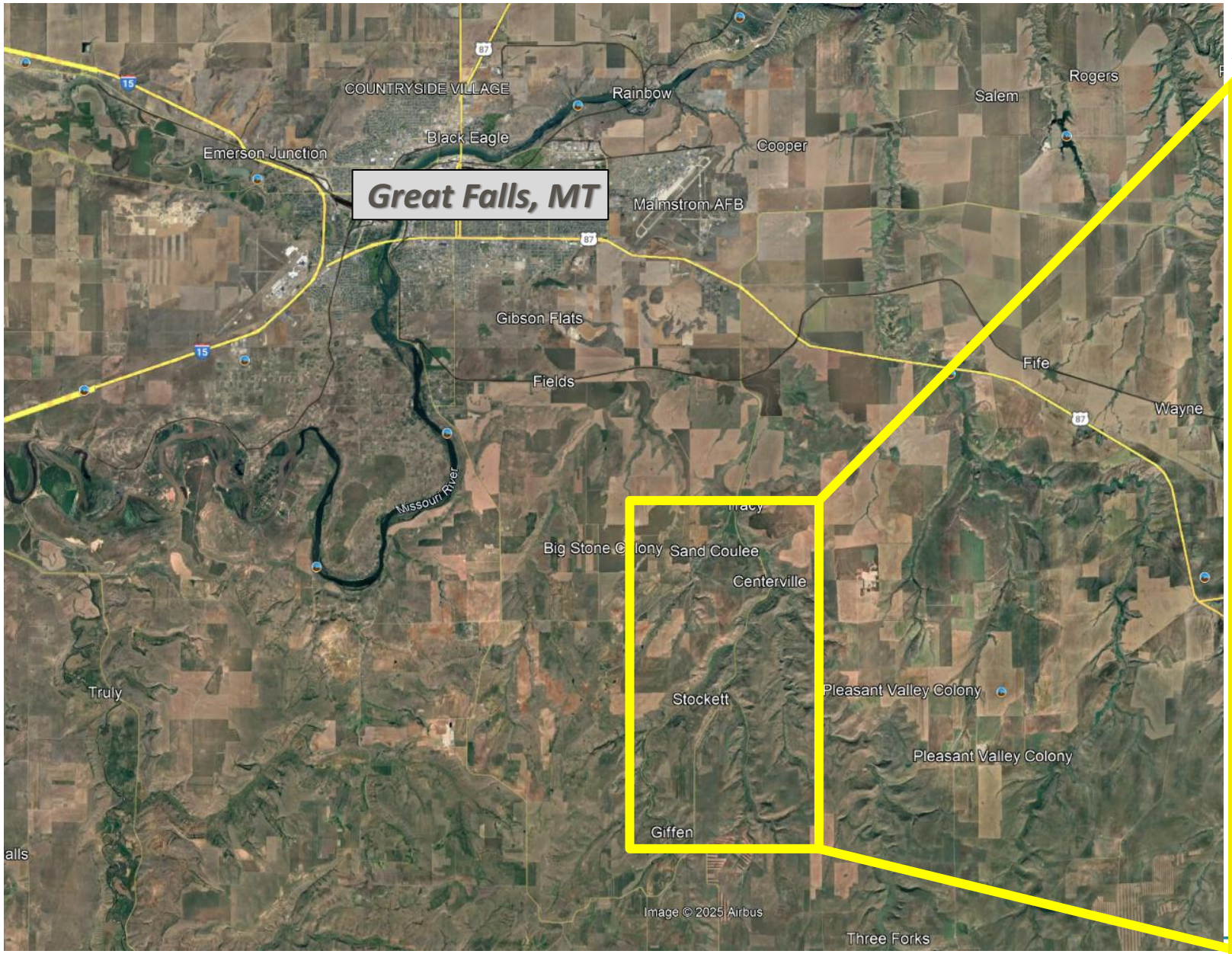
(Bio)geochemical Evaluations of ARD in Central Montana

Scott Hensel, PG – Geochemist

Great Falls Coal Field

There are hundreds of miles of mine workings in the area.



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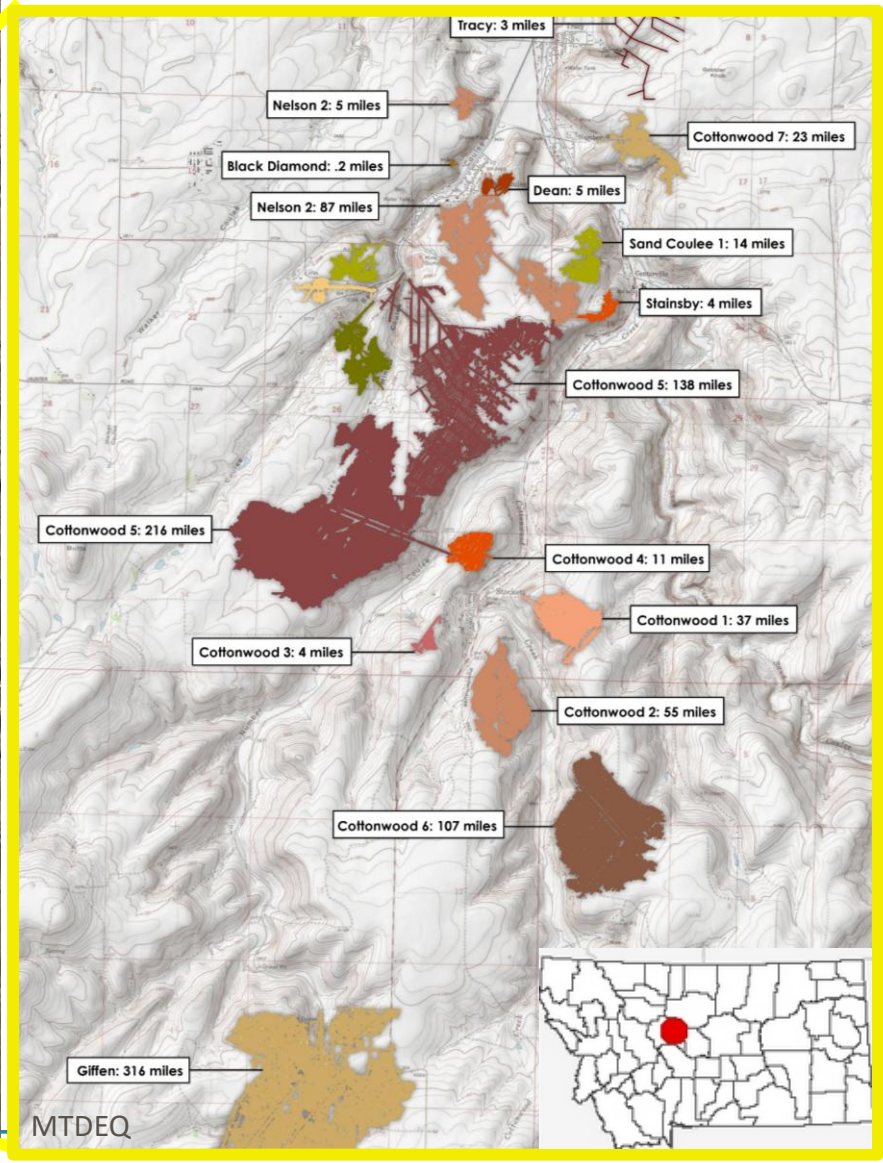

Local Mining History

Sand Coulee, 1905

- Mining began in the Great Falls Coal Field in 1876.
- In 1887 the Sand Coulee Branch of Montana Central Railway was completed.
- Acidic Mine water is and was an issue for the majority of the mines in the area.
- It was soon discovered that the acidic mine water quickly dissolved anything made of iron.
- The majority of the mining in the area was complete by the 1940's.

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Some Current Projects

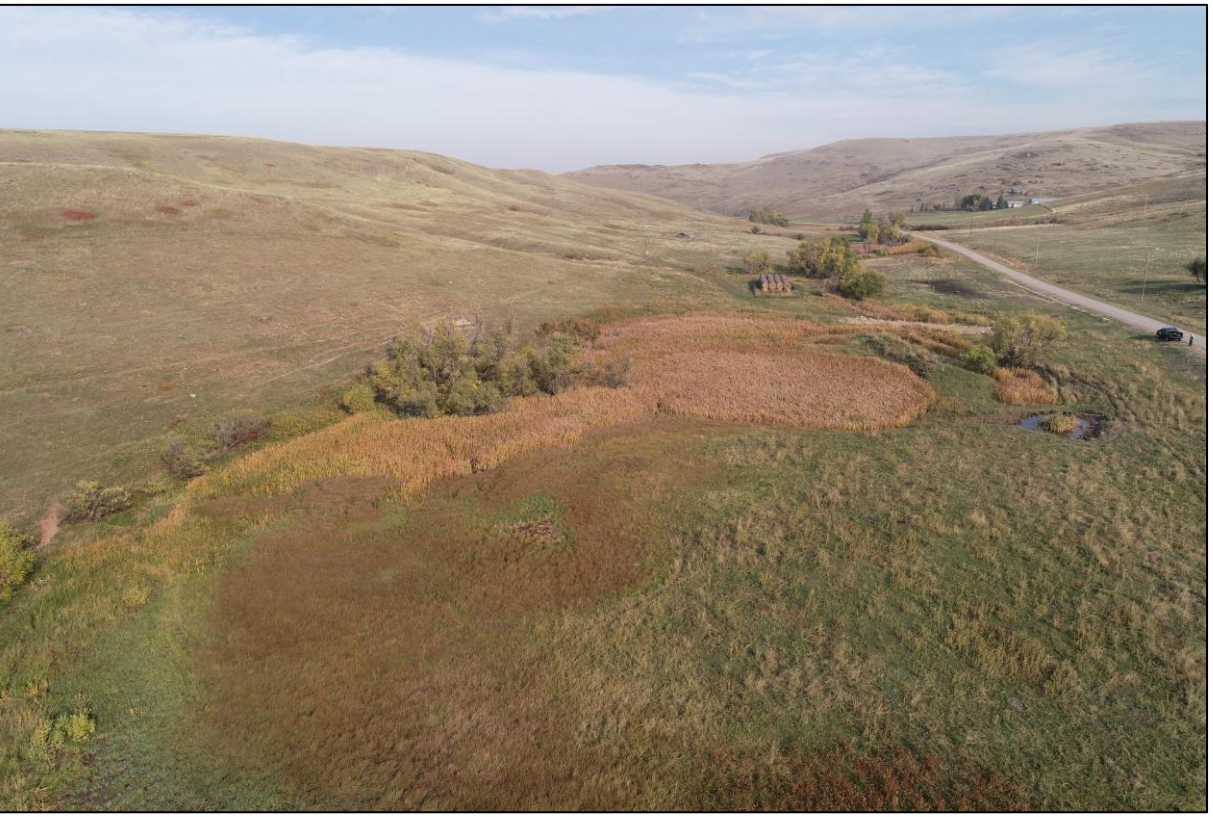
1. **Giffen Wetlands Assessment –** Natural ARD treatment. What are the mechanisms?

