PFAS Occurrence in New Hampshire Groundwater

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2019 NH Waste & Contaminated Sites Conference

September 11, 2019

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

Agenda

I. Challenges of PFAS as emerging contaminants

II. New MCLs/AGQS & Waste Site Approach

III. Broad Overview of PFAS in New Hampshire

IV. Water Supply Data

V. Waste Site Data

VI. PFAS Background References

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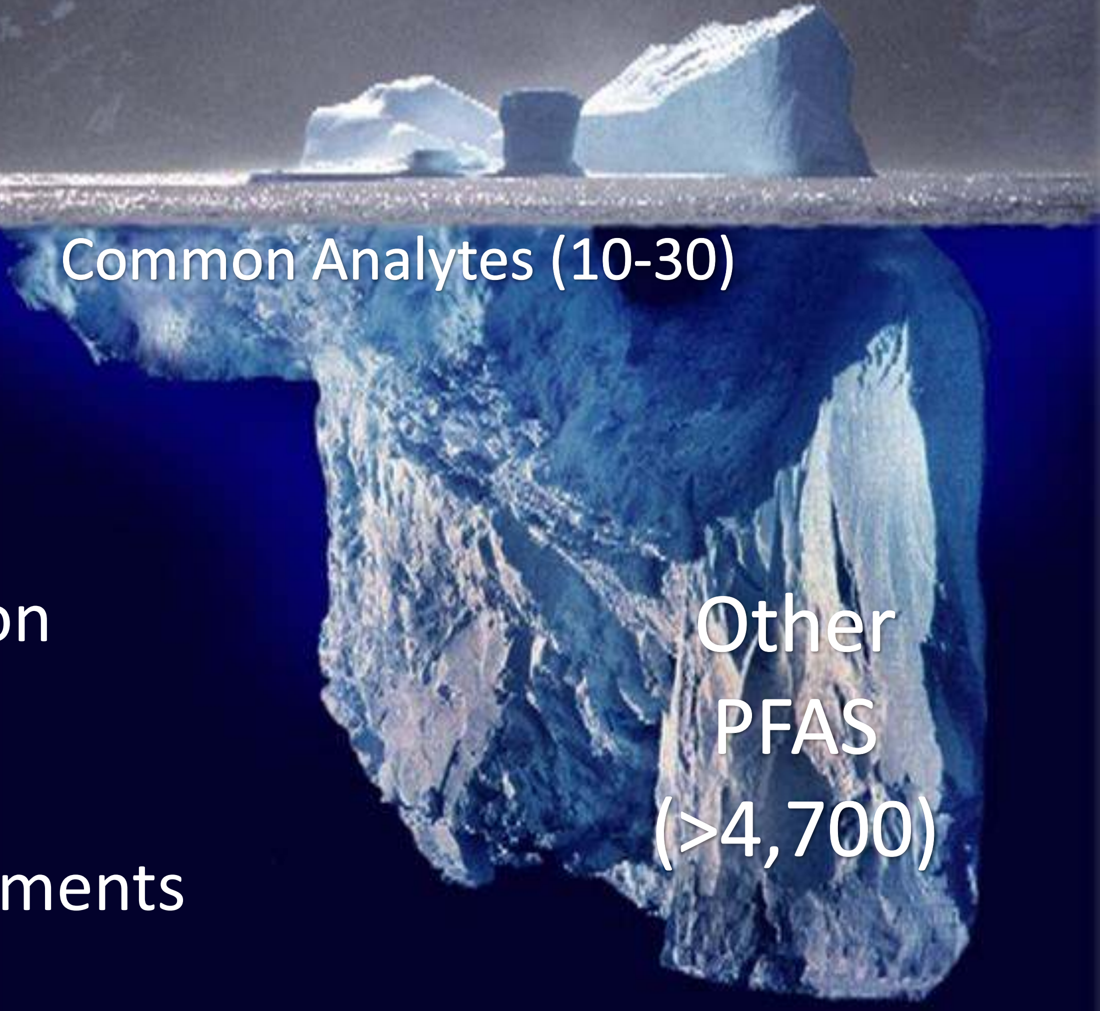
I. Challenges of PFAS as Emerging Contaminants



- Precursor transformation
- Emerging science
- Proprietary mixtures
- Phase-outs and replacements

II. HWRB’s Waste Site Approach to New MCLs/AGQS

*effective September 30, 2019

- Review open sites with PFAS data <70 ppt
- Prioritize sites where drinking water is potentially at risk
- Only revisit closed sites if new information indicates a need.

PFAS	MCL and AGQS
PFOA	12 ppt
PFOS	15 ppt
PFHxS	18 ppt
PFNA	11 ppt

For sites with new exceedances, the RP/PRP should:

- Provide alternative water
- Re-assess CSM /Delineate / Expand GMZ and update RAP / Augment Permit Monitoring

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III. Broad Overview of PFAS in New Hampshire

Data collected since 2016 shows PFAS impacts to a wide range of environmental media

Statewide and Site-Specific Water Quality Data

- Public water supplies
- Private drinking water
- Groundwater
- Surface water

Statewide Waste Quality Data

- Wastewater
- Wastewater sludge and biosolids
- Landfill leachate

Additional Site-Specific Data

- Soil
- Sediment
- Fish
- Loon eggs
- Air
- Stack residue

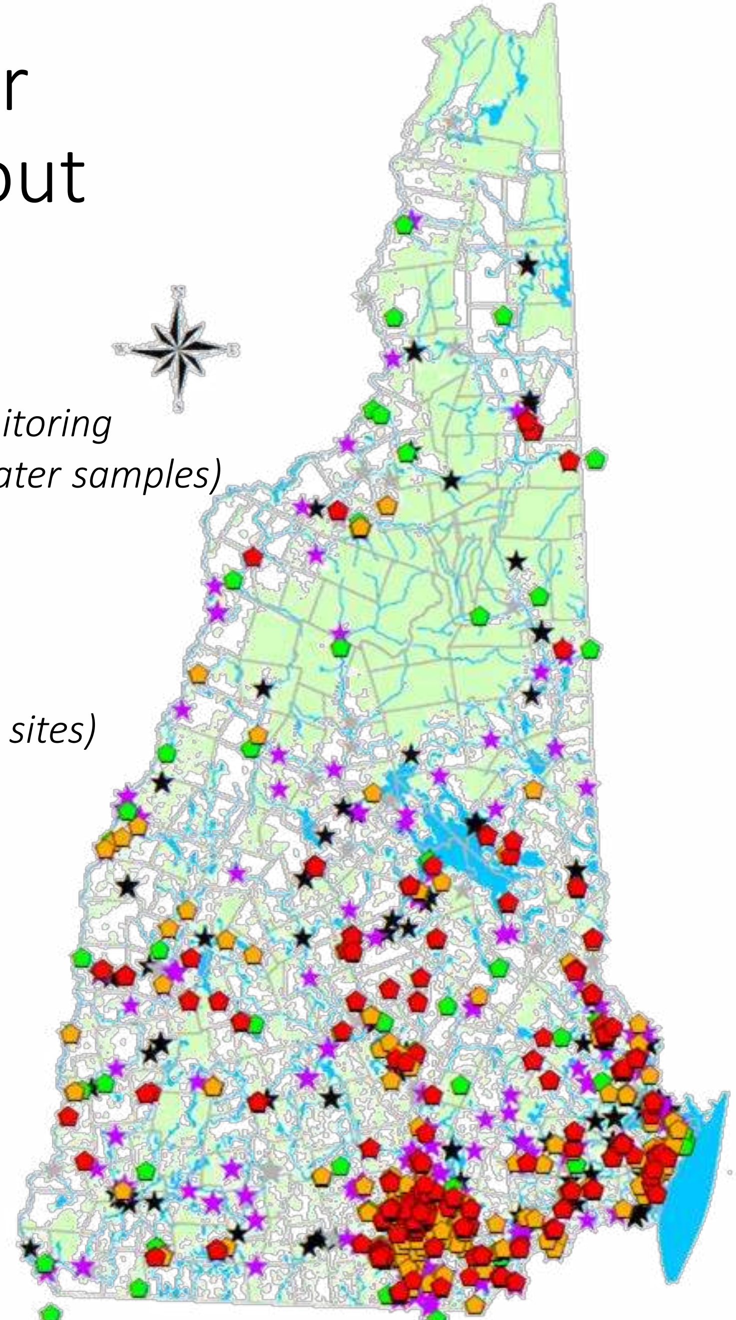
PFAS Impacts To Groundwater Quality Are Present Throughout New Hampshire

PFAS SAMPLES (*Data in NHDES' Environmental Monitoring Database [EMD] ~6,500 groundwater samples)*

- > Existing AGQS
- > New AGQS
- < New AGQS

PFAS SITES *(Data in NHDES' Onestop Database ~415 sites)*

- Site with PFAS Detections > New AGQS
- Site with PFAS Detections < New AGQS
- Site with PFAS Screening No Detections



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**Data current through 08/30/2019*

IV. Water Supply Data

Public Water Systems & Private Well Water Supplies in NH

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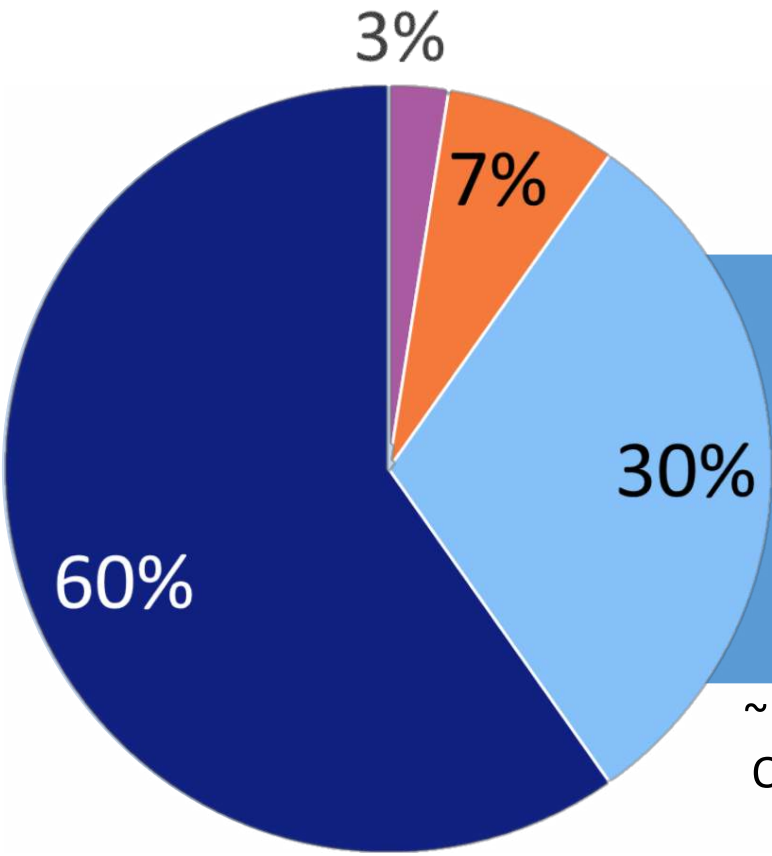
DWGB PFAS Data

Drinking Water – Public Water Systems



Public Water Systems

Approx. 360 of 3,800 PWS have screened for PFAS

~ 1,800 PWS will be required to sample starting Q3 2019 per MCL based on type of system and population served

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Approximate data through 07/31/2019

HWRB/DWGB PFAS Data

Drinking Water – Private Water Supplies

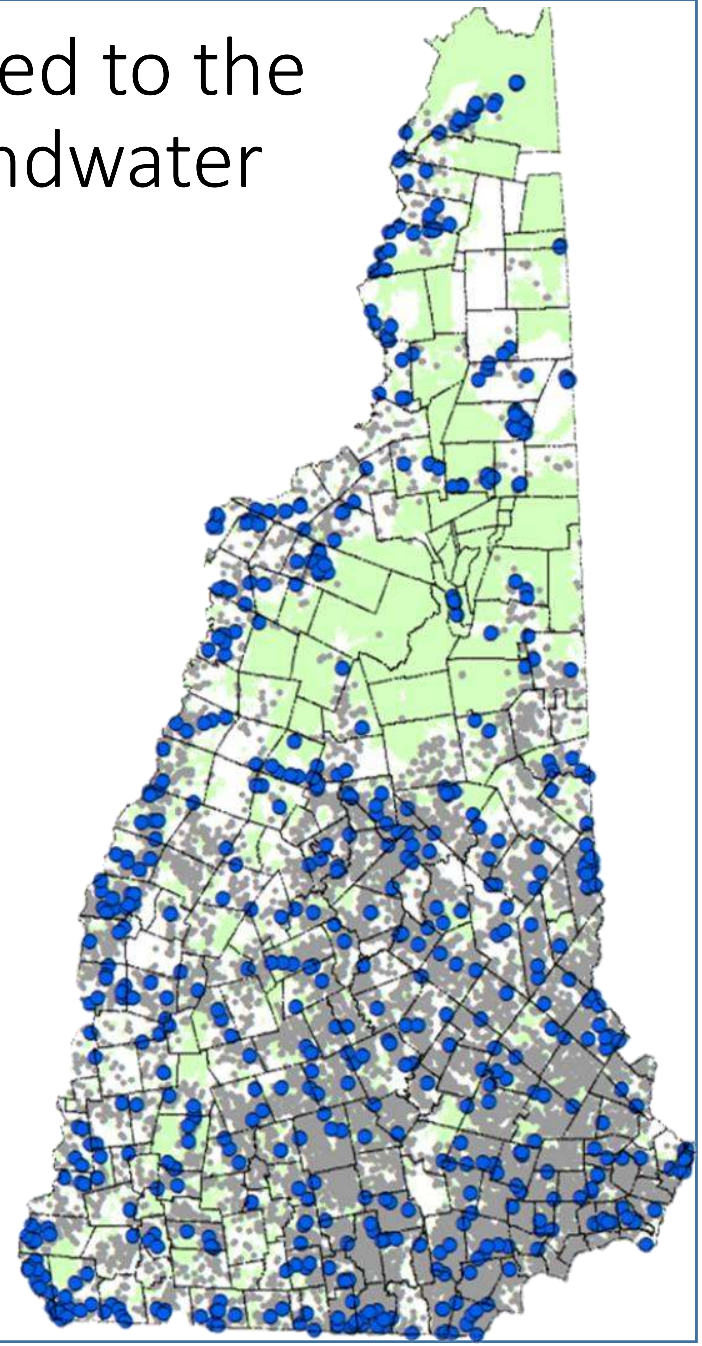
~250,000 private wells | ~46% of the state's population

Not a lot of private well data outside of So. NH

- Limited private well sampling based on proximity to:
  - Sensitive receptors of concern (i.e. childcare facilities, schools, etc.)
  - Industrial sites with known intensive PFAS use
  - Fire / fire department / fire training areas
  - Active waste sites / waste disposal facilities
  - Airports
  - Air Permit Sites
  - Agricultural sites / nurseries / growers

Ongoing NHDES Initiatives Related to the Occurrence of PFAS in NH Groundwater

- Soil background and leaching
- DWGWTF background sampling
  - ~ 500 random wells
  - ~100 co-located biomonitoring samples
- Fire service water supply sampling
- Surface water sampling
- Control of air emissions



Domestic Well Candidates

Randomly Selected Well

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Ongoing Initiatives *continued*

- Landfill leachate
  - 18 samples from lined facilities in 2018
- Wastewater Influent and Effluent
  - Sampled 13 WWTPs delegated to implement federal pretreatment standards, of the more than 60 WWTPs in NH in 2017
- Residuals – Sludge and Biosolids
  - 33 samples from 24 of 24 certificate holders (permittees) in 2017-2018
  - Sampling underway for all permittees in 2019, requirement in 2020 onward
  - Some application sites under assessment

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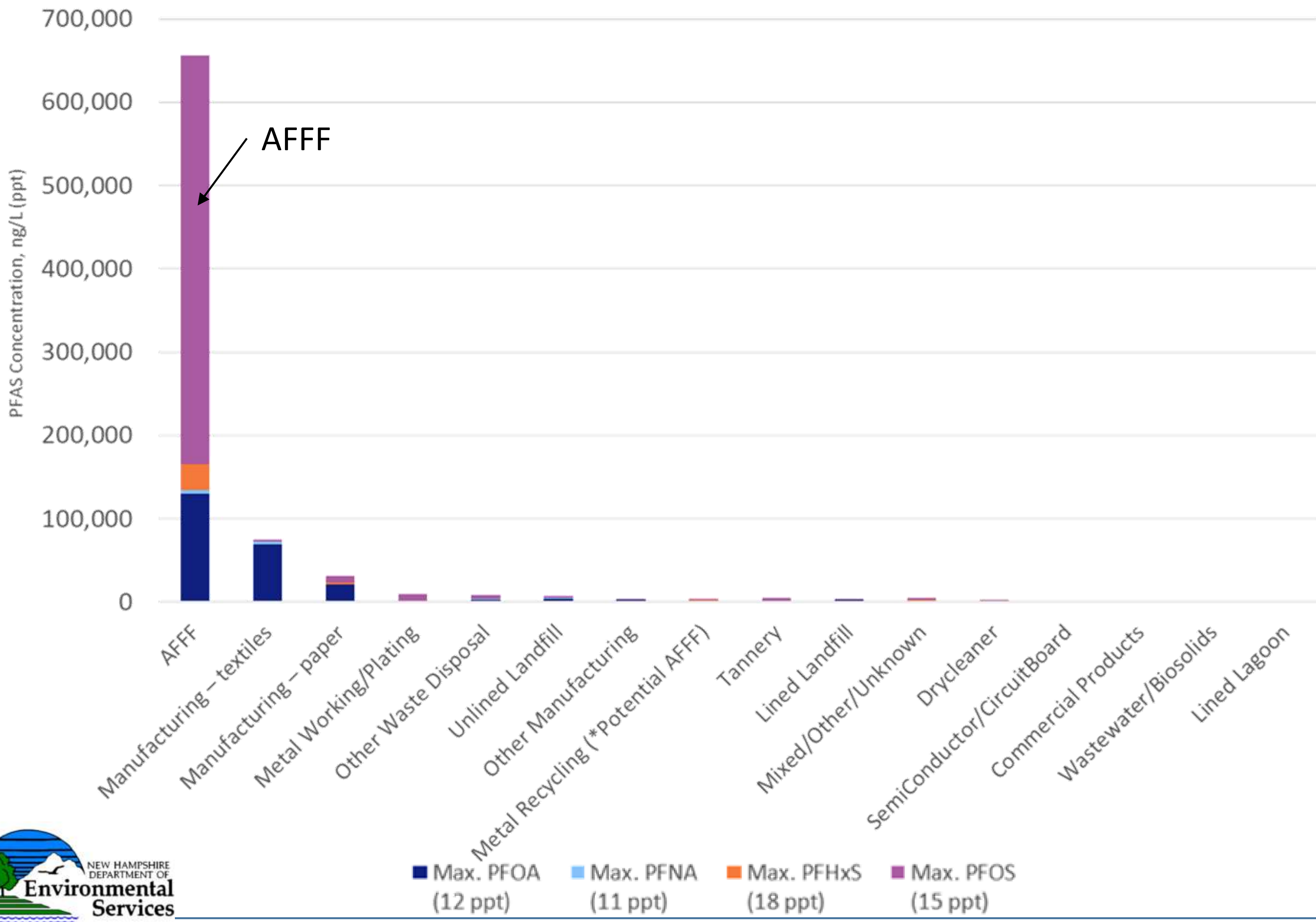
V. Waste Site Data

