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Practical and Risk-Based Management of Potential PFAS Contamination for Your Project

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Abstract: PFASs (per- and polyfluoroalkyl substances) are a group of more than 12,000 man-made chemicals used in industrial, commercial, and consumer products since the 1940s. Their unique chemical structure resists degradation and they are often referred to as "forever chemicals" because of how long they persist in the environment. PFASs are also known to accumulate in human tissue. Exposure to certain PFAS at very low concentrations can cause kidney and testicular cancer, hormone disruption, and liver and thyroid diseases. Based on our experience managing PFAS impacted soil and groundwater at geotechnical construction vertical (structures) and horizontal (infrastructure and roads) projects, we present case studies to describe the current federal and state regulatory landscape for this group of emerging contaminants. This paper will provide a summary of basic sampling, testing, and risk-assessment approaches as well as solutions for cost effective treatment and acceptable disposal options.

Key words: PFAS, AFFF (aqueous fire-fighting foam), groundwater contamination, soil contamination.

1. Introduction

PFAS (per- and polyfluoroalkyl substance) impacted soil, groundwater, and sediments are most commonly associated with facilities that manufacture these compounds as well as at fire-response training centers that use AFFFs (aqueous fire-fighting foams), airports, and military installations [1]. PFASs are also associated with a number of other industries or products that include wastewater treatment plants, biosolid management areas, landfills, adhesives, building/construction materials, coatings, metal finishes, even some environmental sampling equipment (i.e., protective equipment, Teflon™ tubing and bailers) and refrigerants [2].

Geotechnical site investigations for all types of construction projects can become more labor intensive and costly because of the occurrence of PFAS in soil, groundwater, and sediments due to testing and handling requirements of these contaminated materials. Educating owners and accurately estimating the financial and scheduling impact on projects can be difficult due to the continuously changing regulatory environment. Analytical test methods are continuing to evolve as the list of quantifiable PFAS analytes continues to grow. PFAS impacts on human health are also continuing to change resulting in lower allowable concentrations for residual contamination in soil. Also in flux are PFAS impacted soil disposal regulations, changes to dewatering permits for managing PFAS impacted groundwater, and even disposal of investigative derived wastes.

There are multiple state, federal and organizational-based guidance documents and Standard Operating Procedures that detail the proper field sampling, laboratory testing, risk assessment approaches, storage, transportation, treatment, and disposal options for PFAS and PFAS-containing media. Many states have set allowable PFAS limits for water, soil, and other media; however, several states do not yet have regulatory-based limits and guidance for handling of

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PFAS-containing material. In these cases, USEPA (U.S. Environmental Protection Agency) RSLs (Regional Screening Levels) or disposal facility permitting requirements are the driving factors.

In 2021 the EPA [3] published a roadmap covering its comprehensive approach to addressing PFAS. This includes a set of key actions, including regulatory initiatives. In 2022 USEPA [4] published their first-year progress report. The following paragraphs summarize the main initiatives related to infrastructure projects.

Since May 2022, USEPA [5] published and periodically updates RSLs for a range PFAS. These include conservative, risk-based levels for potential exposure to PFAS in soil, tap water, and the leaching of PFAS in soil to groundwater. RSLs are not enforceable "standards"; however, they are commonly used during the initial stages of federal, state, or tribal investigation at sites with PFAS-containing media. Typically, if the highest PFAS concentration is below the RSL, then further investigation is not warranted.

