Stage 2C Environmental Investigation – Human Health Risk Assessment, Army Aviation Centre Oakey

Executive Summary

Prepared for
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FINAL

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Executive Summary

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) contamination associated with the historic use of legacy aqueous film forming foam (AFFF) at the Army Aviation Centre Oakey (AACO), in Oakey, Queensland (the Site).

Fire-fighting training and emergency response services involving the use of AFFF containing PFAS have occurred at the Site since the 1970s. The main AFFF product used historically by Defence was 3M Lightwater™, which contains PFAS including perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA). It is understood that 3M Lightwater™ was phased out and replaced by Ansulite®, which was reported to contain significantly lower concentrations of PFOS and PFOA (AECOM, 2015a). Based on anecdotal evidence, for the purposes of this report, it has been assumed that Defence commenced phasing out the use of AFFF products containing PFOS and PFOA from 2005. This assumption has not been verified by Defence.

PFOS and PFOA were first identified in the groundwater at the Site during an investigation undertaken by URS Australia Pty Ltd (URS) on behalf of Defence in 2010. Environmental studies conducted between 2010 and 2014 identified that soil, sediment, surface water and groundwater on- and off-Site were affected by a range of contaminants associated with historical Defence activities.

Environmental investigations undertaken by AECOM in 2014 and early 2015 confirmed:

- the presence of detectable concentrations of PFAS in soil on the Site
- the presence of detectable concentrations of PFAS in surface water, sediment and groundwater both at the Site and in the surrounding area off-Site to the south and west.

The HHRA considers both the Site and the surrounding off-Site areas, herein referred to as the Investigation Area (IA) and the Detection Area (DA). The IA is the broader area, and includes the Site and surrounds being studied to assess the extent of PFAS detections in groundwater. The DA is defined by locations within the IA at which PFOS and PFOA have been detected in groundwater samples above the laboratory limit of reporting (LOR) of 0.01 μg/L. The boundaries of the DA have also changed over time, as more information has become available. The current extent of the DA encompasses the south-western portion of the Site and extends approximately 4.5 km south to the confluence of Oakey Creek and Westbrook Creek and 2.5 km west of the Site, as depicted on **Figure F2**, **Appendix A**.

The use of groundwater containing detectable concentrations of PFAS for irrigation in the DA is considered likely to have resulted in PFAS detections reported in soil in areas off-Site.

Objective

The objective of this HHRA is to assess the potential for risks to health of identified groups of people (referred to as 'receptors') on- and off-Site within the IA who may be exposed to PFAS that have been detected in the environment as a result of historic use of legacy AFFF at the Site. The HHRA assesses potential exposure that could occur as a result of current and ongoing activities at the Site and the current land uses and groundwater uses within the DA and the IA. This includes exposure to PFAS reported in soil, groundwater, surface water, sediment, terrestrial biota and aquatic biota.

Consistent with the *Environmental Protection Act 1994* (Qld), this assessment has been conducted based on the framework outlined in the *National Environment Protection (Assessment of Site Contamination) Measure 1999* (as amended 2013) [ASC NEPM, 2013] and with reference to methodology outlined in enHealth (2012b) *Environmental Health Risk Assessment, Guidelines for Assessing Human Health Risks from Environmental Hazards*.

Data Evaluation

The previous investigations that have been completed within the IA were reviewed and considered to provide appropriate quality and quantity of data for use in this HHRA. Based on this review, the HHRA has identified two groundwater impact zones off-Site within the DA, as depicted on **Figure F6**, **Appendix A**:

- '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 use of generic assessment criteria in a 'Tier 1' screening step for the selection of chemicals of potential concern (CoPC) is not considered appropriate for this HHRA, because PFAS have the potential to bioaccumulate within the food chain. No Tier 1 guideline values have been established that are protective of the potential for bioaccumulation via all potential pathways. The identification of PFAS for assessment in the quantitative HHRA was therefore based on the availability of toxicity reference values (TRV), which are numerical values derived from toxicity dose-response studies in a manner consistent with relevant Australian science policy, for those PFAS detected above the laboratory LOR. Typical LORs for the various media analysed are presented in **Appendix D**.

