Britannia Mine - Potted History
- 1890's - "Jane" ore body discovered at Britannia
- 1904 - Mine began production
- 1930's - Largest producing copper mine in Canada
- 1974 - Owners ordered to collect/treat ARD discharge
- 1974 - Anaconda Canada Ltd. closed mine
- 2001 - Former owners/operators settled with Province of BC ($30m) - this 'kick-starts' remediation efforts

Quick Facts About The Mine
- Mine Site Area: 36.5sq. km (>9,000 acres)
- Orebodies worked: 7
- Working life of Mine: 70 years
- Mining methods: open pit, gloryhole, open stoping
- Ore produced: 48 million tonnes (peaking at 2 million tonnes/year in early 1930's)
- Mineralogy: mainly pyrite, with secondary chalcopyrite and sphalerite
- Length of underground workings: >80km
- No road or rail access until mid-1950's
- Two main townites, several 'camps'
- Largely self-sufficient: wood mills, machine shops, hydro-electric infrastructure, water supply

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The Problem
- Britannia Mine (was) often cited as... "the largest point source of metal pollution in North America discharging to a marine environment" [until October, 2005]
- Naturally occurring metal sulphide orebody penetrated by > 80 km of mine workings

The Problem
- Acid Rock Drainage (MRD) discharging from the mine (4 to 5 million m³/year) - copper, zinc, cadmium, pH~3.5
- Metal-contaminated groundwater:
  - 4-sided fan of Britannia Creek
  - Waste dump leaching
- Metal-contaminated surface water (run-off)
- Mine tailings along shoreline
- At the above impact aquatic life in Howe Sound and local waterways (eg. Jane Creek, Britannia Creek):
  - Spanish River salmon run

Approach – Initial Remediation Phase

Presentation Overview
- History/background
- Closure approach
- Summary of remedial actions taken and underway
- Next steps
**Initial Remediation Planning - ORP**

**ORP Objectives**
- Reduce discharge of metals to environment
- Protect, sustain and promote recovery
- Risk reduction (human health and safety)
- Implement actions in a timely and cost effective manner

**ORP Outcome**
- Advanced remedial efforts across the whole site
- Addressed many of the largest sources of metals leading to Howe Sound
- Lower priority issues were carried forward for further investigation / risk assessment

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**Approach - Closure Planning Phase**

2020 2021 2022 2023 2024 2025 2026 2027 2028
- Applied a risk-based approach to achieve closure under EMA objectives
- Ensuring mine safety, monitoring and mine safety
- Projected to close in 2026

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**Installation of 2200 Level Plug**
- ARD diverted at the 2200 L level and discharged to Britannia Creek
- Plug installed in 2001
- Diverted ARD back into the mine to 4200 Level

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**Surface Water Diversions**
- Three diversions constructed (2004-2006)
- Objective is to reduce volume of (clean) water entering the mine:
  - Upper Jane Creek
  - East Bluff
  - Victoria

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**Deep Outfall**
- Old outfall extended to only 26 metres depth
  - Located on unstable sub-sea terrain
  - Susceptible to blockages
- Modelling indicated outfall requires 50 m depth and diffuser to meet receiving environment criteria
- Desired a location that is geotechnically stable to reduce risk of future failure
- South of Britannia Beach

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**ORP Concept (2003)**
- Inflow Diversions
- Collection/storage of ARD
- Treatment of ARD
- Deep outfall
- Groundwater cap/fence/treatment
- Surface water management
- Contaminated soil management
- Monitoring & Risk Assessment

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**Mine Water Collection & Treatment**
- Concept: use mine workings to store ARD and then treat it

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**Mine Water Collection & Treatment**
- Water Treatment Plant
  - Design-Build-Finance-Operate (DBFO) in a Public-Private Partnership (P3): 20-year contract
  - Winning contractor (EPCOR) proposed High Density Sludge (HDS) technology
  - Construction commenced March 3, 2005. First water treated October 20, 2005, flowrates up to 1,400 m³/day (≈ 400 L/s) treated to date
  - Treats mine water and groundwater

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**Surface Water Diversions**
- Over 3.5 million cubic metres of clean water diverted from entering the mine through to December 2010
  - Benefits:
    - Reduces peak inflows to the mine
    - Saves on treatment costs
    - Sustainable
Fan Area Groundwater Management

