Battelle

2019 Bioremediation Symposium | April 15-18 | Baltimore, Maryland

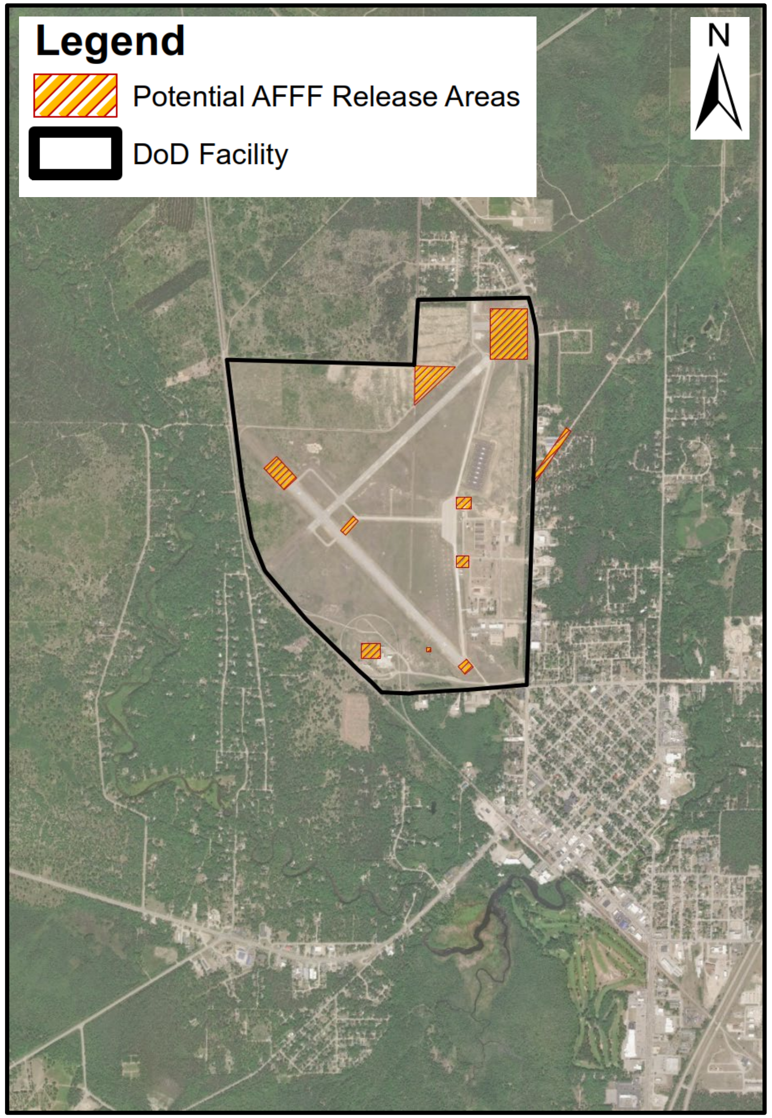
AECOM Imagine it. Delivered.

Building a Robust Fate and Transport Model for PFAS Using Vertical Aquifer Profiling and a Novel Linear-to-Branched Ratio Approach

Dorin Bogdan

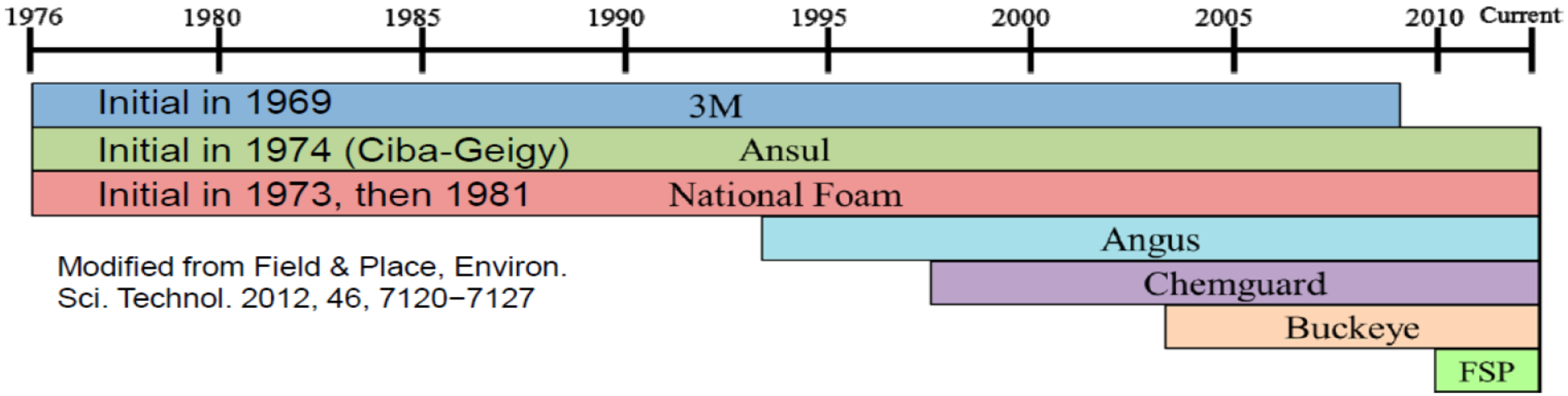
April, 16, 2019

Potential PFAS Releases



- Ten (10) Potential Release Areas of AFFF
- AFFF use in early 1970's through 1980's.
- 3M and Ansul AFFFs were used

