PFAS and Landfills

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Northern New England Chapter

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Presentation Outline

- Introduction
- PFAS Basics
- Health Effects and Risk Assessment
- PFAS and Landfills
- Conclusions and Discussion

Technical Resources to Respond to Environmental Releases of Poly- and Perfluoroalkyl Substances (PFAS)

Interstate Technology & Regulatory Council
October 2017

ITRC PFAS Team

- ITRC: Public-private coalition working to reduce barriers to the use of innovative environmental technologies. Produces documents and training that broaden and deepen technical knowledge and expedite quality regulatory decision-making while protecting human health and the environment. More at www.itrcweb.org
- ITRC has assembled a team of over 300 PFAS experts from all sectors: academics, stakeholders; state and local; federal; industry and consulting
- PFAS team producing concise technical resources for project managers – regulators, consultants, responsible parties, and stakeholders
- 2017: Series of six PFAS Fact Sheets
- 2018-2019: Web-based Technical and Regulatory Guidance Document; Internet-based Training
- Why: State and federal environmental regulators and others need easily accessible information to aid them in evaluating risks and selecting appropriate response actions at PFAS release sites

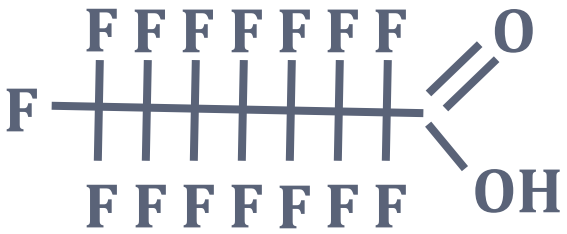
2017: PFAS Fact Sheets

- Summarize key information in the following areas:
  - History, Use, and Environmental Sources
  - Naming Conventions & Physical and Chemical Properties
  - Regulations, Guidance and Advisories
  - Environmental Fate & Transport
  - Site Characterization Tools, Sampling Techniques, & Laboratory Analytical Methods
  - Remediation Technologies & Methods
- Tailored to the needs of state regulatory program staff
  - Concise (~10-15 pages)
  - Current references
  - Web-based, updated information tables

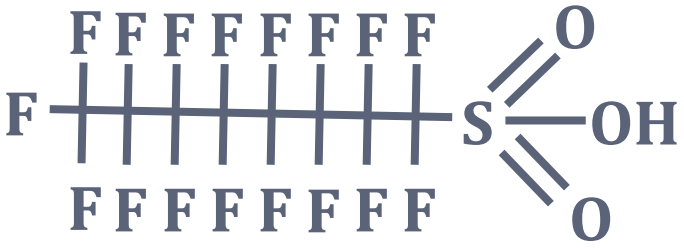
PFAS BASICS

PFAS – A class of chemicals

- PFAS – Per- and Polyfluorinated Alkylated Substances
- PFCs– Perfluorinated Compounds

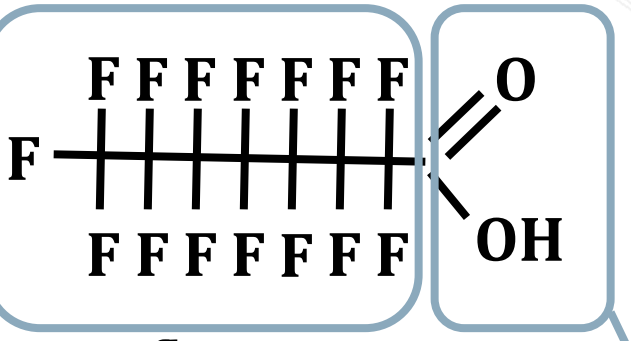


perfluorooctanoic acid
(PFOA)



perfluorooctane sulfonic acid
(PFOS)

PFAS – A class of chemicals



perfluorooctanoic acid (PFOA)

Fluorocarbon tail

- Strong bonds
- Hydrophobic
- Oleophobic
- Varying length

Functional group

- Strong to weak acids
- Hydrophilic

PFAS Production and Use in U.S.

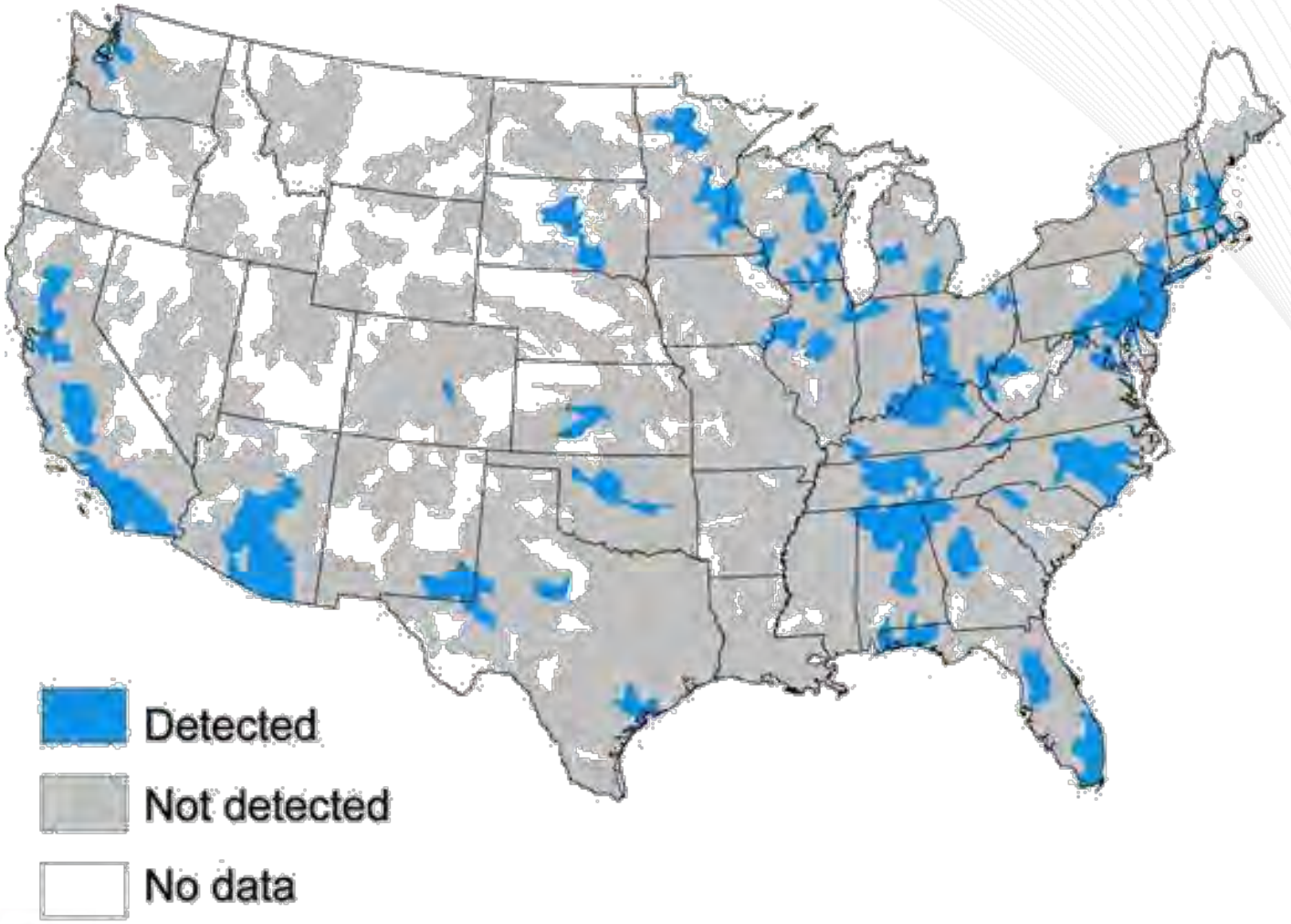
- PFAS first manufactured in 1949
- PFOS
  - Phased out in 1990s
  - Domestic large-scale use discontinued in 2002
- PFOA
  - Phased out starting in 2006
  - Domestic manufacture ceased
  - Still in use (imports/existing stock)
- PFAS usage shifted to shorter-chain compounds

Uses of PFAS

- Fabric treatments
- Chemical/oil/heat-resistant coatings
- Performance materials
  - Plastics, adhesives, waxes
- Process surfactants
- Fire fighting (aqueous film forming foams [AFFF])

PFAS in Public Drinking Water

Hu et al., ES&T Letters, August 2016,
http://pubs.acs.org/doi/abs/10.1021/acs.estlett.6b00260



