Canada

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Innovative *In-Situ* Remediation Approach to Treat PFAS-Impacted Groundwater

Pilot Scale Design and Implementation

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PFAS; The Scale of Issue

Dr. Chris Higgins (Colorado School of Mines):

- "***One 5-gallon bucket*** *of "PFOS Legacy" AFFF formulations has sufficient PFOS to contaminate the annual water supply of more than* ***94 million people*** *(to 0.02 ng/L based on the new EPA advisory level)"*

ECCC/HC (Draft State of PFAS Report) – May 2023:

- *"PFAS contamination is present* ***throughout Canada*** *and is not limited to a few sources or areas"*
- *"Certain PFAS have been found in the blood of the* ***general population*** *in Canada"*

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Groundwater PFAS Remediation Challenges

- They are ubiquitous, ranging from pg/L to mg/L in aqueous media, with wide range of detected compounds (various fate and transport mechanisms)
- Highly soluble and mobile in groundwater (particularly short-chain PFAS), which make the removal from environmental media extremely challenging.
- The current focus is on PFAS removal, not destruction. No destructive methods are fully demonstrated in the field to treat PFAS (beyond incineration / thermal treatment).
- The majority of the current full-scale remediation techniques for groundwater are being conducted via pump and treat method (an *ex-situ* approach). P&T requires electrical infrastructure, could be a costly approach due to operation and maintenance costs.
- *In-situ* approaches (e.g., injection) are less expensive, but mainly are containment techniques, where PFAS physically stabilized but remain in the impacted zones.

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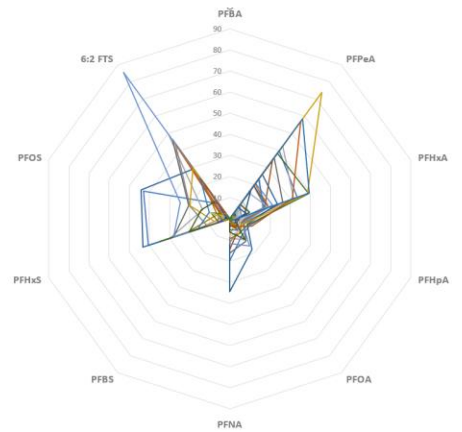
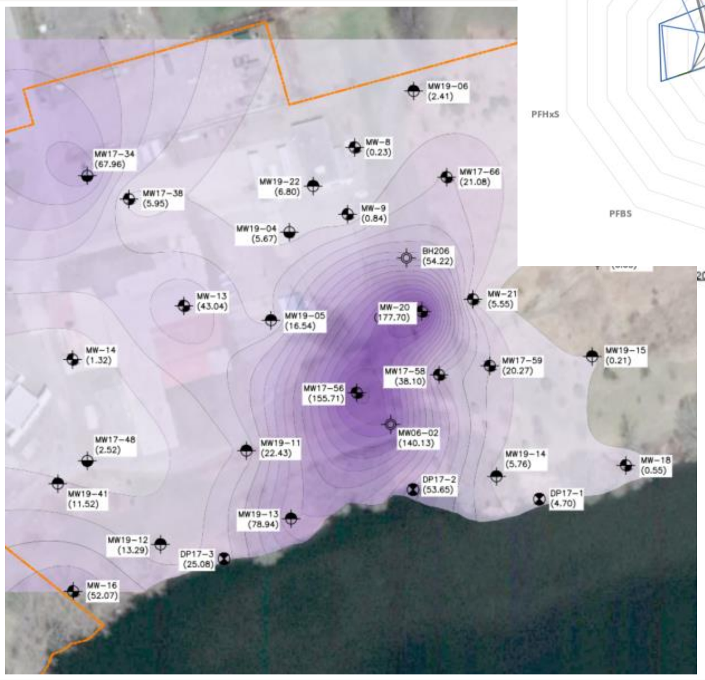
Site Description