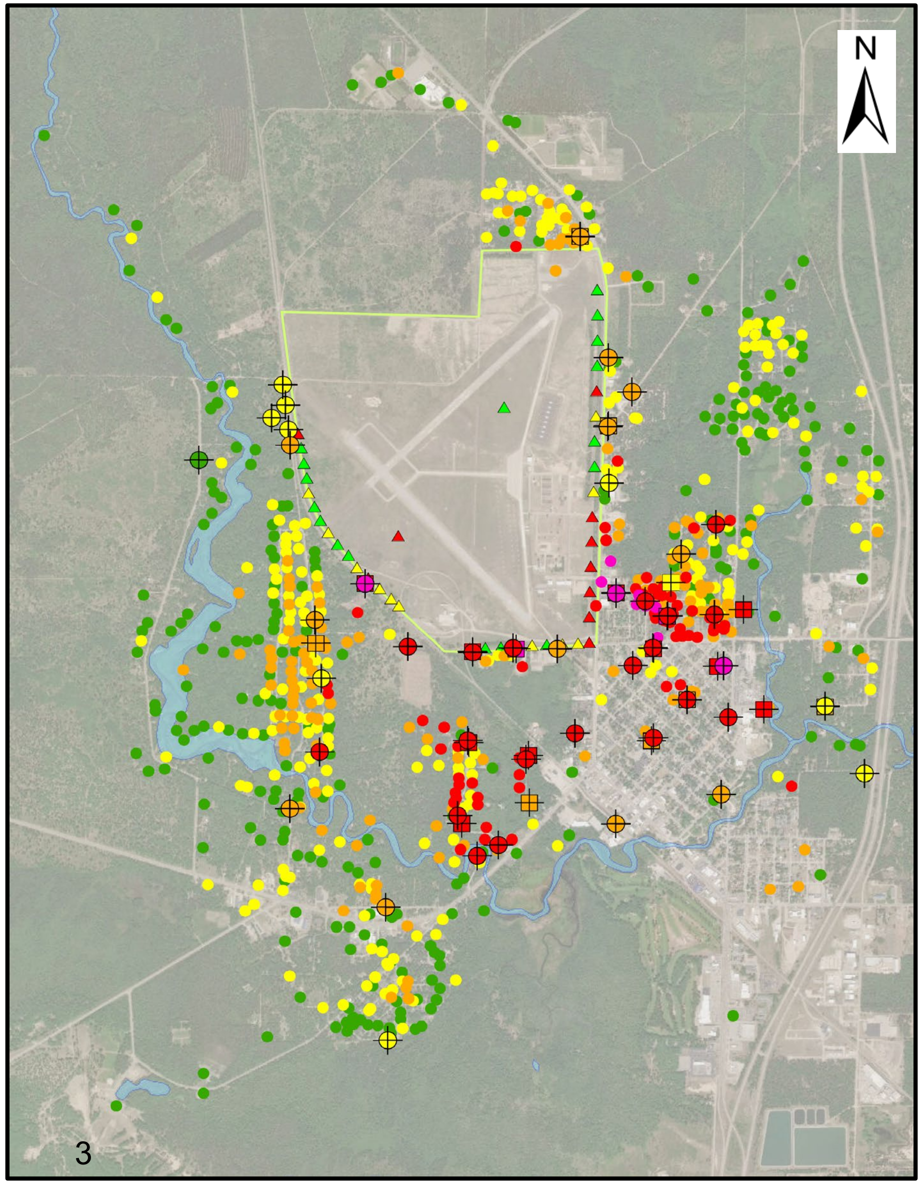
DoD Use of AFFF



Modified from Field & Place, Environ. Sci. Technol. 2012, 46, 7120−7127

AECOM

Total PFAS – DoD Facility



– 549 Residential Wells

– 210 Vertical Aquifer Samples (VAS)

– 74 Monitoring Wells

Initial VAS Sampling Locations
- Non-Detect
- < 70 ppt (PFOA + PFOS)
- > 70 ppt (PFOA + PFOS)
- DoD Facility

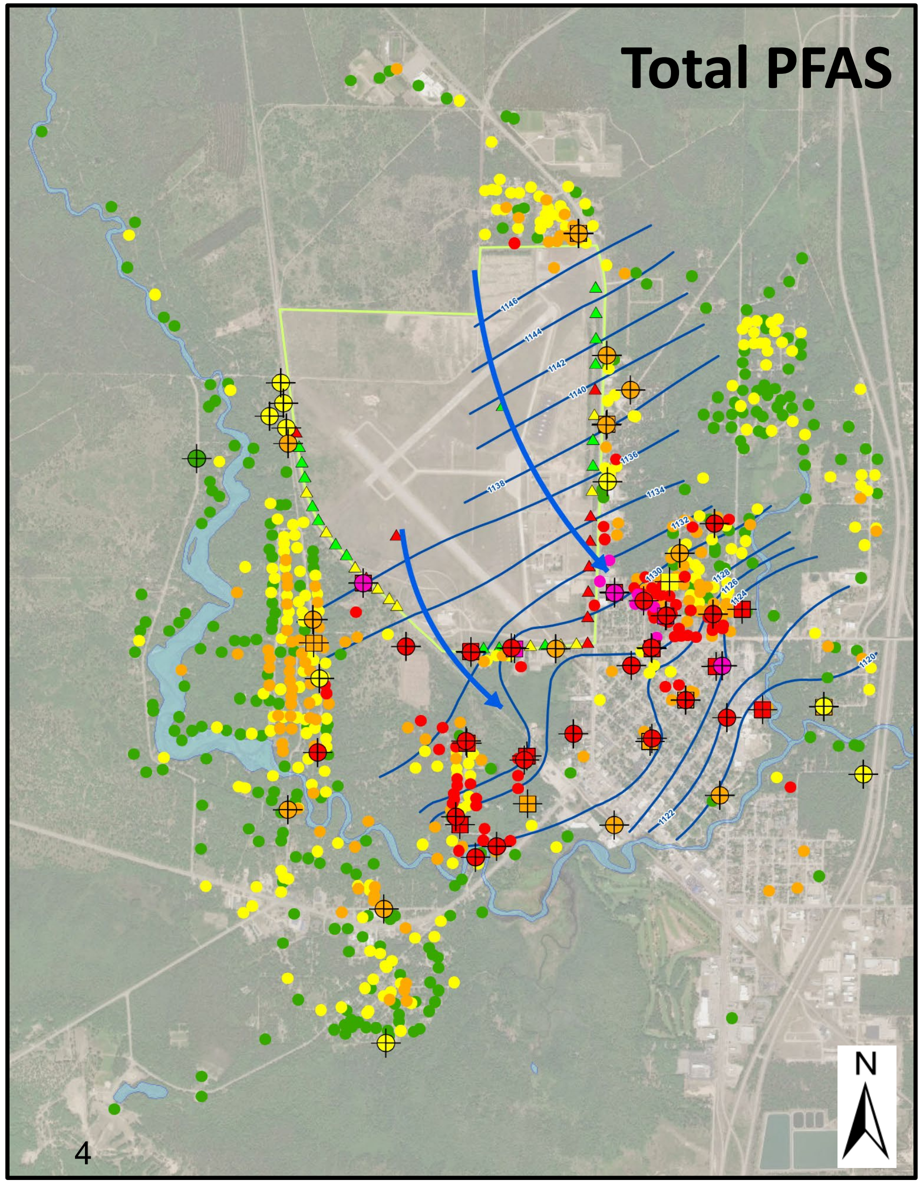
Residential Well Location Total PFAS, ppt
- Non-Detect
- >0 to 10
- >10 to 70
- >70 to 1,000
- > 1,000

