Characterization & Fate & Transport of PFAS at An Active Industrial Site in the Great Plains

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Thanks To:

BEM

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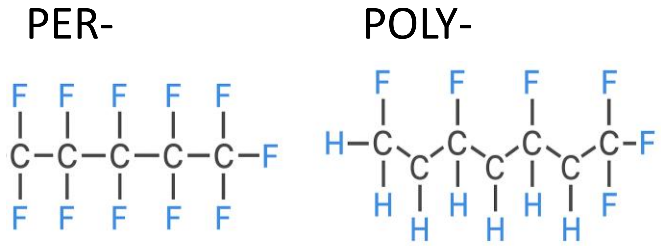
PFAS (“Forever Chemical”) Primer: Chemistry

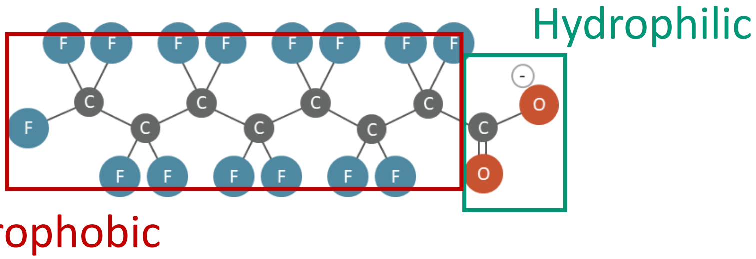
PFAS →Per- and Polyfluoroalkyl Substances

- *Perfluoro*: All hydrogens replaced by fluorine (**PFOS**, PFOA)
- *Polyfluoro*: Some hydrogens remain (often precursor compounds)



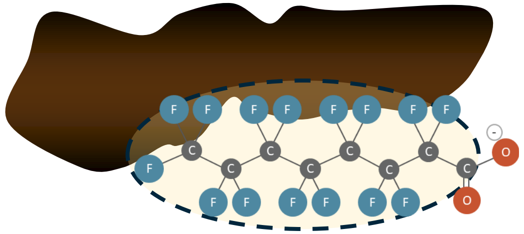
Structure Drives Behavior

- Hydrophobic Fluorinated tail
- Hydrophilic head group



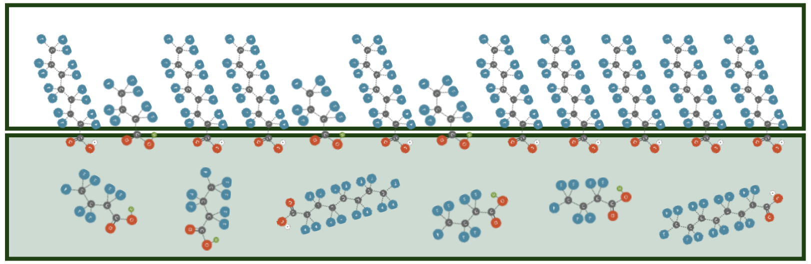
Chain Length

- Long-chain PFAS (≥8 C): more bioaccumulative, higher sorption
- Short-chain PFAS (≤6 C): more mobile, less retained



Surfactant Properties

- Reduce surface tension → accumulate at interfaces
- Effect is stronger for PFAS than HC surfactants

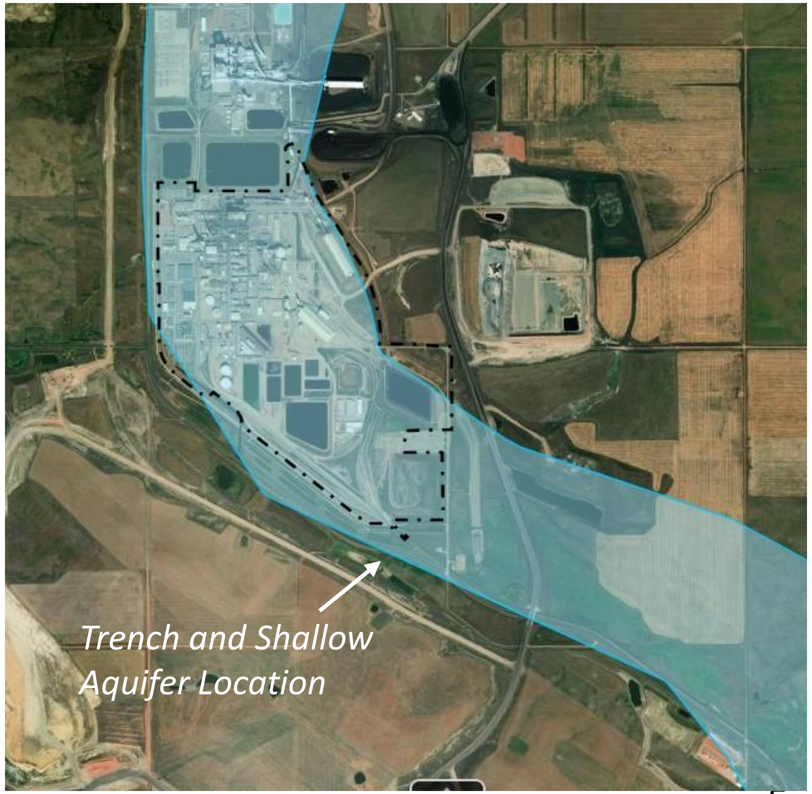


Site Setting

- Industrial Facility in Great Plains
- Extensive monitoring well network
- Sampling for PFAS began in 2021
- PFAS identified in GW in several wells
- Fire training activities since mid 1980’s

Geologic Setting

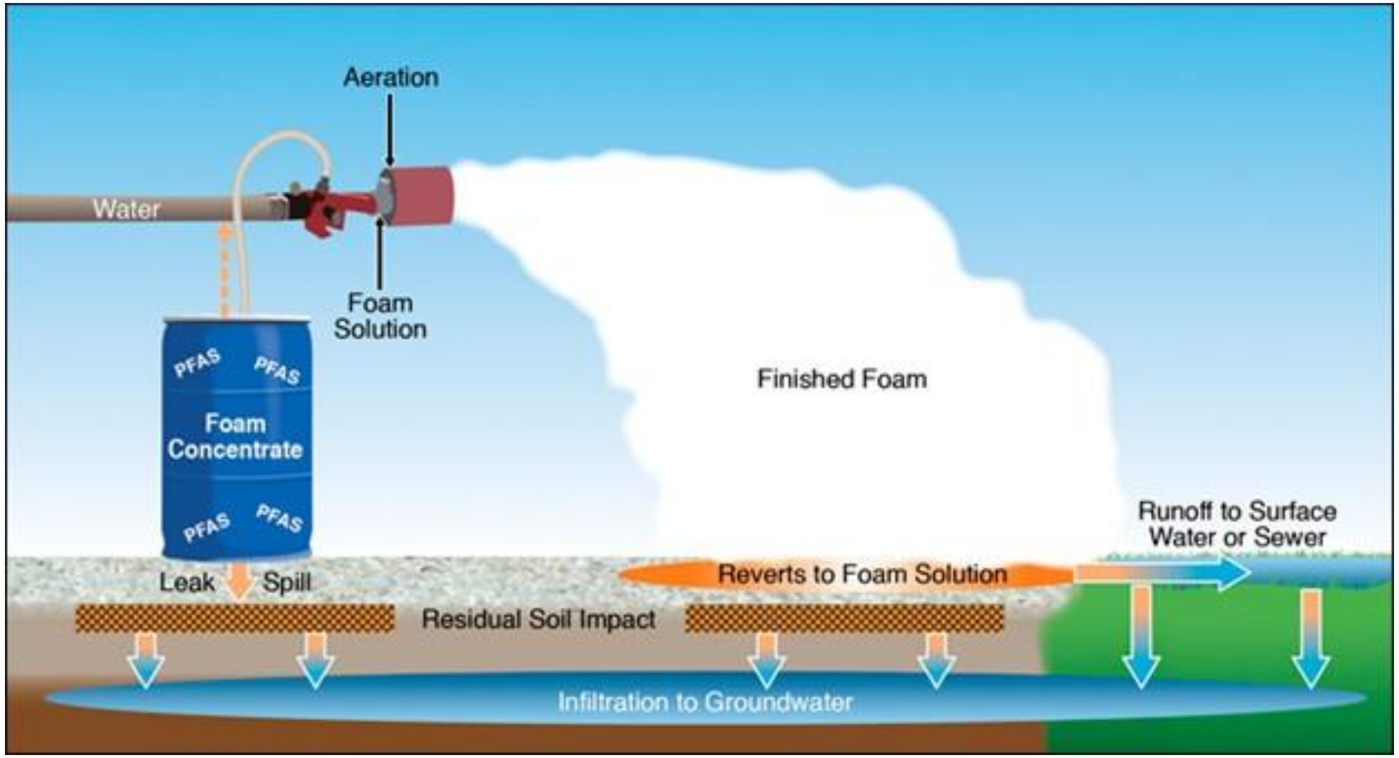
- Glaciofluvial Sediments in “trench”
  - Approximately 500 feet thick interbedded silt, sand and gravel
  - Upper portion is unconfined shallow aquifer
  - Underlies site
  - No immediate downgradient users
- Tertiary Bedrock
  - Tertiary aged lignite, silt and clay beds
  - “Trench” lies within the bedrock
  - Vertically stratified aquifer
    - Lignites are water bearing



