



3 Firefighting Foams

The purpose of this section is to assist aqueous film-forming foam (AFFF) users (first responders, regulators, environmental managers and environmental professionals) who manage AFFF releases. The section includes information about various aspects of using firefighting foams.

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It should be noted that the priority of firefighters and first responders is to protect life and property. The information provided supports decision-making about firefighting using AFFF so that potential impacts to the environment can be minimized and mitigated once the fire emergency is ended, or at such time that sufficient resources are deployed to the scene to both handle the fire emergency and mitigate the environmental risks posed by AFFF use. [Figure 3-1](#) illustrates the life cycle considerations of AFFF. The considerations are discussed in sections 3.3 to 3.8.



Figure 3-1. Life cycle considerations for AFFF.

Source: S. Thomas, Wood, PLC.

3.1 Foam Formulations

Class B firefighting foams are commercial surfactant solutions that are designed and used to combat Class B flammable fuel fires. Class B foams have been (and continue to be) stored and used for fire suppression, fire training, and flammable vapor suppression at military installations and civilian facilities and airports (Hu et al. 2016), as well as at petroleum refineries and bulk storage facilities and chemical manufacturing plants (CONCAWE 2016). Additionally, local community fire departments have used and may maintain quantities of firefighting foam in their inventories for use in training and emergency response. Facilities that manufactured firefighting foams and landfills that received firefighting waste are also potential sources.

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 PFAS perspective: fluorinated foams that contain PFAS and fluorine-free foams (F3) that do not contain PFAS. Figure 3-2 highlights the two broad categories of Class B foams and their subcategories.

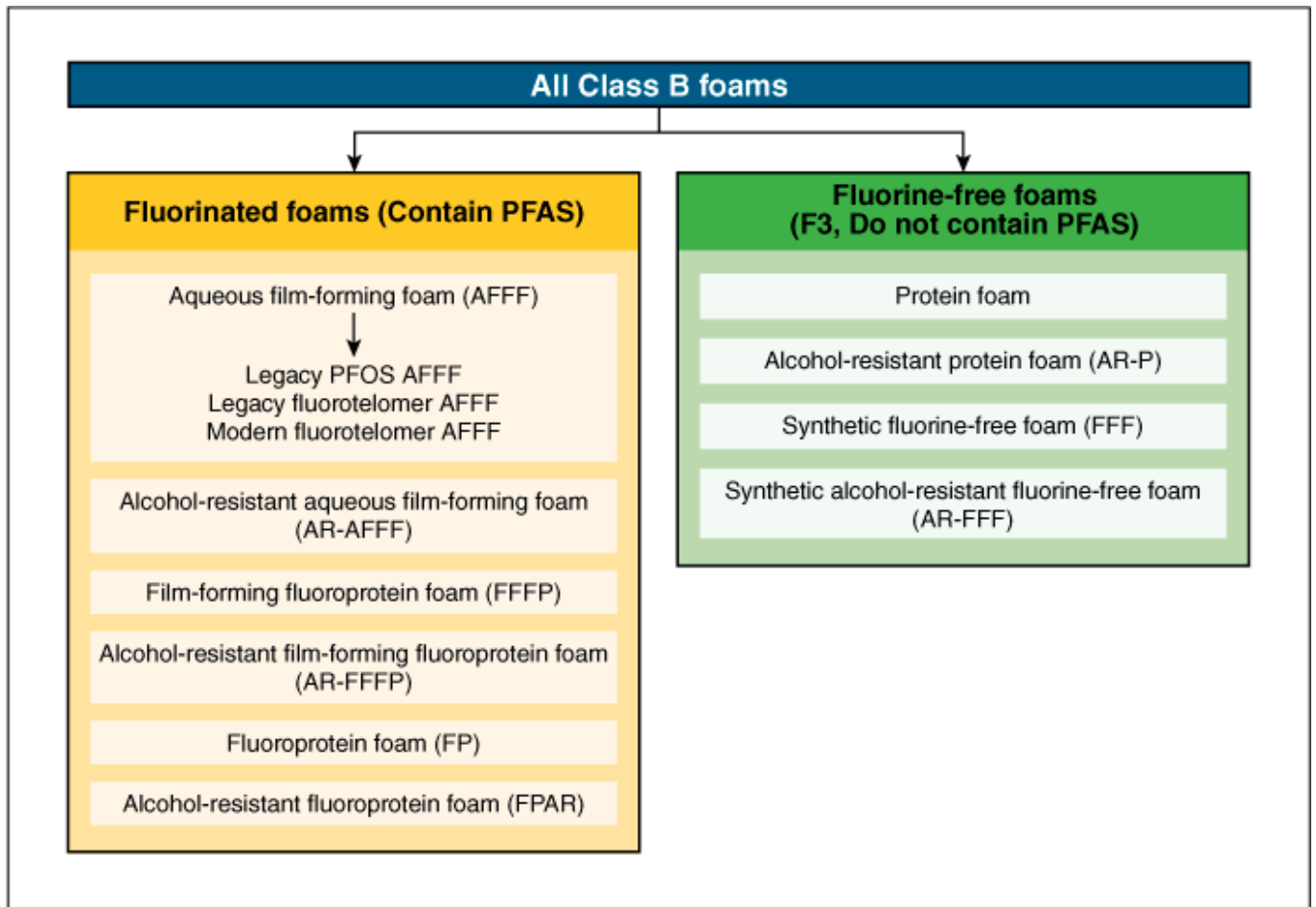


Figure 3-2. Types of Class B foams

Source: S. Thomas, Wood, PLC. Used with permission.

All Class B foams have the potential to create an adverse environmental impact if released uncontrolled to the environment, particularly if the foam reaches drinking water sources, groundwater, surface water, or other natural waters. For all Class B foams, including F3, there is a potential for acute aquatic toxicity and excessive biological and chemical oxygen demand, as well as nutrient loading, depending on where the discharge occurs.

This section is focused on AFFF because it is the most widely used and available type of Class B foam. AFFF is a highly effective type of Class B foam that is especially effective on large liquid fuel fires. AFFF is of particular concern because it contains PFAS. As discussed elsewhere in this document, many PFAS are highly persistent and mobile in the environment and are not removed by traditional drinking water treatment methods typically used by public water suppliers.

The fluorosurfactants in AFFF formulations can be produced either using the ECF process or the fluorotelomerization process. Both ECF-derived and telomer-derived AFFF contain diverse mixtures of PFAS (Barzen-Hanson et al. 2017). The ECF process results in a PFAS mixture dominated by PFAAs—both PFSA and PFCA homologues, while the fluorotelomerization process exclusively produces AFFF formulations consisting of polyfluorinated compounds (Houtz et al. 2013). ECF-based AFFF formulations were voluntarily phased out of production in the United States in approximately 2002 (Section 2.4.1). Despite the phaseout, however, ongoing permitted use of legacy AFFF can still result in long-chain PFAA contamination. Several organizations (for example, U.S. Department of Defense) commenced replacement of legacy PFOS AFFF with modern fluorotelomer AFFF, but some legacy AFFF remains in service or stockpiled at other facilities (Section 3.7.1).

Fluorotelomer foams have been in use since the 1970s and became the predominant foam after 2001, when the major manufacturer (3M) of long-chain ECF-based foams (legacy PFOS foam) discontinued production. Fluorotelomerization-derived AFFF is still manufactured and used in the United States but has been reformulated to limit, if not eliminate, long-chain PFAS; these foams are now referred to as modern fluorotelomer foams. Studies show ECF-based AFFF is the dominant source of PFAS at AFFF-impacted sites, likely due to the longer period of ECF-based AFFF use and the relative coincidence of implementation of engineering controls for releases with increased use of telomer-based AFFF (CONCAWE 2016; Anderson et al. 2016).

