Addendum to Stage 2C Environmental Investigation - Human Health Risk Assessment

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

Army Aviation Centre Oakey

Report excerpt (Appendices excluded)

Prepared for
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Addendum to Stage 2C Environmental Investigation - Human Health Risk Assessment

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

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This document presents Sections 1-8 of the following report: Addendum to Stage 2C Environmental Investigation – Human Health Risk Assessment: Sensitivity Assessment of HHRA Outcomes of Food Standards Australia New Zealand Tolerable Daily Intake (the "HHRA Addendum Report"), prepared by AECOM (04 April 2017).

This excerpt of the HHRA Addendum Report does not include the Appendices contained with the HHRA Addendum Report and is for information purposes only, is not to be used as a basis for decision making and may not be relied upon by any party. For further information regarding the HHRA Addendum, including appendices referred to in this document, the reader is requested to refer to the HHRA Addendum Report.

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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-fluoroalkyl substances (PFAS) in the environment in association with the historic use of legacy aqueous film forming foam (AFFF) at the Army Aviation Centre Oakey (AACO), in Oakey, Queensland (the Site). The HHRA is documented in:

- AECOM, 2016. *Stage 2C Environmental Investigation - Human Health Risk Assessment. Army Aviation Centre Oakey (AACO), Oakey QLD*. 1 September 2016 (referred to herein as the AECOM (2016) HHRA Report).

The AECOM (2016) HHRA Report adopted toxicity reference values (TRV) presented as 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 potential 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), Perfluorooctanic 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 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 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 4.8** 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 (PFHxA) as Chemicals of Potential Concern (CoPC), as documented in **Section 4.3** 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:

- Identification of the relevant available information relating to previous investigations conducted in relation to the Investigation Area (IA). The data considered in the AECOM (2016) HHRA were primarily sourced from various investigations conducted by AECOM since November 2013 to facilitate Defence's long term objective of identifying and managing risks associated with PFAS contamination. The IA is described as the broader area including the Site and surrounds which is being studied as part of assessing the extent of PFAS detections in the groundwater. The boundaries of the IA have changed over time as more information has become available. Currently the IA encompasses the majority of the Site and includes a buffer area beyond the known extent of PFOS and PFOA detected in groundwater (referred to as the Detection Area) and extends approximately 5.5 km south and 3.5 km west of the Site. The current inferred extent of the IA is depicted in Figure 2 of the AECOM (2016) HHRA Report.
- Assessment of the quality and quantity of data available for use in the HHRA. Investigation locations are depicted in Figure 3 to Figure 8 of the AECOM (2016) HHRA Report.
- Assessment of the data gaps and their significance with respect to the HHRA.

The Data Collection and Evaluation stage of the HHRA was documented in **Section 4** of the AECOM (2016) HHRA Report. This included (in **Section 4.4.3** of the AECOM (2016) HHRA) the identification of two off-Site groundwater impact zones for consideration in the HHRA:

- 'Zone 1' to the south and west of the Site, which is inferred to have resulted primarily from lateral groundwater migration and vertical migration from surface water
- 'Zone 2' immediately south of the Site, which is inferred to have greater magnitude PFOS concentrations owing to proximity to the Site, plus a potential greater contribution from vertical migration from surface water in the vicinity of stormwater Drain 1 and Drain 2 that originate from the Site.

The off-Site groundwater impact zones are depicted in Figure 8 of the AECOM (2016) HHRA Report.

The AECOM (2016) HHRA Report considered environmental data collected up to 27 May 2016. No additional data or revisions to the inferred boundaries of these two groundwater impact zones have been included in 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.

As discussed in **Section 5.1** 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:

- A '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 parameters. The use of upper values was intended to:
  - be representative of a reasonable maximum exposure (RME)
  - 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 maximum Exposure Point Concentrations (EPC) for soil, groundwater, sediment and surface water. 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 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 16.4 g (child) and 32.8 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 from the Investigation Area over the lifetime contains the average reported PFAS concentration.

When undertaking this sensitivity assessment, no amendments have been made 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 the PFOS TDI be adopted for the assessment of potential exposure to PFHxS. This 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 in 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 threshold TRV which is typically termed an acceptable daily intake (ADI) or TDI or reference dose (RfD). For the purpose of this assessment, the threshold 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 as well as 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 FSANZ TDI for PFOS, PFOA and PFHxS 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 sensitivity assessment

Compound	Application	Oral TDI (mg/kg bw/day)	Source	Notes on Derivation
PFOS	TDI adopted in this sensitivity assessment	2×10^{-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	1.5×10^{-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	1.6×10^{-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 fetal toxicity. • UF of 30
	TDI adopted in the AECOM (2016) HHRA Report	1.5×10^{-3}	EFSA (2008) – also adopted by enHealth (2016)	• Point of departure: Benchmark dose lower confidence limit for a 10% response ($BMDL_{10}$) 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	2×10^{-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
	TDI adopted in the AECOM (2016) HHRA Report	1.5×10^{-4}	EFSA (2008) – also adopted by enHealth (2016)	• ToxConsult (2016) recommended adopting the TDI for PFOS, consistent with subsequent advice from enHealth (2016).
PFHxA	TDI adopted in both the AECOM (2016) HHRA Report and this sensitivity assessment	1×10^{-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 values documented in **Section 6.3** of the AECOM (2016) HHRA Report.