Interim guidance from enHealth on appropriate TRV for PFOS, PFOA and PFHxS for use in Australian risk assessments was released informally by NSW Health in June 2016 (referred to herein as enHealth, 2016b). At the time this report was prepared, formal publication of this interim guidance by the Australian Government had not occurred.

Conceptual Site Model

To facilitate preparation of the HHRA a conceptual site model (CSM) was prepared based on the available information to identify 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 potentially complete exposure pathways.

Where a linkage between a source and receptor via a complete pathway was identified, these were assessed quantitatively in the HHRA.

This report includes consideration of PFAS that have been detected in the environment as a result of historic use of legacy AFFF at the Site and pathways by which people on- and off-Site within the IA may be exposed in association with the current and ongoing activities at the Site and the current land uses and groundwater uses within the DA and the IA. This includes direct contact exposures to environmental media (e.g. soil, groundwater, surface water, pore water and sediment) as well as secondary exposures via dietary intakes, including both fish and home grown plant and animal produce.

The groups of people who may be exposed to PFAS detected in the environment and who were therefore assessed in the HHRA were:

- residents within the DA and the IA surrounding the Site
- recreational users of publicly accessible areas including playing fields and local waterways within the DA surrounding the Site
- commercial (agricultural) workers at properties within the DA surrounding the Site
- on-Site personnel who work at the Site (this is considered to encompass all personnel who undertake training or other operational works at the Site as well as infrequent visitors).

A total of 47 exposure pathways were considered in the HHRA. These can be broadly characterised as:

- consumption of groundwater used for domestic drinking water supply

- incidental ingestion and dermal contact exposure associated with indoor domestic uses of groundwater (e.g. bathing/ showering, household cleaning, laundry)
- incidental ingestion and dermal contact exposure associated with outdoor domestic uses of groundwater (e.g. swimming in pools, sprinkler play, irrigation, washing vehicles, washing animals)
- consumption of plant produce (e.g. fruit, vegetables) irrigated with groundwater or grown in soil historically irrigated with groundwater
- consumption of animal produce (e.g. chicken eggs, red meat, milk) where animals drink groundwater or eat plants irrigated with groundwater or grown in soil historically irrigated with groundwater
- consumption of fish from local waterways
- incidental ingestion and dermal contact exposure associated with outdoor recreation at playing fields or local waterways (e.g. fishing, boating, swimming)
- incidental ingestion and dermal contact exposure associated with commercial agriculture uses of groundwater (e.g. irrigation, washing vehicles, washing animals)

AECOM is not aware of people in the IA using surface water for drinking water supply, however surface water may be used for irrigation or stock watering purposes (although this may be limited by the ephemeral nature of the surface waterways). Based on higher reported PFAS concentrations in groundwater compared to surface water, and the greater variability in surface water PFAS concentrations (in response to rainfall) the assessment of groundwater use for irrigation or stock watering purposes over the long term is considered to be conservative compared to scenarios where surface water may be used for irrigation.

It is possible that other exposure pathways may exist in the future, for example potential future uses of water on-Site and off-Site or intakes of specific plant or animal products that are not currently occurring (e.g. aquaculture). These exposure pathways have not been included in the HHRA and ongoing engagement with the community by Defence will assist with identification of water use and food production/consumption trends within the IA and the possible requirement for the HHRA to be revisited to include additional pathways.

Exposure Assessment

Identification of the potential frequency, extent and duration of exposure to PFAS in the environment by the above groups of receptors via identified exposure pathways was based on information gathered from community surveys and from published data from Australian and international sources (as referenced in **Section 5.1.2**).

Representative exposure point concentrations (EPC) were identified by evaluating the available data characterising environmental media and the current understanding of the potential methods of exposure for the identified groups of people to the PFAS detected in the environment.

The EPC adopted in the HHRA for PFAS in environmental media (soil, groundwater, surface water and sediment) were maximum concentrations because it is intended that the HHRA provides outcomes that can be applied to all people who may be exposed to the PFAS detected in the environment within the IA. Using the maximum concentration is likely to overestimate intakes for the average person in the IA. However, if there is low or negligible risk from certain groundwater use at the maximum concentration, lower concentrations will result in lower risks. The EPC adopted in the HHRA for plant and animal produce consumed by humans were the average of detected PFAS concentrations, as these were considered most representative of long term dietary intakes for frequent consumers of those produce.

