Jansen, is high severity burn.
- Burn is concentrated in the headwaters area.
- The severe burn is mostly on a relatively gentle plateau, which drains into steep gullies below.
- The debris flows started at a discrete point in the channel, due to high peak discharge.



Kuskonook debris flows, 6-7 August 2004





Strong water repellency was present in most severely burned areas.



This led to widespread overland flow during a localized, high-intensity rainstorm.



Extensive, shallow, sheet and rill erosion occurred.

However, most of the debris flow volume was derived from the channel.

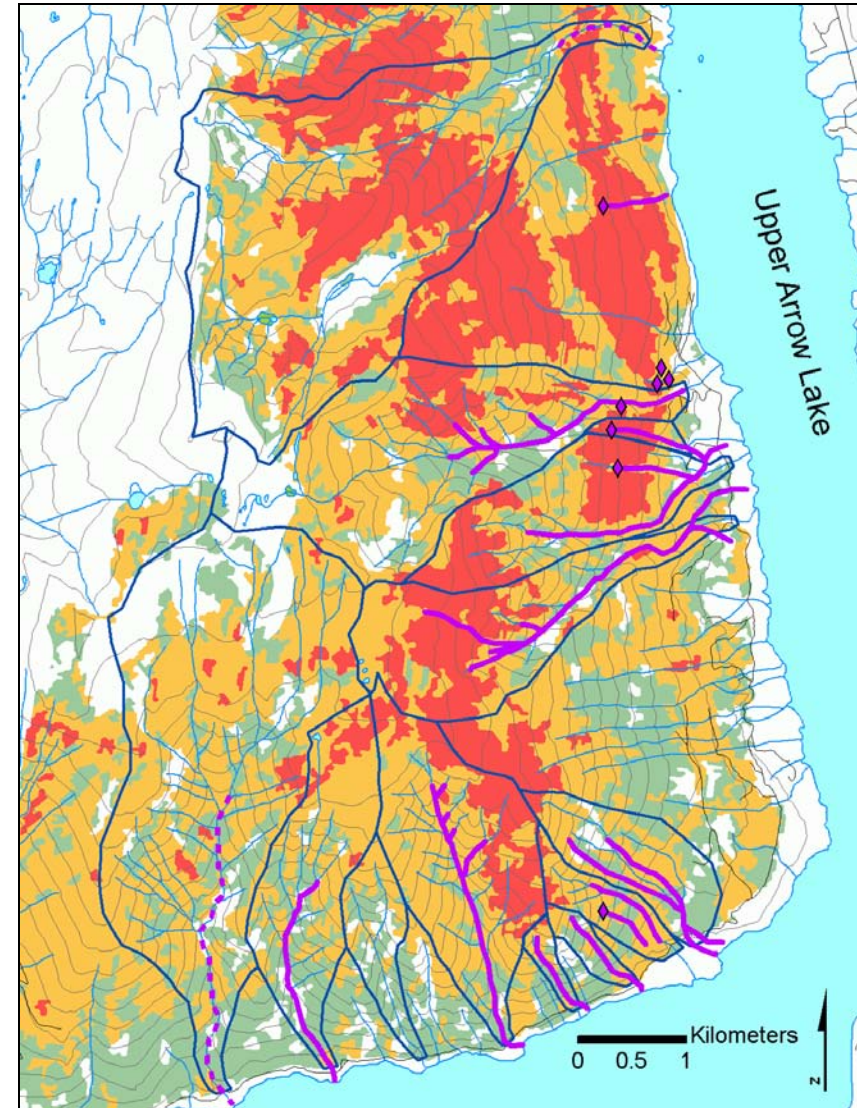


(A few days after the event)

Debris flow initiation point (four years later)

Mt. Ingersoll Fire (Burton):

15 debris flows and landslides occurred in and below the burn during a 3-day rainstorm in October 2005



