Context

An Underground Water Impact Report (UWIR), and associated groundwater monitoring strategy for Santos' Cooper Basin oil and gas operations was approved by the then Department of Environmental and Heritage Protection on the 8 July 2013. As required by section 370 of the Water Act 2000, updates to the UWIR are required every three years.

The latest revision of the UWIR was submitted for approval in December 2019 following an extension to the submission date as granted by the Queensland Department of Environment and Science (DES). As at the time of this assessment in February 2020, the next revision to the UWIR had not yet been approved by DES.

Purpose

A recent change in the long-term development plan has resulted in the need to revise the December 2019 UWIR. This memo has been prepared to outline the changes in the model and the Long-term Affected Area (LAA). This is reported in the attached report "Revised Scenario for the UWIR" (Appendix B).

The change is induced by a modelled increase in the number of operational oil and gas wells by Santos within the Cooper and Eromanga Basins. There are no changes to the number of wells currently being operated, and hence no change to the Immediately Affected Area (IAA) as submitted for approval in 2019.

Changes to development

Table A-1 summarises the additional number of wells proposed to be developed within each Environmental Authority. The number of modelled wells (existing and proposed) has increased from 469 to 655 oil wells in the Eromanga Basin and 617 to 823 gas wells in the Cooper Basin.

Changes to underground water impact

Due to the greater number of modelled oil and gas wells, the LAA areas have grown slightly. This is shown in Figures 38-41 for the Eromanga Basin and Figures 48-49 for the Cooper Basin in Appendix B.

This increase in impact area increases the number of potentially impacted groundwater bores. An additional bore, RN 23059, is predicted to see a drawdown impact of 6m in the long-term (ie > 3years into the future), 1m above the 5m trigger drawdown threshold. This bore lies outside the modelled IAA however.

This increase in impact area does not change the potential risk to Environmental Values such as springs or groundwater dependent ecosystems since the affected formations are not in hydraulic continuity with the surface water environment or sediments at ground surface level. This is consistent with the assessment of all previously approved UWIRs for the project area and the UWIR submitted in 2019.

Groundwater Monitoring Strategy

The groundwater monitoring strategy proposed in the UWIR submitted in 2019 does not need to be amended based on the new predicted impact because the scale of the impact has not significantly changed.

Bore Assessment and Make Good

There are no new requirements to undertake Bore Assessments or Make Good because there are no changes to the Immediately Affected Area (IAA).

Produced Formation Water Volumes

The predictions and assumptions used within the model to determine water production rates for the IAA have not changed. Validation for the LAA model scenario will only be possible in future years (i.e. beyond the next three-years).

There has been no material change in the information or predictions used to prepare maps detailed in the UWIR, insofar as the predictions are considered more conservative when compared to expected actual impacts.

Annual report

Santos expects the UWIR dated December 2019 to be approved with conditions.

In accordance with s376 (e) of the *Water Act 2000*, an annual review must be submitted within 20 business days after the anniversary day of the approval. The annual report due in August 2020 will include the assessment of potential impacts of changes to long-term development plans, as reported here.

Santos

[redacted]
Principal Environmental Advisor |
Hydrogeologist
Environment and Access
Santos Limited, [redacted]
t: [redacted] m: +[redacted]

santos.com

Appendix A

Table A-1 LTAA Modelled Wells (in addition to existing operational wells)

EA Reference	Tenure	No. modelled wells (LAA)
EPPG03517715	PL59, PL60/1072, PL61, PL81, PL83, PL85, PL86, PL97/508, PL106/288, PL108, PL111, PL112, PL131, PL132, PL135, PL139/1035, PL146, PL147, PL205, PL207/1014, PL208/1051	121
EPPG00303413	PL177	9
EPPG00303013	PL152	9
EPPG00303213	PL155	21
EPPG00309213	PL151	22
EPPG02656814	PL509, PL1013	27
EPPG03516015	PL58, PL136, PL137, PL159	33
EPPG00303313	PL156	9
EPPG00383613	PL249	3
EPPG00407213	PL80, PL1087	22
EPPG03518115	PL23, PL24, PL25, PL26, PL35, PL36, PL62, PL76, PL77, PL78, PL82, PL87, PL105/287, PL133, PL149, PL175, PL495, PL496, PL1047	100
EPPG00303613	PL181	3
EPPG00303713	PL182	3
EPPG00307213	PL79	3
EPPG00322013	PL189/1026	2
EPPG03517915	PL29, PL38, PL39, PL52, PL57, PL95, PL169/1027, PL170/1029	47
EPPG00382813	PL295	41
EPPG03517415	PL34, PL37, PL63, PL68, PL75, PL84, PL88, PL129, PL130, PL134, PL140, PL142, PL143/1057, PL144, PL150, PL186, PL110/497, PL502, PL1046	134
EPPG00300513	PL241	3
EPPG00304113	PL193/513	21
EPPG00307813	PL255	6
EPPG00383513	PL301, PL1077	19
EPPG03517215	PL113/1054, PL114, PL141, PL145, PL148, PL153, PL157, PL158, PL1016	65
EPPG00303913	PL187	3
EPPG00715013	PL303, PL1028	39
EPPG00747513	ATP752	3
EPPG03518715	PL138, PL154	6
EPPG03517315	PL55	3
EPPG03518215	ATP1189	35
EPPG00146313	ATP636	3
EPPG00307913	PL117	1
EPPG00304013	PL188	1
EPPG00307713	PL254	6
EPPG00892413	ATP1063, ATP1174, PL33, PL50, PL51, PL244	35

EA Reference	Tenure	No. modelled wells (LAA)
EPPG00641613	PL302, PL1060	10
EPPG00757313	PL411	1
None	PL1055	10
None	PL1058	10
None	PCAs associated with ATP1189 and ATP752	129

Appendix B – Underground Water Impact Report for Santos Cooper Basin Oil and Gas Fields, South-West Queensland (February 2020)

Santos

Revised Scenario for the UWIR Santos Cooper Basin Oil and Gas Fields, South-West Queensland

February 2020

Date	Rev	Reason For Issue	Author	Checked	Approved
12/02/20	0	Regulatory submission	KB / HG		

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Abbreviations and Units

Acronym	Description
σ_h	minimum horizontal stress
σ_H	horizontal overburden stress
σ_v	minimum vertical stress
σ_V	vertical overburden stress
µS/cm	microSiemens per centimetre
AHD	Australian Height Datum
bgl	below ground level
BOM	Bureau of Meteorology
DEHP	Department of Environment and Heritage Protection
DERM	(former) Department of Environment and Resource Management
DNRM	Department of Natural Resources and Mines
EA	Environmental Authority
EC	electrical conductivity
EHS	Environment, Health and Safety
EHSMS	Environment, Health and Safety Management System
EP Act	Environmental Protection Act 1994
EP Reg	Environmental Protection Regulation 2008
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
EPP Water	Environmental Protection (Water) Policy 2009
ERE	endangered regional ecosystems
GAB	Great Artesian Basin
GAB ROP	Great Artesian Basin Resource Operations Plan
GAB WRP	Great Artesian Basin Water Management Plan
GDE	groundwater dependent ecosystems
GL	gigalitre per year
GMA	Groundwater Management Area
GMU	Groundwater Management Unit
IAA	Immediately Affected Area
LTAA	Long Term Affected Area
mb	body-wave magnitude
meq/L	milliequivalents per litre
ML	megalitre per year
Mpa/km	megapascal per kilometre
P&G Act	Petroleum and Gas (Production and Safety) Act 2004
PFW	produced formation water
PL	Petroleum Lease
QLD	Queensland
SA	South Australia
SWQ	South West Queensland
TDS	total dissolved solids
UWIR	Underground Water Impact Report
Water Act	Water Act 2000

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1.0 Introduction

This report provides an updated assessment of underground water impacts for the Santos' Cooper Basin Oil and Gas Field South West Queensland (SWQ). It has been updated to reflect a change in the development scenario. This report has been prepared in accordance with the Queensland *Water Act 2000* (the Water Act) and the Guideline for Underground Water Impact Reports and Final Reports (the Guideline). The intent of this report is to describe, make predictions about and manage the impacts of extraction of underground water by petroleum tenure holders where production testing or production is taking place.

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2.0 Background

Santos currently operates conventional oil and gas fields within the Cooper Basin of South Western Queensland (SWQ) (Figure 1). The area occupied by these Petroleum Licences (PLs) within which the fields occur covers in excess of 8,160km² of largely semi-arid agricultural land and was developed for petroleum operations in the early 1970s. Santos petroleum tenements comprise approximately 212 producing gas wells and 250 producing oil wells (Figure 2) over SWQ. Santos' Cooper Basin petroleum fields produce both conventional gas and oil:

Conventional oil is produced from the formations of the Eromanga Basin (a sub-basin within the Great Artesian Basin (GAB) formations) with some additional production from the Tirrawarra Formation and basal Patchawarra Formation (both of which lie within the deeper Cooper Basin). There are several types of oil reservoirs that are targeted for the economic production of hydrocarbons and these are discussed in more detail in Section 4.3.5.

Conventional gas production is from porous sandstone formations which does not require the depressurisation of the target beds (with respect to groundwater, and the need to remove groundwater to release the gas) to produce at economic quantities. Some water is produced as a by-product, however, the volumes are relatively small (discussed in Section 4.3.4). Within the study area, conventional gas production is typically from the deep formations of the Cooper Basin (underlying the GAB system).

Note: "Santos" refers to Santos and its subsidiary companies that operate the oil and gas tenements on behalf of various joint venture parties.

1.1. Previous Groundwater Studies

Groundwater investigations or reports that have been undertaken or prepared within the Santos SWQ operational areas include:

Water Flooding Impact Assessment: Further Information to Support Assessment of Potential Impacts of Water Flooding in PL295, URS, 2010.

Response to DERM (now DNRM) Re: Use of fracture fluids containing BTEX, Santos 2010.

Underground Water impact Report for Santos' Cooper Basin Oil & Gas Fields, SW QLD, Golder, 2011.

Underground Water impact Report for Santos' Cooper Basin Oil & Gas Fields, SW QLD, Golder, 2013 (Appendix A).

Southwest Queensland 2014 Annual Groundwater Monitoring Report, Golder, July 2015 (Appendix B).

Underground Water impact Report for Santos` Cooper Basin Oil & Gas Fields, SW QLD, 2016

South-West Queensland UWIR 2018 Annual Groundwater Monitoring Report, LBWCo (2019)

References for regional groundwater studies and regional groundwater related literature are included in Section 12.0 at the end of this report.

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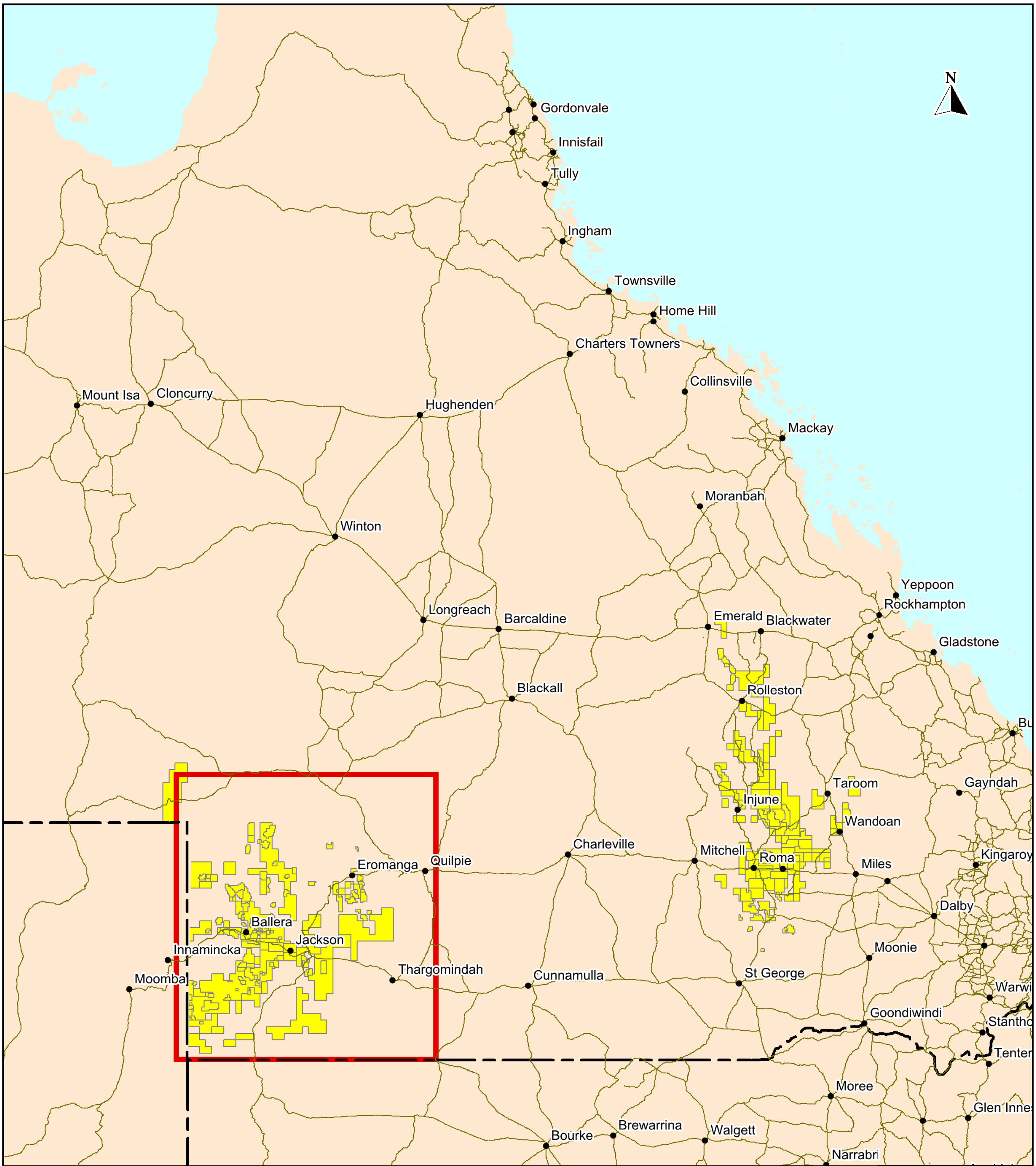


Town / Locality

Highway / Major Road

Santos Queensland Acreage

Study Area

Santos

Cooper Basin UWIR

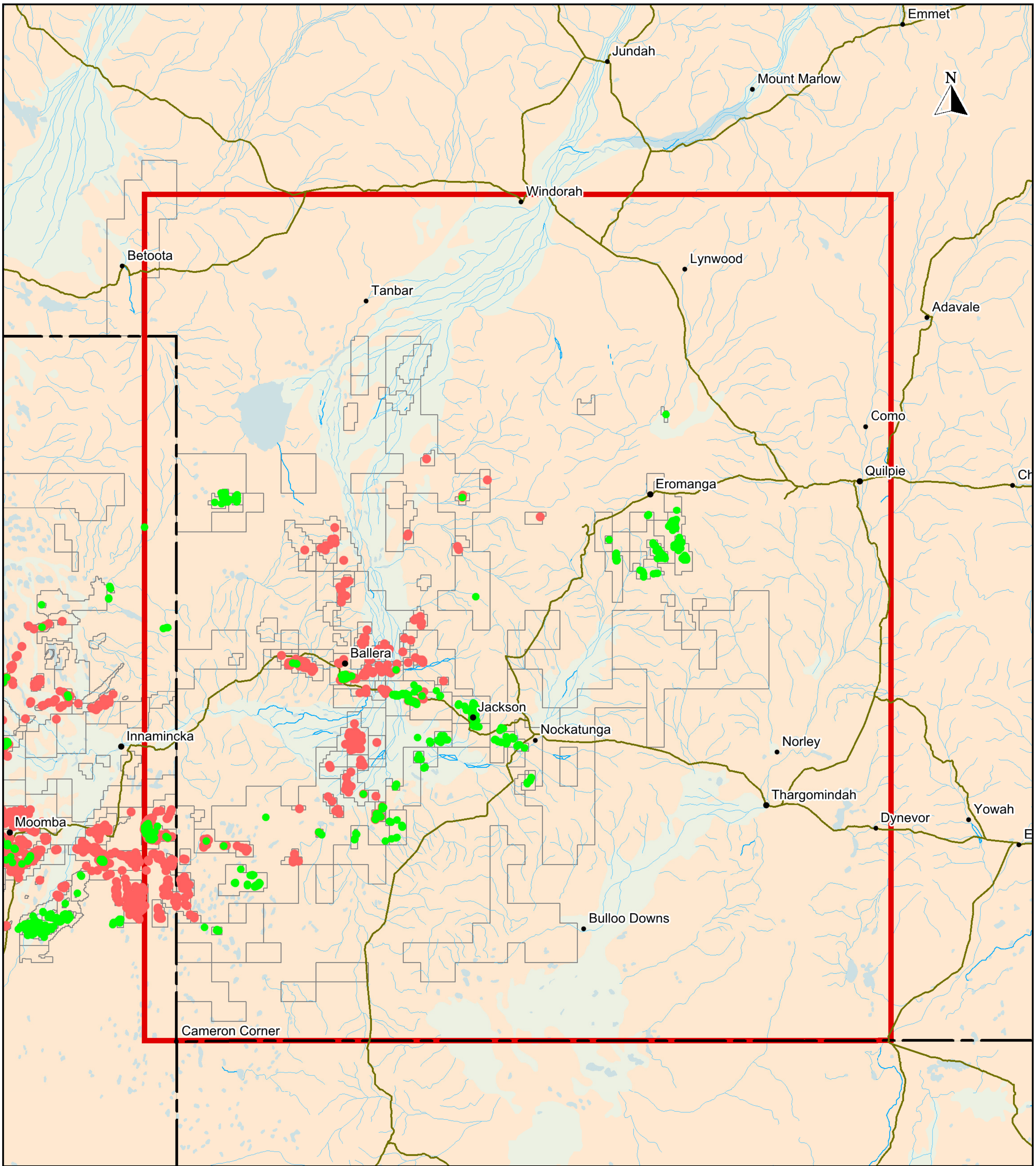
Santos SWQ Oil and Gas Operation Locations

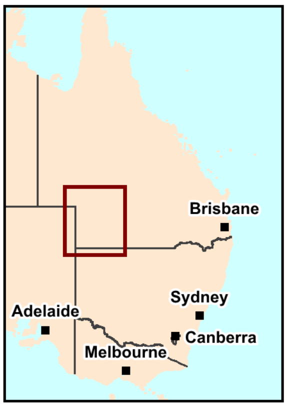
Kilometres

0 50 100 150 200 250

20 May 2016, File No. ENVIR 661

Figure 1





Town / Locality

Santos Acreage

Study Area

Gas Production Well

Oil Production Well

Highway / Major Road

River / Creek

Santos

Cooper Basin UWIR

Santos SWQ Oil and Gas Field Locations

Kilometres

0 20 40 60 80 100

20 May 2016, File No. ENVIR 661

Figure 2

3.0 Legislative Framework

Legislation and regulation requires petroleum tenure holders to manage the access, use and disposal of produced water generated through oil and gas development activities in an environmentally sustainable manner. This section provides a summary of the key Queensland (QLD) and Commonwealth legislative requirements related to the extraction of groundwater from deep aquifers and management of produced water.

Santos activities in the Cooper Basin are subject to general QLD and/or Commonwealth regulation, and to site and activities specific Environmental Authorities (EAs) determined by DEHP under the *Environmental Protection Act 1994*.

The legislative texts discussed below provide the general driver for the regulation and how it applies to Santos activities.

3.1 Petroleum and Gas (Production and Safety) Act 2004

The *Water and Other Legislation Amendment Act 2010* amends the *Water Act 2000* (Water Act) and other relevant legislation with the aim of improving the management of impacts associated with groundwater extraction that form part of petroleum activities. These amendments transfer the regulatory framework for underground water from the *Petroleum and Gas (Production and Safety) Act 2004* (P&G Act) to the Water Act.

The P&G Act originally provided all rights of water extraction to a petroleum activity. However through recent updates of the P&G Act and the Water Act (see Section 3.2), a petroleum tenure holder has an obligation to identify impact, establish baseline conditions and maintain groundwater supplies in private bores in the vicinity of petroleum operations. Where a bore owner can demonstrate reduced access to groundwater supplies, or a reduction in beneficial use class due to water quality changes, as a result of petroleum operations, “make good” provisions are available to address the loss incurred by an affected bore owner.

3.2 Water Act 2000

The Water Act regulates access to water resources. Under the Water Act, a water licence is required to take water for any use other than domestic and stock watering. When a water licence is required, there may be a requirement under Section 214(e) to carry out and report on a monitoring program. If water is to be provided to others as part of the activities, the operator is required to be registered as a Water Service Provider.

In 2010, groundwater management requirements that were previously regulated under the P&G Act and the *Petroleum Act 1923* were removed and included in an amendment to the *Water Act.* Those requirements included the obligations to:

- Prepare UWIRs.
- Establish groundwater baseline conditions through baseline assessment of private bores.
- Define make good provisions as a contingency to address losses incurred by private bore owners resulting from petroleum activities.

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The Water Act also defines the drawdown thresholds which if reached will trigger investigations and make good actions.

3.2.1 Underground Water Impact Report (UWIR)

The amendments to the Water Act support management and protection of water resources, by requiring operators to prepare periodic UWIR's. Subsequent UWIR's are to be prepared every three years. The approved reports must be publicly notified and published on the Queensland DEHP website.

The following details the requirements as per s376 of the Water Act that apply to the preparation of a UWIR, and reference to the section(s) in this report where the requirement is addressed:

(a) for the area to which the report relates:

- (i) the quantity of water produced or taken from the area because of the exercise of any previous relevant underground water rights (Section 5.0)
- (ii) an estimate of the quantity of water to be produced or taken because of the exercise of the relevant underground water rights for a 3 year period starting on the consultation day for the report (Section 5.0).

(b) for each aquifer affected, or likely to be affected, by the exercise of the relevant underground water right:

- (i) a description of the aquifer (Section 5.2)
- (ii) an analysis of the movement of underground water to and from the aquifer, including how the aquifer interacts with other aquifers (Sections 5.8)
- (iii) an analysis of the trends in water level change for the aquifer because of the exercise of the [extraction] rights (Section 7.0).
- (iv) a map showing the area of the aquifer where the water level is predicted to decline, because of the taking of the quantities of water forecasted, by more than the bore trigger threshold within 3 years after the consultation day for the report (Section 7.0).
- (v) a map showing the area of the aquifer where the water level is predicted to decline, because of the exercise of relevant underground water rights, by more than the bore trigger threshold at any time (Section 7.0)

(c) a description of the methods and techniques used to obtain the information and modelled predictions (Section 7.0)

(d) a summary of information about all potentially impacted water bores in the area, including the number of bores, and the location and authorised use or purpose of each bore (Sections 7.5 and 7.6).

(e) a program for:

- (i) conducting an annual review of the accuracy of each map

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(ii) giving the chief executive a summary of the outcome of each review, including a statement of whether there has been a material change in the information or predictions used to prepare the maps

(f) a water monitoring strategy (Section 9.3).

(g) a spring impact management strategy (Section 9.0).

The water monitoring strategy must include a strategy for monitoring water levels and water quality in aquifers in the area, and a strategy for monitoring the quantity of water produced from oil and gas wells. A timetable for the implementation and reporting program must also be completed.

The spring impact management strategy must include details as to the potentially affected springs, an assessment of the connectivity between the springs and the aquifers and an assessment of the impact of the predicted water level decline on ecosystem health and cultural values. The strategy should provide options to prevent or mitigate impacts. An implementation timetable and a monitoring and reporting program should be included.

3.2.2 Drawdown Trigger Thresholds

DEHP has defined a regime for drawdown trigger threshold values as follows:

5m decline for consolidated aquifers such as sandstone.

2m decline for shallow alluvial aquifers.

0.2m for active springs.

In accordance with The Water Act, Santos is expected to investigate complaints from landowners within an Immediately Affected Area (IAA) which is defined as an area where the water level is expected to exceed the trigger threshold within three years from the reporting day. If the investigation concludes that a material impact to water production will occur, then Santos and the affected groundwater user will need to negotiate on an appropriate make-good arrangement.

3.3 Other Applicable Water Regulations

Table 1 summarises the additional legislative requirements applicable to the oil and gas production and the Study Area.

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Table 1. Additional Legislative Requirements Related to Groundwater

Legislation/Section	Driver	Key Points as they Apply to the Santos Operations
Environmental Protection Act 1994	Section 309Z can be imposed on a petroleum activity and cause the activity to prepare an environmental report and/or implement water management plans.	Conditions are issued through Environmental Authorities.
Environmental Protection (Water) Policy, 2009	An environmental plan must be developed and implemented for water management, including plans for managing stormwater, sewage and trade waste for protection of surface and groundwater. In the case of produced water recycling, water releases on land, water releases to surface water or stormwater management, the administrating authority must consider the existing quality of waters that may be affected, the cumulative effect of the release in question, the water quality objectives for waters affected and the maintenance of acceptable health risks.	Contamination must be minimised or prevented and any release, or potential release, must be monitored against site baseline conditions.
Great Artesian Basin Resource Operations Plan February 2007, Amended November 2012	Defines the maximum amount of water that can sustainably be extracted from the recognised aquifers within each groundwater management area. Requires monitoring for all licensed bores.	Santos production wells are not licensed for water extraction with DNRM as they are covered by the Petroleum Legislation.
Environmental Protection and Biodiversity Conservation (EPBC) Act 1999	Provides the regulatory framework for Matter of National and Environmental Significance (MNES).	The most significant groundwater related MNES in the GAB are GAB artesian discharge springs.
Water Resource (Cooper Creek) Plan 2011	The Plan applies to watercourses and non-artesian groundwater systems.	Defines water rights for accessing non-GAB groundwater systems and surface water

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4.0 Existing Environment

The Cooper Basin covers a total area of 130,000km^2, of which approximately 80,000km^2 lies within SWQ (refer to Figure 1). The Queensland portion of the Cooper Basin can generally be described as arid with a uniform climate. It contains a wide diversity of land systems that are defined by geological, geomorphological and hydrological influences.

This section provides an overview of the operational areas regional climatic conditions, biophysical and physical environment and its environmental values.

4.1 Climate

The Cooper Basin is located within the south-western portion of Queensland, which is an arid to semi-arid region of central Australia. The seasons are generally characterised by hot summers and dry winters. December to February are the wettest and hottest months and temperatures exceed 35°C. For more detailed description please refer to http://www.bom.gov.au/.

Rainfall variability in the Cooper Basin is amongst the highest in Australia, while average annual totals are amongst the lowest. Rainfall is generally less than 300mm per year and average evaporation can be up to 3,500mm per year.

The prevailing wind direction throughout the year is from the south-east, however wind direction is more southerly in the south of the basin and more easterly in the north. Light winds (<20km/h) are most common from May to July, while the greatest frequency of strong winds (41-61km/h) is from September to January.

Table 2 presents the average minimum and maximum monthly temperatures, and average monthly total rainfall for the study area collected from Windorah Post Office as the closest station to Durham. Maximum values are in red and minimum values in green. Annual average values for temperature and rainfall are also presented in Table 2 and Figure 3.

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Table 2. Climate Characteristics within the Cooper Basin Operations Area - Windorah Station

Mean	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years
Temp (°C) - Max	38.1	36.5	34.5	30.2	25.4	21.7	21.4	24.1	28.5	32.6	35.5	37.8	30.5	1931-2014
Temp (°C) - Min	24.2	23.5	21.1	16.1	11.3	7.6	6.6	8.1	12.2	16.5	19.9	22.6	15.8	1931-2014
Rainfall (mm)	43.3	49.0	42.6	19.3	18.6	16.5	14.7	9.8	10.3	17.2	22.1	30.8	290.6	1887-2016

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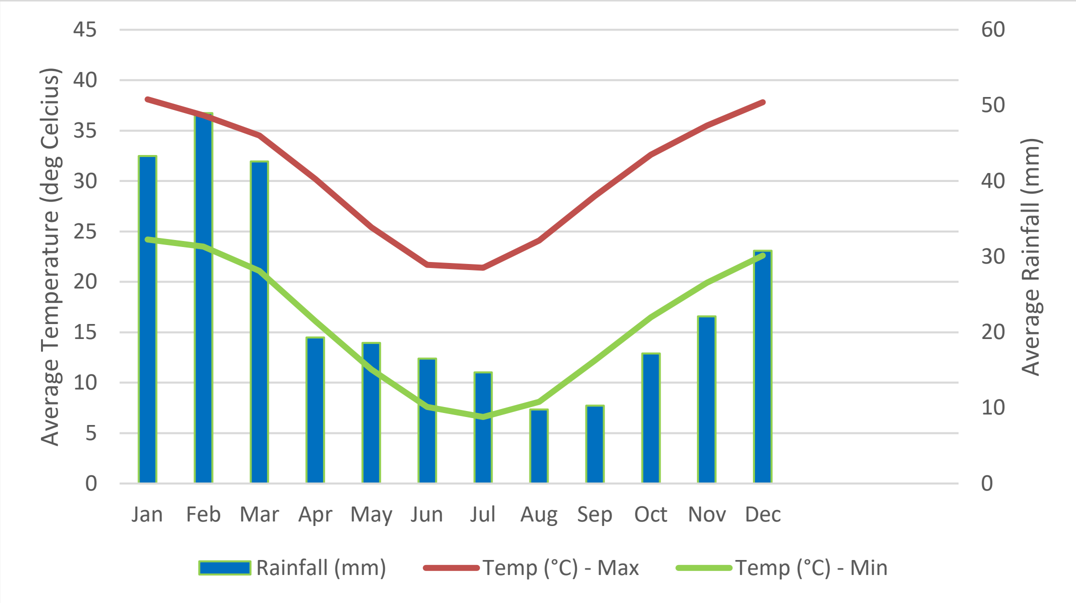


Figure 3. Rainfall and Temperature Data – 1931 to 2016 for Windorah Station (BOM, 2016).

4.2 Topography and Drainage

Much of Santos' SWQ operations are located within the Channel Country, which is a large, generally flat drainage area which extends into South Australia.

The general topography is limited to low undulating hills and ridges between the drainage channel systems. The Channel Country is characterised by vast flat lying braided, flood and alluvial plains of the Diamantina and Coopers Plains. Surrounding the floodplains are gravel or gibber plains, dunefields and low ranges. The low resistant hills and tablelands are remnants of the flat-lying Cretaceous (65-140 million years ago) sediments.

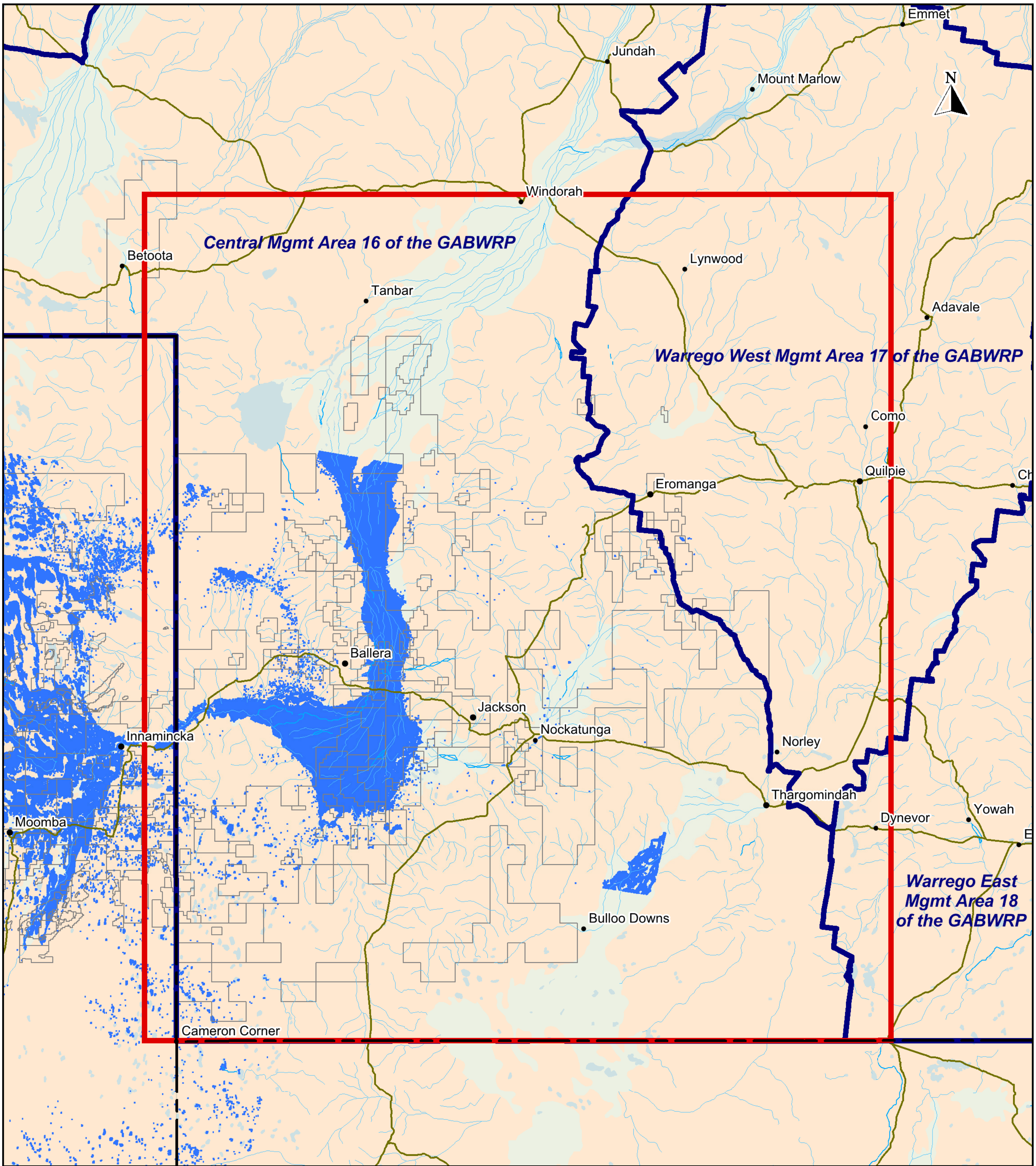
The area is dominated by the Cooper Creek Basin which drains towards Lake Eyre (Figure 4 and Figure 5). During period of high rainfall, the flat topography and drainage channel system becomes inundated and the water flow bottlenecks where the Cooper Creek crosses the Queensland-South Australia border.

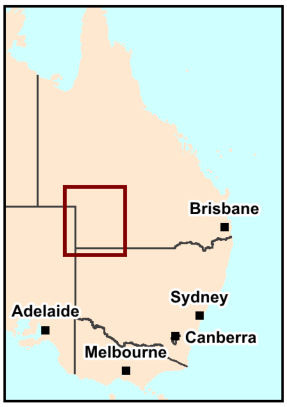
The Cooper Creek is an inland river which is 1,523km in length and covers a catchment area of 306,000km^2. Water flows across the catchment vary significantly however, most of the creek reaches, braided channels and the main tributary (Cooper Creek and Wilson River) are dry for most of the year and little more than a string of waterholes.

Generally, Cooper Creek stream flows are confined to the main channels, but every 3 to 4 years flows are sufficient to inundate parts of the Cooper floodplain, via a network of tributary channels. During extended periods of no flow, the Cooper contracts to a series of semi-permanent and permanent waterholes, which provide drought refuges for a variety of flora and fauna.

Within the study area (largely confined to the Cooper Creek catchment basin), there are also intermittent surface water flows following storm events that cause ponding of surface water on interdune clay pans, predominantly in the dunefield regions.

The most recent significant flood event occurred in January and February 2010.





Town / Locality
Santos Acreage
Study Area
2010 Flood Extent
Groundwater Management Area
Highway / Major Road
River / Creek

Santos

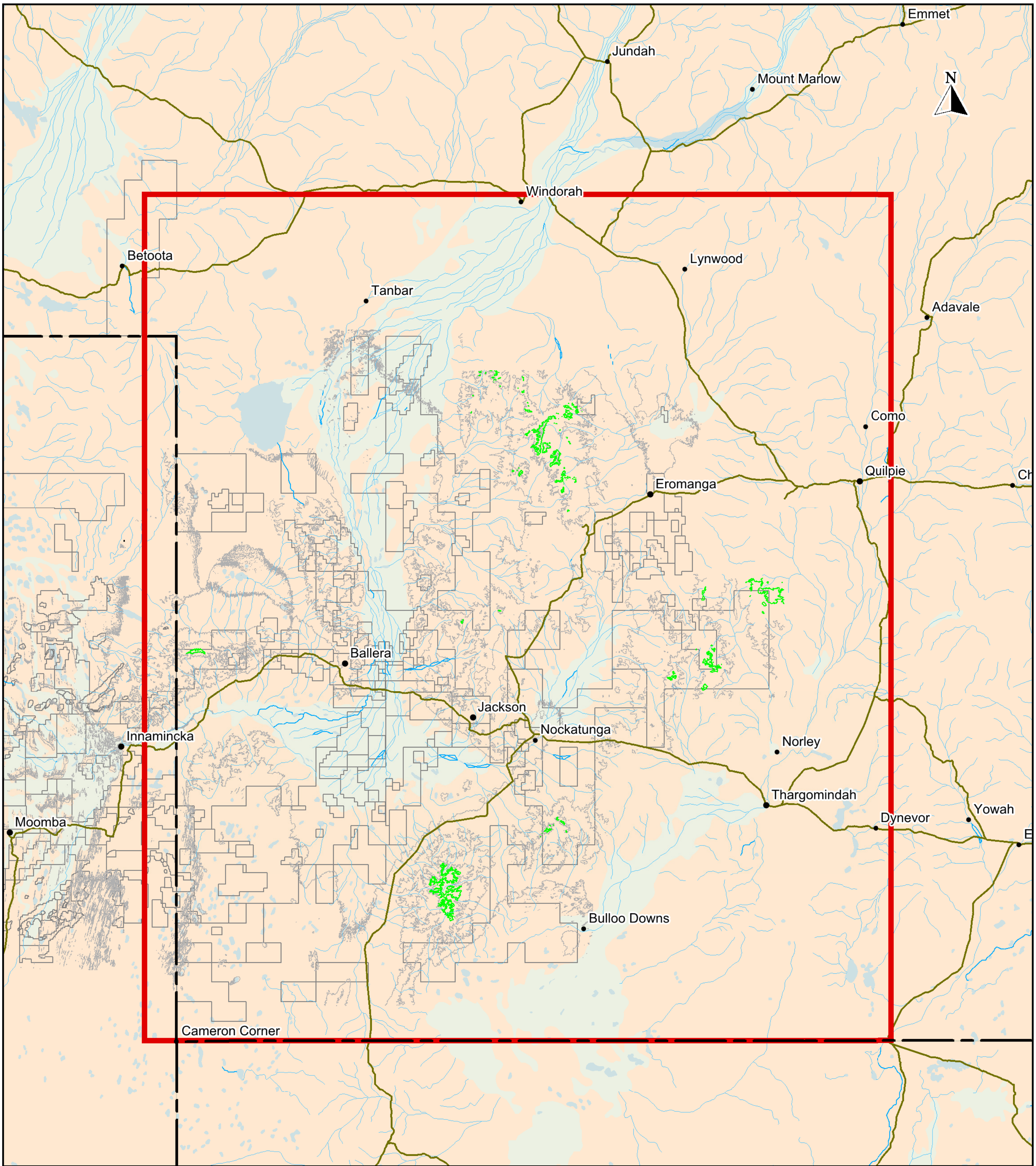
Cooper Basin UWIR

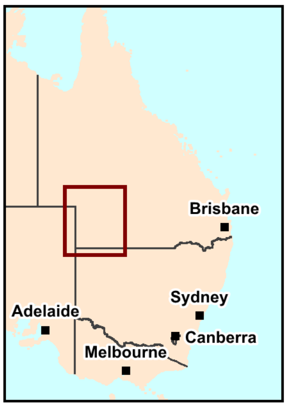
Santos SWQ
2010 Floods

Kilometres
0 20 40 60 80 100

Figure 4

20 May 2016, File No. ENVIR 661





- Town / Locality
- Santos Acreage
- Study Area
- Elevation Contour - 250m AHD
- Elevation Contour - 50m Interval
- Highway / Major Road
- River / Creek

Santos

Cooper Basin UWIR

Topography and Drainage

Kilometres

0 20 40 60 80 100

20 May 2016, File No. ENVIR 661

Figure 5

4.3 Geology

4.3.1 Regional Setting

This section defines the regional geological setting of the study area.

Santos SWQ oil and gas operations are located within the Eromanga Basin and the Cooper basin. While in QLD the regulation relevant to management of the GAB includes the upper formations of the Cooper Basin in the definition of the GAB, geologists consider the Cooper Basin and the Eromanga Basin as two separate basins not belonging to the GAB.

4.3.2 Depositional Configuration

At surface, the geology of the area is dominated by Quaternary alluvium deposits (Figure 6) associated with the flood plains and consolidated sediments of the Glendower Formation (Tertiary) or Winton Formation (Cretaceous).

The GAB underlies approximately one-fifth of the Australian continental area and extends beneath a large portion of Queensland, South Australia, New South Wales and the Northern Territory, stretching between the Great Dividing Range and the Lake Eyre depression (Figure 7). The Eromanga Basin is the largest sub-basin within the GAB, and it contains two major centres of subsidence: the Central Eromanga depositional centre and the Poolowanna Trough, separated by the Birdsville Track Ridge (Figure 7). Total sedimentary thickness range between 100m and 3000m.

The GAB is underlain by several older sedimentary basins, of which the Permian-age Cooper Basin is one example, with the Cooper Basin being entirely overlain by the Eromanga Basin. A major unconformity at the base of the Jurassic succession separates the Jurassic- Cretaceous Eromanga basin from the underlying Carboniferous-Triassic Cooper Basin.

It is noted that names of the formations within the Cooper Basin and the GAB vary between different areas. This section aims to use the geological nomenclature defined for SWQ by Draper (2002) and as reported in Figure 8. Reference to "equivalent naming" will be required in order to link with the nomenclature used in the QLD GAB regulation.