Toxicity Assessment

At the time of commencement of this HHRA, there was no published Australian guidance on the toxicological assessment of PFAS. Consequently, AECOM commissioned ToxConsult Pty Ltd (ToxConsult) to prepare toxicological profiles for the following PFAS to inform this HHRA:

- PFOS
- PFOA
- perfluorohexane sulfonic acid (PFHxS)
- perfluorohexanoic acid (PFHxA)

- 6:2 fluorotelomer sulfonate (6:2 FtS)
- 8:2 fluorotelomer sulfonic acid (8:2 FtS).

ToxConsult was also engaged to provide input to the preparation of the HHRA.

The ToxConsult (2016a, 2016b) toxicological profiles include:

- 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 and recommendation of no adverse effect levels (NOAELs) for human blood serum
- review of available dose-response TRV and recommendation of defensible TRV for PFOS, PFOA, PFHxS and PFHxA for use in this HHRA. The toxicity profiles concluded that the toxicological information for 6:2 FtS and 8:2 FtS is currently too limited to recommend defensible TRV for these chemicals.

The ToxConsult (2016a, 2016b) toxicological profiles are included in **Appendix J**, a summary of the health hazard associated with PFAS is included in **Section 6.1** and a summary the adopted TRV is included in **Section 6.2**.

The TRV recommended by ToxConsult for oral (i.e. ingestion) intakes of these PFAS is termed a tolerable daily intake (TDI). The TDI is a daily intake which, over a lifetime, is considered to be without appreciable adverse health effects, based on toxicological studies and incorporating a range of uncertainty (safety) factors. As recommended in these toxicological profiles, the HHRA has adopted TDI from the European Food Safety Authority (EFSA, 2008) for PFOS, PFOA and PFHxS. ToxConsult has also considered the current body of international toxicological research for PFHxA to be sufficient to develop chemical-specific TRV for use in an HHRA.

It is noted that exceeding the TDI does not necessarily mean that health effects will occur. As described in **Section 6.2.1**, the EFSA (2008) TDI for PFOS and PFHxS adopted in this HHRA was derived based on:

- an intake that was not associated with adverse health effects in monkeys and was five times lower than the lowest intake rate in the same study that was associated with health effects
- an uncertainty factor of 200 to account for animal to human differences in toxicodynamics and toxicokinetics, human variability in toxicodynamics and human variability in toxicokinetics
- the most sensitive health effects noted in experimental animal studies, including increased liver weight and decreases in body weight, cholesterol, high density lipoprotein, triglycerides and thyroid hormone. These health effects were shown to be completely reversible within 30 weeks of the animal's experimental exposure ceasing as serum concentrations decrease
- the health effects that the TDI is based on is a dose that was more than five times lower than the dose at which tumour formation had been observed in rat studies (Thomford, 2002), meaning the TDI can be considered to be protective of potential for cancer effects. Even at intakes greater than the TDI, based on the way high exposures to PFOS may induce cancer in rats (the non-genotoxic mechanisms of PPARα and CAR/PXR receptor activation) and the differences between rats and humans, humans are unlikely to develop cancer (ATSDR, 2015).

Risk Characterisation

The risk characterisation stage of this HHRA considered a number of lines of evidence as discussed below.

Estimated intakes for each potentially complete exposure pathway (or group of pathways) were compared to published background intakes for Australian populations and the TDI adopted in this HHRA. These indicated that use of groundwater for drinking water supply has the greatest potential of all pathways to result in intakes that exceed the TDI for combined exposure to PFOS and PFHxS. For residents in both Zones, PFOS and PFHxS intakes from drinking groundwater were estimated to be more than one order of magnitude (i.e. ten times) greater

than intakes from all other pathways combined. A precautionary approach would therefore be to continue to follow the advice not to use groundwater for drinking water supply within the IA (including water used for cooking).

Hazard indices (HI) were presented to provide a quantitative estimate of cumulative risk via multiple pathways. The HI is the ratio of the estimated intake to the adopted TRV, summed for all CoPC and relevant pathways. 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”.

