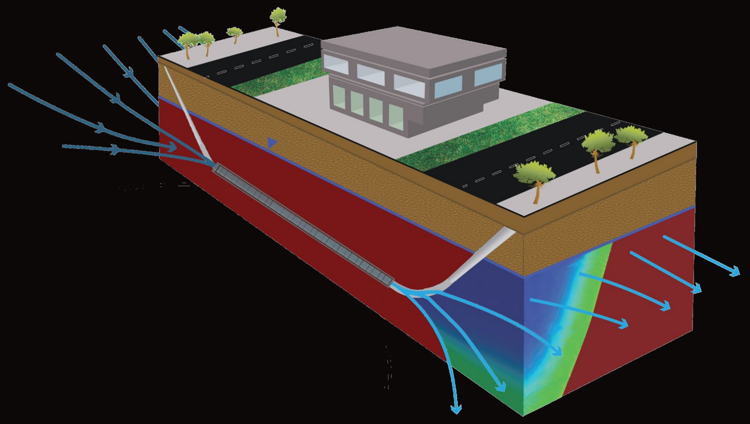
Multi-Year Passive In Situ Treatment of Per- and Polyfluoroalkyl Substances (PFAS) with an HRX Well®

Jesse Wright and Craig Divine

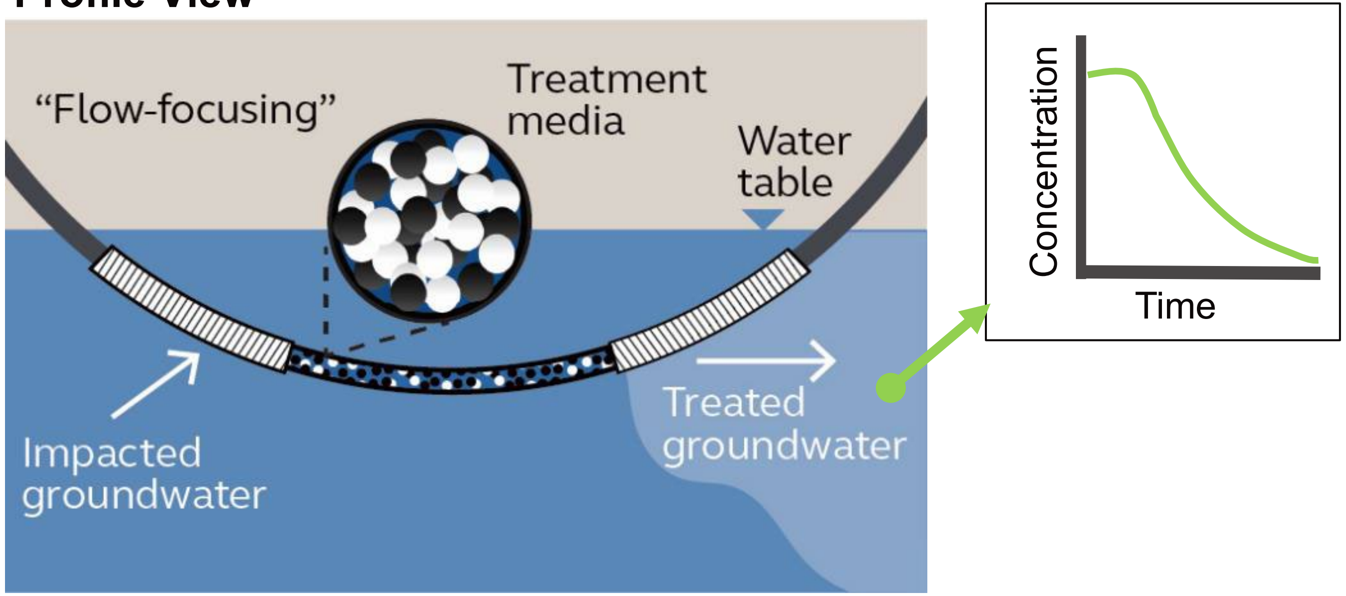
November 2025



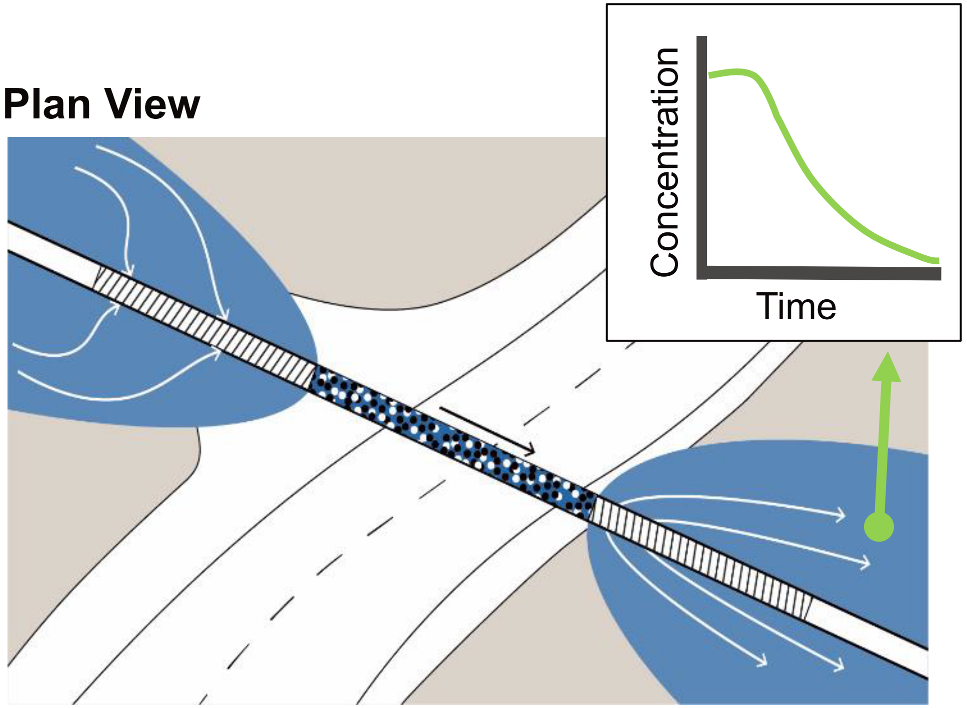
HRX Well® Description (Passive Configuration)