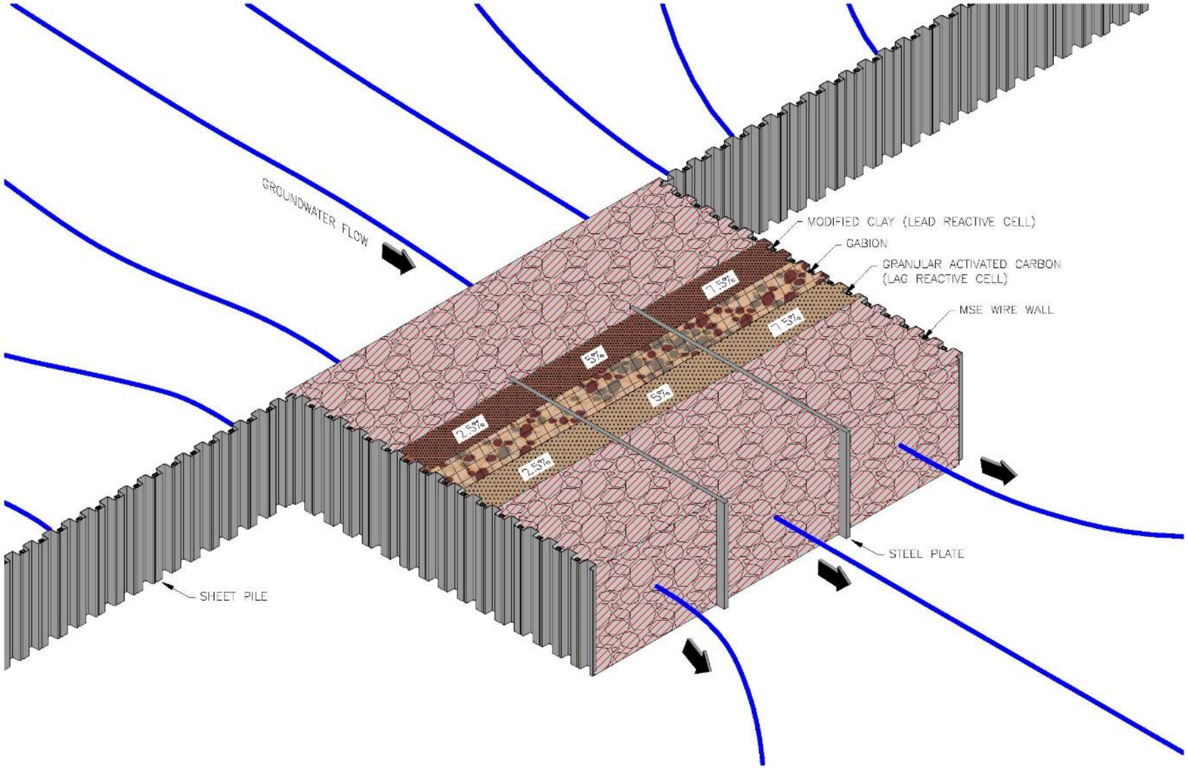
- A Canadian Forces Base in Ontario;
- AFFF was identified as the main source of PFAS;
- Impacted media; soil & groundwater;
- Proximity of the site to a significant water body; potential risk of adverse effects to human and the aquatic receptors;
- An effective remediation approach was required to prevent PFAS-impacted groundwater from discharging to surface water





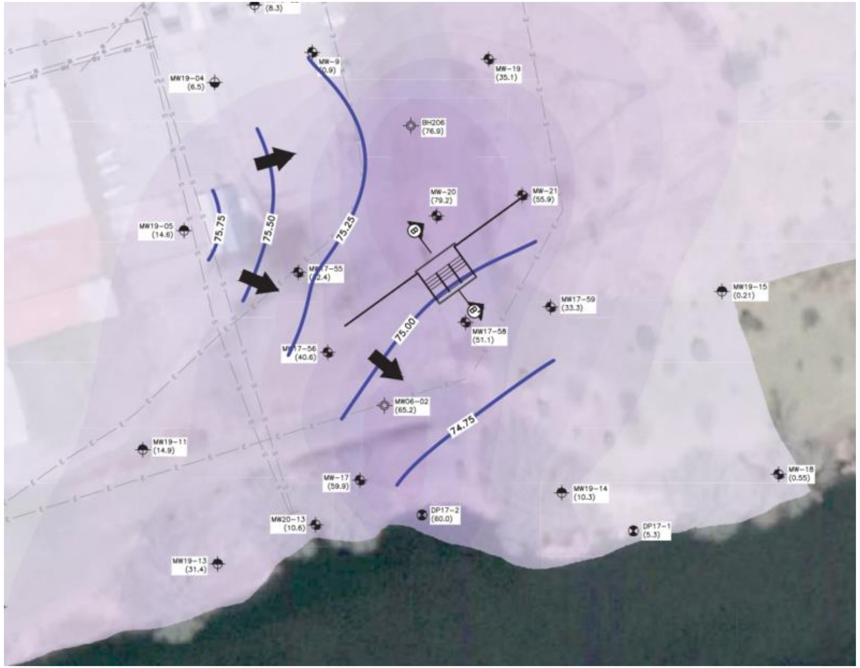
Conceptual Design

In-Situ Treatment Train Permeable Reactive Barrier (ISTT-PRB)



In-Situ Treatment Train - Permeable Reactive Barrier (ISTT-PRB)

- ISTT-PRB is a passive remediation approach, aligned with FCSAP guidance to support sustainable and less energy-intensive remediation technique
- Consisting of different sorbent media to remove/remediate PFAS from groundwater, with ability to replace the spent treatment media.
- Assessing the effects of varying the mixture percentages of sorbent media (in lead & lag reactive cells).



