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PATTLE DELAMORE PARTNERS LTD

PFAS Detailed Site Investigation: Devonport Naval Base

New Zealand Defence Force

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Prepared for

New Zealand Defence Force

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This assessment is limited to collection and analysis of biota, sediment and groundwater samples from sampling locations that have been selected based on underground and above ground infrastructure constraints, and the comparison of laboratory test results with environmental and health guidelines. Subsurface conditions, including contaminant concentrations, can vary in time and distance so that conditions found at any specific point of sampling might not be representative of subsurface conditions that could occur away from the specific point of sampling.

The information contained within this report applies to sampling undertaken on the dates stated in this report, or if none is stated, the date of this report. With time, the site conditions and environmental standards could change so that the reported assessment and conclusions are no longer valid. Accordingly, the report should not be used to refer to site conditions and environmental standards applying at a later date without first confirming the validity of the report's information at that time.

Executive Summary

This report documents a detailed site investigation (DSI) undertaken for the New Zealand Defence Force (NZDF) to investigate the potential for groundwater, marine sediment and marine biota contamination relating to the historic use of products which contained per- and poly-fluoroalkyl substances (PFAS) at the HMNZS Devonport Naval Base (the 'site').

This report follows on from a preliminary site investigation (PSI) to identify potential sources of PFAS at the site (PDP, 2017a).

Sampling and laboratory analysis of groundwater and wastewater from selected locations within Devonport Naval Base, and of sediment and marine biota from Ngataringa Bay has confirmed the presence of PFAS at all locations, with the exception of a single wastewater sample site. Sampling and analysis of marine biota at a control site in the upper Waitemata Harbour has also confirmed PFAS presence, albeit at lower concentrations in most instances.

Groundwater

Groundwater sampling was conducted in November 2017. Samples were collected from six groundwater monitoring wells, PFAS were detected above the laboratory limit of reporting (LOR) in all samples.

Groundwater samples from the Sea Safety Training Squadron (SSTS) contained concentrations of PFAS exceeding the ANZECC ecosystem protection guidelines. The concentrations of PFAS observed in the groundwater wells in the South Yard were below the applicable ecological guidelines. Similar results were obtained during previous sampling of groundwater at the SSTS, undertaken in April 2016, October 2016 and April 2017 by others.

Water supply for the Naval Base, and the wider Devonport area, is from reticulated Council supply.

It is unlikely people would ingest the groundwater from beneath the SSTS and, therefore, the pathway for human ingestion of groundwater is incomplete. Nevertheless, the results indicate groundwater from beneath the site is unsuitable for human consumption.

Groundwater containing PFAS compounds is likely to be migrating off-site to the Ngataringa Bay, and, in considerably lower concentrations, to the Waitemata Harbour near Stanley Bay.

Wastewater

Wastewater samples were collected from three locations in the vicinity of the SSTS in November 2017. PFAS was detected in the sample collected from the wastewater pre-treatment system at the SSTS and in the Ngataringa Bay pump station, indicating that wastewater from the SSTS discharges off-site via the Ngataringa Bay pump station and then to the Council reticulated sewer network.

It is very unlikely people would ingest wastewater from the SSTS and, therefore, the pathway is incomplete.

Sediment

Eighty sediment samples were collected from three quadrats adjacent to the SSTS in Ngataringa Bay and one quadrat in the control site in Hellyers Creek. Samples were initially composited into one sample per quadrat. PFOS was the only compound detected above the LOR in any of the sediment samples.

Concentrations of PFOS above the LOR in composite samples were limited to one quadrat in Ngataringa Bay. Subsequent analysis of discrete individual sediment samples from Ngataringa Bay identified PFOS above the LOR in seven of the 20 discrete samples analysed.

A low risk for invertebrates inhabiting Ngataringa Bay, adjacent to the SSTS has been identified.

Biota

Nine composite mollusc samples were collected in March 2018. Samples were collected of four different mollusc species (*Amphibola crenata / Zedilom* sp., *Cominella glandiformis*, *Turbo smaragdus*, *Diloma substrata*, *Zeacumantus lutulenus*). Three composite crab samples were collected in March 2018 (*Helice* sp.) PFAS was detected in all samples, including those from the control site.

Five of the eleven invertebrate samples from Ngataringa Bay exceeded the avian wildlife diet guidelines for the protection of birds from secondary poisoning i.e. bioaccumulation. Consequently, invertebrates inhabiting the mudflats adjacent to the SSTS pose a potential risk to birds that consume them.

Five fish tissue samples of flounder (*Rhombosolea sp*) were collected in March 2018. Three samples from Ngataringa Bay and one sample from the control site. PFOS was detected in all samples in concentrations ranging from 0.31 – 0.73 µg/kg.

Seafood Consumption

Three mollusc samples collected from Ngataringa Bay exceeded the FSANZ human health trigger point for investigation. Therefore, further investigation would be required to determine if there is a risk associated with consumption of invertebrates from Ngataringa Bay. Such an assessment should include consideration of whether these species are in fact used for human consumption.

All fish tissue results were below the applicable guidelines for human consumption.

No risk for fish or for human consumption of fish was identified.

Note on Sediment Quality Guidelines

To establish the degree of risk to sediment-dwelling organisms, the results of sediment sampling are normally compared to sediment quality guidelines. However, neither the Australian and New Zealand Environmental Conservation Council (ANZECC) nor the PFAS National Environmental Management Plan (HEPA, 2018) has derived any sediment quality guideline values for the protection of aquatic ecosystems. The Norwegian Pollution Control Authority have developed Predicted No Effect Concentrations (PNECs) for sediment based on expected background concentration levels and using equilibrium partitioning relationships[1] with seawater to calculate $PNEC_{sediment}$ based on water quality toxicity data (Bakke et al, 2010).

At sediment concentrations less than the Norwegian $PNEC_{sediment}$ trigger values (concentrations which are either within the range of categories I or II) are unlikely to cause adverse effects in aquatic organisms. However, concentrations above this range represent a possible effects range but do not necessarily mean that adverse effects will actually occur. This is for four reasons:

i. The Norwegian $PNEC_{sediment}$ are have been derived using a theoretical relationship between sediment concentration and water quality concentration based on a partitioning co-efficient (K_{oc}).

ii. No actual sediment toxicity data is available for use in validating these predictions so these guidelines are considered to be 'low reliability guidelines'[2].

iii. PNEC are values designed to predict no effect rather than the onset of toxicity. PNEC values are, therefore, considered to be poor predictors of likely toxicity as toxic effects may occur only at significantly higher concentrations than the PNEC values.

[1] PFAS compounds are emerging contaminants, therefore, there is a lot of uncertainty in the data and relationship used to calculate the $PNEC_{sediment}$ trigger values. It is likely that as more data becomes available, and the scientific uncertainty regarding the behaviour of these compounds reduces, these trigger values could change and the risks may need to be re-assessed in the future.

[2] For the purpose of this report, water and sediment quality guidelines can be assessed as being high reliability, moderate reliability or low reliability. High reliability guidelines are based on a species sensitive distribution of a sufficient robust eco-toxicological dataset. Moderate reliability guidelines have been derived using a dataset which includes a smaller number of eco-toxicological data from at least three different species (ANZECC (2000) sediment quality guidelines are an example of a moderate reliability sediment quality guideline). Low reliability guidelines do not have datasets which meet the above requirements. Low reliability guidelines have been calculated from insufficient datasets and, therefore, provide less confidence that aquatic ecosystems will be protected. For this report, it was considered preferable to have low-reliability guidelines than no guidelines to assess the data. However, a reassessment of the data should be undertaken once higher reliability sediment guidelines become available.

iv. Site-specific factors such as the concentration of organic matter, iron oxides and the clay content of the sediment may all modify how much organisms will be exposed to PFAS chemicals at a specific site which will affect the risk at that site.

Given these limitations, values below the PNECs for these chemicals do not guarantee that the concentrations are safe but they provide an indication of likely risk and allow ranking of sampling locations. Also, PFAS compounds are known to bio-accumulate in organisms and bio-magnify up the food-chain. The Norwegian PNEC guidelines do not account for bioaccumulation – they are based on direct toxicity for aquatic organisms in water, adjusted to account for the characteristics of sediments. Therefore, the Norwegian PNEC guidelines are designed to be trigger values to indicate which sites may warrant closer investigation. They do not assess the risk to aquatic organisms from dietary borne toxicity nor do they assess the potential for a compound to bio-accumulate up the food chain.

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1.0 Introduction

Pattle Delamore Partners Ltd (PDP) has been engaged by the New Zealand Defence Force (NZDF) to undertake a detailed site investigation (DSI) to investigate the potential for biota, sediment, groundwater and wastewater contamination relating to the historic use of products which contained per- and poly-fluoroalkyl substances (PFAS) at the Devonport Naval Base (DPT) in Devonport (the 'site'). The site is displayed on Figure 1.

This report provides the detail of the site investigation, including groundwater, wastewater, biota and sediment sampling and conceptual site model for the site. The investigation activities and this report have been undertaken in accordance with *'Reporting Templates for Per and poly-fluoroalkyl Substances (PFAS) Investigations on the New Zealand Defence Force Estate'* (PDP, 2017), and in general accordance with the Ministry for the Environment (MfE) '*Contaminated Land Management Guideline No. 1 – Reporting on Contaminated Sites in New Zealand*' (MfE, 2011a), and '*Contaminated Land Management Guideline No. 5 – Site Investigation and Analysis of Soils*' (MfE, 2011b). This report has been prepared under the guidance of, and approved by, a suitably qualified and experienced practitioner (SQEP).

NZDF maintains a Hazardous Activities and Industries List (HAIL) database. Each PFAS specific HAIL site identified through this DSI or prior investigations has been given a unique code in accordance with the *NZDF HAIL Investigation Report & GIS Specifications* (PDP, 2016), e.g. HL_03_NGA SSTS, these are shown on Figure 2.

1.1 Objectives

The objective of the investigation was to assess whether the contaminants of concern are present in biota, sediment, groundwater and wastewater at specified locations identified in the preliminary site investigation (PSI) (PDP, 2017a). The investigation was not designed to determine the extent of any identified PFAS contamination.

In the investigation, the following potential sources and pathways of PFAS were investigated:

- Sea Safety Training Squadron:
  - Infiltration in to groundwater;
  - Wind and spray drift;
  - Discharge of groundwater off-site to marine receptors in the Waitemata Harbour (Ngataringa Bay);
  - Discharge of stormwater off-site to marine receptors in the Waitemata Harbour (note this pathway was not able to be

investigated due to a lack of stormwater flow on the scheduled days for sampling); and

- Discharge of trade waste off-site to municipal sewerage network.

- Dockyard and Naval Fuel Installation:
  - Infiltration in to groundwater;
- Direct contact by human and ecological receptors, either with marine sediment, trade waste or groundwater;
- To assess the concentration of the contaminants of concern and determine if they pose a potential risk to human health or ecological receptors.

1.2 Scope

The scope of work undertaken to achieve the project objectives was as follows:

- Sampling of groundwater, wastewater, sediment and biota;
- Analysis of these samples for PFAS;
- Updating the conceptual site model (CSM) developed in the PSI, and;
- Comparison of the laboratory results to applicable guidelines for the purposes of undertaking a human health and ecological (Tier 1/Screening) risk assessment.

Further details on the tasks carried out as part of this scope of works are provided below.

2.0 Site Description

The Devonport Naval Base is described below with legal descriptions stated in Table 1:

- North Yard – offices for teaching and administration and a supply depot including Ngataringa Bay sport fields and the Sea Safety Training Squadron (SSTS), located on Jim Titchener Parade and Ngataringa Bay Access Road, Stanley Point.
- South Yard – the operational part of the Naval Base including the Calliope dry dock, located at the end of Queens Parade, Devonport.
- Calliope Road housing and base associated facilities, Devonport.

Table 1: Site Description

Address	Legal Description [1]
Queens Parade, Devonport (includes Calliope Road and North and South Yards)	Lots 43, 44, 45, 46, 47, 48, 49, 50, Part Lot 52 DP 382, Part Lots 1 and 2 DP 25207, SO 33383, Pts Lots 21, 22 and 24 Allot 30 Sec 2 Takapuna Parish. Part Lot 52 DP 382, SO 33383, Part Lots 2 and 3 DP 29302 and Part Lot 3 Allotment 30, Section 2, Parish of Takapuna, closed road, SO 33703, Part Harbour Bed SO 36655, Part Harbour Bed SO 40439, Part Lot 2 DP 83163, and Part Lot 2 DP 29302, SO 56394, Part Auckland Harbour Bed SO 64512 Portion of Lots 53, 54, 55, 56, 57, 58 and 59, DP 1055, SO 22783, Lots 18, 19, Part Lot 59, Lot 60 and 61, DP 1055, SO 25401, Lot 64 and 65, DP 1055, SO 25991, Section 45 SO 25991, Closed road SO 26225, Part Harbour Bed DP 23202, Section 44 SO 22783, Part Allot 32 and 33 of Section 2 and part Harbour Bed, Part Lots 72, 73, 74, 75, 76, Lot 77 DP 1055 SO 28801, Closed Road SO 28803, Part Lot 15 DP 1055, Lots 62, 63, Part Lot 15, 16 and 17, Part Lot 58, Part Lots 56, 57, Part Lot 55, Part Lots 53, 54, DP 1055, and Lot 50 DP 19244, Lots 1, 2, 3, 20, 21, 22, 23, 24, 48, 49 DP 19244, Lot 4 DP 19244, Lots 46 and 47 DP 19244, Part Allot 24A SO 32155, Lots 41 and 42 DP 1055, Part Allot 24A SO 32155, Lots 78, 79, 85 and Part Lot 84 DP 1055, Closed Road SO 32885, Part Waitemata Harbour, Part Allotment 43, Lot 71 DP 1055 SO 33509, Parts Lot 82 DP 1055, Lot 67 DP 1055, Part Lots 74 and 75 DP 1055, Lot 2 DP 21210, Part Lot 66 DP 1055, Lot 1 and 3 DP 21210, Part Waitemata Harbour Bed, Part Lot 66 DP 1055, Lot 1 DP 21210, Lot 3 DP 21210, Part Harbour Bed SO 31401, Part Lot 66 and 68 DP 1055, Parts Lot 68 and 76 DP 1055, Part Lot 90 and 91 DP 1055, Lot 80 DP 1055, Part Lots 91 and 92 DP 1055, Part Allotment 43 and Part Waitemata Harbour, Part Lot 77 DP 1055, Lot 81 DP 1055, Land below Mean High Water Mark, Part Lots 92 and 93 DP 1055, Part Lot 72 DP 1055, Part Lot 73 DP 1055, Part Closed Road, Part Lot 75 DP 1055, Part Allotment 33, Lot 5 DP 1055, Lot 6 and 10 DP 1055, Lot 1 DP 1055, Lot 3 DP 1055, Lot 11 DP 1055, Lot 2 DP 1055, Lot 9 DP 1055, Lot 83 and Part Lot 84 DP 1055, Lot 12 DP 1055, Lot 1 and 2 DP 47545, Lot 51 and 52 DP 1055, Part Bed Waitemata Harbour SO 56784, Part Bed Waitemata Harbour and Part Allotment 32 and 33 SO 61856, Part Lot 92 DP 1055, Lot 1 DP 64521 (CT 20A/1106).