The HRX Well* is a large-diameter horizontal well installed along the groundwater flow path that is filled with treatment media for long-term in situ mass flux/discharge control

Profile View



Plan View



*Patent US20120261125A1

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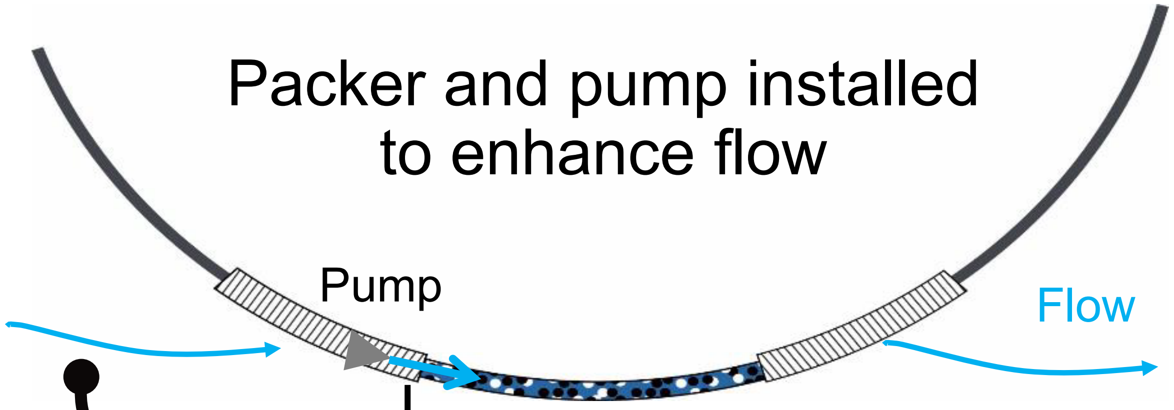
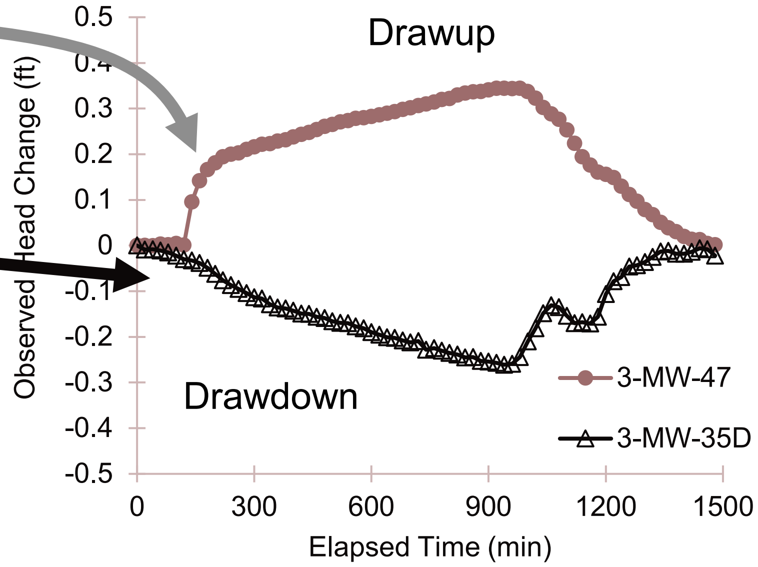
HRX Well Description (Active Configuration)



Packer

Appropriate for more permeable aquifer settings



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Treatment Zone Size

Passive Configuration

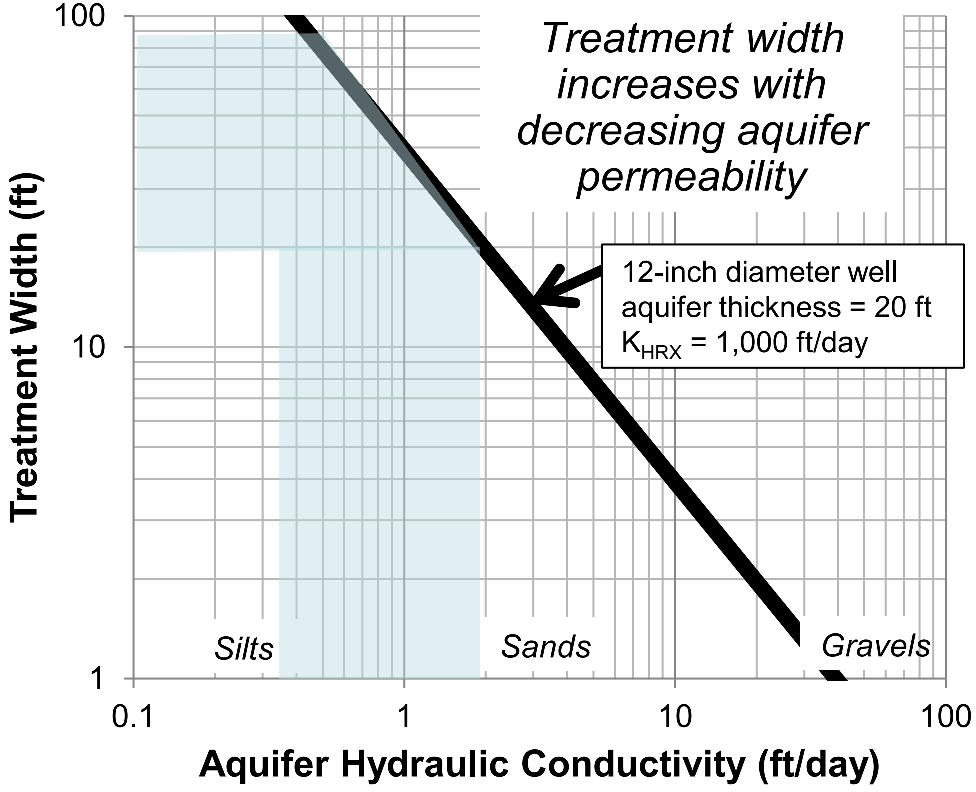
$$w_{treatment} = \frac{K_{HRX} A_{HRX} i_{HRX}}{K_A \; b_A \; i_A}$$