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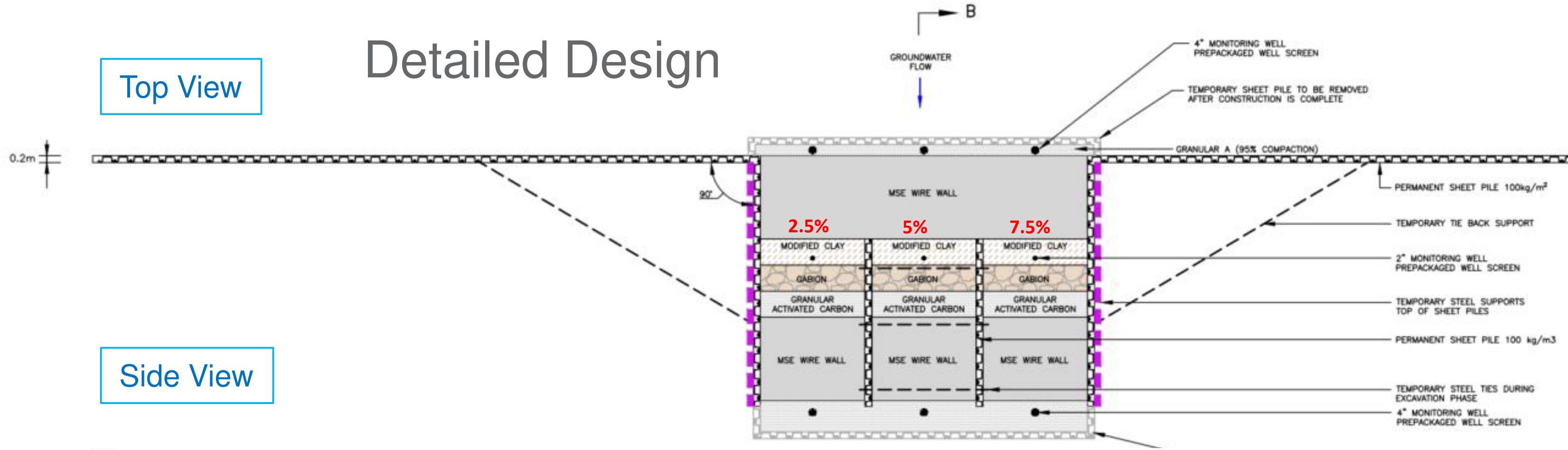
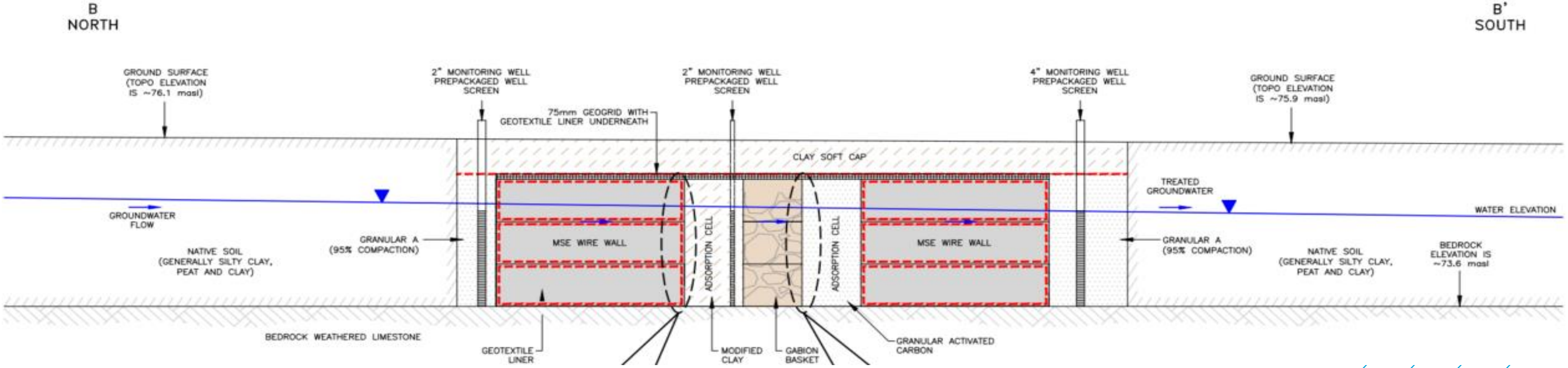
Detailed Design

Top View



Side View



Construction of Funnels and Gate Structure Side-Walls

The funnel walls were excavated to the depth of bedrock (~2.4 m)

Bentonite slurry was pumped into the trench to maintain geotechnical stability

As excavation continued, concrete was pumped into the base of the trenches, thereby displacing the slurry and filling the trench with concrete.

The concrete placement for the funnel walls was carried out in a single monolithic pour.

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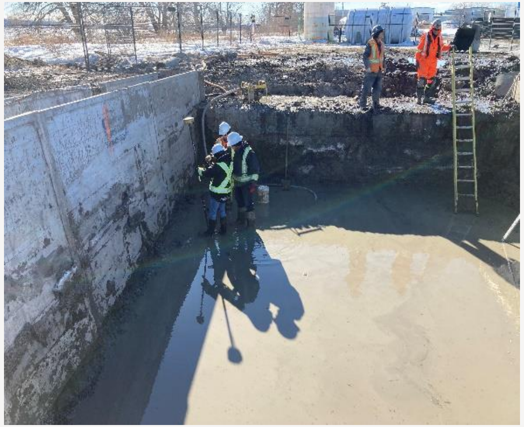
Construction of Funnels and Gate Structure Side-Walls

Temporary trench boxes were installed along the inlet and outlet sides of the gate

~650 metric tonnes of soil and rock were excavated



Vertical steel plates were embedded in the concrete floor to provide stability and a water-tight seal between chambers

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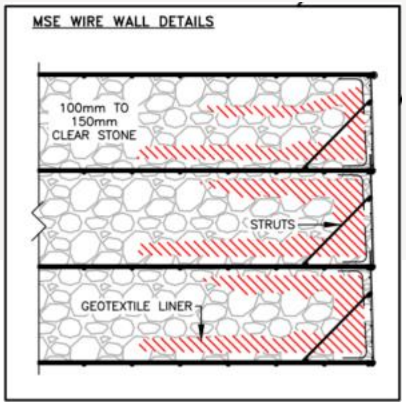
Below-Grade MSE Retaining Wall

The MSE retaining walls at the north and south ends of the gate structure consisted of four tiers of L-shaped welded wire, galvanized steel sections at the face of each retaining wall.



