PFC Conceptual Site Model
Army Aviation Centre Oakey

Client: Department of Defence
ABN: N/A

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1.0 Introduction

AECOM Australia Pty Ltd (AECOM) was commissioned by the Department of Defence (Defence) to expand on the preliminary conceptual site model (CSM) which has been prepared for the Army Aviation Centre Oakey (AACO) as presented in Background Review and PFC Summary Report, Army Aviation Centre Oakey (AECOM, March 2015).

1.1 Background

The information used to form the basis of the current report has been sourced mainly from the Background Review and PFC Source Study (AECOM 2015). The AECOM (2015) report ‘leveraged off and supplements information provided in the many previous environmental reports prepared for the AACO since 1988.’

1.2 Objectives

The objectives of this report are to:
- expand upon the information presented in the preliminary conceptual site model (CSM) (as presented in AECOM, 2015)
- provide a conceptual understanding of the pathways via which identified receptors at the AACO, and in surrounding area, may be exposed to perfluorinated compounds (PFCs).

It is noted that other chemicals of potential concern (CoPC) have been identified to be present at the AACO, however the current CSM has focused on sources, receptors and potentially complete exposure pathways related to PFCs only.

This CSM document has been prepared in accordance with guidance provided in the ASC NEPM (NEPC, 2013) which states that:

‘The development of a CSM is a dynamic process and it is important that all the information and data from each stage of an assessment are reviewed in an integrated manner to refine the CSM.’

Iterative development of the CSM is an important process to ensure that all relevant data is included in the overall conceptual understanding of issues and impacts at the site. A dynamic and iterative CSM is an effective tool for decision making processes, and the current CSM document provides a representative conceptual understanding of current information. This CSM is intended to be a dynamic document which can be updated throughout the course of the Oakey investigation to include new data as it becomes available.

This report is limited to identifying and understanding sources, pathways and receptors and is not in any way indicative of health or ecological risks.

1.3 Scope of Work

The scope of work undertaken to achieve the above listed objectives consisted of the following:
- Assessment of the nature and extent of contamination and identification of contaminant transport pathways.
- Compilation of information currently available with regard to human and ecological receptors at the AACO and in surrounding areas.
- Determination of potentially complete exposure pathways.
- Compilation of a detailed CSM for the AACO and surrounding areas.
The above scope of work has been conducted in accordance with relevant nationally adopted guidance including:

- National Environment Protection (Assessment of Site Contamination) Measure 1999 (as amended April 2013), National Environment Protection Council (NEPC) 2013, specifically:
  - Schedule B(2) Guideline on Site Characterisation (Section 4 – Conceptual Site Models)
  - Schedule B(4) Guideline on Site-Specific Health Risk Assessment Methodology.

2.0 Conceptual Site Model

2.1 Site Description and Environmental Site Setting

A detailed description of the AACO was provided in AECOM (2015) and therefore will not be re-iterated in the current report. However the following is provided in summary:

- The AACO is located within the township of Oakey, approximately 35 km north-west of Toowoomba on the western side of the Great Dividing Range. Oakey is located within the Darling Downs region approximately 126 km west of Brisbane (refer to Figure 1 in Appendix A).

- The AACO occupies approximately 860 ha, of which approximately 33 ha is leased for agriculture (off Base to the west of the AACO). The AACO is bounded by Corfe Road, Oakey Cooyar Road, Withorne Kelvinhaugh Road and Oakey Kelvinhaugh Road. The main access point to the training centre is via Beale Street and Orr Road. The Warrego Highway is located approximately 3 km to the south of the Base (refer to Figure 2 in Appendix A).

- The Base is located approximately two kilometres north east of the town centre of Oakey. Current land uses surrounding the Base are largely agricultural and rural in nature. Land uses within the town of Oakey include detached housing, commercial premises and industrial properties. The closest urban uses to the AACO are a grouping of industrial properties located on Orr Road.

- Oakey is located within the Great Artesian Basin (GAB), which is one of the largest groundwater basins in the world. It underlies approximately one-fifth of Australia and extends beneath arid and semi-arid regions of Queensland, New South Wales, South Australia and the Northern Territory, stretching from east of the Great Dividing Range to the Lake Eyre depression. The GAB has an estimated total water storage of 65,000 gigalitres (GL) (Department of Natural Resources and Mines, 2012). A hydrogeological desktop study was conducted as part of the AECOM (2015) assessment, and further details of hydrogeological conditions at the AACO and in surrounding areas has therefore not been included in the current report. The following summary of information from this study is provided:
  - Three regional aquifers have been identified beneath Oakey (the Oakey Creek Alluvial Aquifer; the Main Range Volcanics Aquifer; and the Walloon Coal Measures Aquifer).
  - The hydrogeology of the Oakey Creek alluvium has been summarised within AECOM (2015) along with the underlying basalt aquifer of the Main Range Volcanics and the deep sandstone of the Walloon Coal Measures. The geometry and structure of the deeply incised basalt landscape produces hydraulic barriers and preferred groundwater flow paths which influences contaminant plume movement. In addition it is postulated that the presence of an east west oriented palaeochannel within the lower Oakey Creek Alluvium acts as a preferred pathway increasing plume mobility.
  - Groundwater flow within the Oakey Creek Alluvium is south-westerly towards Oakey Creek, the Condamine River and the town water supply bores. Discharge from the aquifer is via pumping extraction for irrigation and town water supply, groundwater through-flow and possibly leakage to underlying aquifers.

