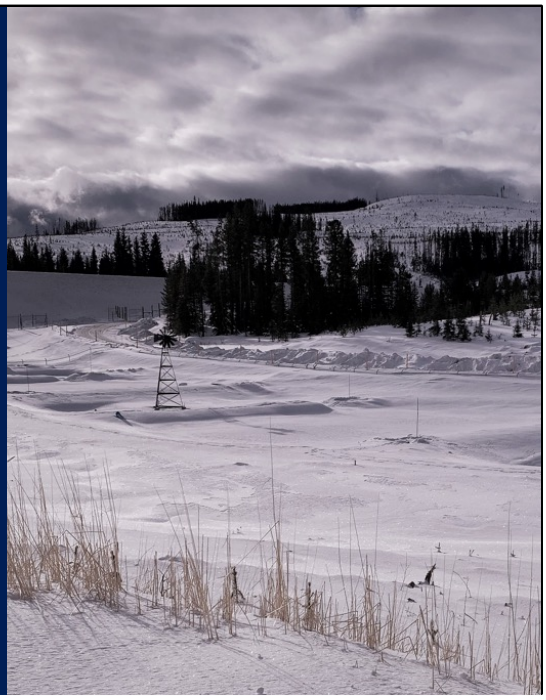
Passive Water Treatment at a High Elevation Highway Site in British Columbia

Highway Creek Remediation Project
Ministry of Transportation and Transit

Jacobs

Challenging today.
Reinventing tomorrow.



Site Location

- The Highway Creek project site is located on Highway 97C, approximately 32km west of West Kelowna, elevation of approximately 1,650m.
- Highway Creek is a tributary of Pennask Creek that flows into Pennask Lake –
- Home of the Pennask strain rainbow trout and wild brood stock for hundreds of BC lakes
- 15,000 to 25,000 trout move up from Pennask Lake to spawn in Pennask Creek annually

Background

- 1989 – Highway 97C construction
  - Rock excavation exposed sulphide rich bedrock
  - PAG fill used to construct highway embankments at Unnamed Creek Crossing
- 1990 - Highway opened to the public
- 1997 - Discoloured water reported flowing in highway ditches
- 2000 – Treatment with limestone in ditches, environmental studies
- 2006 – Aquafix chemical treatment units installed (lime dosing), creek lining on ROW
- 2016 – Start of remediation phase

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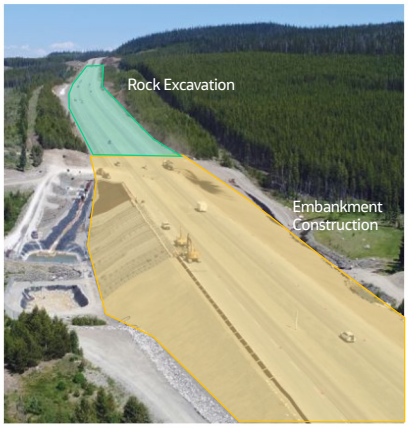
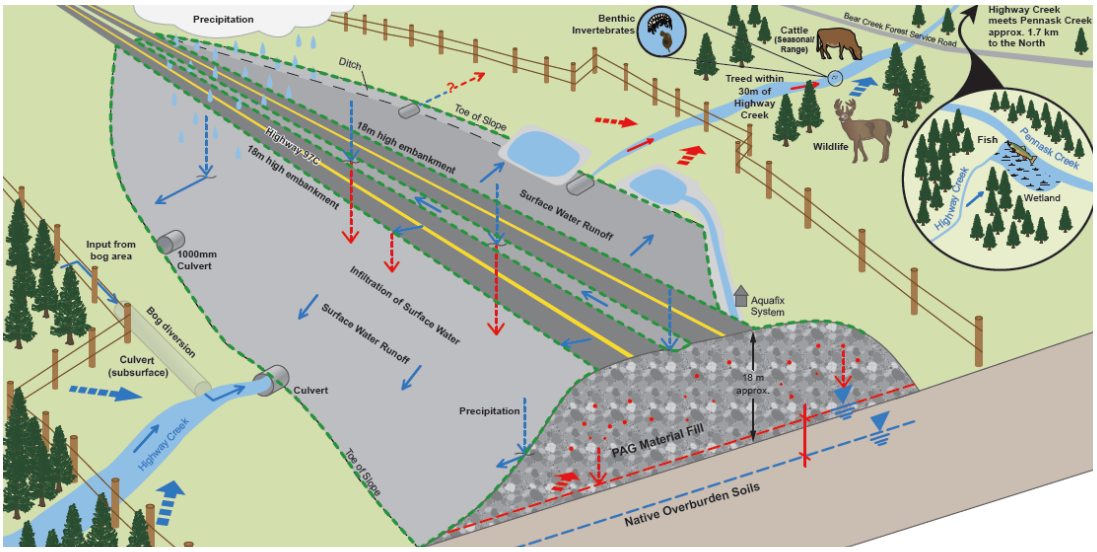