Lead and Lag Reactive Cells

Gabion Partitioning Walls

Placing of Pre-Packed Monitoring Wells

Placing of Adsorption Materials

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Placement and Compaction of Cover Materials

Removing Trench Boxes

Placing of Granular A on top of Grid and Geotextile layers

Installing/Compacting of a Low-Permeability Clay Cap

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Reinstatement and Clean-up

- The ISTT-PRB surface was topped with an approximately 0.05 m layer of gravel to protect against erosion.
- The surface was graded to shed water at 2% slope, and runoff is directed to the existing ditch.
- Concrete blocks were placed around the remediation system to protect the ISTT-PRB against future heavy equipment activities.

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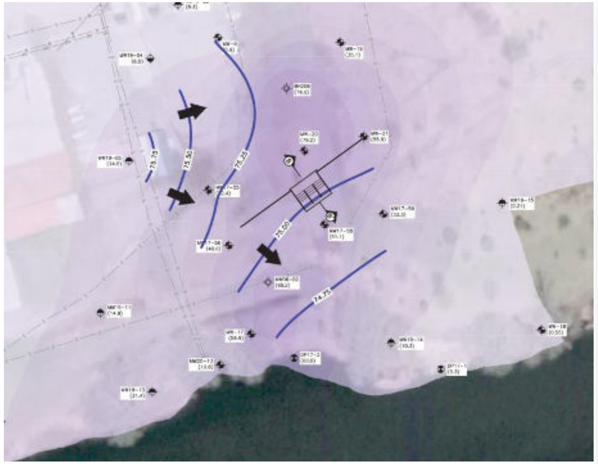
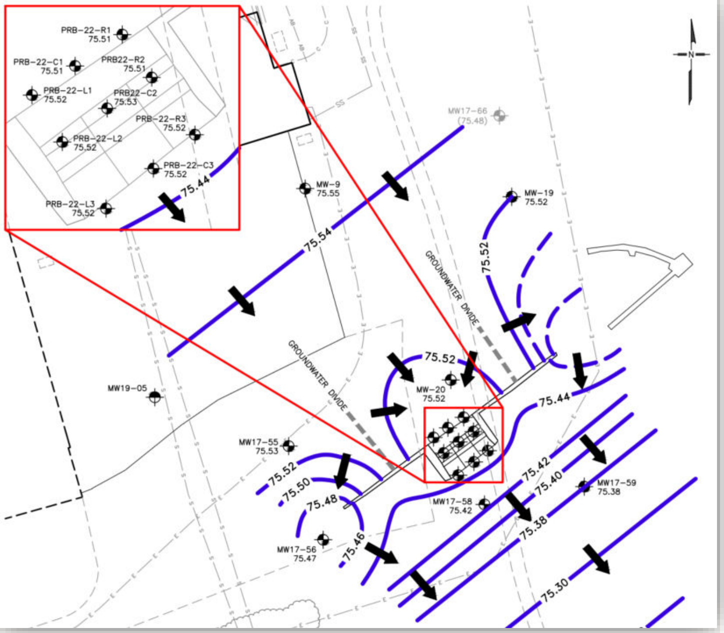
Pre and Post Construction Monitoring and Sampling

- Pre-Construction Monitoring and Sampling (to establish a baseline)
- Post-Construction Purging Event (to establish the new GW flow regime)





- Post-Construction Monitoring and Sampling Event (to assess the performance of the ISTT-PRB) – Quarterly Sampling (2022-2023)