To further classify AFFF products in terms of current usage and environmental considerations, they can be divided into three categories, including legacy PFOS AFFF, legacy fluorotelomer AFFF, and modern fluorotelomer AFFF (as shown in [Figure 3-2](#)).

- Legacy PFOS AFFF was manufactured in the United States from the late 1960s until 2002 exclusively by 3M and sold under the brand name “Lightwater” ([USDOD 2014a](#)). 3M did license some companies overseas to use their products and formulations. Legacy PFOS AFFFs contain PFOS and perfluoroalkane sulfonates (PFASs) such as perfluorohexane sulfonate (PFHxS) ([Backe, Day, and Field 2013](#)). Although phased out of production in 2002, legacy PFOS AFFFs are the dominant source of PFAS at AFFF-impacted sites ([CONCAWE 2016](#)). Furthermore, because of its long shelf life, stock of legacy PFOS AFFF could exist at any given fire department today.
- Legacy fluorotelomer AFFF were manufactured and sold in the United States from the 1970s until 2016 and encompass all other brands of AFFF besides 3M Lightwater or their licensed products ([Schultz et al. 2006](#)). Although they are not made with PFOA, they contain polyfluorinated precursors ([Backe, Day, and Field 2013](#)) ([Place and Field 2012](#)) that are known to degrade to PFCAs, including PFOA ([Weiner et al. 2013](#)) ([Harding-Marjanovic et al. 2015](#)).

Modern fluorotelomer AFFF was developed in response to the USEPA 2010/2015 voluntary PFOA Stewardship Program ([USEPA 2018a](#)). Most foam manufacturers have now transitioned to the production of only short-chain (C6) fluorotelomer-based fluorosurfactants. These modern fluorotelomer AFFFs, or “C6 foams,” do not contain or break down in the environment to PFOS or PFOA and are currently considered to be less toxic and have reduced bioaccumulative potential compared to long-chain (C8) fluorosurfactants. But under particular environmental conditions, breakdown products of C6 foams can include PFHxA, PFPeA, and 5:3 FTCA ([Kempisty, Xing, and Racz 2018](#)). Modern fluorotelomer AFFF may contain trace levels of PFOA as an unintended manufacturing impurity or byproduct.

Fluorotelomer foams, short-chain fluorotelomer foams, and C6 foams are analogous and will be referred to as “modern fluorotelomer foams.” When discussing legacy PFOS or C8 foams, the term “legacy foams” will include both legacy PFOS AFFF and legacy fluorotelomer AFFF.

Legacy foams were first introduced by the naval firefighting services in 1964 ([Gipe and Peterson 1972](#)). The U.S. Naval Research Laboratory (NRL) began research on the development of firefighting foams in the 1960s. This led to advancements in fire suppression performance and increased firefighting safety ([US Naval Research Laboratory 2017](#)). In 1969, the U.S. Department of Defense (USDOD) issued military specification MIL-F-24385, which dictates the performance of all AFFF (with performance standards referred to as “Mil-Spec”). AFFFs shown to perform to MIL-F-24385 requirements are listed on the U.S. military’s AFFF Qualified Product Listing (QPL). The first date AFFF was placed on this list was May 15, 1970 (MIL-F-24385 QPL/QPD History of Type 6 AFFF). DOD maintains the online qualified products database (QPD) that lists all AFFF agents that have been tested and qualified by the NRL to meet the Mil-Spec, currently referenced as MIL-PRF-24385, ([USDOD 2018b](#)). On July 1, 2006, the Federal Aviation Administration (FAA) required that commercial airports certified under 14 CFR Part 139 purchase only AFFF that is Mil-Spec compliant (FAA 2006, 2016; 14 CFR 139.317). Recently, the FAA Reauthorization Act modified that requirement. More information can be found in [Section 3.9.3.1](#).

Different types of AFFF were produced to meet firefighting specifications, such as Mil-Spec, rather than formulated to contain a specified mixture of PFAS. Firefighting foams are a complex mixture of both known and unidentified PFAS. Multiple AFFF formulations have been produced over the years, and the exact composition of any given AFFF used or manufactured in any given year is variable ([Backe, Day, and Field 2013](#)). However, due to the production methods, any given AFFF formulation contains complex mixtures of PFAS, many of which can be identified only by nontargeted analytical methods ([Barzen-Hanson et al. 2017](#)).

AFFF is typically formed by combining hydrocarbon surfactants, organic solvents, fluorosurfactants, polymers, and other additives ([Kempisty, Xing, and Racz 2018](#)). AFFF concentrates are commercially available in both 3% and 6%. [Figure 3-3](#) illustrates the typical composition of a 3% AFFF concentrate; water/diluent makes up more than 60% of the concentrate, up to 20% is solvents, and as much as 18% is surfactants, of which less than 2% is fluorosurfactants. When the concentrate is 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 or reduce the hydrocarbon vapors.

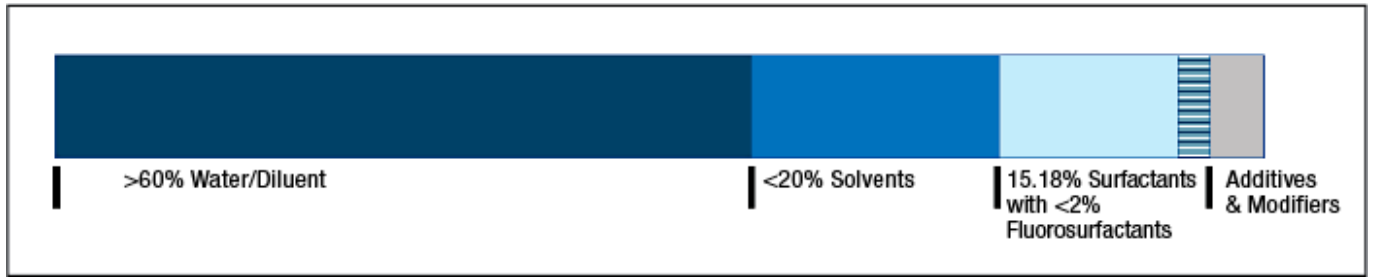


Figure 3-3. Typical composition of 3% AFFF concentrate.

Source: S. Thomas, Wood, PLC. Adapted from Kempisty, Xing, and Racz 2018.

3.2 Mechanisms for Release to the Environment

Firefighting foam is applied by mixing foam concentrate and water to make the firefighting foam solution, which typically contains less than a fraction of a percent of fluorinated surfactants once in mixture. When applied to a fire, the foam solution is aerated at the nozzle, yielding finished firefighting foam. Thousands of gallons of foam solution may be applied during a given event. [Figure 3-4](#) illustrates the use of firefighting foam, how it may be released to the environment, and potentially affected media. Once released to the environment, AFFF can contaminate soil, surface water, and groundwater.

