EXECUTIVE SUMMARY

Approach for Assessing PFAS Risk to Threatened and Endangered Species

SERDP Project ER18-1653

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ACRONYMS AND ABBREVIATIONS

AFFF	aqueous film-forming foam
BAF	bioaccumulation factor
BSAF	biota sediment accumulation factor
DoD	Department of Defense
EC10	effect concentration affecting 10 percent of the population
EcoSSL	Ecological Soil Screening Level
FTOH	fluorotelomer alcohols
g	grams
GLI	Great Lakes Initiative
kg	kilogram
kg/day	kilograms per day
L	liters
L/day	liters per day
LOAEL	lowest-observed adverse effect level
LOEC	lowest-observed effect concentration
mg	milligrams
mg/kg	milligrams per kilogram
mg/kg-bw/day	milligrams per kilogram body weight per day
mg/L	milligrams per liter
NOAEL	no-observed adverse effect level
NOEC	no-observed effect concentration
PFAS	per- and polyfluoroalkyl substance
PFBA	pentafluorobenzoic acid
PFBS	perfluorobutane sulfonic acid
PFDA	perfluorodecanoic acid
PFDoA	perfluorododecanoic acid
PFHpA	perfluoroheptanoic acid
PFHxA	perfluorohexanoic acid
PFHxS	perfluorohexane sulfonic acid
PFNA	perfluorononanoic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctanesulfonic acid
PFPrA	perfluoropropanoic acid
PFUnA	perfluoroundecanoic acid

RBSL	risk-based screening level
RWQ	recommended water quality
SL	screening level
T&E	threatened and endangered
TRV	toxicity reference value
UF	uncertainty factor
USEPA	United States Environmental Protection Agency
µg/L	micrograms per liter
µg/g	micrograms per gram

KEYWORDS:

PFAS, threatened, endangered, ecological, RBSL, screening level

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1.0 INTRODUCTION

Per- and polyfluoroalkyl substances (PFAS) are a class of compounds with wide-ranging uses in industrial and commercial products and processes. Use of aqueous film-forming foams (AFFF) represents a known and/or potential source of PFAS contamination at many Department of Defense (DoD) sites due to frequent use of these foams during maintenance activities and fire- training drills. The PFAS-containing AFFFs were subsequently released directly to the ground or unlined pits. Additional sources of PFAS may also be present, as PFAS are used in a variety of applications (e.g., in certain paints, during chrome-plating, in photo- processing) employed at DoD sites.

PFAS do not degrade in the environment and have been measured in abiotic media as well as aquatic and terrestrial wildlife. In addition, there is concern regarding adverse health effects of PFAS in humans. Thus, their potential toxicity to ecological receptors (i.e., aquatic life, including fish and aquatic plants and invertebrates, terrestrial plants and invertebrates, and wildlife) is also a concern. However ecological risk-based screening levels (RBSLs) are unavailable for most individual PFAS. RBSLs were developed herein for aquatic life and aquatic and terrestrial wildlife. The screening levels (SLs) were developed using standard United States Environmental Protection Agency (USEPA) approaches (USEPA 2005; USEPA 2012) and were designed to be protective of threatened and endangered (T&E) species that are potentially found at DoD sites. These SLs are available for use at DoD sites to rapidly assess potential for risk to ecological receptors that may be exposed to PFAS-contaminated soils, sediments, water, and prey.

2.0 OBJECTIVES

A key component of Superfund ecological risk assessments is the evaluation of risk to T&E species. The primary purpose of this evaluation is to develop RBSLs protective of T&E species that are potentially present at DoD sites. Calculating RBSLs for aquatic life, terrestrial plants, soil invertebrates, and benthic invertebrates, requires acute and chronic toxicity data for individual PFAS. Calculating RBSLs for wildlife requires bioaccumulation factors and toxicity values for individual PFAS. Therefore, intermediate objectives of this evaluation include compiling appropriate toxicity and uptake data for individual PFAS and developing media and PFAS-specific bioaccumulation factors and toxicity values for wildlife.