On September 6, 2022, USEPA [6] proposed to list PFOA (perfluorooctanoic acid) and PFOS (perfluorooctane sulfonic acid) as hazardous substances under the federal Superfund Act. If PFOA and PFOS are designated as hazardous substances by the EPA, this would require owners or operators of sites that release one pound or more of PFOA/PFOS in a 24-h period to immediately notify the Natural Response Center, SERC (State Emergency Response Commission), and LEPC (Local Emergency Planning Committee). USEPA is considering a petition to designate PFOA/PFOS as hazardous waste. If this occurs, the treatment, storage, and disposal burden for these PFASs could increase significantly. These PFAS-containing sites would be placed on the federal Superfund cleanup list. USEPA is considering using its discretion and may not take enforcement action against certain entities (i.e., passive receivers) that used PFAS. Previously closed sites could be reopened for additional investigation and/or cleanup. Finally, this change would facilitate private-party cost-recovery actions and class action litigation. On April 13, 2023, USEPA [7] proposed to designate additional PFAS compounds as hazardous substances.

On October 11, 2023, EPA issued a final rule requiring additional reporting of PFAS data to increase protection of communities from these "forever chemicals". Under this rule, 41 additional PFASs were identified as being of concern. At that time, at least 1,462 PFASs were known to have been made or used in the United States since 2011. The rule requires reporting by all manufacturers, including importers, who have processed PFAS and PFAS-containing materials at any time since 2011.

On March 29, 2023, the USEPA [8] proposed MCLs (maximum contaminant levels) for drinking water for six PFASs. These MCLs are in the parts per trillion (1×10^{-12}) range. USEPA determined that PFOA and PFOS are likely to cause cancer. Therefore, the MCLs for these two PFASs were proposed as the practical quantification limit that an analytical laboratory could achieve. If laboratory testing capabilities improve, then these two MCLs may be lowered accordingly. States may promulgate their own MCLs for drinking water; however, they cannot be less stringent than USEPA's MCLs. USEPA finalized these MCLs on April 10, 2024. Public water supply systems have three years to comply and the MCLs are enforceable groundwater cleanup standards under Superfund.

Laboratory test methods continue to evolve with more sensitive, lower detection limits. It is likely that more PFAS sources and PFAS-containing water, soil, and other impacted media will be discovered. Additionally, as toxicological information on PFAS compounds continues to expand, it is anticipated regulatory limits and the number of regulated PFAS compounds will continue to evolve.

Many soil treatment methods for PFAS are still in their infancy, can be very expensive, and have untested long-term effectiveness. Given the regulatory uncertainties and potential liabilities, finding acceptable treatment or disposal options can be challenging for a site due to monetary and logistical considerations. Feasibility studies are recommended to determine the best handling and disposal options for each site based on the unique conditions. For example, due to site location it may be more feasible to mobilize an on-site treatment option compared to transporting contaminated materials great distances to a landfill permitted to accept PFAS.

Based on a wealth of practical PFAS management experience with vertical and horizontal (infrastructure) projects, we present the following case studies to illustrate the dynamic federal and state regulatory landscape; summarize practical sampling, testing, and risk-assessment approaches; and provide suggestions for economic, effective treatment, and acceptable disposal options. Our case studies are intended to provide insight and high-level guidance to understand project implications and successfully navigate through the ever-changing world of PFAS.

We stress the importance of working with a consultant who understands the PFAS landscape in order to make the best decisions at the right time for your projects, taking the future into consideration.

2. Case Study: International Airport

This case study illustrates a geotechnical solution that saved time and money during construction. The runway at an international airport was being repaved, and a portion of the runway needed reconstruction of the underlying pavement structural section, due to excessive settlement. The site and regional groundwater downgradient of the site are contaminated with PFAS, including residential neighborhoods. As a result of the extensive PFAS contamination in groundwater, the owner paid to connect many households to municipal water.

An approximately 100-foot length at one end of the runway had experienced settlement over a 10- to 15-year period, resulting in a 2- to 3-inch depression in the area. A depression of this depth does not seem like much over a 100-foot-long area; however, it was hazardous to incoming and outgoing aircraft. Pilots took off or landed “short” to avoid the settlement area.

Geotechnical borings were advanced to provide data for use in identifying the cause of ongoing settlement.