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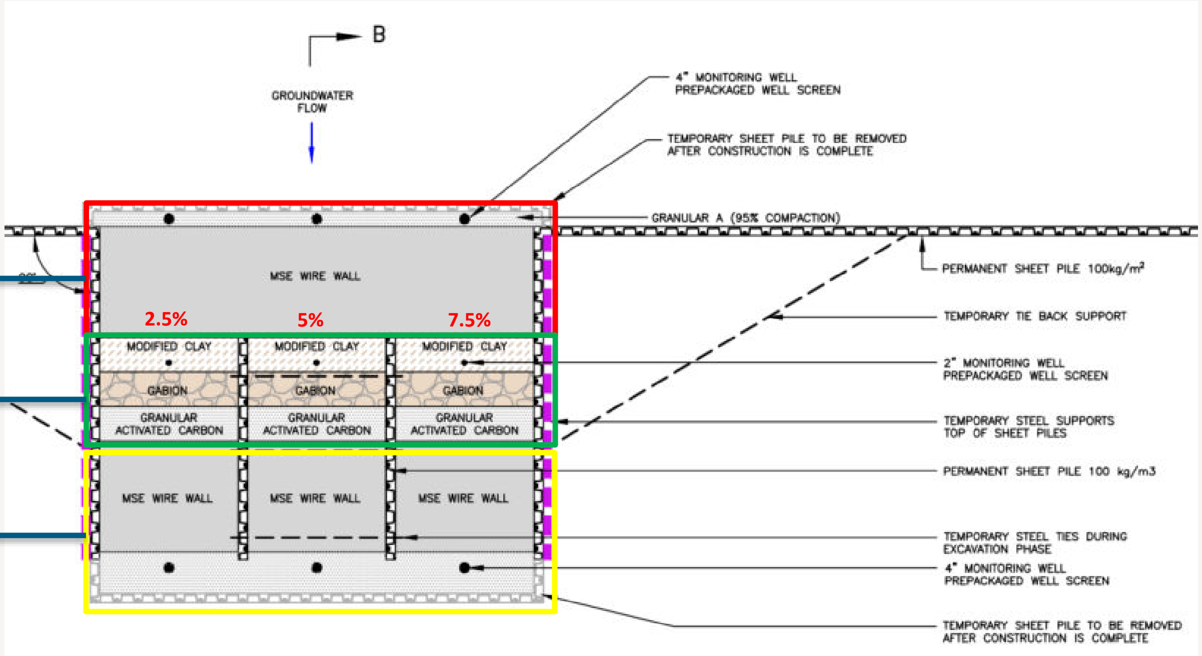
Post-Construction Sampling Event

Influx Zone

Reactive Zone

Discharge Zone



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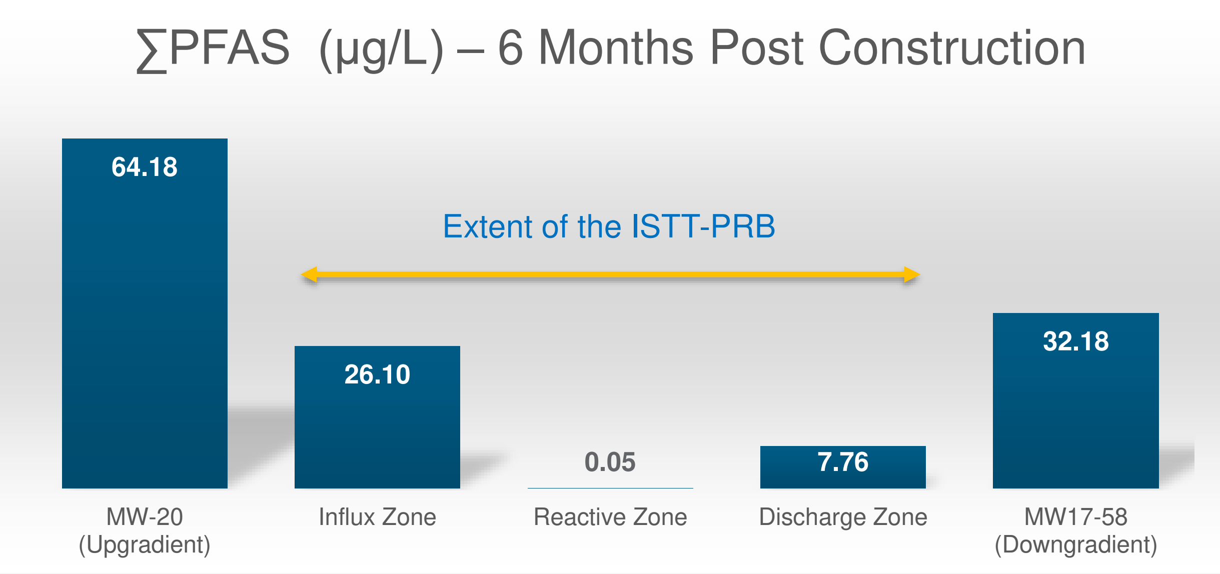
Results – 6 Months Post Construction



	2.5% MC	5% MC	7.5% MC
Vol. of Treated Water (m^3)	~22.27	~20.82	~20.76
Adsorbed ∑PFAS (mg)	~370	~420	~430
Removal Efficiency (%)	99.6%	99.9%	100%

Total Volume of Treated Water: **63.85 m^3**

Total Adsorbed PFAS: **1,220 mg** / 6-month

TOP Assay PFAS Analysis

(***7 months*** Post Construction from Lag Reactive Cells)

100% PFAS Removal
(Including PFAA Precursors)

