Risk Based Remediation at the Britannia Mine

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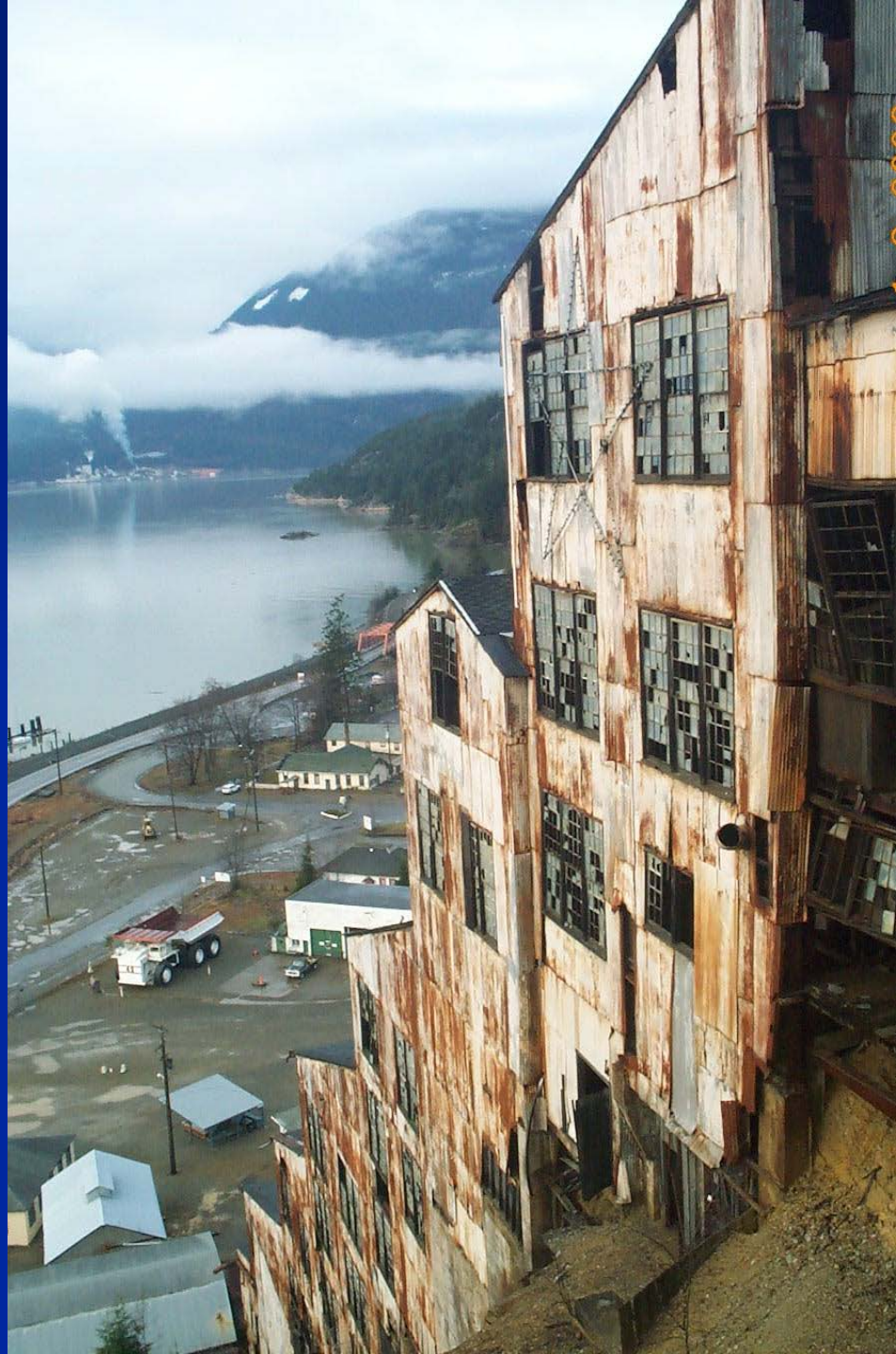

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Britannia Fan Area Remediation

