FOREVER CHEMICALS

Per- & Polyfluoroalkyl Substances (PFAS)

Dr Ken Scally MSc FRSC
Technical & Quality Director, SUEZ

Duncan Sanders MSc C.Geol, SiLC
Director, ATG group

suez

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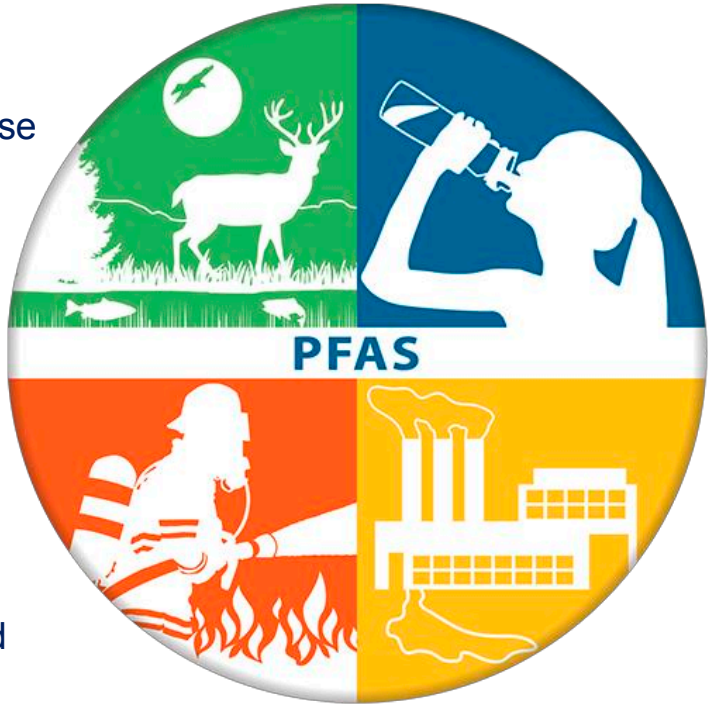
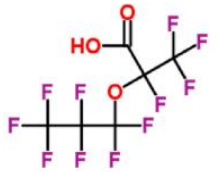
What are Per- & Poly- fluoroalkyl Substances (PFAS)?

- **PFAS** comprises many thousands of compounds – multiple sources
- **Widely used** around the world to make products that resist heat, stains, grease and water
- Used in **legacy** aqueous **film forming foam (AFFF)** to extinguish liquid fuel fires by both civilian and military authorities
- PFAS tend to be **soluble** in water, **environmentally persistent** and **stable**, therefore very mobile in the environment and are known to impact **drinking water** supplies
- Some **PFAS** have been found to be **toxic** to both **humans** and **ecosystem**. Most people have been exposed to PFAS. Some PFAS can **accumulate** and stay in the human body for long periods of time
- Advanced **analytical methods** are being adopted to measure some PFAS
- Dramatically increasing **regulatory concern**.