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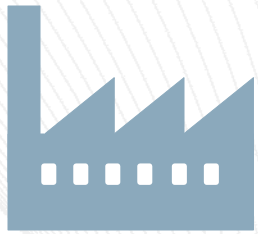
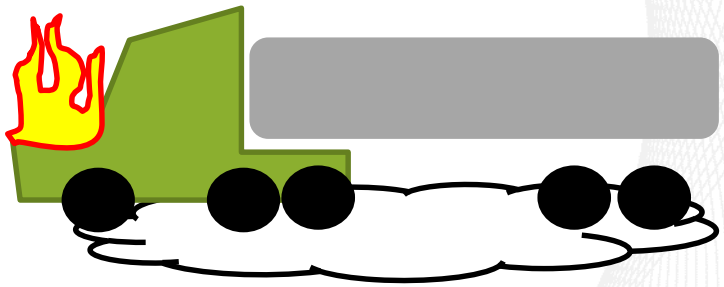
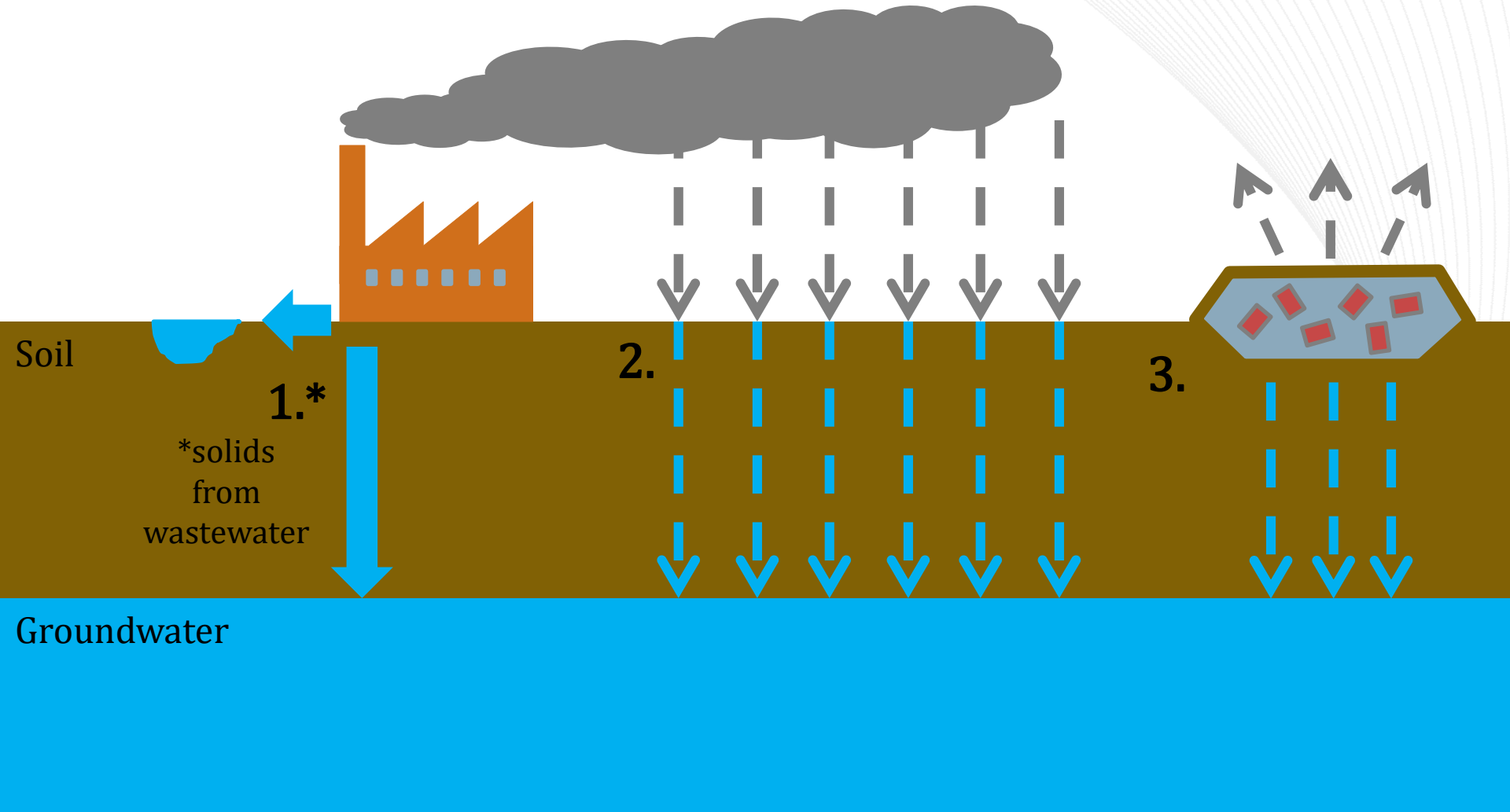
Sources to the Environment

- Release of aqueous film forming foams (AFFF) via firefighting
- Household products
- Runoff of stormwater and street dust
- Industrial facilities
- PFAS wastes
- Others



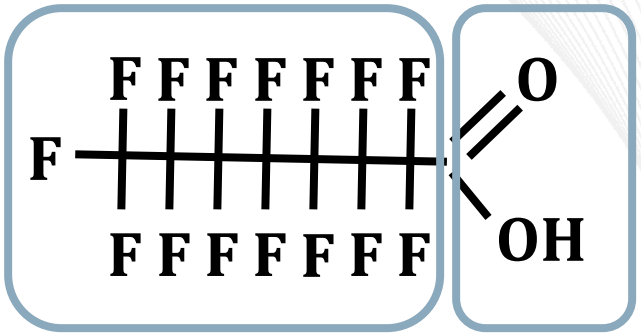


Three Potential Pathways for Industrial Releases



PFOA/PFOS Fate and Transport Properties

- Very soluble
- Some sorption
- Not volatile
- Very stable
- Surfactant quality



perfluorooctanoic acid (PFOA)

PFAS Sampling and Analysis

- Sampling
  - PFAS prevalent in field supplies & PPE
- Analysis
  - Variability across labs
  - Large list of potential analytes
  - Reporting limits vary (~1-10 ppt)

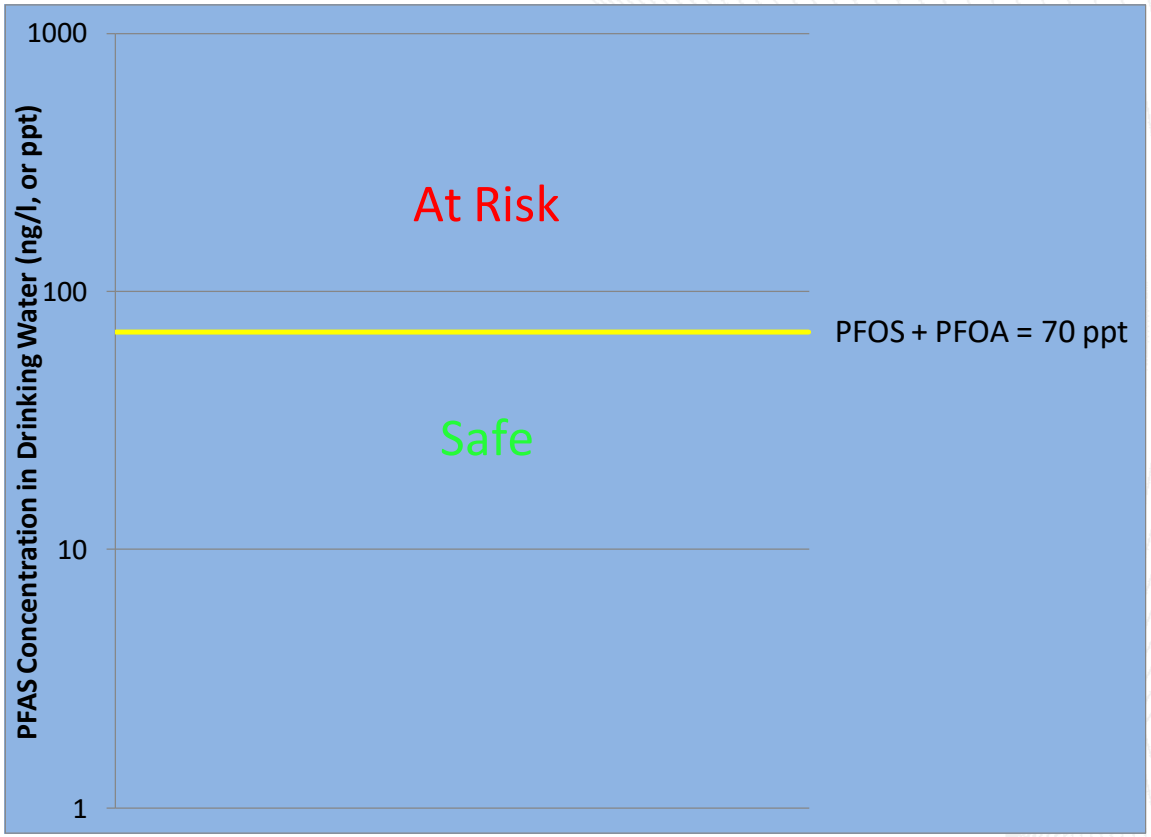
PFAS Treatment and Remediation (soil and groundwater)

- Offsite disposal/incineration
- Groundwater extraction
  - Granular activated carbon (GAC)
  - Ion Exchange
- In-situ
  - Oxidation/Reduction
  - Stabilization

HEALTH EFFECTS AND RISK ASSESSMENT

What Level of PFAS in Drinking Water is Safe?

- U.S. EPA
  - January 2009
    - PFOA = 400 ppt
    - PFOS = 200 ppt
  - Early 2016
    - PFOA = 100 ppt
  - May 2016
    - PFOA + PFOS = 70 ppt
- New Jersey
  - 2009
    - PFOA = 40 ppt
  - 2016
    - PFOA = 14 ppt
- Vermont
  - March 2016
    - PFOA = 20 ppt



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Recent Review of PFAS Toxicity

- Drs. David Klein & Joseph Braun, Brown University, 10/3/2016, NEWMOA webinar
  - http://www.newmoa.org/events/docs/236_210/KleinPFAS_ToxWebinarOct2016.pdf
  - http://www.newmoa.org/events/docs/236_210/BraunPFAS_ToxWebinarOct2016.pdf
- Summary: both laboratory (animal) and epidemiology studies pointing to various developmental (non-cancer) effects
- Evidence on cancer is suggestive but inconsistent, but also of secondary importance

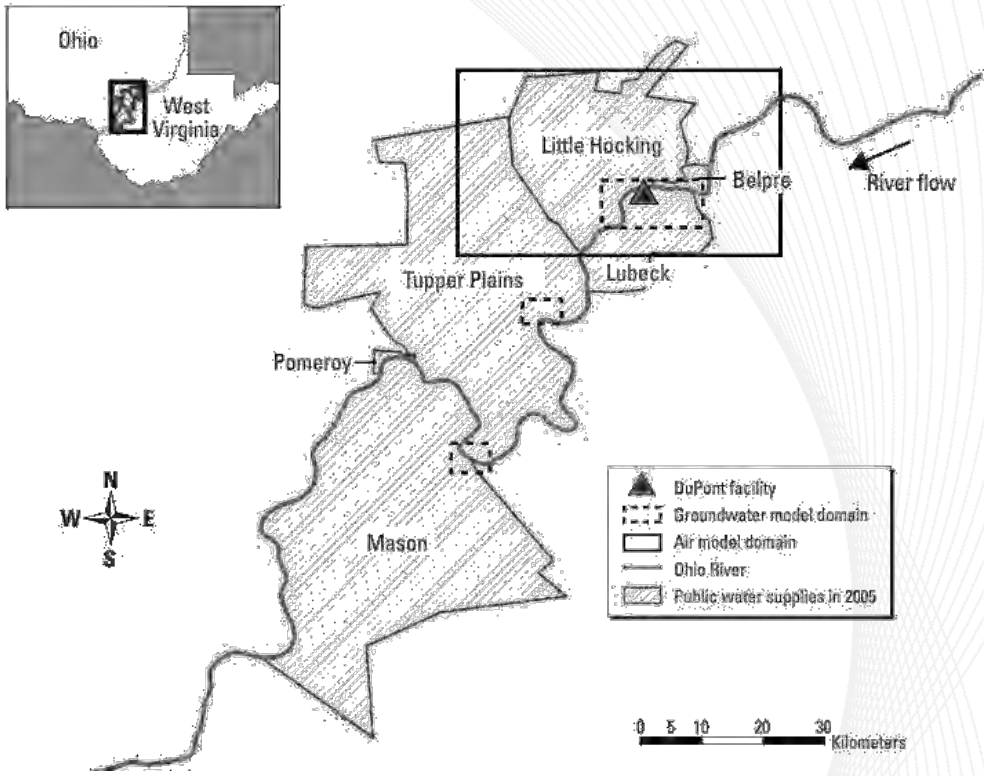
PFAS Health Effects and Toxicology

- Most studies have focused on PFOA and PFOS
- Both PFOA and PFOS bioaccumulate in human blood, PFOS more so
- PFAS chain length roughly relates to half-life and potential toxicity
- PFAS persist in humans for years, but in rats and mice for only days to weeks

C8 Science Panel Studies

http://www.c8sciencepanel.org/prob_link.html and Shin et al (2011). Environ Health Perspect. 119(12):1760–1765.

