REPORT

Groundwater Treatment Plant - March 2020 Biannual Groundwater and Surface Water Monitoring Report

Orica Botany Environmental Survey Stage 4 - Remediation

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EXECUTIVE SUMMARY

This report presents the results of groundwater and surface water data collected for the March 2020 biannual monitoring event as part of the Groundwater Treatment Plant (GTP) – Groundwater and Surface Water Monitoring Program. The scope of services of the March 2020 monitoring program is intended to fulfil the requirements of a biannual sampling event as specified in the 2017-2020 GTP Groundwater and Surface Water Monitoring Program (Golder 2017b). The March 2020 biannual assessment considers the preceding six months (i.e. September 2019 through February 2020 inclusive) of continuous hydraulic data. In March 2020 a scheduled maintenance shutdown was conducted at the GTP. As a result, sampling for the March 2020 program was conducted in April 2020.

Hydraulic Monitoring

A detailed assessment of hydraulic containment at the Botany Industrial Park (BIP), Primary Containment Area (PCA) and Secondary Containment Area (SCA) containment lines was undertaken by JBS&G (2012) using the approach presented in: *A Systematic Approach for the Evaluation of Capture Zones at Pump and Treat Systems* by the United States Environment Protection Agency (USEPA, 2008b). Golder updated this assessment to incorporate more recent hydraulic and chemical monitoring data in September 2013 (Golder, 2013e). The assessments concluded that effective hydraulic containment was being achieved at the containment lines and that the remedy objective of the Botany Groundwater Cleanup (BGC) Project “to achieve protection for slightly to moderately disturbed ecosystems using the Australian and New Zealand Guidelines for Marine and Fresh Water (ANZG, 2018))” in surface water at Penrhyn Estuary was also being achieved.

Assessment of hydraulic data for the March 2020 monitoring event, with consideration of the six-step evaluation approach adopted by JBS&G (2012) and Golder (2013e), indicates that although some inconsistencies in hydraulic containment were noted, in particular at the SCA, the overall BGC Project remedy objectives were met during this period.

With the exception of parts of the SCA, groundwater levels were generally lower than during the previous monitoring period (i.e. September 2019), predominantly as a result of consistently lower than average rainfall. Lower groundwater extraction rates associated with reduced pumping performance and efficiency caused by well biofouling and the failure of EWF28D at SCA was also evident.

Overall, effective hydraulic containment at BIP and within the target capture zones of the intermediate and deep aquifers at PCA was evidenced by the averaged groundwater flow pattern and the achievement of target water levels for the monitoring period.

Elevated groundwater levels at the SCA do not support consistent hydraulic containment of the target capture zones at the SCA. Evidence of hydraulic containment on the basis of reverse hydraulic gradients was apparent in the shallow aquifer of the SCA and intermediate aquifer in the eastern and western portion of the SCA. A flat hydraulic gradient can be inferred in water levels achieved in the intermediate aquifer within the central portion of the SCA. However, elevated averaged groundwater levels were particularly evident in the eastern portion of the deep aquifer at SCA where the failure of extraction well EWF28D in April 2019 has reduced groundwater extraction efficiency.

Assessment of contaminant concentrations at Springvale Drain and Penrhyn Estuary, located downgradient of the SCA, indicates that the BGC Project remedy objectives continue to be achieved, noting the expected lag for CHC migration due to the relatively flat hydraulic gradient between the SCA and Penrhyn Estuary.

It should also be noted that the slow migration rates between the SCA and Penrhyn Estuary allow for potential recapture of CHCs that migrate beyond the SCA during periods or poor hydraulic containment.

Well rehabilitation works and the planned installation of two deep extraction wells (EWF25D and EWF28D) in June 2020 (pending regulatory approval) are expected to improve pump performance and contaminant recapture within the eastern portion of the SCA. In addition, pump performance and hydraulic containment are expected to improve following the maintenance operations completed as part of the scheduled GTP shutdown in March 2020.

Chemical Monitoring

The March 2020 sampling program represents a biannual monitoring event focused on assessment of volatile chlorinated hydrocarbon (CHC) concentrations in pore water, groundwater and surface water at Penrhyn Estuary and surface water at Springvale Drain and Floodvale Drain. Groundwater sampling was undertaken at key locations downgradient of the SCA in order to supplement the dataset that will be used to assess contaminant trends in the annual/biennial monitoring reports.

A parametric test has been used to identify increasing/decreasing trends in contaminant concentrations at sampling locations.

Penrhyn Estuary Groundwater

Reported CHC concentrations at BP01, BP117, MWF15, MWF17, MWF18 and MWF19 located on the shoreline of Penrhyn Estuary can be generally characterised by stable or decreasing trends in most CHC concentrations.

Increasing CHC contamination trends (both long- and short-term trends) are noted at MWF15D for EDC; at MWF17S for EDC and CFM; at MWF19I for EDC and CFM; and at MWF18D for EDC, PCE, TCE, CFM and VC, however these are not considered to represent a significant change in contaminant distribution.

An historical maximum concentration was reported for TCE at MWF18D. The increasing trend of TCE in the deep aquifer at MWF18 potentially represents limited migration of groundwater containing higher concentrations of dissolved phased TCE associated with the Southern Plumes within and upgradient of the central portion of the SCA. TCE was not detected in downgradient surface water monitoring locations, however consideration is being given to the augmentation of the monitoring program downgradient of this location to ensure adequacy of coverage within Penrhyn Estuary.

An historical maximum concentration was reported for PCE at BP117. CHC concentrations are historically highly variable at this monitoring location and consistent with or lower than those reported at downgradient monitoring locations. These increases potentially represent remnant Southern Plumes contamination being flushed from the generally stagnant area by the heavy rainfall in February 2020 or a result of inconsistent hydraulic containment.

The overall CHC concentrations within this area remain significantly lower than historical concentrations reported prior to operation of the SCA and the downgradient CHC concentrations in surface water remain low. Furthermore, the planned installation of new and replacement extractions wells (EWF25D and EWF28D) is expected to improve hydraulic containment of the eastern portion of the SCA, upgradient of this location.

Continued monitoring of this location in consideration of the downgradient pore water transect locations is required to ensure the remedy objectives of the BCG at Penrhyn Estuary continue to be met.

Penrhyn Estuary Pore Water

In general, the March 2020 Penrhyn Estuary pore water data are consistent with previous monitoring rounds with the concentrations of the chemicals of potential concern (CoPC) generally decreasing with decreasing depth towards the discharge interface.

The concentrations of the key contaminants of concern in pore water reported in the March 2020 monitoring round are less than the ANZG (2018) Trigger Values for all samples with the exception of VC at BP42 in the 0.5 m and 2 m sample ports. It is noted that VC concentrations at BP42 are historically highly variable, the concentrations are significantly lower than the historical maximum concentrations for those depths, and VC concentrations did not exceed the trigger values at the discharge interface (0.1 m sample) ports nor in nearby surface water samples. No historical maximum concentrations for key contaminants were reported in samples collected from Penrhyn Estuary pore water during the March 2020 monitoring round.

Surface Water

The review of historical surface water monitoring data shows CHC concentrations have been generally consistent with, or less than, those reported in previous monitoring events. Comparison of the March 2020 surface water data with historical data shows CHC concentrations in Springvale Drain (in particular 1,2-dichloroethane (EDC)) have generally decreased several orders of magnitude compared to historical maximum concentrations. The decrease in EDC concentrations within surface water is attributable to the operation of the hydraulic containment system reducing groundwater levels and subsequently reducing groundwater seepage to Springvale Drain. Similarly, concentrations of all CHCs in Floodvale Drain significantly decreased following the commencement of groundwater extraction and remain low.

Key contaminant concentrations reported in the March 2020 monitoring round were less than the relevant ANZG (2018) Trigger Values at all locations. No historical maximum concentrations for key contaminants were reported in surface water samples collected during the March 2020 monitoring round.

Implications for Human Health Risk Assessment

A review of Springvale Drain surface water data collected in accordance with EnRiskS (2018) did not indicate potential issues during the monitoring period with respect to workplace inhalation exposures adjacent to Springvale Drain. Water levels at MWB03S, which is located close to Springvale Drain where it flows under McPherson Street, exceeded the risk review trigger level for a cumulative period of 23 days during the monitoring period, which is less than the period recommended by EnRiskS (2012a) (three months) for a further review of analytical data.

There are no data presented in the March 2020 monitoring round that affect the conclusions of the CHHRA (EnRiskS, 2018) in relation to the Penrhyn Estuary and Floodvale and Springvale Drains (i.e., provided groundwater is not extracted and used for any purpose, health risks associated with exposure to CoPC are low and acceptable).