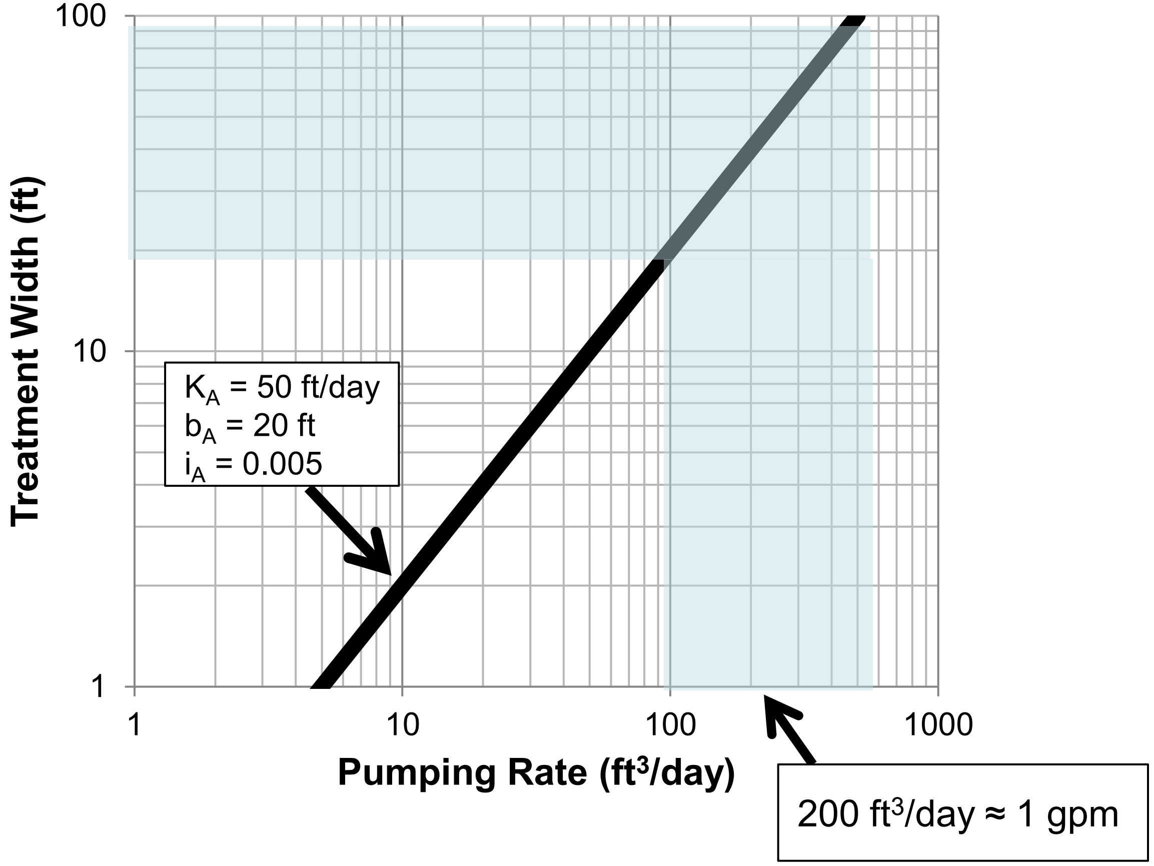
Flow through the well

Flow through the aquifer

Active Configuration

$$w_{treatment} = \frac{Q_{HRX}}{K_A \; b_A \; i_A}$$





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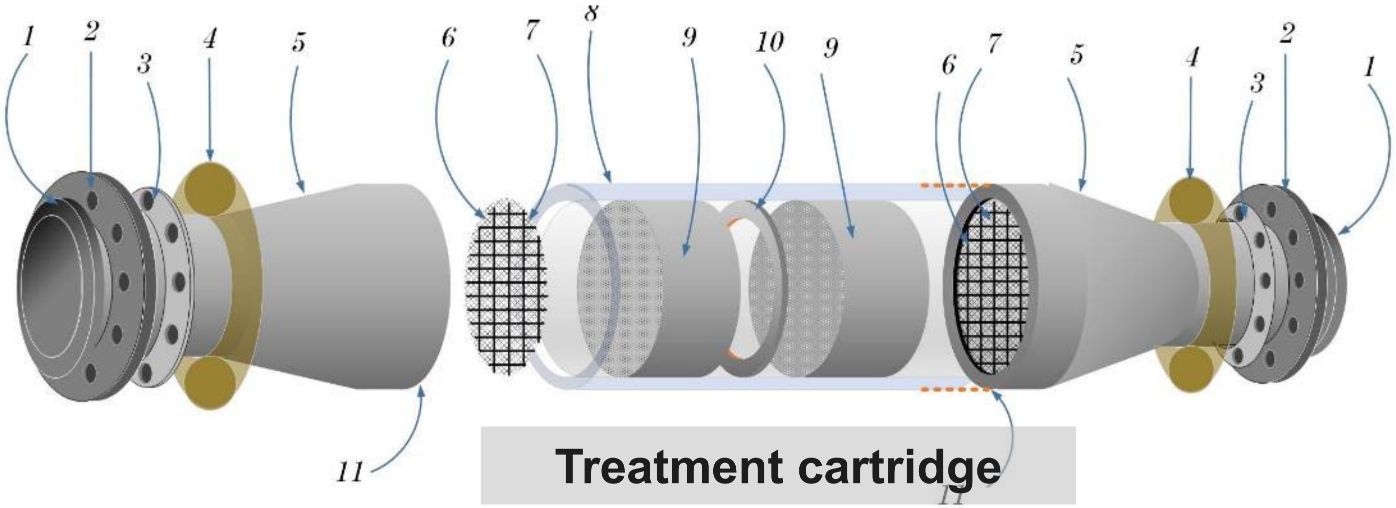
Treatment Media Cartridges



