

Modification Application – Regulation 23

Interest Holder	Santos QNT Pty Ltd		EMP Title	McArthur Basin 2019 Civil and Seismic Program	Unique EMP ID No.	STO1-4	Mod No.	3	Date	18/08/2020
Brief Description	The Water Resources Division Technical Report 20/2020 confirms the presence of a newly discovered aquifer, referred to as the Inacumba aquifer. Identification of the new Inacumba aquifer at Tanumbirini Station has subsequently triggered a change in the existing environment relevant to this EMP. This EMP modification application is required under Regulation 23 to give the Minister a notice that specifies details of the changes to the EMP.									
Geospatial Files Included?	No									
Does the change in existing environment result in a new, or increased, potential or actual environmental impact or risk?	If a NEW potential or actual environmental impact or risk, is it provided for in the approved EMP?	If an INCREASE in an existing potential or actual environmental impact or risk, is it provided for in the approved EMP?	Does the change in the existing environment require additional mitigation measures to be included?	Has additional stakeholder engagement been conducted?	Does it require additional environmental performance standards and measurement criteria?	Does it affect compliance with Sacred Site Authority Certificates?	Does it affect current rehabilitation, weed, fire, wastewater, erosion and sediment control, spill or emergency response plans?	Will the environmental outcome continue to be achieved and will the impacts and risks be managed to ALARP and acceptable?		
No	N/A	N/A	No	No	No	No	No	No	Yes	
Current EMP Text					Amended EMP Text					
Table ES-1: Summary of Environmental Values and Sensitivities					Table ES-1: Summary of Environmental Values and Sensitivities					
Environmental Factors	Environmental Values and Sensitivities	Summary								
Inland water environmental quality	Groundwater	The Cambrian Limestone Aquifer is a regional scale aquifer that provides groundwater resources for pastoral enterprises, domestic bores at homesteads and town water supplies at a number of small communities across the region.								

	Environmental Factors	Environmental Values and Sensitivities	Summary
	Inland water environmental quality	Groundwater	<p>The Cambrian Limestone Aquifer is a regional scale aquifer that provides groundwater resources for pastoral enterprises, domestic bores at homesteads and town water supplies at a number of small communities across the region. In addition, the Water Resources Division Technical Report 20/2020 confirms the presence of a newly discovered aquifer, referred to as the Inacumba aquifer. Presently, there is limited information available regarding the regional and stratigraphic extent of the Inacumba aquifer. Its productivity as a water resource aquifer is only confirmed in a few bores within the vicinity of the Inacumba 1 well lease. The value of this aquifer as a groundwater resource is limited due to the presence of overlying and highly productive water bearing formations of the Gum Ridge Formation (Cambrian Limestone Aquifer).</p> <p>The Gum Ridge Formation groundwater resource in this area is understood to connect to the Roper River, where groundwater discharge supports aquatic, riparian and floodplain ecosystem function.</p>
<p>4.1.6 Groundwater Table 4-3 summarises the regional hydrostratigraphy of the Beetaloo Basin.</p>	<p>4.1.6 Groundwater Table 4-3 summarises the regional hydrostratigraphy of the Beetaloo Sub-basin.</p>		