1.0 INTRODUCTION

The Groundwater Cleanup Plan (GCP) was developed by Orica Australia Pty Ltd (Orica) in response to condition 3B of Notice of Clean Up Action (NCUA) No 1030236. The NCUA was revoked on 3 December 2010 and replaced by a Voluntary Management Proposal (VMP) (Approval No. 20101714). The VMP and the associated Groundwater Remediation and Management Plan (GRAMP) (Orica, 2010) included a series of commitments in relation to operation of the containment lines, groundwater and surface water monitoring, assessment of risk to human health, review of alternative remediation strategies and community consultation. Although the VMP and GRAMP have been updated several times since 2010 – the most recent being in 2020 (Approval No. 20201704 and Orica, 2020, respectively) – the commitments remain largely unchanged.

The GCP included a quarterly monitoring program that was superseded by the Groundwater Treatment Plant (GTP) – Groundwater and Surface Water Monitoring Program (URS, 2005e) which was subsequently amended in January 2007 (URS, 2007a), October 2009 (URS, 2009e) and June 2013 (Golder, 2013d) and more recently in May 2017 (Golder, 2017b). The most recent revision to the GTP monitoring program includes three types of monitoring events: biannual, annual, and biennial (in order of sampling program magnitude).

Groundwater and surface water monitoring completed for the March 2020 program was conducted in accordance with the 2017-2020 GTP Monitoring Program (Golder, 2017b). As specified in the amended program, the March 2020 program is a biannual monitoring event. Sampling for the March 2020 program was conducted in April 2020 due to the scheduled maintenance shutdown of the GTP from 28 February 2020 to 4 April 2020.

1.1 GTP Monitoring Program Methodology

The GTP monitoring program has two distinct monitoring functions:

- Chemical monitoring of the distribution of the contaminants of concern within surface water and groundwater; and
- Monitoring of hydraulic containment performance.

1.1.1 Chemical Monitoring

The chemical monitoring program (presented in Table 1.1) is based on the following methodology (Golder, 2017b):

- Biannual monitoring of surface water within Springvale Drain, Floodvale Drain and Penrhyn Estuary aims to collect data critical to environmental and human health receptors. It includes collection of groundwater and pore water at the inter-tidal groundwater discharge zone at low tide in Penrhyn Estuary.
- Annual chemical monitoring focuses on assessing chemical changes in areas where plume migration is expected to occur as well as detailed assessment of data with respect to the assumptions made in the Consolidated Human Health Risk Assessment (CHHRA) (EnRiskS, 2018).
- Biennial chemical monitoring focuses on identifying major changes to plume geochemistry and distribution throughout the Groundwater Extraction Exclusion Area (GEEA).

1.1.2 Hydraulic Monitoring

The strategy selected to achieve hydraulic containment of groundwater contamination was described in the Botany Groundwater Cleanup (BGC) Project Environmental Impact Statement (EIS) (URS, 2004d). The hydraulic monitoring approval requirements detailed in the BGC Project EIS can be summarised as a number of specific objectives, including the monitoring of aquifer levels to demonstrate:

- Capture of contaminated groundwater at the three hydraulic containment lines, comprising

  - Botany Industrial Park (BIP);
  - The Primary Containment Area (PCA); and
  - The Secondary Containment Area (SCA).
- Excessive drawdown, which could result in ground subsidence, does not occur.

Hydraulic monitoring and regular review of pumping rates are also conducted to minimise the rate of saltwater intrusion at the SCA, which is undesirable for GTP operation.

The amended hydraulic monitoring program (Golder, 2017b) is based on the use of automated data loggers and transducers to enable continuous water level monitoring in the lower GEEA (see Table 1.2 for locations). The methodology for the hydraulic monitoring program is as follows:

- Biannual hydraulic monitoring to focus on assessing hydraulic containment at the SCA, PCA and BIP containment lines; and
- Annual and biennial hydraulic monitoring to assess long-term data and the groundwater flow regime within the broader area of the lower GEEA.

1.2 Previous Groundwater and Surface Monitoring

Groundwater monitoring has been regularly conducted throughout the Stage 3 and Stage 4 Surveys. Previous quarterly monitoring programs completed and reported under the GCP and GTP programs are presented in the following table.

Previous GCP and GTP Monitoring Programs

	Year	Month	Reference
GCP Programs	2004	March, June, September, December	URS, 2004a/b/c/2005a
	2005	March, June	URS, 2005b/d
GTP Programs	2005	September, December	URS, 2005f/2006a
	2006	March, June, September, December	URS, 2006c/d/e/2007b
	2007	March, June, September, December	URS, 2007c/d/e/2008a
	2008	March, June, September, December	URS, 2008b/c/d/2009a
	2009	March, June, September, December	URS, 2009b/d/f/2010a
	2010	March, June, September, December	Golder, 2010a/b/c/2011b
	2011	March, June, September, December	Golder, 2011c/d/e/2012a
	2012	March, June, September, December	Golder, 2012b/c/d/2013a
	2013	March, June, September, December	Golder, 2013b/c/e/2014a
	2014	March, June, September, December	Golder, 2014b/c/d/2015a
	2015	March, June, September, December	Golder, 2015b/c/d/2016a
	2016	March, June, September, December	Golder, 2016b/c/d/2017a
	2017	March, September	Golder, 2017c/d
	2018	March, September	Golder, 2018a/b
	2019	March, September	Golder, 2019a/b

2.0 SCOPE OF SERVICES

2.1 General

The scope of the March 2020 biannual monitoring program is summarised in this section. The results of the hydraulic monitoring program are presented and discussed in Section 3. The results of the chemical monitoring program are presented in Section 4. The human health risk implications (if any) of the monitoring program results are discussed in Section 5.

2.2 Hydraulic Containment Water Level Monitoring

A comprehensive water level monitoring program utilising automated data loggers and transducers was undertaken in accordance with the GTP monitoring program (Golder, 2017b) as shown in Figure 2.1. The monitoring well locations used for the March 2020 GTP monitoring program are presented in Table 1.2. The program involved the collection and processing of data from 275 continuously logged monitoring and extraction wells.

2.3 GTP Chemical Sampling Program

In accordance with the GTP program (see Table 1.1 and Golder, 2017b) the March 2020 sampling program represents a biannual monitoring event. It includes an analytical program with sampling locations focused on assessment of volatile chlorinated hydrocarbon (CHC) concentrations in pore water, groundwater and surface water at Penrhyn Estuary and surface water at Springvale Drain and Floodvale Drain. Additional porewater samples were collected from newly installed piezometers in Penrhyn Estuary to compare results to samples collected from existing piezometers. The chemical monitoring locations are shown on Figure 2.2. All proposed chemical samples were collected.

Additional groundwater and surface water samples were collected at locations along Springvale Drain to compare the concentrations of contaminants during the March 2020 GTP shutdown period as discussed in the Orica 2020 Strategy Review Workshop, however, this will be reported separately.

2.4 Sample Analyses

Groundwater, pore water and surface water samples were analysed for a suite of volatile and semi-volatile chlorinated hydrocarbons (CHCs). The analytical suite includes the list of compounds specified in the VMP and GTP Monitoring Program (Golder, 2017b), and is presented in the table below.

Volatile Chlorinated Hydrocarbons	
Carbon Tetrachloride (CTC)	Chloroform (CFM)
Methylene Chloride (DCM)	Chloromethane
Pentachloroethane	1,1,1,2-Tetrachloroethane
1,1,2,2-Tetrachloroethane (1,1,2,2-TeCA)	1,1,2-Trichloroethane (1,1,2-TCA)
1,1,1-Trichloroethane	1,1-Dichloroethane (1,1-DCA)
1,2-Dichloroethane (EDC)	Chloroethane
Tetrachloroethene (PCE)	Trichloroethene (TCE)
trans-1,2-Dichloroethene (trans-1,2-DCE)	*cis*-1,2-Dichloroethene (cis-1,2-DCE)
Vinyl Chloride (VC)	

A summary of the properties of volatile and semi-volatile CHCs is presented in Appendix B.

2.5 Quality Assurance (QA) and Quality Control (QC)

2.5.1 Quality Assurance Plan

Sample collection, sample handling and decontamination procedures were performed in general accordance with the Groundwater Treatment Plant Groundwater and Surface Water Monitoring Program 2017 – 2020 (Golder, 2017b).

2.5.2 QA/QC Samples

The analyses of laboratory and field QA/QC samples are mechanisms for checking the accuracy and precision of analytical data in order to ensure that the program data quality objectives (DQOs) are being met. The QA/QC samples collected in the field during this sampling round included trip blanks, field duplicates and field triplicates.

In addition to field QA/QC samples, the primary and secondary analytical laboratories (ALS and Envirolab, respectively) have used laboratory and batch specific QA/QC processes including laboratory duplicates, laboratory blanks, surrogate spikes, matrix spikes and laboratory control samples.

2.5.3 Data Validation

2.5.3.1 General

To ensure that data of known quality are reported and to identify whether data are suitable to fulfil the overall project objectives, analytical data validation is conducted by Golder. The validation process is based upon the following data validation guidance documents:

- NEPC (1999 and 2013). National Environmental Protection (Assessment of Site Contamination) Measure 1999 and National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013 (No.1), and
- USEPA Contract Laboratory Program National Functional Guidelines for Superfund Organic Methods Data Review (USEPA, 2008a).