- Groundwater was used on Base for a range of applications (it is noted that groundwater is no longer extracted at the base for any of the uses below) including:
  - vehicle and aircraft wash down, noting that only demineralised water is used so as to protect the aircraft
  - workshop washdown
  - airfield dust suppression and skidded landing aircraft
  - irrigation (sporting oval and gardens)
  - fire fighting purposes
  - air conditioning
  - pool (recreational) water
  - domestic purposes (cooking, washing, laundry etc.).
- Groundwater was also treated onsite by a desalination plant for domestic supply to the on-base living quarters and for supply to the local community for irrigation and domestic purposes (HLA, 2006). It is noted that the desalination plant has been decommissioned.

- Regional (off-base) groundwater is beneficially used for:
  - municipal and private drinking water (noting that Defence has provided advice to residents located within the Investigation Area (http://www.defence.gov.au/id/oakey/))
  - irrigation (grain crops, fruit crops and private botanical gardens and edible vegetable gardens)
  - livestock and domestic animals
  - aquaculture
  - domestic purposes (cooking, showering, cleaning and laundry)
  - commercial (local hospital and abattoir)
  - mining
  - recreational (filling of swimming pools and irrigation of sporting fields).

- The Jondaryan Shire War Memorial Swimming Pool located at 50 Campbell Street, Oakey, is for public use, however, the pool is filled with reticulated town water.

- Oakey Creek flows from east to west approximately 1 km south of the AACO, and is understood to be used for a range of recreational purposes (i.e. swimming, kayaking etc.). Though it is noted that Oakey Creek is ephemeral in nature and thus does not maintain a continuous flow year round, it is anticipated that recreational activities are significantly reduced during low flow periods (i.e. in summer months). Two drainage channels have been identified to flow from the AACO and discharge to Oakey Creek which provide a direct transport pathway for chemical contaminants to flow from the AACO to Oakey Creek.

- AECOM completed a preliminary desktop ecological assessment at the AACO and surrounding environments downstream of the site (inclusive of Oakey Creek).
  - A number of ecological receptors, in the form of potential terrestrial and aquatic food chains, were identified, based on available habitat (the series of potential food chains identified during the ecological assessment are presented in Figure 1-Figure 7, below). Also of note is the observation of freshwater mussels which were numerous in several locations including in the vicinity of the confluence between the western AACO drainage line and Oakey Creek. Oakey Creek is ephemeral and forms discrete pools during times of low flow, therefore aquatic food chains are considered likely to vary based on flow conditions in the creek.

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**Figure 1** Indicative food chain for modified pasture

**Figure 2** Indicative food chain riparian vegetation / wetlands
Figure 3  Indicative food chain remnant/regenerating woodlands

Primary producers  
- Poplar Box Trees  
- Shrubs  
- Grassland pasture

Herbivores  
- Arthropods i.e. White Ants  
- Arboreal mammals

First level carnivores  
- Small reptiles i.e. Long-legged Worm-Shrike  
- Mammals i.e. Echidna

Second level carnivores  
- Birds of prey i.e. owls  
- Mammals i.e. foxes, cats

Figure 4  Indicative food chain public open space

Primary producers  
- Native and exotic trees  
- Shrubs  
- Grasses

Herbivores  
- Leep insects  
- Koala  
- Birds i.e. honeyeaters

First level carnivores  
- Birds of prey i.e. owls  
- Reptiles i.e. Lace Monitor

Second level carnivores  
- Insectivorous birds i.e. pardalotes

Figure 5  Indicative food chain road side vegetation

Primary producers  
- Grassland  
- Scattered native and exotic trees

Herbivores  
- Fruit/seed eating birds  
- Small mammals  
- Fruit bats  
- Invertebrates

First level carnivores  
- Omnivorous birds i.e. ravens, magpies  
- Snakes i.e. Eastern Brown Snake

Second level carnivores  
- Birds of prey i.e. Red Goshawk, Black Shouldered Kite

Figure 6  Indicative food chain for residential gardens

Primary producers  
- Garden plants  
- Fungi

Herbivores  
- Small mammals  
- arboreal mammals i.e. possums  
- Birds

First level carnivores  
- Birds of prey i.e. owls, Whistling Kite, Red Goshawk  
- Snakes

Second level carnivores  
- Introduced predatory mammals i.e. foxes, cats

Third level Carnivores  
- Larger fish species i.e. Murray Cod

Figure 7  Indicative food chain Oakey Creek

Primary producers  
- Algae  
- Submerged, emergent and floating aquatic vegetation  
- Phytoplankton

Herbivores  
- Micro and macro invertebrates  
- Molluscs i.e. freshwater mussels  
- Crustaceans

First level carnivores  
- Dragonfly nymphs  
- Small Fish i.e. Apatinus glassfish  
- Crayfishes

Second level carnivores  
- Medium sized fish i.e. Purple Spotted Wedgegon  
- Crustaceans

Third level Carnivores  
- Larger fish species i.e. Murray Cod
2.2 Nature and Extent of Contamination

2.2.1 Potential Contamination Sources

The following current and historical activities undertaken at the AACO were considered in the AECOM (2015) reports to have the potential to result in adverse environmental impacts, based on review of available information:

- Bulk fuel and chemical handling and storage
- Paint spraying/stripping
- Non-destructive testing (laboratory)
- Liquid waste collection, storage and treatment
- Solid waste disposal
- Aircraft, vehicle and battery maintenance
- Fire fighting training and maintenance
- Fire related incident response
- Vehicle and aircraft wash down and maintenance.