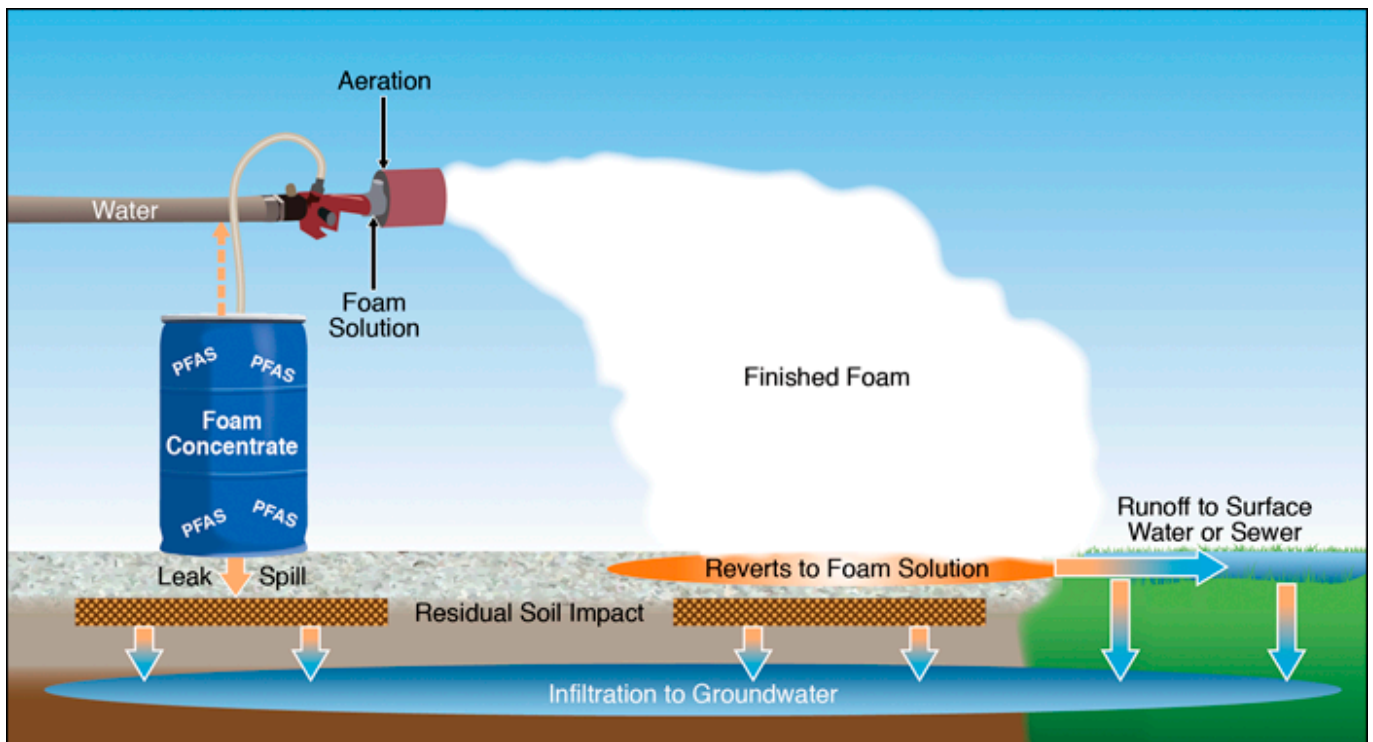


Figure 3-4. Release of firefighting foam.

Source: Adapted from figure by J. Hale, Kleinfelder. Used with permission.

Firefighting foams are released into the environment through various practices and mechanisms ([Anderson et al. 2016](#)) ([Hale 2016](#)) ([Thalheimer 2017](#)) such as:

- low-volume releases of foam concentrate during storage, transfer, or operational requirements that mandate periodic equipment calibration
- moderate-volume discharge of foam solution for apparatus testing and episodic discharge of AFFF-containing fire suppression systems within large aircraft hangars and buildings
- occasional, high-volume, broadcast discharge of foam solution for firefighting and fire suppression/prevention for emergency response
- periodic, high-volume, broadcast discharge for fire training
- accidental leaks from foam distribution piping between storage and pumping locations, and from storage tanks

and railcars.

AFFF-impacted sites often are also contaminated with petroleum hydrocarbons from unburned fuel. PFAS and hydrocarbon plumes at these sites may follow the same flow paths, though the extent of contamination may be significantly different. These co-contaminants, particularly light nonaqueous phase liquids (LNAPLs), may affect the fate and transport of AFFF-derived PFAS (Guelfo and Higgins 2013) (Lipson, Raine, and Webb 2013) (McKenzie et al. 2016), see Section 5.2.5. Certain air-based or in situ oxidation remedial activities aimed at treating co-contaminants may affect PFAS composition, fate, and transport as well (McKenzie et al. 2015). Additionally, the altered soil and groundwater geochemistry and redox conditions may result in oxidation of some PFAS precursor compounds, degrading them to terminal PFAAs (Harding-Marjanovic et al. 2016) McKenzie (McKenzie et al. 2016; McGuire et al. 2014). For additional detail on fate and transport of PFAS from AFFF releases see Section 5.

The USDOD has undertaken an evaluation of potential firefighting foam contamination at its facilities nationwide (Anderson et al. 2016). Similar efforts have been undertaken by some states. For example, the Minnesota Pollution Control Agency (MPCA) conducted a statewide survey of firefighting foam use at training sites. Working with the State Fire Chiefs Association, the MPCA identified more than two dozen locations where Class B foams were likely used in firefighting training (Antea Group 2011).

Figure 2-17 illustrates common elements of CSMs associated with the potential AFFF release scenarios at fire training areas.

3.3 AFFF Procurement and Inventory

This section discusses procurement and inventory of AFFF, including suggestions for storing inventory to minimize the potential for accidental releases.

3.3.1 Foam Selection and Requirements

Multiple manufacturers in the United States and abroad produce AFFF concentrate in 1%, 3%, or 6% concentrations. Most AFFF sold or in stock in the United States is either 1) listed by Underwriters Laboratory (UL) based on conformance with UL Standard 162, "Foam Equipment and Liquid Concentrates," or 2) tested by NRL and granted qualification by U.S. Naval Sea Systems Command in accordance with the Mil-Spec. Only AFFF meeting the Mil-Spec is used in military applications and at FAA-regulated airports.

Military and FAA AFFF applications subject to Mil-Spec account for more than 75% of AFFF used in the United States (Airport Cooperative Research Program ACRP (2017)). Hence, the production of AFFFs has historically been driven by firefighting specifications, such as Mil-Spec, which requires a specific percentage concentration of PFAS. Current Mil-Spec AFFFs contain $\leq 1\%$ (approx. 0.5–0.6%) fluorosurfactants after the concentrate is mixed with water to create the final foam solution used to extinguish or prevent high-hazard flammable liquid fires; however, the exact AFFF PFAS mixtures are highly variable. Non-Mil-Spec Class B foams can vary from fluorine-free to having concentrations of PFAS similar to Mil-Spec AFFF. Furthermore, where fire risk allows it, users who are not subject to Mil-Spec requirements are less likely to use foam formulations that contain PFAS given the environmental implications and increasing prevalence of F3. However, the knowledge of environmental implications of PFAS was historically lacking and is still not widely understood by first responders, and there are many historical examples of AFFF use by municipal fire departments during fire response activities.

3.3.2 AFFF Storage and Handling

AFFF concentrate is available from the manufacturers in containers ranging from 5-gallon buckets to 5,000-gallon tanker trucks. The most common method of shipping is in 5-gallon buckets, 55-gallon drums, or 265-gallon intermediate bulk containers. Shipping containers are typically not double walled but made of plastic, steel, or steel reinforced plastic tote construction to resist damage/puncture. Per National Fire Protection Association (NFPA) 11, Section 4.3.2.3, bulk liquid storage tanks should be fabricated from or be lined with materials compatible with the concentrate, designed to minimize evaporation of foam concentrate, and stored within the listed temperature limitations (NFPA 2016b).

In fire suppression systems, the AFFF concentrate is typically stored in either an atmospheric (non-pressurized) tank or a bladder tank (pressurized). Atmospheric tanks are single- or double- walled tanks and can supply proportioning foam concentrate pumps or venturi-based proportioners that feed the suppression system. Atmospheric tank piping arrangements may include recirculation from downstream of the pump back to the tank. The bladder tanks contain a bladder filled with foam concentrate that is squeezed by water between the shell of the tank and the bladder. As long as the bladder integrity

is maintained, the foam concentrate does not mix with the shell water.

