Land Use Changes and Impacts on Water Resources

Hans Schreier
Faculty of Land & Food Systems
University of British Columbia Vancouver, B.C.

Introduction to Land Use Changes

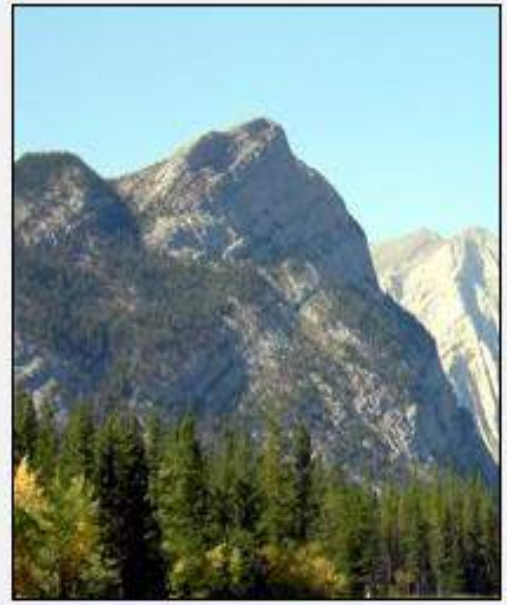
Forestry → **Land Use Change & Impacts on Water**

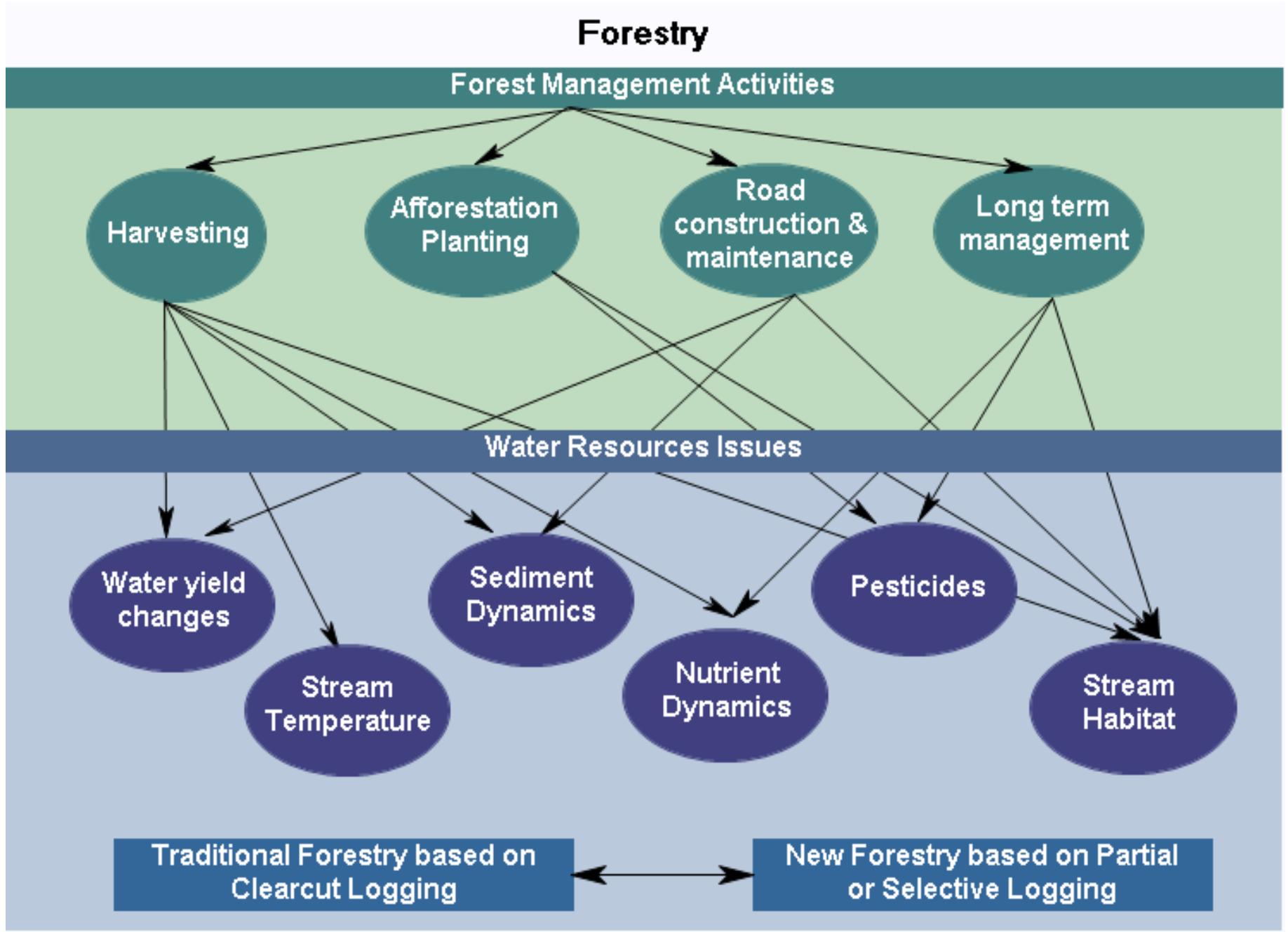
Mining → **Land Use Change & Impacts on Water**

Drivers of Environmental Change

Land Use Changes in Mountains

Pressure to produce Hydro-Power
More Agricultural Intensification
More Summer and Winter Tourism
More Forest Use & Management
Fire and Disease




Forestry
Forest Management Activities
Harvesting
Afforestation Planting
Road construction & maintenance
Long term management
Water Resources Issues
Water yield changes
Stream Temperature
Sediment Dynamics
Nutrient Dynamics
Pesticides
Stream Habitat
Traditional Forestry based on Clearcut Logging
New Forestry based on Partial or Selective Logging