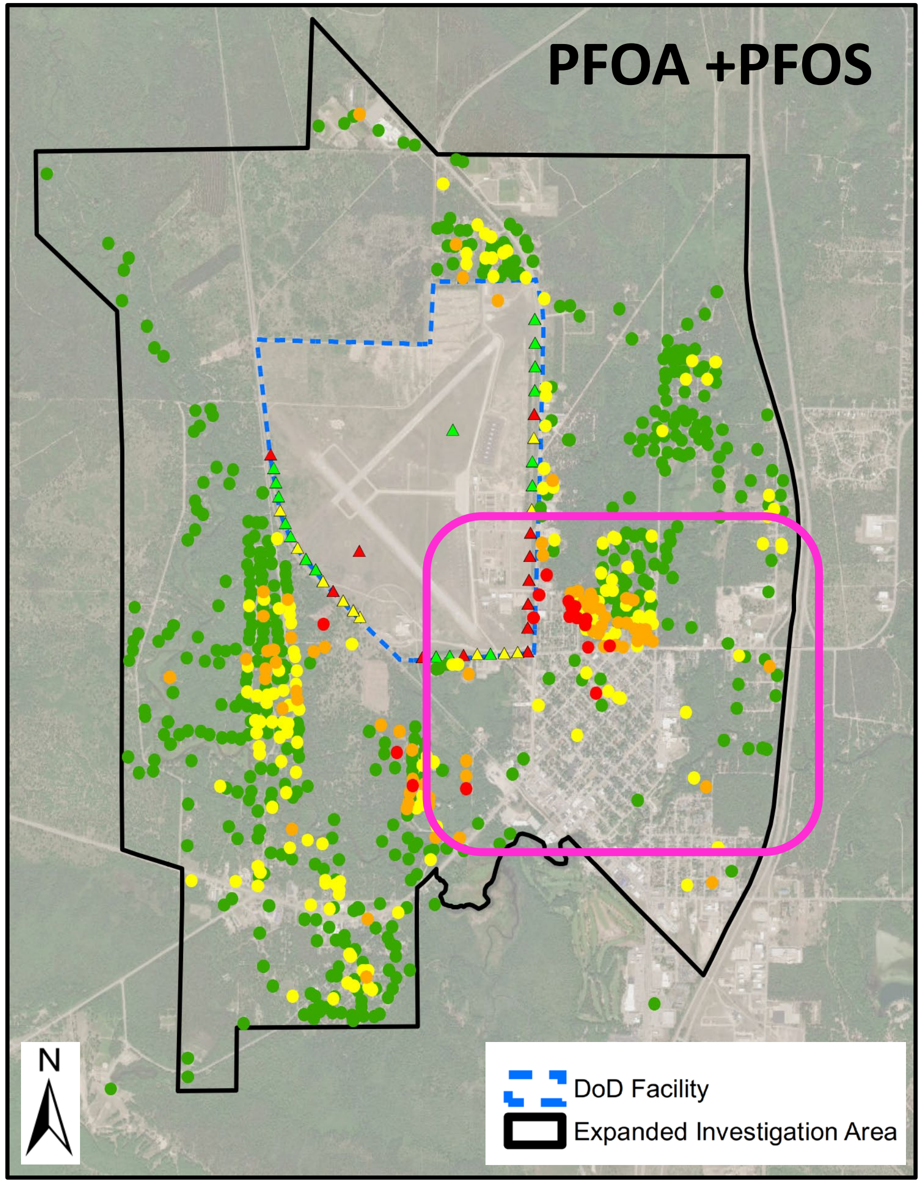
VAS Sampling Locations Total PFAS, ppt
- Non-Detect
- >0 to 10
- >10 to 70
- >70 to 1,000
- > 1,000

Monitoring Well Locations Total PFAS, ppt
- Non-Detect
- >0 to 10
- >10 to 70
- >70 to 1,000
- > 1,000