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 an 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. An HI less than or equal to a target value of 1 is considered to indicate that cumulative PFAS intakes via identified pathways are unlikely to exceed the relevant TDI and therefore risk to health is termed “low and acceptable”. An HI greater than a target value of 1 is considered to indicate a potential for elevated health risk.
- 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. The sensitivity assessment presented in 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 is presented in **Appendix A**. Calculations are included in **Appendix B**.

6.2 Measured and Modelled PFAS Blood Serum Concentrations

As an additional line of evidence, the AECOM (2016) HHRA included an assessment undertaken by ToxConsult of the potential for health effects based on PFAS concentrations in human blood. This component of the HHRA concluded:

- Measured PFOS and PFOA concentrations in blood of 75 people from Oakey do not indicate that adverse health effects are likely to occur.
- Based on potential modelled PFAS concentrations in blood there are theoretical upper range exposure scenarios where PFAS exposure due to consumption of meat, liver or fish could exceed tolerable limits. Measured concentrations of PFAS in blood do not indicate that these theoretical scenarios have actually been realised.
- However, PFAS concentrations in blood are elevated above typical background concentrations for people in Australia. Minimising future PFAS exposure by observing precautionary recommendations will result in blood PFAS concentrations declining over time.

The assessment based on measured and modelled blood PFAS concentrations did not utilise the TDI described in **Section 5.1**, rather, it involved comparison directly to a human blood serum NOAEL derived by ToxConsult and published NOAEL or LOAEL derived from animal experiments. Therefore the previous conclusion based on this approach to risk characterisation would not be directly affected by the adoption of the FSANZ TDI in the HHRA.

7.0 Conclusions

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.

7.1 Use of Groundwater for Drinking Water Supply

The previous conclusion of potential for intake via this pathway to exceed the TDI would remain unchanged. Potential PFAS exposure from consumption of groundwater used for drinking water supply is estimated to be more than ten times greater than PFAS exposure from all other pathways combined. An example of these relative HI values is depicted in **Figure 1** for Residents in Groundwater Zone 1 - Typical exposure scenario.

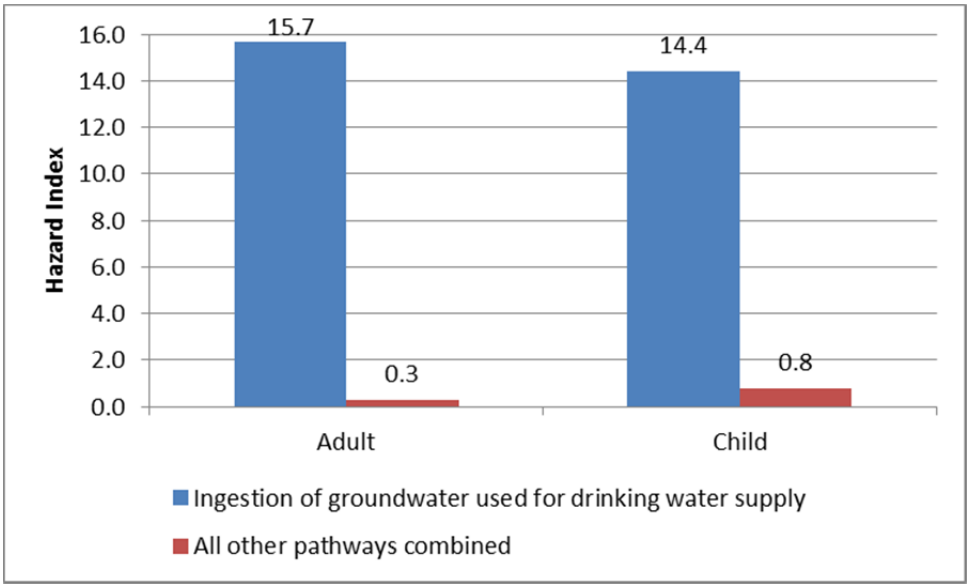

Figure 1 Comparison of HI for Residents in Groundwater Zone 1 - Typical exposure scenario

This exposure pathway was historically complete, but is currently being managed through a precautionary recommendation from Defence not to drink the groundwater within the IA, and provision of water assistance to residents on a case-by-case basis. Therefore, it was not included when modelling the scenarios discussed below in either the AECOM (2016) HHRA Report or this sensitivity assessment.

The previous precautionary recommendation, suggested by the AECOM (2016) HHRA Report, to not use groundwater for drinking water supply within the IA (including water used for cooking) remains appropriate if the FSANZ TDI are adopted. No additional recommendations would therefore be suggested regarding use of groundwater for drinking purposes.

7.2 Exposure Scenarios Excluding Use of Groundwater for Drinking Water Supply

The potential influence of the adoption of the FSANZ TDI on the outcomes of the AECOM (2016) HHRA is summarised in **Table 2**.

Receptors for whom adoption of the FSANZ TDI did not change the conclusion of the AECOM (2016) HHRA that risks to health were low and acceptable, are summarised in **Section 7.2.1**.

Where the total HI for a particular exposure scenario and receptor 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 HI of greater than 0.5 are considered to have the greatest potential to result in elevated PFAS exposure. These receptors and exposure pathways are discussed in more detail in the **Sections 7.2.2** to **7.2.5**.

