

18 August 2023

Director Petroleum Operations
Department of Environment, Parks and Water Security
PO Box 3675
Darwin NT 0801
[REDACTED]

[REDACTED]

Re: Annual Interpretative Groundwater Quality Report - Beetaloo Sub-Basin Multi-well Drilling, Stimulation and Well Testing Program Amungee NW ORI10-3

Ministerial approval condition 5(iii) for the *Beetaloo Sub-basin Multi-well Drilling, Stimulation and Well Testing Program Exploration Permit (EP) 98 & 76 Environment Management Plan ORI10-3* (the EMP) requires an interpretative report of groundwater quality based on the groundwater monitoring required to be conducted at the well site(s) in accordance with Table 6 of the Code. The interpretative report must be provided annually within 3 months of the anniversary of the approval date of the EMP and include:

- identification of any change to groundwater quality or level attributable to conduct of the regulated activity at the well site(s) and discussion of the significance and cause of any such observed change
- interpretation of any statistical outliers observed from baseline measured values for each of the analytes
- discussion of any trends observed
- a summary of the results including descriptive statistics
- description of the layout of the groundwater monitoring bores and wells, indicative groundwater flow directions and levels in accordance with the Preliminary Guideline Groundwater Monitoring Bores for Exploration Petroleum Wells in the Beetaloo Sub-basin.

The Code is in reference to the Code of Practice: Onshore petroleum activities in the Northern Territory (DENR, 2019). It is referred to as the “Code” throughout this report.

This letter constitutes the annual interpretative groundwater quality report for the Amungee NW well site for 2023.

Site layout and groundwater flow direction

Figure 1 presents the layout of the Amungee NW1 wellsite, showing the locations of the Amungee NW1H and Amungee NW 2H appraisal wells and the control monitoring bore (CMB – RN040894) and the impact monitoring bore (IMB – RN040318).

The CMB is 100 m to the south-southeast of Amungee NW2H and the IMB is 20 m northwest of the same well. The CMB and IMB and up hydraulic gradient and down hydraulic gradient of the well, based on the regional groundwater flow direction (Figure 1, after DEPWS, 2022). The CMB and IMB are fully penetrating

of the Gum Ridge Formation aquifer. The Anthony Lagoon Formation aquifer is not present at the Amungee NW wellsite.

The indicative groundwater flow direction, based on the SREBA (DEPWS, 2022) and monitoring results collected onsite, is from the southwest to the northeast in the vicinity of the Amungee NW well site.

The Amungee NW 2H well was drilled in November/December 2022 and was hydraulically fractured between 15 February 2023 and 21 March 2023.

Figure 1 Site layout and indicative groundwater flow direction



Water level trends

Water level monitoring in the CMB and IMB commenced in 2018 and in 2023 respectively using InSitu® LevelTroll automatic water level sensors installed in the bores. Figure 2 presents timeseries water level data for the CMB (blue line) and IMB (orange line) for the period January to July 2023, with a full record for the CMB provided as Figure 3. These data show:

- High frequency (four-minute) water level measurements commenced on 18 January 2023, and have continued through to 10 July 2023.
- The CMB was used to supply water for regulated activities in July/August 2022, for civil works associated with the preparation of the wellsite for the drilling of Amungee NW 2H.
- Both bores were used to supply water for regulated activities for the period 17 February to 24 March 2023, associated with the hydraulic fracturing of Amungee NW 2H.
- While pumping, the water level in the bore was drawn down by up to approximately 3 m, with effectively instantaneous recovery thereafter.
- There has been periodic groundwater extraction of the bores post March 2023, primarily for the purpose of collecting groundwater samples for analysis.
- Prior to the commencement of water take, the water levels were essentially stable, but showed a seasonal fluctuation of approximately 0.1 m.
- There has been a slight rising trend in groundwater level in both bores following the cessation of extraction for authorised activities.
- The differences in groundwater depths measured in the bores is most likely to relate to the relative difference in the reference point from which the measurement is made.
- There are some periods where there has been no logger in the CMB due to equipment failure.

There has been no significant change to the water level in the Gum Ridge Formation due to the regulated activities.

