



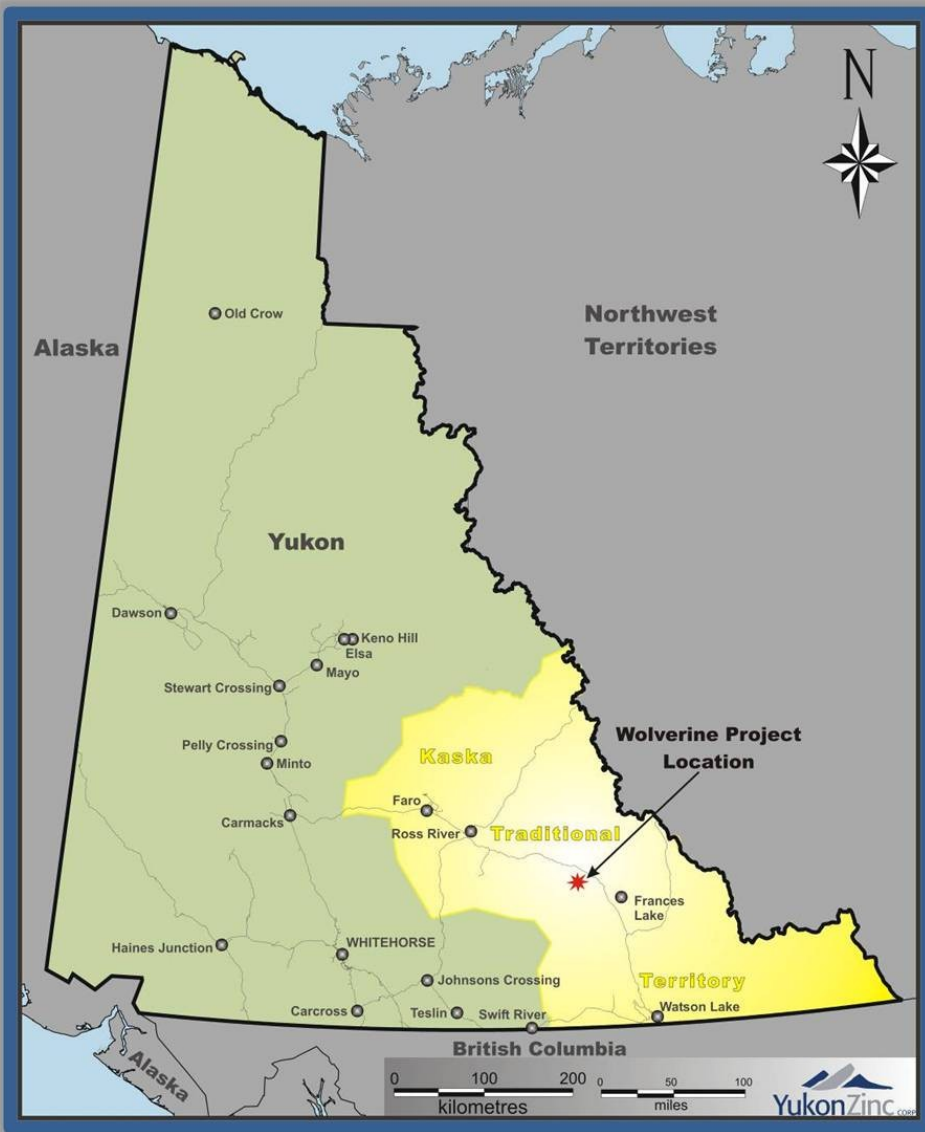
# Column Experiments for Groundwater Remediation Post Closure at the Wolverine Mine