Intakes of groundwater used for drinking water supply based on typical amounts of water consumed per day were estimated to exceed the TDI; however, this is not currently considered to be a complete pathway, as it is 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, the estimated HI discussed below excludes the drinking water pathway:

- HI were calculated for each receptor based on cumulative exposure via multiple pathways, excluding use of groundwater for drinking. The estimated total HI for all receptors based on typical exposure parameters were considered to indicate that the average person within the IA would not be likely to have PFAS intakes exceeding the TDI adopted in this HHRA, provided they continue to follow the precautionary recommendation to not use groundwater within the IA for drinking purposes
- However, the modelled upper range exposure parameters have the potential to result in cumulative intakes greater than the TDI in circumstances where the resident has particularly frequent deliberate or incidental ingestion of groundwater containing the maximum concentrations of PFAS and upper range rates of ingestion of plant and animal produce (i.e. vegetables, meat) that have been grown with groundwater containing detectable concentrations of PFAS
- It is important to note that, with the exception of drinking groundwater and incidental ingestion of water by children swimming in domestic pools in Groundwater Zone 2, none of the other pathways assessed (refer to the description of the CSM above) have been identified to individually result in estimated intakes greater than the TDI.

To assist with identifying the non-drinking water exposure pathways that contribute most to these estimated intakes for residential receptors, the contribution of each exposure pathway to the total HI was evaluated for adults and children in Groundwater Zone 1 and Zone 2. Pathways that were considered to be significant contributors to overall cumulative PFAS intake (i.e. pathway-specific HI greater than 0.5) based on upper range exposure parameters are summarised in **Table ES1**.

Table ES1 Identified significant pathways for upper range exposures

Pathway	Resident, Groundwater Zone 1		Resident, Groundwater Zone 2		Comments
	Adult HI	Child HI	Adult HI	Child HI	
Incidental ingestion of groundwater used in home swimming pools	0.09	0.2	0.5	1.2	Defence provides assistance for residents on a case-by-case basis to access an alternative water supply, including for household purposes and for domestic swimming pools that had previously been topped up with groundwater. Therefore, this pathway may not necessarily be complete for all people in the IA
Incidental ingestion of groundwater used for showering/bathing	0.02	0.1	0.1	0.6	
Incidental ingestion of groundwater used for sprinkler play	0.01	0.08	0.04	0.5	This pathway may currently be complete for people in the IA.

Pathway	Resident, Groundwater Zone 1		Resident, Groundwater Zone 2		Comments
Ingestion of chicken eggs	0.1	0.5	0.1	0.5	The egg samples used in this HHRA were from chickens from Groundwater Zone 2. These are likely to represent the upper range of potential PFAS concentrations in eggs and will overestimate potential intakes by the average person in the IA. Until additional data can be collected to further characterise PFAS concentrations in eggs at a range of groundwater PFAS concentrations in both Groundwater Zone 1 and Zone 2, minimising consumption of home grown eggs from chickens that drink water with detectable PFAS concentrations may be considered as a precaution.

The TDI is a daily intake which, over a lifetime, is considered to be without appreciable adverse health effects. Exceeding the TDI does not necessarily mean that health effects will occur. The potential for health effects to result from PFAS intakes has therefore been further evaluated on the basis of blood serum PFAS concentrations reported for the Oakey cohort by Heffernan (2015) or estimated from ingestion intakes, as detailed in **Appendix L** and summarised in **Sections 7.6** to **Section 7.8,** rather than by comparison of estimated intakes to a TDI.

Measured PFAS concentrations in de-identified blood serum samples from the Oakey cohort (Heffernan, 2015) were compared with background serum concentrations reported in scientific literature.

PFOA concentrations in blood serum are consistent with background and do not indicate that the environmental impacts are a significant source of exposure

ToxConsult concluded that PFOS and PFHxS are present in blood serum of many persons at concentrations greater than might be expected due to background sources, and are therefore the PFAS of concern within the IA and the focus of the components in the risk assessment discussed below.

Margin of exposure (MOE) assessments were undertaken by ToxConsult using experimental animal serum no effect and low effect concentrations.