Waste Site Sources	Sites Sampled	% Sites > AGQS	Max. PFOA (12 ppt)	Max. PFNA (11 ppt)	Max. PFHxS (18 ppt)	Max. PFOS (15 ppt)
Class B Foam / AFFF	20	100%	130,000	4,500	31,000	490,000
Manufacturing – textiles	3	100%	69,500	2,960	200	2,560
Manufacturing – paper	6	75%	21,000	320	2,400	7,600
Metal Working/Plating	22	65%	1,070	22	806	7,080
Other Waste Disposal	15	67%	3,200	31	89	4,750
Unlined Landfill	161	74%	3,700	774	663	1,600
Other Manufacturing	14	36%	2,510	110	75	162
Metal Recycling*	14	80%	1,700	100	674	1,440
Tannery	3	100%	1,230	4	769	2,410
Lined Landfill	13	69%	2,200	30	107	632
Mixed/Other/Unknown	93	58%	1,090	960	745	1,700
Drycleaner	21	75%	160	29	88	1,800
Semiconductor/Circuit Board	9	67%	170	13	150	850
Commercial Products	4	100%	242	102	69	405
Wastewater/Biosolids	6	83%	560	13	81	204
Lined Lagoon	12	8%	18	0	14	7

Approximate data through 07/31/2019

Waste Sites – Maximum Groundwater Concentrations



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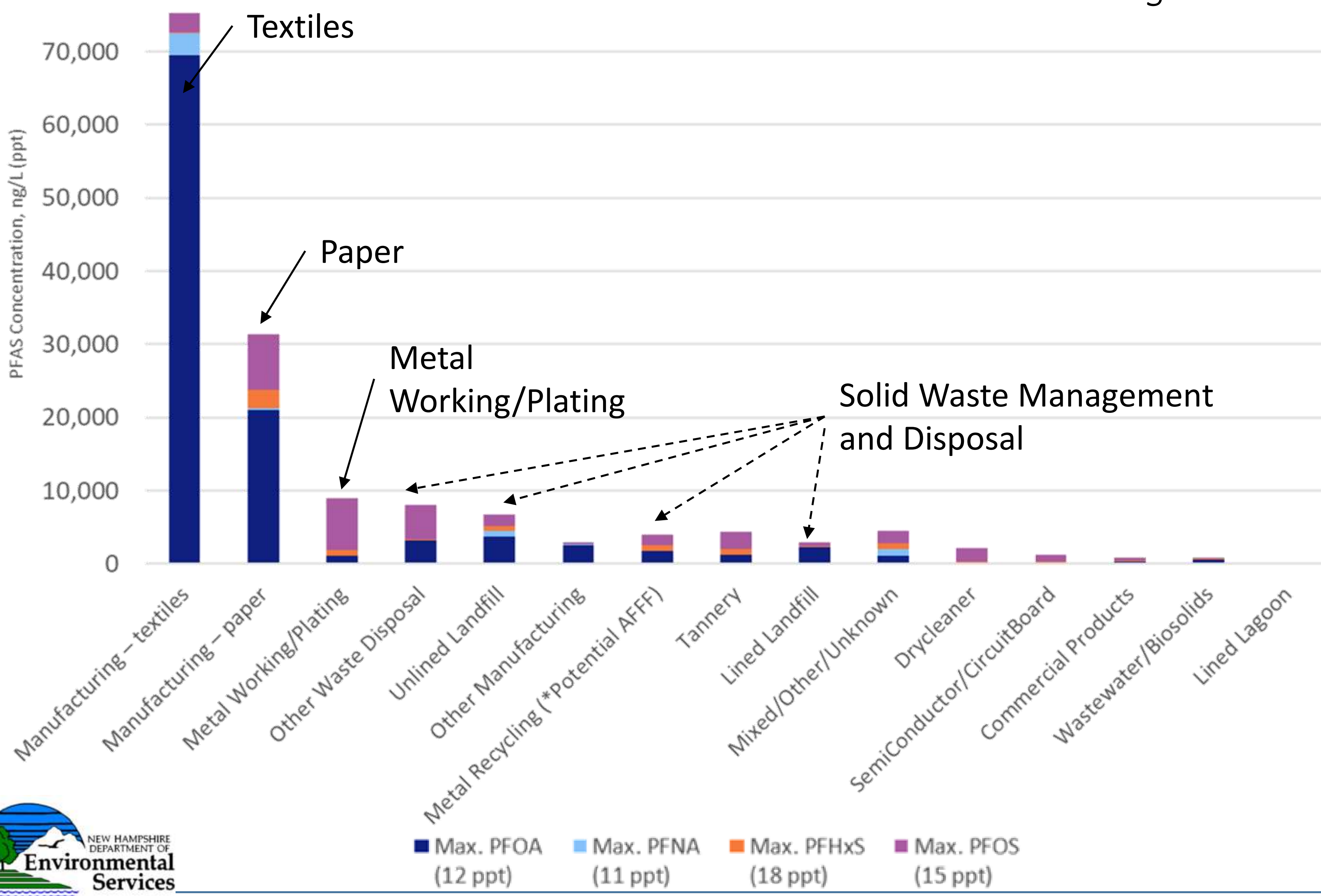
Approximate data through 07/31/2019

Waste Sites – Maximum Groundwater Concentrations – *excluding AFFF*



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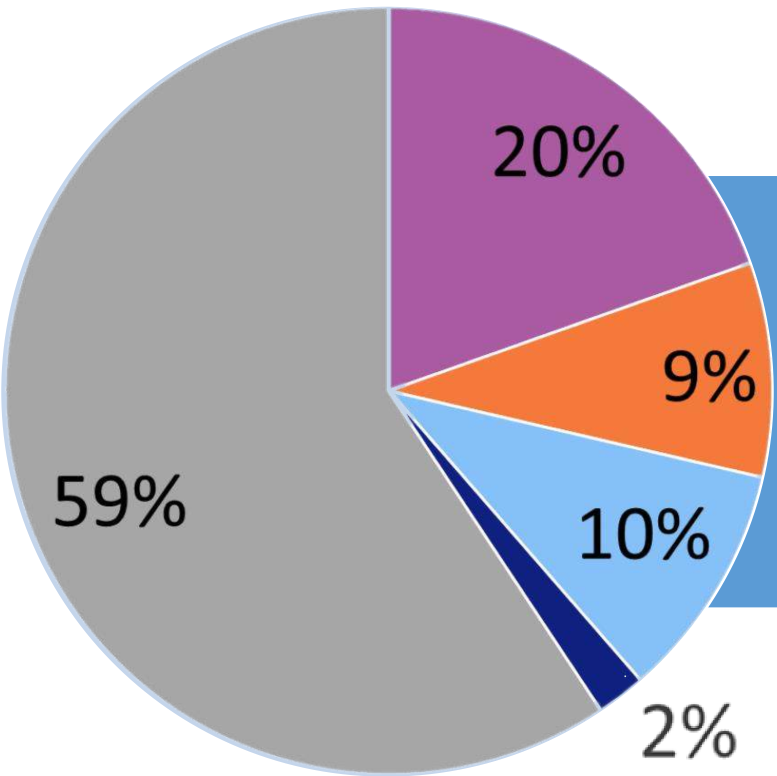
Approximate data through 07/31/2019

HWRB PFAS Data



Open HWRB Sites

Approx. 215 of 530 sites (state, CERCLA, Brownfields, landfills) have screened for PFAS

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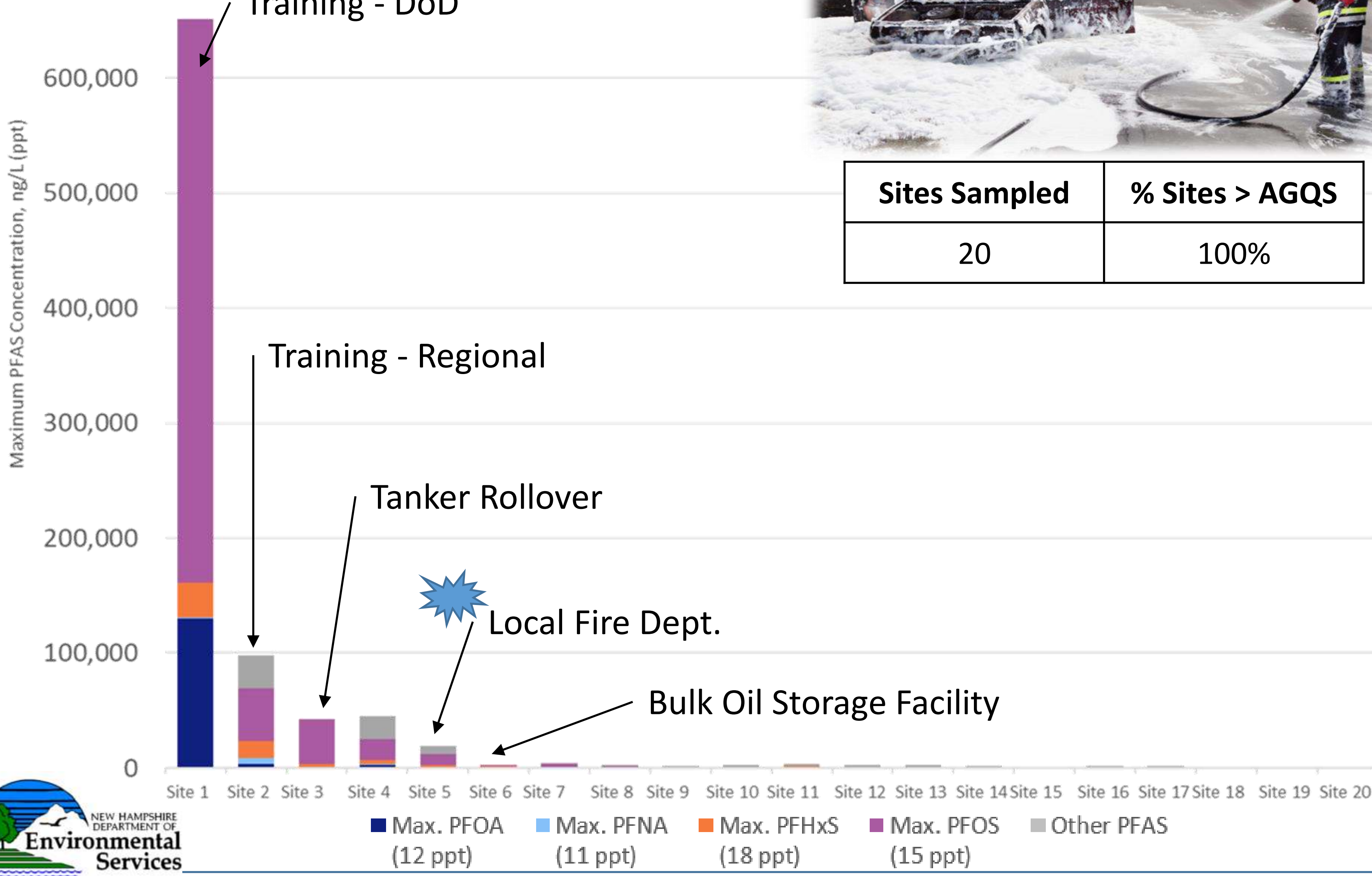
Approximate data through 07/31/2019

AFFF Sites



Sites Sampled	% Sites > AGQS
20	100%

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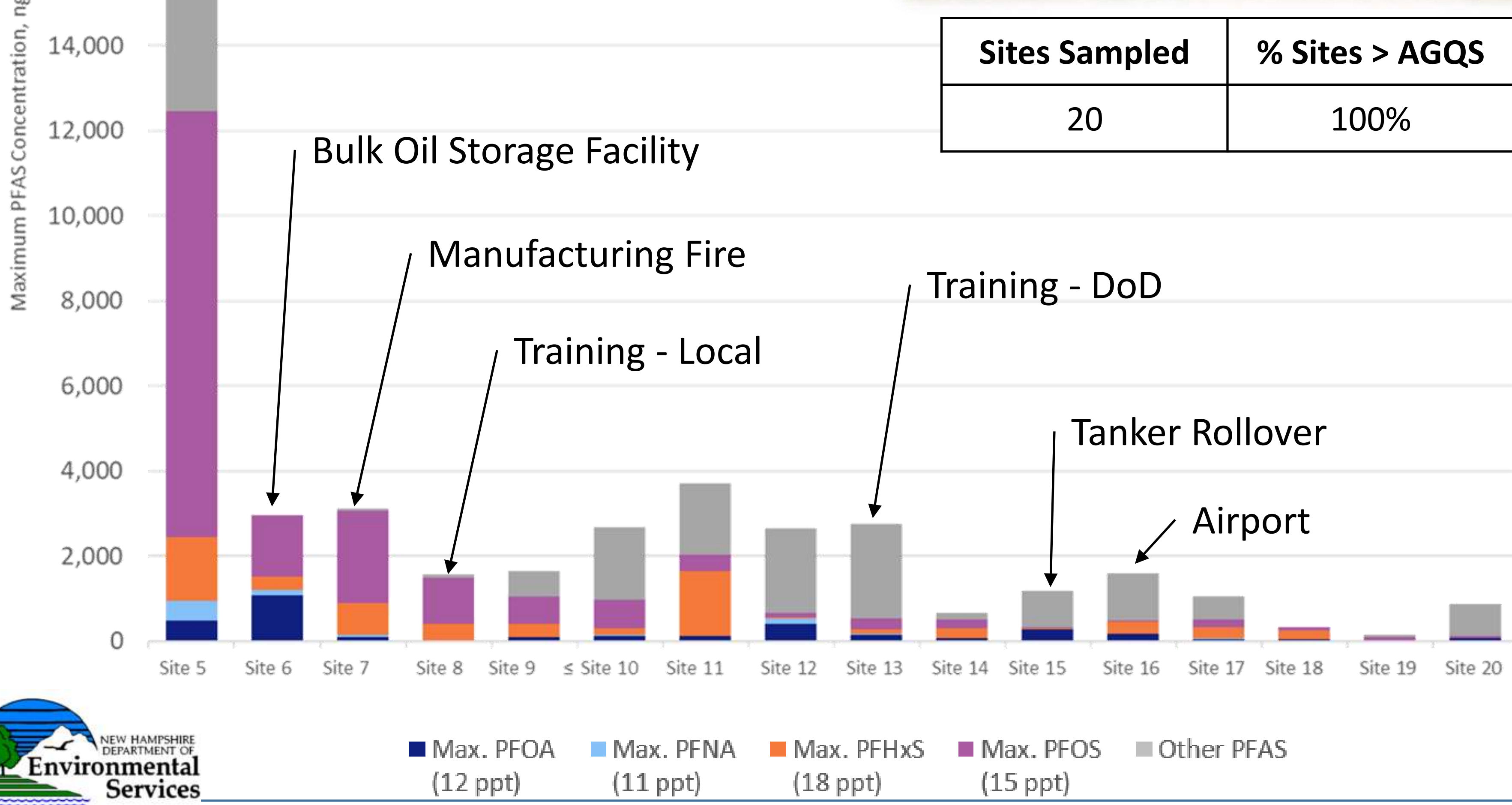
Approximate data through 07/31/2019

AFFF Sites, *continued*

Sites Sampled	% Sites > AGQS
20	100%



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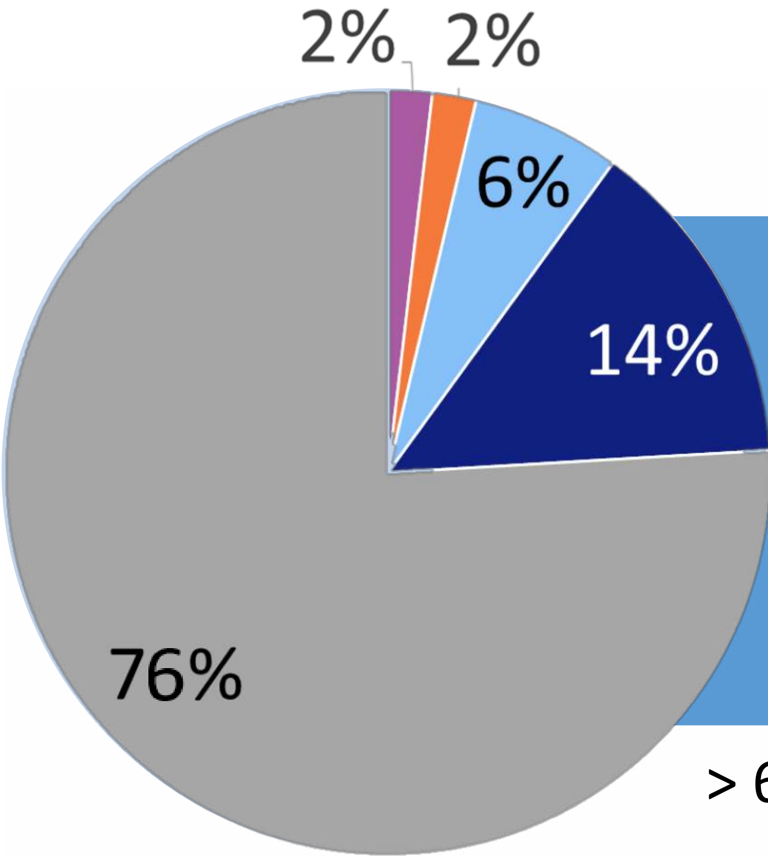
Approximate data through 07/31/2019

Fire Station Water Supply Well Sampling Initiative



Private Wells Serve 171 (of 237) Stations

2016: Foam use survey

2017: Recommendation to test

2019: Screening effort

> 65 Stations Have Screened for PFAS

■ >70 ppt AGQS ■ >New AGQS and <70 ppt AGQS
■ <New AGQS ■ Non-Detect ■ Not Sampled

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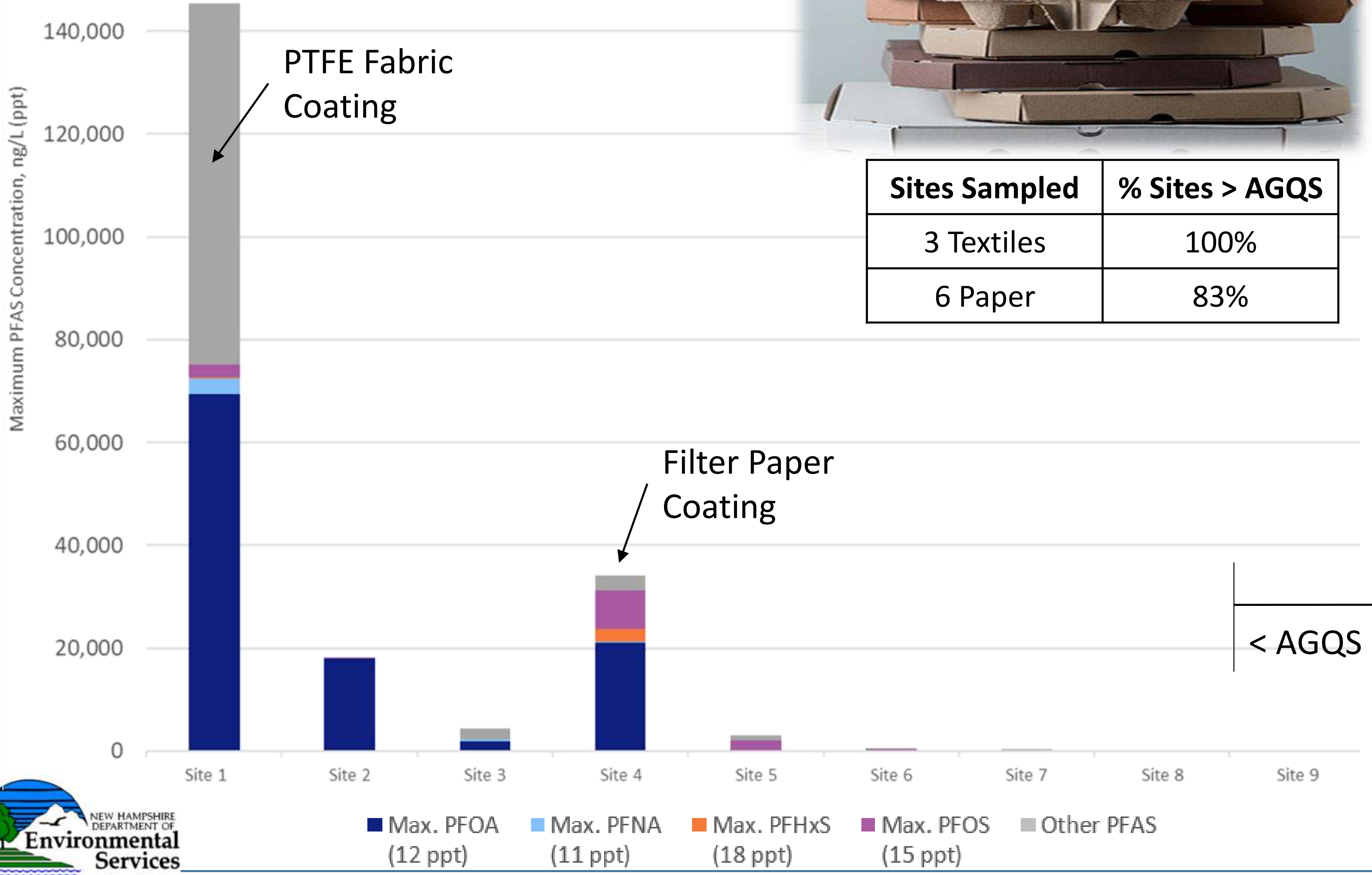
Approximate data through 07/31/2019