2. **Kate's Coulee – Mt Oregon Mine (Sand Coulee Source Control Project) –** Planned dilution of ARD water as it leaves the mine. Additional treatment? Water source for dilution?

3. **Anaconda #4/Heal Mine Reclamation –** Burnout remediation. What's the source like?

Kate's Coulee

Giffen Mine Site
Wetlands Complex Study



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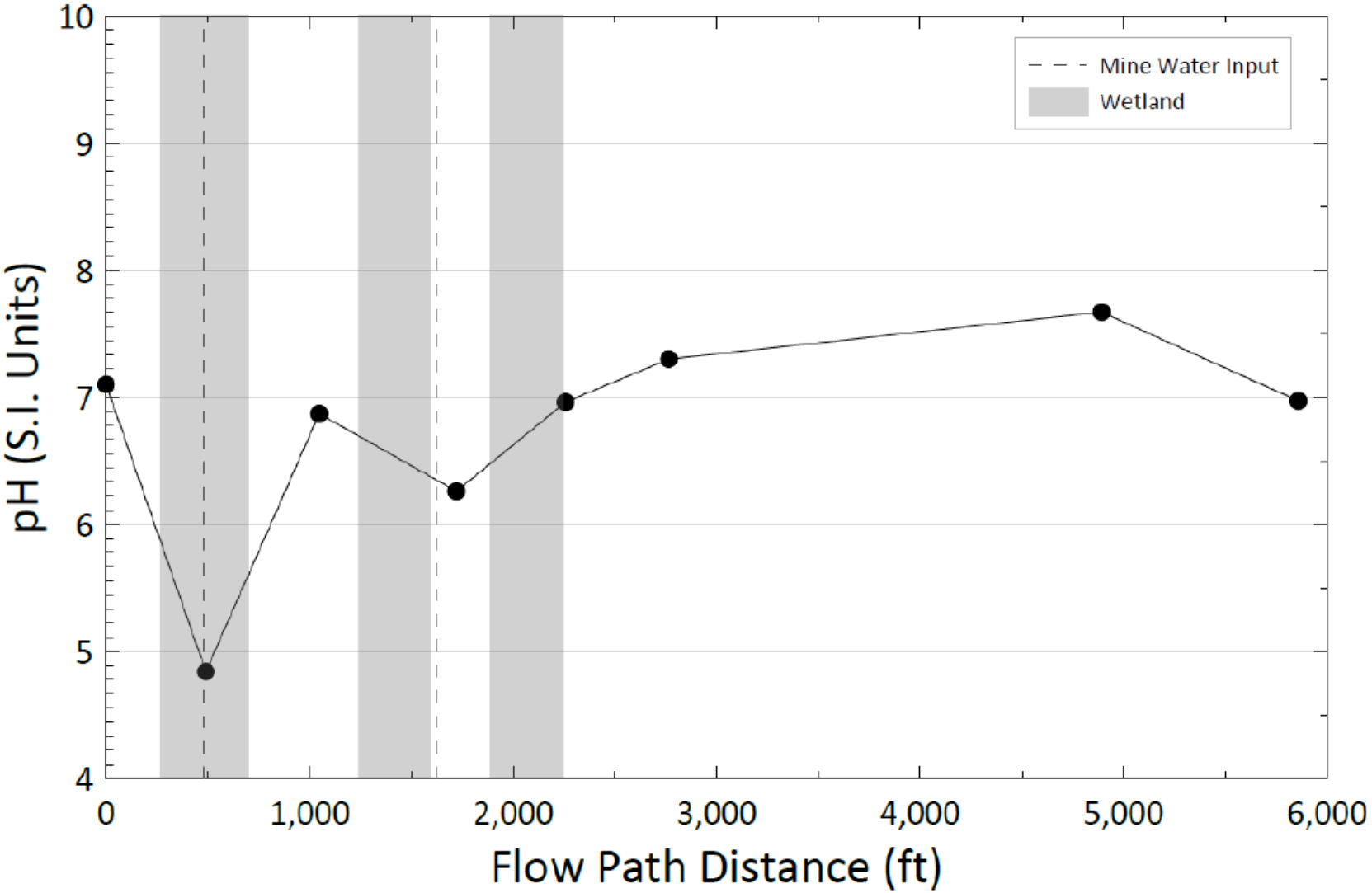
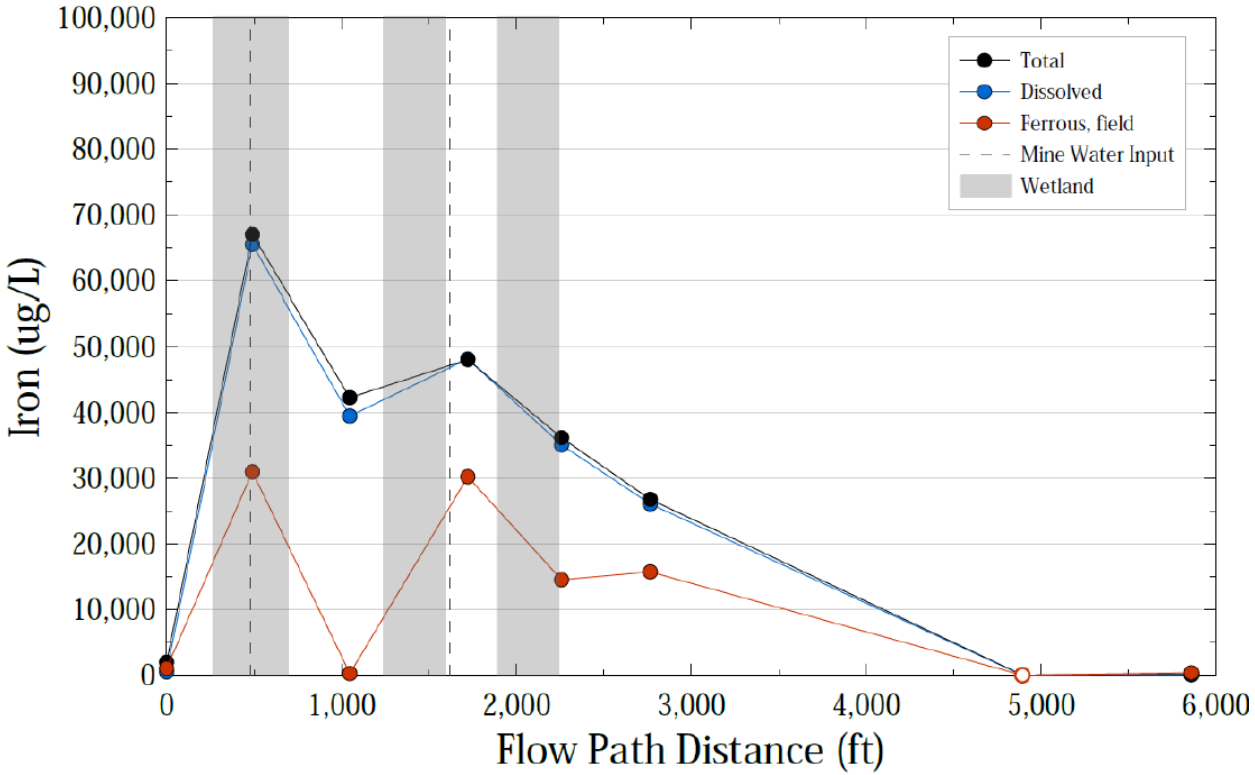
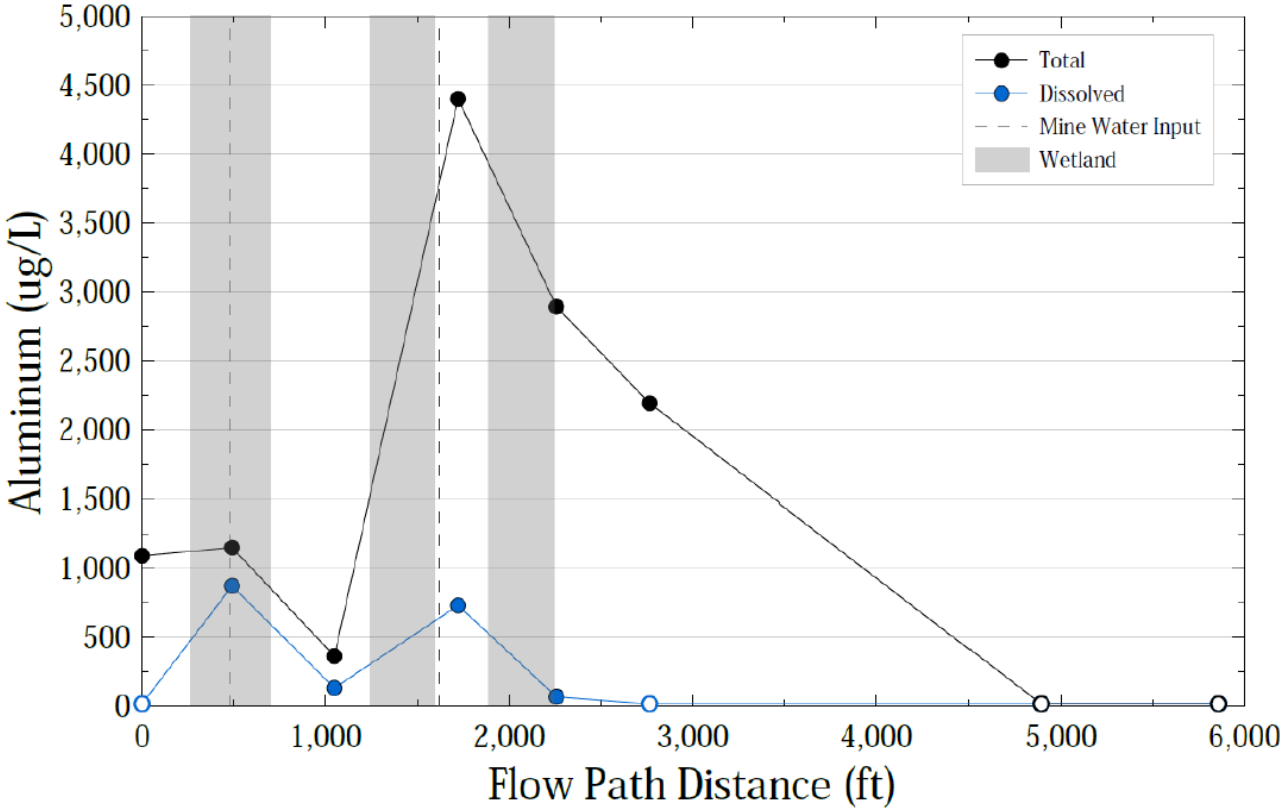
Surface Water

