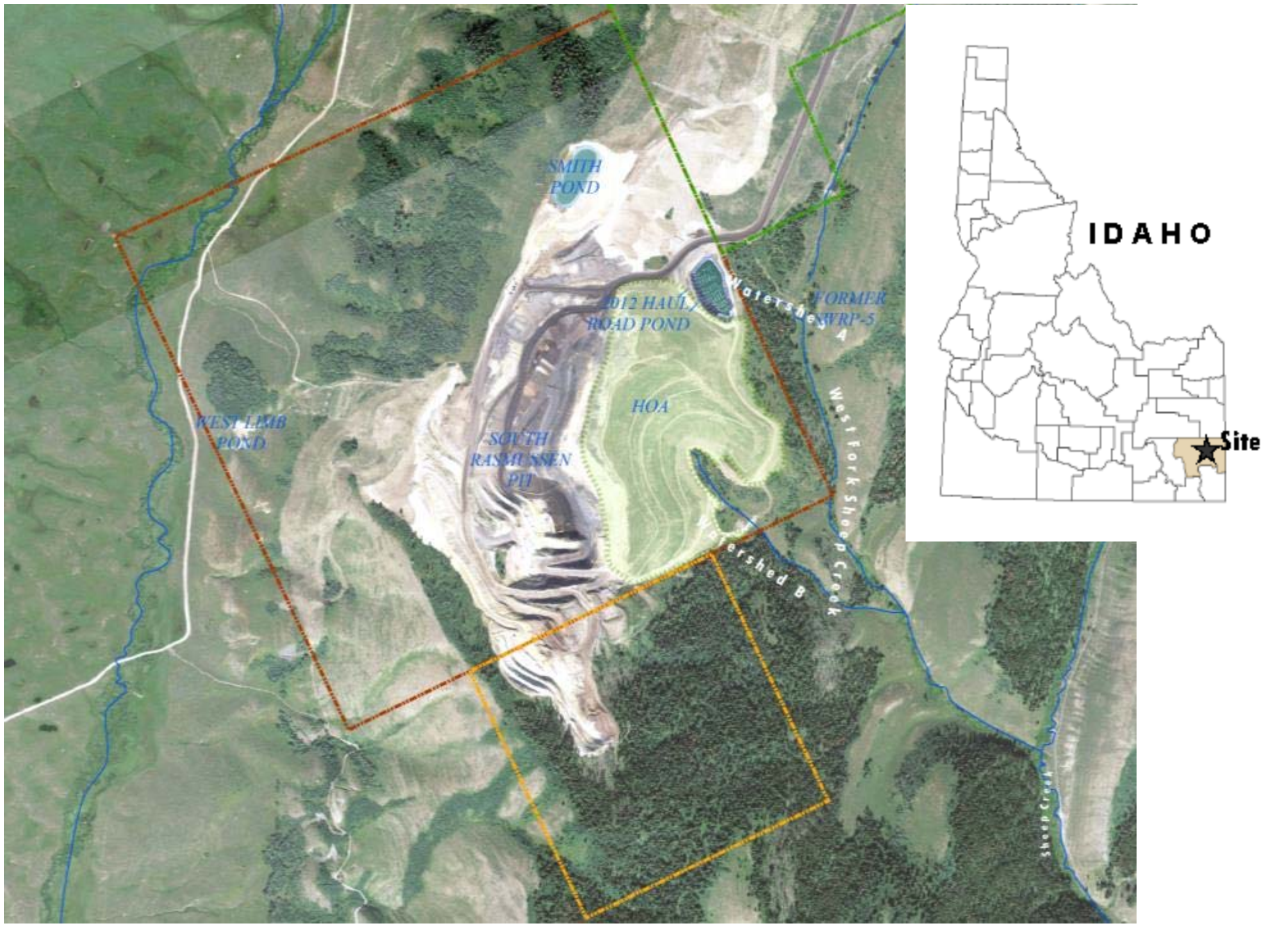

PASSIVE TREATMENT OF SELENIUM IMPACTED GROUNDWATER WITH A BIOWALL

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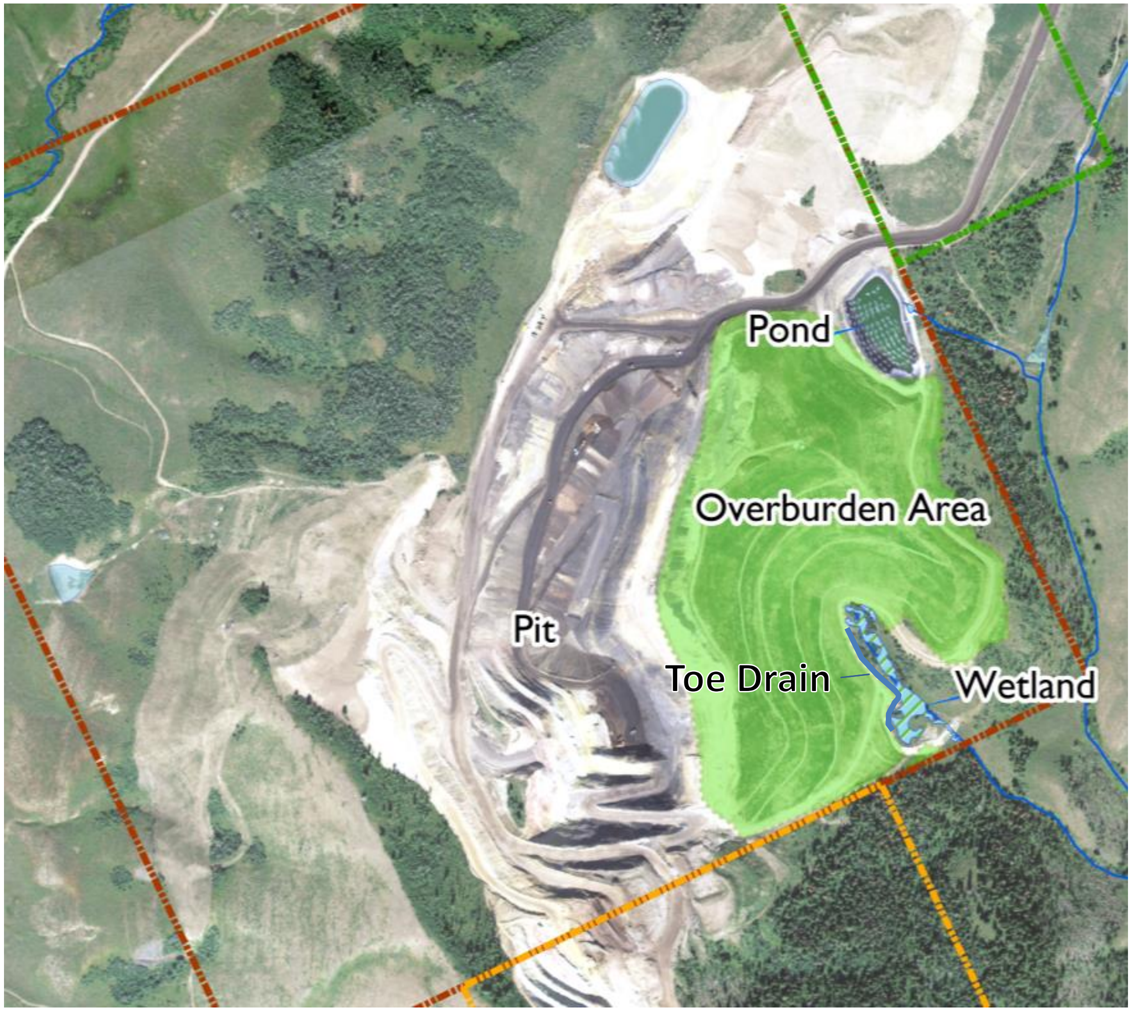
Chris Leatherman, P4 Production