Figure 2 CMB and IMB groundwater levels from high frequency data

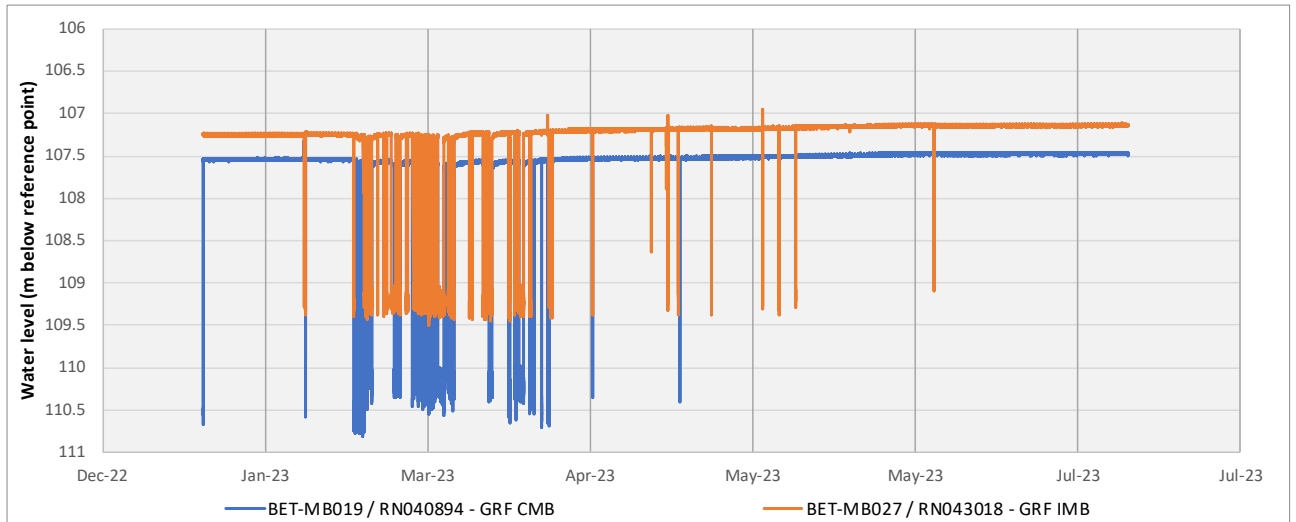
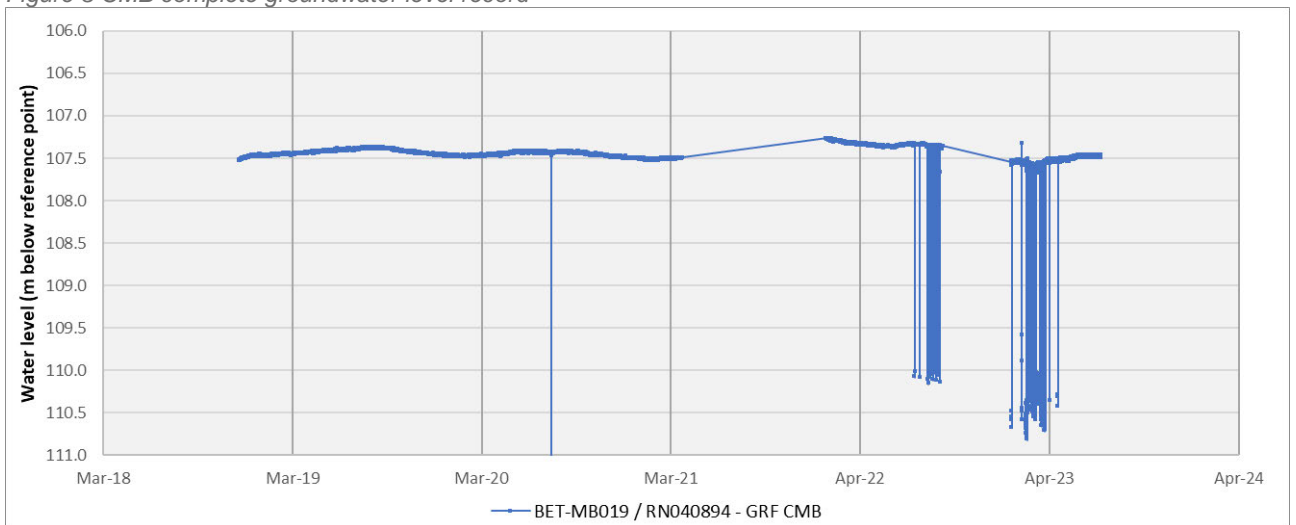