3.0 TECHNICAL APPROACH

SLs were developed for aquatic life (aquatic plants, invertebrates, fish, and amphibians) terrestrial plants and soil invertebrates, and terrestrial and aquatic wildlife (birds and mammals) as outlined in **Figure ES-1** and summarized below. Appropriate toxicity data for development of SLs for reptiles and sediment SLs for benthic invertebrates and fish were not located. Although SLs for these receptors were not developed, the available toxicity information is discussed qualitatively.

For aquatic life, recommended water quality (RWQ) RBSLs were calculated for surface water following Great Lakes Initiative methodology (USEPA 2012). A comprehensive literature search was conducted to identify aquatic toxicity values, and the compiled aquatic toxicity datasets were used to calculate acute and chronic RWQ RBSLs protective of aquatic plants, aquatic invertebrates, fish, and amphibians. The available toxicity data for individual PFAS were sufficient to calculate RWQ RBSLs for perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA) using Tier I methods.

Tier II methods were used to calculate RWQ RBSLs for the other 21 individual PFAS. As noted above, PFOS and PFOA had the most robust datasets, whereas the RWQ RBSLs calculated for other PFAS are based on fewer toxicity data; therefore, they are more likely to evolve as additional toxicity information becomes available.

For terrestrial plants and soil invertebrates, RBSLs for soil were calculated following Ecological Soil Screening Level (EcoSSL) methodology (USEPA 2005). The available media-specific toxicity data (i.e., based on soil concentrations in units of milligrams per kilogram [mg/kg]) for survival, reproduction, and growth/development effects were compiled from the literature. No observed adverse effect level (NOAEL)-based SLs were calculated based on the geometric mean of available NOAEL and effective concentration at 10 percent effect (EC10) data; lowest observed adverse effect level (LOAEL)-based SLs were calculated based on the geometric mean of available LOAEL and effective concentration at 20 percent effect (EC20) data.

For wildlife (e.g., birds and mammals), RBSLs for soil, sediment, and water were also calculated following the EcoSSL methodology (USEPA 2005) based on foodweb models (**Figure ES-2**). Nine mammal and six bird representative T&E receptors were selected based on consideration of T&E species potentially present a DoD sites. The selected receptors represent a variety of feeding guilds (e.g., herbivore, invertivore, carnivore) and habitat preferences (i.e., aquatic or terrestrial).

Exposure factors were developed based on data for surrogate species considered representative of the selected receptors. T&E wildlife receptors and surrogate representatives for which SLs were developed are presented in **Table ES-1**.

Table ES-1. Selected T&E Representative and Surrogate Species

Feeding Guilds		T&E Representative Species	Representative Surrogate Species
Mammals			
Aquatic	Carnivore /Piscivore[1]	Guadalupe fur seal, Southern sea otter	Harbor Seal, River Otter, Mink
	Insectivore	Gray Bat	Little Brown Bat
	Herbivore	Point arena mountain beaver	Muskrat
Terrestrial	Carnivore	Black-footed ferret	Long-tailed weasel
	Insectivore	Northern Long-Eared Bat	Little brown bat
	Invertivore	Ornate shrew	Short-tailed shrew
	Herbivore	Amargosa vole	Meadow vole
Birds			
Terrestrial	Carnivore	Mexican spotted owl	Red-Tailed Hawk
	Insectivore	Red-cockaded woodpecker	House Wren
	Herbivore	Palila (honeycreeper)	American Goldfinch
Feeding Guilds	**T&E Representative Species**	**Representative Surrogate Species**	
Aquatic	Piscivore	California least tern	Brown Pelican
	Invertivore	Snowy plover	Tree swallow
	Omnivore	Yellow-shouldered blackbird	Red-Winged Blackbird

Note:
1. Feeding guild is inclusive of receptors with diets of crustaceans and cephalopods such as the blue whale. Harbor seal, river otter, and mink were selected as representative surrogate species. The harbor seal was considered a representative surrogate species for Guadalupe fur seal. River otters and mink were selected to model exposure for an inland aquatic piscivore or opportunistic carnivore receptor.