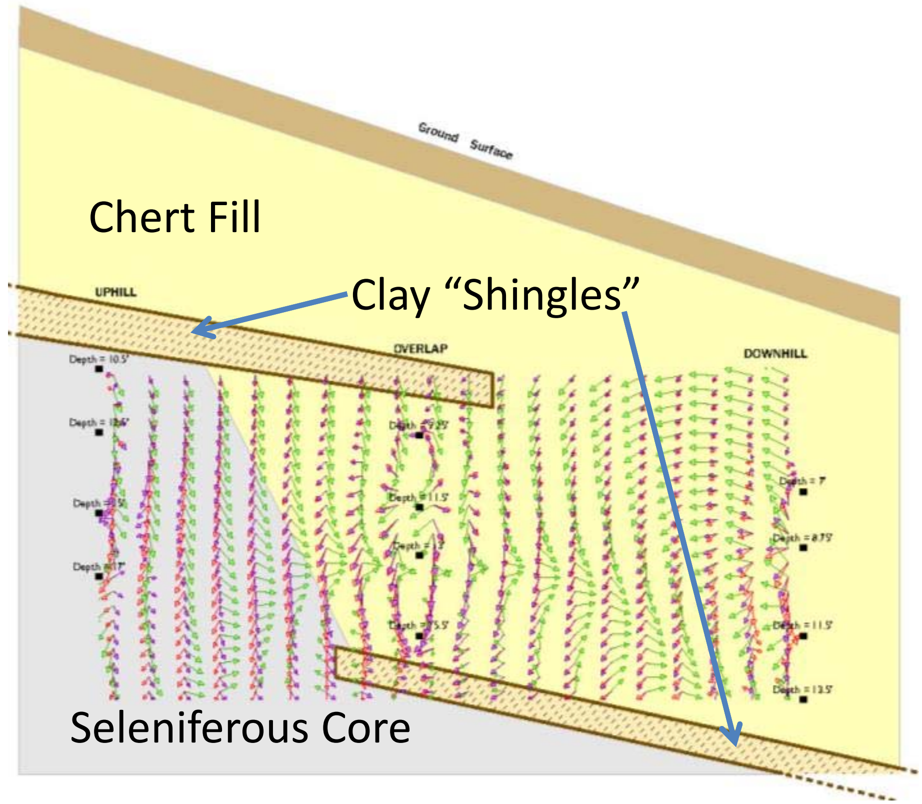
Background

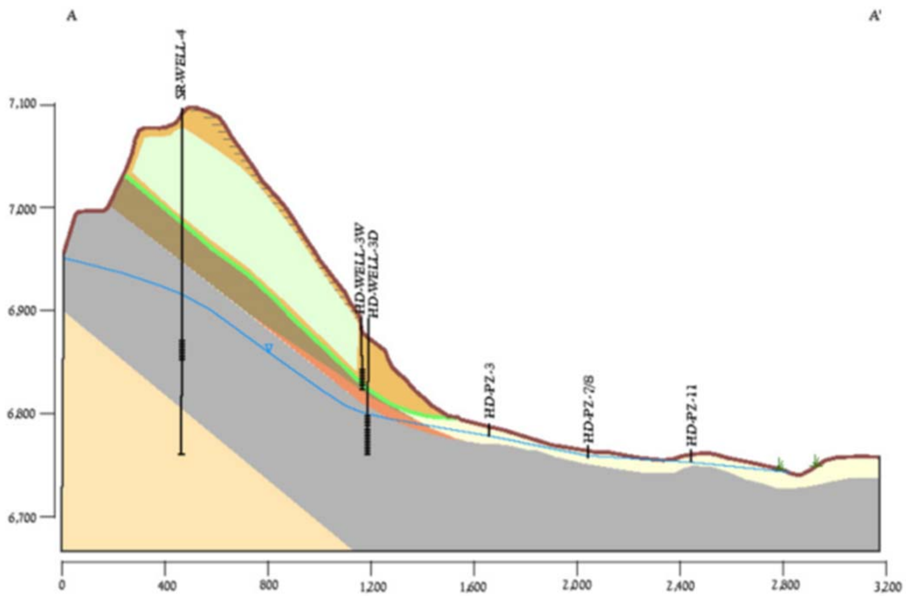
- Phosphate mine in southeast Idaho
- Construction of overburden area outside pit in headwaters
- Design included shingled clay cover and toe drain to prevent slope failure