Phase I – Review Existing Data

- KCH/BEM Developed Initial Conceptual Site Model (CSM)
  - Reviewed drill logs for wells in proximity to site
  - Reviewed existing GW data
    - Water quality
    - Static water levels
  - Identified Fire Training Area (FTA) and use of Aqueous Film-Forming Foam (AFFF) as likely source of PFAS
    - AFFF used for intended purpose of training and emergency response; industry standard
    - Site has discontinued use of PFAS-containing AFFF for training purposes

PFAS Transport from FTA - Schematic

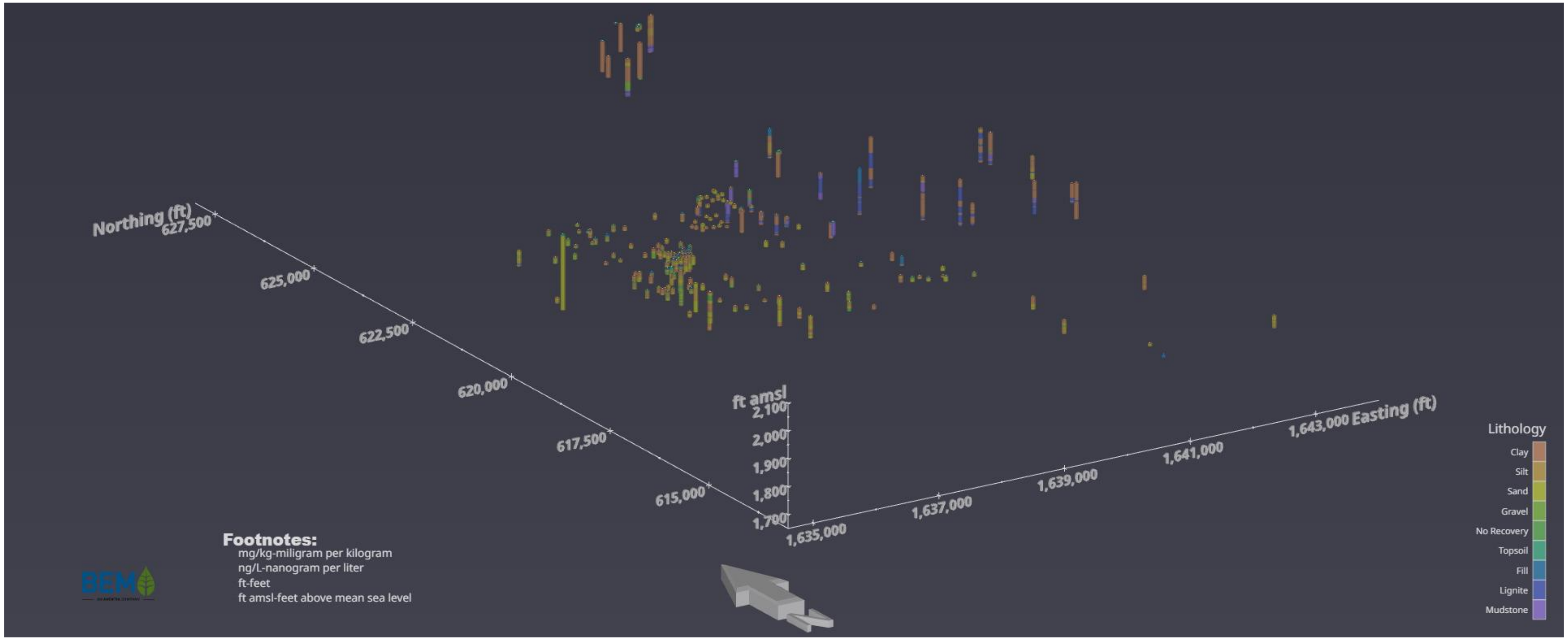


Adapted from figure by J. Hale, Kleinfelder.

Phase I Findings

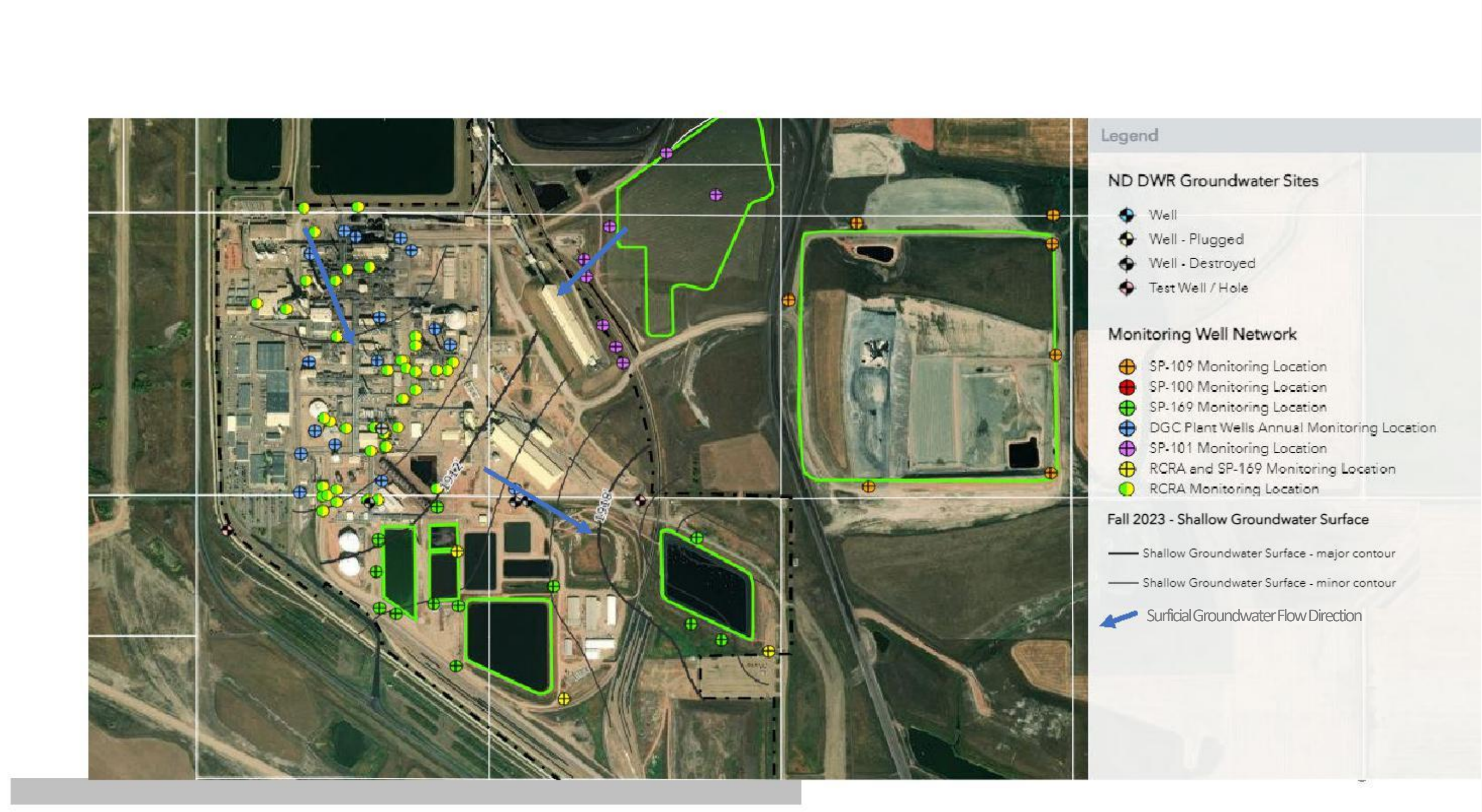
- East edge of glaciofluvial trench delineated
- Shallow GW potentiometric surface defined
- PFAS concentrations extent in shallow GW delineated near Site