- Water quality improvement:
  - Microbially catalyzed oxidation reactions
  - Oxide mineral precipitation
  - Dilution
- All trace metals in the surface water improve throughout the flow path. Many falling below DEQ-7 Human Health Standards.
- pH increases from <5 to >7



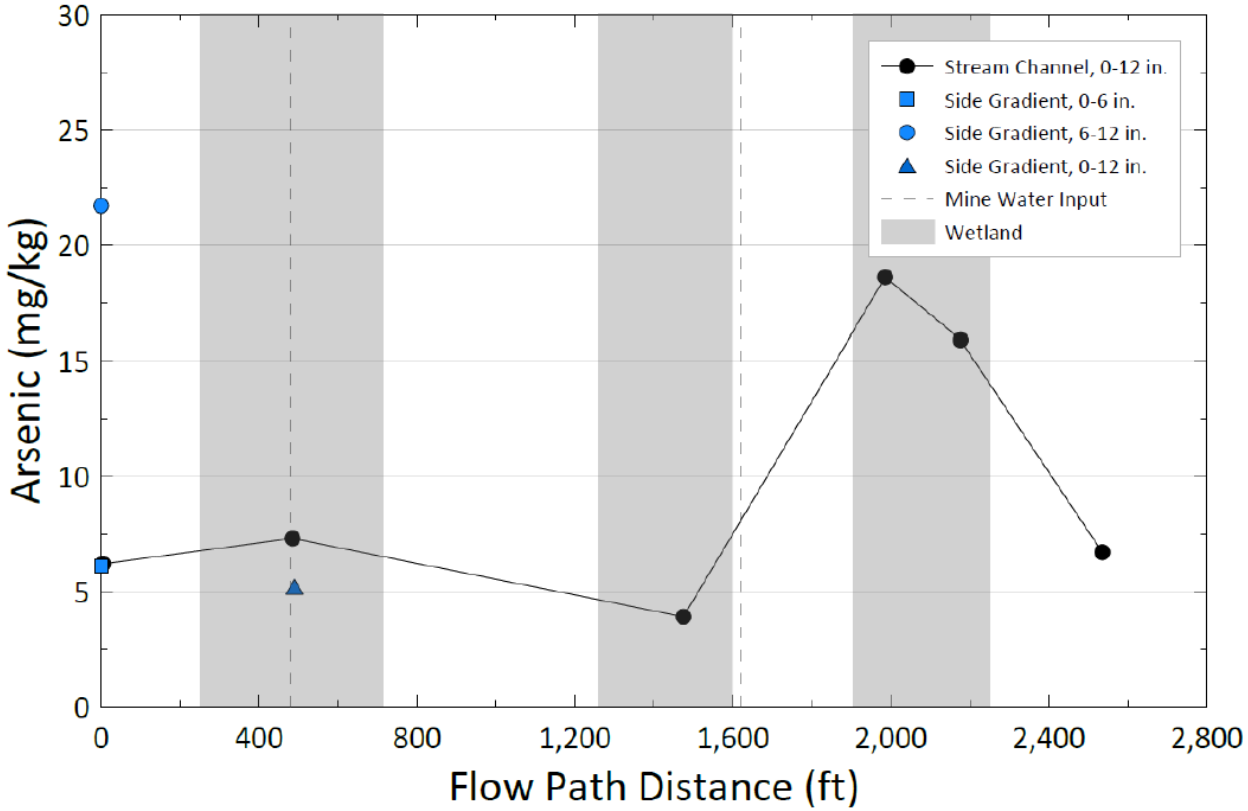
Giffen Surface Water

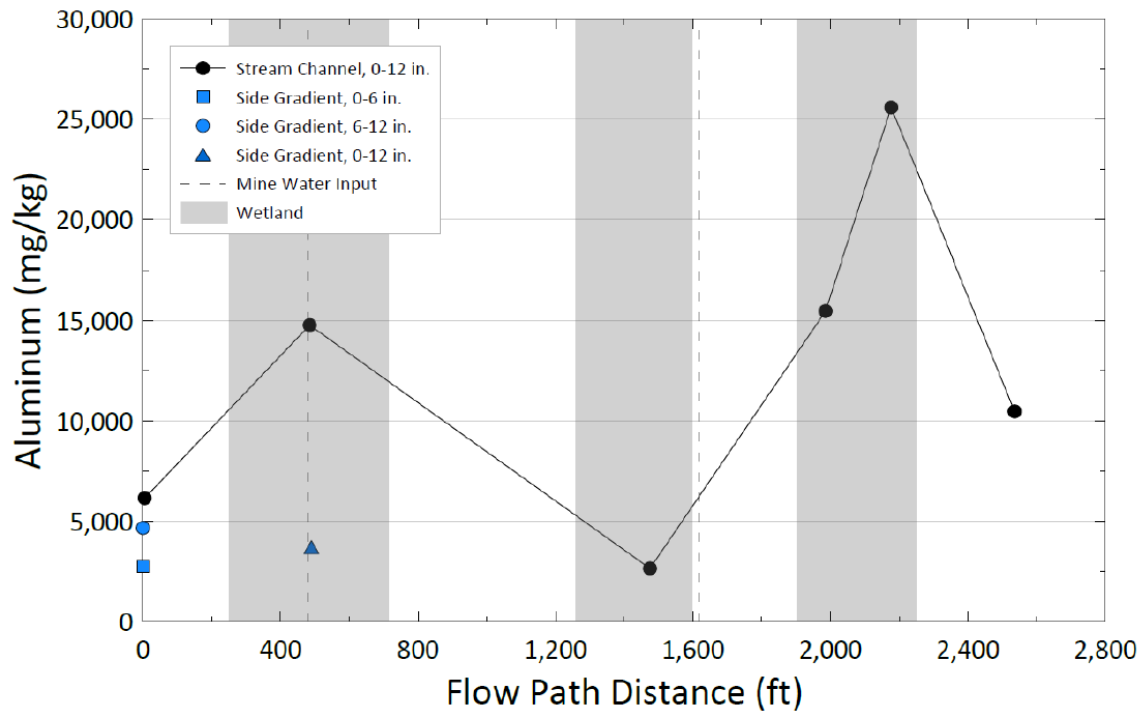


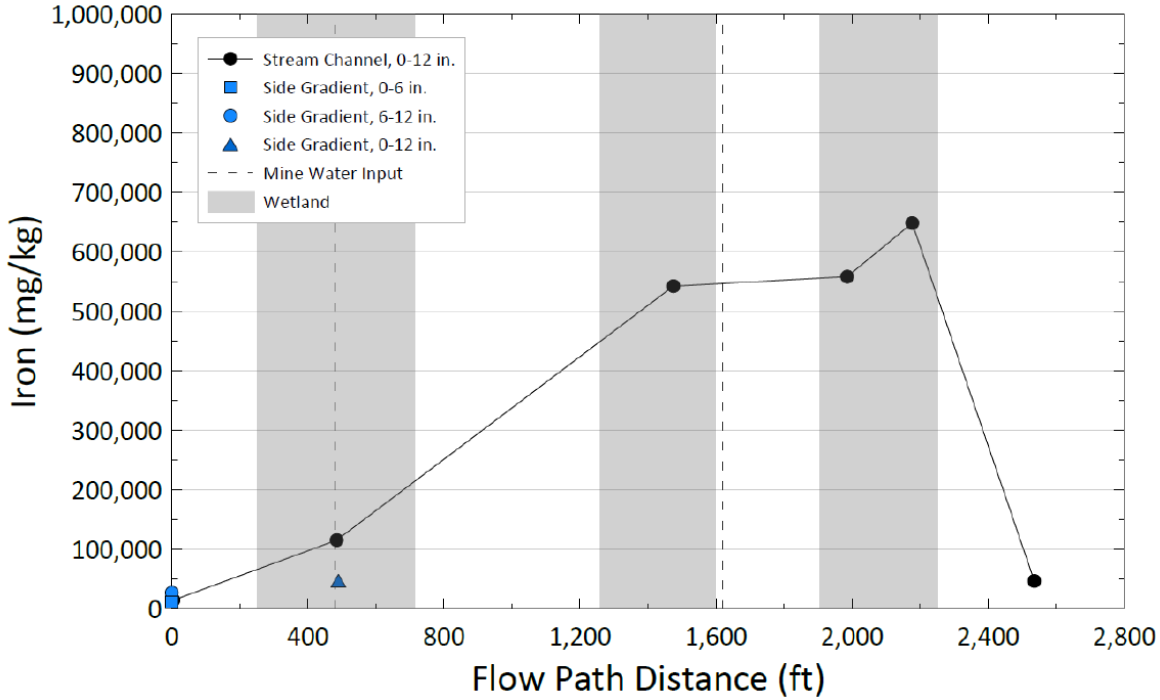


Giffen Soil

Loading of soil with mine water constituents.