It is noted that the current CSM has focused primarily on potential contamination associated with the use of aqueous film forming foams (AFFF) for fire fighting training and maintenance and fire related incident responses. These activities are considered to be associated with the potential release of PFCs to the environment.

2.2.2 Impacted Media

The following information has been obtained directly from the AECOM (2015) report, and has focused primarily on PFC impacts identified at the AACO and in surrounding areas.

It is noted also that samples of concrete infrastructure have been collected and analysed for PFCs. Results of concrete sampling indicates that concrete infrastructure which has come in contact with AFFF has the potential to be impacted with PFCs which may leach to surface run-off and act as an ongoing source of contamination.

2.2.2.1 Identified Soil PFC Impacts

Impacted soil has been identified at:

- **The former FTA** (Area North): soil in this area was land farmed by Thiess in 1997 to reduce the petroleum hydrocarbon concentrations to appropriate levels. AECOM notes that the adopted method of remediation would not have addressed PFC impact (if present) and therefore this material if replaced in the excavation may still contain PFC concentrations in soil which may leach to surface water and or groundwater.

- **Area North** drainage line sample (N_G_0.8) had a PFOS concentration of 30 mg/kg. The sample was taken in the vicinity of the former fire training area.

It should be noted that very limited soil characterisation for PFC concentrations has been conducted in any of the previous investigations undertaken at the AACO since 1991, although such testing when undertaken identified low concentrations of PFOS and PFOA (excluding sample N_G_0.8).

2.2.2.2 Identified Groundwater PFC Impacts

Dissolved PFC impact to groundwater was first reported in 2010 and has been identified by different consultants at different times in groundwater at the following Base locations:

- Area A1 - Fuel farm (AFFF recovery tank)
- Area A2 – Hot refuelling pads (Facility Asset A83 - Spent AFFF collection tank) – fluctuates
- Area B1 – Former refuelling tanker parking bays
- Area B2 – Former battery and vehicle workshop (B21) and truck maintenance (B20)
- Area B3 – Former fire station (highest concentrations)
- Area B4 – Former fire training area (former Facility Asset B9)
- Area B5 – Defence operations pre the 1971 AACO construction
- Area C1 – The concrete Spent AFFF collection tank (to the rear of the Blackhawk Maintenance Hangar)
- Area C2 – Engineering Workshop (C12), Battery Workshop (C15), paint treatment plant (C11) and historical waste pond (C5)
- Area C3 – Vehicle Refuelling Point (Facility Asset C26)
- Area F1 – Facility Asset C61 (Aircraft wash point)
- Area S1 – RSAF (Spent AFFF collection tank).

It is most likely that co-mingled plumes of PFCs are located within the upper and lower zones of the Alluvial Aquifer across the Base.

### 2.2.2.3 Identified Surface Water Impacts

PFC concentrations have been variably detected in surface water obtained from the drainage lines across and exiting the AACO and in Oakey Creek at a number of locations.

### 2.2.3 Chemicals of Potential Concern

For the purposes of the current CSM, key chemicals of potential concern (CoPC) detected at the AACO and in surrounding areas are considered to include:
- Perfluorinated compounds (PFCs) primarily:
  - Perfluorooctane sulfonate (PFOS)
  - Perfluorooctanoic acid (PFOA)
  - 6:2 Fluorotelomer sulfonate (6:2FtS)
  - 8:2 Fluorotelomer sulfonate (8:2FtS).

It is noted that petroleum hydrocarbon compounds have been identified to be present in soil and groundwater at the AACO, including the presence of non-aqueous phase liquids (NAPL). However as stated in Section 1.2, the current CSM has focused on the potential exposure pathways via which identified receptors may be exposed to PFCs.

### 2.3 Contaminant Transport Pathways

Potential transport pathways by which identified CoPC may migrate within and from the AACO are summarised in Table 1.

<table>
<thead>
<tr>
<th>Transport Pathways</th>
<th>Comments</th>
<th>Likelihood or Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind dispersion of foams and spray mists.</td>
<td>Fire-fighting foams and spray mists associated with fire training and fire-fighting activities have the potential to be dispersed away from application areas and deposit on surrounding surface soils.</td>
<td>Likely. Based on the available information it is considered likely that this transport mechanism has occurred in the past and may currently occur during fire-training/fighting exercises.</td>
</tr>
<tr>
<td>Wind erosion and atmospheric dispersion of upper layers of surface soils.</td>
<td>The majority of the AACO site area consists of open grassed spaces, where there is potential for wind erosion and atmospheric dispersion of soil*.</td>
<td>Likely. Based on the reported use of foams at the AACO site and the potential for PFC contamination to be dispersed in surface soils it is considered likely that this transport pathway is occurring or has occurred in the past.</td>
</tr>
</tbody>
</table>
Transport Pathways | Comments | Likelihood or Significance
--- | --- | ---
Leaching from impacted infrastructure (e.g. concrete training surfaces) to surface run-off and adsorption to soil. | Analysis of concrete samples collected from the AACO indicates that concrete surfaces where AFFF has been used have become impacted with PFCs. Leaching tests on these samples also indicates that PFCs can be re-mobilised from impacted concrete to surface run-off. | Likely. Based on reported leachable concentrations from concrete samples and the potential for surface run-off to be transported away from concrete infrastructure.