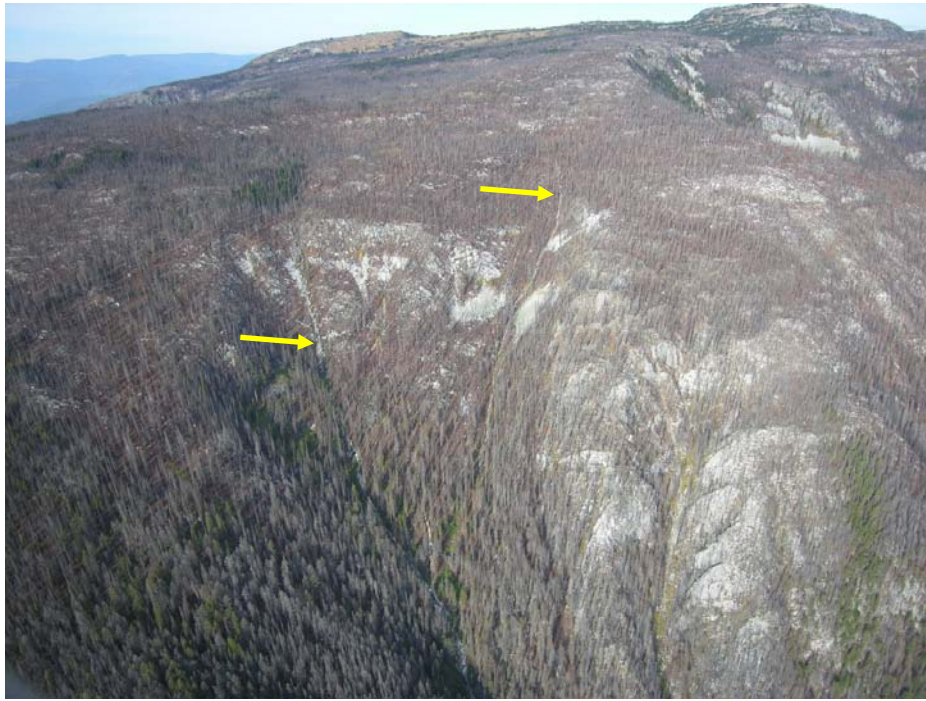
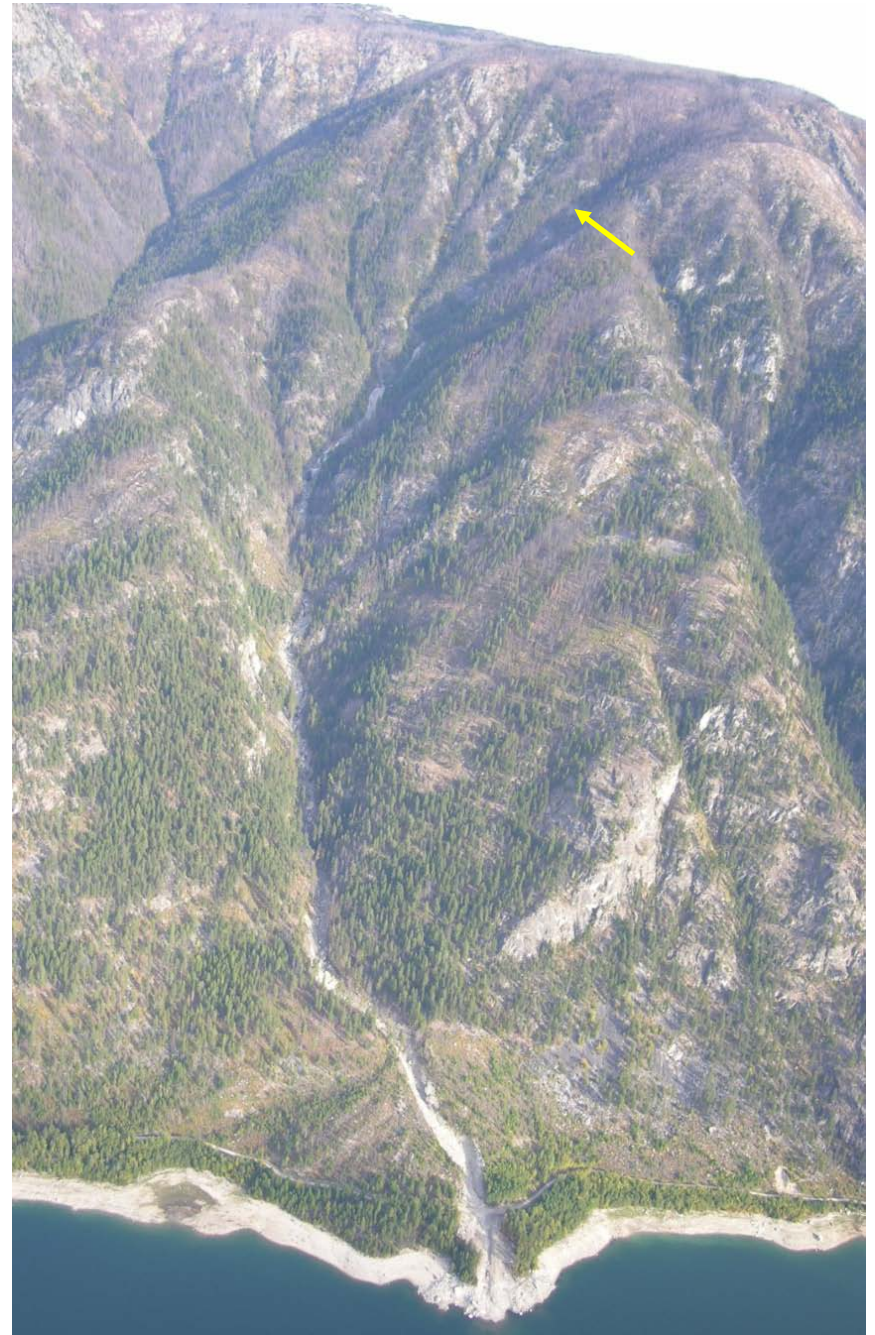
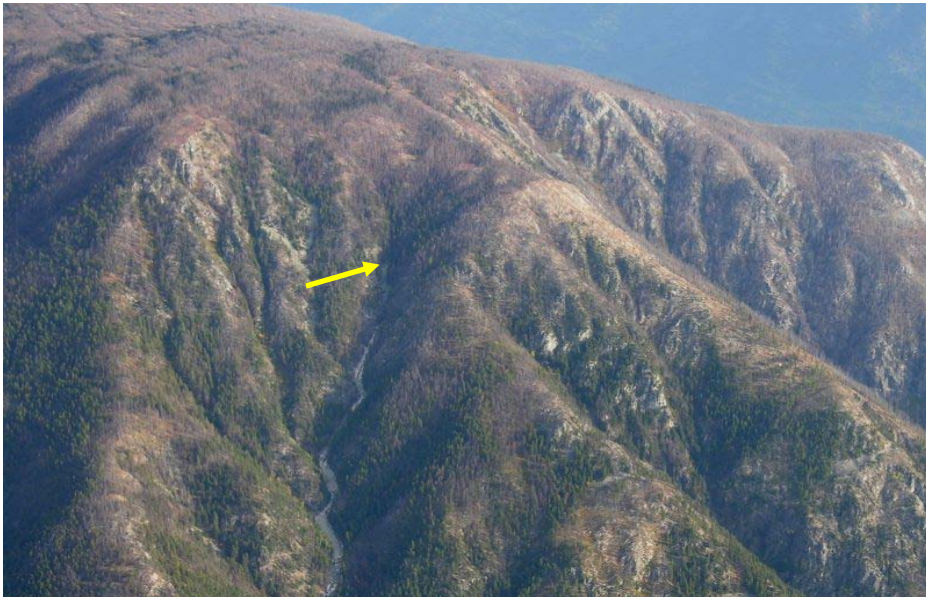


The largest debris flow was about 30,000 m³ (granitic material, very coarse-textured).