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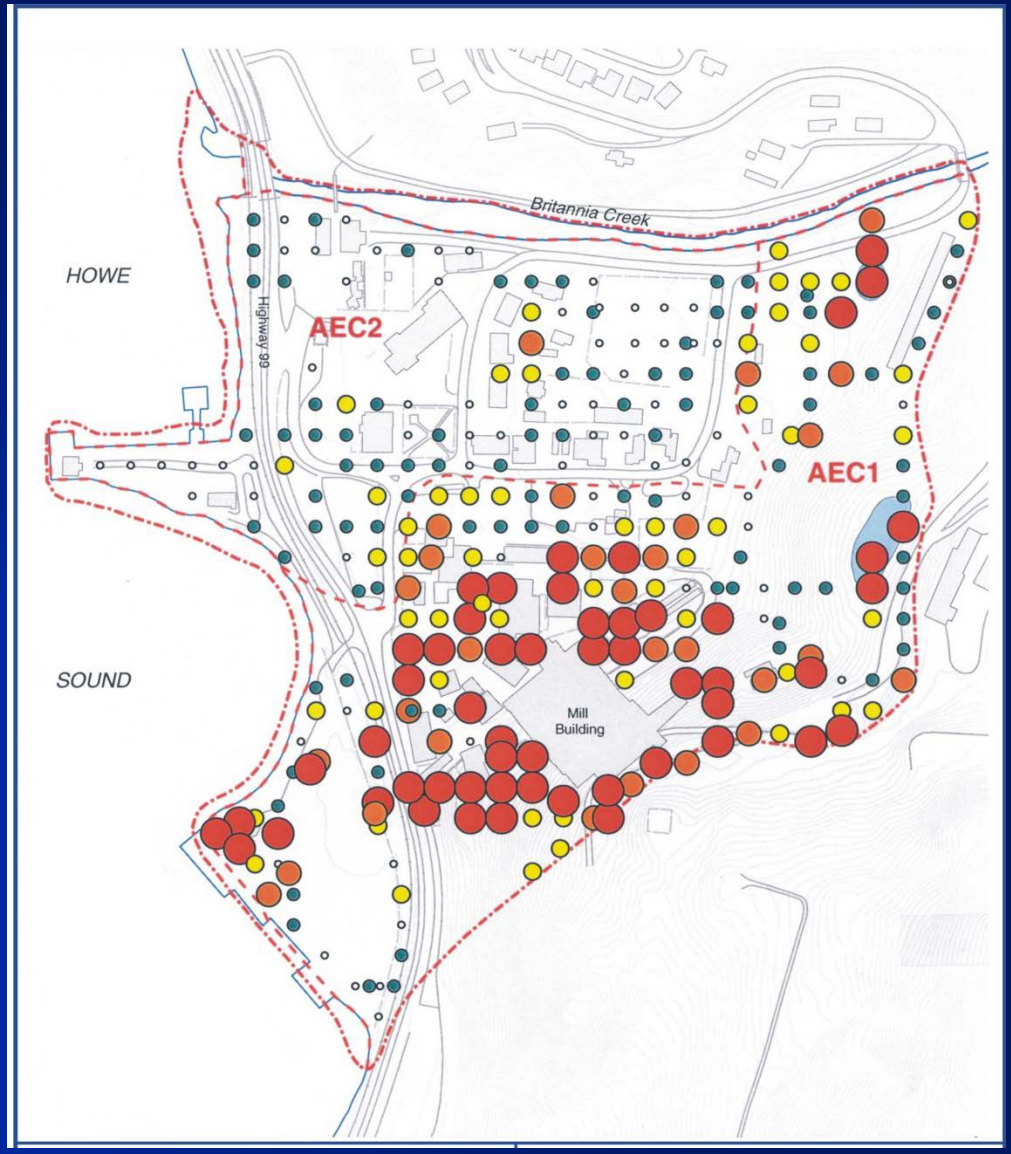
Two pronged approach

Assess what realistic remediation efforts could be done and at what cost

Assess the acceptable risk to the environment to determine the minimum requirements of the remediation

DSI Summary - Soils

Soil metal contamination is widespread, but areas of very high concentrations are restricted to a limited number of areas.



