

Department of Defence

RAAF Base Darwin

PFAS Ecological Risk Assessment
Executive Summary

26 October 2018



When you
think with a
global mind
problems
get smaller

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RAAF Base Darwin

Prepared for
Department of Defence

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Introduction

As part of the Comprehensive Investigation of per- and polyfluoroalkyl substances (PFAS) at RAAF Base Darwin (the Base), the Australian Department of Defence (Defence) commissioned Coffey Environments Australia Pty Ltd (Coffey) to conduct an Ecological Risk Assessment (ERA) for the Base. The purpose of the ERA is to assess the potential for risks to the environment resulting from exposure to Base-derived PFAS in the area on and near the Base.

This ERA was prepared using guidance provided in the National Environment Protection (Assessment of Site Contamination) Measure 1999, as amended in 2013 (NEPC 2013), including Schedule B5a *Guideline on Ecological Risk Assessment*, and other pertinent Schedules. Ecological risk assessment guidance published by the United States Environmental Protection Agency (US EPA) was also applied. Water-based (aquatic) and land-based (terrestrial) ecosystems that are potentially exposed to PFAS in the RAAF Base Darwin PFAS Investigation Area have been investigated as part of the Ecological Risk Assessment.

Background

Per- and poly-fluoroalkyl substances (PFAS) including per-fluorooctane sulfonate (PFOS) and per-fluorooctanoic acid (PFOA) are found in legacy Aqueous Film-forming Foam (AFFF) that were historically used to prevent or extinguish Class B fires - flammable liquid fires. AFFF is a fire-fighting foam that has been used extensively worldwide, and within Australia, from the 1970s by both civilian and military authorities, due to its effectiveness in extinguishing liquid fuel fires. AFFF works by cooling the fire and creates a barrier between the fire's fuel source and oxygen thereby preventing further combustion.

There are hundreds of compounds within the PFAS class, but analytical methods do not exist for all of them, and some are more prevalent than others. The active ingredient in the manufactured products (i.e. 3M Lightwater) were typically per-fluorooctane sulfonate (PFOS), per-fluorohexane sulfonate (PFHxS) or per-fluorooctanoic acid (PFOA). Newer AFFF products contain shorter chain PFAS compounds (less than six carbons) and poly-fluorinated precursor compounds (i.e. PFBS, 8:2 FTS and compounds not quantified by PFAS analysis).

The per-fluorinated alkyl substances may be formed from the degradation or transformation of their precursors, which may not be able to be specifically analysed for. Therefore, on-going sources of PFOS, PFHxS and PFOA may be underestimated by analysis of these PFAS compounds alone. The full PFAS suite includes some specific known PFOS and PFOA precursor compounds.

The fully fluorinated compounds (per) do not degrade and are expected to remain in the environment for many decades. The compounds are water soluble and mobile and will tend to migrate with water. The strength of adsorption to organic carbon in the soil of different compounds in the group varies depending on the number of carbon atoms in the compound. Long chain compounds (six or more carbons) also bioaccumulate in animals. Due to the mobility, PFAS compounds can be present in very large plumes associated with groundwater migration and surface waters. Organic rich sediments may act as ongoing or seasonal sources of PFAS contamination to surface waters through resuspension and desorption.

The area considered in this ERA is the Investigation Area (IA) evaluated in the *RAAF Base Darwin Detailed Site Investigation (DSI) – Per- and Poly-fluoroalkyl Substances (PFAS)* (Coffey 2018). The Investigation Area includes RAAF Base Darwin and the surrounding area that is potentially impacted by PFAS contamination, including Rapid Creek, Ludmilla Creek, Sadgroves Creek and Reichardt Creek. The Investigation Area also includes Darwin International Airport (DIA) which is immediately north of the Base, as it receives contaminated groundwater and surface water from some of the source areas on-Base. The location of RAAF Base Darwin and the Investigation Area (IA) for this ERA is shown on Figure A.

A separate Human Health Risk Assessment (HHRA) was completed and published in June 2018. This ERA document is limited to addressing risks to flora and fauna in the terrestrial and aquatic environment that are potentially impacted by Base-derived PFAS compounds.

