

5. Results

The results from the 2019 groundwater monitoring program are provided in the below sections.

5.1 Site conditions

During the 2019 monitoring period, all monitoring well locations were accessible, with the exception of CCBH1 and SE5 (see Section 3.3 for further details). In addition, a number of shallow groundwater wells (including monitoring wells SE1S –SE7S) were unable to be sampled during the 2019 monitoring event due to insufficient standing water. Samples from both SE9S and SE10S were able to be recovered during the April 2019 GME only.

The shallow groundwater wells installed by GHD in 2018 (GW1S, GW5S, GW7S and GW9S) were able to be sampled during the 2019 monitoring events. Newly installed monitoring well, GW5D, was noted as being dry for both the April and September 2019 monitoring events.

5.2 Groundwater elevation and flow direction

Water level gauging data and corrected groundwater elevations (m AHD) for each monitoring event are included in Table 5-1 below with contours presented on Figure 3, Appendix A for the lower superficial aquifer and Figure 4, Appendix A for the upper superficial aquifer. As per Figure 3 and Figure 4, Appendix A, groundwater flow is inferred to be in a north-westerly direction within the lower superficial aquifer and a westerly direction within the upper superficial aquifer, which is consistent with previous investigations and monitoring events.

Groundwater elevation ranges are shown as follows:

- April: 34.58 m AHD (CCBH2) to 57.26 m AHD (GW5S).
- September: 34.82 m AHD (SE4D) to 57.27 m AHD (GW5S).

Table 5-1 Groundwater elevation April and September 2019

Well ID	Monitoring Event	Easting	Northing	TOC elevation (m AHD)	Groundwater depth (m bTOC)	Groundwater elevation (m AHD)
SE1S	April	38348	6300786	74.36	28.08	46.28
	September				-	-
SE1D	April	38348	6300786	74.36	34.68	39.68
	September				34.76	39.60
GW1S	April	387263	6300801	71.17	35.30	35.87
	September				35.60	35.57
GW1D	April	387250	6300802	70.06	35.05	35.01
	September				35.15	34.91
SE3D	April	387248	6300402	73.10	37.43	35.67
	September				37.69	35.41
SE4D	April	387171	6300237	71.70	36.14	35.56
	September				36.35	34.82
SE5D	April	388021	6300376	103.99	-	-

Well ID	Monitoring Event	Easting	Northing	TOC elevation (m AHD)	Groundwater depth (m bTOC)	Groundwater elevation (m AHD)
GW5S	September	388120	6300253	105.97	-	-
	April				48.71	57.26
	September				48.70	57.27
GW5D	April	388120	6300263	105.30	-	-
	September				-	-
SE6D	April	387099	6300773	63.98	28.18	35.80
	September				28.55	35.43
SE7D	April	387095	6300625	67.01	31.15	35.86
	September				31.52	35.49
GW7S	April	387105	6300536	67.45	31.39	36.06
	September				31.81	35.64
GW7D	April	387102	6300536	67.64	32.49	35.15
	September				32.67	34.97
SE8	April	387128	6300437	67.05	N/A	N/A
	September				N/A	N/A
SE9D	April	386942	6300285	63.89	26.20	37.69
	September				26.32	37.57
GW9S	April	386870	6300306	60.56	24.76	35.80
	September				25.14	35.41
GW9D	April	386871	6300310	60.55	24.08	36.47
	September				25.41	35.14
SE10S	April	386942	6300232	64.43	24.27	40.16
	September				25.01	39.42
SE10D	April	386942	6300232	64.43	26.98	37.45
	September				26.84	37.59
CCBH1	April	386586	6300487	52.00	-	-
	September				-	-
CCBH2	April	386712	6300747	53.50	18.92	34.58
	September				-	-

'-' denotes the well was unable to be sampled

'N/A' denotes that a pump was pre-installed into this monitoring well (i.e. no depth to water could be obtained).

Given the uncertainties around the exact construction details and screened aquifer for existing groundwater wells SE1D, SE6D, SE7D, SE9D, SE10D and CCBH2 (based on the findings from

the GHD Hydrogeological Investigation (GHD, 2018a); GHD has excluded the water elevation data from these points in terms of contouring groundwater heights to derive flow direction (as presented on Figure 3, Appendix A). The groundwater flow direction inferred for the deep aquifer was relied upon through the groundwater heights obtained from the newly installed groundwater well network.