- Focused on PFOA from Dupont's Washington Works facility in Wood County, WV
- Conducted as a condition of a lawsuit settlement
- Populations studied
  - Community residents of six Mid-Ohio River Valley districts with PFOA-contaminated drinking water supplies
  - Former workers at the Dupont plant
  - Combined residents and workers (for follow-up cancer studies)



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C8 Science Panel Studies

http://www.c8sciencepanel.org/prob_link.html

- Probable links between PFOA exposure and:
  - Diagnosed high cholesterol
  - Ulcerative colitis (autoimmune disease)
  - Thyroid disease
  - Testicular and **kidney** cancers
  - Pregnancy-induced hypertension

C8 Science Panel Studies

http://www.c8sciencepanel.org/prob_link.html

- No probable links between PFOA exposure and:
  - Diagnosed hypertension
  - Coronary artery disease
  - Chronic kidney disease
  - **Liver disease**
  - Osteoarthritis
  - Rheumatoid arthritis, lupus, Type I diabetes, Crohn's disease, and multiple sclerosis (autoimmune diseases other than ulcerative colitis)
  - Parkinson's disease
  - Common infections (including influenza)
  - Neurodevelopmental disorders in children (*e.g.,* ADD)
  - Asthma and chronic obstructive pulmonary disease (COPD)
  - Stroke
  - Nineteen types of cancer (other than kidney and testicular)
  - Type II diabetes
  - **Birth defects**
  - **Miscarriages and stillbirths**
  - **Preterm birth and low birth weight**

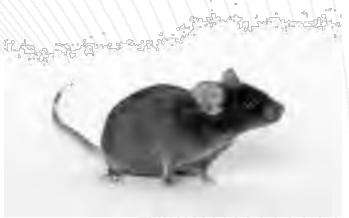
U.S. EPA's Lifetime Health Advisory

- Issued May 19, 2016
- Applies to sum of PFOA + PFOS
- 70 ng/l based on developmental study in mice
  - Basis: Lowest effects level of 1 mg/kg-d delayed ossification in pups and hastened male puberty
  - Metabolic adjustment to 0.0053 mg/kg-d to account for much longer half-life in humans
  - Add safety/uncertainty factors totaling 300:
    - 10 (sensitive individuals)
    - 3 (inter-species)
    - 10 (LOAEL to NOAEL)

    to get reference dose of 0.00002 mg/kg-d = 20 ng/kg-d
  - Only 20% of exposure from drinking water

PFAS Reference Dose

- Opinion: EPA's Reference Dose of 20 ng/kg-d for PFOA+PFOS has received inadequate peer review
- What studies/effects are proper for the basis?
  - Liver enlargement proposed then dropped
  - Chosen development effects are arguably tenuous
- Other authorities have assigned higher values



Authority	Reference Dose (ng/kg-d)	
	PFOA	PFOS
U.S. EPA (2016)	20 (total for both)	
European Food Safety Authority (2008)	150	1500
Danish EPA (2015)	30	100
Health Canada (2016, proposed)	25	60

Drinking Water Criteria Examples

Maximum Contaminant Level (MCL)

- Legally enforceable
- **2 liter/day water ingestion**
- 70 kg adult
- Background exposure 80%

Lifetime Health Advisory (LHA)

- Guidance
- **4.3 l/day water ingestion**
- 70 kg adult
- Background exposure 80%

$$\frac{0.2 \times 20\ \text{ng/kg-d} \times 70\ \text{kg}}{2\ \text{l/d}} = 140\ \text{ng/l}$$

$$\frac{0.2 \times 20\ \text{ng/kg-d} \times 70\ \text{kg}}{4.3\ \text{l/d}} = 65\ \text{ng/l}$$

Background Exposure to PFAS

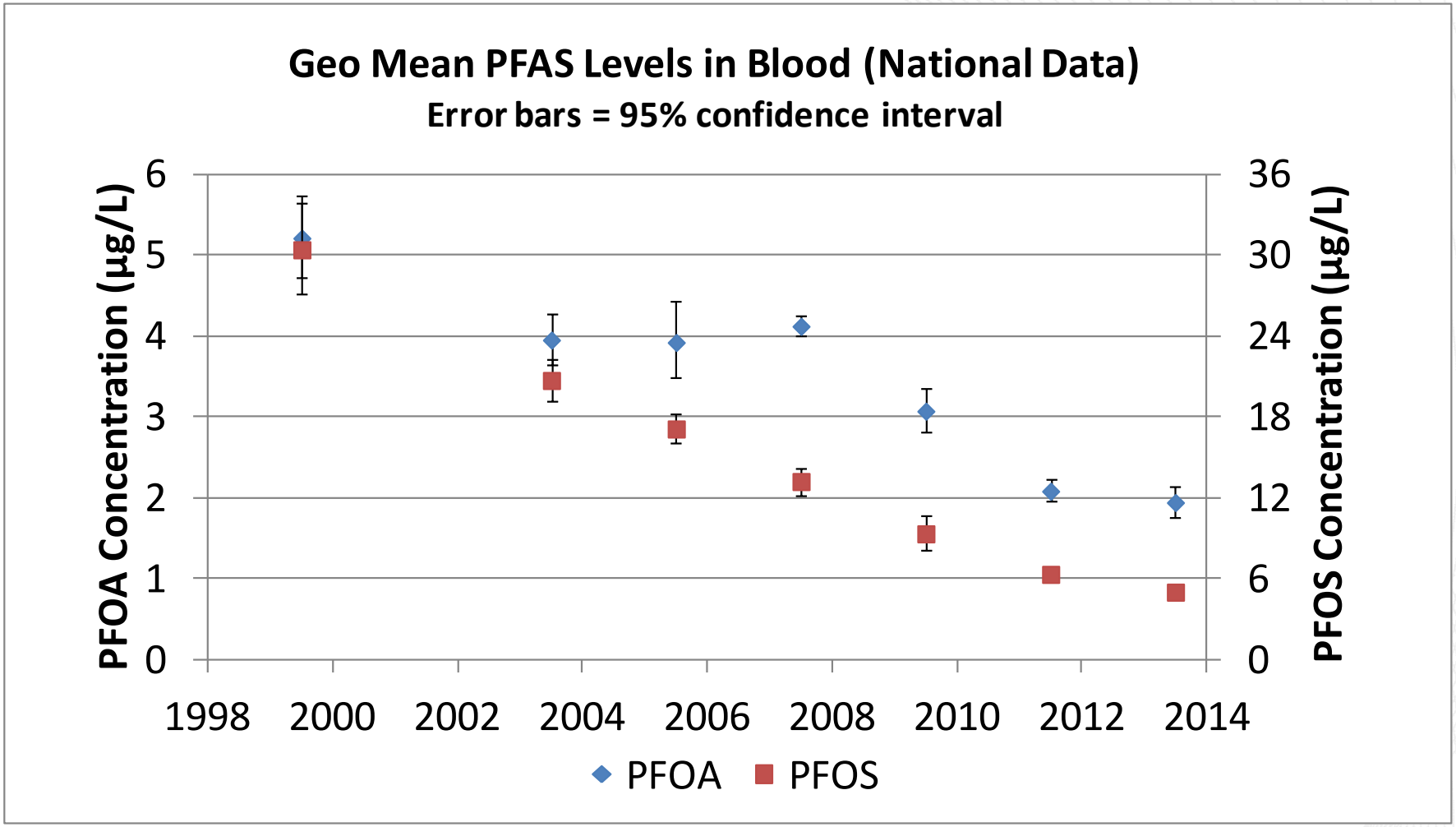
- Gebbink et al. (2015) PFOA+PFOS exposure estimates for a 70 kg adult

	Low	Intermediate	High
Exposure (ng/day)	9	48	343
% of RfD	0.7%	3%	25%

- Observation: Reserving 80% of RfD for background seems conservative
- But … all PFAS are not considered, and what percentile background is appropriate?

PFOA in Blood in U.S. Population

NHANES data https://www.cdc.gov/exposurereport/pdf/FourthReport_UpdatedTables_Volume1_Jan2017.pdf



Current PFOA ~ 2 µg/l (ppb), PFOS ~ 5.5 µg/l (ppb)

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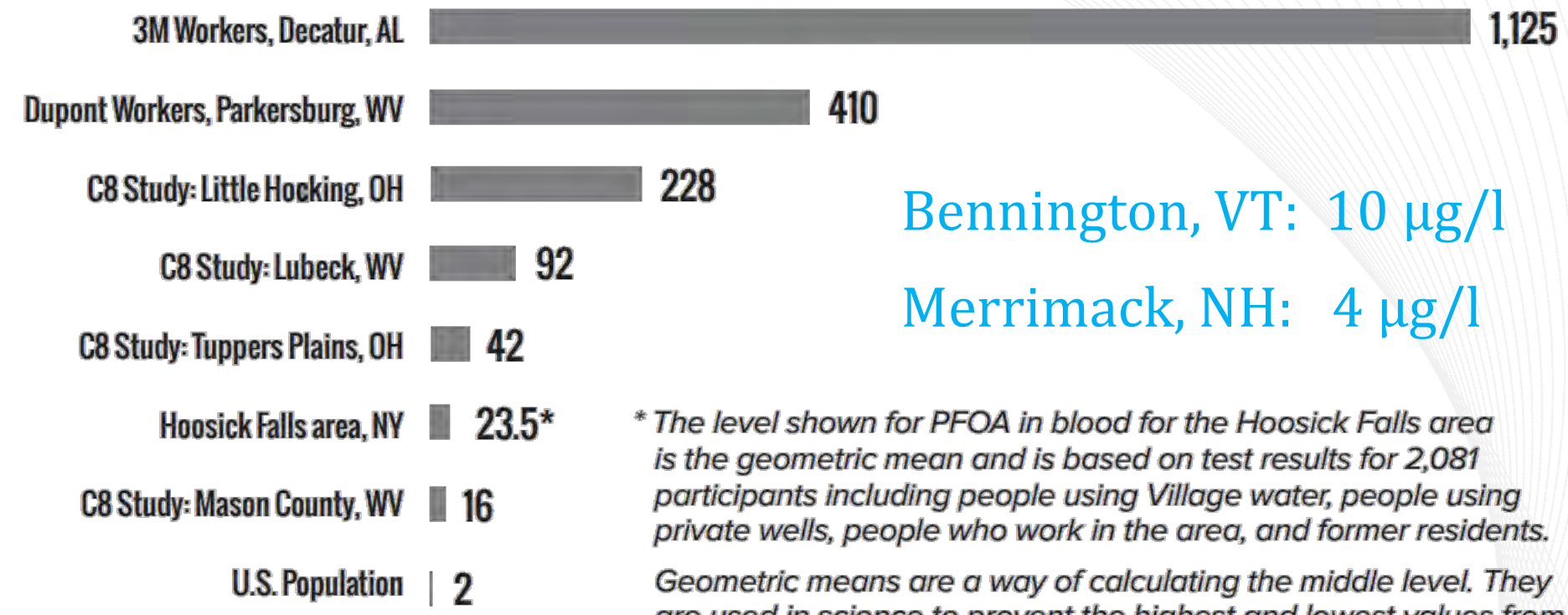
Average PFOA Levels in Blood (µg/L)

