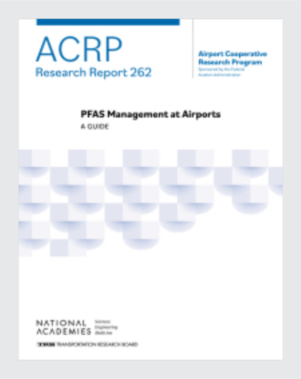

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AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP RESEARCH REPORT 262

PFAS Management at Airports

A GUIDE

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TRB TRANSPORTATION RESEARCH BOARD

2024

AIRPORT COOPERATIVE RESEARCH PROGRAM

Airports are vital national resources. They serve a key role in transportation of people and goods and in regional, national, and international commerce. They are where the nation's aviation system connects with other modes of transportation and where federal responsibility for managing and regulating air traffic operations intersects with the role of state and local governments that own and operate most airports. Research is necessary to solve common operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the airport industry. The Airport Cooperative Research Program (ACRP) serves as one of the principal means by which the airport industry can develop innovative near-term solutions to meet demands placed on it.

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FOREWORD

By Joseph D. Navarrete
Staff Officer
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ACRP Research Report 262 provides information and practical considerations for managing aqueous film forming foams (AFFFs) containing per- and polyfluoroalkyl substances (PFAS) used for firefighting at airports. It also includes education and public outreach materials to support community involvement efforts. The report will be of particular interest to practitioners who wish to better understand AFFF characteristics and management, institutional and programmatic controls, and regulatory requirements.

PFAS are found in many products, from consumer products to building materials. For airports, the primary implication is associated with firefighting foams (e.g., AFFFs). For many years, airport operators were required to use AFFF and, as a result of recommended training requirements and fire response, may have had releases of AFFF to the environment. Emerging science, increased regulatory attention, and heightened community focus are elevating PFAS issues at airports, and research was needed to help airport operators address potential impacts and manage PFAS at their facility.

The research, led by RS&H, Inc., began with a review of the latest scientific, technological, and regulatory developments regarding PFAS. The research team engaged the aviation industry through a comprehensive survey to better understand PFAS issues and handling practices at airports. The team relied on its members' scientific, engineering, legal, regulatory, and outreach experience to translate its findings into a guide and supporting tools and resources.

The guide provides a background on the use of AFFF at airports and leads the reader through the chemistry of PFAS compounds and fate and transport processes in the environment. It includes practices for assessing past and current activities; reviewing policies, procedures, and operations; considering regulatory actions, financial planning, and remediation; and planning for communications and public engagement. A comprehensive set of tools and resources is provided as appendices, including material for communication and engagement (e.g., a template brochure and presentation slide deck); tutorials for inspections, document reviews, and other assessments; and checklists for developing or implementing management methods. These appendices are available on the National Academies Press website (nap.nationalacademies.org) by searching for *ACRP Research Report 262: PFAS Management at Airports: A Guide* and looking under "Resources."

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SUMMARY

PFAS Management at Airports: A Guide

Per-and polyfluoroalkyl substances (PFAS) are a class of emerging contaminants that could present operational and management challenges to airports nationwide. Federal Aviation Administration (FAA) Part 139–certificated airports are required to use fire-extinguishing agents that meet the U.S. Department of Defense (DoD) military specifications (MIL-SPECs) and are listed in the military Qualified Products Database (QPD). As of early September 2023, only aqueous film-forming foam (AFFF) products containing PFAS compounds met the AFFF MIL-SPEC requirements (MIL-PRF-24385F(SH)) for firefighting capabilities and knockdown time. On September 13, 2023, one fluorine-free foam (F3) was added to the QPD; it meets the DoD MIL-SPEC (MIL-PRF-32725) for F3 and is commercially available. On Feb. 8, 2024, a second F3 was approved and listed by the DOD on its Qualified Products List, and an additional product was expected to be approved in spring 2024. (Note: Unless otherwise indicated, the information and data provided in this guidebook are current through early September 2023, when the content was finalized. Changes in regulatory status, research results, or other information regarding PFAS may have occurred since the content was developed.)

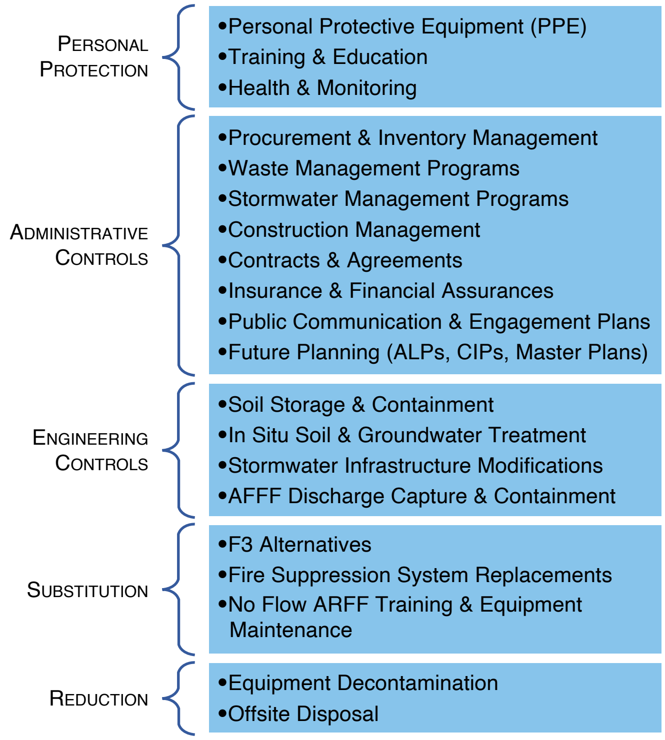
While progress has been made with alternatives to AFFF and in understanding the characteristics of PFAS in the environment in recent years, uncertainty in regulatory requirements, acceptable management and transition practices, and disposal approaches remain. However, airport operators are managing their PFAS challenges by understanding

- Chemistry, fate, and transport processes in the environment;
- Assessment techniques, including site assessments, sampling, and testing;
- Remediation, removal, and ultimate disposal methods and technologies;
- Risk reduction and cost recovery options;
- Policies, procedures, and methods for improving health and safety; and
- Public engagement strategies.

Current trends are toward stricter regulatory standards for several individual PFAS compounds, with lower allowable concentration limitations in environmental media and potable water sources anticipated. *ACRP Research Report 262: PFAS Management at Airports: A Guide* provides airport personnel and aviation professionals with information and practical considerations relevant to the topics above, as illustrated in Figure S-1.

Chapter 1 lays out the uses and goals of the guide. Chapters 2–5 of the guide address four main topic areas:

- Chapter 2: Assessment of Historical and Current Product Use and Activities
- Chapter 3: Policies, Procedures, and Operations
- Chapter 4: Regulatory Action, Financial Planning, and Remediation
- Chapter 5: Communication and Public Engagement



Note: ALP = airport layout plan, CIP = capital improvement plan, ARFF = aircraft rescue and firefighting

Figure S-1. PFAS management topics addressed by guide.

While AFFF is the primary challenge for airports and the principal focus of this report, there may be other activities involving products containing PFAS occurring on or adjacent to an airport and which an airport may want to understand. Where appropriate, the guide also provides supplemental information and options associated with managing those activities.

CHAPTER 1

Use and Goals of the Guide

Information about per- and polyfluoroalkyl substances (PFAS) in an aviation setting is changing rapidly, and finding information on how to manage, control, remediate, and dispose of affected media and aqueous film-forming foam (AFFF) in accordance with stricter and frequently changing regulatory standards creates more challenges. The purpose of this guide is to help equip airport personnel with information needed to tackle PFAS issues and implement management strategies. The guide takes an institutional planning approach that emphasizes modifications to current operational procedures, managerial policies, and public engagement approaches. Currently available information is summarized and management considerations are provided.

The guide addresses four main themes, each of which is the subject of both a chapter and a toolkit associated with the chapter:

- **Assessment of Historical and Current Product Use and Activities (Chapter 2 and Appendix A)**
  - Characterization of historical AFFF use across airport property, including tenants and military joint-use facilities;
  - Identification of activities involving PFAS products, both on and off property; and
  - Evaluation of mechanisms and pathways for transport onto or off of airport property.
- **Policies, Procedures, and Operations (Chapter 3 and Appendix B)**
  - AFFF procurement, inventory tracking, and supply management methods;
  - Methods for responsible AFFF disposal;
  - Aircraft rescue and firefighting (ARFF) procedures and operations;
  - AFFF procurement, use, handling, storage, and disposal policies;
  - Development and redevelopment activities and possible management of PFAS materials; and
  - Ongoing operations and considerations associated with stormwater runoff.
- **Regulatory Action, Financial Planning, and Remediation (Chapter 4 and Appendix C)**
  - Regulatory trends;
  - Considerations for airport planning documents;
  - Legal considerations and cost recovery options; and
  - Remediation methods.
- **Communication and Public Engagement (Chapter 5 and Appendix D)**
  - Environmental justice considerations and
  - Communication methods and techniques for public engagement.

The toolkits contain actionable information and customizable templates that can be used to develop and implement management plans for AFFF and PFAS. The tools provided can be used either to develop new policies, procedures, and planning documents or to enhance current

Toolkits

The toolkits developed for this guide contain summarized information and customizable materials, or tools. They are provided as Appendices A through D and are available on the National Academies Press website (nap.nationalacademies.org) by searching for *ACRP Research Report 262: PFAS Management at Airports: A Guide* and looking under "Resources."

The tools include

- Template brochures and flyers and presentation slide decks with suggested language and customization instructions;
- Tutorials for inspections, document reviews, and other assessments;
- Checklists for developing or implementing management methods; and
- Comparison summaries formatted as flyers or handouts.

ones. If appropriate, airport operators may want to consider engaging legal counsel, as well as outside consultants and technical experts, for assistance with implementing these tools and methods to develop an institutionally specific AFFF adaptive management plan.

In addition to this primary research, an aviation stakeholder group that represented airport staff from diverse aviation facilities nationwide was surveyed regarding current issues, practices, and challenges with PFAS management at their institutions. The respondents represented airports of diverse sizes, climates, and land use settings, and feedback was solicited from personnel within a variety of aviation roles. Information regarding the research methodology, the industry needs identified by the survey of airport personnel nationwide, and other information sources used to create this guide is provided in Appendices E and F.

The use of AFFF containing PFAS was studied earlier in *ACRP Research Report 173: Use and Potential Impacts of AFFF Containing PFASs at Airports* (Thalheimer et al. 2017). That report provides background and information regarding the management of AFFF and includes the Managing AFFF and PFASs at Airports (MAPA) tool. The present guide updates information presented in *ACRP Research Report 173*. In addition to *ACRP Research Report 173*, *ACRP Research Report 255: PFAS Source Differentiation Guide for Airports* (Anderson et al. 2023) can be used in concert with this guide, depending on an individual airport's situation.

CHAPTER 2

Assessment of Historical and Current Product Use and Activities

PFAS are a complex group of man-made chemicals widely manufactured since the 1940s (EPA 2021i). PFAS, as a group, are fluorinated carbon chain molecules with polar and nonpolar ends, which give PFAS-containing products beneficial properties such as performance resiliency under extreme heat, cold, and vacuum or pressure as well as stain resistance and water repellence. This chapter's overall goal is to assist airport operators in understanding the historical and current conditions relevant to AFFF use; nonaviation activities involving PFAS both on- and off-site; and PFAS migration mechanisms and pathways to potential sensitive receptors.

Chapter 2 Topics

- Overview of PFAS characteristics
- Aviation and nonaviation activities involving products containing PFAS
- How to investigate historical AFFF use, storage, and handling practices
- PFAS behavior in the environment, including transformational processes and migration pathways

2.1 PFAS Properties Overview

While it is estimated that there are more than 4,700 individual PFAS compounds, these compounds tend to have similar structures and perform as surfactants for a wide variety of uses. This section describes the basic chemical structure and properties of PFAS compounds and then describes how these properties contribute to AFFF's overall effectiveness in combating aviation fuel fires.

2.1.1 Basic PFAS Structure and Characteristics

While PFAS include compounds from many distinct chemical classes containing various functional groups, they also display common traits such as having both hydrophilic, or polar, and hydrophobic, or nonpolar components. The hydrophilic and hydrophobic components create the capacity for PFAS to form micelles. Micelle formation is the critical element that creates the surfactant behavior of many PFAS-containing products, including the function of AFFF. Conversely, many of the challenges associated with developing a fluorine-free foam (F3) alternative product that performs with the same efficacy as AFFF derive from the difficulty in replicating the micellar surfactant properties without using fluorine or other halogens. The properties and function of AFFF relative to micelle formation are examined in the next section.

For Your Information

- F3 transition planning is discussed in Section 3.3.4.
- Regulatory progress toward F3 product authorization is covered in Section 3.3.4.1.

Hydrophilic compounds, such as table salt, mix with or dissolve in water. Hydrophobic compounds, such as oil, are immiscible in, or fail to mix with, water. Similarly, polar compounds dissolve in other polar solutions, such as water, acids, or bases, while nonpolar compounds dissolve in nonpolar substances, such as petroleum products or other organic compounds. PFAS are

Toolkit on Assessing Current and Historical Product Use and Activities

Appendix A provides the following supporting materials that provide a starting point for assessing sources and determining exposure assessment strategies and controls for PFAS: Appendix A is available on the National Academies Press website (nap.nationalacademies.org) by searching for *ACRP Research Report 262: PFAS Management at Airports: A Guide* and looking under "Resources."

Tool 2.1: Guide to PFAS Fate and Transport in Subsurface Environments

Summary of factors affecting PFAS fate and transport in subsurface environments.

Tool 2.2: Guide to PFAS Fate and Transport in Surface and Groundwater Environments

Summary of factors affecting PFAS fate and transport in surface and groundwater environments.

Tool 2.3: Guide to PFAS Fate and Transport in Air

Summary of factors affecting PFAS fate and transport in air.

Tool 2.4: Tutorial for Conducting a Baseline Analysis

- Step-by-step guide for finding airport-specific information and locating potential receptors.
- Provides links to helpful government websites and shows how data can be accessed and utilized for a baseline review.

Tool 2.5: Tutorial for Assessing Off-Site Source Areas

- Step-by-step guide to assist with identifying historical and current industrial and commercial facilities near an airport.
- Provides links to helpful government websites and shows how data can be accessed and utilized for assessing potential off-site sources or activities.

Tool 2.6: Considerations for Selecting a Method of PFAS Testing

Checklist for determining the appropriate laboratory analytical testing method on the basis of the environmental media containing the sample and the anticipated or predicted PFAS compounds.

Tool 2.7: Tutorial for Conducting an AFFF Exposure Study

- Step-by-step tutorial for assessing current and former AFFF use on-site.
- Provides example interview questions for ARFF and airport staff about use, storage, disposal, and other facilities that use AFFF.

also known to display oleophobic (oil-repelling) and oleophilic (oil-mixing) properties. Therefore, PFAS fluorocarbon chains perform exceptionally well as either water-active or oil-active surfactants and therefore are highly effective in extinguishing Class B petroleum fires. However, these properties contribute to the ability of certain PFAS compounds to migrate through environmental media and persist in the environment for long periods of time.

In their most basic form, PFAS are composed of a fluorinated carbon tail and a nonfluorinated head (Figure 2-1). The fluorinated carbon chain tail can be various lengths and have a linear or branched structure, depending on the compound. This tail also repels water and has affinity for organic matter and nonpolar compounds. The nonfluorinated head is hydrophilic, and often consists of a polar, water-soluble functional group that can interact with electrically charged, or ionized, particles, such as those found in some soils.

PFAS may contain either negatively charged (anionic), or positively charged (cationic) polar groups. Anionic and cationic PFAS exhibit unique properties that reflect their utility in consumer end products. For example, anionic fluorinated surfactants are commonly used in metal plating, ultraviolet (UV) light–resistant coatings, and inks, while cationic fluorosurfactants are widely utilized in cleaning products and cosmetics. In addition, both groups have been used in AFFF formulations (Buck et al. 2012).

Zwitterionic PFAS contain both negatively charged and positively charged polar groups in their molecular structures, and amphoteric PFAS can act as either an acid or a base, depending on the chemical mixture in which they are used. The hydrophilic and hydrophobic components of PFAS allows them to be highly effective surfactants that are used to lower the surface tension between two liquids, a gas and a liquid, or a liquid and a solid. The unique surfactant behavior of PFAS has key implications for their environmental fate and transport, which are discussed in greater detail in Section 2.5.

Toolkit Tip

Tools 2.1, 2.2, and 2.3 also provide guides for assessing PFAS fate and transport in the environment.

2.1.2 PFAS and Surfactant Behavior

Surfactant molecules dispersed in a liquid—for example, molecules of PFAS in water—can aggregate together to form a colloidal suspension. In this colloidal suspension, the hydrophilic heads, which are polar, or water soluble, interact with the water in the solution. The hydrophobic tails, which are nonpolar, or water repelling, interact with each other. That is, the tails stick together. As a result, the PFAS micelle typically results in a spherical shape, like a soap bubble, with the hydrophilic heads forming the outside of the sphere in direct contact with the water in the solution. The hydrophobic tails, which are repelled by the water in solution, point in toward the center of the bubble, as shown in Figure 2-2. The outside of the micelle is soluble in water, but when it encounters oils or dirt, the nonpolar tails of the micelle bind to the oil or

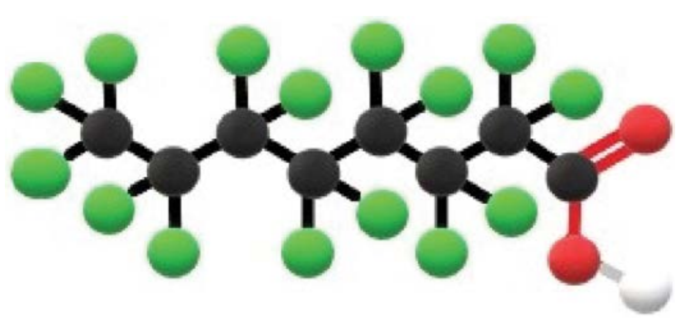


Figure 2-1. Example of PFAS structure showing fluorinated and nonfluorinated regions.

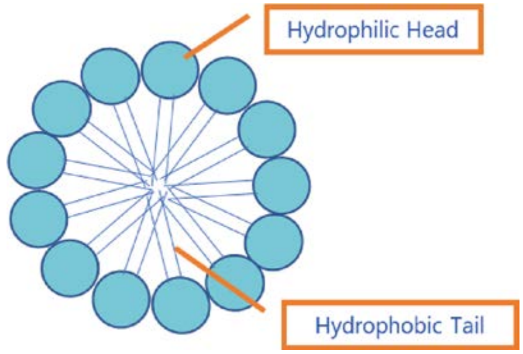


Figure 2-2. Conceptual drawing of PFAS micelle structure.

dirt and encapsulate it within the micelle. A mixture or solution may form micelles when PFAS are present in sufficiently high concentrations, and the micelles are what gives the solution its foam-forming properties.

The critical micelle concentration (CMC) is the concentration of PFAS in a solution in which the chemical creates a visible, separate phase liquid or film that floats on and completely coats the water or solution's surface. The addition of PFAS changes the surface tension of the water or solution, especially if enough is added to achieve a CMC. Once the CMC has been reached, PFAS quantities added above the CMC threshold convert into micelles but have little to no effect on the surface tension of the solution. That is, PFAS form a film or sheet across the water surface until the surface is completely covered and the CMC is reached, at which point any further addition of PFAS forms micelles with the bubble shape.

The competing tendencies of PFAS hydrophobic and hydrophilic components typically lead to uneven environmental distribution, with high accumulation at interfaces, such as soil and water, air and water, or water and nonaqueous phase liquid (NAPL) within the source areas (Guelfo and Higgins 2013, McKenzie et al. 2016, Brusseau 2018). Due to their surfactant behavior and tendency to accumulate at interfaces, the vertical migration of PFAS released in subsurface environments may be significantly delayed, and PFAS may persist within source areas and in subsurface environments for decades. In most cases, PFAS will partition to the interface, transform into precursors, and migrate via biotic and abiotic processes. A more-detailed discussion of how PFAS may be transported through a variety of environmental media is provided in Section 2.5.

2.2 Aviation Activities

Many formulations of PFAS, including some PFAS in AFFF products, are listed as proprietary or were historically considered inert ingredients, and therefore are often not listed in product Safety Data Sheets (SDSs). While other products and applications have been identified as potentially containing at least one PFAS compound, the research conducted to develop this guide determined that AFFF remains the primary concern for airports. The following discussion generally summarizes where and how AFFF is more commonly used or stored in an airport setting. For the purposes of this section, aviation activities refers to aircraft rescue and firefighting (ARFF) facilities and activities, structures that use fixed AFFF fire suppression systems, and military joint-use facilities on or adjacent to the airport property.

2.2.1 ARFF Activities and Vehicles

ARFF facilities store AFFF, and ARFF crews train with and use AFFF. AFFF can be released to the environment under various scenarios. It may be accidentally released during delivery, transfer, or storage. It can also be deployed intentionally for training, testing, operational requirements, or emergency response. ARFF staff are no longer required to flow foam during training exercises or for maintenance purposes or equipment testing, due to the approval of no-flow equipment. However, past required AFFF deployment may have resulted in PFAS-exposed materials and media (FAA 2021a, 117th Congress of the United States of America 2019).

As F3 products become more readily available, operators will transition ARFF vehicles from AFFF to F3. Processes and procedures for transitioning are not yet defined, nor are requirements associated with AFFF residuals established. FAA's latest guidance on F3 and related information is available on its web page "Fluorine-Free Foam (F3) Transition for Aircraft Firefighting" (FAA n.d.-c).

2.2.2 Fixed AFFF Systems

Hangars, bulk fuel storage facilities, and multilevel quick turnaround rental car facilities may use a fixed AFFF system for fire suppression. Historical testing of systems, accidental releases, or fires may have resulted in the discharge of AFFF from the fire suppression system. Releases may have historically been directed to sanitary sewer systems, but, in some cases, AFFF could be released to the environment. Additionally, if the fire suppression systems are upgraded or replaced, inclusion of procedures for characterization and proper disposal of AFFF-containing materials and equipment may be considered.

2.2.2.1 Hangar Fire Suppression Systems

High-expansion foam (HEF) and AFFF are the two main types of foam used in hangar fire suppression systems, but only AFFF contains PFAS. While HEF does not contain PFAS, typical HEF installations require hose lines for manual fire-extinguishing systems, which may utilize AFFF. HEF systems use foam generators to entrain air into foam and water solutions. The HEF generators have expansion ratios typically in the range of 100:1 to 1000:1 which creates a foam resembling foamy shaving cream that spreads as it levels out. While HEF systems generally only discharge quantities to the minimum foam depth necessary to extinguish a fire, these depths are generally measured in terms of feet rather than inches. However, HEF does not produce significant amounts of liquid runoff. On the other hand, AFFF produces a thin film layer of foam, typically only a few inches thick. Different AFFF delivery systems produce different foam thicknesses based on the agitation of the foam and water solution. As a result, AFFF discharges are mostly liquid and generate significant volumes of liquid runoff.

The most common elements of hangar foam fire suppression systems are foam concentrate storage tanks. Most tanks are either vertical or horizontal bladder tanks, often painted red, typically ranging from 500 to 1,500 gallons in size, although similarly sized atmospheric storage tanks may also be used with foam concentrate pump systems (Figure 2-3).

HEF systems use foam generators, which are located at the roof level of the hangar, and each foam generator can cover several thousand square feet of floor area. Many older systems have outside air ducted from roof vents, and may also have many louvers to relieve the pressure from the outside air. Older systems typically have two tanks—one primary and one reserve. HEF systems may also have a smaller AFFF concentrate tank, typically less than 100 gallons, for supplying hand lines. Some hose stations will have integral tanks at each station instead of a centralized foam and water distribution system.

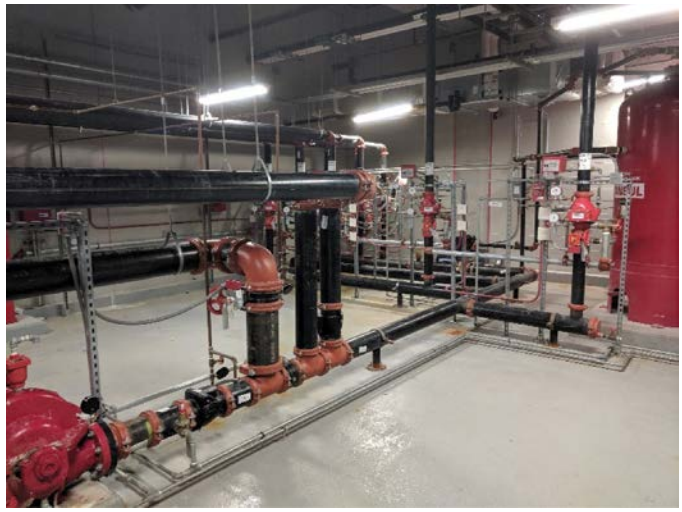


Figure 2-3. AFFF fire suppression system with AFFF concentrate storage tank.

Multiple discharge devices are used for AFFF deployment in hangars. The most common method delivers AFFF through standard sprinklers, although sprinklers are typically present with all foam systems, whether delivering AFFF solutions or providing overhead protection for other AFFF or HEF systems. Foam monitor nozzles are also used to deliver foam, and monitor nozzles are required in larger hangars for underwing protection. Specially designed trench drain nozzles are another method that distributes foam at the floor level.

2.2.2.2 Inadvertent Discharges from Suppression Systems

Fire protection regulatory codes and suppression system designs focus on the system's reliability and verifying that the systems will function as designed during a fire event. While AFFF is a proven firefighting medium that offers significant advantages, potential releases of AFFF during inadvertent discharges may be a challenge. Both the type of AFFF delivery method and type of fire detection system can affect the potential for false system activation and inadvertent discharges.

Closed-Head Sprinkler Systems. Closed-head foam and water sprinkler systems are the simplest, and these utilize the same basic type of sprinklers used in commercial and residential applications. Each individual sprinkler has a fusible link or glass bulb that activates only the associated individual sprinkler head when heated. Closed-head sprinklers are used in hangars where the link or bulb is intact. Sprinklers rarely have inadvertent activations, so most leaks involve some form of physical damage to the sprinklers or piping. Closed systems refer to the following three main types of sprinkler systems:

- Wet-pipe systems are the most common and deliver foam or water within seconds of sprinkler activation.
- Dry-pipe systems are installed when hangars may be subject to freezing. They use pressurized air to keep valves closed.
  - Sprinkler activation releases the air pressure, which opens the valve and allows foam or water to flow through activated sprinklers.
  - A time delay results from the delay in pressure drop and the delivery time to flow water to an activated sprinkler, thereby requiring calculation for a larger discharge area. These systems typically have larger pipe sizes.

- Preaction systems eliminate the delay in water delivery time by using detection systems that open valves and charge pipes with water before the sprinkler activates. The size of the pipes in preaction systems are generally the same as those in wet-pipe systems,

While closed-head foam and water systems are the most reliable for avoiding inadvertent discharges, they are limited by fire codes to Class II and Class III hangars, which are less than 40,000 square feet (ft^2) and are only used for AFFF. Hose valve stations used for manual firefighting are typically activated by manually opening a valve; thus, the risk of inadvertent discharge is relatively low.

Deluge Systems. Larger hangars require foam to be discharged simultaneously over large areas of the hangar and may require foam to be discharged over the entire hangar surface area. To meet this need, large hangars often use deluge systems. Deluge system discharge devices are opened, and a deluge valve activates to flow the foam and water solution through all discharge devices downstream of each valve. Discharge devices include open sprinklers, which are sprinklers with the fusible link or glass bulb removed. Other discharge devices include monitor nozzles, trench drain nozzles, and HEF generators.

Detection Systems. The detection system is the primary source for inadvertent AFFF discharges from deluge systems. The numerous types of detection systems utilized in hangars are based on three main categories: heat detection, smoke detection, and flame detection. These systems have different advantages and disadvantages regarding reaction time and the potential for false activation. False activation may not necessarily imply malfunctioning equipment, as it also includes activation from nonfire conditions that the detector picks up as a fire scenario. For example, a flame detector may activate because of a gas grill located outside of the facility. While the detector is accurately detecting an actual fire condition, this scenario does not warrant foam system activation.

Heat detection systems often have slower response times than smoke or flame detection systems but are less likely to have false activations. Hangar fire codes do not usually dictate the type of detection system that must be used, so these are normally chosen by the owner and system's design engineer.

2.2.3 Tenant Facilities

Tenants may operate facilities with AFFF fixed fire suppression systems, and these may include some or all of the types of systems and associated fire detectors discussed in the previous section. Tenants may also conduct industrial activities involving PFAS-containing chemicals that are not necessarily aviation related. Lease agreements often provide tenants with a degree of autonomy and privacy, and airport tenants are typically responsible for their handling and storage of chemicals and fire suppression systems within their leasehold. For these reasons, coordination and collaboration with tenants is important to understand the potential for chemical use, storage, and disposal.

Fuel farms and fuel storage facilities may use AFFF fire suppression systems, and these facilities may store AFFF concentrates on-site.

2.2.4 Joint-Use Military Facilities

FAA defines the term "joint-use airport" as an airport owned by the Department of Defense (DoD) at which both military and civilian aircraft make shared use of the airfield. Airports may also have DoD entities as tenants with shared roles (ARFF, airport traffic control towers, airfield operations). Joint-use facilities with military operations may use AFFF in either fixed fire suppression systems or during ARFF-related activities. DoD has been investigating facilities around the United States, including shared commercial airports, for releases of PFAS to the environment and potential contamination of soils, groundwater, surface water, or sediments. Airports should coordinate with DoD personnel about the fate and transport of PFAS nearby or on airport property and seek to understand the potential for adverse effects on airport operations or property.

2.3 Off-Airport Activities

Common off-site source areas of PFAS are landfill sites, industrial sites, fueling facilities, wastewater treatment plants, groundwater recharge and injection wells, and agricultural fields.

Airport operators may want to understand off-airport activities involving PFAS in the vicinity of their airports, even though these activities are not directly related to airport operations. Airport operators should be aware of adjacent land uses and their potential for releasing PFAS to the environment. Although the following discussion does not address every activity, industry, or scenario in which PFAS environmental exposure could occur adjacent to an airport, it does identify potential activities that could affect an airport, depending on setting.

2.3.1 Solid Waste Management Facilities

Products in landfills that could contain PFAS include cosmetics, food packaging and containers, cleaning products, paints or sealants, waterproof apparel, coated paper products, pharmaceuticals, and other products containing fluorinated surfactants (Glüge et al. 2020).

Airport operators may want to determine their proximity to nearby landfills and, if applicable, assess the probability of PFAS migrating onto airport property should landfill leachate escape containment. Federal regulations impose statutory limitations on the construction of new landfills within 5 miles of a public airport; however, these restrictions were not applicable before April 5, 2000 (FAA 2006). Some states, such as North Carolina and Texas, host websites with geographic information systems (GIS)-enabled tools that show landfill locations (TCEQ 2022, NCDEQ 2022), but identifying closed and capped former landfills may be more challenging. While redevelopment of appropriately closed and capped landfills is a commonly accepted land reuse procedure, the widespread use of PFAS in consumer products means these sites may be introducing PFAS to surrounding environmental media if leachate containment was insufficient or has been compromised.

For Your Information

Nonaviation industrial PFAS activities include

- Aerospace
- Building and construction
- Dry cleaning
- Pharmaceuticals manufacturing
- Plastics production
- Printing and inks
- Tanneries
- Textiles manufacturing
- Metals fabrication and electroplating
- Electronics fabrication
- Chemical manufacturing of products such as soaps and cleaning products
- Paints and sealants
- Cosmetics
- Treated paper products
- Enhanced oil and gas recovery with fracking

2.3.2 Industrial Facilities

Industrial activities that may involve PFAS-containing products include aerospace; building and construction; dry cleaning; pharmaceuticals; plastics production; printing and inks; tanneries; textiles manufacturing; metals fabrication and electroplating; electronics fabrication; chemical manufacturing of products such as soaps and cleaning products, paints and sealants, cosmetics, and treated paper products; and many others (Glüge et al. 2020). Many airports across the United States are contained within a commercial or industrial district, which may include manufacturing plants, factories, and other heavy industrial activity. These facilities may process, produce, or use PFAS-containing chemicals, and releases to the air, stormwater systems, or groundwater may have occurred through normal operations. Depending on the location and geophysical conditions in the area, migration to airport property could occur.

