Document 1

From: s 22(1)(a)(ii)
To: s 22(1)(a)(ii)
Cc: s 22(1)(a)(ii)
Subject: FW: Letter [SEC=PROTECTED, DLM=Sensitive:Cabinet]
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s 22(1)(a)(ii) – is this one filed as well?

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Subject: Letter [SEC=PROTECTED, DLM=Sensitive:Cabinet]

PROTECTED Sensitive:Cabinet

Very rough draft, but here you go.

s 22(1)(a)(ii)

Director – Policy
PFAS Investigation & Management Branch
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Dear Prime Minister

I am writing to you to provide an overview of the Department of Defence's (Defence) national Environmental Investigation Program to manage the impacts of the legacy use of aqueous film forming foam (AFFF) containing per- and poly-fluoroalkyl substances (PFAS) on, and in the vicinity of, a number of Defence establishments. [Insert language about submission] The following is an outline of Defence's actions to date and planned activities moving forward.

Defence's Environmental Investigation Program is arguably the largest suite of environmental investigations ever conducted in Australia, currently encompassing 23 properties. Investigations are now [almost] complete at RAAF Base Williamtown and the Army Aviation Centre Oakey and these properties will soon transition from the investigation to the next, strategic management phase. Investigations are well advanced at several other sites and at the remaining sites investigations have been underway for three to six months or more.

The environmental investigations have provided considerable information on the human health, ecological and environmental impacts of PFAS and how those impacts can best be mitigated. We have been actively using the knowledge and experience gained from the more mature investigations over the last few years, including the extent of PFAS contamination and possible exposure pathways at each site, to develop and implement a range of remediation solutions. Current efforts have been focussed on treating contaminated water because water is the primary way that PFAS moves in the environment and water treatment technologies are able to deliver the outcomes that Defence requires.

Defence is conducting its investigations using an evidence-based approach, in line with the nationally consistent framework outlined in the *National Environment Protection (Assessment of Site Contamination) Measure 1999* (ASC NEPM). Defence's investigations will also be governed by broader Commonwealth and national approaches being developed, including the proposed PFAS National Environmental Management Plan (PFAS NEMP) and the Intergovernmental Agreement on a National Framework for responding to PFAS Contamination (IGA). Direct ingestion of contaminated drinking water is the major PFAS human exposure pathway. The Department of Health has provided health based guidance values for drinking water and recreational water quality to safeguard public health by assisting the community in identifying and minimising their exposure to PFAS. Defence uses the guidance values in site investigations and for conducting Human Health Risk Assessments.

Defence has adopted a precautionary approach to the provision of drinking water associated with PFAS investigations. Immediately upon the announcement of an investigation site, where no formal investigation area has been identified and no preliminary testing has occurred to provide a scientific basis for decision-making, Defence provides alternative drinking water to residents who are not connected to town water and who rely on bore water for drinking purposes. Each household's drinking water requirements are assessed on a case-by-case basis to determine the most appropriate water supply arrangements that Defence may be able to provide. In most cases bottled or cask water is supplied as a first response. Defence has also refilled rainwater tanks that contain, or have in the past contained, bore water, replaced concrete tanks that cannot be cleaned and provided new rainwater tanks to residents, particularly in Katherine.

In order to provide more sustainable drinking water assistance to residents in the Williamtown and Oakey investigation areas, Defence has funded Hunter Water Corporation and Toowoomba Regional Council respectively to connect around 230 properties to town water. This has included the installation of new water mains infrastructure and plumbing connections from the water mains to private properties. When all connections have been established, residents in both areas will have access to high-quality drinking water and the continued provision of bottled water or rainwater tank refills will cease.

Defence has engaged an environmental company in the United States to provide state-of-the-art water treatment plants that use a specialised synthetic substance to filter PFAS from water. Demonstration plants have been installed at Williamtown and Oakey and another plant will be [has been] installed at the Katherine Power and Water Corporation facility to mitigate the impact of PFAS in the groundwater which is mixed with Katherine river water for the town water supply.

Over recent years Defence has undertaken extensive onsite open drain excavation and containment works at Williamtown and Oakey. This involves excavating the sediment from open drains on base to reduce the migration of PFAS contamination to both surface and groundwater. The material removed is being safely disposed offsite in accordance with relevant guidelines. PFAS is also being removed from source areas with elevated levels of PFAS, such as the disused Fire Training Area at Williamtown. Contaminated soil is contained on base in an appropriately designed stockpile as prepared in the open drain excavation works, to be later treated with appropriate technology when available, prior to offsite disposal or amelioration and reuse.

Defence is also examining a range of other technologies to remediate contaminated water, some of which are showing promise but there is considerable work still to be done. Remediating contaminated soil is proving more challenging. Defence has received around 70 proposals from industry and research organisations and will continue to work with industry experts in Australia and abroad to find ways to manage and contain PFAS. The recently announced PFAS Remediation Research Program, which will be administered by the Australian Research Council, will support the development of innovative technologies to investigate and remediate PFAS contaminated areas, including soil and other solid contaminated debris, groundwater, waterways and marine systems.

In addition to management and remediation measures, Defence continues its work to inform residents about how PFAS contamination may impact their lifestyles and/or the local environment. Defence holds regular community consultation and “walk-in” sessions and has appointed dedicated personnel as Senior Defence Liaison Officers to act as points of contact in communities where environmental investigations are most advanced.

In recognition of the uncertainty and anxiety which the environmental investigations are creating in some affected communities, Defence has also worked closely with the Department of Human Services to identify appropriately qualified and trained Community Liaison Officers to provide residents with access to counselling and other support services. Appointed initially in Oakey and Williamtown, CLOs have more recently been embedded at RAAF Base Tindal in Katherine and at RAAF Base Edinburgh in South Australia. The “wellness” program of community-driven activities and services being offered to Oakey residents, in particular, has been very well received and offers a model for this type of community support. Defence will continue to look for opportunities to expand the network of CLOs for other affected communities as necessary.

s 34(3) [redacted]

Defence currently makes a significant contribution to the communities of Williamtown and Oakey through the operations of the Army Aviation Centre Oakey and RAAF Base Williamtown. Infrastructure investment at RAAF Base Williamtown in the period 2017-20 will deliver approximately $670m in facilities upgrades. This includes facilities in support of the New Air Combat Capability (AIR 6000) and the Base Redevelopment. Defence expenditure at the Army Aviation Centre Oakey over the same period is estimated to total over $160m. This includes an upgrade of facilities to support the growth of the Republic of Singapore Air Force (RSAF) contingent based at Oakey. A summary of approved planned Defence infrastructure investment at RAAF Base Williamtown and the Army Aviation Centre Oakey between 2017 and 2020 is at Attachment A.

In addition to infrastructure investment, the capability operating at these bases require sustainment and the properties and infrastructure require servicing and maintenance. Defence expenditure at the Army Aviation Centre Oakey to support these capabilities is $Xm over the Financial Years 2017-2019 and at Williamtown is in excess of $452m. A summary of sustainment contracts in place at the Army Aviation Centre Oakey and RAAF Base Williamtown is at Attachment B. Defence's future force disposition and capability requirements are further detailed in the Defence White Paper and the Integrated Investment Program.

In addition to the considerable and ongoing investments that are made at these bases, including in infrastructure and the capability that operates from them, the Defence presence supports the economies of these areas through employment and procurement opportunities, support for local businesses and as a catalyst for improved infrastructure spending. For example, the current rotation of 25 RSAF personnel at Oakey is expected to increase to about 300 in 2018. This growth will provide a significant injection of additional disposable income to the local economy.

I have copied this letter to the Minister for Finance, Senator the Hon Mathias Cormann, the Minister for Infrastructure and Transport, the Hon Darren Chester MP, and the Assistant Minister to the Prime Minister, Senator the Hon James McGrath.

Yours sincerely

MARISE PAYNE

Summary: possible health effects of per- and poly-fluoroalkyl substances (PFAS)

- The scientific community is uncertain about the potential effects on people living in contaminated areas. More research is being done now and our understanding of any possible health effects of PFAS exposure will grow.
- Most research into the health effects of PFAS is relatively recent. Most studies have looked at effects on animals (who can respond differently to humans) or in people who have had extremely high exposure through working for manufacturers of PFAS-containing products.
- As PFAS are known to be persistent and bioaccmulative in the environment, governments globally are recommending a precautionary approach to their management—advising to reduce use and exposure as far as practicable.

Human studies

- There is a lack of scientific data to date, particularly with people. Research has found an 'association' between PFOS exposure with increased cholesterol and triglycerides, and changes in thyroid hormones. An association between PFOA exposure in pregnant women and reduced birth weight has also been found. However, these studies have not determined whether it is PFAS or another factor that causes the changes.
    - To date, there is no proven causal relationship between PFAS exposure and adverse human health effects.
- Blood levels of PFAS in PFAS factory workers have been found to be 100 – 1 000 times higher than the general population. There is still no conclusive evidence of exposure to PFAS causing illness in humans.
- After exposure, it takes about 3.8 years for perfluorooctanoic acid (PFOA) and 5.4 years for perfluorooctane sulfonate (PFOS) for half of the chemical to be excreted from the body.

Animal studies

- Studies in animals and cultured cells show various toxicities for PFAS. These can be alarming for the public to read, and determining the relevance of these findings to humans is complex.
- PFOS and PFOA are readily absorbed after ingestion, and are mainly stored in the liver, lungs, kidneys and blood. They also cross the protective brain and placenta membrane barriers.
- PFOS or PFOA are not converted into anything else in the body (not metabolised) and are eliminated mainly in the urine. Elimination takes days for animals compared to years for humans.
- PFOS and PFOA do not damage DNA (are non-genotoxic) in animal and cultured cell studies.
- Studies observing liver tumours in animals suggest that both PFOS and PFOA may be carcinogenic (have potential to cause cancer) with prolonged exposure to high levels.
- For hormones, animal studies showed PFOS can increase oestradiol, change thyroid hormone levels, and increase noradrenaline in the brain. PFOA decreased testosterone levels.
- PFOS interferes with the metabolism of fatty acids, lipids and lipoproteins, which can disrupt normal cell transport and communication systems in animal and cultured cell studies.
- PFOS and PFOA adversely impacted immune system responsiveness, but varying results were seen at different doses in some animal studies and more immunotoxicity research is needed.
- PFOS and PFOA caused reproductive and developmental toxicity in animal studies. However, the underlying mechanism for this toxicity remains unclear.

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Document 3

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Per- and polyfluoroalkyl substances (PFAS) in American Red Cross adult blood donors, 2000–2015☆

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ABSTRACT

In 2015, thirteen per- and polyfluoroalkyl substances (PFAS), including perfluorohexanesulfonate (PFHxS), perfluorooctanesulfonate (PFOS), perfluorooctanoate (PFOA), perfluorononanoate (PFNA), and perfluorodecanoate (PFDA) were analyzed in human plasma that were collected from a total of 616 American Red Cross male and female blood donors (ages 20–69) at 6 regional blood collection centers. Plasma samples were analyzed using a validated solvent precipitation-isotope dilution direction-liquid chromatography tandem mass spectrometry method. The data were analyzed in conjunction with prior cross-sectional investigations [2000–2001 (n =645), 2006 (n =600), and 2010 (n =600)] to determine PFAS trends. Age- and sex-adjusted geometric mean serum (2000–2001) and plasma (2006, 2010, 2015) concentrations (ng/mL) were, respectively: PFHxS (2.3, 1.5, 1.3, 0.9); PFOS (35.1, 14.5, 8.4, 4.3); PFOA (4.7, 3.4, 2.4, 1.1); PFNA (0.6, 1.0, 0.8, 0.4); and PFDA (0.2, 0.3, 0.3, 0.1). The percentage decline in these geometric mean concentrations from 2000–2001 to 2015 were: PFHxS (61%); PFOS (88%); PFOA (77%); PFNA (33%); and PFDA (50%). The results indicate a continued decline of PFHxS, PFOS, and PFOA concentrations in American Red Cross blood donors. For the remaining PFAS measured in 2015, including the shorter chain perfluoroalkyls perfluorobutanesulfonate (PFBS) and perfluorohexanoate (PFHxA), the majority of samples were below the lower limit of quantitation.

1. Introduction

Per and polyfluoroalkyl substances (PFAS) and surfactants and polymers made with the aid of PFAS have been widely used in industrial and commercial applications (Buck et al., 2011). There have been two main PFAS production processes: electrochemical fluorination and telomerization. Polyfluoroalkyls have the potential to be transformed under abiotic or biotic conditions to perfluoroalkyls. PFAS are chemically and thermally stable compounds because of their strong C–F bonds. The perfluoroalkyl (C_nF_{2n+1}) moiety provides hydrophobic and lipophobic properties. Perfluoroalkyl carboxylic acids with 7 or more perfluorinated carbons and perfluoroalkane sulfonates with 6 or more perfluorinated carbons are considered to be 'long chain' perfluoroalkyls. Perfluorooctanesulfonate (PFOS, $C_8F_{17}SO_3$) and perfluorooctanoate (PFOA, $C_7F_{15}CO_2$) are the most frequently reported and highest PFAS concentrations measured in the blood (serum/plasma) of the general population.

PFAS commercial use has included stain and soil repellant applications for fabrics, carpets, and leather and for grease proof food contact paper (Buck et al., 2011; Butenhoff et al., 2006). Surfactant applications also included fluoropolymer processing aids (e.g., ammonium perfluorooctanoate used in polytetrafluoroethylene (PTFE) production), aqu

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☆ The American Red Cross financially supported the collection and shipment of the samples from each blood collection center. 3M financially supported the laboratory analyses of the samples and Dr. Church for the statistical analysis of the data.The American Red Cross Biomedical Services Institutional Review Board approved this study.

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eous film forming foams (AFFF) used to extinguish major hydrocarbon fires, acid mist suppression in metal plating, incorporation in hydraulic fluids used in aviation, chemically driven oil production, and photolithographic use in the semiconductor industry.

Human exposure to PFAS may occur via direct and indirect sources including food, drinking water, consumer products, household dust, and ambient air (D'eon and Mabury, 2011). Human exposure to PFOS or PFOA through one or more exposure pathways is considered direct exposure. Indirect refers to exposure to one of their precursors with subsequent biotransformation to PFOS or PFOA.

In 2000, a major U.S. manufacturer (3M Company) announced a voluntary phase out of PFOS and PFOS related products as well as other long chain PFAS including PFOA and perfluorohexanesulfonate (PFHxS) because analytical capabilities showed these persistent compounds could be detected at low levels in the environment and in humans (Butenhoff et al., 2006). In 2006, the United States Environmental Protection Agency (EPA) announced a Product Stewardship agreement with 8 global manufacturing companies who pledged to reduce PFOA emissions and product content by 95% in 2010 and work towards its elimination by 2015 (US EPA, 2006). Other important global regulatory activities occurred in Canada (Environment Canada, 2011) and Europe (European Parliament Directive, 2006). PFOS was listed as a persistent organic pollutant (Annex B) by the Stockholm Convention (2009). The reporting of the widespread presence and persistence of PFAS in the environment has now resulted in more than 3000 environmental and health related publications since the year 2000 (Lau, 2014) including Hansen et al.'s novel method to measure perfluorinated compounds, PFOS, perfluorooctanesulfonamide (FOSA), PFHxS, and PFOA at low (ng/mL) levels by using tissue (serum) extract with high performance liquid chromatography negative ion electrospray tandem mass spectrometry (Hansen et al., 2001).

The measurement of PFAS and their trends on a cross sectional basis became the focus of two research investigations in the United States. In 2003, Olsen et al. (2003) initially reported concentrations of 7 PFAS in 645 American Red Cross adult blood donors (ages 20 69). These donors' bloods (sera) were collected in 2000 2001. In 2007, Calafat et al. (2007) reported on 8 PFAS serum measurements from archived blood samples that were collected in 1999 2000 from the much larger Centers for Disease Control and Prevention (CDC) National Health and Nutrition Examination Survey (NHANES). Olsen et al. (2007a) then reported a preliminary study of 40 American Red Cross adult blood donors from Minneapolis St. Paul, whose blood was collected in 2006, to suggest a decline in serum PFOS after the phase out as well the study by Spliethoff et al. (2008) analyzing 110 blood spot composites from infants (n =2640) born in New York state. These preliminary observations were later confirmed by the American Red Cross (Olsen et al., 2008, 2011, 2012) and the NHANES (Kato et al., 2011; CDC, 2017) PFAS biomonitoring studies.

Whereas only NHANES is a nationally representative sample of the U.S. general population, the American Red Cross study does offer, unlike NHANES, regional analyses based on the same six blood collection centers since the study's inception in 2000 2001. The purpose of this updated American Red Cross study was to extend these regional trend analyses through blood collected in 2015 for 13 PFAS compounds, including PFHxS, PFOS, and PFOA.

