The InSitu Remediation of PFAS-Impacted Groundwater Using Colloidal Activated Carbon

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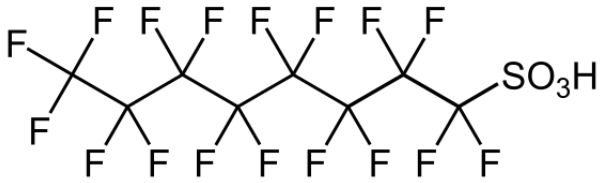
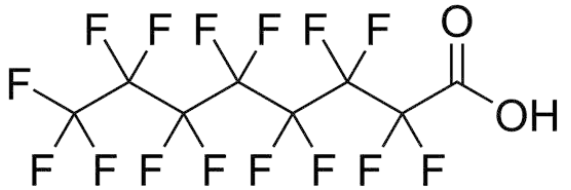
InSitu Remediation Services

RemTech 2018

Background

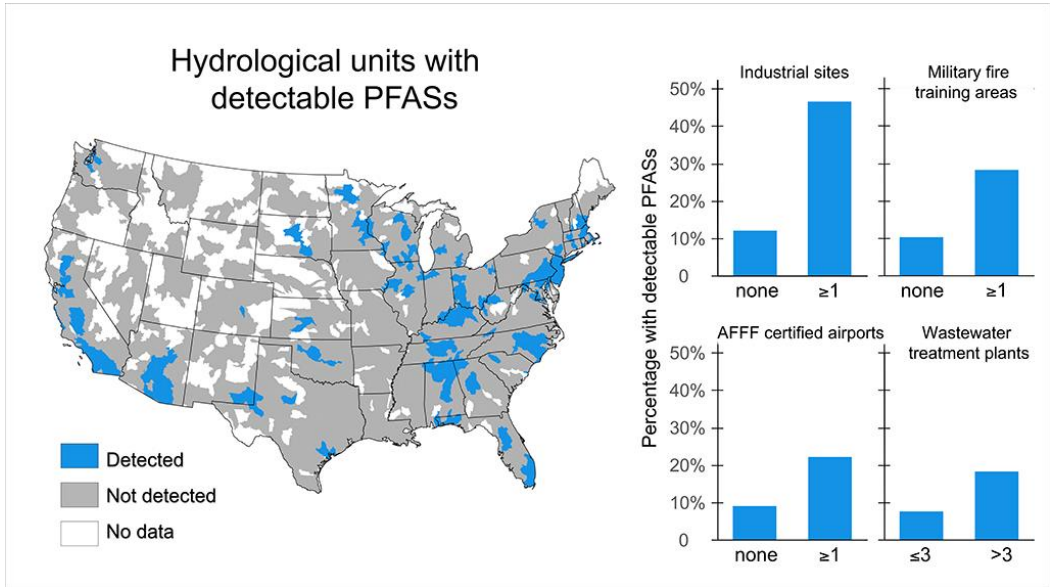
- Per & Polyfluoroalkyl Substances (PFAS)
- Emerging Compounds of Concern
  - Perfluorooctane Sulfonate (PFOS)
  - Perfluorooctanic acid (PFOA)
  - Thousands of compounds
  - Shown to bioaccumulate
  - Analytical challenges
  - Health Advisory Levels 10s of ng/L (ppt)
  - Fate & transport not well understood
    - A. Weber et al. (ES&T, 2017)
    - Anderson et al. (Chemosphere, 2016)
    - Xiao et al. (Water Research, 2015)





Background

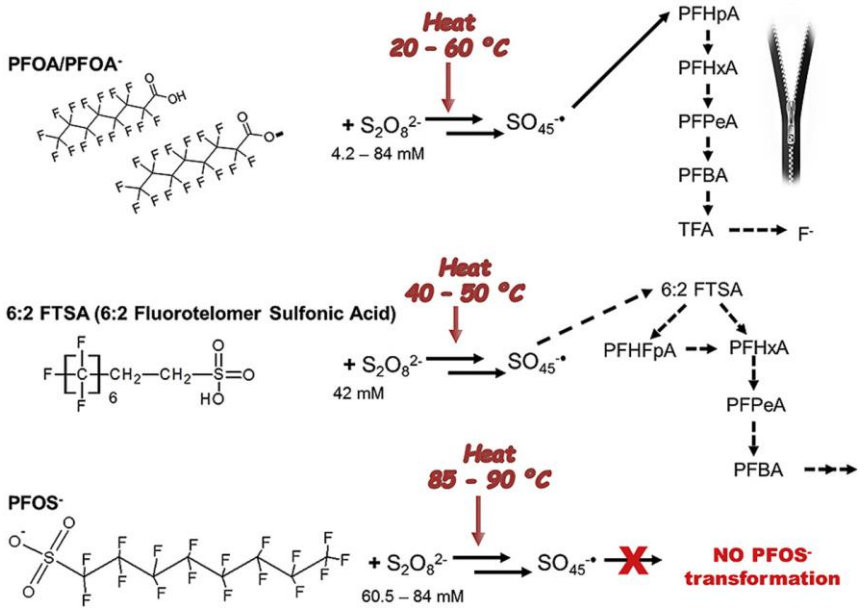
- Perfluorinated Compounds
  - 6 million Americans exposed
  - Reagents for aqueous film forming foam (AFFF)
  - Coating Agents
  - Repellants for fabrics



U.S. EPA (https://www.epa.gov/dwucmr/occurrence-data-unregulated-contaminant-monitoring-rule)

Background

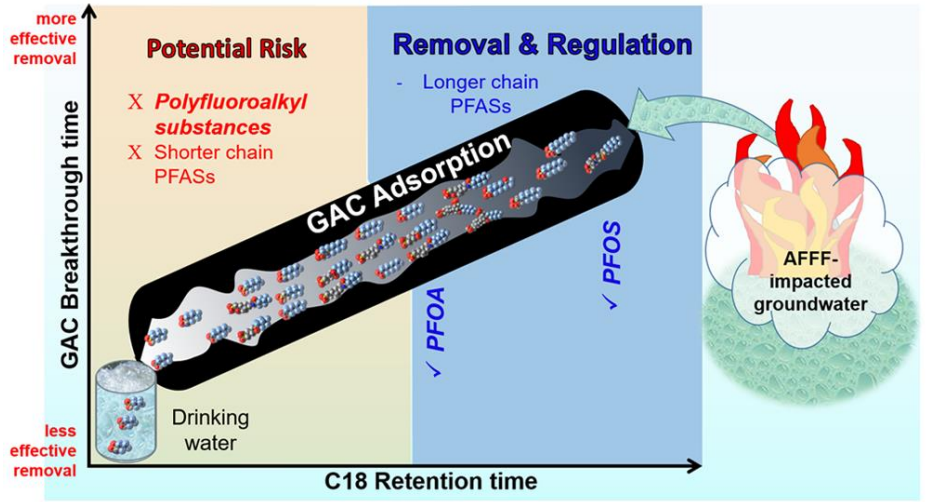
- InSitu Treatment
  - Limited demonstrated options
  - Resistant to chemical oxidation due to C-F bond
  - Low remedial concentrations required
  - Sensitive to back & matrix diffusion
- Lab or Pilot Approaches
  - Chemox
  - Nano Pd/ZVI
  - Activated Persulfate
  - B12
  - Activated Carbon