2.3.3 Oil and Gas Exploration and Refining Facilities

Fluorosurfactants have applications in the oil and gas industry, and petroleum extraction, transmission, or refining facilities near the airport may be off-site sources of PFAS migration onto airport property. Fluorosurfactants, including PFAS surfactants, are used for pipeline and other gas transportation clearing, condensate unloading, hydrocarbon removal, and paraffin solubilizing (Glüge et al. 2020). They can also function as a hydrocarbon foaming agent, which has a comparatively lesser density and aides in bringing condensate to the surface in gas wells with low gas rates (Buck et al. 2012). Fluorosurfactants can also increase the tension between the hydrocarbon and salt solution interface, which is effective for desalting and demulsifying applications (ICT 2021). PFAS and petroleum hydrocarbon fuels in the form of NAPLs may commingle at locations where fuels were used or disposed of (Brusseau 2018).

2.3.4 Wastewater Treatment Plants, Biosolids Applications, and Septic Systems

If there are wastewater treatment plants nearby, airport operators should consider whether PFAS have a reasonable probability of migrating onto airport property from affected environmental media such as soils, stormwater, or groundwater. PFAS may not be destroyed or removed by current municipal wastewater treatment methods for effluent or sludge, which means these chemicals may be conveyed to other areas in biosolids generated from the water treatment process (Sepulvado et al. 2011, Venkatesan and Halden 2013). Biosolids may be applied directly to land as fertilizers or allowed to reincorporate into soils through biodegradation. Biosolids containing PFAS can contaminate environmental media if they are applied directly to soils, or if, when dry, they become airborne as dust and deposit on other nearby properties. Septic systems are used to treat wastewater on-site. If septic systems are located on or near the airport property, PFAS derived from consumer products or industrial facilities could be introduced to the environment. Streams that receive wastewater treatment discharges may be adversely affected by PFAS.

Toolkit Tip

Tool 2.5: Tutorial for Assessing Off-Site Source Areas

- Step-by-step guide for determining historical and current industrial and commercial facilities near airport properties.
- Provides links to helpful government websites.
- Shows how to access and utilize data for assessing potential off-site sources of PFAS.

2.3.5 Groundwater Recharge

Dry wells are underground structures that may be used to artificially recharge groundwater supplies (USGS 2019). Often, surface water runoff, stormwater, and greywater are channeled into these wells, where the water moves underground. The porous-walled chambers allow the water to gradually infiltrate into the soil and recharge groundwater supply volumes. Surface water or stormwater affected by PFAS can contaminate aquifers or potable groundwater supplies. Groundwater near an airport property could then be affected by these adjacent land uses.

2.3.6 Agricultural Areas

Pesticides, fungicides, and herbicides that contain PFAS may be applied to agricultural areas on properties adjacent to the airport and could then migrate onto airport property through aerial deposition by dust or overspray, surface water or stormwater flows, or groundwater transport (Ogawa et al. 2020, OECD 2013, Glüge et al. 2020). Fluorinated chemicals can be found in pyrethroid control products and pesticides used to control mosquitoes, termites, wasps, and other agricultural pests (OECD 2013, BCPC 2021). Several fungicides containing fluorinated

For Your Information

- Consider reviewing SDS documentation for pesticides, fungicides, and herbicides routinely used on airport property.
- A desktop evaluation would show adjacent agricultural land uses where these products may also have been applied.
- While these products may be used outdoors in accordance with the manufacturer's instructions, they may contain PFAS.

functional groups may also be applied to ornamental or landscape vegetation. Many PFAS-containing commercially available herbicides may be used for controlling noxious weeds and landscaping. Pesticides, fungicides, and herbicides may be applied as emulsions by sprays, broadcast as dissolving pellets over soils, or as coatings or safeners on grass seed. One study assessed 10 insecticide formulations used in the United States and found perfluorooctane sulfonic acid (PFOS) in six of the products in concentrations ranging from 3.92 to 19.2 milligrams per kilogram (mg/kg) [3,920,000 to 19,200,000 parts per trillion (ppt)] (Lasee et al. 2022, PEER 2022).

In 2022, EPA announced a proposal to remove 12 PFAS chemicals from the current list of inert ingredients approved for use in pesticide products (EPA 2022g). Removal from the inert ingredients list would restrict the use of these chemicals in pesticide products in the future, if a request was made by a manufacturer.

2.4 Assessing the Presence of PFAS and Associated Activities

This section summarizes an approach to gathering information and understanding how AFFF-related activities and off-site activities may affect an airport's environmental condition.

2.4.1 Establish a Baseline

Conducting a baseline analysis and site assessment are helpful first steps for airports in determining their exposure risk.

A baseline analysis of past and present on-site AFFF activities and other potential off-site sources of PFAS will help an airport operator understand, plan, and mitigate possible adverse effects to ongoing operations or development activities. Airport operators should direct attention to former and current firefighting training areas as well as any release sites or disposal areas of PFAS-affected soil. Records reviews and desktop analyses can provide a guide for future site assessments by indicating locations of possible contamination and factors that may warrant further verification studies.

2.4.1.1 Records Review

For Your Information

When conducting a baseline analysis to evaluate PFAS risk, airport operators should verify that AFFF usage complies with FAA requirements and other applicable laws.

The first step in establishing a baseline is to review available records. A records review may find evidence about historical releases, including what was released, where, the duration, whether or how it was contained or remediated, where any waste materials were placed, and any other relevant information. Purchase orders; ARFF operational records, including emergency events and training; documentation of construction activity; equipment inspection sheets; spill documentation; disposal records; and chain-of-custody documentation are examples of possible information sources for conducting a baseline analysis of AFFF use. Airport personnel who have worked on-site for a long time may offer insight on finding information on emergency events, ARFF training, or other activities in which AFFF may have been used. While anecdotal evidence will need to be substantiated by a records review or other assessment method, senior personnel can help start a project by sharing their institutional knowledge.

Purchase Orders. In the past, market alternatives to traditional AFFF concentrate formulations with long-chain PFAS surfactant additives were limited to short-chain PFAS formulations that met MIL-SPEC criteria and were approved in the Qualified Products Database (QPD)

(DoD 2020). "Long-chain PFAS" is the shorthand terminology for PFAS molecules with eight or more carbon atoms in the alkyl chain and is often shortened in the context of AFFF to "C8" or "C8 foam." Certain long-chain PFAS AFFF formulations in the past may have included perfluorooctanoic acid (PFOA) or PFOS surfactants, which are the chemicals currently under the greatest regulatory scrutiny. Similarly, "short-chain PFAS" commonly refers to compounds with six or fewer carbons in the alkyl chain and may be referred to as "C6" or "C6 foam." While short-chain PFAS chemicals have not received the same degree of regulatory attention in the past, some may be regulated in the future. C8 foams were prevalent in the market from the beginning of AFFF's commercial production and use in the early 1960s through the mid-2010s. C6 foams emerged in response to EPA's voluntary PFOA stewardship program around the same time; however, C8 foams may still be present in facility inventories.

Consider reviewing historical purchase orders, invoices, and other procurement records to understand the quantities of AFFF ordered, stored, and used on-site in the past and the types of AFFF involved—that is, C6 or C8 foams. It may be possible to develop a rough time frame for how long and how frequently various types of AFFF were used on-site from these records. Often an Internet search for a specific product by brand name will reveal necessary information if there is uncertainty over whether a product contained C6 or C8 PFAS. With this information, it may be possible to determine the chemical compositions AFFF products used in the past and then to ascertain the various factors potentially affecting fate and transport on-site. These records, considered in conjunction with SDS documentation, should create a more comprehensive understanding of potential AFFF issues on-site.

ARFF Operational Records. Another way to identify the amount of AFFF historically used is to review ARFF operational and training records. Emergency records from crashes and fires may identify dates and locations where AFFF may have been used. ARFF training records could include

- Frequency of training,
- Type of equipment used,
- Frequency of equipment inspection, and
- Secondary containment measures.

Documentation of Construction Activity. An airport may also consider reviewing documentation of construction activity and municipal agreements such as records of soil or other fill materials received from off-site and soil movement. If soil or fill materials are suspected to contain PFAS, a construction record review might lend insight into whether soil was moved to another location at the facility or if it was moved off-site. If soil was moved off-site, the review should consider where it was moved. More discussion on this is provided in Chapter 3, Section 3.4.

Equipment Inspection Sheets. Airports should consider reviewing equipment inspection sheets to determine what ARFF equipment has been stored on-site. The records may serve to corroborate inventory records or incomplete purchase order or invoice documentation. Equipment inspection sheets may also be able to confirm the presence of fire suppression systems in hangars, transfer equipment, and other equipment that may contain or be used to move AFFF. Inspection sheets might also indicate whether any of the equipment was damaged, which could mean that there had been leaks or spills of AFFF.

Toolkit Tip

Tool 2.4: Tutorial for Conducting a Baseline Analysis

Step-by-step guide for determining historical weather data, identifying nearby water sources and wetlands, and locating wells.

This tool provides links to helpful government websites and shows how data can be accessed and utilized for a baseline review of AFFF exposure.

Spill Documentation. Airports should review spill documentation for mentions of AFFF or areas of suspected AFFF storage or use. If reviews indicate that spills occurred in areas that likely contained AFFF equipment or were used for transferring, testing, or training, then it is possible that AFFF was used in these areas. In the case of fuel spills, AFFF may have been deployed as a precautionary measure.

Disposal Records. Disposal records may provide insight into AFFF use and disposal methods. Airports may be able to determine prior AFFF use if there are records of contaminated environmental media, ARFF equipment use, or decontamination or disposal of spent AFFF following an emergency response. Disposal records can also show how the materials were designated and whether they were treated and disposed of as hazardous waste or discarded through municipal waste streams.

Chain-of-Custody Documentation. Chain-of-custody documentation may be one of the most useful resources for determining AFFF use and movement from sourcing to disposal. If chain-of-custody documentation is available, there may be records of procurement, use and transfer, and disposal. These records may provide insight into the extent of AFFF use on the property.

2.4.1.2 Data Analysis

After identifying AFFF application sites, the frequency of releases, the chemical signatures of AFFF used, and other factors listed above, airports may consider conducting a desktop analysis, which could provide insight into potential AFFF migration patterns. If the dates of AFFF accidental or intentional releases are known, airports may be able to research weather conditions to determine whether AFFF was likely to reach stormwater conveyances. Sensitive receptors that could be affected by PFAS contamination can be identified through a desktop analysis.

After locations of AFFF storage; use in training, emergency activities, testing, and maintenance; and disposal practices have been determined, the potential of release is assessed. The assessment considers the proximity of potential receptors, including water supply wells and surface waters such as reservoirs, rivers, and canals. A data analysis should assess whether potable water supply wells are downgradient of AFFF application areas. Stormwater can convey PFAS off-site or connect areas to other conveyances, such as groundwater, that could transport toward potential receptors. Therefore, locations of storm drains, drainage swales, and other areas where stormwater is stored, conveyed, or discharged should be identified.

More information on how to conduct a baseline analysis, including step-by-step guidance in how to navigate websites and retrieve data, is provided in Tool 2.4. Tool 2.7 provides a tutorial for conducting an AFFF exposure study. The fate and transport processes and factors that affect PFAS migration in environmental media are discussed in Section 2.5: Evaluating Fate and Transport.

What Is a Receptor?

A receptor is a natural or human-constructed feature that could be adversely affected by a substance such as PFAS.

Examples of receptors:

- Public or potable water supplies, such as groundwater and groundwater wells;
- Surface waters, such as reservoirs or rivers;
- Agricultural crops or fields where food for human consumption is grown; and
- Public utilities, such as sanitary sewer systems.

2.4.2 Investigating Potential Releases

Airport operators may find embarking on an investigation of PFAS to be a formidable task, given the unpredictability of what may be found and the scientific and regulatory uncertainty that exists. However, obtaining knowledge about the extent of an airport's past PFAS releases allows an airport operator to make more-informed decisions regarding PFAS risk.

Key principles for PFAS investigations include expert guidance, a conceptual site model (CSM), and goal orientation.

- **Expert guidance.** PFAS investigations should be directed and performed with input from qualified environmental professionals. A well-designed investigation will yield the most useful results and form the foundation for a plan to respond to what is discovered.
- **Conceptual site model.** Development of a CSM can aid an airport operator's risk management efforts by identifying how PFAS from the airport could affect humans or the environment and using that information to address the risk. A CSM identifies physical, chemical, and biological processes that cause contaminant migration and determines possible locations of groundwater and surface water affected by PFAS, such as pathways to drinking water wells or intakes in proximity to the airport. The CSM should consider surrounding industry and land uses as potential nonairport-related sources of PFAS. If PFAS data are available, they will make the CSM more useful in identifying and controlling pathways.
- **Goal orientation.** Airport operators should verify that their investigation, testing, and analysis has a specific goal. In a preliminary investigation, the goal should be to conduct a baseline assessment. Later, the goal may be characterizing PFAS impacts in the soil around a specific planned construction activity zone, characterizing PFAS impacts in groundwater sitewide, or determining whether known PFAS contamination in groundwater is moving off-site. Each scenario would require a slightly different investigation. Focusing on the specific goal and the steps to achieve that goal reduces project time and lowers project costs.

Involving legal counsel in PFAS assessments is worth considering. Some states recognize an environmental audit privilege—an evidentiary privilege that protects the results of an organization's internal environmental audit from disclosure during litigation. However, state laws on the topic vary, and understanding when and how to incorporate legal support will be location specific.

In nonlitigation contexts, because most airports are public or semipublic entities, state open records laws may compel disclosure of documents to a requesting third party, for example, the media, potential plaintiffs, or concerned citizens, unless a privilege or exception applies. The precise strategy will depend on applicable state law, the PFAS issue at hand, and the policy of the airport with respect to public disclosure. An airport can maximize protection of this information by having its attorney complete the following actions:

- Directing the environmental audit throughout the process from start to completion;
- Retaining and supervising necessary consultants;
- Attending relevant interviews;
- Taking part in communications, email exchanges, and creation of documents; and
- Labeling any documents created as confidential so that protections of the attorney-client privilege and attorney work product doctrine may fully apply.

Finally, the results of consultants' investigation and analysis should be added to an airport's risk management plan and distributed to the airport leadership team for their input and review. Airport leadership may also want to consider the investigation's findings in the context of wider airport planning development.

2.4.3 Assessment of Nonairport Activities

Airports may consider assessing PFAS exposure from nonairport sources, including tenants, fixed-base operators (FBOs), and joint-use facilities. Off-site sources from commercial or industrial facilities should also be considered if migration onto airport property through aerial deposition, groundwater transport, or surface water movement is possible given an airport's location.

2.4.3.1 Assessment of Tenant, FBO, and Joint-Use Facility Sources

During a PFAS exposure assessment, airports may also consider contacting tenants, FBOs, or the joint-use facility directly. They may have their own documentation regarding the chemicals used on-site, any training they perform, construction activities, and emergency events as well as other documentation relevant to determining the extent of PFAS used at their facility. Lease agreement documents may provide some insight into the activities associated with a facility's use. Reviewing this information could help investigators determine which facilities might warrant attention as part of the overall study effort.

2.4.3.2 Assessment of Off-Site Activities or Locations

Toolkit Tip

Tool 2.5: Tutorial for Assessing Off-Site Sources

- Step-by-step guide for determining historical and current industrial and commercial facilities near airport properties.
- Provides links to helpful government websites.
- Shows how to access and utilize data for assessing potential off-site sources of PFAS.

To determine potential off-site sources of exposure, airports may consider identifying nearby industrial or commercial facilities. Reviewing current and historical imagery available through Google Earth (https://earth.google.com) and topoView (https://ngmdb.usgs.gov/topoview/) may be a good starting point. Airports can follow up this review by researching information on the business, industrial site, or owner of the nearby property; this information is typically available on the county tax assessor's website.

Once the airport has narrowed down a list of potential off-site sources, information can be purchased through third-party environmental databases. Alternatively, the airport can utilize the Freedom of Information Act to acquire data from regulatory agencies about another business's activities. Chemical data reporting under the Toxic Substances Control Act provides information on the industries that regularly use PFAS chemicals and the relative quantities by industry, although some data are confidential and not reported (EPA 2021g). EPA also provides a tool called InertFinder that enables searches for inert ingredients in a variety of products by product use or trade name (EPA n.d.-d), as well as the Safer Choice program, which helps consumers identify PFAS-free product alternatives (EPA n.d.-h). These resources may prove useful when off-site activities or locations are being evaluated. More information on how to assess off-site sources, including step-by-step guidance on navigating the websites and resources described above, is provided in Tool 2.5.

2.4.4 Investigation Sampling Considerations

After a baseline analysis and site investigation, airports should consider whether sampling is appropriate for their situation. Airports should evaluate airport staff health and safety, the potential for receptor exposure, regulatory requirements, and future development plans as part of the decision-making process regarding sampling. The airport may find it prudent to sample in certain areas that may host future project sites to reduce the likelihood of delays and unexpected costs during development. Sampling mandates from state regulatory agencies may also require airports to sample for PFAS in environmental media or infrastructure materials. The following sections provide a high-level overview of what to include in sampling plans, how to incorporate environmental fingerprinting and forensic techniques, and how to evaluate available laboratory analytical testing methods.

2.4.5 Sampling Plan Development and Implementation

Sampling plans are used to document the reason for sampling, the type of media, the testing methods, and other details associated with sampling and analyses of environmental media. When prioritizing sampling areas, the airport may want to consider locations where the releases are suspected to have occurred on the property or on upgradient off-site or nonairport sources.

The airport should keep in mind that PFAS can migrate on and off the property and through different environmental media, meaning that the site of initial release may not be the site where PFAS accumulation occurs. Airport operators should consider contracting with independent service providers with experience in soil, surface water, and groundwater sampling for field collection of samples.

For Your Information

Consider adding sampling results to an existing airport GIS database.

In developing a sampling plan, there are different approaches based on the media being sampled and the method of sampling. Regardless of the media sampled and the method chosen, airports should always consider the potential for cross contamination. Generally, analytical laboratories have very low detection thresholds for PFAS, so any PFAS-containing items used during sampling could easily contaminate a sample and produce a false positive. If the airport is sampling for other contaminants of concern, it should consider sampling for PFAS before anything else, as used sampling containers may be composed of or contain PFAS and lead to cross contamination. Airports should also avoid using items that contain fluoropolymers during sampling collection or transport, including the following (Michigan EGLE 2018):

- Polytetrafluoroethylene (PTFE) and fluorinated ethylene propylene (FEP),
- Polyvinylidene fluoride (PVDF),
- Polychlorotrifluoroethylene (PCTFE), and
- Ethylene-tetrafluoro-ethylene (ETFE).

Many types of equipment and supplies used for environmental sampling may contain PFAS chemicals that could contaminate samples (ITRC 2018). Table 2-1 lists equipment used for PFAS sampling by category and general industry practices to avoid contamination (MassDEP 2021, Michigan EGLE 2018).

In addition, staff who are conducting sampling should also consider taking the following precautions to avoid the potential for cross-contamination of PFAS:

- Washing hands and putting on new nitrile gloves after each sample has been retrieved.
- Using chemical-free, or "natural," sunscreens and insect repellents.
- Avoiding cosmetics, moisturizers, creams, and other hand products that are more likely to come into contact with samples.
- Wearing synthetic or cotton fabrics that have been washed more than six times and avoiding any clothing or boots that are water or stain resistant.
- Bringing food in resealable plastic storage bags and aluminum foil, as opposed to prepackaging, and avoiding contact with fast-food wrappers.
- Utilizing ice instead of chemical frozen packs wherever possible.

A project health and safety plan should also be developed in accordance with appropriate Occupational Safety and Health Administration requirements as a part of the sampling plan to promote the safety and health of field staff.

2.4.5.1 Decontamination Procedures

Sampling and measurement equipment should be decontaminated before and after each use, and the clean hands/dirty hands method should be employed. Team members should put on a new pair of disposable, powderless nitrile gloves before decontaminating each piece of equipment. The equipment for sampling use should be placed into new, clean, clear plastic bags, and once these bags have been used, they should not be reused. No piece of decontaminated

Table 2-1. PFAS sampling equipment considerations to avoid potential cross-contamination.

Suggested for Use	Avoid Use
High-density polyethylene (HDPE) or low-density polyethylene (LDPE) bladders	PTFE tape or other consumables
Silicone tubing and silicone lubricants	Fluorinated lubricants, such as perfluoropolyether (PFPE)
Peristaltic pump or stainless-steel submersible pump	Waterproof coatings containing PFAS, such as GORE-TEX or Tyvek
Potable water followed by deionized rinse for decontamination and equipment washing	Municipal water for washing or decontamination
A clean, new pair of nitrile gloves for handling each sample	Chemically treated or recycled paper towels
Laboratory-provided sample containers that remain sealed until use	LDPE bottles or other unsealed plastic bottles
Polypropylene bottles or glass containers for samples and rinse water	PTFE-lined caps for sample containers or PTFE consumables of any kind
HDPE sheeting, regular ice, bubble wrap, and passive diffusion bags	Chemical ice packs (e.g., blue ice packs) and waterproof labels
Regular loose paper and paper products	Waterproof or treated paper or field books, including spiral-bound notebooks
Aluminum, polypropylene, or Masonite clipboards	Plastic clipboards, binders, or notepads
Regular ballpoint pens	Permanent markers
Plastic bags and aluminum foil	Nonplastic bags or food containers while on-site

equipment should be placed directly onto the ground, and equipment should be handled as minimally as possible.

If heavy equipment is required where the above process is impractical, the equipment should be cleaned with potable water by using a high-pressure washer or steam. This process should take place at a facility with secondary containment, to prevent the release of PFAS, and the potable water to be used should be tested in advance for PFAS. Rinsates, purge waters, and wash waters used to decontaminate equipment should be treated as PFAS-contaminated water. Soils and nonreusable equipment should also be treated as PFAS contaminated waste material and disposed of via an approved waste disposal facility.

2.4.5.2 General Quality Assurance and Quality Control for Sampling

Quality assurance (QA) and quality control (QC) procedures may vary according to the types of media sampled and site conditions, but sampling plan protocols should follow these general QA/QC standard operating procedures during the sampling effort:

- One blind duplicate sample collected per 20 samples, or a 5% QA/QC sample rate;
- One blind duplicate sample per sampling round for laboratory analysis check;
- One rinsate blank per day collected from each type of field-sampling equipment;
- One equipment blank per day collected for each piece of sampling equipment;
- One field blank collected per day; and
- One trip blank collected per sample storage container.

PFAS-free water, preferably deionized, should be ordered from the laboratory or obtained from a known, chemically clean source. Samples should be kept at or below 4°C by packing with frozen water ice only. To prevent contamination from melted ice within the cooler, extra sample bottles should be filled with PFAS-free water, sealed, and then frozen. These bottles of PFAS-free ice can then be used in sample coolers to maintain sample temperatures of 4°C or less. *Standard Methods for the Examination of Water and Wastewater* provides more-detailed instructions on general sampling procedures and QA/QC protocols see (APHA, AWWA, and WEF 2023).

Control Samples: Blanks. Field blanks should be collected by pouring PFAS-free water from the containment vessel into a sample container provided by the analyzing laboratory while on-site in the field. The sample bottle is then labeled in the same fashion as sample bottles and submitted to the laboratory for analysis. A trip blank should be ordered from the laboratory conducting the sample analysis and supplying the sample containers. It must arrive in the same packaging as the sample containers, and the trip blank should be inspected on arrival for breakage, leaks, or air bubbles. The trip blank must not be opened, and it should be returned to the laboratory within the same packaging as the samples. A rinsate blank should be collected immediately before equipment is used for sampling. PFAS-free water is poured over the equipment and collected in a laboratory-supplied water sample container. An equipment blank should be collected immediately after an item has been decontaminated, in the same fashion as the rinsate blank.

Control Samples: Duplicates. Blind duplicate samples should be collected by using the same methodology used to collect the original sample. The duplicate sample containers should be filled from the sample location, so that the chemistry is as close to identical as possible. It is important to label the blind duplicate sample, so that the laboratory cannot identify the sample as a duplicate. The two sample containers—the test sample and the duplicate sample should be opened simultaneously and each sample container filled to approximately 20% of the volume of the given container before the discharge of the sampling equipment is switched to the other sampling container. This process is then replicated, alternating back and forth between sample and duplicate sample containers until both containers are full.

2.4.5.3 Chain of Custody and Data Management

Each sample container should be labeled in ink in the field. Due to the potential for contamination from permanent markers, ballpoint pens should be used. Labels may be printed ahead of time and affixed to sample bottles, but confirm the labels or the adhesives do not contain PFAS chemicals. Each bottle should clearly show the sample date and time; incorporating the date and time into the sample identification number is suggested to avoid sample misidentification. Recording dates as year, month, and day and times according to the 24-hour system is preferred, but whatever method is chosen, the party responsible for directing the sampling effort should verify that the methods chosen for recording the date and time are used consistently on all labels and documentation.

Depending on the duration of the sampling effort and number of samples to be collected, this person should also be responsible for routinely checking or auditing containers and maintaining audit records, as appropriate. Each sample's identification number should be unique and reflect the sample's identity. For example, a subsurface soil sample collected from 2 ft below the ground surface at Borehole 1 within Site A on June 15, 2019, at 1:17 p.m. could read as follows: *2.0BH1SASubSurf201906151317*. Since no two boreholes will be sampled in the same location at the exact same time, this labeling convention allows all team members to decipher when and where a sample was collected, even if they themselves were not part of that particular sampling team. Using this method will expedite sample data analysis when reports return from the laboratory as well.

Chain of custody (CoC) forms must be kept by field personnel—preferably with one person designated as the responsible party—to document the possession of all samples collected from the moment of collection until the sample is disposed of. At a minimum, the CoC form must include the following information:

- Project name;
- Location, date, and time of collection;
- Name(s) of samplers;
- The unique sample identification number for each sample documented on the form;
- Sample type and any preservation measures used;
- Laboratory analyses required; and
- Date, time, and signatures for each transaction in which there is a change in sample custody.

Following is an example of a change in sample custody: The person who collected the sample hands the sample over to the laboratory, recording the date and time when the sample was submitted on the CoC form and signing it. Then the laboratory staff member receiving the sample puts the date and time received on the form and signs it; that person is now responsible for the sample until it is transferred to another responsible party and the CoC process is repeated.

Original CoC forms should be kept in sealable LDPE bags taped to the inside of the cooler or sample storage container or to the shipping container lid. Filled coolers with CoC forms affixed to the lids should be sealed with tape, and the responsible party should put her or his initials over the tape in pen. Copies of the CoC forms are kept by a designated member of the sampling team for the project's records.

2.4.6 Laboratory Analytical Testing Methods

There are currently multiple methods for laboratory analytical testing based on the environmental media containing the sample. In 2021, EPA published Method 1633, the first validated draft, for testing for 40 different types of PFAS (EPA 2021a). In June of 2022, EPA released the second draft method (EPA 2022g). DoD has compiled rigorous QA criteria for PFAS testing under the *Quality Systems Manual* (DoD and DOE 2019), and these criteria were used in validation studies for Method 1633. Once this testing method becomes a part of Clean Water Act compliance monitoring requirements through rulemaking, airports will have a way to monitor PFAS in wastewater, surface water, groundwater, soils, biosolids, sediment, landfill leachate, and fish tissue.

Several methods have been published for PFAS in drinking water, non-drinking water, and solid matrices, including EPA and ASTM methods, but validation studies for these methods have not yet been published. When determining the appropriate laboratory analytical testing method to use, airports should consider reviewing state regulatory requirements for PFAS analytical method compliance and target lists of compounds. More information about the methods used for testing, the specific PFAS types detectable by each method, and each method's applicability to different types of environmental media can be found in Tool 2.6, ASTM D7968-17a and ASTM D7979-20, and the EPA website (EPA 2020a, 2021c, 2022b, n.d.-b, n.d.-f).

For Your Information

A reliable PFAS fingerprinting program should

- Target the types and amount of individual PFAS compounds that can be measured in a sample.
- Identify the potential changes in the measured individual PFAS compounds in the sample due to environmental transformations.

Environmental fingerprinting and forensic techniques involve evaluating the source or age of environmental contaminants at exposed sites to establish who is responsible for paying remediation costs, predict accurate fate and transport, and implement efficient remediation strategies. A large array of forensic techniques has been developed, and these are available for common environmental contaminants. These techniques include chemical fingerprinting, signature chemicals, isotopic fingerprinting, mineralogical fingerprinting, atmospheric tracers, DNA fingerprinting, tree-ring fingerprinting, and contaminant transport modeling. Typically, specific fingerprints are generated that may be compared between samples and with suspected sources. To date, very few of the methods listed have been applied to PFAS. However, as of September 2023, there were four techniques available that are based on chemical analyses and statistical evaluations and include environmental fingerprinting: chemical fingerprinting via targeted analysis, total oxidizable precursors, total organic fluorine, and nontarget analysis.

For Your Information

ACRP Research Report 255 (Anderson et al. 2023) includes more information on source identification and differentiation techniques.

2.4.6.1 Targeted Analysis

Targeted analysis is used to identify and analyze the targeted PFAS compounds, including the type and amount of individual PFAS, in a sample. The chemical fingerprint of the sample is then compared with published source signatures in the scientific literature. Researchers may also use known fate and transport properties to aid in targeted analysis.

2.4.6.2 Total Oxidizable Precursors

Total oxidizable precursors are determined by oxidizing environmental samples in the laboratory and analyzing the number of individual PFAS before and after oxidation. This method can help predict the changes in PFAS signatures due to environmental transformations. Therefore, samples can be matched to source materials even if their fingerprints have changed.

2.4.6.3 Total Organic Fluorine

Collection of total organic fluorine data does not require sample preparation. This technique requires direct injection of an aqueous sample into a combustion ion chromatograph system. Similar methods used to test the concentrations of organic fluorine in a sample include adsorbable organic fluorine (AOF) and extractable organic fluorine (EOF). However, for AOF and EOF, the samples must undergo a preparation process before being analyzed by the combustion ion chromatograph system. In AOF testing, a 100-milliliter (mL) sample is passed through activated charcoal beds and is washed with a nitrate solution to remove inorganic fluorine. For EOF testing, a 100-mL sample is passed through a wax solid-phase extraction column. Then, PFAS are eluted with methanol from the column and concentrated to 1 mL. These three methods provide additional chemical signatures for source evaluation.

Toolkit Tip

Tool 2.6: Considerations for Selecting a Method of PFAS Testing

Guide for determining the appropriate laboratory analytical testing method based on the environmental media containing the sample and the anticipated or predicted PFAS compounds.

2.4.6.4 Nontarget Analysis

This technique involves the determination of unidentified PFAS profiles, that is, PFAS compounds without a known chemical structure or analytical reference standards, in a sample. Nontarget analysis can be used to obtain unique PFAS signatures on the basis of peaks of unidentified PFAS compounds present in the sample. This process may be used to report new PFAS, including the identification of novel structures and chemical formulas. While currently there are only nonstandard, or user-defined, methodologies for identifying PFAS compounds, increased interest from regulatory agencies could lead to the development of standardized methods for nontarget analysis.

Before the techniques described above are applied, the forensic investigation can help support the validity of sample data results by

- Collecting samples from representative locations;
- Avoiding cross-contamination during sampling, handling, and shipping; and
- Utilizing reliable and comparable analytical techniques for PFAS analyses across sets of samples.

Additional information on each forensic technique and specific considerations are provided in Tool 2.6. For more information on sampling, several guidance documents are available (DoD 2017, Michigan DEQ 2018, Government of Western Australia 2017). These sources provide information on materials and equipment used in PFAS-focused investigations as well as materials to avoid because of known or suspected PFAS constituents in those products.