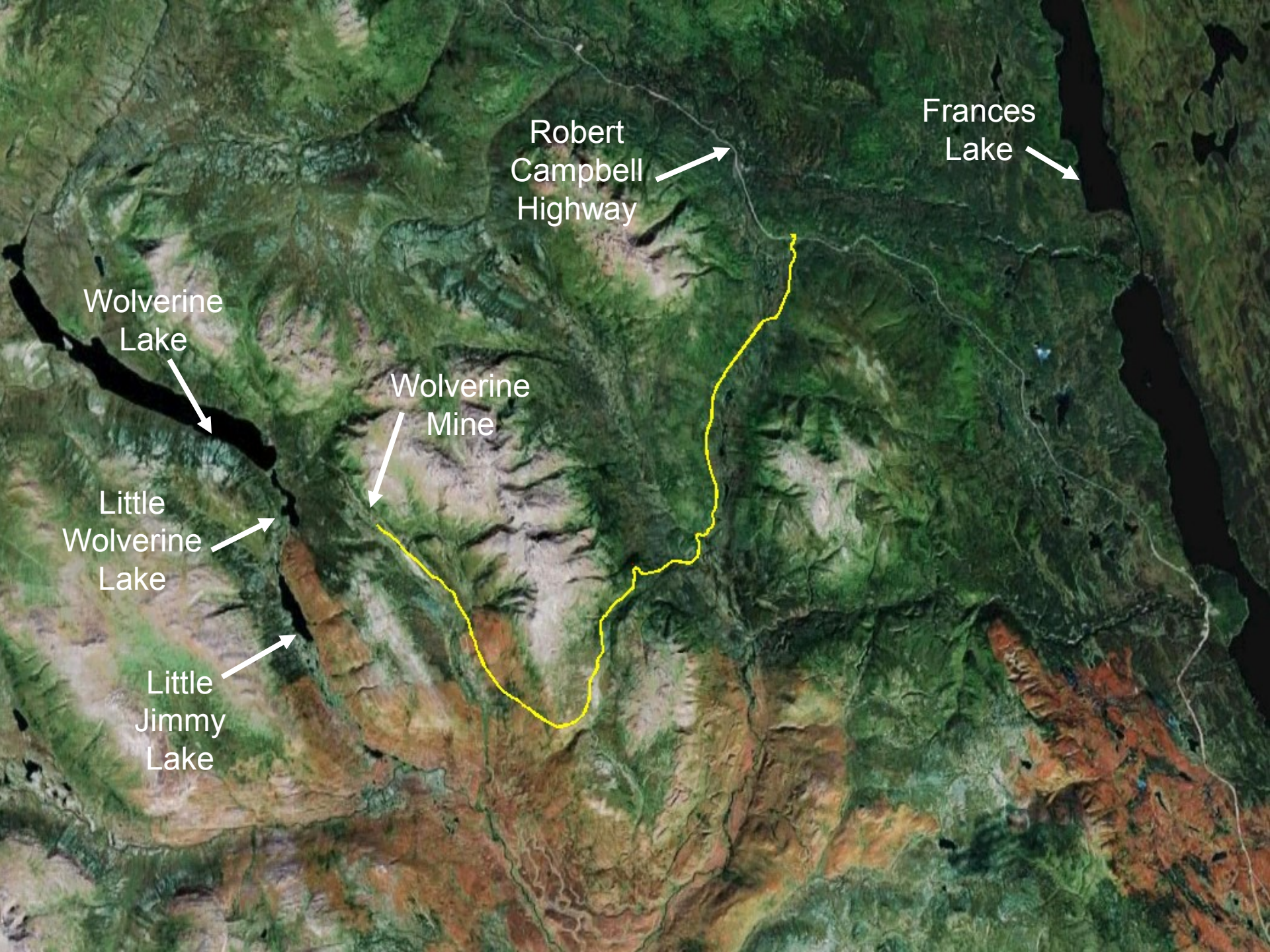
# Outline

- Wolverine Mine
  - Mine description
  - Closure issues for potentially contaminated groundwater
- Biopass passive water treatment system
- Column experiments
  - Methods
  - Results
- Next steps
- Conclusion

# Wolverine Mine Location



- The Wolverine Mine is located in the south-east Yukon
- 190 km north-west of Watson Lake
- 175 km south-east of Ross River
- In the Kaska traditional territory