Notes:

1. *Golders Associates (NZ) Limited, 2010; Ramboll Environ New Zealand Limited, 2017; Auckland Council GIS viewer accessed August 2017 (https://geomapspublic.aucklandcouncil.govt.nz/viewer/index.html).*

2.1 Site Layout

Devonport Naval Base (Figure 1) is a large operating naval base located in Devonport in Auckland's Waitemata Harbour. The North Yard includes a number of offices for training and administration purposes, accommodation, a large supply depot and storage facilities. The South Yard includes the Calliope dry dock, Babcock workshops, wastewater treatment plant, bulk fuel storage facilities and along the eastern side: accommodation, dining facilities and offices. Most of the site is covered with impervious material comprising buildings or sealed areas. The Sea Safety Training Squadron (SSTS), sports complex and playing fields are located at Ngataringa Bay.

2.2 Natural Features

2.2.1 Geology and Hydrogeology

The Geological Map of the Auckland Urban Area (Kermode, 1992) indicates that North Yard (including the SSTS) and South Yard are underlain by construction fill consisting of recompacted clay – to gravel-sized materials which may include demolition debris. The prominent sea cliffs along the northeast boundary of South Yard are comprised of greenish grey alternating muddy sandstone and mudstone with occasional interbedded lenses of grit (Parnell Grit) of the East Coast Bays Formation (ECBF) of the Waitemata Group. Rocks of the ECBF are expected to make up the bedrock beneath the entire site.

At the SSTS and Ngataringa Bay Sports field, the groundwater flow direction is expected to be in a northeast to northwest direction towards Ngataringa Bay and the harbour. Groundwater flow direction at North Yard is expected to be in a general north direction towards Ngataringa Bay and the Waitemata Harbour. At South Yard, the groundwater flow direction is expected to be in a south to southwest direction towards Stanley Bay and the Waitemata Harbour.

Previous intrusive investigations at the South Yard indicate a layer of construction fill comprising compacted gravel, coarse sand, silt and clay of variable thickness (0.2 – 3.5 m) underlain by rocks of the ECBF. The groundwater table is 1.4 m to > 4.5 m bgl (PDP, 2009; Golder Associates (NZ) Limited, 2010).

Previous intrusive investigations at the SSTS have shown that a shallow layer of fill comprised of gravelly silty, shelly clay to a depth of at least 1.2 m is underlain by marine silty sand. The groundwater table is 0.5 to 1.0 m below ground level (m bgl) (PDP, 2010; Golder Associates (NZ) Limited, 2016).

At the time of reporting, PDP was not aware of any groundwater monitoring wells in the vicinity of North Yard, however, based on the close proximity of the harbour, groundwater is inferred to be at a depth of 1 m to 1.5 m bgl.

PDP understands that groundwater beneath the site is not used for potable or non-potable purposes. Groundwater from beneath the site is inferred to

discharge directly to the harbour. Therefore, a bore search was not requested from Auckland Council.

2.2.1.1 Sensitivity of the Underlying Aquifer

The sensitivity of the underlying aquifer beneath the site was assessed in accordance with Section 5.2.3 of the MfE (2011c) guidelines:

- The shallow aquifer beneath the site is not artesian;
- The depth to the first water bearing unit is less than 10 m below the potential contaminant source;
- The site is immediately adjacent to an environmental receptor (the Waitemata Harbour).

In accordance with the guidelines, the shallow groundwater is considered to be sensitive due to the close proximity to the harbour.

2.2.2 Topography and Hydrology

North Yard, South Yard, and the SSTS are constructed on reclaimed land at the base of the Calliope Point cliffs. Calliope Point, which divides North Yard from South Yard, is comprised of ECBF rocks approximately 25 m above sea level (asl). Ngataringa Bay on the northern side is relatively shallow and there are extensive tidal flats. The majority of the site is flat and there are no streams on-site.

2.2.3 Marine Ecology

Ngataringa Bay, which borders the North Yard and SSTS is identified as a Significant Ecological Area Marine 1 and Marine 2 in the Auckland Unitary Plan (AUP [OP], 2018). The Unitary Plan describes the several factors of ecological value in Ngataringa Bay such as the varied habitat including salt marsh and mangrove communities. The intertidal zone is an important wading bird habitat.

The South Yard borders the lower Waitemata Harbour. The marine environment adjacent to the South Yard is extensively modified with wharves and jetties that are part of the Naval Base. Nevertheless, such areas typically support a variety of tolerant marine species.

3.0 Site Investigation Methodology

The site investigation included a programme of sediment, biota, groundwater and wastewater sampling, described further in Table 2. Selected groundwater and surface water locations were sampled in two separate monitoring rounds. All samples were analysed for PFAS.

3.1 Environmental Sampling Programme

The sampling programme was designed to target potential PFAS source areas identified in the Preliminary Site Investigation. The initial sampling programme consisted of:

- Collecting groundwater samples from six groundwater monitoring wells;
- Collecting three wastewater samples; one from the recycled fire wastewater tank in SSTS and two from wastewater pump stations;
- Collecting up to three surface water samples along the seawall adjacent to the SSTS;
- Collecting 80 sediment samples across three quadrats in Ngataringa Bay and one control site in Hellyers Creek, Beach Haven;
- Collecting a variety of crustacean and mollusc samples across the same locations as the sediment samples; and
- Collecting finfish samples from six nets, four located in Ngataringa Bay and two at a control site at Hellyers Creek.

Table 2: Sample Locations

Potential Source / Pathway of PFAS	Sample ID	Location	Sample Media	November 2017 [1]	March 2018 [1]
SSTS fire training area / groundwater infiltration	MW1	Concrete path between SSTS fire training area and Ngataringa Bay	Groundwater	Yes	
	MW2	Concrete path between SSTS fire training area and Ngataringa Bay	Groundwater	Yes	
	MW3	SSTS fire training area	Groundwater	Yes	
	SW1	Stormwater outflow along the seawall adjacent to the SSTS.	Surface Water	Insufficient flow to sample	
Naval Fuel Installation (fire suppressant system), Cliff Rd hazardous goods storage / spills, groundwater infiltration	GABH10	South Yard	Groundwater	Yes	
Industrial Coatings Workshop / Cliff Rd hazardous goods storage / spills, groundwater infiltration	GABH19	South Yard	Groundwater	Yes	
Paint Storage, Cliff Rd hazardous goods storage / spills, groundwater infiltration	GABH32	South Yard	Groundwater	Yes	
SSTS Fire Training area / Site wastewater treatment	WW1	Recycled fire-fighting water from SSTS wastewater tank	Wastewater	Yes	
	WW2	Ngataringa Bay pump station	Wastewater	Yes	
	WW3	Well at Marae pump station	Wastewater	Yes	
SSTS Fire Training area / groundwater and storm water discharge into Ngataringa Bay	FS3.1	NET 3	Biota (Flounder Fish)		Yes
	FS4.1 – FS4.3	NET 4	Biota (Flounder Fish)		Yes
	SD1.1 – SD1.20	Quadrat 1	Sediment		Yes
	SD2.1 – SD2.20	Quadrat 2	Sediment		Yes
	SD3.1 – SD3.20	Quadrat 3	Sediment		Yes
	BT1.1	Quadrat 1	Biota (Crabs)		Yes
	BT1.2	Quadrat 1	Biota (Whelks)		Yes
	BT1.3	Quadrat 1	Biota (Horn shells)		Yes
	BT2.1	Quadrat 2	Biota (Crabs)		Yes
	BT2.2	Quadrat 2	Biota (Horn shells)		Yes
	BT2.3	Quadrat 2	Biota (Whelks)		Yes
	BT2.4	Quadrat 2	Biota (Cats eyes)		Yes
	BT3.1	Quadrat 3	Biota (Crabs)		Yes
	BT3.2	Quadrat 3	Biota (Horn shells)		Yes
	BT3.3	Quadrat 3	Biota (Whelks)		Yes
	BT3.5	Quadrat 3	Biota (Cats eyes)		Yes
	BT3.6	Quadrat 3	Biota (Harbour top shell)		Yes
Control site	FS1.1	Hellyers Creek, Beach Haven	Biota (Flounder Fish)		Yes
	SD4.1 – SD4.20	Hellyers Creek, Beach Haven	Sediment		Yes
	BT4.1	Hellyers Creek, Beach Haven	Biota (Crabs)		Yes
	BT4.2	Hellyers Creek, Beach Haven	Biota (Harbour top shell)		Yes
	BT4.3	Hellyers Creek, Beach Haven	Biota (Horn shells)		Yes

Notes:

1. *"Yes" denotes a sample was collected from that location during the specified monitoring round.*

3.1.1 Contaminants of Concern

The analytical suite is listed below in Table 3 where both the linear and branched isomers of PFOS and PFHxS are combined (reported as T-PFOS and T-PFHxS). The WA DER[3] guidelines recommend a suite of minimum target compounds in the analytical suite which are bold in the table below.

Analytical detection limits for water and ground water samples were 0.01 to 0.001 µg/L and 0.025 µg/kg or less for sediment and soil samples.

Table 3: Total Analytical Suite for PFAS

Abbreviation	Compound Name	Abbreviation	Compound Name
PFPrS	Perfluoropropanesulfonic acid	**PFBA [1]**	**Perfluorobutanoic acid**
PFBS [1]	**Perfluorobutanesulfonic acid**	**PFPeA [1]**	**Perfluoropentanoic acid**
PFPeS	Perfluoropentanesulfonic acid	**PFHxA [1]**	**Perfluorohexanoic acid (PFHxA)**
di-PFHxS	Total Perfluorodimethylbutane sulfonic acids	**PFHpA [1]**	**Perfluoroheptanoic acid**
mono-PFHxS	Total Perfluoromethylpentane sulfonic acids	**PFOA [1]**	**Perfluorooctanoic acid**
L-PFHxS	Linear Perfluorohexanesulfonic acid	PFNA	Perfluorononanoic acid
T-PFHxS [1]	**Total Perfluorohexanesulfonic acid**	PFDA	Perfluorodecanoic acid
PFHpS [1]	**Perfluoroheptanesulfonic acid**	PFUnDA	Perfluoroundecanoic acid
di-PFOS	Total Perfluorodimethylhexane sulfonic acids	PFDoDA	Perfluorododecanoic acid
mono-PFOS	Total Perfluoromethylheptane sulfonic acids	PFTrDA	Perfluorotridecanoic acid

[3] *Western Australia Department of Environment Regulation. Interim Guidance on the Assessment and Management of Perfluoroalkyl and Polyfluoroalkyl substances (PFAS). Contaminated Sites Guidelines.*

Table 3: Total Analytical Suite for PFAS			
Abbreviation	**Compound Name**	**Abbreviation**	**Compound Name**
L-PFOS	Linear Perfluorooctanesulfonic acid	PFTeDA	Perfluorotetradecanoic acid
T-PFOS [1]	**Total Perfluorooctanesulfonic acid**	PFOSA	Perfluorooctanesulfonamide
PFNS	Perfluorononanesulfonic acid	NEtFOSA-M	N-ethylperfluoro-1-octanesulfonamide
PFDS	Perfluorodecanesulfonic acid	NMeFOSA-M	N-methylperfluoro-1-octanesulfonamide
4:2 FTS	1H,1H,2H,2H-perfluorohexanesulfonic acid	NEtFOSAA	N-ethylperfluorooctanesulfonamidoacetic acid
6:2 FTS [1]	**1H,1H,2H,2H-perfluorooctanesulfonic acid**	NMeFOSAA	N-methylperfluorooctanesulfonamidoacetic acid
8:2 FTS [1]	**1H,1H,2H,2H-perfluorodecanesulfonic acid**	NEtFOSE-M	2-(N-ethylperfluoro-1-octanesulfonamido)-ethanol
		NMeFOSE-M	2-(N-methylperfluoro-1-octanesulfonamido)-ethanol

Note:

1. *Compound is part of recommended analytical suite for PFAS as per WA DER guidelines.*

3.1.2 Groundwater Sampling

A groundwater sampling round of wells MW1, MW2, MW3, GABH10, GABH19 and GABH32 was undertaken on the 13 and 14 November 2017. Groundwater sampling locations are displayed on Figure 1.