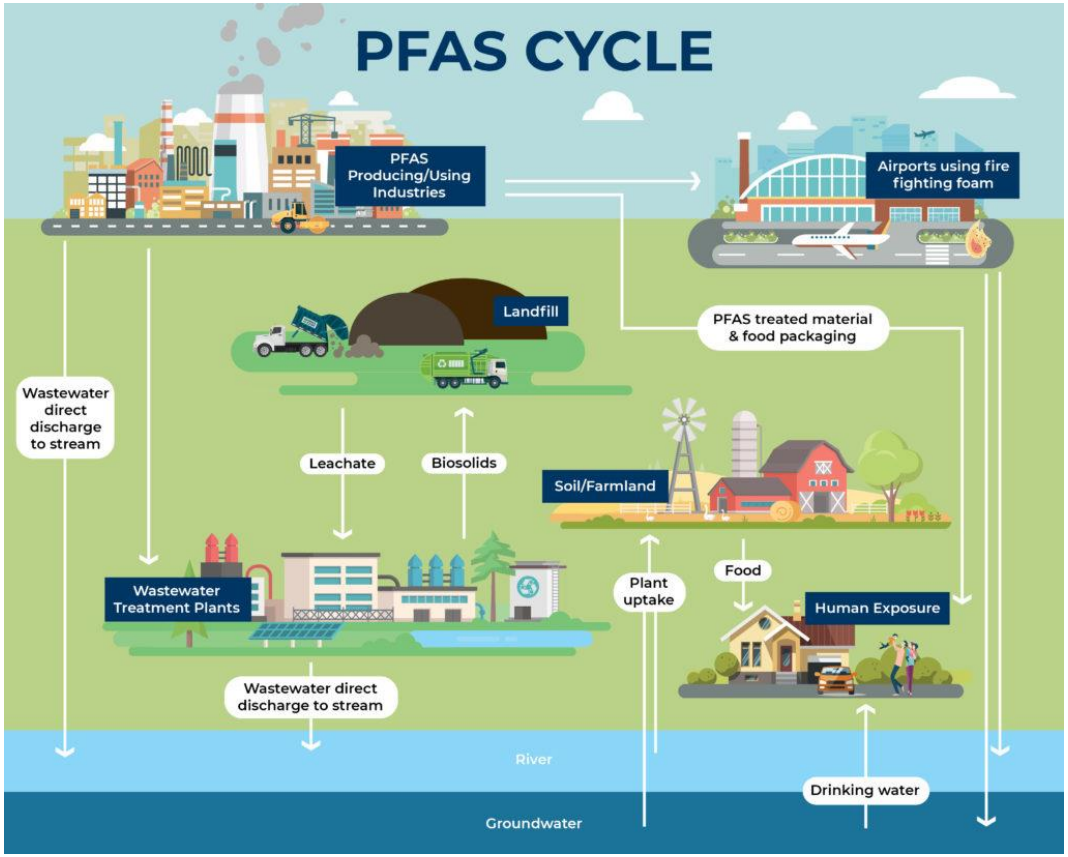


GenX



HFPO-DA

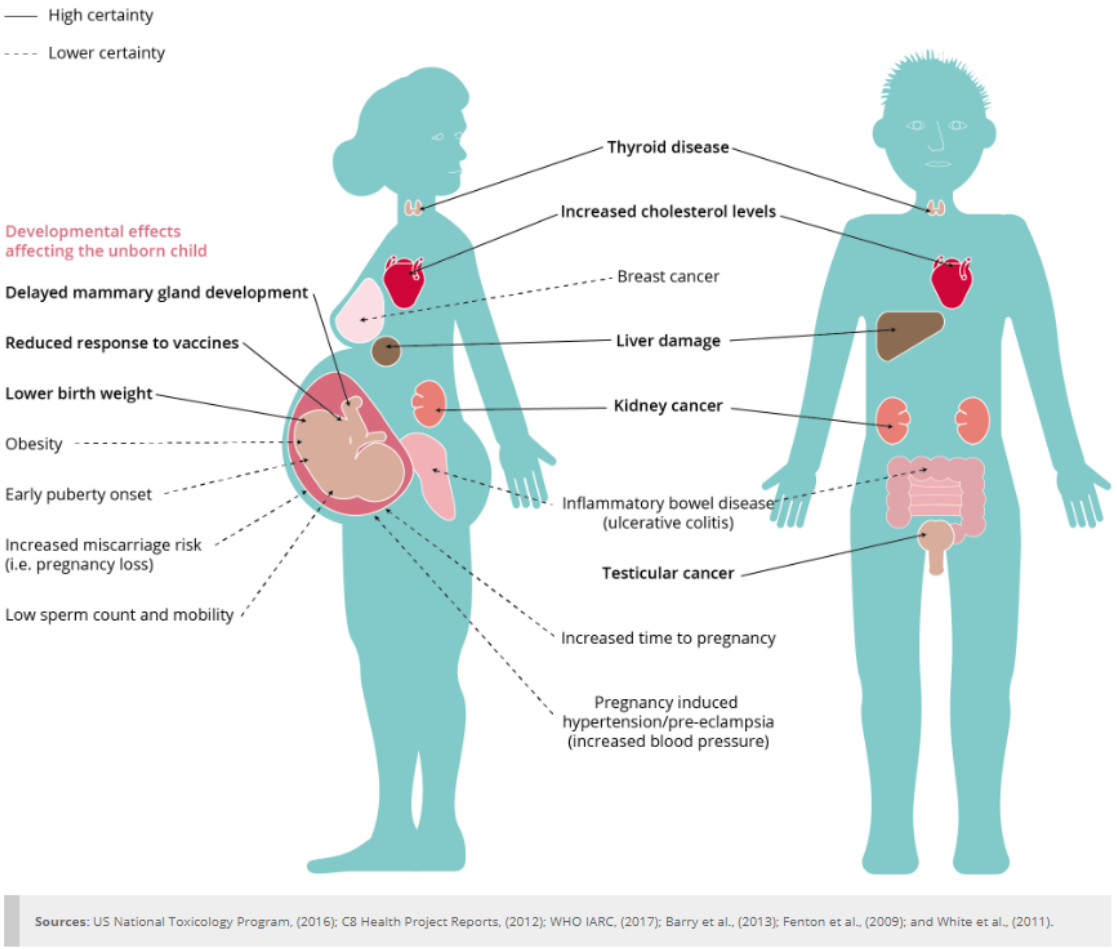
PFAS Life Cycle



Source: https://www.dirtyproperty.com/pfas_2020esls/

Source: https://riversideca.gov/press/understanding-pfas

Effects of PFAS on Human Health



Reference: https://www.eea.europa.eu/publications/emerging-chemical-risks-in-europe/emerging-chemical-risks-in-europe

Measuring PFAS

Method	Media	Analytical Instruments
USEPA 537.1	Drinking Water only	LC/MS/MS
USEPA 533	Drinking Water	LC/MS/MS
USEPA SW-846 Method 3512 / 8327	Surface water, groundwater and wastewater	LC/MS/MS
USEPA Draft Method 1633	Surface water, groundwater, wastewater, landfill leachate, soil, sediment, biosolid and tissue	LC/MS/MS
USEPA Draft Method 1621	Water and wastewater	CIC
USEPA Draft Method 45 (OTM 45)	Air emissions from stationary sources	LC/MS/MS

ULTIVO LC-MS/MS

Measuring PFAS

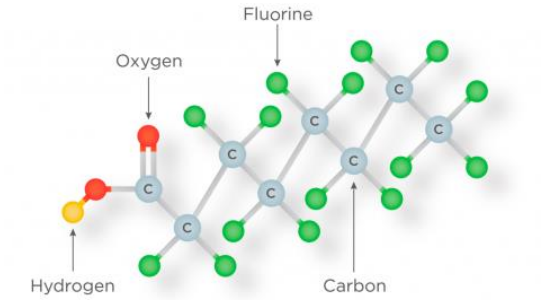
Targeted Analysis

Target LC/MS/MS Analysis

- USEPA 537.1, USEPA 533, USEPA 1633 and OTM 45
- Range of PFAS compounds of interest 18, 25, 40 up to 75 compounds
- Reporting limits sub-low ng/l range and getting lower

Target GC/MS Analysis

- Targeted volatile and neutral PFAS
- Fluorotelomer alcohols



Screening Analysis

Non Target Screening

- LCMS Screen
- High resolution accurate mass (HRAM) LC/TOF or LC -Orbitrap