2. Materials and methods

2.1. Sample collection

In 2015, six American Red Cross blood centers collected a total of 616 plasma samples for analysis of 13 PFAS concentrations. Blood was obtained during June August 2015. Five locations (Boston, Massachusetts; Hagerstown, Maryland; Los Angeles, California; Minneapolis St. Paul, Minnesota; and Portland, Oregon) provided 10 samples per every 10 year age interval (20 29, 30 39, 40 49, 50 59, and 60 69) for each sex. The sixth location (Charlotte, North Carolina) provided 116 samples (12 samples per every 10 year age and sex interval). The only available demographic factors were age, sex, and location. Samples were similarly collected from the same six locations (but different donors) in 2000 2001 (n =645 serum samples), 2006 (n =600 plasma samples), and 2010 (n =600 plasma samples). Plasma and serum matrices provide comparable PFAS results (Ehresman et al., 2007). The American Red Cross Biomedical Services Institutional Review Board approved this study.

2.2. Laboratory assay

The samples from 2006, 2010, and 2015 were analyzed at the 3M Environmental Laboratory. Tandem Labs (Salt Lake City, UT), under the direction and validation procedures of the 3M Environmental Laboratory, analyzed samples collected in 2000 2001.

2.3. Experimental analytical

Samples were prepared and analyzed for the target analytes: PFBS (pefluorobutanesulfonate), PFHxS (perfluorohexanesulfonate), PFOS (perfluorooctanesulfonate), EtFOSAA (*N* ethyl perfluorooctanesulfonamidoacetate), MeFOSAA (*N* methyl perfluorooctanesulfonamidoacetate), FOSA (perfluorooctanesulfonamide),PFHxA (perfluorohexanoate), PFHpA (perfluoroheptanoate), PFOA (perfluorooctanoate), PFNA (perfluorononanoate), PFDA (perfluorodecanoate), PFUnA (perfluoroundecanoate), and PFDoA (perfluorododecanoate). These compounds and their respective stable isotope labeled isomer standards (ISs) and surrogate recovery standards (SRSs) are also listed in supplemental file Table S1. The analytical laboratory was blinded to the identities of all samples during analysis. Results were determined for 616 adult donor samples collected in 2015. Additionally, there were 120 laboratory blinded samples used for quality assurance purposes: 60 randomly selected 2015 duplicate splits and 60 nonrandomly selected archived (−80 °C) samples whose selection was based on a distribution of prior concentrations measured and sample volumes that remained in the archived tubes from the previous years (2000 2001 (n =20), 2006 (n =20) and 2010 (n =20)) for a total of 736 samples analyzed in this study. The validated analytical test method employing protein precipitation extraction and quantitation by liquid chromatography tandem mass spectrometry (LC MS/MS) used for analysis of the 2015 American Red Cross study samples has been previously described (Harrington et al., 2017). The analytical test method and quality control data for the study are in the Supplemental File.

2.4. Data quality

The American Red Cross sample specific SRS recoveries for all study samples provided a measure of sample specific accuracy and precision that compared well with the target analyte and SRS recoveries from control human plasma QCs, as shown in the supplemental file (Table S2). Excellent average method accuracy (100% ± 7%) and precision (RSD < 15%) were demonstrated in control human plasma for the perfluorinated carboxylates and perfluorinated sulfonates, FOSA, and the SRSs. EtFOSAA and MeFOSAA had average accuracies of 83.9% and 83.8%, respectively. The data mean accuracy and precision for SRS recoveries for the 736 analyzed samples were 89.0% (8.8% Relative Standard Deviation (RSD)) for [1,2,3,4 $^{13}\mathrm{C}_4$]PFOA, 91.8% (10% RSD) for [1,2 $^{13}\mathrm{C}_2$]PFUnA, and 89.4% (7.9% RSD) for [1,2,3,4 $^{13}\mathrm{C}_4$]PFOS (Table S2).

2.5. Isomer quantification

While differences in relative response factors for branched and linear PFOS isomers have been observed for selected matrices or due to instrumentation conditions (Berger et al., 2011; Riddell et al., 2009), the levels of linear and branched isomers can be inferred from visual observations of the LC MS/MS chromatographic data when the proper instrument conditions are used. The PFOS isomer composition in the American Red Cross study samples was not characterized for each individual possible isomer, however, chromatographic results visibly indicated separation of branched isomer peaks from the linear isomer and analysis results suggested enrichment of the branched isomers for PFOS in several samples at $\geq$ 50% branched isomer content relative to the branched isomer content of reference substance brPFOS at ~30% (w/w). In contrast, the PFOA in the blood samples was observable as mostly linear isomer ($< 5\%$ branched). The quantitation of fortified mixed linear and branched reference materials in human plasma QCs, as brPFOS (30% branched) at 10 and 40 ng/mL, and brPFHxS (19% branched) and brPFOA (5% branched) at 2.5 and 10 ng/mL, demonstrated average recoveries for brPFOS, brPFHxS and brPFOA at 101%, 87.8% and 102%, respectively.

2.6. NIST SRM 1957 ANalysis Results

The National Institutes of Standards and Technology (NIST) standard reference material (SRM) 1957 (Keller et al., 2010) results are shown in the supplemental file (Table S3). The average results from the SRM 1957 analysis showed good agreement based on relative percent difference (RPD) of determined values compared to the SRM 1957 reference values for PFOS (RPD 6.9%), PFHxS (RPD 21.7%), PFOA (RPD 20.7%) and PFNA (RPD 23.9%). Lower agreement was observed for PFHpA, PFDA and PFUnA with RPDs of 41.3%, 58.6%, and 63.9%, respectively. SRSs fortified into the SRM recovered at 86.5%, 94.6% and 90.8% for $^{13}C_4$ PFOA, $^{13}C_2$ PFUnA and $^{13}C_4$ PFOS, respectively. Lower agreement for PFHpA, PFDA and PFUnA could be caused by higher variance in results for those lower concentration analytes in SRM 1957 compared to less variance for the higher level PFOS, PFHxS, PFOA and PFNA.

2.7. Data analysis

Measures of central tendency (e.g., geometric mean) pertinent to log normally distributed data were used. Samples reported as < LLOQ (lower limit of quantitation) were estimated to be the LLOQ divided by the square root of two; however, geometric means were not calculated for several compounds (PFBS, EtFOSAA, FOSA, PFHxA, PFHpA, PFUnA, and PFDoA) because the number of samples reported as below LLOQ (ng/mL) was considered too high to provide a valid result. Those PFAS with large number of subjects (in parentheses) below LLOQ were PFBS: < 0.047 (339); < 0.023 (225) EtFOSAA: < 0.02 (91); < 0.05 (206); < 0.09 (242); < 0.23 (27) FOSA: < 0.093 (446); < 0.023 (170) PFHxA: < 0.093 (469); < 0.023 (127) PFHpA: < 0.09 (453); < 0.047 (100); PFUnA: < 0.466 (25); < 0.233 (73); < 0.093 (114); < 0.047 (109); PFDoA: < 0.932 (34); < 0.233 (115); < 0.093 (463).

To compare the means overall between 2000 2001, 2006, 2010, and 2015, while adjusting for age, sex, and location the general linear model with a logarithmic link function and normal error was specified as follows:

$$\mathrm{Ln[PFAS]} = \mathbf{Location}\cdot\beta_c + \mathbf{Year}\cdot\beta_y + \mathbf{Age}\cdot\beta_a + \mathrm{Sex}\cdot\beta_s + \mathrm{Sex}\cdot\mathbf{Age}\cdot\beta_{sa} + \varepsilon$$

where PFAS is the analyte of interest, **Location, Year,** and **Age** are vectors indicating location, year of collection and age category, respectively. Sex is an indicator variable, and ε is a normally distributed error term with mean zero. The model was fit to 1000 bootstrap samples for each compound, and the maximum likelihood estimates of means were contrasted using two sided 95% confidence intervals that were constructed using the bias corrected, accelerated bootstrap method (Efron and Tibshirani, 1993). The bias correction factor is derived by comparing empirical percentiles to bootstrap percentiles and acceleration is accomplished by partial jackknifing, a method of systematically resampling the data. A similar model, excluding location, was used for analysis by location. All the generalized linear models were fit using maximum likelihood in the S Plus (S Plus 7, ©Insightful Corporation, 2005) program "lm" and the bootstrap estimates were generated using the S Plus program "bootstrap."

In order to minimize parametric assumptions in the estimation of upper percentiles of the population, the bias corrected, accelerated bootstrap method with 3000 replications was used to generate confidence intervals around the empirical percentiles for plasma concentrations of the analyzed compounds. These analyses provided upper 95% confidence bounds on the tolerance limits (90th, 95th, and 99th percentiles) that represented the concentration of each perfluoroalkyl below which the stated proportion of the population is expected to be found. This same methodology was used to calculate these estimates in the prior years as previously reported (Olsen et al., 2003, 2008, 2011, 2012).

3. Results

3.1. Quality assurance

For the 60 2015 split samples, the Spearman rank order correlations (in parentheses) were the following ($p < 0.0001$): PFHxS (0.966); PFOS (0.917); PFOA (0.951); PFNA (0.905); and PFDA (0.931). For the sixty archived samples that were originally analyzed in either 2000 2001 ($n = 20$), 2006 ($n = 20$), or 2010 ($n = 20$), and then reanalyzed in this study, the Spearman rank order correlations (in parentheses) were the following ($p < 0.0001$): PFHxS (0.919); PFOS (0.968); PFOA (0.973); PFNA (0.944); and PFDA (0.926).

3.2. Comparison of 2015 American Red Cross samples to prior collection years

In 2015, the age , sex , and location adjusted geometric means were the following: PFHxS 0.86 ng/mL (95% confidence interval (CI) 0.81 – 0.92); PFOS 4.30 ng/mL (95% CI 4.11 – 4.50); PFOA 1.09 ng/mL (95% CI 1.03 – 1.14); PFNA 0.43 ng/mL (95% CI 0.41 0.45); and PFDA 0.15 ng/mL (95% CI 0.14 0.16). Fig. 1a (PFOS) and 1b (PFHxS, MeFOSAA PFOA, PFNA, PFDA) show temporal trends for the age , sex , and location adjusted geometric means for these American Red Cross studies. Table S4 provides the data. The percentage decline in these geometric mean concentrations from 2000 to 2015 were PFHxS (61%), PFOS (88%), PFOA (77%), PFNA (33%), and PFDA (50%). Only two time points are shown for MeFOSAA (2006 and 2015) in Fig. 1b due to a high proportion of values below LLOQ in 2000 2001 that likely biased the estimated central tendency measurements in that time period. MeFOSAA was not analyzed in 2010.

In 2015, males had significantly ($p < 0.01$) higher geometric mean concentrations than females for PFHxS (1.16 ng/mL vs. 0.65 ng/mL), PFOS (5.32 ng/mL vs. 3.52 ng/mL), and PFOA (1.23 ng/mL vs. 0.98 ng/mL). For most comparisons as shown by the non overlapping 95% confidence intervals, significantly higher geometric mean concentrations were observed in males compared to females for PFOS (Fig. 2a), PFHxS (Fig. 2b), and PFOA (Fig. 2c) for each 10 year age group by the collection year. These trends were not as apparent for PFNA and PFDA. (See supplemental file Table S5 for the data.) The LLOQs, percentiles, and unadjusted geometric means for all sampling years and PFASs are presented in supplemental file Table S6 (see footnotes a d of Table S6 for LLOQs.

Age and sex adjusted geometric mean temporal trends for each location are presented in Fig. 3 for PFOS (Fig. 3a), PFHxS (Fig. 3b), and PFOA (Fig. 3c). Likewise, Fig. 4a c show these trends for MeFOSAA, PFNA, and PFDA, respectively, for these six American Red Cross blood collection centers. (See supplemental file Table S7 for the location specific age and sex adjusted perfluoroalkyl geometric mean data and Table S8 for the unadjusted data).

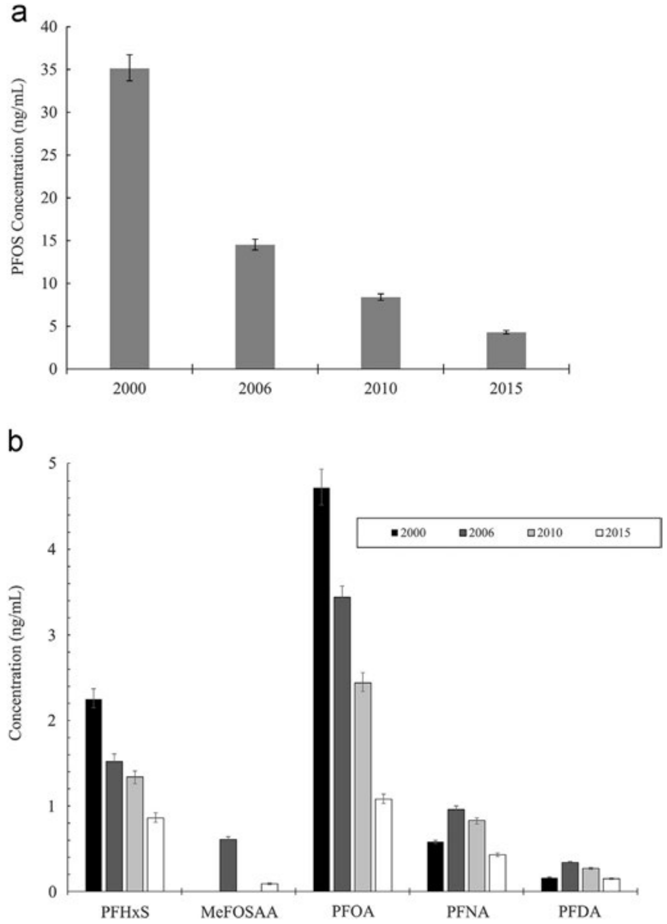

Fig. 1. Age-, sex-, and location-adjusted geometric mean (with 95% confidence intervals) PFOS (Fig. 1a) and PFHxS, MeFOSAA, PFOA, PFNA, and PFDA (Fig. 1b) serum (2000–2001) and plasma (2006, 2010, and 2015) concentrations (ng/mL), American Red Cross adult blood donors, 2000 2015.

A possible explanation for the higher age and sex adjusted mean plasma perfluoroalkyl concentrations in the Charlotte location may be from potential exposures to PFAS commercial applications that occurred in the historic textile and apparel industry that was situated in the southwest region of North Carolina (Key industries, 2016). This region's textile and apparel industry declined in the 1990s. As part of their analysis of the third U.S. EPA Unregulated Contaminant Monitoring Rule (UCMR3) municipal water sample data collected between 2013 and 2015, Hu et al. (2016) reported higher PFAS concentrations in the Raleigh to Fayetteville region of North Carolina, located approximately 200 km northeast of Charlotte. These researchers found UCMR3 areas to have higher PFAS water concentrations due to greater percentages of industrial sites, military fire training areas, and wastewater treatment plants.

Table 1 provides estimates for the 90th, 95th, and 99th tolerance limits along with their bias corrected upper one sided confidence limit (bound) for 2000 2001, 2006, 2010, and 2015. For PFOS the 90th, 95th, and 99th tolerance limits in 2015 were 9.6, 11.6, and 18.7 ng/mL with their 95% confidence limits calculated at 10.3, 13.2, and 22.0 ng/mL, respectively. Similar in magnitude to the percentage change in the geometric means between 2000 2001 and 2015, the percentage decline (in parentheses) of the estimates of the 95th percentile in this 15 year trend analysis were PFOS (88%), PFHxS (63%), and PFOA (73%). Because the calculation of the upper tolerance limits in these analyses is not influenced by the values below LLOQ, it could be calculated that there was a 92% decline in MeFOSAA at the 95th percent tolerance limit between 2000 2001 and 2015.

Fig. 5a (PFOS) and 5b (PFHxS, PFOA) provide trends for the geometric means (95% CI) for the American Red Cross series of studies and NHANES by year of blood collection. An approximate population halving time of 4.6 years for PFOS was estimated for the geometric mean serum/plasma concentrations the American Red Cross studies between 2000 2001 and 2015 that had been also estimated previously through the 2010 collection year (Olsen et al., 2012). This estimate is similar to the geometric mean serum elimination half life of 4.8 years (95% CI 4.0 5.8) for PFOS that was reported in a 5 year longitudinal study of 26 manufacturing production retirees (Olsen et al., 2007b).

