Aqueous Film-Forming Foam (AFFF)

1 Introduction

1.1 What is AFFF?

Aqueous film-forming foam (AFFF) is highly effective foam intended for fighting high-hazard flammable liquid fires. AFFF products are typically formed by combining hydrocarbon foaming agents with fluorinated surfactants. When mixed with water, the resulting solution achieves the interfacial tension characteristics needed to produce an aqueous film that spreads across the surface of a hydrocarbon fuel to extinguish the flame and to form a vapor barrier between the fuel and atmospheric oxygen to prevent re-ignition. This film formation is the defining feature of AFFF.

There are two major classes of firefighting foams: Class A and Class B. Class A foams were developed in the 1980s for fighting wildfires. They are also used to fight structure fires. Class B foams are any firefighting foams that have been designed to effectively extinguish flammable and combustible liquids and gases; petroleum greases, tars, oils and gasoline; and solvents and alcohols. Class B foams can be synthetic foams, including aqueous film-forming foam (AFFF) or alcohol-resistant aqueous film-forming foam (AR-AFFF), or protein foams. This fact sheet focuses on AFFF as these foams contain fluorosurfactants and they are widely used. Per- and polyfluoroalkyl substances (PFAS) are the active ingredients in fluorosurfactants.

All Class B foams are not the same. Although not usually categorized this way from a fire protection viewpoint, they can be divided into two broad categories from a per- and polyfluoroalkyl substances (PFAS) perspective: Fluorinated foams that contain PFAS and fluorine-free foams that do not contain PFAS.

ITRC has developed a series of fact sheets that summarize the latest science and emerging technologies regarding PFAS. This fact sheet is targeted to local, state, and federal regulators and tribes in environmental, health, and safety roles as well as AFFF users at municipalities, airports, and industrial facilities.

The purpose of this fact sheet is to outline how to properly identify, handle, store, capture, collect, manage, and dispose of AFFF.

The fact sheet is not intended to replace manufacturer specifications, or industry guidance for AFFF use, or discuss alternatives in detail. It is only intended to educate users on AFFF use to reduce and eliminate potential harm to human health and the environment.

For further information, please see the ITRC Technical and Regulatory Guidance Document for PFAS dated April 2020.

The vast majority of Class B firefighting foam that is currently in stock or service in the United States is AFFF or AR-AFFF. All AFFF products contain PFAS. This applies to foams used in the past and those being sold today. Foam currently in stock or new foam that is labeled as AFFF or AR-AFFF, contains perfluoroalkyl or polyfluoroalkyl substances, or both, as active ingredients (DOD 2018; Darwin 2004).

AFFF is used where there is a significant flammable liquid hazard present, including but not limited to the following locations:

- chemical plants
- flammable liquid storage and processing facilities
- merchant operations (oil tankers, offshore platforms)
- municipal services (fire departments, firefighting training centers)
- oil refineries, terminals, and bulk fuel storage farms
- aviation operations (aircraft rescue and firefighting, hangars)
- military facilities

Most AFFF products sold and currently stocked in the United States are either listed by Underwriters Laboratory (UL) based on conformance with UL Standard 162, “Foam Equipment and Liquid Concentrates” or have been tested by the U.S. Naval Research Laboratory (NRL) and qualified as meeting the requirements of the U.S. Department of Defense (DOD) Military Specification (MILSPEC), MIL-PRF-24385, “Fire Extinguishing Agent, Aqueous Film-Forming Foam” (DOD 2017). AFFF foams that meet the MILSPEC are required for use in military applications and at Federal

Perfluoroalkyl substances are fully fluorinated (perfluoro-) alkane (carbon-chain) molecules. Their basic chemical structure is a chain of two or more carbon atoms with a charged functional group attached at one end.

Polyfluoroalkyl substances are not fully fluorinated. Instead, they have a non-fluorine atom (typically hydrogen or oxygen) attached to at least one, but not all, carbon atoms, while at least two or more of the remaining carbon atoms in the carbon chain are fully fluorinated.

More information is included in the ITRC *Naming Conventions and Physical and Chemical Properties of Per- and Polyfluoroalkyl Substances (PFAS)* fact sheet.

Aviation Administration (FAA) regulated airports. All other AFFF foams are specified to UL Standard 162 (UL 2018) or other specifications for applications outside of military and FAA applications. DOD maintains an online qualified products database (QPD) that lists all the AFFF foams that have been qualified to meet the MILSPEC (DOD 2018).

1.2 Human Health and Environmental Concerns with AFFF Use

All Class B foams have the potential to create an adverse environmental impact if released uncontrolled to the environment, particularly if the foam solutions reach drinking water sources, groundwater, or surface waters. Discharge of foams to surface waters, including fluorine-free foams, may potentially harm aquatic life due to excessive biological and chemical oxygen demand and, in some cases, acute toxicity, and may increase nutrient loading.