The analytical data validation process involves the checking of analytical procedure compliance and the assessment of accuracy, precision and completeness of analytical data.

Analytical data validation summary sheets are presented in Appendix C.

2.6 Data Management

Analytical data for the Botany project are stored on a secure SQL server and managed via the EQuIS® 5 Environmental Data Management System (EDMS) off site. Warehoused data sets are linked to ArcGIS, proprietary Geographical Information System (GIS) software. This GIS is used in the spatial presentation of the site’s monitoring locations and the creation of contaminant distribution figures as well as geochemical and hydraulic figures.

3.0 HYDRAULIC MONITORING

3.1 General

The March 2020 monitoring round is a biannual event that focuses on assessing hydraulic containment at the SCA, PCA and BIP containment lines.

The following comments are noted with regards to the hydraulic monitoring program:

- Historical (from March 2016) and current hydraulic monitoring data are tabulated and presented in Table 3.1;
- Water table elevation (shallow aquifer) and inferred potentiometric surface (deep aquifer) maps, and associated groundwater flow lines are presented in Figures 3.1 and 3.2, respectively. The contours are inferred from transducer and automated logger data averaged for the period between 1 September 2019 and 29 February 2020;
- A scheduled GTP maintenance shutdown occurred 9 September 2019 to 20 September 2019 (The March 2020 maintenance shutdown commenced at the end of the monitoring period, and will be discussed in the next monitoring report). The effect of the September 2019 shutdown on water levels in the vicinity of the BIP, PCA and SCA at the beginning of the monitoring period is evident in the hydrographs included in Appendix A. An assessment of the maximum time periods that the SCA and PCA containment lines can be off-line before groundwater at the containment line cannot be recaptured was presented in previous GTP monitoring reports (URS, 2007b). The slow migration of groundwater and the potential for increased pumping to recapture groundwater mean that hydraulic containment can still be maintained through extended periods of no, or low, groundwater extraction;
- Detailed hydrographs for wells equipped with transducers/loggers are presented in Appendix A. Monitoring well hydrographs for the SCA include a representation of the target water level that is used to assess hydraulic containment. Hydrographs for wells located along Springvale Drain include a representation of the target water levels that are used to assess the potential for groundwater to discharge to the drain. Additionally, the hydrograph for MWB03S (Figure A.16) includes a target level that is used as a basis for considering whether additional water and air quality assessments are required in the vicinity of Springvale Drain (see Section 5);
- During the March 2020 field program, water levels were manually measured at each logger location and compared against the logged water level in order to assess data quality and reliability. A summary of these data is presented in Table 3.2. A number of minor discrepancies were identified and, where appropriate, the data have been corrected. In some cases, where the cause of the discrepancy was not clear, further assessment will be undertaken during the next GTP monitoring event (September 2020). The identified discrepancies are not considered to affect interpretation of groundwater flow directions and the overall data are considered suitable for assessing hydraulic containment;
- A number of faulty pressure transducers and data loggers were identified during the monitoring period. An ongoing program to identify, repair/replace inoperable loggers/transducers is undertaken as part of ongoing maintenance works for the GTP. Given the historical data set and extent of monitoring at adjacent locations, the absence of reliable data at these locations is not considered to affect the quality of the overall assessment.
- Each hydrograph includes a daily rainfall chart for Sydney Airport.

- Rainfall during the period was above the long-term averages in September 2019 and February 2020. Rainfall in October 2019, November 2019 and January 2020 was below the long-term averages, and significantly less than the long-term average for December 2019.

	September 2019	October 2019	November 2019	December 2019	January 2020	February 2020
Total Monthly Rainfall (mm)	83.8	30.0	24.4	0.8	63.4	395.2
Long-Term Average Monthly Rainfall (mm)	60.0	70.1	79.9	72.8	94.1	114.2

Source: www.bom.gov.au

3.2 Assessment of Hydraulic Containment

3.2.1 General

A detailed assessment of hydraulic containment at BIP, PCA and SCA was undertaken by JBS&G (2012) using the approach presented in *A Systematic Approach for the Evaluation of Capture Zones at Pump and Treat Systems* by United States Environmental Protection Agency (USEPA, 2008b). The USEPA (2008b) evaluation approach uses multiple lines of evidence in a series of six 'steps' to assess hydraulic containment. The JBS&G (2012) assessment concluded that effective hydraulic containment was being achieved at the containment lines, as was the remediation objective of the BGC Project "to achieve protection for slightly to moderately disturbed ecosystems using the Australian and New Zealand Guidelines for Marine and Fresh Water (ANZECC/ARMCANZ, 2000[1])" in surface water at Penrhyn Estuary.

Golder (2013e) reviewed relevant hydraulic and chemical monitoring data in September 2013 using the six lines-of-evidence 'steps' against those considered by JBS&G (2012). Golder (2013e) reviewed relevant hydraulic and chemical monitoring data in September 2013 using the six lines-of-evidence 'steps' against those considered by JBS&G (2012). The assessment concluded that there were no significant changes in hydraulic monitoring data which would affect the conclusion of JBS&G (2012) that effective hydraulic containment of the target capture zones and BGC Project remediation objectives were being achieved.

The following section reviews the recent hydraulic monitoring data for the March 2020 round using the six lines-of-evidence 'steps' considered by JBS&G (2012) and Golder (2013e) in the assessment of hydraulic containment. A revision of the hydraulic containment assessment report and associated target capture zones has been undertaken by JBS&G using more recent data collected as part of the GTP monitoring programs and is currently being reviewed by NSW EPA.

Step 1: Review Site Data, Site Conceptual Model, Remedy Objectives

Step 1	Review Site Data, Site Conceptual Model, Remedy Objectives
JBS&G (2012), Golder (2013e)	The site conceptual model (Golder, 2011a) is suitable for use. The remedy objective of the BGC Project is "*to achieve protection for slightly to moderately disturbed ecosystems using the Australian and New Zealand Guidelines for Marine and Fresh Water (2018)*" in surface water at Penrhyn Estuary.

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[1] ANZECC/ARMCANZ 2000 has been superseded by ANZG 2018, which is adopted from hereon

Step 1	Review Site Data, Site Conceptual Model, Remedy Objectives
March 2020	The hydraulic monitoring data presented in this report are considered to be suitable for the purpose of assessing hydraulic containment. The site conceptual model (Orica, 2017) is considered to be suitable for ongoing use. The groundwater flow regime and contaminant plume dynamics for the monitoring period are considered to be consistent with those reviewed by JBS&G (2012) and Golder (2013e). The BGC Project remedy objective has not changed.

Step 2: Define Target Capture Zones

Step 2	Define "Target Capture Zones"
JBS&G (2012), Golder (2013e)	The remedy objective does not require complete hydraulic capture at all containment lines but requires that the mass flux of contaminants entering the estuary in groundwater does not result in surface water concentrations exceeding the guidelines values. Thus, effective hydraulic containment is based on contaminant flux in groundwater that has passed the containment lines. Target capture zones for containment lines were based on depth-averaged concentrations of CHCs, which are representative of the contaminant flux past the containment lines. These depth-averaged concentrations were compared against an adjusted ANZG (2018) Trigger Value. Target capture zones were revised in Golder (2013e) on the basis of monitoring data collected between July and October 2013 from containment line extraction and monitoring wells. Groundwater flux-averaged contaminant concentrations were used rather than depth-averaged concentrations due to the relative paucity of vertical discretisation in contaminant concentrations at the containment lines (compared to the 2006 data used by JBS&G (2012)). Flux-averaged concentrations were estimated from extraction well data (as water quality of operating extraction wells with long well-screens across the shallow or deep aquifer is considered to represent the flux-averaged concentration across the entire thickness of the respective aquifer). Monitoring well contaminant data were also considered to conservatively supplement extraction well data. On the basis of comparison of these flux-averaged concentration data against the adjusted ANZG (2018) Trigger Values and assumptions used by JBS&G (2012), the target capture zones considered in September 2013 were: ■ Effective hydraulic containment at: ▪ SCA (deep aquifer): EWF28D – EWF14D ▪ SCA (shallow aquifer): EWF28S - EWF02S ▪ PCA: EWB07D – EWB15D ▪ BIP: EWD01S/I – EWD16D and EWD21S/I/D ■ At Springvale Drain: Maintenance of water levels at or below 2.3 m AHD at MWB03S (where this level is exceeded for 3 months (EnRiskS, 2012a) additional monitoring is required to assess potential risks). At SCA, the following was noted:

Step 2	Define “Target Capture Zones”
	■ Contaminant concentrations in the shallow aquifer were below the adjusted Trigger Values with the exception of MWF01S, MWF14S and EWF21S. ■ The lateral extent of elevated total volatile CHC concentrations (>50 mg/L) in the deep aquifer had increased, and extended from MWF14I/D to EWF12D.
March 2020	The assessment of hydraulic containment in the following steps considers the target capture zones as described in Golder 2013e. A revision of the target capture zones has been undertaken by JBS&G using more recent data collected as part of the GTP monitoring programs and is currently being reviewed by NSW EPA.