DSI Summary - Soils

Significant acid generation potential still exists in some of the mine wastes (tailings/concentrate).

However, many of the surface and near-surface materials appear to have almost fully oxidized. No acid buffering capacity is available.

DSI Summary - Soils

All soils contained significant levels of stored acidity and leachable metals

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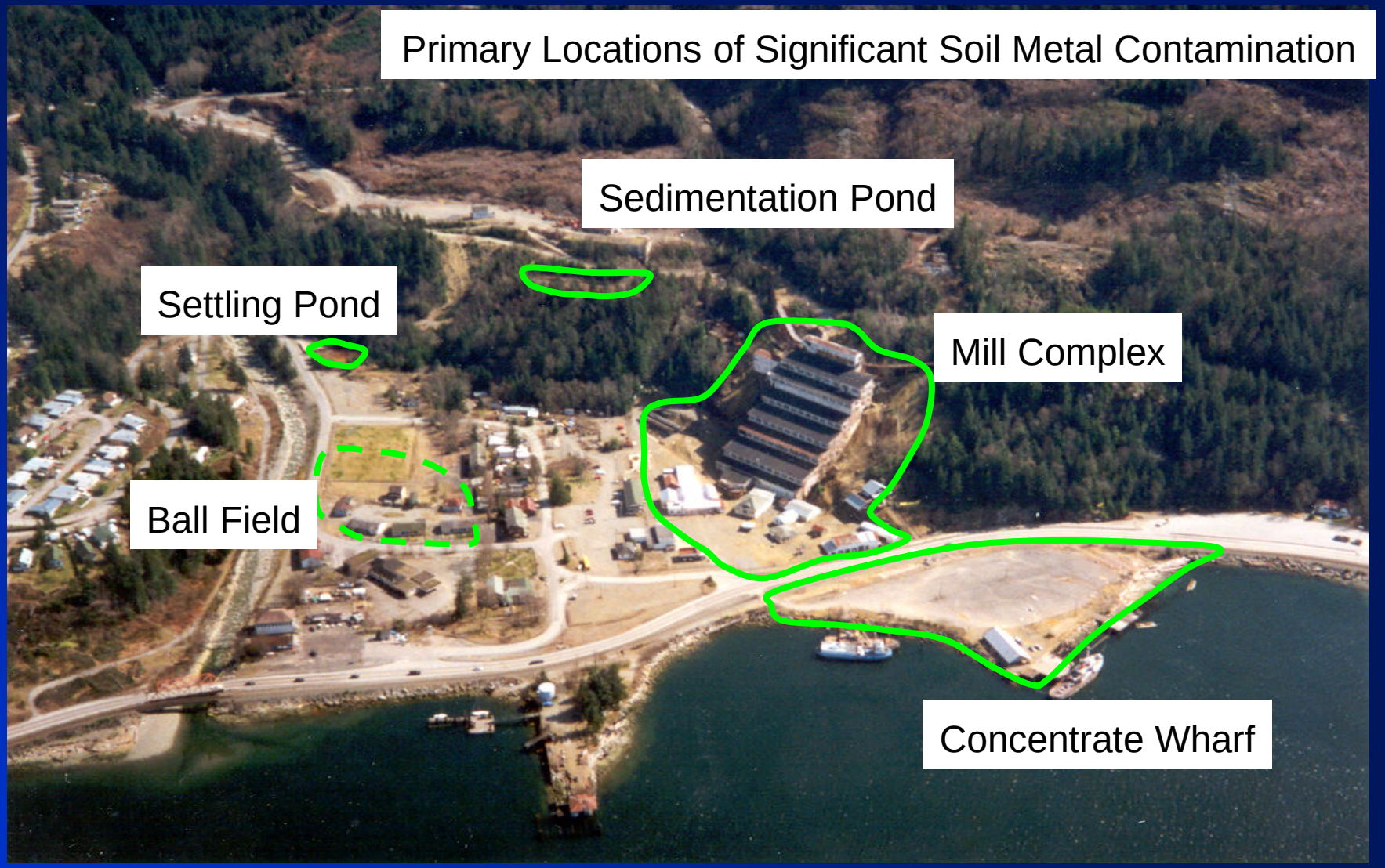

DSI Summary - Groundwater

Groundwater metal concentrations generally increase along their flow path.

