Groundwater monitoring results at petroleum well sites in the Beetalo sub-basin in accordance with the Code of Practice – Quarter 1&2 2019/2020

1. Introduction

Groundwater quality is a key environmental value that must be protected during onshore petroleum exploration and development activities in the Northern Territory. The Scientific Inquiry into Hydraulic Fracturing in the Northern Territory (the HFI Report) identified the need for a groundwater monitoring program at each petroleum well site to confirm natural groundwater characteristics are unaltered and to provide early detection of any potential contamination or altered hydrology and rapid assessment, investigation and remedial action if required.

In accordance with the Code of Practice: Onshore Petroleum Activities in the Northern Territory (the Code), at least six months of local baseline data for water quality indicators must be acquired prior to drilling or hydraulic fracturing. Groundwater monitoring data is submitted quarterly by petroleum interest holders in compliance with the Code. The Department of Environment and Natural Resources (DENR) has committed to publishing these results to increase the transparency of groundwater use by the onshore gas industry.

This is the first report on baseline groundwater data since the HFI Report. It presents data collected between December 2018 and July 2019 by Origin Energy and Santos Pty Ltd in the Beetaloo sub-basin. At this stage no new petroleum wells have been drilled at the monitoring well sites. This report will be updated as new results are submitted and a reasonably reliable interquartile range for the analytes in groundwater at each well site can be derived for detecting possible change versus natural background variance.

Groundwater monitoring program

The Beetaloo groundwater monitoring program consists of:

- a **Control monitoring bore array** which is located up-gradient (i.e. upstream) and within 100m of the planned or existing location of a petroleum well pad,= and
- an **Impact monitoring bore array**, 20m down-gradient (i.e. “downstream) of the location of the petroleum well, as shown in Figure 1.

This layout is based on the requirements set out in the Preliminary Guideline: Groundwater Monitoring Bores for Exploration Petroleum Wells in the Beetaloo Sub-basin (the Guideline). It enables a comparison of groundwater quality between the two bores which are upstream and downstream of the petroleum well. The upstream bore provides an ongoing measure of natural background groundwater quality at the well site. The downstream bore which is immediately adjacent to the petroleum well is used to detect any water quality changes above natural background values that may occur because of a “leaky” petroleum well due to failure in well integrity, including as a result of hydraulic fracturing. In the event that a significant anomalous variation above natural background values in ground water quality at the Impact bore did occur then the impact can be detected and managed within an appropriate timeframe, through follow-up investigation and potentially remediation and/or a well workover.

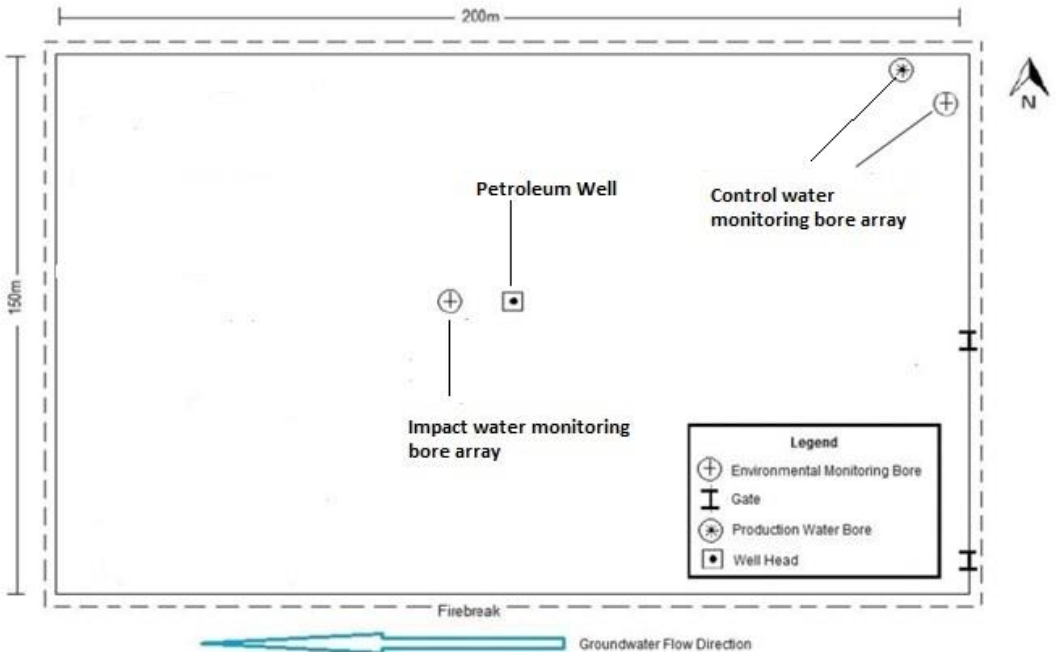


Figure 1: Indicative environmental groundwater monitoring bore layout on a petroleum well pad. Groundwater flow (gradient) direction in this example is from R-L of layout.

One monitoring bore is required for each aquifer present at a well site, with water quality tested at the top, middle and bottom of each aquifer. In the Beetaloo Basin this may include the Anthony Lagoon aquifer and/or the deeper regional Gum Ridge aquifer. The Gum Ridge aquifer is significant as a regional water resource for present and future uses. The NT Water Allocation Planning Framework estimates the total current extraction from the Gum Ridge aquifer is approximately 1,500 ML which is less than 0.0001% of the Gum Ridge aquifer estimated sustainable yield.

Groundwater is sampled from each bore on a regular basis and analysed at a NATA accredited laboratory with results published on the DENR webpage. In accordance with the Code and Guideline, quarterly monitoring will continue for at least three years following hydraulic fracturing in a well.

In addittion, the water level in each monitoring bore at a well site is monitored using continuous loggers. This provides an accurate understanding of potential site drawdown of each aquifer due to water extraction during onshore petroleum exploration and development activities.

Groundwater quality

The groundwater quality results of particular interest from an environmental impact perspective include chloride, and electrical conductivity (E.C.) because these analytes are present in high concentrations in drilling fluids, hydraulic fracturing fluids, well suspension fluids and flowback. Concentrations may be orders of magnitude (100s~1000s) times higher than found in potable (drinkable) water.

Produced waters (including flowback following hydraulic fracturing) that come out of a petroleum well are characterised by high concentrations and complex mixtures of inorganic salts, organic compounds and other materials. They may contain Naturally-Occurring Radionuclide Material (NORM) from uranium and thorium decay in concentrations higher than routinely observed in environmental water samples. This decay is measured in Becquerels (Bq). One Becquerel is defined as the activity of a quantity of radioactive material in which one nucleus decays per second.

Other useful tracers include barium, boron and strontium which are also typically in higher concentrations in water from hydraulic fracturing activities and well above background values normally seen in groundwater. Dissolved methane is important to monitor as a baseline and over the longer term to confirm petroleum well integrity. There is no guideline drinking water standard for methane, which may be naturally present in groundwater, because it is not toxic.

Drinking water guideline standards provide a useful reference point for groundwater quality baseline data. They are based on annual ingested volume of drinking-water, assumed to be 730 litres/year, and are generally a health safety-factor of ten lower than what is considered an intervention level which is that level at which authorities will then need to make a decision regarding the need to implement remedial measures or to place some restriction on the continued use of the water supply for drinking purposes. Certain standards such as chloride are based on aesthetic rather than health measures.