AFFF products (as well as other fluorinated foams, see Figure 1) are of concern because they contain PFAS. Some PFAS pose a risk to groundwater and surface water quality, but they are also highly persistent, may be highly mobile, and some bioaccumulate in organisms. PFAS are also not removed or destroyed by conventional wastewater treatment processes unlike many other hazardous substances.

- Long-chain PFAS are defined as perfluoroalkyl carboxylates (PFCAs) with eight or more carbons, including perfluorooctanoate (PFOA), and perfluoroalkane sulfonates (PFSAs) with six or more carbons, including perfluorohexane sulfonate (PFHxS) and perfluorooctane sulfonate (PFOS).
- Short-chain PFAS are defined as PFCAs with seven or fewer carbons, such as perfluorohexanoate (PFHxA), and PFSAs with five or fewer carbons, such as perfluorobutane sulfonate (PFBS).

Naming Conventions and Physical and Chemical Properties of Per- and Polyfluoroalkyl Substances (PFAS) fact sheet

The health effects of PFOS, PFOA, PFHxS, and perfluorononanoate (PFNA) have been more widely studied than other PFAS. Numerous animal and human studies have evaluated both non-cancer and cancer health effects related to exposure to a limited number of PFAS, including PFOA and PFOS. Little to no health-effects data are available for many PFAS. See the *Regulations, Guidance, and Advisories for Per- and Polyfluoroalkyl Substances (PFAS)* fact sheet for more detailed discussion of potential health effects related to PFAS.

To date there have been only limited studies of human health effects specifically related to use of AFFF. Glass et al. (2014) reported elevated rates of some cancers among more highly exposed firefighters, but their study was not designed to evaluate specific associations between these health effects and any particular chemical among the many chemicals to which firefighters may be exposed. Rotander et al. (2015) measured PFOA, PFOS, and PFHxS levels in firefighters' serum but did not observe any association with studied health effects. A limited study in Norway observed elevated PFOS and PFHxS serum levels in 10% of firefighters studied, (Kärrman et al. 2016), and suggested that use of personal protective equipment (PPE) may account for why elevated levels were not seen in more of the firefighters. Studies suggest that perfluoroalkyl acids like PFOS and PFOA are not well absorbed through the skin (ATSDR 2018), which is the most likely exposure pathway for AFFF foams. However, should the PFAS in AFFF enter the body they could cause health problems, so appropriate PPE should be used to prevent or minimize direct contact, ingestion, or inhalation of AFFF.

PFAS encompass a wide range of fluorinated carbon-chain compounds of differing carbon chain lengths, physical and toxicological properties, and environmental impacts. Long-chain PFAS are of particular concern and include PFOS and PFOA, which are recognized as persistent, bioaccumulative and toxic (PBT). Depending on when it was manufactured, AFFF may also contain fluorinated precursors, some of which are known as fluorotelomers, that can breakdown in the environment to PFOA or other PFCAs. See the *Naming Conventions and Physical and Chemical Properties and the History and Use of Per- and Polyfluoroalkyl Substances (PFAS)* fact sheets for more information.

1.3 Determining the Type of PFAS in AFFF in Current Inventory

Within these broad categories of Class B foams there are different types of foams. Figure 1 illustrates the categories of Class B foams and AFFF specifically. There are three possible types of AFFF products including:

- legacy PFOS AFFF
- legacy fluorotelomer AFFF (contain some long-chain PFAS)
- modern fluorotelomer AFFF (contain almost exclusively short-chain PFAS)