Additionally, uptake and toxicity data were compiled from the literature. Toxicity values were compiled for mammals and birds and incorporated into dose-based toxicity reference values (TRVs; in units of mg/kg body weight-day) following USEPA's EcoSSL methodology. TRVs were developed for nine PFAS. Bioaccumulation factors (BAFs) were identified from a targeted literature search that resulted in development of BAFs for six PFAS. Foodweb models were used to back-calculate concentrations in soil, sediment, and surface water that correspond to the NOAEL- and LOAEL-based TRVs, resulting in the wildlife RBSLs. These SLs were calculated for each medium relevant to a receptor—soil and surface water for terrestrial receptors and sediment and surface water for aquatic receptors. NOAEL RBSLs are the traditional screening tool used when evaluating risk to T&E species where the goal is to protect individuals, so no observed effects are acceptable. LOAEL-based RBSLs were also provided for each medium to allow for risk estimation at sites where protection of ecological populations (instead of individuals) is considered appropriate.

Neither appropriate dose-based toxicity data were identified for reptiles or fish, nor were toxicity data identified for benthic invertebrates exposed to sediment. SLs were not developed for these receptor-media pairs.

4.0 RESULTS AND DISCUSSION

Surface water SLs protective of aquatic life were derived for 23 individual PFAS, as summarized in **Table ES-2**.

Table ES-2. Recommended Water Quality RBSL Summary

Constituent	GLI Species Groups[1]	Tier I or Tier II Methodology	Acute RWQ RBSL (mg/L)[4]	Chronic RWQ RBSL (mg/L)[4]
PFDoA	1	Tier II	6.4E-01	7.2E-02
PFUnA	1	Tier II	4.4E-01	4.9E-02
PFDA	2	Tier II	1.2E+00	1.4E-01
PFNA	2	Tier II	1.1E+00	1.2E-01
PFOS	8	Tier I	5.7E-01	5.1E-02
PFOA	8	Tier I	5.3E+01	3.9E+00
PFHpA[2]	1	Tier II	7.8E+00	8.7E-01
PFHxA	3	Tier II	8.8E+00	2.3E+00
PFPeA[3]	2	Tier II	1.2E+00	1.4E-01
PFBS	4	Tier II	1.7E+01	3.4E+00
PFBA	2	Tier II	4.2E+00	4.7E-01
PFPrA[2]	1	Tier II	1.8E+00	2.0E-01
10:2 FTCA	1	Tier II	6.8E-04	2.0E-04
10:2 FTuCA	1	Tier II	6.4E-03	1.2E-03
8:2 FTCA	1	Tier II	6.0E-02	6.7E-03
8:2 FTuCA	2	Tier II	1.4E-01	1.5E-02
7:3 Acid	2	Tier II	3.7E-02	4.1E-03
6:2 Cl-PFESA[2]	1	Tier II	3.3E-01	6.9E-02
6:2 FTCA[3]	1	Tier II	5.7E-01	6.4E-02
6:2 FTuCA	1	Tier II	6.8E-01	7.5E-02
6:2 FTAB[2]	1	Tier II	1.5E+00	1.6E-01
5H 4:1 FTOH	1	Tier II	4.5E+00	5.0E-01
FC807[2]	1	Tier II	4.8E+00	5.4E-01

Notes:
1. The Great Lakes Initiative (GLI) species group count is the number of species groups (out of 8 possible groups) fulfilled by the dataset.

2. The GLI Tier II methodology recommends deriving a value only when a daphnia sp. toxicity value is available and a daphnia value was not identified for this PFAS.
3. The GLI Tier II methodology recommends deriving a value only when a daphnia sp. toxicity value is available and all daphnia values identified were (> or <) acute data.
4. mg/L - milligram per liter

PFDoA - perfluorododecanoic acid; PFUnA - perfluoroundecanoic acid; PFDA - perfluorodecanoic acid; ; PFNA - perfluorononanoic acid; PFOS - perfluorooctanesulfonic acid; PFOA – perfluorooctanoic acid; PFHpA – perfluoroheptanoic acid; PFHxS - perfluorohexane sulfonic acid; PFBS - perfluorobutane sulfonic acid; PFBA - pentafluorobenzoic acid; PFPrA - perfluoropropanoic acid

Soil SLs for terrestrial plants were derived for six individual PFAS, as summarized in **Table ES- 3**.

