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FORMER WASTE CONTROL SITE

2017 Groundwater Monitoring Report

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REPORT

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Distribution:

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Executive Summary

LandCorp, acting on behalf of the Department Water an Environmental Regulation (DWER) engaged Golder Associates Pty Ltd (Golder) to undertake a groundwater monitoring event (GME) for the former Waste Control Site located in Bellevue, WA (the site). The Waste Control site operated as a chemical/oil recycling and waste treatment facility between 1987 and 2001. In February 2001, a large fire occurred destroying the treatment and recycling plant and a stockpile of drummed waste chemicals. Following the fire, drums and waste material such as shallow impacted soils were removed off-site and stockpiled on the adjacent Lot 2. The material was then segregated with metal from drums being disposed of at a licensed landfill and impacted soil material undergoing bioremediation on Lot 2. The site has been the subject to numerous investigations to understand the extent of contamination and is generally subject to annual groundwater monitoring events.

The overall objective of the GME was to complete a groundwater and surface water monitoring event for comparison against pre-remediation baseline monitoring conducted in 2015. The objective of the GME was also to:

- provide information confirming current risks to groundwater and risks they may pose to sensitive receptors, and other information required to enable the Auditor to recommend a reclassification for Lot 2 from *Contaminated – Remediation Required* to *Contaminated – Restricted Use* or *Remediated for Restricted Use*
- provide an additional round of confirmatory sampling with regard to per- and polyfluoroalkyl substances (PFAS) occurrence in groundwater.

As well as sampling at the site, the GME was conducted at off-site properties defined as the Study Area, which includes upgradient of the site, Lot 2, the Southwest Industrial Area, the Damplands, and the Helena River. The GME included the measuring of groundwater levels and sampling of 82 monitoring wells and 2 surface water sampling locations.

Exceedences of the risk based criteria derived for the Study Area were only detected in monitoring wells screened in the Regional Watertable and exceedances of aquatic screening criteria in the Alluvium formation. This is consistent with historical results and indicate the predominant contaminant mass is still present in the superficial water bearing formation. The exceedances preclude groundwater extraction on-site, Lot 2, and Damplands. The risk based criteria for indoor air vapour intrusion was also exceeded on-site, however, soil vapour results indicate that concentrations are below the limit of reporting. Therefore, it is likely that the risk of exposure from groundwater to indoor air vapour intrusion is low.

Exceedances of aquatic ecosystems criteria were also reported within the Damplands, indicating a potential risk to the Helena River if groundwater discharges occur. However, surface water results indicates that overall, groundwater from the Damplands is not having a significant impact on the water quality in the Helena River at this time, and it is likely that the Helena River is more representative of the Leederville formation rather than the Regional Watertable.

Increasing chlorinated ethene concentration trends were observed in some wells down hydraulic gradient of the site, which was predominantly due to increases in vinyl chloride and in some wells cis-1,2-dichloroethene, as a result of trichloroethene degradation.

One on-site well was also indicated to have an increasing concentration trend of chlorinated ethenes and monocyclic aromatic hydrocarbons. The mechanism for the increase is not known, however, it may be due to a pathway through a thin or absent clay layer that provides separation between the contaminated unsaturated zone and the underlying Regional Watertable.

The PFAS composition was assessed across the Study Area. It was observed that there are consistent characteristic compositions within wells upgradient and on the Hanson property that screen the Base of Guildford formation or Leederville formation. This composition was different to that observed on-site and suggest that there is an upgradient source of PFAS. The composition on-site in the Regional Watertable was reflected in wells downgradient, including wells located on Lot 2, the Southwest Industrial Area, and in the Damplands. Comparison between the composition in wells upgradient, site and the Helena River indicated that the Helena River appears consistent with the Leederville formation, i.e. consistent with the background groundwater composition which was observed in wells hydraulically upgradient to the site. This may indicate that there is regional discharge of PFAS from the Leederville formation to the Helena River.

This executive summary should be read in the context of the whole report.

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1.0 INTRODUCTION

LandCorp, acting on behalf of the Department Water an Environmental Regulation (DWER) engaged Golder Associates Pty Ltd (Golder) to undertake a groundwater monitoring event (GME) for the former Waste Control Site located in Bellevue, WA (the site), shown in Figure 1.

The GME was undertaken in general accordance with Golder's *Proposal For Groundwater Monitoring, Former Waste Control Site, Bellevue WA* (Golder, 2017a), issued 24 April 2017. Variations to the scope of work of this proposal are noted within Section 3.1.

This report presents the results from the 2017 GME. A more detailed discussion regarding results from sampling of the permeable reactive barrier (PRB) system in included under a separate cover (1523086-046-R-Rev0).

1.1 Objectives

The overall objective of the GME was to complete a groundwater and surface water monitoring event for comparison against pre-remediation baseline monitoring conducted in 2015. The objective of the GME was also to:

- provide information confirming current risks to groundwater and risks they may pose to sensitive receptors, and other information required to enable the Auditor to recommend a reclassification for Lot 2 from *Contaminated – Remediation Required* to *Contaminated – Restricted Use* or *Remediated for Restricted Use*
- provide an additional round of confirmatory sampling with regard to PFAS occurrence in groundwater.

1.2 Scope of Works

The scope of works undertaken to address the objectives were:

- Gauging of groundwater level of monitoring wells positioned on and off site. During the gauging round the condition of monitoring well was noted as well as whether a monitoring well required redevelopment due to the presence of sediment build-up or roots within the well.
- Redevelopment of monitoring wells where required, as noted during the gauging round.
- Groundwater sampling from 87 monitoring wells screening the following:
  - Perched aquifer (three wells)
  - Guildford (Regional Watertable) aquifer (23 wells)
  - Base of Guildford aquifer (15 wells)
  - Leederville aquifer (three wells)
  - Alluvium aquifer (nine wells)
  - Positioned around the PRB (34 wells).

Not all proposed groundwater sampling locations were able to be sampled, this is discussed further in Section 3.1).

- Surface water sampling from five locations on the Helena River. Two rounds of river samples were proposed to be obtained: one at the commencement of the monitoring event and the other towards the completion. Only one round at limited locations were completed due to a lack of surface water in the Helena River (Section 3.1).

- Comparison of groundwater concentrations to site-specific risk based criteria to evaluate the potential risk to receptors.
- Evaluation of groundwater concentration trends using historical groundwater data.

2.0 SITE AND STUDY AREA BACKGROUND

2.1 Site Background

The site operated as a chemical/oil recycling and waste treatment facility between 1987 and 2001. In February 2001, a large fire occurred destroying the treatment and recycling plant and a stockpile of drummed waste chemicals. Several investigations of the site and surrounds have identified hydrocarbon and halogenated hydrocarbon groundwater impacts associated with the former chemical/oil recycling and waste treatment facility. Numerous groundwater monitoring wells have been installed as part of the previous investigations, including the 'WCT' Series (HRS, 2000), the WCB Series (DoE, 2001-2004), the MW Series (URS, 2002 and 2003) and the MWG Series (Golder, 2008a and 2009a).

Results from investigations in 2008 and 2009 (Golder, 2009b) indicated that a separate off-site plume originated from a local source near the eastern end of Stanley Street (to the south of the site) containing primarily trichloroethene (TCE) and more recently minor concentrations of tetrachloroethene (PCE). Groundwater impacts in the Damplands Area (Figure 2) are primarily associated with the off-site TCE plume. The two separate plumes were interpreted to converge beneath the escarpment prior to entering the Damplands Area (Golder, 2009a). As a remediation strategy, a sequenced denitrification PRB and a zero valent iron (ZVI) PRB were installed in the Damplands Area with construction completed in May 2010.

The PRB system was installed to remediate concentrations of halogenated organic compounds (primarily TCE) *in situ* to concentrations below risk based criteria (RBC). The PRB system has been positioned at the base of the river valley escarpment where the groundwater plumes naturally converge and site conditions are suitable for PRB construction.

Golder (2006a, 2008b, 2008c, and 2009c) conducted a health and ecological risk assessment of the groundwater and soil at site and surrounds. Concentrations of contaminants in groundwater exceeding human health RBC were identified at the site and Lot 2. In addition, RBC exceedences were identified in groundwater located off-site beneath the Hanson property, the Southwest Industrial Area, and in the Damplands/Helena River. Concentrations exceeding ecological screening criteria and, where available, RBC, were identified in groundwater entering the Damplands. In 2011-2012, the RBC were amended for the purpose of remediation taking into account more recent toxicological reference values and reflecting other changes associated with planned land use and relevant exposure scenarios since the last revision in 2008 (Golder, 2013a and 2013c). These amended RBC were referred to as remediation RBC or RRBC. For the purpose of this report the historical the RBC have been updated with the RBC and will be referred to as RBC.

2.2 Study Area Description

The site comprises Lot 88, Oliver St frontage, and Lot 99, Bulbey St frontage, Bellevue, WA. Previous investigations have identified that off-site groundwater has also been impacted. Off-site properties included in the Study Area are as follows:

- Lot 88 and Lot 99 – the site
- Lot 5 Oliver Street – Hanson Property
- Lot 1 to the south of the site (commonly referred to as the Damplands)
- Lot 2, immediately adjacent to the site to the east (Main Roads)
- Lot 87 (Oliver St frontage) and Lot 84 (Stanley St frontage): A&P Transport
- Lot 82: 3 Stanley Street

- Portion of Stanley Street Road Reserve
- Upgradient of the site on Irwin Street.

Monitoring wells from these properties that were included in the 2017 GME are presented in Figure 2.

2.3 Hydrogeological Setting

Regionally, Perth is underlain by a series of aquifers separated by confining beds. Three main aquifers have been identified (Commander, 2004), however, only the upper two aquifers present beneath the study area have been identified as being impacted by contamination from the site. These aquifers are:

- The unconfined Superficial Aquifer comprising the permeable units of the Swan Coastal Plain; the Guildford Formation and alluvial sediments. Locally, groundwater flows south/south-west in the Guildford Formation/alluvial sediments towards the Helena River but regionally groundwater flows to the west. Elsewhere, groundwater may be used for public water supply but in the vicinity of the study area groundwater is used for irrigation (watering parks, irrigation of domestic crops, garden watering etc.).
- The semi-confined Leederville Formation in which groundwater flows generally south south-west from the area of the site. The Leederville Formation is a major aquifer used for public water supply and irrigation.

Where encountered in the local study area, the upper portion of the Leederville Formation included relatively low permeability clay and clayey sand deposits (aquitard). This is consistent with the semi-confined description of this unit with lower permeability layers marking the interface with the overlying Guildford sediments.

Clay intervals present within the Guildford Formation can act as a barrier to the downward migration of recharge water and/or contaminants and result in the formation of a perched aquifer located above the Regional Watertable. Wells installed within the perched aquifer have been identified as being located in the "Shallow Perched Aquifer". These perched groundwater zones have been identified above the Regional Watertable beneath the site and portions of Lot 2 but not in the downgradient off-site study area.

Water level data indicate the regional 'true' groundwater table (referred to herein as the 'Regional Watertable') was located between 7 and 9 m AHD (Australian Height Datum), approximately 8 to 12 m below ground level in the Guildford Formation. A more detailed hydrogeological interpretation was presented in *"Geological and Hydrogeological Conditions, Bellevue Waste Control Site"* (Golder, 2005) and *"Hydrogeological Site Assessment"* (Golder, 2006b).

3.0 FIELDWORK METHODOLOGY

3.1 General

The field works undertaken during the GME are listed in Table 1. These components are then discussed in more detail in subsequent sections of this report. Of the sampling locations proposed, the following variations are noted:

- MW40, MW41, and MW43: Insufficient groundwater to sample (well was dry). Each of these wells are located in Lot 2.
- MWG65: Monitoring well has been destroyed. This well was located in A & P Transport (Lot 87, Oliver St).
- MWG108C and MWG108D: wells do not exist. These wells were noted in the proposal to be located adjacent to the PRB, however, it is likely that they were incorrectly included in the proposal as an error.
- MWG90D and MWG116: additional to the proposed sampling program. These monitoring wells were not included in the proposed list of wells to be sampled for the GME, however, as some wells could not be sampled (e.g. above), MWG90D and MWG116 were added to the program after commencement of the GME.

- River sampling at the commencement of the GME was not undertaken due to a lack of surface water within Helena River. Over the course of the GME (and shortly after completion of the GME), rainfall occurred that increased the quantity of water within the river. Therefore, only sampling at completion of the GME could occur; however, this could only occur at river sampling location 1 (shown on Figure 2). At the time of sampling, the water level in the river was surveyed during a walkover, however other river sampling locations (SG05, SG06, SG07, and River 2), could not be sampled as there was still insufficient water and/or the water was stagnant.

Table 1: Timeline of Field Tasks

Task	Date	Description of task
Gauging of Study Area Monitoring Wells	6 and 7 June 2017	Gauging of 119 monitoring wells. Further described in Section 3.2.
Redevelopment of Monitoring Wells	7 June 2017	Redevelopment of three monitoring wells due to the presence of roots within well. Further described in Section 3.3.
Groundwater sampling	8 June to 22 June 2017	Sampling of 82 wells. Further described in Section 3.4.
Surface water sampling	6 July 2017	Sampling at completion of GME. Further described in Section 3.5.

3.2 Groundwater Gauging

A round of groundwater gauging was conducted at the commencement of the field programme. During this round, an oil/water interface probe was used to assess whether non-aqueous phase liquids (NAPLs) were present in groundwater. The interface probe was also visually examined by field staff to check for either the presence of chemical beading on the probe or for odour coming from the probe. The interface probe was cleaned using Decon 90, and then rinsed with deionised water between wells to reduce the potential for cross contamination.

No NAPL was observed during this monitoring event.

3.3 Well Redevelopment

Based on the results of the groundwater gauging, three wells (MWG46, MWG45, and MWG49) were considered to require redevelopment. This was based on the measured total depth of well, which measured a greater than 0.5 m difference with the constructed total depth of well. The difference was due to a blockage caused by tree roots within the well.

Redevelopment was undertaken using a rod to remove roots that had entered the monitoring well. The monitoring well was then purged to remove debris that had fallen into the well. The redevelopment records are included in Appendix A.

Well development records for MWG46 and MWG49 were misplaced and hence, these records are not included in the Appendix.

3.4 Groundwater Sampling Methodology

Two groundwater sampling methodologies were used during the GME either by using a submersible QED Sample Pro® MicroPurge submersible pump (QED submersible pump) or a peristaltic pump. The use of either pump depended on the depth to groundwater at a monitoring well. The peristaltic pump has a depth to groundwater pumping limit of approximately 8 m. Hence, for groundwater wells with a groundwater depth deeper than 8 m, a submersible pump was used.

At each monitoring well, a water level was taken prior to purging using an oil/water interface meter. During purging, drawdown was monitored to ensure that it did not exceed the parameters set in the Golder technical procedure for groundwater sampling.

Near continuous measurement of field groundwater parameters (pH, temperature, conductivity, reduction potential and dissolved oxygen) was undertaken during purging. A YSI water quality meter placed in a flow through cell was used for this purpose. Field parameters observed at each well at the time of sampling are presented in Table B (attached). Groundwater samples were collected when field parameters stabilised ((±0.05 for pH, ±5% for EC, ±0.5°C for temperature, ±10 mV for redox and ±10% for DO for the last three field parameter readings) or when water level draws down more than 10% of the water column and the pump is set to the lowest achievable flow rate (typically ≤ 0.1 L/min). Field data sheets showing parameters measured in the field are provided in Appendix B. The calibration certificate and the daily calibration check form for the water quality meter are provided in Appendix C.

Each of the sampling methodologies are further described in the following subsections. Groundwater sampling field sheets are included in Appendix B.

Groundwater was stored on site in IBCs and collected by a licensed facility operator following the finalisation of the field program.

3.4.1 Submersible Pump

Groundwater samples were obtained from 38 wells on and off-site using a QED submersible pump. The purging rate during the GME ranged between 100 mL/min and 300 mL/min. Due to low recharge, reduced flow rates (<100 mL/min) were used in order to minimise the rate of drawdown for some wells (MW21i, MWG52, MWG59, and MWG125).

Sampling was undertaken in accordance with technical procedures adopted by Golder to minimise the risk of cross-contamination. In particular, the QED submersible pump was decontaminated prior to use and between each sampling location. The decontamination procedure consisted of disassembling the pump and a two stage distilled water rinse. The pump was finally sprayed with distilled water using a hand sprayer prior to reassembling with a new bladder and deployment into the well. Nitrile gloves were replaced between each of the wash stations and hand spray rinse.

Nitrile gloves were replaced between each of the wash stations and hand spray rinse.

One rinsate blank was sampled from the submersible pump per day of groundwater sampling as a check on the decontamination process. Rinsate blanks were sampled between sampling points following the decontamination of the submersible pump. Laboratory-supplied water was poured over the internal components of the submersible pump that were in contact with purge water during sampling and collected into new laboratory bottles for subsequent laboratory analysis.

