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NZDF PFAS Investigation – Summary Report: RNZAF Base Woodbourne Stage B

New Zealand Defence Force

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Prepared for

New Zealand Defence Force

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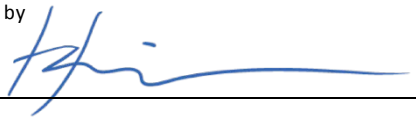
SIGNATURE 

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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time, the site conditions and environmental standards could change so that the reported assessment and conclusions are no longer valid.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 sampling investigation undertaken on private properties adjacent to the Royal New Zealand Air Force (RNZAF) Base Woodbourne (the 'site') for the New Zealand Defence Force (NZDF) to investigate the potential for surface water and groundwater contamination relating to the use of per- and poly-fluoroalkyl substances (PFAS) at the site.

Sampling and laboratory analysis of 168 groundwater samples and 25 surface water samples has confirmed the presence of PFAS at some locations.

Groundwater

Groundwater samples were obtained from 168 groundwater bores over two weeks, from 13 February to 28 February 2018.

Of the 168 groundwater samples collected:

- PFAS was detected by the laboratory in 78 samples (46%).
- PFAS was detected in 45 bores where landowners/occupants confirmed that the water is used for drinking water purposes.
- One sample was found to contain PFAS concentrations which exceed the interim drinking water guidelines (MoH, 2017), but the bore from which this sample was obtained is not utilised for drinking water purposes.
- 51 samples (30%) reported concentrations of PFAS above the screening value for milk consumption (home grown) (stock watering and fodder irrigation); 28 samples (16%) reported concentrations of PFAS above the screening value for milk consumption (home grown) (stock watering only); and one sample (0.6%) reported concentrations of PFAS above the screening value for Beef Consumption (home grown) (stock watering and fodder irrigation).
- Of the samples where PFAS was detected, 11 landowners/occupants reported that the sampled water was used for stock watering purposes; and nine of these samples exceeded the Milk Consumption (home grown) screening values for stock watering and / or fodder irrigation.

Surface Water

Surface water samples were collected from 25 locations.

Of these:

- PFAS was detected by the laboratory in 13 samples.
- PFAS concentrations in seven surface water samples (28%) were above the adopted screening values for milk consumption (home grown) (stock watering and fodder irrigation), and milk consumption (home grown) (stock watering only).

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1.0 Introduction

Pattle Delamore Partners Ltd (PDP), in conjunction with a number of other Environmental Consultancies, has been engaged by the New Zealand Defence Force (NZDF) to undertake a sampling investigation to assess the potential for surface water and groundwater contamination by per- and poly-fluoroalkyl substances (PFAS) at properties adjacent to the Royal New Zealand Air Force (RNZAF) Base Woodbourne.

Stage A sample results, from sampling undertaken in December 2017, have been reported in a previous Summary Report[1] (PDP, 2018a). Based on the Stage A sample results, an expanded investigation area was proposed (being Stage B).

Stage B sampling has involved:

- repeat sampling of those locations sampled during Stage A; and
- sampling at new surface water and groundwater locations identified within the expanded investigation area.

The Stage B results for landowners of adjacent properties have been reported in individual landowner reports, with recommendations regarding ongoing use of the water. This summary report provides a summary of the Stage B sampling results in the context of the entire investigation area.

1.1 Project Objectives

The key project objectives for this sampling investigation were:

- To assess groundwater and surface water from sites adjacent to Base Woodbourne and determine if PFAS compounds are present;
- To compare the concentrations of PFAS compounds present against interim drinking water guideline values and applicable screening values; and
- Provide further data to update preliminary estimates of PFAS plume extent in groundwater made following the Stage A sampling.

1.2 Scope of Summary Report

The scope of work undertaken to achieve the project objectives involved:

- Collecting representative samples of groundwater and surface water from adjacent sites, and analyses of these samples for PFAS.
- Comparison of the laboratory results to guideline and screening value criteria (where available).

[1] It is noted that the February 2018 summary report refers to the 'Stage 1' sampling area. The Stage 1 sampling area has subsequently been renamed 'Stage A'.