2.5 Evaluating Fate and Transport

Previous sections in this chapter reviewed general PFAS characteristics, on-site and off-site activities potentially involving PFAS, and methods for establishing a basic understanding of possible exposure areas. This section covers how PFAS may migrate from or onto an airport property given how PFAS move in and through environmental media. Evaluating fate and transport depends on the type of environmental media involved, site characteristics, and potential exposure pathways. This section outlines PFAS transformation mechanisms and migratory pathways in soils and subsurface environments, groundwater, surface water, and air. Following are some of the factors affecting fate and transport:

- Local environmental characteristics;
- Physical and chemical parameters of the exposed media;
- Weather patterns and climatology at the release site;
- Type, structure, and surfactant properties of the released PFAS;
- Presence of other non-PFAS co-contaminants; and
- Circumstances surrounding the rate and duration of a release.

Each fate and transport process results in a variety of outcomes, some of which may result in chemical transformations, a change in the concentration of PFAS, or uptake by biotic or abiotic processes.

2.5.1 Transport in Soils and Subsurface Environments

PFAS may be released to soils and subsurface environments in the following representative scenarios:

- Surface applications;
- Leaks and spills during transport, handling, or storage;
- Exfiltration from sewer lines or leaching from storm drains;
- Waste storage, such as potential leaching from waste storage ponds; and
- Atmospheric deposition, including both wet and dry deposition.

If released to soils, PFAS tend to concentrate within or near the source area and are subjected to downward leaching by precipitation, flooding, or irrigation events through the dissolution of the soil-bound contaminant mass (Sepulvado et al. 2011, Ahrens and Bundschuh 2014) or via colloidal transport (ITRC n.d.-c). The result is a gradual vertical migration of PFAS toward groundwater. PFAS may disproportionately accumulate at interfaces, such as the soil–groundwater, air–groundwater, or NAPL–groundwater interfaces. For example, PFAS may be found within soil pores at the capillary fringe, which is the subsurface layer in which groundwater seeps up from the water table by capillary action to fill pores. PFAS may also be contained within a smear zone, which occurs when the water table fluctuates between historical high and low elevations, smearing PFAS across the soil. This situation could take place when AFFF is used to respond to petroleum fires, so that PFAS becomes mixed with light NAPL. The vertical migration through soil of PFAS partitioned at interfaces is slower, and these interfaces may be considered secondary PFAS sources. Figure 2-4 describes the process by which PFAS may move through soil and subsurface environments.

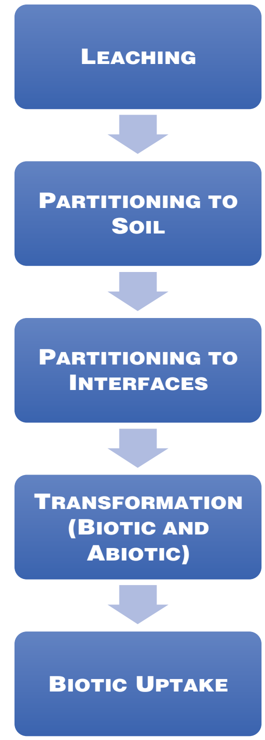


Figure 2-4. Fate and transport pathway for PFAS in subsurface environments.

Both biotic and abiotic PFAS transformation processes may occur in subsurface zones. Often, polyfluorinated compounds, or precursors, transform into perfluorinated compounds with shorter chain lengths. Basically, while the carbon–fluorine bond is very strong and not readily destroyed naturally, other bonds, such as the carbon–carbon bond, may break more easily. The result is a precursor transformation in which the area no longer contains the original PFAS compound but is now contaminated with several smaller fluorinated organic compounds. PFAS contamination in the environment at concentrations below the CMC may form hemimicelles or bilayer structures, which may result in increased PFAS persistence in subsurface areas exposed to AFFF or other PFAS (Yu et al. 2009, Du et al. 2014, Brusseau 2018). PFAS may persist in soil-bound source areas longer than other contaminants without this surfactant behavior, leading to contamination lasting for years to decades (Baduel et al. 2015, Guo et al. 2020).

Due to PFAS transformation in subsurface zones, the extent of contamination with fluorinated organic compounds at source areas could be substantially greater than the PFAS concentrations measured in samples, since most of the precursor compounds could not yet be identified with the methods available as of September 2023. In effect, PFAS subsurface transformation processes may alter the original signature of the released PFAS; therefore, the extent of PFAS contamination may be more difficult to measure with currently available technologies.

Soil characteristics, such as clay and organic matter content, affect how quickly PFAS will migrate through soils or where PFAS may accumulate. Vertical migration toward groundwater may be slowed, depending on the charge of the PFAS lipophilic head versus the charge of adsorbent subsurface substrates such as soils or other organic chemicals present in soils or groundwater. When PFAS are released to soils, the hydrophobic tails have an affinity for soil organic material, which increases retention in soils. At the same time, the negatively charged hydrophilic heads display electrostatic repulsion to the negatively charged soil particles, decreasing the soil retention of the released PFAS. That is, when PFAS lipophilic heads and adsorbent oil particles have opposing charges, PFAS micelles, hemimicelles, and bilayers may accumulate and persist in subsurface soils for a long time.

For Your Information

Surface applications over less permeable surfaces such as concrete may still result in PFAS migration into subsurface soils through absorption or diffusion.

Studies are underway to determine whether perfluorinated compounds can undergo biodegradation, but the data are inconclusive. PFAS may be removed from subsurface soils by plant uptake and biological sequestration, leading to decreased PFAS concentrations in soil. Additional information on PFAS released to soils and subsurface environments can be found in Tool 2.1.

For Your Information

PFAS subsurface transformation processes may alter the original signature of released PFAS; therefore, the extent of PFAS contamination may be more difficult to measure with currently available technologies.

2.5.2 Transport in Groundwater and Surface Water

PFAS may migrate from source areas into groundwater by gradual vertical migration in unsaturated soils through a series of mechanisms, including leaching and colloidal transport. PFAS typically dissolve in groundwater and may travel long distances by advection, generating long contamination plumes that may extend over several miles. PFAS transport in groundwater may be affected by adsorption to

Toolkit Tip

Tool 2.2: Guide to PFAS Fate and Transport in Surface and Groundwater Environments

Considerations and factors affecting fate and transport in surface and groundwater environments.

the organic fraction of soils in the saturated zone as well as by diffusion in and out of lower-permeability soils or bedrock. With partitioning to soil, PFAS lateral migration in groundwater slows, leading to decreased PFAS concentration in groundwater. However, back-diffusion out of these low-permeability materials may result in the long-term persistence of PFAS in groundwater even after source removal and remediation (ITRC n.d.-c). Due to matrix diffusion, the interface of low-permeability layers and groundwater could be considered a secondary PFAS source. Figure 2-5 describes the process by which PFAS may move through groundwater and surface water. PFAS also dissolve in surface water, where they may be sequestered in sediments by processes influenced by the organic matter content of the sediment, may partition to air–water interfaces, or may form foams at higher concentrations and under certain conditions. In still bodies of water, or lentic systems, PFAS may gradually increase in concentration, while in flowing water, or lotic systems, concentrations of PFAS may remain constant or gradually decrease away from the source. Uptake by fish, aquatic organisms, and plants may also occur in surface water, and long-chain PFAS containing eight or more carbons are known to bioconcentrate in aquatic organisms (ITRC n.d.-b).

PFAS may be subjected to biotic and abiotic transformation in water. As for PFAS in soil, these processes typically involve precursor transformations that potentially result in significant increases in total PFAS concentrations and distinct signatures away from the source zone. PFAS signatures in surface water generally do not change significantly over long distances, which would suggest precursor transformations may be less significant in this medium. However, more research is needed to better understand the factors governing PFAS transformations in

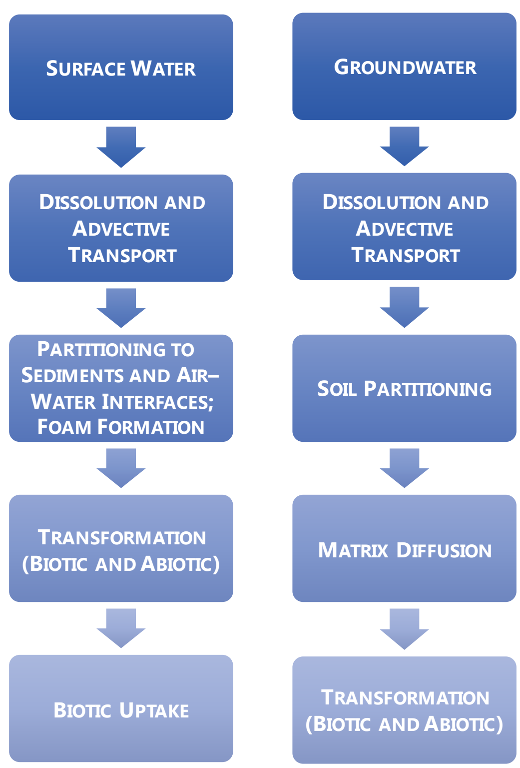


Figure 2-5. Fate and transport processes for PFAS in groundwater and surface water.

surface versus groundwater. Additional information on PFAS transport and processes in water can be found in Tool 2.2.

Toolkit Tip

Tool 2.3: Guide to PFAS Fate and Transport in Air

Provides considerations and factors affecting fate and transport in air.

2.5.3 Release to Air

PFAS may become airborne when in contact with air or when inadvertently aerosolized during use. PFAS products or materials may be released to air through the following uses:

- Surface applications of products;
- Handling;
- Construction and demolition activities; and
- Waste storage, treatment, or disposal activities.

Most classes of PFAS may partition to particles suspended in air or to liquid droplets dispersed in air. Partitioning to air occurs when concentrated PFAS in contaminated surface water or soil are picked up by wind and aerosolized as airborne dust particles. PFAS are typically transported short distances in air. However, once airborne, volatile PFAS may occur in a gaseous state (e.g., fluorotelomer alcohols) or may be incorporated within aerosols and other particulate matter in the air and then potentially travel long distances. Wet and dry depositions are the major mechanisms of removal of PFAS from the atmosphere and can occur from the scavenging of particle-bound PFAS or partitioning of gaseous PFAS to water droplets (Dreyer et al. 2010, Barton et al. 2007, Hurley et al. 2003). Figure 2-6 summarizes the process by which PFAS may move through air.

PFAS may also transform in air due to photooxidation processes (ITRC n.d.-b). While direct photolysis of PFAS has not been observed, indirect photolysis of some precursors was shown to occur in the atmosphere, resulting in significant contributions to the deposition of perfluoroalkyl carboxylic acids (PFCAs) and perfluoroalkyl sulfonic acids (PFSAs) (Armitage et al. 2009, Yarwood et al. 2007, Ellis et al. 2004). Some precursor compounds may transform into more stable carboxylic perfluorinated acids, such as PFOA. Additional information on PFAS released to air can be found in Tool 2.3.

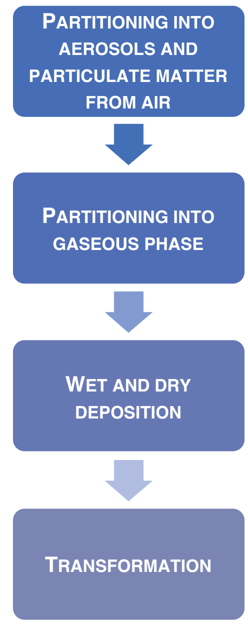


Figure 2-6. Fate and transport processes for PFAS in air.

CHAPTER 3

Policies, Procedures, and Operations

Chapter 3 Topics

- Procurement and recordkeeping strategies to control AFFF liabilities
- Modifying ARFF procedures to enhance staff safety
- Assessing possible modifications to current waste, stormwater, and environmental management programs to mitigate risk
- Construction management policies and procedures to limit PFAS exposure and regulatory risk

For Your Information

Inventory management planning may better prepare airports for upcoming PFAS regulations and litigation. Practices include

- Developing an inventory and tracking system documenting the foam composition, brand, age, and manufacturer;
- Tracking AFFF in storage, on vehicles, and other operational areas;
- Labeling containers;
- Tracking use and transfer volumes; and
- Maintaining records of any accidental releases.

The overall goal of Chapter 2 was to help airport operators establish a baseline understanding of current on-site conditions. Chapter 3 focuses on how airport operators can modify their current policies, procedures, and operating methods to reduce potential adverse impacts and liabilities.

3.1 Procurement Policies and Procedures

Procurement considerations for AFFF include meeting applicable firefighting foam performance standards and reviewing environmental data, where available, from a product's specification. A revised MIL-SPEC (MIL-PRF-32725) for F3 alternative formulations has been published (DoD 2023), and at least one F3 product had been approved as of September 2023. Airport operators should review their procurement programs to confirm that the policies and procedures adequately address the transition from AFFF to F3 products.

3.1.1 Procurement Product Review and Approval

As part of the product approval process, product content labels and SDSs are reviewed for possible issues, but this may be insufficient with regard to AFFF or F3 alternatives, as surfactant additives might still be considered proprietary and not provided. For future purchases, product subsampling and laboratory analysis (see Tool 2.6 for laboratory methods) for regulated PFAS to verify product contents prior to purchasing may be considered. Currently, laboratory costs for this kind of sampling are usually in the range of a few hundred dollars per sample.

If subsampling and laboratory analysis are infeasible, published information from state or federal regulatory agencies; data reviews of information from "green chemistry" database providers such as EPA's Safer Choice program (EPA n.d.-h); or consultations with industry counterparts, environmental professionals, and local laboratory service providers may be resources to confirm product contents.

If a product contains fluorinated organic chemicals, the following actions may be considered:

- Include the product in inventories of airport-regulated chemicals and track the product's procurement, handling, storage, and disposal with records kept and CoC protocols in place as if it had already been designated a hazardous substance.

- Determine appropriate disposal methods and establish product disposal protocols.
- Investigate available fluorine-free alternatives, then consider transition planning and costs.
- Review possible spill scenarios and consider changing standard operating procedures for spill control and cleanup, if warranted.
  - Update spill response procedures, health and safety protocols, and staff training or educational materials as necessary.
  - Procure appropriate personal protective equipment (PPE) and cleanup materials if the products currently used are insufficient.
- Limit personnel access and verify that designated users have appropriate training in handling, storage, use, and disposal procedures, including inventory tracking protocols.
- Restrict use or storage in areas where direct contact with the environment, stormwater infrastructure, or sanitary sewer infrastructure is possible in a spill event.
- Reduce product handling or use to the minimum amount necessary until replacement with a fluorine-free alternative is accomplished.

Toolkit on Policies, Procedures, and Operations

Appendix B provides supporting materials that provide a starting point for addressing and altering policies, procedures, and operations at the airport in response to PFAS legal and regulatory changes. While these resources are not a comprehensive list of everything an airport may need, they can help during airport planning to reduce risk related to AFFF use.

Appendix B is available on the National Academies Press website (nap.nationalacademies.org) by searching for *ACRP Research Report 262: PFAS Management at Airports: A Guide* and looking under "Resources."

Tool 3.1: AFFF Inspection Checklist

Template checklist for monthly inspections of AFFF storage areas, containers, and equipment.

Tool 3.2: Template for Job Hazard Analysis

Customizable hazard analysis tool with a corresponding risk assessment matrix and outline of hazards and controls for AFFF handling and transfer.

Tool 3.3: Federal Regulations for Hazardous Waste Generation

Checklist of requirements for airports that produce hazardous waste.

3.1.2 Inventory Management Procedures

As of September 2023, there were no federal standards for PFAS reporting or inventory management directly applicable to airports. To maintain an inventory of AFFF materials currently stored on-site, first reference the purchase orders and waste manifests on file. As part of inventory assessments or audits, gather information about AFFF materials on-site (e.g., SDSs) from the distributor, manufacturer, or from the product's website. Airports can document where these items are located, how they are stored, and how much is present, including the number and types of containers and their respective volumes. Inventory inspection forms can also note the product's apparent use, a product description, and any other identifying information, including information on container hazard labels.

Because PFAS chemicals are not currently recognized as hazardous substances, PFAS constituents in AFFF products could potentially be unidentified on SDSs or may only be labeled as "proprietary ingredients," "proprietary fluorinated surfactants," or "inert ingredients." In this case, the manufacturer may be willing to provide this information if contacted, or resources such as EPA's Safer Choice website (EPA n.d.-h), InertFinder website (EPA n.d.-e), or Toxics Release Inventory (TRI) website (EPA n.d.-i, n.d.-j) may be able to provide details on the AFFF product's contents.

For Your Information

A Chemical Abstract Service (CAS) number is a chemical identification number assigned by CAS and can be found at https://commonchemistry.cas.org/.

In addition to ARFF facilities, fueling and fuel storage areas, emergency response equipment and material storage areas, chemical delivery and receiving areas, maintenance facilities and storage areas, and other locations where AFFF may be used, handled, or stored can be inventoried. When documenting AFFF materials and equipment during an on-site inspection, record the following:

- Description of the AFFF-containing product or equipment;
- Product manufacturer;
- Type of AFFF product (if known);
- Chemical Abstract Service (CAS) numbers (if applicable);
- Product location with descriptions for how to access the item;
- Product quantity per container and number of containers;
- Condition and type of product containers (e.g., plastic barrels), and whether these are the original manufacturer's containers;
- Product's intended use;
- Surrounding storage conditions, including secondary containment or potential access to the outdoors;
- Repairs or alterations made to containers or equipment; and
- When the product was received at the facility and by whom.

A CAS number is a chemical identification number assigned by CAS. CAS numbers can be found at https://commonchemistry.cas.org/ if they are not available on an SDS, invoice, purchase order, or material packaging. Having a CAS number is helpful for identifying the exact material present, but a CAS number may not be provided if PFAS constituents are considered proprietary or in trace amounts.

Toolkit Tip

Tool 3.3: Federal Regulations for Hazardous Waste Generation

Checklist of regulatory requirements for airports that produce hazardous waste.

In addition to product inventories, airport operators can retain the following documentation of disposed materials or products:

- Quantity disposed and descriptions of disposal containers,
- Final disposal facility's contact information,
- Disposal transport company's contact information,
- Waste tracking numbers, and
- CoC forms with the date and time of pickup that are signed both by the party surrendering the materials and the party accepting them.

Inventories should be updated as changes occur, and airport operators may want to consider a full inventory review annually.

3.2 Waste Management and Disposal Options

The Resource Conservation and Recovery Act (RCRA) dictates the proper management of hazardous and nonhazardous solid waste (EPA n.d.-c). If PFOS and PFOA are designated as hazardous substances, operators may need to enhance procedures for identifying, collecting, and disposing of hazardous and nonhazardous waste. It is important to monitor EPA's website for announcements regarding the hazardous waste listing of PFAS compounds. Some states may have more stringent requirements, so websites and information from state regulatory agencies should also be routinely reviewed to verify compliance. This section covers how to review and update waste management procedures if PFAS is designated as a hazardous waste.

3.2.1 PFAS Status Under RCRA

EPA's Council on PFAS developed the PFAS Strategic Roadmap, which outlines the key actions EPA intends to take, including adding the following four PFAS compounds to the list of RCRA hazardous constituents: PFOA, PFOS, perfluorobutanesulfonic acid (PFBS), and hexafluoropropylene oxide dimer acid (HFPO-DA or GenX). If listed under RCRA, these compounds will be subject to requirements for corrective action and may become listed as hazardous waste (EPA 2021b). Further information about the financial, legal, and regulatory policy implications for airports is provided in Chapter 4.

Listing PFAS under RCRA could have an impact on an airport's environmental and waste management programs. EPA's action would require airport operators to reevaluate existing waste streams, and this, in turn, might result in additional waste-associated handling, storage, use, and disposal requirements and possible modifications to procurement protocols. The action could also potentially change a facility's status as a hazardous waste generator. RCRA, however, is not retroactive and will not impose hazardous waste obligations on purchases or use of AFFF prior to the date those materials were first regulated under RCRA. If RCRA listing occurs, the disturbance of soils containing listed PFAS compounds may be considered "generation" and thus subject to RCRA hazardous waste requirements.

More information on definitions of hazardous generator categories is available at EPA's Categories of Hazardous Waste Generators web page (EPA n.d.-a). Additionally, Tool 3.3 summarizes federal regulations for hazardous waste generators. States may have different limits on hazardous waste quantities and other restrictions, so airport operators should check with their state regulatory agency for additional requirements. Furthermore, hazardous regulations can be amended, and airport operators should periodically check EPA and state agencies for updates.

3.2.2 Currently Available Disposal Methods

Although many lines of research are currently underway, as of 2021, EPA has only suggested two forms of PFAS waste disposal: destructive incineration and long-term storage, either at a hazardous waste landfill facility or through underground injection into Class I deep injection wells (EPA 2020b). EPA recommends a limit of 2 to 5 years' on-site interim storage if immediate destruction of the material is not necessary before the ultimate disposal. When decisions are being made as to whether to temporarily store PFAS-containing materials on-site or send materials for disposal, EPA recommends the facility storing the materials consider its ability to effectively handle and temporarily store the materials in a manner that will prevent environmental exposure. This should be weighed against the efficacy of currently available disposal methods before a course of action is decided on. These considerations include the availability and costs of destruction and

For Your Information

Even though PFAS are not regulated as hazardous, EPA published recommendations and guidelines for PFAS waste management in 2021.

disposal options, the type of PFAS compounds in the material and their concentrations, and whether interim storage on-site is a viable option until more technology is developed (Holland & Hart LLP 2021, EPA 2020b).

Issues have been noted for both destructive incineration and disposal through long-term storage. Incineration currently requires high temperatures and large amounts of energy to completely degrade and defluorinate PFAS. Also, the effects of waste fumes and methods to remove fluorinated particles from incineration plant discharges to air are still being researched (EPA 2020b). Landfills have historically accepted PFAS waste, and studies have found PFAS in landfill leachate. Deep well underground injection is only applicable for liquid waste, and PFAS interactions within these wells remain unknown.

3.2.2.1 Destructive Incineration

Thermal technologies such as specialized commercial incinerators and kilns can achieve the necessary temperatures and residence times to break the chemical bonds in PFAS waste. Incineration is an effective and approved method for destroying other halogenated organic compounds, such as polychlorinated biphenyls (PCBs) and ozone-depleting substances (Gullett and Gillespie 2020). Some facilities have a 99.99% destruction efficiency for non-PFAS organic chemicals through combustion processes; however, few data are available on PFAS destruction efficiencies. As of 2021, only commercial incinerators permitted for hazardous waste destruction and lightweight aggregate kilns have been successfully used for PFAS destruction, so disposal facilities implementing one of these disposal technologies could be a viable disposal option where available (EPA 2020b).

PFAS are difficult to destroy thermally because of the carbon–fluorine bond, which requires at least 1.5 times more energy to break than a carbon–hydrogen bond. Incomplete defluorination could lead to the formation of new PFAS compounds or other products of incomplete combustion (EPA 2020b). However, there is promising research promoting the ability of oxidation to break apart the fluorinated chains and lead to 35% to 95% defluorination, depending on the chain length of the PFAS compound (Liu et al. 2021).

Assessing the capabilities of various PFAS incineration technologies is currently limited by the inability to accurately compare the amount of PFAS in soil media before incineration with the quantity of fluorine in emissions from the incineration process. In a joint study by EPA and the Strategic Environmental Research and Development Program (SERDP), a modified EPA Method 0010 was used in conjunction with an emerging technology for incinerator stack scrubbers to successfully quantify PFAS concentrations in contaminated soils (Ryan and Gullett 2020). Researchers doped soil samples with known, isotopically labeled PFAS compounds to serve as indicators or benchmarks of method measurement quality. Contaminated soil samples were analyzed and compared with emissions samples collected at incinerator stack scrubber outlets. This modified approach allowed researchers to compare measurements of fluorine emissions from incinerator stacks with original quantities within the incinerated materials. With further development, this method could be used to confirm that fluorinated emissions are fully captured by exhaust scrubbers and not released to the environment.

3.2.2.2 Long-Term Storage Disposal: Landfills

As an option for long-term disposal, landfills can receive PFAS-containing materials as part of a municipal waste stream. In particular, landfills accept solid waste, such as storage containers or exposed materials, that would otherwise need to be stored on-site or sent to a hazardous waste storage or incineration facility. Landfills are often more numerous, in closer proximity, and, depending on the waste, more affordable. However, many landfills are not accepting sizable amounts of PFAS-containing substances, which may be a response to current regulatory uncertainties and a situation that could improve over time.

Hazardous waste and municipal solid waste landfills can contain and prevent PFAS from reaching the environment when they are constructed with modern controls. Without modern controls, PFAS may be released to the environment through landfill leachate. EPA is currently researching the effects of PFAS on liner integrity, gaseous emissions from landfills, and PFAS quantities in landfill leachate by compound type. Given the uncertainty regarding PFAS fate and transport in landfills, more research is needed to evaluate the feasibility of this disposal method. Historically, landfill operators have not been required to treat leachate for PFAS, so ongoing research is focusing on methods for PFAS destruction in leachate media. Oxidation treatment technology shows promise but is still in the preliminary phases of development (EPA 2020b).

3.2.2.3 Long-Term Storage Disposal: Underground Injection

Underground injection is another currently viable disposal method for liquid PFAS waste, but only a few deep injection well facilities in the U.S. are accepting PFAS waste. Under the Safe Drinking Water Act (SDWA), EPA is authorized to regulate the permitting of underground injection facilities to verify that injection wells will not affect underground sources of potable water. These facilities are regulated under EPA's Underground Injection Control Program, and well types are categorized by the type of waste stored into Classes I–IV (2020b).

Class I wells are authorized to accept municipal wastewater, radioactive waste, hazardous waste, and nonhazardous industrial waste and, as such, are suited for disposal of liquid PFAS waste. Extensive testing and monitoring requirements are mandated for Class I wells by the Underground Injection Control Program under 40 CFR Parts 144–148(EPA 2020b), but PFAS fate and transport mechanisms in these locations are unknown because of the lack of information about the chemical and physical properties of specific PFAS compounds. It is unknown whether the geochemical properties of injection sites will affect the chemical behavior of certain PFAS. As such, the viability of underground injection as a possible disposal option may change on the basis of the outcome of future research (EPA 2020b, Roesch et al. 2020).

3.2.3 Emerging Disposal Technologies

EPA has identified key areas in which more research is needed to better understand the efficacy of potential degradation, destruction, and disposal practices. This includes information on chemical and physical characteristics related to PFAS persistence, which is needed to identify appropriate treatment methods for a given PFAS compound. EPA also plans to reevaluate the performance of existing degradation and destruction methods with a particular focus on breaking the carbon–fluorine bonds and the possible harmful substances created by incomplete destruction. Although critical to guidance and policy development, research is often hampered by current technological inadequacies regarding individual PFAS compounds or precursor identification and the ability to accurately measure small quantities in samples (EPA 2020b).

Research into thermal destruction methods that use less energy to successfully degrade and completely defluorinate PFAS molecules is ongoing, and some possibilities for technology with enhanced efficiency have been identified. Direct contact with flames is likely to improve the efficiency of PFAS destruction. Calcium and aluminum may be added as catalysts to lower the temperatures necessary for complete destruction, even within the moderate temperature range of 200°C to 900°C, or approximately 400°F to 1,650°F. However, fluorinated gas byproducts from this method may cause damage to the ductwork system if wet scrubbing and semidry scrubbing are not installed (EPA 2020b).

EPA and DoD are funding research on end-of-life management for wastewater sludge and landfill leachate, primarily through thermal treatment, advanced oxidation processes, and other long-term disposal options. Thermal treatment research focuses on temperature variations, residence time, the effects of different catalysts, and minimizing products of incomplete combustion. More-accurate methods of sampling are also needed to determine the viability of incineration for fully destroying PFAS. To determine the effectiveness of full-scale PFAS thermal treatment, EPA is partnering with various thermal treatment facilities worldwide, as substantial sampling data are required (EPA 2020b).

Current nonincineration options for PFAS destruction have failed to demonstrate the complete defluorination of PFAS substances. Preliminary research into UV remediation methods showed 35% to 95% defluorination, but the degradation efficiency varies for different PFAS compounds varies. Some UV technologies show promise for PFAS degradation, but these alternatives have only been tested within small-scale laboratory settings using free aqueous electrons to break apart carbon–fluorine bonds. However, most of these UV methods require a large amount of energy, so scaling of experiments for practical applications has proven difficult (Lee et al. 2016). There are also public health concerns about radiation leakage at the treatment plant scale, but these concerns could be addressed by installing proper controls at wastewater treatment plants (EPA 2020b).

In the near term, EPA intends to focus on sampling and analysis methods that more accurately quantify PFAS in environmental media and waste streams. In studies evaluating the effectiveness of current technologies, high-resolution mass spectrometry has shown the most promise. EPA is also partnering with the PFAS Innovative Treatment Team to expedite reviews into the identification and testing of novel solutions to PFAS destruction (EPA n.d.-g). These include nontraditional thermal treatment, photolysis, hydrolysis, catalysis, and bioremediation (EPA 2020b).

3.3 ARFF Operations and Safety

AFFF is handled by ARFF staff in and around ARFF facilities during aircraft rescue operations, training, testing, and accidental discharges from deluge systems in aircraft hangars (Figure 3-1). In addition, ARFF staff work with AFFF concentrate when periodically removing and replacing AFFF concentrate in ARFF vehicles. As of October 2019, ARFF staff are no longer required to flow foam during training exercises or for maintenance purposes (FAA 2021b, 117th Congress of the United States of America 2019).

Figure 3-1. ARFF staff responding to a private aircraft crash just outside of a general aviation airport.

Figure 3-2. Key phases of an ARFF management strategy.

This section addresses ARFF facilities and equipment, including considerations for storage procedures, equipment testing and maintenance, and spill prevention and cleanup, as illustrated in Figure 3-2. The section also provides options for ARFF training and health and safety considerations such as PPE practices, equipment decontamination, and enhancements to fire response plans. The section ends with a discussion of the transition to fluorine-free alternatives to AFFF, the regulatory progress, and steps to prepare for equipment decontamination or replacement.

3.3.1 ARFF Facilities

ARFF facilities contain storage areas for ARFF equipment and vehicles; equipment testing, maintenance, and training activities typically occur in or around the facility. More information about ARFF facilities is available in *ACRP Research Report 173* (Thalheimer et al. 2017).

3.3.1.1 AFFF Storage

FAA requires an on-site reserve supply of firefighting foam of sufficient quantity to fill all ARFF vehicles with at least twice their assigned capacity. This reserve supply of AFFF may be stored in a single container, a storage tank, or a storage area and is known as bundled storage. FAA regulations dictate the amount of AFFF concentrate that should be stored on-site based on the size of the airport and the types of aircraft serving the airport (14 CFR 139.315, 139.317).

Proper storage of AFFF concentrates greatly decreases the likelihood of accidental releases or spills and prolongs the shelf life of the product. AFFF concentrate should be stored in ARFF vehicles, on-site in manufacturers' containers, in storage tanks designed for AFFF, or within hangar dispersion systems. Regardless of how AFFF is stored within a facility, the storage facility itself should be an enclosed area with a concrete or asphalt floor to provide general secondary containment. The design and construction of containment areas should consider the following:

- Volume to be stored;
- Access points;

For Your Information

Airports should check manufacturer guidance for storage conditions.

Recommended temperatures for AFFF concentrates range from 36°F to 120°F (2°C to 49°C).

- Location on the property;
- Transfer operations;
- Spill controls and cleanup equipment and materials;
- Surface materials, including flooring; and
- Storage procedures outlined in SDSs.

There may be additional considerations to prevent accidental damage and AFFF release from manufacturer containers or storage tanks. First, the area should be protected from vehicles and equipment that may accidentally contact and damage the containers. Containers should also be stored on level ground above hard, impermeable surfaces to avoid absorption or infiltration of liquid materials. It may also be advisable to use a properly sized and constructed rack system for totes, drums, and tanks. Finally, the need to stack or crowd containers should be reduced or avoided where possible.

ARFF trucks and mobile units should be located within contained areas during AFFF transfer and loading operations. Drainage from vehicle bays where ARFF trucks are regularly stored and maintained should provide containment, with no floor drains or mechanisms that would allow spills or leaks to migrate. If floor drains are present and necessary for conducting regular operations, these drains should be equipped with shutoff valves or systems to plug the drains for containment. Valves or plugs should remain in the closed position to provide containment from accidental releases. If drains are present, the discharge should be directed to the sanitary sewers with appropriate permit authorization.