Textile / Paper Coating Sites

Sites Sampled	% Sites > AGQS
3 Textiles	100%
6 Paper	83%



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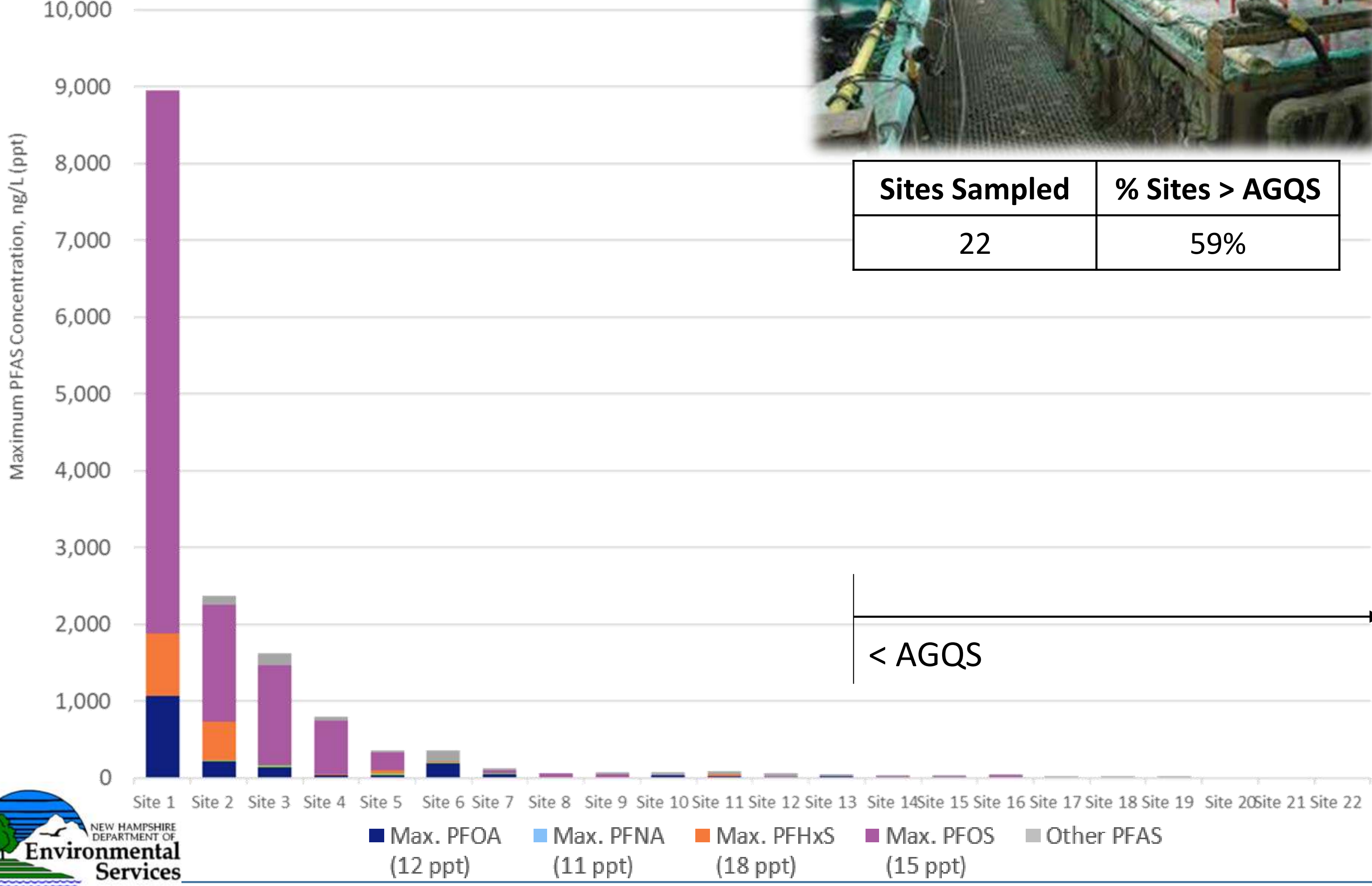
Approximate data through 07/31/2019

Metal Working, Plating, & Machining Sites

Sites Sampled	% Sites > AGQS
22	59%



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Approximate data through 07/31/2019

Dry Cleaning Sites

Sites Sampled	% Sites > AGQS
21	76%

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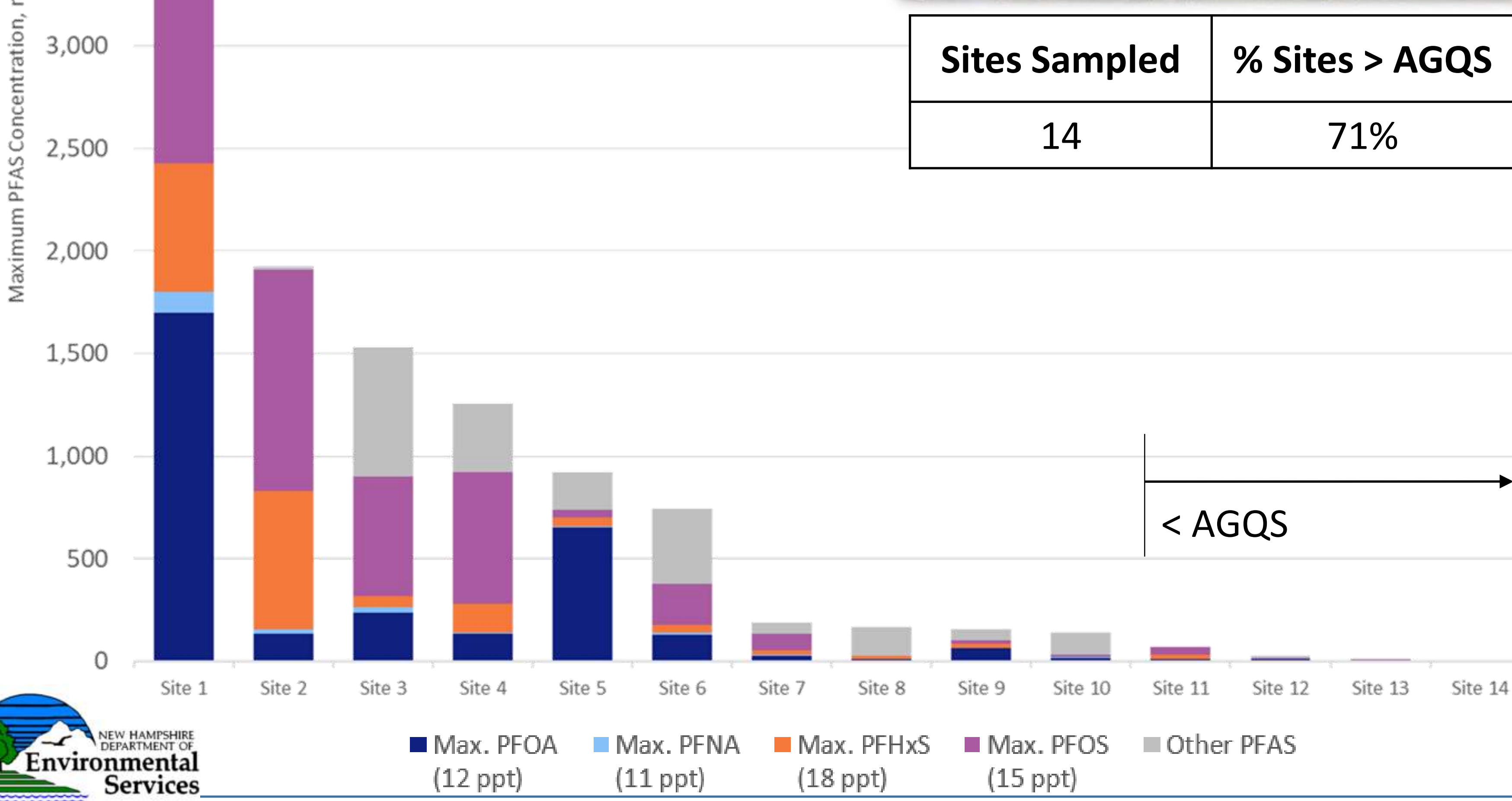
Approximate data through 07/31/2019

Metal Recycling

Sites Sampled	% Sites > AGQS
14	71%



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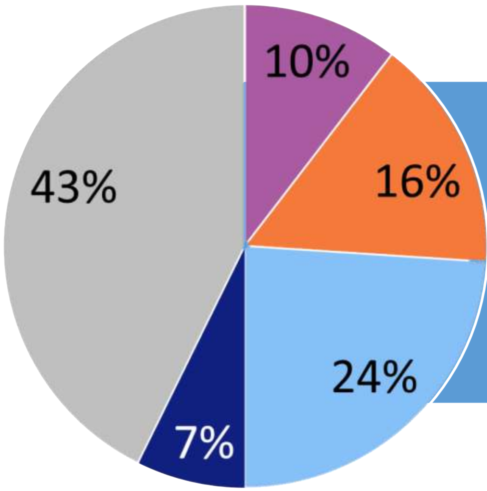
Approximate data through 07/31/2019

HWRB/DWGB PFAS Data

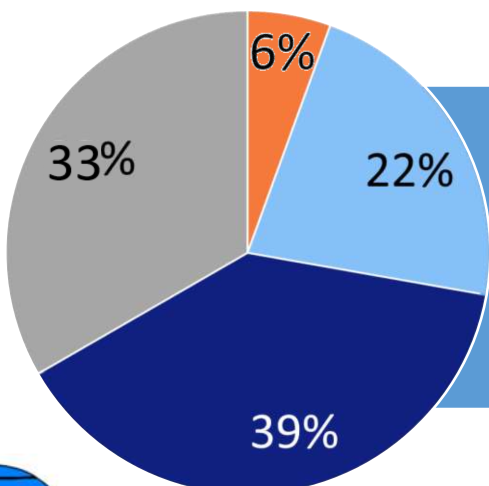
Maximum Wastewater-Related Impacts in Groundwater Monitoring Wells

(Not compliance boundary violations)



Groundwater Discharge Permit Sites

Wastewater Disposal to Groundwater (~ 96)



Groundwater Release Detection (RD) Permit Sites

Lined Lagoons (~ 18)

■ >70 ppt AGQS ■ >New AGQS and <70 ppt AGQS

■ <New AGQS ■ Non-Detect ■ Not Sampled

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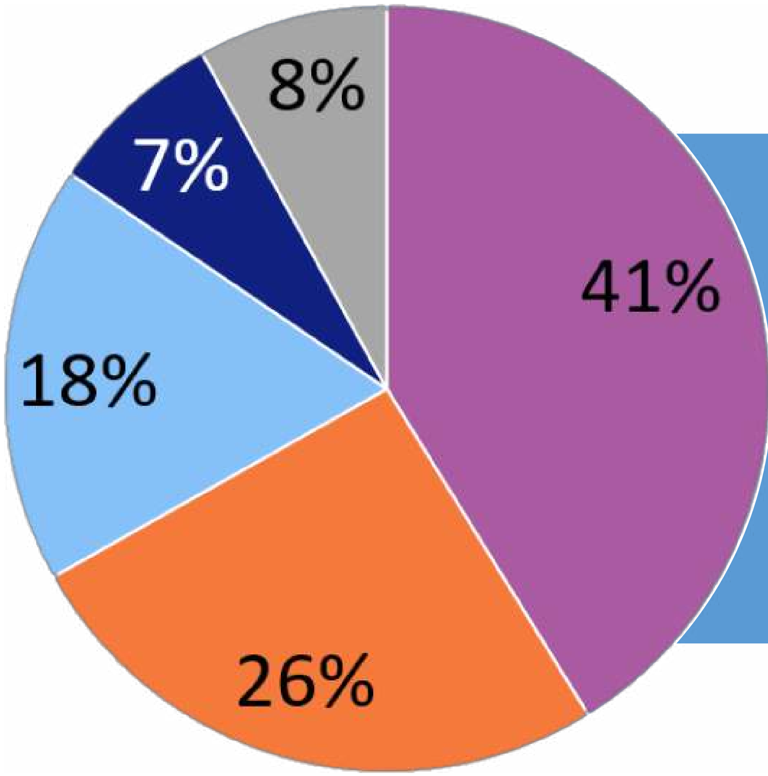
Approximate data through 07/31/2019

HWRB PFAS Data



MSW Landfills

(Lined and Unlined)

172 of 187 Screened for PFAS

>70 ppt AGQS
>New AGQS and <70 ppt AGQS
<New AGQS
Non-Detect
Not Sampled

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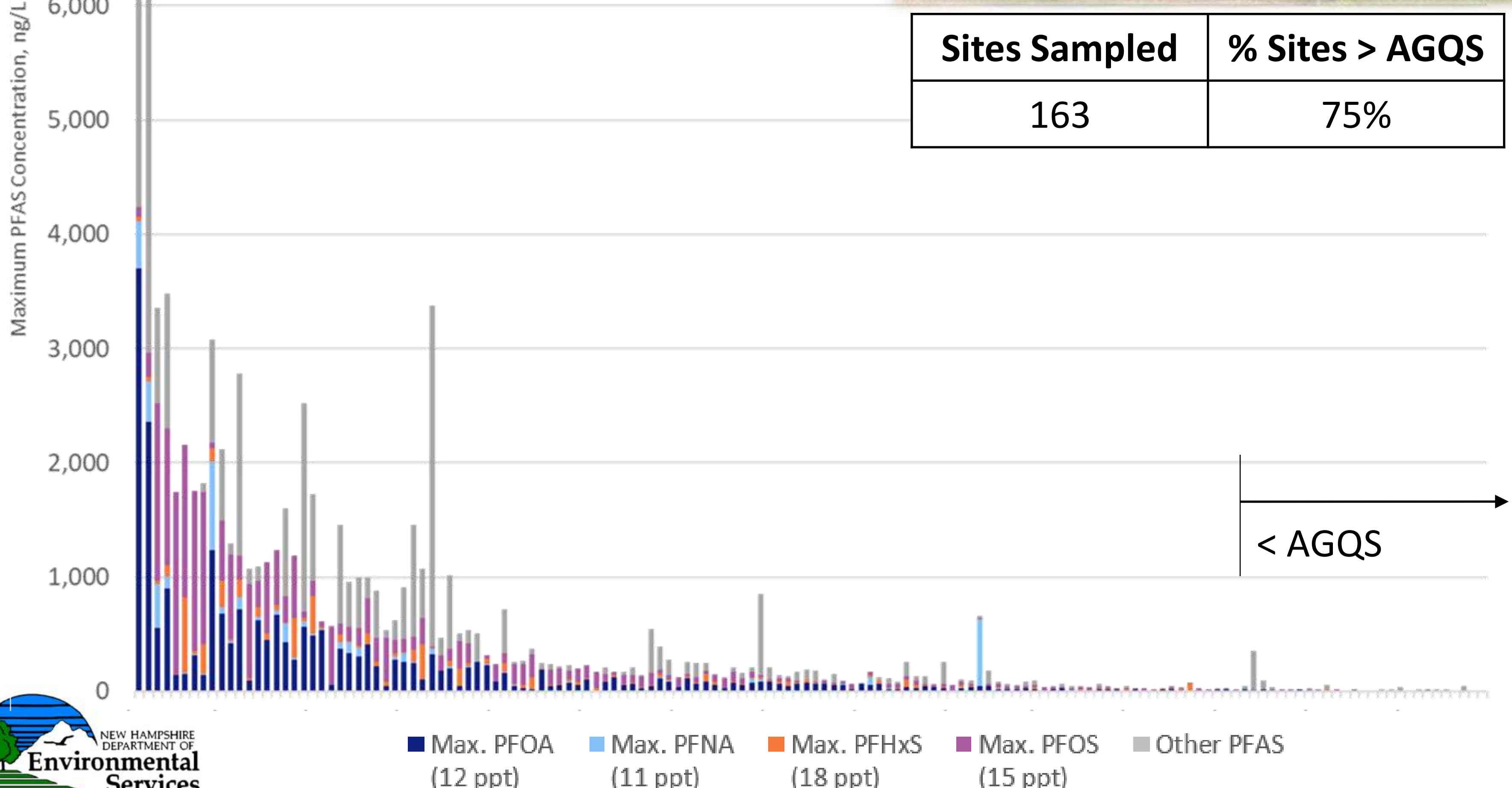
Approximate data through 07/31/2019

Unlined Landfills

Sites Sampled	% Sites > AGQS
163	75%



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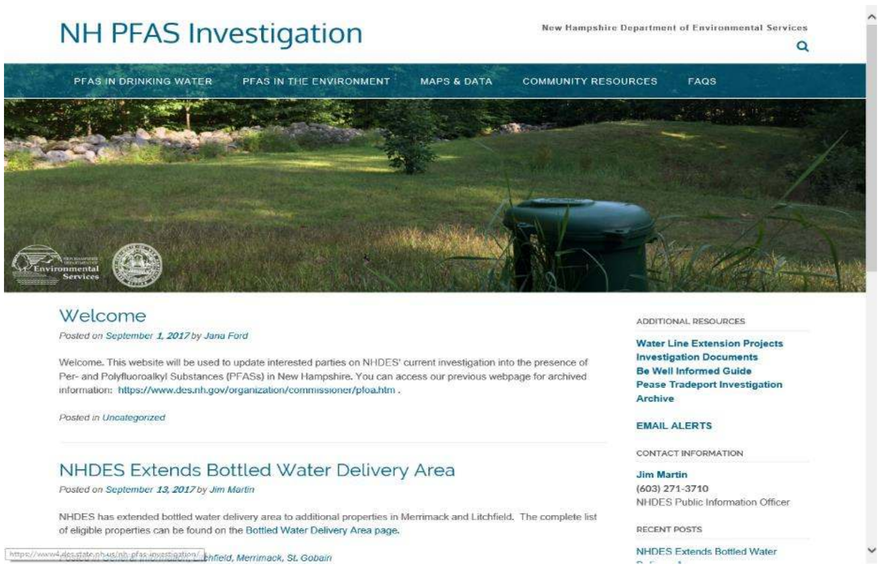
Approximate data through 07/31/2019