They are highest immediately downgradient of deposits of tailings and concentrate.

DSI Summary - Groundwater

The primary source of groundwater metal contamination is infiltrating surface water flowing through mine waste above the groundwater table.

Groundwater levels are controlled by precipitation and runoff, and fluctuate seasonally.

DSI Summary - Stormwater

Stormwater discharges of contaminated surface water appear to be a significant loading source of metals to Howe Sound

up to ~50 mg/L Cu, (similar to 4100 discharge).

Britannia Fan Area Remediation

Calculated Groundwater Fluxes to Howe Sound

Copper

500 to 9,800 g/day

Zinc

900 to 15,700 g/day

~ 26 kg/day combined Copper and Zinc

Mine Discharge ~ 670 kg/day

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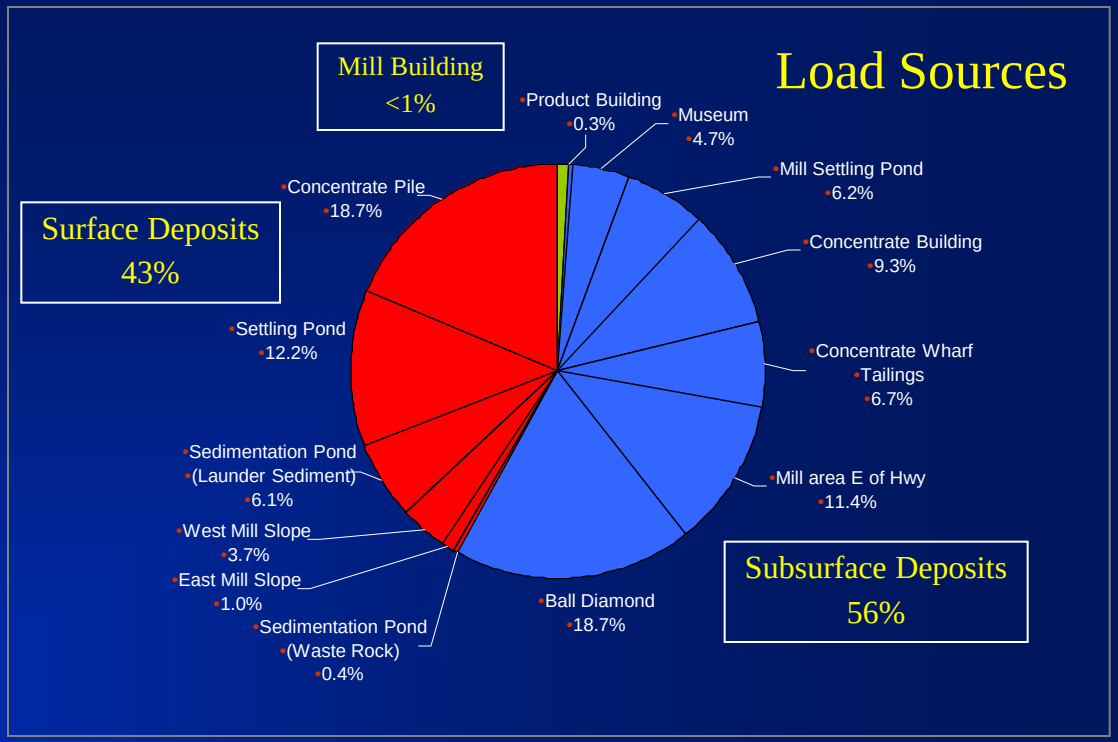
Loading Model

Developed site-specific model to estimate loading to Howe Sound from different Fan Area sources



Model can be used to predict changes to loading by removal of sources or control of surface water and precipitation