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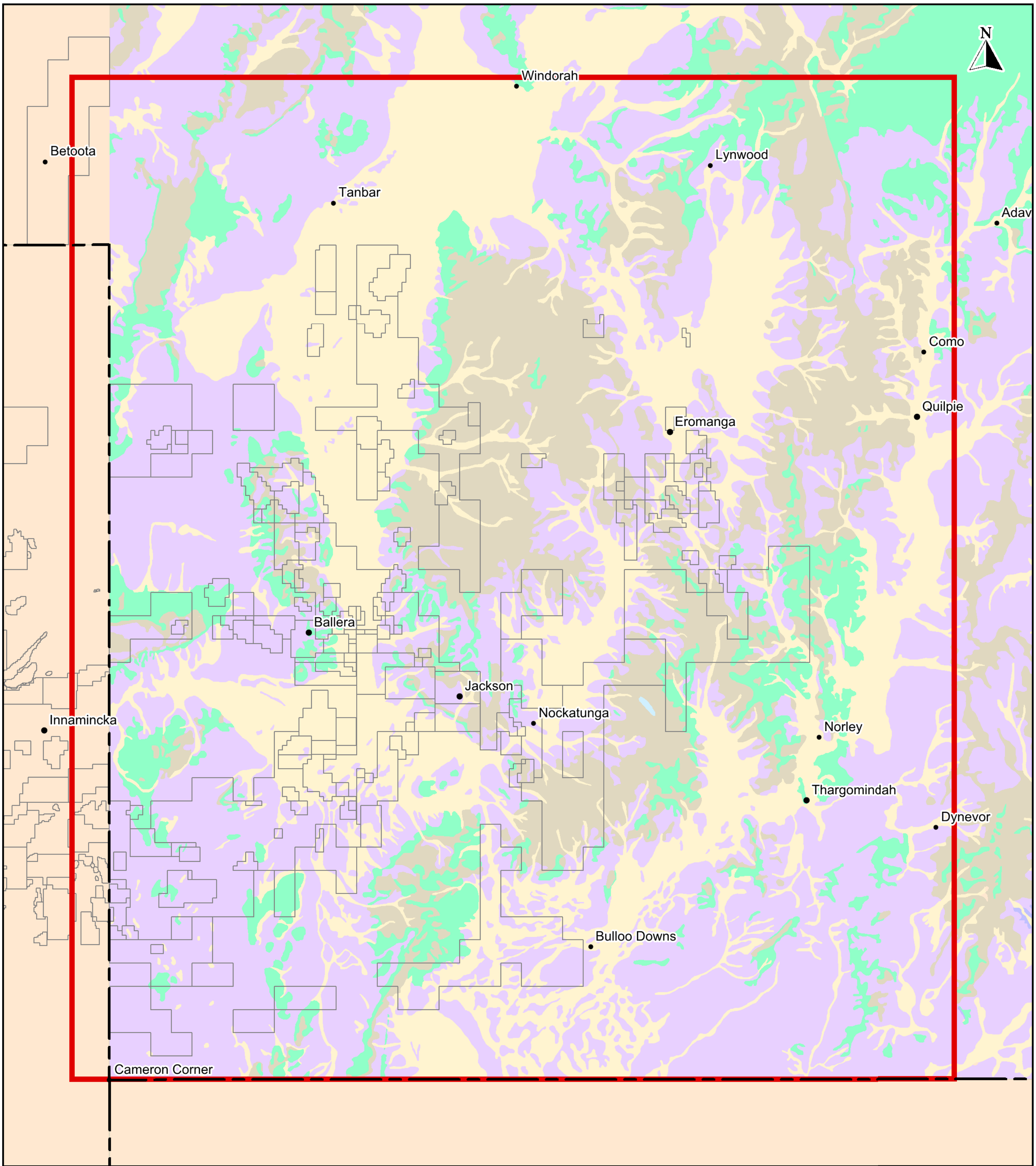


- Town / Locality
- Santos Acreage
- Study Area
- Doncaster Member
- Glendower Formation
- Mackunda Formation
- Q-CER
- Qa-CER
- Winton Formation

Santos

Cooper Basin UWIR

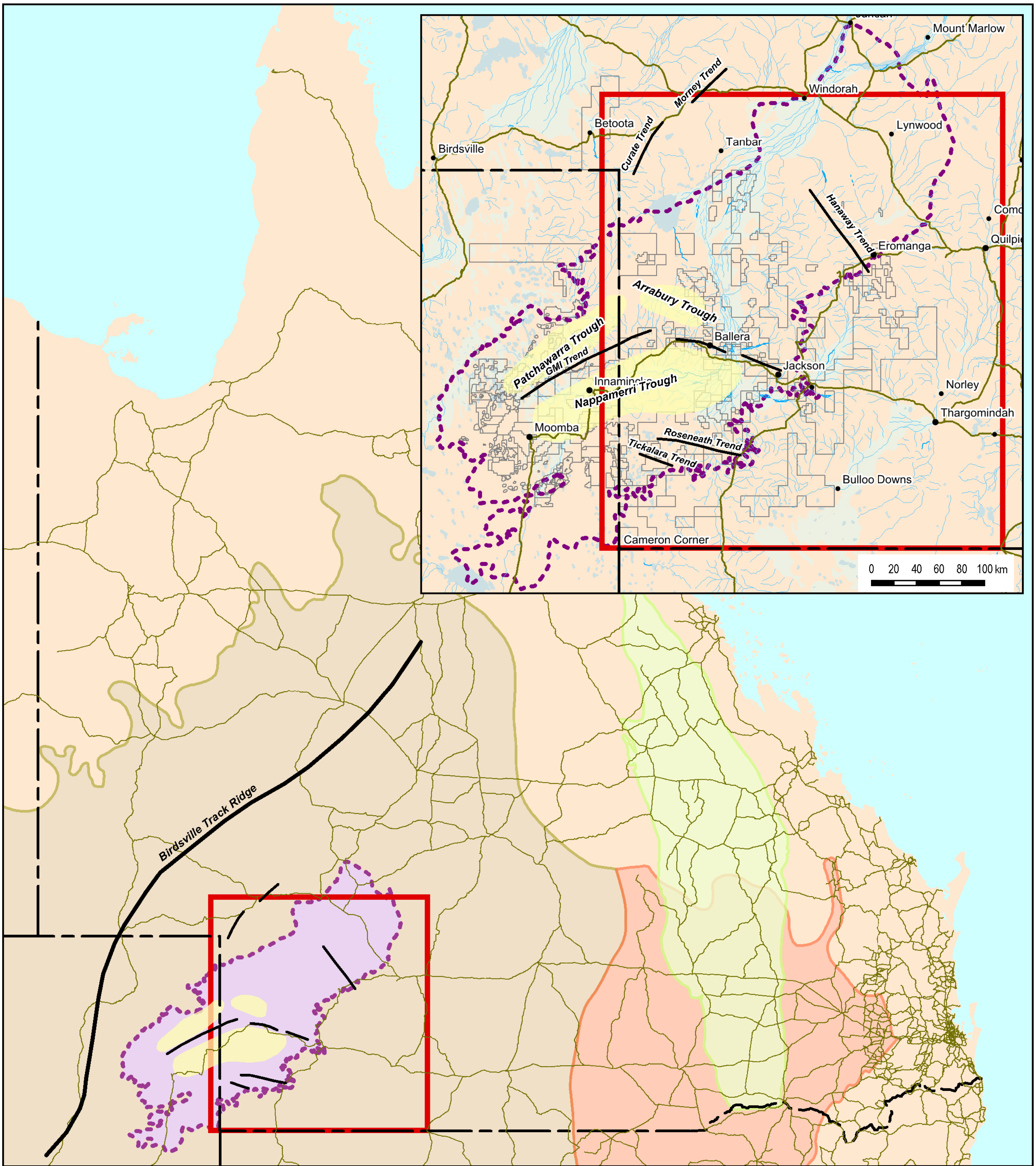
Surface Geology

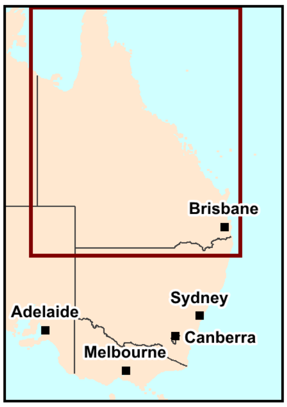
Kilometres

0 20 40 60 80 100

20 May 2016, File No. ENVIR 661

Figure 6





Town / Locality

Santos Acreage

Study Area

Bowen Basin

Surat Basin

Cooper Basin

Eromanga Basin

Geological / Structural Trough

Highway / Major Road

River / Creek

Santos

Cooper Basin UWIR

GAB Structural Geology of the Study Area

Kilometres

0 50 100 150 200 250

Figure 7

20 May 2016, File No. ENVIR 661

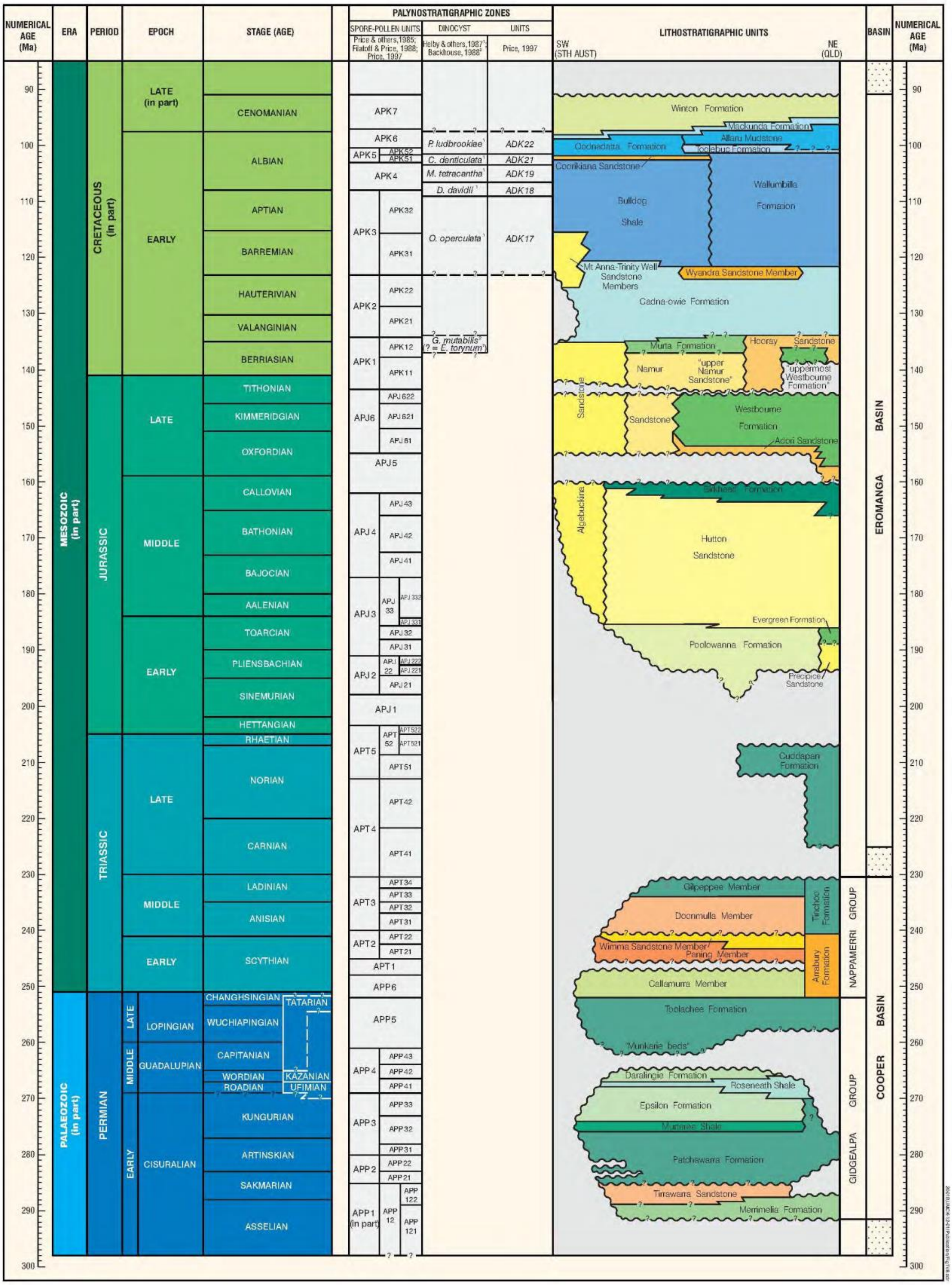


Figure 8. Chronology and stratigraphy of the Cooper and Eromanga Basins

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4.3.3 Tectonic Setting and Basin Stress Regime

Introduction

The primary stresses within the Cooper-Eromanga Basin are vertical overburden stress σ_H and minimum horizontal stress $\sigma_{h.}$ The stress regime within the basins are based on the assumption that σ_V is a principal stress and therefore σ_H and σ_h are also principal stresses, however, σ_h is considered the lesser of the stresses. This assumption is considered valid given the relatively flat topography across the basins.

General stress orientation

The maximum horizontal stresses σ_H, in the basin generally follow an east to west orientation at approximately 101° which is indicated by stress data from borehole breakout testing (Hills *et al*, 1998; Reynolds et al, 2004). The east-west trending nature of σ_H predominates in the Nappamerri Trough, however regional variations across the basin have been observed. In the Patchawarra Trough σ_H is oriented southeast to north-west, north of Gigealpa σ_H was oriented west-northwest to east-southeast. The orientation of σ_h does not exhibit significant variation with depth (Reynolds et al, 2004).

The vertical overburden stress σ_v is governed by overlying rock mass and the stress gradient does not exhibit significant variation with depth. The σ_v stress is gradient is approximately 20.3Mpa/km at 1000m depth and approaches approximately 22.6Mpa/km at 3000m depth.

The magnitude of σ_h varies significantly across the basin(s); with the σ_h stress gradient ranging from 13.6Mpa/km up to 22.6Mpa/km, with σ_h approaching σ_v in some local areas (Reynolds et al, 2004). σ_h decreases with depth up to approximately 1000m (below surface) and then stabilises. At 1000 to 4000m depth σ_h is between 0.6 to 0.7 $\sigma_{v,}$ with σ_h generally approaching the higher end of this range (Hills et al, 1998). At lower depths σ_h approaches, and may exceed $\sigma_{v,}$ resulting in σ_v, becoming the minimum principal stress (Reynolds et al, 2004).

Stress Assumptions and principal stresses – general faulting regime

On the basis that σ_v is the minimum principal stress, the Cooper-Eromanga basin stress regime is primarily associated with strike-slip faulting $\sigma_{H,} > \sigma_{V,} > \sigma_h$, normal faulting $\sigma_{v,} > \sigma_{H,} > \sigma_h$, and transitional strike-slip/reverse faulting ($\sigma_{H,} > \sigma_h \approx \sigma_v$) at depth where $\sigma_h \approx \sigma_{v.}$ Reverse faulting ($\sigma_{H,} > \sigma_{h,} > \sigma_v$) is not associated with the stress regime in the basin however, at lower depth where $\sigma_h > \sigma_v$ may occur some reverse faulting may exist (Reynolds et al, 2004).

Hydrostatic stress

Pore pressures within the basin are generally hydrostatic. Overpressure are thought to occur in deeper shalier strata within the basin and have been observed in the Nappamerri Trough from depths of 2.7km (Hills et at, 1998). Local under-pressures have also been observed and are attributed to extensive production within the basin (Reynolds et al, 2004). This is of particular importance when considering the impact of depressuring formation though oil and gas extraction. The implication is that impact translation though the depositional sequences are minimised or negated completely. This is further discussed in the following sections.

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Seismic activity

Major earthquake events within the region surrounding the basin include:

- Tennant Creek, NT (6.7Mb) in January 1988.
- Simpson Desert, NT (5.6Mb) in August 1972.
- Simpson Desert, NT/QLD/SA (4.7Mb) in November 1978.

The region has been subject to intermittent earthquakes of low to moderate magnitude (0 – 3.5Mb) each year since seismic records were established.

4.3.4 Geological Summary of the Cooper Basin

The Cooper Basin comprises a thick late Carboniferous to Middle or late Triassic non-marine sedimentary stratigraphic pile within a broad basin setting located in central Australia.

Structurally, the Cooper Basin is one of a number of remnant Late Carboniferous to Early Permian depositional centres which lay in the Australian interior of the Gondwana Supercontinent. The Cooper Basin differs from the other depositional centres by containing an additional sequence which ranges in age from Late Permian to Middle Triassic and spans the Permo-Triassic boundary without a break in deposition. It is also the only such basin with major oil and gas production (Petroleum Geology of South Australia, Volume 4 - Cooper Basin, PIRSA, 1998). Three major troughs (Patchawarra, Nappamerri and Tanapperra) are identified within the basin, each separated by structurally high ridges.

The Cooper Basin depositional episode was terminated by a period of gentle regional compressional deformation resulting in landmass uplift and sustained erosion within the basin. Sedimentary basin development re-initiated subsequently with the formation of the Eromanga Basin (Section 4.3.5) during the Early Jurassic to Late Cretaceous times.

The Cooper Basin is completely overlain by the Eromanga Basin and contains a succession of fluvio-lacustrine sandstone, shales and coals ranging from 600m thick in the north and up to 1800m in the south.

The description of the stratigraphy and lithology for the study area is provided in Figure 9 which provides information on the continuity of the deposition process and discontinuities or major unconformities present in the stratigraphic sequence.

The Cooper Basin can be subdivided into two major geological groups:

- Late Carboniferous.
- Permian Gidgealpa Group and the Triassic Nappamerri group.

The earliest formations of the Cooper Basina are glacial in origin. The subsequent formations are generally finer sediments forming a succession of sandstone and shale formations. The Tirrawarra Sandstone represents low sinuosity fluvial to proglacial outwash deposits overlain by peat swamp, floodplains and high sinuosity fluvial facies of the Patchawarra Formation. Two lacustrine shale units (Murteree and Roseneath Shales) with intervening fluvio-deltaic sediments (Epsilon and Daralingie Formations) were deposited during a phase of continued subsidence. Early Permian uplift led to erosion of the Daralingie Formation and underlying units from basement highs (SA DPI 1998).

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The upper sequence of the Cooper Basin, the Gilpeppee Member of the Tinchoo Formation, is dominated by siltstones and shales. Draper (2002) has mapped the thickness of the Tinchoo Formation shales in SWQ. The mudstone (both shale and siltstone) thicknesses average between 80 and 160m in the centre of the Cooper Basin with maximum thickness of 182m.

The formations of most interest to Santos are the Tirrawarra Sandstone, Patchawarra Formation, Epsilon Formation and Toolachee Formation:

The Tirrawarra Sandstone comprises fine to coarse-grained and pebbly sandstone with locally common interbeds of conglomerate and minor interbeds of carbonaceous siltstone, shale and coal. On average, the Tirrawarra Sandstone is 30 to 40m thick in SWQ.

The Patchawarra Formation comprises interbedded, variable size sandstone beds with siltstone, shale and coal beds, sandstone and mudrock beds. The Patchawarra Formation is thickest (up to 680m in the Nappamerri Trough and up to 550m in SWQ near the SA border - Figure 7) of the Cooper Basin formations and in QLD the second most widespread Permian unit after the Toolachee Formation (Draper, 2002).

The early Permian Epsilon Formation is defined as a series of sandstones, siltstone and shales with minor coals and is widespread across the Cooper Basin. The maximum thickness of the formation is observed in the Nappamerri Trough (156m), but averages between 30 to 40m.

The late Permian Toolachee Formation comprises sandstones, siltstones and shale with thin coal seams and some conglomerates. It spreads unconformably over older formations across the whole Cooper Basin and is observed at its thickest in the Patchawarra and Nappamerri Troughs. In QLD, the average thickness ranges from 25 to 50m, with the maximum thickness observed north of the Jackson–Naccowlah–Pepita Trend(100 to 130m thick (Draper, 2002)).

Geological contour maps for the following formations are presented in Section 4.3.6, including:

Depth to Toolachee Formation.

Depth to Patchawarra Formation.

Thickness of Patchawarra Formation.

Thickness of Toolachee Formation.

Thickness of shale within the Nappamerri Group.

The top pre-Permian faults provide the basin's overall fabric, whereas the younger faults of the basal Toolachee Formation and basal Eromanga unconformity are generally reactivated Permian faults (refer to 4.3.3).

The Tirrawarra Sandstone, Patchawarra Formation, Epsilon Formation and Toolachee Formation (Figure 8) are the main gas producers in the Cooper Basin. Minor gas reservoirs are also present in the Tirrawarra Sandstone, the Wimma Sandstone Member of the Arraburry Formation and the Tinchoo Formation. Some oil reservoirs are present in the Paning Member of the Arraburry Formation.

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4.3.5 Geological Summary of the Eromanga Basin

The Jurassic – Cretaceous Eromanga Basin unconformably overlies the older Carboniferous - Permian Cooper Basin. The sedimentary sequences which comprise the Eromanga Basin reaches a total thickness of up to 2,500m and were deposited during a period of subsidence subsequent to that of the Cooper Basin. There are two main sub-basin centres in the Eromanga Basin: the *Central Eromanga Depositional centre* and the *Poolowanna Trough* separated by the Birdsville Track Ridge (Figure 10). The top of the Eromanga Basin is delineated by an unconformity.

The study area for this UWIR is located in the *Central Eromanga Basin*.

The deposits of the Eromanga Basin follow three episodes (and three different origins) of deposition:

- Lower non-marine sediments from early Jurassic to Mid-Cretaceous corresponding to the Poolowanna Formation to the Cadna-owie Formation. During that period the largest transgression over the Eromanga Basin was the “Birkhead Lake” transgression.
- Marine sediments from mid-cretaceous to late Cretaceous corresponding to the Wallumbilla Formation to the Mackunda Formation.
- Upper non marine sediments (fluviolacustrine) of the Winton Formation.

The formations of the Eromanga Basin are a succession of well identified sandstones and siltstones and mudstones with interbedded minor sandstones and occasional coal seams (Figure 9).

The formations of the Eromanga Basin occur throughout the GAB (Figure 7), however the naming nomenclature is not always consistent. The nomenclature used in this section aims at using the SWQ naming convention as presented in

Figure 8.

The GAB is Australia’s largest groundwater system, with confined artesian and sub-artesian aquifers. However, it is noted that some aquifers are also oil and/or gas reservoirs.

The major formations of the Eromanga Basin are (from top to bottom):

- *The Winton Formation:* The Winton Formation comprises interbedded, fine to coarse sandstone, shale, siltstone and coal seams deposited in fluvio-lacustrine environments. The Winton Formation outcrops on higher relief areas surrounding the valleys and flood plains of the study area and show lateral facies changes from east to west.
- *The Wallumbilla Formation or Rolling Downs Group*: The confining beds of the Rolling Downs Group, and, in particular, the Lower Wallumbilla Formation and Upper Wallumbilla Formation, referred to as Doncaster and Coreena Members in other parts of the GAB, occur throughout the Eromanga Basin, Surat Basin and Carpentaria Basin. The fine-grained nature of the Rolling Downs Group sediments is reflected in the low to very low porosity and permeability of these units. The thickness averages at 500m in the component basins but thins to less than 300m over the Eulo-Nebine Ridge and Euroka Arch (Appendix B of Appendix A). Within the Eromanga Basin, the sequence reaches a maximum thickness of 1,000m (BRS, 2000).
- *The Cadna-Owie and Hooray Formations:* The Cadna-owie and Hooray formations are thinnest (<50 m) on the existing erosional margins, and thickens toward the basin centre, reaching a maximum interpreted thickness of 800m in the Surat Basin (Figure 9). The aquifer reaches a

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maximum saturated thickness of 350m over the southwestern regions of the underlying Patchawarra, Nappamerri, Allunga and Tenappera Troughs which occur within the Cooper Basin (BRS, 2000).

The Westbourne Formation, Adori Sandstone and Birkhead Formation: This group is dominated by shale and mudstone beds with thicknesses of up to 140m in the Westbourne Formation and 110m in the Birkhead Formation. The Adori Sandstone contains the main sandstone beds of the group, with thicknesses varying from 20 to 130m in the Cooper region but limited to 55m in SWQ, whcih are cemented in the lower section.

The Hutton and Poolowanna Formations: these formations are major sandstone formations of the GAB and can reach thickness of up to 200m in the Poolowanna Trough and up to 360m in the Hutton Sandstone in the Patchawarra Trough. In SWQ, the Hutton reaches 244m and is typically 90 to 210m thick and the Poolowanna Formation reaches a maximum thickness of 165m. The equivalent of the Poolowanna Formation in the eastern parts of the GAB is the Precipice Sandstone. In the study area, the Evergreen Formation which separates the two sandstone formations in the Surat Basin is absent.

Geological contour maps for the following formations can be found in (Appendix A):

Depth to Winton Formation.

Depth to Cadna-owie Formation.

Depth to Hooray Sandstone.

Depth to the Hutton Formation.

Depth to the Poolowanna Formation.

Thickness of the Cadna-owie Formation.

Thickness of the Hooray Sandstone.

Thickness of the Hutton Sandstone.

Thickness of the Poolowanna Formation.

Major faulting events and structural uplifts have occurred within the eastern region of the Eromanga Basin, however they have not had a structural effect on the portion of the Eromanga Basin covered by Santos tenements.

Within the study area, significant oil reservoirs are present in the Hutton Sandstone, the Birkhead Formation and the Murta Formation. The Wyandra Sandstone Member, McKinlay Member (which forms part of the Murta Formation) and Namur Sandstone, Westbourne Formation and Adori Sandstone and Lower Poolowanna hold minor oil reservoirs (Figure 9).

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WRP Management Units		Litho-stratigraphy									
Central GMA 16	Warrego West GMA 17			Unit name	Sub-unit	Equivalent Formation in other parts of the GAB***	Depositional environment*	Lithology Description** ****	Geological Age	Thickness*****	Santos Current Production Reservoir (oil & Gas)	Hydrogeological Characteristics
				Whittula Formation			Fluvial to lacustrine	Interbedded sandstone, siltstone, mudstone and claystone	Tertiary	Maximum of 150 m, confined to downwarps	no	
				Marion Formation			Fluvial deposits	Sandstone and quartz pebble conglomerate. Some clays, silt/Marion	Tertiary	About 6m, limited geographical extend	no	
				Glendower Formation			Fluvial deposits	Sandstone, siltstone, conglomerate and minor mudstone	Tertiary	In QLD, 70m in average, maximum 145 m ???	no	Aquifer
		Eromanga Basin		Winton Formation			Terrestrial deposition environment. Fluvial-lacustrine.	Interbedded fine to coarse-grained sandstone, shale, siltstone and coal seams with intraclast conglomerates.	Cretaceous	Over 400m in the Cooper region, maximum thickness of 1100m in the northern Patchawarra Trough	no	Aquifer (possibly limited)
		Eromanga Basin		Mackunda Formation			Marine environment	Interbedded, partly calcareous very fine-grained sandstone, siltstone and shale in the basin centre.	Cretaceous	60–120m thick in the Cooper region	no	Aquifer
		Eromanga Basin		Allaru Mudstone			Low-energy, shallow-marine environment	Mudstone with thin calcareous siltstone and minor thin, very fine-grained sandstone interbeds	Cretaceous	From 100 to over 200m thick, generally being over 200m in QLD, thinner in outcrop areas.	no	Water bearing
Central 1	Warrego West 1	Eromanga Basin		Toolebuc Formation		Surat Siltstone	Marine environment	Mudstone	Cretaceous	In QLD, 20–45m thick	no	Confining bed
Central 1	Warrego West 1	Eromanga Basin		Wallumbilla Formation	Upper Wallumbilla	Coreena Member	Marine environment	Mudstone and siltstone with minor interbeds of fine grained sandstone	Cretaceous	In QLD, 200 to over 250m thick	no	Aquifer
Central 1	Warrego West 1	Eromanga Basin		Wallumbilla Formation	Lower Wallumbilla	Doncaster Member	Marine environment	Mudstone and siltstone with minor interbeds of fine grained sandstone	Cretaceous	In QLD, 200 to over 250m thick	no	Aquifer
Central 2	Warrego West 2	Eromanga Basin		Cadna-owie Formation	Upper Cadna-owie including the Wyandra Sandstone Member	Cadna-owie Formation, Bungil Formation, Gilbert River Formation	Low-stand systems infilling fluvial channels then transgressive systems	Medium to coarse-grained, quartzose to labile sandstone with scattered pebbles	Cretaceous	Mainly 60–90m in QLD. Wyandra Sandstone Member from 3 to 18 m in Queensland. Lower Cadna-owie Formation typically 10–20m thick around the basin margin, increasing to 75–100m in the deeper parts of the basin. Maximum thickness of >115m in the Nappamerri Trough.	Oil (not frequent)	Aquifer
Central 2	Warrego West 2	Eromanga Basin		Cadna-owie Formation	Lower Cadna-owie	Cadna-owie Formation, Bungil Formation, Gilbert River Formation	Transition from terrestrial to marine deposition environment	Siltstone with very fine to fine-grained sandstone interbeds and minor carbonaceous claystone. Pebbly layers, dolomites and coarse breccia layers occur around the basin margin.	Cretaceous		no	Confining bed
Central 3	Warrego West 3	Eromanga Basin		Hooray Sandstone	Murta Formation (including the McKinlay Member)	Hooray Sandstone, Mooga Sandstone, Orallo Formation and Gubberamunda Sandstone	Meandering fluvial, floodplain and lacustrine environment	Thinly interbedded siltstone, shale, very fine to fine-grained sandstone and minor medium and coarse-grained sandstone. A basal siltstone is widespread in the Cooper region.	Cretaceous	In QLD, typically between 60-65 m thick	Oil, some gas (not frequent) Seal	Aquifer
Central 3	Warrego West 3	Eromanga Basin		Hooray Sandstone	Upper Namur Sandstone	Hooray Sandstone, Mooga Sandstone, Orallo Formation and Gubberamunda Sandstone	Meandering braided fluvial systems	Fine to coarse-grained sandstone with minor interbedded siltstone and mudstone. The basal Namur Sandstone, like the Adori Sandstone, has been strongly cemented with diagenetic calcite in places.	Cretaceous	In QLD, 50 to 70m thick in average however can be less or thicker.	Oil (not frequent)	Aquifer
Central 4	Warrego West 4	Eromanga Basin		Westbourne Formation		Injune Creek Group	Lacustrine deposits (transgression)	Interbedded dark grey shale and siltstone with minor sandstone interbeds	Jurassic	In QLD, 70 to 140m thick in the Cooper region	Oil (not frequent)	Confining bed
Central 4	Warrego West 4	Eromanga Basin		Adori Sandstone		Injune Creek Group	Amalgamated braided fluvial sandstone deposited in low-stand systems tract.	Well-sorted, subrounded, cross-bedded, fine to coarse-grained sandstone. Calcite cemented zones up to 45 m thick are developed locally in the basal Adori and Namur Sandstones	Jurassic	30 to 120m thick in the Cooper region (maximum 55m in QLD)	Oil (not frequent)	Aquifer
Central 4	Warrego West 4	Eromanga Basin		Birkhead Formation	Upper Birkhead	Injune Creek Group	Meandering to lacustrine deposition. Birkhead "lake", largest transgression of the Eromanga Basin.	Interbedded siltstone, mudstone and fine to medium grained sandstone with thin, lenticular coal seams (<0.3 m thick)	Jurassic	In QLD 40–100 m thick, maximum of 110m. A maximum thickness of >150m occurs in the Patchawarra and Nappamerri Troughs	Oil - Basal Birkhead and Middle Birkhead (scattered)	Water bearing
Central 4	Warrego West 4	Eromanga Basin		Birkhead Formation	Middle Birkhead	Injune Creek Group			Jurassic			Water bearing
Central 4	Warrego West 4	Eromanga Basin		Birkhead Formation	Lower Birkhead	Injune Creek Group			Jurassic			Water bearing
Central 5	Warrego West 5	Eromanga Basin		Hutton Sandstone			Erosion then low-stand systems	Fine to coarse-grained quartzose sandstone with minor siltstone interbeds	Jurassic	In QLD, 30–210m thick, maximum of 244m.	Oil, some gas (not frequent) - mostly in upper part	Aquifer
Central 6	Warrego West 6	Eromanga Basin		Poolowanna Formation	Upper Poolowanna	Precipice Sandstone	Transgression to highstand systems	Interbedded siltstone, sandstone and rare coal seams. Sandstone beds range from very fine to medium grained, and contain minor pebbles and granules of quartzite and reworked basement.	Jurassic	In QLD, maximum of 165m		Aquifer
Central 6	Warrego West 6	Eromanga Basin		Poolowanna Formation	Lower Poolowanna	Precipice Sandstone	Low-stand (fluvial) and early transgressive systems		Jurassic		Oil (not frequent)	Aquifer
		Cooper Basin		Cuddapan Formation			High sinuosity fluvial and coal swamp development	Sublabile to quartzose sandstone in lower part, with interbedded siltstone, mudstone and coal in upper part	Triassic	In QLD, mainly 20m to over 50 m. Restricted geographically.		
MAJOR UNCONFORMITY				MAJOR UNCONFORMITY								
Central 7	Warrego West 7	Cooper Basin	Nappamerri Group	Tinchoo Formation	Gilpeppee Member	Moolayember Formation		Interbedded dense siltstones and light grey sandstone	Triassic	In QLD, from 125–200m thick, maximum of 260 m. The Gilpeppee Member is generally 45 to 60m thick.	Gas (not frequent)	Confining bed
Central 7	Warrego West 7	Cooper Basin	Nappamerri Group	Tinchoo Formation	Doonmulla Member	Moolayember Formation		Uniform dense siltstone, with minor coal seams (Gilpeppee Member) and intraclast conglomerates.	Triassic			Confining bed
Central 7	Warrego West 7	Cooper Basin	Nappamerri Group	Arrabury Formation	Wimma Sandstone Member	Clematis Sandstone		Fine to medium-grained quartzose sandstone with minor interbeds of siltstone and mudstone.	Triassic	Maximum total thickness of 400 m in the Nappamerri Trough. Callamurra Member up to 150m and thins. Paning Member up to 200 m and more. Wimma Sandstone ~115 m maximum	Gas (not frequent)	Aquifer
Central 7	Warrego West 7	Cooper Basin	Nappamerri Group	Arrabury Formation	Paning Member	Rewan Formation		Upward-fining cycles of fine to medium-grained sandstone grading into siltstone/mudstone and siltstone units.	Triassic		Oil (not frequent)	Confining bed
Central 7	Warrego West 7	Cooper Basin	Nappamerri Group	Arrabury Formation	Callamurra Member			Siltstone and mudstone, minor sandstone interbeds (Early Triassic). Siderite and carbonate have formed in siltstone and sandstone beds.	Triassic			Confining bed
		Cooper Basin	Gidgealpa Group	Toolachee Formation			Channel deposits	Interbedded fine to coarse-grained sandstone, siltstone and carbonaceous shale, sometimes with thin coal seams (<3m thick), and conglomerates.	Permian	Up to 180 m	Gas	Aquifer
		Cooper Basin	Gidgealpa Group	Daralingie Formation			Deltaic deposits	Siltstone and mudstone with interbedded fine to very fine-grained sandstone. Minor coal seams and carbonaceous partings and streaks occur.	Permian	In QLD, mostly 15-30m thick, up to 96m in Nappamerri Trough		Confining bed
		Cooper Basin	Gidgealpa Group	Roseneath Shale			Lacustrine deposits	Siltstone, mudstone and minor sandstone.	Permian	Up to 100 m, generally 50-60 m thick in QLD		Confining bed
		Cooper Basin	Gidgealpa Group	Epsilon Formation			Deltaic deposits	Thinly bedded, fine to medium-grained sandstone with carbonaceous siltstone and shale, and thin to occasionally thick (2-20m) coal seams.	Permian	Maximum thickness of 156m in Nappamerri Trough. In Nappamerri Trough, over 60m thick, elsewhere mainly 30-40m thick.	Gas	Aquifer
		Cooper Basin	Gidgealpa Group	Murteree Shale			Mainly lacustrine	Argillaceous siltstone and fine-grained sandstone.	Permian	In QLD, mostly less than 50m thick.		Confining bed
		Cooper Basin	Gidgealpa Group	Patchawarra Formation			Individual and stacked channels	Interbedded fine to medium-grained, locally coarse-grained and pebbly sandstone, siltstone, shale and coal.	Permian	50 to 150m with up to 550 m in QLD	Gas	Aquifer
		Cooper Basin	Gidgealpa Group	Tirrawarra Sandstone			Braided channel deposits	Fine to coarse-grained and pebbly sandstone with locally common interbeds of conglomerate and minor interbeds of carbonaceous siltstone, shale and coal.	Permian	30-40 m range in QLD, maximum 75 m total thickness	Gas (not frequent)	Aquifer
		Cooper Basin	Gidgealpa Group	Merrimelia Formation			Glacial sediments deposits, deep glacio-lacustrine sediments	Conglomerate, sandstone, conglomeratic mudstone, siltstone and shale	Late Carboniferous to Early Permian	Maximum 84m in QLD		Water bearing

Figure 9. Stratigraphy Sequence in the Study Area

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4.3.6 Conceptual Geological Cross Section

A schematic geological cross-section across the Eromanga Basin is presented as Figure 10. The "A-B" section cuts the main depositional centre of the basin in SWQ and corresponds generally to the location of the study area. As shown on the cross section, the upper formations of the Eromanga Basin (from Cadna-Owie and Hooray systems up) are continuous which is in contrast to the older formations which are confined to areas within sub-basins (these formations or their equivalent may be present in several basins).

Abbreviations commonly used by Santos as stratigraphy markers or reservoir markers, and used in some of the geological figures are summarised in Table 3.

Table 3. Geological Abbreviations for Stratigraphic markers of the Eromanga and Cooper Basin Fms

Name of Marker	Definition
'C' Horizon	Top Cadna-owie
'E' Horizon	Top Birkhead Formation
'H' Horizon	Top Hutton Sandstone
'L*' Horizon	Basal Eromanga Unconformity
'PC00' Horizon	Top Toolachee Formation (chrono-marker)
'PU-70' Horizon	Basal Toolachee Formation (chrono-marker and Daralingie Unconformity)
'VC00' Horizon	Top Patchawarra Formation (chrono-marker)
'VC50' Horizon	Lower Patchawarra Formation (chrono-marker)
'VCxx' - Horizon	Chrono-stratigraphic marker within the Patchawarra Formation
'ZU00' Horizon	Top Pre-Permian (Basement)

A geological conceptual cross section across the Cooper and Eromanga Basins has been generated in a SW to NE axis and is presented as Figure 11. The section cuts the study area passing through the Barrolka fields (Barrolka Trough).

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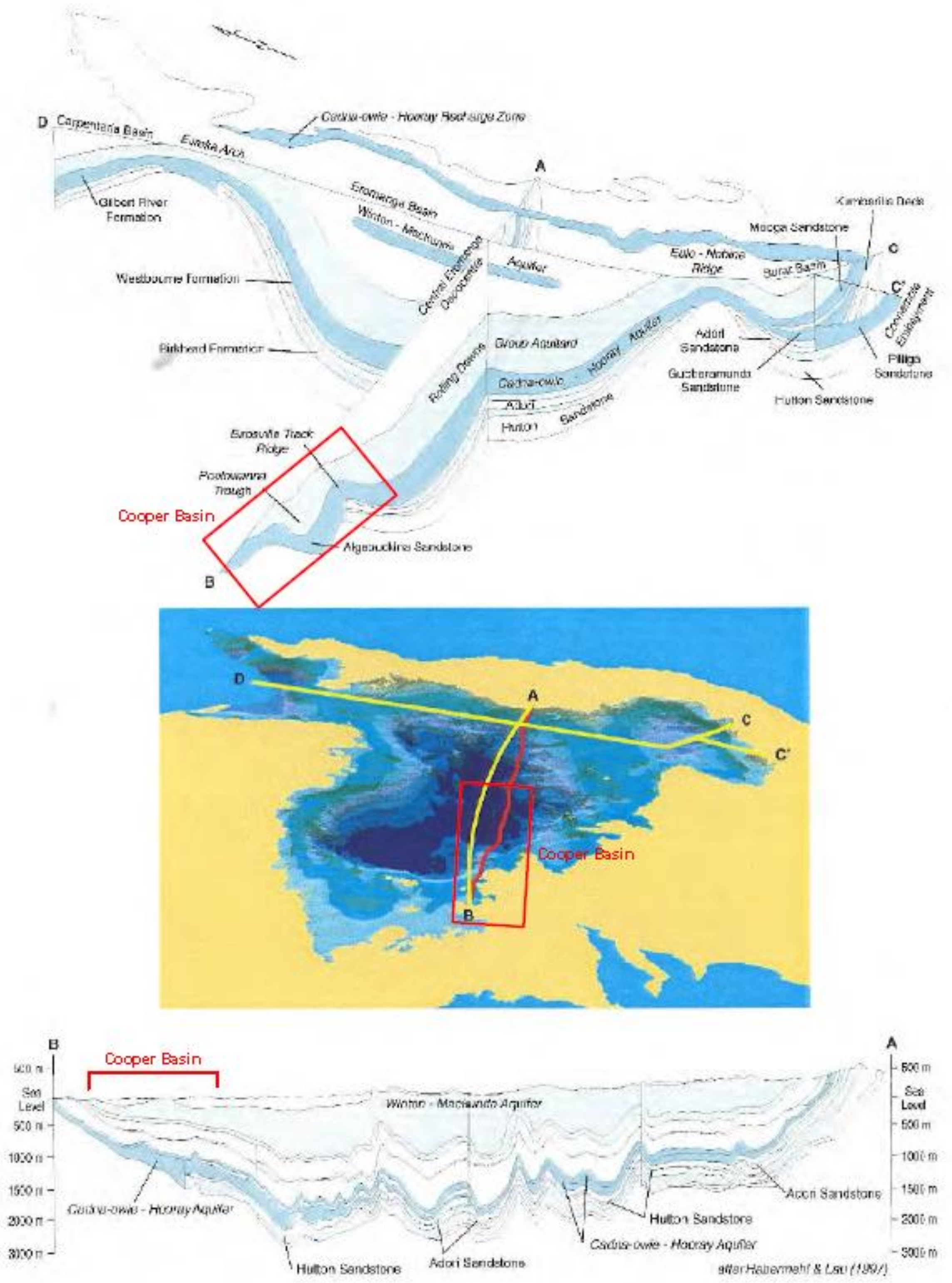

Figure 10. Geological Schematic Cross Section across the GAB Eromanga Basin

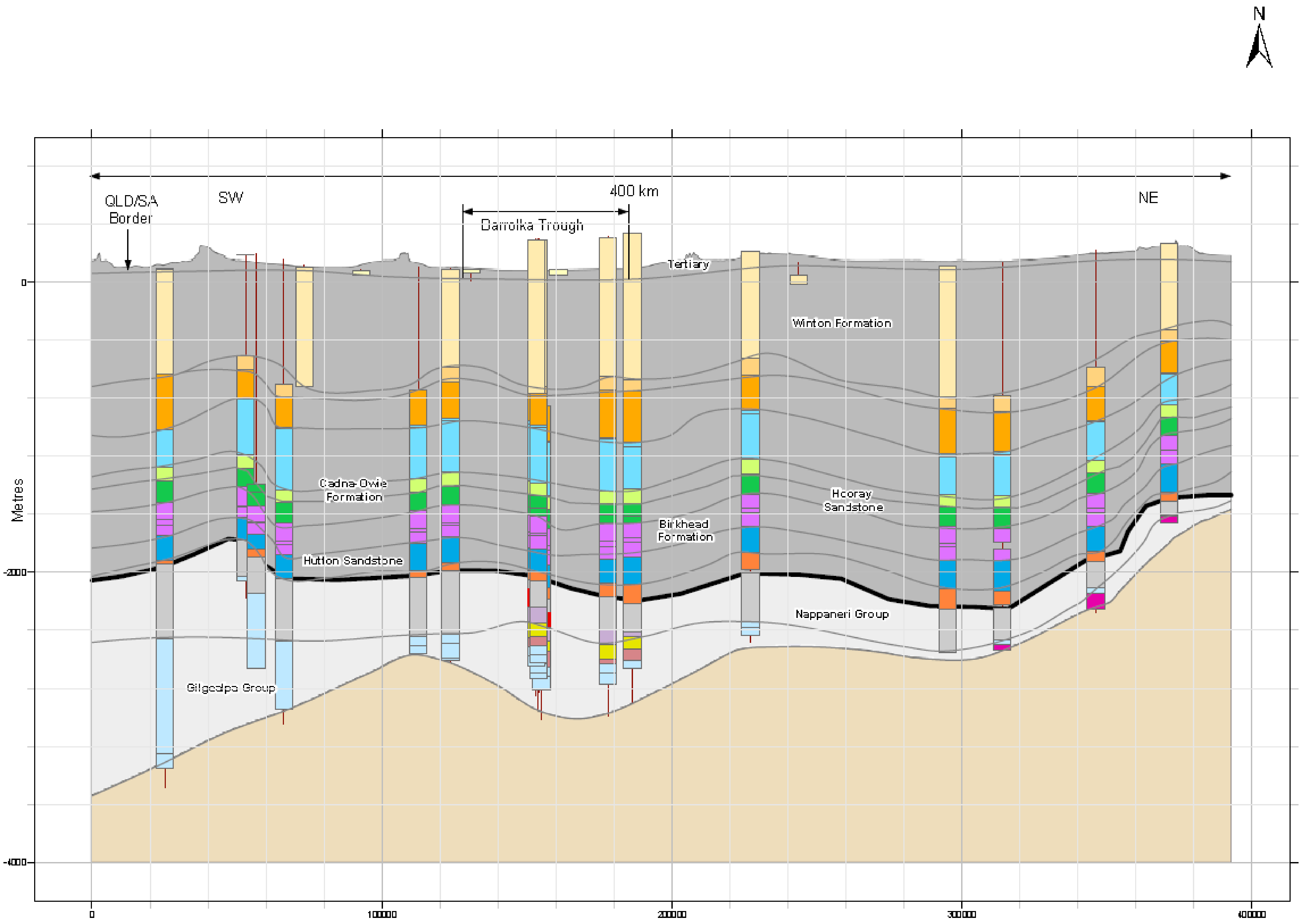

Figure 11. Geological Conceptual Cross Section across the Study Area

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4.3.7 Tectonic Controls and Trapping Mechanisms

Faults

The structural framework of the Cooper Basin, particularly in relation to faulting, is complex in the study area. However, in 2004, Santos undertook a mapping exercise to simplify the tectonic features within the basin(s). The primary driver for the mapping was to identify likely fault conduits (likely to enhance vertical migration of petroleum fluids) and fault baffles (likely to prevent lateral migration of petroleum fluid).

