Characterization and Modeling of Per- and Polyfluoroalkyl Substances (PFAS) Leaching in a Vadose Zone Source Area

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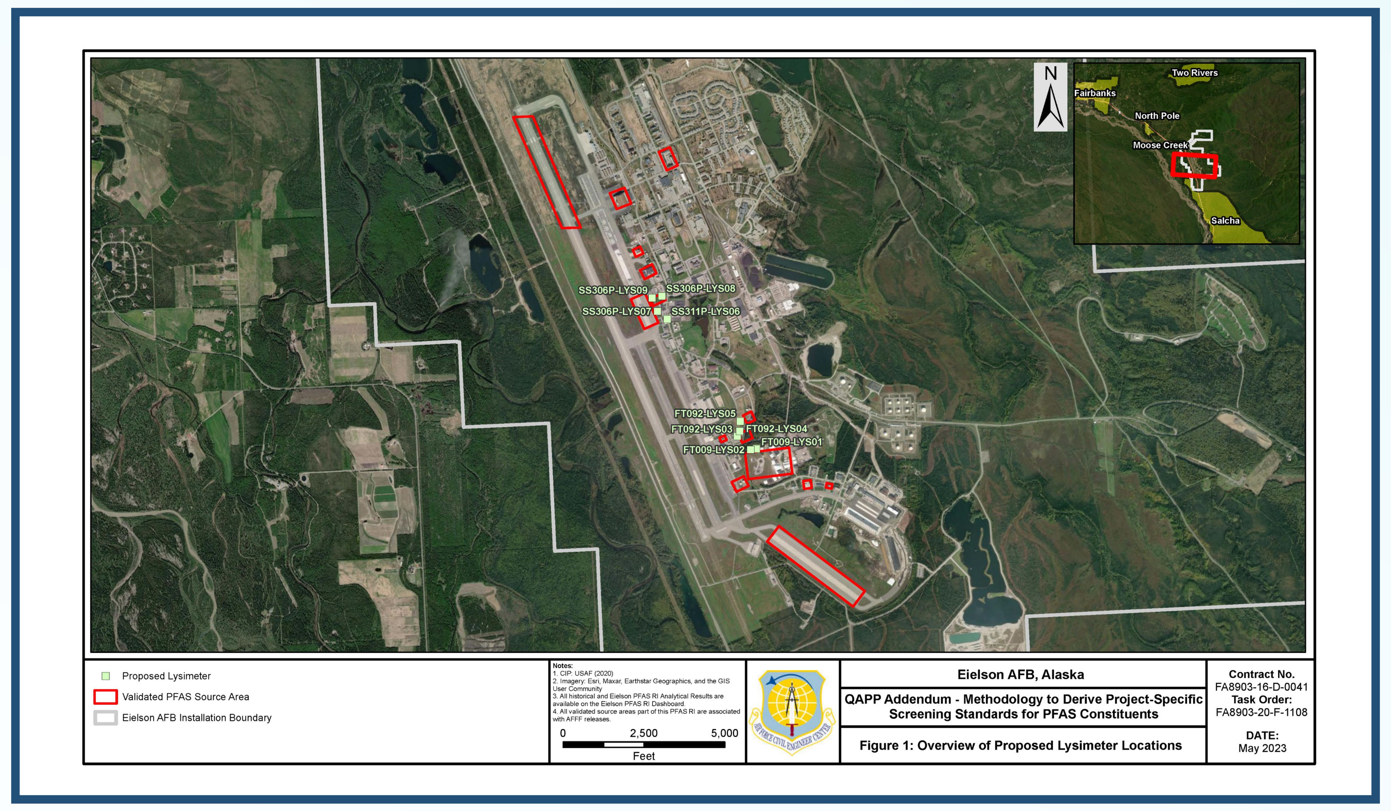
Introduction

This ongoing study evaluates the factors and processes that mediate PFAS mass discharge to groundwater at an aqueous film-forming foam (AFFF) impacted military installation in subarctic Alaska. The project combines field sampling of soil and porewater PFAS concentrations, detailed characterization of soil hydraulic, physical, and geochemical properties, and high-resolution mathematical modeling.

Key site characteristics:

- shallow depth to water (6 to 10 feet)
- semi-arid (average of 13 inches annual precipitation)
- below freezing temperatures from October to March
- sandy loam and silt loam (NRCS) or silty sand (USCS)



Nine sampling locations with up to three lysimeters each were selected within multiple source areas to represent the range of PFAS concentrations and soil types across the site.