2. Summary and Interpretation of Results

The results from groundwater monitoring conducted by petroleum companies in accordance with the Guideline are reported to DENR on a quarterly basis. The results for the Beetaloo Sub-basin are summarised below, with the full data provided at Appendix 1 (Origin EnergyLimited) and Appendix 2 (Santos).

Origin Energy Limited

Background

Origin is proposing to drill a petroleum exploration well at its Kyalla location on Exploration Permit 117, located in the Beetaloo sub-basin on Hayfield Station, approximately 300 km southeast of Katherine in the Northern Territory.

At the Kyalla well site both the Anthony Lagoon aquifer and the deeper Gum Ridge aquifer are present. Consequently a separate monitoring bore is required for each aquifer. Two Control monitoring bores have been constructed at Kyalla prior to construction of the Kyalla petroleum well. These bores are labelled RN40895 (screened in the Gum Ridge aquifer) and RN40896 (screened in the Anthony Lagoon aquifer). The Control monitoring bores provide ongoing natural background (baseline) water quality values and hence a measure of natural variation for groundwater quality at the Kyalla well site.

At this stage (July 2019) Origin has not yet drilled the Kyalla petroleum well and hence there are no impact monitoring bore results available.

Summary or results

Table 1 lists a summary of results (average and standard deviation) for each key analyte from February to June 2019 for Origin Kyalla well site. The summary results show that groundwater level increased approximately 0.5 m during the monitoring period in both aquifers at this location. Electrical conductivity is slightly above ideal level for drinking water. Other key analytes are below maximum levels in drinking water guidelines, where applicable. Trace levels of methane were present in both aquifers. The raw data in Appendix 1 shows that all other hydrocarbons are below detection limits. All metals were below detection limits or below drinking water guidelines except for iron. Results for most analytes in the Gum Ridge aquifer were similar to the shallower Anthony Lagoon aquifer. Total dissolved solids, calcium, iron and sulphate were slightly higher on average in the Gum Ridge aquifer (Appendix 1).

At this stage it is apparent that groundwater may on occasion exceed NORM Gross alpha drinking water guidance standard in natural backgound values in the Gum Ridge aquifer at this location (Table

1). This is not uncommon in groundwater systems where concentrations of dissolved constituents can build up during prolonged periods of water/rock contact. NORM will continue to be monitored in accordance with the Code and Guideline.

Table 1: Average ± standard deviation for key analytes for Control monitoring bores at Kyalla petroleum well site - RN40895 and RN40896

Key analyte	Drinking Water Guidance[1]	RN40895 Gum Ridge aquifer	RN40896 Anthony Lagoon aquifer
Standing Water Level mbTOC (m)		~114.5 - 115	~114.6 – 114.8
Electrical Conductivity (µS/cm)	~ 800	1202 ± 61	1191 ± 424
Chloride (mg/L)	~ 250	160 ± 8.3	157 ± 62
Barium (mg/L)	0.7	0.06 ± 0.002	0.08 ± 0.03
Boron (mg/L)	4.0	0.22 ± 0.01	0.21 ± 0.08
Strontium (mg/L)		0.82 ± 0.07	0.68 ± 0.25
Methane µg/L	N.A.	0.012 ± 0.007	0.038 ± 0.02
Gross alpha (Bq/L)	0.5	1.1 ± 0.5	0.35 ± 0.13
Gross beta (Bq/L)	1.0	0.52 ± 0.22	0.22 ± 0.01

Figure 2 shows the natural background (baseline) interquartile range for key analytes in the Gum Ridge aquifer at the Origin Kyalla well site based on sampling from February 2019 to June 2019. The **interquartile range**, also called the midspread or middle 50%, is a measure of statistical dispersion, being equal to the difference between upper and lower quartiles. The “box-whisker” plot in Figure 2 shows the interquartile range for each analyte as the “box” and the “whiskers” show the highest and lowest measured value for that analyte over time.

Barium, boron and methane are present at trace levels and have the smallest relative interquartile ranges in natural background values. Alpha radionuclide emissions has the highest relative interquartile range in natural background values. When Impact monitoring bores are installed following construction of the Kyalla petroleum well and more data is acquired in the monitoring program for both Control and Impact monitoring bores, the plots for each analyte in both bores at a well site, will be used to graphically display the results of natural background values compared to the Impact monitoring bores.

Figure 3 presents results for water level expressed as metres below top of casing (mbTOC) for Control monitoring bores - RN40895 (Gum Ridge aquifer) and RN40896 (Anthony Lagoon aquifer) during December 2018 - July 2019. The water level data is acquired by use of continuous monitoring loggers installed in the bores. Data is periodically downloaded to a computer. Ground water level

[1] NHMRC, NRMMC 2011. *Australian Drinking Water Guidelines 6 National Water Quality Management Strategy.* Version 3.6 Updated August 2018.

increased approximately 0.5m in the Gum Ridge aquifer during the logging period from Dec ’18 to Aug ‘19. A similar trend was measured in the Anthony Lagoo aquifer.

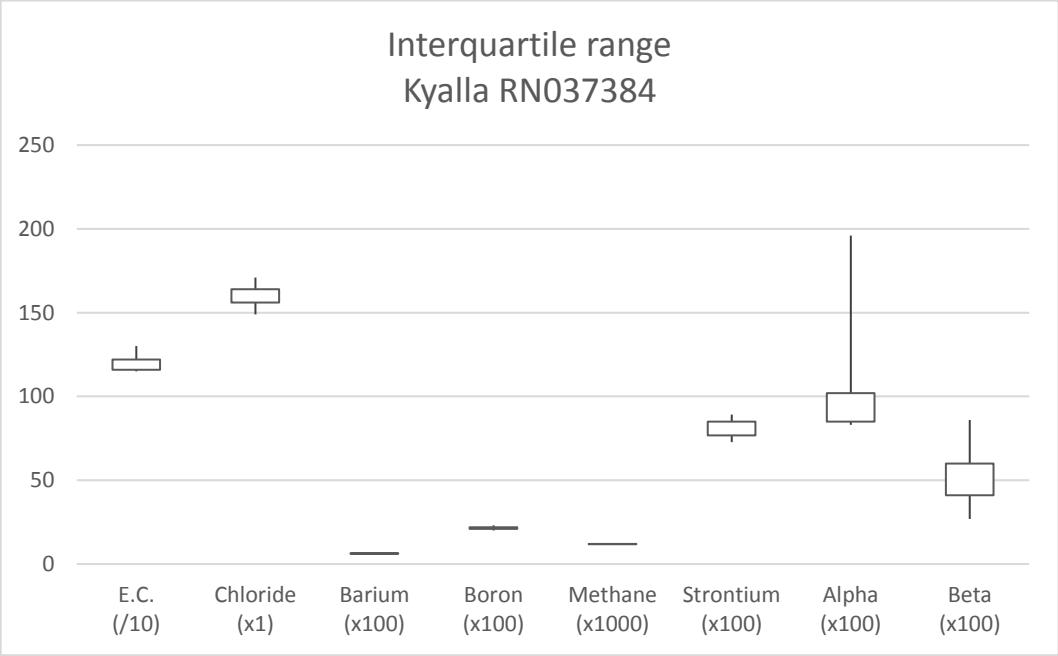


Figure 2: Interquartile range for key analytes at Control monitoring bore RN40895 in the Gum Ridge aquifer at Kyalla petroleum well site