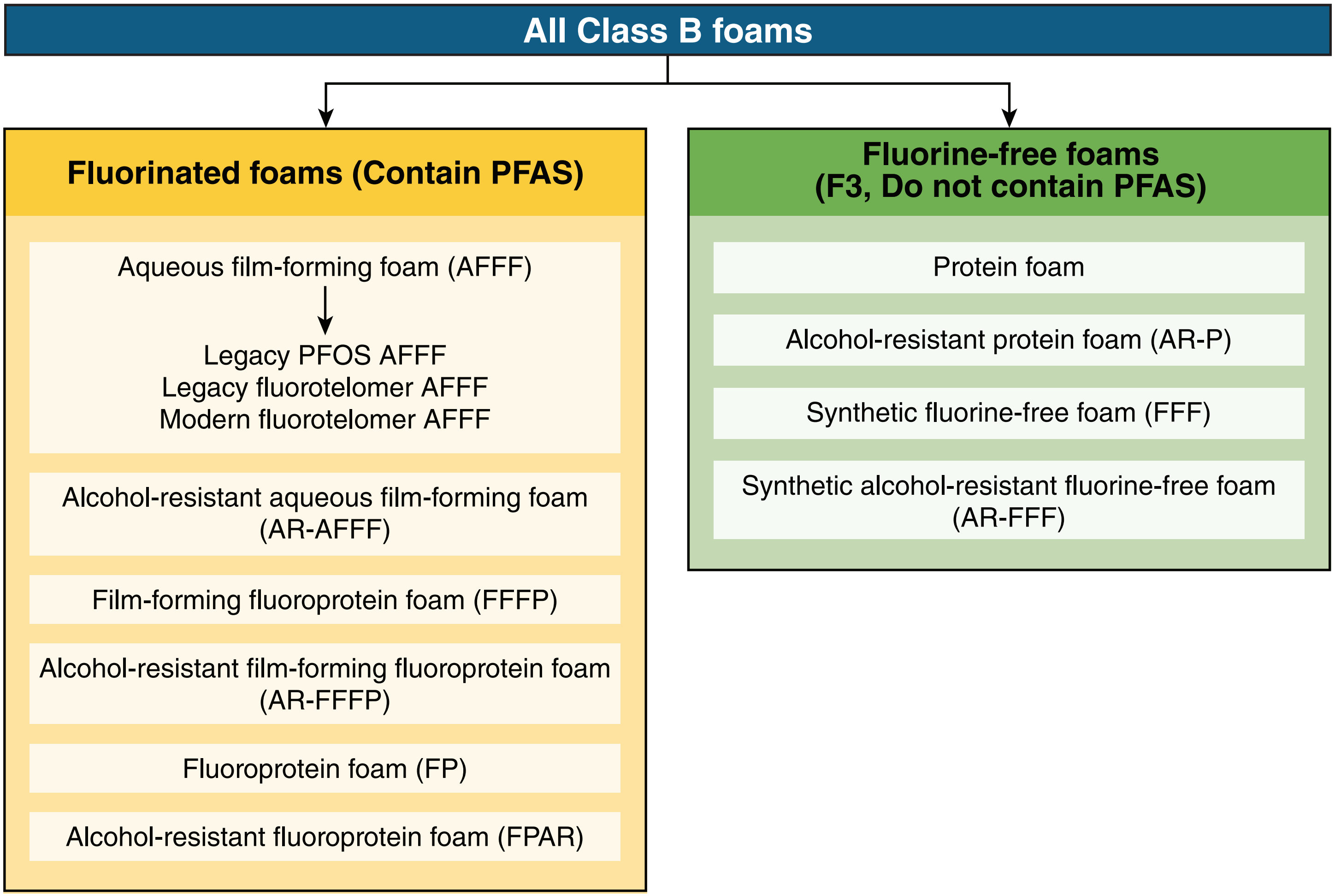

Figure 1. Types of Class B foams
(Source: S. Thomas, Wood plc, used with permission)

1.3.1 Legacy PFOS AFFF

These foams were manufactured in the United States from the late 1960s until 2002 exclusively by 3M and sold under the brand name "Lightwater" (DOD 2014). Lightwater AFFF contains PFOS and various precursors that could potentially break down in the environment to PFOS and shorter chain PFSAs such as PFHxS. Some of these PFSAs, including PFHxS, are also considered to be persistent. Older formulations may also contain PFOA as well as fluorinated precursors. The fluorinated precursors may also break down in the environment to PFOA and other perfluoroalkyl carboxylates (PFCAs) (Backe, Day, and Field 2013).

1.3.2 Legacy Fluorotelomer AFFF (contain some long-chain PFAS)

These foams were manufactured and sold in the United States from the 1970s until 2016 and encompass all other brands of AFFF besides 3M Lightwater (Schultz, Barofsky, and Field 2004). Although not made with PFOA, they contain polyfluorinated precursors (Backe, Day and Field 2013; Place and Field 2012) that are shown to degrade to PFOA and other PFCAs in the natural environment (Weiner et al. 2013; Harding-Majanovic et al. 2015). They may contain trace quantities of PFOA as an unavoidable byproduct of the manufacturing process. Legacy fluorotelomer-based AFFF foams have historically contained predominantly short-chain (C6) PFAS with formulations ranging from about 50–98% short-chains and the balance as long-chain PFAS. Importantly, the long-chain PFAS content of these foams has the potential to break down in the environment to PFOA and other PFCAs, but not to PFOS or other PFSAs (Weiner et al. 2013).