Groundwater sampling was undertaken in accordance with PDP low flow groundwater sampling procedures, the Sampling and Analysis Plan (SAP) (PDP, 2017b) and the WA DER (2016) Interim Guidelines on the Assessment and Management of Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS).

Samples were collected in order from bores furthest from potential sources first, to sites closest to potential contamination sources last to minimise the potential for cross-contamination. Therefore, the order of sampling was GABH32, GABH19, GABH10, MW1, MW2, and then MW3. At all wells, low-flow sampling with a peristaltic pump was used to collect a representative water sample using dedicated tubing in each well. Using a peristaltic pump ensured no moving parts were in contact with the water, thus reducing the potential for cross contamination. All non-disposable equipment was triple rinse decontaminated

between sites. The field staff had set tasks at each site (clean hands and dirty hands) which further reduced the potential for cross contamination. A cleaned rental car was taken to ensure sampling equipment and clothing was free from PFAS given the ubiquitous nature of PFAS in a wide variety of materials and products such as car upholstery and carpet.

3.1.3 Wastewater Sampling

Wastewater samples were collected from the Marae and Ngataringa Bay pump stations, located east and south-west of the SSTS, respectively. Both wastewater pump stations were sampled due to uncertainty in the direction of wastewater drainage exiting the SSTS. A wastewater sample was also collected from the recycled fire wastewater tank within the SSTS.

The aim of the wastewater sample collection was to determine the concentrations of PFAS compounds in the SSTS wastewater and whether the treatment was removing PFAS from the wastewater prior to discharge to the Council sewer.

The wastewater samples collected from the Marae and Ngataringa Bay pump stations (WW3 and WW2), respectively, were collected using a bailer and the clean hands/dirty hands sampling procedure detailed in the SAP (PDP, 2017b). The recycled fire wastewater sample (WW1) was collected by hand from the outfall pipe. Locations for wastewater samples are displayed on Figure 1.

3.1.4 Surface Water Sampling

Samples from the stormwater outflows along the seawall adjacent to the SSTS were unable to be collected because outflows were dry on all occasions when the site was visited.

3.1.5 Biota Sampling

3.1.5.1 Finfish

Finfish samples were collected within Ngataringa Bay and at Hellyers Creek using set nets and gee minnow traps. Fishing was conducted under Ministry of Primary Industries (MPI) Special Permit 578 and followed the Set Net Code of Practice (MPI, 2016).

The nets and techniques used are designed to catch flounder which were the primary target species as they are known to frequent the bay and be fished there.

Four nets were set within Ngataringa Bay (Net 1 – Net 4; Figure 1). These were selected based on proximity to the SSTS, research of local fishing spots and safe access. Two nets were set at Hellyers Creek; Beach Haven (the control site).

Set nets (each approximately 40 m in length) and gee minnow fish traps were set during high tide on the 1st and 2nd March 2018 using a small aluminium dinghy. Nets were left for a couple of hours until the tide receded. Nets were retrieved prior to the low tide to prevent the nets being exposed above the water "going dry". This allowed the return of any unwanted fish. The target species were flounder (*Rhombosolea sp.*), kahawai (*Arripis trutta*), mullet (*Mugil cephalus*), snapper (*Pagrus auratus*) and piper (*Hyporhamphus ihi*).

A total of 20 flounder were collected from Ngataringa Bay; one from Net 3 and 19 from Net 4. No fish were caught in the gee minnow traps or in Net 1 and Net 2. Five flounder from Net 4 were returned as they were undersized. Five flounder were collected at Hellyers Creek; one from Net 5 and four from Net 6.

Fish kept for analysis were humanely killed using an iki spike, a tool to euthanize fish. The fish were photographed and measured before being tripled bagged and placed on dry ice. Samples were frozen prior to transport to the laboratory.

Fish samples were composited (composite samples are the collection of several individual organisms combined into one sample) for analysis where more than one fish was caught at a location. For Hellyers Creek the five fish caught were composited and sub-sampled for analysis. For Ngataringa Bay, the single fish from Net 3 was analysed separately. The 14 fish from Net 4 were randomly divided and composited into two samples of five composited fish, one sample of four composited fish for analysis. The fish were analysed using the laboratory's standard methods for PFAS.

3.1.5.2 Molluscs and Crustaceans

Molluscs and crustaceans were collected from three 20 m x 30 m quadrats located in the intertidal zone adjacent to the SSTS and from one 20 m x 30 m quadrat located at Hellyers Creek (the control site). The quadrat locations focused on the extent of the shoreline directly in front of the SSTS, this section of the shoreline receives stormwater from the SSTS and groundwater is likely to seep through the seawall. The collection of molluscs and crustaceans were conducted under Ministry of Primary Industries (MPI) Special Permit 578.

The following species were collected:

- Mud Crab (*Helice* sp.)
- Mud Snail (*Amphibola crenata / Zedilom* sp.)
- Mud Whelk (*Cominella glandiformis*)
- Cat Eye (*Turbo smaragdus*)
- Harbour Top shell (*Diloma substrata*)
- Horn Shell (*Zeacumantus lutulenus*)

Samples were put on dry ice immediately following collection. Prior to transportation to the laboratory, the different species from each quadrat were separated into individual containers. The samples for each species were composited using between 10 – 15 individuals from each quadrat per sample and analysed by the laboratory via their PFAS suite of analytical procedures.

3.1.6 Sediment Sampling

Sediment samples were collected within the same 20 m x 30 m quadrats as the molluscs and crustaceans. Within each quadrat, 20 sediment samples were collected; from 10 different locations. At each sampling location; a surface sample (0-2 cm) and a deep (10 cm) sample were collected into individual sediment jars supplied by the laboratory using a trowel.

The laboratory composited the surface samples and sub-surface samples separately for each quadrat. The samples were then analysed via their PFAS suite.

3.2 Laboratory Analysis

The samples were analysed at AsureQuality in Wellington which is an IANZ accredited laboratory to meet the requirements of MfE (2004) Contaminated Land Management Guideline (CLMG) #5. Samples were sent to AsureQuality in specially designated PFAS/PFAS laboratory supplied plastic (polypropylene or HDPE) sample containers using PDP standard Chain of Custody procedures for analysis via their PFAS suite.

Duplicate samples for intra-lab comparison were sent to Eurofins in Brisbane, Australia for analysis for their PFAS, PFC, AFFF suite (refer Section 4.0). The laboratory reports are provided in Appendix A.

3.3 Applicable Guidelines

Appropriate guidelines have been selected for comparison to carry out a preliminary health and environmental risk assessment for the PFAS detected in groundwater, wastewater, and biota (crustaceans, molluscs and finfish).

The guideline values presented in Table 4 were used to evaluate the data collected as part of this project.

Table 4: Environmental and Human Health Guidelines

Guideline Grouping	Media / Guideline	PFOS / PFHxS	PFOA	PFBS	PFBA	Land Use / Environmental Value	Source
Human Health Guidelines	Recreation	0.7 µg/L	5.6 µg/L	NGV [1]	NGV [1]	NGV [1]	AGDoH [2]
	Finfish (all) proposed trigger points for investigation	5.2 µg/kg (PFOS, sum of PFOS+ PFHxS combined)	41 µg/kg	NGV [1]	NGV [1]	NGV [1]	FSANZ, 2017 [3]
	Crustaceans and Molluscs proposed trigger points for investigation [4]	65 µg/kg (PFOS, sum of PFOS+ PFHxS combined)	520 µg/kg	NGV [1]	NGV [1]	NGV [1]	FSANZ, 2017 [3]
Environmental Guidelines	Ecological Freshwater Guidelines						
		31 µg/L	1,824 µg/L	NGV [1]	NGV [1]	80% species protection [5]	HEPA [6]
		2 µg/L	632 µg/L	NGV [1]	NGV [1]	90% species protection	HEPA [6]
		0.13 µg/L	220 µg/L	NGV [1]	NGV [1]	95% species protection	HEPA [6]
		0.00023 µg/L	19 µg/L	NGV [1]	NGV [1]	99% species protection	HEPA [6]
	Avian Wildlife Diet Guideline	8.2 µg/kg	NGV [1]	NGV [1]	NGV [1]	NGV [1]	E&CCC [7]
	Fish Tissue Guideline	9,400 µg/kg ww (PFOS)	NGV [1]	NGV [1]	NGV [1]	NGV [1]	E&CCC [7]

Notes:

1. *NGV = No Guideline Value.*
2. *Australian Government Department of Health (AGDoH, 2017) Health Based Guidance values for PFAS for Use in Site Investigations in Australia.*
3. *Food Standards Australia New Zealand (FSANZ), Supporting Document 2: Assessment of potential dietary exposure to perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA) and perfluorohexane sulfonate (PFHxS) occurring in foods sampled from contaminated sites (FSANZ, 2017).*
4. *Occasionally consumed food, trigger points for investigation for crustaceans applied to molluscs due to small number of consumers of molluscs.*
5. *Applied to groundwater only.*
6. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality – technical draft guideline values. Sourced from PFAS National Environmental Management Plan (HEPA, 2018).*
7. *Guideline from Canadian Environmental Protection Act, 1999 Federal Environmental Quality Guidelines Perfluorooctane Sulfonate, June 2018, Environment and Climate Change Canada. Guideline is reported as µg/kg wet weight (body weight of fish).*

3.3.1 Groundwater Quality Guidelines

Groundwater results have been compared to international guidelines due to the lack of New Zealand derived guidelines available.

Results were compared conservatively compared to recreation guidelines to assess the potential human risk associated with incidental ingestion of the water, e.g. during excavation. The Australian Government Department of Health (DoH, 2017) derives the guidelines from the tolerable daily intake using a methodology described in Chapter 6.3.3 of the National Health and Medical Research Council's Australian Drinking Water Guidelines – where a drinking water guideline is multiplied by 10 to get a recreational water quality guideline. This approach is also in line with the World Health Organisation (WHO) guidance for recreational water quality. This health based guidance value indicates the amount of PFAS (specifically the sum of PFOS/PFHxS, and PFOA) in water that a person can incidentally consume while in contact with water for recreational purposes, on a regular basis over their lifetime without a significant risk to their health. The recreational water quality guideline value developed by AGDoH is based on the drinking water guideline and allows for ingestion of 200 mL of PFAS contaminated water during recreational water use.

The AGDoH provides recreational water values for the sum of Total PFOS+PFHxS and PFOA.

As explained in Section 2.2, groundwater beneath the South Yard and SSTS discharges into the Waitemata Harbour (i.e. a marine environment). However, due to the lack of a marine water guideline for PFAS compounds, the ecological freshwater guidelines sourced from the PFAS National Environmental Management Plan (HEPA, 2018) have been applied. The guidelines provide screening levels for PFOS and PFOA. The screening levels displayed in Table 4 are at the 80%, 90%, 95% and 99% species protection levels. The methodology to derive these guidelines does not account specifically for biomagnification.

3.3.2 Wastewater Guidelines

Guideline values have not been selected to compare to wastewater samples because there are no appropriate guidelines available.

3.3.3 Sediment Guidelines

Currently there are no ANZECC guidelines for PFAS in sediment.

The Norway Sediment Quality Guidelines developed by Bakke *et al.* (2010) have guidelines for PFOS only. However, it is important to note that these guidelines have been derived using a theoretical relationship and have not been validated by ecotoxicological data. For this reason, the Norwegian guidelines have been applied as initial screening criteria. The sediment quality guidelines are reproduced below in Table 5.

Table 5: Norway Sediment Quality Guidelines [1,2]					
Compound	**Background Levels**	**No Toxic Effect**	**Toxic Effects Following Chronic Exposure**	**Toxic Effects Following Short Term Exposure**	**Severe Acute Toxic Effects**
PFOS	< 0.17	0.17 - 220	220 - 630	630 – 3,100	> 3,100

Notes:

1. *Sediment guidelines reported in µg/kg dry weight.*
2. *Norway Sediment Quality Guidelines. Obtained from Bakke, T., Kailquist, T., Ruus, A., Breedveld, G. and Huylland, K. (2010). Journal of Soils and Sediment, 10, pp 172-178.*

3.3.4 Biota Guidelines

Fish and invertebrate tissue samples have been compared to the trigger points for further investigation developed by Food Standards Australia and New Zealand (FSANZ, 2017). FSANZ (2017) provides investigation trigger point values for PFOS+PFHxS and PFOA. The "trigger points" are the maximum concentration level of these chemicals that could be present in individual foods or food groups so that even high consumers of these foods would not exceed the relevant TDI [tolerable daily intake]" (FSANZ, p.2, 2017). The trigger points are based on consumption by a child 2 – 6 years old of 73 g per day of fish or 2 g per day of molluscs or crustaceans.

Fish samples have also been compared to the Canadian Environmental Quality Guidelines for PFOS (Environment and Climate Change Canada, 2018). These guidelines have been developed to assist in the protection of fish from toxic effects on the fish themselves. The Canadian Environmental Quality guideline for avian wildlife diet (freshwater biota) has been provisionally applied in the absence of specific marine guidelines for the protection of birds consuming marine aquatic biota.

4.0 Quality Assurance Sampling

Quality Assurance (QA) and Quality Control (QC) procedures and analysis are essential to a robust environmental monitoring campaign. Sound QA procedures for groundwater sampling result in comparable, representative samples and data. QC analysis of results provides confidence that the interpretations and recommendations made on the data are as accurate as reasonably possible. QA/QC testing also aids in providing some qualification of the inherent uncertainty and limits of accuracy within the results.