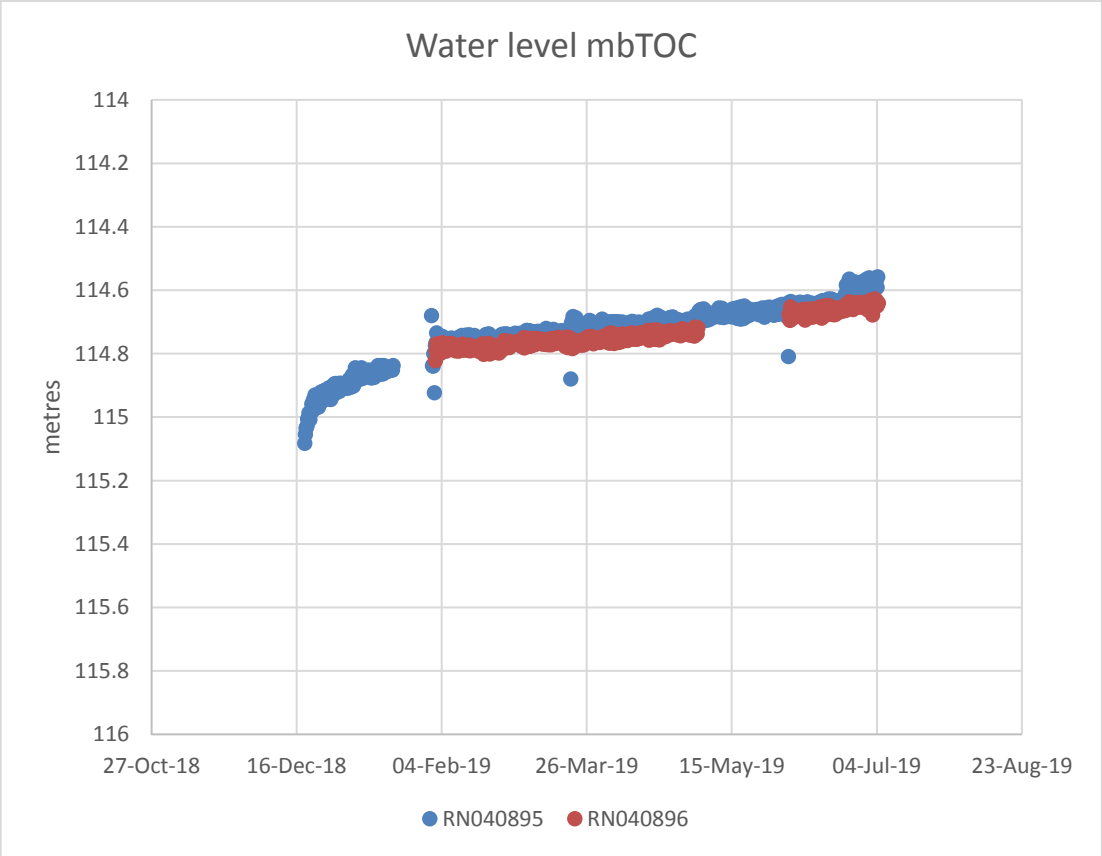


Figure 3: Results for water level for Origin EP117 Control monitoring bores - RN40895 (Gum Ridge aquifer) and RN40896 (Anthony Lagoon aquifer) at Kyalla well site during Dec 18-Jul 2019.

Santos QNT Pty Ltd

Background

Santos is proposing to drill petroleum exploration wells at two locations on Exploration Permit 161, located in the Beetaloo sub-basin on Tanumbirini Station, approximately 280 km southeast of Katherine in the Northern Territory. At these well site locations only the Gum Ridge aquifer is present. Santos has installed Control monitoring bore RN040930 at its Tanumbirini petroleum well site and Control monitoring bore RN040931 at its Inacumba petroleum well site in the Gum Ridge aquifer.

At this stage (July 2019) Santos has not yet drilled the Tanumbirini or Inacumba petroleum wells and hence there are no impact monitoring bore results available.

Summary of results

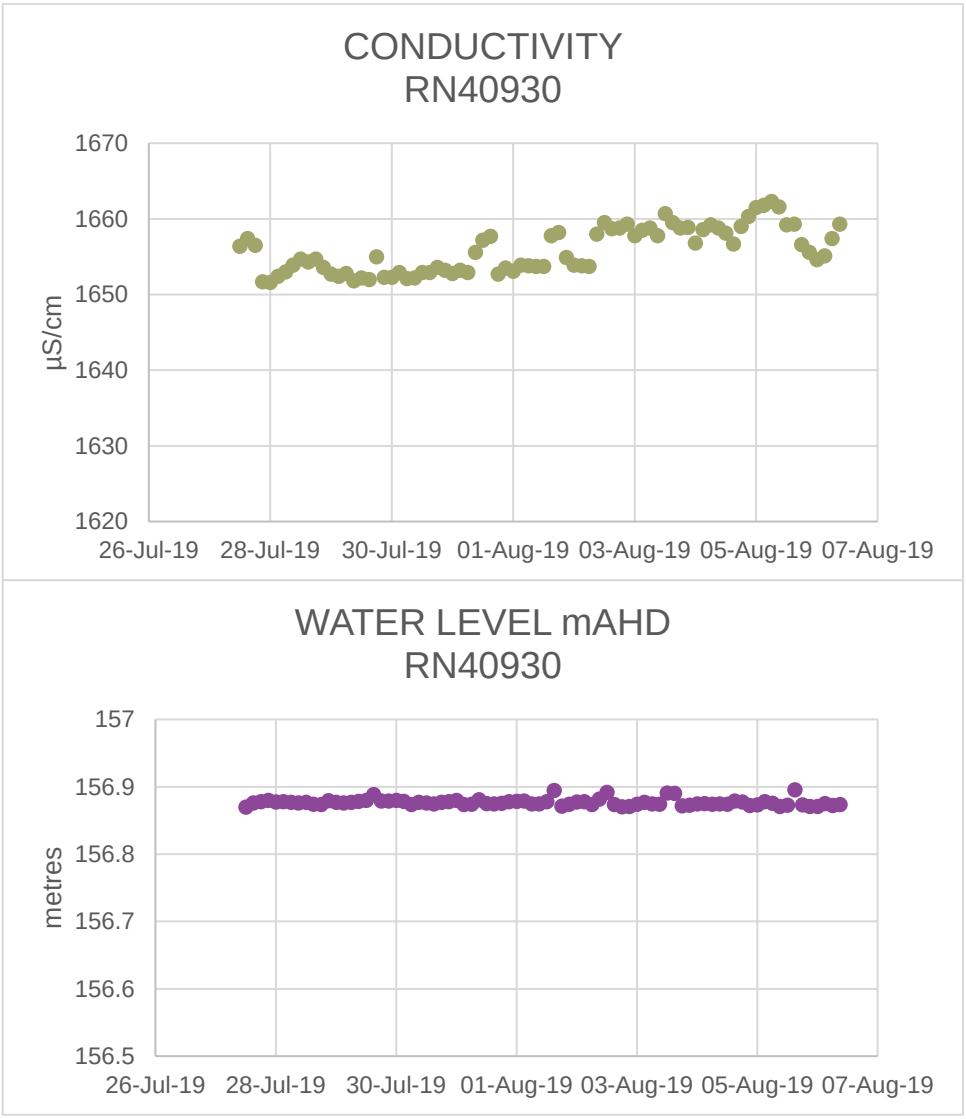
Table 2 lists a summary of groundwater monitoring results reported to date. The Control monitoring bores provide ongoing natural background (baseline) values and a measure of natural variation for groundwater quality at the Tanumbirini and Inacumba well sites.