(https://www.health.ny.gov/environmental/investigations/hoosick/docs/qandabloodtestingshort.pdf)



Bennington, VT: 10 µg/l

Merrimack, NH: 4 µg/l

** The level shown for PFOA in blood for the Hoosick Falls area is the geometric mean and is based on test results for 2,081 participants including people using Village water, people using private wells, people who work in the area, and former residents.*

Geometric means are a way of calculating the middle level. They are used in science to prevent the highest and lowest values from distorting the average when rest of the data are close together.

Drinking water is an important source of exposure

Blood:H_2O ratio > 100

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PFAS AND LANDFILLS

PFAS Sources in Landfills

- PFAS containing wastes (?)
  - Industrial wastes
  - Discarded consumer products
    - Carpeting/upholstery
    - Waterproofed clothing
  - Food waste
  - Biosolids
- Landfill fires (foam use)

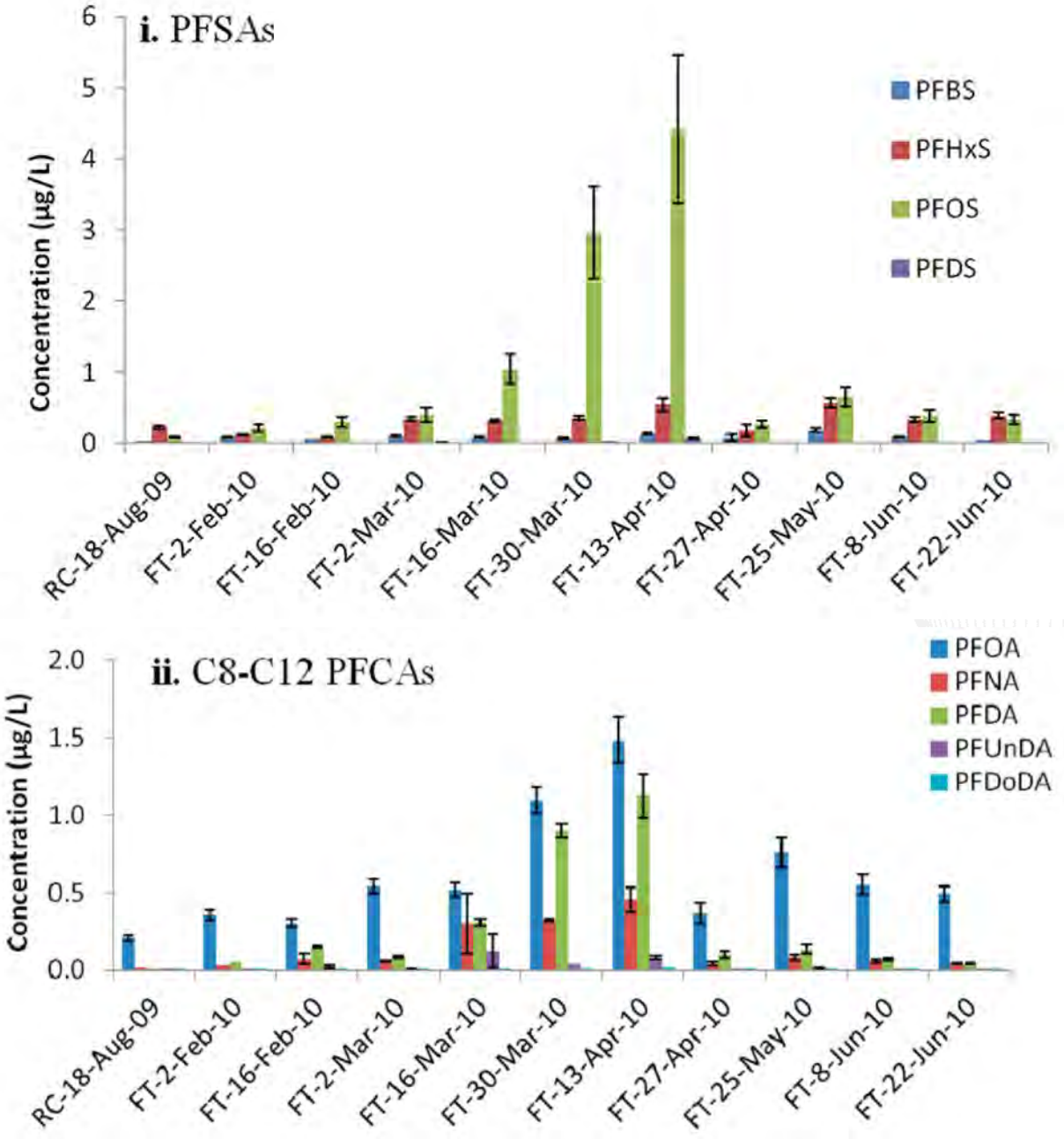
PFAS in Landfill Leachate Pertinent Publications

- Benskin J, Li B, Ikonomou M, Grace J, Li L (2012). Per- and Polyfluoroalkyl Substances in Landfill Leachate: Patterns, Time Trends, and Sources. *Environ Sci Technol* **46**:11532-11540.
- Lang J, Allred B, Field J, Levis J, Barlaz M (2017). National Estimate of Per- and Polyfluoroalkyl Substance (PFAS) Release to U.S. Municipal Landfill Leachate. *Environ Sci Technol* **51(4)**:2197-2205.
- Ahrens L, Hedlund J, Dürig W, Tröger R, Wiberg K (2016). Screening of PFASs in groundwater and surface water. Rapport 2016:2, Sveriges lantbruksuniversitet, Institutionen för vatten och miljö, ISBN 978-91-576-9386-0.

PFAS in Landfill Leachate

(Benskin *et al.*, 2012)

Order of 1,000 ppt



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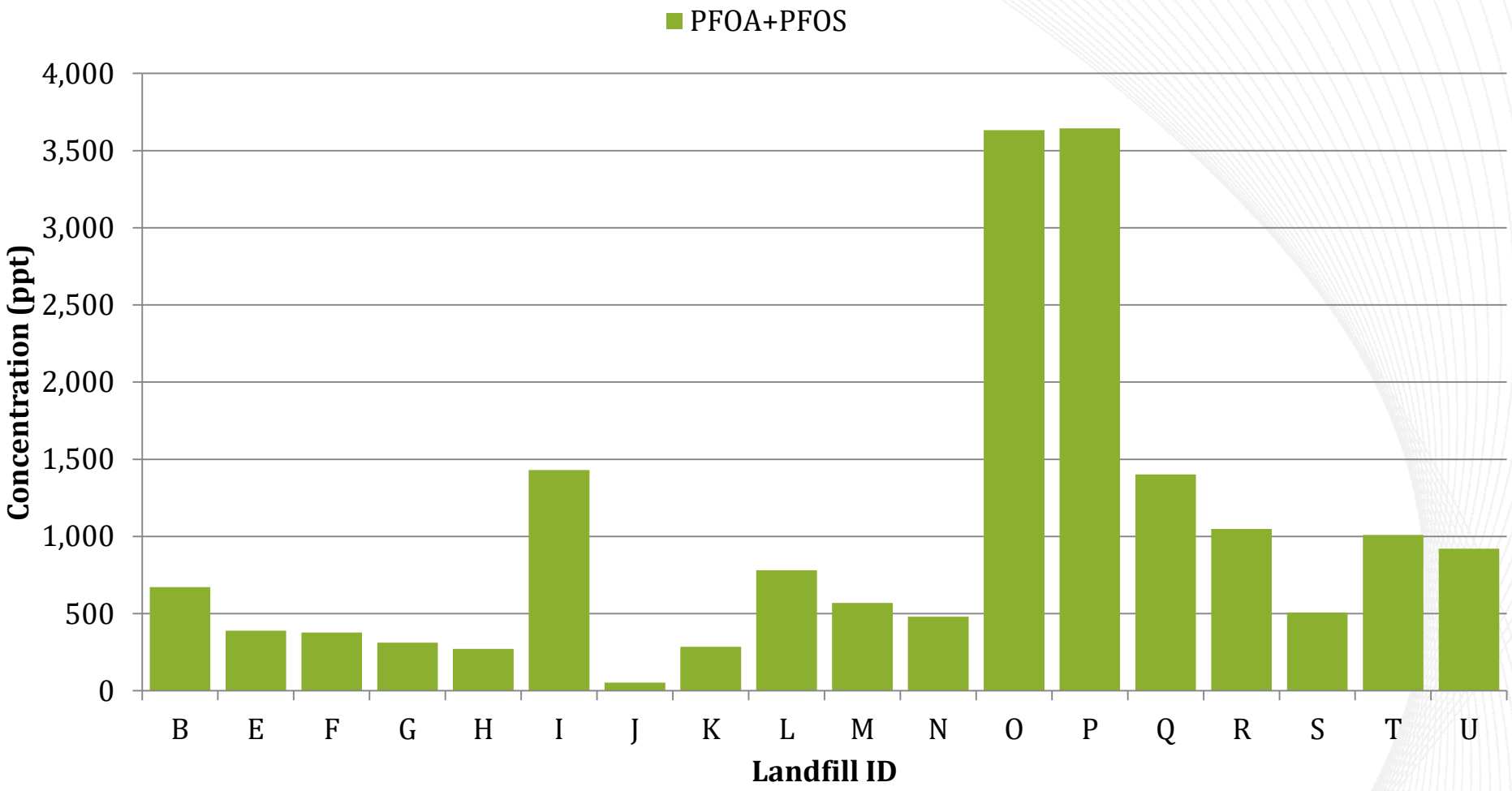
PFAS in Landfill Leachate