Table 2 Summary of potential changes to the AECOM (2016) HHRA conclusions based on HI calculated using FSANZ TDI

Scenario	Adult/ Child HI based on FSANZ TDI (excluding drinking groundwater)	Risk Description *	Change to AECOM (2016) HHRA Conclusion?
Resident, Groundwater Zone 1 – Typical exposure scenario	0.3 / 0.8	Low and acceptable	No change
Resident, Groundwater Zone 1 – Upper exposure scenario	2.6 / 8.3	Elevated	No change to overall conclusion, but additional pathways identified with potential for elevated PFAS exposure – refer to **Section 7.2.3**
Resident, Groundwater Zone 2 – Typical exposure scenario	0.7 / 2.5	Elevated	Yes – refer to discussion of risk-driving pathways in **Section 7.2.2**
Resident, Groundwater Zone 2 – Upper exposure scenario	8.5 / 25	Elevated	No change to overall conclusion, but additional pathways identified with potential for elevated PFAS exposure – refer to **Section 7.2.3**
Commercial agriculture worker, Groundwater Zone 1 – Typical exposure scenario	0.1 / 0.2	Low and acceptable	No change
Commercial agriculture worker, Groundwater Zone 1 – Upper exposure scenario	0.6 / 1.1	Elevated	Yes - refer to discussion of risk-driving pathways in **Section 7.2.4**
Commercial agriculture worker, Groundwater Zone 2 – Typical exposure scenario	0.01 / -	Low and acceptable	No change
Commercial agriculture worker, Groundwater Zone 2 – Upper exposure scenario	0.6 / -	Low and acceptable	No change
Recreational users of local waterways– Typical exposure scenario	0.04 / 0.08	Low and acceptable	No change
Recreational users of local waterways– Upper exposure scenario	0.4 / 1.0	Elevated	Yes - refer to discussion of risk-driving pathways in **Section 7.2.5**
On-Site personnel– Typical exposure scenario	0.002 / -	Low and acceptable	No change
On-Site personnel– Upper exposure scenario	0.002 / -	Low and acceptable	No change

* An HI less than a target value of 1 is considered to indicate that cumulative PFAS intakes via identified pathways are unlikely to exceed the relevant TDI and therefore risk to health is termed “low and acceptable”. Where the cumulative PFAS intakes via identified pathways have the potential to exceed the relevant TDI, the risk is described as “elevated”.
- No child receptor identified for this scenario.

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

If the FSANZ TDI were adopted, there would be no change to the outcomes of the AECOM (2016) HHRA Report, that there is a low and acceptable risk for the following receptor groups based on typical exposure scenarios:

- Residents in Groundwater Zone 1
- Commercial agriculture worker (and their family) in Groundwater Zone 1
- Commercial agriculture worker in Groundwater Zone 2
- Recreational users of local waterways
- On-site personnel

If the FSANZ TDI were adopted, there would be no change to the AECOM (2016) HHRA Report outcomes that there is a low and acceptable risk to the following receptor groups based on upper range exposure scenarios:

- Commercial agriculture worker in Groundwater Zone 2
- On-site personnel

7.2.2 Residents in Groundwater Zone 2 - Typical exposure scenario (excluding drinking water) - changes to AECOM (2016) HHRA Report Risk Outcomes

If the FSANZ TDI were adopted, there would be a change to the conclusion of the AECOM (2016) HHRA to indicate a potential for elevated health risk to residents in Groundwater Zone 2 (previously concluded to have a low and acceptable risk). The primary pathways associated with this elevated PFAS exposure are:

- Incidental ingestion of groundwater during showering/bathing
- Incidental ingestion of groundwater used in home swimming pools/ paddling pools

It is suggested that the previous precautionary recommendation to avoid or minimise the use of groundwater containing detectable concentrations of PFAS in Groundwater Zone 2 for showering/bathing, for sprinkler play or to fill swimming pools or paddling pools remains appropriate. As depicted in **Figure 2**, excluding the pathways which are subject to existing precautionary recommendations, the HI would not exceed the target value of 1 and therefore the risk to residents would be considered to be low and acceptable.

No additional recommendations are therefore considered to be required regarding use of groundwater to minimise typical PFAS exposure in Groundwater Zone 2.

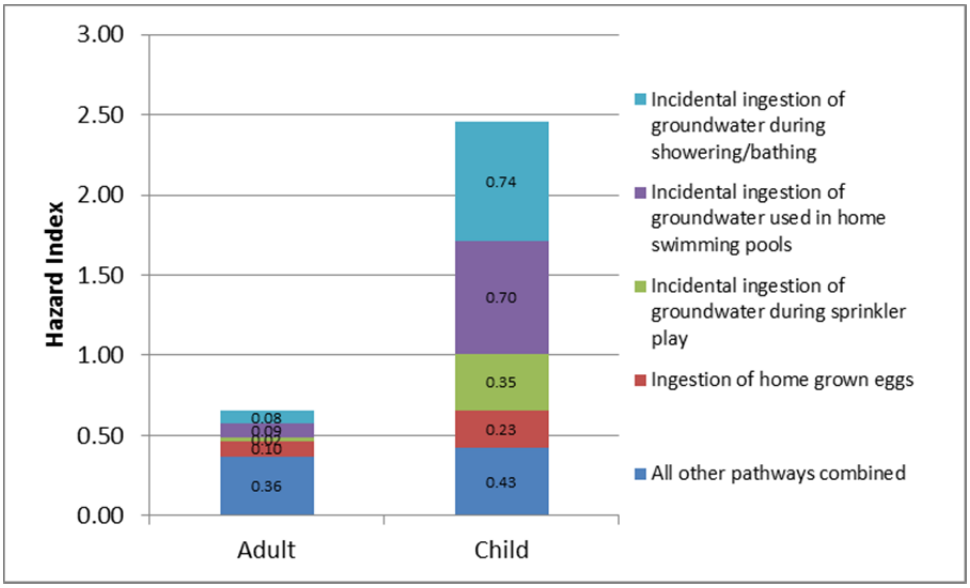

Figure 2 HI breakdown by exposure pathway for Residents in Groundwater Zone 2 - Typical exposure scenario (excluding drinking groundwater) based on FSANZ TDI