Across Santos SWQ activities, the major episodic faults occur in the top pre-Permian (basement), the basal Toolachee Formation and the basal Eromanga unconformity (Figure 13). The top pre-Permian faults provide the basin's overall fabric, whereas the younger faults from the basal Toolachee Formation and basal Eromanga unconformity are generally reactivated Permian faults.

In the Eromanga Basin formations, very few regional faults are observed as very little fault movement occurred during deposition of Eromanga Basin sediments. Subsidence and compaction dominated the structural geology (PIRSA, 2006).

Hydrocarbon Trapping Mechanisms

Eromanga Basin

Trapping mechanisms are predominantly structural, with a minor stratigraphic component (e.g. Hutton–Birkhead transition, Poolowanna facies, McKinlay Member and Murta Formation). Seals consist of intraformational siltstones and shales of the Poolowanna, Birkhead and Murta Formations. Where these units are absent, potential seals higher in the sequence include the Bulldog Shale and Wallumbilla Formation (SA DPI, 1998).

Cooper Basin

Anticlinal and faulted anticlinal traps have been relied on as proven exploration targets but potential remains high for discoveries in stratigraphic and sub-unconformity traps, especially where the Permian sediments are truncated by the overlying Eromanga Basin succession. Economic oil and gas in the Nappamerri Group are reservoir sands, with the majority of mudrocks in this unit forming a regional seal to the Cooper Basin. Intraformational shale and coals form local seals in the major reservoir units. Underlying the Daralingie Unconformity are two important early Permian regional seals - the Roseneath and Murteree Shales. The Roseneath Shale is the top seal of the Epsilon Formation and the Murteree Shale seals the Patchawarra Formation.

Tectonics and Uplifts

Tectonics and uplifts are discussed in the PIRSA reports on the Eromanga and Cooper Basins geology (PIRSA, 1998).

In the Cooper Basin, the Permo - Carboniferous – Triassic depositional episode terminated at the end of the Early Triassic by regional uplift, tilting and erosion.

Deposition in the Eromanga Basin commenced in the Early Jurassic and was governed by the topography of the unconformity surface. No major depositional breaks occur in the Eromanga Basin, indicating a period of minimal tectonic activity. As part of the large scale Early Cretaceous marine

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inundation of the Australian continent, a rapid period of subsidence took place in the Eromanga Basin.

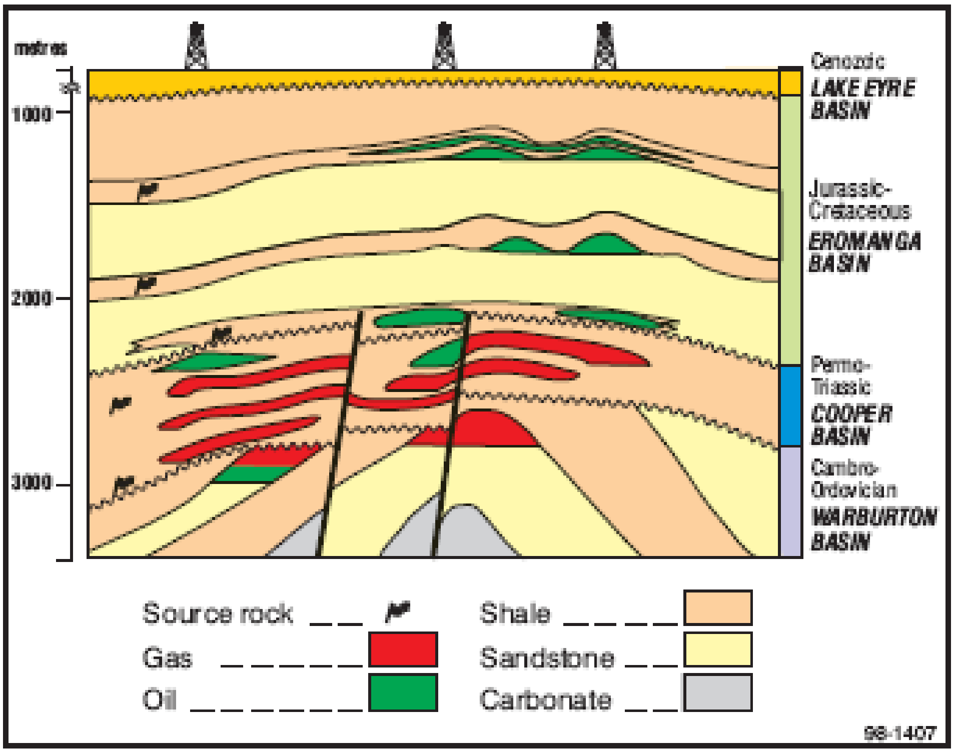

Figure 12. Petroleum Reservoirs Trapping Mechanisms of the Cooper and Eromanga Basins (from SA DPI, 1998).

Environmental Values

The environmental values defined in this section include surface water or groundwater resource within the study area. They are defined as "those qualities of the waterway that make it suitable to support particular aquatic ecosystems or human use" (*Environmental Protection (Water) Policy, 2009*, referred to as EPP Water). The EPP Water provides guidelines on determining the environmental value that should be considered for a particular project site or area, which follow the framework set out in *Appendix H* of the *Queensland Water Quality Guidelines 2006* (QWQG 2006).

There are a number of environmental values associated with surface water bodies, however, these may or may not be related to groundwater systems. Environmental ecosystems depending on groundwater are referred to as Groundwater Dependent Ecosystems (GDE).

Environmental values depending relevant to groundwater resources in the study area are:

Groundwater Dependent Ecosystems (Incl. wetlands and springs).

Drinking Water.

Sandstone Aquifers of the Great Artesian Basin.

Groundwater Users.

The hydrogeology of the study area is described in Section 5.0

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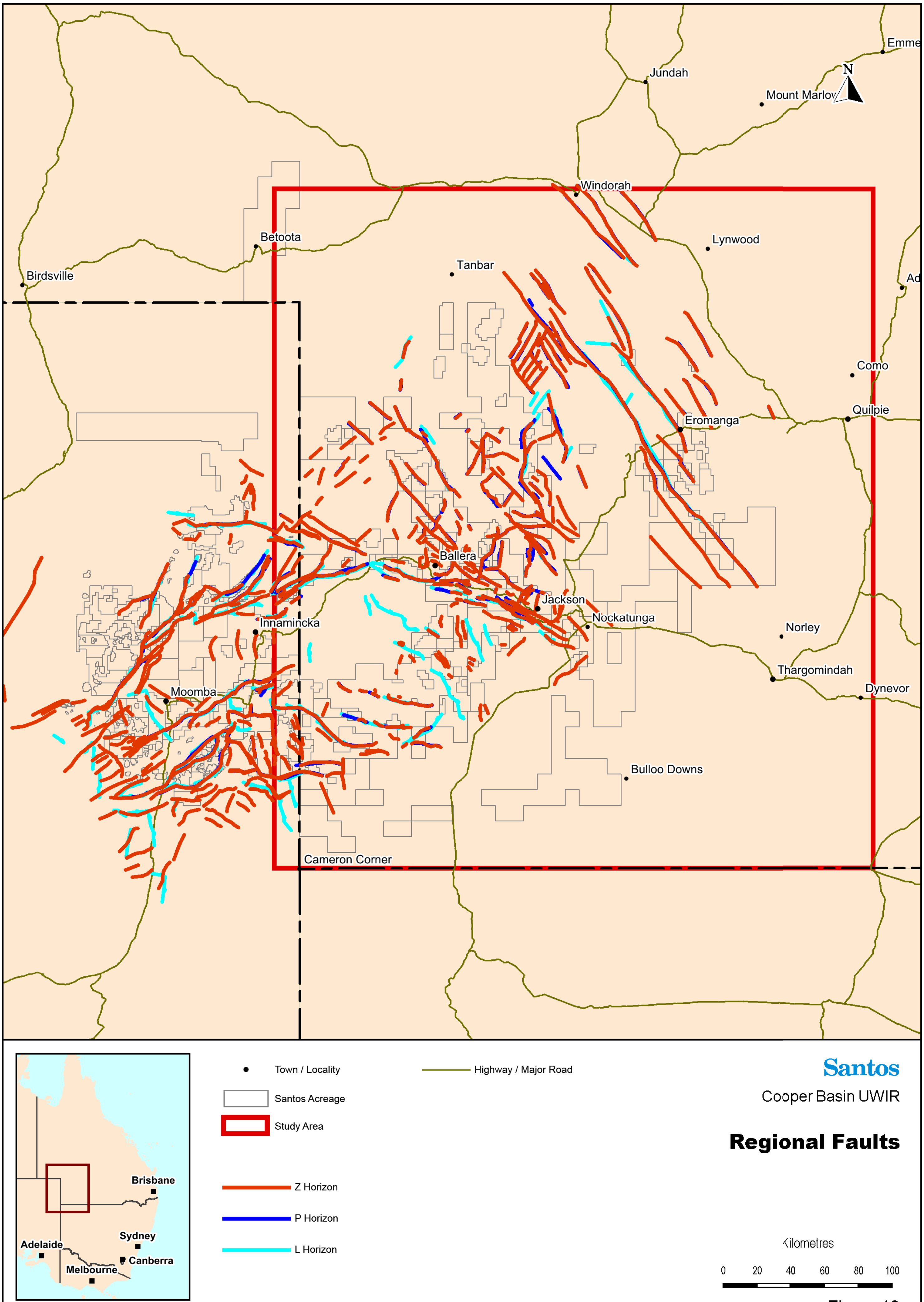

Santos

Cooper Basin UWIR

Regional Faults

Figure 13

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4.3.8 Groundwater dependent ecosystems (Incl. Springs)

GDEs can be defined as those ecosystems whose ecological processes and biodiversity are wholly or partially reliant on groundwater. The extent of GDE dependency on groundwater can range from being marginally or episodically dependent to being entirely dependent on groundwater (SKM, 2001).

Examples of GDEs include:

- Terrestrial vegetation supported by shallow groundwater.
- Aquatic ecosystems in rivers and streams that receive groundwater baseflow. Baseflow typically accounts for a significant portion of total flow volume in major rivers and streams. Baseflow can sustain streamflow volumes long after rainfall events, or throughout dry seasons, and is therefore critical to the maintenance of aquatic ecosystems in rivers and streams in many Australian environments. Baseflow can occur as springs discharging into a river or stream, or as diffuse influx of groundwater through banks and bed sediments.
- Wetlands, which are often established in areas of groundwater discharge.
- Springs and associated aquatic ecosystems in spring pools.
- Aquifers and caves, where stygofauna (groundwater-inhabiting organisms) reside.

Potential GDEs in the Study Area are presented on Figure 14

The closest QLD GAB spring to a Santos tenement is located 95km to the east-east.

Cooper Creek Basin is the largest catchment in the Lake Eyre Basin region.

The Cooper Creek has been recognised as one of Australia's most iconic inland rivers and largely intact natural values. The *Cooper Creek Basin Wild River Area Summary: Natural Values Assessment* (DERM, 2010) concluded that "the persistence of waterholes in the Cooper Creek is largely influenced by surface water flows and evaporation, with little inputs from groundwater". As a result, the Cooper Creek system is not classified as a GDE.

As noted above, the study area lies within the Channel Country regional ecosystem. Within this region, there are no recognised endangered regional ecosystems (EREs) (Santos, 2011).

Within the study area, only the Currawinya Lakes National Park *wetland* is listed as being of international significance under the EPBC Act Protected Matters database (Ramsar sites). The Currawinya Lakes National Park is located in the south eastern corner of the study area. It includes low dunefields, lakes, clay and saltpans, dissected tablelands and low hills. The Currawinya Lakes National Park is located more than 240km to the east of Santos' Cooper Basin petroleum activities. The wetland is underlain by the Eromanga Basin but not by the Cooper Basin.

Other nearby national parks include the Lake Bindegolly National Park which is located to the west of the town of Thargomindah and the Innamincka Recreation Reserve located to the east in SA.

To summarise, there are no known GDE's in the study area.

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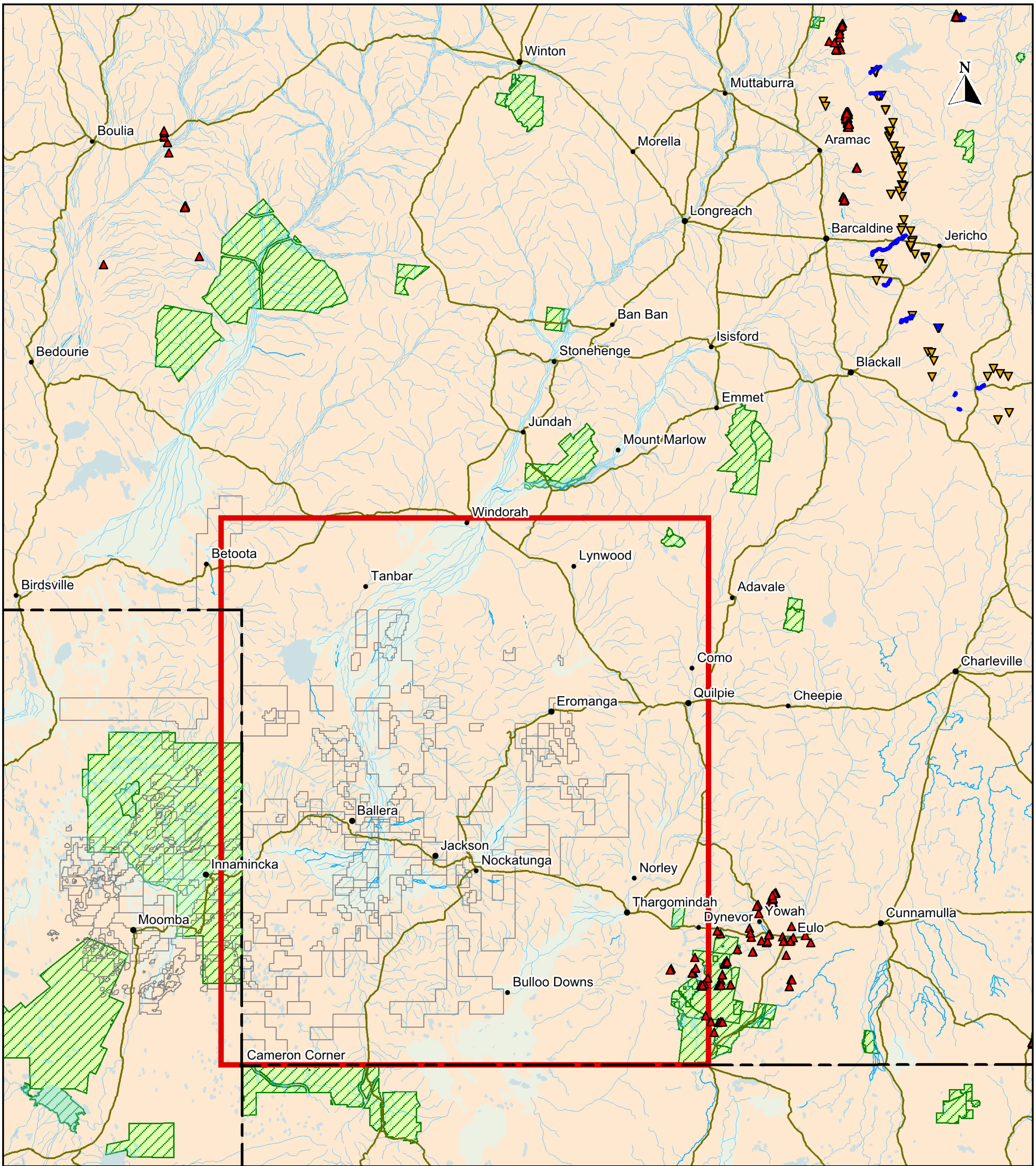

Town / Locality

Santos Acreage

Study Area

National Park / Regional Reserve

Watercourse Spring

GAB ROP Discharge Spring

GAB ROP Recharge Spring

Highway / Major Road

River / Creek

Santos

Cooper Basin UWIR

Groundwater Dependant Ecosystems

Kilometres

0 20 40 60 80 100

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Figure 14

4.3.9 Drinking Water and Groundwater Users

Groundwater is a common drinking water source for many inland areas of Australia, especially where aquifers of good quality and yield are present at reasonably shallow depths.

Municipal water supply accounts for the majority of large volume licensed groundwater allocations across the study area and may represent up to 10% of the total number of groundwater licences. Municipal water supply bores found in the QLD Government database are licensed in the Hooray Sandstone.

In addition to municipal water, individual properties in remote areas are likely to access groundwater for water supply. These water supplies do not typically require a license.

Groundwater as a drinking water supply and water resource for the rural community is considered to be an important environmental value in the study area.

It should be noted that groundwater use by the local communities is limited to the formations of the Eromanga Basin and overlying sediments and more generally, the shallower formations. A large proportion of the water supply bores target the Winton Formation aquifer (based on information in the DERM groundwater database).

Groundwater use is further discussed in Section 5.7

4.3.10 Sandstone Aquifers of the Great Artesian Basin

The main GAB aquifers (i.e. in the Eromanga Basin stratigraphy) over the study area are the Winton Formation, Cadna-owie Formation, Hooray Sandstone, Hutton Sandstone and Poolowanna Formation (Precipice Sandstone equivalent).

The aquifers of the Eromanga Basin are considered highly productive aquifers over most of the GAB.

The aquifers of the Cooper Basin (pre-GAB) are not considered by the regulator within the defined "*sandstone aquifers of the GAB*". Nevertheless, the major aquifers are the Wimma Sandstone, Toolachee Formation, Epsilon Formation, Patchawarra Formation and Tirrawarra Formation.

In the study area, only the upper aquifers of the Eromanga Basin sequence are of interest to the local community due to the significant depth of the deeper aquifers. As such, the Hutton and Poolowanna Sandstone aquifers are not used by the community (with the possible exception of exploration bores converted to groundwater supply bores).

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5.0 Hydrogeological Conceptual Model

5.1 Hydrogeological Setting

The Cooper and Eromanga basins are two chronologically successive stacked basins. The Cooper Basin is often considered by geologists as not being part of the GAB, however the upper formations of the Cooper Basin are included in the QLD GAB regulation (Great Artesian Basin Resource Operations Plan (GAB ROP) and Water Resource (Great Artesian Basin) Plan 2006(GAB WRP)). The Eromanga Basin is one of the main basins of the GAB and covers the whole of the Cooper Basin. The connection between the two basins is geologically marked by a major discontinuity.

The Cooper Basin and Eromanga Basin are multi-layered systems comprising alternating layers of sandstone, shales, mudstones and siltstones (Section 4.3). The sandstone formations of the Eromanga Basin correspond generally to water bearing formations and aquifer formations, and may yield significant quantities of groundwater to springs and for extraction from water supply bores.

The siltstone, shale and mudstone formations are generally low permeability rocks and are not classified as aquifers. However, lenses of sandstone are present within the some mudstone and siltstone beds, which may provide limited groundwater to low yielding supply bores.

In general, the formations are laterally continuous and hydraulically connected. However, due to the variability in the nature of the deposits this may not always be the case.

For management purposes, the GAB is subdivided in Groundwater Management Area (GMA) as defined in the *GAB Hydrogeological Framework for the GAB WRP Area* (DERM, 2005) [Section 2.0]. Each area is further divided in Groundwater Management Units (GMU) as represented on Figure 9 GMU groupings follow stratigraphy and hydrogeological characteristics as presented on Figure 9. The identification of GMUs allows for administration of access to water and water entitlements.

5.2 Hydrostratigraphy

Santos tenements are located within the Great Artesian Basin Water Resources Plan *Central Management Area* (AP12099) mostly, and the western part of *Warrego West Management Area* (AP12100) as illustrated on Figure 7.

The main aquifer and aquitard units are presented in Table 4. The main aquifer groupings, in relation to groundwater production include:

- Shallow Quaternary formations and Tertiary sediments
- The GAB aquifers of the Eromanga Basin (water supply for agricultural and drinking water, and groundwater extraction associated with the production of oil).
- The older and deeper Cooper Basin aquifers (groundwater extraction associated with the production of gas).

The targeted development of the main aquifer units of the Eromanga Basin is due primarily to accessibility (i.e. aquifer units occur at shallower depths and are therefore easier and cheaper to access). The aquifers of the Cooper Basin occur at much greater depths and are therefore usually only accessed during the production of gas.

Detailed hydrostratigraphy data of the Eromanga Basin has been sourced from the DERM database and some other relevant literature. Insufficient information is available to provide a detailed description of the hydrostratigraphy of the Cooper Basin formations.

Note that the Quaternary and Tertiary sediment aquifers and the Winton Formation are not administered under the GAB ROP (DERM, 2007).

Table 4. Hydrostratigraphy of the Study Area

GMA Unit		Unit name	Sub-unit	Equivalent Formation other parts of the GAB
	Eromanga Basin	Glendower Formation		
		Winton Formation		
		Mackunda Formation		
		Alluru Mudstone		
Central 1 - Warrego West 1		Toolebuc Formation		Surat Siltstone
		Wallumbilla Formation	Coreena Member	Wallumbilla Formation
			Doncaster Member	
Central 2 - Warrego West 2		Cadna-owie Formation	Wyandra Sandstone Member	Cadna-owie Formation, Bungil formation, Gilbert River Formation
			Lower Cadna-owie	
Central 3 - Warrego West 3		Hooray Sandstone	Murta Formation	Hooray Sandstone, Mooga Sandstone, Orallo Formation and Gubberamunda Sandstone
			Namur Sandstone	
Central 4 - Warrego West 4		Westbourne Formation		Injune Creek Group
		Adori Sandstone		
		Birkhead Formation	Upper Birkhead	
			Middle Birkhead	
			Lower Birkhead	
Central 5 - Warrego West 5		Hutton Sandstone		
Central 6 - Warrego West 6		Poolowanna Formation	Upper Poolowanna	Precipice Sandstone
			Lower Poolowanna	
MAJOR UNCONFORMITY				

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GMA Unit		Unit name		Sub-unit	Equivalent Formation other parts of the GAB
Central 7 - Warrego West 7	Cooper Basin	Nappamerri Group	Tinchoo Formation	Gilpepee Shale	Moolayember Formation
				Doonmulla Member	
			Arraburry Formation	Wimma Sandstone Member	Clematis Sandstone
				Panning Member	Rewan Formation
				Callamurra Member	
		Gilgealpa Group	Toolachee Formation		
			Daralingie Formation		
			Roseneath Shale		
			Epsilon Formation		
			Murteree Shale		
			Patchawarra Formation		
			Tirrawarra Sandstone		
			Merrimelia Formation		

Colour	Legend
(bright blue)	Major Aquifer
(light blue)	Water Bearing
(orange)	Confining Bed

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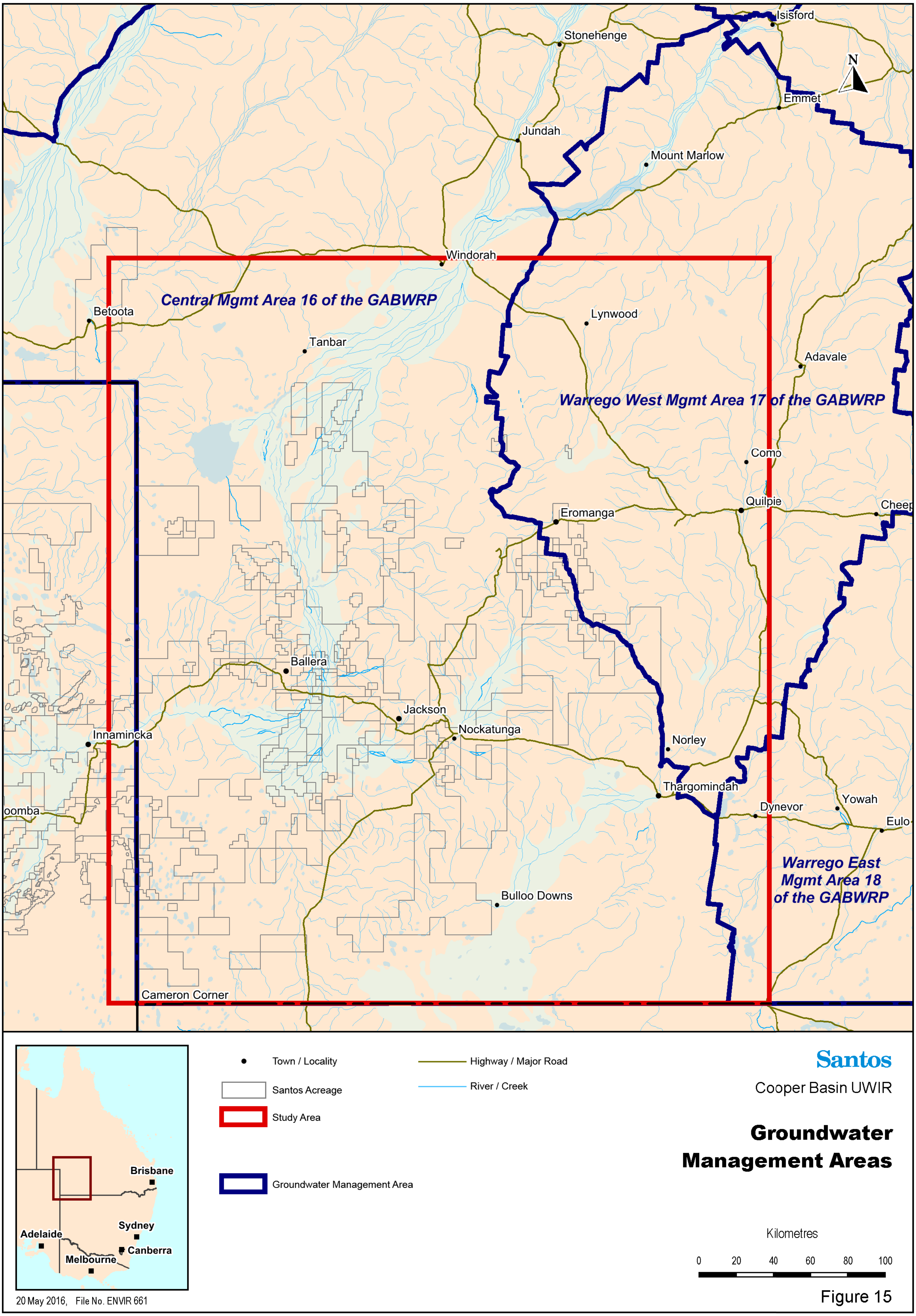

Santos

Cooper Basin UWIR

Groundwater Management Areas

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Figure 15

5.2.1 Quaternary and Tertiary Alluvium

The Quaternary and Tertiary alluvium formations cover a large portion of the study area and are often associated with the very flat structures of the flood plains. In general they are absent where the Winton Formation outcrops.

The Quaternary and Tertiary sediments are generally unconfined and form the uppermost phreatic water table (where present). Insufficient water level data is available for the Quaternary formations to determine the level of continuity.

The Glendower Formation is the primary Tertiary formation in the study area. The Australian Stratigraphic Database identifies the Whitula Formation as overlying the Glendower Formation, however the significance of the Whitula Formation in the study area is unknown.

The Glendower Formation comprises consolidated sediments of sandstones, sandy siltstones and minor conglomerate and mudstones (Australian Stratigraphic Database, Geosciences Australia).

In general, groundwater flow follows the topographical profile of the study area, with the only limitations imposed by the fluvial nature of the sediments. A hydrogeological map of the area is presented as Figure 16, which indicates that the hydraulic gradient is small.

According to the data available in the DERM database, the salinity of the aquifer water is brackish, with electrical conductivity (EC) values ranging from 3,000 to 7,000µS/cm or 2,000 to 4,700mg/L Total Dissolved Solids (TDS).

5.2.2 Winton Formation

Based on the information available through the DERM database, the Winton Formation is a significant aquifer as it supplies community stock and domestic water bores. As shown on Figure 17, the depth to, and thickness of the Winton Formation is on average 50m below ground level (bgl) and in some areas may be up to 970m thick.

Contrary to the information provided in the DERM database data, Santos does not consider that the Winton Formation is a significant aquifer in SWQ. Although it covers a large area of QLD, the quality of the water present in the Winton Formation decreases progressively to the west as you move away from central QLD toward SA (Pers. Comm. N. Lemon, Santos, November 2011).

It is also noted that the top and the bottom of the Winton are so poorly defined in the subsurface that it is difficult to determine with any real certainty that water production currently assigned to the Winton Formation does not come from the overlying Tertiary (Eyre Formation in South Australia) or underlying Mackunda Formation. The uncertainty around water production currently assigned to the Winton Formation was also reported by Gravestock et al. (1995)

The Winton Formation is overlain by Tertiary sediments. It is expected that there is some level of hydraulic conductivity between the two formations however, no data is available to confirm this.

The water quality in the Winton Formation is brackish (to saline) with ECs ranging from 900 to 13,000µS/cm or 600 to 9000mg/L TDS. In general, groundwater flow is to the south west.

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5.2.3 Cadna-Owie Formation

The Cadna-Owie Formation is considered a major unit of the GAB. Its upper section, the Wyandra Sandstone, is an aquifer however, its thickness is limited over SWQ. The Lower Cadna-Owie is considered an aquitard.

The limited data available in the DERM groundwater database indicate fresh to slightly brackish water quality with the Wyandra Sandstone. Insufficient water level information is available to describe water flows and water levels and therefore a hydrogeological map has not been generated. Habermehl defines the Cadna-Owie unit as non-artesian (1986, 1997), however the DERM groundwater database identifies a number of artesian bores present in the Formation.

The proportion and spatial distribution of aquifer bearing sandstones and siltstones in the Cadna-owie is much lower than that in the Hooray Sandstone. The Wyandra Sandstone is recognised as the ‘productive unit’ in this formation. It is a highly permeable shallow marine sandstone, and most prevalent in the eastern regions of the Formation (BRS, 2000).

5.2.4 Hooray Sandstone

The Hooray Sandstone system is a major GAB unit. Oil reservoirs and minor gas reservoir are also present within this unit (Figure 18). Two sub-units are identified in the Hooray Sandstone and include:

- The Murta Formation: the equivalent in other GAB basins are the Mooga and Gubberamunda Sandstones. However, it is noted that in the study area, the Murta is considered to be a confining bed. The confining layer is a siltstone at the base of the Formation which is widespread accross the Cooper region. Oil and some gas reservoirs are present in the Murta Formation. The McKinlay Member, which forms part of the Murta Formation, is not always present in SWQ, and contains only minor oil reservoirs.
- The Namur Sandstone: is the major water bearing unit of the Hooray Sandstone. Oil is present in this unit.

The water quality in the Hooray Sandstone is generally fresh but may be slightly brackish. EC values (DERM groundwater database) range from 675 to 3,930µS/cm or 450 to 2700mg/L TDS. A number of Hooray water supply bores have salinity values measured over a 40 year period, the latest of which compare well with historical values.

It is noted that a number of bores within the Hooray Sandstone may be artesian. Groundwater bores are concentrated in the south-eastern region of the study area however, water level and salinity data is limited for the majority of the bores in the study area (i.e. within Santos tenements).

Based on the information that is available, the groundwater flow direction is generally towards the southeast and the water salinity is fresh to slightly brackish.

5.2.5 Westbourne Formation, Adori Sandstone and Birkhead Formation

Limited hydrogeological information is available for the Westbourne Formation, Adori Sandstone and Birkhead Formation.

In general, the Westbourne Formation is considered to be a confining bed with homogeneous characteristics (lacustrine deposits associated with a large transgression). However, in the south-

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eastern region of the study area, a number of private bores have been completed in the Westbourne Formation, most likely in some of the minor sandstone beds/lenses of the formation.

The Adori Sandstone is an aquifer however, insufficient information is available to fully characterise it. The Birkhead formation comprises of a succession of discontinuous confining beds and water bearing sandstone units.

Salinity data are not available for the Westbourne, Adori and Birkhead Formations.

5.2.6 Hutton Sandstone

The Hutton Sandstone is a significant GAB aquifer however, given its depth (2,000mbgl – refer to Figure 11) in the study area, access other than for oil activities is highly unlikely. The groundwater flow is expected to be to the south west i.e. consistent with the flow of the major GAB units as described in the literature (Note: there is insufficient water level data in the Hutton Sandstone to characterise groundwater flow direction further).

The water quality of the Hutton Sandstone in the study area cannot be commented on as no reliable data can be found.

5.2.7 Poolowanna Formation

Also referred to as the Basal Jurassic Formation (older name in the nomenclature), the Poolowanna Formation is the equivalent of the Precipice Sandstone (in SE QLD). As per the Hutton Sandstone, groundwater flow is expected to be to the south west, which is consistent with the flow of the major GAB units as described in the literature.

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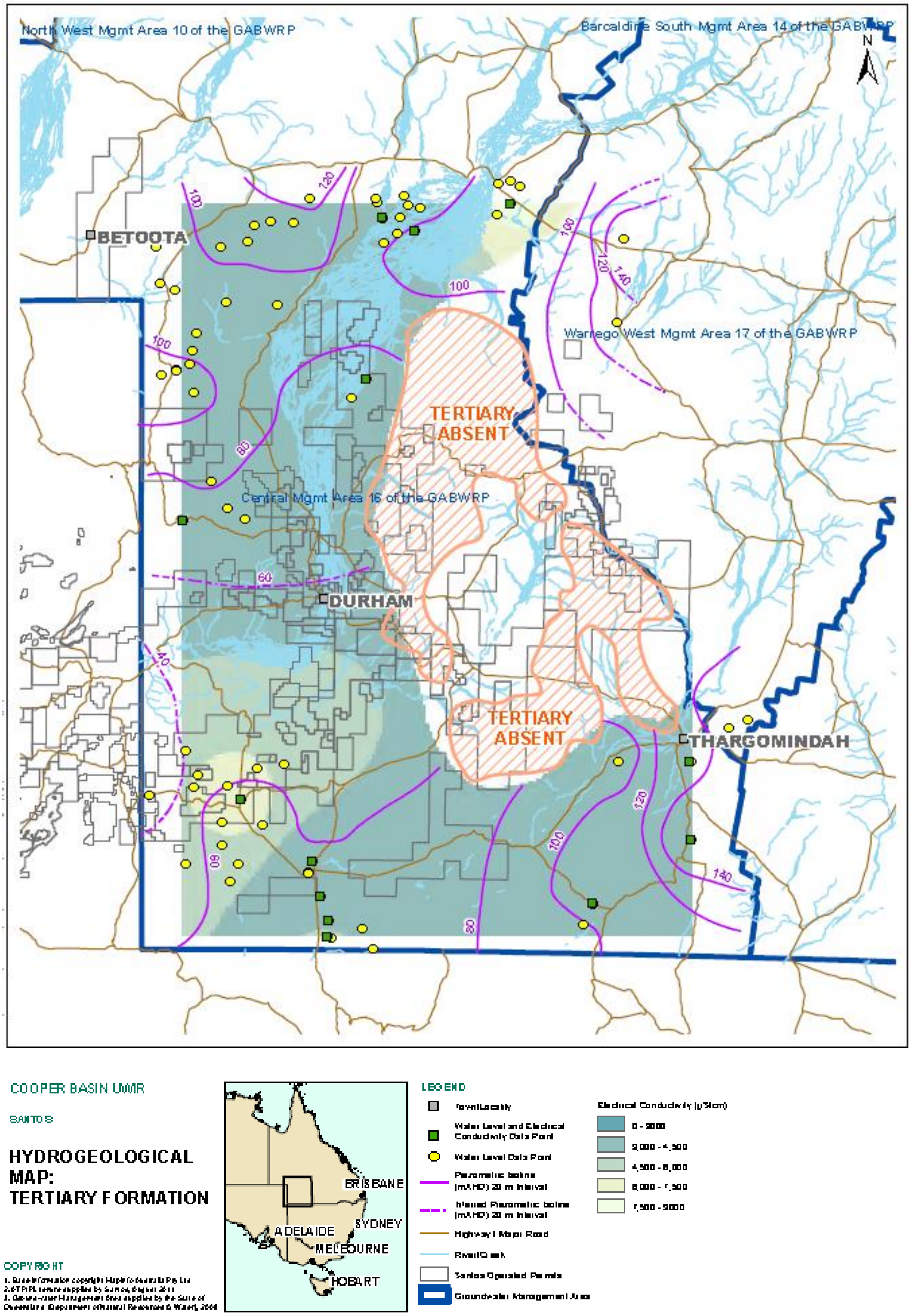

Figure 16. Hydrogeological Map: Tertiary Formation

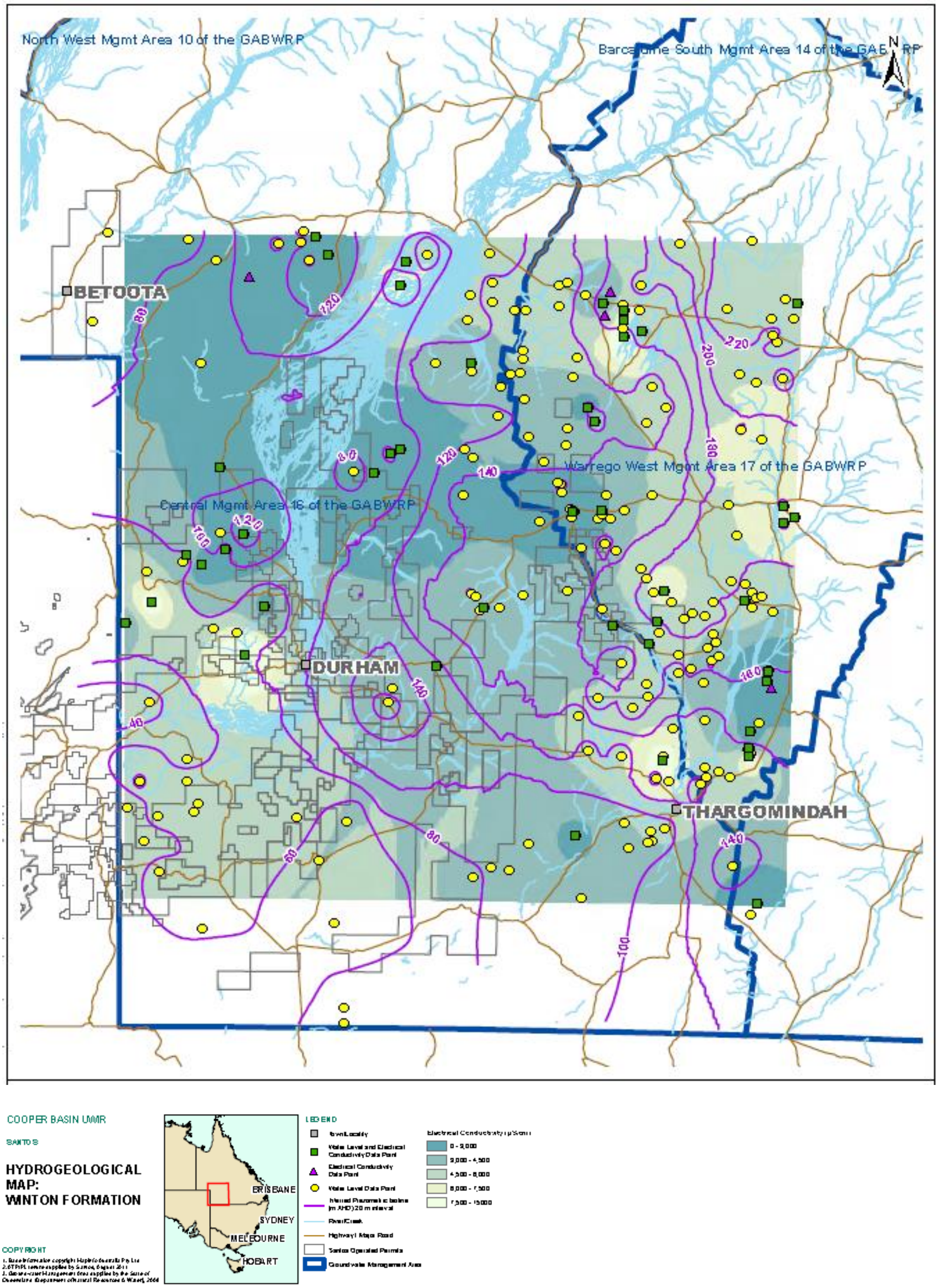

Figure 17. Hydrogeological Map – Winton Formation

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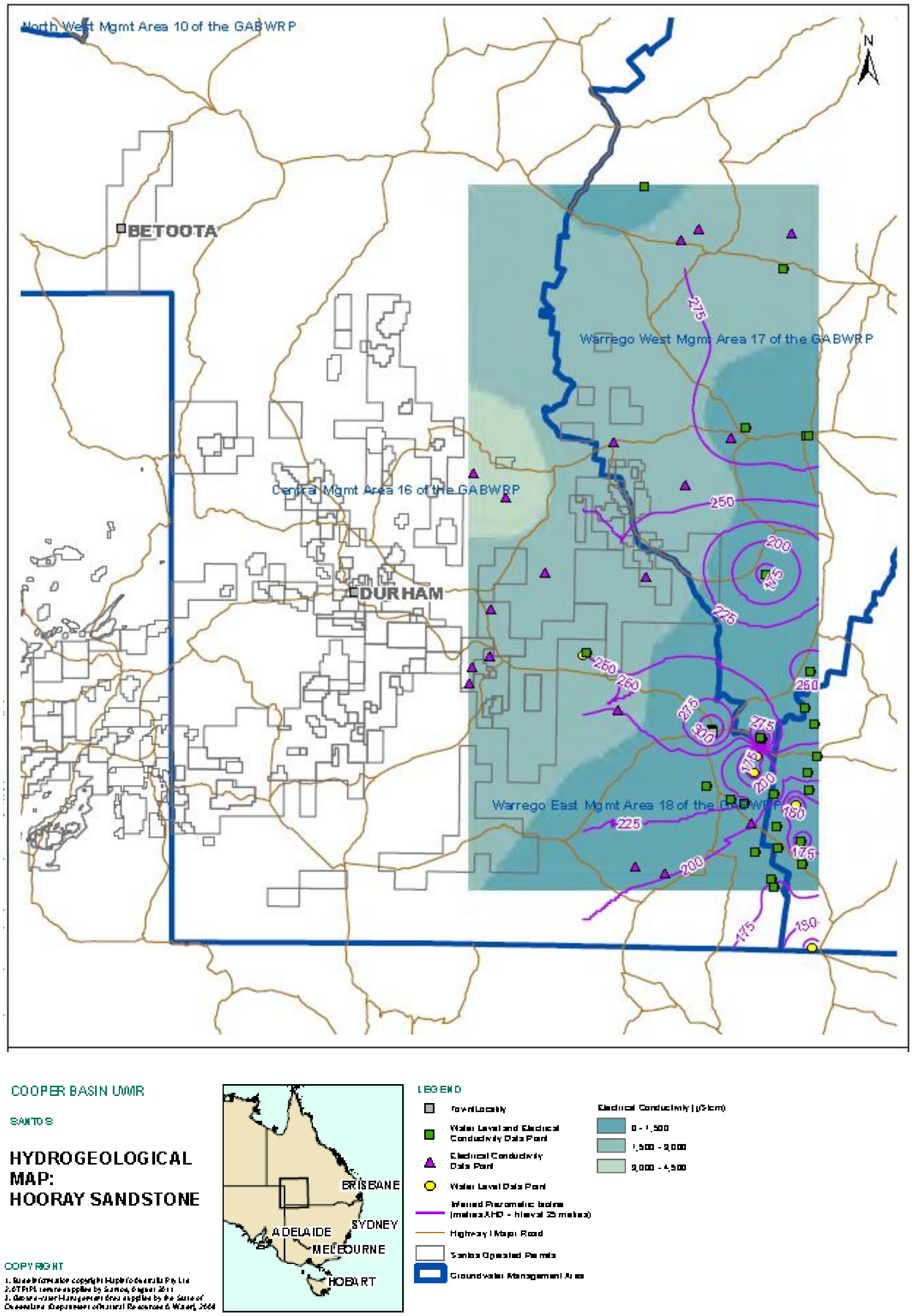

Figure 18. Hydrogeological Map – Hooray Sandstone

5.3 Structural Influence on Groundwater Flow

Section 4.3.3 of this report provides details on the tectonic setting and basin stress regime within the Cooper-Eromanga Basins, which provides that, the primary influences are strike-slip faulting, normal faulting and transitional strike-slip/reverse faulting at depth. Consideration of these regimes in relation to groundwater flow (i.e. tight compressive (non-tensional) fault creation) suggests that faults are largely self-sealing and unlikely to form conduits for preferential groundwater (or oil and gas) flow. This position is supported by pressure measurement and profile data as presented in

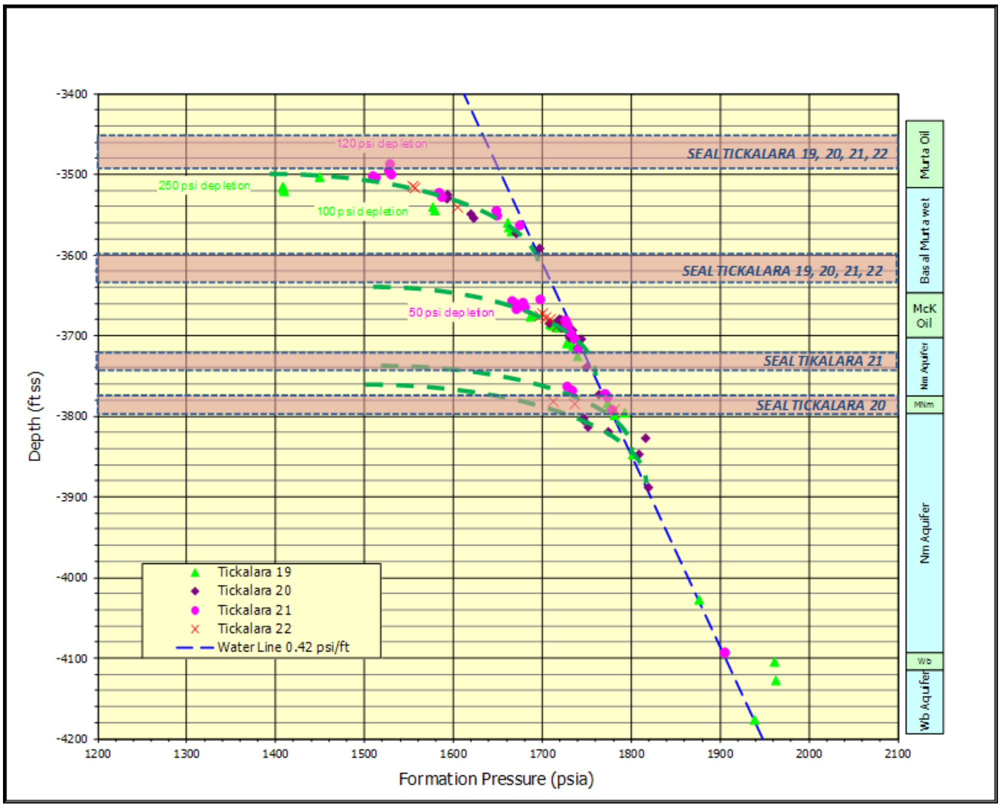

Figure 22 and Figure 23.