Factors Impacting Mountain Forest Cover

Increases

Out-Migration by People Abandoning Agriculture

Conservation Efforts Afforestation

Natural Expansion in Elevation due to Climate Warming

Mainly Due to Human Activities

Mainly Due to Climate Change

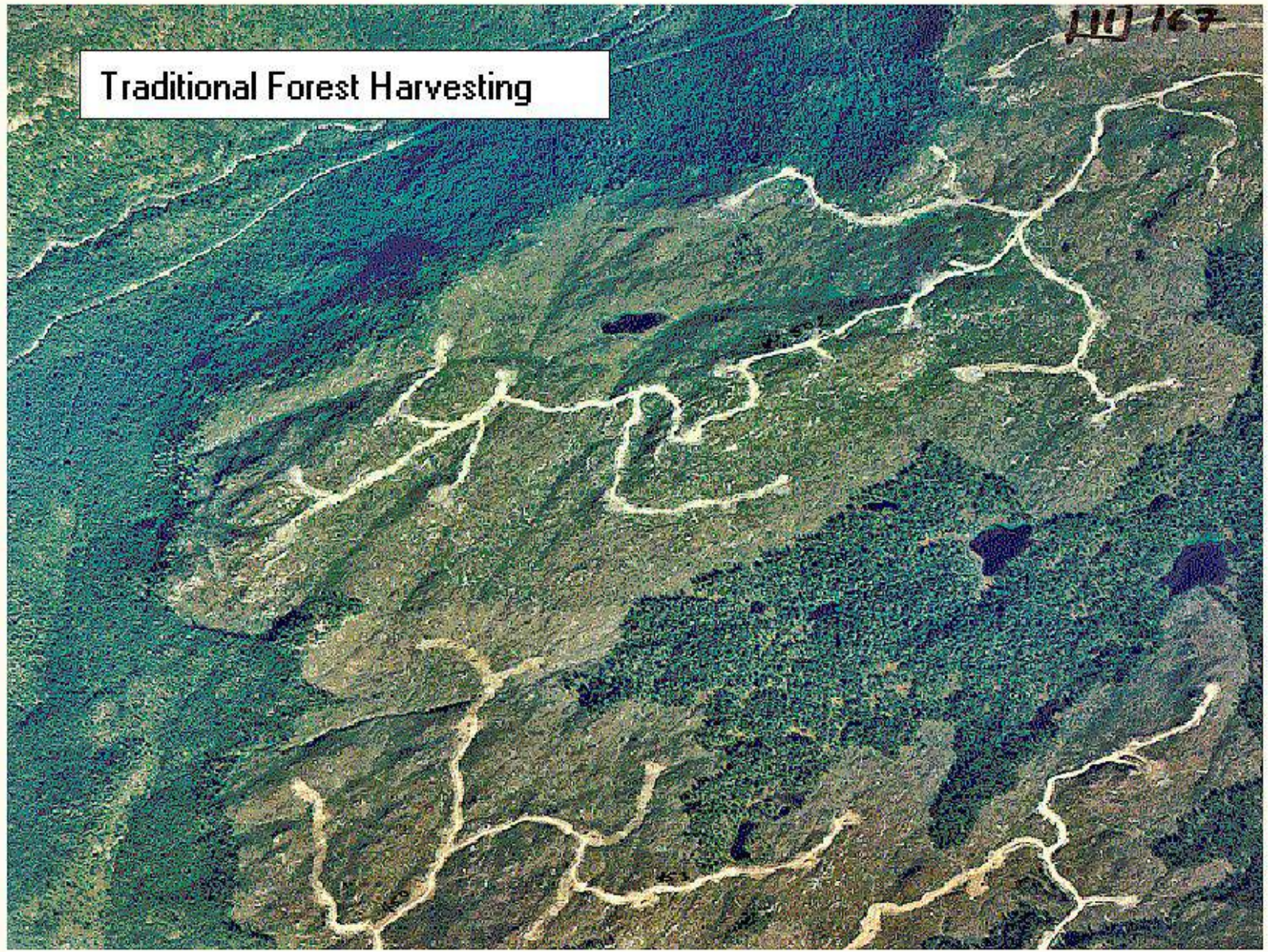
Decreases

Agricultural Expansion Recreation, Mining

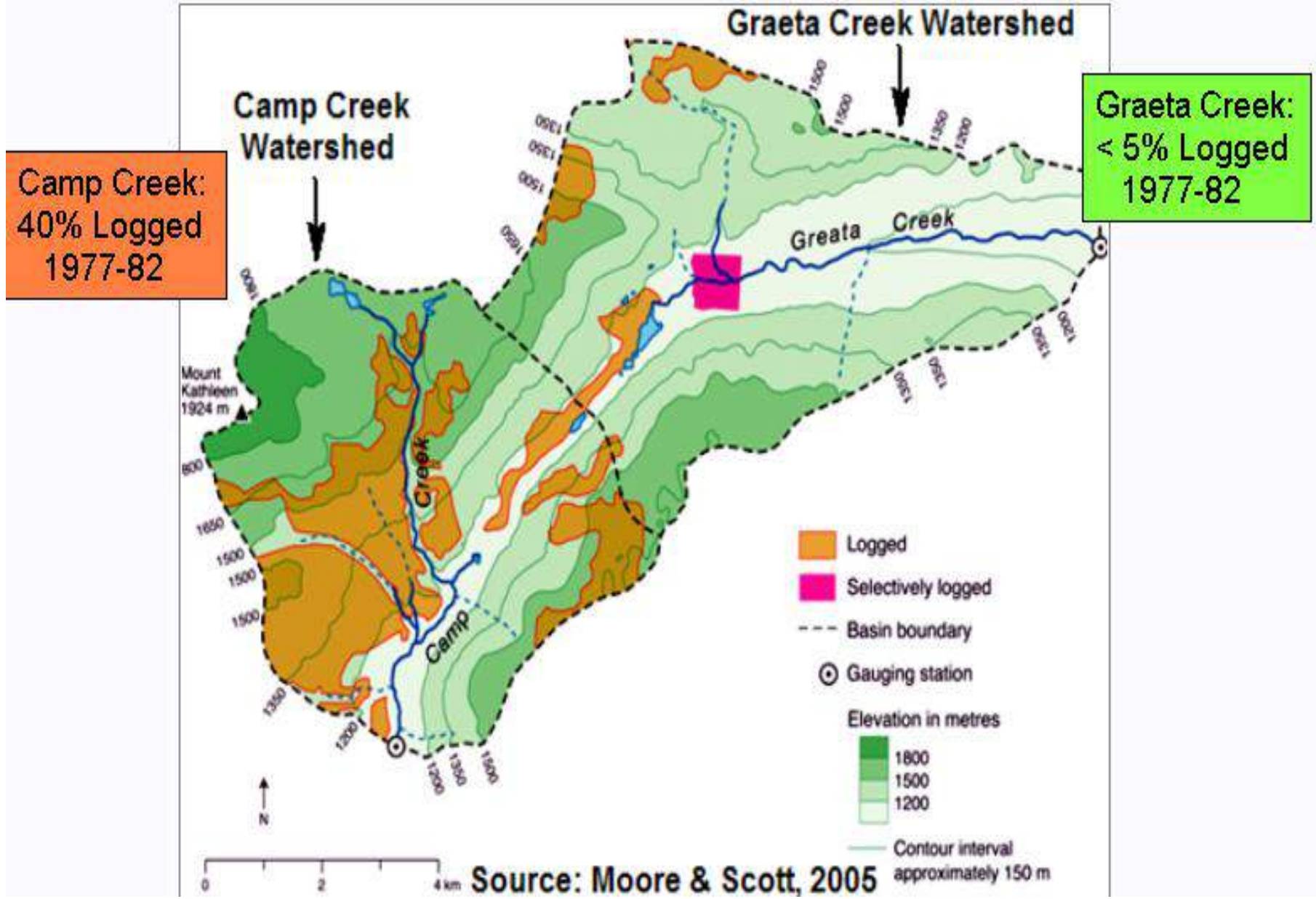
Forest Harvesting Degradation by Overuse

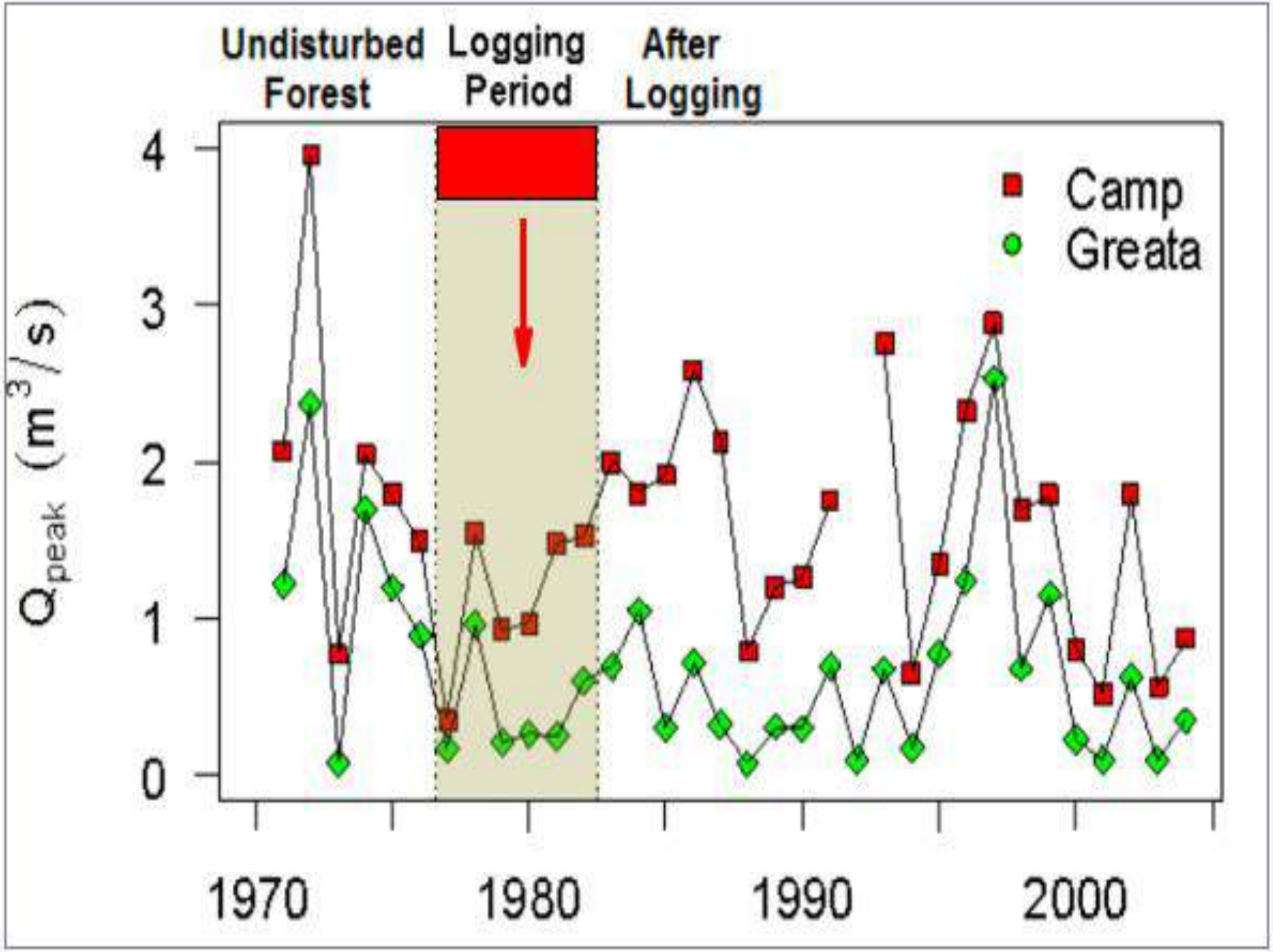
Fires, Wind Storms, Insects, Avalanches Warming

Forestry Issues



Example of a Paired Watershed Analysis
Comparing the Hydrological Response: Before, During and after Logging




Undisturbed Forest
Logging Period
After Logging
Camp
Greata
Q_{peak} (m^3/s)
0
1
2
3
4
1970
1980
1990
2000

Resource roads are the greatest source of sediments

British Columbia has:

200,000 km of paved roads but

450,000-500,000 km of resource roads

Forest Fires

Forest fire impacts on watershed

- Creates Hydrophobisity
- Reduces soil infiltration rates
- Lead to increased Erosion & sediment transport
- Increased streamflow
- Nutrient flush (short term increase in Nitrate)
- Increase in Total Organic Carbon (TOC) in water