Drill Log Lithology



- Drill logs identify E boundary of trench

Site Hydrology – Fall 2023 Potentiometric Surface



- Bedrock aquifer flows SW and discharges into shallow aquifer near FTA
- Shallow aquifer flows SE in trench glaciofluvial sediments
- Low gradient

2023 Groundwater Results – PFOS (EPA MCL)

- Groundwater plume indicates known extent of PFAS impacts in shallow groundwater
- Concentrations greatest in FTA vicinity
- 6 “hotspots” identified
- Low groundwater PFAS between FTA and hotspots to west
- *Note: units are parts per TRILLION (1 ppt is about 1 drop in 20 Olympic-sized swimming pools)*

•Surficial Groundwater Flow6 Direction

Phase II - Project Objectives and Scope

- Soil investigation (Source):
  - Characterize and delineate the nature and extent of PFAS in soils at the FTA
  - Confirm absence/presence of PFAS in shallow soils at six ‘hotspots’

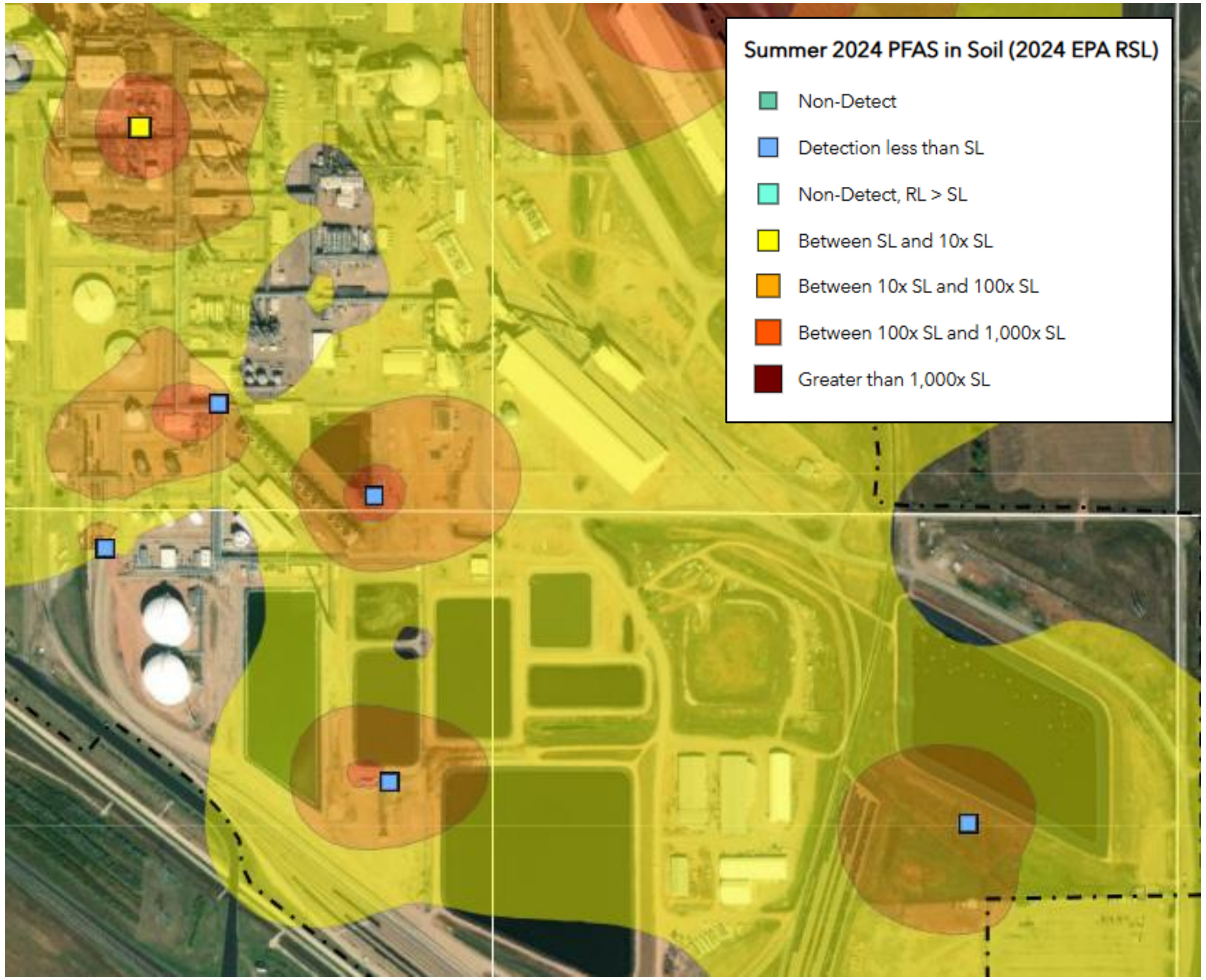
- Groundwater investigation (Transport):
  - Characterize and delineate PFAS in groundwater to the west (cross-gradient – W edge of trench) and southeast (downgradient) of the Site
  - Inform assessment of off-site migration potential, support desktop fate & transport evaluation

Methods

- Phased Approach and Split Sampling
  - Prescribed sample locations based on initial CSM with adaptive “step outs” as needed
  - High density, multi-interval sample collection → rapid lab turnaround time
  - Complex lab program - Initial screening with ASTM D8421 and definitive analysis with EPA Method 1633
  - Single mobilization/cost effective
- Soil
  - Direct push or hand auger
- Groundwater
  - Temporary wells with grab samples
  - Used to site permanent monitoring wells
  - Hydrologic Profiling Tool
    - Downhole K values and lithology

Source Soil Investigation – Interior GPSP "Hotspots"

- *Objective:* Confirm absence or presence of PFAS in soils in areas of groundwater exceedances
- *Sampling approach*:
  - Six locations based on historic GW data, one test pit per location – three samples per test pit to a max. depth of 10 ft bgs
- *Results*:
  - Hotspot 1– PFOS above SLs at 0.0-1.0 ft interval
  - PFAS below the SLs at other locations/samples
- *Interpretation*:
  - Isolated surficial soil impact unlikely to contribute to groundwater impacts



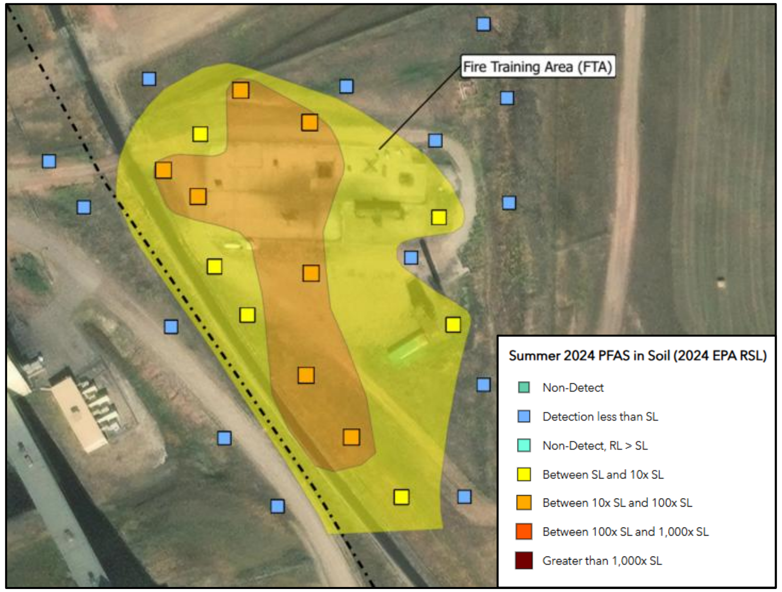
*Note this plume is the Spring/Fall '23 data vs. 2024 MCLs as was used during scoping/planning.

