# Overcoming Hurdles and Unexpected Help in Maintaining Tailings Ponds as Wetlands, Fisheries and Bioreactors at Highland Valley Copper, BC

LARRATT AQUATIC

Highland Valley Copper

Teck

# Presentation Outline

- Goals of tailings pond reclamation at HVC
- Overview of techniques we used
- How are we doing with tailings ponds as bioreactors?
- How are we doing as wetlands and fisheries?
- *Before / After* - decade shots of 3 HVC tailings

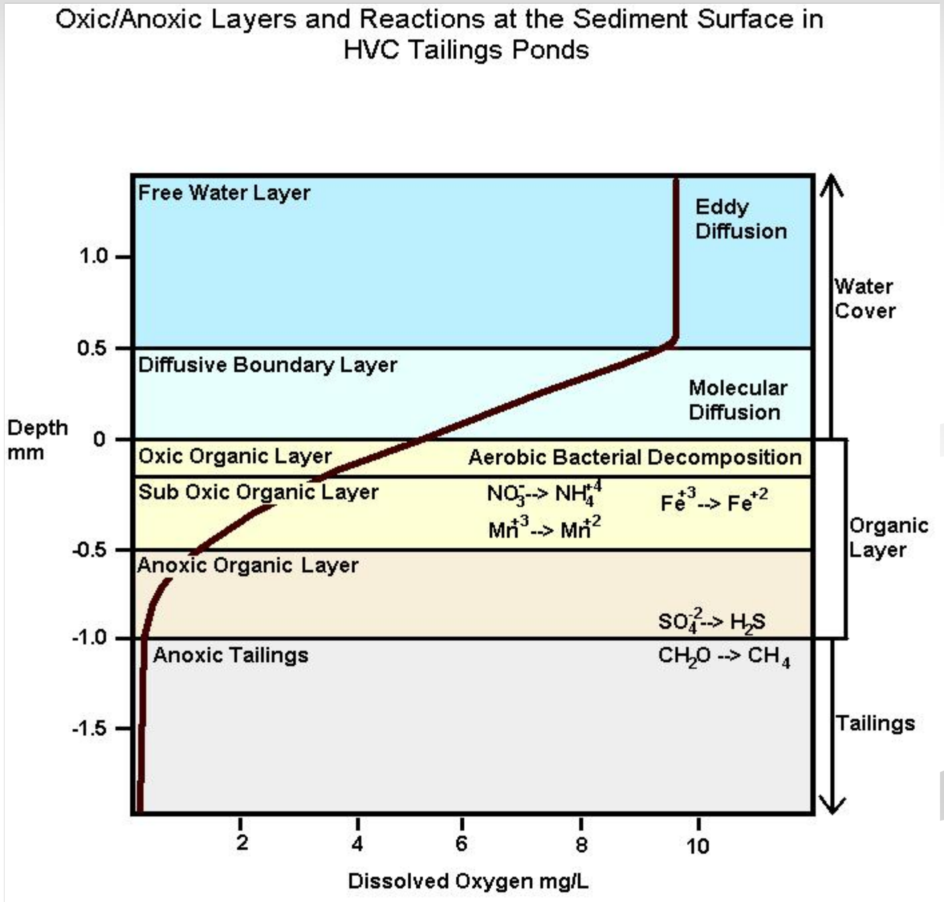
# The Goal: Reclaim the tailings facility as sustainable habitat,

Trojan tailings pond: fishing derby

Trojan tailings pond: Great Blue Heron

# ….that also acts as a bioreactor

- Removes metals
- Removes nitrogen
- Removes sulphate




**Equations for metal sulphide formation:**

$2H^+ + SO_4^{2-} + 2\mathbf{CH_2O} > ^{SRB} > H_2S + 2HCO_3^-$

$H_2S + M^{2+} >> MS + 2H^+$

**$2CH_2O$ = organic compounds**

$2HCO_3^-$ = bicarbonate

M = metal ions

MS = metal sulphide precipitate

# Shallow versus deep habitat goals

**Shallow (1-5 m) tailings ponds**

- Waterfowl + shorebird + wildlife habitat

**Deep (>7 m) tailings ponds**

- Fisheries + wildlife

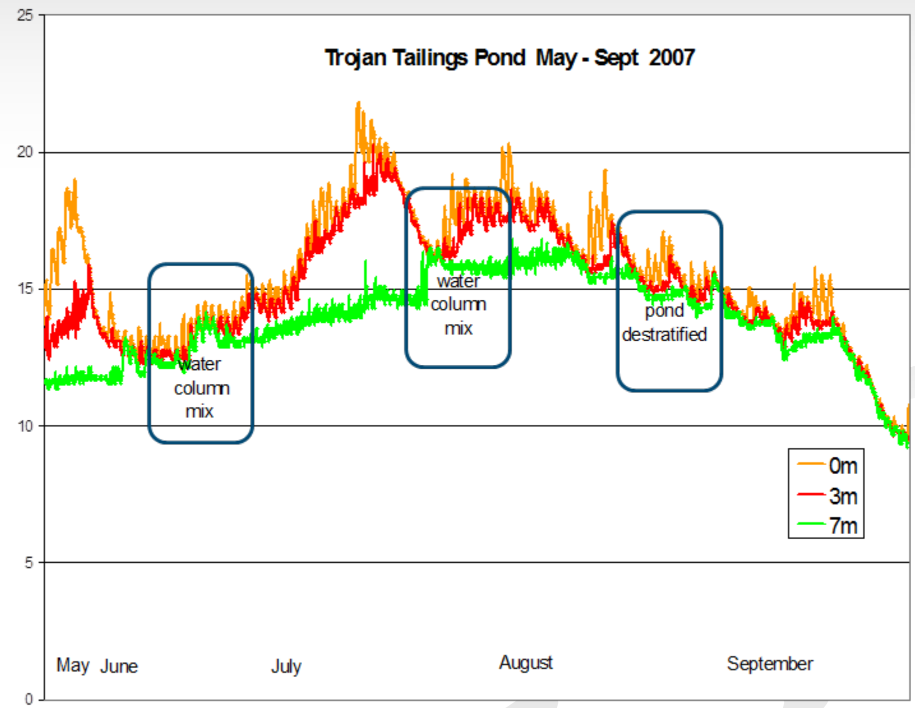
# Stable ponds water levels are ideal but expensive

- High water drowns shoreline plantings in high water (challenging on shallow slopes)
- Too many low water seasons desiccates aquatics, reducing them to seed banks

# Tailings pond volume and depth affects thermal behavior

Ponds deep enough to thermally stratify with periodic mixing, 6-8 m in the case of Trojan,

is ideal to maintain productivity during the summer.