VI. PFAS Background References

NHDES Website

https://www4.des.state.nh.us/nh-pfas-investigation/



ITRC

- Fact Sheets

  https://pfas-1.itrcweb.org/

- Technical Guidance Document (2020)
- Education and training

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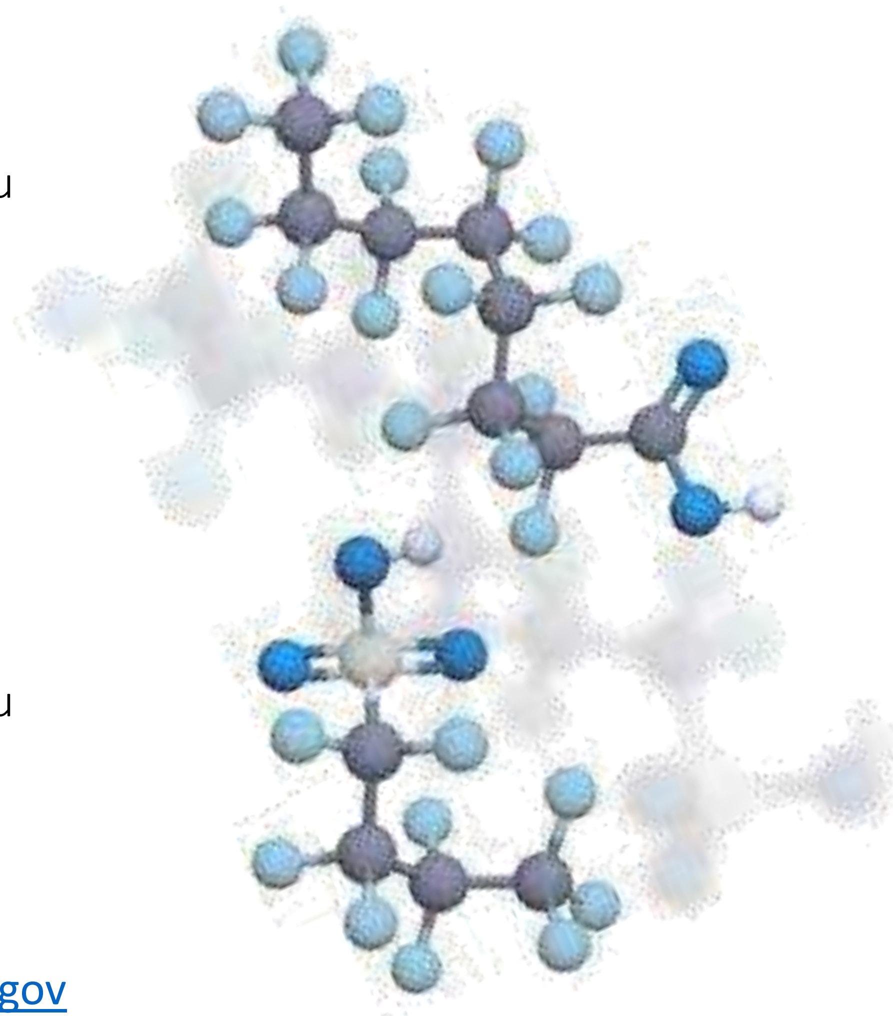

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Proposed (and Now Adopted) PFAS Maximum Contaminant Levels & Ambient Groundwater Quality Standards:

How did NH get here, and where are other States?

Jonathan M. Ali, Ph.D.
2019 New Hampshire Waste & Contaminated Sites Conference
September 11th, 2019

Presentation Overview

1. **Introductions & New Hampshire Context for MCLs/AGQS**

2. **NH's Health-Based Risk Assessment**
   - **Hazard Identification**
   - **Reference Dose (RfD) Derivation**
   - **Exposure Assumptions**
   - **Application of Minnesota's Breastfeeding Model**
   - **Resulting MCLs/AGQS**

3. **Where are other agencies?**

4. **Questions**

Permitting & Environmental Health Bureau Team

Jonathan Ali
Toxicologist

Guy at the mic

Mary Butow
Health Risk Assessor

David Gordon
Health Risk Assessor

(currently doesn't have a picture available in the staff directory)

New Hampshire Context for MCLs/AGQS

Response to previous identification of impacted sites, specifically drinking water, in **Southern NH** and the **Seacoast**.

SB309 Passed in the Summer of 2018.

Facilitated the establishment of Drinking Water Maximum Contaminant Levels (MCLs/AGQS) for four PFAS:

- Perfluorooctanoic acid (PFOA)
- Perfluorononanoic acid (PFNA)
- Perfluorooctane sulfonic acid (PFOS)
- Perfluorohexane sulfonic acid (PFHxS)

Initial proposal of MCLs/AGQS due January 1st, 2019.

SB309 also granted NHDES additional staff including: a Human Health Risk Assessor and a Toxicologist

Per the CDC's **Agency for Toxic Substances and Disease Registry** (ATSDR) draft toxicity profile on PFAS (ATSDR, 2018), suspected health outcomes include:

Rodent Experiments

- Immune system modulation
- Altered lipid metabolism
- Liver stress and inflammation
- Altered liver enzyme levels
- Thyroid disruption
- Reduced birth weight
- Fetal skeletal defects
- Fetal loss (death)
- Neurobehavioral defects
- Delayed mammary gland development
- Liver, testicular & kidney cancer

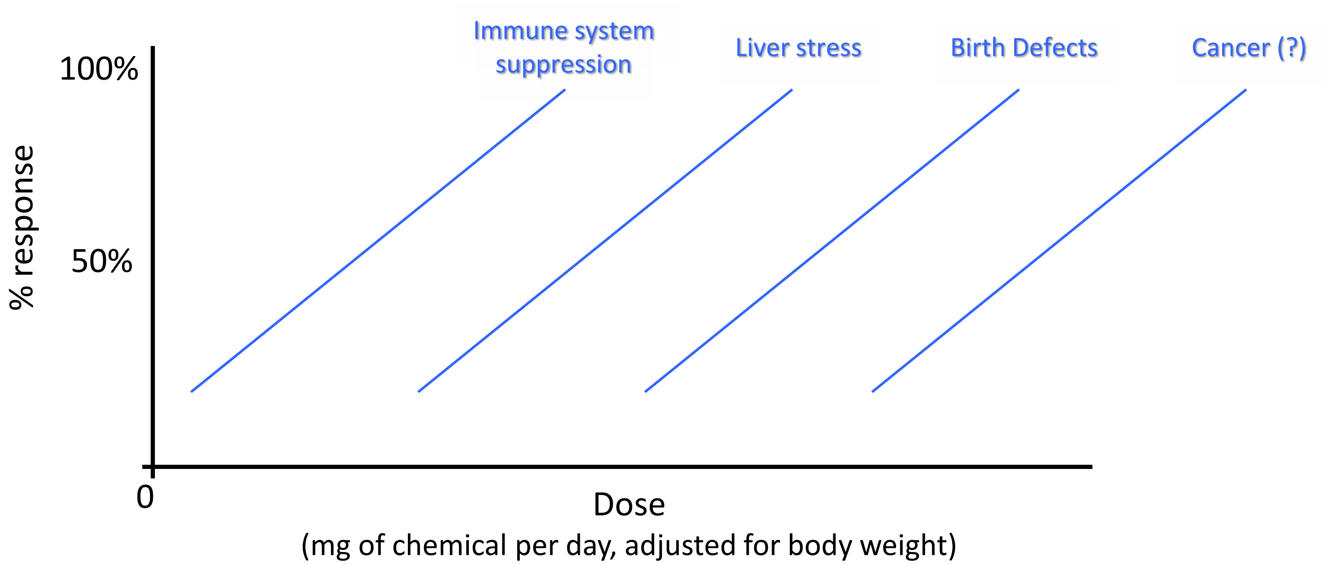
?

Human Epidemiology

- **Immune system modulation**
- **Altered lipid metabolism**
- **Altered liver enzyme levels**
- **Altered thyroid hormone levels**
- Altered behavior in infants, children & adolescents
- **Infertility in women**
- Reduced birth weight
- Potentially testicular & kidney cancer

Health-Based Risk Assessment: Hazard Identification

A Conceptual Example of NHDES Approach to Hazard Identification & Dose Considerations



Health-Based Risk Assessment: RfD Derivation

A **Reference Dose (RfD)** is:

> "An estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime." – EPA 2002

RfDs are not synonymous to ATSDR minimal risk levels (MRLs).

Measured internal dose (blood concentration) from animal study ↓

Estimated external (orally administered) dose ↓

Used for the calculation of a drinking water or other environmental standards ↓

$$\frac{\textbf{Animal Serum (ng/mL)}}{\textbf{Total Uncertainty}} \times \textbf{Dosimetric Adjustment Factor (mL/kg–d)} = \textbf{Reference Dose (ng/kg–d)}$$

↑ **Accounts for animal-to-human differences and quality of studies**

Health-Based Risk Assessment: RfD Derivation

Animal toxicokinetics ≠ Human toxicokinetics

Significant half-life differences result is disparate internal (serum) dosimetry of PFAS.

Requires use of internal (serum) doses..

Internal Dose (ng/mL) × Dosimetric Adjustment Factor = External Dose (mg/kg-d)

EPA Science Advisory Board (SAB) and other U.S. agencies acknowledge this issue.

EPA. 2006. SAB review of EPA's draft risk assessment of potential human health effects associated with PFOA and its salts. U.S. Environmental Protection Agency. http://yosemite.epa.gov/sab/sabproduct.nsf/A3C83648E77252828525717F004B9099/$File/sab_06_006.pdf.

(*Ali et al., under review*) **Half-life Differences of PFHxS**

Reference	Sample Population	Sample Size & Sex	Half-Life Estimates for PFHxS	
Human Studies				
Li et al. 2018	Sweden	n = 30, ♀ n = 20, ♂	4.7 years 7.4 years	(95% CI 3.9-5.9) (95% CI 6.0-9.7)
Worley et al. 2017	USA	n = 30, ♀/♂	15.5 years	(estimate range 13.4-17.6)
Zhang et al. 2013	China	n = 66, ♀/♂ n = 30, ♀	35.0 years* 7.7 years**	
Spliethoff et al. 2009	USA	n = 240 ♀/♂	8.2 years	(95% CI 5.4-16.2)
Olsen et al. 2007	USA	n = 24, ♀ n = 2, ♂	8.5 years	(95% CI 6.4-10.6)
Animal Studies	**Species**			
Sundström et al. 2012	Cynomolgus Monkey	n = 3, ♀ n = 3, ♂	87 days 141 days	(SE ± 27) (SE ± 30)
Kim et al. 2016	Sprague-Dawley Rat	n = 5, ♀ n = 5, ♂	0.9-1.7 days 20.7-26.9 days	(averages) (averages)
Sundström et al. 2012	Sprague-Dawley Rat	n = 4, ♀ n = 4, ♂	1.6 days 28.7 days	(SE ± 0.1) (SE ± 0.6)
Benskin et al. 2009	Sprague-Dawley Rat	n = 4, ♂	15.9 days	
Sundström et al. 2012	CD-1 Mice	n = 4, ♀ n = 4, ♂	24.9-26.8 days 28.0-30.5 days	(averages) (averages)

Health-Based Risk Assessment: RfD Derivation

External (oral) doses from animal studies are not acceptable for long-chain PFAS risk assessment.

The **dosimetric adjustment factor (DAF)** utilized current methodology to account for the remarkably long physiological half-lives of PFAS.

Often chemical specific, but data is limited for PFAS

$$\text{Volume of Distribution (mL/kg)} \times \frac{\text{Ln(2)}}{\text{Half–life (days)}} = \text{DAF (mL/kg–d)}$$

Estimates based on populations with elevated environmental exposure to PFAS

Other dosimetric considerations included:
Use of ¾ Body Weight Adjustment
- *Failed to account for half-lives*

Uncertainty related to other human half-life estimates base don epidemiology (e.g., **Convertino et al. 2018**)
- *Failed to account for saturation of renal transporters likely responsible for PFAS reabsorption*
- *Serum levels in late-stage cancer patients were 90,000-120,000 x higher than background levels*

Health-Based Risk Assessment: RfD Derivation

Uncertainty Factors (UFs) were applied

Table 2. Interagency Differences in Uncertainty Factors. Summary of uncertainty factor allocations, RfDs and MRLs by government risk assessment groups.

Specific Uncertainty Factors	ATSDR[a] (MRLs)	US EPA[b,c] (RfD)	TX CEQ[d] (RfD)	MN DOH[e-g] (RfD)	NJ DWQI[h-j] (RfD)	NH DES (RfD)	NY DOH[k] (RfD)
PFOA							
Principal Study	Koskela et al. 2016	Lau et al. 2006	Macon et al. 2011	Lau et al. 2006	Loveless et al. 2006	Loveless et al. 2006	Macon et al. 2011
Human Variability	10	10	10	10	10	10	10

Table 2. Interagency Differences in Uncertainty Factors. Summary of uncertainty factor allocations, RfDs and MRLs by government risk assessment groups.

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PFOA							
Principal Study	Koskela et al. 2016	Lau et al. 2006	Macon et al. 2011	Lau et al. 2006	Loveless et al. 2006	Loveless et al. 2006	Macon et al. 2011
Human Variability	10	10	10	10	10	10	10
Interspecies Differences	3	3	1	3	3	3	3
Duration of Exposure	1	1	1	1	1	1	1
LOAEL to NOAEL	10	10	30	1	1	1	1
Database Insufficiency	1	1	1	3	10	3	3
Total Uncertainty Factor	300	300	300	100	300	100	100
RfD (ng/kg-d)	3.0	20.0	12.0	18.0	2.0	6.1	1.5

LOAEL to NOAEL	1	-	3	1	-	1	-
Database Insufficiency	10	-	10	10	-	3	-
Total Uncertainty Factor	300	-	300	300	-	300	-
RfD (ng/kg-d)	20.0		3.8	9.7		4.0	

n.a. indicates the specific compound was not assessed or reported on by the specific agency.
[a] ATSDR, 2018b. Draft Toxicological Profile for Perfluoroalkyls
[b] U.S. EPA, 2016a. Health Effects Support Document for Perfluorooctanic Acid (PFOA)
[c] U.S. EPA, 2016b. Health Effects Support Document for Perfluorooctane Sulfonate (PFOS)
[d] TX Commission on Environmental Quality (TXCEQ), 2016. Perfluoro Compounds (PFCs): available at: https://www.tceq.texas.gov/assets/public/implementation/tox/evaluations/pfcs.pdf
[e] Minnesota Department of Health (MDH), 2018. Toxicological Summary for: Perfluorooctanoate.
[f] Minnesota Department of Health (MDH), 2019a. Toxicological Summary for: Perfluorooctane sulfonate.
[g] Minnesota Department of Health (MDH), 2019b. Toxicological Summary for: Perfluorohexane sulfonate.

Perfluorooctanoic acid (PFOA) RfD Derivation

Animal Starting Point (Internal Dose and Effect)

Animal Serum Level
(Benchmark Model, NJDWQI calculation)

Increased relative liver weight, or the onset of hepatotoxicity — 4,351 ng/mL

Uncertainty Factors

Human-to-Human Variation	10
Rodent versus Human Sensitivity (assumes humans are more sensitive than mice)	$10^{0.5}$
Database Uncertainty (suspected growth & immune effects)	$\times 10^{0.5}$
Total Uncertainty Factor	100

Internal Target Serum Level →

4,351 ng/mL
÷ 100
43.5 ng/mL

Estimation of Human External Dose

Dosimetric Adjustment Factor (DAF)

Converts the internal blood dose (above) to an external (oral) dose of the chemical.

$$DAF = Vd \times \left(\frac{Ln2}{\text{Halflife (days)}}\right)$$

$$DAF = 0.17\ L/kg \times \left(\frac{Ln2}{\mathbf{840\ days}}\right) = 1.40\text{x}10^{-4}\ L/kg\text{-}d$$

Assumed a **2.3 year half-life**

43.5 ng/mL
$1.40\text{x}10^{-4}$ L/kg-d
× 1,000 mL/L
6.1 ng/kg-d

PFOA RfD, 6.1 ng/kg-d

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Health-Based Risk Assessment: RfD Derivation

RfDs for the four evaluated PFAS in comparison to values from other agencies.
All values below are presented in **ng/kg-d**

Specific PFAS	NHDES (RfD)	NJDWQI (RfD)	US EPA 2016 (RfD)	ATSDR 2018 (draft MRL)	EFSA 2019 (draft RfD)
PFOA	**6.1**	2.0	20.0	3.0	0.8
PFOS	**3.0**	1.8	20.0	2.0	1.8
PFHxS	**4.0**	-	-	20	-
PFNA	**4.3**	0.73	-	3.0	-

USEPA. 2016. Drinking Water Advisory for Perfluoroctanoic acid (PFOA).
USEPA. 2016. Drinking Water Advisory for Perfluorooctane sulfonic acid (PFOS).
ASTDR. 2018. Toxicological Profile for Perfluoroalkyls Draft for Public Comment. https://www.atsdr.cdc.gov/toxprofiles/tp.asp?id=1117&tid=237
EFSA. 2018. http://www.efsa.europa.eu/en/press/news/181213

Health-Based Risk Assessment: Exposure Assumptions

Exposure characterization considers how much PFAS is permissible given:

1. Protective assumptions about water ingestion rates
2. Estimation of other non-drinking water sources of exposure (relative source contribution).

The U.S. EPA (2016) assumed:

- water ingestion rate of the 90th percentile of lactating women, and
- that 20% of exposure is through drinking water
- Lifetime Health Advisory for PFOA & PFOS at 70 ng/L

These assumptions vary by state agencies, sometimes resulting in different drinking water values.

image: medium.com

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Health-Based Risk Assessment: Exposure Assumptions

$$\frac{\text{RfD (ng/kg–day)} \times \text{Relative Source Contribution (\%)}}{\text{Water Ingestion Rate (L/kg–day)}} = \text{Maximum Contaminant Level (ng/L)}$$

<table>
<tr><th>Specific PFAS</th><th>Reference Dose (ng/kg-day)</th><th>Water Ingestion Rate (L/kg-day)</th><th>Relative Source Contribution</th><th>Proposed MCL (ng/L)</th></tr>
<tr><td>PFOA</td><td rowspan="4">These values changed in response to technical comments</td><td rowspan="4">These values changed in the EPA Exposure Factor Handbook (Feb 2019)</td><td rowspan="4">These values changed in response to technical comments</td><td>38</td></tr>
<tr><td>PFOS</td><td>70</td></tr>
<tr><td>PFHxS</td><td>85</td></tr>
<tr><td>PFNA</td><td>23</td></tr>
</table>

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Health-Based Risk Assessment: Exposure Assumptions

$$\frac{\text{RfD (ng/kg–day)} \times \text{Relative Source Contribution (\%)}}{\text{Water Ingestion Rate (L/kg–day)}} = \text{Maximum Contaminant Level (ng/L)}$$

Specific PFAS	Reference Dose (ng/kg-day)	Water Ingestion Rate (L/kg-day)	Relative Source Contribution	*Example* Drinking Water Value (ng/L)
PFOA	6.1	These values do not account for the transfer of PFAS across the placenta and into breastmilk.	50%	These values would result in unacceptable serum levels in breastfed infants.
PFOS	3.0		50%	
PFHxS	4.0		50%	
PFNA	4.3		50%	

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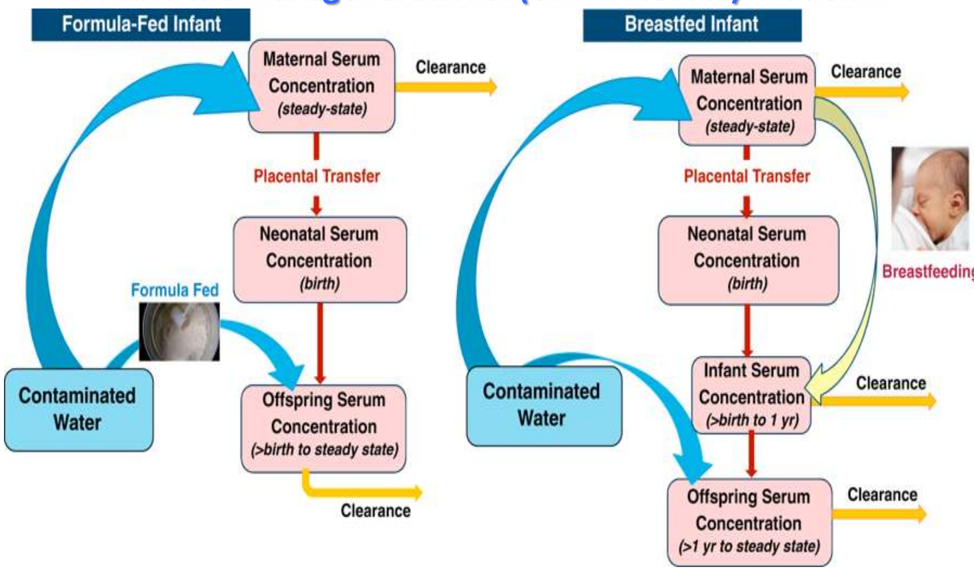
Health-Based Risk Assessment: Minnesota Model

What is the Transgenerational (or Minnesota) Model?