Fig. 1 presents the Geoprobe® drill rig and drilling subcontractor, preparing to advance MacroCore® continuous samplers into the soil. MacroCore sleeves are utilized to minimize cross-contamination of analytical samples collected for PFAS analysis. Soils below the runway fill were silt that contained organics, and wood debris extending into the shallow groundwater table throughout the area. Chemical testing of samples indicated the presence of PFAS above levels of concern. The owner indicated excavating the unsuitable soils and replacing them with non-frost susceptible gravel fill would be cost-prohibitive due to the presence of PFAS-containing soil and groundwater, and disposal requirements for disturbed materials. When this project was initiated, accessible on-site treatment options were not available. One alternative for disposing of PFAS containing soil was to ship the soil in supersacks to a facility in the lower 48 states for disposal.

We worked with the owner and design team to develop a plan to mitigate the potential for future soil settlement without disturbing the PFAS-containing media. DDC (deep dynamic compaction) ground improvement was selected. DDC is a ground-improvement method whereby a heavy tamper (Fig. 2) is dropped from a specified height above the ground surface. Following

Fig. 1 Subcontracted driller preparing to advance borings.

Fig. 2 Contractor performing DDC ground improvement.

guidance from the U.S. Department of Transportation [9], we developed a ground improvement program that consisted of dropping a 15-ton tamper from a height of 30 feet on a 10-foot grid across the area. The tamper was dropped four times at each drop point, completed in two passes. A topographic survey of the ground improvement area before and after DDC showed an average 6-inch decrease in elevation of the ground surface. We believe the energy applied to the soils during deep ground improvement was sufficient to mitigate potential future settlement. After DDC was completed, crushed aggregate base course was added to the surface to raise grade back to the desired elevation for asphalt pavement.

This compacted ground was repaved for continued use as a taxiway which eliminated direct contact with the PFAS-containing soil. The low permeability of pavement reduced the infiltration of precipitation and potential leaching of PFAS from the soil to the underlying groundwater.

The strategy for this project included leaving the PFAS in place. This resulted in lower project costs for the owner. The PFAS-containing soil remained beneath the taxiway and expensive offsite transportation for treatment and/or disposal was not needed. We understand the cost of deep ground improvement was approximately one fifth the cost of treating the PFAS-contaminated soil at the time this project was completed.

3. Case Study: Site on Permafrost

This project presents a unique opportunity to conduct site work prior to allowing groundwater to flow through the site, essentially allowing the contractor to "get ahead of" contamination.

The federal government planned to construct an aerospace ground equipment storage facility at a military installation. The site was selected based on proximity to the existing airfield and operational needs of the installation. The site had not been developed and was heavily vegetated until site clearing was performed in preparation for subsurface explorations to develop design and construction recommendations for a planned facility. Fig. 3 shows the ground surface at the time of drilling. The site had recently been cleared of vegetation, similar to that in the background, using hydro axe methods. Several construction projects had occurred nearby during the 2 to 3 years prior to development of this site. The site was underlain by warm permafrost; some neighboring sites were only partially underlain by permafrost.

The site subsurface explorations indicated soils underlying the project area were characterized by warm permafrost from near the ground surface to the depth of the borings, which extended more than 50 feet bgs (below the ground surface). Unfrozen water was not

Fig. 3 Ground surface during drilling.

observed in any of the borings; however, groundwater in the neighboring area is known to be shallow, usually 10 to 15 feet bgs. Groundwater in the area is known to contain PFAS above regulatory action levels. Chemical analyses were conducted on samples collected from the subsurface exploration and determined that PFAS was not present in the soils or frozen groundwater underlying the site. The permafrost had prevented migration of contaminants onto the site.

The site is surrounded by thawed soils, or areas with warm, thawing permafrost. One option to prevent PFAS from migrating from the adjacent areas to the site was to maintain the frozen ground at the site using passive or active cooling techniques. These systems require extending construction schedules and contain elements requiring future maintenance, especially for active systems. The federal government did not wish to install a cooling system for the site.