PROVINCE	PERIOD / AGE	FORMATION	AQUIFER STATUS	THICKNESS (m)	YIELD (l/s)	AVE. EC (µs/cm)	
CARPENTARIA BASIN	CRETACEOUS 145 – 66 Ma	Undifferentiated	<i>Local Aquifer</i>	0 - 130	0.3 - 4	1800	
GEORGINA BASIN	CAMBRIAN 497-630 Ma	Cambrian Limestone Aquifer (CLA)	Anthony Lagoon Beds	REGIONAL AQUIFER	0 – 200	1 - 10	1600
			Gum Ridge Formation	REGIONAL AQUIFER	0 – 300	0.3 - >20	1400
		Antrim Plateau Volcanics		REGIONAL AQUITARD <i>Local Aquifer</i>	0 – 440	0.3 - 5	900
		Bukalara Sandstone		<i>Local Aquifer</i>	0 – 75	0.3 - 5	1000
BEETALOO BASIN (ROPER GROUP)	NOT KNOWN	Hayfield Mudstone	REGIONAL AQUITARD <i>Local Aquifer</i>	0 – 450	-	32000	
		Jamison Sandstone	<i>Local Aquifer</i>	0 – 150	-	138000	
	MESO-PROTEROZOIC 1430-1500 Ma	Kyalla Formation	REGIONAL AQUITARD	0 – 800	-	-	
		Moroak Sandstone	<i>Local Aquifer</i>	0 – 500	0.5 - 5	131000	
		Velkerri Formation	REGIONAL AQUITARD	700 – 900	-	-	
		Bessie Ck Sandstone	<i>Local Aquifer</i>	450	0.5 - 5	-	

The major hydrogeological units of the Roper River catchment are the Cambrian limestones of the Daly, Wiso and Georgina Basins. These major groundwater systems provide dry season inputs to the Roper River (Knapton, 2009). The Cambrian Limestone Aquifer (CLA) forms the major water resource in the region and where it is absent, local scale, Proterozoic fractured rock aquifers are utilised with varied success.

The CLA is a regional scale aquifer that provides groundwater resources for pastoral enterprises, domestic bores at homesteads and town water supplies at a number of small communities across the region. The CLA is subdivided into the Anthony Lagoon Beds (ALB) and the Gum Ridge Formation (GRF). The CLA is the only aquifer at the location of the proposed activities, as confirmed by hydrogeologists DENR. There are no other formations present which are considered aquifers.

Where fractured and cavernous the GRF can support bore yields of up to 100 l/s although yields from pastoral bores are typically less than 5 L/s but often reflect the stock water demand rather than the potential aquifer yield (Fulton 2018).

Depth to groundwater in the CLA ranges from 32 to 123 mBGS (metres below ground surface) with groundwater levels generally deeper further away from the basin margin in the south-west of EP 161 (Fulton 2018).

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GEORGINA BASIN	CAMBRIAN 497-541 Ma	Cambrian Limestone Aquifer (CLA)	Anthony Lagoon Beds	REGIONAL AQUIFER	0 – 200	1 - 10	1600
			Gum Ridge Formation	REGIONAL AQUIFER	0 – 300	0.3 - >20	1400
		Antrim Plateau Volcanics		REGIONAL AQUITARD <i>Local Aquifer</i>	0 – 440	0.3 - 5	900
		Inacumba unit		<i>Local Aquifer</i>	0 – 75	0.3 - 5	1000
BEETALOO BASIN (ROPER GROUP)	NEO-PROTEROZOIC 541-1000 Ma	Cox Formation	REGIONAL AQUITARD <i>Local Aquifer</i>	0 – 450	-	32000	
		Bukalara Sandstone	<i>Local Aquifer</i>	0 – 150	-	138000	
	MESO-PROTEROZOIC 1430-1500 Ma	Kyalla Formation	REGIONAL AQUITARD	0 – 800	-	-	
		Moroak Sandstone	<i>Local Aquifer</i>	0 – 500	0.5 - 5	131000	
		Velkerri Formation	REGIONAL AQUITARD	700 – 900	-	-	
		Bessie Ck Sandstone	<i>Local Aquifer</i>	450	0.5 - 5	-	

The major hydrogeological units of the Roper River catchment are the Cambrian limestones of the Daly, Wiso and Georgina Basins. These major groundwater systems provide dry season inputs to the Roper River (Knapton, 2009). The Cambrian Limestone Aquifer (CLA) forms the major water resource in the region and where it is absent, local scale, Proterozoic fractured rock aquifers are utilised with varied success. The Inacumba aquifer is also considered to be a local aquifer in the Project Area. However, the nearest recognised water bores drilled into a geologically time-equivalent unit similar to the Inacumba unit are located north of Nutwood Downs Station, approximately 100 km from the Project Area.