The conceptual diagram for the toxicokinetic model.
Image from: Goeden et al. (2019), *Journal of Exposure Science & Environmental Epidemiology* vol. 29, 183–195.

Excel-based model is available upon request from Minnesota Department of Health.

Human Half-life Assumptions

- NHDES applied **average** (**central tendency**) half-life estimates for PFOA (2.3 years), PFOS (3.4 years), PFNA (4.3 years) and PFHxS (4.7 years).
- NHDES did not apply the 95th percentile, or other high-end values derived from occupational exposures.

Placental & breastmilk transfer efficiencies

- NHDES applied **average** (**central tendency**) transfer efficiencies, similar to MDH and MIDHHS.

Duration of *exclusive* breastfeeding

- NHDES applied a **12-month exclusive breastfeeding duration (conservative)** for the modeled exposure scenarios.

Breastmilk & water ingestion rates

- NHDES applied the **95th percentile** (**conservative**) ingestion rates for water and breastmilk across life.

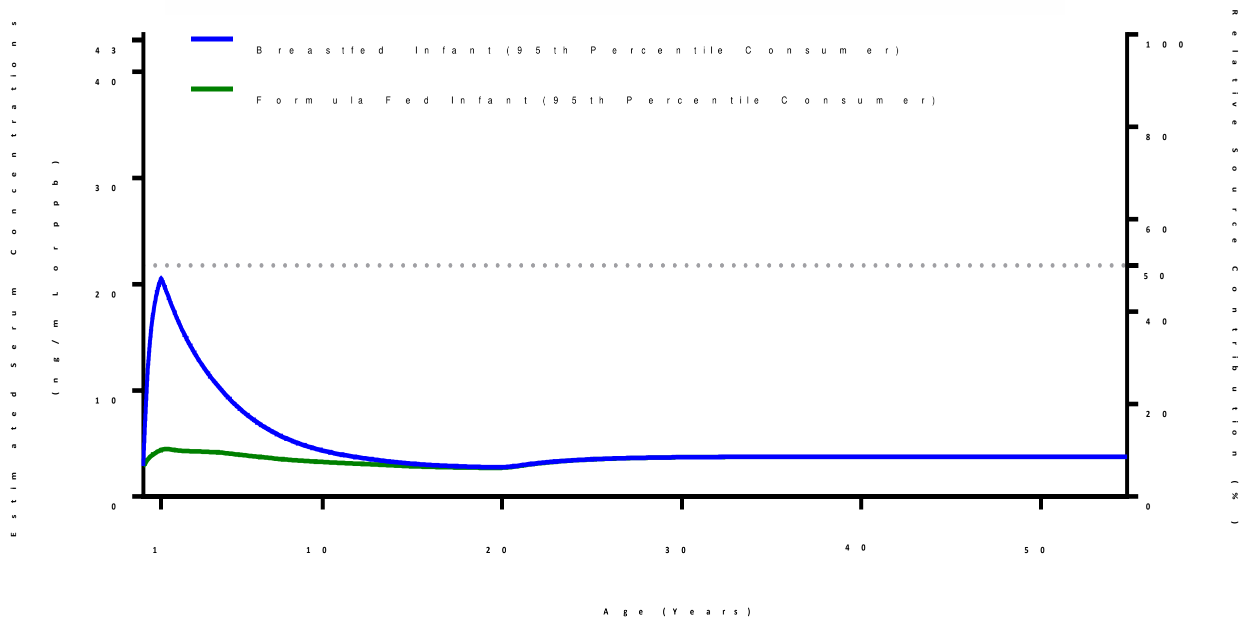
Values are summarized in Table 3 of the June Report.

Health-Based Risk Assessment: Minnesota Model

The model allows for the comparison of:

- predicted blood levels (left y-axis) to
- the % of allowable maximum dose (right y-axis).

Predicted Serum Concentrations of PFOA, MCL of 12 ng/L

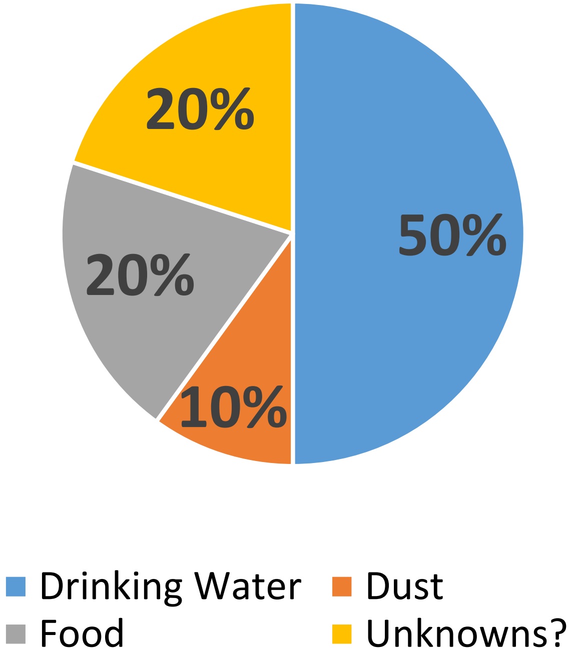


Health-Based Risk Assessment: Minnesota Model

This is **how we "budget" the daily dose (RfD)** for water versus non-drinking water sources of exposure.

- **20%** - Low and the default EPA recommendation when "we don't know". Results in the most restrictive MCL.
- **50%** - Consistent with values derived from NHANES to estimate background & EPA guidance
- **80%** -Results in a higher MCL value and assumes that other sources are not contributing to exposure (20% or less).

Relative Source Contribution
(example below for visualization purposes)



Health-Based Risk Assessment: Minnesota Model

20%

U.S. EPA (2016)
- 20% RSC for PFOA & PFOS for the lifetime health advisory of 70 ng/L, based on RfDs of 20 ng/kg-d.

Vermont - VTDOH (2016-2017)
- 20% RSC across all for health-based screening values (HBSVs).

New Jersey - NJDWQI (2017-2018)
- 20% RSC for PFOA & PFOS because of insufficient serum data (proposed MCL).
- 50% RSC for PFNA because of sufficient serum data from NHANES and a NJ community (MCL).

New York - NYDWQC (2018)
- ≤60% RSC for PFOA & PFOS recommendation based on serum data (proposed MCL).

Minnesota - MDH (2017-2019)
- 50% RSC for PFOA, PFOS & PFHxS in their model for (HBSVs).

Michigan - MIDHHS (2019)
- 50% RSC for PFOA, PFOS, PFNA & PFHxS in MDH's transgenerational model (HBSVs).

50-60%

How did the NHDES MCLs arrive at a 50% RSC?

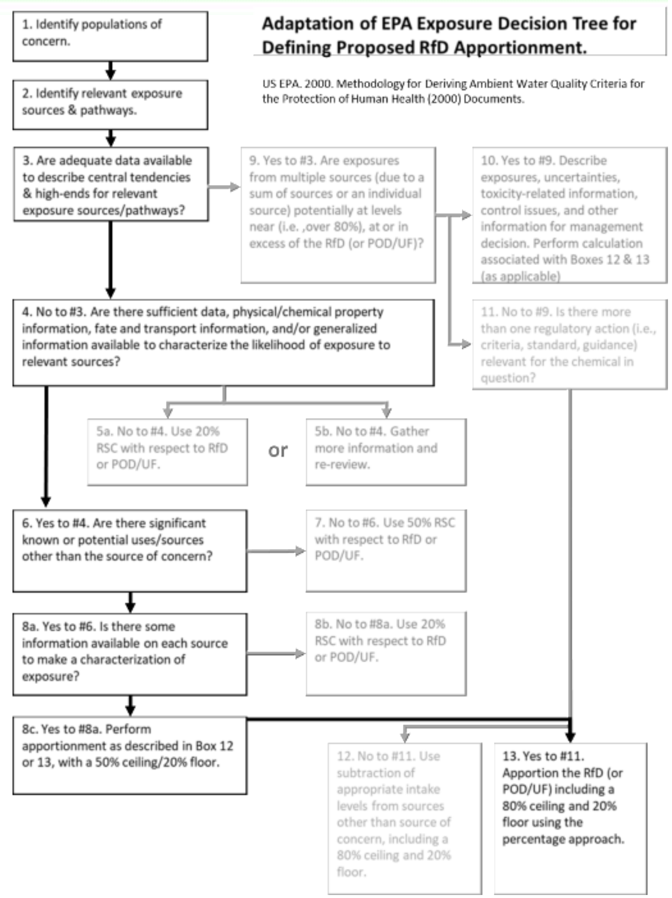
Health-Based Risk Assessment: Minnesota Model

NHDES referred to the EPA Decision Tree for determining the relative source contribution.

Arrived at a **50% ceiling** combined with apportionment (**subtraction method**) to derive chemical specific RSCs.

US EPA. 2000. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000) Documents.

Accessed online at: https://www.epa.gov/wqc/methodology-deriving-ambient-water-quality-criteria-protection-human-health-2000-documents



Health-Based Risk Assessment: Minnesota Model

In the initial proposal, NHDES estimated "background" using existing blood data. However, this value should reflect the typical non-drinking water exposures.

Used the EPA subtraction method:

$$\frac{\text{Target serum level (ng/mL)} - \text{Population background (ng/mL)}}{\text{Target serum level (ng/mL)}} = \text{RSC}$$

Using the NHANES (average) for PFOA:

$$\frac{43.5\ \text{ng/L} - 1.8\ \text{ng/L}}{43.5\ \text{ng/L}} = 0.96 \text{ or } 96\%$$

Using Adults from Southern NH (95th percentile) for PFOA:

$$\frac{43.5\ \text{ng/L} - 26.6\ \text{ng/L}}{43.5\ \text{ng/L}} = 0.39 \text{ or } 39\%$$

The use of the *NH-specific data likely overestimates* the background (non-drinking water) exposure.

But, the current lack of regulations on PFAS means an 80% RSC, especially for adults, is inadequately protective.

US EPA. 2000. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000) Documents.
Accessed online at: https://www.epa.gov/wqc/methodology-deriving-ambient-water-quality-criteria-protection-human-health-2000-documents

Health-Based Risk Assessment: Minnesota Model

Estimation of RSC Using NHANES Data & EPA Method

RSC estimates using the NHANES 2013-2014 dataset (summarized by Daly et al. 2018):

- **geometric mean (GM) and**
- **95th percentile.**

NHANES data more likely to reflect background exposure levels from non-drinking water sources.

Other sources remain a significant concern, so a 50% cap was applied.

	Reference Population	Reference Serum Level (ng/mL)	Target Serum Level (ng/mL)	Resulting RSC Allotment for Drinking Water (%)
PFOA	3-5 year olds (GM)	2.00	43.5	**95.4**
	6-11 year olds (GM)	1.89	43.5	**95.7**
	12-19 year olds (GM)	1.66	43.5	**96.2**
	3-5 year olds (95th percentile)	5.58	43.5	**87.2**
	6-11 year olds (95th percentile)	3.84	43.5	**91.2**
	12-19 year olds (95th percentile)	3.47	43.5	**92.0**
PFOS	3-5 year olds (GM)	3.38	24.0	**85.9**
	6-11 year olds (GM)	4.15	24.0	**82.7**
	12-19 year olds (GM)	3.54	24.0	**85.3**
	3-5 year olds (95th percentile)	8.82	24.0	**63.3**
	6-11 year olds (95th percentile)	12.40	24.0	**48.3**
	12-19 year olds (95th percentile)	9.30	24.0	**61.3**
PFNA	3-5 year olds (GM)	0.76	49.0	**98.4**
	6-11 year olds (GM)	0.81	49.0	**98.3**
	12-19 year olds (GM)	0.60	49.0	**98.8**
	3-5 year olds (95th percentile)	3.49	49.0	**92.9**
	6-11 year olds (95th percentile)	3.19	49.0	**93.5**
	12-19 year olds (95th percentile)	2.00	49.0	**95.9**
PFHxS	3-5 year olds (GM)	0.72	46.3	**98.4**
	6-11 year olds (GM)	0.91	46.3	**98.0**
	12-19 year olds (GM)	1.27	46.3	**97.3**
	3-5 year olds (95th percentile)	1.62	46.3	**96.5**
	6-11 year olds (95th percentile)	4.14	46.3	**91.1**
	12-19 year olds (95th percentile)	6.30	46.3	**86.4**

Health-Based Risk Assessment: Resulting MCLs/AGQS

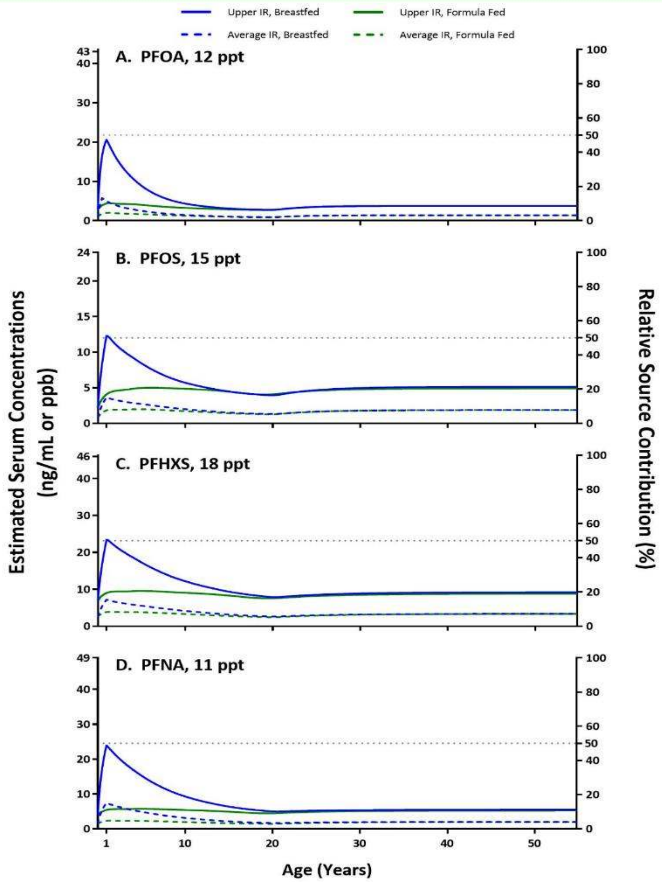
Given these **reference doses** and **exposure assumptions**, the proposed MCLs/AGQS are:

PFOA	**12 ng/L**
PFOS	**15 ng/L**
PFHxS	**18 ng/L**
PFNA	**11 ng/L**

Because of the unique properties of PFAS, accounting for breastmilk transfer is necessary.

The 50% RSC (upper limit) protects children from additional exposures to from other non-drinking water (or breastmilk) sources of PFAS.

Thus, these proposed MCLs are protective across all life stages for associated chronic health outcomes.



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Where are other agencies? – Feds & Other States

Specific PFAS	NH DES (MCLs)	NJ DWQI (MCLs)	NY DOH (MCLs)	MN DOH (HBGV)	MI DHHS (SL)	CA OEHHA (DWLC)	US EPA (LHA)	VT DEP (advisory)	CT DPH (advisory)	MA DEP† (proposed)
PFOA	12 ng/L	13 ng/L	10 ng/L†	38 ng/L	9 ng/L	0.1 ng/L	70 ng/L combined*	20 ng/L combined*	70 ng/L combined*	20 ng/L combined*
PFOS	15 ng/L	14 ng/L†	10 ng/L†	15 ng/L	8 ng/L	0.4 ng/L	*	*	*	*
PFHxS	18 ng/L	-	-	47 ng/L	84 ng/L	-	-	*	*	*
PFNA	11 ng/L	13 ng/L†	-	-	9 ng/L	-	-	*	*	*
PFHpA	-	-	-	-	-	-	-	*	*	*
PFDA	-	-	-	-	-	-	-	-	-	*

MCL= maximum contaminant Level HBGV = health-based guidance value SL = screening level LHA = lifetime health advisory
† Proposed value(s) DWLC = Drinking Water Limit for Cancer

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Where are other agencies? – Feds & Other States

Considerations Across States

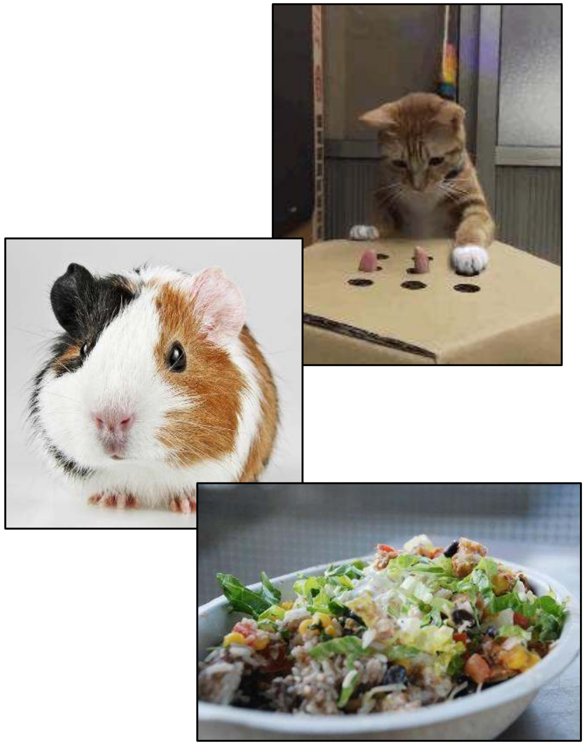
1. There is growing interest in class or sub-group regulation (tired playing whack-a-mole).

2. Emerging evidence of biological effects at lower doses. Are these relevant to human health?

3. Concern for contamination of other environmental media.

4. What role do food-related exposures play?

5. Are there more reliable PBPK models for environmentally-relevant exposures?



Acknowledgements

The New Hampshire Department of Environmental Services (NHDES) acknowledges the following groups for technical comments submitted by New Hampshire's:

- **residents and community stakeholders,**
- **academic institutions,**
- **community advocacy groups,**
- **representatives for the business community,**
- **and municipalities.**

Additionally, NHDES acknowledges the productive and professional discussions and information sharing by the following entities:

- **Connecticut Department of Public Health (CTDPH)**
- **Environmental Council of the States (ECOS) PFAS Caucus**
- **Federal-State Toxicology & Risk Analysis Committee (FSTRAC)**
- **Interstate Technology & Regulatory Council (ITRC) PFAS Working Group**
- **Massachusetts Department of Environmental Protection (MADEP)**
- **Michigan Department of Health & Human Services (MIDHHS)**
- **Minnesota Department of Health (MDH)**
- **New England Interstate Water Pollution Control Commission (NEIWPCC)**
- **New Jersey Department of Environmental Protection (NJDEP)**
- **Northeast Waste Management Officials' Association (NEWMOA)**

Questions?