5.4 Hydraulic Parameters

A review of the hydraulic parameters for the formations in the study area has been undertaken and is summarised in Table 5.

Table 5. Hydraulic Parameters

Basin	Formation	Hydraulic Conductivity (m/d)		Porosity (fraction)
		Min	Max	
Eromanga Basin	Quaternary and Tertiary Alluvium	-	-	-
	Winton Formation	-	-	-
	Mackunda Formation Alluru Mudstone Toolebuc Formation Wallumbilla Formation	-	-	-
	Cana-Owie Formation	-	-	-

Basin	Formation	Hydraulic Conductivity (m/d)		Porosity (fraction)
		Min	Max	
	Hooray Sandstone	4.3×10^{-4}	4.3×10^{-1}	-
	Westbourne Formation, Adori Sandstone and Birkhead Formation	8.0×10^{-7} [2]	2.5×10^{-4} [2]	0.2 [2]
	Hutton Sandstone	3.5×10^{-1}	9.8×10^{-3}	
	Poolowanna Formation	1×10^{-7} [2]	3.7×10^{-3} [2]	0.18 [2]
Cooper Basin	Tinchoo / Arrabury Formations			
	Toolachee Formation	2.0×10^{-3} [1]	4.3×10^{-3}	0.15 0.08 to 0.12[3]
	Daralingie, Roseneath Shale, Epsilon and Murteree Shale Formations	-	-	-
	Patchawarra Formation	3.3×10^{-4} [1]	3.5×10^{-3} [1]	0.13 0.08 to 0.12[3]

[1] Gov. of South Australia, Primary Industries and Resources, SA. Petroleum and Geothermal in South Australia – Cooper Basin, 2009.
[2] Alexander, E.M., Reservoirs and Seals of the Eromanga Basin (undated).
[3] Santos, 2011.

5.5 Groundwater Level Variations

A network of groundwater monitoring bores was selected by the QLD government to monitor groundwater pressures over the whole of the GAB (see Figure 19). Twenty six (26) groundwater monitoring locations are located within the study area, the majority of which target Eromanga Basin GAB aquifers. Although water level data is available from 1974 to 2011, records are limited and the quality of the data cannot be substantiated. Hydrographs for the representative bores are presented in Figure 20 and have been selected based on their proximity to Santos tenements and the number of data points available for review.

It is noted that there is no current water level information available for these bores in the DNRM database.

There are no Santos owned regional groundwater monitoring bores in the study area.

Table 6. GAB Monitoring Network - Target Aquifers

RN	Latitude	Longitude	Formation*
326	-27.227627	144.3736947	Coreena Member
358	-26.6693889	143.2727374	Hooray Sandstone
3770	-25.845405	144.1222963	Hooray Sandstone
5994	-28.54135	144.33206	Cadna-owie Formation
12900	-28.3065933	143.9151356	Hooray Sandstone
13488	-28.6094707	143.3081558	Wallumbilla Formation
15286	-28.6813277	143.9381618	Cadna-owie Formation
16768	-27.4510425	141.0574634	Hutton Sandstone
17428	-28.2743291	144.1420228	Hooray Sandstone

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RN	Latitude	Longitude	Formation*
18144	-28.3921154	144.3032971	Wallumbilla Formation
22945	-25.4831149	143.409366	Hooray Sandstone
23233	-25.7300197	143.5999248	Hooray Sandstone
23349	-27.9054058	143.3229819	Hooray Sandstone
23569	-27.7188708	142.5648591	Hooray Sandstone
50503	-27.2872927	143.4556593	Hooray Sandstone
50623	-27.274913	142.9318421	Hooray Sandstone
8 bores	Refer to map	Refer to map	unknown

**Target formation either provided in the DERM groundwater database or inferred from the DERM database information.*

The water levels presented in Figure 20 have been converted from calculated static head (as reported on the Bureau of Meteorology Groundwater Information website) to m AHD (Australian Height Datum). In general, water levels recorded in sub-artesian bores are reported as the standing water however, in artesian bores temperature and depressurisation must be taken into consideration to determine the actual static head or standing water level.

Groundwater levels for the Hutton and Hooray Sandstones and the Cadna-Owie and Wallumbiila Formations are presented as Figure 20. The monitoring data available is sporadic and seasonal trends cannot be interpreted.

Water levels for the Hooray Sandstone show an overall decreasing trend however, from 1991 to 2009 show an increase in standing water level.

Water levels in the Cadna-Owie Formation show an overall increase in standing water level from the 1960's through to 2012.

Standing water levels in the Wullumbilla Formation show a small (8m) increase in trend from 1981 to 2008. However, the most recent data point, collected in 2011, indicates a decrease in standing water level of 26m. No additional data is available and therefore an assessment of any changes in long term trends cannot be made.

Groundwater pressure and water level trends is presented in the 2018 Annual Groundwater Monitoring Report (Appendix B).

5.6 Aquifer Recharge and Discharge

Primary recharge of the GAB aquifers occurs through uptake at the boundary of the system (Figure 21). Recharge via infiltration through overlying formations is limited to the upper GAB formations and is considered only a minor recharge mechanism.

In general, groundwater flow in the GAB is towards the low-lying areas of Central Australia. From the eastern margin of the basin, groundwater flows are predominantly to the west, south and southwest. From the Western Australian recharge beds, flow is generally towards the east (Figure 21).

Naturally occurring discharge areas in the GAB generally manifest as springs, leakage to alluvium aquifers (Tertiary-Recent), and discharge to inland lakes. In the study area there are no identified GDEs (Section 4.3.8) and no inland lakes.

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The primary discharge mechanism for GAB water within the study area is anthropogenic water production. Oil and gas operations, and local community extract groundwater for industrial and domestic use. Artificial recharge of water occurs where flooding techniques are used in associated with oil production such as enhanced oil recovery (Appendix A – Section 4.4.1).

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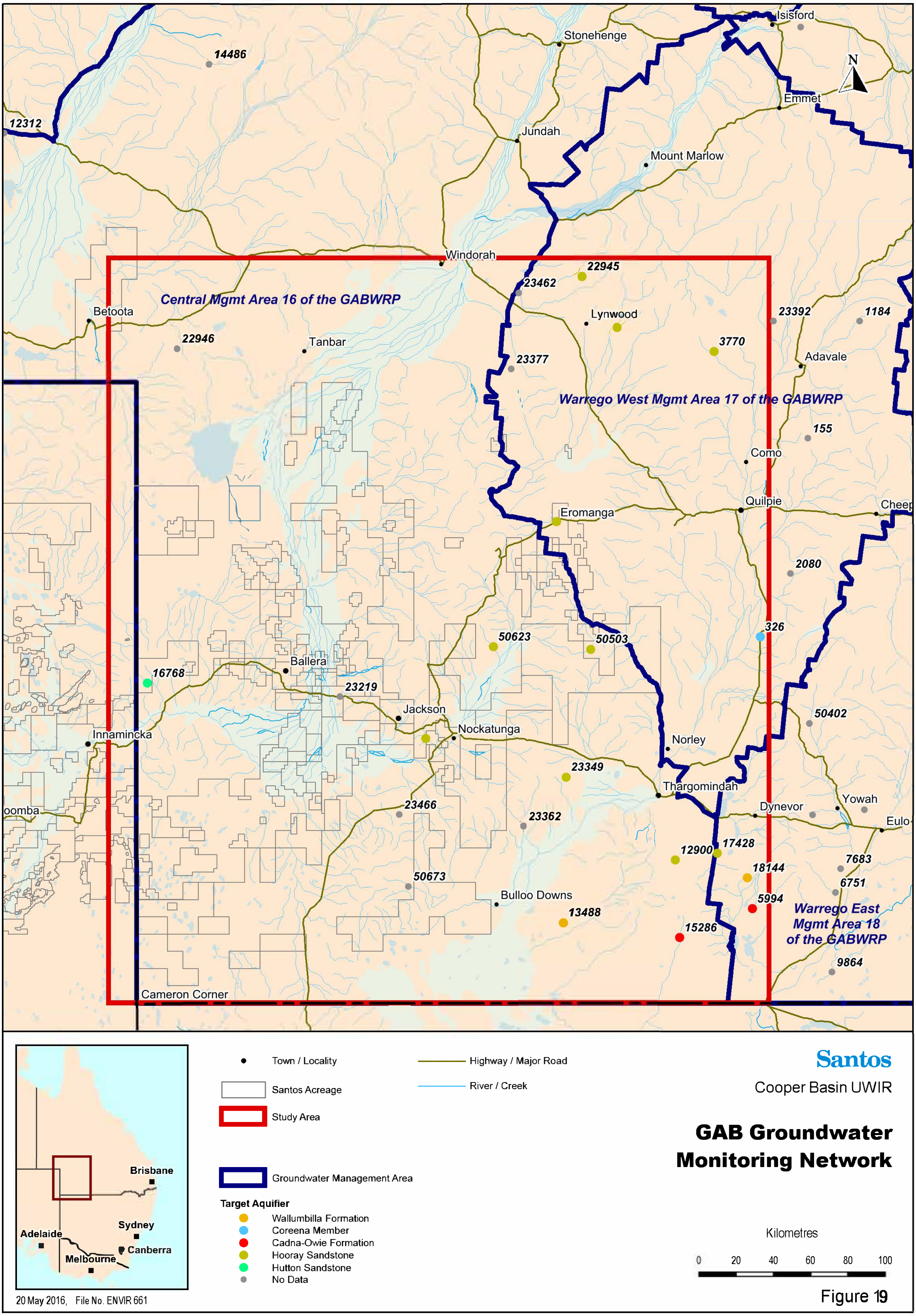
Isisford
Stonehenge
14486
12312
Emmet
Jundah
Mount Marlow
Windorah
22945
23462
Central Mgmt Area 16 of the GABWRP
Betoota
Lynwood
23392
1184
22946
Tanbar
3770
Adavale
23377
Warrego West Mgmt Area 17 of the GABWRP
155
Como
Quilpie
Eromanga
Cheep
2080
326
50623
50503
Ballera
16768
23219
Jackson
50402
Nockatunga
Innamincka
Norley
23349
Thargomindah
Yowah
Dynevor
oomba
23466
23362
Eulo
12900
17428
7683
18144
50673
6751
5994
Bulloo Downs
13488
Warrego East Mgmt Area 18 of the GABWRP
15286
9864
Cameron Corner
Brisbane
Sydney
Adelaide
Canberra
Melbourne
Town / Locality
Highway / Major Road
Santos Acreage
River / Creek
Study Area
Groundwater Management Area
Target Aquifier
Wallumbilla Formation
Coreena Member
Cadna-Owie Formation
Hooray Sandstone
Hutton Sandstone
No Data
Santos
Cooper Basin UWIR
GAB Groundwater Monitoring Network
Kilometres
0 20 40 60 80 100
20 May 2016, File No. ENVIR 661
Figure 19

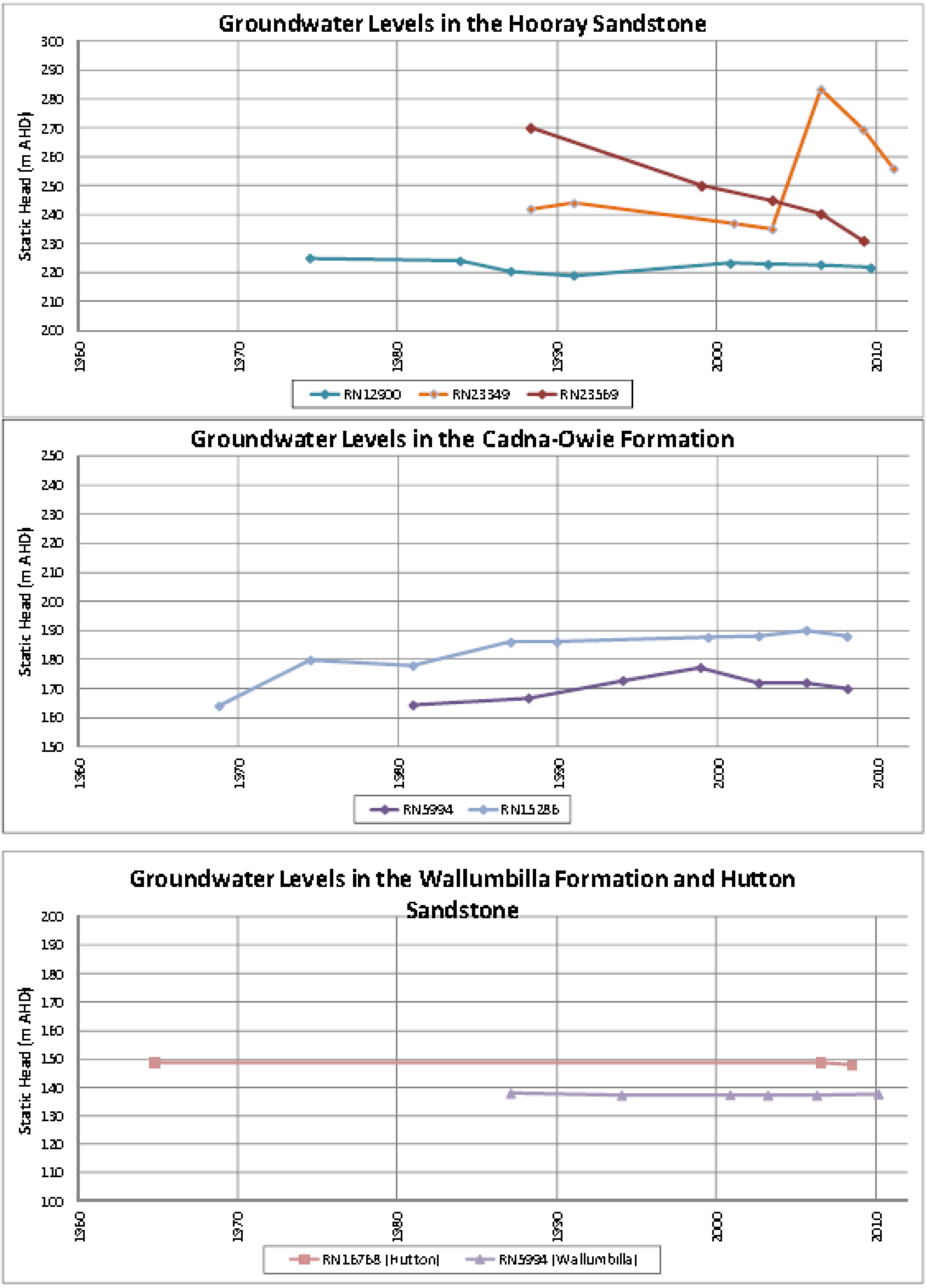

Figure 20. GAB Monitoring Bore Hydrographs (bases on data available in the DERM groundwater database).

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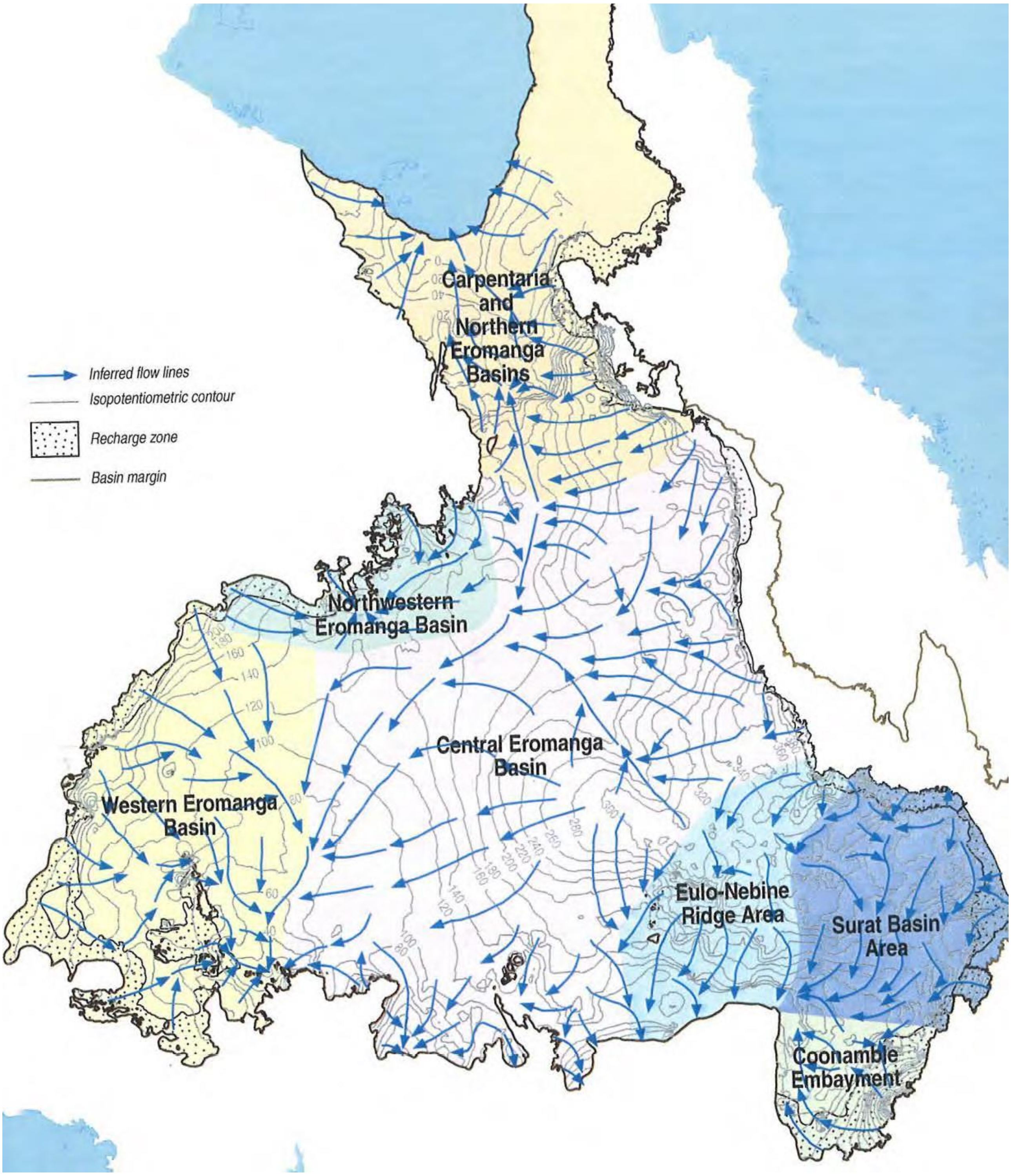

Figure 21. GAB Regional Groundwater Flow and Recharge Intake Beds (BRS, 2000)

5.7 Groundwater Quality

5.7.1 Data Quality Assessment

The groundwater chemistry data available within the study area was collected between 1950 and 2012 (BOM Groundwater website) however, the quality of the data cannot be verified.

5.7.2 Water Quality Description

Physical Parameters

Assessment of groundwater quality included analysis of pH, TDS and major ion chemistry. Groundwater classification in terms of pH is presented in Table 7.

Table 7. Groundwater pH

Range	Description
pH < 5	Acid
pH 5 - 7	Slightly Acid
pH 7	Neutral
pH 7 - 9	Slightly Alkaline
pH >9	Alkaline

TDS and electrical conductivity (EC) are measures of the dissolved salt content in water. TDS is reported as a concentration (in mg/L) and is either measured by evaporating a known volume of water and weighing the residual solids, or calculated by adding the major ion concentrations.

A range of salinity classifications (based on TDS concentration) have been published in literature. Classifications are generally based on beneficial use applications (irrigation or livestock watering) and do not define the full range of TDS found in natural waters (e.g. seawater or brines). The water salinity classification adopted for this study is presented in Table 8, as adopted from Fetter (1994). A further division of brackish water - slightly brackish and brackish (USDA, 2007) is also presented.

Table 8. Groundwater classification based on TDS (Salinity classes modified from Fetter, 1994)

Water type	TDS (mg/L)
Fresh	< 1,000
Slightly brackish	1,000 to 3,000
Brackish	3,000 to 10,000
Saline	10,000 to 100,000
Brine	> 100,000

EC is a measure of the conductance of a liquid and is reported in microSiemens per centimetre (µS/cm) at 25°C. There is a linear relationship between dissolved salt load and EC values for water samples. In general, EC is a salinity measurement taken in the field, and TDS is reported following laboratory analysis of a groundwater sample.

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5.8 Observed Reservoir Pressure Data

Formation pressure data is collected by Santos during drilling operations by means of:

- Drill stem test (DST).
- Repeat formation tester (RFT).
- Formation micro tester (FMT).

Pressure testing is undertaken to assess the likely thickness of the oil or gas column found at any particular depth. This is achieved by comparing the pressure in the hydrocarbon-bearing zone with the expected water pressure, predicted by the water pressure-depth line (Figure 17 and Figure 18).

Models for predicting the influence of gas and oil, and associated water production at depth requires data on the pressure transmissibility of the strata that separates the target formations (referred to as seals). In SWQ the following for seals have been identified:

- Seals between the Glendower and Winton aquifers.
- Seals between the Murta, Namur, (Hooray) and Hutton Sandstone, from which oil is produced.

Numerous Santos wells have been subject to pressure measurements in the Cadna-Owie to establish water pressure-depth lines. This data can be used to evaluate if depletion from underlying hydrocarbon production zones has influenced the aquifers used for water supply. If no depletion is observed in the Cadna-Owie Formation, then production is assumed not to have had an influence on the overlying aquifers.

Where groundwater has been abstracted from the same aquifers as those associated with hydrocarbon production, observed pressure data may provide a direct indication of the groundwater pressure in that aquifer and aquitard. The extrapolation of the water pressure gradient to the surface provides an indication of the level to which water will now rise compared to what it may have been in the past.

Interrogation of historical pressure data, provides an opportunity to evaluate potential reductions in groundwater level. It should be noted however, that results are considered to reflect a combined influence of water resource abstraction and cumulative impact from the hydrocarbon industries.

Two examples of pressure data versus depth for the Tickalara and Iliad Fields are presented in Figure 19 and Figure 20.

The figures show pressure depletion below the predicted water pressure line (blue dashed line that increases in pressure with increasing depth) confined to each target formation (shown as yellow layers) by the presence of an overlying aquitard (seal bed, shown as brown layers).

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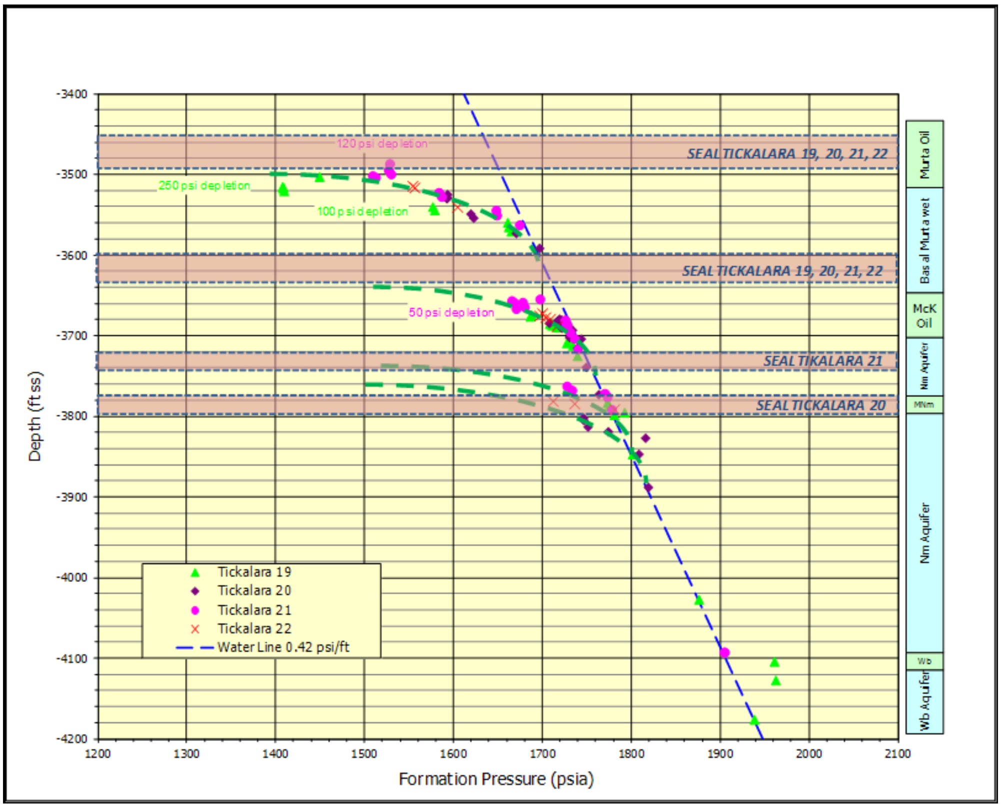

Figure 22. Observed Tickalara Oil Field Pressure with Depth Plots

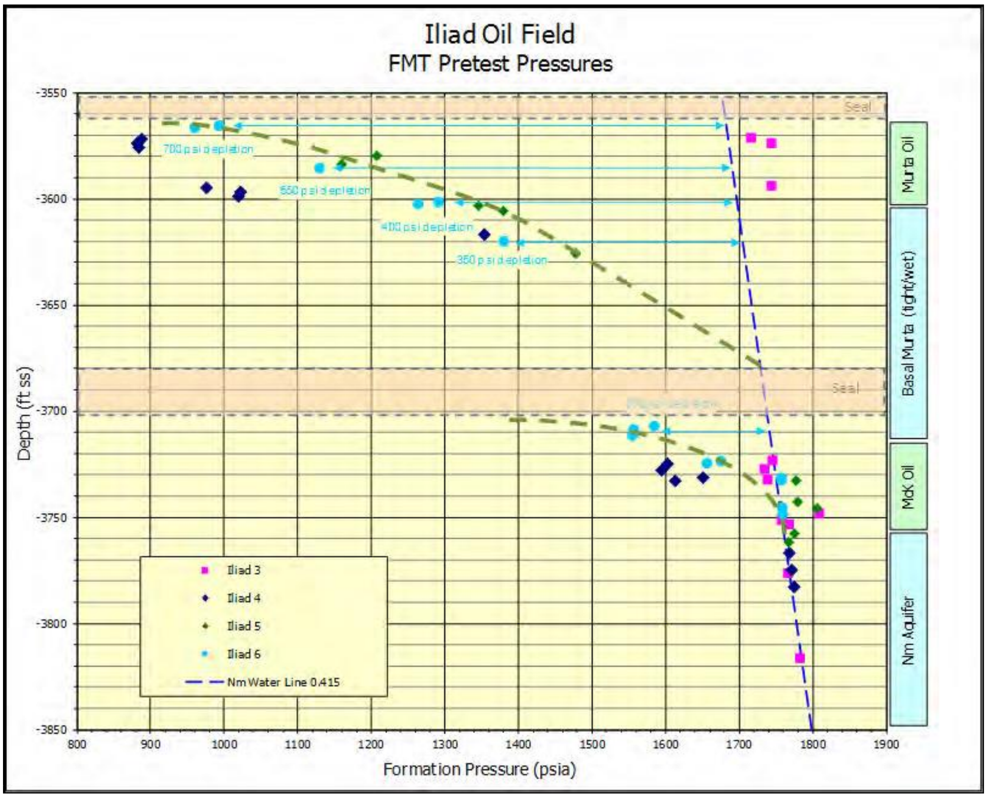

Figure 23. Observed Iliad Field Pressure with Depth Plots

Major Ion Chemistry

Evaluation of groundwater anions and cations can provide an indication as to the source of a water (i.e. from which aquifer formation it comes) and the potential for interaction between different aquifer formations (i.e. communication or mixing of waters due to recharge or discharge).

One of the most common methods of comparing the ionic composition of groundwater samples is to use a Piper diagram. Piper diagrams provide a graphical representation of the chemistry of a water sample and allow for classification based on the relative major ion composition.

Piper Diagram

Cation and anion concentrations for each groundwater sample are converted to milliequivalents per litre (meq/L) and plotted as percentages of their respective totals in two triangles (see Figure 24). The cation and anion relative percentages in each triangle are then projected into a quadrilateral polygon that describes the water type.

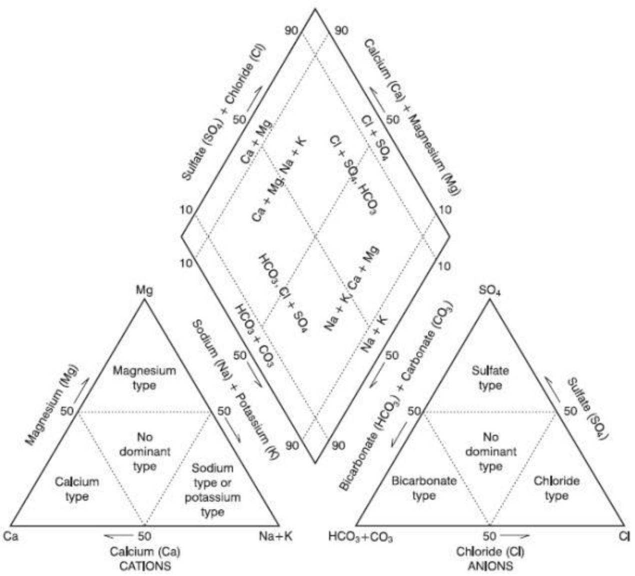

Figure 24. Classification of Hydrochemical Facies using Piper Plot

5.8.1 Groundwater Quality Data in the Study Area

Available Data

Water quality data for groundwater bores located within the study area was extracted from the DERM groundwater database (494 samples in total). Using this information, groundwater has been assigned to the following aquifer formations:

- Tertiary sediments (10 samples).
- Glendower Formation (31 samples).
- Winton Formation (160 samples).
- Mackunda Formation (16 samples).
- Alluru Mudstone (7 samples).
- Wallumbilla Formation (97 samples).

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Cadna-owie Formation (20 samples).

Hooray Sandstone (147 samples).

Adori Sandstone (1 sample).

Hutton Sandstone (5 samples).

Groundwater pH values in the study area ranged from 6.2 to 9.9 (slightly acidic to alkaline). The slightly acidic pH (6.2) was associated with groundwater from the *Winton Formation* aquifer and the most alkaline sample was collected from the *Wallumbilla Formation*. For the majority of reported values, the pH ranged between 7.5 and 8.5 (slightly acidic to slightly alkaline).

Evaluation of reported TDS concentrations indicate that majority of groundwater is slightly brackish (TDS<3,000 mg/L). Some samples from Winton Formation, Wallumbilla Formation, Glendower Formation and Hutton Sandstone are classified as brackish with TDS concentrations ranging 3,000 to 10,000 mg/L. The most saline sample was collected from the *Winton Formation* aquifer.

Water Types of the Study Area Formations

As presented in

Figure 25 and Figure 26, the dominant ions in groundwater samples collected from within the study area are sodium, bicarbonate and chloride. The corresponding water types can be described as either sodium-bicarbonate or sodium-bicarbonate-chloride. Groundwater from the Winton Formation, Wallumbilla Formation, Hooray Sandstone and Tertiary Sediments/Glendower Formation in general have higher proportion of sodium and magnesium.

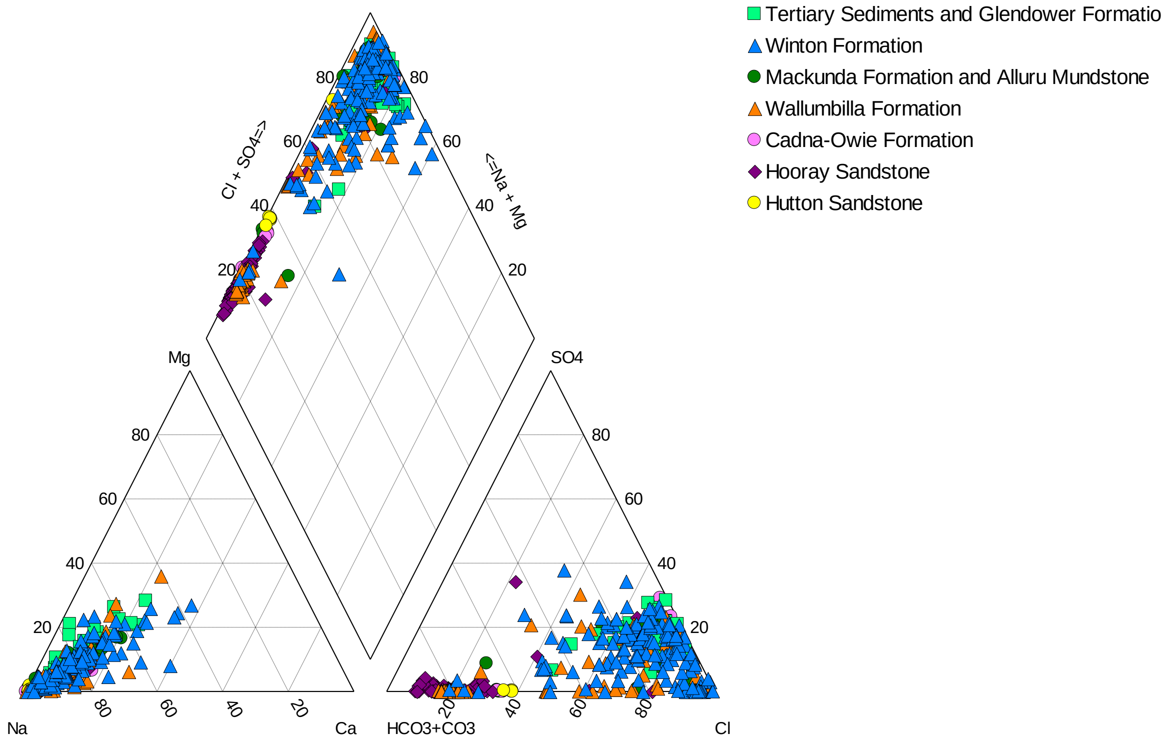

Figure 25. Piper Diagram – Groundwater samples collected within study area.

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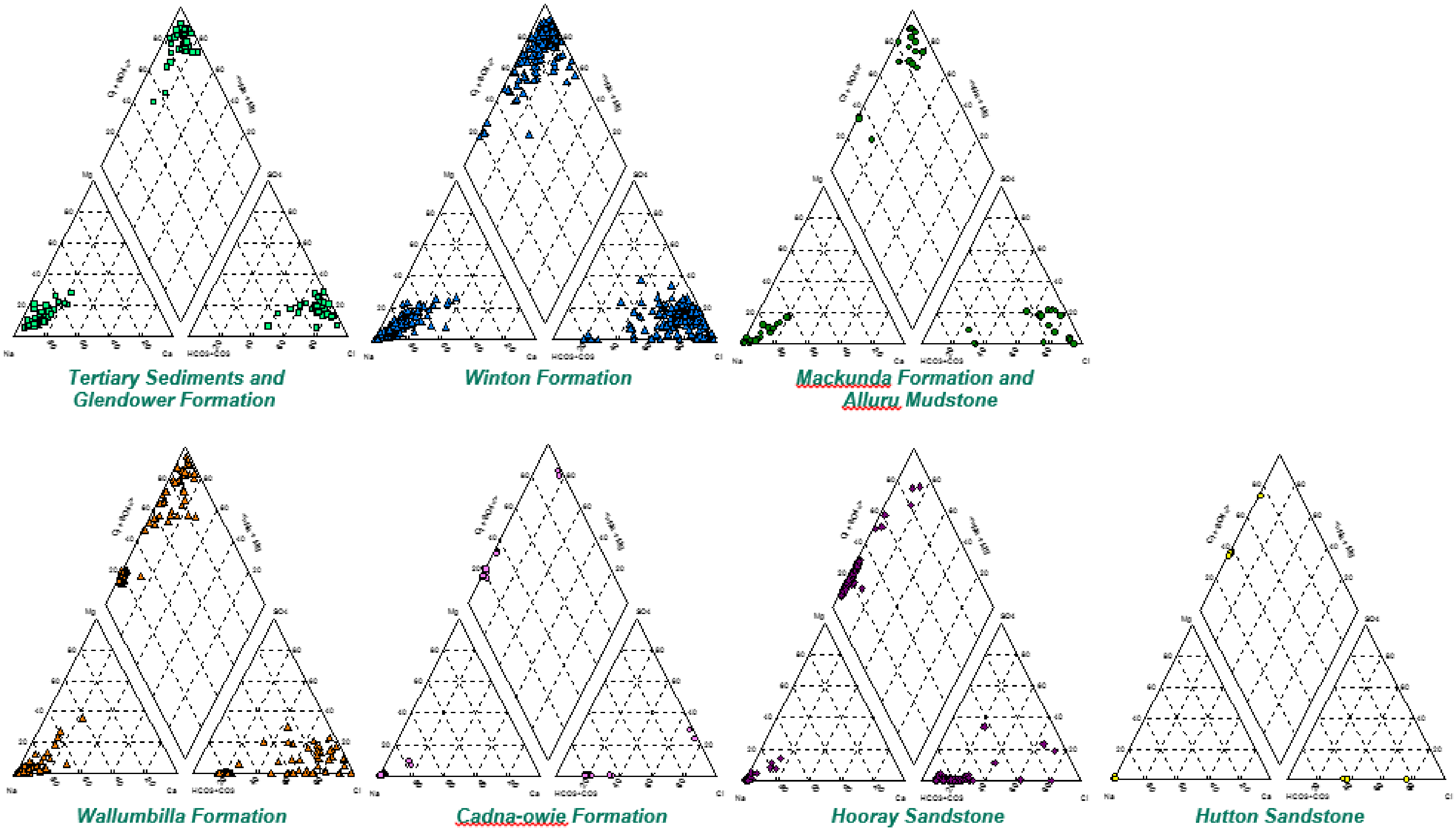

Figure 26. Piper Diagrams of Individual Formations within the Study Area (Golder 2013) Groundwater Use (other than Produced Water)

5.9 Groundwater Use (other than Produced Water)

The suitability of groundwater for different uses (potable, livestock, industrial) is largely dependent on aesthetics (taste) including, but not limited to pH and salinity. Groundwater for potable use generally has a pH value between 6.5 and 8.5 and a TDS value of <500mg/L (however TDS values of up to 1,000 mg/L TDS are tolerable). Groundwater suitable for livestock watering depends on the type of livestock (i.e. beef cattle verses sheep) and the length of time livestock will be exposed the water.

In the study area, groundwater is used primarily for stock and domestic use (not limited to potable) and some town water supply bores (municipal bores licenced with the Department of Natural Resource Management) have also been identified for the townships of Eromanga and Thargomindah.

No bores are registered for the Ballera and Jackson production facilities, however it is noted that Santos owns 104 water production bores.

Groundwater is sourced primarily from Tertiary and the upper GAB formations in the Eromanga Basin. Figure 27 presents a graphical representation of the distribution of groundwater sources over the study area.

The geographical distribution of groundwater sources for private bores and Santos bores is provided on Figure 28.