When using the QED submersible pump the monitoring wells were generally sampled in order from least contaminated to most contaminated based on previous chemical data to further minimise the potential for cross-contamination.

3.4.2 Peristaltic Pump

Groundwater samples were obtained from 46 off-site monitoring well locations in the Damplands and around the PRB using a peristaltic pump. Constant pumping rates were operated using this method, which ranged between 100 mL/min and 240 mL/min. The peristaltic pump was used in conjunction with dedicated tubing. As the pump is external to the well in this method there is minimal potential for cross-contamination. Rinsate samples are not required when using the peristaltic pump as all equipment in direct contact with groundwater was replaced between sampling points.

3.5 Surface Water Sampling

Surface water samples were obtained from one location along the Helena River. Peristaltic sampling was used as the sampling methodology for this location. The sampling methodology for surface water samples was generally consistent with wells which were sampled using a peristaltic pump. HDPE tubing was placed into the river from the river bank ensuring that the intake remained below the water surface (approximately 100 mm) and above the riverbed (approximately 600 mm). Three field parameter readings were obtained but field parameters were not required to stabilise prior to sampling.

3.6 Analytical Schedule

Groundwater samples were analysed for one of the following analytical suites:

- Suite 1: TPH, VOCs, Brominated VOCs, Solvents, TOC and PFAS. This suite was selected for samples obtained from monitoring wells located on Lot 2 and the Southwest Industrial Area (23 monitoring wells).
- Suite 2: TPH, VOCs, Brominated VOCs, Solvents, dissolved metals, TOC and PFAS. This suite was selected for samples obtained from monitoring wells located on-site and upgradient of the site (10 locations).
- Suite 3: TPH, VOCs, Brominated VOCs, Solvents, dissolved metals, nitrate as N, TOC and PFAS (ultra-trace). This suite was selected for samples obtained from monitoring wells in the Damplands (14 locations). The suite was also selected for surface water samples obtained from the Helena River (one location), with the exception that total metals were analysed for sampled from Helena River and not dissolved metals.
- Suite 4: Water Quality, Nitrates as N, TOC, TDS, Ferrous and Ferric Iron, VOCs and PFAS. This suite was selected for samples obtained from monitoring wells in the vicinity of the PRB (32 locations).

The primary laboratory for sample analysis was SGS Australia Pty Ltd (SGS) with Australian Laboratory Services Pty Ltd (ALS) as the secondary laboratory. The exception to this was for the analysis of PFAS, where ALS was the primary laboratory and Eurofins MGT Pty Ltd (Eurofins) was the secondary laboratory.

3.7 Quality Control/Quality Assurance

The field QA/QC programme adopted for the investigation complied with recommendations in the SAP (Golder, 2010). In particular, the field QA/QC included the following:

- The use of dedicated equipment at each location coupled with stringent field decontamination procedures to minimise the potential risk of cross-contamination.
- The collection of samples into laboratory supplied sample containers with appropriate preservatives where required.
- The collection and review of trip blanks as a check on sample integrity and laboratory data quality.
- Field duplicates submitted to the primary NATA-accredited laboratory, with triplicate samples being sent to an alternative NATA-accredited laboratory.
- Consideration of internal laboratory QA/QC results, including a review of laboratory duplicate and blank sample results, as well as the results of surrogate and spike analyses.
- Discussion of QA/QC issues that arose.

The laboratory QA/QC programme adopted for the investigation also complied with recommendations in the SAP (Golder, 2010) and included the following:

- The laboratories are NATA–accredited for the required analyses.

- A minimum of one laboratory duplicate performed on each batch of samples provided to the laboratory. The relative percent difference (RPD) is considered satisfactory if below 50%. Laboratory method blanks were conducted for each batch of samples. Spike recovery analyses for each analytical suite, for each batch of samples received, were undertaken (i.e. one spike recovery analyses for every 10 samples). Spike recovery analysis results within the acceptable range set by the laboratory are considered satisfactory for QA/QC purposes.

4.0 EVALUATION CRITERIA

4.1 Risk-based Criteria

Analytical results from groundwater monitoring were compared against appropriate site-specific RBC developed in the human health and ecological risk assessment conducted for the site and surrounds (Golder 2008b, 2008c, 2009c, 2013a and 2013c). These RBCs have been developed for the Damplands for two vapour exposure scenarios (park user (outside) and outdoor worker) and an extractive use scenario (extraction of groundwater for use within a swimming pool). RBCs have also been developed for the site, the Hanson property, the Southwest Industrial Area, and Lot 2 for a vapour exposure scenario (indoor worker) and a groundwater extractive use scenario (irrigation worker).

RBC were not developed for aquatic receptors. Instead published screening criteria based on the protection of a mixture of aquatic species in moderately disturbed ecosystems were used (Golder, 2008c). These considered exposure scenarios relating to the aquatic ecosystem within Helena River, livestock drinking from Helena River, and native terrestrial receptors that may drink from Helena River. Application of these screening criteria to Damplands monitoring wells upgradient of the Helena River provides a conservative assessment of risks to the aquatic ecosystems as some attenuation of chemical concentrations is expected prior to discharge into the Helena River.

The groundwater results along with the adopted RBCs for each location are provided in analytical result tables, as follows:

- Table C: Upgradient Groundwater Analytical Results
- Table D: Former Waste Control Site Groundwater Analytical Results
- Table E: Lot 2 Groundwater Analytical Results
- Table F: Southwest Industrial Area Groundwater Analytical Results
- Table G: Hanson Groundwater Analytical Results
- Table H: Damplands Groundwater Analytical Results
- Table I: PRB Groundwater Analytical Results (PFAS Only)

4.2 PFAS

Analytical results from groundwater monitoring for PFAS were compared against:

- *PFAS National Environmental Management Plan, January 2018*, Heads of EPAs Australia and New Zealand (HEPA) and the Australian Government Department of the Environment and Energy (DoEE).

Previously, ecological criteria have not been considered for the site, southwest industrial area and Lot 2 as it was deemed that none were present. Therefore, to be consistent with the pathways already considered for other contaminants in groundwater at and migrating from the site the main criteria of interest is considered to be for the protection of human health.

For site, Lot 2 and the Southwest Industrial Area, the pathways of exposure adopted for other contaminants were irrigation from a bore and inhalation of vapours from migration through the soil. Due to the high solubility and typically low volatility properties of larger molecular weight PFAS, the vapour pathway has not been considered. Therefore, this report has adopted the recreation water criteria as best reflecting the reduced potential for ingestion of the groundwater in an irrigation scenario. The HEPA PFAS NEMP (2018) provides criteria for the sum of PFHxS and PFOS as well as PFOA.

Due to the emerging nature of PFAS, which results in frequent updates to the understanding of its fate and transport and risk profiles we have included a comparison to the relevant criteria for protection freshwater ecosystems. The freshwater ecosystem of interest is the Helena River. In the vicinity of the site, the river can be dry for a significant part of the year. As PFAS can bioaccumulate, we have conservatively adopted a higher level of ecosystem protection (i.e. 95%) for this report. With respect to PFAS, ecological criteria have been applied for to provide a conservative risk estimate of potential long-term trends in consideration of its recalcitrant and bioaccumulative nature. It is acknowledged that original criteria for protection of freshwater ecosystem in the Damplands adopted a 95% level of protection; however, given the overall highly disturbed nature of the river and Damplands, this is considered to be a very conservative position and hence was not adopted for PFAS. In addition, the result from the 2017 GME demonstrated that PFAS from the site was not likely to be impacting the quality of water within the Helena River.

5.0 RESULTS

5.1 Rainfall

A review of annual rainfall data from the last seven years (Figure A) indicated that there was increased rainfall around the time of the GME. This appears to be consistent with GMEs conducted in previous years.

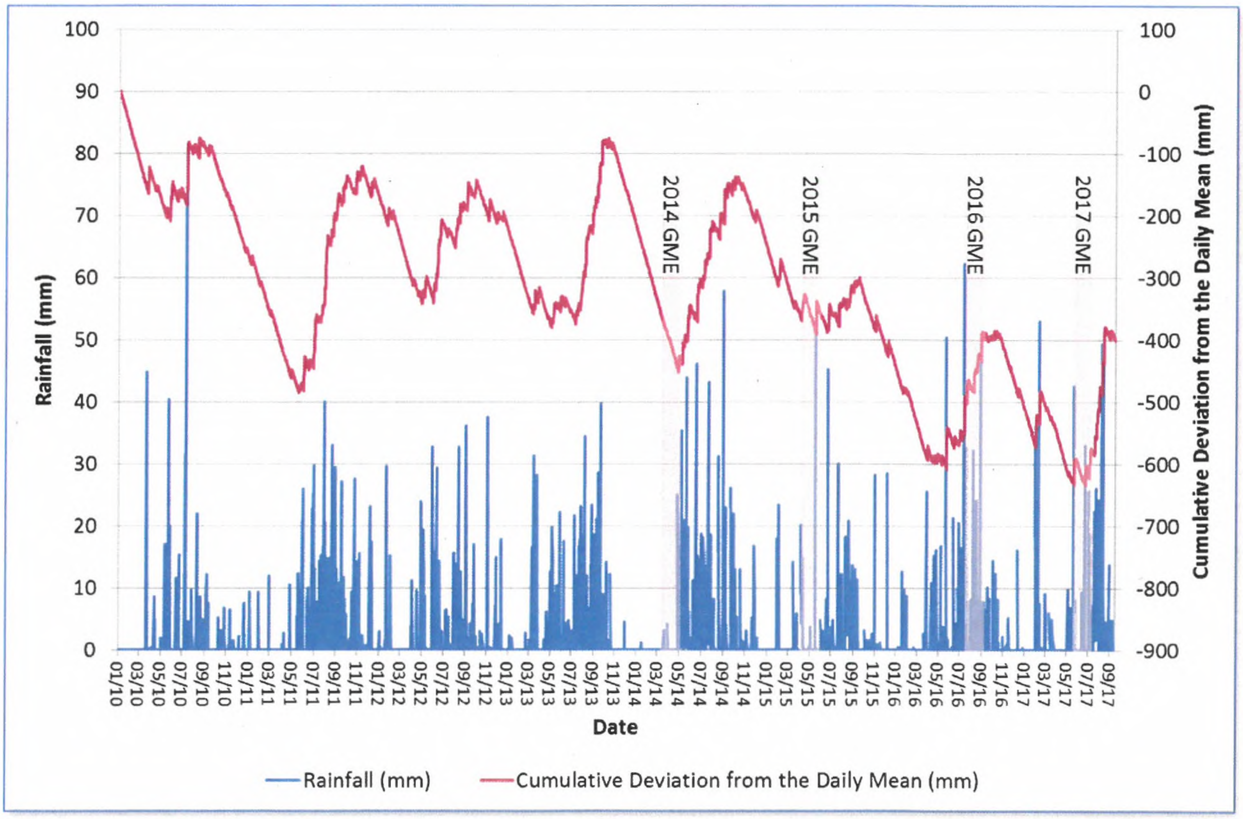

Figure A: Rainfall vs Cumulative Deviation from the Daily Mean (2010-2017)

5.2 Groundwater Levels and Movement

Groundwater levels measured during the GME have been included in Table A along with historical measurements. The most recent historical Study Area wide gauging events were conducted in 2016, 2015, and 2014. The groundwater elevation data measured during 2017 appears to be consistent with previous gauging events, in particular with consideration to seasonal variations, and there is indicated to be a slight increase in most wells (about 0.1 m) compared with previous gauging results in 2015 and 2016.

Groundwater surface elevation maps for the Leederville Formation, Base of Guildford, and Regional Watertable are presented in Figure 3, Figure 4, and Figure 5, respectively. Groundwater surface elevations at the Regional Watertable in the Guildford Formation and in the Damplands Alluvial Formations have been interpreted as a single continuous unit.

The inferred groundwater contours and flow direction are generally consistent with previous results. In particular, the groundwater flow direction in the Regional Watertable in the Guildford Formation and in the Damplands Alluvial Formations (Figure 5) has again indicated (consistent with the 2015 gauging results) that the flow direction along the escarpment has a more southerly component rather than a south-easterly component as previously identified.

5.3 Groundwater Results

The following discussion summarises locations where key analytes were detected which were above the site-specific RBC and aquatic ecosystem criteria appropriate for each of the main land blocks within the study area.

Monitoring well locations (except Damplands) with groundwater concentrations that exceed the site-specific RBC are shown on Figure 6. Monitoring well locations from the Damplands with groundwater concentrations exceeding the relevant criteria (Health RBC or Aquatic Ecosystem Screening Criteria) are shown in Figure 7.

5.3.1 Field Parameters

Field parameters recorded from each well during sampling are included in Table B. This table includes pH, oxidation/reduction potential (ORP), temperature, electrical conductivity (EC), dissolved oxygen (DO), odours, colour and sheen. The original field sheets are provided in Appendix B. The following is a summary of the field observations and a summary of the range of field measured parameters

Visual Observations

Sheen was noted in MW22i, but this was likely an inorganic sheen as the sheen broke into pieces when disturbed.

Odour Observations

The following odours were noted during the field programme:

- Chemical odours were noted at odour at MW21i, MW22i, MW23i (each located on-site, screening the Regional Watertable), and MW25 (site, Base of Guildford)
- Slight sulfur odour noted at MWG68 (Damplands, Alluvium)
- Organic odour at MWG116 (PRB)

pH

Excluding the PRB monitoring wells, pH ranged from 4.61 (MWG61, Damplands, Regional Watertable) to 7.23 (MWG56, Hanson, Base of Guildford). PRB monitoring wells had a pH range from 4.47 (MWG106A) to 10.66 (MWG104B).

In general groundwater at the Study Area is considered to be slightly acidic.

Dissolved Oxygen

There were 17 monitoring wells with DO concentrations above 1 mg/L, with the highest concentration being 7.06 mg/L at MWG38 (Lot 2, Leederville Formation). Conversely, there were 31 monitoring wells with DO concentrations below 1 mg/L, with the lowest concentration being 0.13 mg/L at MWG90A (Lot 2, Regional Watertable).

The majority of wells within the PRB measured DO concentrations below 1 mg/L (29 out of 33 wells sampled). Monitoring wells MWG106A, MWG107A, MWG111A, and MWG115 measured DO concentrations above 1 mg/L ranging from 1.01 mg/L to 2.84 mg/L.

Electrical Conductivity

Excluding the PRB, EC values ranged from 3,862 µS/cm (MWG38, Lot 2, Leederville Formation) to 227 µS/cm (MWG61, Damplands, Regional Watertable).

Within the PRB, the EC ranged from 650 µS/cm (MWG115) to 3,141 µS/cm (MWG110A).

Redox Potential

Excluding the PRB area, the ORP ranged from -202 mV (MWG66, Damplands, Alluvium) to 484 mV (MWG90D, Damplands, Alluvium). In total, 12 monitoring wells contained ORP values less than 0 mV, indicating slightly reducing conditions. Of the locations with negative ORP, six are located within the Regional Watertable where impacted groundwater has been identified. The remaining locations are within the Leederville and Alluvium formations. There were 36 monitoring wells with an ORP greater than 0 mV, with a range of between 2.3 mV (MWG60) to 484 mV (MWG90D), indicating conditions ranging from slightly oxidising to strongly oxidising.

Within the PRB, 18 monitoring wells measured a negative ORP, ranging from -286 mV (MWG104C) to -1.0 mV (MWG116), and 15 monitoring wells measured a positive ORP, ranging from 2.1 mV (MWG112B) to 288 mV (MWG115).

5.3.2 Upgradient

Two upgradient monitoring wells MWG45 (Leederville) and MWG46 (Base of Guildford) both located on Irwin Street were sampled for background purposes. Both upgradient samples were analysed for Suite 2 analytes. The results are included in Table C, along with historical groundwater sampling results.

The results indicated that, with the exception of PFAS, some metals, total organic carbon (TOC), and total recoverable hydrocarbons (TRHs), analyte concentrations were below the limit of reporting (LOR). The results were below the RBC criteria.

The following is noted regarding the analytes above the LOR:

- PFAS: MWG45 reported numerous PFAS above the LOR, including PFOA, PFOS, PFHxS, Perfluorohexanoic acid (PFHxA), Perfluoroheptanoic acid (PFHpA), Perfluoropentanoic acid (PFPeA), Perfluoroheptane sulfonic acid (PFHpS), Perfluoropentane sulfonic acid (PFPeS), and Perfluorobutane sulfonic acid (PFBS). Of these compounds, criteria are only available for PFOA, PFOS, and PFOS+PFHxS. Concentrations of PFOS exceeded ecological guidelines, and concentrations of PFOS+PFHxS exceeded recreation criteria. Monitoring well MWG46 also reported concentrations of PFOA, PFOS, and PFHxS above the LOR but below the evaluation criteria. PFAS assessment criteria exceedances are shown on Figure 8. The distribution of PFAS, and relative composition in each well, are further discussed in Section 6.0.
- Metals: MWG45 reported iron, manganese, and nickel above the LOR, and MWG46 reported manganese and nickel above the LOR. Concentrations were generally consistent with historical results and were also below the RBC.