Park et al., 2015

Background

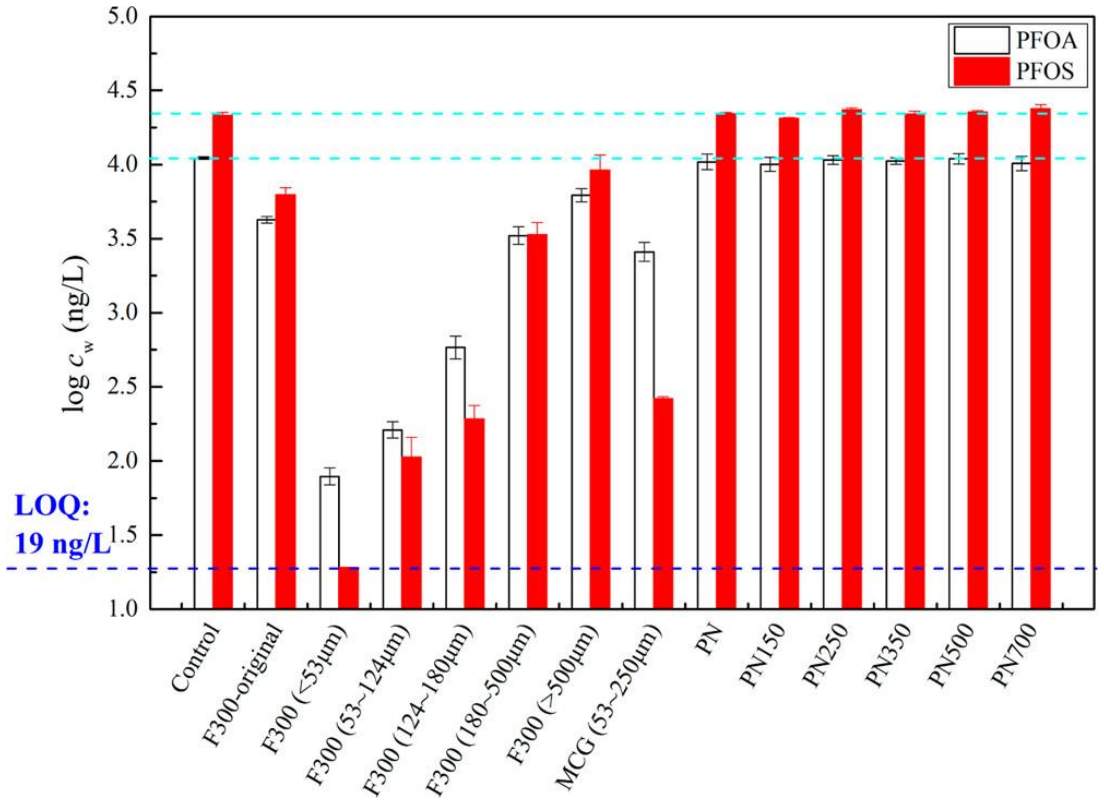
- Activated Carbon
  - Well demonstrated for above ground treatment
  - Limited data on insitu performance
    - Fate & transport not well understood
    - Injectability
    - Distribution
    - Lifespan
      - Capacity differs for various PFAS
      - Competition for sites
      - Destruction vs unavailability
    - Back diffusion

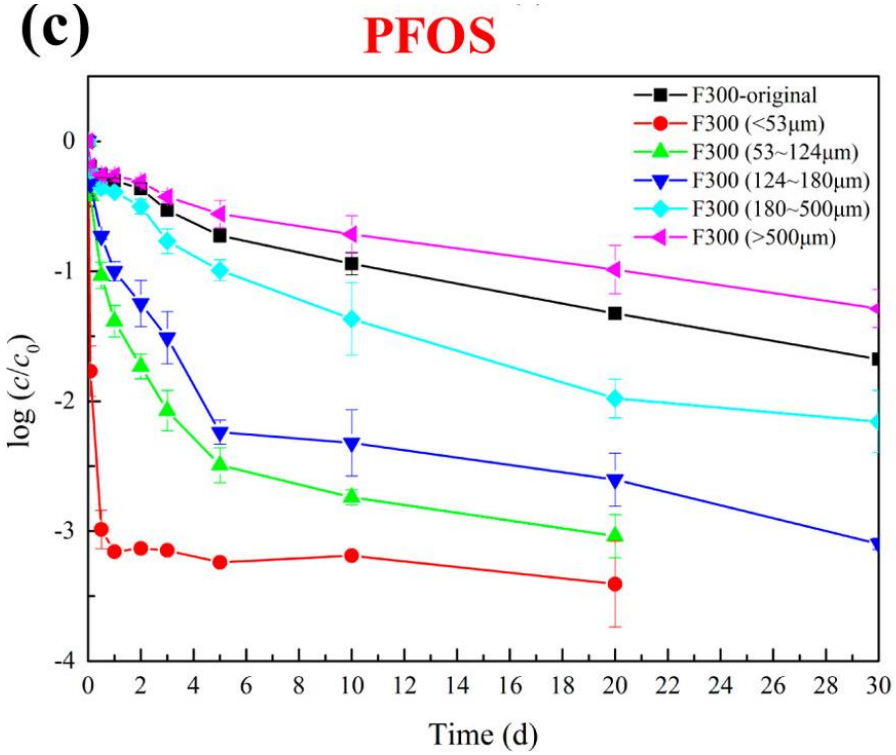


Source: Xiao et ., 2017

Background

- Particle Size
  - In general the smaller the particle size the greater the capacity