Objectives and Approach

The objectives of this study are to:

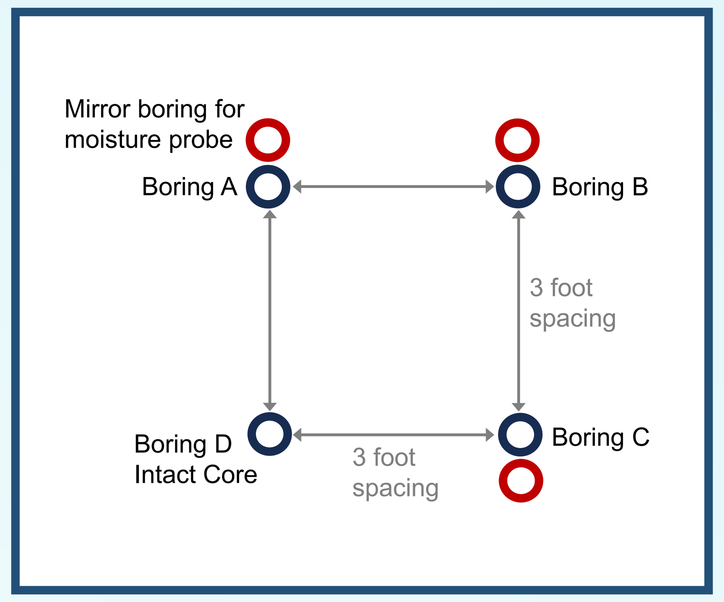
- quantify site-specific PFAS retention, leaching, and mass discharge
- identify the critical factors and processes mediating PFAS retention, leaching, and mass discharge

We use an integrated approach comprising:

- soil and porewater sampling for PFAS analysis
- soil moisture probes to monitor in-situ water content
- detailed hydraulic, physical, and geochemical soil characterization
- bench-scale sorption and leaching tests
- mathematical modeling simulations

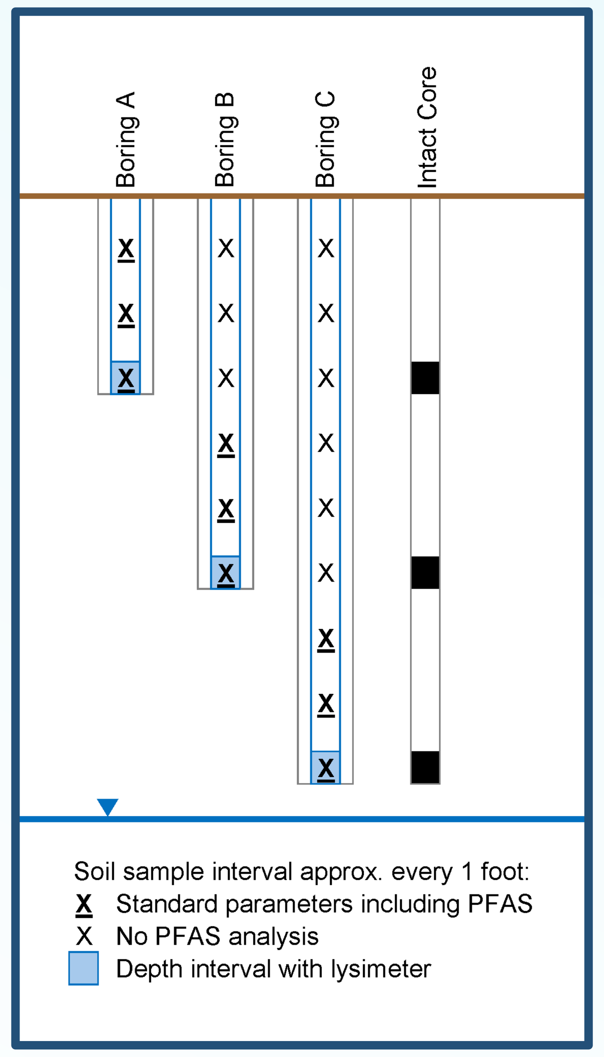
Field Methods

Lysimeters were installed in May 2023 and sampled four times during the summer season.

