INVESTIGATING LOADINGS FROM TAILINGS AND WASTE ROCK FOR CLOSURE PLANNING AT NYRSTAR MYRA FALLS

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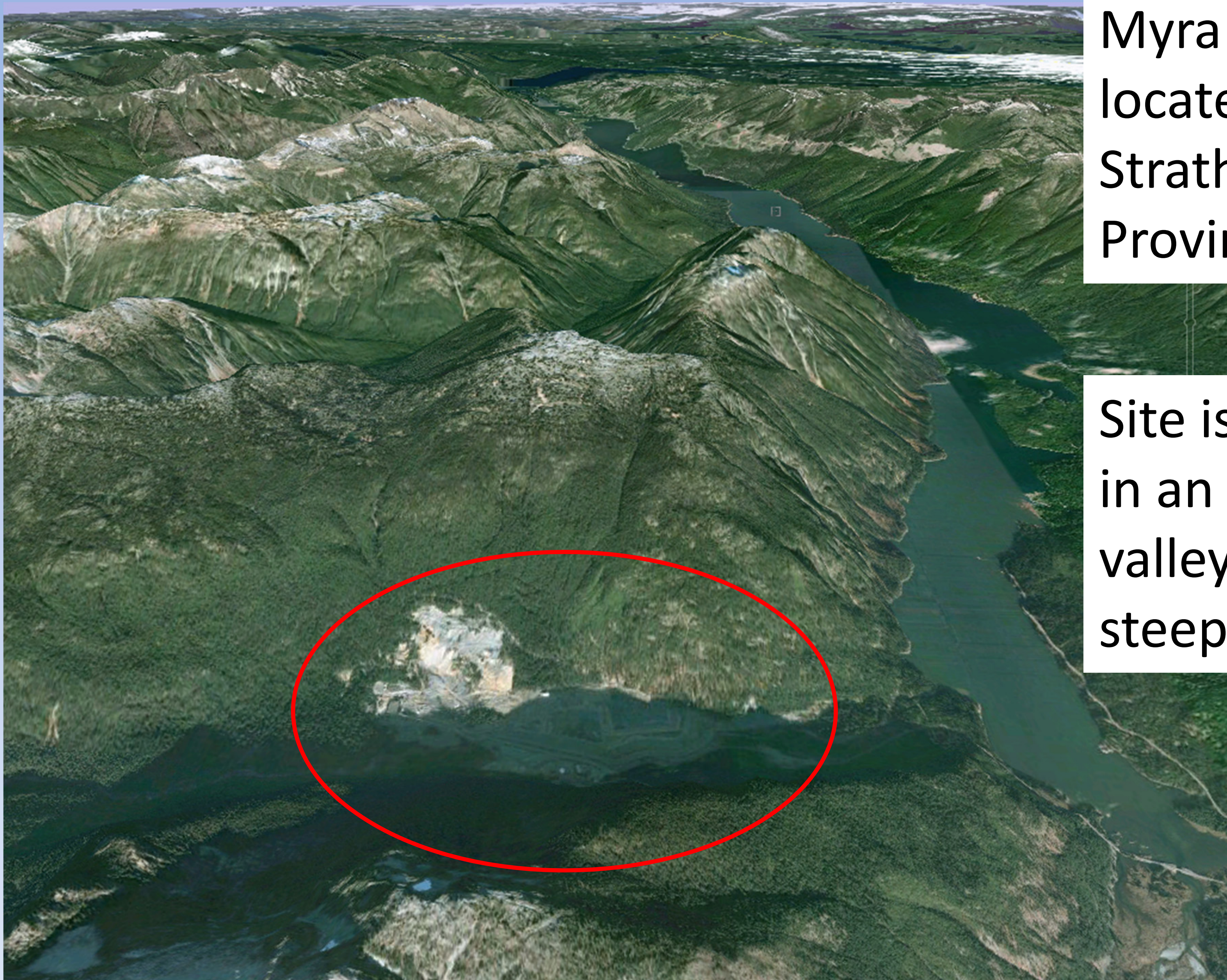
Outline

- Contaminant load model
- Calibrated groundwater model
- Closure Plan Cover system

Myra Falls is located in Strathcona Provincial Park

Site is located in an alluvial valley with steep terrain



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Introduction to Myra Falls

- Mine has been operating since 1966
- Producing copper, lead & zinc concentrates with silver and gold credits
- Currently owned by Nyrstar, following purchase of Breakwater Resources Limited in Aug 2011
- Site Status: closing the Tailings Disposal Facility while continuing to operate for another 10-20 years

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Looking east down the valley

MAP is ~2600 mm/yr

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Aerial Photo of the TDF, 2006

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Tailings Disposal Facility

- Tailings Disposal Facility is 44 ha
- 30 m of sub-aerially deposited conventional tailings
- 10 m of paste tailings placed on top
- The "strip" is the conventional tails
- A reclaim sand area stores coarser tails
- The TDF is supported by a stabilizing toe-berm referred to as the Seismic Upgrade Berm

Components of TDF

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Pump House and Myra Creek

5 under drain lines connected to pump house

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Summary of Under Drains

- Inner Drain – twinned drainage collection
- Outer Drains – 4 perforated lines connected
  - act as a hydraulic barrier to protect Myra Ceek
- New Outer Drain system came on-line in 2008
  - Constructed with Seismic Upgrade
  - Improved seepage collection