At this stage only a few sampling events at both well sites have been conducted. However it is apparent that groundwater exceeds NORM Gross alpha drinking water guidance standard in natural background values in the Gum Ridge aquifer (Table 1) at both well sites. Methane and all other hydrocarbons (Appendix 2) were below detection limits. Inacumba well site is up-gradient of Tanumbirini as evidenced by higher elevation of the standing water level at this site relative to Australian Height Datum. Electrical conductivity and associated analytes such as chloride and total dissolved solids are also slightly higher at Inacumba. Electrical conductivity at both these well sites are higher than in the Gum Ridge aquifer at the Kyalla well site

Table 2: Results for key analytes for Santos EP161 Control monitoring bores at Tanumbirini RN40930 and Inacumba RN40931

Key analyte	Drinking Water Guidance	RN040930 Tanumbirini Gum Ridge aquifer	RN040931 Inacumba Gum Ridge aquifer
Standing Water Level AHD (m)		~156.9	~158.6
Electrical Conductivity (µS/cm)	~ 800	1330	1560
Chloride (mg/L)	~ 250	106	148
Barium (mg/L)	0.7	0.040	0.036
Boron (mg/L)	4.0	0.16	0.27
Strontium (mg/L)		0.70	0.84
Methane µg/L	N.A.	<10	<10
Gross alpha (Bq/L)	0.5	1.46	1.70
Gross beta (Bq/L)	1.0	0.82	0.84

Figure 4 below shows measured water level measured in relation to Australia Height Datum (AHD - approximately mean sea level) and electrical conductivity at the Santos RN040930 Tanumbirini Control Monitoring Bore during July 2019. Measurements include field instrument measurements and continuous logger measurements for comparison. Water level for RN040931 Inacumba well site from December 2018 – August 2019 is also shown. Water level in both RN040930 and RN40931 is relatively constant during the monitoring period.



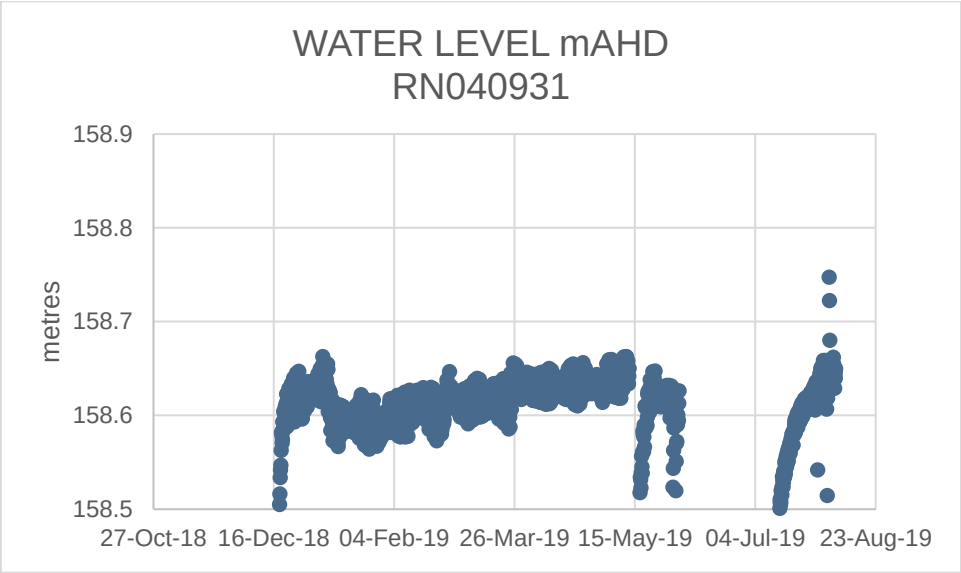


Figure 4: Results for water level and electrical conductivity from continuous loggers in Control monitoring bore at Santos EP161 - RN40930 Tanumbirini well site during July-Aug 2019 and water level for RN040931 Inacumba well site from Dec '18 – Aug '19. Outliers in RN040931 measurements occurred when the logger was retrieved and serviced

Acronyms, initialisms and glossary

AHD	Australian Height Datum
LoR	Limits of Reporting
mbTOC	Metres below top of casing
NORM	Naturally Occurring Radionuclide Material
PAH	Poly-aromatic hydrocarbons

Units and symbols

%	Percentage
Bq/L	Becquerel per litre
mg/L	Milligrams per litre
µg/L	Micrograms per litre
ML	Mega litres
µS/cm	Micro Siemens/centimetre

Appendix 1: Origin Energy (EP117) Groundwater monitoring program – Beetaloo Sub-basin