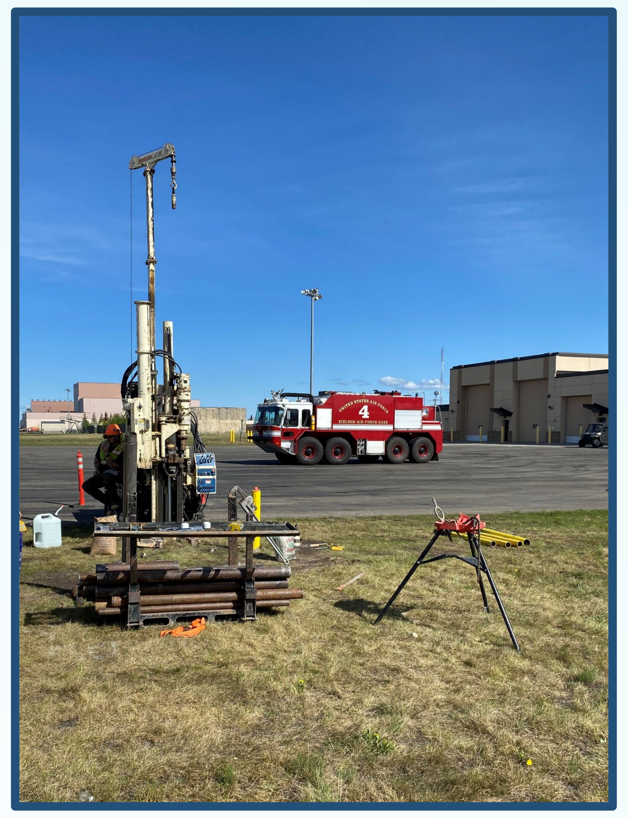


Plan view showing up to three lysimeters and in-situ soil moisture probes per location

Example soil core and stainless steel lysimeter



Cross section schematic of lysimeters and soil borings



Direct push drilling near the runway ramp and fire station

Laboratory and Modeling Effort

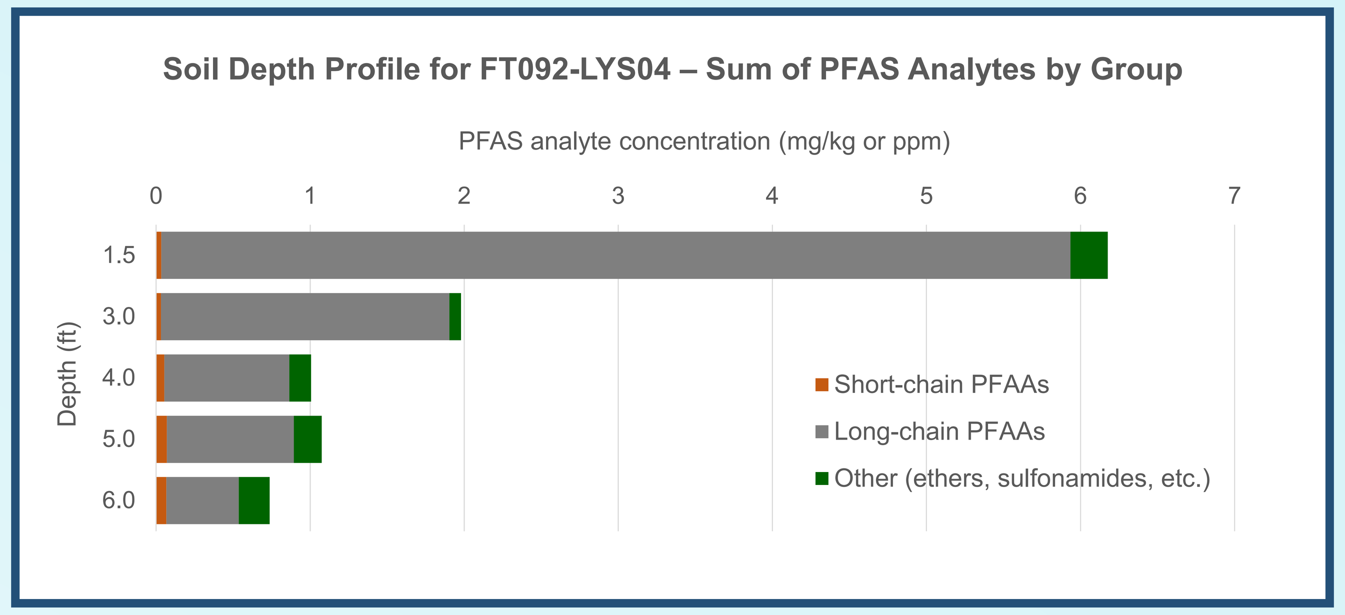
The soil and field-collected datasets are being used to parameterize and validate a suite of tiered mathematical models that incorporate PFAS-specific retention and transport properties.