As part of the sampling program, the following QA/QC samples were collected:

- One inter-lab duplicate groundwater sample, collected for analysis at Eurofins in Australia;

- One blind duplicate groundwater sample, collected for analysis at AsureQuality;
- Two equipment rinsate blanks collected, one for the water level dip meter and one for the YSI meter, for analysis at AsureQuality;
- Two samples of Decon90 (one from bulk, one from the PDP field operative's field kit) used to decontaminate sampling equipment, for analysis at AsureQuality;
- One sample of the control water used to decontaminate sampling equipment, for analysis at AsureQuality; and
- One trip blank, for analysis at AsureQuality.

The methods in which the QA/QC samples were obtained are detailed in the Sampling Analysis Plan (PDP, 2017b).

4.1 Duplicate Analysis

The results of the quality assurance programme are presented in Tables B-1 and B-2, Appendix B.

Water Samples

In order to determine the precision of the sampling and laboratory analysis, the similarity between the inter-laboratory duplicate and blind field duplicate samples was quantified by calculating the Relative Percent Difference (RPD) for each individual parameter where the parameters were detected in both the duplicate and parent samples. Using the Horwitz equation, a calculated RPD within ± 66% is deemed acceptable, as outlined in the SAP (PDP, 2017b).

When interpreting the RPD calculations, it is important to recognise that the results are from the laboratory analysis of chemicals that are present at very low concentrations. Variation in the results may, therefore, be attributed in part to the analytical method rather than a representation of a true trend of chemical concentration changes.

In general, the, RPDs calculated were within the acceptable 66% range (as per the Horwitz Equation) with an average RPD for all duplicate samples of 18% (Table B-1, Appendix B).

The highest RPD calculated for duplicate samples analysed by different laboratories was 75% for both PFPeS and 6:2 FTS. PFPeS recorded 1.0 µg/L in the parent sample and 2.2 µg/L in the inter-lab duplicate sample from MW2 (analysed by AsureQuality and Eurofins, respectively). 6:2 FTS recorded 15.0 µg/L in the parent sample and 6.8 µg/L in the duplicate sample from MW2 (analysed by AsureQuality and Eurofins, respectively). The highest RPD calculated for the blind field duplicates (both samples analysed by AsureQuality) was 27% for PFNA which recorded 0.13 µg/L in MW1 and 0.17 µg/L in MWC.

The large RPD recorded for PFPeS and 6:2 FTS may indicate variability for these compounds in the sampled water; however, the results for those analytes should be treated with caution until a standard range of concentrations can be established by future sampling and analysis. The higher value has been using for comparison with the water guidelines to ensure no underestimate of risk.

4.2 Rinsate Blanks

The rinsate blanks were collected to verify the effectiveness of field equipment cleaning procedures. The rinsate blanks analysed were for the YSI flow through cell (MWA) and the water level meter (MWD). The analytical results for the rinsate blanks for the water level dip meter and YSI flow through cell came back with all compounds below detection (Table B-2, Appendix B). Hence, all rinsate blank concentrations meet the data quality objectives set out in the SAP (PDP, 2017b).

All rinsate, field blanks and trip blanks collected during the water monitoring in November 2017 returned PFAS concentrations below the laboratory limit of reporting, indicating that field equipment cleaning procedures were effective and resulted in no cross contamination with PFAS during sampling activities.

4.3 Control Water Blanks

The control water used to decontaminate sampling equipment was sourced from the PDP storeroom's reticulated water supply located in Newmarket. One control water blank was collected prior to the groundwater sampling in November 2017.

The control water blank sample (MWB) showed all compounds analysed, below detection limits. These concentrations meet the quality data objectives set out in the SAP (PDP, 2017b).

5.0 Results

5.1 Changes from the Sampling and Analysis Plan

The Sampling and Analysis Plan (PDP, 2017b) was followed as closely as practicable, however, some minor changes were required, and these are noted below:

- The analytical methodology used by the laboratory differed from the original proposed methodology which used bottles with no preservative. The bottles provided by the laboratory contained a preservative so the triple rinse methodology, that was prescribed, could not be used. If a blank bottle was used to transfer sample water to sample bottles it was rinsed following the triple rinse procedure before the sample was collected.

- Stormwater sampling along the seawall adjacent to the SSTS was unable to be undertaken due to there being no outflow during the two days PDP were on-site.
- Due to the difficulty of finding suitable specimens; the SAP was amended during sampling to collect any mollusc or crab species when found in the 20 m x 30 m quadrat including within the mangroves.

5.2 Field Observations

Groundwater conditions for wells MW1, MW2, GABH10, GABH19 and GABH32 were satisfactory for the low flow sampling criteria with the wells taking between 20 and 40 minutes for parameters to stabilise. MW3 exhibited very low K (hydraulic permeability), where at the lowest pump setting, the drawdown exceeded the low flow criteria. Therefore, the pump was turned off to allow recharge, then back on to continue purge then back off again. This process was repeated until one well volume was removed. Subsequently, the sample was taken.

MW1 exhibited a slight hydrocarbon odour. No odour or visual contamination was observed in any other sample during the water and sediment sampling exercises. The sampling sheets and field notes are attached in Appendix C; refer to Figure 1 for locations.

5.3 Groundwater Results and Comparison to Applicable Criteria

The results of the laboratory analysis for groundwater monitoring are presented in Table 6, appended.

PFAS compounds were detected above the limit of reporting in all groundwater samples. The highest concentration of a single compound was Total PFOS in MW3 at the SSTS.

The sum of total PFHxS+PFOS ranged from 0.0098 to 0.061 µg/L in the South Yard wells and 30 – 75 µg/L in the SSTS wells.

6:2FTS and 8:2FTS were detected above the limit of reporting in all three of the SSTS wells.

Samples MW2 and MW3 exceeded the ecological freshwater level at the 80 %, 90 %, and 95% protection levels for total PFOS. Sample MW1 exceeded the ecological freshwater level at the 90 % and 95 % protection levels (for slightly to moderately disturbed systems), for total PFOS.

5.4 Wastewater Results

The results of the laboratory analysis for PFAS in wastewater are presented in Table 7, appended.

Samples WW1 and WW2, obtained from the recycled fire-fighting water and the Ngataringa Bay pump station, respectively, recorded detections of PFAS above the limit of reporting. The sum of total PFHxS+PFOS ranged from 5.6 µg/L in the sample collected from the recycled fire-fighting water tank (WW1) to 6 µg/L in the sample collected from the Ngataringa Bay pump station (WW2).

The remaining wastewater sample (WW3), collected from the Marae pump station, showed no detection of PFAS above the laboratory limit of reporting.

5.5 Sediment Sampling Results and Comparison to Applicable Criteria

Sediment samples were initially analysed as composite samples separated by quadrat and sample depth (refer to Table 8, appended).

PFOS was the only compound detected above the laboratory limit of reporting. Total PFOS was detected at 1.4 and 1.2 µg/kg within the surface and sub-surface composite samples for Quadrat 2 respectively. Neither result exceeded the low-reliability guideline.

For all other sediment samples (including control site samples), no PFAS were detected above the laboratory limit of reporting.

Because PFAS were detected above the limit of reporting in two composite samples, 20 samples across Quadrats 1, 2 and 3 were selected using a random number generator to be re-analysed individually.

PFOS was detected above the limit of reporting in seven of the 20 samples (SD2.1, SD2.11, SD2.2, SD2.3, SD2.7, SD2.9 and SD3.1), refer to Table 9, appended. Concentrations ranged from 1.1 to 2.2 µg/kg, similar to the concentrations reported for the composite samples.

5.6 Biota Sampling Results and Comparison to Applicable Criteria

5.6.1 Crustaceans and Molluscs

The crustacean and molluscs were composited into samples according to species (crabs, whelks, horn shells, cats eyes and harbour top shells), for each quadrat.

- All samples showed detection of at least one PFAS compound.
- Three out of the 12 samples were above the trigger values for further investigations (Table 10, appended).
- Horn shells collected from Quadrats 2 and 3 (samples BT2.2 and BT3.2, respectively) exceeded the human health trigger point for both total PFOS and the sum of total PFHxS+PFOS.
- Six samples (BT4.3, BT2.2, BT2.4, BT3.2, BT3.3, BT3.5) exceeded the Federal Environmental Quality guidelines for avian wildlife diet for total PFOS. Five of these samples were collected from Ngataringa Bay and one

from the control site in Hellyers Creek where the concentration of Total PFOS 8.7 µg/kg (BT4.3) slightly exceeded the guideline of 8.2 µg/kg.

- The cats eyes samples from Quadrat 2 and 3 (BT2.4, BT3.5) exceeded the human health trigger point.
- The highest concentration of the sum of total PFHxS+PFOS was 300 µg/kg in the horn shell composite sample from Quadrat 2 (BT2.2).
- The highest concentration of the sum of total PFHxS+PFOS by species was, in descending order: horn shells, cats eyes, whelks, crabs and harbour top shells.
- Horn shells also showed higher concentrations of 6:2 FTS than other biota, however, currently there are no guidelines for this compound.
- 6:2 FTS was detected in 7 samples (BT4.3, BT1.3, BT2.2, BT3.2, BT3.3, BT3.5), the two highest concentrations were the horn shell samples from Quadrat 2 and 3 (BT2.2 and BT3.2).
- PFAS was also detected in the horn shell composite sample (BT4.3) at the control site at Hellyers Creek.
- PFNA was detected in four samples (BT4.3, BT2.4, BT3.2 and BT3.5), with the highest concentration being the horn shell sample from Quadrat 3 (BT3.2).
- Three samples had no detection of PFAS above the laboratory LOR, these were not included in Table 10.

5.6.2 Finfish

The results of the laboratory analysis for flounder are presented in Table 11, appended. All flounder recorded detections of PFAS above the laboratory LOR.

Results show that samples collected from Nets 3 and 4 in Ngataringa Bay have detections of total PFOS ranging 0.36 to 0.7 µg/kg. No fish were caught in Nets 1 and 2.

The control site in Hellyers Creek recorded the highest concentration of total PFOS out of all of the samples analysed with a result of 0.73 µg/kg. Nevertheless, all results were below the human health trigger point for investigation (5.2 µg/kg), below the ecological guideline for the protection of fish (9,400 µg/kg) and below the Federal Environmental Quality guidelines for avian wildlife diet (8.2 µg/kg).

6.0 Conceptual Site Model

A risk to human health can only exist if there is a hazard (i.e. a source, for example – contaminated soil, dust or water), a receptor (i.e. people) and an exposure pathway linking the hazard and the receptor. An absence of any one of these components means no risk can exist. A conceptual site model (CSM) is designed to identify the hazards, receptors and possible links between these.

An initial CSM was developed during the PSI (PDP, 2017a). Based on the sampling results of the DSI, the CSM has been updated (Figure 3).

A hazard or source may exist in the form of contaminated concrete, soil, sediment, stormwater, waste water, surface water or groundwater resulting from the storage and / or use of PFAS containing products (e.g. AFFF) at the NZDF Base.

The potentially complete exposure pathways that were identified in the PSI for the Base (PDP, 2017a) include:

- Runoff from contaminated concrete or soil in to stormwater on-site;
- Infiltration in to groundwater;
- Wind and spray drift;
- Discharge of groundwater off-site to marine receptors in the Waitemata Harbour (Ngataringa Bay and Stanley Bay);
- Discharge of stormwater off-site to marine receptors in the Waitemata Harbour (Ngataringa Bay and Stanley Bay);
- Discharge of trade waste off-site to municipal sewerage network; and
- Direct contact by human and ecological receptors, with AFFF spray drift, sediment (including marine sediment), stormwater, trade waste, groundwater and sea water.

The principal receptors of concern are:

- Workers on Base who may come into contact with soil, stormwater, groundwater and trade waste;
- Workers in the municipal sewerage network who may come into contact with trade waste;
- Public using Ngataringa Bay and Stanley Bay for recreation or seafood collection; and
- Plants and animals inhabiting Ngataringa Bay and Stanley Bay.

There are typically three potential exposure routes for human receptors; ingestion, dermal contact and inhalation. For this CSM, ingestion is considered to be the primary exposure route. In accordance with PDP (2017), direct

exposure of Base personnel to AFFF products (e.g. via dermal contact or inhalation) is not assessed in the CSM because NZDF addresses this potential exposure as part of its responsibilities under the Health and Safety at Work Act, 2015.

For an inhalation exposure pathway, the human health risk arises primarily from inhalation of aspirated foam. For the dermal contact exposure pathway, the risk is considered to be negligible due to the low dermal permeability values for PFAS compounds (ATSDR 2015). It is noted that the public are excluded from the site and, therefore, there is no direct contact for the public with aspirated AFFF.

The pathways are also summarised in the attached CSMs. Figure 3 provides the CSM laid out in a flow chart that identifies sources, pathways and potential receptors. Figure 4 shows a plan view of the site and surrounding area, and identifies the location and spatial relationship of sources, pathways and receptors (note, due to the plan layout of Figure 4, only some of the sources, pathways and receptors presented in Figure 3, the Flow Chart are able to be displayed).

Figure 5 provides a pictorial cross section of the site and surrounding area, and provides further information on sources, pathways and receptors, particularly subsurface.

The sources, pathways and receptors investigated are shown on Figure 6 and Table 12 below.

Table 12: PFAS Sources, Pathways and Receptors Directly Investigated

Source	Pathway	Receptor
Storage and use of AFFF at the SSTS	Infiltration to groundwater and subsequent discharge to Ngataringa Bay	Molluscs and crustaceans in Ngataringa Bay Fish in Ngataringa Bay
Trade waste containing AFFF from the SSTS	Discharge of trade waste to municipal sewerage network	Workers on the municipal sewerage network (not directly investigated)
Storage and use of AFFF in the Dockyard	Infiltration to groundwater	Waitemata Harbour near Stanley Point (not directly investigated)

The complete exposure pathways that were confirmed during this investigation were:

- Infiltration to groundwater;
- Discharge of groundwater off-site to Ngataringa Bay;

- Discharge of trade waste from the SSTS off-site to the municipal sewerage network; and
- Direct contact by ecological receptors with marine sediment.