Total Oxidizable Precursor (TOP) Assay

- Assessment of wide range of PFAS including majority of precursors
- PFAAs, majority of precursors, will convert cationic / zwitterionic PFAS to measurable anionic PFAS
- Excludes ultra shorts, proprionic.

Total Organic Fluorine

- Combustion Ion Chromatography
- Extractable (EOF), adsorbable (AOF), total (TOF)

Particle Induced Gamma-ray Emission (PIGE)

- Primarily US only within academics or small specialist laboratories
- Single measure of Total Organofluorine capturing PFAS which are sorbed to the SPE cartridge

THANK YOU

CONTACT

Dr Ken Scally MSc FRSC
ken.scally@suez.com

Duncan Sanders MSc, C.Geol. SiLC
Duncan.sanders@atg-group.co.uk

suez.com

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Introduction to PFAS Remediation

ChemUK Expo NEC 11th May 2023

Duncan Sanders - Director

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Queens Award 2020

- In April 2020 we won the Queen's Award for Enterprise: Sustainable Development
- This award recognises companies that:
  - Demonstrate strong corporate social responsibility
  - Have achieved outstanding sustainable development for more than 2 years
  - And are able to provide evidence of the benefits & positive outcomes of their actions

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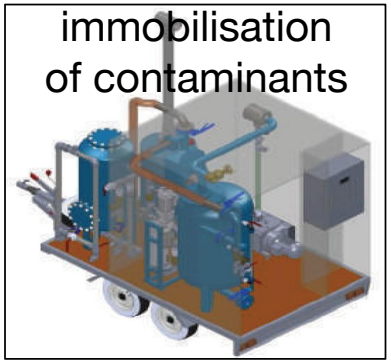
Our Capabilities