Movement through and leaching from soil to groundwater, and transport within groundwater. | Groundwater impacts have been reported beneath the AACO site and in groundwater to the south and south-west of the AACO site. | The reported widespread presence of impacts in groundwater indicates that this transport pathway has occurred and is likely to be currently occurring.

Leaching from soil, impacted infrastructure and/or sediment to surface run-off and transport to surface water bodies. | Testing of surface water and sediment from drainage channels which flow between the AACO site and Oakey Creek indicates that PFCs are transport from the AACO to connected waterways. | The reported presence of impacts in surface waters from drainage channels and Oakey Creek indicates that this transport mechanism has occurred in the past and is potentially still occurring.

Extraction of groundwater and use of groundwater for irrigation purposes, sorption of groundwater derived impacts to soil. | It is understood that groundwater is widely extracted from properties surrounding the AACO. Groundwater impacts have been reported in extraction bores up to 4 km from the AACO site. | Based on the currently available information with regard to the use of groundwater for irrigation purposes, and the reported presence of PFCs in groundwater, this transport mechanism is considered likely to have occurred in the past and is likely to be currently occurring.

Leaching of groundwater derived impacts from soils irrigated (and thus impacted) with groundwater and further transported in groundwater. |  | * It is noted that this transport pathway is considered likely to be complete only during extended dry periods, and is not considered to be a transport pathway that is always present.

2.4 Potential Human Receptors

Based on currently available information with regard to the current and ongoing use of the AACO and the current land uses of the surrounding areas the following human receptors have been identified:

- **AACO receptors:**
  - AACO Personnel who work at the base (this is considered to encompass all personnel who undertake training or other operational works at the AACO facility. However, for the purposes of this report it is assumed that relevant AACO personnel use personal protective equipment during application of foams and fire training exercises and, therefore, occupational exposure from these activities is not considered as part of this CSM).
  - Intrusive maintenance workers who may conduct infrequent maintenance works on underground services at the AACO.
  - Maintenance workers who conduct non-intrusive maintenance activities at the AACO (i.e. personnel who maintain the gardens and grassed areas at the AACO)
  - Visitors to the AACO who stay for a short period and are not frequently present at the Site (e.g. people who attend training or short term contractors).
- **Identified receptors in surrounding areas:**
  - Residents of the area surrounding the AACO.
  - Recreational users of the land, and waterways, surrounding the AACO.
  - Commercial (agricultural) workers at the properties surrounding the AACO. Considered to consist mostly of farm workers and abattoir workers who use groundwater during their work day, and potentially council workers where groundwater is used by council for irrigation.

### 2.5 Potential Human Exposure Pathways

In order for a human receptor to be exposed to a chemical contaminant deriving from a Site, a complete exposure pathway must exist. An exposure pathway describes the course a chemical or physical agent takes from the source to the exposed individual and generally includes the following elements (USEPA, 1989):

- A source and mechanism of chemical release.
- A retention or transport medium (or media where chemicals are transferred between media).
- A point of potential human contact with the contaminated media.
- An exposure route (e.g. ingestion, inhalation) at the point of exposure.

Where one or more of the above elements is missing, the exposure pathway is considered to be incomplete and there is therefore no direct risk to the receptor.

Pathways that are considered to be complete based on currently available information have been summarised below (Table 2 and Table 3). For ease of interpretation, receptors and exposure pathways have been divided into AACO and off-Site (i.e. receptors who do not access the AACO site).

#### Table 2  Exposure Pathway Analysis – AACO Receptors

<table>
<thead>
<tr>
<th>Exposure Pathway</th>
<th>Complete?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>AACO Personnel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dermal contact with and incidental ingestion of impacts present in soils at the AACO.</td>
<td>✓</td>
<td>This pathway is considered to be potentially complete for these receptors as there is potential for personnel at the AACO to be undertaking activities (i.e. maintenance of gardens) which may result in direct contact with impacted surface soils.</td>
</tr>
<tr>
<td>Inhalation of dust generated from impacted surface soils at the AACO.</td>
<td>✓</td>
<td>The current conditions at the AACO are such that there is potential for wind erosion of surface soils and atmospheric dispersion across the AACO.</td>
</tr>
<tr>
<td>Dermal contact with and incidental ingestion of impacted groundwater.</td>
<td>✓</td>
<td>This exposure pathway was historically complete but is currently being managed such that no groundwater extraction is occurring at the AACO.</td>
</tr>
<tr>
<td>Dermal contact with and incidental ingestion of impacts in surface water and sediment contained within drainage channels.</td>
<td>✓</td>
<td>There is potential for this exposure pathway to be complete for AACO personnel who maintain the on-site drainage channels.</td>
</tr>
<tr>
<td>AACO Maintenance Workers (both intrusive and non-intrusive)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dermal contact with and incidental ingestion of impacts present in soils at the AACO.</td>
<td>✓</td>
<td>There is potential that maintenance (both intrusive and non-intrusive) works may be conducted in areas where soil impacts are present.</td>
</tr>
<tr>
<td>Inhalation of dust generated from impacted surface soils at the AACO.</td>
<td>✓</td>
<td>The current conditions at the AACO are such that there is potential for wind erosion of surface soils and atmospheric dispersion across the AACO. There is also potential for generation of dust during maintenance activities.</td>
</tr>
<tr>
<td>Exposure Pathway</td>
<td>Complete?</td>
<td>Comments</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------------</td>
<td>-----------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Dermal contact with and incidental ingestion of impacted groundwater.</td>
<td>✗</td>
<td>There is currently no extraction of groundwater occurring at the AACO, and depth to groundwater is in excess of 2m bgl therefore direct contact with groundwater at the AACO is not considered likely to occur for these receptors.</td>
</tr>
<tr>
<td>Dermal contact with and incidental ingestion of impacts in surface water and sediment contained within drainage channels.</td>
<td>✓</td>
<td>There is potential for intrusive works to be associated with (or in the vicinity of) drainage channels present at the AACO. Thus there is potential for this exposure pathway to be complete for these receptors.</td>
</tr>
<tr>
<td>AACO Visitors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dermal contact with and incidental ingestion of impacts present in soils at the AACO.</td>
<td>✗</td>
<td>It is considered unlikely that visitors to the AACO will directly contact impacted soils.</td>
</tr>
<tr>
<td>Inhalation of dust generated from impacted surface soils at the AACO.</td>
<td>✓</td>
<td>The current conditions at the AACO are such that there is potential for wind erosion of surface soils and atmospheric dispersion across the AACO.</td>
</tr>
<tr>
<td>Dermal contact with and incidental ingestion of impacted groundwater.</td>
<td>✗</td>
<td>This exposure pathway is currently being managed such that no groundwater extraction is currently occurring at the AACO. Therefore under current conditions this exposure pathway is considered to be incomplete.</td>
</tr>
<tr>
<td>Dermal contact with and incidental ingestion of impacts in surface water and sediment contained within drainage channels.</td>
<td>✗</td>
<td>Visitors to the AACO are considered unlikely to be directly contacting surface water and sediments within drainage channels.</td>
</tr>
</tbody>
</table>