Risk Based Approach

- HHRA
- Ecological RA
- Risk Based Remediation Strategy

Human Health Risk Assessment

- **2 chemicals**
  - tin and selenium
- **3 populations**
  - commercial workers, construction workers, and child trespassers
- **Hazard indices were all several orders of magnitude below one**
- **no unacceptable risk to any population**
- **no corrective action required**

Ecological Risk - Britannia Creek Sediment

- **COCs**
  - copper and iron
- **ROC**
  - amphipod

Ecological Risk - Surface Soil

- **COCs**
  - copper and tin
- **ROCs**
  - terrestrial plants
  - soil invertebrates
  - American Robin

Ecological Risk - Intertidal Sediment

- **COCs**
  - copper, lead and zinc
- **ROCs**
  - marine amphipod

Ecological Risk - Intertidal Water

- **COCs**
  - copper and zinc
- **ROCs**
  - fucoid algae
  - phytoplankton
  - blue mussel
  - purple shore crab
  - staghorn sculpin
  - dolly varden

Summary of Fan Area Risk Assessments

- **Key Results**
  - Phase I Human Health RA - None
  - Tier 1 Ecological RA - Potential for adverse effects from copper and zinc and possibly other chemicals to mainly aquatic receptors and some terrestrial receptors.
  - Intertidal habitat physical characteristics - primarily riprap

Remediation Goal

- **To recommend and implement a remediation strategy that**
  - reduces risk to the environment
  - efficient
  - cost effective
  - acceptable to stakeholders

Risk Assessment Objective

Increase habitable area in the aquatic environment by reducing the discharge of potentially harmful constituents in a cost effective manner

Site Specific Remediation Objectives

- **Risk assessment guidance**
  - goal is not protection of individual but protection of enough individuals so a viable population can be maintained
- **Water Quality Objective development use of initial dilution zones (IDZ)**
- **Choose IDZ of only 5 m discharging into Howe Sound**
  - minimizes toxic effects to individuals and maintains populations

Two Concessions

- Limited habitat areas cannot be totally restored to past functions and services
- Concept of incremental benefit for each dollar spent on remedy is important

Risk Based Approach

- Define magnitude of environmental risk relative to the threshold effects values for various receptors
- Risk is reduced to less than threshold values by application of control measures

Risk Based Approach

- Source and pathway controls used to reduce risk to receiving environment
- Performance Monitoring

Approach to Remedial Design

Constraints and Opportunities

- Permanence of Solution

  eliminating contaminant generation in short term is more desirable than treating contaminants over the long term

- Mitigative Timeframe

  mitigation of contaminants left in place will be required forever, essentially risk will never diminish and must be controlled

- Fan Area Redevelopment

  opportunity to piggyback remedial activities with other initiatives in Fan Area to increase effectiveness and reduce cost

Potential Remedial Options

- **Stormwater Control**
  - Diversions
  - Source Removal
  - Capping
- **Groundwater Control**
  - Pump and Treat
  - Reactive Barrier
  - Infiltration Control
- **Mine Wastes**
  - Removal
  - Capping

- **Risk Based Corrective Action**
  - Use RA to guide scope of remediation

Predicted Receiving Environment Concentrations for COCs Under Various Remediation Scenarios

	Scenario	Loadings Reduction	Concentration (µg/l)	
			5 m	
			Cu	Zn
Present Condition		0%	17	27
Diversions and Capping				
1	Surface Diversions	18%	14	22
2	Capping	37%	11	17
3	Diversions and Capping	42%	10	16
Source Removal				
4	Surface Source Removal	36%	11	17
5	Selective Source Removal	62%	6.4	10
6	Comprehensive Source Removal	92%	1.3	2
7	Complete Source Removal	100%	0.0	0
Groundwater Control and Containment Systems				
8	Pump and Treat	100%	0	0
9	Pump and Treat with Barrier Wall	100%	0.0	0
Combined Remedial Activities				
10	Surface Source Removal, Diversions and Capping	78%	3.7	5.9
11	**Selective Source Removal, Diversions and Capping**	**87%**	**2.2**	**3.5**
12	Comprehensive Source Removal, Diversions and Capping	97%	0.5	0.8
	TRV for Phytoplankton		**4**	**96**