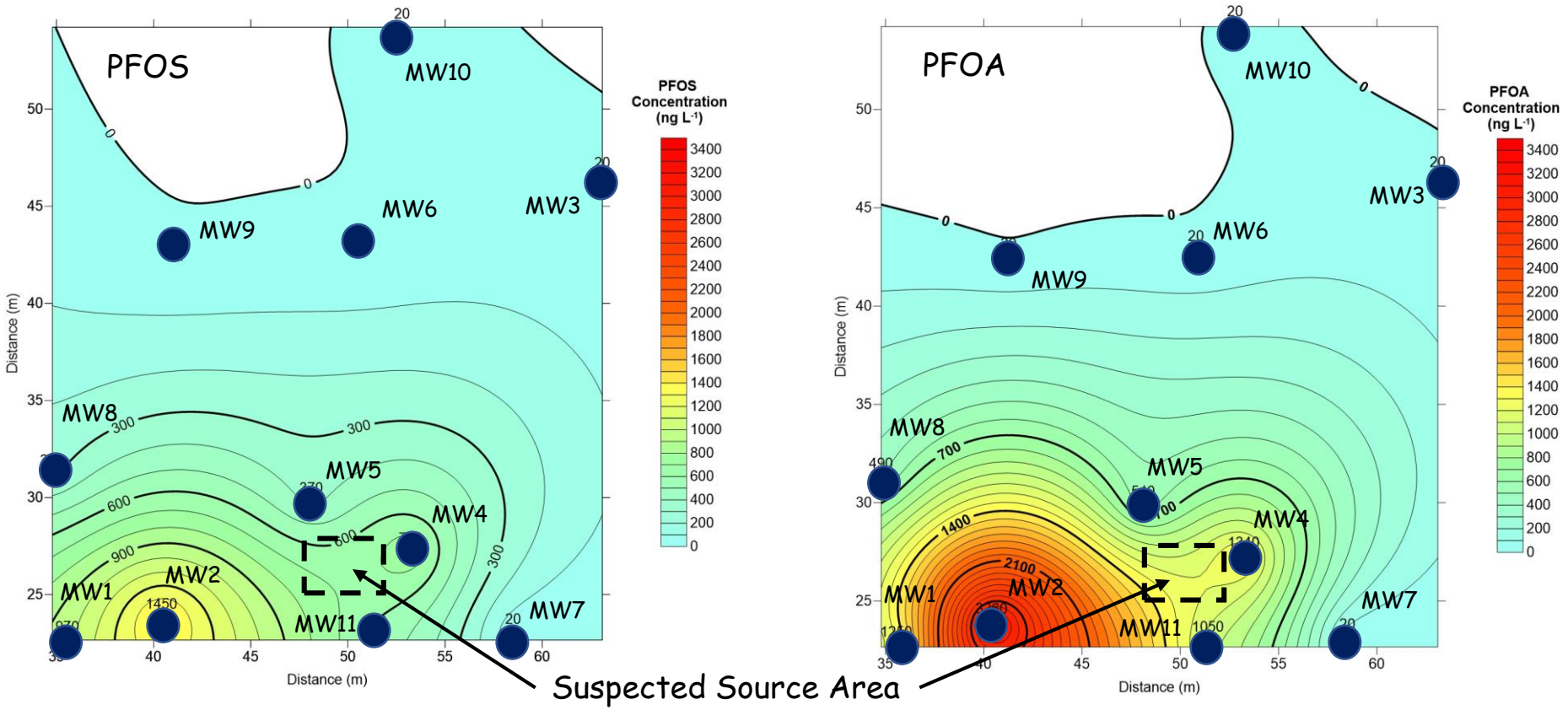


Source: Xiao et al.,2017

Study Site

- Petroleum Hydrocarbon Spill
  - Source excavated
  - Residue PHCs in soil and groundwater
    - BTEX < 300 ug/L
    - F1 < 2,000 ug/L
    - F2 < 3,500 ug/L
  - Mention of site being used as a fire fighting training site and old building used for fabric coating
  - Grabbed groundwater samples for PFOA and PFOS analyses
  - Detected!
    - PFOS up to 1,450 ng/L
    - PFOA up to 3,260 ng/L

Study Site


PFOS
MW10
MW9
MW6
MW3
MW8
MW5
MW4
MW2
MW1
MW11
MW7
PFOS Concentration (ng L-1)
PFOA
PFOA Concentration (ng L-1)
Distance (m)
Suspected Source Area
Groundwater Flow

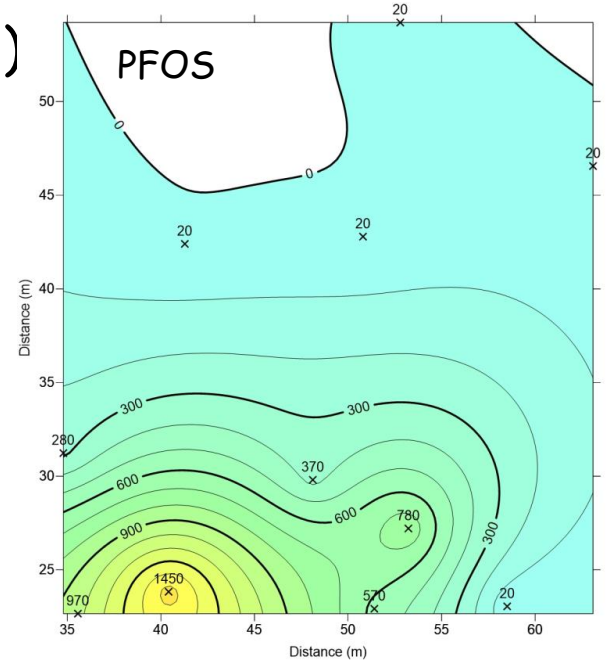
Study Site

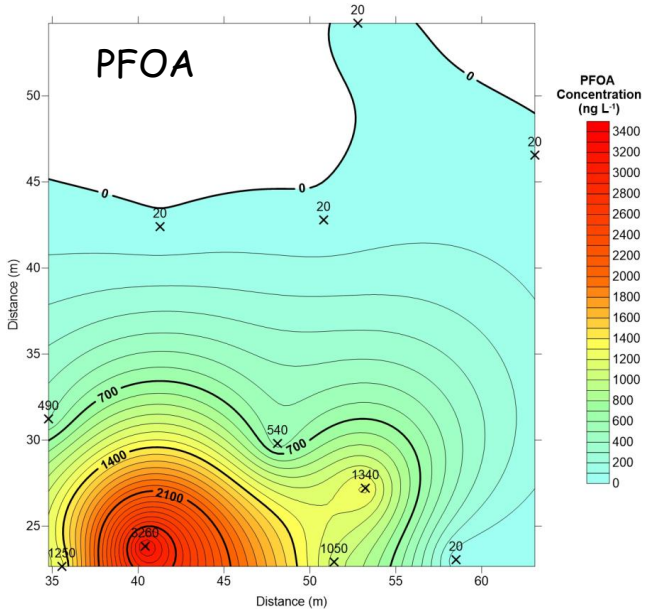
Geology

- Glacial-fluvial deposit
- Sand to silty sand
- Sand lens (less than 0.02 metres thick)

Hydrogeology

- Shallow water table (~1 mbgs)
- Unconfined
- K ~ 2.6 m/day
- i ~ 0.06
- V ~ 0.8 m/day
- Effective porosity ~0.2





Groundwater Flow

Study Site

Geochemistry

- Carbonate-bearing aquifer
  - Alkalinity ~270-400 mg/L as CaCO3
- Reducing
  - Nitrate and oxygen depleted
  - Iron-sulfate reducing
- High chloride concentration
  - ~180 mg/L Cl
  - ~140 mg/L Na

Source

- Excavated
- Calculated mass flux of ~1.8 g/year (G. Carey)

Remedial Review

- Why liquid activated carbon?
  - ~30 sites in Canada
  - Excellent injection "properties"
    - Viscosity and density of water
    - Colloidal (1-2 microns)
    - Surface area ~5,500 m^2
  - Potentially quick
    - One time application
    - Less disruption
  - Cost
    - ~$75,000 CDN