Figure A – Base location and investigation area



Objectives and scope

The objectives of the ERA were to:

- To assess the potential for PFAS contaminants in soil, sediment, and surface water to pose adverse effects to ecological receptors within ecological habitats present on-Base.
- To assess the potential for reported Base-derived PFAS contaminants present in off-Base environmental media and habitats to pose adverse effects to ecological receptors that inhabit the area surrounding the Base.
- To assist in guiding the remediation and risk management measures to address PFAS contamination at the Base.

To address these objectives the potential for adverse ecological impacts (i.e. risks) were estimated for receptors of concern. The risks were characterised for plants and animals that are low in the food chain, based on direct toxicity, and for animals higher in the food chain, based on food web-modelling.

The risk characterisation was achieved through a three-step process:

- Step 1: Development of a Conceptual Site Model (CSM), including a source, pathway, receptor exposure analysis.
- Step 2: Screening of maximum reported concentrations in soil and surface water against adopted screening values and direct toxicity benchmarks.
- Step 3: Modelling of the intake of PFOS and PFOA based on diet and measured concentrations in plants and animals across different areas. The estimated intakes were then compared to adopted toxicity values to indicate potential ecological risks.

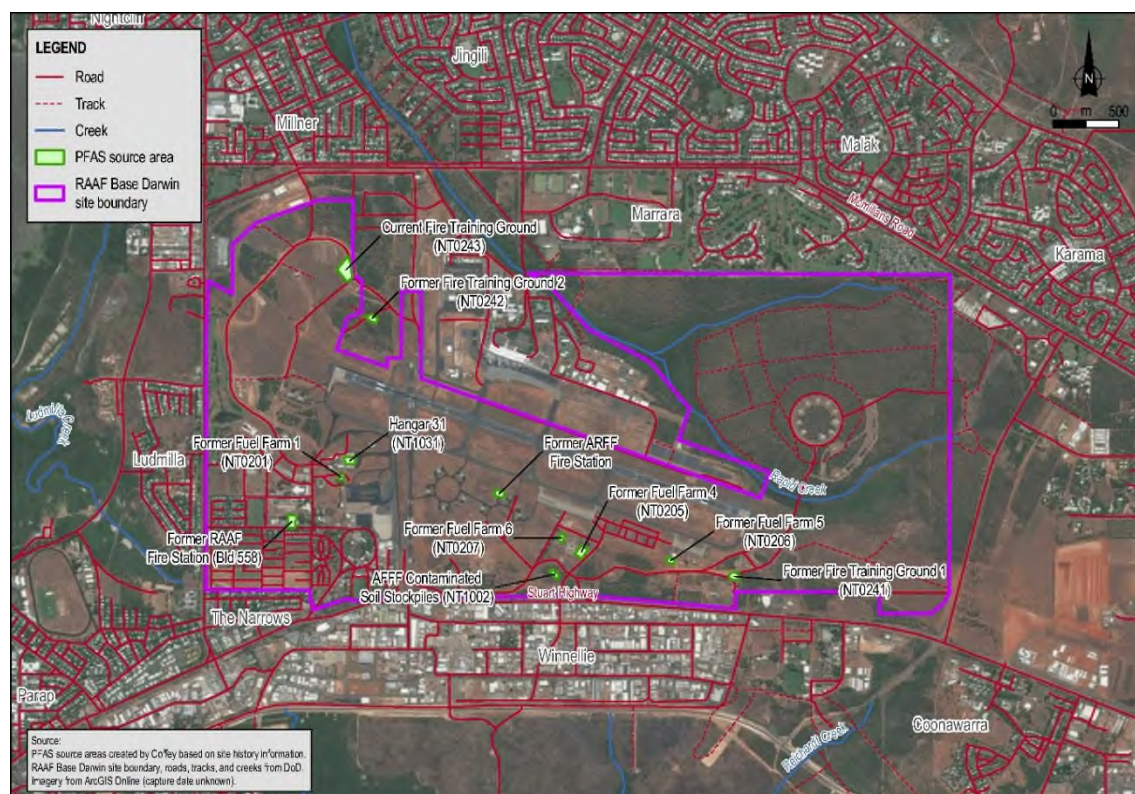
Conceptual Site Model

As part of the ERA, a Conceptual Site Model (CSM) was developed to identify and illustrate the exposure pathways (both complete and incomplete) by which ecological receptors may be exposed to PFAS compounds on- and off-Base. The CSM considered source areas of contamination, the pathways by which contaminants may migrate through environmental media on-Base and off-Base, the exposure pathways to receptors, and the types of ecological receptors that may be exposed both on-Base and off-Base. The CSM is summarised below.