# Organic sediments are essential to habitat value and bioreactor function

- With the inorganic nutrients in place, bacterial development starts and a nutrient/vitamin-rich organic sediment layer will begin to form (<1 mm/year, initially)
- The upper few mm of sediments hosts 99% of all the bacteria in the water body and is crucial habitat for invertebrates

# Bacteria are crucial to bioreactors

- After water chemistry is suitable, photosynthetic bacteria and chemotrophs grow without assistance.
- Accelerate bacteria colonization by introducing surface substrate from other ponds or by introducing aquatic plants.
- After algae and plant organic carbon is available, bacterial flora expand rapidly.
- Bacterial colonization only took 4 – 5 years in Trojan but is still expanding after 18 years.

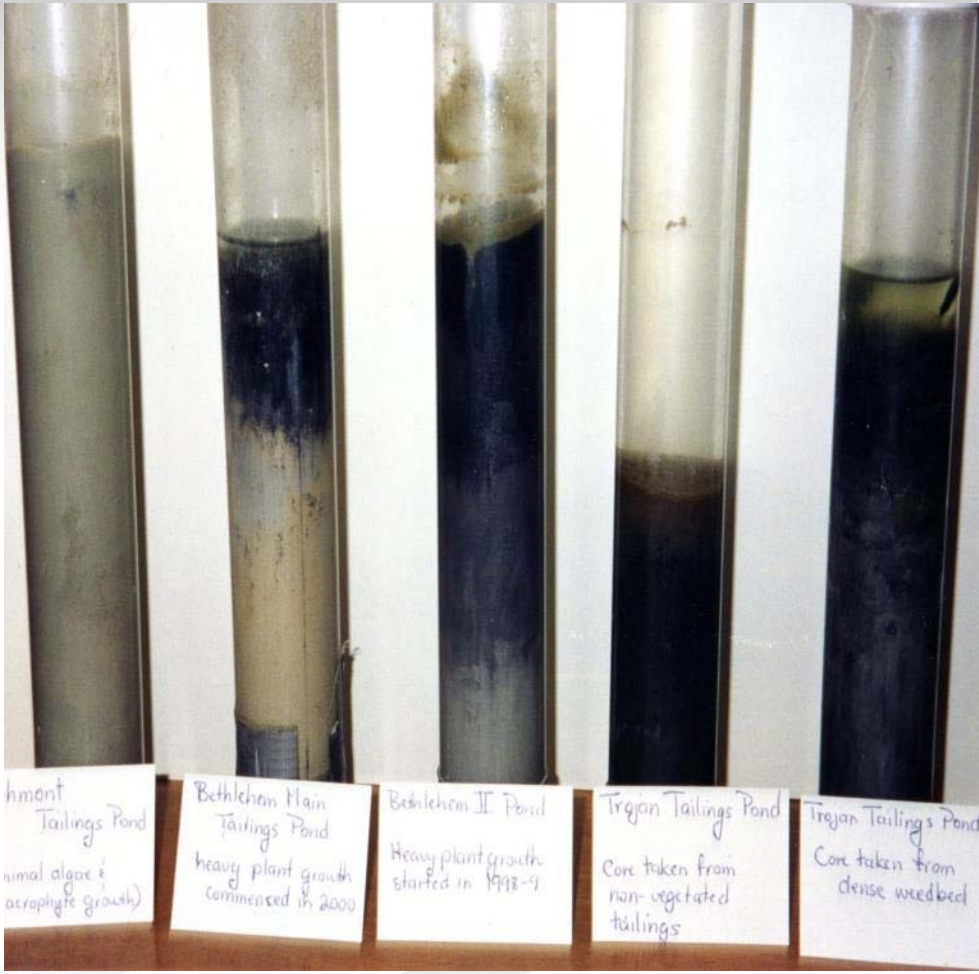


Photo 4.2-4: IRIS Tubes Installed in Water-Covered and Dry Tailings at Bethlehem Dam

# Getting grown-in-place organics started, incrementally

# Reclamation Techniques
# Submerged aquatic plant introductions

# Reclamation Techniques

# Submerged aquatic plant introductions

## Reclamation Techniques
# Riparian Emergent Introductions

sedge transplants + 4 years =

Reclamation Techniques

# Riparian Emergent Introductions

- Rush transplants + 7 years =

Reclamation Techniques

# Riparian Emergent Introductions

- Cattail transplants and seed + 8 years =

Reclamation Techniques

# Riparian Emergent Introductions

Cattails from seed after 1, 2, and 4 years =



Reclamation Techniques

# Shrubs from Stakes

- Willow - readily roots from stakes in moist substrate; tolerates inundation after it is established
- Cottonwood - roots from stakes, takes drier conditions than willow after the stakes are established

## Reclamation Techniques

# Shrubs from Stakes

- Stakes-in-pots growing in a mix of tailings and organic material so plants are used to tailings
- works for willow, cottonwood, and red osier dogwood
- Similar survival to planting tree plugs

## Reclamation Techniques

# Shrubs from Stakes

- Live Logs/ living retaining walls

- Live Wattling

## Reclamation Techniques

# Potted trees – Byland Poplar




# Reclamation Techniques

# Riparian Grass Seed Mix (Richardson's)

**Photo 4.0-1: High Spring and Low Fall Water Levels Showing Riparian Seed Trial, Trojan Tailings, 2012**

After the seed trial was raked into the tails in June (photo left), it was flooded within two weeks and remained flooded until late August. It subsequently sprouted and some grasses set seed by early October (photo above)