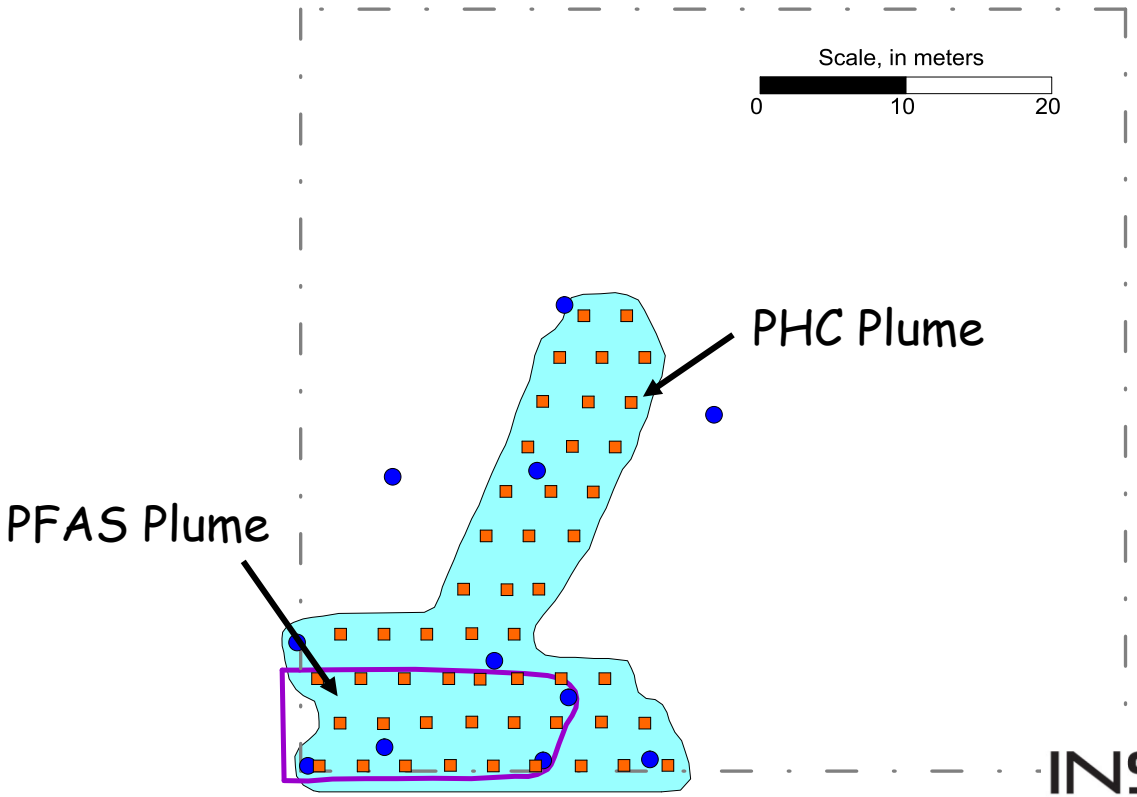
Injection Methodology

- Based on Pore Volume
  - One event
- Direct Push
- Geology Specific Tools
- Multiple Locations
- Multiple Intervals
- Low Pressure
  - <25 psi
- Low Volume
  - ~100 to 200 litres/location

Injection Methodology

- Both Plumes - combination of adsorption-aerobic bio
  - 725 kg of concentrated liquid activated carbon
  - 440 kg of oxygen-releasing material
  - 7,800 litres of water
  - 50 locations

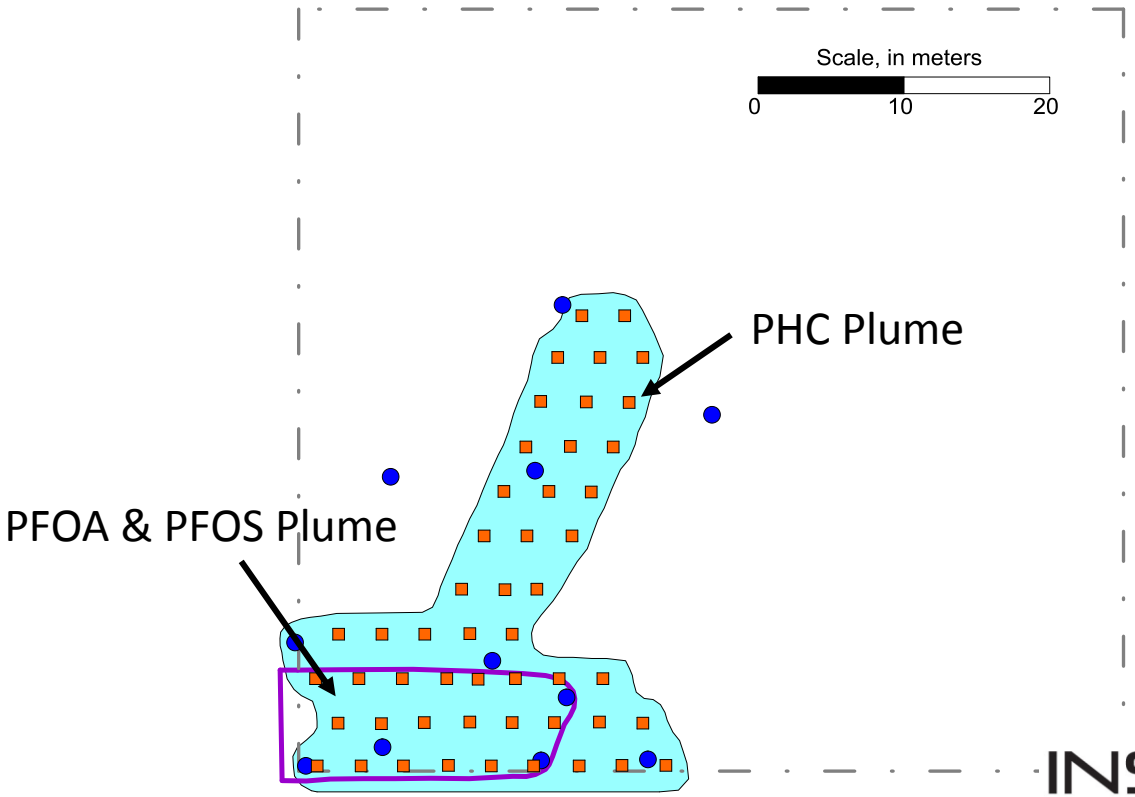
Courtesy: G. Carey



Injection Methodology

- PFAS Plume - combination of adsorption-aerobic bio
  - 290 kg of concentrated liquid activated carbon
  - 176 kg of oxygen-releasing material
  - 3,120 litres of water
  - 20 locations

Courtesy: G. Carey



Results

Evaluation Criteria

- Budget
  - Timing and Budget
- Distribution
  - Target Zone
  - Area of Influence
- Short term results
  - Up to 1 year
- Long term results
  - Post 1 year