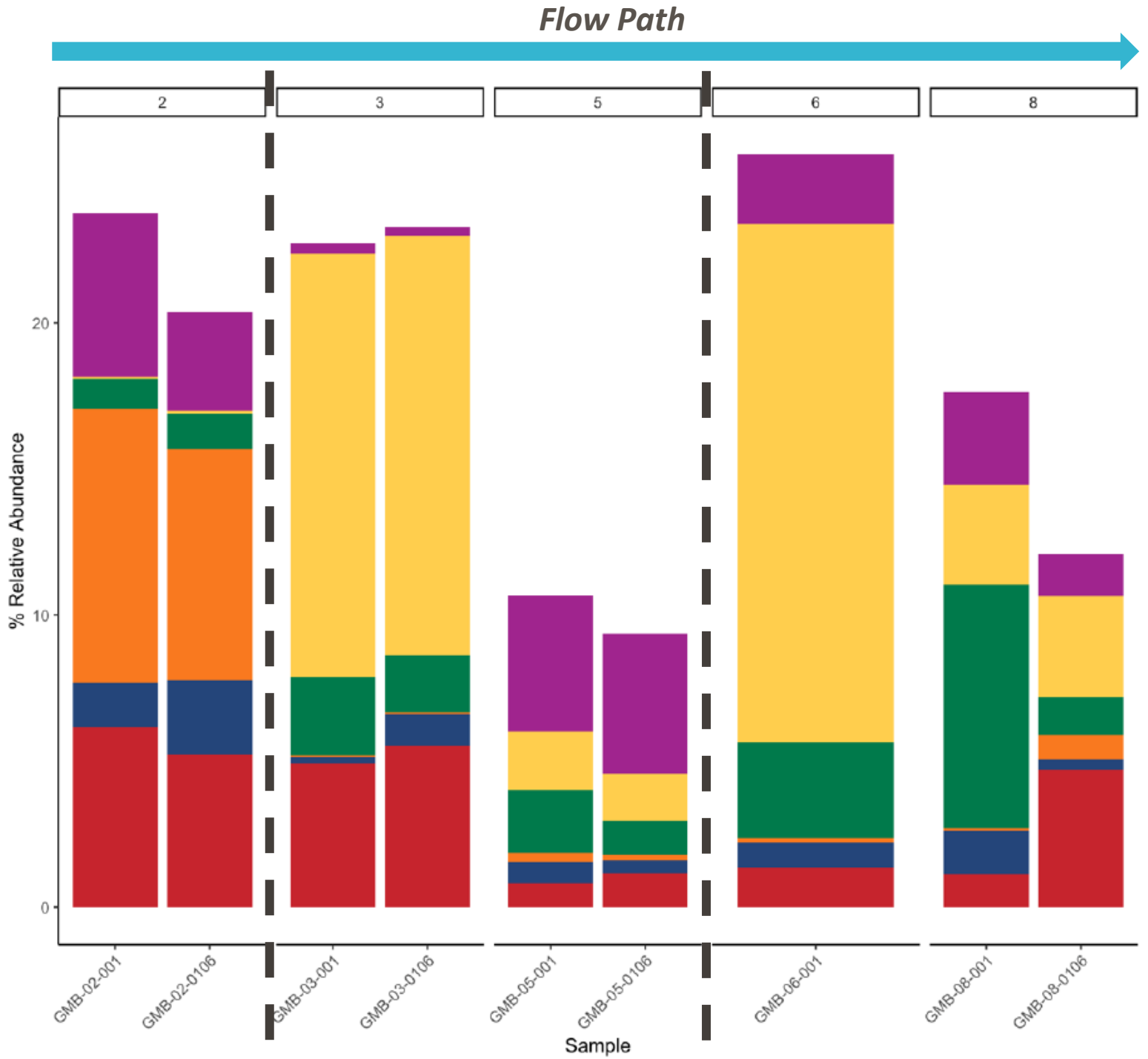






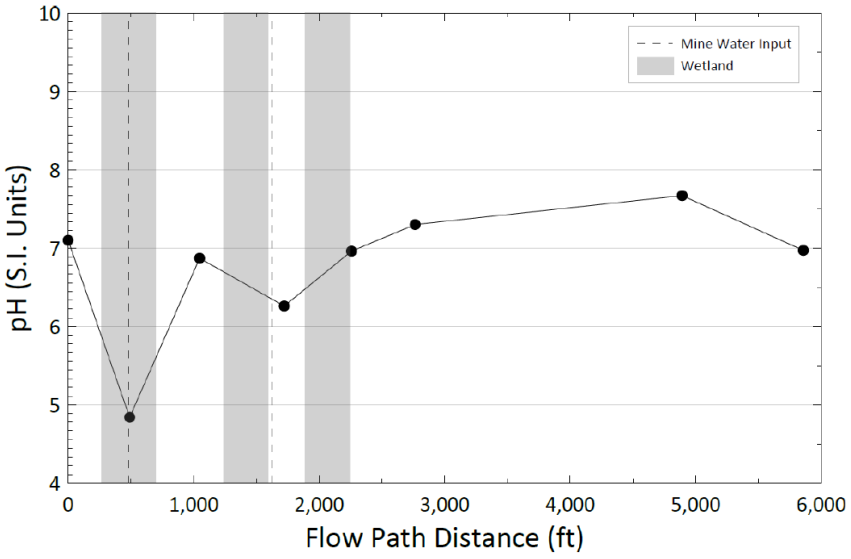
Giffen Microbes

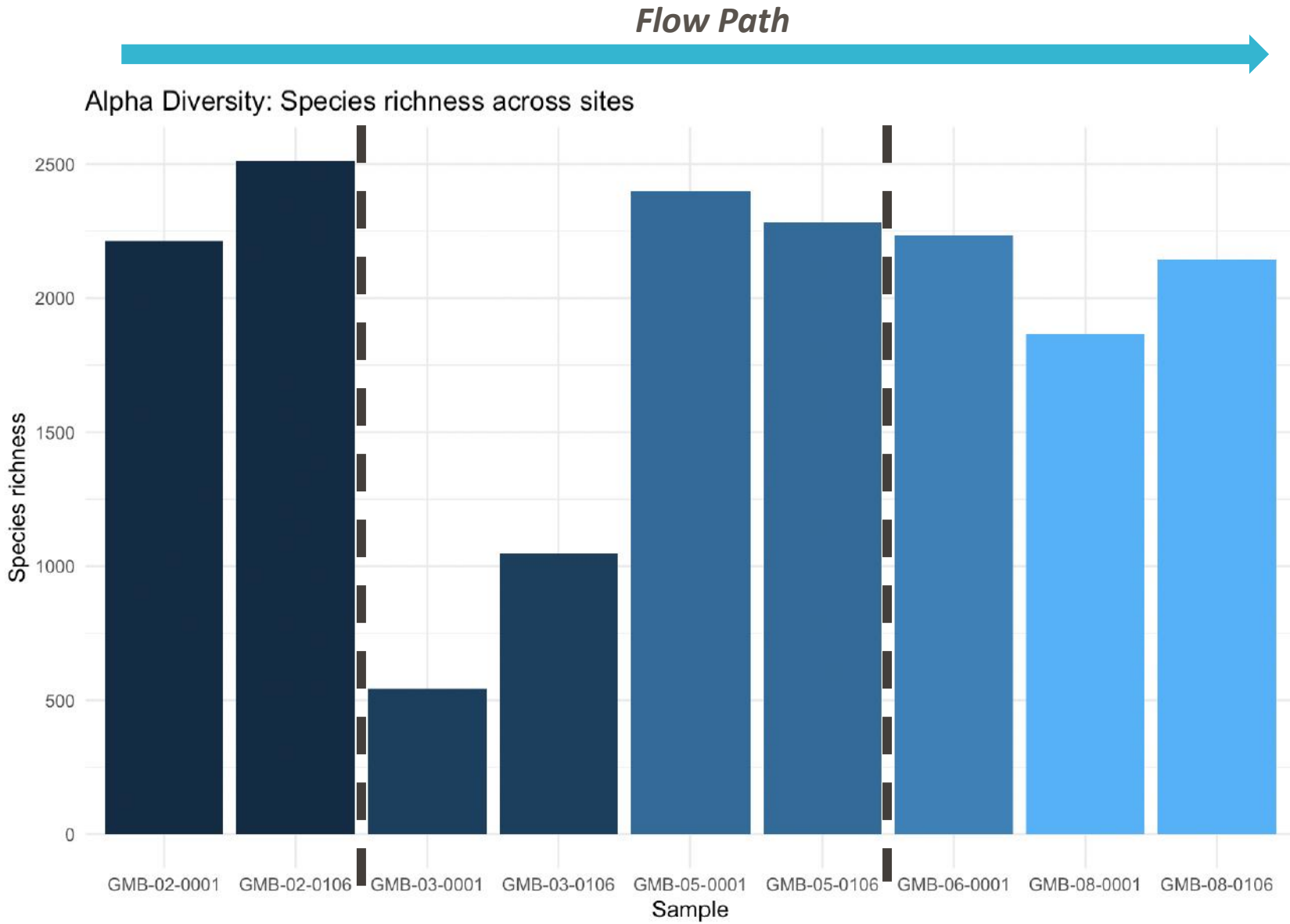
- Samples collected at surface and at 6 inches depth.
- DNA extraction, rRNA sequencing.
- Show dominant iron oxidation following mine water inputs.



Giffen Microbes

Lower number of different species after first mine water input.





Kate’s Coulee

- Mt. Oregon Mine discharge flows into Kate’s Coulee Creek, and then into Sand Coulee Creek.
- Kate’s Coulee Creek is seasonal, rough average flow rate of 30 GPM
- Sand Coulee impacted upstream of Kate’s Coulee confluence.