Pine Beetles and Fire

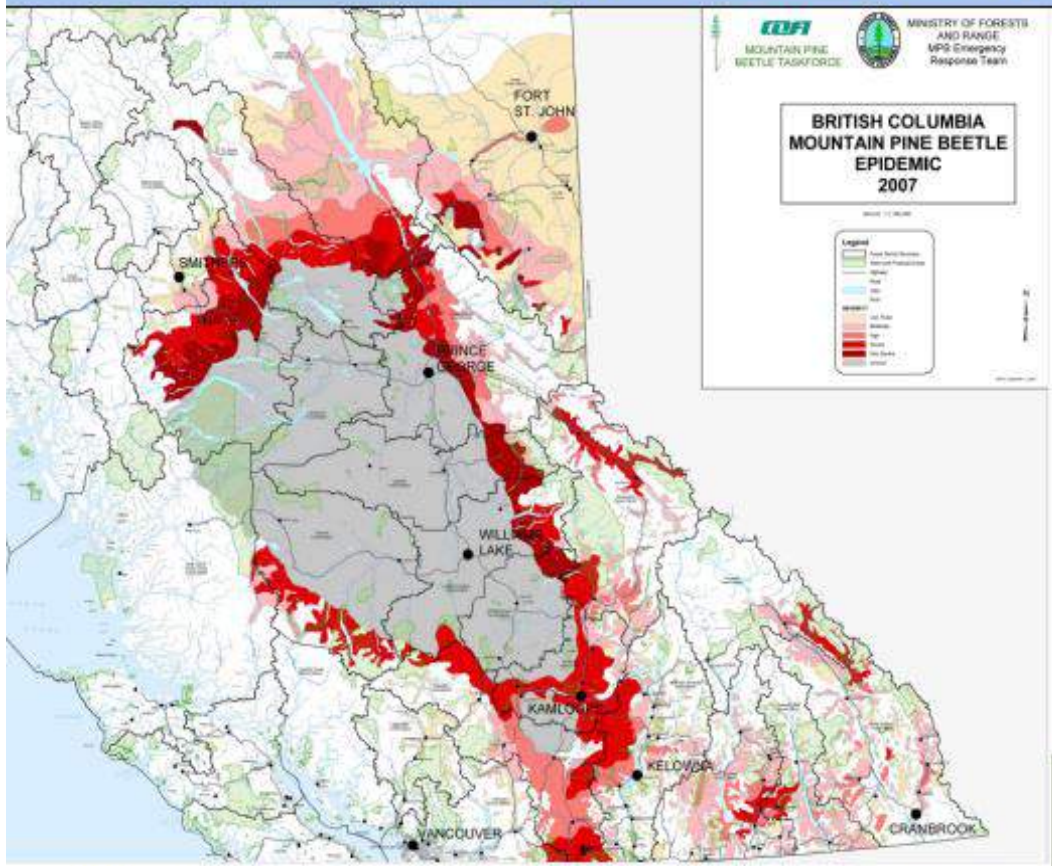
Estimated Area Affected in between 1999 and 2014: 18 Million ha (2 times the size of Austria)

Impact since 1999: 800 Mio m^3 of timber

Dilemma:

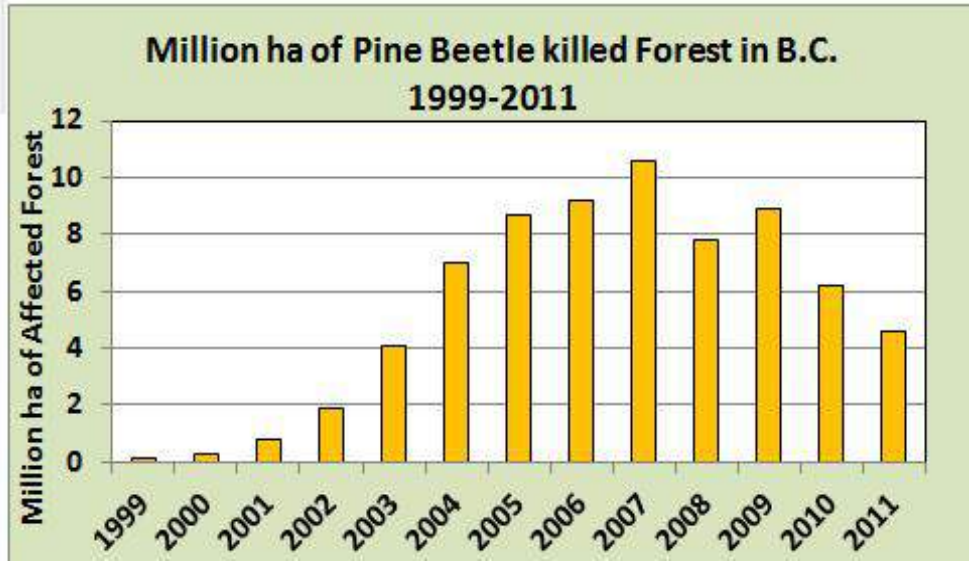
If harvested within 2-3 years the wood can still be used
If left standing it creates a forest fire hazard
In both cases it is a problem for Carbon Balance
The impact on the hydrological cycle is uncertain

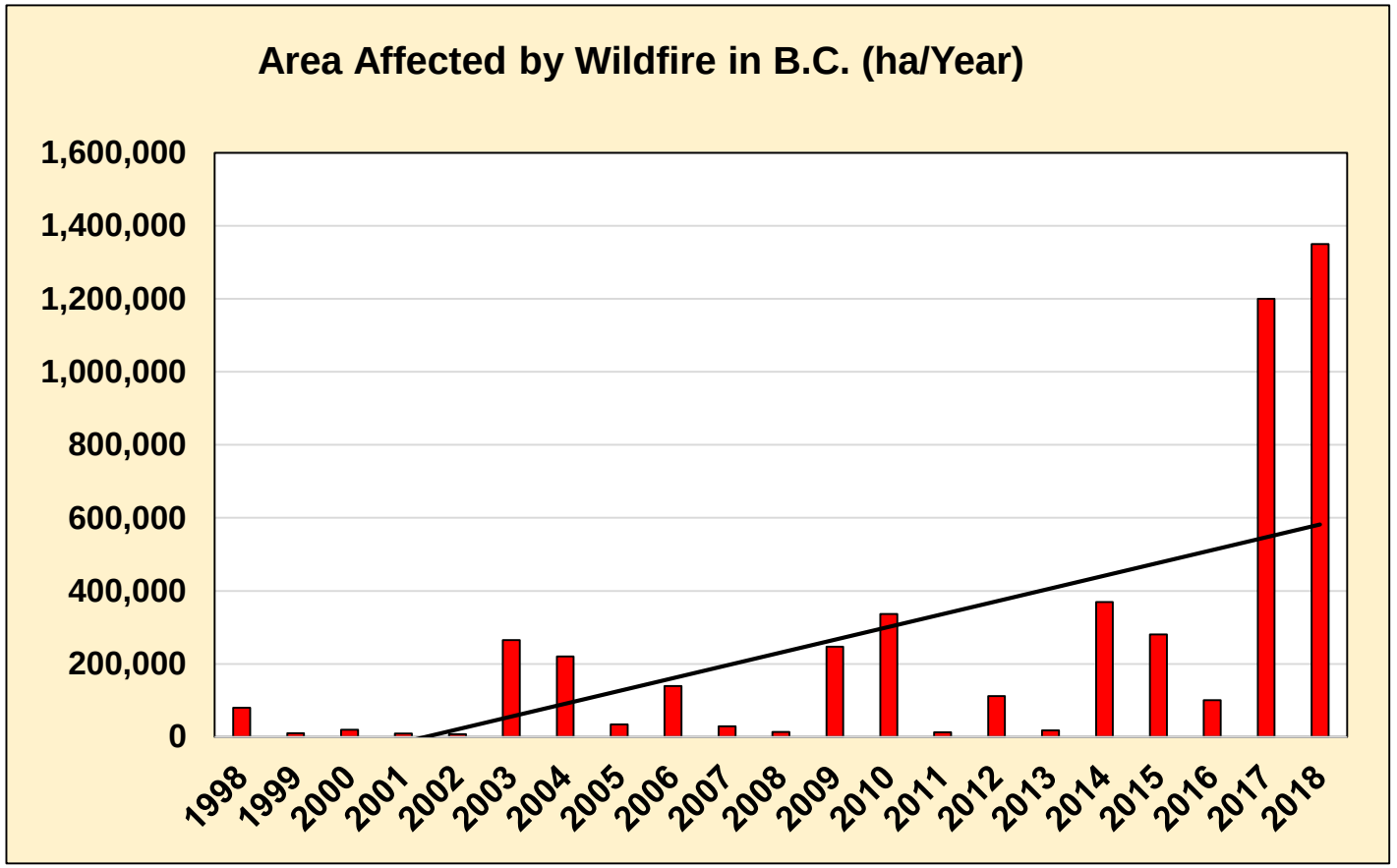
Pine Beetle Infestation in B.C.



By 2014: 60 % of Merchantable Pine Killed
Cumulative Losses: 800 Million m3 of Timber

Dilemma:
Leave infested trees but increase fire risk. or
Harvest timber within 2 years of infestation =
Wood can still be used.




Area Affected by Wildfire in B.C. (ha/Year)
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018

Weather: Denve

THE DENVER POST

DENVER AND THE WEST

Spruce beetles moving into more Colorado forests, survey shows

While size of forests devastated by pine beetles is dwindling, the number of acres hit by spruce beetles continues to climb

By David Migoya
The Denver Post

POSTED: 01/28/2016 11:53:26 AM MST | UPDATED: 18 DAYS AGO 16 COMMENTS

The devastation caused by spruce beetles across Colorado forests accelerated for a fourth consecutive year, according to a new survey, while the once widespread infestation of mountain pine beetles has largely subsided.