Sources

Source areas have been identified across the investigation area related to the use, storage or discharge of PFAS-based contaminants. Identified on-Base sources are shown on Figure B. Details of AFFF usage and residual concentrations are provided in the Detailed Site Investigation and Supplementary Detailed Site Investigation reports.

Figure B – Potential PFAS source areas



Transport of PFAS through the environment is predominantly with water flows. Therefore, PFAS from the on-Base sources migrates with groundwater beneath the surface, and with contaminated surface water run-off towards the receiving water ways of Rapid Creek to the north, Ludmilla Creek to the west and to a lesser extent, Sadgroves Creek and Reichardt Creek to the south.

Exposure pathways

Based on the current understanding of the impacted media and the ecological receptors that may occur on-Base and in the affected off-Base areas, the following potentially complete exposure pathways were evaluated:

- Direct contact with soil by soil invertebrates.
- Direct contact with soil by terrestrial plants.

- Incidental ingestion of soil or sediment by wildlife while foraging.
- Surface water ingestion by wildlife.
- Ingestion by wildlife of animals and plants that have accumulated PFAS substances.
- Direct contact with surface water by fish, aquatic invertebrates, amphibians and aquatic plants.

Ecological Investigation Area

This ERA considered different habitats within the Investigation Area where aquatic or terrestrial flora and fauna may be exposed. The ecological exposure areas adopted for this ERA are as follows (and shown on Figure C).

Terrestrial ecological exposure areas

Zone A – Represents the northeast quadrant of the investigation area and encompasses the upper portion of Rapid Creek.

Zone B – Represents the northwest quadrant of the investigation area and encompasses the middle and lower portions of Rapid Creek and eucalyptus woodland on-Base.

Zone C – Represents the southwest quadrant of the investigation area and encompasses the main operating part of the Base and the area draining to Ludmilla Creek.

Zone D – Represents the southeast quadrant and encompasses facilities in the southern part of the Base and the main airstrip.

Aquatic ecological exposure areas

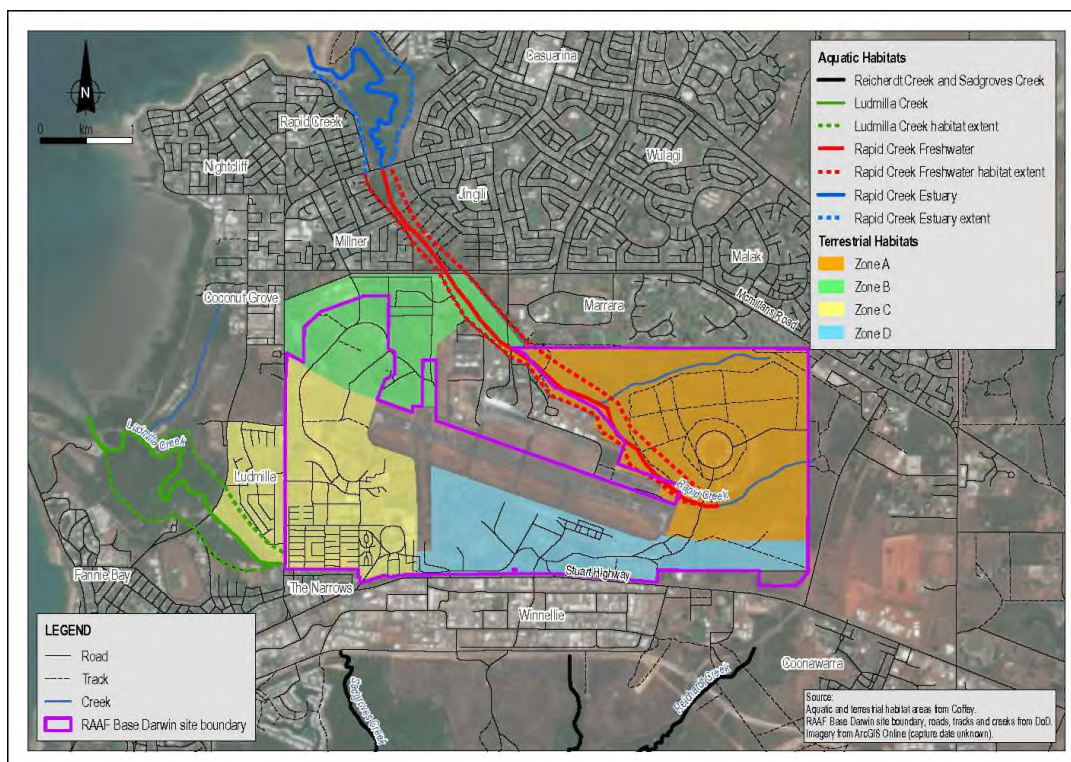
Freshwater reach of Rapid Creek – includes the Marrara Swamp and Rapid Creek through Pandanus swamps and Monsoon Rainforest.