AECOM

Total PFAS – DoD Facility

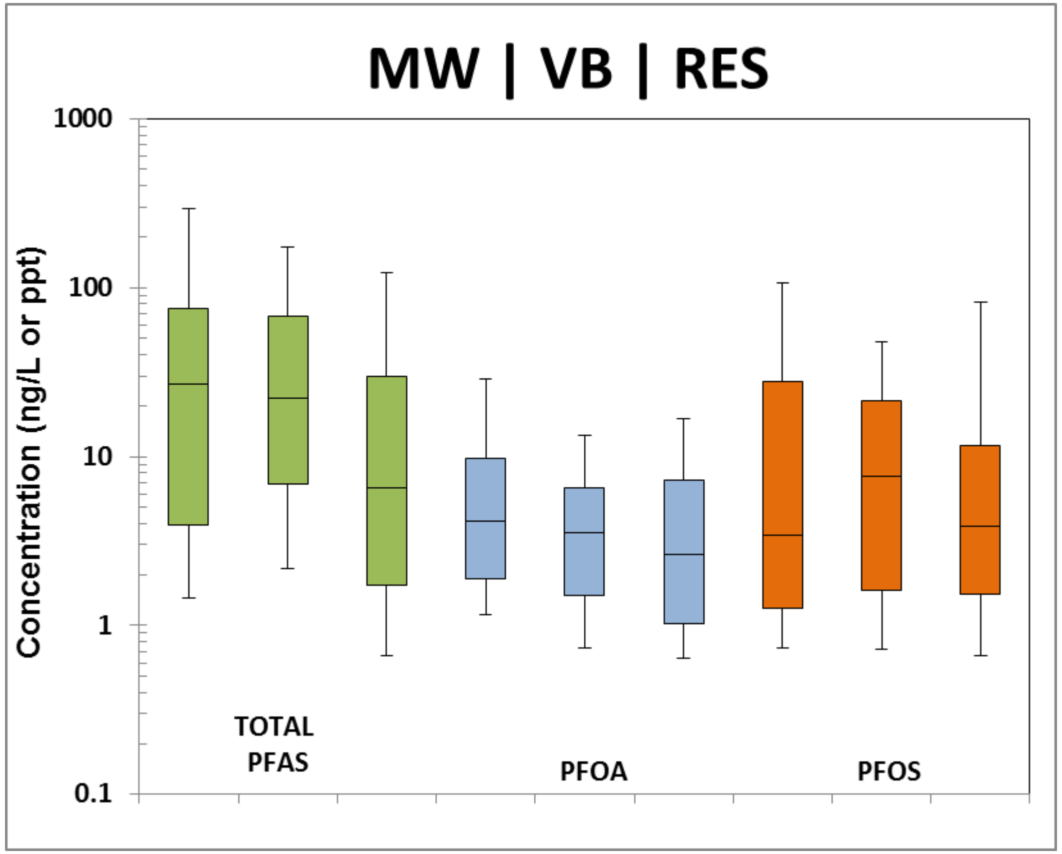


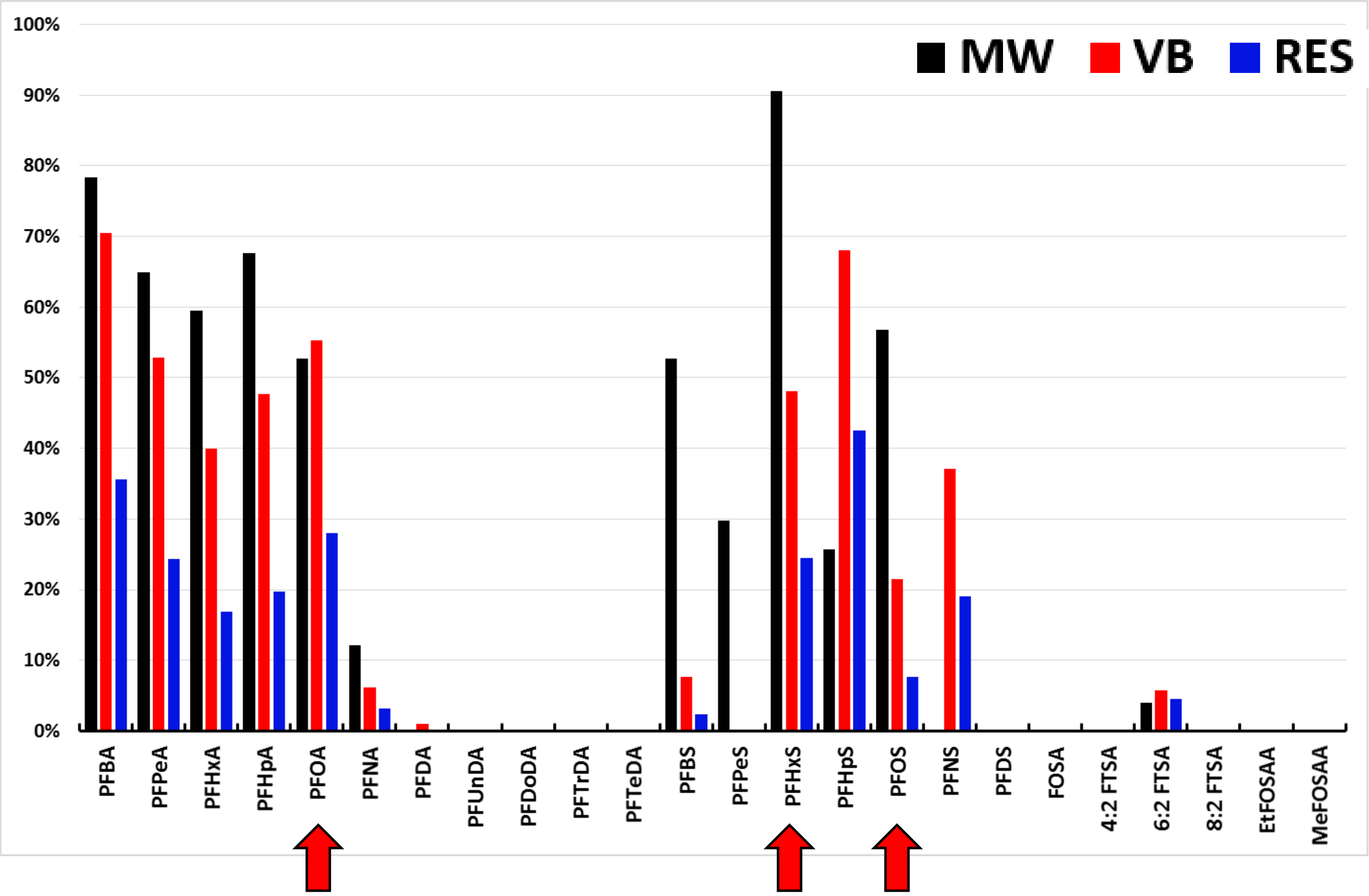


PFOA+PFOS, ppt

- Non-Detect
- > 0 to 10
- > 10 to 70
- > 70
- Evaluation Area

PFAS Results Summary





AECOM

PFAS Fate and Transport

1989-2001 - 3M AFFF Concentrate

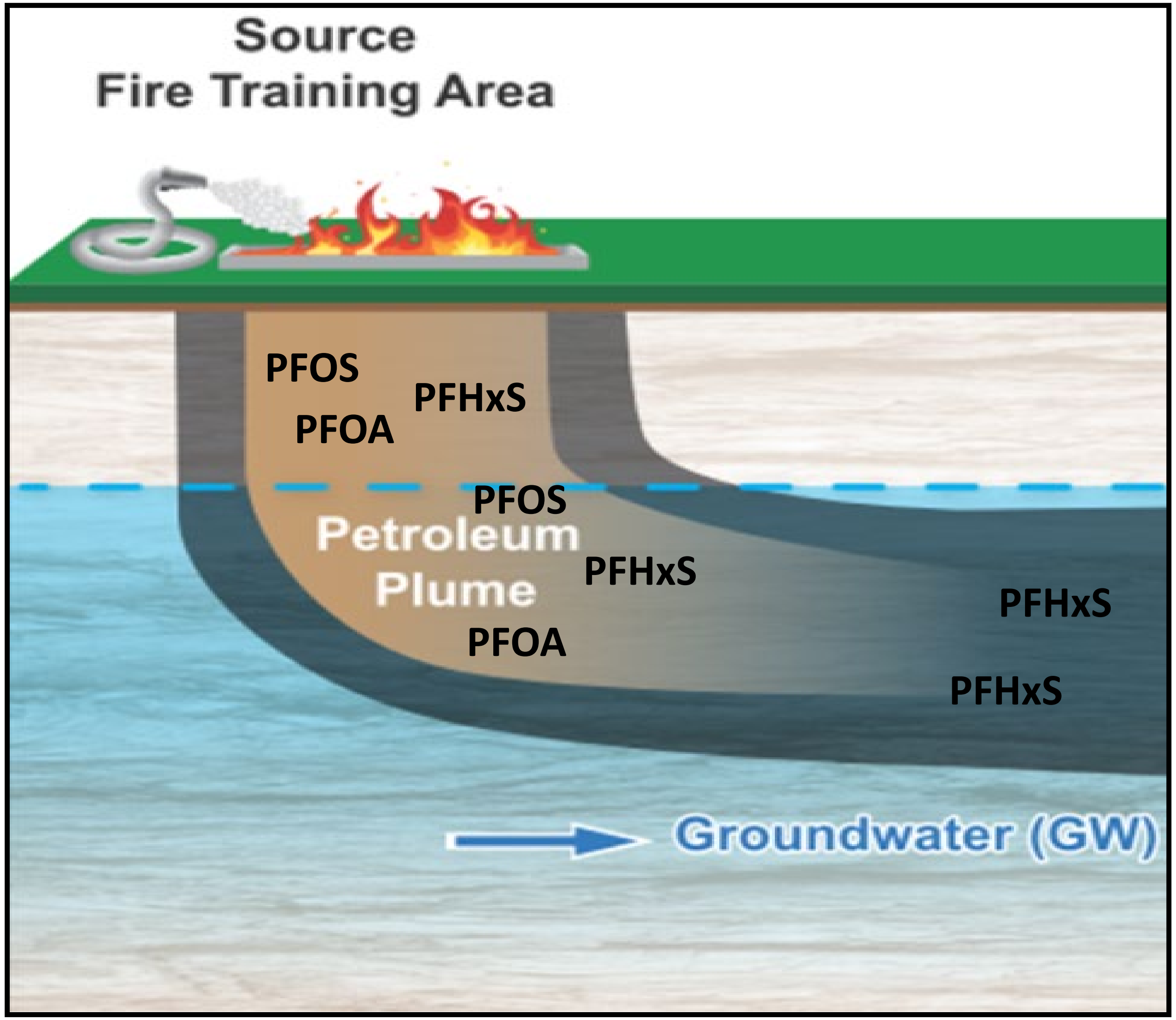
PFAS	%
C4 Precursors	1.8%
C6 Precursors	11.3%
PFBS (C4)	1.3%
PFHxS	7.6%
PFOS	69.4%
PFOA	0.9%
PFOA/PFOS	0.01
PFHxS/PFOS	0.11

Fire Training Area – Multiple AFFFs

PFAS	%
PFHxS	9%
PFOS	75%
PFOA	7%
PFHxS Br/L	0.20
PFOA Br/L	0.10
PFOS Br/L	0.48
PFOA/PFOS	0.09
PFHxS/PFOS	0.12

– Typical raw PFAS Br/L ratios ~ 0.43 (30% Branched & 70% Linear)

PFAS Source Zone Signature



Physical/Chemical Properties	Short-Chain	Long-Chain
Water Solubility	Higher	Lower
Adsorption to Soil and Sediment	Lower	Higher

– Shorter chain and branched isomers are expected to travel faster and further than longer chained PFAS.