1.3.3 Modern Fluorotelomer AFFF (contain almost exclusively short-chain PFAS)

In response to the U.S. Environmental Protection Agency (USEPA) 2010/2015 voluntary PFOA Stewardship Program (USEPA 2015), most foam manufacturers have now transitioned to the production of short-chain (C6) fluorotelomer-based PFAS. These foams are referred to as "modern" to distinguish them from the legacy foams manufactured before the phase-out. Short-chain (C6) PFAS do not contain or breakdown in the environment to PFOS and other long-chained

PFAS such as PFHxS and PFOA (see below) and are currently considered lower in toxicity and have significantly reduced bioaccumulation potential compared to long-chain PFAS (USEPA 2018). However, foams made with only short-chain (C6) PFAS may still contain trace quantities (parts per billion [ppb] levels) of PFOA and PFOA precursors as byproducts of the manufacturing process. As documented in the Helsingør Statement: "although some of the long-chain PFAS are being regulated or phased out, the most common replacements are short-chain PFAS with similar structures, or compounds with fluorinated segments joined by ether linkages. While some shorter-chain fluorinated alternatives seem to be less bioaccumulative, they are still as environmentally persistent as long-chain substances or have persistent degradation products" (Scheringer et al. 2014). Concerns have been raised that "little information is publicly available on [the] chemical structures, properties, uses, and toxicological profiles" of these shorter-chain formulations and that "increasing use of fluorinated alternatives will lead to increasing levels of stable perfluorinated degradation products in the environment, and possibly also in biota and humans" (Blum et al. 2015). Under the recently published European Union Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) regulation on PFOA and PFOA-related substances, foams based on short-chain PFAS can contain no more than 25 ppb PFOA and 1,000 ppb total PFOA-related substances to be sold in the European Union (EU) after July 4, 2020 (Commission Regulation (EU) 2017).

1.4 When to Use Legacy AFFF

The decision about whether to use legacy AFFF should be considered in the development of Best Management Practices (BMPs; see Section 3) and in fire response plans. The decision should be based on a site-specific evaluation that considers likely fire hazards and potential risks associated with use of legacy AFFF. These decisions should be made prior to an emergency where Class B AFFF would be used so that BMP equipment, procedures, and training are already in place. During an actual response to a fire, the final decision on whether to use any Class B AFFF should be made by the emergency manager (for example, fire chief, incident commander or terminal manager) based on federal, state and local laws and the nature of the emergency. Decisions regarding the use of any type of foam should consider the nature of the firefighting properties of the foam and the benefits they provide for preservation of life, public safety, and property protection versus the potential environmental, public health, and financial risks the use of such foam could pose.

> Decisions about when and how to use PFAS-containing foams should be made before, not during, an emergency. The team should consider key factors such as these:
>
> - The nature of the firefighting properties of the foam
> - The nature of the emergency
> - The risk to life, public safety, and property
> - Potential environmental, public health, and financial liabilities of using the foam

Currrently, federal law does not prohibit the use of legacy AFFF remaining in existing stocks, whether containing PFOS or other long-chain PFAS. Efforts should be made to limit releases to the ground or water sources. Releases could impact water sources above USEPA drinking water health advisory levels or above more stringent state and local regulatory criteria. During emergency response planning, potential liabilities should be weighed against the cost of disposal and replacement of legacy AFFF, and maintaining an inventory of alternative foams (DOD 2014).

While the disposal cost of legacy PFOS AFFF or certain formulations of legacy fluorotelomer (polyfluoroalkyl compounds produced by the telomerization process) AFFF solutions may be much greater than the cost of purchasing modern, shorter-chain replacement foam, the potential risks of keeping and using this legacy foam may be even greater. Also, replacement of legacy AFFF with short-chain AFFF or other foams may require thorough flushing and possible modification of existing systems that could produce significant amounts of flush water containing PFAS that would require proper disposal. Despite these issues, serious consideration should be given to the continued use, storage, and disposal of legacy AFFF. Organizations that are considering replacing their legacy AFFF stocks should focus first on removing from service legacy PFOS AFFF. A release of legacy PFOS AFFF to the environment, that is not mitigated, is likely to result in PFOS impacts to soils and possibly groundwater and surface water.

Legacy AFFF should only be used for emergency purposes in cases where insufficient amounts of short-chain AFFF or other foams are available and where there is a risk to human life, public safety or property. Where no regulation exists to the contrary, use of legacy AFFF containing PFAS remaining in inventory may depend on whether the facility can contain, collect, and treat the wastewater generated fighting the fire, and on the sensitivity of the surrounding environment. Use of alternative firefighting materials (for example, Class B fluorine-free foams) or Class A foams for smaller fires should be strongly considered whenever possible (FFFC 2016).

Firefighting industry best practice for Class B foams calls for the use of fluorine-free foam (FFF) for testing and training (FFFC 2016; Lastfire 2016). If the authority having jurisdiction requires testing of foam equipment or training of firefighters with AFFF, then only modern fluorotelomer AFFF should be considered for this purpose and any foam discharge should be collected and disposed of properly (see Table 1, Disposal).