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Potential Reactive Media and Contaminants

Target Groundwater Contaminant	Reactive Media
Chlorinated solvents (CVOCs), Arsenic, Cobalt, Chromium, Molybdenum, Selenium, Thallium, nitrate, perchlorate, energetics	Zero valent iron (ZVI), Bimetallics (e.g., ZVI + Pd, Pt, or Ni)
PFAS, CVOCs, hydrocarbons, halomethanes	Granulated Activated Carbon (GAC), Organosilicates (e.g., Osorb®)
CVOCs, 1,4-dioxane, hydrocarbons, polyaromatic hydrocarbons (PAHs), phenolic compounds (e.g., pentachlorophenol; PCP), energetics	Sustained Release Oxidants (e.g., RemOxSR+ISCO)
CVOCs, nitrate, perchlorate	Biodegradable particulate organic carbon (e.g., mulch)
Boron, brines, PFAS	Ion exchange resins
Cobalt, Low pH, acid rock drainage	Limestone, lime, magnesium oxide
Chromium, Molybdenum, high pH	Iron sulfide
Antimony, Selenium, Ammonium, radionuclides, PFAS	Zeolites
Radium	Barium sulfate (barite)
Lithium	Hydrotalcite
Boron, Arsenic, Thallium	Activated Alumina

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Advantages

Treatment and Contaminants

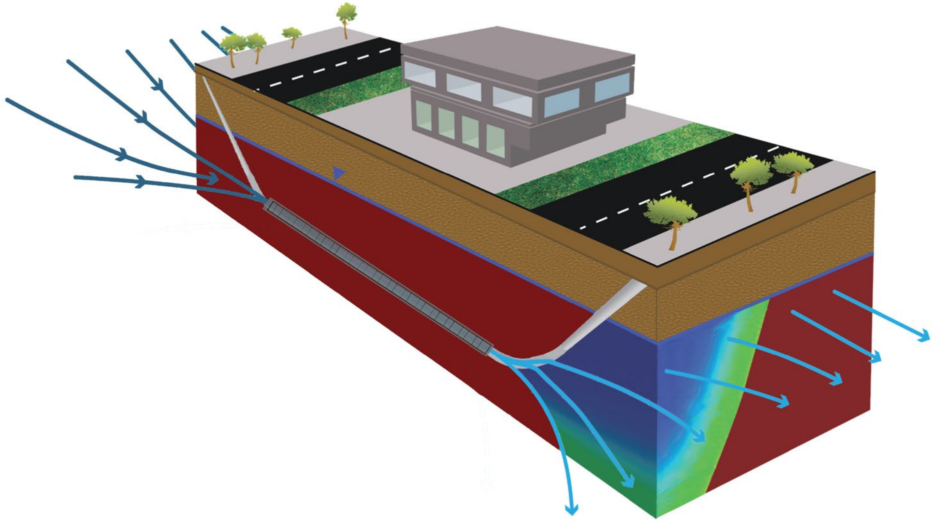
- Many solid-phase reactive media options
- Efficient use of reactive media (replaceable/serviceable)
- Treatment trains for multiple contaminants

Site Conditions

- Works for both low and high-permeability aquifers
- Can be applied in relatively deep settings
- Access under infrastructure
- Limited above-ground footprint

Operation

- Minimal O&M, energy use
- In situ; no above-ground water management
- Pumping can optimize residence time and treatment zone size



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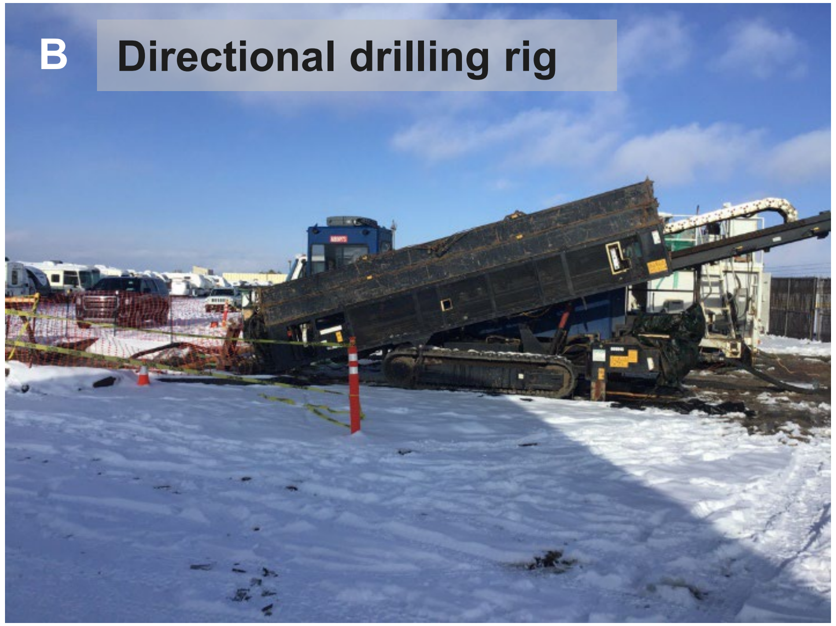
HRX Well Field Installation