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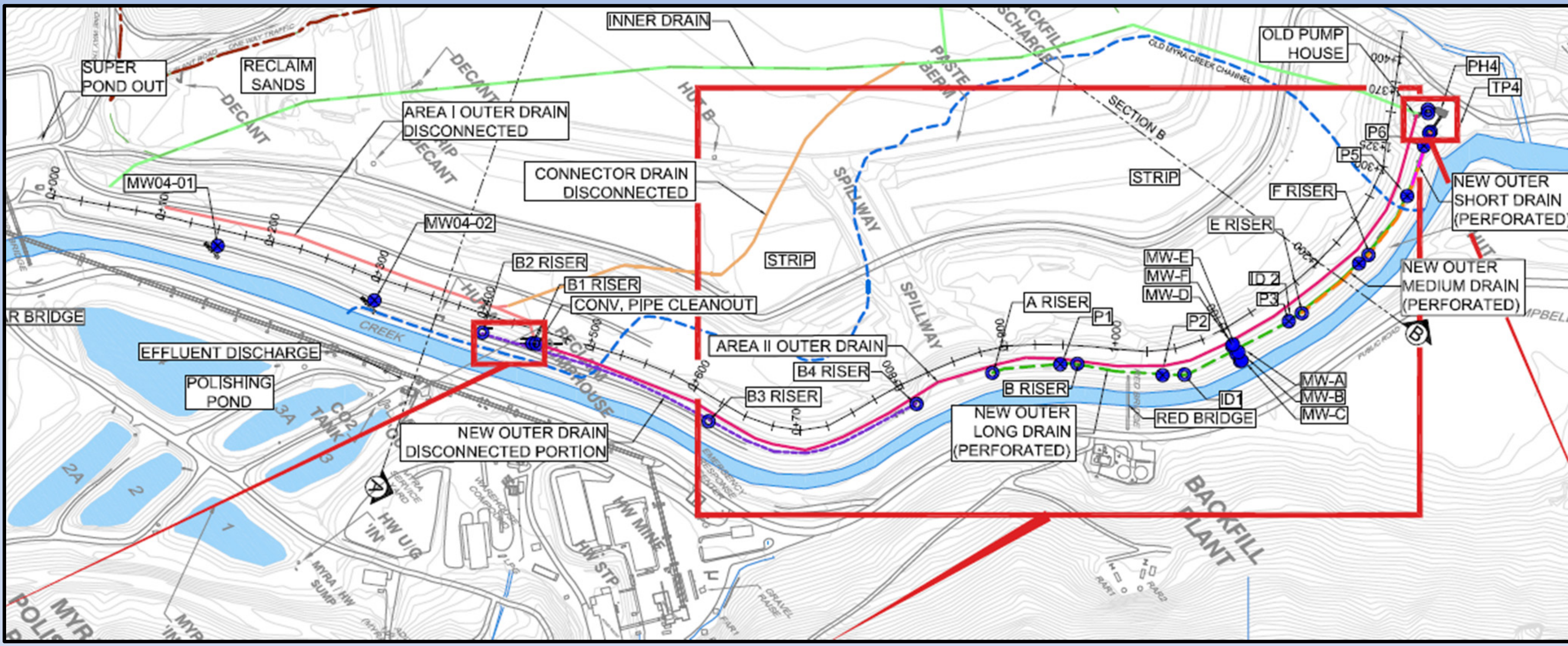
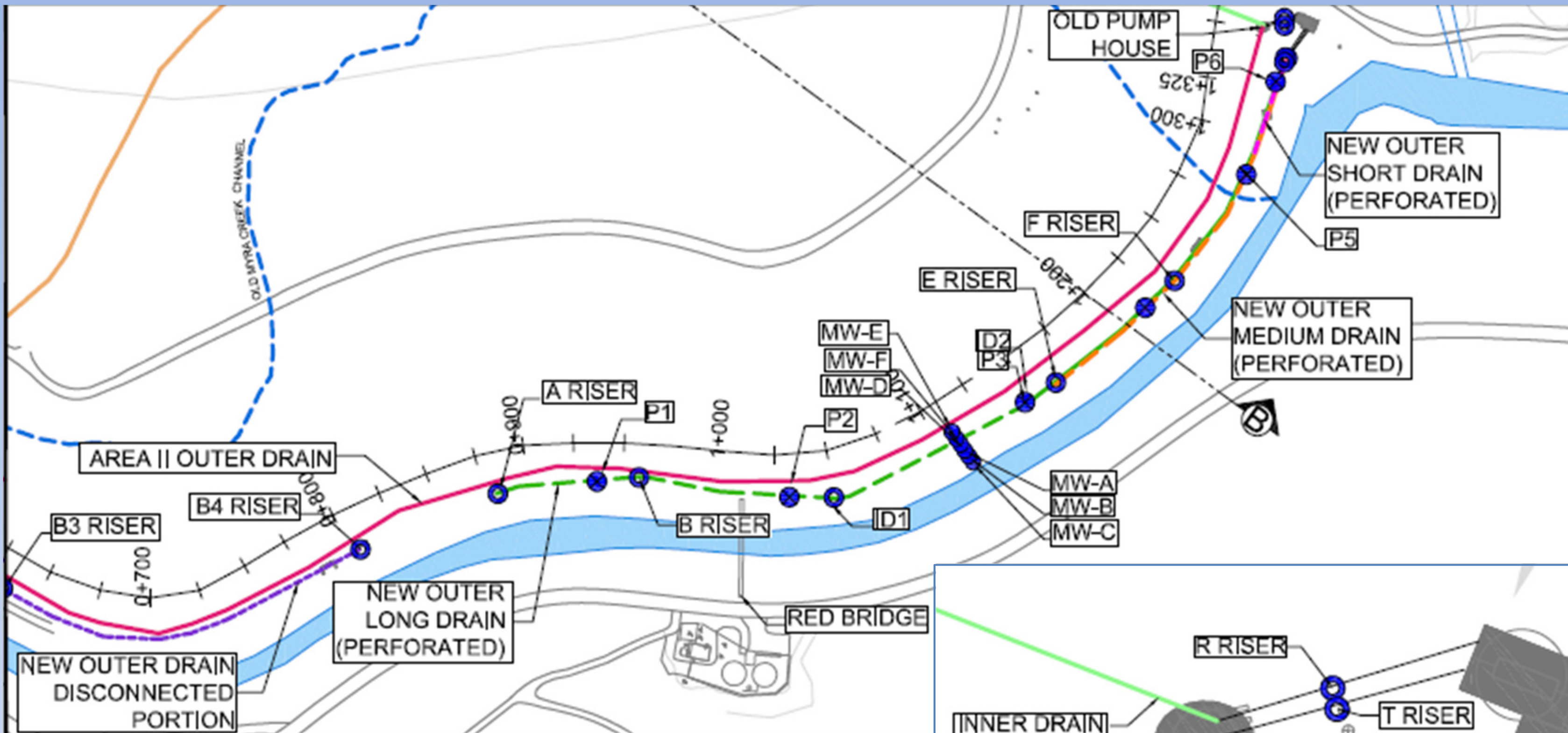
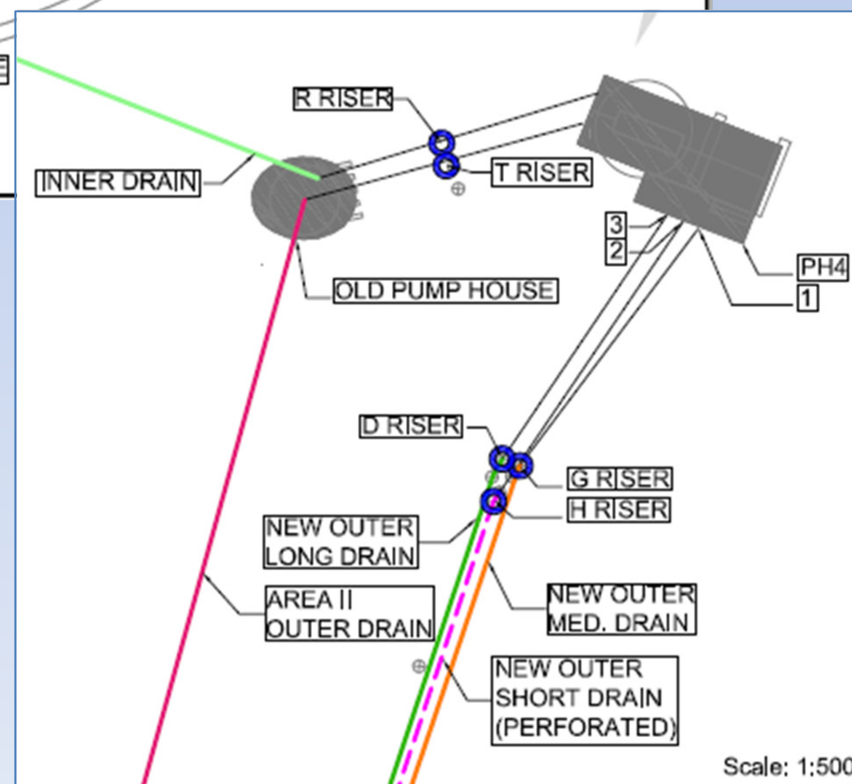
TDF Under Drains



Five lines gravity-drain to pump house (PH4), then are pumped to water treatment





New Outer Drain

- Medium, Short, Long Drain
- Perforation in 3 segments
- Risers, Standpipes, Monitors

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Waste Rock

- Waste rock has been generating acidic drainage for decades
- The under-drains collect contaminated groundwater seepage coming from waste rock
- In the 80s and 90s there were monitoring wells and active investigation of the waste rock

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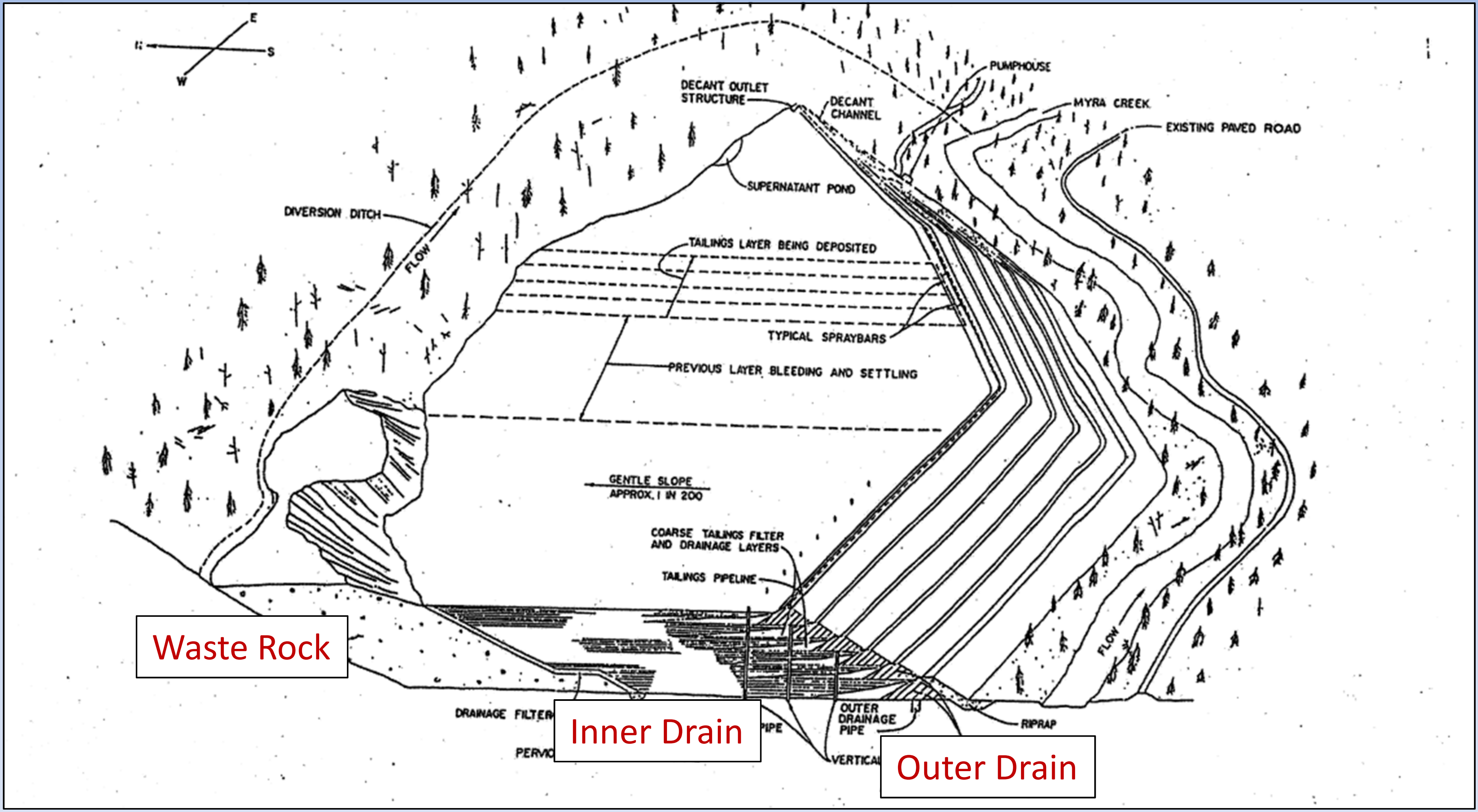
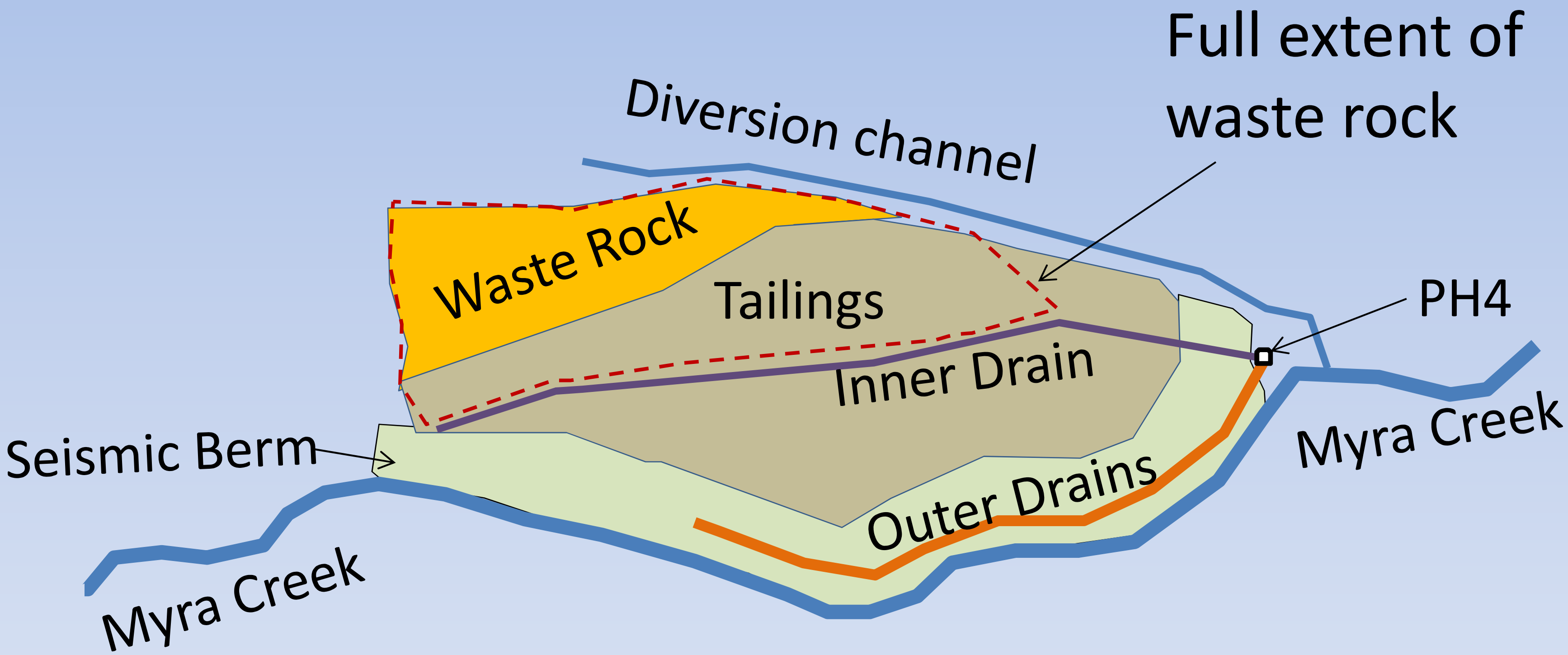
Waste Rock Under TDF