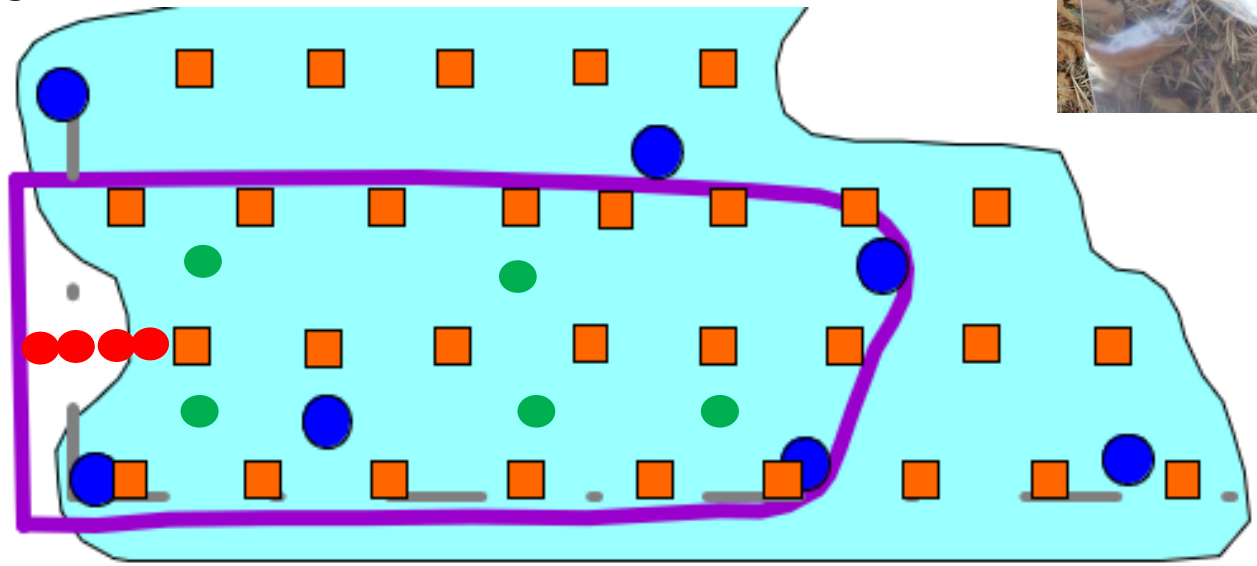
Results

- Budget
  - 50 locations
  - 3 days
    - On time
  - Minimal daylighting
    - Injection ~ 0.8 m below grade
    - Less than 8 litres of solution total
  - Budget
    - $75,000 CDN (~$60,000 US)
    - On budget

Results

Distribution

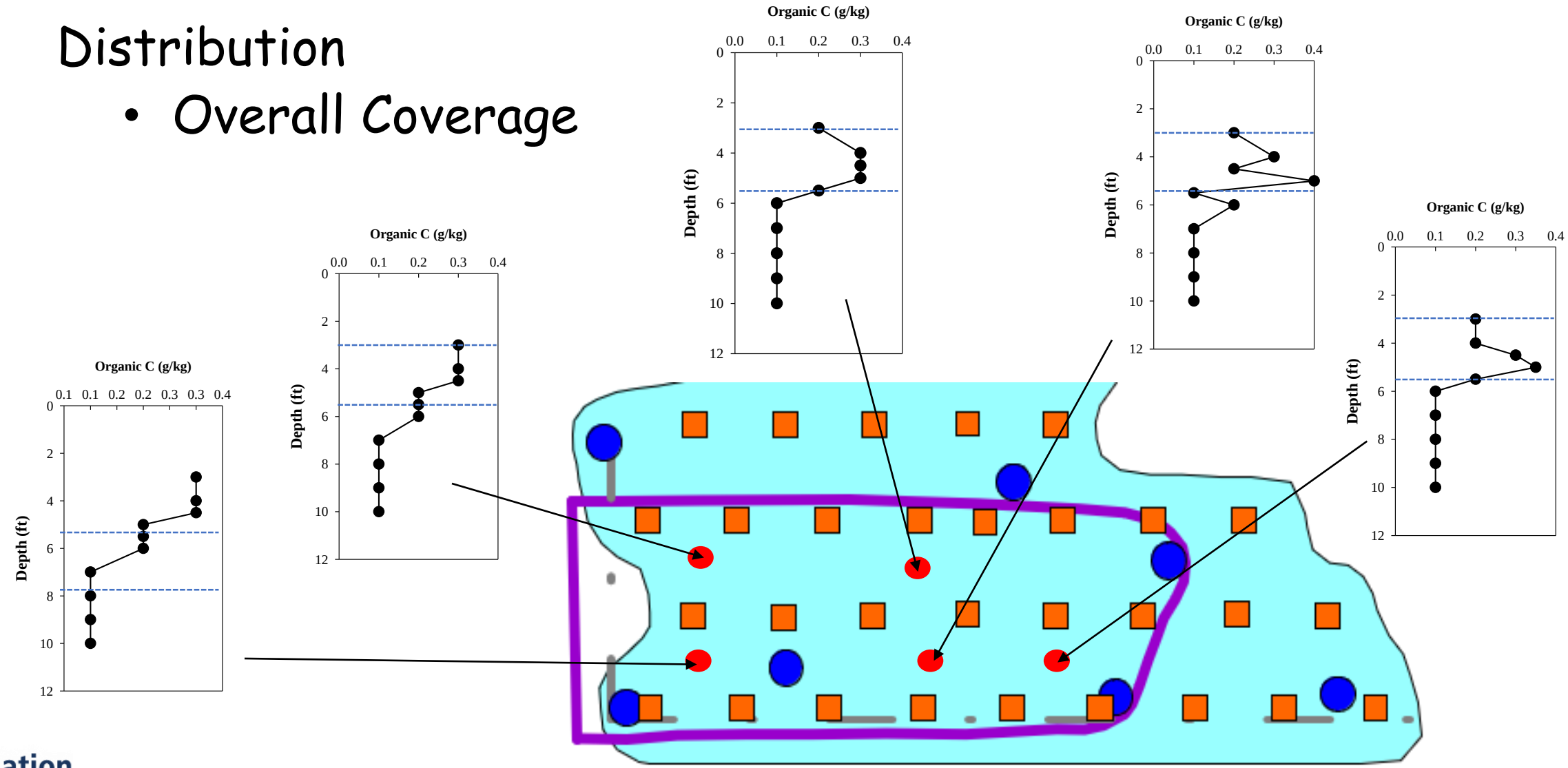
- Observation in wells during injection
- Cores
  - Radius of influence
  - Target zone
  - Overall coverage