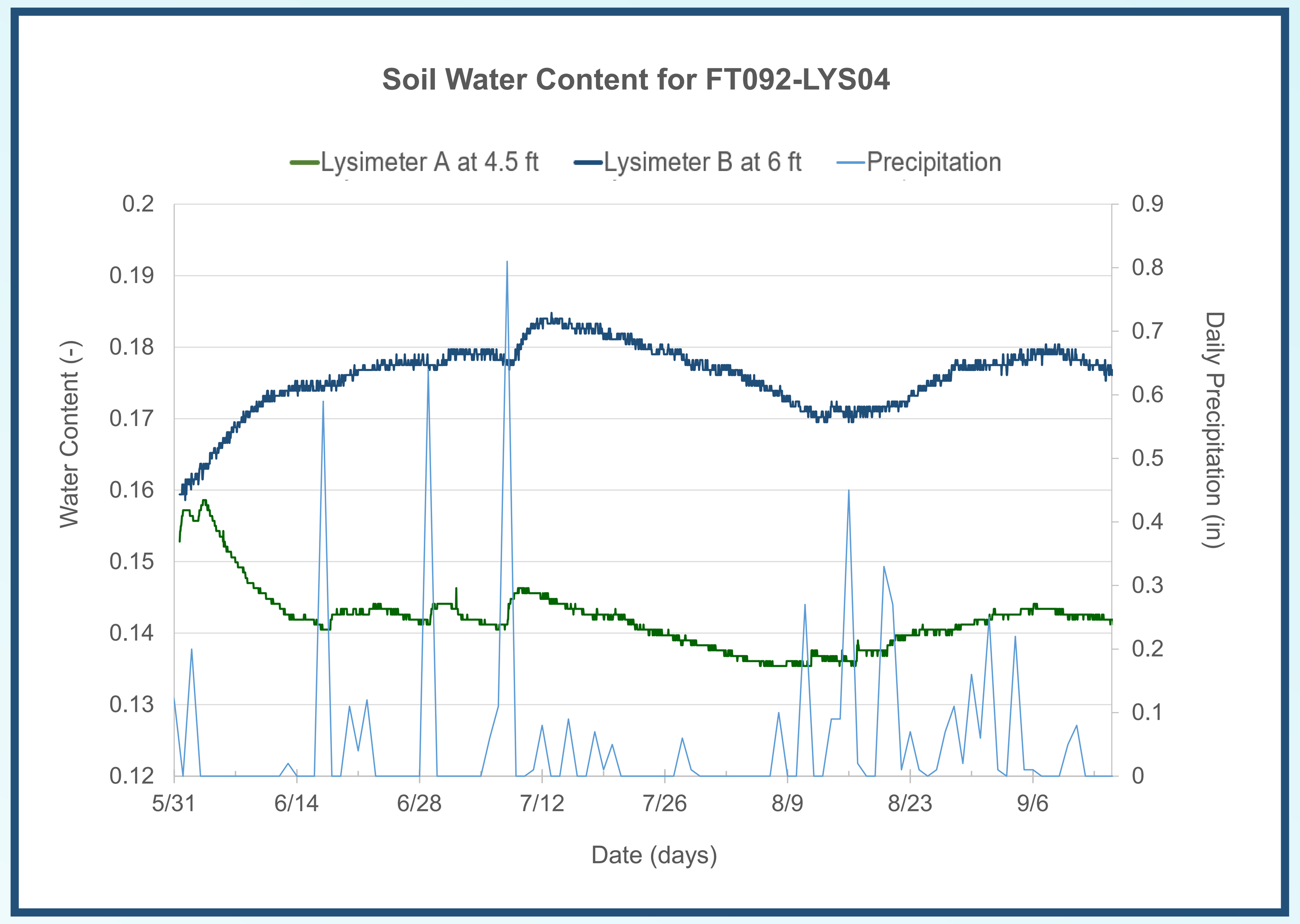
Soil characterization:

- PFAS
- Moisture
- Soil texture/particle size
- pH
- Cation exchange capacity (CEC)
- Anion exchange capacity (AEC)
- Electrical conductivity (EC)
- Organic carbon
- Total carbon
- Porosity
- Hydraulic conductivity (K_{sat})
- Soil water characteristic curve
- Solid surface area
- Metal oxides
- Clay mineralogy
- Air-water interfacial area (A_{aw}) and adsorption coefficient (K_{aw})
- Sorption coefficient (K_d)

Porewater characterization:

- Conductivity
- Total dissolved solids
- pH
- Oxidation-reduction potential
- Dissolved anions (e.g. SO_4^{2-}, NO^{3-})
- Dissolved cations (e.g. Na^+, Ca^{2+}, Mg^{2+}, K^+, Mn^{2+})
- Dissolved carbon





Ongoing and future work includes:

- tiered modeling framework ranging from a simple dilution-attenuation model to a comprehensive 3D PFAS-specific model accounting for transient and nonlinear flow and transport processes