Table ES-3. Plant Screening Level Summary

Constituent	NOEC Count	LOEC Count	NOEC Soil SL (mg/kg soil)	LOEC Soil SL (mg/kg soil)
PFDA	1	0	51	NA
PFNA	1	0	46	NA
PFOS[1]	6	7	11	33
PFOA[2]	8	14	0.084	0.84
PFBA	1	0	642	NA
5H 4:1 FTOH	1	0	23	NA

Notes:

1. NOEC count for PFOS includes only bounded NOECs.
2. NOEC count for PFOA includes only bounded NOECs and EC10 values.

EC10 – effect concentration affecting 10 percent of the population; LOEC - lowest-observed effect concentration; mg/kg – milligrams per kilogram; NA – not applicable; NOEC – no-observed effect concentration; SL – screening level

Soil SLs for soil invertebrates were derived for six individual PFAS, as summarized in **Table ES-4**.

Table ES-4. Soil Invertebrate Screening Level Summary

Constituent	NOEC Count	LOEC Count	NOEC Soil SL (mg/kg soil)	LOEC Soil SL (mg/kg soil)
PFNA[1]	1	1	1	100
PFOS[1,2]	1	1	7.7	141
PFOA[1,2]	1	0	50	NA
PFHpA[1]	1	1	1	100
PFHxS[1]	1	1	1	100
PFBS[1,2]	1	0	10	NA

Notes:

1. PFNA, PFOS, PFHpA, and PFHxS soil SLs are based on a single paired no observed effect concentration (NOEC) and lowest observed effect concentration (LOEC) (Table 2b). The PFOA and PFBS soil SLs are based on a single unbounded NOEC (Table 2b). Although all are based on survival, a UF (uncertainty factor) was not applied to the PFNA, PFHpA, and PFHxS NOEC SLs as the NOEC is already two orders of magnitude lower than the LOEC.
2. A UF of 10 was applied to the PFOS NOEC of 77 mg/kg as it was less than an order of magnitude lower than the LOEC of 141 mg/kg. The PFOA and PFBS NOEC soil SLs are based on an unbounded NOEC with a survival endpoint. Based on this uncertainty, a UF of 10 was applied to calculate the final PFOA and PFBS SLs.

LOEC - lowest-observed effect concentration; mg/kg – milligrams per kilogram; NOEC – no-observed effect concentration; SL – screening level

Soil and surface water SLs for terrestrial wildlife and sediment and surface water SLs for aquatic wildlife were derived for the six individual PFAS for which both TRVs and BAFs were available. For each wildlife receptor, these RBSLs were derived for protection at both the NOAEL level, appropriate for evaluation of individual T&E species, and the LOAEL level, appropriate for evaluation of ecological populations. The values are presented for aquatic wildlife receptors in **Table ES-5**; terrestrial values are presented in **Table ES-6**.