Problem

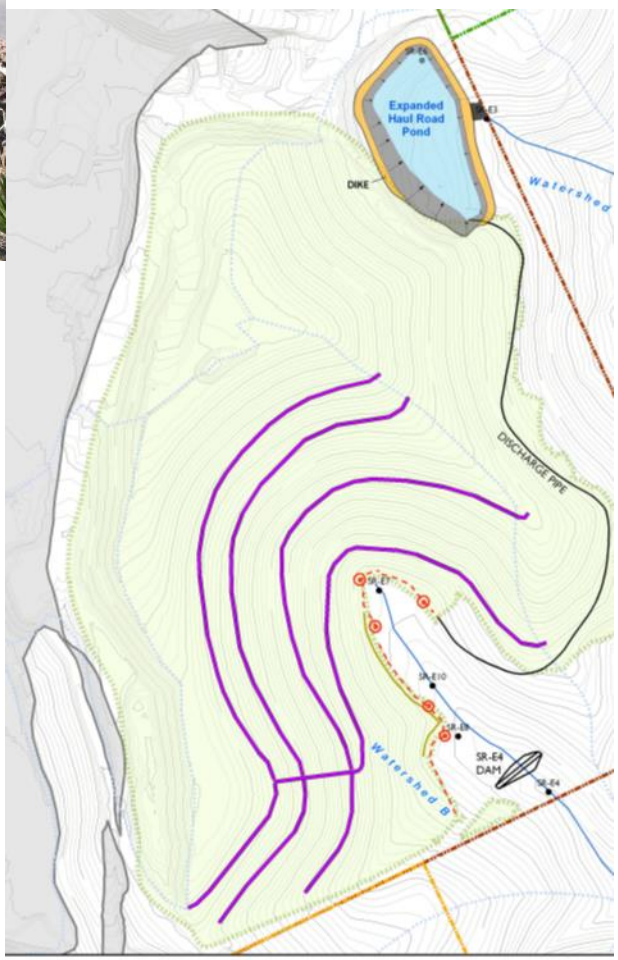
- Overburden area has core of seleniferous material surrounded by chert fill
- Shingled cap design
- Water containing selenium and other constituents (SO_4, Cd, Fe, Mn, Ni, Zi) began to emanate from toe drain
- Impacted stream and wetlands downgradient of Overburden Area





Interim Measures

- Toe Drain collection
- Clean Water Diversion
- Groundwater Interception System
- Expanded and lined HRP
- Captured water that was used for dust suppression and evaporated



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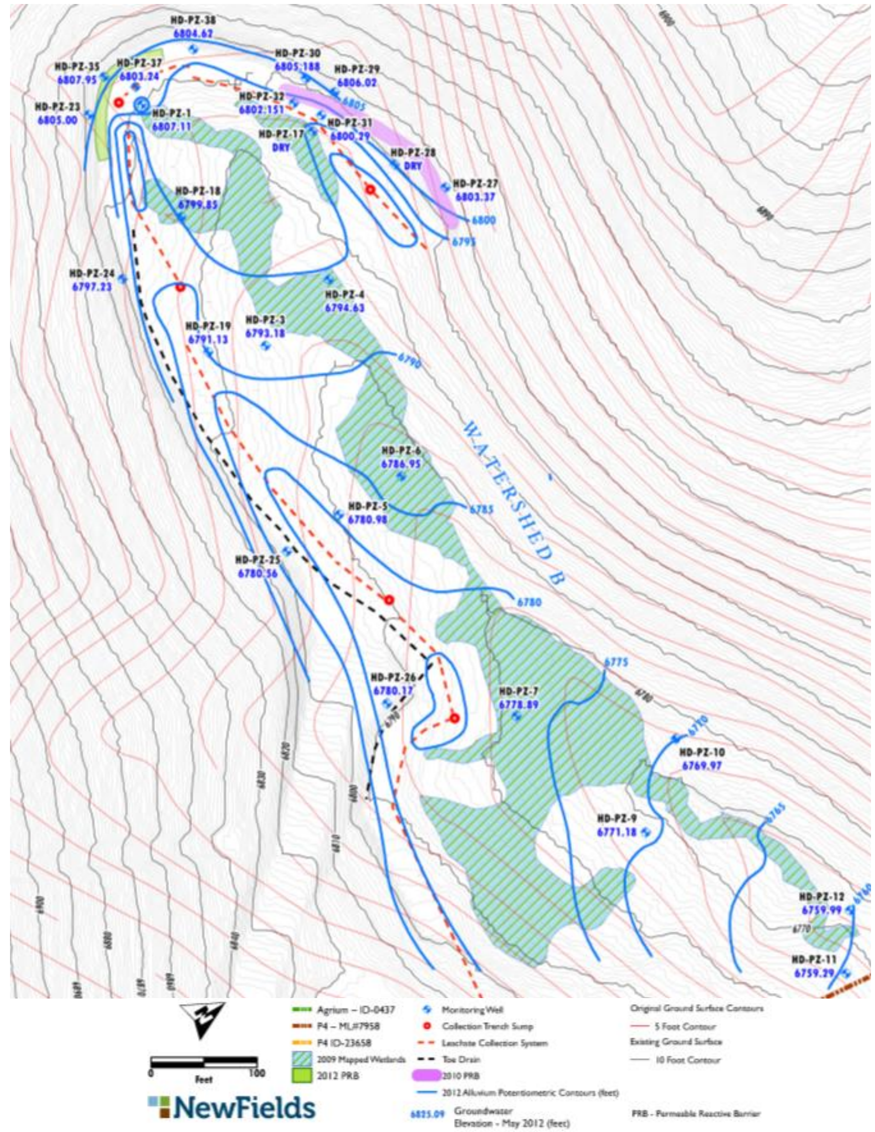
Groundwater Flow

- Flow from under overburden pile through alluvial drainages and Chert fill to wetland.
- Stream was gaining reach in wetland
- Flow in alluvium was parallel to stream in wetland.
- Flow affected by drawdown of interception trenches.