Note:  
✦ Pathway considered incomplete for this receptor  
✓ Pathway considered to be complete for this receptor

It has previously been reported that the swimming pool present at the AACO was filled with groundwater extracted from a bore at the AACO. When groundwater impacts were identified this practice was discontinued and thus this exposure pathway has not been included in the current CSM. However there is potential for PFCs to have leached from pool infrastructure into pool water and for this exposure pathway to be resulting in exposures by base personnel who use the swimming pool.

Table 3 Exposure Pathway Analysis - Receptors in Surrounding Areas

<table>
<thead>
<tr>
<th>Exposure Pathway</th>
<th>Complete</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential Receptors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potable ingestion of impacts in extracted groundwater.</td>
<td>✗</td>
<td>This exposure pathway was historically complete (a), but is currently being managed through advice from Defence not to drink the groundwater, and provision of potable water to residents who do not have an alternative water supply.</td>
</tr>
<tr>
<td>Dermal contact with and incidental ingestion of impacted groundwater during some household activities (e.g. showering)</td>
<td>✓</td>
<td>It is understood that residents use groundwater for household purposes including showering, laundering, and washing dishes etc. This exposure pathway is currently being managed through the supply of potable water for household purposes. However this exposure pathway was historically complete and may be complete for some receptors.</td>
</tr>
</tbody>
</table>

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Exposure Pathway | Complete | Comments
--- | --- | ---
Dermal contact with and incidental ingestion of groundwater during irrigation and recreational activities (e.g. playing in a sprinkler). | ✓ | Based on currently available information, residents are continuing to use groundwater for household irrigation purposes.

Dermal contact with and incidental ingestion of groundwater used to fill residential swimming pools. | ✓ | It is understood that a number of residents use groundwater to re-fill/top-up their residential swimming pools. This exposure pathway is currently being managed as part of the ongoing groundwater investigation however this pathway is still considered to be potentially complete for some residential receptors.

Dermal contact with and incidental ingestion of impacts in soil irrigated with impacted groundwater. | ✓ | There is currently no data from soils where impacted groundwater has been used for irrigation purposes. However there is potential that soils have become impacted and thus soil related exposure pathways may be complete for residential receptors.

Inhalation of surface soil derived dust where impacted groundwater has been used for irrigation purposes. | ✓ | It is understood that a number of residential receptors in the area surrounding the AACO use extracted groundwater for irrigation of vegetable gardens (these gardens are considered to potentially include any edible plant, including fruit trees etc.).

Ingestion of groundwater derived impacts in home-grown produce irrigated with groundwater. | ✓ | Based on the potential for the use of impacted groundwater for irrigation purposes, there is potential for incidental ingestion of soil which may have become impacted.

Incidental ingestion of impacted soil adhered to home-grown produce which has been irrigated with groundwater. | ✓ | It is understood that a number of residential receptors in the vicinity of the AACO use groundwater for livestock watering purposes, and that these residents may consume their livestock which is considered to include (but may not be limited to) poultry (including their eggs), sheep and cattle.

Ingestion of groundwater derived impacts accumulated in home-grown livestock and produce (including ingestion of eggs from poultry) which is watered with impacted groundwater. | ✓ | There is currently limited data available to understand this exposure pathway. However AACO derived impacts have been reported to be present in Oakey Creek, thus there is potential for ingestion of accumulated impacts in aquatic organisms. This exposure pathway is also potentially complete for residents who raise their own fish for human consumption and use groundwater in the fish ponds.