- TOC: concentrations in both wells were generally consistent with historical results of around 1 mg/L.
- TRHs: MWG46 reported concentrations above the LOR for TRH C_{10}-C_{16} (0.075 mg/L), C_{15} – C_{28} (0.3 mg/L), and C_{29} – C_{36} (0.22 mg/L). TRHs have not been reported in this well historically, however the concentrations reported in 2017 were below the RBC.

5.3.3 Site

Groundwater samples were obtained from the following on-site monitoring wells:

- Regional Watertable: MW21i, MW22i, MW23i
- Base of Guildford Formation: MW24, MW25, MW27

The samples obtained from the site were analysed for Suite 2. The analytical results are included in Table D, which also includes historical groundwater sampling results.

5.3.3.1 RBC Exceedances

Groundwater results were compared against relevant RBC for the site and Lot 2, being indoor air vapour intrusion and exposure to outdoor worker/irrigation worker from extracted groundwater. Table 2 lists the analytes detected at concentrations above relevant RBC. RBC exceedances for site are shown on Figure 6.

Table 2: Site Results above Relevant RBC (all units mg/L)

	Location	Analytes	Site and Lot 2 RBC	2010	2011	2012	2013	2015	2017
Regional Watertable	MW21i	VC	***172*** **0.11**	<0.001	0.007	**0.2**	**0.15**	0.09	**0.35**
	MW22i	C_{10}-C_{14}	***67*** **2.05**	**2.1**	**1.9***	**4.1**	**4.6***	**8.1**	**6.4**
		CA	***0.0118*** **0.0862**	0.006	0.006	0.009	<0.001	***0.034***	***0.037***
		VC	***172*** **0.11**	0.003	0.004	0.003	0.008	**0.68**	**2.2**
	MW23i	VC	***172*** **0.11**	0.001	<0.001	<0.001	<0.001	0.0006	**0.27**

Notes: VC = Vinyl chloride, CA = chloroethane, C_{10}-C_{14} = TRH C_{10}-C_{14}
Bold italics indicates exceedance for indoor worker RBC (vapour exposure pathway)
Bold underline indicates exceedance for outdoor worker/irrigation worker (direct contact exposure pathway)

Concentrations of vinyl chloride in MW21i, MW22i, and MW23i were highest in 2017 compared with historical results. As was noted in the 2015 GME, vinyl chloride is a degradation product that can indicate that degradation of parent products such as PCE and TCE are ongoing on-site. Well MW22i is in a source area and MW23i is approximately 20 to 30 metres down gradient of the source area. A discussion of these results in the context of a statistical trend analysis is provided in Section 5.3.3.3.

5.3.3.2 Other Results

A number of analytes were detected above the relevant laboratory LOR but were below relevant RBC (where applicable). Generally, the results are consistent with historical results.

The exceptions to this are concentrations of PFOS in MW21i and MW22i, which exceeded ecological criteria. PFAS have only been sampled once previously, in 2016, and the 2017 results are generally consistent with that measured in 2016. PFAS assessment criteria exceedances are shown on Figure 8. The distribution of PFAS, and relative composition in each well, are further discussed in Section 6.0.

5.3.3.3 *Comparison to previous monitoring event results*

To compare the 2017 results with previous monitoring events and to understand what the long-term concentration trend is, a Mann-Kendall trend analysis was undertaken. The Mann-Kendall test is a statistical method that can be applied to assess the significance of concentration changes over a period of time. The results of the Mann-Kendall analysis are listed in Table 3 and supporting files are presented in Appendix E. For the purposes of the Mann-Kendall analysis, the following rules were adopted:

- All historical data for a well was included, however, a minimum of four results for a compound were required to perform the analysis.
- Concentrations reported at the laboratory LOR were included as a concentration of half the LOR. However, where the majority of results for a compound were at the laboratory LOR or concentrations were a mix of at the laboratory LOR and close to the laboratory LOR, the compound was not included in the analysis. This is due to the accuracy of laboratory methodology decreasing with increasing proximity to the LOR.

Table 3 also provides the maximum (for decreasing trends) or minimum (for increasing trends) historical concentration compared with the concentration in 2017. Where a well or analyte is not listed in Table 3 the Mann-Kendall result was unable to be analysed due to insufficient results to determine a concentration trend. The exception to this is for vinyl chloride, as discussed after Table 3.

Table 3: Result of Mann-Kendall Trend Analysis – Site Monitoring Wells

Well	COI Group	Analyte	Trend	Concentration Change
MW21i	Chloro-benzenes	1,2-Dichlorobenzene	Down	0.0655 mg/L (2004) to <0.0005 (2017)
		1,4-Dichlorobenzene	Down	0.003 mg/L (2003) to <0.0003 (2017)
	Metals	Iron	Down	40 mg/L (2005) to 4 mg/L (2017)
	MAH	1,2,4-trimethylbenzene	Down	1.45 mg/L (2004) to <0.0005 (2017)
		1,3,5-Trimethylbenzene	Down	0.613 mg/L (2004) to <0.0005 (2017)
		Benzene	Down	0.018 mg/L (2003) to <0.0005 (2017)
		Ethylbenzene	Down	4.91 mg/L (2004) to <0.0005 (2017)
		Toluene	Down	14.2 mg/L (2004) to <0.0005 (2017)
		Isopropylbenzene	Down	0.022 mg/L (2005) to <0.0005 (2017)
		n-Propylbenzene	Down	0.152 mg/L (2004) to <0.0005 (2017)
		p-Isopropyltoluene	Down	0.038 mg/L (2003) to 0.0007 (2017)
		Xylene (o)	Down	13.3 mg/L (2005) to <0.0005 (2017)
		Xylenes (m & p)	Down	7.9 mg/L (2005) to <0.001 (2017)
	PAH	Naphthalene	Down	0.0254 mg/L (2004) to <0.0005 (2017)
	TPH	TRH C10 – C14 Fraction	Down	82.4 mg/L (2004) to 1.9 mg/L (2017)
		TRH C6 – C9 Fraction	Down	66 mg/L (2005) to 0.077mg/L (2017)
	VOC	1,1-Dichloroethane	Down	0.3 mg/L (2004) to 0.033 mg/L (2017)
		Chloroethane	Down	0.009 mg/L (2011) to <0.005 mg/L (2017)
		Chloroform	Down	0.1 mg/L (2001) to <0.0005 mg/L (2017)
		cis-1,2-Dichloroethene	Down	1.75 mg/L (2004) to 0.0014 mg/L (2017)
		Tetrachloroethene	Down	0.25 mg/L (2004) to <0.0005 mg/L (2017)
		Trichloroethene	Down	0.129 mg/L (2004) to <0.0005 mg/L (2017)
		Trichlorofluoromethane	Down	1.29 mg/L (2004) to <0.001 mg/L (2017)
		Vinyl chloride	No Trend	0.35 mg/L (2017). See Note 1

Well	COI Group	Analyte	Trend	Concentration Change
MW22i	Chloro-benzenes	1,2-Dichlorobenzene	Up	<0.0005 mg/L (2004) to 0.01 mg/L (2017)
		Chlorobenzene	Up	<0.0005 mg/L (2004) to 0.015 mg/L (2017)
	MAH	Ethylbenzene	Up	0.026 mg/L (2004) to 3.1 mg/L (2017)
	VOC	1,1-Dichloroethane	Down	0.162 mg/L (2003) to 0.012 mg/L (2017)
		1,1-Dichloroethene	Down	0.013 mg/L (2003) to <0.0005 mg/L (2017)
		cis-1,2-Dichloroethene	Up	0.044 mg/L (2017). See Note 2
		Tetrachloroethene	Down	0.011 mg/L (2004) to <0.0005 mg/L (2017)
		Trichloroethene	Down	0.022 mg/L (2008) to <0.0005 mg/L (2017)
		Vinyl chloride	No Trend	2.2 mg/L (2017). See Note 1
MW23i	Metals	Iron	Down	49 mg/L (2005) to 21 mg/L (2017)
	MAH	1,2,4-trimethylbenzene	Down	0.13 mg/L (2005) to <0.0005 (2017)
		p-Isopropyltoluene	Down	0.046 mg/L (2005) to 0.0008 (2017)
	TPH	TRH C10 – C14 Fraction	Down	3.71 mg/L (2003) to 0.76 mg/L (2017)
		TRH C6 – C9 Fraction	Down	18 mg/L (2006) to 0.31 mg/L (2017)
	VOC	1,1-Dichloroethane	Down	0.281 mg/L (2003) to 0.011 mg/L (2017)
		1,1-Dichloroethene	Down	0.029 mg/L (2005) to <0.0005 mg/L (2017)
		Chloroethane	Down	0.013 mg/L (2004) to <0.005 mg/L (2017)
		Chloroform	Down	0.105 mg/L (2001) to <0.0005 mg/L (2017)
		Vinyl chloride	Down. See Note 3	0.27 mg/L (2017). See Note 3.
MW27	Metals	Iron	Down	0.65 mg/L (2005) to <0.005 mg/L (2017)

Table Notes:

- **Note 1**: The vinyl chloride concentration in MW21i and MW22i both exceed RBC and both increased from the 2015 result (the most recently available concentration). The result of the MK trend analysis indicated no trend, i.e. neither increasing nor decreasing. This is based on the statistical analysis of results over the monitoring period for this well. Therefore, further monitoring results may clarify the concentration with respect to whether the trend is increasing or decreasing (or if it remains as no trend).
- **Note 2**: The MK trend assessment calculated an overall upward concentration trend for cDCE in MW22i well. The historical minimum was 0.124 mg/L (2001) and the historical maximum was 2.6 mg/L (2015). Between 2001 and 2015 there is indicated to be an incremental concentration increase, however the 2017 concentration was 0.044 mg/L, which is below the historical minimum. Therefore, the most recent concentration appears to be inconsistent with an increasing concentration trend, however, further monitoring may clarify whether concentration trend is still increasing or if it has changed to be decreasing.
- **Note 3**: Most recent result for vinyl chloride was 0.27 mg/L, which exceeds RBC. The MK analysis calculated a decreasing trend for this compound; however, this MK trend result is considered to be an artefact of the trend assessment used. This is due to the manner in which LOR results are used in the trend assessment, i.e. LOR are treated as a concentration of half the LOR. The previous result for this well was 0.0006 mg/L (2015), the previous maximum result for this well was 0.002 mg/L (2009), and the concentration has been LOR on several occasions. Hence, there has been an increase in vinyl chloride over the course of the monitoring period.

Discussion of the concentration trends for the site, in particular the results for MAHs and chlorinated hydrocarbons, is included in Section 6.0.

5.3.4 Lot 2

The following 19 monitoring wells on Lot 2 were included as part of the GME:

- Regional Watertable: MW37, MW39, MW42, MWG49, MWG52, MWG54, MWG57, MWG59, MWG84, MWG91A.
- Leederville: MWG47
- Base of Guildford: MW38, MWG48, MWG53, MWG55, MWG58, MWG83, MWG91B, and MWG91C.

The samples obtained from Lot 2 were analysed for Suite 1. Analytical results are included in Table E, along with historical groundwater sampling results dating back to 2005.

5.3.4.1 *RBC Exceedances*

Results for Lot 2 were compared against the relevant RBC for the site and Lot 2, being indoor air vapour intrusion and exposure to outdoor worker/irrigation worker from extracted groundwater. Table 4 lists the analytes detected at concentrations above relevant RBC. No exceedances of the Indoor Worker RBC were noted. RBC exceedances for Lot 2 are shown on Figure 6.

Table 4: Lot 2 Results above Relevant RBC (all units mg/L)

Location		Analytes	Site and Lot 2 RBC	2010	2011	2012	2013	2015	2016	2017
RW	MWG57	TCE	***2.67*** **0.15**	**0.46**	**0.4**	**1.1**	**0.79**	**0.79**	NS	**0.41**
	MWG84	VC	***172*** **0.11**	NS	NS	NS	NS	**0.11**	**0.14**	**0.14**
	MWG59	VC	***172*** **0.11**	<0.001	<0.001	<0.001	0.001	0.058	NS	**0.13**

Notes: VC = Vinyl chloride, TCE = trichloroethene; Bold indicates RBC exceedance; RW = Regional Watertable; BoG = Base of Guildford; NS = Not Sampled

Bold italics indicates exceedance for indoor worker RBC (vapour exposure pathway)

Bold underline indicates exceedance for outdoor worker/irrigation worker (direct contact exposure pathway)

5.3.4.2 *Other Results*

A number of analytes were detected above the relevant laboratory LOR but were below relevant RBC (where applicable). Generally, the results are consistent with historical results. The exception to this is PFAS, which has only been sampled once before in 2016. Although none of the PFAS concentrations exceeded beneficial use assessment criteria assessment of the PFAS composition was undertaken to understand the similarities/differences with elsewhere within the Study Area. This is discussed in Section 6.0.

5.3.4.3 *Comparison to previous monitoring event results*

As with site monitoring wells, a Mann-Kendall trend analysis was undertaken on the Lot 2 groundwater analytical data. The results of the Mann-Kendall analysis are listed in Table 5 and supporting work is included in Appendix E.

Table 5 also provides the maximum (for decreasing trends) or minimum (for increasing trends) historical concentration compared with the concentration in 2017. Where a well or analyte is not listed in Table 5 the Mann-Kendall result was unable to be analysed due to insufficient results to determine a concentration trend for the analysis to be undertaken.

Table 5: Result of Mann-Kendall Trend Analysis – Lot 2 Monitoring Wells

Well	COI Group	Analyte	Trend	Concentration Change
MW37	VOC	Tetrachloroethene	Up	<0.001 mg/L (2003-2008) to 0.04 mg/L (2017)
MW42	VOC	cis-1,2-Dichloroethene	Down	0.55 mg/L (2005) to 0.0016 mg/L (2017)
		Tetrachloroethene	Down	0.064 mg/L (2008) to 0.0063 mg/L (2017)
		trans-1,2-dichloroethene	Down	0.08 mg/L (2006) to <0.0005 mg/L (2017)
		Trichloroethene	Down	0.17 mg/L (2006-2008) to 0.001 mg/L (2017)
MWG49	VOC	1,1-Dichloroethane	Down	0.053 mg/L (2006) to 0.0067 mg/L (2017)
		1,1-Dichloroethene	Down	0.016 mg/L (2005) to 0.0015 mg/L (2017)
		Chloroform	Down	0.044 mg/L (2005) to 0.0036 mg/L (2017)
		Tetrachloroethene	Down	0.076 mg/L (2005) to 0.017 mg/L (2017)
		cis-1,2-Dibromoethene	Down	0.002 mg/L (2009) to <0.001 mg/L (2017)
		Trichloroethene	Down	0.44 mg/L (2005) to 0.021 mg/L (2017)
MWG59	Chlorobenzenes	1,2-Dichlorobenzene	Up	<0.001 mg/L (2006-2009) to 0.0048 mg/L (2017)
	MAH	Benzene	Up	<0.001 mg/L (2006-2011) to 0.0018 mg/L (2017) See Note 1
	VOC	1,1-Dichloroethane	Up	0.003 mg/L (2006) to 0.023 mg/L (2017)
		1,1-Dichloroethene	Down	0.064 mg/L (2009) to 0.0038 mg/L (2017)
		cis-1,2-Dibromoethene	Down	0.078 mg/L (2010) to 0.004 mg/L (2017)
		cis-1,2-Dichloroethene	Up	0.006 mg/L (2006) to 0.073 mg/l (2017)
		trans-1,2-Dibromoethene	Down	0.015 mg/L (2010) to <0.001 mg/L (2017)
		Trichloroethene	Down	0.056 mg/L (2009) to 0.0066 mg/L (2017)
		Vinyl bromide (bromoethene)	Up	0.0006 mg/L (2006) to 0.32 mg/L (2017)
		Vinyl chloride	Up	<0.001 mg/L (2006-2012) to 0.13 mg/L (2017)
MWG83	VOC	Tetrachloroethene	Down	0.003 mg/L (2008) to <0.0005 mg/L (2017)
MWG84	MAH	Xylene (o)	Down	0.006 mg/L (2008) to <0.0005 mg/L (2017)
	VOC	1,1-Dichloroethane	Down	0.047 mg/L (2008) to 0.011 mg/L (2017)
		Trichloroethene	Down	0.006 mg/L (2009) to 0.007 mg/L (2017)
		Tetrachloroethene	Down	0.058 mg/L (2008) to 0.0031 mg/L (2017)
		Vinyl chloride	Up	<0.001 mg/L (2008-2010) to 0.14 mg/L (2017)

Note 1: benzene concentrations are indicated to be marginally increasing over the monitoring period, changing from LOR to marginally above the LOR over an 11 year period. However, concentrations are at least two orders of magnitude below the RBC.

Discussion of the concentration trends for Lot 2, in particular the results for MAHs and chlorinated hydrocarbons, is included in Section 6.0.