Step 3: Interpret Water Levels

Interpretation of water levels was undertaken by using water level maps to infer groundwater flow directions and assess gradients between well pairs at, and downgradient of, containment lines. Averaged water level data for the monitoring period were used.

With respect to assessing the flow of groundwater at the three containment areas it is important to highlight the following:

- The primary purpose of the SCA is to reduce the mass flux of contaminants entering Penrhyn Estuary in groundwater so that surface water concentrations remain below the guideline values. Pumping priority is based on contaminant concentrations along the SCA and, on the basis of the most recent data, the western end has been designated a lower pumping priority. Target groundwater levels for SCA monitoring wells are based on subsidence constraints and an assessment of groundwater levels at the discharge point in the intertidal zone. Field studies (Turner et al 1996, Nielsen 1999, Cartwright & Nielsen 2001) have demonstrated the average groundwater elevation in the intertidal zone discharge point is above 0 mAHD. The field studies show that water levels at the discharge point (even in the quiescent conditions of Penrhyn Estuary) could exceed 0.2 mAHD, which has previously been confirmed by water levels at BP117 located in the vicinity of the groundwater discharge zone at Penrhyn Estuary which typically range between 0.2 and 0.4 mAHD. As a result, a conservative target level of 0.1 mAHD has historically been adopted for long-term operation of the SCA;
- While a nominal target water level of 0.1 mAHD at the SCA is presented on the hydrographs to aid interpretation, it is important to note that observed levels above these targets do not directly imply hydraulic containment was not achieved. As indicated above, assessment of hydraulic containment requires incorporation and analysis of a number of lines of evidence; and
- The slow migration of groundwater and the potential for increased pumping to recapture groundwater mean that hydraulic containment can still be maintained through extended periods of no, or low, groundwater extraction.

Step 3a	Water Level Maps
JBS&G (2012), Golder (2013e)	Extensive (spatial and temporal) water level monitoring locations were available for analysis. Vertical water maps were not used as two horizontal aquifers/layers were assessed as part of the capture zone analysis while extraction wells capture the full depth of each aquifer.

Step 3a	Water Level Maps
	Extraction well water levels were not used in interpreting water levels and do not bias the assessment of containment. While extraction well levels overestimate drawdown due to well losses, the levels are lower than adjacent monitoring wells, and their exclusion is conservative. Horizontal capture zones were larger than target capture zones.
March 2020	Historical (from March 2016) and current hydraulic monitoring data are tabulated in Table 3.1. Water table elevation (shallow aquifer) and inferred potentiometric surface (deep aquifer) maps, and associated groundwater flow lines based on averaged water levels for the monitoring period are presented in Figures 3.1 and 3.2, respectively. **Shallow Aquifer:** The averaged water levels were generally lower than the previous monitoring period. The lower groundwater elevations are likely to be predominantly associated with the lower than average rainfall during the monitoring period, and also as a result of improved pump performance following the maintenance works performed during the September 2019 scheduled GTP shutdown. Flow lines at BIP and SCA indicate hydraulic containment within the target capture zones occurred during the period. Hydraulic containment of the shallow aquifer at PCA is less clear, however it is noted that this area is characterised by relatively low contaminant concentrations in the shallow aquifer. **Deep Aquifer:** Groundwater contours of averaged water levels for the period of GTP operation show a pattern of groundwater flow influenced by groundwater extraction at BIP and PCA. Groundwater contours at SCA indicate a comparatively weaker influence, consistent with a more intermittent pattern of hydraulic containment in the intermediate/deep aquifers as a consequence of the elevated groundwater levels associated with the scheduled GTP shutdown in September 2019, significant rainfall in February 2020 and well fouling that has been identified to occur within target capture zones. The deep extraction well at MWF28D, located within the target capture zone at the eastern portion of SCA failed in March 2019, significantly impacting groundwater extraction rates from the SCA. Water levels in the deep aquifer at BIP and PCA were generally within or lower than the range of levels predicted to be required for hydraulic containment by Laase (2005) (approximately between 3.0 and 4.0 mAHD at BIP and between 1.0 and 1.5 mAHD at the PCA). Achievement of target levels at SCA was more intermittent with averaged water levels higher than the target level of 0.1 m AHD. As noted above, this target level is considered conservative (refer Figure A.01 to A.14 in Appendix A), with evidence of a flat hydraulic gradient in the central portion of SCA between the containment line and Penrhyn Estuary. Averaged groundwater levels in the eastern portion of SCA, where the failure of EWF28D limits groundwater extraction, and in the western portion of the SCA do not suggest achievement of effective hydraulic containment. Overall, the observed pattern of groundwater flow in the monitoring period is different to that observed during the baseline monitoring in October 2004 (URS, 2005a), exhibiting greater similarity to that presented in monitoring reports since operation of the full GTP system commenced in 2007, albeit weaker at SCA as detailed above.

Step 3a	**Water Level Maps**
	Springvale Drain: During the monitoring period, the groundwater level at MWB03S exceeded the risk review trigger level (refer Figure A.16 in Appendix A) for a cumulative period of 23 days (in two intervals) during the six-month monitoring period. The elevated groundwater levels are expected to have primarily resulted from the GTP maintenance shutdown in September 2019, and high rainfall events in February 2020. This is discussed further in relation to potential risks to human health in Section 5.1.1.

<table>
<tr><th>Step 3b</th><th>Water Level Gradient Pairs</th></tr>
<tr><td>JBS&G (2012), Golder (2013e)</td><td>PCA: An assessment of gradient control pairs for the shallow aquifer inferred that hydraulic containment of the shallow aquifer was achieved in the central portion of the PCA.
SCA: An assessment of gradient control pairs showed that:
■ An average reverse gradient was achieved in the shallow aquifer during the monitoring period.
■ An average reverse gradient was not observed in the intermediate aquifer in the vicinity of MWF15I, although there was a slight reverse gradient towards MWF11I. The adverse gradient at MWF12/MWF15 was not considered significant given the small flow represented by the gradient and the presence of reversed gradients at adjacent locations and depths.
■ An average reverse gradient or average water levels less than the nominal target of 0.1 mAHD was achieved in the deeper aquifer in the vicinity of MWF17I/D, MWF18I/D and MWF19I/D.
The analyses of gradient control pairs by JBS&G (2012) and Golder (2013e) concluded that effective hydraulic containment was achieved.</td></tr>
<tr><td>March 2020</td><td>PCA: An assessment of gradient control pairs for the shallow aquifer is presented in the following table and shown on Figure A.22 in Appendix A.
Gradient Control Pairs - PCA
<table>
<tr><th>Downgradient Well ID</th><th>Average SWL (mAHD)</th><th>PCA Well ID</th><th>Average SWL (mAHD)</th><th>Indicative Gradient</th><th>Flat or Reverse Gradient</th></tr>
<tr><td>MWB15S</td><td>1.61</td><td>MWB02S</td><td>FL</td><td>-</td><td>N/A</td></tr>
<tr><td>MWB15S</td><td>1.61</td><td>MWB03S</td><td>1.83</td><td>0.0072</td><td>No</td></tr>
<tr><td>MWB13S</td><td>1.22</td><td>MWB05S</td><td>1.67</td><td>0.0152</td><td>No</td></tr>
<tr><td>MWB11S</td><td>1.25</td><td>MWB06S</td><td>1.31</td><td>0.0020</td><td>No</td></tr>
<tr><td>MWB14S</td><td>1.24</td><td>MWB07S</td><td>1.27</td><td>0.0010</td><td>No</td></tr>
</table>
FL = Faulty Logger
FT = Faulty Transducer
The assessment shows that an average reverse gradient was not achieved in the central and western portions of the PCA in the shallow aquifer during the monitoring period. Assessment of hydraulic gradient pairs was not possible in the eastern portion of the PCA as a result of a faulty</td></tr>
</table>

Step 3b	Water Level Gradient Pairs

logger. Although a flat or reverse gradient was not identified in the vicinity of MWB07S, wider analysis of target water levels (refer to Figure 3.2) suggests that hydraulic containment was achieved in the intermediate and deep aquifers of the PCA, with a downward hydraulic gradient from both the eastern and western portions of the PCA towards the centre. As discussed above in Step 3a, limited hydraulic containment in the shallow aquifer at PCA is not expected to affect achievement of the remedy objective.

SCA: The primary assessment of gradient control pairs is presented in the following table. Comparison of gradient control pairs is further illustrated in hydrographs A.12, A.13 and A.14 presented in Appendix A. Well locations are shown in Figure 2.1.