Estuarine portion of Rapid Creek – includes the permanent estuarine reaches of Rapid Creek, nominally downstream of Trower Road.

Ludmilla Creek – includes the permanent estuarine portion of Ludmilla Creek.

Reichardt Creek and Sadgroves Creek – these creeks are tidal arms of Darwin Harbour which also receive freshwater run-off and stormwater from the southern portion of the Base.

Figure C – Terrestrial and aquatic ecological exposure areas



Receptors of concern

A variety of animals and plants found in aquatic and terrestrial habitats may be exposed to PFAS compounds both on-Base and off-Base. It is not feasible to evaluate the potential risks to all the wildlife species that may occur within the Investigation Area. Therefore, a subset of species (indicator species) was selected for evaluation in the ERA that are considered representative of the habitats and diets (e.g., herbivores, carnivores) in the Investigation Area. The species selected are considered to represent a range of likely intake and therefore indicate the range of potential risk to ecology.

Below is a list of the generic trophic levels evaluated. The ERA report provides details of the specific indicator species selected to represent receptors of concern for each of these trophic levels.

Aquatic Environment (including Rapid Creek, Ludmilla Creek, Reichardt Creek and Sadgroves Creek)	Terrestrial Environment
<ul style="list-style-type: none"> • Aquatic plants. • Aquatic invertebrates. • Aquatic vertebrates (i.e., fish). • Invertivorous (i.e., primarily feeding on aquatic invertebrates) and omnivorous birds (e.g., jacana). • Piscivorous (i.e., primarily feeding on fish) birds (e.g., egrets, cormorants, jabiru). • Piscivorous mammals (e.g., water rat). • Piscivorous reptiles (e.g., water snakes). 	<ul style="list-style-type: none"> • Terrestrial plants. • Terrestrial invertebrates. • Herbivorous (i.e., primarily feeding on plant matter) birds (e.g., fruit dove, fig bird) • Herbivorous mammals (e.g., flying fox). • Invertivorous (i.e., primarily feeding on terrestrial/soil invertebrates) and omnivorous birds (e.g., woodland birds). • Invertivorous and omnivorous mammals (e.g., rodents). • Invertivorous and omnivorous reptiles (e.g., skinks, gecko). • Carnivorous (i.e., primarily feeding on other vertebrate animals) birds (e.g., eagles, kites). • Carnivorous mammals (e.g., quoll). • Carnivorous reptiles (e.g., goanna).

Exposure assessment

Exposure assessment involves compiling information about habitat for ecological receptors at the Base, receptor diet, potentially complete exposure pathways, exposure point concentrations, exposure duration and estimated chemical intakes to assess the likely magnitude of exposure (ASC NEPM, 2013, ANZECC, 2000).