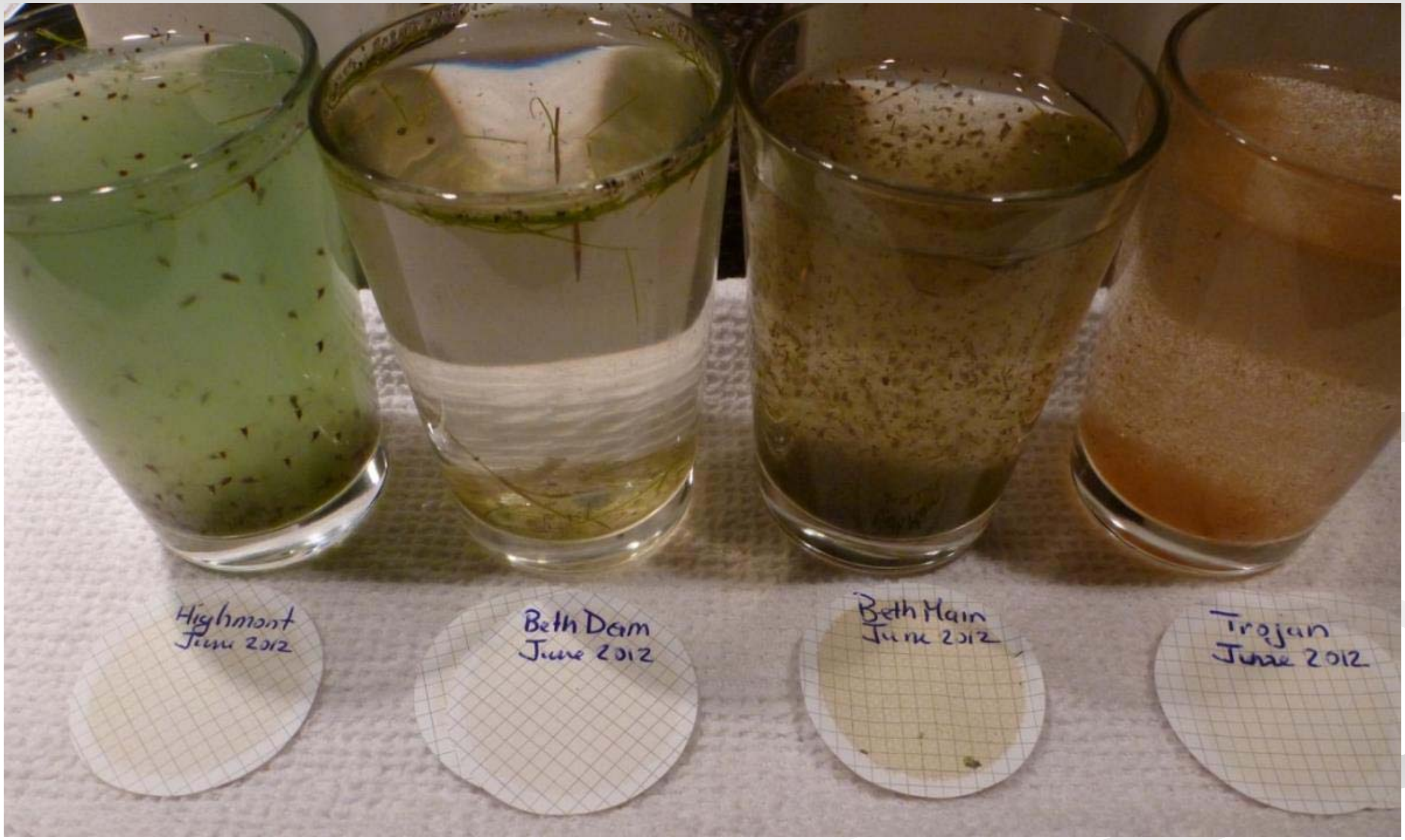
Reclamation Techniques

# Zooplankton & Invertebrate Introductions

## Invertebrate collection

- Caution!! Permit needed
- Screen bucket (selective)
- Soaked hay bales (non-selective)
- With plant introductions (non-selective)

# Each HVC tailings pond developed different chemistry, microflora and zooplankton



# Introducing fish

- Initially used hatchery fish (gradually acclimatize before introduction)
- Trojan spawning channel
- Balance recruitment/yr from spawning channel vs fish size in pond. We want a “balanced, managed, age class structure”
- In 2012, Trojan fishing derby results showed 219 RBT caught per session versus 37 RBT in nearby Tunkwa Lk
- Fish size ranged from 20– 46 cm with an average of 28 cm (SD 5.7)
- Thanks to a golden eagle, we have too many fish in one age class