Site Conceptual Model



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beryllium, cobalt, copper, nickel, zinc

Remediation Plan

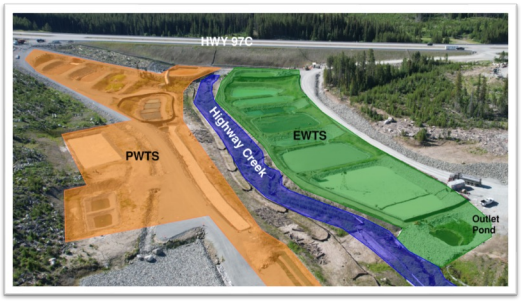
Remediation Plan

- Phase 1: Lining & Capping
  - Lining of 1.5 km of highway ditches at the rock excavation
  - Capping of embankment fill
  - Isolate ARD sources & keep clean water clean
  - Completed in 2017
- Phase 2: Capture & Treatment
  - Capture groundwater
    - below highway ditch liners
    - at base of embankment before discharge into Highway Creek
  - Treatment of groundwater with discharge to Highway Creek

Passive Treatment System Design

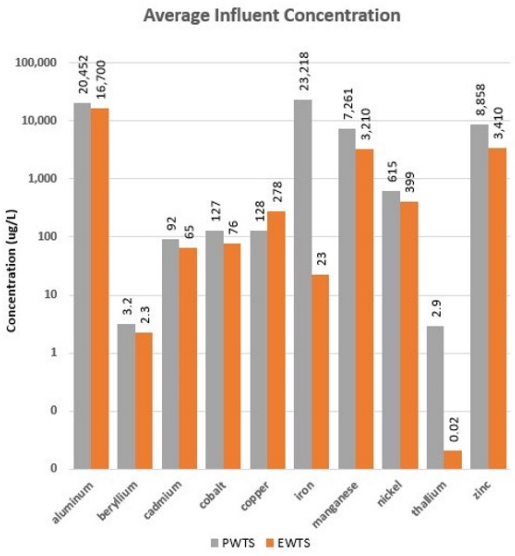
Treatment System Concept

- Passive treatment selected as best applicable technology
  - Power is unavailable at the site
  - Site access can be challenging
- **Passive Water Treatment System**
  Smaller system designed to treat base flow of higher concentration ARD from the rock excavation area
- **Enhanced Wetland Treatment System**
  Larger system designed to treat ARD impacted groundwater below the embankment and high flow bypass from the PWTS
- Single point of discharge to the creek