Table ES-5. Aquatic Risk-Based Screening Level Summary for Wildlife

Habitat			**Aquatic RBSL**						
Feeding Guild		**Herbivore**	**Insectivore**	**Carnivore**	**Carnivore**	**Carnivore**	**Omnivore**	**Invertivore**	**Piscivore**
Receptor		**Muskrat**	**Little Brown Bat**	**River Otter**	**Harbor Seal**	**Mink**	**Red-Winged Blackbird**	**Tree Swallow**	**Brown Pelican**
Constituent	**Units**								
	NOAEL-based RBSLs								
Sediment									
PFNA	mg/kg	3.6E+00	1.0E-02	2.4E-01	2.0E-01	2.5E-01	NA	NA	NA
PFOS	mg/kg	2.3E-02	5.3E-03	4.7E-02	4.6E-02	3.8E-02	7.0E-03	1.4E-03	1.4E-02
PFOA	mg/kg	1.2E+00	6.0E-03	2.8E-01	1.9E-01	4.0E-01	NA	NA	NA
PFHxA	mg/kg	2.4E+02	1.8E+00	2.9E+01	2.6E+01	2.5E+01	NA	NA	NA
PFBS	mg/kg	3.7E+02	1.1E+00	1.8E+01	1.6E+01	1.5E+01	2.4E+01	7.3E-01	1.3E+01
PFBA	mg/kg	1.6E+02	1.6E+00	2.6E+01	2.3E+01	2.2E+01	NA	NA	NA
Surface Water									
PFNA	mg/L	2.2E-03	4.7E-03	9.2E-03	9.7E-03	6.8E-03	NA	NA	NA
PFOS	mg/L	1.1E-03	3.6E-04	2.8E-04	3.1E-04	2.1E-04	3.4E-04	9.1E-05	7.5E-05
PFOA	mg/L	1.8E-02	4.4E-03	1.2E-02	1.3E-02	9.4E-03	NA	NA	NA
PFHxA	mg/L	6.1E+00	2.1E-01	6.4E+00	5.0E+00	6.9E+00	NA	NA	NA
PFBS	mg/L	7.6E+01	9.4E-01	2.0E+00	2.1E+00	1.5E+00	1.7E+01	6.4E-01	1.3E+00
PFBA	mg/L	4.9E+01	1.4E+00	8.6E-01	9.3E-01	6.6E-01	NA	NA	NA
	LOAEL-based RBSLs								
Sediment									
PFNA	mg/kg	4.7E+00	1.3E-02	3.2E-01	2.7E-01	3.3E-01	NA	NA	NA
PFOS	mg/kg	3.8E-02	8.8E-03	7.7E-02	7.7E-02	6.3E-02	7.0E-02	1.4E-02	1.4E-01
PFOA	mg/kg	2.3E+00	1.2E-02	5.7E-01	3.9E-01	8.0E-01	NA	NA	NA
PFHxA	mg/kg	5.1E+02	3.8E+00	6.1E+01	5.5E+01	5.3E+01	NA	NA	NA
PFBS	mg/kg	1.5E+03	4.3E+00	7.0E+01	6.3E+01	6.0E+01	4.0E+01	1.2E+00	2.2E+01
PFBA	mg/kg	3.8E+02	3.8E+00	6.1E+01	5.5E+01	5.3E+01	NA	NA	NA
Surface Water									
PFNA	mg/L	2.9E-03	6.3E-03	1.2E-02	1.3E-02	9.0E-03	NA	NA	NA
PFOS	mg/L	1.8E-03	6.0E-04	4.7E-04	5.1E-04	3.6E-04	3.4E-03	9.1E-04	7.5E-04
PFOA	mg/L	3.6E-02	8.9E-03	2.4E-02	2.6E-02	1.9E-02	NA	NA	NA
PFHxA	mg/L	1.3E+01	4.4E-01	1.3E+01	1.0E+01	1.4E+01	NA	NA	NA
PFBS	mg/L	3.0E+02	3.8E+00	8.0E+00	8.5E+00	6.0E+00	2.9E+01	1.1E+00	2.1E+00
PFBA	mg/L	1.2E+02	3.3E+00	2.1E+00	2.2E+00	1.6E+00	NA	NA	NA

Notes: LOAEL - lowest-observed adverse effect level; mg/kg – milligrams per kilogram; mg/L – milligrams per liter; NA – not available; NOAEL – no-observed adverse effect level; RBSL – risk-based screening level; Gray shading indicates the minimum SL for each PFAS.