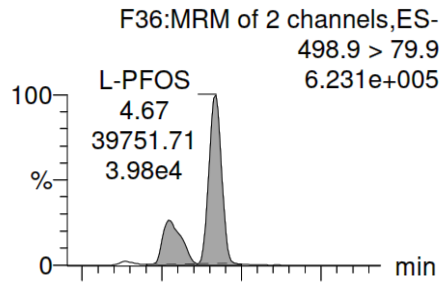
– Downgradient from the source:
  - Branched /Linear > 0.50
  - PFHxS / PFOS > 0.11

AECOM

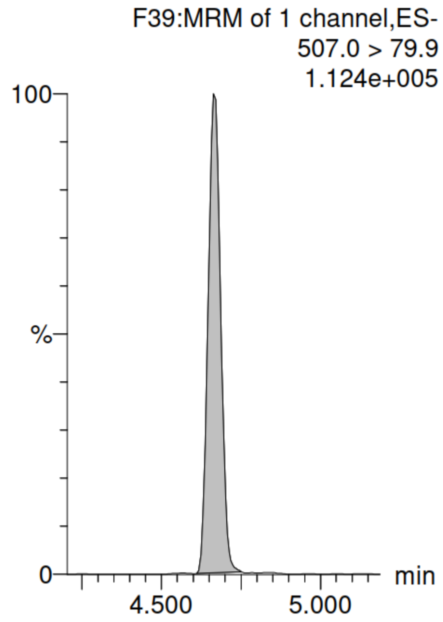
Branched and Linear Analysis

Typical

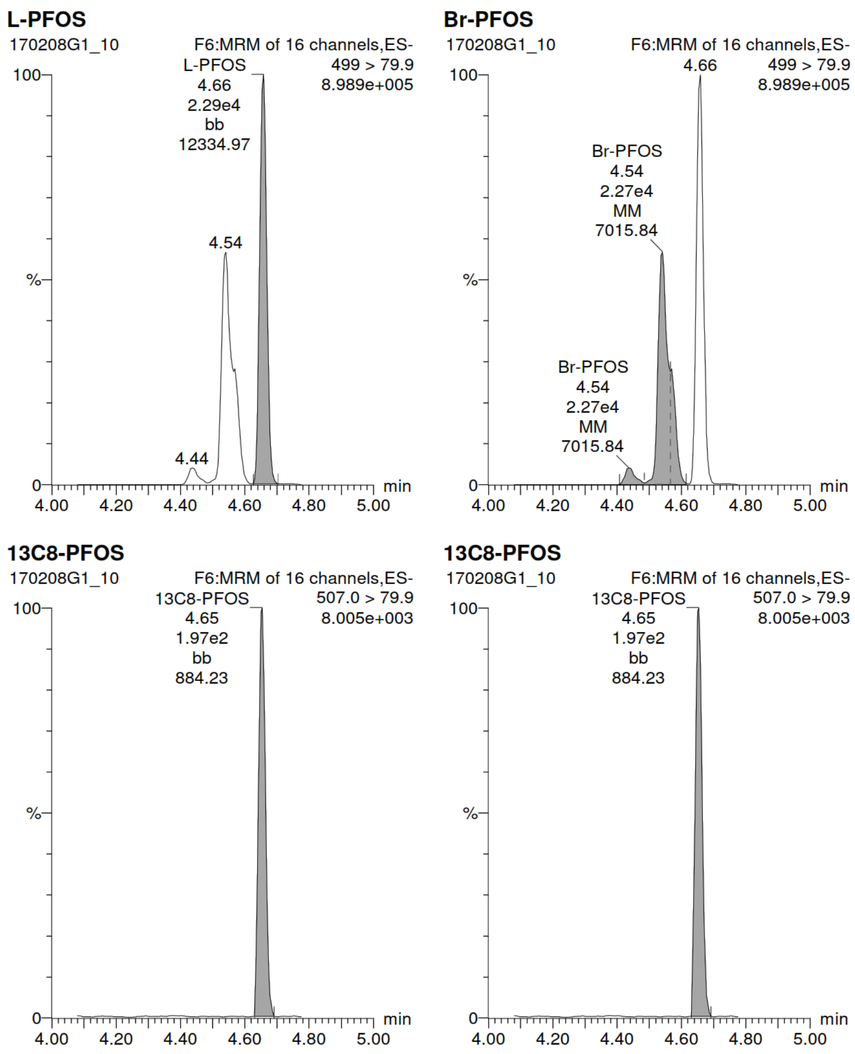
Total PFOS



13C8-PFOS



Linear & Branched Isomers



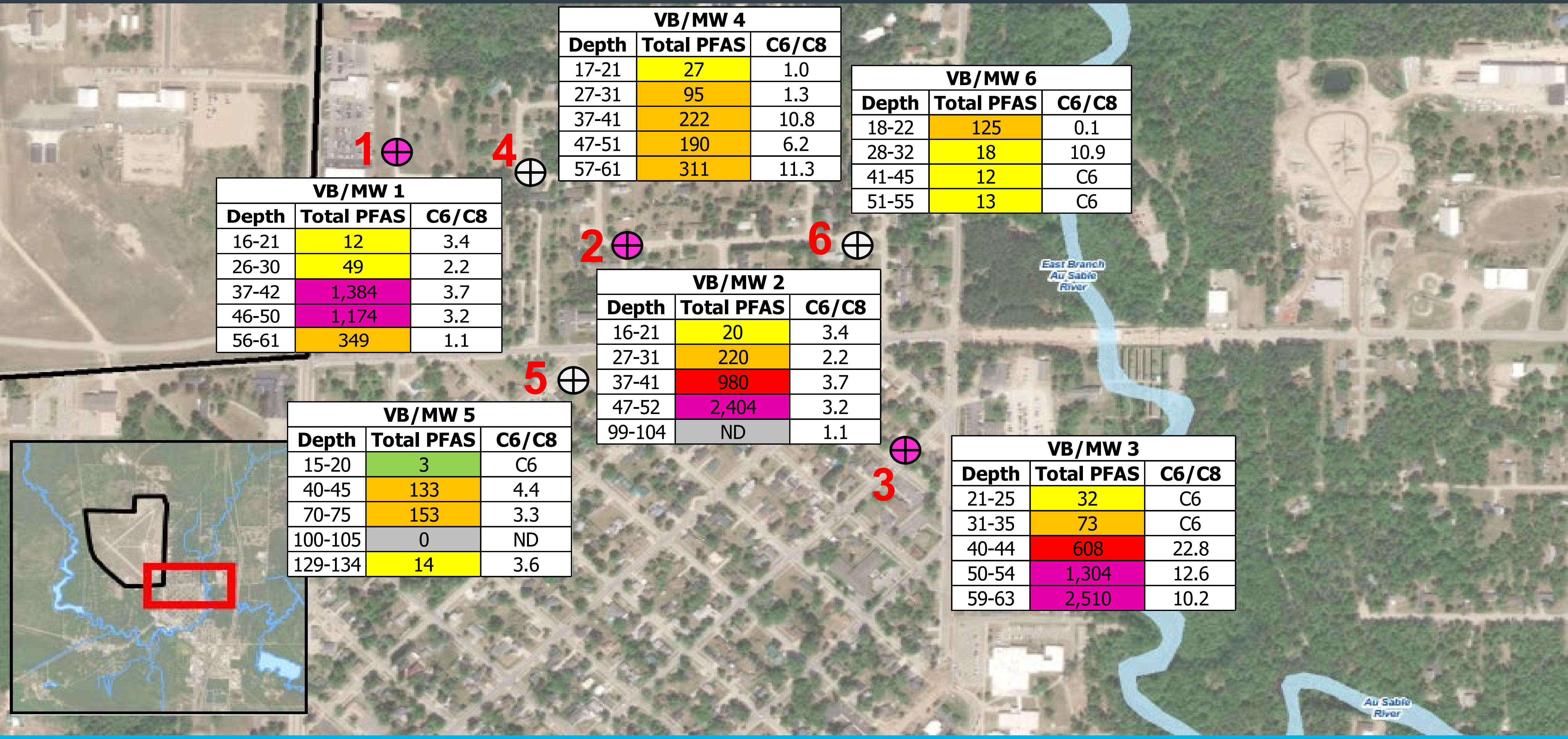
– Typical Analysis
  - Br + L Isomers Quantified **Together** Against the Linear Standard.