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PFAS - Passive and Active Configuration

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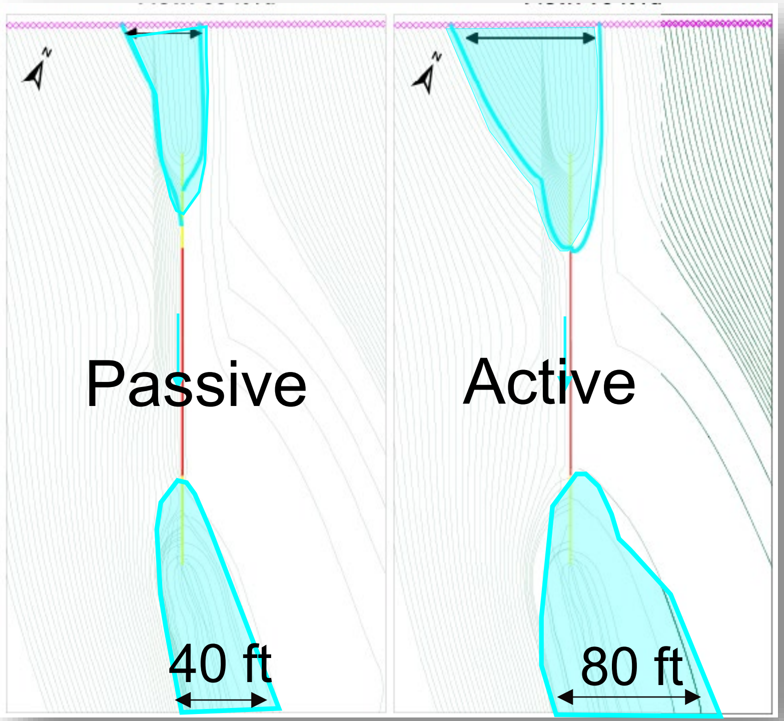
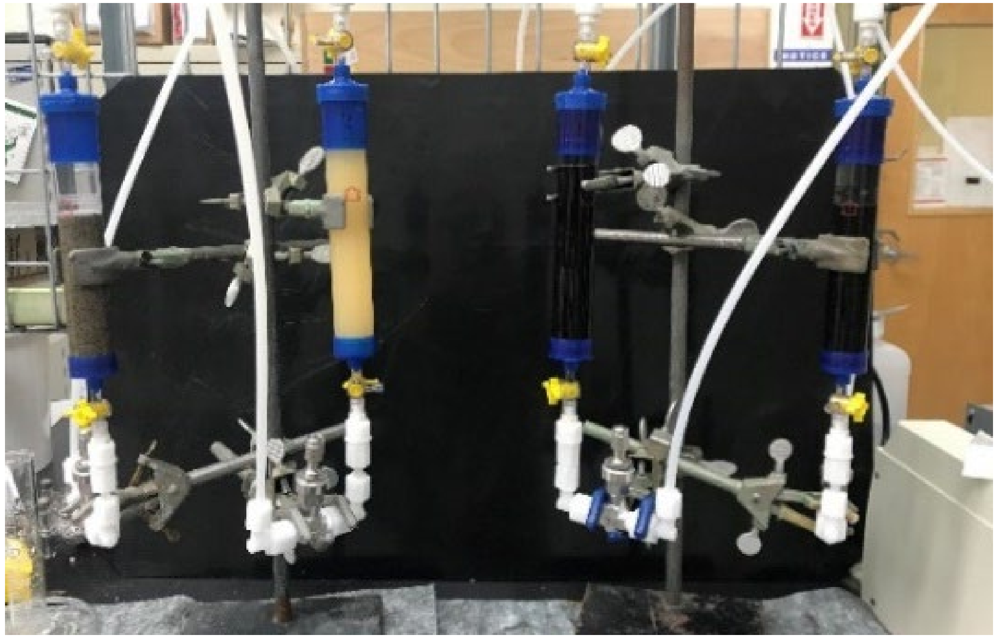
- Aquifer thickness 5-10 ft
- Target depth: 35 ft
- Sandy alluvium within paleochannel
- Hydraulic conductivity: 3 ft/day



Design model results

- Passive: 40 ft width, residence time 8 hrs
- Active: 80 ft width, residence time 4 hrs

