



2026 RITS

REMEDIATION INNOVATIVE TECHNOLOGY SEMINAR

Student Handbook
Summer 2026

Day One

- Groundwater Treatment Technologies for Per- and Polyfluoroalkyl Substances (PFAS): Sorption, Separation, and Destruction
- Applying PFAS Forensics to Complex, Multi-Source Sites
- Public Outreach for PFAS Off-Base Drinking Water Well Sampling

Day Two

- Optimizing the Journey to Long-Term Management and Site Closure
- Groundwater-Surface Water Interactions
- Evaluation of PFAS Sources under the Watershed Contaminated Source Document (WCSD) Process



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Applying PFAS Forensics to Complex, Multi-Source Sites

Public Outreach for PFAS Off-Base Drinking Water Well Sampling

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Groundwater-Surface Water Interactions

**Evaluation of PFAS Sources under the Watershed Contaminated
Source Document (WCSD) Process**



Agenda

RITS Day 1 Presentations

(Times subject to change)

0800 – 0830	Welcome & Introduction
0830 – 1045	Groundwater Treatment Technologies for PFAS: Sorption, Separation, and Destruction There are several management strategies for PFAS-impacted groundwater, including in situ approaches, (e.g., enhanced retention via colloidal activated carbon), and ex situ approaches, (e.g., sorption and separation followed by destruction of concentrates). Central to these technologies is the evaluation of the full lifecycle – from selection of the most appropriate technology and application to end-of-process management of resulting waste streams and residuals via disposal and destruction. This presentation will focus on the suitability of these technologies, examining critical factors related to site conditions such as site characterization/conceptual site model (CSM) factors, PFAS concentrations and composition, plume dimensions and hydrology, available infrastructure, safety, disposition of waste streams via disposal or destructive treatment, and cost. Illustrative, field-based case studies from DON and DoW installations will be used to highlight these key factors and performance of the selected technologies. While currently available technologies will be featured, the presentation will also include technologies at advanced development levels from various research, testing, development and evaluation (RDT&E) programs. Speakers: Tony Danko (NAVFAC EXWC) and John Kornuc (NAVFAC EXWC)
1045 – 1100	Break
1100 – 1230	Applying PFAS Forensics to Complex, Multi-Source Sites PFAS chemistry is complex. While not all sites under PFAS remedial investigation require PFAS forensics, some sites with multiple known and unknown on-site and off-site sources may use advanced data interpretation techniques to visualize trends, identify spatial and temporal patterns, and understand background levels, sources, and transformation processes. This presentation will build upon the concepts presented during the 2025 RITS presentation “Contextualizing PFAS Detections: Background and Forensics.” It will go further into targeted PFAS forensics and analytics methodology considerations for PFAS sites, including using automated data processing and a PFAS data analytics framework to i) identify extent of exceedances; ii) map spatial and temporal distributions; iii) detect unique data clusters for source fingerprinting and precursor transformation; iv) compare to an up-to-date repository of literature-based biotransformation pathways; v) implement robust source differentiation functionalities; and vi) employ data gap recognition techniques. This presentation will also discuss a non-DoW case study that has different sources using target PFAS data contributing to a site-wide PFAS plume with multi-year data to evaluate how temporal and spatial PFAS data clusters change and how PFAS precursor transformation can impact forensics and CSM understanding. Speaker: Dora Chiang (Jacobs)
1230 – 1345	Lunch
1345 – 1600	Public Outreach for PFAS Off-Base Drinking Water Well Sampling PFAS have been found in groundwater at many Navy and Marine Corps installations due to past use of aqueous film forming foam (AFFF) and other PFAS-containing materials. As a result, many of these installations are working on or toward testing off-base private drinking water wells to ensure the protectiveness of the surrounding communities. This off-base effort requires the Navy and Marine Corps to engage the community and key stakeholders in the community before sampling to inform them about what PFAS is and what and why testing is being performed, as well as offer an opportunity to ask questions and express concerns. This presentation will outline outreach options for engaging diverse audiences using risk communication principles as applied directly to DON PFAS off-base private drinking water well sampling projects. It will also detail how to effectively plan for an open house meeting, incorporating lessons learned from past meetings. Speaker: Sharon Baumann (Navy and Marine Corps Force Health Protection Command)
1600	Adjourn



Agenda

RITS Day 2 Presentations

(Times subject to change)

0800 – 0815	Welcome & Introduction
0815 – 1000	Optimizing the Journey to Long-Term Management and Site Closure Successful site closure is a pressing challenge within the DON ER Program, requiring a balance of technical feasibility, costs, and regulatory alignment. For cleanup sites where site closure is not feasible (e.g., due to residual contamination or land-use constraints), optimizing long-term management (LTMgt) is essential to maintain protectiveness while minimizing lifecycle costs. This presentation will discuss various exit strategy options, importance of decision frameworks (e.g., decision trees and flow charts), and resources to conduct transition assessments – all assisting RPMs to translate complex site conditions and findings into clear decision pathways that support stakeholder communication and consensus-building. Case studies using these optimization approaches will also be presented to illustrate how RPMs can realize cost avoidance and accelerate advancement toward LTMgt and site closure, aligning with the NORM Optimization Module. Speakers: Paul Favara (Jacobs) and Kim-Lee Yarberry (Jacobs)
1000 – 1015	Break
1015 – 1215	Groundwater-Surface Water Interactions (GSI) GSI investigations are often performed when groundwater with highly mobile contaminants, like PFAS, have the potential to migrate to surface water bodies and therefore are focused on the transition zone where shallow groundwater and surface water interact. These investigations help optimize site characterization by confirming groundwater migration pathways, defining the extent of contaminant releases, informing risk assessments, quantifying groundwater discharge and contaminant flux, informing remedial design strategies, and monitoring remedy effectiveness. This presentation will introduce GSI, identify scenarios in which GSI investigations are necessary, review common methods for GSI investigations, discuss how to plan for and scope GSI investigations, and address the unique challenges that PFAS GSI investigations pose. Case studies will be discussed from Joint Base Cape Cod and Naval Station Newport. Demonstration and validation of new and promising techniques will also be covered, including unmanned aircraft systems (UAS) thermal infrared imaging, passive samplers, specialized seepage meters, and a multiscale thermal and electromagnetic technologies toolbox for mapping and monitoring GSI. Speaker: Michael Mathioudakis (GSI Environmental)
1215 – 1330	Lunch
1330 – 1515	Evaluation of PFAS Sources under the WCSD Process Sediment and surface water at DON cleanup sites can be influenced by multiple pathways, including on-site releases, off-site sources, regional background, groundwater migration, and stormwater transport. Where off-site sources can contribute to sediment impacts at a DON site, these pathways must be evaluated to support defensible sediment investigations and response decisions. The WCSD is a concise, policy-driven report used to identify and document potential DON and non-DON contaminant sources within a watershed that could affect sediments associated with DON cleanup sites. This presentation will provide an overview of the WCSD process, including when a WCSD is required and the key steps for development, with emphasis on the recent updates regarding PFAS-related considerations for literature review, CSM development, and source evaluation. Examples from recent DON WCSDs will be used to illustrate application of the process and highlight key considerations for RPMs, particularly at sediment sites where PFAS are a concern. Speaker: Wendy Hovel (Geosyntec)
1515	Adjourn

Acronyms

°C	degrees Celsius
µg	microgram(s)
µg/kg	microgram(s) per kilogram
µg/L	microgram(s) per liter
ΔT	temperature difference
1,1,2-TCA	1,1,2-trichloroethane
ACL	alternative concentration limit
AFB	Air Force Base
AFCEC	Air Force Civil Engineer Center
AFFF	Aqueous Film Forming Foam
AI	artificial intelligence
AM	Adaptive Management
AMP	adaptive management plan
AOC	area of concern
AOF	adsorbable organic fluorine
AOR	Area of Responsibility
ARAR	applicable or relevant and appropriate requirement
ARFF	Aircraft Rescue and Fire Fighting
ASN	Assistant Secretary of the Navy
BA	Bachelor of Arts
BFI	Baseflow Index
bgs	below ground surface
Br-PFAS	branched PFAS
BRAC	Base Realignment and Closure
BS	Bachelor of Science
BV	bed volume
CAC	colloidal activated carbon
CAO	corrective action objective
CCEHGI	Clemson Cooperative Extension Home and Garden Information Center
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF&T	contaminant fate and transport
CIC	combustion ion chromatography
cis-1,2,-DCE	cis-1,2-dichloroethane
CLEAN	Comprehensive Long-term Environmental Action—Navy
CNO	Chief of Naval Operations
COC	chemical of concern
CODEL	congressional delegation
COPC	chemical of potential concern
CSM	conceptual site model
CUI	Controlled Unclassified Information
CVOC	chlorinated volatile organic compound

Acronyms

CWT	centralized water treatment
DASN(MR&E)	Deputy Assistant Secretary of the Navy for Mission Readiness and Environment
DCE	dichloroethylene
DIU	Defense Innovation Unit
DJI	Da Jiang Innovations
DNAPL	dense nonaqueous phase liquid
DO	dissolved oxygen
DoD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
DoW	Department of War
dpm/L	disintegrations per minute per liter
DQO	data quality objective
DRNA	Department of Natural and Environmental Resources
DRE	destruction removal efficiency
DW	drinking water
EBCT	empty bed contact time
ECF	electrochemical fluorination
EDR	environmental database report
EE/CA	Engineering Evaluation/Cost Analysis
EISB	enhanced in situ bioremediation
ELAP	Environmental Laboratory Accreditation Program
EM	electromagnetic
EO	electrochemical oxidation
EOF	extractable organic fluorine
EPA	United States Environmental Protection Agency
EQB	Environmental Quality Board
ER	Environmental Restoration
ER, N	Environmental Restoration, Navy
ERD	enhanced reductive dechlorination
ERDC	Engineer Research and Development Center
ERP	Environmental Restoration Program
ERT	electrical resistivity tomography
ESD	explanation of significant differences
ESTCP	Environmental Security Technology Certification Program
EVO	emulsified vegetable oil
EVS	Earth Volumetric Studio
EXWC	Engineering and Expeditionary Warfare Center
FAA	Federal Aviation Administration
FF	foam fractionation
FFS	focused feasibility study
FFTA	firefighter training area
FO-DTS	fiber optic distributed temperature sensing
FS	feasibility study

Acronyms

FTA	fire training area
FTCA	fluorotelomer carboxylic acid
FTOH	fluorotelomer alcohols
FTS	fluorotelomer sulfonate
FY	fiscal year
GAC	granular activated carbon
gal	gallon(s)
GC/MS	gas chromatography/mass spectrometry
GFFP	guaranteed firm fixed price
GMS	groundwater modeling system
gpd	gallons per day
GSI	groundwater-surface water interactions
GUI	graphic user interface
GW	groundwater
GWRS	groundwater replenishment system
HALT	Hydroalkaline Thermal
HF	hydrofluoric acid
HFC	hydrofluorocarbons
HFPO-DA	hexafluoropropylene oxide dimer acid
HH	human health
HI	hazard index
HHRA	human health risk assessment
I-RACR	Interim Remedial Action Completion Report
ID	identification
IDW	investigation-derived waste
IR	installation restoration
IRP	Installation Restoration Program
ISFF	in situ foam fractionation
ITRC	Interstate Technology & Regulatory Council
IX	ion exchange
JEB	Joint Expeditionary Base
L/day	liters per day
L/hr	liters per hour
L/min	liters per minute
L-PFAS	linear PFAS
lb	pound(s)
LC/HRMS	liquid chromatography high-resolution mass spectrometry
LC/MS/MS	liquid chromatography tandem mass spectrometer
LC-qToF	liquid chromatography – quadrupole time of flight mass spectrometry
LNAPL	light nonaqueous-phase liquid
LOE	line of evidence
LTMgt	long-term management

Acronyms

LUC	land use control
LUST	leaking underground storage tank
m/day	meters per day
MCAS	Marine Corps Air Station
MCL	maximum contaminant level
mg/kg	milligram(s) per kilogram
mg/L	milligram(s) per liter
MGD	million gallons per day
ML	machine learning
MNA	monitored natural attenuation
MS	Master of Science
MW	monitoring well
NA	not available
NAF	Naval Air Facility
NAIP	natural attenuation indicator parameters
NAPL	nonaqueous phase liquid
NAPR	Naval Activity Puerto Rico
NAS	Naval Air Station
NAVFAC	Naval Facilities Engineering Systems Command
Navy	Department of the Navy
NB	Naval Base
NBPL	Naval Base Point Lima
NC	not calculated
ND	nondetect
NDAA	National Defense Authorization Act
NESDI	Navy's Environmental Sustainability Development to Integration
NIST	National Institute of Standards and Technology
NFA	no further action
ng	nanogram(s)
ng/kg	nanogram(s) per kilogram
ng/L	nanogram(s) per liter
NMCRHPC	Navy and Marine Corps Force Health Protection Command
NOAA	National Oceanic and Atmospheric Administration
NOM	natural organic matter
NORM	Normalization of Environmental Data Systems
NPDES	National Pollutant Discharge Elimination System
NRL-CBD	Naval Research Laboratory – Chesapeake Bay Detachment
NSWC	Naval Surface Warfare Center
NSZD	natural source zone depletion
NTA	non-targeted analysis
NTCRA	Non-Time-Critical Removal Action
NWS	Naval Weapons Station
O&M	operations and maintenance
OASW(EI&E)	Office of the Assistant Secretary of War for Energy, Installations, and Environment

Acronyms

OCONUS	Outside the Continental United States
OCWD	Orange County Water District
OH•	hydroxide radical
OLEM	Office of Land and Emergency Management
OOM	order(s) of magnitude
OPSEC	Operational Security
OTI	Optimization and Technology Innovation
OTM	other test method

P&T	pump and treat
PA	preliminary assessment
PAC	powdered activated carbon
PAH	polycyclic aromatic hydrocarbon
PAL	project action level
PAO	Public Affairs Office
PCB	polychlorinated biphenyl
PDI	predesign investigation
PDP	preferential discharge point
PE	professional engineer
PFAA	perfluoroalkyl acid
PFAS	per- and polyfluoroalkyl substances
PFBA	perfluorobutanoic acid
PFBS	perfluorobutanesulfonic acid
PFCA	perfluoroalkyl carboxylic acid
PFDA	perfluorodecanoic acid
PFDaA	perfluorododecanoic acid
PFDoS	perfluorododecane sulfonate
PFDS	perfluorodecane sulfonate
PFHpA	perfluoroheptanoic acid
PFHpS	perfluoroheptanesulfonic acid
PFHxA	perfluorohexanoic acid
PFHxS	perfluorohexanesulfonic acid
PFNA	perfluorononanoic acid
PFNS	perfluorononanesulfonic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctanesulfonic acid
PFPeA	perfluoropentanoic acid
PFPeS	perfluoropentanesulfonic acid
PFPrA	perfluoropropionic acid
PFSA	perfluorosulfonic acid
PFUnA	perfluoroundecanoic acid
PFUnS	perfluoroundecanesulfonic acid
PG	professional geologist
PhD	Doctor of Philosophy
PIC	product of incomplete combustion
PID	product of incomplete destruction
PII	personally identifiable information

Acronyms

POC	point of compliance
poly-DADMAC	polydiallyldimethylammonium chloride
POTW	publicly owned treatment works
ppt	part(s) per trillion
PQL	practical quantitation level
PRB	permeable reactive barrier
PRMS	Precipitation Runoff Modeling System
psi	pounds per square inch
PWO	Public Works Officer
Q&A	questions and answers
QA	quality assurance
QC	quality control
RA	remedial action
RA-C	remedial action-construction
RA-O	remedial action optimization
RAB	Restoration Advisory Board
RAC	Remedial Action Contract
RACR	Remedial Action Completion Report
RC	Response Complete
RCRA	Resource Conservation and Recovery Act
RD	remedial design
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine
RFA	RCRA facility assessment
RI	remedial investigation
RIP	remedy-in-place
RITS	Remediation Innovative Technology Seminar
RO	reverse osmosis
ROD	record of decision
ROE	right of entry
ROI	return on investment
RPM	remedial project manager
RSL	regional screening level
RSSCT	Rapid Small Scale Column Testing
RTAI	Remediation Transition Assessment Index
SB-RAC	Small Business Remedial Action Contract
SBPFM	sediment bed passive flux meter
SC	site closeout
SCADA	Supervisory Control and Data Acquisition
SCWO	supercritical water oxidation
SDWA	Safe Drinking Water Act
SERDP	Strategic Environmental Research and Development Program
SGD	submarine groundwater discharge
SI	site inspection
SJCA	St. Juliens Creek Annex

Acronyms

SOM	soil organic material
SOP	standard operating procedure
SME	subject matter expert
SVE	soil vapor extraction
SW	surface water
SWMU	solid waste management unit
TarGOST	Tar-specific Green Optical Screening Tool
TCE	trichloroethene
TCRA	time-critical removal action
TDS	total dissolved solids
TF	total fluorine
TFA	trifluoroacetic acid
TFMS	trifluoromethanesulfonic acid
TI	technical impracticality
TIF	total inorganic fluorine
TIR	thermal infrared imaging
TMB	trimethylbenzene
TMDL	total maximum daily load
TOC	total organic carbon
TOF	total organic fluorine
TOF-CIC	total organic fluorine analyzed by combustion ion chromatography
TOPA	total oxidizable precursor assay
TOR	Time of Remediation
TPH	total petroleum hydrocarbons
TRDL	technology readiness level
TSDF	treatment, storage, and disposal facility
TSS	total suspended solids
TTA	target treatment area
TTZ	target treatment zone
TW	treatment well
TWFF	Tow Way Field Farm
UAS	unmanned aircraft system
UCL	upper confidence limit
UCMR	Unregulated Contaminant Monitoring Rule
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UST	underground storage tank
UV	ultraviolet
V	volts
VC	vinyl chloride
VGAC	vapor-phase granular activated carbon
VOC	volatile organic compound
VTP	vertical temperature profiler

Acronyms

WSCD	Watershed Contaminated Source Document
WTF	water table fluctuation
WW	wastewater
WWTP	wastewater treatment plant
XO	Executive Officer
ZVI	zero-valent iron

Glossary

Aqueous Film Forming Foam (AFFF): A fire suppressant used to extinguish flammable liquid fires, such as fuel fires. Often used in shipboard and shore facility fire suppression systems, fire-fighting vehicles, and at fire-training facilities.

Artificial tracer: A tracer that is deliberately released or injected in groundwater for measurement to infer groundwater flux and contaminant fate and transport.

Asymptotic: A mathematical curve that approaches a single value but never reaches it. In the context of environmental cleanup, asymptotic concentrations indicate the active remedy has reached a limit for efficiently treating a contaminant and other management or technologic strategies should be considered.

Background: Substances or locations that are not influenced by releases from a site and are usually described as naturally occurring or anthropogenic.

Base Realignment and Closure (BRAC): A federal program authorized by Congress to realign, close, and transfer military installations, including investigation and remediation of environmental contamination under CERCLA.

Background concentration: The concentration of a substance that is naturally occurring or resulting from human/anthropogenic impacts unrelated to the discharge of pollutants or hazardous substances at a site.

Baseflow: The portion of streamflow derived from groundwater discharge, bank storage, and delayed subsurface flow rather than direct runoff.

Baseflow Index (BFI): The ratio of long-term mean baseflow to total streamflow.

Breakthrough time: The time between when a solute or tracer is released from a specific source (like a spill site or recharge area) and when it reaches a receptor, such as a monitoring well or surface water body.

Chemical(s) of concern (COCs): Specific chemicals that are identified for evaluation in the site assessment process.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA): A United States federal law, also known as Superfund, aimed at cleaning up sites contaminated with hazardous substances and pollutants. CERCLA is codified in 42 United States Code Chapter 103. This law created a tax on the chemical and petroleum industries and provided broad federal authority to respond directly to releases or threatened releases of hazardous substances that may endanger public health or the environment.

Conceptual site model (CSM): A written, illustrative, or graphic framework for understanding the key processes and mechanisms controlling the nature, extent, fate, and transport of COCs from the source, through the pathway, to the receptor at a site. It should outline the potential exposure pathways and receptors for consideration in an ecological risk assessment, provide a road map to which pathways require quantified assessment, and reflect the best interpretation of available information at any point in time.

Glossary

Confining layer: A geologic unit of impermeable or low-permeability material that restricts the flow of groundwater.

Corrective Action Objectives (CAOs): Media-specific cleanup goals that identify the chemicals of concern, exposure pathways, and target concentrations or conditions necessary to protect human health and the environment.

Data gaps: Missing or incomplete data in a dataset that can impact analysis and decision-making processes.

Data quality objective (DQO): Statements derived from the DQO process that clarify technical objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decision making about a site.

Decision framework: A structured process that uses site data, performance metrics, and decision criteria to guide exit strategies and transition decisions toward long-term management or site closure.

Defensible: In the context of data and analysis, it refers to results or methodologies that are scientifically and logically sound and can withstand scrutiny.

Dense nonaqueous phase liquid (DNAPL): Chemicals or mixtures of chemicals that are heavier than water and only slightly soluble in water (e.g., chlorinated solvents).

Disintegrations per minute (dpm): Unit of measure of radioactivity indicating the number of radioactive decays occurring in a radioactive sample over a minute.

Electrical Resistivity Tomography (ERT): A geophysical technique for measuring the spatial distribution and contrast of electrical resistivity in the subsurface.

Engineering Evaluation/Cost Analysis (EE/CA): A CERCLA study, typically more streamlined than an RI/FS, prepared to evaluate removal action alternatives and associated costs, typically supporting a non-time-critical removal action.

Environmental Database Report (EDR): A report that compiles and summarizes information from federal, state, and local environmental databases to identify known or potential environmental conditions, regulatory listings, and compliance considerations for a site or project area.

Environmental Laboratory Accreditation Program (ELAP): A nationwide accreditation program that ensures laboratories generate environmental and public health data of known, consistent, and documented quality to meet stakeholder needs through effective program implementation and continuous improvement.

Environmental Restoration, Navy (ER,N): The Department of the Navy (Navy) Environmental Restoration Program (ERP) account funding all Environmental Restoration activities at active bases where contamination is suspected or confirmed within the environment for the Navy and the Marine Corps.

Glossary

Environmental Restoration Program (ERP): The ERP is a Navy initiative to identify, investigate, and clean up former waste disposal sites on military property. The ERP's objectives are to reduce the risk to human health and the environment from past waste disposal operations and hazardous material spills in a cost-effective manner.

Exit strategy: A detailed, dynamic and succinct plan for accomplishing specific performance goals within a defined time period to assure protection of human health and the environment.

Eutrophication: An increase in the amount of plant and algae growth when the environment becomes enriched with nutrients, often leading to excessive algal blooms and oxygen depletion.

Feasibility study (FS): A detailed assessment of cleanup options for a contaminated site, determining the most effective, cost-efficient, and feasible remedial alternative.

Fiberoptic Distributed Temperature Sensing (FO-DTS): A technique that uses laser pulses sent through fiber-optic cables to measure temperature along the cable length. Applications include measurement of hydrologic processes that occur at the groundwater-surface water interface.

Five-year review (FYR): A periodic assessment of the progress and effectiveness of a remedial action plan or project at contaminated sites.

Forensics: the methodologies and practices to identify the sources and pathways of chemicals in the environmental, including sampling, laboratory analyses, and data interpretation.

Freshwater-Saltwater Interface: The subsurface boundary between fresh groundwater and saltwater.

GenX: Chemours® trademark name for a synthetic, short-chain organofluorine chemical compound, the ammonium salt of hexafluoropropylene oxide dimer acid (HFPO-DA). It can also be used more informally to refer to the group of related fluorochemicals that are used to produce GenX.

Geophysical methods: A variety of tools and techniques for characterizing subsurface structure, composition, and dynamics. Includes electrical resistivity, seismic, electromagnetic, and gravity methods.

Ghyben-Herzberg Principle: The mathematical relationship establishing that for every foot of fresh water in an unconfined aquifer above sea level, there will be 40 feet of fresh water in the aquifer below sea level.

Granular Activated Carbon (GAC): A porous adsorption media with extremely high internal surface area that can efficiently remove a variety of chemicals from air and water. GAC can be manufactured from a variety of raw materials with porous structures.

Groundwater-Surface Water Interactions (GSI): Interactions between interconnected groundwater and surface water at the Groundwater-Surface Water Interface.

Hazard index (HI): The sum of more than one hazard quotient for multiple substances and/or multiple exposure pathways. The HI is calculated separately for chronic, subchronic, and shorter-duration exposures.

Glossary

Hazard quotient (HQ): Numerical ratio that compares the exposure level of a substance to a reference level that is considered safe or harmless. The reference level can be a dose, a concentration, or a toxicity value for a specific type of organism or population. If the hazard quotient is less than 1, no adverse effects are expected from the exposure. If the hazard quotient is greater than 1, adverse effects are possible or likely.

Hydraulic gradient: The slope of the water table or other potentiometric surface, indicating the direction and rate of groundwater flow.

Hydrophilic: Having a tendency to mix with, dissolve in, or be wetted by water. Oil-resistant.

Hyporheic Zone: The transition zone below and alongside a streambed where shallow groundwater and surface water mix.

Ion Exchange (IX): The reversible interchange of one charged species of ion for another, typically used for water treatment.

Installation Restoration Program (IRP): A Department of War program established to investigate and remediate environmental contamination at active and former military installations in accordance with CERCLA.

Land use control(s) (LUCs): Non-engineered instruments, such as administrative and legal controls, or engineered and physical barriers, such as fences and security guards, implemented to minimize the potential for exposure to contamination and/or protect the integrity of a response action. They are typically designed to work by limiting land and/or resource use or by providing information that helps modify or guide human behavior at a site.

Life cycle costs (LCCs): The total cost of a project or system over its entire lifespan, including investigation, design, construction, operating and maintenance, performance monitoring, and decommissioning costs.

Light non-aqueous phase liquid (LNAPL): A class of organic liquids that are less dense than water and immiscible with water, allowing them to float on the water table and move within the subsurface.

Lithology: The physical characteristics of rocks, including texture, composition, and grain size.

Long chain per- and polyfluoroalkyl substances (PFAS): Perfluoroalkyl carboxylic acids (PFCAs) with more than 8 carbons, and perfluorosulfonic acids (PFSAs) with more than 6 carbons.

Long-term management (LTMgt): Following the Response Complete milestone, this phase may be required to monitor long-term protectiveness of the remedy when the cleanup goals do not allow unrestricted use. Actions during this phase may involve groundwater monitoring, implementation, and management of LUCs, as well as conducting 5-year reviews. All remedial operations should be completed prior to start of the LTMgt Phase.

Long-term monitoring: Monitoring conducted over an extended period to evaluate contaminant trends, verify remedy performance, and ensure continued protection of human health and the environment.

Glossary

Mass discharge: The total mass of a contaminant moving across a control plane of interest, such as the downgradient edge of the source zone or the groundwater-surface water interface.

Maximum contaminant level (MCL): The legally enforceable primary standards and treatment techniques that apply to public drinking water systems. The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to the maximum containment level goal as feasible using the best available analytical and treatment technologies and taking cost into consideration.

Modeling: Creating and using models to simulate and analyze complex systems, such as climate or environmental systems.

MODFLOW: The United States Geological Survey's modular hydrologic model. Considered an international standard for simulating and predicting groundwater conditions and groundwater-surface water interactions.

Monitored natural attenuation (MNA): A remedy that relies on naturally occurring physical, chemical, and biological processes to reduce contaminant concentrations in soil or groundwater, with monitoring used to verify that these processes are protective of human health and the environment and progressing toward site-specific remedial objectives.

National Pollutant Discharge Elimination System (NPDES): A Clean Water Act permitting program that regulates discharges of pollutants from point sources to waters of the United States.

Natural Source Zone Depletion (NSZD): The collective suite of natural processes that reduce the mass of LNAPL in the subsurface over time, including volatilization, dissolution, and biodegradation.

Natural tracer: A tracer that is naturally present in groundwater. Measured to infer groundwater flux and contaminant fate & transport.

Naval Installation Restoration Information Solution (NIRIS): A specific system or tool used for managing restoration information at naval installations, likely involving environmental data.

Navy Optimization and Reporting Module (NORM): A NAVFAC data management and reporting tool used to track remedy performance, optimization efforts, costs, and progress toward site closeout across the Environmental Restoration program.

Non-Time-Critical Removal Action (NTCRA): A CERCLA removal action implemented when sufficient time exists to evaluate response alternatives through an EE/CA.

Open House-style meeting: A public meeting that includes informational poster displays that allow community members to access information at their own pace and encourage one-on-one interaction with technical experts. Also referred to as "Public Information Session," "Poster Display Session," or "Public Availability Session."

Operation and maintenance (O&M): Combination of system operation, repair, optimization, monitoring, and reporting that are collectively used for the proper functioning of a remedy and to ensure that the remedy remains protective of human health and the environment.

Glossary

Operational Security review (Op Sec): A systematic evaluation of government information to ensure sensitive data is protected from unauthorized public release.

OPTI: Optimization initiative focused on improving return on investment or reducing costs, accelerating or reaching remedial goals, using innovative technologies or approaches, and/or involving unique stakeholders negotiations.

Optimization: Systematic site review at any phase of a cleanup process to identify opportunities to improve remedy protectiveness, effectiveness and cost efficiency, and to facilitate progress toward completion of site work.

Per- and polyfluoroalkyl substances (PFAS): A group of human-made chemicals that have been used in industry and consumer products since the 1940s. They have multiple fluorine atoms attached to an alkyl chain and can repel oil, grease, and water. They are found in many products, such as nonstick cookware, stain-resistant textiles, food packaging, firefighting foams, and medical devices. Perfluoroalkyl substances have a fully fluorinated carbon backbone with the exception of one functional group. The strong carbon-fluorine bonds of PFAS make some of them resistant to degradation and thus highly persistent in the environment.

Perfluorobutanoic acid (PFBA): A perfluorinated PFAS species with four carbon backbone atoms, ending in a carboxylic acid group.

Perfluorobutanesulfonic acid (PFBS): A perfluorinated PFAS species with four carbon backbone atoms and an attached sulfonate end group.

Perfluorohexanoic acid (PFHxA): A perfluorinated PFAS species with six carbon backbone atoms, ending in a carboxylic acid group.

Perfluorohexanesulfonic acid (PFHxS): A perfluorinated PFAS species with six carbon backbone atoms and an attached sulfonate end group.

Perfluorononanoic acid (PFNA): A perfluorinated PFAS species with nine carbon backbone atoms, ending in a carboxylic acid group.

Perfluorooctanoic acid (PFOA): A perfluorinated PFAS species with eight carbon backbone atoms and an attached carboxylic acid head group and a n-heptyl end group. One of two PFAS species receiving the most regulatory and public attention due to its environmental stability and potential toxicity to humans.

Perfluorooctanesulfonic acid (PFOS): A perfluorinated PFAS species with eight carbon backbone atoms and an attached sulfonate end group. One of two PFAS species receiving the most regulatory and public attention due to its environmental stability and potential toxicity to humans.

Perfluoropentanoic acid (PFPeA): A perfluorinated PFAS species with five carbon backbone atoms, ending in a carboxylic acid group.

Preliminary assessment (PA): This first phase of a CERCLA site investigation identifies contaminated sites based mostly on the review of the existing information about hazardous

Glossary

waste disposal practices at an installation to determine if a release is known, or suspected, to have occurred at a site.

Public outreach: The process of communicating with the public to raise awareness, share information, and encourage participation in matters that affect the community or organization.

Record of Decision (ROD): A CERCLA decision document that formally identifies the selected remedial action for a site and documents the basis for that decision.

Remedial action objectives (RAOs): Medium-specific goals that the remedial action is expected to meet to protect human health and the environment and to comply with the Applicable or Relevant and Appropriate Requirements established in the decision document. The remedial action objectives guide the formulation and evaluation of remedial alternatives.

Remedial alternatives: Different strategies or options considered for cleaning up or mitigating environmental contamination.

Remedial design (RD): Phase in Superfund site cleanup where the technical basis, drawings, and specifications for remedies and technologies are designed.

Remedial investigation (RI): A detailed on-site investigation to fully characterize the nature and extent and fate and transport of the release and the potential risks to human health and the environment.

Resource Conservation and Recovery Act (RCRA): RCRA is the public law that creates the framework for the proper management of hazardous and nonhazardous solid waste. The law describes the waste management program mandated by Congress that gave the United States Environmental Protection Agency authority to develop the RCRA program.

Response Complete (RC): This milestone signifies that the RAOs have been met and the RAO phase has achieved cleanup goals specified in the ROD or Decision Document. Formal documentation for the RC milestone is essential to ensure recognition of completion of cleanup goals at the site. Operation of an active or passive remedy should be complete prior to meeting the RC milestone. Prior to claiming completion of the RC milestone, regulatory concurrence of this documentation is required..

Restoration Advisory Board (RAB): A group of stakeholders that meet regularly to exchange information and discuss cleanup at Defense Environmental Restoration Program-eligible sites.

Risk assessment: Evaluating potential risks and their consequences, including the likelihood and severity of climate-related impacts.

Risk communication: The exchange of information about threats to that which people value. It is a two-way interactive process that respects the interests, values, fears and concerns of stakeholders and treats those involved in communication as partners.

Risk management: The process of identifying, evaluating, selecting, and implementing actions to reduce risk to human health and to ecosystems. The goal of risk management is scientifically sound, cost-effective, integrated actions that reduce or prevent risks while taking into account social, cultural, ethical, political, and legal considerations.

Glossary

Salinity: The dissolved salt content of a body of water.

Salting Out: The process whereby increased salinity reduces the solubility of contaminants, causing them to sorb onto soil and sediments.

Saltwater Intrusion: The movement of saltwater into freshwater aquifers.

Screening level: Environmental concentration used to determine whether chemicals in the environmental warrant further evaluation. This is not an action level.

Sediment Bed Passive Flux Meter (SBPFM): A permeable device that passively intercepts groundwater flow without retaining it for the purpose of making passive in situ point-measurements of cumulative groundwater and contaminant mass fluxes.

Seepage Meter: A device used to measure the flux of water between groundwater and a surface water feature by isolating a portion of the sediment within a cylinder and measuring the volume of water flowing into or out of a connected collection bag over time.

Seepage Run: A hydrologic technique used to measure stream discharge at upstream and downstream edges of stream reaches to determine the net exchange between groundwater and surface water for classification and quantification of gaining and losing sections.

Short-chain PFAS: PFCAs with fewer than eight carbons and PFSAs with fewer than six carbons.

Site closeout (SC): This milestone signifies that the Navy has completed active management and monitoring at a site, the remaining site condition is protective of human health and the environment without restrictions on future land use (Unlimited Use and Unrestricted Exposure), without additional monitoring or LUCs, and no additional funds are expected to be expended at the site. As such, SC is an important milestone; but, unlike remedy in place or RC, it is not a Department of War metric for measuring progress of the Environmental Restoration program.

Site inspection (SI): A CERCLA investigation phase conducted after a preliminary assessment to collect limited sampling data and other information to determine whether a site poses a potential release and whether further investigation is warranted.

Submarine groundwater discharge (SGD): The discharge of groundwater and recirculated seawater from an aquifer into coastal waters.

Subterranean Estuary: The subsurface zone in coastal aquifers where fresh groundwater mixes with recirculated seawater.

Thermal infrared (TIR) imaging: The use of remote technology to detect heat emissions (infrared radiation) from objects to create visible images known as thermograms.

Time-Critical Removal Action (TCRA): A CERCLA removal action conducted when an imminent threat to human health or the environment requires response before an EE/CA can be completed.

Glossary

Town Hall-style meeting: A public meeting during which government representatives and hired experts sit or stand at a head table or in the front of the room, facing an audience of concerned citizens who are seated in rows of chairs.

Transition Assessment: A process to determine when a transition from an active treatment to a long-term passive treatment such as MNA.

Transport and migration pathways: The routes by which contaminants or other materials move through environmental media, such as soil, groundwater, or air.

Unmanned Aircraft System (UAS): A system that consists of a remotely controlled aircraft (“drone”), a ground control station, and a communication link.

Vapor intrusion: The migration of vapor-forming compounds from the subsurface to indoor air.

Visualization: The process of representing data graphically to make it easier to understand and interpret.

Wastewater treatment plant (WWTP): A facility designed to treat domestic, industrial, or mixed wastewater to remove contaminants prior to discharge to surface waters or reuse.

Watershed Contaminated Source Document (WCSD): A potential source-identification and scoping tool prepared in accordance with Chief of Naval Operations policy to document potential Navy and non-Navy contaminant sources within a drainage area that may influence sediments at a Navy IRP or BRAC site; the WCSD supports conceptual site model development but does not replace RI/FS or EE/CA processes. The WCSD does not confirm releases from potential sources.

Speaker Information



Sharon Baumann

Risk Communicator

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Navy and Marine Corps Force Health Protection Command

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Sharon Baumann began working as a Risk Communicator at the Navy and Marine Corps Force Health Protection Command (NMCFHPC) in October 2022. She supports commands throughout the Navy and Marine Corps in preparing for and executing public outreach meetings.

Prior to joining the NMCFHPC, Sharon Baumann worked at Naval Facilities Engineering Systems Command Mid-Atlantic (NAVFAC MIDLANT) for 27 years in numerous positions. She filled in as Acting Environmental Business Line Leader from February through May 2022. In this capacity, she was responsible for overseeing the management of the Environmental Regional Program on behalf of the Commander, Navy Region Mid-Atlantic. At the same time, she served as Director, Regional Environmental Coordination (REC) for NAVFAC MIDLANT, a position she held from May 2017 to October 2022. In this position, she was responsible for managing the REC program on behalf of the Commander, Navy Region Mid-Atlantic, as Department of Defense REC for United States Environmental Protection Agency (EPA) Regions I & III and as Navy REC for Regions II & V. Ms. Baumann held other positions within NAVFAC MIDLANT organization, including Director of Environmental Assessments Branch, Department of Defense Chesapeake Bay Program State Coordinator, and Installation Environmental Program Director for Naval Station Norfolk. Additionally, she was a media manager in the Drinking Water, Storm Water, Wastewater, Pollution Prevention, Emergency Planning & Community Right to Know Act and Pesticide management programs. She also served as an environmental chemist.

Sharon Baumann received a Bachelor of Science degree in Biochemistry from Old Dominion University. She graduated Magna Cum Laude in December 1992.

Speaker Information



Dora Chiang, Ph.D., P.E.
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Dora Chiang, Ph.D., P.E. is the Global Principal for PFAS and Emerging Contaminants at Jacobs, where she provides technical leadership on some of the most challenging site investigation and remediation projects involving regulated and emerging contaminants. With more than 25 years of experience in environmental consulting, Dr. Chiang has led global technical practices focused on emerging contaminants, innovative remediation technologies, and science-based decision-making.

Dr. Chiang specializes in PFAS, 1,4-dioxane, and complex contaminant mixtures, with deep expertise in site characterization, conceptual site model development, fate and transport analysis, and the design and implementation of in situ and ex situ treatment systems. She has served as principal investigator or technical director for multiple Department of Defense and industry-funded research programs, including field demonstrations of PFAS treatment, passive flux measurement, electrochemical oxidation, supercritical water oxidation, and nature-based solutions.

Throughout her career, Dr. Chiang has been instrumental in bridging academic research and applied remediation practice through collaborations with leading universities and technology developers. She has authored and co-authored numerous peer-reviewed journal articles, book chapters, and technical guidance documents, and is a frequent speaker at national and international conferences.

Dr. Chiang holds a Ph.D. in Environmental Engineering from Georgia Institute of Technology and two master's degrees in environmental engineering and chemistry. She is a licensed Professional Engineer. Dr. Chiang is recognized for her strategic vision, technical depth, and leadership in advancing practical solutions for emerging contaminant challenges worldwide.

Speaker Information



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Tony Danko serves as an Environmental Engineer at NAVFAC EXWC. Tony has a Ph.D. in Environmental Engineering and Science and is a licensed professional engineer. His focus areas are chlorinated solvents, petroleum hydrocarbons, munitions constituents, and emerging chemicals, such as per- and polyfluoroalkyl substances (PFAS), and 1,4-dioxane. At EXWC, Tony is involved in various NAVFAC projects and initiatives, including providing technical support to various remedial project managers and Facilities Engineering Commands (FECs). Tony also serves as a member of the Strategic Environmental Research and Development Program/Environmental Security Technology Certification Program (SERDP/ESTCP) Technical Committee in Environmental Restoration, which supports the research, development, testing, and evaluation of innovative technologies.

Speaker Information



Paul Favara, PE, LEED Green Associate
Technology Fellow
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Paul has over 43 years of professional experience, including 26 years with Jacobs/CH2M Hill, Inc. He has served as a project manager, program manager, and technology leader, managing multidisciplinary projects involving site investigations, engineering studies, remedial design and construction, and multimedia compliance audits.

His experience spans more than 17 federal regulatory programs and numerous state programs, with work across major federal portfolios including the United States Navy, United States Army Corps of Engineers, National Aeronautics and Space Administration, Army Environmental Center, Air Force Civil Engineering Center, EPA, and Department of Energy, as well as industrial and state-led projects. He has worked in all 10 EPA regions and across a wide range of geologic and hydrogeologic settings.

Paul is a recognized leader in the development and implementation of innovative remedial technologies and strategies, with a strong track record of successful project delivery and client satisfaction. His technical expertise includes in situ chemical oxidation, hexavalent chromium reduction, in situ bioremediation, monitored natural attenuation, enhanced reductive dechlorination, phytoremediation, green and sustainable remediation, groundwater geochemistry, fate and transport, modeling, and geographic information systems. He also has experience in mass transfer-based groundwater treatment systems, heavy metals treatment, and landfill leachate management.

Paul specializes in remedial process optimization and serves as a Decision Science leader at Jacobs. He has contributed to multiple Interstate Technology and Regulatory Council (ITRC) and ASTM International guidance documents. For NAVFAC, he has supported Guaranteed Firm Fixed Price, Navy CLEAN, Navy RAC, and Small Business RAC contracts. He is a past President of the Sustainable Remediation Forum. He is a Professional Engineer registered in Florida.

Speaker Information



Wendy Rose Hovel, Ph.D., P.E.
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Dr. Wendy Rose Hovel is an aquatic toxicologist and sediment practitioner with more than 20 years of experience supporting sediment management at contaminated and non-contaminated sites. Her work focuses on sediment characterization and management in harbors, ports, rivers, and other waterways, particularly at sites regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Clean Water Act, and related federal and state sediment programs. She has extensive experience supporting United States Navy projects, including sediment investigations where her work has informed dredging, remediation, monitored natural recovery, and regulatory compliance decisions. Dr. Hovel's technical expertise includes sediment toxicity and bioaccumulation, contaminant flux, and exposure pathway evaluation. She applies sediment quality objectives and site-specific, risk-based thresholds to evaluate organic contaminants (including per- and polyfluoroalkyl substances [PFAS]) and metals in sediments. Her experience evaluating sediment contamination and understanding how upstream and off-site sources influence sediment conditions informed her contribution to the Watershed Contaminant Source Document (WCSD) technical report update and its application at both PFAS and non-PFAS-impacted sites.

Speaker Information



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With a BS in microbiology from Ohio State University and a PhD in biochemistry from University of California Los Angeles, Dr. John Kornuc has accrued 35+ years of experience in private consulting and with NAVFAC EXWC in Port Hueneme, California, where he currently serves as a senior scientist in Environmental Restoration. Dr. Kornuc has focused on bioremediation, groundwater management, and treatment at sites contaminated with fuels, chlorinated solvents, and, for the past 10 years, PFAS. He is currently recognized in the Navy as a subject matter expert (SME) in the characterization, fate and transport, and treatment of various liquid and solid matrices containing PFAS. Dr. Kornuc has partnered closely with leading experts on PFAS from academia and private industry and was recognized as Civilian of the Year (FY25) by NAVFAC EXWC for his technical insight resulting in significant cost reductions in the remediation of problematic contaminated sites in NAVFAC Far East (Marine Corps Air Station Iwakuni), NAVFAC Pacific (Red Hill), and several other Navy installations.

Speaker Information



Michael Mathioudakis, PE
Senior Engineer/Geologist
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Michael Mathioudakis is a licensed professional engineer with a BS in Environmental Engineering and a MS in Geology and Geophysics. Michael is a groundwater-surface water interactions (GSI) SME with extensive experience managing in situ and ex situ remediation projects, large-scale natural source-zone depletion studies, and hydrogeologic investigations and modeling. As a Federal Aviation Administration–licensed drone pilot, Michael uses drones to study GSI via thermal imaging. Michael works on research and development and regulatory projects for the Department of War, serving as a co-Principal Investigator and/or subject matter expert for several NAVFAC, Air Force Civil Engineering Center, and Environmental Security Technology Certification Program (ESTCP) projects. Michael has been an invited speaker on GSI at international conferences, universities, community outreach events, technical trainings, and legal forums.

Speaker Information



Kim-Lee Yarberry, PG
Program Technology Manager
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Kim-Lee Yarberry is a senior hydrogeologist at Jacobs with over 25 years of experience in environmental consulting and leader of Jacobs' Field Methods Characterization Community of Practice. She has served as a senior technical consultant for multiple private and federal clients, providing expertise on accelerated and high-resolution site characterization, conceptual site model development and modeling, fate and transport processes, and optimization of long-term monitoring systems. Her experience allows her to develop approaches to address site data gaps, including defining source areas and migration pathways, refining mass distribution, matrix diffusion, and target treatment zones, and identifying factors that may be limiting effectiveness of remedial actions at complex sites. She has led multiple Triad investigations, developing and implementing real-time decision logic and collaborating with various stakeholders.

She currently serves as the program technology manager for one of the Navy's CLEAN contracts, helping to provide environmental solutions, innovations, and efficiencies under the installation restoration program and munitions response program. Kim-Lee received her undergraduate degree at the University of Connecticut and her master's degree at Clemson University. She is a professional geologist registered in Georgia and Mississippi.



HANDBOOK CONTENT

Presentations

**Groundwater Treatment Technologies for Per- and Polyfluoroalkyl
Substances (PFAS): Sorption, Separation, and Destruction**

Applying PFAS Forensics to Complex, Multi-Source Sites

Public Outreach for PFAS Off-Base Drinking Water Well Sampling

Optimizing the Journey to Long-Term Management and Site Closure

Groundwater-Surface Water Interactions

**Evaluation of PFAS Sources under the Watershed Contaminated
Source Document (WCSD) Process**



Groundwater Treatment Technologies for Per- and Polyfluoroalkyl Substances (PFAS): Sorption, Separation, and Destruction

Tony Danko, PhD, P.E., and John Kornuc, PhD

NAVFAC EXWC

RITS 2026

Disclaimer



This seminar is intended to be informational and does not indicate endorsement of a particular product or technology by the Department of War or NAVFAC EXWC, nor should the presentation be construed as reflecting the official policy or position of any of those agencies. Mention of specific product names, vendors, or sources of information, trademarks, or manufacturers is for informational purposes only and does not constitute an endorsement or recommendation by the Department of War or NAVFAC EXWC. Although every attempt is made to provide reliable and accurate information, there is no warranty or representation as to the accuracy, adequacy, efficiency, or applicability of any product or technology discussed or mentioned during the seminar, including the suitability of any product or technology for a particular purpose.

Information in this presentation is current as of 24 April 2026.

EXWC: Engineering and Expeditionary Warfare Center
NAVFAC: Naval Facilities Engineering Systems Command

Speaker Introductions



Tony Danko, PhD, PE NAVFAC EXWC



- Environmental Engineer
- 15+ years experience
- Natural attenuation, bioremediation, and environmental molecular diagnostic tools
- PFAS SME

PE: Professional Engineer
PhD: Doctor of Philosophy
SME: subject matter expert

John Kornuc, PhD NAVFAC EXWC



- Physical Scientist
- 40 years experience
- Site characterization, remediation, treatment wetlands
- PFAS SME

Presentation Overview



- **Introduction**
- PFAS in the Subsurface: Properties and Treatment Challenges
- Regulatory Drivers, Guidance, and Policy
- Treatment
- Case Studies
- Guidelines for Selecting Water Treatment Technologies
- Summary/Key Takeaways

Purpose of Presentation



1. Understand the **chemical/physical properties of PFAS** and their **occurrence** in groundwater, and how these factors **impact treatment choices**
2. Evaluate **treatment technologies for PFAS in groundwater**, including technologies in current use and those in development at higher TRLs, for both ***ex situ*** and ***in situ*** application
3. Understand the general approach of **Separation/Concentration** followed by **Destruction**
4. Understand **technical and economic factors** influencing the selection of cost- effective treatments

Past PFAS RITS

2015

- Emerging Information on Emerging Chemicals

2016

- Managing PFAS at Navy Sites

2017

- Risk Communication for PFAS Sites

2018

- PFAS Remediation: Technologies, Guidance, and Application

2019

- Managing Emerging Chemicals at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Sites
- PFAS Site Characterization

2021

- Best Practices for Conducting PFAS Remedial Investigations

2022

- Navigating the 2021 EPA PFAS Strategic Roadmap
- Emerging Technologies for PFAS Treatment

2023

- Best Practices for PFAS Sampling and Data Interpretation

2024

- Considerations for Conducting Ecological Risk Assessments (ERAs) at PFAS sites
- Considerations for Human Health Risk Assessments (HHRAs) During Remedial Investigations at PFAS Sites

2025

- Remediation of PFAS-Impacted Solids

2026

- **We are HERE: Groundwater Treatment Technologies for PFAS: Sorption, Separation, and Destruction**

Presentation Overview



- Introduction
- **PFAS in the Subsurface: Properties and Treatment Challenges**
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What Makes PFAS Unique

- PFAS are a large group of man-made chemicals (~15,000) characterized by carbon-fluorine bonds
- Degradation resistant—**persistent**
- Water soluble—**mobile**
- Some are **bioaccumulative** and linked to adverse health effects
- Used in many products and processes, in addition to AFFF—**ubiquitous**
- Low-level detections may reflect **background** ubiquity rather than a CERCLA/RCRA release
- FFTAs can have complex site histories using varied AFFF formulations; hundreds of PFAS typically present
- Plumes may have developed without detection for decades
- Challenging for traditional in situ destructive approaches: bioremediation, chemical oxidation/reduction, SVE, etc.

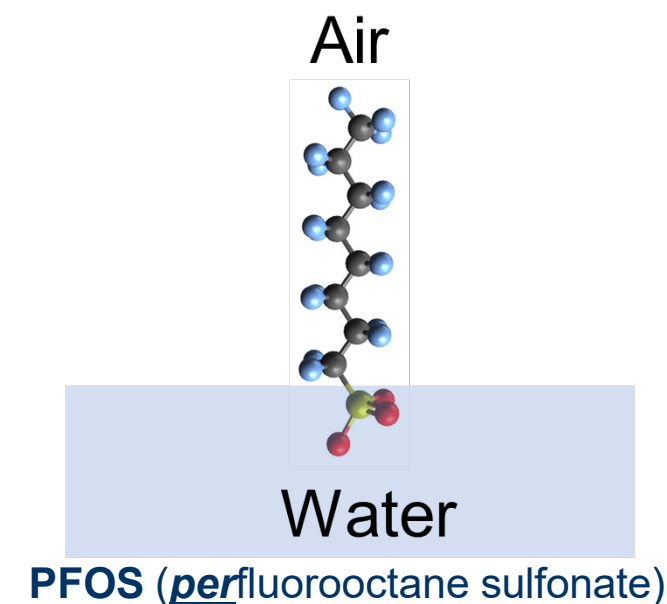
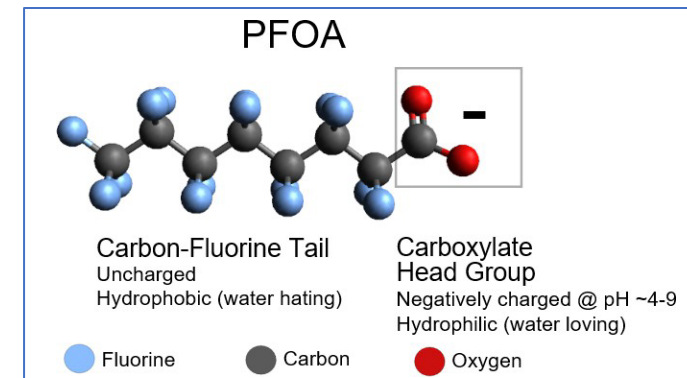


*Firefighter Training, Camp
Lemonnier, Djibouti Africa
(Denton 2011)*

AFFF: aqueous film-forming foam
RCRA: Resource Conservation and
Recovery Act

FFTA: firefighter training area
SVE: soil vapor extraction
PFAA: perfluoroalkyl acid

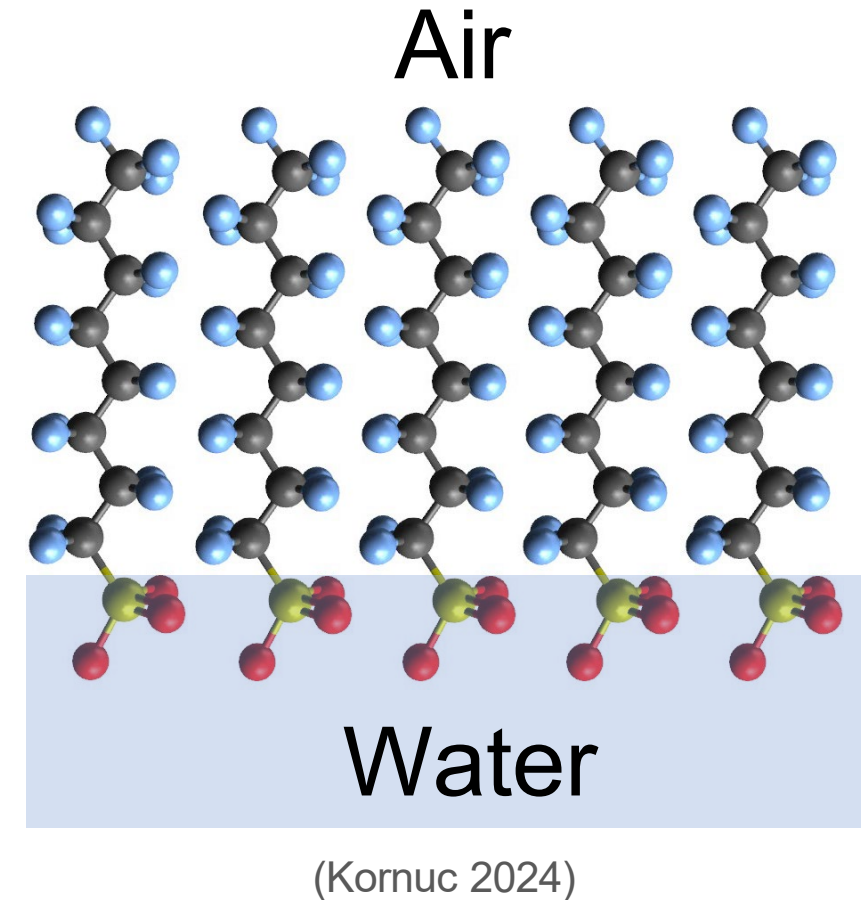
- **C-F bond** is one of organic chemistry's shortest and **strongest single bonds**—difficult to break
- PFAS are inherently both **hydrophobic and oleophobic**
- Most PFAS of current concern in water are **anions** at environmentally-relevant pH's
- **Cationic** and many **zwitterionic** PFAS have net positive charge and included in AFFF formulations; often **sorb** to negatively charged soil minerals
- Transport rates: **anions > zwitterions > cations**
- **Extreme Persistence:** little to no biodegradation or abiotic degradation, though precursor PFAS can transform to “dead end” PFAAs



(Kornuc 2024)

Air-Water Interface Sorption

- **Air-water interface** can account for 50%–75% of retention (Lyu et al. 2018)
- Hydrophilic polar head group seeks water; hydrophobic C-F tail avoids water by extending into air
- **Influencing Factors**
 - Carbon chain length (longer means stronger air-water interface sorption)
 - Ionic strength
 - NAPL Significantly increases PFAS retention (McKenzie et al. 2016)
 - Groundwater composition dictates adsorption magnitudes (Brusseau and Glubt 2019)



NAPL: nonaqueous phase liquid

Low Vapor Pressure and Henry's Constant

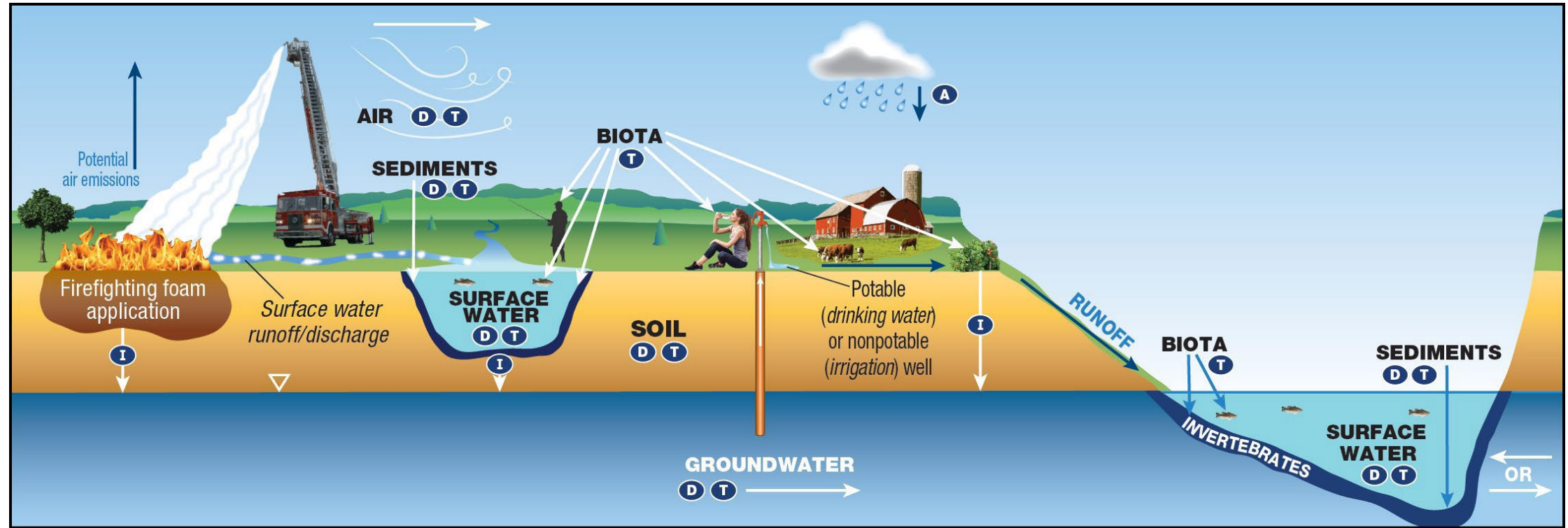


PFAS have low vapor pressure and low Henry's Law constants; therefore **cannot be air-stripped**

Chemical Property	PCB (Arochlor 1260)	PFOA	PFOS	TCE	Benzene
Molecular Weight g/mol	357.7	414.07	538	131.5	78.11
Solubility mg/L ~20 °C	0.0027	3400-9500	519	1100	1780
Vapor Pressure mm Hg (25 °C)	4.05×10^{-5}	0.03	2.48×10^{-6}	77.5	97
Henry's Constant atm-m ³ /mol	4.6×10^{-3}	3.57×10^{-6}	3.05×10^{-6}	0.0103	0.0056
Organic Carbon Part. Coeff. (log K _{oc})	4.8-6.8	2.06	2.57	2.42	2.15

(Adapted from AECOM 2015)

Fire Fighting Site CSM



KEY A Atmospheric Deposition D Diffusion/Dispersion/Advection I Infiltration T Transformation of precursors (abiotic/biotic)

“Environmental Fate and Transport for Per- and Polyfluoroalkyl Substances (PFAS)”, ITRC, 2023.

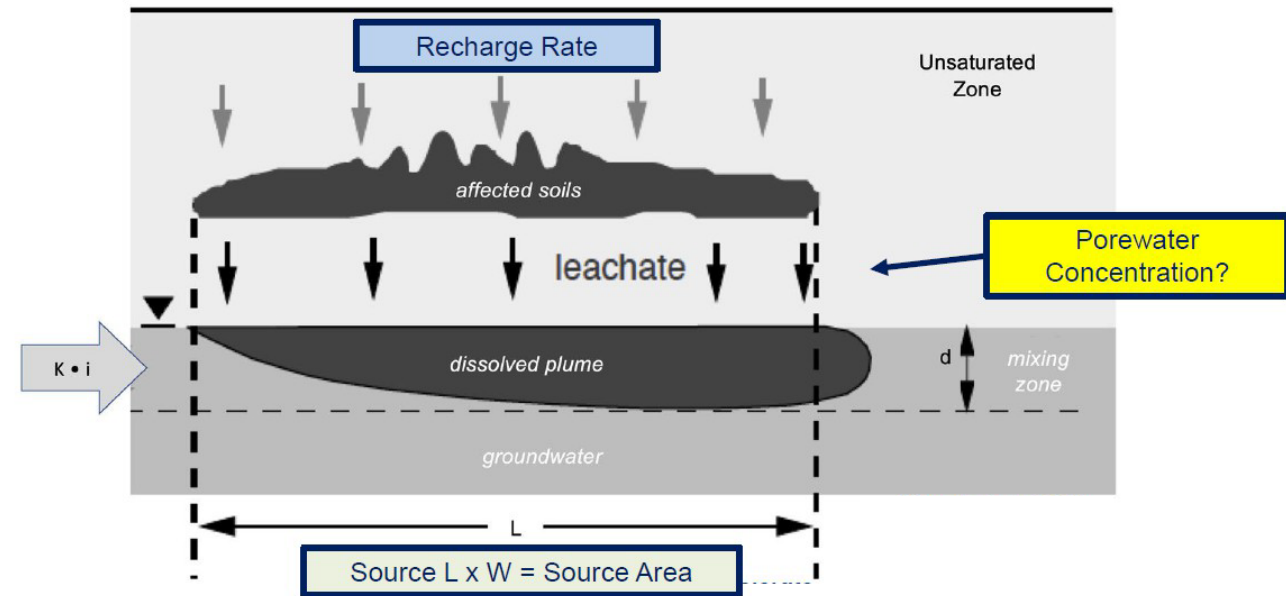
Key: An accurate CSM is essential in developing treatment strategies

Plume Characteristics

- Large dilute plumes
- Plumes long/wide of low concentration (outside of source area)
 - low analytical detection levels (< 1 ng/L) “increases” plume size
 - bulk of plume often <100 ng/L
- PFOS and PFOA typically among highest concentrations
 - PFHxS, 6:2 FTS also high
 - AFFF sites have highest levels in DoW

$$\text{Recharge} \times \text{PFAS Leachate Concentration} = \text{PFAS Mass Flux}$$

$$\text{PFAS Mass Flux} \times \text{Area} = \text{PFAS Mass Discharge (mass/time)}$$



(Schaefer and Newell 2025)

DoW: Department of War
PFOA: perfluorooctanoic acid

FTS: fluorotelomer sulfonic acid
PFOS: perfluorooctansulfonic acid

ng/L: nanograms per liter
PFHxS: perfluorohexanesulfonic acid

Take Aways: PFAS Characteristics



- PFAS are highly resistant to degradation
 - Precursors can transform into intermediates or persistent, terminal PFAAs
 - Recalcitrance makes conventional treatments largely ineffective
- Air-water interfacial sorption is a major retention mechanism in unsaturated media, responsible for 50%–75% of retardation
- Low vapor pressure and low Henry's Law constants means PFAS cannot be air-stripped
- Transport rates depend on PFAS ionic charge (anions > zwitterions > cations) and carbon chain length (shorter = faster)
 - Transport of carboxylates (PFCAs) > sulfonates (PFSAAs) of same C-F chain lengths

PFCA: perfluoroalkyl carboxylic acid

PFSA: perfluorosulfonic acid

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Regulatory Drivers, Guidance and Policy



- US EPA MCLs April 10, 2024 – Maximum Contaminant Levels for 5 PFAS and a Hazard Index (HI) for 2 or more of 4 PFAS (including PFBS, but not PFOS or PFOA)
- MCLs are NOT cleanup levels for groundwater; PFAS not included in RCRA, CAA or CWA

Chemical	Maximum Contaminant Level Goal (MCLG)	Maximum Contaminant Level (MCL)
PFOA	0	4.0 ppt
PFOS	0	4.0 ppt
PFNA	10 ppt	10 ppt
PFHxS	10 ppt	10 ppt
HFPO-DA (GenX chemicals)	10 ppt	10 ppt
Mixture of two or more: PFNA, PFHxS, HFPO-DA, and PFBS	Hazard Index of 1	Hazard Index of 1
Maximum Contaminant Level Goal (MCLG): The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals. Maximum Contaminant Level (MCL): The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards. ppt: parts per trillion		

<https://www.epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas>

(EPA 2024)

Regulatory Drivers, Guidance and Policy

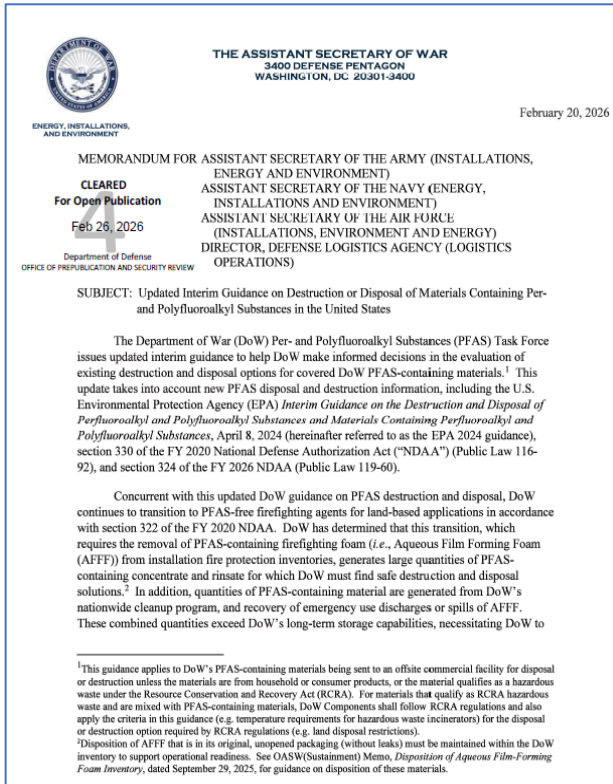


 PER- AND POLYFLUOROALKYL SUBSTANCES (PFAS) Environmental Restoration & Compliance		Search Policies...			FAQs PFAS 101 ▾ PFAS Task Force ▾ DoD Addresses PFAS ▾ Public Outreach ▾ News 🔍	
The Task Force has strategically prioritized actions aligned with goals and objectives and is working to complete them by evaluating and establishing policy positions and reporting requirements, encouraging and accelerating research and development, and ensuring the DoD Components are addressing and communicating about PFAS in a consistent, open, and transparent matter. These policies ensure consistency across the DoD Components and help DoD track its PFAS cleanup progress and investments. As a result of the Task Force's efforts, the Department issued the following policies.	#	Title	Date	Type		
	1	Policy for Monitoring and Treatment of Per-and Polyfluoroalkyl Substances in Department of Defense Drinking Water Systems outside the United States	September 28, 2025	ASW(EI&E) Memorandum		
	2	Investigating Per- and Polyfluoroalkyl Substances within the Department of Defense Cleanup Program RSLs Used in DoD Cleanups	January 17, 2025	ASD(EI&E) Memorandum		
	3	Policy for Per-and Polyfluoroalkyl Substances Monitoring and Treatment in DoD-Owned Drinking Water Systems in the United States	December 4, 2024	ASD(EI&E) Memorandum		
	4	Prioritization of Department of Defense Cleanup Actions to Implement the Federal Drinking Water Standards for Per-and Polyfluoroalkyl Substances Under the Defense Environmental Restoration Program	September 3, 2024	ASD(EI&E) Memorandum		
	5	Guidance for Procurement of Fluorine-Free Firefighting Foam Agents Other than Products Qualified Under MIL-PRF-32725	August 23, 2024	ASD(EI&E) Memorandum		
	6	Guidance for the Change Out from Aqueous Film Forming Foam to Fluorine-Free Firefighting Systems in Facilities	July 30, 2024	ASD(EI&E) Memorandum		
	7	Guidance for Fluorine-Free Foam Usage and Accidental Releases on Military Installations and National Guard Facilities	May 17, 2024	ASD(EI&E) Memorandum		

<https://www.acq.osd.mil/eie/eer/ecc/pfas/tf/policies.html>

(OSD 2026)

Updated Interim Guidance on Destruction or Disposal



(DoW 2026b)

NDAA moratorium on Incineration: Incineration now permitted for RCRA waste that also contains PFAS materials (See Footnote 1 of Guidance). Also need to reach destruction temperature of 1,100°C and have proper permits.

Destruction/Disposal Options Identified: DoW has identified the following commercially available options to be used by the DoW Components (with environmental permits)

- Carbon reactivation units (for used GAC only)
- Hazardous waste landfills
- Solid waste landfills that have composite liners, and gas and leachate collection and treatment systems (not an option for AFFF concentrate)
- Hazardous waste incinerators
- Underground injection control wells
- Thermal desorption units that use off-gas collection and thermal oxidation with environmental permits (for soils)
- Other PFAS destruction options, with pre-notification to OASW(EI&E)
 - E.g., mechanochemical degradation, electrochemical oxidation, gasification and pyrolysis, and SCWO, but only SCWO is currently permitted.

Details provided at <https://www.acq.osd.mil/eie/eer/ecc/pfas/index.html>

GAC: granular activated carbon

EPA: United States Environmental Protection Agency

NDAA: National Defense Authorization Act

OASW(EI&E): Office of the Assistant Secretary of War for

Energy, Installations, and Environment

SCWO: supercritical water oxidation

Analytical Method for Groundwater



- **EPA 1633** is the required method for **nondrinking water matrices including groundwater**
- **EPA 1633 ~40** compounds in aqueous, solid, tissue, and landfill media
- Method 533 is now the recommended method for drinking water (537.1 includes 4 additional PFAS which are low occurrence for DoW)
- Prior PFAS Analytical Methods listed as few as 3 analytes, so early reporting may not have included some PFAS (did not mean they were “nondetect”)
- Some accredited labs that offer 533 also include some of the 4 additional PFAS in 537.1 as part of 533
- Ensure current lab accreditation for all analytes and matrices
<https://www.denix.osd.mil/edqw/accreditation/accreditedlabs/>

EPA Methods 537.1, 533, and 1633 Analyte Comparison



Analyte	EPA 533	EPA 537.1	EPA 1633
11CI-PF3OUdS	x	x	x
9CI-PF3ONS	x	x	x
ADONA	x	x	x
HFPO-DA	x	x	x
PFBS	x	x	x
PFDA	x	x	x
PFDaA	x	x	x
PFHpA	x	x	x
PFHxA	x	x	x
PFHxS	x	x	x
PFNA	x	x	x
PFOA	x	x	x
PFOS	x	x	x
PFUnA	x	x	x
4:2FTS	x		x
6:2FTS	x		x
8:2FTS	x		x
NFDHA	x		x
PFBA	x		x
PFEESA	x		x

Analyte	EPA 533	EPA 537.1	EPA 1633
PFHpS	x		x
PFMBA	x		x
PFMPA	x		x
PFPeA	x		x
PFPeS	x		x
NEtFOSAA		x	x
NMeFOSAA		x	x
PFTeDA or PFTA		x	x
PFTrDA		x	x
NEtFOSA			x
NMeFOSA			x
NEtFOSE			x
NMeFOSE			x
3:3FTCA			x
5:3FTCA			x
7:3FTCA			x
PFOSA			x
PFDoS			x
PFDS			x
PFNS			x

Presentation Overview



- Introduction
- PFAS in the Subsurface: Properties and Treatment Challenges
- Regulatory Drivers, Guidance, and Policy
- **Treatment**
 - Case Studies
 - Guidelines for Selecting Water Treatment Technologies
 - Summary/Key Takeaways

Treatment: The Two General Categories



- 1. Separate and concentrate**
 - Includes both in situ and ex situ processes**
2. Destroy/Mineralize (Concentrates)

Separation and Concentration from Water



Technology Category	Technology	Maturity/Availability (May 2026)
Sorption	Activated Carbon*	Commercialized, can be purchased from vendors
	Anion Exchange Resin*	
	Zeolites/Modified clays	
	Cyclodextrin	
Concentration	Foam Fractionation	
Membrane Filtration	Reverse Osmosis/Nanofiltration	
Coagulation	Specialty Coagulants	Full Scale application being conducted by researchers

Separation and Concentration: Proven Technologies

Sorption

- Granular Activated Carbon (GAC)
- Ion exchange (IX) resin



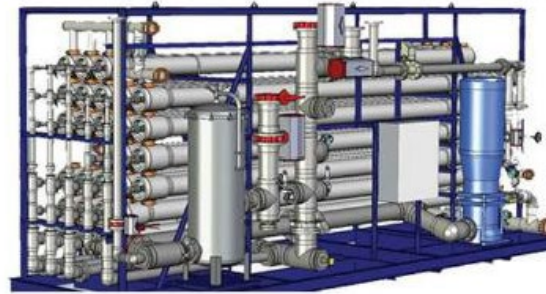
(Pelton Environmental 2025)



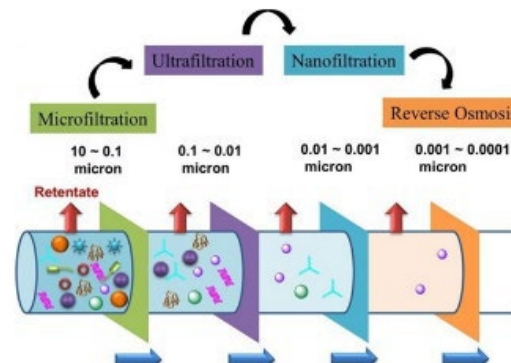
(Calgon Carbon 2026)

Membrane

- Separation based on size



(Brownlee-Morrow 2025)



(Elsevier 2024)

Foam Fractionation

- Air/Water Interfacial Concentration



(Allonnia 2026)

- More recently proven
- Wider performance variability

Pump-and-Treat – Granular Activated Carbon



- **Granular activated carbon (GAC)**

- **Adsorbs PFAS** primarily by hydrophobic interactions (van der Waals forces)
 - Long C-F chain = more hydrophobic, greater affinity
 - Short chain = lower affinity
- Typically used for **groundwater in pump-and-treat** systems (also in situ applications)
- **Lead/lag** configuration
- Is **widely available**; bituminous GACs (e.g. F400) more effective, simple to operate, established for remediation and drinking water production

- Can be used for **high TDS** (salinity) water
- **Limitations:** Early breakthrough of short-chain PFAS; natural organic matter competes w/ PFAS binding; media replacement generates PFAS-laden solid needing disposal/reactivation



(Todd 2026)

TDS: total dissolved solids

Treatment

Pump-and-Treat – GAC

- **GAC**

- Standard vessel sizes available on short notice, though increasing demand for PFAS treatment may require longer lead times
- As lead vessel loads up with PFAS, short chain PFAS (esp. PFCAs) break through in effluent; lag vessel then sorbs these PFAS
- Valves switched so lag vessel becomes new lead vessel
- Spent GAC exchanged out for new (which becomes new lag vessel)
 - Spent GAC can be disposed or **reactivated** (*regeneration* is a different process, carried out in the vessel on-site at lower temperatures using steam, but inappropriate for GAC with PFAS)



Pump-and-Treat, GAC Reactivation

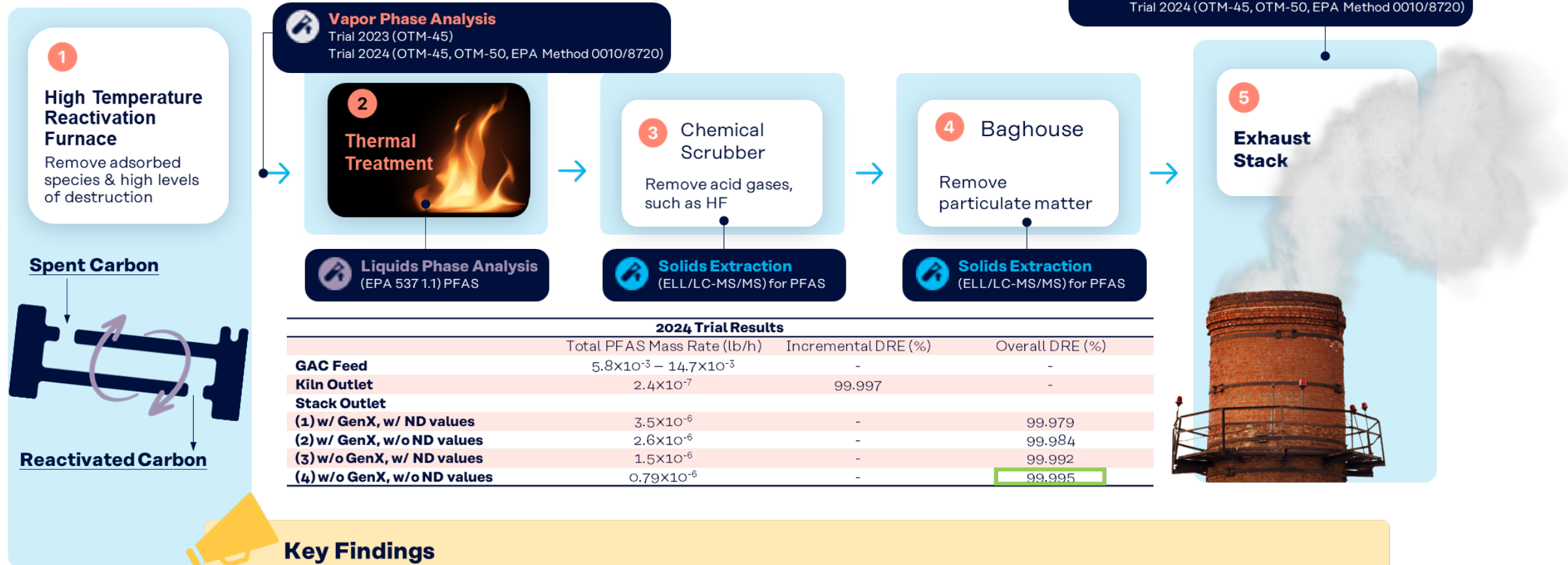
- GAC Reactivation (Calgon) takes place in one of six United States furnaces (Norit also performs reactivation in Oklahoma)
 - Three for potable water—New York, Ohio, and Arizona (a fourth location planned for South Carolina); also Italy and Belgium
 - GAC heated (to 1,000°C) in a rotary kiln to high temperature with limited oxygen and the PFAS destroyed
 - Batches of GAC are kept separate during treatment so they are returned to the same customer as reactivated GAC (which decreases costs ~30%+)
 - Three for nonpotable water—Pennsylvania, Kentucky, Texas— GAC from various customers is mixed during reactivation in Herreshoff furnace (difficult to segregate batches)
 - Carbon profiling (description of use, laboratory analyses) required for reactivation and must conform to limits for certain constituents (e.g. Hg, Pb, Cl, F)



(Calgon Carbon 2025)

Pump-and-Treat, GAC Reactivation

Finding: Overall DRE > 99.9% for Total PFAS



Key Findings

- **> 99.9% PFAS DRE** was achieved using the most conservative calculation methodology (w/ GenX and w/ ND values) for the 2024 Trial
- **Overall process DRE was > 99.99%** when calculated without GenX and/or non-detect species for the 2024 Trial

DRE: destruction and removal efficiency

Treatment

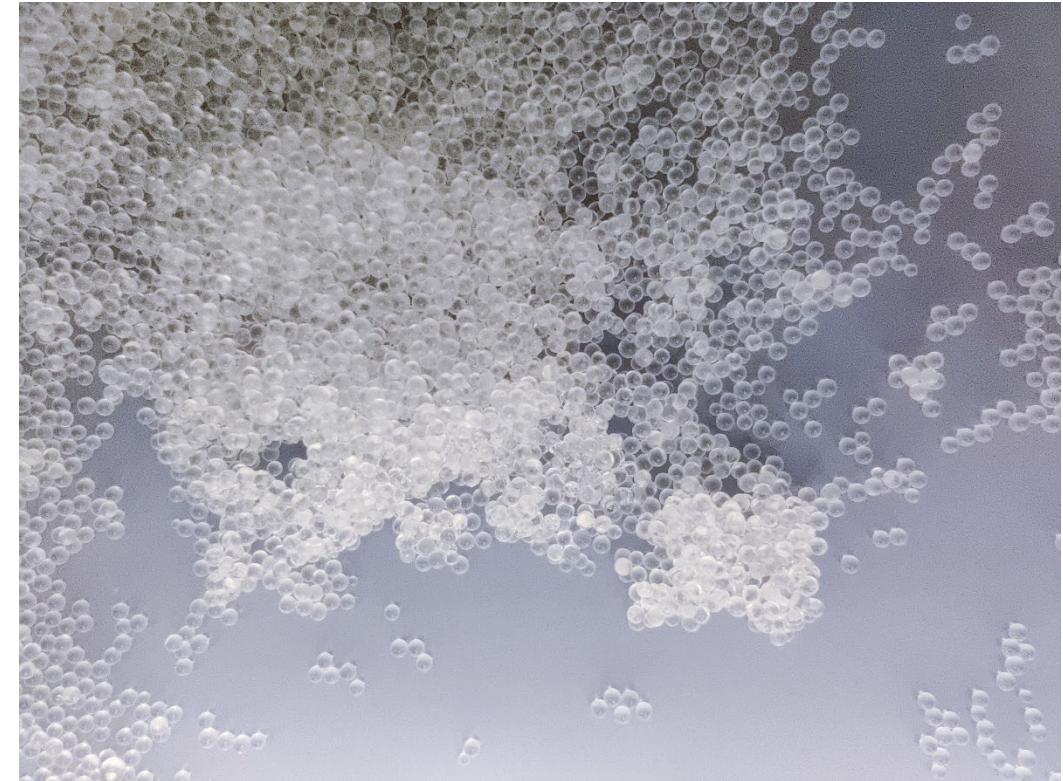
(Calgon Carbon 2025)

Ion Exchange Resin

- **Adsorbs PFAS** primarily by ionic interactions
- Higher capacity per unit volume compared to GAC and shorter EBCTs (1–2 minutes vs 10–15 minutes) result in **smaller reactors**
- Single use resin most common use; may perform better than GAC for short chain and other PFAS
- Regenerable resins available but perform less well than single use and requires infrastructure to regenerate
- Cost per mass PFAS removed similar to GAC
- **Cannot** be used for **high TDS** (salinity) water
- Limitations: Early breakthrough of short-chain PFAS; natural organic matter competes w/ PFAS binding (but less than GAC); media replacement generates PFAS-laden solid needing disposal

mm: millimeter(s)

EBCT: empty bed contact time



IX resin: Purolite PFA694E, single use resin. Styrene beads 0.6-0.75 mm diameter, coated with a quaternary amine and exchangeable cation.
(Kornuc 2026)

Other Sorbents



- Cyclodextrin (Dexsorb): a D-glucose polymer (starch) chemically modified by cross-linking
 - Cup-shaped with a 0.78 nm open end, only allowing small molecules such as PFAS to enter
 - Molecular exclusion limits large organic molecules such as NOM (e.g., humic acids) from entering and depleting binding capacity, reserving binding capacity for PFAS and other small molecules which can fit into the opening
 - High capacity similar to IX
 - Regenerable using base and alcohol (by returning to manufacturer, Cyclopure)
- Other types of GAC (e.g. coconut shell): these less costly forms of GAC can be used to remove NOM to reserve binding capacity of more costly bituminous GAC to bind PFAS
- Modified clays (Fluorosorb): less costly than GAC, can also be effective, also good for up-front treatment to remove NOM in series with F400 GAC

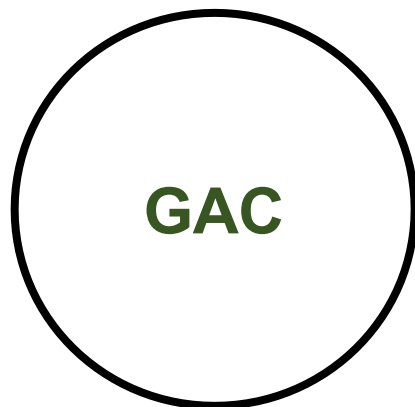
KEY POINT

Treatability testing should be conducted where large amounts of sorbent are anticipated to be purchased; even small differences in cost of materials/performance can translate to large costs over the life of a project.

In Situ Sorption: Enhanced Retention



- Binding mechanisms same as ex situ sorption
 - Sorbents can include activated carbon, IX, cationic polymers, modified clays
- Most applications have used activated carbon
- GAC → CAC with a particle size in the lower μm range
 - GAC generally 0.4–1.2 mm; PAC ~ 0.075 mm; CAC 0.1–3 micron (0.003 mm)
 - CAC can be suspended for better aquifer injection, mobility/flow in porous media, and deposition onto soils and sediment



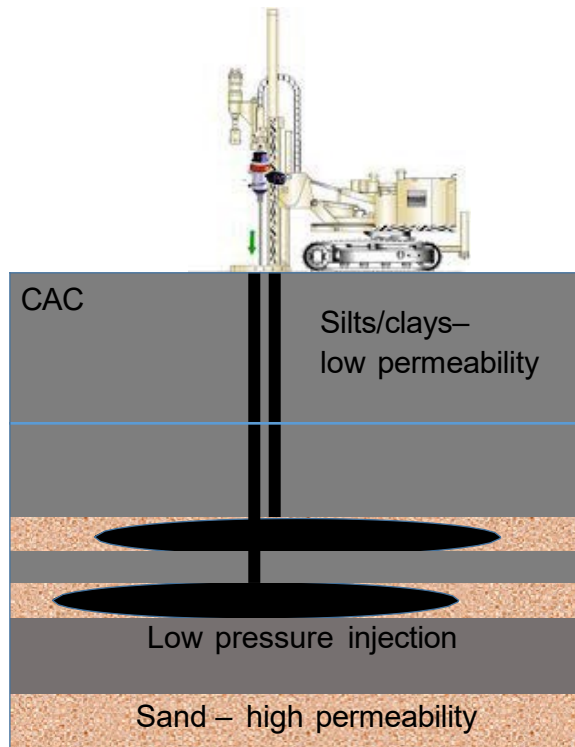
•
PAC

•
CAC
~1,500x smaller than GAC

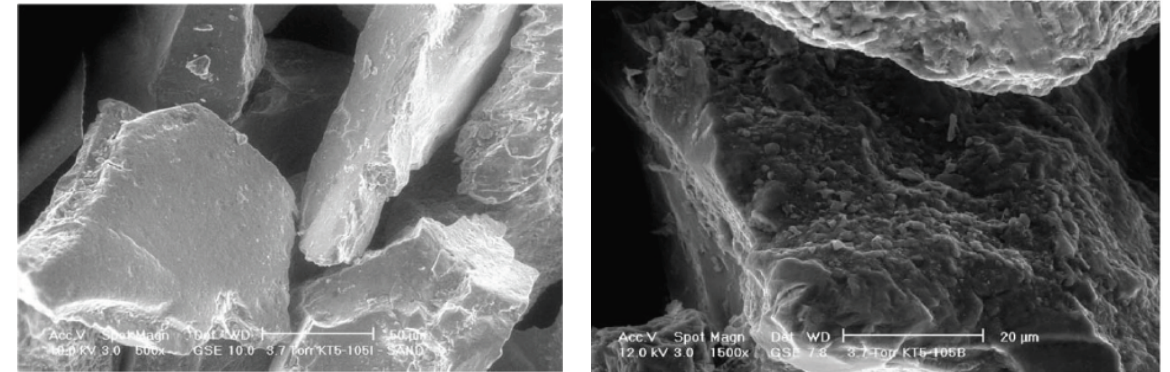
CAC: colloidal activated carbon

In Situ Sorption: Enhanced Retention

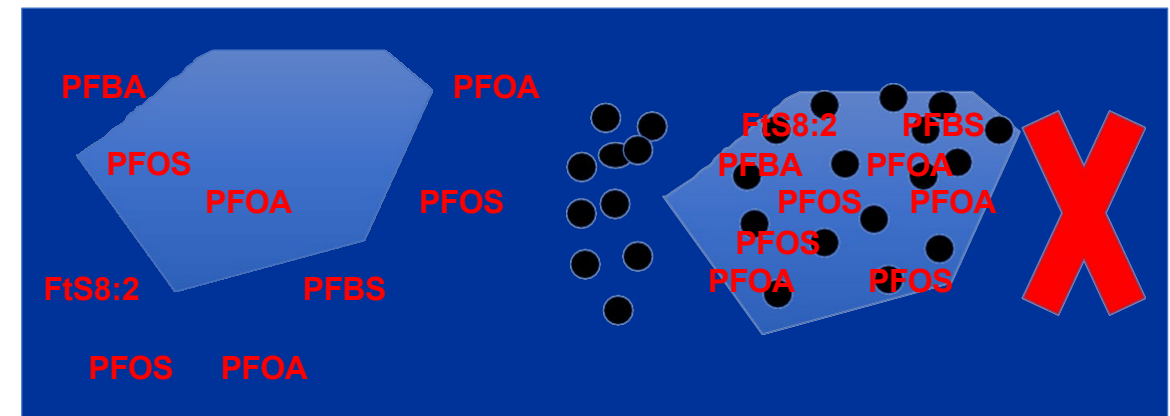
CAC is now being marketed and applied as an in situ adsorbent and sequestrant for **PFAS**



(Hatzinger 2020)



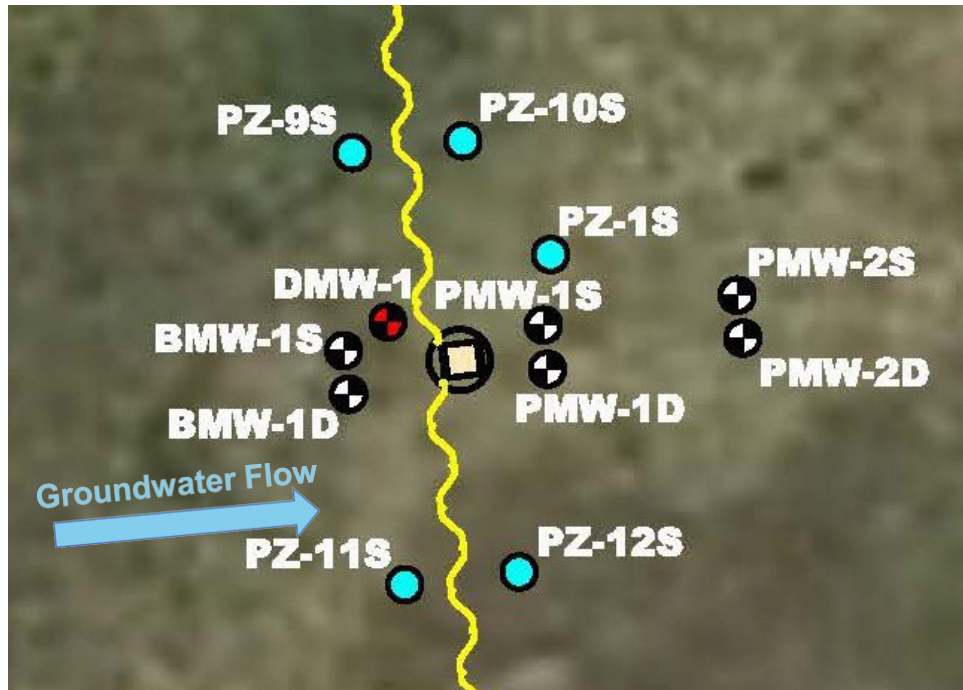
(Birnstingl et al. 2014)



(Hatzinger 2020)

In Situ Sorption: Funnel and Gate

Most applications have focused on injections of the sorbent, but teams are exploring funnel and gate applications



ESTCP ER20-5252



Sheet Pile Installation



Completed
Funnel & Gate

- Protective vault in cement pad
- High visibility cones & chain

(Lippincott 2024)

In Situ Sorption Considerations (1)



- Column testing was a useful tool in assisting dosing requirements and answering questions from the agencies
- Some surfacing of CAC should be expected
 - Causes: Misunderstood aquifer characteristics, oversized pumps, or short-circuiting via poorly constructed wells
 - Important to evaluate avenues for migration of CAC prior to injection
- Photographic logs and a CAC distribution assessment are recommended
- Downgradient well performance variability increases with distance from treatment zone
- Barrier longevity (i.e. sorption capacity)
 - More rapid breakthrough of shorter chains and carboxylates

In Situ Sorption Considerations (2)



- Water levels should be used to determine if flow is going around the barrier (piezometers, transducers, etc.)
- CSM and the site itself plays a significant role in the design and implementation of CAC injection locations, etc.
- Well inspection (especially in barrier wells) and rehabilitation should be included due to CAC migration during and after injection
- Geologic considerations
 - High permeability zones, low pressure injection
- Unlikely to be a standalone remedy
- Can be part of a treatment train
- Can be useful as an interim action to help mitigate migration to sensitive receptors

In Situ Sorption Considerations (3)

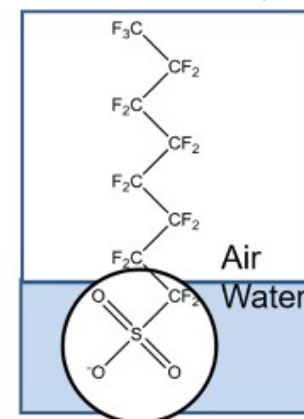


- If a CAC barrier is being considered, additional site investigation may be needed to assist in barrier design and performance assessments
 - Obtain sorption parameters (co-located soil and GW PFAS concentrations)
 - Fraction of organic carbon
- Importance of water table fluctuations in interpreting results, as well as the height of these barriers (tidal and seasonal rainfalls)
- Coastal sites may have challenges that are not present at freshwater sites
 - Tides, impact of geochemistry, etc.
- Note that not all amendments have been thoroughly demonstrated.
- **Please check with your SME!**

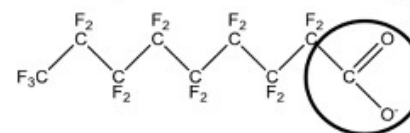
Foam Fractionation

- Exploits air/water interface sorption of PFAS using bubbles
- PFAS concentrate in foam layer; foam can be skimmed off
- Excellent mass separation for high strength liquid matrices
 - GW, IDW, Wastewater, Landfill Leachate
- Both in situ and ex situ approaches
 - Allonnia (SAFF®), E2METRIX™ (Olift™), Onterris (FOAM-X™), etc.
 - Approaches vary

PFOS (perfluorooctane sulfonate)



PFOA perfluorooctanoate



(Reynolds 2022)



(Nelson 2021)

GW: groundwater; IDW: investigation-derived waste

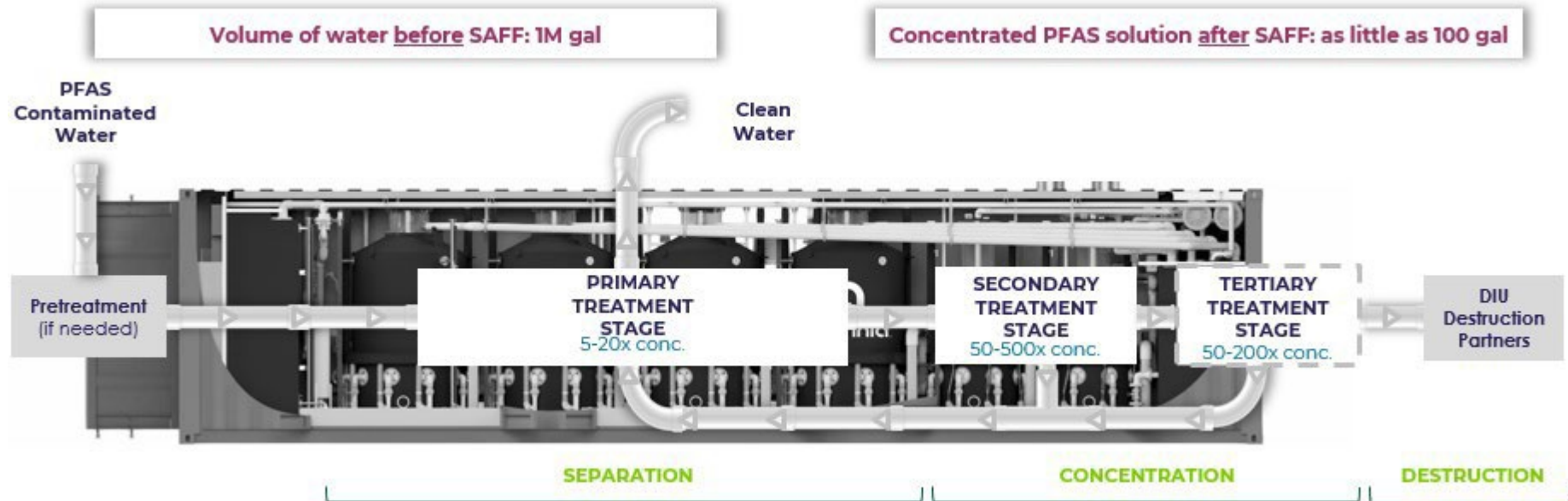
Foam Fractionation

- Short chain PFAS removed less efficiently (like almost all other approaches); can add surfactants to enhance removal
- For these foam enhancers, consider the following
 - Toxicity, effectiveness, availability, and cost
 - Proprietary
 - Regulatory approval might be needed
 - Most of the added foam enhancers may end up in the foam



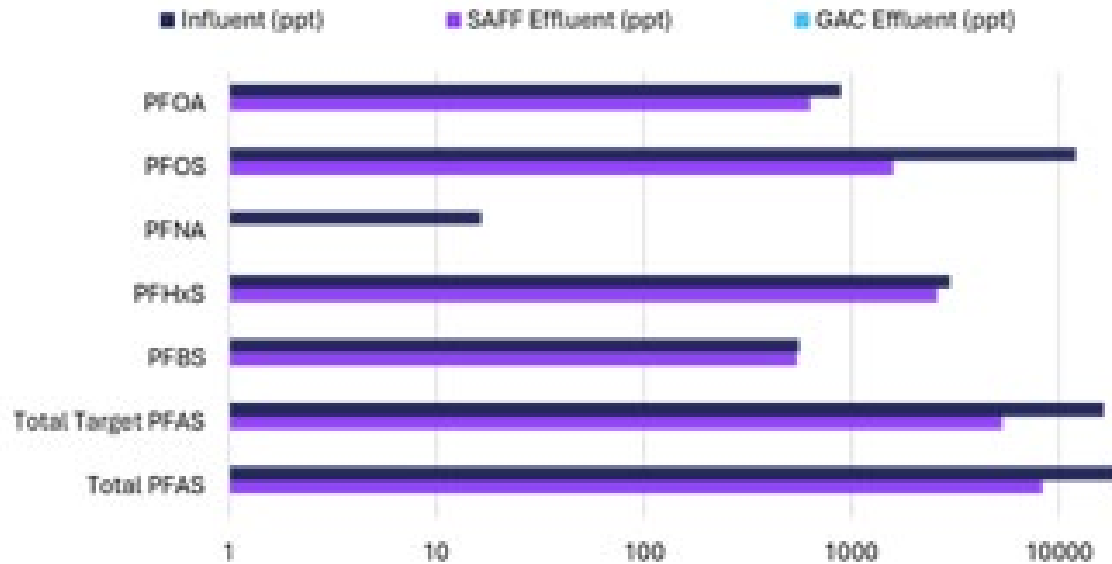
(Nelson 2021)

Example of an Ex Situ Foam Fractionation System

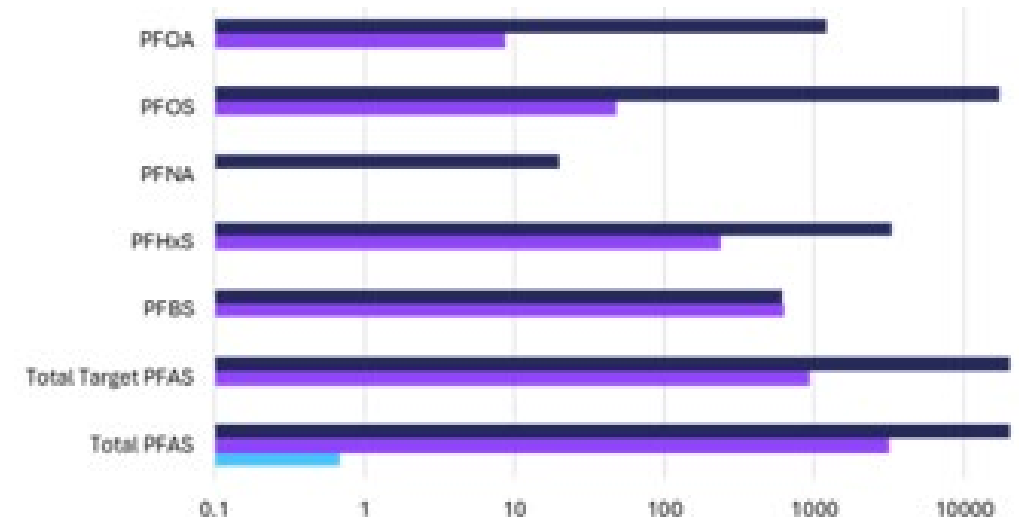


(Allonnia 2025)

SAFF 40[®] Performance at Biddle Air National Guard (Pennsylvania)



No Additive
68% Total Target PFAS removal



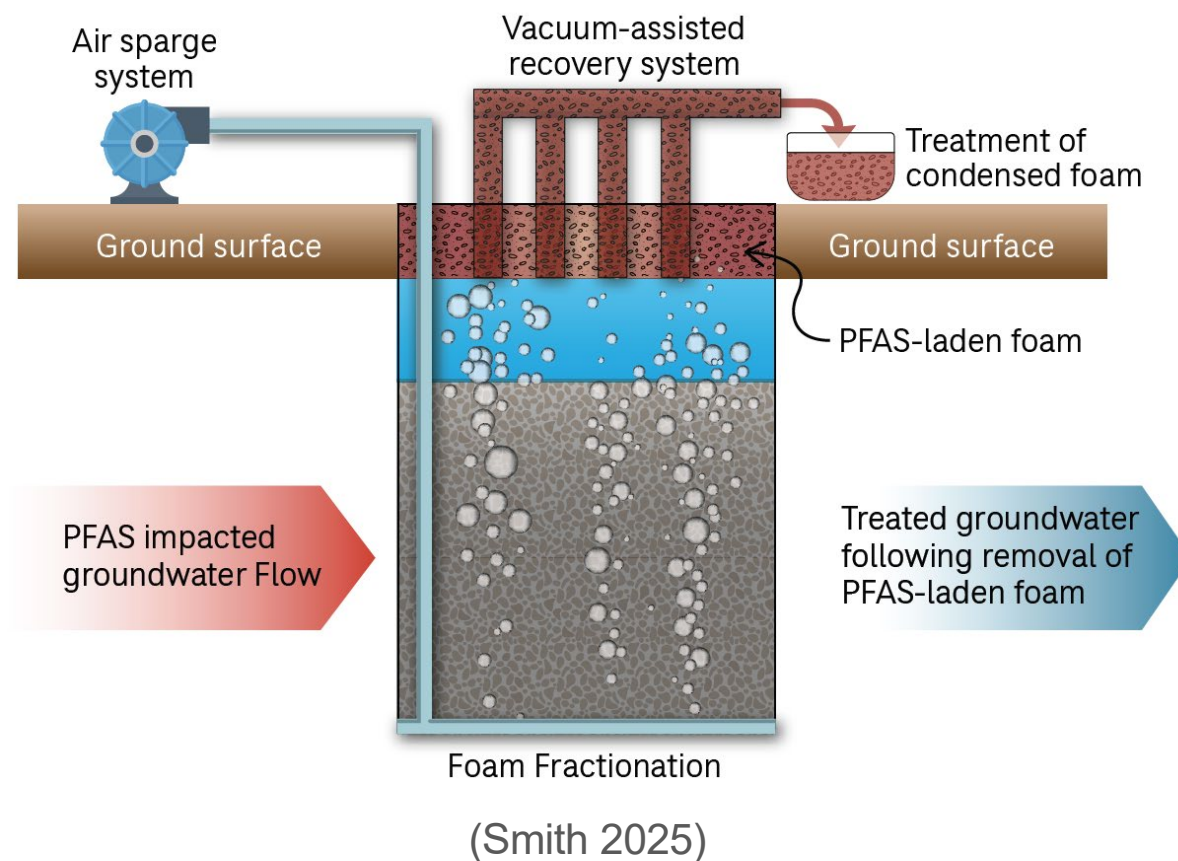
With Additive (Saponin (plant derived surfactant))
96% Total Target PFAS Removal

Note: Treatment performance at your site may vary

ESTCP ER23-8381
(Allonnia 2025)

In Situ Foam Fractionation Example

- ESTCP ER21-5124
 - Title: Low-Cost, Passive In Situ Treatment of PFAS-Impacted Groundwater Using Foam Fractionation in an Air Sparge Trench
- Project Objective
 - Demonstrate and validate the use of a novel treatment approach for PFAS-impacted groundwater from AFFF source areas



In Situ Foam Fractionation Example



ESTCP ER21-5124

System Installation: Spring 2026

Startup/Optimization: Summer 2026

Operation: 6 Months

Key parameters

- PFAS reduction within treatment zone
- Volume of foam production
- PFAS destruction in collected foam
- Assess ease of operation

(CDM Smith 2026)



Foam Fractionation Considerations (1)



- Significant concentration factors can be achieved, but be wary of these claimed factors at every site
- Bench scale testing is important to determine if site GW naturally foams or whether a foam enhancer is needed
- A sorption unit will likely be needed to treat the effluent
 - PFAS and foam enhancer
- Please check with your SME!
- There is such a thing as too much foam
- Consideration of air emissions (VGAC)
- What to do with the foam?
 - How much do you expect to produce?
 - On-site versus off-site
 - Spills and containment (potential reporting requirements!)
- What is the application?
 - Different sizes and throughput

VGAC: vapor-phase granular activated carbon

Foam Fractionation Considerations (2)



- Regional/Installation considerations
 - Winterization
 - Can the trailer get to the location (length and height)?
- Analysis of foam may be challenging
- In situ foam fractionation is a mass removal technology and by itself is unlikely to achieve remedial action levels
 - Rebound of PFAS from lower permeability units
 - Flushing from PFAS in the vadose zone
 - PFAS coming from upgradient/outside of the treatment zone
- The permeability of a site is important because air is introduced into subsurface
- Impacts of groundwater geochemistry (for example, dissolved iron and manganese)
- Water table fluctuations can create challenges for in situ foam removal efforts
- Many foam fractionation systems are designed to be contained within a CONEX box which can lead to some difficulty with O&M and component replacement

Knowledge Check



If a site groundwater has high concentrations of total dissolved solids and low natural organic matter (NOM), which sorbent(s) would be appropriate?