from Knight Piesold (1982)

Waste Rock and Under Drains



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Current Condition – Myra Creek

- Zinc is the main contaminant indicator for the mine
- 2010 annual average:
  - Upstream of the mine ~ 0.0006 mg/L Zn
  - Downstream of the mine ~ 0.1 mg/L Zn
- Water quality d/s varies seasonally, with higher Zn in the rainy season, Nov to Apr

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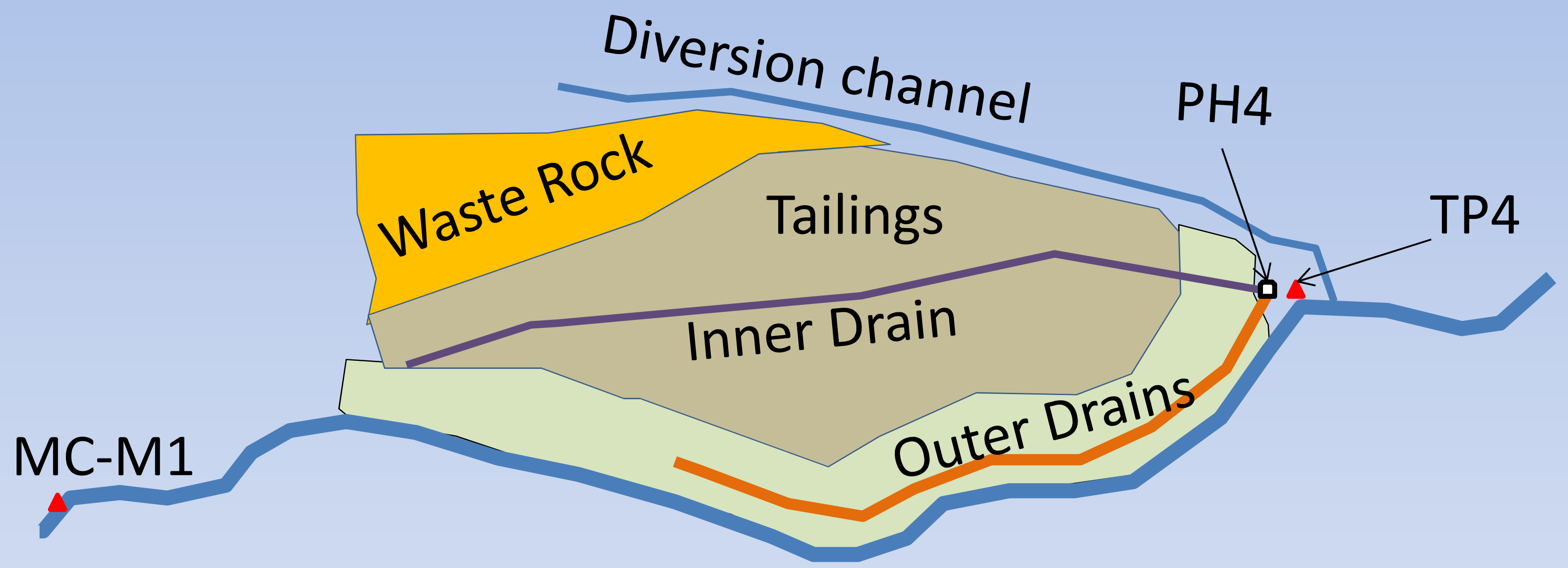
Myra Creek Stations



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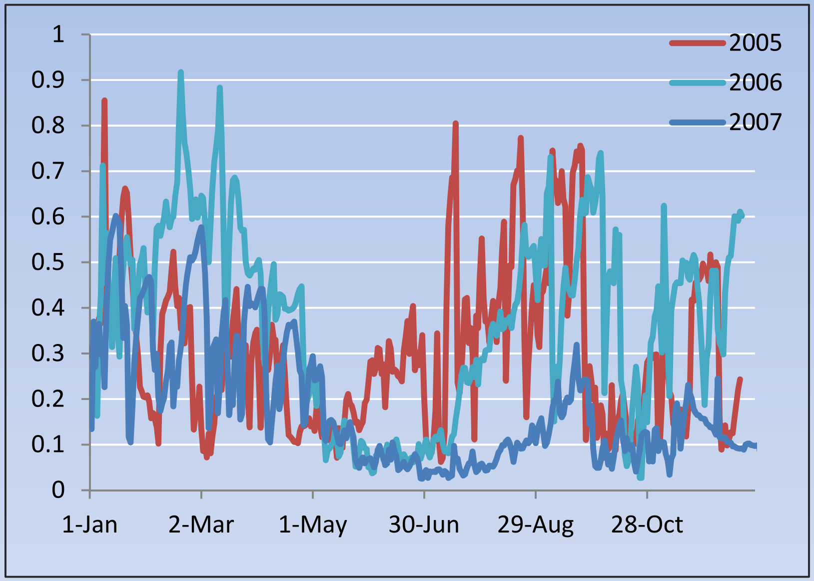
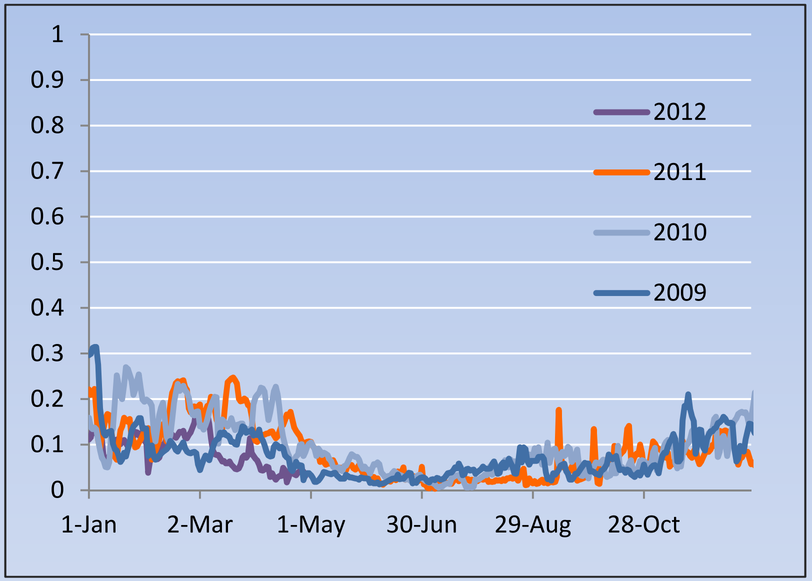
Zinc at TP4, 2005 to 2012 (mg/L)