Figure 3 CMB complete groundwater level record



Water quality trends

Groundwater from the CMB and IMB has been sampled for the suite of analytes listed in Table 6 of Section B.4.17 of the Code. Water quality monitoring of the CMB commenced on 17 December 2018, greater than four years prior to the hydraulic fracturing of Amungee NW 2H. Water quality monitoring of the IMB commenced on December 2022, prior to the stimulation activities. Sampling has been conducted quarterly since the hydraulic fracturing was performed, with the most recent sample collected from both bores on 11 July 2023.

Summary statistics of the analytical results are provided in Table 1 and Table 2 for the CMB and IMB respectively. Where an analyte concentration was reported as less than the effective quantification limit (EQL), it was assumed to be equal to the EQL for the calculation of the statistic.

To identify whether there has been any change in water quality due to the regulated activities, a statistical assessment was made using a Student T-Test to test whether there was a significant difference in the results between the CMB (upgradient) and the IMB (downgradient). An F-Test was used to determine whether the homoscedastic (statistically similar variance) or heteroscedastic (statistically different variance) formula for the T-Test was used. Where a concentration was reported as less than the limit of reporting, the limit of reporting was assumed as the sample concentration. The statistical significance was assessed to a 95% confidence. The results of the analysis are provided in Table 3.

The analytes where the P-value was less 0.05 (95% confidence that there is a significant difference between the CMB and IMB data) are listed below with timeseries graphs for these analytes provided in Attachment A. Discussion of the data trends are as follows:

- **Electrical Conductivity (Lab)** – The electrical conductivity of the CMB has shown some variability over the period of monitoring from a minimum of 1,080 $\mu\text{S}/\text{cm}$ to 1,210 $\mu\text{S}/\text{cm}$ in the most recent sample, which was also its maximum reported concentration, with an overall gradually rising trend. Results from the IMB reported electrical conductivity above the average concentration from the CMB (1,157 $\mu\text{S}/\text{cm}$), and also show a rising trend.
- **Chloride** – The chloride concentrations in the CMB report a gradually rising trend, which is consistent with the gradually increasing electrical conductivity, more rapidly in later time. The chloride concentration in the IMB was initially stable, and then increased to greater than the CMB concentration.
- **Sulphate as SO_4** – Sulphate concentrations in the CMB have gradually declined over time, but were generally between 120 mg/L and 140 mg/L. In the IMB, the first reported sulphate concentration was 127 mg/L, but then declined to 111 mg/L in the two subsequent samples.
- **Potassium** – The potassium concentration in the CMB has been relatively stable throughout the monitoring period, with an average concentration of 10 mg/L and a maximum concentration of 12 mg/L. The first potassium concentration from the IMB was 15 mg/L before increasing to 43 mg/L, following which it reduced to 23 mg/L and then increased again to 36 mg/L.
- **Nitrate (as N)** – The CMB nitrate concentration initially varied from less than the EQL (0.01 mg/L) to twice the EQL, but in September 2022, prior to the undertaking of the regulated activity rose to 0.03 mg/L (three times the EQL), and then to 0.04 mg/L in the most recent sample. The first reported IMB nitrate concentration was 0.05 mg/L, it then decreases to the EQL prior to showing a rising trend

in the subsequent two samples, with a most recent concentration of 0.04 mg/L, equal to that of the CMB.