5.3.5 Southwest Industrial Area

Samples were obtained from four monitoring wells in the Southwest Industrial Area:

- Regional Watertable: MWG51 and MWG70
- Base of Guildford: MWG50 and MWG69

The samples were analysed for Suite 1. The results of the GME for the locations on the Southwest Industrial Area are included in Table F, along with historical groundwater sampling results.

5.3.5.1 RBC Exceedances

Results for the Southwest Industrial Area were compared against the relevant RBC. Concentrations for the analytes in wells sampled in this area were below the relevant RBC.

5.3.5.2 Other Results

A number of analytes were detected above the relevant laboratory LOR but were below relevant RBC (where applicable). Generally, the results are consistent with historical results. The exception to this is PFAS, which has only been sampled once before in 2016. Although none of the PFAS concentrations exceeded beneficial use assessment criteria assessment of the PFAS composition was undertaken to understand the similarities/differences with elsewhere within the Study Area. This is discussed in Section 6.0.

5.3.5.3 Comparison to Previous Monitoring Event Results

As with site monitoring wells, a Mann-Kendall trend analysis was undertaken on the Southwest Industrial Area groundwater analytical data. The results of the Mann-Kendall analysis are listed in Table 6 and supporting work is included in Appendix E.

Table 6 also provides the maximum (for decreasing trends) or minimum (for increasing trends) historical concentration compared with the concentration in 2017. Where a well or analyte is not listed in Table 6 the Mann-Kendall result was that there were insufficient results for the analysis to be undertaken.

Table 6: Result of Mann-Kendall Trend Analysis – Southwest Industrial Area Monitoring Wells

Well	COI Group	Analyte	Trend	Concentration Change
MWG42	VOC	Vinyl Chloride	Down	
		cis-1,2-Dibromoethene	Down	
MWG51	VOC	cis-1,2-Dibromoethene	Down	0.015mg/L (2005) to <0.001 mg/L (2017).
	MAH	Toluene	Down	
		Xylenes	Down	
		Ethylbenzene	Down	
MWG70	TPH	TRH C6 – C9 Fraction	Up	<0.01 mg/L (2008-2012) to 0.15 mg/L (2017). See Note 1

Note 1: Prior to 2017 the maximum concentration was 0.24 mg/L (2014). There are only a limited number of results above LOR within the dataset for this compound; however, on two occasions the concentration was an order of magnitude greater than the LOR. Reported concentrations are several orders of magnitude below RBC.

5.3.6 Hanson Property

Two monitoring wells were sampled on the Hanson property:

- Regional Watertable: MWG64
- Base of Guildford: MWG56

The samples were analysed for Suite 2. The results of the GME are included in Table G, along with historical groundwater sampling results.

5.3.6.1 RBC Exceedances

Results for the Hanson Property sample were compared against the relevant RBC. There were no analytes detected at concentrations exceeding the relevant RBC.

5.3.6.2 Other Results

A number of analytes were detected above the relevant laboratory LOR but were below relevant RBC (where applicable). Generally, the results are consistent with historical results. The exception to this is PFAS, which has only been sampled once before in 2016. Although none of the PFAS concentrations exceeded beneficial use assessment criteria assessment of the PFAS composition was undertaken to understand the similarities/differences with elsewhere within the Study Area. This is discussed in Section 6.0.

5.3.6.3 Comparison to Previous Monitoring Event Results

As with site monitoring wells, a Mann-Kendall trend analysis was undertaken on the Hanson groundwater analytical data. The results of the Mann-Kendall analysis are listed in Table 6 and supporting work is included in Appendix E.

Table 7 also provides the maximum (for decreasing trends) or minimum (for increasing trends) historical concentration compared with the concentration in 2017. Where a well or analyte is not listed in Table 7 the Mann-Kendall result was unable to be analysed due to insufficient results to determine a concentration trend.

Table 7: Result of Mann-Kendall Trend Analysis – Hanson Monitoring Wells

Well	COI Group	Analyte	Trend	Concentration Change
MWG64	VOC	1,1-Dichloroethane	Down	0.073 mg/L (2006) to 0.0046 mg/L (2017)
		1,1-Dichloroethene	Down	0.009 mg/L (2006) to 0.0008 mg/L (2017)
		Vinyl Chloride	Down	0.001 mg/L (2006) to 0.0008 mg/L (2017)
	TPH	TRH C_6-C_{36} (Sum of total)	Down	

5.3.7 Damplands

Samples were collected from 14 locations in the Damplands during the GME, as follows:

- Alluvium: MW36, MWG60, MWG66, MWG67, MWG68, MWG77, MWG90A, MWG90B, MWG90C, MWG124, and MWG125.
- Regional Watertable: MWG61, MWG62, and MWG63

The wells were analysed for Suite 3. The results of the GME for the locations in the Damplands are included in Table H, along with historical groundwater sampling results.

Note that the monitoring wells in immediate vicinity of the PRB have not been included in this report and instead are presented under a separate cover (Golder, 2017b). This includes the wells ranging from MWG100 to MWG123.

5.3.7.1 RBC Exceedances

Results for the Damplands were compared against both the health RBC for the Damplands and Aquatic Ecosystem Screening Criteria. Table 8 lists the locations where concentrations were above relevant criteria. RBC exceedances for the Damplands are shown on Figure 7.

Table 8: Damplands Analyte Concentrations Above Relevant RBC (all units mg/L)

Location		Analyte	Criteria	2010	2011	2012	2013	2015	2017
Regional Watertable	MWG61	Al	*309* **151.6** 0.055	NS	NS	NS	NS	0.16	0.18
		Zn	0.008	NS	NS	NS	NS	0.013	0.014
		Nitrate	7	NS	NS	NS	NS	10	11
	MWG62	Fe	*217* **106.1** 0.3	0.029	0.006	0.01	0.21	0.01	3.5
		Nitrate	7	9.6	2	3.7	6.3	12	10
		TCE^2	*0.0847* **0.04** 0.33	0.007	**0.082**	***0.13***	***0.25***	***0.5***	***0.64***
	MWG63	Al	*309* **151.6** 0.055	NS	0.011^1	0.024^1	NS	0.038	0.082
		Zn	0.008	0.01	0.026	0.018	NS	0.015	0.029
		TCE^2	*0.0847* **0.04** 0.33	***0.42***	***0.56***	***0.66***	***0.55***	***0.61***	***0.43***
Alluvium	MW36	Fe	*217* **106.1** 0.3	16	17	14	15	1.6	16
	MWG60	Fe		NS	1.7	2.4	2.2	0.013	3.9
	MWG66	Fe		1.1	3	0.77	2.2	0.035	4.2
	MWG67	Fe		NS	NS	NS	NS	8.5	43
	MWG68	Fe		0.71	0.68	0.54	0.52	0.53	0.52
	MWG77	Fe		12	1.9	14	15	5.9	13
		Zn	0.008	NS	NS	NS	NS	<0.005	0.009
	MWG90A	Al	*309* **151.6** 0.055	NS	NS	NS	NS	<0.005	0.095
		Nitrate	7	NS	NS	NS	NS	2.6	8.4
	MWG90B	Nitrate	7	NS	NS	NS	NS	9.6	10
	MWG90C	Nitrate	7	NS	NS	NS	NS	13	12
	MWG90D	Cr	0.001	NS	NS	NS	NS	NS	0.004
	MWG124	Zn	0.008	NS	NS	NS	NS	0.053	0.009
		Nitrate	7	NS	NS	NS	NS	7.2	7.4
		TCE^2	*0.0847* **0.04** 0.33	NS	NS	NS	NS	*0.13*	*0.28*
	MWG125	Zn	0.008	NS	NS	NS	NS	0.036	0.009
		Nitrate	7	NS	NS	NS	NS	3.1	7.3
		TCE^2	*0.0847* **0.04** 0.33	N/A	N/A	N/A	N/A	***0.38***	**0.043**

Notes: NS = Not sampled; N/A = Well did not exist at this point in time; Fe = iron, Al = aluminium, Zn = zinc, TCE = trichloroethene, Cr = Chromium (total);

1 = duplicate result

2 = RBCs not listed for TCE include: Damplands Outdoor Worker (Vapour Exposure Pathway) of 401.8 mg/L, and Damplands Park User Outdoor (Vapour Exposure Pathway) of 643 mg/L.

Italics indicate RBC Damplands Worker Irrigator (Direct Exposure Pathway)

Bold indicates RBC Damplands Recreational Swimmer (Groundwater Direct Contact Exposure Pathway)

Underline results indicates exceedance of Aquatic Ecosystem Screening Criteria

5.3.7.2 Other Results

A number of analytes were detected above the relevant laboratory LOR but were below relevant RBC (where applicable). Generally, the results are consistent with historical results. The exception to this is PFAS, which has only been sampled once before in 2016. Although none of the PFAS concentrations exceeded beneficial use assessment criteria assessment of the PFAS composition was undertaken to understand the similarities/differences with elsewhere within the Study Area. This is discussed in Section 6.0.

5.3.7.3 Comparison to Previous Monitoring Event Results

As with site monitoring wells, a Mann-Kendall trend analysis was undertaken on the Damplands groundwater analytical data. The results of the Mann-Kendall analysis are listed in Table 9 and supporting work is included in Appendix E.

Table 9 also provides the maximum (for decreasing trends) or minimum (for increasing trends) historical concentration compared with the concentration in 2017. Where a well or analyte is not listed in Table 9 the Mann-Kendall result was unable to be analysed due to insufficient results to determine a concentration trend.

Table 9: Result of Mann-Kendall Trend Analysis – Damplands Monitoring Wells

Well	COI Group	Analyte	Trend	Concentration Change
MW36	VOC	Trihalomethanes	Down	
MWG60	VOC	cis-1,2-Dichloroethene	Down	0.006 mg/L (2011) to 0.0008 mg/L (2017)
	Metals	Iron (ferrous)	Up	
MWG62	TPH	TRH C6 – C9 Fraction	Up	<0.01 mg/L (2006-2010) to 0.47 mg/L (2017)
	VOC	Tetrachloroethene	Up	<0.001 mg/L (2006-2013) to 0.0013 mg/L (2017)
		Trichloroethene	Up	0.008 mg/L (2006) to 0.64 mg/L (2017)
MWG63	Water Quality	Nitrate (as N)	Down	47 mg/L (2006) to 5.4 mg/L (2017)
	TPH	TRH C6 – C9 Fraction	Up	<0.01 mg/L (2006) to 0.26 mg/L (2017)
	VOC	Tetrachloroethene	Up	<0.001 mg/L (2006) to 0.004 mg/L (2017)
MWG66	TPH	TRH C6 – C9 Fraction	Up	<0.01 mg/L or <0.04 mg/L (2006-2012) to 0.041 mg/L (2017). See Note 1.
	VOC	1,1-Dichloroethane	Up	<0.001 mg/L (2006-2010) to 0.0022 mg/L (2017)
		cis-1,2-Dichloroethene	Up	<0.001 mg/L (2006-2010) to 0.01 mg/L (2017)
		Trichloroethene	Up	<0.001 mg/L (2008) to 0.011 mg/L (2017)
		Vinyl chloride	Up	<0.001 mg/L and <0.0003 (2006-2011) to 0.002 mg/L (2017)
MWG68	Metals	Iron	Down	

Note 1: The most recent TRH C_6-C_9 Fraction concentration was marginally above the LOR; however, historically the maximum concentration was 0.11 mg/L (2014). Reported concentrations are several orders of magnitude below RBC.

Discussion of the concentration trends for the Damplands, in particular the results for chlorinated hydrocarbons, is included in Section 6.0.

5.3.8 Permeable Reactive Barrier

Groundwater samples were obtained from 35 monitoring wells in close vicinity to the PRB. These monitoring wells either screen the Regional Watertable, the Leederville formation, or are multiport wells. A discussion of the analytical results with respect the effectiveness of the PRB, comparison with RBCs, and concentration trends of chlorinated hydrocarbons is included under a separate report cover (Golder, 2017b). The exception to this is for PFAS, which are discussed in the following subsection.

Groundwater analytical results for PRB monitoring wells for PFAS are included in Table I.

5.3.8.1 *PFAS Results*

Groundwater analytical results for PFAS were compared with assessment criteria protective of aquatic ecosystems and human health (recreational waters) (as outlined in Section 4.2).

There was one result for PFOS (in MWG110A, 0.2 µg/L) that exceeded the criterion for the protection of aquatic ecosystems of 0.13 µg/L. PFAS assessment criteria exceedances are shown on Figure 8. Other results above the laboratory LOR included: PFOA (26 wells), PFOS (14 wells (including 1 well with an exceedance), PFHxS (30 wells), PFBA (17 wells), PFHxA (28 wells), PFHpA (22 wells), PFPeA (27 wells), PFHpS (1 well), PFPeS (13 wells), PFBS (19 wells), 6:2 FTSA (18 wells).

5.4 Surface Water Results

Samples were obtained from the river sampling location 1A and 1B. These locations are in close vicinity of historical river sampling location 1. Due to limited flow, other river samples could not be obtained.

Samples obtained were analysed for Suite 3 and results were compared with Aquatic Ecosystem Screening Criteria. With the exception of zinc, concentrations were below aquatic ecosystem screening criteria (where available). Zinc exceeded the criterion (0.008 mg/L) in both samples with concentrations of 0.015 mg/L (River1A) and 0.018 mg/L (River 1B). These exceedances are shown on Figure 9.

Other analytes that were above the LOR, but below RBC, are listed in Table 10. Assessment criteria are also listed in Table 10 where available.

Table 10: Surface Water Results Above LOR

COI Group (units)	Analyte	Criteria	River1A	River1B
PFAS (µg/L)	Perfluorooctanoic Acid (PFOA)	*220* 5.6	0.0029	0.0053
	Perfluorooctane sulfonic acid (PFOS)	*0.13*	0.0068	0.0069
	Perfluorohexane sulfonic acid (PFHxS)	-	0.0147	0.0177
	Sum of PFHxS and PFOS (calculated)	0.7	0.0215	0.0246
	Perfluorohexanoic acid (PFHxA)	-	0.0051	0.0071
	Perfluoroheptanoic acid (PFHpA)	-	0.0012	0.0018
	Perfluorodecanoic acid (PFDA)	-	0.0008	0.001
	Perfluoropentanoic acid (PFPeA)	-	0.0023	0.0029
	Perfluoropentane sulfonic acid (PFPeS)	-	0.0045	0.0045
	Perfluorobutane sulfonic acid (PFBS)	-	0.0067	0.0092
	6:2 Fluorotelomer sulfonic acid (6:2 FTSA)	-	0.003	0.002
Metals (mg/L)	Aluminium (Filtered)	*0.055*	0.008	0.01
	Iron (Filtered)	*0.3*	0.16	0.14
	Manganese (Filtered)	*1.9*	0.096	0.099
	Zinc (Filtered)	*0.0008*	*0.015*	*0.018*
Sample Quality Parameters (mg/L)	Nitrate (as N) (Filtered)	7	0.96	1.1
	Total Organic Carbon	-	3.8	3.3
TPH (mg/L)	TRH C_{15}-C_{28} Fraction	-	0.2	–
VOC (mg/L)	cis-1,2-Dichloroethene	-	0.0005	–

Notes: Italics criterion indicates aquatic ecosystems criterion. Underline indicate health based recreational waters criterion. " – " indicate criterion or result not available.

5.5 Quality Assurance and Quality Control

As per the requirements of the SAP (Golder, 2010), the following field QA/QC was conducted:

- three primary duplicate (intra-laboratory) and five secondary duplicate (inter-laboratory) samples
- 11 trip blank samples
- 24 equipment rinsate samples.

The result of QA/QC assessment is listed in Table 11. The results of field duplicate comparisons are included in Table K and the results of equipment rinsate samples and trip blank samples are included in Table L.

The QA/QC programme implemented for the GME was consistent with the guidelines outlined in the Golder SAP (Golder, 2010). Golder considers that based on the results from the QA/QC assessment that the data collected during the investigation are suitable for use.

Table 11: QA/QC Results

Item	Golder Objective	Summary of Results	Compliance
Calibration check of water quality meter	Ensure water quality meter is calibrated within acceptable limits	Some checks were outside acceptable limits	Yes, See Note 1
Chain of Custody Records	Completed in full	Completed in full, included in Appendix D.	Yes
Recovery and analysis of trip blanks	No contamination of blanks	No contamination of blanks (refer to Table L)	Yes
Recovery and analysis of equipment rinsate samples	No contamination of rinsate samples	Some compounds detected above laboratory LOR (refer to Table L)	No, See Note 2
Recovery and analysis of duplicate samples	Collect replicate samples at a minimum rate of 10% and assess that RPDs are within ±30% for results >5 × LOR	Not all RPDs within ±30% for results > 5 × LOR (refer to Table K).	No, See Note 3
NATA-certification and approved analytical methods	Comply with reference	Comply with reference	Yes
Sample preservation and holding times	Comply with reference	Comply with reference	Yes
Analysis of laboratory method blanks	No contamination of blanks	No contamination of blanks	Yes
Analysis of laboratory duplicates	RPDs with laboratory's acceptable range	Comply in full	Yes
Analysis of surrogate and spike recoveries	Percentage recovery within laboratory's acceptable range	Surrogate recoveries within acceptable limits	Yes
Frequency of Laboratory Duplicate Samples	Frequency ≥ 10%	Frequency ≥ 10%	Yes
LORs	LORs were below the adopted screening guidelines	LORs were below RBC values.	Yes

Table Notes:

1) Daily calibration checks confirmed that the water quality meters were generally within acceptable limits. However, the start and end of day calibration checks for conductivity were outside the acceptable range on 12, 13, 19, 20 and 21 June 2017. The conductivity was recalibrated on 14 June 2017 for one YSI that remained within the acceptable range by the end of the day. Conductivity readings collected on this day were comparable to historical data; therefore, this is not considered to affect the outcomes of this investigation.