- A. GAC
- B. Ion Exchange
- C. Cyclodextrin
- D. Polypropylene

Knowledge Check



If a site groundwater has high concentrations of total dissolved solids and low natural organic matter (NOM), which sorbent(s) would be appropriate?

A. GAC

B. Ion Exchange

C. Cyclodextrin

D. Polypropylene

Treatment: The Two General Categories



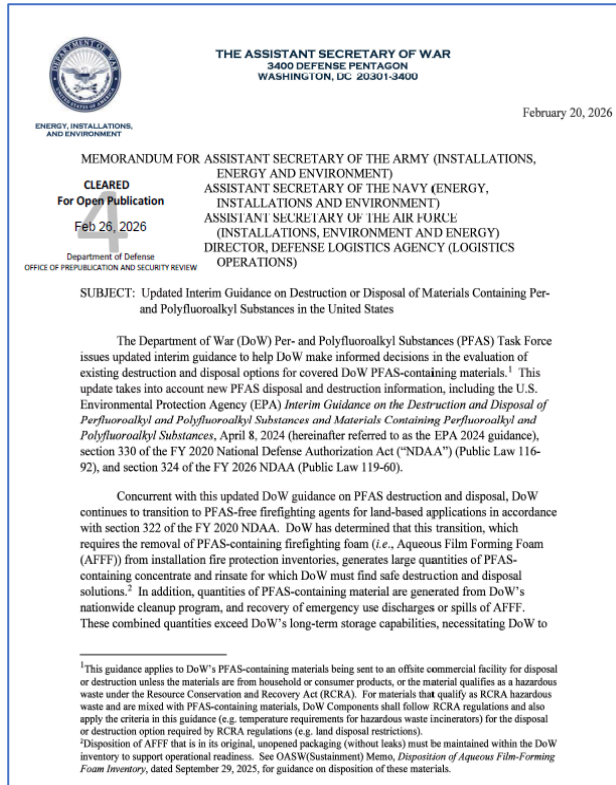
1. Separate and concentrate
 - Includes both in situ and ex situ processes
- 2. Destroy/Mineralize (Concentrates)**

PFAS Destruction Technologies



- Technologies should be considered for low volume/high concentration waste streams
 - "Separation" and "Concentration" PFAS streams
- Variety of PFAS destruction technologies have been tested with different destruction mechanisms
- Status among technologies varies with commercial status
- Most are focusing on liquids
- Treatment of effluent may be required

Reminder: Updated Interim Guidance



(DoW 2026b)

NDAA moratorium on Incineration: Incineration now permitted for RCRA waste that also contains PFAS materials (See Footnote 1 of Guidance). Also need to reach destruction temperature of 1,100°C and have proper permits.

Destruction/Disposal Options Identified: DoW has identified the following commercially available options to be used by the DoW Components (with environmental permits)

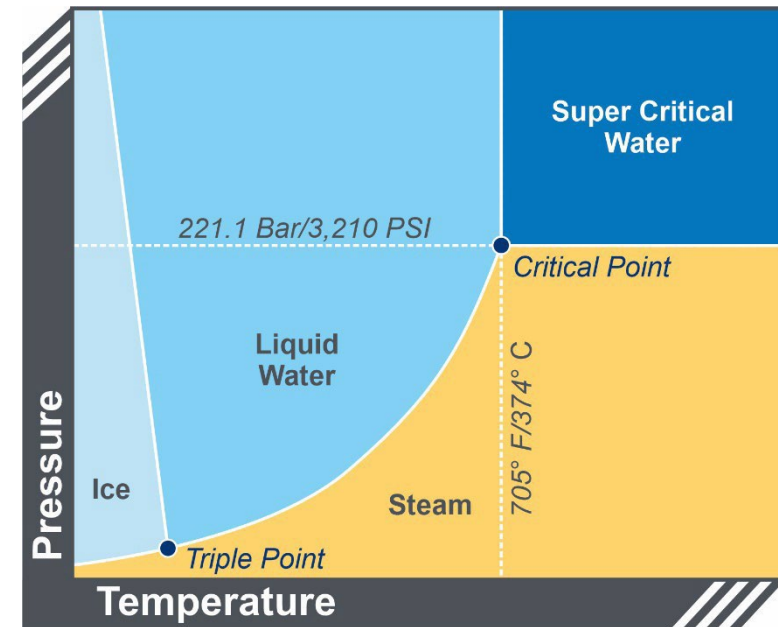
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- Other PFAS destruction options, with prenotification to OASW(EI&E)
 - E.g., mechanochemical degradation, electrochemical oxidation, gasification and pyrolysis, and SCWO, but only SCWO is currently permitted.

Details provided at <https://www.acq.osd.mil/eie/eer/ecc/pfas/index.html>

Supercritical Water Oxidation (SCWO)



- Leverages unique properties of supercritical water
- High temperature and pressure
 - Gas and liquid phases become indistinguishable
 - Density is about 10% of water above the supercritical point
 - Water no longer behaves as a polar solvent
 - Oxygen is fully soluble
- High temperature in an oxidizing environment overcomes activation energy to break C-F bond
- SCWO has been used since the 1980s to treat recalcitrant compounds, but only recently to treat PFAS



(Battelle 2022)

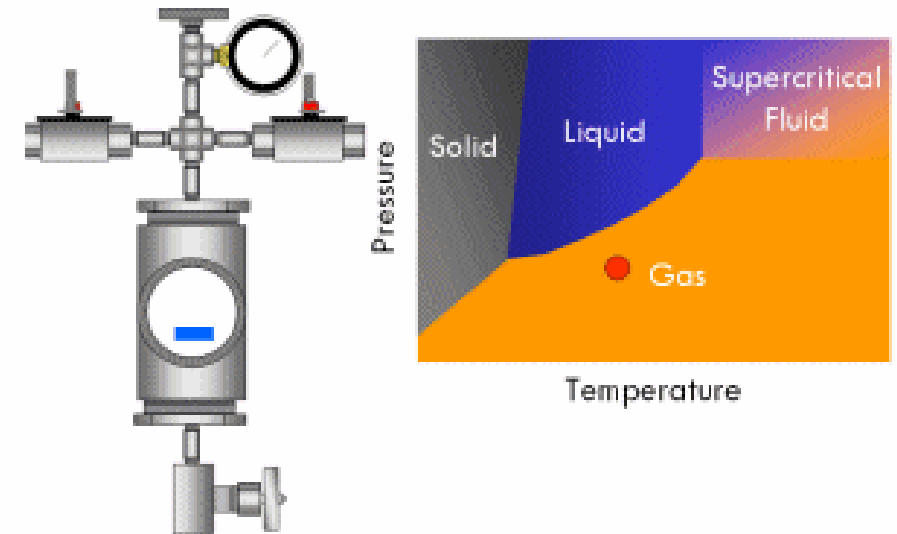
SCWO Considerations

Capabilities and Deployment

- Effective oxidative process for liquids and solids
- Capable of treating solids like spent GAC and resins (not all vendors accept solids for treatment)
- Allowable solids percentage varies depending on vendor
- Often better suited for shipping material offsite to a vendor
- Vendors are actively iterating on process designs and equipment

Technical and Commercial Constraints

- High energy use; extreme pressure/temp (zero tolerance for failure)
- Sensitive to salts (IX bottoms); requires costly, specialty alloys
- Limited commercial availability for treating concentrates at permitted TSDFs
- Effluent polishing likely required



(CCYYSA n.d.)

TSDF: treatment, storage, and disposal facility

SCWO: 374Water AirSCWO™ Field Deployment



- ESTCP ER23-8398
- Demonstration at a Clean Earth facility (TSDf) in Detroit
 - CWT Plant
- Shipped in a CONEX Box (AS6)
 - Unloaded with a crane
- Operated using a generator
- Tested various PFAS-impacted materials
 - Foam fractionate, spent sorbent media, AFFF

CWT: centralized water treatment

Treatment



(Arcadis 2025)

SCWO: 374Water AirSCWO™ Field Deployment



- Operation

- Feedstock: 1,200 gallons foam fractionate
- Airflow rate = 240 kg/hr
- Cofuel = 0.35 L/hr
- Feedstock flowrate = 1.3 L/min
- Reactor > 595 °C

- Results

- Preliminary DRE greater than at least 99.9% total PFAS for all media tested
 - Carryover possible
- HF was nondetect via 26A
- OTM (45, 50, and 55) showed hits of PFAS plus some other compounds, but overall < 0.001%



Allonnia foamate

Total PFAS Influent Concentration (1633) (ng/L)	Total PFAS Effluent Concentration (1633) (ng/L)	Total PFAS DRE
33,668,000	0	100%

Sample Type	PFOS (ng/L)	PFOA (ng/L)	PFHxS (ng/L)	PFHxA (ng/L)	6:2 FTS (ng/L)	PFHpS (ng/L)	PFPeA (ng/L)
FEED	23,000,000	2,500,000	3,400,000	310,000	3,000,000	680,000	150,000
EFF	<1.6	0.9	<1.6	<1.6	2.4 J	<1.6	<1.6
DRE	99.999997%	99.999996%	99.999998%	99.99997%	99.999992%	99.999988%	99.99995%

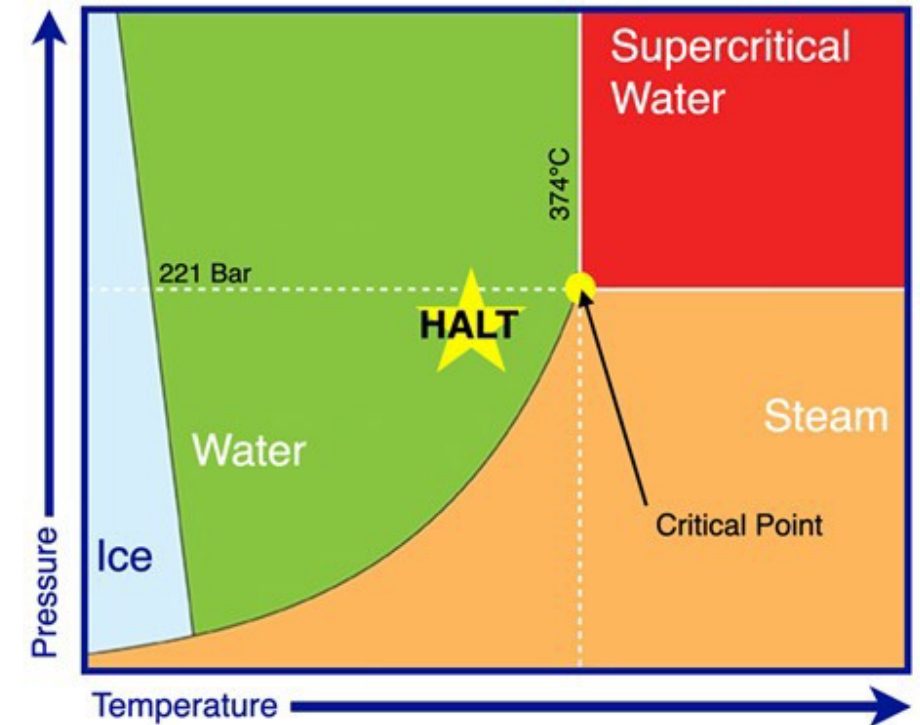
(Arcadis 2025)

HF: hydrofluoric acid
kg/hr: kilograms per hour
L/hr: liters per hour

L/min: liters per minute
OTM: other test method

Hydroalkaline Thermal (HALT)

- PFAS destruction under subcritical water conditions (300 to 350 °C, ~3,000 psi, pH > 14)
- Sodium hydroxide used for high pH
- Capable of >99% destruction of individual and total PFAS, with complete conversion to inorganic fluoride (mineralization)
- First developed under SERDP project ER18-1501 at Colorado School of Mines (Strathmann et al.)
- Foundational HALT patent exclusively licensed to Aquagga



 *HALT operates at subcritical conditions, eliminating complexities associated with containing supercritical water*

(Aguagga 2025)

psi: pounds per square inch

SERDP: Strategic Environmental Research and Development Program

HALT Considerations

- Less energy than SCWO
- Ability to handle high salt matrices
- Liquids only (not focused on treating solids)
- Effluent has relatively high concentration TDS effluent (neutralize NaOH)
- Does not effectively treat many organics
- Current throughput is 10 gallons per hour
 - New unit planned (Stampede Series) in 2026 with potential for 1 gallon per minute



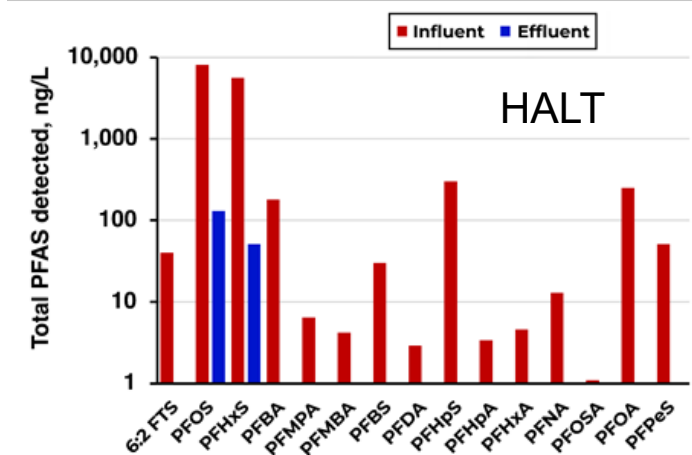
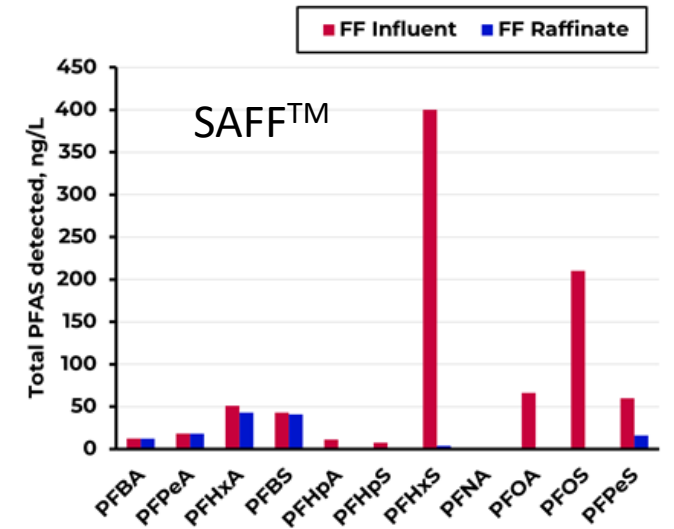
Steed Series – 8' x 10'
(Aguagga 2025)

HALT Project Example: Groundwater Remediation



- Pump & treat system for AFFF-impacted GW
- Foam fractionation + HALT
- Project goals
 - Reduce PFAS concentrations to the groundwater extraction and treatment system
- Significant reduction in PFAS concentrations
- On-site concentration + destruction
 - No processing challenges with foam fractionation concentrate
 - 24/7 operations with automated sample collection

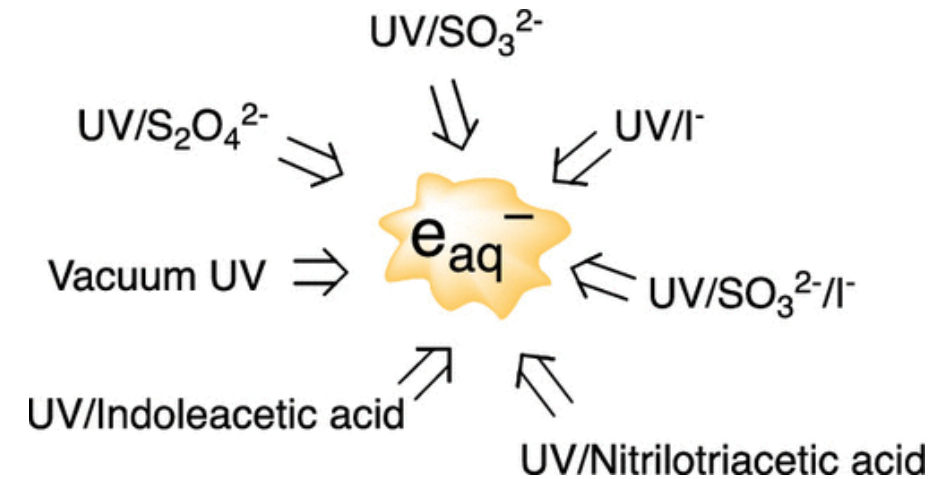
ppt: parts per trillion



(Aquagga 2025)

UV Destruction Technologies

- Chemistries can be different, but these destructive processes are based on the production of oxidative and/or reductive reactants from UV
 - Example reactants
 - e_{aq}^- is a strong reductant (standard potential = -2.9 V)
 - $OH\cdot$ is a strong oxidant (standard potential = $+2.9$ V)



Several ways to produce e_{aq}^- as shown here

(Haley & Aldrich 2025)

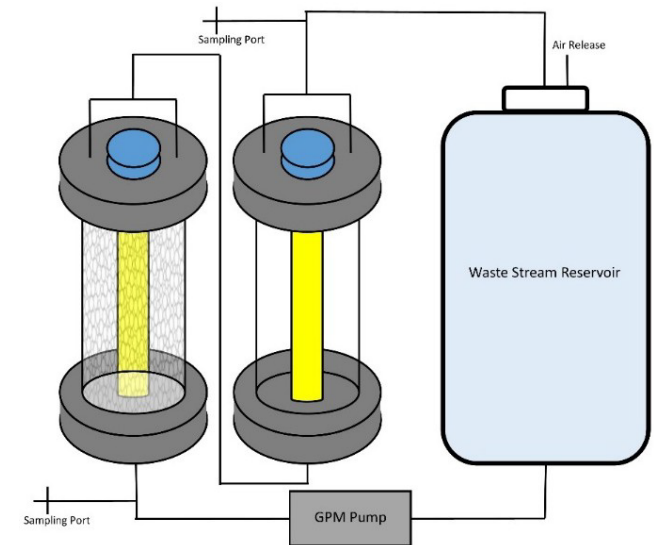
$OH\cdot$: hydroxide radical

UV: ultraviolet

V: volts

UV Destruction Technologies: Considerations

- Several different technologies and vendors at various stages of development, testing, and commercialization
 - EradiFluor™, PFASigator™, UV/SGM, etc.
- Destruction can be from oxidation, reduction, or a combination from highly reactive species
- Currently focused on batch operation
- Treatment of effluent from these systems may be required
- Potential to take effluent to influent of foam fractionation system



(Geosyntec 2025)

UV Destruction Technologies: Considerations

- Some systems are trailerable and can be operated onsite at ambient or slightly elevated temperatures
- Applications so far are focused on highly concentrated, low volume liquids (common element among all PFAS destructive technologies)
- Due to the need for UV for reaction, some matrices are challenging to treat (color absorbs UV light)
- Uncertainties with O&M due to limited deployment times



(Enspired Solutions 2025)



UV Technologies: EradiFluor™



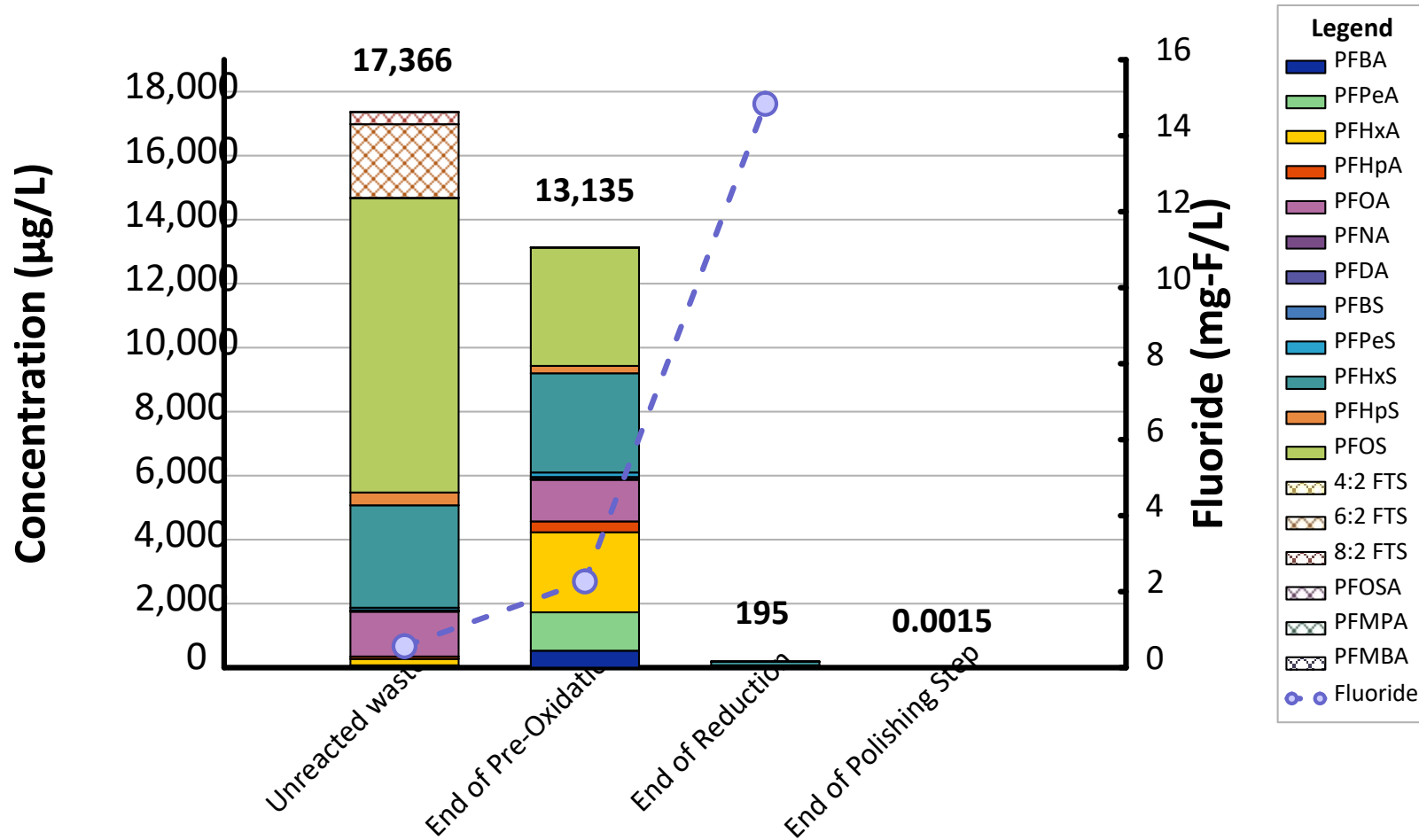
- Haley & Aldrich designed and constructed this PFAS treatment system
 - UV/sulfite-based treatment process
 - Mobile, on-site treatment unit
 - Ambient reaction conditions
 - Control/monitoring components
- System deployed at an East Coast NAS for ISFF destruction testing

ISFF: in situ foam fractionation
NAS: Naval Air Station



(Haley & Aldrich 2025)

UV Technologies: EradiFluor™



(Haley&Aldrich 2025)

About 99% of PFAS were destroyed at end of reduction step

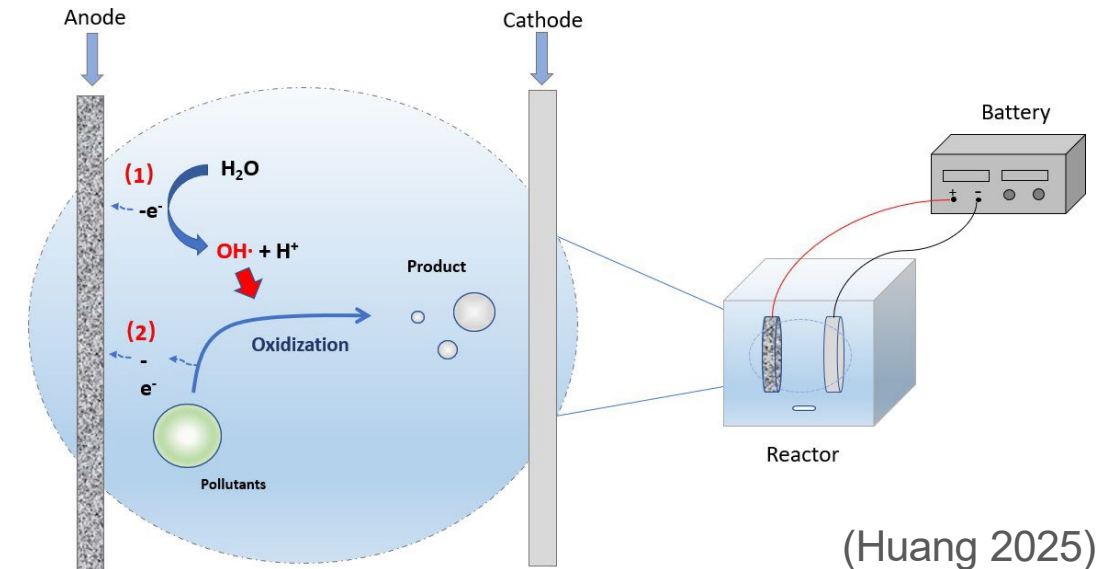
After polishing step, all residual PFAS were removed to the nondetect level, except one compound PFOS reported as 1.5 ng/L



(Haley & Aldrich 2025)

Electrochemical Oxidation

- Electrochemical oxidation (EO) involves applying a direct current to electrodes (anode and cathode) which then drives oxidation reactions through (1) reactive oxygen species that are generated (e.g., $\text{OH}\cdot$) and (2) direct electron transfer on surface of anode
- EO defluorinates and mineralizes PFAS by breaking C-F bonds; PFAS compounds are sequentially defluorinated and ultimately mineralized to CO_2 and fluoride
- Two most common types of electrodes
 - Magnéli phase titanium suboxide ($\text{Ti}_n\text{O}_{2n-1}$)
 - Lower cost
 - Can be manufactured as plates, porous ceramic membrane, porous monolith
 - More scalable
 - Boron doped diamond (BDD)
 - Faster treatment kinetics
 - Manufactured as plates

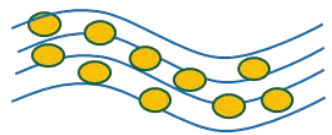


Electrochemical Oxidation Considerations



- Operates and ambient temperature and pressure
- Kinetics generally slower than more aggressive technologies
- Focus is on liquids (foamate, soil washing wastewater, etc.)
- Perchlorate generation
 - Continuing efforts to address
- Potential for mineral buildup on electrodes
 - Continuing efforts to address

EO Field Deployment: DE-FLUORO™



PFAS Impacted Groundwater
and Surface Water
(30,000-40,000 gpd)
GW ΣPFAS: ~2,000 ppt
ΣPFAS: 1,300 to 6,000 ppt

Potential to
Recirculate
Effluent



Clean Water
Discharged to
Surface Water



PFAS
Concentrate
<0.5 gpd

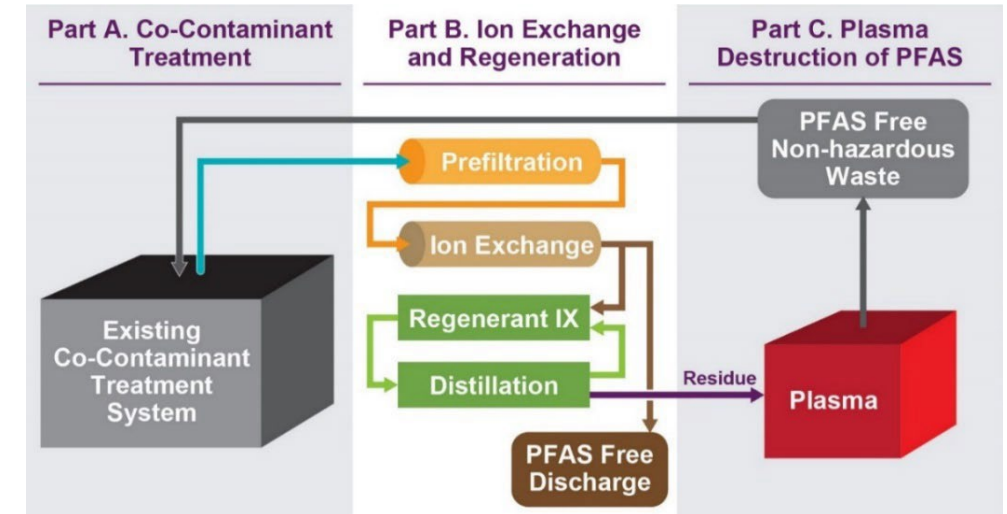
gpd: gallons per day

Treatment

(AECOM 2025)

Plasma Destruction

- **Plasma (nonthermal/cold plasma)**
 - **Generate highly reactive species** that attack PFAS, mainly used on concentrated streams
 - **Potentially complete destruction** with recirculation
 - Can pair with foam fractionation concentrate
- **Considerations**
 - Plasma destruction occurs in narrow layer
 - May experience plasma instability and system overflow with certain applications
 - Requires argon gas and (typically) multiple modular reactors



(DMAX Plasma 2025)

Knowledge Check



What Temperature and Pressure does SCWO need to achieve for PFAS destruction?

- A. 374 C and 221.1 Bar
- B. 225 C and 100.3 Bar
- C. 125 C and 350.6 Bar
- D. 0.01 C and 0.006 Bar

Knowledge Check



What Temperature and Pressure does SCWO need to achieve for PFAS destruction?

- A. 374 C and 221.1 Bar**
- B. 225 C and 100.3 Bar
- C. 125 C and 350.6 Bar
- D. 0.01 C and 0.006 Bar

Presentation Overview



- Introduction
- PFAS in the Subsurface: Properties and Treatment Challenges
- Regulatory Drivers, Guidance, and Policy
- Treatment
- **Case Studies**
 - Guidelines for Selecting Water Treatment Technologies
 - Summary/Key Takeaways

Case Study 1: Sorption of PFAS from Water



- MCAS Iwakuni needed to treat ~350,000 gallons PFAS-impacted water collected from various locations:
 - 110,000+ gallons ARFF Training Facility pond
 - Water runoff and infiltration at hangars (including PFAS-impacted concrete) in cisterns
 - Fire water supply tanks



(Kornuc 2024)

ARFF: Aircraft Rescue and Fire Fighting
MCAS: Marine Corps Air Station

MCAS Iwakuni: PFAS Mobile Treatment System



Trailer, F400 GAC drums and effluent tank
(Kornuc 2024)



Influent ballast tank at Site 1
(Kornuc 2024)

MCAS Iwakuni: PFAS Mobile Treatment System



- **Designed for simplicity, ease of O&M**
 - Cartridge filter for solids separation
 - F400 GAC sorbent
 - Modular to accommodate site constraints
 - 5 gpm
- Treated water held in 20k gallon bladders pending analysis
- Successfully treated water to below discharge requirements
 - Used 8 drums of F400 GAC, ~20 filter cartridges



Change-out of GAC to cyclodextrin sorbent (Dexsorb canisters)

(Kornuc 2025)



SCADA and sorbent vessel valves

(Kornuc 2024)

SCADA: Supervisory Control and Data Acquisition

Case Study 2: NAF Atsugi PFAS Sorbent Selection Study



- NAF Atsugi supplies **drinking water and irrigation water** to installation by pumping **on-site groundwater**
- Groundwater impacted by low levels of **PFAS**
- Current treatment includes air-stripping for intermittent, low levels of **CVOCs**
- EXWC is assessing performance of **sorbents** for removal of PFAS from groundwater from production wells
 - Collected ~400 gallons of water prior to air stripping tower
 - Shipped to EXWC for testing
 - Rapid Small Scale Column Testing (RSSCT)
 - Laboratory-scale pilot column test
- Provide estimates of various sorbent performance in full-scale (2.4 MGD) system

CVOC(s): chlorinated volatile organic compound(s)

MGD: million gallons per day

NAF: Naval Air Facility

NAF Atsugi PFAS Treatability Study



- Available space is limited
- Air stripping tower is nearing end of life, sorbent may treat both low levels of PFAS and CVOCs
- Small space favors use of IX resin
 - Short EBCT, higher capacity means smaller footprint
- Low PFAS, DOC, and TDS (“uncomplicated” chemistry) favors simple sorbent treatment



(Kornuc 2025)

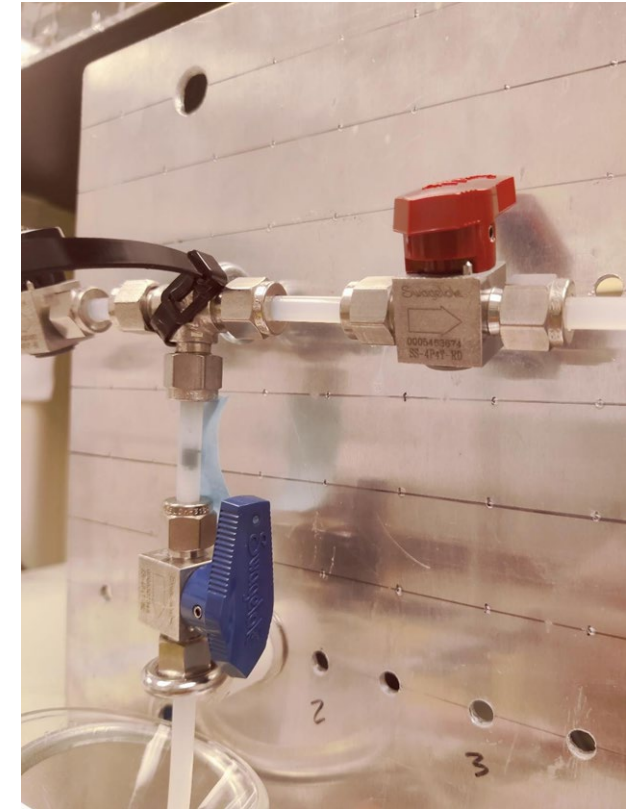
DOC: dissolved organic carbon

NAF Atsugi PFAS Treatability Study: RSSCT

- Rapid Small Scale Column Tests (RSSCT) predicts full scale treatment
- Runs require only days rather than years
- Water volumes much reduced -2-5 gallons (small bed volumes, BVs)
- Particle size of media proportionally smaller (grind media, 200-230 mesh)



(Kornuc 2026)



(Kornuc 2026)

BV: bed volume

NAF Atsugi PFAS Treatability Study



- Testing GAC (three types), IX (two types) and cyclodextrin
- Samples collected at up to 1,000,000 BVs
- Analytical range finding or “bookending” to preserve analytical budget

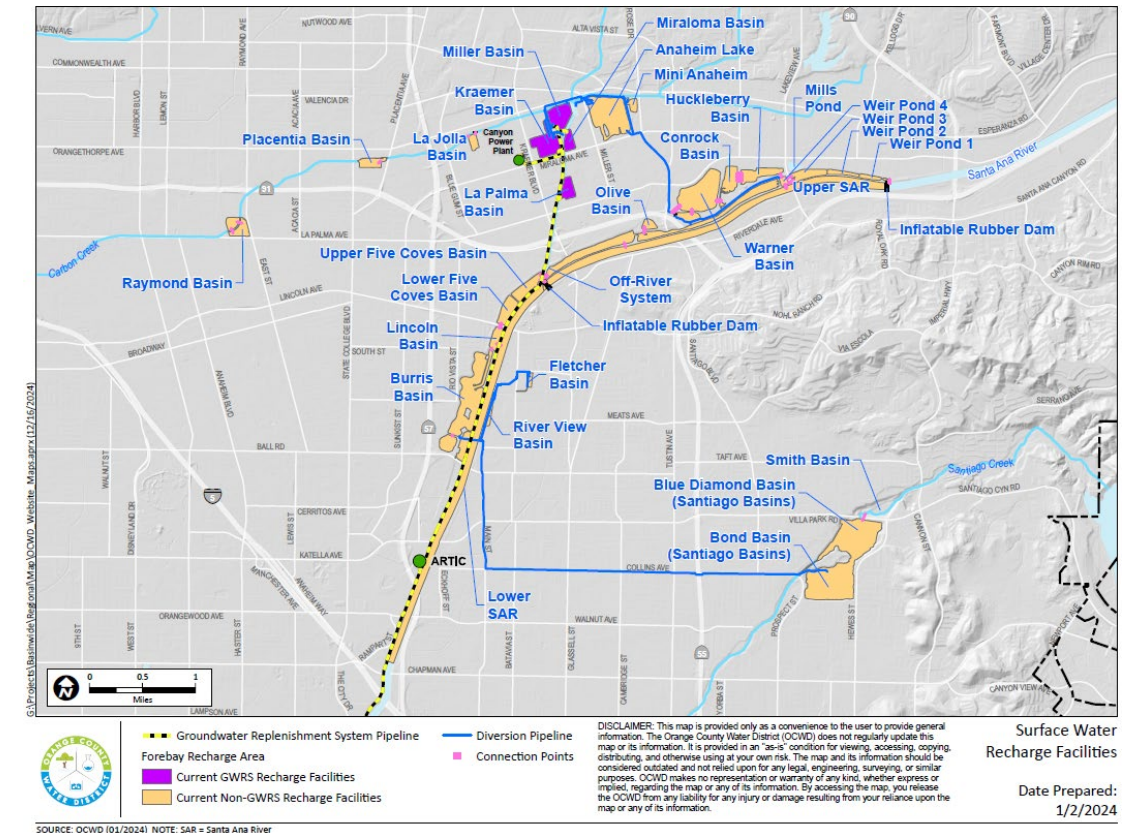


(Kornuc 2026)

Case Study 3: Orange County Water District PFAS Treatment



- OCWD manages groundwater basin serving 2.5M residents
- Manage the largest indirect potable water reuse system—GWRS—1,600 acres of recharge basins that also helped mobilize PFAS
- 400 wells managed, 106 exceed 80% of California Reporting Limit for PFOS or PFOA (2019)
- \$1.8B projected cost for construction and O&M over 30 years
- OCWD ran a detailed treatability study using 10 representative wells



(OCWD 2021)

GWRS: groundwater replenishment system

OCWD: Orange County Water District

OCWD Treatability RSSCT and Pilot Columns



- Ran RSSCTs and Pilot Columns (pictured to the right)
 - Performed tests on-site, near wells, so nearly unlimited water sources
 - Not always the case for Navy, especially OCONUS
 - RSSCTs require relatively little water
- Tested eight GACs, four IX, and two alternative sorbents
- Tested different source waters from different plants in watershed
 - Representative range of PFAS concentrations low to high
 - Range of TOC/DOC

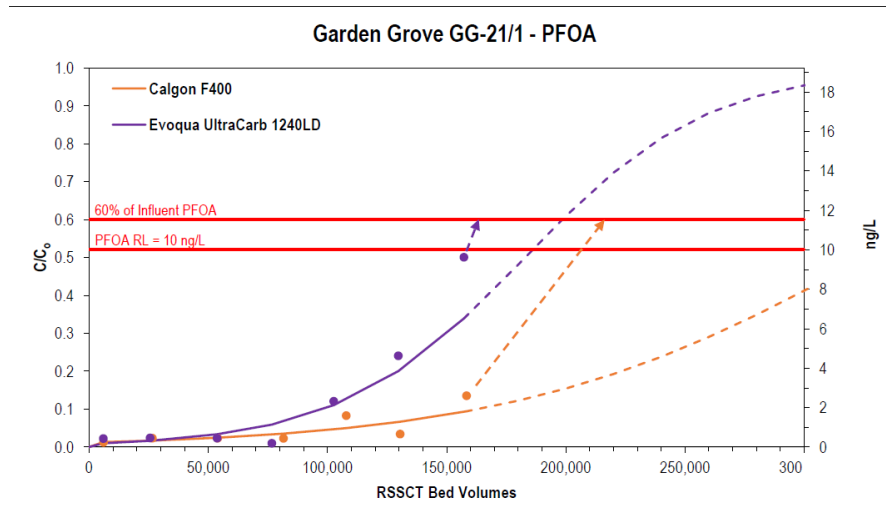
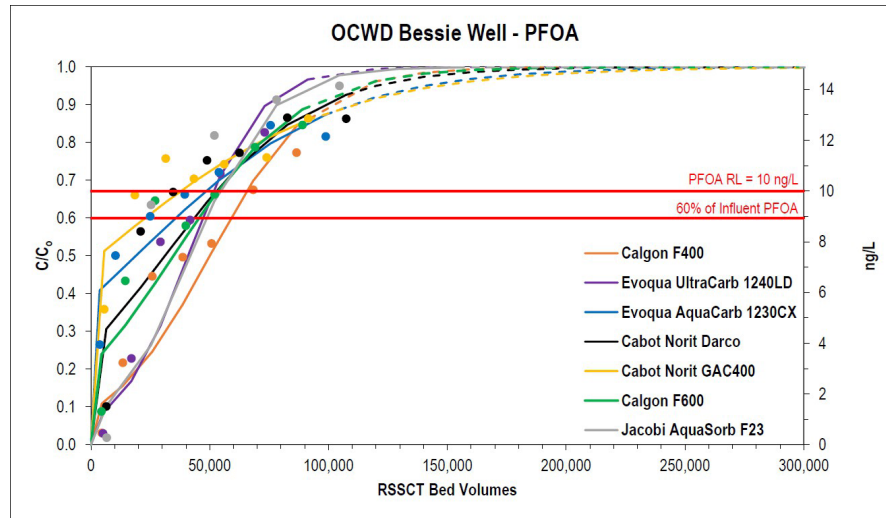


(OCWD 2022)

OCONUS: Outside the Continental United States

TOC: total organic carbon

OCWD Treatability RSSCT and Pilot Column Results

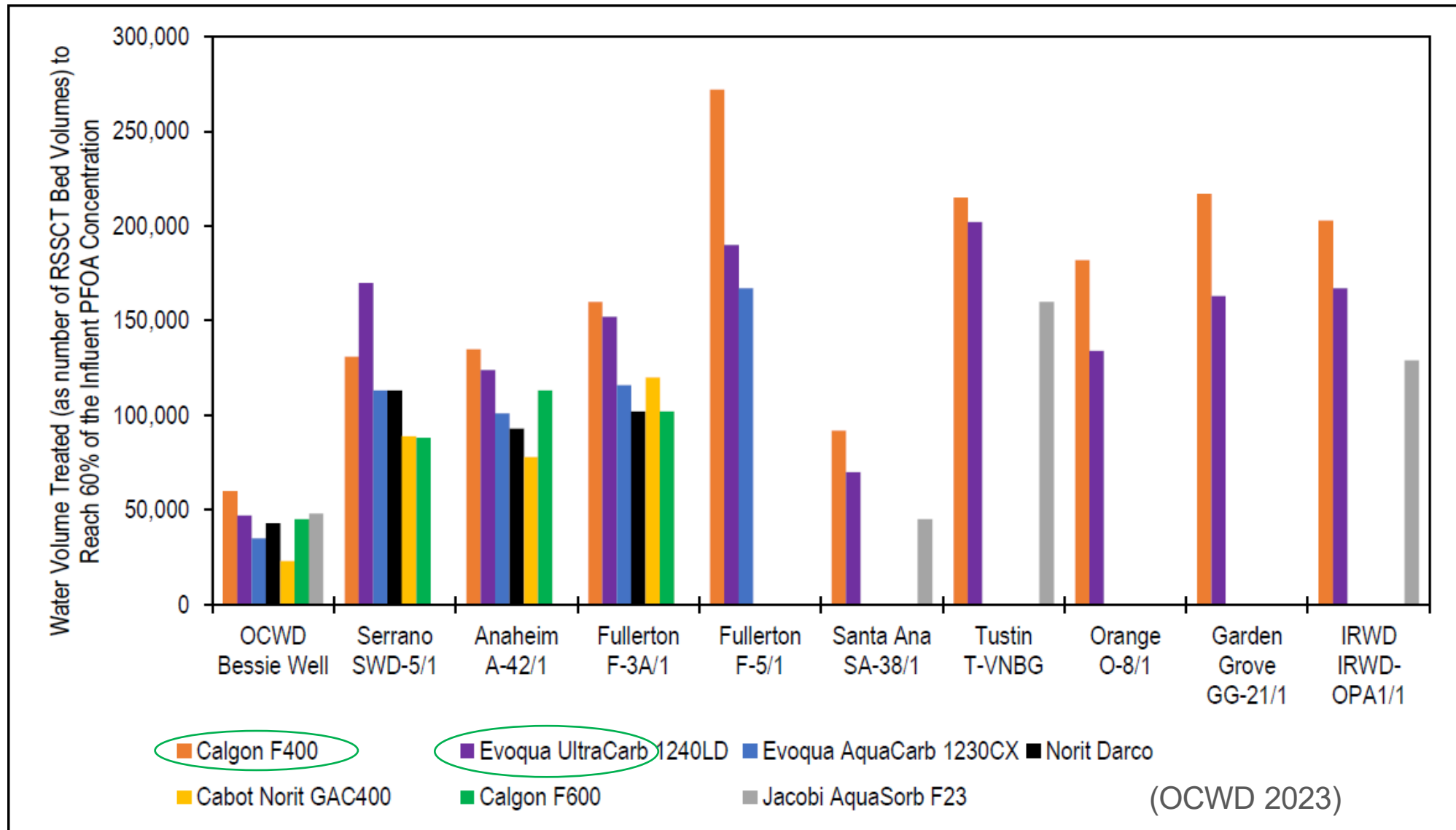


(OCWD 2023)

Adsorbent Media	Time (Months) to Reach PFOA Breakthrough	
	Initial Breakthrough Above Detection Limit	Effluent Concentration at ~60% of Influent Concentration ^(a)
Granular Activated Carbon		
Calgon F400 (Virgin and Reactivated)	5.7 (V), 5.2 (R)	> 13
Calgon F600	2.7	> 13
Cabot Norit GAC 400	3.1	> 13
Evoqua AquaCarb 1230CX	2.7	12.8
Cabot Norit HYDRODARCO 4000	4.3	9.0
Jacobi AquaSorb F23	5.2	8.9
Evoqua UltraCarb 1240LD	3.8	8.7
Ion Exchange (IX) Resins		
Evoqua PSR2+	7.1	> 13
Calgon CalRes 2301	4.3	7.9
Purolite Purofine PFA694E	4.3	7.9
ECT2 Sorbix LC4	3.9	7.1
Alternative (Novel) Adsorbents		
CETCO FLUORO-SORB® 200	8.7	> 11
Cyclopure DEXSORB+®	2.7	5.6

(OCWD 2023)

OCWD Treatability RSSCT Results Varied by Source Water



(OCWD 2023)

OCWD Treatability Study: Key Takeaways



- IX (Amberlite PSR2+) was determined to be best performer overall for most water sources, F400 performed best for some sources
- IX performs best for PFOA, which was driver for most sources
- IX also performed better for short chains (PFBS)
- Performance was **different** for **same media** compared to test results using water from other source locations and projects

KEY POINT

Performance is very site-specific for sorbents. Small differences can add up to large life cycle cost variances.

OCWD Treatment Systems

- 53 of 106 impacted production wells have been brought back online
- Treatment plants range from a single pair of lead/lag sorbent vessels to 11 pairs of vessels, and sediment filtration bag or cartridge filters
- Sorbent vessels are mainly 1220 or 1240 (12-foot diameter x 20,000 or 40,000 pounds of media)
- Average 1220 vessel pair cost is ~\$600k, media ~\$200k each, so ~\$1M total/pair
- Mix of systems: Amberlite PSR2+ IX resin and Calgon GAC F400

Issues/Lessons Learned

- SCADA controls – add to existing PLC or is upgrade/replacement required
- Non chlorinated water source for flushing – IX Media incompatible with chlorine
- Sanding in wells – wastes prefiltration media



Issues/Lessons Learned

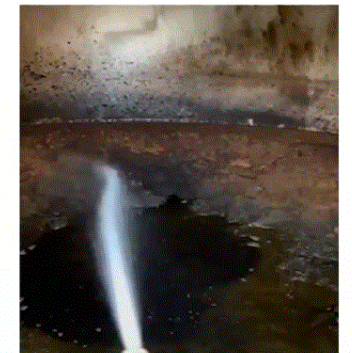
Ryan Bouley

- Co-contaminate clogging and “skimming” – Remove surface Manganese and Iron buildup

Clean Media



Media with Iron and Manganese



(OCWD 2023)

OCWD Treatment Systems: Largest Plant



Yorba Linda Water District – Central Plant

(OCWD 2023)

Case Study 4: In Situ Sorption



- NESDI 569
- Project Objective
- Evaluate effectiveness of CAC for in situ enhanced retention
- Environmental Questions
 - Does CAC distribute well in aquifers—influence of lithology?
 - What is the general in situ treatment effectiveness on different PFAS?
 - What is the long-term adsorption capacity and potential for rerelease of PFAS?
 - Are there any significant aquifer effects (CAC in monitoring wells or hydraulic conductivity impacts)



Conceptual Site Model

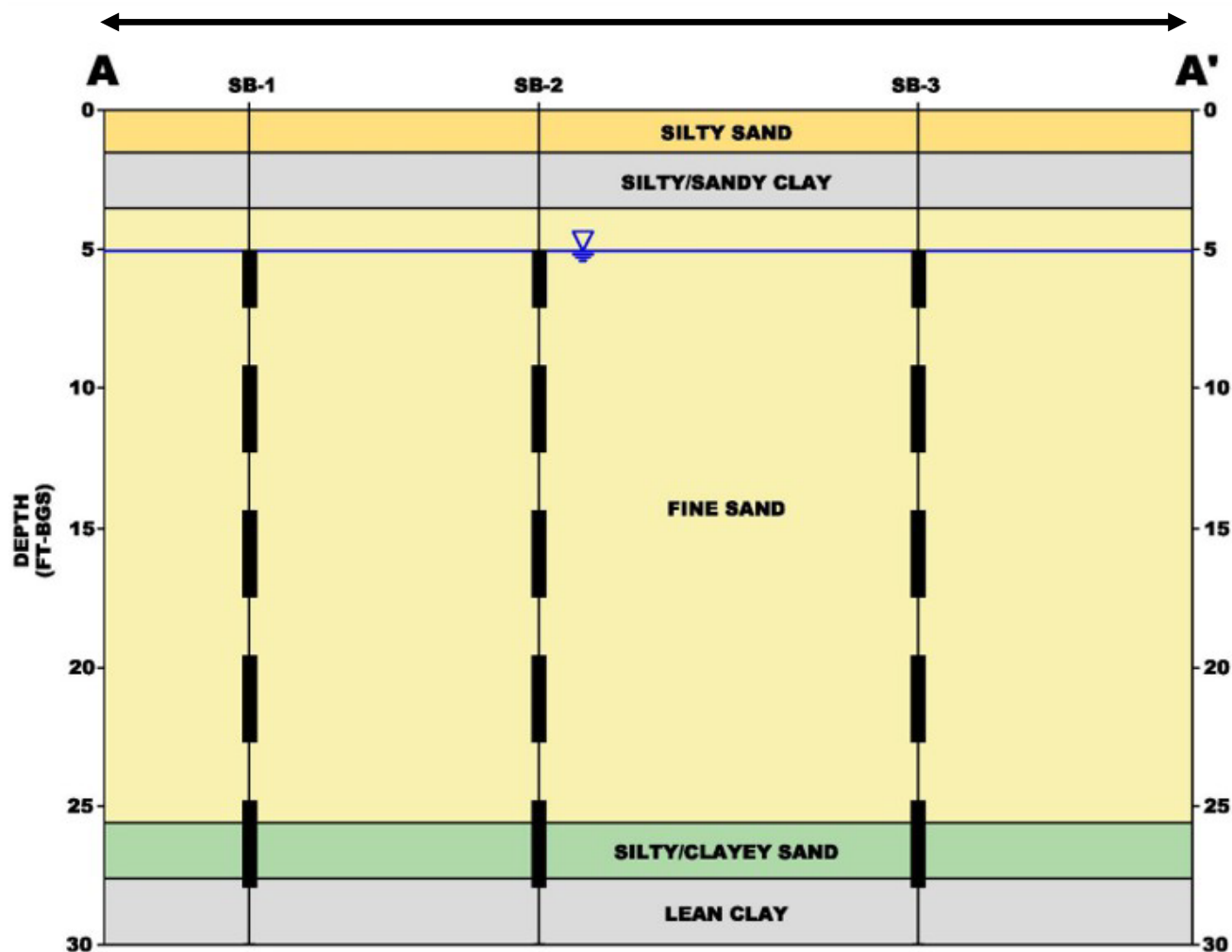
- Field carrier landing practice and helicopter training operations
- High permeability (medium sand or better)
- Water table close to the surface (5–6 feet bgs)
- Homogeneous
- Relatively high concentrations of PFAS



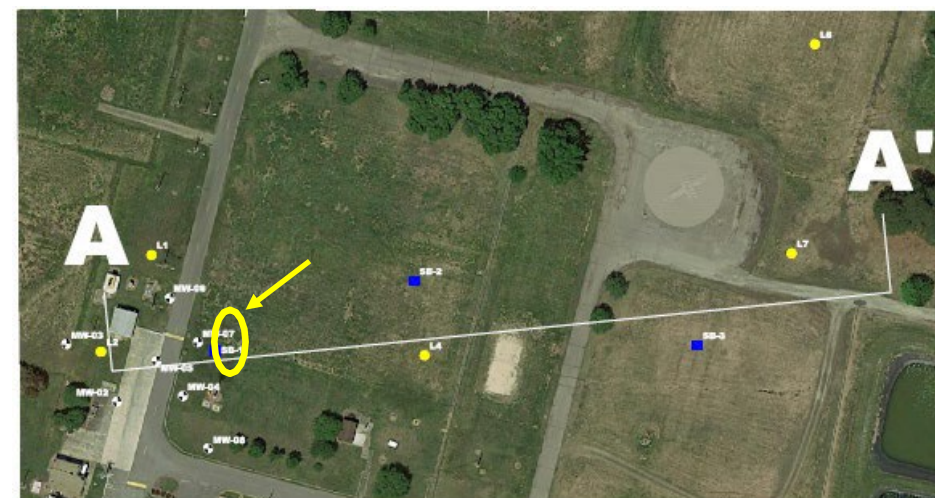
(CH2M 2021)

bgs: below ground surface

Site Characterization Activities



(Danko 2024)

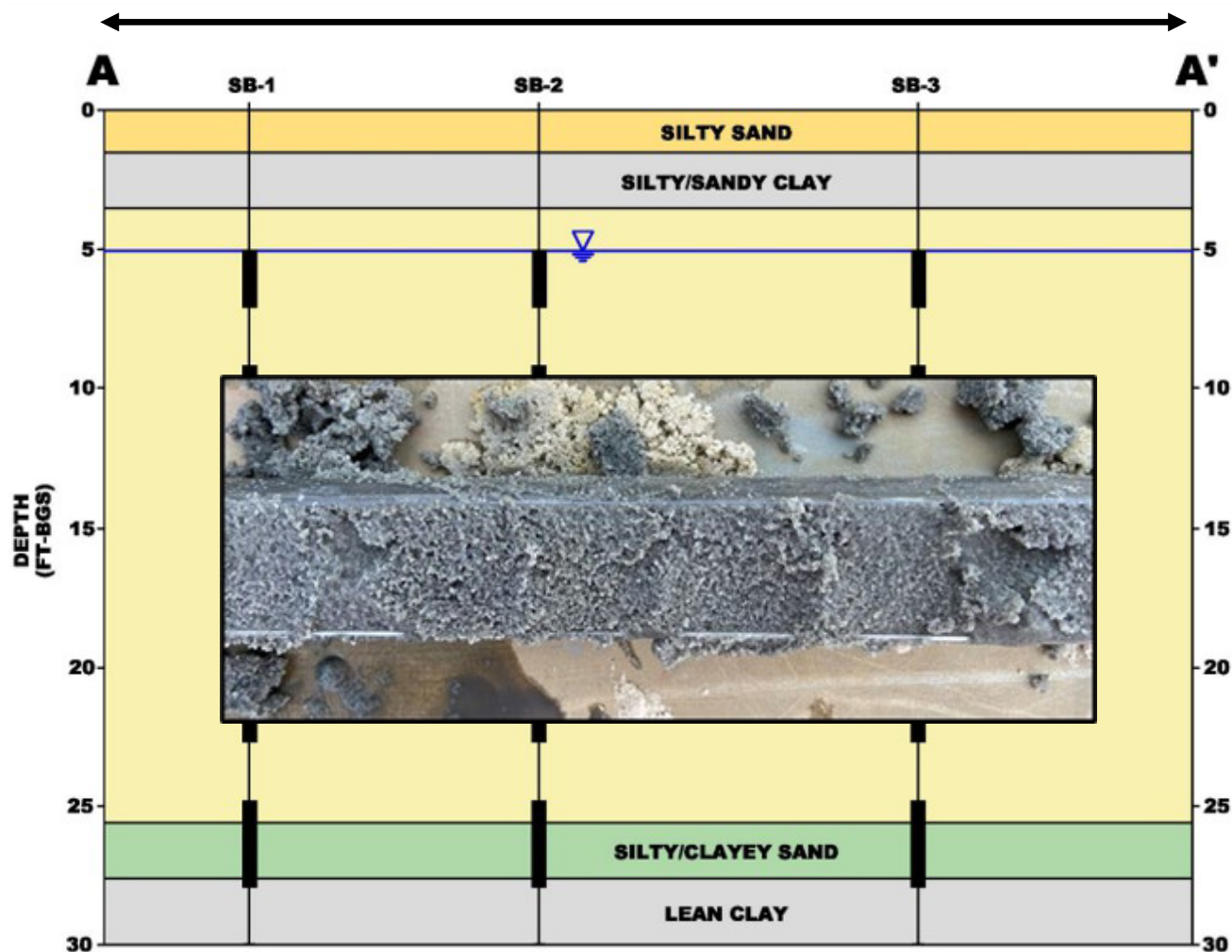


INSET SCALE
0 300 600 FEET

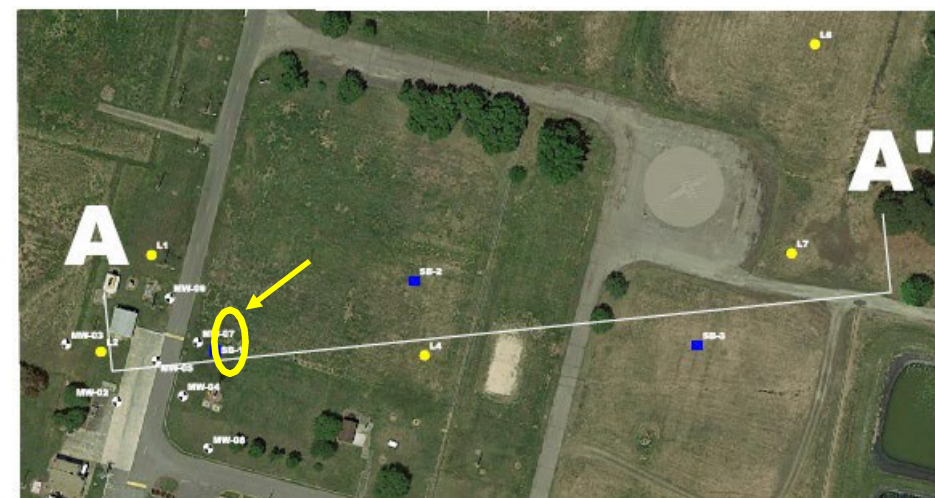
Site Characterization

- Soil cores for lithology
- Discrete groundwater sampling

Site Characterization Activities



(Danko 2024)



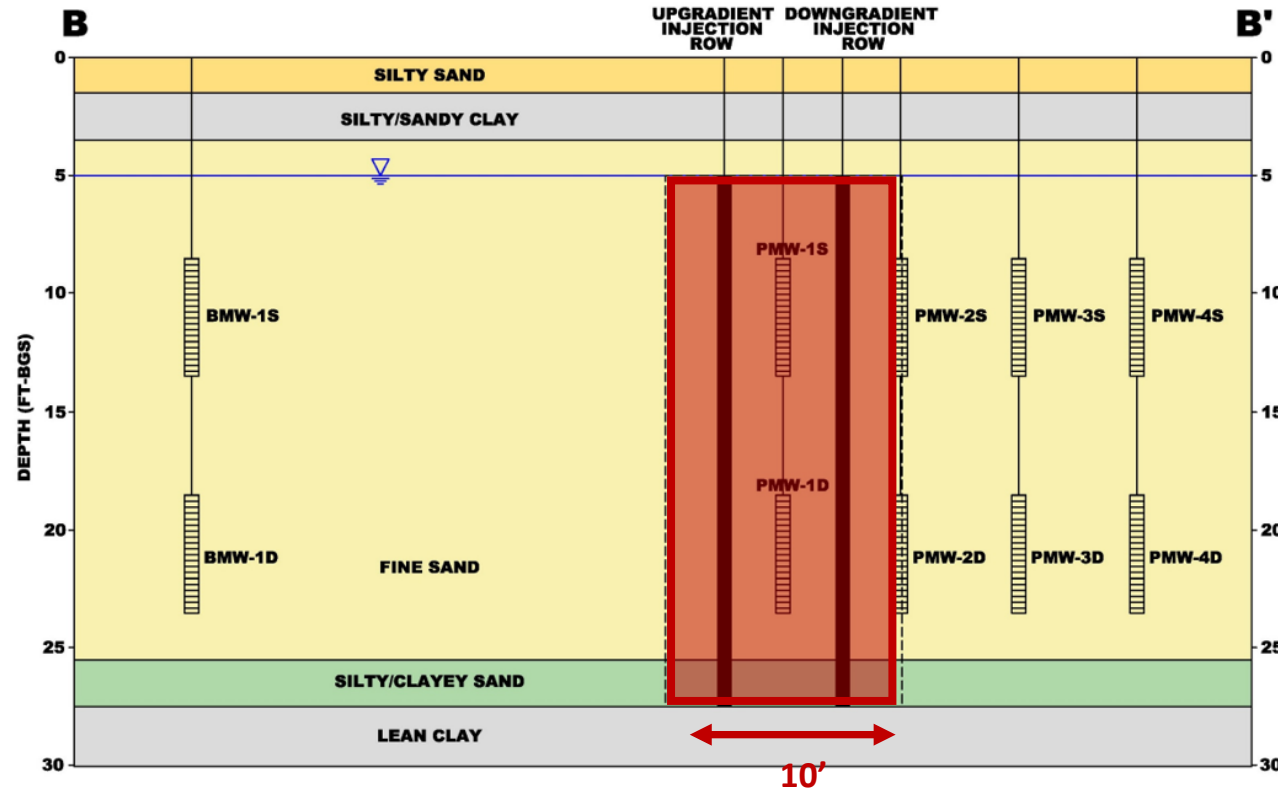
INSET SCALE

0 300 600 FEET

Site Characterization

- Soil cores for lithology
- Discrete groundwater sampling

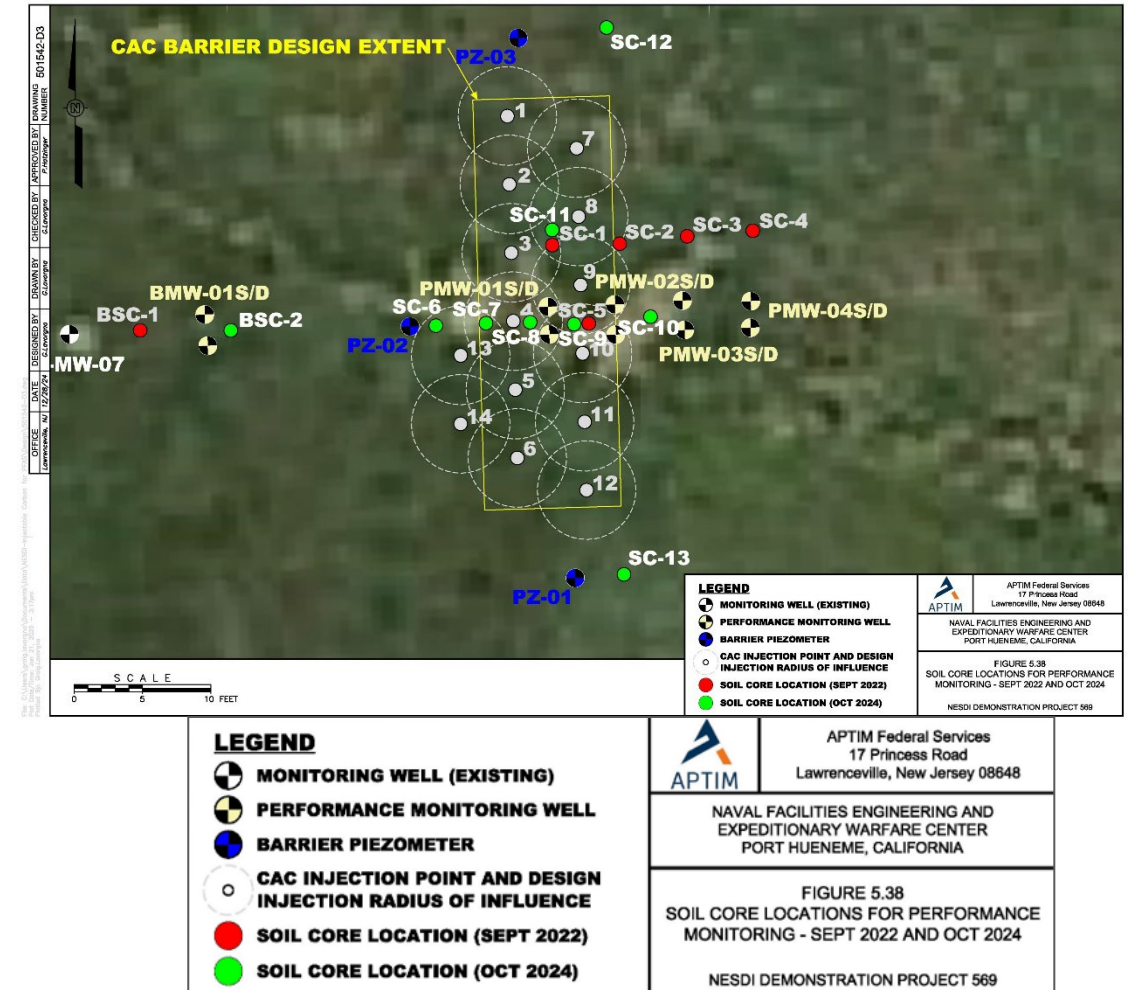
In Situ Sorption: Design



30-foot long x 10-foot wide barrier
2 injection rows/12 points

(Danko 2024)

DEMONSTRATION WELL AND INJECTION POINT LAYOUT



(NESDI 2025)

In Situ Sorption: CAC Injection



9,600 lbs/1,065 gal of CAC and 10,456 gal mix water
Target concentration = 2,000 mg carbon per kg soil

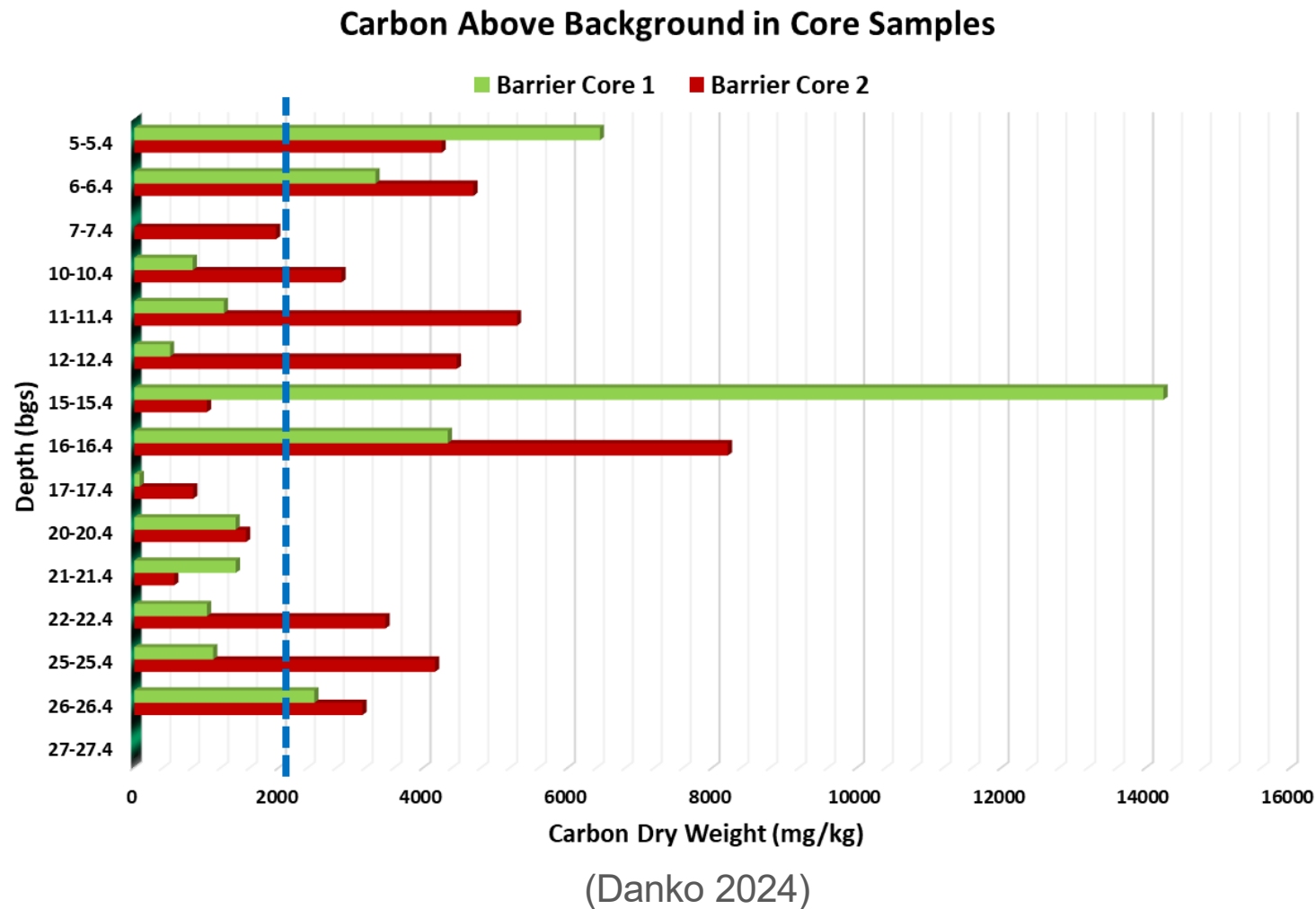
gal: gallons

mg: milligrams

lbs: pounds

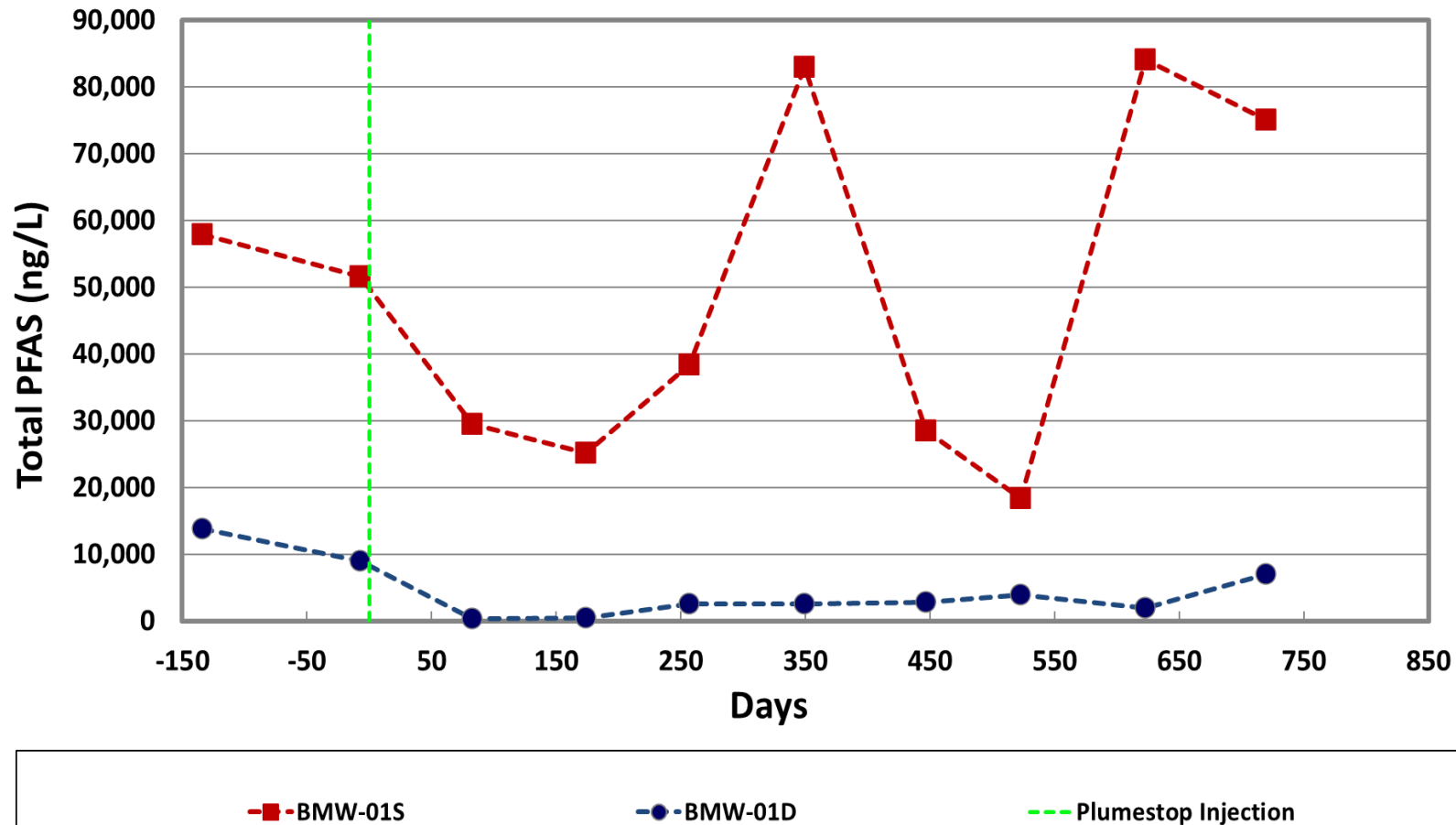
(Danko 2024)

In Situ Sorption: CAC Distribution Assessment



In Situ Sorption

Upgradient Total PFAS Concentrations



Upgradient– 2 YRS

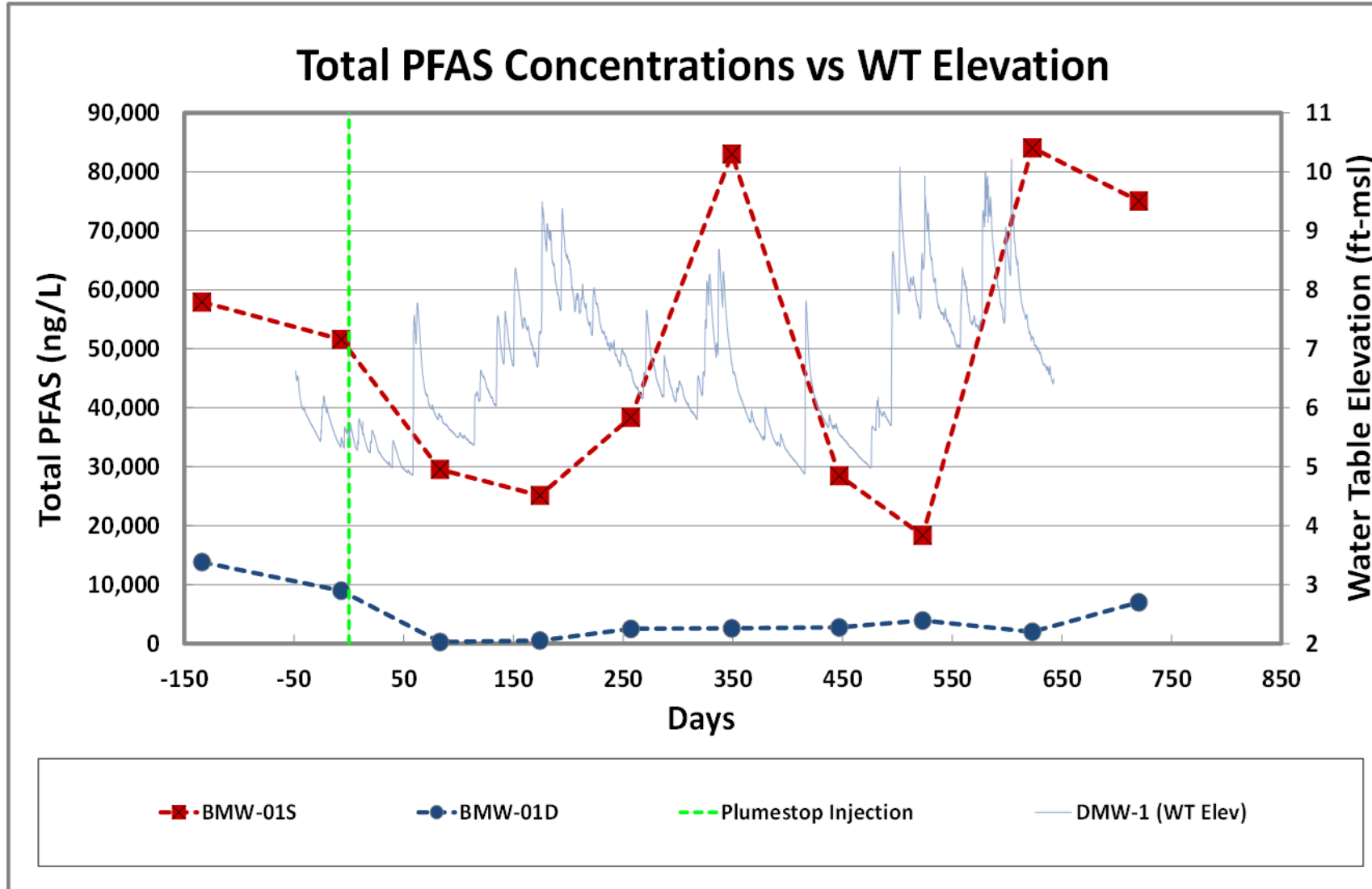
- Pre-injection baseline
 - Shallow: 52–58 µg/L
 - Deep: 9–14 µg/L

- Less variability in Deep Zone

- Why more variability in Shallow Zone?

µg/L: micrograms per liter
(Danko 2024)

In Situ Sorption: Impact of Water Table Fluctuations

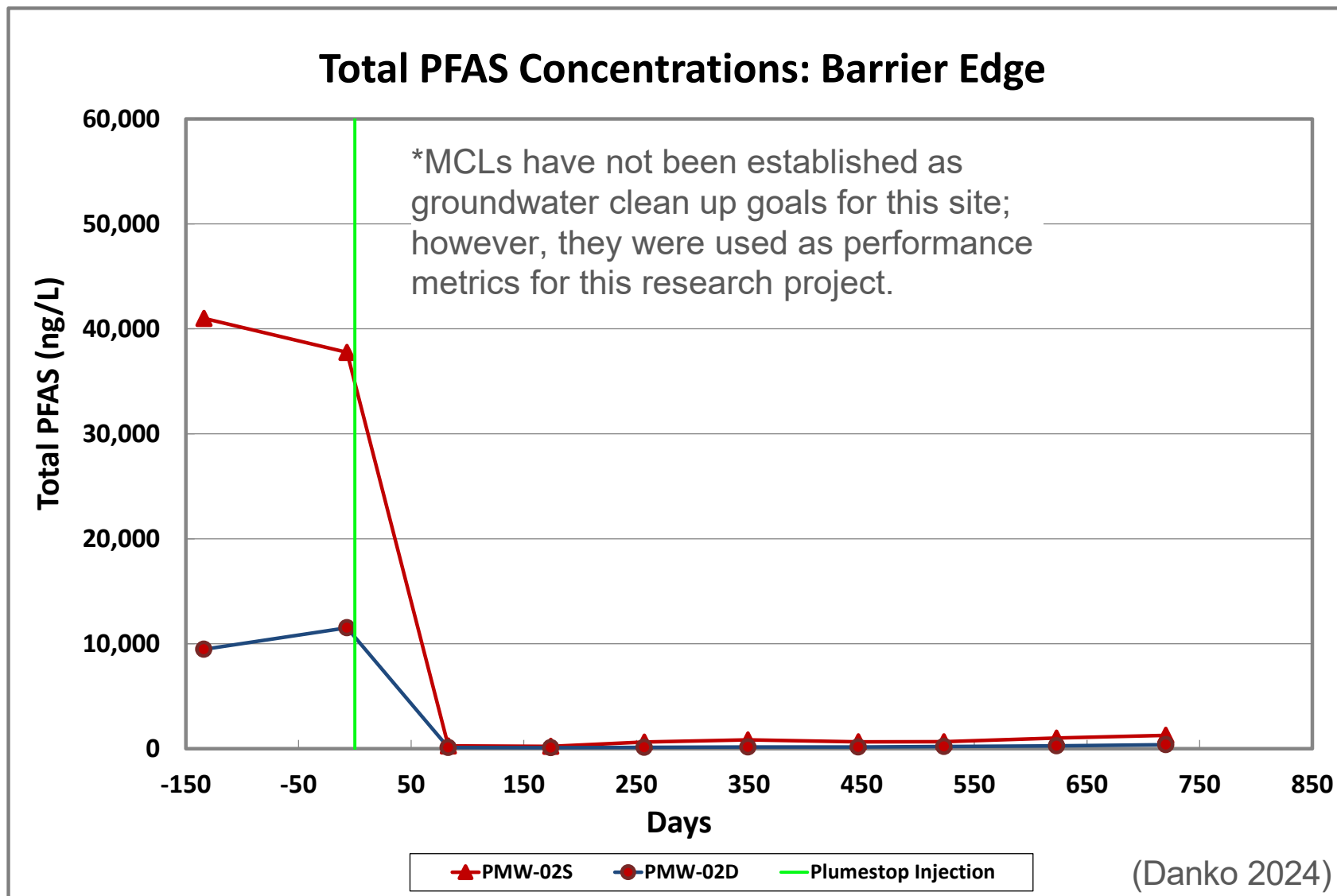


Upgradient– 2 YRS

- Pre-injection baseline
 - Shallow: 52–58 µg/L
 - Deep: 9–14 µg/L
- Over time variability in shallow GW suggests vadose zone impacts - groundwater elevation
- Less variability in Deep Zone

µg/L: micrograms per liter
(Danko 2024)

PFAS Data (Total): Downgradient Barrier Edge

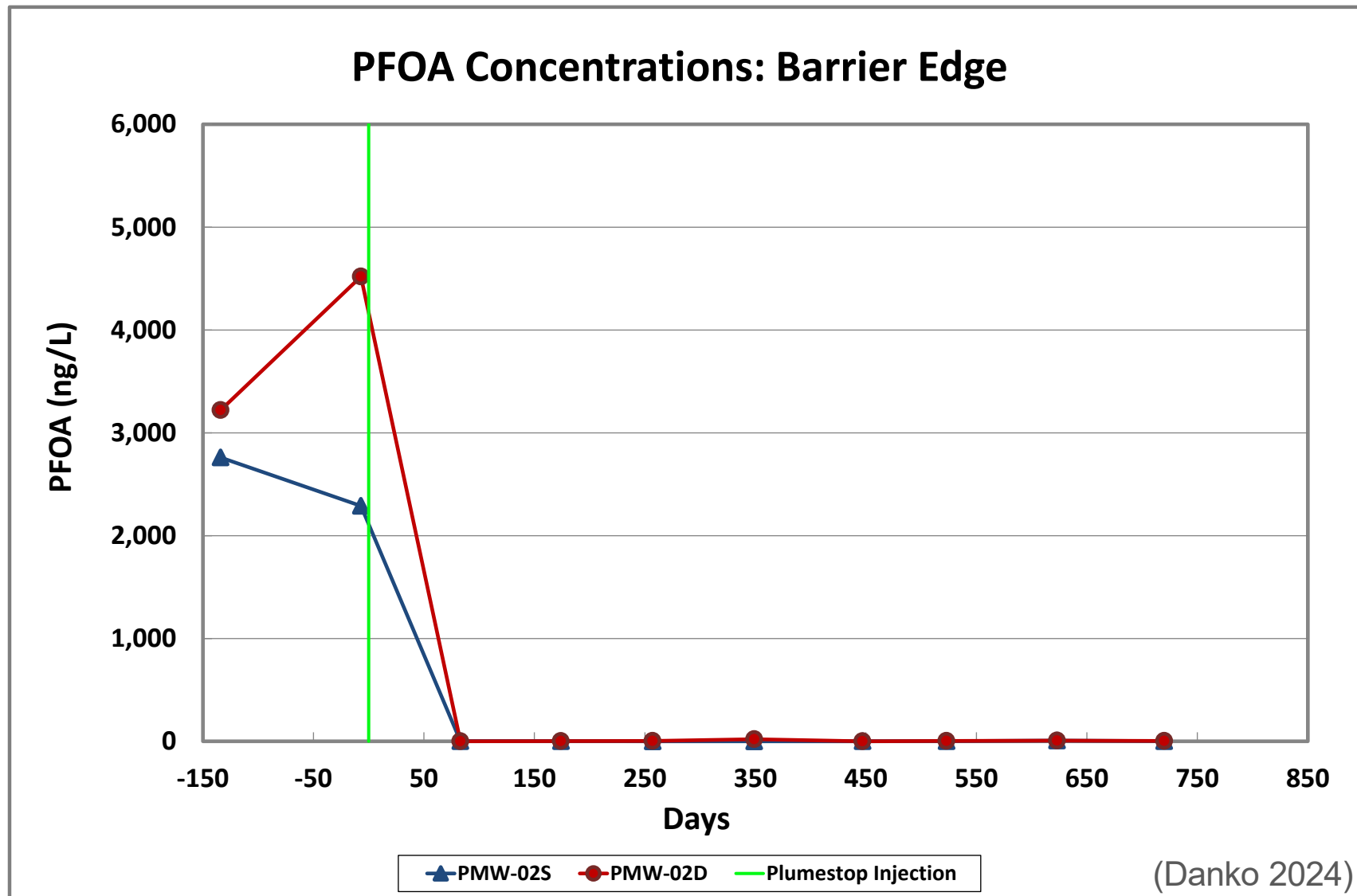


2 years after injection

- 96.8% reduction in shallow zone
- 96.3% reduction in deep zone
- EPA MCLs met*
- Complete breakthrough of PFBA
- PFPeA, PFHxA also increasing gradually with time
- Excluding PFBA, 99.85% removal at downgradient edge

MCL: maximum contaminant level

PFAS Data (PFOA): Downgradient Barrier Edge

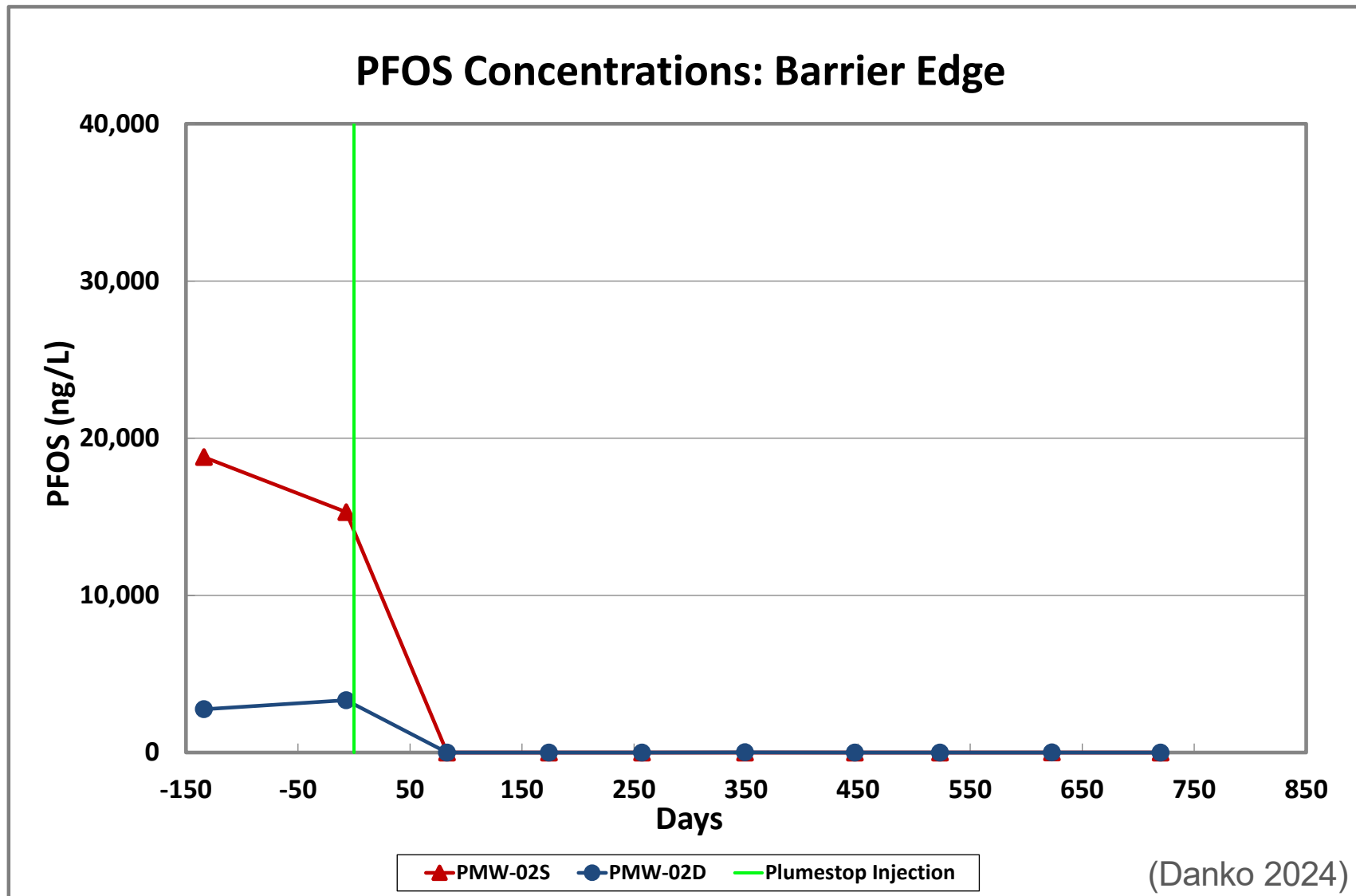


2 years after injection

- 96.8% reduction in shallow zone
- 96.3% reduction in deep zone
- EPA MCLs met*
- Complete breakthrough of PFBA
- PFPeA, PFHxA also increasing gradually with time
- Excluding PFBA, 99.85% removal at downgradient edge

MCL: maximum contaminant level

PFAS Data (PFOS): Downgradient Barrier Edge

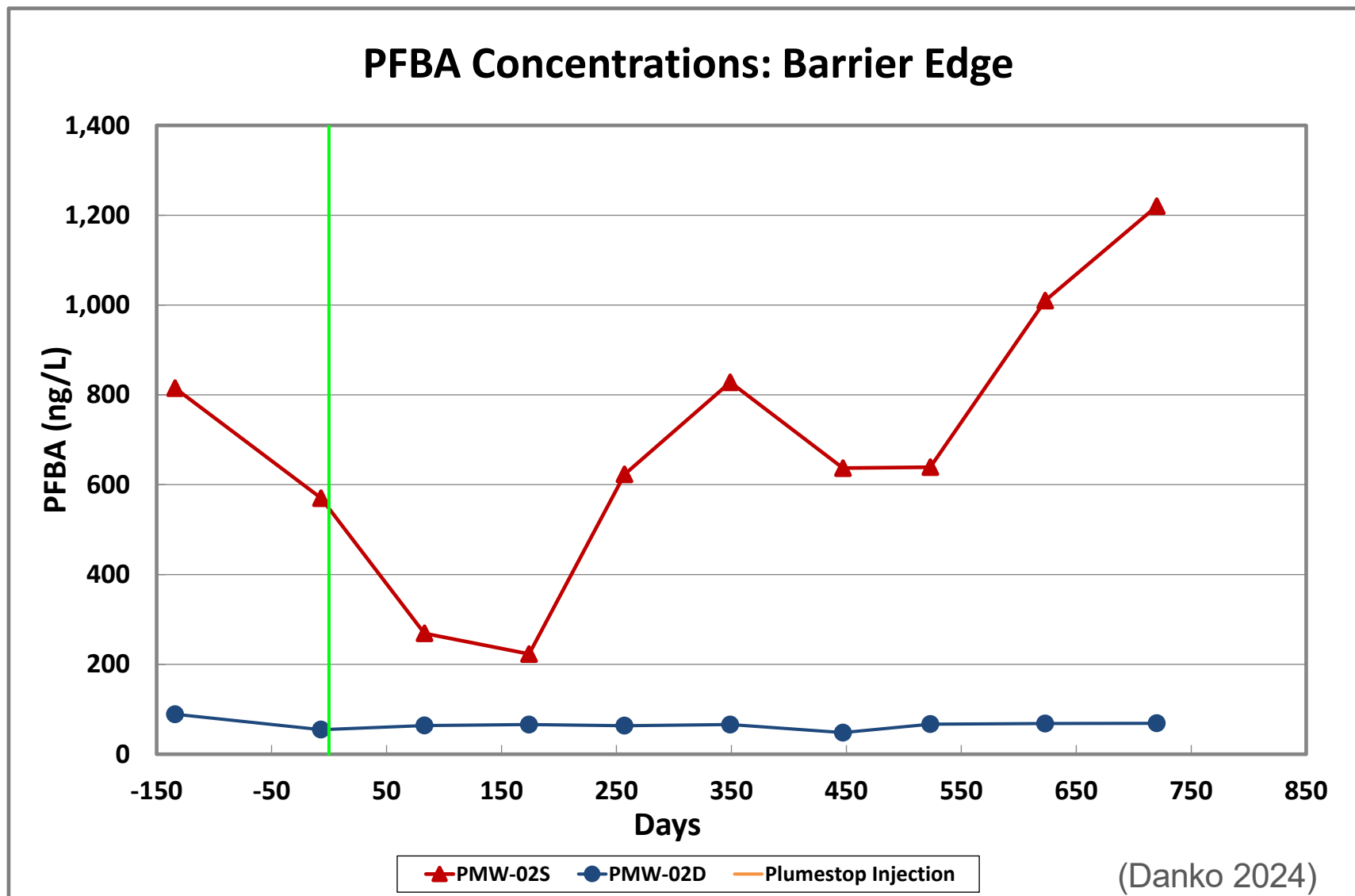


2 years after injection

- 96.8% reduction in shallow zone
- 96.3% reduction in deep zone
- EPA MCLs met*
- Complete breakthrough of PFBA
- PFPeA, PFHxA also increasing gradually with time
- Excluding PFBA, 99.85% removal at downgradient edge

MCL: maximum contaminant level

PFAS Data (PFBA): Downgradient Barrier Edge

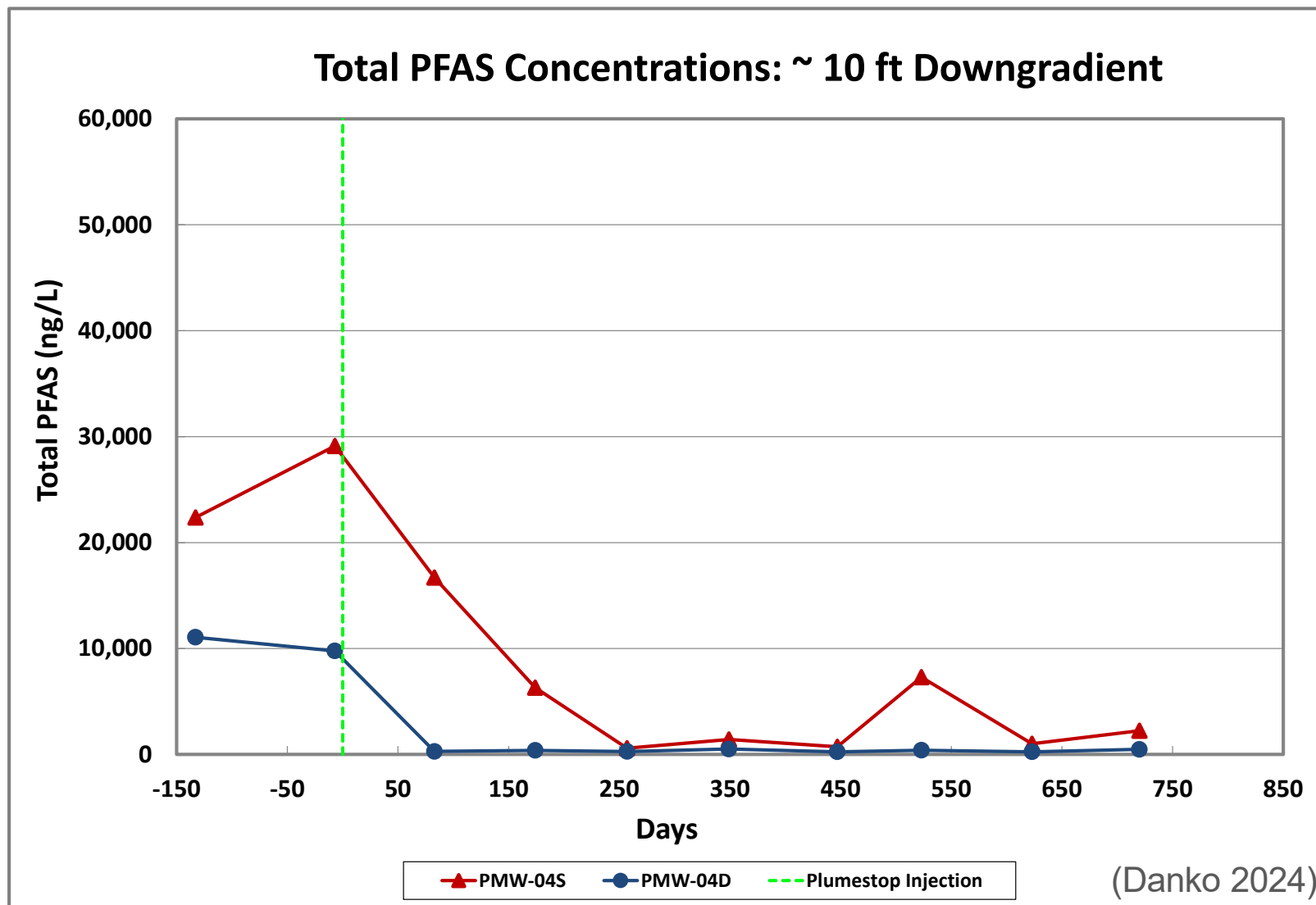


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MCL: maximum contaminant level