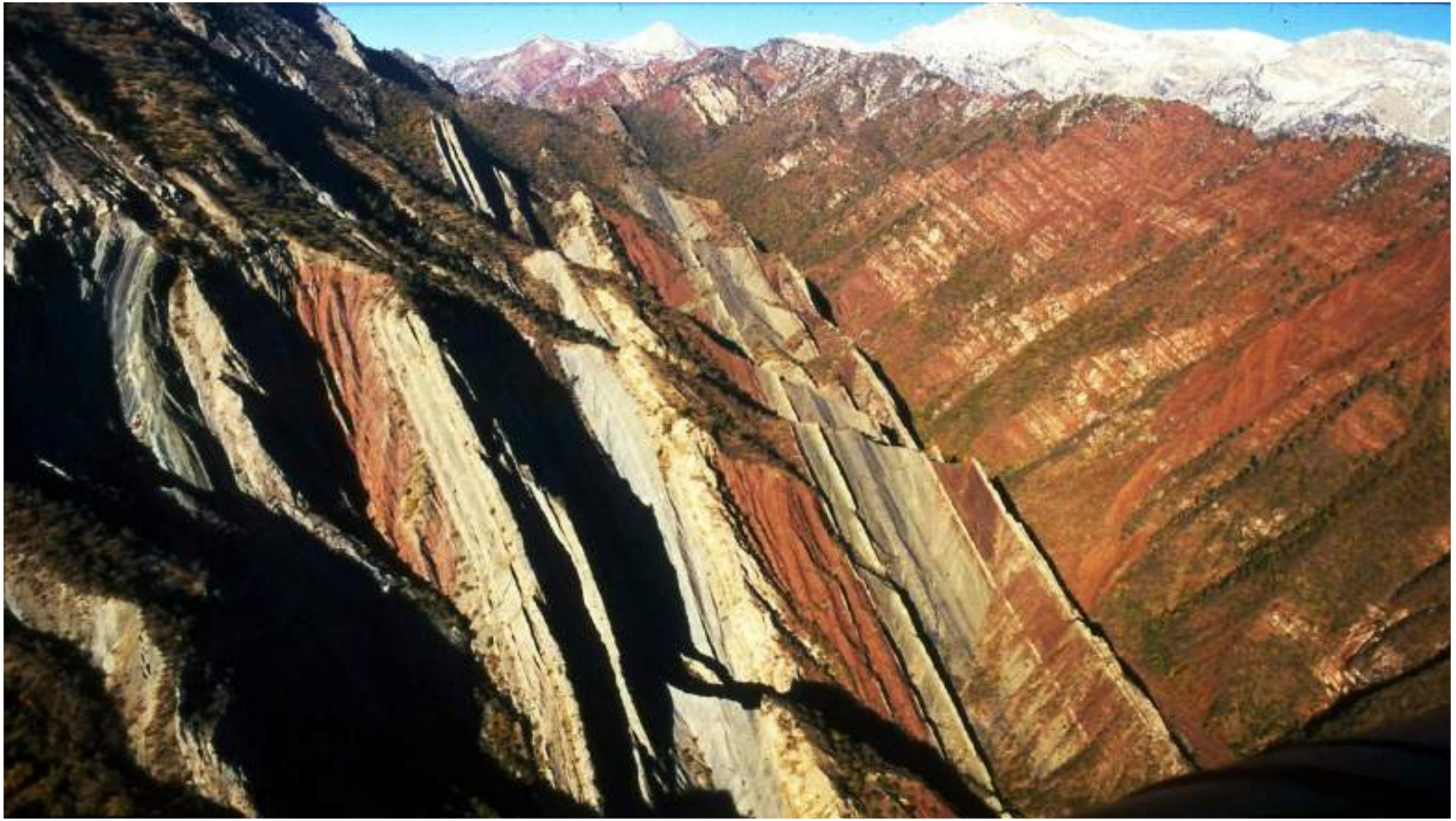
The spruce beetle was found to have newly infected 182,000 acres of previously unaffected forests, bringing the number of acres currently impacted to 409,000 across the state, according to the annual aerial survey conducted by the U.S. Forest Service and the Colorado State Forest Service.

Pine trees in the White River National Forest near Frisco, Colo., glow rusty red after being killed by the mountain pinebeetle in this July 6, 2005, file photo. The pine beetle infestation that ran across Colorado, Wyoming and South Dakota has affected an area roughly the size of Massachusetts. (*Ed Andrieski, Associated Press*)

Currently impacted Spruce Dominated Forests in the USA in 2016:

409 000 Acres (165 500ha)

Water Issues in Mining



Mining in Mountains

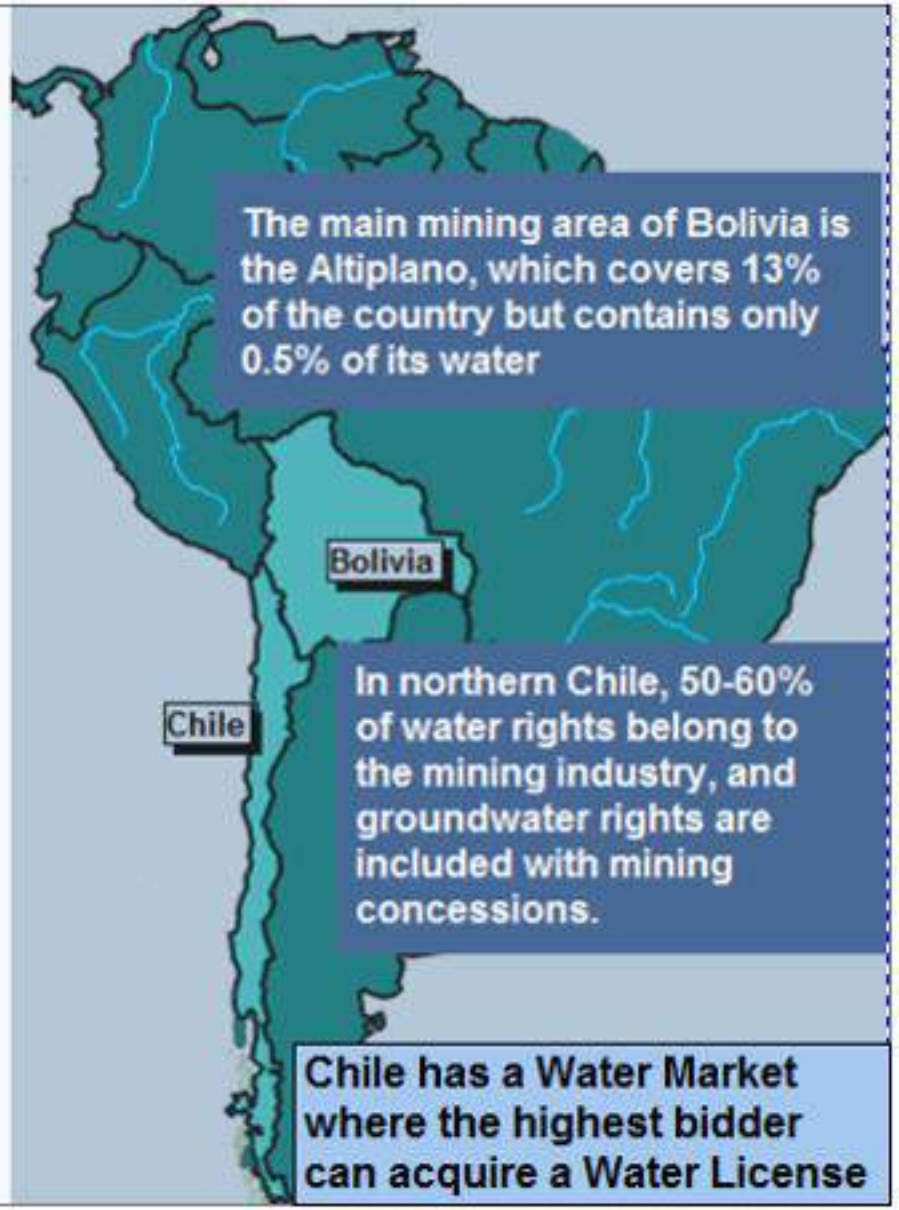
The water use and release problems of mining are typically accentuated by the areas where mining is located.