– New Analysis
  - Br + L Isomers Quantified **Separate** Against the Linear Standard

Well 1

Area of Interest

PFAS Plume Evaluation



VB/MW 1		
Depth	Total PFAS	C6/C8
16-21	12	3.4
26-30	49	2.2
37-42	1,384	3.7
46-50	1,174	3.2
56-61	349	1.1

VB/MW 2		
Depth	Total PFAS	C6/C8
16-21	20	3.4
27-31	220	2.2
37-41	980	3.7
47-52	2,404	3.2
99-104	ND	1.1

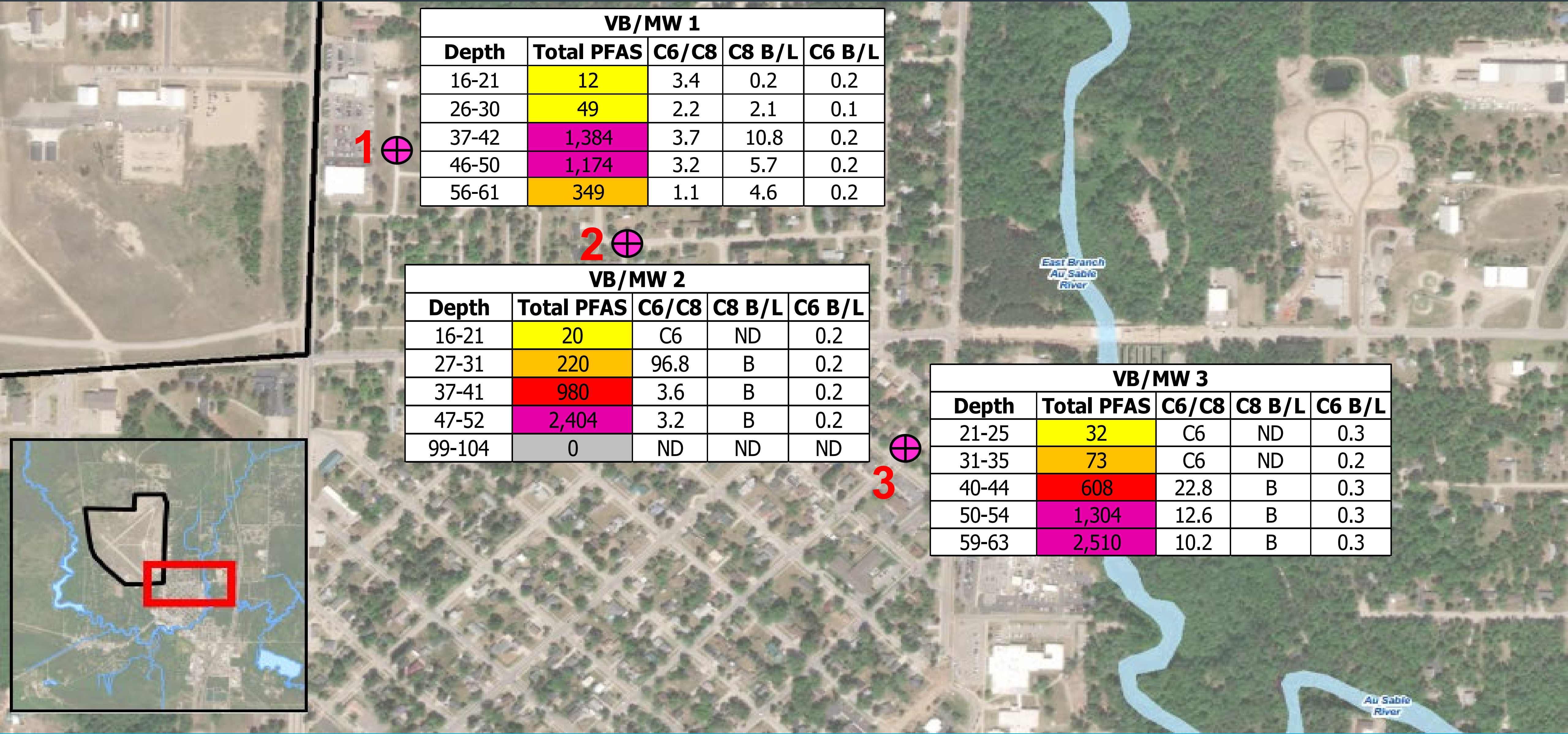
VB/MW 3		
Depth	Total PFAS	C6/C8
21-25	32	C6
31-35	73	C6
40-44	608	22.8
50-54	1,304	12.6
59-63	2,510	10.2

VB/MW 4		
Depth	Total PFAS	C6/C8
17-21	27	1.0
27-31	95	1.3
37-41	222	10.8
47-51	190	6.2
57-61	311	11.3

VB/MW 5		
Depth	Total PFAS	C6/C8
15-20	3	C6
40-45	133	4.4
70-75	153	3.3
100-105	0	ND
129-134	14	3.6

VB/MW 6		
Depth	Total PFAS	C6/C8
18-22	125	0.1
28-32	18	10.9
41-45	12	C6
51-55	13	C6