Lang *et al.* (2017)



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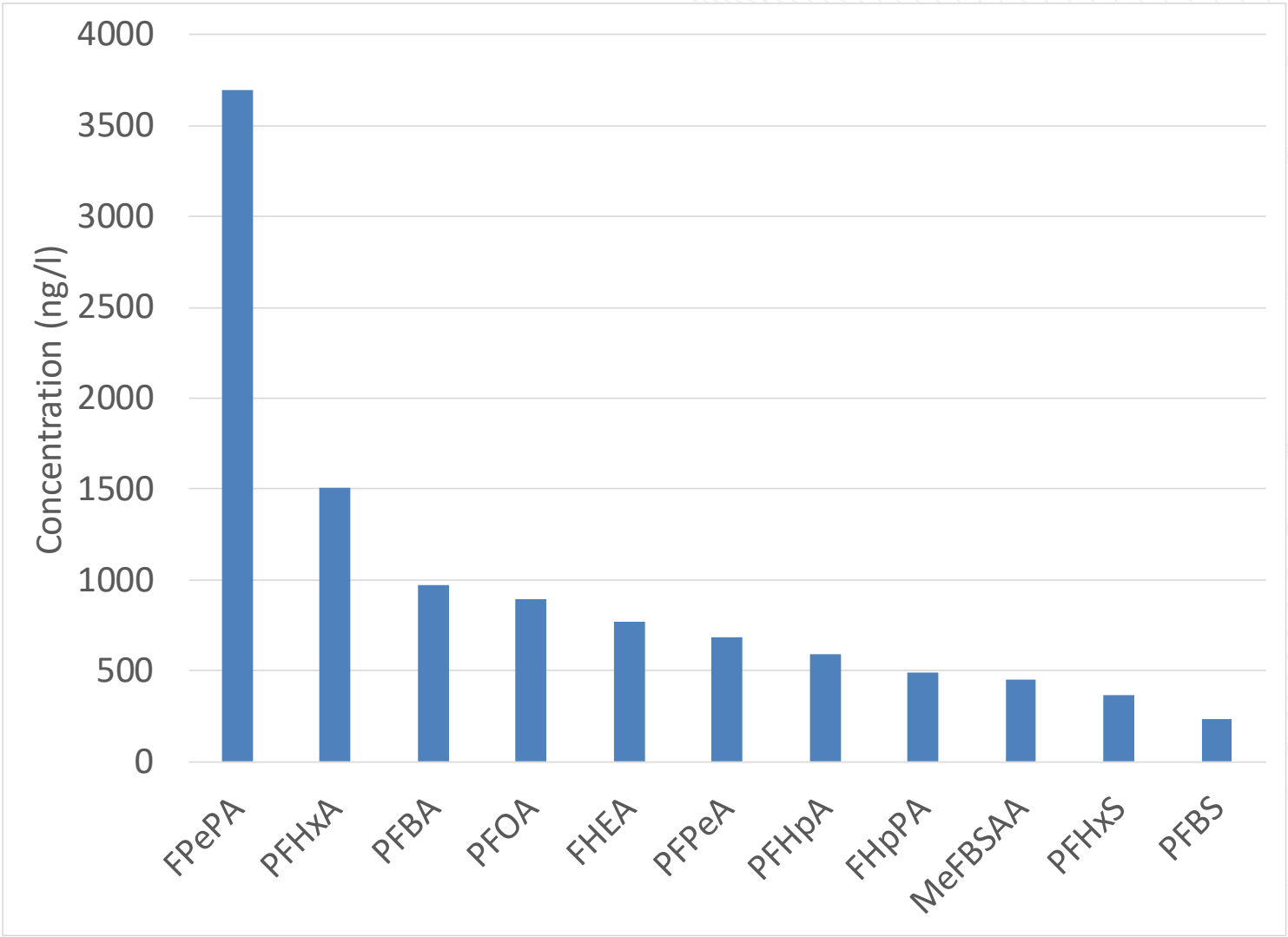
Concentrations of PFAS in Leachate

Lang *et al*. (2017)

87 samples
from
20 landfills

Average
detected
concentration



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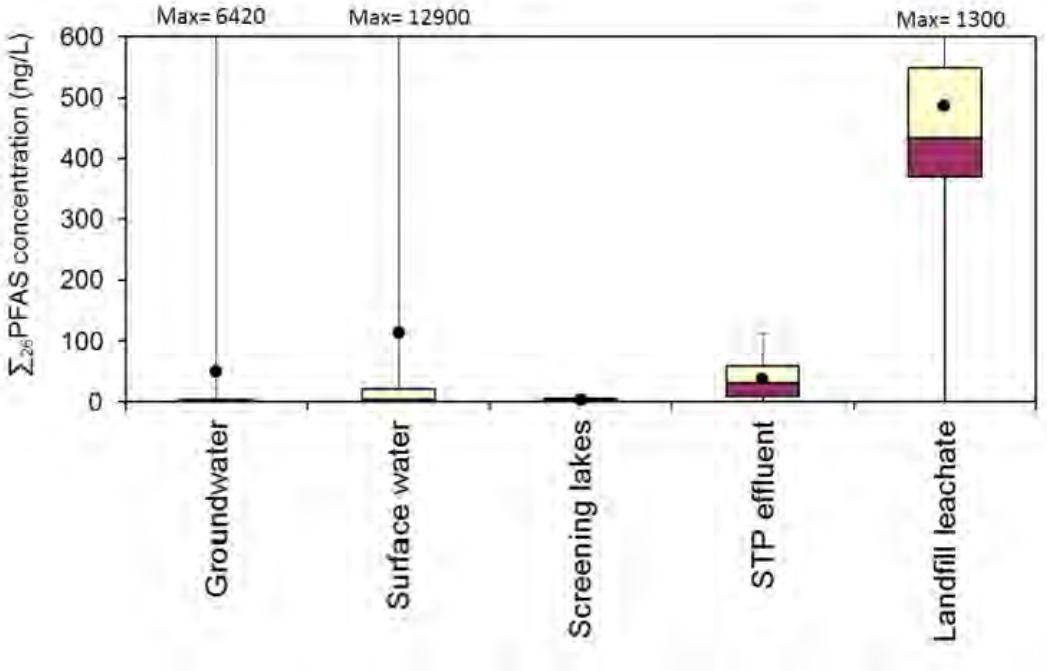
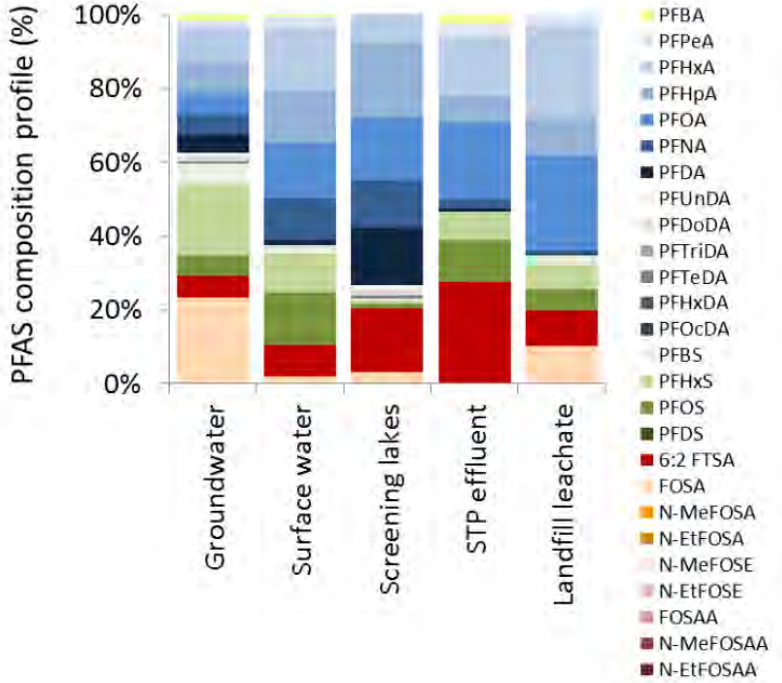
PFAS in Sweden

Ahrens *et al*. (2016)

- PFAS concentrations in leachate several hundred ng/l





STP = Sewage Treatment Plant

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PFAS Site Investigations

- Some PFAS groundwater investigations have focused on landfills or sampled near them
- Generally, PFAS concentrations in nearby drinking water wells have not been significantly affected
- More data will be emerging

Hoosick Falls, NY

Landfill & Wastewater Treatment Plant

- Landfill operated from 1930 to 1994
- Accepted industrial wastes

http://www.villageofhoosickfalls.com, accessed 10/4/2016

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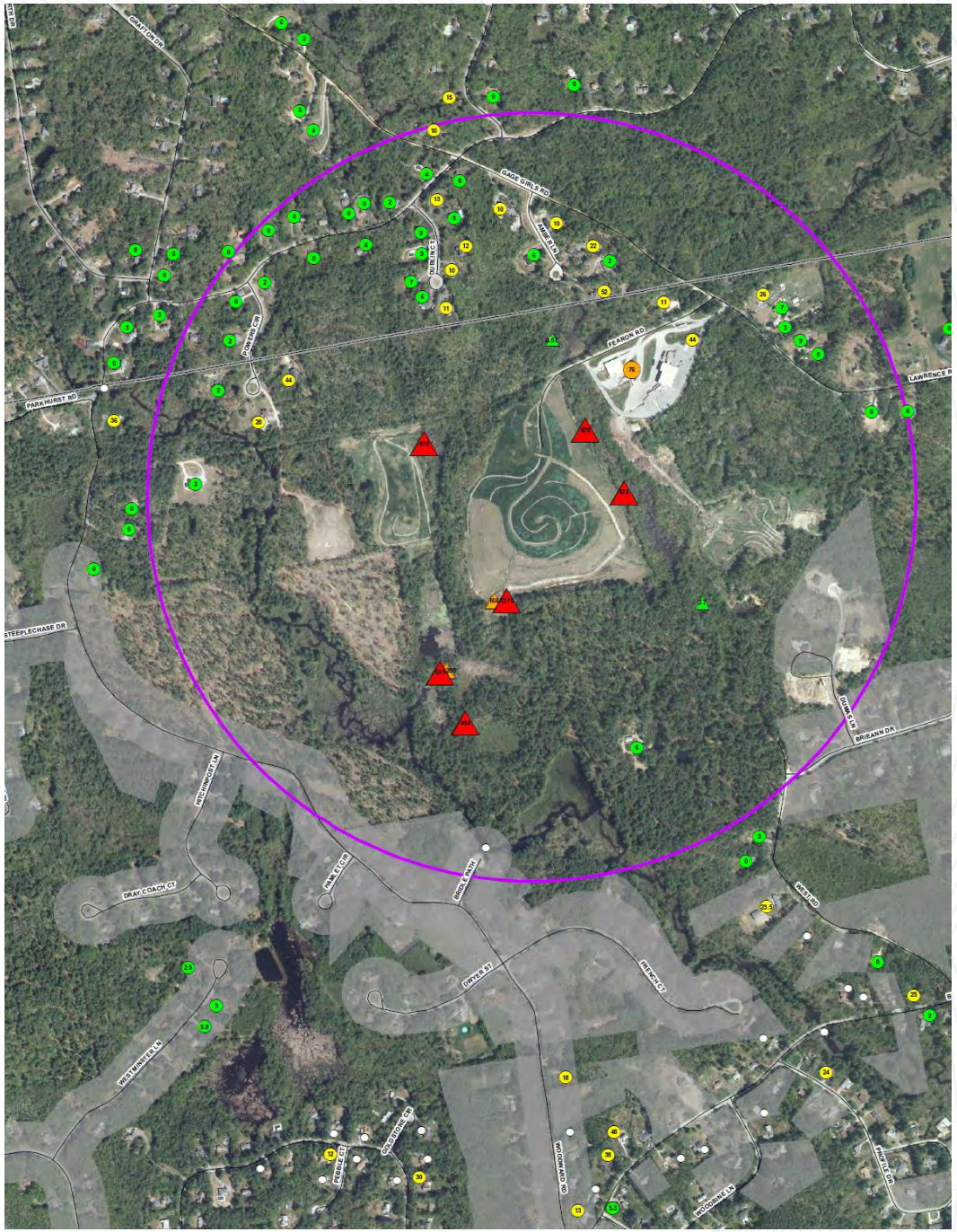
NEW YORK STATE OF OPPORTUNITY Department of Environmental Conservation