						KYA117-N2 CMB-AL	KYA117-N2 CMB-AL	KYA117-N2 CMB-AL	KYA117-N2 CMB-AL	KYA117-N2 CMB-AL	KYA117-N2 CMB-AL	KYA117-N2 CMB-AL	KYA117-N2 CMB-AL
SP-EC(Field) normalised to 25 oC	µS/cm					-	1351	1303					
Dissolved Oxygen (Field)	mg/L					-	-	0.1					
pH (Field)	pH_Units					-	7.05	7.1					
Purged_time	min					-	-	160					
Redox Potential (Field)	mV					-	18.9	160					
Vol_Purged	L					-	5562	19,200					
Alkalinity (Bicarbonate) as CaCO3	mg/L	1				292	259 - 261	268	246	268	246	248	249
Alkalinity (Carbonate) as CaCO3	mg/L	1				<1	<1	<1	<1	<1	<1	<1	<1
Alkalinity (Hydroxide) as CaCO3	mg/L	1				<1	<1	<1	<1	<1	<1	<1	<1
Alkalinity (Total) as CaCO3	mg/L	1				292	259 - 261	268	246	268	246	248	249
Anions Total	meq/L	0.01				13.1	13.9 - 14.1	12.9	11.9	12.9	11.9	12.1	12.6
Bicarbonate	mg/L					356.24	315.98 - 318.42	-	-	326.96	-		-
Calcium (Filtered)	mg/L	1				81	79 - 82	88	70	88			
Carbonate	mg/L					0.6	0.6	-	-	0.6			
Cations Total	meq/L	0.01				12.5	12 - 12.3	13.6	11.7	13.6	11.7	11.8	12.9
Chloride	mg/L	1	250			157	190 - 192	168	174	91	174	174	164
Electrical Conductivity (Lab)	µS/cm	1				1090	1180 - 1190	1150	1190	1150	1190	1180	1340
Fluoride	mg/L	0.1				1	0.9 - 1	1	1.1		1.1	1.1	1
Ionic Balance	%	0.01				2.11	6.84 - 7.35	2.57	1.03	2.57	1.03	0.96	1.03
Magnesium (Filtered)	mg/L	1				41	40	45	40	45	40	40	42
Nitrate (as N)	mg/L	0.01				0.07	0.02	0.04	0.04	0.04	0.04	0.05	<0.01
Nitrite (as N)	mg/L	0.01				<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrite + Nitrate (as N)	mg/L	0.01				0.07	0.02	0.04	0.04	0.04	0.04	0.05	<0.01
pH (Lab)	pH_Units	0.01				7.31	7.39 - 7.43	7.51	7.46	7.51	7.46	7.43	7.68
Potassium (Filtered)	mg/L	1				13	11 - 12	14	12	14	12	12	13
Silicon as Si (Filtered)	mg/L	0.05				9.73	10 - 10.1	11.6	9.25	11.6	9.25	9.16	10.1
Sodium (Filtered)	mg/L	1				110	104 - 106	119	106	119	106	108	115
Sulphate as SO4 (Filtered)	mg/L	1				135	164 - 167	137	102	137	102	106	145
Suspended Solids	mg/L	5				<5	58 - 73	<5	<5	<5	<5	<5	7
Total Dissolved Solids	mg/L	10	600		3000	787	712 - 738	716	704	716	704	701	682
Gross alpha activity	Bq/L	0.05		0.5		0.46	0.32 - 0.34	0.39	0.29	0.39	0.29	0.36	0.32
Gross beta activity	Bq/L	0.1		1		0.42	0.28 - 0.34	0.19	0.23	0.19	0.23	0.16	0.18
Arsenic	mg/L	0.001				0.002	0.007 - 0.008	0.003	0.007	0.003	0.007	0.006	0.006
Arsenic (Filtered)	mg/L	0.001				0.002	0.004	0.003	0.006	0.003	0.006	0.006	0.005
Barium (Filtered)	mg/L	0.001				0.051	0.104 - 0.105	0.087	0.082	0.087	0.082	0.081	0.077
Boron (Filtered)	mg/L	0.05				0.22	0.19 - 0.2	0.23	0.2	0.23	0.2	0.2	0.21
Cadmium	mg/L	0.0001				<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cadmium (Filtered)	mg/L	0.0001				<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium (III+VI)	mg/L	0.001				<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium (III+VI) (Filtered)	mg/L	0.001				<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	mg/L	0.001				0.001	<0.001	0.012	<0.001	0.012	<0.001	<0.001	0.011
Copper (Filtered)	mg/L	0.001				<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Iron	mg/L	0.05				0.68	2.56 - 2.8	0.53	0.6	0.53	0.6	0.65	1.66
Iron (Filtered)	mg/L	0.05				0.4	<0.05	0.6	0.57	0.6	0.57	0.52	1.55
Lead	mg/L	0.001				0.004	<0.001	0.006	<0.001	0.006	<0.001	<0.001	0.002
Lead (Filtered)	mg/L	0.001				0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lithium	mg/L	0.001				0.056	0.066 - 0.068	0.052	0.051	0.052	0.051	0.05	0.051
Lithium (Filtered)	mg/L	0.001				0.052	0.056 - 0.058	0.055	0.048	0.055	0.048	0.05	0.051
Manganese	mg/L	0.001				0.023	0.119 - 0.124	0.047	0.047	0.047	0.047	0.045	0.067
Manganese (Filtered)	mg/L	0.001				0.017	0.076 - 0.078	0.05	0.042	0.05	0.042	0.04	0.063
Mercury	mg/L	0.0001				<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Mercury (Filtered)	mg/L	0.0001				<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel	mg/L	0.001				0.002	0.001 - 0.003	0.016	<0.001	0.016	<0.001	<0.001	0.018
Nickel (Filtered)	mg/L	0.001				<0.001	<0.001	0.002	<0.001	0.002	<0.001	<0.001	0.002
Selenium	mg/L	0.01				<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Selenium (Filtered)	mg/L	0.01				<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	mg/L	0.001				<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Silver (Filtered)	mg/L	0.001				<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Strontium (Filtered)	mg/L	0.001				0.611	0.564 - 0.59	0.718	0.594	0.718	0.594	0.611	0.629
Zinc	mg/L	0.005				0.018	0.011 - 0.012	0.026	<0.005	0.026	<0.005	<0.005	0.098
Zinc (Filtered)	mg/L	0.005				0.008	<0.005	0.007	<0.005	0.007	<0.005	<0.005	0.015
Total Reportable PAH	µg/L	0.5				<0.5	<0.5	<0.5	<0.5		<0.5		<0.5
Ethane	µg/L	10				<10	<10	<10	<10	<10	<10		<10
Ethene	µg/L	10				<10	<10	<10	<10	<10	<10		<10
Propane	mg/L	0.01				<0.01	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01
Propene	µg/L	10				<10	<10	<10	<10	<10	<10		<10
Benzene	µg/L	1				<1	<1	<1	<1	<1	<1		<1
Ethylbenzene	µg/L	2				<2	<2	<2	<2	<2	<2		<2
Toluene	µg/L	2				<2	<2	<2	<2	<2	<2		<2
Xylene (m & p)	µg/L	2				<2	<2	<2	<2	<2	<2		<2
Xylene (o)	µg/L	2				<2	<2	<2	<2	<2	<2		<2
Xylene Total	µg/L	2				<2	<2	<2	<2	<2	<2		<2
Sum of BTEX	µg/L	1				<1	<1	<1	<1	<1	<1		<1
Acenaphthene	µg/L	1				<1	<1	<1	<1	<1	<1		<1
Acenaphthylene	µg/L	1				<1	<1	<1	<1	<1	<1		<1
Anthracene	µg/L	1				<1	<1	<1	<1	<1	<1		<1
Benz(a)anthracene	µg/L	1				<1	<1	<1	<1	<1	<1		<1
Benzo(a)pyrene	µg/L	0.5				<0.5	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5
Benzo(a)pyrene TEQ (zero)	µg/L	0.5				<0.5	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5
Benzo(b&j)fluoranthene	µg/L	1				<1	<1	<1	<1	<1	<1		<1
Benzo(g,h,i)perylene	µg/L	1				<1	<1	<1	<1	<1	<1		<1
Benzo(k)fluoranthene	µg/L	1				<1	<1	<1	<1	<1	<1		<1
Chrysene	µg/L	1				<1	<1	<1	<1	<1	<1		<1
Dibenz(a,h)anthracene	µg/L	1				<1	<1	<1	<1	<1	<1		<1
Fluoranthene	µg/L	1				<1	<1	<1	<1	<1	<1		<1
Fluorene	µg/L	1				<1	<1	<1	<1	<1	<1		<1
Indeno(1,2,3-c,d)pyrene	µg/L	1				<1	<1	<1	<1	<1	<1		<1
Naphthalene	µg/L	1				<1	<1	<1	<1	<1	<1		<1
Phenanthrene	µg/L	1				<1	<1	<1	<1	<1	<1		<1
Pyrene	µg/L	1				<1	<1	<1	<1	<1	<1		<1
C6 - C9 Fraction	µg/L	20				<20	<20	<20	<20	<20	<20		<20
C6 - C10 Fraction	µg/L	20				<20	<20	<20	<20	<20	<20		<20
C6 - C10 Fraction minus BTEX	µg/L	20				<20	<20	<20	<20	<20	<20		<20
C10 - C14 Fraction	µg/L	50				<50	<50	<50	<50	<50	<50		<50
C10 - C16 Fraction	µg/L	100				<100	<100	<100	<100	<100	<100		<100
C10 - C16 Fraction	µg/L	100				<100	<100	<100	<100	<100	<100		<100
C15 - C28 Fraction	µg/L	100				<100	<100	<100	<100	<100	<100		<100
C16 - C34 Fraction	µg/L	100				<100	<100	<100	<100	<100	<100		<100
C29 - C36 Fraction	µg/L	50				<50	<50	<50	<50	<50	<50		<50
C34 - C40 Fraction	µg/L	100				<100	<100	<100	<100	<100	<100		<100
C10 - C36 Fraction (Sum)	µg/L	50				<50	<50	<50	<50	<50	<50		<50
C10 - C40 Fraction (Sum)	µg/L	100				<100	<100	<100	<100	<100	<100		<100

