Addendum to Off-Site Human Health Risk Assessment - July 2016

Sensitivity Assessment of Outcomes for Food Standards Australia New Zealand Tolerable Daily Intake

RAAF Base Williamtown, Williamtown NSW

Report excerpt (Appendices excluded)

Department of Defence
Addendum to Off-Site Human Health Risk Assessment - July 2016
Sensitivity Assessment of Outcomes of Food Standards Australia New Zealand Tolerable Daily Intakes

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04-Apr-2017

Job No.: 60527153

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04-Apr-2017
Prepared for – Department of Defence – ABN: 68 706 814 312
Quality Information

Document: Addendum to Off-Site Human Health Risk Assessment - July 2016
Ref: 60527153
Date: 04-Apr-2017
Prepared by: Lesley Limage and Roisin Smit
Reviewed by: Amanda Lee

Revision History

<table>
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<tr>
<th>Rev</th>
<th>Revision Date</th>
<th>Details</th>
<th>Authorised</th>
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| 1   | 04-Apr-2017   | Final   | Michael Jones  
Director - Environment NSW & ACT |
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1.0 Introduction

1.1 Background

AECOM Australia Pty Ltd (AECOM) was engaged by the Department of Defence (Defence) to undertake a quantitative human health risk assessment (HHRA) as part of Defence’s response to the detection of per- and poly-fluorinated alkyl substances (PFAS) in the environment in association with the historic use of aqueous film forming foam (AFFF) at the Royal Australian Air Force (RAAF) Base Williamtown, New South Wales (NSW) (the Site). The HHRA is documented in:


The AECOM (2016) HHRA Report adopted toxicity reference values (TRV) presented as a Tolerable Daily Intake (TDI) which were recommended by an independent toxicologist as being appropriate for use and were consistent with subsequent Australian interim guidance on PFAS toxicity (enHealth, 2016a). AECOM was requested by Defence to complete a sensitivity assessment in order to evaluate the impact of adopting the Food Standards Australia New Zealand (FSANZ) TDI for perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA) and perfluorohexane sulfonate (PFHxS). The FSANZ TDI were provided in the following document:

- Food Standards Australia New Zealand Hazard assessment report – Perfluorooctane sulfonate (PFOS), Perfluorooctanoic Acid (PFOA), Perfluorohexane sulfonate (PFHxS) (herein referred to as the FSANZ Report).

This Addendum to the AECOM (2016) HHRA Report documents the outcomes of this sensitivity assessment and must be read in conjunction with the AECOM (2016) HHRA Report.

Subsequent to preparation of the AECOM (2016) HHRA Report, AECOM was engaged by Defence to undertake a 2017 environmental investigation. The scope of work included in the 2017 environmental investigation includes additional groundwater, surface water, sediment, soil and biota sampling, hydrogeological investigations and trials into the plant uptake of PFAS. The results of these ongoing investigations will be used to refine the conceptual site model (CSM), address data gaps identified by the AECOM (2016) HHRA Report and prepare an updated HHRA Report in the second half of 2017.

1.2 Sensitivity Assessment

The risk assessment process involves a number of assumptions regarding Site conditions, human exposure and chemical toxicity. These assumptions are based on site-specific information (where available), but it is not always possible to fully predict or describe site conditions and human activities at a site for the exposure period considered in the risk assessment. The assumptions adopted in the AECOM (2016) HHRA Report have therefore been selected to provide a deliberate margin of safety for all scenarios assessed.

Sensitivity assessment is the process of changing one HHRA input parameter while leaving the others constant and determining the effect on the output.

The sensitivity assessment documented in this Addendum explores the effect of adopting the FSANZ TDI for PFOS, PFOA and PFHxS on the estimated hazard index (HI).

The FSANZ TDI adopt a similar approach to the guidance published by enHealth (2016a), which indicates that the toxicity of PFHxS should be considered to be equal to that of PFOS. All other assumptions and parameters adopted by this sensitivity assessment are consistent with the AECOM (2016) HHRA Report. That is, the TDI is the only HHRA input parameter that has been changed in this sensitivity assessment. All other parameters are consistent with the AECOM (2016) HHRA Report.
1.3 Objective

The objective of this sensitivity assessment is to assess whether the adoption of the FSANZ TDI for PFOS, PFOA and PFHxS (with all other parameters consistent with the AECOM (2016) HHRA Report) would affect the conclusions of the AECOM (2016) HHRA Report.
2.0 Issues Identification

Issues identification is the process of planning and scoping the risk assessment and determining the potential source-pathway-receptor (SPR) linkages that will form the basis of the HHRA. The Issues Identification stage of the HHRA was documented in Section 3 of the AECOM (2016) HHRA Report. Specifically, this stage includes:

- Development of a preliminary Conceptual Site Model (CSM), which identifies the following:
  - the source(s) of PFAS contamination
  - potential PFAS contaminant transport and/or migration pathways
  - potential human receptors that may be exposed to PFAS contamination via complete and potentially significant exposure pathways.

  The CSM was documented in Section 4.6 of the AECOM (2016) HHRA Report. No amendments have been made to the CSM considered in this sensitivity assessment.

- Identification of PFOS, PFOA, PFHxS and perfluorohexanoic acid (PFHpA) as Contaminants of Potential Concern (CoPC), as documented in Section 4.8 of the AECOM (2016) HHRA Report.
3.0 Data Collection and Evaluation

Data evaluation is the process of reviewing the available data and determining whether it is appropriate for use in the risk assessment. Specifically, this stage includes:

- Review of the relevant available information relating to previous investigations conducted in relation to the Stage 2B Investigation Area. The Stage 2B Investigation Area, including the Southern Area, is defined in Table 1 of the AECOM (2016) HHRA Report.

- Assessment of the quality and quantity of data available for use in the HHRA.