1.5 Regulations Affecting the Sale and Use of AFFF

In the United States, 3M voluntarily ended production of PFOS-based AFFF in 2002. The USEPA subsequently restricted the future manufacture and import of most PFOS-based products, including firefighting foams, through two Significant New Use Rules (SNURs) (40 CFR 721.9582, Final Rules published 03-11-02 [13 PFAS] and 12-9-02 [75 PFAS]). In 2006, USEPA instituted the 2010/2015 voluntary PFOA Stewardship Program that resulted in the elimination of PFOA and other long-chain PFAS production by eight major fluorochemical manufacturers by 95% by 2010 and entirely by 2015. As a result, foam manufacturers have transitioned to the production of modern fluorotelomer AFFF (based on short-chain [C6] PFAS) and other fluorinated Class B foams. In 2007, USEPA issued amendment to 40 CFR 721.9582 regulating another 183 PFAS (SNUR on 10-09-07). In 2015, USEPA proposed a SNUR for PFOA and other long-chain PFAS as a regulatory follow-up to the voluntary PFOA Stewardship Program (USEPA 2015); the SNUR has not been finalized. The SNURs subject specific PFAS chemicals to reporting requirements, but do not restrict the use of existing stocks of legacy AFFF containing those PFAS chemicals.

Currently, the DOD and FAA-regulated airports must meet the requirements established in the military specification MIL-PRF-24385 for AFFF formulations (DOD 2017; FAA 2004). Only AFFF formulations containing fluorosurfactants currently meet the MILSPEC, but the DOD is actively evaluating fluorine-free foams to determine if any can meet the MILSPEC performance requirements (SERDP-ESTCP 2017).

In addition to federal efforts for managing AFFF, several state governments have regulations or other programs that address the use of PFAS-containing foams. Organizations should check with their state and local government for regulations or policies that could impact their use and disposal of AFFF and other Class B foams. Examples of state regulations and policies are included in the following sections.

1.5.1 New York

State regulation 6 NYCRR Part 597 identifies PFOS and PFOA as hazardous substances. The release of more than 1 pound of PFOS and/or PFOA must be reported to the state. (For legacy fluorotelomer AFFF, it would normally require a release of thousands of gallons of foam concentrate to result in release of 1 pound of PFOA.) (New York State 2017).

1.5.2 Washington

In March 2018, the state of Washington passed a new law (Washington State 2018) that restricts the sale and use of Class B foams that contain PFAS. As of July 1, 2018, PFAS-containing foams may not be discharged or otherwise used in the state of Washington for training purposes. Beginning on July 1, 2020, PFAS-containing foams may be sold or distributed in the state only for the following specific uses:

- applications where federal law requires the use of a PFAS-containing firefighting foam, including but not limited to the requirements of 14 CFR 139.317 (such as military and FAA-regulated airports)
- petroleum terminals (as defined in RCW 82.23A.010)
- oil refineries
- chemical plants (WAC 296-24-33001)

1.6 Legacy Foam Replacements

Several states have implemented take-back programs for AFFF products. For example, in May 2018, the Massachusetts Department of Environmental Protection, in partnership with the Massachusetts Department of Fire Services, implemented a take-back program to assist fire departments in the proper disposal of legacy firefighting foams that could impact water resources (MA DEP 2018). Vermont has also announced a take-back program (VT 2018). Users should contact their state regulatory agency for information on available take-back programs.

1.6.1 Synthetic Fluorine-free Foam

Organizations should determine whether a Class B fluorine-free foam (FFF) can achieve the required performance specifications for specific hazards as part of their pre-planning for replacement materials (FFFC 2016). Most foam manufacturers now produce Class B FFF. The performance of these foams has improved significantly over the last decade and is expected to continue to improve in the future. Purchasers of Class B foams, especially those not required to use MILSPEC AFFF, should investigate whether a Class B FFF will meet the site-specific requirements and should continue to review the performance specifications of FFF products as they make future purchasing decisions.

1.6.2 Modern Fluorotelomer AFFF

If it is determined that the performance of a fluorinated Class B foam is required for a specific hazard, or where federal regulations require AFFF use (for example, military applications and FAA-regulated airports), then organizations should purchase foams that consist of short-chain (C6) PFAS, modern fluorotelomer AFFF. U.S. foam manufacturers have switched over to using short-chain (C6) PFAS so it is likely that any AFFF bought today would meet that requirement (Tyco 2016). Users should confirm with their supplier. There is likely to be some designation on the label and the Safety Data Sheet that the foam contains short-chain (C6) PFAS, but even then, there will be a small amount of longer-chain (C8) impurities as stated in Section 1.3.3.

2 Best Management Practices (BMPs) For Class B AFFF Use

Firefighting foams are an important tool to protect human health and property from flammable liquid fire threats. Proper management and usage strategies combined with the current refinement of environmental regulations will allow an informed selection of the viable options to sustainably use firefighting foams.