5.3 Groundwater field parameters

Groundwater at the Site was generally observed as turbid but becoming clear during purging with no sheen observed. Water quality parameters observed during the 2018 monitoring events are presented in Table 5-2 below.

Table 5-2 Field parameters April and September 2019

Sample ID	Date	pH	EC (µS/cm)	TDS (mg/L)	REDOX (mV)	Dissolved oxygen (mg/L)	Temperature (°C)	Comments
SE1S	11/04/19	4.75	232.7	151.5	-19.7	2.38	20.6	Brown-grey cloudy, no odour, no sheen, moderate to high sediment load
SE1D	11/04/19	4.61	465.5	303.0	-0.2	4.05	20.5	Clear, low-no sediment, no odour, no sheen
	24/09/19	5.22	438.0	284.7	-20.8	1.89	19.6	Clear, no sheen, no odour, low sediment load
GW1S	11/04/2019	5.95	982.0	637.0	-43.8	2.54	20.4	Clear-slightly cloudy, organic odour, no sheen, moderate sediment
	24/09/19	6.13	873.0	567.5	1.7	3.15	22.3	Cloudy brown, no odour, no sheen, moderate sediment
GW1D	11/04/2019	8.35	1085.0	708.5	-152.1	3.56	21.0	Clear, no odour, no sheen, low sediment
	24/09/19	7.32	1138.0	741.0	-169.3	3.09	20.9	Clear, no odour, no sheen, low sediment
SE3D	10/04/19	4.55	563.0	364.0	0.4	4.21	22.6	Clear, low-moderate sediment load, slight odour (sulphur/organic), no sheen
	25/09/19	5.41	522.6	340.0	8.9	1.61	21.9	No odour, no sheen, clear, low sediment
SE4D	10/04/19	4.41	269.7	175.5	-1.0	3.67	21.6	Clear, no sheen/odour, low sediment
	25/09/19	5.73	295.2	192.4	101.4	5.56	18.6	Clear, no odour, no sheen, low sediment
GW5S	24/09/19	4.81	2260.0	1469.0	79.6	2.66	23.4	Cloudy brown, high sediment load, no odour, no sheen
GW5D	-	-	-	-	-	-	-	Well dry
SE6D	10/04/19	5.08	353.2	224.5	-18.3	9.64	21.3	Clear, no odour, no sheen, low-no sediment
	24/09/19	5.3	399.6	260.0	28.5	3.15	21.4	No sheen, no odour, clear, low sediment
SE7D	10/04/19	4.49	291.4	189.8	-2.8	4.52	21.2	Cloudy white, moderate sediment load, no odour, no sheen
	24/09/19	5.27	262.6	171.0	-59.1	2.30	19.2	Clear, low sediment load, no odour, no sheen
GW7S	10/04/19	5.53	181.6	118.3	-21.8	6.69	23.8	Clear, no odour, no sheen, low-no sediment
	24/09/19	6.91	237.2	154.1	26.4	2.76	20.7	Clear, no odour, no sheen, low-no sediment
GW7D	10/04/19	5.98	501.8	326.3	-25.4	2.91	21.6	Clear, no odour, no sheen, low-no sediment
	25/09/19	11.49	1012.0	656.5	-56.4	2.15	19.8	Cloudy brown, no odour, no sheen, moderate sediment
SE8D	11/04/19	4.78	328.8	214.9	2.4	6.85	20.2	Clear, no odour, no sheen, low-no sediment
	25/09/19	4.68	345.4	224.9	124.2	4.68	18	Clear, low sediment, no odour, no sheen
SE9S	10/04/19	4.68	156.5	102.1	-3.4	4.95	23.0	Cloudy brown, no odour, no sheen, moderate sediment
SE9D	10/04/19	4.23	376.6	245.1	14.8	4.77	20.7	Clear, no odour, no sheen, low-no sediment
	25/09/19	4.73	350.8	228.2	-38.5	0.98	20.1	Clear, no odour, no sheen, low sediment
GW9S	10/04/19	4.80	325.5	211.9	0.4	4.54	22.4	Clear, no odour, no sheen, low sediment
	24/09/19	5.07	291.9	190.0	33.7	2.61	19.2	No odour, no sheen, clear, low sediment
GW9D	10/04/19	5.34	378.9	246.4	-10.1	5.07	21.6	Clear, low sediment, no odour, no sheen
	24/09/19	6.1	454.3	295.1	21.2	1.45	19.6	Clear-cloudy brown, no odour, no sheen, low sediment
SE10S	24/09/19	4.98	186.6	121.6	44.4	3.10	19.7	Cloudy brown, no odour, no sheen, moderate sediment
	10/04/19	4.47	368.2	239.2	4.4	4.17	23.1	No odour, no sheen, clear, low-no sediment load
SE10D	24/09/19	4.62	339.4	222.3	79.5	3.23	19.9	No odour, no sheen, clear, low sediment