- Assessment of the data gaps and their significance with respect to the HHRA.

The data considered in this sensitivity assessment are presented in Section 3 of the AECOM (2016) HHRA Report. No further data have been included in this sensitivity assessment (i.e. no additional data collected after April 2016 have been adopted).

As discussed in the AECOM (2016) HHRA Report, based on assessment of the distribution of unsaturated soil and groundwater PFAS concentrations, it was considered that the shallow groundwater data collected from the area immediately south of the Site (i.e. the Southern Area) was not consistent with the shallow groundwater data reported for the broader Stage 2B Investigation Area (excluding the Site). Therefore, for the purpose of the HHRA, risk to human health was been assessed separately in the Southern Area and the Stage 2B Investigation Area (excluding the Site and Southern Area). These areas are presented on Figure F2, Appendix A of the AECOM (2016) HHRA Report.

Given that the estimated extent of the Southern Area is defined by higher PFAS concentrations in unsaturated soil and groundwater, it is independent of the adopted TDI and has therefore not changed as part of this sensitivity assessment.
4.0 Exposure Assessment

Exposure assessment is the process of estimating the magnitude, frequency, extent and duration of human exposure to PFAS and refinement of the CSM based on these considerations. The exposure assessment is presented in Section 5 of the AECOM (2016) HHRA Report.

To account for variability in human behavioural patterns, while remaining protective of general population exposures, the HHRA considered a range of exposure assumptions:

- 'Typical' exposure was based on mean or median parameters for the general population. The use of typical values was intended to capture the typical and average exposure for the majority of the population based on a combination of 'common sense' professional judgement and published values regarding exposure frequency and potential PFAS ingestion. It is anticipated that the assessment of the typical scenario will be applicable to the majority of the population.

- Upper range exposure was based on reasonable maximum exposure (RME) parameters. The use of upper values was intended to:
  - be representative of a reasonable maximum exposure
  - capture receptors who undertake activities at a higher frequency or ingest more than the average person
  - provide an estimate of exposure that is reflective of the upper/high end of the scale of potential exposure. It is considered that the exposure frequency and quantity assumed by the upper scenario will only apply to small percentage of the population.

It was noted that both the typical and upper range exposure assumptions were coupled with Exposure Point Concentrations (EPC) for soil, groundwater, sediment and surface water determined based on applying a range of statistical approaches to the available data (for example maximum reported concentrations or 95\textsuperscript{th} percentile concentrations). As a result, the HHRA outcomes are considered to be conservative and likely to over-estimate, rather than under-estimate, risks to human health. In particular, the combination of upper exposure assumptions (which were based on high exposure frequency and/or high exposure quantity) and maximum or 95\textsuperscript{th} percentile (where statistical analysis was appropriate) EPC is considered likely to be highly conservative. For example, the upper exposure scenario for consumption of finfish is based on the assumption that the recreational fisher consumes 32.8 g (child) and 65.5 g (adult) of finfish every day for a lifetime (6 years for a child and 35 years for an adult) and that all of the finfish consumed over the lifetime contains the median reported PFAS concentration.

No amendments have been made in this sensitivity assessment to the adopted exposure assumptions and parameters nor to the adopted EPC originally adopted by the AECOM (2016) HHRA Report.
5.0 Toxicity Assessment

Toxicity assessment is the process of understanding the health effects associated with exposure to PFAS and making a quantitative link between the degree of exposure and the effect realised. Hazard identification is discussed in Section 6.1 of the AECOM (2016) HHRA Report.

5.1 TDI Adopted in AECOM (2016) HHRA Report

At the time of commencement of the AECOM (2016) HHRA Report, there were no published Australian toxicity profiles for PFAS. Consequently, AECOM used current toxicological profiles prepared by Toxconsult Pty Ltd (ToxConsult) for the following PFAS to inform the HHRA:

- PFOS
- PFOA
- 1H,1H,2H,2H-perfluoro decane sulfonate (8:2 FtS)
- 1H, 1H, 2H, 2H- perfluoro octane sulfonate fluorotelemer (6:2 FtS)
- PFHxS
- PFHxA.

The toxicity assessment involved:

- description of toxicokinetics, including adsorption, distribution, metabolism, elimination and kinetic modelling
- review of available animal studies including acute and repeat dose toxicity, chronic toxicity, carcinogenicity, reproductive toxicity, immunotoxicity, neurotoxicity and genotoxicity
- review of available epidemiological studies, pivotal modes of action, identification of potentially sensitive sub-populations
- establishment of background concentrations
- review of all available TDI published by state, national or international authorities and provide recommendation of defensible TDI for use in the HHRA.

Toxconsult recommended:

- adoption of the TDI for PFOS and PFOA from the European Food Safety Authority (EFSA, 2008), which were consistent with subsequent Australian interim guidance on PFAS toxicity (enHealth, 2016a).
- it be assumed that the toxicity of PFHxS should be considered to be equal to that of PFOS and therefore that the PFOS TDI be adopted for the assessment of potential exposure to PFHxS. This approach was also consistent with subsequent Australian interim guidance on PFAS toxicity (enHealth, 2016a).
- that there was sufficient data from international research to derive a chemical specific TDI for PFHxA. The value proposed was consistent with a value previously published by the Swedish National Food Agency, however no TDI for this compound has subsequently been published for use in Australia.
- that the toxicological information for 6:2 FtS and 8:2 FtS was too limited to recommend defensible chemical-specific TRVs for use in HHRA.

AECOM undertook a quantitative assessment of potential risk for PFAS compounds for which a defensible TDI was identified by the ToxConsult toxicity profiles (i.e. PFOS, PFOA, PFHxS and PFHxA).