Thawed soils in the area are liquefiable when subjected to seismic activity. For this reason, the design included briefly thawing subsurface soils and performing DDC to mitigate the potential for seismically induced settlement. Thawing of the on-site soils was anticipated to allow PFAS to migrate into groundwater underlying the site.

To achieve the design intent and reduce the potential for encountering PFAS-containing groundwater, the contractor began excavating in early spring. Geotechnically unsuitable soils (i.e., silt and frost-susceptible soils) were identified in the explorations. These soils were removed while frozen, followed by thawing of the upper 30 feet of the soil profile underlying the site using ground heat probes. Fig. 4 presents typical site conditions during excavation of frozen soil. As the excavation progressed, soils near the surface began to thaw naturally, creating ponded water at the surface. The contractor dealt with surface water by maintaining a relatively small area of excavation, removing unsuitable soils and stockpiling them nearby, backfilling with gravel as the excavation progressed.

Typically, ground thawing was performed beginning on the upgradient side of the site, taking advantage of the natural flow direction of regional groundwater, progressing toward the downgradient side. Because the contractor removed unsuitable soil prior to thawing, allowing PFAS-containing groundwater to naturally migrate onto the site was not a concern for construction. After thawing, DDC ground improvement was conducted to mitigate liquefaction potential and reduce the potential for seismically induced settlement. Potential PFAS migration was limited to groundwater that entered the site after thawing; therefore, shallow excavations for subsurface utilities and pavement did not encounter PFAS-containing groundwater.

However, the contractor needed to dewater for the later installation of a utility manhole, which occurred after site thawing, allowing potentially PFAS-containing water to enter the site. For this project, the Department of Environmental Conservation approved a dewatering plan that permitted dewatering into an onsite pit known to contain PFAS. This scenario was not permitted on subsequent projects at the same military installation, occurring within the same construction season due to concerns with moving PFAS contamination around within the facility. The facility now requires excess contaminated media be treated or disposed of upon disturbance of PFAS-containing materials. The change in owner policy illustrates the rapid rate of change regarding regulatory policy.

Fig. 4 Excavating frozen soil (note organic stockpiles beyond).

4. Case Study: Airport Infrastructure Project

Prior to PFAS emerging onto the environmental landscape, the state planned to conduct a ground-disturbing project at the ARFF (Airport Rescue and Fire Fighting) Building at an international airport. ARFF Buildings have historically stored PFAS materials and firefighting equipment known to contain PFAS. The project scope included demolishing the ARFF Building and constructing a new structure to be combined with the SREB (Snow Removal Equipment Building). Additionally, the project included improvements to the parking lot and driveway associated with the new facility. Our initial scope of services involved a subsurface geotechnical investigation (Fig. 5), hazardous materials survey of the existing ARFF Building, and limited sampling of geotechnical borings for fuel-related environmental contaminants. Due to recent discovery of PFAS at other state airports, regulators requested additional sampling for PFAS during review of our environmental sampling work plan.

Results from the preliminary sampling event identified PFAS in near-surface soils and identified unknown Class V injection wells (i.e., floor drains) which triggered additional regulatory involvement and characterization. The injection wells were believed to be likely sources of some of the PFAS contamination at the site. After the discovery of PFAS at the site, our scope of services expanded to include additional sampling from the areas anticipated to be disturbed by construction activities, characterization of two Class V injection wells in anticipation of closure with the EPA, and development of a CMMP (contaminated materials management plan). Soil and groundwater contamination associated with the site is regulated by the state regulators, and closure of the injection wells is regulated by the EPA under the Clean Water Act.

Due to the uses of the ARFF building and standard practices before the toxicity of PFAS was understood, the area immediately surrounding the building contained PFAS concentrations above regulatory limits. Contamination for the site was segregated into various levels of contamination: Category 1 (PFAS not detected), Category 2 (PFAS detected below allowable limits), Category 3 (PFAS detected above allowable limits), and by material type (soil, asphalt, and concrete). Our team assisted with determining the volume of material that would require disposal based on the initial design plans and conducted a feasibility study of the available remediation/treatment options/costs. At this time, several new technologies had become available, including treatment options to wash the soils or thermally treat the contaminated material on-site.