- Update of the Woodbourne sampling investigation area.

2.0 Background

PFAS compounds, such as perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) are a group of manufactured chemicals used since the 1950s. PFAS have been and continue to be used in a wide range of industrial and commercial products including aqueous film forming foam (AFFF) used for fighting fuel fires. Recently PFAS have gained increasing scientific and regulatory interest due to their widespread use, their environmental persistence and because some PFAS (primarily PFOS and PFOA) display bioaccumulative and toxic properties to humans and wildlife (CONCAWE, 2016).

PFAS are emerging contaminants. NZDF is investigating the potential for contamination of ground and water associated with the use and storage of AFFF containing PFAS at its camps and bases. Investigations at Woodbourne have identified PFAS in the water on the base.

Woodbourne is surrounded by productive land, predominantly vineyards. Shallow (and deep) groundwater is used relatively extensively surrounding the base for water supply.

3.0 Methodology

Groundwater and surface water sampling was undertaken in groundwater supply wells and surface water at selected locations adjacent to the base following the methodology outlined in the *Sampling Protocols for Monitoring Per and Poly-fluorinated Compounds in Groundwater and Surface Water for New Zealand Defence Force* (PDP, 2018b) and the guidance documents referenced therein.

Sampling was undertaken over two weeks, from 13 February to 28 February 2018. All samples were sent to AsureQuality laboratories, Wellington, under standard chain of custody procedures and analysed for their PFAS suite.

4.0 Guidelines and Screening Values

The interim guidelines for drinking water and non-potable water/contact recreation currently used in New Zealand to compare with the water sample data collected during this project are presented in Table 1. Additional screening criteria have been prepared by NZDF consultants EnRisks, for water supply for animals/products grown and consumed at home (home-grown produce).

Guidelines are provided for three PFAS compounds only. These compounds are known to be associated with certain types of AFFF. Henceforth results are discussed for these three compounds only. Results for the full analytical suite of 28 PFAS are available in the laboratory reports. These are provided in a separate electronic file.

Table 1: Environmental and Human Health Guidelines					
Media	**Sum of Total PFOS + PFHxS**	**PFOA**	**Total PFHxS**	**Total PFOS**	**Source**
Drinking Water	0.07 µg/L	0.56 µg/L	-	-	MoH[1], AGDoH [2]
Non-potable water/contact recreation	0.7 µg/L	5.6 µg/L	-	-	AGDoH [2]
Stock Watering Only (home grown consumption)	-	Beef 150 µg/L	Beef 0.1 µg/L	Beef 0.1 µg/L	EnRisks [3]
	-	Milk 30 µg/L	Milk 0.02 µg/L	Milk 0.02 µg/L	
	-	Eggs 4 µg/L	Eggs 0.2 µg/L	Eggs 0.09 µg/L	
Stock Watering and Fodder Irrigation (home grown consumption)	-	Beef 60 µg/L	Beef 0.06 µg/L	Beef 0.05 µg/L	EnRisks [3]
	-	Milk 14 µg/L	Milk 0.008 µg/L	Milk 0.008 µg/L	

Notes:

1. *Ministry of Health (MoH, 2017) Interim Guidance Level for Drinking Water, PFOA, PFOS and PFHxS.*
2. *Australian Government Department of Health (AGDoH, 2017) Health Based Guidance Values for PFAS for Use in Site Investigations in Australia.*
3. *Site specific screening values from Livestock Uptake Modelling and Screening Criteria Development for PFAS. EnRisks, November 2017. Screening values calculated using a scenario of 10% of the tolerable daily intake. This is the most conservative scenario developed.*

5.0 Quality Assurance / Quality Control

5.1 Project Data Quality Objectives

The project data quality objectives (DQOs) were to:

1. Determine the presence or absence (less than 0.005 µg/L) of PFASs in groundwater from groundwater bores.
2. Determine the presence or absence (less than 0.005 µg/L) of PFASs in surface water.

To determine if the DQOs were met, the internal quality assurance/quality control (QA/QC) function ('QAChecker') in the environmental database software ESdat was used to calculate relative percent differences between sample duplicates and to check for detections of PFAS in blanks.