As discussed in Section 6.2 of the AECOM (2016) HHRA Report, PFOS, PFOA, PFHxS and PFHxA have been assessed as threshold chemicals, as standard tests for genotoxic carcinogenicity have been negative.
Potential health effects that are assessed on the basis of a threshold dose response utilise a TRV which is typically termed an acceptable daily intake (ADI) or TDI or reference dose (RfD). For the purpose of this assessment, the TRV adopted has been termed a TDI. A TDI is a lifetime daily chemical intake below which it is considered unlikely that adverse effects would occur in human populations, including sensitive sub-groups (e.g. the very young or elderly). Hence, the TDI relates to intakes from all sources, including source-related impacts and background intakes (where relevant). It is important to note that where estimated intakes exceed the TDI, it does not necessarily mean that adverse health effects will occur.

5.2 TDI Adopted in Sensitivity Assessment

This sensitivity assessment adopts the PFOS, PFOA and PFHxS TDI from the FSANZ Report. The TDI recommended by ToxConsult (2016) for PFHxA has been retained in this sensitivity assessment as no additional guidance for the assessment of this chemical was provided in the FSANZ Report.

A summary of the oral (i.e. ingestion) exposure threshold TDI from the AECOM (2016) HHRA Report compared with the more conservative TDI from the FSANZ Report (used to inform this sensitivity assessment) are presented in Table 1. No TRV specific to inhalation or dermal exposure (i.e. exposure via breathing or skin contact) have been identified for PFAS that would allow a separate evaluation of intakes via these pathways. Hence, the TDI from the FSANZ Report for the oral exposure pathway have also been adopted for direct contact and inhalation pathways in the sensitivity assessment.
Table 1  TDI adopted in the sensitivity assessment

<table>
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<tr>
<th>Compound</th>
<th>Application</th>
<th>Oral TDI (mg/kg bw/day)</th>
<th>Source</th>
<th>Notes on Derivation</th>
</tr>
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</table>
| PFOS     | TDI adopted in this sensitivity assessment | $2 \times 10^{-5}$ | FSANZ Report | - Point of departure: a Human Equivalent Dose (HED) No Observed Adverse Effect Level (NOAEL) of 0.0006 mg/kg/day identified for female rats (Luebker et al 2005).  
- The critical effects considered were parental toxicity (decreased body weight gain and food consumption) and offspring toxicity (reduced body weight and weight gain).  
- Uncertainty Factor (UF) of 30 |
|          | TDI adopted in the AECOM (2016) HHRA Report | $1.5 \times 10^{-4}$ | EFSA (2008) – also adopted by enHealth (2016) | - Point of departure: A NOAEL of 0.03 mg/kg/day based on a 26-week study on monkeys (Seacat et al., 2002)  
- UF of 200. |
| PFOA     | TDI adopted in this sensitivity assessment | $1.6 \times 10^{-4}$ | FSANZ Report | - Point of departure: an HED Lowest Observed Adverse Effect Level (LOAEL) of 0.0049 mg/kg/day identified for mice (Lau et al, 2006).  
- The critical effect considered was foetal toxicity.  
- UF of 30 |
|          | TDI adopted in the AECOM (2016) HHRA Report | $1.5 \times 10^{-3}$ | EFSA (2008) – also adopted by enHealth (2016) | - Point of departure: Benchmark dose lower confidence limit for a 10% response (BMDL10) of 0.3 mg/kg/day based on studies of liver effects in rats by Perkins et al., 2004; Sibinski, 1983; Butenhoff et al., 2004 and studies in mice by Lau et al., 2006  
- UF of 200. |
| PFHxS    | TDI adopted in this sensitivity assessment | $2 \times 10^{-5}$ | FSANZ Report | - The FSANZ Report states "there was insufficient toxicological and epidemiological information to justify establishing a TDI for PFHxS. In the absence of a TDI, it is reasonable to conclude that the enHealth (2016) approach of using the TDI for PFOS is likely to be conservative and protective of public health as an interim measure".  
- See notes above for PFOS oral TDI |
| PFHxA    | TDI adopted in both the AECOM (2016) HHRA Report and this sensitivity assessment | $1 \times 10^{-1}$ | ToxConsult (2016) | - Point of departure: a NOAEL of 30 mg/kg/day identified for female rats (Klaunig et al 2015).  
- UF of 300 |
5.3 Background Exposure

Background exposure to chemicals present in the environment can occur as a result of everyday activities or natural sources. PFAS may be present in food, water and consumer products and represent non-Site based sources of exposure. This is commonly referred to as ‘background exposure’. In accordance with the approach adopted in the National Environmental Protection (Assessment of Site Contamination) Measure 1999 as amended in 2013 (ASC NEPM 2013) background exposure has been taken into account through adjustment (reduction) of TDI to account for non-Site related exposure.

The background exposure concentrations adopted by this sensitivity assessment are consistent with the AECOM (2016) HHRA Report, as documented in Section 6.3.
6.0 Risk Characterisation

Risk characterisation is the process of summarising information from the previous stages of the risk assessment approach and integrating it into a quantitative expression of risk. Specifically, this stage includes:

- Comparison of estimated contaminant intake to adopted TDI for each CoPC (i.e. calculation of hazard quotients):
  - the hazard quotient for each CoPC (PFOS, PFOA, PFHxS and PFHxA) was summed to provide a HI for each individual exposure pathway
  - the HI for each individual exposure pathway was then further summed to produce a cumulative risk estimate for each identified multi-pathway exposure scenario.
- Comparison of risk estimates against risk acceptance criteria recommended and/or adopted by State and Federal regulatory agencies as appropriate
- Discussion of the key uncertainties associated with the HHRA process and the assumptions and exposure modelling undertaken for this HHRA
- Consideration of the risk estimates in the context of the identified uncertainties.

The risk characterisation stage was presented in Section 7 of the AECOM (2016) HHRA Report.