Both being field tested



Column testing to support adsorbent media selection

Tested media: Fluorosorb 400, Osorb 4-mesh, Filtrasorb 400 GAC, Purolite IX

Selected: Filtrasorb 400, Filtrasorb 800 pretreatment

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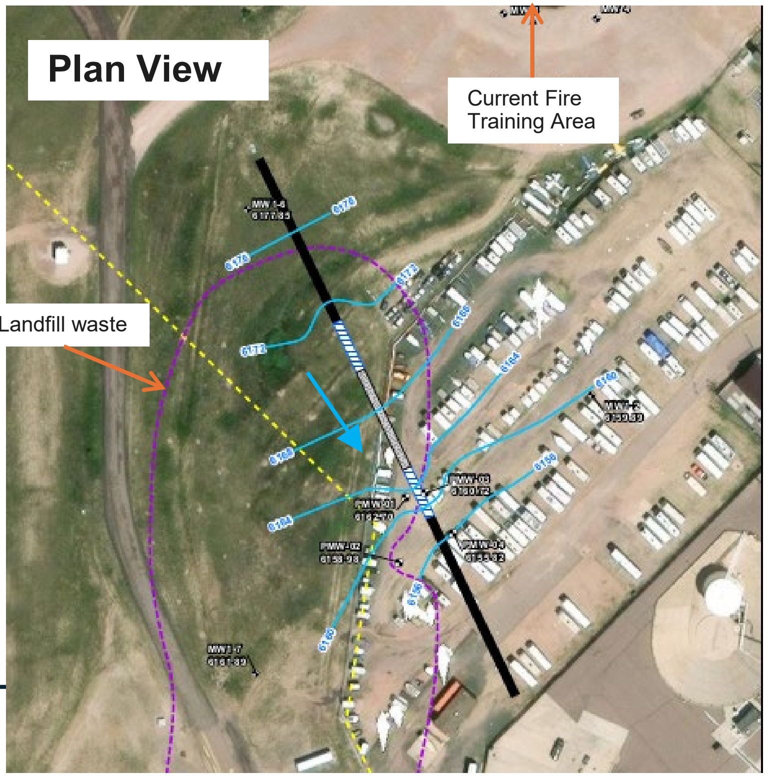
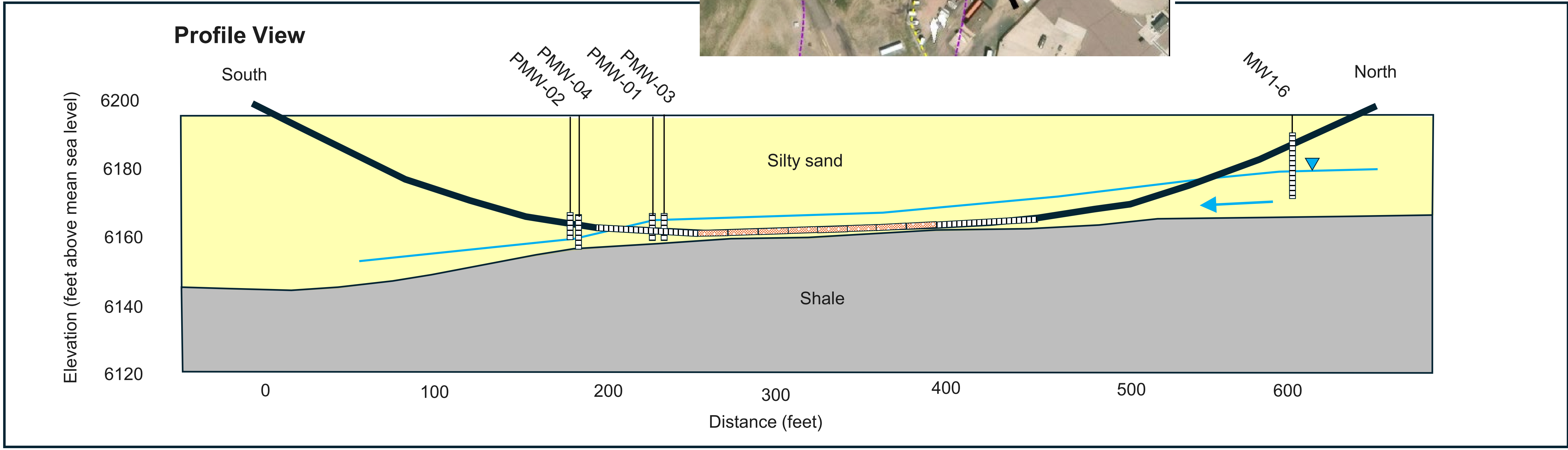
HRX Well Location





Performance

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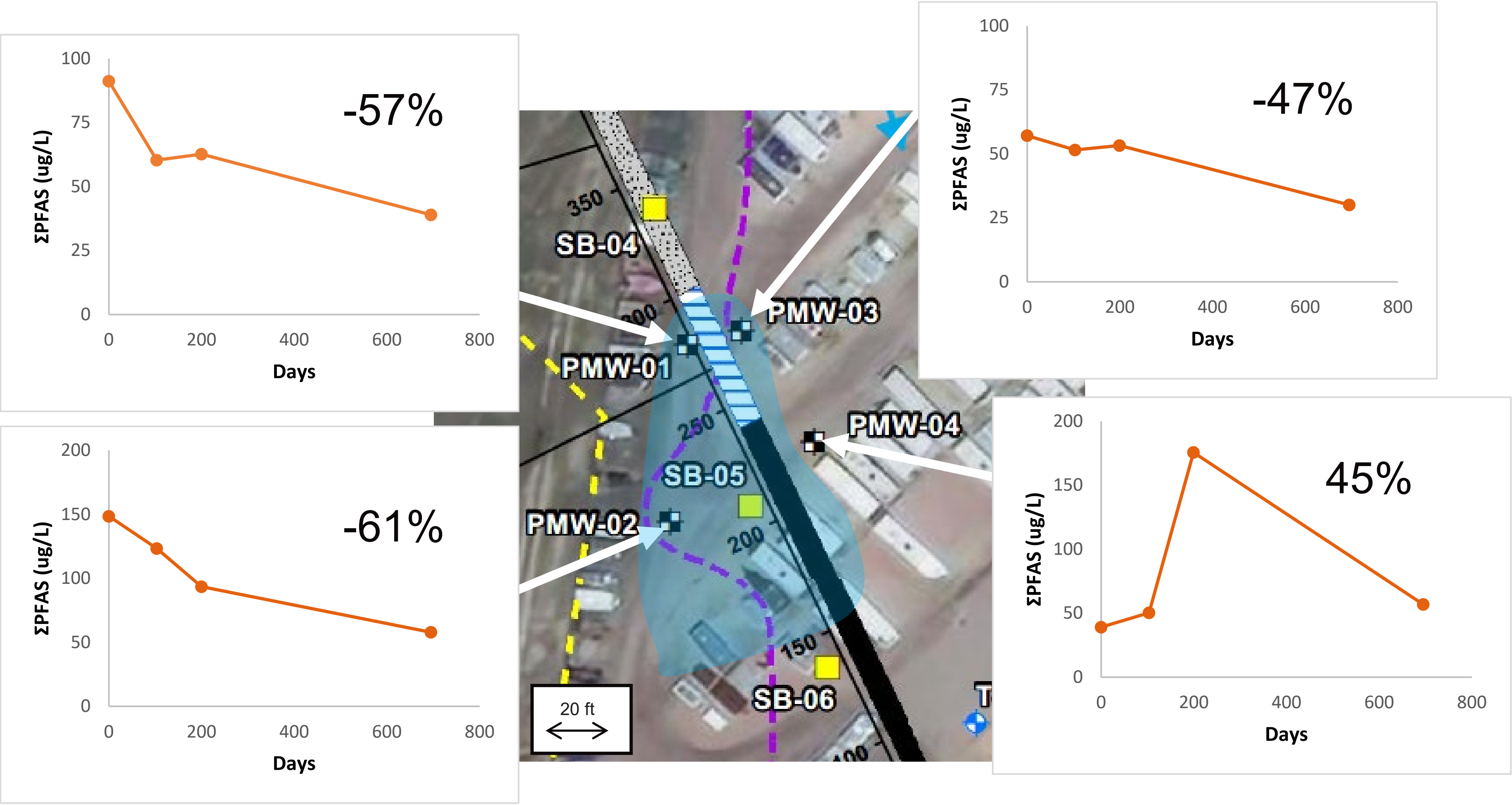