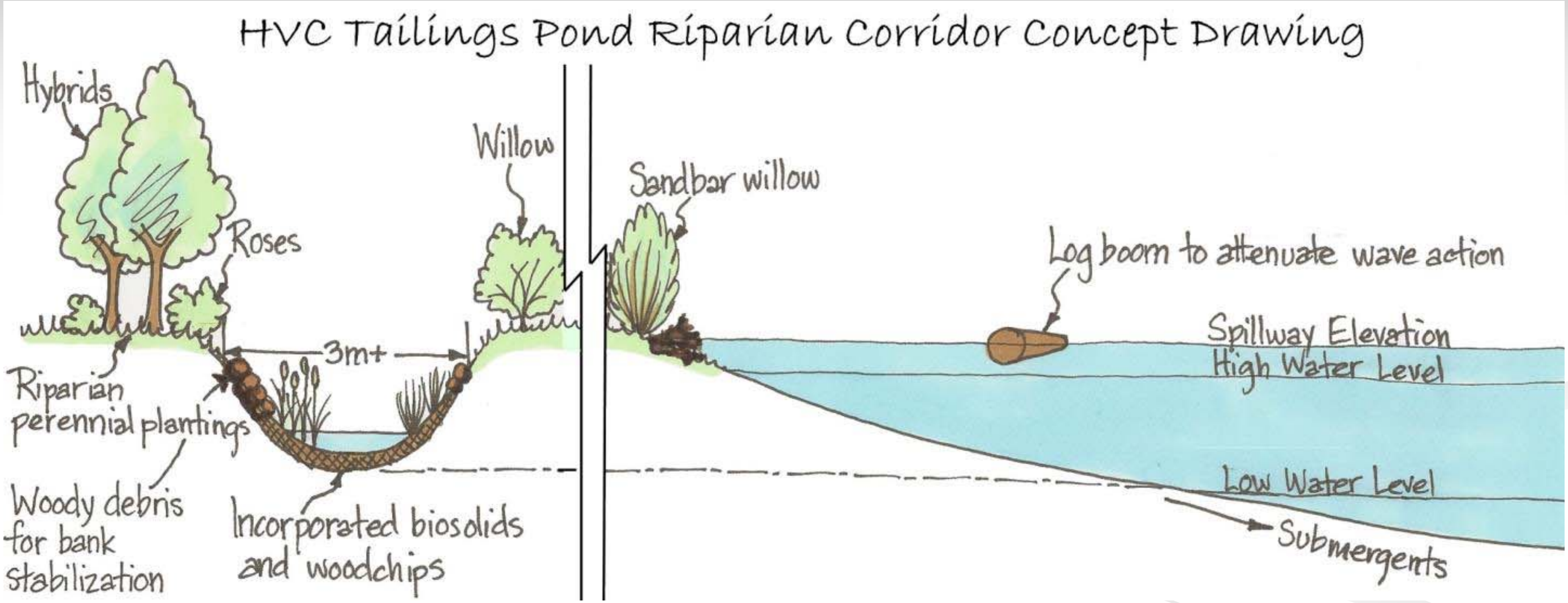
# Problems - Predators

- Deer / Moose
- Rodent girdling

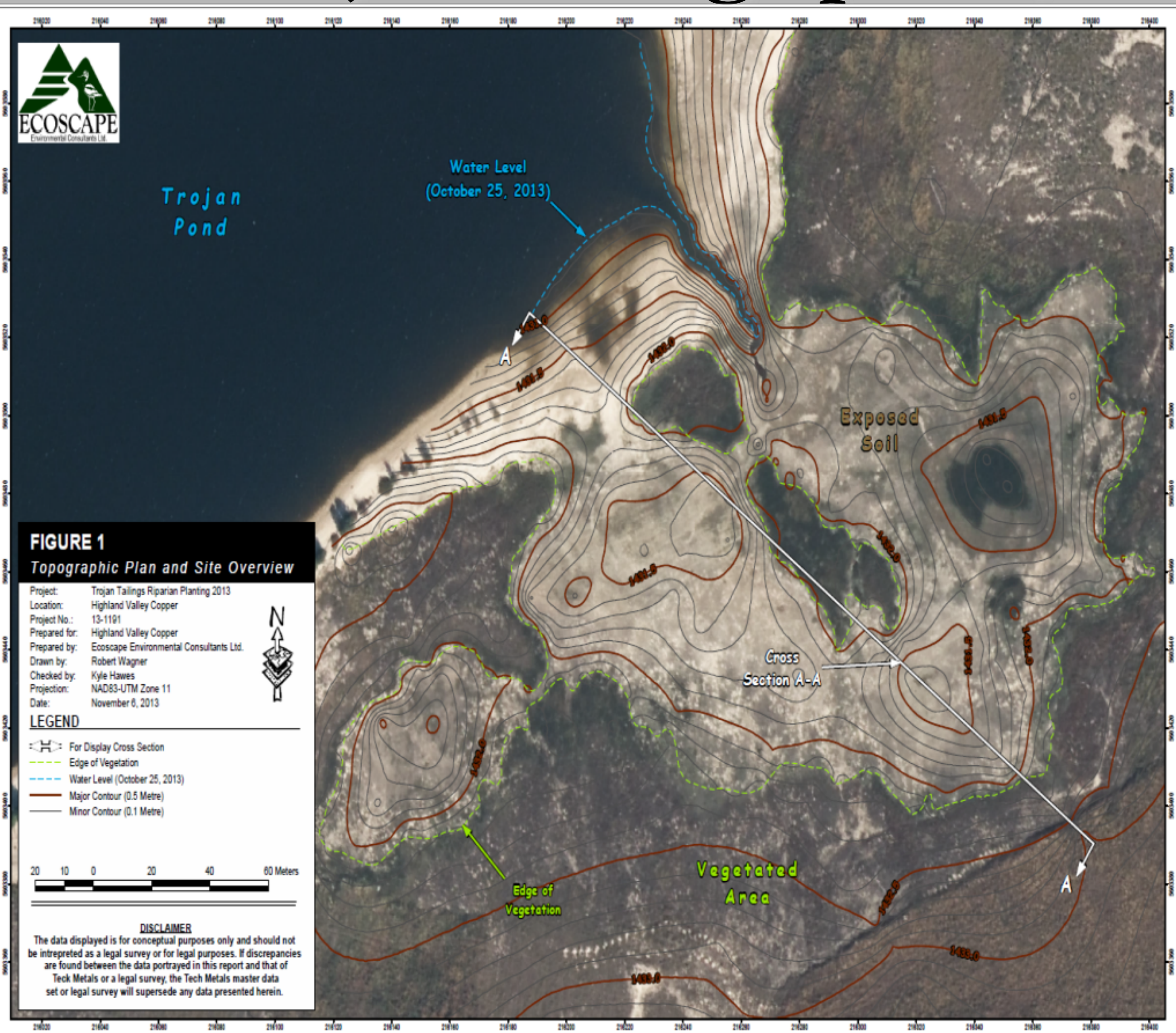


# Enter, Mountain Pine Beetle

# Flooding. rethink



# Trojan tailings pond, next phase




# So how are we doing??

# Water chemistry in shallow HVC tailings ponds

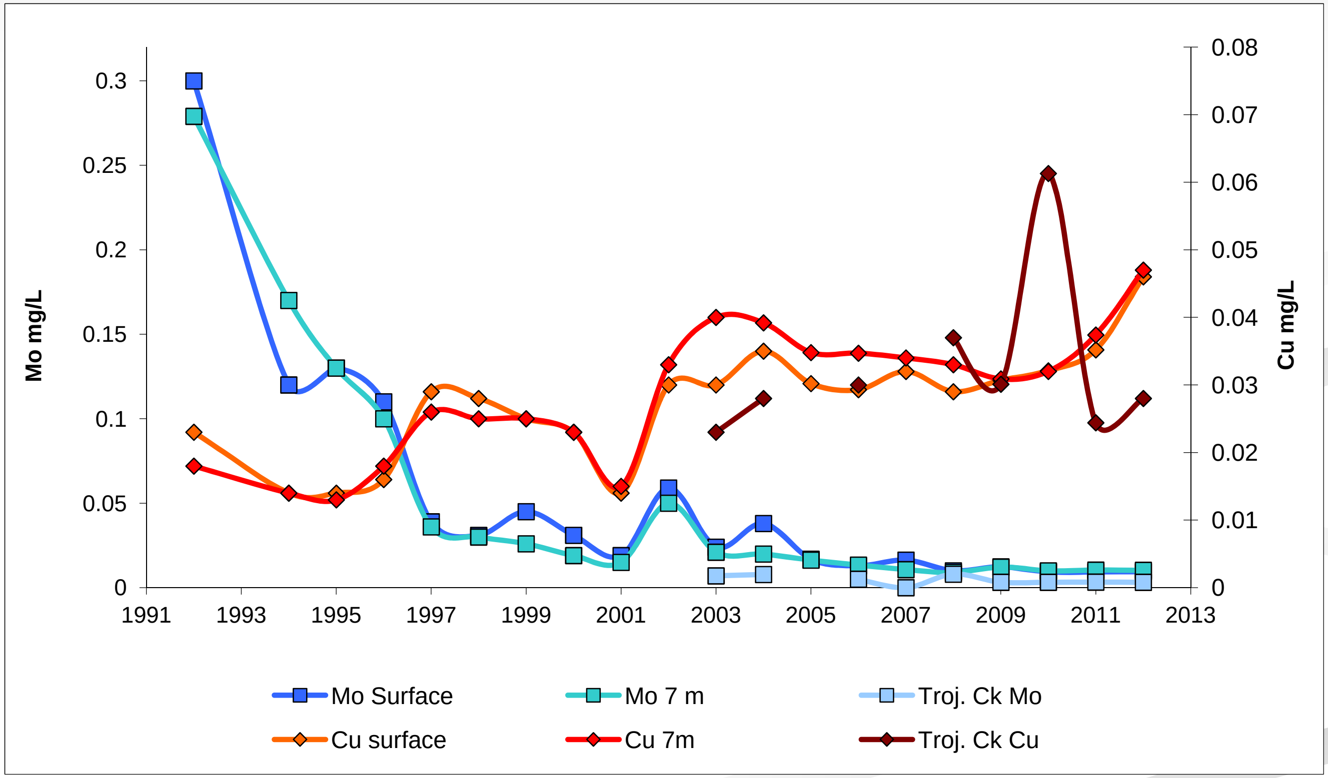
Table 4.2-2: Water Chemistry in Bethlehem and Highmont Tailings Ponds

| 2012 HVC Tailings Maximum Summer Water Cover | Units | RDL | Beth Dam 7/18/2012 | Beth Main 6/26/2012 | Highmont 6/27/2012 |
|---|---|---|---|---|---|
| Alkalinity | mg/l | 1 | 105 | 115 | 178 |
| Turbidity | NTU | | 3.75 | 3.21 | 3.37 |
| $NO_2$ & $NO_3$ | mg/l | 0.01 | <0.010 | <0.001 | <0.0010 |
| $NH_3$ | mg/l | 0.01 | 0.0309 | 0.0223 | 0.0171 |
| Total N | mg/l | 0.01 | 1.49 | 1.62 | 1.13 |
| $SO_4$ | mg/l | 10 | 568 | 16.8 | 149 |
| pH | pH unit | | 10.14 | 8.38 | 8.84 |
| Conductivity | us/cm | 2 | 1120 | 246 | 648 |