The forest floor was consumed in large parts of the high-elevation source area, although there was considerable recovery of vegetation two years after the fire.

Water repellency was present in patches, but was probably not a major factor.



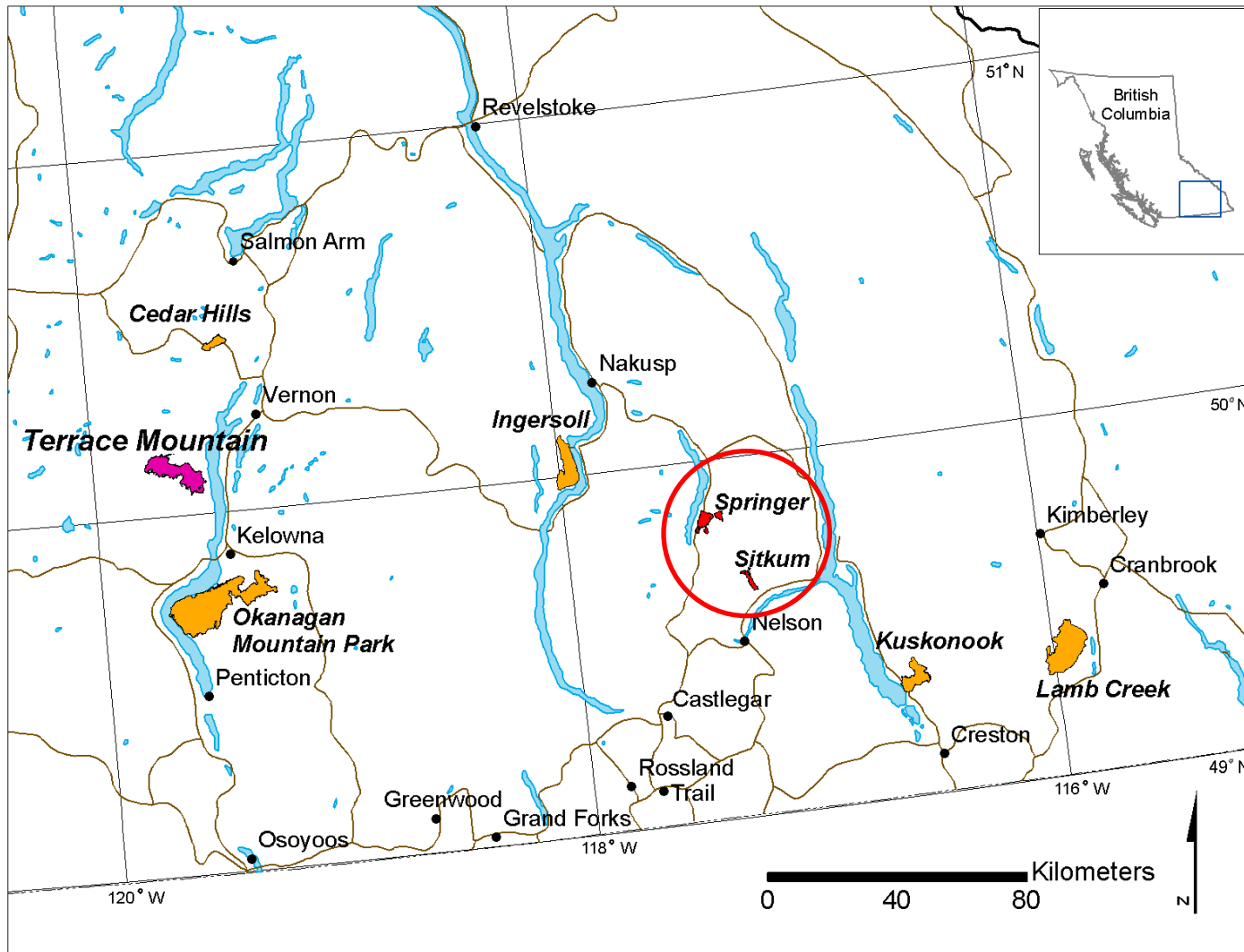


Drainage basins with a large contributing plateau area experienced debris flows; those without such areas did not.

The initiating rainfall event was a three-day frontal rainstorm, about 60 mm total, with no intensities over about 4 mm/h (estimated from radar). Melting of early-season snow may have contributed runoff.