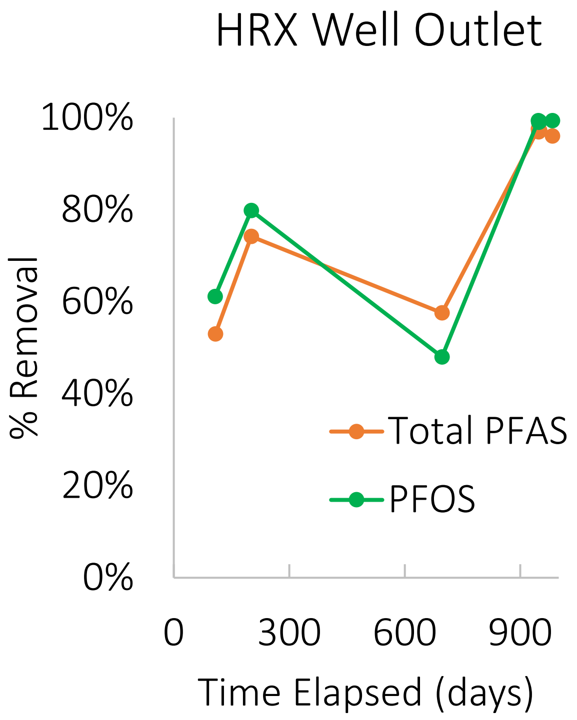

- **Treatment zone width at least 20-40 ft under passive configuration**
- **50-99% PFAS treatment for 3 yrs at HRX Well Outlet**
- **47-61% ΣPFAS concentration reduction at wells**

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In Situ Reactors for Destructive PFAS Treatment

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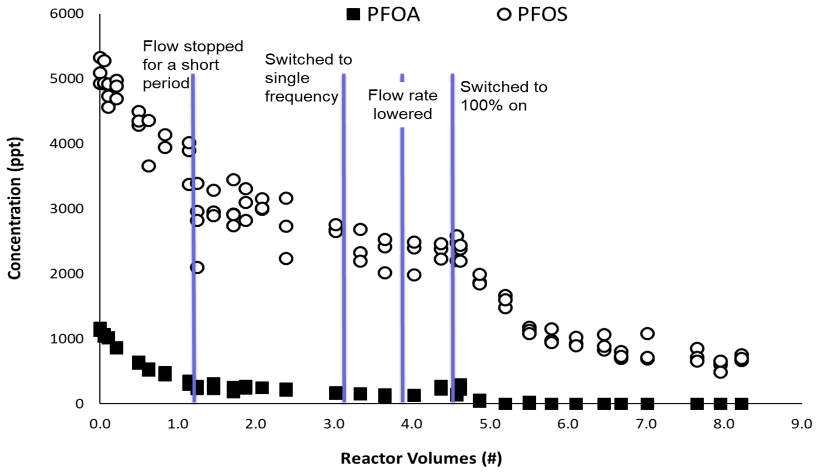
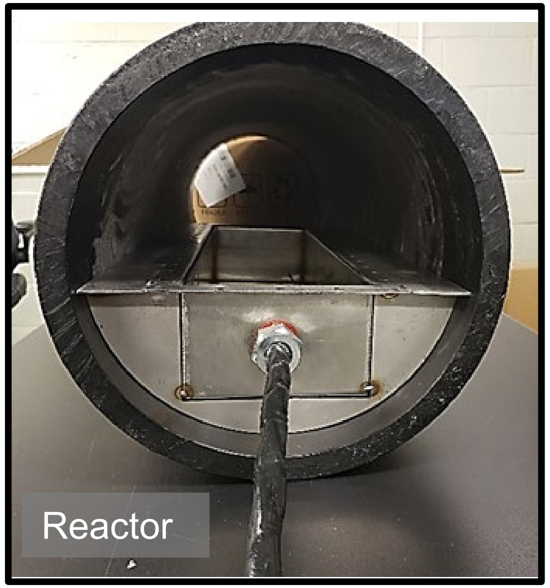
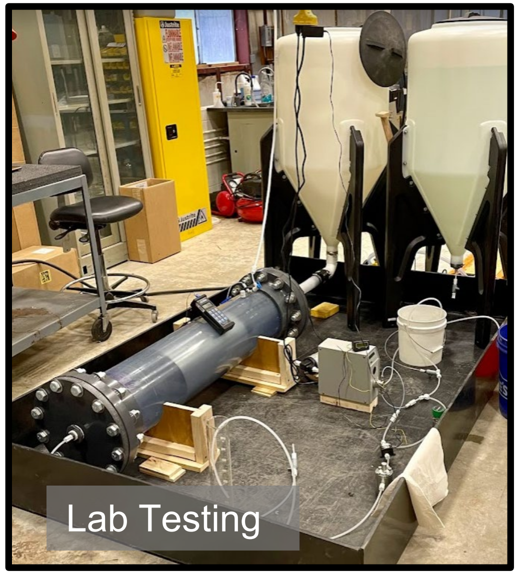
- Sonolytic reactor developed for destructive PFAS treatment in PSFB HRX Well (ESTCP ER21-5045)
- Lab prototype achieved 99% PFOA and 86% PFOS treatment, field data collection on-going