Ingestion of groundwater (or AACO) derived impacts accumulated in aquatic organisms (e.g. fish, freshwater mussels etc.) collected from waterways which may be connected to the AACO. | ✓ | There is currently limited data available to understand this exposure pathway. However AACO derived impacts have been reported to be present in Oakey Creek, thus there is potential for ingestion of accumulated impacts in aquatic organisms. This exposure pathway is also potentially complete for recreational users of Oakey Creek.

Recreational Receptor

Dermal contact with and incidental ingestion of impacts in soil irrigated with impacted groundwater. | ✓ | It has been assumed that there is potential for soil impacts to be present where impacted groundwater has been used for irrigation purposes (i.e. as a result of irrigation of grass at parks and sporting grounds).

Dermal contact with and Incidental ingestion of sediment and surface water in water ways which are hydraulically connected to the AACO. | ✓ | AACO derived impacts have been reported to be present in sediment and surface water within Oakey Creek. Thus there is potential for this exposure pathway to be complete for recreational users of Oakey Creek.
### Exposure Pathway

<table>
<thead>
<tr>
<th>Exposure Pathway</th>
<th>Complete</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingestion of groundwater (or AACO) derived impacts accumulated in aquatic organisms (e.g. fish, freshwater mussels etc.) collected from waterways which may be connected to the AACO.</td>
<td>✓</td>
<td>There is currently limited data available to understand this exposure pathway. However AACO derived impacts have been reported to be present in Oakey Creek, thus there is potential for ingestion of accumulated impacts in aquatic organisms.</td>
</tr>
<tr>
<td>Commercial (Agricultural) Workers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dermal contact with and incidental ingestion of impacted extracted groundwater</td>
<td>✓</td>
<td>This exposure pathway is considered likely to be complete for these receptors. It is noted that this exposure pathway is currently being managed for abattoir workers as groundwater is no longer used in meat processing at the abattoir.</td>
</tr>
<tr>
<td>Dermal contact with and incidental ingestion of impacts in soil irrigated with impacted groundwater.</td>
<td>✓</td>
<td>This exposure pathway is considered likely to be complete for these receptors.</td>
</tr>
<tr>
<td>Inhalation of surface soil derived dust where impacted groundwater has been used for irrigation purposes.</td>
<td>✓</td>
<td>This exposure pathway is considered likely to be complete for these receptors.</td>
</tr>
<tr>
<td>Ingestion of groundwater derived impacts in produce irrigated with groundwater.</td>
<td>✓</td>
<td>It is considered likely that where a commercial worker is employed for farm related purposes that they would consume produce from the farm. Consumers of food products produced in Oakey are considered likely to have a lower exposure to PFCs than farm workers as they are likely to source food products from a range of producers (i.e. not all their food will come from Oakey). Therefore assessment of consumption of food products for commercial (agricultural) workers is considered likely to be protective of wider consumers.</td>
</tr>
<tr>
<td>Incidental ingestion of impacted soil adhered to produce which has been irrigated with groundwater.</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Ingestion of groundwater derived impacts accumulated in livestock (including ingestion of eggs from poultry, and ingestion of fish grown in aquaculture ponds where groundwater has been used) watered with impacted groundwater.</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

(a) It is noted that this exposure pathway is currently being managed by Defence. However historically it has been reported that the Toowoomba Regional Council (TRC) used to extract groundwater from near the AACO to supplement the town water supply. Extracted groundwater was reported to have been filtered using reverse-osmosis, however, PFCs are large compounds which are known to easily overload the filters in reverse osmosis systems, thus there is no guarantee that the filtration removed all PFCs from extracted groundwater prior to distribution to the domestic supply. TRC no longer extract groundwater from the Oakey area for use in the domestic supply and thus this exposure pathway is not considered to be currently complete.

Note:

- Pathway considered incomplete for this receptor
- Pathway considered to be complete for this receptor
- Pathway considered to be potentially complete for this receptor, however management measures are currently in place to reduce the potential for exposure via this pathway.
2.6 Potential Ecological Receptors
Based on currently available information with regard to the current ecological environment at the AACO and the current ecological environment in the surrounding areas, the following ecological receptors have been identified:

- Terrestrial ecological receptors (this is considered to include both first order and higher order organisms as per the indicative food webs presented in Section 2.1).
- Aquatic ecological receptors (this is considered to include both native and introduced species as per the indicated food webs presented in Section 2.1).
- Domestic animals (consideration of domestic animals has been included in this section as it is known that livestock and domestic pets are consuming extracted groundwater and impacted produce).

2.7 Potential Ecological Exposure Pathways
Ecological receptors are considered likely to be exposed through one or several of the following exposure pathways:

- Direct contact with impacts in soil
- Ingestion of impacts in soil
- Ingestion of impacts in groundwater
- Direct contact and ingestion of impacts in surface water (and sediment)
- Ingestion of bioaccumulated chemicals in animal or plants which have been exposed to chemical contaminants in soil, groundwater or surface water (and sediment).

PFCs, such as PFOS, are known to be bioaccumulative and therefore the presence of these compounds may have implications to higher order organisms which may be exposed to higher concentrations than those present in environmental media.

2.8 Conceptual Site Model Summary
The information presented in Section 2.1 – Section 2.7 has been summarised and presented in Figures F3 – F5 (in Appendix A). It is noted that Figures F3-F5 contain a summary of information provided in Section 2.4 and Section 2.5, exposure scenarios are depicted pictorially in these figures to provide an overview of the identified exposure scenarios, however these figures should be considered relative to all information presented in Section 2.0.