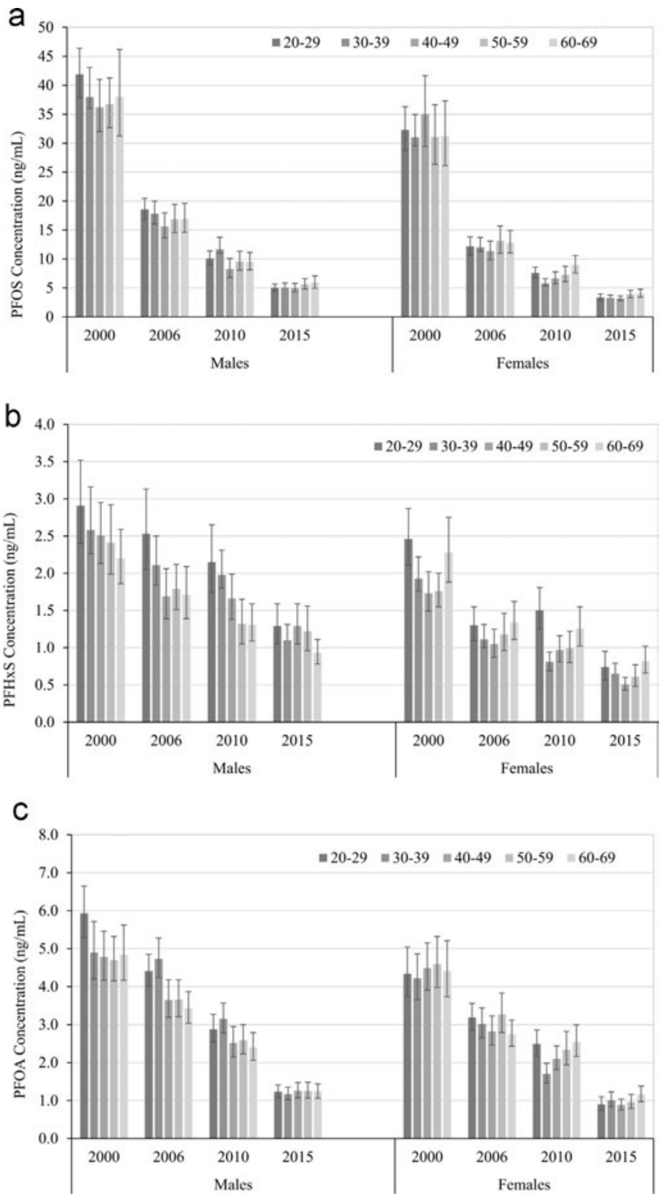

Fig. 2. Geometric means (with 95% confidence intervals) by age and sex, for PFOS (Fig. 2a), PFHxS (Fig. 2b) and PFOA (Fig. 2c), American Red Cross adult blood donors, 2000 2015.

4. Discussion

The percentage concentration declines of PFOS and PFOA concentrations observed in these American Red Cross adult blood donors is similar to those being reported in other non representative sampling studies being conducted in other countries including Germany (Yeung et al., 2013a, 2013b), Sweden (Glynn et al., 2012; Gebbink et al., 2015a), and Australia (Toms et al., 2014; Eriksson et al., 2017). Although percentage declines may be similar, absolute concentrations

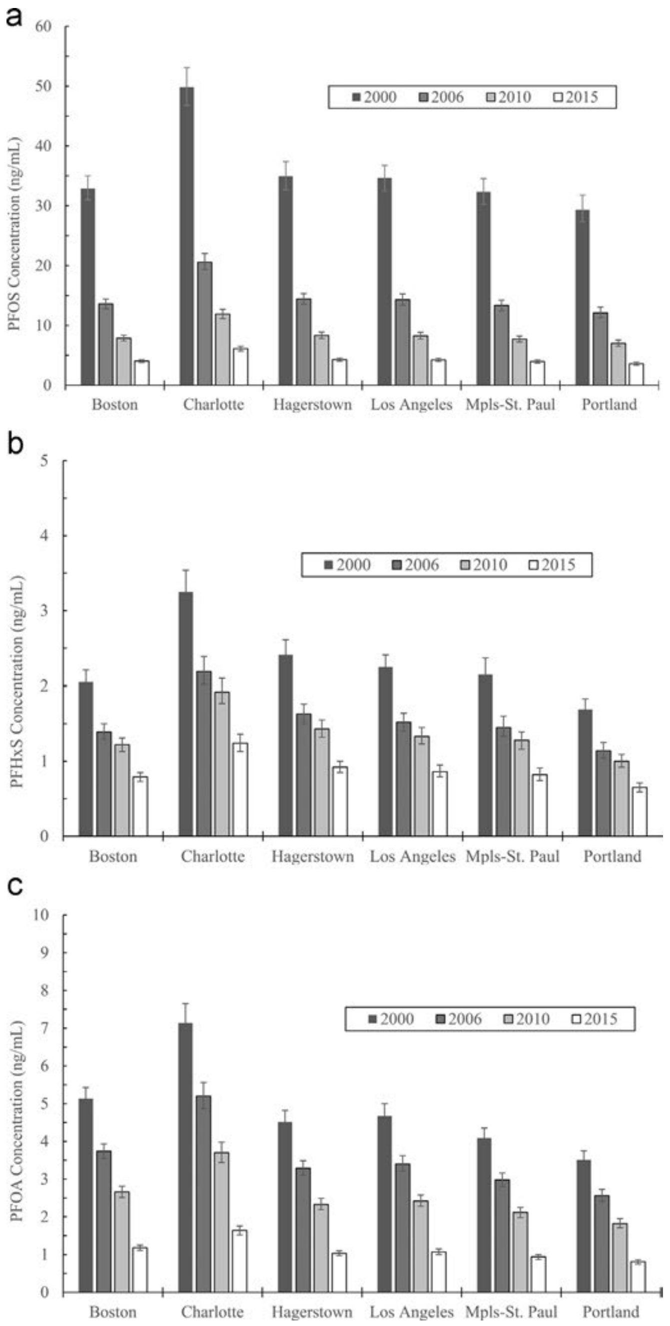

Fig. 3. Age- and sex-adjusted geometric mean (with 95% confidence intervals) PFOS (Fig. 3a), PFHxS (Fig. 3b), and PFOA (Fig. 3c) for serum (2000–2001) and plasma (2006, 2010, and 2015) concentrations (ng/mL) for six regional American Red Cross adult blood donor centers, 2000–2015.

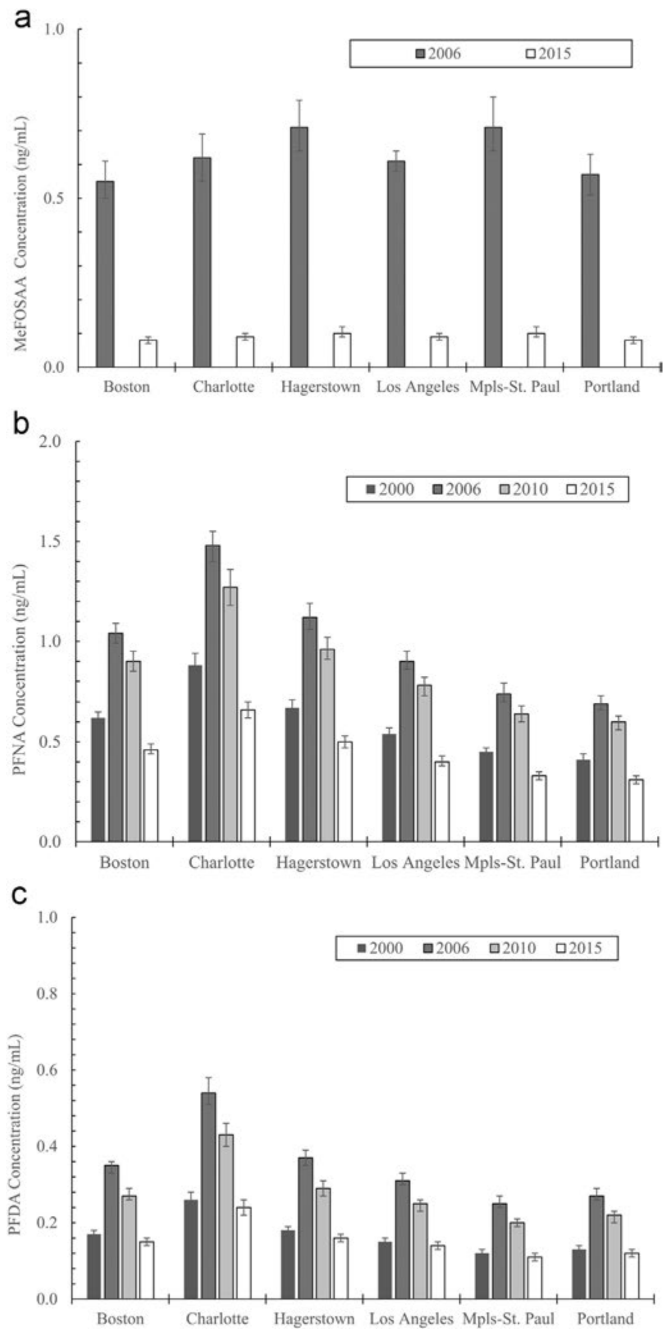

Fig. 4. Age- and sex-adjusted geometric mean (95% confidence interval) MeFOSAA (2006, 2015) (Fig. 4a), PFNA (Fig. 4b), and PFDA (Fig. 4c) serum (2000-2001) and plasma (2006, 2010, 2015) concentrations (ng/mL) for six regional American Red Cross adult blood donor centers.

may differ due to past and present potential exposures, time periods, and population studied. For example, the German studies (Yeung et al., 2013a; 2013b) collected samples through 2009 with few samples analyzed for any year. The Swedish studies were collected through 2010 (Glynn et al., 2012) and 2012 (Gebbink et al., 2015a) but represented primparous women who provided serum samples in the 4th week after delivery of an infant. Pregnancy and lactation would factor into measured PFAS concentrations. During this same time period, the manufacture of PFOS and other PFAS related products rapidly expanded in China resulting in higher serum concentrations of the Chinese population, particularly those residing in the eastern and coastal cities where segments of the fluoropolymer industry can be found that includes textiles, paper making, and electroplating (Wang et al., 2015). Thus, PFAS trend comparisons between populations should proceed cautiously.

Diet has been considered a major source of perfluoroalkyl exposure (Domingo, 2012; Domingo and Nadal, 2017). The European Food Safety Authority (EFSA, 2012) reported PFASs were often found in fish, seafood, meat, and meat byproducts (especially liver). EFSA estimated the tolerable daily intake (TDI) for PFOS and PFOA among high consumers was less than 6.7% and 0.5% of the TDI, respectively. Among adults, the 95th percentile exposure for PFOS ranged from 1.4 ng/kg/b.w. per day to 10 ng/kg/b.w. per day. For PFOA, the 95th percentile exposure ranged from 0.22 ng/kg/b.w. per day to 7.7 ng/kg b.w. per day. Johansson et al. (2014) have reported decreasing temporal trends in Sweden (1999–2010) of concentrations of PFOS

Table 1
Trend in Estimates of Serum (2000–2001) and Plasma (2006, 2010, 2015) Perfluoroalkyl Concentrations (ng/mL) for the 90th, 95th, and 99th Percent Tolerance Limits and Their Upper 95% Confidence Limits (CL).

		2000–2001		2006		2010		2015	
Compound	Percentile Tolerance Limit	Estimate	Upper 95% CL	Estimate	Upper 95% CL	Estimate	Upper 95% CL	Estimate	Upper 95% CL
PFHxS	90%	6.3	7.0	3.7	4.1	3.8	4.1	2.8	3.0
	95%	9.5	10.8	5.6	7.0	5.2	5.9	3.5	4.0
	99%	17.0	22.4	14.4	31.2	9.8	13.9	5.8	10.5
PFOS	90%	70.7	74.3	29.6	31.5	17.9	19.3	9.6	10.3
	95%	88.5	100.0	35.2	36.8	22.3	24.9	11.6	13.2
	99%	157.3	207.0	49.7	62.4	38.4	45.6	18.7	22.0
EtFOSAA	90%	5.3	5.9	0.7	1.0	N/A[a]	N/A	-[b]	–
	95%	7.6	8.5	0.7	1.0	N/A	N/A	–	–
	99%	19.4	27.6	1.0	1.4	N/A	N/A	–	–
MeFOSAA	90%	3.7	4.0	1.4	1.5	N/A	N/A	0.3	0.3
	95%	5.0	5.4	1.8	2.0	N/A	N/A	0.4	0.5
	99%	8.1	10.3	3.5	4.6	N/A	N/A	1.0	1.3
PFOA	90%	9.4	10.1	6.4	6.8	4.8	5.3	2.4	2.6
	95%	12.3	13.8	7.7	8.3	6.6	7.6	3.3	3.7
	95%	19.9	25.8	10.9	11.9	12.8	15.6	6.0	7.7
PFNA	90%	1.1	1.2	1.8	1.9	1.6	1.9	0.9	1.0
	95%	1.4	1.5	2.2	2.3	2.3	2.6	1.1	1.3
	99%	2.0	2.4	3.1	3.6	4.7	7.2	2.2	2.4
PFDA	90%	0.3	0.3	0.6	0.7	0.6	0.7	0.3	0.4
	95%	0.4	0.5	0.8	0.8	0.8	0.9	0.6	0.6
	99%	0.6	0.7	1.1	1.3	1.3	2.2	1.1	1.3

[a] Did not measure in year.

[b] EtFOSAA was measured in 2015 but did not calculate in 2015 as 95% of the 616 measurements were below LLOQ. 95th percentile was 0.04 ng/mL. See supplemental file Table S4.

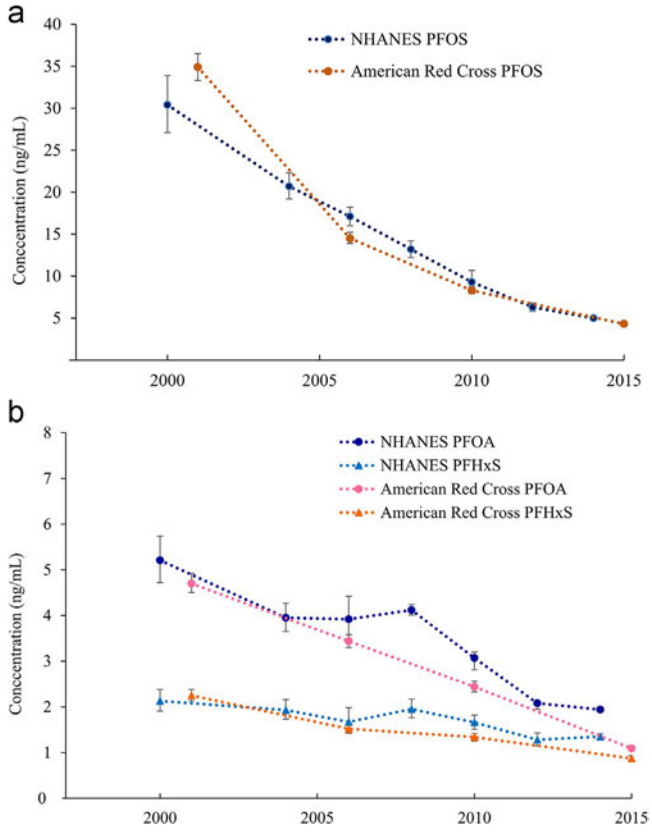

Fig. 5. Trends in American Red Cross and NHANES PFOS (Fig. 5a) and PFHxS and PFOA (Fig. 5b) geometric mean serum/plasma concentrations (with 95% confidence intervals), 2000 2015.

and PFHxS found in milk, eggs, and farmed rainbow trout with the latter two dietary items likely due to contamination declines in the feed offered to hens and farmed fish. In the United States, Christensen et al. (2017) recently reported an association between serum perfluoroalkyl measurements and self reported fish consumption data in 4 NHANES cycles of data collected between 2007 and 2014. They found associations between MeFOSAA, PFNA, and PFDA with self reported fish consumption in the 30 days prior to the blood collection. Several PFASs were also associated with shellfish, including PFOS. Such meals, however, were reported infrequently (median of 1.2 fish meals and 0.14 shellfish meals per month) in these NHANES populations. Zhang et al. (2010) collected meat and egg samples from a wide geographical distribution of 17 cities in 15 provinces in China. Assuming values ½ the lower limit of quantitation, they estimated daily intake for PFOS was 8.8 15 ng/d and 255 577 ng/d for PFOA. Most dietary exposure to PFOS was from fish and seafood whereas meat was a major source for PFOA.

Indirect exposures from commercial PFOS based products are also significant sources of exposure to PFOS as higher molecular weight derivatives have the potential to degrade to PFOS (D'eon and Mabury, 2011). These included the precursors MeFOSAA and EtFOSAA that were measured in this study. For these two compounds, geometric means could not be determined in 2015 due to the high proportion of samples below the LLOQ as compared to prior years. For example, the 95th percentile of PFOS, MeFOSAA, and EtFOSAA concentrations in 2000 2001 were 75.1 ng/mL, 4.8 ng/mL, and 6.5 ng/mL, respectively (supplemental file Table S6). In 2015, these 95th percentiles were 8.6 ng/mL, 0.4 ng/mL, and 0.05 ng/mL, respectively, suggesting MeFOSAA and EtFOSAA may have been important precursors of exposure in the past given the decline of PFOS. Martin et al. (2010) recommended more precise analytical methods might distinguish directly manufactured PFOS from that biotransformed from PFOS precursors. They reported non racemic PFOS body burdens of the α branched PFOS (1m PFOS, i.e., $C_6F_{13}CF(CF_3)SO_3$) could be a biomarker of significant exposure to PFOS precursors. Others in Japan (Miyake et al., 2007) and China (Yeung et al., 2008; Yeung and Mabury, 2016) have estimated the percent of extractable organic fluorine that is not accounted for in PFAS analyses as this percentage would reflect other unknown PFAS precursors. Depending on the occupational or non occupational population studied, the unaccounted fraction reported by these investigators ranges between 30% and 70%. Neither NHANES nor the American Red Cross studies have reported total organic fluorine measurements.