= Analyte of interest

KYA117-N2 CMB-AL = Kyalla Control Monitoring Bore - Anthony Lagoon aquifer
KYA117-N2 CMB G = Kyalla Control Monitoring Bore - Gumridge aquifer

Appendix 1: Origin Energy (EP117) Groundwater monitoring program – Beetaloo Sub-basin

Bore number	Units	Limit of detection	ADWG 2015 Aesthetic	ADWG 2015 Health	ANZECC Livestock	RN40895 KYA117-N2 CMB-G	RN40895 KYA117-N2 CMB-G	RN40895 KYA117-N2 CMB-G	RN40895 KYA117-N2 CMB-G	RN40895 KYA117-N2 CMB-G
Sample date						01/02/2019	23/02/2019	20/03/2019	03/05/2019	03/06/2019
SP-EC(Field) normalised to 25 oC	µS/cm					-	1364	1335		
Dissolved Oxygen (Field)	mg/L					-	-	0.1		
pH (Field)	pH_Units					-	7.29	7.1		
Purged_time	min					-	-	160		
Redox Potential (Field)	mV					-	82.5	120		
Vol_Purged	L					-	17553	170,000		
Alkalinity (Bicarbonate) as CaCO3	mg/L	1				340	306	303	275	274
Alkalinity (Carbonate) as CaCO3	mg/L	1				<1	<1	<1	<1	<1
Alkalinity (Hydroxide) as CaCO3	mg/L	1				<1	<1	<1	<1	<1
Alkalinity (Total) as CaCO3	mg/L	1				340	306	303	275	274
Anions Total	meq/L	0.01				15.9	14.1	13.4	12.1	12.3
Bicarbonate	mg/L					414.8	373.32	369.66	-	-
Calcium (Filtered)	mg/L	1			1000	110	95	100	79	88
Carbonate	mg/L					0.6	-	-	-	-
Cations Total	meq/L	0.01				14.2	12.5	13.8	11.7	12.2
Chloride	mg/L	1	250			171	164	160	156	149
Electrical Conductivity (Lab)	µS/cm	1				1220	1180	1160	1150	1300
Fluoride	mg/L	0.1		1.5	2	1.4	1.3	1.3	1.4	1.4
Ionic Balance	%	0.01				5.65	5.9	1.53	1.57	0.32
Magnesium (Filtered)	mg/L	1			600	49	40	46	39	39
Nitrate (as N)	mg/L	0.01			30	<0.01	<0.01	<0.01	0.02	<0.01
Nitrite (as N)	mg/L	0.01			10	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrite + Nitrate (as N)	mg/L	0.01				<0.01	<0.01	<0.01	0.02	<0.01
pH (Lab)	pH_Units	0.01	6.5-8.5			7.23	7.44	7.46	7.37	7.63
Potassium (Filtered)	mg/L	1				14	13	15	13	14
Silicon as Si (Filtered)	mg/L	0.05				7.73	9.58	10.7	9.16	9.98
Sodium (Filtered)	mg/L	1	180			99	96	108	98	98
Sulphate as SO4 (Filtered)	mg/L	1	250		1000	205	162	138	107	126
Suspended Solids	mg/L	5				<5	29	<5	<5	8
Total Dissolved Solids	mg/L	10	600		3000	927	737	733	695	670
Gross alpha activity	Bq/L	0.05		0.5		1.96	0.92	0.83	0.85	1.02
Gross beta activity	Bq/L	0.1		1		0.86	0.6	0.27	0.41	0.48
METALS										
Arsenic	mg/L	0.001		0.01	0.5	0.008	0.009	0.011	0.009	0.009
Arsenic (Filtered)	mg/L	0.001		0.01	0.5	0.008	0.004	0.01	0.008	0.008
Barium	mg/L	0.001		2		0.064	0.061	0.061	0.061	0.066
Barium (Filtered)	mg/L	0.001		2		0.054	0.055	0.064	0.059	0.062
Boron	mg/L	0.05		4	5	0.23	0.22	0.22	0.2	0.21
Boron (Filtered)	mg/L	0.05		4	5	0.21	0.22	0.23	0.21	0.25
Cadmium	mg/L	0.0001		0.002	0.01	<0.0001	0.0001	0.0002	<0.0001	<0.0001
Cadmium (Filtered)	mg/L	0.0001		0.002	0.01	<0.0001	<0.0001	0.0001	<0.0001	<0.0001
Chromium (III+VI)	mg/L	0.001			1	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium (III+VI) (Filtered)	mg/L	0.001			1	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	mg/L	0.001	1	2	0.5	0.004	0.011	0.002	<0.001	0.008
Copper (Filtered)	mg/L	0.001	1	2	0.5	0.031	<0.001	<0.001	<0.001	0.001
Iron	mg/L	0.05	0.3			0.48	1.41	1.16	1.19	1.44
Iron (Filtered)	mg/L	0.05	0.3			0.36	<0.05	1.16	1.16	1.13
Lead	mg/L	0.001		0.01	0.1	0.011	0.011	0.004	<0.001	0.001
Lead (Filtered)	mg/L	0.001		0.01	0.1	0.006	<0.001	<0.001	<0.001	<0.001
Lithium	mg/L	0.001				0.051	0.043	0.046	0.044	0.044
Lithium (Filtered)	mg/L	0.001				0.048	0.044	0.045	0.045	0.042
Manganese	mg/L	0.001	0.1	0.5		0.091	0.042	0.032	0.026	0.03
Manganese (Filtered)	mg/L	0.001	0.1	0.5		0.09	0.037	0.038	0.027	0.027
Mercury	mg/L	0.0001		0.001	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Mercury (Filtered)	mg/L	0.0001		0.001	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel	mg/L	0.001		0.02	1	0.052	0.01	0.02	0.004	0.024
Nickel (Filtered)	mg/L	0.001		0.02	1	0.047	0.006	0.01	0.002	0.008
Selenium	mg/L	0.01		0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01
Selenium (Filtered)	mg/L	0.01		0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	mg/L	0.001		0.1		<0.001	<0.001	<0.001	<0.001	<0.001
Silver (Filtered)	mg/L	0.001		0.1		<0.001	<0.001	<0.001	<0.001	<0.001
Strontium	mg/L	0.001				0.85	0.767	0.892	0.728	0.848
Strontium (Filtered)	mg/L	0.001				0.745	0.684	0.821	0.702	0.746
Zinc	mg/L	0.005	3		20	0.07	0.166	0.055	0.006	0.094
Zinc (Filtered)	mg/L	0.005	3		20	0.068	<0.005	0.015	<0.005	0.02
ORGANICS										
Total Reportable PAH	µg/L	0.5				<0.5	<0.5	<0.5	<0.5	<0.5
Methane	mg/L	0.01				<0.01	<0.01	<0.01	0.012	0.012
Ethane	µg/L	10				<10	<10	<10	<10	<10
Ethene	µg/L	10				<10	<10	<10	<10	<10
Propane	mg/L	0.01				<0.01	<0.01	<0.01	<0.01	<0.01
Propene	µg/L	10				<10	<10	<10	<10	<10
Benzene	µg/L	1		1		<1	<1	<1	<1	<1
Ethylbenzene	µg/L	2	3	300		<2	<2	<2	<2	<2
Toluene	µg/L	2	25	800		<2	<2	<2	<2	<2
Xylene (m & p)	µg/L	2				<2	<2	<2	<2	<2
Xylene (o)	µg/L	2				<2	<2	<2	<2	<2
Xylene Total	µg/L	2	20	600		<2	<2	<2	<2	<2
Sum of BTEX	µg/L	1				<1	<1	<1	<1	<1
Acenaphthene	µg/L	1				<1	<1	<1	<1	<1
Acenaphthylene	µg/L	1				<1	<1	<1	<1	<1
Anthracene	µg/L	1				<1	<1	<1	<1	<1
Benz(a)anthracene	µg/L	1				<1	<1	<1	<1	<1
Benzo(a)pyrene	µg/L	0.5		0.01		<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(a)pyrene TEQ (zero)	µg/L	0.5				<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(b&j)fluoranthene	µg/L	1				<1	<1	<1	<1	<1
Benzo(g,h,i)perylene	µg/L	1				<1	<1	<1	<1	<1
Benzo(k)fluoranthene	µg/L	1				<1	<1	<1	<1	<1
Chrysene	µg/L	1				<1	<1	<1	<1	<1
Dibenz(a,h)anthracene	µg/L	1				<1	<1	<1	<1	<1
Fluoranthene	µg/L	1				<1	<1	<1	<1	<1
Fluorene	µg/L	1				<1	<1	<1	<1	<1
Indeno(1,2,3-c,d)pyrene	µg/L	1				<1	<1	<1	<1	<1
Naphthalene	µg/L	1				<1	<1	<1	<1	<1
Phenanthrene	µg/L	1				<1	<1	<1	-	-
Pyrene	µg/L	1				<1	<1	<1	<1	<1
C6 - C9 Fraction	µg/L	20				<20	<20	<20	<20	<20
C6 - C10 Fraction	µg/L	20				<20	<20	<20	<20	<20
C6 - C10 Fraction minus BTEX	µg/L	20				<20	<20	<20	<20	<20
C10 - C14 Fraction	µg/L	50				<50	<50	<50	<50	<50
C10 - C16 Fraction	µg/L	100				<100	<100	<100	<100	<100
C10 - C16 Fraction	µg/L	100				<100	<100	<100	<100	<100
C15 - C28 Fraction	µg/L	100				<100	<100	<100	<100	<100
C16 - C34 Fraction	µg/L	100				<100	<100	<100	<100	<100
C29 - C36 Fraction	µg/L	50				<50	<50	<50	<50	<50
C34 - C40 Fraction	µg/L	100				<100	<100	<100	<100	<100
C10 - C36 Fraction (Sum)	µg/L	50				<50	<50	<50	<50	<50
C10 - C40 Fraction (Sum)	µg/L	100				<100	<100	<100	<100	<100