- Electrochemical oxidation reactor will be installed in Summer 2026 (ESTCP ER25-8685)
- Multiple reactors could be installed in series, could be paired with GAC





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Summary of HRX Wells Installed (and Planned) at Field Sites

Location	VSFB, CA	FAAFS, WI	PSFB, CO	Confidential, Sweden	Confidential, MI
Installation Date	August 2018	November 2021	April 2021	*TBD*	*Summer 2027*
Target Contaminant, (ug/L)	CVOCs, 40,000	CVOCs, 120	PFAS, 35	PFAS, 13	PFAS, >100
Length, depth (ft)	550	1,140	650	345	700
Maximum Depth (ft)	20	125	35	40	30
Well Diameter (in)	12	8	10	10	12
Average Aquifer Hydraulic Conductivity (K_A; ft/day)	0.35	0.55	2.0	10	200
Hydraulic Configuration	Passive	Active	Passive, Active	Active	Active
Approximate Treatment Zone Width (ft)	50	120	20-40	80	1,600 (5 HRX Wells)
Treatment Media	ZVI	ZVI + GAC	GAC	GAC	GAC
Treatment Media Residence Time (day)	9	0.5	6, 2	<3	<1

Notes:
VSFB - Vandenberg Space Force Base
FAAFS - former Antigo Air Force Station
PSFB - Peterson Space Force Base
ZVI - Zero Valent Iron
GAC - Granular Activated Carbon

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Design and Implementation

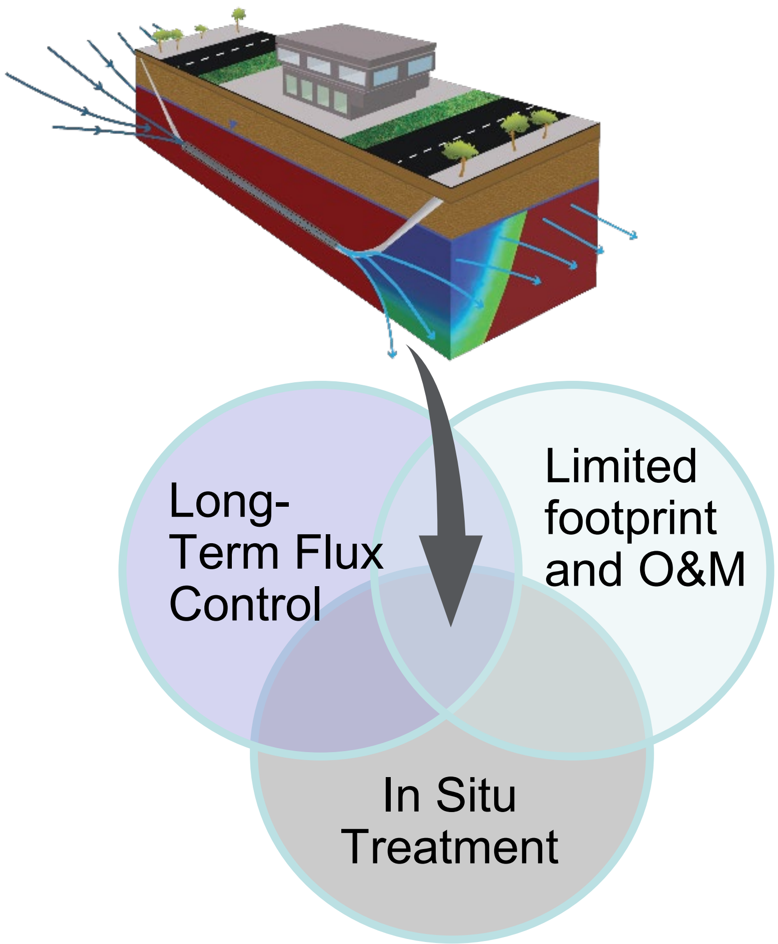
1. Complete simple **screening analysis**

2. Perform **treatability study** to optimize treatment media

3. Collect **focused field data** along HRX Well alignment

4. Construct local numerical **design model** to optimize design

5. Install HRX Well and initiate **performance monitoring**



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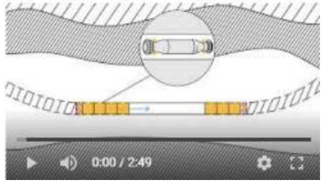
Resources



Explainer Video: https://youtu.be/1I8CwiYIjS4

Divine, et al., 2025. Multi-Year Passive In Situ Treatment of Per- and Polyfluoroalkyl Substances (PFAS) with an HRX Well®. *Remediation*, 35(3), e70021; https://doi.org/10.1002/rem.70021

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Nzeribe, et al., 2020. Hydraulic Performance of the Horizontal Reactive Media Treatment Well: Pilot and Numerical Study. GWMR, 40(3): 30-41. https://doi.org/10.1111/gwmr.12406

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ER-2016 Final Report and Design Tool anticipated 2Q2020. https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Persistent-Contamination/ER-201631/ER-201631

2019 National Groundwater Association Technology Award

2020 ESTCP Project of the Year Award

2021 Environment Business Journal Project Merit Award

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