In 2006, the U.S. Environmental Protection Agency (EPA) invited eight fluoropolymer manufacturers (Arkema, Asahi, BASF Corporation, Clariant, Daikin, 3M/Dyneon, DuPont, and Solvay Solexis) to commit to a 95% reduction (measured from year 2000 baseline) of PFOA (including facility emissions, precursors that break down to PFOA and product content of PFOA) by 2010, and to work toward their elimination from emissions and products by 2015 (US EPA, 2006) By 2013, seven of the eight companies had reported at least a 99.8% reduction or more in emissions and six of eight companies reached a 99% or more reduction in product content as fluoropolymer dispersions, other fluoropolymers, and telomer based products. Although the American Red Cross data suggested a continuous decline in PFOA concentrations between 2000 and 2015, NHANES data suggested a plateau occurred between 2003 2004 and 2007 2008 with a resumption in decline thereafter, indicating the U.S. EPA PFOA Production Stewardship program was likely instrumental in this subsequent decline of PFOA after 2008. It is possible that the American Red Cross study missed this plateau in the mid 2000 time period because it sampled only every 4 years. At this time, the percentage reduction in the NHANES geometric mean serum PFOA concentrations from 1999 to 2000 2014 (63%) is somewhat lower than that calculated for the American Red Cross biomonitoring data from 2000 to 2001 2015 (77%). This may be partially explained by the fact that the American Red Cross study collected blood samples (mid 2015) 1.5 years after that reported in NHANES (2013 2014) which resulted in different geometric means (1.09 ng/mL vs 1.94 ng/mL), respectfully.

While PFOS and PFOA concentrations have declined in the United States general population and elsewhere (Kato et al., 2014) and extensive research of levels of PFAS in environmental matrices has been published (Houde et al., 2011; Reiner and Place, 2014), significant gaps remain in the reporting of general environmental trends and correlation to human exposure levels. Recent reviews cite the complexity of environmental fate of PFAS and the shortcomings in the scientific knowledge relating to transport, partitioning, and the PFAS transformation processes after their release into the environment (Riget et al., 2013; Ahrens and Bundschuh, 2014; Richardson and Kimura, 2014; Miralles Marco and Harrad, 2015). Nevertheless, site specific environmentally related exposures have been identified that could result in local communities with higher serum PFOS, PFHxS, PFOA, and other PFAS concentrations than observed in the general population. These affected communities tend to reside near: 1) industrial plants that used PFOA in fluoropolymer production activities (Frisbee et al., 2009); 2) military or commercial airports that have used aqueous film forming foam for emergency and fire training needs (Place et al., 2012, Weiss et al., 2012) as well as other sporadic industrial accidents including railcar derailments (Munoz et al., 2017); 3) landfills where PFAS leachate can occur (Busch et al., 2010; Lang et al., 2017) and 4) agricultural fields where biosolids from waste water treatment plants have been applied (Skutlarek et al., 2006; Wilhelm et al., 2008; Lindstrom et al., 2011; ATSDR, 2013). For these exposures, environmental release into surface and/or ground water can result in PFAS to be found in drinking water sources. Exposure reduction activities (e.g., installation and routine replacement of granulated activated charcoal (GAC) filters into a municipal water system) have been effective at reducing long chain PFAS water concentrations which has resulted in lowered serum perfluoroalkyl (e.g., PFOS, PFOA) concentrations in affected populations (Bartell et al., 2010; Minnesota Dept. Health, 2015).

The U.S. EPA recently issued a lifetime drinking water health advisory of 0.07 μg/L for PFOS, PFOA, or their sum (U.S. EPA, 2016a, 2016b). Other national and state assessments based on drinking water, as well as dietary exposure guidelines, for PFOS and PFOA have been reviewed by Butenhoff and Rodricks (2014). For example, The German Drinking Water Commission of the Federal Environment Agency has issued a guideline of 0.1 μg/L for PFOA and 0.1 μg/L for PFOS (Germany, 2016). The Canadian Federal Provincial Territorial Committee on Drinking Water has a proposed guideline of a maximum acceptable value of 0.2 μg/L for PFOA (Canada, 2016).

Both the American Red Cross and the NHANES investigations continue to indicate a weak decline in the geometric mean for PFHxS. Because PFHxS appears to be slowly eliminated from human serum (Olsen et al., 2007b) and has often been measured in household dust along with other PFASs (Kato et al., 2009; Fraser et al., 2013), the question arises as to what proportion of this slow decline in PFHxS concentrations is a function of its pharmacokinetics versus background exposures to consumer household or office applications including dust (Beesoon et al., 2012), through the diet (EFSA, 2012), drinking water (MDH 2017), or other possible exposures (Favreau et al., 2017). The long but imprecise serum elimination half life of PFHxS in humans, reported as a geometric mean of 7.3 years (95% CI 5.8 − 9.2), is likely the primary contributor to this observation.

Replacement PFAS chemistries that have been introduced into the marketplace and measured in this study were two shorter chain PFAS (PFBS, PFHxA) that are considered to have more favorable environmental and biological properties than longer chain PFASs (Buck et al., 2014). Others have expressed reservations about the alternative shorter chain PFAS (Scheringer et al., 2014; Blum et al., 2015) including whether these compounds will become ubiquitous in the environment, whether they can be filtered from affected drinking water, and the formation of persistent terminal transformation products in the environment. For some manufacturers, their focus has centered on the production of PFBS and perfluorobutanesulfonyl related products. The present study showed only 8.4% of the 2015 American Red Cross samples had a quantifiable serum PFBS concentration (range LLOQ 4.2 ng/mL). The 95th percentile was 0.02 ng/mL. The NHANES 2013 2014 data reported the 95th percentile for PFBS at below the level of detection (0.1 ng/mL). PFBS has been estimated to have a serum elimination half life approximating 26 days (range 13 46 days) in the human with the kidney the primary elimination pathway (Olsen et al., 2009). Other companies have commercialized the 6:2 fluorotelomer and its precursor products as an alternative to the 8:2 fluorotelomer that can metabolize to PFOA (Nilsson et al., 2013). The 6:2 fluorotelomer can metabolize to PFHxA. There were 3.3% of the 2015 American Red Cross samples that had a quantifiable PFHxA concentration (range LLOQ 0.27 ng/mL). The serum elimination half life of PFHxA has been estimated to be 32 days (range 14 49 days) (Russell et al., 2013).

Study limitations included the fact that the American Red Cross studies, as well as NHANES, are both a series of cross sectional investigations. Individuals were not followed longitudinally as this type of study design is infrequently reported (Nøst et al., 2014; Stubleski et al., 2016). The study's laboratory analytical methods improved over time especially with the introduction of labeled standards and now this validated single injection method; thus greater analytical variation likely existed in the earlier measurements. Other classes of perfluoroalkyl precursors were not analyzed in this study including the polyfluoroalkyl phosphate diesters (diPAPs) that have been used as food packaging grease protectants and fluorotelomer sulfonic acids that have been used as wetting or foaming agents. These PFAS have been measured in human serum at low pg/mL levels (Lee and Mabury, 2011; Gebbink et al., 2015b; Eriksson et al., 2017). The declining trends observed in these American Red Cross adult blood donors should not be extrapolated to other country trends without consideration of these nations' potential direct and indirect exposure scenarios.

5. Conclusion

Age and sex adjusted geometric mean serum (2000 2001) and plasma (2006, 2010, 2015) concentrations (ng/mL) were compared across six American Red Cross blood collection centers. The results indicate a continued decline of PFHxS, PFOS, and PFOA concentrations in American Red Cross adult blood donors. For the shorter chain perfluoroalkyls PFBS and PFHxA that were measured in 2015, the majority of samples were below the lower limit of quantitation.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.envres.2017.05.013.

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Document 4

Australian Government
Department of the Environment and Energy

Commonwealth Environmental Management Guidance on Perfluorooctane Sulfonic Acid (PFOS) and Perfluorooctanoic Acid (PFOA)

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Disclaimers

Acronyms

AA	annual average
ASC NEPM	Assessment of Site Contamination National Environment Protection Measure
BAT	best available technology (or technique)
BEP	best environmental practice
bw	body weight
CSM	conceptual site model
CRC CARE	Cooperative Research Centre for Contamination Assessment and Remediation of the Environment
DGV	Default Guideline Value
dwt	dry weight
EC_{10}	the concentration that will have an effect on 10% of the population of test organisms
EPA	Environmental Protection Agency
EPBC Act	Environment Protection and Biodiversity Conservation Act, 1999
EQS	environmental quality standards
FEQG	Federal Environmental Quality Guideline (Canada)
FTS	fluorotelomer sulfonic acid
LC_{50}	lethal concentration, 50%
LOR	limit of reporting
MNES	matters of national environmental significance
MRL	maximum residue limit
NEPM	National Environment Protection Measure
NICNAS	National Industrial Chemicals Notification and Assessment Scheme
NWQMS	National Water Quality Management Strategy
PFAS	perfluoroalkyl and polyfluoroalkyl substances*
PFBA	perfluorobutanoic acid
PFBS	perfluorobutane sulfonic acid
PFDA	perfluorodecanoic acid
PFHpA	perfluoroheptanoic acid
PFHxA	perfluorohexanoic acid
PFHxS	perfluorohexane sulfonic acid
PFNA	perfluorononanoic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulfonic acid
PFOSA	perfluorooctane sulfonamide
PFOSF	perfluorooctane sulfonyl fluoride
PFPeA	perfluoropentanoic acid
PNEC	predicted no effect concentration
POP	persistent organic pollutant
ppm	parts per million
RAP	remediation action plan
RIVM	Netherlands National Institute for Public Health and the Environment
SAQP	sampling and analysis quality plan
WGSs	Australian and New Zealand Guidelines for Fresh and Marine Water Quality

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* Perfluoroalkyl refers to an alkyl group where every hydrogen has been replaced with a fluorine. Polyfluoroalkyl groups are not fully fluorinated; polyfluoroalkyl groups include fluorotelomer compounds which have one or more methylene groups in addition to a perfluoro moiety. Fluorotelomers were developed as they are less persistent but they may break down to persistent perflouro compounds in the environment.

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1. Preface

Per- and poly fluorinated alkyl substances (PFASs) and their derivatives are in a group of chemicals that has many speciality applications. They provide resistance to heat, to other chemicals or to abrasion, and can be used as dispersion, wetting or surface-treatment agents.

PFASs and their derivatives are man-made chemicals and have been used in a wide range of industrial processes and consumer products, including in aqueous film forming foams (AFFF) for fire fighting, in chromium plating (in plastic etching and as a mist suppressant to protect workers from toxic hexavalent chromium fumes) in medical imaging (e.g. x-ray films), in various fabric and cooking applications and potentially in aviation hydraulic fluid.

Two PFASs of concern in Australia and internationally are perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA) (see Box 1). PFOS was listed on the Stockholm Convention for Persistent Organic Pollutants in 2009 and as such is internationally recognised as being persistent and bioaccumulative, undergoing long range transport and having or potentially having adverse effects on human health and the environment. In particular the expert Review Committee of the Stockholm Convention decided in November 2006:

> *that perfluorooctane sulfonate is likely, as a result of its long-range environmental transport, to lead to significant adverse human health and environmental effects such that global action is warranted.*

Australia's national industrial chemicals assessment body also concluded that PFOS and PFOA are persistent, bioaccumulative, toxic, undergo long range transport, including in water and air, and transfer between different media[*].

Box 1: International Obligations

Australia is a party to the Stockholm Convention on Persistent Organic Pollutants (POPs) and the Basel Convention on the Transboundary Movements of Hazardous Waste and their Disposal (further information at Appendix D). These Conventions work together in the case of POP wastes. PFOS is listed under the Stockholm Convention, although Australia is yet to ratify its listing. PFOA is not yet listed but it has met the Annex D screening criteria for persistence, bioaccumulation, potential for long range transport and evidence for adverse effects on humans or the environment.

Commonwealth actions should be consistent with the internationally-accepted standards set under the Stockholm and Basel Conventions, unless and until the government were to decide not to accept the requirements of the Stockholm Convention after consideration as part of Australia's domestic treaty making process by the Joint Standing Committee on Treaties. This includes disposal of POPs content in accordance with Article 6 of the Stockholm Convention, and application of the low content limit for PFOS (50mg/kg) and other waste management approaches in the Basel POPs Technical Guidelines and PFOS Technical Guidelines.

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[*] The National Industrial Chemicals Notification and Assessment Scheme (NICNAS) assessments of PFOS and PFOA (including direct precursors) found: *[The chemicals] have been identified as PBT [persistent, bioaccumulative and toxic] substances. It is not currently possible to derive a safe environmental exposure level for such chemicals and it is therefore not appropriate to characterise the environmental risks for these chemicals in terms of a risk quotient. Due to their persistence, PBT chemicals have the potential to become widely dispersed environmental contaminants. Once in the environment, persistent chemicals that are also highly bioaccumulative pose an increased risk of accumulating in exposed organisms and of causing adverse effects. They may also biomagnify through the food chain resulting in very high internal concentrations, especially in top predators. As a result, these chemicals are considered to be of high concern for the environment.* (https://www.nicnas.gov.au/chemical-information/imap-assessments/imap-assessments/tier-ii-environment-assessments/direct-precursors-to-perfluorooctanesulfonate-pfos and https://www.nicnas.gov.au/chemical-information/imap-assessments/imap-assessments/tier-ii-environment-assessments/perfluorooctanoic-acid-and-its-direct-precursors).

Due to these properties international action has been taken to limit production and use of PFOS with a view to eventual elimination of production and use. PFOA was nominated for listing on the Stockholm Convention in 2015. It is currently progressing through a multi-stage assessment process having met the screening criteria for persistence, bioaccumulation, long range transport and adverse effects by the Convention's subsidiary body. The earliest it could be considered for listing on the Stockholm Convention is at the Conference of the Parties in 2019.

Many countries have now also established standards for PFOS and PFOA levels for the protection of the environment and human health (see Appendix A). International standards can differ between countries for a variety of reasons including changes over time, or methodologies, national circumstances or national conditions. While many organisations no longer use PFOS or PFOA, a significant challenge is associated with the legacy contamination of soils and water from their past use. This has occurred both domestically and internationally.

2. Scope

This Guidance focuses on PFOS and PFOA as potential indicators of wider contamination by related PFASs. The reasons for this approach include:

- Most research undertaken on PFASs internationally and in Australia has focused on PFOS and PFOA due to their frequent occurrence in the environment, persistence, and bioaccumulation.
- PFOS and PFOA can also be the breakdown endpoint of other precursor products.
- PFOS and PFOA are the most commonly encountered PFAS in the environment and wildlife.
- Information on other PFASs, of which there are several hundred known, is more limited.
- Effective management of PFOS and PFOA may help address potential contamination where other PFASs may also be present.

The Guidance will be reviewed and updated to ensure effectiveness, suitability and currency of information both internationally and within Australia. This will also ensure that should further chemicals become of concern [e.g. perfluorohexane sulfonate (PFHxS)] then appropriate guidance will be provided.

3. Objective

This Guidance has been prepared to provide Commonwealth agencies with a consistent, practical, risk-based framework for the assessment and management of PFOS and PFOA contamination on and potentially originating from Commonwealth sites (including airports subject to the *Airports Act, 1996*).

It provides for Commonwealth agencies to:

- investigate and identify where potential contamination exists on Commonwealth sites
- diagnose the potential risks to the receiving environment and
- respond by establishing management plans where appropriate and undertaking targeted actions

This Guidance includes Australian-derived guideline levels for PFOS and PFOA in water and soil, for the protection of ecological values. Note that this Guidance is based on the *National Environment Protection (Assessment of Site Contamination) Measure 1999* (ASC NEPM)[1] and the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC and ARMCANZ, 2000)[2] (water quality guidelines) under the Australian National Water Quality Management Strategy (NWQMS). Accordingly, this Guidance does not replicate all requirements under the ASC NEPM or the water quality guidelines and those applying the Guidance should refer to those mechanisms for specific directions.

The Guidance does not specify Australian-derived guideline levels for the protection of human health (see NSW Health, 2016[3]). Similarly, it does not implement for PFOS and PFOA the various guidelines under the NWQMS that target health outcomes including drinking water, recreational water quality and aesthetics, agricultural water use or water recycling. For easy reference, international levels for the protection of environmental and human health are noted in Appendix A. However, this Guidance notes that the ASC NEPM method allows for human health risks to be assessed alongside ecological risks once these become available.

It is anticipated when finalised, the environmental and the human health guidance together will provide a complimentary suite of standards for the effective protection of environmental and human health aspects of PFOS and PFOA contamination on Commonwealth sites. This Guidance has no regulatory status and it does not replace existing legal requirements including those under occupational health and safety and other laws.

3.1. General principles

This Guidance proposes an implementation framework that recognises the following principles:

- Assessment of site contamination and approaches to risk management including remediation should be proportionate to risks, and consistent with sound environmental practices and national and international obligations.

- If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation[*].

- Intergenerational equity - the present generation should ensure that the health, diversity and productivity of the environment are maintained or enhanced for the benefit of future generations.

- Conservation of biological diversity and ecological integrity shall be fundamental considerations in any decision-making.

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[*] This principle is included in Section 3 (b) of the *Environment Protection and Biodiversity Conservation Act, 1999* (EPBC Act); in its application, decisions should be guided by:

- careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment;
- an assessment of risk-weighted consequence of various options including broader environmental and non-environmental consequences of precautionary measures; and
- the availability of reasonable and practicable mitigation technologies.