Gradient Control Pairs - SCA

Downgradient Well ID	Average SWL (mAHD)	SCA Well ID	Average SWL (mAHD)	Indicative Gradient	Flat/Reverse Gradient
MWF17D	0.63	MWF13D	0.61	-0.001	Yes
MWF17I	0.63	MWF13I	0.70	0.002	No
MWF17S	FL	MWF13S	0.02	-	N/A
MWF17D	0.63	MWF14D	0.71	0.002	No
MWF17I	0.63	MWF14I	0.62	0.000	Yes
MWF17S	FL	MWF14S	0.27	-	N/A
MWF15D	0.51	MWF12D	0.96	0.013	No
MWF15I	0.48	MWF12I	0.64	0.005	No
MWF15S	0.56	MWF12S	0.15	-0.012	Yes
MWF15D	0.51	MWF13D	0.61	0.002	No
MWF15I	0.48	MWF13I	0.70	0.004	No
MWF15S	0.56	MWF13S	0.02	-0.011	Yes
MWF15D	0.51	MWF11D	0.44	-0.001	Yes
MWF15I	0.48	MWF11I	0.29	-0.004	Yes
MWF15S	0.56	MWF11S	0.06	-0.010	Yes
MWF18D	0.19	MWF02D	0.42	0.008	No
MWF18I	0.38	MWF02I	0.73	0.012	No
MWF18S	FL	MWF02S	0.27	-	N/A
MWF19D	0.14	MWF07D	0.28	0.004	No
MWF19I	0.34	MWF07I	0.20	-0.004	Yes
MWF19S	0.30	MWF07S	0.27	-0.001	Yes
MWF19D	0.14	MWF08D	0.37	0.006	No
MWF19I	0.34	MWF08I	0.21	-0.003	Yes
MWF19S	0.30	MWF08S	0.25	-0.001	Yes

*MWF15D is screened in a lower aquifer unit FL = Faulty Logger

This analysis shows that during the monitoring period:

- An average reverse gradient was achieved in the shallow aquifer in the central-eastern and western portions of the SCA in the vicinity of MWF15S and MWF19S. The absence of logger data (the data loggers at MWF17S and MWF18S were identified to be faulty during

Step 3b	Water Level Gradient Pairs
	the period) in the eastern and central portions of SCA limits the assessment of shallow gradient control pairs. ■ The broader analysis of average shallow water levels provided in Table 3.1 (MWF01, MWF02, MWF03, MWF04, MWF05 and MWF12, MWF13 and MWF14) indicate a flat hydraulic gradient exists between the eastern and central portions of the SCA and the Penrhyn Estuary shoreline, where average levels range between 0.2 and 0.4 m AHD. ■ An average reverse gradient was achieved in the intermediate aquifer in the eastern and western portions of the aquifer in the vicinity of MWF17I/MWF14I, MWF15I/MWF11I, MWF19I/MWF07I and MWF19I/MWF08I. Evidence of average reverse gradients was less clear in the central portion of the SCA in the vicinity of MWF15I and MWF18I during the monitoring period, although a flat hydraulic gradient can be inferred from averaged water levels in the central portion of the SCA and Penrhyn Estuary between MWF04I and MWF09I (Table 3.1) ■ Average reverse gradients in the deep aquifer at the SCA were observed in the eastern and central-eastern portion of the SCA in the vicinities of MWF15D/MWF11D and MWF17D/MWF13D. A reverse hydraulic gradient in the central portion of the SCA is also periodically evident in the vicinity of MWF03/MWF18 (refer to hydrograph A.14 in Appendix A). Hydraulic containment in the western end of the SCA is less clear although it is noted that this area is characterised by relatively low CHC concentrations and falls outside of the SCA Target Capture Zone (refer Step 2). This analysis of gradient control pairs at SCA supports the conclusion that effective hydraulic containment was achieved in the shallow aquifer across the SCA and within the intermediate aquifer in the eastern and western portion. Hydraulic containment in the deep aquifer is less clear. It is noted that the adopted target levels are considered conservative and have been designed for the long-term operation of the SCA. Elevated averaged groundwater levels were particularly evident in the eastern portion of the deep aquifer at SCA where the failure of extraction well EWF28D in April 2019 has significantly reduced groundwater extraction.

It should be emphasised that the assessment of reversed gradient at monitoring wells is highly conservative with respect to hydraulic containment, and the observed water level difference between well pairs is generally similar to the measurement error (especially when density differences are considered at SCA – see Golder, 2010c).

It is also important to highlight that intermediate and deep monitoring wells at SCA are generally screened within the same aquifer unit (except for MWF15D which is screened within a lower unit) and that the downward hydraulic gradient suggests that groundwater in the intermediate aquifer zone will also be drawn towards deeper sections of the SCA containment line.

Step 4: Perform Calculations

Step 4a	Simple Horizontal Capture Zone Analysis
JBS&G (2012), Golder (2013e)	The horizontal capture zone analysis included detailed groundwater modelling (incorporating particle tracking). The modelled estimate of total extraction flow rate required for hydraulic containment is 6.2 ML/day. Actual groundwater extraction rates are typically approximately 6

<table>
<tr><th>Step 4a</th><th>Simple Horizontal Capture Zone Analysis</th></tr>
<tr><td></td><td>ML/day during normal climatic conditions, which are considered sufficient to achieve hydraulic containment.</td></tr>
<tr><td>March 2020</td><td>Average extraction flow rates for each containment line are compared against Scenario F (considered the most representative modelling scenario) of the groundwater flow model (Laase, 2005) in the table below.

Flow Rates (ML/day)
<table>
<tr><th>Containment Line</th><th>Laase (2005), Scenario F</th><th>Current Period*</th></tr>
<tr><td>BIP</td><td>3.5</td><td>3.54</td></tr>
<tr><td>PCA</td><td>1.3</td><td>0.62</td></tr>
<tr><td>SCA</td><td>1.4</td><td>0.78</td></tr>
<tr><td>Total</td><td>6.2</td><td>4.93</td></tr>
</table>
*Period (GTP data provided from 6 September 2019 to 29 February 2020)

Average groundwater extraction rates at PCA and SCA during the monitoring period were less than the modelled rates for normal climatic conditions. The significantly lower extraction rates at PCA have previously been attributed to the decommissioning of CHC mass removal wells (EWB02D, EWB06D and EWB14D) in March 2011. The extraction rates during the monitoring program have also been affected by the exceptionally dry weather – four of the six months had less than average rainfall (three of which were less than half of the average, with almost no rain recorded in December 2019). It is evident from a review of the hydrographs for the monitoring wells that the step change in water levels due to significant rainfall events such as in early February 2020 is greatest in the SCA and least in the BIP containment lines. In addition, at SCA, extraction rates have been affected by the failure of extraction well EWF28D in April 2019. Groundwater extraction rates at PCA and SCA have also been affected by well biofouling. Improvement in extraction rates is evident following the completion of the GTP maintenance shutdown that occurred in September 2019. The overall reduction in groundwater extraction has been partially offset by groundwater extraction at BIP at rates predicted in the model where the extraction rates are less dependent on rainfall conditions.</td></tr>
</table>

Step 4b	Particle Tracking
JBS&G (2012), Golder (2013e)	Particle tracking completed as part of the numerical model (Laase, 2005) indicated that hydraulic containment was achieved for flows of 6.2 ML/day. As discussed in Step 4a, extraction rates are generally reported to be of a similar order to those modelled for BIP and SCA. There are lower extraction rates from PCA and less significant drawdown in the deep aquifer between the PCA and the SCA (as indicated by the 1.0 mAHD contour which extends north of the PCA in modelled contours). This is largely attributable to decommissioning of CHC mass removal wells (EWB02D, EWB06D and EWB14D) after modelling was undertaken. However, hydraulic containment was still considered to be achieved in the deep aquifer at the PCA.

Step 4b	Particle Tracking
	Isocontours of potentiometric surfaces considered by JBS&G (2012) and Golder (2013e) were similar in pattern to those predicted in groundwater modelling (and particle tracking) of Scenario F (Laase, 2005) to achieve hydraulic containment.
March 2020	The March 2020 contours (Figures 3.1 and 3.2) of potentiometric surfaces are similar in pattern to those assessed by JBS&G (2012) and Golder (2013e) and predicted in groundwater modelling (and particle tracking) of Scenario F (Laase, 2005).

Step 5: Concentration Trends

Step 5	Concentration Trends
JBS&G (2012), Golder (2013e)	Due to the age of the plume(s) and their distribution prior to commencement of groundwater extraction, no sentinel wells are available. Assessment of major changes to contaminant plume geochemistry and distribution was presented in Golder (2013e). While changes in plume distribution have been observed, these are consistent with plume dynamics considered by JBS&G (2012) and the conceptual site model (Golder, 2011a). Surface water concentrations at Penrhyn Estuary have decreased dramatically since commencement of groundwater extraction and now satisfy the remedy objective.
March 2020	Groundwater concentrations and distribution have been characterised by stable or decreasing trends in most CHC concentrations. Surface water concentrations at Springvale Drain and Penrhyn Estuary reported in the monitoring period (see Sections 4 and 5) are similarly low compared to those reported historically and satisfy the remedy objective.