Results

Distribution

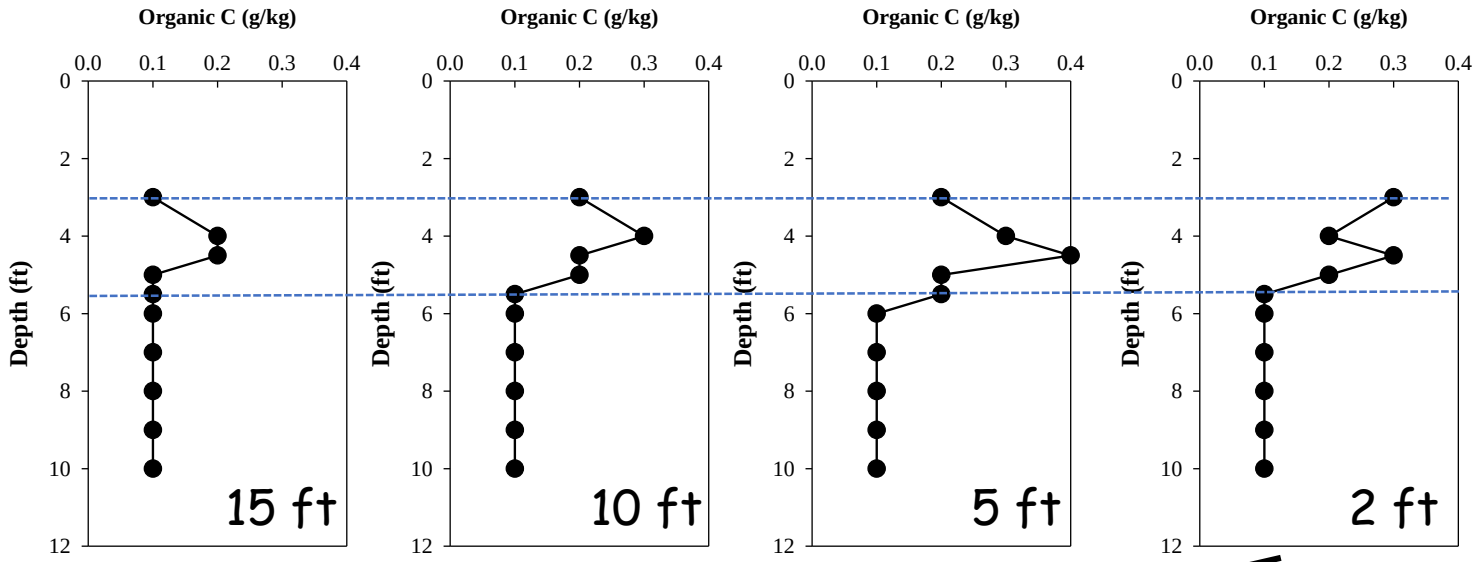
- Overall Coverage

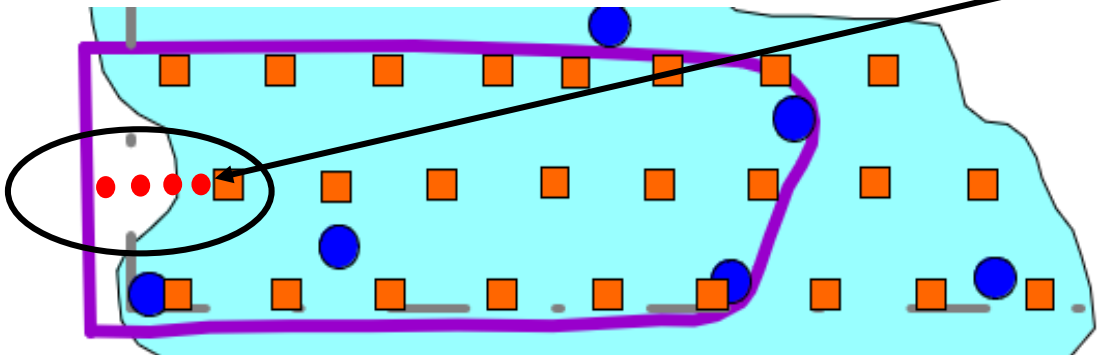


Results

Distribution

- Radius of Influence

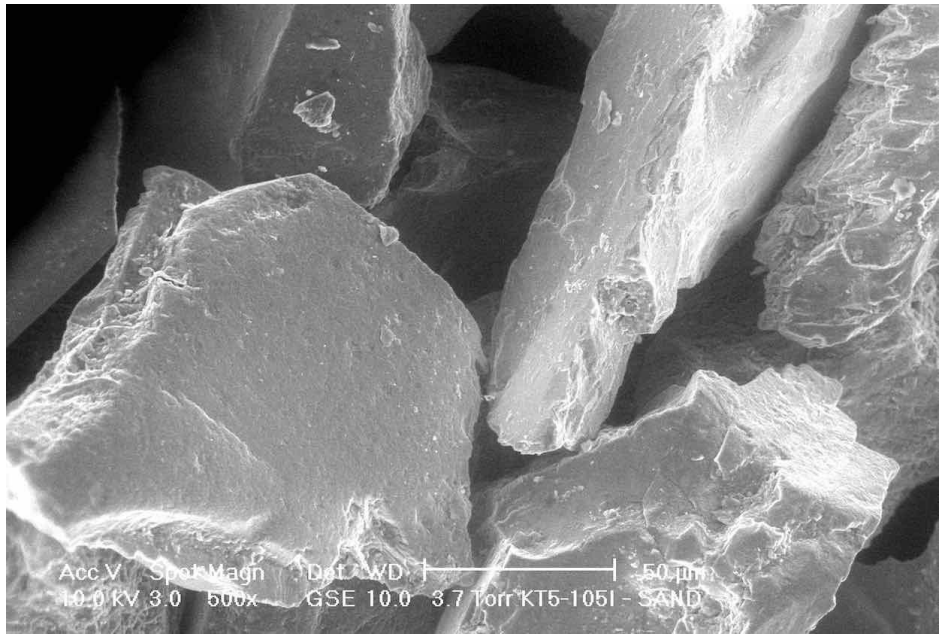




Injection Pt

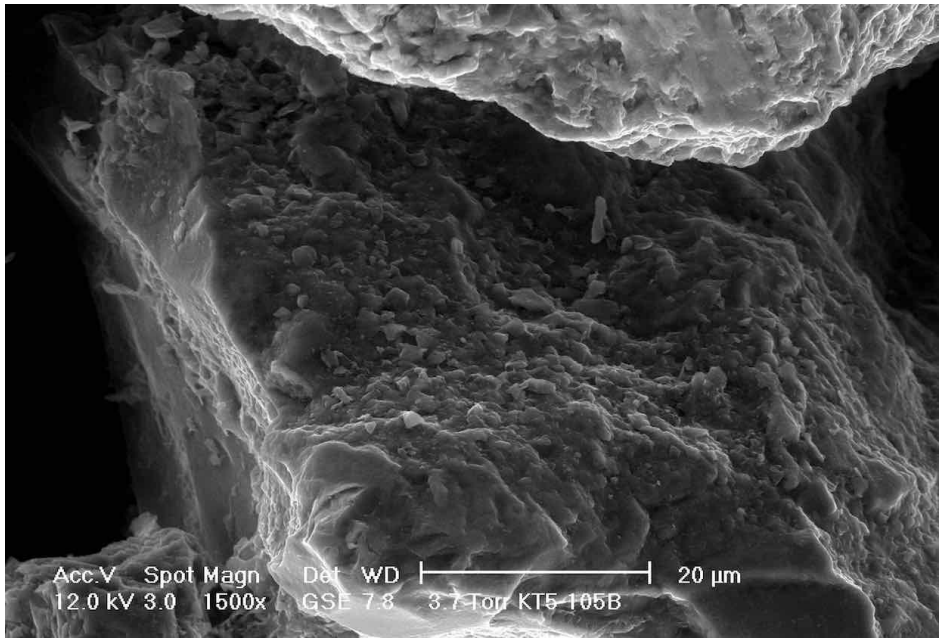
Background

SEM Photography Sand Grain



Courtesy: Regenesis

SEM Photography Sand Grain with PlumeStop

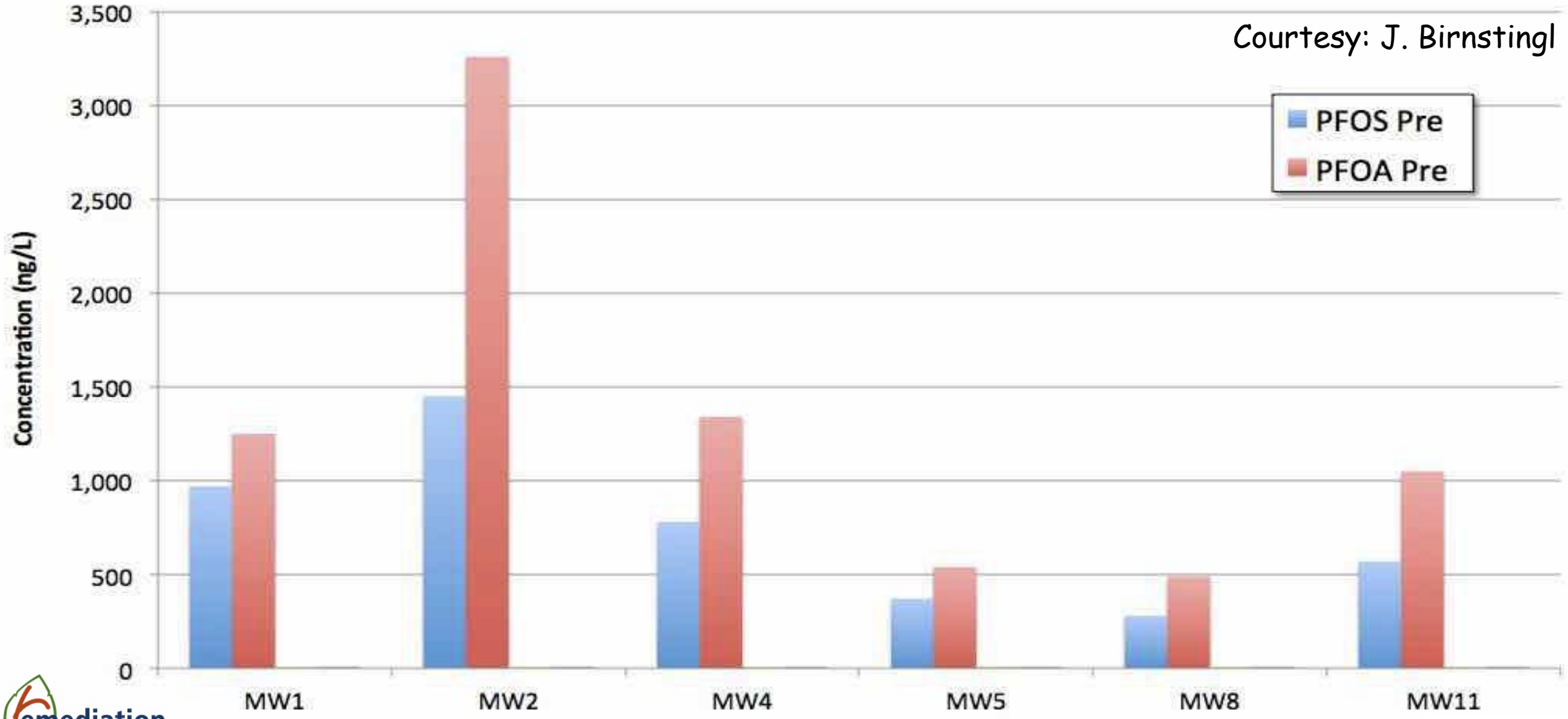