AFFF should be stored downwind and away from areas such as break rooms, meeting areas or conference rooms, fitness gyms, and training locations where ARFF personnel are regularly present. It may also be beneficial to verify that storage areas have proper ventilation if inhalation of aerosolized AFFF is a possibility. Proper storage strategies may also be more cost-effective over time, as many AFFF concentrate products will remain viable for 20 to 25 years if stored correctly (Thalheimer et al. 2017).

Airports may want to consider how transfer operations and equipment can be integrated with storage areas and ARFF vehicles or equipment. Locating or relocating AFFF product storage to an area close to where filling activities take place can limit travel distances. Finally, training in health and safety and standard operating procedures for handling and transferring AFFF should be conducted.

3.3.1.2 ARFF Equipment Testing and Maintenance

For Your Information

Per changes in FAA policy published in CertAlert 21-01 (FAA 2021a), Part 139–certificated airports are no longer required to flow fluorinated foam during training exercises or for maintenance purposes.

ARFF departments are required to maintain their ARFF vehicles and their fire suppression operating systems. FAA recommends conducting vehicle system testing within 6 months of the periodic airport certification safety inspection (FAA 2021a). Airports must maintain proper documentation of testing and have the documentation available during the periodic inspection. This testing ensures the vehicle is proportioning the AFFF and water within tolerance and demonstrates that the operator is knowledgeable about the equipment.

FAA has released guidance for inspecting the AFFF proportioning system and testing AFFF systems. FAA CertAlert 16-09 advises airports to inspect their vehicles, foam trailers, and bulk storage tanks for crystalized particulates, which have been found in some AFFF tanks on ARFF vehicles (FAA 2016a). Such particulates may affect the AFFF proportioning system and AFFF production. FAA suggests using a heavy-duty flashlight to check for these particulates, which may settle at the bottom of tanks. If particulates are found, samples should be sent to FAA (ITRC n.d.-b). In 2021, FAA published CertAlert 21-01 (FAA 2021a), which allows airports to use one of the following technologies to test AFFF systems without dispensing AFFF:

- ECOLOGIC system from E-One,
- NoFoam System,
- Eco EFP (Electronic Foam Proportioning) System from Oshkosh, and
- FIXMIX 2.0E Input-Based Proportioning Test System from Rosenbauer.

ARFF departments should contact their vehicle manufacturer for information on necessary modifications to begin using these testing systems.

In addition, implementing an inspection program to review and document the condition of storage areas, containers, and equipment should be considered. During inspection and maintenance activities, the condition of transfer hoses, piping, containers, and equipment should be inspected for deterioration, abrasion, and leaks. Hose or piping connections should be checked prior to any product transfer and during equipment testing. Tool 3.1 provides suggested considerations for developing or improving an AFFF inspection program.

Toolkit Tip

Tool 3.1: AFFF Inspection Checklist

Template checklist for monthly inspections of AFFF storage areas, containers, and equipment.

3.3.1.3 Fixed Fire Suppression System Testing and Maintenance

Potential AFFF releases from fixed fire suppression systems are a concern for operators.

Proportioning devices on AFFF fixed systems should be flow tested every 5 years to maintain compliance with fire codes and safety regulations. Fixed systems should have a test header, which allows flow through the proportioning device by isolating the system from the test header. The test header allows a hose to be connected to the valves; the hose then discharges the AFFF directly into a collection tank or a tank vehicle. The foam can then be disposed of properly. For acceptance testing of new AFFF systems, environmentally friendly surrogate chemicals can be used to test proportioning equipment and verify the proper ratio of foam and water without the need to use AFFF.

3.3.1.4 Spill Prevention and Cleanup

Airports should consider revising applicable spill prevention and control plans to incorporate elements for deployed foam containment, collection of foam runoff, appropriate PPE for response staff, and disposal methods.

Initial mitigation efforts following a release of AFFF should include source control and containment and removal of the affected media. Given the highly miscible nature of AFFF, reducing the footprint of the spread of foam and water as soon as possible after the release is suggested. For accidental spills or leaks on a small scale, spill kits with cleanup equipment and materials should be located near operations involving AFFF to allow for quick cleanup and reduced potential for contamination. Preliminary efforts to contain runoff from larger releases include installing temporary dikes, berms, or dams and blocking storm drains, culverts, or other conveyances.

For Your Information

A more thorough discussion of remediation technologies and considerations is available in Chapter 4, Section 4.3.

Most hangars with fixed fire suppression systems are required to have a drainage system capable of handling sprinkler and foam system discharge in quantities that are typically thousands of gallons per minute. Codes also require an oil–water separator, which should be bypassed during a foam discharge event. Older hangars may not have drainage systems capable of the full system flow rate, and facility improvements or upgrades may be necessary to contain and control future foam discharges. Fire codes generally focus on removing burning fuel from a hangar and discharging it to a safe location away from the building. These codes often do not mandate a specific form of deployed foam containment, other than meeting local environmental requirements. Therefore, containment has typically involved discharging to lined or unlined ditches, detention or retention ponds, other conveyances, or storage tanks. It may also be necessary to close sluice gates, storm drain shutoff valves, or similar devices to contain discharge from a fixed foam system.

Removal and disposal of contaminated media will reduce the extent of environmental impacts. Airports should consider removing materials such as soil, vegetation, asphalt, and concrete exposed to spilled AFFF in accordance with federal, state, and local regulations. Cleanup activities may require a licensed contractor to collect and transport affected materials. Airports should also consider keeping documentation of material disposal and should review the latest state or federal guidance on technologies available for AFFF containment and disposal.

Staff training programs that cover spill prevention, control, and cleanup may also require revisions to account for AFFF. If the airport has mutual aid agreements with other organizations or municipalities, these materials can be reviewed to verify that AFFF handling, use, cleanup, and disposal procedures are addressed, as applicable. Public communication plans could also be enhanced with information on how to interact with regulatory agencies, the surrounding community, or local media in the event of an accidental release or emergency use. More information on public communication and engagement is provided in Chapter 5.

3.3.2 ARFF Training

FAA AC 150/5210-17C requires ARFF training (FAA 2015b). Firefighting personnel are required to complete a live-fire firefighting drill every 12 months. These drills involve a pit fire with an aircraft mock-up using fuel to simulate crash conditions that could be encountered at an airport rescue situation.

Historically, ARFF training often did not involve containment, as AFFF was advertised by manufacturers as being inert to the environment, but future training should consider appropriate containment for discharges.

FAA provides a list of ARFF training facilities as an addendum to AC 150/5210-17C. This list is updated quarterly and is linked on the AC 150/5210-17C Document Information webpage (FAA 2023b).

If an airport has fire training facilities, it typically has dedicated areas and structures in which to conduct training exercises involving flammable liquids and foam systems. Control of training fires and applied foam is maintained by the facility's design. The fire training area allows for collection and recovery of unburned fuels, foam solutions, and used water. The following actions should be considered when ARFF training procedures are being reviewed:

- Minimizing the volume of foam used and wastewater generated to the greatest extent possible;
- Discontinuing the practice of using expired legacy AFFF and modern fluorotelomer AFFF as training foam;
- Seeking fluorine-free alternatives for training events and training with water or training foam where practicable;
- Restricting foam spraying to target areas; and
- Avoiding conducting outside exercises during inclement weather to avoid additional runoff, natural aspiration, and windblown transport of the foam solutions (ITRC n.d.-a).

ARFF training should be conducted over impervious areas with appropriate containment devices to collect spent fuel and extinguishing agent runoff for proper disposal.

Current guidance is to dispense AFFF in contained areas and to reduce the amount of foam released. During the time response drill for ARFF vehicles, FAA does not require foam discharge. Training activities can also be conducted at regional facilities (Thalheimer et al. 2017).

FAA provides guidance for design, construction, and operation of ARFF training facilities (FAA 2009).

3.3.3 ARFF Health and Safety Considerations

Firefighting personnel are protected from contact and exposure through structural firefighting gear or fire proximity suits, access to adequate ventilation, and material handling equipment. Following an emergency incident or training, a common practice is to perform proper cleaning and decontamination of firefighting gear.

3.3.3.1 Personnel Protection and Risk Awareness

Proper PPE use is critical for reducing exposure to AFFF. PPE includes boots, safety glasses and shields, chemical-resistant nitrile or disposable gloves, and long-sleeve shirts. For general firefighting, turnout gear should be used. If liquids are pumped, poured, or can be splashed onto personnel, then a liquid chemical protective suit should be utilized. During the application or immediate cleanup of AFFF, using a self-contained breathing apparatus or positive pressure–supplied air respirator will limit respiratory exposure. Dermal exposure should be avoided, as skin contact can result in irritation and dryness. When handling AFFF concentrate or foam, hand-to-mouth contact should be avoided. After the use or cleanup of AFFF, responders should wash hands and use other decontamination procedures to remove any residual AFFF from the skin (ITRC n.d.-a). More information on ARFF equipment, tools, and clothing, including PPE, is provided in *AC 150/5210-14B: Aircraft Rescue Fire Fighting Equipment, Tools, and Clothing* (FAA 2008).

While ARFF leadership may already have an Emergency Responder Health Monitoring and Surveillance (ERHMS) plan, this program may not yet cover, or fully cover, AFFF exposure. For ARFF departments without an ERHMS plan, heightened staff and public awareness of AFFF-associated risks may lead to the necessity to develop health monitoring and surveillance protocols. These programs should incorporate training before deployment of AFFF, recordkeeping of personnel on-site during deployments, the amount of AFFF deployed during the event, assessments of actions taken, and health surveillance in the postdeployment phase (CDC 2018, National Academies 2022).

Toolkit Tip

Tool 3.2: Template for Job Hazard Analysis

Customizable hazard analysis tool with a corresponding risk assessment matrix and outline of hazards and controls for AFFF handling and transfer.

Through an ERHMS plan, the activities and health of ARFF staff can be monitored and tracked over time. ARFF staff will have a greater awareness of steps they can take to protect their health and safety and more opportunities to improve their personal medical literacy regarding PFAS exposure. More information on PPE and assessing hazards that may affect health and safety is provided in Tool 3.2.

3.3.3.2 Equipment Decontamination

Although PPE will prevent initial exposure to AFFF, contamination of the PPE itself may present risks. Decontamination of PPE should be considered to reduce exposure and avoid cross-contamination of equipment. If turnout gear is exposed to AFFF or other foams, it should be removed, placed in a bag, and contained for laundering or disposition.

In 2020, the National Fire Protection Association (NFPA) released its latest edition of *NFPA 1851: Standard on Selection, Care and Maintenance of Protective Ensembles for Structural Firefighting and Proximity Firefighting* (NFPA 2020). This standard provides guidance on proper care of firefighting protective gear as well as on health hazards associated with improper maintenance or contamination of protective equipment. NFPA 1851 outlines different decontamination measures for turnout gear and proximity gear. Airports should consider adopting the following standard operating procedures for the handling, cleaning, and disposition of PPE:

- Evaluate the PPE for preliminary exposure reduction or cleaning after each use (evaluation to be performed by the wearer or a designated individual);
- Implement preliminary exposure reduction;
- Wear a self-contained breathing apparatus;
- Conduct wet mitigation by gently rinsing the exterior, using low-pressure and low-volume water flow;
- Apply a mild detergent with a soft brush, then rinse gently;
- Wear either latex or PVC protective gloves when washing equipment and rinsing turnout gear, to avoid skin contact with residual AFFF; and
- Avoid using fabric softener, bleach, or other chemicals when cleaning.

NFPA 1851 provides guidance on proper care of firefighting protective gear as well as on health hazards associated with improper maintenance and decontamination of protective equipment.

Turnout gear should be further assessed by a qualified individual with regard to the exposure and need for advanced cleaning or potential disposal of the equipment. Advanced cleaning, however, should be performed by the manufacturer, a licensed or manufacturer-verified contractor, or manufacturer-trained personnel. If the contaminant can be sufficiently removed, specific procedures for cleaning, treating, or decontaminating the turnout gear should be based on one of the following conditions:

- Evidence that the applied procedures have shown effectiveness in the past under similar exposure circumstances and contamination conditions is provided from a documented source or
- Testing of the contaminated clothing items provides detailed results showing the absence of any residual contamination or that the remaining levels of contaminants are deemed to be safe.

Turnout gear should never be washed in home washing machines or public laundries, so as to avoid the potential to contaminate personal clothing. When turnout gear is being decontaminated or laundered, the disposition of the waste stream should be considered. The potential for environmental impacts resulting from laundering in washing machines is not well defined but is being studied.

Although decontamination of PPE prior to reuse is important, it is equally important to recognize when decontamination is not possible. In this case, the gear may need to be discarded in accordance with local, state, and federal regulations. Regulatory agencies may publish decontamination and disposal procedures for firefighters, and airports should stay current on the most recent requirements (NFPA 2020).

3.3.3.3 Fire Response Plan

Specific department or facility wastewater management considerations may be outlined in a fire response plan, which should include information about the resources available within the facility or fire department jurisdiction. The fire response plan may include strategies for containment and recovery of water used in firefighting and the protection of sensitive receptors such as public and private water systems, storm drains, and surface waters.

3.3.4 Fluorine-Free Alternatives to AFFF and Transition Planning

One F3 alternative was added to the QPD in mid-September 2023. Considerations for transition planning are discussed here.

3.3.4.1 F3 Alternative Regulatory Progress

The FAA Reauthorization Act of 2018, Section 332, directed FAA to not require the use of fluorinated chemicals as a prerequisite for compliance with *AC 150/5210-6D: Aircraft Fire Extinguishing Agents* (FAA 2004a).

In January 2023, DoD promulgated a new MIL-SPEC specifically for F3 extinguishing agents, MIL-PRF-32725 (DoD 2023). The new MIL-SPEC requires manufacturers to certify that PFAS have not been intentionally added to concentrates but does allow for PFAS in products up to 1 part per billion (ppb). While the new MIL-SPEC is only applicable to land-based applications where freshwater is used to produce the foam solution, this represents a critical step in the AFFF to F3 transition process. Congress required DoD to have products qualified and listed within the QPD no later than October 1, 2023 (FAA 2023c).

Following the announcement of MIL-PRF-32725, FAA published Part 139 *CertAlert No. 23-01: New Military Specification for Performance-Based Standards for Fluorine-Free Aircraft Fire Fighting Foam* (FAA 2023d), which has two critical elements. First, FAA will allow Part 139-certificated airports to use F3 firefighting agents if the product in question has passed MIL-PRF-32725 qualification testing and has been added to DoD's Qualified Product's List (QPL) or the QPD. Second, FAA will not require Part 139-certificated airports to transition to the new F3 products at this time to meet safety requirements; these airports may continue to use AFFF products listed in the QPL that meet MIL-F-24385 standards. FAA issued *AC 150/5210-6E: Aircraft Fire Extinguishing Agents for Airports* (FAA 2023a) [an update of *AC 150/5210-6D: Aircraft Fire Extinguishing Agents* (FAA 2004a)] on November 27, 2023. The new Advisory Circular primarily added the availability and use of F3 with a significant directive to not mix different F3 agents.

For Your Information

Key Takeaways for FAA Part 139 CertAlert No. 23-01

- Airports can use F3 products listed in the QPL or QPD that meet MIL-PRF-32725 criteria.
- Airports are not required to transition from AFFF to F3 products at this time to maintain Part 139 certification.

FAA published the *Aircraft Firefighting Foam Transition Plan*, which outlines the agency's strategy for assisting the aviation industry with the transition process from AFFF to F3 (FAA 2023c). Many details remain to be worked out, and the aviation industry was coordinating with FAA on the transition plan as of September 2023. A large part of the transition plan is not only the supply chain associated with F3, but also the identification of means and methods for decontaminating storage, transfer, and ARFF equipment (Ross 2023). As of September 2023, no approved method of decontamination had been identified, although the plan does provide information about ongoing research with links to project websites.

3.3.4.2 Transition Planning Considerations

Many questions remain regarding how airports can quickly and efficiently transition from traditional AFFF products to PFAS-free alternatives. Section 3.3.4.3 looks at equipment decontamination and firefighting alternatives that do not use foam. Following is a generalized summary of considerations when an AFFF to F3 transition strategy is being developed. While this list may not be wholly applicable to every airport or sufficiently comprehensive for others, it may assist airport operators with beginning the transition planning process.

- Inventory and prioritize affected equipment and facilities. Consider operational requirements and acceptable periods of downtime when prioritizing and scheduling decontamination efforts.
- Assess fire risk scenarios and determine whether a particular item of firefighting equipment is needed or whether a facility warrants foam fire suppression.
- Analyze multiple fire suppression strategies and effective firefighting methods or equipment options for a comparison of risk reduction options available.

- Evaluate the following factors for available decontamination technologies:
  - Time to complete the process and time that affected equipment will be out of service, or the downtime.
  - Space required for decontamination technology and associated equipment.
  - How the technology or method works regarding PFAS removal versus PFAS sequestration—
    - PFAS removal methods should be evaluated for possible rebound issues, or the risk of an "incomplete clean."
    - PFAS sequestration methods should be assessed for product longevity and potential for future breakthrough, rebound, or leaching.
  - Quantity of waste generated by the process, waste disposal options, and potential regulatory impacts from waste handling, storage, and disposal.
  - Health and safety concerns associated with the technology's implementation or processes.
  - PFAS verification testing and assurances provided by the contractor or manufacturer of the technology regarding the method's success.
  - Overall cost for the process, which should include implementation, waste disposal, process consumables, and replacement materials for equipment parts that cannot be cleaned by the process (e.g., gaskets, flexible tubing).
- Develop strategies and protocols for maintaining sufficient fire suppression capabilities during decontamination efforts or the system replacement process.
- Identify compatible F3 products by equipment type (e.g., trucks versus fixed suppression systems).
  - Determine potential environmental concerns associated with new F3 products. Include considerations for secondary containment, facility structural modifications, or other control measures necessary, depending on final disposition of the deployed product.
  - Consider the anticipated effort required to clean up deployed foam or potential damage it may cause to aircraft or other property.
  - Evaluate compatibility with current systems or equipment. Inventory equipment, parts, or consumables that will need to be replaced and calculate replacement costs.
  - Understand differences in application techniques during fire scenarios, firefighting performance in terms of extinguishing time and burnback, and training requirements for ARFF staff.
  - Assess current and anticipated commercial availability of each type of F3 product considered and procurement costs.

As the final step in the transition planning process, use the information gathered during the assessment exercise outlined above to complete a cost–benefit analysis that compares options for decontamination, partial replacement of specific system components, complete replacement with an F3-compatible system, or a transition to fire suppression systems or methods that do not use foam (Ross 2023, Horst et al. 2021, FAA 2016a). Airport operators should also keep in mind that changes in fire suppression methods or strategy may warrant revisions to their airport certification manual, and these minimum requirements for Part 139 certification should be included in transition planning considerations (FAA 2004b).

3.3.4.3 Equipment Decontamination or Replacement

Storage vessels, transfer systems, and firefighting equipment will have to undergo decontamination or be replaced before F3 products can be used. These actions could be costly and time consuming but may be necessary to avoid retaining PFAS residue or contaminating new systems. Decontamination may necessitate taking equipment out of service or completely replacing it to confirm that newly procured F3s are not contaminated with past PFAS residues.

Need for Decontamination. PFAS surfactants can adhere to and coat the insides of pipes, fittings, and other surfaces, and this coating is very difficult to remove in situ. Decontamination technologies currently available have been shown to remove substantial amounts of this PFAS coating, but difficulties have been experienced with several of these technologies in the transition from laboratory demonstrations to field implementation at full-scale application (SERDP-ESTCP 2020, FAA 2023d). Some technologies appeared successful when first implemented at full scale, and PFAS were not detected in flushed water after treatment. However, when the systems were flushed again at some point in the future, PFAS were detected in rinse waters (Lang et al. 2022). This is known as contaminant rebound.

Without a proven cleaning method, residual PFAS may still discharge from the system, but the quantities in discharges are uncertain and may be product dependent. The water, oil, and chemical resistance properties of PFAS that enhance the effectiveness of firefighting foams also make thorough cleaning of storage and delivery systems difficult. Research on methods of decontamination is being conducted with various types and combinations of granular activated carbon (GAC), flocculants, supercritical water, and nanofiltration technologies (Bellona 2020). In addition, the Air Force Institute of Technology and the EPA Office of Research and Development are assessing the feasibility of decontamination versus replacement of firefighting equipment and hangar systems to address the likelihood of recontamination of the systems (Magnuson et al. 2020).

Cleaning AFFF from equipment is critical when transitioning equipment to F3 solutions.

Equipment preparation, such as draining foam, concentrates, and fluids from affected tanks, pipes, and pumps, is needed, regardless of the methods used. Cleaning methods currently under development appear to take between 5 and 10 days to complete, and estimating each method's cost is difficult. The costs will vary depending on the size and number of equipment pieces as well as on local disposal costs for waste products. If exposed equipment is replaced, PFAS removal may still be required prior to disposal or resale of old equipment (Iles 2021).

Changing foam types or application objectives, including changes in the F3 products used, could require a complete system review and, potentially, a redesign and modification of system components to meet performance requirements. When objectives or foam product types are changed, each subject system should be evaluated individually. ARFF vehicles may require installation of new equipment or a retrofit to be compatible with new firefighting foam technology.

Fixed Fire Suppression Systems. In the case of fixed fire suppression systems in hangars or other structures, equipment that has been in direct contact with AFFF concentrates or foam may need to be decontaminated or replaced. This equipment would include the foam concentrate tanks, piping between concentrate tanks and the riser, the riser equipment above the check valve, the proportioner, the piping between the proportioner and discharge devices, and the discharge devices themselves. Foam concentrate pumps, hose stations, and other associated equipment would also be included. The piping upstream of the risers, fire pumps, water supply tanks, and other equipment upstream of the risers should not have been exposed to foam concentrate or foam water solutions, and therefore would not need replacement.

Before F3 use, suppression system equipment, including tanks, piping, riser equipment, proportioners, discharge devices, foam concentrate pumps, hose stations, and other equipment must be decontaminated or replaced.

Although some new F3 products in development have the goal of mimicking traditional AFFF concentrates, effective cleaning technologies for decontaminating equipment are still needed. Therefore, AFFF alternatives currently available for fixed fire suppression systems that do require equipment and facility system retrofits are worth considering. Where building or fire codes require foam fire suppression, HEF is the foam traditionally used, and HEF does not contain PFAS. As previously described, HEF is delivered through foam generators and produces a thick foam layer with a consistency like that of shaving cream Figure 3-3.

A positive attribute of HEF is that it is not corrosive or wet during discharge, which reduces damage to aircraft and equipment if exposed. HEF also generates very little runoff. However, HEF can pose risks, as the foam is thick and engulfs hangars in large quantities of foam, which

Figure 3-3. Hangar equipped with an HEF fire suppression system, where the red foam generators are mounted to the ceiling.

presents a risk to staff safety. That said, the more common issue with HEF systems is the cost of installation. The generators and other system components can be much more expensive than a typical AFFF system. Because the foam generator requires relatively high pressure, the installation will likely include fire pumps as additional necessary equipment. Fire codes also require the foam generators to use outside air, which necessitates the installation of ducts from the roof as well as pressure relief dampers (NFPA 2022). Using inside air would require, at a minimum, obtaining a variance from the local fire code enforcement agency. HEF system costs are more directly comparable with those of AFFF systems if both systems require fire pumps or water tanks and the HEF system uses inside air.

Another recently approved novel technology is the ignitable liquid drainage floor assembly (ILDFA), which can be used in lieu of a foam suppression system (NFPA 2022, Wells et al. 2022). An ILDFA system is essentially a perforated flooring that allows sprinkler discharges and fuel to flow through and drain to a safe location, such as a containment tank. The flooring system must cover any potential fuel spill points from aircraft. In a flexible-use hangar, this means most of the hangar floor would contain the drainage assembly. The flooring system is also aircraft rated. Unfortunately, installing and using an ILDFA will likely require a variance from the local fire code enforcement agency for several years until new standards are adopted by the local jurisdiction. However, the primary concern with ILDFAs as a new technology is the lack of information based on user experience.

3.4 Construction Management Procedures

Construction activities at airports should be completed with the understanding that AFFF releases could have resulted in adverse impacts to construction materials. The design and implementation of construction work should include precautions and strategies to minimize contact, movement, and waste generation of contaminated materials. This section provides guidelines for managing PFAS during construction activities.

3.4.1 Review and Sampling of Historical Records

Before commencing construction activities, airports should investigate whether the proposed site has been adversely impacted by AFFF releases. Conducting a baseline assessment and site investigation is described in Chapter 2, Section 2.4.

3.4.2 Preconstruction Planning

This section summarizes construction-related scenarios for consideration during design, construction contract negotiations, and before construction begins. Legal counsel should be consulted throughout this process.

For Your Information

Additional information about how to conduct a baseline assessment and considerations for when to conduct a more thorough site investigation is available in Chapter 2, Section 2.4.

3.4.2.1 Considerations During the Engineering Design Process

Airport operators often collaborate with the design team to avoid or minimize work in potentially affected or contaminated areas, such as brownfields or areas of known fuel spills. Going forward, airport operators may want to consider adding PFAS and AFFF application sites to this discussion. More information on AFFF and considerations related to long-term planning and development are provided in Chapter 4, Section 4.2.1.

For Your Information

Consider including PFAS considerations in the Construction Safety and Phasing Plan or requesting construction contractors to include PFAS information in their Safety Plan Compliance Document.

For more discussion about risk mitigation, financial considerations, and planning, see Chapter 4.

A review of construction plans and specifications as well as project stormwater plans can be an effective way to assess the possibility of encountering PFAS-affected soils or groundwater, understand what PPE might be required to protect workers, and know who to contact about the issue if it arises. Contractors should have a clear understanding of where the airport operator believes potential contaminated materials may be and what is expected from them in terms of soil management, groundwater management, runoff management, materials testing associated with bringing materials on- or off-site, and appropriate disposal methods, with accompanying documentation. In addition, airport operators and their environmental support personnel should inform engineering design teams of possible pathways for receptor exposure, so they can consider ways to avoid these scenarios when designing infrastructure.

As a final step, airport operators will want to verify that potentially contaminated areas or facilities are documented on final designs with instructions on avoidance, testing, or sampling of suspected media, soil stockpiling, waste management requirements, and contaminated media storage and disposal included within plan sets for eventual use by the construction contractor. Airport operators should also confirm that the project team has evaluated options and identified a disposal facility that will accept project-derived PFAS-contaminated materials, should it be necessary, and that information has been accurately included, along with associated cost estimates for disposal, into planning, design, and procurement documents. Airport operators may want to consider adding these PFAS considerations into Construction Safety and Phasing Plans or requiring contractors to include this information in their Safety Plan Compliance Document (FAA 2017).

After consultation with legal counsel, the airport operator may want to consider consultation meetings or coordination with applicable regulatory agencies. The level of regulatory interaction will be highly dependent on the individual states' regulatory status.

3.4.2.2 Construction Contract Negotiations and Contractor Requirements

Airport operators should evaluate and determine insurance needs associated with construction activities. Airports should verify that construction contractors carry sufficient insurance to cover PFAS-related issues discovered during construction activities. Contract mechanisms such as specific notice, change order, or indemnification provisions related to contamination or hazardous materials may provide airport operators with some additional liability protections in the event of an unanticipated discovery.

For Your Information

If contracts stipulate that health and safety plans must be followed and specifically outline PPE requirements for workers accessing potentially affected areas, consider setting penalties for noncompliance with these standards.

Contractor Training Considerations. Airport operators may want to consider requiring documentation that contractors and construction workers have received training pertaining to the safe handling and disposal of PFAS-containing materials or in how to respond if PFAS-affected soils or groundwater are encountered during construction.

Health and Safety Planning. Contractors working on-site should develop and implement a health and safety plan that identifies worker PPE and incorporates record-keeping activities and surveillance procedures for monitoring workers' health and safety. Implementing these plans will give contractors and construction company leadership a better understanding of the potential pathways of exposure, controls they can implement, improvements they can make to their training programs, and ways they can mitigate adverse health impacts.

Finally, airport operators may want to consider some form of health monitoring and surveillance requirements for construction workers and contractors on-site in relation to PFAS (CDC 2018). This may not be permissible by law in all states, so airport operators should consult legal counsel first regarding the development of these types of requirements. However, baseline medical testing or health screenings before beginning work on airport property may help to avert potential legal claims brought later by project contractors or staff.

3.4.3 Soil Management Practices

Soil management during construction is important for minimizing waste, maintaining the integrity of noncontaminated soils, reducing aerial redeposition and transport of soils via stormwater, and protecting human health.

3.4.3.1 Management of Off-Site Soil or Fill Material

Many airports already require contractors to document that off-site soils have been tested for pollutants. With state regulatory trends moving toward more stringent requirements for PFAS, airports may want to incorporate PFAS into their standard testing requirements for soils before they are brought on-site.

3.4.3.2 Management of On-Site Soil or Fill Material

Since construction may disturb contaminated soils, measures to minimize the volume of, movement of, and contact with soils should be considered. FAA provides a framework for dealing with excavations, subgrade, and embankments (FAA 2018).

If off-site soils are required to be sourced, construction managers should request analytical data detailing that PFAS and other contaminants of concern are not present or believed to be present in the soils.

To avoid future challenges, airport operators should consider implementing policies that prohibit the reuse or resale of soils or fill material sourced from the airport's property for off-site use. Contractors may offer to remove excess soil or fill material generated during construction. These materials may then be resold by the contractor, either with or without the airport operator's knowledge, but this practice can expose the airport operator to risk. If a strict prohibition on the resale of soils or fill materials sourced from the airport property is not practical, then operators may want to consider a minimum requirement of soil testing, including testing for PFAS, before soils are allowed to be transported off-site, either for resale or for other purposes.

3.4.3.3 Segregation and Stockpiling

Airport engineers should work with construction contractors to create a plan to maintain physical segregation of potentially contaminated soils during excavation activity. Segregated areas for contaminated soil should be coordinated with the airport operator, along with signage depicting health and safety hazards. The contractor and airport engineers should keep a generalized diagram showing the construction site, excavations, and stockpiled areas of contaminated and uncontaminated material. The goal is to keep clean materials from becoming contaminated by materials that have been affected by PFAS and other contaminants of concern.

The location of soil stockpiles and construction support zones should be identified in advance and tested to verify that they are free of PFAS or other contaminants prior to their use in construction activities. Soil stockpiles believed to contain PFAS should be placed on top of heavy-duty PFAS-free plastic sheeting or on areas with asphalt or concrete surfaces. Access to the stockpile areas should be fenced and covered with PFAS-free material that is adequate to prevent soil transport by wind or water runoff. Soil stockpile covers should be inspected regularly and maintained in good condition.

3.4.3.4 Dust Control

Dust-control measures should be implemented in compliance with applicable laws and regulations. During excavation activities, exposed soil surfaces should be kept moist by water spray and covered with PFAS-free heavy-duty plastic sheeting or other PFAS-free covering to minimize emissions of particulates. Additionally, soil loaded into vehicles to be transported to a different location of the airport or for off-site disposal should be covered with PFAS-free tarps or other coverings to minimize emissions.

During construction, dust control is essential in areas with potentially affected soils to prevent the aerial mobilization and redeposition of materials that may contain PFAS.

3.4.4 Construction Demolition Activities with Debris Removal

A predemolition survey of regulated materials often includes material sampling, laboratory analysis, and reporting with schematic drawings that identify locations of regulated materials or affected infrastructure. Commonly identified regulated materials may include asbestos, lead, mercury, PCBs, freon, rubber tires, petroleum products, and metals, among others.

If prior AFFF contamination is suspected within a building or if facility equipment used AFFF (e.g., a hangar fire suppression system), an airport operator may want to expand the predemolition survey of regulated materials to include AFFF and PFAS. Airport operators should also consider treating these materials as hazardous waste, including waste characterization, disposition reporting with records retention, and final disposal at a regulated waste facility.