Step 6: Compare Actual Capture and Target Capture Zone

Step 6	Compare Actual Capture and Target Capture Zone
JBS&G (2012), Golder (2013e)	Comparison of actual capture to the target capture zones indicates that hydraulic containment is being effectively achieved. Further, assessment of contaminant concentrations indicates that the BGC Project remedy objectives are being achieved.
March 2020	Comparison of actual capture to the target capture zones indicates that effective hydraulic containment is most evident in the BIP and the eastern-central portion of SCA. Further, assessment of contaminant concentrations at Springvale Drain and Penrhyn Estuary (see Sections 4 and 5) indicates that the BGC Project remedy objectives are being achieved.

4.0 CHEMICAL MONITORING

In accordance with the GTP program (see Table 1.1 and Golder, 2017b) the March 2020 sampling program represents a biannual monitoring event. As such, chemical sampling was focused on assessment of volatile CHCs concentrations in pore water, groundwater and surface water at, and hydraulically upgradient of, Penrhyn Estuary. Surface water samples were also collected from within Springvale Drain and Floodvale Drain upstream of Penrhyn Estuary. Sampling occurred during April 2020 due to the scheduled maintenance shutdown of the GTP in March 2020.

Table 4.1 presents field parameters collected at the time of sampling. Tables 4.2, 4.3 and 4.4 present volatile CHC analytical results for Penrhyn Estuary groundwater, pore water and surface water, respectively. Short- and long-term historical trends, detection limit flags and historical maximum concentrations are presented in Tables 4.5 to 4.10 for groundwater, in Tables 5.1 to 5.5 for pore water and in Table 5.6 for surface water. Assessment of historical trends will be undertaken as part of the annual/biennial reports.

The chemical monitoring locations are presented in Figure 2.2.

4.1 Penrhyn Estuary Groundwater

The collection of groundwater samples at BP01/BP117, MWF15S/I/D, MWF17S/I/D, MWF18S/I/D and MWF19S/I/D is undertaken on a biannual basis to allow assessment of variability in CHC concentrations and to supplement pore water monitoring within the estuary. Table 4.2 presents the volatile CHC analytical results for groundwater samples. Historical concentrations, detection limit variations, historical maxima, as well as short-term (previous four year’s data) and long-term trends are presented in Tables 4.5 to 4.10 for key contaminants in groundwater.

Increasing CHC contamination trends (both long- and short-term trends) are noted at MWF15D for EDC; MWF17S for EDC and CFM, and at MWF18D for EDC, PCE, TCE, CFM and VC.

An historical maximum was reported for TCE (3.970 mg/L) at MWF18D. The increasing trend of TCE in the deep aquifer at MWF18 potentially represents limited migration of groundwater containing higher concentrations of dissolved phased TCE associated with the Southern Plumes within and upgradient of the central portion of the SCA. Similarly, increasing trends were also reported for EDC, PCE, VC and CFM at this location and depth. Groundwater extraction within this portion of the SCA is expected to improve following the scheduled GTP maintenance shutdown completed in March 2020 to maintain reliable performance of hydraulic containment in the SCA and improve recapture of CHCs in the area immediately downgradient. Consideration is being given to the augmentation of the monitoring program downgradient of this location within Penrhyn Estuary.

BP01 and BP117, located on the shoreline of Penrhyn Estuary were sampled in conjunction with the pore water and surface water sampling. CHC concentrations have historically been highly variable at this monitoring location. Reported CHC concentrations were generally consistent with, or less than, those reported in previous monitoring events. An historical maximum concentration was reported for PCE (0.030 mg/L) at BP117_1.5. Similarly, increasing trends were reported for TCE, EDC and VC at this location and depth. In addition, increasing trends were reported for EDC and CFM at BP117_1.0, PCE at BP01_8.0 and PCE and CTC at BP117_3.5. These increases potentially represent remnant Southern Plumes contamination (i.e., preceding commencement of operation of the SCA) being flushed from the generally stagnant area by the heavy rainfall in February 2020 or a result of inconsistent hydraulic containment. The groundwater concentrations at SCA have been also affected by decommissioning extraction well EWF28D in April 2019 due to loss of hydraulic containment. It is noteworthy that the overall CHC concentrations within this area remain significantly lower than historical concentrations reported prior to operation of the SCA and the downgradient CHC concentrations in surface water remain low. Furthermore, the planned installation of new and replacement extractions wells (EWF25D and EWF28D) is expected to improve hydraulic containment of the eastern portion of the SCA, upgradient of this location. Continued monitoring of this location in consideration of the downgradient pore water transect locations is required to ensure the remedy objectives of the BCG at Penrhyn Estuary continue to be met.

4.2 Penrhyn Estuary Pore Water Monitoring

Pore water samples were collected on 24 April 2020 from two transects of bundle piezometers installed in Penrhyn Estuary. Transect A (BP42 and BP43) is located down gradient of the inferred axis of the Southern Plumes (Plumes S2/S3), while Transect B (BP64 and BP65) is located on the western arm of the estuary down gradient of the Central EDC Plume (C1 Plume). The locations of the piezometers are shown on Figure 2.2. The bundle piezometers in Transect A and Transect B were sampled at low tide. Samples were collected at low tide only as historical monitoring data have shown that CHC concentrations (when present) are consistently higher at low tide and therefore provide a more conservative assessment of pore-water quality within Penrhyn Estuary. Pore water samples were collected at the discharge interface (0.1 m) and at depths of 0.5 m and 2.0 m below the ground surface of the estuary within the intertidal zone.

A comparison of concentrations of key contaminants in samples collected from the discharge interface (0.1 m port) and from shallow pore water in Penrhyn Estuary against the ANZG (2018) Trigger Values has been conducted. These data are presented in Table 4.3.

Key contaminant concentrations reported in the March 2020 monitoring round were less than the relevant ANZG (2018) Trigger Values at all sampled pore water monitoring locations with the exception of VC at BP42 in the 0.5 m (0.148 mg/L) and 2 m sample port (1.37 mg/L). It is noted that VC concentrations at BP42 are historically highly variable and that the concentrations are lower than the historical maximum concentrations at these depths. It should also be noted that the concentration of VC in the shallower 0.1 m sample port and nearby surface water monitoring locations did not exceed the trigger value.

4.2.1 Discharge Interface Pore Water Volatile CHC Concentrations

Concentrations of volatile CHCs at the discharge interface (0.1 m port) are considered the most relevant in terms of assessing potential impacts to surface waters within Penrhyn Estuary.

As discussed above, the concentrations of the key contaminants reported in the March 2020 monitoring round are less than the ANZG (2018) Trigger Values for all the samples collected at the discharge interface (0.1 m port).

4.2.2 Comparison with Historical Pore Water Volatile CHC Concentrations

Historical concentrations, detection limit variations, historical maxima and short-term (previous four years' data) and long-term trends are presented in Tables 5.1 to 5.5 for key contaminants in Penrhyn Estuary pore water.

In general, the March 2020 data are consistent with previous monitoring rounds with the concentrations of the CoPC generally decreasing with decreasing depth towards the discharge interface.

No historical maximum concentrations for key contaminants were reported during the March 2020 monitoring round.

4.3 Surface Water

Surface water samples were collected within Penrhyn Estuary in conjunction with pore water sampling on 24 April 2020. Samples were collected at low tide as historical monitoring data have shown that CHC concentrations (when present) are consistently higher at low tide than at high tide and therefore provide a more conservative assessment of water quality within Penrhyn Estuary. Surface water samples were also collected from locations within Floodvale and Springvale Drains at locations upstream from Penrhyn Estuary on 15 April 2020.

Table 4.4 presents the volatile CHC analytical results for surface water samples and a comparison against the ANZG (2018) Trigger Values.

Key contaminant concentrations reported in the March 2020 monitoring round were less than the relevant ANZG (2018) Trigger Values at all locations.

Surface Water Variability and Comparison with Historical Data

Historical concentrations, detection limit variations, historical maxima and short-term (previous year's data) and long-term trends are presented in Table 5.6 for EDC, VC, PCE, TCE, CFM, cis-1,2-DCE and CTC. All available historical data have been used in assessing historical trends, but only data since March 2016 are presented in the table.

Reported CHC concentrations were generally consistent with, or less than, those reported in previous monitoring events. Short-term increases relative to the preceding four years of averaged data were reported, however these were significantly lower than the long-term historical averages. No historical maximum concentrations for key contaminants were reported during the March 2020 monitoring round.

5.0 IMPLICATIONS FOR HUMAN HEALTH RISK ASSESSMENT

The CHHRA (EnRiskS, 2018) considered risks to human health in the following areas surrounding the BIP: Western Margin of the Northern Plumes, Main Plume, Penrhyn Estuary and the Surface Water and Ambient Air Monitoring for Springvale Drain report. The risk assessment follows from previous detailed assessments presented in the Stage 2 Risk Assessment (Woodward-Clyde 1996), 2005 Consolidated Human Health Risk Assessment (CHHRA) and addendum (URS 2005c, 2006b) and the 2010 CHHRA (EnRiskS 2010).