Physical Containment Physical immobilisation of contaminants



Groundwater Remediation Remediation of contaminated groundwater

Eraginate® Process - Japanese Knotweed eradication

Chemical Oxidation Fentons reagent

LockedIn® Physio-chemical stabilisation

Bio Remediation In-situ and ex-situ (biopiles)

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PFAS in the Headlines

CHEMISTRY WORLD

RESEARCH

Study finds 55 previously unreported chemicals in pregnant women and newborns

25 MARCH 2021

Two per- and polyfluoroalkyl substances discovered along with 53 other compounds never seen before in the literature

BUSINESS

DuPont and spinoffs reach $4bn settlement to resolve PFAS liability issues

28 JANUARY 2021

DuPont, Chemours and Corteva have also reached an $83mn agreement to settle 95 pending personal injury cases in Ohio related to PFAS

RESEARCH

PFAS exposure found to increase risk of severe Covid-19

12 JANUARY 2021

Warnings that high levels of per- or poly-fluorinated substances might also reduce the effectiveness of a vaccine

The Guardian

UK 'flying blind' on levels of toxic chemicals in tap water

Government is not testing drinking water for PFAS, which studies have linked to numerous health issues

▲ Defra says it takes 'the risks posed by PFAS chemicals very seriously'. Photograph: Nick Ansell/PA

High levels of toxic chemicals found in Cambridgeshire drinking water

Exclusive: Cambridge Water admits supply to homes contained above the legal limit and customers never told

14th March 2023

EPA sets 'groundbreaking' limits on toxic 'forever chemicals' in drinking water

Extraordinary new limits introduced to require municipal utilities to **remove six PFAS** compounds from drinking water

PFAS in the Headlines

US EPA Takes Important Step to Advance PFAS Strategic Roadmap, Requests Public Input and Data to Inform Potential Future Regulations under CERCLA

April 13, 2023

- Advanced Notice of Proposed Rule Making (ANPRM) for making PFOS and PFOA hazardous substances under CERCLA (aka Superfund)
- 60 day consultation period
- 2016-22 **Advisory** levels **70 ppt** PFOS and POA
- Now **legal** limits **4 ppt** each proposed
- As industry phased out some PFAS replacements GenX, PFBS are worse!
- The six to be removed from dw PFOS, PFOA, PFBS, GenX, PFHxs, PFNA

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PFAS in the Headlines

3. PFAS Remediation Technologies

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PFAS Characteristics relevant to Remediation

i) Soluble in water so mobile in groundwater
ii) Very strong carbon to fluorine co-valent bonds – highly resistant to chemical and biological breakdown
iii) hydrophobic tail and anionic hydrophilic head – strong affinity to sorb to reactive media
iv) will desorb from soils at 350-400 ^{0}C and be destroyed by incineration at temperatures above 1200 ^{0}C.
v) chain length and branching, partitioning coefficients, phase behavior, volatility, solubility, acidity, total PFAS mass, and total concentration along with co-contaminants are also important.

Lock up and concentrate not Destroy

Existing technologies, GAC, chemox, bioremediation …. largely ineffective

Sequestration technologies are the way forward- concentrate , lock-in, flocculate, desorb , transfer

Destruction technologies – not there yet – may follow

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PFAS Remediation Technologies

	SOILS	WATER
In SItu	1.Soil stabilisation Locked-In Technology 2. Thermal Resistive Heating	1. Colloidal Activated Carbon (CAC) 2. Permeable Reactive Barrier – Adsorbtion Media
Ex-Situ	1. Soil stabilisation Locked-In Technology 2. Thermal conductive heating 3. Soils washing	1. Pump and treat , Locked-In adsorption media 2. Foam Fractionation 3. Flushing , precipitation and filtration

Locked - In Adsorption Technology

Soils – Locked in stabilisation
Groundwater – Pump and treat and PRBs

GAC

IEX

- GAC very inefficient, expensive and doesn't deal well with short chain PFAS or co-contaminants
- Ion exchange resins – work well but expensive
- PFAS targeting adsorption media now commercially available – much better