This Addendum should be read in the context of the uncertainty assessment reported in Section 8 of the AECOM (2016) HHRA Report.

6.1 Sensitivity Assessment Hazard Quotients and Hazard Indices

A table of hazard indices based on the adoption of the FSANZ TDI (as described in Table 1) compared to hazard indices based on the TDI adopted in the AECOM (2016) HHRA Report for each scenario is presented in Appendix A, while a breakdown of the HI calculated for each of the individual exposure pathways that make up the scenarios is illustrated in Appendix B. The revised HHRA models for each scenario are provided in Appendix C.
7.0 Conclusions

7.1 Comparison with AECOM (2016) HHRA Report Outcomes

The overall outcome of adopting more conservative (i.e. lower) FSANZ TDI in this sensitivity assessment is an increase in the estimated HI for each pathway/scenario modelled. A comparison of the estimated HI based on the FSANZ TDI to those presented in the AECOM (2016) HHRA Report is presented in Appendix A. The impact of adopting the FSANZ TDI on the outcomes and recommendations of the AECOM (2016) HHRA Report is presented in Section 7.2 to Section 7.5.

Where the total HI for a particular exposure scenario following adoption of the FSANZ TDI exceeded the target value of 1, a review was undertaken of the individual pathways that contributed to this risk estimate. Individual pathways with an individual HI of greater than 0.5 are considered to have the greatest potential to result in elevated risks.

The below conclusions should be read in conjunction with the data gaps presented in Section 3.9 of the AECOM (2016) HHRA Report and the sensitivity assessment presented in Section 8 of the AECOM (2016) HHRA Report. A summary of the conclusions is presented in Table 2, Section 7.6.

7.2 Typical exposure scenarios

As described by Section 4, the ‘Typical’ exposure scenarios were based on typical or average exposure parameters considered to be applicable to the majority of the population.

7.2.1 No change to AECOM (2016) HHRA Report Low and Acceptable Risk Outcomes

If the FSANZ TDI were adopted there would be no change to the AECOM (2016) HHRA Report outcome that there is a low and acceptable risk to residents (including recreational and commercial fishers and beef farmers), non-resident commercial fishers, non-resident council workers and visitors from exposure to PFAS impact through the following exposure pathways:

**Off-Site Stage 2B Investigation Area (excluding the Southern Area)**
- inhalation of dust (from soil irrigated by PFAS impacted groundwater or flooded by PFAS impacted surface water)
- incidental ingestion of groundwater or surface water as a result of indoor use (excluding drinking water), outdoor use (including swimming pools, dams and surface water bodies) and irrigation
- dermal contact with groundwater or surface water as a result of indoor use, outdoor use (including swimming pools, dams and surface water bodies) and irrigation
- incidental ingestion of soil or sediment as a result of outdoor activities
- dermal contact with soil or sediment as a result of outdoor activities
- consumption of locally sourced seafood (including finfish, prawns, crabs and oysters)
- consumption of locally grown fruit and vegetables
- consumption of beef from locally grown cattle and exposed to surface water as their primary drinking water supply
- consumption of eggs from locally grown backyard chickens that are exposed to groundwater as their primary drinking water supply
- consumption of milk from locally grown dairy cows that are exposed to surface water as their primary drinking water supply.

**Southern Area**
- inhalation of dust (from soil irrigated by PFAS impacted groundwater or flooded by PFAS impacted surface water)
• dermal contact with groundwater or surface water as a result of indoor use, outdoor use (including swimming pools, dams and surface water bodies) and irrigation
• incidental ingestion of soil or sediment as a result of outdoor activities
• dermal contact with soil or sediment as a result of outdoor activities
• consumption of locally sourced seafood (including finfish, prawns, crabs and oysters)
• consumption of locally grown fruit and vegetables
• consumption of milk from locally grown dairy cows that are exposed to surface water as their primary drinking water supply.

7.2.2 No change to AECOM (2016) HHRA Report Elevated Risk Outcomes
If the FSANZ TDI were adopted there would be no change to the AECOM (2016) HHRA Report outcome that there is a potential for elevated risk to residents (including recreational and commercial fishers) from exposure to PFAS impact through the following exposure pathways:

Southern Area
• ingestion of groundwater

7.2.3 Changes to AECOM (2016) HHRA Report Risk Outcomes
If the FSANZ TDI were adopted, there would be a change to the outcomes of the AECOM (2016) HHRA Report to indicate a potential for an elevated risk to residents (including recreational and commercial fishers and beef farmers) and visitors from exposure to PFAS impact through the following exposure pathways:

Off-Site Stage 2B Investigation Area (excluding the Southern Area)
• ingestion of groundwater

Southern Area
• incidental ingestion of groundwater as a result of indoor use and outdoor use, specifically:
  - showering and bathing using extracted groundwater
  - filling swimming pools and children’s wading pools with extracted groundwater
  - sprinkler play with extracted groundwater.
• consumption of beef from locally grown cattle and exposed to surface water as their primary drinking water supply.

7.3 Upper exposure scenarios
As described by Section 4, the upper range exposure scenarios were based on reasonable maximum exposure parameters intended to be representative of human receptors who undertake activities at a higher frequency or ingest more than the average person. As such, they are considered applicable to only a small percentage of the population.