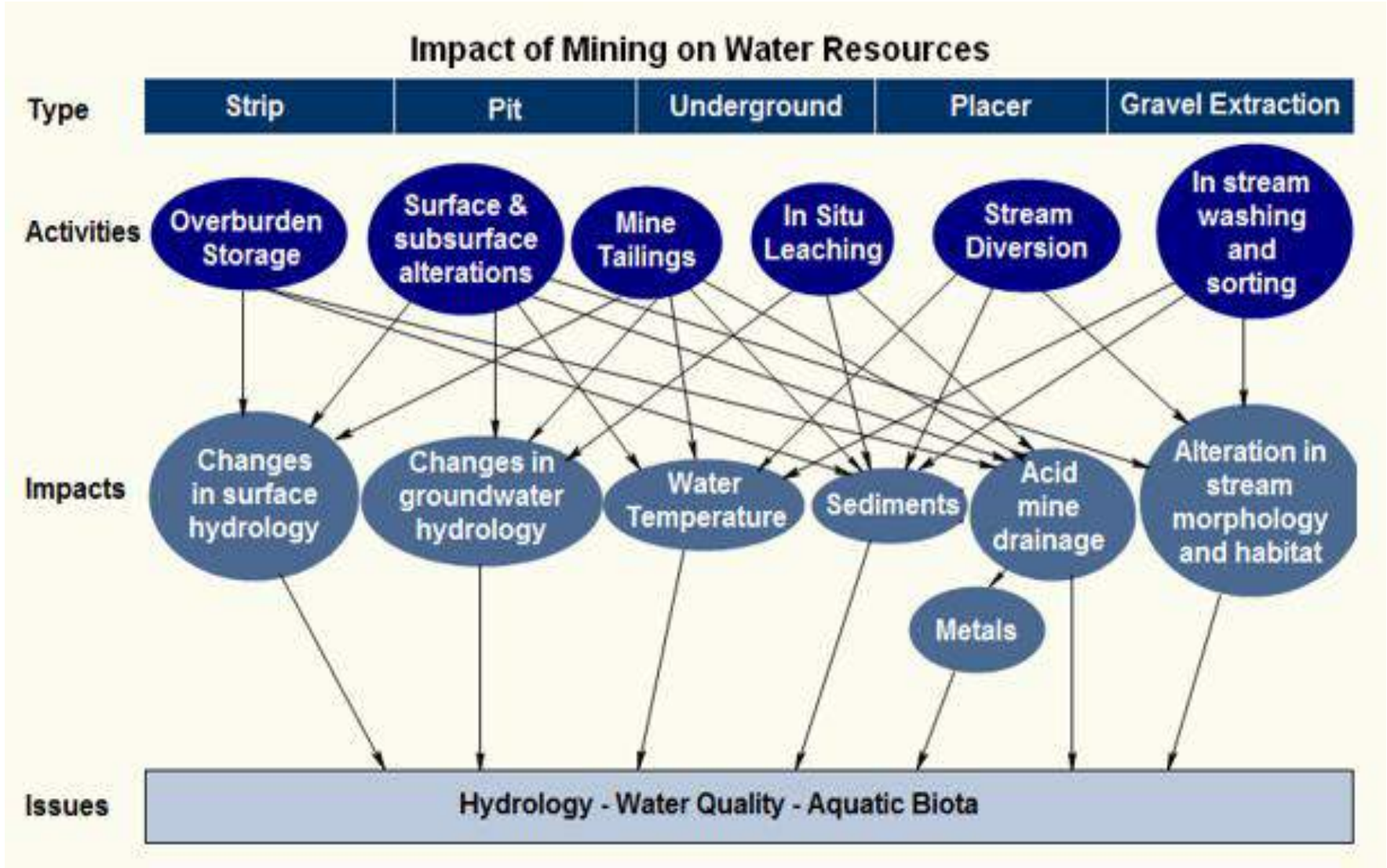
Generally, mines do not require large quantities of water.

Problematic mine locations:

- Mountainous areas where water courses are small
- Arid areas (the mines can then take a large proportion of all easily available water and deprive local farmers and downstream communities of water that they have been using)
- Areas of exceptional natural beauty
- Areas protected for natural or historical heritage
- Traditional lands of indigenous peoples (the patterns of water use for these people are critical to their culture and livelihood

Water is critical to the maintenance of these areas and there are often conflicts between the mining companies and the local communities




Impact of Mining on Water Resources
Type
Strip
Pit
Underground
Placer
Gravel Extraction
Activities
Overburden Storage
Surface & subsurface alterations
Mine Tailings
In Situ Leaching
Stream Diversion
In stream washing and sorting
Impacts
Changes in surface hydrology
Changes in groundwater hydrology
Water Temperature
Sediments
Acid mine drainage
Alteration in stream morphology and habitat
Metals
Issues
Hydrology - Water Quality - Aquatic Biota

Two Major Problems:
Acid Mine Drainage
Metal Sulfide (most common form in B.C. Mines) oxidize when exposed to air and produce acidic runoff that dissolves Metals

Increase Sediments leading to turbidity problems that affects aquatic organisms and stream productivity

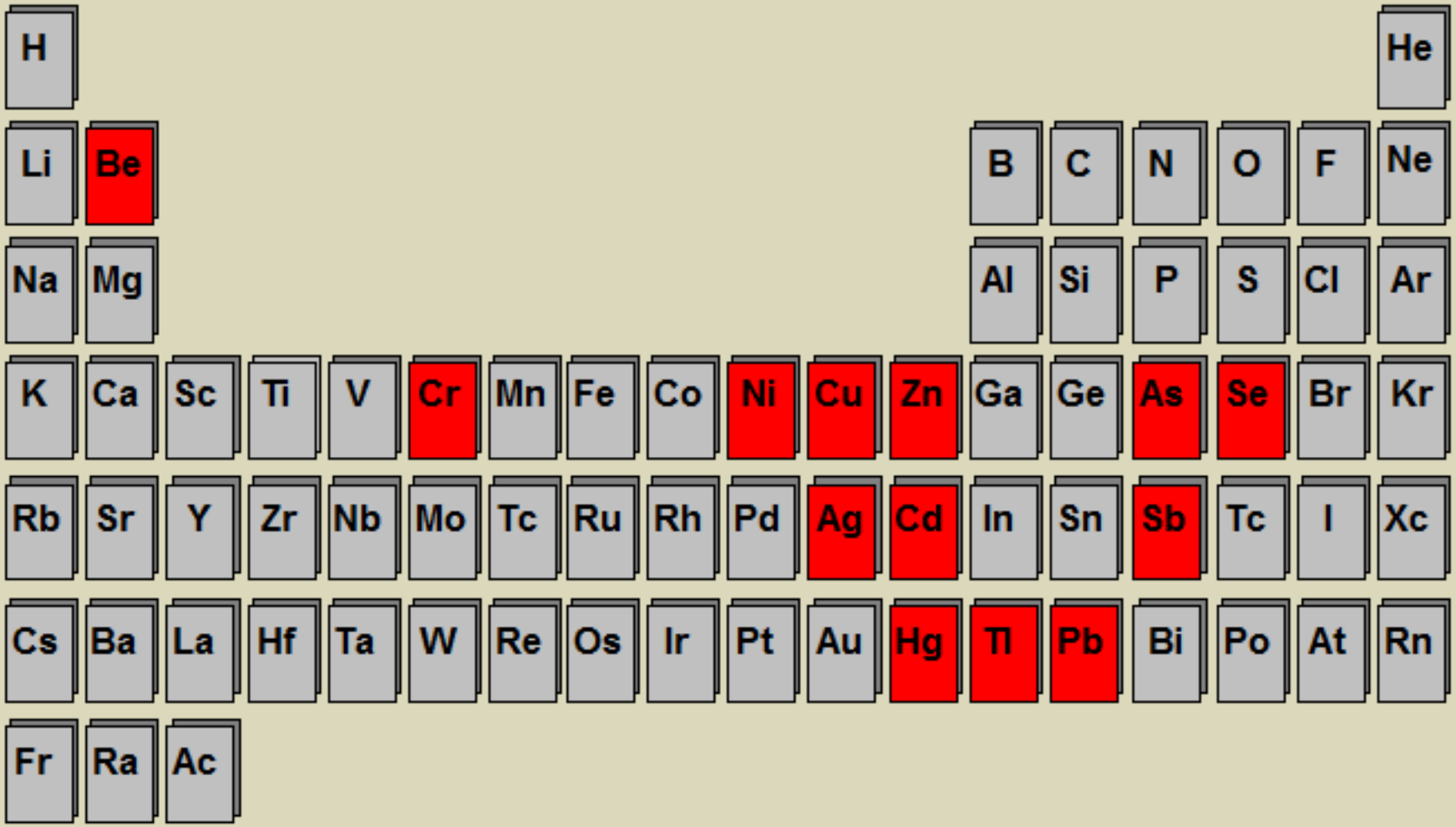
Activities and Processes

Land surface modification	Crushing and screening	Stockpiling overburden
Subsurface changes	Chemical extractions	Tailing pond construction
Modifications of Drainage	Floatation processes	Collection and
Removal of overburden	Smelting & washing	Surface reconfiguration
Moving & depositing materials	In-situ leaching	Revegetation

Environmental & Hydrological Challenges

Habitat changes	Dust generation	Erosion & sediment control
Surface erosion (wind & water)	Leaching of contaminants	Contain acid drainage
Alteration to hydrology	Acid mine drainage	Control subsurface leachates
Land Subsidence	Storage & contain chemicals	Minimize hydrological impacts
Changes to local climate	Water & Air pollution	Control land instability