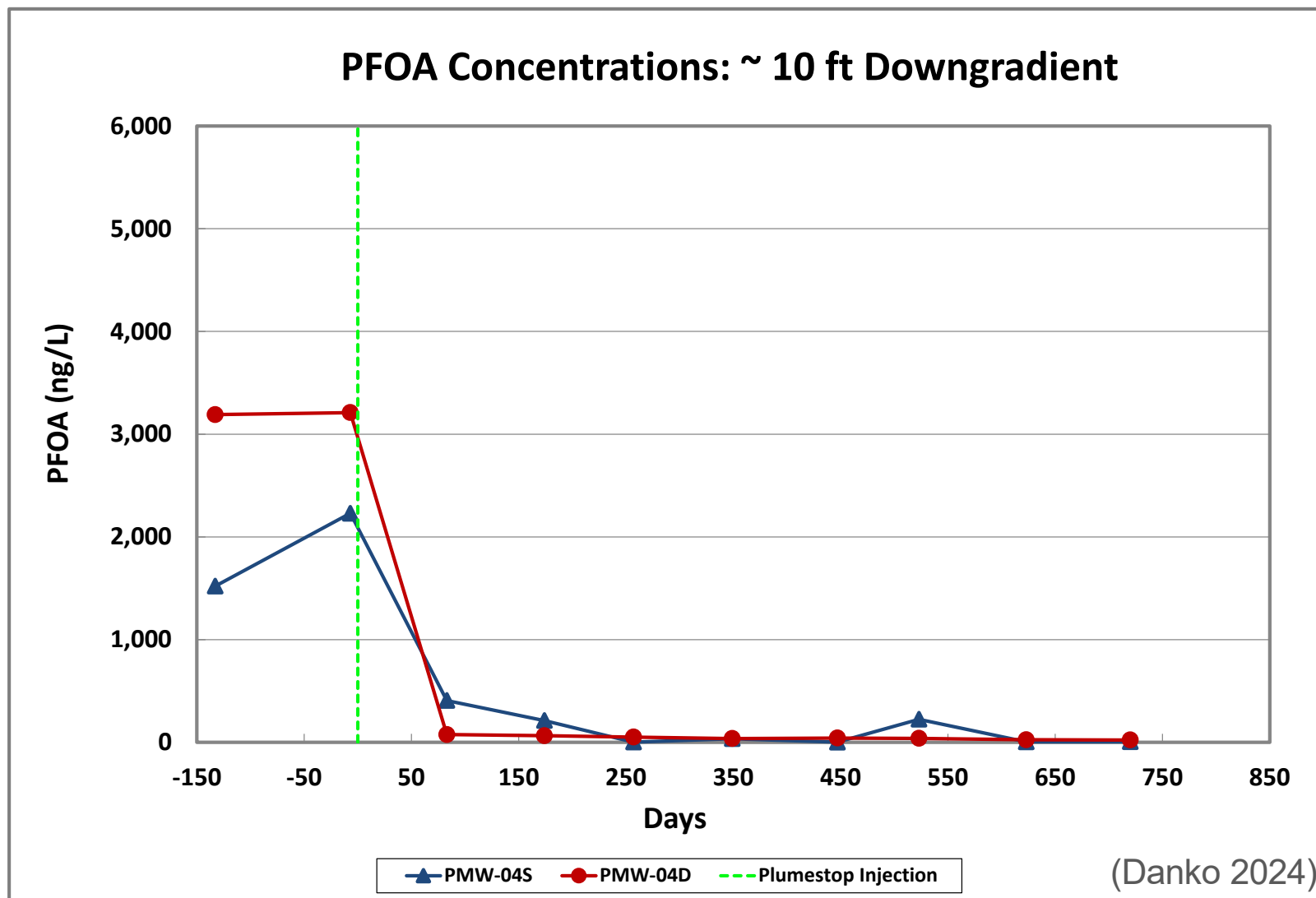
PFAS Data (Total): 10-Foot Downgradient



2 years after injection

- 91.2% reduction in shallow zone
- 95.3% reduction in deep zone
- EPA MCLs not met*
- Complete breakthrough of PFBA
- Rate-limited and back-diffusion downgradient of barrier + new vadose zone addition

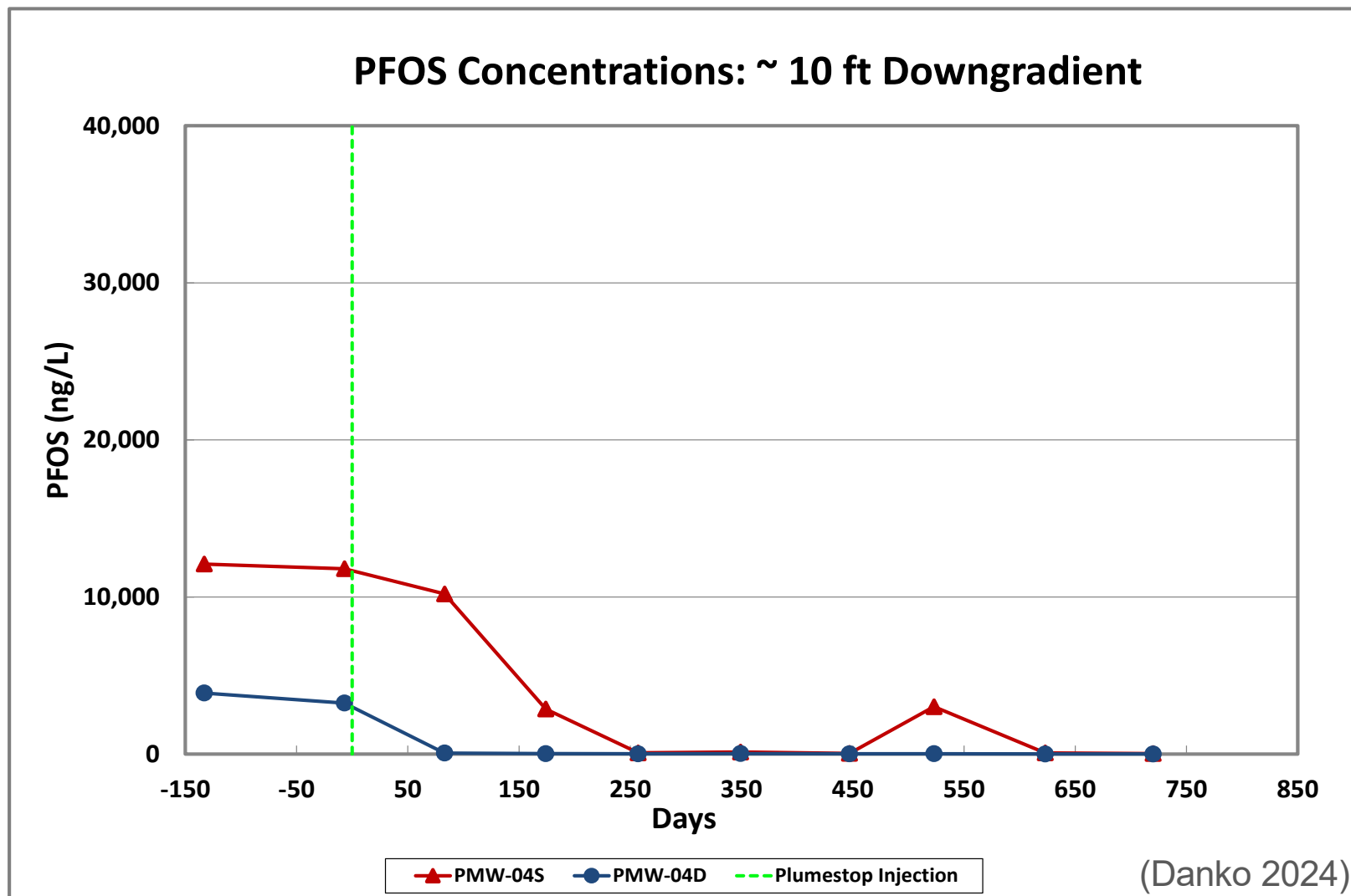
PFAS Data (PFOA): 10-Foot Downgradient



2 years after injection

- 91.2% reduction in shallow zone
- 95.3% reduction in deep zone
- EPA MCLs not met*
- Complete breakthrough of PFBA
- Rate-limited and back-diffusion downgradient of barrier + new vadose zone addition

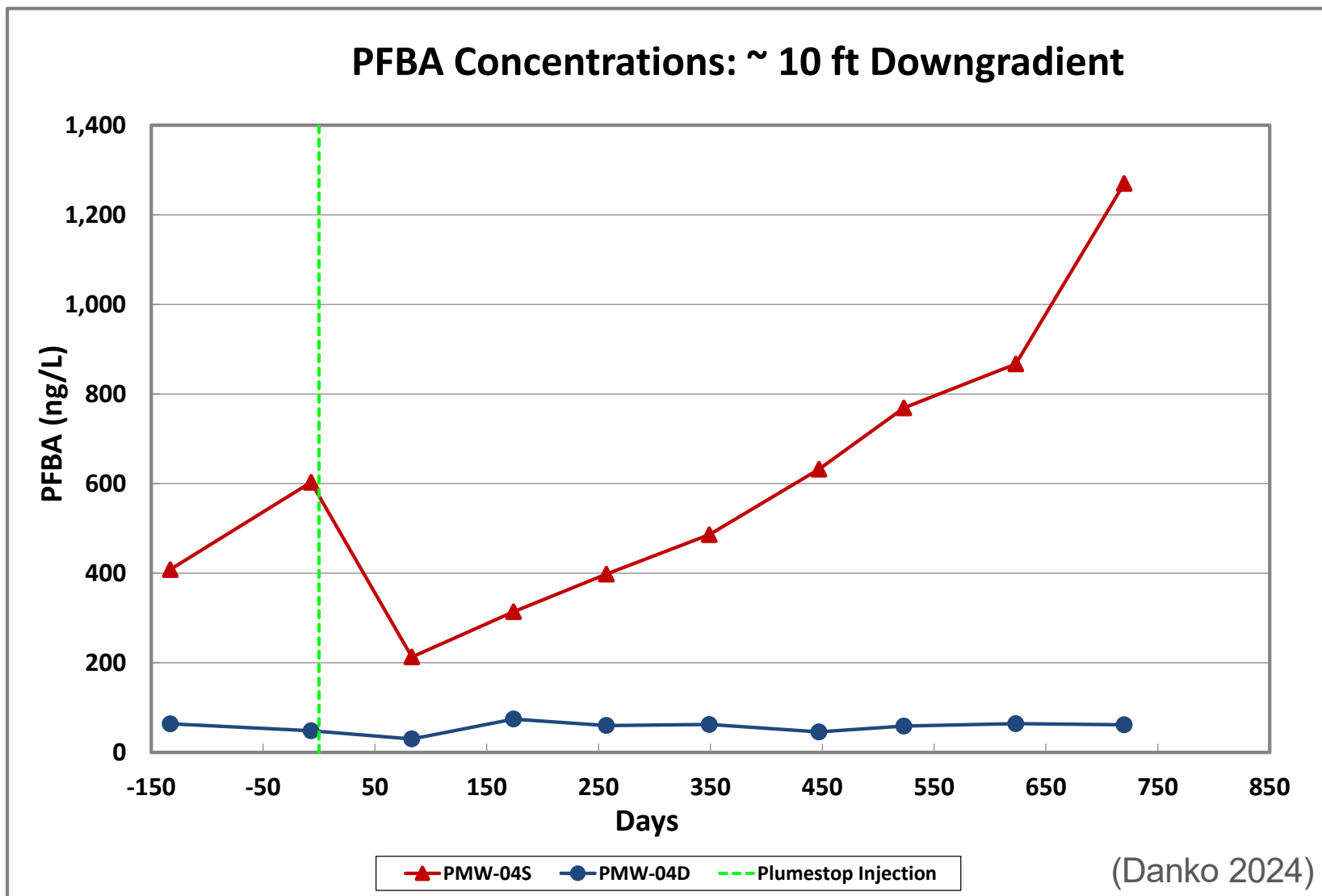
PFAS Data (PFOS): 10-Foot Downgradient



2 years after injection

- 91.2% reduction in shallow zone
- 95.3% reduction in deep zone
- EPA MCLs not met*
- Complete breakthrough of PFBA
- Rate-limited and back-diffusion downgradient of barrier + new vadose zone addition

PFAS Data (PFBA): 10-Foot Downgradient



2 years after injection

- 91.2% reduction in shallow zone
- 95.3% reduction in deep zone
- EPA MCLs not met*
- Complete breakthrough of PFBA
- Rate-limited and back-diffusion downgradient of barrier + new vadose zone addition

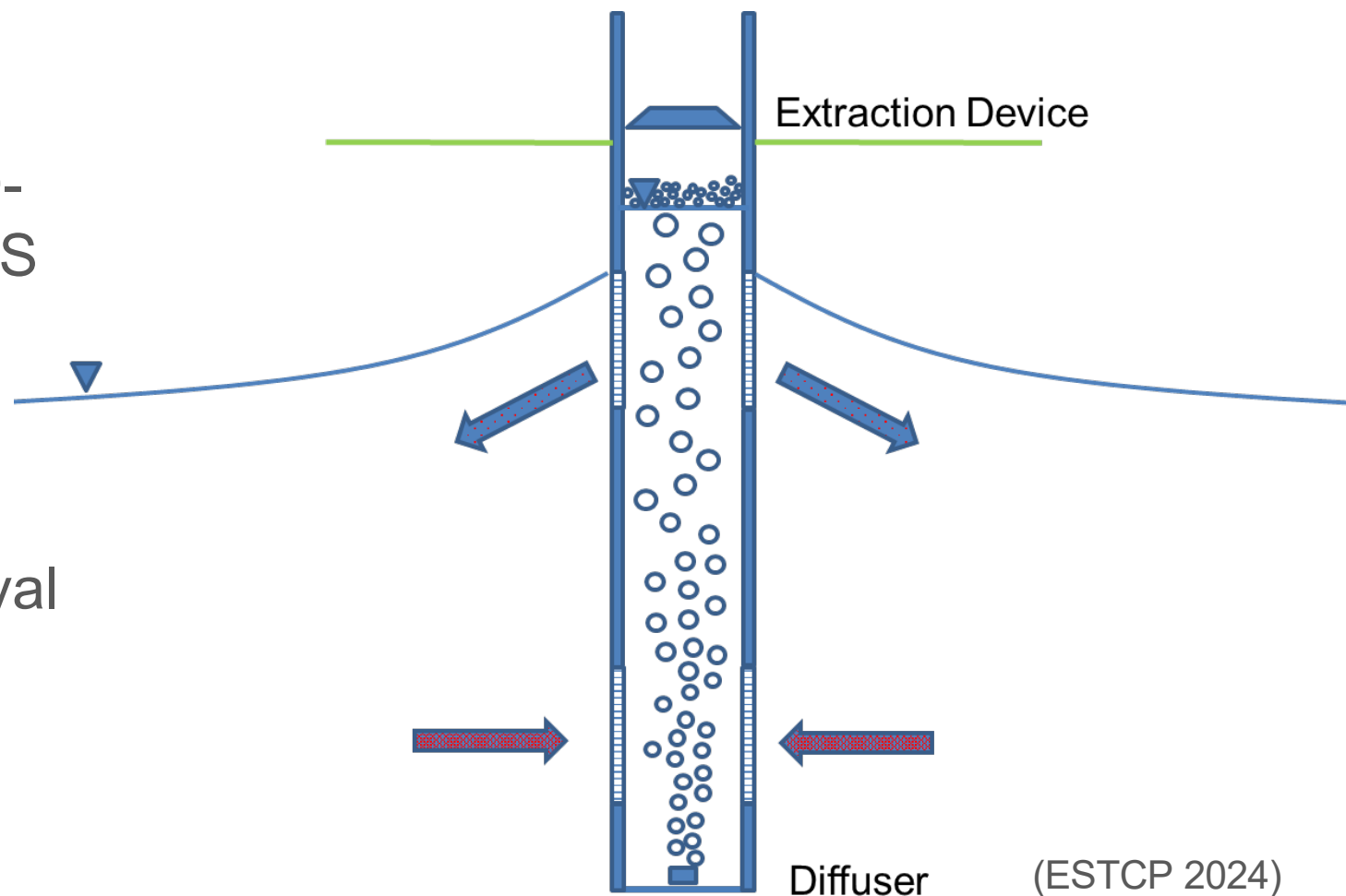
In Situ Sorption: Key Takeaways



- Injected CAC barriers can sequester PFAS and reduce downgradient migration in groundwater
- Breakthrough of short chain PFAS like PFBA can occur
- If source mass still remains downgradient of treatment, achieving cleanup goals may be challenging due to vadose zone leaching and matrix diffusion/desorption
- A reminder to please check with a SME!

Case Study 5: In Situ Foam Fractionation

- ESTCP ER19-5075
- Demonstrate capability of D-FAS system to remove PFAS mass from source zones
- Determine return on investment of system
- Estimate PFAS mass removal
- Estimate treatment cost efficiency
- Assess ease of operation



U.S. Patent 10,752,521

Conceptual Site Model

- East Coast Master Jet Base
- High permeability (medium sand or better)
- Water table close to the surface (5–6 feet bgs)
- Homogeneous
- Relatively high concentrations of PFAS
- TTA close to fire station burn pit (SWMU 26) and fire station



TTA, Adapted from ER19-5075 Final Report

PFOA = 22,600 ng/L

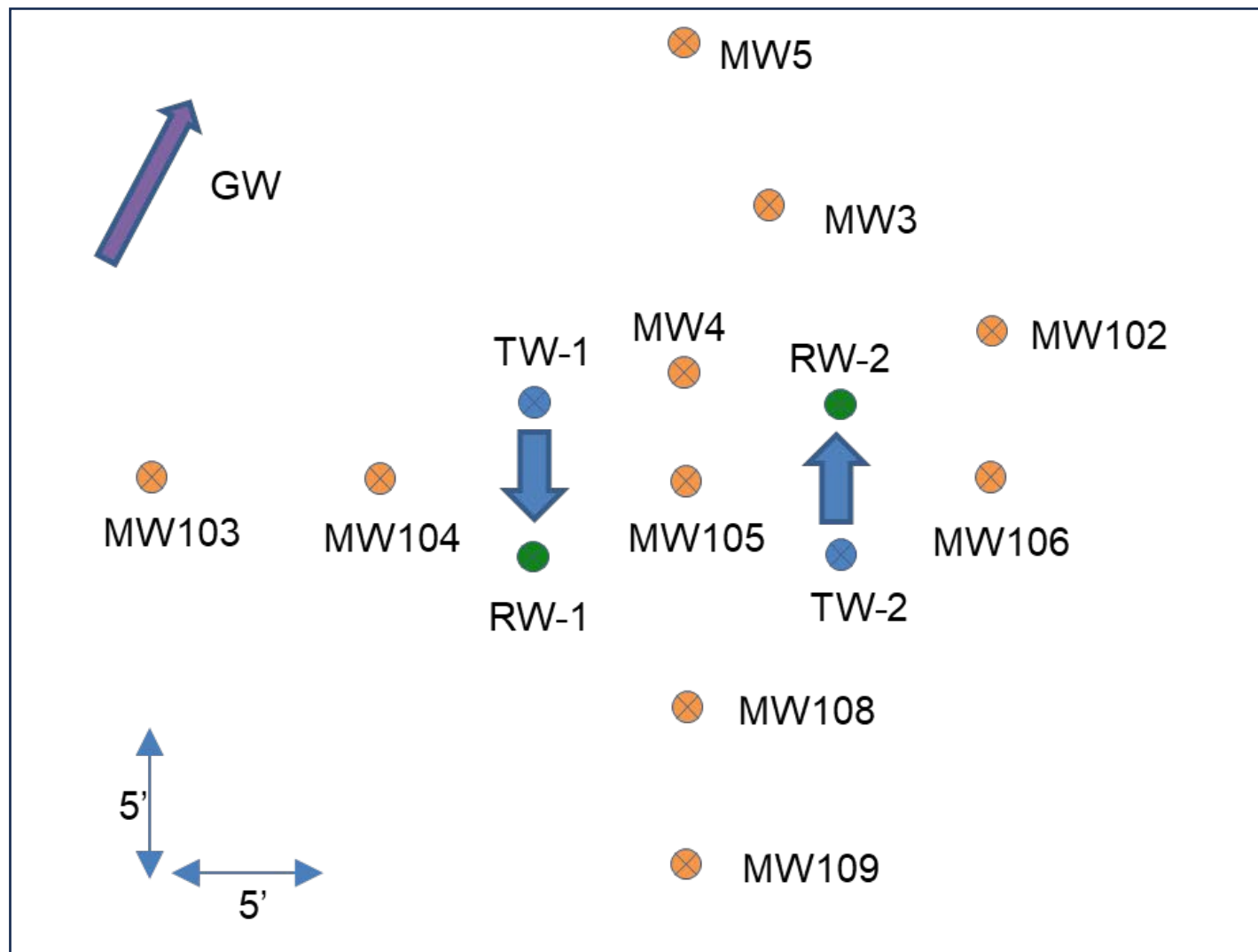
PFOS = 493,600 ng/L

(CH2M Hill 2018)

SWMU: solid waste management unit

TTA: target treatment area

System Infrastructure Layout



- Treatment Well (TW)
- Recirculation Well (RW)
- Monitoring Well (MW)
- ↑ Pumping Direction

(Reynolds 2022)

System Infrastructure Layout



(Nelson 2021)



(Nelson 2021)

Example of an In Situ Foam Fractionation System



During Extraction

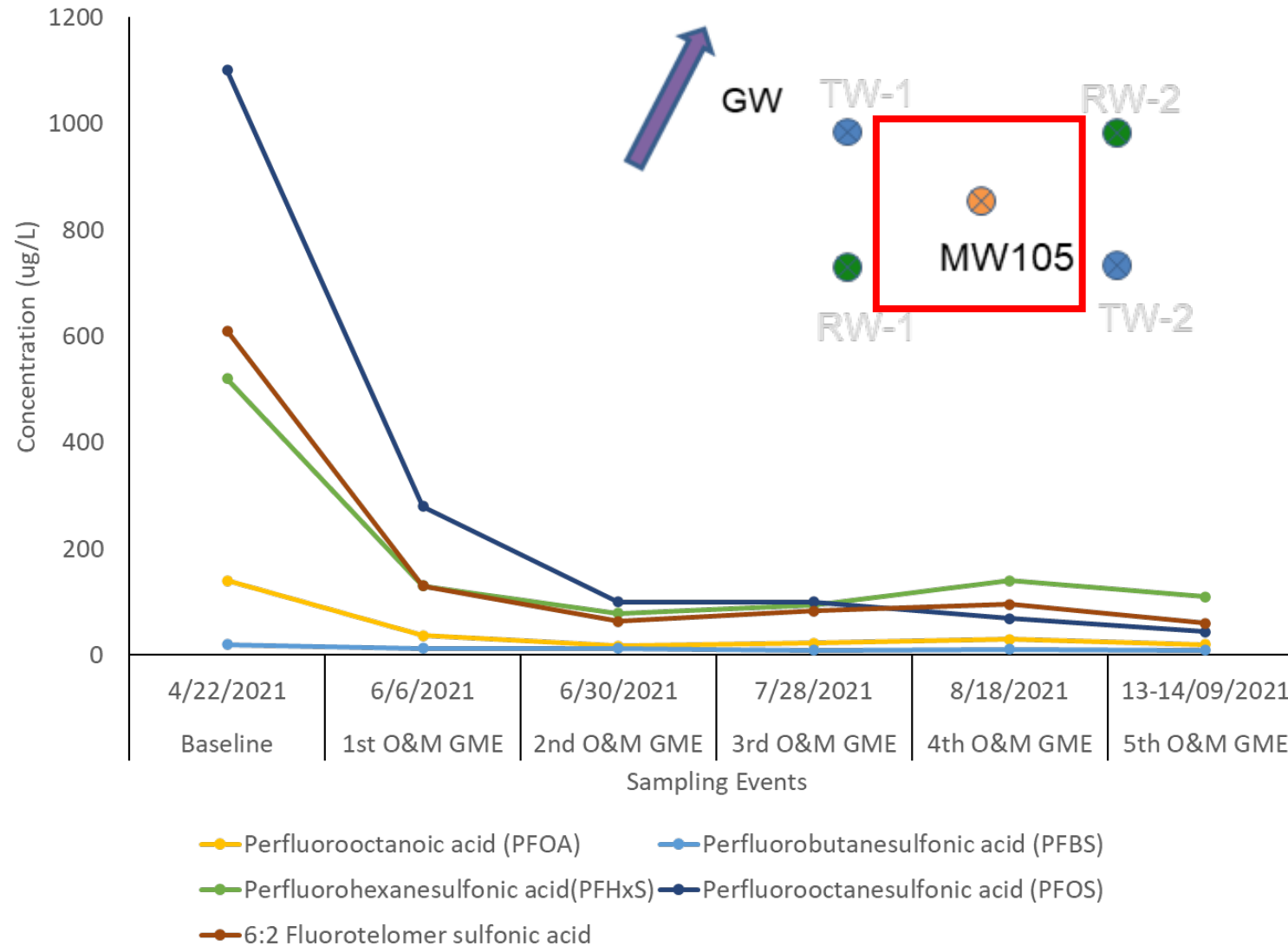


After Settling

Note: Foam collection tank should be in secondary containment and contents clearly labeled.

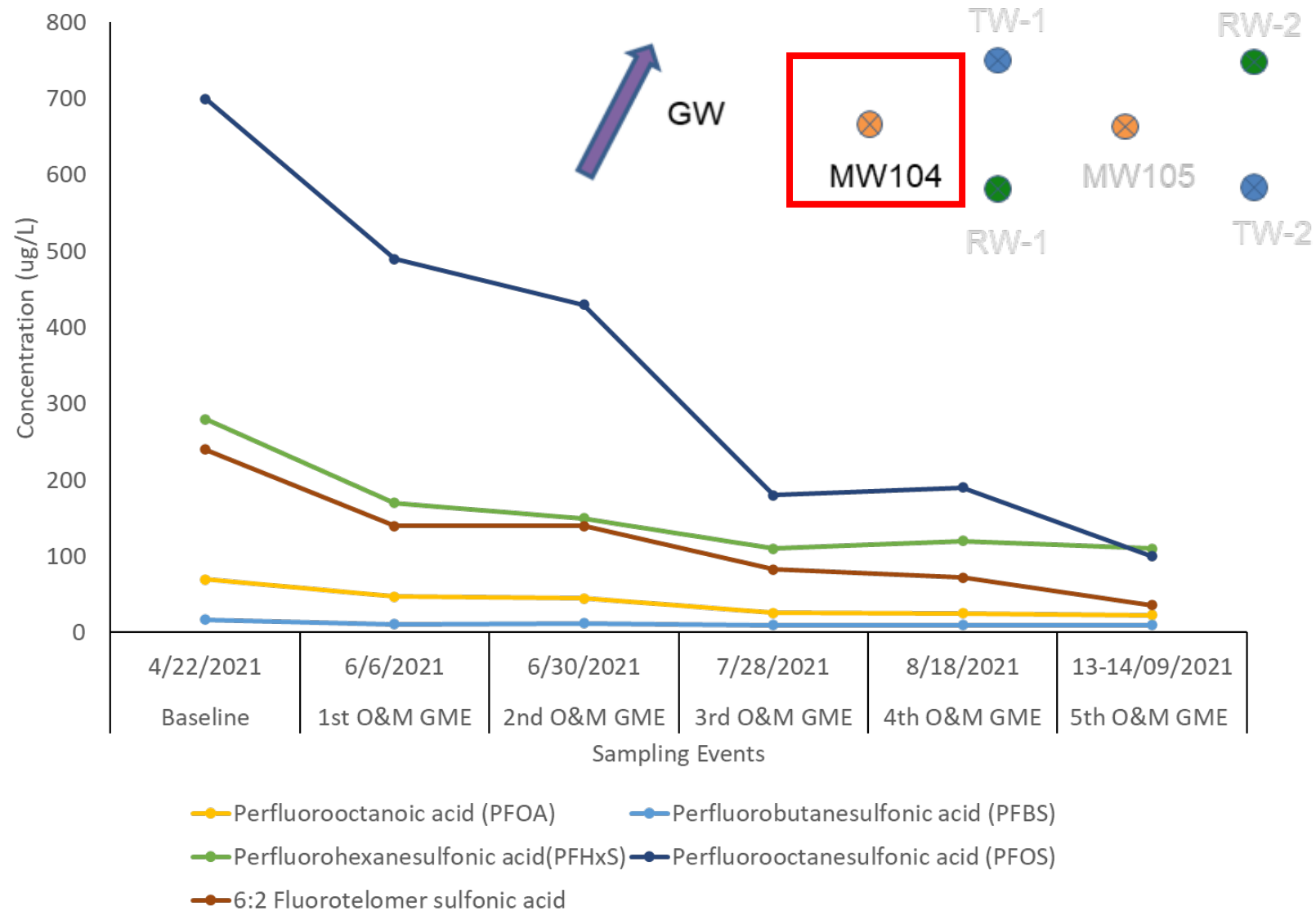
(Nelson 2021)

Results in Monitoring Wells Inside Target Treatment Zone



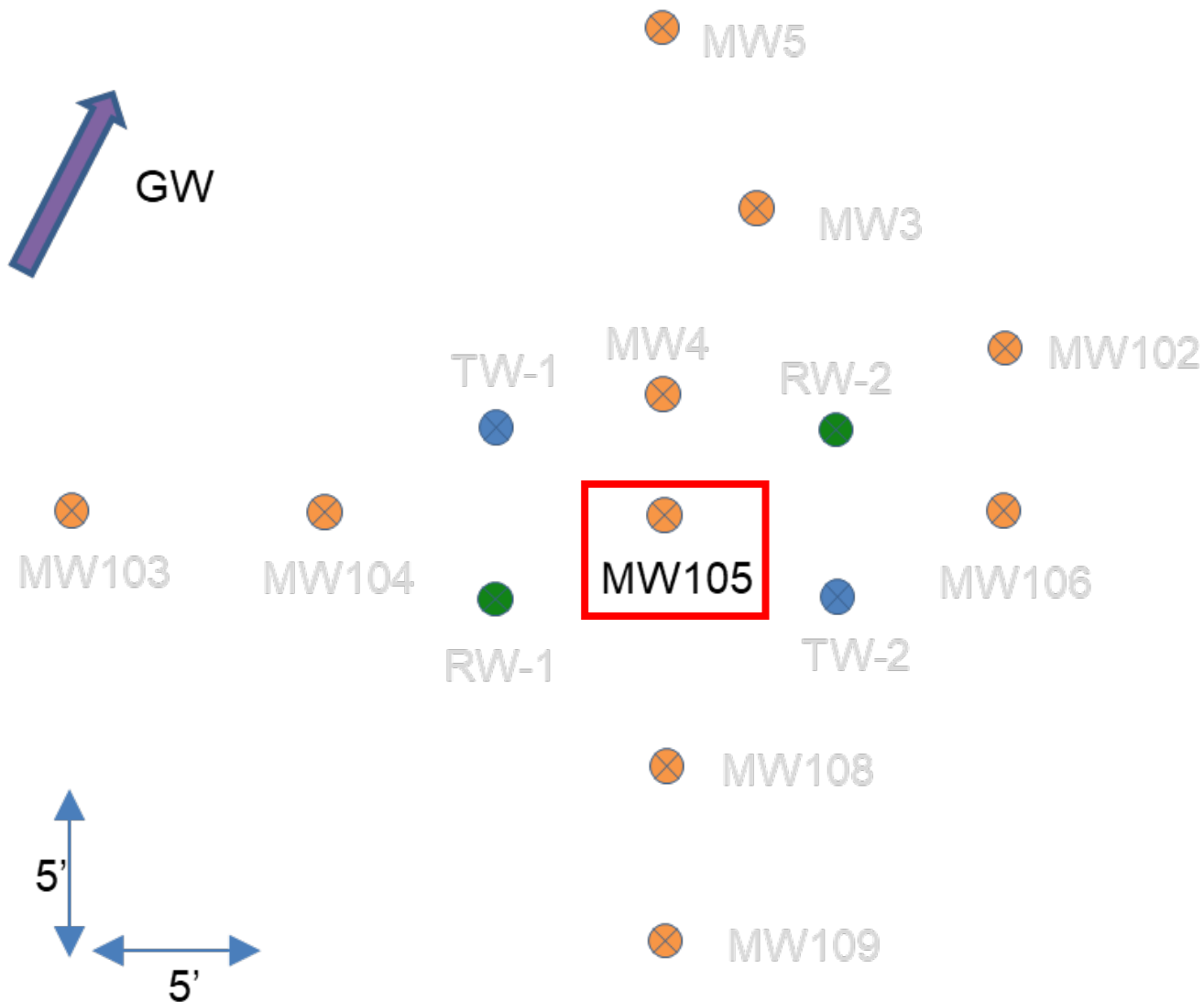
(Reynolds 2022)

Results in Monitoring Wells Outside of Target Treatment Zone



(Reynolds 2022)

Soil Results (Percent Reduction)



Depth (feet)	PFOS	PFOA	Sum PFAS
11 - 12	94	85	86
14 - 15	62	55	64
16 - 17	78	43	70

Percent Reduction in Water

PFOS = 96%

PFOA = 86%

(Reynolds 2022)

Soil Results (Percent Reduction)



Depth (feet)	PFOS	PFOA	Sum PFAS
11 - 12	74	80	71
14 - 15	82	82	81
16 - 17	78	33	69

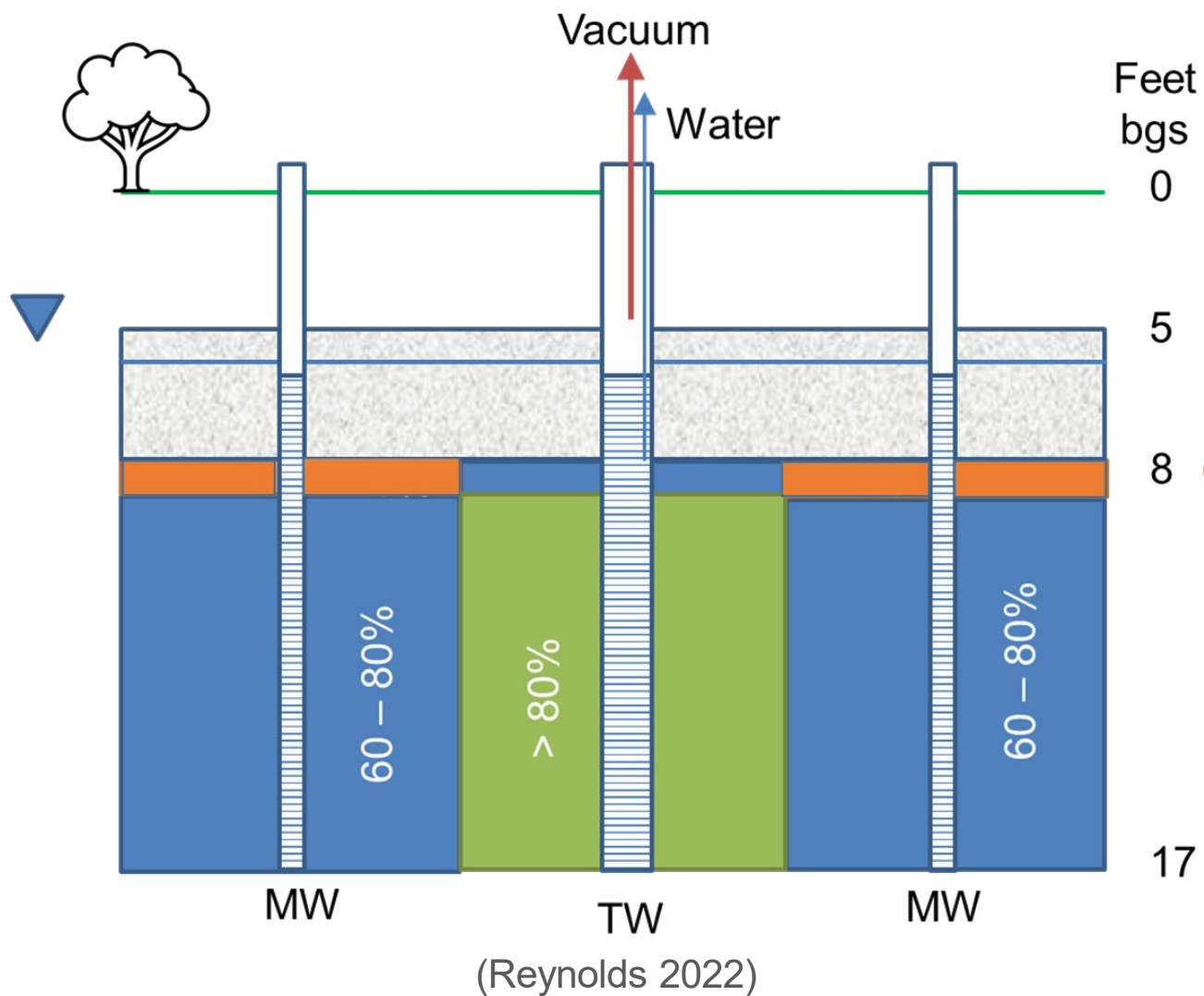
Percent Reduction in Water

PFOS = 86%

PFOA = 67%

(Reynolds 2022)

PFOS Reductions in Soil



(Reynolds 2022)

ISSF Performance Key Takeaways



- PFAS reductions in groundwater ranged from 79% to 96%
- PFAS reductions in soil decreased up to 94%
- System operating > 95% uptime by GME4
- Removed 107 grams of total PFAS in 12 weeks with 2 wells
- Potential to couple to PFAS condensate destruction technology
- Expanded pilot follow-on expected to start in the spring 2026 timeframe and run for approximately 4–5 months
- A reminder to please check with a SME!

Presentation Overview



- Introduction
- PFAS in the Subsurface: Properties and Treatment Challenges
- Regulatory Drivers, Guidance, and Policy
- Treatment
- Case Studies
- **Guidelines for Selecting Water Treatment Technologies**
- Summary/Key Takeaways

Selecting the Treatment Approach: Key Considerations



- Accurate Conceptual Site Model (PFAS nature and extent, soils, hydrology, etc.)
- Risk (beneficial use/ecological impacts)
 - Potential for **human health drinking water exposure** at levels creating **unacceptable risk** may require more aggressive approach (e.g. pump and treat)
 - In situ methods should be considered
- PFAS Concentration
 - **Low** PFAS concentration: water can be concentrated using **sorbents**, possibly foam fractionation; destructive methods require low volume/high concentration to be economically feasible
 - **High** PFAS concentrations may be appropriate for **foam fractionation** (since direct sorbent treatment could require frequent sorbent change-outs) with **sorbent** used for **polishing** treatment only
- Other Water Chemistry
 - **High TDS** precludes IX, narrowing sorbent choice to GAC, organoclay or cyclodextrin
 - Elevated **TOC/DOC**: pre-treatment, e.g. organoclay, can preserve capacity of main sorbent for PFAS
 - **Metals** such as dissolved iron and manganese can be removed via pre-treatment using aeration/precipitation, flocculation, to prevent clogging of sorbent
 - **High TSS** may require filtration; subsequent disposal of solids

TSS: total suspended solids

Selecting the Treatment Approach (cont'd)



- Destructive Treatment of Concentrates or Spent Sorbents
 - **Refer to DoW memorandum on PFAS Destruction**
 - **Incineration**
 - **GAC Reactivation**
 - On-site destruction vs off-site
 - Destructive methods in various stages of validation, commercialization, and/or permitting
 - Some sorbents can be regenerated (typically off-site) such as Dexsorb, GAC
- Disposal in Appropriate Landfills (Subtitle D, C)
- **Site Constraints/Logistics**
 - OCONUS sites could make sorbent disposal more costly due to lack of disposal options and transportation to and from CONUS
 - e.g. Calgon does not operate GAC reactivation furnaces outside of CONUS, Italy and Belgium, so transportation of spent GAC could be cost-prohibitive; incinerators may not be properly permitted outside of CONUS for destruction of PFAS-containing materials
 - Utilities availability
- Procurement
 - Increasing demand for sorbents; 10-week lead times in some cases
 - Other equipment, such as vessels, may become more difficult to obtain/costly
 - Municipalities and water suppliers may create high demand

Selecting the Treatment Approach: Treated Water Discharge



- Discharge/Reuse of Treated Water
 - Ex situ treatment often requires treated water to be treated as wastewater
 - Sanitary sewer may be acceptable (may need to comply with discharge requirements)
 - Land application (irrigation) requires approvals
 - Uncommon, but other possibilities: soil flushing, evaporation, groundwater recharge, etc.
- Long-term Monitoring
 - Rebound
 - Soil concentrations/desorption
 - Additional/future analytes and regulated compounds
 - Transformation products from non-target precursors that feed plumes

Selecting the Treatment Approach: Vendor Information



Vendors should have:

- Multiple, peer-reviewed case studies with verifiable data
- Case studies treating real-world matrices (e.g., on-site treatment, or site-collected material such as foam fractionate)
- Case studies should be validated by an independent third-party technical body such as ESTCP, DIU, ERDC, EXWC, etc.
- Commercial availability: Systems, including ancillary equipment, should be available from technology vendor with clear pricing/performance criteria
- Relationship between technology and TSDF and/or POTW
- Ability to provide permits for operation and final effluent discharge; payment contingent on successful treatment and disposition of all effluent and generated waste

Adapted from Arcadis 2025

Be Cautious

- Claims of “100% destruction”
- Case studies without third-party oversight (e.g., only “gray literature” articles)
- No verifiable third-party analytical
- Fluorine mass balance not provided
- Significant pre- or post-treatment is still required; is this only a “polishing” step, and will further treatment be needed?
- Disposal of waste stream(s) is still required; volume/mass? Subtitle C Landfill?
- Vendor will not divulge general technology employed, obfuscates with “proprietary” language
- No related published literature from universities regarding basic mechanisms (“black box”)

Adapted from Arcadis 2025

Selecting the Treatment Approach: Additional Considerations



- Is pretreatment required, what type? (e.g., sorbent treatment may use a “sacrificial” sorbent up-front to sorb high TOC/NOM, or TSS filtration)
- Is a high DRE (>99%) likely for the target waste stream? Consider performing treatability testing of representative samples
- Is treatment more practical/cost effective on-site or off-site?
- Off-site treatment may be favored for smaller projects (which are more typical)
- On-site treatment requires operators which often are unavailable or not programmed in budgets
- Some technologies may require significant site prep (e.g., power, water, footprint area, subbase)
- In situ treatment should be considered

Adapted from Arcadis 2025

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Key Takeaways



- Concentration/separation using sorbents is current “Go-To” approach; foam fractionation is up and coming
 - **GAC** is most common sorbent, especially bituminous F400, but **IX** can be more appropriate and effective for some applications, as can alternative sorbents such as Dexsorb (cyclodextrin) and FluoroSorb (modified clay)
 - Multiple sorbents in a **treatment train** may be appropriate (e.g. to first knock out high TOC/NOM)
 - **Treatability studies** can optimize technology selection, including sorbent type, and should be used when treatment is anticipated over long time periods or large volumes (i.e. where incremental differences in performance translate to large cost savings over time of treatment)
- **Foam fractionation** may be appropriate at some sites but a **polishing sorbent** is almost always necessary

Key Takeaways



- **Disposal and Destruction**

- **See ‘Updated Interim Guidance on Destruction or Disposal of Materials Containing Per- and Polyfluoroalkyl Substances’**

(https://www.acq.osd.mil/eie/eer/ecc/pfas/docs/policies/DoW_PFAS%20DD%20DetailedAnalysis_clear.pdf)

- **Effectively rescinds 2022 NDAA moratorium on Incineration:** Incineration permitted for RCRA waste and also contains PFAS materials (See Footnote 1 of Guidance). Also need to reach destruction temperature of 1,100 °C, and with proper permits

- **Destruction/Disposal Options Identified:** DoW has identified commercially available options to be used by the DoW Components (all must be appropriately permitted):

- Carbon Reactivation Units (for GAC only)
- Hazardous Waste Landfills
- Solid Waste Landfills (NOT for AFFF concentrate)
- Hazardous Waste Incinerators that meet specific temperature requirements
- Underground injection control wells (liquids only)
- Thermal desorption units that use off-gas collection and thermal oxidation (for soils)
- Other PFAS destruction technologies with Environmental permits or regulator acceptance

- Overall, **cost** will be a central factor and a **primary driver**

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- ESTCP ER23-8381: Surface Active Foam Fractionation® for PFAS Treatment.
- ESTCP ER23-8398: Destruction of PFAS Wastes with AirSCWO™ in a Centralized Destruction Approach.

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Additional Resources: NAVFAC OER2 Webinars



- **Lessons Learned from In Situ Per- and Polyfluoroalkyl Substances (PFAS) Sequestration (May 2026)**
 - This webinar will provide an overview of in situ sequestration approaches for PFAS, including commonly used amendments and application methods. Drawing from case studies, the webinar will highlight key lessons learned from implementing a range of PFAS sequestration strategies.
- **Understanding PFAS Leaching: Key Processes, Decision Frameworks and Management Strategies (May 2025)**
 - This OER2 webinar provides insights into PFAS leaching processes from soil to groundwater, along with practical tools to understand, assess, and manage PFAS leaching. It focuses on key processes, essential data requirements, and modeling techniques.
- **PFAS Remedial Investigation Sampling and Analysis Plan Case Studies (October 2024)**
 - This OER2 webinar provides insights into the development of per- and polyfluoroalkyl substances (PFAS) Remedial Investigation (RI) Sampling and Analysis Plan (SAPs).
- **Revised Interim General Guidelines for PFAS Remedial Investigations (RI) (December 2023)**
 - This OER2 webinar series is a two-part presentation on general guidelines that the Navy has updated for PFAS RIs. Part 1 of this presentation focuses on the document overview and discusses site characterization, analytical methodologies, screening/cleanup levels, risk assessments, and investigative-derived waste (IDW) management for PFAS RIs.

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Questions



Applying PFAS Forensics to Complex, Multi-Source Sites

Dora Chiang, Ph.D., P.E.
Jacobs

RITS 2026

Disclaimer



This seminar is intended to be informational and does not indicate endorsement of a particular product or technology by the Department of War or NAVFAC EXWC, nor should the presentation be construed as reflecting the official policy or position of any of those agencies. Mention of specific product names, vendors, or sources of information, trademarks, or manufacturers is for informational purposes only and does not constitute an endorsement or recommendation by the Department of War or NAVFAC EXWC. Although every attempt is made to provide reliable and accurate information, there is no warranty or representation as to the accuracy, adequacy, efficiency, or applicability of any product or technology discussed or mentioned during the seminar, including the suitability of any product or technology for a particular purpose.

Information in this presentation is current as of May 14, 2026.

EXWC: Engineering and Expeditionary Warfare Center
NAVFAC: Naval Facilities Engineering Systems Command

Speaker Introduction



Dora Chiang Ph.D., P.E.



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- M.S., Environmental Engineering, Illinois Institute of Technology, Chicago, Illinois, USA
- M.S., Chemistry, Chung Yuan University, ChungLi, Taiwan
- B.S., Chemistry, Chung Yuan University, ChungLi Taiwan
- 25 years in site investigation and remediation
- Practice leader of PFAS and emerging contaminants at multiple engineering consulting firms
- Global principal of PFAS and emerging contaminants at Jacobs since 2024
- Technical director of Jacobs PFAS Forensics Toolset – Pfluorensic
- Principal investigator of PFAS destruction technologies (EO, SCWO, enzyme)
- Co-editor of PFAS Treatment Technologies Book

EO: Electrochemical Oxidation

PFAS: per- and polyfluoroalkyl substances

SCWO: Supercritical Water Oxidation

Past RITS Trainings



- Related Past RITS Presentations
 - FY2025 RITS: [Contextualizing PFAS Detections: Background and Forensics](#) (Jeff Gamlin/GSI Environmental)
 - FY2024 RITS: [Applications of Multivariate Analysis \(MVA\) for Environmental Restoration Sites](#) (Loren Lund/Jacobs)

FY: fiscal year

RITS: Remediation Innovation Technology Seminar

Presentation Overview



- Introduction

- Refresh on Chemistry, Sources, Fate, and Transport
- PFAS in Ambient Environment (Background Study)
- Targeted PFAS Forensics Study Design and Case Study
- DoW-funded PFAS Source Databases
- Key Takeaways

Fingerprinting versus Forensics

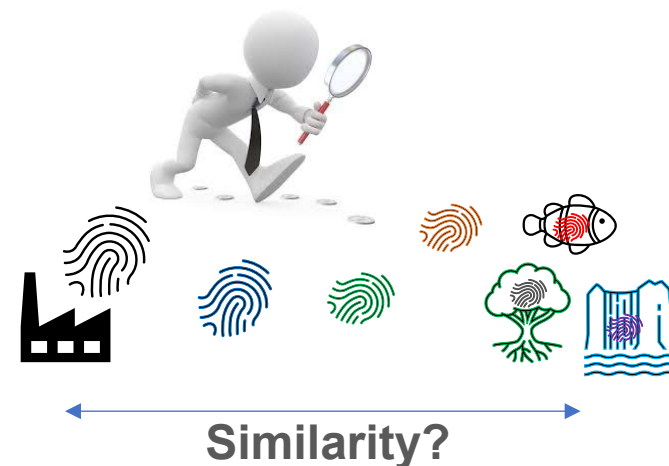
- Fingerprinting

- Primarily used for source identification based on unique chemical signatures
- Useful in verifying identities, linking a chemical to an object, a source, a scene, or eliminate suspects
- Focus solely on fingerprint evidence



- Forensics

- Used to reconstruct events (e.g., CSM), determine causes or sources, and support legal decisions
- Goals are to find truths, attribution, causation, and evidence validation
- A broader field that can involve chemistry, biology, geology, engineering, data science, toxicology, etc.



CSM: conceptual site model

Applications of PFAS Forensics



- PFAS forensics may be considered when:
 - Multiple onsite sources are detected, some with unknown nature and source
 - Background study confirms offsite PFAS sources; can help differentiate background vs. onsite sources
 - Characterization of precursors will assist to identify their source, migration pathways, and transformation
- **PFAS forensic study should start with assessing target PFAS data (EPA Method 1633) first**

KEY POINT

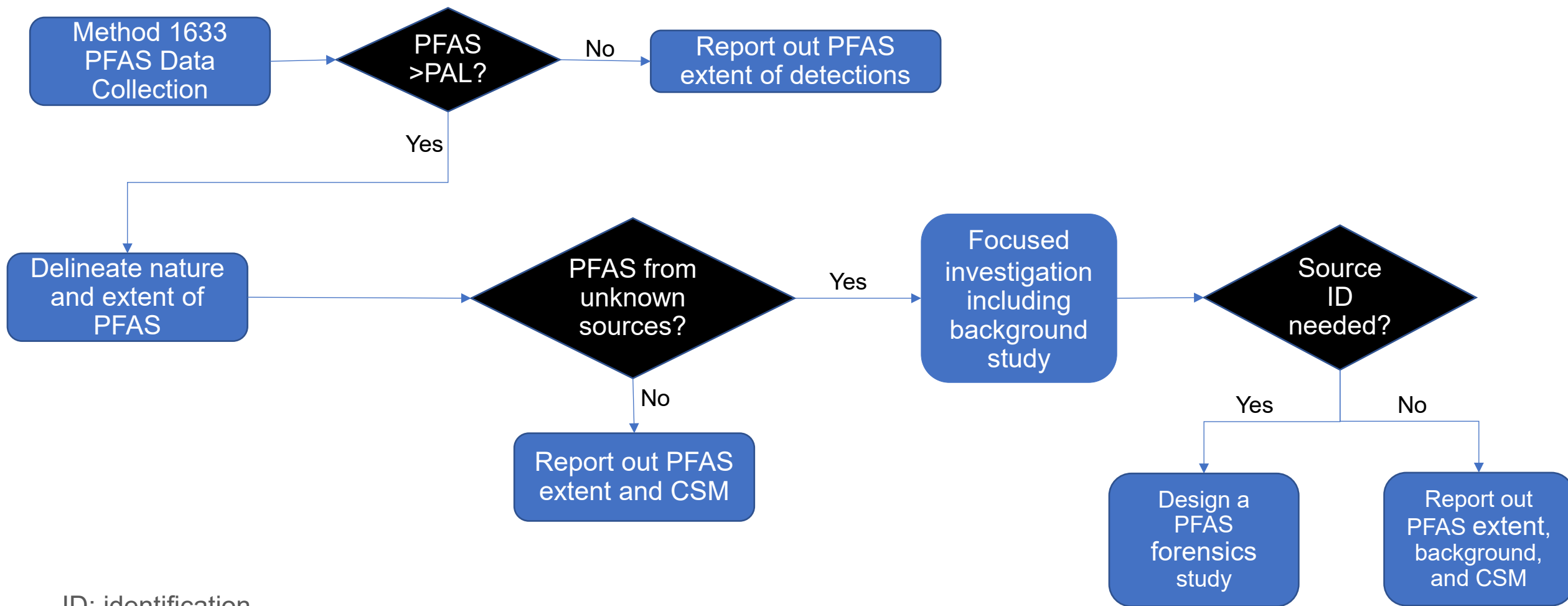
PFAS forensics can be considered in limited site-specific cases. The need must be clearly identified, method selection understood, data quality objectives clearly articulated, and line-of-evidence approach used in accordance with applicable DoW Policy* and in coordination with regulatory partners.

Benefits of PFAS Forensics



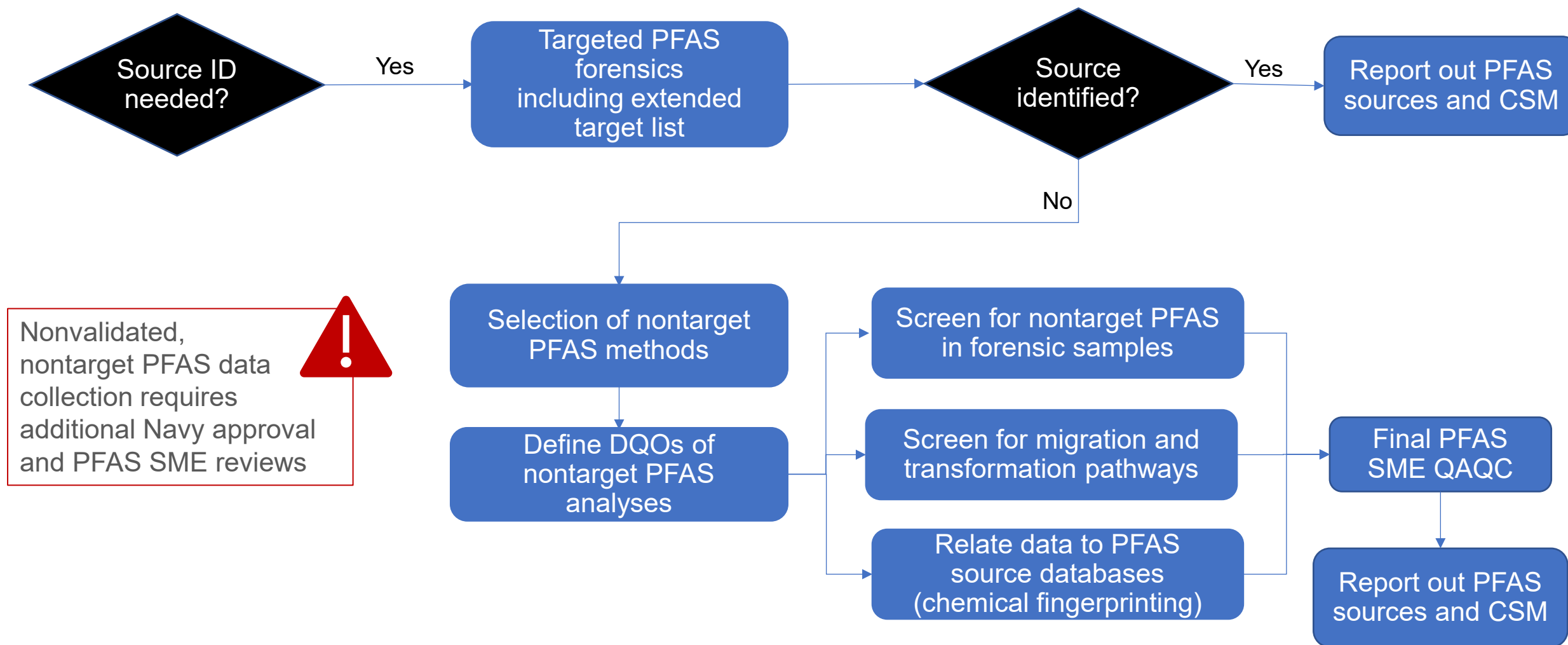
- Refine CSM when the site is impacted by multiple, onsite, and offsite PFAS sources
- Support PFAS background assessment
- Optimize more PFAS management efforts knowing from where the sources originate
- Improve risk assessment and communications
- Better protect human health and reduced exposure pathways

PFAS Investigation – Example Workflow



ID: identification
PAL: project action level

Advanced Forensics (Only Limited Cases Would Apply)



DQO: data quality objective
Navy: Department of the Navy

QAQC: quality assurance quality control
SME: Subject Matter Expert

Presentation Objectives



- Differentiate sources vs. background data
- Design and conduct targeted PFAS forensic study using Method 1633 PFAS data only
- Be familiar with PFAS data analytic techniques (e.g., cluster analysis) for forensic study assessment

Presentation Overview

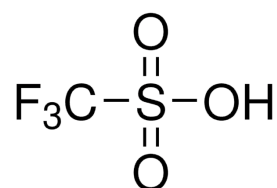


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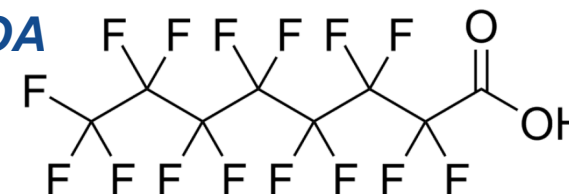
Complexity of PFAS Chemistry

Carbon No.	1	2	3	4	5	6	7	8	9	10	11	12
PFCAs	Ultrashort			Short-Chain				Long-Chain				
			PFPPrA	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFUnA	PFDoA
PFSAs	Ultrashort			Short-Chain		Long-Chain						
	TFMS	PFEtS	PFPPrS	PFBS	PFPeS	PFHxS	PFHpS	PFOS	PFNS	PFDS	PFUnS	PFDoS

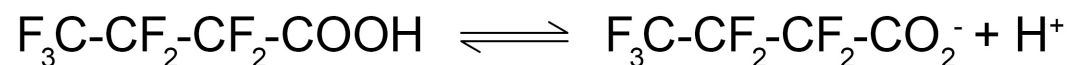
TFMS



PFOA



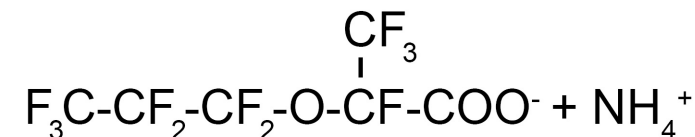
- **PFAS** can contain negative (anionic), positive (cationic), or both charges (zwitterionic)



Perfluorobutanoic acid

Perfluorobutanoate (+ dissociated proton)

- **PFAA replacements** such as GenX chemicals



GenX Ammonium Salt

PFAA: perfluoroalkyl acid

PFOA: perfluorooctanoic acid

PFSA: perfluoroalkyl sulfonic acid

PFCA: perfluoroalkyl carboxylic acid

PFOS: perfluorooctanesulfonic acid

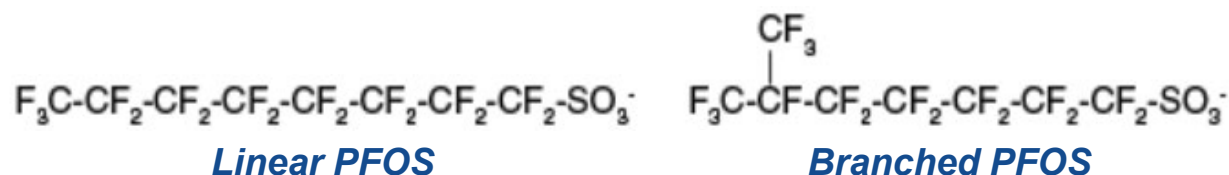
TFMS: trifluoromethanesulfonic acid

Complexity of PFAS Chemistry



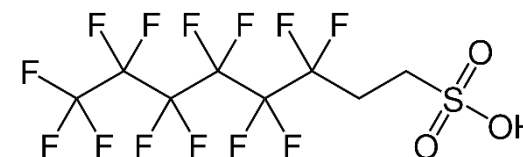
Linear and branched isomers of PFAS

- Example



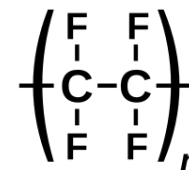
PFAA Precursors

- Example: 6:2 fluorotelomer sulfonic acid



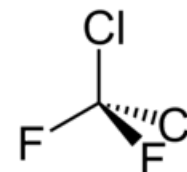
Polymeric PFAS

- Example: Polytetrafluoroethylene (PTFE)



HFCs: Hydrofluorine carbons

- Example: Dichlorodifluoromethane



Considerations of PFAS Detections



- PFAS detection limits are getting sensitive for solids and liquids
- Low concentration detections should be put into perspective with regard to uncertainty interpretation (e.g., false positives, laboratory contamination, etc.)
- When PFAS concentrations are higher, PFAS interpretation for forensics is more certain
- When PFAS concentrations are lower near PQLs, forensic evaluation must keep uncertainty and more scrutiny in mind
- Certain PFAS such as TFA (outside of EPA PFAS definition) can be found in almost any laboratory, and thus low levels should be expected even in laboratory and field blanks; additional considerations are needed for forensic evaluation

PQL: Practical Quantitation Level

TFA: trifluoroacetic acid



Knowledge Check



True or False?

All precursors are considered “poly-fluoroalkyl substances”

True or False?

False. PFAS precursors are those PFAS which can be transformed into terminal PFAAs (PFCAs and PFSAs). Polyfluorinated compounds contain carbons that are not fully fluorinated like FTS, there is great chance that they are precursors. However, not all polyfluorinated compounds are biotically or abiotically transformable. On the other hand, for perfluorinated compounds, although the carbon backbone (the tail) is fully fluorinated, the “head” of PFAS structures can contain functional groups that are transformable.

PFAS Potential Related Sources



Oil and Gas Extraction	Mining	Sewage Treatment Facilities	Textile Mills
Textile Product Mills	Leather and Allied Product Manufacturing	Paper Manufacturing	Printing and Related Support
Petroleum and Coal Products Manufacturing	Chemical Manufacturing	Plastics and Rubber Products Manufacturing	Carpet/Flooring/Building Material Manufacturing
Primary Metal Manufacturing	Fabricated Metal Product Manufacturing	Machinery Manufacturing	Computer and Electronic Product Manufacturing
Electrical Equipment	Appliance and Component Manufacturing	Petroleum and Bulk Terminals	Surgical and Medical Instrument Manufacturing
Airports, Port, and Harbor Operations	Carpet and Upholstery Cleaning	Rail and Truck Transportation	Waste Management
Car Wash, Furniture Repair	Dry Cleaner and Laundry Operators	Fire Protection	National Security

(EPA 2024)

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PFAS Background Study



- RITS 2025: Contextualizing PFAS Detections: Background and Forensics, Jeff Gamlin, GSI Environmental
 - Excerpt from Memorandum on Background PFAS (September 3, 2024)

Long-Term Remedial Actions

CERCLA requires a site-specific risk assessment during the remedial investigation to establish risk-based cleanup levels. This includes considerations of “background” levels of chemicals present at a site, which can be highly variable across the country. Throughout the CERCLA process DoD coordinates with both EPA and state regulators and EPA and DoD jointly select remedies at National Priorities List sites. Accordingly, DoD will work with EPA and state regulators, as appropriate, to evaluate background levels of PFAS on a site-specific basis to determine a final cleanup level.

For remedial actions, the DoD Components will address drinking water down to the MCLs or background, in accordance with CERCLA, once the DoD Component has established levels of PFAS are below the MCLs, then DoD Components will take remedial actions to address PFAS that will meet the MCLs as the final cleanup levels.⁶ If background levels of PFAS are found above an MCL at a site, DoD Components will work collaboratively with regulators and transparently with the public to determine the appropriate remedial goals (i.e., final cleanup levels) at that site.

(DoD 2024)

CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act of 1980

DoD: U.S. Department of Defense

MCL: maximum contaminant level

Statewide PFAS Background Studies



- PFAS background data available for assessment continue to expand
- UCMR data are not included in the tables
- Background samples can be collected by state agencies, consultants, universities and samples were analyzed using different methods for different sets of PFAS analytes

State	Sample Matrix	Analytical Methods or Analytes	Reference
EPA	Water, tissue, air, soil, sediment	Target PFAS	PFAS Analytic Tools (EPA n.d.)
AL	Surface water	17 PFAS	Viticoski et al. 2022
CA	DW, SW	533, 537, 537.1, 1633, AOF	California GeoTracker PFAS Map (SWRCB n.d.)
CO	GW, SW, soil sediment	533, 537.1, 1633	Colorado PFAS Concentration Map (CDPHE 2026)
FL	SW	50 PFAS	Camacho et al. 2024
GA	SW, DW	Target PFAS	Georgia PFAS Story Map (GEPD 2026)
MA	SW, fish	533, 537, 537.1, 1633	ERG 2023

AOF: adsorbable organic fluorine
DW: drinking water
GW: groundwater

SW: surface water
UCMR: Unregulated Contaminant Monitoring Rule

Statewide PFAS Background Studies



State	Sample Matrix	Analytical Methods or Analytes	Reference
ME	GW, DW, SW, WW, biosolids, sludge, soil	533, 537, 537.1, 1633	Maine DEP PFAS Investigation (Maine DEP n.d.)
MI	WWTP, residuals, ambient air,	Target PFAS	EGLE 2025; Woodward et al. 2025
MN	GW, SW, Air, Soil	Target PFAS	MPCA 2025
NC	WWTP, biosolids	537.1 modified for 57 PFAS	NCDEQ 2025
NJ*	Soil, SW	1633	NJDEP 2025; Goodrow et al. 2020
NY	Soil	1633	AECOM 2025
PA	SW	1633	Breitmeyer 2023
VA	SW, fish, sediment	533, 537.1, 1633	VDEQ PFAS Dashboard (2025)
VT	Soil	Target PFAS	Zhu et al. 2022
WA	Biosolids	1633, TOPA, EOF, NTA	Ecology 2025
WI	DW, SW, fish, GW	Target PFAS	WI PFAS Interactive Data Viewer (DNR n.d.); Silver et al. 2023

EOF: extractable organic fluorine

NTA: non-target analysis

TOPA: Total Oxidizable Precursor Assay

WW: wastewater

WWTP: wastewater treatment plant

*Ambient study

PFAS Background Study – Literature Review

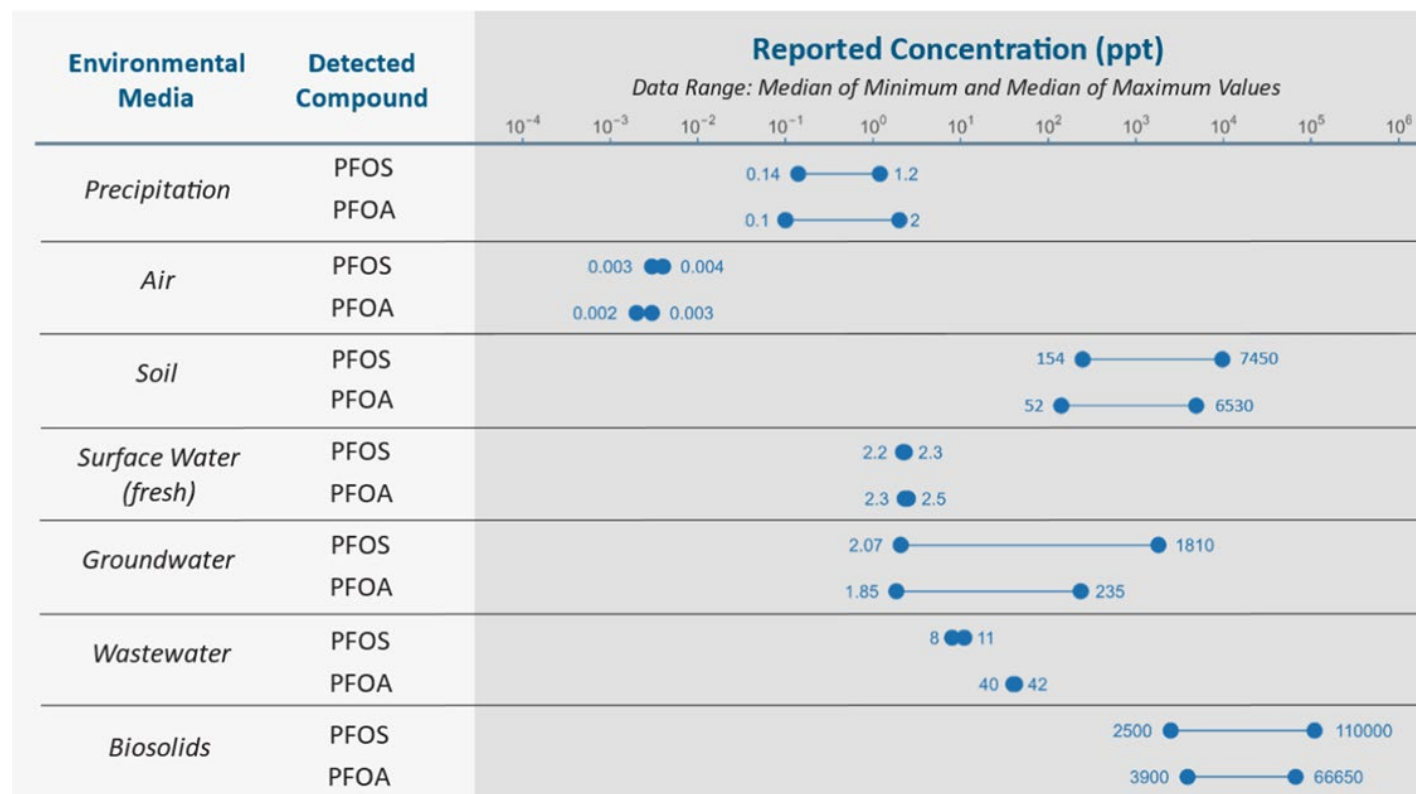


KEY POINT

Published background study data quality may vary.

- PFAS background levels have been reported
 - Precipitation
 - Soils
 - Groundwater
 - Wastewater
 - Biosolids
 - Surface water
- Be aware of data quality
 - Data may be collected before EPA Method 1633 is finalized (January 2024)
 - Data may be collected without considering PFAS cross-contamination (e.g., groundwater monitoring well construction)

Comparison of PFAS Occurrence and Concentration Data by Media Based on U.S. Datasets Only



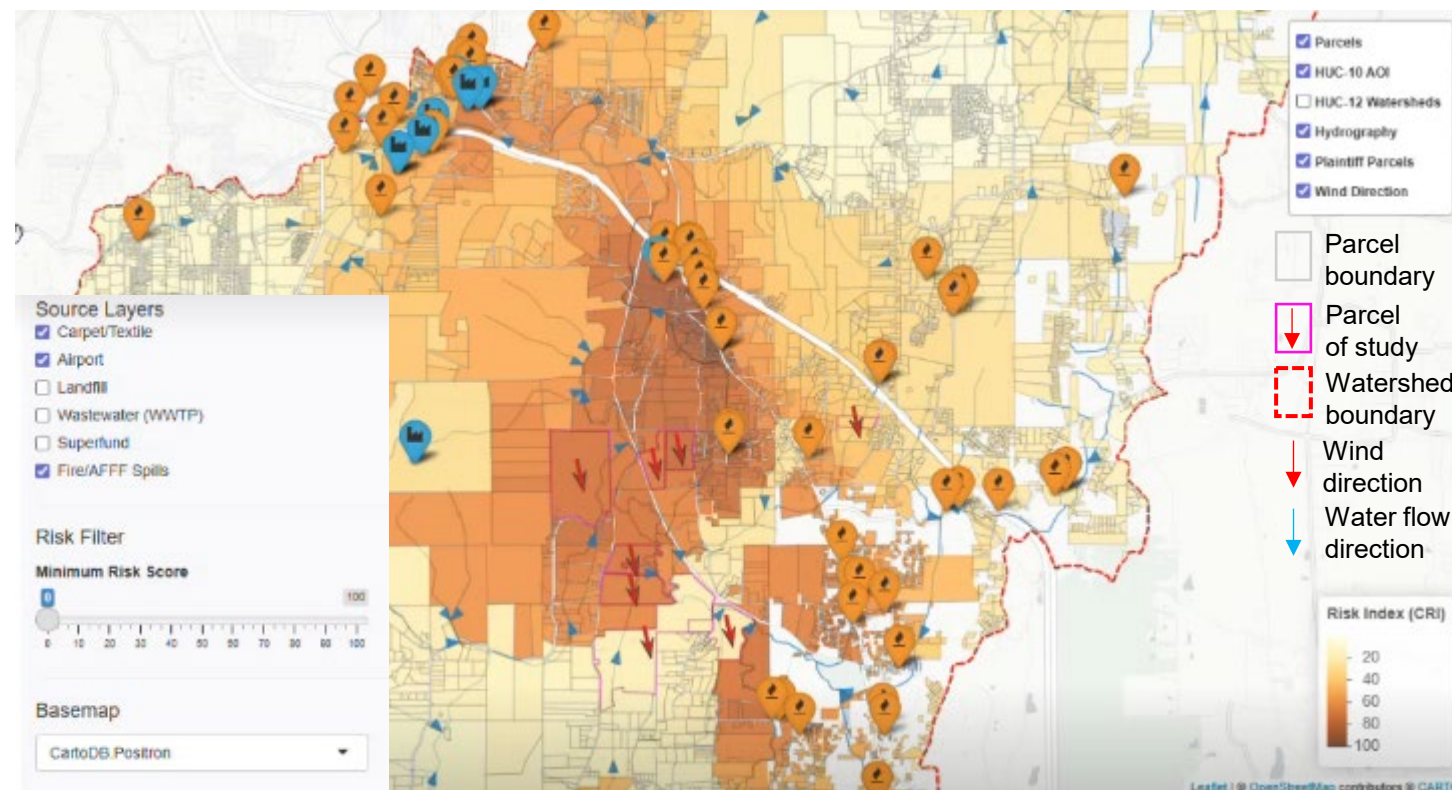
ppt: part(s) per trillion

(Adamson et al. 2026)

Environmental Due Diligence Prior to Background Study

- Environmental due diligence can be conducted prior to background sample collection
- Assess potential PFAS impact in the background study area without PFAS data collection
- Record search
 - Environmental database report
 - Land uses
 - Regional wind and water flow directions
 - State-level compost and biosolid land application records
 - And more

Non-DoW Example of PFAS Risk Mapping to guide selection of background sampling locations



(Conceptual PFAS background risk mapping modeled by Jacobs)

Knowledge Check



True or False? And Why?

PFAS background levels in soil, groundwater, surface water, and biota will change with time

Knowledge Check



True or False? And Why?

PFAS background levels in soil, groundwater, surface water, and biota will change with time

Yes. Legacy PFAS have been phased out or replaced, but their changes may be slow, complex (e.g., precursor transformation, and media-dependent). Modern PFAS can appear to increase. Site cleanups can help reduce background levels. Even the background level decreased, it does not mean the site cleanup needs to be repeated.

Presentation Overview



- Introduction
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- Key Takeaways

Ask and Answer These Questions Before Considering PFAS Forensics Study



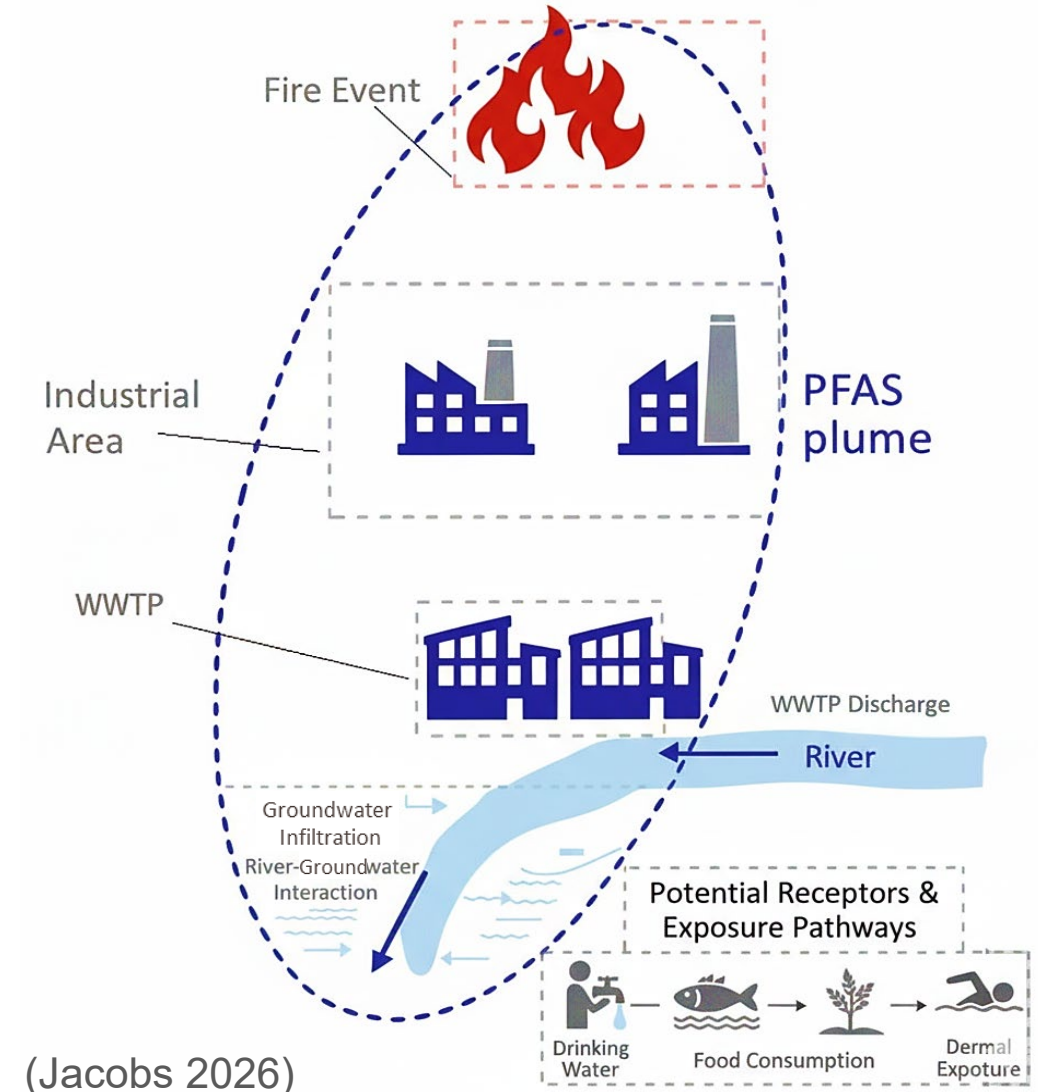
KEY POINT

Not all PFAS sites need PFAS forensic study.

Decision Point	Yes/No	Descriptions
PFAS>PALs?	Yes	PALs were exceeded
PFAS are likely from unknown onsite and offsite sources?	Yes	• Multiple know and unknown sources onsite • Target precursors detected from sources with potential to transform into regulated PFAAs • Environmental data reports suggested potential offsite sources • Target PFAS detected exceeding PALs from unknown background and onsite locations
Are source identification needed for clarity of CSM and for appropriate remedial goals?	Yes	• Suggest to conduct a targeted PFAS forensic study • Navy PFAS SME should be involved for targeted PFAS forensics design and implementation

Targeted PFAS Forensics – Non-DoW Case Study

- Pre-1990 Fire Event
 - Large storage facility fire in late 1980s
 - Firefighting foams used for suppression
 - Site remained inactive for several years afterward
- Industrial Manufacturing Area
 - Textile and paper-coating operations since 1970s
 - Produce treated materials for consumer/commercial use
- WWTP
 - Operating since 1980s to manage industrial wastewater
 - Continues to treat influent from facility



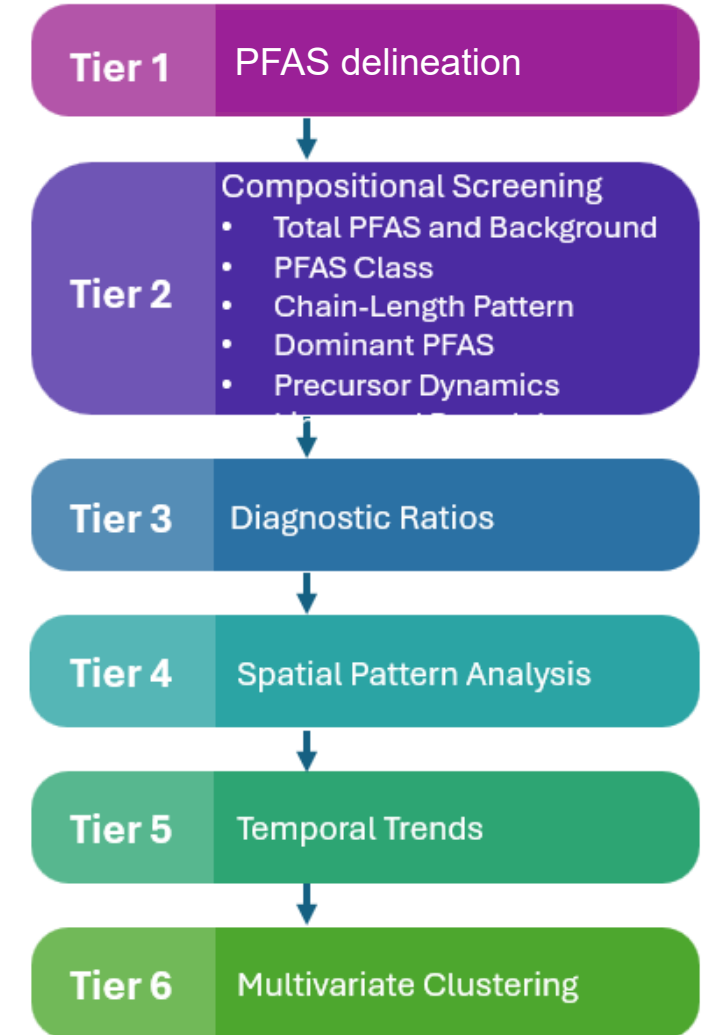
Targeted PFAS Forensics



KEY POINT

PFAS forensics study is site specific. DoW guidance and policy need to be followed for investigating DoW PFAS sites.

- Only target PFAS data are used for targeted PFAS forensics
 - Method 1633
 - Target analytes may vary due to addition of other analytes (e.g., TFSI, PFPrA and additional precursors), extended target analytes can be considered in selected samples assisting in “Targeted PFAS Forensics” when such need is identified on a site-specific basis.
- Analytic techniques used in targeted PFAS forensics should be well documented and are communicated with federal and state agencies



PFPrA: Perfluoropropanoic acid

TFSI: Trifluoromethanesulfonimide

(Zenobio et al. 2026)

PFAS Compositional Screening

- Multiple approaches on PFAS composition evaluation; Pie charts are used in this case study
- Pie sizes
 - Total PFAS concentrations
- Pie slide colors
 - PFAS class-level composition
 - Chain-length composition
- Pie sizes and colors
 - Precursor dynamics



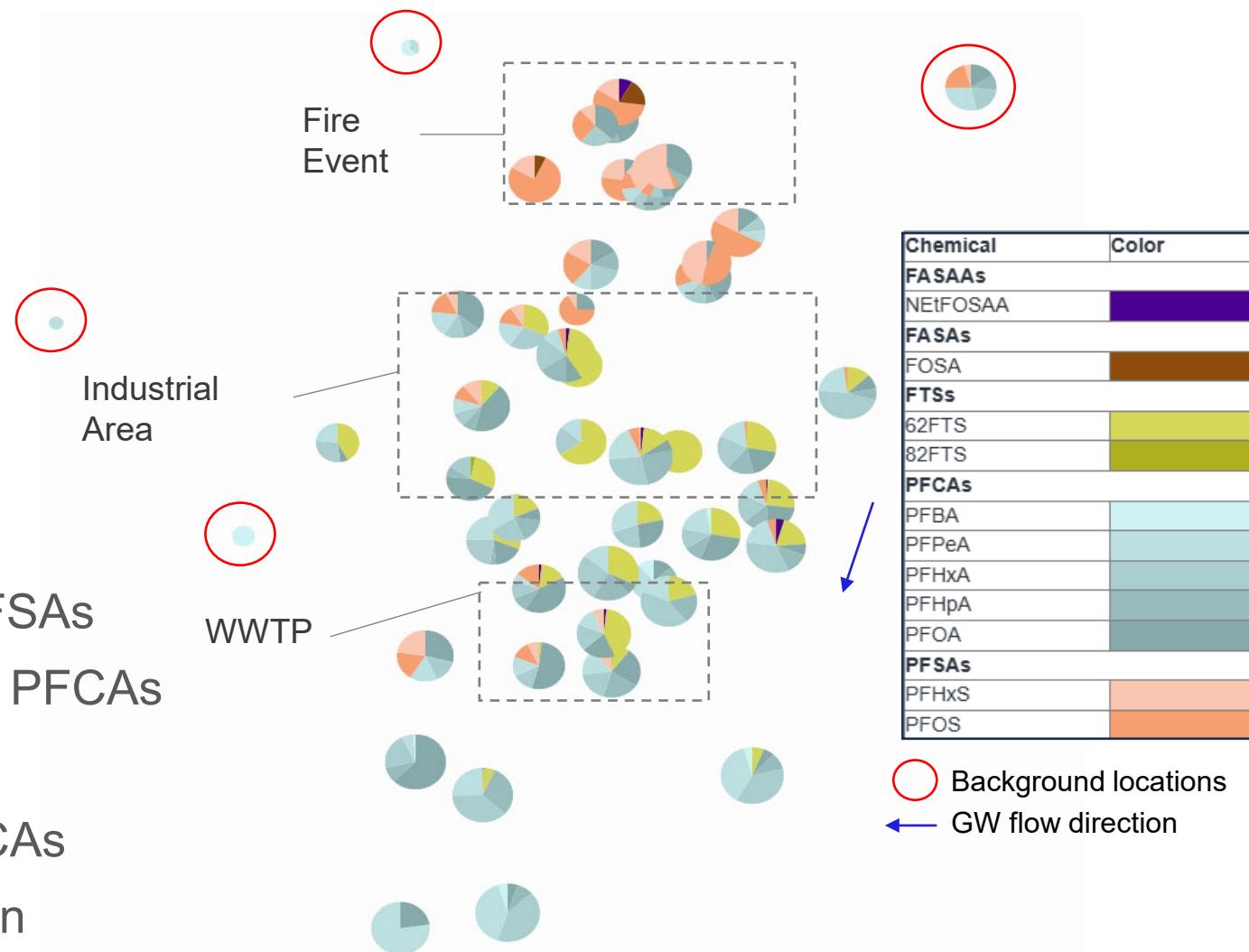
Pie slide color groups: PFAS subclasses
Darker colors: Longer chain PFAS
Lighter colors: Shorter chain PFAS

Chemical	Color
FASAAs	
NEtFOSAA	Dark Purple
FASAs	
FOSA	Dark Brown
FTSs	
62FTS	Yellow-Green
82FTS	Green
PFCAs	
PFBA	Light Blue
PFPeA	Teal
PFHxA	Dark Teal
PFHpA	Dark Teal
PFOA	Dark Teal
PFSAs	
PFHxS	Light Orange
PFOS	Orange

(Jacobs 2026)

PFAS Compositional Screening

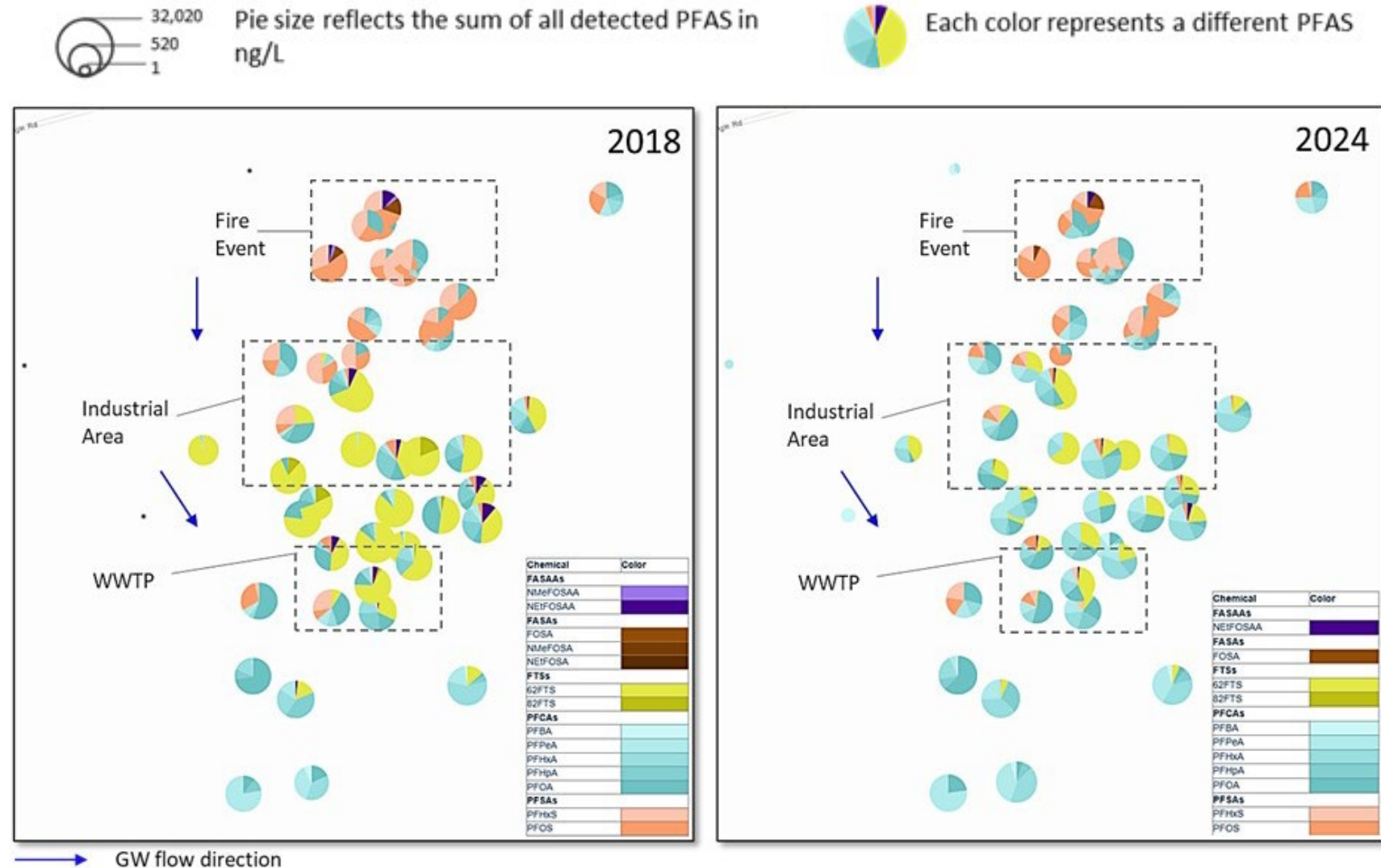
- Most PFAS detections exceeded PALs
- Background locations exhibit low PFAS concentrations and dominant by PFCA only, except one exhibits PFAS composition similar to fire event area
- Multiple onsite sources:
 - High FTS and PFCA compositions in the industrial area
 - FTS and PFCA also dominant in the WWTP area with some locations with PFSA
 - Downgradient locations are dominant by PFCAs
- Data gaps
 - FTS biotransformation potential into PFCAs
 - Statistical similarities/differences between background vs. source areas



(Jacobs 2026)

Temporal Trends

- Notable PFAS composition changes from 2018 to 2024 in the industrial and WWTP areas
 - FTS conversion into PFCAs
- No significant changes on total PFAS concentrations
- Total PFAS in some background wells have increased

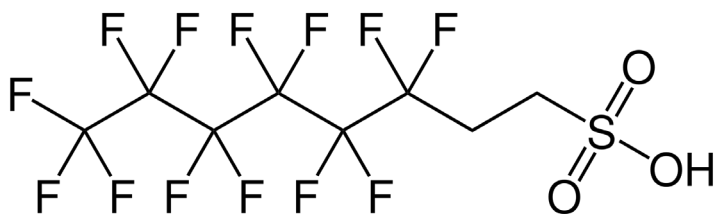


ng/L: nanogram(s) per liter

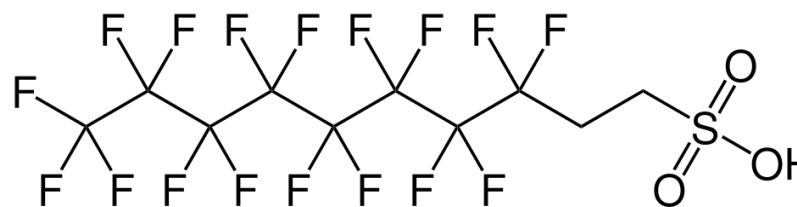
(Jacobs 2026)

Precursor Transformation Dynamics

- Multiple precursors were detected
- Dominant precursors were 6:2 FTS and 8:2 FTS



6:2 FTS

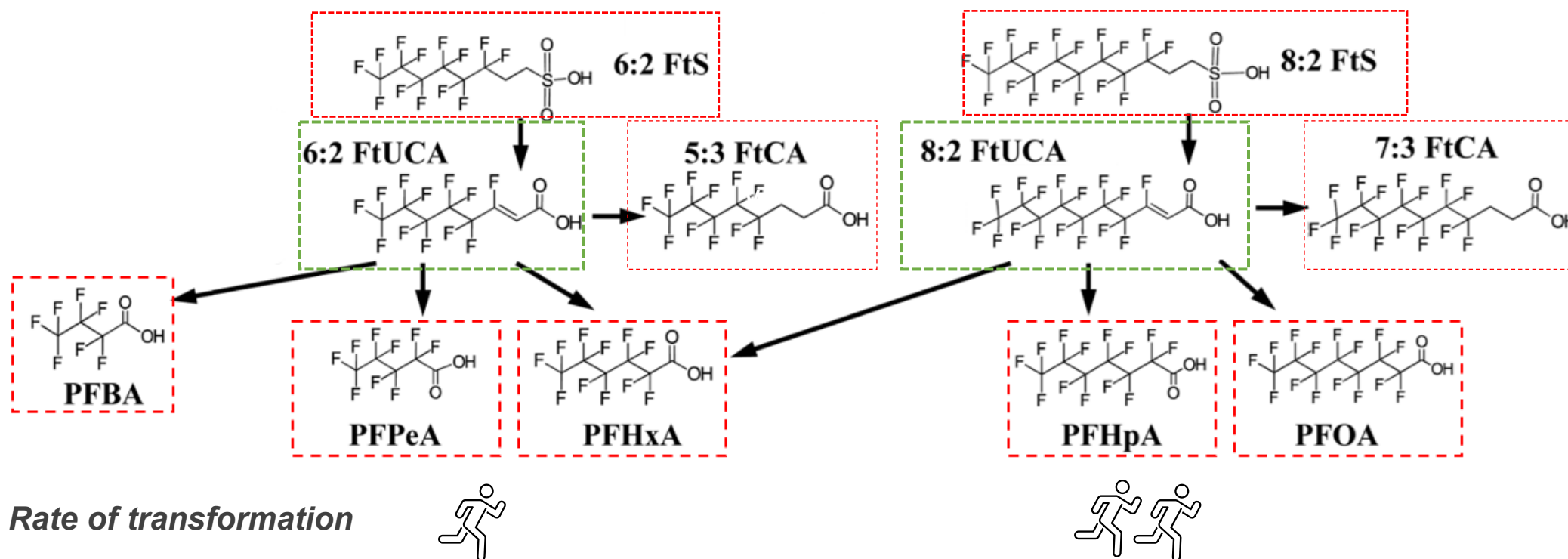


8:2 FTS

- Apparent precursor transformation patterns in industrial and WWTP areas were observed
- Without temporal datasets, forensics and source differentiation can be misleading

Precursor Dynamics

Pathway identified for 6:2 FTS and 8:2 FTS using the biotransformation library

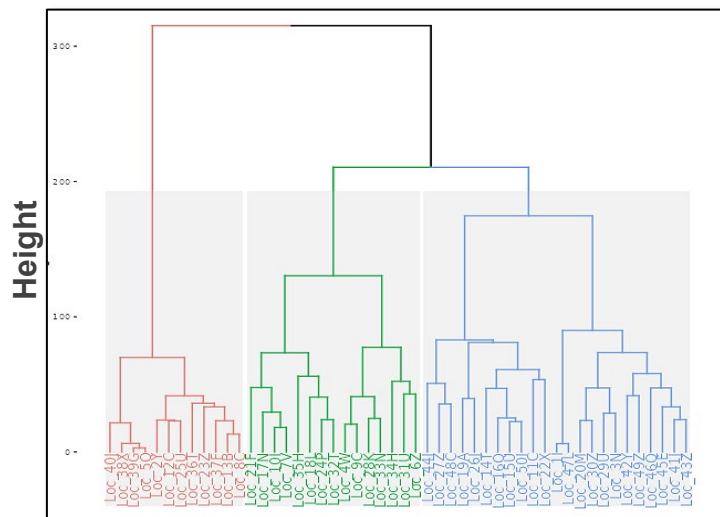


 EPA Method 1633

 Extended target PFAS analyte list

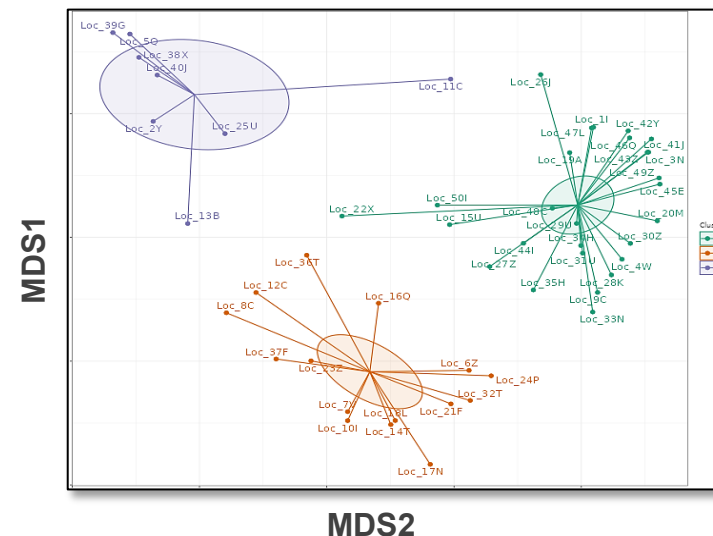
Clustering Analysis

Hierarchical Clustering



- Builds nested clusters that reveal relationships among PFAS datasets
- Provides a dendrogram for visualizing similarity and grouping of samples
- Useful for exploratory analysis when the number of clusters is unknown

K-Means Clustering



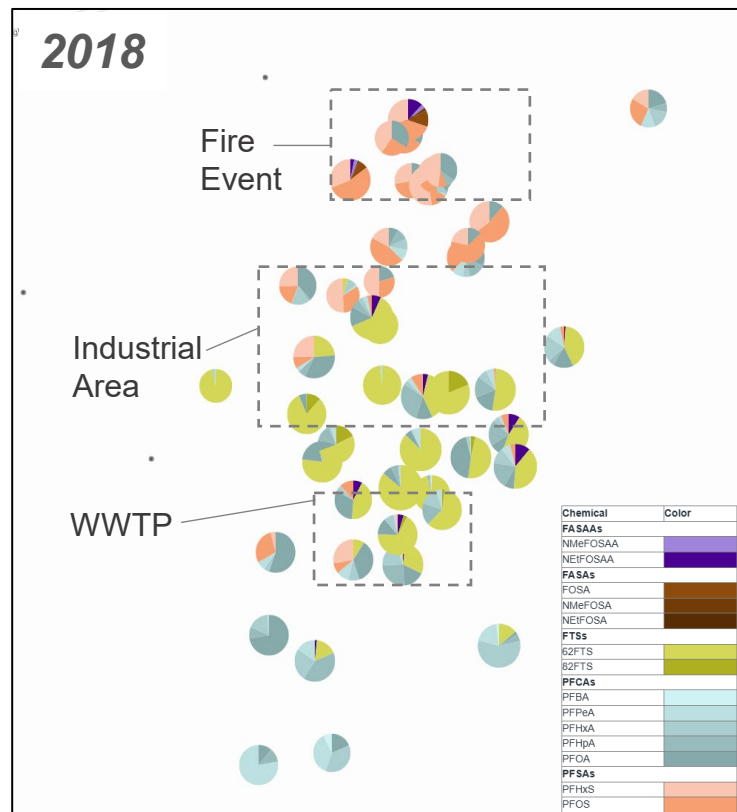
- Groups samples into clusters based on PFAS composition and concentration magnitude
- Recognizes broad patterns of contamination sources or sitewide concentration gradients
- Computationally efficient; makes it practical for large monitoring datasets

KEY POINT

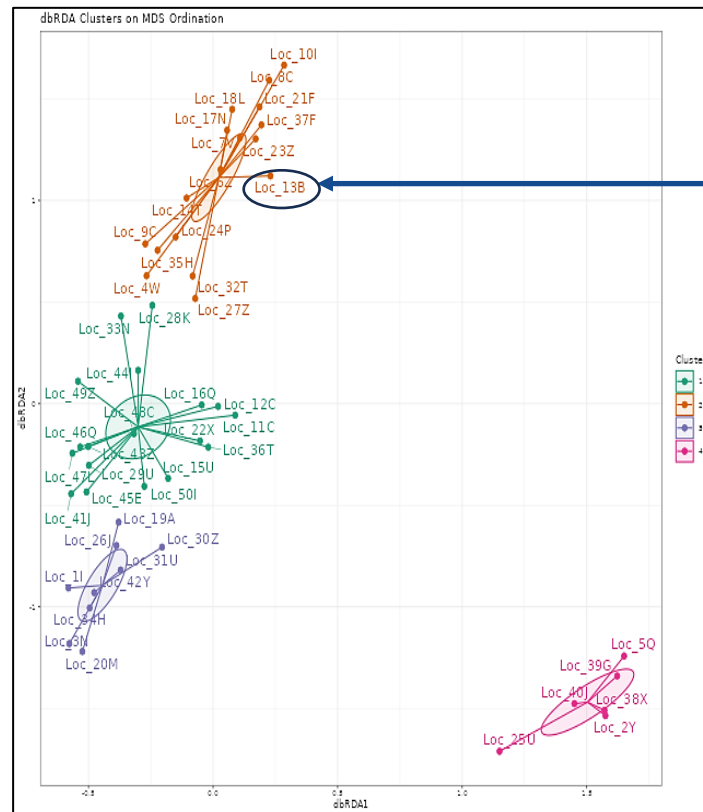
The cluster analysis may not be appropriate for dilute plumes where PFAS used to differentiate sources are not detected.