Table ES-6. Terrestrial Risk-Based Screening Level Summary for Wildlife

Habitat		Terrestrial RBSL						
Feeding Guild		Herbivore	Invertivore	Insectivore	Carnivore	Herbivore	Insectivore	Carnivore
Receptor		Meadow Vole	Short-Tailed Shrew	Little Brown Bat	Long-Tailed Weasel	American Goldfinch	House Wren	Red-Tailed Hawk
Constituent	Units							
NOAEL-based RBSLs								
Soil								
PFNA	mg/kg	2.3E+00	1.5E+00	1.0E+00	1.5E+00	NA	NA	NA
PFOS	mg/kg	3.1E-01	4.8E-02	3.0E-02	1.7E-01	3.8E-01	1.3E-02	8.7E-02
PFOA	mg/kg	5.8E+00	1.3E+00	8.4E-01	5.7E-01	NA	NA	NA
PFHxA	mg/kg	1.2E+02	3.4E+02	2.5E+02	1.6E+02	NA	NA	NA
PFBS	mg/kg	3.8E+01	1.4E+01	9.1E+00	7.8E+01	8.9E+01	9.3E+00	1.0E+02
PFBA	mg/kg	2.9E+01	7.8E+01	5.8E+01	1.3E+02	NA	NA	NA
Surface Water								
PFNA	mg/L	6.0E+00	5.6E+00	5.2E+00	7.2E+00	NA	NA	NA
PFOS	mg/L	7.3E-01	6.7E-01	6.3E-01	8.6E-01	3.2E-01	3.0E-01	1.4E+00
PFOA	mg/L	2.2E+00	2.0E+00	1.9E+00	2.6E+00	NA	NA	NA
PFHxA	mg/L	6.1E+02	5.6E+02	5.3E+02	7.2E+02	NA	NA	NA
PFBS	mg/L	3.6E+02	3.4E+02	3.2E+02	4.3E+02	3.7E+02	3.5E+02	1.6E+03
PFBA	mg/L	5.3E+02	4.9E+02	4.6E+02	6.3E+02	NA	NA	NA
LOAEL-based RBSLs								
Soil								
PFNA	mg/kg	3.0E+00	2.0E+00	1.3E+00	2.0E+00	NA	NA	NA
PFOS	mg/kg	5.1E-01	7.9E-02	5.0E-02	2.8E-01	3.8E+00	1.3E-01	8.7E-01
PFOA	mg/kg	1.2E+01	2.6E+00	1.7E+00	1.1E+00	NA	NA	NA
PFHxA	mg/kg	2.6E+02	7.0E+02	5.3E+02	3.3E+02	NA	NA	NA
PFBS	mg/kg	1.5E+02	5.7E+01	3.6E+01	3.1E+02	1.5E+02	1.5E+01	1.7E+02
PFBA	mg/kg	7.0E+01	1.9E+02	1.4E+02	3.2E+02	NA	NA	NA
Surface Water								
PFNA	mg/L	8.0E+00	7.4E+00	6.9E+00	9.5E+00	NA	NA	NA
PFOS	mg/L	1.2E+00	1.1E+00	1.0E+00	1.4E+00	3.2E+00	3.0E+00	1.4E+01
PFOA	mg/L	4.4E+00	4.0E+00	3.8E+00	5.2E+00	NA	NA	NA
PFHxA	mg/L	1.3E+03	1.2E+03	1.1E+03	1.5E+03	NA	NA	NA
PFBS	mg/L	1.5E+03	1.3E+03	1.3E+03	1.7E+03	6.2E+02	5.8E+02	2.7E+03
PFBA	mg/L	1.3E+03	1.2E+03	1.1E+03	1.5E+03	NA	NA	NA

Notes: LOAEL - lowest-observed adverse effect level; mg/kg – milligrams per kilogram; mg/L – milligrams per liter; NA – not available; NOAEL – no-observed adverse effect level; RBSL – risk-based screening level; Gray shading indicates the minimum SL for each PFAS.

The soil NOAEL-based RBSLs range from 0.013 mg/kg (PFOS) to 340 mg/kg (pentafluorobenzoic acid [PFHxA]). Sediment NOAEL-based RBSLs range from 0.00143 mg/kg (PFOS) to 370 mg/kg (perfluorobutane sulfonic acid [PFBS]). Aquatic receptor surface water NOAEL-based RBSLs had the greatest range of 0.000075 milligrams per liter (mg/L) (PFOS) to 76 mg/L (PFBS).

The majority of minimum NOAEL-based RBSLs for each PFAS are based on invertivore or insectivore receptors, such as the little brown bat, tree swallow, and house wren. The lowest soil NOAEL-based RBSL is associated with the house wren and the lowest sediment NOAEL-based RBSL is associated with the tree swallow. Terrestrial receptors tended to have higher relative RBSLs, as might be expected due to generally lower potential for uptake from dietary sources.

Uncertainties in the calculated SLs for aquatic life, terrestrial plants and soil invertebrates, and wildlife are related primarily to the limited data available for individual PFAS and species. As a result, there is higher confidence in the SLs calculated herein for PFAS and receptors with relatively robust datasets (e.g., PFOS and PFOA RWQ RBSLs and mammalian RBSLs) than for those SLs for PFAS and receptors based on smaller toxicity datasets (e.g., soil invertebrate SLs and bird RBSLs).