BMPs should be established for the use of any firefighting foam to prevent possible releases to the environment that can lead to soil, groundwater, surface water, and potentially drinking water contamination. The discharge of firefighting foam to the environment is of concern because of the potential negative impacts it can have on ecosystems and biota due to the presence of chemicals such as PFAS. For example, for AFFF, the amount of PFAS from foam that may enter groundwater depends on information such as the type and amount of foam used, when and where it was used, the type of soil, and the depth to groundwater. AFFF is typically discharged on land but can run off into surface water or stormwater or infiltrate to groundwater. A more detailed description of the fate and transport of PFAS is included in the ITRC PFAS *Environmental Fate and Transport for Per- and Polyfluoroalkyl Substances (PFAS)* fact sheet.

BMPs are particularly important when Class B foams are used near sensitive environmental areas where impacts from chemicals present in foams have potential for lasting damage. Example sensitive areas:

- wetlands
- surface water bodies (particularly those used for water supplies like reservoirs or rivers with municipal water supply intakes)
- sensitive or endangered species habitat
- areas close to public and private drinking water supply wells
- sole source aquifers
- groundwater recharge areas

BMPs start with pre-planning and deciding which foam to keep in stock. The team should consider key factors such as these:

- Whether fluorine-free foams can meet site-specific performance requirements
- Site-specific evaluation of likely fire hazards and potential risks for life, public safety, and property
- Potential environmental, human health, and financial liabilities associated with AFFF releases
- Site constraints, including existing equipment retrofit requirements to adapt to alternate foams

BMPs are key to fostering the safest use of AFFF in an environmentally responsible manner with the goal of minimizing risk from its use. It is important to establish BMPs before an emergency where AFFF would be used so that BMP equipment, procedures, and training are already in place. Although firefighting personnel may be aware that the foams they are using contain chemicals, they may not be aware of the potential environmental effects of AFFF use. Training of firefighting personnel is important to ensure BMPs are discussed and employed consistently and effectively.

Table 1 gives a summary of example BMPs. Users should follow BMPs to protect themselves, others, and the environment when using AFFF. Further BMP guidance can be found in other documents, such as the *Best Practice Guidance* developed by the Fire Fighting Foam Coalition (FFFC 2016), the US National Fire Protection Association's NFPA 11 (2016), and the Airport Cooperative Research Program's *Use and Potential Impacts of AFFF Containing PFASs at Airports* (ACRP 2017). Users at DOD facilities have other BMPs to follow and other requirements to meet MILSPEC, which would be followed in those circumstances.

Table 1. BMPs for Foam Selection, Storage, Use, Planning, Mitigation, and Disposal

Foam Selection
Evaluate whether a Class B fluorine-free foam (FFF) can provide the required performance for the specific hazard. "Alternative techniques and agents must be evaluated well in advance of an emergency situation" (FFFC 2016).
Use AFFF and other fluorinated Class B foams only in situations of significant flammable liquid hazard with risk for public safety or significant property loss, where the performance of other foams has not been demonstrated to date.
Consider adopting a two-foam approach with FFF used to respond to small incidents and AFFF kept as emergency backup for major incidents. Ensure that proper labeling is in place and personnel are trained when multiple inventories exist at one facility to avoid comingling of foams.
Storage
Develop a foam inventory and stock tracking system documenting the foam composition, brand, and manufacturer.
"Obtain and follow manufacturers' recommendations for foam concentrate and equipment" (FFFC 2016). The amount of foam in the system should be at least sufficient for the group of hazards that simultaneously need to be protected against.
Designate transfer areas and store fluorinated Class B foam concentrate in a covered area with secondary containment.
Design storage tanks to minimize evaporation of concentrate, label clearly to identify the type of concentrate and its intended concentration in solution. Keep foam within the temperature limitations provided by the manufacturer.
Properly maintain foam systems to ensure minimal accidental discharges. It is important to recognize the nature of the foam concentrates; small leaks of concentrate can create environmental impacts. Conduct regular inspections of tanks, storage containers, and any associated piping and machinery. Ensure that leaks are addressed promptly.
Consider the materials used for storage and handling. Corrosion is generally not an issue with foam concentrates, but some exceptions do exist. Manufacturers recommend stainless steel, high-density polyethylene (HDPE), or polypropylene containers for AFFF storage. Avoid using aluminum, galvanized metal, and zinc in storage tanks, piping, and handling equipment for foam concentrates (Angus 2017).
Ensure compatibility of foams before change-outs. Do not mix different types or brands of foam concentrates.
Use
Eliminate the use of AFFF products and other fluorinated "Class B foams for training and testing of foam systems and equipment" whenever possible (FFFC 2016). Instead, use specially designed non-fluorinated, PFAS-free training foams and surrogate liquid test methods available from most foam manufacturers.
If the authority having jurisdiction requires testing of foam equipment or training of firefighters with AFFF, then avoid the use of legacy AFFF and instead use modern AFFF that contains only short-chain (C6) PFAS whenever possible.
Evaluate if Class B foam is needed to fight a fire or if a Class A foam or just water can succeed in fighting the fire.
Provide containment, treatment, and proper disposal of foam solution. Avoid direct release to the environment to the greatest possible extent.
Collect, treat, and properly dispose of runoff/wastewater from training events or live fire events to the greatest extent possible.
Use appropriate personal protective equipment (PPE) when handling and using AFFF, and identify how to decontaminate materials and gear that comes into contact with foam.
"Follow applicable industry standards for design, installation, maintenance, and testing of foam systems" (FFFC 2016).
Keep records of when and where foam is used to respond to incidents, including foam type, manufacturer and brand, and amount used.
Make note of sensitive receptors (for example, streams, lakes, homes, areas served by wells) identified in the vicinity of foam use and report to environmental agencies as required.
Consider firefighter and public safety first.