Clustering Analysis

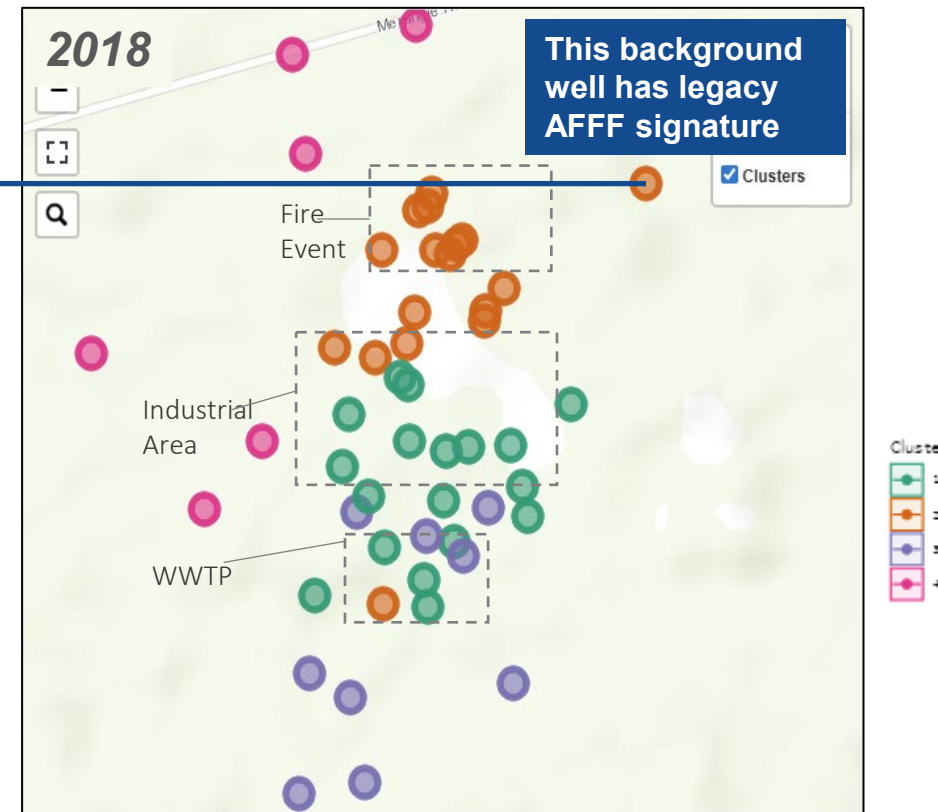
Cluster analysis shows agreement with compositional differences observed in the pie plots



PFAS composition and extent



*K-mean clustering analysis
(K=4)*



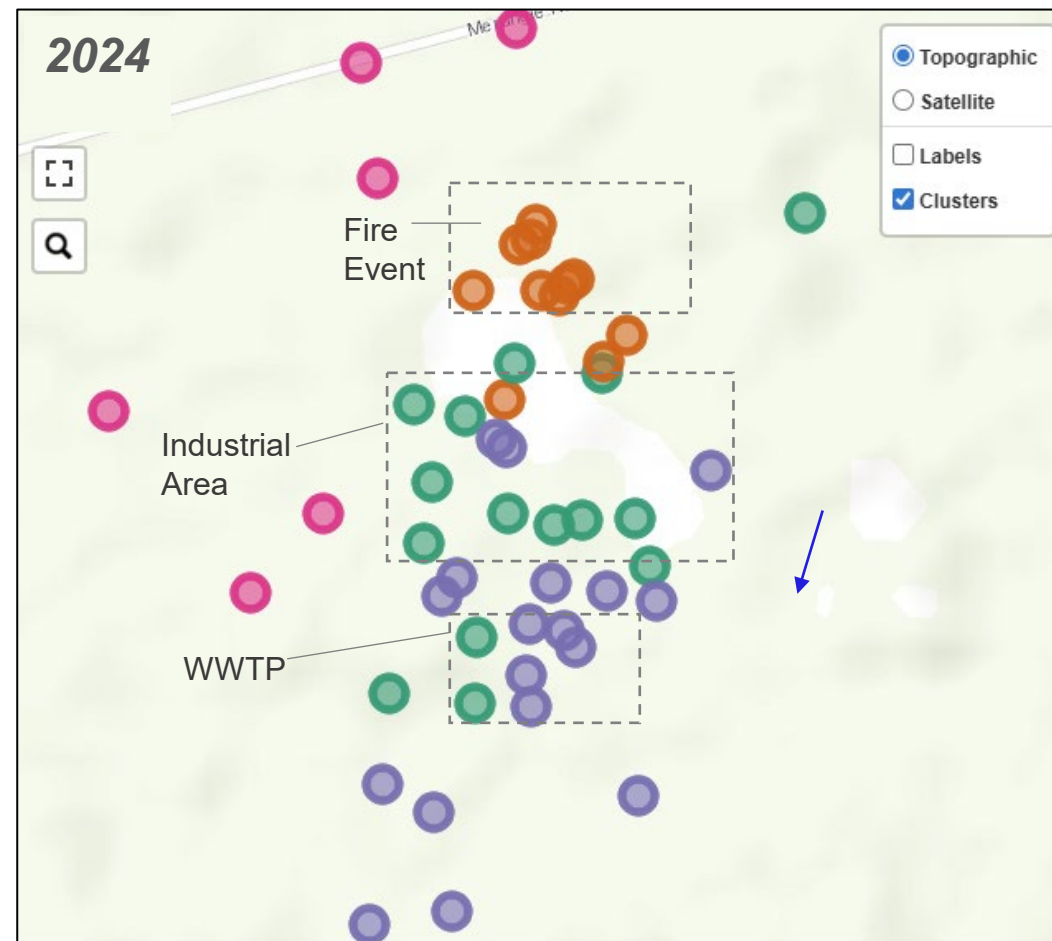
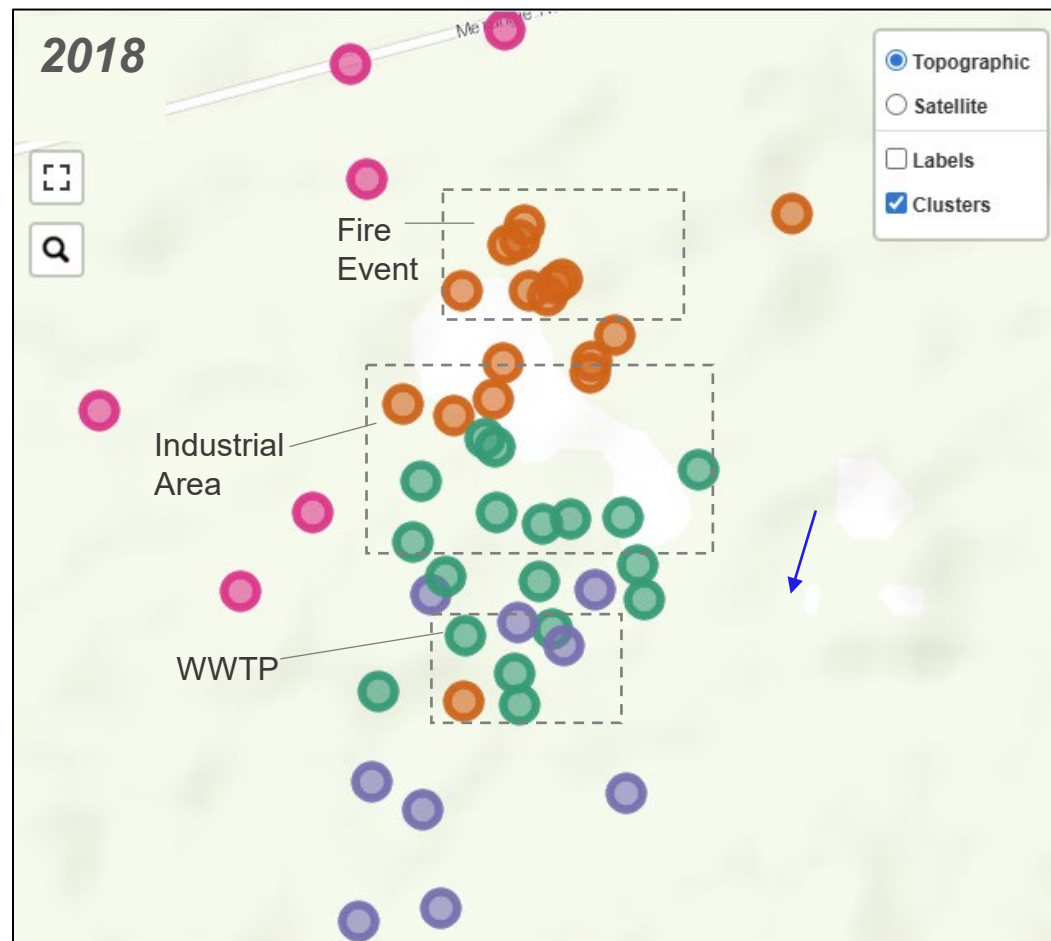
Locations of 4 clusters

AFFF: aqueous film-forming foam

(Jacobs 2026)

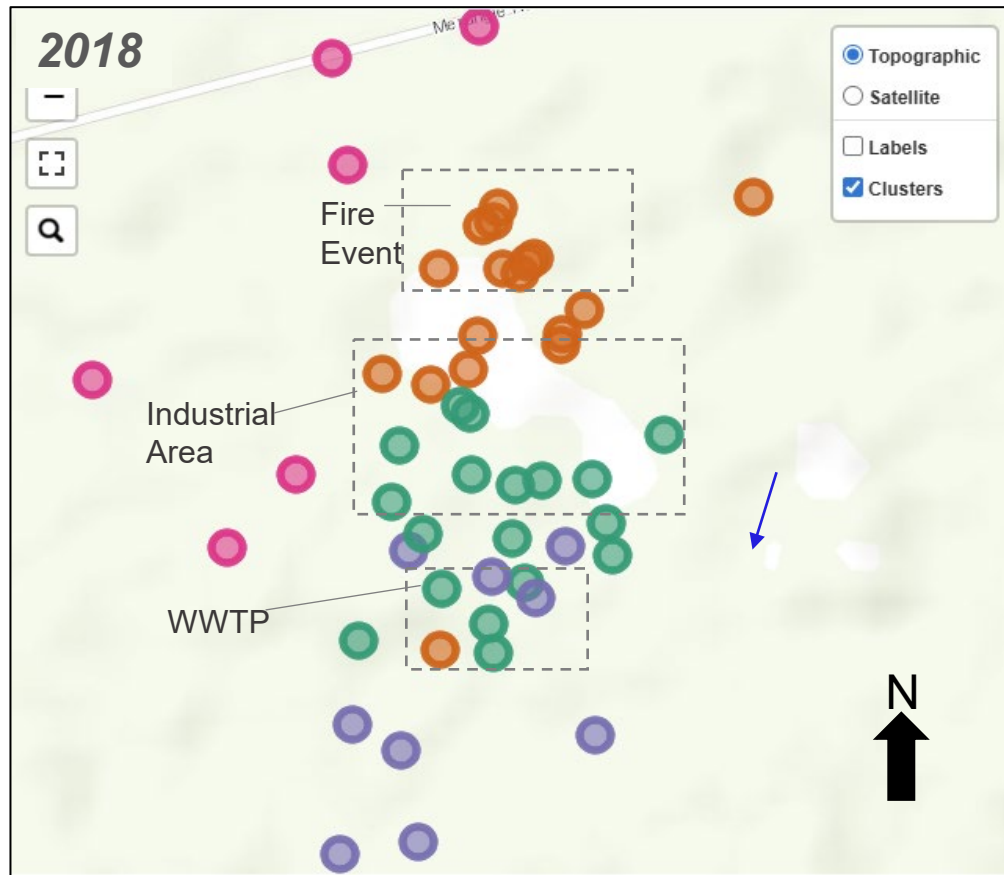
Temporal Trends + Clustering Analysis

Temporal clustering analysis shows compositional shifts due to precursor transformation



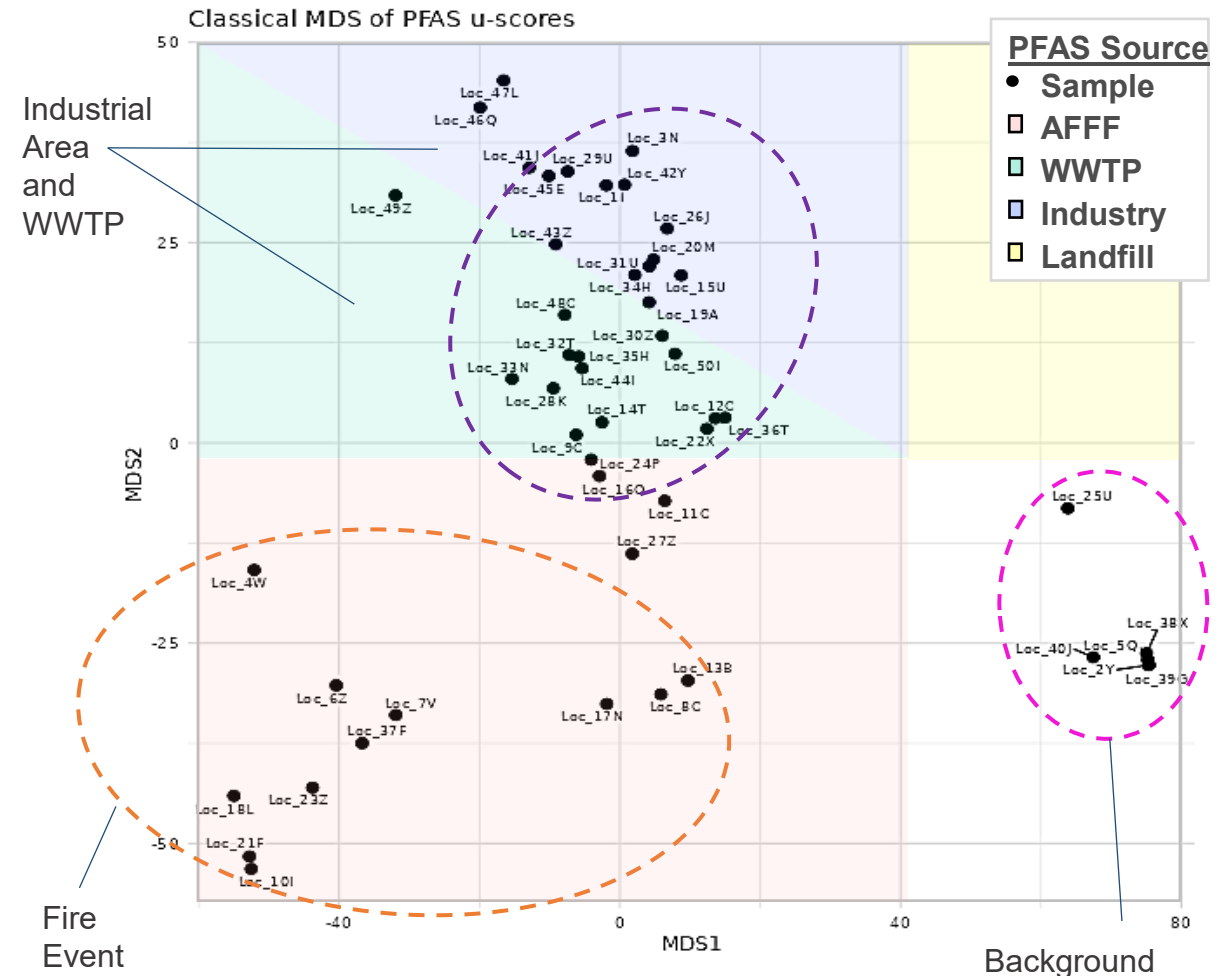
Matching Target PFAS Data with Specific Chemical Fingerprints

Spatial distribution of PFAS clusters



(Jacobs 2026)

Multidimensional scaling (MDS) technique to visualize similarity PFAS source



Knowledge Check



True or False

Spatial and temporal data are equally important on source identifications

Knowledge Check



True or False

Spatial and temporal data are equally important on source identifications

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Source Databases



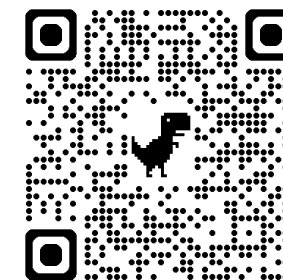
- Introduce DoW-R&D funded PFAS source databases
 - AFFF chemical fingerprinting database
 - PFAS biotransformation pathway database
- Discuss how applications of these databases for source identifications can be potentially used

PFAS Source Databases

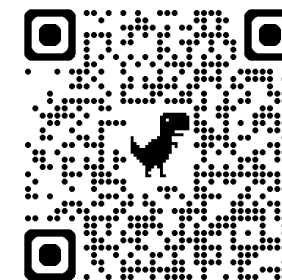


- DoW SERDP/ESTCP Projects
 - ER20-1375 and ER20-1121: Developed "forensic library" (e.g., landfill leachate, AFFF, municipal wastewater effluent, and chromium plating facilities)
 - ER20-1056: Store and manage PFAS mass spectral information and metadata ([complete](#))
 - ER20-1205: Machine learning to search for patterns in samples, aiming to assign probabilities that originate from specific sources ([complete](#))
 - ER20-1265: Apply ultra-high-resolution mass spectrometry to identify unique marker compounds in different AFFF formulations and other sources ([complete](#))

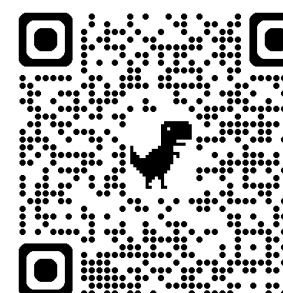
ER20-1375



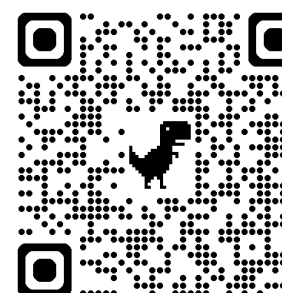
ER20-1205



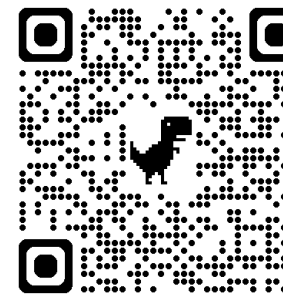
ER20-1121



ER20-1265



ER20-1056



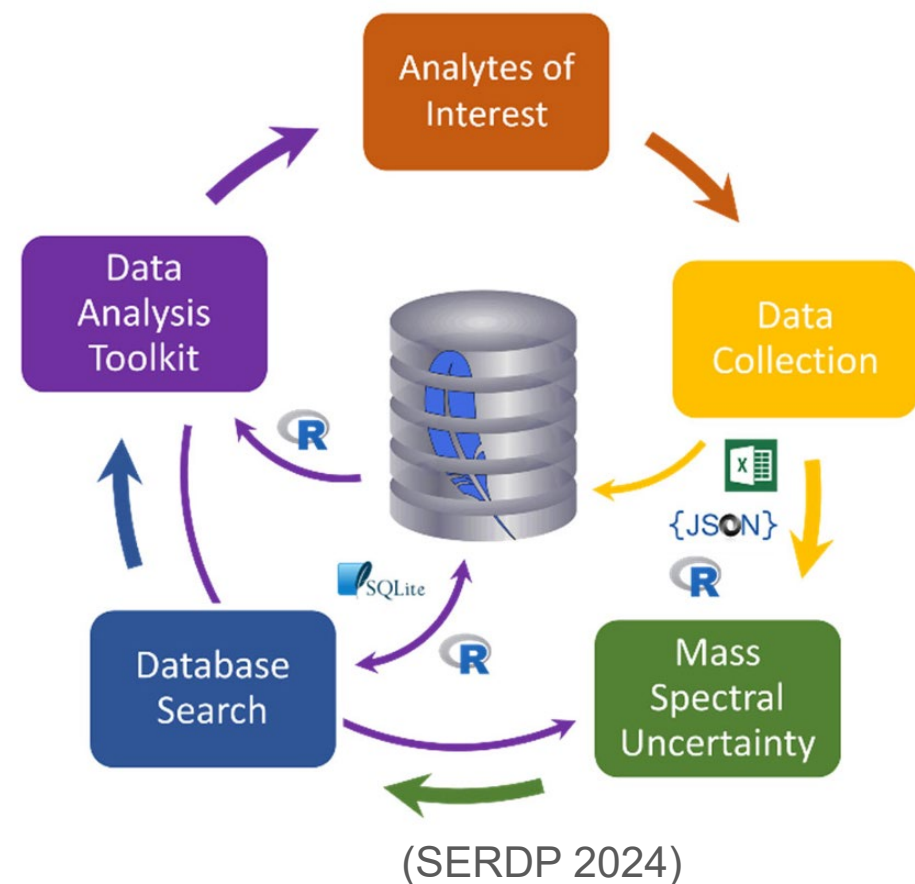
*Also see
references
for links*

SERDP: Strategic Environmental Research and Development Program
ESTCP: Environmental Security Technology Certification Program

ER20-1056 NIST Library and NTA Data Comparability



- Created and curated a NIST PFAS suspect list containing nearly 5,000 PFAS structures, providing a comprehensive chemical universe of suspect screening and discovery workflow
- Generated and quality-assured 351 consensus reference mass spectra covering 132 PFAS addressing a critical gap in high-quality reference data for PFAS NTA
- Built an integrated toolkit to support standardized data reporting, quality control, and spectral matching for PFAS identification
- Established a world-class quality assurance and training framework ensuring database remains freely available, expandable, and capable of supporting future PFAS research, forensics source attribution, and regulatory needs
- **Conducted a large interlaboratory study with 34 laboratories demonstrating wide variability in PFAS identification performance**



NIST: National Institute of Standards and Technology

SERDP: Department of Defense Strategic Environmental Research and Development Program

- Open-source Biotransformation data package (access login required)
- A collection of literature-reported biotransformation pathways for PFAS, last updated Jan 7, 2026

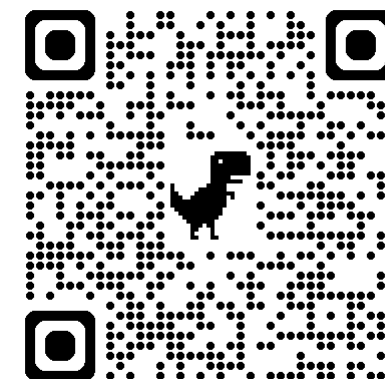
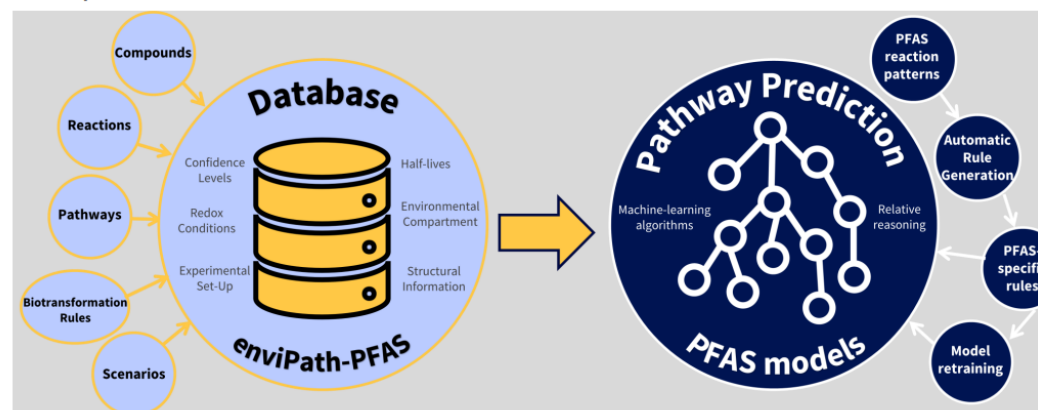


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Zürich

eawag
aquatic research

Outlook for the enviPath-PFAS package

1. We need more data!
2. New pathway prediction models will be trained with PFAS biotransformation data
3. There are likely new PFAS-specific biotransformation rules that need to be implemented into prediction models



<https://legacy.envipath.org/package/d2cfb5af-4ea0-4375-9a48-f2e776e44636>

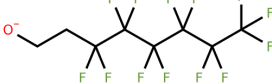
<https://community.envipath.org/t/pfas-resources-in-envipath/122>

- [illegible]

[O-]CCCC(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)

6:2 FTS_intermediate1

Image representation



SMILES representation

C([O-])C(C(F)(F)F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)F

Canonical SMILES

[O-]CCCC(F)(F)C(F)(F)C(F)(F)C(F)(F)C(F)(F)F

InChIKey

SZIBBSGBFMPQGM-UHFFFAOYSA-N

Pathways

Presentation Overview

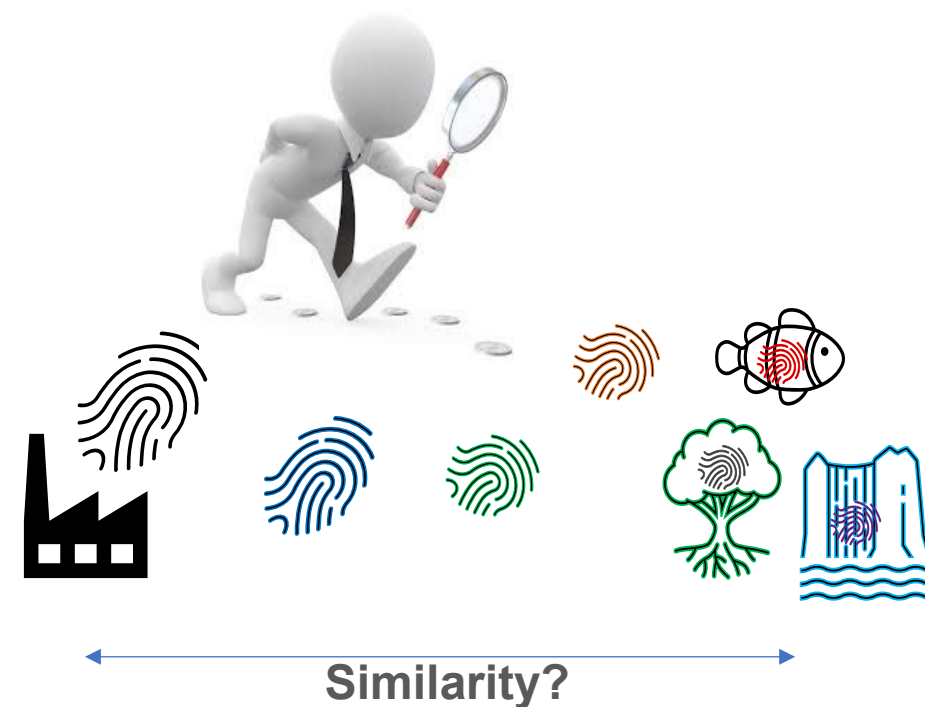


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PFAS Forensics Techniques Summary



- PFAS RI and background study data can help determine if PFAS forensics may be helpful
- PFAS forensic study should start with target PFAS data only
- While PFAS forensic study could be used with appropriate approvals, projects need to ensure compliance with applicable DoW requirements for decision-making



PFAS Forensics Techniques Summary



- When targeted PFAS forensics is not sufficient to identify PFAS sources that are critical to site management considerations:
 - Nontarget data collection may be applied, but to limited cases with management/SME support, and based on budget availability
 - Nontargeted forensic study plan should identify/define DQO with clear and transparent justifications for completion
 - There should be awareness of the potential cost impacts to an RI project when nontargeted forensic study is proposed
- Each PFAS forensics technique has its pros, cons, and limitations
 - Analytical techniques
 - Data analytic techniques
- There could be data and knowledge gaps

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Questions



Public Outreach for PFAS Off-Base Drinking Water Well Sampling

Sharon Baumann
Navy and Marine Corps Force Health Protection Command

RITS 2026

Disclaimer



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Information in this presentation is current as of April 16, 2026.

EXWC: Engineering and Expeditionary Warfare Center
NAVFAC: Naval Facilities Engineering Systems Command

Speaker Introduction



Sharon L. Baumann

Risk Communicator



- NMCFHPC Environmental Risk Communicator since October 2022
 - Supports commands throughout the Navy and Marine Corps preparing for and executing public outreach
- NAVFAC Mid-Atlantic for 27 years
 - Acting Environmental Business Line Leader, Director of Regional Environmental Coordination, Director of Environmental Assessments Branch, and DoW Chesapeake Bay Program State Coordinator
 - Installation Environmental Program Director for Naval Station Norfolk
 - Media manager in the Drinking Water, Stormwater, Wastewater, Pollution Prevention, Emergency Planning and Community Right to Know Act, and pesticide management programs
- Environmental Chemist

DoW: Department of War

Navy: Department of the Navy

NMCFHPC: Navy and Marine Corps Force Health Protection Command

Presentation Overview



- Introduction
- Public Outreach
- Risk Communication Principles
- Planning an Effective Open House Meeting
- Case Study: NRL-CBD
- How Do You Start?
- Summary and Closing Statements

The Public Outreach “Problem”



- The DoW supports regular and open engagement with communities during cleanup
- Public participation, as well as public affairs and community involvement activities are necessary for Navy Environmental Restoration Program response actions
- Public involvement is required under CERCLA at certain steps
 - Even when not required, it is important
- Navy community involvement requirements are more comprehensive than CERCLA requirements
 - Build trust and relationships with the community
 - Provide the community with an accurate information base
 - Result in smoother project completion
- PFAS investigations and potential groundwater contamination have the potential to become controversial and can cause the public to be concerned

KEY POINT

PFAS public outreach is necessary but can be difficult.

CERCLA: Comprehensive Environmental Response,
Compensation, and Liability Act
PFAS: per- and polyfluoroalkyl substances

Purpose



- Provide options for communicating with public about PFAS on-Base investigations and off-Base private drinking water well sampling
- Explain risk communication principles and how to apply them to speaking with the public about potential PFAS in their drinking water wells because of past activities by their Navy and Marine Corps neighbor

Timeline of EPA PFAS SDWA Advisories and Standards

2009 EPA Provisional Health Advisory

- PFOA: **400 ppt**
- PFOS: **200 ppt**

(EPA 2009)

2016 EPA Lifetime Health Advisory

- PFOA: **70 ppt**
- PFOS: **70 ppt**
- PFOA + PFOS: **70 ppt**

(EPA 2016)

2022 EPA Interim Lifetime Health Advisory

- PFOA: **0.004 ppt**
- PFOS: **0.02 ppt**

(EPA 2022)

2023 EPA Proposed MCLs

- PFOA: **4 ppt**
- PFOS: **4 ppt**
- HFPO-DA: **10 ppt**
- Mixtures with 1+ of PFHxS, PFNA, HFPO-DA, and PFBS: **Hazard Index of 1**

(EPA 2023)

April 2024 EPA Final MCLs

- PFOA: **4 ppt**
- PFOS: **4 ppt**
- PFHxS: **10 ppt**
- PFNA: **10 ppt**
- HFPO-DA: **10 ppt**
- Mixtures with 2+ of PFHxS, PFNA, HFPO-DA, and PFBS: **Hazard Index of 1**

(EPA 2024)

SDWA: Safe Drinking Water Act

EPA: United States Environmental Protection Agency

HFPO-DA: hexafluoropropylene oxide dimer acid (GenX)

MCL: Maximum Contaminant Level

PFOA: perfluorooctanoic acid

PFOS: perfluorooctanesulfonic acid

PFHxS: perfluorohexanesulfonic acid

PFNA: perfluorononanoic acid

PFBS: perfluorobutanesulfonic acid

ppt: part(s) per trillion

KEY POINT

PFAS are emerging chemicals and a regulatory moving target as science evolves.

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Lesson Learned/Best Practice



(Jenni 2025)

KEY POINT

Do not try to “Fly Under the Radar.”

- Communicate early and often
 - Push information (Google results are scary, transparency is good)
 - Complex issue (manageable “bites” of information)
 - Begin building relationships and building an information base before the first sample is taken

Objectives of Public Outreach



- Build public trust
- Build relationships
- Build a knowledge base
- Listen to public concerns and answer questions

KEY POINT

Public outreach is key to a successful PFAS off-base drinking water well sampling project.

Target Audience for Public Outreach



- Communities around Navy and Marine Corps bases
- State and local elected officials
- Key community stakeholders
- RAB members
- Advocacy groups and organizations
- Local businesses
- Schools/Daycares

KEY
POINT

Get to know stakeholders.

RAB: Restoration Advisory Board

Lesson Learned/Best Practice

KEY POINT

More notification = less confusion

- Notify all parcel owners and occupants in sampling area
 - Neighbors talk
 - Must confirm wells have not been missed
- Clarify sampling area question
- Clarify public water question



(NAVFAC 2016)

Lesson Learned/Best Practice

KEY POINT

It takes a team!

- Who will community turn to for answers?
 - Inform elected officials and other key stakeholders in advance
- Supporting agencies are critical
 - Non-Navy and Marine Corps health experts
 - EPA/State explanation of PFAS health effects
 - Agency support of Navy way forward
- Team involvement and preparation a must
 - Multi-agency strategy sessions for public meetings



(Baumann 2025)

Partners for Public Outreach

External Partners

- Regulators: federal, state, and local
- Health Departments: state and local
 - Navy and Marine Corps Occupational Health if there is an on-base impacted community
- Contractor

Internal Partners

- Base personnel: Uniformed leadership, Public Affairs, Community Plans and Liaison, Environmental
- NAVFAC Atlantic: Environmental Restoration (required)
- NAVFAC Region: Environmental Restoration
- NMCFHPC



(Baumann 2025)

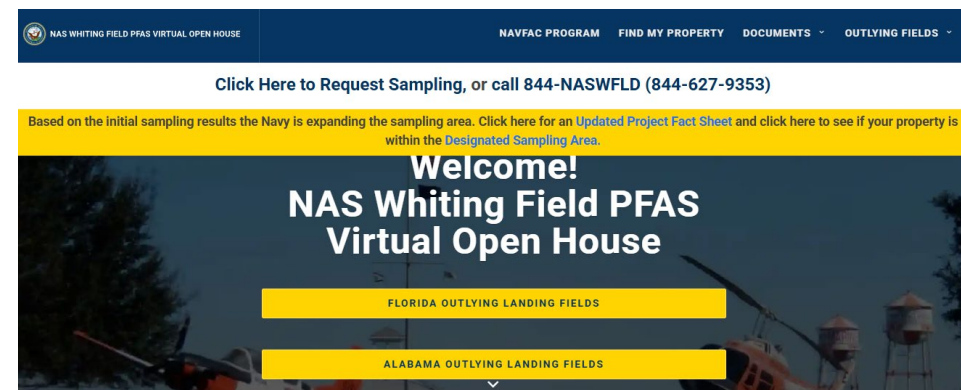
KEY
POINT

**Partner collaboration
is KEY!**

Community Engagement Platforms



- Mailings
- Door-to-door
- Phone calls
- Email
- Social media (Facebook, Instagram, and community pages)
- Traditional media
- Websites and virtual meetings
- In-person public meetings
 - “Open House” style (poster display)
 - “Town Hall” style (RAB meetings)



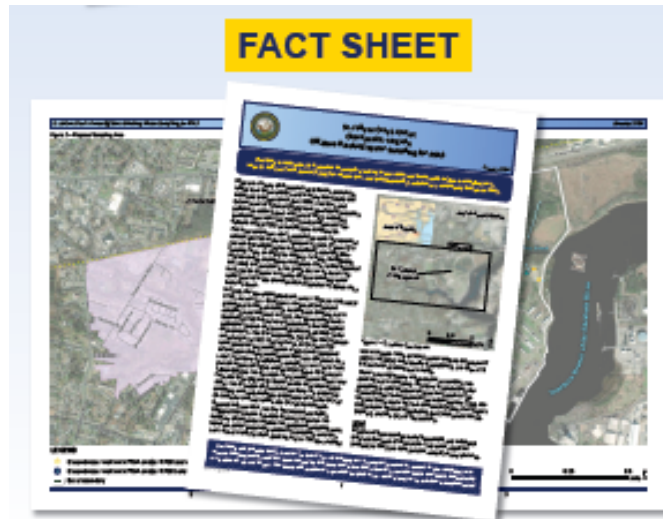
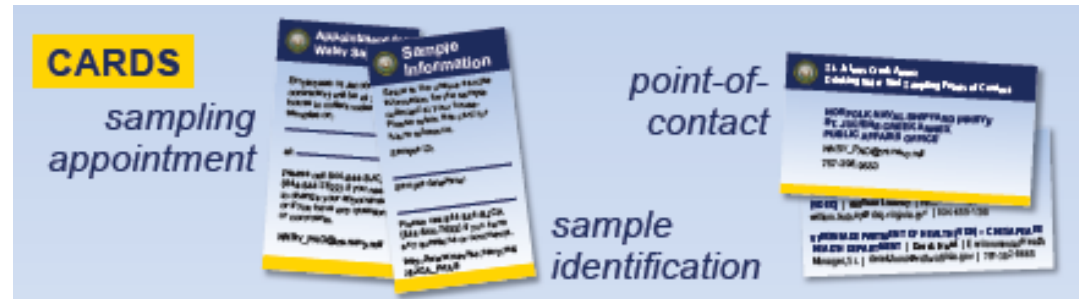
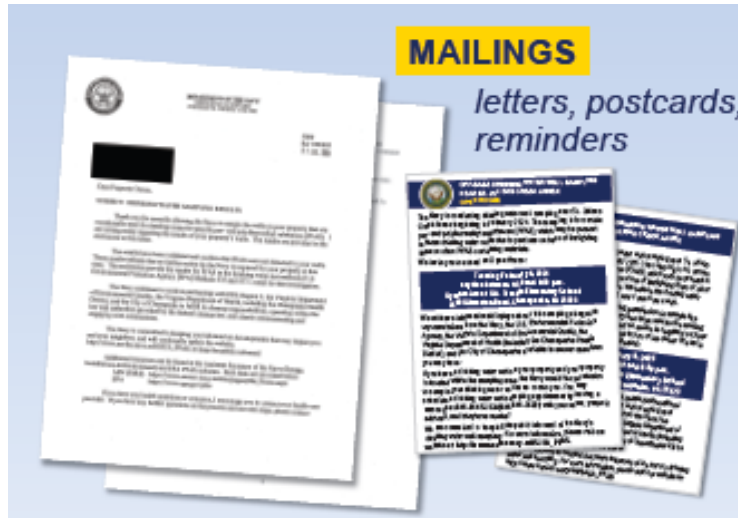
(NAVFAC Southeast 2025)



(Baumann 2023)

(NMCFHPC 2025)

Outreach Materials



Information Control



- **Ensure all pre-final outreach materials are labeled with “INTERNAL DELIBERATIVE – DO NOT RELEASE”**
 - Include label on email when sending to the team
- **Ensure all outreach and outreach materials provide consistent information**
 - Have materials reviewed by team (including Public Affairs) and leadership
 - Materials may need an Operational Security review – check with Base personnel
- **Ensure all information stays updated**
 - Do not forget the public website – public will be frustrated when they search for information and find it is out of date

- **What NOT to put on websites**

- Remedial Project Manager-specific information (name or name-specific email address)
- Unvalidated results
- Clear depictions of individual parcel boundaries in sampling area
- Public, private, community, and installation drinking water well locations
- Anything posing Base security concern
- Controlled Unclassified Information

Information Control – CUI



Managing CUI in Environmental Cleanup Data and Reports – DoD Memorandum of August 24, 2023

- Must safeguard PII information about private parties when sharing data
 - DoW Components **will not release names and addresses** associated with privately owned residential drinking water wells sampled by DoW without written consent of property owner
 - DoW Components **will not release latitude/longitude** of residential drinking water wells associated with specific DoW sampling results **without written permission from, or notification to the property owner**
 - ROE forms after August 2023 include notification that latitude/longitude will be shared if permission to access the property is granted
 - May be shared with state regulatory agencies and may become publicly available
 - ROE agreements established previously, if state regulatory agencies request PII, DoW Components must request written permission from property owner to release latitude/longitude
- Other cleanup data and reports that may meet CUI criteria and will not be released include technical and geographical information, images and photographs, critical infrastructure, and geodetic data that are not already publicly available and that if made public may pose an operational security risk

CUI: Controlled Unclassified Information PII: personally identifiable information

DoD: Department of Defense

ROE: right of entry

(DoD 2023)

Mandatory Outreach Requirement



FEDERAL CODEL NOTIFICATION MUST BE MADE BEFORE THE COMMUNITY IS INFORMED!

- Project fact sheet must be reviewed and approved by NAVFAC Headquarters and the Office of the Deputy Assistant Secretary of the Navy (Mission Readiness and Environment) before requesting CODEL
- CODEL notification is an email typically sent from the RPM, the RPM's supervisor, or ER Manager to NAVFAC Headquarters
 - NAVFAC HQ reports to ASN (Mission Readiness and Environment) who reports to Office of Legislative Affairs who notifies Congress
 - A template can be found in the work plan
 - The final fact sheet must be attached to the CODEL email
- Request should be made approximately 30 days prior to open house
- CODEL notification must be **confirmed as complete** before any public outreach can occur
 - NOTE: CODEL does not have to be complete before you can include partners as part of the outreach team

ASN: Assistant Secretary of the Navy

ER: Environmental Restoration

CODEL: congressional delegation

RPM: Remedial Project Manager

(Navy 2016)

Knowledge Check



Why is it important to get to know the public before starting outreach?

- A. It will help in planning outreach strategy
- B. It will identify concerns they have and therefore types of questions they may ask
- C. It will help identify what to put in outreach materials
- D. All of the above

Knowledge Check



Why is it important to get to know the public before starting outreach?

- A. It will help in planning outreach strategy
- B. It will identify concerns they have and therefore types of questions they may ask
- C. It will help identify what to put in outreach materials
- D. All of the above

True or False?

“RPM is the only one that needs to review and approve outreach materials.”

Knowledge Check



True or False?

“RPM is the only one that needs to review and approve outreach materials.”

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What is Risk?



A threat to that which we value

- Family and pets
- Health
- Home
- Job

KEY POINT

Risk is personal. What is acceptable to one person may be unacceptable or a threat to another.

What is Risk Communication?



Risk communication is the exchange of information about risks

- Is a two-way interactive process
- Respects interests, values, fears, and concerns of stakeholders
- Treats those involved in communication as partners

It is not an exact science.

What is a Risk Communication Issue?



Any issue or situation with potential for the following

- High concern
- Low trust
- High emotions
- Controversy
- Sensitive circumstances

Could PFAS in drinking water be considered a risk communication issue?

Fundamental Challenge



There is virtually no correlation between ranking of hazards by experts and ranking of those same hazards by the public.

KEY POINT

Just because CERCLA was followed and no risk to human health or the environment was determined does not mean the public will agree.

KEY POINT

Just because the site met regulatory standards does not mean the public will be okay with having ANY PFAS in their drinking water.

Why is Risk Communication Difficult?



- Lack of trust and credibility
"I want to speak to an expert and that means NOT someone from the Navy..."
- Lack of scientific understanding
Does public understand what PFAS are and the process used to clean up sites?
- A person's perception IS their reality
Risk Perception = Hazard + Emotion
- Mental noise
 - *People interpret information differently when stressed*
 - *Ability to process information is impaired*
 - *80/20 Rule*
 - *Focus on negatives*
- Media influence
Have you ever Googled "PFAS"?

What Do You Consider Risky?



(Baumann 2000)

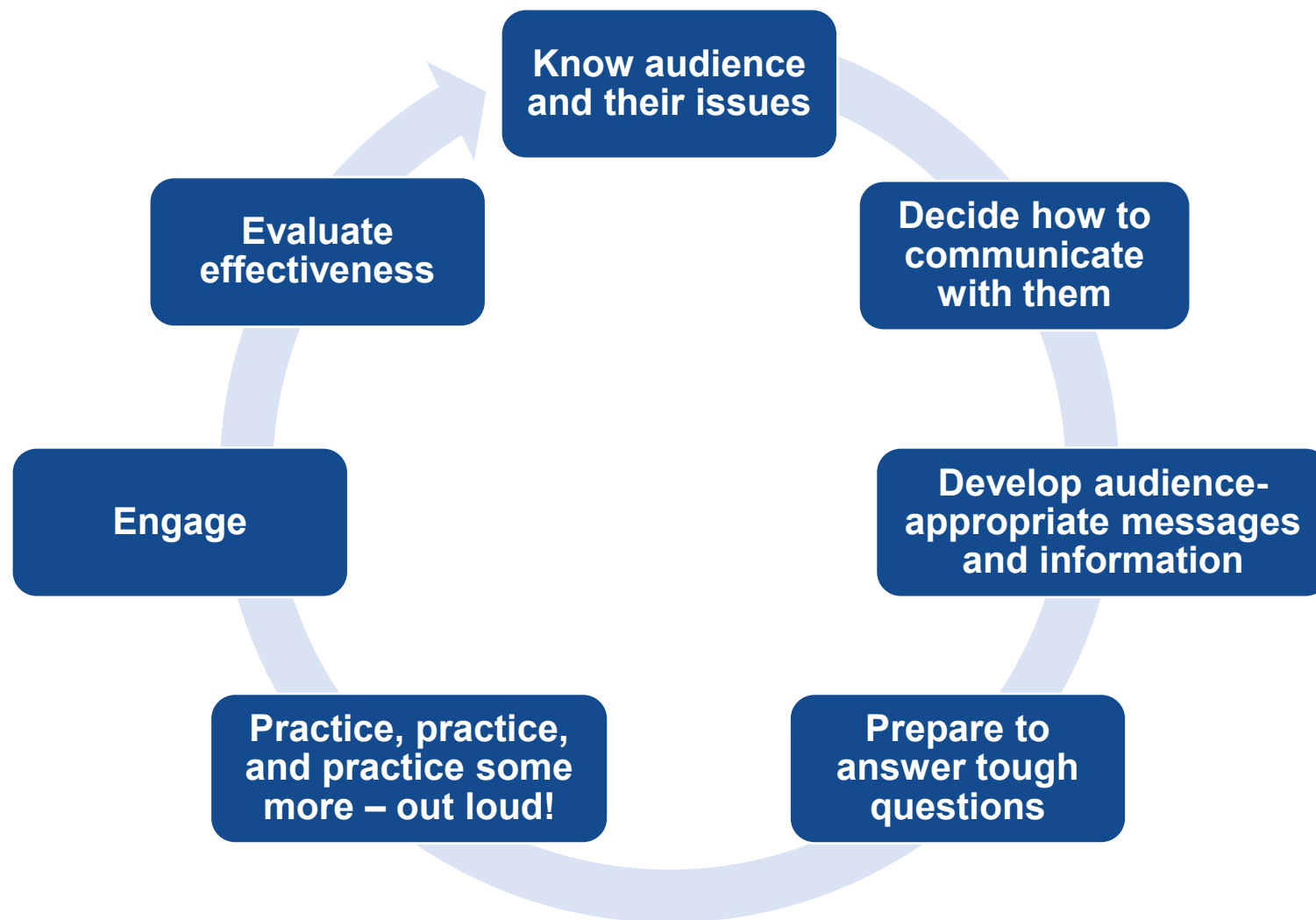


(Baumann 2000)



(Adamyk 2018)

How to Communicate Effectively



Develop Key Messages



KEY POINTS

- A key message is the most important information for people to remember.
- Key messages need to be team-created with consensus.

Develop manageable “bites” of information on a complex topic.

Ask three questions:

- What does the audience want to know?
- What is important to tell the audience?
 - What might be misunderstood?

(NMCFHPC 2025)

In what situations should risk communication principles be used?
(choose all that apply)

- A. The project may cause a hazard to audience's health
- B. The topic is complex and may be misunderstood
- C. The public has the potential to be confrontational
- D. The community has no or little trust in Navy or Marine Corps

Knowledge Check



In what situations should risk communication principles be used?
(choose all that apply)

- A. The project may cause a hazard to audience's health
- B. The topic is complex and may be misunderstood
- C. The public has the potential to be confrontational
- D. The community has no or little trust in Navy or Marine Corps

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PFAS Public Meeting Goals



- Present a project overview
 - Why are we sampling?
 - Where are we sampling?
 - What will we do with results?
- Encourage people to sign up for sampling **if eligible**
- Listen to concerns and answer questions

Public Meeting Challenges



- There is no such thing as “one public”
 - Different issues and concerns
 - Different levels of knowledge and information needs
 - Different levels of trust and emotion
- Public speaking issues
 - Representatives
 - Audience
- Maintaining control
 - Angry people and the mob mentality
 - Hijackers
- Time constraints

Open House Versus Town Hall

Open House



(Baumann 2025)

Town Hall



(Baumann 2024)

Lesson Learned/Best Practice

KEY POINT

Personal conversations are KEY!

- Written information does not satisfy everyone
- People want to discuss *their* situation
- **Open House meetings work**



(Baumann 2025)

Benefits of an Open House



- Allows for many more questions to be addressed
 - Multiple one-on-one conversations at once
 - No need to limit number of questions or time for each response
- Does not require anyone to be a public speaker
- Allows the ability to better meet individual needs with layered information
- Allows for community participation without confrontations
- Provides a more relaxed atmosphere
- **Emphasizes the team and not just Navy and Marine Corps**
 - Respected subject matter experts from other agencies participate

Public Meeting Goals



Desirable

- Environment for comfortable one-on-one conversations
- Consistent information
- Meet individual needs
 - Layers of information available
- Community participation without confrontations



Not Desirable

- “People jams”
- Confusion over where to go for information
- Conflicting answers
- People leaving without key messages
- Unanswered “easy” questions

(Baumann 2024, 2025)

Meeting Components and Support



- Five to seven poster stations
 - Can be multiple posters per station
 - Each is a separate topic
- Two to three subject matter experts per station
 - Allows for multiple conversations
- Relaxed atmosphere
 - Office attire: business casual

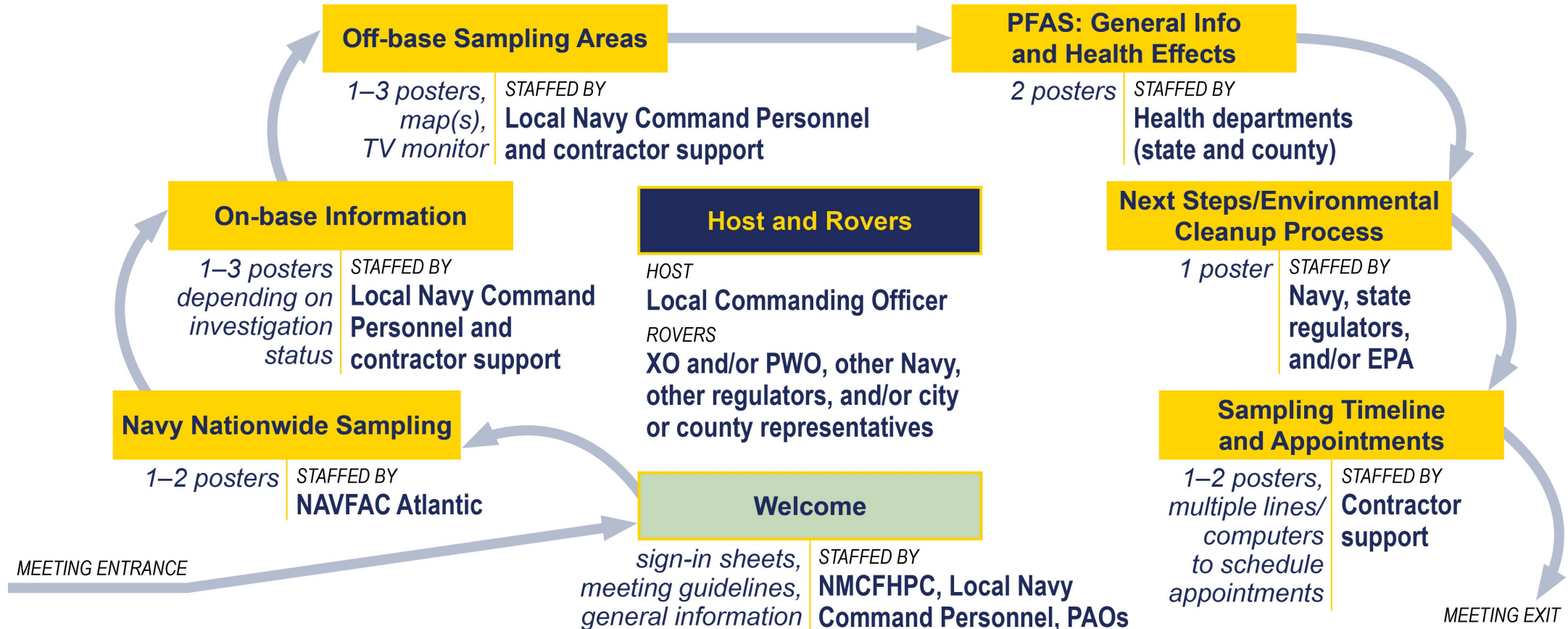


(Baumann 2023)

KEY POINTS

- **Organize posters to best tell “the story.”**
- **People can visit in any order.**

Example Poster Topics and Layout



(NAVFAC 2025)

PAO: Public Affairs Office
PWO: Public Works Officer
XO: Executive Officer

**KEY
POINT**

It takes a team!

Open House Participants

Host: uniformed leadership

- “Meet and Greet”
- Reinforce top line key messages
- Encourage people to “talk to the experts” and highlight expert team
- Media interviews (if preferred)



(Forrest 2026)

Subject matter experts

- Staff poster stations
- Focus on their topic

Greeters

- Set tone
- Sign in attendees
- Explain format
- Escort to first poster

“Rovers”

- Help with people flow, overloaded stations, and difficult situations
- General knowledge and public meeting experience

Develop Key Messages



- “Big-picture” and “top-line” messages (or talking point themes)
 - Three or four (if possible to limit)
 - Project summary
 - Emphasizes **“what is important to tell the audience”**
- Poster station messages
 - Three or four key messages, with supporting facts highlighted for each poster topic
 - Focused more on **“what the audience wants to know”** or **“might be misunderstood”**
 - Visuals make great supporting facts

Example PFAS Top-Line Messages



Navy and Marine Corps are requesting to sample private drinking water wells for PFAS to be sure nearby community members are not drinking water with PFAS at or greater than DoW Interim Action Levels for Private Drinking Water Wells.

RESPONSIBILITY/PROTECTIVE INVESTIGATION:

- PFAS have been found in the groundwater wells on [base]
- Navy and Marine Corps are taking a phased approach; one of the priorities is to sample private drinking water wells in the sampling area
- Navy and Marine Corps will take action in accordance with DoW policy
- Sampling area will be expanded, if needed, based on results
- If audience receives drinking water from [Public Water System(s)], Navy and Marine Corps do not need to sample the drinking water at their home

COMMITMENT

- Navy and Marine Corps are committed to fulfilling cleanup responsibilities
- Navy and Marine Corps will continue to evaluate existing and new sampling data to determine next steps
- Navy and Marine Corps remain committed to addressing PFAS in drinking water as science and regulatory standards continue to evolve
- Navy and Marine Corps are committed to keeping you informed as new information becomes available

TEAM OF EXPERTS

- Navy and Marine Corps are coordinating with state and local agencies on this sampling activity

Off-Base Sampling Poster Key Messaging Example



- Navy is offering to sample private drinking water wells in both previous and expanded drinking water sampling areas
- Groundwater sampling area was expanded based on direction of groundwater flow and exceedance of new DoW PFAS Interim Action Levels for Private Drinking Water Wells
- Groundwater sampling area may be expanded depending on results of additional sampling
- If you are in either of the sampling areas and have a private drinking water well, please sign up to have your well sampled

Layer Information



KEY POINT

We better meet needs of the public by layering information.

Each additional layer contains more detail.

- Layer 1: Posters
- Layer 2: Fact sheets
- Layer 3: Experts
- Layer 4: Additional reference materials

(NMCFHPC 2025)

Sampling and Resampling Posters



KEY POINT

Posters are a backdrop to start a conversation.

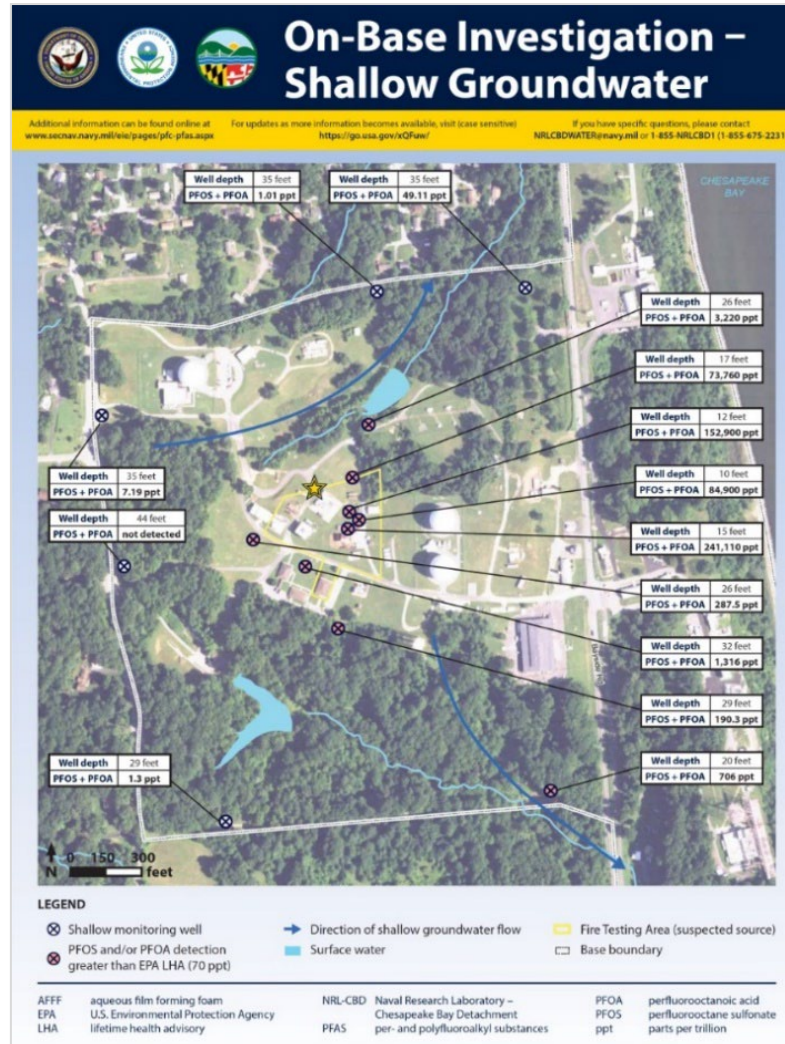
- For sampling and resampling posters, answer basic questions
 - **What** are Navy and Marine Corps doing?
 - **Why** are they doing it?
 - **When** will it be done?
 - **How** will Navy and Marine Corps keep public informed?

Develop Posters for the Average Person



- Content at 6th- to 8th-grade reading level
- **Minimal jargon, acronyms, and numbers**
- Sufficient “white space”
- Large enough font
- Bulletized lists instead of paragraphs
- Obvious key messages

Graphics

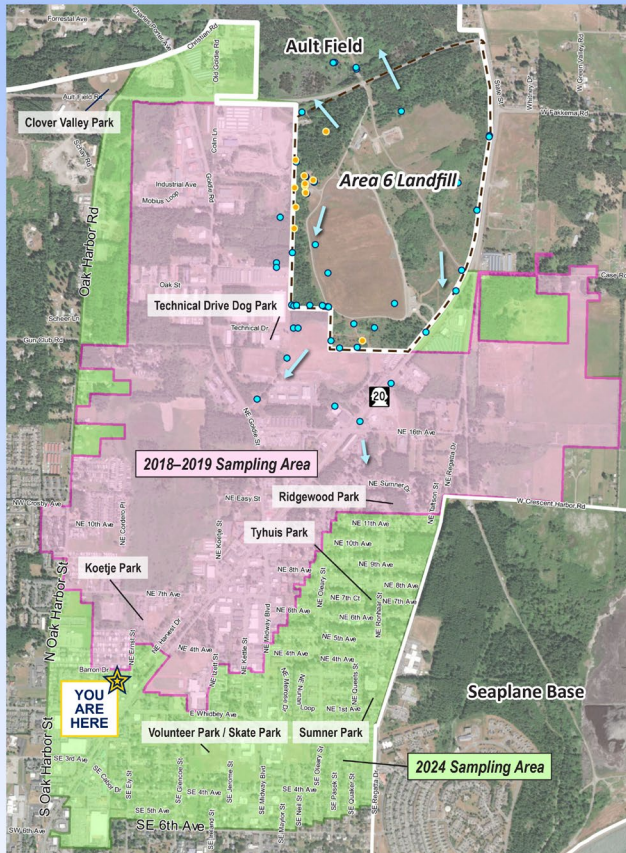


(NAVFAC 2018)

- Less is often more
- Consider not using site numbers
- For graphs, do not make audience guess the conclusion

Maps: Are They Clear?

NAS Whidbey Island Area 6 Landfill 2024 Off-Base PFAS Drinking Water Sampling

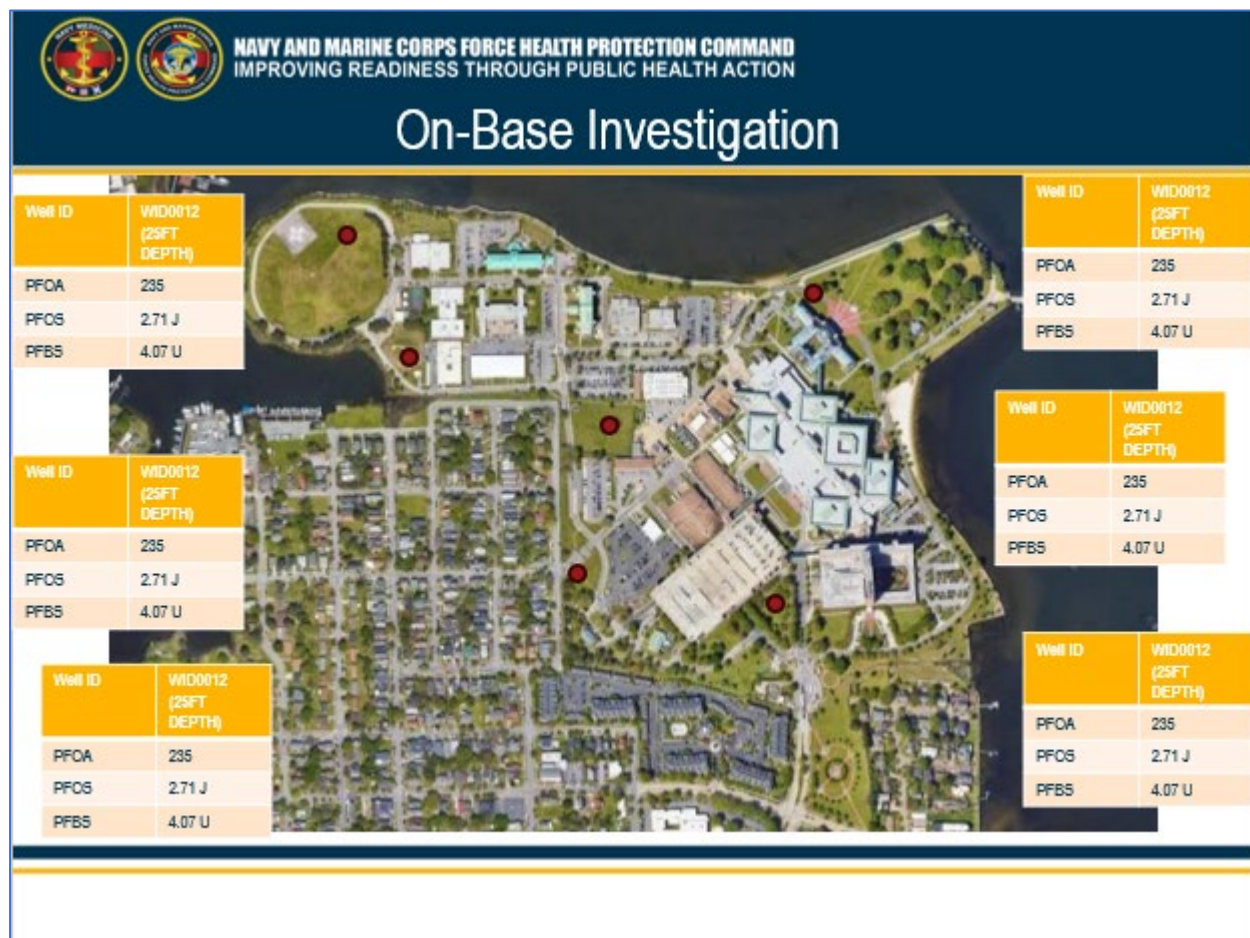


(NAVFAC 2024)

- What will public be looking for?
 - Where is my house?
 - Where is sampling area?
 - Am I in sampling area?
 - Where do I live in relation to release areas and sampled areas?
 - What are results for areas already sampled?
- Information needed to answer common questions
 - **Clearly delineated Navy property boundary**
 - Main streets and highways in visible text
 - Key landmarks
 - **Clearly marked and visible release areas and sampling areas**
 - Groundwater flow arrows to explain sampling areas

Map subject matter experts must know local area

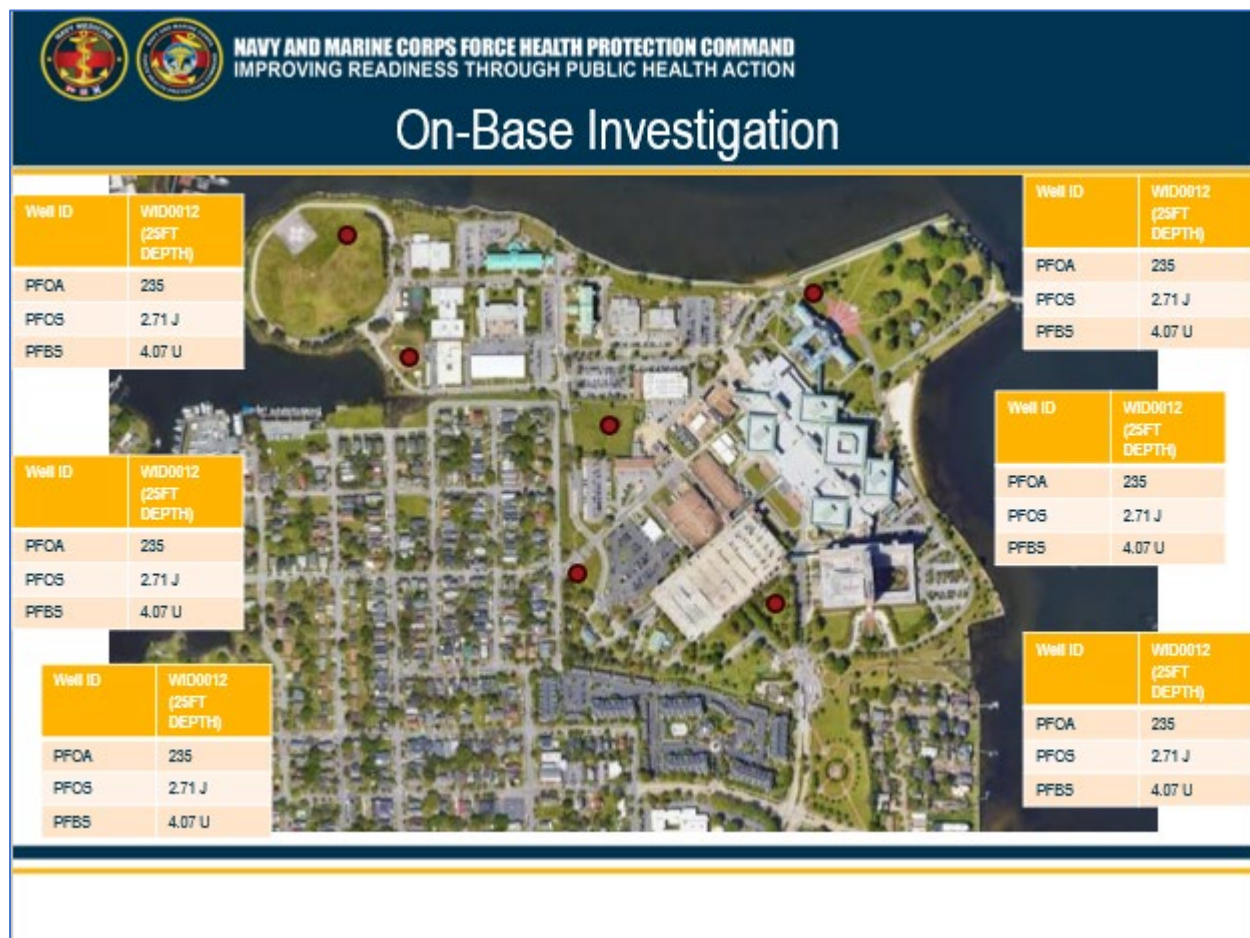
Knowledge Check



(Google Maps 2026)

How could this graphic be changed to make it clearer?

Knowledge Check



(Google Maps 2026)

How could this graphic be changed to make it clearer?

- Decrease numbers, only including those necessary
- Remove well numbers and codes
- Add flow direction arrows
- Label Base, streets, water body, key buildings and other landmarks
- Add legend
- Show Base boundaries
- Define acronyms
- Add lines from data to location

Know the public; communication style depends on location and audience.

- Geography (where people live)
- Country of origin, ethnicity, or tribal affiliation
- Jobs, resources, and audience concerns
- How local people communicate

Depend on base personnel or include key community stakeholders as partners.



Logistical Considerations

Venue

- Only on-base if entire audience lives or works on base
- Central location
- Large enough to space posters, but not too large
 - **Fire code**
- Acoustics and lighting
- Handicap accessible
- Plenty of nearby parking (preferably free)
- Access time
- No open bar

Security

- Who is providing?
- Who are decision makers?
- What will be tolerated?



(Baumann 2023)

Timeline Considerations



Timeline – Planning and Preparation Prior to Open House



(NAVFAC 2025)

Timing for Meeting(s)

- Usually multiple hours (recommend 2 hours)
- Possibly more than one time of day
 - Plan for no more than 100 to 200 visitors per meeting
- Plan for early arrivals and late departure (+1 hour)
- Consider need for meetings at more than one location

Practice, Practice, and Practice



(Baumann 2025)

- Mock meetings
- Study guide
 - Know key messages
 - Review common Q&A
 - Understand meeting layout
- Brainstorm questions: $3 \times 5 = 80$
 - Most common
 - What is not desired from meeting
 - Desired outcome
- Do more role-play type practice for Q&A
- Practice delivering summary talk and key messages

Q&A: questions and answers

Follow Through



KEY POINT

Project outreach does not end with a public meeting or even with the end of sampling.

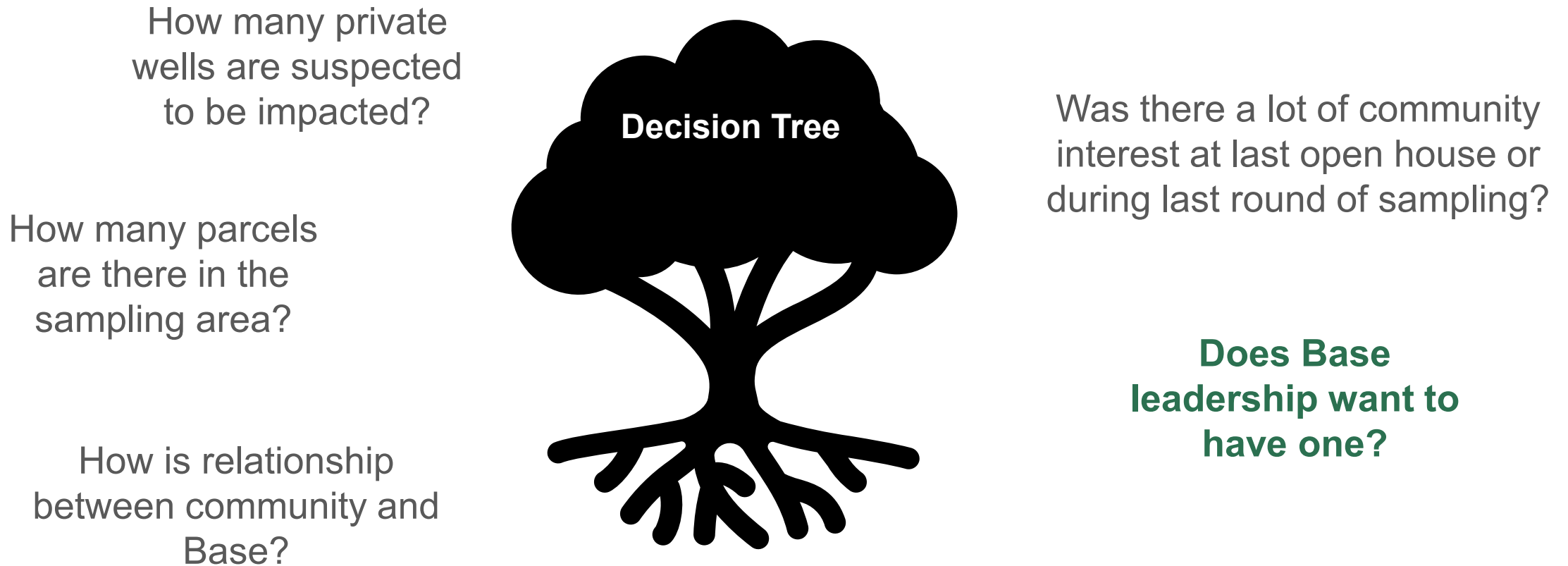
- Have outstanding questions been answered?
- Is additional outreach needed?
- Does public need to be updated on new information?
 - Step-out sampling
 - Discovery of new groundwater flow information
- Is website being kept up to date?

What Does Success Look Like?



- How many people signed up for well sampling?
- Did speakers build trust with the community?
- Did public learn more about the project?
- Did anyone leave indicating they felt better than when they arrived?

Is an Open House Necessary?



Rely on team input to make the decision.

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Case Study: NRL-CBD



(Baumann 2025)

**Off-base PFAS drinking
water step-out sampling
open house held
September 10, 2025.**

29 Team Members



- Internal team
 - NAVFAC Atlantic (2)
 - NAVFAC Washington (7)
 - Naval Support Activity Annapolis (3)
 - Naval Research Laboratory (3)
 - NMCFHPC (1)
- Partners
 - Maryland Department of the Environment (3)
 - Maryland Department of Health (1)
 - Calvert County Health Department (3)
- Contractor support
 - Jacobs (6)

Timeline Milestones



March 24, 2025: **Kickoff meeting**

August 13–14, 2025: **Preparation session**

August 26, 2025: **Congressional Delegation**

August 28, 2025: **Meeting outreach began**

September 8, 2025: **Reminder door hangers distributed**

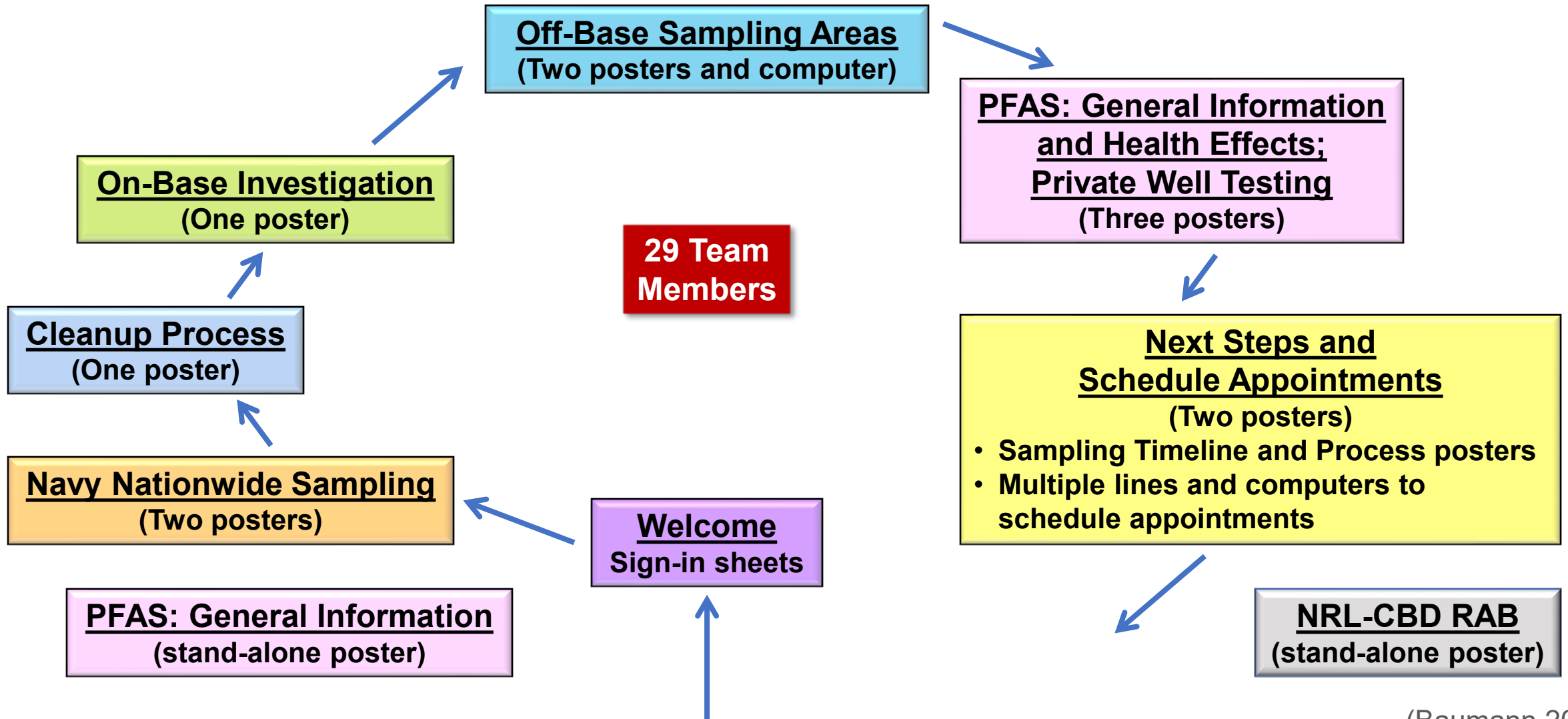
September 10, 2025: **Open House**

September 11, 2025: **Sampling began**

December 22, 2025: **Final results letters mailed out**

February 2026: **Planning meetings ended**

Posters Topics and Layout



(Baumann 2025)

Poster Station Assignments



Host: Commanding Officer, NSA Annapolis

Station	Subject Matter Experts	Rovers
Welcome/PAOs	Regina (NAVFAC Washington Public Affairs), Naval Support Activity Annapolis Public Affairs Officer, Greg (NRL Public Affairs), and Sharon (Navy and Marine Corps Force Health Protection Command)	Zoe (Naval Support Activity Annapolis)
Navy Nationwide Sampling	Paul and Laura (NAVFAC Atlantic)	Josh (NAVFAC Washington)
Environmental Cleanup Process	Curtis and Linda (Maryland Department of the Environment)	Josh and Alex (NAVFAC Washington)
On-Base Investigation	Morgan (NAVFAC Washington) and Andy (Jacobs)	Colin and Alex (NAVFAC Washington)
Off-Base Sampling (computer and television monitor)	Maggie and Mark (Jacobs), Cait (NAVFAC Washington RPM)	Colin and Alex (NAVFAC Washington)
PFAS (General Information and Health Effects) and Private Well Testing	General Information: Michael (Maryland Department of the Environment Toxicologist) Health Effects: Nimfa (County Health Department) and Clifford (Maryland Department of Health) Private Well Testing: Brooke and Jessica (County Health Department)	Jennifer and Anna (NRL)
Next Steps and Sampling Timeline and Appointments	Next Steps: Cassie (NAVFAC Washington) and Andrew (Jacobs) Sampling Appointments: Marita and Laura (Jacobs)	Jennifer and Anna (NRL)

(Baumann 2025)

Handouts and Reference Materials



- NRL-CBD Fact Sheet (*Welcome*)
- Point of Contact card (*Welcome*)
- Map of the room (*Welcome*)
- “What is PFAS” handout (*Welcome*)
- Health Department Fact Sheet (*PFAS*)
- Sampling appointment card (*Sampling*)
- ROE, questionnaire, and Frequently Asked Questions document (*Sampling*)
- Claim card (*Public Affairs Officer*)
- Reference materials
 - DoW policy
 - Previous results
 - Cross section

**Naval Research Laboratory – Chesapeake Bay Detachment**
Chesapeake Beach, Maryland
Private Drinking Water Well Sampling for PFAS

August 2025

The Navy is requesting property owner permission to sample private drinking water wells for per- and polyfluoroalkyl substances, or PFAS, within sampling areas near Naval Research Laboratory – Chesapeake Bay Detachment (NRL-CBD).

PFAS have been used in many household and industrial products because of their stain- and water-repellent properties. PFAS are now present virtually everywhere in the world because of the large amounts that have been manufactured and used. Once these compounds are released, many of them tend to stay in the environment for a very long time.

The most common activity associated with the historical release of PFAS to the environment at NRL-CBD (Figure 1) is the use of firefighting foam (specifically aqueous film-forming foam, or AFFF). Due to this historical use, PFAS are present in the groundwater on base and may be present in nearby private drinking water wells located in the direction that groundwater flows away from the base.

SEPTEMBER 2024 POLICY FOR PFAS IN PRIVATE DRINKING WATER WELLS

On April 26, 2024, the United States Environmental Protection Agency (EPA) published a National Primary Drinking Water Regulation (NPDWR) establishing nationwide drinking water standards for certain PFAS under the Safe Drinking Water Act. The regulation applies to public drinking water systems. Operators of public drinking water systems regulated by the NPDWR have until April 26, 2029, to meet these standards. In September 2024, the Department of Defense (DoD) published “Prioritization of Department of Defense Cleanup Actions to Implement the Federal Drinking Water Standards for Per- and Polyfluoroalkyl Substances under the Defense Environmental Restoration Program,” which describes DoD’s plans to incorporate the EPA’s drinking water regulation into DoD’s ongoing PFAS cleanups and prioritize actions to address private drinking water wells with the highest levels of PFAS from DoD activities. **Table 1** shows the DoD PFAS Interim Action Levels for Private Drinking Water Wells.

PREVIOUS PRIVATE DRINKING WATER WELL SAMPLING

In 2018, the Navy sampled 42 private drinking water wells near NRL-CBD. PFAS were detected in three private drinking water wells. Detections of PFOA and/or PFOS were not identified above 70 parts per trillion (ppt), the DoD action level at the time.

CURRENT EFFORTS

The Navy is requesting property owner permission to sample any private drinking water wells in the sampling areas near NRL-CBD (Figure 1). Due to improvements in laboratory methods, the Navy is also requesting property owner permission to resample private drinking water wells that were sampled in 2018.

Additionally, the Navy is requesting property owner permission to take an interim action to address PFAS at one private drinking water well sampled in 2018 where PFAS were detected at or above the current DoD PFAS Interim Action Levels for Private Drinking Water Wells (Table 1). Considering the levels in Table 1, the Navy has also determined that the off-base sampling area near NRL-CBD should be expanded.

PFAS	Level
perfluorooctanoic acid (PFOA)	12 ppt
perfluorooctane sulfonic acid (PFOS)	12 ppt
perfluorononanoic acid (PFNA)	30 ppt
perfluorohexane sulfonic acid (PFHxS)	30 ppt
hexafluoropropylene oxide dimer acid (HFPO-DA, or GenX)	30 ppt
hazard index for mixture of at least two of PFHxS, PFNA, HFPO-DA, and perfluorobutane sulfonic acid (PFBS)	3 (no units)

ppt = part(s) per trillion

These levels are based on current EPA NPDWR levels. If EPA updates applicable requirements, DoD will review and update its policy as appropriate.

PFAS are a family of thousands of different chemicals that have been widely used in many household and industrial products since the 1960s. The Navy and DoD have developed proactive policies to address past releases of PFAS, including perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS), at installations nationwide.

1

**Sample Information**

Below is the unique sample information for the sample collected at your house. Please retain this card for future reference.

Sample ID: _____

Sample date/time: _____

Please call **833-483-2637** if you have any questions or comments.

<https://go.usa.gov/xSeKE>



**Appointment for Water Sampling**

Employees of Jacobs (Navy contractor) will be at your house to collect water samples on: _____

at: _____

Please call **833-483-2637** if you need to change your appointment or if you have any questions or comments.



navfac_wash_publicaffairs@us.navy.mil

**Naval Research Laboratory – Chesapeake Bay Detachment**
Drinking Water Well Sampling Points of Contact

PUBLIC AFFAIRS OFFICER
NAVAL FACILITIES ENGINEERING
SYSTEMS COMMAND, WASHINGTON

navfac_wash_publicaffairs@us.navy.mil
(202) 685-0384

MARYLAND DEPARTMENT OF THE ENVIRONMENT /
Curtis Detore | Land Restoration Program, Federal Assessment and Remediation Division Chief |
curtis.detore@maryland.gov | 410-537-3791

MARYLAND DEPARTMENT OF PUBLIC HEALTH /
Dr. Clifford S. Mitchell | Director |
cliff.mitchell@maryland.gov | 410-767-7438

CALVERT COUNTY HEALTH DEPARTMENT /
Dr. Nimfa Teneza-Mora | Health Officer |
nimfa.teneza-mora@maryland.gov | 410-535-5400, Ext. 305

(NAVFAC 2025)

PFAS General Information Poster



What Are PFAS?

- A diverse group of manufactured chemicals
- PFOA (perfluorooctanoic acid) and PFOS (perfluorooctane sulfonic acid) have been widely studied
- Present in the environment around the world (in air, water, soil, animals, plants, and humans)
- Widely used since 1940s in many products, such as:



firefighting foam



nonstick cookware



food packaging



personal care products



stain-resistant carpets and fabrics



water-resistant fabrics

- Called "forever chemicals" because they can last a long time in the environment
- Ongoing nationwide effort to phase out PFAS in manufactured products

TO REQUEST DRINKING WATER WELL SAMPLING
leave a message at (833) 483-2637 or email
NAVFAC_WASH_PublicAffairsOffice@us.navy.mil

FOR MORE INFORMATION
visit <https://go.usa.gov/xSeKE>
or scan the QR code →



(Stand-alone
mini-poster)

(NAVFAC 2025)

DoW and Navy Policy Nationwide Sampling Posters



Why Is the Navy Sampling for PFAS in Private Drinking Water Wells Nationwide?

- The Navy is addressing PFAS across all installations
- Since 2016, the Navy's priority has been to address potential exposure in drinking water wells in neighboring communities
 - At that time, the Navy could respond if two PFAS (PFOA and PFOS) were in drinking water greater than 70 ppt
- In April 2024, the EPA published standards (maximum contaminant levels) for PFAS in public drinking water systems
- In response, DoD implemented a policy to address exposure in private drinking water wells

PFAS

PFAS	EPA Maximum Contaminant Levels	DoD PFAS Interim Action Levels for Private Drinking Water Wells
perfluorooctanoic acid (PFOA)	4 ppt	12 ppt
perfluorooctane sulfonic acid (PFOS)	4 ppt	12 ppt
perfluorononanoic acid (PFNA)	10 ppt	30 ppt
perfluorohexane sulfonic acid (PFHxS)	10 ppt	30 ppt
hexafluoropropylene oxide dimer acid (HFPO-DA, or GenX)	10 ppt	30 ppt
hazard index for mixture of at least two of PFHxS, PFNA, HFPO-DA, and perfluorobutane sulfonic acid (PFBS)	1 (no units)	3 (no units)

Note: These levels are based on current EPA National Primary Drinking Water Regulation levels. If EPA updates applicable requirements, DoD will review and update its policy as appropriate.

The Navy continually evaluates PFAS exposure and takes action as necessary.

TO REQUEST DRINKING WATER WELL SAMPLING
leave a message at (833) 483-2637 or email
NAVFAC_WASH_PublicAffairsOffice@us.navy.mil

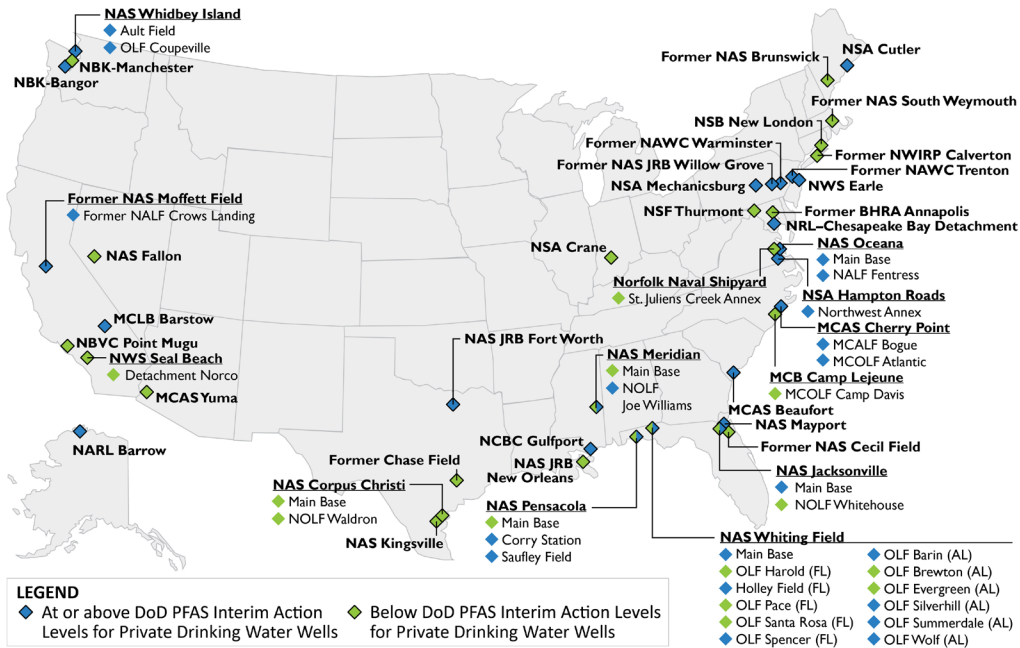
FOR MORE INFORMATION
visit <https://go.usa.gov/xSeKE>
or scan the QR code →



ACRONYMS & ABBREVIATIONS

DoD	Department of Defense	PFAS	per- and polyfluoroalkyl substances
EPA	U.S. Environmental Protection Agency	ppt	part(s) per trillion
NRL-CBD	Naval Research Laboratory – Chesapeake Bay Detachment		

Navy Private Drinking Water Well Sampling



As of May 30, 2025

TO REQUEST DRINKING WATER WELL SAMPLING
leave a message at (833) 483-2637 or email
NAVFAC_WASH_PublicAffairsOffice@us.navy.mil

FOR MORE INFORMATION
visit <https://go.usa.gov/xSeKE>
or scan the QR code →



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(NAVFAC 2025)

Environmental Cleanup Poster



Environmental Cleanup Process

PRIORITY: Protect Human Health and the Environment

- The EPA cleanup process is used to identify and clean up past environmental releases, including PFAS
- The Navy is responsible for implementing the investigation and cleanup process
- Maryland Department of the Environment provides regulatory oversight in consultation with other state and local agencies
- The investigation and cleanup process depends on multiple factors and can be lengthy to complete

Protective interim actions can be taken at any time

PFAS Environmental Cleanup Process



Investigate

- Evaluate potential releases
- Determine amount and size of contamination
- Determine and address potential exposures and risks

Determine cleanup options

- Evaluate:
 - Length of cleanup
 - Regulatory requirements
 - Costs
 - Current technology
- Request public input
- Make cleanup decisions

Plan and implement

- Develop and implement plans
- Provide long-term management

Cleanup complete

- Achieve long-term project goals

TO REQUEST DRINKING WATER WELL SAMPLING
leave a message at (833) 483-2637 or email
NAVFAC_WASH_PublicAffairsOffice@us.navy.mil

FOR MORE INFORMATION
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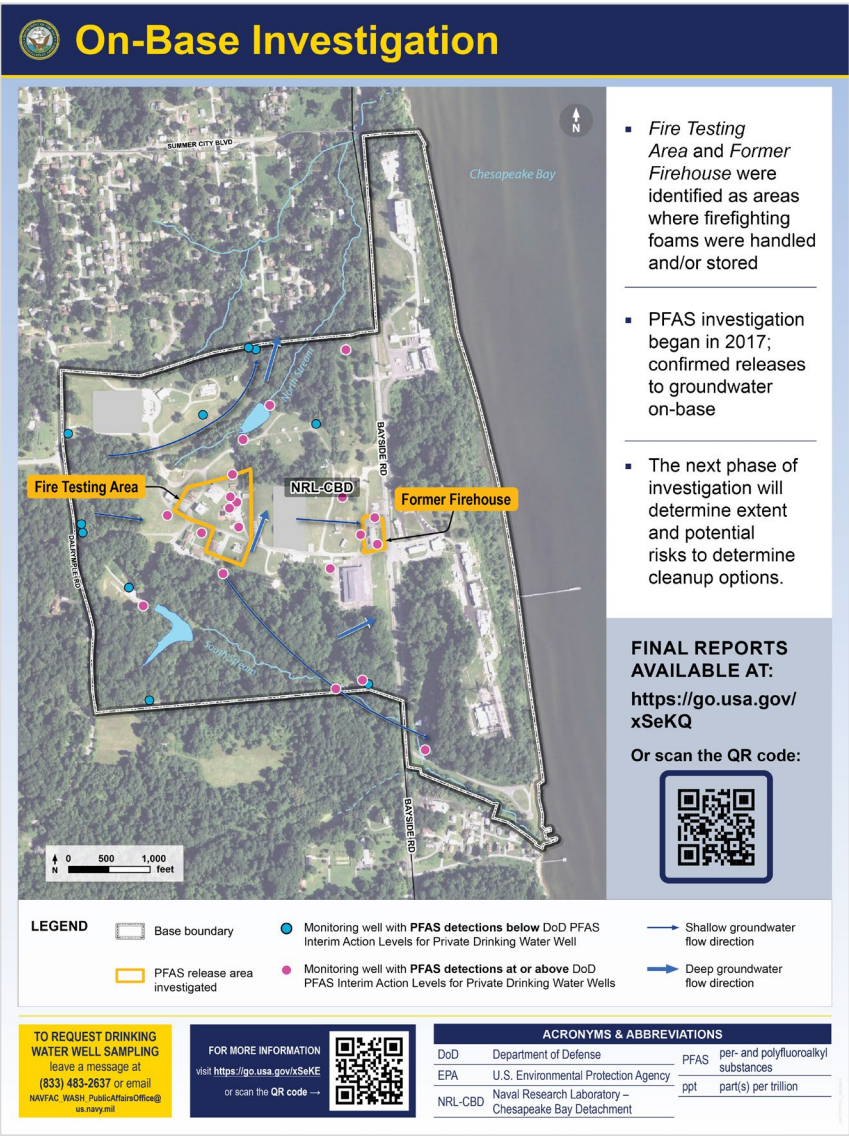


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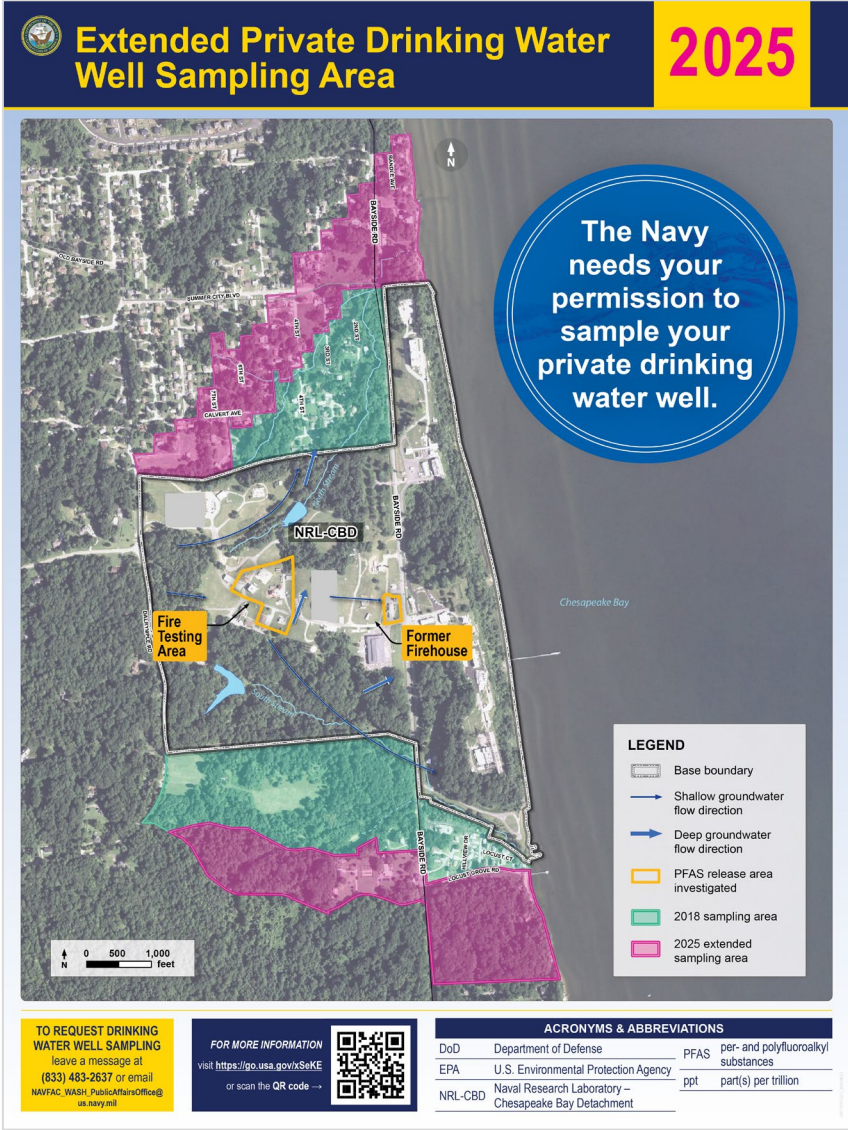
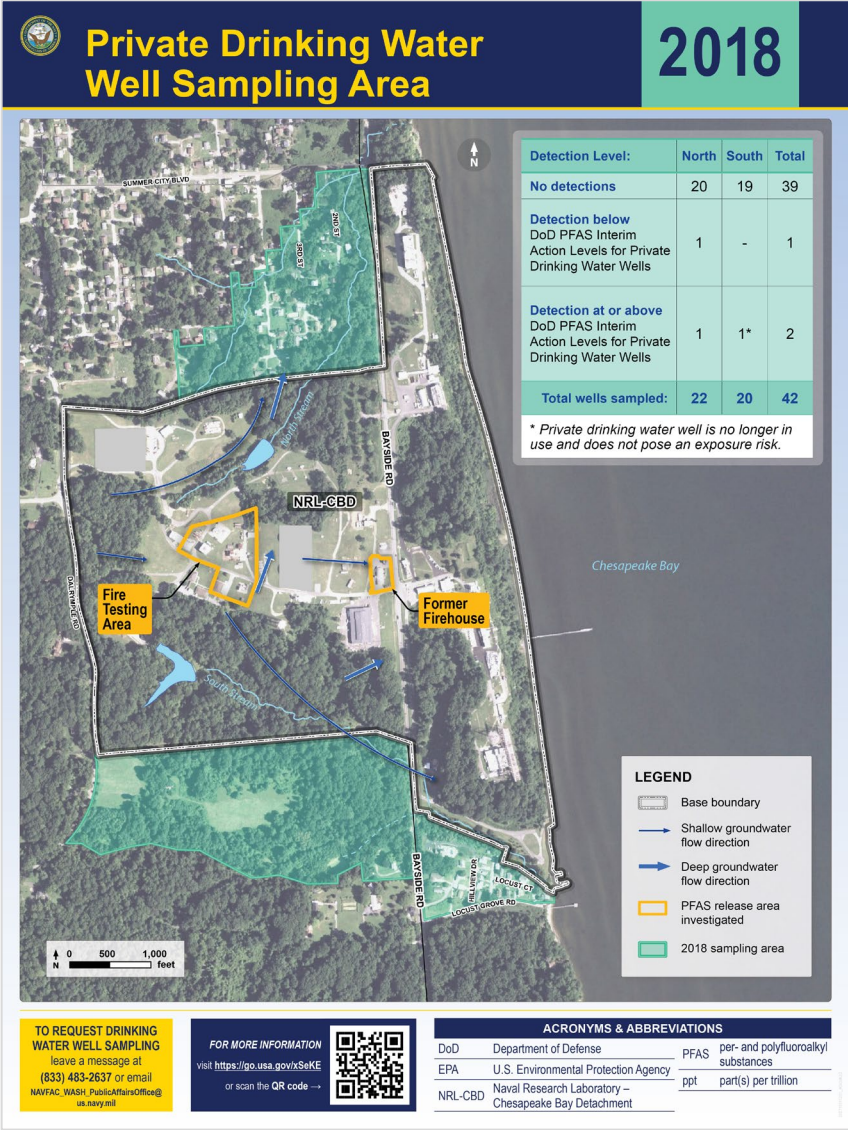
(NAVFAC 2025)

On-Base Investigation Poster



(NAVFAC 2025)

Off-Base Sampling Posters



(NAVFAC 2025)

PFAS General Information and Health Effects Posters



Per- and Polyfluoroalkyl Substances (PFAS)

What Are PFAS?

- A diverse group of manufactured chemicals
- PFOA (perfluorooctanoic acid) and PFOS (perfluorooctane sulfonic acid) have been widely studied
- Present in the environment around the world (in air, water, soil, animals, plants, and humans)
- Widely used since 1940s in many products, such as:



firefighting foam



nonstick cookware



food packaging



personal care products



stain-resistant carpets and fabrics



water-resistant fabrics

- Called "forever chemicals" because they can last a long time in the environment
- Ongoing nationwide effort to phase out PFAS in manufactured products

How Can People Be Exposed to PFAS?

- PFAS may be present in drinking water, food, indoor dust, some consumer products, and workplaces
- Most non-work-related exposure sources are drinking water and eating food that contains PFAS
- PFAS can transfer to unborn offspring or nursing infants by mothers exposed to PFAS

How Can People Reduce Exposure to PFAS?

- **GET YOUR DRINKING WATER WELL TESTED**
- If test results warrant, use an alternative water source for drinking, cooking, and making baby formula
- Certain certified filters can reduce PFAS in drinking water



For more information from the EPA about PFAS filtration systems, scan the QR code or visit: <http://www.epa.gov/system/files/documents/2024-04/water-filter-fact-sheet.pdf>

ACRONYMS & ABBREVIATIONS

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TO REQUEST DRINKING WATER WELL SAMPLING
leave a message at (833) 483-2637 or email
NAVFAC_WASH_PublicAffairsOffice@us.navy.mil

FOR MORE INFORMATION
visit <https://go.usa.gov/xSeKE>
or scan the QR code →



PFAS Exposure and Health Effects

What Are the Possible Health Effects?

- Scientists are actively studying PFAS and how PFAS exposure can affect human health
- Exposure to PFAS could increase the risk of:
 - 1 High cholesterol levels
 - 2 Lower response to some vaccinations
 - 3 Lower infant birth weight
 - 4 Some cancers
 - 5 Higher blood pressure in pregnant women
 - 6 Changes in liver enzymes

Chemical exposures do not always lead to health effects.



Are Blood Tests Available for PFAS?