7.2.3 Residents in Groundwater Zone 1 and Zone 2 - Upper exposure scenario (excluding drinking water) – no changes to AECOM (2016) HHRA Report Risk Outcomes

If the FSANZ TDI were adopted, there would be no change to the AECOM (2016) HHRA Report outcomes that there is a potential for elevated health risk for the following receptor groups based on upper range exposure scenarios:

- Residents in Groundwater Zone 1
- Residents in Groundwater Zone 2

Consistent with the AECOM (2016) HHRA Report, the pathways contributing most significantly to the elevated PFAS exposure for these scenarios are:

- Incidental ingestion of groundwater during showering/bathing
- Incidental ingestion of groundwater used in home swimming pools/ paddling pools
- Incidental ingestion of groundwater used in sprinkler play.
- Ingestion of home grown eggs.

The relative contributions of these pathways to the total estimated HI are depicted in **Figure 3** for Groundwater Zone 1 and **Figure 4** for Groundwater Zone 2. Based on the outcomes of the AECOM (2016) HHRA Report, these pathways are currently subject to precautionary recommendations, which remain relevant if the FSANZ TDI were adopted.

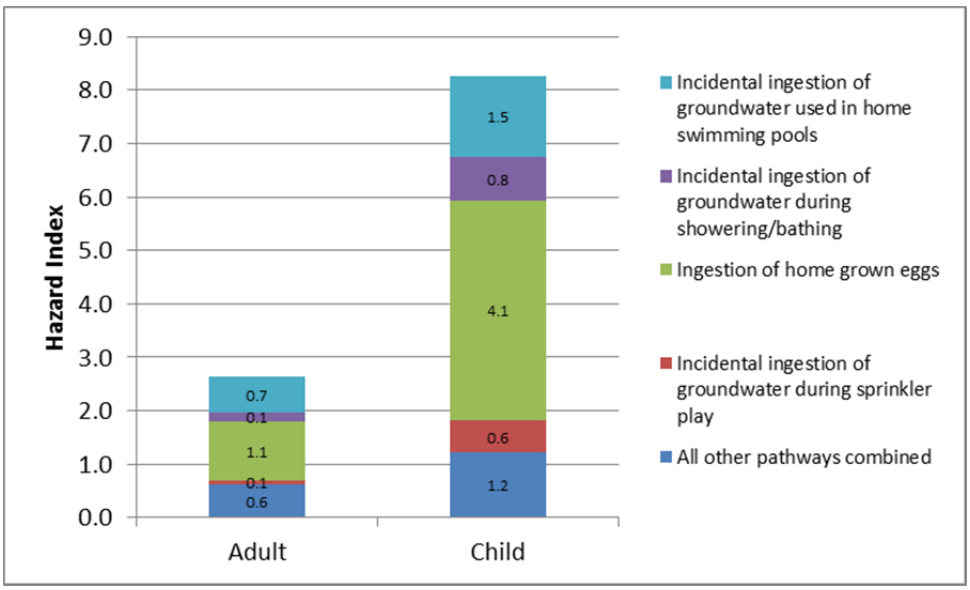

Figure 3 HI breakdown by exposure pathway for Residents in Groundwater Zone1 – Upper range exposure scenario (excluding drinking groundwater) FSANZ TDI

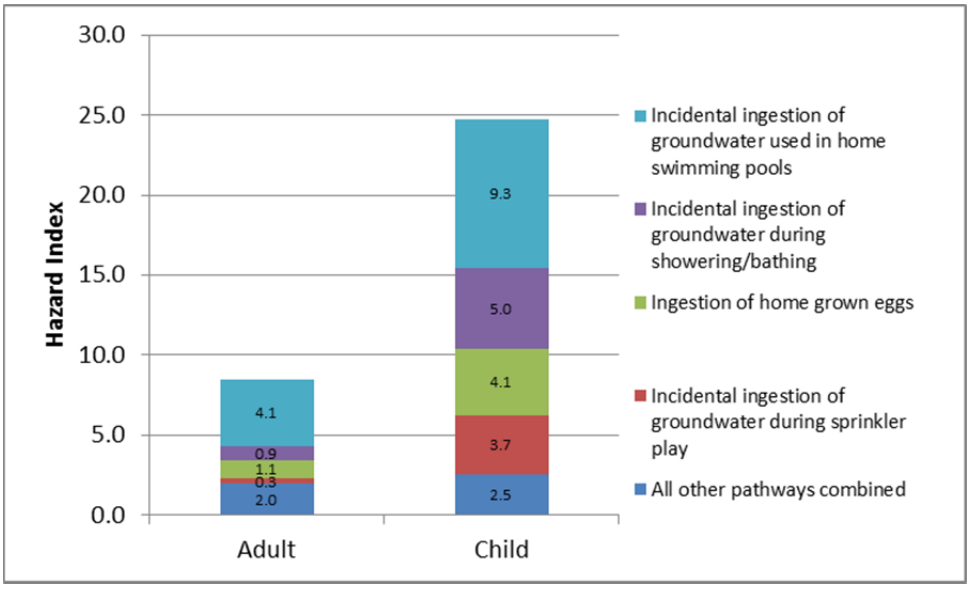

Figure 4 HI breakdown by exposure pathway for Residents in Groundwater Zone 2 – Upper range exposure scenario (excluding drinking groundwater) FSANZ TDI

A further breakdown of the HI for pathways not currently subject to precautionary recommendations (shown on **Figure 3** and **Figure 4** as *All other pathways combined*) has been prepared to assist with identifying exposure pathways that may require further more detailed evaluation to reduce uncertainties and/or that may require consideration of additional precautionary recommendations.