Merrimack, NH

- Possibly accepted industrial wastes



http://des.nh.gov/, accessed 10/4/2016

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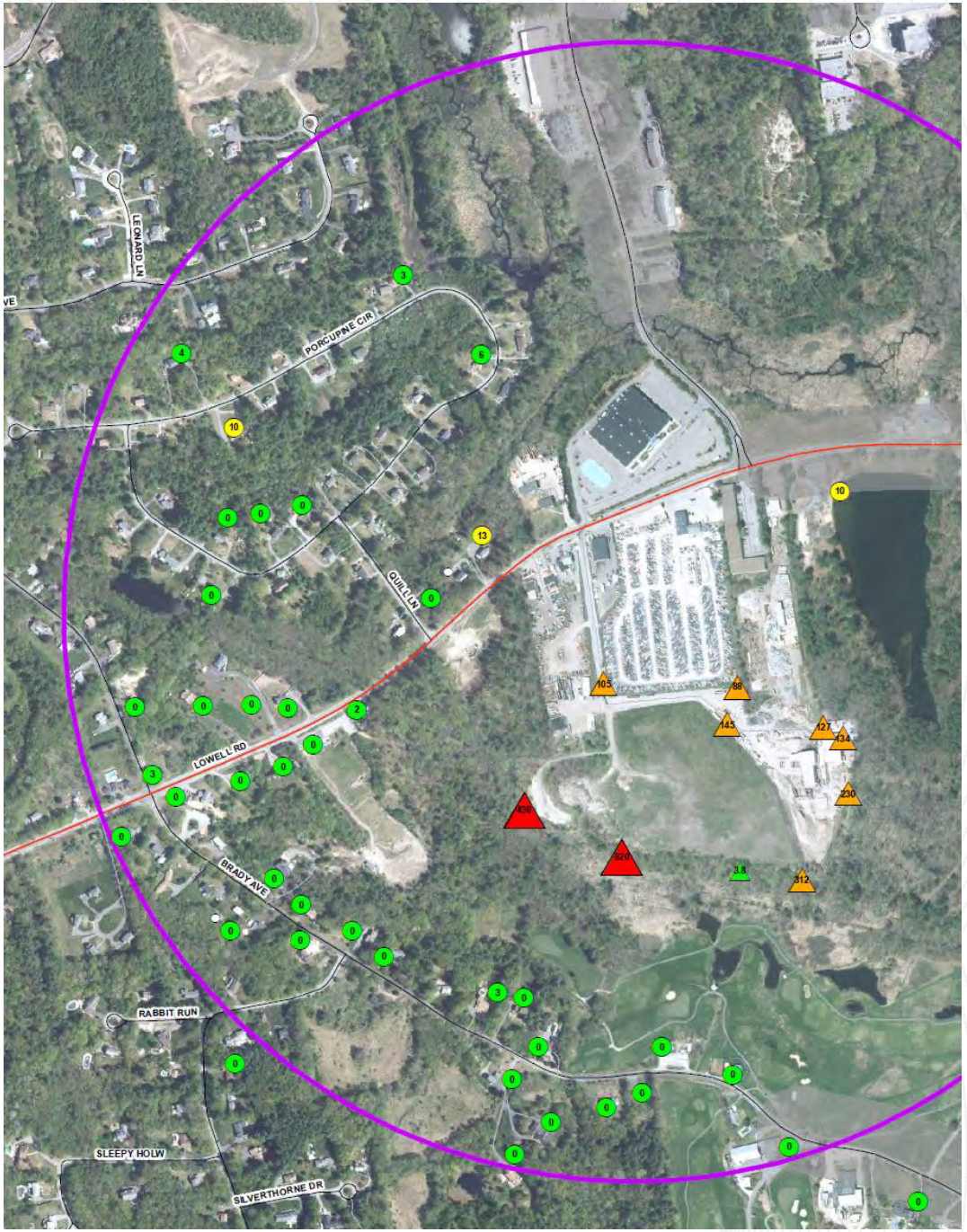
NEW HAMPSHIRE DEPARTMENT OF Environmental Services

LL&S Landfill
Salem, NH

- C&D wastes, 1978 – 1984
- Unlined, capped in 1986
- Foam use at landfill fires



0.5 Mile Radius

Private/Public Wells PFOA + PFOS (PPT)	Monitoring Wells PFOA + PFOS (PPT)
≥400	≥400
70 - <400	70 - <400
10 - <70	10 - <70
<10	<10
Result Pending	Result Pending

http://des.nh.gov/, accessed 10/4/2016

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NEW HAMPSHIRE DEPARTMENT OF Environmental Services

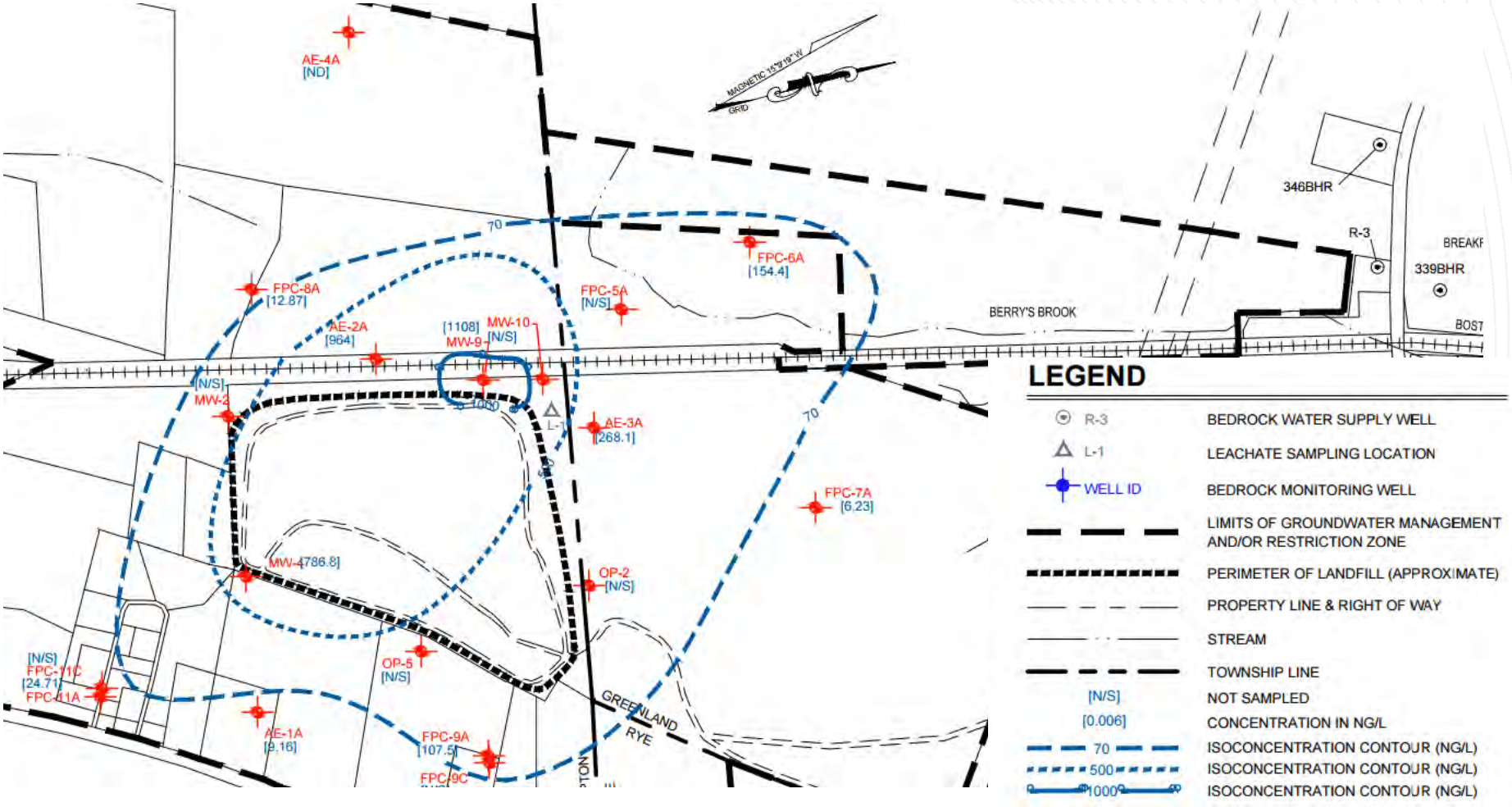
Coakley Landfill

North Hampton and Greenland, NH

- 27 acre, unlined landfill
- 1972-1985, accepted municipal and industrial wastes and incinerator residue
- 1,4-dioxane and PFAS concerns
- Groundwater sampling for six PFAS in July 2016, per NHDES and EPA request

- Following figures from a report titled: *Results of Perfluorinated Chemical Groundwater Sampling for Selected Wells within OU-1 and OU-2 at the Coakley Landfill - North Hampton, New Hampshire* prepared for the Coakley Landfill Group by CES, Inc., dated September 2, 2016.