Results

Short and Long Term Chemistry

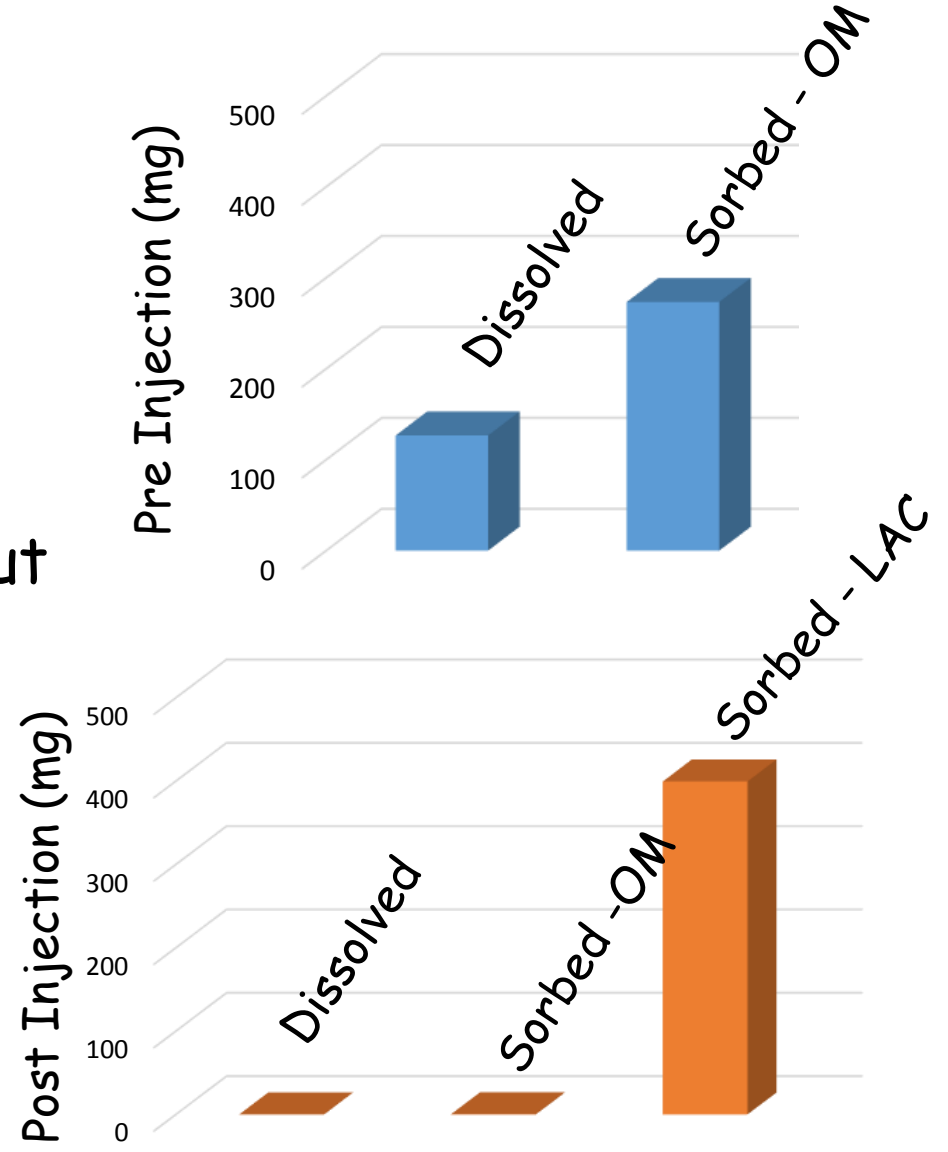
- PFOS & PFOA
  - 3 months
  - 6 months
  - 9 months
  - 12 months
  - 18 months
  - 21 months
- Other PFAS Compounds
  - 18 & 21 months
  - PFBS, PFHxS, PFDS, PFOSA, PFBA, PFPeA, PFHxA, PFHpA, PFNA, PFDA, PFUnA & PFDoA
- Detailed Inorganic Parameters
  - 18 months
- Next Generation Sequencing
  - 18 months