Source Soil Investigation – Fire Training Area (FTA)

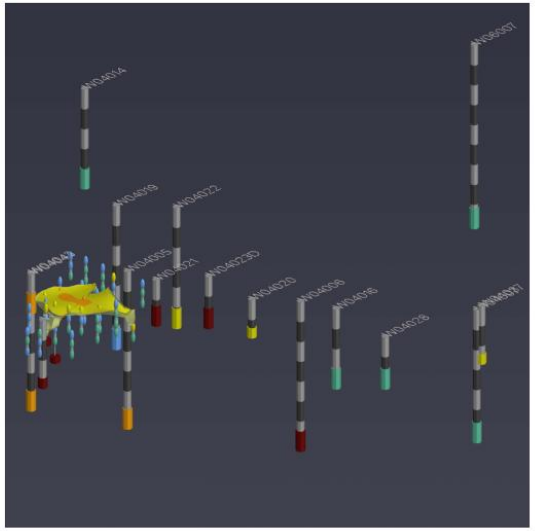
- *Objective: Characterize and delineate nature and lateral and vertical extent of PFAS in soils*
- *Sampling approach*:
  - Twenty-seven (27) hand auger and DPT boring locations advanced
  - Prescriptive:
    - Borings advanced to 10 ft bgs; three (3) soil sample intervals
    - Analyzed by ASTM D8421 (screening)
  - Adaptive:
    - Additional soil samples collected for vertical and lateral delineation
    - Analyzed by EPA Method 1633 (definitive)
  - Grab groundwater samples collected beneath FTA

Source Soil Investigation – Fire Training Area (FTA)

- *Results*:
  - Soil – PFOS 10-100x RSL in shallow soils
    - Majority of impacts <10 ft bgs
    - Groundwater – PFAS above SLs
- *Interpretation*:
  - Delineated vertically and horizontally to the north, west, and east
  - ~7,500 cubic meters > PFOS RSL (0.16 mg/kg)
  - Further delineation required to the SSE along the drainage ditch
  - Tertiary bedrock encountered at ~28 ft bgs
  - DTW in the FTA: ~8.5 to 24 ft bgs



3D Conceptual Site Model of PFAS in Soil and Groundwater
Fire Training Area (FTA)
Plan View



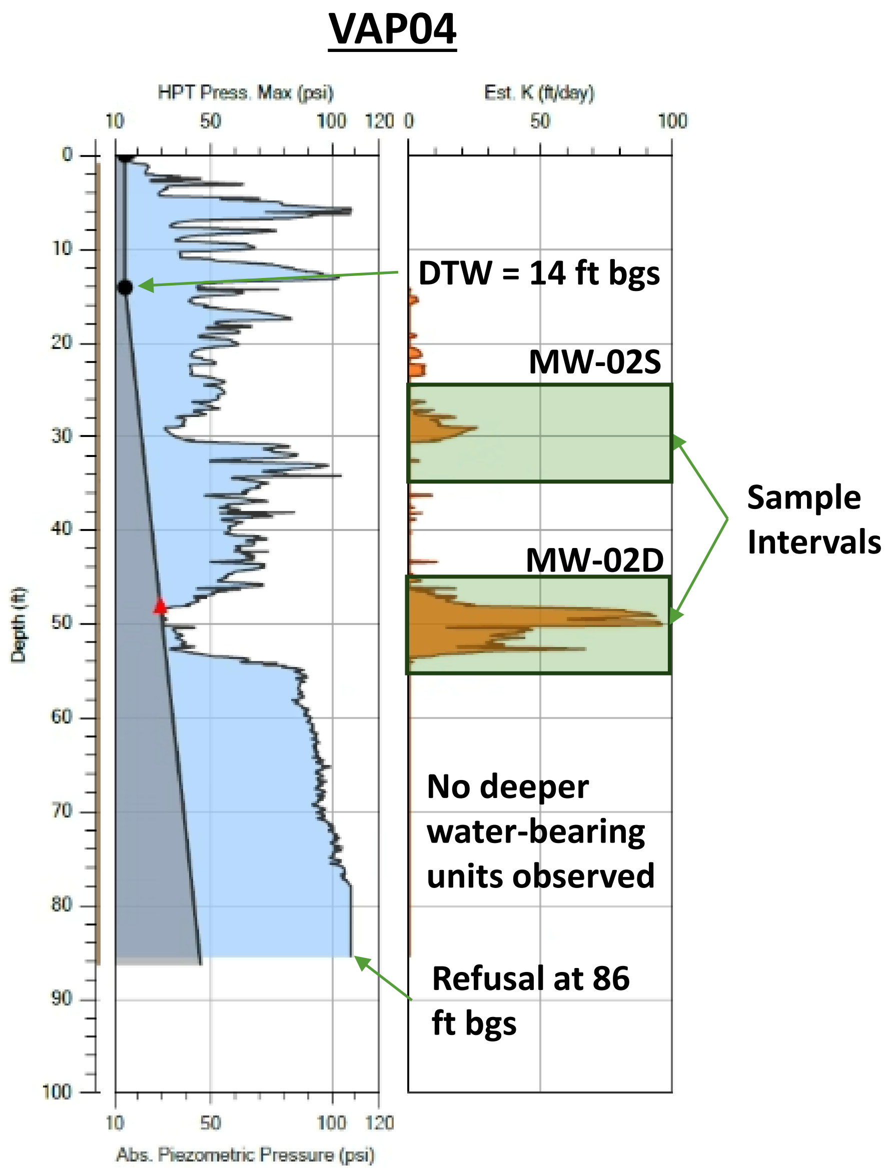
3D Conceptual Site Model of PFAS in Soil and Groundwater
Fire Training Area (FTA)
Looking Northeast

Includes 10x Vertical Exaggeration

Soil Plume = PFOS in soil exceeding Project Screening Limit (0.17 mg/kg)

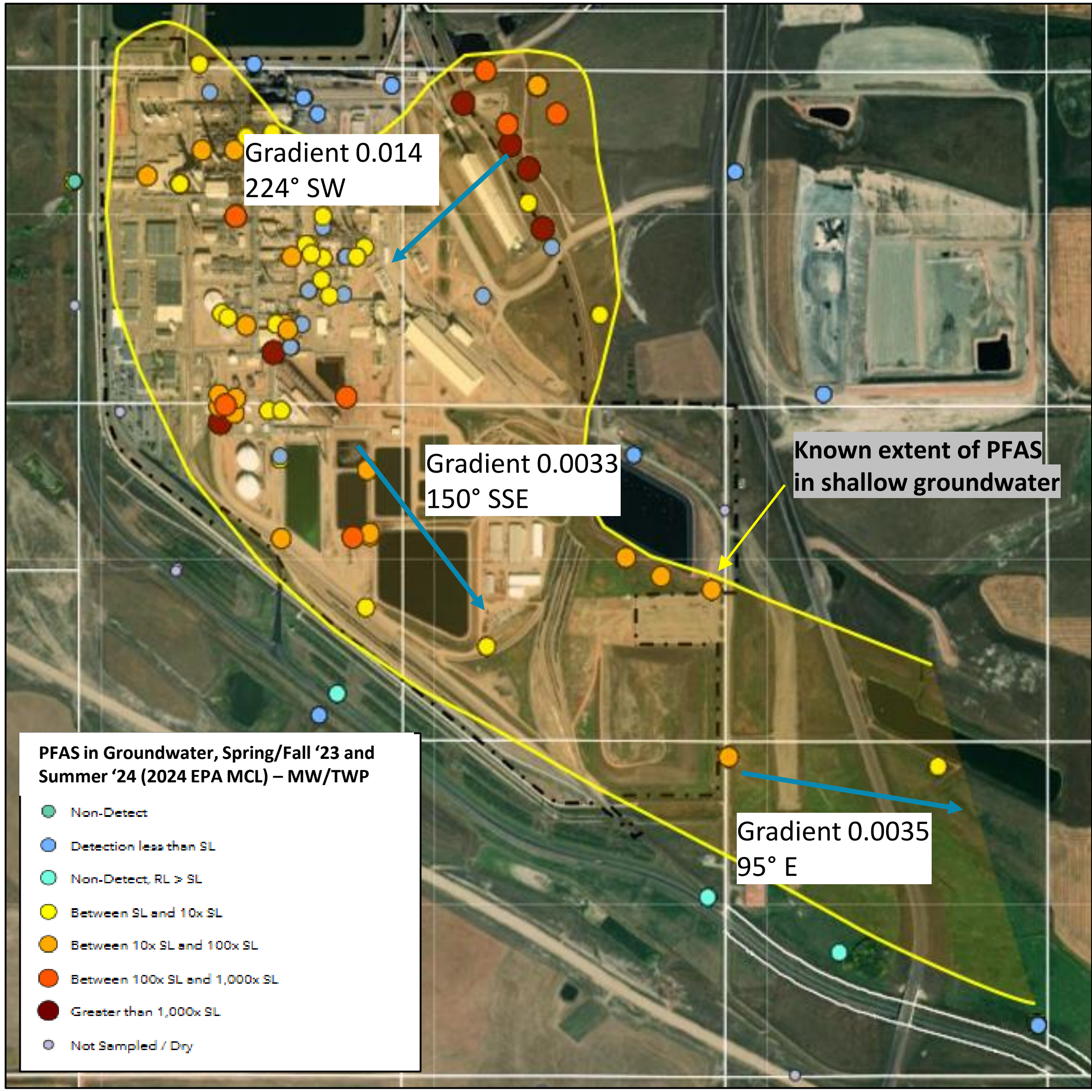
Groundwater Investigation

- *Objective: Characterize groundwater quality and aquifer properties at W boundary and downgradient Site boundary*
- *Sampling Approach:*
  - Used DPT with Temporary Well Points (TWP) on W boundary and S boundary
  - Monitoring Well location based on TWP data
  - Advanced five (5) additional borings: Vertical Aquifer Profiling (VAP) transect near S boundary of site to refine extent of impacts.
  - Hydraulic Profile Tool (HPT) implemented at select TWPs and all VAP locations to refusal – K values
- *HPT Results:*
  - High K (50-100ft/day) zones observed in HPT logs, 30-50ft bgs
    - Actual *transport velocity* is 50-350ft/year
  - A very low permeability zone is present approximately 50-60ft bgs – decreasing chance of PFAS being present at depth beyond 60ft bgs.