The results of the QA/QC check indicate that all samples meet the DQOs.

This is with the exception of five rinsate samples which reported concentrations of 6:2FTS above the LOR. Of these five rinsate samples, three samples were slightly above the LOR, and are therefore not statistically significantly different from the stated LOR. Two samples contained concentrations of 6:2FTS which were an order of magnitude above the LOR.

However, based on a review of the sample results data set it is considered unlikely that the field sampling procedures have resulted in cross contamination of samples as a very low proportion of the actual samples detected 6:2FTS, even when other PFAS compounds were measured. Similarly, no other PFAS compounds were detected in the rinsate blanks. This indicates that 6:2FTS is not being contributed to samples from sampling equipment.

In addition, where an initial assessment of the Stage B laboratory results indicated potential inconsistencies in the results (e.g. significant changes in concentrations between Stage A and Stage B results), laboratory analysis of the duplicate sample was ordered to confirm the result. Where necessary, the bore was resampled to confirm the result. This process was undertaken in relation to four sample locations; and was able to confirm the interpretation of the sample results.

6.0 Results

A total of 168 groundwater samples and 25 surface water samples were collected during this sampling investigation.

The groundwater and surface water results are summarised in Sections 6.1 and 6.2 respectively.

6.1 Groundwater Samples

A summary of the groundwater sample results is presented below along with a comparison of the results to the interim drinking water guidelines, the non-potable guidelines and the screening values for stock watering and fodder irrigation developed by EnRisks (2017). Screening values defined for beef would also be conservative for the consumption of home-grown sheep meat (EnRisks, 2017).

6.1.1 Drinking Water Interim Guideline Value

Of the 168 groundwater samples collected:

- PFAS was detected in 78 samples (46%).
- One sample (0.6%) exceeded the interim drinking water guideline for the sum of total PFOS + PFHxS (MoH, 2017).
- No groundwater samples were found to exceed the interim drinking water guideline for PFOA (MoH, 2017).
- 77 samples (45%) returned concentrations of the sum of total PFOS + PFHxS above the LOR but below the interim drinking water guideline (MoH, 2017).
- 47 samples (28%) returned concentrations of PFOA above the LOR but below the interim drinking water guideline (MoH, 2017).
- 90 samples (54%) were reported as less than the LOR for the sum of total PFOS + PFHxS.
- 121 samples (72%) were reported as less than the LOR for PFOA.

6.1.2 Non-potable, Stock Watering and Fodder Irrigation Screening Values

Of the 168 samples tested:

- 51 samples (30%) reported concentrations of PFAS above the screening value for milk consumption (home grown) (stock watering and fodder irrigation).
- 28 samples (16%) reported concentrations of PFAS above the screening value for milk consumption (home grown) (stock watering only).
- One sample (0.6%) reported concentrations of PFAS above the screening value for beef consumption (home grown) (stock watering and fodder irrigation).
- No samples reported concentrations above the screening value for non-potable/contact recreation, beef consumption (home grown) (stock watering only), or egg consumption (home grown) (stock watering only).

6.1.3 Groundwater Results Summary Table

A summary of the results described in Sections 6.1.1 and 6.1.2 is provided in Table 2 below. It is noted that changes in the numbers, and percentages of samples found to exceed guideline or screening values must be considered in the context of the greater number of samples that were obtained during the Stage B sampling event, compared to the Stage A sampling event (162 in Stage B vs 67 in Stage A). Values in brackets denote results from the Stage A sampling event.