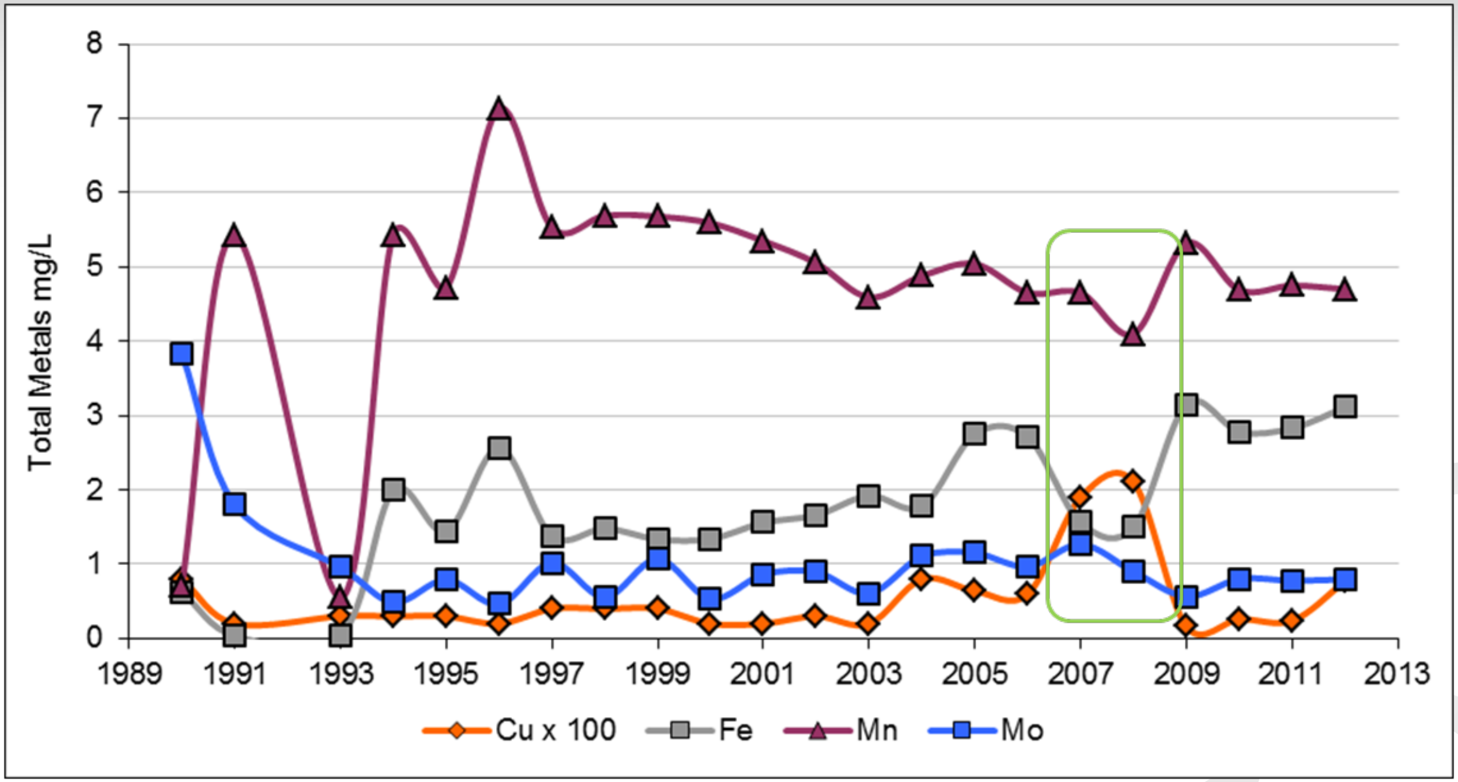
NOTE: RDL = Reportable Detection Limit

# Metals in Trojan pond and inflow

**Figure 4.1-3: Annual Average Total Aqueous Metals in Trojan Tailings Pond, Growing Seasons of 1992 – 2012**

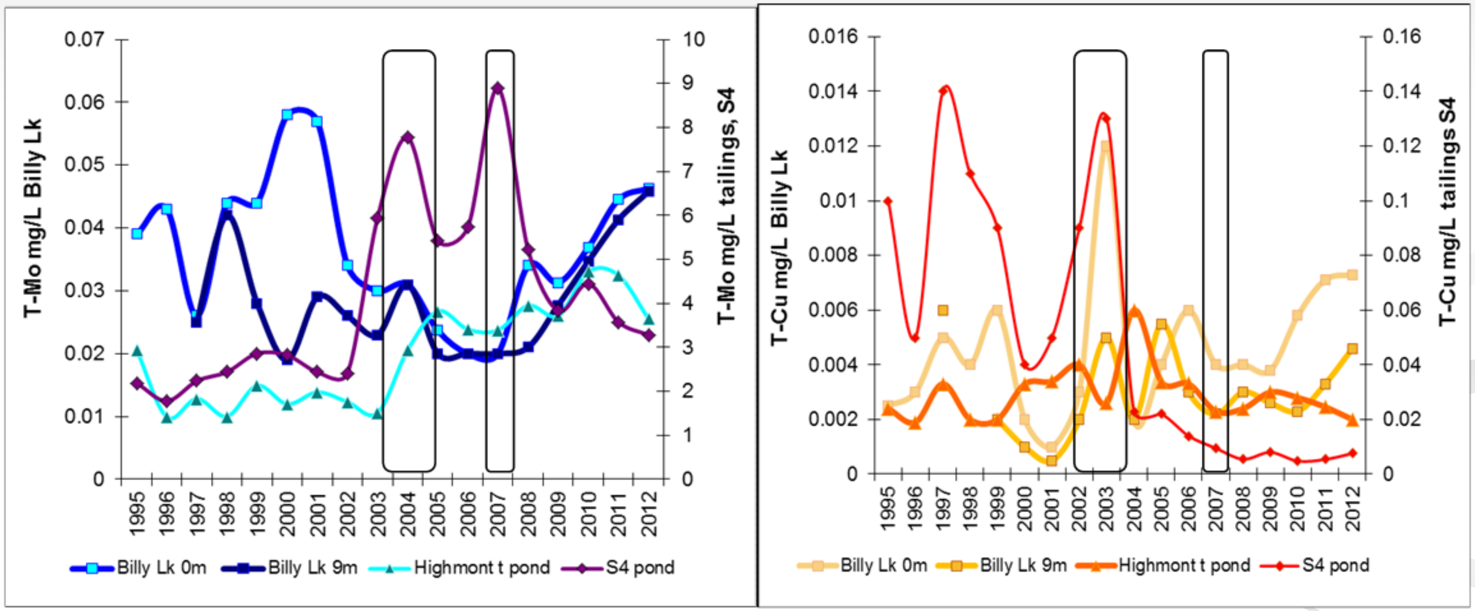


# Total Metals in Bethlehem Tailings Seepage



# Highmont Tailings Total Mo and Cu

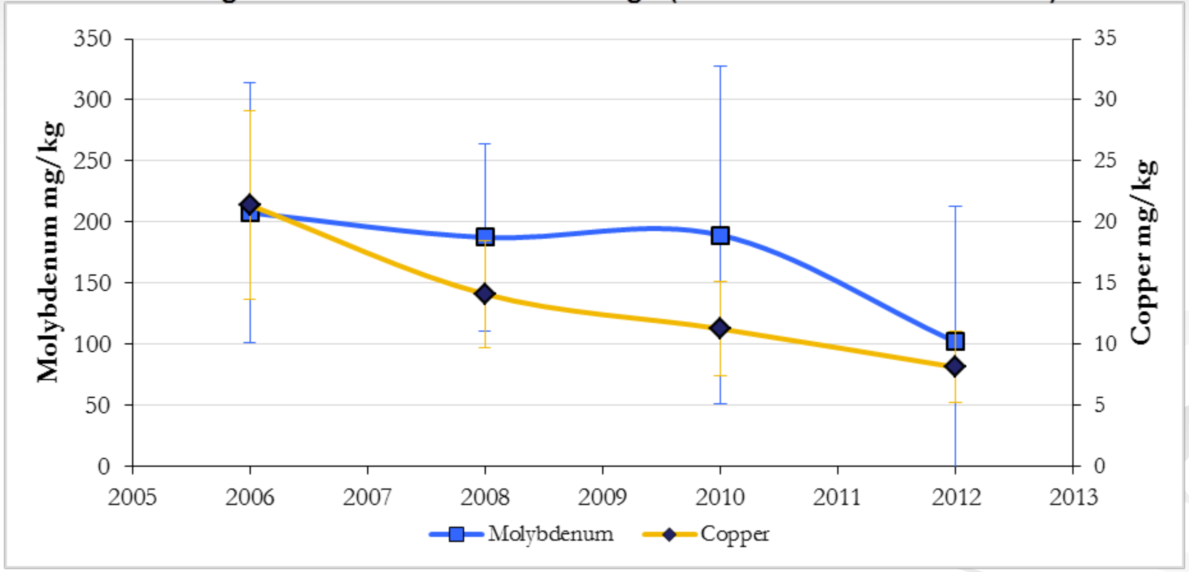
**Figure 4.3-1: Total Mo and Cu in Highmont Tailings Pond and Seepage, Compared to Billy Lake 1995 – 2012**




*first box 2004-5 refilling Highmont pond, second box, dam re-sloping

# metals in riparian vegetation over time

Figure 4.0-2: Autumn Copper and Molybdenum Foliar Concentrations for Riparian Vegetation Grown on HVC tailings (standard error bars shown)



# Tissue metals and bioaccumulation at HVC

**Table 4.0-4: Summary of Mo and Cu Content in Aquatic Plant and Invertebrate Tissue at HVC Tailings Ponds, 1995 – 2012**

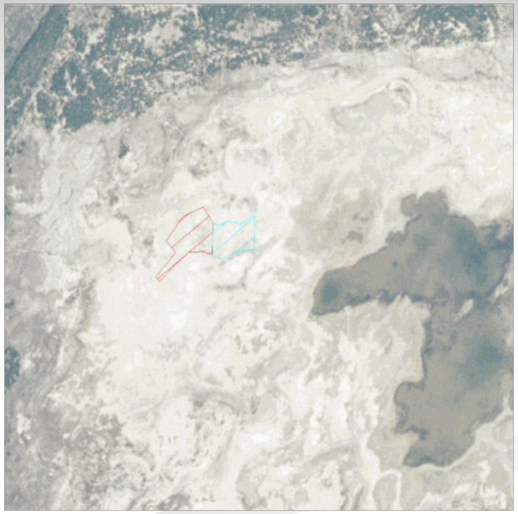
| Tissue type | Species | Mo range mg/kg | Mo mean | Cu range mg/kg | Cu mean | # samples |
|---|---|---|---|---|---|---|
| Blue-green algae | *Anabaena, Anacystis* | 1.4 – 20 | 10.6 | 240 - 360 | 300 | 4 |
| Benthic + b-g mat | Many species | 34 - 520 | 180 | 720 - 3300 | **1600** | 7 |