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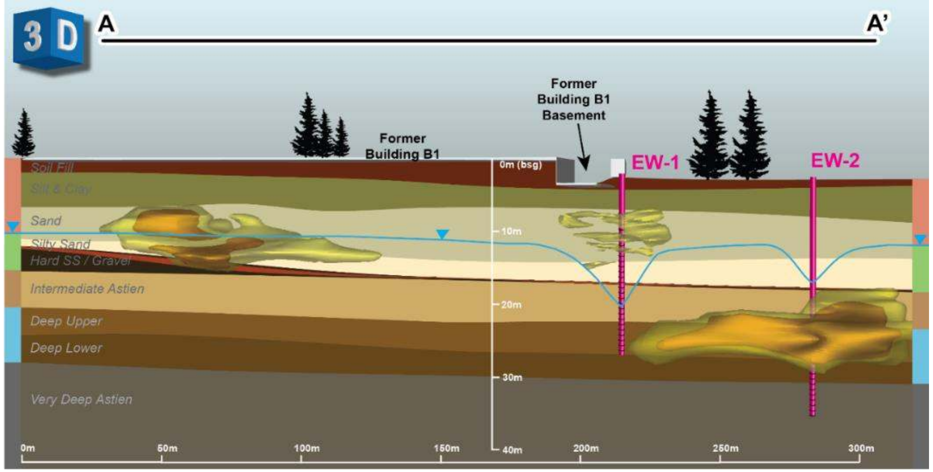
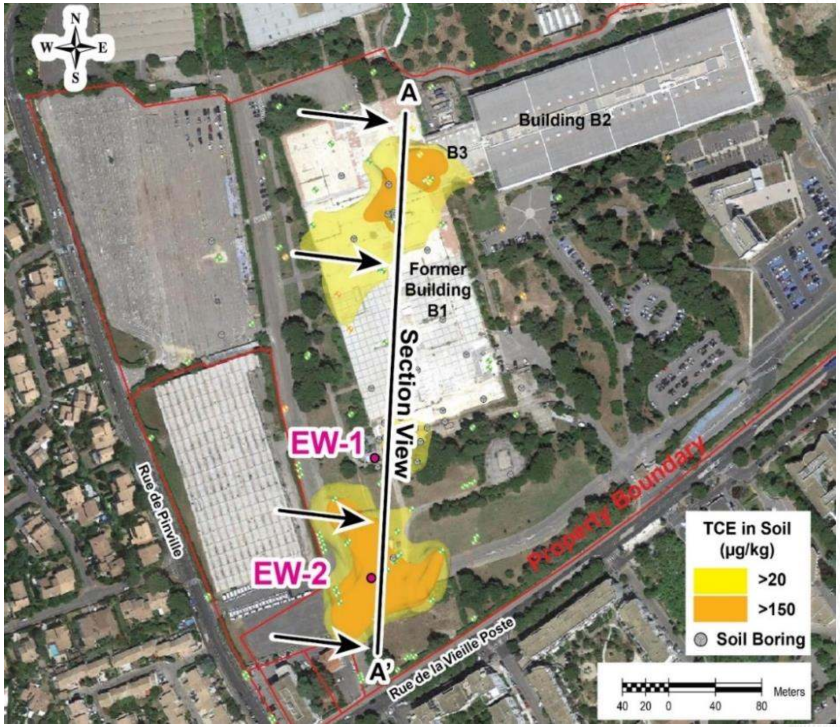
High Resolution Site Characterization and Data Visualization for Improved Remedial Alternatives Evaluation

Bradley A. Green, P.G.

Samuel L. Warner

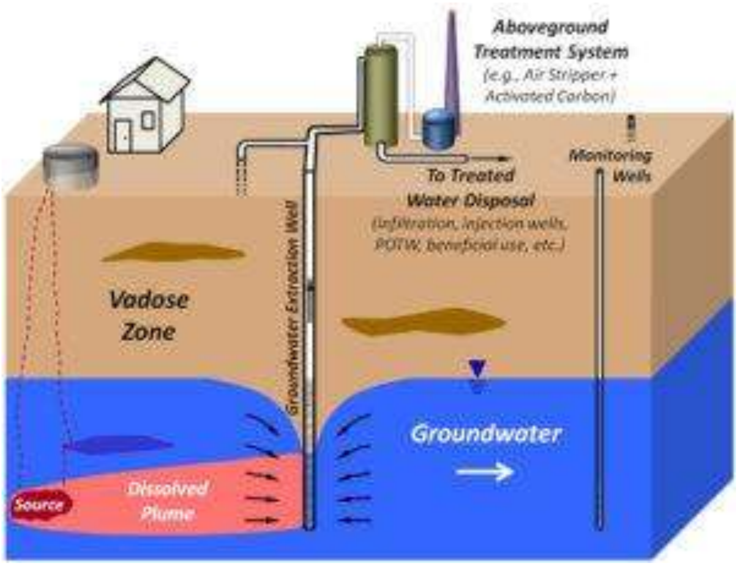




Agenda

- Key paradigm shifts in our understanding of contaminated sites
- Summary of high resolution methods with examples
- Case study in the value of high resolution data collection coupled with 3D renderings

1st Generation / Conventional investigation and remediation (e.g., MWs / EWs) approaches focus on transmissive zones in the NAPL and aqueous phases (1970s – 1990s)



http://hazmatmag.com/2017/10/performance-assessment-of-pump-and-treat-systems/

	Source Zone		Plume	
Phase/Zone	Low Permeability	Transmissive	Transmissive	Low Permeability
Vapor				
DNAPL			NA	NA
Aqueous				
Sorbed				

Sale and Newell, 2009

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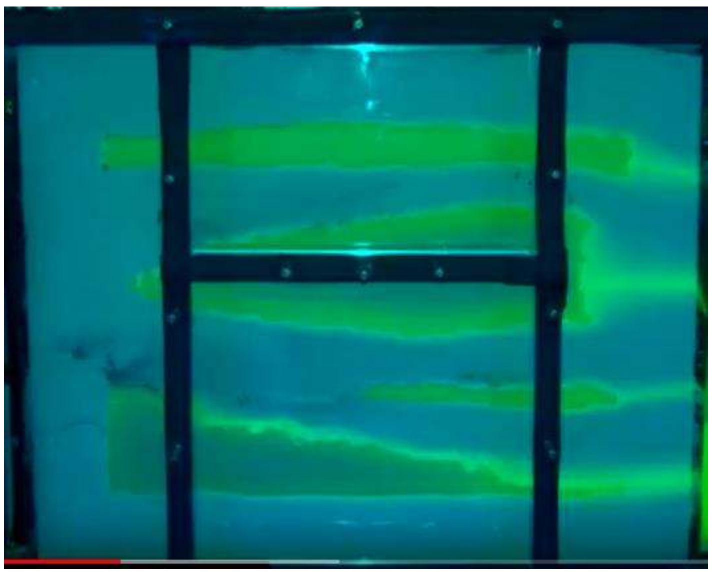
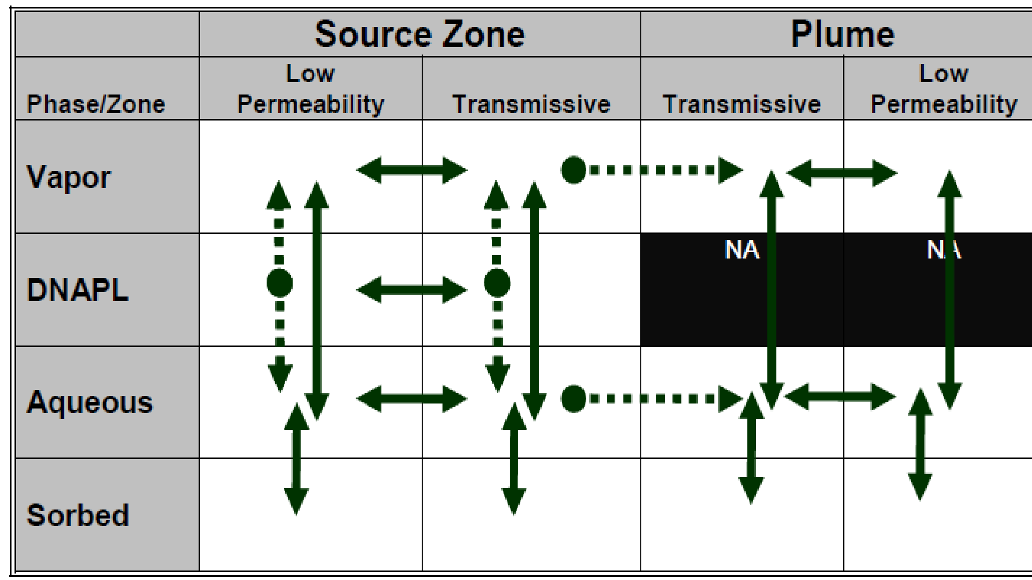
2nd Generation characterization (high-resolution) methods have helped establish that contaminant mass occurs in multiple phases, in particular within low permeability zones (1990s to mid 2000s)



https://www.youtube.com/watch?v=iLwsIjkVybU



Sale and Newell, 2009

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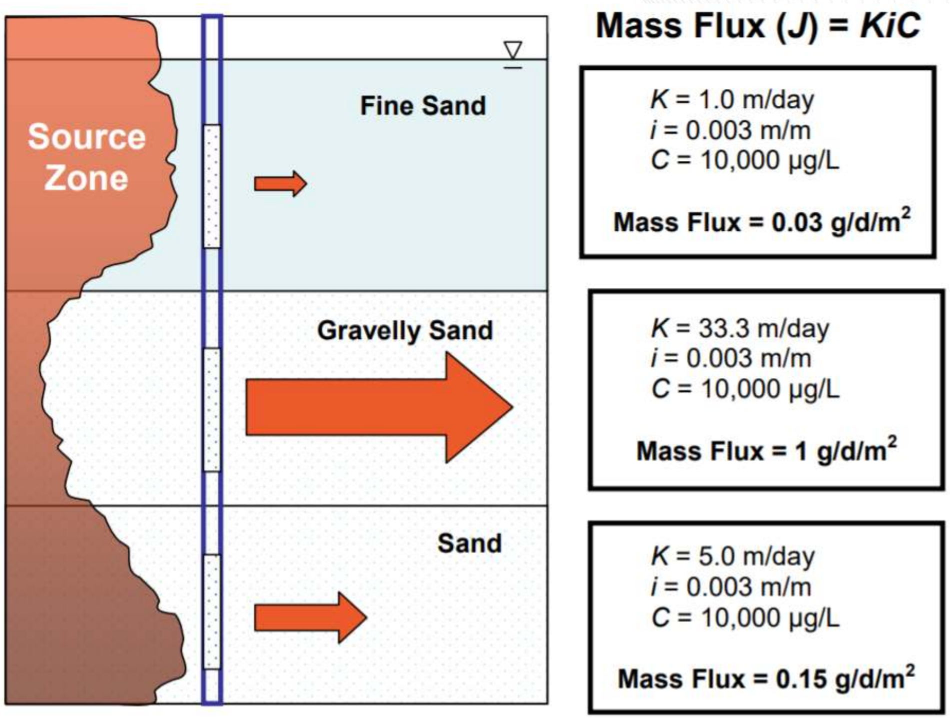
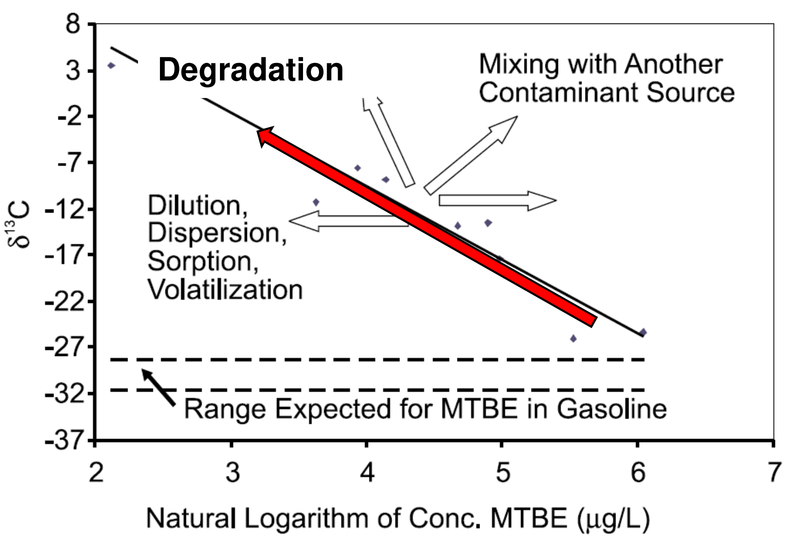
2^{nd} generation tools typically focus on concentration and permeability and help us understand mass flux / discharge

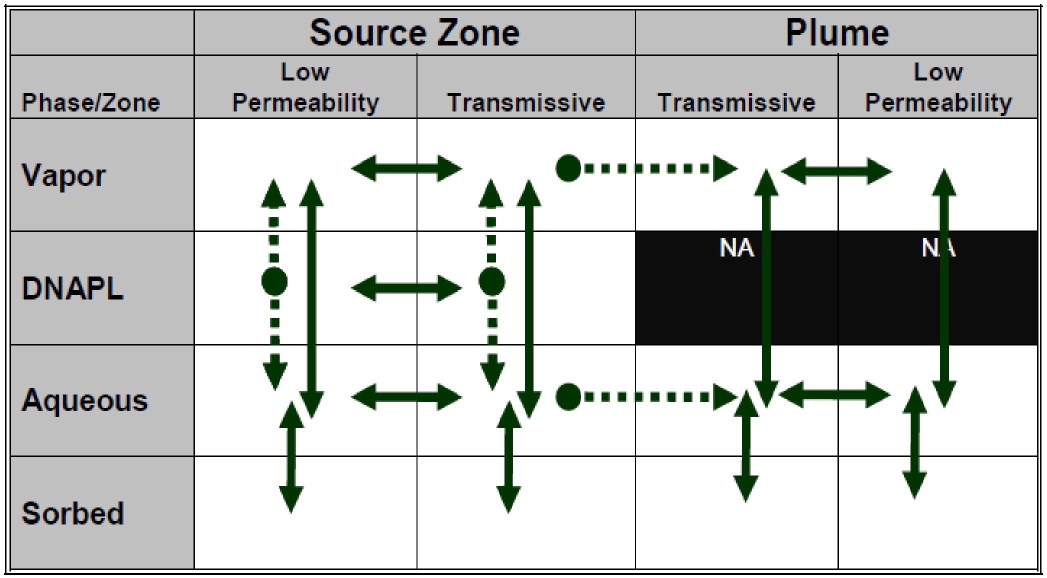
- High resolution core sampling of soil or rock with in-field lab analysis
- In-situ screening of contaminant concentrations (e.g., MIP, LIF, Waterloo APS)
- Multiple level sampling systems (e.g., FLUTe, Solinst, Westbay)
- Refined hydraulic testing options (e.g., MiHPT, small scale slug testing, FLUTe, tracer testing)



ITRC, 2010

3G methods include techniques that focus on addressing the limitations of 1G and 2G methods, and help assess the processes that govern the transport and fate of contaminants (mid 2000s – present)





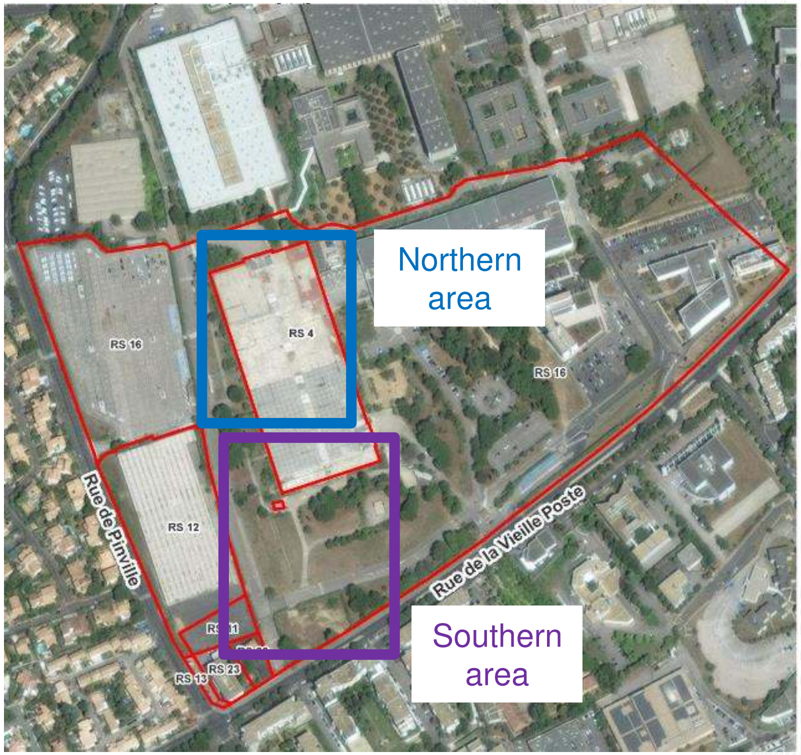
Sale and Newell, 2009

Examples of 3G Characterization Methods

Evolution of 2G methods	Enhanced Analytical Tools	Improved collection methods	Proxy parameters
Rapid field analytical methods	Compound Specific Isotope Analysis	Cryogenic coring	Temperature
MIP with speciation / Optical Screening Tools (e.g., Dye LIF)	Microbial Ecology Assessment (DNA/RNA)	Multi-parameter passive sampling	Inert tracers (e.g., Fluorescein)
Refined geophysical methods	Element / molecule scale evaluation (SEM/TEM)	Passive flux meters	Methane / ORP

Case Study – TCE Contamination at Former Semi-Conductor Manufacturing Facility in Sud de France

- Former semi-conductor manufacturing facility. Limited historical records of chlorinated solvent operations. Operations ceased in 2004.
- 1979 to 2005: Iterative groundwater investigations completed with long-screen monitoring wells (>10 meters). TCE identified in groundwater south of building B1.
- 2006 – 2010: Conventional multi-level monitoring well investigations completed in southern area. Single groundwater extraction well installed and operated to manage migration of TCE-impacted groundwater.