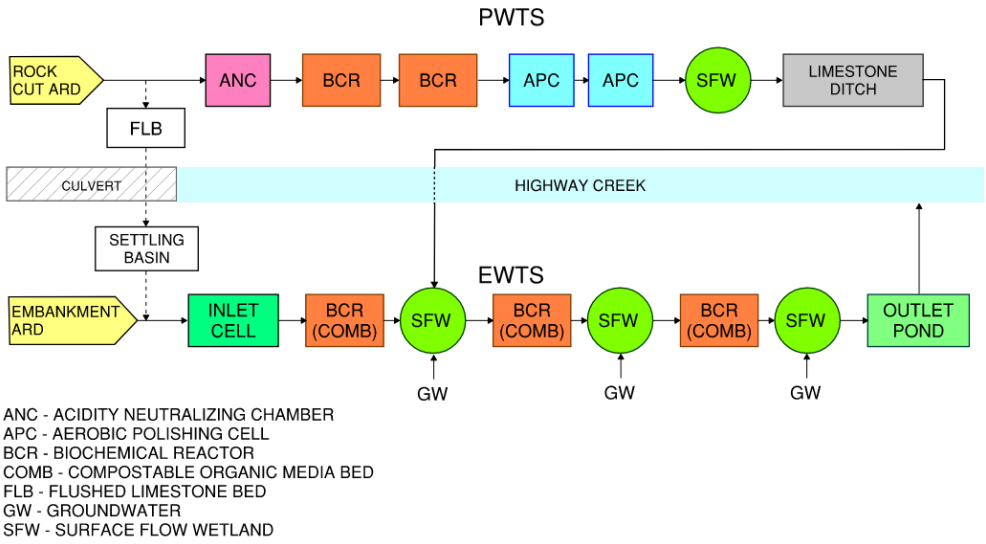


Treatment System Design Criteria

- Year-round treatment of uninterrupted groundwater inflow using gravity
- PWTS
  - Inflow: 0.2 L/s (3.1 gpm) to 2.0 L/s (32 gpm)
  - >2.0 L/s diverted to EWTS
  - pH ≈3.2
- EWTS
  - Inflow: 1.6 L/s (26 gpm) to 13.5 L/s (215 gpm)
  - Includes max. 11.7 L/s from PWTS
  - Groundwater inflow pH≈4.2
- Plot shows influent metals concentrations potentially exceeding discharge criteria
- Required removal to meet discharge criteria ranges from 70% to 99.9%



Passive Treatment Trains



ANC - ACIDITY NEUTRALIZING CHAMBER
APC - AEROBIC POLISHING CELL
BCR - BIOCHEMICAL REACTOR
COMB - COMPOSTABLE ORGANIC MEDIA BED
FLB - FLUSHED LIMESTONE BED
GW - GROUNDWATER
SFW - SURFACE FLOW WETLAND

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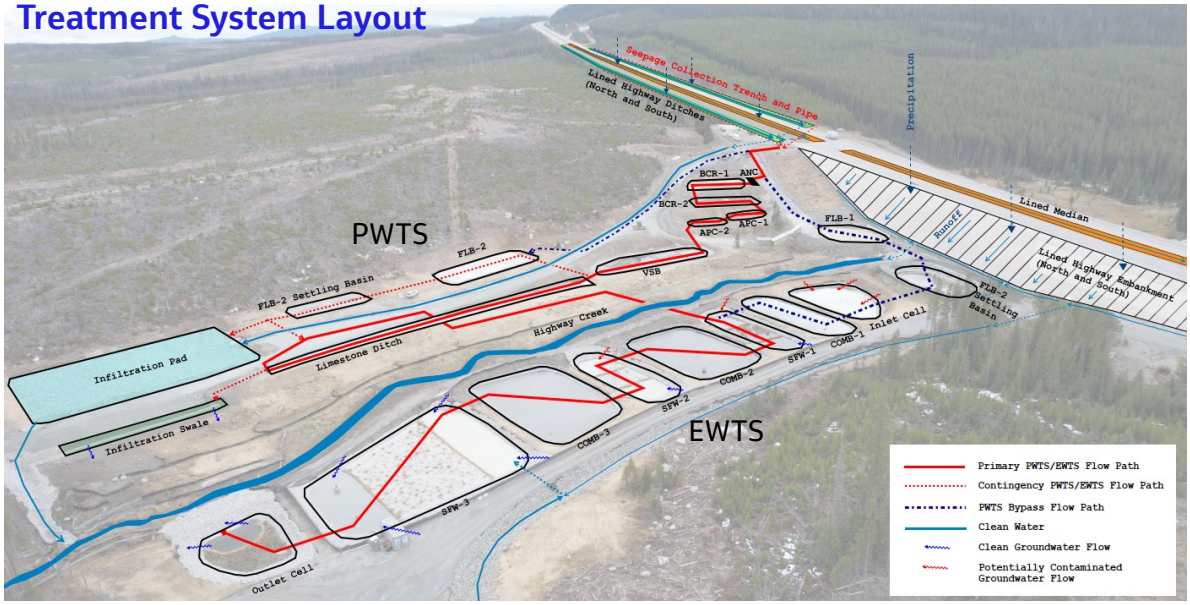
Simplified and high level