- Water quality improved in Myra Creek since 2008

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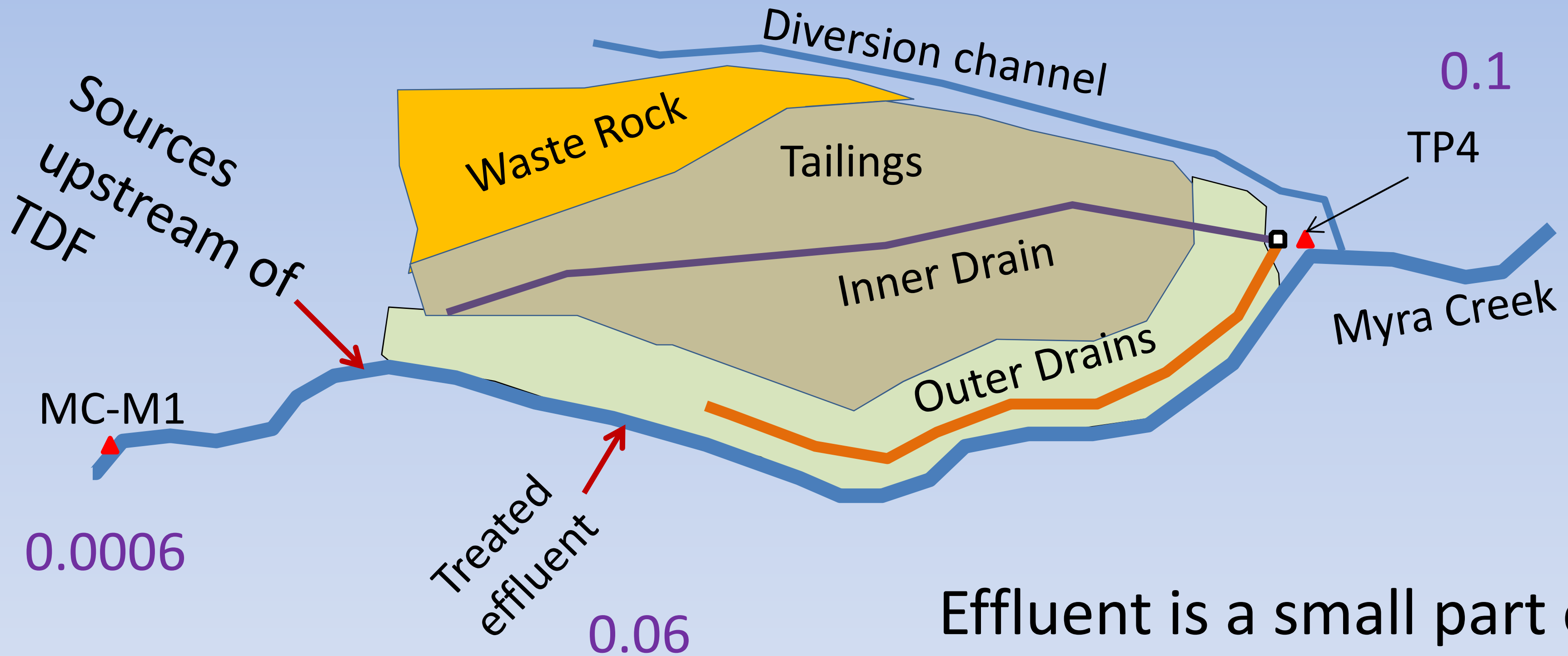
Water Quality of Sources



Effluent is a small part of the load to Myra Creek

Groundwater Monitoring

- MEA repaired existing wells and installed additional wells
- Paired, nested monitoring wells are located hill side and creek side of the outer drains
- Results show:
  - Outer drains are functioning to protect the creek
  - Deep groundwater is not completely captured by the drains

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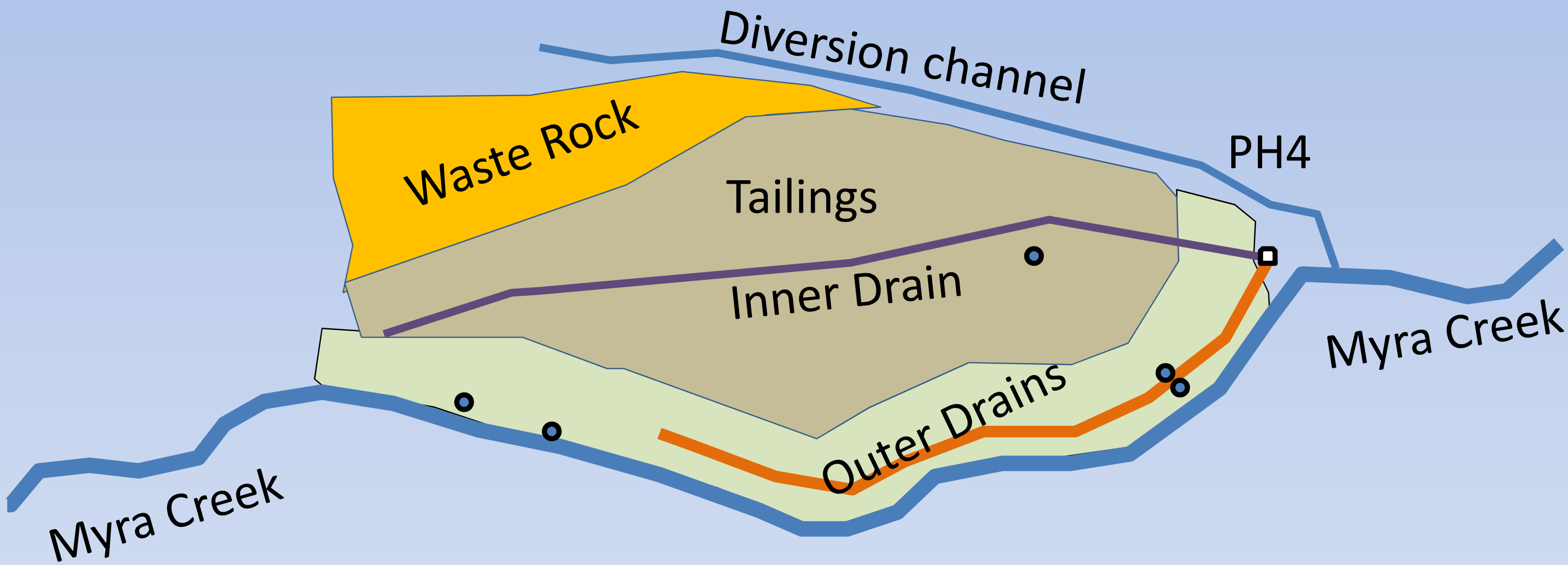
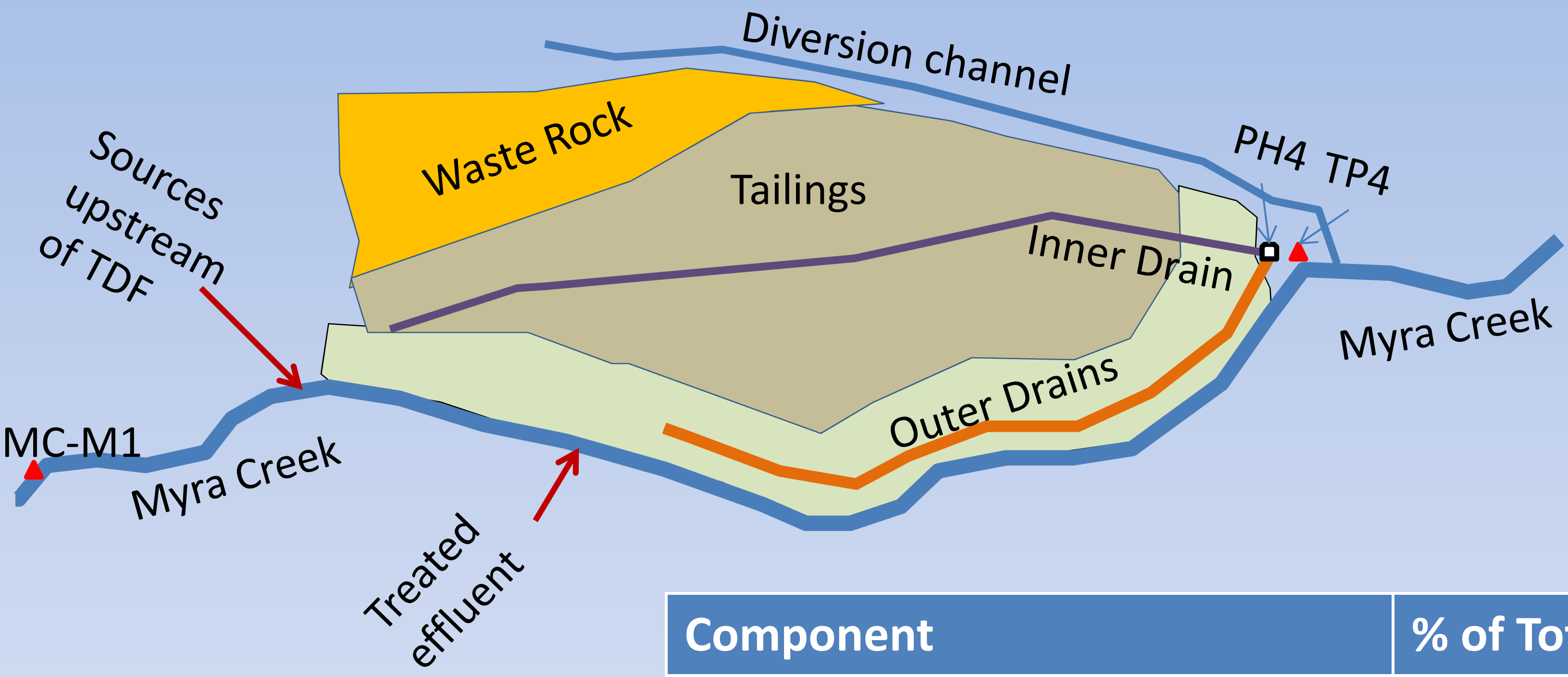
Active Groundwater Monitoring