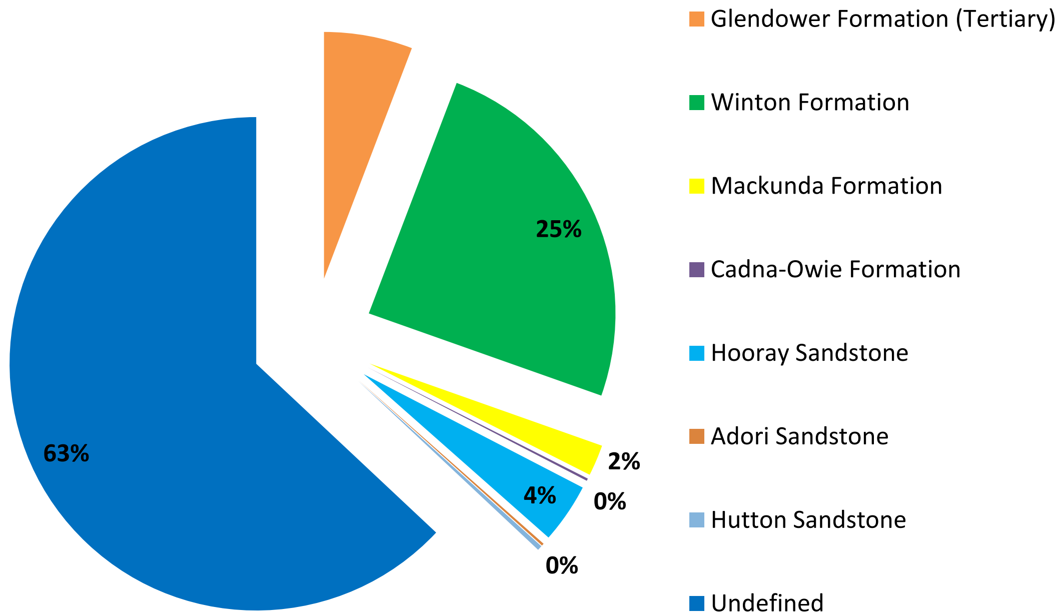

Figure 27. Groundwater Sources for Usage in the Study Area

Note: Figure 27 was generated using the data available in the DERM groundwater database. A total of 138 supply bores are licensed in the study area, and data sets provided information on either the type of pump infrastructure in place or if a bore is artesian. Where this information is available, is has been assumed that the groundwater is used by the community for various types of supply. It is noted that the information available assigns 63% of the bores in use to the Hooray Sandstone aquifer.

It is assumed that the properties in the study area have access to their own water supply through licenced stock and domestic bores. There is no groundwater entitlement associated with these licences however it is understood the bores extract a maximum of 5 ML/year.

Santos' water production, associated with oil and gas operations (as described in Section 6.3), is primarily from the Hutton Sandstone (82% of average annual production), the Birkhead Formation (7.8%) and the oil reservoirs of the Hooray Sandstone (8.6%).

The total volumetric water entitlement in the study area is 2,425ML/yr. Seven (7) urban and town supply bores are licenced however, it is noted that four of the licensed bores (totalling 900ML) were listed as "Lapsed/Never Constructed" and/or expired. The total nominal allowance for stock and domestic bores is 635ML/yr for 127 bores. The total extraction volume for the 134 licensed bores listed in the QLD Government website is therefore 1,525ML/yr (excluding lapsed/non-constructed bores entitlements.

Table 9 provides a summary of the estimated extraction from bores in the study area.

Table 9. Estimated Extraction from Bores in the Study Area

RN	Bore Status	Purpose	Entitlement (ML/yr)
Various (127 Bores)	Installed	Stock and Domestic (5ML/yr each)	635
358	Installed	Stock, Urban	70
390 n	Installed	Urban	600
50887	Installed	Domestic Supply, Stock, Urban	220
100219	Lapsed (Never Constructed)	Irrigation	100
116117	Lapsed (Never Constructed)	Urban	-
116117	Lapsed (Never Constructed)	Urban	600
116117	Lapsed (Never Constructed)	Town Water Supply	200
TOTAL			2,425

Note: Extraction data in italics have not been included in the total estimated water extraction for the study area (Lapsed/Never)

Figure 28 shows the geographical distribution of known bores in the study area. Bores with known target formations shown in Figure 28 are tabulated in Appendix E of Appendix A.

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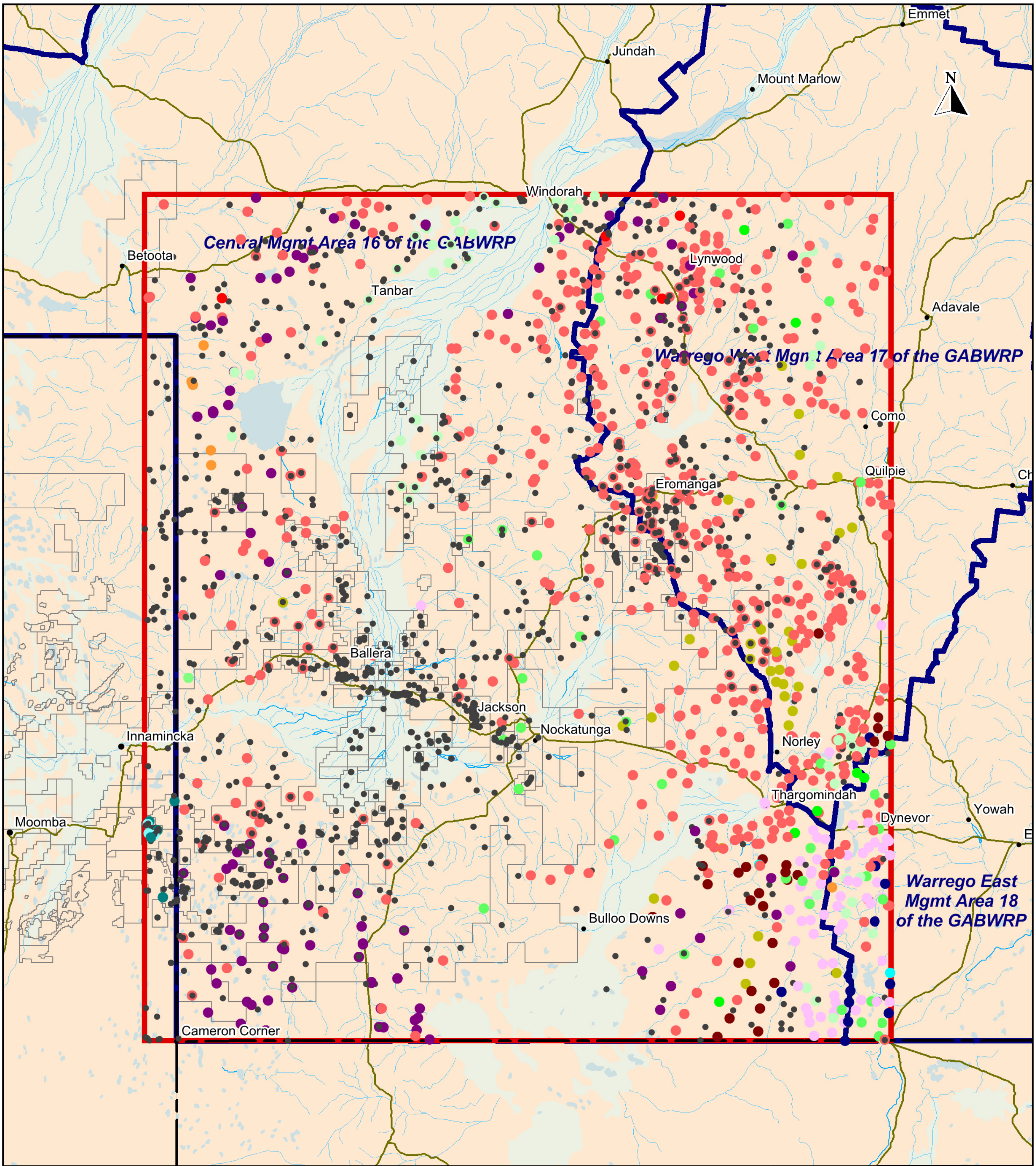

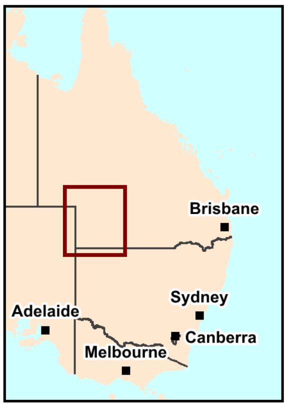

Town / Locality
Santos Acreage
Study Area
Groundwater Management Area
Highway / Major Road
River / Creek

Adori Sandstone
Allaru Mudstone
Cadna-owie Formation
Coreena Member
Doncaster Member
Glendower Formation
Helidon Sandstone
Hooray Sandstone
Hutton Sandstone
Mackunda Formation
Main Range Volcanics
Quaternary
Tertiary Sediments
Wallumbilla Formation
Winton Formation
Unknown

Santos

Cooper Basin UWIR

Geographical Distribution of Groundwater Use

Kilometres

0 20 40 60 80 100

Figure 28

20 May 2016, File No. ENVIR 661

6.0 Santos SWQ Operations

6.1 Gas Extraction

6.1.1 Areas of Production and Target Beds

Gas is extracted primarily from the formations of the Cooper Basin. Details on the geology of the Cooper Basin is presented in Section 4.3.4. The major gas reservoirs as include:

The Toolachee Formation.

The Epsilon Formation.

The Patchawarra Formation.

These reservoirs are stacked porous sandstone formations separated by finer grained siltstones and mudstone formations (refer to detailed stratigraphy in Figure 29. The latter are typically referred to as the seal or cap rock beds where they are located over the reservoirs.

There are approximately 190 producing gas wells within Santos SWQ tenements.

The deep geological setting of the gas targets prohibits access by domestic and municipal users.

6.2 Oil Production

6.2.1 Areas of Production and Target Beds

Oil is extracted primarily from the GAB formations within the Eromanga Basin at depth averaging 1,000m below ground level. Details on the geology of the Cooper Basin is presented in Section 4.3.4. The major oil reservoirs include:

The Murta Formation and the Namur Formation: these are the upper and lower formations of the Hooray Sandstone. Oil reservoirs are not frequent in the Namur Formation (a sandstone) but more abundant in the Murta Formation (interbedded mudstones, siltstones and fine grained sandstones).

The Birkhead Formation: the Birkhead formations are interbedded siltstone, mudstone and fine sandstone. Oil reservoirs are present in the basal Birkhead mostly, scattered oil reservoirs are found in the middle Birkhead Formation.

The Hutton Sandstone: this is the main extraction unit for oil over the Santos tenements in SWQ.

Minor oil reservoirs are also found in other formations:

The Wyandra Sandstone Member: this is the upper formation of the Cadna-Owie Formation, oil occurrence is not frequent

The Westbourne Formation and the Adori Sandstone.

Figure 30 summarises the occurrence of oil reservoir through the stratigraphic profile.

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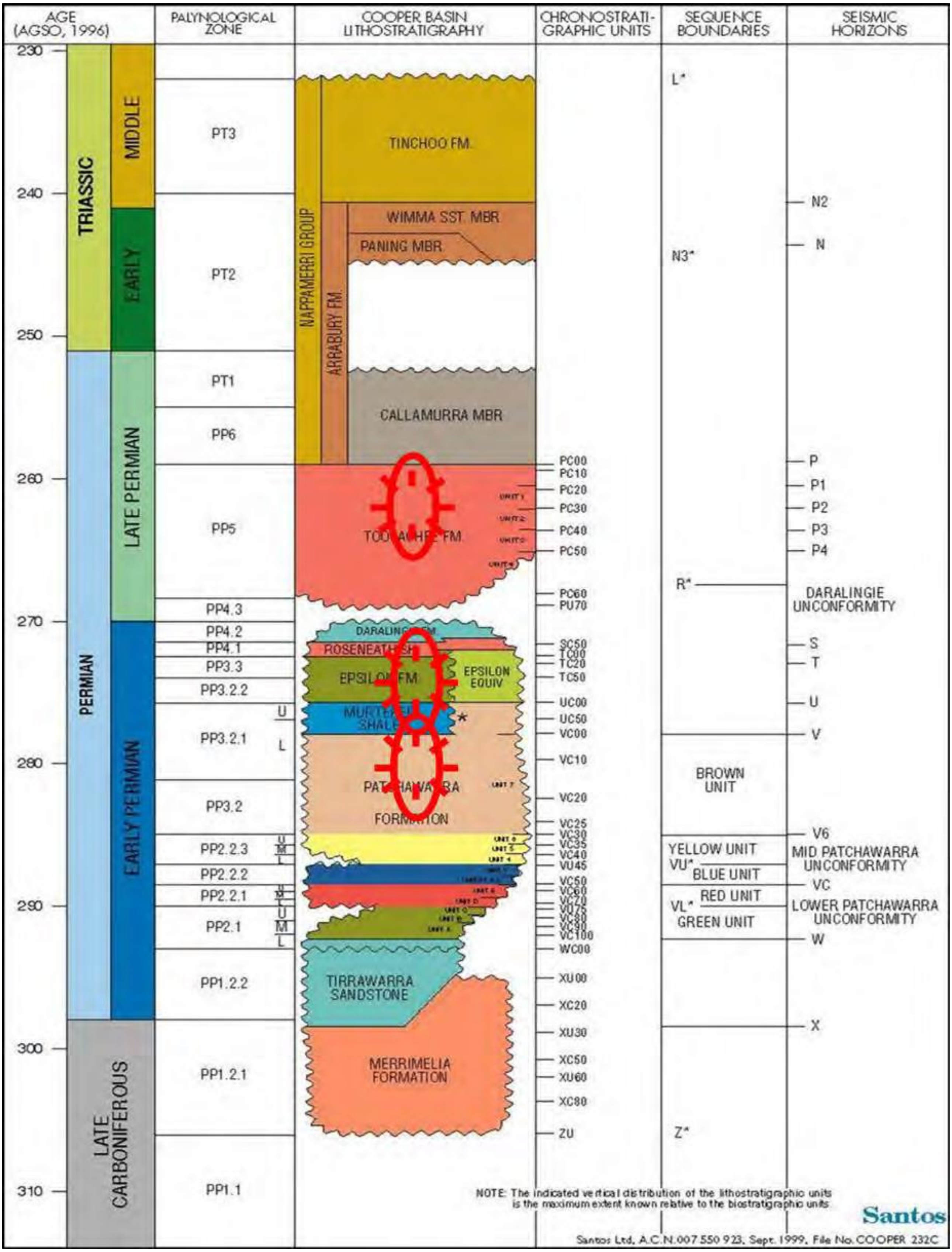

Figure 29. Gas Reservoirs Stratigraphical Distribution

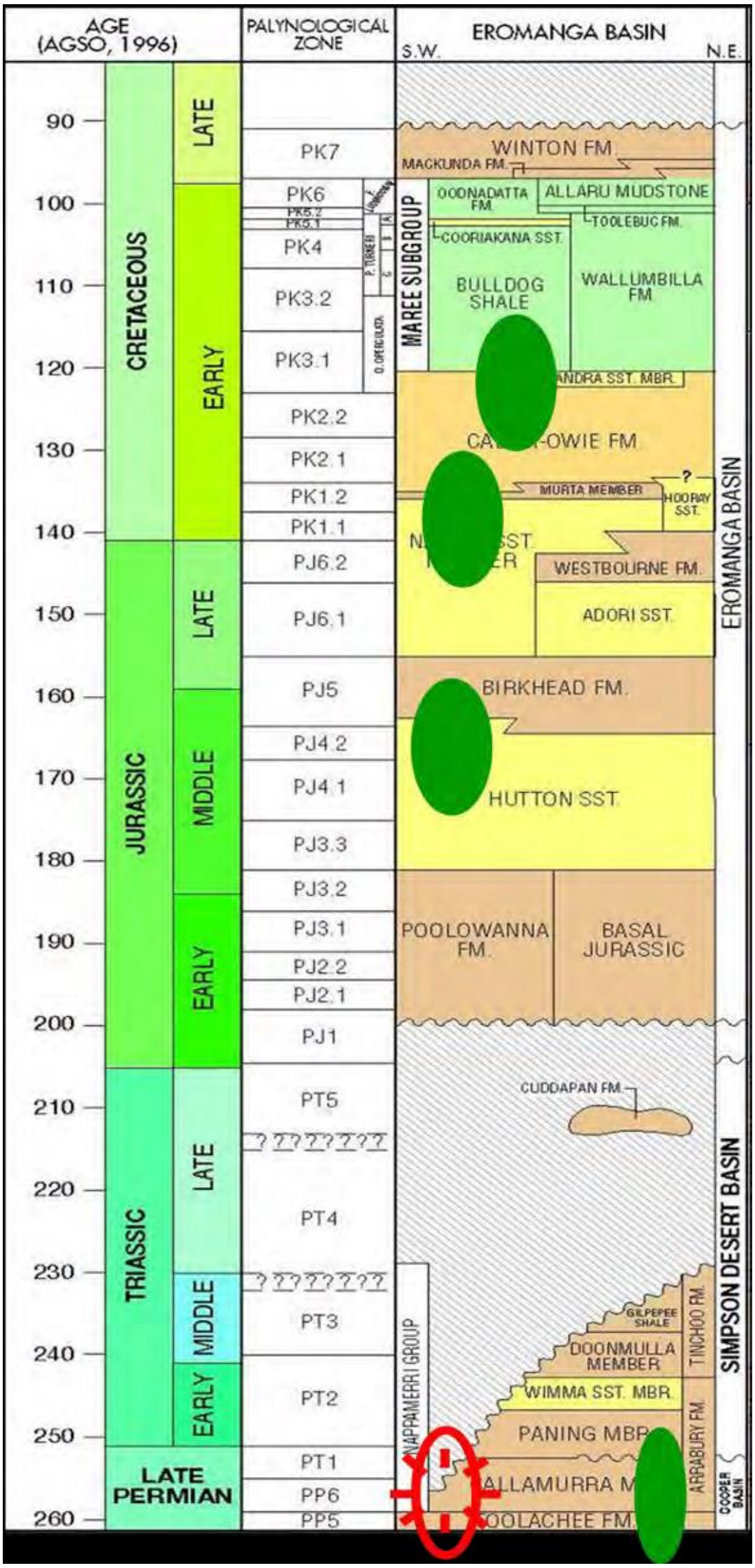

Figure 30. Oil Reservoirs Stratigraphic Distribution

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6.3 Produced Water Production

Water is produced as a co-product of oil and gas operations. The volume of water generated depends on a number of factors including (but not limited to) the type of well (i.e oil well versus gas well), the hydrocarbon formation and the age of the well. By comparison, gas wells generate smaller volumes of water than oil wells.

Santos currently (2019) operate 250 oil wells and 212 gas wells and in the study area.

6.4 Produced Water Monitoring Methodology

6.4.1 Produced Water Monitoring – Gas

The volume of water co-produced as part of Santos' gas operations is estimated based on the average water content of the gas produced.

The certainty around the volume of water produced as a result of gas production is lower than that for oil. However, given that gas production accounts for only 3% (approximately) of the total volume of water produced as a result of Santos' SWQ Cooper and Eromanga Basin operations, small variations in estimated versus actual produced volumes will not have a material impact on the overall drawdown calculations.

6.4.2 Produced Water Monitoring – Oil

The methodology for monitoring water produced as a result of oil operations includes:

- Individual well water-cut meters (Red-eye or DNOC).
- Wellhead water-cut samples.
- Tank dips.

Monthly allocation to any given well is based on:

- Estimation of the theoretical monthly oil and water production by well (using latest individual well test rates multiplied by the number of days the well was producing (i.e. uptime)).
- Summing the theoretical volume of a well or wells that collect into some fixed, known gathering point to give the monthly total theoretical oil & water volumes.
- Comparing theoretical volumes to actual monthly oil and water production at a fixed, known gathering point (where the monthly actual oil and water production is based on measurement of trucked oil loads, or oil piped through a fiscal metering point).
- Allocating (pro-rating) the total theoretical volumes to the individual wells based on the ratio of "actual total"/"theoretical total".

Santos' monitoring methodology for produced water (i.e. the approximately 5GL/year abstracted through oil production) is a reasonable approximation of actual volumes based on the premise that the total volume for each well is recorded at 2 points i.e. a known gathering point and a fiscal metering point.

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6.4.3 Methodology for Predicting Water Extraction

Santos does not estimate future produced water extraction for oil or gas activities in the Cooper and Eromanga Basins for operational planning purposes.

For the purposes of predictive modelling of the Eromanga and Cooper Basins however, Santos has used historical extraction data to estimate future extraction rates, taking into account an allowance for planned new wells within existing petroleum leases and also development of new leases. The history of activities in the Cooper and Eromanga Basins demonstrates an overall declining trend in extraction rates. Assuming water production rates do not decline is a conservative approach for determining depressurisation impact to groundwater because such extraction rates are likely to be higher than actual extraction rates in the future.

The methods used to determine these rates for both the IAA and Long Term Affected Along term (LTAA) for both the Eromanga and Cooper Basins are detailed below. Figure 31 presents the Cooper and Eromanga Basin water production rates over time. Note that annual production is shown on the basis of model layers (refer Section 7.0).

Water extraction rates were reported in Mega-Litres (ML) and sub-divided based on model layers presented in Section 7.0. The final volume for the year was converted into cubic metres per day (m^3/day) and divided by the number of wells within the model domain to obtain a representative extraction rate for each extraction point.

Eromanga Basin

For the purposes of IAA predictive modelling of the Eromanga Basin (i.e. extraction for the next 3 years), Santos has used extraction data from the last year of historical data (2019) to represent future extraction rates. The total 2019 annual water production rates were evenly distributed across the extraction points.

For the purposes of LTAA predictive modelling of the Eromanga Basin, the long term extraction rates applied were calculated using the following approach:

The same extraction rate per well is assumed as for the IAA calculations;

The total number of wells is increased at existing petroleum leases according to Santos plans;

In addition, at planned new leases additional wells were incorporated in the model with the same rate.

Cooper Basin

For the purposes of IAA predictive modelling of the Cooper Basin (i.e. extraction for the next 3 years), Santos has used extraction data from the last year of historical data (2019) to represent future extraction rates. The total 2019 annual water production rates were evenly distributed across the extraction points.

For the purposes of LTAA predictive modelling of the Eromanga Basin (i.e. extraction for the next 20 years), the longterm extraction rates applied were calculated using the following approach.

The same extraction rate per well is assumed as for the IAA calculations;

The total number of wells is increased at existing petroleum leases according to Santos plans;

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In addition, at planned new leases additional wells were incorporated in the model with the same rate.

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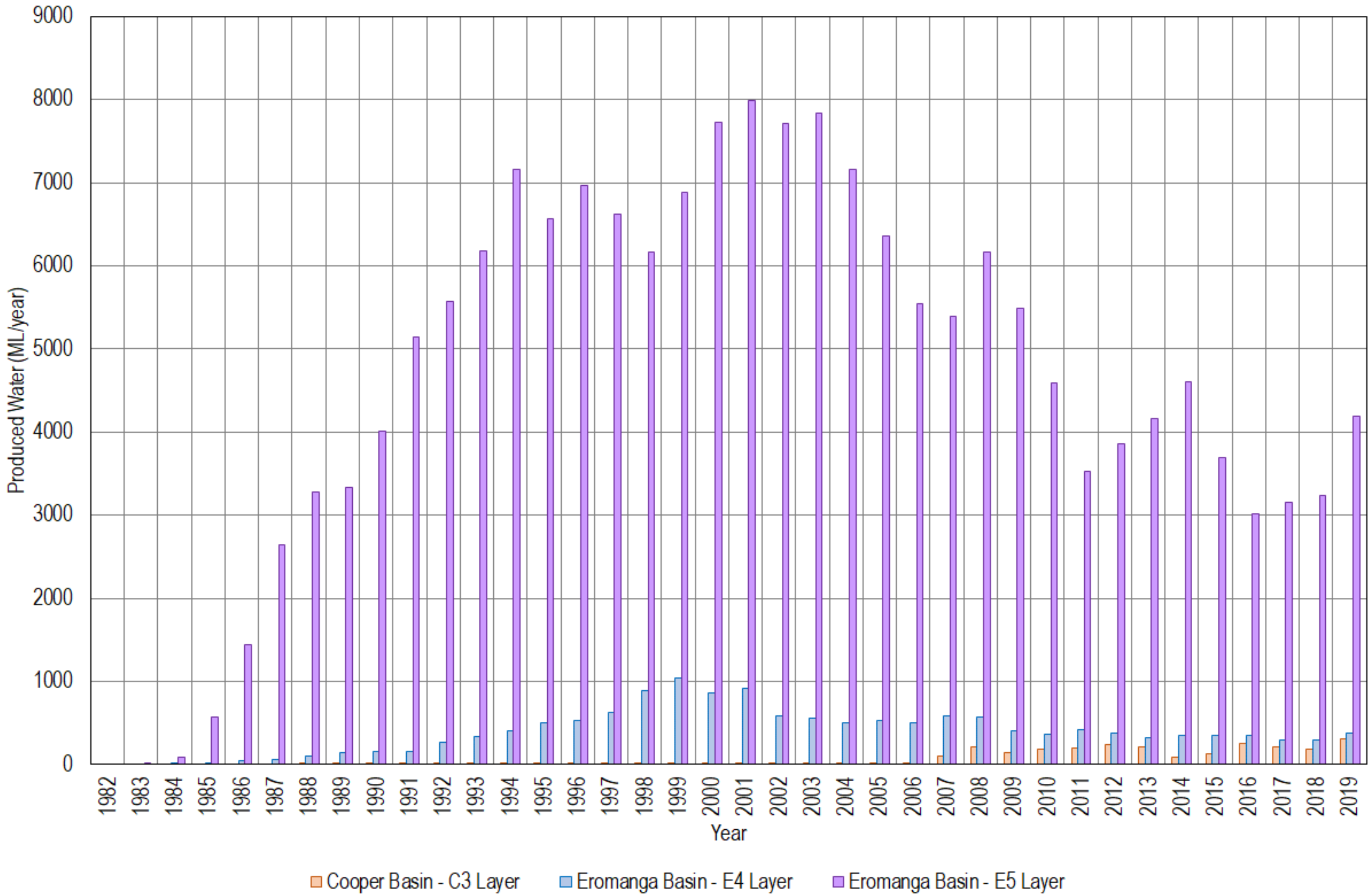

Figure 31. Variation over time of produced Water in Santos SWQ Oil and Gas Fields.

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7.0 Groundwater Impact Estimation

For the purposes of this UWIR, the 'affected area' in shallow alluvial aquifers is considered the areas where a drawdown of 2m is observed and in consolidated rock aquifers areas where a drawdown of greater than 5m is observed. Impacts to groundwater dependant ecosystems (GAB springs) is a calculated drawdown of 0.2 m directly beneath the spring.

7.1 Analytical Approach

Analytical groundwater modelling has been undertaken by independent consultants Golder Associates, to provide estimates of the decline in water level response to the extraction of co-produced water from the Cooper and Eromanga Basins. The model used to inform this UWIR is the model that used to develop the 2016 Santos UWIR, approved by DRNM in December 2016. No changes to the 2016 model framework were undertaken in this review period (2016-2019). The 2013 UWIR is attached to this report as Appendix A, since it documents the general geometry, parametrization and boundary conditions of the model.

As per the 2016 UWIR, Golder applied analytical modelling to represent the potential drawdown in the target hydrocarbon reservoirs and adjacent formations of the Cooper and Eromanga Basins for the 2019 review period. Drawdown estimates were made for both the immediate and long term to provide an indication of the magnitude of impact.

An analytical approach was considered appropriate based on the following:

Depth of extraction: Santos extracts co-produced water from depths greater than 2,000m bgl in the Cooper Basin and for more than 90% of Eromanga Basin wells,1000m bgl. It is noted that most private bores in the Eromanga Basin target the upper (Quaternary and Tertiary) formations where economic hydrocarbons are not present.

Stratigraphic settings: numerous confining beds separate the deeper target hydrocarbon bearing formations and the upper aquifers which are accessed primarily by private users for water supply.

Geographic extent: Santos' SWQ operations cover an area in excess of 8,000km² and are classified as remote. The density of production activities (including water extraction) is therefore considered to be very low.

Data availability: Based on the depth of extraction, stratigraphic setting and geographical extent of Santos' SWQ operations, the quality and quantity of data available is not suitable for numerical interpretation.

7.1.1 AnAqSim Analytical Software

The groundwater impact estimation was undertaken using the AnAqSim analytical solution (version 2019-1). Details on the AnAqSim modelling package are presented in Section 7.1.2 of the 2013 UWIR (Attachment A).

To evaluate the potential impact of extraction in the study area, analysis was divided into two separate calculation exercises:

- *Eromanga Basin*: containing the Early Jurassic to Late Cretaceous strata, namely the GAB aquifers.
- *Cooper Basin*: containing the Late Carboniferous, Permian and to Triassic strata, namely the older pre- GAB aquifers.

The model domains are presented in Table 25 and Table 26 of the 2013 UWIR attached to this report as Appendix A.

The division into two separate domains permitted the allocation of five layers in the Eromanga Basin, which was considered as a separate hydraulic system from the underlying Cooper Basin strata. Based on the thickness of the low permeability layers, and the small abstraction rate in the Cooper Basin, it was anticipated that impact beyond the top of the Tinchoo Formation (i.e. the top of the Cooper Basin) would not occur. Therefore, if no impact was predicted by the analysis at the top of the Cooper Basin, it is considered reasonable to omit this from the overlying Eromanga Basin calculations.

7.1.2 2020 Assumptions and Limitations

The assumptions and limitations associated with development of the 2013 and 2016 AnAqSim analytical model are presented in Section 7.1.3 of 2013 UWIR (Attachment A) and 7.1.2 of 2016 UWIR (see Appendix C).

The assumptions and limitations associated with the 2020 analytical modelling include:

- Predictive simulation production rates were based on operational records and run in steady state, which is a conservative approach providing a maximum drawdown scenario for the groundwater impact estimation.

The number and location of extraction points representing production wells in the 2016 UWIR/AnAqSim model were changed in the 2020 model:

- Total annual extraction in 2019 was divided equally between all wells. All the active wells in the Santos data base were explicitly incorporated in the models.
- The 2020 UWIR AnAqSim models include 250 extraction points in the Eromanga Basin and 212 extraction points in the Cooper Basin.
- Given the resolution of the model, this approach was considered representative of the total extraction, both volumetrically and spatially. This was further refined for the immediately affected and long term calculations, as follows:
  - For the purposes of IAA predictive modelling of both the Eromanga and Coopers Basins, Santos has used extraction data from the last year of historical data (2019) to represent future extraction rates. These values are considered to be representative over the next three years. This was considered conservative as the actual extraction is likely to decline over this period.
  - For the purposes of LTAA predictive modelling of both the Eromanga and Cooper Basins, Santos applied extraction data for both basins that was calculated by taking into account an increase in the number of production wells in existing petroleum leases and

production from planned new petroleum leases. The number of additional wells is summarized in Table 10

Table 10. Number of existing and additional wells in the long term affected area model

Basin	Number of Existing Wells	Number of Proposed New Wells at Existing PL`s	Number of Proposed New Wells at New PL`s
Eromanga	250	287	118
Cooper	212	348	263

7.2 Groundwater Impact Calculation Input Parameters

The simplified geological layering used in the calculation for the Eromanga Basin and Cooper Basin is presented in Table 25 and Table 26 of the 2013 UWIR attached as Appendix A to this report. The simplified layering structure grouped similar adjacent strata together (where appropriate), to reduce the observed stratigraphy into no more than five (5) layers.

Input parameters were sourced from Santos records and historical reports, literature values and from Golder's experience in the area (as discussed in Section 5.4). The impact of the selected hydraulic property values was interrogated using a specified sensitivity analysis (Section 7.6 of Appendix A).

QLD Government groundwater level monitoring data including artesian pressure data (Section 5.5) was used to establish a representative initial groundwater levels for each model layer as well as observed pressure data from Santos wells.

7.2.1 Analytical Model Abstraction Rates

Details on the extraction rates applied to the study area model layers, and the proportion of extraction assigned to each field is detailed in Section 7.2.4 of the 2013 UWIR provided as Attachment A.

To summarise, the proportion of extraction from each field in the study area was assigned as follows based on the 2019 data set:

Eromanga Basin - Layer 4 (Cadna-Owie Formation and Hooray Sandstone): accounting for 7.7% of the total annual extraction.

Eromanga Basin - Layer 5 (Late to Early Jurassic (Westbourne Formation, Adori Sandstone, Birkhead Formation, Hutton Sandstone and Poolowanna Formation)): accounting for 85.9% of the total annual extraction.

Cooper Basin - Layer 3 (Early to Late Permian (Toolachee and Daralingie Formations, Roseneath Shale, Epsilon Formation, Murtree Shale and Patchwarra Formation)) accounting for 6.4% of the total annual extraction.

As mentioned in the 2013 and 2016 UWIR, abstraction from Layer 4 was assigned to the underlying Layer 5 to maintain numerical stability in the model and that assigning extraction in the base layer of the model provided additional numerical stability. Layer 5 was selected as the majority of extraction is likely to be sourced from these stratums. Concentrating extraction in this manner was considered suitable as drawdown was still able to propagate upwards through Layer 4 to the overlying layer.

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7.2.2 Model Extent and Boundary Conditions

Details on the model extent, boundary conditions and model layers used to represent the study area and associated stratigraphy are presented in Sections 7.2.1 and 7.2.3 of the 2013 UWIR attached to this report (Appendix A). Figure 32 presents a graphical representation of the Eromanga Basin model extent and Figure 33 presents the Cooper Basin model extent.

7.3 Sensitivity Analysis

As noted in Section 7.1, the analytical model developed for the 2013 UWIR and approved by DRNM in July 2013 has been used to inform this UWIR. No changes to the 2013 model framework have been made in this review period and subsequently no sensitivity analysis undertaken as part of this UWIR. Details on the sensitivity analysis undertaken as part of the 2013 UWIR are presented in Section 7.6 of the report (Appendix A).

7.4 Water Production Volumes Used for the Analytical Modelling

Water extraction rates were reported in mega litres (ML) and sub-divided based on the geological formations and petroleum lease. The final volume for the year was converted into cubic metres per day (m^3/day) and divided by the number of wells within the model domain to obtain a representative extraction rate for each extraction point.

- For the purposes of IAA predictive modelling of both the Eromanga and Coopers Basins, Santos has used extraction data from the last year of historical data (2019) to represent future extraction rates.
- For the purposes of LTAA predictive modelling of both the Eromanga and Coopers Basins, Santos applied the same extraction data as in case of IAA for both basins but considered additional new wells at existing petroleum leases and at new petroleum leases.

The rate of groundwater extraction in the analytical model is representative of a steady state solution. Extraction rates used in the modelling are provided in Table 11 and summarised as follows:

Eromanga Basin

- For the purposes of IAA predictive modelling for the Eromanga Basin an extraction rate of 49.92m^3/day per well was used. This approach ensures that production rate per tenement is proportional to the number of existing wells on the tenements. Note this value per well is higher than used in the 2016 model due to the lower number of wells included in the model.
- For the purposes of LTAA predictive modelling for the Eromanga Basin the same extraction rate of 49.92m^3/day per well was used. The flow rate to individual wells has been assigned in the following way:
  - For the existing petroleum leases, use the same number of wells in the model to represent water extraction (since we don`t know the coordinates of the planned wells) as used in the IAA model and increase flow rate from that used in the IAA model in proportion with the number of new wells planned; and

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For the proposed new petroleum leases, add one well per lease (since we don`t know the coordinates of planned wells) and use a flow rate proportional to the number of proposed wells.

This approach ensures that the extraction rate per well remains 49.92m^3/day and the total extraction rate per tenement matches the number of existing and proposed wells.

Cooper Basin

For the purposes of IAA predictive modelling of the Cooper Basin an extraction rate of 4.01m^3/day per representative well.

For the purposes of LTAA predictive modelling of the Cooper Basin the same extraction rate of 4.01m^3/day per well. The methodology used was the same as for the Eromanga Basin model.

Table 11. Water Extraction Rates - 2020 UWIR Model

Analytical Model	Immediately Affected Area	Long Term Affected Area
Cooper Basin[1]	No. of representative wells = 212 Extraction per well = 4.01 m^3/day/well Total extraction = 310 ML/year	No. of representative wells = 823 Extraction per well = 4.01 m^3/day/well Total extraction = 1205 ML/year
Eromanga Basin[2]	No. of representative wells = 250 Extraction per well = 49.92 m^3/day/well Total extraction = 4560 ML/year	No. of representative wells = 655 Extraction per well = 49.92 m^3/day/well Total extraction = 11945 ML/year

Notes:

1. Extraction from the C3 layer in the Cooper Basin model
2. Combined extraction from layers E4 and E5 in the Eromanga Basin model

7.4.2 Observed Groundwater Levels and Calibration Targets

Details of the analytical model calibration process are presented in Section 7.2.5 of the 2013 UWIR provided as Attachment A.

To summarise, hydrostatic pressure and groundwater levels in select, targeted oil or gas formations, in conjunction with data available in the DNRM groundwater database were used to calibrate the study area model. Calibration was undertaken on both model domains using observed groundwater levels and calculated groundwater levels in un-pumped conditions. The bottom flux and hydraulic conductivity values were altered until a satisfactory fit was achieved. A plot of modelled verses observed groundwater level for the Eromanga Basin is provided as Figure 40 of the 2013 UWIR attached as Appendix A.

The analytical model was not re-calibrated as part of the 2020 review period, as no changes to the boundary conditions, extent or domain were made.

7.5 Calculated Impact in the Eromanga Basin

The 2020 model was run in steady state using updated extraction rates (2019) to provide a conservative, worst case scenario for the IAA and LTAA. The calculated drawdown for each layer is presented on Figure 34 to Figure 41.

The maximum calculated drawdown in each layer along the cross sectional lines is presented in Table 12. The impacts associated with the predicted drawdown include:

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The maximum estimated drawdown in the IAA due to extraction from the Eromanga Basin in the Tertiary and Quaternary strata (Layer 2, this includes the Glendower and Winton Formations where they are confined) is less than 2m. The maximum estimated long term drawdown in the same units is less than 4m.

A maximum drawdown of approximately 57m (IAA) and 115m (LAA) was estimated for the Cadna-Owie Formation and Hooray Sandstone. The computed 5m drawdown contour does not extend outside of Santos tenements.

A maximum drawdown of 11m (IAA) and 21m (LAA) was estimated in Layer 3 of the model (representing the Mackunda Formation, Allura Mudstone, Toolebuc and Wallumbilla Formations). The computed 5m drawdown contour does not extend beyond Santos tenement boundaries.

A maximum drawdown of approximately 182m (IAA) and 268m (LAA) was estimated for the Westbourne Formation, Adori Sandstone, Birkhead Formation, Hutton Sandstone and Poolowanna Formation of the Eromanga Basin. The calculated 5m drawdown contour line does not extend outside of Santos tenements; however, the drawdown radius of influence has increased from previous modelling and is likely the result of increased pumping rates.

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Table 12. Calculated maximum drawdown along lines of section – Eromanga Basin

Layer Number	Layer Description	Maximum Drawdown in the Eromanga Basin (m)	
		Immediately Affected Area	Long Term Affected Area
2	Quaternary, Tertiary and Winton Formation	2	4
3	Alluru, Toolebuc and Wallumbilla Formations	11	21
4	Cadna-owie Formation and Hooray Sandstone	57	115
5	Westbourne, Adori and Birkhead Formations / Hutton Sandstone and Poolowanna Formation	182	268

Groundwater level and pressure model outputs indicate that even under steady state conditions, limited drawdown or pressure decline propagation (from artesian aquifers) into Layer 2 has occurred. It is expected that actual drawdown will be less than the calculated drawdown based on:

intermittent and time-limited operation of the extraction wells.

Conservative assessment of flow rate assigned to each well.

Figure 40 also presents the spatial distribution of contours representing greater than 5m of drawdown. It is noted that contours (>5m) are limited to the areas where wells are most concentrated.