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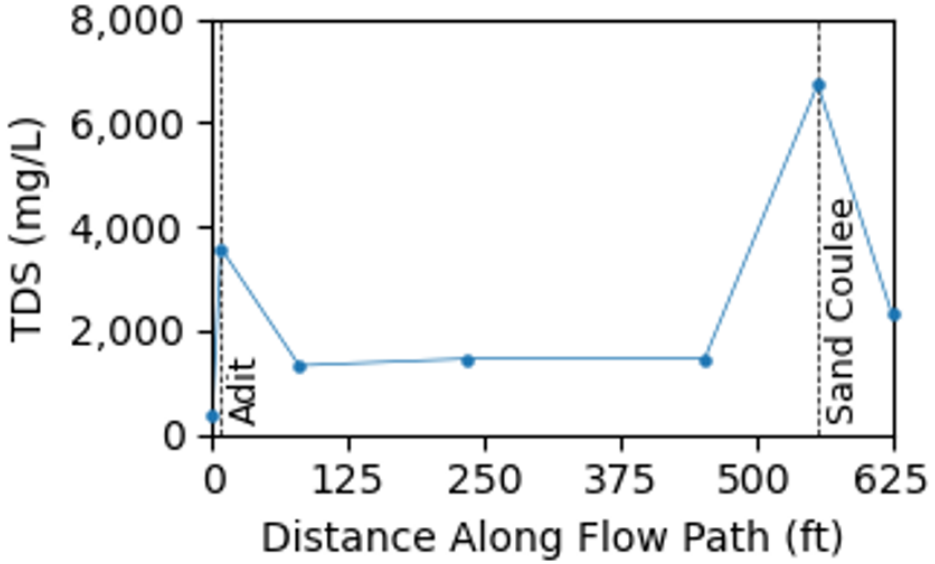
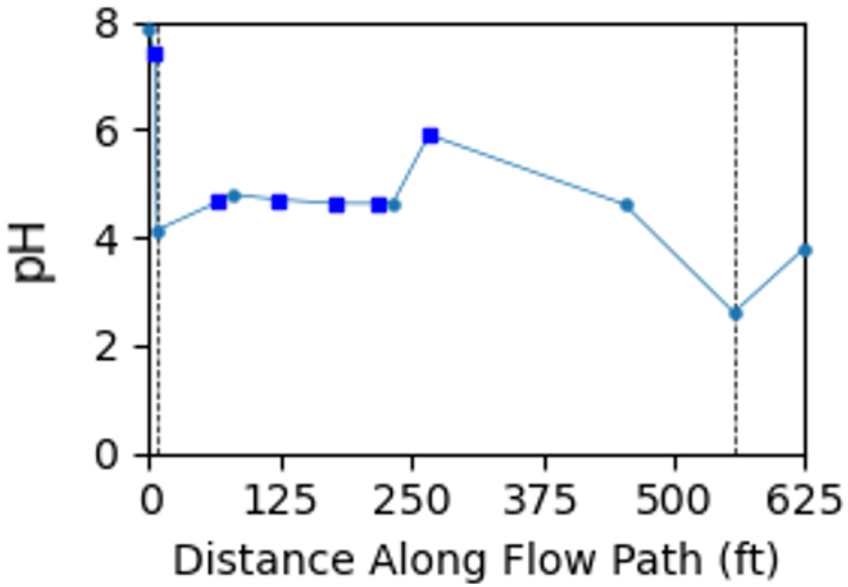
Kate’s Coulee

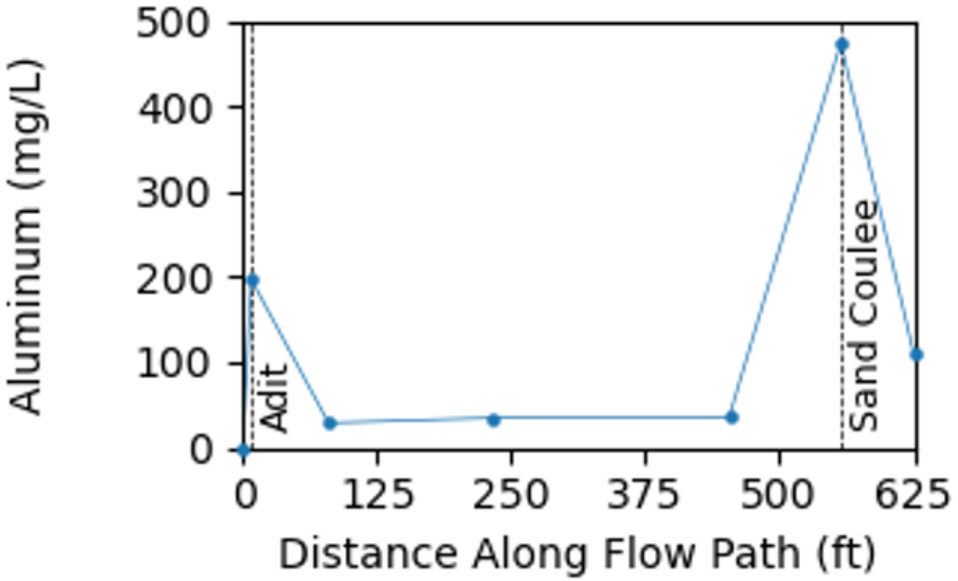
Kate’s Coulee Surface Water

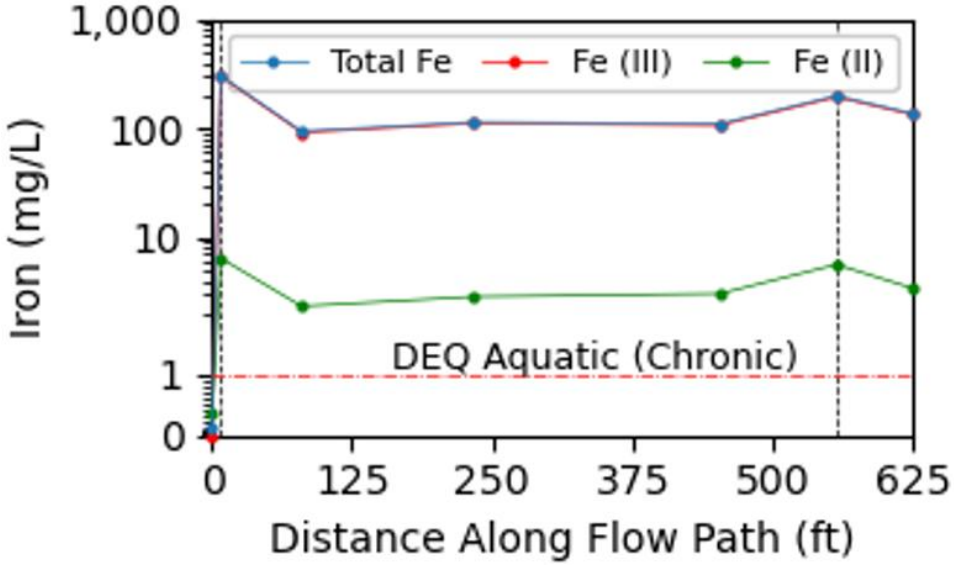
- Kate’s Coulee relatively unimpacted upstream of Mt. Oregon discharge.
- Post discharge: low pH, high metals.

Kate's Coulee Surface Water – Filtered







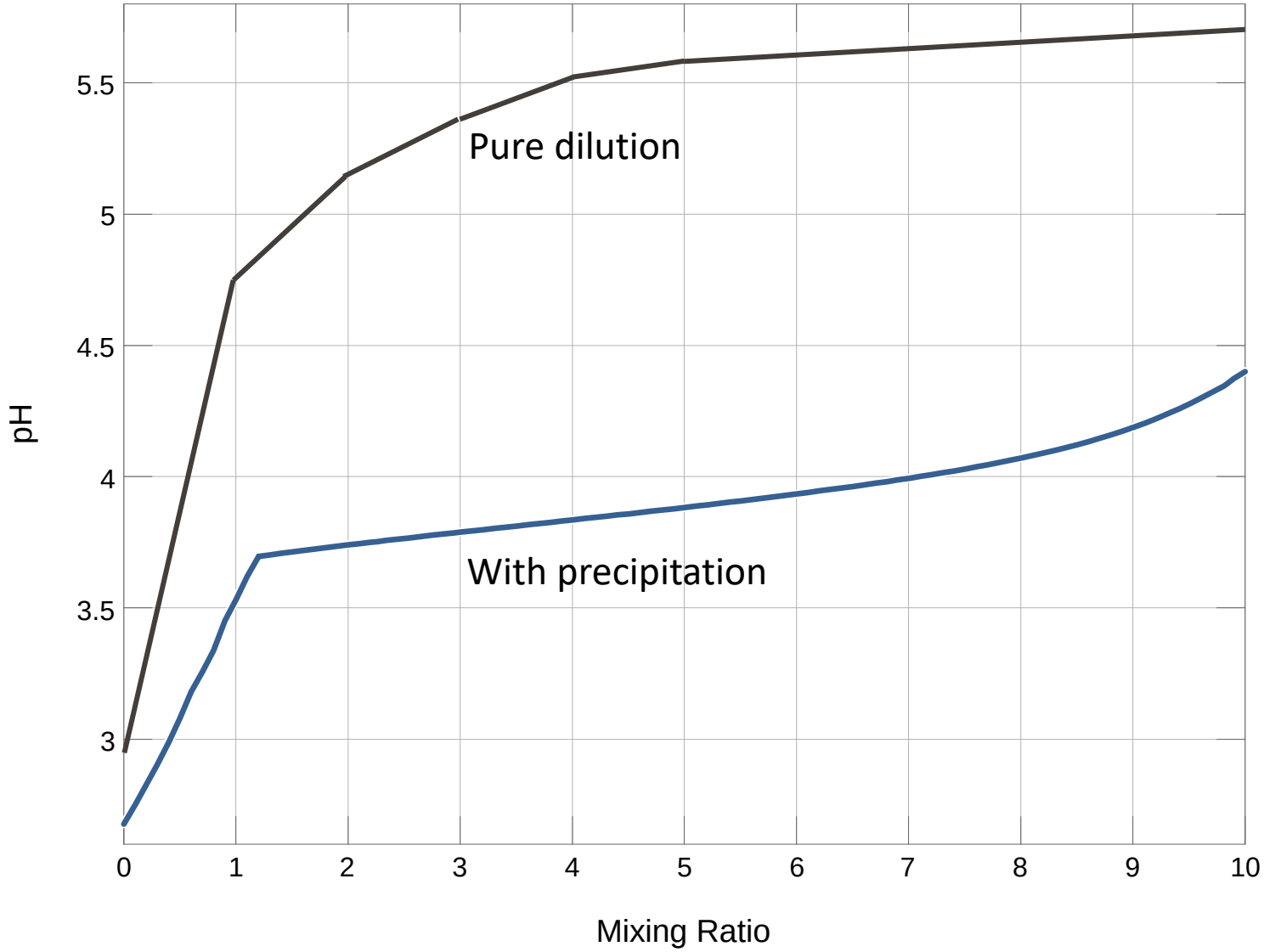


Dilution Modeling

- Comparison of water quality criteria: Sand Coulee vs. nearby Well 3 (Kootenai Formation).
- Geochemical modeling used to estimate conservative results from a variety of mixing ratios.
  - GWB (LLNL database)