Subsurface exploration was accomplished using hollow-stem auger drilling with split-spoon sampling. Samples were collected at intervals of 2.5 feet to 5 feet throughout the boring depths, which extended as deep as 181.6 feet bgs. Cone penetrometer testing was conducted to a depth of 80 feet bgs (Fig. 6). Additionally, shear wave velocity testing was performed in one of the boreholes. The drilling subcontractor was required to decontaminate drill tooling between boreholes, and sampling equipment between samples. Samples were collected for analytical testing from the soils recovered during geotechnical drilling. The various drilling techniques were not an attempt to minimize exposure to contamination or reduce costs; the drilling program was largely specified by the Owner in the Request for Proposal.

Fig. 5 Logging soils recovered using MacroCore techniques.

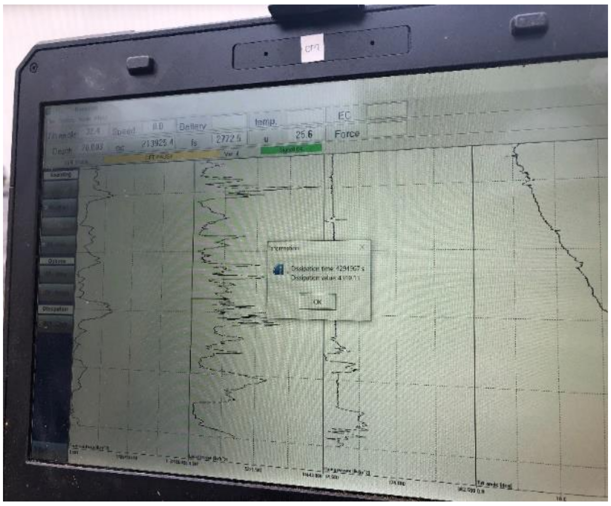

Fig. 6 Driller's display during CPT (cone penetrometer testing.).

The presence of PFAS in soils near the ARFF has caused significant delays to the project due to the prohibitive cost of handling excavated PFAS-containing material and federal funding restrictions. Disposal and/or treatment of the contaminated material would have added an additional two to four million dollars in expenses. The project team has regrouped to seek alternative design plans that would reduce the amount of excavated material requiring remediation and/or disposal.

The design team considered several options to limit excavation during construction, including raising the foundation grade, retaining walls, and/or installing a geogrid. They have also assessed the potential for using controlled low strength material for building and pavement structure foundation, or otherwise re-using existing contaminated material excavated during site preparation and encapsulating the PFAS-containing material beneath the structure. Redesigning the project focused on reducing the excess Category 2 and 3 materials, where possible. The design team settled on raising the grade of the building and moving an associated shed structure outside of the contaminated area.

This project is currently scheduled to be funded in 2025; however, we expect additional delays due to pending revisions to PFAS regulations. Documents associated with the site will be revisited prior to the start of the project and submitted for approval by the applicable regulators. The purpose of introducing this project in this paper is to stress the importance of collecting PFAS data prior to the design of a project and using the PFAS data to make informed design decisions. Had this project begun even one year later, when PFAS was emerging, the design team could have considered this during the initial design phase.

5. Case Study: Future Airport Improvements Project

The state plans to conduct an airport improvements project at an international airport in the arctic (Fig. 7). The project includes improvements to drainage near the runways, relocating utilities impacted by the drainage upgrades, regrading and filling in-fields, and installing fencing for wildlife control. The airport is a state-owned facility known to have used AFFF during routine training and emergency operations; however, concentrations of PFAS throughout the facility were unknown to the design team drafting the construction plans. The state has been requiring construction bid documents to include a CSMP (contaminated soils management plan) to direct contractors on handling PFAS-containing materials. We participated with the design team to provide geotechnical design and construction recommendations, and to assist with delineating PFAS in areas impacted by the project. Our scope also included creating a CSMP.