- Blood testing for PFAS is not a regular test offered by a doctor
- Blood test results will not tell you if PFAS exposure will cause current or future health issues

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Private Well Testing Poster

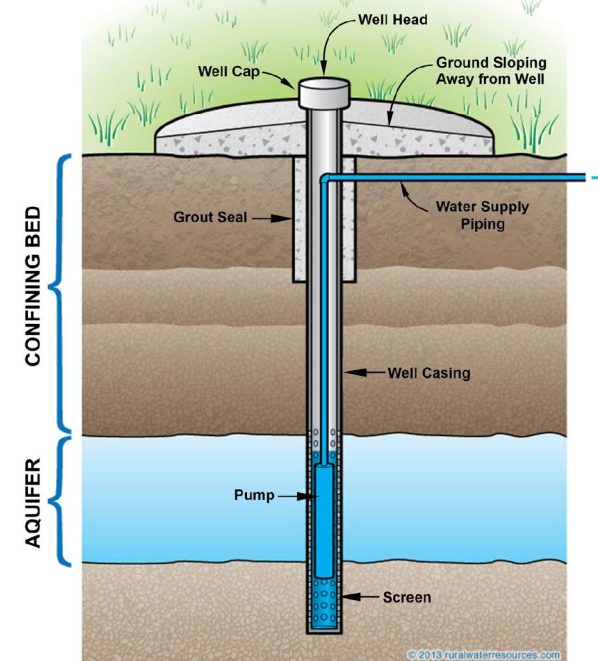


Private Well Maintenance

Minimizing the Risks

- Testing of private drinking water wells is recommended to ensure water quality.
- The National Ground Water Association recommends well owners test their water at least annually for contaminants, including bacteria and nitrates.
- More frequent testing is recommended if your water changes in taste, odor, or appearance.
- If using water conditioner (aka, “water softener”) equipment, it should be maintained and kept in working order.
- Do not dispose of or store hazardous materials or chemicals near your well.

Typical Well Design



TO REQUEST DRINKING WATER WELL SAMPLING
leave a message at (833) 483-2637 or email
NAVFAC_WASH_PublicAffairsOffice@us.navy.mil

FOR MORE INFORMATION ABOUT DRINKING WATER
LABORATORIES THAT CAN TEST FOR PFAS, VISIT:
[https://mde.maryland.gov/programs/
water/water_supply/Documents/
PFAS-Certified-Labs.pdf](https://mde.maryland.gov/programs/water/water_supply/Documents/PFAS-Certified-Labs.pdf)
or scan the QR code →



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(NAVFAC 2025)

Next Steps and Scheduling Appointments Posters



What Happens Next?

Within **30 days** of sampling,
a Navy representative will contact property owner

Results below DoD PFAS Interim Action Levels for Private Drinking Water Wells

- Final results mailed within 3 months of sampling



The Navy will continue to expand the sampling area as needed.

Results at or above DoD PFAS Interim Action Levels for Private Drinking Water Wells

- The Navy will set up an appointment to discuss preliminary results and next steps
- Final results mailed within 3 months of sampling

Next steps

- DoD enduring solutions may include:
 - Connection to public water, if available
 - Treatment system installation
- If PFOA and PFOS are above 70 ppt, the Navy will provide bottled water until an enduring solution is implemented

For more information from the EPA about PFAS filtration systems, scan the QR code or visit:

<http://www.epa.gov/system/files/documents/2024-04/water-filter-fact-sheet.pdf>



For more information

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FOR MORE INFORMATION
visit <https://go.usa.gov/xSeKE>
or scan the QR code →



Sign Up for Your Sampling Appointment

Sampling Appointment

- No cost to you
- Available daily (including weekends) from 8 a.m. to 6 p.m.
- Starting Thursday, September 11, through Wednesday, September 24
- Additional times are available upon request

Sampling Process

- Samples will be collected by a team of two experienced professionals:
 - Sampling is non-intrusive and typically takes less than an hour
 - Collected directly from a tap as close to well as possible
 - Water is run prior to sample collection
- Samples will be collected and analyzed according to EPA-approved methods
- Specific safety and/or health precautions during sampling will be considered, if requested in advance by property owner or tenant

What We Need from You

- Right-of-Entry Agreement signed by property owner
- Completed drinking water well questionnaire
- Authorized adult (18 or older) must be present at the property during sampling

To schedule an appointment after the Open House, please call
(833) 483-2637
and leave a message.

TO REQUEST DRINKING WATER WELL SAMPLING
leave a message at (833) 483-2637 or email
NAVFAC_WASH_PublicAffairsOffice@us.navy.mil

FOR MORE INFORMATION
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NRL-CBD RAB Poster





Community Involvement

Option for Increased Community Involvement

Restoration Advisory Board (RAB)

- A group of interested local community members who meet with and provide input to the Navy and state regulatory agency staff on environmental cleanup plans and actions.

- The NRL-CBD RAB currently **meets biannually**
- All meetings are **open to the public**

What are RAB Member Responsibilities?

- Provide community input to the Navy, regulators, and other government agencies on environmental clean-up activities.
- Attend routine RAB meetings and discuss and exchange information regarding site cleanup.
- Review and comment on various technical documents and related site information.
- Serve as a liaison with the community and provide them with information discussed at the RAB meetings.

UPCOMING RAB MEETING

Wednesday,
October 22, 2025

at 6:00 p.m.

Calvert Library
Twin Beaches Branch
4100 5th St.
North Beach, MD 20714

Fill out sign-up sheet to receive email notifications.

For more information visit:

1 <https://go.usa.gov/xSeKn>

2 or scan the QR code:



NRL-CBD NAVAL RESEARCH LABORATORY - CHESAPEAKE BAY DETACHMENT

(Stand-alone
mini-poster)

(NAVFAC 2025)

Open House Meeting



- Attendance: 25 people
- Difficult situations
 - Shared wells
 - Newly renovated well
- Several sampling sign-ups (there was a line)



(Baumann 2025)

Presentation Overview



- Introduction
- Public Outreach
- Risk Communication Principles
- Planning an Effective Open House Meeting
- Case Study: NRL-CBD
- How Do You Start?
- Summary and Closing Statements

Get NAVFAC Atlantic Involved EARLY



- **DASN(MR&E) would like NAVFAC Atlantic to be involved in the process**
- Experienced personnel are an extremely valuable source
- Read the Private Drinking Water Well Sampling Community Outreach Work Plan
 - Guide that provides an outlined approach for informing the community of planned private drinking water well sampling
 - Can be obtained from NAVFAC Atlantic
 - Several outreach material templates provided as starting point
 - Template to build project schedule
- NAVFAC Atlantic personnel will steer team in right direction

DASN(MR&E): Deputy Assistant Secretary of the Navy for Mission Readiness and Environment

Contact “The Force”



- **DASN(MR&E) recommends that NMCFHPC be involved**
- NMCFHPC is already funded by NAVFAC Headquarters Environmental Restoration
 - Outreach planning team participant
 - Outreach material review
 - Preparation training and workshop for meetings and other outreach
 - RAB presentation review
 - Community Involvement Plan
 - Online survey
 - Review of Community Involvement section of the plan

*Use this QR code to
test it out!*



Presentation Overview



- Introduction
- Public Outreach
- Risk Communication Principles
- Planning an Effective Open House Meeting
- Case Study: NRL-CBD
- How Do You Start?
- Summary and Closing Statements

Key Takeaways



KEY POINT

PFAS public outreach is necessary but can be confrontational.

KEY POINT

Risk communication principles can help when speaking to public about PFAS off-Base sampling.

KEY POINT

Preparing for PFAS off-Base sampling public outreach takes a lot of time and effort but is well worth it and there is help to get it done.

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Questions



Optimizing the Journey to Long-Term Management and Site Closure

Paul Favara, P.E., and Kim-Lee Yarberry, P.G.
Jacobs

RITS 2026

Disclaimer



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Information in this presentation is current as of April 22, 2026.

EXWC: Engineering and Expeditionary Warfare Center
NAVFAC: Naval Facilities Engineering Systems Command

Speaker Introduction



Paul Favara, P.E. Sr. Principal Technologist



- M.S., Environmental Engineering, Illinois Institute of Technology, 1987
- B.S., Business Oriented Chemistry, Western Michigan University, 1983
- P.E., Florida, 1990
- LEED Green Associate, 2013
- 41 years (26 years with Jacobs)
- Working on Navy projects since 2000 (GFFP, CLEAN, RAC, SB-RAC)

CLEAN: Comprehensive Long-term Environmental Action—Navy
GFFP: guaranteed firm fixed price
LEED: Leadership in Energy and Environmental Design

Navy: Department of the Navy
RAC: Remedial Action Contract
SB-RAC: Small Business Remedial Action Contract

Speaker Introduction



Kim-Lee Yarberry, P.G. Senior Technologist



- M.S., Environmental Engineering and Science, Clemson University, 1999
 - Fate and Transport Focus
- B.S., Environmental Geoscience, University of Connecticut, 1997
- P.G., Georgia and Mississippi
- Joined CH2M HILL, Inc. (now Jacobs) in 1999
 - Program Technology Manager for Navy CLEAN contract
 - Leader of Jacobs' Field Characterization Method Community of Practice

Presentation Overview



- Introduction
- Overview of Exit Strategy Options
- Decision Frameworks
- Transition Assessments
- Case Studies
- Overcoming Challenges
- Wrap Up

Objectives



1. **Overview of Exit Strategy Options:** Create awareness of endpoints, core components, approaches, and best management practices
2. **Decision Frameworks:** Plan future decisions points and potential outcomes
3. **Transition Assessments:** Identify points where active remedies can transition to passive strategies
4. **Case Studies:** Provide examples of how above topics have been implemented in Navy projects
5. **Overcoming Challenges:** Identify common challenges and approaches to overcoming those challenges

Key Definitions



- **Exit Strategy:** Detailed, dynamic, and succinct plan for accomplishing specific performance goals within a defined time period to assure protection of human health and the environment (ITRC 2006 as cited in NAVFAC 2022a)
- **Decision Framework:** A structured process that uses site data, performance metrics, and decision criteria to guide exit strategies and transition decisions toward LTMgt or site closure (consistent with regulatory and NAVFAC guidance)
- **Transition Assessment:** A process to determine when a transition from an active treatment to a long-term passive treatment such as MNA (NRC 2013 as cited by SERDP 2024)

LTMgt: long-term management

MNA: monitored natural attenuation

Past Related RITS Offerings



- **2025:** Optimization Tools and Strategies Implemented at Sites with Long-Term Remediation Systems
- **2023:** Best Practices and Risk Management Options for Metal-Impacted Sites
- **2019:** How Much Risk Does LNAPL Pose at Legacy Petroleum Impacted Sites?

LNAPL: light nonaqueous phase liquid

Navy Optimization Policy



- Policy for Optimizing Remedial and Removal Action at Navy ER Program Sites (NAVFAC 2012)
 - Re-emphasizes that “opportunities to improve performance...shall be considered and implemented throughout all phases of remediation...”
 - SiteWise should continue to be used to assess life cycle considerations when evaluating remedial alternatives within the Feasibility Study
 - Solely considering energy usage, water usage, criteria pollutants, and safety – primary metrics that impact our efficiency and cost-effectiveness in remediating our cleanup sites
- Policy for Optimizing Remedial and Removal Actions under the ER Programs (Navy 2004)
 - Establishes procedures for optimizing the screening, evaluation, selection, design, and implementation for long-term operation and management of response actions

ER: environmental restoration

NORM Optimization Module



- Optimization actions shall be entered and tracked in the NORM Optimization Module
 - Supports adherence to Navy Optimization Policy
 - Provides visibility to Headquarters/Assistant Secretary of the Navy on potential future cost avoidances
 - Demonstrates continued fiscal responsibility within the program
- NORM Optimization Module required data include:
 - CERCLA phase
 - Goal and success indicators
 - Implementation date and cost
 - Cost avoidance and final potential cost avoidance
 - Acceleration dates
 - Description of the optimization review
 - Reduced impacts of energy consumption, criteria air pollutants, water usage, and worker safety



(NAVFAC n.d.)

CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act

NORM: Normalization of Environmental Data Systems

New OPTI Award!

- Advancing an optimized approach or technology that:
 - Improves ROI or reduces costs
 - Accelerates reaching remedial goal
 - Is innovative
 - Requires extra/unique stakeholder negotiations
- Action MUST be entered into the NORM Optimization Module for consideration
- Annual award for accomplishments over past 2 years
- Two awardees—one from Atlantic AOR and one from Pacific AOR
- OTI Workgroup Members review NORM entries and recommend awardees to Headquarters and ER Managers

AOR: area of responsibility

OTI: Optimization and Technology Innovations

ROI: return on investment



(Stanley London n.d.)



Presentation Overview



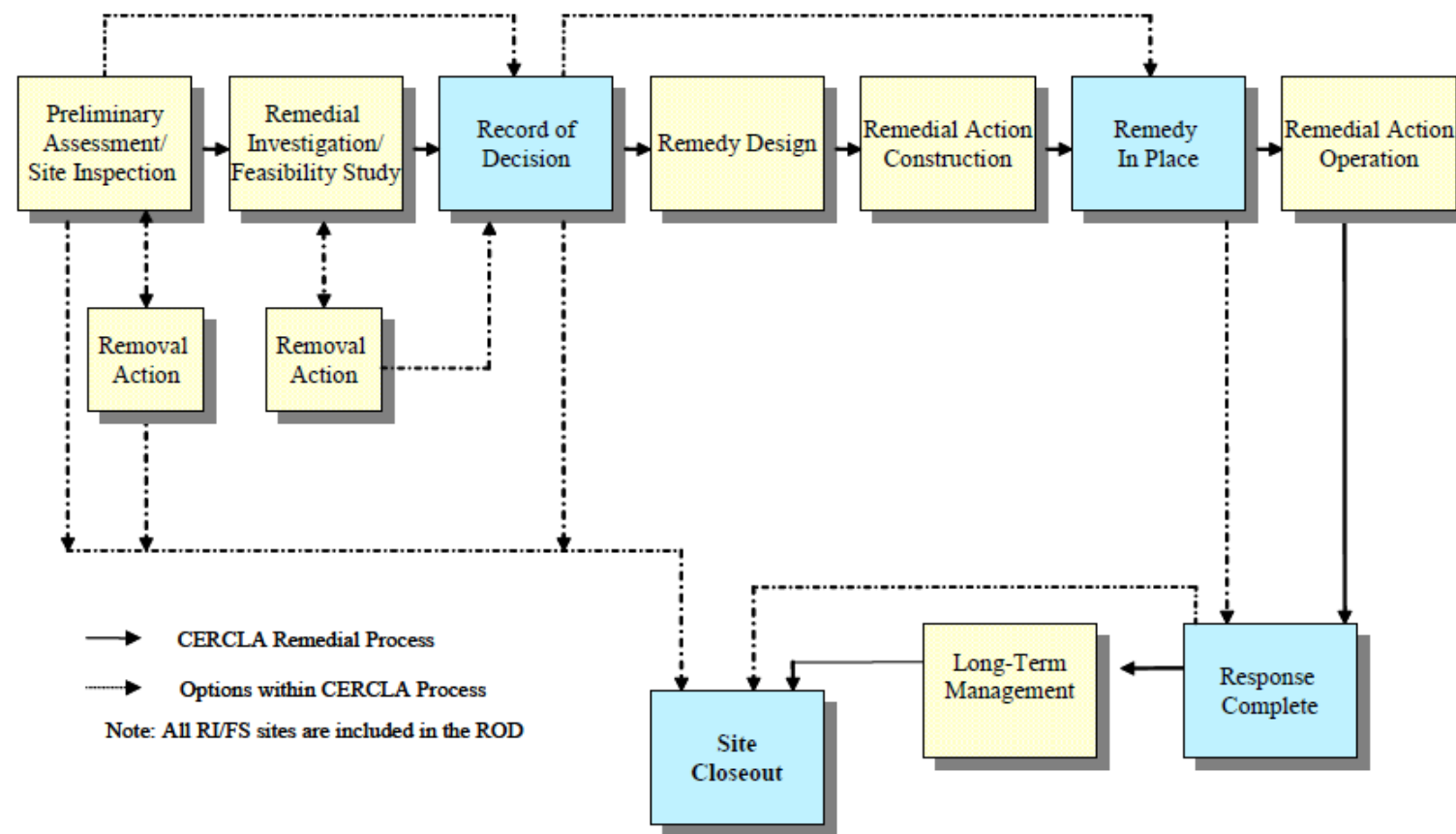
- Introduction
- Overview of Exit Strategy Options
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- Wrap Up

Navy ER Process: Key Exit Strategy Terms



Navy Environmental Restoration Process – Phases and Milestones

- Milestone metrics used to measure ER Program progress
- SC is the ultimate endpoint objective in an exit strategy
- LTMgt may be an acceptable endpoint at complex or perpetual care (e.g., landfill sites)



(NFESC 2006)

FS: Feasibility Study
RI: Remedial Investigation
ROD: Record of Decision
SC: site closeout

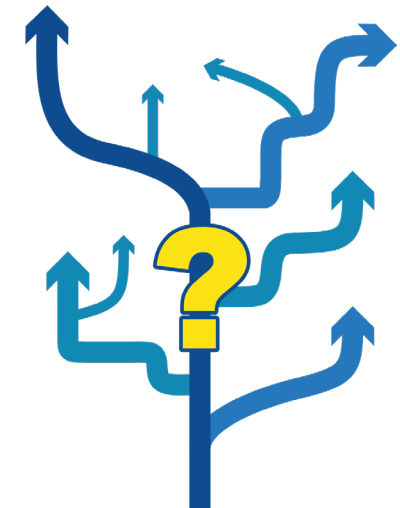
Factors that Favor Exit Strategy with LTMgt Endpoint



- Lack of regulatory pathway to SC
- Persistence of NAPL
- Persistent groundwater contamination
- Very low numeric ARARs
- Engineered and/or administrative institutional controls can be enforced to maintain protectiveness of HH and environment with in-place residual contaminants
- Natural processes or engineered remedy demonstrated to mitigate migration of NAPL and dissolved plume
- Heterogeneous fine-grained and/or bedrock lithology
- Sites with significant resiliency concerns
- Alternate, lower costs to achieve ARARs
- Ineffective prior source removal remedial activities

KEY POINT

Groundwater impacts typically drive both SC and LTMgt decisions.



ARARs: applicable or relevant and appropriate requirements

HH: human health

NAPL: nonaqueous phase liquid

Examples of SC and LTMgt Endpoints

KEY POINT

Note difference between soil and groundwater is RA-O.

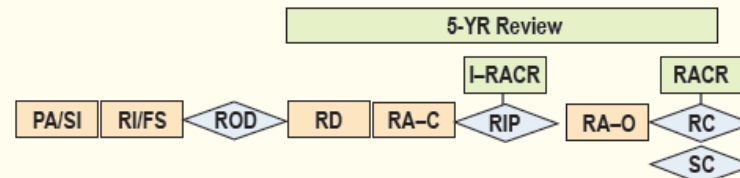
SC
endpoint

LTMgt
endpoint

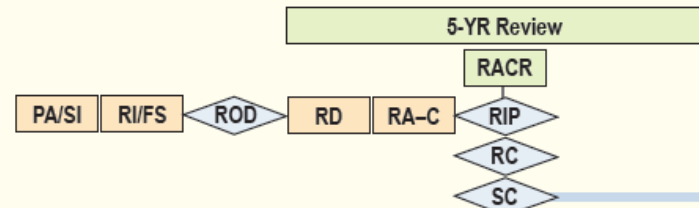
I-RACR: Interim Remedial Action Completion Report
 LUC: land use control
 MCL: maximum contaminant level
 PA: preliminary assessment
 RA-C: remedial action-construction
 RA-O: remedial action-optimization
 RACR: Remedial Action Completion Report
 RC: response complete
 RD: remedial design
 RIP: remedy in place
 SI: site inspection

Remedial Action Objective: Unlimited Use and Unrestricted Exposure (UU/UE)

Example: Groundwater remediation to MCLs requires RA-O to achieve UU/UE

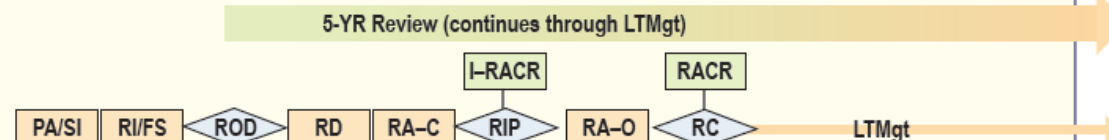


Example: Soil Excavation/Off-Site Disposal Achieves UU/UE

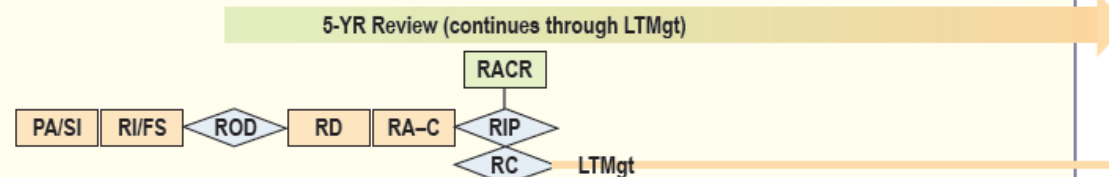


Remedial Action Objective: Restricted Land Use

Example: Groundwater remediation to industrial levels (or alternate concentration limits), LUCs, LTMgt



Example: Landfill Cover, LUCs, LTMgt



(NAVFAC n.d.)

Response complete for all sites at the installation – Navy issues Final RACR
 EPA prepares documentation for NPL delisting (FCOR)

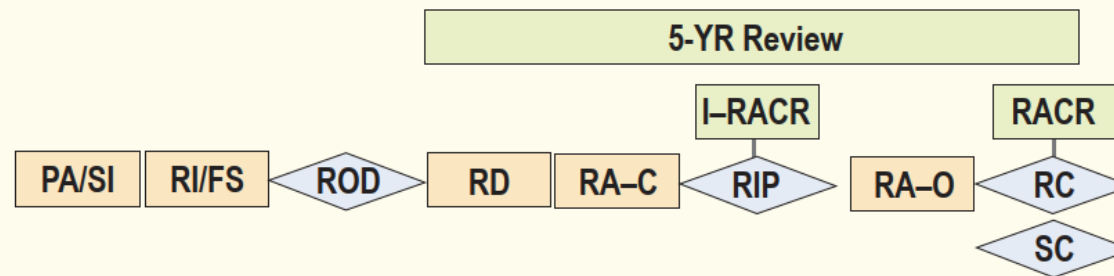
Groundwater, SC, and LTMgt Examples



SC

Remedial Action Objective: Unlimited Use and Unrestricted Exposure (UU/UE)

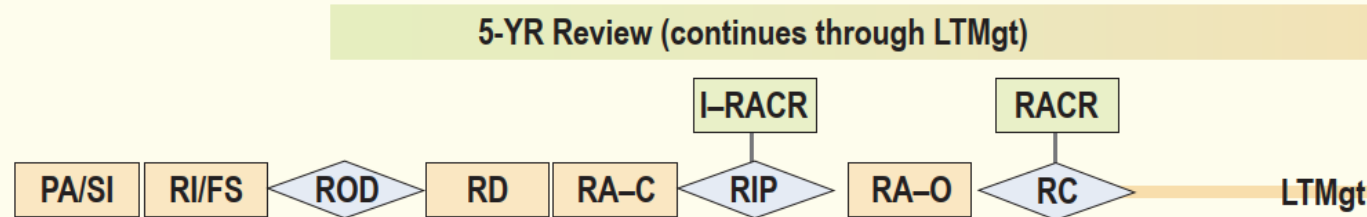
Example: Groundwater remediation to MCLs requires RA-O to achieve UU/UE



LTMgt

Remedial Action Objective: Restricted Land Use

Example: Groundwater remediation to industrial levels (or alternate concentration limits), LUCs, LTMgt



Adapted from
(NAVFAC n.d.)

KEY
POINT

Both require RC. For SC,
RC achieves UU/UE.

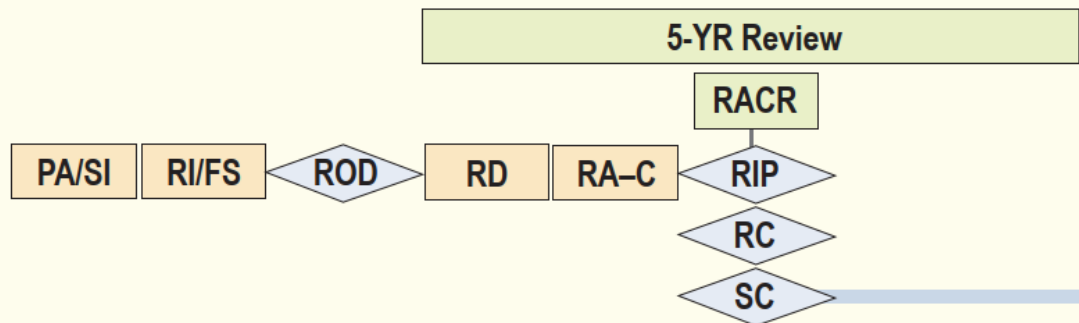
UU/UE: unlimited use and unrestricted exposure

Soil, SC, and LTMgt Examples



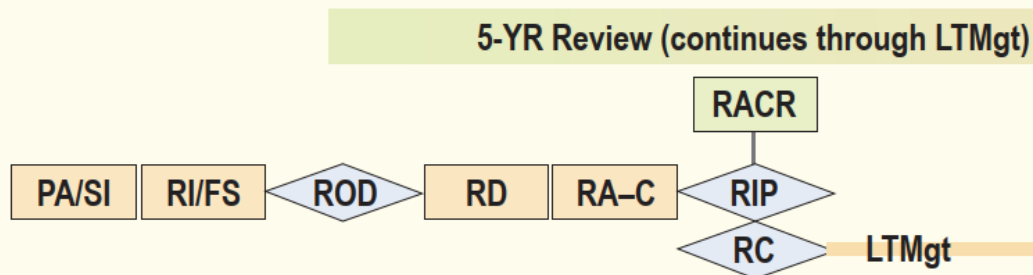
SC

Example: Soil Excavation/Off-Site Disposal Achieves UU/UE



LTMgt

Example: Landfill Cover, LUCs, LTMgt



Adapted from
(NAVFAC n.d.)

KEY
POINT

**Both require RC. For SC,
RC achieves UU/UE.**

Exit Strategies: Core Components



- Document and routinely assess exit strategy
 - Include updated milestones and metrics for success
- Apply optimization principles to track progress and transition remedies
 - Metrics for transition
 - Routine performance evaluations
 - Revisit original assumptions, cost estimates, and remedial time frames
- Update the CSM as site conditions change
 - Data gaps needed to facilitate site understanding
- Select effective remedial technologies
 - Consider contingency actions
- Flexible decision documents
 - ESD can document changes

CSM: conceptual site model

ESD: Explanation of Significant Differences

KEY
POINT

Document and then
routinely assess and
adapt your exit strategy.

*Example engaging
graphical exit
strategy presentation*

EPA: United States Environmental Protection Agency

EVS: Earth Volumetric Studio

GW: groundwater

MNA: monitored natural attenuation

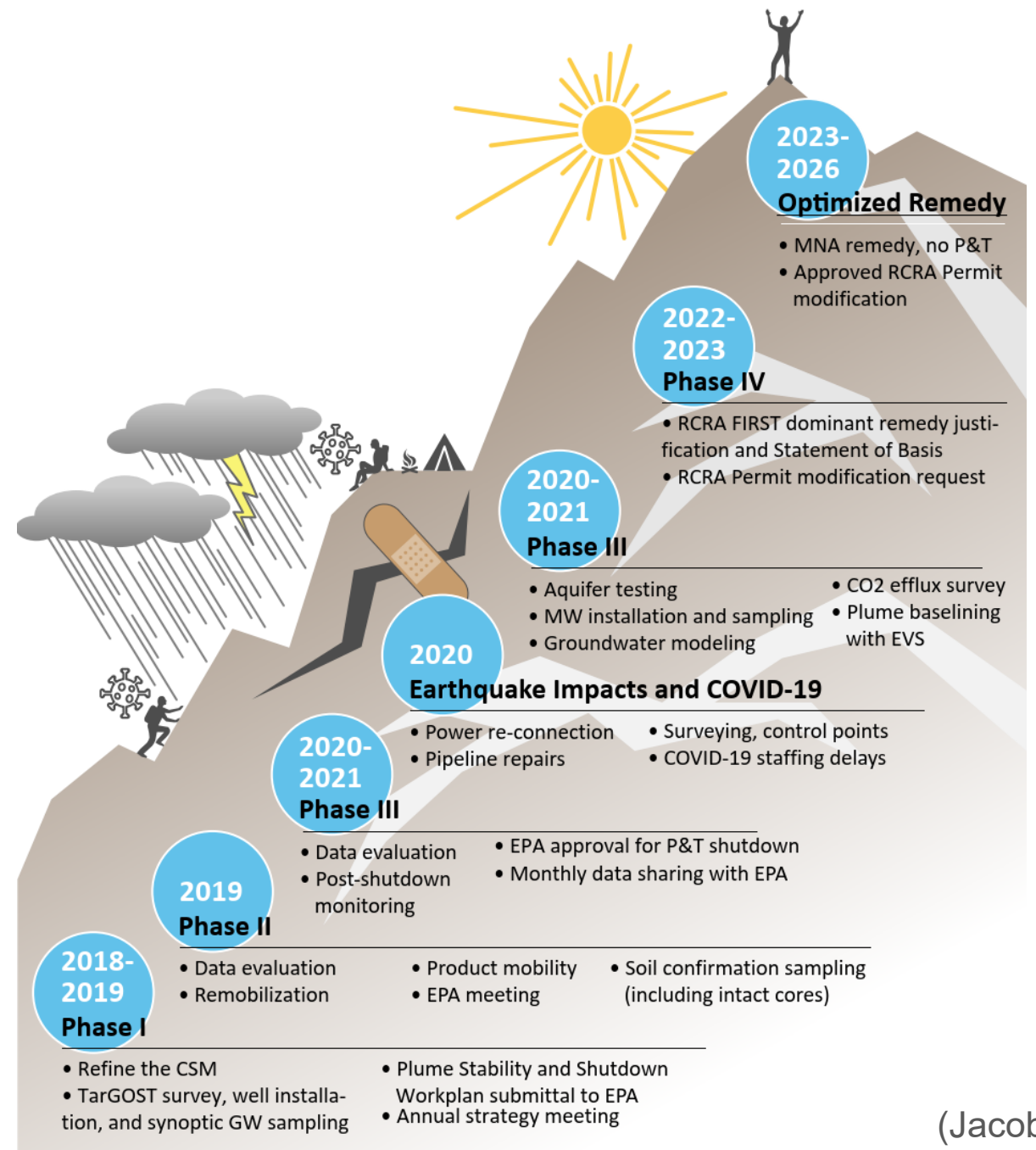
MW: monitoring well

P&T: pump and treat

RCRA: Resource Conservation and Recovery Act

TarGOST: Tar-specific Green Optical Screening Tool

Overview of Exit Strategy Options



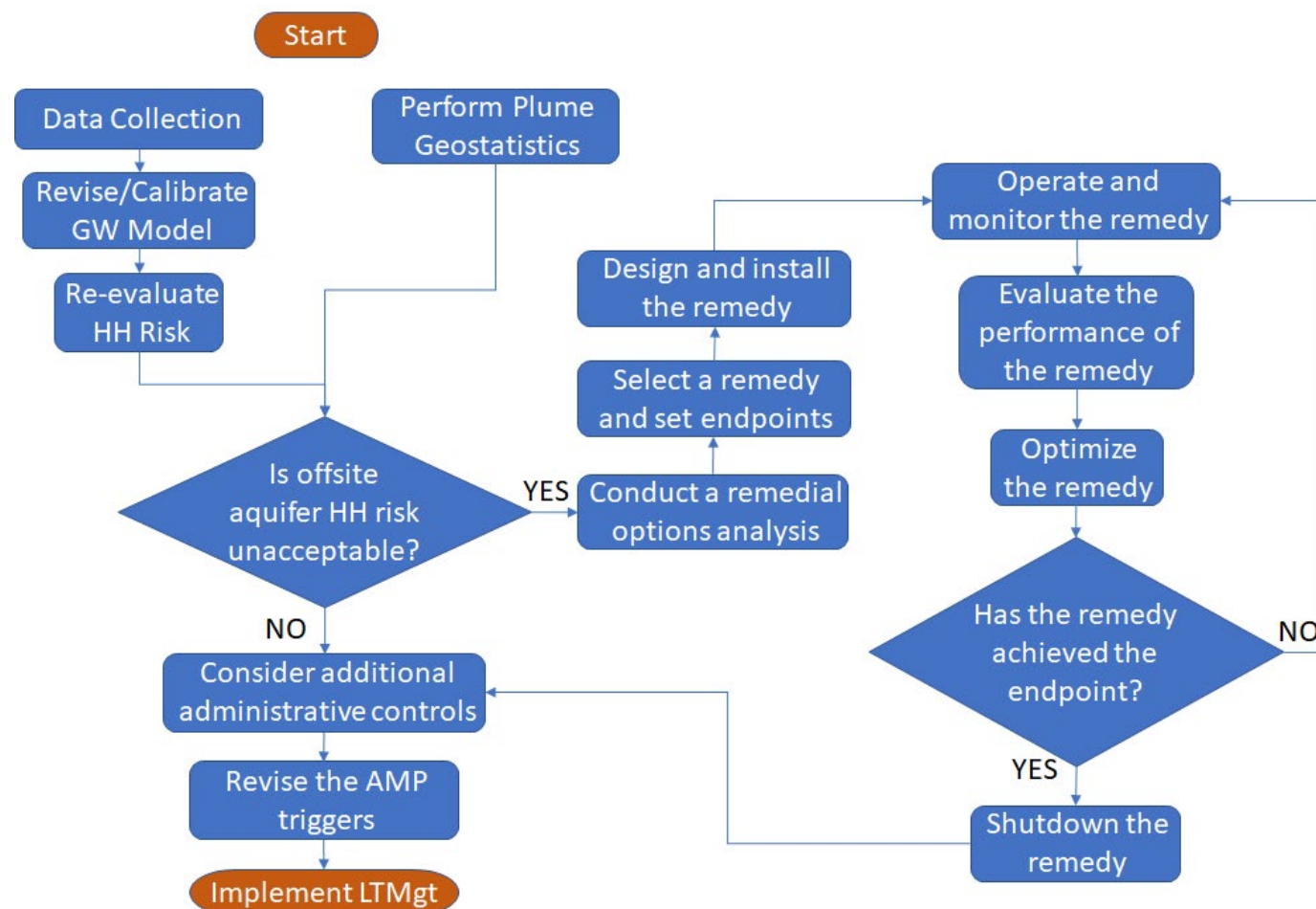
(Jacobs 2025)

Example Path to LTMgt for Risk Management



- Risk-based assessment of site conditions
- Exit strategy depends on the outcome of the HHRA
- Proposed approach to ultimately achieve LTMgt
- SC not viable
- Cost increment to SC should always be a consideration

AMP: adaptive management plan
HHRA: human health risk assessment



Exit Strategy Approach Options



Regulatory and Administrative

- Groundwater use reclassification
- ACLs
- Points of compliance
- LUCs, including institutional and engineering controls
- TI waivers

ACL: alternate concentration limit

TI: technical impracticability

Exit Strategy Approach Options (continued)



Technical and Remedy-Based

- Risk-based or low-threat closure
- Source control or partial removal
- Transition from active to passive technologies
- MNA: NSZD
- California Low Threat Closure Criteria for UST Sites (CSWRCB 2025)

NSZD: natural source zone depletion

UST: underground storage tank

Exit Strategy Best Management Practices



- Engage stakeholders early, socialize approach
 - Follow a clear regulatory pathway for SC or LTMgt
 - Document all decisions and rationale
 - Use multiple lines of evidence to demonstrate plume stability and risk mitigation
 - Apply lessons learned from similar sites or installations
 - Adapt exit strategies and update CSM based on new data
 - Incorporate optimization throughout (policy link below) and document to support team changeover
- [DON Optimization Policy \(NAVFAC 2012\)](#)

KEY POINT

**An effective exit strategy
is a critical success factor.**

Knowledge Check: Exit Strategy Options



Question: What are important components of an exit strategy?

Answers:

- a. Review historical documents, summarize remedial objectives, evaluate remedial progress, and create a new exit strategy to fit the intentions
- b. Conduct a remedy performance evaluation to assess its ability to achieve the existing remedial objectives
- c. Revisit the CSM and past remedial technology selection assumptions, verify their validity, and close data gaps necessary to refine site understanding
- d. Evaluate and discuss remedial options to achieve SC (or LTMgt if SC not achievable) with stakeholders including the regulatory agency
- e. All of the above

Knowledge Check: Exit Strategy Options



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**KEY
POINT**

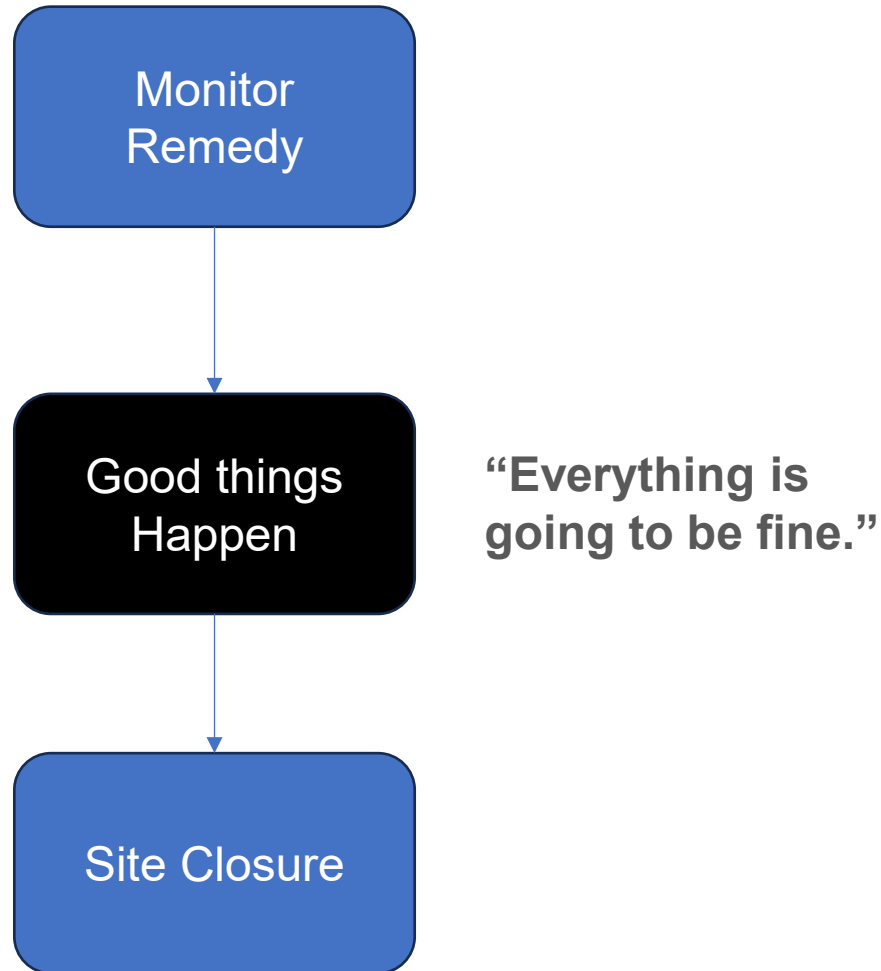
Hop in the driver's seat and chart your course to closure. It's not a regulatory required document but could be one of the most important to write.

Presentation Overview



- Introduction
- Overview of Exit Strategy Options
- **Decision Frameworks**
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Importance of Decision Frameworks



- Monitoring alone does not equal closure progress
- Performance data are collected, but not translated into decisions
- Assumptions made during remedy selection may persist long after site conditions change
- Without decision points, monitoring becomes end state instead of pathway

Define Decision Points and Potential Outcomes



- 1 What are metrics for the successful selected remedy?
- 2 What metrics will be used to measure progress?
- 3 What happens if performance objectives are not achieved?



LTM: long-term monitoring

(NAVFAC 2022)

Decision Points and Potential Outcomes



- Every selected remedy has multiple possible futures, including:
 - Performing as expected
 - Plateauing due to site complexity
 - Requiring optimization or augmentation, or transitioning to passive management or long-term stewardship
- Decision flowcharts help RPMs ask critical questions before issues arise:
 - What indicators suggest remedy is plateauing?
 - At what point does optimization make sense?
 - When should transition to MNA or LTMgt be evaluated?

RPM: Remedial Project Manager

Decision Points and Potential Outcomes



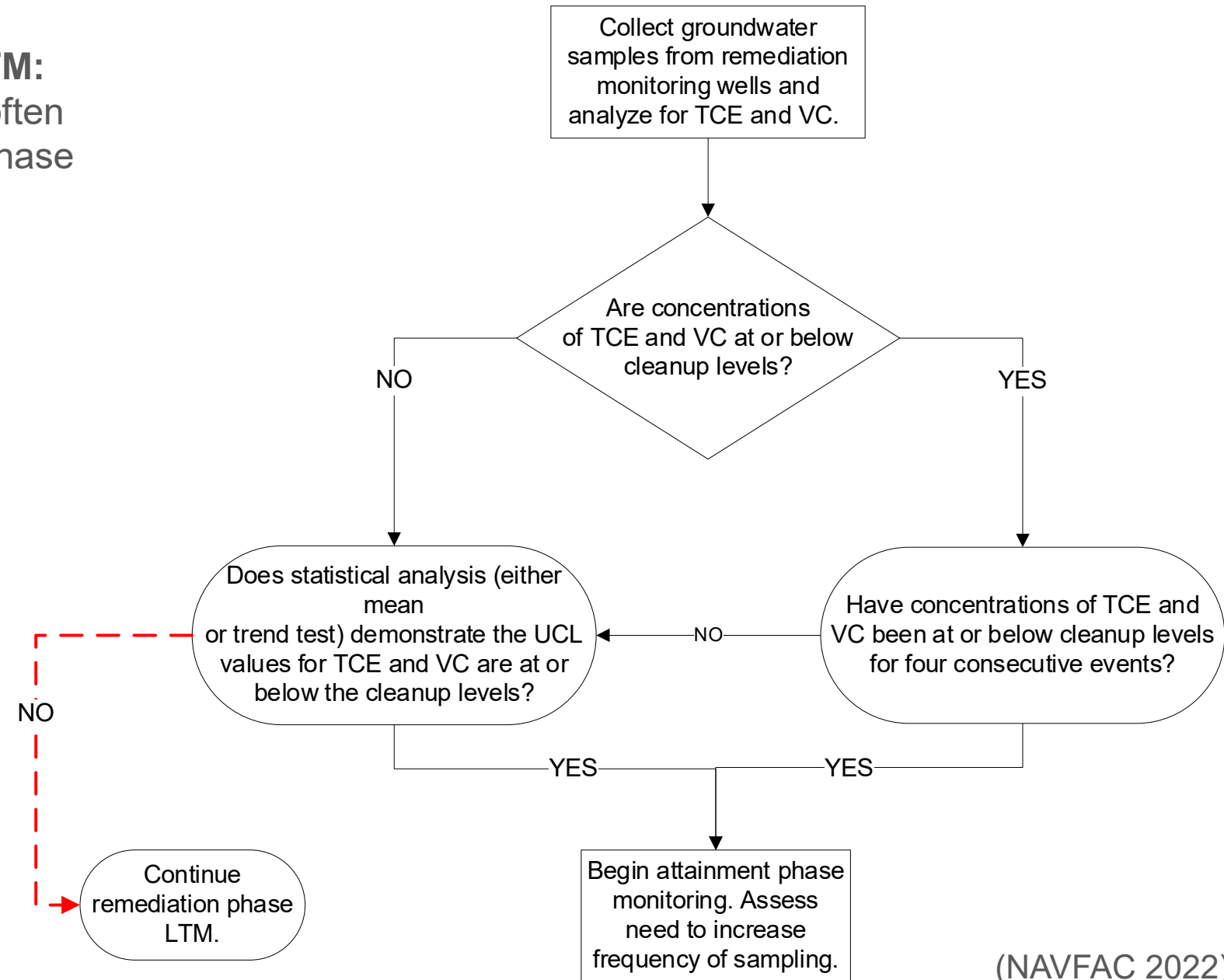
- Department of War and Navy guidance explicitly recognize that:
 - Active remedies may not achieve closure at complex sites
 - Transitioning remedies can still be protective and cost effective
 - LTMgt can be a planned outcome and not a failure
- Formal decision frameworks:
 - Reduce uncertainty for regulators and stakeholders
 - Support defensible transitions (e.g., active to passive)
 - Reduce life cycle costs and long-term liabilities
- To the extent possible, bake in flexibility

Decision Logic for JEB Little Creek Site 12



- **Remediation Monitoring** evaluates performance to assess if goals are achieved
- Predetermined number of samples are assessed to transition to attainment monitoring
- Flowchart is based on individual wells
- Does not address site as a whole

Remediation Phase LTM:
Groundwater sites are often challenged to exit this phase when goals are UU/UE.



TCE: trichloroethene
UCL: upper confidence level
VC: vinyl chloride

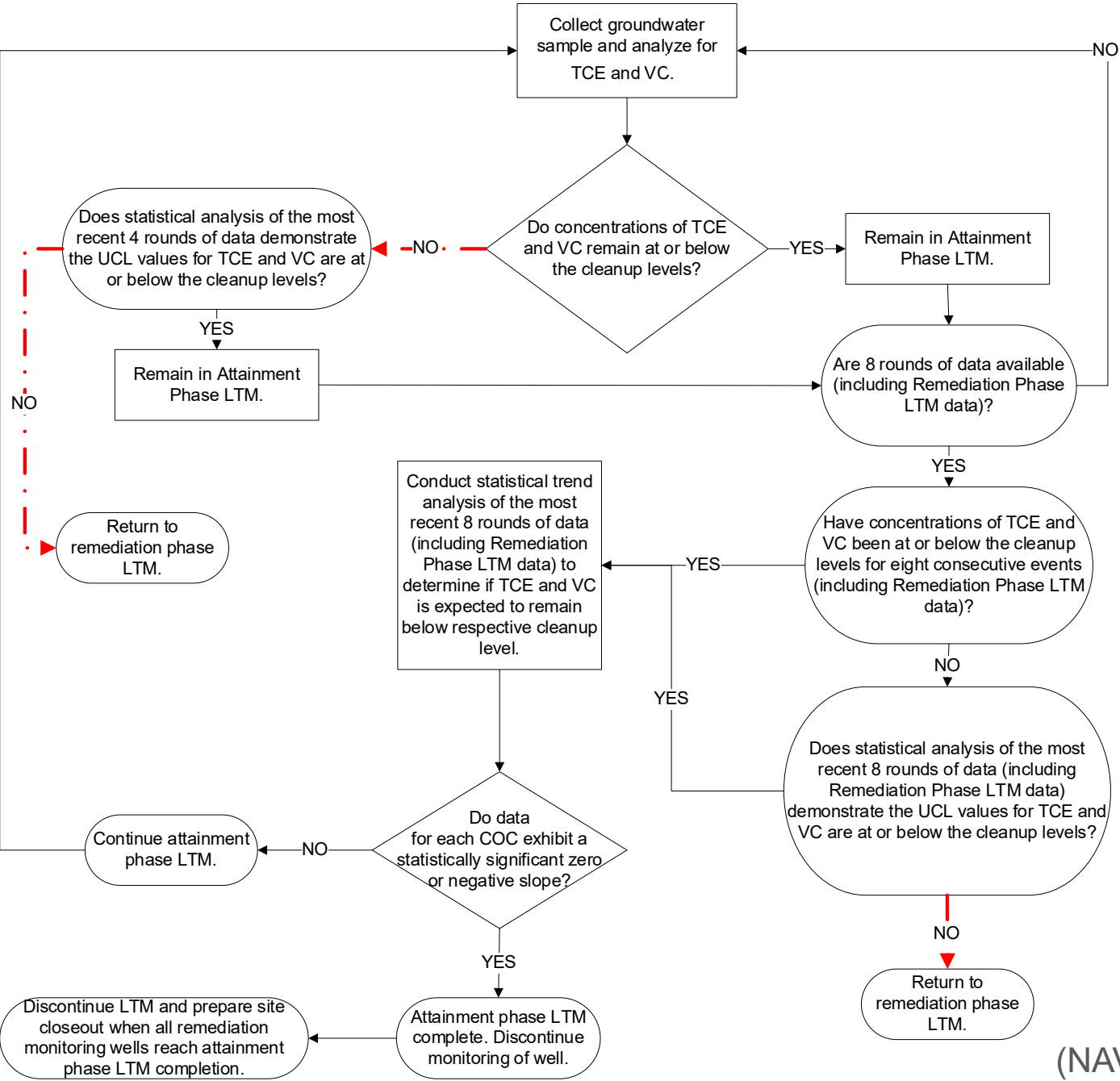
(NAVFAC 2022)

Decision Logic for JEB Little Creek Site 12



- **Attainment Monitoring** is conducted after remediation monitoring to confirm that groundwater cleanup levels have been achieved and will continue to be met in the future
- Predetermined number of samples are assessed to transition to attainment monitoring (frequency independent, but needs to be reasonable)
- Flowchart is based on individual wells
- Does not address site as a whole

Attainment Phase LTM



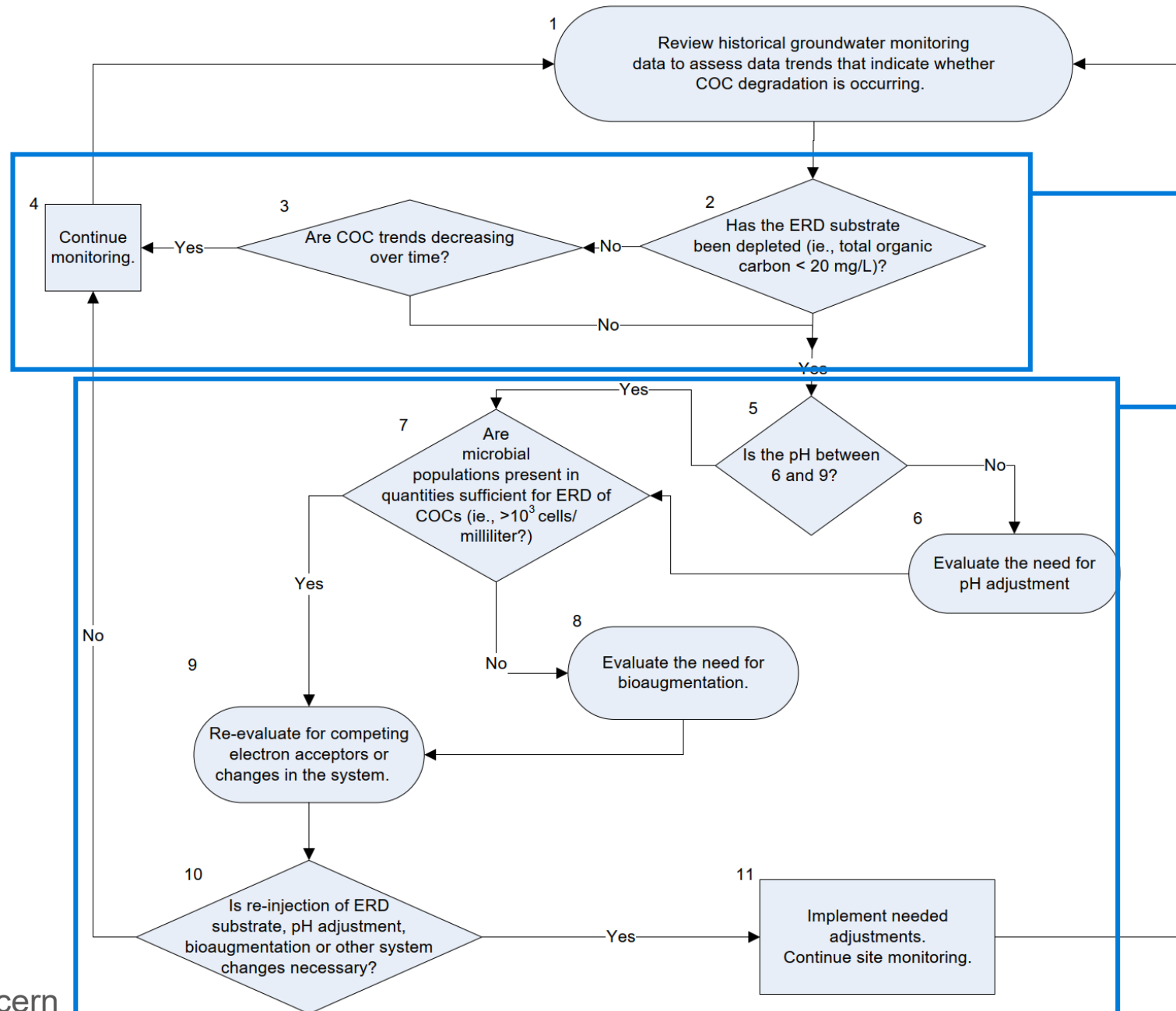
(NAVFAC 2022)

ERD Flow Chart for JEB Little Creek Site 12



- Example of how in situ remedy metrics assess field conditions
- Decision point to determine when reinjection is necessary

ERD: enhanced reductive dechlorination



This box is ideal, supports progress towards exiting Remediation LTM

This box indicates more evaluation is needed to progress toward exiting Remediation LTM (evaluate pH, microbial population, fermentable carbon, competing electron acceptors)

(NAVFAC 2022b)

COC: chemical of concern
mg/L: milligram(s) per liter

Knowledge Check: Decision Frameworks



Question: Why are decision frameworks (e.g., flowcharts) critical for managing remediation projects on path to SC or LTMgt?

Answers:

- a. They ensure remedies are operated consistently without need for periodic re-evaluation
- b. They help translate monitoring data into clear decision points for optimization, transition, or continued operation
- c. They replace regulatory requirements by defining when remedies can be shut down
- d. They eliminate uncertainty by predicting future site conditions with certainty

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- b. They help translate monitoring data into clear decision points for optimization, transition, or continued operation**
- c. They replace regulatory requirements by defining when remedies can be shut down
- d. They eliminate uncertainty by predicting future site conditions with certainty

KEY POINT

Decision frameworks ensure monitoring results lead to deliberate actions. They define, in advance, what success looks like and what to do when performance falls short.

Presentation Overview



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Transition Assessments inform SC and LTMgt

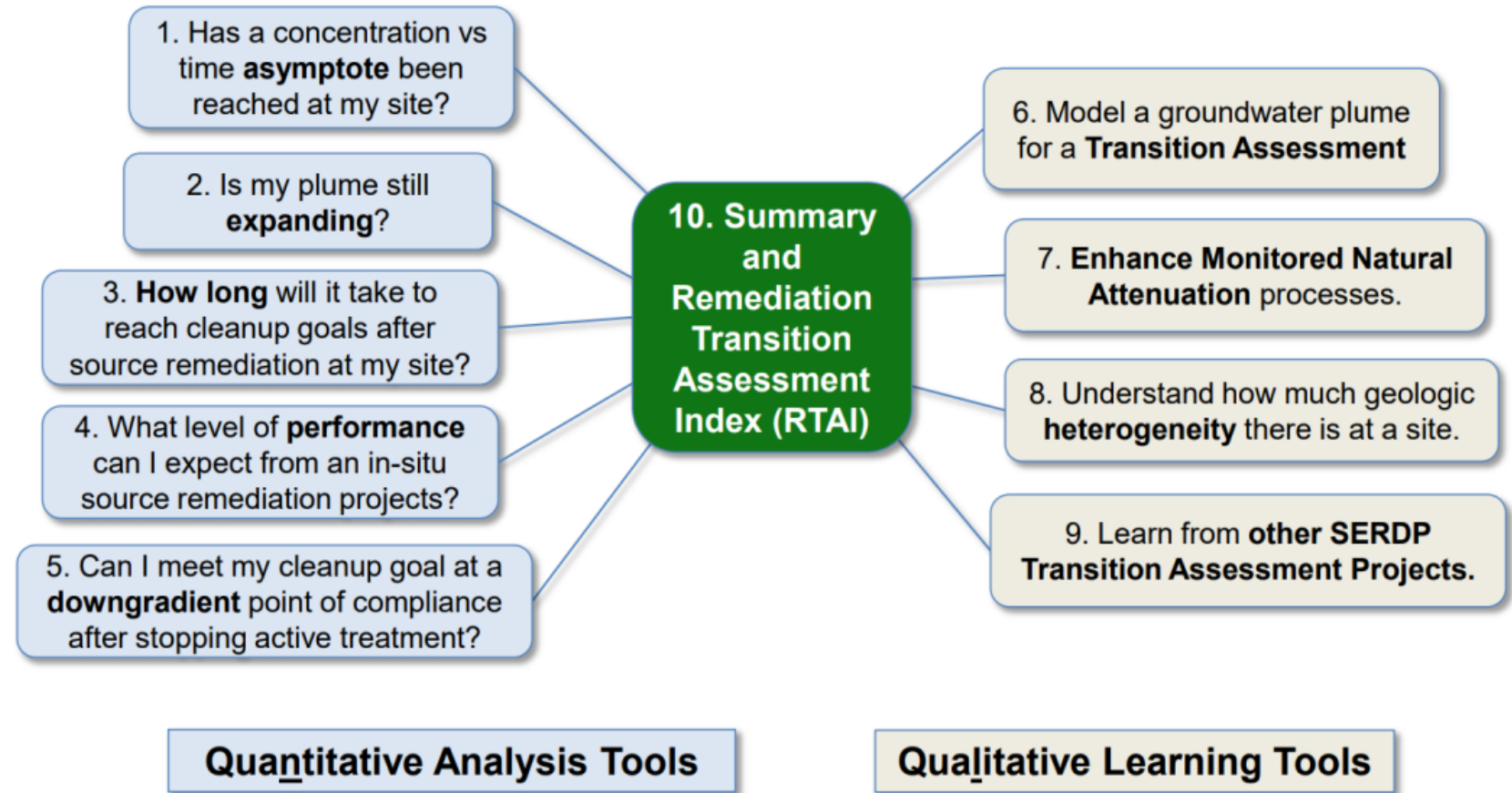


- Identifying defensible points where active remedies can transition to passive strategies or MNA
- Demonstrating protectiveness and long-term risk stability through clear lines of evidence
- Reducing life cycle costs in cases where SC is not attainable

NAVFAC 2024 Fact Sheet – Transitioning from Active Remedies to MNA



- Provided a technical framework for if/when site should transition from active remediation to MNA
- Helps identify sites where active remedies plateau due to matrix diffusion or diminishing returns
- Addresses common challenges
- More details in SERDP Project ER20-1429 (Transitioning from Active Remedies to Monitored Natural Attenuation, Principal Investigator GSI Environmental)



(NAVFAC 2024)

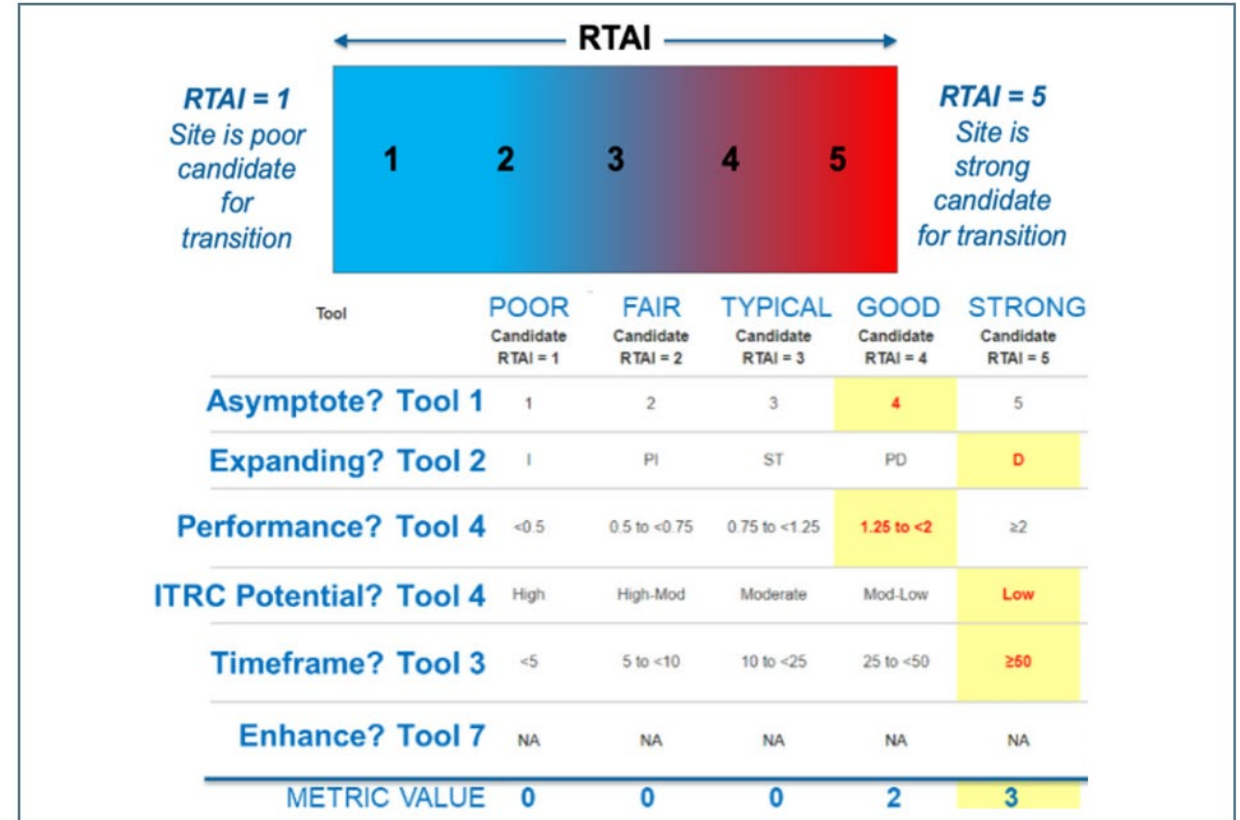
SERDP: Strategic Environmental Research and Development Program

How NAVFAC 2024 Fact Sheet Helps RPMs Transition to MNA



- Provides structured, defensible lines of evidence for deciding whether transitioning to MNA is appropriate
- Ensures protectiveness while informing opportunities to reduce long-term operation and maintenance costs
- Supports use in FS, optimization evaluations, and remedy transition decisions

ITRC: Interstate Technology and Regulatory Council
RTAI: Remediation Transition Assessment Index



Top: RTAI scale definition. Bottom: Example of RTAI result with 2 metrics with a score of “4” and 3 metrics with a score of “5”. Based on an unweighted average of these values, the final RTAI = 4.6.

(NAVFAC 2024)

- Provides structured framework for determining when to optimize, transition, or maintain remedies as part of LTM
- Introduced LTM-specific tools for monitoring reduction and system right-sizing
- 3-step process
 - Step 1: Identify trigger conditions and affirm need for P&T transition
 - Step 2: Identify transition approach and develop lines of evidence for P&T transition
 - Step 3: Implement P&T transition

Plan for Transition Example: NWS Yorktown Site 1 – Dudley Road Landfill



- Site was used for sand mining
- Two borrow pits were filled with waste materials
- HHRA showed unacceptable risks for TCE, cis-1,2-DCE, VC, and 1,1,2-TCA
- Excavation, in situ groundwater treatment with reductive dechlorination was chosen as recommended remedy, with MNA contingency
- AM principles were incorporated into project management plan as part of EPA pilot project



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
LAND AND EMERGENCY
MANAGEMENT

OLEM Directive 9200.3-123

MEMORANDUM

SUBJECT: Considerations for Adaptive Management at Superfund Sites
FROM: LARRY DOUCHAND, Director
Office of Superfund Remediation and Technology Innovation
TO: Superfund and Emergency Management Division Directors, Regions 1-10

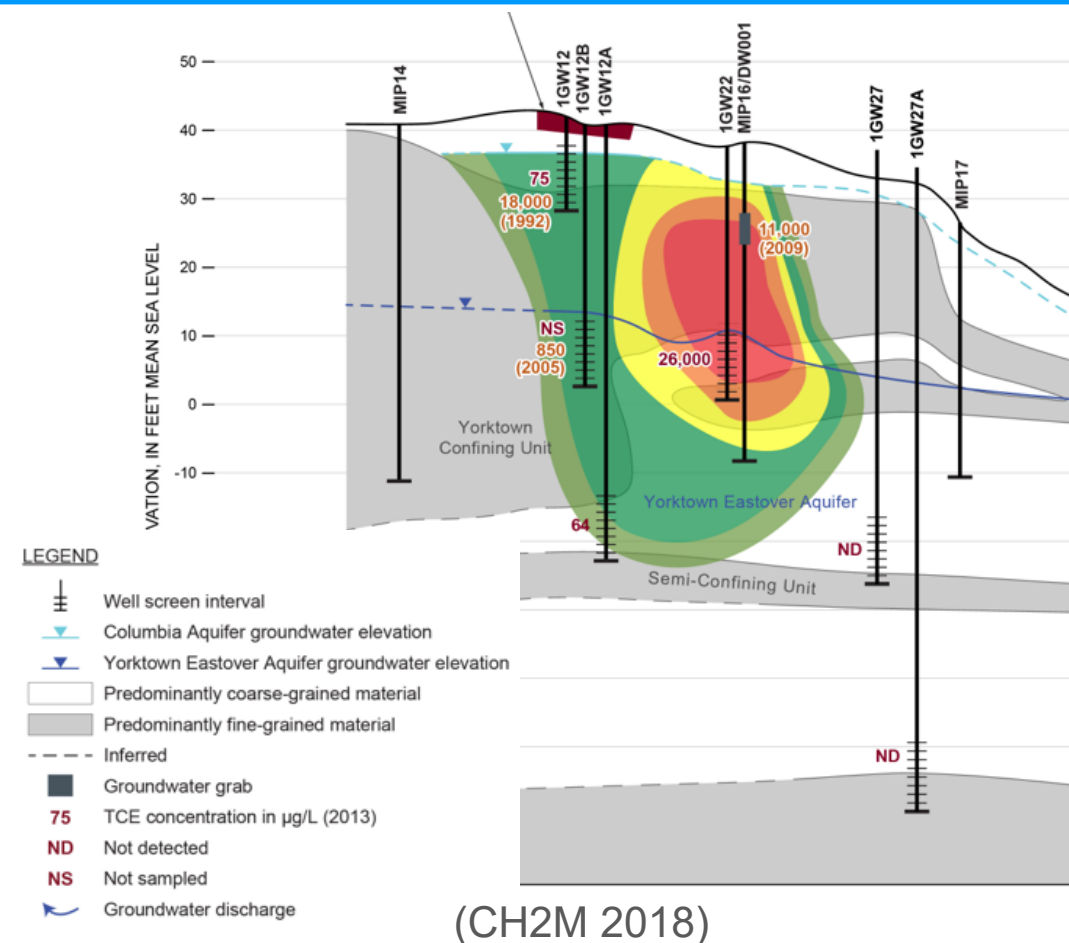
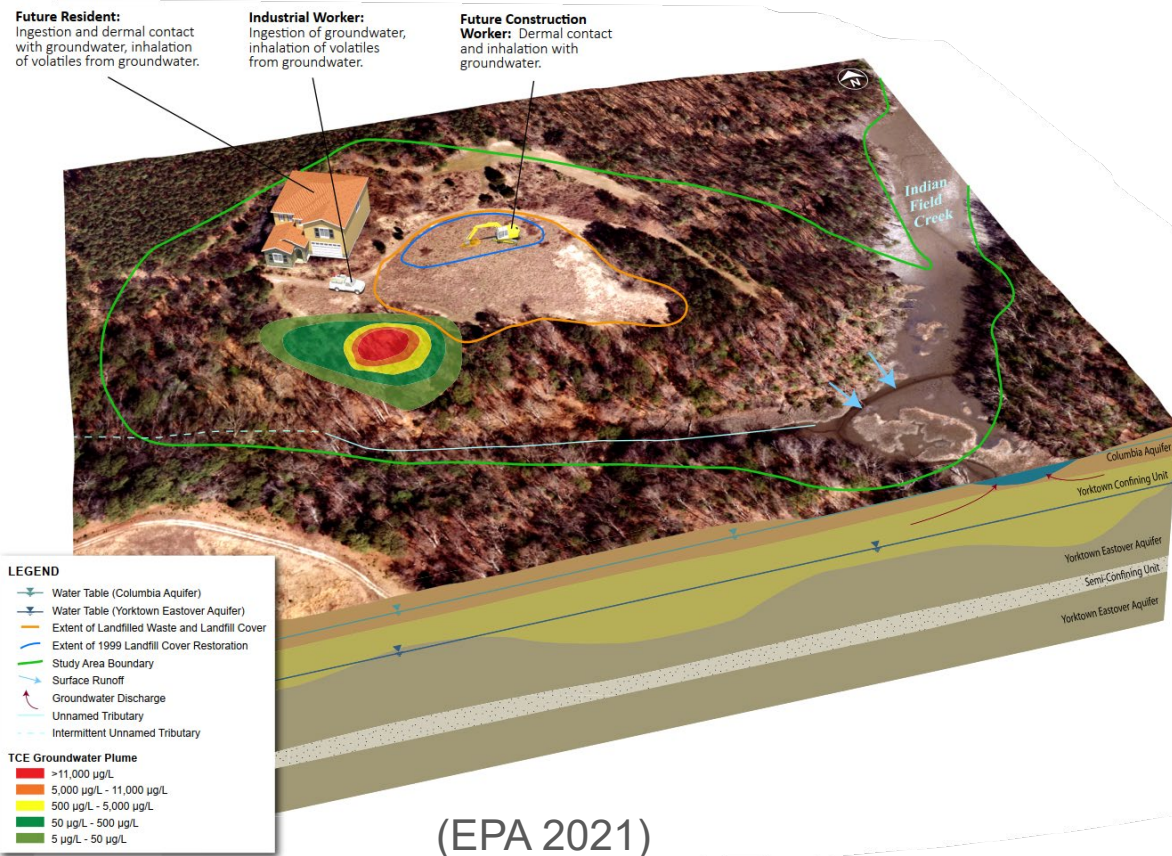
Digitally signed by LARRY
DOUCHAND
Date: 2022.06.23
14:05:36 -04'00'

1,1,2-TCA: 1,1,2-trichloroethane
AM: Adaptive Management
cis-1,2-DCE: cis-1,2-dichloroethene
NWS: Naval Weapons Station

KEY POINT

**Modeled after plan-do-check-act process for considering future decisions and metrics.
Underscores CERCLA process is not always linear.**

Conceptual Site Model



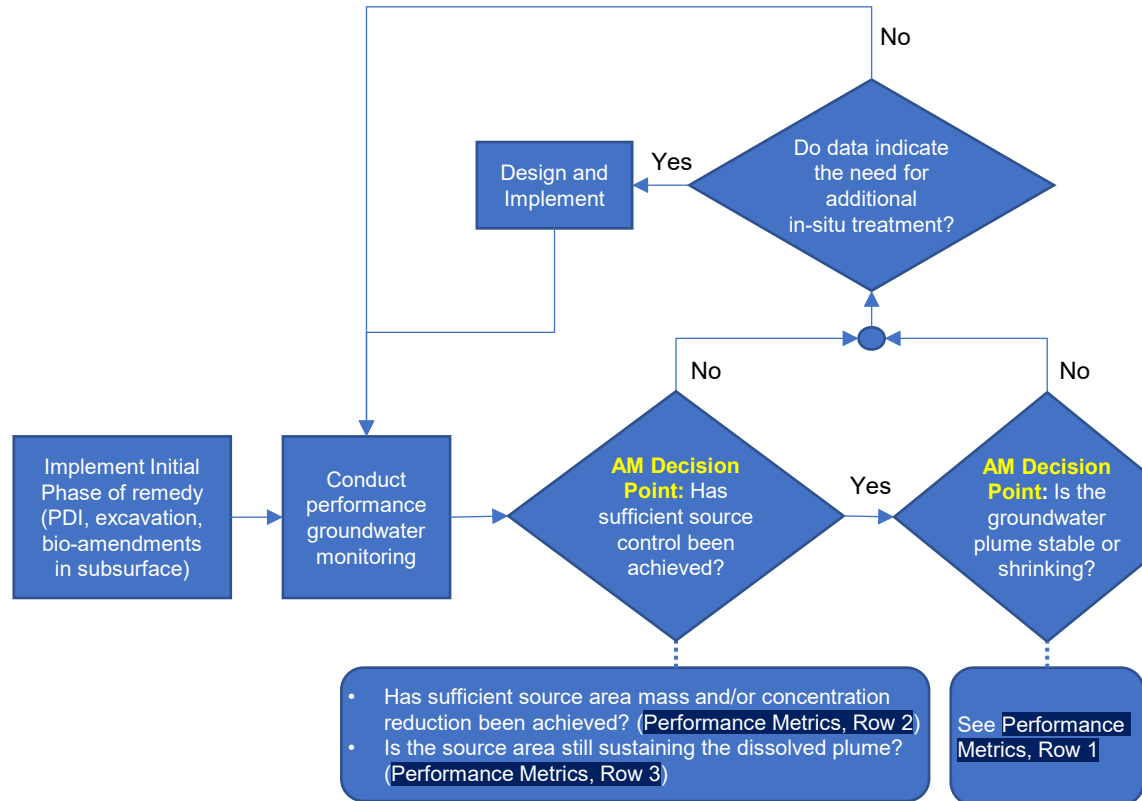
KEY POINT

Challenging site conditions; contamination in fine-grained material unit. Expect contaminant rebound after initial injections.

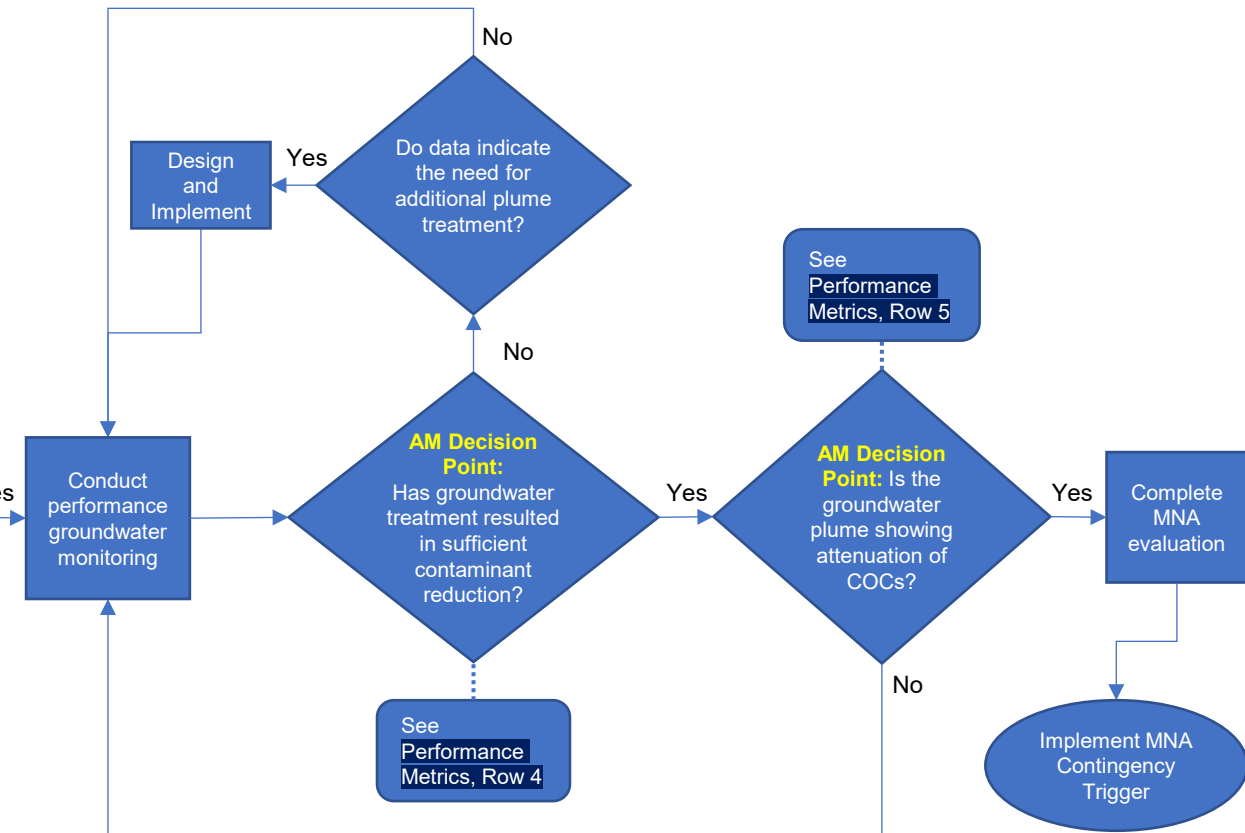
Decision Flow Chart for Adaptive Management



Is plume stable or shrinking?

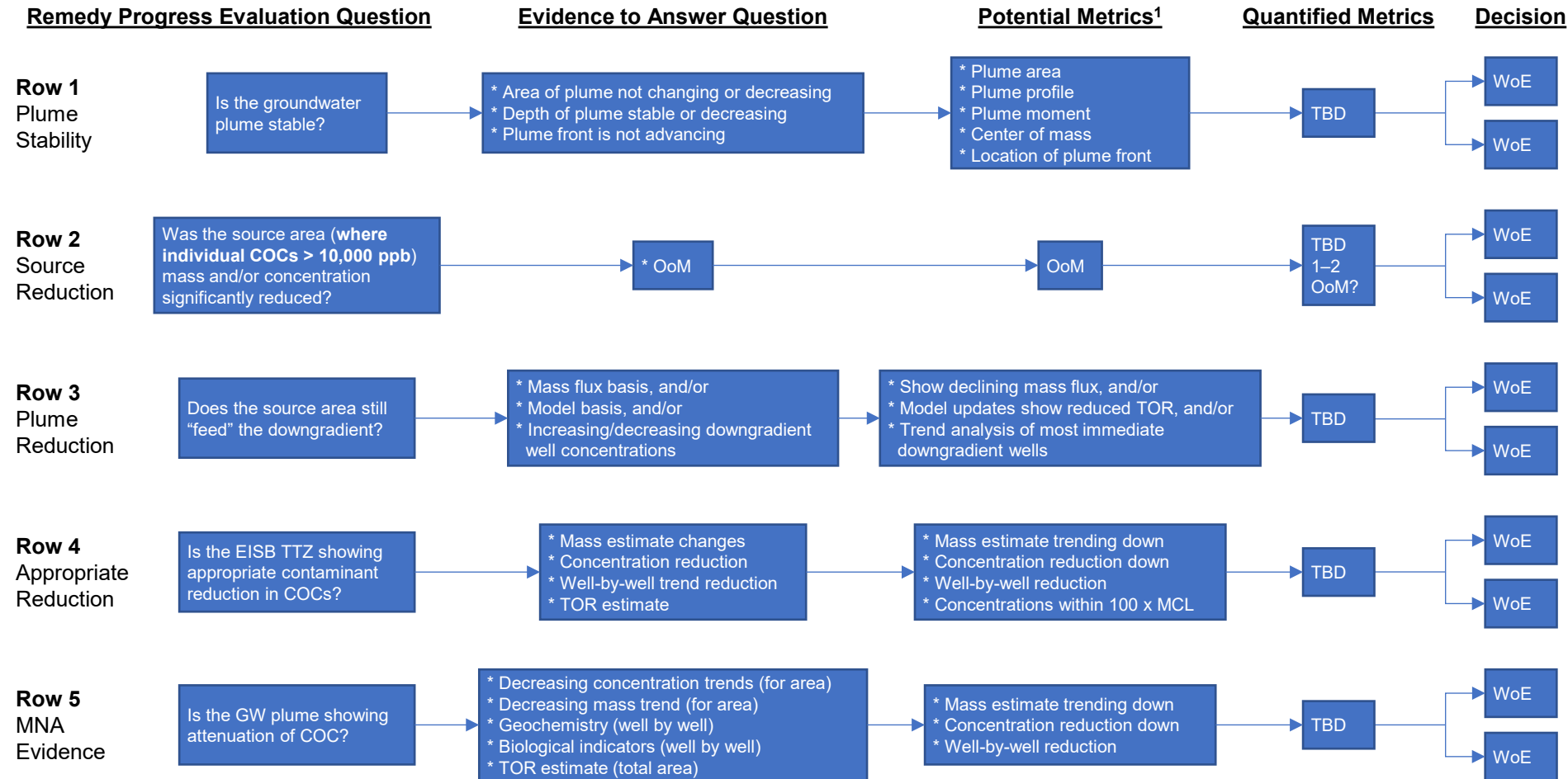


Is there evidence of attenuation?



(Jacobs 2025)

Performance Monitoring and Metrics



Columns

- Remedy Progress Evaluation Question
- Evidence to Answer Question
- Potential Metrics
- Quantified Metrics
- Decision Based on Metrics

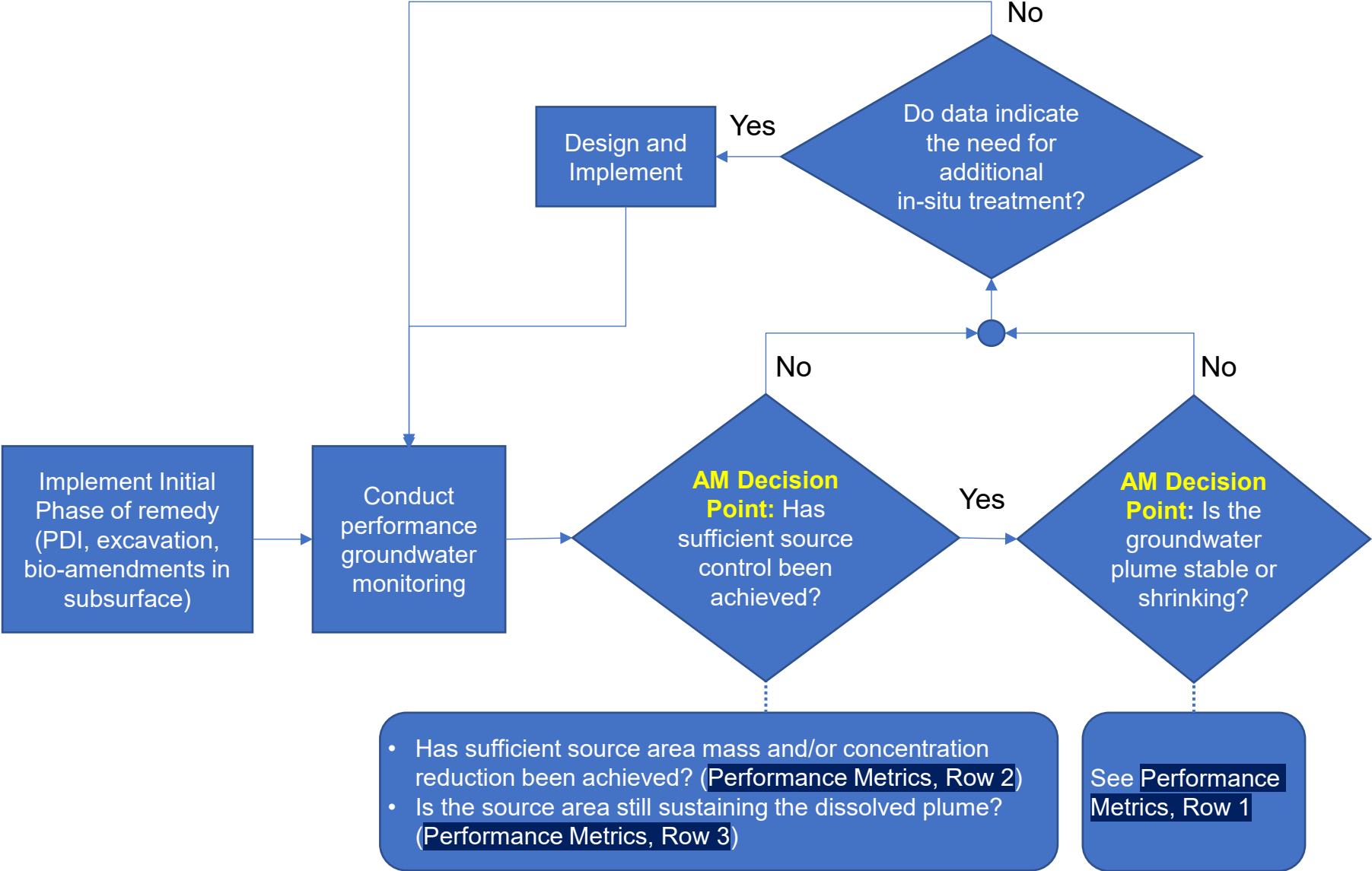
Rows

- Plume Stability
- Source Reduction
- Plume Reduction
- Appropriate Reduction
- MNA Evidence

¹ These metrics can be used to answer the remedy progress evaluation questions. They will be considered as part of the AM process and finalized based on the results of the PDI. These metrics are only example considerations at this time. Metrics will be finalized in SAP and may change based on results of the PDI future work at the site, as agreed upon by the partnering team.

(Adapted from Jacobs n.d.)

Is plume stable or shrinking?



Remedy Progress Evaluation Question

Evidence to Answer Question

Potential Metrics

Row 1 Plume Stability

Is the groundwater
plume stable?

- * Area of plume not changing or decreasing
- * Depth of plume stable or decreasing
- * Plume front is not advancing

- * Plume area
- * Plume profile
- * Plume moment
- * Center of mass
- * Location of plume front

Row 2 Source Reduction

Was the source area (where
individual COCs > 10,000 ppb)
mass and/or concentration
significantly reduced?

* OoM

OoM

Row 3 Plume Reduction

Does the source area still
“feed” the downgradient?

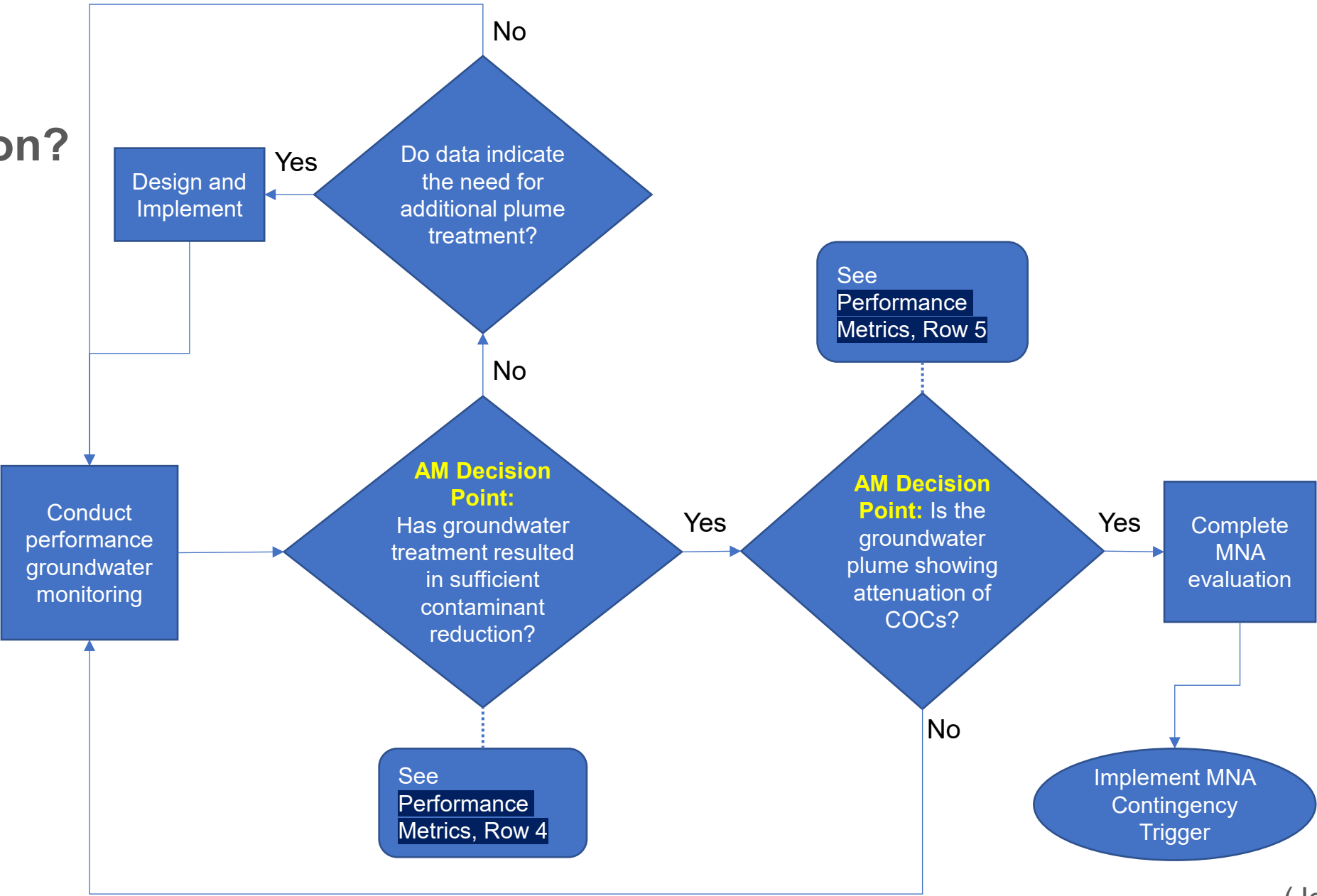
- * Mass flux basis, and/or
- * Model basis, and/or
- * Increasing/decreasing downgradient
well concentrations

- * Show declining mass flux, and/or
- * Model updates show reduced TOR, and/or
- * Trend analysis of most immediate
downgradient wells

OoM: Order-of-Magnitude
ppb: part(s) per billion
TOR: Time of Remediation

(EPA 2021)

Is there evidence of attenuation?



(Jacobs 2025)

Remedy Progress Evaluation Question

Evidence to Answer Question

Potential Metrics

Row 4 Appropriate Reduction

Is the EISB TTZ showing appropriate contaminant reduction in COCs?

- * Mass estimate changes
- * Concentration reduction
- * Well-by-well trend reduction
- * TOR estimate

- * Mass estimate trending down
- * Concentration reduction down
- * Well-by-well reduction
- * Concentrations within 100 x MCL

Row 5 MNA Evidence

Is the GW plume showing attenuation of COC?

- * Decreasing concentration trends (for area)
- * Decreasing mass trend (for area)
- * Geochemistry (well by well)
- * Biological indicators (well by well)
- * TOR estimate (total area)

- * Mass estimate trending down
- * Concentration reduction down
- * Well-by-well reduction

EISB: enhanced in situ bioremediation
TTZ: target treatment zone

(EPA 2021)

Adaptive Management Pilot Lessons Learned



- Recommendations: OLEM Directive 9200.3-123 (June 2022)
 - Early engagement by stakeholders
 - Technical, legal, and management staff
- AM process may be too early for pre-decisional document phase
- There is greater project resolution in the design and RA-O phase

KEY POINT

Requires a high level of coordination with regulators. AM is not a common process, so there is still learning curve. If you have the right team chemistry, could result in expanding scope definition in later project phases.

Knowledge Check: Transition Assessment



Question: What is primary purpose of transition assessment?

Answers:

- a. To document remedy has been operating for sufficient period of time
- b. To determine whether MNA should replace all active remedies
- c. To evaluate whether active remedy can transition to passive approach or optimized LTMgt while remaining protective
- d. To satisfy regulatory requirement before site closure

Knowledge Check: Transition Assessment



Question: What is primary purpose of transition assessment?

Answers:

- a. To document remedy has been operating for sufficient period of time
- b. To determine whether MNA should replace all active remedies
- c. To evaluate whether active remedy can transition to passive approach or optimized LTMgt while remaining protective**
- d. To satisfy regulatory requirement before site closure

**KEY
POINT**

Transition assessments turn monitoring data into defensible decisions about when and how to change remedy, rather than letting remedies operate indefinitely without evaluation.