Outer Drains and wells: 5 - 20 mg/L zinc
Inner Drain: 25 - 35 mg/L zinc
Tailings well: 1 – 3 mg/L zinc
U/s wells near creek: 1-2 mg/L zinc

Contaminant Loading Balance - Creek



TP4: 27,000 Kg/yr Zn

Component	% of Total
Background	0.6
Sources upstream of TDF	24
Treated Effluent	7
TDF groundwater (by difference)	68
TP4 total load	100

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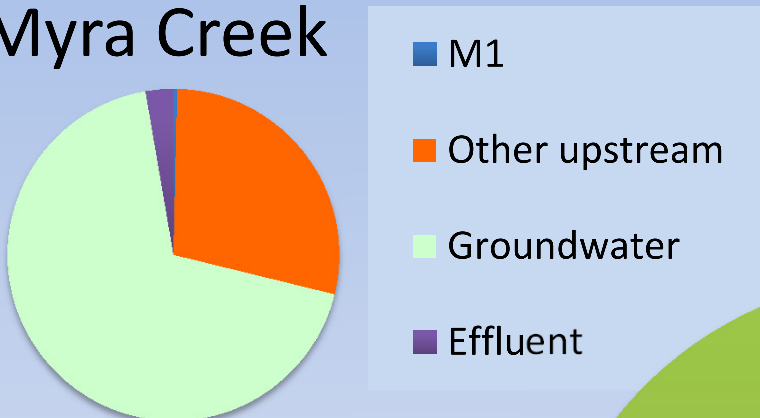
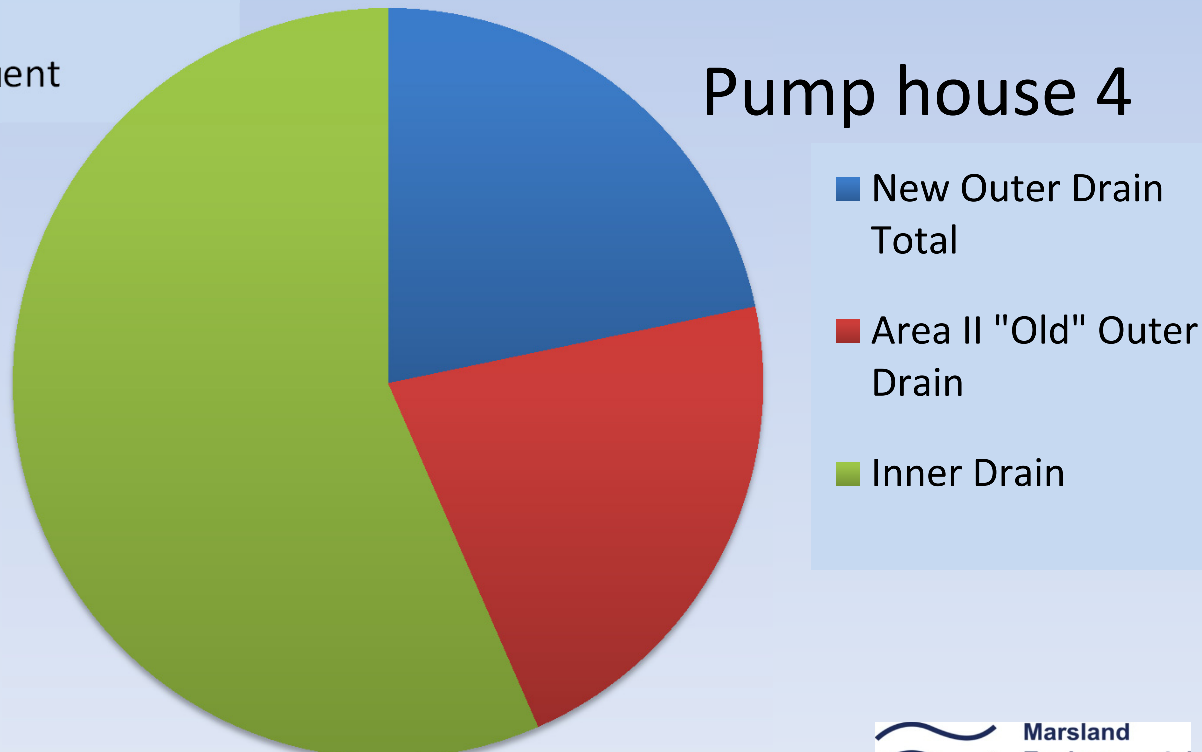
Zn Loadings - Myra Creek and PH4

Myra Creek



PH4 load is ~3 times Myra Creek

Pump house 4



Drains are essential for protecting Myra Creek long term

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Groundwater Model

- Regional 3-D groundwater model was developed and calibrated for the TDF Closure Plan
- Developed in MODFLOW
- Objective was to help assess closure cover alternatives such as a liner on the TDF
- Groundwater model contributes information for the loading balance

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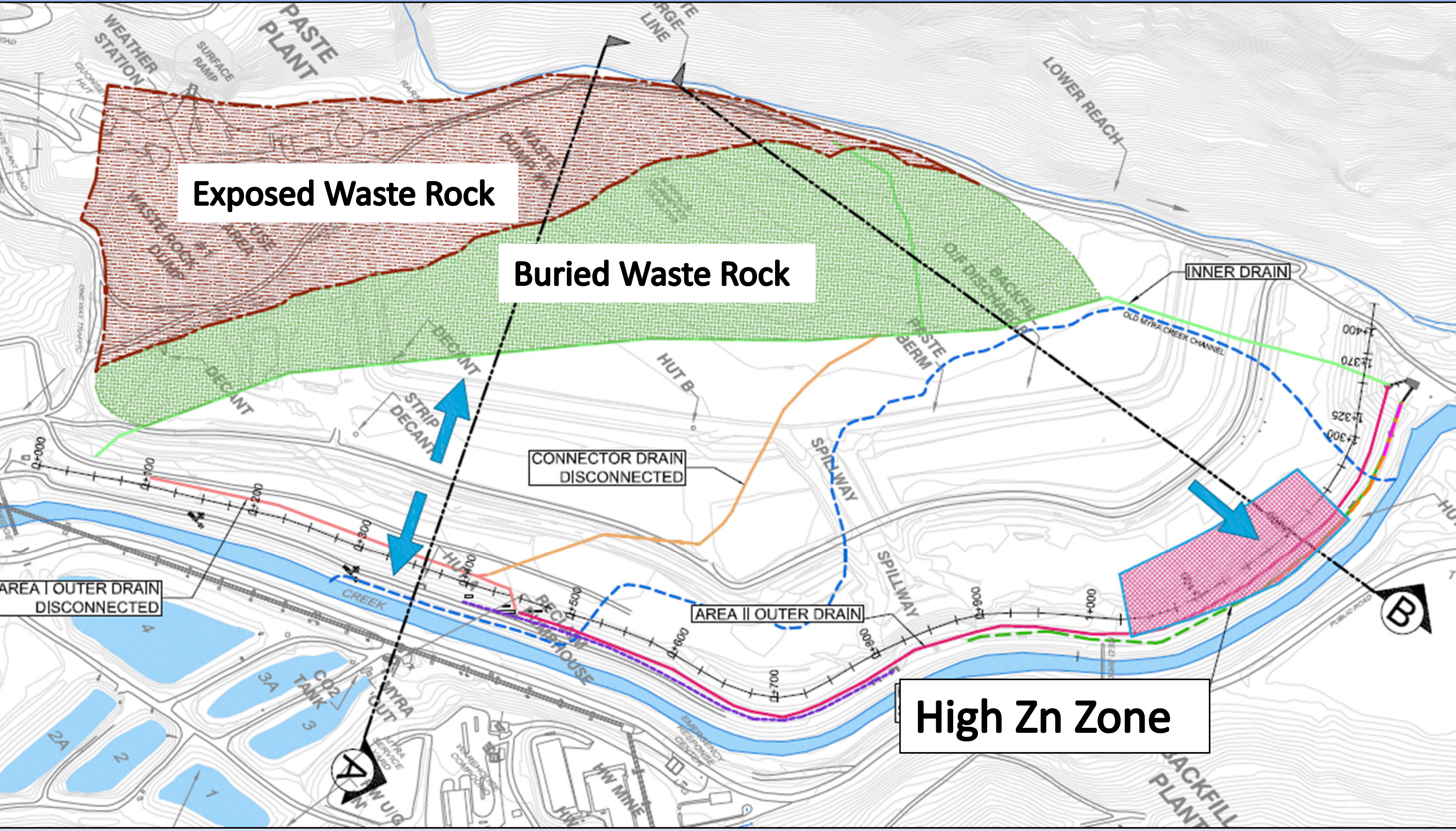
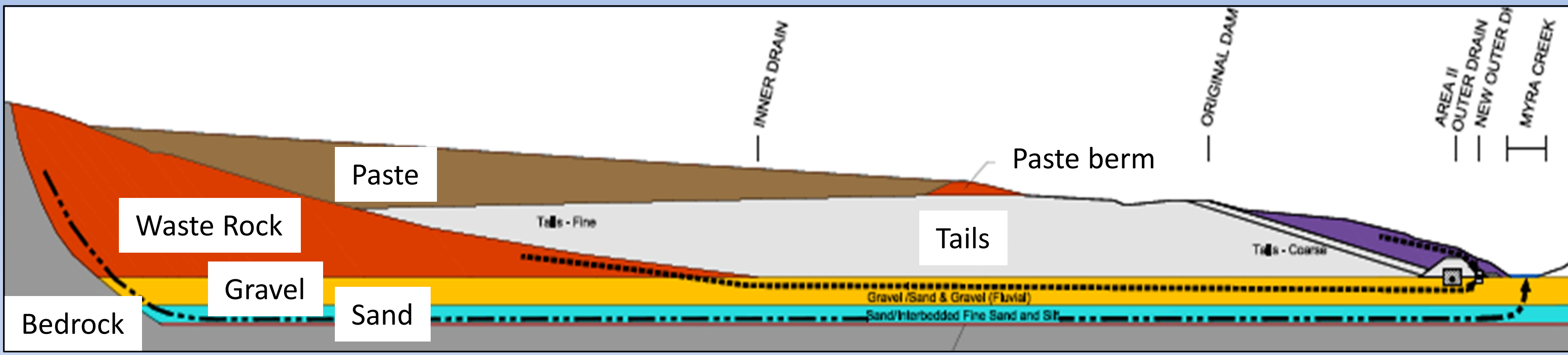