Safety data sheets are provided by all manufacturers for each specific type of AFFF. Labels on shipping containers conform to U.S. Department of Transportation (USDOT) standards. AFFF and AFFF-impacted materials (soils and absorption materials), including concentrate being disposed, rinsate, and foam supply system materials, are not currently considered to be hazardous materials under federal regulations. Some individual states have passed legislation to include PFOS, PFOA, and other PFAS on their hazardous substances list and otherwise restrict the sale and use of AFFF (for example, [Washington Senate 2018](#)) ([New York State 2017](#)). Regulations are discussed further in [Section 3.9](#).

Best practice is to treat foam concentrate with caution and to ensure containment until proper disposal. AFFF materials should be labeled to clearly indicate the contents of the container. It is important that all containers are kept clean so that any signs of leakage can be easily and quickly identified during container inspections, with the labeling pointed outward for easier reading. Refer to the best management practices (BMP) table in the ITRC AFFF fact sheet ([ITRC 2018a](#)) for more information.

3.4 Foam Systems and Operations

Class B firefighting foams are employed globally to fight flammable liquids fires where risk of damage to property or human life is high. These products are particularly prevalent in airport settings. This section describes common AFFF system operations, including system testing and training. Additionally, information is provided in [Section 3.8](#) for organizations that want to replace legacy PFOS AFFF systems with modern fluorotelomer AFFF or F3.

3.4.1 Fixed System Testing

Fixed fire suppression systems that utilize any of the foam types and application methods are permanent designs and should incorporate the containment, collection, and runoff components in the event of system discharge into the design. Examples include flammable liquid warehouse, waste treatment facility, and aircraft hanger fire suppression systems. New systems should be designed to include foam containment and collection mechanisms such that foam releases that occur during testing or activation are not released to the environment, or the AFFF can be captured for disposal. AFFF design standards require minimum durations for foam system discharge to meet the suppression/control requirements and in some cases require specific volumes of concentrates and foam solution to be contained in on-site storage tanks. Fixed AFFF proportioning systems that are connected to city water mains should be fitted with backflow preventers to protect the city water mains from potential AFFF contamination.

Codes, standards, and authorities having jurisdiction over fixed system testing, such as NFPA Standards 16 ([NFPA 2019](#)) and 25 ([NFPA 2017](#)), can require that the equipment produce a foam/foam solution that can be tested and compared to laboratory standards. System testing generates a small amount of foam that should be contained or controlled by the design to the best extent possible for proper disposal. Foam can be wetted with fog nozzles/mist to knock down the foam and dilute it. Gentle squeegee and sweeping are required to keep the solution from aspirating during cleanup and dilution. Alternatives, such as testing with water (without foam) or testing with fluorine-free training foam or surrogate liquids having similar physical properties, may be considered to minimize disposal issues. Check applicable regulatory requirements for testing to determine frequency and type of testing required, as well as what is specifically mandated for foam type before any alternatives are considered to ensure compliance with appropriate laws.

3.4.2 Mobile Firefighting Equipment Testing

Firefighting equipment requires inspection, calibration, and testing to ensure reliability and performance to specifications. In accordance with fire protection standards (for example, NFPA Standard 412, [NFPA 2020](#)) and manufacturer's recommendations, the testing of mobile firefighting equipment should be conducted routinely and documented.

Multiple pieces of equipment can be tested or inspected simultaneously. Mobile equipment, including but not limited to mobile foam extinguishers, firefighting vehicles, and marine craft, can be collected, tested, and cleaned and foam concentrate samples can be collected in a single location to minimize potential impacts. It is recommended that testing of mobile firefighting equipment is executed at purpose-built facilities specifically designed to capture and contain all generated foam and wastewater for treatment, reuse, or disposal.

Conditions during equipment testing should include secondary containment measures to ensure foam solutions can be captured and managed and environmental impact minimized. Alternatives to traditional testing methods may be considered,

such as:

- using water or surrogate solutions for training
- testing equipment indoors
- spraying into drums or other containers
- testing within lined pits or spill containment equipment
- testing with closed-loop AFFF testing systems to minimize and eliminate discharge (for example, FAA CertAlert 19-01 ([FAA 2019](#))).

Other controls include not testing during adverse weather conditions, not testing where the facility is not deemed fit for purpose, conducting a risk assessment of the activity, and minimizing foam wastewater volume generated wherever possible. As with fixed fire suppression systems, mobile equipment that complies with NFPA Standard 412 requires that the equipment produce a foam/foam solution that can be tested and compared to laboratory-analyzed solutions ([NFPA 2020](#)).

3.4.3 Training Exercises

Facilities should have specifically designed areas and structures to conduct training exercises involving flammable liquid fires and foam systems. The fire training areas (FTAs) should be arranged to contain/control the training site for the safety of the persons being trained. Control of training fires as well as applied foam and/or foam solutions is maintained by the facility design. The FTA should also be designed for collection/recovery of unburned fuels as well as the foam solution and fire water following the completion of training exercises. Conducting outside exercises during windy weather conditions should be avoided, as the foam solutions can be difficult to contain due to natural aspiration and windblown transport.

Past training exercises at airports and military installations employed large quantities of foam/foam solutions. To prevent further releases to groundwater, USDOD issued a policy in January 2016 requiring prevention of uncontrolled land-based AFFF releases during maintenance, testing, and training activities. Current USDOD policies prohibit using AFFF with PFOS for testing, maintenance, or training exercises with the exception of shipboard activities.

Consider minimizing the volume of foam used to the greatest extent possible. If permitted by the applicable regulatory requirements for training, consider entirely discontinuing the practice of using expired legacy AFFF and modern fluorotelomer AFFF as training foam. Whenever possible, seek fluorine-free alternatives for training events; consider training with water or training foam where practicable, not Class B foam, and certainly not with Class B foam containing PFAS. Any wastewater or foam generated from training activities should be kept to a minimum and foam spraying should be restricted to target areas only (not sprayed over wide areas). Preplanning responses that deploy AFFF can identify weaknesses in both AFFF use strategies and in fuel and fire water runoff and containment. This can also identify the need for calling mutual aid early to assist with containment tactics.

3.5 Emergency Firefighting Operations

Fire response planning in advance can identify various options for firefighting and contingency planning for fire wastewater capture. Where possible and as setup allows, consider containing and recovering AFFF used for emergencies for disposal. Use mutual aid resources to assist with containing the fuel and fire water runoff should your department not have the resources available to fight the fire emergency and contain the runoff ([Section 3.4](#)). Although federal law currently does not prohibit the use of existing stocks of legacy AFFF, any discharge of foam containing PFAS to public waters can be considered a release of a “pollutant or contaminant” under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA), 42 U.S. Code § 9601, and therefore may be subject to remediation requirements.

Emergency scenarios vary case by case. Industrial plant fire brigades and responding emergency crews utilize portable foam generators or monitor nozzles to apply foam to pooled flammable liquids (potential fires) or existing fires. In cases where the fire involves a fixed system, it is critical that an arrangement for containment/control of runoff is included in the design. The following are examples of how preplanning can better inform the use and containment of AFFF at an industrial facility:

Consideration should be given to parts of facilities not protected by the fixed foam system that could be subject to AFFF application in the event of an emergency incident and opportunity for containment of foam.