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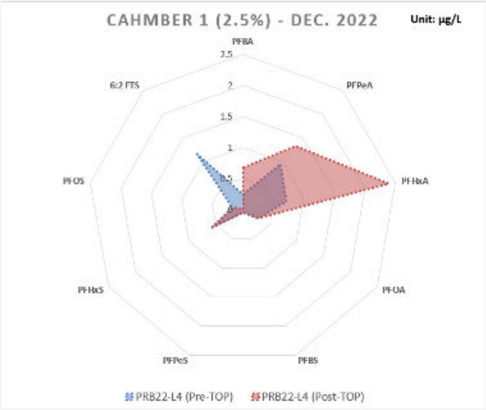
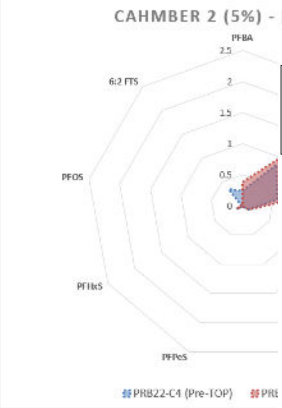
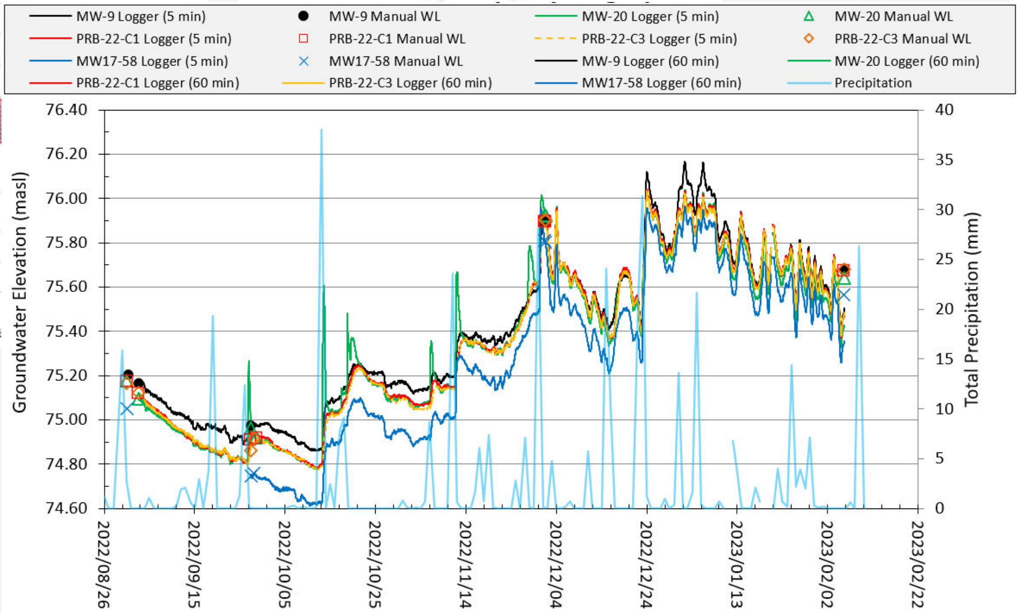
Results – 9 Months Post Construction (Initial Breakthrough)







9-Month Post Construction	2.5% MC	5% MC	7.5% MC
Vol. of Treated Water (m^3)	~38.2	~36.4	~35.7
Adsorbed ∑PFAS (mg)	~736	~879	~865
Removal Efficiency (%)	85.9%	92.4%	96.0%

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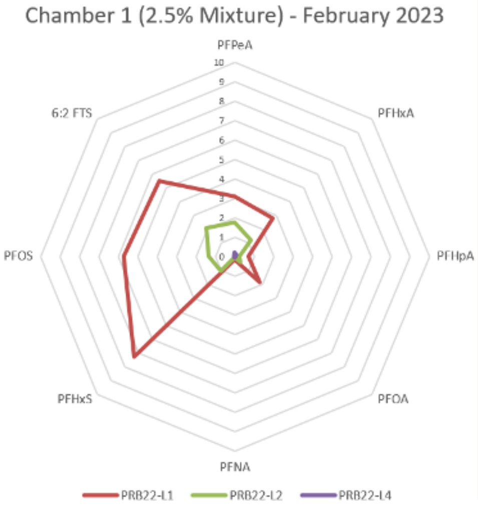
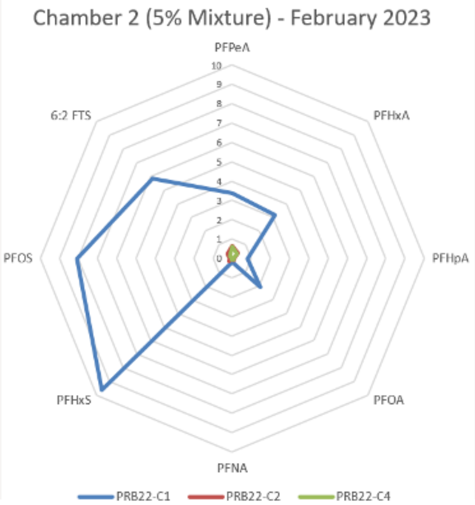
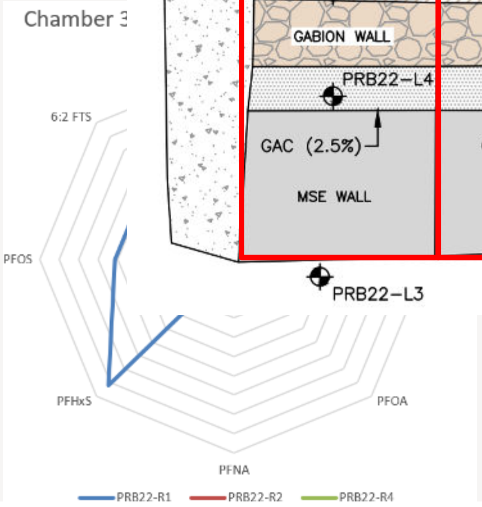
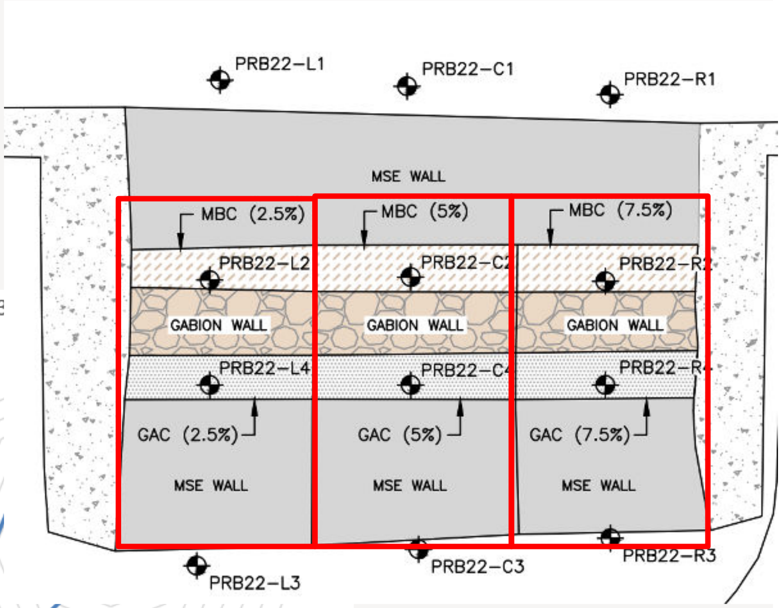
Results – 11 Months Post Construction