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Where fractured and cavernous the GRF can support bore yields of up to 100 l/s although yields from pastoral bores are typically less than 5 L/s but often reflect the stock water

The regional groundwater flow direction in the GRF is north-west toward Mataranka, where the aquifer discharges into the Roper River approximately 100 km north-west of the Beetaloo Basin where it supports significant groundwater dependent ecosystems (Fulton 2018).

The groundwater flow direction in the GRF broadly follows the north-west regional flow pattern however, gradients are very flat (0.0001) with little change in groundwater elevations observed over large distances. Large decadal changes in discharge rates to the Roper River suggest that most recharge of the Roper River occurs close to the discharge zone, i.e. beyond the Beetaloo Sub-basin region (Fulton 2018).

Groundwater recharge mechanisms to the CLA are poorly characterised but are likely to be dominated by infiltration through sinkholes and soil cavities. Recharge is likely to be lower in areas where the overlying Cretaceous deposits, which contain clay and mudstone sequences, are thick and continuous (Fulton 2018). The Project Area straddles the north-east margin of the Georgina Basin. The Top Springs Limestone (main constituent of the CLA in the area) is present across the centre and south-west of the Project Area but pinches out in the north-east where Roper Group formations outcrop (Fulton 2018).

Drilling and geophysical logs confirm a local stratigraphy as per Table 4-4. This was confirmed by geophysical logging of the Tanumbirini 1 exploration well at the location of the proposed well sites.

Table 4-4 Stratigraphy logged at the location of Tanumbirini 1

Formation	Depth to formation top (m)	Thickness (m)
Undifferentiated Cretaceous	Surface	43.9
Gum Ridge Formation	52	150
Bukalara Sandstone	202	380
Chambers River Formation	582	570
Bukalorkmi Sandstone	1152	145
Kyalla Sandstone	1297	772
Moroak Sandstone	2069	368
Velkerri Formation	2437	1482.5
Bessie Ck Sandstone	3920	>30.5

A baseline survey of water bores in the vicinity of the proposed well sites was undertaken in 2018. Groundwater Electrical Conductivity (EC) in the CLA ranges from 1170 - 2260 $\mu\text{S}/\text{cm}$ (average of 1580 $\mu\text{S}/\text{cm}$) and the pH is typically neutral (6.3 - 7.3) (Fulton 2018). Santos has established groundwater monitoring bores at the Tanumbirini-1/2H location and Inacumba-1/1H location. The groundwater from these bores is fresh, ranging between 800-1000 mg/L TDS. Table 4-5 provides a more detailed breakdown of the groundwater chemistry in the Gum Ridge Formation (compliant with the sampling and testing requirements outlined in the

demand rather than the potential aquifer yield (Fulton 2018). Bore RN040939 penetrated the Inacumba aquifer with a maximum yield of 23 L/s reported.

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Bukalara Sandstone	1152	145
Kyalla Formation	1297	772
Moroak Sandstone	2069	368
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<p>Preliminary Guideline: Groundwater Monitoring Bores for Exploration Wells in the Beetaloo Sub-basin (DENR, 2018)).</p> <p>The existing bores that Santos will monitor as part of their groundwater monitoring program are shown in Figure 4-5. In addition, CSIRO led baseline studies underway with extensive effort being put into understanding of recharge.</p>	<p>1/1H location. The groundwater from these bores is fresh, ranging between 800-1000 mg/L TDS. Table 4-5 provides a more detailed breakdown of the groundwater chemistry in the Gum Ridge Formation (compliant with the sampling and testing requirements outlined in the Preliminary Guideline: Groundwater Monitoring Bores for Exploration Wells in the Beetaloo Sub-basin (DENR, 2018)).</p> <p>The existing bores that Santos will monitor as part of their groundwater monitoring program are shown in Figure 4-5. In addition, CSIRO led baseline studies underway with extensive effort being put into understanding of recharge.</p>
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