Site Geochemistry

- Primary source of Se & trace metals in unweathered waste rock are pyrite & sphalerite
- Se also found in elemental Se^0
- Weathering oxidation releases and selenium and trace metals
- Shallow alluvial groundwater and seeps have slightly acidic to slightly alkaline pH and are oxygenated
- Selenium and metals correlated with sulfate concentrations

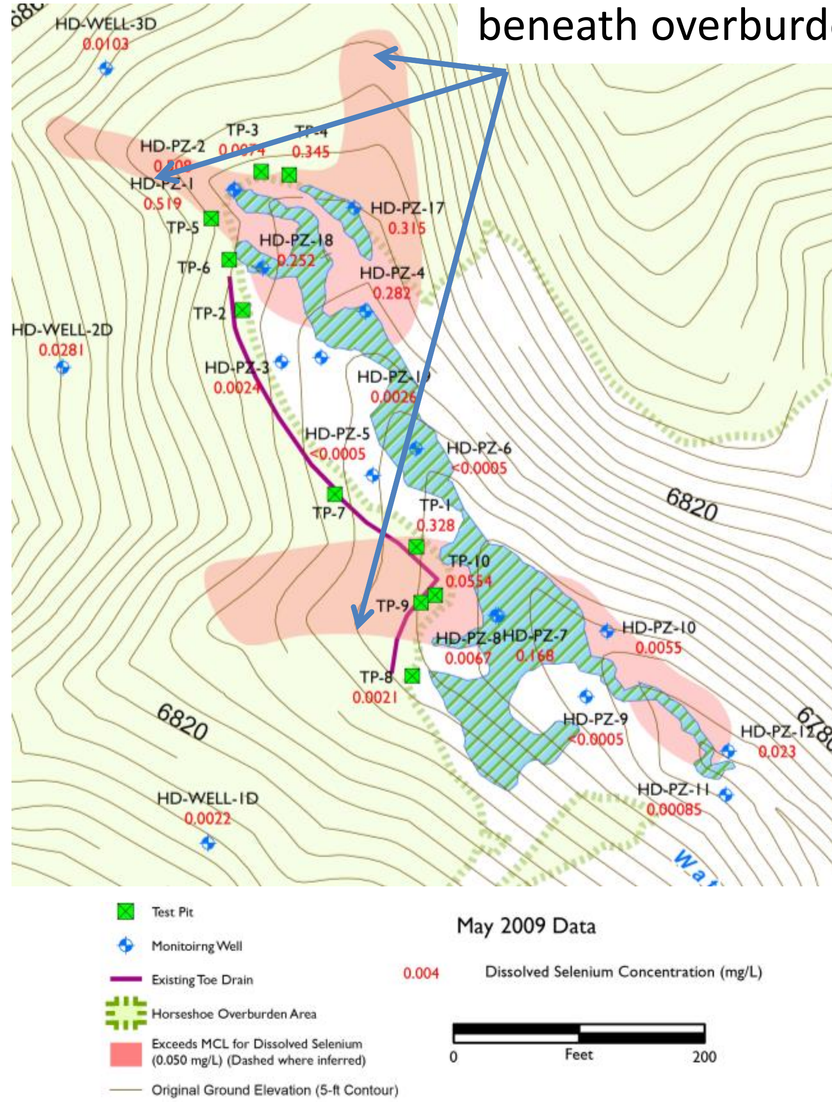
Site Conceptual Model

Alluvial drainages beneath overburden

<u>Sources</u>: core and possibly some chert fill

<u>Pathways</u>: alluvial channel deposits

<u>Receptors</u>: stream and wetland



Selenium Geochemistry

- Selenium is a REDOX sensitive element
- Oxidation state significantly controls mobility and fate
- Four common oxidation states; selenate (Se^{6+}), selenite (Se^{4+}), elemental selenium (Se^{0}), and selenide (Se^{2-})
  - Selenate is transported conservatively, much like sulfate
  - Selenite has tendency to adsorptions, similar to phosphate
  - Under reducing conditions (*i.e.* Eh<200 milli-Volts (mV)) elemental selenium is expected to precipitate.

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Biowall Theory

- Microbial oxidation of organic material in biowall coupled with reduction of various electron acceptors
- Many types of bacteria ubiquitous in the environment known to reduce selenate and selenite to elemental selenium
- Reduction of sulfate to sulfide under strongly reducing conditions expected to also remove other metals as metal sulfides

$CH_2O + O_{2\,(g)} \rightarrow HCO_3^- + H^+$ *(where CH_2O = organic matter)*

$5CH_2O + 4NO_3^- \rightarrow 2N_{2(g)} + 5HCO_3^- + H^+ + 2H_2O$

$SeO_3^{2-} + CH_2O + 2H^+ \rightarrow Se^0_{(s)} + CO_2 + 2H_2O$

$2CH_2O + SO_4^{2-} \rightarrow HS^-_{(aq)} + 2HCO_3^- + H^+$

$HS^-_{(aq)} + Me^{2+} \rightarrow MeS_{(s)} + H^+$ (Me^{2+} = divalent metal ion, i.e. Fe^{2+} etc.)