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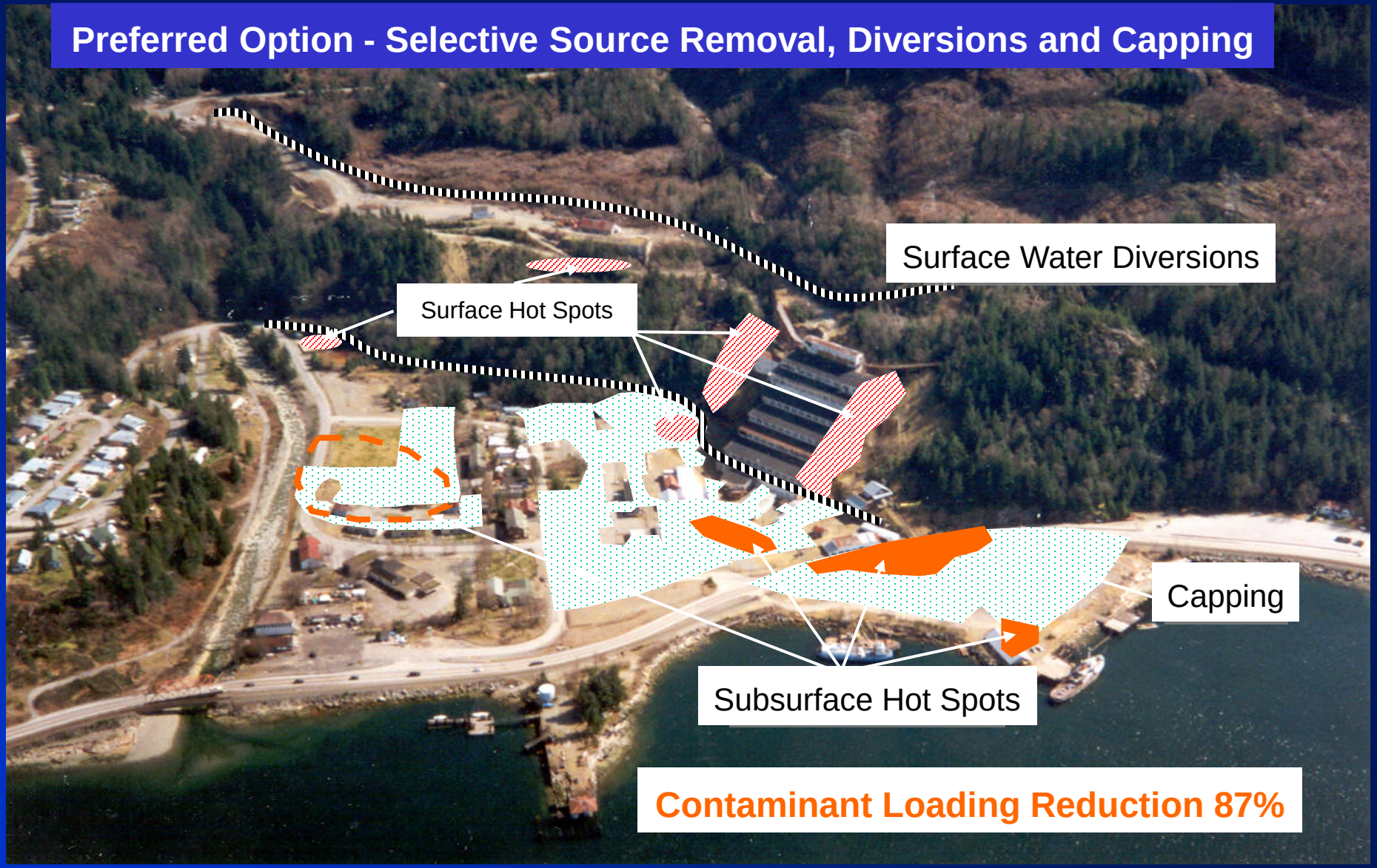
Preferred Option - Selective Source Removal, Diversions and Capping



Contaminant Loading Reduction 87%