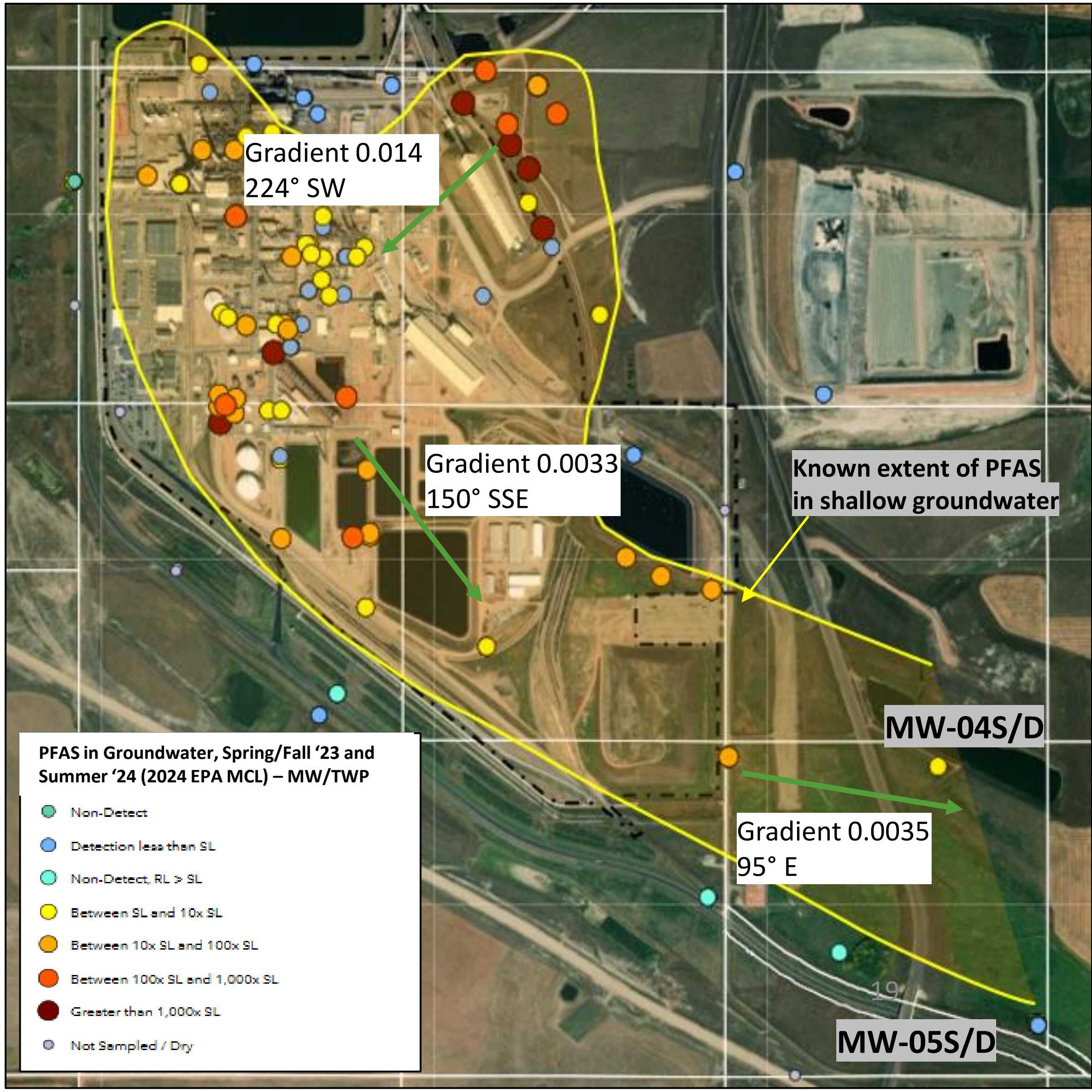
Groundwater Investigation – Findings

- Shallow aquifer flow direction follows trench
- Nested monitoring wells in the trench confirm that it is a stratified single unit
- Extent of shallow alluvial aquifer defined to W/SW
- PFAS in bedrock aquifer groundwater is delineated cross-gradient (dry wells + PFAS < SL) on W boundary
- PFAS detected in furthest downgradient well locations
- Greatest concentrations of PFAS observed in vicinity of FTA
- Groundwater data indicate zone of lower PFAS concentrations in N central portion of plume
  - Groundwater from FTA may not be dominating downgradient transport



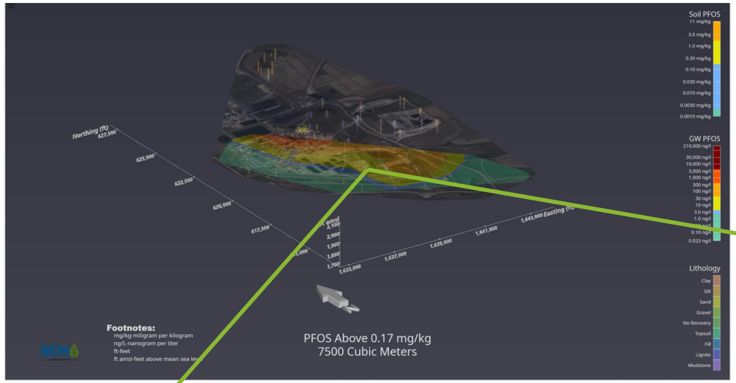
Groundwater Investigation – Findings (continued)

- Based on PFOS concentrations near Site S boundary and the estimated site seepage velocity:
  - Any off site PFAS likely at low concentration
- *So how far may have it gone and what are the next steps?*