Excluding the pathways currently subject to precautionary recommendations, the HI for the sum of all other pathways for children (HI = 1.2) in Groundwater Zone 1 exceeds the target value of 1. The HI for adults (HI = 0.65) does not exceed the target value of 1. The relative contributions of selected pathways to these total HI values are depicted in **Figure 5**.

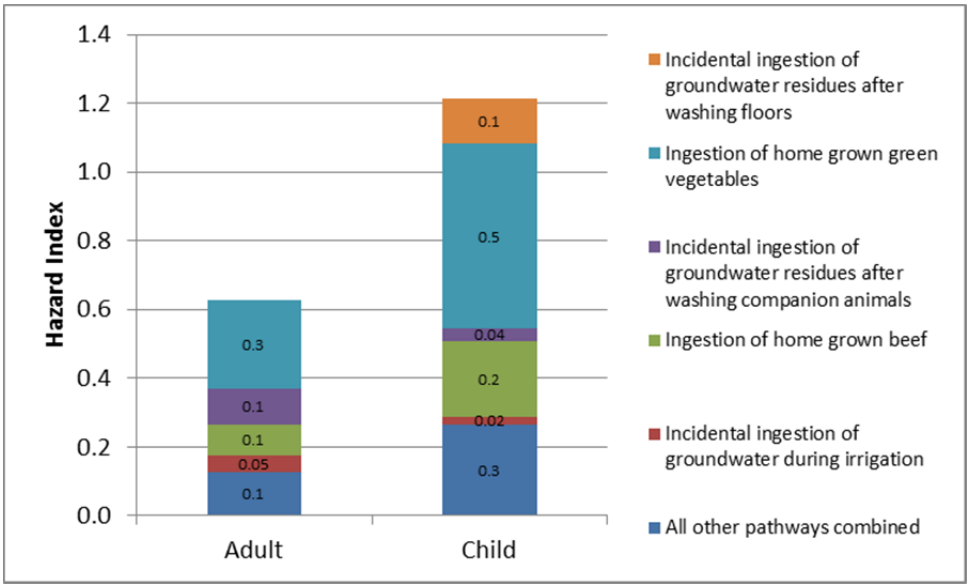

Figure 5 HI breakdown for pathways not currently subject to precautionary recommendations – Residents in Groundwater Zone 1, Upper Exposure scenario

Excluding the pathways currently subject to precautionary recommendations, the HI for the sum of all other pathways for both adults (HI = 1.95) and children (HI = 2.5) in Groundwater Zone 2 exceed the target value of 1. The relative contributions of selected pathways to these total HI values are depicted in **Figure 6**.

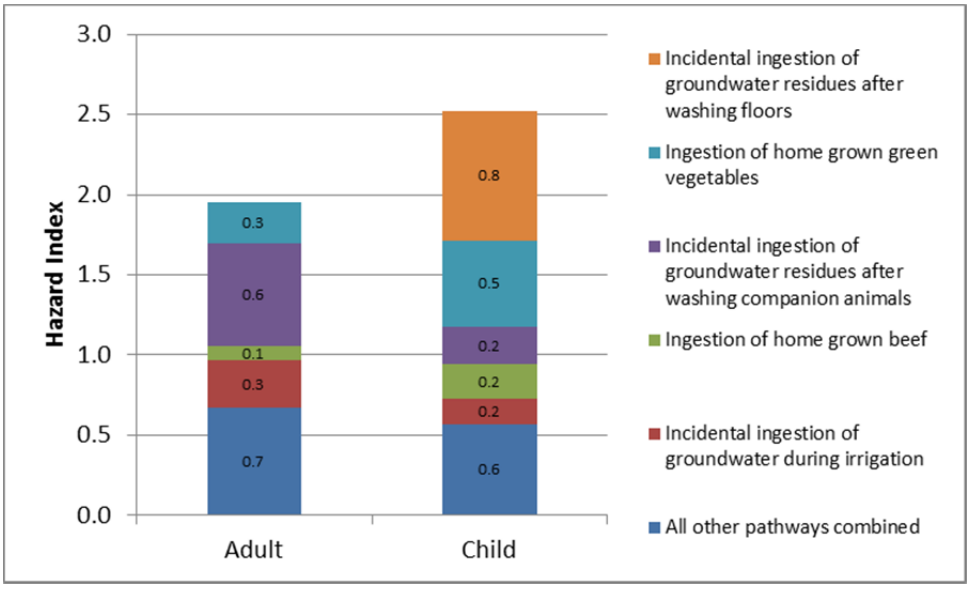

Figure 6 HI breakdown for pathways not currently subject to precautionary recommendations – Residents in Groundwater Zone 2, Upper Exposure scenario

It is noted that the adoption of the more conservative FSANZ TDI results in three additional pathways being identified as having pathway-specific HI of greater than 0.5 and therefore having a greater potential to contribute to elevated PFAS exposure. These additional pathways are:

- Ingestion of home grown vegetables
- Incidental ingestion of groundwater residues after washing floors
- Incidental ingestion of groundwater residues after washing companion animals.