2) Aluminium, iron, nickel, total organic carbon, and 1,2-Dibromo-3-chloropropane were detected in at least one of the rinsate samples. An assessment of whether these rinsate detections affect the outcomes of the investigation can be made by comparison of the rinsate concentrations to relevant RBC. There are no RBC for total organic carbon or 1,2-Dibromo-3-chloropropane, therefore the detections of these analytes in rinsates does not affect the outcomes of this investigation. There are RBC for aluminium, iron and nickel, however the concentration detected in the rinsate samples are marginally above the laboratory LOR and hence several orders of magnitude below the RBC. Therefore, it is considered that the detections of these analytes in rinsates does not affect the outcomes of this investigation. On 21 June 2017 aluminium was detected in rinsate sample Q13013-08 (0.007 mg/L) at concentrations slightly above the LOR, and over an order of magnitude below the aluminium (filtered) detected in sample Q13013-01 (0.011 mg/L) that same day. These two results combined were orders of magnitude below the RBC for aluminium. On 19 June 2017 iron (0.01 mg/L) and nickel (0.001 mg/L) were detected in samples Q13006-09 and Q13006-10, respectively. Samples Q13006-02 (0.01 mg/L), Q13006-03 (0.98 mg/L) and Q13006-07 (21 mg/L) detected concentrations of iron (filtered) above the laboratory LOR that same day. These results combined were still orders of magnitude below the RBC for iron. Samples Q13006-02 (0.005 mg/L), Q13006-03 (0.002 mg/L), Q13006-04 (0.007 mg/L) and Q13006-07 (0.005 mg/L) detected concentrations of nickel (filtered) above the laboratory LOR that same day. Any of these results combined with the result in the rinsate would be orders of magnitude below the RBC for nickel. Due to the small detections in the rinsate, and the significant difference between detections of COPC's and the RBC, the decontamination procedure is considered adequate for the purposes of this investigation.

3) The duplicate frequency of ≥ 10% was not achieved for the June 2017 site-wide GME. A duplicate frequency of approximately 9.5% was achieved. Due to the small difference in planned duplicate sampling against the achieved outcome, this result is not considered to significantly affect the outcome of the investigation. Several RPD exceedances (>30%) were also noted and are summarised below. Where higher concentrations have been noted for triplicate samples compared to the primary sample, although both concentrations are considered, the higher concentration has been adopted for calculations when interpreting the results as a conservative approach.

   a) PFAS: Elevated RPDs were noted for the primary and primary duplicate samples from MWG84 for PFOS (67%), PFHxS (33%), PFBA (93%), and 6:2 FTSA (82%). Of these analytes, PFOS is the only analyte with an assessment criterion (for the protection of aquatic ecosystems). The concentration in both the primary and duplicate samples was below this criterion. Therefore, this RPD exceedence is noted. The remainder of the PFAS compounds do not have assessment criteria, therefore, they are not considered to affect the outcome of the monitoring event.

   b) TOC: Elevated RPDs were noted for MWG84 (62%), MW25 (130%), and MW24 (133%) between the primary and secondary duplicate samples. The exceedances have been noted, however, they are not considered to affect the outcome of the monitoring event given that there is no criteria value for total organic carbon.

   c) Vinyl chloride: Elevated RPDs were noted for the primary and secondary duplicate samples from MWG84 (55%). The primary sample concentration exceeds the RBC for Lot 2 whereas the secondary duplicate concentration is below the RBC. Therefore, although there is an elevated RPD for this analyte, the primary sample result is adopted for the assessment and is more conservative (as the concentration is higher). The elevated RPD is not considered to affect the outcome of the monitoring event.

d) Vinyl bromide: Elevated RPDs were noted for the primary and secondary duplicate samples from MWG84 (160%). The primary sample was an order of magnitude higher compared with the secondary duplicate sample. Nether the primary or secondary duplicate sample concentration exceeded the RBC for this analyte. Therefore, the primary sample result is adopted for the assessment and is more conservative (as the concentration is higher). The elevated RPD is not considered to affect the outcome of the monitoring event.

6.0 DISCUSSION

6.1 Concentration Trends

Assessment of analytes with an increasing concentration trend was undertaken to understand, if possible, what mechanism was involved in the increasing trend, i.e. was it a result of degradation or is there potentially another reason for the increasing trend.

As listed in Table 5, Table 6, Table 7, and Table 9, the majority of the increasing trends were observed for either chlorinated ethenes (VC, cDCE or TCE) across the Study Area, or the majority of wells on site for MAHs. Increasing trends were also observed for chlorinated benzenes (chlorobenzene or dichlorobenzene isomers) and TPH C_6-C_9, in some wells, however, these were considered to be limited in occurrence compared with chlorinated ethenes.

The majority of increasing concentration trends occurred for wells screening the Regional Watertable (Guildford Formation and Alluvium). This is likely due to groundwater impacts being predominantly present within this aquifer.

A discussion of the trends for chlorinated ethenes and MAHs, focussing on impacts within the Regional Watertable, is included in the following subsections.

6.1.1 Chlorinated Ethenes

The wells with increasing or decreasing concentration trends for either VC, cDCE, TCE or PCE are listed in Table 12. The total molar Mann-Kendall trend was also calculated to evaluate whether there was evidence of overall mass reduction for these VOCs through natural attenuation. The molar concentration trend for the wells listed in Table 12 is shown in Figure B to Figure E and supporting work for Mann-Kendall analysis is included in Appendix E.

Table 12: Chlorinated Ethene Trends

Zone	Well	VC	cDCE	TCE	PCE	Total Molar
Hanson	MWG64	Decr.	Decr.	Stable	Stable	Decr.
Site	MW21i	No Trend	Decr.	Decr.	Decr.	Prob. Decr.
	MW22i	No Trend	Incr.	Decr.	Decr.	Incr.
	MW23i	Decr.	No Trend	No Trend	No Trend	Stable
Immediately off-site (Lot 2 and Oliver St)	MW42	No Trend	Decr.	Decr.	Decr.	Decr.
	MWG51	No Trend	No Trend	Prob. Incr.	Prob. Decr.	No Trend
	MWG54	No Trend	No Trend	Decr.	Decr.	Decr.
Lot 2	MW37	No Trend	No Trend	No Trend	Incr.	No Trend
	MWG59	Incr.	No Trend	Decr.	Decr.	Prob. Incr.
	MWG84	Prob. Incr.	Prob. Decr.	Decr.	Decr.	Decr.
Damplands	MWG62	Stable	Stable	Incr.	Incr.	Incr.
	MWG63	No Trend	No Trend	Stable	Incr.	Stable
	MWG66	Incr.	Incr.	Incr.	Stable	Incr.

For many of the wells, the trends were decreasing, stable or returned no trend.

Regarding the increasing total molar trends, the following is noted:

- Site: The increasing total molar trend within MW22i is due to degradation of cDCE to VC (Figure B). Elsewhere on-site (MW21i and MW23i) there is indicated to be an increase in VC concentration due to cDCE degradation (Figure B) but the total molar trend is either stable or no trend.
- Immediately off-site: Either a decreasing or no total molar trend was indicated (Table 12). Generally, concentrations are low and indicate an overall decrease with time (Figure C). The exception is TCE at MWG51 which has increased in molar mass between 2005 and 2017. However, concentrations have been more than an order magnitude lower than the RBC and the last two monitoring rounds have recorded a decrease from the maximum measurement in 2011. More importantly, these wells are immediately adjacent to the site boundary and do not indicate migration of site impacts off-site.
- Lot 2: Well MWG59 is indicated to have an increasing total molar trend. Well MWG84 is also indicated to have a probable increase in VC (Figure D); however, the Mann-Kendall trend was calculated to be no trend. The recent results in MWG37 indicate an increase in PCE compared with results prior to 2015 which were below detection, however the concentration and total molar mass is relatively low compared with MWG59 and MWG84.
- Damplands: Wells MWG62 and MWG66 are indicated to have an increasing total molar trend (Table 12). Within MWG62, this is predominantly due to an increasing TCE concentration trend (Figure E). The increase in PCE concentration at MWG63 is considered marginal from 0.001 mg/L in 2008 to 0.004 mg/L in 2017. Both MWG62 and MWG63 are both located upgradient from the PRB and are influenced by the altered groundwater flow direction from the PRB (refer to Section 5.2). Recent result for MWG62 indicate that this trend may have stabilised. The trend in MWG66 has been observed in previous monitoring events and is inferred to be associated with a slight change in groundwater flow direction. Notwithstanding, recent concentrations indicate a decrease compared with 2015 results.

The chlorinated ethene impacts observed, and the pattern of degrading parent compounds to daughter compounds, are consistent with historical distribution of these compounds at the site, Lot 2 (south-western portion) and the Damplands. The exceedance of RBCs within the site, Lot 2 (south-western portion), and the Damplands due to concentrations of VC means that there would be a potential risk to human health if groundwater was extracted for the purposes of filling a swimming pool; however, the RBC for vapour intrusion to indoor air was not exceeded.

Summary of Chlorinated Ethene Concentration Trends

Increasing chlorinated ethene concentration trends were observed in some wells within the Study Area. This increasing trend was predominantly due to increases in VC, and in some wells cDCE, as a result of degradation of TCE.

The impacts observed are considered to be consistent with the historical distribution.

Chlorinated ethene concentrations have resulted in the exceedance of RBCs within the site, Lot 2 (south-western portion), and the Damplands. The RBCs exceeded are for human health as a result of groundwater extraction, however the RBCs protective of human health for vapour intrusion to indoor air were not exceeded. Therefore, it is likely that a restriction on groundwater extraction would apply.

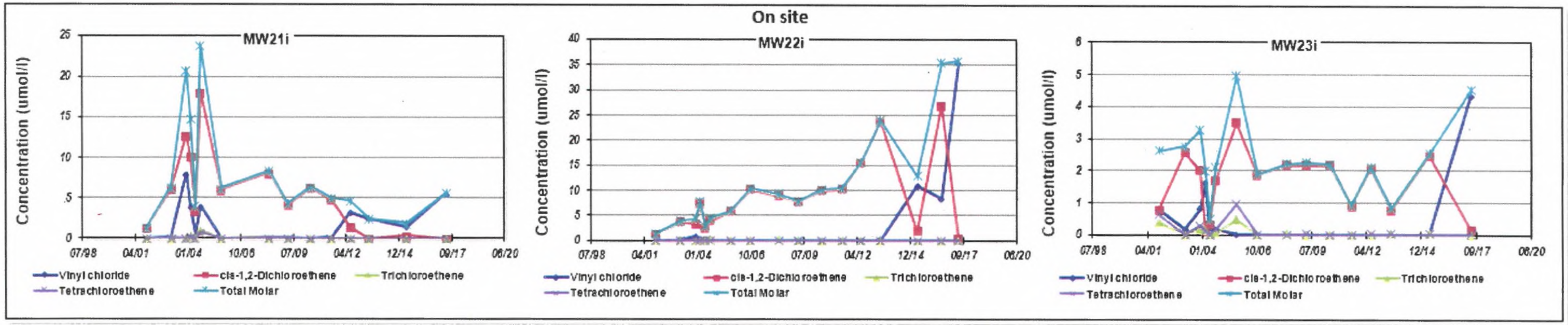

Figure B: Concentration Trend of VC, cDCE, TCE, and PCE – Site Wells (MW21i, MW22i, MW23i)

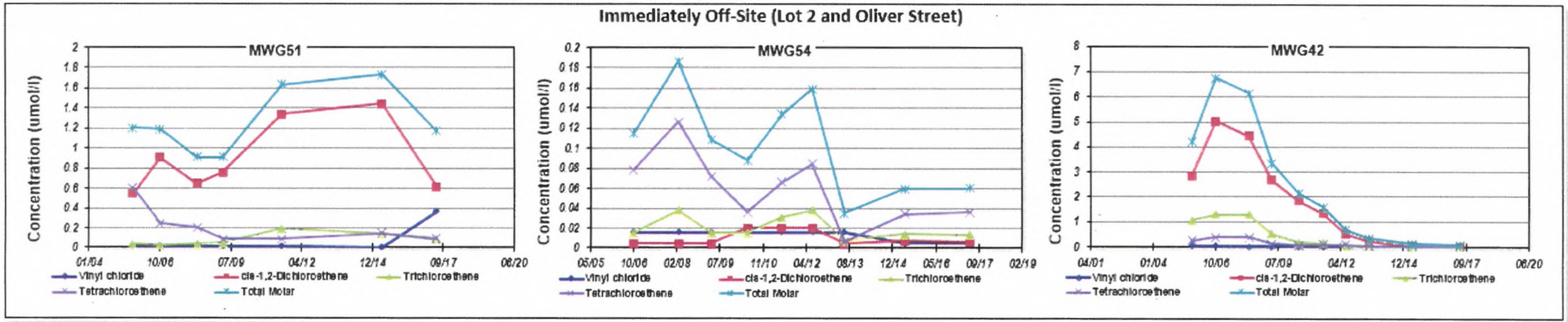

Figure C: Concentration Trend of VC, cDCE, TCE, and PCE – Immediately off-site (Lot 2 and Oliver St) (MWG42, MWG51, MWG54)

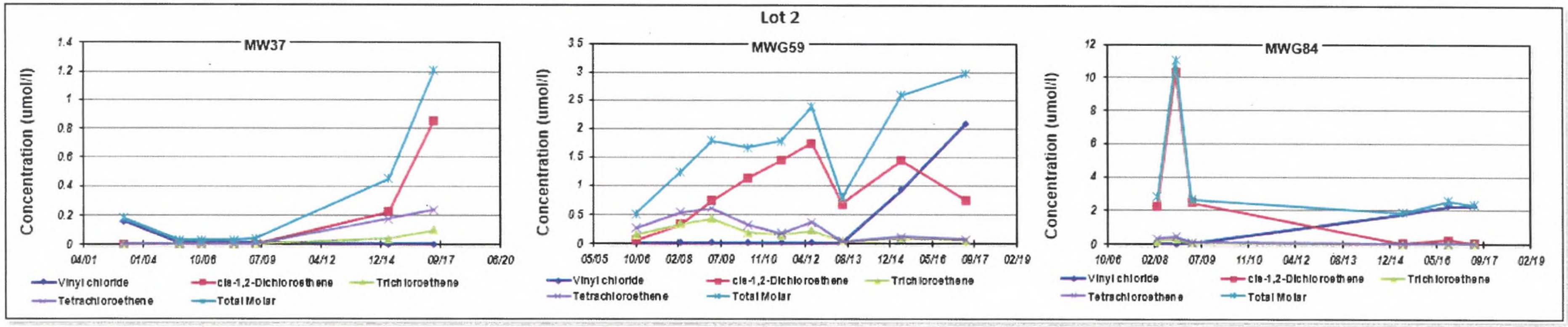

Figure D: Concentration Trend of VC, cDCE, TCE, and PCE – Lot 2 Wells (MW37, MWG59, MWG84)

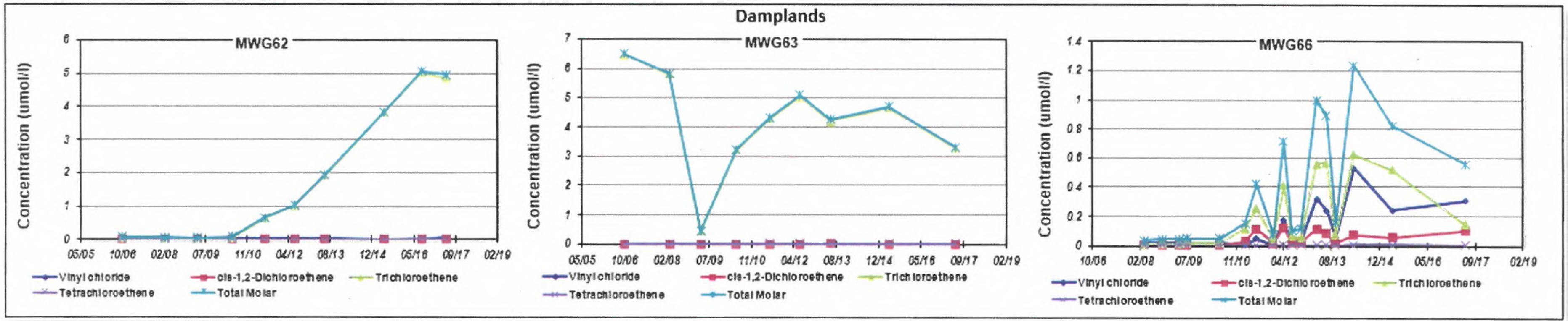

Figure E: Concentration Trend of VC, cDCE, TCE, and PCE – Dampland Wells (MWG62, MWG63, MWG66)

6.1.2 MAHs

The concentration trend of site monitoring wells is listed in Table 13 and shown in Figure F. Elsewhere within the Study Area the concentration of BTEX were generally either below the laboratory LOR or generally an insufficient number of results to conduct a Mann-Kendall trend analysis.