Periodic table of elements with metals of interest highlighted



Acid Mine Drainage

Process

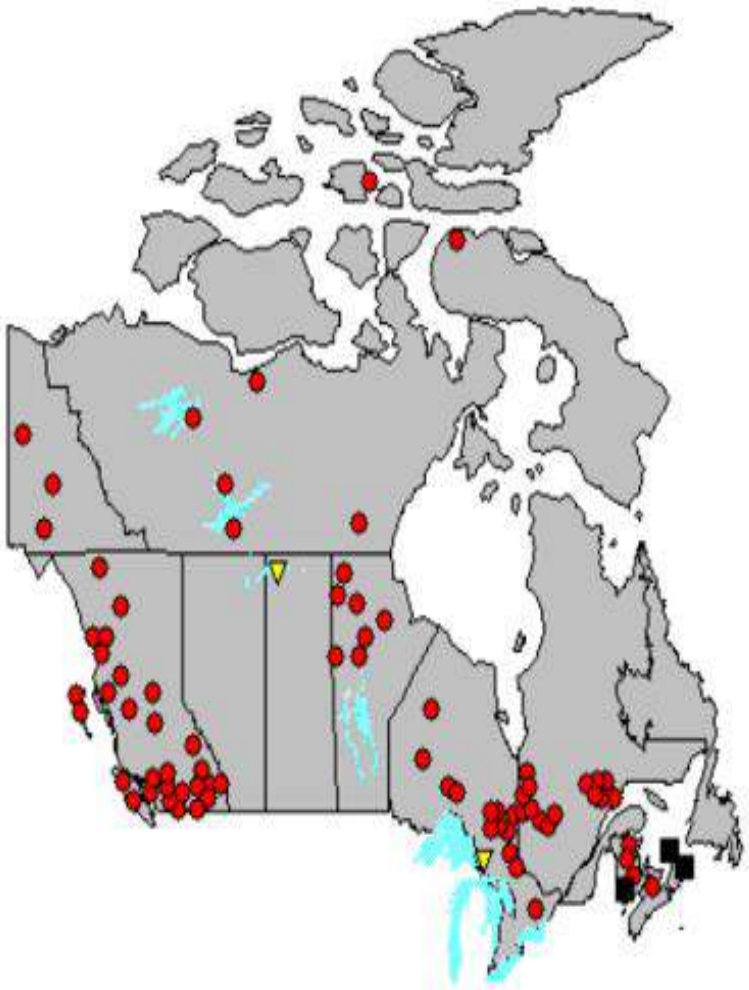
Most Metals occur as Metal-Sulfide (CuS, ZnS, PbS)
When exposed to Air --- Oxidize to form H_2SO_4
Fe +3 + S + H2O --- 8 FE+2 + SO4 + H+
Enhanced by Bacterial Action (Thiobacillius)

Impacts

Creates Acidity (pH < 4.0) Lethal to Organisms
Fe Hydroxides coats sediments & organisms
Metals become Soluble & Bioavailable
Impacts most Organisms (Food Chain Effect)

Controls

Create Anaerobic Conditions (Water Saturation)
Collect & Treat Leachate & Treat with Lime
Inactivate Bacterial Action
Time Issue: Depends on Buffer Capacity of Rocks



Acid mine drainage areas in Canada

- Metal mines
- Uranium mines
- Coal mines

Source: Environment Canada

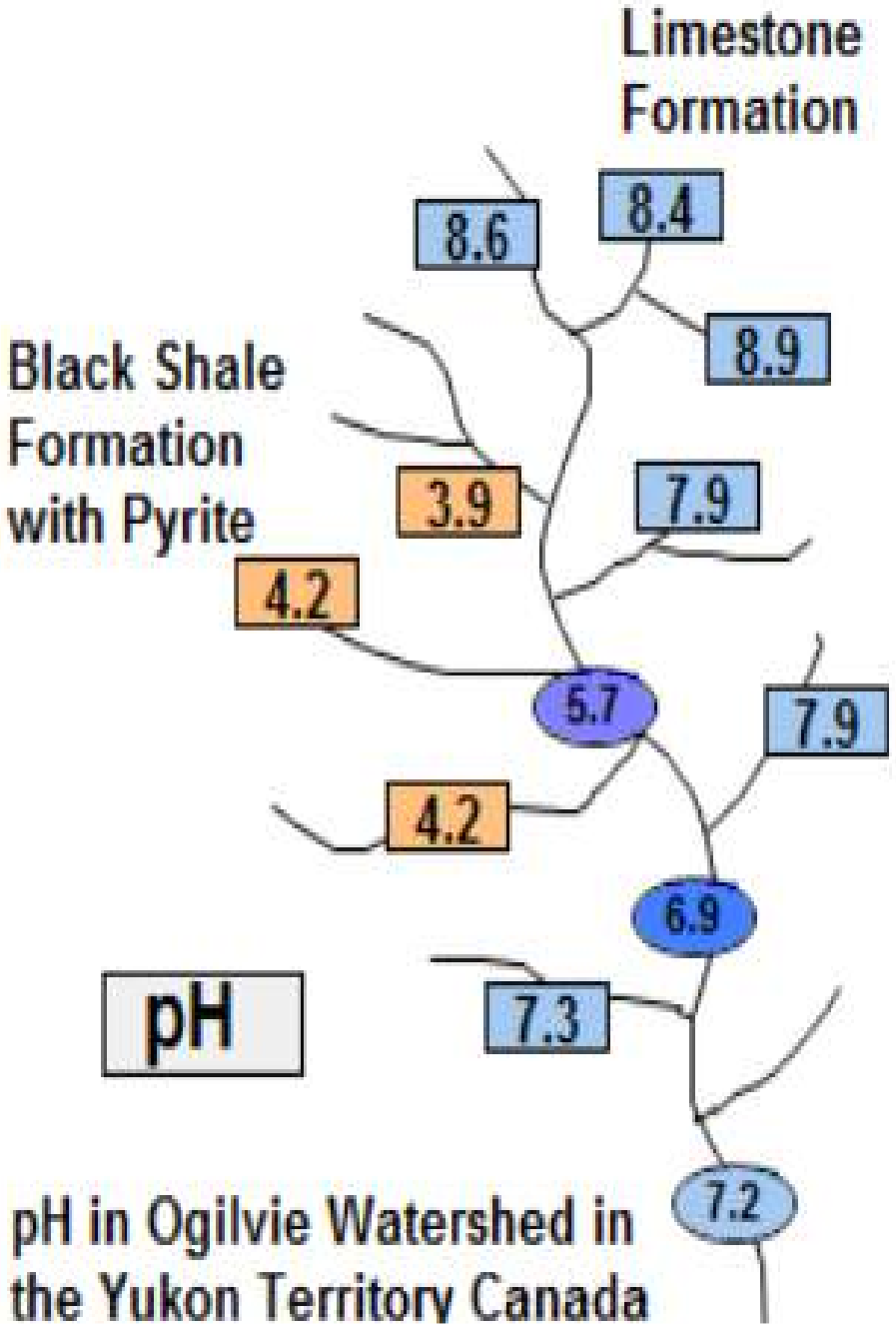
Chemical Reactions:

$$Fe^{+2} \rightarrow Fe^{+3} + e$$

(Iron II) (Iron III)

$$8\,Fe^{+3} + S^{--} + 4\,H_2O \rightarrow 8\,Fe^{+2} + SO_4^{--} + 8\,H^{+}$$

(Iron III) (Sulphide) (Iron II) (Sulphuric Acid)



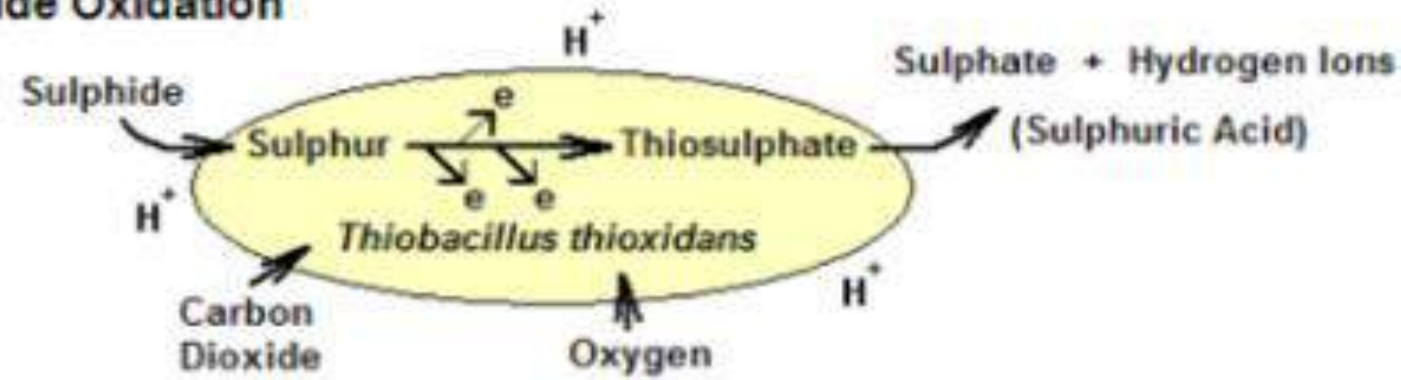
pH in Ogilvie Watershed in the Yukon Territory Canada