7.3.1 No Change to AECOM (2016) HHRA Report Low and Acceptable Risk Outcome
If the FSANZ TDI were adopted there would be no change the AECOM (2016) HHRA Report outcome that there is a low and acceptable risk to residents (including recreational and commercial fishers and beef farmers), non-resident commercial fishers, non-resident council workers and visitors from exposure to PFAS impact through the following exposure pathways:

Off-Site Stage 2B Investigation Area (excluding the Southern Area)
• inhalation of dust (from soil irrigated by PFAS impacted groundwater or flooded by PFAS impacted surface water)
• dermal contact with groundwater or surface water as a result of indoor use, outdoor use (including swimming pools, dams and surface water bodies) and irrigation
7.3.2 No change to AECOM (2016) HHRA Report Elevated Risk Outcomes

If the FSANZ TDI were adopted, there would be no change to the AECOM (2016) HHRA Report conclusion that there is a potential for elevated risk to residents (including recreational and commercial fishers) from exposure to PFAS impact through the following exposure pathways:

**Off-Site Stage 2B Investigation Area (excluding the Southern Area)**
- ingestion of groundwater
- consumption of eggs from locally grown backyard chicken that are exposed to groundwater as their primary drinking water supply
- consumption of milk from locally grown dairy cows that are exposed to surface water as their primary drinking water supply.

**Southern Area**
- ingestion of groundwater
- incidental ingestion of groundwater as a result of indoor use, outdoor use and irrigation, specifically:
  - showering and bathing using extracted groundwater
  - filling swimming pools and children’s wading pools with extracted groundwater
  - sprinkler play with extracted groundwater.
- consumption of beef from locally grown cattle and exposed to surface water as their primary drinking water supply
- consumption of eggs from locally grown backyard chicken that are exposed to groundwater as their primary drinking water supply
- consumption of milk from locally grown dairy cows that are exposed to surface water as their primary drinking water supply.

7.3.3 Changes to AECOM (2016) HHRA Report Risk Outcomes

If the FSANZ TDI were adopted, there would be a change to the outcomes of the AECOM (2016) HHRA Report to indicate a potential for an elevated risk to residents (including recreational and commercial fishers) and visitors from exposure to PFAS impact through the following exposure pathways:

**Off-Site Stage 2B Investigation Area (excluding the Southern Area)**
- incidental ingestion of surface water as a result of outdoor use (including swimming pools, dams and surface water bodies)
- consumption of locally sourced seafood (i.e. finfish)
- consumption of locally grown fruit and vegetables
• consumption of beef from locally grown cattle and exposed to surface water as their primary drinking water supply

Southern Area
• incidental ingestion of groundwater as a result of indoor use and outdoor use, specifically:
  - residues after washing floors with extracted groundwater
  - residues after washing companion animals with extracted groundwater.
• incidental ingestion of surface water as a result of outdoor use (including swimming pools, dams and surface water bodies)
• consumption of locally sourced seafood (i.e. finfish)
• consumption of locally grown fruit and vegetables.

7.4 Exposure Pathways Potentially Requiring Management

7.4.1 No change to AECOM (2016) HHRA Report Recommendations
Adoption of the FSANZ TDI does not change the AECOM (2016) HHRA Report suggestion that consideration be given to restricting the following activities:

Off-Site Stage 2B Investigation Area (excluding the Southern Area)
• drinking groundwater, particularly where elevated PFAS concentrations have been reported in groundwater
• consumption of eggs from backyard chickens that are exposed to surface water or groundwater as their primary source of drinking water
• consumption of milk from dairy cows that exposed to surface water as their primary source of drinking water 1.

Southern Area
• drinking groundwater, particularly where elevated PFAS concentrations have been reported in groundwater
• incidental ingestion of groundwater as a result of indoor use, outdoor use and irrigation, specifically:
  - showering and bathing using extracted groundwater
  - filling swimming pools and children’s wading pools with extracted groundwater
  - sprinkler play with extracted groundwater
• incidental ingestion of surface water as a result of swimming in pools, dams and surface water bodies
• consumption of beef from cattle exposed to surface water or groundwater as their primary source of drinking water
• consumption of eggs from backyard chickens that are exposed to surface water or groundwater as their primary source of drinking water
• consumption of milk from dairy cows that exposed to surface water or groundwater as their primary source of drinking water 2.

1 It is noted that the consumption of unpasteurised milk from cows is not recommended by the NSW Food Authority.
2 It is noted that the consumption of unpasteurised milk from cows is not recommended by the NSW Food Authority.
7.4.2 Changes to the AECOM (2016) HHRA Report Recommendations

In addition to the recommendations from the AECOM (2016) HHRA Report, based on the outcomes of this sensitivity assessment, it is suggested that consideration also be given to restricting the following activities:

**Off-Site Stage 2B Investigation Area (excluding the Southern Area)**
- incidental ingestion of surface water as a result of swimming in pools filled with surface water, dams and surface water bodies
- consumption of locally sourced seafood (i.e. finfish)
- consumption of locally grown fruit and vegetables that are exposed to surface water or groundwater
- consumption of beef from cattle exposed to surface water or groundwater as their primary source of drinking water.

**Southern Area**
- incidental ingestion of groundwater as a result of indoor use and outdoor use, specifically:
  - washing floors with extracted groundwater
  - washing companion animals with extracted groundwater
- consumption of locally sourced seafood (i.e. finfish)
- consumption of locally grown fruit and vegetables that are exposed to surface water or groundwater (based on the off-Site Stage 2B Investigation Area outcomes).