PFAS Fate and Transport

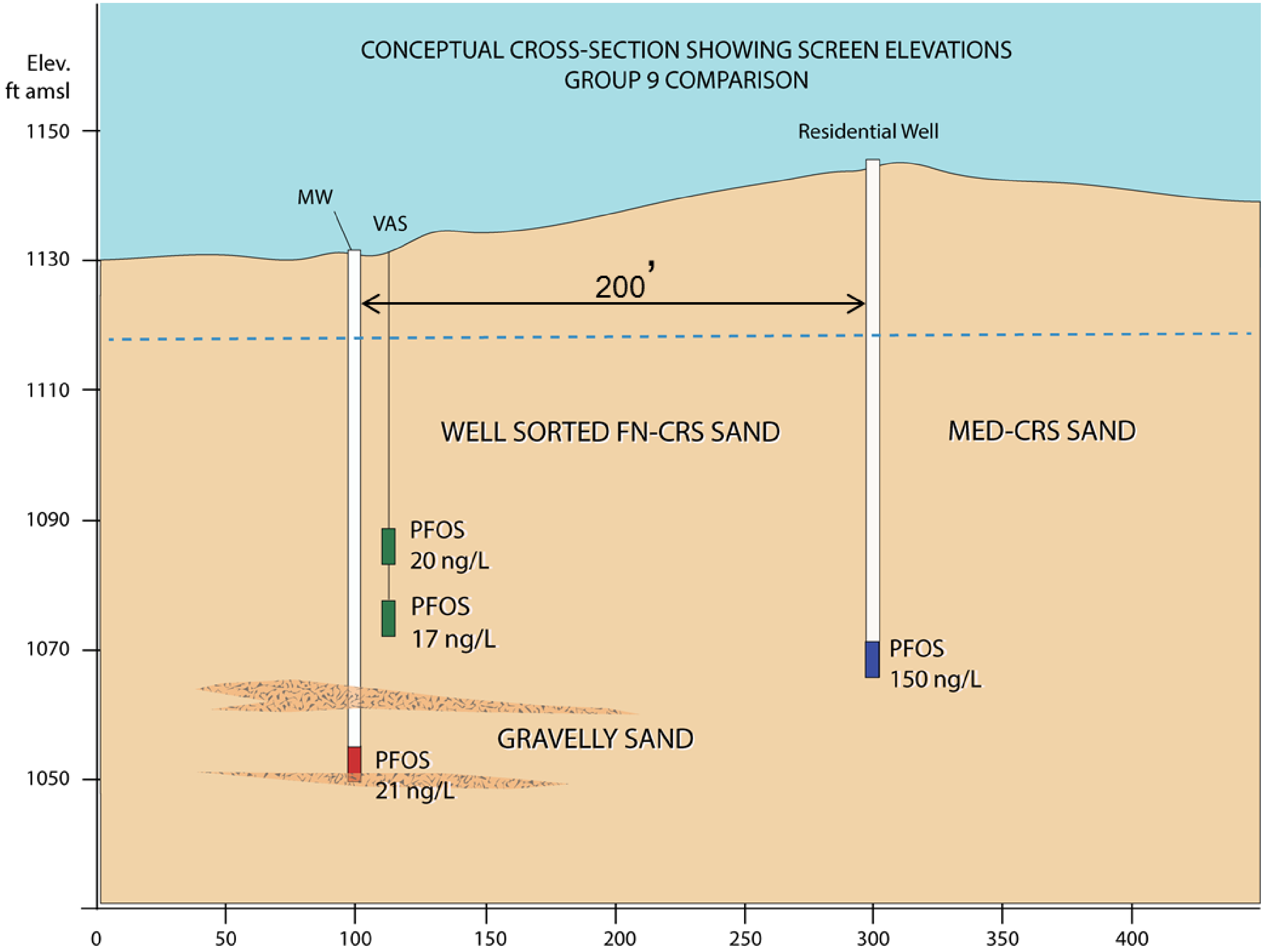


VB/MW 1				
Depth	Total PFAS	C6/C8	C8 B/L	C6 B/L
16-21	12	3.4	0.2	0.2
26-30	49	2.2	2.1	0.1
37-42	1,384	3.7	10.8	0.2
46-50	1,174	3.2	5.7	0.2
56-61	349	1.1	4.6	0.2

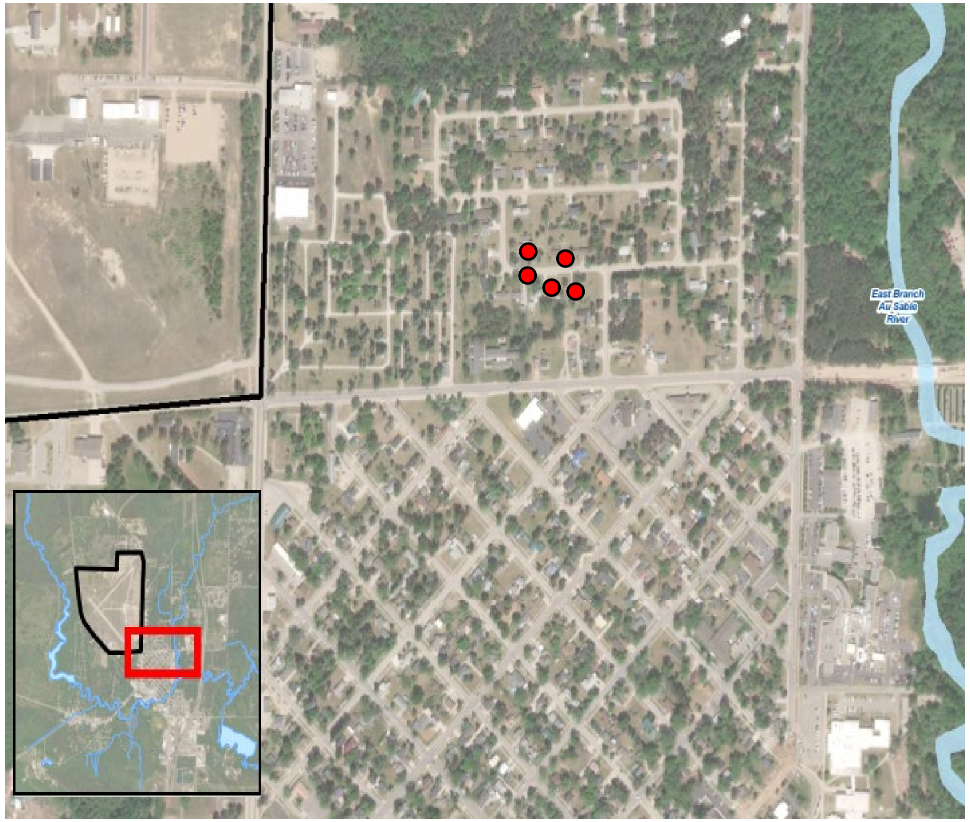
VB/MW 2				
Depth	Total PFAS	C6/C8	C8 B/L	C6 B/L
16-21	20	C6	ND	0.2
27-31	220	96.8	B	0.2
37-41	980	3.6	B	0.2
47-52	2,404	3.2	B	0.2
99-104	0	ND	ND	ND