11-Month Post Construction	2.5% MC	5% MC	7.5% MC
Vol. of Treated Water (m^3)	~50	~48	~47
Adsorbed ∑PFAS (mg)	~1,021	~1,233	~1,216
Removal Efficiency (%)	98.1%	95.3%	97.4%









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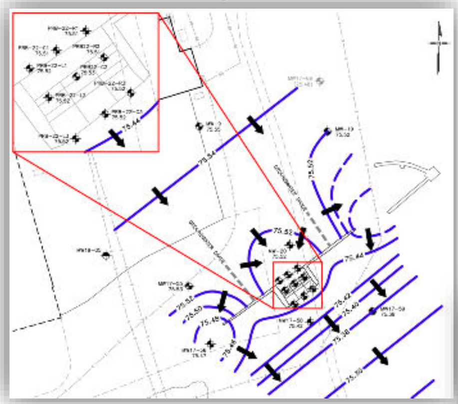
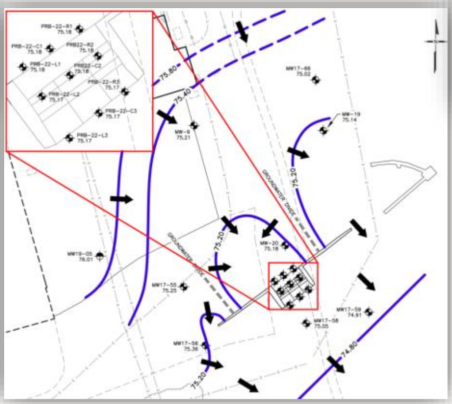
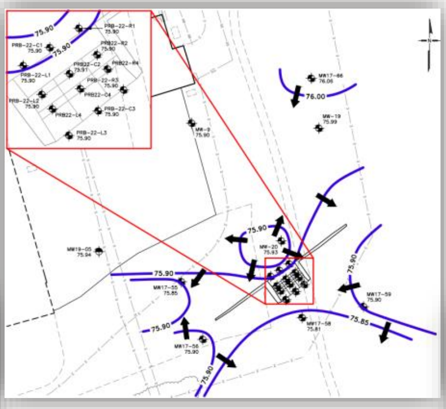
Interpreted GW Flow Directions



Post-Construction
(May 24, 2022)

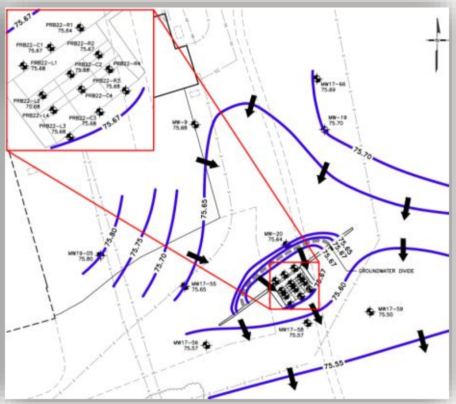
Post-Construction
(August 31, 2022)





Post-Construction
(December 1, 2022)

Post-Construction
(February 5, 2023)