Robert  
Campbell  
Highway

Frances  
Lake

Wolverine  
Lake

Wolverine  
Mine

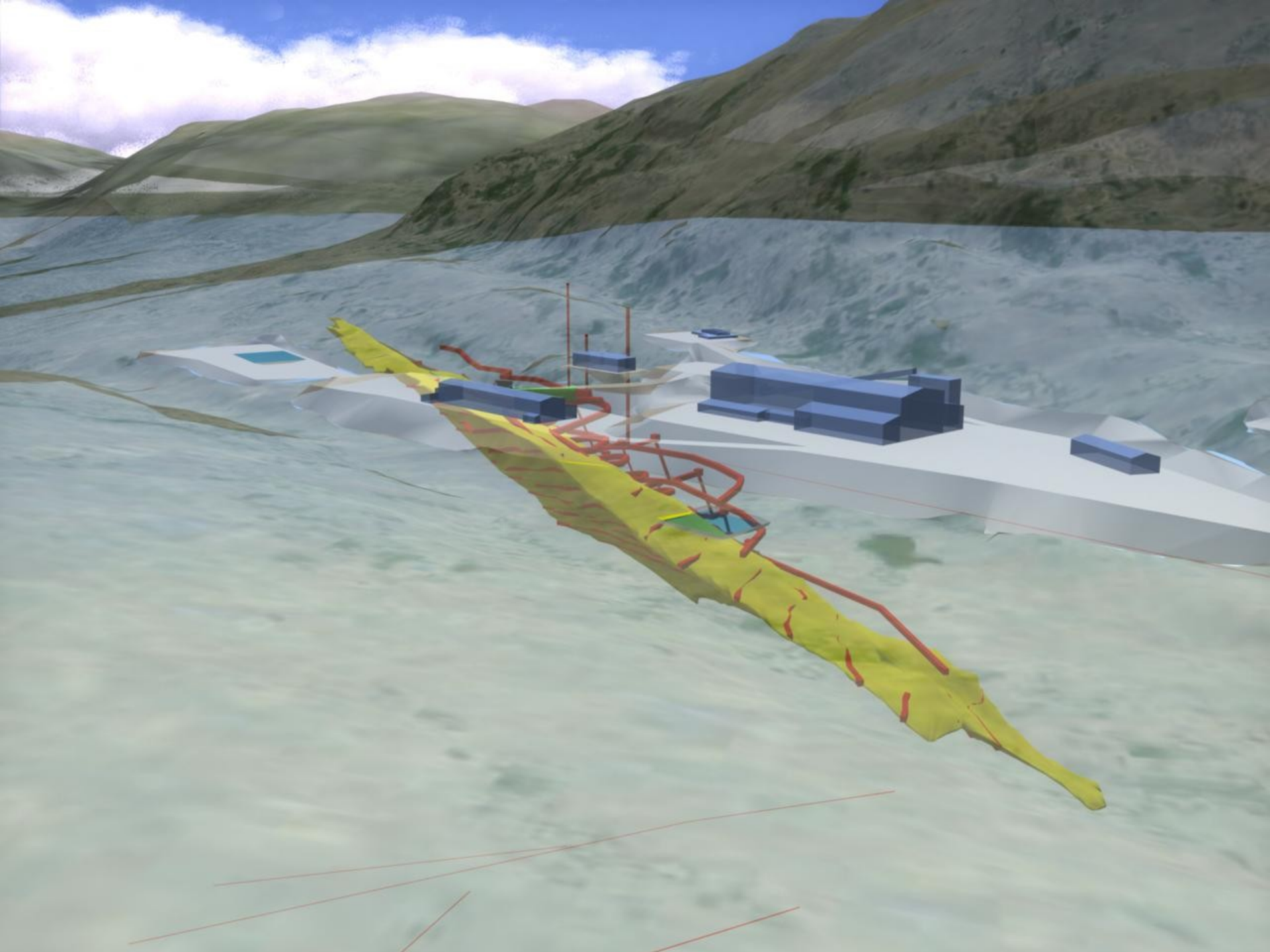
Little  
Wolverine  
Lake

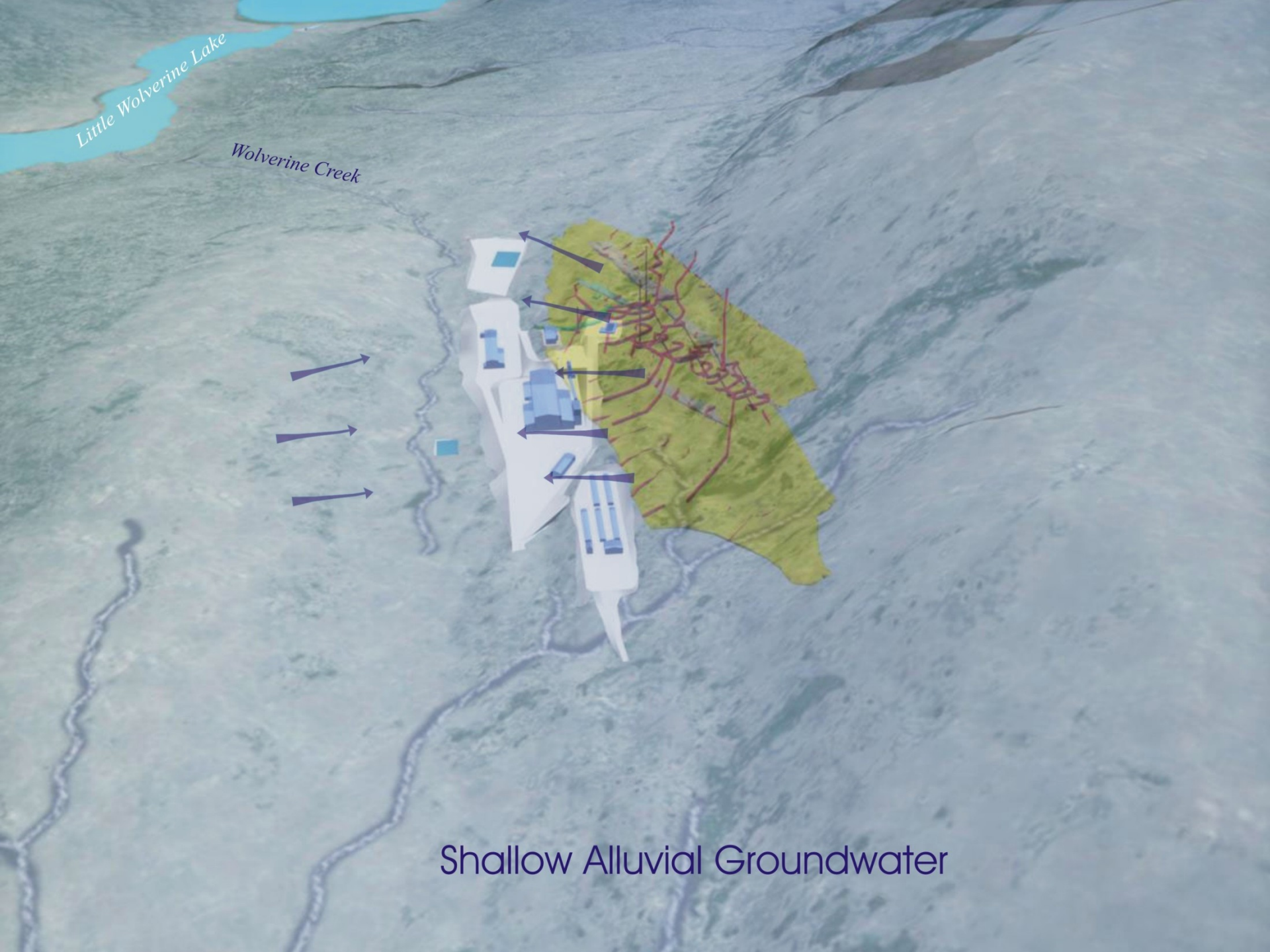
Little  
Jimmy  
Lake



Wolverine Creek







Little Wolverine Lake

Wolverine Creek

Shallow Alluvial Groundwater

# Wolverine Creek – Receiving Environment



- Wolverine Creek is small (~0.75 m wetted width) and short (length ~ 2 km)
- Naturally elevated metal concentrations:
  - Aluminum 43 ppb
  - Cadmium 2 ppb
  - Chromium 0.5 ppb
  - Copper 4 ppb
  - Iron 50 ppb
  - Selenium 2 ppb
  - Zinc 180 ppb