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Intial Pilot Biowall

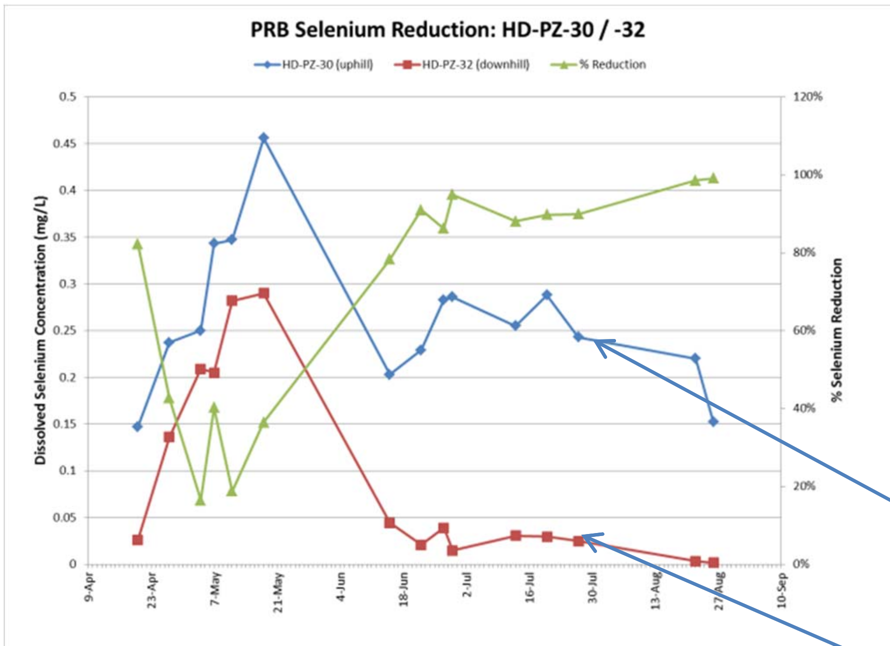
Field Investigation

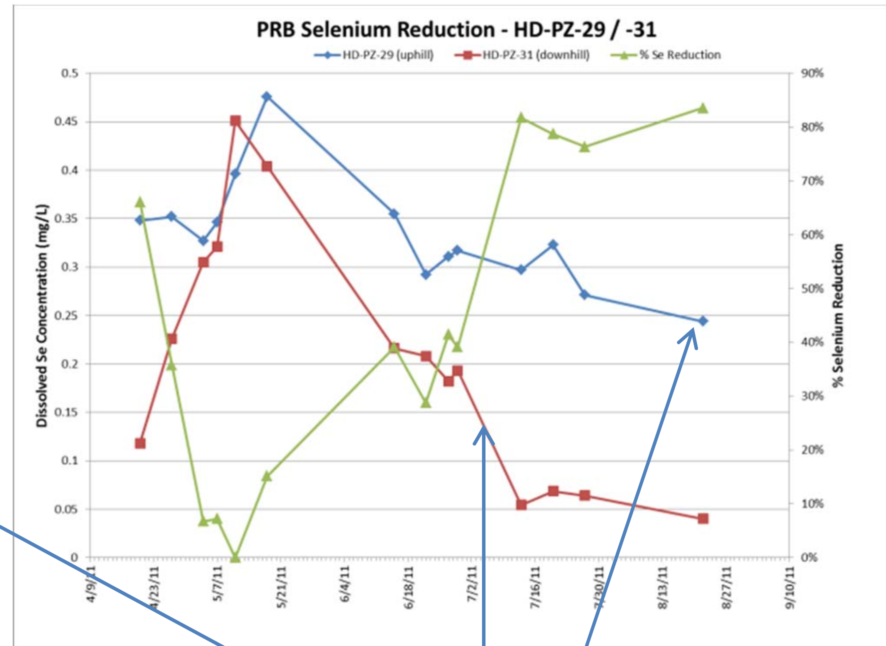
- Test pits and shallow monitoring wells
- Physical and chemical analysis of potential backfill materials

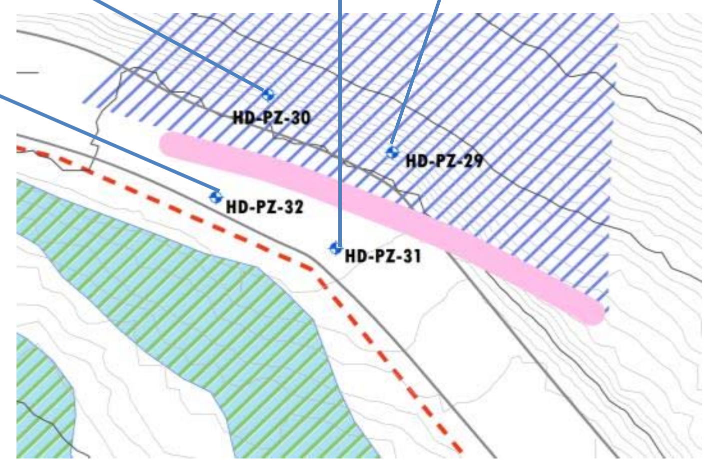
Design

- Limestone gravel
- Carbon substrate
  - alflalfa & wood chips
- Residence time

Effectiveness of Initial Biowall





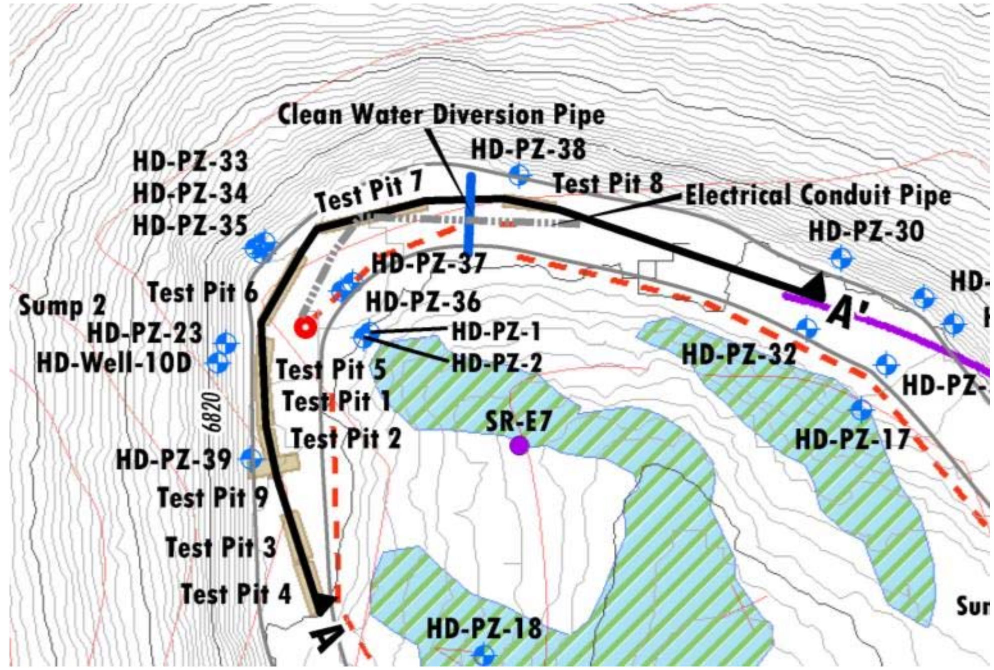


Lessons learned:

- Better characterization of hydrogeology needed
- Residence time must be assured

Detailed Hydrogeologic Investigation

- Nine test pits up to 17 feet deep
- Seven monitoring wells
- Nested wells upgradient and downgradient
- Water levels
- Water quality sampling and analysis
- Material testing
- Thorough slug testing
- SPLP batch testing

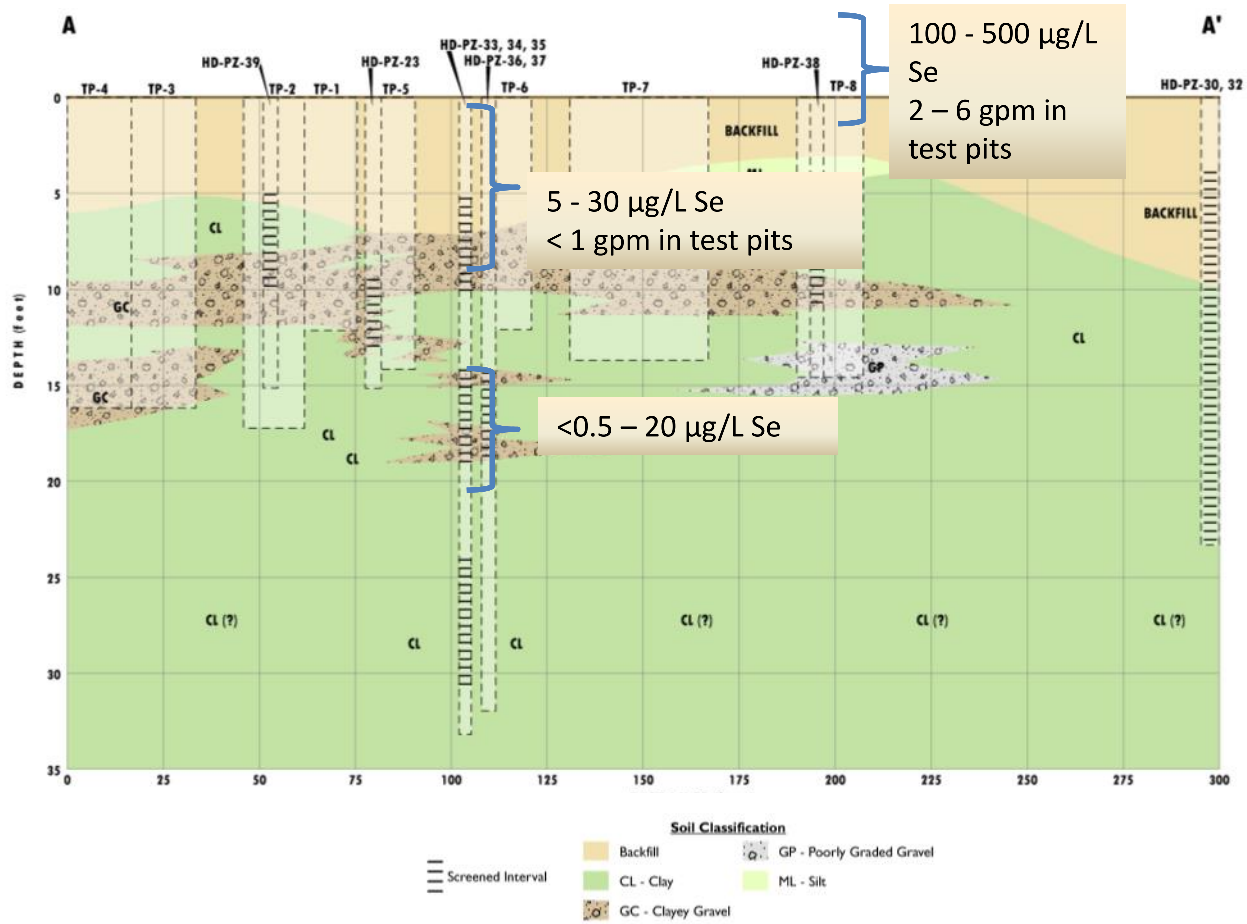


Investigation Results

Fill and shallow channels had greatest permeability and highest concentrations of selenium and other constituents

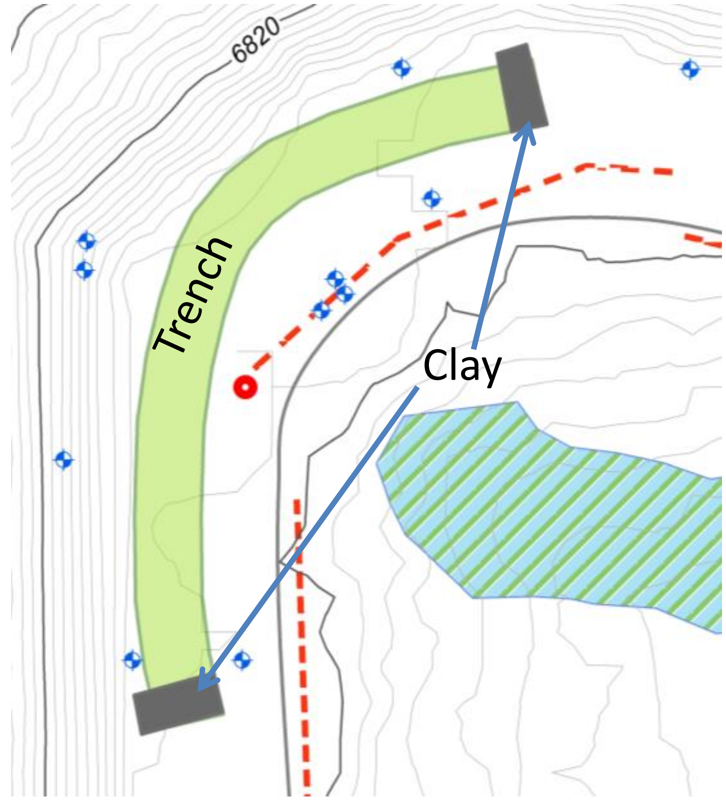
SPLP Results (µg/L)