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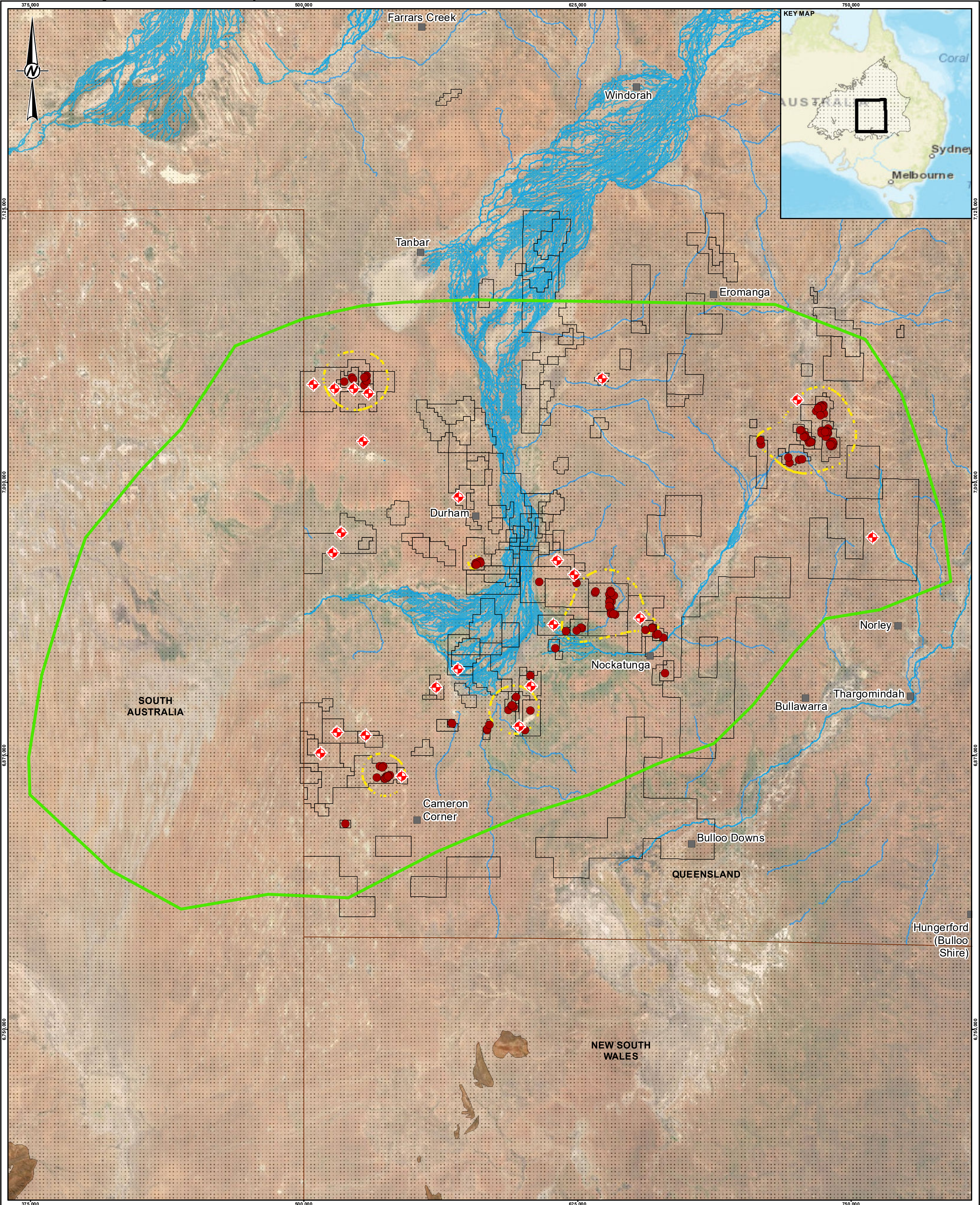

LEGEND

- Bounded Locality
- Existing Production Well
- Planned Production Well
- Model Drawdown - Layer 1 (0.2 m)
- Watercourse
- Eromanga Model Extent
- Santos Operated Permits
- Australian State Boundary
- Eromanga Basin

Coordinate System: GDA 1994 MGA Zone 54
Projection: Transverse Mercator
Datum: GDA 1994

0 25 50
1:1,600,000 @ A3 KILOMETRES

REFERENCE(S)

1. Australian State Boundaries, Bounded Localities, Petroleum Leases, Waterways: © State of Queensland (Department of Natural Resources, Mines and Energy) 2019
2. Eromanga Basin Extent: Geological Provinces - Full Extent, Creative Commons Attribution 3.0 Australia, http://creativecommons.org/licenses/by/3.0/au/, (c) Commonwealth of Australia (Geoscience Australia) 2014
3. Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

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APPROVED	KB

TITLE
EXTENT OF THE EROMANGA BASIN MODEL DOMAIN

PROJECT NO.	CONTROL	REV.	FIGURE
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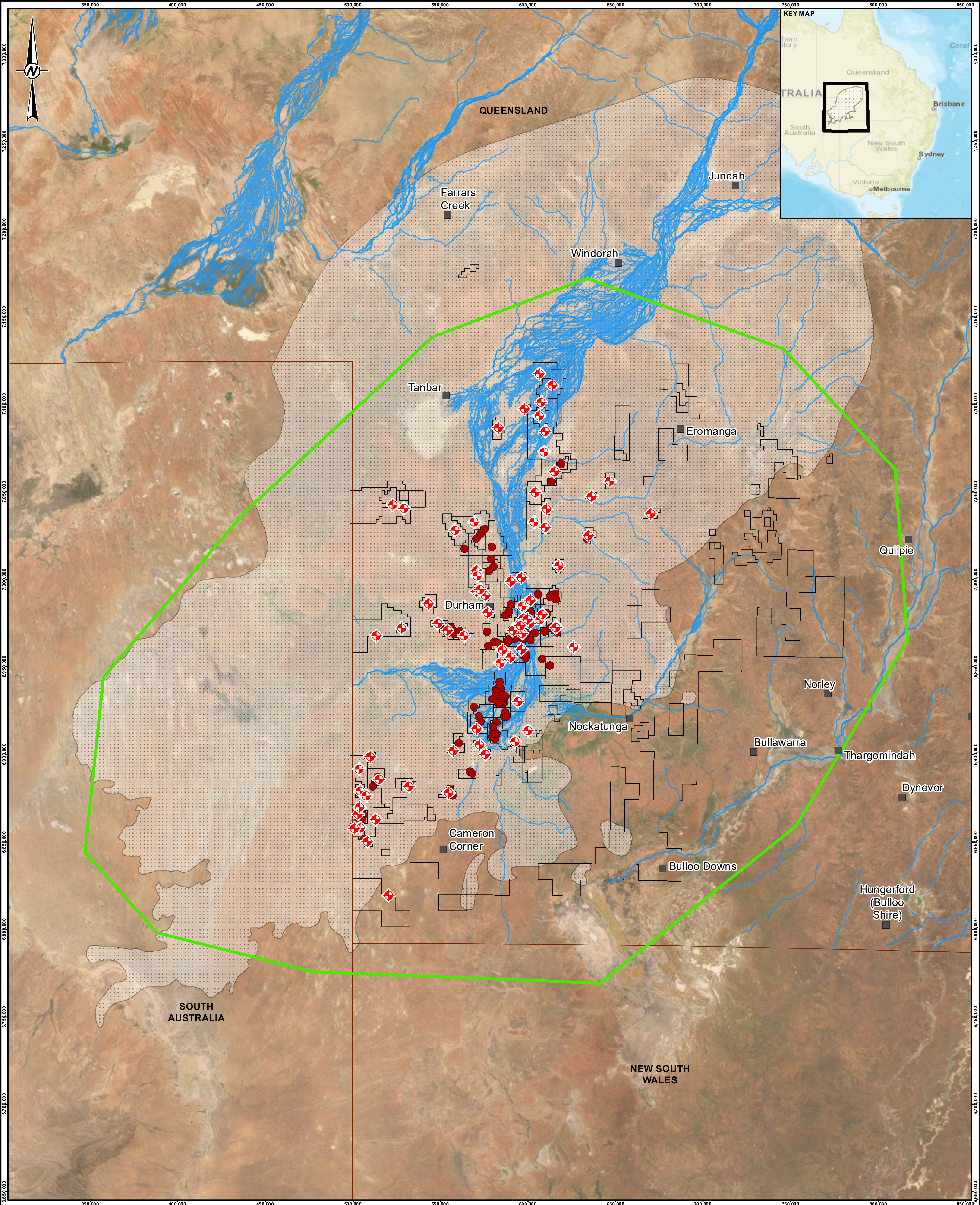

LEGEND

- Bounded Locality
- Existing Production Well
- Planned Production Well
- Watercourse
- Cooper Basin Model Domain
- Santos Operated Permits
- Australian State Boundary
- Eromanga Basin

Coordinate System: GDA 1994 MGA Zone 54
Projection: Transverse Mercator
Datum: GDA 1994

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1:2,000,000 @ A3 KILOMETRES

REFERENCE(S)

1. Australian State Boundaries, Bounded Localities, Petroleum Leases, Waterways: © State of Queensland (Department of Natural Resources, Mines and Energy) 2019
2. Eromanga Basin Extent: Geological Provinces - Full Extent, Creative Commons Attribution 3.0 Australia, http://creativecommons.org/licenses/by/3.0/au/, (c) Commonwealth of Australia (Geoscience Australia) 2014
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PREPARED	HG
REVIEWED	KB
APPROVED	KB

TITLE
EXTENT OF THE COOPER BASIN MODEL DOMAIN

PROJECT NO.	CONTROL	REV.	FIGURE
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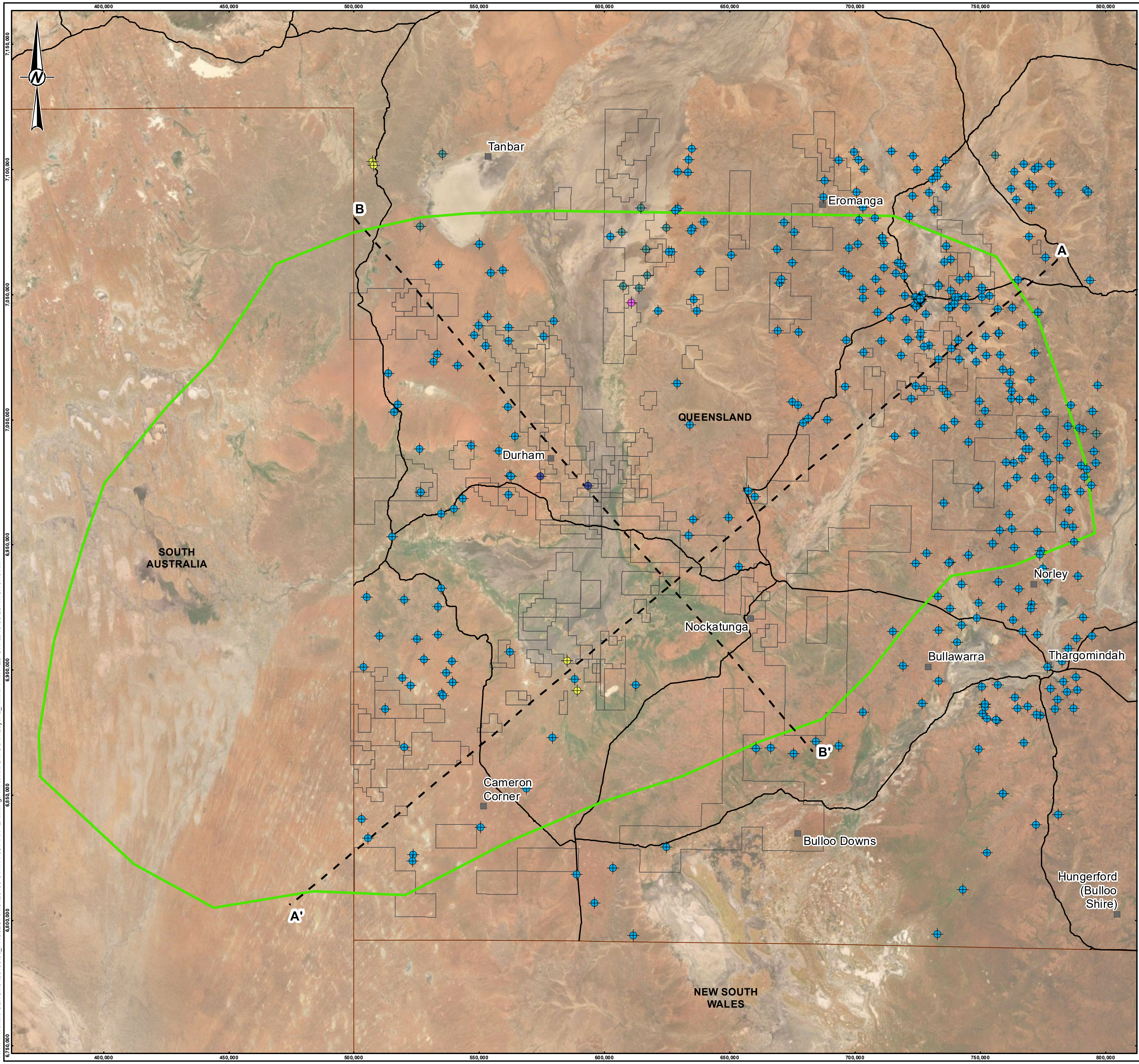

LEGEND

Registered Bore

Formation Description

- Tertiary Sedimeform
- Tertiary - Undefined
- Quaternary - Undefined
- Winton Formation
- Winton/Muckunda Formation
- Bounded Locality
- Groundwater Line in Section
- Roads/Tracks
- Eromanga Model Extent
- Drawdown (5 m)
- Santos Operated Permits
- Australian State Boundary

Coordinate System: GDA 1994 MGA Zone 54
Projection: Transverse Mercator
Datum: GDA 1994

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REFERENCE(S)

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TITLE
IMMEDIATELY AFFECTED AREA - EROMANGA BASIN MODELLED GROUNDWATER DRAWDOWN IN LAYER 2

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PREPARED	HG
REVIEWED	DP
APPROVED	KB

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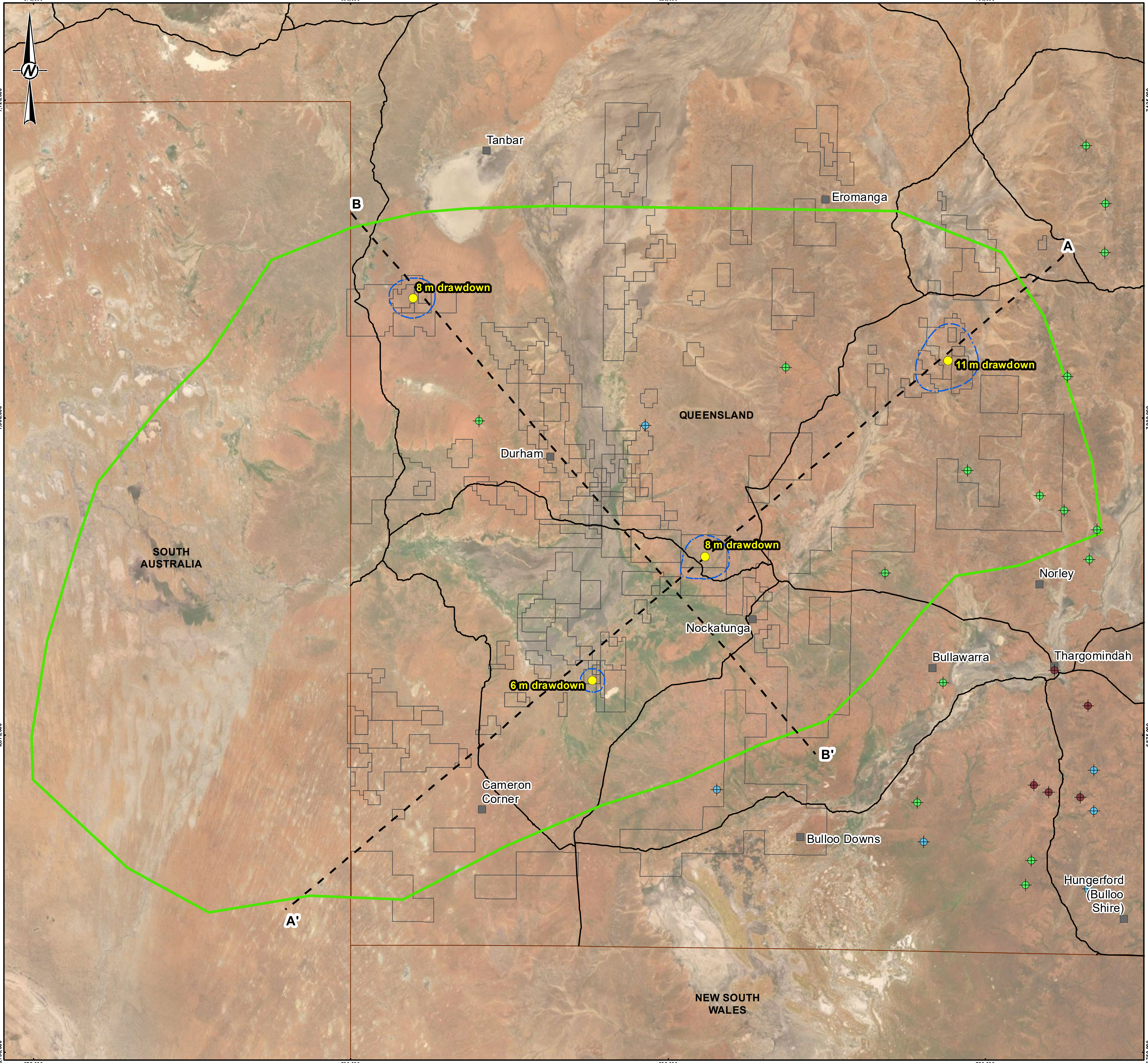

LEGEND

Registered Bore

Formation Description

- Makunda Formation
- Allaru Mudstone
- Wallumbilla Formation
- Maximum Drawdown (m AHD)
- Bounded Locality
- Groundwater Line in Section
- Roads/Tracks
- Eromanga Model Extent
- Drawdown (5 m)
- Santos Operated Permits
- Australian State Boundary

Coordinate System: GDA 1994 MGA Zone 54
Projection: Transverse Mercator
Datum: GDA 1994

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REFERENCE(S)

1. Australian State Boundaries, Bounded Localities, Petroleum Leases, Roads/Tracks: © State of Queensland (Department of Natural Resources, Mines and Energy) 2019
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PROJECT	SANTOS UWIR UPDATE SOUTHWEST QLD
TITLE	**IMMEDIATELY AFFECTED AREA - EROMANGA BASIN MODELLED GROUNDWATER DRAWDOWN IN LAYER 3**

CONSULTANT

GOLDER

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DESIGNED	HG
PREPARED	HG
REVIEWED	KB
APPROVED	KB

PROJECT NO.	CONTROL	REV.	FIGURE
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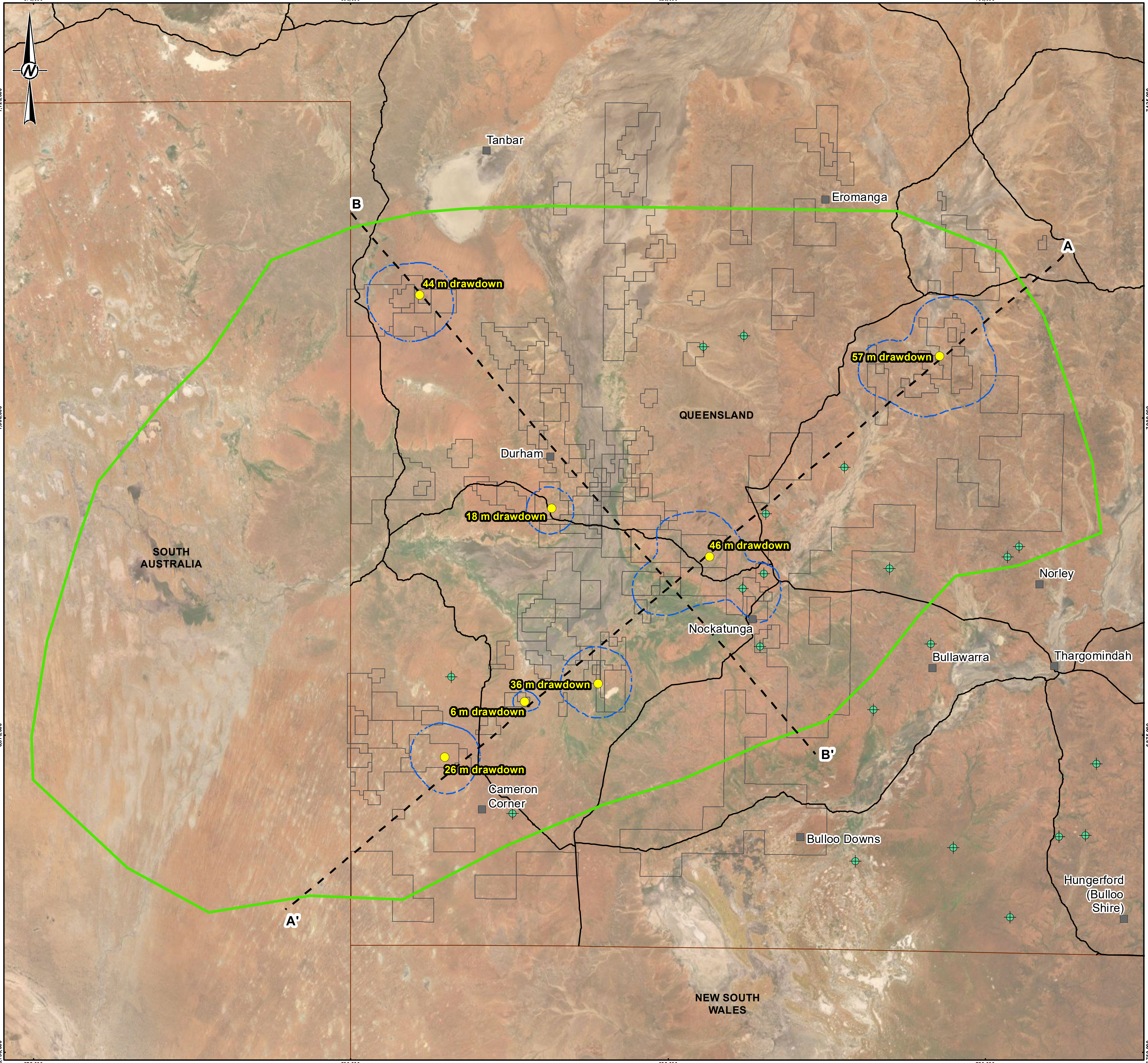

LEGEND

Registered Bore

Formation Description

- Hooray Sandstone
- Maximum Drawdown (m AHD)
- Bounded Locality
- Groundwater Line in Section
- Roads/Tracks
- Eromanga Model Extent
- Drawdown (5 m)
- Santos Operated Permits
- Australian State Boundary

Coordinate System: GDA 1994 MGA Zone 54
Projection: Transverse Mercator
Datum: GDA 1994

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REFERENCE(S)

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TITLE
IMMEDIATELY AFFECTED AREA - EROMANGA BASIN MODELLED GROUNDWATER DRAWDOWN IN LAYER 4

CONSULTANT

GOLDER

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PREPARED	HG
REVIEWED	DP
APPROVED	KB

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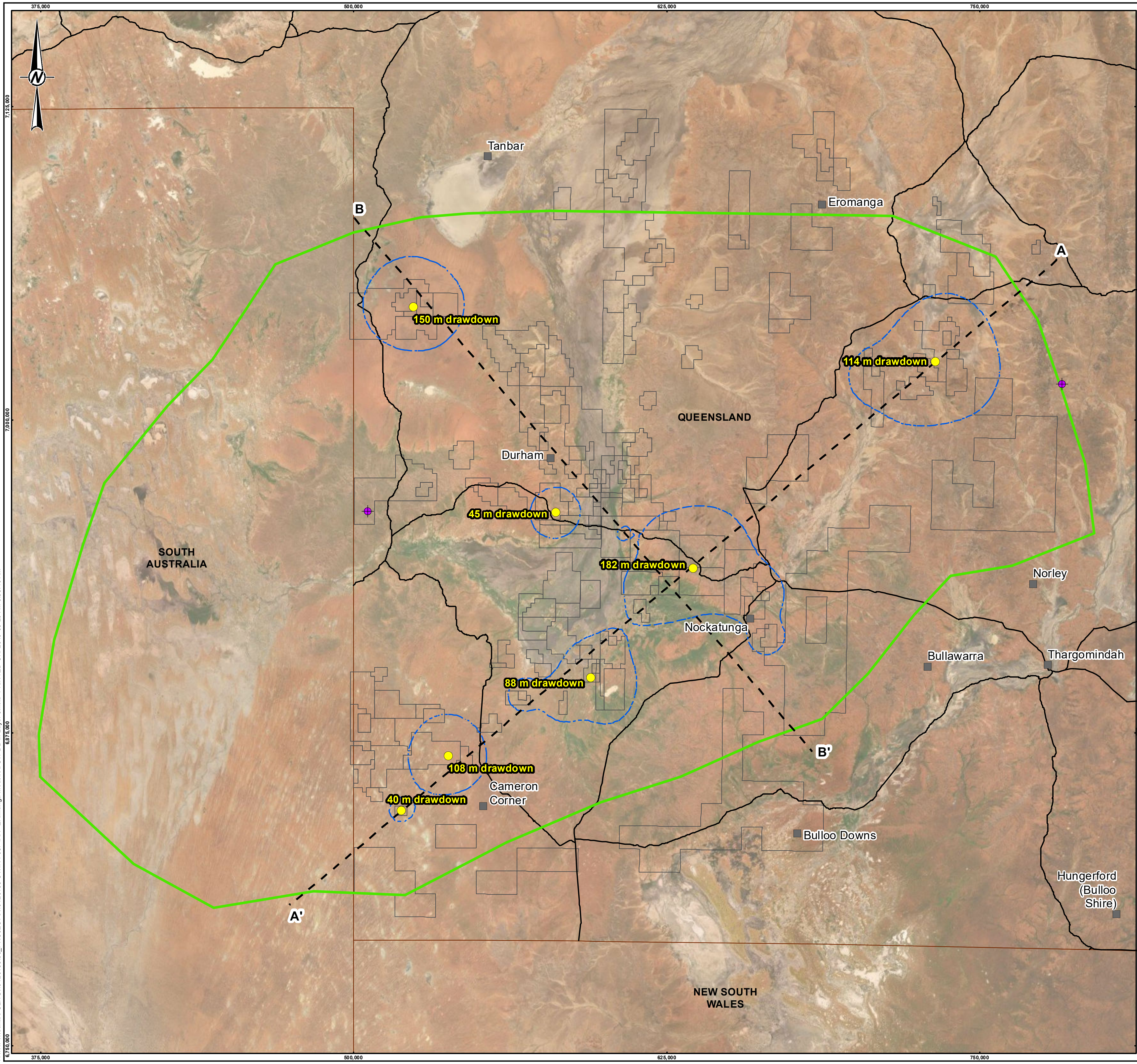

LEGEND

Registered Bore

Formation Description

- Hutton Sandstone
- Maximum Drawdown (m AHD)
- Bounded Locality
- Groundwater Line in Section
- Roads/Tracks
- Eromanga Model Extent
- Drawdown (5 m)
- Santos Operated Permits
- Australian State Boundary

Coordinate System: GDA 1994 MGA Zone 54
Projection: Transverse Mercator
Datum: GDA 1994

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REFERENCE(S)

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TITLE
IMMEDIATELY AFFECTED AREA - EROMANGA BASIN MODELLED GROUNDWATER DRAWDOWN IN LAYER 5

CONSULTANT

GOLDER

DD-MM-YYYY	29-08-2019
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REVIEWED	DP
APPROVED	KB

PROJECT NO.	CONTROL	REV.	FIGURE
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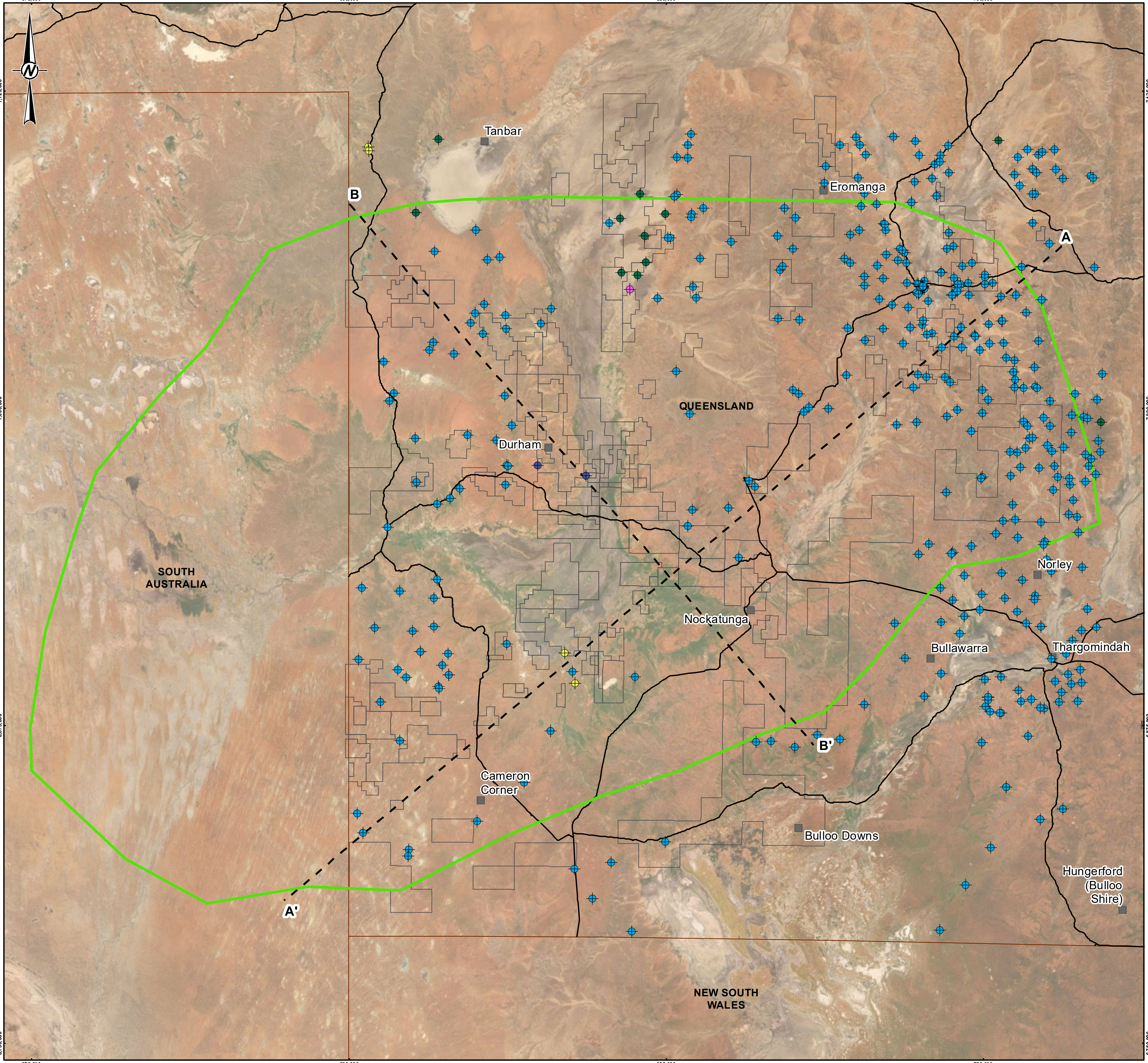

LEGEND

Registered Bore

Formation Description

- Tertiary Sedimeform
- Tertiary - Undefined
- Quaternary - Undefined
- Winton Formation
- Winton/Mackunda Formation
- Bounded Locality
- Groundwater Line in Section
- Roads/Tracks
- Eromanga Model Extent
- Santos Operated Permits
- Australian State Boundary

Coordinate System: GDA 1994 MGA Zone 54
Projection: Transverse Mercator
Datum: GDA 1994

0 25 50
1:1,500,000 @ A3 KILOMETRES

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TITLE
LONG TERM AFFECTED AREA - EROMANGA BASIN MODELLED GROUNDWATER DRAWDOWN IN LAYER 2

CONSULTANT

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DD-MM-YYYY	28-01-2020
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PREPARED	HG
REVIEWED	DP
APPROVED	KB

PROJECT NO.	CONTROL	REV.	FIGURE
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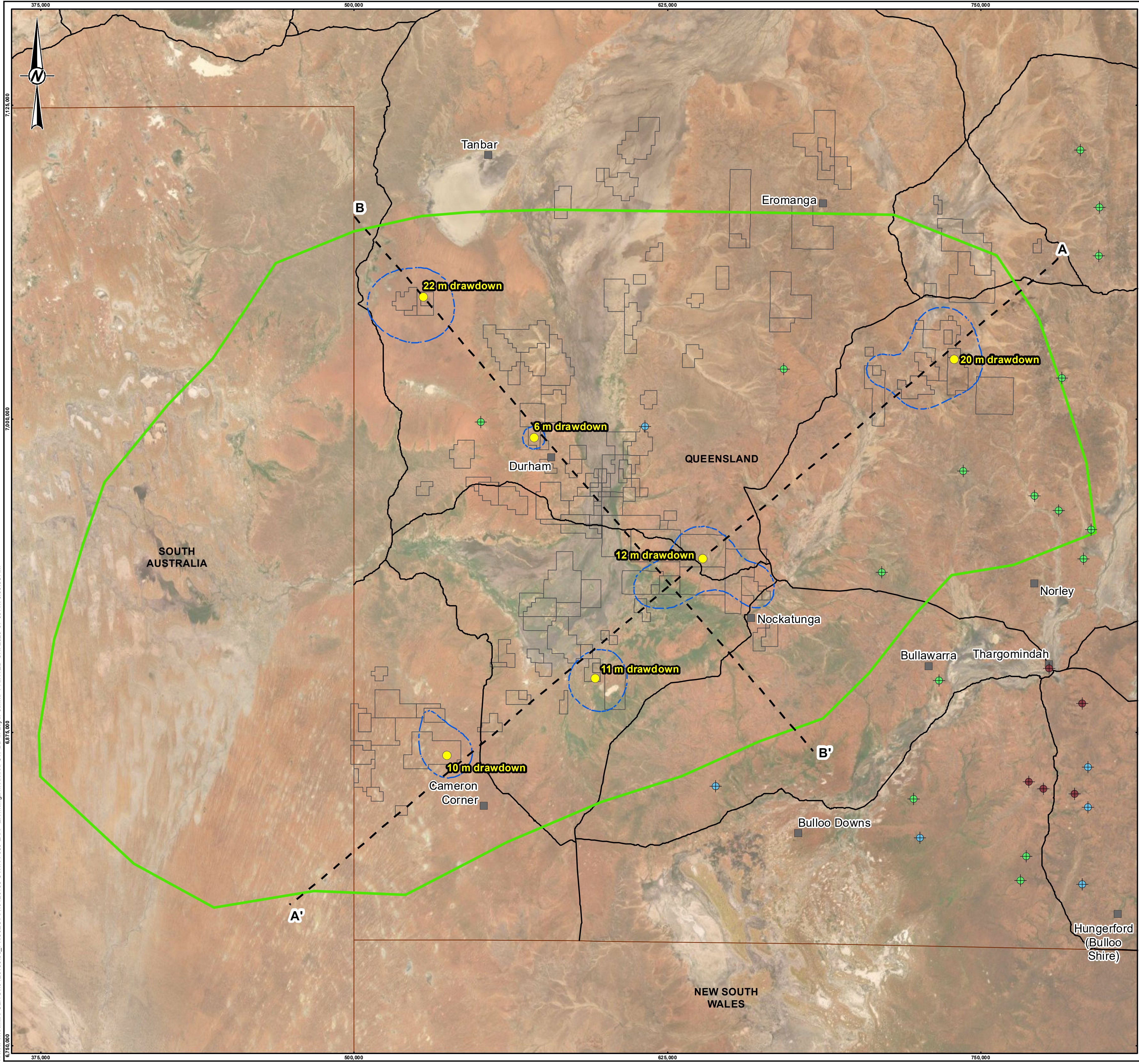

LEGEND

Registered Bore

Formation Description

- Makunda Formation
- Allaru Mudstone
- Wallumbilla Formation
- Maximum Drawdown (m AHD)
- Bounded Locality
- Groundwater Line in Section
- Drawdown (5 m)
- Roads/Tracks
- Eromanga Model Extent
- Australian State Boundary
- Santos Operated Permits

Coordinate System: GDA 1994 MGA Zone 54
Projection: Transverse Mercator
Datum: GDA 1994

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1:1,500,000 @ A3 KILOMETRES

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1. Australian State Boundaries, Bounded Localities, Petroleum Leases, Roads/Tracks: © State of Queensland (Department of Natural Resources, Mines and Energy) 2019
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TITLE
LONG TERM AFFECTED AREA - EROMANGA BASIN MODELLED GROUNDWATER DRAWDOWN IN LAYER 3

CONSULTANT
GOLDER

DD-MM-YYYY	30-01-2020
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PREPARED	HG
REVIEWED	DP
APPROVED	KB

PROJECT NO.	CONTROL	REV.	FIGURE
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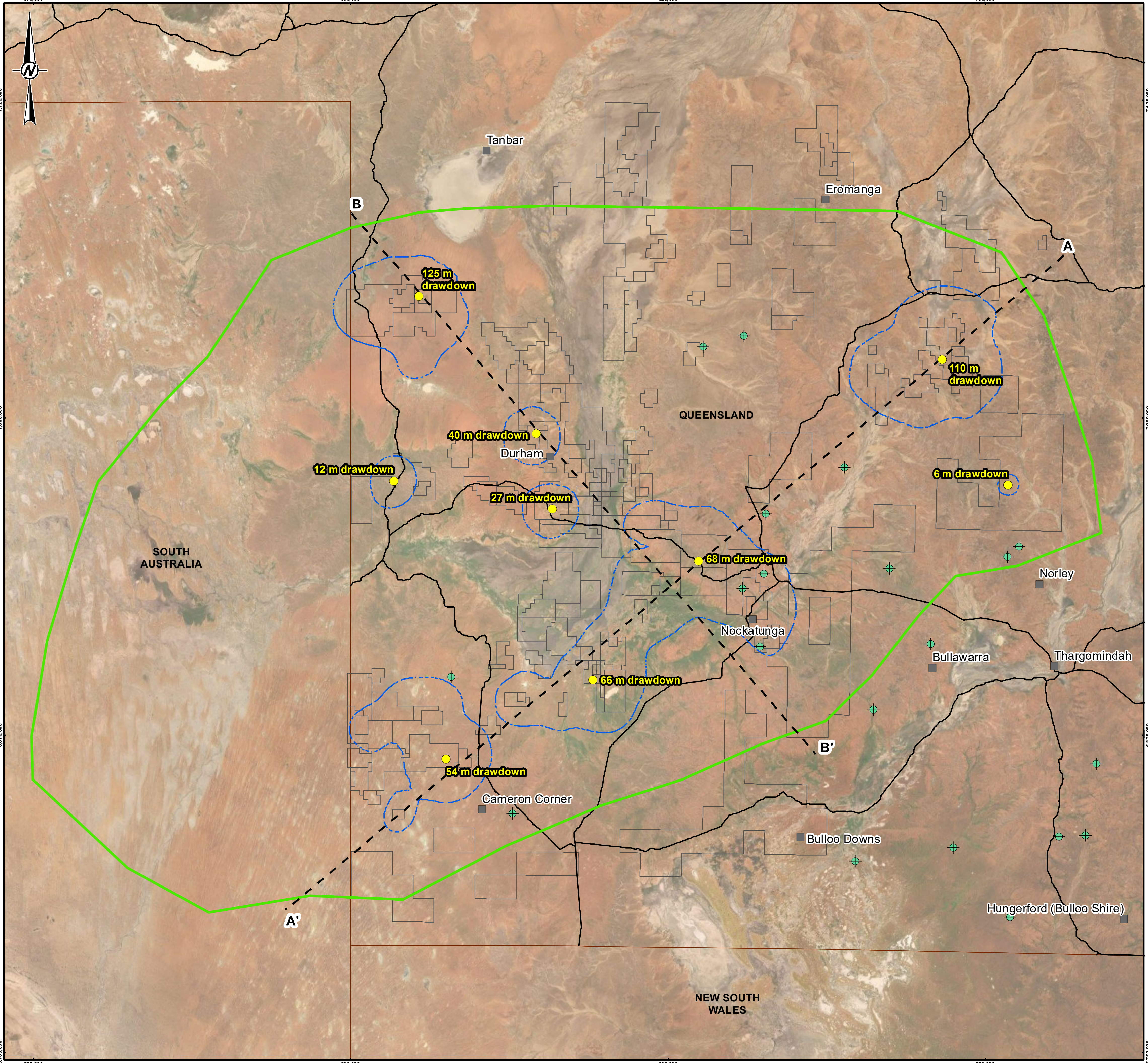

LEGEND

Registered Bore

Formation Description

- Hooray Sandstone
- Maximum Drawdown (m AHD)
- Bounded Locality
- Groundwater Line in Section
- Drawdown (5 m)
- Roads/Tracks
- Eromanga Model Extent
- Australian State Boundary
- Santos Operated Permits

Coordinate System: GDA 1994 MGA Zone 54
Projection: Transverse Mercator
Datum: GDA 1994

0 25 50
1:1,500,000 @ A3 KILOMETRES

REFERENCE(S)

1. Bounded Localities, Petroleum Leases, Roads/Tracks: © State of Queensland (Department of Natural Resources, Mines and Energy) 2019
2. Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
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TITLE
LONG TERM AFFECTED AREA - EROMANGA BASIN MODELLED GROUNDWATER DRAWDOWN IN LAYER 4

CONSULTANT
GOLDER

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PREPARED	HG
REVIEWED	DP
APPROVED	KB

PROJECT NO.	CONTROL	REV.	FIGURE
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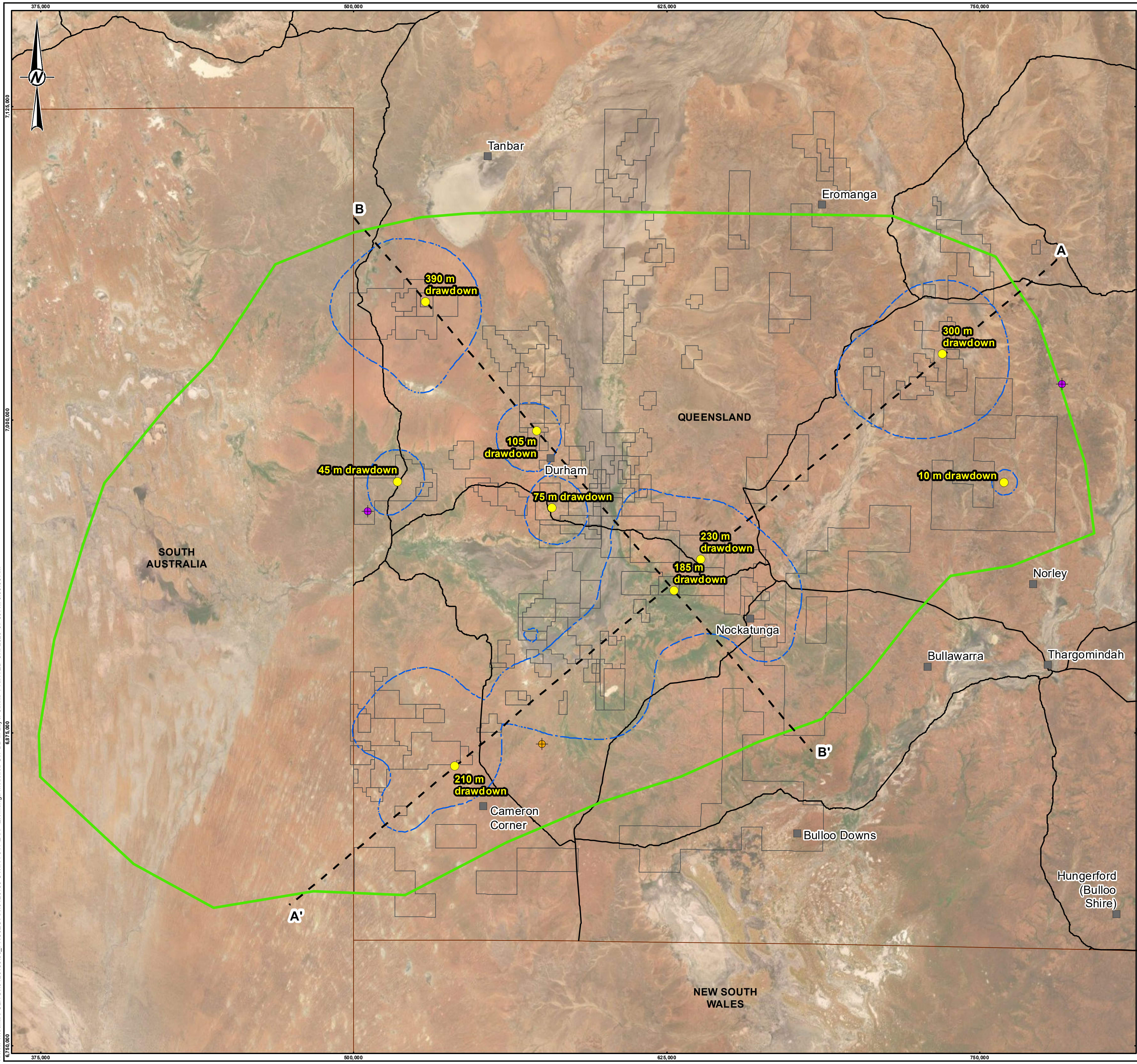

LEGEND

Registered Bore

Formation Description

- Hutton Sandstone
- Westbourne Formation
- Maximum Drawdown (m AHD)
- Bounded Locality
- Groundwater Line in Section
- Drawdown (5 m)
- Roads/Tracks
- Eromanga Model Extent
- Australian State Boundary
- Santos Operated Permits

Coordinate System: GDA 1994 MGA Zone 54
Projection: Transverse Mercator
Datum: GDA 1994

0 25 50
1:1,500,000 @ A3 KILOMETRES

REFERENCE(S)

1. Australian State Boundaries, Bounded Localities, Petroleum Leases, Roads/Tracks: © State of Queensland (Department of Natural Resources, Mines and Energy) 2019
2. Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
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PROJECT
SANTOS UWIR UPDATE SOUTHWEST QLD

TITLE
LONG TERM AFFECTED AREA - EROMANGA BASIN MODELLED GROUNDWATER DRAWDOWN IN LAYER 5

CONSULTANT

GOLDER

DD-MM-YYYY	30-01-2020
DESIGNED	HG
PREPARED	HG
REVIEWED	DP
APPROVED	KB

PROJECT NO.	CONTROL	REV.	FIGURE
19126485	001	0	41

PATH: V:\Santos GLNG\19126485\99_PROJECTS\19126485-UWIR-F041-LAA - Eromanga Modelled GW DD in Layer 5.mxd PRINTED ON: 2020-01-30 AT: 9:50:33 AM