Once the above conditions or thresholds are satisfied, a precautionary measure should be taken to avert the anticipated threat of environmental damage, but it should be proportionate.

Consistent with Australian community expectations, Commonwealth agencies will seek to fully understand the nature of potential contamination by PFOS and PFOA, to take appropriate pro-active and precautionary action, and keep the community appropriately informed.

While preliminary and/or detailed site investigation processes can take time before agencies are in a position to consider management objectives and strategies, the Commonwealth will ensure the following principles are applied:

- Where an initial preliminary site investigation indicates the potential for contamination to have migrated from Commonwealth land, Commonwealth agencies must consult with the relevant jurisdiction to establish mutual protection goals consistent with the NWQMS. This recognises the importance of informing the community, ensuring the scientific rigour of investigation findings and coordinating investigation efforts where feasible It notes that non-Commonwealth activities may have released PFOS/PFOA into the environment and contributed to the contamination being investigated.

- The timeframe within which a Commonwealth agency commences an offsite investigation will be subject to risk-based prioritisation in the context of the agency's national program for assessment of site contamination. Timeframes will be discussed with the relevant jurisdiction and interim measures should be considered where appropriate, commensurate with risk.

- Any person who proposes to take an action which is either situated on Commonwealth land or which may impact on Commonwealth land, and/or representatives of Commonwealth agencies who propose to take an action that may impact on the environment anywhere in the world need to undertake a self-assessment as to whether or not that action is likely to have a significant impact on the environment[*].

- If after undertaking a self-assessment the conclusion is that an action is likely to have a significant impact on the environment, or if the Commonwealth agency is unsure, they should refer the action to the Australian Government Minister for Environment and Energy[†].

- Commonwealth agencies are to document their strategies for dealing with the identification and management of contamination on their estate (where relevant and contamination is or has migrated off their estate).

4. Risk-based framework

The approach contained in this Guidance to address contamination on Commonwealth owned sites incorporates three stages:

i. investigation

ii. diagnosis and

iii. response.

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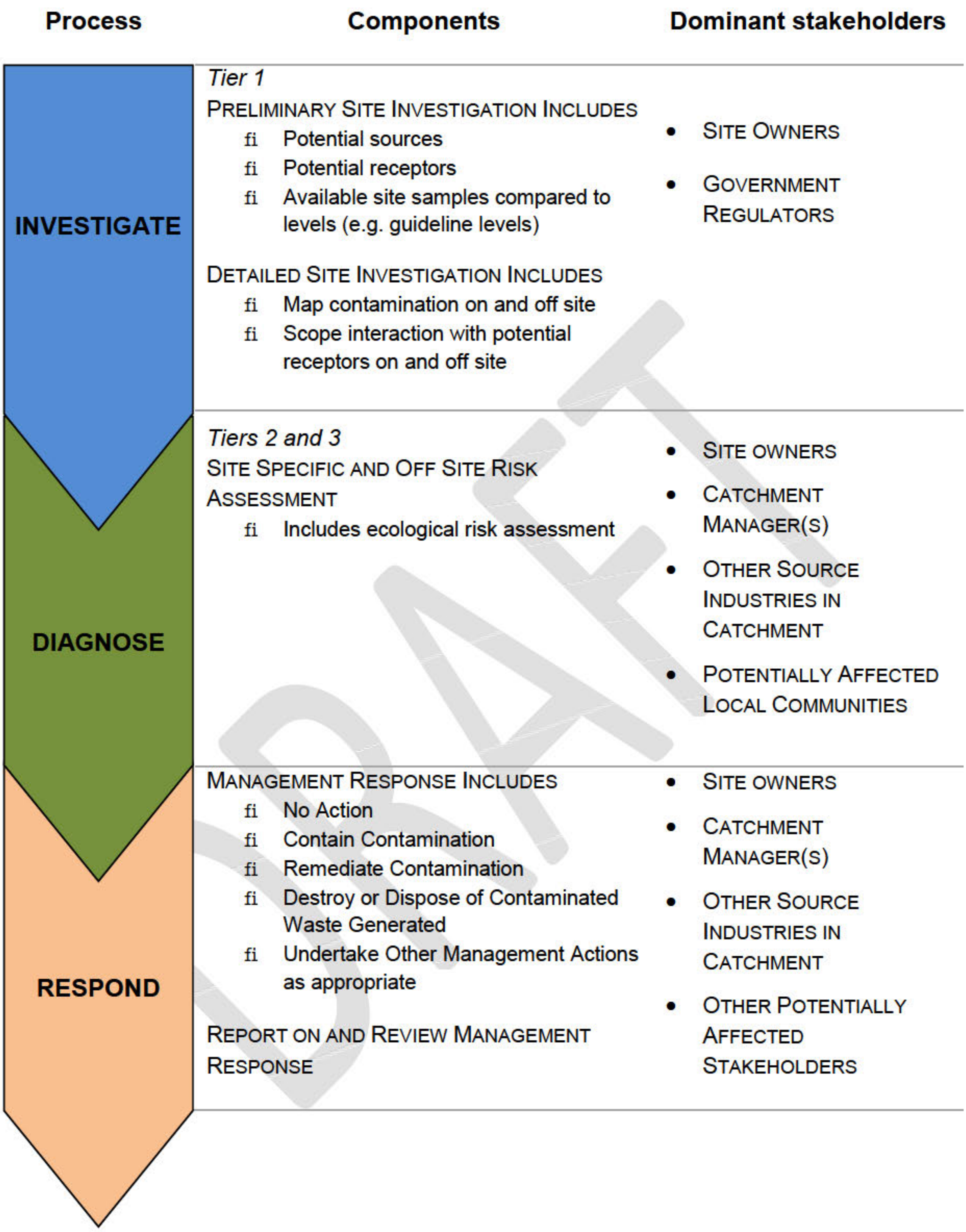
[*] Refer to EPBC Act Significant impact guidelines: 1.1 Matters of National Environmental Significance; and 1.2 Actions on, or impacting upon, Commonwealth land, and actions by Commonwealth agencies.

[†] Note that substantial penalties apply for taking an action without approval that has, will have or is likely to have a significant impact on a matter of national environmental significance or on the environment where the action is taken on, or may impact upon, Commonwealth land and/or the action is taken by a Commonwealth agency. See http://www.environment.gov.au/system/files/resources/a0af2153-29dc-453c-8f04-3de35bca5264/files/commonwealth-guidelines_1.pdf

Figure 1 illustrates this approach.



Process	Components	Dominant stakeholders
INVESTIGATE	*Tier 1* Preliminary Site Investigation Includes fi Potential sources fi Potential receptors fi Available site samples compared to levels (e.g. guideline levels) Detailed Site Investigation Includes fi Map contamination on and off site fi Scope interaction with potential receptors on and off site	• Site Owners • Government Regulators
DIAGNOSE	*Tiers 2 and 3* Site Specific and Off Site Risk Assessment fi Includes ecological risk assessment	• Site owners • Catchment Manager(s) • Other Source Industries in Catchment • Potentially Affected Local Communities
RESPOND	Management Response Includes fi No Action fi Contain Contamination fi Remediate Contamination fi Destroy or Dispose of Contaminated Waste Generated fi Undertake Other Management Actions as appropriate Report on and Review Management Response	• Site owners • Catchment Manager(s) • Other Source Industries in Catchment • Other Potentially Affected Stakeholders

Figure 1 – Overview of the approach taken in this Guidance

4.1. Investigation

This Guidance recognises that a wide range of circumstances exist for contaminated sites and that site specific approaches will be necessary. Commonwealth agencies should adopt a staged approach to assessing and managing potential PFOS/PFOA contaminated sites, consistent with the ASC NEPM tiered assessment, to inform risk management decisions. A flowchart based on the approach contained in the ASC NEPM approach is presented in Figure 2 and this includes an indication of how the ASC NEPM steps may broadly fit with the investigate, diagnose or response elements of this Guidance.

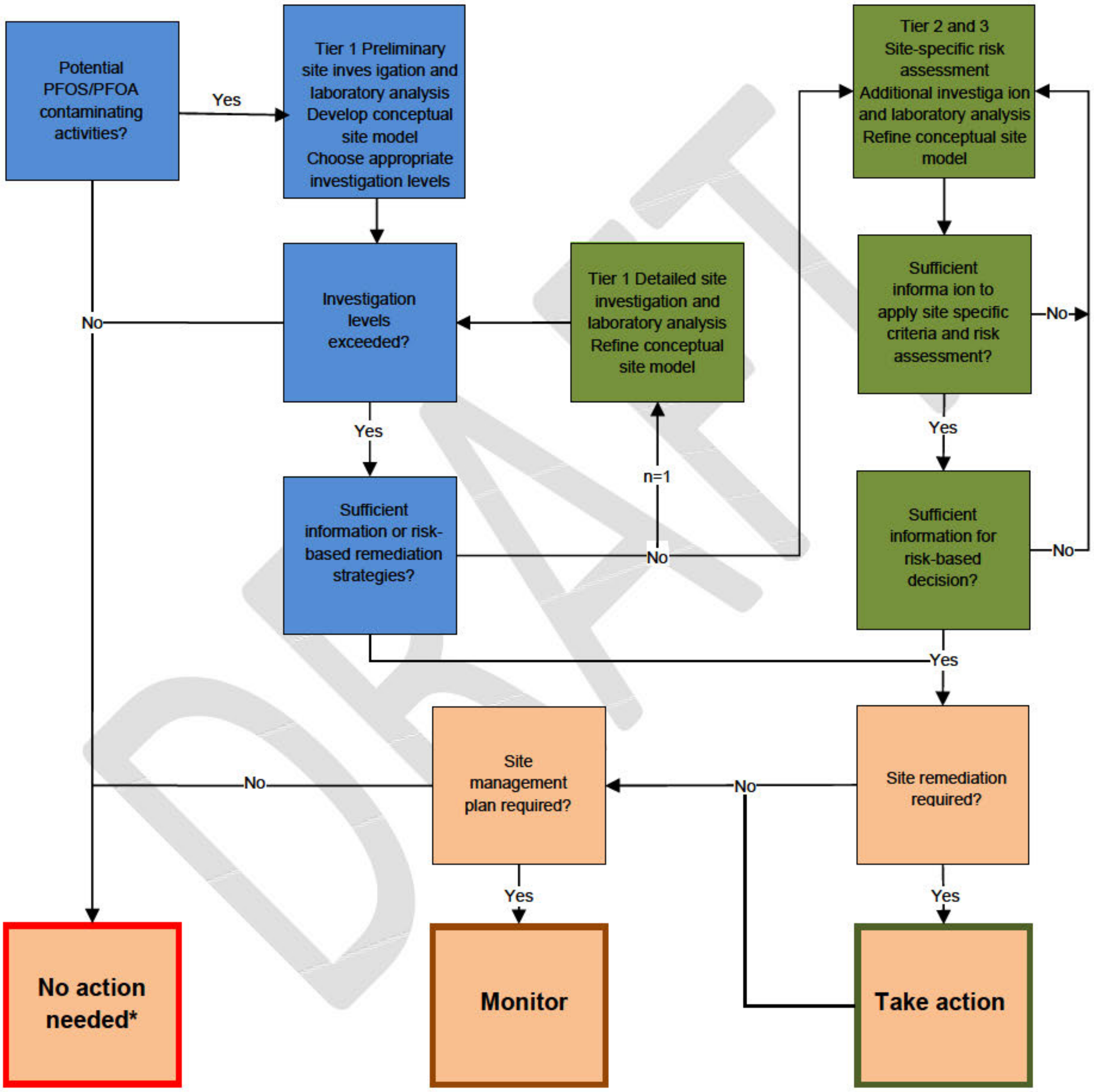


Figure 2 - Risk-based framework for the assessment and remediation of PFOS/PFOA contamination on Commonwealth land (adapted from Schedule A of the ASC NEPM)[*]

The ASC NEPM states:

> *"the purpose of contaminated site assessment is to determine whether site contamination poses an actual or potential risk to human health and the environment, either on or off the site, of sufficient*

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[*] The 'No action needed' scenario recognises that investigations may still be warranted for other contaminants, and consideration should be given to those contaminants that affect and are affected by the PFAS contamination.

> *magnitude to warrant remediation (or management) appropriate to the current or proposed land use. ...The broader objective of assessment is to ensure that the people of Australia enjoy the benefit of equivalent protection from air, water and soil pollution wherever they live; that the environmental values of water are maintained for future generations; that the capacity of the soil is maintained for future generations; and that there is consistency of approach between jurisdictions to aid government and business decision making."*

The ASC NEPM itself directs users to the NWQMS *Water Quality Guidelines* where risks to aquatic ecosystems are identified. It is recommended that Commonwealth agencies use the risk-based decision frameworks in the water quality guidelines to inform management decisions for environmental water resources where appropriate. Note that these ecological water quality guidelines are not to be confused with drinking water guidelines which, although a part of the NWQMS, are subject to revision from time to time by the National Health and Medical Research Council. The management framework for applying the water quality guidelines broadly aligns with the ASC NEPM processes.

4.1.1. Preliminary Site Investigation

The first stage of the assessment process is a preliminary site investigation. This may involve a desktop study and site inspections (including interviews with site representatives) to establish a site history and site characteristics to identify all past and present potentially contaminating activities and determine if the site is likely to have been impacted by PFOS/PFOA.

Where the preliminary site investigation clearly demonstrates that site activities have been non-contaminating this information can be used to justify why further assessment action is not needed.

Where there is an indication that the land either in whole or in part may potentially be contaminated, the preliminary investigation should be sufficient to identify potential sources of contamination, areas of contamination, human and ecological receptors, and affected media (such as soil and water). Within the investigation it is important to consider both primary and secondary sources (i.e. areas connected to primary source via migration pathways such as a surface water drain). The persistence of the chemicals, their sorption and desorption behaviour in soil including their propensity to move through water, and the potential for bioaccumulation and biomagnification in the food chain should be taken into account.

The information captured in the preliminary site investigation should be sufficient enough to create an initial Conceptual Site Model (CSM). A CSM is fundamentally a written or pictorial representation of an environmental system defining the contaminants of potential concern, their likely or known sources and the possible pathways of exposure to human and environmental receptors.

Where a preliminary site investigation demonstrates that the land is not contaminated or the potential for risk to human health and the local or wider environment is limited based on current or intended future land use, there may be no need for further investigation. However, where contaminating activities are suspected or known to have occurred – or if the site history is incomplete or where further delineation of contamination is required to determine the risk (that is, where sampling indicates levels above investigation levels) – it may be necessary to undertake a detailed site investigation. In this context, however, note that limited intrusive sampling can be undertaken in a preliminary site investigation where deemed warranted to fill data gaps in keeping with the nature of the preliminary site investigation.

See Section 8, Schedule A, Schedule B2 and Schedule B5a of the ASC NEPM for more detail on preliminary investigations.

4.1.2. Detailed Site Investigation

A detailed site investigation is required when the results of the preliminary investigation indicate that contamination is present or is likely to be present, and the information available is insufficient to enable site management strategies to be devised. The detailed investigation stage should identify the nature of the contamination and delineate its lateral and vertical extent to a sufficient degree that an appropriate level of risk assessment may be undertaken and, if necessary, provide the basis for the development of an appropriate remediation or management strategy.

The ASC NEPM notes that an environmental risk assessment (ERA) requires an integrated approach, using multiple lines of evidence gathered from physical, chemical and biological data combined with site-specific data about exposure, toxicological and chemical parameters and the consideration of properties of soil, sediments and water relevant to the site, in order to estimate the level of effects. The movement of contaminants from soil to other environmental media (that is, air, water or sediment) and subsequent exposure to biota should be addressed in the ERA.

The potential outcomes of a detailed site assessment include (the intermediate outcome for) higher tier assessment, remediation, management or no further action. Where management is proposed for residual contamination and not remediation, the approach should be justified and where required approved by the relevant state and territory environmental authority. The management measures should also be appropriate to the current and/or future use or development of the site.

4.1.3. Sampling and analysis

Field sampling in soil, groundwater or other water sources may be required to confirm the presence or absence of suspected PFOS/PFOA contamination identified in the preliminary site investigation and other contaminants of concern.

Sampling should be consistent with methods for contaminated site investigation (refer to Schedule B2, Appendix B of the ASC NEPM). This includes the development of data quality objectives based on the initial CSM, and a Sampling and Analysis Quality Plan (SAQP). The SAQP sets the sampling program and data quality objectives as well as the quality assurance and quality control methodologies to be employed to manage the field work stage of the assessment.

Several sampling events may be required to delineate the contamination and determine the risks to human health and the environment. Any additional sampling events or changes to the sampling methodology should be reflected by amending the SAQP where time permits. Where the SAQP has been agreed with an environmental regulator, any proposed or actual changes to the SAQP's implementation should be raised with the regulator as soon as possible.

Sampling should recognise that there may be multiple sources of PFOS and PFOA contamination onsite and offsite. Any sampling program should seek to take this into account and identify all potential sources of contamination. This information will play an important role in selecting effective management approaches that target the main sources of contamination.