Sample ID	Date	pH	EC (µS/cm)	TDS (mg/L)	REDOX (mV)	Dissolved oxygen (mg/L)	Temperature (°C)	Comments
CCBH1	-	-	-	-	-	-	-	Well dry
CCBH2	11/04/19	4.82	158.3	102.7	-7.8	4.49	22.0	Monument overgrown with bushes, no sheen, cloudy brown, no odour, moderate sediment.
-	-	-	-	-	-	-	-	Insufficient water for sampling.

‘-’ denotes that the well was dry or unable to be sampled, ‘*’ denotes that no comment was noted on the field sheet at this location, ‘**’ denotes that the highly alkaline (outlier) pH value observed which is not considered representative of groundwater conditions at this location

A summary of the main observations from Table 5-2 is provided below:

- The recorded pH measurements from all of the wells sampled (shallow and deep) indicated that the groundwater was slightly acidic to slightly alkaline and ranged between a pH of 4.23 in April (SE9D) and 8.35 in April (GW1D).
- Elevated alkaline pH values were observed at GW7D (11.49) during the September 2019 monitoring event which GHD consider may now be representative of seasonal groundwater variance at this location (pH values have been neutral in April event and Alkaline (~10 and ~11) during September 2018 and 2019 monitoring events). The pH will continue to be reassessed in future monitoring rounds, particularly at these locations, given the limited dataset (constructed in 2018).
- Field EC ranged from 156.5 $\mu\text{S}/\text{cm}$ in April (SE9S) to 2,260.0 $\mu\text{S}/\text{cm}$ in September (GW5S). Overall, the results indicate that groundwater within the deeper wells tends to be of 'fresh' water quality and the shallow wells were more associated with a 'marginal' water quality.
- TDS concentrations were highest in September at GW5S (1469.0 mg/L) and the lowest in April at SE9S (102.1 mg/L) which correlates with the measured EC concentrations.
- REDOX ranged from -169.3 mV in September (GS1D) to 124.2 mV in September (SE8D).
- Dissolved oxygen concentrations ranged between 0.98 mg/L in September (GW9S) to 9.64 mg/L in April (SE6D).
- Overall most monitored locations reported a light brown (became clear following purging) to brown colouring, no odour, a low-no sediment load and no sheen with the following exceptions noted:
 - Monitoring well GW5S (September 2019), CCBH2 (April 2019) and SE1S (April 2019) were observed to have a cloudy brown colouring, and moderate to high sediment load.
 - An odour (possibly organic or sulphurous) was noted at SE3D in April 2019, which persisted throughout sampling at this location. This odour was not present in the subsequent September 2019 monitoring round.

5.4 Laboratory analytical results

The detailed analytical results for the April and September 2019 GMEs are presented in Appendix D – Table D. 1. Associated QA/QC results tables are also presented in Appendix D- Table D. 2 and Table D. 3. Laboratory Certificates of Analysis are included in Appendix E

Analytical results reported above the adopted assessment criteria are summarised in Table 5-3 and Table 5-4 below. It is noted that concentrations of PAH, Phenols, PCBs, OCP or OPP compounds (monitored in the September event only as part of the annual analytical suite) were reported below the LOR, which is consistent with historical monitoring observations.

Concentrations of TRH (NEPM 2013 fractions) were reported above the LOR at SE1D, GW1D, GW1S, SE3D, GW5S. Low concentrations of PFAS were reported marginally above the LOR at SE1D, GW1D, GW1S, GW7D, SE9D, SE10D. The detections of PFAS and TRH compounds were below the adopted assessment criteria.