| Filamentous algae | *Cladophora* etc | 36 – 479 | **260** | 12 – 1322 | 218 | 11 |
| Large stonewort algae | *Chara vulgaris* | 8 - 67 | 14 | 15 – 250 | 220 | 4 |
| Fully submerged | Native milfoil | 5 - 90 | 22 | 100 – 700 | 250 | 8 |
| | *P. pectinatus* | 5 -154 | 111 | 117- 2204 | 220 | 9 |
| | *P. pusillus* | 5 -158 | 32 | 100 – 919 | **500** | 8 |
| Floating leaves | *Ranunculus aquatilus* | 5 - 466 | 87 | 180 –811 | 350 | 9 |
| | *P. Richardsonii* | 25 - 166 | 101 | 112 – 301 | 212 | 8 |
| Decomp plant muck | Many species | 24 - 325 | 185 | 118 - 1173 | **525** | 7 |
| Invertebrates | Many types | 2.8 -13.3 | 7.7 | 100 -274 | 145 | 10 |
| Riparian Tree | Willow Salix spp | 16 - 390 | 81.4 | 6.5 – 41 | 24.9 | 25 |
| | Cottonwood | 7 - 230 | 61 | 5 – 55 | 19 | 11 |
| | Hybrid aspen/cwood | 56 - 1000 | **263** | 5 – 73 | 17 | 34 |
| Riparian Emergents | Sedge | 5 - 280 | 90 | 2 – 44 | 14 | 17 |
| | Cattail | 6 - 318 | 70 | 1.9 – 78 | 10.6 | 13 |
| | Rush Juncus sp | 34 - 780 | **193** | 2.3 – 76 | 19.7 | 14 |
| | Bulrush | 2.9 - 870 | **275** | 2.4 -8.5 | 4.7 | 4 |
| Terrestrial (HVC Report) | Grasses | 5 – 380 | 50 | 9 - 53 | 9.4 | many |
| | Giant Wild Rye (BD) | 9.2 - 17 | 13 | 6.2 - 11 | 8.6 | 2 |
| | Legumes – alfalfa | 110 - 810 | 175 | 15 – 19 | 12 | many |