Events following the 2007 and 2009 wildfires:



Orange – 2003 fires

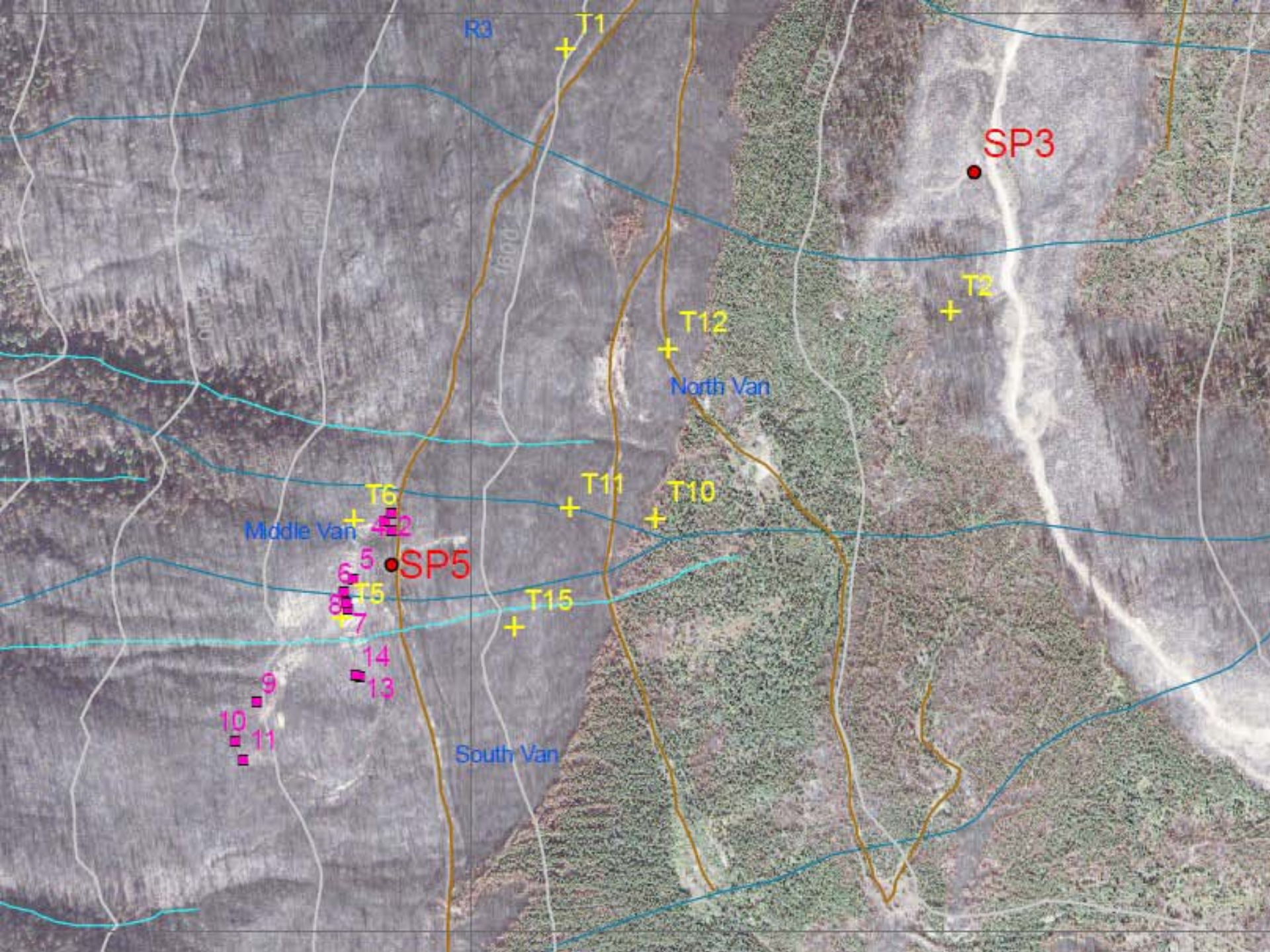
Red – 2007 fires

Purple – 2009 fires

Springer fire:

- field assessment when fire was contained, to identify risks
- further field work for research; silt fences, rain sim, transects







Springer fire: typical forest and soils

Forest – D fir, balsam fir, spruce, larch, cedar, hemlock, lodgepole pine, W white pine, shrub understory