The CHHRA (EnRiskS, 2018) provides an update of the 2010 CHHRA (EnRiskS 2010), incorporating data and information relevant to the nature and presence of contamination in off-site areas to June 2017. The assessment has been undertaken in accordance with current Australian guidelines (enHealth 2012; NEPC 1999 amended 2013) with consideration of relevant international guidance (where relevant).

In 2018, the CHHRA was updated (EnRiskS, 2018) to incorporate the following:

- Human Health Risk Assessment addressed the potential for exposure to site-related chemicals in all areas located above or near the contaminated groundwater plumes derived from BIP. This includes the following areas:
  - *Western Margin of the Northern Plumes* - assessment of exposures relevant to residential areas that are located along the edge of these plumes, and in areas where groundwater may be extracted and utilised within residential properties;
  - *Main Plumes including Mercury Plume* – assessment of exposures relevant to recreational and commercial/industrial areas located above the main groundwater plumes (CHC and mercury plumes) (Northern, Central and Southern Plumes), as well as commercial/industrial premises located near Springvale Drain (not including Southlands); and
  - *Penrhyn Estuary* - due to changes in access to this area as a result of the Port Botany Expansion, the potential for exposure to site-related chemicals in surface water and biota is limited.
- Consideration of additional assessments conducted including:
  - Air emission data from the operation of the GTP and Hexachlorobenzene (HCB) Repackaging Plant;
  - The potential presence of mercury impacted air and groundwater from the Former ChlorAlkali Plant (FCAP); and
  - The presence of contamination on Southlands and its potential future development.

The following scenarios have not been further assessed in the 2018 CHHRA and fall outside the scope of the annual and biennial monitoring program:

  - *Car Park Waste Encapsulation (CPWE)* - The CPWE has been remediated such that it is no longer a source of contamination on the site.
  - *Southlands* – The CHHRA indicates there are no current exposures in this area, as the site was remediated and redeveloped for commercial/industrial purposes. There are no residual risk issues that remain for the development of Block 2. Portions of Block 1 are also proposed to be redeveloped for commercial/industrial purposes. Soil within Block 1 has been remediated and the site is subject to a Long-Term Environmental Management Plan to address residual risks. No residual risks required assessment in the 2018 CHHRA.

The CHHRA (EnRiskS, 2018) assessed risks to human health based on review of the additional information and data from 2010 to 2017, evaluation of whether the potential for exposure has changed from that evaluated in the 2010 CHHRA (EnRiskS, 2010), review and update of information and values used to characterise the toxicity of the CoPC, and the quantification of risk. The quantification of risk was undertaken on the basis of a Reasonable Maximum Exposure (RME) that aims to present a worst-case estimate of exposure and health risk.

Risk and exposure scenarios associated with volatile CHC concentrations in groundwater within the western margin of the Northern Plumes, Main Plumes and Penrhyn Estuary will be considered in the annual and biennial GTP monitoring reports.

A review of the data collected as part of the March 2020 monitoring program in the context of data previously reported and/or used in the CHHRA is presented in the following sections.

5.1 Springvale Drain

A review of data from Springvale Drain (URS, 2009c) identified a strong relationship between shallow groundwater levels, concentrations of volatile CHCs in surface water and concentrations of volatile CHCs in ambient air adjacent to the drain. This review also identified shallow groundwater elevations (less than 2.3 m AHD at MWB03S) where the potential for inhalation exposures adjacent to the drain were not considered to be high.

Surface water samples have been collected from Springvale Drain and Floodvale Drain in conjunction with groundwater sampling from 1994 to September 2017. A review of additional data from Springvale Drain and ambient air adjacent to the drain (EnRiskS, 2012a) refined the procedure for review of potential risk issues. Where assessment of groundwater elevations in MWB03S indicates a potential for elevated inhalation exposures from Springvale Drain, the refined procedure requires that surface water samples are screened against risk-based criteria in addition to ANZG (2018) Trigger Values (see Section 5.0).

The table below, adapted from EnRiskS (2018), presents a summary of the average concentrations of CHCs reported in Springvale Drain (excluding within Southlands) between 2010 and 2017 with comparison against the health-based criteria (EnRiskS, 2012a). The average concentrations have been considered as the criteria relevant to long-term exposures.

The surface water risk-based assessment criteria were derived to be protective of potential vapour inhalation exposures by workers in existing workplaces located down-stream of McPherson Street. Additional risk-based surface water assessment criteria were subsequently derived and presented in a subsequent addendum report (EnRiskS, 2012b). These were designed to be protective of potential vapour inhalation exposures by workers operating in the vicinity of the Nant Street Tankfarm (to the north of Southlands), where workplace exposure scenarios are expected to be infrequent and of shorter duration.

Summary and Review of Surface Water Concentrations in Springvale Drain (mg/L) (adapted from Table 5-6 of EnRiskS, 2018)

CHC	South of McPherson Street		Nant Street Tank Farm	
	Average Concentration 2010-2017	Surface Water Criteria[1]	Average Concentration 2010-2017	Surface Water Criteria[2]
Vinyl chloride	0.0077	0.1	0.025	0.8
cis-1.2-Dichloroethene	0.021	0.18	0.21	1.5
1.2-Dichloroethane	0.019	0.42	0.0043	3.5
Trichloroethene	0.0051	0.1	0.11	0.8

CHC	South of McPherson Street		Nant Street Tank Farm	
	Average Concentration 2010-2017	Surface Water Criteria[1]	Average Concentration 2010-2017	Surface Water Criteria[2]
Tetrachloroethene	0.0014	0.35	0.03	3
Chloroform	0.0033	0.17	0.078	1.4
Carbon Tetrachloride	0.0028	0.085	0.13	0.7

Notes:

1 Criteria relevant to chronic inhalation exposures in workplace areas adjacent to Springvale Drain south of McPherson Street. Data from monitoring locations SW049, SW064 and SW005 have been considered (EnRiskS, 2012a).

2 Criteria relevant to chronic inhalation exposures in workplace areas adjacent to Nant Street tank farm, located north of Southlands. Data from monitoring location SW046 have been considered (EnRiskS, 2012b).

Shaded cells are the Adopted Current Screening Levels.

5.1.1 Review of March 2020 Monitoring Data

During the six-month monitoring period, the groundwater level at MWB03S exceeded the risk review trigger level for a cumulative period of 23 days during the monitoring period (refer Figure A.16 in Appendix A), which is less than the period recommended by EnRiskS (2018) (three months) as a trigger for further assessment. As illustrated in Figure A.16, the elevated groundwater levels are expected to have resulted from the scheduled GTP maintenance shutdown in September 2019 and the significant rainfall event in February 2020 (378 mm).

The concentrations of the identified CoPC in surface water samples in the March 2020 program were also less than those considered in the CHHRA (EnRiskS, 2018). No issues that might require further assessment were identified during the monitoring period with respect to potential CHC inhalation exposures adjacent to Springvale Drain.

5.2 Penrhyn Estuary

The CHHRA (EnRiskS, 2018) noted that Penrhyn Estuary is no longer accessible for recreational or fishing purposes due to the Port Botany Expansion. As such, the exposure pathways considered in the CHHRA include the inhalation of volatile CHCs by the general public from surface water in the estuary and the ingestion of fish species caught outside the estuary area that may be derived from the estuary.

The 2010 CHHRA (EnRiskS, 2010) did not identify elevated concentrations within the estuary that were of concern for visitors and maintenance workers. Hence no further detailed assessment of exposure (to volatile CHCs that may be derived from surface water in the area) was undertaken in the 2018 CHHRA update.

The table below presents a summary of CHCs detected in surface water within the estuary considered in EnRiskS (2018). These concentrations were compared with risk-based surface water criteria that have been derived for the protection of long-term workplace inhalation exposures adjacent to Springvale Drain (EnRiskS 2012a). Exposures within the Penrhyn Estuary are expected to be infrequent and of short duration. In addition, exposures by the general public will occur further away from the surface water than was considered in the development of the guidelines for Springvale Drain. These criteria are more relevant and appropriate (for the exposures that are likely to occur) but remain conservative (for infrequent exposures) than more generic recreational water guidelines used in the 2010 CHHRA (EnRiskS, 2010). Hence the use of these surface water criteria for reviewing concentrations in Penrhyn Estuary is considered to be highly conservative.

Summary of Surface Water Data – Penrhyn Estuary (mg/L) (adapted from Table 6-2 of EnRiskS, 2018)

CHC detected	Maximum concentration in Estuary – 2010 CHHRA*	Average concentration in Estuary – 2010-2017**	Average concentration at Springvale Drain: 2010-2017***	Long-term Risk-Based Screening Level Guideline
1,2-Dichloroethane	0.007	0.00057	0.0017	0.42
cis-1.2-Dichloroethene	0.01	0.00065	0.011	0.18
trans-1,2-Dichloroethene	0.001	<0.001	0.0017	0.18 (adopting the value for cis-1,2-DCE)
Chloroform	0.002	0.0005	0.002	0.17
Trichloroethene	0.002	0.00052	0.002	0.1
Tetrachloroethene	0.008	<0.001	0.00069	0.35
Vinyl chloride	0.001	0.0023	0.0097	0.1

Notes:

* Maximum reported from March 2008 to March 2010 from locations SW028, SW029, SW060 and SW048 as considered in the 2010 CHHRA (EnRiskS 2010).