3.4.5 Temporary Storage of Demolition Debris

Recent research has shown that concrete in areas of heavy AFFF use can remain a source of PFAS through leaching into shallow soils, groundwater, and stormwater (Fiorenza 2022). Exposed concrete can adsorb certain PFAS to surfaces, and some PFAS can absorb into and soak through concrete to surrounding media.

One study indicates that PFAS had penetrated as far as 12 centimeters, or approximately 5 inches (in.), into concrete at a firefighting training area, with diffusion being identified as a contributing process (Baduel et al. 2015). Another study demonstrated absorption, or penetration, of four PFAS chemicals—perfluorohexanoic acid (PFHxA), perfluorohexanesulfonic acid (PFHxS), PFOA, and PFOS—into concrete to a depth of 162 millimeters (mm), or 6.5 in., but also showed 15 types of PFAS penetrated concrete to a depth of at least 75 mm, or approximately 3 in. (McDonald 2021). Considering this information, airports should evaluate the need for policy or procedural modifications related to recycling or reuse of asphalt or concrete as future construction materials and to disposal of demolition debris.

Consider storing soils and recycled materials sourced from either on-site or off-site in areas that are geologically preferred or have impervious containment until they are confirmed PFAS free. Impervious containment is not necessary in all cases, depending on the CSM, conditions, PFAS concentrations, and threshold determinations used for determining segregation and their level of conservatism.

3.4.6 Construction Stormwater Management Plan

Excavated soil should be managed in a way that will not cause sediment to enter stormwater runoff. The following considerations may apply to any excavation project or construction work for surface water protection:

- Designate a contained area away from storm drains for refueling or maintenance work that must be performed at the site.
- Clean up all spills and leaks using dry methods, such as absorbent materials or rags.
- Protect storm drains by using earth dikes, straw bales, sandbags, absorbent socks, or other controls to divert or trap and filter runoff.
- Prevent the contact of rainfall or runoff with contaminated soil or debris by covering excavations with PFAS-free heavy-duty plastic and temporary roofs and berms.
- Avoid over-application of water for dust control.

Other considerations may be necessary, depending on the nature and location of the proposed project, and should be determined by the airport.

3.4.7 Documentation of Construction Activities and Material Management

The construction team may also consider preparing field notes and photographs that document soil management activities, including excavation, segregation, stockpiling, reuse, and disposal. Photographs and sketches of the work performed are helpful in identifying areas where contamination may have been present, based upon sampling or other information about the past use of AFFF.

3.4.8 Decontamination

Decontamination protects workers and reduces the potential for cross-contamination during construction projects. Construction and excavation equipment, such as drilling and excavating vehicles, should be decontaminated at a designated location, for example, a decontamination zone. The chosen location should be readily accessible and downwind and downgradient of work areas. Equipment in contact with contaminated soils should be decontaminated by either a high-pressure wash with an approved solution and PFAS-free water or other suitable means prior to mobilization to an uncontaminated portion of the site. The construction team should visually inspect vehicles and equipment before leaving the site.

Construction staff and decontamination personnel should receive training on the proper procedures and techniques for decontaminating excavation equipment, use of PPE and safety equipment, and appropriate use, handling, and disposal protocols for decontamination-related waste. Water used for cleaning and decontamination should be captured and placed in containers to prevent runoff from leaving the immediate work site. Decontamination water generated should be sampled and disposed of appropriately based on sampling results in accordance with local, state, or federal requirements. The following should be considered if discharge of decontamination water to sanitary sewer systems is permitted:

- The wastewater treatment system operator may decide later that they were not adequately informed of the discharge constituents or the risks associated with those discharges.
- The wastewater treatment facility involves the airport operator as another responsible party in a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) action.

More information on potential legal repercussions associated with sanitary sewer discharges is provided in Chapter 4. Discharges of pollutants into the storm drain system, waters of the state, or the environment should be avoided.

CHAPTER 4

Regulatory Action, Financial Planning, and Remediation

Airports continue to evolve as they maintain their facilities and grow to meet the needs of the flying public. At this time, it is difficult to predict how regulations regarding PFAS will affect airport development and redevelopment and what the implications might be for project costs or schedules.

Each section in this chapter addresses a defined issue and provides supporting information to prepare for anticipated regulatory requirements. Discussion begins with an overview of the current federal and state PFAS regulatory trends and future expected regulations. The next section examines ways airports can reduce their financial and legal challenges. The chapter's toolkit, which provides checklists and strategy summaries airports may use to implement remediation projects, engineering controls, or institutional controls, is provided as Appendix C.

Chapter 4 Topics

- Current and future PFAS regulations
- Development of financial and legal plans and revision of planning documents to incorporate PFAS considerations
- Appropriate remediation techniques

4.1 Regulatory Action

The Biden administration has announced its intent to propose a series of rules over the next 3 years to regulate PFAS at the federal level. State regulations are currently a patchwork of rules, standards, and guidelines. The following sections summarize regulatory activities.

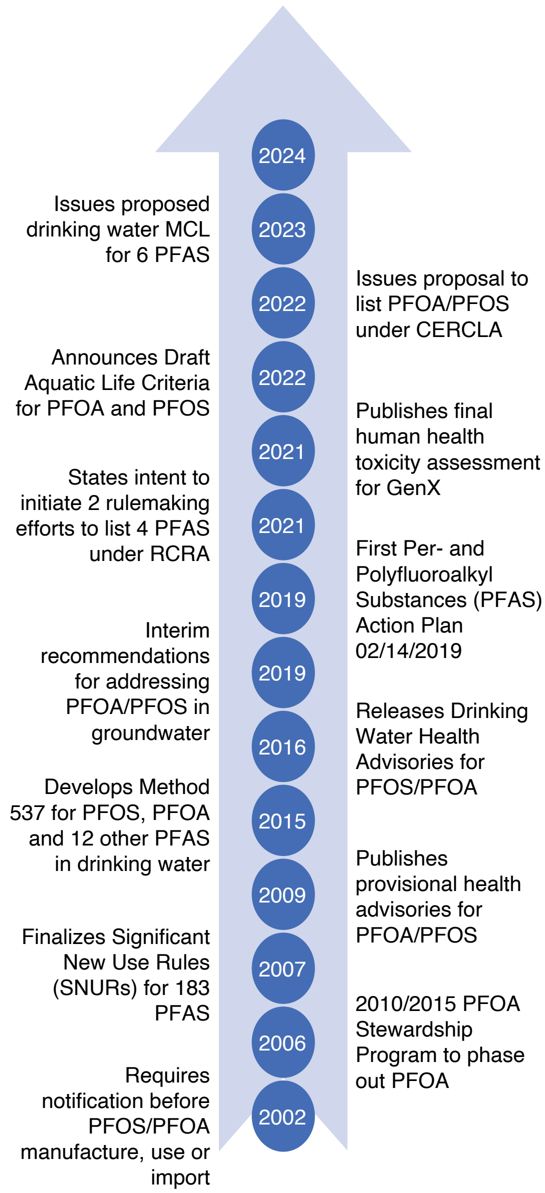
4.1.1 Federal PFAS Regulatory Trends

In 2021, EPA issued its PFAS Strategic Roadmap: EPA's Commitments to Action 2021–2024, which outlines a set of rulemaking measures the agency will undertake to regulate PFAS under several environmental laws (EPA 2021i). Some portions of the PFAS Roadmap relevant to airport operators are summarized here. A summary timeline of EPA actions regarding PFAS is provided in Figure 4-1 to generally illustrate the overall regulatory trends.

4.1.1.1 National Drinking Water Standards

Under the SDWA, EPA sets enforceable National Primary Drinking Water Regulations for drinking water contaminants and requires monitoring of public water supplies. In 2016, EPA first established health advisory levels (HALs) for PFOA and PFOS at 70 ppt (EPA 2016a, 2016b). A HAL is a nonbinding standard developed for a contaminant that is known or is anticipated to occur in drinking water (81 FR 33250, 87 FR 36848).

In June 2022, EPA issued lifetime drinking water health advisories for four PFAS and updated interim HALs for PFOA and PFOS to 0.004 ppt and 0.02 ppt, respectively (87 FR 36848).



Note: MCL = maximum contaminant level.

Figure 4-1. EPA regulatory timeline, 2002–2024 (EPA n.d.-d.).

Additionally, EPA set final HALs for HFPO-DA and its ammonium salt, otherwise known as GenX chemicals, at 10 ppt and for PFBS at 2,000 ppt.

In 2023, EPA proposed maximum contaminant levels (MCLs), which are binding regulatory standards that form the basis for enforcement actions, for PFOA, PFOS, perfluorononanoic acid (PFNA), PFHxS, PFBS, and HFPO-DA and planned to promulgate a final standard by the end of 2023) (EPA 2023a). These regulations fall under the National Primary Drinking Water Regulation authority in accordance with the SDWA regulatory development process. EPA proposed the use of a Hazard Index formula to regulate PFOA, PFOS, PFNA, GenX chemicals, PFHxS, and PFBS as well as health-based, nonenforceable MCL goals for these six PFAS. This proposed rule would require public water systems to monitor for these PFAS, reduce levels of

Toolkit on Regulatory Action, Financial Planning, and Remediation

Appendix C provides supporting materials to help airports consider options between commercially available PFAS remediation technologies applicable to their situations today and technology anticipated in the future that may be worth waiting for. While these resources are not a comprehensive list of all possible remediation techniques, they may be used during airport planning and during discussions with regulators and environmental consultants for cleanup of PFAS contamination of surface water, groundwater, and soil.

Appendix C is available on the National Academies Press website (nap.nationalacademies.org) by searching for *ACRP Research Report 262: PFAS Management at Airports: A Guide* and looking under "Resources."

Tool 4.1: Considerations for Selecting a Method of Ex Situ Water Treatment

Options for ex situ water treatment, presuming groundwater can be extracted and surface water contained, with descriptions; implementability, effectiveness, and availability evaluations; and cost assessments.

Tool 4.2: Considerations for Determining the Feasibility of Ex Situ Water Treatment

Major factors affecting the cost of ex situ water treatment to help airport operators determine whether this method of remediation is cost-effective and feasible.

Tool 4.3: Considerations for Selecting a Method of In Situ Water Treatment

Considerations for in situ groundwater treatment with descriptions; implementability, effectiveness, and availability evaluations; and cost assessments.

Tool 4.4: Considerations for Determining the Feasibility of In Situ Water Treatment

List of major factors affecting the cost of in situ water treatment to help airport operators determine whether this method of remediation is cost-effective and feasible.

Tool 4.5: Considerations for Selecting a Method of Soil Treatment

Options for soil treatment with descriptions; implementability, effectiveness, and availability evaluations; and cost assessments.

Tool 4.6: Considerations for Determining the Feasibility of Soil Treatment

Summary of factors affecting the cost of soil treatment to help airport operators determine whether this method of remediation is cost-effective and feasible.

these chemicals in drinking water if they exceed the proposed standards, and notify the public of these levels of PFAS in drinking water supplies (EPA 2023a).

For airport operators, the practical import of this plan is that drinking water systems nationwide will soon be assessing their systems for compliance with the new MCLs and investigating potential sources of regulated chemicals, if found. This new federal standard would dictate the acceptable levels of PFAS in drinking water and would likely become a de facto cleanup standard for remediation. Additionally, some states already regulate PFAS in drinking water to even lower levels than the proposed federal MCL standards.

4.1.1.2 CERCLA Regulations

EPA announced a proposed rule (87 FR 54415) in 2022 to designate PFOA and PFOS as hazardous substances under CERCLA, or Superfund, and its stated goal was to have a final rule published in the *Federal Register* by 2023 (Schlea 2022). If finalized, the rule would subject parties liable for releases of PFOA and PFOS to regulation under CERCLA. In April 2023, the agency also issued an advance notice of proposed rulemaking regarding the designation of additional PFAS as hazardous substances to seek public input and information on potential additional designations.

CERCLA liability is special, as it is strict, generally joint and several, and retroactive. Figure 4-2 shows a general summary of CERCLA liability. Liable parties under CERCLA include current owners and operators of a facility; owners and operators of a facility at the time hazardous substances were disposed of, regardless of who the current owners or operators are; and generators or parties that arranged for the transport or disposal of the hazardous substances. EPA plans to designate PFOA and PFOS as hazardous substances, which means airport operators may soon be liable parties under CERCLA for current and historical releases of PFAS at their airport. While an airport operator could theoretically avoid joint and several liability by showing its harm is divisible, in practice, this has proven to be quite difficult. Finally, CERCLA liability is retroactive, meaning that a liable party can be held responsible today for releases that occurred in the past, even releases that predate the new rule and the enactment of CERCLA.

Such liability means EPA or state regulators could require airport operators, perhaps jointly with tenants who have liability under CERCLA as well, to conduct a CERCLA-quality investigation of possible PFAS releases to the environment and remediation of PFAS and PFAS-contaminated environmental media. Although less likely, EPA could perform its own response action and require reimbursement from a liable airport operator. EPA would, however, perform its own response action in cases in which an emergency response was required and the airport operator could not respond.

EPA has informally indicated airports will not be a priority for PFAS-related CERCLA enforcement. Even if airport operators become liable parties under the law, EPA may still exercise its enforcement discretion regarding which organizations or facilities the agency pursues. However, it is possible that EPA might pursue airport tenants believed to be responsible for PFAS releases or other liable parties. In these cases, the airport tenant or other liable parties might allege that the airport operator was also liable, and the airport operator could be brought into the ensuing litigation over liability and cost allocation. As of September 2023, the airport industry continued

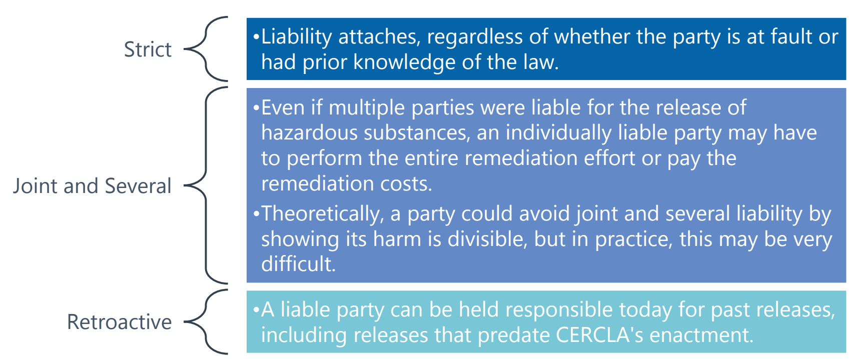


Figure 4-2. Summary description of CERCLA liability.

to encourage Congress to exempt or exclude airport operators from CERCLA liability, given the federal mandates to use AFFF.

Another important consideration for airport operators regarding PFAS is that the CERCLA regulatory statute would allow parties liable for releases to bring lawsuits against other liable parties to recover remediation costs. This means parties affected by PFAS contamination, such as water utilities, landfills, landowners, or tenants completing response actions, might bring lawsuits against the airport operator alleging the operator was a liable party who must pay a portion of the remediation costs. The same is true for airport operators, as they also could bring lawsuits against other entities, such as current and former airport tenants or the military, alleging these parties were also liable for contamination at the airport and must share the financial burden of remediation. Thus, even if EPA does not target airports for CERCLA enforcement, airport operators could be drawn into CERCLA litigation over PFAS contamination anyway and might decide to use CERCLA offensively as a tool for PFAS cost recovery. However, cost recovery under CERCLA is only possible for a CERCLA-quality investigation and cleanup, a point discussed in Section 4.2.5.

For Your Information

Airports should seek FAA and EPA guidance on

- The upcoming transition from AFFF to PFAS-free foams;
- Proper disposal of AFFF products; and
- Effective cleaning methods for ARFF vehicles, hangar fire suppression systems, and more.

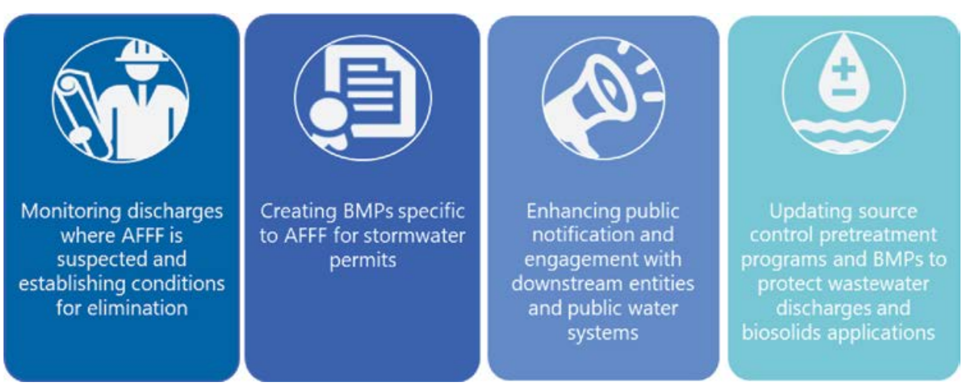
4.1.1.3 National Pollutant Discharge Elimination System Permitting

The National Pollutant Discharge Elimination System (NPDES) permit program under the Clean Water Act addresses water pollution by regulating sources that discharge pollutants into waters of the United States (EPA 2019, 2022a). EPA intends to leverage federally issued permits to reduce PFAS discharges in wastewater and stormwater. EPA's NPDES proposal is expected to cover the items shown in Figure 4-3; however, a stormwater permitting approach from EPA had not been issued as of September 2023.

In its 2021 draft Multi-Sector General Permit for industrial stormwater discharges, EPA did not include specific PFAS requirements. The final Multi-Sector General Permit did include sector-specific fact sheets outlining practices to minimize AFFF in stormwater discharges. The Sector S (Air Transportation Facilities and Airports) fact sheet recommends control measures, including housekeeping methods to prevent AFFF contact with stormwater (EPA 2022h).

4.1.1.4 RCRA Listing

In November 2021, EPA announced it would initiate two new rulemakings for four PFAS compounds (PFOA, PFOS, PFBS, and GenX) under the RCRA list of hazardous constituents (EPA 2021e). Hazardous constituents are defined as carrying the chemical or physical risk that



Note: BMP = best management practice.

Figure 4-3. Anticipated requirements in future NPDES stormwater permits.

For Your Information

For more discussion about programmatic improvements and operational considerations for RCRA compliance, see Chapter 3, Section 2.

causes the waste they are contained in, or chemical mixture they are a part of, to be considered a hazardous waste under RCRA [40 CFR Part 261.1(a)(1)]. For the first rulemaking, EPA plans to initiate the process to propose listing these four chemicals as RCRA hazardous constituents under 40 CFR Part 261, Appendix VIII—Hazardous Constituents. The second rulemaking is expected to clarify regulations regarding the RCRA Corrective Action Program's authority to require investigation and cleanup of waste meeting the definitions of RCRA Section 1004(5) (EPA 2021b). If EPA moves forward with the proposed regulation, there are potential ramifications for airport operators.

In addition to RCRA, state-specific regulations should be consulted before waste profiling and disposal.

If regulated as hazardous constituents under RCRA and Appendix VIII, these four PFAS chemicals would become subject to RCRA corrective action requirements at hazardous waste treatment, storage, and disposal facilities. Facilities subject to corrective action requirements, including airports that currently have RCRA permits due to their use of other RCRA hazardous materials, would be required to clean up releases into soil, groundwater, surface water, and air. If PFAS are included within RCRA's scope, regulators will have another enforcement tool to require airport operators with RCRA permits to investigate and clean up PFAS contamination. This could also provide potential citizen plaintiffs with an additional route to bring legal action, as RCRA allows citizen lawsuits for violations of a RCRA permit, laws, or regulations. Finally, such listing would be the first step toward a formal rulemaking process to regulate the four chemicals as listed RCRA hazardous waste.

Unlike CERCLA, RCRA is not retroactive, so even if EPA enacts the proposed RCRA regulation, it cannot impose regulatory obligations for RCRA-listed hazardous waste generation that occurred prior to the date those materials were first regulated under RCRA. However, after these chemicals are listed, disturbing soils containing the four chemicals will be considered hazardous waste generation and subject to RCRA regulations, including storage and disposal requirements.

4.1.2 State Regulations

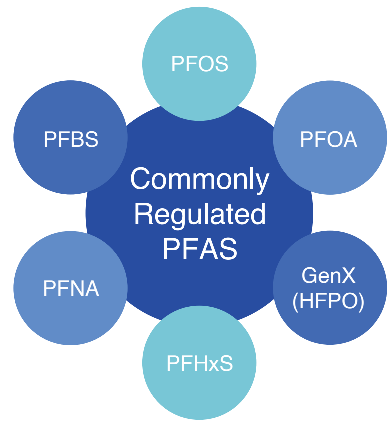
More than half of states regulate PFAS compounds in drinking water or other media, including soil, groundwater, and surface water (ITRC n.d.-d). While state-specific regulations vary in their focus and stringency, drinking water regulations appear to be the most common in the form of state MCLs, HALs, or notification levels for PFAS. Notification levels are a quantified limit of a pollutant in a water supply, and when the amount of the pollutant exceeds this limit, drinking water systems or private entities must notify the state or customers. While almost every state with PFAS drinking water regulations regulates PFOA and PFOS, several states also regulate additional PFAS compounds, such as PFHxS and PFNA.

The standards imposed vary in their stringency and reflect a lack of scientific consensus on the risks of PFAS and the level of exposure that causes harm. Among states regulating PFAS, the trend is to regulate more varieties of PFAS chemicals to lower levels. Aggregate limits are becoming more common, but a significant issue with this approach is currently under debate among many regulatory and industry advocacy groups. Namely, can groups of PFAS be properly regulated together under a combined standard, or does each compound have its own unique toxicity analysis and, therefore, require a separate standard? Environmental advocacy groups are pushing for all PFAS to be regulated as a class of chemicals and considered hazardous, while industry groups are often in support of listing each type of PFAS chemical independently on the basis of scientific analysis of toxicity and potential health impacts. While no clear resolution seems forthcoming at this time, airport operators should stay informed on the progress of this debate.

Many states have developed groundwater, surface water, and soil screening criteria for one or more PFAS. Some states have promulgated these criteria as state-specific MCLs, while others are using EPA's HAL PFAS criteria as the basis for their own state-specific screening levels, pending further EPA action and guidance. Screening criteria may vary by a factor of 10 or more from state to state, depending on the state's default criteria and underlying toxicological and exposure assumptions. The Interstate Technology and Regulatory Council (ITRC) compiles and updates state-specific screening criteria for soil and groundwater periodically as part of its technical and regulatory guidance (ITRC n.d.-e). Airport operators may want to consider ITRC as a resource for updates and further information.

In addition, some states define certain types of PFAS, or an individual PFAS chemical, as hazardous substances, or may have chemically specific PFAS hazardous waste codes (ITRC n.d.-d). Therefore, different rules may apply to various types of PFAS remediation waste. States may also have differing requirements for storage, handling, and reporting of certain groups of PFAS or a specific PFAS chemical.

Some states have taken targeted action to investigate entities, such as airports, that may have released PFAS on the basis of these drinking water, groundwater, and soil standards and hazardous waste designations. For example, California has issued investigative orders to multiple airports to require those organizations to investigate whether groundwater or soil was affected by PFAS from federally mandated AFFF use. Further, as of January 26, 2022, 26 states had enacted one or more regulations regarding AFFF containing PFAS (BCLP 2021). These regulations often restrict AFFF use, handling, and disposal.



Overall, state regulations are dynamic and complex. Airport operators should expect a regulatory trend toward corrective action requirements for lower detected levels in drinking water, groundwater, stormwater, and soil and increased scrutiny regarding AFFF use. Airport operators may want to pay close attention to their state's regulatory strategy and stay abreast of changes, which are occurring with increased frequency and are likely to continue.

4.1.3 Other Regulatory Considerations

Fire protection requirements for hangars are primarily dictated by building and fire codes. Insurance carriers or the terms and conditions of a given insurance policy may also affect the code requirements for hangars.

The two main sources of code requirements are the International Building Code (IBC) developed by the International Code Council, Inc. (ICC 2020) and the NFPA Codes and Standards, specifically *NFPA 409: Standard for Aircraft Hangars* (NFPA 2022). Either the IBC is used directly as the required building code for most jurisdictions, or states may adopt a modified version of the IBC. While some states adopt NFPA 409 in its entirety, most states partially adopt NFPA 409 through reference from IBC. The extent of adoption of NFPA 409 does affect the foam requirements for Group II hangars; thus, it is important for the design professional to confirm the code requirements for the hangar.

Very few jurisdictions adopt new codes or standards quickly, especially the NFPA codes and standards, which are typically updated on 2- to 6-year cycles. The IBC and *NFPA 1: Fire Code*, including *NFPA 101: Life Safety Code (2024)*, are adopted on 3-year cycles, with the most recent edition being 2023 (NFPA 2023). Whether at the state or local level, various jurisdictions will often have adoption cycles that mirror the IBC cycle, but it is not unusual for adoption cycles to be more than 3 years. Unless specifically amended, the adopted version of the NFPA standard at the state or local level typically will be the version that was current when the IBC was last updated.

NFPA 409 had significant changes in both the 2016 and 2022 editions. As it may take a significant amount of time for the current IBC 2024 edition (ICC 2023) to be adopted, it may also take several years for the 2022 edition of NFPA 409 to be officially adopted by state and local government agencies. Realistically, the IBC 2024 edition and associated NFPA 409 2022 edition will likely be adopted by most jurisdictions somewhere between 2025 and 2027. Therefore, to use the newer NFPA 409 2022 edition, airports may need to obtain a variance, which is typically granted by the local building official and fire marshal.

Currently, most building and fire codes do not prevent the installation, use, or replacement of fixed fire suppression systems that use AFFF. AFFF products containing long-chain, or C8, PFAS surfactants are generally no longer available for purchase in the United States, although some facilities may still have reserves of AFFF concentrates containing C8 PFAS surfactants, which may still be used to replace spent or expired AFFF in fixed systems.

AFFF concentrates with short-chain, or C6, PFAS surfactants can generally be used to replace AFFF with C8 PFAS in fire suppression systems and other equipment, although proportioners may need to be replaced to maintain compliance with the Underwriters Laboratories, Inc. criteria, or UL Listing. Although use is currently allowed in new installations of fixed fire suppression systems, AFFF products containing C6 PFAS surfactants still contain PFAS, if not PFOA or PFOS. As a result, these products may also be phased out of manufacturing in the near future, and their continued use could create issues in other regulatory areas.

Many chemicals and materials historically used for fire protection are now banned from manufacturing, including asbestos, halons, and AFFF containing PFOA and PFOS surfactants. While there was a regulatory requirement to phase out the production of these materials, building fire codes often do not require the removal of these materials from buildings. However, if AFFF products containing C6 PFAS surfactants are banned, replacement will likely require redesign and replacement of the entire system.

4.1.4 The Role of Uncertainty

Several key areas of uncertainty remain regarding future impacts to airports from PFAS (Figure 4-4). Despite EPA's Roadmap, the development of federal regulations remains slow, in part because of significant data gaps regarding PFAS (EPA 2021h). The Roadmap acknowledges these information gaps concerning impacts; appropriate safe levels in the environment; and usage, storage, and disposal options.

For example, EPA recognizes that toxicity data are limited or nonexistent for most PFAS This makes it difficult to determine whether regulation is warranted and, if it is, the appropriate standards to set. In October 2021, EPA issued its National PFAS Testing Strategy, which identified and selected PFAS for testing, funded by PFAS manufacturers, for their hazards to human health and environment pursuant to the agency's authorities under other environmental laws (EPA 2021g). Even PFOA and PFOS, the two most-studied PFAS, are now widely believed to be toxic at levels lower than the initial 2016 70 ppt HAL. An EPA draft toxicity report advised that a 70 ppt HAL for drinking water was insufficient and that scientific evidence may support levels in the parts per quadrillion (ppq) (EPA 2021f, n.d.-j). Toxicity levels drive regulatory levels, and a lower toxicity level will require even more precise and accurate testing and analysis, which was currently unavailable as of September 2023.

EPA also has only limited information about how PFAS are used, and though it started in 2020 to gather information on PFAS use and releases under the TRI, the effort only included reporting from certain industries with sufficient amounts of covered chemicals (EPA n.d.-j, n.d.-k). EPA plans to expand the list of PFAS that require reporting on the TRI and will lower the threshold amounts to improve information.

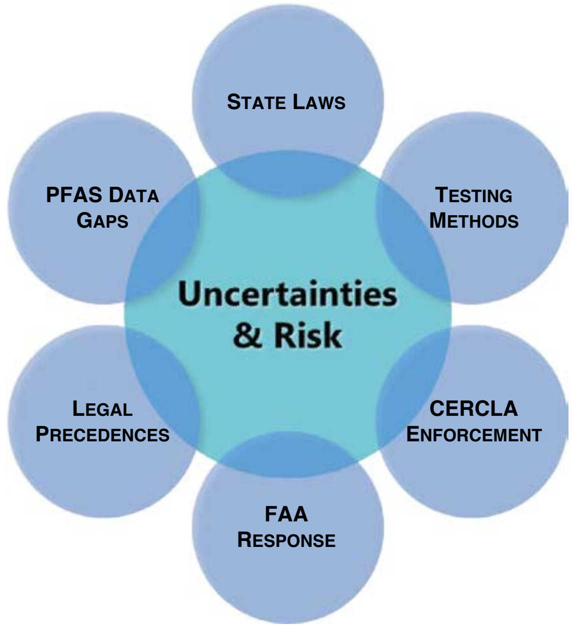


Figure 4-4. Illustrative summary of key areas of uncertainty regarding PFAS.

EPA has been studying the prevalence of certain PFAS in water supplies pursuant to the SDWA's unregulated contaminant monitoring rule, but EPA now intends to expand the number of drinking water systems surveilled and to increase the number of PFAS studied to 29 PFAS chemicals (EPA 2021d). The results of this effort will inform future regulation of PFAS under the SDWA. As these and other data gaps are replaced with greater scientific consensus, EPA is expected to fine-tune its current PFAS regulatory efforts. In the meantime, airport operators should consider seeking technical and legal guidance when establishing or revising their policies and standard operating procedures.

Even with the enactment of federal PFAS rules and laws, it is unclear how states will adjust their regulatory regimes in response to federal action. In general, federal environmental standards will form a baseline, minimum standard, but states may develop more stringent standards than the federal minimum requirements if no state limitations to exceeding federal requirements exist. Therefore, even after federal action, a patchwork of state laws will likely remain in place, although some states may decide it is in their interests to cease development of state-specific standards in favor of the federal standards or to modify their standards to align with new federal programs more closely.

One critical source of scientific uncertainty concerns proper laboratory methods for identifying PFAS in a variety of environmental media, which is necessary for the development and implementation of successful PFAS regulations. In 2021, EPA and DoD collaborated to publish a single laboratory-validated method to detect PFAS, which can identify up to 40 specific PFAS compounds within eight environmental matrices (EPA 2022c). EPA and DoD continue to collaborate.

4.2 Risk Reduction and Cost Recovery

Risk management, in the context of this chapter, is the process of identifying, assessing, and controlling threats to an organization's capital and earnings. AFFF risk management refers to this process as it relates to planned development projects, the environment, and an airport's reputation. As AFFF emerges as an issue facing growing regulatory scrutiny, airport operators should consider incorporating risk reduction actions and policies to reduce operational impacts, delays in airport development projects, and financial burdens. This section outlines ways airport operators could incorporate risk reduction actions and policies to reduce potential operational and financial impacts, including

- Incorporating AFFF topics into airport planning documents and policies;
- Adopting measures to reduce legal liability; and
- Considering cost-recovery mechanisms, such as insurance, to recoup costs related to AFFF.

Risk management is an iterative process, and periodically reviewing the considerations discussed in the following sections is recommended to confirm that the approaches taken continue achieve risk reduction goals.

4.2.1 Airport Planning

Airport planning is a systematic process used to efficiently guide future development at airports in a manner consistent with local, state, and federal goals and regulations. FAA establishes standards and provides guidance on airport master planning and system planning (FAA n.d.-b).

PFAS regulations may influence development plans and have an impact on financial needs. Operators may want to review their airport master plans, layout plans, and capital improvement plans (CIPs) and update plans as necessary to address the potential for PFAS in the environment or infrastructure. Completing these reviews and updates may help minimize delays in project funding, design, or construction.