7.5 Exposure of infants to breast milk

If the FSANZ TDI were adopted:

- The risk outcome for the upper exposure scenario for Scenario 1, including PFAS intake from breast milk (averaged over a lifetime exposure) would be consistent with the outcomes for the AECOM (2016) HHRA Report. In particular:
  - The calculated HI for the upper exposure scenario for Scenario 1 including PFAS intake from breast milk is greater than the target HI of 1 for both child and adult receptors (refer to Appendix A)
  - This risk outcome is consistent with the calculated HI for the upper exposure scenario for Scenario 1 excluding PFAS intake from breast milk.
- The risk outcome for the typical exposure scenario for Scenario 1, including PFAS intake from breast milk (averaged over a lifetime exposure) is different from the outcomes for the AECOM (2016) HHRA Report. In particular:
  - The calculated HI for the typical exposure scenario for Scenario 1, including PFAS intake from breast milk is greater than the target HI of 1 for both child and adult receptors (refer to Appendix A)
  - This risk outcome is consistent with the calculated HI for the typical exposure scenario for Scenario 1 excluding PFAS intake from breast milk (which would also change from the AECOM (2016) HHRA Report if the FSANZ TDI are adopted).
- The difference between the HI calculated for Scenario 1 including PFAS intake from breast milk, and the HI calculated for Scenario 1 excluding PFAS intake from breast milk (refer to Appendix A) approaches 1 for: an adult, under the upper exposure scenario; and a child, under the typical exposure scenario.

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3 A resident who uses groundwater for drinking, indoor, outdoor and irrigation purposes.
By way of comparison, the HI for Scenario 2\(^4\) (which excludes the drinking water pathway) was also calculated both including and excluding PFAS intake from breast milk (refer to Appendix A). The calculated HI for Scenario 2 is significantly less than those calculated for Scenario 1.

It is noted that the enHealth (2016b) Guidance Statements on Perfluorinated Chemicals state that “the significant health benefits of breast feeding are well established and far outweigh any potential health risks to an infant from any PFOS or PFOA transferred through breast milk”. Similar statements have also been made by other international authorities, including the Agency for Toxic Substances and Disease Registry (ATSDR, 2016), State of New Jersey Department of Health (2015) and Massachusetts Department of Environmental Protection (2015). The Queensland Health “Breastfeeding: Best for baby and for Mum” factsheet states that in addition to providing optimal nutrition for infants, breast feeding reduces the risk of infections and diseases such as urinary tract infections, gastrointestinal infections (e.g. diarrhoea), respiratory illnesses (e.g. asthma), some childhood cancers, obesity, diabetes and heart disease later in life.

It is recommended that the assessment of risk from PFAS intake from breast milk requires further discussion with state and national health authorities.

7.6 Summary

A summary of how adoption of the FSANZ TDI would affect the outcomes and recommendations of the AECOM (2016) HHRA Report is presented in Table 2. A breakdown of the HI calculated for each of the individual exposure pathways that make up the scenarios is illustrated in Appendix B.

It is important to note that while this sensitivity assessment has identified additional pathways (relative to those identified by the AECOM (2016) HHRA Report) with potential elevated risk, the EPC on which these calculations are based were typically based on analytical results from an initial sampling event that was targeted to potential areas of greater PFAS impact. Further, a number of the assumptions made regarding exposure frequency and duration or quantity (in the case of dietary intakes) are considered conservative and unlikely to be representative of the majority of the population. Therefore, the resultant HI may over-estimate exposure risk.

Additional environmental investigations are currently being completed in order to assess data gaps identified by the AECOM (2016) HHRA Report (among other things). These investigations include additional groundwater, surface water, sediment, soil and biota sampling. The results of these ongoing investigations will be used by AECOM to refine the CSM, address data gaps identified by the AECOM (2016) HHRA Report and prepare an updated HHRA Report in the second half of 2017.

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\(^4\) A resident who uses groundwater for indoor, outdoor and irrigation purposes.
## Table 2  Summary of HHRA Conclusions for Residents based on FSANZ TDI

<table>
<thead>
<tr>
<th>Exposure Pathway</th>
<th>Receptor/Exposed Community</th>
<th>Potential Risk – Off-Site Stage 2B Investigation Area</th>
<th>Potential Risk - Southern Area</th>
<th>Suggested precautions if the FSANZ TDI were adopted in the HHRA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Upper(^6)</td>
<td>Typical(^7)</td>
<td>Upper(^6)</td>
</tr>
<tr>
<td><strong>Groundwater</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ingestion of groundwater</td>
<td>Residents(^1)</td>
<td>Elevated</td>
<td>Elevated (previously low &amp; acceptable)</td>
<td>Elevated(^6)</td>
</tr>
<tr>
<td>Incidental ingestion of groundwater as a result of indoor use (excluding drinking water), outdoor use (including swimming pools, dams and surface water bodies) and irrigation(^7)</td>
<td>Residents(^1), non-resident council workers and visitors(^2)</td>
<td>Low &amp; Acceptable</td>
<td>Low &amp; Acceptable</td>
<td>Elevated</td>
</tr>
<tr>
<td>Dermal contact with groundwater as a result of indoor use, outdoor use (including swimming pools, and dams) and irrigation(^7)</td>
<td>Residents(^1), non-resident council workers and visitors(^2)</td>
<td>Low &amp; Acceptable</td>
<td>Low &amp; Acceptable</td>
<td>Low &amp; Acceptable</td>
</tr>
<tr>
<td><strong>Surface Water</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incidental ingestion of surface water as a result of outdoor use- (including swimming pools, dams and surface water bodies) and irrigation(^7)</td>
<td>Residents(^1), non-resident commercial fishers, non-resident council workers and visitors(^2)</td>
<td>Elevated (previously low &amp; acceptable)</td>
<td>Low &amp; Acceptable</td>
<td>Elevated (previously low &amp; acceptable)</td>
</tr>
</tbody>
</table>