6.1 CSM Limitations

The information used to inform the CSM has been based on the work undertaken during the PSI and has been updated based on the sampling undertaken during the DSI. In some cases, a relatively small number of samples have been collected and, as such, these may not fully represent the conditions found on-site. In addition, some information is anecdotal and has not been confirmed by other means. At present, there is no evidence that other significant sources of PFAS exist on the site.

There are other sources of PFAS to the marine environment, these have not been considered in this investigation.

7.0 Risk Assessment

A Tier 1 or screening risk assessment, based on the updated CSM, has been undertaken to determine the likelihood that the sources identified pose a risk to the receptors.

7.1 Groundwater Users

Groundwater on the Base is not used for potable water supply. Potable water supply for the Naval Base and wider Devonport area is from the Council reticulated water supply. The location of the Base immediately adjacent to the harbour also means that there are no down-gradient users of groundwater. On this basis, the pathway for ingestion of groundwater is incomplete. Nevertheless, the concentrations of PFAS identified beneath the SSTS mean that the groundwater is not suitable for human consumption.

Groundwater sampling from monitoring wells has confirmed that concentrations of PFAS are present beneath the SSTS at concentrations that exceed the recreation guideline for the protection of human health. The recreational guideline is the concentration of the sum of PFOS+PFHxS that can be in water that a person can incidentally consume while in contact with water for recreational purposes without a significant risk to their health. It assumes people would be undertaking recreational activities in a particular location every day of their lives and that they could ingest 200 mL of the water every time they visit that location for recreation. It is a conservative approach if people are only likely to visit a location occasionally. Nevertheless, the risk of accidental ingestion of this water, for example by workers during excavation activities, is negligible.

Groundwater sampling from monitoring wells located in the Dockyard of the South Yard has identified concentrations of PFAS below the recreation water use guideline. A risk to human health from ingestion of this groundwater has not been identified.

7.2 Surface Water Receptors

7.2.1 Ecological Receptors

Results from the sediment sampling undertaken have confirmed the presence of PFAS in sediment. All samples were below the Norwegian PNEC trigger values and, therefore, the concentrations of PFAS compounds present in the sediments analysed from Ngataringa Bay are thought to pose a low level of risk to the invertebrate community.

The results of sampling of invertebrates have confirmed the presence of PFAS in molluscs and crustaceans adjacent to the SSTS in Ngataringa Bay. PFAS was also detected in molluscs in the control site, however, at concentrations more than an order of magnitude lower than at Ngataringa Bay for the same species. Five of the eleven invertebrate samples from Ngataringa Bay exceeded the avian wildlife diet guidelines for the protection of birds from secondary poisoning i.e. bioaccumulation. Consequently, invertebrates inhabiting the mudflats adjacent to the SSTS pose a potential risk to birds that consume them.

The results of sampling of flounder fish tissue have confirmed low concentrations of PFAS in all the fish sampled, including those from the control site, with no significant difference between concentrations of PFAS in flounder in Ngataringa Bay and the control site. However, none of the locations sampled were as close to the SSTS as those where invertebrates were collected. This may explain why concentrations of PFAS in fish were similar in Ngataringa Bay and Hellyers Creek. The results are below the applicable ecological guidelines (including those for dietary components for protection of birds from secondary poisoning i.e. bioaccumulation) and, therefore, on the basis of the above sample results, a risk to flounder frequenting Ngataringa Bay has not been identified (in relation to PFAS contamination).

7.2.2 Surface Water Users

Given the significant dilution available within the water of Ngataringa Bay, which flushes twice a day, and the low volume of groundwater likely to be seeping through the seawall, seawater in the Bay is not considered likely to be a potential pathway for exposure of the public to PFAS from groundwater discharging into the Bay. Consequently, sampling and analysis of seawater from the Bay was not considered to be necessary and further, a risk assessment for exposure of the public to seawater within the Bay has not been conducted.

Whilst PFAS was detected in sediment at Ngataringa Bay, PFAS was also detected in sediment at the control site. There are no applicable guidelines for exposure of people to sediment, and, therefore, a Tier 1 risk assessment for exposure of the public to sediment in the area sampled within Ngataringa Bay has not been conducted.

7.2.3 Consumers of Seafood

The results of tissue samples collected from molluscs and crustaceans adjacent to the SSTS in Ngataringa Bay confirmed concentrations of PFAS which exceed the human health trigger points for investigation. It is not known whether these species from this location are collected for consumption. However, the results of this investigation indicate there is the potential for a risk to human health from regular consumption of these species at quantities at or exceeding those nominated in the FSANZ guideline.

The results of sampling of flounder fish tissue have confirmed concentrations of PFAS in all the fish sampled are well below the trigger value for further investigation, albeit for a limited number of samples and only for a single fish species.

7.3 Wastewater

There is no applicable guideline for exposure of workers to PFAS in wastewater. While the concentration of the sum of total PFHxS+PFOS in sample WW2 is an order of magnitude higher than the recreation water quality guideline for the protection of human health, the risk of accidental ingestion of this water, for example by workers during maintenance of the wastewater system on Base, is negligible. As a result, there is no complete exposure pathway for this exposure scenario.

It should also be noted that there are many reasons to prevent contact with wastewater (e.g. sewage) not just the presence of PFAS. The microbiological quality of such wastewater is the main driver of occupational controls when managing such systems. These controls will also minimise exposure to any PFAS that would be present in the wastewater.

Similarly, the exposure pathway for staff at the council wastewater treatment plant associated with PFAS exposure is considered to be incomplete. While staff may have more exposure to the wastewater at the treatment plant, staff health and safety protocols for their handling of wastewater would mean that risks to staff at the plant associated with PFAS is negligible.

7.4 Risk Assessment Limitations

Currently, there are a small number of samples, small number of species and small number of sampled locations. Due to their physio-chemical properties, the fate and transport of PFAS is complicated and poorly understood. As such,

extrapolation of these results, particularly to locations off-site, is uncertain and may not represent the actual conditions present. On this basis, any assessment of risk to off-site receptors is limited.

8.0 Discussion

Groundwater

Groundwater samples indicated the presence of PFAS in groundwater beneath or down-hydraulic gradient from parts of the sites that were identified as potential sources of PFAS during the PSI. The wells near the SSTS in Ngataringa Bay where fire-fighting training is conducted, and the Dockyard in the South Yard of the Base where several activities are, or have been, conducted with the potential to be a source of PFAS including: AFFF storage, fire prevention foam blankets and maintenance of vessels confirm the movement of PFAS from the areas where the foams were used into other media. The concentrations of PFAS observed in groundwater beneath the SSTS significantly exceeded ecological and human health guidelines. The location of the site immediately adjacent to the coast and detection of PFAS in invertebrates in the adjacent mudflats (animals with very small home ranges) indicate that PFAS-containing groundwater is likely to be migrating off-site into Ngataringa Bay.

The concentrations of PFAS observed in the groundwater wells in the South Yard are, by contrast, considerably lower, nevertheless there is the potential for PFAS-containing groundwater to migrate off-site into the adjacent Waitemata Harbour.

The groundwater wells at the SSTS have previously been sampled and analysed for PFAS on three separate occasions (Appendix D) by Golder Associates (2016) and by Tonkin and Taylor (2017). The reported concentrations of the sum of Total PFOS + PFHxS from the previous monitoring rounds ranged from 37.9 to 42.9 µg/L for MW1, 53.2 to 79.6 µg/L for MW2 and 76 – 9,800 µg/L for MW3. Excluding the unusually high result obtained from a single sample collected from MW3 of 9,800 µg/L which was noted by Tonkin and Taylor (2017) to have been potentially contaminated during sampling, the results collected during this investigation are generally comparable with previous results.

Wastewater

The results of the wastewater sampling conducted indicate that wastewater is discharged from the SSTS via the Ngataringa Bay pump station to the south-west of the SSTS. Wastewater, at the time of sampling, contained PFAS three orders of magnitude above the LOR.

The Environmental Protection Authority has provided recommendations to councils for (interim) acceptance criteria for PFOS in trade waste discharges of 0.1 µg/L (EPA, 2018). The concentration of PFOS in the wastewater at Ngataringa Bay pump station at the time of sampling was an order of magnitude higher than the recommended criteria. NZDF holds a trade waste permit for the discharge.

A comparison of the sample results from the SSTS recycled water tank (following treatment via the SEPA unit) with the results from the Ngataringa Bay pump station, indicate that the pre-treatment plant is not removing PFAS and that PFAS-containing wastewater is discharging off-site into the Council reticulated sewer system. It should be noted that SEPA is not designed to remove PFAS. Other studies internationally have also shown that most sewage treatment plants remove only limited amounts of PFAS from sewerage so this finding is not unusual.

Sediment

Linear PFOS was the only compound detected above the LOR in the sediment samples submitted for analysis. Concentrations of total PFOS in discrete sediment samples from Ngataringa Bay ranged from 1.1 to 2.2 µg/kg. PFOS was detected above the LOR in Quadrat 2 and 3 only. These two quadrats were located directly in front of the operational area of the SSTS where fire training using AFFF was historically conducted.

Considerably higher concentrations of PFOS were identified in the nine sediment samples collected from Ngataringa Bay by Golder Associates (2016), where the concentration of total PFOS ranged from 0.6 to 109 µg/kg, and the average concentration was 32 µg/kg (Appendix D, samples Mangrove 01 – Mangrove 04 and Mangrove QC). In those samples, a wider range of PFAS were reported above the LOR (12 compounds in the samples collected by Golder compared to a single compound in the samples collected for this DSI). The samples collected in the earlier investigation were collected from sediment amongst the mangroves directly adjacent to the SSTS (i.e. closer to the SSTS than the samples collected in this investigation), this may be an indication that the concentration of PFAS in sediment decreases with distance away from the SSTS.

Biota

The results of sampling indicate that PFAS is present in molluscs, crustaceans and fish adjacent to the Devonport Naval Base. Sampling indicates that PFAS concentrations vary amongst species, with horn shells reporting the highest concentrations of PFAS across all sample sites. Horn shells are known to feed on wet sediment (ARC, 2003)

Concentrations of the sum of total PFHxS + PFOS ranged between 0.74 to 300 µg/kg. Concentrations above screening guidelines for human health protection were reported for horn shells and for cats eyes. Concentrations above the avian wildlife diet guideline were found in horn shells, cats eyes and one whelk composite sample. Other species reported concentrations below the human health protection guidelines.

PFAS was detected in all fish samples, however, the concentration of PFOS was higher in the invertebrates. The fish samples were collected further away from the Naval Base than the invertebrate samples which were collected directly

adjacent to the SSTS. Fish also travel further and more often than invertebrates. The sample in the control area, Hellyers Creek, had higher concentrations of PFOS than fish sampled near the Devonport Naval Base.

There are many potential sources of PFAS including wastewater treatment plants, landfills, and consumer products that would be relevant in an urban harbour like this one. However, assessing other sources of PFAS in the Waitemata Harbour is beyond the scope of this report.

9.0 Summary and Conclusions

A DSI has been undertaken to investigate PFAS at locations identified to be potential sources of PFAS in the Devonport Naval Base, and in the adjacent Ngataringa Bay. The purpose of the investigation was to establish the presence or absence of PFAS in various media adjacent to potential sources of PFAS. The investigation was not designed to determine the extent of PFAS contamination. Sampling and laboratory analysis of groundwater (from 6 monitoring wells), marine sediment, molluscs, crustaceans and fish has confirmed the presence of PFAS. Sampling and analysis of molluscs, crustaceans and fish at a control site has also confirmed PFAS presence. (The summary and conclusions presented below relate to risks associated with PFAS only.)

Groundwater

Groundwater sampling was conducted in November 2017. Samples were collected from six groundwater monitoring wells, PFAS was reported above the laboratory limit of reporting (LOR) in all samples.

Groundwater samples from the Sea Safety Training Squadron (SSTS) contained concentrations of PFAS exceeding the ANZECC ecosystem protection guidelines and the human health based guidelines for recreational water use. The concentrations of PFAS observed in the groundwater wells in the South Yard were below the applicable ecological and human health based guidelines. Similar results were obtained during previous sampling of groundwater at the SSTS, undertaken in April 2016, October 2016 and April 2017 by others.

It is unlikely people would ingest the groundwater from beneath the SSTS and, therefore, the pathway for consumption of groundwater is incomplete. Nevertheless, the results indicate groundwater from beneath the site is unsuitable for human consumption.

Groundwater containing some PFAS compounds is likely to be migrating off-site to the Ngataringa Bay, and, in considerably lower concentrations, to the Waitemata Harbour near Stanley Bay.

Wastewater

Wastewater samples were collected from three locations in the vicinity of the SSTS in November 2017. PFAS was detected in the sample collected from the wastewater pre-treatment system at the SSTS and in the Ngataringa Bay pump station sample, indicating that wastewater from the SSTS containing PFAS discharges off-site via the Ngataringa Bay pump station and then to the Council reticulated sewer network.

It is very unlikely people would ingest the wastewater from the SSTS and, therefore, the pathway is incomplete.

Sediment

Eighty sediment samples were collected from three quadrats adjacent to the SSTS in Ngataringa Bay and one quadrat in the control site in Hellyers Creek (i.e. 20 samples per quadrat). Samples were initially composited into one sample per quadrat. PFOS was the only compound detected above the LOR in any of the sediment samples.

Concentrations of PFOS above the LOR in composite samples were limited to one quadrat in Ngataringa Bay. Subsequent analysis of discrete individual sediment samples from Ngataringa Bay identified PFOS above the LOR in seven of the 20 discrete samples analysed.