5.0 IMPLICATIONS FOR FUTURE RESEARCH AND BENEFITS

The SLs calculated in this evaluation provide default SLs for Superfund risk assessments at DoD sites. Prior to this effort, it was difficult to correlate PFAS measured in soil, sediment, or surface water with potential for risk to wildlife (and specifically for the T&E species evaluated). The NOAEL and LOAEL wildlife RBSLs presented in this evaluation bracket possible ecological risk and allow for consistency in risk assessments conducted at DoD sites. The approaches used herein to calculate screening levels were derived with the goal of producing conservative values that are expected to be protective of ecological receptors. The RWQ RBSLs, plant and invertebrate soil SLs, and wildlife RBSLs for surface water, sediment, and soil—in combination—cover each environmental medium that would be sampled in an ecological risk assessment and allow for rapid evaluation of potential risk via a variety of possible exposure pathways. Additionally, the input parameters in the assessment, such as dietary composition of receptors or BAFs, may be adjusted to be site-specific in future risk assessments and/or updated as additional data become available.

Soil RBSLs for reptiles, sediment RBSLs for fish, and sediment SLs for benthic invertebrates could not be developed in this evaluation as there were no available or insufficient laboratory toxicity data available for these receptors and exposure pathways. Development of appropriate toxicity data and subsequent RBSLs and SLs are potential areas of additional future work. Exposure assumptions for the wildlife receptors were evaluated but may not be sufficiently conservative for an upper trophic level predator and a biomagnifying PFAS.

5.1 IMPLICATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

A significant data gap in this evaluation is the lack of data on bioaccumulation and toxicity of most PFAS. The majority of relevant papers included in the evaluation studied effects of PFOS and PFOA. While this provides greater confidence in the PFOS and PFOA aquatic and terrestrial screening values, the SLs developed for the remaining PFAS are based on limited data and are more likely to be updated as new literature becomes available.

Use of surrogate BAFs based on assumptions of structural similarity introduces uncertainty in the evaluation. Additional PFAS bioaccumulation research, particularly for polyfluorinated substances and newer replacement compounds would enable more informed selection of BAFs, biota sediment accumulation factors (BSAFs), or surrogate values for each PFAS. Availability of BAFs among the full range of dietary groups was also limited. The soil to small mammal BAF is restricted to PFOS and was converted to a whole body BAF using additional calculations to account for organ weights and partitioning as described in Section 3.3.3. This BAF was then applied to all PFAS as the soil to small mammal BAF. Amphibian BSAFs, aerial insect BAFs and BSAFs, and terrestrial reptile BAFs were not identified, requiring use of surrogate BAFs from a similar dietary group.

Field studies sampling these biota and soil and sediment concentrations in known areas of PFAS release would provide valuable new information to the RBSL exposure assumptions.

No benthic invertebrate or reptile toxicity studies were identified, and no relevant dose-based toxicity data were located for fish. Bird toxicity studies were identified for only PFOS and PFBS and were all conducted by the same laboratory on two test species. These species groups represent areas for continuing research.

The potential for PFAS toxicity to be additive among all or a subset of PFAS with similar structures is a current area of scientific research. Existing state and federal human health advisory levels recommend screening criteria be applied to the sum of specific PFAS. For example, the USEPA PFOS and PFOA Health Advisory Levels are individually 70 parts per trillion and well as 70 parts per trillion for the sum of PFOS and PFOA (USEPA 2016c; USEPA 2016d). There is precedent for evaluation of chemicals additively in an ecological risk assessment. Consideration of additive ecological risk among a class of chemicals is currently common practice for some classes of chemicals (e.g., polycyclic aromatic hydrocarbons and some organochlorine pesticides). However, additive toxicity of PFAS in wildlife is considered insufficiently characterized to be assessed or included in this evaluation. Furthermore, additivity of PFAS in wildlife may vary between species. A deeper understanding of the mechanisms of PFAS toxicity in various species is required in order to estimate additivity.

6.0 REFERENCES

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