\(^1\)It is noted that the risk estimate for incidental ingestion of groundwater residues after washing floors or companion animals is based on some highly conservative modelling assumptions which are likely to result in an overestimation of potential risk and should be reviewed prior to making any additional recommendations regarding this pathway.
<table>
<thead>
<tr>
<th>Exposure Pathway</th>
<th>Receptor/Exposed Community</th>
<th>Potential Risk – Off-Site Stage 2B Investigation Area</th>
<th>Potential Risk - Southern Area</th>
<th>Suggested precautions if the FSANZ TDI were adopted in the HHRA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dermal contact with surface water</strong> as a result of outdoor use (including swimming pools, dams and surface water bodies) and irrigation</td>
<td>Residents¹, non-resident commercial fishers, non-resident council workers and visitors²</td>
<td>Low &amp; Acceptable</td>
<td>Low &amp; Acceptable</td>
<td>Low &amp; Acceptable</td>
</tr>
<tr>
<td><strong>Incidental ingestion of soil and sediment</strong> as a result of outdoor activities</td>
<td>Residents¹, non-resident commercial fishers, non-resident council workers and visitors²</td>
<td>Low &amp; Acceptable</td>
<td>Low &amp; Acceptable</td>
<td>Low &amp; Acceptable</td>
</tr>
<tr>
<td><strong>Dermal contact with soil and sediment</strong> as a result of outdoor activities</td>
<td>Residents¹, non-resident commercial fishers, non-resident council workers and visitors²</td>
<td>Low &amp; Acceptable</td>
<td>Low &amp; Acceptable</td>
<td>Low &amp; Acceptable</td>
</tr>
<tr>
<td><strong>Inhalation of Dust</strong> as a result of indoor⁶ and outdoor⁷ activities (from soil irrigated by PFAS impacted groundwater or flooded by PFAS impacted surface water)</td>
<td>Residents¹, non-resident commercial fishers, non-resident council workers and visitors²</td>
<td>Low &amp; Acceptable</td>
<td>Low &amp; Acceptable</td>
<td>Low &amp; Acceptable</td>
</tr>
</tbody>
</table>

**Locally sourced food**

<p>| Consumption of locally sourced seafood (including finfish, prawns, crabs and oysters) | Residents¹, non-resident commercial fishers | Elevated (previously low &amp; acceptable) | Low &amp; Acceptable | Elevated (previously low &amp; acceptable) | Low &amp; Acceptable | Avoid or minimise ‘high’ consumption of locally sourced finfish by a child. The sensitivity of the input parameters adopted for this exposure pathway is further discussed in Section 7.7.3. |</p>
<table>
<thead>
<tr>
<th>Exposure Pathway</th>
<th>Receptor/Exposed Community</th>
<th>Potential Risk – Off-Site Stage 2B Investigation Area</th>
<th>Potential Risk - Southern Area</th>
<th>Suggested precautions if the FSANZ TDI were adopted in the HHRA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Upper&lt;sup&gt;6&lt;/sup&gt; Typical&lt;sup&gt;7&lt;/sup&gt;</td>
<td>Upper&lt;sup&gt;6&lt;/sup&gt; Typical&lt;sup&gt;7&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td><strong>Consumption of locally grown fruit and vegetables</strong></td>
<td>Residents&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Elevated (previously low &amp; acceptable)</td>
<td>Low &amp; Acceptable</td>
<td>Elevated (previously low &amp; acceptable)</td>
</tr>
<tr>
<td><strong>Consumption of honey</strong></td>
<td>Residents&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Low &amp; Acceptable</td>
<td>Low &amp; Acceptable</td>
<td>Low &amp; Acceptable</td>
</tr>
<tr>
<td><strong>Consumption of beef</strong> from locally grown cattle and exposed to surface water as their primary drinking water supply</td>
<td>Residents&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Elevated (previously low &amp; acceptable)</td>
<td>Low &amp; Acceptable</td>
<td>Elevated (previously low &amp; acceptable)</td>
</tr>
<tr>
<td><strong>Consumption of eggs</strong> from locally grown backyard chicken that are exposed to groundwater as their primary drinking water supply</td>
<td>Residents&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Elevated</td>
<td>Low &amp; Acceptable</td>
<td>Elevated&lt;sup&gt;4&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>5</sup> It is noted that the risk estimates for the ingestion of fruit and vegetables are based on conservative transfer factors of PFAS from water/soil to plants provided by ToxConsult (2016) which are likely to result in an overestimation of potential risk and should be reviewed prior to making any additional recommendations regarding this pathway.
### Exposure Pathway

<table>
<thead>
<tr>
<th>Receptor/Exposed Community</th>
<th>Potential Risk – Off-Site Stage 2B Investigation Area[^3]</th>
<th>Potential Risk - Southern Area</th>
<th>Suggested precautions if the FSANZ TDI were adopted in the HHRA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Consumption of milk</strong> from locally grown dairy cows that are exposed to surface water as their primary drinking water supply</td>
<td>Residents[^1]</td>
<td>Elevated</td>
<td>Low &amp; Acceptable</td>
</tr>
</tbody>
</table>

**Notes:**

1. Residents includes recreational fishers/moderate locally sourced seafood consumers and commercial fishers/high locally sourced seafood consumers
2. Visitors were not assessed in the Southern Area
3. Stage 2B Investigation Area excludes the Site and the Southern Area
4. Risk estimates were not calculated for the consumption of eggs exposure pathway within the Southern Area. The conclusions presented in Table 2 for the Southern Area were based on the assumption that as an elevated risk was reported for the Stage 2B Investigation Area (upper exposure scenario) where PFAS concentrations in groundwater are lower, then an elevated risk would also exist where PFAS concentrations in groundwater are higher i.e. the Southern Area.
5. Risk estimates for consumption of beef and milk were assessed based on the assumption that the cattle were exposed to surface water as their primary source of drinking water. However, the groundwater concentrations reported in the Southern Area are greater than those reported in the surface water. Therefore, if the risk estimate was based on the groundwater concentrations, the risk estimates for consumption of beef and milk would also be elevated.
6. Indoor activities with groundwater comprise showering/bathing, food preparation and clean-up, domestic laundry, washing clothes, household cleaning and washing floors.
7. Outdoor activities with groundwater or surface water comprise sprinkler play, washing of animals, washing of vehicles, irrigation and swimming in home pools, dams or other surface water bodies.
7.7 Discussion of Key Exposure Pathways

Based on the conclusions presented in Section 7.2 to Section 7.5 and summarised in Table 2, a number of pathways which were previously considered by the AECOM (2016) HHRA Report to represent a low and acceptable risk for all exposure scenarios in both the Stage 2B Investigation Area and Southern Area have been found to present an elevated risk for one or more exposure scenario if the FSANZ TDI is adopted.