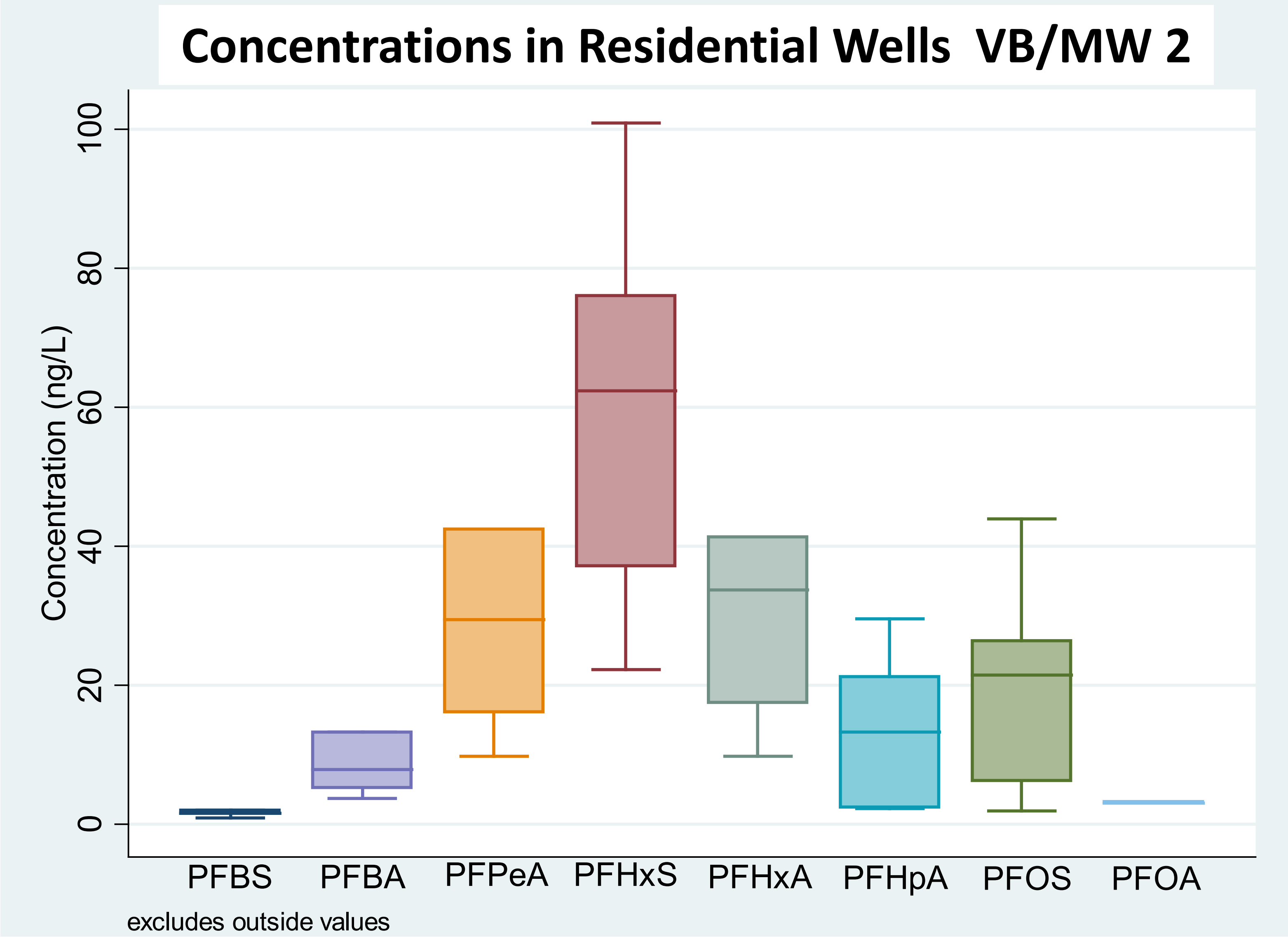
VB/MW 3				
Depth	Total PFAS	C6/C8	C8 B/L	C6 B/L
21-25	32	C6	ND	0.3
31-35	73	C6	ND	0.2
40-44	608	22.8	B	0.3
50-54	1,304	12.6	B	0.3
59-63	2,510	10.2	B	0.3

Challenges – VB/MW 5



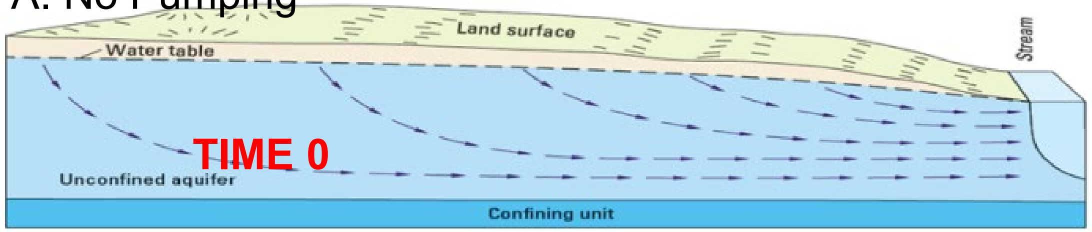
Challenges – VB/MW 2 – Residential Wells



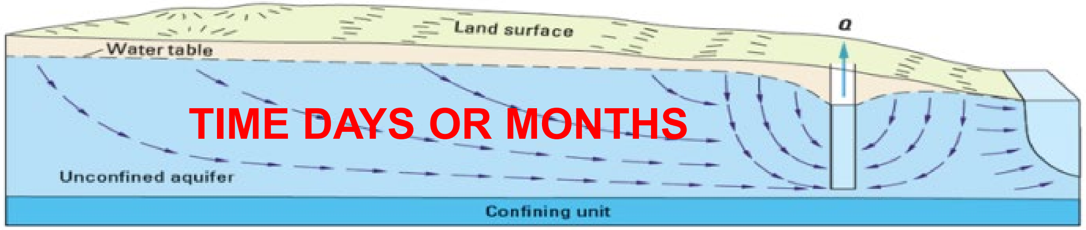


Aquifer Flow Paths

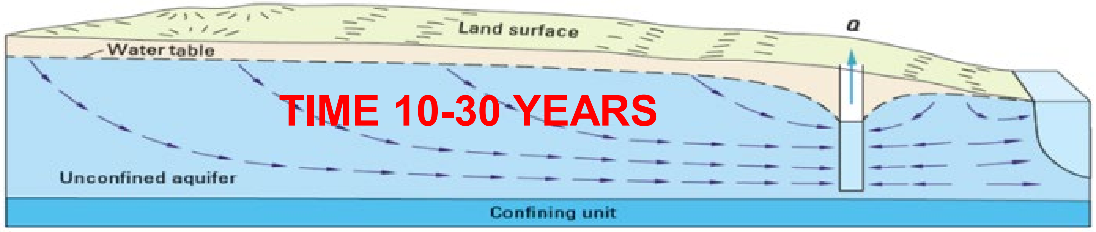
A. No Pumping



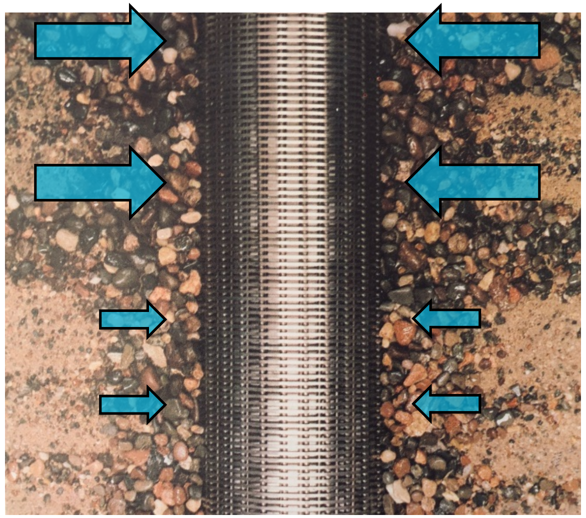
B. Start of Pumping: Well Initially draws water from aquifer storage (e.g. ENV MW or VAS).



C. Sustained Pumping: Cone of depression expands and stabilizes, flow paths established (e.g. RES).



Rathfelder, 2016 modified from Heath, 1983.



Driscoll, 1986

AECOM

Thank You!

T: 616-481-4009
E: John.Cuthbertson@aecom.com