W9

0.072 mg/L

0.119 mg/L

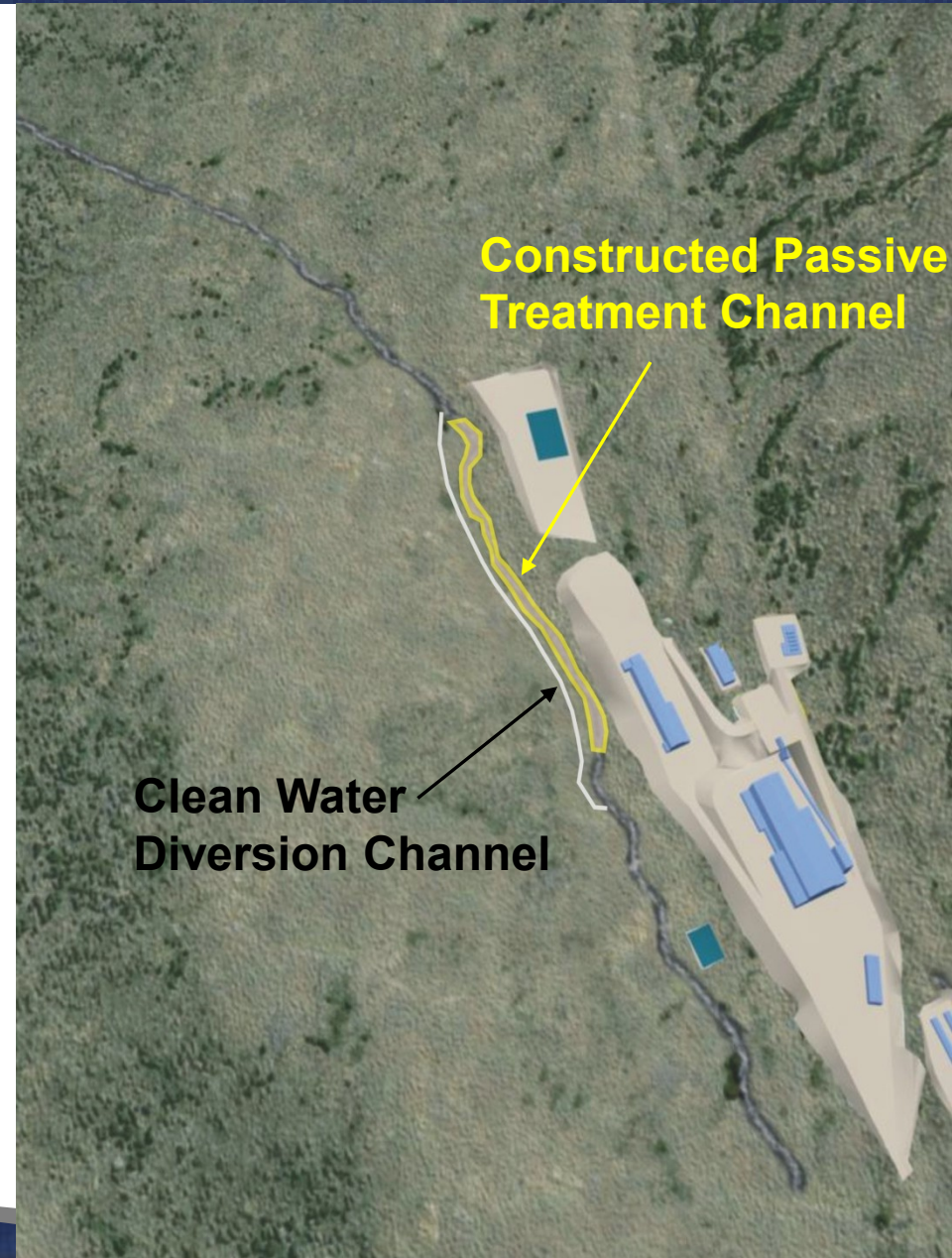
0.14 mg/L

0.0044 mg/L

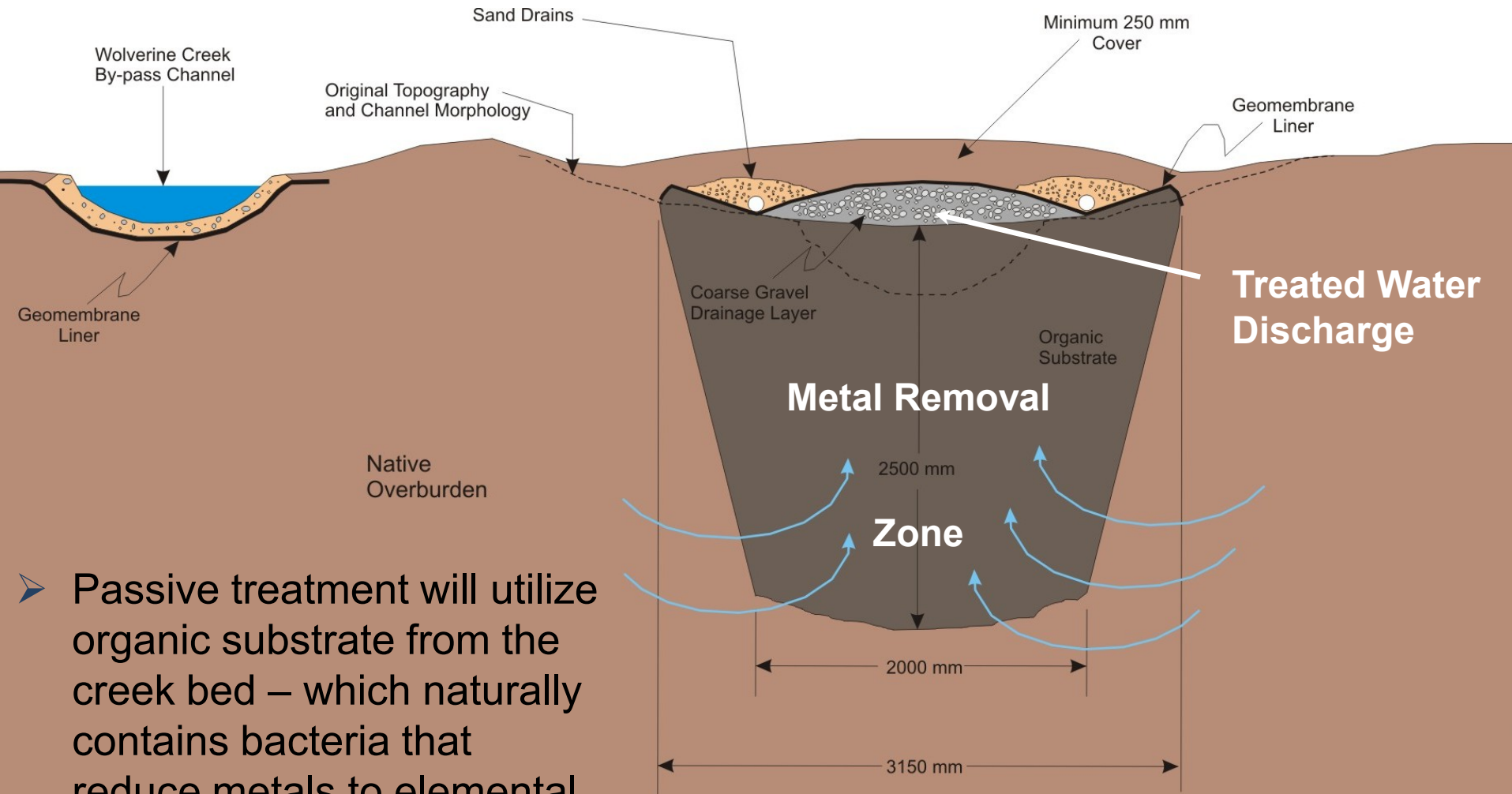
*Transect of [Zn] in Wolverine Creek*

# In Situ Groundwater Treatment at Closure

- To mitigate impacts to the receiving environment, YZC has proposed a passive water treatment system to be installed in Wolverine Creek (the biopass).



# Biopass Treatment System



➤ Passive treatment will utilize organic substrate from the creek bed – which naturally contains bacteria that reduce metals to elemental states