It is noted that PFOS and PFOA require specialised sampling equipment and containers to prevent cross-contamination – see the UNEP 2015 *PFAS analysis in water for the Global Monitoring Plan of the Stockholm Convention: Set-up and guidelines for monitoring*[4].

4.1.4. Investigation levels

Proposed Australian-derived guidelines for PFOS and PFOA levels in water and soil to achieve ecological protection are outlined in Table 1. These investigation levels may be used to indicate whether PFOS and/or PFOA is likely to be a contamination issue for the site or the wider environment. If the site soil and water contamination levels exceed the relevant levels or are likely to lead to an exceedance of the relevant levels, further assessment of the risks posed is required or a conservative management approach should be adopted. Box 2 sets out what investigation levels do and do not do.

Commonwealth agencies will need to decide and justify which investigation (species protection) levels are used. These will depend on the risk profile of the site, and be informed by the current environmental condition of the local water quality catchment and agreed community objectives for that catchment. For PFOS and PFOA, which are mobile in water, the relevant water quality guideline (freshwater and/or marine, whichever is/are applicable) is likely to be the key ecological investigation level. The water quality guideline applies to both surface and, where appropriate, to ground water. See below in the Diagnose section for contextual information to assist in applying the default guideline values.

When assessing groundwater risks, the ASC NEPM (Schedule B6) emphasises that current and realistic future uses be considered, compared with the emphasis on current and intended uses for soil assessment. Investigation levels for groundwater should therefore be selected with all realistic future uses in mind. Risks to receptors not necessarily on site (i.e. off site receptors) should also be considered.

Box 2: Investigation levels – What they can and cannot be used for

Adapted from the ASC NEPM and NWQMS

What investigation levels do:

- provide a guide as to when more detailed investigation might be appropriate
- in the case of water quality guidelines, provide guidance to policy formulation in the states and territories taking into account local conditions and associated costs and benefits
- in the case of water quality guidelines, provide assistance to the formulation of regional water quality guidelines and water quality objectives
- in the case of water quality guidelines, provide certainty that there will be no significant impact on water resource values if the guidelines are achieved.

What investigation levels are not:

- mandatory
- levels up to which contamination may be allowed to occur
- trigger levels for remediation
- clean-up or response levels
- applicable to recycled water quality (which is covered by separate a policy process under the NWQMS), contaminant levels in discharges from industry, mixing zones, or stormwater quality (unless stormwater systems are regarded as having conservation value)
- health reference levels for drinking water which are covered by separate a policy process under the NWQMS).
- default levels for regulating specific emissions and/or application of wastes to soil which are to be set taking into account the results of the preliminary or detailed site investigations and national guidelines for both water and soil.

Table 1 - Investigation levels for PFOS and PFOA by exposure scenario

PFOS	PFOA	Exposure scenario	Source and Comments
Freshwater			
0.00023 µg/L	19 µg/L	99% species protection– high conservation value systems	Australian and New Zealand Guidelines for Fresh and Marine Water Quality – technical draft default guideline values. *Important*: These investigation levels are protective of environmental values only and are not to be used in setting drinking water guideline values which are derived according to different methods – human health effects can differ from effects observed for aquatic organisms. *Note 1:* The 99% species protection level for PFOS is close to the level of detection. Agencies may wish to apply a 'detect' threshold in such circumstances rather than a quantified measurement. *Note 2*: The draft guidelines may not account for effects which result from the biomagnification of toxicants in air-breathing animals or in animals which prey on aquatic organisms
0.13 µg/L	220 µg/L	95% species protection– slightly to moderately disturbed systems	
2 µg/L	632 µg/L	90% species protection– highly disturbed systems	
31 µg/L	1824 µg/L	80% species protection– highly disturbed systems	
Marine water			
0.29 µg/L	3000 µg/L	99% species protection– high conservation value systems	Draft default guideline values prepared for CRC CARE, version as at July 2016. *Note 1:* there are fewer data available for marine species than for freshwater. *Note 2:* sorption to marine sediments is expected to be much stronger than for freshwater.
7.8 µg/L	8500 µg/L	95% species protection– slightly to moderately disturbed systems	
32 µg/L	14,000 µg/L	90% species protection– highly disturbed systems	
130 µg/L	22,000 µg/L	80% species protection– highly disturbed systems	
Soil – not taking into account water transport			
6.6 mg/kg	1 mg/kg	National parks/areas with high ecological values	Draft default guideline values prepared for CRC CARE, version as at July 2016, to be used ONLY if hydrogeology of the site assessed and levels in pore water, groundwater or nearby surface water sustaining aquatic life (i.e. within 10km) are also tested if present. *Note 1:* waste soil containing above 50 mg/kg of PFOS and PFOA must be managed in accordance with Stockholm Convention requirements.
32 mg/kg	29 mg/kg	Urban residential/public open spaces	
60 mg/kg	81 mg/kg	Commercial and industrial spaces	

4.2. Diagnose

Diagnosis involves site specific risk assessment. This will include consideration of the broader context and particulars of the site being examined. This, in turn, will involve a detailed ecological risk assessment and associated risk calculations.

The context for application of the water quality and soil guideline values is particularly relevant in the diagnosis stage.

4.2.1. Context for application of water quality investigation levels

The Water Quality Guidelines state the following:

> *Water resource management is best implemented by integrating national, state and regional powers and responsibilities, and by using complementary water quality planning and policy tools.*

The process for applying the water quality guidelines includes the following steps:

Step 1) Document current understanding

Step 2) Define primary management aims

Step 3) Determine relevant indicators, taking into account multiple lines of evidence

Step 4) Determine the Water Quality Guidelines preferably using existing site specific information or, if this is not available using the national default guideline values such as those provided for PFOS and PFOA in this Guidance

Step 5) Define draft water quality objectives and articulate the specific water quality to be achieved

Step 6) Define draft water quality objectives for the water body

Step 7) Determine if the water quality objectives are met

Step 8) Consider refining the water quality objectives

Step 9) Assess alternative management strategies

In terms of application of the default guideline values, the Water Quality Guidelines state:

> *In some cases, the water quality needed to support the desired environmental value may not be attainable immediately. Where restoration is possible, there may be costs associated with restoring the level of quality that the community desires. Once full costs of restoration are known, the community may choose to accept a lower quality based on a full cost–benefit analysis. The environmental values and management goals for a particular area need to be well thought out, with full knowledge of the implications to the broader community. This is a process involving broad consultation with representatives of the whole community, with the aim of reaching a desirable, practical and agreed set of management goals, and hence water quality objectives.*
>
> *In the absence of a clear and agreed set of environmental values for a particular water resource, managers should take a conservative approach and assume that all appropriate environmental values apply to the resource, by default.*

According to the Water Quality Guidelines, default guideline values (which now include draft technical guideline values for PFOS and PFOA) have been derived to provide some confidence that there will be no significant impact on the environmental values if they are achieved. Exceedance of the guidelines indicates that there is potential for an impact to occur (or to have occurred), but it should be noted that this does not provide any certainty that an impact will occur (or has occurred).

Box 3: Case study – 99% species protection level for PFOS

The draft Default Guideline Value (DGV) for PFOS in freshwater is 0.00023 µg/L. This value was derived using the agreed technical methodology developed for the Australian and New Zealand Guidelines for Fresh and Marine Water Quality. The guideline values are not intended to specify species protection concentrations for air-breathing animals which live in aquatic ecosystems, or prey on aquatic organisms. The DGVs for aquatic ecosystems may not account for effects which result from the biomagnification of toxicants such as PFOS in air breathing animals.

How were the guideline values derived?

High reliability DGVs for toxicants in aquatic ecosystems are derived by the application of a standard species sensitivity distribution to the most reliable chronic aquatic toxicity data from multiple trophic levels. The values for PFOS were derived from the results of eighteen reliable chronic toxicity studies on test species comprising algae, crustaceans, insects, fish and amphibians. Some of the key results from these studies and the species sensitivity distribution for PFOS are presented in Appendix C.

What impacts are seen in chronic aquatic toxicity tests for PFOS?

The most sensitive species in the range of reliable results identified for PFOS is the zebra fish (*Danio rerio*). This is a standard test species that is used in the assessment of the aquatic hazards of chemicals in Australia and overseas. The results from this test showed multigenerational effects from exposure to PFOS at an exposure concentration of 0.734 µg/L, which included effects on the growth, length and weight of male zebra fish. Reliable chronic toxicity tests on other species of fish demonstrated adverse effects on the offspring of fish exposed to PFOS at concentrations in the range of 1 to 10 µg/L.

Why is the 99% protection level three orders of magnitude lower than the toxicity result for the most sensitive species

The species sensitivity distribution takes into account that some species are particularly sensitive to a given toxicant, and there are relatively few of these species compared to the total number of species in an aquatic ecosystem. The 95% species protection level derived for PFOS is 0.13 µg/L, which is of comparable magnitude to the measured toxicity values for the most sensitive test species. When the standard species distribution model is applied, an extra 4% of species protection requires an exposure concentration that is lower by three orders of magnitude to take these sensitive species into account.

What are the potential broader consequences for the species or ecosystem of impacts at this level?

For toxicants that are *not* bioaccumulative, a 95% species protection level is recommended in the Guidelines for a *slightly to moderately* disturbed aquatic ecosystem. However, to achieve a 95% species protection level for bioaccumulative toxicants such as PFOS, the 99% species protection level is recommended to account for the increased level of concern resulting from effects such as secondary poisoning. Therefore, when the 95% species protection guideline value is adopted, no more than 5% of species in an aquatic ecosystem are expected to be adversely affected.

Note: for PFOS, highly or even slightly modified systems exist or are common and hence this loss may have already occurred already ether through the impacts of PFOS or other toxicants that may have or be impacting the ecosystem.

This Guidance recognises that limited information is currently available on multi-generation effects of PFOS and PFOA on aquatic organisms as can often be the case with emerging contaminants.

Such studies can be key in the derivation calculations for default water quality guideline values and this will be an important area for attention as new studies become available. The Water Quality Guidelines and this Guidance allow for rolling review to accommodate new findings (see Section 6).

The Guidance notes that derivation of default water quality guideline values for very persistent and highly bioaccumulative toxicants such as PFOA and PFOS pose significant technical challenges and that this is leading to areas where there is contested professional judgement. Following agreement to the Guidance, additional steps will be taken to clarify the default guideline values for PFOS and PFOA based on the best available data and scientific expertise. For example, this could involve bringing technical experts together to focus on areas of greatest significance for assessing the direct and indirect effects of PFOS and PFOA on aquatic ecosystems and potentially commissioning work that could focus on the areas considered to be of highest species sensitivity such as multi-generation studies.

This Guidance also notes that default water quality guideline values are non-enforceable and non-regulatory and do not establish clean up levels or pass/fail levels but are intended to provide technical information to state and territory agencies and assist water catchment managers make informed choices.

4.2.2. Context for application of soil investigation levels

This Guidance provides two soil investigation levels. The soil investigation level in Table 1 has been derived for CRC CARE through the application of Australia's ASC NEPM methodology. Soil investigation levels in Table 2 are taken from the Canadian Federal Environmental Quality Guidelines.

There are important qualifications on the use of these investigations levels. According to the ASC NEPM the soil investigation levels in Table 1:

> *[The method applies] principally to contaminants in the top 2 m of soil at the finished surface/ground level which corresponds to the root zone and habitation of many species*[*] .

The ASC NEPM further notes[†]:

> *The methodology was developed to protect soil processes, soil biota (flora and fauna) and terrestrial invertebrates and vertebrates and is presented in this Schedule.*

and that

> *The methodology aims to protect soil and terrestrial species and soil processes. Potential off-site migration and its potential impacts are not included in the methodology.*

Given the mobility of PFOS and PFOA in water (surface water, ground water and soil pore water) it is essential that migration is taken into account when investigating a site contaminated with PFOS and PFOA. An assessment that incorporates both the water quality (fresh and marine) guidelines and the soil guidelines in Table 1 will do this. Application of the soil guidelines in Table 1 in a site assessment alone will not achieve this.

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[*] Guideline on Investigation Levels for Soil and Groundwater, Schedule B1 ASC NEPM

[†] Schedule B5b, ASC NEPM

The Canadian Federal Environmental Quality Guidelines in Table 2 provide site assessors with further soil investigation level options that also take into account soil and water and off-site migration factors and take an initial step towards identifying the influence of soil type on transport behaviour of the PFOS. The Canadian Guidelines also take into account bioaccumulation, particularly to secondary consumers (which in Australia could include echidnas, birds and native marsupials that eat plants or invertebrates living on the site).

Table 2: Soil – taking into account water transport

PFOS	PFOA	Exposure scenario	Source and Comments
0.010 mg/kg	-	Agricultural land	2015 Canadian Federal Environmental Quality Guidelines note that the identified concentrations are the concentrations in soil that are expected to protect against potential impacts on freshwater life from PFOS originating in soil that may enter the groundwater and subsequently discharge to a surface water body. In Australia, they are to be used when levels in pore water, groundwater or nearby surface water sustaining aquatic life (i.e. within 10km) are not tested. Where the distance to the nearest surface water body is greater than 10kms, application of the pathway is to be evaluated on a case-by-case basis, considering site-specific conditions. Levels for PFOA are being developed. The decision as to which values to apply should be determined on a site by site basis in the context of the local risk assessment.
0.010 mg/kg	-	Residential and parkland	
0.130 mg/kg	-	Commercial and industrial – coarse soil	
0.190 mg/kg	-	Commercial and industrial – fine soil	

The Canadian Guidelines were derived considering direct soil contact, the protection of primary, secondary and tertiary consumers exposed to PFOS via soil and food ingestion, the protection of freshwater life, the protection of livestock watering and irrigation water among other pathways.

For PFOS, the soil investigation levels included in Table 2 are to be used when a water assessment at the site is not undertaken, noting the guidance regarding the proximity of water sustaining aquatic life. Soil investigation levels for PFOS included in Table 1 are to be used only when a water assessment is undertaken. For PFOA, the water and soil investigation levels in Table 1 are to be applied.

4.3. Respond

4.3.1. Management of impacted sites

The desired outcome of management actions at PFOS and PFOA contaminated sites is to ensure that environmental exposure and through it, harm, is reduced. Management actions should be risk-based and prioritised to undertake targeted actions that most effectively minimises further exposure of the environment to unacceptable levels of contaminants, commensurate with the risk posed to human health, the environment and environmental values.

Where management is proposed for residual contamination and not remediation, the Commonwealth agency should justify the approach and ensure the management measures are appropriate to the current and/or future use or development of the site.

4.3.2. Remediation and management

Assessment of site contamination should be undertaken to the extent necessary to provide sufficient information to enable risk-based decision-making. If the risk assessment process identifies unacceptable risks to the environment, environmental values and/or human health, early action (that is, clean-up and/or management) will be required to mitigate those risks.

In the first instance, appropriate site management strategies should be determined. The risk-based decision on whether and when clean-up is required, and the extent of any clean up, should be based on the outcome of prior site-specific assessment and analysis taking in to account the range of investigation levels provided in this Guidance (e.g. the appropriate species protection levels). Health and ecological risk assessments are the primary drivers for making site management decisions. Other considerations such as practicality, timescale, effectiveness, cost, sustainability and associated ecological risk assessment are also relevant (ASC NEPM, 2013)[5].

The ASC NEPM provides in Section 6(16) that the preferred hierarchy of options for site clean-up and/or management should be taken into account when assessing a site (see Box 4) (ASC NEPM, 2013)[6].

Box 4: Preferred Hierarchy of Options for Site Clean-Up as defined in the ASC NEPM

Most preferred:

- on-site treatment of the contamination so that it is destroyed or the associated risk is reduced to an acceptable level; and
- off-site treatment of excavated soil (or contaminated water), so that the contamination is destroyed or the associated risk is reduced to an acceptable level, after which soil is returned to the site.

If the above is not practicable:

- consolidation and isolation of the soil (or contaminated water) on site by containment with a properly designed barrier; and
- removal of contaminated material to an approved site or facility followed, where necessary, by replacement with appropriate material.

Where the assessment indicates remediation would have no net environmental benefit or would have a net adverse environmental effect:

- implementation of an appropriate management strategy.

When deciding which option to choose, the sustainability (environmental, economic and social) of each option should be considered, in terms of achieving an appropriate balance between the benefits and effects of undertaking the option.

In cases where no readily available or economically feasible method is available for remediation, it may be possible to adopt appropriate regulatory controls or develop other forms of remediation.

Note that the appropriateness of any particular option will vary depending on a range of local factors. Acceptance of any specific option or mix of options in any particular set of circumstances is therefore a matter for the responsible decision-maker/agency.

A Remedial Action Plan (RAP) should be developed for complex remediation. The RAP is usually based on information from the preliminary site history and detailed investigation stages and should outline what remediation measures are required to address any indentified contamination in order to render the site fit for purpose. The key components of a RAP are:

- Identification of the key stakeholders and responsibilities
- Development of remediation goals and clean-up acceptance criteria
- Assessment of the remediation options and determination of the preferred remediation option
- Documentation of the remediation methodology including any regulatory permit/licensing requirements
- Development of an Environmental Management Plan
- Defining the validation program to demonstrate the successful completion of the remediation, including monitoring.