It is important to note that none of these three additional pathways has been identified to individually result in estimated intakes greater than the TDI. However, under circumstances where many pathways occur together at upper range exposures, there is the potential for the TDI to be exceeded.

The risk estimate for ingestion of home grown vegetables is based on an assumption that a child consumes 76 g vegetables per day, 365 days per year (equivalent to seven standard servings per week), 50% of which is sourced from plants exposed to PFAS within the IA. These assumptions are considered conservative and unlikely to be representative of exposure by the general community. Further, the EPC for this scenario were based on analytical results from an initial sampling event that was targeted to potential areas of greater PFAS impact. As a result this may over-estimate typical exposure in the HHRA. Additional environmental investigations are currently being completed in order to assess this, and other, uncertainties.

AECOM has conducted a review of the risk estimate for incidental ingestion of groundwater residues after washing floors or companion animals. This review identified that the approach previously recommended by ToxConsult over-estimates potential PFAS exposure by a factor of between 2 and 25 compared to current guidance from the USEPA (2012) on the assessment of these pathways. These modelling assumptions will therefore be revised in the HHRA update to be completed in 2017.

7.2.4 Commercial Agriculture Workers in Groundwater Zone 1 - Upper exposure scenario (excluding drinking water) - changes to AECOM (2016) HHRA Report Risk Outcomes

If the FSANZ TDI were adopted, there would be a change to the conclusion of the AECOM (2016) HHRA to indicate a potential for elevated health risk to commercial agriculture workers (and their family consuming farm produce grown at the place of work) in Groundwater Zone 1 (previously concluded to have a low and acceptable risk). The relative contributions of selected pathways to the total HI value are depicted in **Figure 7**.

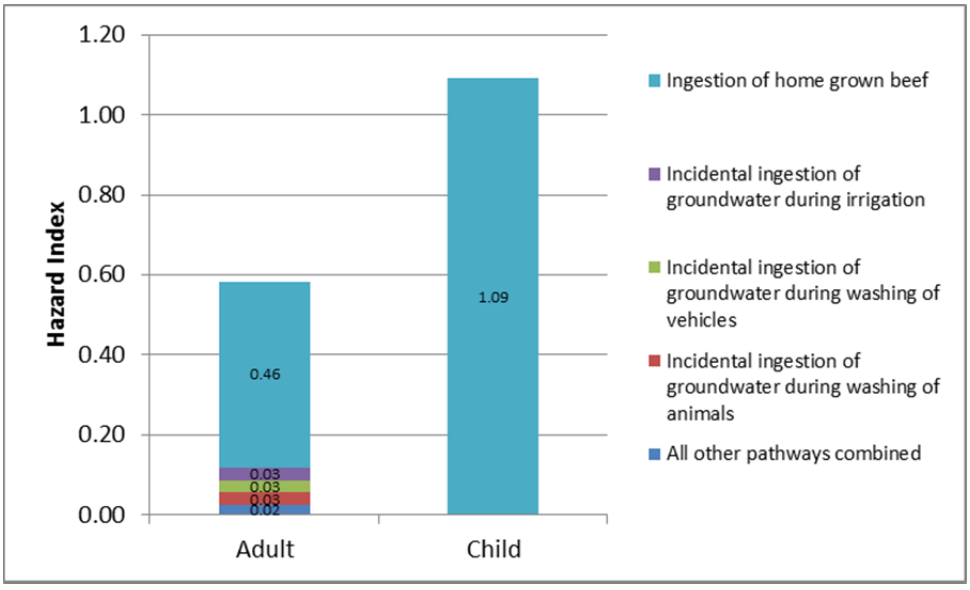

Figure 7 HI breakdown – Commercial Agriculture Workers (and family consuming farm produce) in Groundwater Zone 1, Upper Exposure scenario

The primary pathway associated with this elevated PFAS exposure is:

- Consumption of red meat from cattle/ sheep.

The revised risk estimate for this pathway only marginally exceeds the target HI (an estimate of 1.09 compared to a target value of 1) and would therefore warrant further evaluation as to the representativeness of the adopted input parameters.

This risk estimate is based on an assumption that a child consumes 30 g red meat per day, 365 days per year (equivalent to two standard servings per week), 50% of which is sourced from animals exposed to PFAS within the IA. These assumptions are considered conservative and unlikely to be representative of exposure by the general community. Further, the EPC for this scenario were based

on analytical results from an initial sampling event that was targeted to potential areas of greater PFAS impact. As a result, this may over-estimate typical exposure in the HHRA.

7.2.5 Recreational Users of Local Waterways - Upper exposure scenario (excluding drinking water) – changes to AECOM (2016) HHRA Report Risk Outcomes

If the FSANZ TDI were adopted, there would be a change to the conclusion of the AECOM (2016) HHRA to indicate a potential for elevated health risk to recreational users of local waterways (previously concluded to have a low and acceptable risk). The relative contributions of selected pathways to the total HI value are depicted in **Figure 8**.