Groundwater flow arrow

Data from Klohn, 2004

Section Through TDF



- Waste rock and tailings sit on a gravel aquifer
- Conceptual groundwater model

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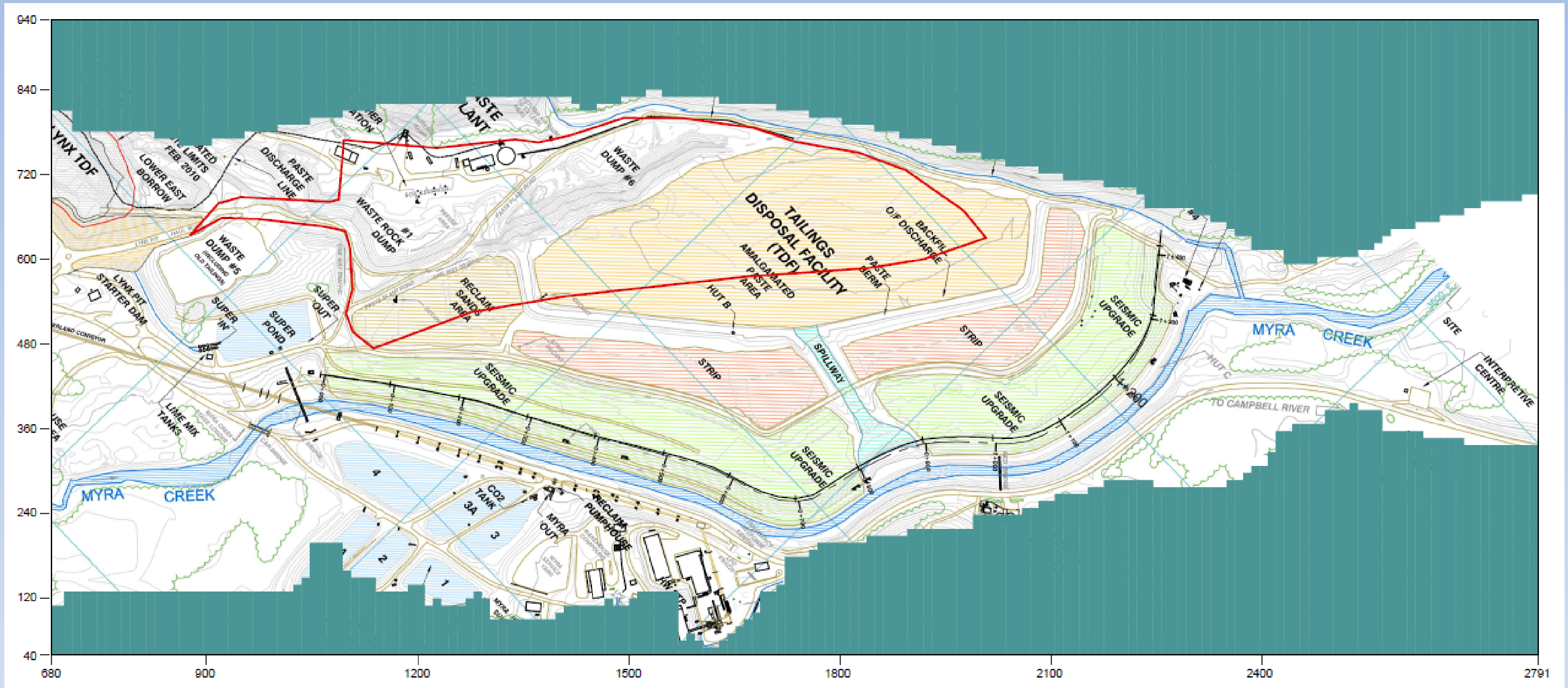
Groundwater Model Domain



- Centred on TDF

Historical Groundwater Data

- The site has historical data back to pre-TDF period:
- 1980-1981 Study by Simco (published 1982)
- 1989-1990 Study by NW Geochem (published 1990 & 1992)
- TDF Monitoring Data (2001-present)
- Model was constructed for three dates – 1982, 1990 and 2010

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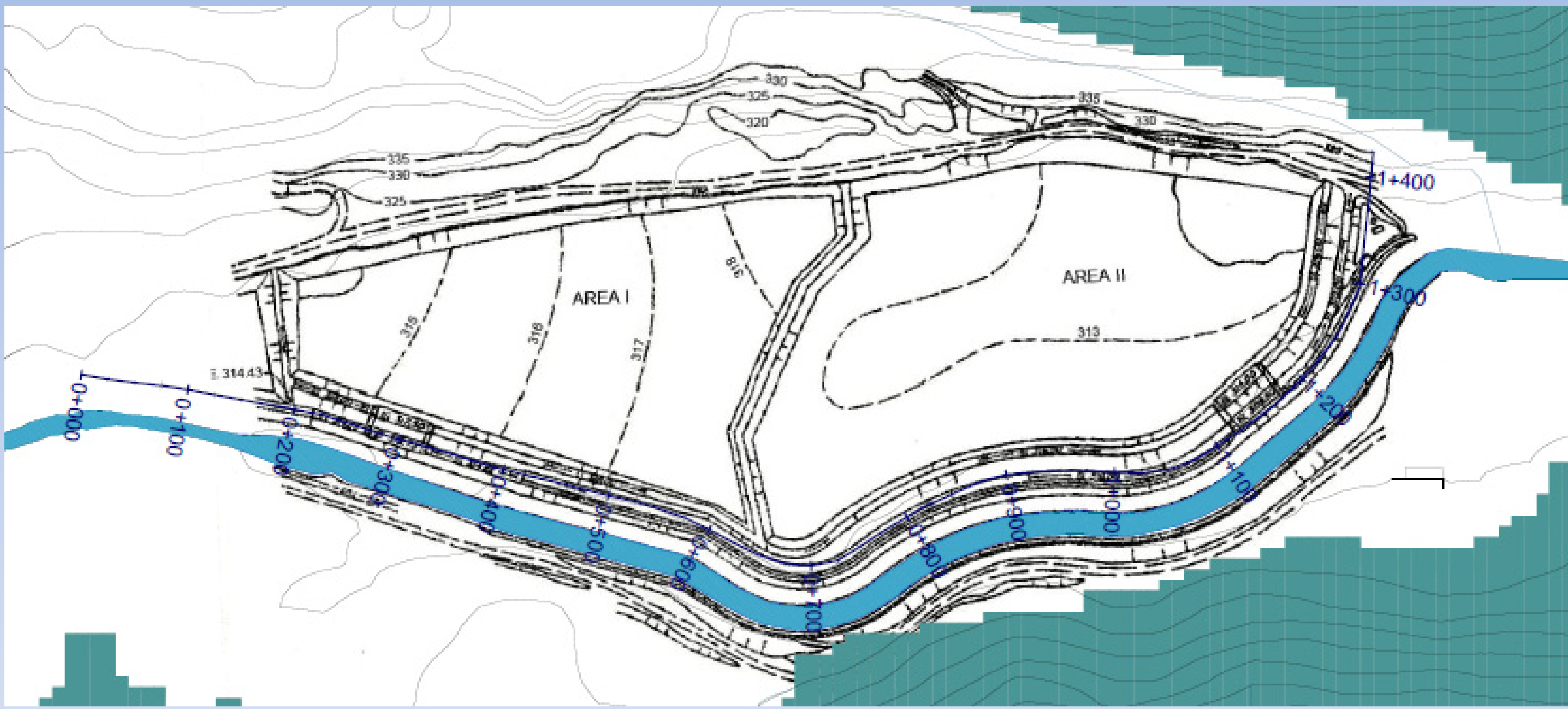
Versions of Model - 1982 Setting

- 1982 calibration run for foundation materials (gravel, sand, clay)

Versions of Model - 1990 Setting



- 1990 calibration run for waste dump, Inner Drain conductance and general head conductance