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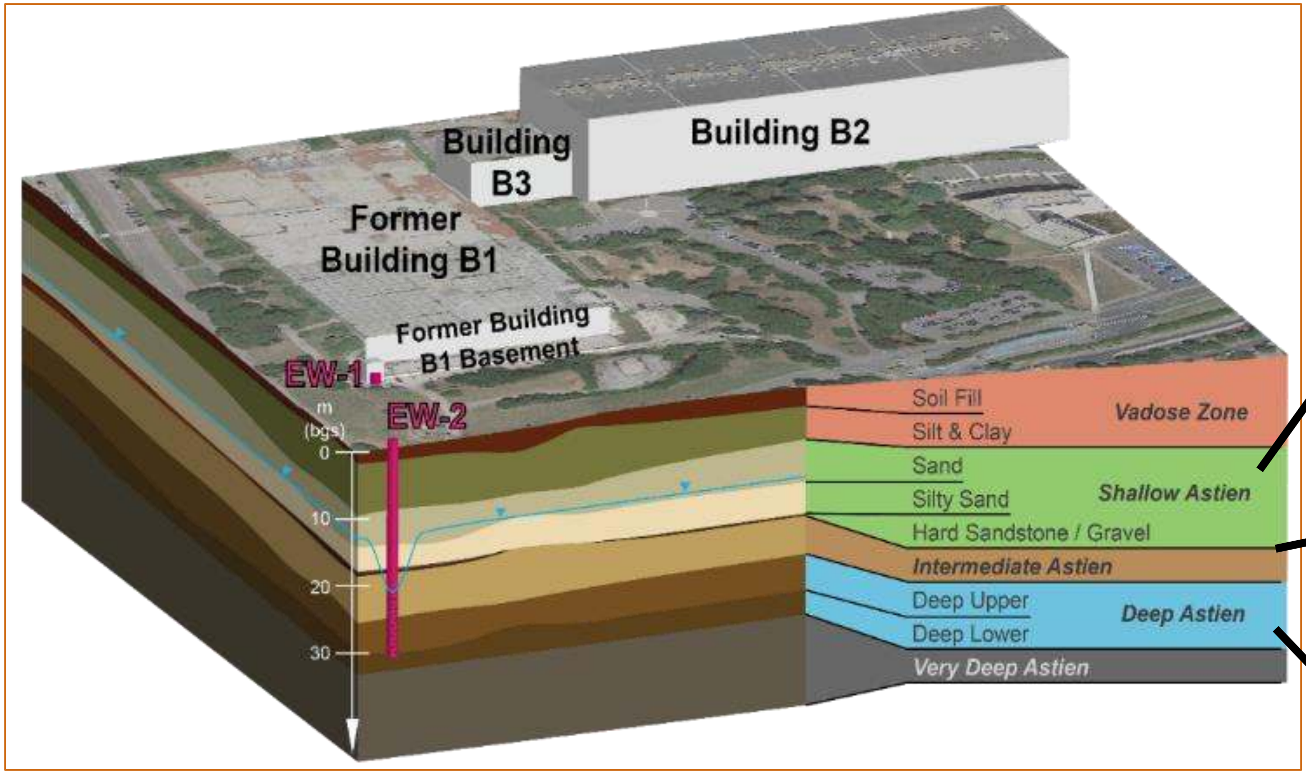
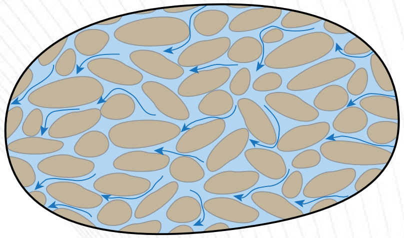
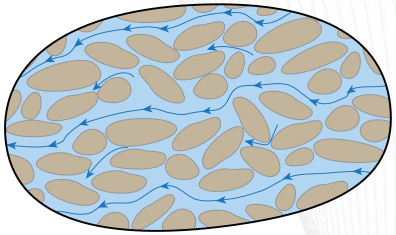
Aquifer Characteristics

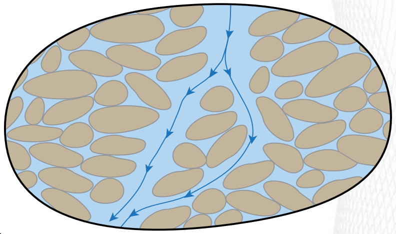




Primary porosity flow

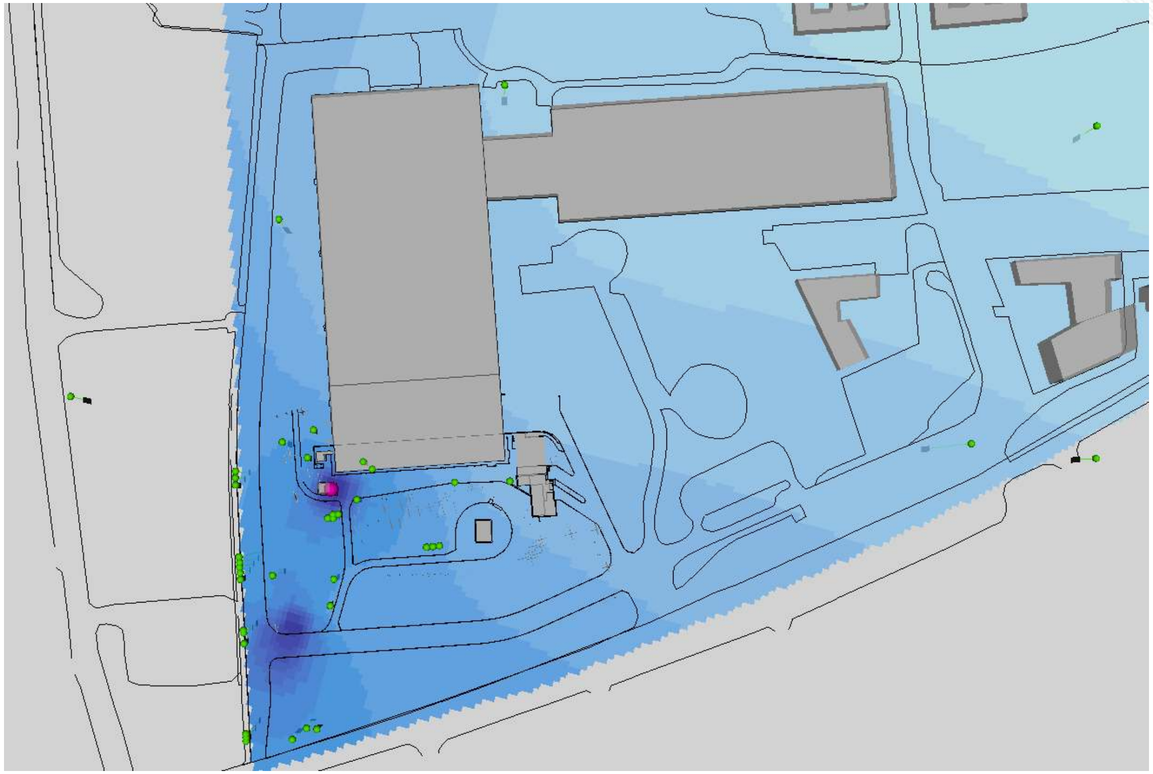


Dual porosity flow

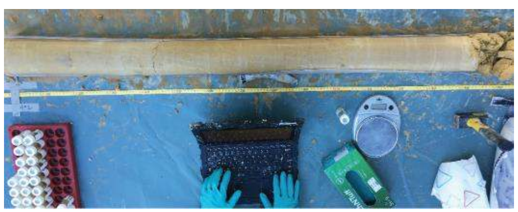


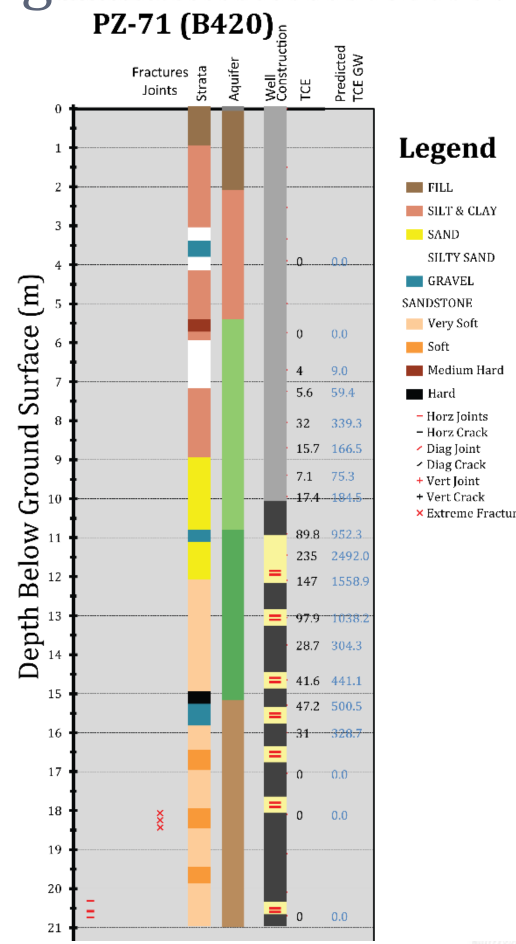
Secondary porosity flow

2015 Site conditions

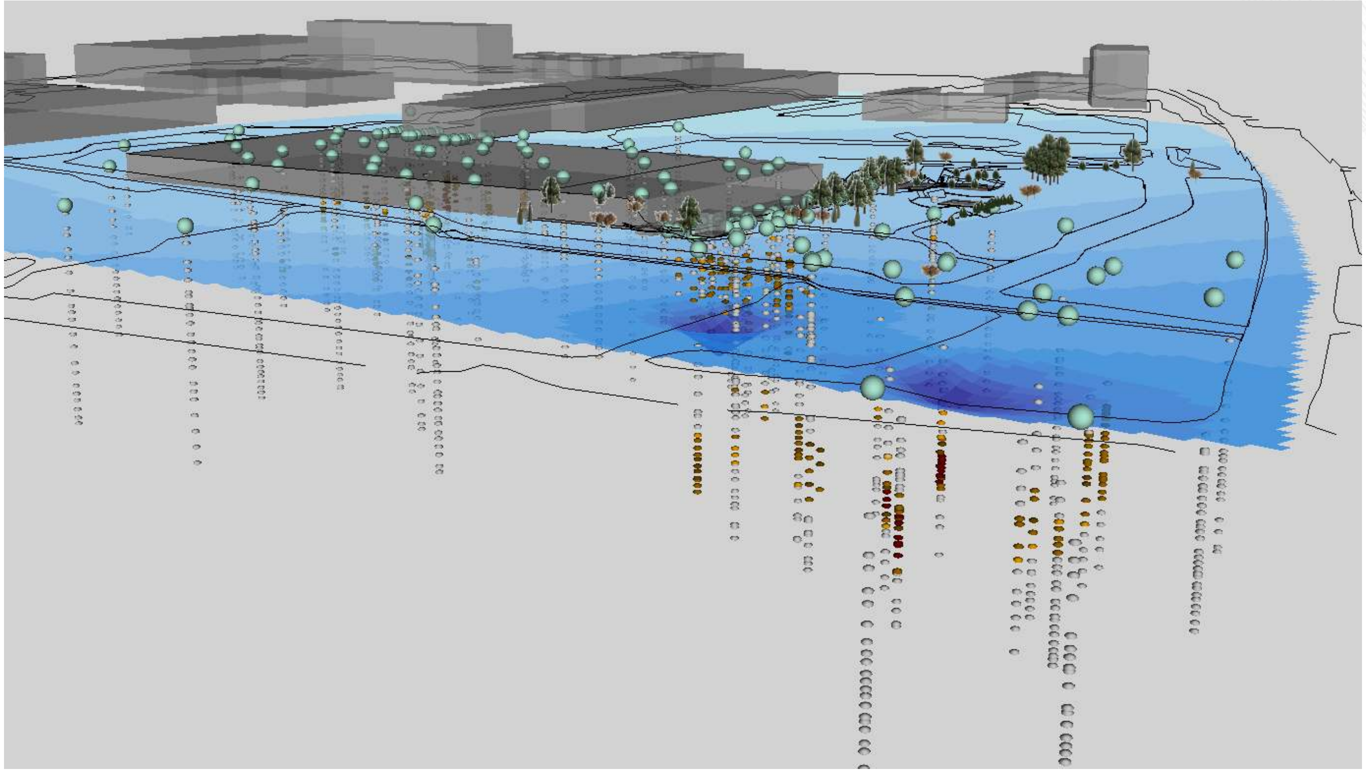


High resolution soil and groundwater sampling with mobile laboratory analysis

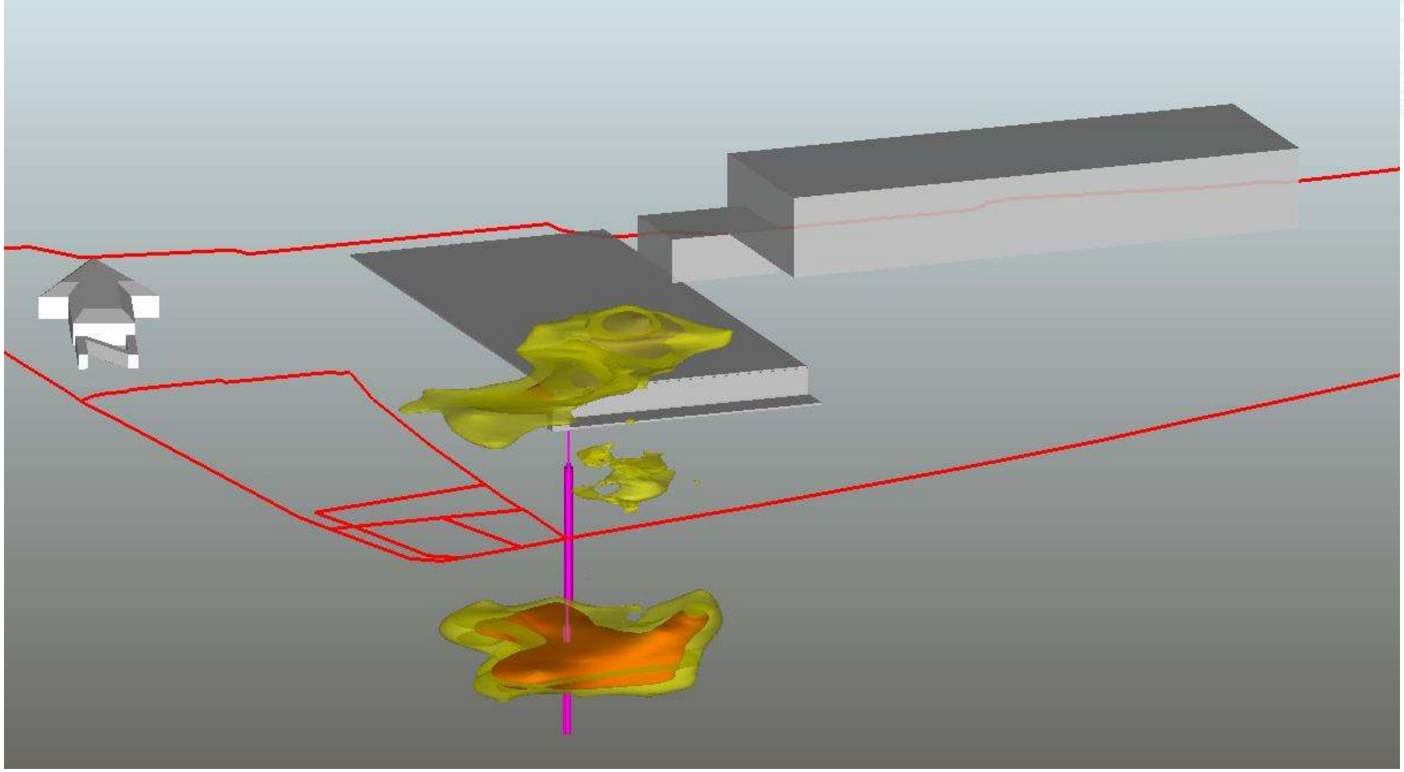




Real-Time 3D Visualization Example



3D EVS Visualization Example



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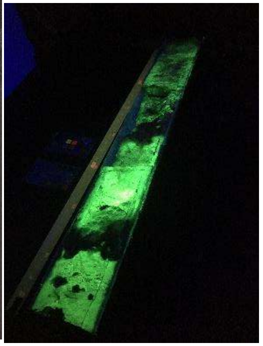
High resolution sampling for in-situ remediation feasibility evaluation