Table 2: Stage B Guideline and Screening Value Exceedences – Groundwater Samples (n=168)

Guideline	Number Exceeding the Relevant Guideline	Percent Exceeding the Relevant Guideline	Source
Interim Drinking Water Guidelines	1 (2 during previous sampling event)	0.6% (3% during previous sampling event)	MoH[1]
Non-potable water/contact recreation	0 (0 during previous sampling event)	0% (0% during previous sampling event)	AGDoH [2]
Site Specific Screening Value – Beef Consumption (home grown)			
Stock Watering and Fodder Irrigation	1 (0 during previous sampling event)	0.6% (0% during previous sampling event)	EnRisks [3]
Stock Watering Only	0 (0 during previous sampling event)	0% (0% during previous sampling event)	EnRisks [3]
Site Specific Screening Value – Milk Consumption (home grown)			
Stock Watering and Fodder Irrigation	51 (14 during previous sampling event)	30% (21% during previous sampling event)	EnRisks [3]
Stock Watering Only	28 (12 during previous sampling event)	16% (18% during previous sampling event)	EnRisks [3]
Site Specific Screening Value – Egg Consumption (home grown)			
Stock Watering Only	0 (0 during previous monitoring event)	0% (0% during previous monitoring event)	EnRisks [3]

Notes:

1. *Ministry of Health (MoH, 2017) Interim Guidance Level for Drinking Water, PFOA, PFOS and PFHxS.*
2. *Australian Government Department of Health (AGDoH, 2017) Health Based Guidance Values for PFAS for Use in Site Investigations in Australia.*
3. *Site specific screening values from Livestock Uptake Modelling and Screening Criteria Development for PFAS. EnRisks, November 2017.*

6.1.4 Comparison with Stage A Groundwater Sampling Results

In general, the bores where PFAS was detected during the Stage A sampling event also showed detects of PFAS during the Stage B sampling event (where resampling of the bores occurred: it is noted that 21 sites from Stage A were not re-sampled during Stage B). A comparison of the groundwater analysis data from Stage A and Stage B, where the same bores were re-sampled, shows that:

- 14 samples have decreased in concentration (with a median decrease of 77% and a median absolute decrease of 0.0095 ug/L);
- Eight samples have increased concentration (with a median increase of 69% and a median absolute increase of 0.0085 ug/L);
- 25 samples displayed no change between sampling rounds (i.e. remained non-detect);

Some notable changes between the Stage A and Stage B sampling events with respect to individual groundwater bores were:

- Two bores were found to contain PFAS at concentrations above the potable guideline value during Stage A, but concentrations in both these bores have decreased to below the LOR during Stage B;
- One bore was found to contain PFAS at concentrations below the potable guideline value during Stage A, but concentrations in this bore have increased to above the potable guideline value during Stage B;
- Two bores contained concentrations of PFAS above the LOR during Stage A, but have decreased to below the LOR during Stage B;

6.2 Surface Water Samples

A summary of the surface water sample results is presented below. It is likely that surface water sampled within the investigation area is not used for drinking water (based on landowner feedback). Therefore, results have been compared to the non-potable guideline and the stock watering and fodder irrigation screening values.

Of the 25 surface water samples collected:

- Concentrations of total PFHxS, and / or total PFOS, and / or total PFOA, and / or the sum of total PFHxS + PFOS were above the LOR in 13 samples (52%).
- PFAS concentrations in surface water samples were above the adopted screening values for milk consumption (home grown) (stock watering and fodder irrigation), and milk consumption (home grown) (stock watering only) in seven samples (28%).

- PFAS concentrations in all samples where it was detected were below the adopted screening values for non-potable / contact recreation, beef consumption (home grown) (stock watering only) and beef consumption (home grown) (stock watering and fodder irrigation), or egg consumption (home grown) (stock watering only).

7.0 Discussion

Results from this groundwater and surface water sampling investigation indicate that a 'plume' of PFAS contaminated groundwater exists to the east of the RNZAF Base Woodbourne. Albeit the majority (70%) of sample results were below the adopted guideline values, 46% of samples tested in this investigation showed detectable concentrations of PFAS compounds, in a predominantly easterly direction beyond the RNZAF Base.

7.1 Groundwater Users

It is noted that where a landowner/occupant did not specify that bore water was used for drinking water / domestic supply, or for stock watering purposes, the presumed use of the bore water is for produce / crop irrigation.

7.1.1 Drinking Water

Of the 168 groundwater samples tested, 78 samples (46%) reported concentrations of PFAS above the LOR. Of these 78 samples, 45 samples were collected from bores that landowners/occupants indicated were used for potable or domestic supply.