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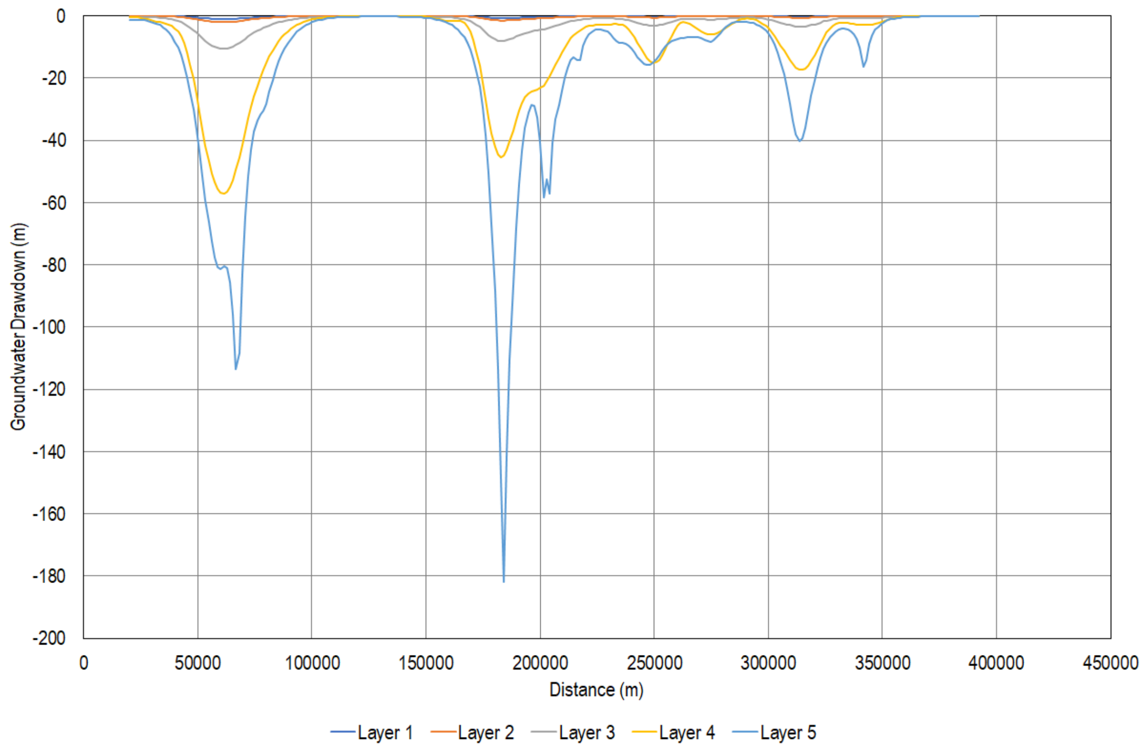

Figure 42. Eromanga Basin: Modelled Immediately Affected Area Groundwater Drawdowns in Cross Section A-A'

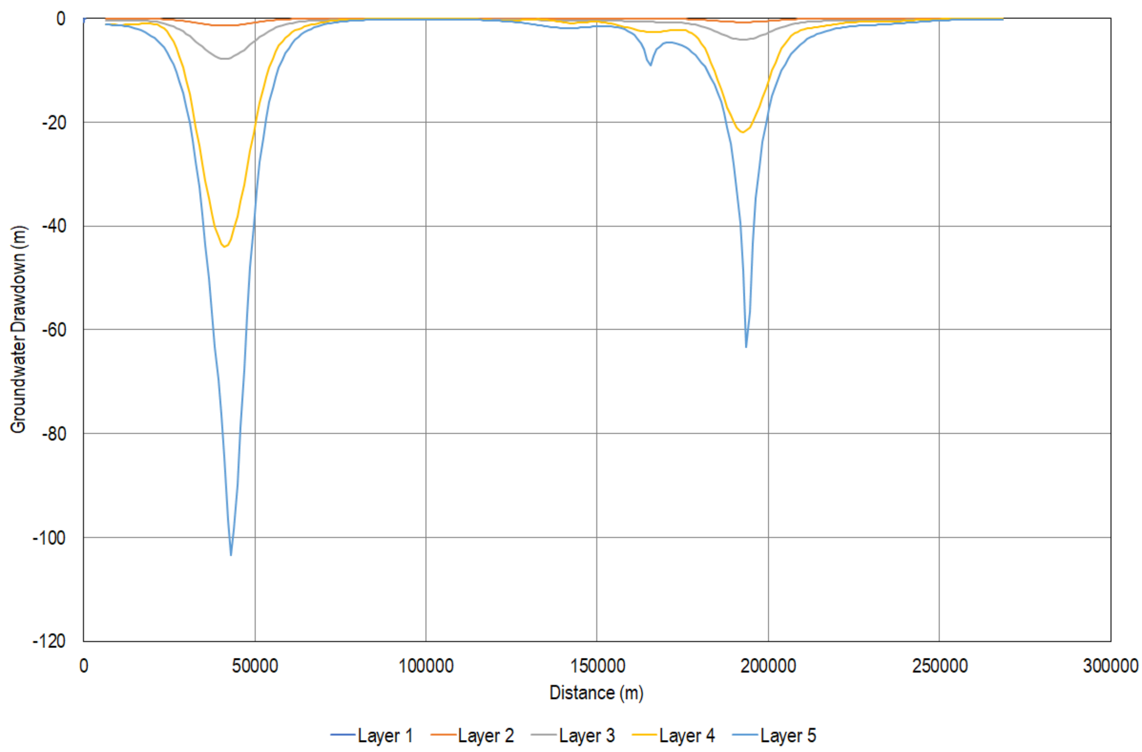

Figure 43. Eromanga Basin: Modelled Immediately Affected Area Groundwater Drawdowns in Cross Section B-B'

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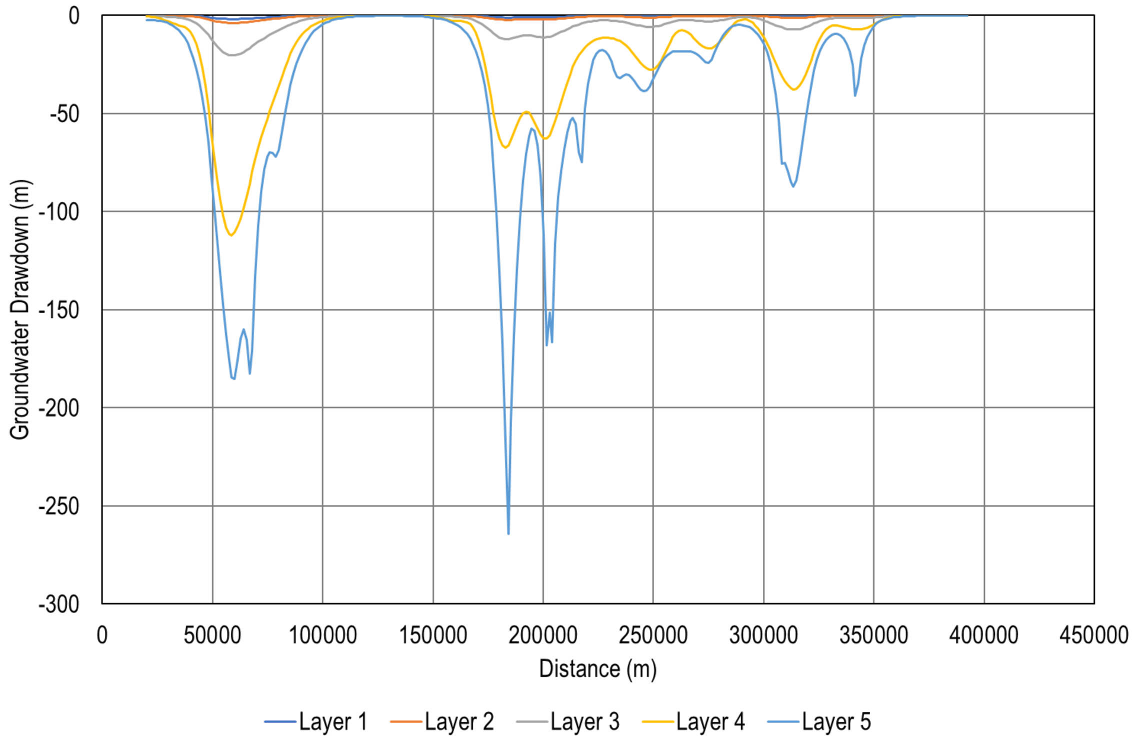

Figure 44. Eromanga Basin: Modelled Long Term Affected Area Groundwater Drawdowns in Cross Section A-A'

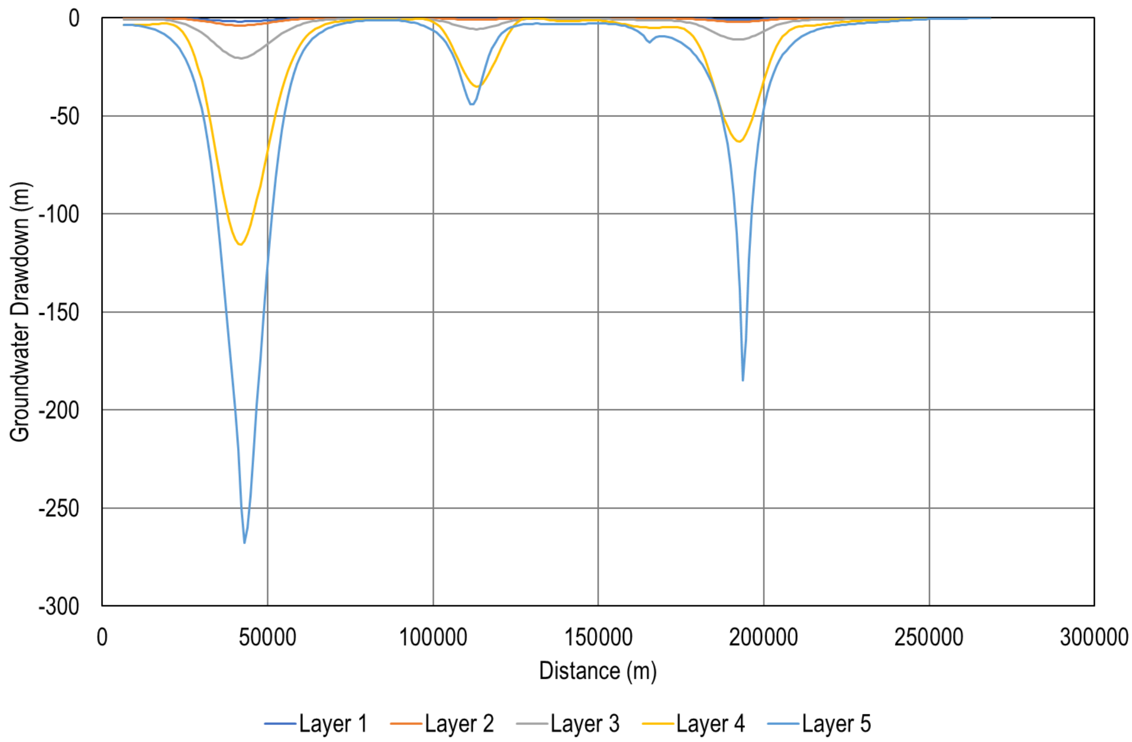

Figure 45. Eromanga Basin: Modelled Long Term Affected Area Groundwater Drawdowns in Cross Section B-B'

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7.6 Calculated Impact in the Cooper Basin

The updated 2016 calibrated model was run in steady state using updated extraction rates (2019) to provide a conservative, worst case scenario for the IAA and LTAA. The calculated drawdown for each layer is presented in Table 13 and Figure 46 to Figure 51 and summarised as follows:

- The maximum estimated drawdown in the IAA due to extraction from the Cooper basin is less than 2m in the Tinchoo and Arraburry Formation (Layer 2).
- The maximum estimated drawdown for the LTAA due to extraction from the Cooper basin is less than 25m in the Toolachee to Patchawarra Formations (Layer 3).

Table 13. Calculated maximum drawdown along lines of section – Cooper Basin

Layer Number	Layer Description	Maximum Drawdown in the Cooper Basin (m)	
		Immediately Affected Area	Long Term Affected Area
2	Tinchoo and Arraburry Formations	2	7
3	Toolachee to Patchawarra Formations	10	25

- Figure 46 and Table 13 show that the calculated pressure decline at the top of the Cooper Basin stratigraphy is very small in relation of the abstraction rate assigned to the wells. No impact is likely to propagate above the top of the Tinchoo and Arraburry Formations due to extraction in the Toolachee to Patchawarra Formations.

The impact of extraction from the wells in Layer 3 is considered minimal.

7.7 Summary of Key Points from the Analytical Modelling

Key points from the analytical modelling include:

- One existing registered bore (RN23059) targeting the Mackunda, Cadna-Owie Formation or Hooray Sandstone may be potentially impacted based on the calculated IAA or the LAA in the Eromanga Basin. The most up-to-date groundwater database compiled by the Department of Natural Resources, Mines and Energy was used for the identification of registered bores within the modelled area (DNRME, 2019). The database identifies registered borehole RN23059 as a GAB monitoring bore. It is unlikely that estimated drawdown in this area will impact local groundwater users.
- The impact of extraction in the Cooper Basin does not affect areas beyond the assumed extraction well locations at the top of the Cooper Basin stratigraphy. These impacts can therefore be discounted from the analysis of the overlying Eromanga Basin.
- The maximum predicted drawdown in the Eromanga Basin stratigraphy, in the strata directly underlying the unconfined Tertiary and Quaternary strata, is 4m under steady state conditions. This is a worst case scenario due to the limited number of extraction well used in the calculation and the steady state analysis conditions applied in the computation. The impact on the Tertiary and Quaternary strata is likely, to be less than 3m.

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A maximum pressure decline of 115m (LAA) is estimated for the modelled unit containing the Cadna-Owie Formation and Hooray Sandstone, however, the 5m contour line does not significantly extend outside of the tenements. Additionally, no private water supply bores targeting the Cadna-Owie Formation and Hooray Sandstone have been identified within the extent of the 5m contours.

A maximum pressure decline of 268m (LAA) was estimated for Westbourne Formation, Adori Sandstone, Birkhead Formation, Hutton Sandstone and Poolowanna Formation under the long term model run. The 5m drawdown contour does not extend outside of Santos tenements and no private bores targeting those formations have been identified.

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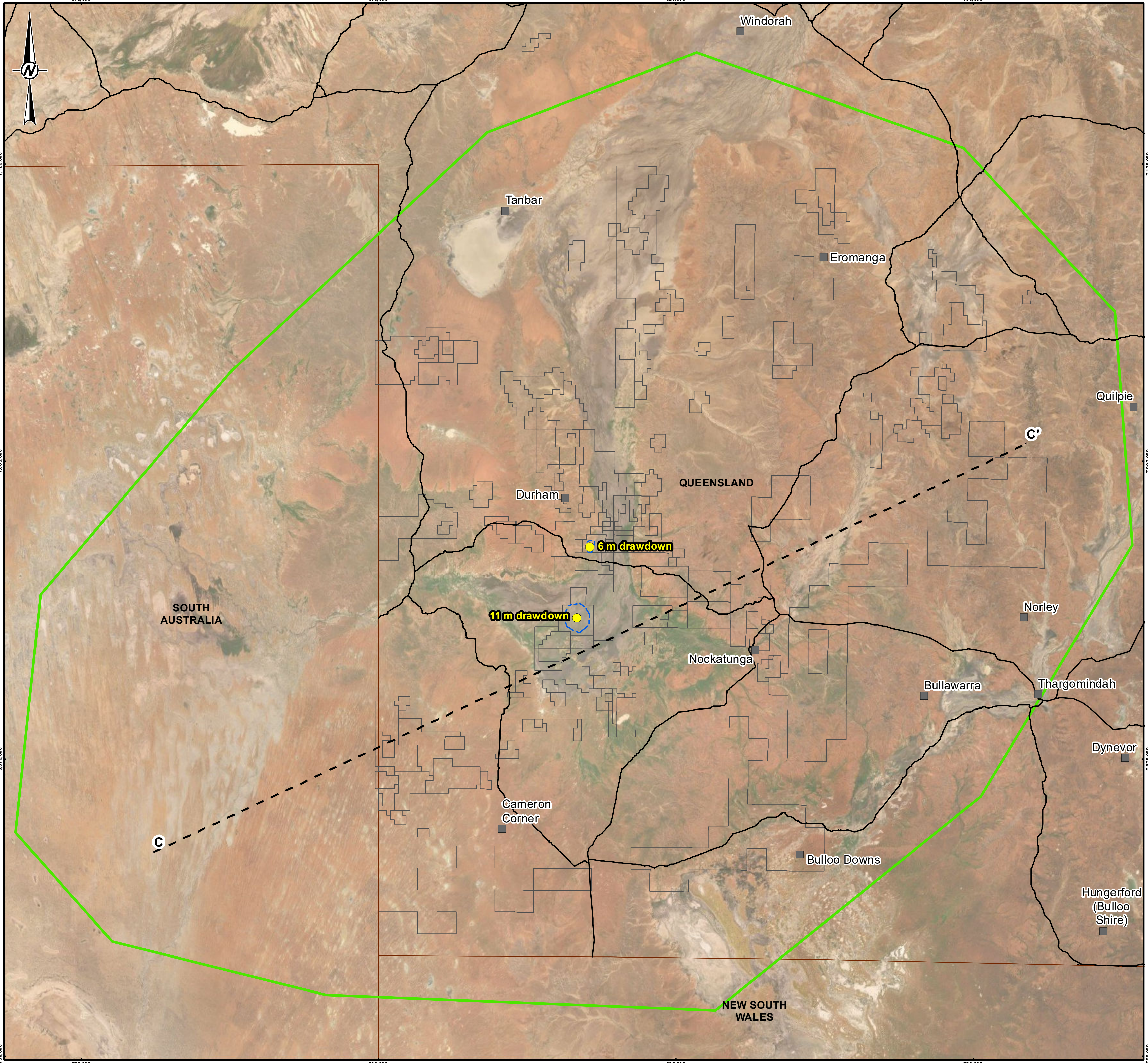

LEGEND

- Maximum Drawdown (m AHD)
- Bounded Locality
- Groundwater Line in Section
- Roads/Tracks
- Drawdown (5 m)
- Cooper Model Boundary
- Santos Operated Permits
- Australian State Boundary

Coordinate System: GDA 1994 MGA Zone 54
Projection: Transverse Mercator
Datum: GDA 1994

0 25 50
1:1,600,000 @ A3 KILOMETRES

REFERENCE(S)

1. Australian State Boundaries, Bounded Localities, Petroleum Leases, Roads/Tracks: © State of Queensland (Department of Natural Resources, Mines and Energy) 2019
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PROJECT
SANTOS UWIR UPDATE SOUTHWEST QLD

TITLE
IMMEDIATELY AFFECTED AREA - COOPER BASIN MODELLED GROUNDWATER DRAWDOWN IN LAYER 2

CONSULTANT

GOLDER

DD-MM-YYYY	29-08-2019
DESIGNED	HG
PREPARED	HG
REVIEWED	DP
APPROVED	KB

PROJECT NO.	CONTROL	REV.	FIGURE
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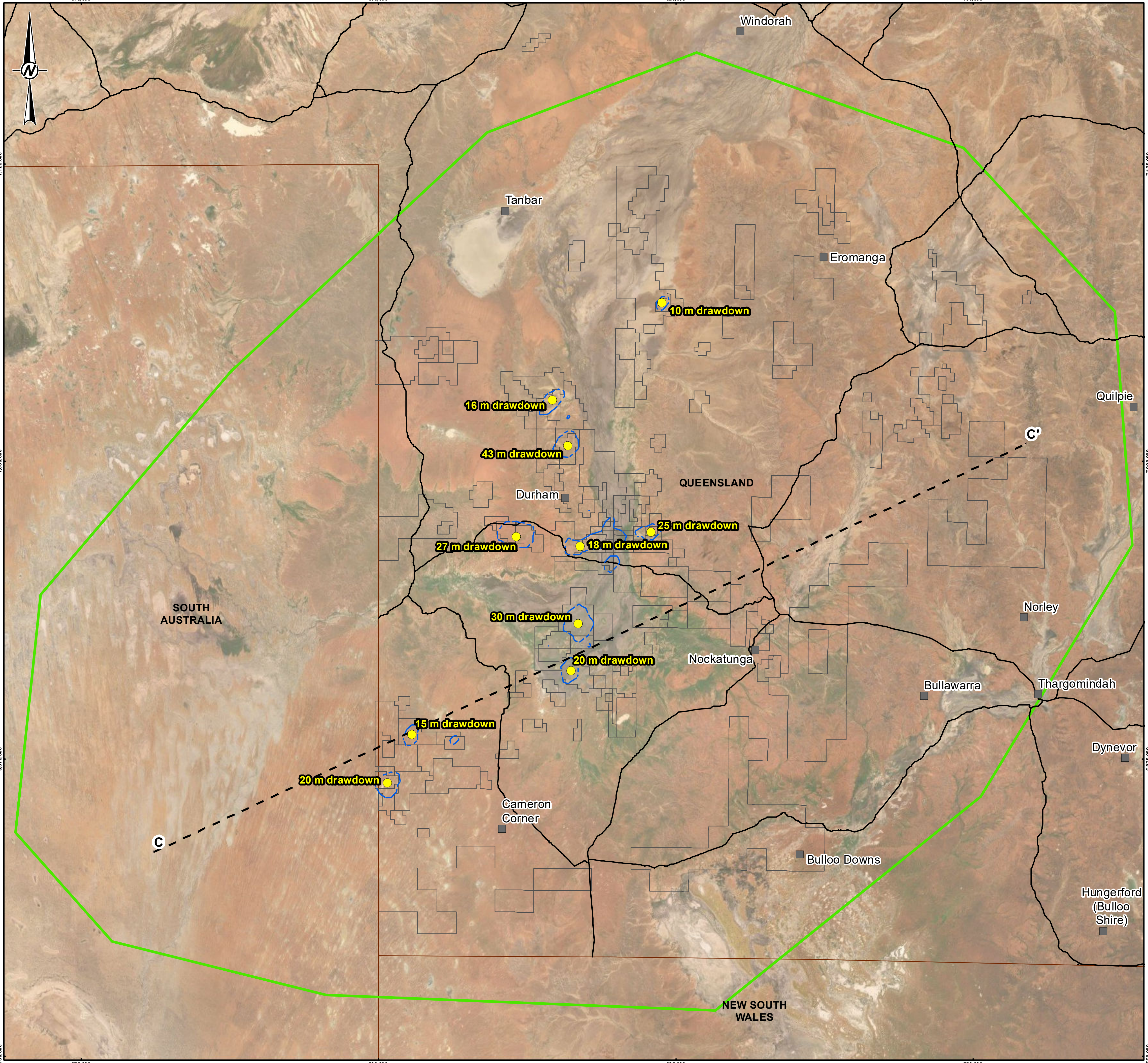

KEY MAP

LEGEND

- Maximum Drawdown (m AHD)
- Bounded Locality
- Groundwater Line in Section
- Roads/Tracks
- Drawdown (5 m)
- Cooper Model Boundary
- Santos Operated Permits
- Australian State Boundary

Coordinate System: GDA 1994 MGA Zone 54
Projection: Transverse Mercator
Datum: GDA 1994

0 25 50
1:1,600,000 @ A3 KILOMETRES

REFERENCE(S)
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PROJECT
SANTOS UWIR UPDATE SOUTHWEST QLD

TITLE
IMMEDIATELY AFFECTED AREA - COOPER BASIN MODELLED GROUNDWATER DRAWDOWN IN LAYER 3

CONSULTANT
GOLDER

DD-MM-YYYY	29-08-2019
DESIGNED	HG
PREPARED	HG
REVIEWED	DP
APPROVED	KB

PROJECT NO.	CONTROL	REV.	FIGURE
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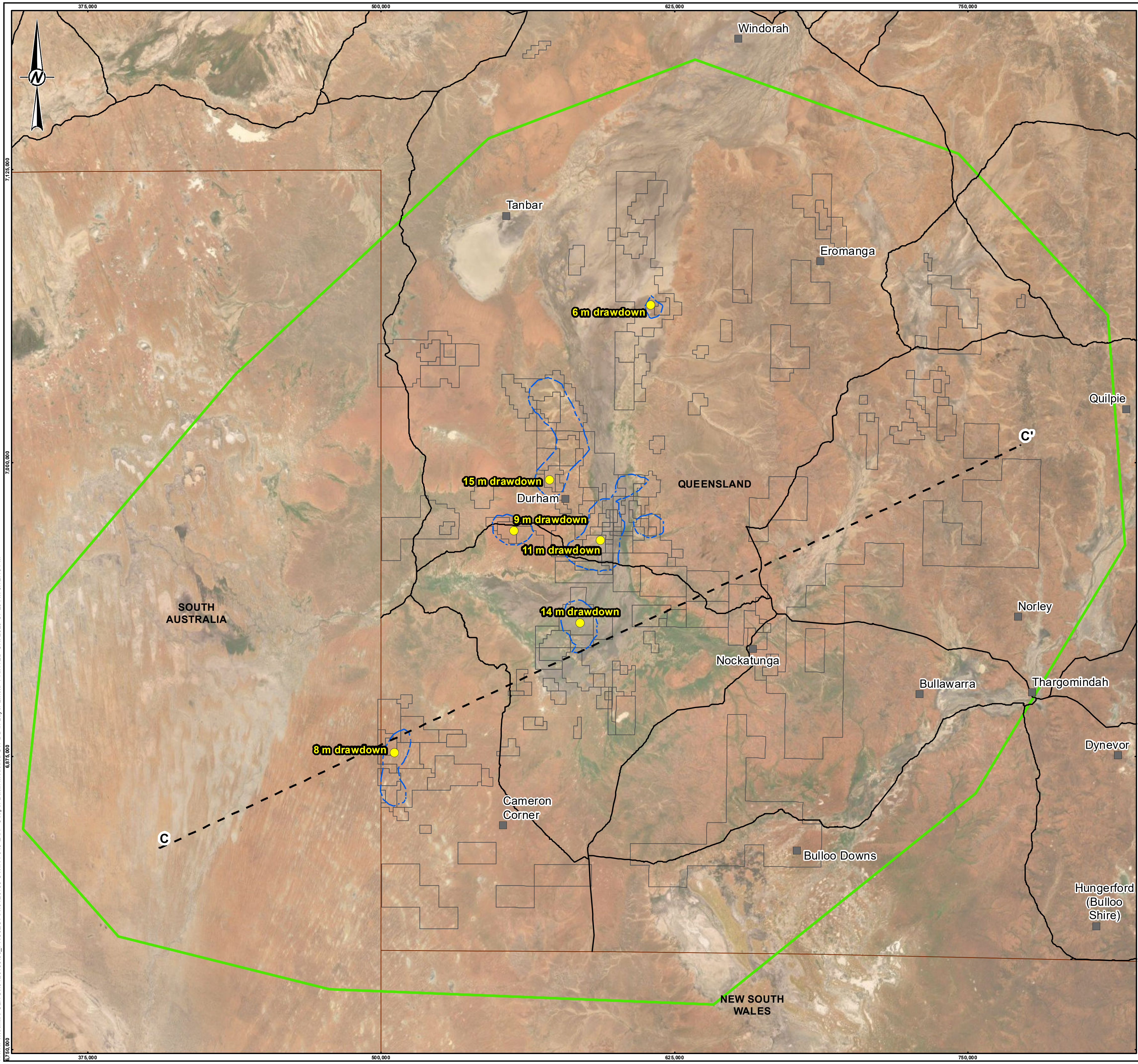

LEGEND

- Maximum Drawdown (m AHD)
- Bounded Locality
- Groundwater Line in Section
- Drawdown (5 m)
- Roads/Tracks
- Cooper Model Boundary
- Australian State Boundary
- Santos Operated Permits

Coordinate System: GDA 1994 MGA Zone 54
Projection: Transverse Mercator
Datum: GDA 1994

0 25 50
1:1,600,000 @ A3 KILOMETRES

REFERENCE(S)

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TITLE
LONG TERM AFFECTED AREA - COOPER BASIN MODELLED GROUNDWATER DRAWDOWN IN LAYER 2

CONSULTANT

GOLDER

DD-MM-YYYY	29-01-2020
DESIGNED	HG
PREPARED	HG
REVIEWED	DP
APPROVED	KB

PROJECT NO.	CONTROL	REV.	FIGURE
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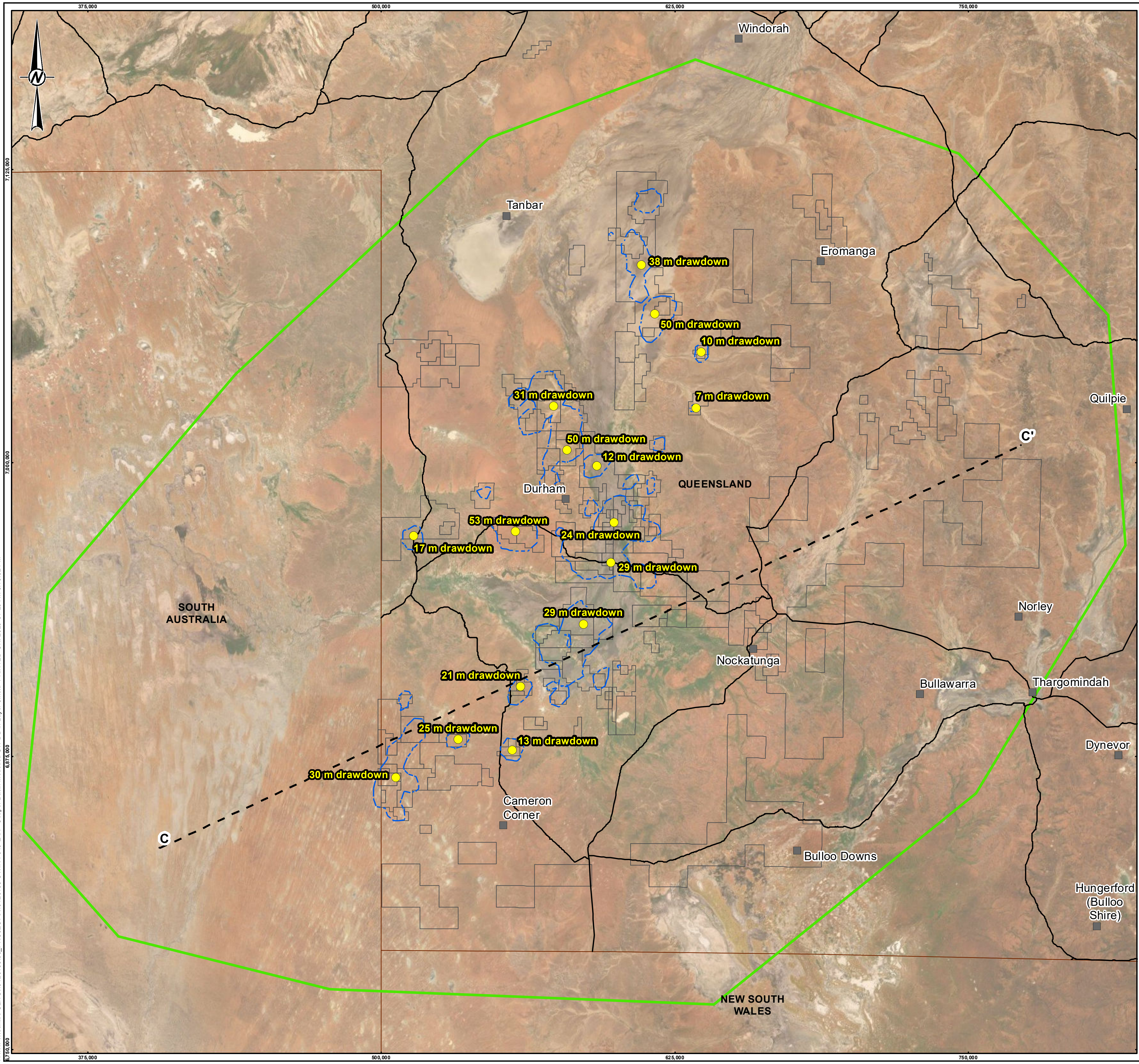

LEGEND

- Maximum Drawdown (m AHD)
- Bounded Locality
- Groundwater Line in Section
- Drawdown (5 m)
- Roads/Tracks
- Cooper Model Boundary
- Australian State Boundary
- Santos Operated Permits

Coordinate System: GDA 1994 MGA Zone 54
Projection: Transverse Mercator
Datum: GDA 1994

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1:1,600,000 @ A3 KILOMETRES

REFERENCE(S)

1. Australian State Boundaries, Bounded Localities, Petroleum Leases, Roads/Tracks: © State of Queensland (Department of Natural Resources, Mines and Energy) 2019
2. Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
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PROJECT
SANTOS UWIR UPDATE SOUTHWEST QLD

TITLE
LONG TERM AFFECTED AREA - COOPER BASIN MODELLED GROUNDWATER DRAWDOWN IN LAYER 3

CONSULTANT

GOLDER

DD-MM-YYYY	29-01-2020
DESIGNED	HG
PREPARED	HG
REVIEWED	DP
APPROVED	KB

PROJECT NO.	CONTROL	REV.	FIGURE
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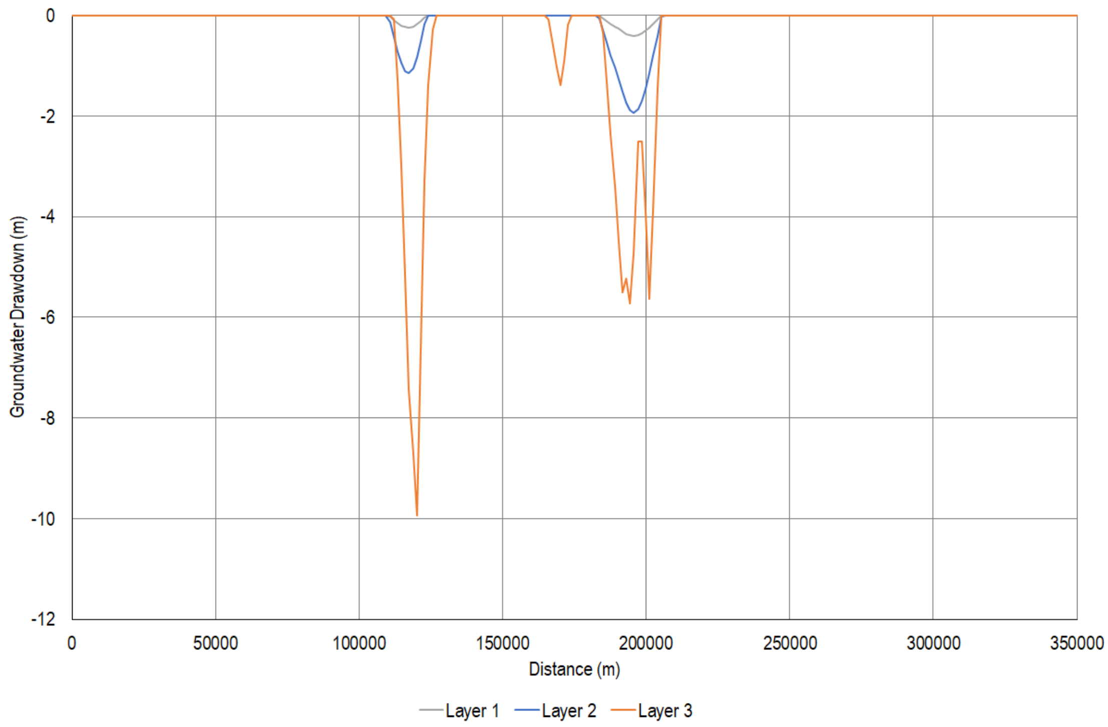

Figure 50. Cooper Basin: Modelled Immediate Affected Area Groundwater Drawdown in Cross Section C-C'

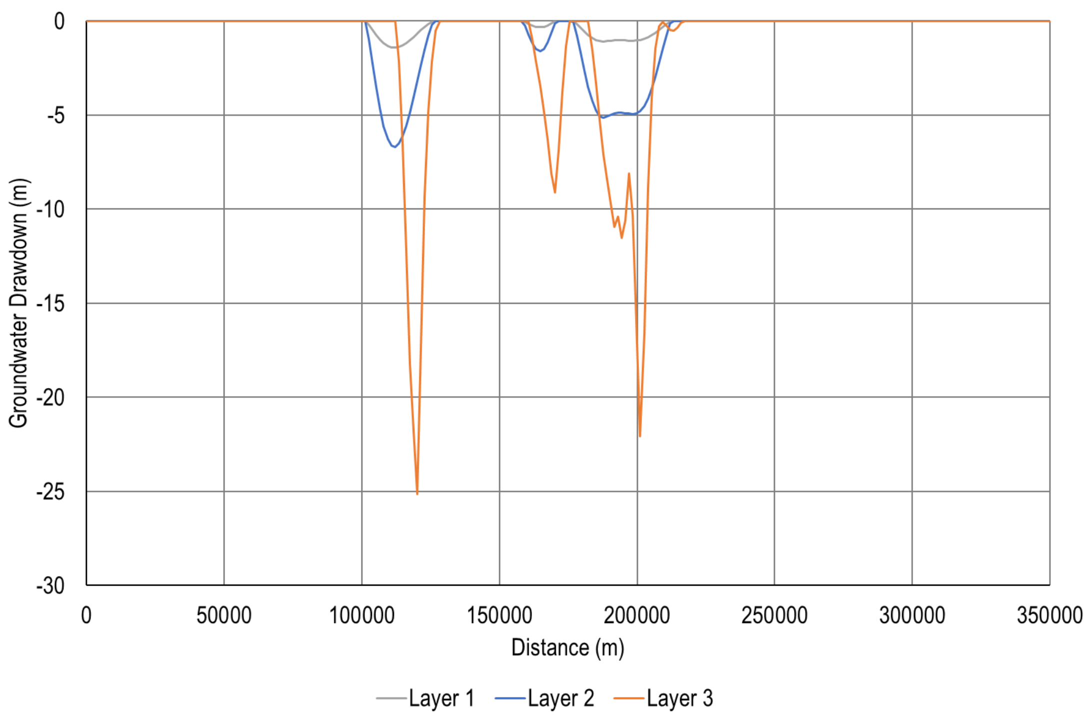

Figure 51. Cooper Basin: Modelled Long Term Affected Area Groundwater Drawdowns in Cross Section C-C'

8.0 Vulnerability Assessment

8.1 Vulnerability of GDEs

No GDEs are located with Santos' SWQ tenements. The nearest GDEs are located >90km from the tenement boundaries.

The *spring trigger threshold* for a decline in groundwater level, beyond which a spring impact management strategy for any potentially affected springs may be required, is defined in the Water Act as a decline of more than 0.2 metres.

The areas of predicted drawdown that are greater than 0.2 metres are within the model domain (Figure 32). This suggests that the 0.2 metre drawdown areas do not overlap with the location of any mapped GDEs, the closest of which are located >50km south and east of Thargomindah (as shown on Figure 14).

A spring impact management strategy has not been developed because no impact to GDE's greater than 0.2 metres of drawdown is predicted.

8.2 Vulnerability of Groundwater Users

The potential for aquifer depletion due to extraction of produced water has been assessed and is discussed in Section 7.0. Table 14 provides a summary of predicted impacts to private bores associated with oil and gas production operations. The results indicate minimal impacts to third party groundwater users.

Changes in groundwater quality and subsequent impacts to third party users could affect bore owners or water supply sources that access Hooray Sandstone (which also hosts oil reservoirs exploited by Santos) within the Murta Formation mostly and to a lower extent within the Namur Sandstone. Note that where no oil produced from the Hooray Sandstone oil reservoirs, the model estimated 5m drawdown contours are considered conservative as pressure measurements data at two oil fields have demonstrated that the depressurisation does not propagate to overlying layers.

Based on the Queensland Groundwater Database (DNRME, 2019) and the simulated drawdown contours for IAA and LAA, three private bores are identified within the IAA and LAA.

Bore RN23372 is a water bore that was identified as being impacted in the 2016 UWIR. A Make Good Agreement, as required under provision in the Water Act, was executed in 2017. The amount of drawdown predicted in the next 3 years is less than was predicted in the 2016 UWIR.

Bore RN23569 was investigated by DES (formerly, as DEHP) and found not to be an authorized bore (does not have a license that permits the owner to extract groundwater). It therefore does not qualify for protection and management in accordance with s363 of the Water Act (as advised by DEHP on 29 July 2014) and no further action is required.

Bore RN23059 is a water bore that has been identified as being impacted by the updated 2020 UWIR. The approximate drawdown calculated in the LAA is 6m. The purpose of this bore is listed as GAB monitoring.

There are less bores predicted to be impacted compared to the 2016 UWIR, largely due to improvements made to the Queensland Groundwater Database (DNRME, 2019). Santos does

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not intend to update the Make Good Agreement on RN23372 until such time that the predicted drawdown in the IAA for that bore exceeds the drawdown that was predicted in the 2016 UWIR.

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Table 14. Registered Groundwater Bores Affected by Modelled Impacts.

Bore RN	Latitude	Longitude	Tenure	Date Drilled	Bore Name	Bore Type	Purpose / *Status*	Formation	Layer Description	Predicted Drawdown (m)
Immediately Affected Area										
23372	-27.6653824	142.6485650	-	1986	PPL Balooma 1	Artesian	Stock / GAB Monitoring	Hooray Sandstone	Eromanga Layer 4	12
23569	-27.7188708	142.5648591	PL33	1987	PPL Coothero 1	Artesian	GAB Monitoring	Hooray Sandstone	Eromanga Layer 4	11
Long Term Affected Area										
23059	-27.92540012	142.6376904	PL245	1982	PPL Noccundra 1	Artesian	GAB Monitoring	Hooray Sandstone	Eromanga Layer 4	6
23372	-27.6653824	142.6485650	-	1986	PPL Balooma 1	Artesian	Stock / GAB Monitoring	Hooray Sandstone	Eromanga Layer 4	23
23569	-27.66538237	142.648565	PL33	1987	PPL Coothero 1	Artesian	GAB Monitoring	Hooray Sandstone	Eromanga Layer 4	27

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9.0 Underground Water Monitoring

In accordance with Section 376(f) of the Water Act 2000, an underground water monitoring strategy is required for the IAA and the LTAA. Monitoring is required to keep track of the quantity of water produced and to monitor changes in underground water level and the underground water quality.

9.1 Rational

Based on the outcomes of the 2019 analytical modelling, the groundwater resources most at risk from Santos activities are the shallow aquifers and the Hooray Sandstone aquifer, which are used by local community for domestic and municipal supply.

In order to mitigate the potential for impact to shallow aquifers and the Hooray Sandstone aquifer within, and adjacent to, the study area, the water monitoring strategy will focus on early detection and protection of these water resources. The monitoring strategy will include evaluation and assessment of the following:

- Changes in water level in shallow unconsolidated aquifers (>2m): evaluate potential to impact third party users.
- Changes in water level in consolidated aquifers i.e. Hooray Sandstone aquifer (>5m): evaluate potential to impact third party users.
- Changes in the water quality in shallow unconsolidated aquifers and consolidated aquifers i.e. Hooray Sandstone aquifer: evaluate the potential to impact third party users.
- Results of previous water monitoring events/programs to inform future monitoring strategies.

9.2 Previous Water Studies / Monitoring

9.2.1 Studies

Previous groundwater reports prepared for Santos' SWQ tenements include:

- URS, Water Flooding Impact Assessment: Further Information to Support Assessment of Potential Impacts of Water Flooding in PL295, 2010.
- Santos, Response to DEHP Re: Use of fracture fluids containing BTEX, 2010.
- Golder Associates Pty Ltd, Underground Water Impact Report for Santos Cooper Basin Oil and Gas Fields, SW QLD (Reference 117636010-3000-001-Rev-1) [UWIR], 2013.
- Golder Associates Pty Ltd, Santos South West Queensland, Regional Water Bore Baseline Assessment Report (Priority 1 and 2 Bores) [WBBA] (Reference 117666006-019-R), 2013.
- South-West Queensland UWIR 2018 Annual Groundwater Monitoring Report, LBWCo (2019)

9.2.2 Monitoring

Historical groundwater monitoring undertaken by Santos in the study area includes:

- Deep groundwater monitoring associated with the water flooding activities as described in the previous UWIRs.