** Average concentration reported from March 2010 to March 2017 from locations SW028, SW029 and SW060.

*** Average concentration reported from March 2010 to March 2017 from locations SW030 and SW031 located where Springvale Drain enters the estuary.

On the basis of the above table, there were no CHCs present in surface water in the estuary that were sufficiently elevated to warrant detailed consideration in the CHHRA (EnRiskS, 2018). The average concentrations reported were well below the risk-based screening criteria (that are highly conservative for evaluating inhalation exposures in the estuary area). Hence, risks to human health associated with the presence of these CHCs in surface water were considered negligible. No further detailed assessment of inhalation exposures was considered to be warranted (EnRiskS 2018).

5.2.1 Review of March 2020 Monitoring Data

The CHHRA (EnRiskS, 2018) considered the surface water data from monitoring locations SW029, SW060, SW028, SW030 and SW031 collected from March 2010 to March 2017 and found that there were no CHCs in surface water in the estuary sufficiently elevated to warrant consideration in the risk assessment.

The concentrations of volatile CHCs at SW028, SW029, SW030, SW031 and SW060 during the March 2020 program were less than the long-term risk screening levels considered in the CHHRA (EnRiskS, 2018).

5.3 Summary

The CHHRA (EnRiskS, 2018) concluded that the calculated risks to human health, assuming groundwater is not extracted and used for any purpose (other than treatment at the GTP), are considered to be low and acceptable. There are no data presented in the March 2020 monitoring round that affect the conclusions in relation to Penrhyn Estuary and Springvale Drain.

6.0 CONCLUSIONS

This report presents the results of groundwater and surface water data collected in March 2020 as part of the Groundwater Treatment Plant (GTP) – Groundwater and Surface Water Monitoring Program. The scope of services of the March 2020 monitoring program is intended to fulfil the requirements of a biannual sampling event as specified in the 2017-2020 GTP Groundwater and Surface Water Monitoring Program (Golder 2017b).

6.1 Hydraulic Monitoring

Assessment of hydraulic data for the March 2020 monitoring event, with consideration of the six-step evaluation approach adopted by JBS&G (2012) and Golder (2013e), indicates that, although effective hydraulic containment of the target capture zones was inconsistent during the period, overall the BGC Project remedy objectives were met.

With the exception of parts of the SCA, groundwater levels were generally lower than during the previous monitoring period (i.e. September 2019), predominantly as a result of consistently lower than average rainfall, and also as a result of improved pump performance following the maintenance works performed during the September 2019 scheduled maintenance shutdown of the GTP. Lower groundwater extraction rates associated with the September 2019 GTP shutdown and reduced pumping performance and efficiency caused by well biofouling and the failure of EWF28D at the SCA is also evident.

Effective hydraulic containment at BIP was evidenced by the achievement of target levels and the average groundwater flow patterns.

The assessment of reverse hydraulic gradients did not support hydraulic capture within the shallow aquifer at the PCA, although this is where CHC concentrations are typically very low. Evidence of effective hydraulic containment within the target capture zones of the PCA (i.e. within the intermediate and deep aquifer) was evidenced by the averaged groundwater flow pattern and the achievement of target water levels.

Elevated groundwater levels at the SCA do not support consistent hydraulic containment of the target capture zones at the SCA. Evidence of hydraulic containment on the basis of reverse hydraulic gradients was apparent in the shallow aquifer of the SCA and intermediate aquifer for the eastern and western portion of the SCA. A flat hydraulic gradient can be inferred in water levels achieved in the intermediate aquifer within the central portion of the SCA. Elevated averaged groundwater levels were particularly evident in the eastern portion of the deep aquifer at SCA where the failure of extraction well EWF28D in April 2019 has reduced groundwater extraction efficiency.

Notwithstanding, the remedy objective does not require complete hydraulic capture at all containment lines but requires that the mass flux of contaminants entering the estuary in groundwater does not result in surface water concentrations exceeding the guidelines values. Thus, effective hydraulic containment is evidenced by contaminant flux in groundwater that has passed the containment lines. Assessment of contaminant concentrations at Springvale Drain and Penrhyn Estuary, located downgradient of the SCA, indicates that the BGC Project remedy objectives continue to be achieved (refer Section 4.3), noting the expected lag for CHC migration due to the relatively flat hydraulic gradient between the SCA and Penrhyn Estuary.

It should also be noted that the slow migration rates between the SCA and Penrhyn Estuary allow for potential recapture of CHCs that migrate beyond the SCA during periods or poor hydraulic containment. Well rehabilitation works and the planned installation of two deep extraction wells (EWF25D and EWF28D) in June 2020 (pending regulatory approval) are expected to improve pump performance and contaminant recapture within the eastern portion of the SCA. In addition, pump performance and hydraulic containment are expected to improve following the maintenance operations completed as part of the scheduled GTP shutdown in March 2020.

6.2 Chemical Monitoring

Reported CHC concentrations in groundwater at MWF15, MWF17, MWF18, MWF19 and BP01/BP117 were generally consistent with, or less than, those reported in previous monitoring events. Increasing CHC contamination trends (both long- and short-term trends) are noted at MWF15D for EDC; MWF17S for EDC and CFM; at MWF19I for EDC and CFM; and at MWF18D for EDC, PCE, TCE, CFM and VC, however these are not considered to represent a significant change in contaminant distribution.

The increasing trend and historical maximum concentration for TCE in the deep aquifer at MWF18 potentially represents limited migration of groundwater containing higher concentrations of dissolved phase TCE associated with the Southern Plumes within and upgradient of the central portion of the SCA. Groundwater extraction within this portion of the SCA is also expected to improve following the scheduled GTP maintenance shutdown completed in March 2020, aimed to maintain reliable performance of hydraulic containment in the SCA and improve recapture of CHCs in the area immediately downgradient. TCE was not detected in downgradient surface water monitoring locations, however consideration is being given to the augmentation of the monitoring program downgradient of this location to ensure adequacy of coverage within Penrhyn Estuary.

The historical maximum concentration reported for PCE at BP117 is consistent with or lower than those reported at downgradient monitoring locations. An increasing trend was also reported for TCE at this location, at similar depth. Similarly, increasing trends were reported for EDC, PCE, VC and CFM. These increases potentially represent remnant Southern Plumes contamination (i.e., preceding commencement of operation of the SCA) being flushed from the generally stagnant area by the heavy rainfall in February and/or could be a result of inconsistent hydraulic containment in the eastern portion of the SCA. It is noteworthy that the overall CHC concentrations within this area remain significantly lower than historical concentrations reported prior to operation of the SCA and the downgradient CHC concentrations in surface water remain low. Furthermore, the planned installation of new and replacement extractions wells (EWF25D and EWF28D) is expected to improve hydraulic containment of the eastern portion of the SCA, upgradient of this location. Continued monitoring of this location in consideration of the downgradient pore water transect locations is required to ensure the remedy objectives of the BCG at Penrhyn Estuary continue to be met.

In general, the March 2020 Penrhyn Estuary pore water data are consistent with previous monitoring rounds with the concentrations of key contaminants generally decreasing with decreasing depth towards the discharge interface. The concentrations of the key contaminants of concern in pore water reported in the March 2020 monitoring round are less than the ANZG (2018) Trigger Values for all pore water samples with the exception of VC at BP42 in the 0.5 and 2 m ports. It is noted that VC concentrations at BP42 are historically highly variable, and that the concentrations are significantly lower than the reported historical maximum concentrations for these location and depths. No historical maximum concentrations for key contaminants were reported in samples collected from Penrhyn Estuary pore water during the March 2020 monitoring round.

Reported CHC concentrations in surface water were generally consistent with, or less than, those reported in previous monitoring events. Key contaminant concentrations were less than the relevant ANZG (2018) Trigger Values at all surface water sampling locations. No historical maximum concentrations for key contaminants in surface water were reported during the March 2020 monitoring round.

6.3 Implications for Human Health Risk Assessment

A review of Springvale Drain surface water data collected in accordance with EnRiskS (2018) did not identify potential issues with respect to workplace inhalation exposures adjacent to Springvale Drain. It is noted that water levels at MWB03S, which is located close to Springvale Drain where it flows under McPherson Street, exceeded the risk review trigger level for a cumulative period of 23 days during the monitoring period, which is less than the period recommended by EnRiskS (2012a) (three months) for a further review of analytical data.

There are no data presented in the March 2020 monitoring round that affect the conclusions of the CHHRA (EnRiskS, 2018) in relation to Penrhyn Estuary and Floodvale and Springvale Drains (i.e., provided groundwater is not extracted and used for any purpose, health risks associated with exposure to CoPC are low and acceptable).

7.0 IMPORTANT INFORMATION RELATING TO THIS 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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