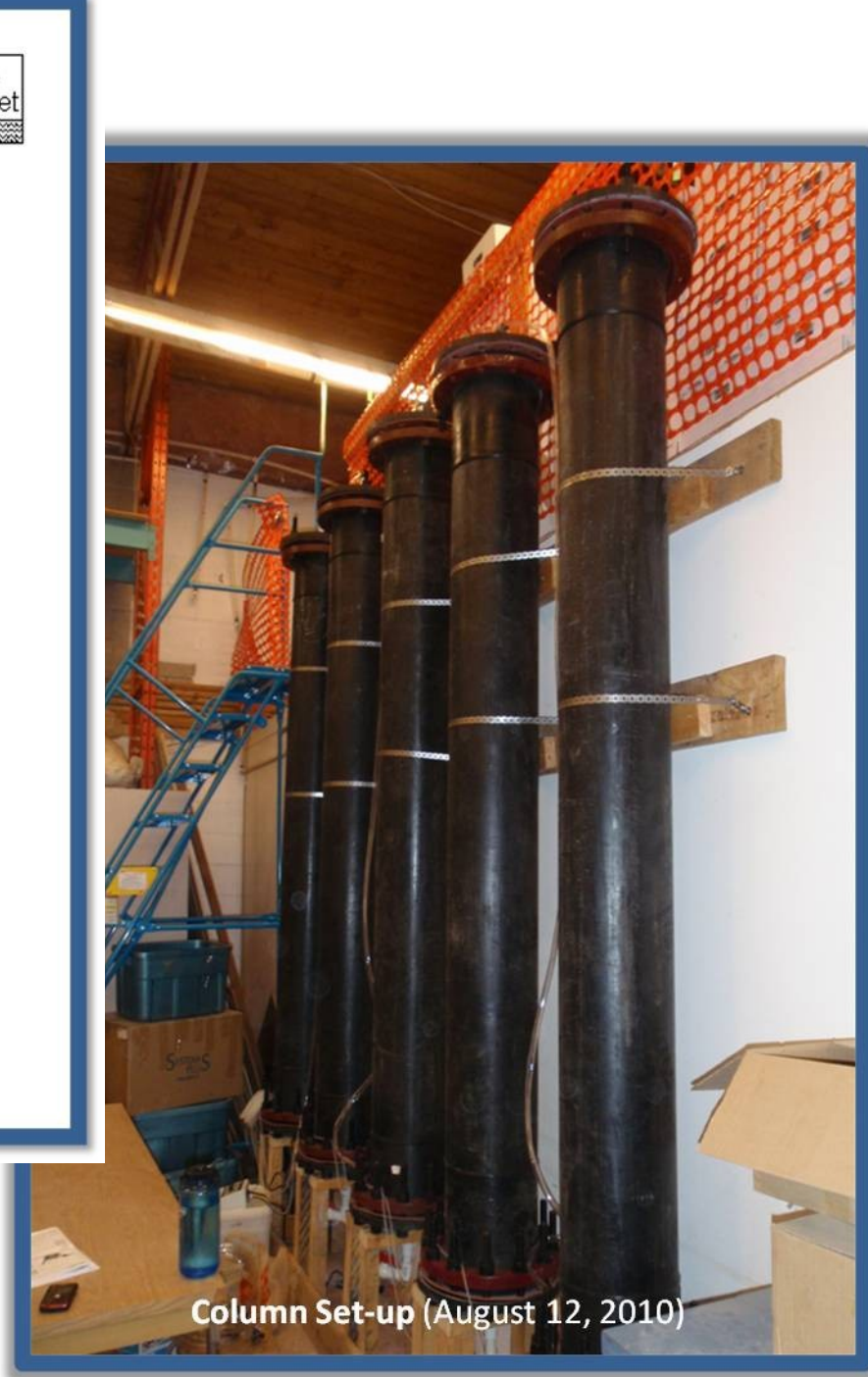
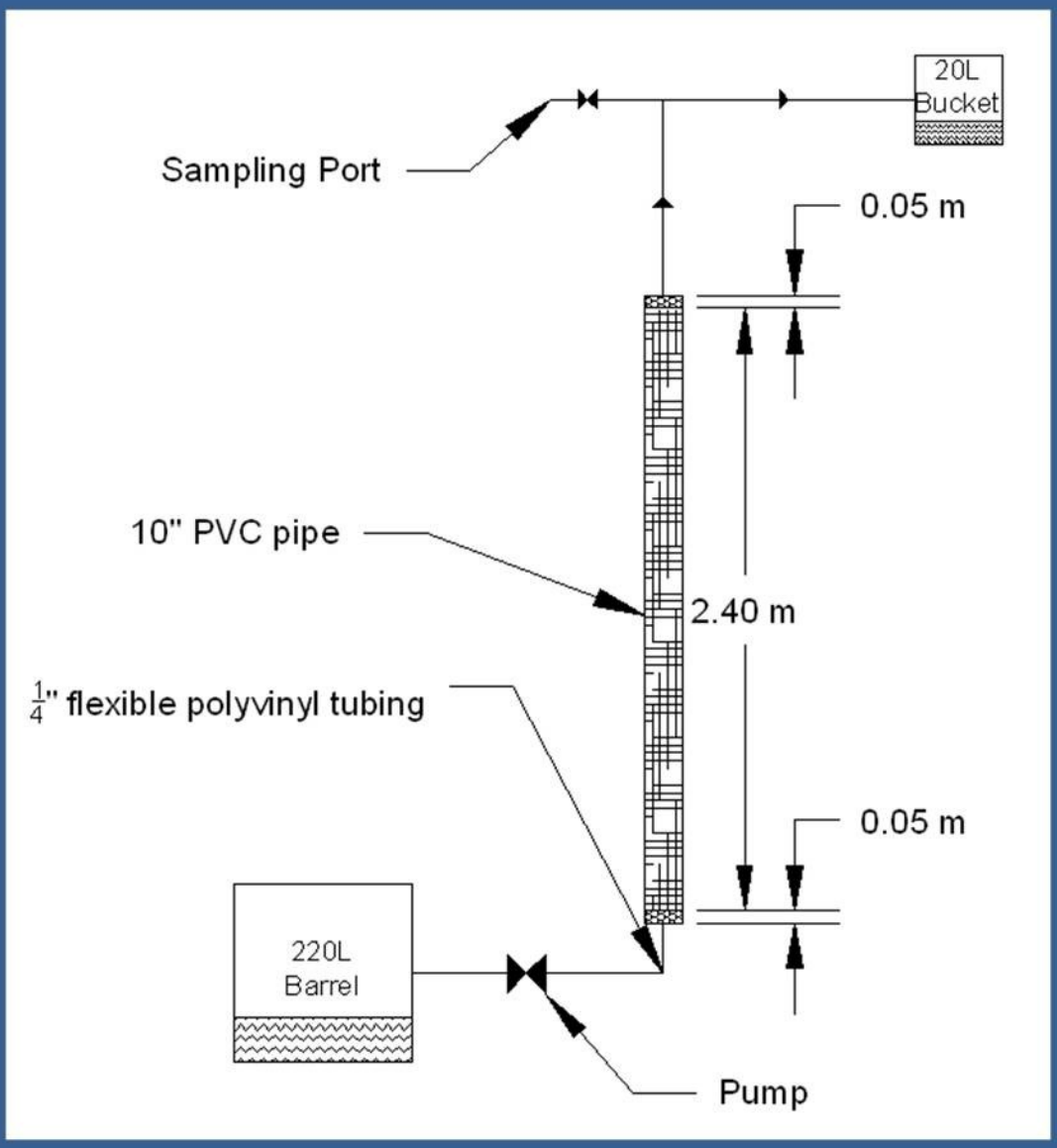
➤ Substrate will be mixed with gravel (for permeability) and unknown amendments to support bacterial growth

# Research Question?

What amendments are required in addition to the organic substrate for the biopass to operate most effectively?