4.2.1.1 Airport Master Plans and Airport Layout Plans

Airport master plans and airport layout plans (ALPs) provide a framework or blueprint for an airport's long-term development. These plans direct or guide airport growth to cost-effectively satisfy aviation demand, but they should also adequately consider and account for potential environmental and socioeconomic impacts (FAA 2015a). The framework provided by master plans and depicted on ALPs can help airport operators develop strategies for development and avoid, minimize, or mitigate impacts to sensitive resources.

Because master plans are long-term planning documents and ALPs present physical airport features, the impact of AFFF may not have been incorporated or considered. Airport operators should consider identifying areas possibly exposed to AFFF within their master plans and on ALPs, as they do for other familiar environmental concerns, such as underground storage tanks, aboveground storage tanks, former military sites, and brownfields, among others. Airport operators might also evaluate the impact an AFFF release could have on projects and then update relevant environmental sections in the existing airport master plan.

For Your Information

Airport planning documents are made more adaptable and resilient by using this process:

- ✓ **Plan:** Set realistic goals with quantifiable outcomes.
- ✓ **Do:** Implement the plan and document outcomes.
- ✓ **Check:** Compare outcomes to plan goals.
- ✓ **Act:** Revise the plan or implementation approach where necessary.

4.2.1.2 Capital Improvement Plans

The national Airports Capital Improvement Plan (ACIP) is an internal FAA document that serves as the primary planning tool for identifying and prioritizing critical airport development and associated capital needs for the National Airspace System (FAA n.d.-a). The ACIP also serves as the basis for the distribution of grant funds under the Airport Improvement Program.

Consider reviewing master plans, ALPs, and CIPs to determine whether AFFF-exposed areas are adequately addressed.

Under the ACIP, airport operators seeking federal funding for large projects identified in their master plan and ALP must submit a CIP to FAA. An airport's CIP identifies projects planned for the near future and includes, among other information, the work's priority, a project sketch, a project justification, and a detailed cost estimate. A CIP Data Sheet with this information is submitted for each CIP work item or project listed for the current year and two subsequent federal fiscal years. Airport operators should note a requested work item must comply with the current approved ALP and be environmentally cleared to proceed as a prerequisite for the ACIP (FAA n.d.-a).

The airport operator should consider how releases of AFFF may affect the current CIP and evaluate whether cost estimates incorporate PFAS-related remedial efforts. If necessary, an operator's CIP could identify costs for further PFAS assessments, consulting, engineering, remediation, and disposal (FAA 2022).

4.2.1.3 PFAS-Specific Planning Documents

Airport master plans and ALPs consider a wide variety of issues, so it may be more useful for an airport operator to create a PFAS-specific plan. Some components of airport master plans (FAA 2004a) can be applied to a PFAS-specific plan to assist with risk identification and reduction and overall airport planning. These plans should determine potential past, present, and future impacts of PFAS use in operational activities and, if necessary, develop budgets for addressing PFAS mitigation and remediation. PFAS may need to be considered as part of the environmental conditions at the airport alongside the planned airport development. Airport operators may want to refer to the current version of *FAA Order 1050: Environmental Impacts: Policies and Procedures*, for a list of environmental conditions to examine; PFAS are also relevant to many of the categories in the document (FAA 2015c).

Depending on an individual airports' condition, a PFAS-specific plan could consider PFAS risks for projects and their alternatives proposed in the master plan. An airport operator may want to consider the following action items in the PFAS-specific plan:

- Determining the extent and quantities of soil, surface water, and groundwater affected by PFAS in the proposed development or verifying the absence of PFAS;
- Evaluating the results of previous site assessments;
- Identifying the locations and scope of additional site assessments, if needed;
- Identifying project specifications that manage (i.e., stockpiling, containerizing, disposal) PFAS-contaminated soils and dewatering water in accordance with federal, state, and local requirements and best management practices;
- Reconfiguring or relocating proposed development to an area that has been characterized as and determined to be clean; and
- Postponing proposed development until further clarity is provided on forthcoming PFAS requirements and guidance.

A PFAS-specific plan should include an airport operator's policies and protocols for PFAS management, procedures for PFAS releases, tenant PFAS requirements, and communications between the airport operator and the public. Chapter 2 provides more information on determining PFAS sources and fate and transport, as do *ACRP Research Report 173: Use and Potential Impacts of AFFF Containing PFASs at Airports* (Thalheimer et al. 2017) and *ACRP Research Report 255: PFAS Source Differentiation Guide for Airports* (Anderson et al. 2023).

In summary, while applicable FAA regulations and guidance do not currently necessitate such in-depth PFAS planning documents, they are a useful way to help an airport operator evaluate PFAS challenges and communicate those to staff as they set operational, developmental, and budgetary priorities. Airport operators should consult legal counsel during development to confirm that plans accurately reflect legal requirements.

4.2.2 Future Development or Renovation Planning

Major renovations or additions typically must meet regulatory requirements for new construction, including the applicable provisions within the IBC and NPFA 409 (ICC 2020, NFPA 2022). While the requirements must be verified through the adopted codes for each, most jurisdictions will adopt a version of the IBC and NFPA 409 codes. The design options discussed in this section are based on the 2022 edition of NFPA 409, which is the most recent.

When the primary renovation involves replacement of the foam fixed suppression system, the requirements may be somewhat different. There are opportunities for noncompliant systems to be grandfathered and allowed to remain; however, this may make it difficult to utilize some options and technologies that do not use foams but are allowable under the requirements for new construction and renovation projects. To take advantage of these options, the existing noncompliant systems or equipment may have to be brought up to current code standards.

4.2.2.1 Considerations for New Hangar Development

Code requirements for fire suppression systems for hangars are directly related to the classification of the hangar and the type of operations inside the hangar. The IBC and NFPA 409 contain four groups of hangar types, labeled Groups I through IV. The hangar classifications are based on the area of the hangar bay portion of the building, the height of the door or aircraft tail, and construction type.

New hangar fire suppression systems can involve significant costs for the initial installation. Following are the four major areas of construction costs for new hangar foam fire suppression systems that constitute additional expenses above and beyond basic hangar construction:

- **Foam equipment:** Costs for concentrate product, concentrate tanks, proportioners, discharge devices, and the detection system.
- **Fire pumps:** At least two fire pumps are required, and when electric power supply or diesel engine provisions are factored in, the required appurtenances represent additional costs.
- **Water storage tanks:** Tank size requirements start at 100,000 gallons and can often exceed 500,000 gallons for larger hangars.
- **Architectural and site space requirements:**
  - Concentrate tanks and fire pumps require additional floor area, which will likely exceed 500 ft^2 of building area.
  - Water tanks are typically at ground level and require adequate space on-site for the tank's size or capacity.
  - HEF systems also typically require roof vents for inside air and wall louvers for pressure relief.

The type of foam system can have a significant impact on what features, such as fire pumps or water tanks, can be eliminated, so one specific system may have a substantial cost advantage over another. However, maintenance costs are not included in the cost assumptions above. Most of the equipment discussed requires annual maintenance. Foam system proportioners must be tested every 5 years, so there are additional associated cleanup and disposal costs.

A new hangar's group classification, intended use, and possible design options can affect the fire suppression system requirements mandated by code, including where foam suppression is required within the hangar and what type of systems can be used. In general terms, Group I and Group II hangars for fueled aircraft and hangars with hazardous operations as defined by the IBC and NFPA codes will have to address foam system requirements or obtain a variance authorizing an exception to code. Hazardous operations are defined in NFPA 409 as fuel transfer, welding, torch cutting, torch soldering, doping, and spray painting (NFPA 2022). Section 412 of the IBC also adds fuel tank repair and maintenance, total aircraft fuel capacity of 1,600 gallons in non-sprinklered buildings, and total aircraft fuel capacity of 7,500 gallons (ICC 2020). The IBC does have a foam requirements exemption for Group II hangars operated by FBOs that are used for storage of transient aircraft, but only if the FBO has separate repair facilities on-site.

Defueled Aircraft. The basis for using foam fire suppression is to provide protection against fires involving fuel spills, that is, pool fires involving burning liquid. Therefore, removing the fuel from the facility removes the necessity for foam fire suppression. NFPA 409 defines a defueled aircraft as one whose individual tanks contain less than 1% of their volumetric capacity or whose tanks have been drained to remove fuel to the greatest extent possible by using sump drawings and other accessible nonmaintenance means (NFPA 2022). If aircraft are defueled before bringing them into a hangar, a foam fire suppression system is no longer required. Additionally, features such as trench drains, internal fire ratings, draft curtains, and other features may be eliminated from the design. Although defueling aircraft can provide significant savings in construction costs, doing this may affect tenant operations, as tenants would have to defuel aircraft before utilizing the hangar.

Hangar Construction Type. For hangars with an area of less than 30,000 ft^2, the construction type is the primary basis for determining the hangar's classification and distinguishing between Group II and Group III hangars. Construction type essentially refers to the fire rating requirements for the building's structural elements. Steel structures without fire-rated structural elements are the most common and least expensive buildings to construct. Such construction is compliant with NFPA for Type II(000) and IBC for Type IIB (NFPA 2022, ICC 2020). The hangar bay area limit for a Group III hangar of Type II(000)/IIB construction is 12,000 ft^2.

If the structural elements are fire rated, then the allowable area of a Group III hangar can be increased. Provided the hangar does not have hazardous operations, especially with regard to total fuel capacity, foam fire suppression would not be required. Although rating the structure is very likely to be less expensive than the cost of foam equipment, there are some concerns with providing fire ratings. Steel fireproofing can create concerns associated with foreign object debris, and enclosing all structural components, including the roof, with gypsum board has its own limitations (NATA 2023).

Historically, hangars approaching 10,000 ft^2 require water-only sprinkler system protection as the aircraft fuel capacity starts to exceed the 1,600-gallon limit. As a result, the limiting factor becomes the 7,500-gallon maximum aircraft capacity for fully sprinklered buildings before foam fire suppression is required (ICC 2020; NFPA 2023).

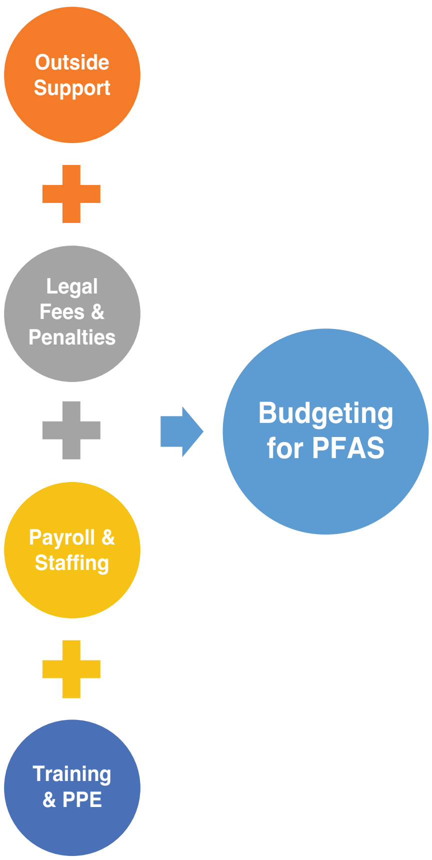
4.2.2.2 Fire Risk Assessments for New Developments

The 2022 edition of NFPA 409 allows for modifications to the requirements for hangar fire protection systems if a fire risk assessment is performed (NFPA 2022). Chapter 4 of NFPA 409 provides the evaluation criteria for the fire risk assessment and the process for approval of the fire protection approach as determined by the fire risk assessment. A fire risk assessment will likely require a variance to utilize the 2022 NFPA edition until the standard is adopted by a given local jurisdiction.

As with the ILDFA technology, the fire risk assessment is a new method for determining the fire protection approach for a hangar. While it is likely that the acceptable approaches identified will exclude the use of AFFF fire suppression systems, the fire risk assessment may be considered as similar to a variance. A building fire code official will review the proposed solution involving the elimination of an AFFF fire suppression system as a trade-off for other fire protection features. These other fire protection accommodations could include specialized detection systems, increased sprinkler flows, increased fire ratings, additional exits, or other safety features. NFPA 409 identifies 21 factors to include in a fire risk assessment, which may produce a wide variety of fire protection approaches (NFPA 2022).

A concern with utilizing fire risk assessments is the potential for lost flexibility in the use of space. Most fire risk assessments that eliminate AFFF fire suppression systems will likely be based on the planned airport or tenant use of the facility. A future change in the types of activities conducted in the hangar or in the tenant occupants could require the fire risk assessment to be updated. This, in turn, might result in required fire protection modifications to the facility to accommodate the new operations or tenant activities.

Given historical data and the probability of the incidence of hangar fires, it is likely that most small and medium hangars will not need an AFFF fire suppression system. Larger hangars may still warrant a foam fire suppression system, or another similarly effective NFPA 409 protection option, on the basis of potential financial losses for aircraft, operations, and structure values. However, when the significant costs of foam systems are factored in, it is likely that a design that utilizes another fire protection system approach in lieu of foam fire suppression will be the less expensive alternative.



4.2.3 Budgeting for PFAS

Airport operators should consider costs associated with PFAS management when preparing a budget. While budgeting for PFAS may seem difficult, generally accepted budgeting standards can be employed. Environmental compliance budgets may also need to be augmented and additional funding set aside to address PFAS activities. Airport operators will want to consider budget requirements for the following items:

- Professional services such as environmental consultants, laboratory fees and sampling costs, industrial historians, or communications specialists, among others;
- Additional construction costs for managing waste, soils, or water;
- Legal services;
- Payroll for additional staff to manage compliance, investigations, remediation, regulator coordination, or other program management needs; and
- Employee training and, possibly, specialized PPE for employees.

In setting actual budget amounts, airport operators should consider using accepted strategies for environmental liability assessments, such as those published by the Securities and Exchange Commission or other recognized accounting authorities (FASB 1984, SEC 1993, AICPA 1996).

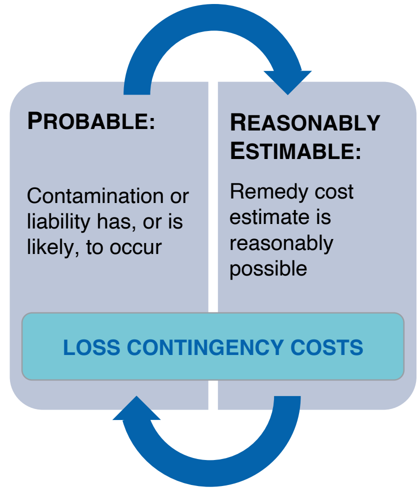
The Sarbanes–Oxley Act of 2002, which regulates financial reporting for public companies, requires disclosure of future environmental liabilities if they are material to the balance sheet (Hall and Pugliese 2004; Crusto 2005). This requirement has now been adopted in the generally accepted accounting principles used by most private and public companies, governmental agencies, and many nonprofit organizations. It is important to note that risk and potential liability involving PFAS either only arise under state law (if applicable) or cannot yet be quantified, since PFAS are not a listed contaminant at the federal level. While these regulations may not be relevant for all airport organizations or to all airport facilities, airport operators should consider

For Your Information

Developing reserves for AFFF-related environmental liabilities may be difficult, given regulatory unknowns and complexities related to investigation and remediation.

these potential issues and determine, with the assistance of legal counsel and qualified professionals, whether they are applicable. Airport operators should consider working with disclosure or bond counsel to craft specific language.

Environmental remediation liabilities are addressed in these standards. Loss contingencies associated with these liabilities should be determined when they are considered "probable" and the amount of the loss is "reasonably estimable." Airport operators can work with accounting and legal counsel to fully understand the requirements for reserve estimate disclosures for environmental remediation.



4.2.4 Limiting PFAS Legal Risk

PFAS litigation has flourished in recent years. Airports have faced fewer PFAS lawsuits than other industries, but some have had to defend against toxic tort or common law tort claims. Toxic tort claims include allegations of exposure from occupational activities. Common law tort claims allege nuisance, trespass, or negligence, as examples. As regulation of PFAS increases, airport operators can expect that state law tort claims are likely to accompany federal claims in lawsuits against them, since they provide plaintiffs with potential additional avenues of redress and chances for success.

Hiring PFAS-specific legal assistance may be necessary, especially when an enforcement action appears imminent, significant on-site or off-site PFAS impacts exist, or a lawsuit has already been filed against an airport operator. Regardless, airport operators should take the following practical steps to limit their PFAS legal liability.

First, airport operators should implement policies to verify that ongoing and future activities will not exacerbate existing contamination. Until there is more regulatory certainty, airport operators should consider a moratorium on off-site soil disposal. This may not be realistic for many airports, so if off-site disposal is necessary, soils should be characterized and sent to an appropriate disposal facility. Soils should be characterized before they are spread or moved within an airport's footprint. Airport operators should refer to state requirements for soil testing, stockpiling, disposal, and on-site reuse and should have soil management plans that comply with those requirements. More information on soil remediation and disposal options is provided in the following sections in addition to the management options provided in Chapters 3 and 4 and in *ACRP Research Report 173* (Thalheimer et al. 2017).

Airport groundwater should not be used for irrigation, consumption, or maintenance if it has been affected. Groundwater or surface water pathways could also be evaluated to minimize comingling of affected areas. As previously discussed, airport operators should know where PFAS-containing materials are stored and used at the airport, including tenant facilities with AFFF fire suppression systems.

If remediation is desired or required, airport operators should focus on risk-based corrective actions. Not all PFAS on-site need to be addressed or remediated at once, and prioritization of corrective action will need to be based on the risks or threats presented in each location or scenario. A risk-based approach employing an appropriate CSM allows an airport operator to address risks appropriately and cost-effectively. For example, an airport operator may need to remediate known source areas affecting groundwater to limit or eliminate exposure pathways to receptors, such as potable groundwater wells, and include administrative controls, such as property use

For Your Information

Options to limit PFAS legal risk:

- Implement policies to prevent further contamination from ongoing and future activities.
- Prohibit off-site soil disposal or dispose of soils as hazardous waste.
- Characterize (test) soils for PFAS before moving them to other airport locations.
- Confirm state requirements for soil testing, stockpiling, disposal, and reuse.
- Include PFAS in soil management plans for the airport and construction projects.

limitations restricting the use of groundwater for drinking water. Low-risk scenarios may also occur where PFAS quantities in groundwater or soils are small enough that exposure pathways to humans or ecological areas are negligible. In these situations, contaminated media may not need to be excavated if safely capped in place to prevent further PFAS migration, which would avoid some remediation costs.

Risk is inherently tied to regulators' and the public's perceptions of the airport. Public communication and media engagement are discussed in Chapter 5.

An airport operator's risk is inherently tied to regulators' and the public's perception. Thus, airport operators should have sound strategies for outward-facing communication. Airports should confirm communication protocols are in place before remedial investigation processes begin. If it is necessary to disclose potential risk for PFAS liability in official statements or other bond or financial disclosure documents, airport operators should verify with legal counsel that their disclosures are sufficient to legal requirements but do not disclose more than is necessary.

While it is beneficial for airport operators to foster productive relationships with state and federal regulatory personnel, operators should take care not to admit liability, either directly or unintentionally. Consultation with legal counsel can prepare airport staff with strategies and language to use when interacting with regulators that may help preserve the airport operator's rights. Airport operators should consult legal counsel before responding to requests for information or engaging in other interactions regarding past or present PFAS management on airport property.

4.2.5 Cost Recovery Strategies

Airport operators should determine potential avenues of cost recovery for sums expended to remediate PFAS contamination, including insurance recovery, CERCLA cost recovery, and contribution claims. CERCLA allows liable parties to seek recovery of costs from other liable parties. Airport operators should consider what other entities may be sources of PFAS and accumulate supporting information for that conclusion. Consult an attorney experienced in cost recovery to develop an appropriate strategy.

Remedial efforts undertaken should be performed in substantial compliance with a federal regulation known as the National Contingency Plan (NCP) and well documented to maximize the possibility that costs can be recovered later under CERCLA cost-recovery mechanisms. If a sampling program is planned, airport operators should take care to select locations that can more easily demonstrate isolation of airport impacts from other sources; if possible, airport operators should try source differentiation techniques to distinguish AFFF-related PFAS from other possible PFAS sources. The research in *ACRP Research Report 255* can assist with this effort (Anderson et al. 2023). Airport operators should also consider the role of insurance policies in defraying AFFF-related costs. CERCLA is another resource for cost recovery. Additionally, many states and jurisdictions offer grants for funding pollution and contamination cleanup.

For Your Information

Before 1970:
CGL insurance policies often fully covered pollution, even from PFAS.

After 1970:
CGL insurance policies often covered accidental releases, and might include PFAS.

After 1986:
CGL policies are unlikely to cover PFAS costs or liabilities.

4.2.5.1 Insurance

Insurance policy considerations should include a backward-looking review of historical insurance policies for any that may cover PFAS releases and forward-looking assessment of whether PFAS coverage under current policies is feasible or desirable.

Before the 1970s, commercial general liability (CGL) insurance policies covered pollution discharge broadly and often included coverage for PFAS-related costs. After the 1970s, CGL policies tended to cover sudden and accidental pollution releases, which could include some PFAS impacts. General liability claims are typically triggered by bodily injury or property damage during the policy period, and groundwater contamination has generally been considered property damage (Jeweler and Miller 2021).

CGL policies issued after 1986 are unlikely to cover PFAS-related liabilities and costs. Older pollution legal liability (PLL) policies may include PFAS coverage, but newer PLL policies from within the past few years will likely exclude PFAS from coverage. At sites with known PFAS contamination, contractor's pollution liability (CPL) coverage generally covers actions that exacerbate existing PFAS conditions or cause new releases of PFAS; that is, PFAS are not generally excluded from coverage in CPL policies that apply to known conditions. PLL, CPL, and environmental impairment liability policies are generally triggered by regulatory actions or orders, remediation, and third-party claims (Jeweler and Miller 2021).

Airport operators should review historical insurance policies to determine whether they may cover releases that occurred during the policy periods. Some policies are claim-based, whereas others may be occurrence based, meaning each documented PFAS release, such as a spill, fuel fire, or other event in which AFFF was released, may provide separate coverage, such that multiple occurrences can be stacked for maximum coverage. Additionally, providing notice of releases is important to preserve insurance rights, as late notice may result in insurance companies rejecting coverage. Guidance about giving notice at this time is mixed, with some experts suggesting giving precedence to pre-1986 general liability policies (Chesler and Horkovich 2021) and others suggesting that notice should be given to any insurance company with potential coverage (Cohara et al. 2021). In general, time constraints on notifications may be a contractual or statutory limitation that is jurisdiction specific.

Further, older policies may provide coverage for defense costs without eroding the limits of coverage. As an example, a policy might have a coverage limit for indemnity of 1 million dollars (US$1,000,000), but it might respond to all defense costs, even those substantially more than the policy limits. In these types of policies, the defense cost coverage might not erode the indemnity coverage, depending on policy language and applicable state insurance laws. These defense costs could include the cost of investigation, defending against lawsuits or agency orders, and, in some cases, might even cover a lawsuit against other parties for cost recovery, if such a lawsuit can be styled as part of defense costs.

Insurance and risk specialists can be instrumental in helping airport operators understand their possible historical coverage. Policy archivists or archeologists can help an airport operator with searching for historical policies. Legal counsel well-versed in environmental insurance can assist with determining which claims may be covered and how to begin investigating and asserting such claims. Airport operators may be overlooking opportunities for cost recovery and financial protection by failing to consider what claims past insurance policies may support. Insurance of tenants with liability may also be a potential source of cost reimbursement, even for tenants who do not seem to have sufficient resources to contribute to cleanup. In some cases, this can include tenants that have gone bankrupt or been dissolved.

For Your Information

Insurance policy archaeology investigates and researches old insurance coverage records for customers, primarily businesses, whose historical insurance records may have been lost or destroyed.

Airport operators may also want to consider purchasing additional insurance coverage for PFAS. While some environmental insurance providers exclude PFAS from coverage, others are more willing to look at the details of each situation and assess what PFAS coverage can be provided. The options will vary depending on the site, but, generally, entities are more likely to obtain PFAS coverage by demonstrating there was no historical use or any prior impact to the site, and coverage for bodily injury and property damage is more likely to be available than coverage for cleanup costs.

However, there are exceptions to these general rules. Even in situations in which PFAS releases have been documented and there are known site impacts, coverage for bodily injury and property damage may be available if, for example, the airport is in a remote area, there are no residential developments nearby or in close proximity, and adequate site characterization confirms contamination has not migrated to potable water sources. Under such circumstances, the case for coverage will be improved if the airport operator can provide sufficient data and a CSM.

4.2.5.2 CERCLA Cost Recovery

A cost recovery or contribution claim under CERCLA may be a viable option once PFAS are listed as a CERCLA hazardous substance. Then, airport operators may offensively bring cost recovery or contribution actions against other parties liable for releases at their sites. To successfully bring such a lawsuit, however, airport operators must verify that the response activities they are seeking reimbursement for were performed consistent with the NCP. This means that a CERCLA-quality cleanup took place, with meaningful public participation and consideration of alternatives, and that no preselection of the remedy took place.

For Your Information

The Gore factors:

1. The ability of each party to demonstrate its own distinguishable share of the discharge or release;
2. The amount of hazardous material contributed;
3. The degree of toxicity of the hazardous material;
4. The degree of involvement in the material's generation, transportation, treatment, storage, or disposal;
5. The degree of care exercised; and
6. The degree of cooperation with federal, state, or local officials to prevent harm to the public health or the environment.

When defending in a CERCLA lawsuit, if an airport operator is found to be a liable party, it will want to demonstrate why its share of total remediation costs should be as small as possible. When courts decide how to allocate the cost obligations of a CERCLA cleanup among responsible parties, they often consider six factors, known as the Gore factors, and how these apply to each party.

Airport operators interested in the possibility of future cost recovery or contribution claims will want to keep these factors in mind and, to the extent possible, confirm their actions reflect favorably for each criterion. For instance, the current airport operator staff and leadership do not have control over past PFAS releases, PFAS toxicity, or the regulatory requirement to use PFAS-containing AFFF to extinguish fuel fires.

However, airport operators can take action to determine their degree of involvement in the materials' generation, transportation, treatment, storage, and disposal by completing a historical study of past AFFF use, and, if it would benefit or support the airport's claim, conducting environmental media sampling to determine the extent of exposure. When developing environmental media sampling programs, airport operators should take care to select locations that best demonstrate isolation of airport impacts from other sources, and operators should attempt to develop a chemical fingerprint that could distinguish airport-related PFAS from other PFAS sources.

Airport operators may want to research opportunities for grants or other government-sponsored funding for PFAS remediation or contamination cleanup.

Finally, airport operators should act cooperatively with regulators and diligently prevent the spread of existing PFAS contamination as well as future unnecessary releases of PFAS. Failure to do so may be viewed negatively by a court considering an airport operator's proper share of CERCLA costs and could yield a higher share of the financial burden for an airport operator. If the potential for a CERCLA action exists, it will be critical to engage appropriate environmental and legal counsel early in the process to maximize the potential for a successful outcome.

4.2.5.3 Other Cost Recovery Options

Some jurisdictions have grant programs with funding devoted to helping clean up or redevelop certain sites. For instance, in California, as of April 2022, the statewide Proposition 1 Groundwater Grant Program has awarded money to local entities for groundwater cleanup and pollution prevention (California Water Boards 2022). Minnesota's Contamination Cleanup and Investigation Grant Program helps public and private entities assess and clean up redevelopment sites (MDEED 2022). Airport operators may want to survey their state and local resources for funding options applicable to their facilities. Further, additional federal funding sources may emerge in the future. Airport operators should be routinely checking local, state, and federal resources for additional funding opportunities and the latest regulatory developments.

4.2.5.4 Emergency Notification and Response Actions

If a PFAS impact threatens a critical downgradient resource—for example a private, potable water supply well or municipal water supply well—it may be necessary to implement immediate emergency response actions, such as providing bottled water to airport users or the surrounding affected community. Emergency response actions are typically implemented over the short term, while response actions such as a household point-of-use treatment system, an ex situ treatment system on the municipal supply well, or replacement of the municipal supply well are typically evaluated and put in place over the medium to long term. Physical relocation of affected wells may be an option but would need to be negotiated with the affected party. This option can be explored on a case-by-case basis with consultants and legal counsel.

4.3 Remediation Options and Controls

This section discusses methods and technologies for mitigating, sequestering, or remediating PFAS in environmental media. The first part of this section addresses remediation strategies, including emergency response actions, considerations for ex situ and in situ treatment and remediation of groundwater and soil, options for treatment of surface water and sediment, and key elements of long-term monitoring programs. The second part of this section focuses on institutional or administrative controls, alternative endpoints, and adaptive management strategies, as well as on evaluating engineering solutions to promote airport user and community safety.

For Your Information

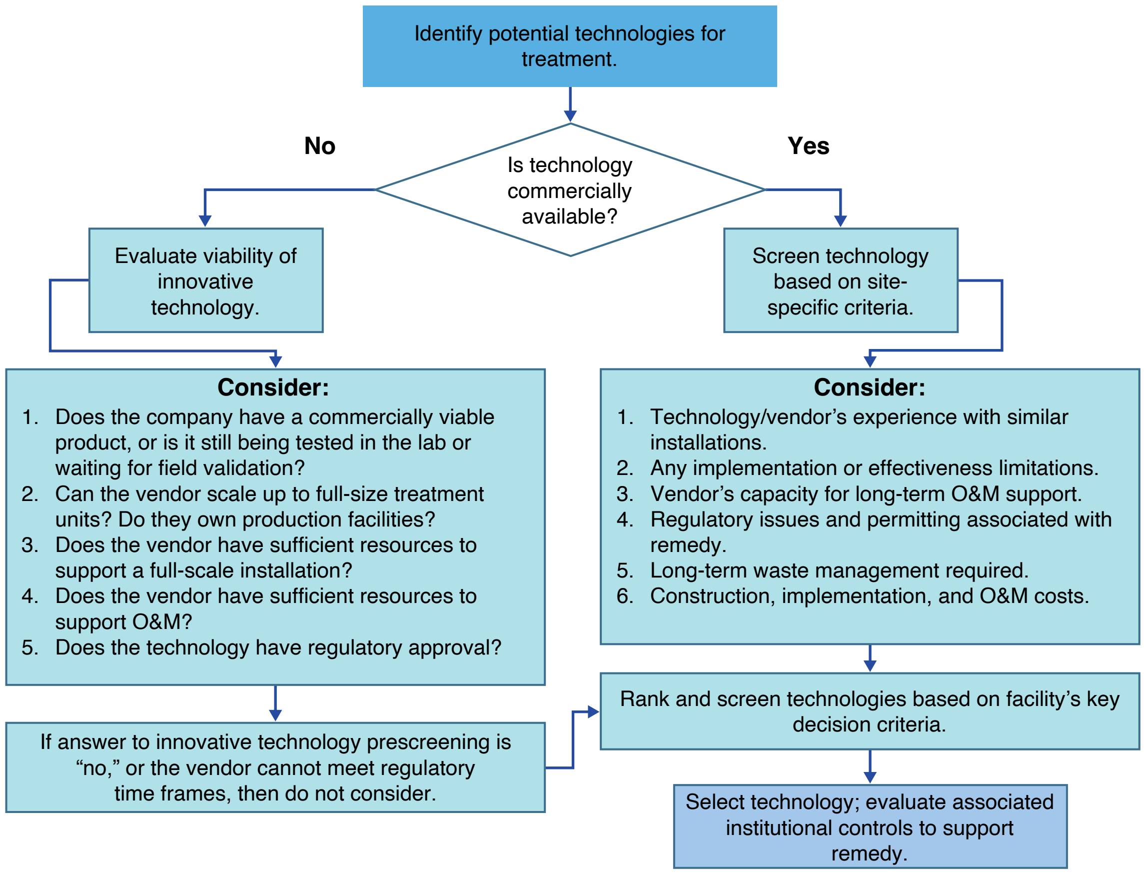
NCP nine criteria analysis (EPA 2022d):

1. Protection of human health and the environment;
2. Compliance with applicable and appropriate requirements;
3. Long-term effectiveness and permanence;
4. Reduction of toxicity, mobility, or volume through treatment;
5. Short-term effectiveness;
6. Implementability;
7. Cost;
8. Community acceptance; and
9. State acceptance.