Treatment System Layout



Highway Creek Lining

- 200m of creek lined downstream of highway to isolate from groundwater
- Allows groundwater to be captured prior to discharge into creek
- Creek was also realigned to provide space for treatment system
- Pool-riffle-run design to replicate the natural structure of the original channel
- Existing highway culvert extended with fish friendly design to connect culvert to new liner
- Slow but successful vegetation establishment

Cold Climate

- Minimum temperature below -30°C
- Average temperature below 0°C for six months of the year
- PWTS
  - Cells buried and covered with topsoil or woodchips and 100mm polystyrene boards
  - Pipes buried and insulated
- EWTS
  - Open water cells with groundwater inflow
  - Ice cover forms but flow below continues throughout the winter
- Year-round operation achieved

Passive Treatment Technologies

Acidity Neutralizing Cell (ANC)

- PWTS influent is ferric iron and aluminum dominated ARD with moderate acidity
- ANC is designed to:
  - Neutralize acidity
  - Abiotic removal of ferric iron and aluminum
- Media bed consists of roughly:
  - 85% aged woodchips
  - 15% limestone sand
- Mix ratio selected to balance the rate of reaction front progression through bed and long-term performance

Parameter	ANC Influent	ANC Effluent
Acidity (pH 4.5)	90 mg/L	<1 mg/L
Acidity (pH 8.3)	210 mg/L	30 mg/L
Aluminum	18,500 ug/L	75 ug/L
Iron	24,500 ug/L	110 Ug/L
Ferric/Ferrous	≈ 85% Ferric	≈ 15% Ferric

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Biochemical Reactors

- BCR design for the removal of trace metals
- Both the PWTS and EWTS include Bioreactors
  - 2 BCRs in series on the PWTS
  - 3 pairs of Compostable Organic Media Bed (COMBs) and Surface Flow Wetlands in series on the EWTS
- BCRs are a **closed** configuration encased in HDPE liner to maintain anaerobic conditions
- COMBs are an **open** configuration, lined at the bottom with approximately 0.5m deep water cap
- Media consists of composted horse manure, hay, aged woodchips, sawdust, peat moss and limestone sand

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beryllium, cadmium, cobalt, copper, thallium and zinc

Aerobic Polishing Cells

- BCR average effluent sulphide concentrations ≈25 mg/L typically higher during the summer
- PWTS includes two Aerobic Polishing Cells in series
  - APCs are inert gravel beds
  - Dosing syphons used for fill and drain cycling
  - Cell are buried with vent pipes to prevent freezing
- Lesson learned – galvanized metal pipe used for dosing chamber replaced with plastic (PVC) due to elevated zinc in effluent

Surface Flow Wetlands

- SFWs are series of shallow and deep zoned wetlands designed to promote additional aeration and setting of solids
- PWTS includes a small Surface Flow Wetland downstream of APCs
  - HRT approx. 2 days
- EWTS includes
  - SFW downstream of each COMB
  - Outlet Pond is constructed as a SFW
- Design to oxidize excess sulphide and BOD and settling of solids, if present