Table 13: MAH Concentration Trends – Site Wells

Well	Benzene	Toluene	Ethylbenzene	Xylenes	Total BTEX
MW21i	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing
MW22i	Stable	No Trend	Increasing	Prob. Increasing	Prob. Increasing
MW23i	Stable	Decreasing	No Trend	Decreasing	Decreasing
MW37	Prob. Decreasing	Prob. Decreasing	Prob. Decreasing	Prob. Decreasing	Prob. Decreasing
MW39	Stable	Stable	Stable	Stable	Stable
MW42	Prob. Decreasing	Prob. Decreasing	Prob. Decreasing	Prob. Decreasing	Prob. Decreasing
MWG49	No Trend	No Trend	Prob. Decreasing	Prob. Decreasing	Stable
MWG54	Prob. Decreasing	Prob. Decreasing	Prob. Decreasing	Prob. Decreasing	Prob. Decreasing
MWG57	Prob. Decreasing	Prob. Decreasing	Prob. Decreasing	Prob. Decreasing	Prob. Decreasing
MWG59	Increasing	Prob. Decreasing	Prob. Decreasing	Prob. Decreasing	Stable
MWG84	Stable	Stable	Prob. Decreasing	No Trend	Stable
MWG91A	No Trend	No Trend	Prob. Decreasing	Prob. Decreasing	Stable
MWG51	Stable	Decreasing	Decreasing	Decreasing	Decreasing
MWG70	Prob. Decreasing	Prob. Decreasing	Prob. Decreasing	Prob. Decreasing	Prob. Decreasing
MWG62	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing
MWG63	Prob. Decreasing	Prob. Decreasing	Prob. Decreasing	Prob. Decreasing	Prob. Decreasing

The concentration trend results indicate that there is an increasing trend of ethylbenzene and a probable increasing trend of xylene in MW22i, overall there is a probably increasing trend for total BTEX. The concentration trend within MW22i also indicates that there has been an increasing trend since approximately 2012, albeit that the most recent result indicates a decrease compared with the 2015 and 2016 results. Notwithstanding, the results from MW21i and MW23i indicate a decreasing trend since approximately 2004. The relatively recent increasing trend within MW22i also coincides with the increasing trend of chlorinated ethenes in this well (Figure B).

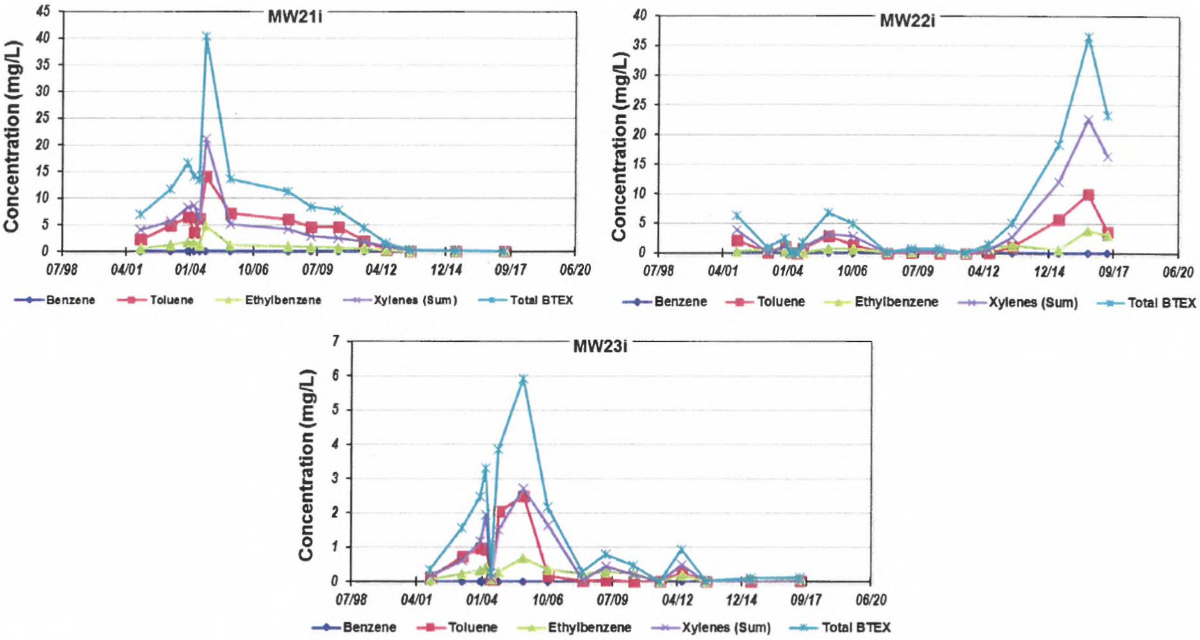

Figure F: Concentration Trend of BTEX in Site Wells (MW21i, MW22i, MW23i)

The mechanics of the concentration increase within MW22i are not known, i.e. potential sources (i.e. USTs) of contamination on-site have been decommissioned and the site is no longer operational. However, it has been hypothesised that contamination historically present within the unsaturated zone above the Regional Watertable migrated downward into the Regional Watertable via areas on-site where the clay confining unit (that separates the unsaturated zone and the Regional Watertable) is absent or thin. Golder characterised the clay thickness on-site (Golder, 2009e), which indicated that in the vicinity of MW22i, the clay confining layer thins and may be absent.

Notwithstanding the above, MAH concentrations do not exceed RBC.

Summary of MAH Concentration Trends

On-site well MW22i is indicated to have an increasing concentration trend of ethylbenzene. Concentrations of BTEX in this well indicate a general increase since approximately 2012, however, the 2017 result has decreased compared with 2015. Wells MW21i and MW23i indicate that concentrations have remained low since a peak around 2004.

The mechanism for the increase in MW22i is not known however it may be due to a pathway through thin or absent clay layer that provides separation between the contaminated upper unsaturated zone and the Regional Watertable.

Overall, the BTEX results do not exceed RBCs and therefore do not indicate a potential risk.

6.2 Distribution of PFAS

As described in earlier sections, PFAS were detected in most wells at the site. The inferred source of PFAS detected on-site is the historic firefighting activities that occurred on-site, however, analysis of the composition of PFAS within each well across the Study Area can indicate if impacts from site have migrated elsewhere within the Study Area or if there are other unknown sources.

The composition of PFAS in each well is shown in Figure G to Figure M, where each Figure represents an area within the Study Area. The composition is depicted by the percentage of each PFAS within a well. By displaying the PFAS in this manner, the individual compounds can be identified that form the majority of the composition. The concentration for PFAS that constitute the majority of the composition, and the total PFAS concentration, are also shown, except for Figure L (PRB) as there are too many wells and the concentrations would not be discernible on the figure.

Wells upgradient of the site, MWG45 and MWG46, are shown in Figure G. These results indicate that the majority of the composition for both wells is PFHxS with minor components of PFHxA, PFOA, and PFOS. The concentration is also at least an order of magnitude higher in the deeper Leederville formation (MWG45) compared with the monitoring well screening the Base of the Guildford formation (MWG46).

Adjacent to the site on the Hanson property, the well screening the Regional Watertable (MWG64) is predominantly PFPeA with a minor amount of PFHxA and is more consistent with impacts observed on the site. In comparison, the well screening the Base of the Guildford formation (MWG56) on the Hanson Property is predominantly PFHxS, which is consistent with the upgradient well and is likely to represent a background composition for the area.

Results from monitoring wells on the site are shown in Figure H. The composition for wells screening the Regional Watertable (MW21i, MW22i, MW23i) are relatively similar and are predominantly PFBA, PFPeA, PFHxA, PFHpA, and 6:2 FTSA. PFHxS also forms a main component within MW23i which may indicate some mixing with impacted upgradient groundwater. Overall, it is inferred that the composition observed on site for the Regional Watertable wells is a result of the historical activities that occurred at the site, i.e. firefighting.

The results for wells on the site that screen the Base of the Guildford formation are predominantly PFHxS and are more in line with the composition observed in the MWG46, which is hydraulically upgradient of the site. However, the overall total PFAS concentration is at least an order of magnitude lower compared with the wells screening the Regional Watertable.

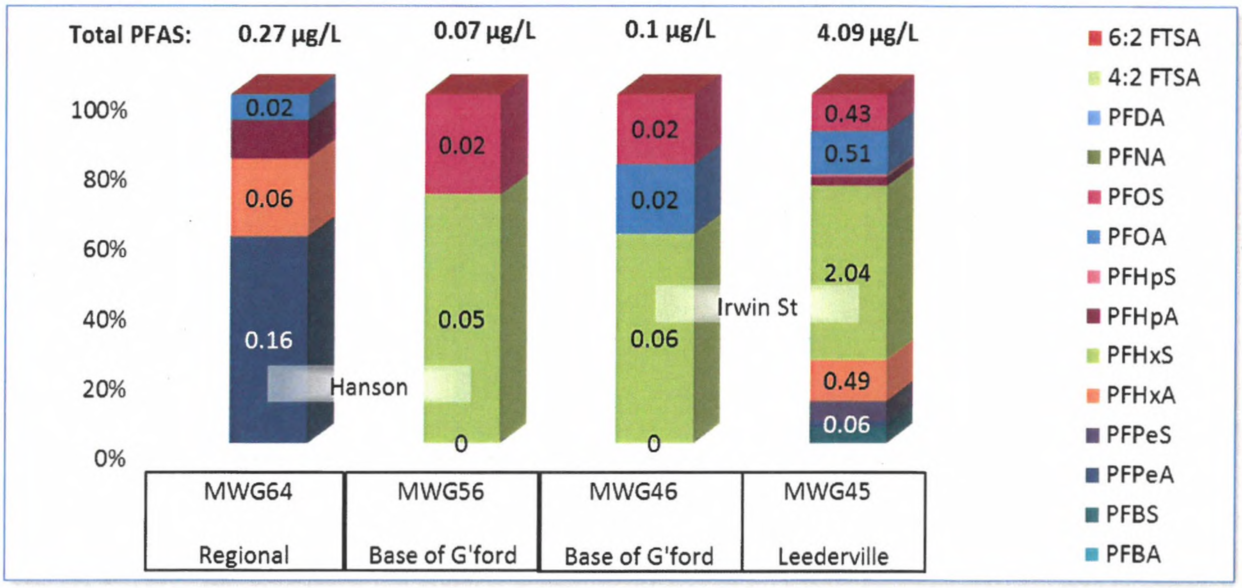

Figure G: Composition of PFAS – Upgradient (Irwin St) and Hanson

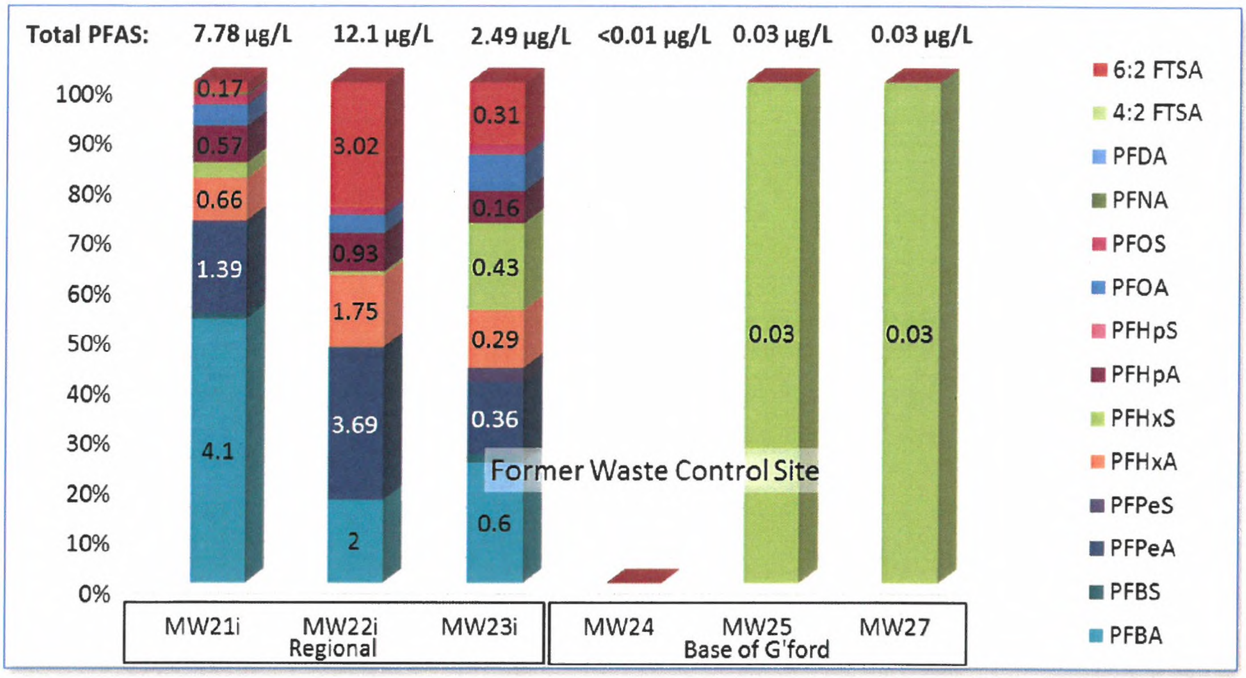

Figure H: Composition of PFAS – Site

Wells within the Southwest Industrial Area are shown on Figure I. These indicate that well MWG51 has a composition that is consistent with wells on-site which screen the Regional Watertable, and that well MWG69 is consistent with other wells that also screen the Base of Guildford formation and that are hydraulically upgradient of the site.

Wells within the Lot 2 area are shown on Figure J. The PFAS composition for wells screening the Regional Watertable (MW37, MW39, MW42, MWG49, MWG54, MWG57, MWG59, MWG84, MWG91A) are predominantly PFBA, PFPeA, PFHxA, PFHxS, and PFHpA. The composition and concentration are relatively consistent with wells on-site.

Wells screening the Base of the Guildford formation on Lot 2 have a slightly different composition and lower concentration compared with the Regional Watertable wells. The Base of the Guildford formation wells are predominantly PFHxS and PFOS, which is consistent with that observed in the wells screening the same aquifer positioned hydraulically upgradient of the site. Likewise, well MW38, which screens the Leederville formation, is generally consistent with the upgradient well MWG45.

Wells within the Damplands (Figure K) (excluding the wells associated with the PRB) generally screen the Regional Watertable or Alluvium. The PFAS results indicate that there is variation across the Damplands area. Wells MWG60, MWG66 and MWG90D are generally consistent with wells on-site, e.g. predominantly PFBA, PFPeA, PFHxA, and PFHxS, albeit at lower concentrations compared with on-site. Wells MWG124, MWG68, and MWG90 (A, B, and C) are also similar to wells on-site, however, they do not have PFBA present. The presence of PFHxS in these wells suggests some mixing with impacted groundwater with a composition similar to the upgradient wells. Other wells in the Dampland area are either predominantly comprised of PHFxS (MWG61, MWG62, MWG63, MWG67), PFOS (MWG125), or PFHxA (MWG36) and appear more related to groundwater compositions from wells that are hydraulic upgradient of the site.

Wells in close vicinity of the PRB (Figure L) indicate a generally consistent composition, which is similar to that observed on-site, with the general exception of the C series wells, e.g. MWG101C, which do not indicate the presence of PFBA. Although some evidence of mixing with impacted groundwater with a composition similar to the upgradient wells is evident. The D series wells indicate a composition that is generally inconsistent with the other PRB wells and appear to be consistent with other wells screening the Base of the Guildford formation and/or Leederville formation hydraulically upgradient of the site.

The two surface water samples obtained from the Helena River (Figure M) have a comparable composition and concentration. These results indicate a composition that is generally consistent with wells screening the Leederville formation in wells hydraulically upgradient of the site, e.g. predominantly PFHxS with minor components of PFBS, PFHxA, PFOA, and PFOS.