4.3.1 Remediation Strategies

If released, PFAS may persist for decades in subsurface environments, often disproportionally accumulating at interfaces. Some sequestration and remediation technologies for management or treatment of soils, groundwater, surface waters, and sediment are available today. Although many of these promising technologies are still in testing phases, the common industry techniques available as of September 2023 are discussed here, along with their positive attributes and potential drawbacks. Critically, it is important to differentiate between commercially available, or developed, technologies and those that are still being evaluated in scale, prototype, or field-testing phases. A summary of considerations for choosing a new technology to implement is provided in Figure 4-5.

As technologies mature, are field tested, and become accepted by regulatory agencies, more PFAS treatment options will be commercially available. Airport operators will want to assess the implementability of a given technology and whether a provider can implement it full scale and support its operations long term. While the NCP provides some implementability-focused questions, PFAS innovations may require more targeted questions, particularly to gauge the long-term performance and reliability of start-ups.



Note: O&M = operations and maintenance.

Figure 4-5. Proposed technology implementation flowchart.

Ex situ methods involve removing or treating contaminants in media at a location away from where the contaminated media were found. Options for ex situ treatment technologies often involve excavating or extracting PFAS-contaminated media, then removing the PFAS from media with equipment located on-site or off-site. Conversely, in situ technologies address PFAS-contaminated media on-site and in place within the environment. While airport operators will evaluate remedial strategies according to the criteria of implementability, effectiveness, and cost, as outlined in the NCP, other criteria specific to the airport and its operating situation may be developed and integrated into the evaluation.

Treatment technologies, including their environmental, financial, and institutional attributes, are discussed in the following sections. The introduction to each section summarizes the state of the technology and provides considerations for remedy implementation. The Toolkit on Regulatory Action, Financial Planning, and Remediation (Appendix C) provides details on technologies and treatment considerations, and Toolkit Tip sidebars are provided in applicable sections to draw attention to which tools may be most helpful for a given subject.

4.3.1.1 Granular Activated Carbon

GAC, an EPA-recommended PFAS water treatment technology, can be very effective in reducing PFAS—specifically, PFOS and PFOA—from water supplies (Calgon Carbon 2019, Crystal Quest 2021). The activated carbon used in GAC applications is composed of carbon-rich organic materials such as wood, coal, coconut shell, and lignite. These materials, when converted into activated carbon granules, act as a porous medium, similar to a sponge, through which contaminated water is filtered (EPA 2018b). As gravity forces the water through the activated carbon, hazardous chemicals, such as PFAS, adhere to the granules and are removed from the water. GAC uses physical separation technology, which means the contaminants are not destroyed in this process; instead, they are transferred from an aqueous phase onto an adsorbent media (Saltworks Technologies 2019).

Powdered activated carbon (PAC) has also been suggested by EPA as a PFAS remediation technology, due to its similarity to GAC. The difference between PAC and GAC is that the granules in GAC are much larger than the powdered carbon in PAC applications (EPA 2018b). Some advantages and disadvantages of GAC are summarized in Table 4-1.

Recent developments have focused on minimizing the volume of affected media or incorporating a destruction component into the treatment train. Many studies have noted that the success of the treatment is highly dependent on localized water chemistry. For example, the Orange County, CA, Water District is currently implementing a pilot study evaluating the site-specific effectiveness of 14 different products to develop protocols and procedures for optimizing removal efficiencies and minimizing costs in 10 different municipalities and more than 70 different wells (Orange County Water District 2020).

4.3.1.2 Ion Exchange Resins

Ion exchange (IX) is another type of water treatment that uses separation technology to remove PFAS from water sources (Saltworks Technologies 2019, EPA 2018b). There are two common IX resin types and associated processes available: single-use and regenerable. IX resins are small beads of charged resin material that attract certain contaminants, including many PFAS. The hydrocarbon beads are added to a water system and chemically attract compounds in solution, such as PFAS, which adsorb or adhere to the resin substrate. Clean water then passes through, and when the process is complete, some resins can be regenerated by chemically dissociating the contaminants for disposal, while other resins are destroyed or disposed of along with the affixed contaminants (EPA 2018b).

To keep the resin suspended in the water and create an even distribution of the contaminant in solution, air is used to continually mix the water. This action enhances the IX process by facilitating more efficient binding between the organic material in the water and the resin (PWNT Water Technology 2018). Once the IX process is completed, the resin is separated from the clean water with a lamella separator, also known as a settling tank for solids (Colloide 2021). This technology can also be used in other water treatment processes, such as demineralization and softening (ITRC n.d.-c). Table 4-2 summarizes the advantages and disadvantages of IX.

IX technology is often used in conjunction with GAC. The contaminated water is first run through a GAC removal process known as the lead column, and then the water is passed through

Table 4-1. Summary of GAC treatment efficacy.

Advantages	Disadvantages
Effective at removing long-chain PFAS from drinking water	Less effective in removing short-chain PFAS
Removes other hazardous organic materials	Nonselective of what organics are removed
Can remove undesirable tastes, colors, and odors from drinking water	Cannot remove inorganic materials
Does not negatively affect surroundings during treatment	Expensive consumables

Table 4-2. Summary of IX resin treatment efficacy.

Advantages	Disadvantages
Effective at removing long-chain PFAS from drinking water	Less effective in removing short-chain PFAS
Adsorption capacity of IX resins is higher than GAC	IX media cost is much higher (U.S. dollars per cubic foot) than GAC media (U.S. dollars per pound)
IX process requires fewer vessels than GAC	Cannot remove inorganic materials

a second filtration stage that uses IX beads, also known as the lag column, to further remove contaminants and prolong the effective lifespan of the IX resins. ITRC provides a more thorough discussion of GAC and IX technology in its overview of treatment technologies (ITRC n.d.-c).

4.3.1.3 Reverse Osmosis Systems

Another method suggested by EPA and ITRC is a reverse osmosis (RO) system. This technology involves pressurized water passing through a semipermeable membrane to extract and remove certain ions, molecules, and larger particles from water (EPA 2018b). The pressurization overcomes the osmotic pressure differential between either side of the filter membrane, and the concentrated solution on the input side, with the filtered or entrained products, is collected and disposed. This method is effective in removing many organic and inorganic compounds and salts from water. A study funded by the National Academies of Science, Engineering, and Medicine found that RO filters and dual-stage filters were able to consistently remove many forms of PFAS with an average of ≥90% efficiency, although this technology was far less effective at removing shorter-chain PFAS such as PFNA and GenX, for which the average removal efficiency was approximately 41% (National Academies 2022).

Reverse osmosis has been used frequently to extract PFAS from drinking water, surface water, reclaimed water, and semiconductor wastewater (ITRC n.d.-c). However, RO membranes are highly susceptible to fouling by materials such as colloidal organic matter, microbial growth, or inorganic salts that accumulate on the membrane's surface and cannot be removed. Fouling can diminish the filter's production capacity and may necessitate frequent replacement of the membrane if the water is not pretreated with filtration for solids prior to processing. Poor water quality—for example, high concentrations of dissolved solids or other co-contaminants such as NAPL—can also inhibit the filtering capabilities of an RO system.

4.3.1.4 Ex Situ Water Treatment

The majority of PFAS treatment methodologies developed as of 2022 address impacts to systems that supply potable water, however, treatment systems may be installed to treat groundwater, surface water, or contained water from AFFF use or releases. Residential point-of-use treatment technologies are ex situ but implemented on a smaller household scale.

Many technologies, such as the application of hydrogen, high-energy electron beam research, and supercritical water oxidation, are still in the early phases of research (Cough-Shulze 2020, ITRC n.d.-c). Research into combined treatment trains is exploring synergistic benefits that could maximize treatment outcomes. These lines of research include combined nanofiltration and electrochemical anodic oxidation and combined electro-Fenton and electrochemical anodic oxidation (Liu et al. 2020). More information about ex situ PFAS treatment technologies that might be considered by the aviation community is provided in Tool 4.1.

Toolkit Tip

Tool 4.1: Considerations for Selecting a Method of Ex Situ Water Treatment

- Options for ex situ water treatment with method descriptions.
- Implementability, effectiveness, and availability evaluations.
- Cost assessment considerations.

The following factors can help airport operators determine the feasibility of ex situ water treatment:

- When groundwater is being addressed, the assumption is that sufficient groundwater extraction can be achieved.
- The feasibility is dependent upon the anticipated water yield, expected water quality, potential for fouling, and difficulty of operation over the long term.
- Site-specific hydrogeologic factors should be used to conduct feasibility analyses at each site, independent of PFAS issues.
- Hydrogeologic assessments should be performed during site investigations.
- When surface water and stormwater or surface spills are being managed, the assumption is that water has been contained and can be pumped to a centralized treatment system.

GAC and IX systems are the most widely used technologies for ex situ treatment of contaminated waters. GAC, IX, or combination methods are used for treatment of municipal water supplies and contaminated groundwater extracted from remediation sites. Instead of destroying PFAS, these techniques transfer the PFAS from one matrix—for example, contaminated groundwater—to the GAC or IX resin absorbent matrix. After a certain volume of water at a given concentration of PFAS or other solutes has been cleaned by the GAC or IX resin, the dirty GAC or IX resin substrates must then be disposed of as hazardous waste or regenerated for further use. Substrate regeneration is the process of dissociating PFAS from the GAC or IX resin surface to a rinsate that is then disposed of as hazardous waste; the GAC or IX resin is returned to the filtration train for future use.

For Your Information

At airport facilities, remediation waste streams may be generated from groundwater, surface water, historical AFFF releases, accidental releases, emergency fire responses, retention ponds, and other sources.

In each case, PFAS may colocate with other contaminants, which will complicate the remediation treatment train.

The design at each site will be highly site specific, depending upon PFAS concentrations, co-contaminants, and the geochemistry of the underlying site.

Commercial grade nanofiltration or RO systems are also used in large-scale applications, but not as widely. GAC, nanofiltration, and RO system technologies are highly effective and commonly implemented for public and private wells (EPA n.d.-b), but membrane fouling in nanofiltration and RO systems can make these technologies too costly or inefficient, to the point of being ineffective for large remediation projects.

The design and selection of an ex situ PFAS treatment system will be based on both capital and estimated long-term operations and maintenance (O&M) expenditures, which are significantly affected by site-specific criteria (see Tool 4.2). Following a technological evaluation of the feasibility of implementation and operation, an engineering design based on site-specific hydraulic testing is needed to determine flow rates, and groundwater sampling is necessary to understand pretreatment needs; bench or pilot-scale testing may also be needed to validate GAC or IX selections and configurations, given a specific site's characteristics.

Toolkit Tip

TOOL 4.2: Considerations for Determining the Feasibility of Ex Situ Water Treatment

- Guide of major factors affecting costs for ex situ water treatment.
- Assists airport operators with cost-effectiveness and feasibility determinations by method.

Design and installation may require review and approval by the regulatory authority. Once affected waters have been treated by the chosen ex situ technology, the remediated water would need to be discharged to the sanitary sewer system or back into the environment. In either scenario, preapproval would be required from the local NPDES enforcement agency or the receiving wastewater treatment plant prior to discharge, and both agencies will likely require commensurate sampling and routine reporting to verify the remediation treatments are effective.

Long-term management and disposal options will be required for the treatment media (GAC, IX resin, or RO concentrates), but disposal options may be limited or very expensive, so options should be assessed as part of a long-term feasibility and liability evaluation. Given

For Your Information

Class I (nonhazardous industrial or hazardous waste) wells are well suited for the management of PFAS waste material.

Permitted underground injection of fluids through Class I wells ensures that injected fluids are confined and cannot enter U.S. drinking waters.

pending regulatory changes, spent carbon (GAC), spent resins (IX), residual IX brine, and RO concentrates will likely be characterized as hazardous waste. Airports may find they are unable to store these materials on-site for an indeterminate amount of time, yet may not be able to afford the services of the hazardous waste disposal facilities available.

For source material, such as AFFF concentrate products, and high-concentration residues from IX brines and RO concentrates, the primary off-site disposal options include deep well injection and incineration. EPA has identified deep well injection as a viable treatment option for PFAS. For small quantities of wastewater (e.g., wastewater generated from high-concentration spills, AFFF product concentrates, or small periodic discharges), off-site disposal at a permitted deep well injection facility may be significantly cheaper than construction and operation of an ex situ water treatment unit (Tow et al. 2021).

4.3.1.5 In Situ Groundwater Treatment

Since PFAS are not readily degradable to inert or safe chemical conformations, in situ remedial options are limited. Many traditional in situ treatment technologies—chemical oxidation, for example—are likely to enhance the transport of PFAS compounds by converting precursors to more mobile PFAS compounds (McGregor 2020). In situ bioremediation techniques are currently deemed ineffective, or development has been too slow to meet common regulatory objectives (Men 2020, Jaffe 2021, Liu 2020).

Toolkit Tip

Tool 4.3: Considerations for Selecting a Method of In Situ Water Treatment

- Options for in situ water treatment with method descriptions.
- Evaluations of implementability, effectiveness, and availability.
- Cost assessment considerations.

Toolkit Tip

Tool 4.4: Considerations for Determining the Feasibility of In Situ Water Treatment

- Guide of major factors affecting costs for in situ water treatment.
- Assists airport operators with cost-effectiveness and feasibility determinations by method.

As of 2022, PFAS sequestration by injected colloidal activated carbon (CAC) was the most-developed commercial in situ treatment technology in attenuating plume migration and achieving containment objectives without active pumping (ITRC 2017, Fagerlund et al. 2020). Implementation of an in situ PFAS remedy will require a detailed understanding of the PFAS plume and potential migration pathways for CAC to be injected into the appropriate zones in the subsurface. Preinjection testing typically includes a range of groundwater flux assessments and baseline injection tests to gauge CAC dosage rates and delivery. Tool 4.3 provides help in determining whether an in situ PFAS remedial option would be effective.

The design and selection of an in situ PFAS remedy is based on both capital and long-term O&M costs, which are affected by site-specific criteria, as described in Tool 4.4. Following technology evaluation, an engineering design is based upon site-specific testing to determine CAC injection quantities, spacing, flow rates, and pressures for injection equipment. Implementation of CAC injection typically requires review and approval by the regulatory authority.

Multiple studies are underway at SERDP and the Environmental Security Technology Certification Program (ESTCP), which are evaluating novel methods for groundwater treatment via PFAS degradation. While some studies have shown transformation of precursors, they have not demonstrated complete degradation of PFAS (Shahsavari et al. 2021).

Other in situ options, such as monitored natural attenuation, are not widely used at this time for PFAS and have yet to gain widespread acceptance by the regulatory community, although they are being evaluated by ESTCP researchers, among others (Adamson 2021, Newell et al. 2021a, 2021b).

Similarly, phytoremediation technologies are emerging for uptake and hydraulic control of PFAS sites (ITRC 2009, Huff et al. 2019). These options are expected to become more accepted by the regulatory community if studies demonstrate their effectiveness.

Identification and testing are also underway for injectable adsorbents for in situ sequestration (Aly et al. 2019, Liu et al. 2020). Other technologies, such as in situ foam fractionation, are also being explored by SERDP and ESTCP researchers in an effort to maximize PFAS recovery and minimize in situ sequestration (Nguyen 2021).

4.3.1.6 Soil Remediation Techniques

Because PFAS are persistent, resist degradation, and are not amenable to traditional biological or oxidation techniques, technologies for remediation of PFAS-affected soil are limited. More research has been done on the treatment of PFAS-contaminated groundwater than on PFAS-contaminated soil; therefore, very few new techniques for treating affected soil have been applied at the field scale. Research is being conducted with nontraditional methods, such as supercritical water oxidation and hydrothermal techniques, but the primary techniques include excavation with on-site or off-site disposal or sorption and stabilization (Coyle et al. 2021). Thermal desorption treatments are also being evaluated, but success is dependent on controlling temperature, managing destruction versus volatilization of PFAS, and verifying evaporation of all free moisture (Coyle et al. 2021).

Excavated soil could be stockpiled, placed in an approved, engineered containment cell, and treated on-site before being placed back in the excavation or hauled to an approved disposal facility. Excavated soils removed and not treated would have to be replaced with clean fill. More information on available soil treatment technologies is provided in Tool 4.5.

Currently, soil excavation with off-site disposal—either incineration or landfilling—are the primary options (EPA 2020b). Disposal in an on-site containment cell with an impervious lining is also a viable option if space is available; however, this presents a future risk of contamination if the containment liner is breached or defective. Further research is required to demonstrate other in situ soil remediation techniques.

The design and selection of a soil excavation remedy will be based on the costs of excavation and waste disposal, which are described in Tool 4.6. Unless a containment cell is constructed on-site, there would be no long-term O&M requirements associated with an excavation remedy. Prior to design, it would be necessary to negotiate a cleanup goal with the regulatory agency and determine the lateral and vertical extent of the excavation. Concurrently, soils would be profiled as hazardous waste for off-site disposal at a facility licensed to receive hazardous waste. Engineering design, including determination of excavation volumes, backfill volumes, and compaction requirements, would need to be prepared. Excavation and off-site disposal actions may require review and completion of an approval process by the applicable regulatory authorities prior to commencement.

4.3.1.7 Strategies for Treatment of Surface Water and Sediment

Treatment of PFAS-contaminated surface water and sediment can be accomplished ex situ or in situ. Surface water can be collected and treated

Toolkit Tip

Tool 4.5: Considerations for Selecting a Method of Soil Treatment

- Options for soil treatments with descriptions of methods.
- Evaluations of implementability, effectiveness, and availability.
- Cost assessment considerations.

Toolkit Tip

Tool 4.6: Considerations for Determining the Feasibility of Soil Treatment

- Guide on major factors affecting costs for soil treatments.
- Assists airport operators with cost-effectiveness and feasibility determinations by method.

For Your Information

Pending regulatory changes in waste management designations will affect how soil is managed, including both disposal off-site (either incineration or landfilling) and design of on-site treatment units.

Designations will have significant impacts on cost.

Federal and state regulations for PFAS should be assessed prior to evaluating soil disposal options.

ex situ using the same techniques used for groundwater treatment, as described earlier, with consideration of possible interfering characteristics (e.g., management of suspended solids/sediment).

For in situ treatment, surface waters are intercepted and treated in situ with a granular adsorptive material (usually a zeolite, modified clay, or activated carbon), which extracts PFAS constituents from the water column onto the adsorptive material as the water flows through. This granular media functions as a reactive barrier within a drainage feature, while discharge controls reduce or prevent PFAS in groundwater from migrating farther along the drainage pathway.

The primary issue with treatment using in situ materials is their hydraulic capacity. In some scenarios, the emplacement of the granular media compromises the operation of the drainage feature, which could potentially cause an overflow situation (e.g., flooding) and exacerbate contamination issues. In other situations, the granular media could become fouled with solids over time, which would also reduce hydraulic capacity.

Sediment can be removed from ponds and ditches by conventional techniques and managed with the methods outlined in Section 4.3.1.5. Sediments should be dewatered and stabilized or solidified prior to being hauled off-site. Sediment can be capped in situ with impermeable material to prevent PFAS from entering surface water, or it can be covered with a geotextile liner filled with adsorptive material. The adsorptive material, usually a zeolite, modified clay, or activated carbon, adsorbs PFAS in the adjacent sediment and further prevents leaching to surface water.

Plans for placement of adsorptive media should include an evaluation of site hydraulics as well as an assessment of the adsorptive medium's longevity. Ex situ techniques are often considered more reliable and can be readily adapted or modified to address variations in stormwater flow conditions. Adsorptive media, such as pond liners, may be highly effective when used in combination with ex situ treatment techniques. Adsorptive media can prevent migration upward into the surface water column by removing the groundwater–to–surface water pathway or by preventing direct contact with deeper impacted sediments. Adsorptive media could also be used to prevent contaminated surface water from affecting underlying sediments and, possibly, groundwater by eliminating infiltration pathways. Multiple companies provide adsorbent materials for both surface water and sediment options in granule, mat, gabion, or other formats, but current data do not indicate the longevity of adsorptive media or replacement rates.

Currently, recommendations regarding the use of in situ surface water or sediment technologies are not possible without site-specific calculations of hydraulic design. Placement of media along the base of retention ponds may be viable if ecological function is not a concern or if wetland quality is already compromised. However, actions such as obstructing flow in ditches to treat flow prior to discharge may have significant hydraulic ramifications under peak flow conditions. This may be of particular concern if climate change alters weather patterns or high-intensity storm events become more frequent.

4.3.1.8 Impacts on Stormwater Infrastructure

Due to the chemical properties of PFAS, stormwater infrastructure may be compromised. This section discusses the mechanisms by which PFAS may be adsorbed onto mineral surfaces and the potential for diffusion and leaching of these chemicals into soil and groundwater. Due to PFAS infiltration of stormwater infrastructure, devices for capturing pollution may be compromised, leading to elevated levels in stormwater. Low levels of PFAS may also continue leaching from pipes after AFFF use has diminished or been eliminated on the airport property. This section concludes with a discussion of research and technological advancements to address these stormwater concerns and help maintain airport compliance with federal and state regulations.

PFAS Adsorption on Porous and Mineral Components. Electrostatic interactions, hydrogen bonding, ion exchange, and other chemical processes may account for the adsorption of PFAS—specifically, PFOS and PFOA—from aqueous media onto mineral surfaces such as concrete pipes and infrastructure (Fiorenza 2022, McDonald 2021). Adsorption of PFAS can also occur on solid–liquid interfaces, air–liquid interfaces, and liquid–liquid interfaces. PFAS may adsorb onto the surface of minerals used in asphalt and concrete, such as kaolinite, alumina, and silica. Adsorption ability may differ on the basis of aqueous pH, surfactant chemistry, and concentration of salt or humic acid (BYJU'S 2019). Understanding PFAS adsorption properties for different surfaces and environments allows for a prediction to be made about the subsequent fate and transport of PFAS. Chapter 2, Section 2.5, provides further information on PFAS fate and transport processes.

Adsorption onto or absorption into stormwater infrastructure concrete may occur where the stormwater system receives runoff from areas where AFFF has frequently been applied, AFFF storage locations, and facilities with AFFF fire suppression systems. As previously mentioned, several known AFFF-related PFAS chemicals can absorb into concrete to depths ranging from 3 to 5 in. (Baduel et al. 2015, McDonald 2021). Once absorbed, the potential exists for PFAS to diffuse through concrete pipes and structures. Thus, contaminated surfaces such as concrete and asphalt have the potential to be ongoing sources of PFAS (Baduel et al. 2015). Water with low pH makes PFAS adsorb to the concrete, whereas higher pH can cause PFAS to be released into the environment (Alves et al. 2020).

Technological Solutions for Compromised Stormwater Infrastructure. Because of the porous nature of concrete pipes and the variety of thermodynamic and chemical processes that may cause PFAS to adhere to the structure walls, stormwater infrastructure may continue to discharge low levels of PFAS. With current regulatory detection levels and acceptable quantity limits set so low, and considering that the anticipated trend is for limits to become lower still and regulations more stringent, airports many want to consider incorporating infrastructure cleaning or replacement into their long-term financial planning. Concrete sanitary sewer lines may also have adsorbed or absorbed PFAS by the same chemical mechanisms as stormwater infrastructure.

For Your Information

In addition to an understanding of PFAS adsorption properties, knowledge of PFAS sources, ecosystem discharge channels, and the types of nonmineral and mineral surfaces involved can help in determining effective removal methods (Alves et al. 2020).

Oil–water separators, grit chambers, and other slug load or pollution capture devices used in both stormwater conveyance and sanitary sewer lines have the potential to accumulate PFAS from AFFF discharges. These pollution capture devices may not function properly with some types of PFAS accumulation due to the reduction in surface tension caused by the surfactant qualities of some PFAS. To maintain these controls in proper functioning condition, cleaning or replacement may be warranted, depending on the degree of prior AFFF exposure.

For Your Information

If devices to capture pollution do not function properly, compliance with general sanitary sewer and stormwater permits may not be achieved.

In many situations, replacement of affected infrastructure can present many logistical challenges, be expensive, and may require regulatory approvals, depending on the details of a given scenario. Researchers are investigating ways to prevent adsorbed PFAS in concrete surfaces from further leaching into stormwater runoff and soils (Alves et al. 2020). Technological advancements in this field may allow for airports to reduce the leaching of PFAS into stormwater, soils, or sanitary flows if past AFFF exposure to infrastructure may have occurred.

Some proprietary slurry mixes have shown a 99.97% reduction in leaching of PFOS over a 5-day monitoring period, with 99.61% of PFOS remaining bound in place after almost 1 year of long-term monitoring. Results are transferable to PFAS, such as PFOA (crcCare 2021). Further research is ongoing for other PFAS compounds (Alves et al. 2020). Various treatment methods and products line or coat affected pipes or infrastructure, creating a surface barrier to stabilize adsorbed concrete and prevent future PFAS leaching to the environment (Toase et al. 2019). These products can also be included as an admixture during concrete batching to prevent PFAS adsorption (Arcadis, Inc. 2022).

Unfortunately, many of these sequestration-in-place products are not yet approved by EPA as sufficient to warrant lawful disposal in landfills. Doubt remains about the long-term stability of these products under prolonged exposure to UV light, weather, chemical interactions, or heat (Toase et al. 2019). However, this work is promising, and the rate of technological development to address these issues has increased exponentially in the time frame between the publication of *ACRP Research Report 173* (Thalheimer et al. 2017) and the research for the present guide.

4.3.1.9 Long-Term Monitoring

Because of current regulatory trends toward lower detection levels in environmental media and lower overall HALs, demonstrating achievement of PFAS cleanup goals will likely require long-term monitoring (LTM) at most sites. LTM requirements may include sampling and laboratory analysis of potable water supplies, groundwater, soil, surface water, stormwater, and sediment. LTM objectives include

- Tracking PFAS concentrations and identifying trends over time;
- Evaluating a treatment system or remedial action to determine progress toward attaining remedial goals;
- Assessing possible off-site migration or PFAS plume mobility;
- Routine monitoring of sensitive receptors, such as drinking water wells or sources of potable surface water, for possible impacts or exposure; and
- Examining PFAS concentrations in target receptors, such as water quality indicator species, to assess impacts.

PFAS sampling protocols have been established by federal and state regulatory programs. Before investigations or LTM work plans are developed, available protocols from these sources should be evaluated. Additional information regarding sampling procedures, potential cross-contamination concerns, and recommended analytical methodologies can be obtained from EPA, DoD, SERDP, ESTCP, ITRC, and other resources.

The frequency of sampling and number of sample locations are the key cost drivers in LTM, as more sampling leads to higher costs. If LTM activities are in response to a regulatory action, the sampling schedule is typically negotiated with regulators on the basis of specific on-site data, the media affected, potential sensitive receptors, and on-site activities, if remedial activities are being implemented. When projecting future LTM costs, airport operators should anticipate higher laboratory costs and subsequent costs for data validation and evaluation than would be expected for a petroleum release or routine stormwater sampling event, given the complexity of currently available PFAS analytical methods.

For Your Information

An institutional control can specify maintenance of an engineering control.

Examples of engineering controls are an asphalt or concrete cap to prevent contact with contaminated soil or fencing to prevent access to an affected property.

4.3.2 Institutional and Programmatic Controls

Once PFAS impacts have been delineated, current and future exposures may be limited by using institutional controls or exploring other alternative endpoints, depending upon the regulatory options available in each state. Adaptive management strategies should also be considered to manage PFAS plumes in the long term.

4.3.2.1 Institutional Controls

EPA has developed multiple guidance documents that describe the types of institutional controls, such as deed restrictions and environmental covenants, that can be placed on a property to help secure the protectiveness and other components of a remedy (EPA 2012a, 2012b). Both EPA and state regulatory agencies have model language that can be used and modified as appropriate to the situation. Figure 4-6 highlights key considerations for site controls.

Institutional controls are recorded on the property deed and filed with the regulatory agency as part of the remedy. They are maintained for as long as contaminants are present above risk-based cleanup goals. More recently, EPA has identified monitoring approaches that can be incorporated into institutional controls to facilitate long-term stewardship (EPA 2018a). Similar efforts have been recommended by ITRC and other industry groups.

Institutional controls may be specified in detail in other documents, such as operations and maintenance plans. However, the institutional controls in these plans should stipulate that maintenance of controls is a requirement as well as provide the reporting mechanisms to document when maintenance occurs; how maintenance should be completed; and the responsible party, or parties, for ongoing maintenance.

4.3.2.2 Alternative Endpoints

SERDP and ESTCP study alternative endpoints and approaches to addressing cleanup at various sites, particularly those that are complex and in which contaminant attenuation mechanisms may occur over extended time frames (Deeb et al. 2011). These approaches may include use of an alternate concentration limit or site-specific cleanup level or a groundwater reclassification or classification exemption.

The use of an alternate concentration level or other site-specific cleanup level depends on whether the contaminant has migrated beyond the site boundary. In general, most regulatory agencies require compliance with standards for drinking water or unrestricted use at the property boundary.

Some states and localities allow restrictions on groundwater use by redesignation of the aquifer as nonpotable. This could range from defining and registering a specific groundwater

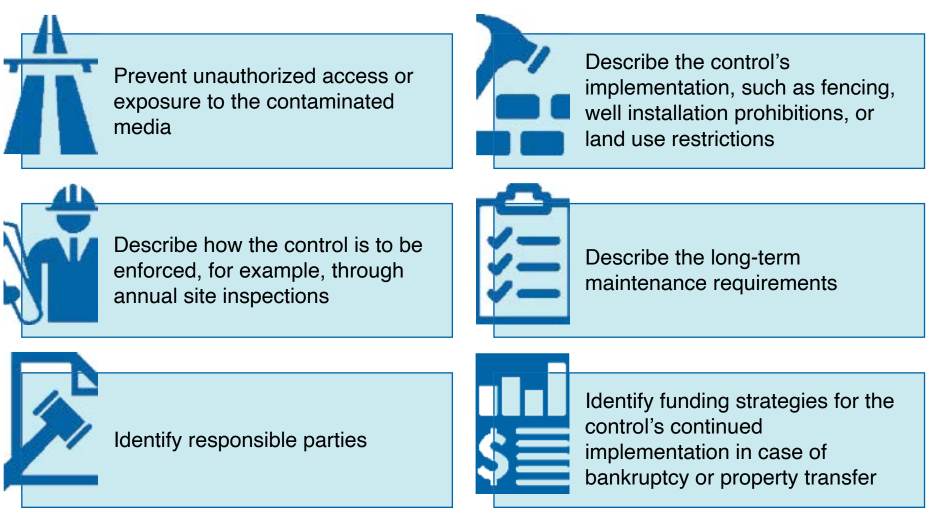


Figure 4-6. Considerations for institutional controls.

plume, commonly known as a groundwater or plume management zone, to passing an ordinance prohibiting groundwater use within a specific geographic area, such as an urban or municipal setting. The process for developing and defining restrictions varies from state to state, and not all states provide an option for a nonpotable restriction.

In addition, several states allow aquifer resources to be reclassified on the basis of low well yield or poor aquifer quality characteristics, such as high turbidity or high salinity. In these cases, the aquifer might be designated nonpotable, or site-specific regulatory criteria for groundwater may be available and incorporated into the airport's LTM program.

Use of alternative endpoints may provide a facility with additional options to prevent groundwater consumption. Use of multiple controls is consistent with the EPA policy on institutional controls, as it provides a layered strategy that is more protective of human health over the long term (EPA 2012a, 2012b).

4.3.2.3 Adaptive Management Strategies

As proposed by ITRC, adaptive management strategies were developed to address complex sites, often ones with residual dense NAPLs that had extended remedial time frames and were not likely to achieve closure within a reasonable time frame. These sites often require multiple remedial techniques over their project life cycle (ITRC 2017). Adaptive management strategies are designed to be flexible in addressing different risk and exposure conditions across the entire plume or to manage different groundwater flow conditions due to various aquifer properties.

Adaptive management strategies require proactive site monitoring and reevaluation of CSMs on the basis of real-time data to respond to changing conditions. Similar approaches can potentially be implemented for PFAS, pending regulatory approval, and will need to consider the following:

- Interim and long-term objectives for PFAS sites;
- Interim and long-term remedies, such as aggressive source controls, monitored natural attenuation, and monitoring of downgradient plumes;
- Institutional controls or alternative endpoints; and
- Adaptive responses based on risk and exposures, changing conditions at the site, and ongoing monitoring data.