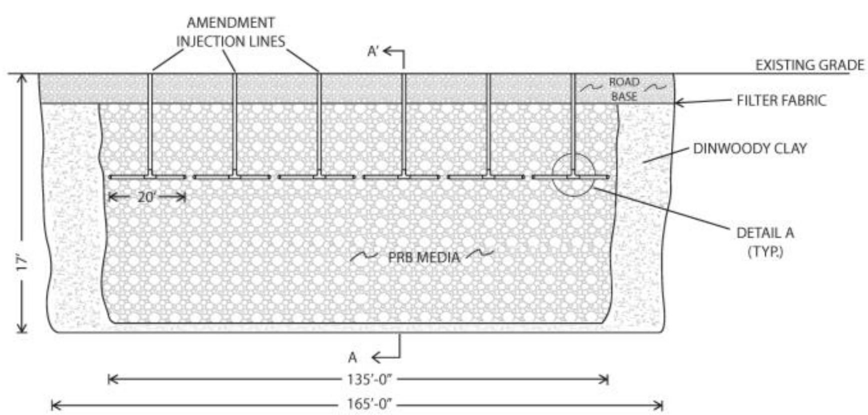
Analyte	Quartzite Sand	Limestone Gravel
Aluminum	2180	12,000
Copper	<39.5	<39.5
Iron	<2240	15,400
Manganese	<27.0	244
Nickel	<26.0	<26.0
Selenium	<0.050	<0.050
Zinc	<288	<288



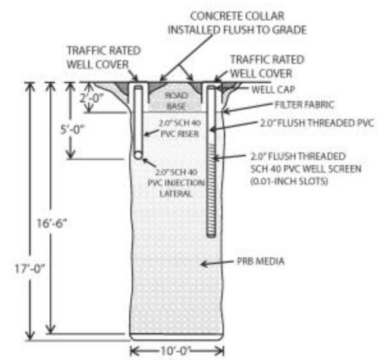
Design

- 137-foot long length
- 10 feet wide
- 17-foot depth
- 24-hour residence time
- Clay plugs
- Fill: quartzite sand, alfalfa, wood shavings
- 7 injection laterals for liquid amendments
- Three monitoring points





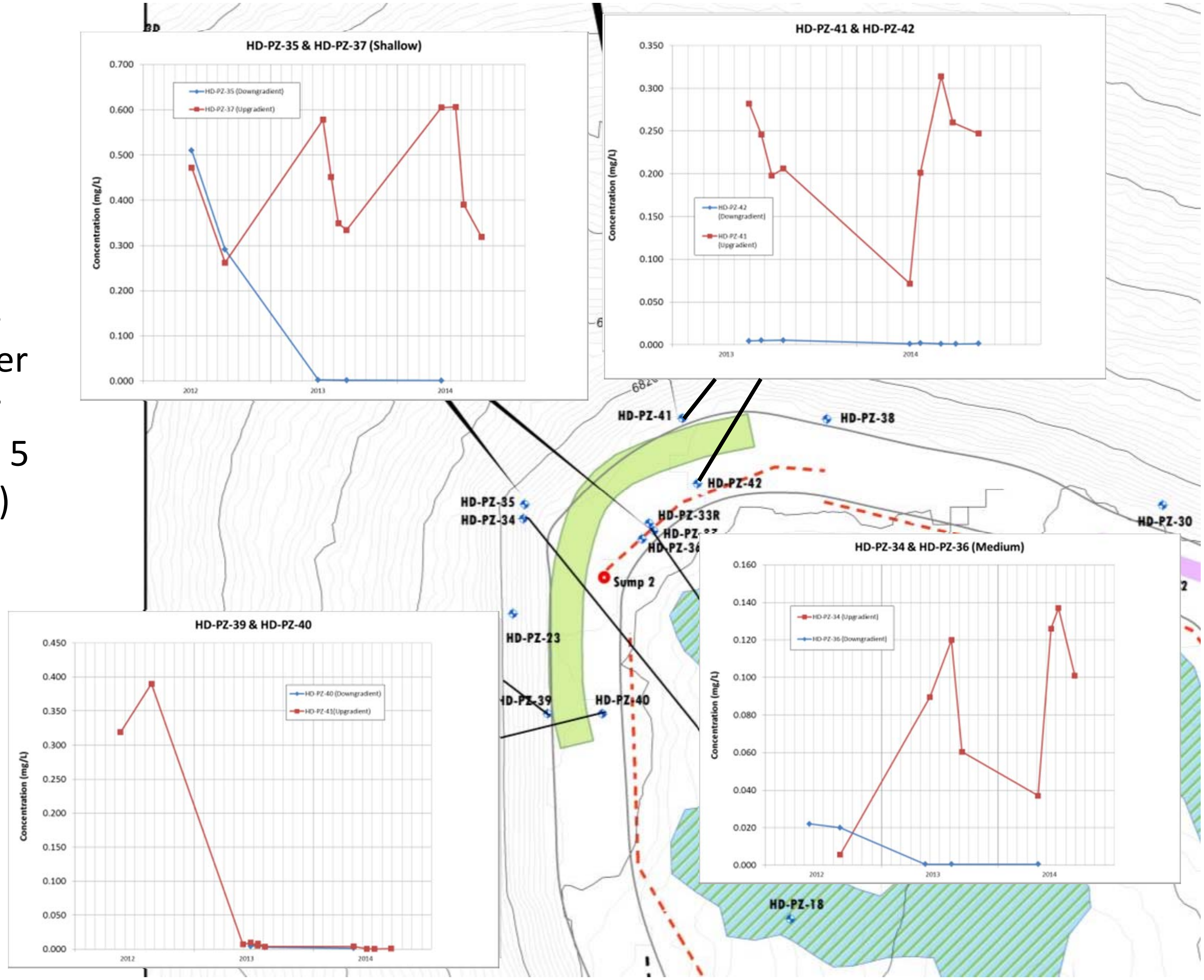
PERMEABLE REACTIVE BARRIER
CROSS SECTION