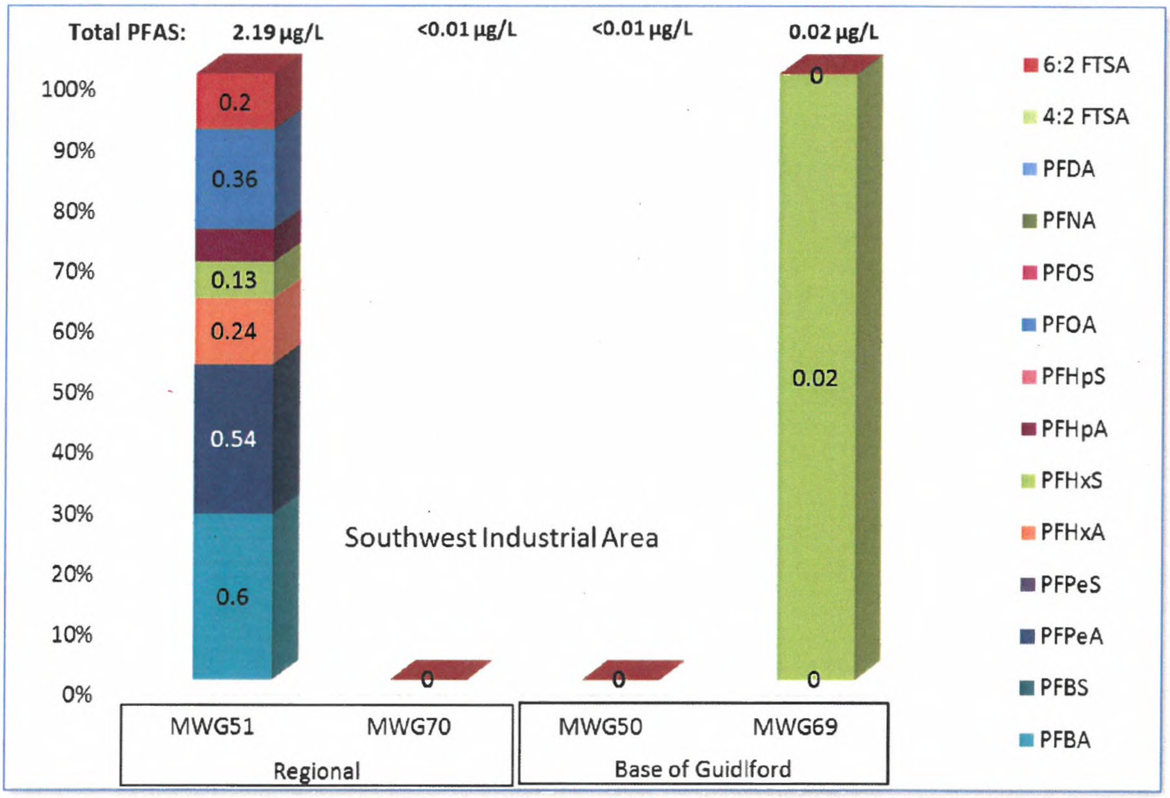

Figure I: Composition of PFAS – Southwest Industrial Area

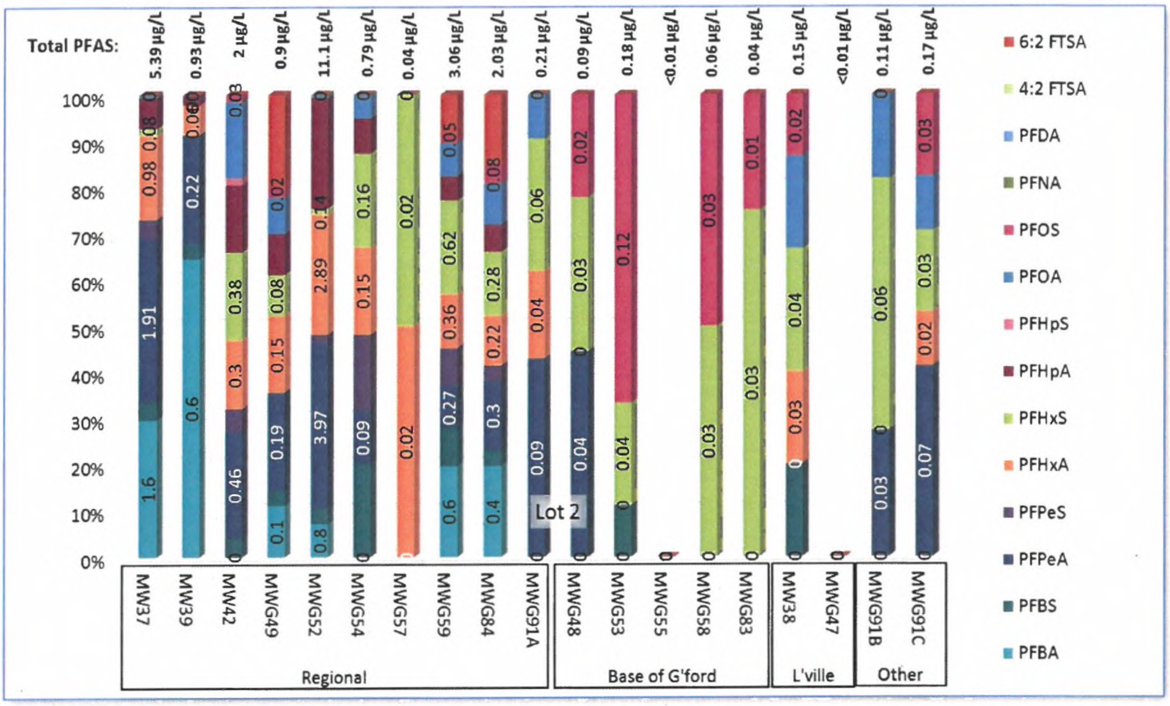

Figure J: Composition of PFAS – Lot 2

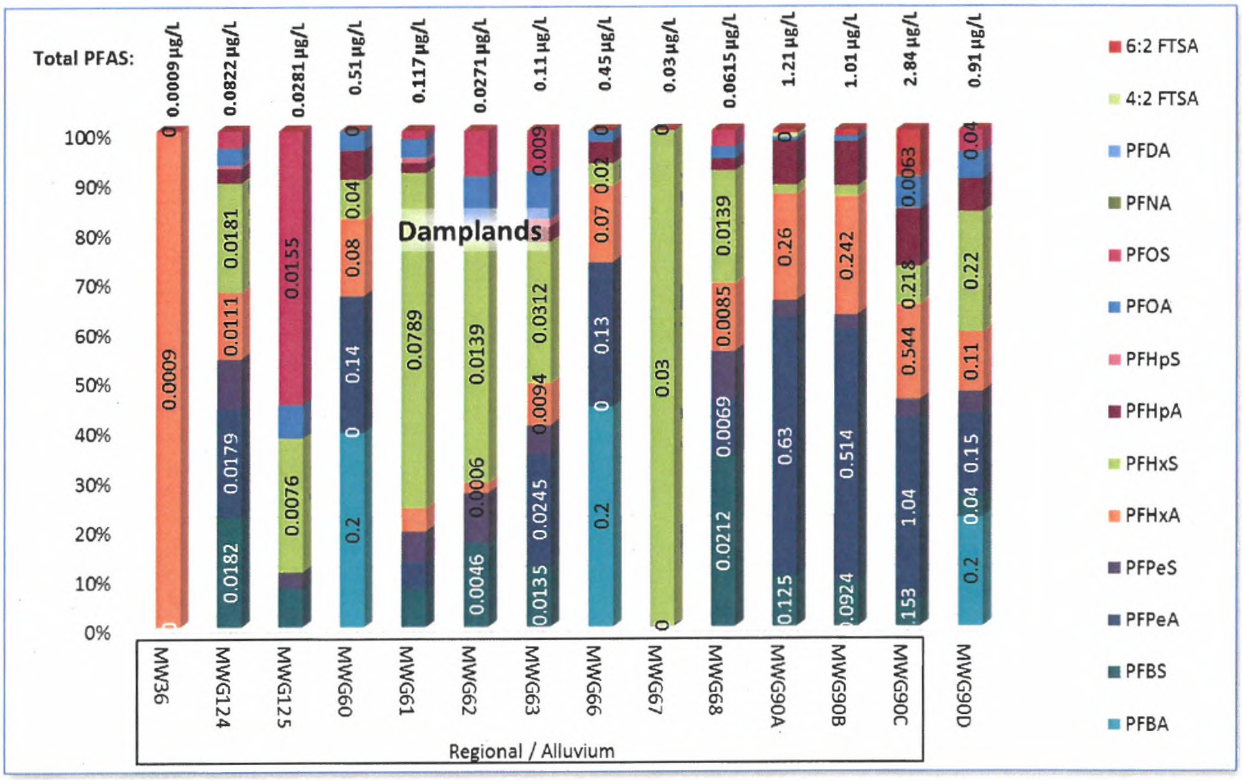

Figure K: Composition of PFAS – Damplands

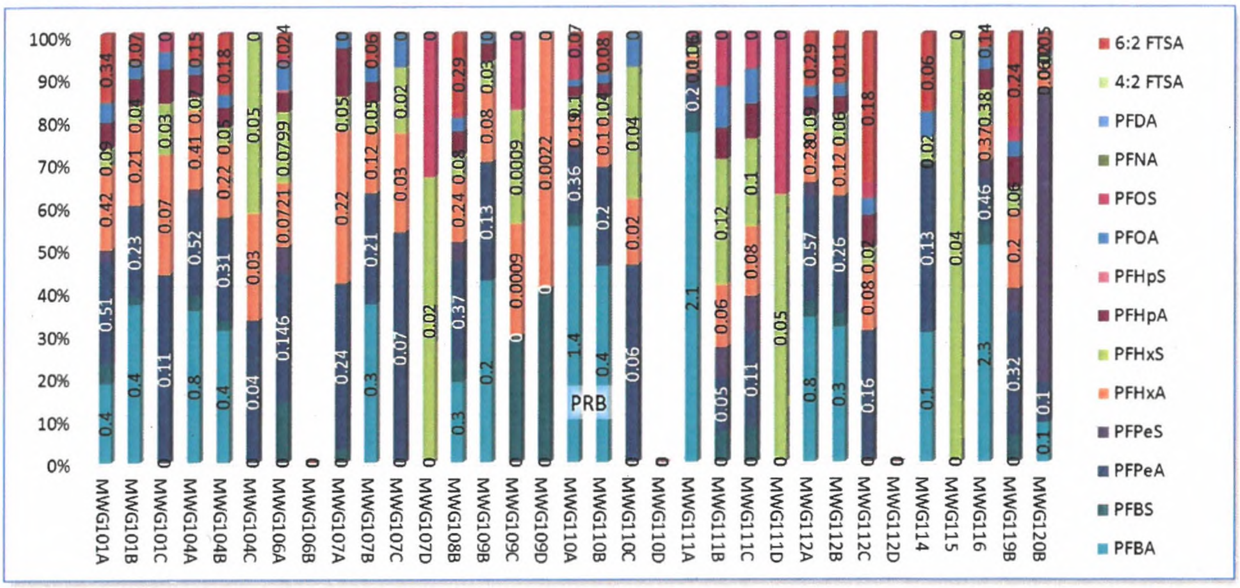

Figure L: Composition of PFAS – PRB

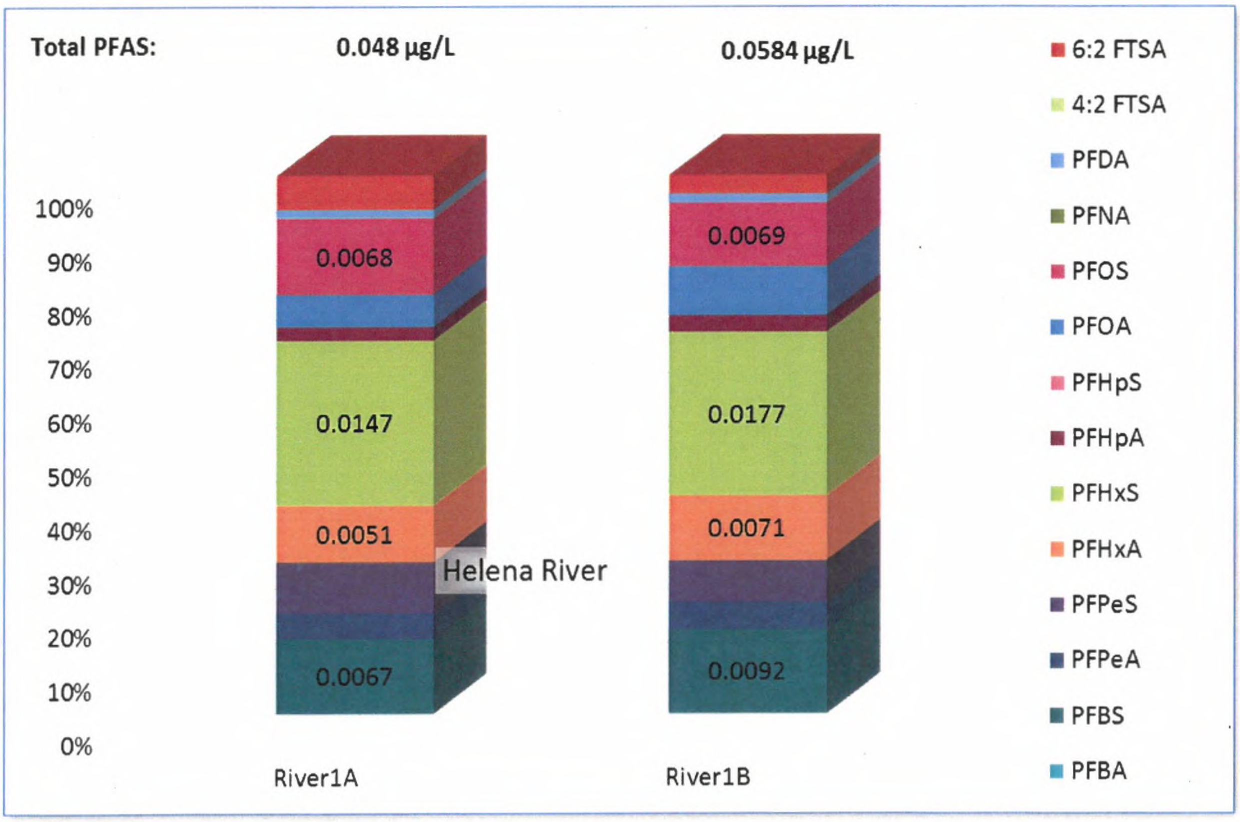

Figure M: Composition of PFAS – Helena River

Summary of PFAS Distribution

The composition of the PFAS results for the different areas within the Study Area were assessed to understand the distribution. There are consistent characteristic compositions within wells upgradient and on the Hanson property that screen the Base of Guildford formation or Leederville formation. This composition was different to that observed on-site. This composition is herein referred to as the 'background' upgradient composition and suggest that here is another upgradient source that is not related to the site.

The composition on-site in the Regional Watertable is also reflected in wells downgradient, including wells located on Lot 2, the Southwest Industrial Area, and in the Damplands. Minor variations were noted, including some wells in the Regional Watertable that did not detect PFBA, which was a major component on-site. The reason for the lack of PFBA is not known as the remainder of the composition in these wells was generally consistent with the composition in on-site Regional Watertable wells.

Comparison between the composition in background upgradient wells, site wells, and surface water from the Helena River is shown in Figure N. This indicates that sample results from the Helena River appear consistent with the results from the upgradient background monitoring well (MWG45) screening the Leederville formation, i.e. consistent with 'background'. This may indicate that there is regional discharge from the Leederville formation that is affecting the water quality in the Helena River.

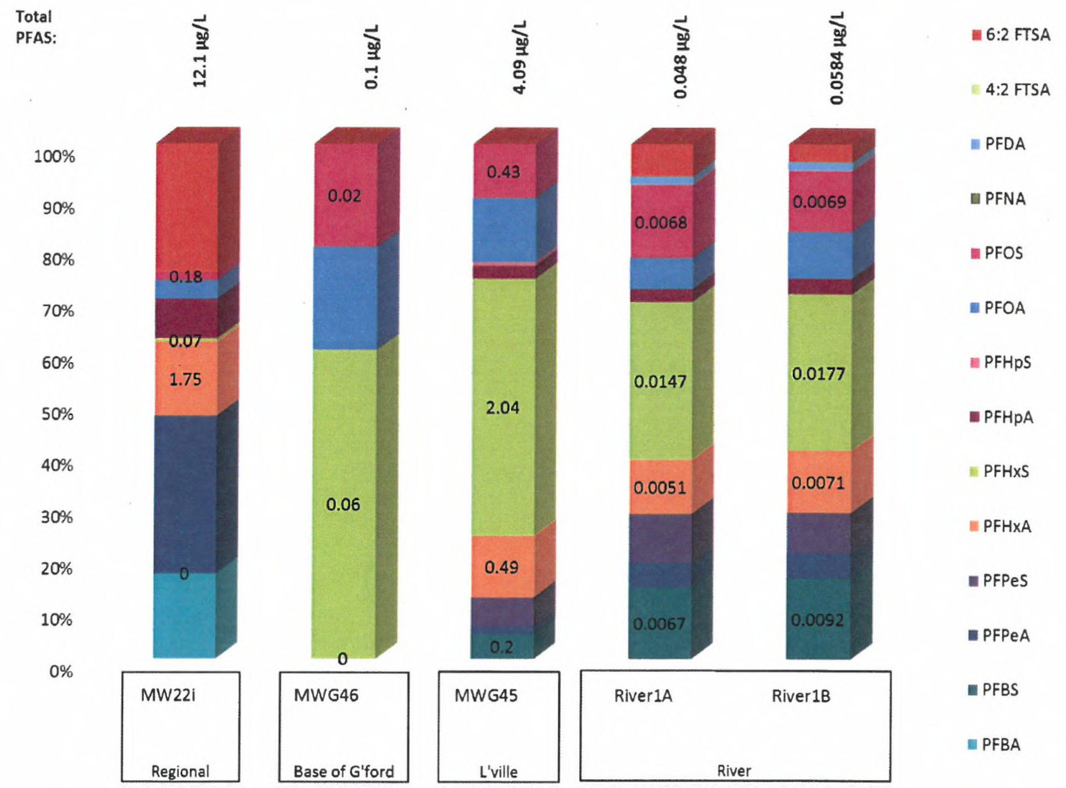

Figure N: PFAS Composition Comparison Between Upgradient, Site, and Helena River

Concentrations of PFAS exceeded assessment criterion for the protection of aquatic ecosystems (95% protection level) in three wells (MWG45, MW21i, and MWG110A), however concentrations in Helena River were below the criterion and, as noted above, the composition in Helena River does not reflect that observed in the Regional Watertable on the site. Assessment criterion protective of human health was also exceeded in an upgradient well that screens the Leederville formation (MWG45); however, based on the PFAS distribution assessment, these impacts are not indicated to be associated with the site.