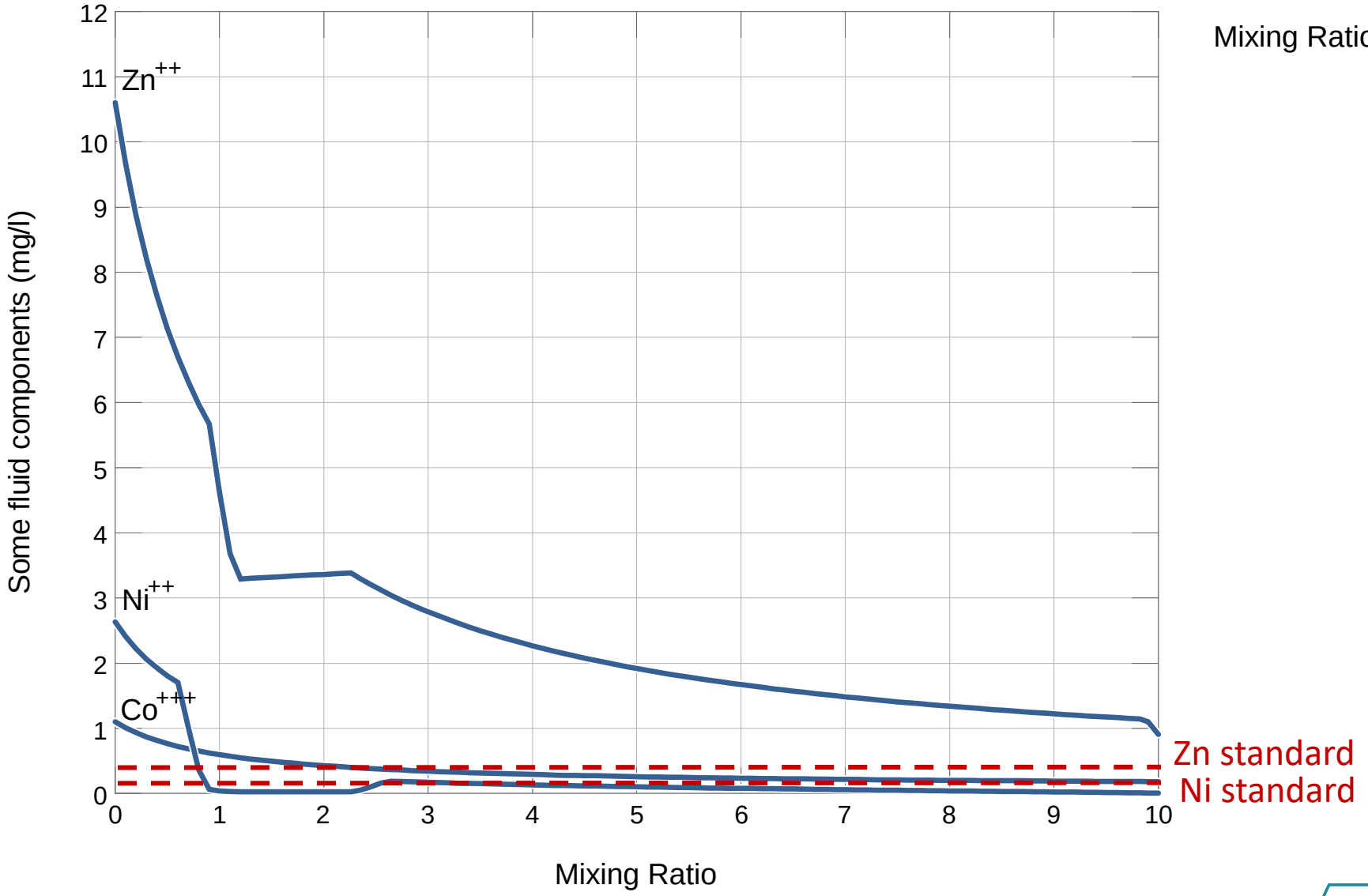
Parameter	KC-06 (ug/L)	Well 3 (ug/L)	Standard (ug/L)	Source
Cadmium	32	1.3	2.39	MDEQ - calculated using hardness
Copper	102	ND	30.5	MDEQ - calculated using hardness
Chromium (III)	68.8	ND	268	MDEQ - calculated using hardness
Lead	2	ND	18.6	MDEQ - calculated using hardness
Nickel	2,630	155	169	MDEQ - calculated using hardness
Zinc	10,600	179	388	MDEQ - calculated using hardness
Iron	480,000	7,400	1,000	MDEQ
Arsenic	18.4	1.0	10	EPA MCL

Model Results: pH



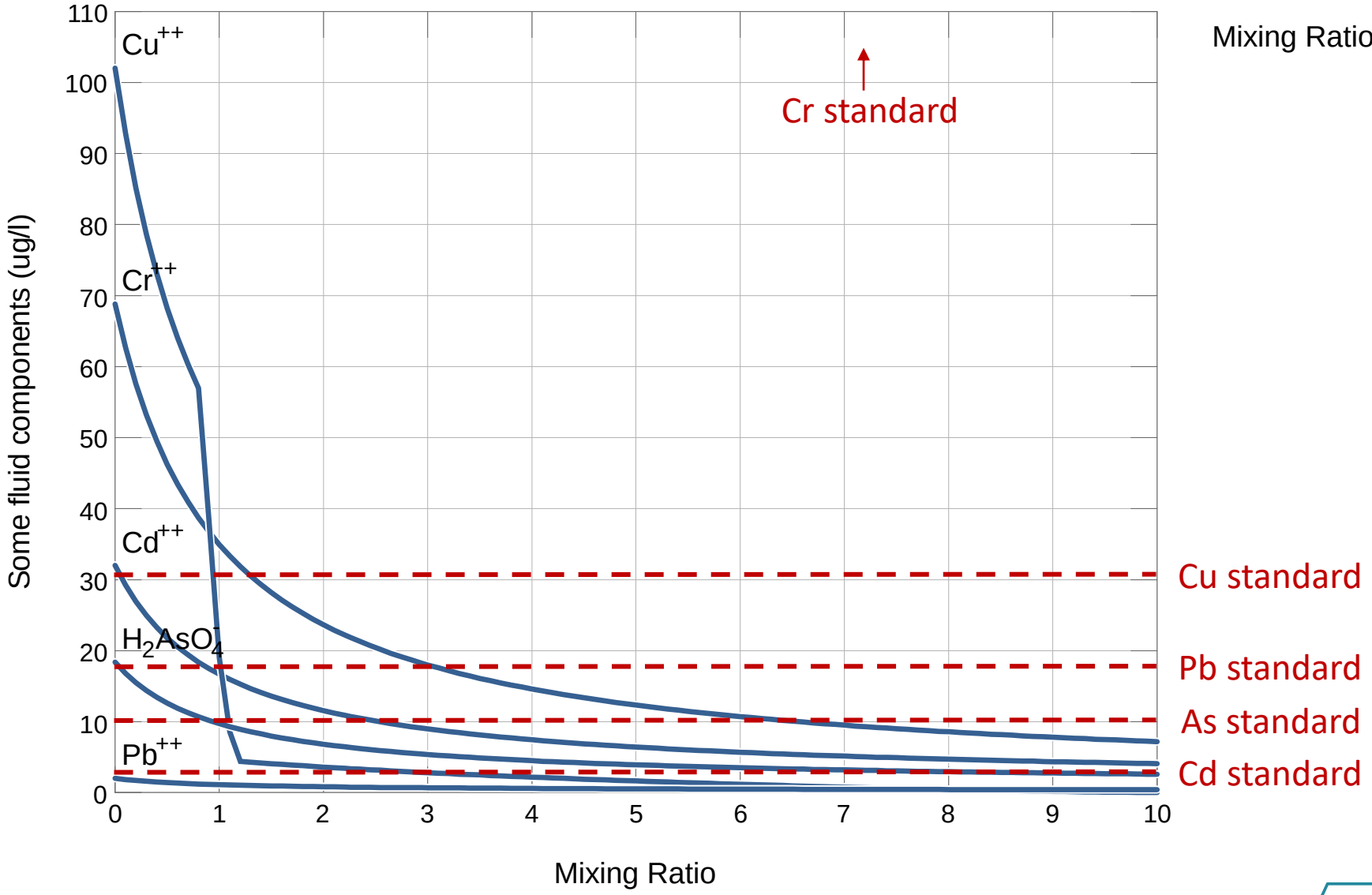
$$\text{Mixing Ratio} = \frac{\text{Well 3 Water}}{\text{Stream Water}}$$