Soils – developed on glacial till, sandy loam, sometimes ash-capped, often stony



2007 SPRINGER FIRE



2010

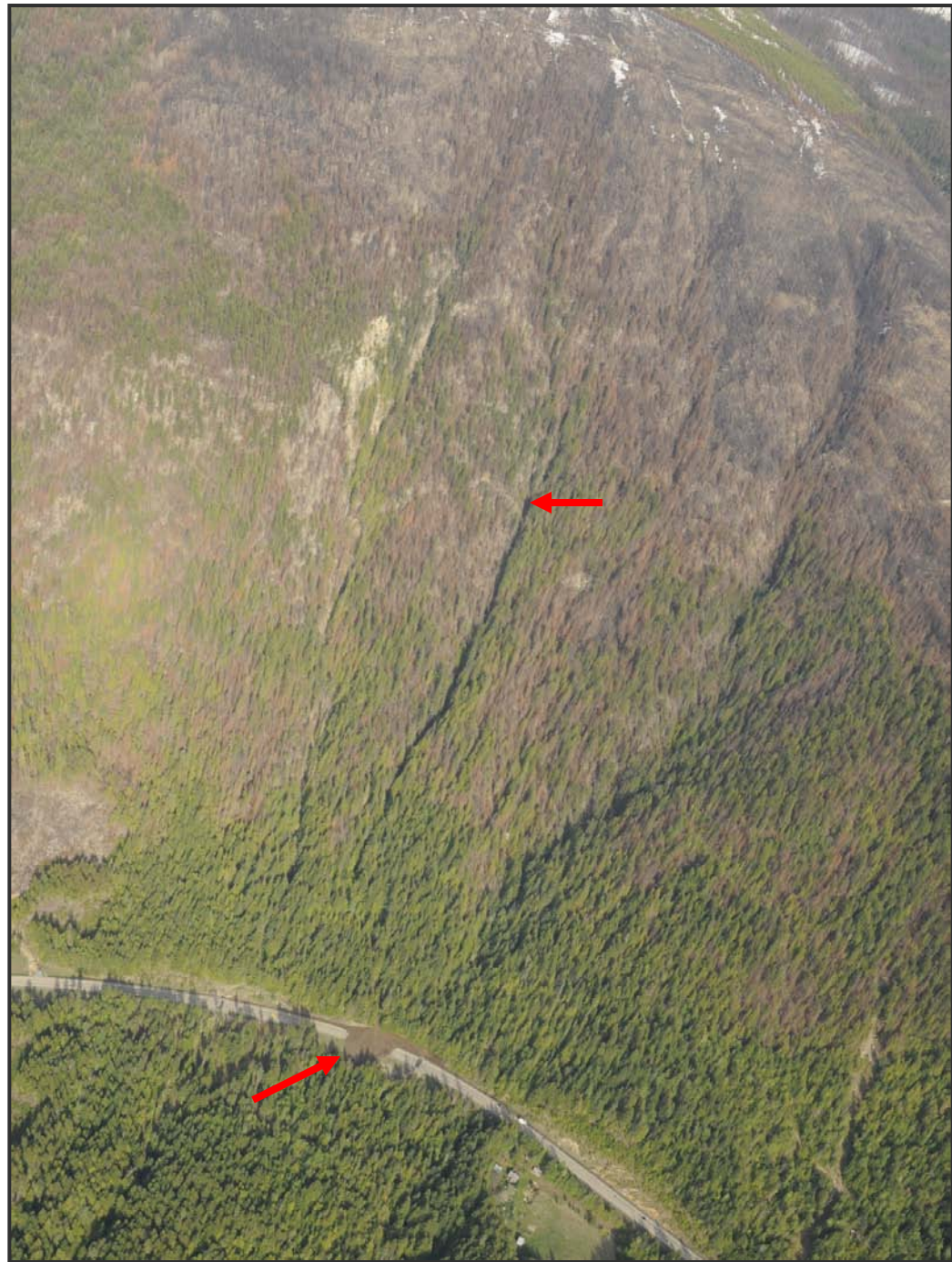
2011

2011

2008

2007 Springer fire: May 2008

- Large debris flow (5000 m³) during spring snowmelt
- increased snowmelt rate in burned area, and diversion by old logging roads, were causes





The debris flows originated at a discrete point in the channel, during snowmelt runoff peak flow. Sediment transport above this point was minimal.