Presentation Overview



- Introduction
- Overview of Exit Strategy Options
- Decision Frameworks
- Transition Assessments
- Case Studies
- Overcoming Challenges
- Wrap Up

Case Study 1: St. Juliens Creek Site 21



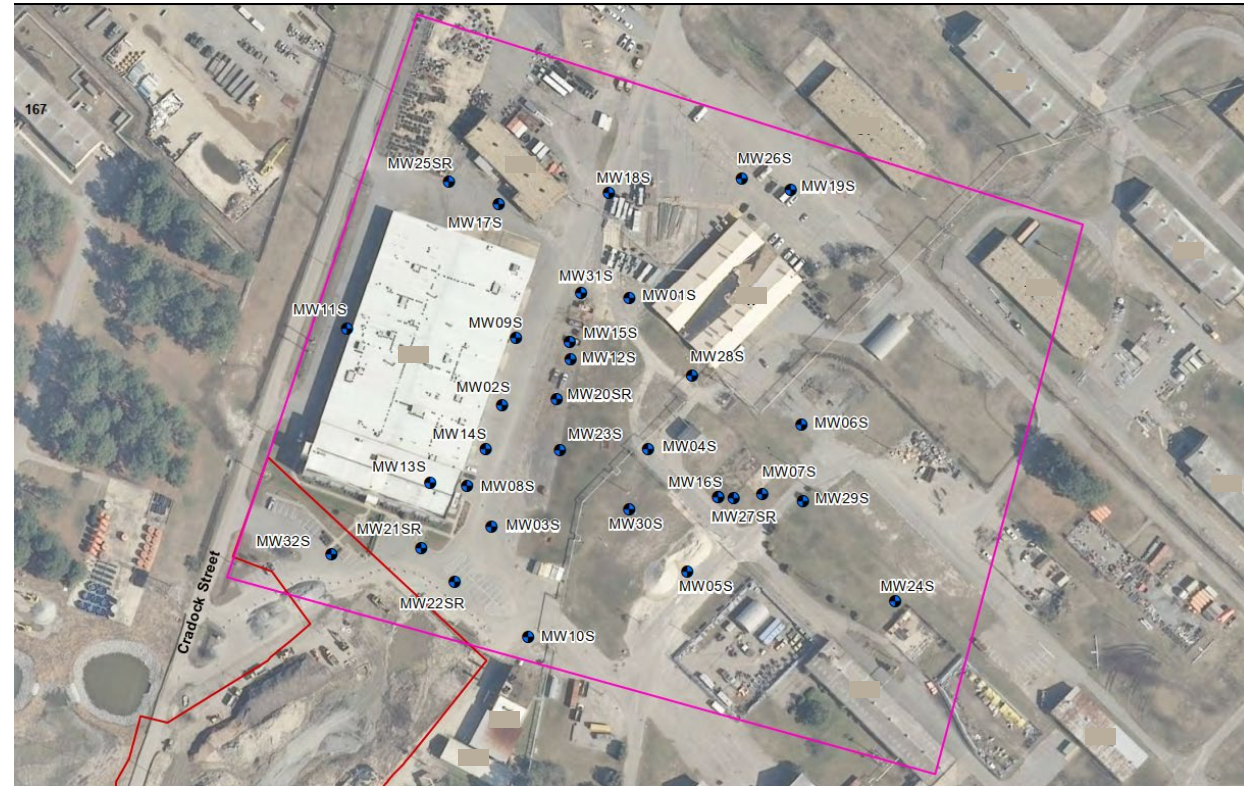
Decision framework supports reduced LTM sampling

Chesapeake, VA
(Meadows 2025)

St. Juliens Creek Site 21 Background



- 20.8-acre area within SJCA with historical industrial and maintenance activities
- TCE and degradation products in groundwater
- Subsurface consists of Columbia aquifer underlain by Yorktown confining unit

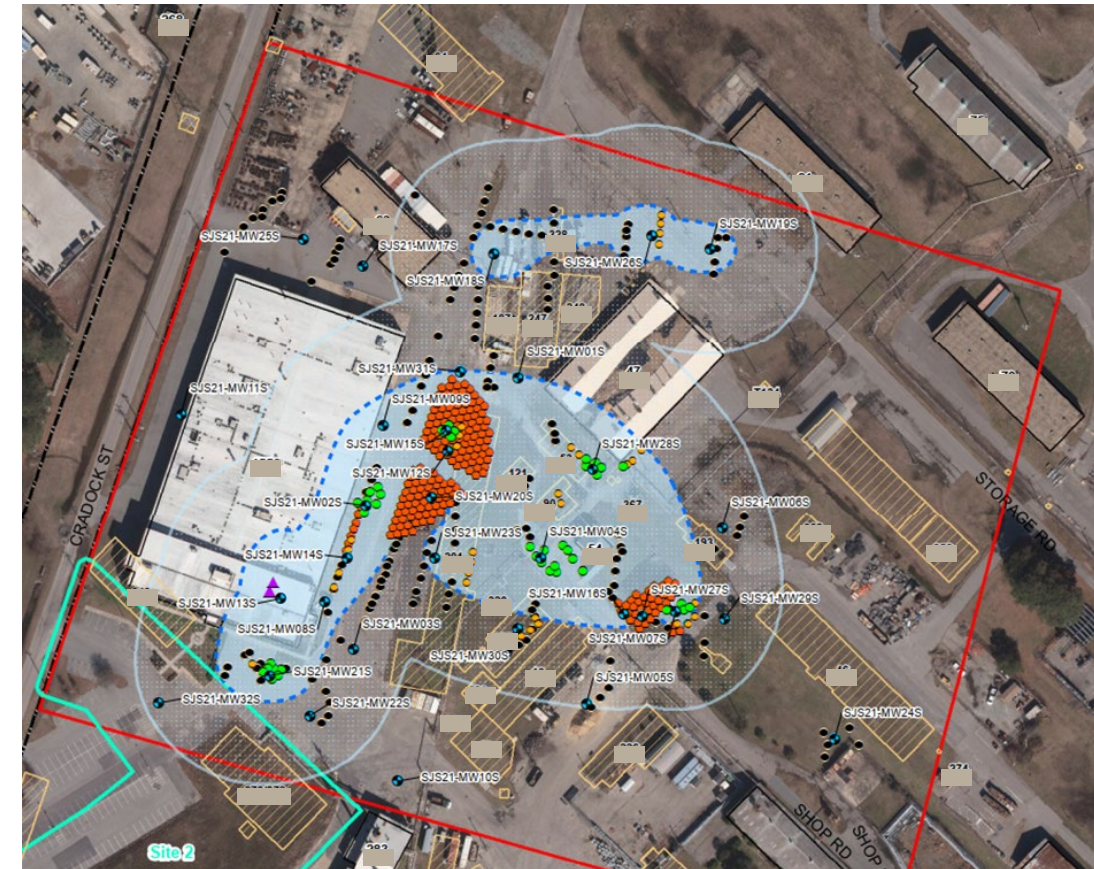


Groundwater Monitoring Well Network
(Meadows 2025)

SJCA: St. Juliens Creek Annex

- In situ chemical reduction conducted using ZVI (orange) and ERD (black) using EVO and LUCs for groundwater use and building use (blue)
- Remedial implementation was completed in 2012, with polishing EVO injections in 2014 and 2019/2020 (green)
- Site is in RA-O phase, with semiannual groundwater, stormwater, and vapor intrusion monitoring, and annual LUC inspections

EVO: emulsified vegetable oil
ZVI: zero-valent iron



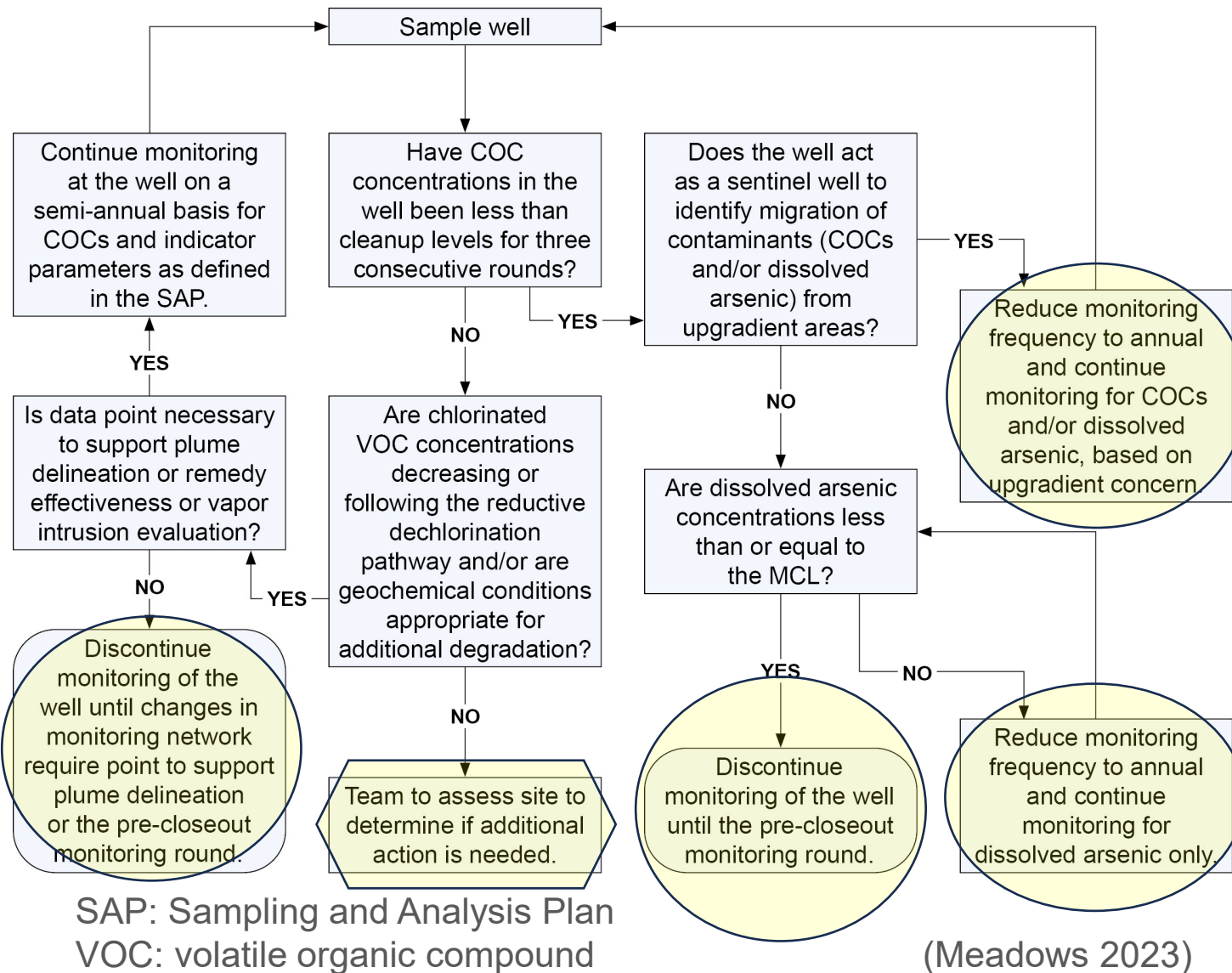
(Meadows 2025)

Legend

	Monitoring Well		Existing Building
	Proposed Temporary EVO & DHC Injection Location (2019/2020)		Site 2 Boundary
	Permanent EVO Injection Well*		Site 21 Boundary
	Temporary EVO Injection Location (2014)		Former Site 2 Inlet
	Temporary ZVI Injection Location (2011)		St. Juliens Creek Annex Boundary
	Temporary EVO Injection Location (2011)		Land Use Control Boundary - Groundwater (Potable use)
	Demolished Building		Cumulative COC Groundwater Plume
	Land Use Control Boundary - Groundwater (Inhalation)		

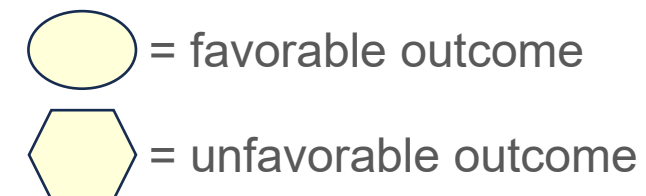
(Meadows 2025)

Decision Logic for Optimizing Sampling



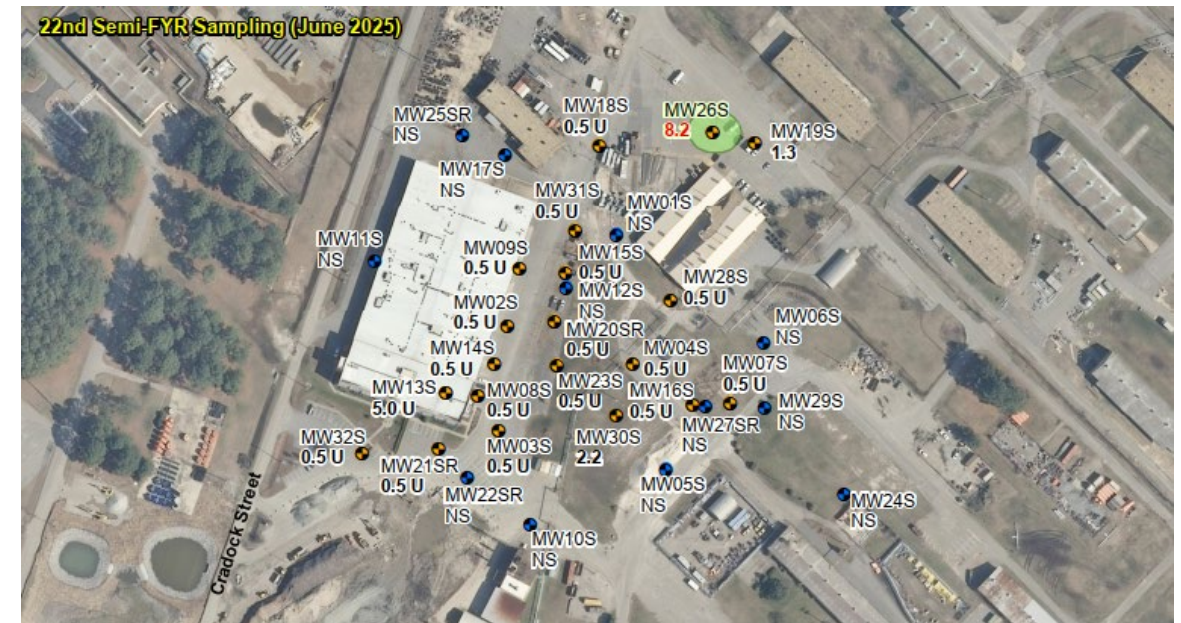
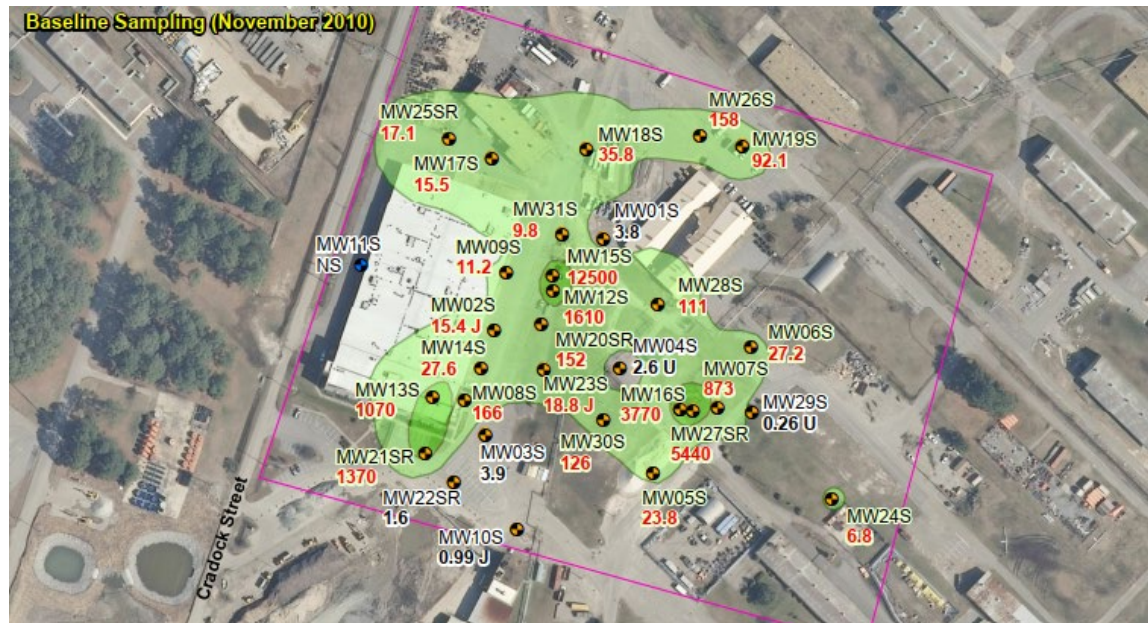
Decision Logic for

- Which parameters are sampled
- When they are sampled
- How often they are sampled
- Conditions for well exiting the sampling network



TCE Changes Over Time

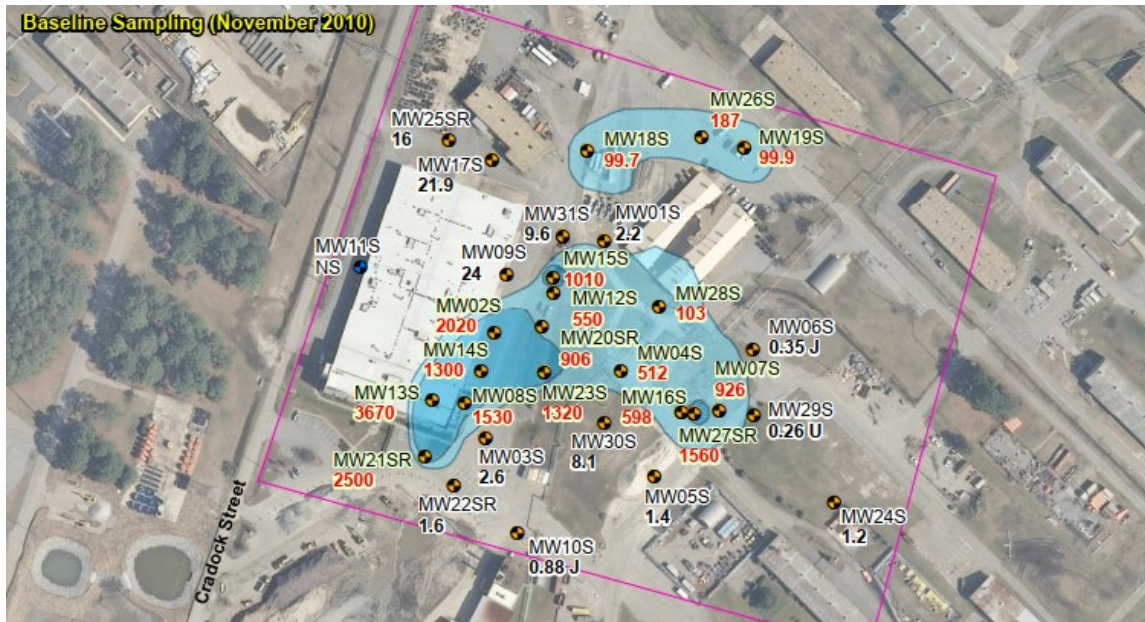
Significant Progress



(Meadows 2025)

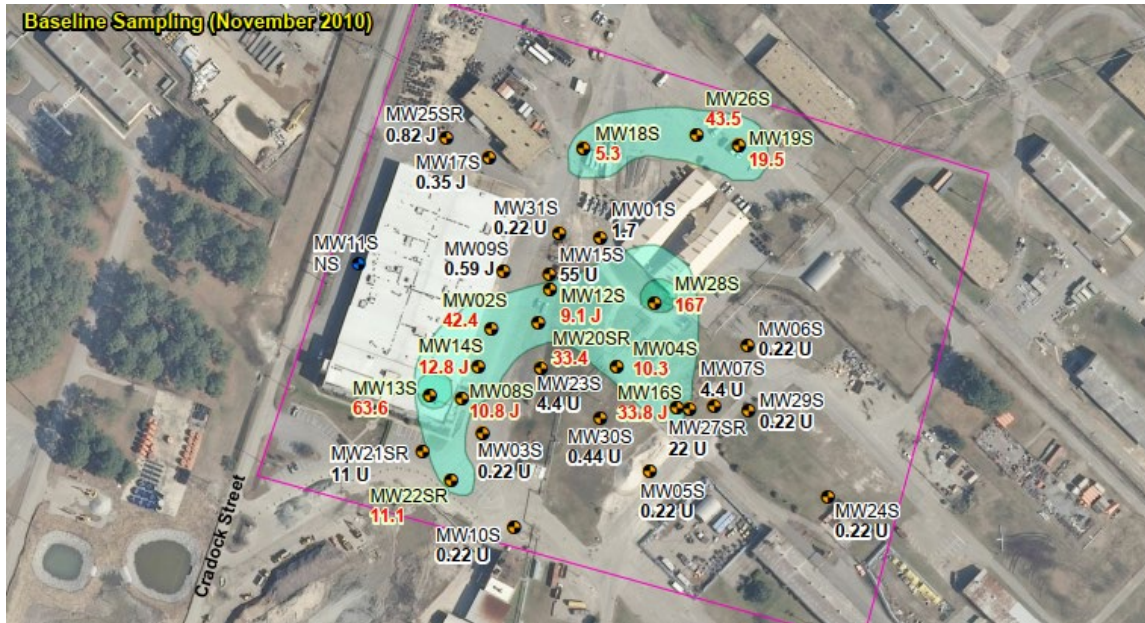
Cis-1,2-DCE Changes Over Time

Significant progress but several pockets remain



(Meadows 2025)

**Expanded footprint and slightly higher concentrations,
compared to pretreatment conditions**



(Meadows 2025)

Remedial Action Monitoring

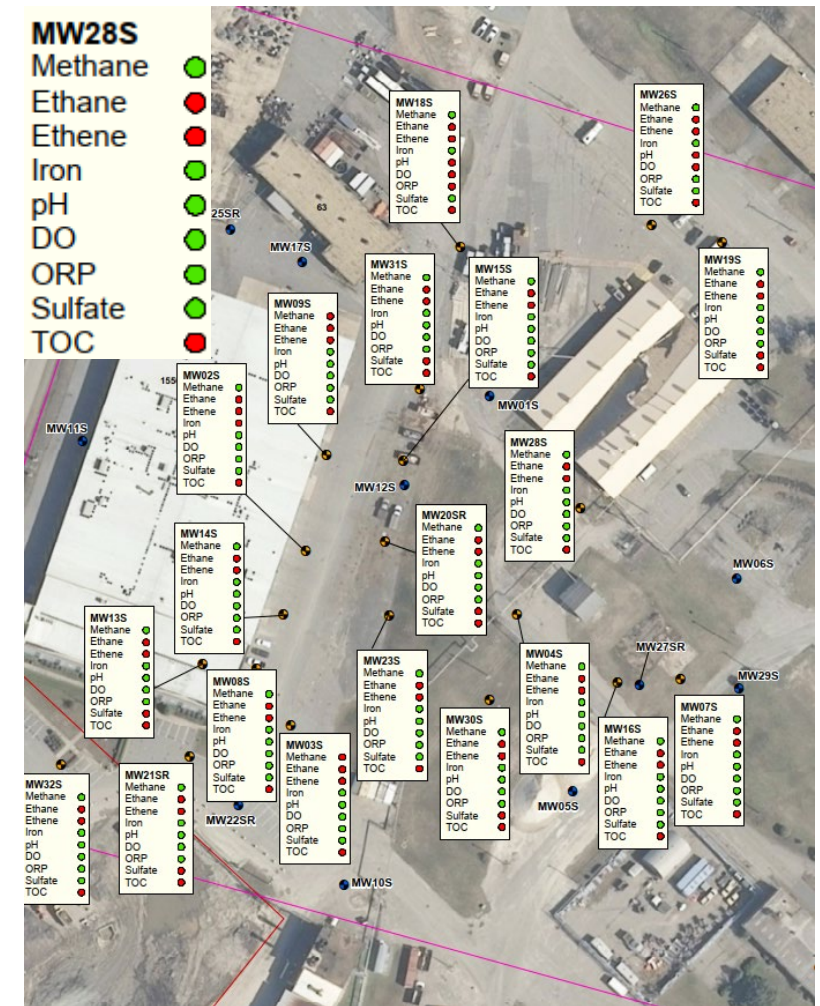


- Chlorinated ethenes, arsenic, and NAIPs were collected semiannually from December 2011 through November 2022
- Results documented in semiannual reports
- Flowchart was evaluated and recommendations made
- Several wells were able to exit network (between higher concentrations areas and sentinel wells)
- Progress was slower than anticipated
- Optimization study was recommended

NAIP: natural attenuation indicator parameter
PIL: project indicator limit

LEGEND

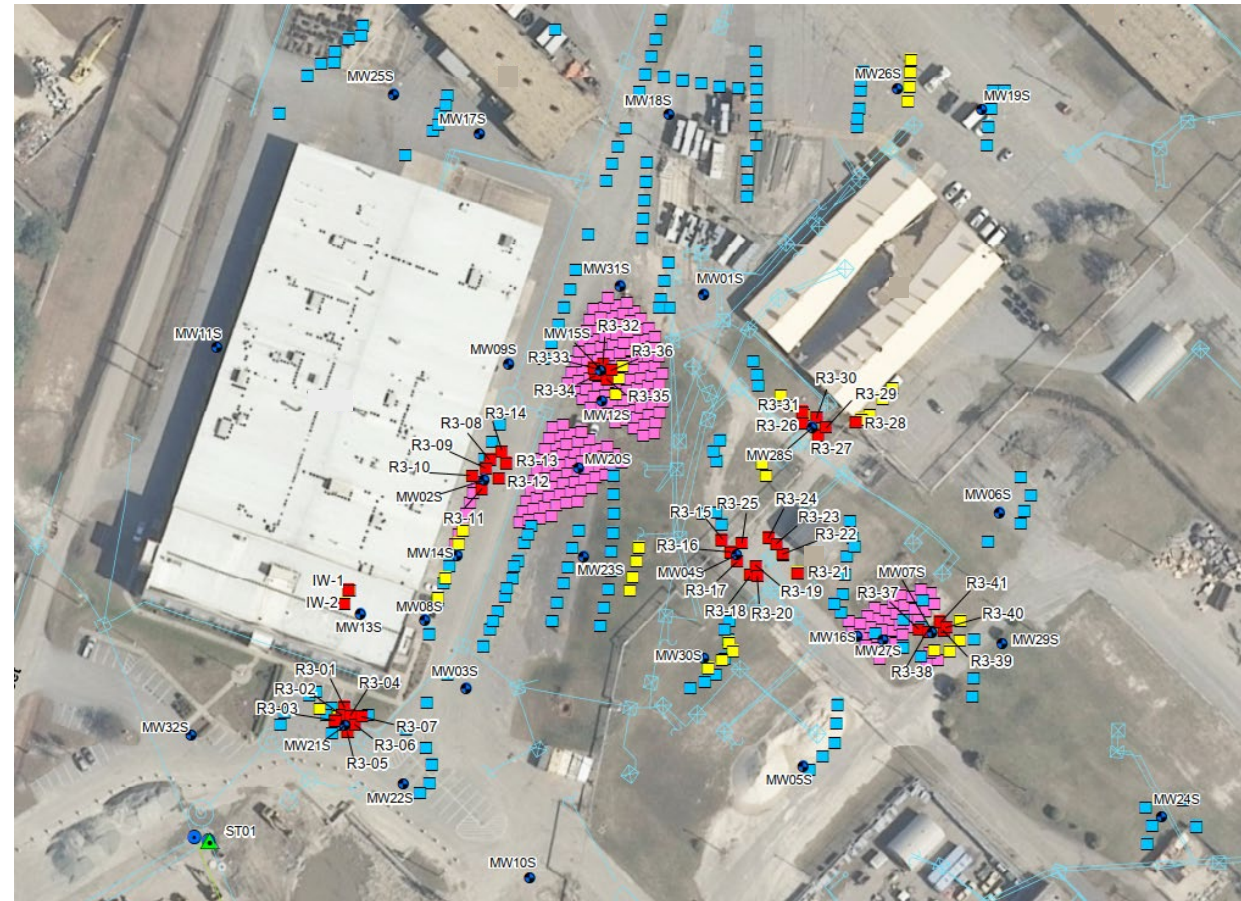
- Within ideal PIL range
- Out of ideal PIL range



(Meadows 2025)

2019 Optimization Study Focus

- Assessing contaminant mass trends since remediation began
- Estimating time frames to achieve cleanup goals using modeling and trend analyses
- Identifying optimization opportunities for existing remedy based on those results



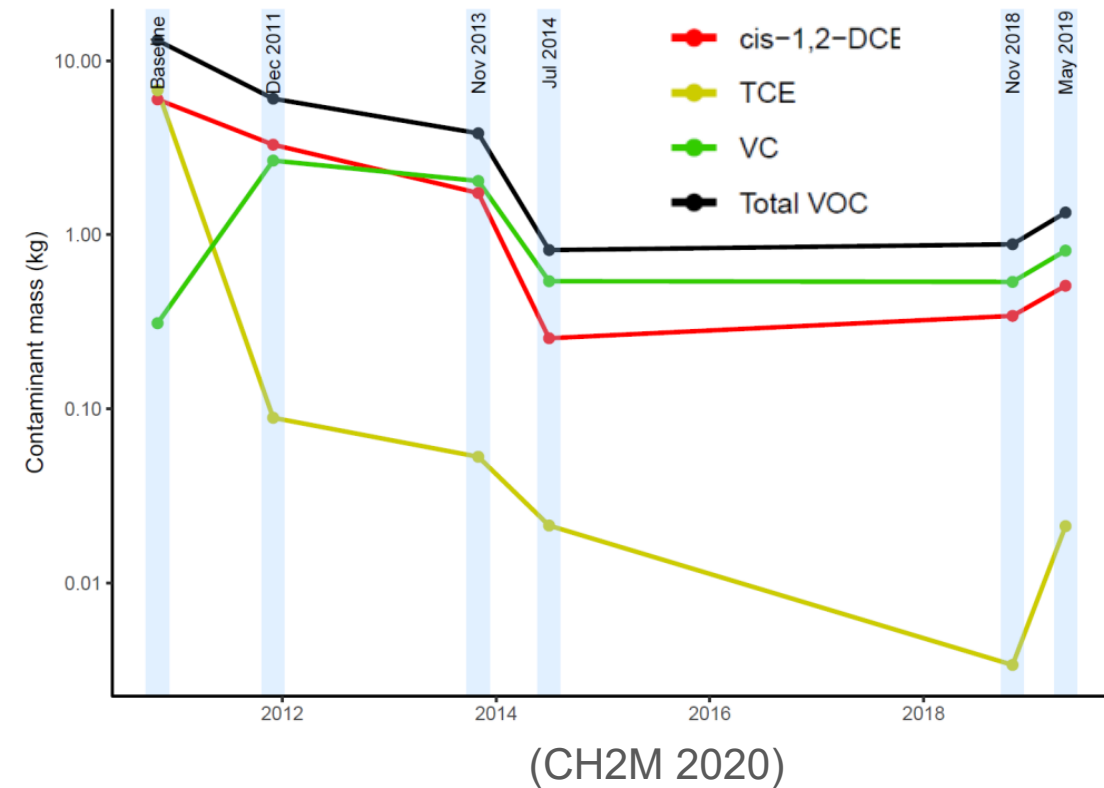
- EVO Injection Location (Round 3)
- EVO Injection Location (Round 2)
- EVO Injection Location (Round 1)
- ZVI Injection Location (Round 1)

(Meadows 2025)

Estimating Contaminant Mass

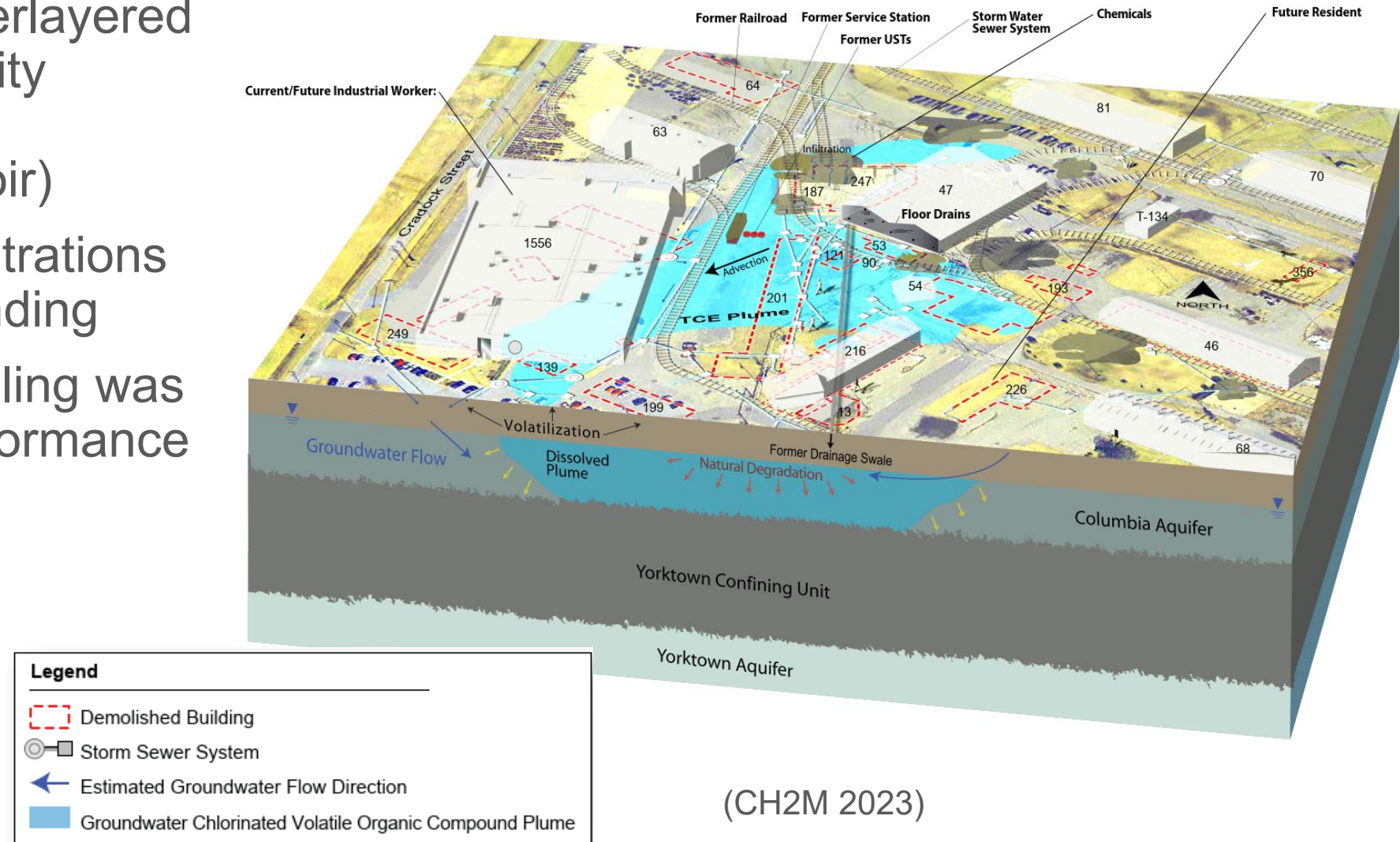


- Well-by-well analysis showed only part of story
- Holistic view of site mass changes as necessary
- Evaluated mass estimates over since baseline levels through 2019
- Optimization findings identifies:
 - Matrix diffusion
 - Depletion of organic carbon
 - Possible migration of higher-concentration “pockets” between monitoring wells



Matrix Diffusion Evaluation

- Columbia aquifer interlayered with lower-permeability clayey materials (contaminant reservoir)
- Groundwater concentrations leveling off or rebounding
- REMChlor-MD modeling was used to forecast performance



REMChlor-MD Conclusions



- Modeling concluded matrix diffusion was significant factor in plume persistence
- Likely outpaced degradation of contaminants
- REMChlor-MD predicted extended remediation time frames with conservative scenarios (designed to avoid underestimating remediation frames)

µg/L: microgram(s) per liter

NC: not calculated, concentration increasing

- 4 of 7 wells – decreasing cis-1,2-DCE trends (3 increasing)
- 2 of 7 wells – decreasing VC trends (5 increasing)
- Remediation time frames with increasing or stable concentrations cannot be predicted

***Estimated Time to Meet MCL for Cis-1,2-DCE
(does not consider VC production)***

Well ID	Years to reach MCL (70 µg/L)
MW2S	5.2
MW4S	NC
MW7S	9.8
MW13S	19.3
MW15S	NC
MW28S	NC
MW26S	4.3

(CH2M 2020)

Optimization Recommendations and Benefits



Optimization Recommendations

- Evaluate supplemental or alternative treatment technologies
- Perform cost-benefit analysis comparing life cycle costs of continued LTM versus additional active treatment
- **Reduce sample frequency from semiannual to twice every 5 years (implemented)**
- Collect NAIP and microbial parameters

Optimized LTM Benefits

- Provides seasonal variation
- Provides two rounds of data for Five-Year Reviews
- Reduces sampling and reporting costs by 80%
- Provides data for Five-Year Reviews

KEY POINT

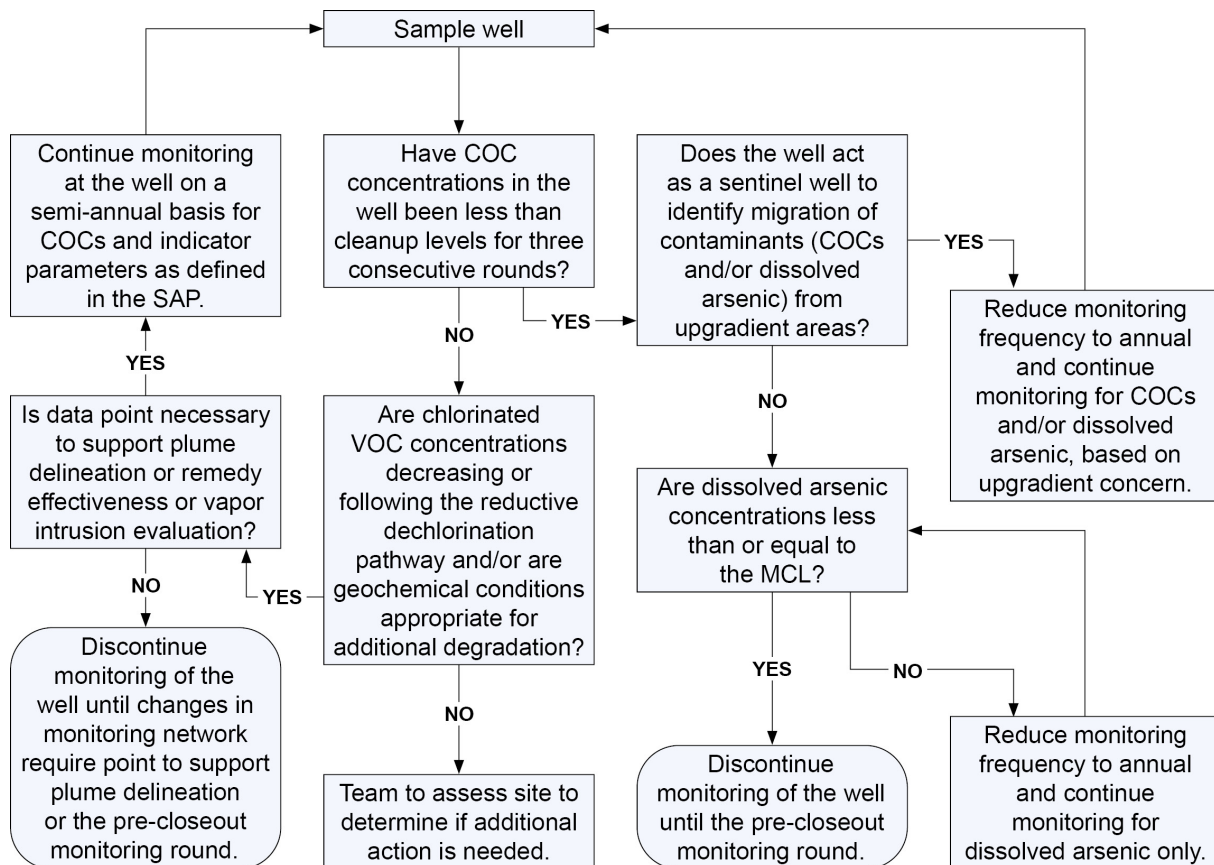
Team selected reducing sampling frequency (waiting on PFAS investigation and potential impacts on treatment technologies).

PFAS: per- and polyfluoroalkyl substances

Updated Decision Logic for Well Network

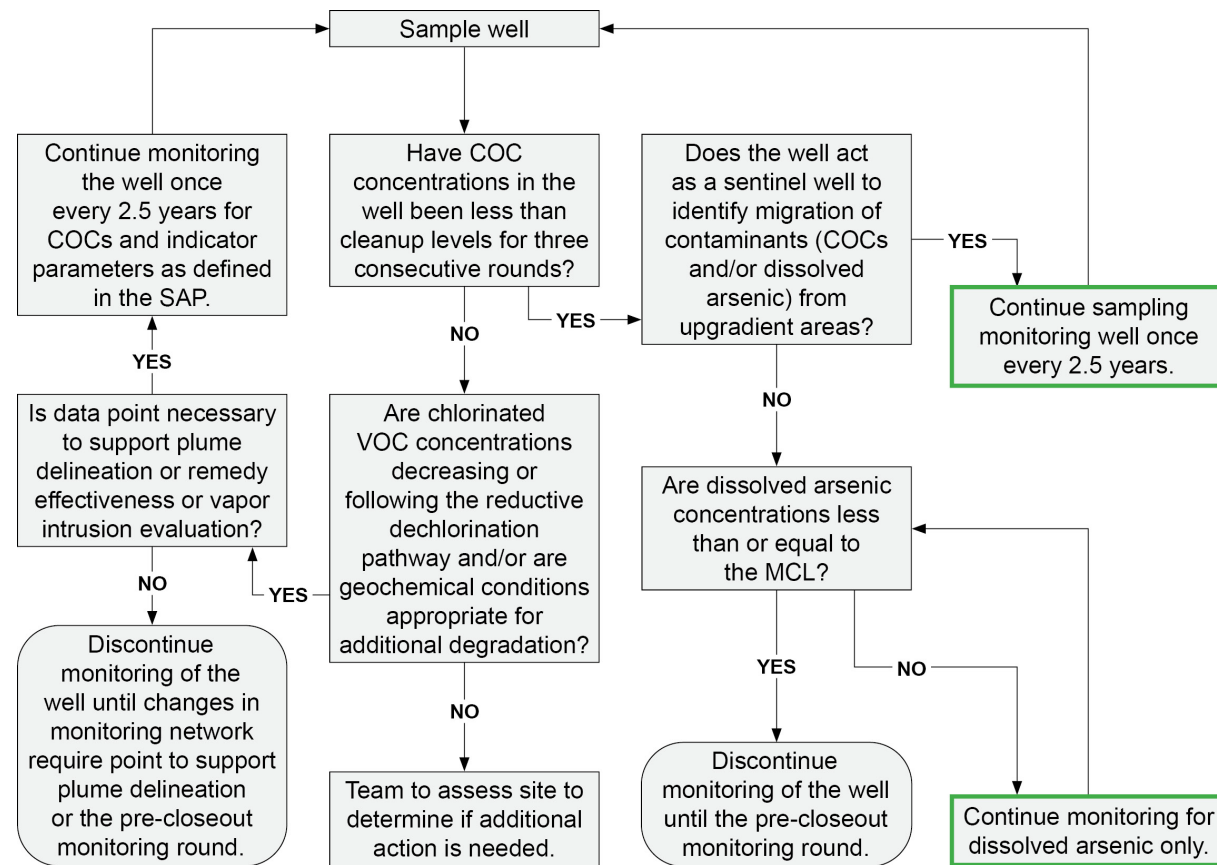


Original



(Meadows 2023)

Optimized



 Adjusted decision logic after optimization study

(Meadows 2025)

Case Study 1 OPTI Award Criteria Evaluation



☒ Improves return on investment or avoids costs

Accelerates reaching remedial goal

Use of innovative technology or approach

☒ Required extra/unique stakeholder negotiations

Case Study 2: NAPR SWMUs 7 and 8 Site History Transition Assessment and Exit Strategy



- Former TWFF constructed in 1957 and ceased operation in 2004
- Eleven USTs
- CAOs
 - LNAPL goal of 0.01 foot or less in-well thickness
 - The CAOs for 1,2,4-TMB, ethylbenzene, and TCE were achieved in 2015
 - Benzene remained, groundwater goal of 160 µg/L
 - Based industrial worker inhalation of benzene from groundwater vapors in an industrial building

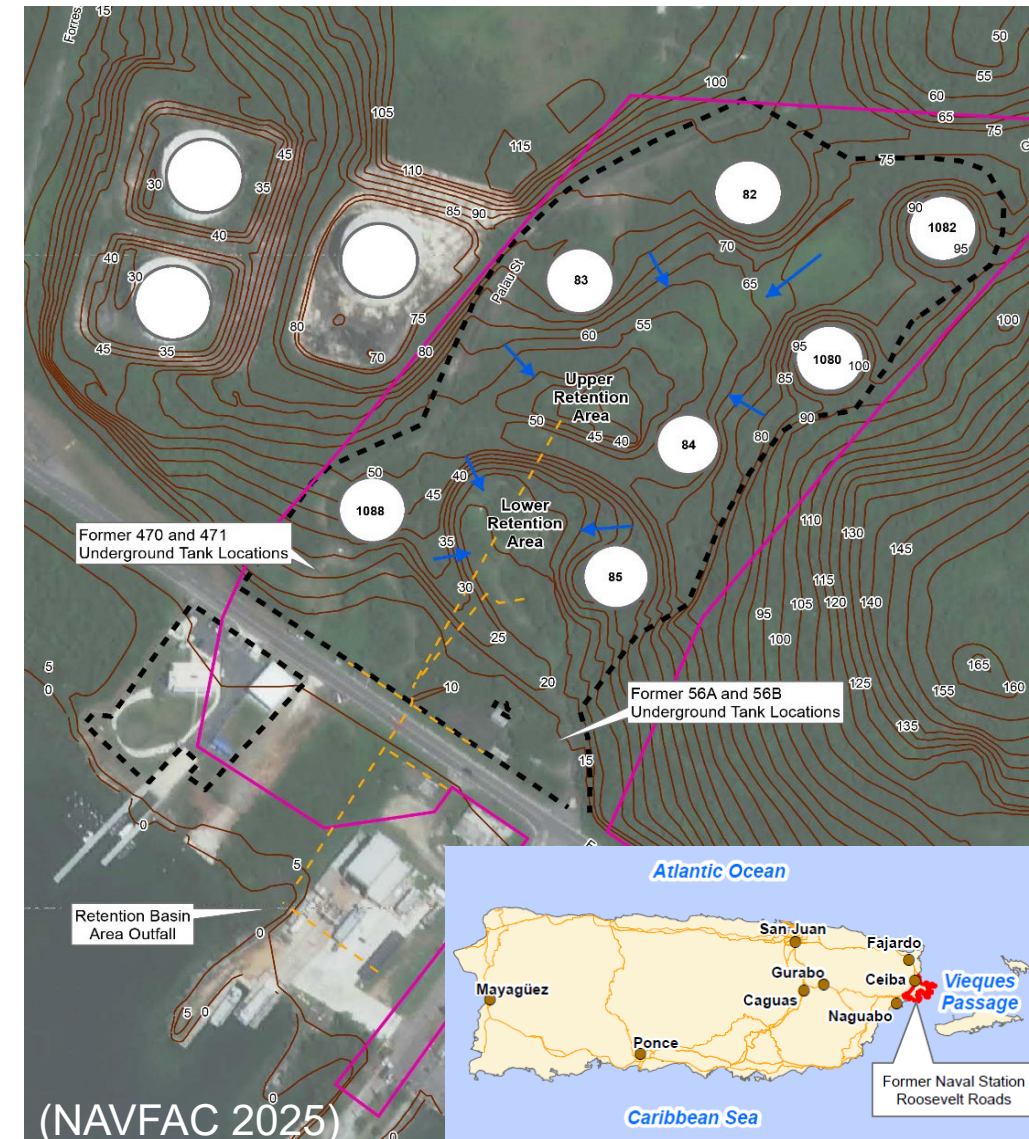
CAO: Corrective Action Objective

NAPR: Naval Activity Puerto Rico

SWMU: solid waste management unit

TMB: trimethylbenzene

TWFF: Tow Way Fuel Farm

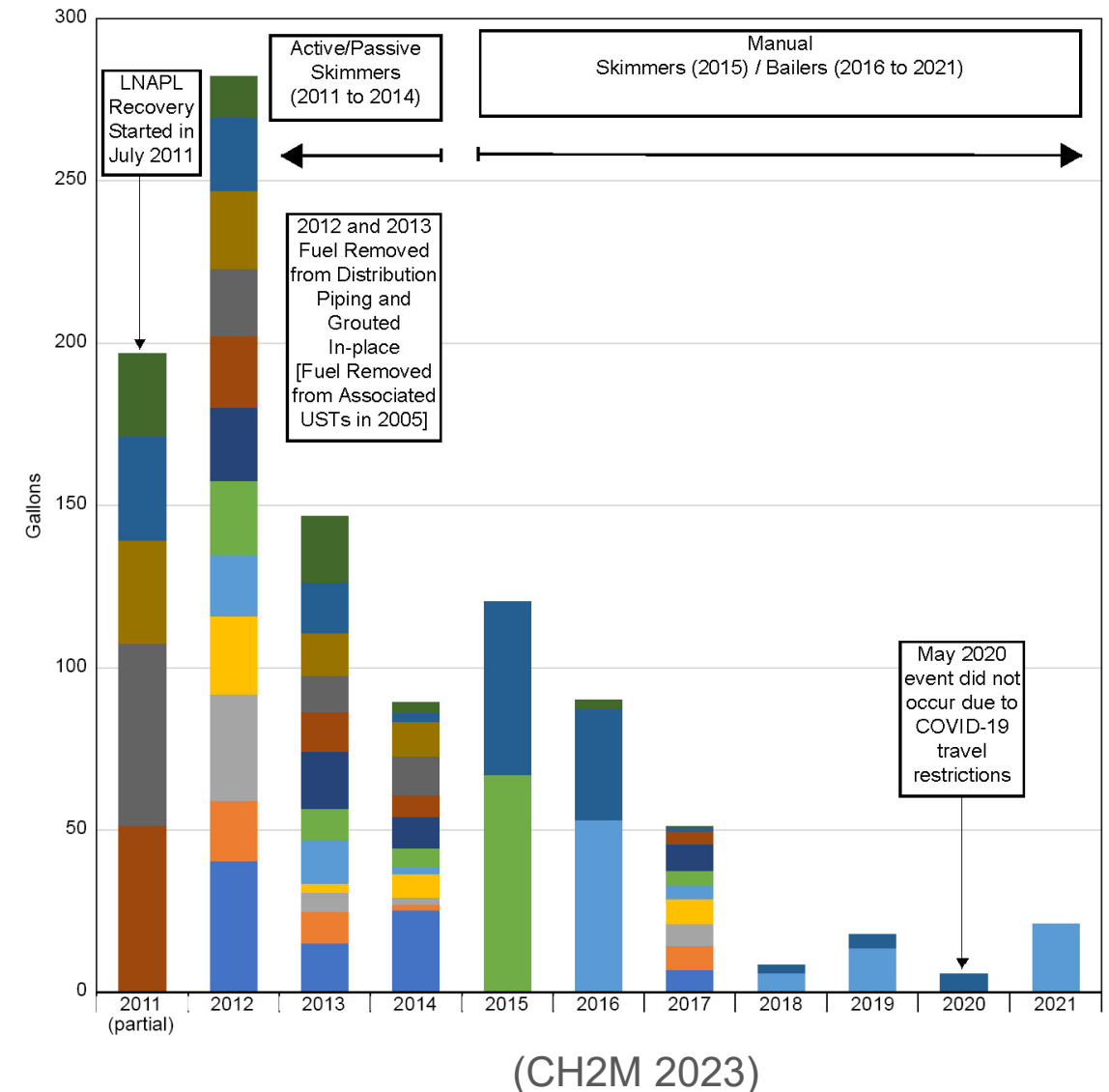


LNAPL Removal Activities

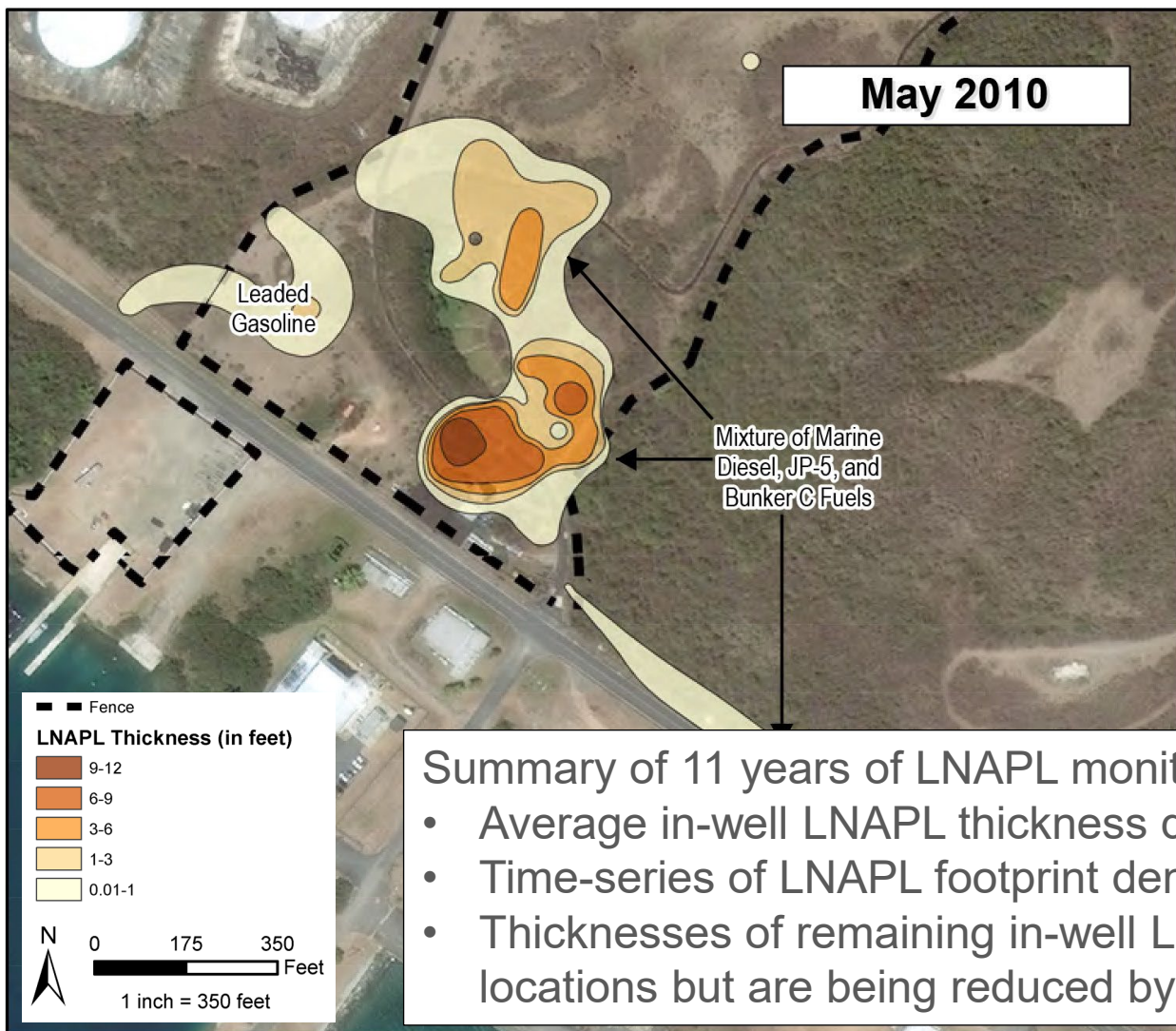


- Since 1994: Biodegradation by natural processes
- 1994 to 1996: Multi-phase product recovery
- 1996 to 2010: Clean-Ox injections, pneumatic fracturing, aggressive fluid vacuum, SVE, and total fluids recovery
- 2011 to 2014: Full-passive/active skimmer system
- 2015 to 2023: Manual product recovery

SVE: soil vapor extraction



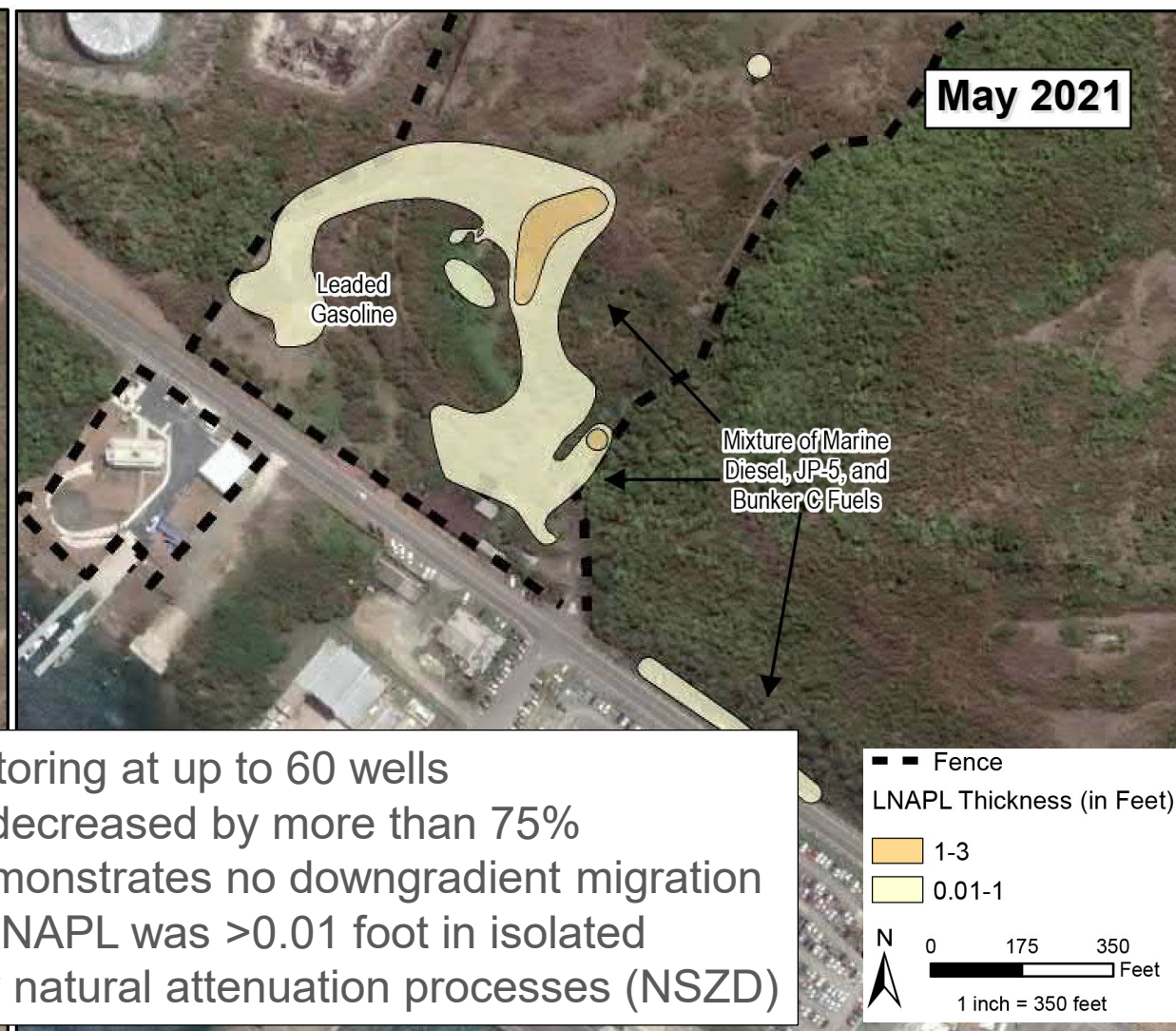
In-well LNAPL Thickness Reductions



Summary of 11 years of LNAPL monitoring at up to 60 wells

- Average in-well LNAPL thickness decreased by more than 75%
- Time-series of LNAPL footprint demonstrates no downgradient migration
- Thicknesses of remaining in-well LNAPL was >0.01 foot in isolated locations but are being reduced by natural attenuation processes (NSZD)

(AGVIQ-CH2M 2012)

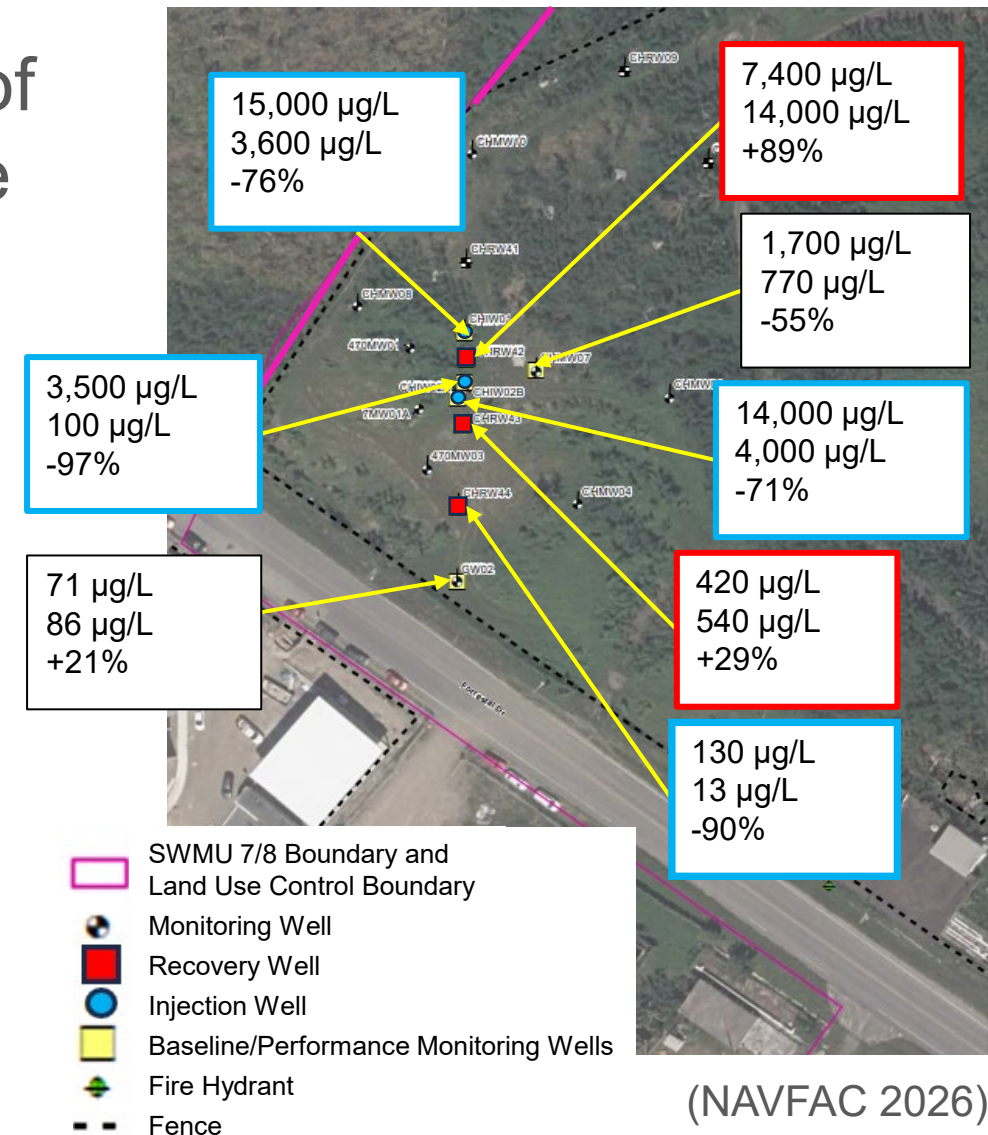


(CH2M 2023)

Remedial Optimization for Benzene Plume

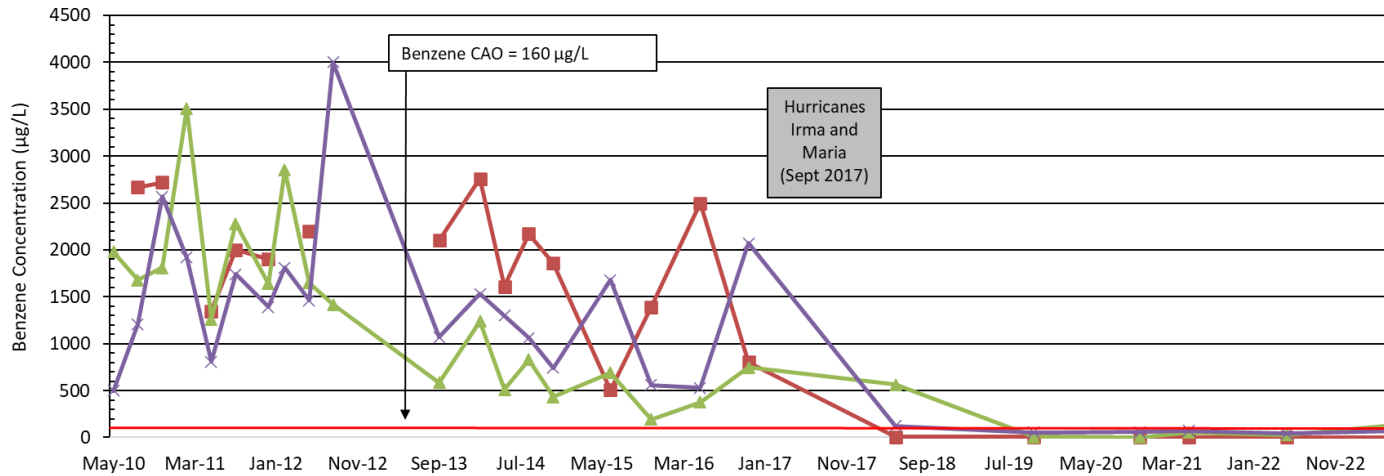


- Pilot study – enhance natural attenuation of persistent benzene in residual LNAPL core
- Approximately 81,000 gallons of sulfate solution injected into three wells in August 2023
- Findings after 14 months
 - Benzene concentrations decreased at some locations and increased at others
 - Mixed results suggest inconsistent sulfate distribution and persistence

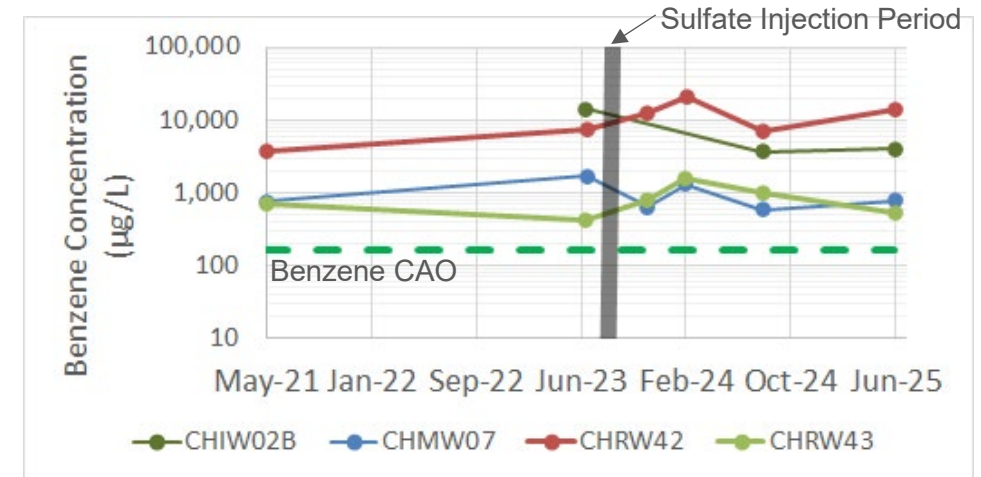
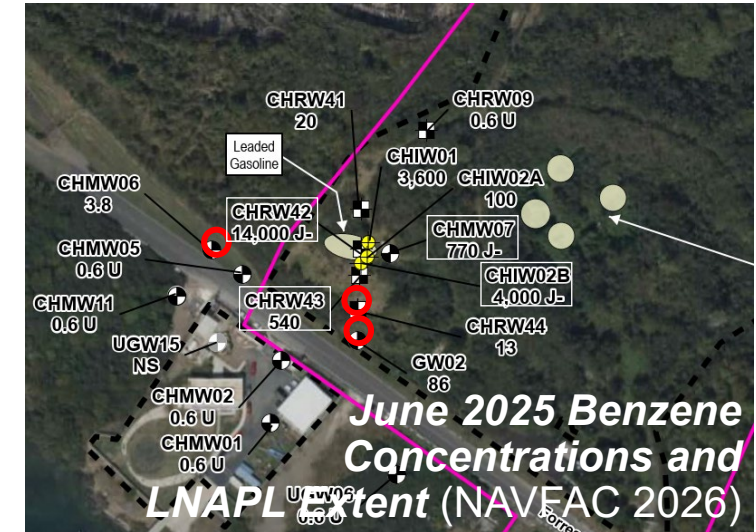


Benzene Reductions

Distal Well Benzene Concentrations (NAVFAC 2024)



- Natural attenuation reduced benzene concentrations downgradient of LNAPL by more than 96% from 2010 to 2021
- After pilot test, source area benzene concentrations remained above CAO of 160 µg/L



Post-sulfate Pilot Test Source Well Benzene Concentrations (NAVFAC 2026)

LNAPL: Phase 1 Optimization



- As described in RITS 2025 Optimization topic, worked through NAVFAC (2021) four lines of evidence to document no lateral migration, restricted exposure, impractical recoverability, and effective natural attenuation
- But also showed persistence of in-well LNAPL above CAO of 0.01 foot
- Made risk-based argument for revision to CAOs to remove in-well thickness requirement
- This will be the third iteration of a CAO change (previously in 2012) based on applying new science

Benzene: Phase 2 Optimization



- Performed pilot test to evaluate treatability of benzene in LNAPL source zone but results were inconclusive
- Initial recommendation was to evaluate additional remedial options such as air sparging or MNA and revisit the benzene CAO
- EPA receptive to revisiting risk-based evaluations driving current CAOs

Next Level Optimization: Revise CAOs



- The in-well LNAPL goal of 0.01 foot (circa ITRC 2006) not consistent with current science or site conditions
- Basis for in-well LNAPL CAO revision
 - ITRC (2018) and EPA Office of Underground Storage Tanks (2023) stepped away from 0.01 foot
 - Puerto Rico EQB Regulation for the Control of USTs (2018 update) permitted use of risk-based cleanup
 - Publications suggest more effective means to monitor remediation of LNAPL bodies
- Work performed
 - Intact soil coring, pore fluid saturation, and water drive mobility analysis to document residual and immobile nature of LNAPL at downgradient edge of LNAPL body
 - Baildown testing to measure LNAPL transmissivity and document it below ITRC recoverability threshold
 - Measurement of efflux to estimate NSZD rates surpass mass removal achieved by ongoing mechanical and manual methods

Next Level Optimization: Revise CAOs



- The 160 µg/L benzene in groundwater goal (circa 2012) not consistent with current science or site conditions
- Basis for groundwater benzene CAO revision
 - Based on outdated version of EPA's RSL Calculator (November 2011)
 - Johnson and Ettinger Model (EPA 2012) excluded biodegradation of petroleum hydrocarbons in oxygenated vadose zone
- Work performed
 - Ran EPA's RSL Calculator with 2024 toxicity values, target cancer risk of 1×10^{-6} , and target hazard quotient of 1
 - Used EPA's PVI-Screen model (2016) to incorporate aerobic biodegradation into vapor intrusion-based CAO

RSL: Regional Screening Level

Revised CAOs: Exit Strategy Adapted

- DRNA and EPA endorsed revised LNAPL CAO, revised benzene CAO pending the following actions
 - Reduce groundwater benzene concentration to less than 12,570 µg/L
 - Demonstrate continued plume stability by gauging and sampling 10 downgradient wells
 - Enforce existing industrial LUCs restricting contact with subsurface LNAPL, groundwater use, and excavations deeper than 10 feet
- Set basis for revised exit strategy
 - RC achieved with pending regulatory approvals of revised Statement of Basis
- Set clear and attainable requirements for LTMgt milestone



KEY POINT

Consider current science and adapting remedial objectives during optimization.

DRNA: Department of Natural and Environmental Resources

Knowledge Check: NAPR SWMUs 7 and 8



Question: What actions led to decision to revise CAOs at NAPR SWMUs 7 and 8 site?

Answers:

- a. It was incidental to ongoing optimization activities and evolved as a sensible and effective recommendation to advance remedial progress
- b. CAO revision was targeted early in optimization project because it was obvious they were not consistent with current science
- c. It happened by accident, was not initially intended, and came up randomly during a project team discussion
- d. Both a and b

Knowledge Check: NAPR SWMUs 7 and 8



Question: What actions led to decision to revise CAOs at NAPR SWMUs 7 and 8 site?

Answers:

- BENZENE a. It was incidental to ongoing optimization activities and evolved as a sensible and effective recommendation to advance remedial progress**
- LNAPL b. CAO revision was targeted early in optimization project because it was obvious they were not consistent with current science**
- c. It happened by accident, was not initially intended, and came up randomly during a project team discussion.
- d. Both a and b**

**KEY
POINT**

Appropriate CAOs are critical to a cost-effective exit strategy. Revision requires careful scientific consideration and stakeholder consultation.

Case Study 2 OPTI Award Criteria Evaluation



- ☒ Improves return on investment or avoids costs
- ☒ Accelerates reaching remedial goal
- ☒ Use of innovative technology or approach
- ☒ Required extra/unique stakeholder negotiations

Case Study 3: Naval Base Point Loma Exit Strategy



(NAVFAC 2024)

- IR Site 7 is approximately 5.8 acres (landfill)
- Site is adjacent to Point Loma Ecological Conservation Area, Cabrillo Memorial Drive (main road through Peninsula), and Command Third Fleet Office Area

IR: installation restoration

Naval Base Point Loma Background

- NBPL manages 22 active IR sites, munition response sites, and UST sites
- IR Site 7 is a landfill on a peninsula, approximately 100 feet above Pacific Ocean
- Site is highly visible, important to military operations, and valued by the surrounding Point Loma community



LEGEND

	Geotechnical Soil Boring		Stormwater Drainage Pipe
	Asbestos Sample Location		Geophysical Survey Transect
	Surface Soil Sample Location		Test Pit Location
	Surface Soil/Sol Boring Location (0-10 Feet)		Stormwater Drainage Outfall
	Surface Soil/Sol Boring and Soil Vapor Sample Location		Potential Disturbance/Disposal Areas Identified During Remedial Investigation
	Approximate Former Landfill Boundary (Dashed Where Inferred)		Time-Critical Removal Action (TCRA) Area
	Approximate Extent of Subsurface Debris (Dashed Where Inferred)		Trench Location
	Stormwater Drainage Channel (Post-TCRA) and Flow Direction		Installation Restoration Site 7 Boundary

Notes:

1. Approximate former landfill boundary based on geophysical results and 1964 aerial photograph review.
2. Approximate extent of subsurface debris boundary based on direct observation (soil borings, test pits, and trenches depicted on this figure).

IMAGERY SOURCE:
SANDAG & SanGIS, Nearmap,
San Diego County, 2020

NBPL: Naval Base Point Loma

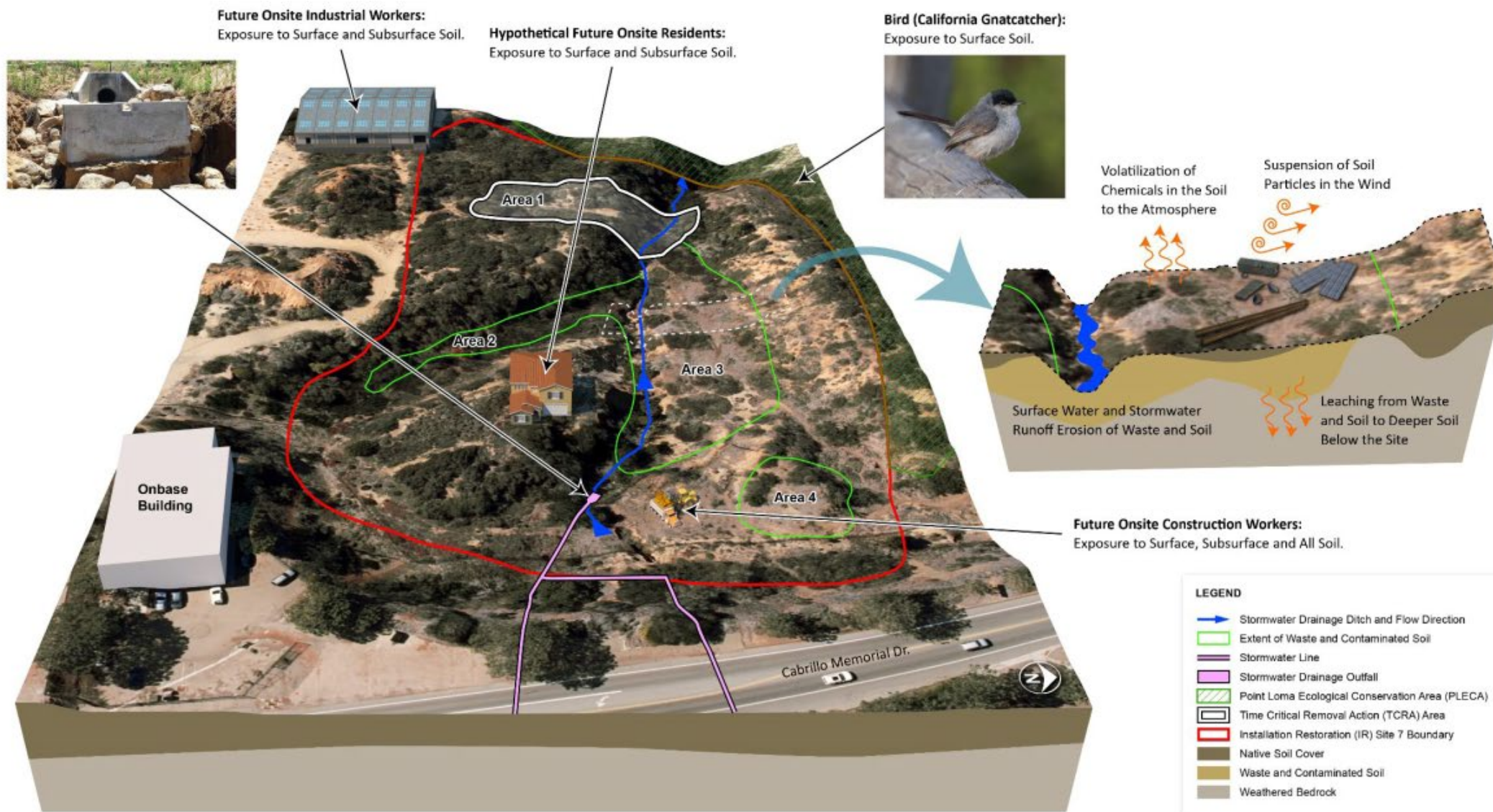
(NAVFAC 2024)

Problem Statement and Drivers



- Stormwater from an adjacent road discharges onto IR Site 7
- Heavy stormwater flows traveled through a channel across the site
- Concerns: Potential impacts on human health and ecological receptors and offsite migration

Conceptual Site Model



(NAVFAC 2024)

Early Actions and TCRA



- Based on RI/FFS, TCRA was implemented to meet human health and ecological protection goals (Area 1)
- Action addressed immediate risks associated with erosion and stormwater impacts at site
- Removal of approximately 5,600 cubic yards of soil and debris, 4 to 19 feet below ground surface
- Subsequent work (additional test pits during TCRA) further refined site conditions and informed later FFS Addendum and the Proposed Plan/ROD

FFS: Focused Feasibility Study

TCRA: Time-Critical Removal Action

San Diego Regional Water Quality Control Board

March 14, 2023

Michael Rafanan
Business Line Team Leader
Navy Facilities Engineering Command Southwest
EV Core, Floor 11
750 Pacific Highway
San Diego, CA 92132
Sent via e-mail to: michaelfrancis.p.rafanan.civ@us.navy.mil

In reply refer to/attn:
SL0607314310:KSchwall

Subject: No Further Action Letter for Installation Restoration Site 7 - Building A-44 Rubble Disposal, Time Critical Removal Area excluding the Storm Water Channel, Naval Base Point Loma, San Diego, California

Michael Rafanan:

This letter confirms the completion of site investigations for the Installation Restoration Site 7 – Building A-44 Rubble Disposal, Time Critical Removal Area excluding the Storm Water Channel, Naval Base Point Loma, San Diego, California (Site). Thank you for your cooperation throughout this site investigation. Your willingness and promptness in responding to our inquiries concerning the Site are greatly appreciated.

Based on information in the above-referenced file and with the provision that the information provided to this agency was accurate and representative of site conditions, this agency finds that the site investigations carried out at the Site¹ are in compliance with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act. Therefore, no further action for the Site is required.

Pursuant to the State and Regional Water Board's Public Participation guidance document, the San Diego Water Board informed the public of its intent to close the Site on January 30, 2023.² No comments were received during the public notification period.

TCRA Completion Report 2023



- Navy received concurrence from state regulatory agencies to consider the TCRA action to require NFA
- RPM saw NFA as success and path to potentially reach SC with full removal of waste and soil (i.e., no groundwater issues)
- Success achieved in closing portion of site and reducing portion of site eligible for UU/UE
- Because of good collaboration with agencies, agencies concurred

NFA: No Further Action

Decision Considerations and Cost Evaluation

- Consolidation and capping (\$6.8 million) alternative included LTMgt and was originally preferred, with perpetual costs estimated in NORM
- Full-scale excavation, estimated at \$10.1 million, was viewed as potential pathway to site closure if additional funding could be secured



*View of site from Cabrillo Memorial Road
(facing west)
(Jacobs n.d.)*

Community Engagement and Decision Support



- Public outreach through RAB meeting presented tradeoffs between long-term landfill management and full excavation
- Community members expressed support for full-scale removal to achieve SC rather than managing site indefinitely



***NBPL RAB members
participating in site tour
(NBPL 2026)***

RAB: Restoration Advisory Board

Proposed Plan Flexibility



Flexible Proposed Plan Text

“However, to ensure the integrity of the landfill cap as part of Alternative 4, the adjacent ravine must have sufficient flow capacity for a 100-year storm event which is currently being evaluated. Based on the results of this evaluation, Alternative 4 may prove less favorable to implement and the excavation alternatives (Alternatives 5 or 6), resulting in UU/UE of the entire site, are identified as contingency measures and one of these alternatives would be selected as the remedy in the ROD.”

(NAVFAC 2023)

- Following TCRA Completion Report in 2023, San Diego Regional Water Quality Control Board issued NFA determination for portion of the site (i.e., no groundwater issues)
- Report demonstrated full excavation could achieve UU/UE
- Proposed Plan presented consolidate and cap remedy but left placeholder in public meeting for full removal, pending availability of funds
- It included acknowledgment that closure with UU/UE on Point Loma peninsula could be possible
- ER,N Southwest manager discussed with Headquarters and received funding

KEY
POINT

Proposed Plan leaves door open for another alternative.

ER,N: Environmental Restoration, Navy

Remedy Change and Record of Decision



- State regulatory agencies concurred with Navy decision to perform a TCRA at IR Site 7
- ROD included a “significant changes” section to support full-scale excavation

Revised ROD Text

“...the Navy, with state agency concurrence, subsequently determined that an alternative other than the Preferred Alternative provided the most appropriate balance of trade-offs among the alternatives with respect to the evaluation criteria. As detailed herein, this significant change could be reasonably anticipated based on information available to the public in the Proposed Plan ...”

(Jacobs 2024)

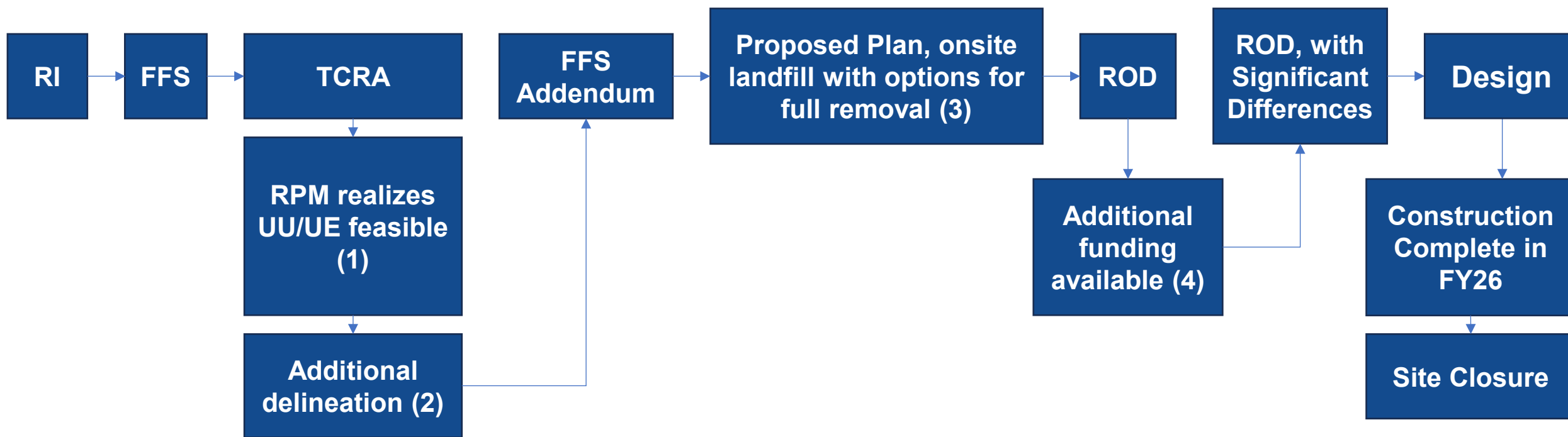
Keys to Success



- Cost plus contract (CLEAN and RA-C) allowed flexible funding
- RA-C was awarded to same contractors as TCRA, which increased confidence in remedy
- Teamwork included
 - Cohesive team of CLEAN and RA contractors
 - NAVFAC's strong regulator relations

RA: remedial action

CERCLA Process for IR Site 7



KEY POINT

1. RPM was aware UU/UE was feasible
2. Additional delineation provided basis for confident remediation quantities
3. Proposed Plan had flexibility
4. Headquarters identified funding

Knowledge Check: NBPL IR Site 7



Question: Which factor most directly enabled NBPL IR Site 7 project team to change selected remedy and advance site toward UU/UE?

Knowledge Check: NBPL IR Site 7



Question: Which factor most directly enabled NBPL IR Site 7 project team to change selected remedy and advance site toward UU/UE?

Answer:

Additional site characterization and risk reduction achieved through TCRA, combined with stakeholder and regulatory concurrence

**KEY
POINT**

This case study demonstrates that maintaining flexibility in CERCLA process allows teams to capitalize on new information, stakeholder support, and funding to achieve SC.

Case Study 3 OPTI Award Criteria Evaluation



Improves return on investment or avoids costs

- ☒ Accelerates reaching remedial goal
- ☒ Use of innovative technology or approach
- ☒ Required extra/unique stakeholder negotiations

Presentation Overview



- Introduction
- Overview of Exit Strategy Options
- Decision Frameworks
- Transition Assessments
- Case Studies
- Overcoming Challenges
- Wrap Up

Overcoming Challenges During the Journey



Category	Challenge	Approach to Overcome
Technical	Evolving understanding of contaminant behavior and remediation processes	Stay current on site science (fate/transport, matrix diffusion, natural attenuation, emerging contaminants)
	CSM uncertainty (spatial/temporal variability, matrix-bound mass, data gaps)	Periodically update CSM and revisit assumptions, performance metrics, and decision logic
	Balancing data density, frequency, and cost	Focus data collection on critical gaps that support optimization and progress toward SC
	Changing risk-based criteria and emerging contaminants	Stay current with evolving regulatory standards and adjust evaluation metrics accordingly
Cost	Upfront investment and long-term ROI uncertainty	Allocate program funds to support periodic evaluation of exit strategy and remedy performance

Overcoming Challenges During the Journey



Category	Challenge	Approach to Overcome
Administrative	Indifferent or absent regulators	Proactively engage regulators and maintain consistent communication on strategy and progress
	Ambiguous regulatory pathways	Leverage Navy–EPA–State partnering and discuss options early to reduce uncertainty
	Shifting administrative priorities	Keep regulators informed of anticipated changes and align on exit strategy adjustments
Programmatic	Complacency/loss of focus on closure	Maintain focus on achieving SC (or LTMgt where appropriate) and routinely revisit exit strategy
	Timing constraints and competing pressures	Be patient and implement strategy changes when conditions are favorable
	Need for sustained life cycle engagement	Make evaluation and refinement of exit strategy a routine part of project management

KEY POINT

Achieving site closure requires persistence, informed decision-making, and consistent engagement throughout the project life cycle.

Presentation Overview



- Introduction
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- Case Studies
- Overcoming Challenges
- Wrap Up

Wrap Up – Advancing Towards LTMgt and SC



- **Exit Strategy and Endpoints**

- Plan for LTMgt and SC early, even when exit strategies are not fully defined
- Recognize that LTMgt can be a planned, defensible endpoint (not a failure) when SC is not achievable

- **Decision Frameworks and Transition Thinking**

- Use decision frameworks and flowcharts to identify optimization, transition, and contingency actions
- Apply transition assessments to develop defensible, data-driven pathways from active remediation to passive strategies or optimized LTM

- **Data-Driven Decision-Making**

- Make the best decisions with available information, recognizing that site understanding will evolve
- Monitoring alone does not equal progress; data must be evaluated and translated into decisions
- Maintain and continually update the CSM to support decision-making

Wrap Up – Advancing Towards LTMgt and SC



- **Optimization and Life Cycle Management**
 - Apply optimization principles throughout the project life cycle
 - Optimization can generate significant cost savings and improve ROI
- **Stakeholder Engagement and Adaptability**
 - Engage regulators and stakeholders early and often to build alignment and avoid delays
 - Remain flexible and opportunistic, leveraging new data, improved science, funding, and stakeholder alignment

KEY POINT

Achieving site closure requires persistence, informed decision-making, and continuous alignment of strategy, data, and stakeholders throughout the project life cycle.

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Please reach out to Nate, Angela, and/or your respective OTI Workgroup Member with ANY optimization needs – we are here to support!

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BRAC: Base Realignment and Closure

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Questions



Groundwater-Surface Water Interactions (GSI)

Michael Mathioudakis, PE
GSI Environmental Inc.

RITS 2026

Disclaimer



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Information in this presentation is current as of 10 April 2026.

EXWC: Engineering and Expeditionary Warfare Center
NAVFAC: Naval Facilities Engineering Systems Command

Speaker Introduction



Michael Mathioudakis, PE

Environmental Engineer
GSI Environmental Inc.



- **BS Environmental Engineering** (Hydrogeology focus)
- **MS Geology and Geophysics** (Coastal Hydrology focus)
- 10 years working on investigation, remediation, and site characterization for DoW and private clients
- **FAA-licensed drone pilot** (Part 107) for mapping groundwater discharges to surface water

BS: Bachelor of Science
DoW: United States Department of War

FAA: Federal Aviation Administration
MS: Master of Science

PE: Professional Engineer

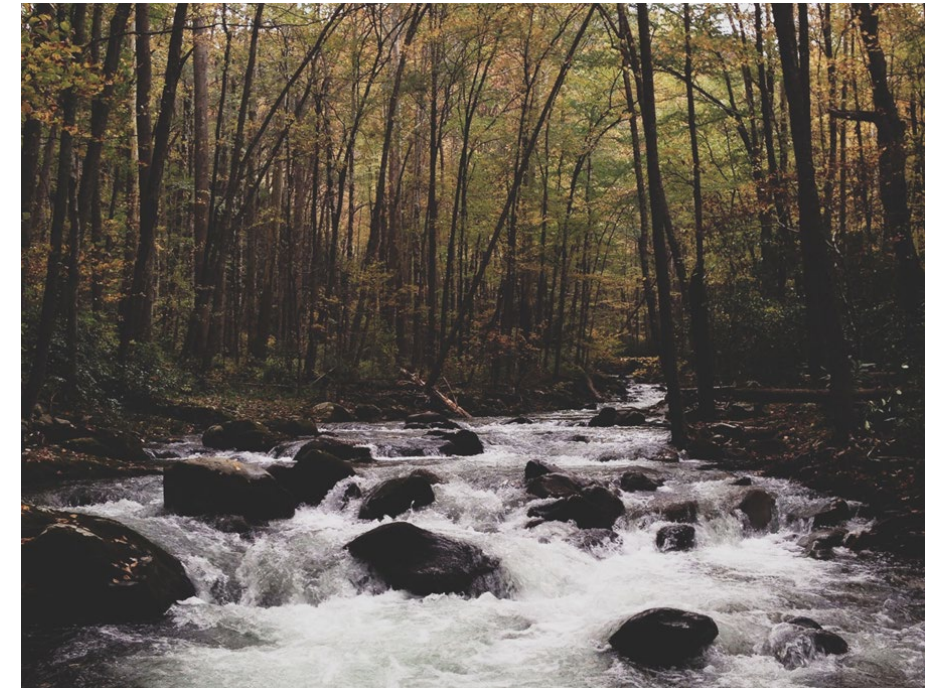
Presentation Overview



- Introduction
- What are GSI?
- When are GSI Important?
- Common Components of GSI Investigations
- How to Plan for and Scope GSI Investigations
- Unique Challenges of GSI Investigations for PFAS
- Case Study #1: Joint Base Cape Cod
- Case Study #2: Naval Station Newport
- Summary and Closing

Objectives

- Learn when and why GSI investigations are important for site characterization and remediation
- Summarize methods that can be used for GSI investigations
 - Field observations and measurements
 - Remote sensing
 - Hydrological methods
 - Geochemical methods
 - Geophysical methods
 - Modeling methods
- Present case studies with real-world examples of GSI investigations at DoW sites



(Mathioudakis 2014)

Past Related RITS Talks



- 2021** Monitoring Tools for Assessing Natural Attenuation in the Groundwater/Surface Water Transition Zone
- 2017** Natural Attenuation Processes at the Groundwater/Surface Water Interface
- 2009** Evaluating the Groundwater/Surface Water Interface

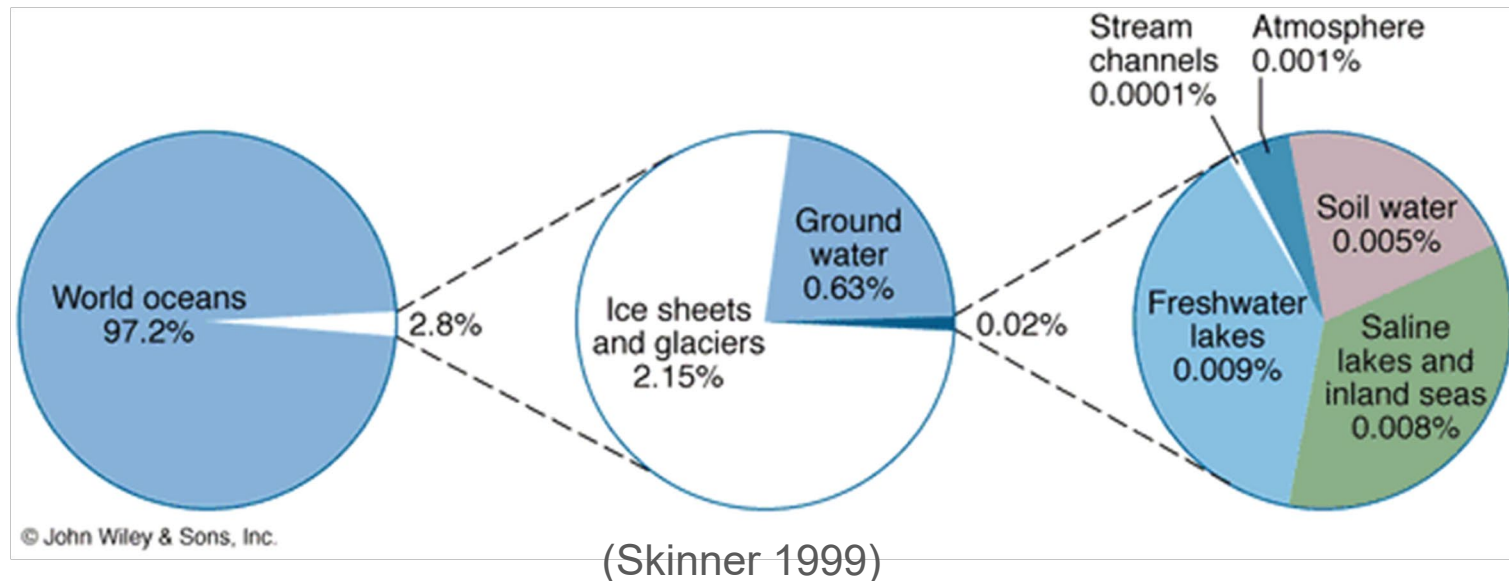
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What are GSI?

- ~10,000x more water in groundwater than in rivers/streams (Gleick 1993)
- Significant flow component in rivers/streams is groundwater (**Baseflow**)
- Flow directly from aquifers to ocean: **SGD**
 - Total: ~3–4x river discharge to ocean
 - Fresh: ~1% of river discharge to ocean (Zhou et al. 2019) but plays a significant role in nutrient cycling, anthropogenic impacts, etc.



SGD: submarine groundwater discharge

What are GSI?

- Hydrologic cycle driven by solar energy and gravity
- Transport time from source to sink depends on topography and geology
- Interfaces between groundwater and streams/rivers (*hyporheic zone*) and coastal waters (*subterranean estuary*) make up the GW-SW interface



(Skinner 1999)

GW: groundwater
SW: surface water

What are GSI?

Hyporheic zone

- Saturated portions of streambeds, banks, and floodplain containing water that originates from stream and returns to channel (Woessner 2017)
- Vital mixing zone for GW/SW, allowing for exchange of water, oxygen, and nutrients; **natural attenuation of contaminants via dilution and degradation**
- Bacteria and small invertebrates reside in hyporheic zone



(CCEHGI 2021)

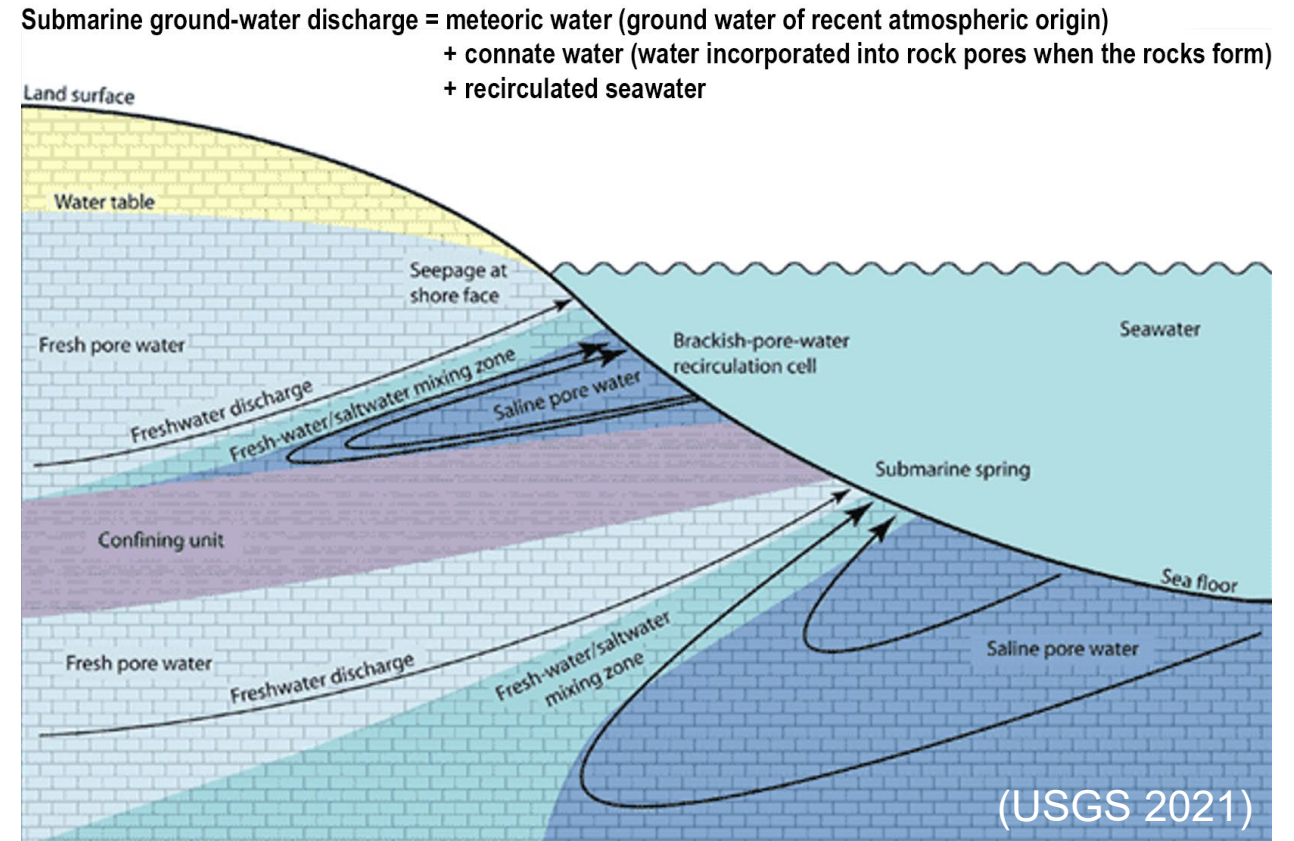
KEY POINT

GW mixes with SW in the hyporheic zone adjacent to streams/rivers.

What are GSI?

Subterranean estuary

- Subsurface zone in which meteoric water mixes with seawater in coastal aquifers
 - Tidal and seasonal variations
 - Natural attenuation of contaminants via dilution and degradation
- Implications of GW flux (SGD)
 - Maintains nutrient, temperature, and pH balance in coastal waters
 - excess nutrients → eutrophication
 - Anthropogenic impacts to coastal waters if GW impacted by contaminants
 - Chemical reactions between mixed waters and aquifer solids modify fluid composition

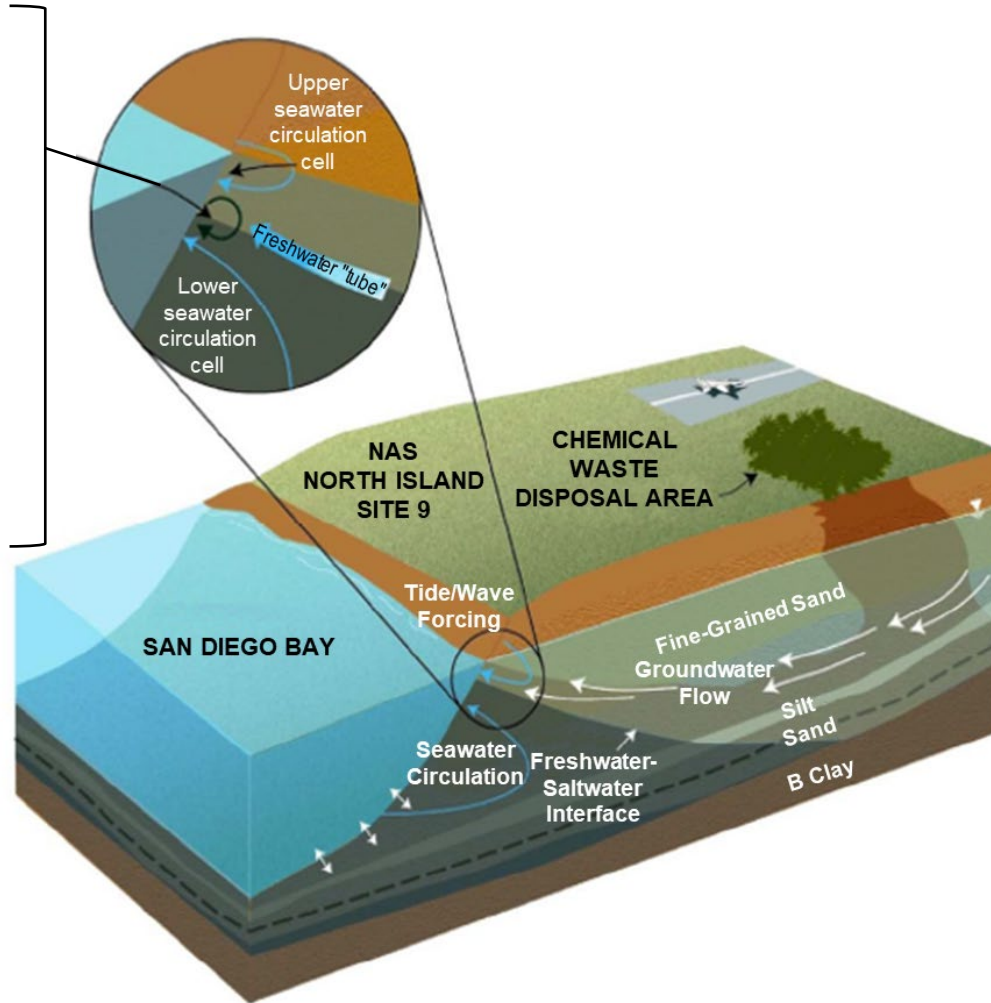


KEY
POINT

GW mixes with ocean water in subterranean estuary.

What are GSI?

- Hydrodynamic mixing
- Redox reactions
- Biotransformation
- Adsorption and ion exchange
- Mineral precipitation/dissolution
- Sorption



(NAVFAC 2011)

Attenuation processes at the GW-SW interface

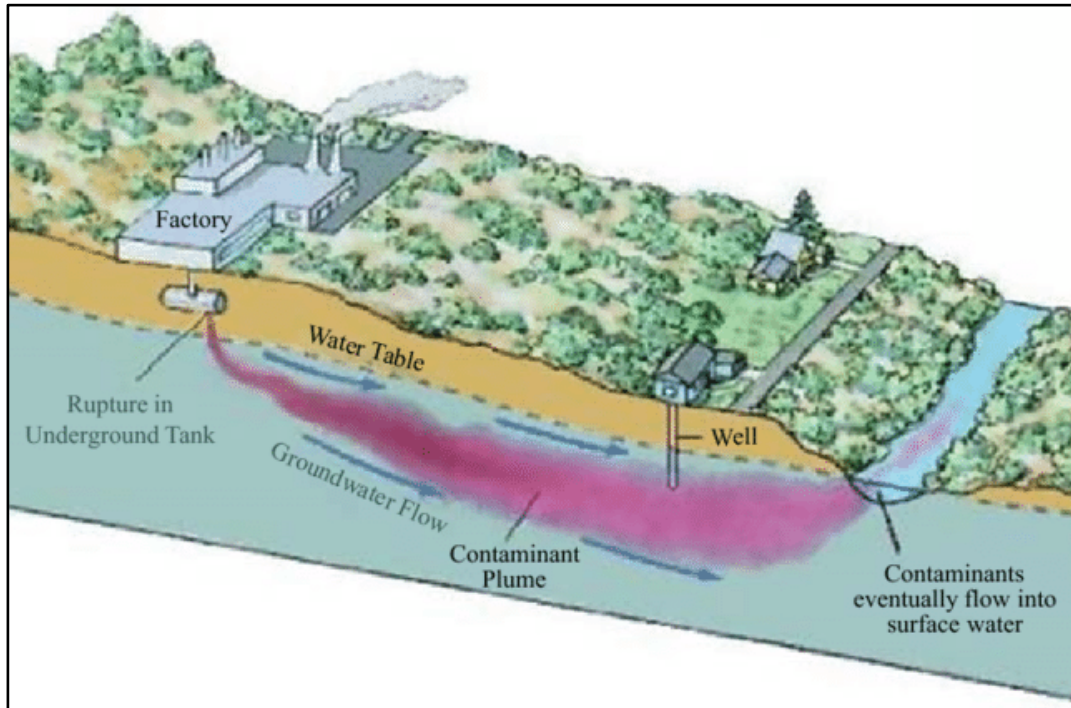
- Mixing/dilution
- Redox reactions
- Biotransformation
- Sorption
- Mineral precipitation/dissolution
- Ion exchange

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When are GSI Important?



(Earth Science Australia n.d.)

Cleanup sites (general)

- 75% of RCRA and CERCLA sites are located within 0.5 miles of SW body (EPA 2000)
- 47% of all CERCLA sites have impacted surface water (EPA 2000)

Cleanup sites (DoW)

- 43% of Navy installations on National Priorities List are in coastal areas (California, Florida, Virginia, Washington; Iery et al. 2022)
- Navy evaluated 32 sites in 2015 for optimization review; GW plumes at 25 of the 32 sites (78%) were discharging to SW and GW discharge zones (Iery et al. 2022)

CERCLA: Comprehensive Environmental Response,
Compensation, and Liability Act
EPA: United States Environmental Protection Agency

Navy: Department of the Navy
RCRA: Resource Conservation and Recovery Act

When are GSI Important?

Objectives of GSI investigation

CSM development/site characterization (sites near SW)

Defining extent of contaminant migration

- Are GW migration pathways complete? (i.e., Do plumes extend to SW?)

Informing risk assessment

- Should receptors in SWs be considered?

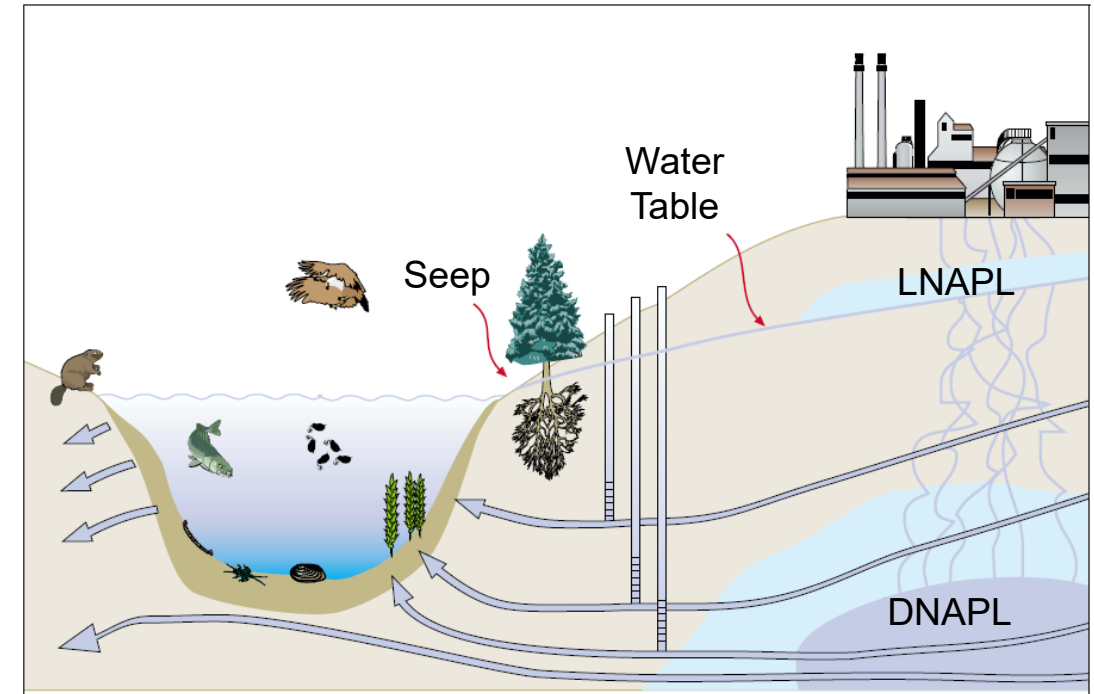
Quantifying GW discharge and contaminant flux

- How much contaminant mass is reaching SW?