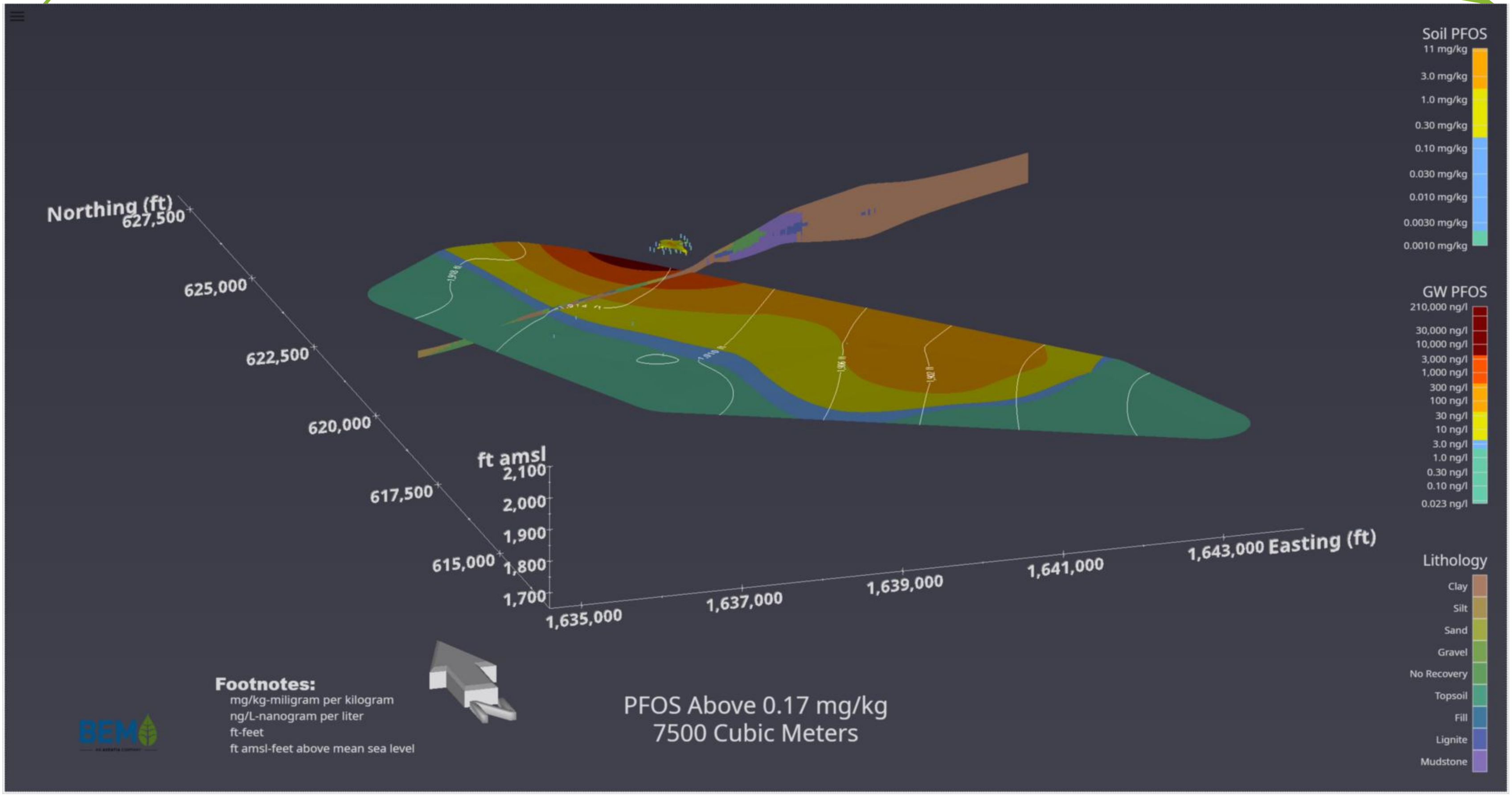


PFAS Fate and Transport

- Use site GW hydrologic and water quality data to make initial prediction of PFAS downgradient movement
- Retardation factors – Empirically estimated based on field observations
- No soil source term input – High concentration already observed in GW



The Setting

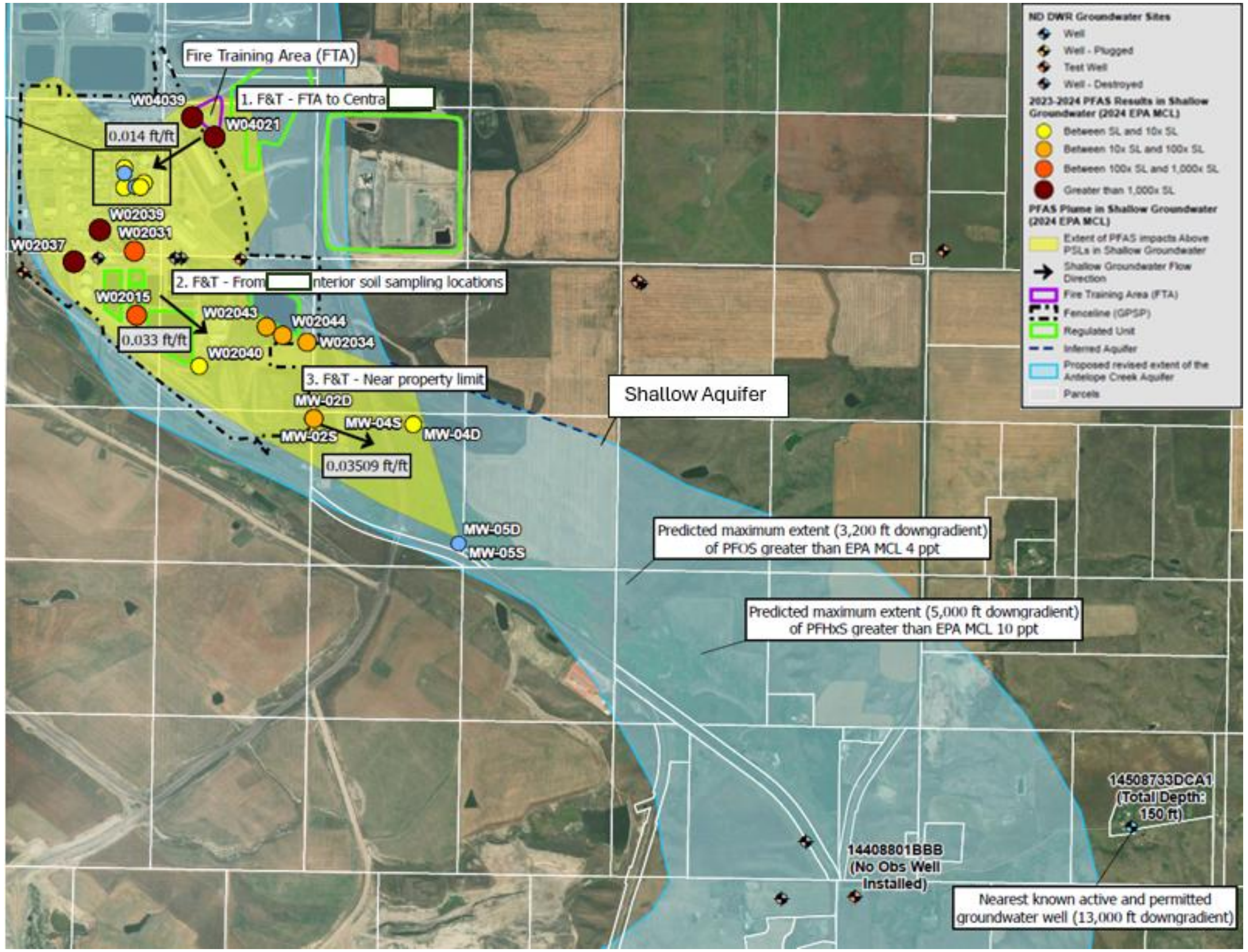


EVS – model
Talk to me after
to get the 3D
flying tour of the Site

Key Findings – GROUNDWATER

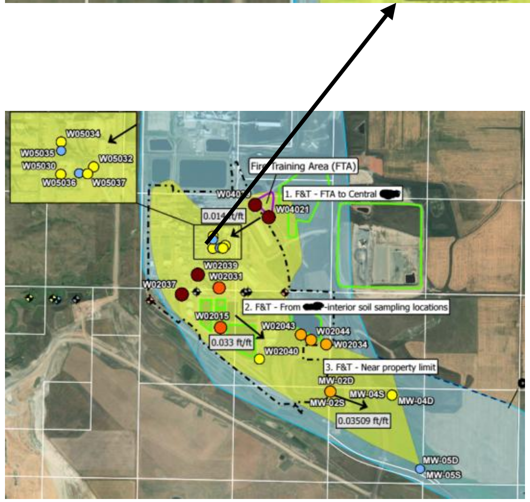
F&T Evaluation

- PFAS migration in groundwater from FTA likely not sole contributor to PFAS observed in 3000 and 5000 series MWs interior to Site.
- PFAS concentrations downgradient are greater than expected if traveling in GW alone
- Predicted PFOS > MCL: up to 3,200 ft off-site.
- Predicted PFHxS > MCL: up to 5,000 ft off-site.
- Nearest permitted shallow GW well is >13,000 ft downgradient



How did we get there? – Step 1

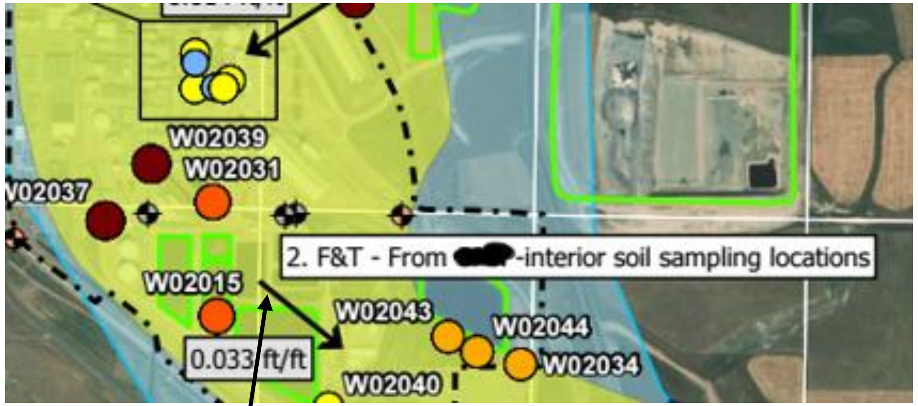
- Concentration in FTA is >10,000 ng/L
- 1500 ft downgradient in the central part
- Concentration is <100 ng/L
- Conductivity is approximately 1-11 ft/day