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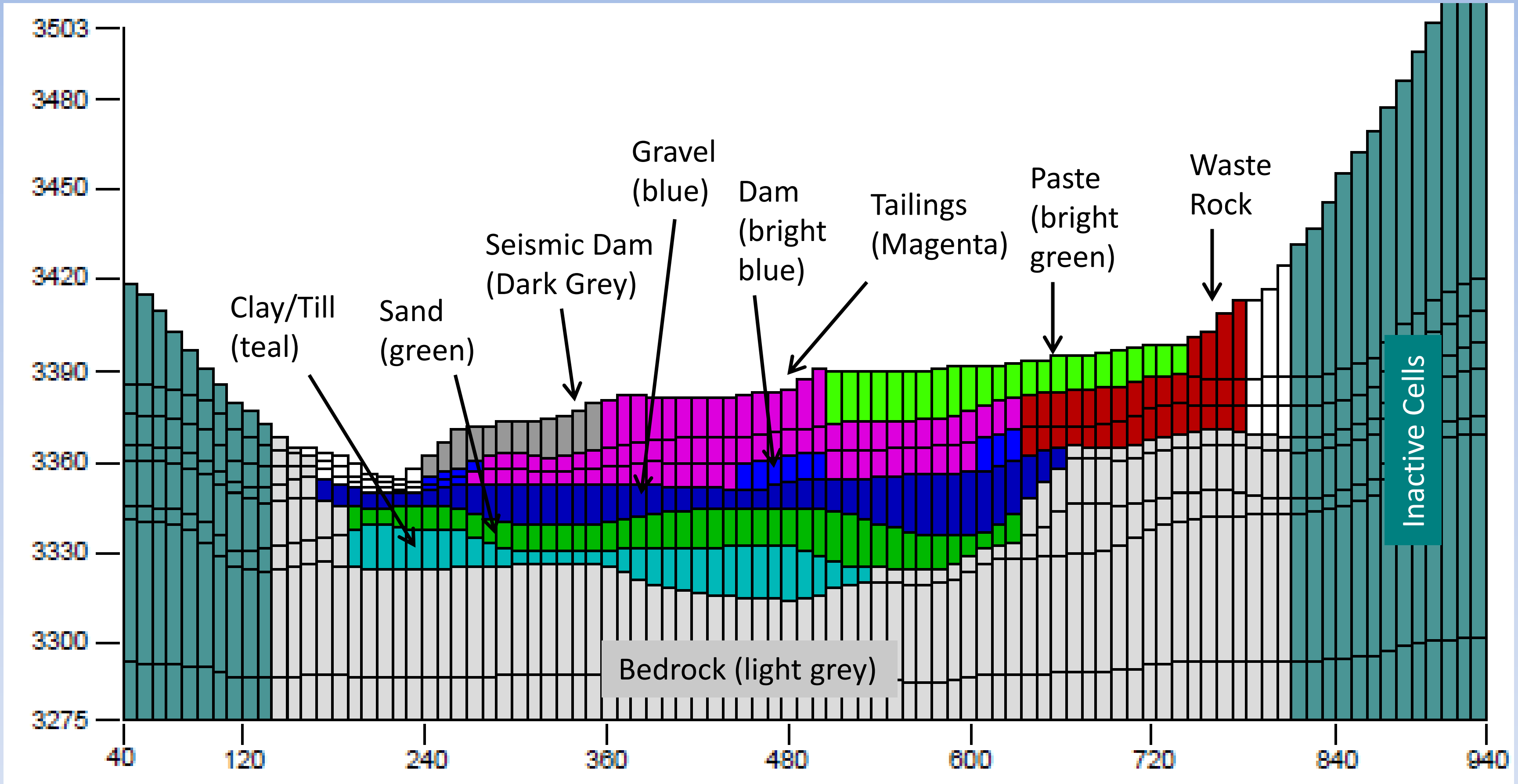
Versions of Model - 2010



- 2010 calibration run for tailings and outer drain conductance

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Key Components of Water Balance

Component	Flux (L/s)
Indirect Recharge - Mountain	290
Direct Recharge - TDF	5
Outflow to Inner Drain	53
Outflow to Outer Drain	63

- Largest component of flow is from indirect recharge from mountain slope
- Fluxes to Inner and Outer Drain are consistent with measured values

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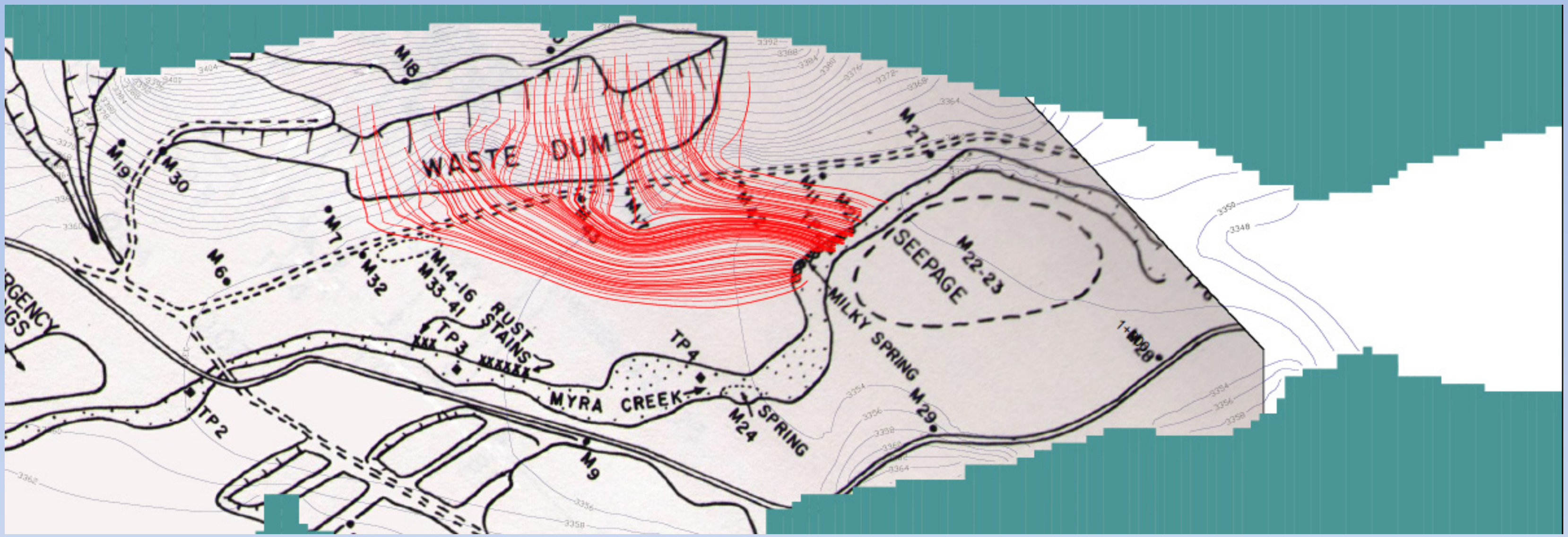
Predicted Pathlines - 1982



- 1982 flux to Milky Spring
- GW flows parallel to Myra Creek rather than down slope because of the high K of gravel aquifer

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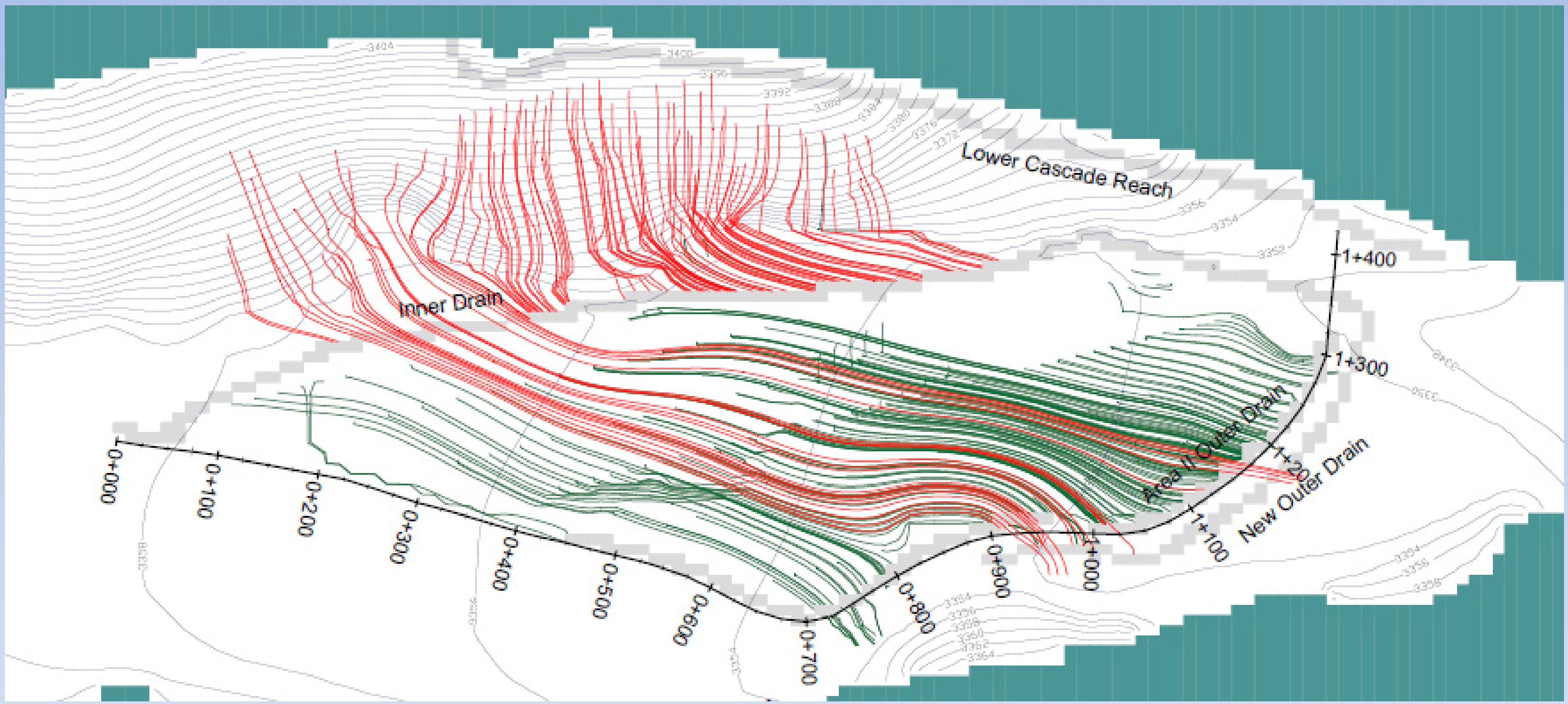
Predicted Pathlines - 2010