- Industrial processes have many components, and only portions of the process are protected by the fixed foam systems. For example, a scrubber, or filter found within industrial smokestacks, may be part of the process that is not protected by the foam system and may be outside the discharge area where design considerations have been made for containment/control. Emergency response units may be required to apply foam/water to the location of the scrubber, outside the planning boundaries, in the event the fire that originated in the process was conveyed to the scrubber unit.
- At oil refineries, F3 may be used for small incidents and fluorinated foam reserved for the large tank fires. Fluorine-free and new generation C6 foams have been tested in large-scale tests (involving up to 40 m foam travel requirements) and could be considered suitable for application to fires involving some tank sizes and the associated dike area fires. But firefighting foam use is rapidly evolving, and as such, those responsible for tank application foam selection should refer to the latest test results from any recognized independent source (for example, LASTFIRE) to determine whether F3 could meet the performance requirements.
- On some remote industrial sites, where no immediate threat to life or property exists, and given the additional resources necessary to manage the wastewater produced, the best response may be to let the fire burn instead of applying AFFF.

3.5.1 Personal Protective Equipment

The use of personal protective equipment (PPE) is highly recommended when exposure to AFFF, as well as other firefighting foams, is anticipated. A critical aspect of PPE is ensuring the proper use of the equipment. The equipment should be used correctly, maintained, and decontaminated routinely ([Queensland Government 2018](#)).

During the application or immediate cleanup of AFFF foam, the use of a self-contained breathing apparatus or positive pressure-supplied air respirator is recommended to avoid respiratory exposure. Dermal exposure should also be avoided, as skin contact can result in irritation and dryness. When responding to fires, first responders should wear appropriate turnout gear, or proximity gear per their specific department requirements.

PPE cleanup after using AFFF (as well as other foams) is discussed in the next section.

3.5.1.1 Decontamination

Although PPE will prevent initial exposure to AFFF, contamination of the PPE itself can present health risks. Decontamination of the PPE and personal hygiene are crucial preventative measures in reducing or avoiding exposure to AFFF, as well as in avoiding cross-contamination.

When handling AFFF concentrate or foam, it is imperative to avoid hand-to-mouth contact. After the use or cleanup of AFFF, responders should wash hands and use other decontamination procedures to remove any residual AFFF from the skin. Responders should remove contaminated clothing and launder before reuse.

PPE should be placed in a bag and container after exposure to AFFF as well as other foams. In 2014, NFPA released its latest edition of NFPA 1851: Selection, Care and Maintenance of Protective Ensembles for Structural Firefighting and Proximity Firefighting. This standard provides guidance for proper care of firefighting protective gear as well as health hazards associated with improper maintenance or contamination of protective equipment ([NFPA 2014](#)). The standard outlines different decontamination measures for turnout gear as well as proximity gear.

Turnout gear is the general PPE for firefighting. It should be machine washed in warm water in the normal cycle. Turnout gear should be spot treated with warm water, a soft brush, and mild detergent prior to being machine washed. When hand washing and spot treating PPE, wear protective gloves—either latex or PVC—to avoid skin contact with any residual AFFF. No fabric softener or bleach should be used. The turnout gear should never be washed in home washing machines, as this practice has the potential to contaminate personal clothing. Advanced cleaning is suggested at least on a yearly basis ([Avsec 2015](#)).

Although PPE decontamination prior to reuse is important, it is equally important to recognize when decontamination is not possible. In this case, the gear should be discarded in accordance with local, state, and federal regulations.

When decontaminating or laundering PPE, the disposition of the waste stream should be considered. The potential for environmental impacts due to laundering in washing machines is not well defined, but the potential does exist. Regulatory agencies should consider including decontamination procedures when working with firefighters, refinery safety personnel, and other potential first responders to develop BMPs.

3.5.2 Initial Mitigation Efforts for Firefighting Foam

Initial mitigation efforts following a release of firefighting foam include source control, containment tactics, and recovery tactics. Each is further described in this section.

Discharges of AFFF can occur during firefighting operations, system testing, equipment malfunctions, or incidental releases. In addition to foam, a large amount of water is often applied when attempting to suppress a fire. Due to the highly miscible nature of AFFF, the main objective of the initial mitigation efforts should be to reduce the footprint of contamination by limiting the spread of foam and fire water. This is often done through various containment and recovery tactics while making sure that the release has been abated and response personnel are safe.

Specific department or facility fire wastewater management considerations may be outlined in a fire response plan, which should include information such as resources available within the facility or department fire protection jurisdiction to contain and recover fire water, protect sensitive areas (for example, public and private water systems, storm drains, surface water, critical wildlife habitat), and address safety considerations when conducting water management tactics. By using the fire response plan, first responders familiar with the content can increase the potential for a successful response while reducing or eliminating any imminent or substantial threat to human health, safety, welfare, or the environment.

3.5.2.1 Source Control

In addition to AFFF application for emergency response, accidental discharge of AFFF can occur from faulty or malfunctioning equipment such as hard-lined fire suppression systems in aircraft hangars or equipment used to apply or contain foam (for example, fire engines or storage tanks). The first step in any response is to stop the accidental discharge or release at the source by disabling or shutting off the system, if possible, and then temporarily or permanently repairing the malfunctioning equipment. By controlling the source, the impact to the environment is minimized.

3.5.2.2 Containment Tactics

Due to AFFF's miscible nature, as well as the large amount of water often applied in combination with the foam, containment tactics that prevent or minimize surface water runoff are critical during and after emergency response activities. Proper containment tactics may also reduce the footprint of the affected area to make the containment and cleanup easier. Depending on resources available to response personnel and conditions of the release, tactics such as ditching, berming, diking, damming, and blocking storm drains, culverts, or other surface inlets can help to contain runoff. When using these tactics, it is important to ensure that any digging activity will not result in breaking through a confining layer that would allow contaminated water to move more quickly into the subsurface and specifically to groundwater. Several response organizations have tactics manuals available online for review, including the Spill Tactics for Alaska Responders (STAR) Manual ([AK DEC 2014](#)) and Alaska Clean Seas Tactics Manual ([Alaska Clean Seas 2017](#)). Most manuals are targeted at tactics proposed to be conducted after a release of oil or other petroleum products, but most of these tactics will also apply to AFFF releases. General guidance, similar to this section, on containment tactics to be conducted after a foam discharge has been provided by several other organizations, including the Firefighting Foam Coalition ([FFFC 2016, 2018](#)) and the Queensland Department of Environment and Science ([Queensland Government 2018](#)).

As stated previously in this section, preplanning can greatly assist with prioritizing sensitive areas or locations that need protection during the mitigation or response effort after an AFFF discharge, as well as the resources necessary to succeed with this strategy. The containment tactics used and resources required will differ among sites. Preparedness can be increased by identifying potentially sensitive areas. Also, designing infrastructure such as aircraft hangars with foam-applying fire suppression systems so that the discharged foam is automatically directed to storage tanks or containment structures can minimize the need for any cleanup. The DOD has provided guidance via Engineer Technical Letters ([USACE 2018](#)) that address containment/disposal system design for AFFF discharges from open systems (such as nozzle and deluge sprinkler systems) and closed systems (in which individual sprinkler heads are activated only by heat of a fire).

Because no single set of containment tactics is going to be applicable to all facilities or departments where a foam discharge occurs, it is important for each user to conduct preplanning to identify solutions that fit its facilities, objectives, and specific response scenarios.

3.5.2.3 Initial Recovery Tactics

Recovery tactics can differ depending on the amount of AFFF released, as well as whether the AFFF is discharged during firefighting operations or accidentally (for example, from malfunctioning equipment). Collection of large volumes of AFFF concentrate or the 1%, 3%, or 6% AFFF mixture combined with water could require the use of mechanical devices such as

pumps or vacuum trucks, while absorbent material might suffice to clean up after a smaller release. The AFFF and water mixture has a low flammability and a high flash point, so there is no need to use intrinsically safe pumps or mechanical devices unless other, more flammable compounds are present in the fire water being recovered.