Informing remediation strategies

- Will remediation impact natural flow regimes? (e.g., pumping wells causing saltwater intrusion)
- If plume is reaching SW, engineering controls might be needed

Monitoring remedy effectiveness

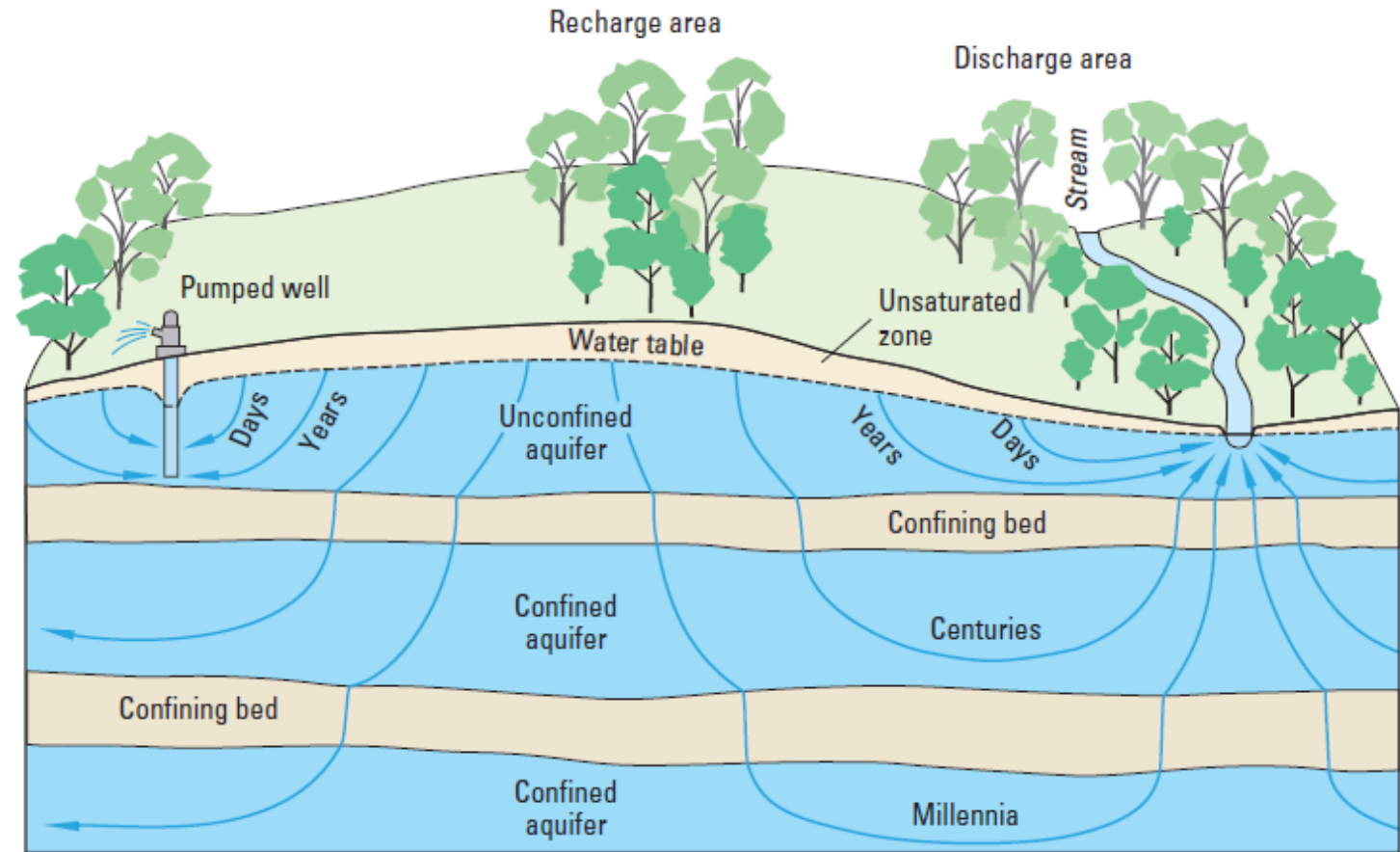


(EPA 2000)

When are GSI Important?

Unconfined conditions

Generally, GW reaches SW much faster (days/years) in unconfined aquifers than in confined aquifers (years/centuries/millennia)



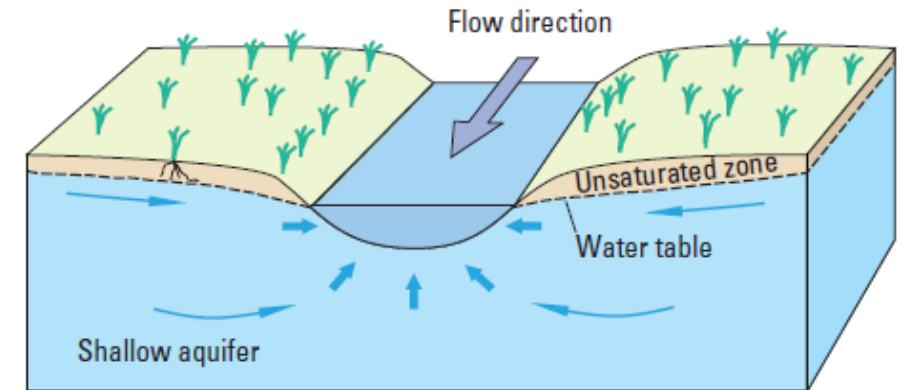
(USGS 2012)

When are GSI Important?

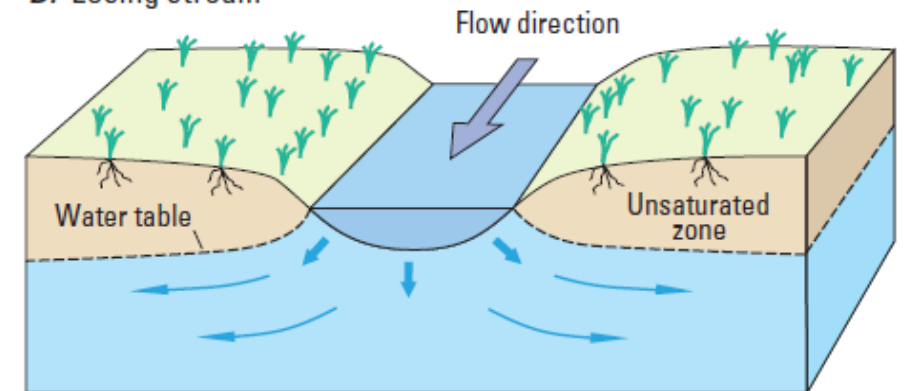
If SW is potential receptor

- Gaining/losing analysis is essential
 - Gaining: GW flowing into stream
 - Losing: SW flowing from stream into GW
 - Losing conditions are typically short-lived; most streams are “gaining” during baseflow conditions
 - If losing, GW Migration Pathway to SW is not complete, BUT...
 - GW head gradient moving away from stream can influence plume dynamics/contaminant transport

A. Gaining stream



B. Losing stream



(USGS 2012)

In which scenarios should GSI be considered?

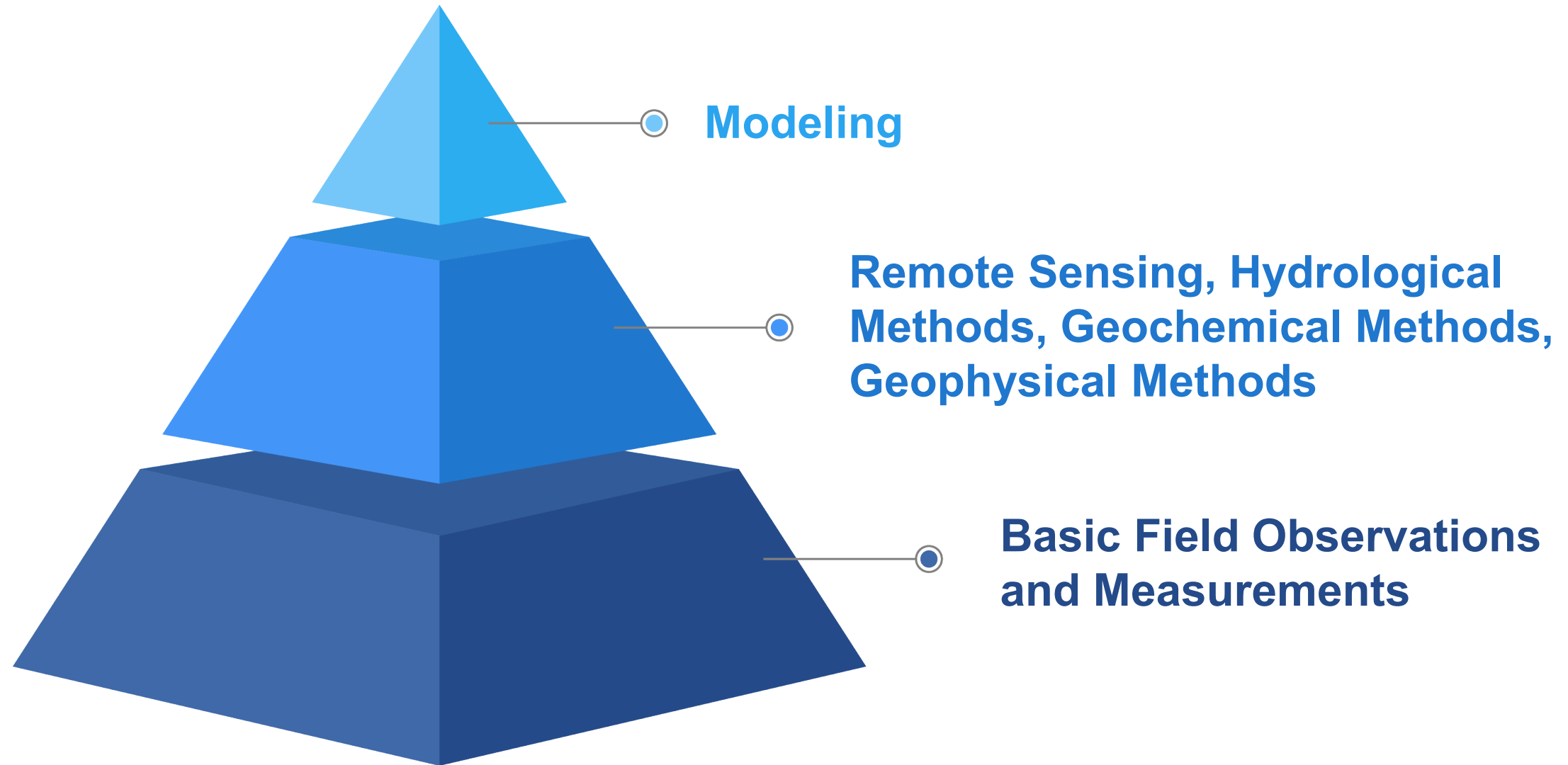
1. A small hydrocarbon release to shallow aerobic aquifer occurs approximately 2 miles from losing stream reach. Should GSI be considered?
2. Historical AFFF releases occurred from FTA approximately 1 mile from coastal estuary. Should GSI be considered?
3. DNAPL release occurs approximately 1 mile from gaining stream and penetrates confining layer in release vicinity due to hydraulic head of the DNAPL body. Should GSI be considered?

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Common Components of GSI Investigations



GSI Methods: Field Observations and Measurements



1. **Look for visual evidence of GW seeps** (bubbling, iron oxide staining, etc.)
2. **Collect basic field measurements**, which requires understanding background values for GW/SW
 - **Temperature** (GW lower than SW in warm climate, higher in cold climate)
 - **DO** (GW typically lower than SW)
 - **Conductivity** (GW lower than coastal SW)
 - **Silica** and **radon** (GW higher than SW)
 - For porewater/shallow GW measurements, use push piezometers or trident probes
 - Basic mixing calculations (any parameter) give % GW in SW
3. **Consider advanced techniques** (next slides)

DO: dissolved oxygen



(Mathioudakis 2016)

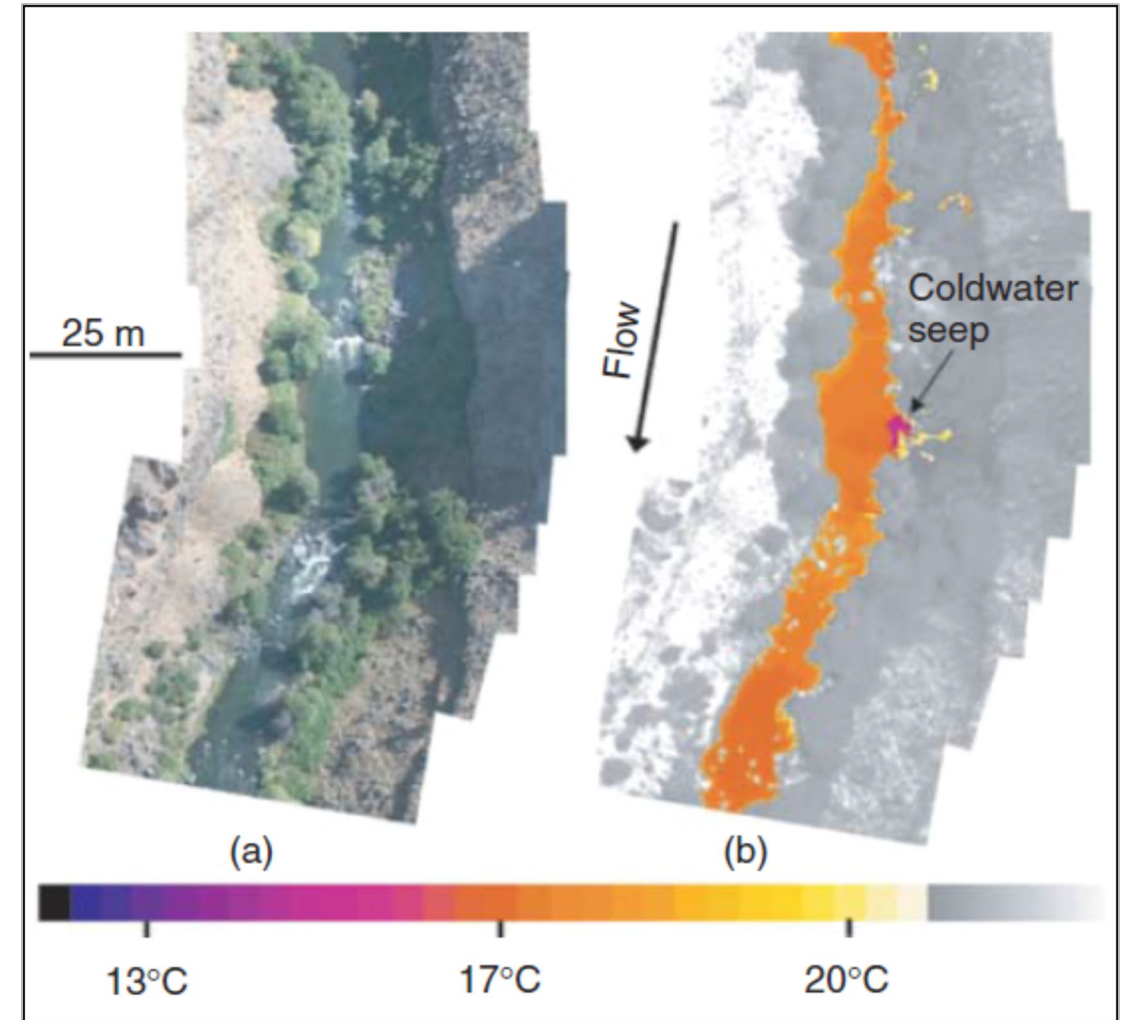


(Phys.org 2020)

GSI Methods: Remote Sensing

- GW is insulated from sun; not subject to same temperature fluctuations as SW
- Thus, there is usually ΔT between GW and SW
- Magnitude of ΔT depends on locale, season, time of day, etc.
- Mapping temperature with TIR allows us to “see” groundwater discharges due to temperature contrast
- Requires understanding of background temperature of GW and SW

ΔT : temperature difference
TIR: thermal infrared imaging



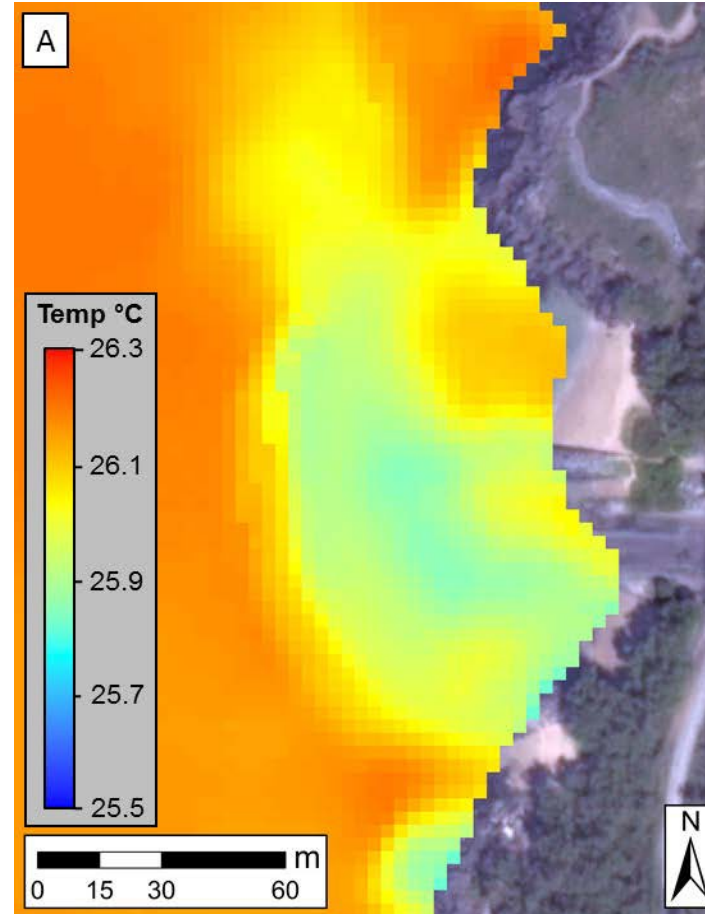
(Handcock et al. 2012)

GSI Methods: Remote Sensing

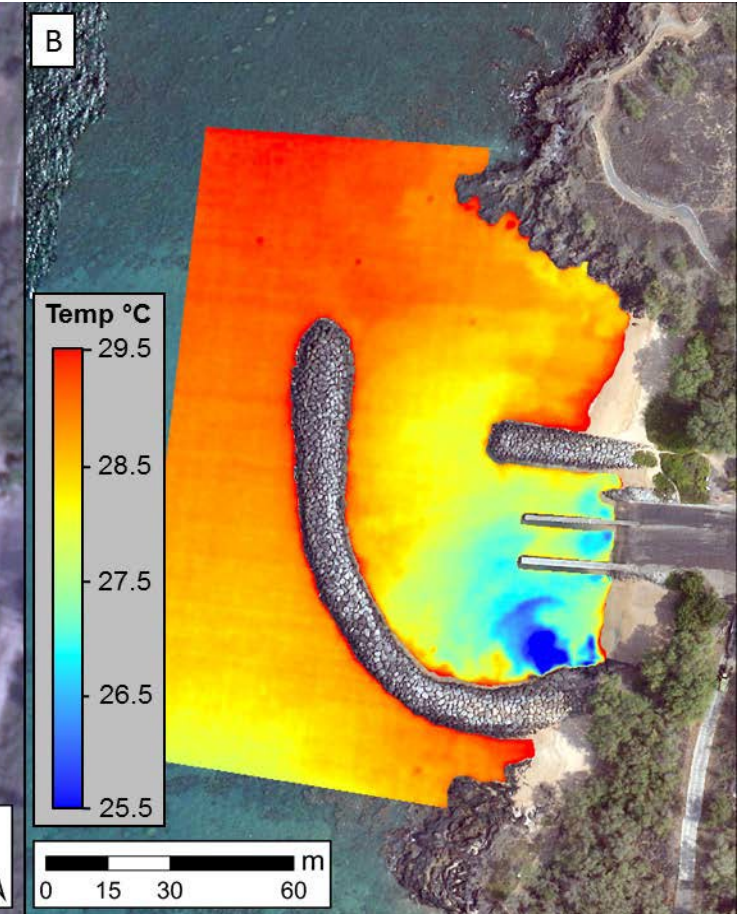
Platform choice
should depend on
scale of survey

Satellite:	global/regional
Aircraft:	regional/local
UAS:	local/site

Aircraft



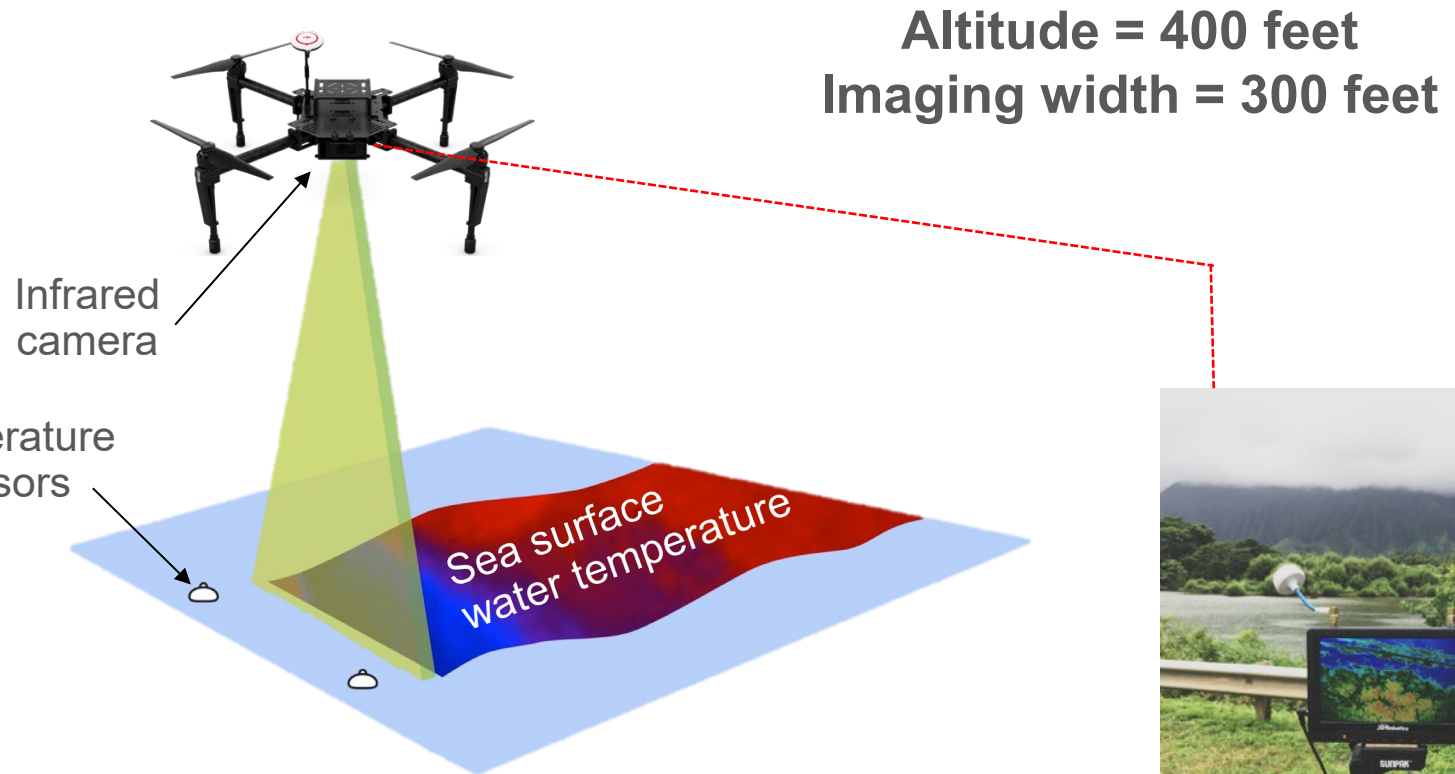
UAS



(Kennedy 2016)

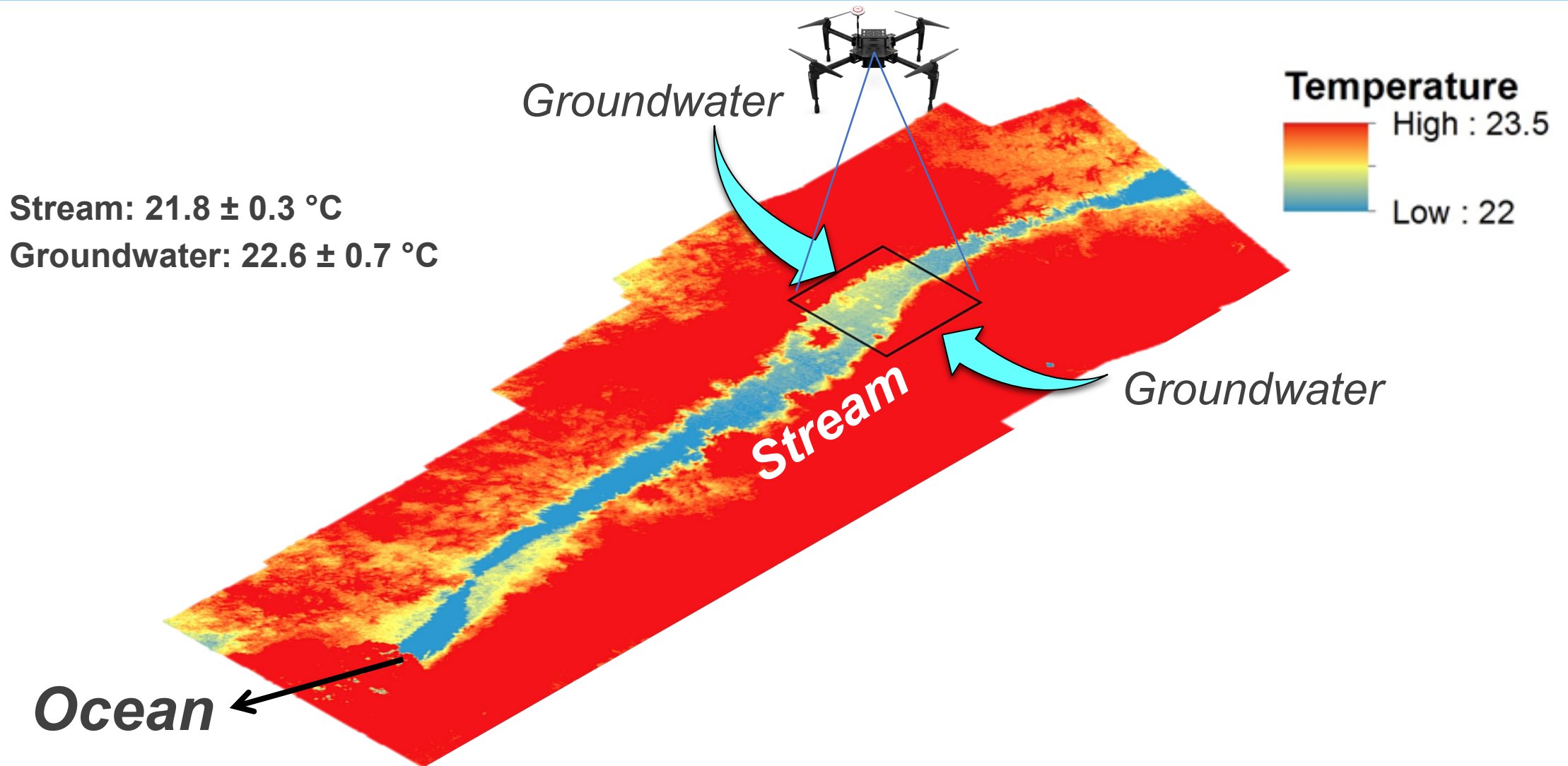
UAS: unmanned aircraft systems

GSI Methods: Remote Sensing—Coastal



(Mathioudakis 2016, 2017)

GSI Methods: Remote Sensing—Streams/Rivers



°C: degrees Celsius

(Mathioudakis 2017)

GSI Methods: Remote Sensing

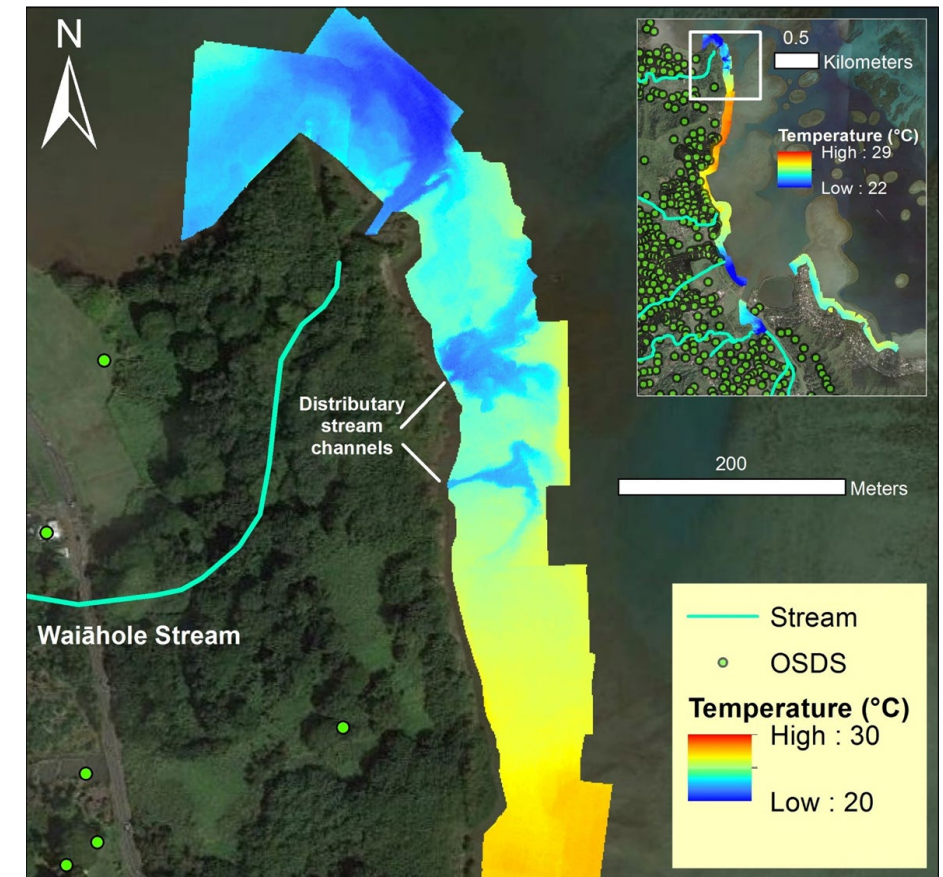


TIR best practices

- Time surveys with low tide, ambient temperature, etc., for optimum contrast
- Deploy in situ temperature sensors (ground-truthing) and ground control points (georeferencing)
- Abide by FAA regulations: pilot licensing, aircraft registration, etc.
- Note relevant restrictions (e.g., no use of DJI drones by federal agencies or contractors)

KEY POINT

Temperature differences between GW and SW allow us to “see” GSI with TIR.

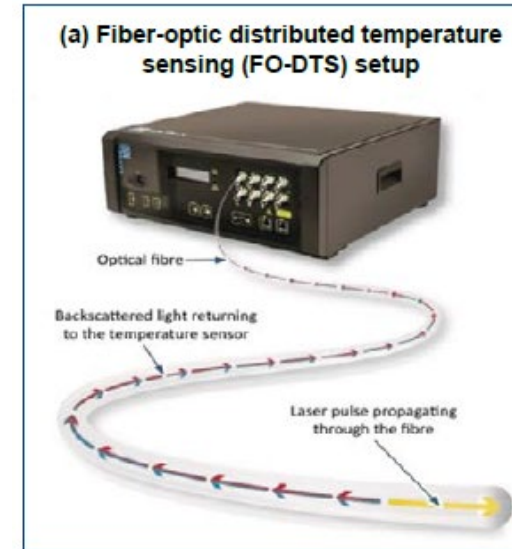


(Mathioudakis et al. 2025)

GSI Methods: Fiberoptic Distributed Temperature Sensing

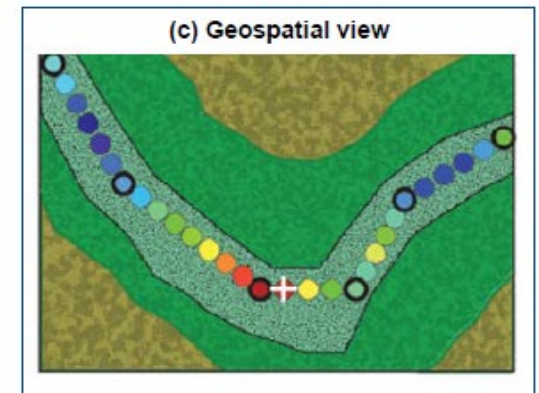
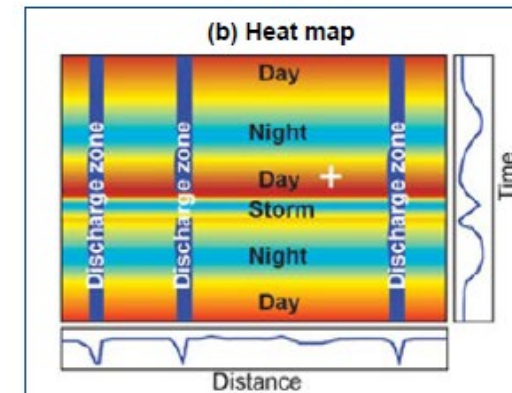
- Fiberoptic cable placed along GW-SW interface
- **Time-series measurements of temperature** along length of cable for detecting GW seeps
- While UAS-TIR is ideal for “snapshot” surveys, FO-DTS allows for evaluation of GW discharge over time where fluctuations are expected due to tides, rainfall, and other external factors

More on this later...



- (a) FO-DTS control unit with fiber-optic cable
- (b) FO-DTS data displayed in a heat map as temperature versus distance and time
- (c) Temperature along the cable, with locations interpolated linearly between points

NOTE: FO-DTS photo courtesy of Silixa LLC. Images adapted from Domanski et al. (2020)



(NAVFAC 2025)

GSI Methods: Hydrological

Physical measurements/analyses

- Seepage runs (gaining/losing analysis)
- Seepage meters
- UltraSeep
- Stream gauge/piezometer pairs



(Mathioudakis 2017)



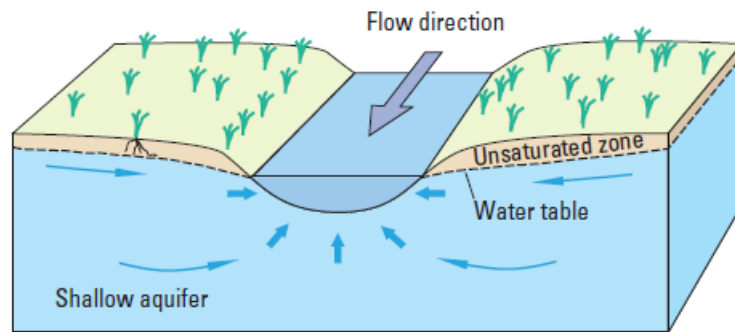
(Mathioudakis 2017)

GSI Methods: Hydrological

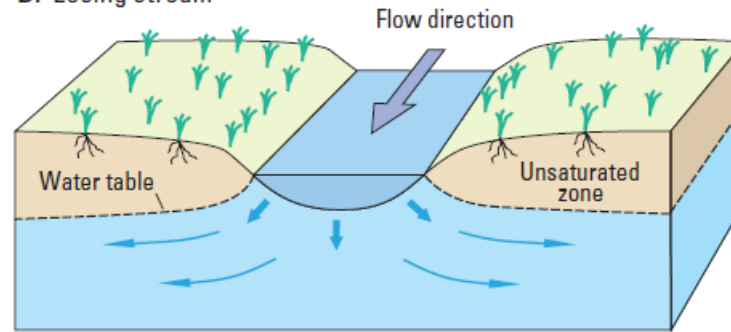
Seepage runs (gaining/losing analysis)

1. Divide stream/river into reaches
2. Measure flow at upstream and downstream boundary of each reach and all tributaries/diversions
3. Use measurements in mass balance equation

A. Gaining stream



B. Losing stream



(USGS 2012)



(Mathioudakis 2017)

$$GW\ Input = Q_{GW} = Q_{downstream} - Q_{upstream} + \Sigma Q_{diversions} - \Sigma Q_{tributaries}$$

(GW Input = downstream flow – upstream flow + diversion flow – tributary flow)



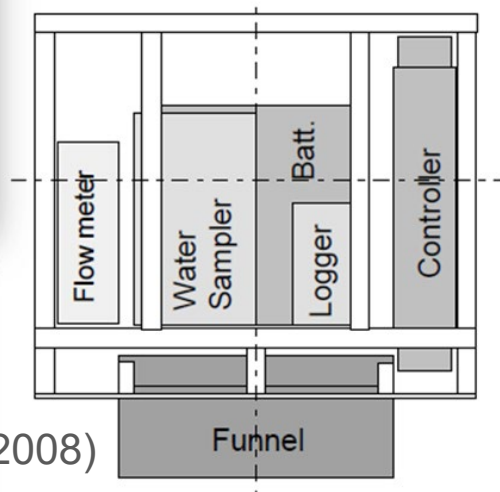
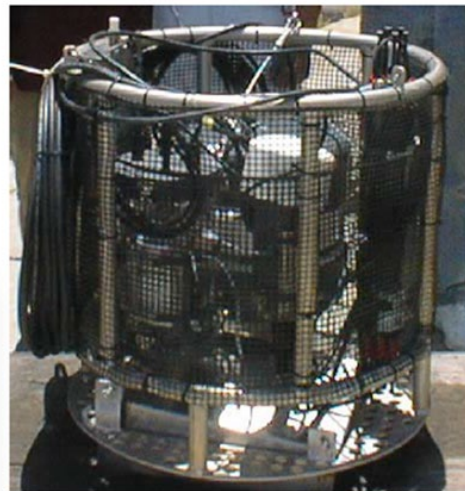
(USGS 2016)

Seepage meters

Directly measure flux (volume/time) between GW and SW

- **Installation:** Bottomless cylinder (e.g., drum or pipe) is pushed into lake or stream bed, isolating portion of sediment
- **Connection:** Clear collection bag filled with known volume of water is attached to tube at top of cylinder
- **Measurement:** Change in water volume after set time indicates GW flux (or discharge) rate
- **Calculation:** Flux rate is determined by volume change, time, and area of cylinder

GSI Methods: Hydrological



(ESTCP 2008)

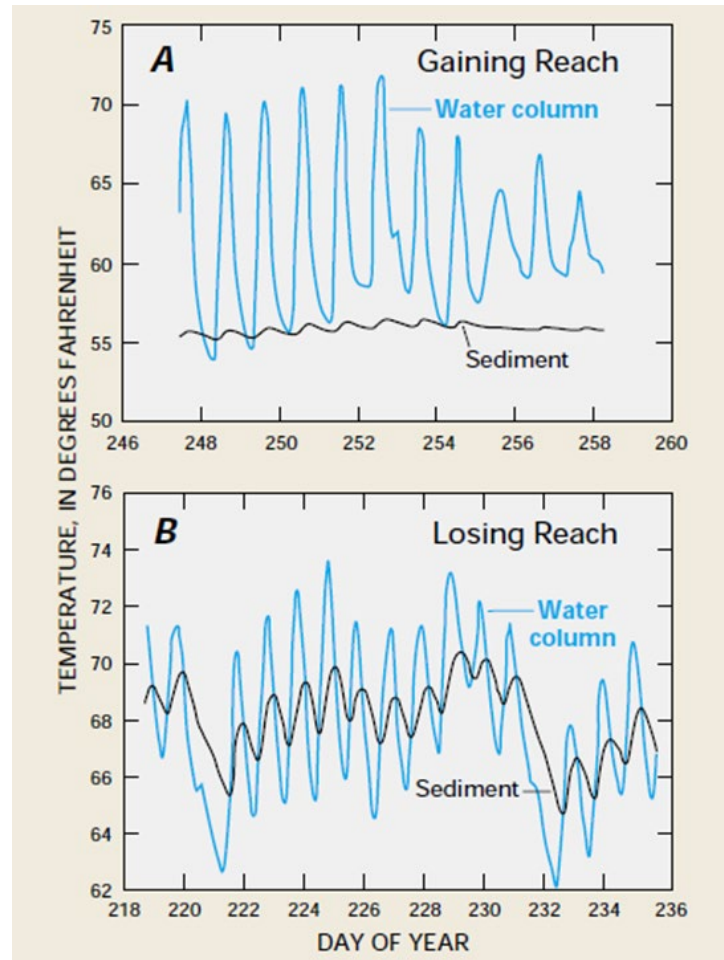
UltraSeep

- Integrated seepage meter and water sampler for quantifying discharge rates and chemical loading from GW to SW
- Continuous flow detection and automated sample collection
- Time-series data can be collected to show GW discharge and concentrations over time

GSI Methods: Hydrological

Stream gauge/ piezometer pairs

- Compare temperatures and/or elevations of stream and water table to determine when stream is gaining and losing at particular location
- Quantify gradient and hydraulic conductivity to allow for volumetric flux calculation
- Use BFI method



(Constantz 2008)



(Mathioudakis 2017)

BFI: Baseflow Index



(Mathioudakis 2017)

SBPFM: sediment bed passive flux meter

Methods

Most geochemical methods rely on tracers (natural or artificial) and associated analytical model or calculations to quantify GSI via **mixing model approach**

- Natural tracers
(radon, isotopes, ions)
- Artificial tracers
(injected tracer dyes, bromide)
- SBPFM

Natural tracers

- Radon, isotopes (water, nitrogen), ions (salinity)
- Analysis depends on concentration differences in GW and SW for chosen tracer (e.g., radon higher in GW than SW)
- Water sampling at surface discharge location and at “endmembers” (background/ baseline locations for GW and SW)



(Mathioudakis 2017)

Artificial tracers

- Inject conservative (nonreactive) tracer in GW (fluorescein dye, rhodamine dye, bromide, etc.)
- Measure concentrations and time lag at discharge location
- Tracer acts as proxy to estimate mass discharge and flow time from source to receptor
- Accurate estimates of breakthrough time (days/weeks/years based on GW velocity) are critical to not miss the response
 - Start measuring response early!

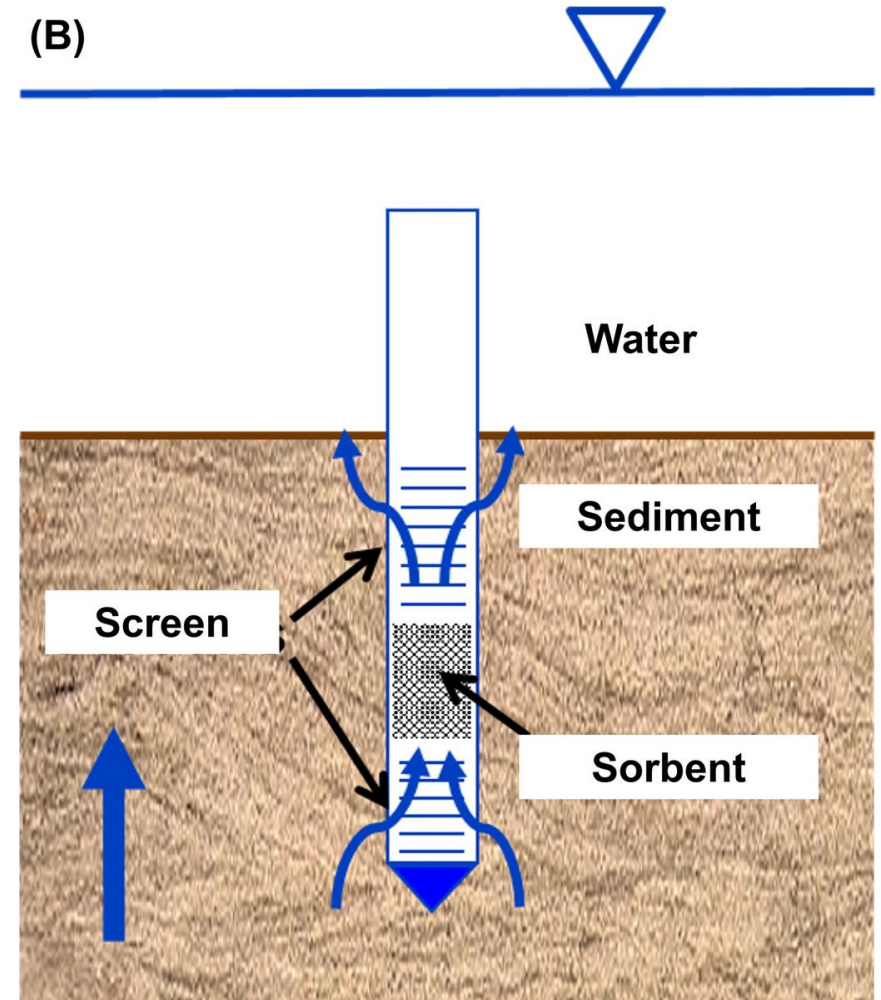


(Whittier et al. 2014)

SBPFM

Direct-push probe used to measure GW and contaminant mass fluxes in lake or stream beds by passively intercepting ambient flow through a sorbent matrix

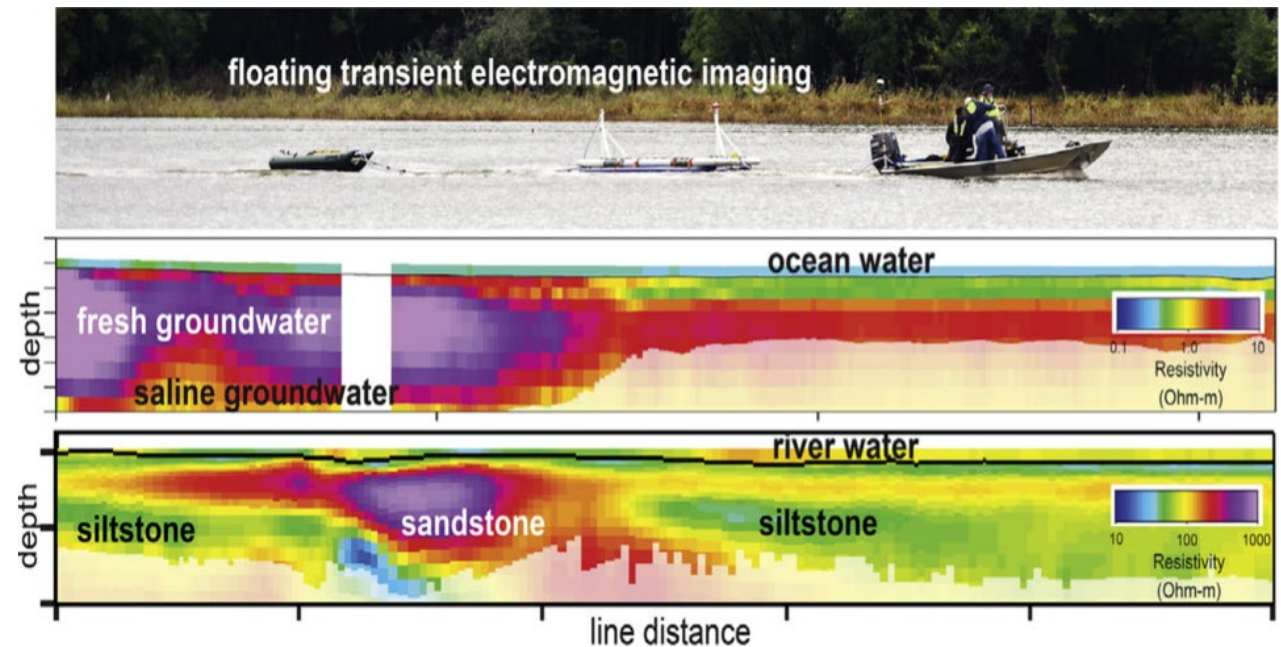
- 1) **Deployment:** SBPFM pushed into sediment
- 2) **Passive Interception:** Ambient vertical water flow (up or down) moves through screens and sorbent matrix
- 3) **Tracer Elution:** Water-soluble tracers (e.g., alcohols) within sorbent are displaced at rate proportional to water flux, measuring water flow
- 4) **Contaminant Capture:** Dissolved contaminants in sediment water are retained (sorbed) onto matrix, proportional to contaminant mass flux
- 5) **Retrieval and Analysis:** Lab analysis quantifies remaining tracers and captured contaminants to calculate fluxes



(Haluska et al. 2024)

Waterborne frequency domain EM

- Ideal for coastal surveys of GSI
- Detects variations in subsurface electrical resistivity using EM induction
- Noninvasive; does not require direct electrical contact with water or earth
- Ideal for moving or continuous surveys and at sites with very resistive surface layers that hinder electrical contact



(EPA 2025)

EM: electromagnetic

GSI Methods: Geophysical

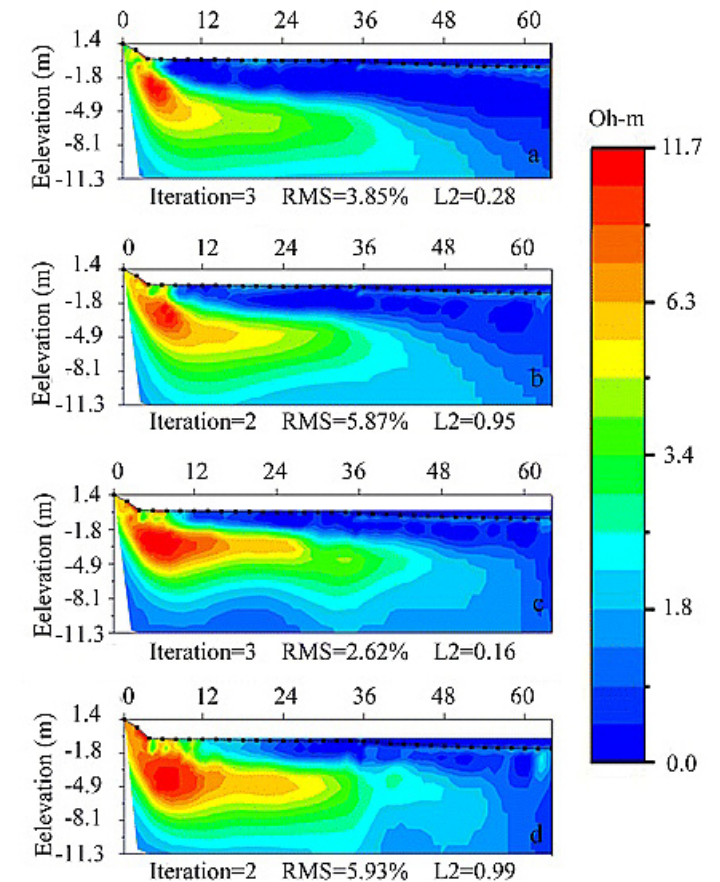
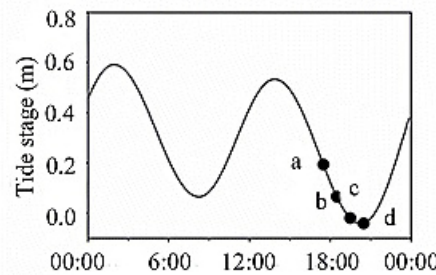
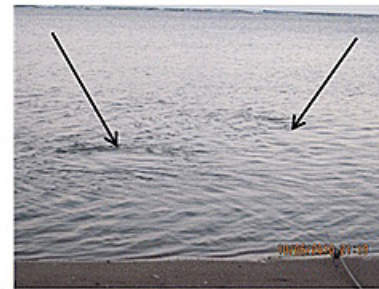
ERT

- Ideal for tidal analysis of GSI at coastal sites
- Electrical resistivity is resistance to flow of electrons (current); inverse of electrical conductance

Fresh water = more resistive

Saltwater = less resistive

- Like temperature or salinity, resistivity can be used as tracer
- Fresh water discharges to saltwater are more resistive compared to seawater



(Dimova et al. 2012)

ERT: electrical resistivity tomography

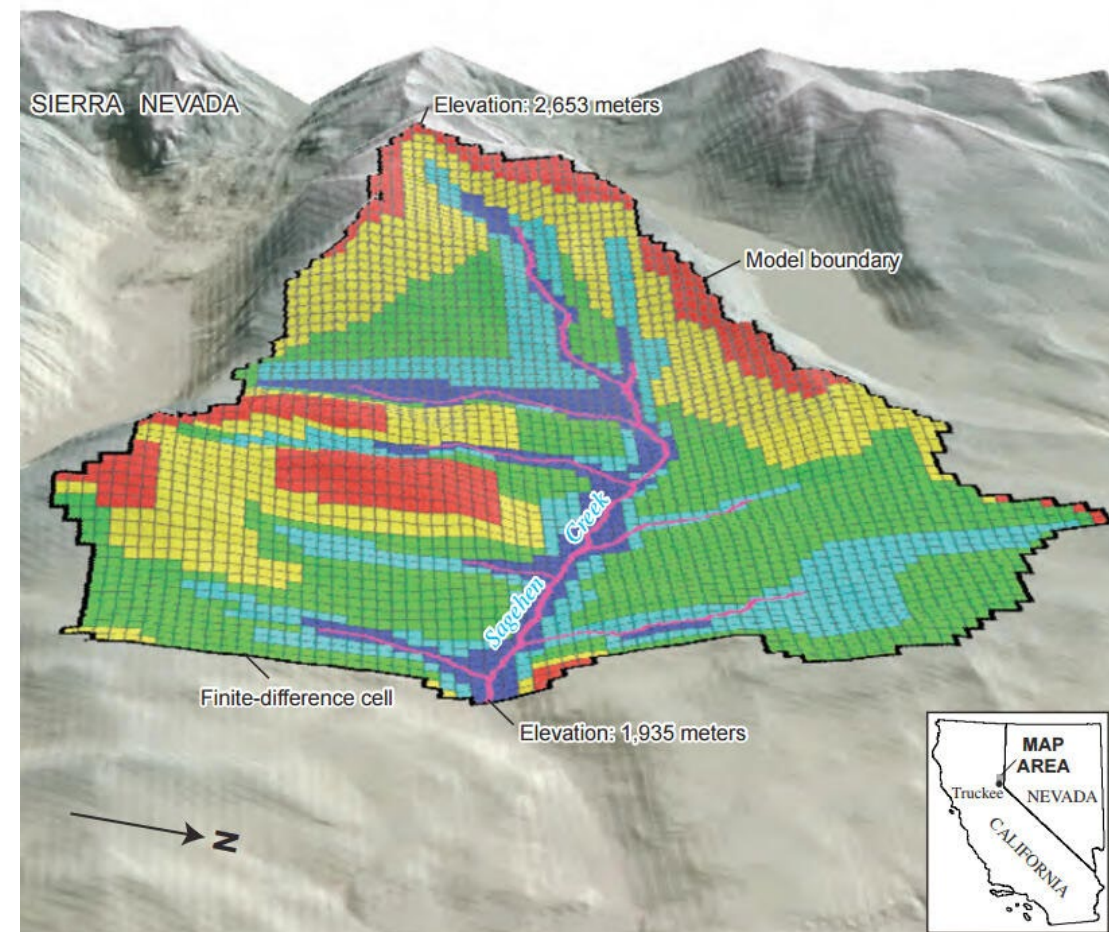
Break

GSI Methods: Modeling

Modeling basics

- Computer code (algorithm) that solves groundwater flow equation
 - Diffusion equation for transient flow;
Laplace equation for steady state flow
- Operates on conservation of mass principle
- Source code free and public domain; GUIs (GMS, GW Vistas) require licenses

GMS: Groundwater Modeling System
GUI: graphical user interface



(USGS 2023)

Basic flow model/code

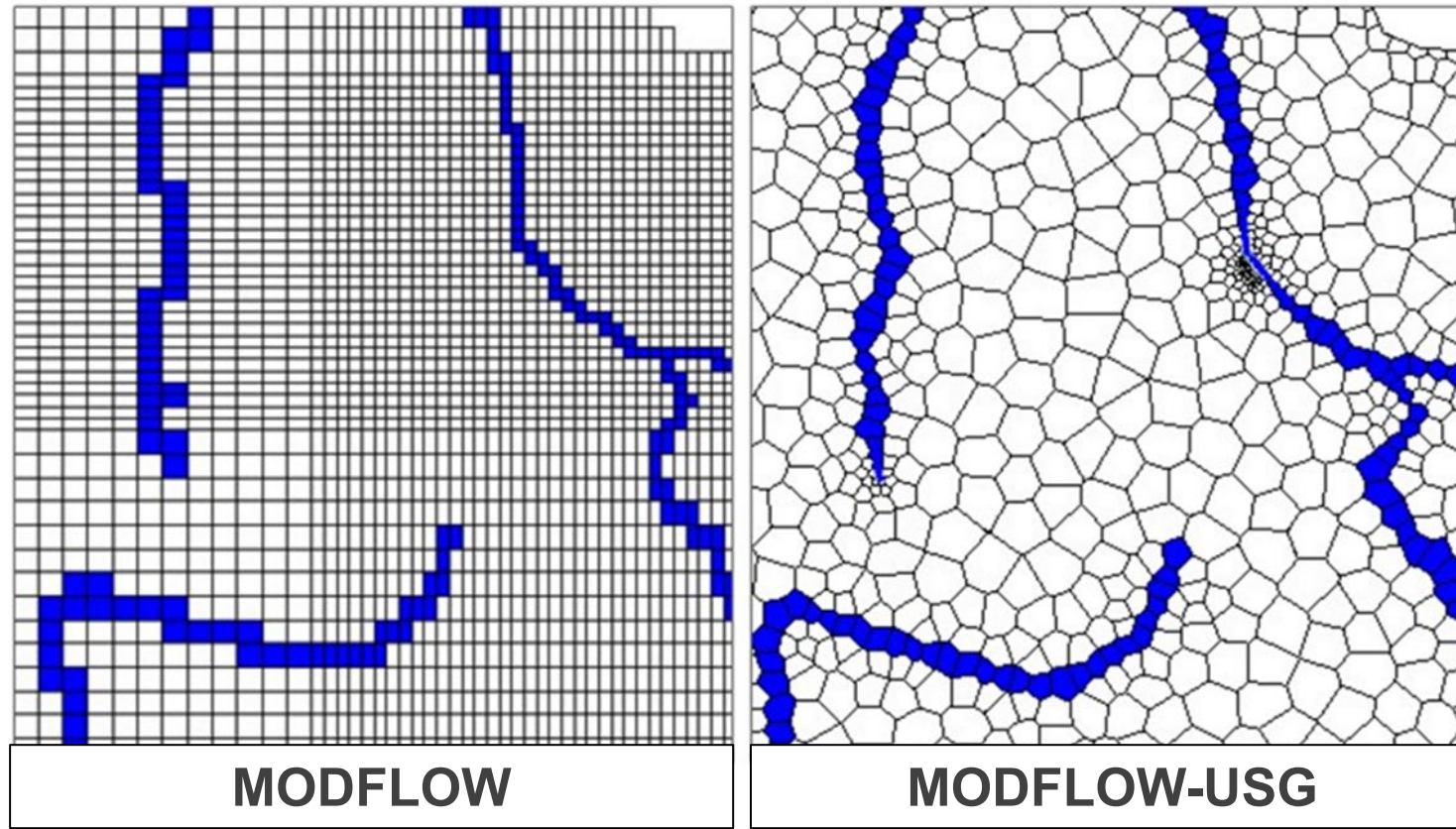
MODFLOW: USGS's modular hydrologic model

- *International standard for simulating and predicting groundwater conditions and groundwater/surface-water interactions.* (USGS 2022)
- All models start in MODFLOW
- MODFLOW-USG (2013) added unstructured grid capabilities

Relevant add-on packages

- **MODPATH:** Computes flow paths from MODFLOW outputs
- **MT3DMS/MT3D-USGS:** Simulates groundwater solute transport
- **SEAWAT:** Simulates variable-density groundwater flow and transport
- **GSFLOW:** Simulates coupled GW/SW flow
- **SWI6:** Sharp-interface saltwater intrusion package

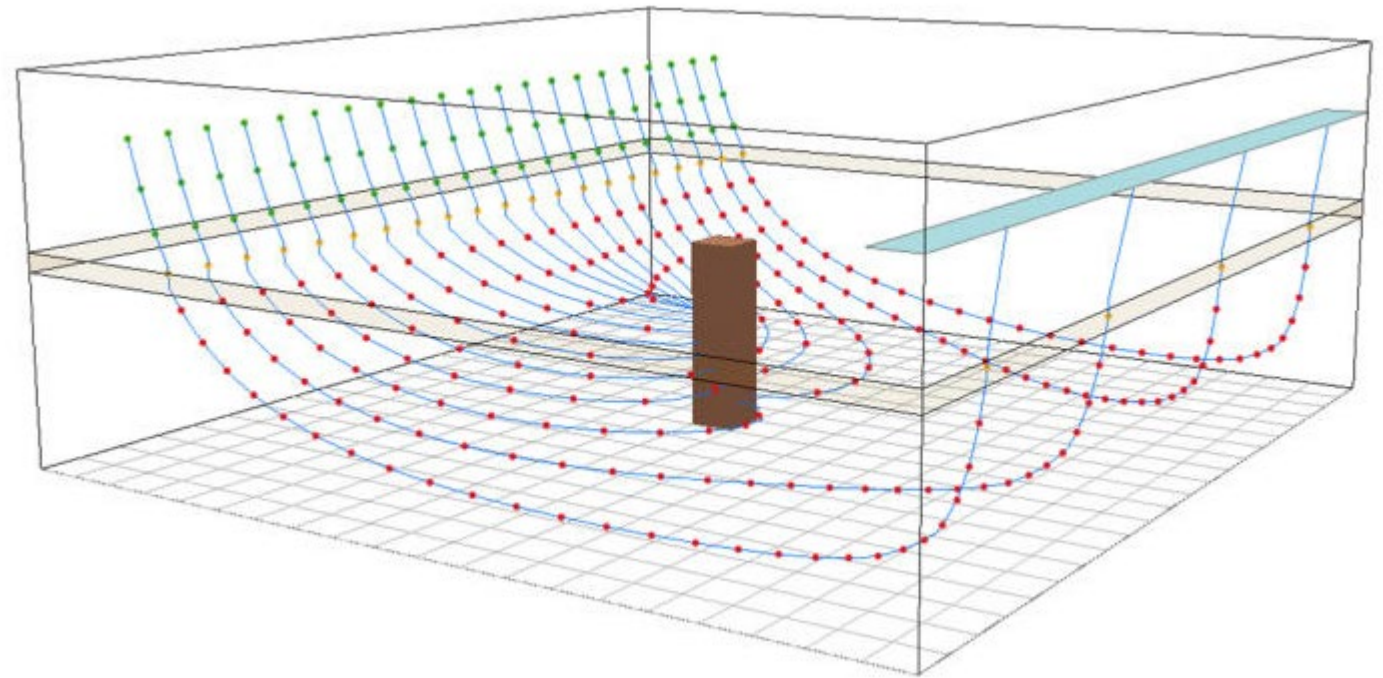
MODFLOW-USG (unstructured grids)



(Waterloo Hydrogeologic 2013)

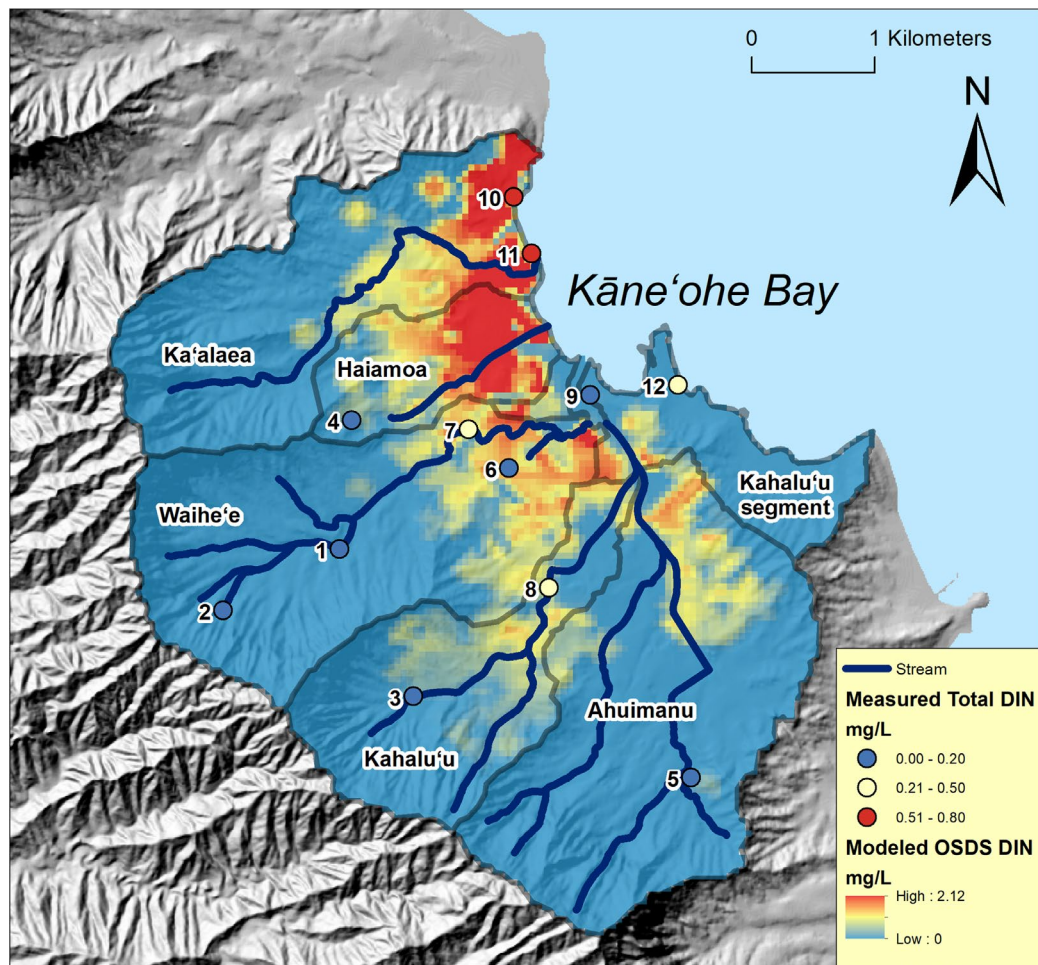
MODPATH

- Computes flow paths from MODFLOW outputs
- Relevant applications include determining/delineating
 - GW travel times and flow paths
 - Capture zones
 - Radius of influence
 - Source of GW seeps



(USGS 2017)

GSI Methods: Modeling



(Mathioudakis et al. 2025)

MT3DMS

- Advection-dispersion solute transport
- Can simulate transport within streams and lakes, including solute exchange with connected groundwater
- Chemical reaction package includes ability to simulate interspecies reactions and parent-daughter chain reactions
- Relevant use cases include the following
 - Simulating contaminant transport based on known chemical properties
 - Simulating three-dimensional heat transport (heat is a GW tracer)

GSI Methods: Modeling

SEAWAT

- Simulates variable-density groundwater flow and transport
- Use cases: brine migration, seawater intrusion, CF&T in coastal aquifers (integrated with MT3DMS)

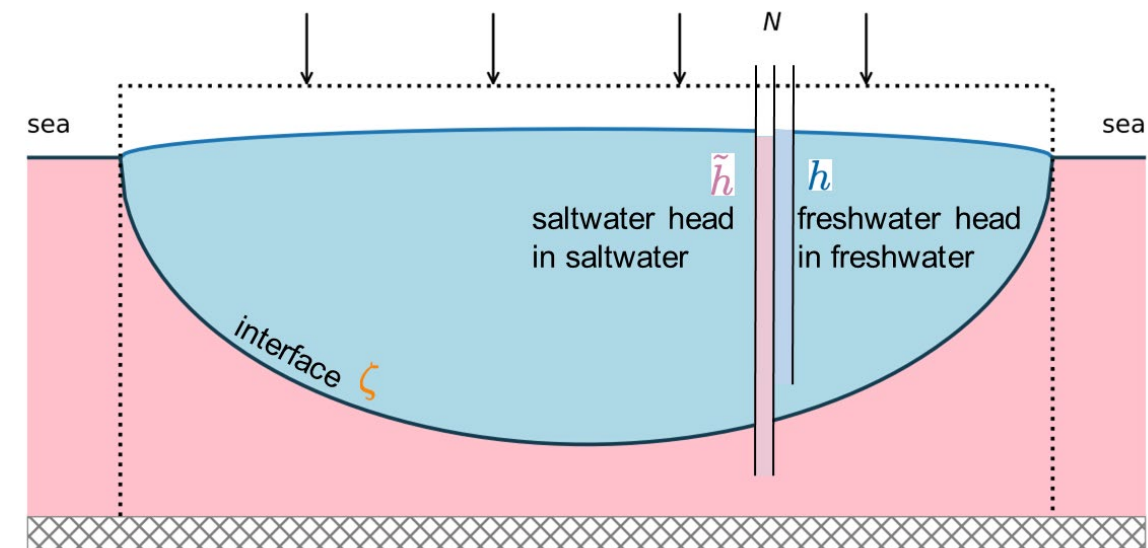
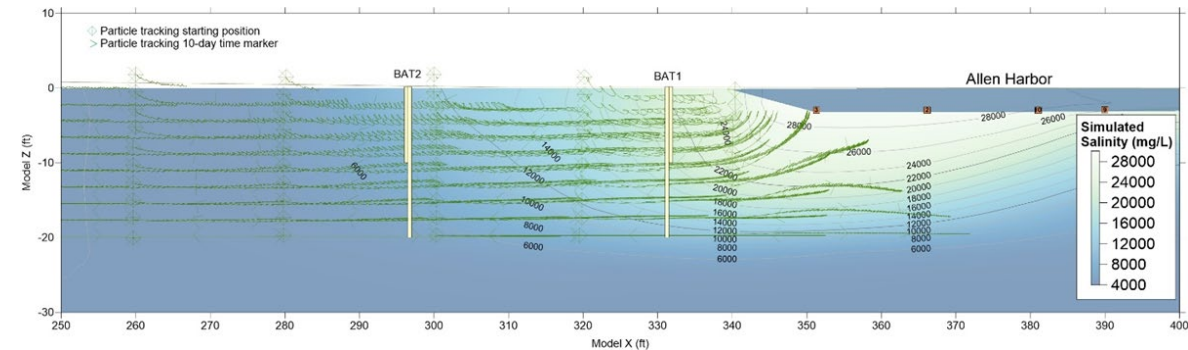
SWI6

- Sharp-interface saltwater intrusion package for MODFLOW 6 based on Ghyben-Herzberg principle
- Simulates interface shifting in response to changes in recharge, pumping, sea level change, etc.
- Differs from SEAWAT by solving for interface elevation within single grid block/layer, rather than requiring high-resolution vertical discretization
- Sharp interface = much quicker computation time than SEAWAT at expense of interface gradient

CF&T: contaminant fate and transport

Common Components of GSI Investigations

(NAVFAC 2021)

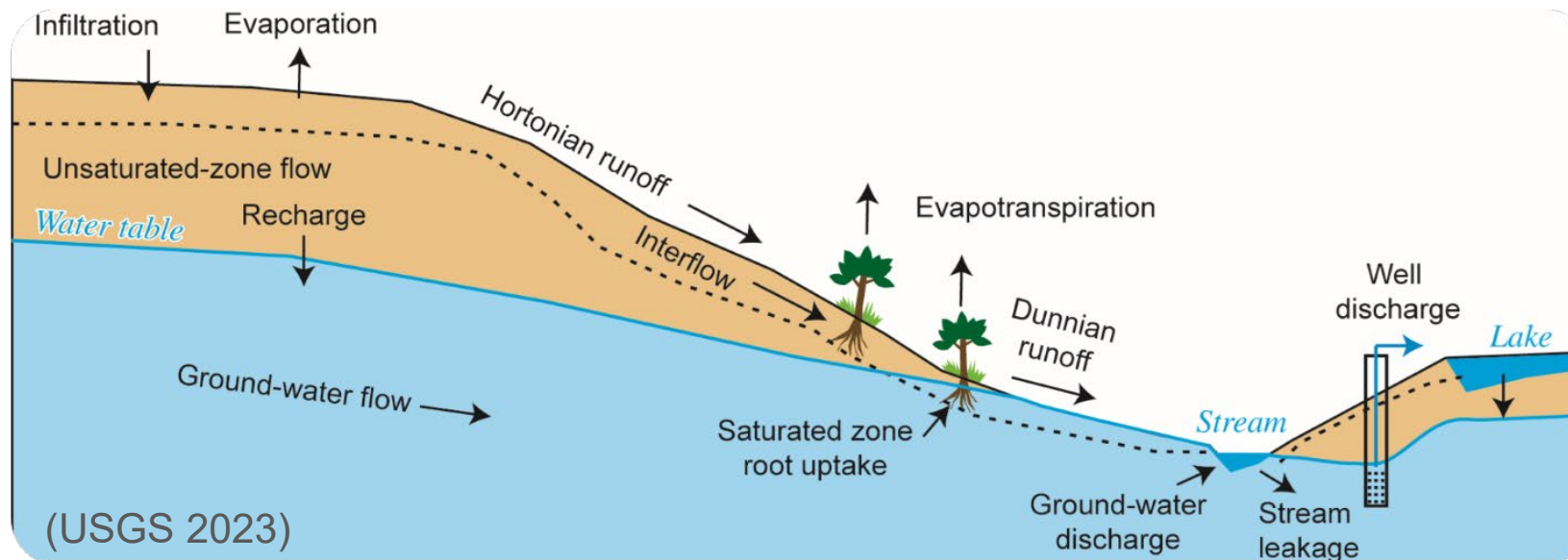


(Bakker et al. 2025)

GSI Methods: Modeling

GSFLOW

- USGS model coupling MODFLOW with PRMS for integrated GW/SW simulation
- Integrated hydrologic model: flows are simulated, not specified
- Calibrate with streamflow data (PRMS) and GW heads (MODFLOW)



PRMS: Precipitation Runoff Modeling System

How can models be useful?

1. Provide answers to specific objectives
2. Provide understanding of behavior of hydrogeologic system
3. Provide information on data gaps and parameters critical to prediction objectives
4. Provide evaluation of uncertainty in predictions due to known uncertainties in model parameterization
5. Provide mechanism for making informed decisions with data you have

A complex numerical model is useless without a robust CSM...

The reliability of model solutions is directly dependent on the quantity and quality of data inputs (recharge, water levels, lithology, etc.): good data in = good solution out

KEY POINT

Managing expectations within project team, including Navy, contractors, regulators, and stakeholders, throughout modeling process is paramount to achieving successful outcomes.

GSI Methods: Paired Approach

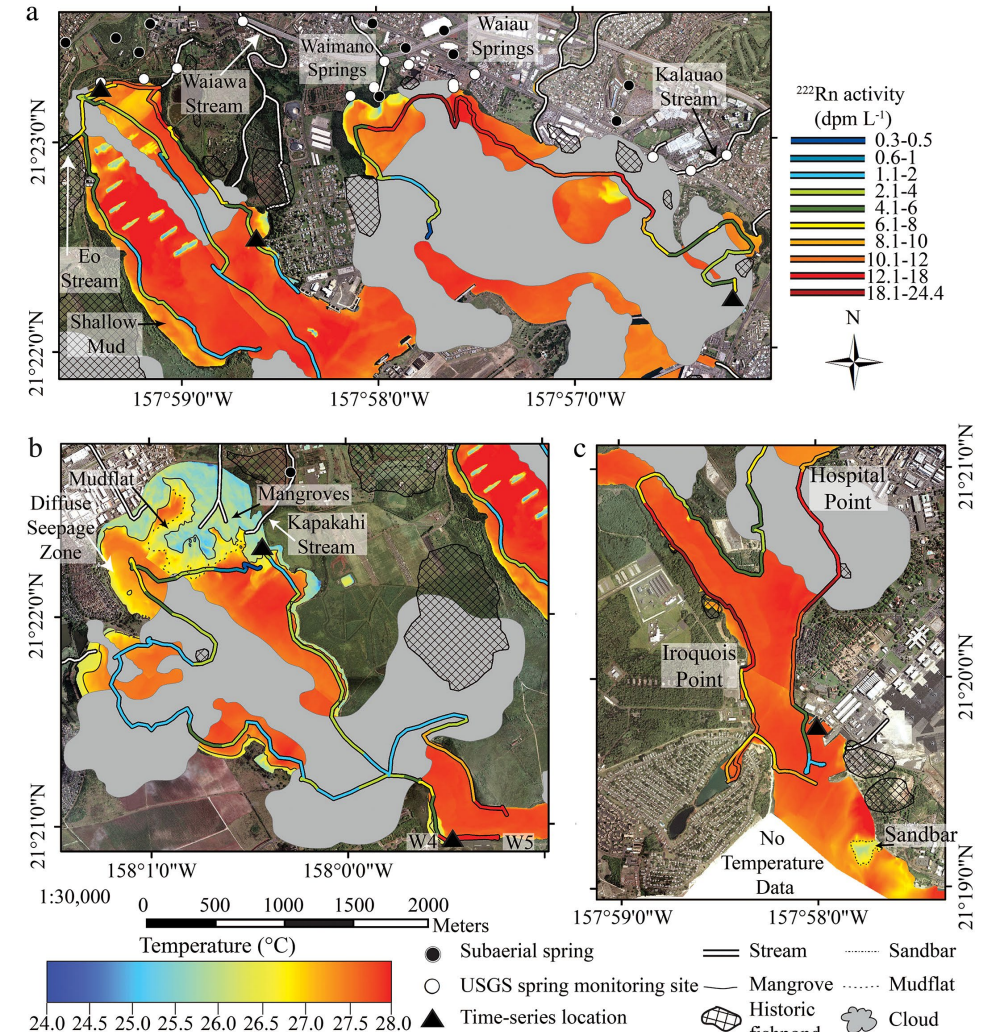
Paired approach is valuable for multiple lines of evidence and comprehensive analysis of flux

Example: radon and thermal imaging

- Radon activity (dpm/L) point measurements
- Thermal imaging gives area of seep
- Discharge rate obtained by extrapolating radon point measurements across area of discharge as obtained by thermal imaging

dpm/L: disintegrations per minute per liter

Common Components of GSI Investigations



(Kelly et al. 2018)

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Potential project-specific objectives of GSI investigation

- Determining whether GW migration pathways are complete
- Defining extent of contaminant migration
- Informing risk assessment
- Quantifying GW discharge and contaminant flux
- Informing remedial design strategies
- Monitoring remedy effectiveness

How to Plan for and Scope GSI Investigations



First, look for publicly-available data

- Water levels, stream flow/stage, and/or temperature (USGS)
- Soil and land use (USDA)
- Tides (NOAA)
- Other sources of available data: universities, state agencies, etc.
- Reports from nearby impacted sites, if any

NOAA: National Oceanic and Atmospheric Association
USDA: United States Department of Agriculture

Defining Extent of Contaminant Migration



Are GW migration pathways complete?

- Do plumes extend to downgradient SW bodies?
- Are baseline SW data available for prerelease conditions?
- Look for signs of GW inputs
 - Start with visual observations (bubbling, iron staining, etc.) and field measurements (temperature, DO, etc.); compare to publicly available data
- For more extensive evaluation, use TIR, tracer methods, hydrologic, or geophysical methods
- For advanced evaluation, use GW model



(Mathioudakis 2020)

Should receptors in SW be considered?

- In small stream/river, even small discharge of impacted GW can have significant effects
- In large stream/river or offshore, discharge may have minimal impact due to buffering capacity of SW
- Point-source vs. diffuse discharges
 - Point-source: greater impact on water quality at discharge location
 - Diffuse: lesser impacts but more widespread

Quantifying GW Discharge and Contaminant Flux



How much contaminant mass is reaching SW?

To quantify mass flux, need to know volume and concentration of discharge

- 1) Locate GW discharge**
(visual evidence, field observations, TIR, etc.)
- 2) Estimate GW discharge rate (volume/time)**
(any number of methods discussed previously)
- 3) Measure COC concentration (mass/volume)**
of contaminant in GW discharge (sample)
- 4) Calculate COC mass discharge (mass/time)**



(Mathioudakis 2021)

COC: contaminant of concern

Knowledge Check



Quantifying Contaminant Flux

GW is discharging to small stream at a rate of 5,000 L/day. PFOS concentrations in piezometers immediately adjacent to the stream are 800 ng/L. What is the PFOS mass flux to the stream in grams per year?

- 1) **Locate GW discharge**
- 2) **Estimate GW discharge rate (volume/time): q_{GW}**
- 3) **Measure COC concentration (mass/volume): C_{PFOS}**
- 4) **Calculate COC mass discharge (mass/time): J_{PFOS}**

$$J_{PFOS} = q_{GW} C_{PFOS}$$

$$J_{PFOS} = 5000 \frac{L}{d} \times 800 \frac{ng}{L} \times \frac{1 g}{1,000,000,000 ng} \times \frac{365 days}{1 year} = 1.5 g/year$$

L/d: liters per day

ng/L: nanograms per liter

PFOS: perfluorooctanesulfonic acid

Informing Remedial Design Strategies

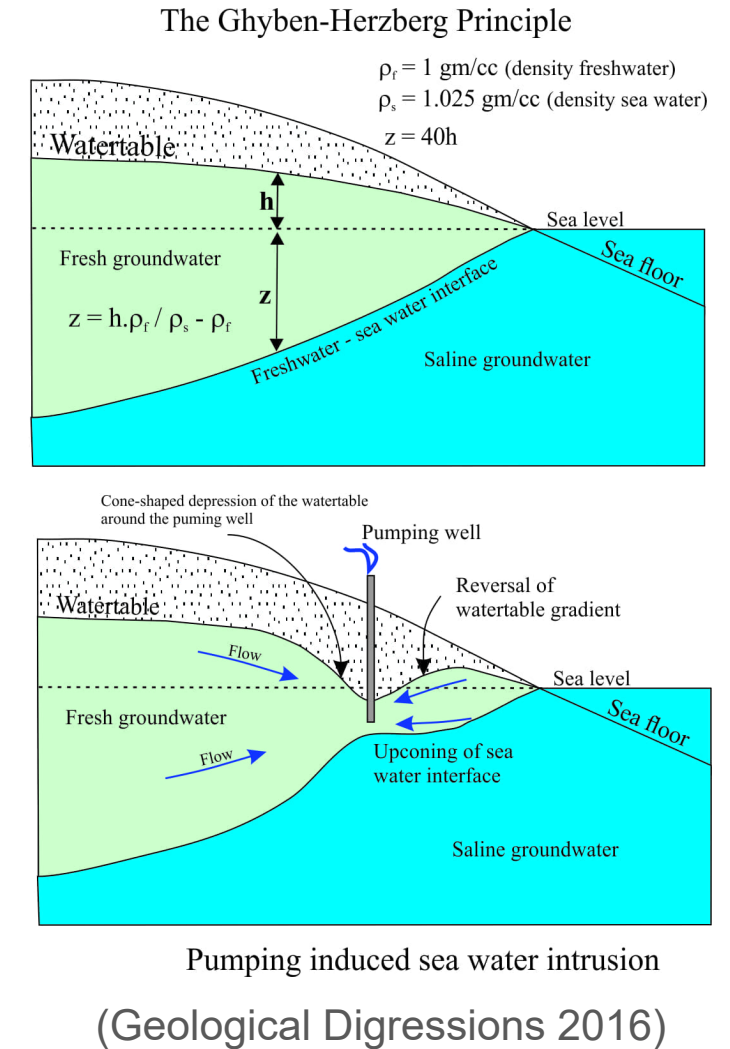
Reduced remediation costs resulting from improved CSMs for seep locations and fluxes

Will remediation impact natural flow regimes?

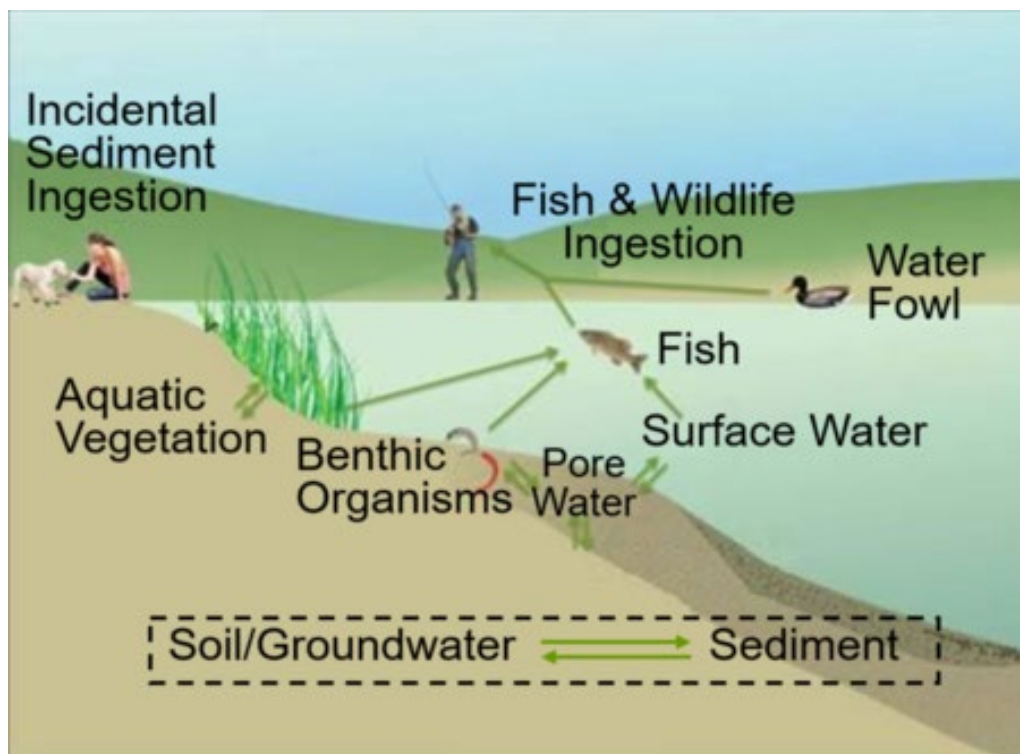
- e.g., pump and treat system could lower stream flows or induce saltwater intrusion into aquifer

If plume is reaching SW, engineering controls may be needed

- e.g., hydraulic controls, oleophilic biobarrier



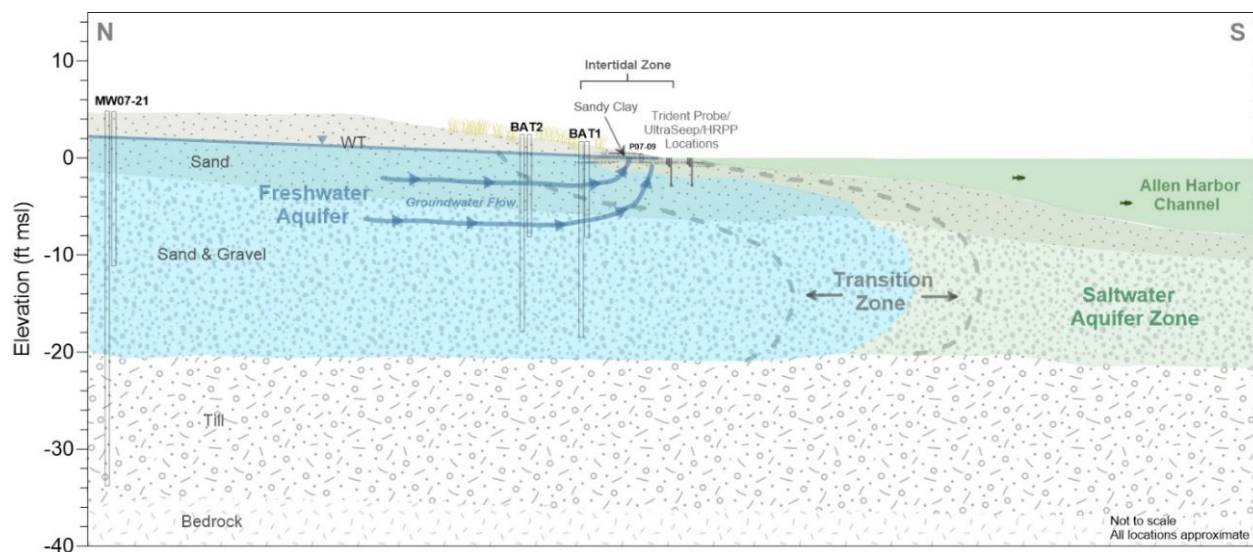
Monitoring Remedy Effectiveness



(Envirowiki 2026)

- Are COC concentrations decreasing in sediment/SW?
- Are geochemistry and riparian/riverine/coastal habitats returning to prerelease conditions?
- Are recovery systems functioning as intended without lowering stream flows?

Monitored Natural Attenuation (MNA)



(NAVFAC 2021)

CVOC: chlorinated volatile organic compound

DCE: dichloroethene

MNA: monitored natural attenuation

OoM: order of magnitude

POC: point of compliance

TCE: trichloroethene

VC: vinyl chloride

2021 NAVFAC Study (Davisville, Rhode Island):

- Reductive dechlorination (TCE → DCE → VC → Ethene) along flow path from shoreline wells to surface sediment
- Degradation + dilution → up to 3 OoM attenuation of CVOC concentrations between shoreline wells and potential points of exposure in surface sediment. SEAWAT model matched empirical (sampling) data.
- Use of shoreline wells as POCs fails to account for attenuation processes
- SW quality criteria can be adjusted for attenuation level to establish interim cleanup goals in GW at shoreline wells.

How to Plan for and Scope GSI Investigations



Cost	Method	Question(s) to Answer
\$	Field observations/measurements	Discharge location
\$\$	Seepage meters, SBFMs	GW flux to SW (single location)
\$\$	Seepage run	GW flux to river/stream (segments)
\$\$	Tracer study (natural)	GW flux to SW, COC mass reaching SW
\$\$-\$\$\$	Thermal infrared imaging	Location and area of GW discharge to SW
\$\$\$	Tracer study (artificial)	GW flux to SW, COC mass reaching SW
\$\$\$	Stream gauge/piezometer pairs	GW flux to SW over time
\$\$\$	Time-series temperature (FO-DTS)	Location and variability of GW discharge to SW
\$\$\$	Geophysics (ERT, waterborne EM)	GW discharge location, infer volume
\$\$\$	Paired study	Discharge locations, Volume flux, COC mass flux
\$\$-\$\$\$	GW model	All (volume flux, mass flux, discharge location, etc.)

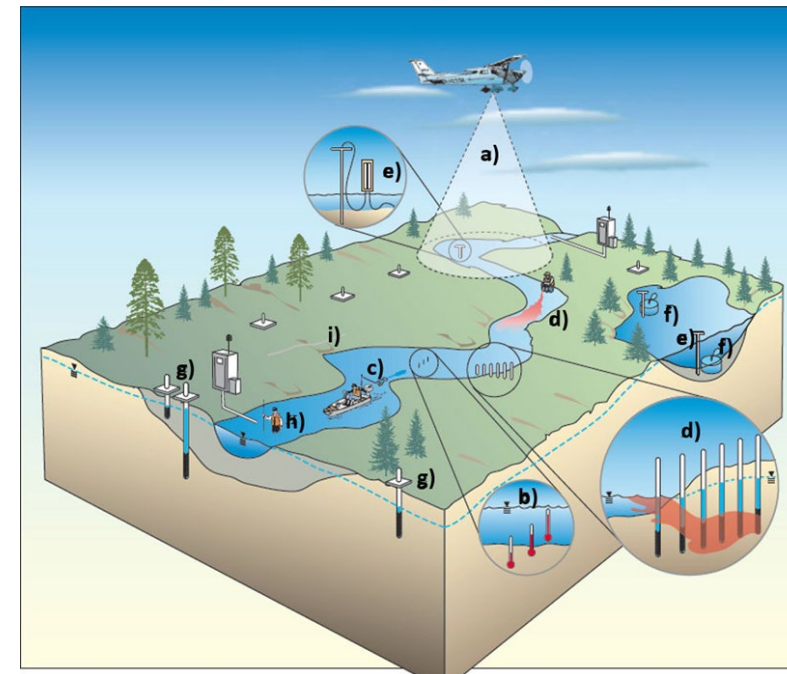
How to Plan for and Scope GSI Investigations

Publicly available tools

[USGS Hydrologic Toolbox](#)

[USGS GW/SW Method Selection Tool](#)

[SERDP Transition Assessment Tool](#)



(The Groundwater Project 2020)

KEY POINT

Scoping a GSI investigation is extremely site-specific, so all site/project-specific considerations should be accounted for by RPM and/or consultant.

RPM: remedial project manager

SERDP: Strategic Environmental Research and Development Program

Break

For each release scenario, which methods are most appropriate for investigating GSI at site?

1. Large hydrocarbon release to shallow anaerobic aquifer occurs approximately 0.5 miles from gaining stream reach. What methods could be employed to assess whether SW is potential receptor?
2. Historical AFFF releases occurred from a fire training area approximately 1 mile from tributary that feeds into coastal estuary. An innovative ex situ treatment system is being installed. Before pumping wells are installed, what methods could be used to investigate impact of pumping on nearby surface water?

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Unique Challenges of GSI Investigations for PFAS

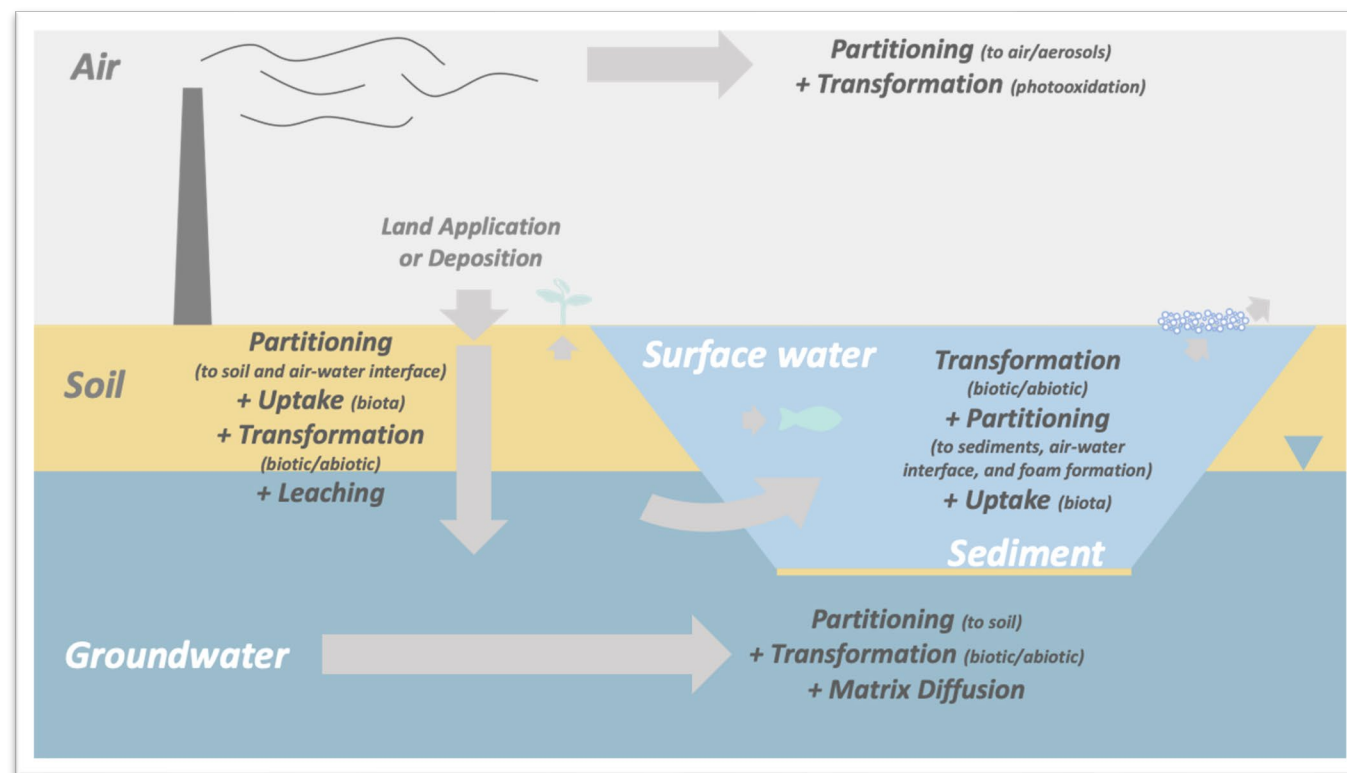


PFAS basics

- PFAS move easily through soil into groundwater, resisting natural degradation due to strength of C-F bond
- Hydrophilic head (functional group) and hydrophobic tail (C-F chain)

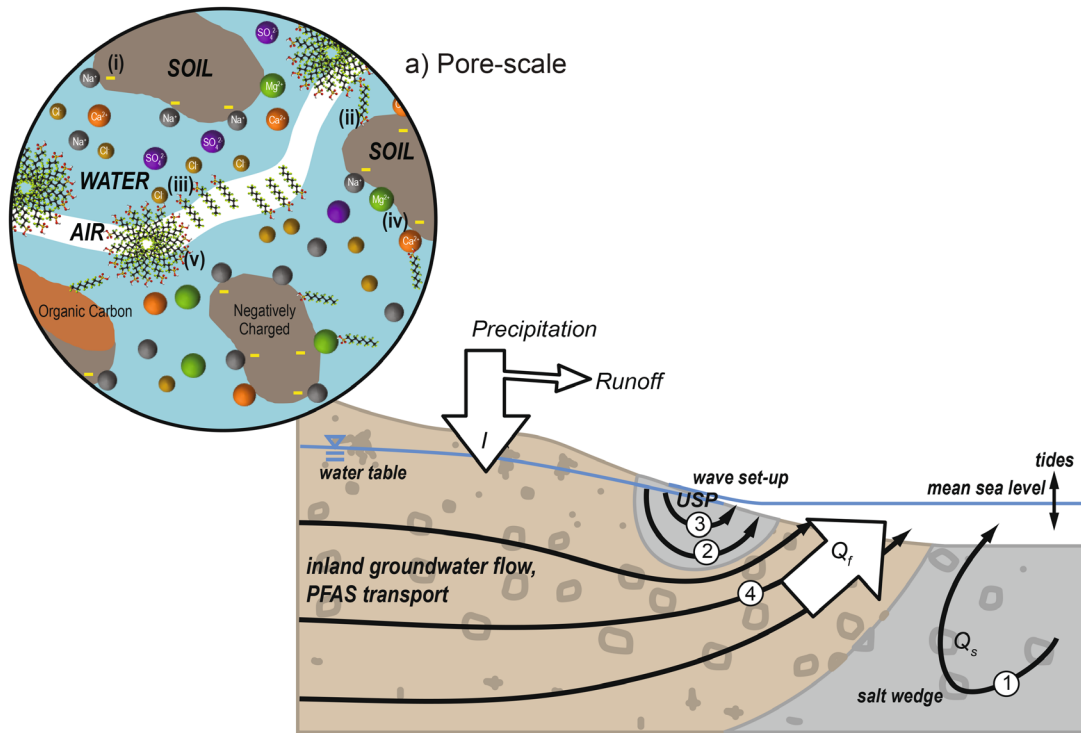
Compound-specific properties to consider for GSI

- **Chain length:** short chain = more soluble
- **Functional group:** sulfonates (-S) have greater sorption affinity for soil; carboxylates (-A) more soluble in water



(ITRC 2026)

Unique Challenges of GSI Investigations for PFAS



(Hort et al. 2024)

PFBA: perfluorobutanoic acid
PFHxA: perfluorohexanoic acid
PFPeA: perfluoropentanoic acid

- **PFAS water solubility** decreases as carbon chain length increases; short-chain carboxylates (e.g., PFHxA, PFBA, PFPeA) are the most mobile PFAS in GW, thus most likely to reach SW from GW release
- **Precursor transformation:** Hyporheic zone and subterranean estuary are extremely biogeochemically-active zones
- **PFAS salting out** onto aquifer solids in coastal GW discharge zones (SGD)
 - Reduces PFAS mass discharge, but PFAS could remobilize under future salinity changes
 - 1-to-25-fold estimated increase in sorption of PFAS depending on salinity increases (highest in West Coast bays and North Atlantic coastline; Hort et al. 2024)

Site-specific considerations

Geology/soil

- Fine-grained lenses can allow plume to persist for decades, sustaining mass flux to SW via matrix diffusion
- Fractured rock systems allow preferential flow to SW
- High organic carbon content = more sorption of long-chain PFAS

Vadose zone thickness and moisture retention

- Thick vadose zone = more sorption, transformation, and retention
- Moisture content affects air-water interfaces

Redox environment

- Oxidic environments favor precursor transformation
- Fluctuating redox conditions (e.g., in hyporheic zone) can enhance transformation

Presence of co-contaminants

- Competitive sorption can affect PFAS partitioning
- Redox conditions can change due to biodegradation of co-contaminants

Presentation Overview

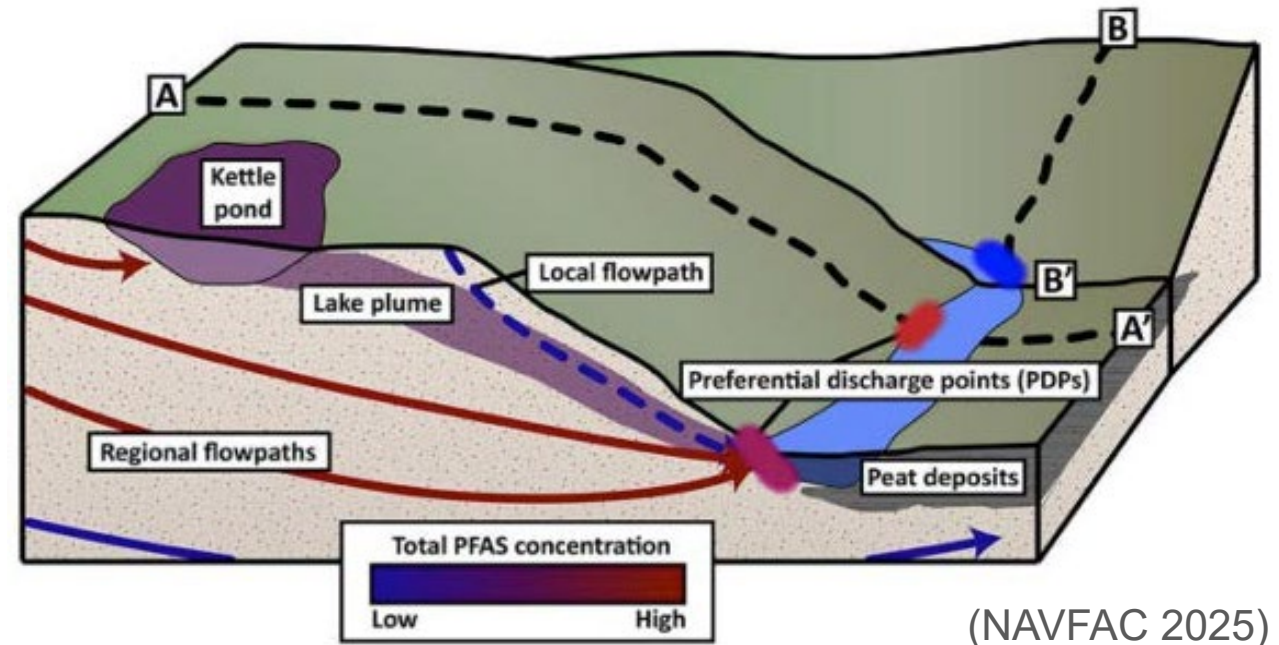


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Case Study #1: Joint Base Cape Cod

Joint Base Cape Cod: PFAS

- ESTCP Project ER21-5237
- Joint Base Cape Cod FTA upgradient of Quashnet River and associated wetlands
- SW temp: 5–25°C; GW temp: 9.5–11.5°C
- Paired approach using FO-DTS, seepage meters, and sampling



KEY POINT

Main objective of case study was to locate discharge zones where PFAS-impacted GW emerges into river and to quantify spatial and temporal variability in PFAS mass loading at those discharge zones.