5.4.1 April 2019 – Assessment criteria comparison

A summary of the April 2019 GME results, against the adopted assessment criteria, are presented in Table 5-3.

Table 5-3 Laboratory results summary – April 2019

Location		Elevated result against the adopted assessment criteria (as defined in Section 3)			
Locational Context	Sample ID	Australian Drinking Water Guidelines	Fresh Waters Guidelines	Long-term Irrigation Guidelines	Non-potable Groundwater Use
Cross Gradient (site)	SE1D	-	Zn	Fe	-
	SE1S	-	N (total), P (total), Cu, Fe, Zn	N (total), P (total), Fe	Fe
	GW1D	-	Al, Cu, Zn	Fe, Mn	Al
	GW1S	Mn	Fe, Zn	Fe, Mn	Fe
Down Gradient (Primary Leachate Pond)	SE3D	-	N (total), Cu, Zn	-	-
Up gradient (Leachate Evaporation Ponds)	SE4D	-	Al, Cu, Zn	Fe	-
Up gradient (site)	GW5S	Mn	N (total), P (total), Al, Cu, Fe, Ni, Zn	P (total), Fe, Mn	Al, Fe, Cl
Down Gradient (Crystal Pigment Cell 1)	SE6D	-	N (total), P (total), Zn	N (total), P (total), Fe	-
	SE7D	-	Cu, Zn	-	-
	GW7D	Mn	Fe, Zn	Fe, Mn	Fe
	GW7S	-	N (total), Cu, Zn	N (total), P (total)	-
	SE8D	-	N (total), Fe	Fe	Fe
Down Gradient (Leachate Evaporation Ponds)	SE9D	-	Zn	Fe	-
	SE9S	-	P (total), Al, Cu, Fe, Zn	P (total), Fe	Fe
	GW9D	-	Fe, Zn	Fe, Mn	Fe
	GW9S	-	Cu, Fe, Zn	Fe	Fe
	SE10D	-	Al, Cu, Zn	Fe	-
	SE10S	-	N (total), Fe, Zn	N (total), Fe	Fe

Location		Elevated result against the adopted assessment criteria (as defined in Section 3)			
Down Gradient (site)	CCBH2	-	N (total), Cu, Fe, Zn	N (total), P (total), Fe	-

5.4.2 September 2019 – Assessment criteria comparison

A summary of the September 2019 GME results against the adopted assessment criteria are presented in Table 5-4. GHD notes the majority of shallow wells (and monitoring well CCBH2) were dry for the September 2019 GME and have subsequently been excluded from Table 5-4.

Table 5-4 Laboratory results summary – September 2019

Location		Elevated result against the adopted assessment criteria (as defined in Section 3)			
Location Context	Sample ID	Australian Drinking Water Guidelines*	Fresh Waters Guidelines	Long-term Irrigation Guidelines	Non-potable Groundwater Use
Cross-gradient	SE1D	-	Zn	Fe, Mn	-
	GW1D	-	Al, Cu, Fe, Zn	Fe, Mn	Fe, Cl
	GW1S	Mn	Cu, Fe, Zn	P (total), Fe, Mn	Fe
Down-gradient (Primary Leachate Pond)	SE3D	-	Cu, Zn	Fe	-
Up-gradient (Leachate Evaporation Ponds)	SE4D	-	Fe	Fe	Fe
Up-gradient (site)	GW5S	-	N (total), Al, Cu, Fe, Zn	P (total), Fe, Mn	Cl, Al, Fe
Down-gradient (Cristal Pigment Cell 1)	SE6D	-	N (total), Zn	N (total), Fe	-
	SE7D	-	Cu, Zn	-	-
	GW7D	-	Al, Fe, Zn	Fe	Al, Fe
	GW7S	-	N (total), Al	-	-
	SE8D	-	N (total), Cu, Pb, Ni, Zn	-	-
Down-gradient (Leachate)	SE9D	-	Al, Zn	-	-
	GW9D	-	Al, Fe, Zn	Fe, Mn	Fe

Location		Elevated result against the adopted assessment criteria (as defined in Section 3)			
Evaporation Ponds)	GW9S	-	Zn	-	-
	SE10D	-	Al, Zn	-	-
	SE10S	-	N (total), Al, Zn	N (total)	-

5.5 Quality assurance / quality control evaluation

5.5.1 Relative percentage difference

Table 5-5 outlines the blind duplicate samples that were collected for groundwater monitoring in 2019 during both events.