- Modelling
- Remedial design

Groundwater Management Status

- 7 pumping well system constructed in 2005
- System operational since 2005 and optimization continues (target is 75-95% capture efficiency):
  - Maximize (fresh) groundwater capture efficiency within design constraints and minimize salt water pumping
  - Installation of 2 additional pumping wells (2008)
- Ongoing control and/or installation improvements
- Foremain scaling an issue developed in late-2011
- System operational since 2005 and continues (target is 75-95% capture efficiency):
  - Maximize (fresh) groundwater capture efficiency within design constraints and minimize salt water pumping
  - Installation of 2 additional pumping wells (2009)
  - Ongoing control and/or installation improvements

Pumping well array running again in early-2016
Optimization underway (includes geochemical modelling)

Fan Area Surface Water Management

- Intercept clear water (eg. minor creeks) before it contacts mine waste
- Remove disintegrated mine infrastructure from the water conveyance system
- Discharge clear storm water directly to Britannia Creek
- Quantify remnant contaminated storm water and assess options for treatment/discharge (ongoing)

Contaminated Soil Management

- Permitted disposal facility in Jane Basin open pits/glory holes
- Leachate directed through mine workings to WTP
- >150,000m$^3$ volume available in Jane Basin pits
- 11km road upgrade (back-country, 1000m elevation difference)
- Disposal cost significantly less than off-site disposal
- All waste managed on-site
- ~2,800m$^3$/yr WTP filter cake
- Facility capacity study currently underway

Results of Remedial Actions Taken as Part of ORP

- Remedial actions linked to ORP completed between 2001 and 2007
- Resulted in a large reduction in metals loadings to Howe Sound

Overall Closure Plan (OCP)

In 2010 transitioned from prioritizing and implementing remedial actions to closure:
- Identify characteristics (leachability, reactivity, transport pathways, risk, etc.) of remaining sources
- Remediate sources and/or
- Feasibility analysis, supported by risk assessment according to EMA
  - Acceptability of residual risk
- ‘Closure’: acceptable levels of environmental and human health risk
  - ‘Institutionalized’ site
  - Care and Maintenance status (WTP, diversions, GMS)

Risk Assessment Approach to Closure

- OCP subdivided the Site into three areas for risk assessment and closure purposes:
  - Furry Creek watershed
  - Britannia Creek watershed
  - Shoreline (including alluvial fan of Britannia Creek)
- Furry Creek adopted as first area for risk assessment – commenced in 2010
- Britannia creek followed, starting in 2014
- Shoreline/Fan Area will be final area to be risk assessed
Furry Creek Risk Assessment
- 2010 to date (due to complete in 2018)
- Identified Beta Portal as the primary contributor of metal loading to Furry Creek and that remedial action should result in acceptable conditions in the Creek.
- Human health and terrestrial RA completed and accepted by MOE in 2016.
- Aquatic RA dependent on remediation of Beta Portal.
- Aquatic RA to be completed in 2018.

Beta Portal Source Mitigation
- All-year discharge of low-pH metal contaminated water.
- Investigation & risk assessment identified:
  - This as primary source of metals to Furry Creek (via Portal Creek).
  - Other sources, eg. waste rock dumps much less significant.
  - Eliminating this source would reduce risk to acceptable levels.
- Remedial Options Analysis & planning undertaken.
- Identified re-injection into mine workings most feasible.
- Three alternatives reviewed:
  - Inclined drillholes into workings at several elevations.
  - Vertical drillholes into 1900 Level adit.
  - Infiltration into Glory Holes.

Glory Hole Infiltration Gallery

Britannia Creek Risk Assessment
- Work in support of the risk-based closure started in 2014 and is progressing from the investigation stage to risk assessment this year.
- Recent results show that concentrations in Britannia Creek have decreased since plug installed at 2200 level.

Britannia Creek - 2200 Level
- Main source of metal loadings to Britannia Creek (waste rock, Jane Creek, former copper plant).
- Updated loadings assessment underway to understand contribution of various sources and to support remedial planning.

Total Copper Loadings Summary

Britannia Creek Risk Assessment

Ecological Monitoring Program
- Objectives:
  - Identify and track changes since 2003 (pre-remediation works).
  - Assess the relationships between potential sources and observed effects.
  - Assess the possible benefits of remedial activities and the need for any additional remediation.
- Included: observations at several locations.
- Ecological Monitoring Program.
Ongoing/Planned Work

- Complete Furry Creek Risk Assessment
- Beta Portal Remediation – upgrades to system
- Complete aquatic risk assessment
- Continue Britannia Creek Risk Assessment
- Loadings assessment & risk assessment
- Identify remedial actions/implement if warranted
- Fan Area:
  - Storm water remediation
  - Investigations/option analysis
  - Engineering
  - Risk Assessment
- Shoreline tailings
- Investigation
- Potential remediation

Thank you – Questions?