6.3 Risk Posed by Groundwater Impact

6.3.1 Site

Exceedances of RBC were reported on-site for indoor air vapour intrusion (for chloroethane), and for exposure to outdoor worker/irrigation worker from extracted groundwater (for vinyl chloride and TPH C_{10}-C_{14}). These exceedances occur in wells screening the Regional Watertable (MW21i, MW22i, and MW23i), which is in the Guildford formation at the site. Due to these exceedances, groundwater extraction from the Regional Watertable would be precluded and a restriction on the extraction of groundwater would be required within the site boundary.

The exceedance of the vapour intrusion would indicate that management controls may be required for future constructions at the site, e.g. vapour barrier. However, soil vapour monitoring completed at the site in 2015 (Golder, 2016a) did not detect chloroethane above the laboratory LOR. The soil vapour monitoring was undertaken at multiple depths in the unsaturated zone above the clay layer that separates the unsaturated zone and the Regional Watertable. Note that groundwater RBCs were conservatively generated and did not consider the presence of the clay layer separating the unsaturated zone and the Regional Watertable, i.e. assumed the clay was not present. Therefore, although the groundwater concentration for chloroethane exceeds the RBC for groundwater, the soil vapour monitoring results indicate that the risk of exposure from groundwater to indoor air vapour intrusion is low.

Notwithstanding the above, groundwater analytical results indicate that chloroethane and some MAH compounds (toluene, ethylbenzene, and xylenes) have increased since 2013. Therefore, it is likely that groundwater monitoring will still be required at site.

Other compounds exceeding beneficial use assessment criteria included PFOS in MW21i and MW22i, which exceeded ecological criteria and the implications of this are discussed in Section 6.3.5.

6.3.2 Lot 2

Exceedances of RBC were reported on Lot 2 for outdoor worker/irrigation worker, i.e. direct contact exposure pathway from groundwater extraction. This indicates that groundwater extraction is precluded on Lot 2 and a restriction on the extraction of groundwater would be required within the property boundary. Other RBCs applicable to Lot 2, e.g. indoor air vapour intrusion, were not exceeded indicating that the only preclusion exists for groundwater extraction.

The groundwater wells where exceedances of the RBC were reported (MWG57, MWG84, MWG59) are located toward the southern end of Lot 2 and are inferred to be due to two different source zones. The impacts in MWG59 and MWG84 are inferred to be sourced from site whereas the impacts in MWG57 are associated with the off-site source zone located at the eastern end of Stanley St. The following is noted regarding these two separate sources:

- The on-site source impacts are observed in off-site monitoring wells MWG51, MWG54, MWG59, and MWG84. The concentration trend of chlorinated ethenes for these wells is shown in Figure C and Figure D. The trend in MWG51 and MWG54 is generally stable or decreasing. The trend observed in wells MW59 and MW84 is generally consistent, e.g. low concentration of TCE and relatively recent increasing concentration of cDCE or VC.
- The Stanley St source is observed in MWG57, MWG62, and MWG63. The concentration trend for MWG62 and MWG63 is shown in Figure E and is characterised by predominantly TCE (that has a higher concentration compared with the on-site source) and relatively low concentrations of VC and cDCE. The Stanley St source is currently undergoing bioremediation of TCE and this may influence the concentration of chlorinated ethenes degradation products (cDCE and VC).

Continued groundwater monitoring in this area of Lot 2 is likely required to assess the progress of the bioremediation and for the presence of degradation products. However, the data indicates that Lot 2 could be developed for commercial industrial use as long a groundwater extraction and use without treatment is prohibited.

6.3.3 Southwest Industrial Area

There were no analytes detected at concentrations exceeding the RBC that apply to the Southwest Industrial Area, being indoor air vapour intrusion and exposure to outdoor worker/irrigation worker from extracted groundwater. Therefore, it is indicated that these uses are not precluded based on the RBC derived.

6.3.4 Hanson Property

There were no analytes detected at concentrations exceeding the RBC that apply to the Hanson property, being indoor air vapour intrusion and exposure to outdoor worker/irrigation worker from extracted groundwater. Therefore, it is indicated that these uses are not precluded based on the RBC derived. However, there is a restriction on the abstraction of groundwater on Hanson property under their Contaminated Sites Classification (*Contaminated – Remediation Required*), which states: *groundwater abstraction is not permitted at these affected Parcels* (Hanson Property) *for the source site due to the nature and extent of groundwater contamination.*

6.3.5 Damplands and Helena River

Exceedances of RBC were reported on Damplands wells for outdoor worker/irrigation worker (direct contact exposure pathway from groundwater extraction), recreational swimmer (direct contact exposure pathway), and/or aquatic ecosystem screening criteria.

The exceedances of the RBCs for the groundwater direct contact exposure pathway were limited to two monitoring wells (MWG62 and MWG63), however, these exceedances indicate that groundwater is precluded for these uses within the Damplands.

The exceedances in MWG62 and MWG63 are located north of the PRB and are down-gradient of the off-site TCE source zone located at the eastern end of Stanley St. The Stanley St source is currently undergoing bioremediation of TCE and this may influence the concentration of chlorinated ethenes degradation products (cDCE and VC) in wells within the Damplands, particularly down-gradient of the source zone over the longer term. For example, recent sample result in MWG62 indicates an increase in the VC and cDCE concentration whereas TCE is indicated to be relatively stable. Therefore, there may be further increases in the VC and cDCE concentrations due to the continued bioremediation and this may affect RBC exceedances until the bioremediation system achieve full dechlorination.

The majority of exceedances were for aquatic ecosystems screening criteria, indicating a potential risk to the Helena River. These exceedances relate to concentrations of nitrate, aluminium, arsenic, total chromium, iron, and zinc. The concentrations of metals observed are generally consistent with background. Sampling results from locations along the Helena River, including up-river (historical and recent results), indicate a variation of up to an order of magnitude in concentrations of metals species, and consistent with the range measured in the Damplands; however, the nitrate concentration is relatively consistent in the river and lower than that measured in the Damplands. With the exception of zinc, concentrations of metals and nitrate within the river were below aquatic ecosystem screening criteria.

Other compounds exceeding beneficial use assessment criteria included PFOS in MWG110A, which exceeded ecological criteria. This is assessed in the context of the Damplands being immediately adjacent to the Helena River and, therefore, groundwater potentially discharging to the Helena River. Review of other PFOS results within the Damplands indicate that the concentration in MWG110A was the highest and most other results were either below the laboratory LOR or about an order of magnitude lower than MWG110A. Comparison of the PFAS composition in MWG110A with MW22i (on-site) indicates a composition that is more consistent with the site than that observed in upgradient wells (MWG45 and MWG46). This comparison is shown in Figure O. However, many of the other monitoring wells in the Damplands indicate a composition that is similar to the upgradient PFAS or a mixture of the both upgradient and the site (as discussed in Section 6.2).

The composition of PFAS impacts measured in the Helena River are consistent with upgradient, background groundwater impacts in the Leederville formation. They are not consistent with the PFAS compositions observed at the site. However, it is evident that PFAS from the site has migrated towards the river. This PFAS typically has a greater composition of short chain length PFAS for which there are currently no criteria. Notwithstanding this, the data indicate that PFAS from the site are not impacting on water quality within the Helena River at this time.

Overall, it is apparent that groundwater from the Damplands is not having a significant impact on the water quality in the Helena River at this time. Although it is noted that only two samples were collected from the Helena River at the end of the GME, and therefore the data should be interpreted with a degree of uncertainty.

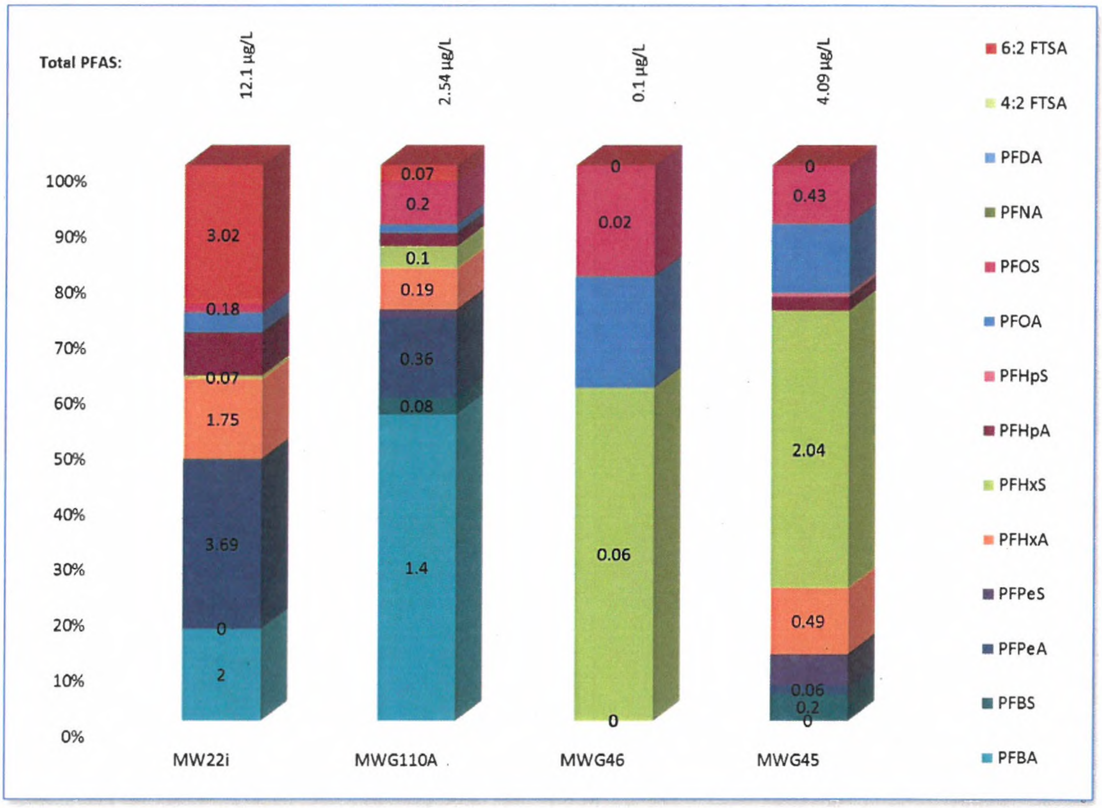

Figure O: Comparison of PFAS Composition (Damplands (MWG110A), Site (MW22i), and Upgradient (MWG45 and MWG46))

7.0 CONCLUSIONS

This report has presented the results of the 2017 groundwater monitoring event undertaken at the site and its surrounds. The GME included measuring of groundwater levels across the site and surrounds and sampling of 82 monitoring wells and two surface water sampling locations. The results from this groundwater monitoring programme are in general agreement with the results of previous GMEs.

The following is a summary of the results of the GME:

- Increasing chlorinated ethene concentration trends were observed in MW22i, MW37, MWG59, MWG62, MWG63, MWG66 and MWG84.

- On-site well MW22i is indicated to have an increasing concentration trend of chlorinated ethenes and MAHs. The mechanism for the increase is not known, however it may be due to a pathway through a thin or absent clay layer that provides separation between the contaminated unsaturated zone and the Regional Watertable.
- The PFAS composition was assessed across the Study Area. It was observed that there are consistent characteristic compositions within wells upgradient and on the Hanson property that screen the Base of Guildford formation or Leederville formation. This composition was different to that observed on-site and suggest that there is an upgradient source of PFAS. The composition on-site in the Regional Watertable was reflected in wells downgradient, including wells located on Lot 2, the Southwest Industrial Area, and in the Damplands. Comparison between the composition in wells upgradient, site and the Helena River indicated that the Helena River appears consistent with the Leederville formation, i.e. consistent with 'background'. This may indicate that there is regional discharge from the Leederville formation to the Helena River.

The assessment of risk posed by groundwater concluded the following:

- **Site:** Exceedances of RBC were reported within the Regional Watertable on-site for indoor air vapour intrusion (for chloroethane), and for exposure to outdoor worker/irrigation worker from extracted groundwater (for vinyl chloride and TPH C_{10}-C_{14}). Due to these exceedances, groundwater extraction from the Regional Watertable would be precluded. The exceedance of the vapour intrusion would indicate that management controls may be required for future constructions at the site, e.g. vapour barrier. However, previously completed soil vapour monitoring at the site did not detect chloroethane above the laboratory LOR. Therefore, although the groundwater concentration for chloroethane exceeds the RBC for groundwater, the soil vapour monitoring results indicate that it is likely that the risk of exposure from groundwater to indoor air vapour intrusion is low.
- **Lot 2:** Exceedances of RBC were reported on Lot 2 for outdoor worker/irrigation worker criteria, i.e. via a direct contact exposure pathway from groundwater extraction. This indicates that groundwater extraction is precluded on Lot 2 and a restriction on the extraction of groundwater would be required within the property boundary, i.e. the data indicates that Lot 2 could be developed for commercial industrial use as long a groundwater extraction and use without treatment is prohibited.
- **Southwest Industrial Area:** There were no analytes detected at concentrations exceeding the RBC for indoor air vapour intrusion and exposure to outdoor worker/irrigation worker from extracted groundwater. Therefore, these uses are not precluded based on the RBC derived.
- **Hanson:** There were no analytes detected at concentrations exceeding the RBC for indoor air vapour intrusion and exposure to outdoor worker/irrigation worker from extracted groundwater. Therefore, these uses are not precluded based on the RBC derived. However, there is a restriction on the abstraction of groundwater on Hanson property under their Contaminated Sites Classification.
- **Damplands and Helena River**: Exceedances of RBC were reported on Damplands wells for outdoor worker/irrigation worker (direct contact exposure pathway from groundwater extraction), recreational swimmer (direct contact exposure pathway), and/or aquatic ecosystem screening criteria. These exceedances indicate that extractive uses of groundwater is precluded within the Damplands. The majority of exceedances were for aquatic ecosystems screening criteria, indicating a potential risk to the Helena River. However, comparison of historical and recent results both up- and down-river with the Damplands groundwater results indicates a variation of up to an order of magnitude in concentrations of metals species, and consistent with the range measured in the Damplands, however, the nitrate concentration is relatively consistent in the river, below applicable criteria, and lower than that measured in the Damplands. Therefore, it is considered that the concentrations in the river are generally consistent with background concentrations. It is noted that only two samples were collected from the Helena River at the end of the GME, and therefore the data should be interpreted with a degree of uncertainty.

PFOS also exceeded ecological criteria within one well (MWG110A) within the Damplands, indicating a potential risk to the Helena River where groundwater discharge occurs. Comparison of the PFAS composition in MWG110A with on-site indicates a composition that is more consistent with the site than that observed in upgradient wells. However, many of the other monitoring wells in the Damplands indicate a composition that is similar to upgradient or a mixture of the both upgradient and the site. The composition of PFAS impacts measured in the Helena River are consistent with upgradient, background groundwater impacts in the Leederville formation; they are not consistent with the PFAS compositions observed at the site. Notwithstanding that PFAS from the site has migrated towards the river, the data indicate that PFAS from the site are not impacting on water quality within the Helena River at this time.

8.0 IMPORTANT INFORMATION ABOUT YOUR REPORT

Your attention is drawn to the document titled – "Important Information Relating to this Report", which is included in Appendix F of this report. The statements presented in that document are intended to inform a reader of the report about its proper use. There are important limitations as to who can use the report and how it can be used. It is important that a reader of the report understands and has realistic expectations about those matters. The Important Information document does not alter the obligations Golder Associates has under the contract between it and its client.

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