Results – Pre Injection



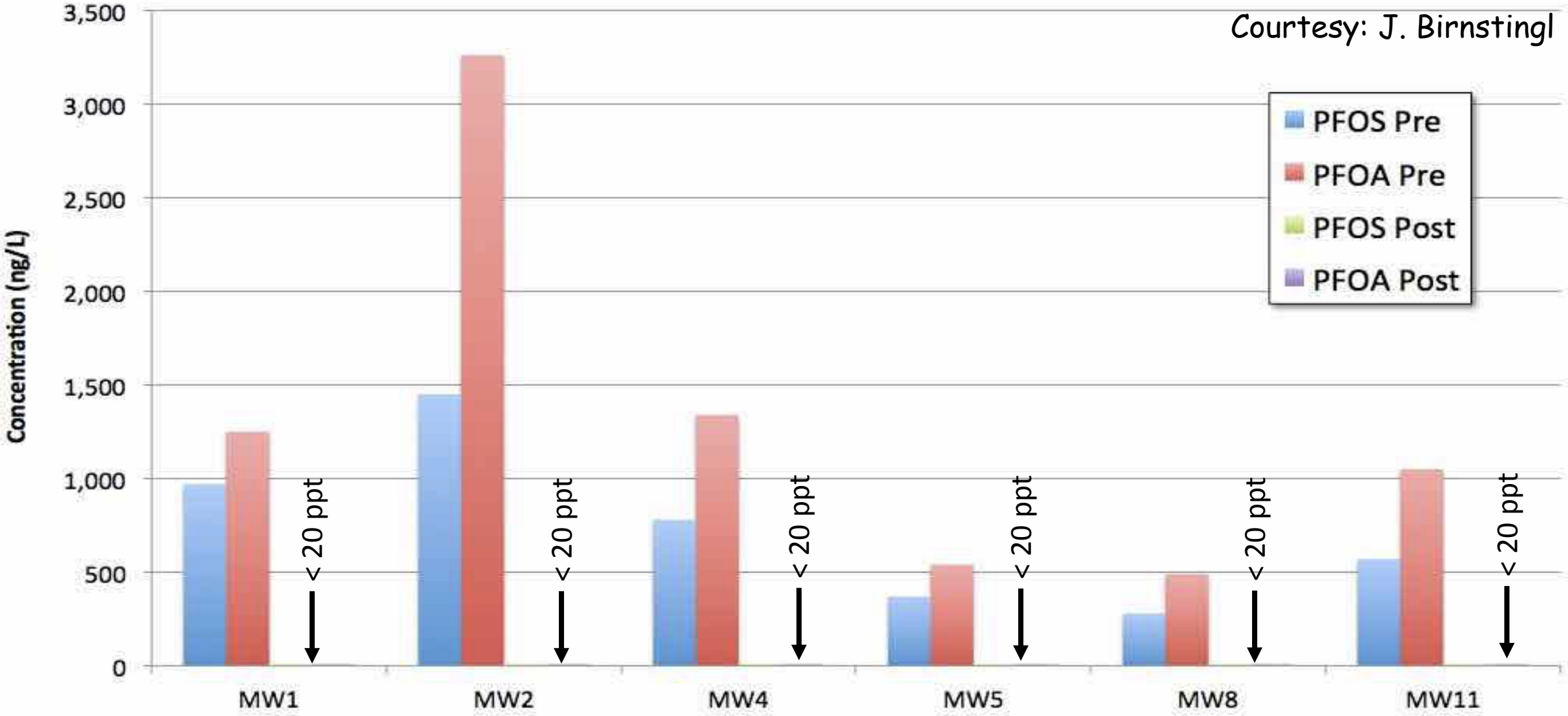
Results

- Short Term Results
  - BTEX and PHC results
    - 3 months
      - Non Detect for BTEX, F1 & F2
    - 12 months
      - Detections for BTEX and F1 but well below the Standards
  - PFOS and PFOA
    - 3, 6, 9 & 12 months
      - Non Detect



Source G. Carey, 2017

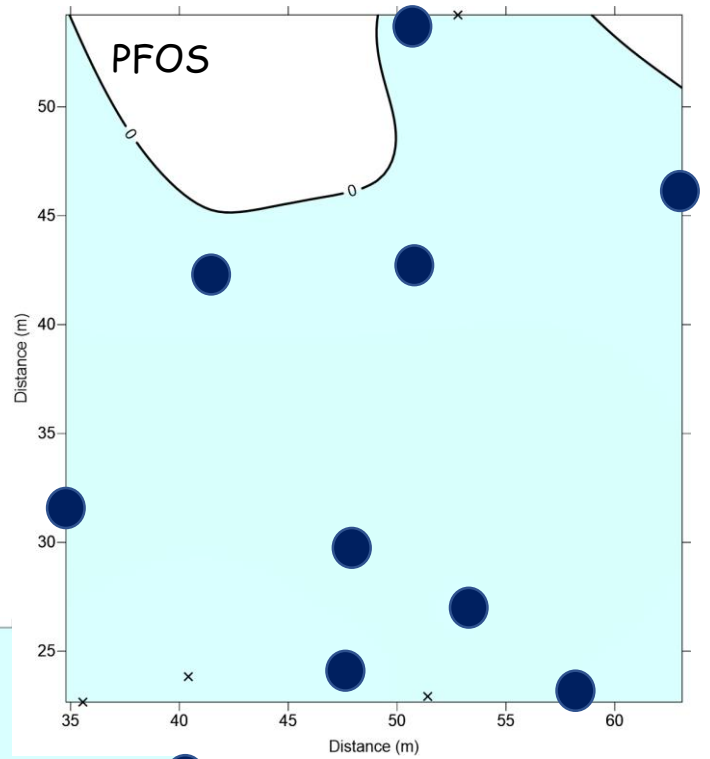
Results – One Year

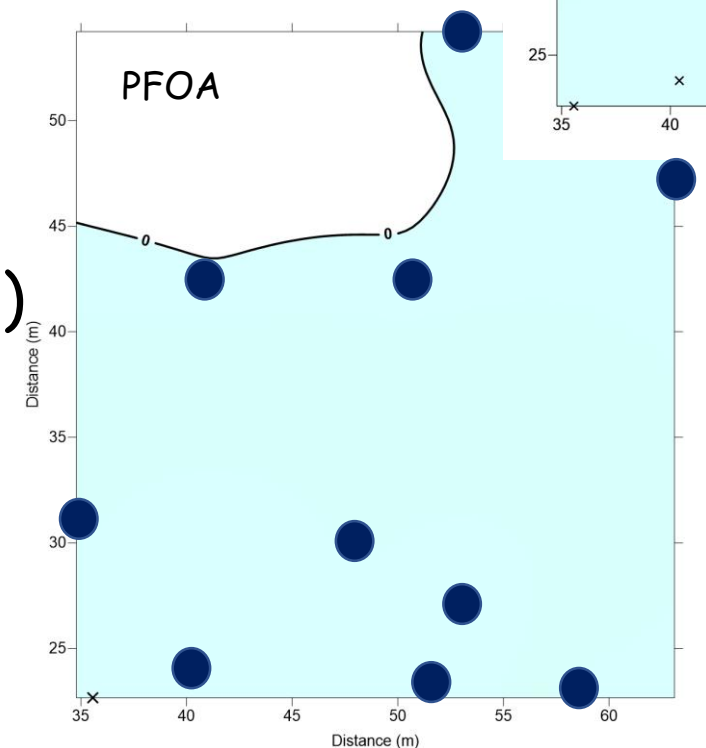


Results

Long Term Results

- BTEX and PHC results
  - 18 & 21 months
    - Detections for BTEX and F1 but well below the Standards
- PFOS and PFOA
  - 18 & 21 months
  - PFOA - ND
  - PFOS – 40 ng/L (18 months)
- Other PFAS
  - All ND except PFUnA
    - 20 ng/L (18 months)





Preliminary Conclusions

- Liquid activated carbon
  - Effective over the short term for removal of PFOS, PFOA and other PFAS
  - Adsorbed, not destroyed
  - Long term monitoring required for:
    - Partitioning
      - Does it stay on LAC?
      - Modelling (Dr Carey) of longterm behaviour
    - Biodegradation PFAS on/near LAC
      - Does it degrade?

PFAS Remediation Research Group

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