However, for PFAS significant retardation factor is well documented

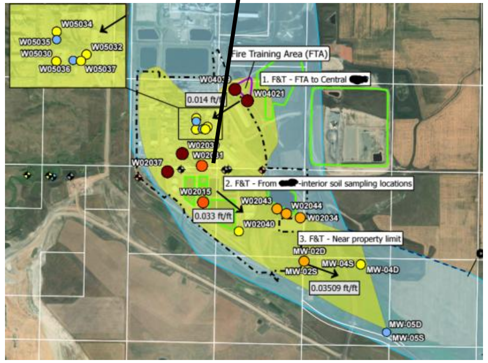
With our measured and estimated hydraulic parameters the empirical retardation factor (RF) is approximately 10 – which is reasonable to low for PFOS

Step-2. Ignore the data (partially)



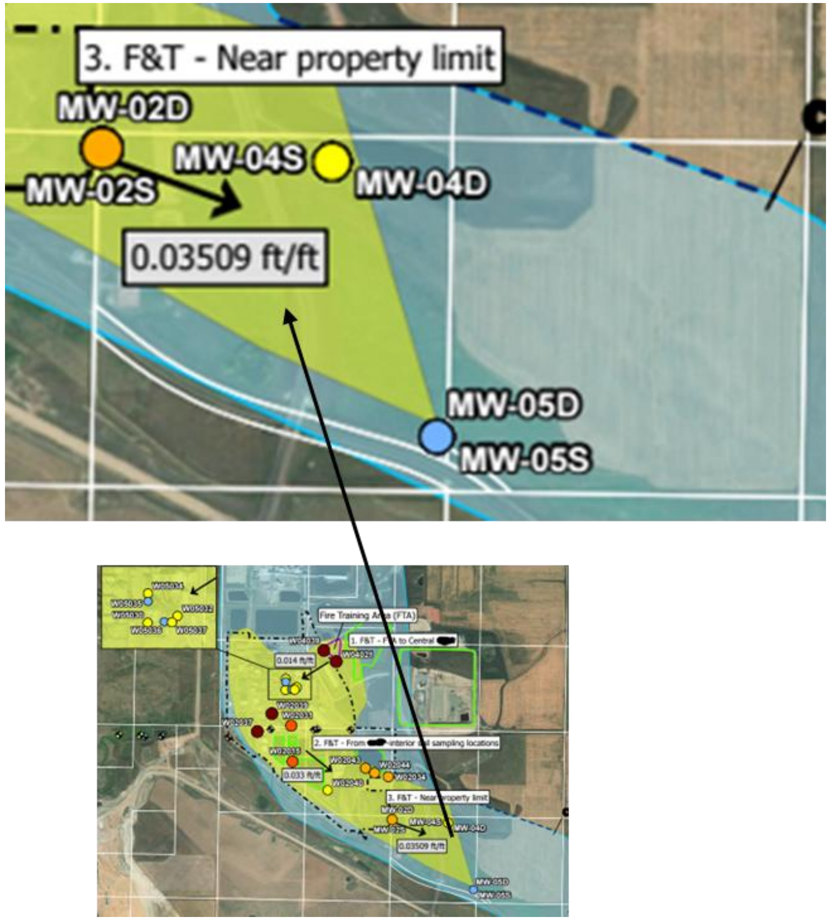
We have elevated concentrations >1000 ng/L in the central part

3000 ft downgradient we have >100 ng/L
Conductivity is up 40 ft/day - > Actual transport velocity 140ft/year



Based these hydraulic parameters
the empirical retardation factor is approximately
<2 – which is very low for PFOS

Step 3 – The Data



The data must be the driver

In 2024 2600 ft from property boundary

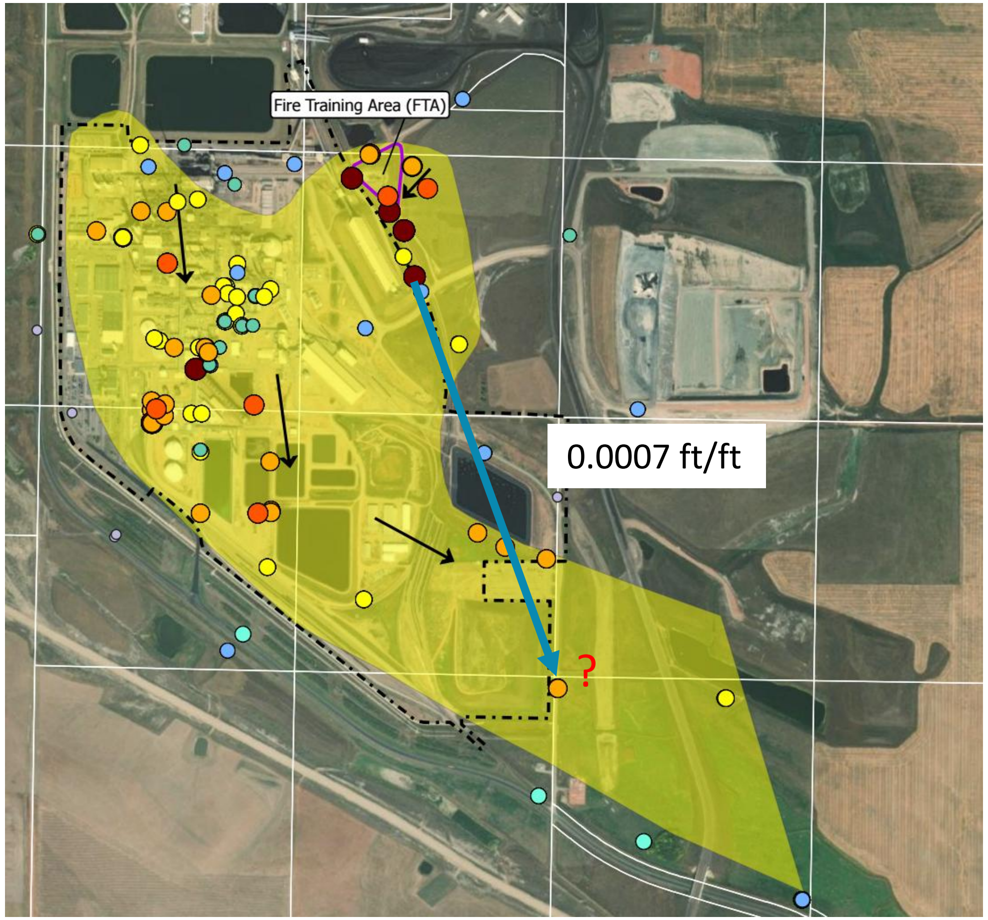
- 240 ng/L PFOS is detected in MW-02S
- Conductivity up 51 ft/day
- 100 ng/L PFOS is detected in MW-02D
- Conductivity up 96 ft/day

Working with regulatory agencies – one must be conservative

Based on our low empirical RF of 2

- PFOS exceeding MCL is occurring 3200 ft downgradient of Site

What if, the conceptual model is Wrong?



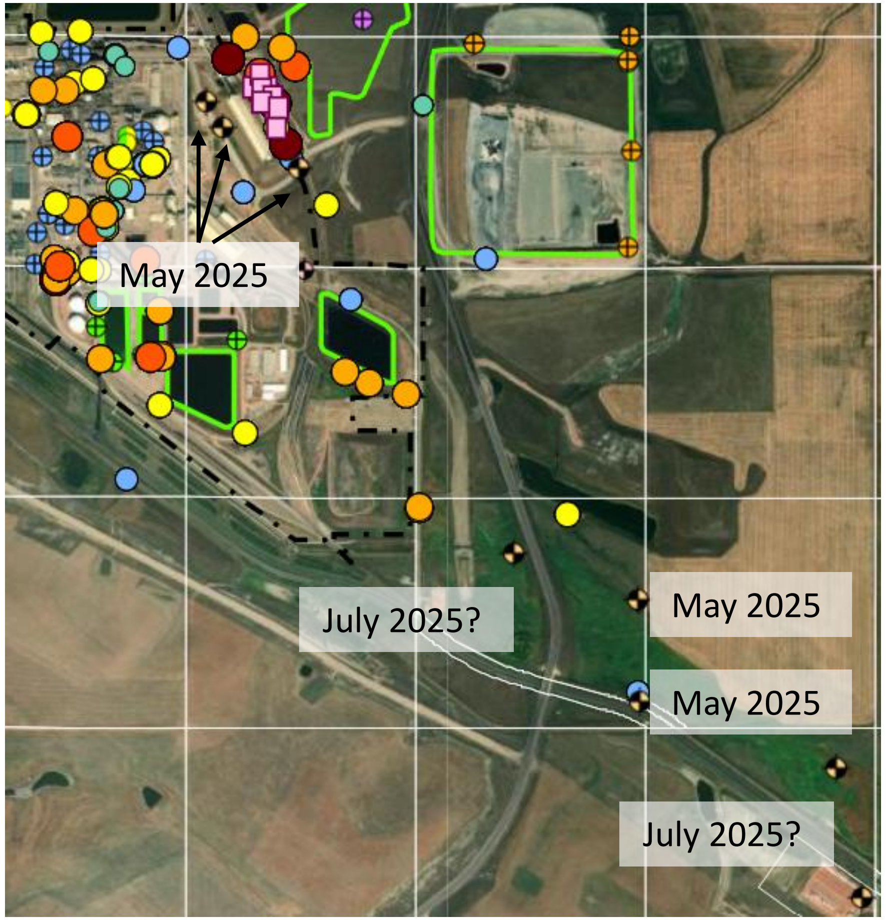
Can the Source bypass the central part of the Plant?