Model Results: Dissolved Concentrations

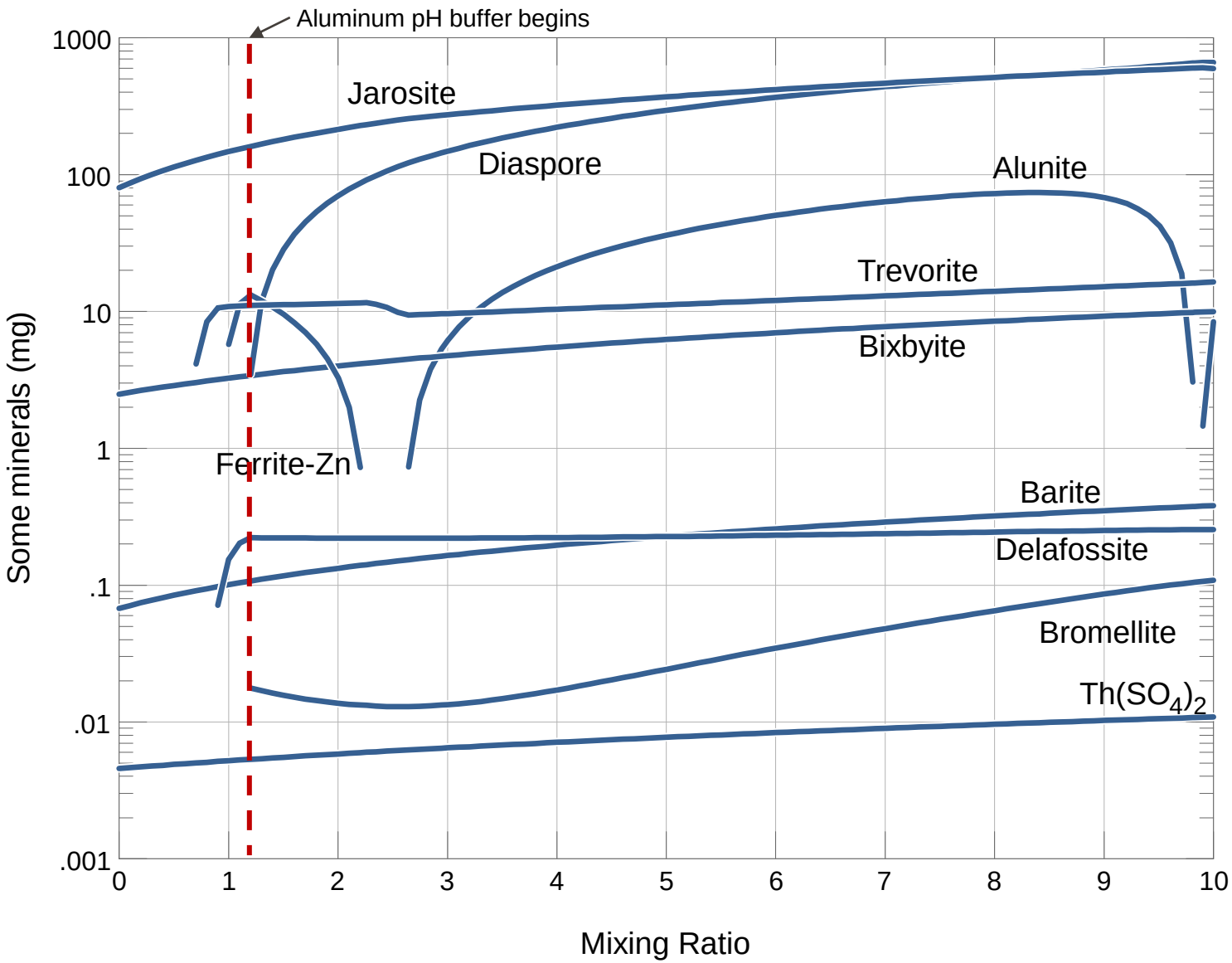


$$\text{Mixing Ratio} = \frac{\text{Well 3 Water}}{\text{Stream Water}}$$

Model Results: Dissolved Concentrations (cont.)



Model Results: Minerals



$$\text{Mixing Ratio} = \frac{\text{Well 3 Water}}{\text{Stream Water}}$$

Diaspore = AlO(OH)

$Al^{+++} + 2H_20 = \text{Diaspore} + 3H^+$

Flooded! Looking Upstream, weir now gone

July 2019

August 2023

Flooded! Looking Downstream

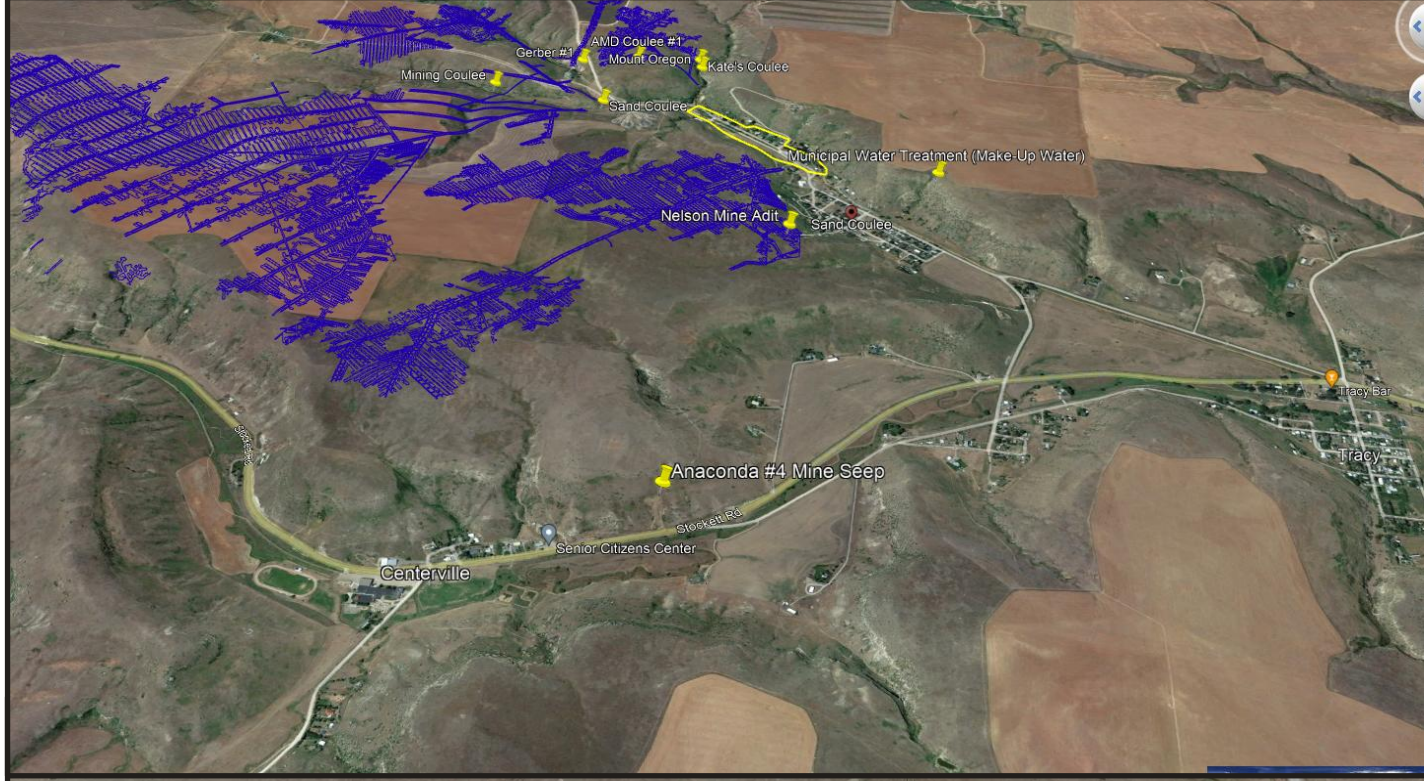
March 2023

September 2024

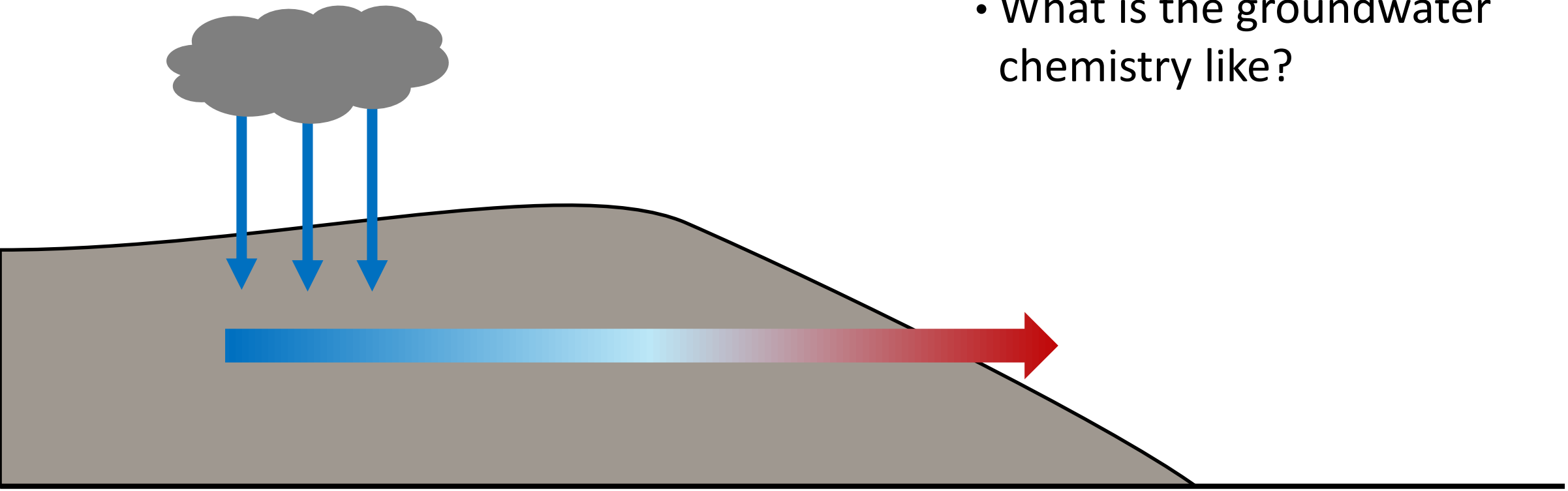
Anaconda #4/Heal Mine Reclamation

The Plan:

1. **Evaluate groundwater**
2. **Design and install adit drain system**
3. **Repair drainage and reclaim burnout area**

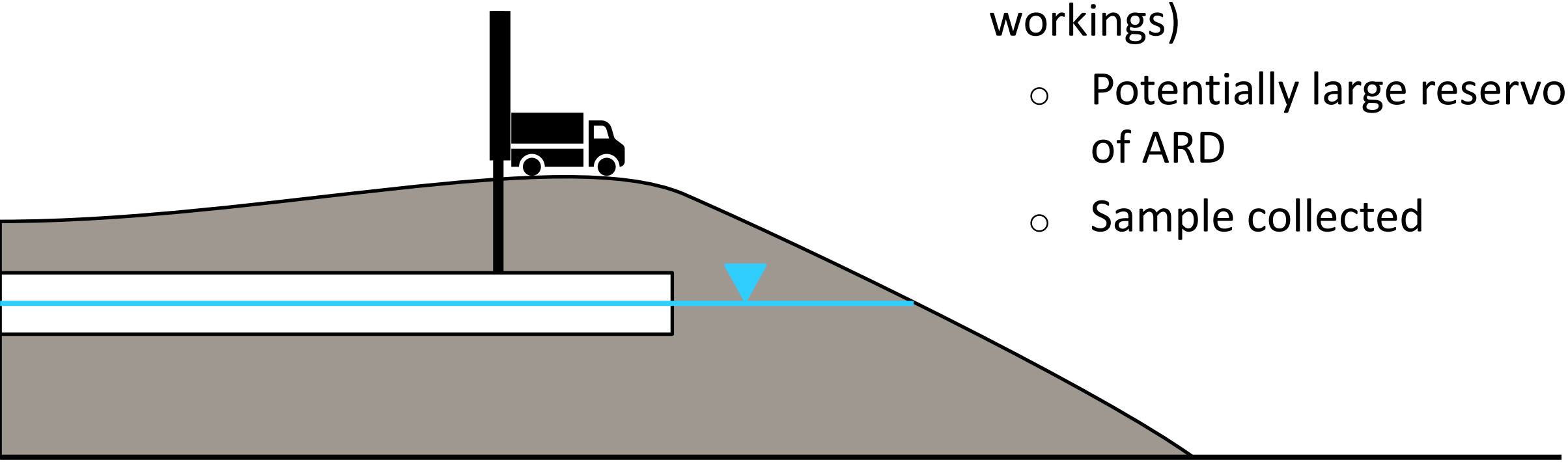


Anaconda #4 Source Sampling



- No nice stream to sample.
- What is the groundwater chemistry like?