Planning and Mitigation
Develop and communicate documented processes for a facility or installation with the stakeholders and regulatory agencies before a release occurs.
Develop runoff collection plans, equipment, and training processes specific to fluorinated Class B foam use.
Develop mitigation plans for uncontrolled releases of foam concentrate or foam solution to minimize environmental impacts.
Quickly and thoroughly clean up contaminated materials after an AFFF release.
Design new firefighting systems, when needed, to accommodate FFF products, considering their different properties, mode of action, and effectiveness.
Prioritize proper education, training, preplanning, and actions at an incident to ensure the most efficient use of the foam and equipment.
Disposal
Dispose of expired or unneeded Class B fluorinated foam concentrate at a Resource Conservation and Recovery Act (RCRA) permitted incinerator or another alternative incinerator that can ensure complete destruction of the PFAS. See *Remediation Technologies and Methods for Per- and Polyfluoroalkyl Substances* (PFAS) fact sheet for details on thermal destruction of PFAS.
Monitor developments in new disposal technologies.
Discontinue expired or unneeded AFFF concentrate donation programs (for example, donation to fire training school).

The ACRP developed a macros-enabled Microsoft Excel™ workbook screening tool that allows users to "better integrate BMPs into the AFFF life cycle at their facilities, identify and manage potential risks associated with historical or current AFFF use at their site, and prioritize where resources need to be allocated to address concerns regarding AFFF and PFAS" (ACRP 2017). Owners of AFFF stocks should consider evaluating this tool to see if it can assist them in implementing BMPs for their specific situation.

3 AFFF Releases and Recommended Investigative Actions

After a release of AFFF and firewater containing AFFF, immediate cleanup of AFFF followed by an environmental investigation may be needed to determine the type and extent of environmental impacts and whether additional response actions are needed. Users should identify if there are state or local environmental agency requirements for notification that apply to their site and circumstances.

3.1 Immediate Cleanup of Standing Foam and Foam-Impacted Materials

One of the most effective and least expensive methods of minimizing human health or environmental impacts of an AFFF release is to quickly and thoroughly clean up contaminated materials. Cleanup may include recovering standing flammable liquids, foam or capturing water used during firefighting operations with a vacuum truck, pumps, or hand-held equipment (for example, shovels, mops, other absorbent materials). Once cleanup is completed, if a large amount of foam soaked into the ground, removal of soils saturated with the foam should be considered. In all of these initial cleanup efforts, response personnel should use proper PPE (for example, turnout gear, Tyvek, gloves, boots) during handling of contaminated media. This task may require temporary stockpiling of these soils (on a liner with a cover) before final disposal or treatment can be arranged. For more information, see the *Remediation Technologies and Methods for Per- and Polyfluoroalkyl Substances (PFAS)* fact sheet.

3.2 Information Gathering After a Release of AFFF

For new releases, it is important to start the information gathering process as soon as possible after a discharge has occurred to maximize the quality of the information gathered and to be protective of human health and the environment. Questions to ask first responders or others with information related to the released AFFF include:

1. Based on readily available information (for example, Safety Data Sheets [formerly MSDSs], applicable MILSPECs), what are the active ingredients (name, concentration, proportions), brand, and manufacturer of the released foam? What volume was discharged?
2. What areas of the site were affected and are there drains, ditches, stormwater drainage systems, or other structures that could cause off-site migration of the foam?

3. Did the release occur inside a building (such as an airport hangar)? If so, it may be beneficial for the personnel to leave the structure until the AFFF has been removed from the building. The owner of the building may consider having the indoor air tested before the building is reoccupied. For more information, see the *Site Characterization Considerations, Sampling Precautions, and Laboratory Analytical Methods for Per- and Polyfluoroalkyl Substances (PFAS)* fact sheet (ITRC, 2018).