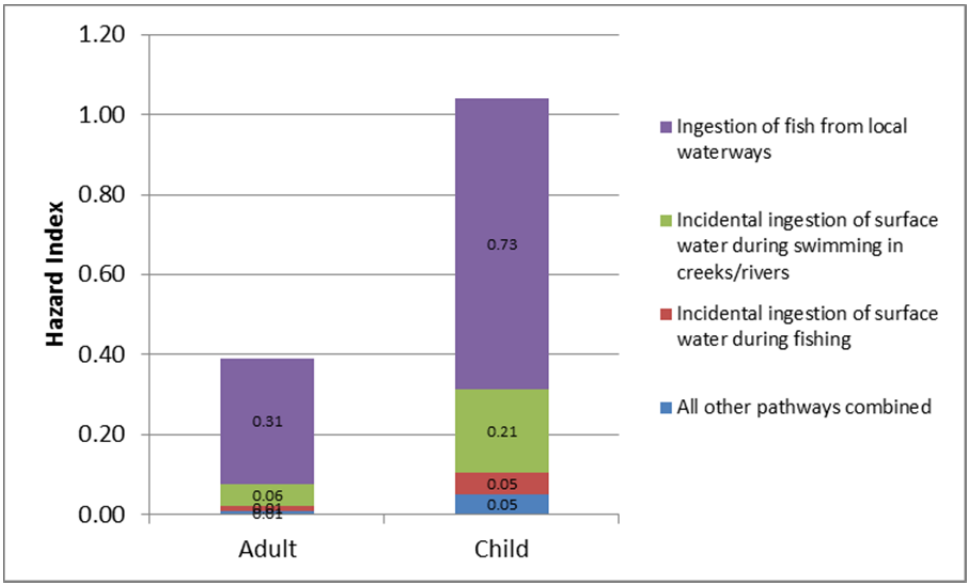

Figure 8 HI breakdown – Recreational users of local waterways, Upper Exposure scenario

The primary pathway associated with this elevated PFAS exposure is:

- Ingestion of fish from local waterways.

The revised risk estimate for this scenario only marginally exceeds the target HI (an estimate of 1.04 compared to a target value of 1) and would therefore warrant further evaluation as to the representativeness of the adopted input parameters.

This risk estimate is based on an assumption that a child consumes 16.4 g fish per day, 365 days per year (equivalent to one standard serving per week), 20% of which is sourced from fish exposed to PFAS in surface water within the IA. These assumptions are considered conservative and unlikely to be representative of exposure by the general community. Further, the EPC for this scenario were based on analytical results from an initial sampling event that was targeted to potential areas of greater PFAS impact. As a result, this may over-estimate typical exposure in the HHRA. Environmental investigations are currently being completed in order to assess this uncertainty in the typical PFAS exposure through the ingestion of fish and other uncertainties.

7.2.6 Infant Intakes via Breast Milk

If the FSANZ TDI were adopted, there would be a change in conclusion of the AECOM (2016) HHRA to indicate that a time weighted daily intake for a 0-6 year period including infant intakes via breast milk (based on typical exposure parameters) could exceed the TDI in both Zones of the IA.

It is noted that the infant intakes via breastmilk were estimated based on measured blood serum concentrations from the Oakey cohort (Heffernan, 2015), as described in Appendix H of the AECOM (2016) HHRA Report. The blood serum data set published for the Oakey cohort by Heffernan (2015) is limited in that it does not provide the age or gender of the individuals in the cohort. As discussed in Section 5.1.4 of the AECOM (2016) HHRA Report, it was conservatively assumed that the typical female blood serum concentration was equal to the 95% upper confidence limit (UCL) of the mean concentration reported for the Oakey cohort (Heffernan, 2015). To further refine this aspect of the

HHRA it would be necessary to confirm whether the assumed blood serum concentrations are representative of females of child-bearing age.

It is noted that the enHealth (2016b) *Guidance Statements on Perfluorinated Chemicals* states 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.

7.3 Summary

A summary of how the adoption of the FSANZ TDI would affect the outcomes and recommendations of the AECOM (2016) HHRA Report is presented in **Table 3** to **Table 6**.

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. As a result this may over-estimate exposure in the HHRA.

It is also noted that the adoption of the FSANZ TDI would not directly affect the conclusion of the AECOM (2016) HHRA that measured PFOS and PFOA concentrations in blood of 75 people from Oakey do not indicate that adverse health effects are likely to occur. Precautionary recommendations to minimise PFAS exposure may however be considered on the basis of the following:

- PFAS concentrations measured in blood of people living in Oakey are elevated above typical background concentrations for people in Australia. Minimising future PFAS exposure by observing precautionary recommendations will result in blood PFAS concentrations declining over time.
- Based on modelling, there are theoretical scenarios where PFAS exposures associated with a limited number of pathways may be elevated and when considered cumulatively may result in PFAS intakes greater than the TDI. Precautionary recommendations related to these pathways aim to minimise the potential for those theoretical elevated PFAS exposure scenarios to occur.

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.