= Analyte of interest

KYA117-N2 CMB-AL = Kyalla Control Monitoring Bore - Anthony Lagoon aquifer
KYA117-N2 CMB G = Kyalla Control Monitoring Bore - Gumridge aquifer

Appendix 2: Santos groundwater monitoring program – Beetaloo Sub-basin

Description				Tanumbirini 2 water supply bore - RN040930 Sample date 9/12/2018 1:30:00 PM	Tanumbirini 2 water supply bore - RN040930 Sample date 14/07/2019 2:00:00 PM	Inacumba 1 Water supply bore - RN040931 Sample date 17/12/2018 2:30:00 PM
Chemical name	**Fraction D/T/N**	**Unit**	**Limit of detection**	**Result**	**Result**	**Result**
Standing Water Level	N	metres	-	56.82	57.93	-
Total Alkalinity as CaCO3	N	mg/L	1	417	467	363
Electrical Conductivity @ 25°C	N	µS/cm	1	1330	1330	1560
Total Dissolved Solids @180°C	T	mg/L	10	824	805	976
Suspended Solids	N	mg/L	5	< 5	< 5	35
Calcium	D	mg/L	1	137	147	134
Potassium	D	mg/L	1	12	13	22
Sodium	D	mg/L	1	78	78	103
Total Hardness as CaCO3	D	mg/L	1	577	-	697
Chloride	N	mg/L	1	106	112	148
Fluoride	N	mg/L	0.1	1.0	0.6	1.8
pH - Lab	N	pH Unit	0.01	7.97	7.78	8.06
Nitrite as N	N	mg/L	0.01	< 0.01	< 0.01	< 0.01
Nitrate as N	N	mg/L	0.01	< 0.01	< 0.01	0.02
Nitrite + Nitrate as N	N	mg/L	0.01	< 0.01	< 0.01	0.02
Silicon as SiO2	N	mg/L	0.1	23.6		19.0
Sulfate as SO4 2-	D	mg/L	1	208	139	328
Gross alpha	N	Bq/L	0.05	1.46	0.43	1.70
Gross beta activity - 40K	N	Bq/L	0.10	0.82	0.21	0.84
METALS						
Aluminium	D	mg/L	0.01	< 0.01	< 0.01	< 0.01
Aluminium	T	mg/L	0.01	< 0.01	< 0.01	0.30
Arsenic	D	mg/L	0.001	0.002	0.004	0.003
Arsenic	T	mg/L	0.001	0.002	0.001	0.010
Barium	D	mg/L	0.001	0.039	0.043	0.028
Barium	T	mg/L	0.001	0.040	0.053	0.036
Beryllium	D	mg/L	0.001	< 0.001	< 0.001	< 0.001
Beryllium	T	mg/L	0.001	< 0.001	< 0.001	< 0.001
Boron	D	mg/L	0.05	0.18	0.18	0.31
Boron	T	mg/L	0.05	0.16	0.19	0.27
Cadmium	D	mg/L	0.0001	0.0002	0.0001	< 0.0001
Cadmium	T	mg/L	0.0001	0.0002	0.0002	< 0.0001
Chromium	D	mg/L	0.001	< 0.001	< 0.001	< 0.001
Chromium	T	mg/L	0.001	< 0.001	< 0.001	< 0.001
Cobalt	D	mg/L	0.001	0.057	0.006	0.033
Cobalt	T	mg/L	0.001	0.060	0.004	0.036
Copper	D	mg/L	0.001	< 0.001	< 0.001	< 0.001
Copper	T	mg/L	0.001	< 0.001	< 0.001	0.002
Iron	D	mg/L	0.05	< 0.05	0.15	< 0.05
Iron	T	mg/L	0.05	0.23	0.32	7.33
Lead	D	mg/L	0.001	< 0.001	0.003	< 0.001
Lead	T	mg/L	0.001	0.001	0.002	< 0.001
Lithium	D	mg/L	0.001	0.069	0.057	0.416
Lithium	T	mg/L	0.001	0.062	0.057	0.365
Magnesium	D	mg/L	1	57	60	88
Manganese	D	mg/L	0.001	0.026	0.008	0.142
Manganese	T	mg/L	0.001	0.029	0.008	0.163
Mercury	D	mg/L	0.0001	< 0.0001	< 0.0001	< 0.0001
Mercury	T	mg/L	0.0001	< 0.0001	< 0.0001	< 0.0001
Molybdenum	D	mg/L	0.001	0.003	< 0.001	0.046
Molybdenum	T	mg/L	0.001	0.003	< 0.001	0.050
Nickel	D	mg/L	0.001	0.220	0.020	0.032
Nickel	T	mg/L	0.001	0.234	0.015	0.034
Selenium	D	mg/L	0.01	< 0.01	< 0.01	< 0.01
Selenium	T	mg/L	0.01	< 0.01	0.05	< 0.01