Site-specific concentration data

An Exposure Point Concentration is the assumed concentration of contaminant in the medium to which the population is exposed, at the point of exposure (ASC NEPM). In accordance with ASC NEPM guidelines exposure point concentrations were estimated through statistical analysis of site-specific data, obtained from the environmental investigations undertaken on-Base and off-Base.

Soil and surface water data collected during the Detailed Site Investigation and subsequent Supplementary Detailed Site Investigation was applied by zone. Addition targeted sampling was undertaken of plants, insects, reptiles, amphibians and mammals in terrestrial zones, and plants, fish, molluscs and crustaceans in aquatic zones to inform the estimates of contaminant levels in wildlife diets.

Toxicity assessment

The assessment of direct PFAS toxicity from soil and water was conducted by reviewing concentrations in different zones against guideline values and concentrations shown to have no adverse effects in laboratory studies. The dietary intakes of indicator species were modelled on assumed food intake and the measured PFAS concentrations in those foods. The calculated dietary intake was then compared against screening values and intake rates that were shown to have no or low adverse effects in laboratory studies on birds or mammals. In the absence of specific studies, assessment of risks to reptiles was assessed against toxicity data for birds, and is acknowledged to have low reliability.

Risk characterisation

A rank from Negligible risk to Very High risk has been applied to species located in certain zones and shown in the table below. There were no scenarios identified that indicated High or Very High risks.

Habitat zone	Direct exposure to PFAS from water and soil		Indirect exposure to PFAS from the foods they eat		
	From soil	From water	Birds	Mammals	Reptiles
Zone A (Marrara Swamp)	Negligible		Low – Very Low	Low – Very Low	Low – Very Low
Zone B (Base north)	Medium		Low – Very Low	Low – Very Low	Negligible
Zone C (Base southeast)	Low		Very Low	Very Low	Negligible
Zone D (Base south)	Medium		Low – Very Low	Low – Very Low	Negligible
Rapid Creek Freshwater		Medium	Low	Low	Negligible – Very Low
Rapid Creek Estuary		Low	Negligible – Very Low	Very Low	Negligible
Ludmilla Creek		Low	Very Low	Very Low	Negligible
Darwin Harbour		Negligible	Negligible	Very Low	Negligible

Negligible Risk	The estimated PFAS exposure is below the conservative screening value, and unlikely to have adverse environmental effects.
Very Low Risk	The concentration or estimated intake exceeds the conservative screening value but there are no observed adverse effects in laboratory studies at those concentrations. There is a very low likelihood of adverse environmental effects.
Low Risk	The concentration or estimated intake exceeds the conservative screening value and the reported no-observed-adverse-effect-levels from laboratory studies but does not exceed the lowest concentrations where adverse effects were reported in laboratory studies. There is a low likelihood of adverse environmental effects, however observable effect cannot be excluded to some individuals or sensitive species.
Medium	The concentration or estimated intake exceeds the lowest reported level that resulted in an adverse effect in laboratory studies. There is potential for adverse effects to some species. Effects are not likely to be lethal or affect the majority of the ecology.

A Human Health Risk Assessment has been completed for the Base and can be found on the RAAF Base Darwin project website. The findings of the Ecological Risk Assessment do not change the outcomes of the Human Health Risk Assessment.

Terrestrial and aquatic habitat along freshwater Rapid Creek (Zone A and freshwater Rapid Creek)

Elevated risk of adverse effects to sensitive species of upper trophic level animals was identified in Zone A (invertivorous, omnivorous and carnivorous birds and mammals) and along the freshwater reach of Rapid Creek (piscivorous birds and mammals). Direct toxicity to plants and lower trophic level animals was a negligible risk, indicating that bioaccumulation through the food web in this area is increasing exposure. The adverse effects most likely to occur, based on toxicological studies used to derive toxicity values, are reproductive effects including reduced hatching rates and reduced fertility. Source areas of PFAS contamination are not present within this area and contamination is entering the area through surface water run-off and groundwater seepage from source areas to the south on RAAF Base Darwin and potentially DIA.