These pathways are further described below in terms of the most sensitive inputs which influence the estimated risk.

Appendix B presents a breakdown of the HI calculated for each of the individual exposure pathways that make up the exposure pathways summarised in Table 2. A separate breakdown is provided for:

- The Stage 2B Investigation Area (excluding the Southern Area):
  - Upper exposure scenario (refer to Section 4)
  - Typical exposure scenario (refer to Section 4)
- The Southern Area:
  - Upper exposure scenario (refer to Section 4)
  - Typical exposure scenario (refer to Section 4)

The breakdown is presented in two formats:

1. Tabular form – the calculated HI for each individual pathway for both the child and adult receptor is presented
2. Graphically – the maximum of the calculated HI for either the child or adult receptor is presented for each individual pathway.

7.7.1 Incidental Ingestion of Groundwater within the Southern Area

The incidental ingestion of groundwater pathway within the Southern Area is driven by five key activities including showering and bathing, swimming in pools, sprinkler play, washing floors and washing companion animals. The elevated risks are based on:

- typical exposure parameters for adults and children within the Southern Area (not including washing floors and companion animals), and
- upper exposure parameters for children within the Southern Area.

The incidental ingestion of groundwater pathways assume that the concentrations of PFAS in impacted groundwater (i.e. the EPC) are equal to:

- for the Southern Area, the maximum reported concentrations.

Overall, the elevated frequency (e.g. a child swimming for 42 minutes a day for 130 days a year), ingestion rates (e.g. a child consuming 0.15 litres of water per hour during each swimming event) and EPC (i.e. maximum PFAS concentration reported in groundwater) assumed in this exposure pathways are considered to be conservative and are likely to overestimate the potential risk.

7.7.2 Incidental Ingestion of Surface Water

The incidental ingestion of surface water pathway is based on adults and children swimming in PFAS impacted land based creeks/drains. The elevated risks are based on upper exposure parameters within both the Stage 2B investigation Area and Southern Area.

Conservative estimates have been adopted for exposure duration which are equivalent to (for the upper exposure assumptions):

- a child swimming in a PFAS impacted land based creek or drain for approximately 1 hour per day, twice per week, each year and
- an adult for 1.5 hours per day, approximately three times per week, each year.
The EPC for incidental ingestion of surface water assume that the concentrations of PFAS in impacted surface water are always equal to the 95 percentile concentration measured across all land based drains/creeks.

Both the frequency and concentration assumed in this exposure pathway are considered to be conservative and are likely to overestimate the potential risk. In particular, the assumption that the concentration deemed representative of 95 percentile in surface water, would be continuously present in the same water body that the receptor would be swimming in over the course of a year is unlikely to be realised due to the fact that: the surface water concentrations are highly variable; and not all measured concentrations are from locations that are suitable for swimming (e.g. a drain adjacent to a busy road).

7.7.3 Consumption of Locally Sourced Seafood

The elevated risk associated with the consumption of locally sourced seafood (i.e. finfish) is based on a child receptor who has a high consumption rate of seafood (i.e. upper exposure parameters).

In particular, it is assumed that all of the fish in the child’s diet is from PFAS impacted water and that all of this fish contains PFAS concentrations that are equal to the median concentration calculated for all samples analysed from the area. The rate of ingestion is also assumed to be equal to 220 g/day, for 365 days a year, which, for a child, is considered to be a very high, and unlikely to be realised.

7.7.4 Consumption of Locally Grown Fruit and Vegetables

The elevated risk associated with the consumption of locally grown fruit and vegetables is based on a child receptor who has a high consumption rate (i.e. upper exposure parameters).

In particular, it assumes that the fruit and vegetables are watered by surface water and uses literature values to estimate uptake to the edible portion of the plant (as only limited empirical data was collected). It also assumed that the child consumes approximately 250 g/day of home grown fruit and vegetables for 365 days of the year and that all of this fruit and vegetable contains this calculated PFAS concentrations.

Both the literature values and the ingestion rate are considered likely to overestimate the risk and could be revisited with further supporting data.

It is noted that PFAS concentrations in all fruit and vegetable samples analysed as part of the Stage 2A Environmental Investigation were reported to be below the laboratory limit of reporting.

7.7.5 Consumption of Locally Grown Beef

The consumption of beef from cattle exposed to groundwater as their primary source of drinking water is based both an adult cattle farmer and their child who are considered ‘high’ consumers (i.e. upper exposure parameters).

Similar to the fruit and vegetables, literature values were used to estimate PFAS concentration in the meat as no empirical data was collected. It is assumed that an adult consumes 124.2 g/day and a child consumes 59 g/day of meat per day for 365 days of the year and that all meat consumed contains the calculated PFAS concentrations.

These parameters are considered conservative and could be revisited with further supporting data.
8.0 References


enHealth, 2016b. enHealth Statement: Interim national guidance on human health reference values for per- and poly-fluoroalkyl substances for use in site investigations in Australia

Food Standards Australia New Zealand (FSANZ) Hazard assessment report – Perfluoroctane sulfonate (PFOS), Perfluorooctanic Acid (PFOA), Perfluorohexane sulfonate (PFHxS)


Appendix A

Hazard Indices
Appendix B

Hazard Indices for each Exposure Pathway
Appendix C

HHRA Calculations