It may be beneficial to remove affected AFFF saturated materials such as soil and vegetation to reduce or eliminate surface or subsurface migration of potential contaminants. Removal of contaminated media may reduce or eliminate the need for additional investigation and cleanup in the future; however, focus during the initial mitigation effort should be on the more easily recoverable media such as affected waters or slurries. Initiating recovery tactics as soon as possible after a release of AFFF will greatly reduce the footprint of PFAS-contaminated materials and lower the cost of the total mitigation effort.

3.6 Immediate Investigative and Cleanup Actions

A series of immediate investigative actions can be taken after the use of AFFF at the site of a fire to determine the level, nature, and extent of the contamination. First responders should collect information regarding the volume of AFFF discharged, its concentration, active ingredients, and discharge location information.

Information about actions to be taken after the immediate actions is included in [Section 10](#), Site Characterization; [Section 11](#), Sampling and Analytical Methods; and [Section 12](#), Treatment Technologies.

Traditional field-screening methods used for other types of contaminants (for example, PID field screening for petroleum) are not effective for PFAS due to their unique chemistry, generally low volatility, and lack of development of colorimetric or reactive chemistry technologies. Some efforts have been made to develop mobile analytical laboratories, which are covered in [Section 10.3.1.2](#) of this document.

3.6.1 Visual Site Delineation

Visual site delineation refers to outlining the affected area of contamination based on visual clues, such as a visible foam and wet ground, as a guide. The extent of foam should be marked using survey tape, lathe, and pin flags placed to identify locations of AFFF contamination. This technique of determining the initial expanse of the contamination is simple to perform directly after a discharge and can be useful for reference in future testing on the site. In addition, photographs of the site taken during or immediately after the incident can be used to determine the extent of AFFF impacts.

3.6.2 The Shake Test

The shake test is an informal qualitative field-screening method that provides a visual analysis of the site contamination. The shake test can apply to both water and soil-water solutions. In the shake test, a small sample (10–25 mL) is collected on site by the field personnel and shaken. After it is shaken, if there is foaming in the sample, it should be noted and then submitted for analysis ([Transport Canada 2017](#)). Photographs of the samples may be helpful. The presence of foam implies the sample is contaminated with AFFF. This test is a good indicator for high concentration contamination. It may not be able to detect lower concentrations of contaminants, so lab testing may still be required.

3.6.3 Initial Investigative Sampling

Investigative sampling is used to determine the nature and extent of contamination, including concentrations at and surrounding release areas. Initial investigative sampling can help to determine whether additional characterization is necessary, in addition to informing the need for and extent of interim or permanent remedial actions. Combining the information gained from investigative and confirmation sampling with information from a CSM will inform project managers as to whether further site characterization and remediation or mitigation efforts are needed. See [Section 5](#) (Environmental Fate and Transport Processes), [Section 10](#) (Site Characterization) and [Section 12](#) (Treatment Technologies) for additional information on the actions that may be needed following initial response.

3.6.4 Interim Removal

Following the information gathering described above, or possibly prior to initial investigative sampling, additional source control can be achieved through removal of soils that are expected to be highly contaminated. During an initial removal action intended to target PFAS hot spots, soil excavation can be guided by shake tests ([Section 3.6.2](#)). An interim removal is not necessarily designed or expected to remove all contamination but can help to reduce the migration of PFAS into other media, including groundwater and surface water. To determine how to dispose of the soil, see [Section 12](#) (Treatment Technologies).

3.6.5 Confirmation Samples

Once removal actions take place, confirmation samples are taken to confirm that an excavation or interim removal successfully removed the soil contamination that exceeds applicable regulatory or risk-based levels. If confirmation sampling determines that soil contamination still exists at levels of concern, additional removal actions or other types of remediation or mitigation may be required. The type, number, and distribution of confirmation samples is determined on a site-specific basis according to local regulatory guidance.

3.7 Treatment and Disposal

BMPs suggest that all AFFF foam concentrate volume be fully accounted for at each storage location, from fire trucks to suppression systems to storage containers. Weights of other AFFF system components requiring disposal should be similarly observed. Disposal certificates for materials bound for removal should indicate volumes of AFFF concentrate or solution or weights of system components or debris, as applicable. Total volumes or weights generated for disposal should match that indicated on disposal certificates.

3.7.1 AFFF Concentrate

The disposal of AFFF concentrate is dependent on the product type and the ingredients present in the product to be disposed. Manufacturers' product literature should be consulted for information regarding the specific foam concentrate to be disposed. As of the writing of this document, the Firefighting Foam Coalition recommends high temperature incineration (that is, at 1,000°C) at a hazardous waste management facility as the preferred disposal method for AFFF concentrate in the United States (FFFC 2016 ([FFFC 2016](#))). In some cases, disposal via burial of a stabilized concentrate at a hazardous waste management facility may be acceptable. AFFF concentrate bound for disposal should be properly documented in compliance with state and federal transportation regulations (as discussed in [Section 3.3.2](#)) and shipped to the selected disposal facility under a proper manifest. After the concentrate product has been incinerated, a certificate of disposal should be generated by the waste management facility and transmitted to the product owner. This certificate of disposal should be transmitted to the state regulatory agency for review and maintained on file by the product owner.

DOD is currently replacing legacy foam concentrates with modern fluorotelomer foams at many installations across the United States. Legacy foams are being removed from active use as part of this replacement project and the removed product is being disposed of through incineration; however, approximately three-quarters of respondents of a 2016 nationwide survey of municipal airports (non-DOD facilities) said that they were not aware that replacements existed (ACRP 2017 ([ACRP 2017](#))).

3.7.2 Fire - and Flush Water Containing AFFF

Fire water produced during training or emergency response, as well as flush water produced during the rinsing of firefighting systems and equipment, is managed and disposed of as a generated waste because these waters contain dilute concentrations of PFAS. Practitioners may consult with local regulatory agency personnel ideally prior to the generation of fire- and flush water so that there is a good understanding of local laws and regulations governing disposal. Standard practices for foam containment and cleanup should be developed prior to use such that response teams have the needed equipment and training before an event occurs. Some fire water disposal options are focused on reducing the volume of wastewater through concentration and disposal of the generated concentrate via incineration, landfilling, stabilization, or other mechanisms. Widely used treatment methods, as presented in [Section 12](#) are as follows:

- granular activated carbon treatment
- discharge to and treatment at a wastewater treatment plant
- pumping AFFF-impacted fire water into watertight, secure containment basins and allowing the water phase to evaporate, leaving behind a solid or semi-solid material containing the AFFF concentrate. The remaining material is then disposed of at a certified waste management facility ([USDOD 1997](#)). This method is an option only in some localities and where climatic conditions are favorable.

3.8 Firefighting Foam System Replacement

The AFFF application design is specific for each foam and use. Changing between foam types or application objectives could require a complete system review and, potentially, redesign and modification of system components to meet the new objectives or material and performance requirements. When objectives or requirements are changed, each subject system

should be evaluated and modified individually to ensure that operational objectives are met.

Procurement at U.S. airports is primarily driven by regulatory performance requirements, notably the DOD Mil-Spec, MIL-PRF-24385, as well as FAA requirements ([ACRP 2017](#)). DOD recommends complete replacement of the required AFFF concentrate supply and rinsing of the storage and discharge system prior to refilling with a different concentrate product ([USDOD 2017](#)). This not only prevents any unforeseen incompatibility issues, but also greatly reduces possible cross-contamination and the uncertainty of AFFF formulations (PFAS profile/content).

Applicable replacement products standards include NFPA Standards 11 ([NFPA 2016b](#)) and 16 ([NFPA 2019](#)) for foam water sprinkler and foam water spray systems and NFPA Standards 1901 ([NFPA 2016a](#)) and 412 ([NFPA 2020](#)) for equipment.