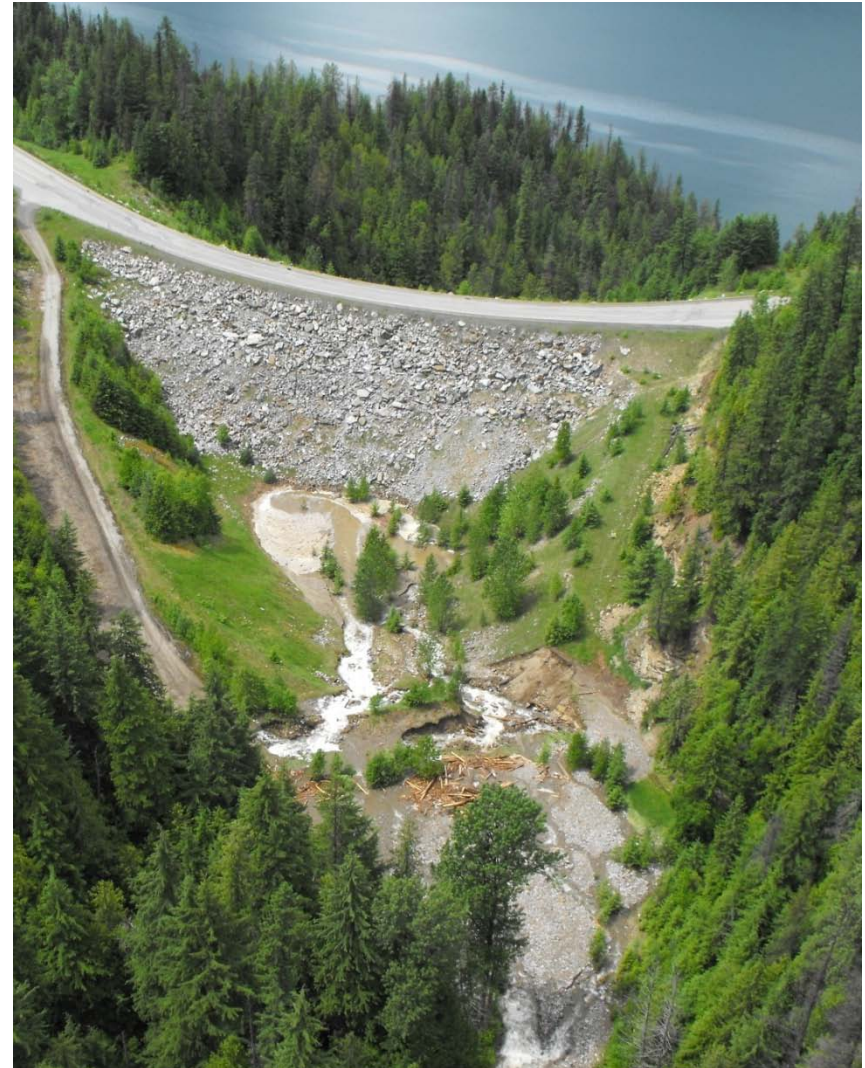


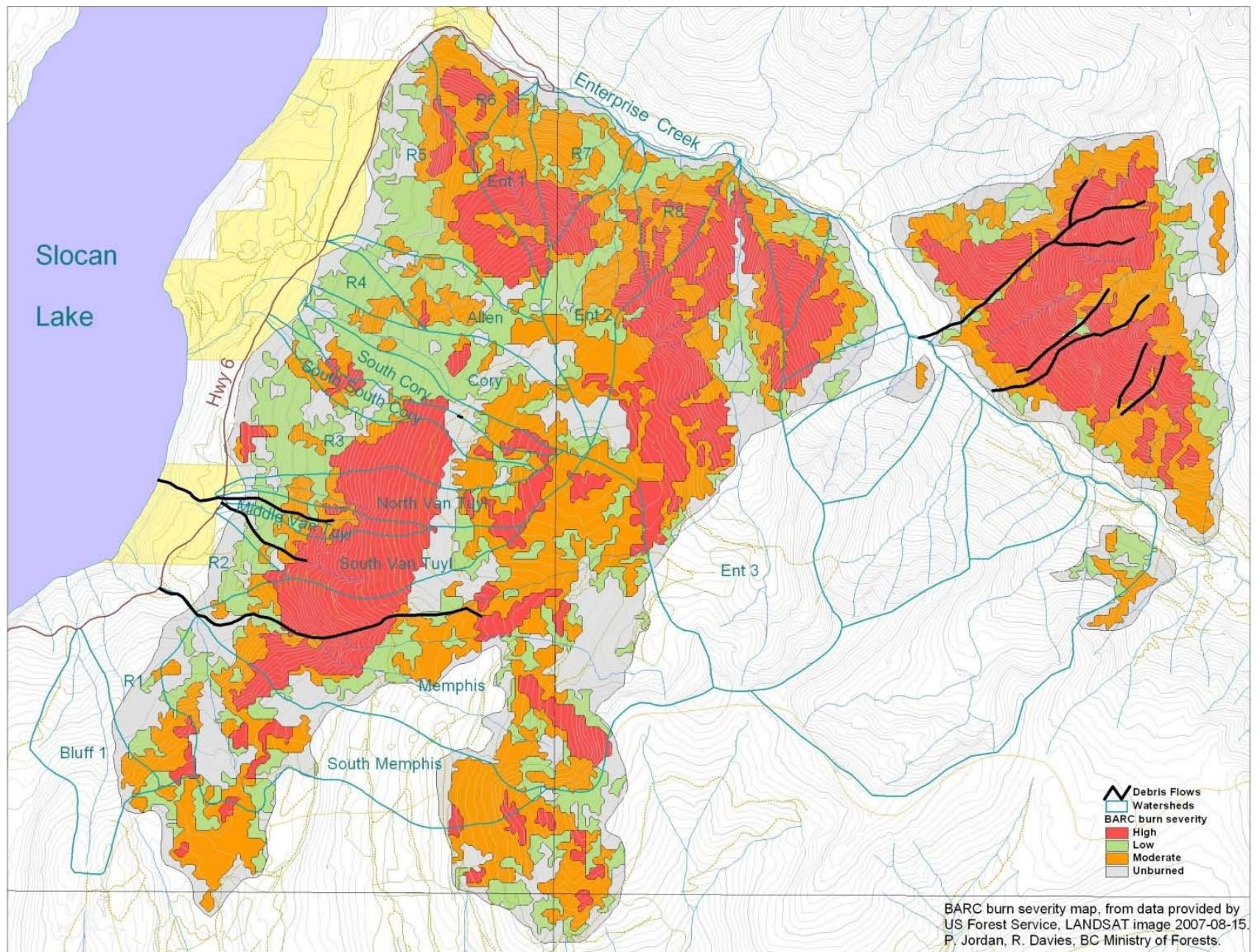


Catch basins constructed in 2007 adjacent to the highway; overflow culverts added.



Springer fire, spring 2011 (year 4) :
A large debris flow began as a shallow debris slide, due to high groundwater levels – also possible decay of tree root strength