Limestone Ditch

- Designed for manganese removal by abiotic precipitation
- Lined ditch filled with coarse limestone gravel
- Constant level maintained with sub-surface stoplog structure (Agri-Drain) at outlet
- Approx 2-day HRT
- Theory is that precipitation is biologically mediated

Limestone Ditch

Construction and Startup

- Phased Construction from 2018 to 2023
  - PWTS → Creek Liner → EWTS
- Short construction season (typ. 3-4 month)
- Construction dewatering required for EWTS
- Lengthy startup under winter conditions
- Discharge to creek only once PWTS and EWTS fully commissioned


Dewatering


Completed EWTS

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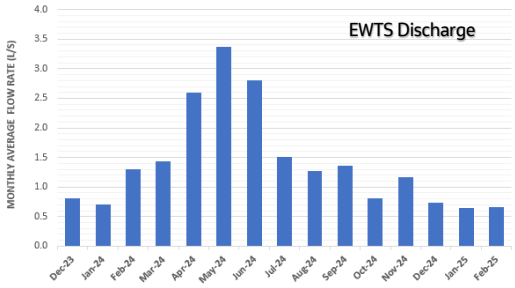
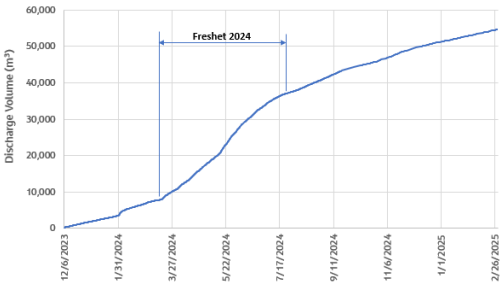
System Performance

System Performance

Performance during temporary discharge authorization from Dec 6, 2023 to March 1, 2025

- Snowpack approximately 80% of normal – low peak inflow
- Monthly average discharge ranged from 0.7 to 3.4 L/s
- Max discharge ≈ 5.6 L/s
- Approximate 55,000 m^3 discharged to Highway Creek via Outlet Pond

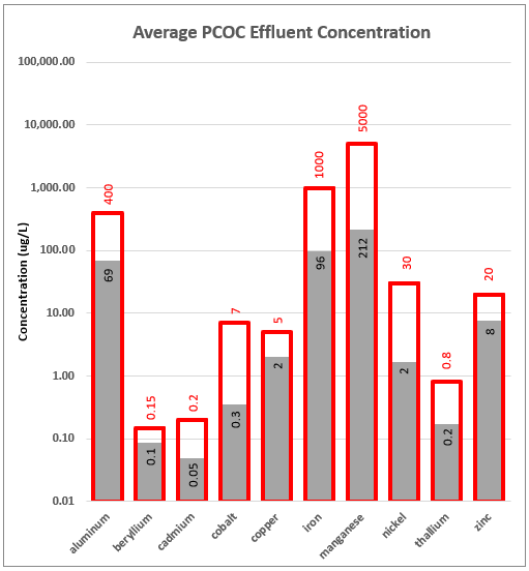




System Performance

- PWTS/EWTS successfully treated ARD from exposed rock cuts and embankment
- Effluent pH ≈ 7.8
- Removal of key PCOC ranged from 93.9% to 99.9%
- Met discharge criteria throughout 15-month temporary authorization discharge period
- As of April 2025 system discharging under new permit

PCOC	Removal
aluminum	99.7%
beryllium	97.3%
cadmium	99.9%
cobalt	99.7%
copper	98.4%
iron	99.6%
manganese	97.1%
nickel	99.7%
thallium	93.9%
zinc	99.9%



Red concentration are discharge limits under temporary authorization

The overarching goal was to develop a passive treatment system that could operate reliably in a remote, cold, and variable-flow environment.
The key objectives were:
– Gravity flow
– No chemical inputs
– Low maintenance
– Long-term sustainability
– Cost effectiveness
This project demonstrates how passive technologies can be adapted to complex environmental conditions to meet regulatory and ecological goals.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