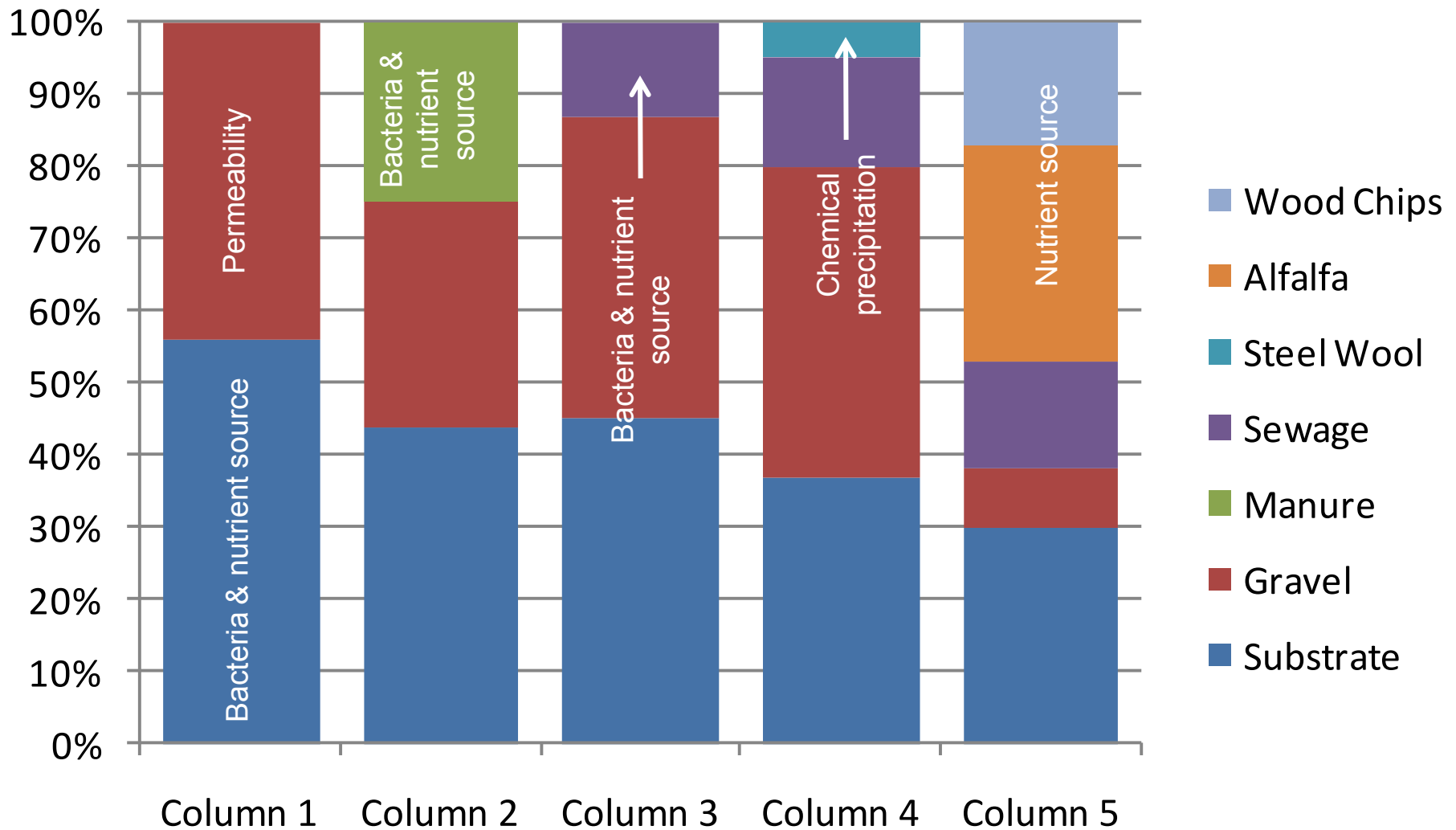
# Column Experiments

- Conducted laboratory experiments to establish what media best supports bacterial growth
- Objective: Maximize remediation of contaminated water for:
  - *Metals* – receiving environment is sensitive to elevated metals in mine affected groundwater
  - *Sulphate* – a concern due to oxidation of exposed rock in underground mine and potential for ARD generation



Column Set-up (August 12, 2010)