Groundwater sampled from one location immediately to the east of RNZAF Base Woodbourne reported a concentration of the sum of total PFOS + PFHxS exceeding the interim drinking water guidelines (MoH, 2017). Levels of PFOA in this sample were below the interim drinking water guidelines. The landowners/occupants at this location have indicated that groundwater from this bore is not used for potable water on-site.

7.1.2 Non-potable Stock Watering and Fodder Irrigation

Sample results have been compared to the site specific screening values (EnRisks, 2017) (refer Table 2). These screening values are used to assess the risk of on-farm consumption of farm grown products (e.g. home kill) only, which is a more conservative exposure pathway given the potential for consumption of larger quantities of beef, milk or eggs from a single animal. These screening values are not applicable for produce supplied to the general market. Screening values defined for beef would also be a conservative screening value for the consumption of sheep meat (EnRisks, 2017).

Of the 78 samples where PFAS was reported above the LOR, 11 samples were collected from bores that landowners/occupants indicated were used for stock watering purposes.

Of the 11 samples obtained from bores where a stock watering use was specified, nine were found to contain concentrations of PFAS which exceed the screening values for Milk Consumption (home grown), for stock watering and fodder irrigation), and / or for Milk Consumption (home grown) for stock watering only.

7.1.3 Vineyard Irrigation

No guideline values exist in regard to vineyards using PFAS contaminated irrigation water, or the products of vineyards exposed to PFAS contamination. Due to the nature of the surrounding Woodbourne area, testing of grapes and grapevine plants has been undertaken. The results of this plant matter analysis are reported on in a separate report.

7.2 Surface Water Receptors

PFAS concentrations in surface water samples from seven locations were found to exceed the adopted screening values for milk consumption (home grown) (stock watering and fodder irrigation), and milk consumption (home grown) (stock watering only). The surface water at these locations is not known to be utilised for stockwatering purposes (based on landowner feedback).

Surface water is not known to be utilised for drinking water / domestic use within the investigation area (based on landowner feedback).

7.3 Discussion of Detection of PFAS in Groundwater

The results of the samples collected during the Stage B monitoring event show a predominant easterly flow direction, with elevated PFAS concentrations extending from the eastern side of RNZAF Base Woodbourne towards Old Fairhall Creek.

Based on the results, the highest concentrations of the sum of total PFHxS and PFOS are predominantly located in a zone between Middle Renwick Road and Fairhall Co-Op Drain / Doctors Creek. In this zone, there is a pattern of PFAS detections which extends continuously from the eastern boundary of RNZAF Base Woodbourne to the western extent of the current investigation area, located approximately at the intersection of David Street and Severne Street (a distance of approximately 3.9 km). The concentration of PFAS in groundwater in this zone (which for the purpose of this discussion includes three bores immediately to the north of Middle Renwick Road where PFAS was detected) ranges between 0.0013 µg/L – 0.11 µg/L. Concentrations are not noted to decrease with distance from RNZAF Base Woodbourne on the west to east vector, although the measured concentrations on or immediately adjacent to Middle Renwick Road in

the north of this zone are lower than the concentrations measured in the middle of the zone.

Two other areas show a grouping of PFAS detections, with generally lower concentrations, and with no continuous pattern of detections back to RNZAF Base Woodbourne. These are:

- An area to the north-east of RNZAF Base Woodbourne, generally clustered along the alignment of Old Renwick Road. The concentration of PFAS in groundwater in this area ranges between 0.011 µg/L – 0.043 µg/L; and
- A smaller area to the south-east of RNZAF Base Woodbourne, around New Renwick Road. The concentration of PFAS in groundwater in this area ranges between 0.012 µg/L – 0.032 µg/L.

An additional, discrete easterly location has shown a detection of PFAS. The municipal supply bore GW117 is located near the intersection of Grove Road and Auckland Street, approximately 6.8 km to the east-north east of RNZAF Base Woodbourne. The concentration of PFAS in GW117 was measured as 0.0014 µg/L.