Fig. 7 International airport located in the Arctic.

Prior to conducting environmental field investigations, we reviewed available airport documents, applicable environmental resources, and interviewed the state employees to determine areas where AFFF use was known. Documentation of AFFF use has not been required for several decades. Research was conducted to obtain information for both the geotechnical investigation, as well as the environmental impacts of concern to the improvements project. While it was not necessary for the project described here, we have learned through sampling various media (asphalt, concrete, etc.) at other sites, analytical sampling of these materials provides answers that the design and construction teams are likely to need in the future. Obtaining PFAS results may take several months, depending on the workload of the laboratory; therefore, conducting the sampling during design allows the owner and designers to provide clear instruction regarding anticipated handling of contaminated materials during construction, which prevents delays for the project.

Due to the lack of field-based testing methods for PFAS that are capable of generating immediate or real time results, we conducted a field investigation to collect analytical samples from areas at the airport that are anticipated to be impacted by the improvements project. PFOS was detected in several areas that will be excavated for the project.

The CSMP describes methods for segregating materials during construction based on the preliminary sampling results. The CSMP further describes field-based methods for segregating potentially contaminated soils associated with petroleum releases. Soil classification and segregation is necessary to avoid spreading excess soils from areas of higher contamination to areas where no contamination has been detected, or lower contamination levels exist. Furthermore, segregation assists with preventing non-contaminated soils from being grouped with soils with detectable contaminant concentrations and generating larger stockpiles that may be expensive to dispose of. Allowable PFAS limits in the arctic zone are much higher than those in other regions of the state; however, for the purposes of segregation, the CSMP uses the more stringent values from other regions due to disposal considerations of excess soils.

Regulators for the site approved the reuse of materials excavated at the site, regardless of potential for contamination. Excess soil (not able to be reused) exceeding regulatory limits will be removed from the site and disposed of. Approval to remove contaminated soils from the site will be requested from the regulator by the contractor. Excess soil where PFAS is not detected above the regulatory limits will be used to assist with filling in-fields, as described by the design plans. Excess soils will only be spread in areas of known contamination. Contamination, even detected below the regulatory limits, may not be spread in areas where PFAS is not detected.

Our geotechnical design recommendations for the proposed airfield fencing, which extends the full length of the runway and across one end, included a raised embankment with a gravel drive surface and a 6-foot chain link fence. The embankment design is sufficiently thick to protect the ice-rich shallow permafrost at the site and creates a barrier to prevent large mammals from crossing the runway. This concept also eliminates the need for any excavation of potentially PFAS contaminated near-surface soils within the embankment footprint. Although permafrost currently underlies the site and is continuous throughout the region, climate warming may lead to PFAS contamination of regional groundwater as permafrost thaws.

6. Conclusions

There are still many technical, regulatory, and procedural uncertainties as more and more PFAS-impacted construction sites are identified through mandated soil and groundwater testing. The fact that PFASs pose a risk to human health is the most critical parameter that drives the regulated community on how

PFAS-impacted soil, groundwater, and sediment will be handled in the future. The challenges for managing PFAS-impacted soil and groundwater at geotechnical construction sites will become even more daunting when the EPA designates certain PFASs as hazardous substances. Many projects may be shut down or delayed by some future regulatory requirements or budgets explode in anticipation of dealing with these emerging contaminants. Without the right team in place, working to address PFAS issues during construction could lead to major schedule or budgetary disturbances.

Our team has worked closely with the regulators to develop methods for handling PFAS-contaminated materials and anticipating appropriate treatment measures to allow projects to move forward. It is possible with prior planning, experienced team members, and potentially some creative design changes to approach projects in a successful manner.

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