# Column Composition

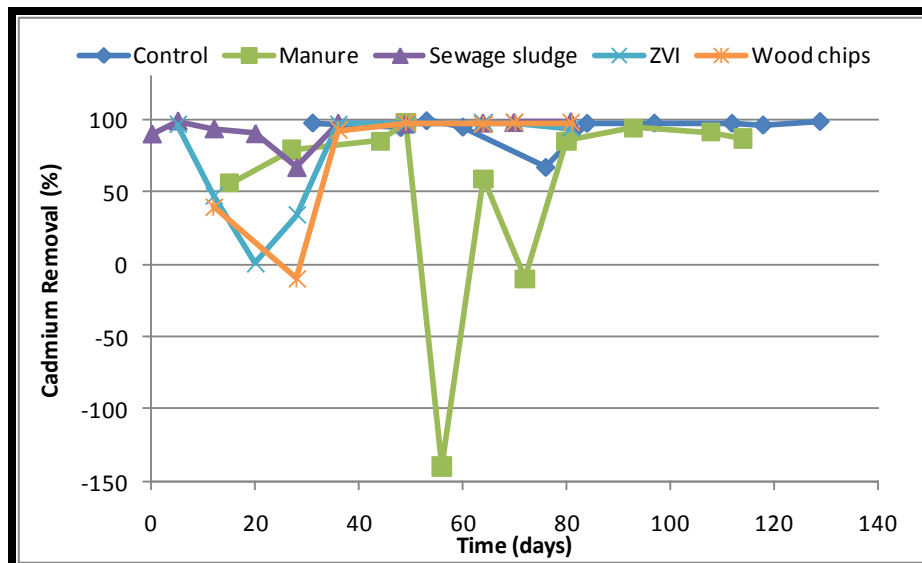
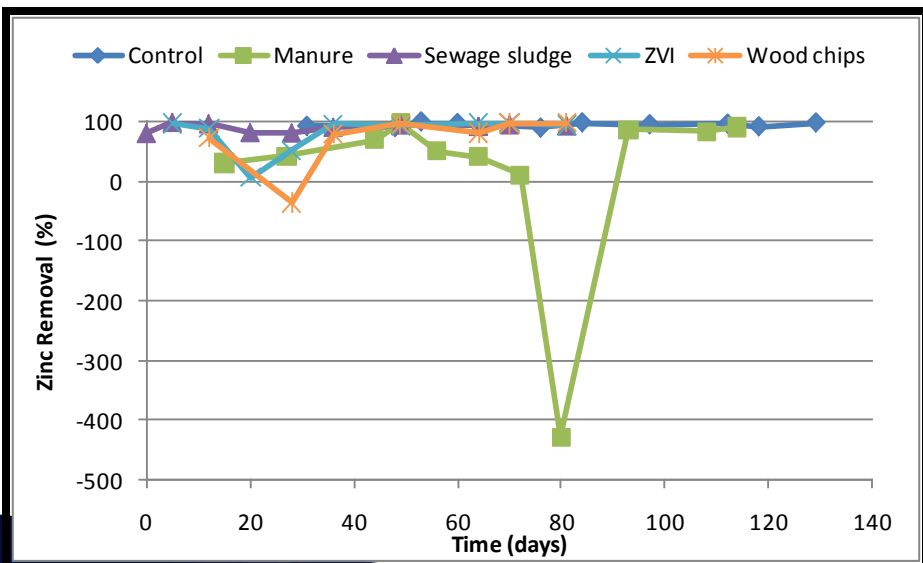
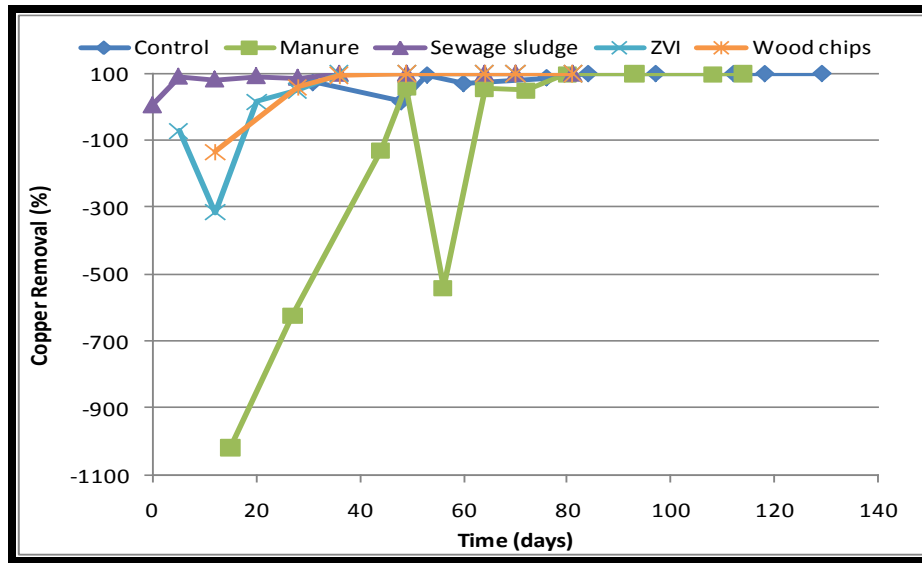
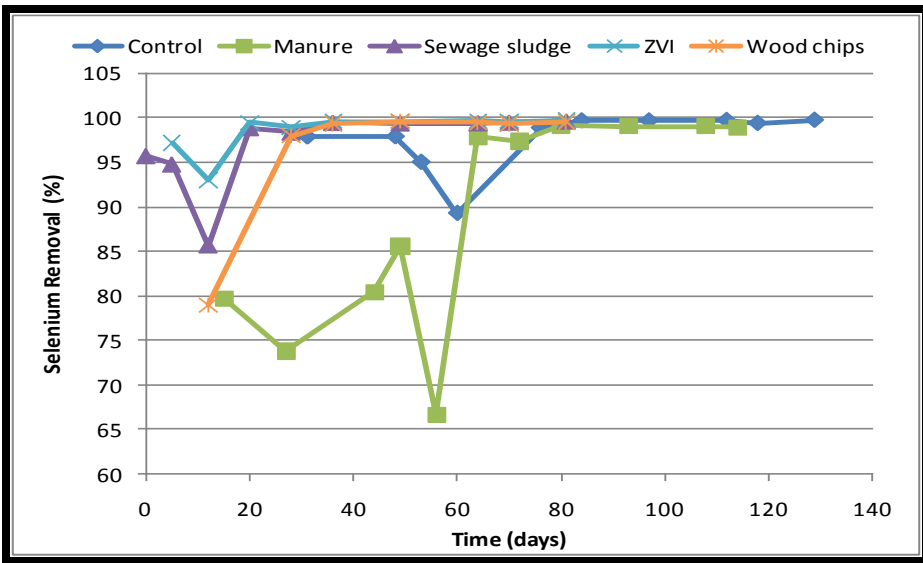


# Water Influent

- Columns ran for 80-130 days with influent at a flow rate of 2.3 L/day.
- Diluted underground mine water was used to simulate groundwater at closure.
- The experiment influent was high in SO<sub>4</sub>, Cu, Se & Fe compared to creek background concentrations.
- Experiment effluent targets were creek background concentrations.

		Experiment Influent Concentrations	Creek Background Concentrations
<b>Sulphate</b>	<b>(mg/L)</b>	365	25
<b>Aluminum</b>	<b>(ppb)</b>	20	43
<b>Cadmium</b>	<b>(ppb)</b>	2	2
<b>Chromium</b>	<b>(ppb)</b>	0.6	0.5
<b>Copper</b>	<b>(ppb)</b>	60	4
<b>Iron</b>	<b>(ppb)</b>	2600	50
<b>Selenium</b>	<b>(ppb)</b>	260	2
<b>Zinc</b>	<b>(ppb)</b>	120	180