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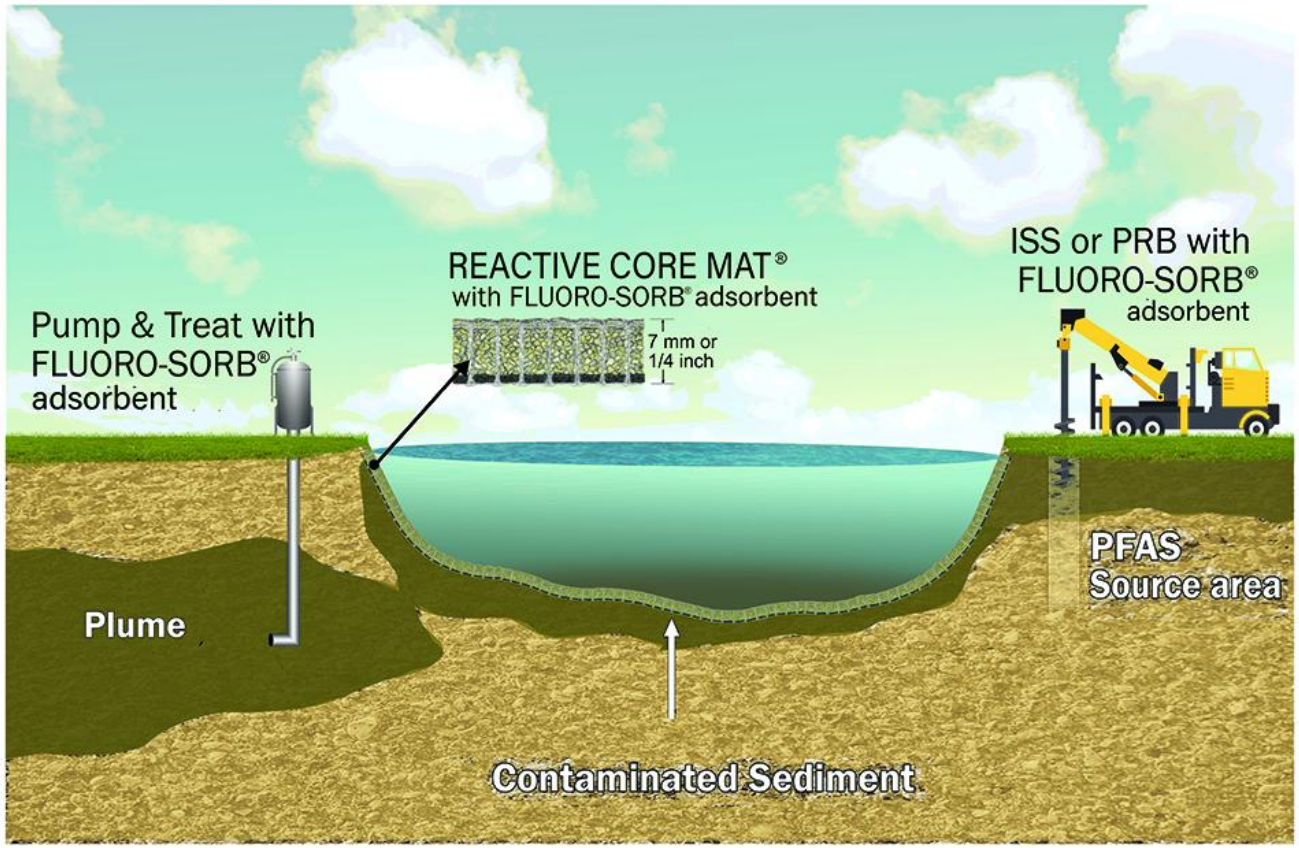
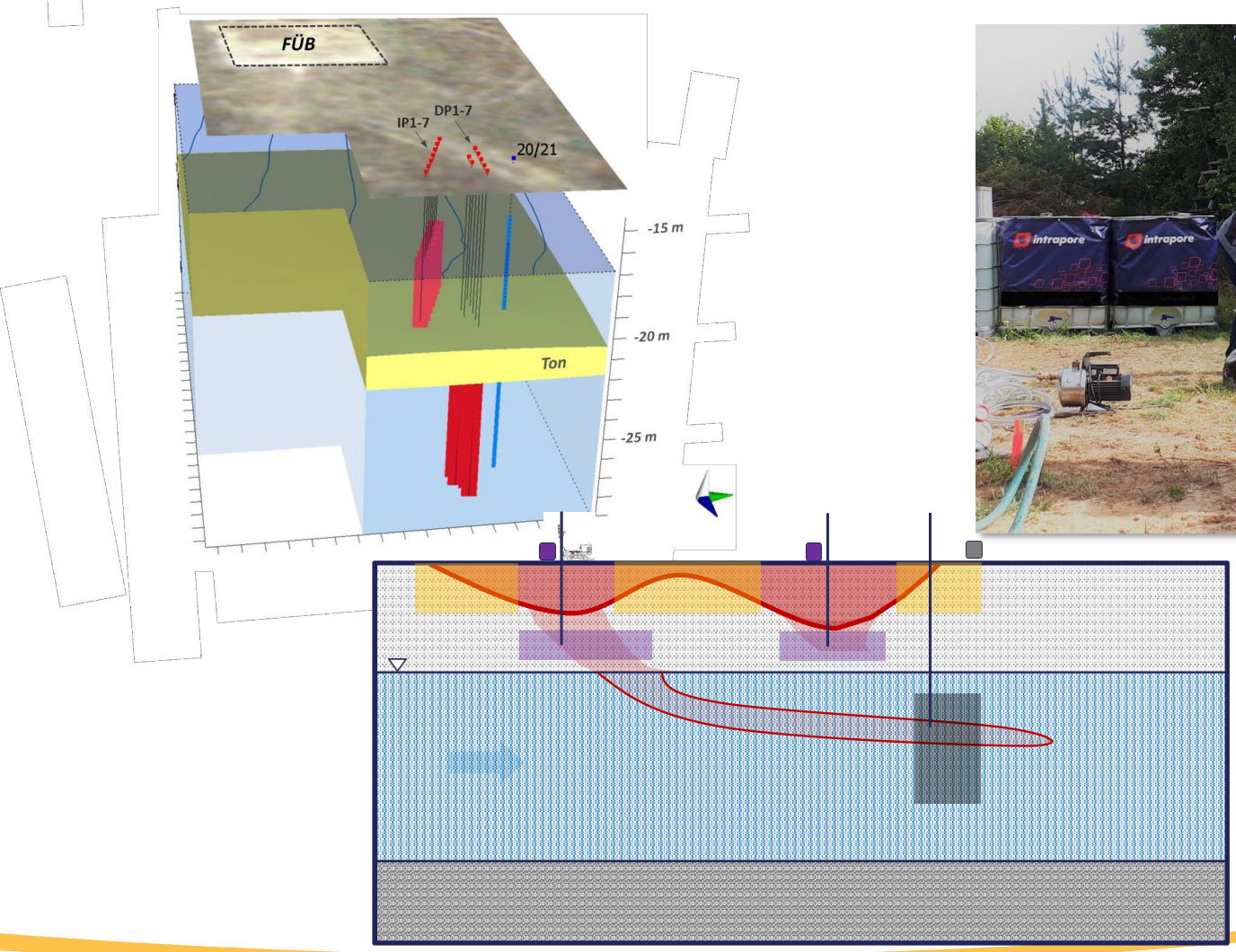