Aerobic Bacteria: Need oxygen

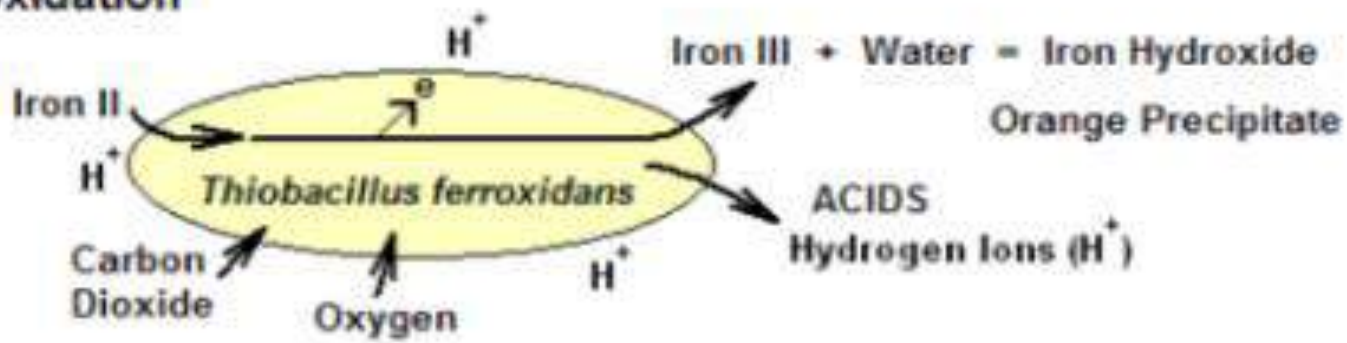
Chemoautotrophic Bacteria:derive energy from oxidation, CO_2 source

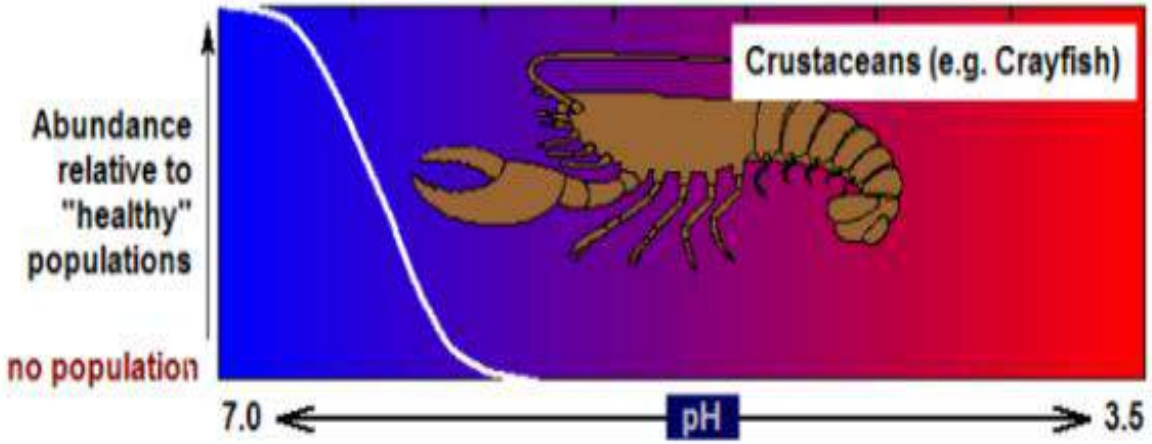
When conditions are favorable for growth, the bacteria can accelerate acid production.

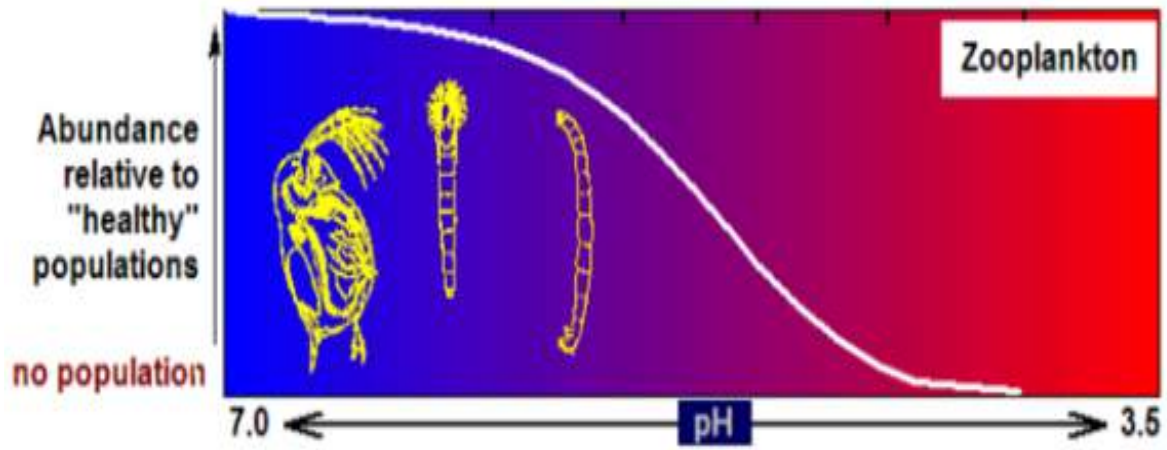
Sulphide Oxidation

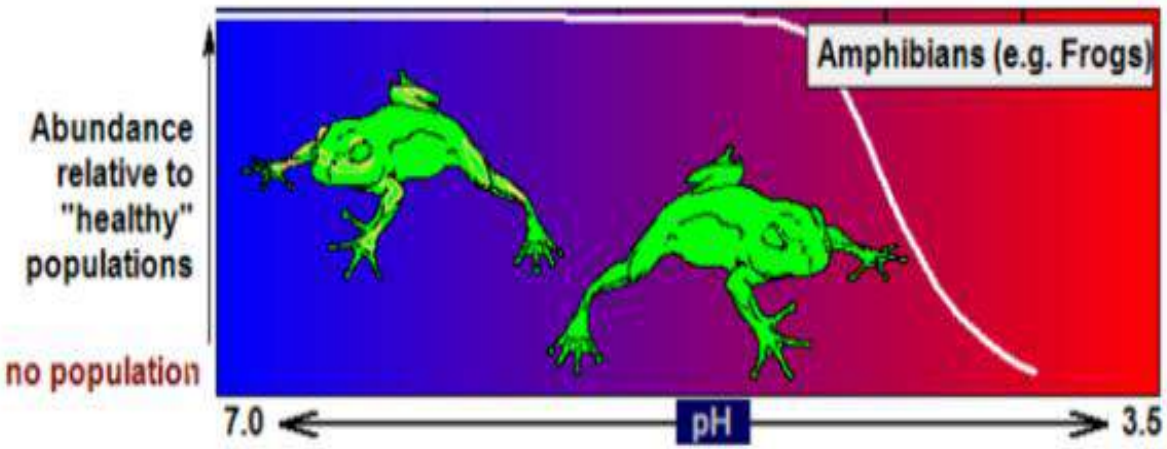


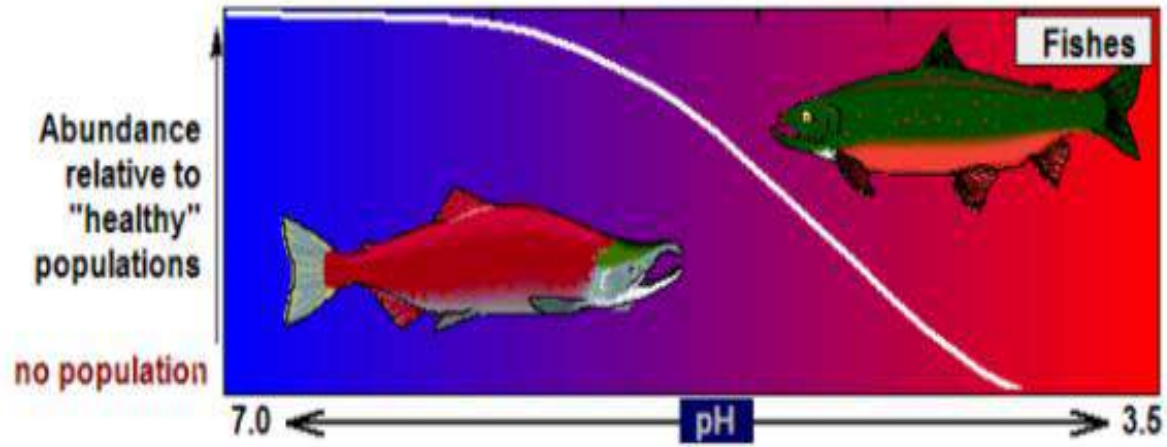
Iron Oxidation




Crustaceans (e.g. Crayfish)
Abundance relative to "healthy" populations
no population
7.0
pH
3.5


Zooplankton
Abundance relative to "healthy" populations
no population
7.0
pH
3.5


Amphibians (e.g. Frogs)
Abundance relative to "healthy" populations
no population
7.0
pH
3.5


Fishes
Abundance relative to "healthy" populations
no population
7.0
pH
3.5

Gold Mining

More than 50 Million People are Engaged in Artisanal Gold Mining

Process

Toxic Chemicals used to amalgamate Gold (Au)
Heating the Amalgamate Releases Hg into the Air

Impacts

These Chemical are Lethal to most Organisms
Hg can easily be mobilized and volatilized
Methys Mercury is highly toxic and mobile

Controls

Artisanal Gold Mining is poorly regulated
Control Amalgamation Process
Concentrate Sediment generated by Placer Mining
Flotation, Magnet, Separation using Gravity

The Atacama Desert in Chile

Chile's Water Market

Water Licenses can be bought and sold on the open market. Market determines price. No Government interference. Water Transfer to the highest value user.

A major challenge for small communities in the Atacama Desert. Indigenous Communities cannot afford to price for water licenses.