3.8.1 Replacement Products

Replacing foams and foam systems generally follows four steps:

1. Assess and understand the specific hazards and application objectives.
2. Ensure that foam product to be adopted is listed and approved for use on the specific assets that are being protected and the hazards that that are being mitigated.
3. Ensure that the foam product storage system and the foam/water application system meet product storage (for example, materials compatibility and storage temperature), proportioning, and application requirements.
4. Ensure that the selected foam product(s) meet applicable requirements (such as Mil-Spec, Underwriters Laboratories (UL), or Factory Mutual compliance). These organizations audit manufacturers to ensure compliance with their standards.

Where two or more foam products meet applicable performance requirements, the foam with the best environmental performance should be selected. Alternatives currently available as replacement products for legacy AFFF include products discussed in the following sections.

3.8.1.1 Fluorine-Free Foams (F3)

Most foam manufacturers now produce Class B F3s. Performance of these foams should be evaluated carefully as future purchasing decisions are made. As of September 2019, F3s are not yet approved for use on Class B fires at federal- and FAA-regulated facilities that require Mil-Spec-compliant AFFF. But a mandate within the FAA Reauthorization Act of 2018 (enacted October 5, 2018) directs the FAA to stop requiring the use of fluorinated foam no later than 3 years from the date of enactment (October 4, 2021), so F3 use is anticipated at FAA-regulated facilities in the near future.

There continues to be robust discussion regarding the replacement of AFFF products with F3 formulations. For example, the organization IPEN has published a document titled *Fluorine-Free Firefighting Foams (3F): Viable Alternatives to Fluorinated Aqueous Film-Forming Foams (AFFF)*, which states that F3 products are as effective in combating Class B fires as AFFF and concludes that because of the lower environmental impact of F3 products, the use of AFFF should be discontinued ([IPEN 2018](#)). The Fire Fighting Foam Coalition (FFFC) produced a three-page document responding to the IPEN paper, which discusses technical details regarding differences in foam performance for certain types of Class B fires and performance standards (as opposed to composition standards) that continue to necessitate the use of AFFF or other fluorochemical products for certain hazards. Additional challenges to the replacement of AFFF with F3 foams are also described in the FFFC document ([FFFC 2018](#)).

3.8.1.2 Modern Fluorotelomer Foams

If it is determined that the performance of a fluorinated Class B foam is required for a specific hazard (for example, the federal regulation requiring AFFF use for military applications, at FAA-regulated airports, and/or other high hazard Class B fires and potential incidents), users should purchase modern fluorotelomer foams. Most foam manufacturers have transitioned to the production of only short-chain (C6) fluorosurfactants, so it is likely that any AFFF bought today meets that requirement. But foams made with only short-chain (C6) PFAS may still contain trace quantities (parts per billion) of PFOA and PFOA precursors as byproducts of the manufacturing process. This should be confirmed with the supplier.

Although there are currently mandated specifications requiring the use of fluorinated foams at airports and military installations, users should be aware that compounds in modern fluorotelomer foams are regulated by several states and are known to have probable effects on human health ([Section 7.1](#)). Use of these foams may be restricted to emergency situations only and not for use in firefighting training activities. Local and state regulations may require reporting of their release, including emergency use. [Section 3.9](#) discusses the current state of regulations on AFFF use.

3.8.2 System Decontamination and Sampling During Foam Replacement

The replacement of Mil-Spec legacy foam with the modern foams requires review of system components, particularly the proportioning system, to ensure that appropriate system performance will be maintained. During foam replacement, a thorough clean-out of storage tanks and associated pipework is highly recommended prior to filling with replacement foam concentrate. There is potential for PFOS and PFOA contamination from legacy AFFF, as described in [Section 3.1](#), and from PFOA and other PFAS from fluorotelomer foams. For nonmilitary applications, legacy AFFF and replacement modern foams may not be compatible. In these cases, the foam manufacturers should be consulted when a foam change is required and current best practices for foam replacement, system decontamination, and verification sampling should be considered.

Currently, there are no regulatory guidelines or requirements pertaining to the clean-out of AFFF firefighting systems when foam concentrates containing legacy foams are replaced with alternative foams; however, local and state governments and other organizations continue to develop policy and guidance on replacing foams. DOD (and other foam users) requires their contractors to perform a triple rinsing step after the legacy AFFF is removed from a system. The rinse water is containerized and managed as a waste material as presented in [Section 3.3.2](#). After the rinse water is removed, the modern fluorotelomer AFFF concentrate is added to the system and the system is function tested and placed back into service. Specific department or facility fire wastewater management considerations may be outlined in the facility or installation spill response plan, which should include information and resources available within the facility or on the installation to contain and recover AFFF-containing fire water to protect the environment. Organizations should check with local and state regulatory agencies regarding local policies and guidance for foam change-out. Sampling of rinsate to ensure that residual contamination has been removed may be considered before adding replacement foams, and sampling of replacement foams that have gone through the system may provide the best assurance that PFAS will not continue to be released when the systems are used.

3.9 Federal, State, and International Regulations and Guidance

3.9.1 Overview

This section summarizes representative information on the regulation of PFAS-containing firefighting foams (AFFF). Although federal law currently does not prohibit the use of existing stocks of legacy AFFF, any discharge of foam containing PFAS to public waters can be considered a release of a “pollutant or contaminant” under CERCLA, 42 U.S. Code § 9601, and therefore subject to remediation requirements. In February 2019, the USEPA announced in its PFAS Action Plan that the agency is beginning to evaluate designating PFOA and PFOS as “hazardous substances” through one of the available statutory mechanisms, including potentially CERCLA Section 102 ([USEPA 2019h](#)).

As of September 2019, AFFF use is explicitly regulated by some states, such as the State of Washington and the State of New York ([Table 3-1](#)); however, other states regulate PFOA, PFOS or their salts, and other PFAS in AFFF as hazardous substances or hazardous waste. These regulations effectively limit the storage and/or environmental release of legacy AFFF (both legacy PFOS AFFF and legacy fluorotelomer AFFF), as well as potentially triggering cleanup actions. Similar bills, banning the use of AFFF for testing and training, have been passed in other states such as Arizona, Colorado, Georgia, Kentucky, and Minnesota.

Examples of hazardous substance and hazardous waste regulations, as well as other federal, state, and international guidance pertaining to AFFF, are presented below. For more information pertaining to the regulation of PFAS, see [Section 8](#). This section addresses only regulations related to AFFF.

Table 3-1. Representative state AFFF regulatory and legislative activity

State	Regulation or Bill	Initial Effective Date	What is Regulated?	Specific Requirement	Reference
New York	6NYCRR Part 597	March 2017	PFOS, PFOA, and Class B foams	PFOS and PFOA are hazardous substances. Storage and registration requirements for class B foams if those foams contain at least 1% by volume of PFOS and PFOA (acid and salt) and prohibit the release of 1 pound or more of each into the environment during use. If a release exceeds the 1-pound threshold, it is considered a hazardous waste spill and must be reported. Clean-up may be required under the state's superfund or brownfields program (NYDEC 2017). New York's Chemical and Bulk Storage regulations may also trigger further registration and storage requirements for foams that contain one of the four PFAS designated as hazardous substances (NY CRR Parts 596-599).	(NY DEC 2017a)
Washington	WAC 296-24-33001	July 2020	Class B foams	Class B firefighting foams cannot be used or discharged for training purposes, and manufacturers of firefighting personal protective equipment must provide written notification to purchasers if the equipment contains PFAS. Beginning July 1, 2020, manufacturers of class B firefighting foams may no longer manufacture, sell, or distribute for sale PFAS-containing class B firefighting foams except for the following uses: applications where the use of a PFAS-containing firefighting foam is required by federal law, including but not limited to the requirements of 14 CFR 139.317 (such as military and FAA-certified airports). Other exceptions include: Petroleum Terminals (as defined in RCW 82.23A.010), Oil Refineries, Chemical Plants (WAC 296-24-33001)	(Washington State Legislature 2018c)
Virginia	House Bill 2762ER	January 2020	PFAS-containing AFFF	Virginia Department of Fire Programs and the Virginia Fire Services Board begin assisting municipal fire departments to transition to fluorine-free foams, where possible. Effective the same date, the bill bans the discharge or use of PFAS-containing AFFF foams for testing or training unless the facility has implemented containment, treatment, and disposal measures to prevent release to the environment.	State of Virginia, 2019