PFOA + PFOS: Overburden Groundwater



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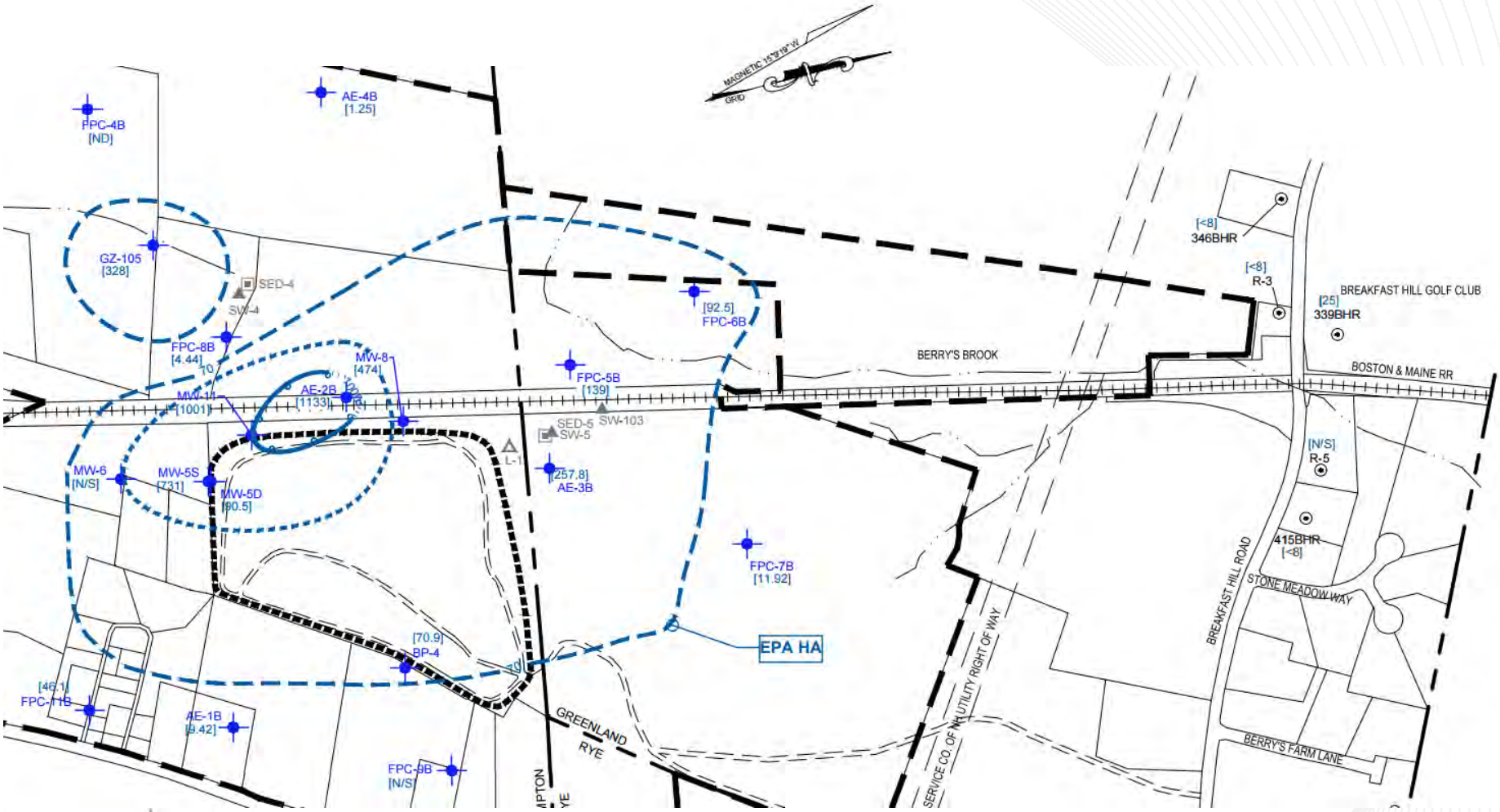
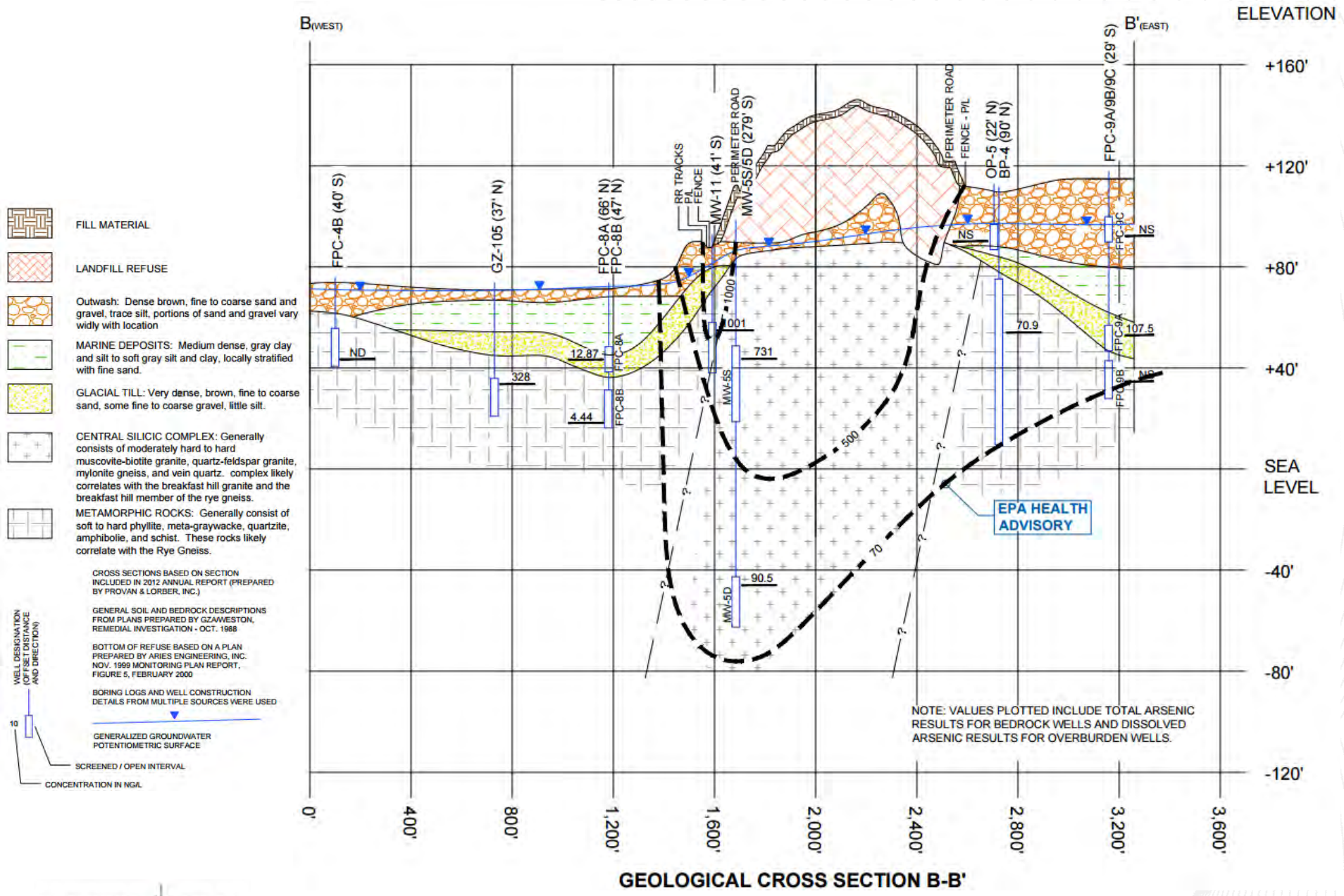
PFOA + PFOS: Bedrock Groundwater





GEOLOGICAL CROSS SECTION B-B'

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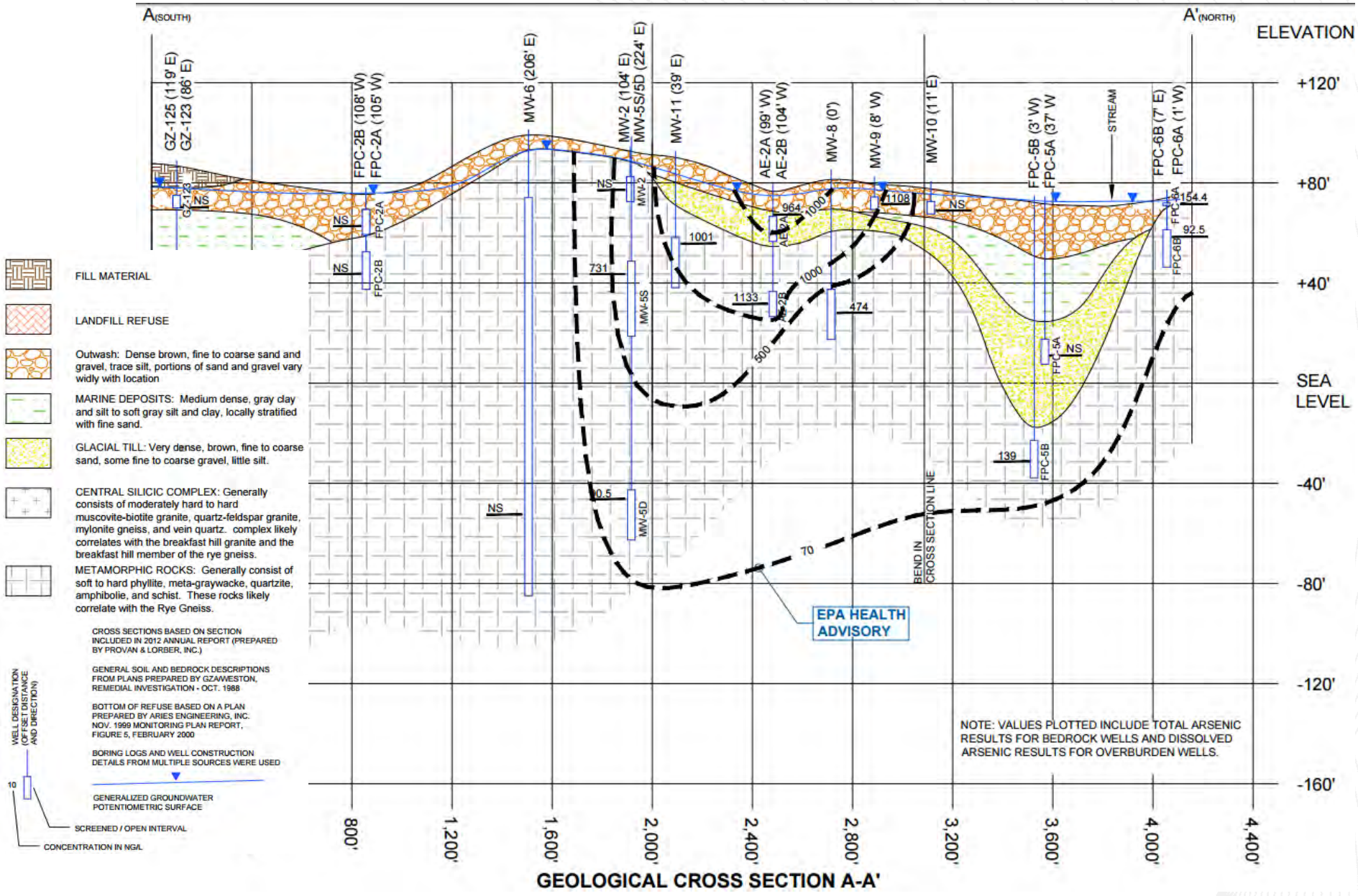