Aquatic habitat of freshwater Rapid Creek

The evaluation of direct toxicity to freshwater aquatic plants, aquatic water column invertebrates, amphibians and fish identified some potential risk in Rapid Creek as indicated by PFOS concentrations exceeding the general guideline value. Further evaluation indicated that risks to aquatic plants and water column invertebrates are likely to be negligible as the maximum PFOS concentration was below the specific direct toxicity benchmarks. Moderate risks were indicated for freshwater fish where the maximum and average water concentrations in Rapid Creek exceeded the benchmark value and may indicate effects on egg development and hatch rate in some species.

Terrestrial habitats on Base (Zones B, C and D)

Elevated risks of adverse effects to plants and invertebrates have been identified on the Base from isolated soil in source areas in Zones B, C and D. Elevated source areas driving the risk from soil contact are the former Fire Training Ground 1, former Fuel Farms 4 and 6, Hangar 31 and the current Fire Training Ground. Potential risk to sensitive species of upper trophic level animals (herbivorous and invertivorous birds and mammals) was also identified in these areas due to incidental ingestion of soil or invertebrates. Risks across these zones would be substantially reduced by limiting access to contaminated soils in source areas.

Aquatic habitat of estuarine Rapid Creek

Risks from direct toxicity or bioaccumulation of PFAS in the estuarine section of Rapid Creek were limited to direct toxicity to aquatic invertebrates from contact with contaminated water. The likelihood of sustained adverse effects is considered low as the concentrations in this area were typically low, with only occasional elevated concentrations, likely during first flush or low tide events.

Aquatic habitat of Ludmilla Creek

Risks from direct toxicity or bioaccumulation of PFAS in Ludmilla Creek were limited to direct toxicity to aquatic invertebrates based on maximum and average PFOS water concentrations. Risks are predominantly related to the section of Ludmilla Creek east of Dick Ward Drive, where elevated concentrations of PFOS in water were consistently reported from stormwater and groundwater seepage into the upper reaches.

Aquatic habitat of Darwin Harbour (including Sadgroves Creek and Reichardt Creek)

Risks from direct toxicity or bioaccumulation of PFAS in the Darwin Harbour, as measured in Sadgroves Creek and Reichardt Creek, were low. Isolated zones of direct toxicity to sensitive aquatic invertebrates may occur in upper reaches where stormwater discharges occasionally introduce PFAS contamination.

These conclusions must be read in conjunction with the uncertainties and limitations of the assessment described in Section 7 of the ERA report and the attached *Important information about your Coffey environmental report* information.

Important information about your **Coffey** Environmental Report

Introduction

This report has been prepared by Coffey for you, as Coffey's client, in accordance with our agreed purpose, scope, schedule and budget.

The report has been prepared using accepted procedures and practices of the consulting profession at the time it was prepared, and the opinions, recommendations and conclusions set out in the report are made in accordance with generally accepted principles and practices of that profession.

The report is based on information gained from environmental conditions (including assessment of some or all of soil, groundwater, vapour and surface water) and supplemented by reported data of the local area and professional experience. Assessment has been scoped with consideration to industry standards, regulations, guidelines and your specific requirements, including budget and timing. The characterisation of site conditions is an interpretation of information collected during assessment, in accordance with industry practice,

This interpretation is not a complete description of all material on or in the vicinity of the site, due to the inherent variation in spatial and temporal patterns of contaminant presence and impact in the natural environment. Coffey may have also relied on data and other information provided by you and other qualified individuals in preparing this report. Coffey has not verified the accuracy or completeness of such data or information except as otherwise stated in the report. For these reasons the report must be regarded as interpretative, in accordance with industry standards and practice, rather than being a definitive record.

Your report has been written for a specific purpose

Your report has been developed for a specific purpose as agreed by us and applies only to the site or area investigated. Unless otherwise stated in the report, this report cannot be applied to an adjacent site or area, nor can it be used when the nature of the specific purpose changes from that which we agreed.

For each purpose, a tailored approach to the assessment of potential soil and groundwater contamination is required. In most cases, a key objective is to identify, and if possible quantify, risks that both recognised and potential contamination pose in the context of the agreed purpose. Such risks may be financial (for example, clean up costs or constraints on site use) and/or physical (for example, potential health risks to users of the site or the general public).