Establishing water quality objectives is needed to inform the management of water resources. These specific water quality targets should be negotiated between all relevant stakeholders and become an indicator of management performance.

In accordance with the NWQMS, management of water resources should focus on continual improvement. Where water quality does not meet the water quality objectives it might be necessary to set intermediate targets. In catchments where water quality does not meet the water quality objectives, consideration should still be given to the need to manage sources of contamination, to ensure that over time ambient water quality meets the water quality objectives.

Clean-up and/or management options for particular sites will be determined by site-specific factors, including the medium that is contaminated, the site's hydrogeology, the range of contaminants that require remediation, and access to the site. For example, containment options are often impractical where large volumes of stormwater or groundwater are involved.

Due to the chemical properties of PFOS and PFOA currently, there is limited availability of proven field scale solutions for remediation. Internationally, solutions are being trialled but are still undergoing evaluation of their success. Within Australia, Commonwealth entities such as the Department of Defence and Airservices Australia are trialling a number of remediation technologies as outlined in Box 5. These trials are in the initial research stage and as such, are not yet proven solutions that can be applied on a broad, field scale basis.

Box 5: Examples of remediation technologies subject to current trials (June 2016)

Stabilisation/Immobilisation

Stabilisation involves mixing particular materials into affected soil which will ensure the compounds are less likely to spread.

Solidification

This involves mixing a binding agent with affected soil to bind the compounds in a solid block, potentially trapping it in place.

***In-situ* Oxidation**

This method involves applying heat and chemicals to break down the PFOS and PFOA into more environmentally friendly forms.

***In-situ* Reduction**

This method involves injecting chemicals into affected soil or groundwater to reduce concentrations of PFOS and PFOA.

Pump and Treat

This method involves extracting contaminated groundwater and treating (which may include adsorption onto appropriate materials and destroying the extracted PFOS and PFOA.

Foam Fractionation / Separation

This involves a method to generate foam from affected groundwater. The foam containing PFOS and PFOA can then be collected from the surface and removed to a treatment facility.

Ultrasonification / Sonochemistry

This involves using intense ultrasonic-wave energy to change the compounds into more environmentally friendly forms.

4.3.3. Waste, Disposal and Reuse

Remediation of, or construction on, Commonwealth sites may lead to soil waste, construction and infrastructure waste and waste water. Disposal of waste that may be generated, such as to state/territory landfills or sewage treatment plants, will need to be done in consultation and agreement with the relevant state/territory agency.

In disposing or reusing contaminated wastes or containing on site, Commonwealth agencies should:

- only use appropriately secure facilities that are capable of monitoring and remediating releases (such as facilities that have in place leachate management systems)[*]. This should be done with regulatory approval, or in situations where such approval is not required, only where it can be demonstrated such disposal or reuse will not cause unacceptable risk to the environment;
- where appropriate, stabilise material to prevent leaching; and
- adhere to international requirements where relevant (refer Box 6).

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[*] The Stockholm Convention on Persistent Organic Pollutants and the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal provide guidance in this regard although the exact process for identifying such facilities is left to the individual country or jurisdictions to determine.

Box 6: International requirements for wastes containing PFOS above 50 mg/kg

Consistent with agreed international approaches, if waste material contains above 50 mg/kg PFOS the waste must be treated using a technique that will destroy or irreversibly transform the PFOS. When destruction or irreversible transformation does not represent the environmentally preferable option due to environmental or human health impacts, then the PFOS in the contaminated soil or sediment should:

- be either immobilised or its mobility substantially reduced, for example, using emerging treatment/immobilisation technologies; or
- be disposed of in highly secure specially engineered landfill or, when commercially available in Australia, permanent storage in underground mines and formations, consistent with Section IV.G.3 of the Basel Convention's *General technical guidelines on the environmentally sound management of waste consisting of, containing or contaminated with persistent organic pollutants*.

The appropriate form of secure containment must be negotiated with each relevant state or territory regulator.

It is noted that Section IV.G.3 of the Basel Convention's *general technical guidelines on the environmentally sound management of waste consisting of, containing or contaminated with persistent organic pollutants* also applies to construction and demolition wastes such as mixtures of, or separate fractions of, concrete, bricks, tiles and ceramics.

Commonwealth agencies should seek, in consultation with the states and territories, to ensure that the chosen disposal method does not lead to unacceptable environmental release of PFOS or PFOA. Agencies should develop strategies to monitor and respond to potential environmental releases in the event of disposal or containment on Commonwealth lands.

The document *Managing PFC Contamination at Airports – Interim Contamination Management Strategy and Decision Framework*, June 2015, includes principles and guidance on beneficial reuse for airports. This guidance could be considered by site managers in determining potential reuse strategies provided this is done in the context of the present Guidance. In particular the Basel and Stockholm Conventions' limit of 50 mg/kg for PFOS should be applied in determining how the waste soil should be managed.

4.3.4. Treatment Technologies

This Guidance is not prescriptive of treatment technologies that may be appropriate. However, treatment technologies employed should be environmentally sound and be consistent with the Stockholm Convention Article 6 requirements and the Basel Convention's General Technical Guidelines where applicable.

While there are presently limited proven commercial treatment (destruction) options for some forms of PFOS and PFOA containing waste including AFFF concentrate, fire water and other forms of contaminated water, options for treatment (destruction) of PFOS and PFOA contaminated debris such as soil and concrete are still emerging. Further, some commercial *in-situ* treatments that can be demonstrated to be effective based on trials are yet to be accepted from a regulatory perspective. There are options for immobilisation of PFOS and PFOA in soils which should be explored as part of the site remediation action plan as appropriate.

Agencies may wish to refer to material prepared by CRC CARE, the WA PFAS guidelines (Government of WA Department of Environmental Regulation, 2016)[7], the document *Managing PFC Contamination at Airports – Interim Contamination Management Strategy and Decision Framework*, May 2015 and the Basel Technical Guidelines for guidance on treatment technologies.

4.3.5. Planning and delivery of site works prior to completion of detailed site assessment

This Guidance recognises that completion of detailed site assessments and the development of appropriate long term management strategies can take time. In the context of an agency's national program for assessment of site contamination and the time required to complete a detailed site investigation, sites may require works to be undertaken for operational reasons in the interim.

Should an action on, or impacting upon Commonwealth land, and/or an action by a Commonwealth agency need to be undertaken prior to the completion of a detailed site assessment then a 'self-assessment' process must be undertaken to determine whether or not the action is likely to have a significant impact on the environment. The self-assessment should be as objective as possible and based on sufficient information to make an informed judgment. In deciding whether or not the proposed action is likely to have a significant impact you must consider:

a) The environmental context

b) Potential impacts likely to be generated by the action, including indirect consequences of the action

c) Whether mitigation measures will avoid or reduce these impacts, and

d) Taking into consideration the above, whether the impacts of the action are likely to be significant.

If an action is being planned in an area with the potential to have PFOS and/or PFOA contamination you should consider the following:

- Does the site have the potential to be contaminated?
    - Targeted sampling: As part of due diligence to inform early works planning, targeted sampling should be undertaken of soil and, where applicable, downstream runoff in surface and stormwater and groundwater water and leachate to determine the levels of PFOS and/or PFOA in the location of the planned works.
- What impacts, both direct and indirect, could result from the action?
- Could this contamination exceed the thresholds outlined in Section 4.4 and in Box 6 of this Guidance?
- What measures could be taken to reduce the level of impact or contamination?

An action would require referral under the EPBC Act if the proposed action were likely to:

- increase the extent or levels of PFOS/PFOA contamination on the property
- increase the bioavailability of PFOS / PFOA on the property

- expedite the rate of migration of existing PFOS/PFOA contamination, either within or outside the property

Substantial penalties apply for taking an action that has, will have or is likely to have a significant impact without approval under the EPBC Act.

Note that Sections 43A (the prior authorisation exemption) and 43B (the continuing use provision) of the EPBC Act exempt certain activities that would otherwise require approval under Part 9 of the Act. For further information on the self-assessment process please refer to: (a) Significant impact guidelines 1.1 Matters of National Environmental Significance the *Environment Protection and Biodiversity Conservation Act 1999 Significant impact guidelines*; and (b) *1.2:Actions on, or impacting upon, Commonwealth land, and actions by Commonwealth agencies.*

5. Human health considerations

In June 2016, enHealth updated a guidance note on PFOS and PFOA reconfirming that human exposure to these chemicals should be minimised as a precaution and in June 2016 also released Australian interim health reference values for PFOS and PFOA (see NSW Health, 2016). Applying this Guidance may play a complementary role in minimising human exposure to these chemicals through the environment by reducing environmental exposure.

6. Review

This Guidance will be updated as additional information becomes available. Significant new and credible data such as on multigeneration effects, significant findings on disease (including cancer), or setting of new standards overseas and in Australia will trigger a review of this Guidance and its investigation levels. Note that, at this stage, the Water Quality Guidelines are expected, along with default guideline values for other substances, to be subject to a rolling review process and that such a review can be initiated following the emergence of credible, new scientific data.

Guidance Endnotes

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[1] ASC NEPM, 2013, National Environment Protection (Assessment of Site Contamination) Measure 1999, available at https://www.legislation.gov.au/Details/F2013C00288/Download

[2] ANZECC and ARMCANZ, 2000, Australian and New Zealand Guidelines for Fresh and Marine Water Quality, available at https://www.environment.gov.au/system/files/resources/53cda9ea-7ec2-49d4-af29-d1dde09e96ef/files/nwqms-guidelines-4-vol1.pdf

[3] NSW Health, 2016, PFOS and PFOA, http://www.health.nsw.gov.au/environment/factsheets/Pages/pfos.aspx

[4] PFAS analysis in water for the Global Monitoring Plan of the Stockholm Convention, April 2015, http://www.unep.org/chemicalsandwaste/Portals/9/POPs/Guide%20PFAS%20water_UNEP%202015.pdf

[5] ASC NEPM, 2013, National Environment Protection (Assessment of Site Contamination) Measure 1999, Schedule B1, Section 2.2, available at: https://www.legislation.gov.au/Details/F2013C00288/Download

[6] ASC NEPM, 2013, National Environment Protection (Assessment of Site Contamination) Measure 1999, Section 6(16), available at: https://www.legislation.gov.au/Details/F2013C00288/Download

[7] Government of WA Department of Environmental Regulation, 2016, Interim Guideline on the Assessment and Management of Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS), available at https://www.der.wa.gov.au/images/documents/your-environment/contaminated-sites/guidelines/Guideline-on-Assessment-and-Management-of-PFAS-.pdf

APPENDIX A – Snapshot of International Standards for PFOS and PFOA

Table A1 includes international health and environmental levels and standards for PFOS and Table A2 for PFOA which are presented, where appropriate, in the same units of micrograms per litre (µg/L) or micrograms per kilogram (µg/kg) for easy comparison. The entries are ordered by date.

It is noted that different countries derive levels using a range of methodologies and goals. For example, the European environment quality standard of PFOS in surface waters is expressed as an annual average value that is intended to ensure the long-term quality of the aquatic environment.

Note that this Guidance is directed towards environmental management. The health levels and standards below are simply included in the table for easy reference. Health levels and standards in Australia are set by enHealth and the National Health and Medical Research Council.

Table A1 – International and national levels and standards for PFOS

PFOS Level	Description	Reference
Water, ecological		
	Australian and New Zealand Water Quality Guidelines, final draft PFOS Default Guideline Values	NWQMS, 2015
0.00023 µg/L	*99% species protection-high conservation*	As above
0.13 µg/L	*95% species protection–slightly to moderately disturbed systems*	As above
2 µg/L	*90% species protection–highly disturbed*	As above
31 µg/L	*80% species protection–highly disturbed*	As above
6 µg/L	Canada: federal environmental quality guidelines (FEQGs) for water	Environment Canada, 2015[1]
0.00065 µg/L	EU Directive 2013/39/EU: annual average Environmental Quality Standard (AA-EQS) for inland surface waters to be met by the end of 2027	The European Parliament and the Council of the European Union, 2013[2]
0.00013 µg/L	EU Directive 2013/39/EU: AA-EQS other surface waters (i.e. **marine**)	As above
36 µg/L	EU Directive 2013/39/EU (and RIVM): Maximum Acceptable Concentration- Environmental Quality Standard, inland surface waters **fresh water**	The European Parliament and the Council of the European Union, 2013 (and Moermond et al, 2010)
7.2 µg/L	EU (and RIVM): Maximum Acceptable Concentration - Environmental Quality Standard, other surface waters (i.e. **marine**)	As above
0.023 µg/L eco water	Netherlands – RIVM: Maximum Permissible Concentration (MPC – levels at which no negative effects expected) **direct exposure**	Moermond et al, 2010
0.0026 µg/L sp water	Netherlands – RIVM: Maximum Permissible Concentration **secondary poisoning** (sp)	As above
0.0046 µg/L eco marine	Netherlands – RIVM: Maximum Permissible Concentration direct exposure **ecological marine**	As above

PFOS Level	Description	Reference
0.00053 µg/L sp marine	Netherlands – RIVM: Maximum Permissible Concentration **secondary poisoning marine**	As above
DIET – CONSUMPTION OF FISH / IN BIOTA		
4.6 µg/kg wet weight (ww) food	Canada: federal environmental quality guidelines (FEQGs) for wildlife diet, **mammalian**	Environment Canada 2015[3]
8.2 µg/kg ww food	Canada: federal environmental quality guidelines (FEQGs) for wildlife diet, **avian**	As above
30 ng/kg bw/day (0.03 µg/kg bw/day)	Agency for Toxic Substances and Disease Registry, Minimal Risk Levels (MRLs), 2015, draft PFOS levels.	Agency for Toxic Substances and Disease Registry 2015[4]
30 ng/kg bw/day	TDI 2015	Danish Ministry of the Environment EPA, 2015
20 ng/kg bw/day	TDI 2014	US EPA 2014
9.1 µg/kg ww	Environmental Quality Standard in biota (fish)	The European Parliament and the Council of the European Union, 2013
0.00065 µg/L freshwater	Netherlands – RIVM: Maximum Permissible Concentration human exposure, via consumption of fish that have been exposed at this level – value allows humans to consume 115 g fish per day without exceeding 10% of the TDI.	Moermond et al 2010
150 ng/kg bw/day (0.15 µg/kg bw/day)	European Food Safety Agency 2008 – currently under **revision** as of October 2015.	EFSA, 2008[5]
0.15 µg/kg bw/day	Australian Tolerable Daily Intake (µg/kg/d)	enHealth, June 2016
SOIL		
	Canada: federal soil quality guidelines (FSQGs)	Environment Canada, 2015
10 µg/kg soil	*Agricultural and residential/parkland – value for soil ingestion by a secondary consumer*	As above
130 µg/kg coarse soil	*Commercial and industrial – value expected to protect against potential impacts to freshwater life from PFOS originating in soil that may enter groundwater and then discharge to surface water*	As above
190 µg/kg fine soil	*Commercial and industrial – value expected to protect against potential impacts to freshwater life from PFOS originating in soil that may enter groundwater and then discharge to surface water*	As above
390 µg/kg soil	Denmark: health based quality criterion for soil	Danish Ministry of the Environment EPA, 2015
1,100 µg/kg	USA: Minnesota draft soil reference level **residential/recreational**	Minnesota Pollution Control Agency, June 2015[6]
14,000 µg/kg	USA: Minnesota draft soil reference level **commercial/industrial**	As above
6000 µg /kg	USA: EPA Region 4 – residential soil screening level	US EPA Region 4, 2009[7]

PFOS Level	Description	Reference
2.3 µg/kg soil	RIVM: Maximum Permissible Concentration	Bodar et at, 2011[8]
373 µg/kg soil	**Earthworms** Predicted No Effect Concentration: a factor of 1000 is applied to the earthworm LC_{50} of 373 mg/kg dwt, giving the PNEC of 373 µg/kg soil.	Brooke et al, 2004[9].
373 µg/kg soil	**Earthworms** Predicted No Effect Concentration: a 14 day LC_{50} for earthworms from Brooke et al (2004) – 373 mg/kg – was used and application of a safety factor of 1,000 provided the PNEC of 373 µg/kg soil	UK Environment Agency Merrington et al, 2009[10]
<39 µg/kg soil	**Plants** Predicted No Effect Concentration: a factor of 100 is applied to the long term growth plant test result of 'no observed effect' below 3.91 mg/kg giving the PNEC of 39 µg/kg soil	As above
280 µg/kg soil	**Plants** EC_{10} of 27.79 mg kg-1 dry weight. Since data are only available for two trophic levels, an assessment factor of 100 is justified. This results in a PNEC of 0.28 mg kg-1.	As above
100 ng/g soil (i.e. 100 µg/kg dw)	Norway: guideline value for PFOS in soils based on effect studies on earthworms	Stubberud, 2006[11]
SEWAGE SLUDGE		
	Some countries have set specific contaminant thresholds for land application of sewage sludge. In Germany, for example, a limit of 0.1 mg/kg has been set for PFOS concentration in fertilizers. See Stockholm Convention document.	Rotterdam Convention, May 2014[12]
39 µg/kg ww 46 µg/kg dry weight	UK: Environment Agency stipulates that for sewage sludge disposal, PFOS concentrations should not exceed these levels to be protective of soil organisms.	This original reference has not yet been identified but is referenced in Jimmy Seow, June 2013[13]
100 µg/kg (0.1 ppm)	Austria: limit for sewage sludge used on agricultural soils – limit values of 100 µg PFOS+PFOA /kg (0.1 ppm)	European Commission ESWI, 2011[14]
5000 µg/kg	EU proposal: 10 ppm and 50 ppm as a transitional alternative. (Restricted option, with stricter limitation on sewage sludge at 5ppm.)	As above