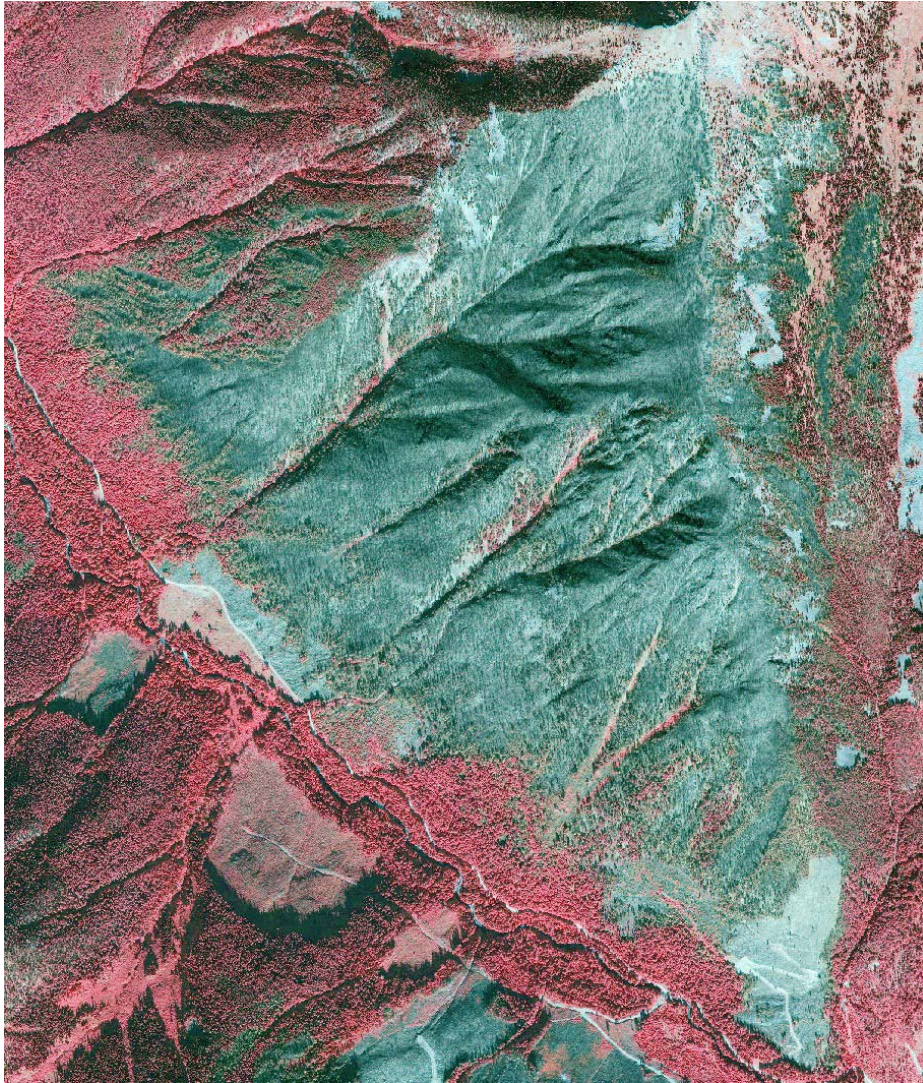
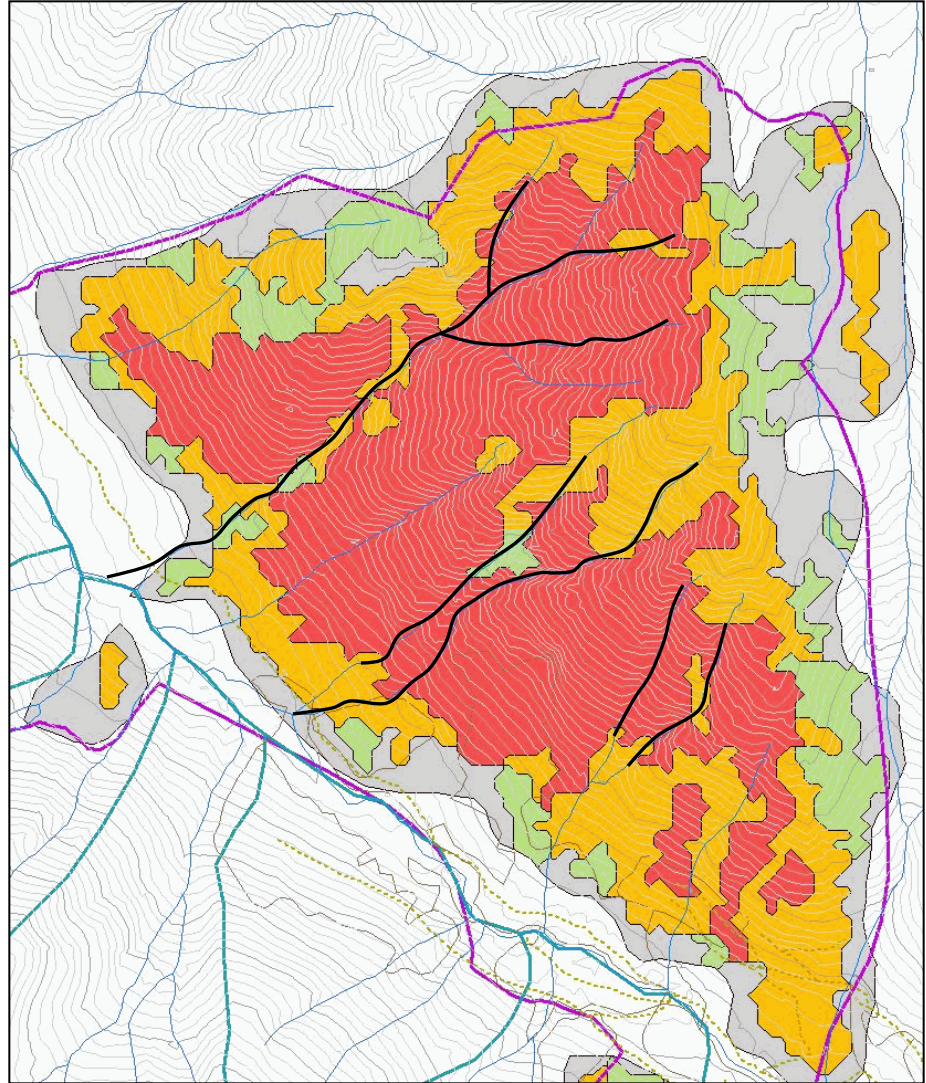






Springer fire, Enterprise Creek

Multiple debris flow events in 2007, 2008, 2009



Springer fire, Enterprise Creek:

- Multiple starting points in steep headwaters gullies
- Rockfall colluvium is the source material
- Loss of stabilizing large organic debris in gullies and on slopes may have been an important contributing factor



Small area of gently sloping, high soil burn severity, on ridgetop – may have contributed overland flow to gullies below.

Terrace Mtn fire, 2009



Mitigation: three general categories

- Road engineering treatments – improvements to road drainage (e.g. culverts, cross-ditches)
- Protective structures – dikes, berms, check-dams etc.
- Broadcast treatments such as straw mulching



Spreading straw mulch by hand, Terrace Mtn fire



Berms and cross-ditches to protect houses, Terrace Mtn fire

All three of these treatment types were applied. In April 2010, a small debris flow occurred in the gully below the treatment area. It was diverted by the berm and did not hit the house.