The predominant apparent migration direction, due east from RNZAF Base Woodbourne, may be attributable to the presence of preferential flow channels within the alluvial strata which are orientated in an easterly direction; and the drainage effect on the groundwater created by springfed streams to the east (e.g. Yelverton Stream), which will draw groundwater towards them. The spring fed west to east flowing section of Fairhall Co-op Drain and Doctors Creek may also draw some groundwater (and PFAS) in a southerly direction, as shown by the detectable concentrations occurring in that surface waterway. The distant easterly detection at GW117 is well within the confined aquifer system and could represent an extension of the plume.

With respect to the area of PFAS detections to the north-east of RNZAF Base Woodbourne, these may be attributable to an intermittent groundwater flow path that occurs away from the predominant easterly flow direction. A north-easterly flow towards Old Renwick Road is feasible during times when flow from the Southern Valleys is more dominant than the recharge influence from the Wairau River. Some groundwater elevation contours and the orientation of the surface channels coming out of the southern valleys support this flow direction.

A south-easterly flow path from RNZAF Base Woodbourne towards New Renwick Road is considered less likely. For groundwater flow to move south-east there would have to be a strongly dominant period of Wairau River recharge and no recharge coming from the Southern Valleys. Further assessment is required to determine the mechanism of migration of PFAS to these south-easterly locations.

There is one groundwater bore located immediately to the north west of RNZAF Base Woodbourne (GW19) which contains concentrations of PFAS compounds above the LOR. PFAS was also detected in GW19 during the Stage A sampling event.

No comment can be made at this time regarding any patterns associated with PFAS detections and bore (aquifer) depth. This is because there is insufficient information available from Council records to accurately determine the depth of the large majority of bores in the investigation area.

7.4 Discussion of Detection of PFAS in Surface Water

A total of 13 surface water samples were found to contain PFAS above the LOR, and these were all obtained from Yelverton Stream, Doctors Creek, and the Fairhall Co-Op Drain located to the east of RNZAF Base Woodbourne. As discussed above, these surface water streams and drains are considered likely to be exerting a drainage effect on the surrounding strata, and in this manner, are acting as a discharge location for PFAS-impacted groundwater.

7.5 PFAS Concentrations at the Limit of Reporting

Very low detections (sum of total PFHxS + PFOS < 0.005 µg/L) have been noted in both groundwater and surface water samples. Very low detected concentrations may not represent a real presence of PFAS in the sampled water but may reflect uncertainty of measurement or sampling and/or analysis error. These should be confirmed by re-sampling.

7.6 Results Interpretation Limitations

Due to their physiochemical properties, the fate and transport of PFAS is complicated and poorly understood. As such, extrapolation of these results, particularly to locations down-gradient, is uncertain and may not represent the actual conditions present. On this basis any assessment of risk to receptors located outside the current investigation area is limited.

8.0 References

AGDoH, 2017. *Final Health Based Guidance Values for PFAS for use in site investigations in Australia.* The Department of Health, Australian Government, Canberra, Australia. Sourced 15/05/2017 https://www.health.gov.au/internet/main/publishing.nsf/Content/2200FE086D480353CA2580C900817CDC/$File/fs-Health-Based-Guidance-Values.pdf

CONCAWE, 2016. *Environmental Fate and Effects of Poly- and Perfluoroalkyl Substances (PFAS)*. Report No. 8/16. 23 June 2016.

EnRiskS, 2017. *Livestock Uptake Modelling and Screening Criteria Development for PFAS, draft.* Revision C. Environmental Risk Sciences Pty Ltd. 1 November 2017.

MoH, 2017. *Poly-fluoroalkyl substances (PFASs), also called perfluoroalkyl substances (PFASs)* draft, Ministry of Health November 2017.

PDP, 2018a. *NZDF PFAS Investigation – Summary Report: RNZAF Base Woodbourne Stage 1*. Version 2, February 2018. Pattle Delamore Partners Ltd for New Zealand Defence Force.

PDP, 2018b. *Sampling Protocols for Monitoring Per and Poly-fluorinated Compounds in Groundwater and Surface Water for New Zealand Defence Force*. Version 2, January 2018. Pattle Delamore Partners Ltd for New Zealand Defence Force.