- The MOE is the ratio between NOAEL or lowest observed adverse effect levels (LOAEL) derived from animal experiments to an estimate of human exposure. A MOE calculated using a NOAEL provides an indication of how far the estimated human exposure is from doses that caused no effect in animals, while the MOE determined using a LOAEL indicates how close the human exposure is to doses that did cause effects in animals. When the MOE is greater than an adopted target value which represents a safety factor, this is considered to indicate that health risks are low and acceptable
- The calculated MOE based on PFOS + PFHxS serum concentrations reported by Heffernan (2015) indicated that adverse health effects are unlikely to be associated with the concentrations of PFOS and PFHxS that have been measured in the Oakey biomonitoring cohort
- The MOE for modelled blood serum concentrations indicated that there is low and acceptable risk to health for the general community associated with the ingestion of the adopted average or high rates of beef or sheep meat or liver, chicken eggs or fish, including at the maximum modelled PFAS concentrations
- At the adopted maximum ingestion rates for beef liver (100 g/day), lamb liver (100 g/day) or fish (300 g/day), the MOE calculated by ToxConsult suggested a potential risk to health for the general community. However, these MOE were based on high daily ingestion rates which are considered unlikely to be representative of the general community and exceedances of the TDI due to intakes of these foods were not considered likely at upper ingestion rates adopted in the assessment undertaken by AECOM. It is also noted that these MOE were based on theoretical blood serum PFAS concentrations that were greater than the maximum measured PFAS concentrations reported in the Oakey cohort (Heffernan, 2015).
- ToxConsult concluded for subsistence farmers who source 100% of their diet from animals with PFAS exposure at the same magnitude as those from which blood serum samples were collected, that high ingestion rates of meat (more than 150 g/day) or liver (more than 15 g/day) from cattle or sheep that have been exposed to water containing detectable PFAS should be avoided. However, these daily ingestion rates

are considered unlikely to be representative of the general community and exceedances of the TDI due to intakes of these foods were not considered likely at upper ingestion rates and percentage of food sourced from the DA adopted for commercial agriculture workers in the assessment undertaken by AECOM.

The measured PFAS concentrations in de-identified blood serum samples collected from the Oakey community were compared with a human steady state serum concentration determined as unlikely to be associated with adverse health effects. All measured serum concentrations of PFOS and PFOA in the Oakey cohort (Heffernan, 2015) were below the human steady state serum NOAEL concentrations proposed by ToxConsult (2016a) in **Appendix J**.

Uncertainty and 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 this risk assessment have therefore been selected to provide a deliberate margin of safety for all scenarios assessed.

The key uncertainties associated with different components of the risk assessment process include:

- sampling and analysis – consideration has been given to identified data gaps and whether collection of further data is warranted to reduce the uncertainty in the exposure modelling and sampling. The HHRA has typically adopted conservative assumptions to deal with the data gaps discussed in **Table 18**. Where additional data are collected in the future, the HHRA outcomes can be further refined.
- human exposure parameters – consideration has been given to potential variability of exposure parameters based on available Site-specific information. Parameters varied include drinking water ingestion rates, percentage of agricultural produce sourced from the DA, child body weight, child ingestion rates for plant and animal produce and exposure frequency for swimming in pools filled with groundwater. Overall it was concluded that the HHRA outcomes were not sensitive to the range of exposure parameters considered in the sensitivity assessment (specifically, that HI were acceptable for typical exposure but there are theoretical upper range exposures where PFAS intakes could exceed the TDI).
- toxicity assessment – consideration has been given to the uncertainty associated with the derivation of adopted TRVs. The sensitivity assessment included consideration of the US EPA (2016) TRV for PFOS. The change in HI for each of the 47 pathways assessed is proportional to the change in the adopted TRV. This indicates that the HHRA conclusions would not change if the US EPA TRV for PFOS was adopted, i.e. the HI based on typical exposure parameters would continue to be acceptable and upper range exposure continue to have the potential to exceed the TDI.

Conclusions

The weight of evidence from the above is considered to indicate, based on the available data, that there is a low and acceptable risk to health associated with typical exposure to the PFAS detected in the environment for the general community within the IA. In particular, exposures for the general community via the following pathways are considered to have low risk of health effects:

- consumption of locally grown beef or sheep meat
- consumption of fish caught in local waterways
- consumption of locally grown fruit and vegetables
- skin contact with water or soil during any of the activities evaluated
- incidental ingestion of water during household cleaning or laundry
- incidental ingestion of water during irrigation or washing vehicles or animals
- incidental ingestion of surface water during recreation in local waterways (fishing, boating, swimming)

However, in certain theoretical scenarios, upper range exposures could result in PFAS intakes that indicate a potential risk to health. The available blood serum data from the Oakey cohort (Heffernan, 2015) indicate that these elevated PFAS exposures (which could be associated with potential health risks) are unlikely to have occurred, however this cannot be stated with certainty.