Appendix B also contains flow diagrams which show the contaminant sources and how these link with identified exposure pathways for human (Diagram 1) and ecological (Diagram 2) receptors. It is noted that the flow diagrams presented in Appendix B provide detail of source-pathway-receptor linkages. Some of these linkages are not depicted in Figure F3-F5 in Appendix A (i.e. direct contact with PFCs in waste water treatment sludge) as they are considered to be minor pathways which require consideration on a large scale, but are not considered to require detailed quantitative assessment of risks associated with exposures by AACO personnel or Oakey residents.
3.0 Conclusions

The following conclusions are provided as a result of the assessment of the currently available information with regard to the contamination status of the AACO and groundwater impacts reported in the vicinity of the AACO:

- Current and historical activities undertaken at the AACO have resulted in PFC impacts in AACO infrastructure (e.g. the fire training pad concrete) soil and groundwater.

- Groundwater impacts have migrated from the AACO and have been reported to be present in extracted groundwater up to 4 km south-west of the AACO boundary.

- Groundwater is extracted for a range of uses in the Oakey area and a number of potentially complete exposure pathways have been identified within this assessment for human and ecological receptors.
4.0 References


Appendix A

Figures
AECOM does not warrant the accuracy or completeness of information displayed in this map and any person using it does so at their own risk. AECOM shall bear no responsibility or liability for any errors, faults, defects, or omissions in the information.

Data sources:
Base Layers: ESRI Basemaps Online
Street: based on @ Street Pro 2011, and Google Earth Pro
Zones: based on AACO Zone Plan prepared by SKM for AU Gov, Department of Defence, Sept 2010,
Drainage Line: Drainage 25k - Queensland © The State of Queensland (Department of Environment and Resource Management); This 1:25000 drainage dataset in the form of contours that are captured to represent selected areas of Queensland’s topographic relief. This data has been devised from digital photogrammetry or scanning of existing 1:25000 mapping.
Chemical storage

Potential PFC impacts in soil resulting from:

• current historical fire training exercises and firefighting
• irrigation using impacted groundwater (note this is no longer undertaken)
• storage and transport of AFFF at the AACO derived impacts leaching to groundwater

PFCs have been detected in groundwater outside the ACCO boundary.

AACO CONCEPTUAL SITE MODEL
ARMY AVIATION CENTRE OAKEY (AACO)
PROJECT NUMBER: 60332238

FIGURE F3

Exposure scenarios are depicted pictorially in this figure to provide an overview of identified exposure scenarios. This figure should be considered relative to all information presented in Section 2.0 of the body report.
COMMERCIAL (AGRICULTURAL) WORKERS

- Dermal contact with and incidental ingestion of impacted extracted groundwater
- Dermal contact with and incidental ingestion of impacts in soil irrigated with impacted groundwater.
- Inhalation of surface soil derived dust where impacted groundwater has been used for irrigation purposes.
- Ingestion of groundwater derived impacts in produce irrigated with groundwater.
- Incidental ingestion of impacted soil adhered to produce which has been irrigated with groundwater.
- Ingestion of groundwater derived impacts accumulated in livestock (including ingestion of eggs from poultry, and ingestion of fish grown in aquaculture ponds where groundwater has been used) watered with impacted groundwater.

HUMAN HEALTH EXPOSURE PATHWAYS

OFF-BASE CONCEPTUAL SITE MODEL
ARMY AVIATION CENTRE OAKEY (AACO)
PROJECT NUMBER: 60332238

FIGURE F4
Exposure scenarios are depicted pictorially in this figure to provide an overview of identified exposure scenarios.
This figure should be considered relative to all information presented in Section 2.0 of the body report.
HUMAN HEALTH EXPOSURE PATHWAYS

RESIDENTIAL RECEPTORS

- Potable ingestion of impacts in extracted groundwater.
- Dermal contact with and incidental ingestion of impacts in soil irrigated with impacted groundwater.
- Inhalation of surface soil derived dust where impacted groundwater has been used for irrigation purposes.
- Ingestion of groundwater derived impacts in home-grown produce irrigated with groundwater.
- Incidental ingestion of impacted soil adhered to home-grown produce which has been irrigated with groundwater.
- Ingestion of groundwater derived impacts accumulated in home-grown livestock (including ingestion of eggs from poultry) which is watered with impacted groundwater.
- Ingestion of groundwater (or AACO) derived impacts accumulated in aquatic organisms (i.e. fish, freshwater mussels etc.) collected from waterways which may be connected to the AACO.

RECREATIONAL RECEPTOR

- Dermal contact with and incidental ingestion of impacts in soil irrigated with impacted groundwater.
- Inhalation of surface soil derived dust where impacted groundwater has been used for irrigation purposes.
- Ingestion of groundwater derived impacts accumulated in aquatic organisms (i.e. fish, freshwater mussels etc.) collected from waterways which may be connected to the AACO.

EXPOSURE SCENARIOS

- Dermal contact with and incidental ingestion of impacts in soil irrigated with impacted groundwater during household activities (i.e. showering).
- Dermal contact with and incidental ingestion of impacts in soil irrigated with impacted groundwater during irrigation and recreational activities (i.e. playing in a sprinkler).
- Dermal contact with and incidental ingestion of groundwater used to fill residential swimming pools.
- Ingestion of groundwater derived impacts in home-grown produce irrigated with groundwater.
- Ingestion of groundwater (or AACO) derived impacts accumulated in aquatic organisms (i.e. fish, freshwater mussels etc.) collected from waterways which may be connected to the AACO.