Table 5-5 Duplicate samples collected for the 2019 biannual monitoring

Primary sample	Date	Duplicate sample ID
SE10D	10/04/2019	FD01
GW1S	24/09/2019	FD01
SE10S	24/09/2019	FD02

The precision of the results for each analyte between the primary sample and the field duplicate is determined by calculating the relative percentage difference (RPD). A quantitative measure of the accuracy of the analytical results reported is made by calculating the RPDs in accordance with the procedure described in AS 4482.1 – 2005 (Standards Australia, 2005). RPD calculations are presented in Table D. 2, Appendix D.

RPDs above the tolerable range specified are summarised in Table 5-6 below. An RPD limit of 30% has been adopted.

Table 5-6 Summary of RPDs above 30%

Primary sample	Date	QC sample ID	Analyte	RPD (%)
SE10D	10/04/2019	FD01	Calcium (filtered)	67%
SE10D	10/04/2019	FD01	Nitrogen (total)	67%
SE10D	10/04/2019	FD01	Kjeldahl Nitrogen total	67%
GW1S	24/09/2019	FD01	Alkalinity (Bicarbonate as CaCO ₃)	36%
GW1S	24/09/2019	FD01	Alkalinity (total as CaCO ₃)	36%
GW1S	24/09/2019	FD01	Nitrogen (total)	55%
GW1S	24/09/2019	FD01	Phosphorus (total)	97%

GHD notes there were no observed RPD results above the trigger level between the primary, field duplicate analysis for PFAS during the September 2019 monitoring round. However, seven RPD results that were above the trigger value across April and September monitoring rounds, comprising calcium, nitrogen, kjeldahl nitrogen, alkalinity (bicarbonate as CaCO₃ and total CaCO₃) and phosphorus. The alkalinity RPD exceedances are considered to be a result of the lack of homogeneity of the sediments suspended in the sample. The remaining RPD results detected over the adopted 30% limit (as outlined in Table 5-6) are considered the result of the concentrations of one or both of samples being very close to the LOR or marginally above the LOR which exaggerates the resultant RPD calculation.

In general, the concentrations of both sample pairs (primary and duplicate) from the 2019 quality control samples collected are considered to be of very similar orders of magnitude and the exaggerated RPD calculations in Table 5-6 are not considered to represent a reproducibility issue within the laboratory analysis.

Blank analytical results

Field, rinsate and trip blanks were collected during the April and September 2019 monitoring events. A summary of blank sample results is provided in Table D. 3, Appendix D.

The analysis of the blank samples indicated that all analytes were below the relevant LORs. The absence of detectable concentrations in the blank samples suggests that the transportation process, the ambient conditions onsite and the use of equipment on multiple locations has not introduced contamination to the samples collected.

5.5.2 Laboratory QA/QC

A review of laboratory holding times, method blanks, duplicates, control outliers and matrix spikes was completed, with the following items identified as being outside the acceptable range:

- April 2019 – Report EP1903456
 - Internal QC frequency: Total metals – QC frequency not met (actual rate was 4.67%, expected rate was 5%).
- September 2019 – Report EP1909864
 - Holding time: Nitrate as N, OC pesticides and PCBs were 1 day overdue, OP pesticides were 6-7 days overdue. This is considered to be a courier error as the samples were sent to the laboratory on the 25 September, however the samples were not received by the laboratory until the 27 September.
 - Internal QC frequency: TRH volatiles/BTEX– QC frequency not met (actual rate was 4.76%, the expected rate was 5%).
 - Matrix spikes: OP pesticides (temephos and fosetyl aluminium) were reported outside acceptable ranges.

Overall, the laboratory QA/QC parameters were largely met and the minor discrepancies mentioned above are not considered to affect the reliability of the laboratory data received.

5.5.3 Data quality review summary

From the data quality review, GHD considers that there is an acceptable level of confidence in the data upon which meaningful conclusions can be drawn. However, as per Section 4.5, GHD recommends that for future monitoring events that PFOS is analysed at ultra-trace levels to ensure that the reportable LORs allow an accurate comparison to the 99% freshwater guidelines (0.00023 ug/L).