There are few statistically significant differences in groundwater chemistry between the CMB and the IMB. The analytes which show statistically significant differences and interpretation of their trends, as discussed above, indicate subtle changes most likely relating to the drilling of the Amungee NW 2H well. These subtle changes are anticipated to be related to the physical disturbance of the formation itself and the loss of circulation of drilling fluids into the highly permeable Gum Ridge Formation. The location of the impact monitoring bore within 20m of the Amungee NW 2H well is a contributing factor for why these results are visible. Essentially, the monitoring bore is within the areal influence (mixing zone) of the well being drilled and highlights that water quality changes in close proximity are not material. The changes in chemistry are localised and are expected to reduce over time as the groundwater chemistry returns to background conditions. The observed subtle changes have not impacted the environmental values of the aquifer and are consistent with the impacts/ risks assessed within the EMP.

Tamboran will continue to monitor the groundwater at the Amungee NW wellsite in accordance with the Ministerial conditions of approval of the EMP.

If you require any further information, please do not hesitate to email me.

Kind Regards

[Redacted signature]

[Redacted contact information]

References

DENR (2018) Preliminary Guideline: Groundwater Monitoring Bores for Exploration Petroleum Wells in the Beetaloo Sub-basin. Department of Environment and Natural Resources, November 2018.

DENR (2019) Code of Practice: Onshore Petroleum Activities in the Northern Territory. May 2019.

DEPWS (2022) Regional Report: Strategic Regional Environmental and Baseline Assessment for the Beetaloo Sub-basin. DEPWS Technical Report 41/2022. Department of Environment, Parks and Water Security, Northern Territory Government. Berrimah, Northern Territory.

Table 1 Amungee NW1 Gum Ridge Formation CMB (BET-MB019/RN040894) Statistical Summary

Analyte	Output Unit	EQL	Count	Min	Max	Average	P10	P50	P90
pH (Field)	pH_Units	0.01	12	6.55	7.10	6.73	6.57	6.71	6.85
Electrical Conductivity (Field)	µS/cm	1	10	1131	1498	1367	1175	1407	1495
pH (Lab)	pH_Units	0.01	11	7	8	7	7	7	8
Electrical Conductivity (Lab)	µS/cm	1	11	1080	1210	1157	1130	1160	1200
Total Dissolved Solids	mg/L	10	12	658	786	718	686	727	745
Suspended Solids	mg/L	5	12	<LOR	11	6	<LOR	<LOR	10
Alkalinity (Bicarbonate as CaCO ₃)	mg/L	1	12	328	456	401	389	402	419
Alkalinity (Carbonate as CaCO ₃)	mg/L	1	12	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Alkalinity (Hydroxide) as CaCO ₃	mg/L	1	12	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Alkalinity (Total) as CaCO ₃	mg/L	1	12	328	456	401	389	402	419
Chloride	mg/L	1	12	73	112	96	79	99	106
Sulphate as SO ₄	mg/L	1	11	116	139	131	125	132	138
Sodium	mg/L	1	12	57	72	66	63	67	69
Potassium	mg/L	1	12	9	12	10	9	10	11
Calcium	mg/L	1	12	93	126	116	107	118	125
Magnesium	mg/L	1	12	39	49	46	43	47	49
Fluoride	mg/L	0.1	12	0.3	0.6	0.5	0.4	0.5	0.6
Nitrate (as N)	mg/L	0.01	12	<LOR	0.04	0.02	<LOR	0.02	0.03
Nitrite (as N)	mg/L	0.01	12	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Gross alpha activity	Bq/L	0.05	8	0	0	0	0	0	0
Gross beta activity (excluding activity of K-40)	Bq/L	0.1	8	<LOR	0.28	0.17	<LOR	0.17	0.22
Methane	mg/L	10	11	0.010	0.010	0.010	0.010	0.010	0.010
Ethane	µg/L	10	11	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Propane	mg/L	0.01	11	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Arsenic	mg/L	0.001	12	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Barium	mg/L	0.001	12	0.040	0.105	0.067	0.042	0.065	0.097
Boron	mg/L	0.05	12	0.11	0.24	0.15	0.12	0.15	0.18
Cadmium	mg/L	0.0001	12	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Chromium (III+VI)	mg/L	0.001	12	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Copper	mg/L	0.001	12	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Iron	mg/L	0.05	12	0.21	2.63	1.06	0.32	0.90	2.06
Lead	mg/L	0.001	12	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Lithium	mg/L	0.001	11	0.041	0.058	0.051	0.045	0.052	0.058
Manganese	mg/L	0.001	12	0.033	0.152	0.087	0.046	0.090	0.124
Mercury	mg/L	0.0001	12	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Selenium	mg/L	0.01	12	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Silicon as Si	mg/L	0.05	11	12600	14900	13882	13100	14000	14600
Silver	mg/L	0.001	12	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Strontium	mg/L	0.001	12	0.544	0.692	0.630	0.592	0.625	0.682
Zinc	mg/L	0.005	12	<LOR	0.013	0.010	0.007	0.010	0.012
TRH C6 - C10 Fraction (Sum)	µg/L	20	12	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
TRH C10 - C40 Fraction (Sum)	µg/L	100	12	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Sum of BTEX	µg/L	1	12	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Total Reportable PAH	µg/L	0.5	11	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR

Table 2 Amungee NW Gum Ridge Formation IMB (BET-MB027/RN043018) Statistical Summary

Analyte	Output Unit	EQL	Count	Min	Max	Average	P10	P50	P90
pH (Field)	pH_Units	0.01	5	6.59	6.94	6.74	6.61	6.75	6.88
Electrical Conductivity (Field)	µS/cm	1	5	1172	1561	1333	1204	1281	1496
pH (Lab)	pH_Units	0.01	3	7	7	7	7	7	7
Electrical Conductivity (Lab)	µS/cm	1	3	1180	1260	1210	1182	1190	1246
Total Dissolved Solids	mg/L	10	4	672	784	721	681	714	766
Suspended Solids	mg/L	5	4	<LOR	9	7	<LOR	6	8
Alkalinity (Bicarbonate as CaCO ₃)	mg/L	1	4	378	404	397	385	402	404
Alkalinity (Carbonate as CaCO ₃)	mg/L	1	4	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Alkalinity (Hydroxide) as CaCO ₃	mg/L	1	4	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Alkalinity (Total) as CaCO ₃	mg/L	1	4	378	404	397	385	402	404
Chloride	mg/L	1	4	100	142	118	101	114	137
Sulphate as SO ₄	mg/L	1	3	111	127	116	111	111	124
Sodium	mg/L	1	4	62	75	69	64	69	74
Potassium	mg/L	1	4	15	43	29	17	30	41
Calcium	mg/L	1	4	97	129	116	101	118	128
Magnesium	mg/L	1	4	42	49	46	43	47	49
Fluoride	mg/L	0.1	4	0.4	0.5	0.5	0.4	0.5	0.5
Nitrate (as N)	mg/L	0.01	4	<LOR	0.05	0.03	0.02	0.04	0.05
Nitrite (as N)	mg/L	0.01	4	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Gross alpha activity	Bq/L	0.05	1	0	0	0	0	0	0
Gross beta activity (excluding activity of K-40)	Bq/L	0.1	1	0.15	0.15	0.15	0.15	0.15	0.15
Methane	mg/L	10	3	0.010	0.021	0.015	0.011	0.013	0.019
Ethane	µg/L	10	3	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Propane	mg/L	0.01	3	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Arsenic	mg/L	0.001	4	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Barium	mg/L	0.001	4	0.055	0.147	0.086	0.059	0.072	0.126
Boron	mg/L	0.05	4	0.10	0.18	0.13	0.10	0.12	0.17
Cadmium	mg/L	0.0001	4	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Chromium (III+VI)	mg/L	0.001	4	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Copper	mg/L	0.001	4	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Iron	mg/L	0.05	4	<LOR	13.40	4.36	0.49	2.00	10.12
Lead	mg/L	0.001	4	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Lithium	mg/L	0.001	3	0.039	0.055	0.046	0.040	0.045	0.053
Manganese	mg/L	0.001	4	0.024	0.316	0.176	0.069	0.182	0.278
Mercury	mg/L	0.0001	4	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Selenium	mg/L	0.01	4	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Silicon as Si	mg/L	0.05	3	12600	14000	13300	12740	13300	13860
Silver	mg/L	0.001	4	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Strontium	mg/L	0.001	4	0.578	0.682	0.643	0.599	0.657	0.677
Zinc	mg/L	0.005	4	0	0.030	0.019	0.010	0.019	0.029
TRH C6 - C10 Fraction (Sum)	µg/L	20	4	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
TRH C10 - C40 Fraction (Sum)	µg/L	100	4	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Sum of BTEX	µg/L	1	4	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Total Reportable PAH	µg/L	0.5	4	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR

Table 3 Amungee NW1 Statistical Assessment

Analyte	Output Unit	EQL	Average Concentration		Statistics	
			CMB (BET-MB019/RN040894)	IMB (BET-MB027/RN043018)	F-Test Statistic	T-Test - P-value
pH (Field)	pH_Units	0.01	6.73	6.74	0.99	0.45
Electrical Conductivity (Field)	µS/cm	1	1367	1333	0.67	0.33
pH (Lab)	pH_Units	0.01	7	7	0.12	0.37
Electrical Conductivity (Lab)	µS/cm	1	1157	1210	0.55	0.03
Total Dissolved Solids	mg/L	10	718	721	0.35	0.44
Suspended Solids	mg/L	5	6	7	0.99	0.39
Alkalinity (Bicarbonate as CaCO3)	mg/L	1	401	397	0.19	0.40
Alkalinity (Carbonate as CaCO3)	mg/L	1	<LOR	<LOR	-	-
Alkalinity (Hydroxide) as CaCO3	mg/L	1	<LOR	<LOR	-	-
Alkalinity (Total) as CaCO3	mg/L	1	401	397	0.19	0.40
Chloride	mg/L	1	96	118	0.15	0.01
Sulphate as SO4	mg/L	1	131	116	0.43	0.01
Sodium	mg/L	1	66	69	0.42	0.17
Potassium	mg/L	1	10	29	0.00	0.03
Calcium	mg/L	1	116	116	0.20	0.50
Magnesium	mg/L	1	46	46	0.78	0.46
Fluoride	mg/L	0.1	0.5	0.5	0.40	0.50
Nitrate (as N)	mg/L	0.01	0.02	0.03	0.10	0.03
Nitrite (as N)	mg/L	0.01	<LOR	<LOR	-	-
Gross alpha activity	Bq/L	0.05	0	0	-	-
Gross beta activity (excluding activity of K-40)	Bq/L	0.1	0.17	0.15	-	-
Methane	mg/L	10	0.010	0.015	0.00	0.15
Ethane	µg/L	10	<LOR	<LOR	-	-
Propane	mg/L	0.01	<LOR	<LOR	-	-
Arsenic	mg/L	0.001	<LOR	<LOR	-	-
Barium	mg/L	0.001	0.067	0.086	0.08	0.12
Boron	mg/L	0.05	0.15	0.13	0.70	0.10
Cadmium	mg/L	0.0001	<LOR	<LOR	-	-
Chromium (III+VI)	mg/L	0.001	<LOR	<LOR	-	-
Copper	mg/L	0.001	<LOR	<LOR	-	-
Iron	mg/L	0.05	1.06	4.36	0.00	0.18
Lead	mg/L	0.001	<LOR	<LOR	-	-
Lithium	mg/L	0.001	0.051	0.046	0.36	0.13
Manganese	mg/L	0.001	0.087	0.176	0.00	0.12
Mercury	mg/L	0.0001	<LOR	<LOR	-	-
Selenium	mg/L	0.01	<LOR	<LOR	-	-
Silicon as Si	mg/L	0.05	13882	13300	0.87	0.12
Silver	mg/L	0.001	<LOR	<LOR	-	-
Strontium	mg/L	0.001	0.630	0.643	0.75	0.30
Zinc	mg/L	0.005	0.010	0.019	0.00	0.07
TRH C6 - C10 Fraction (Sum)	µg/L	20	<LOR	<LOR	-	-
TRH C10 - C40 Fraction (Sum)	µg/L	100	<LOR	<LOR	-	-
Sum of BTEX	µg/L	1	<LOR	<LOR	-	-
Total Reportable PAH	µg/L	0.5	<LOR	<LOR	-	-

Attachment A - Timeseries chemistry charts