NOTE: the international standard and definition for low POP content for wastes consisting of, containing or contaminated with PFOS, its salts and PFOSF was set at 50 mg/kg in May 2015. This is explicitly considered by the Stockholm Convention to apply to the requirements under Article 6:

> *Parties to the listing of particular persistent organic pollutants are to] take appropriate measures so that such wastes, including products and articles upon becoming wastes, are disposed of in such a way that the persistent organic pollutant content is destroyed or irreversibly transformed so that they do not exhibit the characteristics of persistent organic pollutants or otherwise disposed of in an environmentally sound manner when destruction or irreversible transformation does not represent the environmentally preferable option or the persistent organic pollutant content is low, taking into account international rules, standards, and guidelines [Article 6.1 (d)(ii)]*

Table A2 – international and national levels and standards for PFOA

PFOA Level	Description	Reference
DIET – CONSUMPTION OF FISH / IN BIOTA		
1.5 µg/kg/d	Australian Tolerable Daily Intake (µg/kg/d)	As above
WATER, ecological		
	Australian and New Zealand Water Quality Guidelines, draft PFOA values	NWQMS, 2015
19 µg/L	*99% species protection-high conservation*	As above
220 µg/L	*95% species protection–slightly to moderately disturbed systems*	As above
632 µg/L	*90% species protection–highly disturbed*	As above
1,824 µg/L	*80% species protection–highly disturbed*	As above
SOIL		
1,100 µg/kg	USA: Minnesota draft soil reference level **residential/recreational***[*]*	Minnesota Pollution Control Agency, June 2015
14,000 µg/kg	USA: Minnesota draft soil reference level **commercial/industrial**	As above
1,300 µg/kg	Denmark: health based quality criterion for soil	Danish Ministry of the Environment EPA, 2015
1,300 µg/kg (PFOA) 390 µg/kg (PFOS) 390 µg/kg (PFOSA)	Composite soil quality criteria for PFOA, PFOS and PFOSA: PFOA. *Note the Danish reference notes that the addition of the concentration/limit value ratios for PFOA, PFOS and PFOSA should be kept below the value of 1.*	As above
16,000 µg/kg	USA: EPA Region 4 – residential soil screening level **residential**	EPA Region 4, 2009

Appendix A endnotes

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[1] Environment Canada, 2015, Federal Environmental Quality Guidelines: Perfluorooctane Sulfonate (PFOS), National Guidelines and Standards Office, Gatineau, Quebec

[2] The European Parliament and the Council of the European Union, 2013, Directives: Directive 2013/39/EU Of the European Parliament and of the Council of 12 August 2013 amending Directives 2000/60/EU and 2008/105/EC as regards priority substances in the field of water policy, 2013, available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:226:0001:0017:EN:PDF

[3] Environment Canada, 2015, Federal Environmental Quality Guidelines: Perfluorooctane Sulfonate (PFOS), National Guidelines and Standards Office, Gatineau, Quebec, obtained by personal communication

[4] Agency for Toxic Substances and Disease Registry, 2015, Minimal Risk Levels (MRLs), available at http://www.atsdr.cdc.gov/mrls/pdfs/atsdr_mrls.pdf

[5] EFSA, 2008, Perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA) and their salts, available at http://www.efsa.europa.eu/sites/default/files/scientific_output/files/main_documents/653.pdf

[6] Minnesota Pollution Control Agency, June 2015, Draft Remediation Soil Reference Value Spreadsheet, available at www.pca.state.mn.us/index.php/view-document.html?gid=21776

[7] US EPA Region 4, 2009, referenced from: US EPA, 2014, Emerging Contaminants – Perfluorooctane Sulfonate (PFOS) and Perfluorooctanoic Acid (PFOA), available at

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[*] The Minnesota Pollution Control Agency spreadsheet may be used for the following purposes: risk evaluation using the pre-determined exposure assumptions; and site specific risk assessment using site specific exposure assumptions.

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http://nepis.epa.gov/Exe/ZyNET.exe/P100LTG6.TXT?ZyActionD=ZyDocument&Client=EPA&Index=2011+Thru+2015&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C11thru15%5CTxt%5C00000014%5CP100LTG6.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=p%7Cf&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL

[8] C Bodar, J Lijzen, C Moermond, W Peijnenburg, E Smit, E Verbruggen, M Janssen, 2011, Proposal for environmental risk limits for PFOS in soil and groundwater (Advies risicogrenzen grond en grondwater voor PFOS), available at http://www.rivm.nl/en/Documents_and_publications/Scientific/Reports/2011/augustus/Proposal_for_environmental_risk_limits_for_PFOS_in_soil_and_groundwater

[9] D Brooke, A Footitt, TA Nwaogu, 2004, Environmental Risk Evaluation Report: Perfluorooctane sulphonate (PFOS), available at http://www.pops.int/documents/meetings/poprc/submissions/Comments_2006/sia/pfos.uk.risk.eval.report.2004.pdf

[10] UK Environment Agency G Merrington, M Crane, B Barnes, 2009, Review of human health and environmental risks associated with land application of mechanical - biological treatment outputs (Rev1) Report: SC030144/R5, available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/291752/scho1209brqe-e-e.pdf

[11] Stubberud, 2006, referenced from: Norwegian Pollution Control Authority, 2008,Screening of polyfluorinated organic compounds at four fire fighting training facilities in Norway, available at http://www.miljodirektoratet.no/old/klif/publikasjoner/2444/ta2444.pdf

[12] Rotterdam Convention, May 2014, Draft technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with perfluorooctane sulfonic acid (PFOS), its salts and perfluorooctane sulfonyl fluoride (PFOSF), available at http://www.basel.int/Implementation/POPsWastes/TechnicalGuidelines/tabid/2381/Default.aspx

[13] Jimmy Seow, June 2013, Fire Fighting Foams with Perfluorochemicals – Environmental Review, available at http://www.hemmingfire.com/news/fullstory.php/aid/1748/The_final_definitive_version_of__91Fire_Fighting_Foams_with_Perfluorochemicals__96_Environmental_Review_92,_by_Dr_Jimmy_Seow,_Manager,_Pollution_Response_Unit,_Department_of_Environment_and_Conservation_Western_Australia.html

[14] European Commission ESWI, 2011, Final Report “Study on waste related issues of newly listed POPs and candidate POPs”, available at http://ec.europa.eu/environment/waste/studies/pdf/POP_Waste_2011.pdf

APPENDIX B – Derivation of Water Quality Default Guideline Values for PFOS

The following extracts are taken from the default guideline values for PFOS in freshwater:

Ecotoxicological results

A selection of the freshwater PFOS toxicity data is noted in Table B1.

Table B1 – Selection of toxicity data values used to derive the default guideline values for PFOS

Taxonomic group	Species	Life stage	Duration (h)	Type (acute/ chronic)	Toxicity measure	Toxicity value (μg/L)	Estimated chronic NOEC (μg/L)
Crustacean	*Daphnia magna*	Neonates	504	Chronic	NOEC	8	8
Insecta - Odonata	*Enallagma cyathigerum*	Larvae	2,880	Chronic	NOEC	7.95	7.95
Fish	*Danio rerio*	Eggs	2,160	Chronic	LOEC	0.734	0.294
	Oryzias latipes	Eggs	192	Chronic	LOEC	10	4
	Xiphorous helleri	Fry/Larvae	2,160	Chronic	LOEC	100	40
	Pimephales promelas	Fry/Larvae	576	Chronic	NOEC	300	300

Species sensitivity distribution

The species sensitivity distribution of the freshwater PFOS toxicity data is shown in Figure C1.

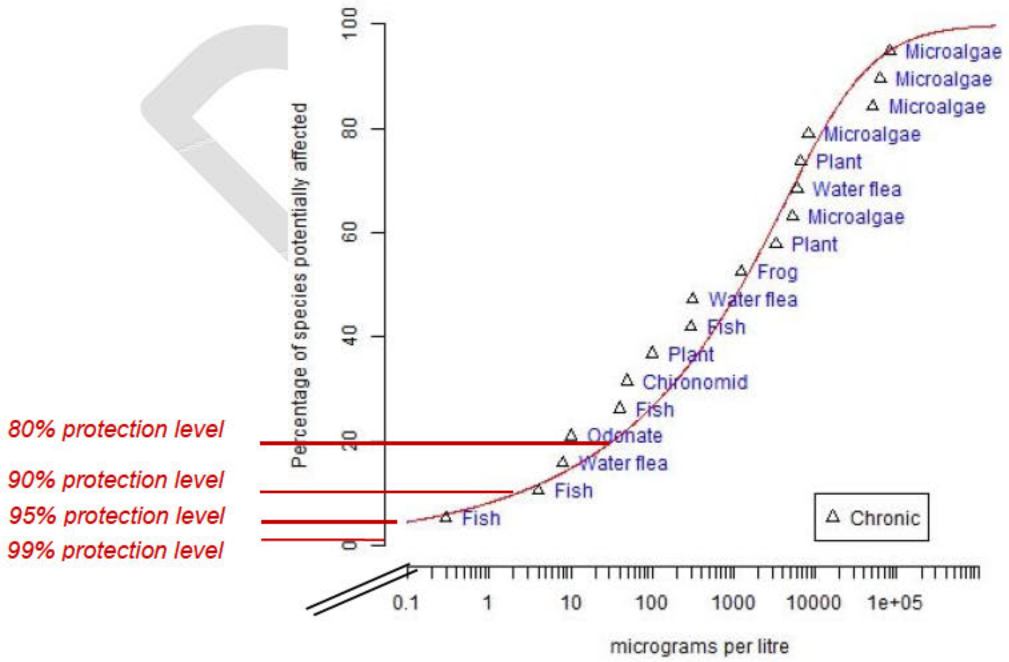

Figure B1 – Cumulative frequency distribution (from Burrlioz 2.0©) for PFOS freshwater chronic toxicity

APPENDIX C – Relevant International Obligations

1. Stockholm Convention

PFOS was added to the Stockholm Convention on Persistent Organic Pollutants in 2009. As of June 2016, 169 of the 180 parties to the Convention have ratified its addition. New Zealand and Slovenia are the only OECD parties apart from Australia that have not ratified the listing of PFOS in the Convention[*].

Parties to the Convention are required to undertake a range of activities to limit releases of listed chemicals into the environment. In relation to contaminated sites, the Convention only requires parties to:

> *Endeavour to develop appropriate strategies for identifying sites contaminated by chemicals listed in Annex A, B or C; if remediation of those sites is undertaken it shall be performed in an environmentally sound manner*[1].

However, in relation to wastes, parties are required to:

> *Take appropriate measures so that such wastes, including products and articles upon becoming wastes, are:*
>
> *(i) Handled, collected, transported and stored in an environmentally sound manner;*
>
> *(ii) Disposed of in such a way that the persistent organic pollutant content is destroyed or irreversibly transformed so that they do not exhibit the characteristics of persistent organic pollutants or otherwise disposed of in an environmentally sound manner when destruction or irreversible transformation does not represent the environmentally preferable option or the persistent organic pollutant content is low, taking into account international rules, standards, and guidelines, including those that may be developed pursuant to paragraph 2, and relevant global and regional regimes governing the management of hazardous wastes;*
>
> *(iii) Not permitted to be subjected to disposal operations that may lead to recovery, recycling, reclamation, direct reuse or alternative uses of persistent organic pollutants; and*
>
> *(iv) Not transported across international boundaries without taking into account relevant international rules, standards and guidelines*[2].

Under the Stockholm Convention, a guidance document has been prepared for best available techniques and best environmental practices (BAT/BEP) for the use of PFOS[3]. Whilst the PFOS BAT/BEP document refers to the potential for site contamination, it does not provide guidance directly relevant to the assessment or remediation of site contamination.

In 2012, the Secretariat for the Stockholm Convention sent questionnaires to all parties seeking information on PFOS. One of the questions asked about contaminated sites.[4] Relevant responses are reproduced in Table D1.

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[*] However, three OECD Countries (Israel, Italy and the United States) are not parties to the Convention. The eleven parties which have not ratified the addition of PFOS to Annex B of the Convention are: Australia, Bahrain, Bangladesh, Botswana, India, Moldova, New Zealand, Russia, Slovenia, Vanuatu and Venezuela.

Table C1: Country responses to the Stockholm Secretariat in relation to PFOS contamination

Country	Response in relation to site contamination from PFOS
Germany	There have been attempts to clean up contaminated sites in North Rhine-Westphalia. Contaminated sites are expected to be around airports (due to use of fluorinated fire fighting foams) and landfills that have been filled with untreated municipal waste until 2005.
Sweden	Sites where manufacturing and use of POPs e.g. the sites where fire extinguishers have been used causing contamination of PFOS are to a large extent identified in the regular inventory of contaminated sites performed in Sweden. These sites are thereby also covered by the Swedish program for the remediation of contaminated sites.
Netherlands	A few sites are known and measures are being taken to remediate these sites within the soil policy framework.
Switzerland	No known PFOS contaminated sites in Switzerland.
Canada	The Government of Canada has committed $3.5B in 2005 through the Federal Contaminated Sites Action Plan to address contaminated sites for which it is responsible. The administration and delivery of this program includes the provision of technical advice and scientific expertise to the custodians on the management of contaminated sites.
United States	Multiple sites in Michigan, Minnesota and Ohio are contaminated with PFOS, PFOSF and/or a number of other long-chain perfluorinated chemicals. Additionally, there are sites in other states where PFOS/PFOSF contamination has been identified. As a result, EPA is building capacity to address PFOS/PFOSF contamination at both operating and abandoned sites in the future, as more site contamination reports are expected.

2. Treaty-making PFOS project

To support the government's decision-making on whether to ratify the 2009 listing of PFOS in the Stockholm Convention, the Department of Environment and Energy has undertaken extensive technical and regulatory impact analysis, including what implementation and management actions may be required for import, export, use and disposal.

3. Basel Convention

Paragraph 1(d)(ii) of the Stockholm Convention (reproduced in the first Section of this appendix) makes reference to the Stockholm Convention's Article 6, paragraph 2 which refers to cooperation with the Basel Convention on the Transboundary Movements of Hazardous Waste and their Disposal in relation to disposal technologies and low content limits. Under the Basel Convention two relevant guidelines exist:

- General technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants (Basel POP Technical Guidelines); and
- Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with perfluorooctane sulfonic acid, its salts and perfluorooctane sulfonyl fluoride (Basel PFOS Technical Guidelines)[5].

These guidelines provide information on managing wastes containing PFOS, including appropriate technologies for destruction. Importantly, they set the low content limit for PFOS wastes for the purposes of Article 6, paragraph 1(d)(ii) of the Stockholm Convention at 50 mg/kg.

4. Rotterdam Convention

Australia is a party to the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade. The Convention does not ban chemicals but provides for information exchange about hazardous chemicals prior to their import and export. A Decision Guidance Document has been developed which contains advice about the hazards of PFOS and helps parties make informed decisions about whether to accept PFOS imports[6].

PFOS and related chemicals are listed in the Convention's Annex III. The range of PFOS related chemicals covered by the Rotterdam listing is wider than that for the Stockholm listing as perfluorooctane sulfonamides are included in the Rotterdam listing but not the Stockholm listing.

Unlike the Stockholm Convention, where Australia is yet to ratify new listings, all chemicals listed in the Rotterdam Convention have been given effect in Australia. Regulation 11C of the Industrial Chemicals (Notification and Assessment) Regulations 1990 gives effect to the PFOS listing and provides that import, export and production of PFOS and related chemicals in Australia is prohibited without the written approval of the Director of the National Industrial Chemicals Notification and Assessment Scheme (NICNAS).

Appendix C Endnotes

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[1] Stockholm Convention on Persistent Organic Pollutants, Article 6, paragraph 1(e).

[2] Stockholm Convention on Persistent Organic Pollutants, Article 6, paragraph 1(d).

[3] Revised draft guidance on best available techniques and best environmental practices for the use of perfluorooctane sulfonic acid and related chemicals listed under the Stockholm Convention available at: http://chm.pops.int/Implementation/BATandBEP/Guidance/tabid/3636/Default.aspx

[4] The questionnaire and responses are available at: http://chm.pops.int/TheConvention/POPsReviewCommittee/Meetings/POPRC8/POPRC8Followup/SubmissionBDEsPFOS/tabid/3064/Default.aspx

[5] The guidelines are available from the Basel Convention web site at: http://www.basel.int/Implementation/POPsWastes/TechnicalGuidelines/tabid/5052/Default.aspx

[6] The PFOS Decision Guidance Document can be obtained from: http://www.pic.int/TheConvention/Chemicals/DecisionGuidanceDocuments/tabid/2413/language/en-US/Default.aspx