# Results

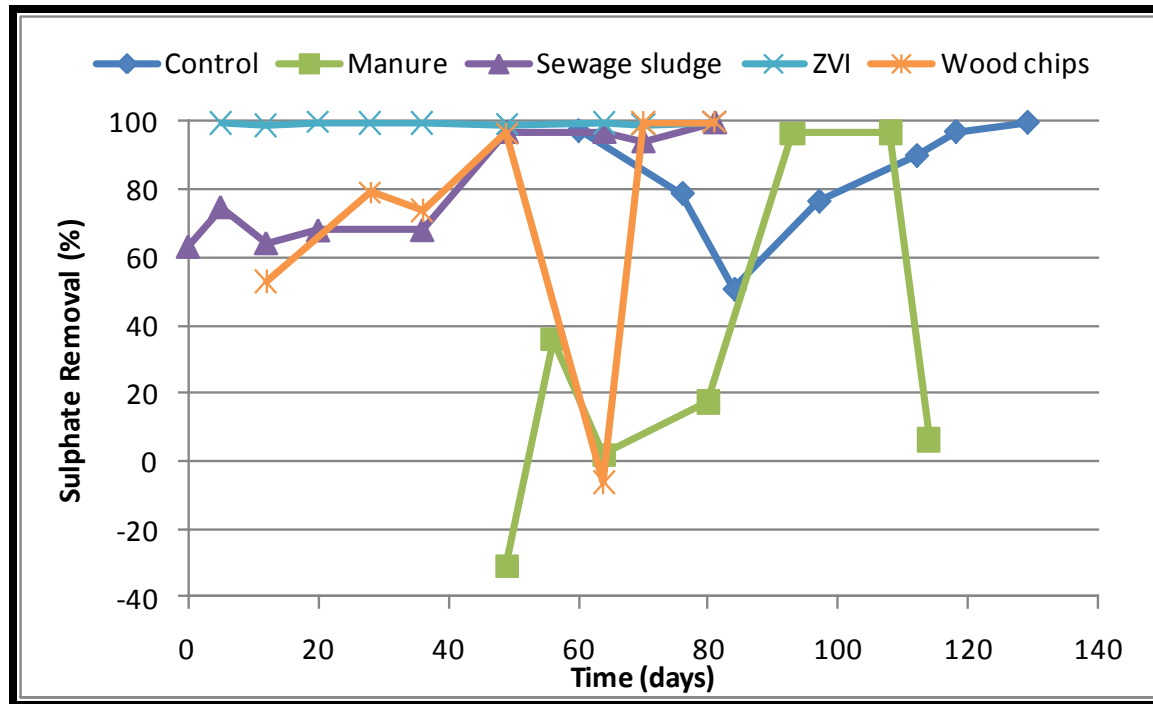


# Metal Concentration Results

- Although initially fluctuating, all five columns removed **>90%** of Se, Cu, Cd & Zn by the end of the experiment.
- Only the control column and the ZVI column consistently achieved target concentrations of selenium.
- All columns met target concentrations for cadmium and zinc.
- The columns with manure and sewage sludge **ADDED** some metals (e.g., Ni, Al, As & Cr) to the effluent stream.
- The **control** column had the best overall removal of metals throughout the duration of the experiment.

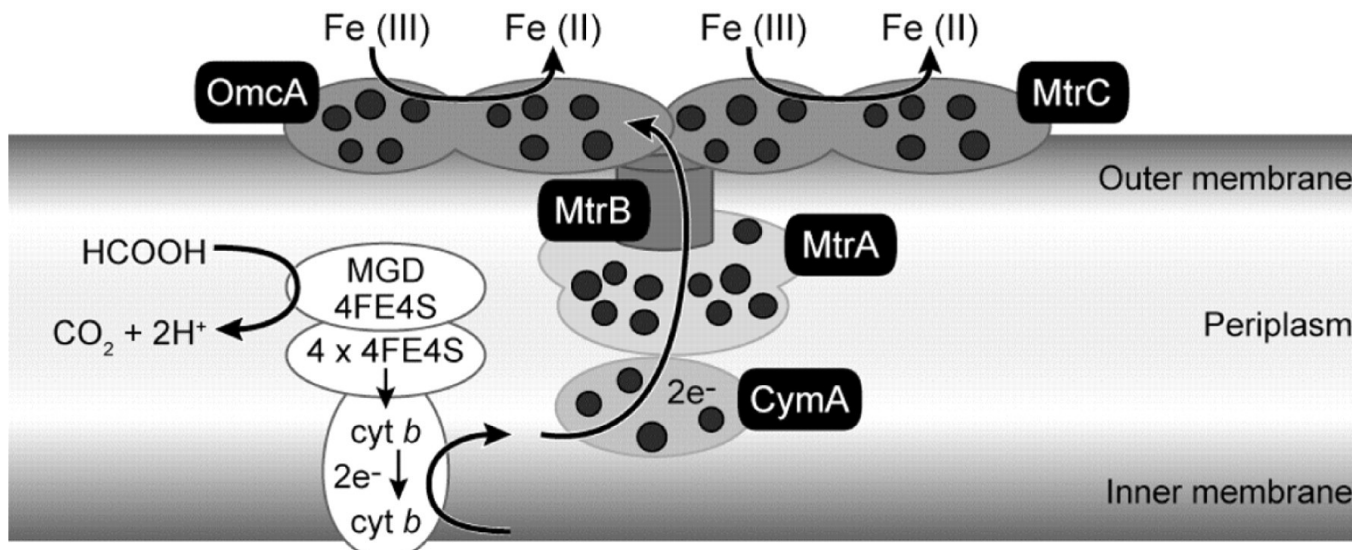
# Sulphate Results

- From the onset of the experiment, the zero-valent iron column removed **99%** of the sulphate in the influent stream.



# Remediation Process in Columns

- The bacteria in the creek substrate are known to be metal reducing from previous laboratory experiments.
- At low flow rates with oxygenated influent, reducing conditions (i.e.,  $ORP < 0$  mV) were achieved within the columns thereby facilitating metal removal through bacterial reduction.
- Bacterial activity was evident from the increased concentrations of iron and manganese, which act as electron acceptors during dissimilatory reduction.



Lall R, Mitchell J Bioinformatics 2007;23:2754-2759

# Next Steps

➤ Next need to evaluate the system in a field setting, to understand the effects of :

## 1. Temperature

The temperature at the mine site, even in the creek bed, is an average of 4°C, vs. 20°C in the laboratory.

## 2. Nutrient requirements

The bacteria may require a long-term source of C,N,P & S, once nutrients in the creek substrate are consumed. However, the source will have to be tested for metal leaching, as the organics (sewage and manure) used in the experiment *contributed* metals to the effluent stream.

## 3. Time

The lab experiments were only run for a few months, whereas the biopass is an in situ long-term installation.

➤ A pilot scale system will be installed at the mine site to evaluate the effects of the above components.

# Conclusion

- Excellent removal of metals with the most cost effective option
- Superior removal of sulphate with a basic addition of zero-valent iron
- Promising treatment method for low-flow contaminated mine water

# Thank You