Limitations of the Report

The work was conducted, and the report has been prepared, in response to an agreed purpose and scope, within time and budgetary constraints, and in reliance on certain data and information made available to Coffey.

The analyses, evaluations, opinions and conclusions presented in this report are based on that purpose and scope, requirements, data or information, and they could change if such requirements or data are inaccurate or incomplete.

This report is valid as of the date of preparation. The condition of the site (including subsurface conditions) and extent or nature of contamination or other environmental hazards can change over time, as a result of either natural processes or human influence. Coffey should be kept apprised of any such events and should be consulted for further investigations if any changes are noted, particularly during construction activities where excavations often reveal subsurface conditions.

In addition, advancements in professional practice regarding contaminated land and changes in applicable statutes and/or guidelines may affect the validity of this report. Consequently, the currency of conclusions and recommendations in this report should be verified if you propose to use this report more than 6 months after its date of issue.

The report does not include the evaluation or assessment of potential geotechnical engineering constraints of the site.

Interpretation of factual data

Environmental site assessments identify actual conditions only at those points where samples are taken and on the date collected. Data derived from indirect field measurements, and sometimes other reports on the site, are interpreted by geologists, engineers or scientists to provide an opinion about overall site conditions, their likely impact with respect to the report purpose and recommended actions.

Variations in soil and groundwater conditions may occur between test or sample locations and actual conditions may differ from those inferred to exist. No environmental assessment program, no matter how comprehensive, can reveal all subsurface details and anomalies. Similarly, no professional, no matter how well qualified, can reveal what is hidden by earth, rock or changed through time.

The actual interface between different materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but

steps can be taken to reduce the impact of unexpected conditions.

For this reason, parties involved with land acquisition, management and/or redevelopment should retain the services of a suitably qualified and experienced environmental consultant through the development and use of the site to identify variances, conduct additional tests if required, and recommend solutions to unexpected conditions or other unrecognised features encountered on site. Coffey would be pleased to assist with any investigation or advice in such circumstances.

Recommendations in this report

This report assumes, in accordance with industry practice, that the site conditions recognised through discrete sampling are representative of actual conditions throughout the investigation area. Recommendations are based on the resulting interpretation.

Should further data be obtained that differs from the data on which the report recommendations are based (such as through excavation or other additional assessment), then the recommendations would need to be reviewed and may need to be revised.

Report for benefit of client

Unless otherwise agreed between us, the report has been prepared for your benefit and no other party. Other parties should not rely upon the report or the accuracy or completeness of any recommendation and should make their own enquiries and obtain independent advice in relation to such matters.

Coffey assumes no responsibility and will not be liable to any other person or organisation for, or in relation to, any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in the report.

To avoid misuse of the information presented in your report, we recommend that Coffey be consulted before the report is provided to another party who may not be familiar with the background and the purpose of the report. In particular, an environmental disclosure report for a property vendor may not be suitable for satisfying the needs of that property's purchaser. This report should not be applied for any purpose other than that stated in the report.

Interpretation by other professionals

Costly problems can occur when other professionals develop their plans based on misinterpretations of a report. To help avoid misinterpretations, a suitably qualified and experienced environmental consultant should be retained to explain the implications of the report to other professionals referring to the report and then review plans and specifications produced to see how other professionals have incorporated the report findings.

Given Coffey prepared the report and has familiarity with the site, Coffey is well placed to provide such

assistance. If another party is engaged to interpret the recommendations of the report, there is a risk that the contents of the report may be misinterpreted and Coffey disowns any responsibility for such misinterpretation.

Data should not be separated from the report

The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way. Logs, figures, laboratory data, drawings, etc. are customarily included in our reports and are developed by scientists or engineers based on their interpretation of field logs, field testing and laboratory evaluation of samples. This information should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

This report should be reproduced in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties.

Responsibility

Environmental reporting relies on interpretation of factual information using professional judgement and opinion and has a level of uncertainty attached to it, which is much less exact than other design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded. As noted earlier, the recommendations and findings set out in this report should only be regarded as interpretive and should not be taken as accurate and complete information about all environmental media at all depths and locations across the site.