**all samples taken in growing season; largest averages are bolded (Cattle Mo tolerance is 64 mg/kg in forage but can*

# "Time Lapse" Glory Shots

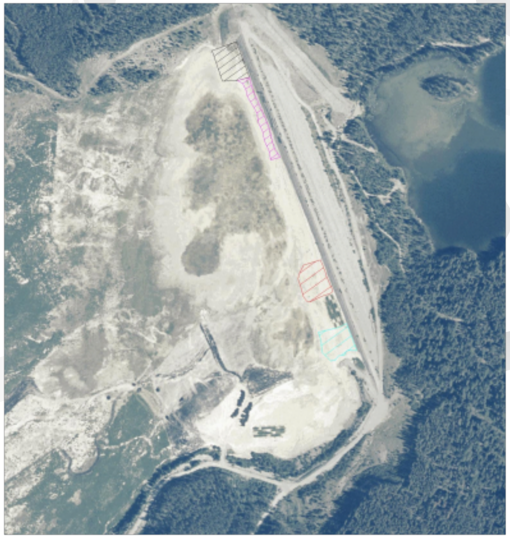
Highmont

Bethlehem Main



Trojan

Bethlehem at Dam



# Bethlehem Dam Tailings

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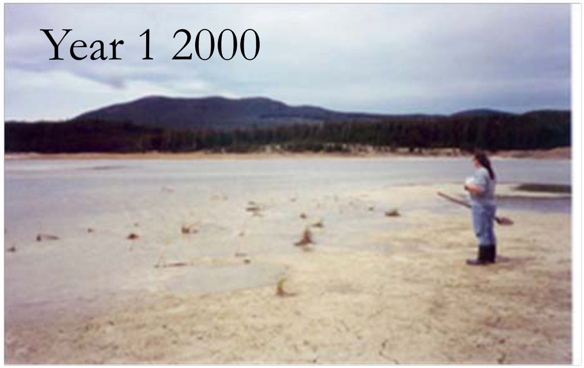



# Bethlehem Dam Tailings (yr 6)
# September 2006 hybrid cottonwood-aspen planting

# Transplanted and Seeded Riparian Vegetation on Bethlehem Dam Tailings June 2010 (yr 10) and July 2012 (yr 12)

# Bethlehem Dam Tailings 2012

Photo 4.2-2: Growth of Introduced Bulrush at Bethlehem Dam Pond, 2012

# Bethlehem Dam Tailings   Fall 2013

# Bethlehem Main Tailings macrophyte resurgence

Photo 4.2-1: Introduced Aquatic Macrophyte and Filamentous Algae Growth in Bethlehem Main Pond, 2012

# Highmont tailings pond Fall 2000

# Highmont tailings pond - Summer 2001

# Highmont tailings pond - Fall 2004

# Highmont Tailings Pond - Summer 2006

# Highmont Tailings Pond - Fall 2007

# Highmont tailings pond - Fall 2013

# SUMMARY

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The establishment of aquatic ecosystems with habitat and bioreactor function would occur naturally without intervention at HVC tailings ponds, but over a much longer period.

# Perspective: HVC tailings water compared to bottled mineral water?

Appendix 10 Comparison of Commercial Mineral Waters and Highland Valley Copper Minewater

| Water quality mg/L | TDS | Cadmium | Floride | Aluminum | Lead | Nickel | Sodium | Calcium | Potassium | Nitrate | Sulphate | Cost/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maximum Acceptible Concentration | | 0.005 | 1.5 | 0.5 | 0.05 | 0.15 | | | | 10 | 500 | cnd 1990 |
| Canada Dry Club Soda | 830 | ND | 1.1 | 0.026 | ND | ND | 390 | 14 | 3.4 | ND | 28 | 0.79 |
| Gerolsteiner Sprudel | 1560 | 0.01 | 0.5 | 0.29 | 0.035 | 0.04 | 300 | 280 | 32 | ND | 28 | 1.69 |
| Perrier | 490 | 0.005 | 0.2 | 0.15 | ND | ND | 14 | 136 | 0.59 | 6 | 58 | 1.85 |
| Pellegrino | 1250 | 0.006 | 0.6 | 0.4 | 0.024 | ND | 42 | 160 | 3.8 | ND | 500 | 2.25 |
| Sparcal | 1170 | 0.006 | 0.2 | 0.25 | 0.016 | ND | 31 | 280 | 2.1 | ND | 759 | 1.56 |
| Vittel Grande Source | 640 | 0.008 | 0.3 | 0.022 | 0.031 | 0.022 | 3 | 240 | 2.1 | 1.5 | 500 | 0.56 |
| Apollinaris | 1870 | 0.007 | 0.5 | 0.038 | 0.014 | 0.026 | 820 | 120 | 56 | 1.8 | 105 | 1.69 |
| MontClair | 1400 | 0.005 | 1 | 0.016 | ND | ND | 850 | 30 | 17 | ND | 50 | 1.98 |
| Montellier | 800 | 0.004 | 1.6 | 0.335 | ND | ND | 555 | ND | 5.7 | ND | ND | 1.58 |
| President's Choice E Canada | 1000 | 0.04 | 3 | 0.078 | ND | ND | 640 | 20 | 12 | ND | ND | 1.45 |
| President's Choice W Canada | 1020 | 0.007 | 0.2 | 2.4 | 0.023 | 0.02 | 45 | 240 | 4.6 | 17 | 270 | 1.18 |
| Radnor | 1950 | 0.008 | 2.2 | 0.02 | ND | 0.022 | 830 | 120 | 19 | ND | 88 | 0.65 |
| KarlSpring | 2900 | 0.01 | 0.2 | 0.072 | 0.029 | 0.041 | 2000 | 140 | 245 | ND | 20 | 1.58 |
| Radenska | 2550 | 0.01 | 0.7 | ND | 0.036 | 0.035 | 1400 | 240 | 220 | ND | 110 | 1.69 |
| Steinberg | 1950 | 0.006 | 1 | ND | ND | 0.023 | 1500 | 20 | 25 | ND | ND | 0.52 |
| Vichy Celestins | 3200 | 0.012 | 4 | ND | 0.036 | 0.041 | 2400 | 115 | 200 | ND | 120 | 1.41 |
| Abenakis | 23000 | 0.064 | 0.2 | ND | 0.14 | 0.2 | 12000 | 320 | 160 | ND | 685 | 1.58 |
| Trojan tailings pond | NS | <0.005 | NS | <0.01 | <0.005 | <0.01 | 4.4 | 23 | 2.4 | <0.003 | 9.6 | 0 |
| S5 discharge | NS | <0.005 | NS | <0.01 | <0.005 | <0.01 | 80 | 78 | 9.1 | <0.003 | 140 | 0 |
| Highmont E Pit surface | NS | <0.005 | NS | <0.01 | <0.005 | <0.01 | 33 | 58 | 3.2 | <0.003 | 180 | 0 |

# Questions?