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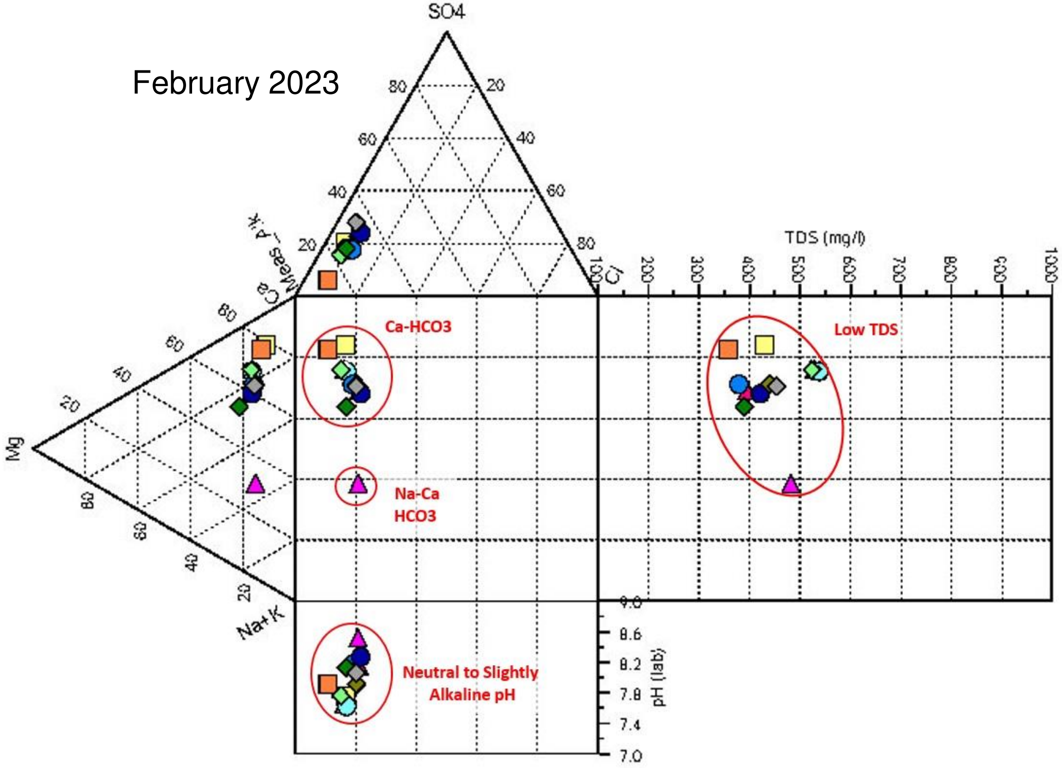
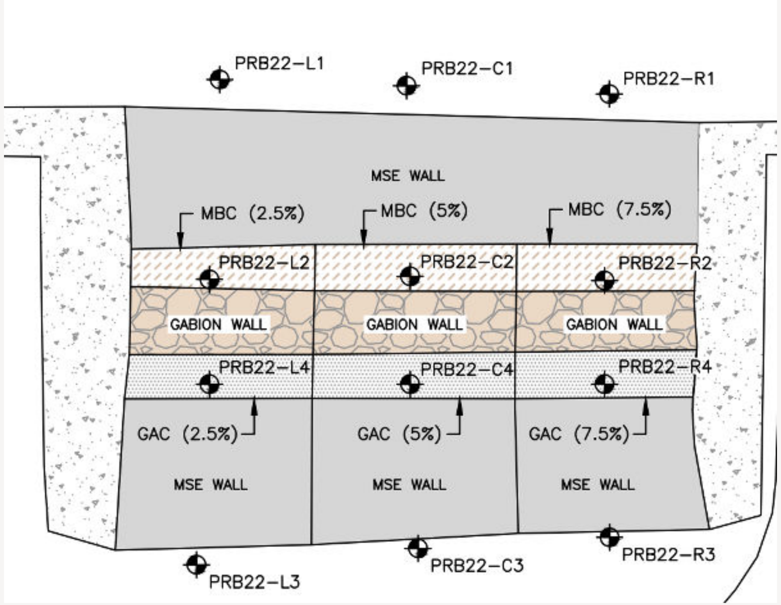
Effects of PRB on Major Ion & General Chemistry of Groundwater

February 2023





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Conclusions

ISTT-PRB:

- Is a passive remediation system, allowing naturally flowing groundwater to pass through the treatment media; low energy-intensive approach with no electrical infrastructure and power costs;
- Does not require operation and maintenance for mechanical treatment system components (no pumps, buildings, piping, controls, remote electronic monitoring system);
- Has a potential ability to treat a wide range of PFAS, through a treatment train system;
- Has ability to replace exhausted treatment media (with different mixing ratios) and physically remove contaminants from the site; and
- Design and change treatment media mixtures to treat different concentrations and to satisfy changing remedial objectives.

Our values are the essence of our company's identity. They represent how we act, speak and behave together, and how we engage with our clients and stakeholders.

SAFETY

We put safety at the heart of everything we do, to safeguard people, assets and the environment.

INTEGRITY

We do the right thing, no matter what, and are accountable for our actions.

COLLABORATION

We work together and embrace each other's unique contribution to deliver amazing results for all.

INNOVATION

We redefine engineering by thinking boldly, proudly and differently.

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