Case Study #1: Joint Base Cape Cod

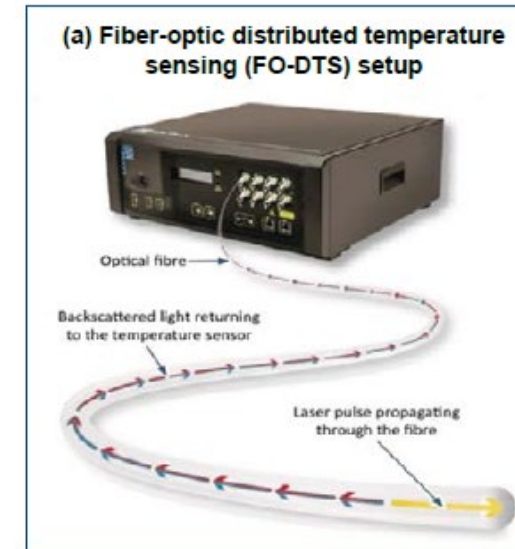
FO-DTS

- Cable placed along GW-SW interface
- **Time-series measurements of temperature** along length of cable for detecting GW seeps (PDPs)
- Surveys conducted in June 2022 following UAS-TIR surveys in March 2022
- 57 PDPs detected

[NAVFAC FO-DTS Fact Sheet](#)

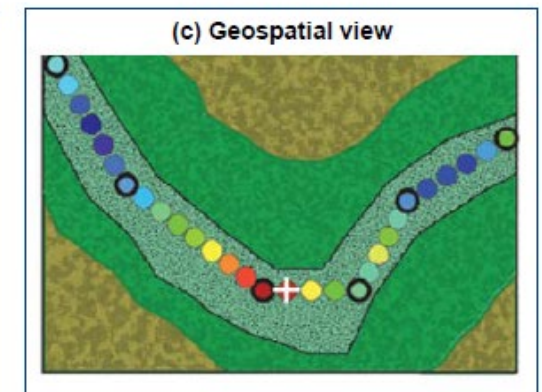
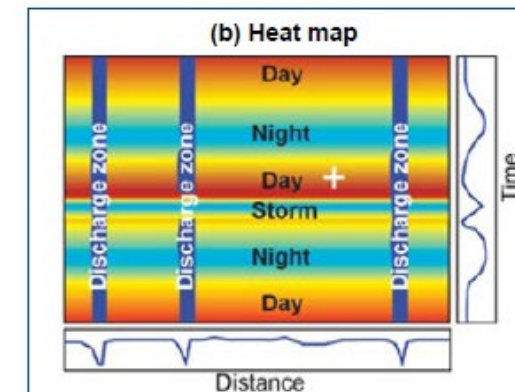


PDP: preferential discharge point



- (a) FO-DTS control unit with fiber-optic cable
- (b) FO-DTS data displayed in a heat map as temperature versus distance and time
- (c) Temperature along the cable, with locations interpolated linearly between points

NOTE: FO-DTS photo courtesy of Silixa LLC. Images adapted from Domanski et al. (2020)



(NAVFAC 2025)

Case Study #1: Joint Base Cape Cod

UAS-TIR

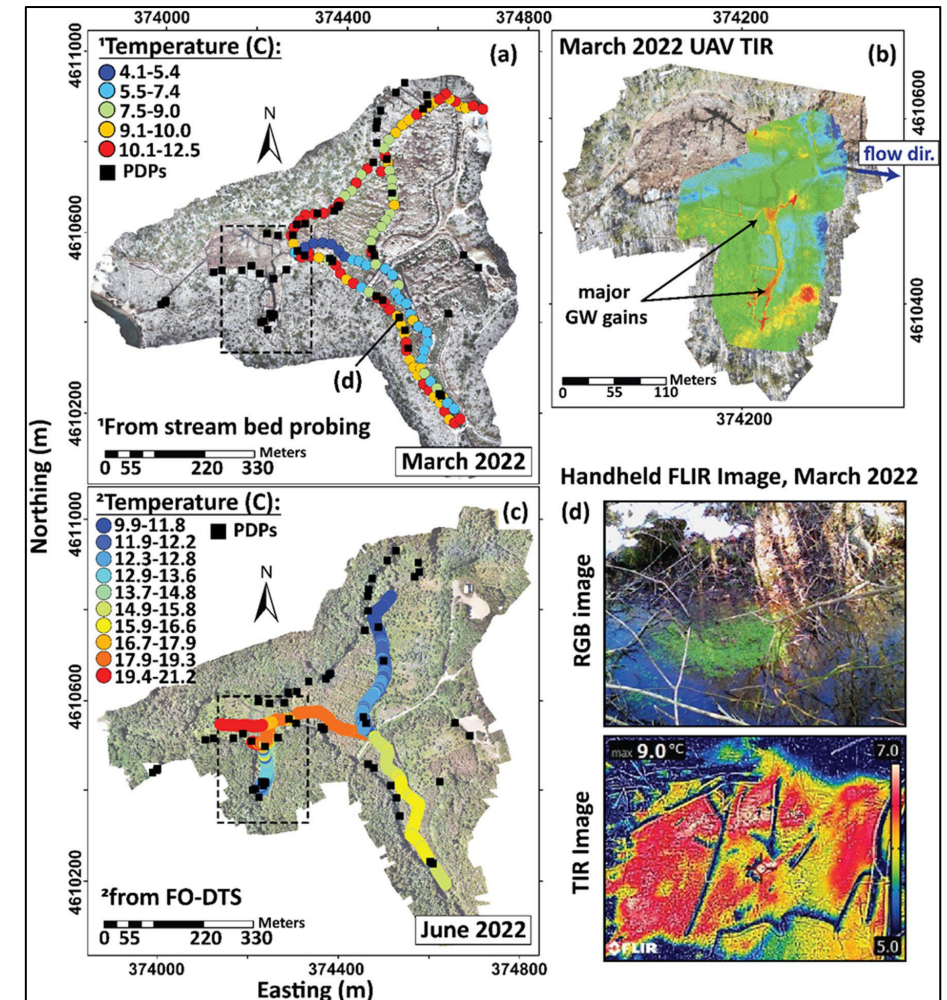
- Surface temperature
- **Pros:** **remote measurements**; can cover large area in short period of time with **limited setup**
- **Cons:** measurements for **single point in time**; can be limited by **overhead obstructions** or vegetation

FO-DTS

- GW-SW interface temperature (e.g., streambed)
- **Pros:** **time-series measurements**; not limited by vegetation or overhead obstructions
- **Cons:** **setup** (requires deployment of cable along full length of streambed)

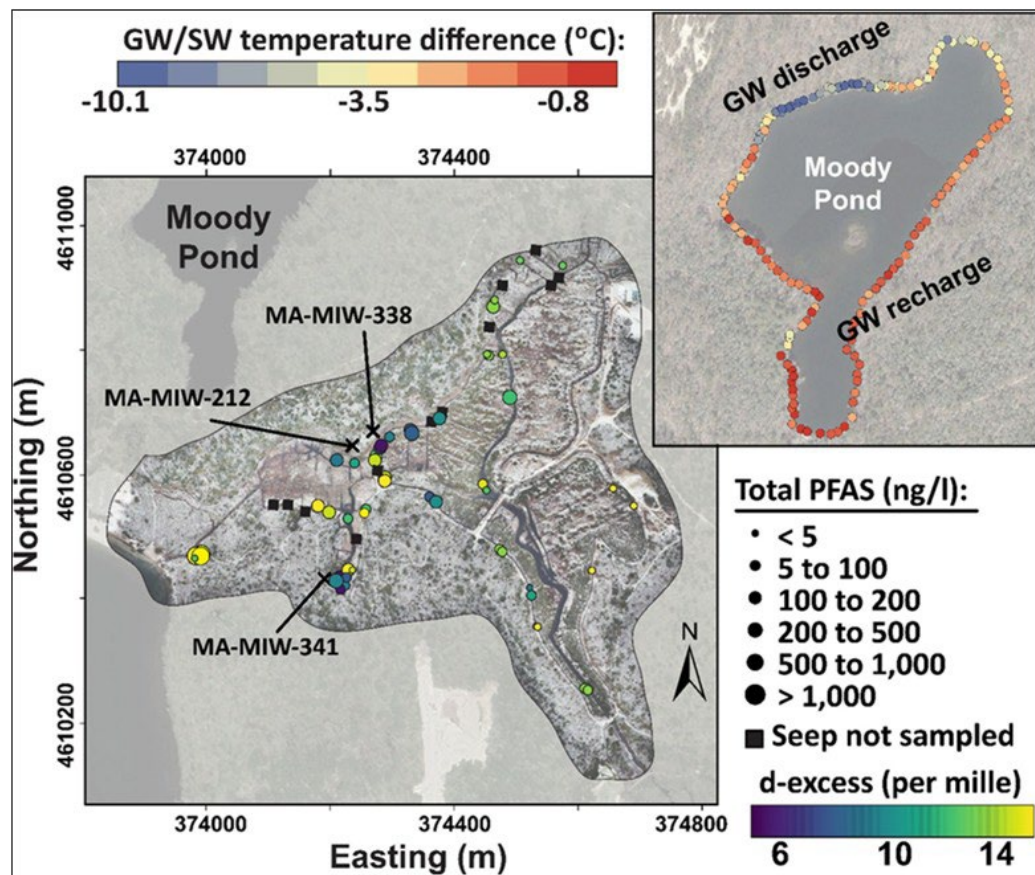
Both technologies can guide targeted sampling for COCs

Paired approach: UAS-TIR for initial survey; FO-DTS for time series at targeted locations



(Rey et al. 2025)

Case Study #1: Joint Base Cape Cod



(Rey et al. 2025)

µg/L: micrograms per liter

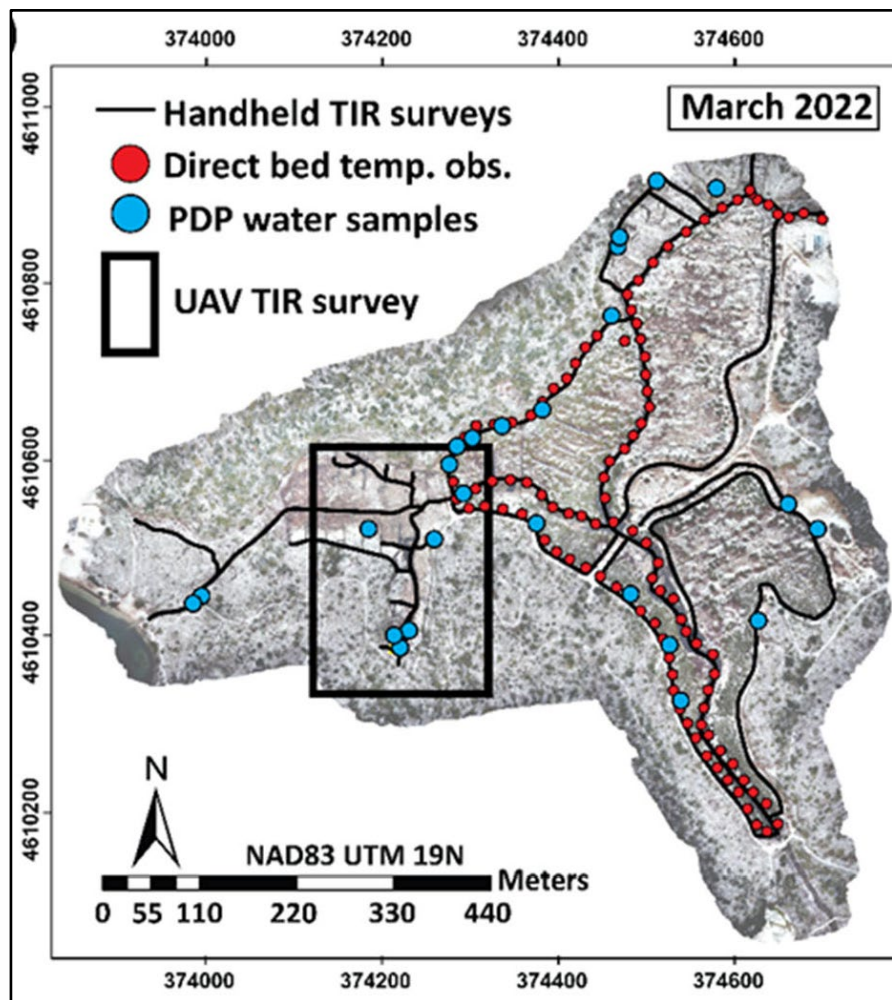
m/day: meters per day

ND: nondetect

Seepage meters and sampling

- Seepage meters placed at nine PDPs to measure discharge
 - 0.2–3.2 m/day (1.1 m/day mean)
- High-flux PDPs sampled for PFAS, DO, and stable isotopes of water
 - PFAS: ND to ~5 µg/L
 - Isotopes showed differing sources (meteoric and lake/pond)
- Some seeps rich in PFOS and others rich in short-chains or precursors
- **Discharge measurements paired with sample concentrations allowed for calculation of PFAS mass loading (seeps ~200–800 µg/d)**

Case Study #1: Joint Base Cape Cod



(Rey et al. 2025)

Summary of GSI investigation process

1. **Locate** GW discharges (PDPs/seeps) based on temperature anomalies found with FO-DTS
2. **Quantify** GW discharges with seepage meters
3. **Calculate** PFAS mass loading from GW with targeted sampling
4. **Determine source** of seeps with water isotopes
5. **Inform** CSM and remedial design strategy

Presentation Overview



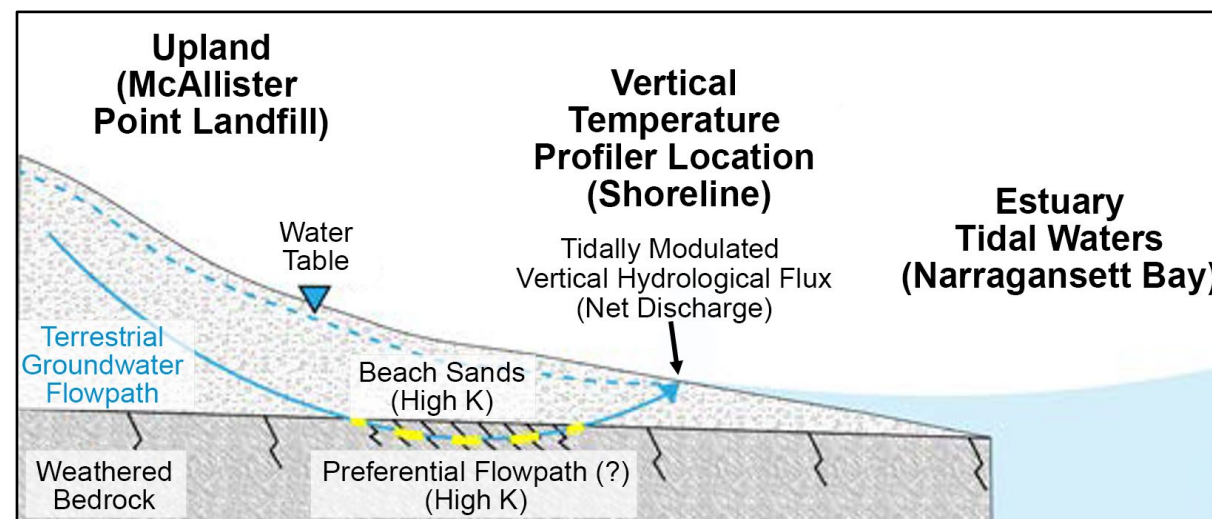
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Case Study #2: Naval Station Newport



McAllister Point Landfill: Metals

- ESTCP Project ER21-5237
- 10.5-acre Installation Restoration Program site
- Capped landfill on Aquidneck Island
- GW ~10–15 feet below ground and influenced by semidiurnal tides
- Paired approach using FO-DTS, waterborne ERT, waterborne EM induction, conductivity measurements, UAS-TIR, handheld TIR, seepage meters, VTPs, and sampling



(NAVFAC 2025)

KEY POINT

Main objective of case study was to validate site investigation approach that integrates multiscale thermal and EM tools to map GSI and quantify mass flux of metals to Narragansett Bay.

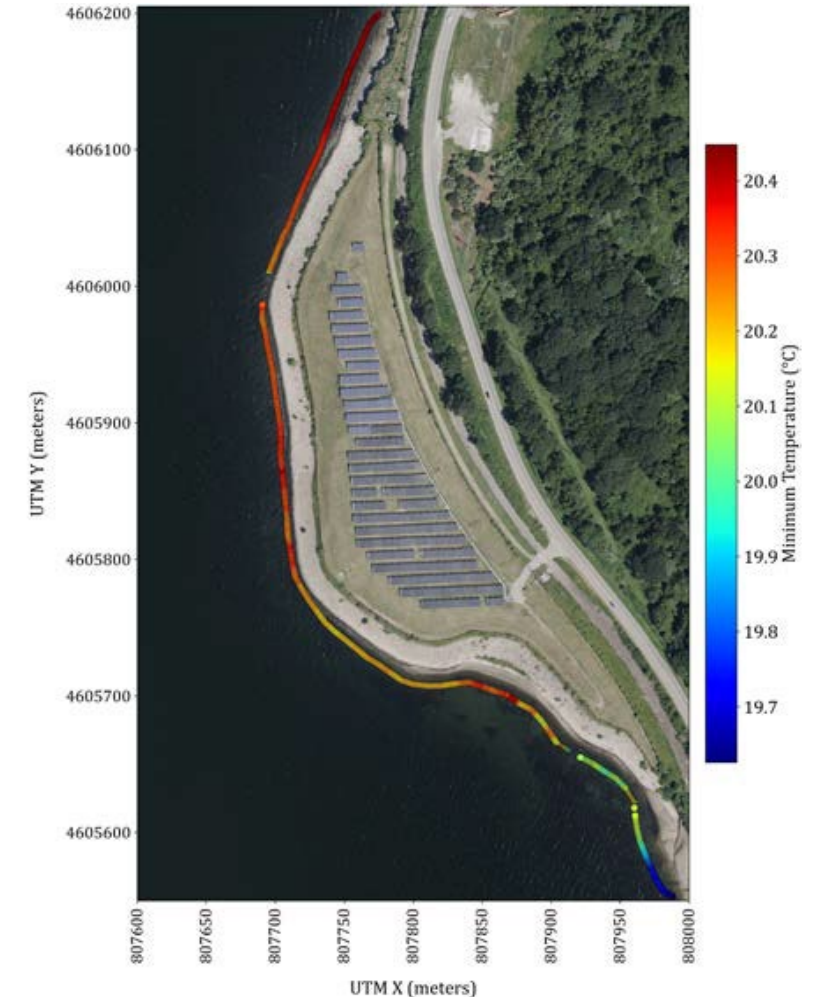
Case Study #2: Naval Station Newport



UAS-TIR and FO-DTS

- UAS-TIR revealed ~600-foot band of cool GW (~17–19°C) that contrasted with bay's SW temperature (~23–25°C); confirmed by follow-up FO-DTS surveys
- Waterborne EM induction, ERT, and conductivity measurements independently confirmed GW seeps
- FO-DTS data revealed GW fluxes are tide-dependent and precipitation enhances flushing (increases mass flux)
- **Seeps samples combined with VTP modeled fluxes to determine metal contaminant mass fluxes into bay**
 - Copper: 0.5–56.5 µg/d
 - Nickel: 0.4–63.1 µg/d

µg/d: micrograms per day



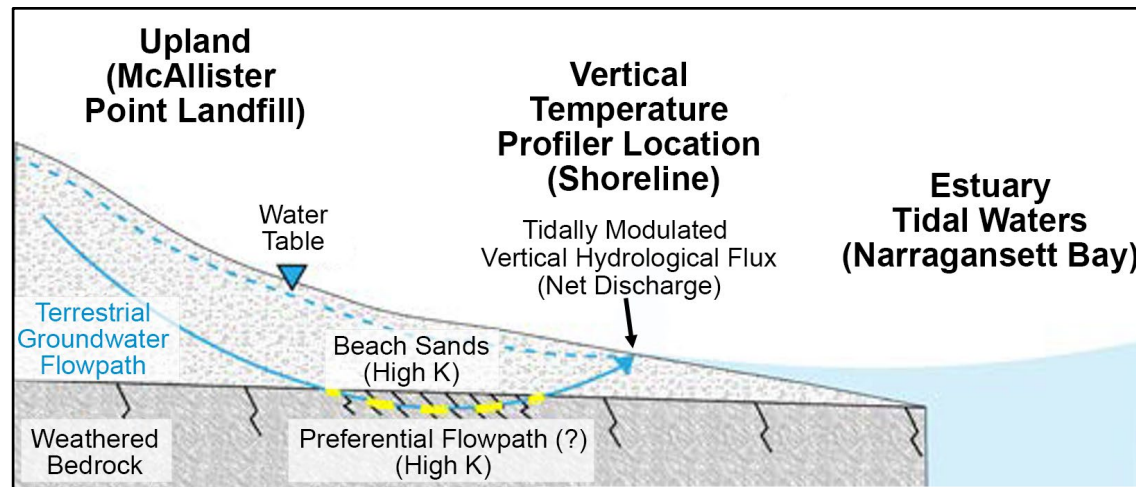
(NAVFAC 2025)

Case Study #2: Naval Station Newport



Conclusions

- Mass flux and variable geochemistry confirmed high-flux seeps drive metals transport into bay
- Future remedial optimization efforts should address the spatial heterogeneity in metals mass flux and target cleanup where highest metals mass loading is occurring



(NAVFAC 2025)

Summary of GSI investigation process

1. **Locate** GW discharges (seeps) based on temperature anomalies found with UAS-TIR and FO-DTS
 - a) **Confirm** GW discharges with waterborne EM induction, ERT, and conductivity
2. **Quantify** GW discharges with VTP modeled fluxes and seepage meters
3. **Calculate** metals mass loading from GW with targeted sampling
4. **Inform** CSM and remedial optimization efforts

Presentation Overview



- Introduction
- What are GSI?
- When are GSI Important?
- Common Components of GSI Investigations
- How to Plan for and Scope GSI Investigations
- Unique Challenges of GSI Investigations for PFAS
- Case Study #1: Joint Base Cape Cod
- Case Study #2: Naval Station Newport
- Summary and Closing

Summary and Closing

There are numerous methods available for GSI investigations; no single best method—each serves different purpose at different cost

Thus, method selection should be done on site-specific basis based on regulatory drivers, cost considerations, CSM, etc.

Summary of typical GSI investigation process

1. **Locate** GW discharges based on tracer measurements
2. **Quantify** GW discharges with various methods
3. **Calculate** mass loading from GW with targeted sampling
4. **Determine source** of seeps with isotopes, modeling, etc.
5. **Inform** CSM and remedial design strategy



(Mathioudakis 2017)

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Questions



Evaluation of PFAS Sources under the Watershed Contaminated Source Document (WCSD) Process

Wendy Rose Hovel
Geosyntec Consultants

RITS 2026

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Information in this presentation is current as of 10 April 2026.

EXWC: Engineering and Expeditionary Warfare Center
NAVFAC: Naval Facilities Engineering Systems Command

Speaker Introduction



Wendy Rose Hovel

Senior Scientist
Sediment and Ecological Risk



(Hovel n.d.)

BA: Bachelor of Arts
CERCLA: Comprehensive Environmental Response,
Compensation, and Liability Act
MS: Master of Science

- BA Biology, MS Marine Science, PhD Toxicology
- 20 years of consulting at sediment sites
 - Pearl Harbor, San Diego Bay, Los Angeles/Long Beach Harbor, Puget Sound, Lake Washington, San Francisco Bay, Sacramento/San Joaquin Rivers, Willamette River, Duwamish Waterway, Victoria Harbour, Terry Creek (Georgia), Toronto Waterfront Area, lakes in Northern/Southern California, reservoirs in various states, Hudson River
- Characterization, delineation, litigation support, risk assessment, RI/FS, beneficial use evaluations, background studies, sediment TMDLs, CERCLA/RCRA and state cleanup sites, dams, ponds, lakes, quarries, and ecological risk assessment

PhD: Doctor of Philosophy
RCRA: Resource Conservation and Recovery Act
RI/FS: remedial investigation/feasibility study
TMDL: total maximum daily load

Presentation Overview



- Introduction

- What is a WCSD?
- When is a WCSD required?
- Steps for Developing a WCSD
 - Steps 1 to 7
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 - Literature review
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 - Case Study #1: St. Mary's River WCSD—PFAS Example
 - Case Study #2: Apra Harbor WCSD—Other Contaminants Example
- WCSD Activity
- Key Takeaways

Introduction



Watershed Contaminated Source Document (WCSD)

- **Concise summary report** that documents both Navy and non-Navy contaminant sources within drainage area that could have impact on sediments associated with Navy IRP or BRAC site*
- Follows CNO Policy on *Sediment Site Investigation and Response Action*

* WCSD can also benefit CSM development at groundwater or surface water sites.

BRAC: Base Realignment and Closure
CNO: Chief of Naval Operations
CSM: conceptual site model

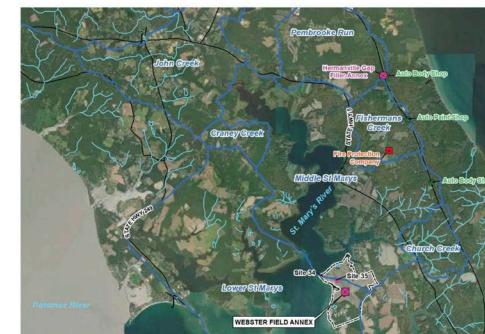
IRP: Installation Restoration Program
Navy: Department of the Navy



Technical Memorandum
TM-NAVFAC EXWC-SH-2601

APRIL 2026

**WATERSHED CONTAMINATED SOURCE DOCUMENT
(WCSD) UPDATE WITH PER- AND
POLYFLUOROALKYL SUBSTANCES (PFAS)
CONSIDERATIONS**



Distribution Statement A: Approved for public release; distribution is unlimited.

(NAVFAC EXWC 2026)
Available [Here!](#)

Basis for the WCSD



CNO policy requires this document if there is potential for non-Navy impacts (*moderate to significant*) to sediment adjacent to a Navy site.

KEY POINT

Sediment contaminant investigations must be directly linked to Navy releases.

 **DEPARTMENT OF THE NAVY**
OFFICE OF THE CHIEF OF NAVAL OPERATIONS
2030 NAVY PENTAGON
WASHINGTON DC 20360-2000

IN REPLY REFER TO

5090
Ser N453E/2U589601
08 FEB 2002

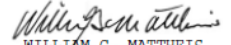
From: Chief of Naval Operations
To: Commander, Naval Facilities Engineering Command

Subj: POLICY ON SEDIMENT SITE INVESTIGATION AND RESPONSE ACTION

End: (1) Navy/Marine Corps Installation Restoration Policy on Sediment Investigations and Response Actions

1. Enclosure (1) is provided in response to concerns received from the field pertaining to investigation and clean up of contaminated sediments. The policy specifies that the source must be identified and controlled before cleanup, the cleanup must be risk-based and have site-specific cleanup goals, and the monitoring criteria for any monitoring plan must be established before the first sample is collected.

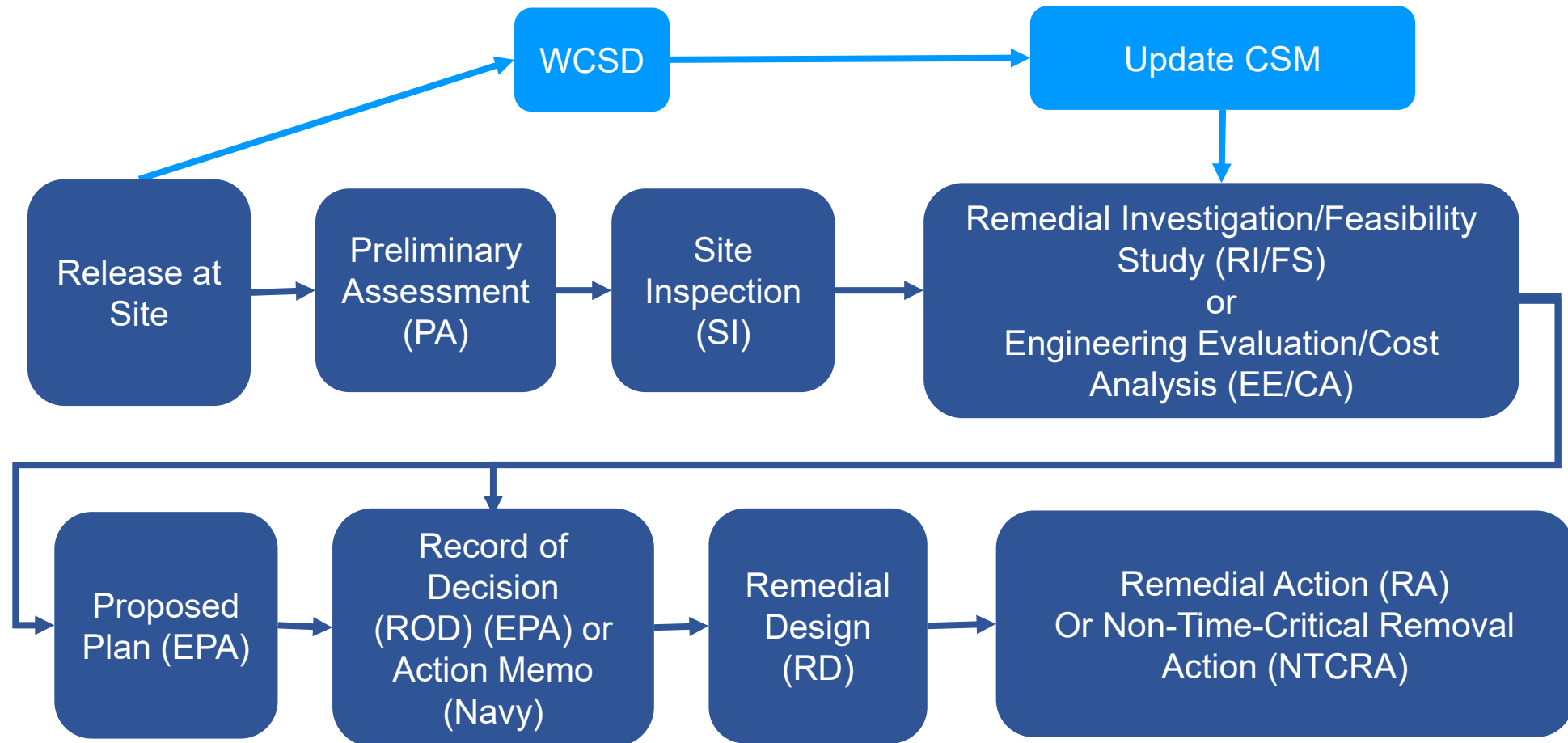
2. Enclosure (1) has been coordinated with the Marine Corps. For further information or questions please contact Wanda L. Holmes of my staff at (703) 604-5420 or DSN 664-5420 or email holmes.wanda@hq.navy.mil.


WILLIAM G. MATTHEIS
Deputy Director, Environmental Protection, Safety and Occupational Health Division

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(CNO 2002)

How the WCSD Fits into CERCLA* Process



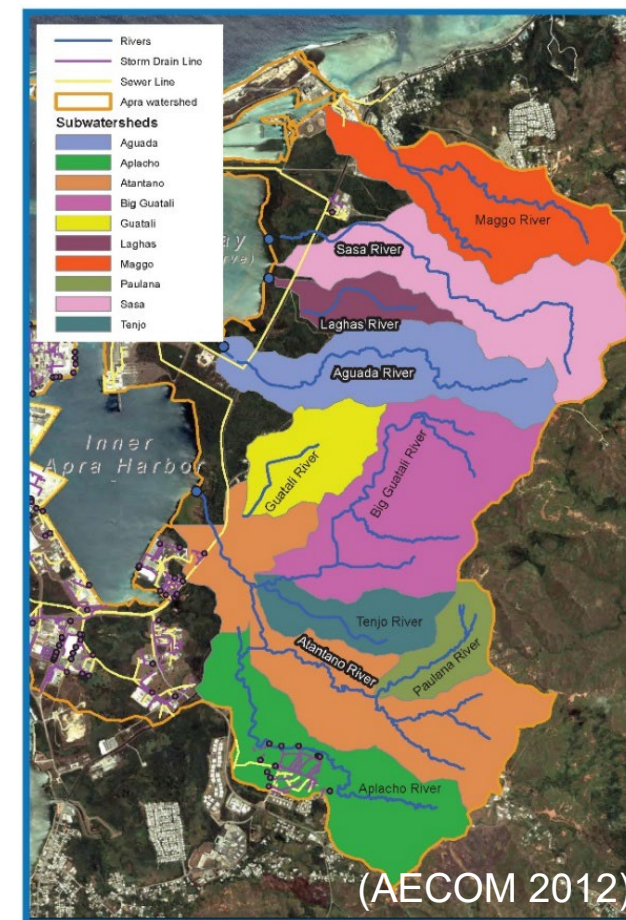
EPA: United States Environmental Protection Agency
 TCRA: time-critical removal action

* Similar Process for RCRA;
 expedited for TCRAs

Elements of the WCSD

- **Identify WCSD scope and area**
 - Limited to area/activities with most impact on Navy sediment investigation area
- **Watershed contaminant source map**
 - Crux of WCSD; watershed-based map of scoped area with locations of potential sources most likely to contribute contaminants to sediment investigation area*
- **Graphic CSM map**
 - Describes sources, transport mechanisms, exposure pathways, and receptors relevant to investigation area
- **Conclusions**
 - Summarizes results of WCSD, indicating whether there are non-Navy sources with potential to impact sediment in investigation area

* Consider potential sources to groundwater, surface water, and sediment in investigation area.



Example of watershed area map

When is a WCSD Required?

- WCSD determination is project-specific
- Use professional judgement
 - **Likely needed** where potential non-Navy sources are significant, or historically have been significant, to contamination at Navy IRP-related sediment investigation area and waterbody receives runoff from non-Navy sources
 - **Not likely needed** where Navy is only potential source and waterbody is within Navy property or does not receive runoff from non-Navy property



KEY POINT

WCSD is required where potential non-Navy sources are (or were) significant to Navy IRP area sediment contamination.

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Steps for Developing a WCSD: A Concise Summary



Step 1: Determine need for WCSD

Step 2: Define WCSD scope and area

Step 3: Conduct literature search on potential sources

Step 4: Develop preliminary watershed contaminant source map

Step 5: Conduct watershed visit to confirm source accuracy

Step 6: Develop graphic CSM

Step 7: Write WCSD

Step 1: Determine Need for WCSD



- **Likely needed** where potential non-Navy sources are significant, or historically have been significant, to contamination at Navy IRP-related sediment investigation area and waterbody receives runoff from non-Navy sources
 - Example: Lake with Navy IRP sediment area and both Navy and non-Navy (industrial) potential sources surrounding the lake
- **Not likely needed** where Navy is only potential source and waterbody is within Navy property or does not receive runoff from non-Navy property
 - Example: Bay with Navy IRP sediment area, with potential upland Navy sources, but in an area with no major industrial sources or riverine inputs
- **Gray area**: Navy IRP sediment area in a river with nearby Navy base; upstream – some non-Navy potential sources but they are not found along the riverbank.

KEY POINT

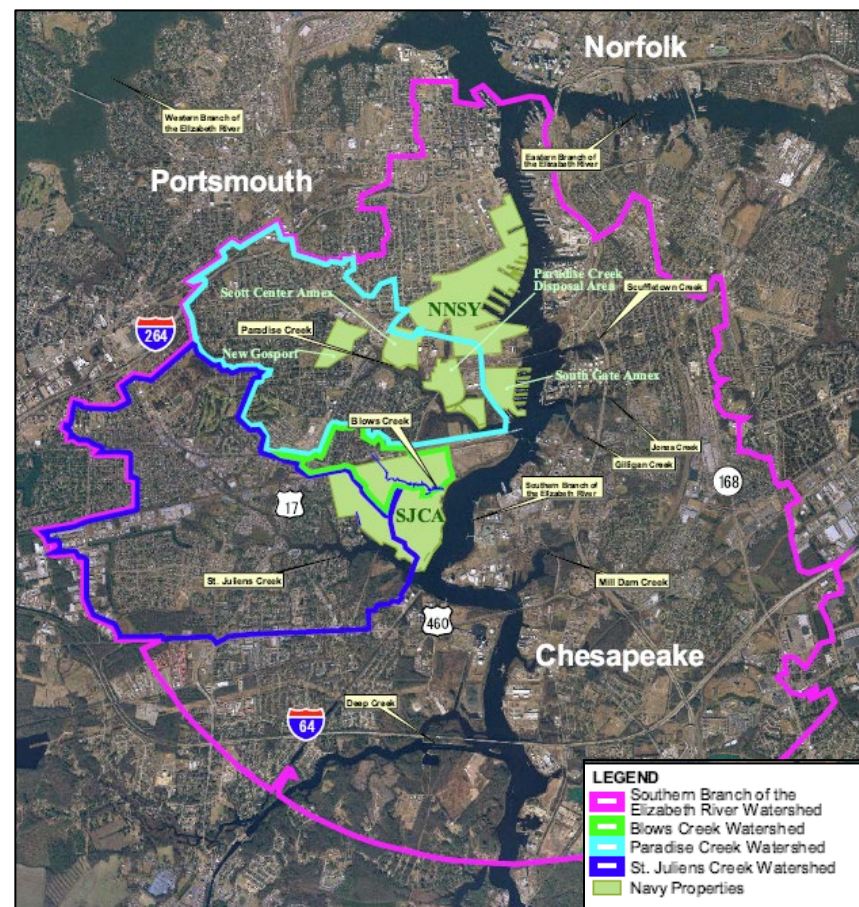
Ultimately, this is a project-specific decision using best professional judgment and the Navy decides whether WCSD is necessary.

Step 2: Define WCSD Scope and Area

- Involves development of geospatial map showing watershed to which WCSD applies along with other key information (IRP/BRAC site locations, adjacent sites, Navy and non-Navy drainage areas, stormwater/storm drains, surface waters, land use types)
- **Note:** there may be Controlled Unclassified Information considerations if showing infrastructure

**CRITICAL
STEP**

**Define scope and area for WCSD.
Refine scope as needed during
WCSD development.***



(CH2M 2005)

* Note: If it is a large watershed, may need to focus on a sub-watershed.

Step 3: Conduct Literature Search on Potential Sources



- Comprehensive literature and data search where publicly available databases and documents are searched for potential Navy and non-Navy sources (both point and non-point sources) within watershed
- Consider potential sources not only to sediment but also to groundwater and surface water

Surface Waters Section 303(d) Listings, Federal and State TMDLs

<https://www.epa.gov/tmdl>

Superfund Enterprise Management System

<https://enviro.epa.gov/envirofacts/sems/search>

EPA Envirofacts Data Warehouse

<https://www.epa.gov/enviro/envirofacts-overview>

Environmental Database Reports

Various service providers can prepare these reports for a fee; impacted sites within a given radius.

NPDES-permitted Discharges

<https://www.epa.gov/hydrowq/metadata-permit-compliance-system-pcs>

Other Search Engines

- Google Earth

State Cleanup Sites

Washington:

<https://ecology.wa.gov/Spills-Cleanup/Contamination-cleanup/Cleanup-sites>

Maryland:

<https://mde.maryland.gov/programs/land/MarylandBrownfieldVCP/Pages/remediationsites.aspx>

California:

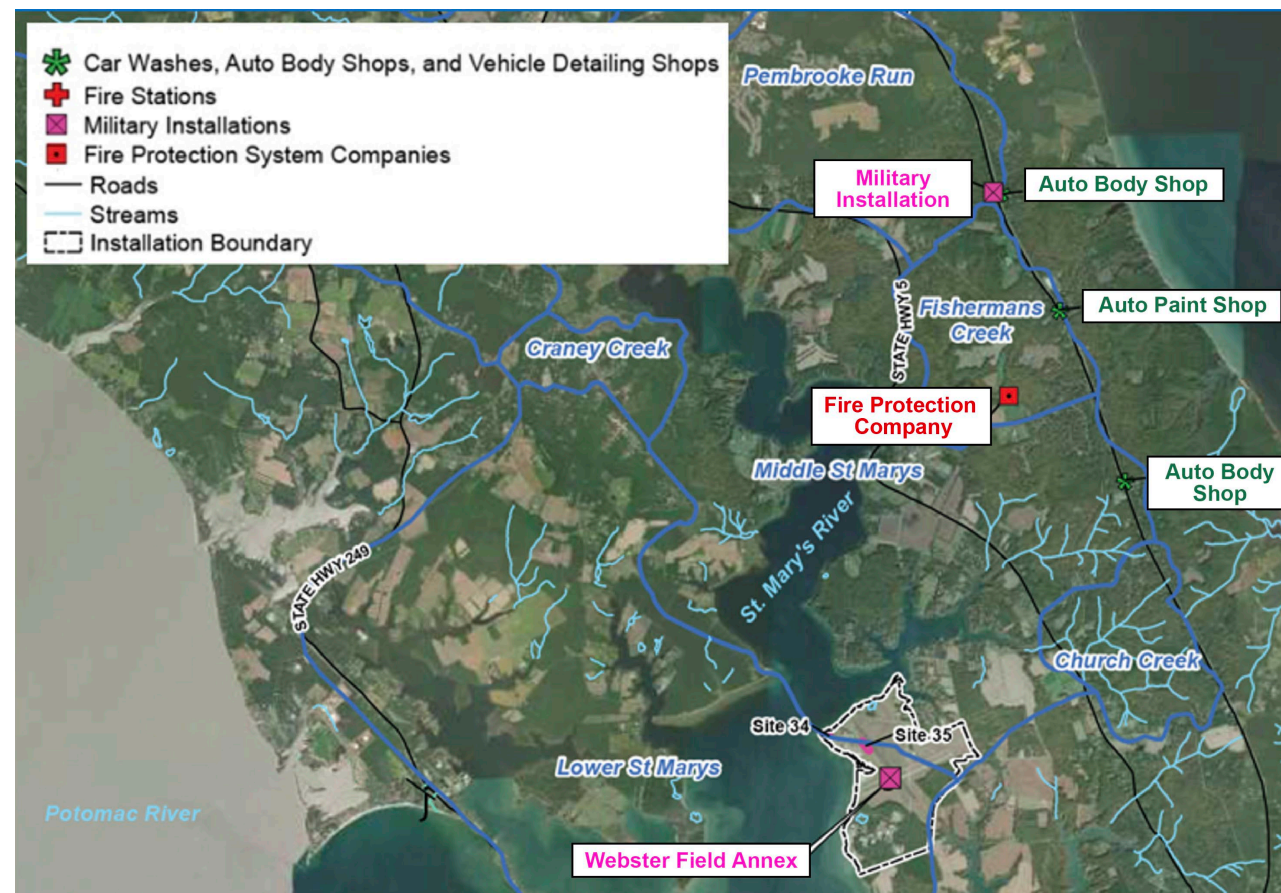
<https://geotracker.waterboards.ca.gov/map/?CMD=runreport&myaddress=Sacramento>

Step 4: Preliminary Watershed Contaminant Source Map

- Geospatial map development in Step 2 is refined to establish preliminary watershed contaminant source map that identifies the following:
 - WCSD scoped area
 - IRP/BRAC site
 - Location of nearby sediment area
 - Locations of potential Navy and non-Navy sources

* Note: Potential PFAS release areas are NOT definitive evidence that a release of PFAS occurred at these addresses unless otherwise noted in this document.

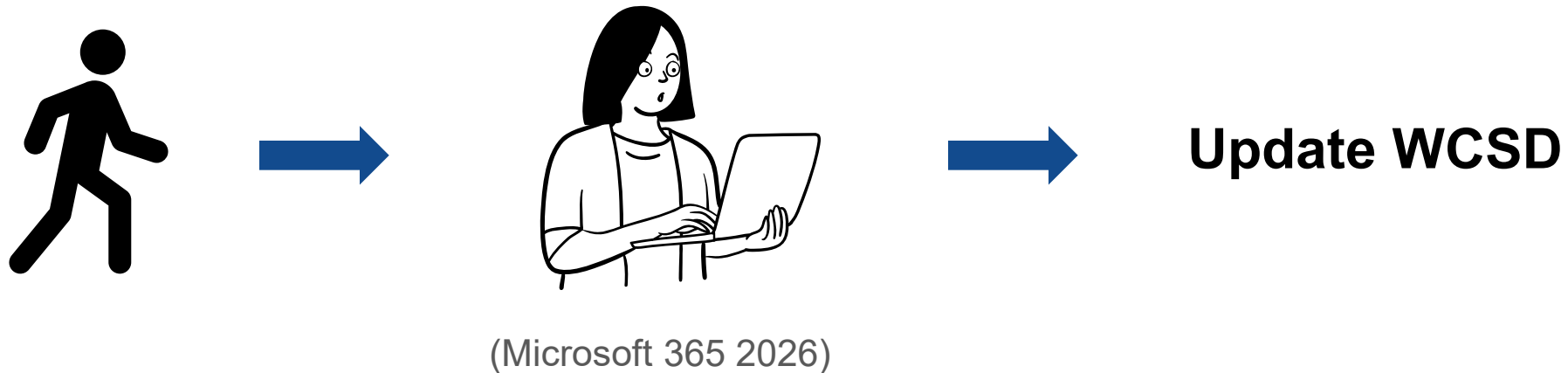
PFAS: per- and polyfluoroalkyl substances



Example of a Watershed Contaminant Source Map
(CH2M 2024)

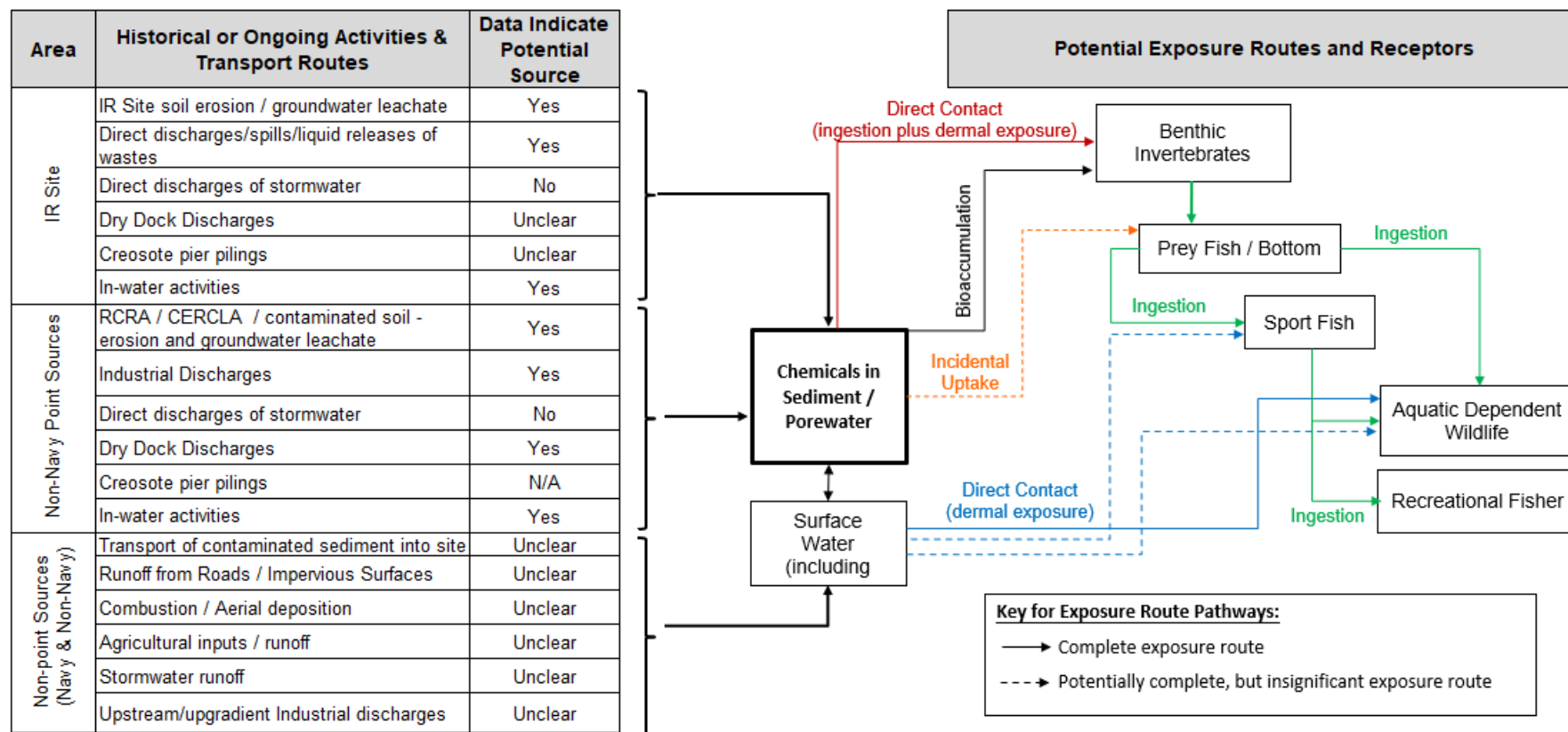
Step 5: Watershed Visit

- **Conduct watershed visit to confirm source accuracy**
- When potential sources have been identified, watershed information should be confirmed by watershed visit, updates to watershed contaminant source map, and further literature searches if necessary
- Look for literature review potential sources, pathways to Navy IRP sediment area



Step 6: Graphic CSM

- Develop a graphic CSM to illustrate potential sources and releases (both Navy and non-Navy) and possible transport mechanisms, exposure pathways, and receptors



Example Conceptual Site Model Illustrating Potential Sources and Releases (both Navy and Non-Navy), Transport Mechanisms, Exposure Pathways, and Receptors
(NAVFAC EXWC 2026)

Step 7: Write the WCSD



Concise document describing all identified potentially significant Navy and non-Navy sources to sediments in the waterbody

- Present watershed area map showing WCSD scoped area
- If available, review and briefly summarize existing analytical data
- Present watershed contaminant source map with all notable potential sources
- Present CSM showing complete and significant pathways
- Present conclusions
 - Numerous point and non-point sources from both Navy and non-Navy sites to sediments
 - Navy is not the only source, so Navy/non-Navy contribution should be considered on site-specific basis
 - Background studies might be valuable; involve other stakeholders

* Recommend stakeholder and regulator engagement, but it is not required.

WCSD Example Summary Table



Example Summary Table for WCSD Showing Potential Sources of Chemicals from Navy and Non-Navy Sources

Primary sources are highlighted

*A Summary Table
Can Be Useful*

Types of Sources	Navy	Non-Navy
Watershed Point Sources		
EPA-Designated Sites		
IR Sites	10	10
Toxic Releases	1	7
Water Dischargers	1	2
Air Emissions	1	5
State Sites of Concern		
Sites		5
Releases of hazardous substances		20
USTs/LUSTs		22
NPDES Stormwater Discharges		15
Watershed Non-Point Sources		
Naturally Occurring Metals		2
Agriculture		numerous
Impaired Waterbodies (Clean Water Act Section 303[d])		2
Storm Drains and Outfalls	numerous	numerous
Other Sources		
Brownfield Sites		1
General Urbanization		numerous
Oil Spills	1	1

IR: installation restoration

LUST: leaking underground storage tank

UST: underground storage tank

(Earth Tech, Inc. 2025)

Test your knowledge!

Quiz Question #1



Put the Steps of the WCSD in Order

- A. Conduct watershed visit to confirm source accuracy
- B. Determine need for WCSD
- C. Develop graphic CSM
- D. Conduct literature search on potential sources
- E. Develop preliminary watershed contaminant source map
- F. Write WCSD
- G. Define WCSD scope and area

Answer



- B. Step 1: Determine need for WCSD
- G. Step 2: Define WCSD scope and area
- D. Step 3: Conduct literature search on potential sources
- E. Step 4: Develop preliminary watershed contaminant source map
- A. Step 5: Conduct watershed visit to confirm source accuracy
- C. Step 6: Develop graphic CSM
- F. Step 7: Write WCSD

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Considerations for PFAS WCSDs*



- PFAS sediment overview
- *Specific considerations pertain to Step 3 (Literature Search), Step 6 (CSM), and Step 7 (WCSD)*

**** PFAS focus only affects certain steps.***

1. PFAS: per- and polyfluoroalkyl substances

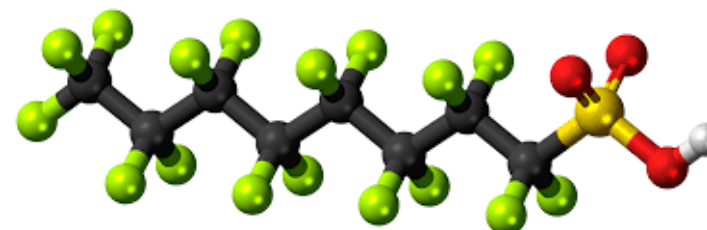
- Family of synthetic organic compounds

2. Characteristics most important for PFAS WCSDs

- **Surfactants** with a charge (anions, cations, zwitterions)
- Hydrophobic, somewhat soluble
- **Persistent** in environment
- Can **travel long distances** (miles!) quickly in water
- **Accumulate** in sediment, bioaccumulate in biota
- **Can be toxic** at environmentally relevant dose

Example: PFOS

Multiple carbon & fluorine atoms = **stability**



sulfonic acid group (anionic) = **solubility**

(Wikimedia Commons 2011)

PFOS: Perfluorooctanesulfonic acid

Why Does it Matter for WCSD?



- PFAS are found in AFFF
- Major PFAS release mechanism
 - Often thousands of liters discharged per use
 - 1%–10% PFAS by weight

Fire-Related Activities	Manufacturing & Materials	Industrial/Commercial Operations	Waste and Applications
• Historical fires where AFFF used • Fire stations/engine maintenance • Airports • Fire protection companies • Fire training areas • Tank farms / facilities with fire suppression systems	• Pesticides • Countertops and coating • Outerwear and shoes • Low volatile organic compound paint • Carpet and stain resistant treatments • Food packaging, coated paper, and cookware	• Military installations • Chromium plating shops • Wastewater treatment plants • Car washes, auto body shops, and vehicle detailing shops	• Landfills • Spills from transformers • Bilge waste disposal areas • Biosolids land application areas • AFFF spray testing areas

(NAVFAC EXWC 2026)

But there are many non-AFFF sources

AFFF: aqueous film-forming foam

For the PFAS Literature Review: Reference Website



Search “ITRC PFAS”

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



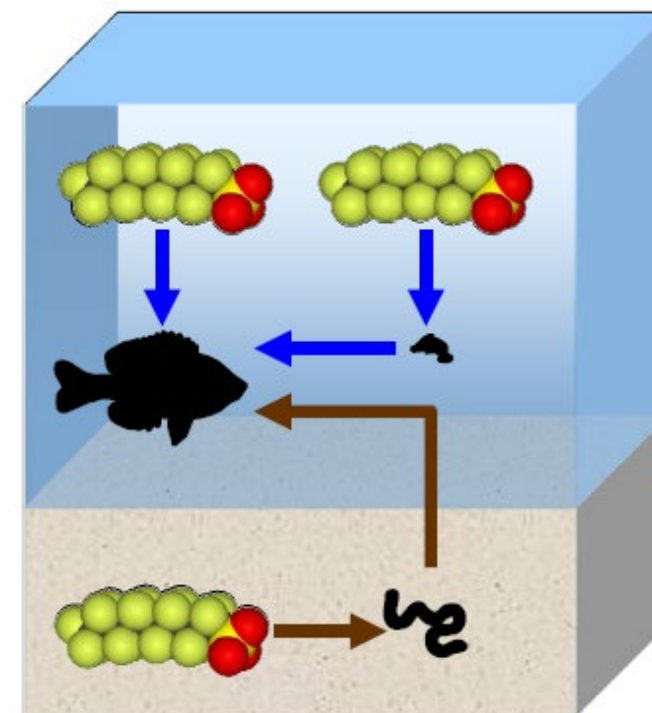
A screenshot of the ITRC PFAS website homepage. The page has a dark blue header with the ITRC logo and the title "PFAS – Per- and Polyfluoroalkyl Substances". Below the header is a green navigation bar with "PFAS HOME" and a list of links: "Navigating This Website", "About ITRC", "Fact Sheets", "1 Introduction", "2 Naming Conventions and Use", "3 Firefighting Foams", "4 Physical and Chemical Properties", "5 Fate and Transport", "6 Occurrence", and "7 Health Effects". The main content area features a large "Welcome" message, a circular graphic with four quadrants showing a deer, a person drinking, a firefighter, and a factory, and a list of resources including "PFAS Fact Sheets", "PFAS Technical and Regulatory Guidance Document", and "Training Resources".

(ITRC 2026)

But is Sediment PFAS a Problem?

Potentially, because of the following

- PFAS can travel long distances quickly
- Like most organic chemicals, PFAS like to sorb to organic carbon
- They are surfactants: lipid-loving tail and anionic/cationic head
- PFAS bioaccumulate into food webs (sediment -> invertebrate -> fish -> human and wildlife fish/invertebrate consumers)



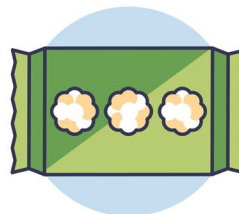
(Conder 2018)

Step 3: PFAS Literature Search

Look for potential PFAS sources, particularly in manufacturing of these and related products



**FIREFIGHTING
FOAMS**



**MICROWAVE
POPCORN BAGS**



**WATER RESISTANT
CLOTHING**



PAINT



**STAIN RESISTANT
PRODUCT**



**PERSONAL CARE
PRODUCTS**

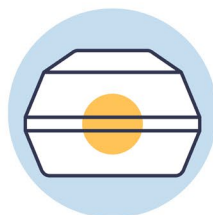
PRODUCTS THAT CONTAIN PFAS



COSMETICS



**NON-STICK
COOKWARE**



**FAST FOOD
PACKAGING**



**STAIN RESISTANT
FURNITURE**



PHOTOGRAPHY



PESTICIDES

(VectorMine 2024)

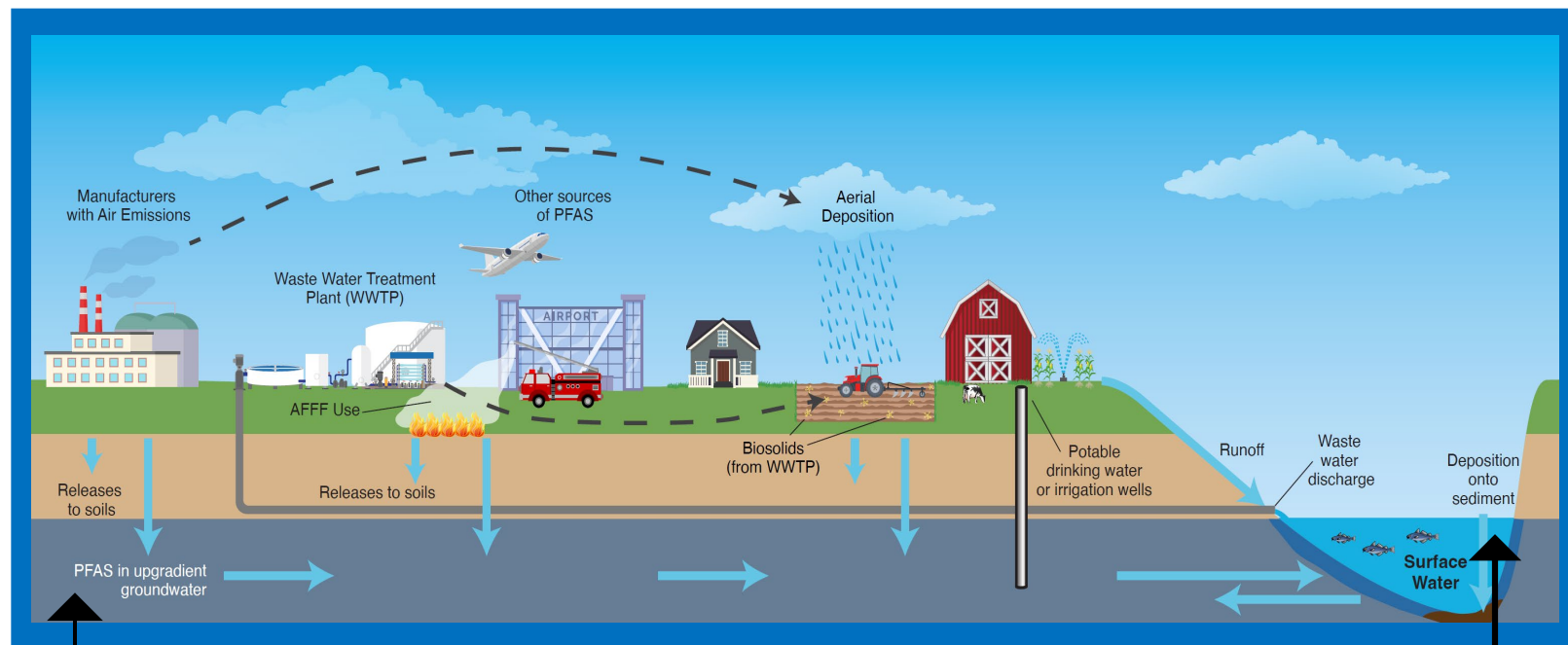
Step 6: PFAS WCSD Graphic CSM



Include PFAS-specific elements of CSM.

Consider the following

- Various and diverse non-Navy PFAS sources
- Fate and transport pathways of importance to PFAS (soil to GW, GW to SW, aerial deposition, discharge from WWTP, SW to sediment)
- Exposure pathways of concern for WCSD (sediment to fish, fish to humans)



(NAVFAC EXWC 2026)

Background,
non-Navy
sources

GW: groundwater

SW: surface water

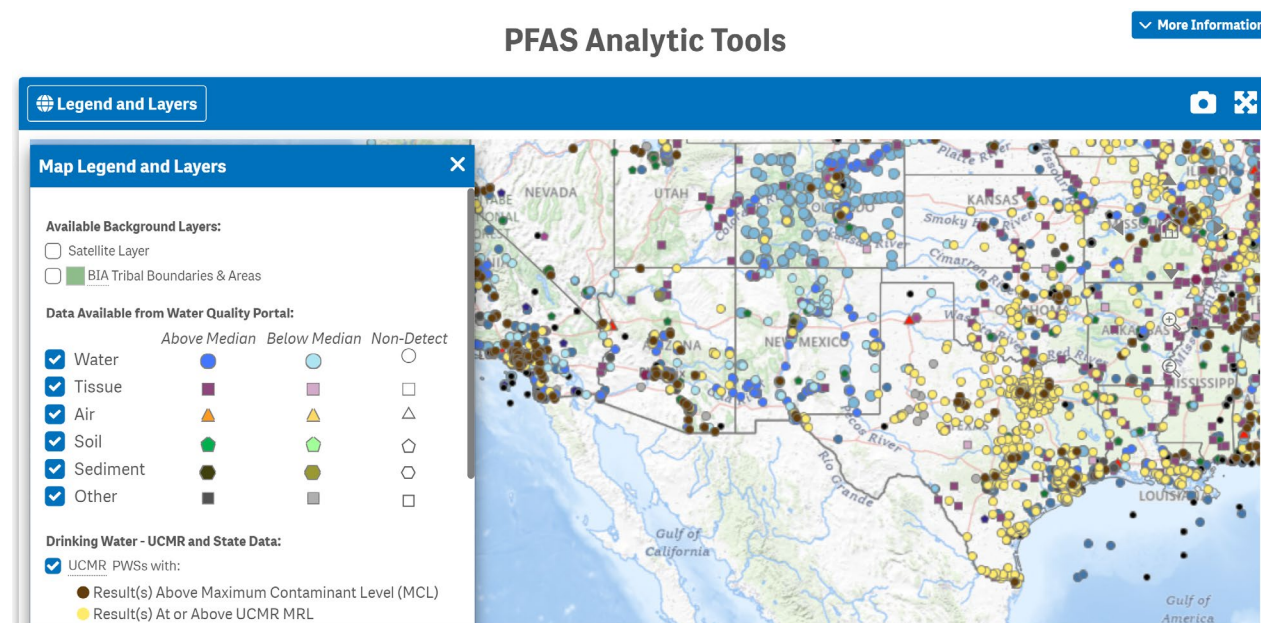
WWTP: wastewater treatment plant

Step 7: WCSD—PFAS Sites: Resources



Agency Resources:

- **EPA PFAS Analytic Tools:**
<https://echo.epa.gov/trends/pfas-tools/>
- **State-specific reports or inventories of PFAS.** For example, the New York State Department of Environmental Conservation
<https://dec.ny.gov/environmental-protection/site-cleanup/database-search>



(EPA n.d.)

Step 7: WCSD—PFAS Sites: Resources



More Agency Resources

- **Regulatory agency surveys/reports** to characterize ambient concentrations of PFAS in the environment
- **State databases on biosolids land application** (e.g., Pennsylvania <https://www.arcgis.com/home/item.html?id=65aaa8fadf9e4a88b2635a60ad935e7b>)



Air, Water,
Land, Climate

Trending
Topics

Business
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Get
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About
MPCA

Air, Water, Land, Climate / Water / [Water quality initiatives](#) / [Minnesota's PFAS Blueprint](#)

PFAS studies and reports

< MINNESOTA'S PFAS BLUEPRINT

PFAS in biosolids strategy

PFAS use prohibitions

Monitoring PFAS

Developing water-quality criteria
for PFAS

PFAS in fish

PFAS studies and reports

PFAS are persistent and problematic chemicals that are found throughout the environment and not just in areas where large quantities have been manufactured, disposed of, or spilled. PFAS are currently detected globally — even in parts of the world that have never been inhabited by humans — due to long-range transport via air and water. Ambient background concentrations inform our understanding of baseline levels of contamination that can be expected even in “pristine” or “non-impacted” regions.

- [PFAS ambient background concentrations \(tdr-g1-25\)](#)

PFAS (per- and polyfluoroalkyl substances) is the preferred abbreviation used to collectively describe PFOA, PFOS, and other chemicals in this group. PFAS were previously referred to as PFCs.

Remediation guidance

The MPCA has developed [PFAS remediation guidance](#) that outlines the approach used to identify, investigate, evaluate, and remediate PFAS contamination at impacted sites in the MPCA Remediation program across Minnesota. The PFAS remediation guidance was developed in coordination with an external stakeholder group.

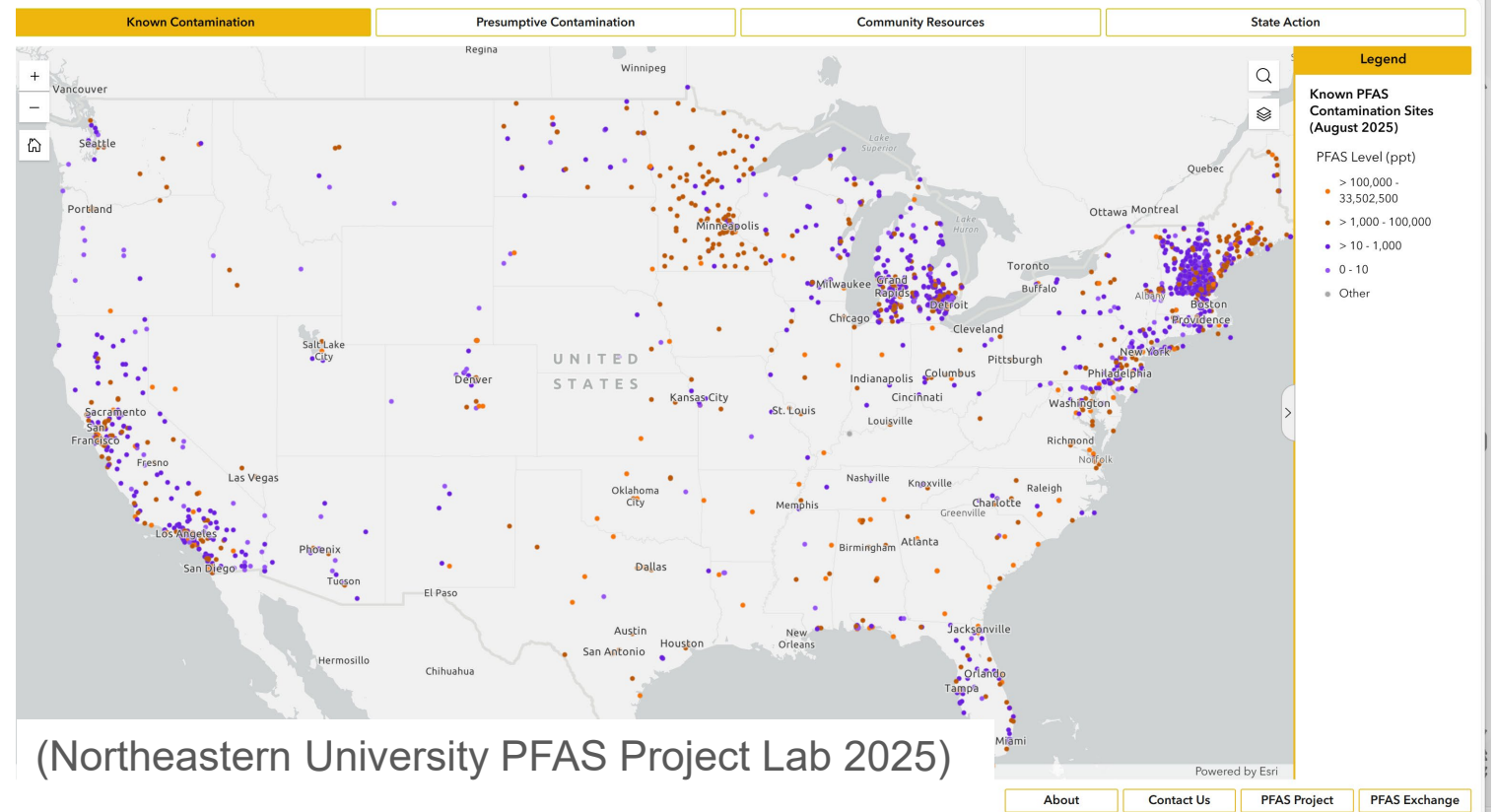
(Minnesota Pollution Control Agency n.d.)

Step 7: WCSD—PFAS Sites: Resources



Non-Agency Resources

- PFAS Project Database: <https://pfasproject.com/pfas-sites-and-community-resources/>
- **Environmental database reports (EDRs)** focused on facilities that used or produced PFAS (e.g., chromium plating shops)



EDR: Report that compiles and summarizes information from federal, state, and local environmental databases to identify known or potential environmental conditions, regulatory listings, and compliance considerations relevant to a site or project area

Step 7: WCSD—PFAS Sites: Resources

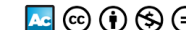


Non-Agency Resources

- Salvatore, et. al. (2022)
(potential businesses at which PFAS may have been used)



pubs.acs.org/journal/estlcu



Letter

Presumptive Contamination: A New Approach to PFAS Contamination Based on Likely Sources

Derrick Salvatore, Kira Mok, Kimberly K. Garrett, Grace Poudrier, Phil Brown, Linda S. Birnbaum, Gretta Goldenman, Mark F. Miller, Sharyle Patton, Maddy Poehlein, Julia Varshavsky, and Alissa Corder*



Cite This: *Environ. Sci. Technol. Lett.* 2022, 9, 983–990



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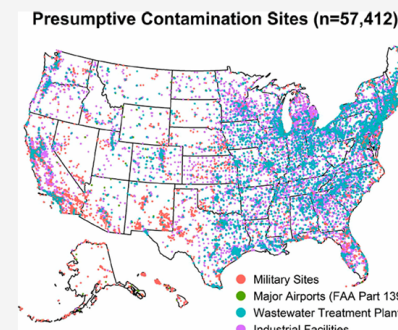
Metrics & More

Article Recommendations

Supporting Information

ABSTRACT: While research and regulatory attention to per- and polyfluoroalkyl substances (PFAS) has increased exponentially in recent years, data are uneven and incomplete about the scale, scope, and severity of PFAS releases and resulting contamination in the United States. This paper argues that in the absence of high-quality testing data, *PFAS contamination can be presumed* around three types of facilities: (1) fluorinated aqueous film-forming foam (AFFF) discharge sites, (2) certain industrial facilities, and (3) sites related to PFAS-containing waste. While data are incomplete on all three types of presumptive PFAS contamination sites, we integrate available geocoded, nationwide data sets into a single map of presumptive contamination sites in the United States, identifying 57,412 sites of presumptive PFAS contamination: 49,145 industrial facilities, 4,255 wastewater treatment plants, 3,493 current or former military sites, and 519 major airports. This conceptual approach allows governments, industries, and communities to rapidly and systematically identify potential exposure sources.

KEYWORDS: per- and polyfluoroalkyl substances (PFAS), presumptive contamination, PFAS testing and investigation, AFFF, PFAS waste and disposal



(Salvatore et al. 2022)

Break

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- Introduction
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PFAS Case Study #1: St. Mary's River WCSD



(CH2M Hill, Inc. 2024)

Step 1: WCSD need was confirmed

Step 2: PFAS WCSD Scope and Area:
St. Mary's River, adjacent to Webster
Outlying Landing Field, St. Mary's
County, Maryland

St. Mary's River WCSD: Literature Review



Step 3: Literature review included the following

- Web-based searches: Google, Google/Maps, PFAS project search
- Environmental data report generated using a 1-mile radius search from the St. Mary's River watershed

WCSD Watershed Contaminant Source Map

St. Mary's River/Webster Field Annex



Step 4: Watershed contaminant source map with potential PFAS source areas identified

- Airplane crash areas
- Airport
- Car washes, autobody shops, etc.
- Fire stations
- One other military installation
- Fire protection system companies
- Municipal landfill
- Biosolids land application areas



Example of a Watershed Contaminant Source Map
(CH2M Hill, Inc. 2024)

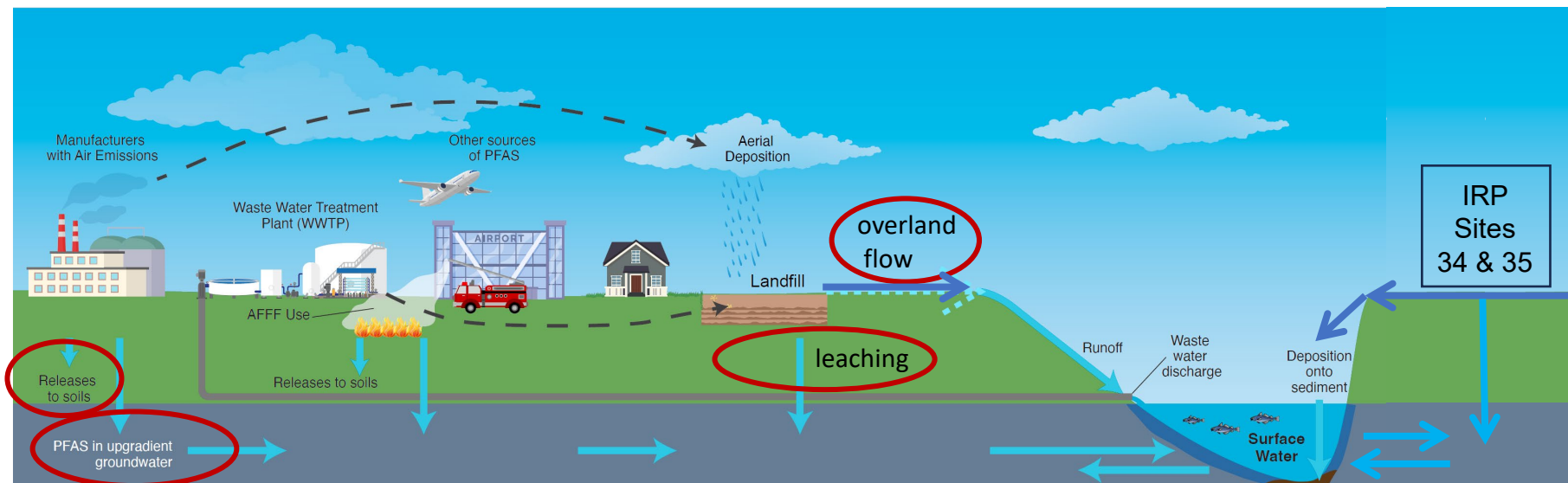
St. Mary's River WCSD: PFAS CSM

Graphic CSM not provided; described as follows

- **Potential Sources**

- No confirmed PFAS releases identified, and no environmental impacts verified
- Two non-Navy locations were potential PFAS-containing source areas; other areas were too far or less significant

- **Migration Pathways**



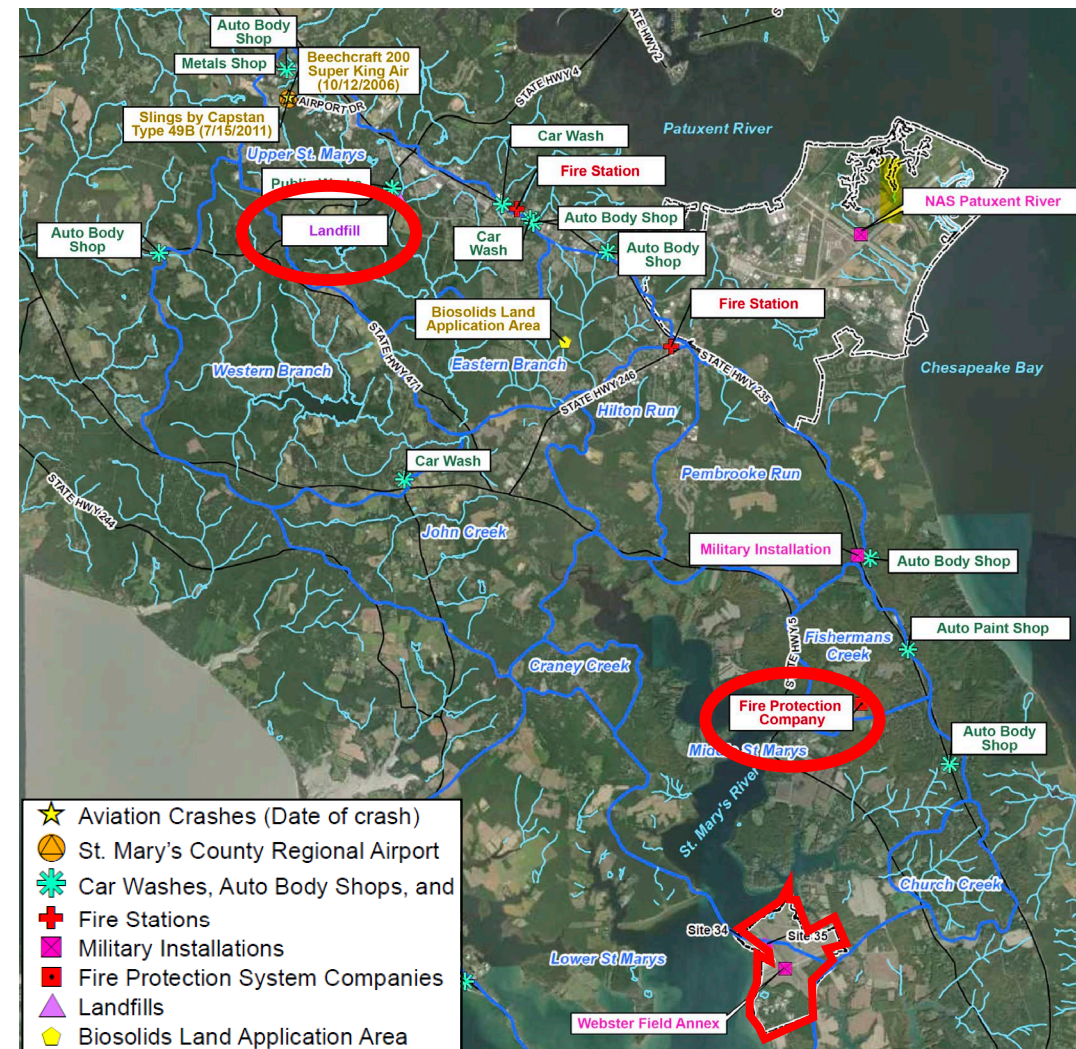
(NAVFAC EXWC 2026)

- On-base potential PFAS source areas include IRP Sites 34 and 35 at Webster Outlying Landing Field
- They have potential to release PFAS to surface water or sediments of the St. Mary's River

St. Mary's River WCSD: Conclusions

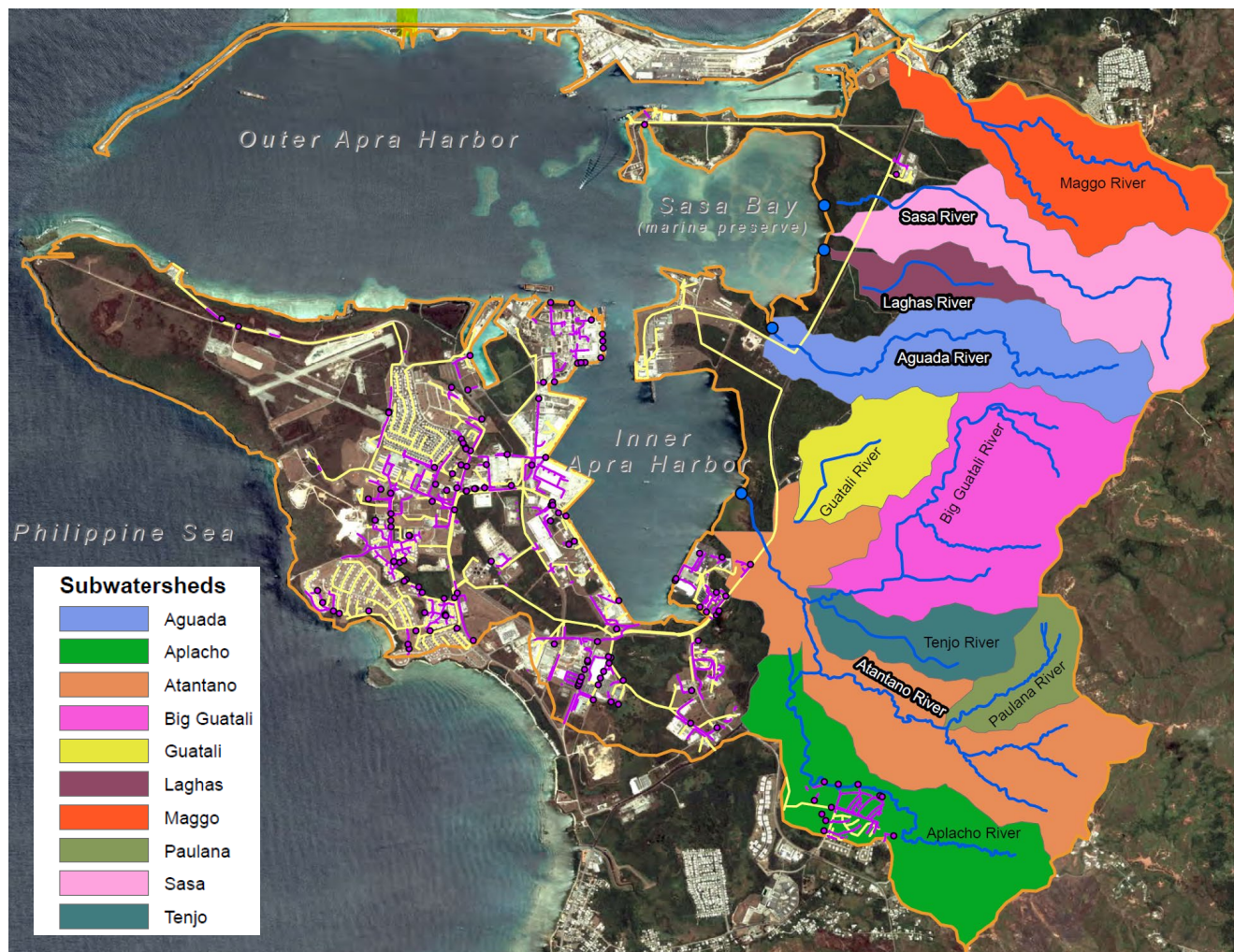


- Non-Navy potential sources of PFAS were identified in St. Mary's River watershed
- Of these, only two are considered to have higher potential for release of PFAS; however, **there is NOT any data to support this: no measures of releases**



(CH2M Hill, Inc. 2024)

Case Study #2: Apra Harbor



(AECOM 2012)

Step 1:
WCSD need was confirmed

Step 2:
WCSD Scope and Area:
Apra Harbor, Guam

Apra Harbor WCSD: Literature Review



Step 3: Literature review included the following

- EPA Envirofacts Data Warehouse Web site (EPA 2004 and 2012) for Navy and non-Navy EPA-regulated sites associated with CERCLA/Superfund/Brownfields, RCRA (hazardous waste), water dischargers, toxic releases, and air emissions for the watershed area discharging to the harbor
- Navy documents considering the following
 - Geology, wetlands, benthic habitat, areas dredged/confined disposal facilities, Navy and non-Navy lands, onshore and offshore activities

Apra Harbor WCSD: Literature Review



Step 3: Table of Activities in the Watershed showing the following

- Potential COPCs associated with each IR Site and RCRA site in the Watershed
- Both included: metals, PAHs, PCBs, TPH, others

COPC: contaminant of potential concern
PAH: polycyclic aromatic hydrocarbon
PCB: polychlorinated biphenyl
TPH: total petroleum hydrocarbons

Table 2: List of Active/Future Navy IR and RCRA Sites in Apra watershed and chemicals of potential concern associated with each site

IR Sites	
FISC – Lower Sasa Fuel Burning Pond	
COPCs: metals, PAHs, TPH	
NAVACTS – NEX Garage Waste Oil Tank	
COPCs: metals, PAHs, PCB, TPH	
NAVACTS – USS Proteus Fire Fighting Training Area	
COPCs: PAHs, TPH	
PWC – Carpentry Shop Dip Tank	
COPCs: dioxins, metals, PCP, PAHs, TPH	
PWC – Former Building 3009	
COPCs: PCBs, TPH	
SRF – Area Behind SRF Fenceline	
COPCs: metals, OC pesticides, organotin, PAHs, PCBs, TPH	
SRF –Plating Shop leach Field	
COPCs: metals	
RCRA Sites	
FISC – Old NSD Drum Storage Lot	
COPCs: metals, PAHs, PCBs, TPH	
NAVACTS – NEX Carpentry Shop Abandoned Drum Area	
COPCs: metals, PAHs, PCBs, TPH	
NAVACTS – Spanish Steps Disposal Area	
COPCs: metals, PAHs, PCBs, TPH	
PWC – PWC Landfill	
COPCs: cyanide, metals, PAHs, TPH	
SRF – Woodworking Shop Dip Tank	
COPCs: metals, naphthalene, PCP	
FISC – Fleet Industrial Supply Center	OC – organochlorine
NAVACTS – Naval Activities	PAHs – polycyclic aromatic hydrocarbon
PWC – Public Works Center	PCBs – polychlorinated biphenyl
SRF – Ship Repair Facility	PCP – pentachlorophenol
	TPH – total petroleum hydrocarbon

(AECOM 2012)

WCSD: Watershed Contaminant Source Map Apra Harbor, Guam



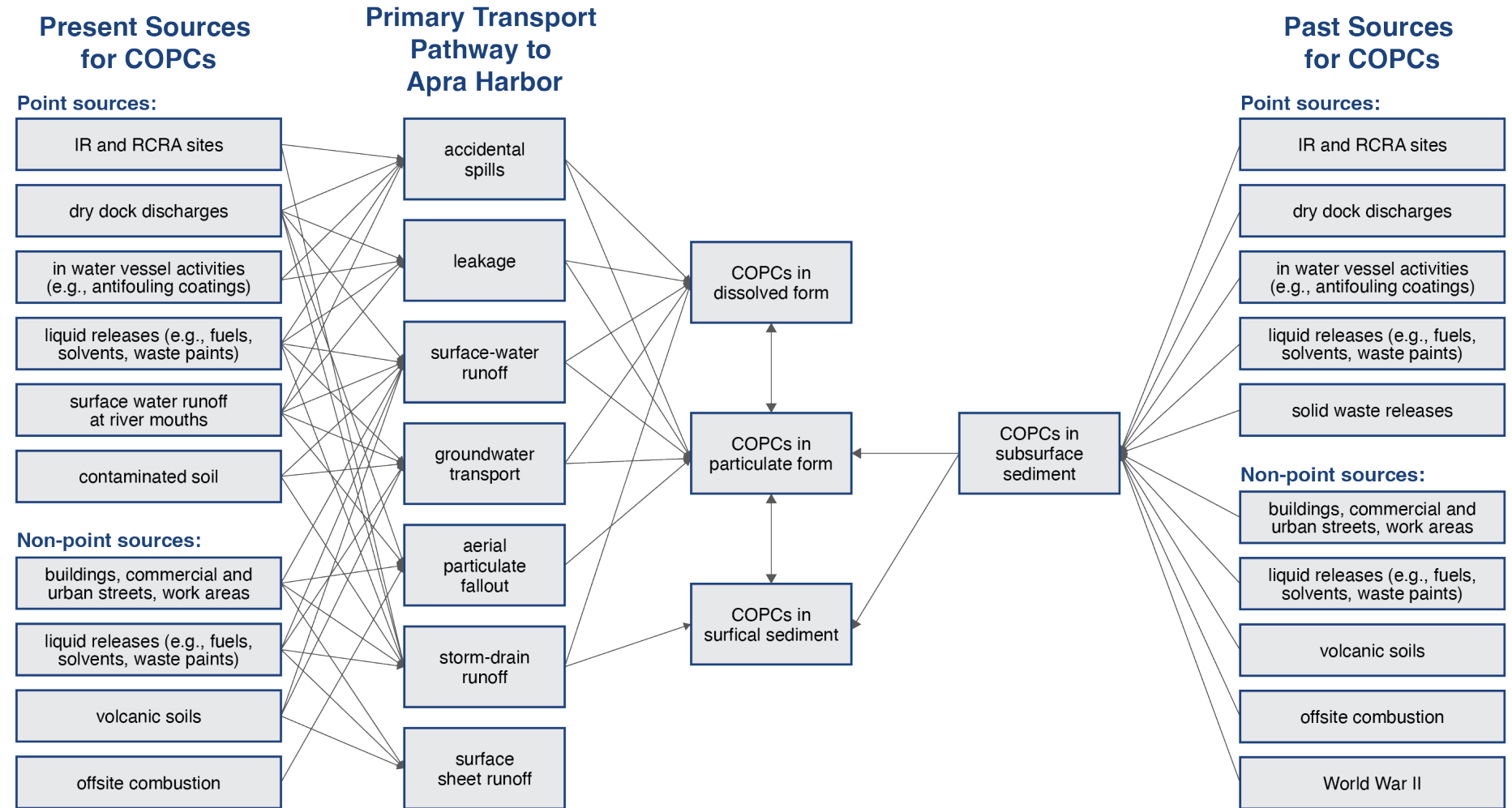
Step 4: Watershed contaminant source map with potential chemical source areas identified

- Oil refineries/terminal
- Water treatment plants
- Shipyard
- Public works
- Salvage yard



(AECOM 2012)

Step 6. Apra Harbor WCSD: CSM Sources Fate and Transport



Preliminary Fate and Transport Pathways for Chemicals to Sediments in Apra Harbor
(AECOM 2012)

Apra Harbor WCSD: Conclusions



- Chemicals in Apra Harbor primarily from Navy point/non-point sources
- But there is potential contribution of chemicals from non-Navy sources
- Navy's contribution should be evaluated on site-specific basis

Table 4: Summary of Potential Sources for Chemicals from Navy and Non-Navy Sites in Apra Harbor Watersheds

Types of Sources	Navy	Non-Navy
Watershed Point Sources:		
<i>EPA Regulated Sites:</i>		
IR/RCRA Sites	12	
RCRA (hazardous waste)	2	2
Toxic Releases	1	2
Water Dischargers		4
Air Emissions		3
Watershed Non-Point Sources:		
Naturally Occurring Metals in Volcanic Soils		Entire Watershed
Storm Drains and Outfalls	Numerous	
Rivers		4
<i>Other Sources:</i>		
General Urbanization	Harbor Shoreline	Harbor Shoreline

(AECOM 2012)

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WCSD Fun Activity: With 1 or 2 People Nearby



1. Hypothetical IR Site Q: WCSD Development Key Steps

- **Navy IR Site Q** is located at mile 0 on **River XYZ**
- Assume upstream industries include municipal airport (2 miles upstream), cookware plant (1 mile upstream), and municipal landfill (3.5 miles upstream)
- River XYZ cuts through land at mile 0
- Assume PFAS has been measured in **River XYZ** upstream surface water, in groundwater within **IR Site Q** and in sediment and surface water within channel adjacent to site that feeds into **River XYZ**

2. Complete the steps typically followed when developing a WCSD (15–20 minutes)

- **Step 1.** Answer: Should you perform the WCSD?
- **Step 2.** WCSD scope: What figure you will start with? Draw a very simple figure and label features. This is Figure 1.
- **Step 3.** Literature review: Name two resources for PFAS WCSDs that can be used to perform the literature review.
- **Step 4.** State what refinement steps are needed for this step and draw and add to your first figure by drawing in additional key information. Label the features.
- **Step 5.** What is step 5? (Hint: you can't do this one right now.)
- **Step 6.** Draw a very basic graphic CSM.
- **Step 7.** State what would be done as part of this step (also can't do this right now).

3. Talk through findings and compare with the larger group

Disclaimer: This is an unlabeled map of a random area from Google Earth and is just a background image. The entities listed, and labels are not real. This is just an exercise.



River XYZ

Municipal Landfill
Mile 3.5

Municipal Airport
Mile 2.0

PFOS SW
= 4 ng/L

Cookware Plant
Mile 1.0

IR Site Q
Mile 0
GW PFOS=200 ng/L
Nearby Sediment
PFOS = 500 µg/kg

Step 1. Answer: Should you perform the WCSD?

Step 2. WCSD scope: What figure you will start with? Draw a very simple figure and label features. This is Figure 1.

Step 3. Literature review: Name two resources for PFAS WCSDs that can be used to perform the literature review.

Step 4. State what refinement steps are needed for this step and draw and add to your first figure by drawing in additional key information. Label the features.

Step 5. What is step 5? (Hint: you can't do this one right now.)

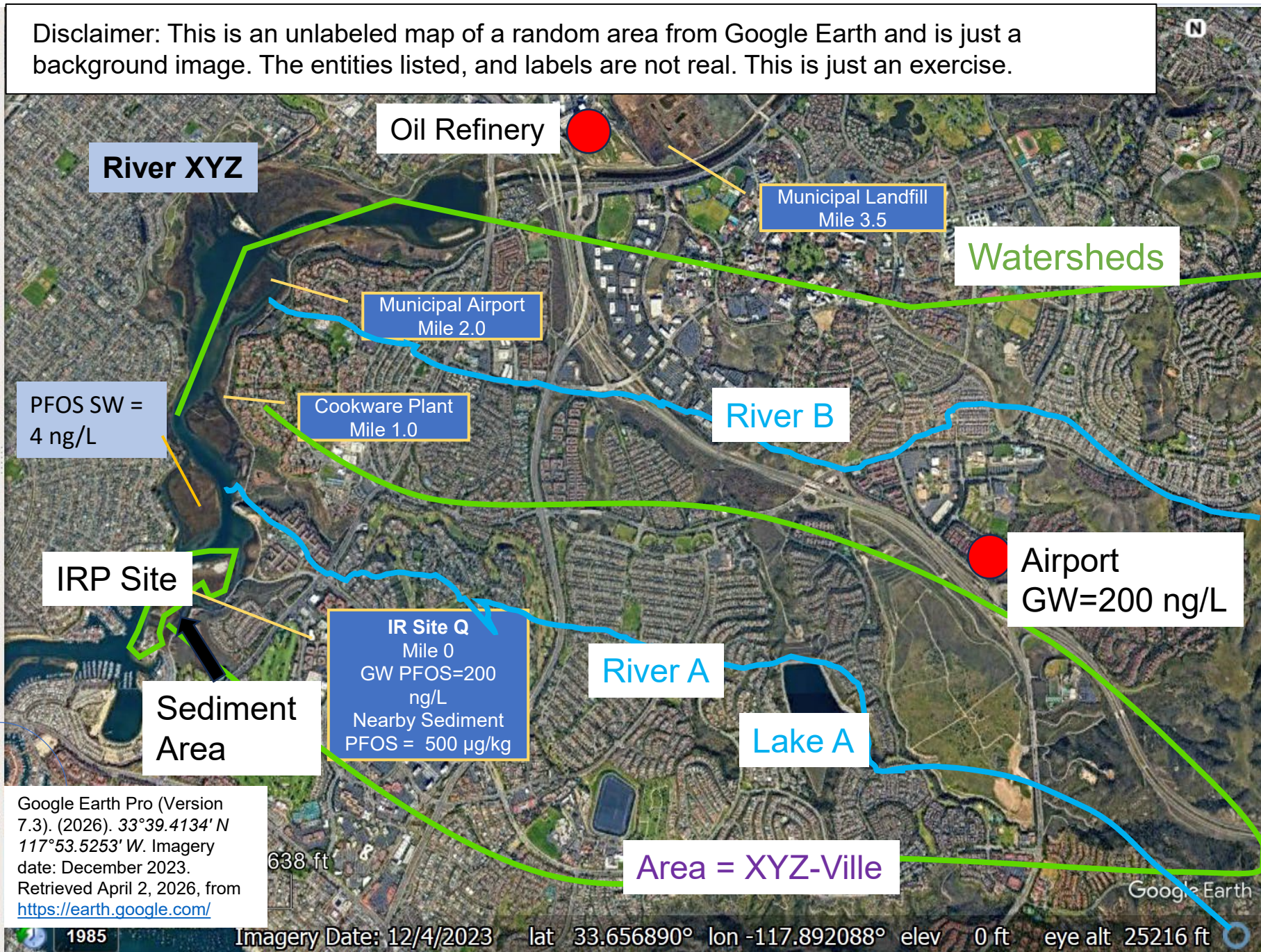
Step 6. Draw a very basic graphic CSM.

Step 7. State what would be done as part of this step (also can't do this right now).

Google Earth Pro (Version 7.3). (2026). 33°39.4134' N 117°53.5253' W. Imagery date: December 2023. Retrieved April 2, 2026, from <https://earth.google.com/>

1985 Imagery Date: 12/4/2023 lat 33.656890° lon -117.892088° elev 0 ft eye alt 25216 ft

Disclaimer: This is an unlabeled map of a random area from Google Earth and is just a background image. The entities listed, and labels are not real. This is just an exercise.



Step 1: Is the WCSD needed? **Yes**

Step 2. WCSD scope: What figure you will start with? Draw a very simple figure and label features. This is Figure 1. **Watershed Features**

Step 3. Literature review: Name two resources for PFAS WCSDs that can be used to perform the literature review.

EPA PFAS Analytic Tool
Google Earth

Step 4. State what refinement steps are needed for this step and draw and add to your first figure by drawing in additional key information. Label the features. **Add potential sources besides the ones shown. Add analytical data if available.**

Step 5. What is step 5? **Site Visit – confirmation**

Step 6. Draw a very basic CSM.

Step 7. State what would be done: **Write the WCSD**

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Key Takeaways



- WCSD is needed if there are non-Navy sources that could significantly contribute, or have contributed, to contamination in sediment investigation area
- WCSD is **concise but technical document** with key figures and tables
- PFAS, like other chemicals, are ubiquitous and can be in non-Navy sources that can impact a nearby Navy sediment site (*groundwater and surface water as well)
 - For PFAS WCSD, PFAS-specific literature review (sources) and PFAS/site-specific CSM are needed
- If non-Navy sources are present and significant, follow-on steps may be needed (e.g., a PFAS background study, engagement of other stakeholders)

Synonyms for long story short

get to the point

to cut a long story short

in summary

to be short and sweet

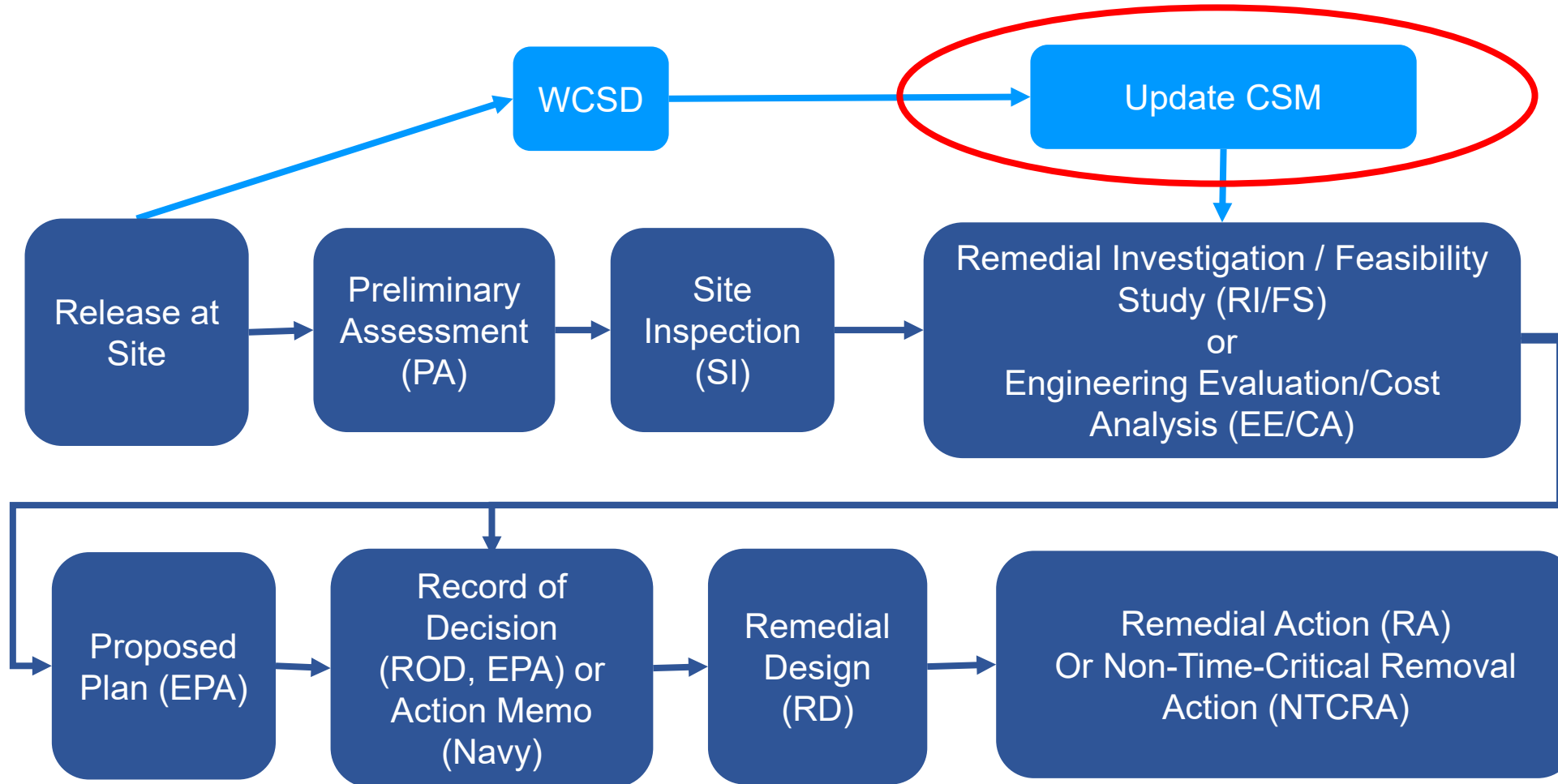
leave out details

in a few words

KEY POINT

**The WCSD is more like
CliffsNotes, not an encyclopedia
(10–12 pages, not 50!)**

WCSD Allows for CSM Updates to Inform CERCLA* Process



- **Before Site Management:** Should we engage stakeholders?
- Is a background study needed?

** Similar Process for RCRA; expedited for TCRAs*

References



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<https://www.environmentalrestoration.wiki/images/d/df/SalvatoreEtAl2022.pdf>

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