Stakeholders would need to understand and agree with the CSM, remedial actions, decision rules that trigger specific actions, and other aspects of adaptive site management to maximize its effectiveness as a remedial management tool.

For Your Information

In an adaptive management strategy, proactive monitoring would be used to gauge the need for additional response actions.

These contingencies would be implemented quickly if data indicated actions were required.

Similarly, data would indicate when active remedies could transition to passive.

CHAPTER 5

Communication and Public Engagement

With proper communication strategies and tools for educating the public, airports may address community concerns and achieve public support as advocates on their behalf with agencies and legislators. The environmental justice (EJ) considerations, communication strategies, and methods for public engagement discussed in this chapter will help airports with internal and external stakeholder communication, community collaboration, and public education. These strategies and methods incorporate responsible messaging techniques and approaches to communicating risk to inform the public as well as demonstrate how to develop and maintain strategic community partnerships. Chapter 5's toolkit in Appendix D provides customizable supporting materials to facilitate developing an airport-specific communication plan. The toolkit is designed for use by airports of all sizes but, in particular, for airports with limited staff and resources. By reviewing this chapter and utilizing the toolkit resources, airports can effectively integrate communication and engagement strategies into their PFAS management planning according to their specific characteristics, setting, and needs.

Chapter 5 Topics

- Identification of potentially disadvantaged communities
- Strategies for reaffirming public trust
- Communication plans for educating the public
- Directing and controlling messaging in the media

5.1 EJ and Airports

EJ addresses the disproportionate environmental burdens carried by disadvantaged communities. This section covers what EJ is, how it relates to airports, and what proactive measures airports could consider regarding EJ when addressing PFAS issues associated with their facilities. Also included are methods for developing airport-specific outreach plans to address EJ issues and examples of effective messaging and engagement.

EJ aims to provide equal access to a healthy environment and achieve the equal distribution of environmental protections and burdens from governmental, commercial, or industrial operations and policies across the national population. Further, EJ seeks to include disenfranchised and marginalized communities in decision-making and implementation of environmental laws, regulations, and policies. EPA has coined the term "meaningful involvement," and outlined the processes for public contribution, the incorporation of community concerns and views, and the responsibility of regulators and industry to seek out public comment (EPA n.d.-f). EJ communities typically comprise low-income households, people of color, or indigenous groups—communities that have experienced a disproportionate burden of environmental hazards and are therefore more vulnerable to further health and environmental impacts. These communities may also lack access to participation in decision-making and political power (EPA n.d.-f).

EJ communities have experienced a disproportionate burden of environmental hazards and may be more vulnerable to further health and environmental impacts.

Toolkit on Communication and Public Engagement

Within the toolkit provided in Appendix D are supporting materials and templates that provide a starting point for developing an institutionally specific PFAS communication and public engagement plan. While this may not be a comprehensive list for every airport, these resources can augment current communications strategies or help with the daunting task of where to begin the planning process.

Appendix D is available on the National Academies Press website (nap.nationalacademies.org) by searching for *ACRP Research Report 262: PFAS Management at Airports: A Guide* and looking under "Resources."

Tool 5.1: Checklist for Strategic Design of a Public Communication and Engagement Plan

Checklist to assist airport public engagement team with developing a public communication and engagement strategy that is appropriate to its operations.

Tool 5.2: Considerations for Appropriate Public Engagement Methods

Options for interacting with stakeholders and community members with benefits, drawbacks, and actions to consider based on the intended audience and desired outcomes.

Tool 5.3: Checklist for Event or Publication Preplanning

Considerations to assist airport management and public relations staff with developing and reviewing the content of public messaging materials.

Tool 5.4: Template for an Airport PFAS Informational Brochure

Modifiable brochure template highlighting the issues, AFFF use in an airport setting, and how associated risks can be reduced.

Tool 5.5: PowerPoint Template for a Public Meeting

Customizable template of a PowerPoint slide deck for public presentations about airport PFAS management.

Tool 5.6: Template for Community Surveys

Template of a survey for gauging public opinion and perceptions regarding the airport, general understanding of airport management issues and regulatory requirements, airport responses to community concerns, or changes in regulatory involvement.

Tool 5.7: Template for Public Meeting Announcements

Template of a meeting announcement with suggested language and phrasing included.

Tool 5.8: Template for a Press Release or Announcement of a Press Conference

Customizable announcement with language and phrasing prompts included.

5.1.1 Regulations and Guidance Concerning EJ

To effectively incorporate EJ and equity considerations into decision-making, airport staff should understand the context of federal policy and recent executive orders (EOs) related to this topic. EJ is a priority for the federal government. The following list of EOs, initiatives, regulations, and guidance documents may be helpful for airports to understand:

- EO 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," issued in 1994, was the first federal order that explicitly identified EJ as a priority for the U.S. government (59 FR 7629). EO 12898 directs federal agencies to identify actions that may disproportionately affect minority, low-income, or disadvantaged populations. It created the Federal Interagency Working Group on Environmental Justice and has also prompted rulemakings by other agencies, such as U.S. Department of Transportation Order 5610.2(a) (U.S. DOT 2012).
- EO 13985, "Advancing Racial Equity and Support for Underserved Communities Through the Federal Government," issued in 2021, instructs federal agencies to examine their policies and adjust them to address racial equity (86 FR 7009).
- EO 14008, "Tackling the Climate Crisis at Home and Abroad," also issued in 2021, directs federal agencies to address climate change and consider how climate change affects EJ concerns (The White House 2021b). EO 14008 also created the Justice40 Initiative.
- The Justice40 Initiative strives to dedicate 40% of the benefits from federal investment in environmental projects to disadvantaged communities (U.S. DOT 2022).
- The Bipartisan Infrastructure Law, or Infrastructure Investment and Jobs Act, which was signed into law on November 15, 2021, includes a focus on EJ and investment in historically marginalized and disadvantaged communities (The White House 2021a). Although it does not explicitly address airport issues or AFFF use, the Bipartisan Infrastructure Law represents a significant investment in clean water on behalf of the federal government and includes $5 billion to address PFAS and emerging contaminants (EPA 2022b).

5.1.2 EJ Communities and Airports

Environmental impacts have the potential to disproportionately affect EJ communities, which could include those adjacent to airports. Proactively identifying and addressing issues builds public trust, and this can be accomplished by developing a public communication and engagement strategy to share information with communities—potential EJ communities in particular—which may be affected or have concerns. This chapter provides instructions for developing a general public communication and engagement strategy along with examples of effective outreach language and engagement activities.

For Your Information

Equitable community engagement should be guided by the following principles:

- Honor the wisdom, voice, and experience of residents;
- Treat participants with integrity and respect;
- Be transparent about motives and power dynamics;
- Share decision-making and initiative leadership; and
- Engage in continuous reflection and willingness to change course.

5.1.2.1 Resources for Accessing EJ Data

Several federal and state agencies, as well as some local municipalities, provide free tools to the public for screening, analyzing, and visualizing quantitative EJ data. Potentially affected communities can be identified by an analysis of environmental indicators, such as air and water quality measurements or groundwater flow direction. Understanding these community characteristics can inform decision-making and enable the development of effective engagement techniques that encourage robust participation.

Many EJ tools utilize various climate, health, demographic, and environmental indicators to identify candidate EJ communities. GIS-based tools display geospatial data associated with these indicators that allow a user to visualize the relative spatial distribution of demographics, inequities, and environmental hazards. EJ indices are calculated on the basis of the indicator scores for comparison of composite data across various geographic scales. When the EJ tools are being used, relevant indicators for the local communities should be selected on the basis of regionally specific knowledge and stakeholder input to avoid potential mischaracterization (Arriens et al. 2020). It is crucial for an EJ analysis to use disaggregated or specific data for the various community indicators included in the study as well as their prevalence within certain EJ communities. Table 5-1 provides an overview of some publicly available EJ tools at the national level; more regionally specific resources may be available from some state agencies. Many state-provided screening and mapping tools were summarized by Indiana University researchers, and these can serve as useful resources in developing an EJ outreach program (Konisky et al. 2021).

5.1.2.2 Strategies for Outreach

When a strategic public communication plan is being developed, tailoring outreach activities to the specific needs of local communities, including low-income and EJ communities, removes barriers to public participation. Strategies for engagement include providing ways to submit questions or concerns by telephone hotline, email, or survey, or hosting listening sessions and public meetings in accessible and conveniently located areas. Figure 5-1 provides examples of strategies for equitable engagement to consider during public outreach planning.

There may be significant levels of mistrust when communities experience disenfranchisement through exclusion from decision-making processes. Communities may believe their involvement will not result in meaningful change if they were unable to shape decisions in the past (Bergstrom et al. 2012). Proactively addressing this perception and other points of contention will promote confidence among community members that their voices will be heard going forward.

Communication that is clear and forthright about an airport's roles and responsibilities for environmental management, regulatory compliance obligations, resource limitations, practical

Table 5-1. National environmental data mapping resources.

Organization	Tool Name	Data and Intended Use	Indicators
CEQ	Climate and Economic Justice Screening Tool (CEQ 2022, The White House 2022)	Publicly available, nationally consistent datasets intended to identify disadvantaged communities to inform federal decision-making and investments	Socioeconomic, environmental, health and climate data
EPA	EJScreen (EPA 2022c)	Nationally consistent datasets that allow for analysis/combination of environmental and demographic indicators and for comparison of data between state, EPA region, and country	12 environmental indicators, 7 demographic indicators, 12 EJ indexes
EPA	EnviroAtlas (EPA 2022d)	National and community-level geospatial data related to ecosystem services and their linkages to human health	Demographic, land use, air quality, tree cover, and hydrologic data
EPA	Toxics Release Inventory (TRI) (EPA n.d.-i)	Mapping tool that provides visualization of facilities that release TRI chemicals to the environment, along with the volume of chemical released	Demographic index and ability to view community profiles; in 2020, TRI added 172 PFAS to the list of chemicals with reporting requirements

Note: Various training materials and background information related to the items in this table are also available on their respective websites. CEQ = Council on Environmental Quality.

Figure 5-1. Strategies for equitable community engagement.

timelines, and financial constraints will be more effective in promoting positive public engagement. Additionally, airports should confirm that their team engages with community members and the public in an inclusive, equitable, just, and respectful way, which includes practicing cultural competence and active listening (Groundwork USA n.d.). Cultural competency can be gained through staff equity and antiracism training, increasing the diversity of staff, and attendance at other community meetings (Bergstrom et al. 2012). EPA provides additional supporting guidance and tools in its Environmental Justice Primer for Ports (EPA 2020a).

5.2 Public Communication Strategies

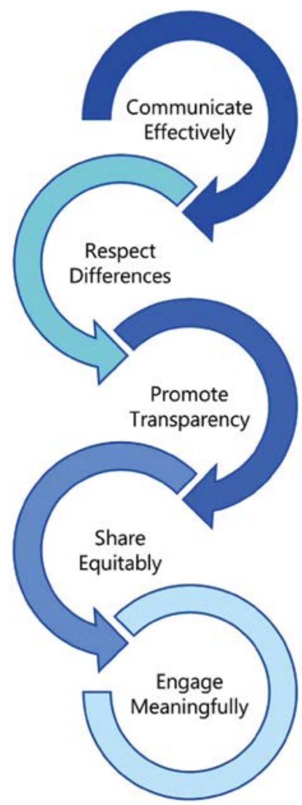
Communities are beginning to seek more information about PFAS issues and may reach out to airport staff about their concerns. This section provides strategies for engaging with stakeholders about these sensitive topics. Considerations for communicating information about environmental issues regarding the specific concerns and needs of historically disadvantaged communities or those disproportionately affected by commercial, industrial, or land development impacts are also discussed.

5.2.1 Establishing Trust

A practical public communication and engagement strategy enables relationship building and promotes trust within a community. Effective community involvement should not only inform the community of airport initiatives but also improve the airport's understanding of the community's concerns.

One engagement strategy is to create forums in which knowledgeable airport staff inform public stakeholders about routine aviation operations, regulatory compliance requirements, firefighting and emergency response operations involving AFFF, aviation safety considerations, procedures for managing environmental releases, and findings from previous studies or plans to conduct studies. Following are several key principles for establishing trust (Pennsylvania State University 2022):

- **Communicate effectively.** Communication should be ongoing and not limited to individual projects or initiatives. Stakeholders will understand processes, potential outcomes, project objectives, and their opportunities for involvement if communication is effective and clear.



- **Respect differences.** Respecting stakeholders and their perspectives, even those of individuals or groups that disagree or have different objectives, is essential. The knowledge, experiences, and positions of stakeholders should be acknowledged and appreciated for trust to develop.
- **Promote transparency.** Stakeholders need to be provided with clear information that allows them to understand the process, the objectives, their ability to influence the outcome, and what is up for negotiation.
- **Share equitably.** Sharing partial information or disclosing information to certain stakeholders and not others can erode trust. The engagement effort should provide the information necessary to participating stakeholders uniformly so they can understand, make informed decisions, and provide significant feedback.
- **Engage meaningfully.** Engagement that acknowledges and incorporates stakeholders' unique perspectives, knowledge, and abilities is more meaningful and contributes to developing positive, trusting relationships.

PFAS contamination is a sensitive and complex emerging environmental concern, and given the potential risks associated with this sensitive topic and the rapidly changing nature of available research, specific persons should be identified to lead a PFAS-specific public engagement team. This would involve leading public interactions and overseeing the distribution of accurate and relevant information in a responsible manner.

5.2.2 Engagement Planning

To dispel misconceptions or refute misinformation, airports may want to be proactive in educating stakeholders about when, how, and why AFFF has been used. This approach may avert future issues with public perception and may even serve to foster advocates for the airport in the community. Before this engagement takes place, the following planning process is suggested:

- Assemble the information available about the facility's history and current situation. Examples include prior ARFF activities, surrounding land uses or industry, and current ARFF practices.
- On the basis of this information, evaluate the possible risks to sensitive receptors.
- Determine the practicable options available to mitigate historical or current issues through either procedural or engineering controls.
- Discuss the potential liabilities involved in sharing or withholding information with legal counsel.
- To keep the public message consistent, establish a clear internal strategy for the organization's management approach going forward.

Often, airports have existing avenues for communicating and engaging with the public. Making use of established, regular meetings or ongoing relationships with key stakeholders and airport advocates can provide an opportunity for communicating airport decisions and actions to the public through their community's leadership. However, before interacting with the public, even with individuals who regularly advocate for the airport within the community, airports should develop a consistent message with input from staff from the following relevant departments:

- Executive leadership,
- Environmental compliance,
- Operations,
- Facility management,
- Legal counsel,
- Public relations,

Toolkit Tip

Tool 5.1: Checklist for Strategic Design of a Public Communication and Engagement Plan

Checklist to assist airport public engagement teams with developing a public communication and engagement strategy that is appropriate to their operations.

- Procurement, and
- Government affairs.

Staff at smaller airports may have limited topical expertise. In this case, engaging outside support from knowledgeable consultants, technical experts, or legal counsel may be appropriate before interacting with groups outside of the airport organization.

5.2.2.1 Topics for Community Discussion

The federal, state, or local regulations applicable to airports should be clearly explained to communities in the context of the airport's current and potential financial burdens, impacts to operations, and challenges regarding future growth.

Currently, F3 alternatives to AFFF that meet DoD MIL-SPEC requirements are limited. Although an F3 alternative compliant with the MIL-SPEC is listed, the commercially available supply may be far less than the overall product demand while the manufacturers transition to producing the new products. This is a key message to share with communities, along with information about FAA and DoD's ongoing efforts to identify other fluorine-free alternatives, remediation techniques, and disposal technologies.

Options for ARFF staff training and equipment testing without flowing foam are available. If applicable, airports may want to highlight their own efforts to minimize or eliminate foam discharges. Perhaps staff training is now conducted off-site or within specially designed training facilities. Staff may now be able to test ARFF truck apportioning equipment without discharge. Airports may want to review their efforts to limit and control potential environmental exposure, as there could be tangible benefits to communicating this information clearly.

Stakeholders should also be made aware that AFFF use may not be the only source of community or environmental PFAS exposure. Although PFAS source differentiation is still a developing science, information about ongoing research could be shared publicly. However, decisions regarding a course of action for remediation prior to a thorough investigation into past and current potential sources may be inappropriate.

5.2.2.2 Considerations for Engagement Approach

Tool 5.1: Checklist for Strategic Design of a Public Communication and Engagement Plan, covers key elements and steps for creating a public communication and engagement plan. The appropriate level of engagement between an airport and its community or stakeholders should depend on the goals of the outreach effort, the airport's knowledge of the PFAS regulatory and scientific landscape, and the amount of local public activity or interest in the subject. Public outreach materials should be concise, consistent, and accessible to a nontechnical audience. The airport should be clear and direct when addressing the community regarding the level of input the community will have on certain topics and how its input will affect future decision-making. Different levels of engagement may be appropriate, depending on the project or issue, and many resources are available for airports to use in designing an appropriate outreach strategy. One example is the International Association for Public Participation's *Spectrum of Public Participation* (IAP2 2007).

5.2.3 Methods of Public Engagement

A variety of options exists for interacting with stakeholders and community members. The method of engagement depends on the intended audience and desired outcomes. Airports will likely want to consider a combination of strategies to increase the effectiveness of community involvement, and the combinations may differ, depending on the audience or on whether a specific action, project, or issue is being addressed.

5.2.3.1 In-Person Meetings

The purpose of in-person engagement may be to share information, listen to public opinions and concerns, or collaborate with community members to reach solutions to problems. In-person meetings help build trust and foster open rapport between the airport and the public through face-to-face interaction and direct conversations. Tool 5.2: Considerations for Appropriate Public Engagement Methods summarizes some of the benefits and drawbacks of different types of in-person interactions and includes actions to consider for successful meeting implementation for a given situation (FAA 2016b, NZMFE 2015). To maximize their effectiveness, public meetings should be accessible to as many community members as possible. For more information on increasing equity and inclusion during outreach activities, see Figure 5-1.

Toolkit Tip

Tool 5.2: Considerations for Appropriate Public Engagement Methods

Checklist of options for interacting with stakeholders and community members regarding benefits, drawbacks, and actions to consider, based on the intended audience and desired outcomes.

5.2.3.2 Print Outreach Materials

In-person public engagement is often complemented by outreach materials, which can be provided to community members at in-person events, posted around town, sent in the mail, or included in print media sources. Tool 5.2, which lists considerations for different strategies and actions to consider for in-person public meetings, can help airports determine which print materials would be most effective. Tool 5.3: Checklist for Event or Publication Preplanning summarizes important elements for developing effective print outreach materials during publication planning and development. Tools 5.4 through 5.8 provide templates for print outreach materials.

When considering written media for public communication, it is critical to provide information at a technical level appropriate for a general audience and to assume the reader has no prior knowledge of the subject. It may also be necessary to translate documents into languages other than English for expanded accessibility to target communities.

Toolkit Tip

Tool 5.3: Checklist for Event or Publication Preplanning

Checklist to assist airport management and public relations staff with developing and reviewing the content of public messaging materials.

5.2.3.3 Digital Media and Websites

In an increasingly computerized age, publishing digital content should be explored as a tool for community engagement. Specifically, websites are an important communication source, since they are often the first place people go to find information on airport operations and areas of public concern.

When publishing digitally, it is important to remember that content can be screen captured or printed and referred to later. Therefore, airports should consult experts and legal counsel whenever they post on websites or share content on social media. Additionally, airports should consider including audio alternative text for people with differing sight capabilities and use social media, pictures, video, and infographics, among other strategies, to increase accessibility and engagement with more sectors of the community (Bergstrom et al. 2012).

Toolkit Tip

Customizable Tools for Public Engagement

- Tool 5.4: Template for an Airport PFAS Informational Brochure
- Tool 5.5: PowerPoint Template for a Public Meeting
- Tool 5.6: Template for Community Surveys
- Tool 5.7: Template for Public Meeting Announcements
- Tool 5.8: Template for a Press Release or Announcement of a Press Conference

5.2.4 Lack of Engagement

Stakeholder engagement involves resources, staff time, and various other costs, but lack of engagement may result in risks to the airport. There are financial, operational, and legal risks associated with inappropriate engagement or poorly delivered communication. Conversely, successful community engagement can create advocates for the airport and its objectives with legislators and regulators. Including multiple stakeholders and resolving conflicts early in planning and community engagement processes is the ideal scenario for any project (Bergstrom et al. 2012).

If airports are not proactive in educating the public or communicating clearly, local news media may contact the airport and request information. Airports should consider planning for this and provide guidance to staff on what to communicate to the media and whom to contact within the organization for assistance. Following are some further steps airports could take:

- Creating a prepared statement that has been vetted by leadership and legal counsel;
- Remaining positive and noncombative in tone whenever interacting with reporters;
- Referring in conversations and documents to state and federal regulations; and
- Reassuring reporters that the airport is cooperating and collaborating with regulators while reminding them of the regulatory requirement to use AFFF and its efficacy in combating fuel fires, which increases the safety of first responders and the flying public.

5.3 Media Engagement Strategies

This section explains the importance of interacting with the media and discusses a template plan for how to engage with the news media in a responsible manner about the airport and its operations. Local news media can have a broad reach among many diverse community groups, and negative messaging from local media can stymy efforts to engage the community and build public trust. To promote the spread of consistent and accurate messaging, customizable content is provided in the Toolkit on Communication and Public Engagement (Appendix D). The tools provided contain prepared language for press statements and guidance for when and how to open a dialog with local media outlets.

5.3.1 Effective Media Engagement

An effective media communication plan enables airport sponsors to proactively reach beyond their closest neighbors and facilitate an open dialogue with a larger audience, which can be invaluable. Having a positive relationship with the media and educating journalists is important, to verify that the messages they communicate to the public have the same nuance the airport staff uses in its direct public communications.

It is important to have a record of disclosure activities and sincere attempts to communicate. Community members may initially seem uninterested in a topic but later may become discontent or fearful that information may have been withheld. Poor communication with the community may result in negative outcomes that could continue to influence perceptions of the airport years after the project or triggering incident.

Utilizing the media can be an effective way to educate the community about evolving topics. Sharing content with a large local audience through traditional, mainstream, and social media channels is paramount to building trust and communicating known facts accurately. Having preapproved, customizable content with prepared language at the ready enables a prompt response to media information requests. Example materials for sharing with the media are included in Appendix D.

Utilizing the media can be an effective way to share content with a large, local audience and educate the community.

5.3.2 Media Communication Strategies

Preparing educational materials on behalf of media outlets increases the probability the message will be communicated appropriately. Additionally, consolidating links to reputable

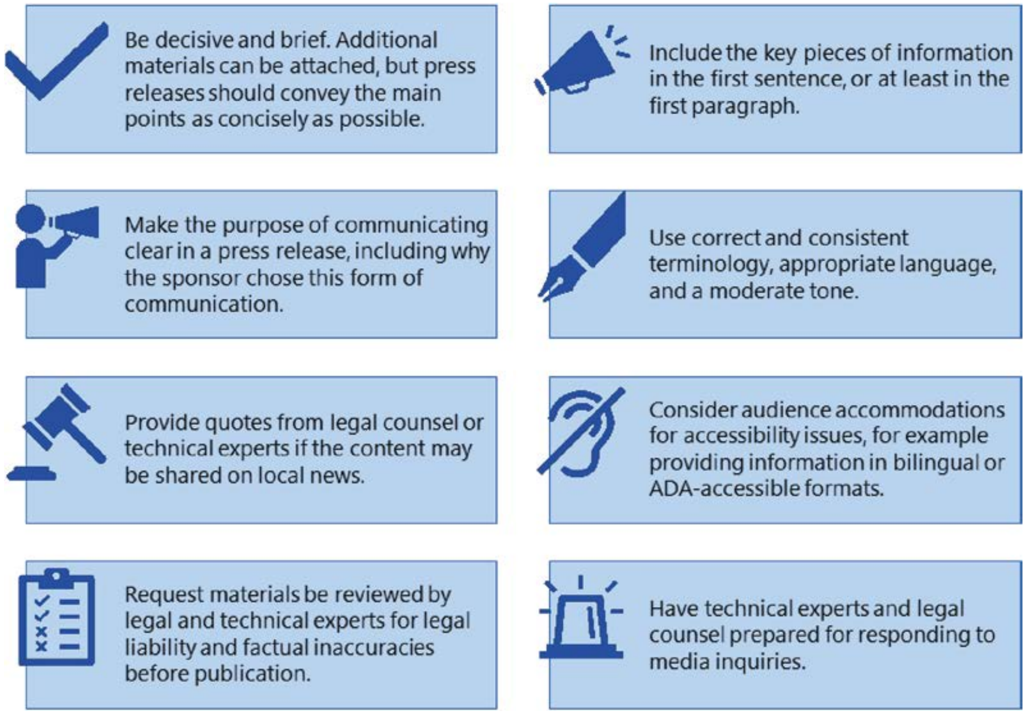


Figure 5-2. Key considerations for materials provided to the media.

external materials that communicate the latest scientific understanding makes it easier for the community, the media, and internal stakeholders to proactively educate themselves. This directs media attention and community interest toward reputable and accurate information rather than spurious sources. Figure 5-2 highlights key considerations for media communication materials.

When a sensitive subject is being dealt with, talking points and materials should be reviewed prior to publication, use positive language, and avoid negative terms. Examples of positive and negative word choices are provided in Figure 5-3.

Figure 5-3. Examples of positive and negative word choice in communication materials.

The messaging should be factual and does not need to be defensive or contrite. For example, messaging could include what the aviation industry is doing to

- Understand the science and new technologies available,
- Limit the use of AFFF to only when required for the safety of the flying public,
- Monitor and support the research and development of listed F3 alternatives, and
- Implement the use of F3 alternatives as available and appropriate.

After disseminating materials to the media, consider monitoring what is being shared by local and national news or on social media. If necessary, endeavor to correct inaccuracies or incorrect information through collaboration with local media outlets (NZMFE 2015). Consider also seeking assistance from community advocates, if appropriate.

5.3.2.1 Media Outlets

Interacting with the media could include communications in traditional newspapers, local television, radio stations, social media platforms, web-based news outlets, college newspapers, and news outlets directed toward non-English-speaking communities. Table 5-2 (next page) describes the trade-offs to be considered in determining the appropriate media outlets for sharing information.

While the media can be helpful in providing information to a large audience, inconsistent or ill-informed media coverage could cause public concern and mistrust that might damage an airport's reputation (NZMFE 2015). Public engagement teams should strive to interact with the media in a proactive and positive way to direct the narrative and messaging.

5.3.2.2 Contacting the Media

Most media outlets have websites with instructions on how to make contact. If relationships are not already established with local media outlets, phone calls or in-person appointments may provide a faster path to attention. If there is a specific journalist of interest, that person can sometimes be contacted through professional social media accounts or the publisher's website.

Table 5-2. Considerations for selecting the appropriate media outlet for public engagement.

Benefits	Drawbacks
Print Media and Newspapers	
Reaching out to journalists proactively will allow for relationship building and a larger chance that a story is written with a narrative that is positive and in line with airport messaging.	Timelines for information dissemination and story publication may not match up with the desired timing for public engagement.
The static nature of print media is good for providing information people can return to, such as information for public meetings, contact information for the public engagement team, and detailed project information.	Print media are available indefinitely. Since the guidance on PFAS is constantly evolving, printed material may be less desired, as it cannot be changed later. Airports may face blowback if what they say now is later used against them in a news story.
Providing specific quotes or phrasing to be used promotes consistent messaging.	Proactive reporting may introduce a news story about a topic people were not already aware of, which may generate concern if the full context of the story is unclear.
Broadcast Media	
These channels have broad outreach and could be helpful if an airport is recruiting community members to a public forum or listening session.	Messages are fleeting, and if people are driving or watching television, they may not write down the number to call or the website for further information.
	Broadcasts are time limited and may not convey information on sensitive topics with the level of detail needed. People might get confused or upset without the appropriate context.
	It may be cost prohibitive for airports to use television, radio, commercials, and podcasts.
Local News Media	
Proactive reporting allows the airport to control the narrative, build relationships with reporters, and give reporters bullet points or quotes with which to frame the story.	As with print media, proactive reporting may unintentionally introduce a news story or draw public attention to a sensitive topic.
Information may reach target audiences more quickly, such as communities near the airport.	Reporters may introduce bias or inadvertently use terminology that disturbs or upsets the public.
Airports could set up a press conference allowing reporters to ask questions while still controlling the overall message.	

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Abbreviations, Acronyms, and Initialisms

ACIP	Airports Capital Improvement Plan
AFFF	aqueous film-forming foam
ALP	airport layout plan
AOF	adsorbable organic fluorine
ARFF	aircraft rescue and firefighting
BMP	best management practice
CAC	colloidal activated carbon
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
CGL	commercial general liability
CIP	capital improvement plan
CMC	critical micelle concentration
CoC	chain of custody
CPL	contractor's pollution liability
CSM	conceptual site model
DoD	Department of Defense
EO	executive order
EOF	extractable organic fluorine
EJ	environmental justice
ERHMS	Emergency Responder Health Monitoring and Surveillance
ESTCP	Environmental Security Technology Certification Program
ETFE	ethylene-tetrafluoro-ethylene
F3	fluorine-free foam
FBO	fixed-base operator
FEP	fluorinated ethylene propylene
ft	foot, feet
ft^2	square foot, square feet
GAC	granular activated carbon
GIS	geographic information systems
HAL	health advisory level
HDPE	high-density polyethylene
HEF	high-expansion foam
HFPO-DA or GenX	hexafluoropropylene oxide dimer acid
IBC	International Building Code
ICC	International Code Council, Inc.
ILDFA	ignitable liquid drainage floor assembly

in.	inch(es)
ITRC	Interstate Technology and Regulatory Council
IX	ion exchange
LDPE	low-density polyethylene
LTM	long-term monitoring
MAPA	Managing AFFF and PFASs at Airports
MCL	maximum contaminant level
MIL-SPEC	military specification
mL	milliliter(s)
mm	millimeter(s)
NAPL	nonaqueous phase liquid
NCP	National Contingency Plan
NFPA	National Fire Protection Association
NPDES	National Pollutant Discharge Elimination System
O&M	operations and maintenance
PAC	powdered activated carbon
PCBs	polychlorinated biphenyl
PCTFE	polychlorotrifluoroethylene
PFAS	per- and polyfluoroalkyl substances
PFBS	perfluorobutanesulfonic acid
PFCA	perfluoroalkyl carboxylic acid
PFHxA	perfluorohexanoic acid
PFHxS	perfluorohexanesulfonic acid
PFNA	perfluorononanoic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulfonic acid
PFPE	perfluoropolyether
PFSA	perfluoroalkyl sulfonic acid
PLL	pollution legal liability
ppb	parts per billion
PPE	personal protective equipment
ppt	parts per trillion
ppq	parts per quadrillion
PTFE	polytetrafluoroethylene
PVDF	polyvinylidene fluoride
QA	quality assurance
QC	quality control
QPD	Qualified Products Database
QPL	Qualified Products List
RCRA	Resource Conservation and Recovery Act
RO	reverse osmosis
SDS	Safety Data Sheet
SDWA	Safe Drinking Water Act
SERDP	Strategic Environmental Research and Development Program
TRI	Toxics Release Inventory
UV	ultraviolet

Appendices

Appendices A through F can be found on the National Academies Press website (nap.nationalacademies.org) by searching for *ACRP Research Report 262: PFAS Management at Airports: A Guide* and looking under "Resources."

Appendix A: Toolkit on Assessing Current and Historical Product Use and Activities
Appendix B: Toolkit on Policies, Procedures, and Operations
Appendix C: Toolkit on Regulatory Action, Financial Planning, and Remediation
Appendix D: Toolkit on Communication and Public Engagement
Appendix E: Research Methodology
Appendix F: Aviation Stakeholder Group Survey

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FAST	Fixing America's Surface Transportation Act (2015)
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
GHSA	Governors Highway Safety Association
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S. DOT	United States Department of Transportation

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