Conflict: Water as a Human Right vs.
Market Control over Water

Tomas Munita for the New York Times:

Quillagua, Chile - The driest place on Earth, residents have sometimes seen glimpses of raindrops above the foothills but they never reach the ground and evaporate like a mirage while still in the air.

What the town did have was a river, feeding an oasis in the Atacama Desert. But Mining companies have polluted and bought up so much water, residents say, that for months each year the river is down to a trickle- and an unsusable at that.

Adaptation Examples

Quebrada Blanca
Carmen de Andacollo
Reliucho

Mining Issues in Chile

1. Royalties
2. Socio-Economic Conflicts: Competition for Water & Energy and Indigenous Populations
3. Environmental Issues: Water, Biodiversity, Air-pollution, and Water for Ecological Services.
4. Water in the Atacama Desert: Most important mining area with the least about of water

Feldt, H. 2008 Current Issues in the Chilean Mining Sector
www.sdsg.org/wp-content/uploads/2010/02/10-10-08-CHILE-REPORT.pdf

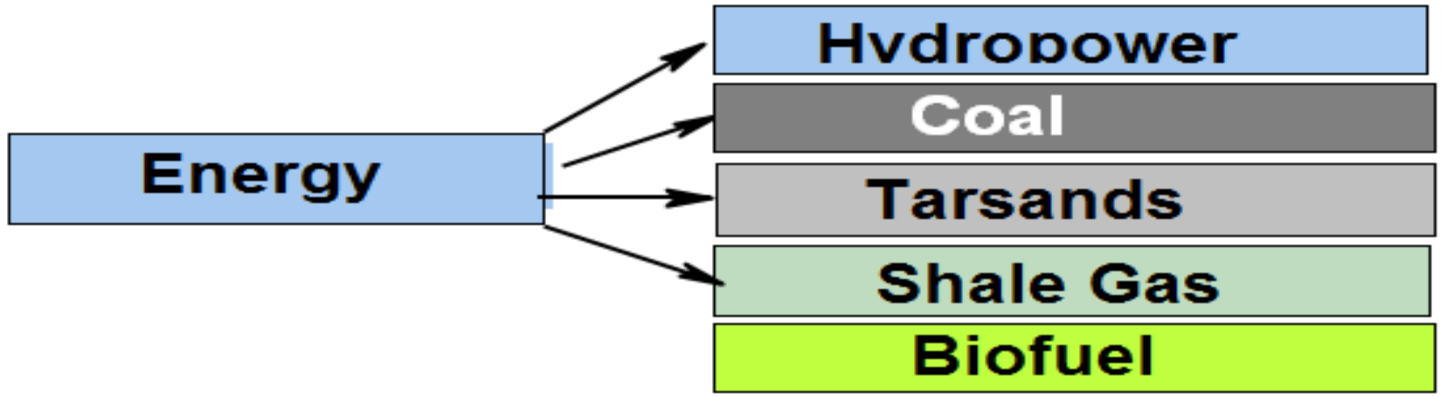
Fracking Operations in NE-B.C.

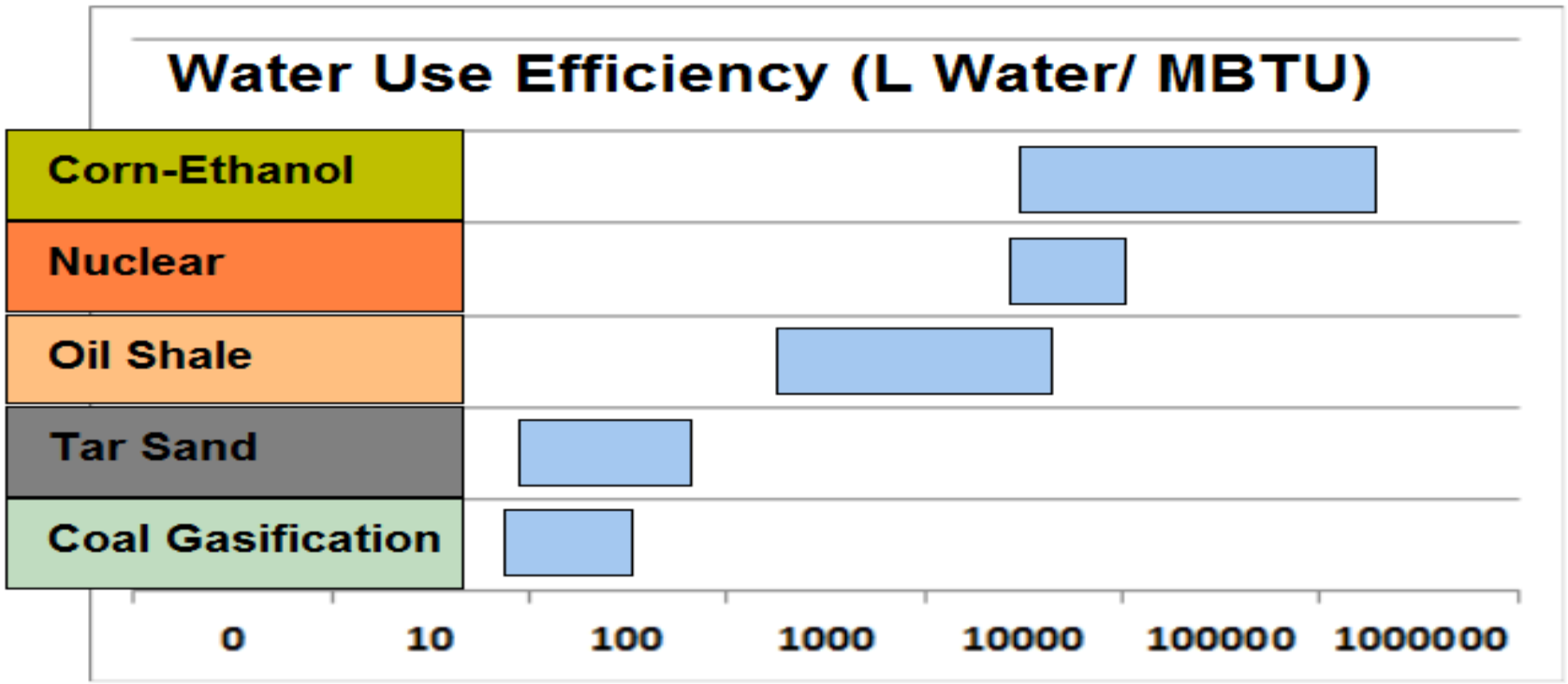
B.C. in 2010:
540 Permitted Water Sources
Amount: 280,000 m3/Water/Day

About 1/4 of daily Consumption of Metro Vancouver (2.2 Mio People)

Chemicals	Safe Exposure	Fracking Conc. ppm.
Diethylenetriamine	1 ppm	0.2
Zirconium amm.complex	5mg/m3	2.7
Ammonium Chloride	10 mg/m3	0.8
Triethanoamine Zirconium	5 md/m3	2.6
Propanol	100 ppm	0.7
Glycerine	10mg/m3	0.7
Hydrated Petroleum	200 mg/kg	1.2
Heay aromatic petroleum	5 mg/m3	3.5
Naphtalene	10 ppm	0.5
1,2,4, Trimethylbenzene	25 ppm	0.1
1-Benzyl quinolinium chloride	?	11.3
2-Bromo-2. nitro-12 propanediol	?	0.1
Naphtha	?	0.1

Source: Rooke, S. & P. Fuhr, 2011. Wireless Sensor Network for Real-Time Situational Awareness of Hydrofracking Operations. Water Resources Impact. Vol. 13 (4) 16-19.





Source: Younos, T. 2012. Water dependency of energy production and power generation systems. ater Resources Impact, Vol 14(1): 9-12

Adaptation to increased Climatic Variability in Elkford, B.C.
Site of Teck's Fording Coal Mining Area

Climate Change

Evidence

Temperatures	Precipitation	Hydrology
SmallTemp. Increases	Less Snow	Earlier Freshet
Warmer Late Winter	5% Annual Precip.	Less Baseflow
Higher Night Temp.	Earlier Snow Melt	More Storms
	More Rain in Winter	Increased Variability

Concerns and Potential Impacts

Risk

Flooding	Water Supply	Wild Fire
Bridge Security	Aquifer Capacity	Town Infrastructure
Water Supply Pump	Recharge & Demand	Road Closure
Sewage Lagoon	Water Quality	Mine Closure
Mine Work Yard	Water Treatment	Smoke Issues

Adaptation to increased Climatic Variability in Elkford, B.C.
Site of Teck's Fording Coal Mining Area

Climate Change Adaptation Strategies in Elkford Incorporated into the OCP

Adaptation Plan

Groundwater
1. Mapping to determine the aquifercapacity, use and recharge
2. Minimize potential Contamination from Stormwater Runoff

Flooding
1. Examine Glacial Source & Snowmelt Events
2. Protect Floodplain Development (Mine Work Yard)
3. Protect the Sewage Treatment Facility in Floodplain
4. Move & Protect Pumping Station for Water Supplies

Fire Hazards
1. Harvest Pine Beetle Infestated Trees
2. Improve Access Road & Develop Alternative Access

Fragile Conditions where Land Use Acrivities can Lead to widespread Erosion

Fragile Soils ←

↓ **Steep Topography**

Access & Protective Infrastructure: Drivers of Environmental Change