3.9.2 Take-Back Programs

Several states have implemented “take-back” programs for AFFF. For example, in May 2018, the Massachusetts Department of Environmental Protection (MA DEP), 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 2018a](#)). MA DEP provided funding to assist local fire departments in identifying these foams in their stockpiles and for MA DEP to dispose of them. Any AFFF manufactured before 2003 is eligible under the take-back program. Vermont also announced a take-back program ([VT DEC 2018a](#)). Users should contact their state regulatory agency for information on available take-back programs.

3.9.3 Federal Guidance

3.9.3.1 Federal Aviation Act

The FAA Reauthorization Act of 2018 was passed on October 5, 2018. Section 332 of that act states that no later than 3 years after the date of enactment, the FAA shall no longer require the use of fluorinated chemicals to meet the performance standards referenced in chapter 6 of Advisory Circular (AC) No: 150/5210-6D and acceptable under 139.319(l) of title 14, Code of Federal Regulations. As a result of this change in law, the FAA (and FAA-regulated facilities) will no longer be required to abide by the DOD Mil-Spec, MIL-PRF-24385, requiring use of PFAS in firefighting foams ([FAA 2018](#)).

3.9.4 International Guidance on AFFF

Internationally, there are many governmental agencies that have developed guidance or operational policy for AFFF. Some examples are briefly presented in [Table 3-2](#).

Table 3-2. Representative international AFFF regulatory and guidance activity

Country	Initial Effective Date	What is Regulated?	Specific Requirement	Reference
Canada	January 2018	PFOS, PFOA, long-chain PFCAs	Canada prohibits the manufacture, use, sale, or import of a number of PFAS-containing chemicals and products, such as AFFF, that have these chemicals. Canada allows certain exemptions, including the use of AFFF that contains residual levels of PFOS at a maximum concentration of 10 ppm; the use and import of AFFF contaminated with PFOS in military equipment returning from a foreign military operation; and the import, use, sale, and offer for sale of AFFF that contains PFOA and/or LC-PFCAs used in firefighting.	(ECCC 2017)
Germany	May 2013	AFFF	The German Federal Environment Agency released a Guide for the Environmentally Responsible Use of Fluorinated Firefighting Foams. The guidance discusses what AFFFs are, when it is necessary for use, why it endangers humans and the environment, and the consequences of use.	(German Federal Environment Agency 2013)
Australia	July 2016	Firefighting foam	The Queensland Department of Environment and Heritage Protection issued an Operational Policy on the Environmental Management of Firefighting Foam. The objective of the policy was to define the requirements and expectations for the handling, transport, storage, use, release, waste treatment, disposal, and environmental protection measures of AFFF.	(Australia Government DOD 2007)

3.10 Foam Research and Development

Current modern AFFF fluorosurfactant alternatives are largely short-chain C6 telomer-based fluorosurfactants. The

fluorosurfactants do persist in the environment, and they have the potential to create breakdown products that are also persistent. Although numerous fluorine-free alternatives are already on the market, there is still a need to develop novel firefighting foams that provide the desired firefighting performance while not being harmful to human health and the environment. Research is currently being conducted to further evaluate modern fluorotelomer and fluorine-free alternatives. Research is discussed below.

3.10.1 Research on Current AFFF

Research is being conducted to provide a better understanding of AFFF in the environment and to develop novel technologies to clean up or remove AFFF at contaminated sites. Due to the ability of these legacy AFFF to spread quickly and prevent re-ignition of fuel fires, combined with the fact the USEPA did not require manufacturers to remove their long-chain inventory as part of the 2010/2015 PFOA Stewardship Program, some legacy stockpiles are still being used today ([Barclift 2013](#)).

Since 2017, the Strategic Environmental Research and Development Program (SERDP) has been funding research intended to identify and test F3s that meet the performance requirements defined in MIL-PRF-24385. New formulations must be compatible with existing AFFF and supporting equipment. Projects include evaluation of persistence and aquatic toxicity of the alternative materials and will provide human health and environmental impact assessments on the ingredients, formulations, and byproducts being studied. [Table 3-3](#) summarizes the AFFF alternatives studies supported by SERDP-Environmental Security Technology Certification Program (ESTCP).

Table 3-3. Summary of the AFFF alternatives studies supported by SERDP-ESTCP

Lead Investigator	Objectives	Expedited Completion	Project Link
Dr. Joseph Tsang, Naval Air Warfare Center Weapons Division	Proof-of-concept for the development of the next generation of fluorine-free firefighting foam formulations as a replacement for existing aqueous film-forming foam (AFFF). The novel foam systems produced in this research are derived from polysaccharide copolymers and nanoparticles that are sustainable, nontoxic, and water-soluble (or water-dispersible), and will be applied using existing military firefighting equipment.	Aug-18	https://serdp-estcp.org/Program-Areas/Weapons-Systems-and-Platforms/Waste-Reduction-and-Treatment-in-DoD-Operations/WP-2737/WP-2737

Lead Investigator	Objectives	Expedited Completion	Project Link
Dr. John Payne, National Foam	<p>Improve understanding of the physical and chemical processes that underlie firefighting foams, and how the components of a foam formulation can deliver the properties required for good fire-extinguishing performance while minimizing environmental burdens.</p> <p>Statistical method will be employed to develop a fluorine-free surfactant formulation that meets the performance requirements defined in MIL-F-24385. A life cycle assessment will compare the environmental impact of each foam type and identify routes to improving environmental performance.</p>	Sept-19	https://serdp-estcp.org/Program-Areas/Weapons-Systems-and-Platforms/Waste-Reduction-and-Treatment-in-DoD-Operations/WP-2738/WP-2738
Dr. Ramagopal Ananth, U.S. Naval Research Laboratory	<p>Develop a fluorine-free firefighting surfactant formulation that meets the performance requirements of MIL-F-24385F and is an environmentally friendly drop-in replacement for the current environmentally hazardous AFFF.</p>	Dec-20	https://serdp-estcp.org/Program-Areas/Weapons-Systems-and-Platforms/Waste-Reduction-and-Treatment-in-DoD-Operations/WP-2739/WP-2739

The results and full reports of these and future projects will be available at the SERDP-ESTCP website (<https://serdp-estcp.org/>).

Examples of other ongoing research includes:

- Petroleum Environmental Research Forum (PERF), 2016. Firefighting Foam Human Health and Environmental Risks at O&G (Oil and Gas) Operations. This project aims to capture the state of knowledge of the fate, transport, and effects of C8 PFAS AFFF alternatives and identify limitations of and data gaps in the current studies or data sets to inform risk assessment and risk-based decision-making.
- European Chemicals Agency, 2019. Assessment of Alternatives to PFAS-Containing Fire-Fighting Foams and the Socio-Economic Impacts of Substitution.
- European Commission, 2019. The Use of PFAS and Fluorine-Free Alternatives in Fire-Fighting Foams.

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