Concentrations of PFAS in sediment were below the low-reliability ecological guideline (Bakke *et al.*, 2010).

A low risk for invertebrates inhabiting Ngataringa Bay, adjacent to the SSTS has been identified.

Biota

Nine composite mollusc samples were collected in March 2018. Samples were collected of four different mollusc species (*Amphibola crenata / Zedilom* sp., *Cominella glandiformis*, *Turbo smaragdus*, *Diloma substrata*, *Zeacumantus lutulenus*). Three composite crab samples were collected in March 2018 (*Helice* sp.) PFAS was detected in all samples, including those from the control site.

Five of the eleven invertebrate samples from Ngataringa Bay exceeded the avian wildlife diet guidelines for the protection of birds from secondary poisoning. Consequently, invertebrates inhabiting the mudflats adjacent to the SSTS pose a potential risk to birds that consume them.

Five fish tissue samples of flounder (*Rhombosolea sp*) were collected in March 2018. Three samples from Ngataringa Bay and one sample from the control site were collected. PFOS was detected in all samples in concentrations ranging from 0.31 – 0.73 µg/kg.

Seafood Consumption

Three mollusc samples collected from Ngataringa Bay exceeded the FSANZ human health trigger point for investigation. Therefore, further investigation would be required to determine if there is a risk associated with consumption of invertebrates from Ngataringa Bay. Such an investigation should include assessment of whether these species are in fact used for human consumption.

All fish tissue results were below the applicable guidelines for human consumption. No risk for fish or for human consumption of fish was identified, however, sampling was limited in number and included only a single fish species.

Limitations to the Investigation

The investigation was constrained by the limited number of samples and sample media and the report should be viewed in this context. Further sampling is beyond the scope of this investigation.

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KEY :

Sample Location

- Groundwater
- Fish
- Macroinvertebrate
- Sediment
- Surface water
- Wastewater
- Quadrat Investigation Area
- Base / Camp Boundary

SOURCE:
Aerial imagery flown 2015-2016 supplied Auckland Council
Topographic information supplied by LINZ.
Cadastral information supplied by NZDF, dated 19/10/16.

NO.	REVISION HISTORY	DATE
C	ISSUE 3	DEC 18
B	ISSUE 2	NOV 18
A	ISSUE 1	OCT 18

pdp

PROJECT NAME:

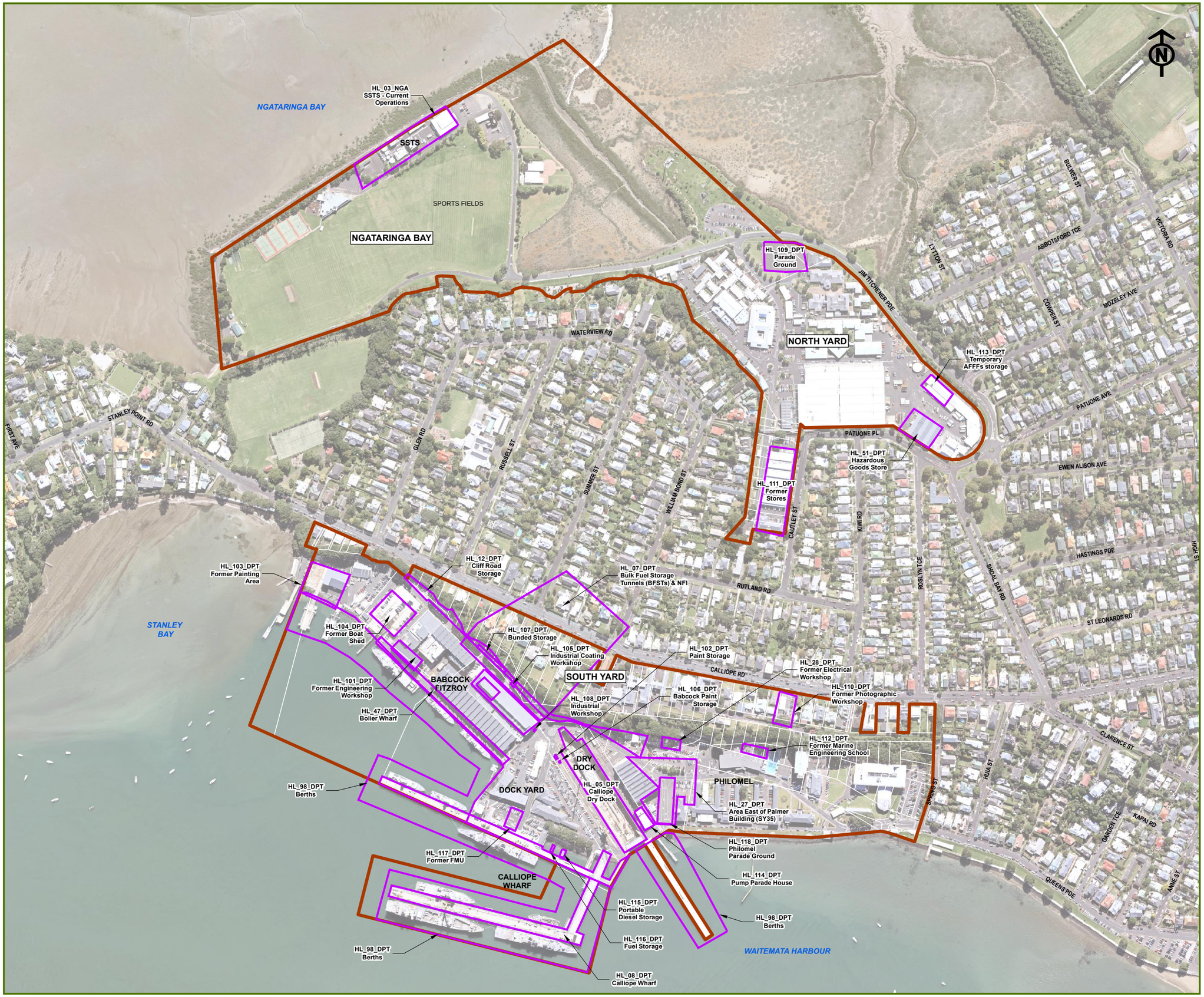
PFAS DETAILED
SITE INVESTIGATION
DEVONPORT NAVAL BASE

FIGURE TITLE:

SITE AND SAMPLE LOCATIONS

SCALE:		FIGURE NO.:	ISSUE NO.:
1:7,500	(A3)	1	C

A02569111Z002_DevonportSampleLocation



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KEY :

PFAS HAIL Areas (Source)

Base / Camp Boundary

SOURCE:
Aerial imagery flown 2015-2016, contours, overland flow path and catchments supplied by Auckland Council. Vertical datum of contours Auckland 1949.
Topographic information supplied by LINZ.
Cadastral information supplied by NZDF, dated 19/10/16.

NO.	REVISION HISTORY	DATE
B	ISSUE 2	DEC 18
A	ISSUE 1	OCT 18

PROJECT NAME:

PFAS DETAILED SITE INVESTIGATION DEVONPORT NAVAL BASE

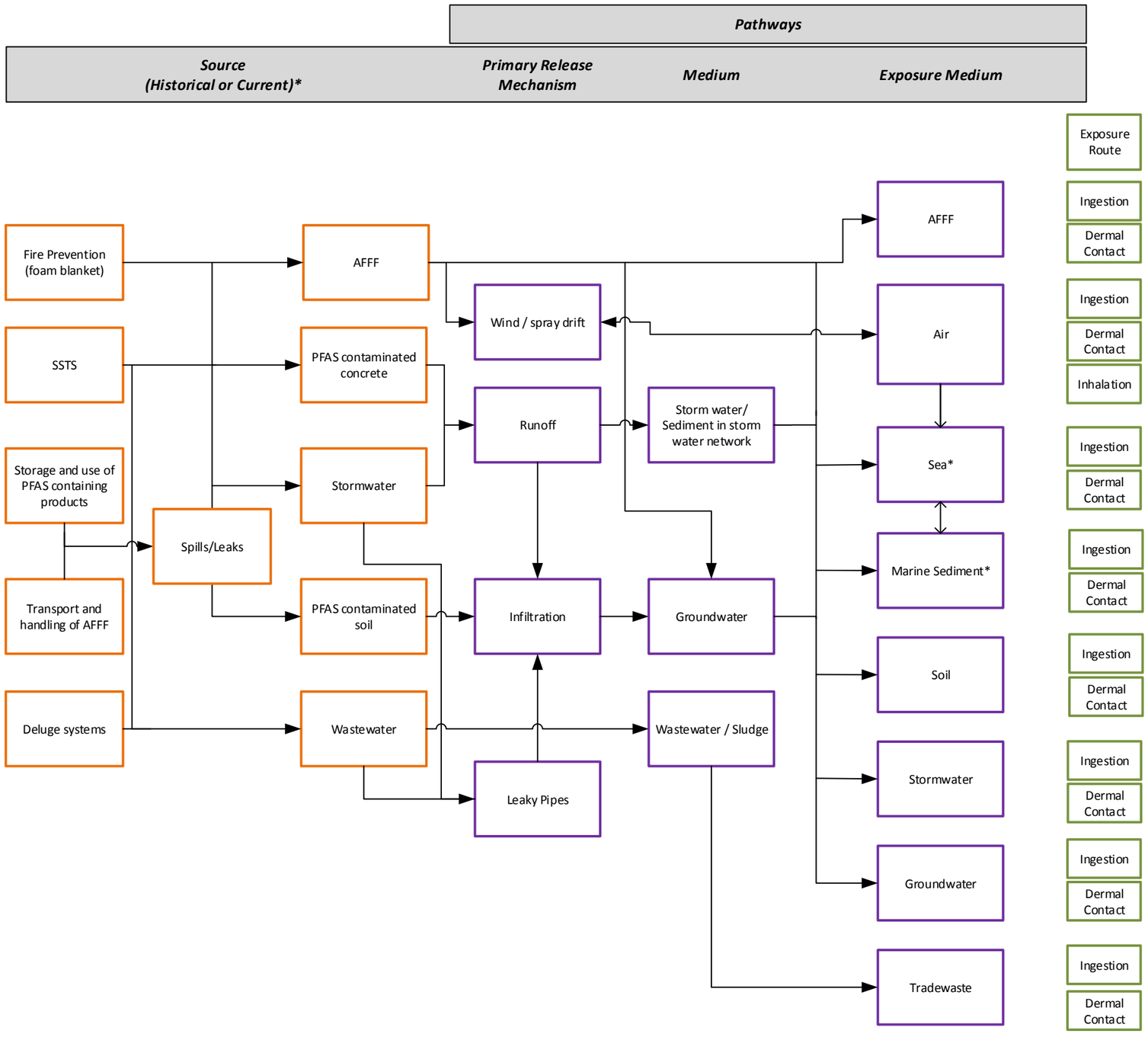
FIGURE TITLE:

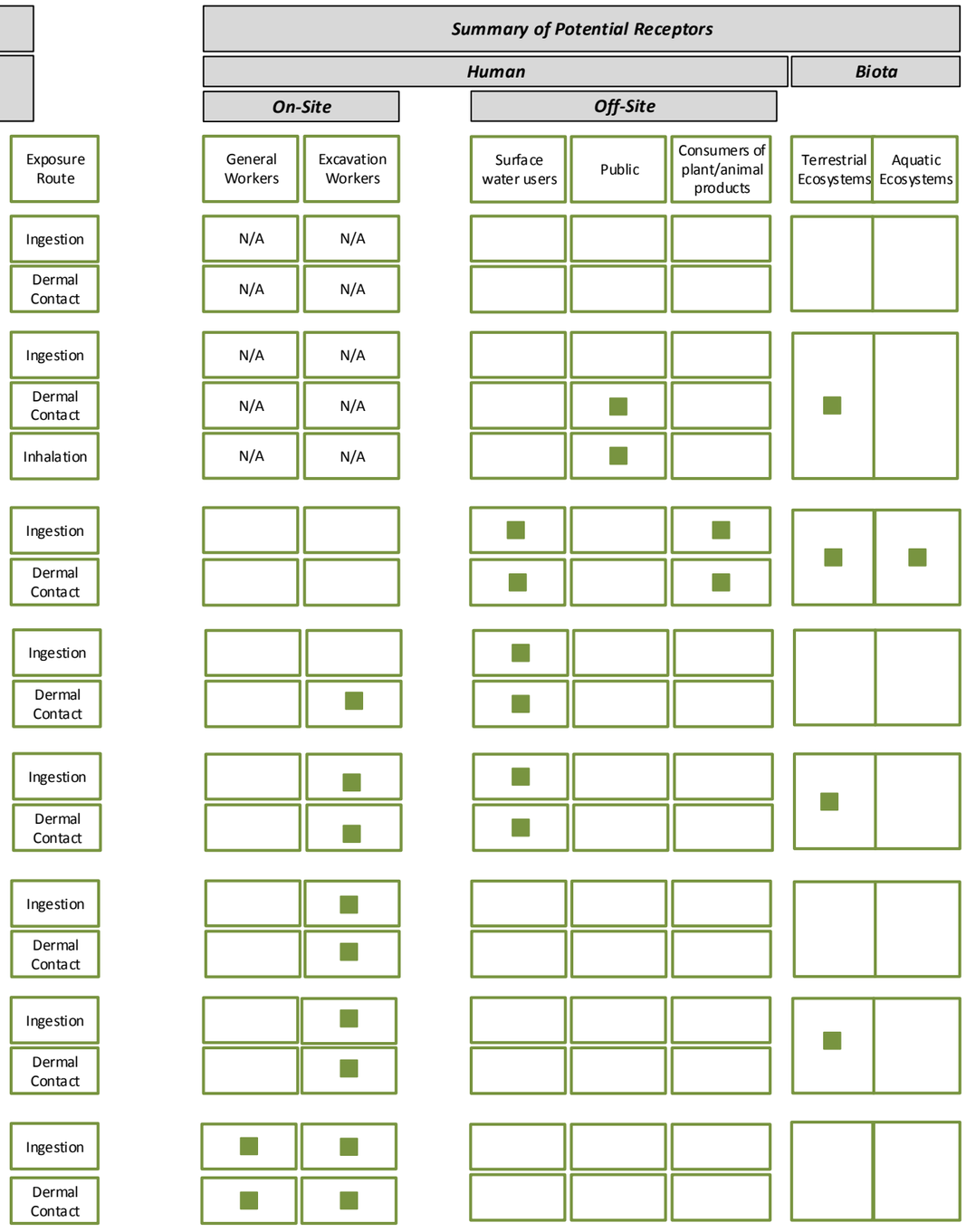
POTENTIAL PFAS SOURCE - HAIL AREAS

SCALE:		FIGURE NO.:	ISSUE NO.:
1:5,000	(A3)	2	B

A02569111Z003_PotentialPFASArea

Conceptual Site Model – Devonport Naval Base





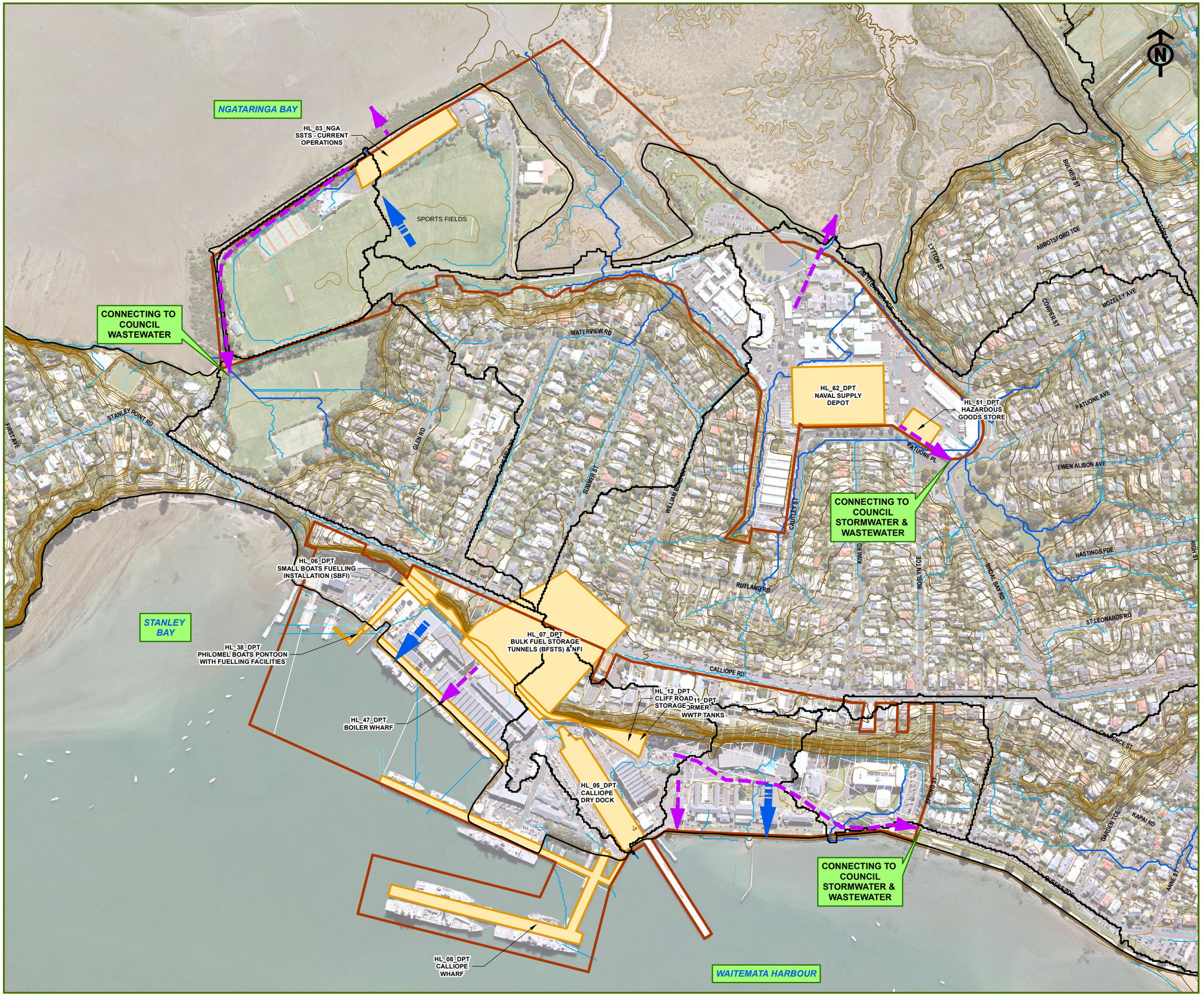
Key:

Potentially Complete Pathway

Incomplete Pathway

N/A — Addressed under the Health and Safety at Work Act, 2015

* There are other potential sources of PFAS to the Waitemata Harbour, these have not been considered in this CSM.



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KEY :

- Pathway (Groundwater and Surfacewater)
- Source
- Inferrred Groundwater Flow Direction

Auckland Council Overland Flow Paths:

- 3ha and above
- 4000m2 to 3ha
- 2000m2 to 4000m2
- Auckland Council River and Overland Flow Path Catchment
- Base/Camp Boundary

SOURCE:
Aerial imagery flown 2015-2016, contours, overland flow path and catchments supplied by Auckland Council. Vertical datum of contours Auckland 1949.
Topographic information supplied by LINZ.
Cadastal information supplied by NZDF, dated 19/10/16.

NO.	REVISION HISTORY	DATE
C	ISSUE 2	AUG 18
B	ISSUE 2	OCT 17
A	ISSUE 1	SEP 17

pdp

PROJECT NAME:

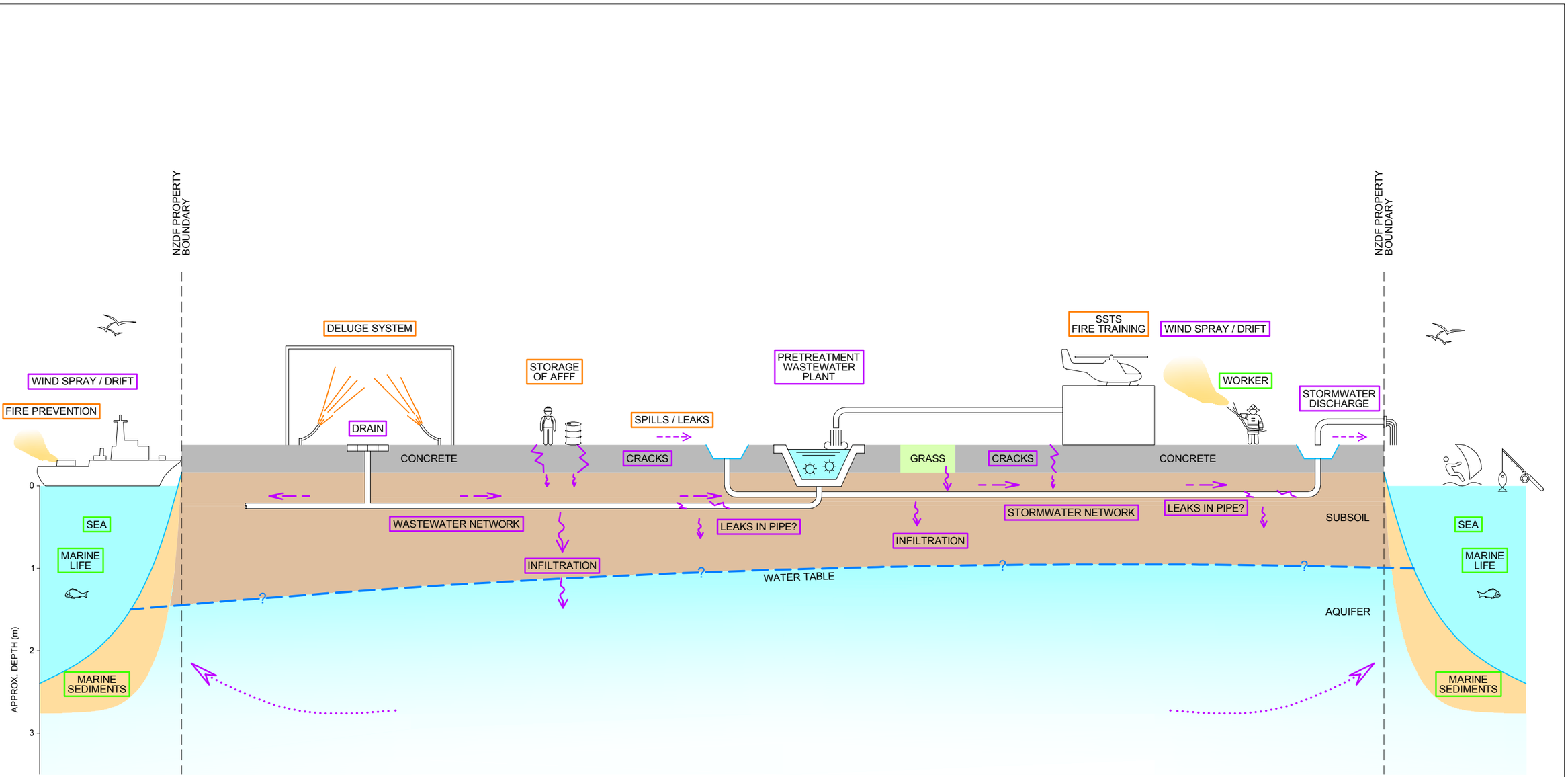
HMNZS DEVONPORT NAVAL BASE
PFAS DETAILED SITE INVESTIGATION

FIGURE TITLE:

CONCEPTUAL SITE MODEL - PLAN

SCALE:		FIGURE NO.:	ISSUE NO.:
1:5,000	(A3)	4	C

A025691102001_DPT_CSMplan_N



KEY

- SOURCE
- PATHWAY
- RECEPTOR

FIGURE 5: HMNZS DEVONPORT NAVAL BASE - PFAS
DSI CONCEPTUAL SITE MODEL - PROFILE

A02569110D001_CSM_Section.dwg Oct-17 FINAL

A02569111Z005_DPT_CSMplan

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KEY :

- Pathway (Groundwater and Surfacewater)
- Source
- Receptor
- Inferrred Groundwater Flow Direction

Auckland Council Overland Flow Paths:

- 3ha and above
- 4000m2 to 3ha
- 2000m2 to 4000m2
- Auckland Council River and Overland Flow Path Catchment
- Base/Camp Boundary

SOURCE:
Aerial imagery flown 2017, contours, overland flow path and catchments supplied by Auckland Council. Vertical datum of contours Auckland 1949.
Topographic information supplied by LINZ.
Cadastal information supplied by NZDF, dated 19/10/16.

NO.	REVISION HISTORY	DATE
B	ISSUE 2	DEC 18
A	ISSUE 1	OCT 18

pdp

PROJECT NAME:

PFAS DETAILED SITE INVESTIGATION DEVONPORT NAVAL BASE

FIGURE TITLE:

CONCEPTUAL SITE MODEL - PLAN

SCALE:		FIGURE NO.:	ISSUE NO.:
1:5,000	(A3)	6	B

Table 6: Groundwater Sampling Results - Per and Poly-Fluoroalkyl Substances (PFAS) - Detects Only [1]

					Sample Name	GABH10	GABH19	GABH32	MW1	MW2	MW3
					Sample Location	South Yard	South Yard	South Yard	SSTS	SSTS	SSTS
					Date Sampled	13/11/2017	13/11/2017	13/11/2017	14/11/2017	14/11/2017	14/11/2017
					Easting NZTM	1759127	1759169	1759269	1759017	1759031	1759052
					Northing NZTM	5922650	5922521	5922435	5923377	5923385	5923373
					Lab Report Number	954409	954409	954409	954409	954409	954409
Chemical Group	**Analyte**	ANZECC 80% Species Protection - Technical Draft Default Guideline Values [2]	ANZECC 90% Species Protection - Technical Draft Default Guideline Values [2]	ANZECC 95% Species Protection - Technical Draft Default Guideline Values [2]	Recreation Guideline [3]						
Perfluoroalkylcarboxylic Acid	PFBA					0.012	-	0.013	1	1.4	1.3
	PFPeA					0.018	0.0033	0.029	6.3	5.8	6.4
	PFHxA					0.017	0.0022	0.018	3.4	4	2.8
	PFHpA					0.011	0.002	0.011	1.6	1.7	1.3
	PFOA	1824	632	*220*	**5.6**	0.0086	0.0011	0.0051	0.69	1.2	1.3
	PFNA					-	-	-	0.13	-	-
Perfluoroalkylsulfonic Acids	PFPrS					-	-	-	0.14	0.25	0.1
	PFBS					0.0073	-	0.0032	0.58	0.98	0.33
	PFPeS					0.0036	-	0.003	0.7	1	0.56
	mono-PFHxS (1)					0.0051	-	0.0041	0.87	1.4	1.1
	L-PFHxS (1)					0.024	0.0029	0.022	5.3	7.7	8.1
	Total PFHxS (3) [4]					0.029	0.0029	0.026	6.2	9.1	9.2
	PFHpS					-	-	-	0.41	0.83	1.2
	di-PFOS (5)					-	-	-	0.32	0.67	0.7
	mono-PFOS (5)					0.0084	0.0021	0.0092	6.5	14	15
	L-PFOS (5)					0.021	0.0048	0.026	17	40	50
	Total PFOS (7) [4]	31	2	*0.13*		0.029	0.0069	0.035	*24*	*55*	*66*
	Sum PFHxS+PFOS (1) [5]				**0.7**	0.058	0.0098	0.061	**30**	**64**	**75**
Perfluorooctanesulfonamides	PFOSA					-	-	-	-	0.14	0.3
Telomere Sulfonic Acid	6:2 FTS					-	-	-	14	15	8.5
	8:2 FTS					-	-	-	1.2	0.82	1.4

Notes:

1. Values in µg/L (parts per billion)

2. Draft ANZECC Australian and New Zealand Water Quality Guidelines reported in PFAS National Environmental Management Plan. Heads of EPAs Australia and New Zealand (HEPA), January 2018.