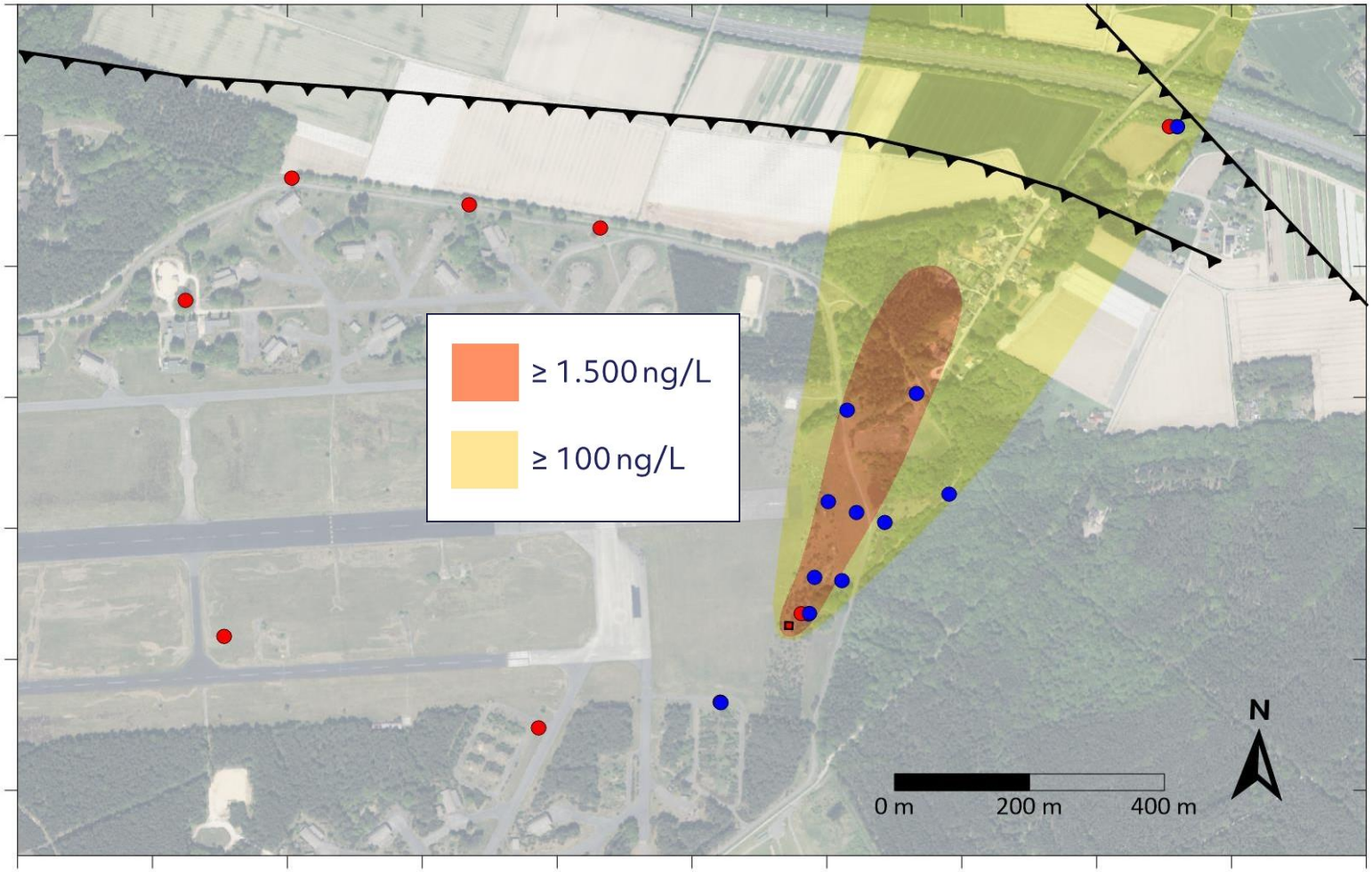
Adsorption Technology