House below debris
flow gully

Terrace Mtn fire – identification of high-risk catchment



Summary of initiating mechanisms: (total of 37 events after 2003, 2007 and 2009 fires)

- | | |
|--|----|
| • Peak flow in channel (runoff-triggered) | 25 |
| • Debris slide/avalanche (infiltration-triggered) | 9 |
| • Sediment bulking – in steep gully headwalls | 2 |
| • Sediment bulking – from distributed soil erosion | 1 |

Season of occurrence :

- | | |
|---|----|
| • Spring (snowmelt) | 9 |
| • Summer (short-duration high-intensity rainstorms) | 13 |
| • Fall (long-duration rainstorms) | 15 |

Some observations on causes of the post-wildfire events:

- in 2003, extensive water repellency was noted in the burned areas
- unusually high soil burn severity may have been due to extreme drought conditions in 2003
- most of the post-2003 events occurred during short, very high-intensity, rainstorms
- many of the post-2007 events occurred during spring snowmelt
- old logging roads were implicated in some events

Conclusions (1):

- There are three main mechanisms for initiation of post-wildfire debris flows in this region:
 - peak flow in channels (most common)
 - infiltration-caused debris slides (less common)
 - sediment bulking from soil or channel erosion (rare).
- Post-wildfire events have occurred in 3 meteorological circumstances:
 - high-intensity summer rainstorms
 - low-intensity fall frontal rainstorms
 - spring snowmelt.
- The likelihood of debris flows in susceptible channels can be greatly increased after a fire, under certain conditions:
 - high soil burn severity (which is favoured by dry antecedent weather conditions) and soil water repellency
 - severely burned area in the upper part of a drainage
 - plateau contributing area draining into a steep channel or gully.

Conclusions (2):

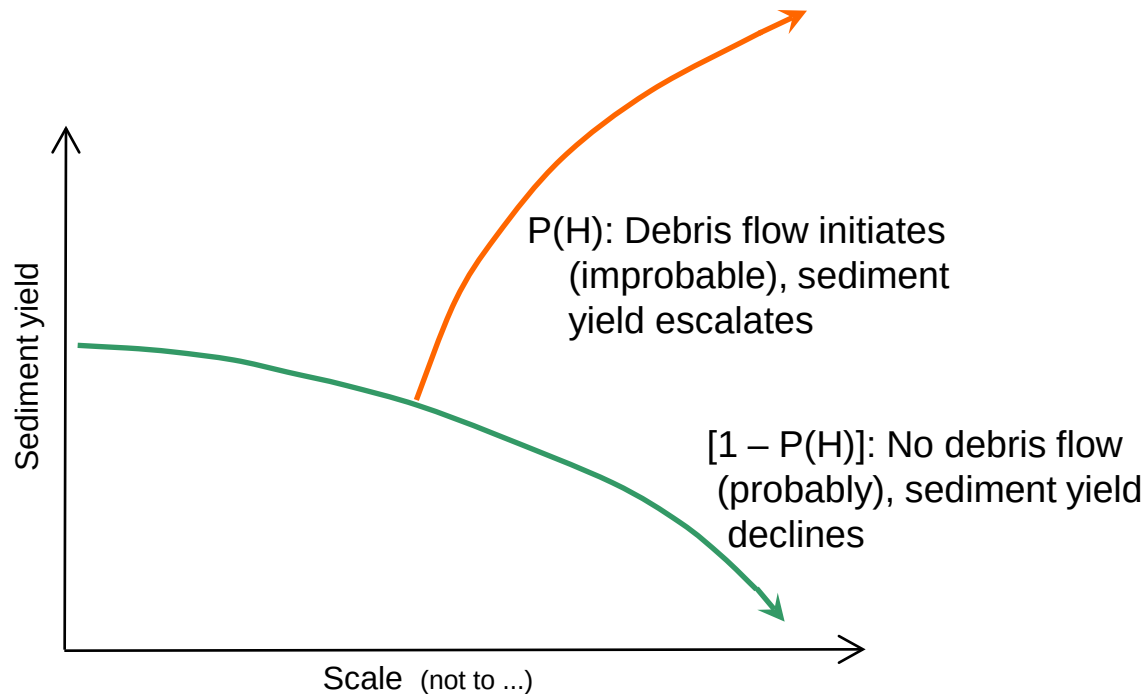
- The distribution of high-severity burn in the watershed is important – severe burn at upper elevations causes the greatest hazard.
- “Gentle-over-steep” topography, where a severely burned plateau area drains into a steep channel or gully, appears to present a greater hazard than steeper, concave-up, topography.
- Forest removal (equivalent to clearcut) due to severe wildfire can approach 100%, which can lead to an increased hazard of spring snowmelt-triggered events.
- Post-wildfire debris flows usually occur in gullies and channels which were subject to hazard under pre-fire conditions, but the likelihood of occurrence can be much greater (or, the return period much shorter) after wildfire.
- The greatest hazard from high-intensity rainfall is in the first 2 to 3 years after fire, until vegetation is re-established. However, the hazard of spring events due to snowmelt can persist for decades.

Conclusions (3): Geomorphic significance of post-wildfire debris flows

Typical post-wildfire sediment yields (very approximate, order of magnitude; applicable to this study area only)

(Caution: only 3 years of record; no unusually large or intense rainstorms have occurred)

- Source area (selected small plots, high soil burn severity): **1 Mg/ha**
- Catchment scale (no large-scale mass movement): **0.001 – 0.01 Mg/ha**
- Debris flows in small catchments: **100 Mg/ha**
(most sediment comes from channel incision, not from burned area)



Debris flows: likelihood of occurrence (= hazard)

- logging and roads – increased 5-10 X
- post-wildfire – increased 10-100 times (if susceptible terrain exists and soil burn severity is high)

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