Silver	D	mg/L	0.001	< 0.001	-	< 0.001
Silver	T	mg/L	0.001	< 0.001	-	< 0.001
Strontium	D	mg/L	0.001	0.719	-	0.868
Strontium	T	mg/L	0.001	0.700	-	0.835
Uranium	D	mg/L	0.001	0.037	0.008	0.010
Uranium	T	mg/L	0.001	0.038	0.005	0.011
Vanadium	D	mg/L	0.01	< 0.01	< 0.01	< 0.01
Vanadium	T	mg/L	0.01	< 0.01	< 0.01	< 0.01
Zinc	D	mg/L	0.005	0.099	0.010	0.014
Zinc	T	mg/L	0.005	0.101	0.010	0.041
ORGANICS						
Butene	N	µg/L	10	< 10	< 10	< 10
Ethane	N	µg/L	10	< 10	< 10	< 10
Ethene (Ethylene)	N	µg/L	10	< 10	< 10	< 10
Methane	N	µg/L	10	< 10	< 10	< 10
n-Butane	N	µg/L	10	< 10	< 10	< 10
Propane	N	µg/L	10	< 10	< 10	< 10
Propene	N	µg/L	10	< 10	< 10	< 10
>C10 - C16 Fraction	N	µg/L	100	< 100	< 100	100
>C10 - C16 Fraction minus Naphthalene (F2	N	µg/L	100	< 100	< 100	100
>C10 - C40 Fraction (sum)	N	µg/L	100	< 100	< 100	380
>C16 - C34 Fraction	N	µg/L	100	< 100	< 100	280
>C34 - C40 Fraction	N	µg/L	100	< 100	< 100	< 100
C10 - C14 Fraction	N	µg/L	50	< 50	< 50	< 50
C10 - C36 Fraction (sum)	N	µg/L	50	< 50	< 50	360
C15 - C28 Fraction	N	µg/L	100	< 100	< 100	240
C29 - C36 Fraction	N	µg/L	50	< 50	< 50	120
Benzene	N	µg/L	1	< 1	< 1	< 1
C6 - C10 Fraction	N	µg/L	20	< 20	< 20	< 20
C6 - C10 Fraction minus BTEX (F1)	N	µg/L	20	< 20	< 20	< 20
C6 - C9 Fraction	N	µg/L	20	< 20	< 20	< 20
Ethylbenzene	N	µg/L	2	< 2	< 2	< 2
meta- & para-Xylene	N	µg/L	2	< 2	< 2	< 2
Naphthalene	N	µg/L	5	< 5	< 5	< 5
ortho-Xylene	N	µg/L	2	< 2	< 2	< 2
Sum of BTEX	N	µg/L	1	< 1	< 1	< 1
Toluene	N	µg/L	2	< 2	< 2	< 2
Total Xylenes	N	µg/L	2	< 2	< 2	< 2
2.4.5-Trichlorophenol	N	µg/L	1.0	< 1.0	-	< 1.0
2.4.6-Trichlorophenol	N	µg/L	1.0	< 1.0	-	< 1.0
2.4-Dichlorophenol	N	µg/L	1.0	< 1.0	-	< 1.0
2.4-Dimethylphenol	N	µg/L	1.0	< 1.0	-	< 1.0
2.6-Dichlorophenol	N	µg/L	1.0	< 1.0	-	< 1.0
2-Chlorophenol	N	µg/L	1.0	< 1.0	-	< 1.0
2-Methylphenol	N	µg/L	1.0	< 1.0	-	< 1.0
2-Nitrophenol	N	µg/L	1.0	< 1.0	-	< 1.0
3- & 4-Methylphenol	N	µg/L	2.0	< 2.0	-	12.3
4-Chloro-3-Methylphenol	N	µg/L	1.0	< 1.0	-	< 1.0
Acenaphthene	N	µg/L	1.0	< 1.0	-	< 1.0
Acenaphthylene	N	µg/L	1.0	< 1.0	-	< 1.0
Anthracene	N	µg/L	1.0	< 1.0	-	< 1.0
Benz(a)anthracene	N	µg/L	1.0	< 1.0	-	< 1.0
Benzo(a)pyrene	N	µg/L	0.5	< 0.5	-	< 0.5
Benzo(a)pyrene TEQ (zero	N	µg/L	0.5	< 0.5	-	< 0.5
Benzo(b+j)fluoranthene	N	µg/L	1.0	< 1.0	-	< 1.0
Benzo(g.h.i)perylene	N	µg/L	1.0	< 1.0	-	< 1.0
Benzo(k)fluoranthene	N	µg/L	1.0	< 1.0	-	< 1.0
Chrysene	N	µg/L	1.0	< 1.0	-	< 1.0
Dibenz(a.h)anthracene	N	µg/L	1.0	< 1.0	-	< 1.0
Fluoranthene	N	µg/L	1.0	< 1.0	-	< 1.0
Fluorene	N	µg/L	1.0	< 1.0	-	< 1.0
Indeno(1.2.3.cd)pyrene	N	µg/L	1.0	< 1.0	-	< 1.0
Naphthalene	N	µg/L	1.0	< 1.0	-	< 1.0
Pentachlorophenol	N	µg/L	2.0	< 2.0	-	< 2.0
Phenanthrene	N	µg/L	1.0	< 1.0	-	< 1.0
Phenol	N	µg/L	1.0	< 1.0	-	1.5
Pyrene	N	µg/L	1.0	< 1.0	-	< 1.0
Sum of polycyclic aromatic hydrocarbons (PAHs	N	µg/L	0.5	< 0.5	-	< 0.5