OFF-BASE CONCEPTUAL SITE MODEL

ARMY AVIATION CENTRE OAKLEY (AACO)
PROJECT NUMBER: 60332238

FIGURE F5

Exposure scenarios are depicted pictorially in this figure to provide an overview of identified exposure scenarios. This figure should be considered relative to all information presented in Section 2.0 of the body report.
Appendix B

Flow Diagrams
Appendix B  Flow Diagrams

The following information is provided to assist in interpretation of Diagram 1 and Diagram 2:

- Information contained within **blue** boxes represents primary exposure pathways.
- Information contained within **green** boxes represents secondary exposure pathways.
Diagram 1: Human Health Conceptual Site Model Summary

Use of Aqueous Film Forming Foams (AFFF) for Fire Fighting Activities

- Wind transport of spray drift away from fire-training/fighting activities

Storage of Aqueous Film Forming Foams (AFFF)

- Direct discharge of AFFF (and/or fire water) to ground surface (accidental or intentional releases)
- Direct discharge of AFFF (and/or fire water) to concrete infrastructure (accidental or intentional releases)

Direct discharge of AFFF (and/or fire water) to ground surface (accidental or intentional releases)

- Wind transport of spray drift away from fire-training/fighting activities
- Direct discharge of AFFF (and/or fire water) to concrete infrastructure (accidental or intentional releases)

Direct discharge of PFC impacted surface run-off to drainage channels

Primary Exposure Pathways associated with release of PFCs to waterways:
- Direct contact with PFCs in sludge and leaching of PFCs to the environment.
- Potential PFC impacts in sludge and leaching of PFCs to the environment.

Secondary Exposure Pathways:
- Ingestion of PFCs accumulated in home-grown produce (including fruit trees, and vegetables etc.) irrigated with impacted groundwater (or impacted surface water).
- Ingestion of PFCs accumulated in meat (or other products i.e. milk/cheese) from livestock watered with impacted water (this is considered to include accumulation of PFCs in eggs from chickens and fish raised in groundwater as part of aquaculture activities).
- Ingestion of PFCs accumulated in fish collected from impacted waterways.

Extractive uses of groundwater

- PFC impacts in soil
- Leaching of PFCs from soil to groundwater

Primary Exposure Pathways resulting from extractive uses of PFC impacted groundwater:
- Direct ingestion of potable groundwater.
- Direct dermal contact with and incidental ingestion of impacted groundwater during:
  - Irrigation activities;
  - Recreational activities using groundwater (i.e. recreational play using sprinklers connected to the groundwater supply);
  - Swimming (in pools where groundwater has been used);
  - Household activities (i.e. laundering clothes, showering etc.) where groundwater is connected to indoor plumbing.
  - Maintenance related activities (i.e. washing pets, watering pets, maintaining agriculture and aquaculture equipment).

** These exposure pathways are currently being managed to to reduce the potential for exposures.

Inhalation of dust derived from surface soils impacted with PFCs.

Note: groundwater is no longer used for extractive purposes at the AACO.
Diagram 2: Ecological Conceptual Site Model Summary

**Use of Aqueous Film Forming Foams (AFFF) for Fire Fighting Activities**
- Wind transport of spray drift away from fire-training/fighting activities
- Direct discharge of AFFF (and/or fire water) to ground surface (accidental or intentional releases)

**Storage of Aqueous Film Forming Foams (AFFF)**
- Direct discharge of AFFF (and/or fire water) to concrete infrastructure (accidental or intentional releases)

**Terrestrial Ecological Receptors:**
- Direct contact with and incidental ingestion of PFC impacts in soil (by: Plants, soil invertebrates, birds and ground-dwelling vertebrates)

**Secondary Exposure Pathways:**
- Ingestion of PFCs accumulated in plants, soil invertebrates and groundwater dwelling vertebrates (i.e. rodents, snakes etc.).

**Primary Exposure Pathways resulting from extractive uses of PFC impacted groundwater:**
- Direct ingestion of groundwater (where groundwater is used for watering purposes). It is noted that livestock watering containers may be accessed by other ecological receptors (i.e. birds).

**Secondary Exposure Pathways:**
- Ingestion of PFCs accumulated in aquatic organisms which inhabit PFC impacted waterways.
- Ingestion of PFCs accumulated in ecological receptors which have accessed livestock watering facilities.

PFCs (specifically PFOS) are known to be highly bioaccumulative in the environment, therefore the presence of these compounds may have implications to higher order organisms which may be exposed to higher concentrations than those present in environmental media. Piscivorous (fish eating) birds are considered to have a high potential for exposure as fish may contain elevated concentrations of PFCs in their tissue.

**Potential PFC impacts in waste water treatment sludge**

Discharge of PFC impacted waste water (both surface run-off and water from fire fighting activities) to Toowoomba Regional Council (TRC) wastewater treatment system under trade waste agreement.

Leaching of PFCs to the surrounding environment.

**Extractive uses of groundwater**
- Note: groundwater is no longer used for extractive purposes at the AACO.

**Primary Exposure Pathways associated with release of PFCs to waterways:**
- Direct contact with and incidental ingestion of PFC impacts in surface water and sediment by aquatic organisms.

**Secondary Exposure Pathways:**
- Ingestion of PFCs accumulated in plants, soil invertebrates and groundwater dwelling vertebrates (i.e. rodents, snakes etc.).