PERMEABLE REACTIVE BARRIER
CROSS SECTION A-A'

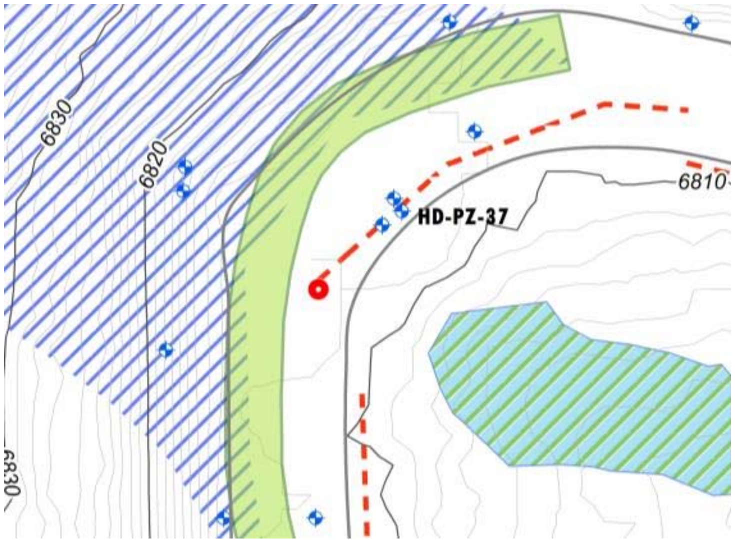
Effective Decrease in Selenium Concentrations

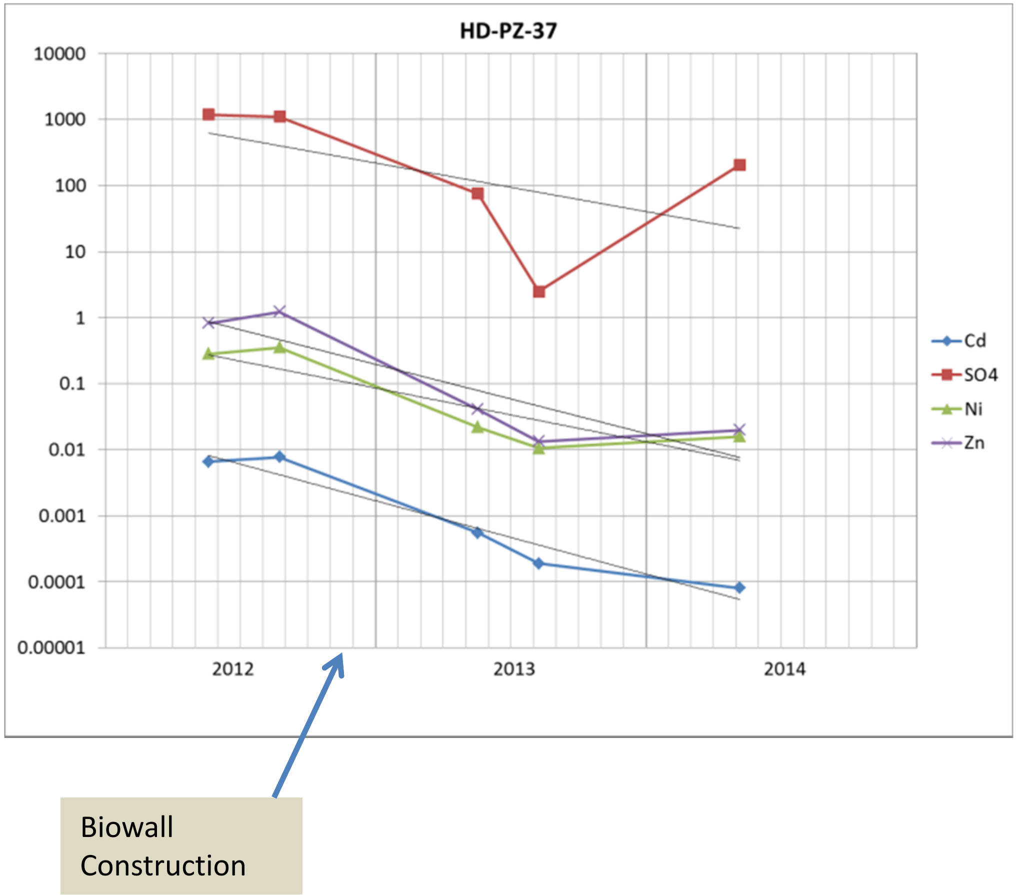
All concentrations below groundwater and surface water standards (50 and 5 µg/L, respectively)



Decrease in other Constituents

- Two to three orders of magnitude decrease in SO_4, Cd, Ni, Zn concentrations





Discussion

- Native bacteria couple the oxidation of organic carbon with the reduction of various terminal electron acceptors during respiration leading to reducing conditions in groundwater
- Also, some bacteria and fungi are capable of reducing selenate and selenite to elemental selenium or selenide
- Organic matter placed in a properly engineered biowall to supply native bacteria with a food source and nutrients is shown to be effective at removing selenium and other trace metals from shallow groundwater

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Summary and Conclusions

- Biowall technology has been demonstrated to decrease selenium concentrations to < 5 µg/L.
- The biowall is currently reducing concentrations of other COPCs.
- Detailed subsurface evaluation is necessary to ensure hydraulic control and achieve adequate residence time.
- Literature suggests organic medium will last more than 10 years.