GEOLOGICAL CROSS SECTION A-A'

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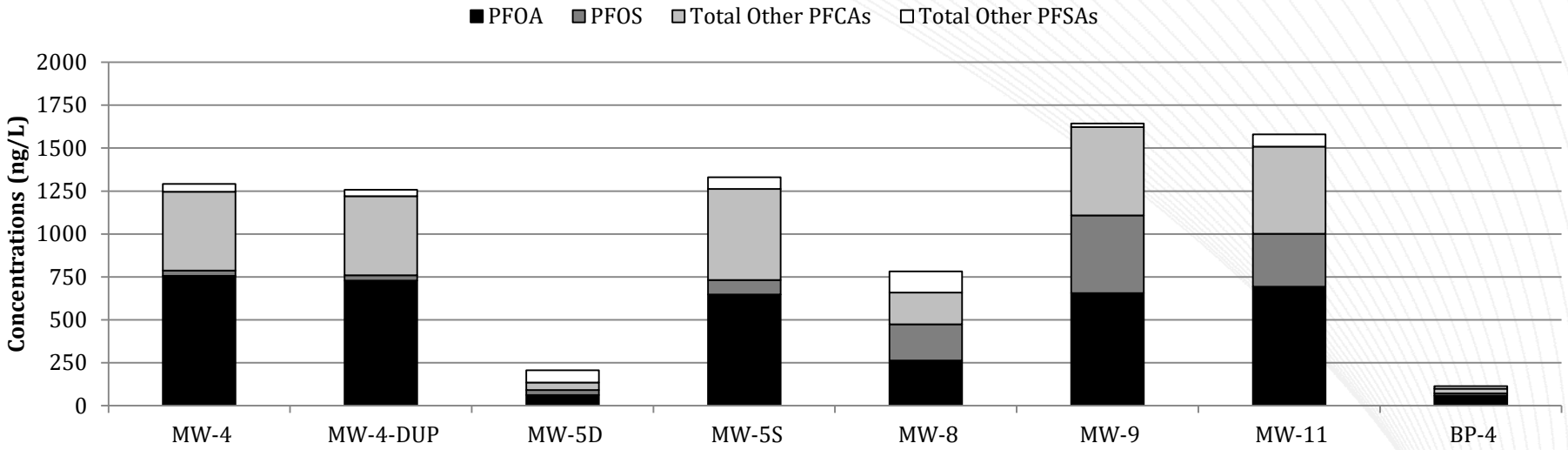
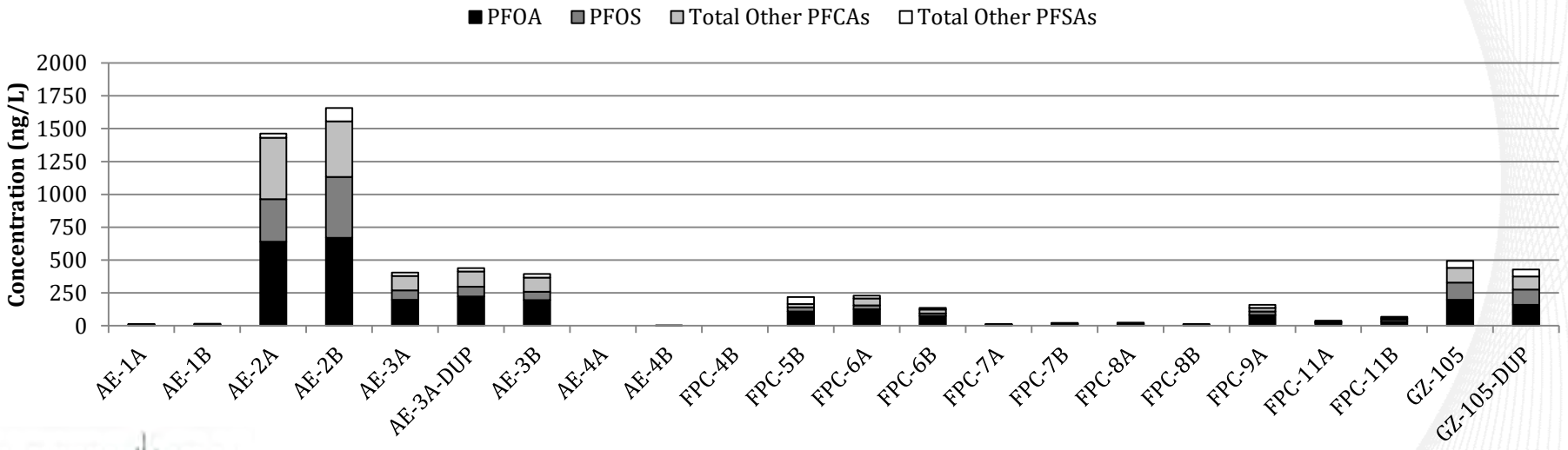
Coakley Landfill, OU-1, PFAS Concentrations by Location



Coakley Landfill, OU-2, PFAS Concentrations by Location



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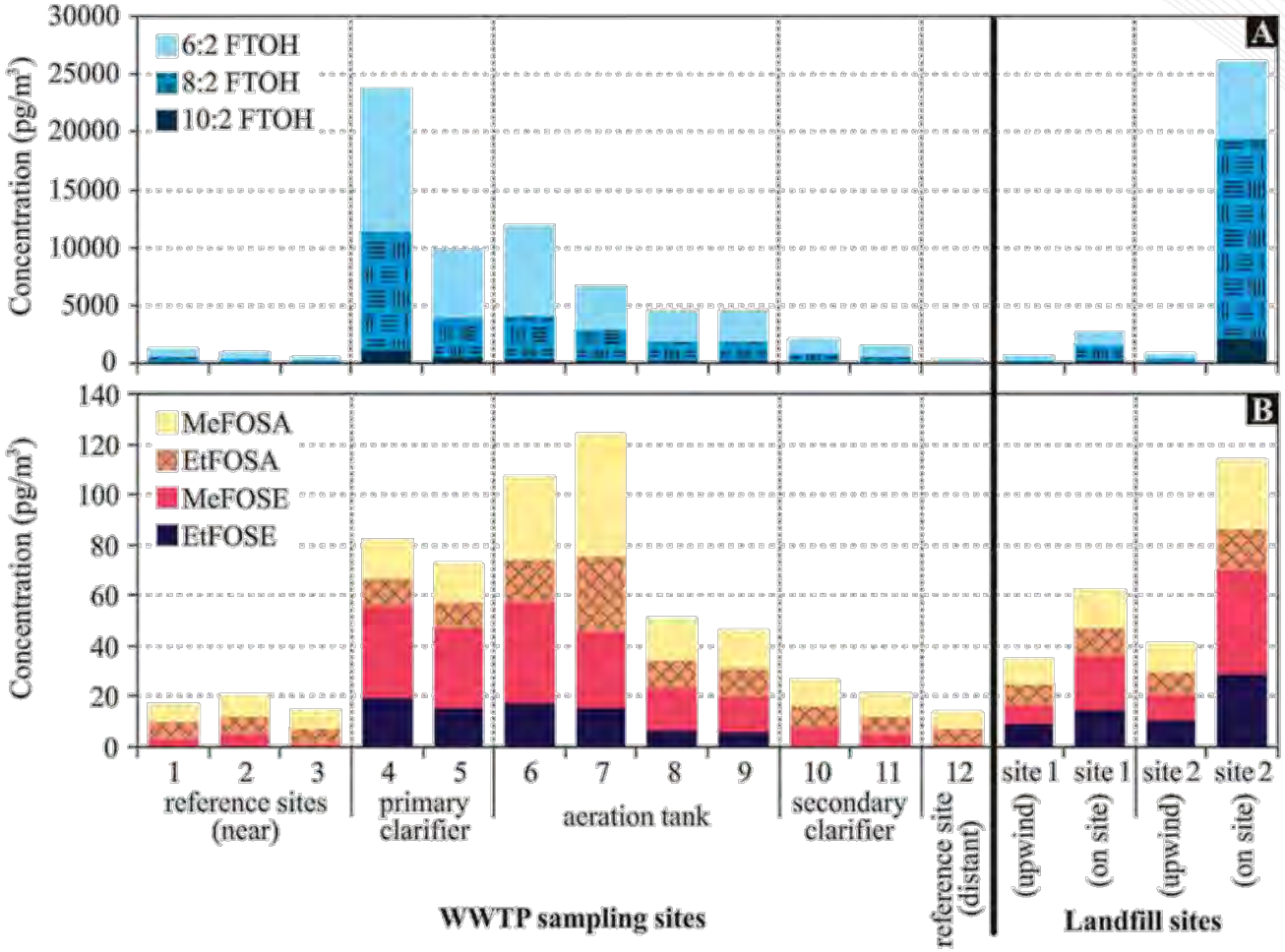
Implications for Landfill Management

- PFAS impacts are being found at landfills
- Potential sampling for PFAS
  - Perimeter/compliance monitoring wells
  - Leachate
  - PFAS plumes ?
- Leachate management
  - Hazardous waste designations ?
  - Restrictions on discharge ?

Airborne PFAS from Landfills

Ahrens et al., ES&T, April 2011,
http://pubs.acs.org/doi/abs/10.1021/es1036173



Volatile PFAS and Precursors

Conclusions

- Landfills receive PFAS in wastes
- PFAS have been found in leachate at levels above drinking water standards/guidelines
- PFAS have been found in groundwater monitoring wells located near landfills
- More data will emerge on landfill impacts
- More data will emerge on PFAS health effects