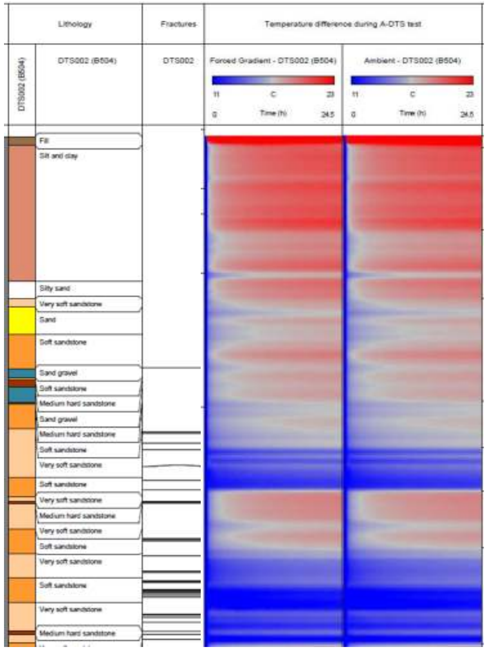
Fluorescein Inj. / Coring

Feasibility of in-situ treatment



Active - Dist. Temp. Sensing

Eval. of preferential GW flow



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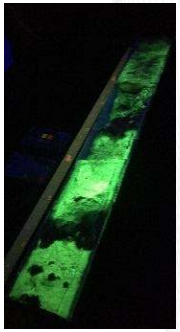
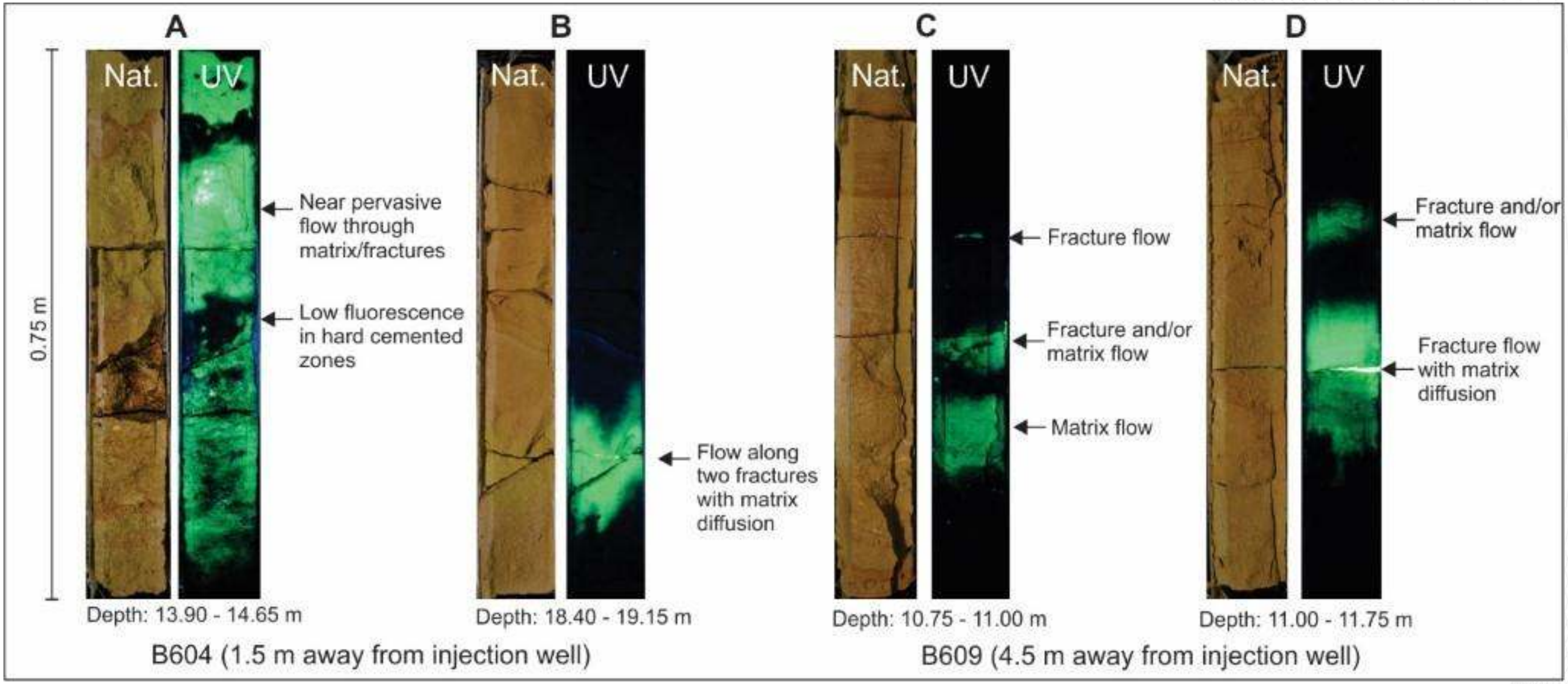
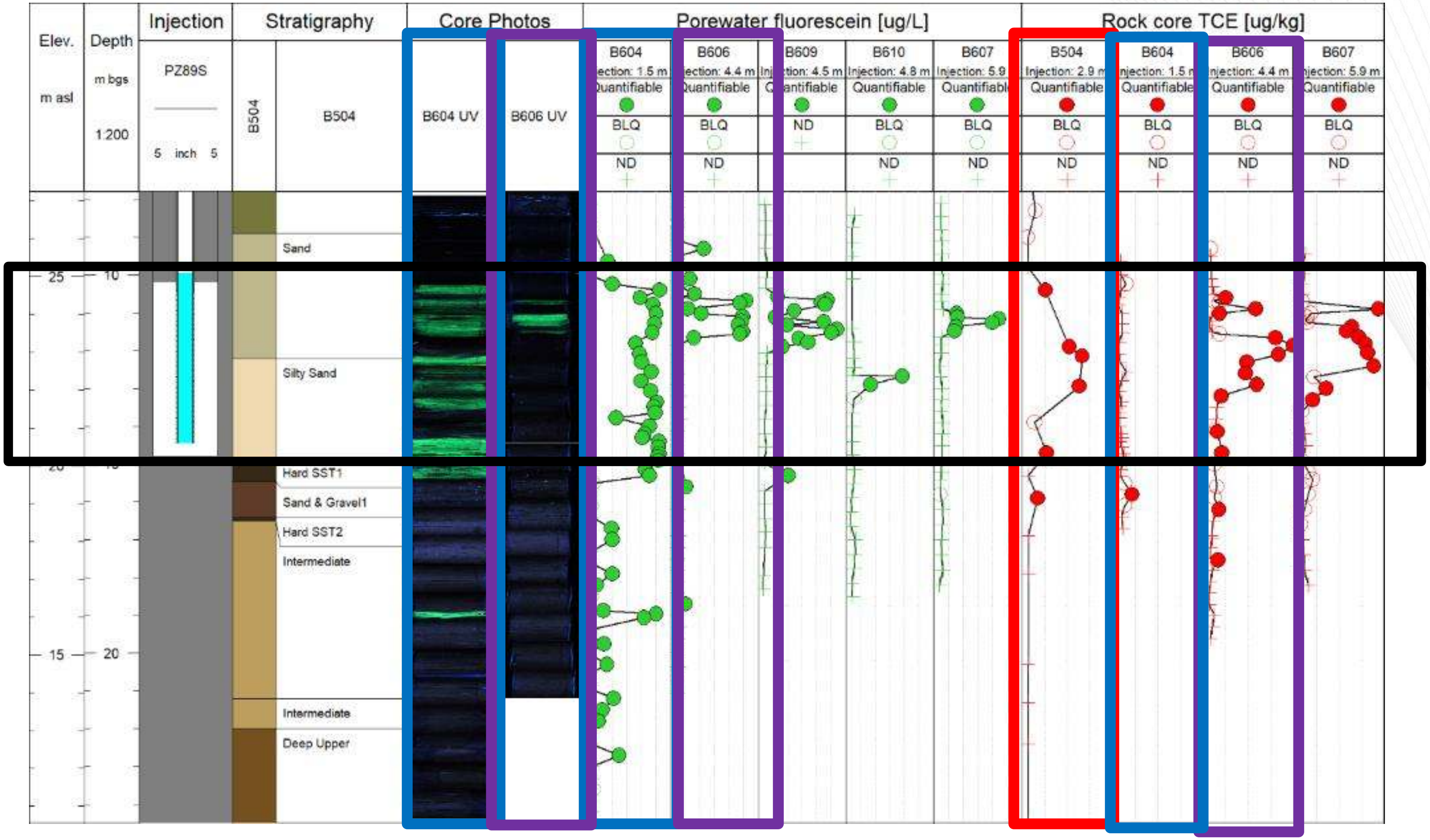
Post-Injection Coring and Fluorescein Sampling



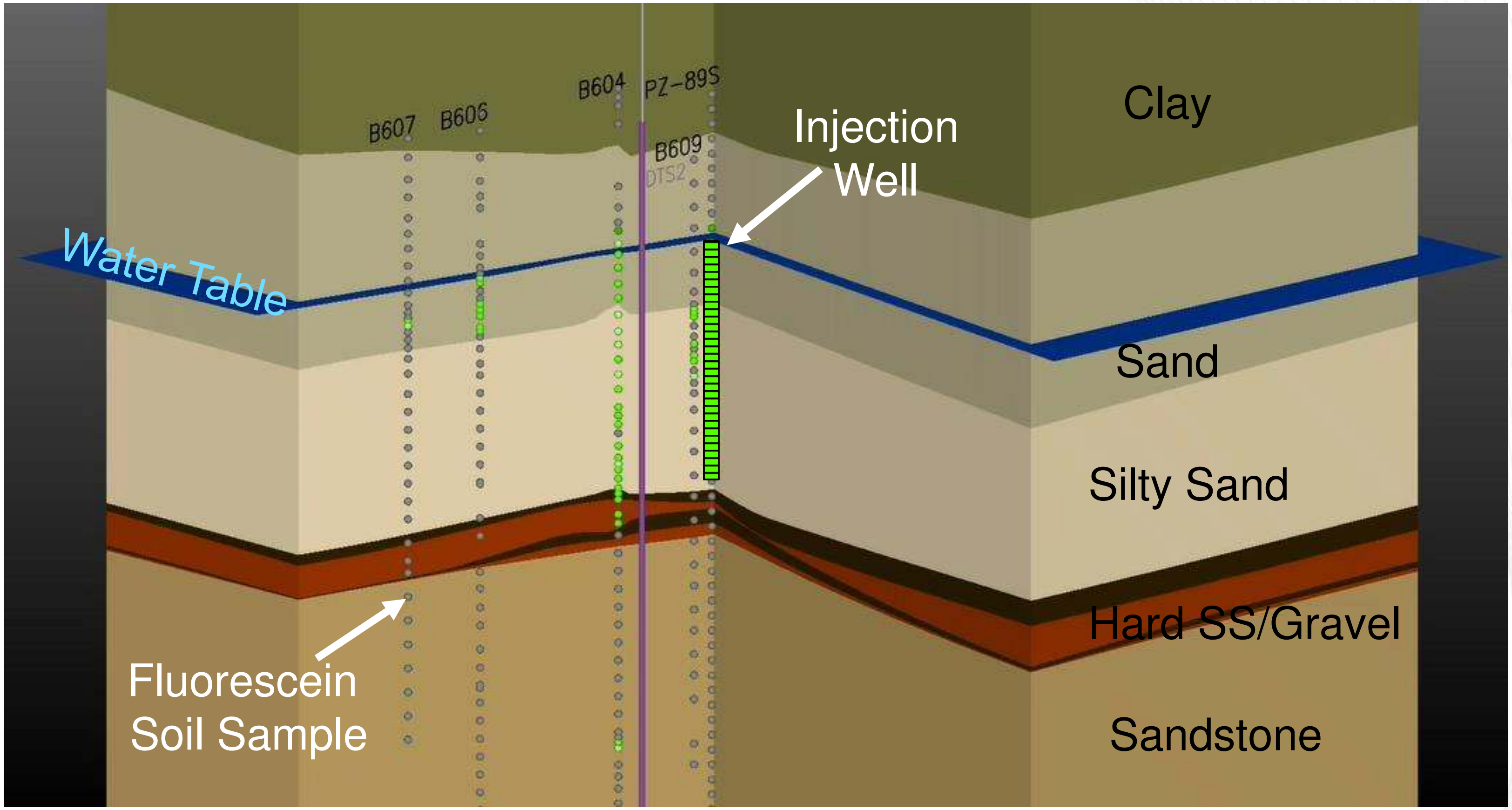
UV Photography of Fluorescein Core Samples



Fluorescein and TCE Core Sample Results



3D Fluorescein Results



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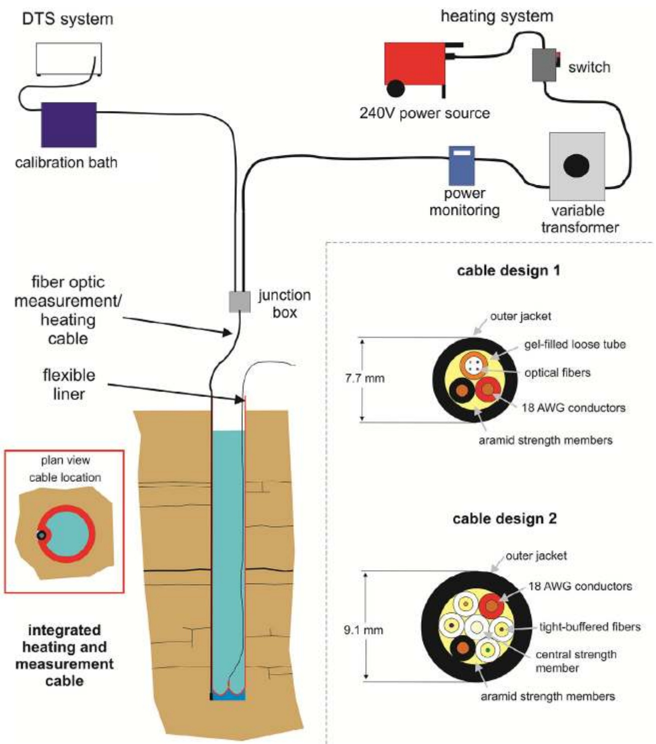
Active-distributed temperature sensing for preferential pathway identification and quantification of flow / flux



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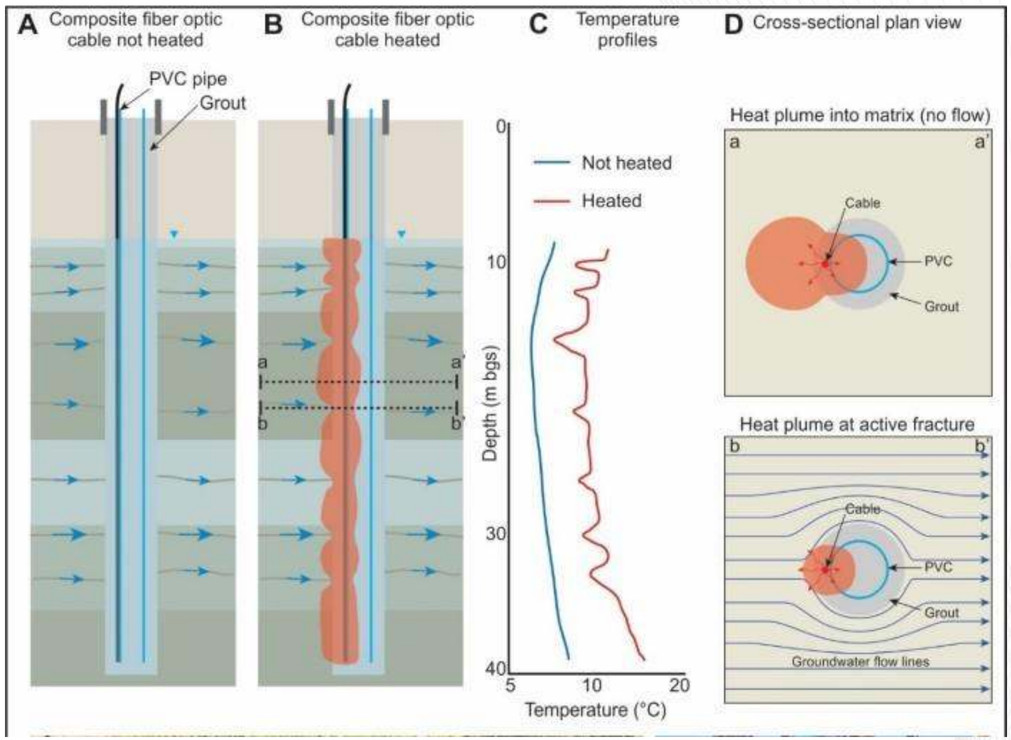
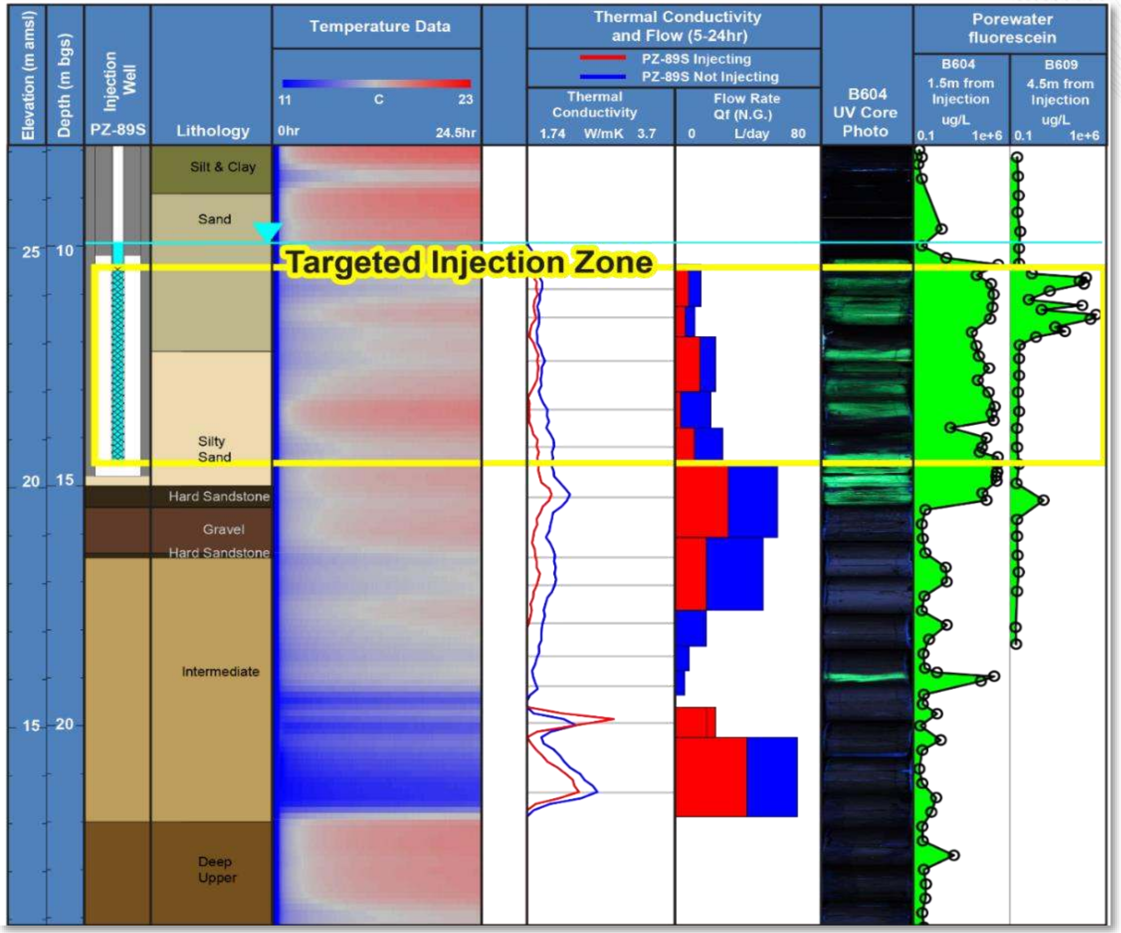


A-DTS Results



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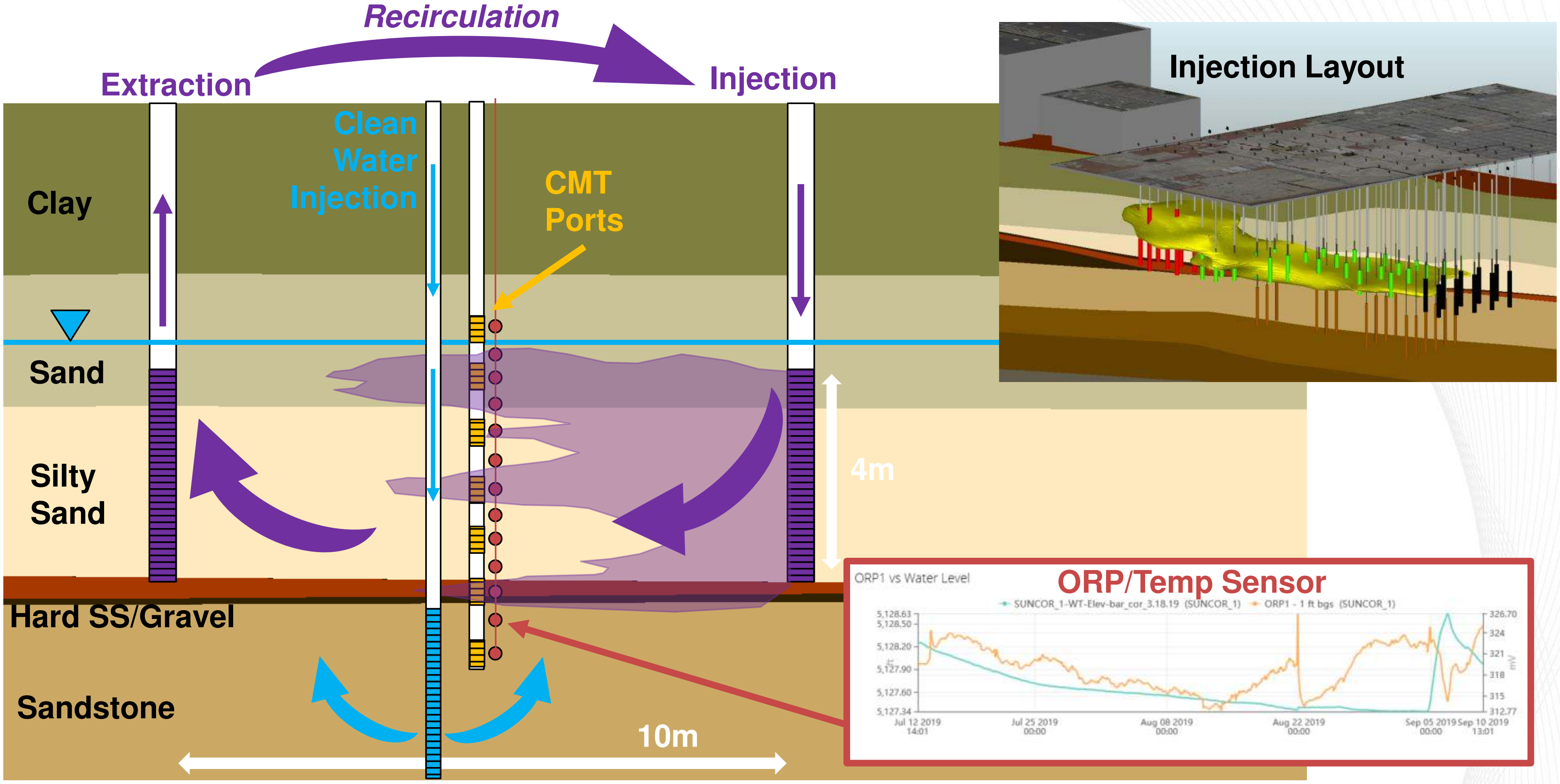
Future In-Situ Remediation Approach



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Humble suggestions

- Distinguish between characterization and monitoring
- Measure and estimate mass flux / discharge
- Evaluate processes before, during, and after remediation
- Re-consider the value of conventional long-term monitoring
- Leverage 3D visualization technologies and predictive models

Thank you!

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