Yes, however the gradient and a conductivity of 100 ft/day
- Approximately 59 years to move 4400 ft downgradient

Which is about 20 years longer than the Site have been
In existence

We need more data
And
Update the Complexity

Next step - 2025



New data points to be collected

- 10 new soil borings by FTA
  - Bench scale in-situ soil treatment testing
- 8 new monitoring wells at 5 locations in May 2025
- Up to 6 new monitoring wells in July 2025

The goal

- Estimate total remaining mass in source area
  - Mitigate future source migration
- Better understanding of migration from FTA (source) in GW
- Down gradient distribution of PFAS in GW
  - Inside and outside property limits
- Enable the establishment of a Complex 3D hydrogeological model in MODFLOW
  - Determine if GW flow is the primary concern
  - Mitigate future off-site flow through GW

Comments and Questions

Thank you for your participation.

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Extra Slides

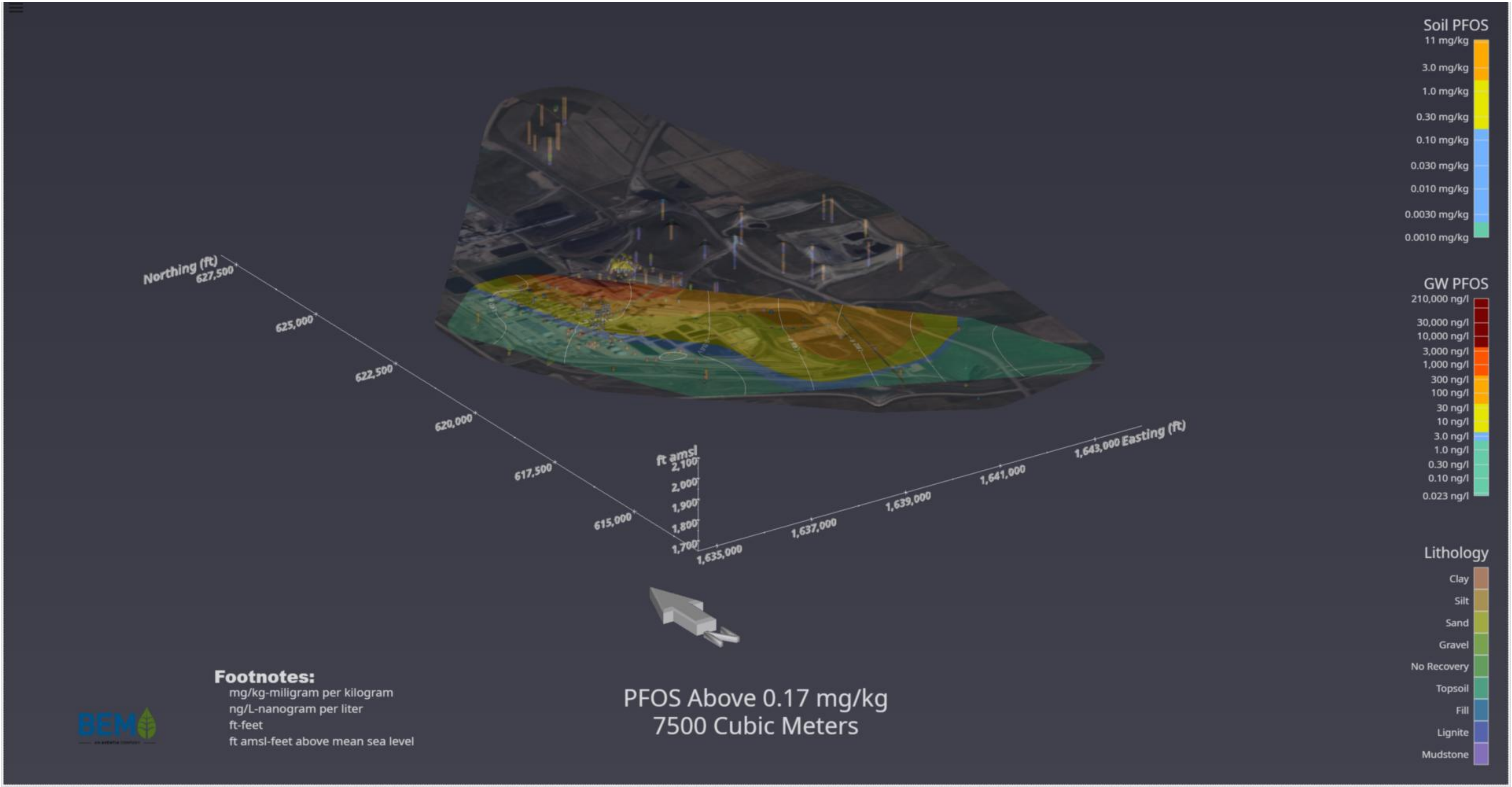
Why does matter?

- In December 2022, U.S. EPA issued a companion memo providing guidance to states on how to use the National Pollutant Discharge Elimination System (NPDES) permitting program to reduce PFAS pollution.
- On March 4, 2025, in a 5-4 decision, the U.S. Supreme Court found that the Clean Water Act (CWA) authorizes narrative (non-effluent based) criteria in National Pollutant Discharge Elimination System (NPDES) permits, but does not authorize “end-result” requirements, **which put responsibility for water quality results on the discharging facility.**

Current Regulated States as of March 2025

State	Effluent Limits	Notes
California	No (Investigation Orders only)	POTWs & industrial dischargers
Colorado	Policy 20-1: 70 ppt (PFOA+PFOS+PFNA), etc.	Permit-specific; phased limits
Connecticut	No (Sampling plan required)	Applies to industrial facilities
Delaware	Screening levels only	Under evaluation
Illinois	Under development	Statewide wastewater sampling underway
Maine	Screening levels	Source identification emphasis
Massachusetts	No (NPDES & SWD permit updates)	PFAS6 used for tracking
Michigan	Yes (5 PFAS compounds; WQVs)	Industrial & stormwater permits
New Hampshire	AGQS standards used	Applies to groundwater dischargers
New Jersey	Yes (PFOA, PFOS, PFNA)	Surface water & indirect discharges
New York	Permit-specific	Emerging contaminant focus
North Carolina	Yes (Chemours Cont Order; others TBD)	Technology-based limits used
Ohio	Under development	Draft guidance published
Oregon	No (Data collection phase)	Data to guide future policy
Pennsylvania	Draft WQS available	Applies to POTWs & industrial
Rhode Island	No (evaluation phase)	Monitoring for known sources
Vermont	Yes (Surface WQS)	POTW biosolids tested too
Virginia	No (data collection only)	Evaluating PFAS sources
Washington	Permit-specific (esp. industrial stormwater)	Biosolids regulation active
Wisconsin	NR 102 WQS under review	Interim PFOS/PFOA limits exist

CSM for Site



Soil PFOS
11 mg/kg
3.0 mg/kg
1.0 mg/kg
0.30 mg/kg
0.10 mg/kg
0.030 mg/kg
0.010 mg/kg
0.0030 mg/kg
0.0010 mg/kg
GW PFOS
210,000 ng/l
30,000 ng/l
10,000 ng/l
3,000 ng/l
1,000 ng/l
300 ng/l
100 ng/l
30 ng/l
10 ng/l
3.0 ng/l
1.0 ng/l
0.30 ng/l
0.10 ng/l
0.023 ng/l
Lithology
Clay
Silt
Sand
Gravel
No Recovery
Topsoil
Fill
Lignite
Mudstone
Northing (ft)
627,500
625,000
622,500
620,000
617,500
615,000
ft amsl
2,100
2,000
1,900
1,800
1,700
1,635,000
1,637,000
1,639,000
1,641,000
1,643,000 Easting (ft)
Footnotes:
mg/kg-miligram per kilogram
ng/L-nanogram per liter
ft-feet
ft amsl-feet above mean sea level
PFOS Above 0.17 mg/kg
7500 Cubic Meters