Permeable Reactive Barriers




≥ 1.500 ng/L
≥ 100 ng/L
N
0 m
200 m
400 m

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General Components of a PFAS Remediation Project

1) Source zone excavation/treatment
2) Groundwater pump and treat
3) Permeable reactive barrier

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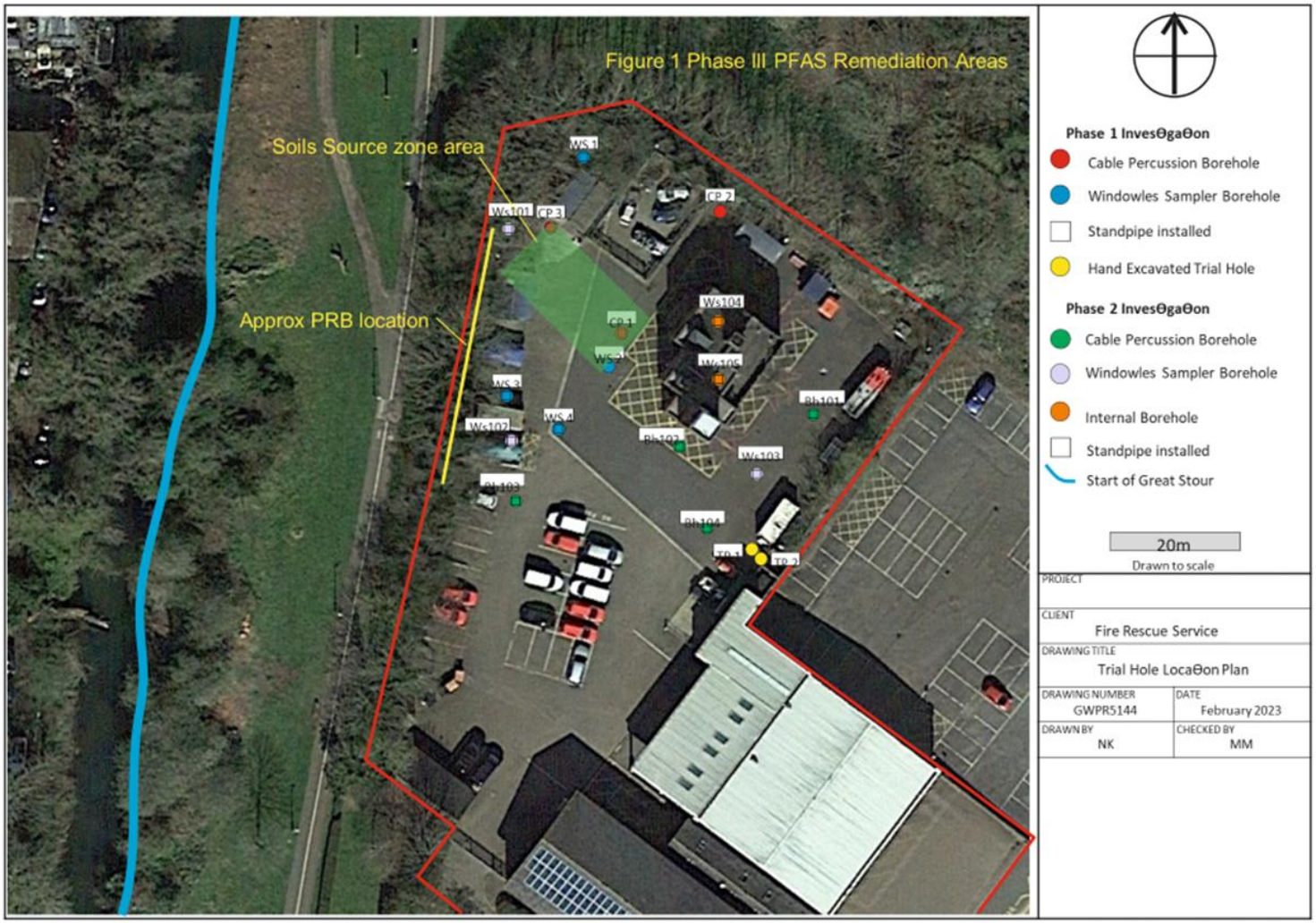
Fire Station Redevelopment South England



Phase 1 InvesƟgaƟon

- Cable Percussion Borehole
- Windowles Sampler Borehole
- Standpipe installed
- Hand Excavated Trial Hole

Phase 2 InvesƟgaƟon

- Cable Percussion Borehole
- Windowles Sampler Borehole
- Internal Borehole
- Standpipe installed
- Start of Great Stour

20m

Drawn to scale

PROJECT	
CLIENT	Fire Rescue Service
DRAWING TITLE	Trial Hole LocaƟon Plan
DRAWING NUMBER	GWPR5144
DATE	February 2023
DRAWN BY	NK
CHECKED BY	MM

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Housing Development NW

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Foam Fractionation Treatment

PFAS	Removal %, Average
PFBA	21%
PFPeA	24%
PFHxA	20%
PFHpA	67%
PFOA	100%
PFNA	100%
PFDA	100%
PFBS	22%
PFHxS	99%
PFOS	100%
6:2 FTS	100%

Turns high flow low concentrations into very low volume high concentration liquors for incineration

100 % (non detect) removal of longer chain PFAS C6 and above , less effective on shorter chains , may require polishing with ‘Locked-in’ media in a treatment train

Assessed against **over 50 million l of treated groundwater**

Research by Research Institute of Sweden (R.I.SE)

Patented sequential foam harvesting and concentration system can produce concentration factors of up to 2 million- back to original PFAS concentration of 1-3 %

0.4-0.7 Kwhr / m3 treated water

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Flushing and Flocculation

- Designed for treatment of relatively smaller volumes of higher concentrated waste waters
- Flushing of tanks pipework , fire suppressant systems – concentration flocculation and destruction
- Firetrucks – 40,000 ppb down to 1.5 ppb – teaming partner UK and Europe

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Thank you for Listening

E: Duncan.sanders@atg-group.co.uk

M: 07841 950632

Questions?