- Waste rock in red, tailings in green
- Under drains capture a large portion of Zn
- Deep groundwater plume

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Contaminant Load Balance – Total

- 2nd contaminant load model estimates the portion of loadings from waste rock and tailings sources
- Annual loadings in Myra Creek and PH4 are the total upper limit for waste rock and tailings loadings - 93,000 Kg/yr Zn
- Contaminant load model draws on groundwater model inflows and outflows

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Sources of Zinc Loadings

- Tailings
  - Source of contamination?
  - Within tails, Zn in groundwater is low
  - At surface oxidation occurs with high Zn in runoff (decants)
- Drainage from Waste Rock
  - Waste Rock adjacent to and underneath tailings is a source of contamination
- Compacted PAG waste rock included in the core of the Seismic Upgrade berm
  - PAG used only where TDF has outer drain collection

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Tailings Source Load Pathways

- Infiltration though tailings to the gravel aquifer beneath
  - The tailings are partially saturated and have a water table that changes seasonally
  - Groundwater conc. much higher for the drains and monitoring wells than the pore water in deeper tails
- Surface of the strip tails is oxidized
  - Water quality in the strip decant is poor (50 mg/L zinc)

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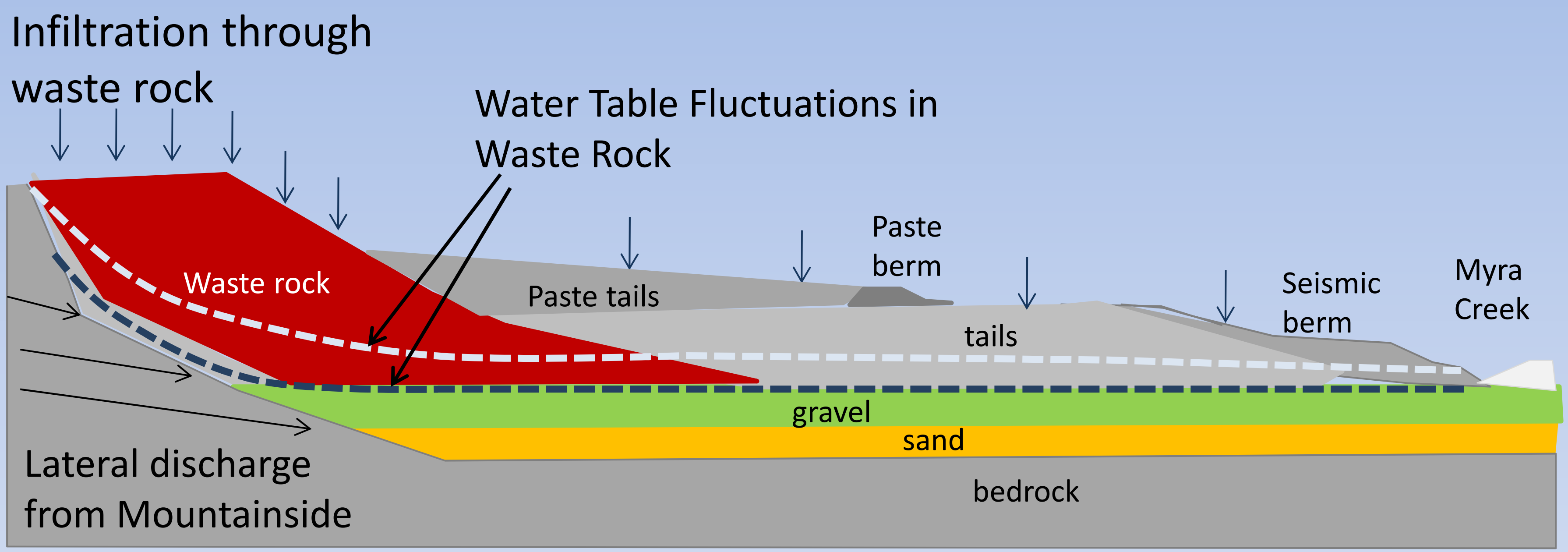
TDF Waste Rock Loadings



- Mountain recharge increases water table fluctuations (Northwest Geochem, 1992)
- Infiltration load was estimated and remaining load was attributed to the mountain recharge mechanism

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Loadings - Waste Rock and Tailings

Source	Zn (Kg/yr)	Flow (L/s)
Waste Rock – Direct Infiltration	59400	3.8
Waste Rock - mountain recharge	29500	127
Waste Rock - PAG in seismic berm	2300	1.8
Tailings - Infiltration	1260	3.3

- Northwest Geochem (1992) measured *saturated* pore water at 470 mg/L zinc within waste rock
- 500 mg/L zinc assumed for *unsaturated* pore water quality contributing loadings from the waste rock (uncertain value)
- Monitoring well installed just beneath the tailings showed 3 mg/L Zinc, we assumed 12 mg/L unsaturated tails pore water

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TDF Closure Design

- The final paste lift of the TDF is at capacity
- Strip, RSA and paste berm
  - Geo-synthetic liner on PAG rock platform; till
- Paste tailings
  - Waste rock & till cover
- Waste rock within the TDF footprint
  - Till cover on the re-contoured surface
- Cover design by O'Kane Consulting
- MEA modelled effect of closure plan on Myra Creek

Closure Plan Cover Design

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Post-Closure Loading Balance Model

- The proposed cover design is expected to reduce loadings in the short-term to ~80% of the current condition
  - From 93,000 Kg/yr to 76,000 Kg/yr
- This prediction does not consider long-term loadings
- The reduction is largely from reduced infiltration rates
  - Cover is expected to reduce infiltration into waste rock from 1350 mm to 600 mm

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Summary

- Treated effluent is a small source of the loadings to Myra Creek
- Groundwater flowing under the TDF is the largest source of loadings to Myra Creek
- Waste rock is the primary cause of these loadings
- The under-drains and treatment system are critical for protecting Myra Creek water quality

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Summary

- Conceptual model for loadings from waste rock includes two pathways
- Seasonal variations in mountain recharge cause water table fluctuations within waste rock
- Covering waste rock is expected to improve water quality in Myra Creek
- A waste rock cover will not remove all loadings because of the mountain recharge

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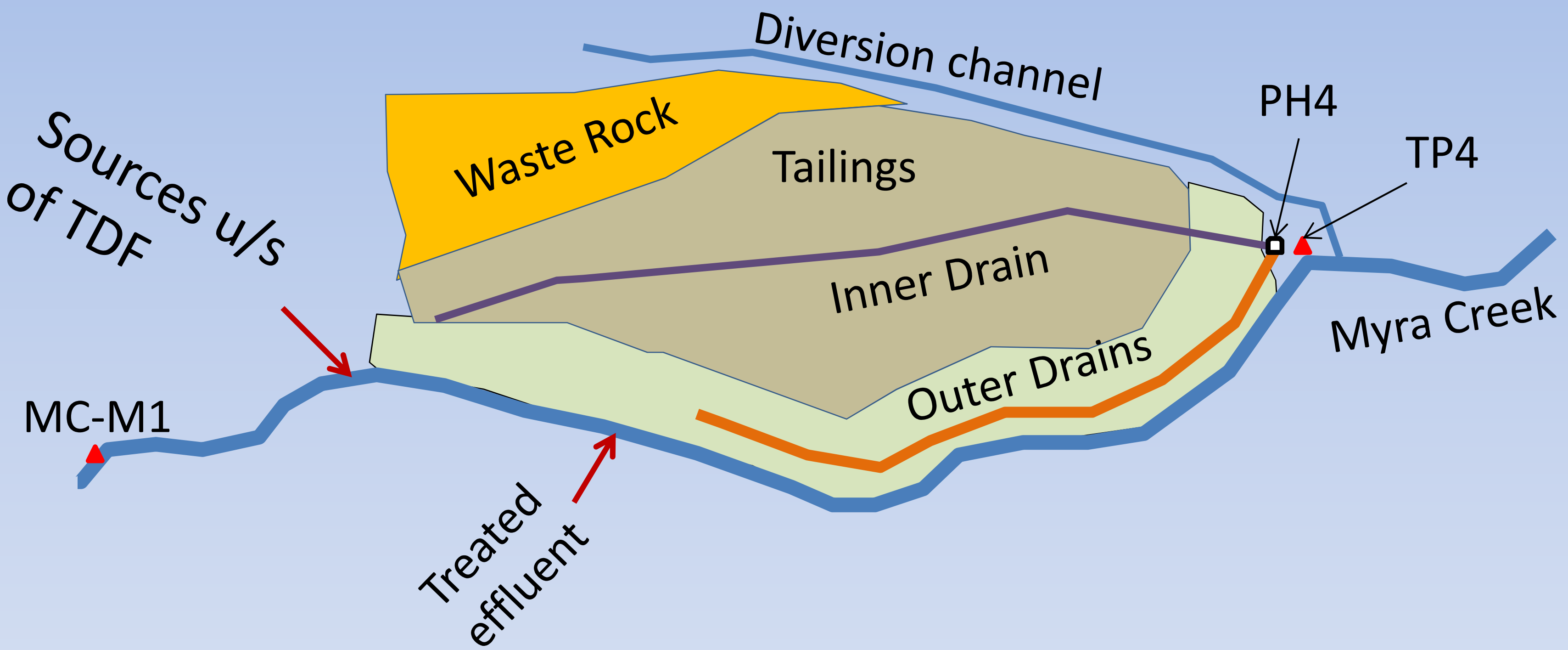
Questions?



Paper included in ICARD proceedings, 2012

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