Anaconda #4 Source Sampling



- Well drilling led to intersection with underground void (mine workings)
  - Potentially large reservoir of ARD
  - Sample collected

Anaconda #4 Source Sampling

Extreme!

- pH: 2.3
- TDS: 20,100 mg/L

Parameter	Result	Unit
Aluminum	1,050	mg/L
Iron	2,320	mg/L
Sulfate	14,100	mg/L
Arsenic	240	µg/L
Cadmium	122	µg/L
Copper	840	µg/L
Lead	6.9	µg/L
Zinc	18,100	µg/L

Anaconda #4 Source Sampling: REEs

Parameter	Result	Unit
Sc	293.807	µg/L
Ge	6.258	µg/L
Y	702.501	µg/L
La	1,075.514	µg/L
Ce	2,876.113	µg/L
Pr	403.205	µg/L
Nd	1,895.670	µg/L
Sm	446.339	µg/L
Eu	117.330	µg/L

Parameter	Result	Unit
Gd	649.302	µg/L
Tb	88.311	µg/L
Dy	498.937	µg/L
Ho	71.979	µg/L
Er	168.685	µg/L
Tm	18.947	µg/L
Yb	110.619	µg/L
Lu	15.346	µg/L

>9 ppm total!

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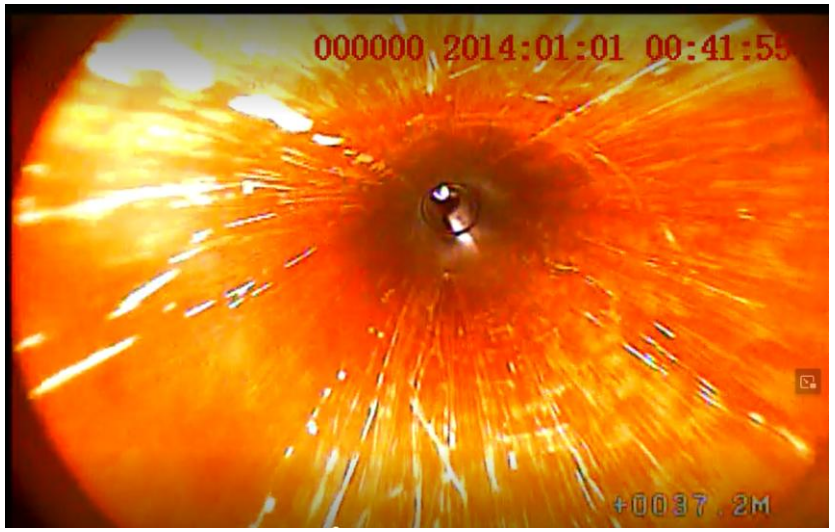
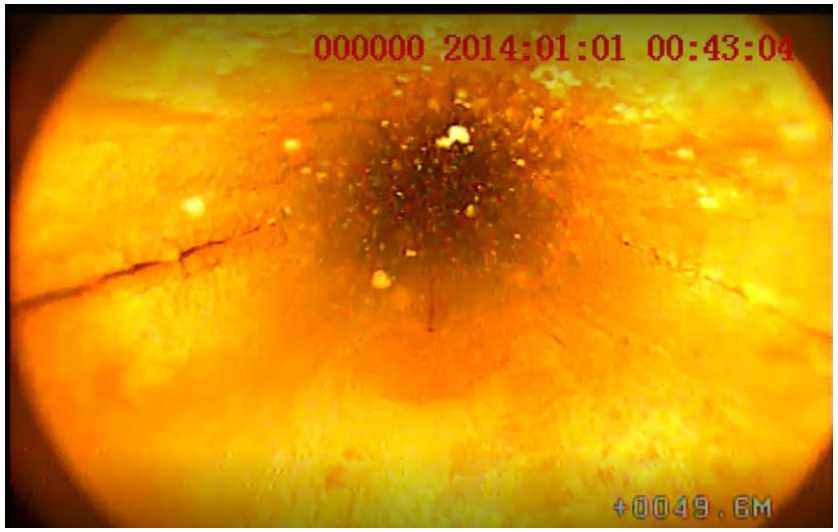
Questions?

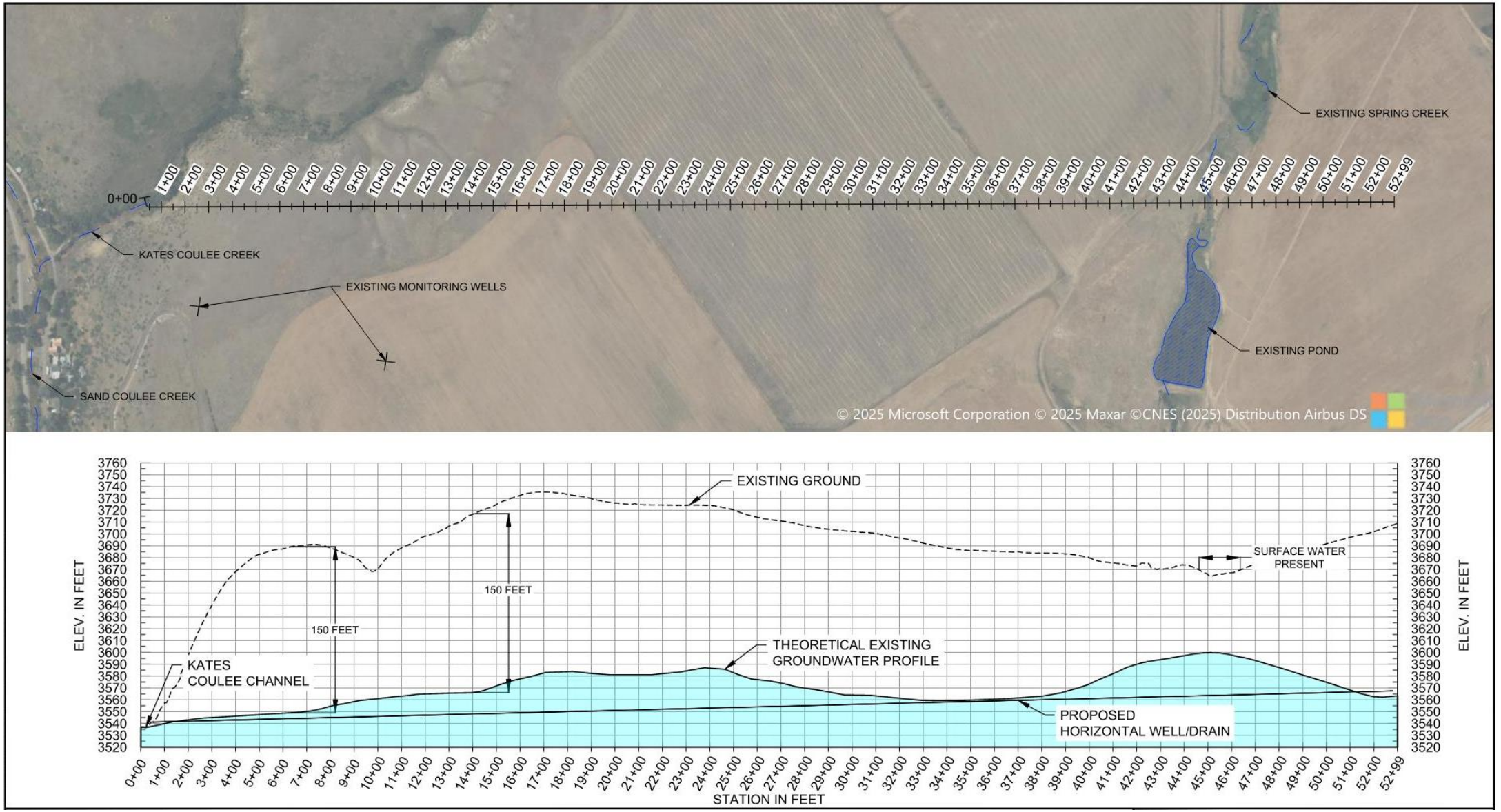
Well Inspection – Not much Flow





Oxide precipitation has resulted in problematic pumping conditions.

- Regular cleaning may be required
- Other options?


EXISTING SPRING CREEK
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1+00
2+00
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6+00
7+00
8+00
9+00
10+00
11+00
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KATES COULEE CREEK
EXISTING MONITORING WELLS
EXISTING POND
SAND COULEE CREEK
© 2025 Microsoft Corporation © 2025 Maxar ©CNES (2025) Distribution Airbus DS
ELEV. IN FEET
3760
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3600
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3530
3520
EXISTING GROUND
SURFACE WATER PRESENT
150 FEET
150 FEET
KATES COULEE CHANNEL
THEORETICAL EXISTING GROUNDWATER PROFILE
PROPOSED HORIZONTAL WELL/DRAIN
STATION IN FEET