Table 3 Summary of HHRA Conclusions for Residents based on FSANZ TDI

Exposure Pathway	Potential PFAS Exposures – Zone 1		Potential PFAS Exposures – Zone 2		Suggested precautions if the FSANZ TDI were adopted in the HHRA
	Upper	Typical	Upper	Typical	
Groundwater					
Ingestion of groundwater	Elevated	Elevated	Elevated	Elevated	Continue not to drink groundwater within the IA (consistent with AECOM (2016) HHRA Report)
Incidental ingestion of groundwater as a result of indoor domestic use (excluding drinking groundwater) and outdoor domestic use	Elevated (previously low & acceptable)	Low & Acceptable	Elevated	Elevated (previously low & acceptable)	Avoid or minimise the use of groundwater for: showering and bathing; filling swimming pools and children's wading pools; and sprinkler play (consistent with AECOM (2016) HHRA Report) [1]
Dermal contact with groundwater as a result of indoor domestic use (excluding drinking groundwater) and outdoor domestic use	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	None Advised
Soil					
Incidental ingestion of soil as a result of outdoor activities	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	None Advised
Dermal contact with soil as a result of outdoor activities	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	None Advised
Inhalation of dust as a result of outdoor activities or dust tracked back into the home	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	None Advised
Locally sourced food					
Consumption of fruit and vegetables irrigated with water containing detectable PFAS or grown in soil that has been irrigated with water containing detectable PFAS	Elevated (previously low & acceptable)	Low & Acceptable	Elevated (previously low & acceptable)	Low & Acceptable	If the FSANZ TDI were adopted in the HHRA it may warrant an additional precautionary recommendation to minimise consumption of vegetables irrigated using water with detectable PFAS concentrations, until additional data can be collected to further characterise potential exposure via this pathway.

[1] It is noted that the risk estimate for incidental ingestion of groundwater residues after washing floors or companion animals is based on modelling approaches and 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.

Exposure Pathway	Potential PFAS Exposures – Zone 1		Potential PFAS Exposures – Zone 2		Suggested precautions if the FSANZ TDI were adopted in the HHRA
	Upper	Typical	Upper	Typical	
Consumption of meat from sheep or cattle that have consumed water containing detectable PFAS and/or consumed plants that have accumulated PFAS from irrigation water	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	None Advised
Consumption of milk from cattle that have consumed water containing detectable PFAS and/or consumed plants that have accumulated PFAS from irrigation water	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	None Advised
Consumption of eggs from chickens that have consumed water containing detectable PFAS and/or consumed plants that have accumulated PFAS from irrigation water	Elevated	Low & Acceptable	Elevated	Low & Acceptable	Restrict consumption of eggs from backyard chickens exposed to water containing detectable PFAS, until additional data can be collected to further characterise PFAS concentrations in eggs at a range of groundwater PFAS concentrations in both Zone 1 and Zone 2 (consistent with AECOM (2016) HHRA Report)

Table 4 Summary of HHRA Conclusions for Commercial Agriculture Workers and Subsistence Farmers based on FSANZ TDI

Exposure Pathway	Potential PFAS Exposures – Zone 1		Potential PFAS Exposures – Zone 2		Suggested precautions if the FSANZ TDI were adopted in the HHRA
	Upper	Typical	Upper	Typical	
Groundwater					
Incidental ingestion of groundwater as a result of outdoor commercial agriculture use	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	None Advised
Dermal contact with groundwater as a result of outdoor commercial agriculture use	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	None Advised
Soil					
Incidental ingestion of soil as a result of outdoor activities	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	None Advised
Dermal contact with soil as a result of outdoor activities	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	None Advised
Inhalation of dust as a result of outdoor activities	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	None Advised
Locally sourced food					
Consumption of meat from sheep or cattle that have consumed water containing detectable PFAS and/or consumed plants that have accumulated PFAS from irrigation water	Elevated (previously low & acceptable)	Low & Acceptable	Not a Complete Pathway	Not a Complete Pathway	If the FSANZ TDI were adopted in the HHRA it may warrant an additional precautionary recommendation to minimise consumption of meat from cattle/ sheep that drink water with detectable PFAS concentrations, until additional data can be collected to further characterise potential exposure via this pathway. For example, diversifying the sources of meat in the diet could reduce overall PFAS exposure. The AECOM (2016) HHRA did not identify livestock that are commercially raised for meat production in association with the groundwater bores that have been sampled within Zone 2. However, because PFAS concentrations are typically greater in groundwater from Zone 2 compared to Zone 1, the above precautionary recommendation should be considered in both Zone 1 and Zone 2.

Table 5 Summary of HHRA Conclusions for Recreational Receptors based on FSANZ TDI

Exposure Pathway	Potential PFAS Exposures – Investigation Area		Suggested precautions if the FSANZ TDI were adopted in the HHRA
	Upper	Typical	
Surface Water			
Incidental ingestion of surface water as a result of outdoor activities	Low & Acceptable	Low & Acceptable	None Advised
Dermal contact with surface water as a result of outdoor activities	Low & Acceptable	Low & Acceptable	None Advised
Soil and Sediment			
Incidental ingestion of soil and sediment as a result of outdoor activities	Low & Acceptable	Low & Acceptable	None Advised
Dermal contact with soil and sediment as a result of outdoor activities	Low & Acceptable	Low & Acceptable	None Advised
Inhalation of dust as a result of outdoor activities	Low & Acceptable	Low & Acceptable	None Advised
Locally sourced food			
Consumption of fish from local waterways *by recreational fishers*	Elevated (previously low & acceptable)	Low & Acceptable	If the FSANZ TDI were adopted in the HHRA it may warrant an additional precautionary recommendation to minimise consumption of fish from local waterways, until additional data can be collected to further characterise potential exposure via this pathway.

Table 6 Summary of HHRA Conclusions for On-Site Employees based on FSANZ TDI

Exposure Pathway	Potential PFAS Exposures – On-Site		Suggested precautions if the FSANZ TDI were adopted in the HHRA
	Upper	Typical	
Soil			
Incidental ingestion of soil as a result of outdoor activities	Low & Acceptable	Low & Acceptable	None Advised
Dermal contact with soil as a result of outdoor activities	Low & Acceptable	Low & Acceptable	None Advised
Inhalation of dust as a result of outdoor activities or dust tracked back into the workplace	Low & Acceptable	Low & Acceptable	None Advised

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