3.3 Surface Delineation (Visual) After New Releases

Site delineation can be performed immediately after a discharge occurs by using visual observations of foam and standing water, as a guide. Site delineation becomes harder to conduct as time passes, so it is important to conduct an initial site evaluation and delineation effort as soon as it can be safely performed. Photographic documentation of the affected areas and the use of markers (for example, survey tape, lath, pin flags) to identify the location of where AFFF was released can help to ensure that the continued characterization effort will provide accurate results and fewer resources will be spent assessing unaffected areas.

3.4 Field-Screening for First Responders After Releases

Currently, field-screening methods are limited to visual observation as described above as well as placing AFFF-contaminated media (add a little water if medium is solid) in a clear container and shaking the container, looking for resulting foam. Foaming in the container would qualitatively indicate that the media in this area may contain residual levels of AFFF that may require cleanup. Screening for released AFFF in the field using mobile instrumentation may soon be a practical alternative and could provide a way to quickly delineate affected surface soils and groundwater. Sensor-based technologies are under development (Chen et al. 2013), as well as inexpensive high-throughput screening tools such as particle-induced gamma emission that quantifies total fluorine on surfaces (Shaider et al. 2017; Ritter et al. 2017) and is being modified for quantifying total fluorine in groundwater.

If field screening during the initial delineation indicates significant surficial and near-surface contamination is present, removing and stockpiling soils should be considered, in consultation with environmental professionals and consistent with regulatory requirements, to minimize potential leaching to groundwater or runoff to nearby surface water. Confirmatory sampling may be needed after removal of contaminated material or after screening if no contaminated material is observable. If concentrations are less than applicable actions levels (check with the individual state authorities to determine the site-specific action levels), then no additional remedial activities may be necessary. Knowledge regarding the volume released, the concentration of PFAS in the released product, whether it was a mixture or concentrate, and the area affected is important. If only a small volume of AFFF concentrate is released in combination with a large amount of fresh water and is dispersed over a large area, the concentration in soil may not warrant cleanup. The initial cleanup actions (capture of AFFF and standing water) and collection of confirmation samples may be all that is needed for site closure. The *Regulations, Guidance, and Advisories for Per- and Polyfluoroalkyl Substances (PFAS)* fact sheet includes more information.

3.5 Determining the Need for Further Actions

It is important to establish a working relationship with relevant stakeholders, including local or state regulatory agencies, preferably before, but at least immediately after a release of AFFF to determine the need for investigation and remedial activities. Developing and communicating documented processes for a facility with the stakeholders and regulatory agencies before a release occurs should be considered a best practice. The environmental media (for example, surface soil, subsurface soil, surface water, groundwater, sediment, biota) to be sampled are determined by identifying the potential media affected and in consultation with environmental professionals and consistent with regulatory requirements. The required site characterization effort will often become more involved and expensive as the time between release, discovery, and potential remedial actions increases. If a release is discovered immediately and remedial actions are taken promptly, the need for sampling activities is often reduced because fewer environmental media will be affected and potential impacts are more limited and easier to identify. Additional information about sampling and site characterization are included in the *Site Characterization Considerations, Sampling Precautions and Laboratory Analytical Methods for Per- and Polyfluoroalkyl Substances (PFAS)* fact sheet. Additional information about remediation methods is included in the *Remediation Technologies and Methods for Per- and Polyfluoroalkyl Substances (PFAS)* fact sheet).

3.6 Sampling After Discovery of a Historical Discharge

The sampling methods used, and locations investigated after an AFFF discharge, will depend on both the amount and type of foam released, as well as site-specific characteristics such as topography, affected media, land use, potential infrastructure, and presence or absence of environmentally sensitive areas. Information about sampling, precautions, equipment, and laboratory analysis methods, are included in the *Site Characterization Considerations, Sampling Precautions and Laboratory Analytical Methods for Per- and Polyfluoroalkyl Substances (PFAS)* fact sheet. PFAS migration within and between different environmental media is influenced by many processes. The *Environmental Fate and Transport for Per- and Polyfluoroalkyl Substances (PFAS)* fact sheet includes more information on these processes. Except for conducting an initial sampling effort to confirm or refute a release of AFFF, entities collecting samples to delineate the degree and extent of PFAS should prepare and follow a detailed site sampling plan.

If a historical release of AFFF is suspected, it may be difficult to use visual observations to determine where to begin the delineation or characterization effort. Environmental professionals and state or local regulatory agencies should be consulted to determine investigation strategies and relevant regulatory requirements. For example, if a release occurred from a permanent structure (such as a tank or hangar fire-suppression system), the topography of the adjacent landscape, potential drainages or preferential pathways, or surface depressions may indicate where to begin a sampling effort. Gathering information from historical records (for example, internal incident reports or summaries, historic aerial photos, various documents available through a local regulatory agency) or interviewing individuals with knowledge of AFFF use and events at a facility may aid location of potential source areas.

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