In consideration of these theoretical scenarios that could be associated with risks to health, the data gaps and uncertainties inherent in these assessments and the fact that people in the Oakey community have PFAS concentrations in blood serum due to past exposure that are greater than would be expected due to background exposure, a precautionary approach would be to minimise future exposure (refer to **Section 7.5**). Based on the pathways estimated to make the greatest contribution to the estimated intakes and HI, and for which the MOE assessment also indicated a potential health risk for the general community, this precautionary approach could include:

- continuance of the precautionary recommendation to not use groundwater for drinking water supply within the IA (including water used for cooking). This recommendation should be considered for groundwater drawn from all aquifers. AECOM is not aware of people in the IA using surface water for drinking water supply, but the precautionary advice would also apply to such a scenario.
- in Groundwater Zone 2, avoiding or minimising the use of groundwater containing detectable concentrations of PFAS for showering/bathing, for sprinkler play or to fill swimming pools or paddling pools (due to the potential for PFAS intakes via incidental ingestion of water).
- until additional data can be collected to further characterise PFAS concentrations in eggs at a range of groundwater PFAS concentrations in both Groundwater Zone 1 and Zone 2, avoiding or minimising consumption of home grown eggs from chickens that drink water with detectable PFAS concentrations.

The HHRA conclusions are summarised in **Table ES2** for residents, **Table ES3** for commercial agriculture workers, **Table ES4** for recreational receptors and **Table ES5** for on-Site personnel.

These conclusions should be read in conjunction with the data gaps presented in **Section 4.6** and the sensitivity assessment presented in **Section 8.2**.

Table ES2 Summary of HHRA Conclusions for Residents

Exposure Pathway	Potential PFAS Exposures – Zone 1		Potential PFAS Exposures – Zone 2		Suggested Precautions
	Upper	Typical	Upper	Typical	
Groundwater					
Ingestion of groundwater	Elevated	Elevated	Elevated	Elevated	Continue not to drink groundwater within the IA
Incidental ingestion of groundwater as a result of indoor domestic use (excluding drinking groundwater) and outdoor domestic use	Low & Acceptable	Low & Acceptable	Elevated	Low & Acceptable	Avoid or minimise the use of groundwater in Zone 2 for: showering and bathing; filling swimming pools and children's wading pools; and sprinkler play.
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	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	None Advised
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

Table ES3 Summary of HHRA Conclusions for Commercial Agriculture Workers and Subsistence Farmers

Exposure Pathway	Potential PFAS Exposures – Zone 1		Potential PFAS Exposures – Zone 2		Suggested Precautions
	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	Low & Acceptable	Low & Acceptable	Not a Complete Pathway	Not a Complete Pathway	None Advised [(a)]

Note:

*(a) ToxConsult concluded for subsistence farmers who source 100% of their diet from animals with PFAS exposure at the same magnitude as those from which blood serum samples were collected, that high ingestion rates of meat (more than 150 g/day) or liver (more than 15 g/day) from cattle or sheep that have been exposed to water containing detectable PFAS should be avoided (refer to **Appendix L**). However, these daily ingestion rates are considered unlikely to be representative of the general community, and exceedances of the TDI due to intakes of these foods were not considered likely at the upper ingestion rates and percentage of food sourced from the DA adopted for Commercial Agriculture Workers in the assessment undertaken by AECOM.*

Table ES4 Summary of HHRA Conclusions for Recreational Receptors

Exposure Pathway	Potential PFAS Exposures – Investigation Area		Suggested Precautions
	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*	Low & Acceptable	Low & Acceptable	None Advised [(a)]

Note:

*(a) ToxConsult concluded for subsistence consumers who source 100% of their fish from the DA, that high ingestion rates (more than 100 g/day) should be avoided (refer to **Appendix L**). However, these daily ingestion rates are considered unlikely to be representative of the general community, and exceedances of the TDI due to intake of fish was not considered likely at upper ingestion rates adopted in the assessment undertaken by AECOM.*

Table ES5 Summary of HHRA Conclusions for On-Site Employees

Exposure Pathway	Potential PFAS Exposures – On-Site		Suggested Precautions
	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