3. Australian Government Department of Health - Health Based Guidance Values for PFAS reported in PFAS National Environmental Management Plan. Heads of EPAs Australia and New Zealand (HEPA), January 2018.

4. Total PFOS and Total PFHxS are calculated by summing monoethyl, dimethyl and linear isomers. Where an isomer is below the limit of reporting it is not added to the summation.

5. Summations are made by adding compounds Total PFOS (7), Total PFHxS (3) together. Where one compound is below detection, it is not included in the summation.

\- Result Is Not Reportable / Result is Below Laboratory Limit of Reporting

Table 7: Wastewater Sampling Results - Per and Poly-Fluoroalkyl Substances (PFAS) - Detects Only [1]

	Sample Name	WW1	WW2	WW3
	Sample Location	Recycled fire-fighting water	Ngataringa Bay pump station	Well at Marae pump station
	Date Sampled	14/11/2017	14/11/2017	14/11/2017
	Easting NZTM	1759005.56	1758896.47	1759188.99
	Northing NZTM	5923348.13	5923280.18	5923322.82
	Lab Report Number	954409	954409	954409
Chemical Group	**Analyte**			
Perfluoroalkylcarboxylic Acid	PFBA	0.6	-	-
	PFPeA	1	1.9	-
	PFHxA	2.8	2	-
	PFHpA	0.67	0.55	-
	PFOA	0.41	0.35	-
Perfluoroalkylsulfonic Acids	PFPrS	0.23	-	-
	PFBS	0.4	0.18	-
	PFPeS	0.34	0.19	-
	mono-PFHxS (1)	0.37	0.21	-
	L-PFHxS (1)	1.5	1.1	-
	Total PFHxS (3) [2]	1.9	1.3	-
	PFHpS	-	0.11	-
	mono-PFOS (5)	0.99	1.3	-
	L-PFOS (5)	2.7	3.4	-
	Total PFOS (7) [2]	3.7	4.7	-
	Sum PFHxS+PFOS (1) [3]	5.6	6	-
Telomere Sulfonic Acid	6:2 FTS	15	14	-
	8:2 FTS	0.49	1.2	-

Notes:

1. Values in µg/L (parts per billion)
2. Total PFOS and Total PFHxS are calculated by summing monoethyl, dimethyl and linear isomers. Where an isomer is below the limit of reporting it is not added to the summation.
3. Summations are made by adding compounds Total PFOS (7), Total PFHxS (3) together. Where one compound is below detection, it is not included in the summation.

-	Result Is Not Reportable / Result is Below Laboratory Limit of Reporting

Table 8: Composite Sediment Sample Results - Per- and Poly-Fluoroalkyl Substances (PFAS) - Detects Only [1]

				Perfluoroalkylsulfonic Acids		
				L-PFOS (5)	Total PFOS (7) [3]	Sum PFHxS+PFOS (1) [4]
Sediment Quality Guidelines - Toxic Effects Following Chronic Exposure [2]					220	
Sediment Quality Guidelines - Toxic Effects Following Short Term Exposure [2]					630	
Sample Name	**Sample Location**	**Date Sampled**	**Sample Depth (m)**			
SD1.1-1.10	DPT Quadrat 1	1/03/2018	0-0.02	-	-	-
SD1.11-1.20			0.1	-	-	-
SD2.1-2.10	DPT Quadrat 2	1/03/2018	0-0.02	1.4	1.4	1.4
SD2.11-2.20			0.1	1.2	1.2	1.2
SD3.1-3.10	DPT Quadrat 3	1/03/2018	0-0.02	-	-	-
SD3.11-3.20			0.1	-	-	-
SD4.1-4.10	Hellyers Creek [5]	2/03/2018	0-0.02	-	-	-
SD4.11-4.20			0.1	-	-	-

Notes:

1. Values in µg/kg (parts per billion), dry weight

2. Norway Sediment Quality Guidelines. Obtained from Bakke, T., Kailquist, T., Ruus, A., Breedveld, G. and Huylland, K. (2010). Journal of Soils and Sediment, 10, pp 172-178.

3. Total PFOS and Total PFHxS are calculated by summing monoethyl, dimethyl and linear isomers. Where an isomer is below the limit of reporting it is not added to the summation.

4. Summations are made by adding compounds Total PFOS (7), Total PFHxS (3) together. Where one compound is below detection, it is not included in the summation.

5. Control Site Located at Hellyers Creek, Beach Haven.

\- Result is Not Reportable / Result is Below Laboratory Limit of Reporting

Table 9: Discrete Sediment Sample Results - Per- and Poly-Fluoroalkyl Substances (PFAS) - Detects Only [1]

				Perfluoroalkylsulfonic Acids		
				L-PFOS (5)	Total PFOS (7) [3]	Sum PFHxS+PFOS (1) [4]
Sediment Quality Guidelines - Toxic Effects Following Chronic Exposure [2]					220	
Sediment Quality Guidelines - Toxic Effects Following Short Term Exposure [2]					630	
Sample Name	**Sample Location**	**Date Sampled**	**Sample Depth (m)**			
SD2.1	DPT Quadrat 2	1/03/2018	0-0.02	2.2	2.2	2.2
SD2.11			0.1	1.5	1.5	1.5
SD2.2			0-0.02	2	2	2
SD2.3			0-0.02	1.4	1.4	1.4
SD2.7			0-0.02	1.3	1.3	1.3
SD2.9			0-0.02	1.1	1.1	1.1
SD3.1	DPT Quadrat 3	1/03/2018	0-0.02	1.4	1.4	1.4

Notes:

1. Values in µg/kg (parts per billion), dry weight

2. Norway Sediment Quality Guidelines. Obtained from Bakke, T., Kailquist, T., Ruus, A., Breedveld, G. and Huylland, K. (2010). Journal of Soils and Sediment, 10, pp 172-178.

3. Total PFOS and Total PFHxS are calculated by summing monoethyl, dimethyl and linear isomers. Where an isomer is below the limit of reporting it is not added to the summation.

4. Summations are made by adding compounds Total PFOS (7), Total PFHxS (3) together. Where one compound is below detection, it is not included in the summation.

Table 10: Crustaceans and Molluscs Composite Sample Results - Per- and Poly-Fluoroalkyl Substances (PFAS) - Detects Only [1]

	Sample Name	BT4.3	BT1.1	BT1.3	BT2.1	BT2.2	BT2.3	BT2.4	BT3.1	BT3.2	BT3.3	BT3.5	BT3.6	Guideline Values	
	Sample Location	Hellyers Creek [2]	DPT Quadrat 1		DPT Quadrat 2				DPT Quadrat 3					Human Health Trigger Points for Investigation - Crustaceans and Molluscs [3,4]	Federal Environmental Quality Guidelines - Avian Wildlife Diet [5]
	Date Sampled	2/03/2018	1/03/2018		1/03/2018				1/03/2018						
	Sample Type	Horn shells	Crabs	Horn shells	Crabs	Horn shells	Whelks	Cats eyes	Crabs	Horn shells	Whelks	Cats eyes	Harbour top shells		
	Lab Report Number	1093607	1093607		1093607				1093607						
Chemical Group	**Analyte**														
Perfluoroalkylcarboxylic Acid	PFHxA	-	-	-	0.35	-	-	-	0.46	-	-	0.43	-		
	PFHpA	-	0.54	-	0.87	-	-	0.48	1.2	1.3	-	0.6	-		
	PFOA	2.1	0.39	-	0.6	10	-	0.78	0.63	3.2	-	1.1	-	**520**	
	PFNA	0.65	-	-	-	-	-	0.38	-	0.79	-	0.53	-		
	PFDA	0.43	-	-	0.33	-	-	0.39	-	-	-	0.4	-		
	PFUnDA	-	-	-	0.25	-	-	-	-	-	-	-	-		
Perfluoroalkylsulfonic Acids	PFBS	-	-	-	-	-	-	0.47	-	-	-	0.62	-		
	PFPeS	-	-	-	-	-	-	1.6	-	1.3	-	2	-		
	mono-PFHxS (1)	-	-	-	-	-	-	3.4	-	0.92	-	4.7	-		
	L-PFHxS (1)	1.8	-	-	0.39	180	-	20	0.97	58	-	25	-		
	Total PFHxS (3) [6]	1.8	-	-	0.39	180	-	23	0.97	59	-	30	-		
	PFHpS	0.37	-	-	-	9.2	-	0.62	-	3.4	-	0.71	-		
	di-PFOS (5)	-	-	-	-	-	-	0.32	-	-	-	0.44	-		
	mono-PFOS (5)	0.79	-	-	-	13	-	5.7	0.47	6.2	1	7.8	-		
	L-PFOS (5)	7.9	2.8	-	3.1	110	0.74	27	7	68	11	30	4.3		
	Total PFOS (7) [6]	8.7	2.8	-	3.1	**120**	0.74	33	7.5	**74**	12	38	4.3	**65**	8.2
	Sum PFHxS+PFOS (1) [7]	10	2.8	-	3.5	**300**	0.74	56	8.5	**130**	12	**68**	4.3	**65**	
Perfluorooctanesulfonamides	PFOSA	0.35	0.25	-	-	-	-	-	0.77	-	-	0.26	-		
Telomere Sulfonic Acid	4:2 FTS	-	-	-	-	-	-	-	-	0.69	-	-	-		
	6:2 FTS	2.3	-	33	-	150	-	-	1.4	200	2	0.72	-		
	8:2 FTS	-	-	-	-	-	-	-	-	1.3	0.56	0.31	-		

Notes:

1. Values in µg/kg (parts per billion)

2. Control Site Located at Hellyers Creek, Beach Haven.

3. Trigger Point from *Assessment of potential dietary exposure to perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA) and perfluorohexane sulfonate (PFHxS) occurring in foods sampled from contaminated sites* – Table 8, Supporting Document 2. Food Standards Australia New Zealand (FSANZ), April 2017.

4. Occasionally consumed food, trigger points for investigation for crustaceans applied to molluscs due to small number of consumers of molluscs.

5. Canadian Environment Quality Guidelines - Perfluorooctane Sulfonate (PFOS). Accessed 28/11/18 (https://www.canada.ca/content/dam/eccc/documents/pdf/pded/feqg-pfos/20180620-PFOS-EN.pdf)

6. Total PFOS and Total PFHxS are calculated by summing monoethyl, dimethyl and linear isomers. Where an isomer is below the limit of reporting it is not added to the summation.

7. Summations are made by adding compounds Total PFOS (7), Total PFHxS (3) together. Where one compound is below detection, it is not included in the summation.

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Result is Not Reportable / Result is Below Laboratory Limit of Reporting

Table 11: Flounder Sample Results - Per- and Poly-Fluoroalkyl Substances (PFAS) - Detects Only [1]

				Sample Name	HC_FS1.1_1_020318	NGA_FS3.1_1_010318	NGA_FS4.1_1_010318	NGA_FS4.2_1_010318	NGA_FS4.3_1_010318
				Sample Location	Hellyers Creek [2]	NET 3	NET 4		
				Date Sampled	1/03/2018	1/03/2018	1/03/2018		
				Sample Type	Flounder	Flounder	Flounder		
				Lab Report Number	1066663	1066663	1066663		
Chemical Group	**Analyte**	Federal Fish Tissue Guideline [3]	Federal Environmental Quality Guidelines - Avian Wildlife Die [4]	Human Health Trigger Points for Investigation - Finfish (all) [5]					
Perfluoroalkylcarboxylic Acid	PFDA				0.33	-	-	-	-
Perfluoroalkylsulfonic Acids	L-PFOS (5)				0.73	0.36	0.54	0.7	0.61
	Total PFOS (7) [7]	9,400 [5]	8.2	5.2	0.73	0.36	0.54	0.7	0.61
	Sum PFHxS+PFOS (1) [8]			5.2	0.73	0.36	0.54	0.7	0.61

Notes:

1. Values in µg/kg (parts per billion)

2. Control Site Located at Hellyers Creek, Beach Haven

3. Guideline from Canadian Environmental Protection Act, 1999 Federal Environmental Quality Guidelines Perfluorooctane Sulfonate, June 2018.

4. Canadian Environment Quality Guidelines - Perfluorooctane Sulfonate (PFOS). Accessed 28/11/18 (https://www.canada.ca/content/dam/eccc/documents/pdf/pded/feqg-pfos/20180620-PFOS-EN.pdf)

5. Trigger Point from Assessment of potential dietary exposure to perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA) and perfluorohexane sulfonate (PFHxS) occurring in foods sampled from contaminated sites – Table 8, Supporting Document 2. Food Standards Australia New Zealand (FSANZ), April 2017.

6. Guideline is 9,400 ug/kg wet weight (body weight of fish).

7. Total PFOS and Total PFHxS are calculated by summing monoethyl, dimethyl and linear isomers. Where an isomer is below the limit of reporting it is not added to the summation.

8. Summations are made by adding compounds Total PFOS (7), Total PFHxS (3) together. Where one compound is below detection, it is not included in the summation.

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Result is Not Reportable / Result is Below Laboratory Detection Limit