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Shallow groundwater monitoring associated with:

Ballera evaporation pond (8 monitoring bores).

Jackson refueling station (3 monitoring bores).

Jackson landfarm activities (4 monitoring bores).

DNRM GAB monitoring network spread over the project area and targeting the formations of the Eromanga Basin; however few exist within the area of interest.

Previous UWIRs identified the quantity of water produced during the production of gas and oil, the potential impact of the groundwater extraction on the groundwater systems environmental values and the existing or proposed groundwater monitoring necessary to manage impact based on a groundwater monitoring strategy. Additional detail on the results of the 2018 UWIR Annual Report are presented below.

2013 Water Bore Baseline Assessment (WBBA) to collect baseline data with regards to the existence, construction, condition and accessibility of water bores (so-called “Water Act”, ‘private’ or ‘farmers’ bores) and, where possible, aquifer data including water level, water quality, pumping and use. The intent of a baseline assessment is also to provide a snap shot of groundwater conditions prior to production. In the case of the Cooper-Eromanga Basins, where operations have been underway for 40+ years, this is not relevant. However, it still provides a basis for future comparison of groundwater conditions, particularly with regard to potential impacts from petroleum production.

9.2.3 2018 Annual Groundwater Monitoring Report

The results of the 2018 Annual Groundwater Monitoring Program (GWMP) undertaken by independent consultants LBWCo (2019), in accordance with the 2016 UWIR reported the following findings:

There is no evidence of decline in groundwater levels in monitoring bores completed in shallow unconsolidated aquifers which exceeded the bore trigger threshold of 2m.

There is no evidence of decline in groundwater level in monitoring bores completed in deep consolidated aquifers which exceed the bore trigger value of 5m.

Shallow unconsolidated aquifer water quality at the monitoring bores locations show no impacts related to oil and gas production.

Deep consolidated aquifer water quality at the monitoring bore locations shows no impacts related to oil and gas production.

The report recommended that the following monitoring points be removed from the ongoing monitoring schedule:

F1 – water levels have consistently declined since 2012, but this is extremely shallow bore. This is not representative of deep aquifer conditions.

Yanda/Munkah Bore – no access to the wellhead and no flow. Cannot guage or sample.

Challum Spine Road Bore – the bore was dry.

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Tarbat Job No. 1947 Bore – no access to the wellhead and no flow. Cannot guage water level or take water samples. The bore is no longer operational.

9.3 Monitoring Strategy

As part of the 2013 UWIR development and the SWQ Water Bore Baseline Assessment, a monitoring network was established to provide information on formation pressure, water levels and water quality in unconsolidated and consolidated aquifer formations.

To evaluate the potential for impacts to shallow unconsolidated aquifers, consolidated aquifers (such as the Hooray Sandstone) and subsequent third party users, Santos propose to amend the long-term monitoring strategy presented in UWIR 2016. The changes will improve the overall quality of monitoring strategy.

Table 15 and Table 16 provides the revised schedule of monitoring. F1, Yanda/Munkah Bore, Challum Spine Bore and Tarbat Job No. 1947 Bore have been removed in accordance with recommendations in Section 9.2.3. Challum Spine Bore No.2, Gordon's Bore, Apollosa 1 and Ballera West 2 bores have been added to replace them.

The 2019 to 2022 monitoring and sampling schedule takes into account the limited changes observed in groundwater level and quality over the previous reporting period (i.e. no discernible change in water level or quality). Santos consider that the proposed changes to the schedule, including a reduction in frequency (quarterly to annual) and a reduced list of groundwater quality analytes meets the requirements of the Water Act.

The quantity of water produced will be measured as per the methodologies presented in Section 6.4.

The monitoring strategy will implemented following approval of the UWIR.

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Table 15. UWIR Monitoring Network – 2016 to 2019

Bore Name	WBBA ID	Latitude	Longitude	Bore RN	Tenure	SWL (mbgl)	Bore Depth (mbgl)	Primary Use	Comments
Challum Spine Road Bore No.2	5018	-27.40219675	141.66764887	-	PL59			Roadwork and construction bore	Sub-artesian. Shallow (Winton Mackunda). Replaces monitoring Challum Spine road bore.
Irtalie 1	5028	-27.7224503	142.2545297	23570	PL36		1915	Roadwork and construction	Artesian. Hutton Sandstone .
PPL Coothero 1	5033	-27.7188708	142.5648591	23569	PL33		1415	Livestock and roadwork	Artesian.
Gordons Bore	-	-26.952184	143.289735	23361	PL170/ PL1029			Roadwork and construction	Artesian. Namur Sandstone Replaces monitoring Tarbat Job No.1947.
Surlow 1 Water Bore	5094	-27.3368192	141.9649231	-	PL205	6.0		Not in use	Sub-artesian. Shallow (Winton Mackunda).
Supply 1	5229	-26.7940241	143.3906457	23923	ATP636		1564	Industrial	Artesian.
PPL Balooma 1	-	-27.6653824	142.6485650	23372	-		1513	Livestock	Artesian.
Apollosa 1	-	-28.079852	141.860269	-	-			Roadwork and construction	Artesian. Naumr Sandstone.
Ballera West 2	5015	-27.3757873	141.7755227	-	PL61/ PL1073			Livestock	Artesian

WBBA – Water Bore Baseline Assessment (WBBA, Golder 2013a)
SWL – Standing Water Level
mbgl – meters below ground level

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Table 16. UWIR Monitoring and Sampling Schedule – 2016 to 2019

Bore Name	Water Level Measurement Method*	Groundwater Sample Collection and Laboratory Analysis		Schedule	Comments
		Sample Collection Y/N	Analytes		
Challum Spine Road Bore no. 2	Not feasible (due to headworks)	Yes	pH, TDS, major ions, dissolved heavy metals	Annual (Q4)	Shallow (sub-artesian)
Irtalie 1	Pressure transducer	Yes	pH, TDS, major ions, dissolved heavy metals	Annual (Q4)	Hutton SS (artesian)
PPL Coothero 1	Pressure transducer	Yes	pH, TDS, major ions, dissolved heavy metals	Annual (Q4)	Artesian
Gordon's Bore	Pressure transducer	Yes	pH, TDS, major ions, dissolved heavy metals	Annual (Q4)	Artesian
Surlow 1 Water Bore	Pressure transducer	Yes	pH, TDS, major ions, dissolved heavy metals	Annual (Q4)	Shallow (sub-artesian)
Supply 1	Pressure transducer	Yes	pH, TDS, major ions, dissolved heavy metals	Annual (Q4)	Artesian
PPL Balooma 1	Pressure transducer	Yes	pH, TDS, major ions, dissolved heavy metals	Annual (Q4)	Artesian
Apollosa 1	Pressure transducer	Yes	pH, TDS, major ions, dissolved heavy metals	Annual (Q4)	Artesian
Ballera West 2	Pressure transducer	Yes	pH, TDS, major ions, dissolved heavy metals	Annual (Q4)	Artesian

* If current condition of bore headworks make it feasible

9.4 Annual Review and Reporting

Monitoring data will be reviewed annually and new data used to determine if a material change in groundwater conditions has occurred or is likely to occur. Results will be reported internally and as required by regulatory requirements.

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10.0 UWIR Review Schedule and Reporting Protocol

In accordance with the Water Act, a review period of no greater than three years will be undertaken. Site data including the following, will be reviewed annually:

- Groundwater level and quality data from the water monitoring plan.
- Santos extraction volumes.
- Santos pressure data.

It is the intention that data will be reviewed and compared to the assumptions made in this UWIR. Significant discrepancies between the assumptions in this UWIR and the monitoring data will trigger a review of the UWIR.

The review cycle will be incorporated in to the water monitoring plan. In addition to the review schedule, reporting to the regulator will be undertaken as required.

11.0 Conclusion

The impacts to groundwater from Santos' oil and gas operations in the Cooper region of SWQ have been assessed in this UWIR and are based on:

- A description of the geological settings of the gas and oil fields and the development of a conceptual geological cross section and geological contour maps for the top of and thicknesses of key formations.
- A review of the hydrogeological settings of the gas and oil fields and the development of a hydrogeological conceptual model and hydrogeological maps.
- An identification of environmental values related to groundwater system, and in particular groundwater dependent ecosystem including GAB artesian discharge springs.
- Characterisation of produced water volumes.
- An assessment of impacts from groundwater extraction on the target petroleum reservoir and surrounding formations and on potential groundwater users.

Santos oil and gas fields in SWQ are located away from any major GDEs. Groundwater extractions associated with the oil and gas operations produce limited volumes of water which do not result in large scale depressurisation of the target aquifers. The results of this groundwater impact assessment demonstrate that aquifer drawdown is largely confined to the oil fields. As a result, Santos' current activities are not expected to have a discernible impact on GAB discharge springs and other GDEs.

Santos oil and gas fields in SWQ are located within the Cooper and Eromanga GAB Basins. Groundwater extraction for oil and gas production is undertaken at depth and does not compete with groundwater extraction for private use. Consequently, Santos' current activities are not expected to have a discernible impact on groundwater resources used by the community with the possible exception of localised impacts to two bores screened within the Hooray Sandstone aquifer located within areas of oil production.

This groundwater impact report demonstrates that impacts to GAB aquifers as a result of Santos' SWQ oil and gas operations is localised, that depressurisation is limited and does not propagate across production formations. As such it is considered that Santos' current SWQ activities pose no risk to the GAB aquifers.

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Appendix A: Underground Water Impact Reports for Santos' Cooper Basin Oil and Gas Fields, SW QLD (Golder, 2013)

5 June 2013

UNDERGROUND WATER IMPACT REPORT FOR SANTOS COOPER BASIN OIL&GAS FIELDS, SW QLD

Santos Ltd

Submitted to:
Santos Ltd
Ground Floor Santos Centre
60 Flinders Street
Adelaide, SA 5000

REPORT

Report Number. 117636010-3000-001-Rev3

Distribution:

Electronic Copy: Santos
File Copy: Golder Associates

Golder Associates

Executive Summary

Under the Water Act 2000, Santos is required to prepare an Underground Water Impact Report (UWIR) for its south west Queensland (SWQ) oil and gas production fields. The UWIR must identify the quantity of water produced during the production of gas and oil, the potential impact of the groundwater extraction on the groundwater systems and identified environmental values, the existing or proposed groundwater monitoring necessary to manage impact based on a groundwater monitoring strategy. Amongst environmental values of potential concerns, impact to private bores and impact to springs are specifically required to be addressed. This document covers the Amend and Resubmit notice issued to Santos Ltd in addressing requested updates and amendments.

Santos Production Licences in SWQ cover an area of over 8,160 km². The development of petroleum fields in SWQ started in the early 1970s. Santos currently produces conventional gas and oil out of 191 gas wells and 230 oil wells in SWQ. The Cooper Basin underlies but is separate from the Eromanga Basin, which is the largest sub-basin within the Great Artesian Basin. (“GAB”). With a couple of localised exceptions, gas is produced from formations within the Cooper Basin, at depths exceeding 2000m, while oil is mainly produced from formations within the Eromanga Basin.

Santos’s Production Licences in SWQ cover an area of over 8,160 km². The development of petroleum fields in SWQ started in the early 1970s. Santos currently produces conventional gas and oil out of 191 gas wells and 230 oil wells in SWQ. The Cooper Basin underlies but is separate from the Eromanga Basin, which is the largest sub-basin within the Great Artesian Basin. (“GAB”). With a couple of localised exceptions, gas is produced from formations within the Cooper Basin, at depths exceeding 2000m, while oil is mainly produced from formations within the Eromanga Basin.

Environmental Values

A review of environmental values was performed including a review of groundwater dependant ecosystems (GDEs), groundwater users and social and cultural environmental values. Within Santos tenements, there are no recognised endangered regional ecosystems, the closest national park and listed wetland, the Currawinya Lakes National Park lies more than 240 km east of Santos tenements. Similarly, no GAB springs were found over the tenements or in the study area, the closest GAB discharge spring being 90 km south east of the tenements. The environmental values of potential concern are those groundwater users accessing groundwater resources in the Hooray Sandstone at depth exceeding 600 m.

Petroleum Target Formations & Produced Water

The petroleum target formations are:

- For oil production (all formations are within the Eromanga Basin unless otherwise stated):
  - The Murta Formation and the Namur Sandstone of the Hooray Sandstone
  - The Birkhead Formation
  - The Hutton Sandstone
  - Minor oil reservoirs are found in the Wyandra Sandstone Member (Cadna-Owie Formation), Westbourne Formation and the Adori Sandstone
  - The Tirrawarra Sandstone and basal Patchawarra Formation (within the Cooper Basin)
- For gas production (all formations are within the Cooper Basin unless otherwise stated):
  - The Toolachee Formation;
  - The Epsilon Formation;

- The Patchawarra Formation;
- Likely future production from the Paning Member and Doonmulla Member; and
- Minor gas production from the Hutton Sandstone (Eromanga Basin)

Over the whole period of production, groundwater extractions associated to oil production is estimated to date at 155 GL with 133 GL originating from the Hutton Sandstone. The production of gas generates a much smaller volume of water, oil production accounting for the larger volume of produced water.

In the last five years, an average of 150 ML/yr of groundwater has been produced from gas extraction (within 191 currently active wells) and 5,176 ML/yr has been produced from oil extraction (within 230 currently active wells) in SWQ.

Groundwater Impact Estimation

The groundwater impact estimation was conducted using an analytical solution called AnAqSim. The groundwater impact to the Eromanga Basin and the Cooper Basin were calculated in two separate calculation exercises as it was anticipated that the impact from groundwater extraction in the Cooper Basin would be quite limited due to the small volume of produced water during gas production and the thickness of low permeability layers overlying the target beds. The calculations are run in steady state conditions (i.e. not time varying) to investigate the *worst case scenario* for the groundwater impact estimation.

The results indicated that:

- Immediate affected area from produced water extraction from the Cooper Basin is less than 12 m calculated at the top of the Cooper Basin stratigraphy.
- The maximum immediate and long term affected area drawdown in the Eromanga Basin in the Tertiary and Quaternary strata (this includes the Glendower and Winton Formations where confined) is 2 m in steady state conditions. The Glendower and the Winton Formations are the most frequently targeted aquifers for water supply by the local community.
- A maximum pressure decline of 12 m was modelled in the long term affected area for Layer 3 of the model (containing the Mackunda Formation, Allura Mudstone, Toolebuc and Wallumbilla Formations). The affected area does not extend significantly beyond the Santos tenement boundaries, however a single private bore potentially targeting these stratum has been identified. *It is recommended that this bore be visited to confirm the status and target aquifer(s).*
- A maximum pressure decline of approximately 58 m head is estimated for model Layer 4 containing the Cadna-Owie Formation and Hooray Sandstone. The calculated 5 m contour line does not significantly extend outside of the tenements and four private bore targeting the Cadna-Owie Formation and Hooray Sandstone have been identified within these 5 m drawdown zones. *It is recommended that these four bores be visited to confirm the targeted aquifers.*
- A maximum pressure decline of approximately 115 m is estimated for model Layer 5 comprising the Westbourne Formation, Adori Sandstone, Birkhead Formation, Hutton Sandstone and Poolowanna Formation of the Eromanga Basin. The calculated 5 m drawdown contour line does not significantly extend outside of the tenements and no private bores target those formations within the affected area.

Risk Assessment and Vulnerability

Risk to groundwater systems arising from oil and gas activities have been assessed through a systematic process of risk analysis. The principal issues of concern with respect to potential risks to groundwater availability and quality arising from oil and gas activities have been identified as:

- Reduced access to groundwater resources supplying stock, domestic and other licensed uses; and

- Potential impacts to groundwater quality (especially to shallow groundwater resources) associated with an uncontrolled release of produced water or hydrocarbons.

Santos has adopted a number of preventive actions and management options to reduce the risk and likelihood of adverse impact occurring and to mitigate those risks.

Vulnerability has been evaluated from a combined assessment of the groundwater impact estimation, local settings, groundwater use and risk assessment outcomes, documented in this report. It can be concluded that:

- Santos current activities are not expected to have any material impact on GAB discharge springs and other GDEs.
- Santos current activities are expected to have an insignificant material impact on groundwater resources used by the community with the possible exception of localised impacts to two bores screened within the Hooray Sandstone aquifer located within areas of oil production. It is noted that the target aquifer formation data from these bores is from the WES database; the reliability of this data should be assessed during the upcoming private bore assessment program.
- Santos current activities in SWQ are expected to pose a negligible risk to the integrity of the GAB.

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1.0 INTRODUCTION

1.1 Cooper Basin Oil and Gas Fields Operations Description

Santos currently operates conventional gas and oil fields within the Cooper Basin of South Western Queensland (SWQ) (Figure 1). The area occupied by the Production Licences within which these petroleum fields lie encompasses in excess of 8,160 km² of largely semi-arid agricultural land and was developed for petroleum operations in the early 1970s. Santos petroleum tenements contain approximately 191 producing gas wells and 230 producing oil wells (Figure 2) over SWQ. Santos Cooper Basin petroleum fields produce both conventional gas and oil:

- *Conventional gas production* is undertaken from porous sandstone formations and as such does not require the depressurisation of the target beds (with respect to groundwater, and the need to remove groundwater to release the gas). Some water is produced as a by-product however the volumes are quite limited (discussed in Section 6.2). In the study area, the majority of gas production is from the deep formations of the Cooper Basin (underlying the GAB system).
- *Conventional oil* is produced primarily from the formations of the Eromanga Basin (a sub-basin with the GAB formations) with some additional production from the Tirrawarra Formation and basal Patchawarra Formation (both of which lie within the deeper Cooper Basin)). There are several types of oil reservoirs resulting from the process of "trapping" of the oil. These are shown in Figure 3 and discussed further in Section 4.3.

Note: "Santos" refers to Santos and its various companies who operate the oil and gas tenements on behalf of the various joint venture parties.

The UWIR (11763010-3000-Rev1, December, 2011) for the Cooper Basin Oil and Gas Field South West Queensland (SWQ) was submitted to the Queensland Department of Environment and Resource Management (DERM, now Department of Environment and Heritage Protection (DEHP); ref: 489261) for consideration. An *Amend and Resubmit* (AaR) Notice was issued by DEHP on 8 May 2012 in response to the submission. This UWIR update is written to address the items raised in this amend and resubmit notice. A copy of the AaR Notice is provided in APPENDIX A. Responses to individual items within the AaR Notice incorporated into this updated UWIR are included in sections as shown in Table 1

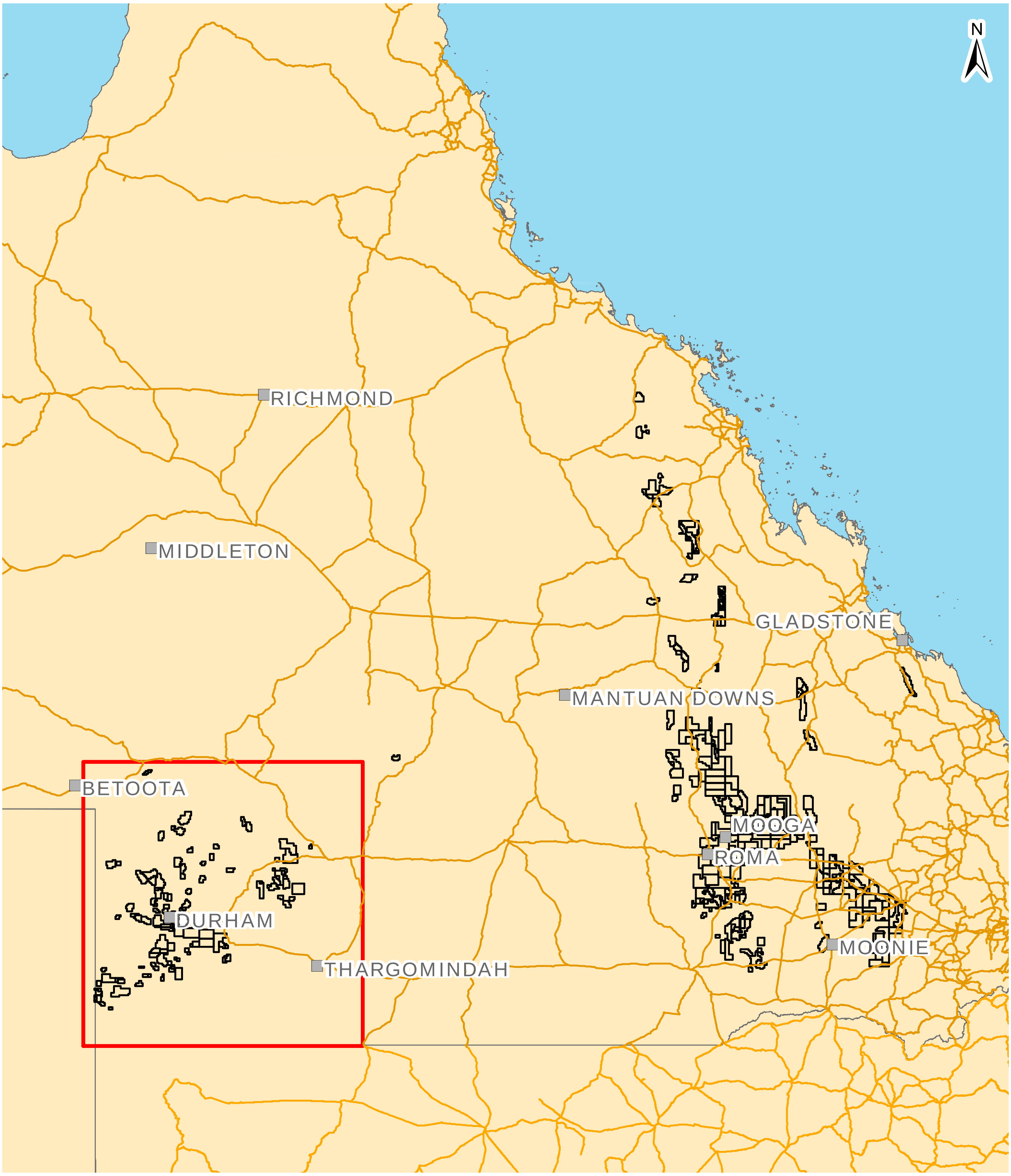
Table 1: Responses to the Amend and Modify Notice within this Updated UWIR

AaR Item Number	DERM Amend or Modify request	Location of Response in this Report	Summary of Response
1	Discuss methodology for extraction monitoring and its reliability	Section 6.4.2	The volumes of produced water associated with the extraction of gas are estimated as a percentage of the volume of produced gas. Similarly for oil, water content is estimated by dividing the total extraction at a monitoring location and extrapolated between wells based on production. This is likely to provide reasonable estimates.
2	Discuss methodology for assigning target formations and source of three year extraction rate predictions	Section 6.4.3 and 7.2.4	No complete record of target formations for each well was available. The target formations within the model were simplified to allow extraction from a single layer. This was considered representative as the model was an equivalent porous medium model.
3a	Discuss the methodology to determine predicted extraction rates over the next three years	Section 6.4.3, Table 23	No predictions for extraction are routinely made. As the total extraction is generally in decline, it was considered conservative to extrapolate the previous years extraction for

AaR Item Number	DERM Amend or Modify request	Location of Response in this Report	Summary of Response
			the next 3 years.
3b	Santos extraction well database	Section 7.2.1 and APPENDIX G	Clarification of the number and locations of the wells has been provided
3c	Santos extraction well locations by tenure	Section 6.3.4	Clarification of the number and locations of the wells has been provided
3d	Data clarification	Figure 41, Table 27 and Table 28	Clarification of the source of the data for these tables and figures has been provided
4a	Discuss the influence of faults on the regional hydrogeology	Section 5.4	The general compressional tectonic regime would suggest faults generally form barriers to groundwater flow.
4b	Use of reservoir pressure data for groundwater level observations	Section 5.3	Reservoir data, where available, suggests a hydraulic barrier exists above the target formations. The proposed collation and interrogation of Santos' historical pressure data will be evaluated as part of the update schedule of this UWIR.
4c	Clarification of data and figure symbology	Figure 30	Symbology has been updated in Figure 29.
4d	Bore locations by tenure	APPENDIX G	Clarification of the number and locations of the wells has been provided
4e	Discussion of estimated groundwater extraction by other users	Section 4.4.2	An estimate and discussion on other groundwater users has been provided.
4f	Clarification of monitoring data	Table 11	Clarification of the monitoring bores has been provided in Table 11.
4g	Discussion of monitoring data from artesian wells	Section 5.6	Available data from DERM monitoring bores including artesian bores discussed in Section 5.6
4h	Clarification of extent of available data when discussing groundwater level trends	Section 5.6 and Section 7.2.5	Long term trends were analysed and provided the basis for starting heads in each of the model scenarios.
8 a and b	Additional figures showing predicted groundwater declines	Section 7.3 and 7.4	Clarification of the immediate and long term affected area provided with additional maps
9	Additional figures at a smaller scale to define impacts	Section 7.3 and 7.4	Clarification of the immediate and long term affected area provided with additional maps
10	Clarification of well locations in predicted affected areas	Section 7.3 and 7.4	Clarification of the immediate and long term affected area provided with additional maps
11a	Discussion on selection of hydraulic parameters	Section 7.2	The source of input data to the model is discussed with reference to its source. It is acknowledged that there is limited data for some strata, in particular low permeability strata at depth in each basin.
11b	Justification of applying target formations to extraction	Table 26 and Section 7.2.4	The simplification required by the software has been justified along with the methodology employed to simplify the model

AaR Item Number	DERM Amend or Modify request	Location of Response in this Report	Summary of Response
			as an equivalent porous medium model where adjacent stratum is grouped together and assigned a single representative hydraulic parameter. It is therefore necessary to also group the extraction in stratum that is grouped for modelling purposes.
11c	Clarification of modelled verses observed groundwater data	Table 28	Clarification and additional tables and plots provided for clarification of the source of the calibration statistics.
11d	Model sensitivity analysis	Section 7.6	Three sets of model sensitivity analysis was undertaken: vertical hydraulic conductivity of the aquitard overlying the target formations in both the Cooper Basin and Eromanga Basin Models (HPSA1 and HPSA2 respectively). In addition, an investigation into the potential impact from extraction in South Australia was investigated. It was concluded that there is minimal change in the results due to sensitivity analysis.
11e	Discuss the use of departmental groundwater level monitoring in modelling	Section 5.6 and 7.2.5	DERM observation bore data was discussed and used in the initial conditions for all model scenarios.
11f (a)	Estimate predictive uncertainty considering potential impact from Santos' South Australian operations	Section 7.6	A sensitivity run comparing predicted drawdown in Queensland to predicted drawdown in Queensland plus South Australia was undertaken. It was concluded that no significant additional drawdown was observed in the model due to extraction in South Australia.
11f (b)	Estimate predictive uncertainty considering potential hydraulic interaction between the Cooper and Eromanga Basins, particularly in South Australia	Section 7.4	The Cooper Basin model was run to include extraction in South Australia. With the given hydraulic parameters in this model, no impact was observed in the Eromanga Basin due to extraction from the Cooper Basin in South Australia.
12	Provide a program for review of the UWIR	Section 11.0	The review schedule for the UWIR will be linked to the water monitoring plan. It is intended that data obtained as part of the water monitoring plan will be reviewed and considered against the assumptions made in this UWIR. Amendments will be considered on a three yearly basis.
13	Provide a protocol for providing the update to the chief executive	Section 11.0	The protocol for reporting to the regulator will be incorporated into the water monitoring plan. This is currently being finalised by Santos.
14	Discuss water monitoring network	Section 11.0 and	The water monitoring plan is currently being finalised by Santos.
15	Clarification on monitoring	Section 11.0	The water monitoring plan is currently being

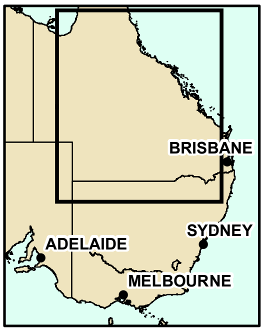
AaR Item Number	DERM Amend or Modify request	Location of Response in this Report	Summary of Response
	frequency	and	finalised by Santos.
16	Provide a program for reporting to the Queensland Water Commission	Section 11.0	The procedure for updating the regulator will be incorporated into the water monitoring plan. The water monitoring plan is currently being finalised by Santos.
17	Clarification of the impact in the vicinity of the identified springs	Section 7.3 and 7.4	Clarification of the immediate and long term affected area in the vicinity of the springs has been provided with additional maps.



COOPER BASIN UWIR

SANTOS

SANTOS SWQ OIL AND GAS OPERATIONS LOCATION



LEGEND

- Town/Locality
- Highway/Major Road
- Study Area

0 25 50 100 150 200 250 Kilometres

SCALE (at A4) **1:8,000,000**

Coordinate System: GCS GDA 1994

PROJECT: **117636010**
DATE: **28/11/2011**
DRAWN: **AJW**
CHECKED: **FH**

FIGURE 1

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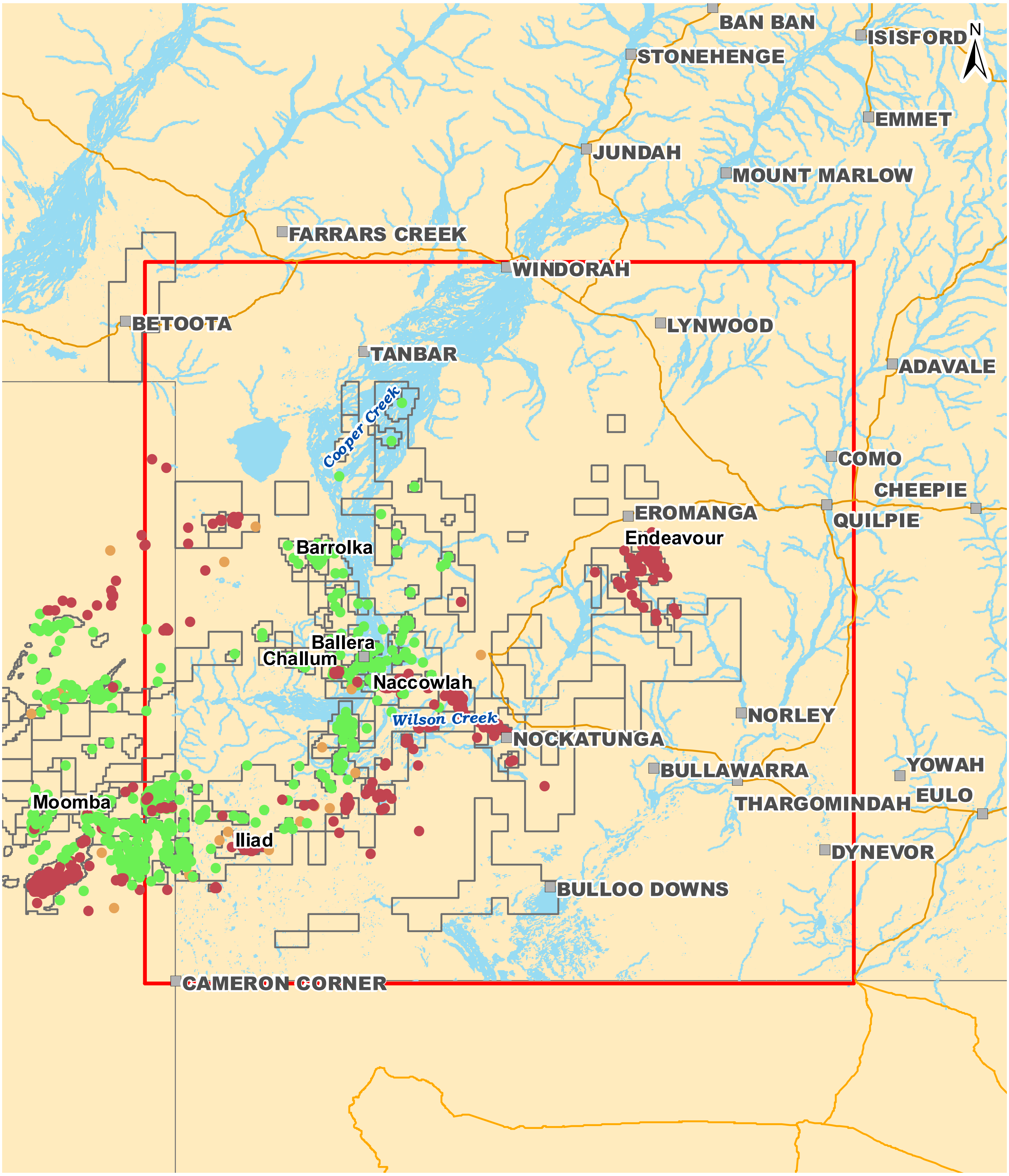
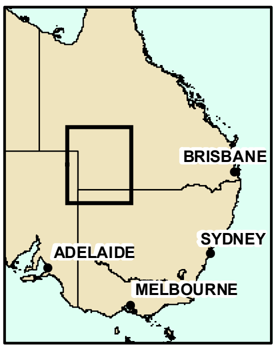


COOPER BASIN UWIR

SANTOS

SANTOS COOPER BASIN OIL AND GAS FIELDS LOCATION



LEGEND

- Town/Locality
- Oil Production Well
- Oil and Gas Production Well
- Gas Production Well
- Highway/Major Road
- River/Creek
- Santos Operated Permits
- Study Area

0 10 20 40 60 80 100 Kilometres

SCALE (at A4) 1:3,000,000

Coordinate System: GCS GDA 1994

PROJECT:	117636010
DATE:	19/12/2011
DRAWN:	AJW
CHECKED:	FH

FIGURE 2

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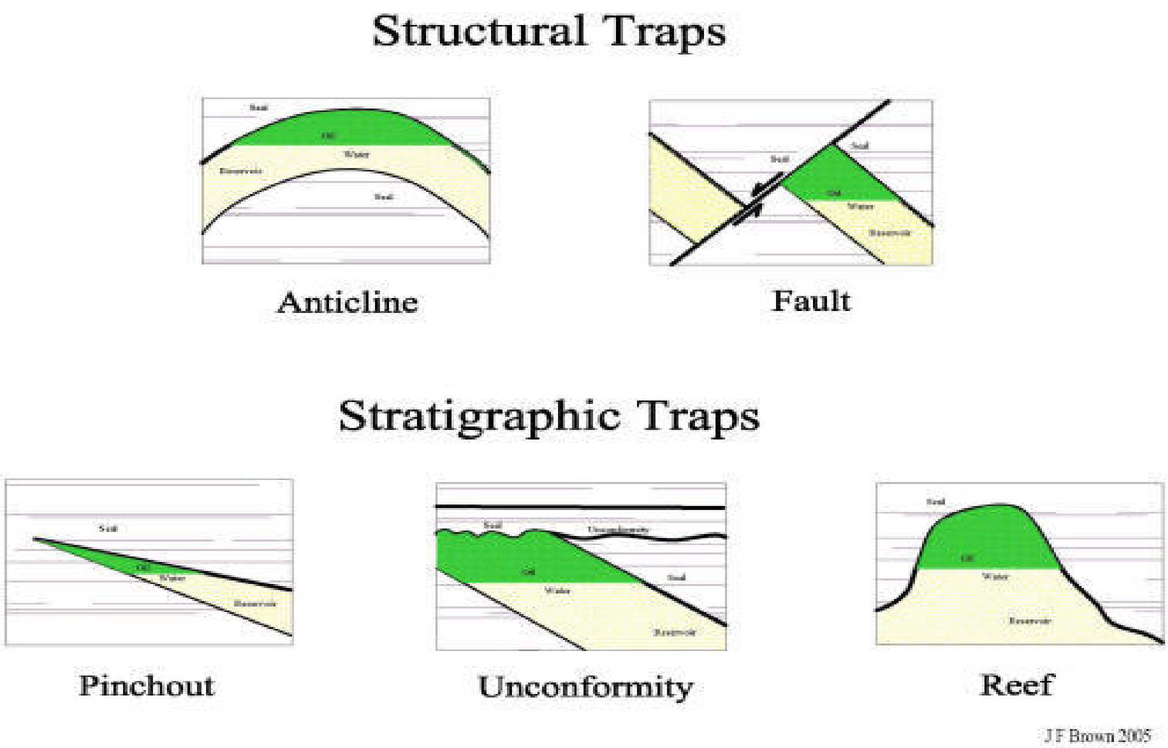


Figure 3: Hydrocarbon 'Traps' Geological Settings

Further information on Santos activities are provided in Section 6.0.

1.2 Previous Groundwater Studies

Previous groundwater investigations or reports have been undertaken or prepared on parts of the Santos SWQ operations and include:

- Water Flooding Impact Assessment: *Further Information to Support Assessment of Potential Impacts of Water Flooding in PL295*, URS, 2010
- Response to DERM Re: Use of fracture fluids containing BTEX, Santos 2010

References for regional groundwater studies and regional groundwater related literature are included in Section 14.0 at the end of this report.

2.0 LEGISLATIVE FRAMEWORK

Legislation and regulation requires petroleum tenure holders to manage the access, use and disposal of produced water generated through oil and gas development activities in an environmentally sustainable manner. This section provides a summary of the key Queensland and National legislation requirements related to the extraction of groundwater from deep aquifers and management of produced water.

Santos activities in the Cooper Basin are subject to general QLD or commonwealth regulation, and to site and activities specific Environmental Authorities (EAs) determined by DERM under the *Environmental Protection Act 1994*.

The legislative texts discussed below provide the general driver for the regulation and how it applies to Santos activities.

2.1 Petroleum and Gas (Production and Safety) Act 2004

The *Water and Other Legislation Amendment Act 2010,* sanctioned on 1 December 2010, amends the *Water Act 2000* (Water Act) and other relevant legislation with the aim of improving the management of impacts associated with groundwater extraction that form part of petroleum activities. These amendments transfer the regulatory framework for underground water from the *Petroleum Act 1923* and the *Petroleum and Gas (Production and Safety) Act 2004* (P&G Act) to the Water Act.

The P&G Act originally provided all rights of water extraction to a petroleum activity. However through recent updates of the P&G Act and the Water Act (See Section 2.2), a petroleum tenure holder has an obligation to identify impact, establish baseline conditions and maintain groundwater supplies in private bores in the vicinity of petroleum operations. Where a bore owner can demonstrate reduced access to groundwater supplies, or a reduction in beneficial use class due to water quality changes, as a result of petroleum operations, “make good” provisions are available to address the loss incurred by an affected bore owner.

Under the P&G Act, the make good obligation for affected bores also applies to petroleum tenure obtained under the *Petroleum Act 1923* and are further defined in the Water Act.

2.2 Water Act 2000, Queensland

The Water Act 2000 (as amended 2010) regulates access to water resources. Under the Water Act, a water licence is required to take water for any use other than domestic and stock watering. When a water licence is required, there may be a requirement under Section 214(e) to carry out and report on a monitoring program. If water is to be provided to others as part of the activities, they are required to be registered as a Water Service Provider.

As mentioned previously, in 2010, groundwater management requirements that were previously regulated under the P&G Act and the *Petroleum Act 1923* were removed and included in an amendment to the *Water Act 2000.* Those requirements included the obligations to:

- Prepare UWIRs;
- Establish groundwater baseline conditions through baseline assessment of private bores; and
- Define make good provisions as a contingency to address losses incurred by private bore owners resulting from petroleum activities.

The Water Act also defines the drawdown thresholds which if reached will trigger investigations and make good actions.

2.2.1 Underground Water Impact Report (UWIR)

The amendments to the Water Act support management and protection of water resources, by requiring operators to prepare periodic UWIR. Subsequent UWIR’s are to be prepared every three years. The approved reports will be publicly notified by Santos and published on the Queensland Department of Environment and Resource Management (DERM) website.

The following requirements apply to the preparation of UWIR, along with the reference to the section(s) in this report where the requirement is addressed:

a) for the area to which the report relates:

   i) the quantity of water produced or taken from the area because of the exercise of any previous relevant underground water rights (Section 6.0)

   ii) an estimate of the quantity of water to be produced or taken because of the exercise of the relevant underground water rights for a 3 year period starting on the consultation day for the report (Section 6.0).

b) for each aquifer affected, or likely to be affected, by the exercise of the relevant underground water right:

   i) a description of the aquifer (Section 5.0)

   ii) an analysis of the movement of underground water to and from the aquifer, including how the aquifer interacts with other aquifers (Sections 5.0, 7.0 and 8.3.3)

   iii) an analysis of the trends in water level change for the aquifer because of the exercise of the [extraction] rights (Sections 7.0 and 8.3.3)

   iv) a map showing the area of the aquifer where the water level is predicted to decline, because of the taking of the quantities of water forecasted, by more than the bore trigger threshold within 3 years after the consultation day for the report (Section 7.3)

   v) a map showing the area of the aquifer where the water level is predicted to decline, because of the exercise of relevant underground water rights, by more than the bore trigger threshold at any time

c) a description of the methods and techniques used to obtain the information and modelled predictions (Section 7.0);

d) a summary of information about all potentially impacted water bores in the area, including the number of bores, and the location and authorised use or purpose of each bore (Section 9.2)

e) a program for:

   i) conducting an annual review of the accuracy of each map

   ii) giving the chief executive a summary of the outcome of each review, including a statement of whether there has been a material change in the information or predictions used to prepare the maps;

f) a water monitoring strategy (Section 10.0)

g) a spring impact management strategy (Section 9.1)

The water monitoring strategy must include a strategy for monitoring water levels and water quality in aquifers in the area, and a strategy for monitoring the quantity of water produced from O&G wells. A timetable for the implementation and reporting program must also be completed.

The spring impact management strategy must include details as to the potentially affected springs, an assessment of the connectivity between the springs and the aquifers and an assessment of the impact of the predicted water level decline on ecosystem health and cultural values. The strategy should provide options to prevent or mitigate impacts. An implementation timetable and a monitoring and reporting program should be included.

2.2.2 Drawdown Trigger Thresholds

DERM has defined a new regime for drawdown trigger threshold new as follows:

- 5 m decline for consolidated aquifers such as sandstone;
- 2 m decline for shallow alluvial aquifers; and
- 0.2 m for active springs.

Under this amendment, Santos will be expected to investigate complaints from landowners within an *Immediately Affected Area* – an area defined where the water level is expected to exceed the trigger threshold within three years from the reporting day. If the investigation concludes that a material impact to water production will occur, then Santos and the affected groundwater user will negotiate an appropriate make-good arrangement.

2.3 Other Applicable Water Regulations

Table 2 summarises the additional legislative requirements applicable to the oil and gas production and the Study Area.

Table 2: Additional Legislative Requirements Related to Groundwater

Legislation/Section	Driver	Key Points as they Apply to the Santos Operations
Environmental Protection Act 1994, Queensland	Section 309Z can be imposed on a petroleum activity and cause the activity to prepare an environmental report and/or implement water management plans.	Conditions are issued through Environmental Authorities.
Environmental Protection (Water) Policy, 2009, Queensland	An environmental plan must be developed and implemented for water management, including plans for managing stormwater, sewage and trade waste for protection of surface and groundwater. In the case of produced water recycling, water releases on land, water releases to surface water or stormwater management, the administrating authority must consider the existing quality of waters that may be affected, the cumulative effect of the release in question, the water quality objectives for waters affected and the maintenance of acceptable health risks.	Contamination must be minimised or prevented and any release, or potential release, must be monitored against site baseline conditions.

Management of Water Produced in Association with Petroleum Activities (produced water), December 2007	To promote the beneficial use of produced water from petroleum activities in Queensland, including the promotion of beneficial use, and re-injection.	The management options chosen by Santos must comply with the conditions of the General Notice, and they must have appropriate facilities at the site where the water is to be used. If Santos wishes to use produced water for purposes other than domestic or stock purposes (such as irrigations), the holder must obtain a water licence under the *Water Act 2000*.
Great Artesian Basin Resource Operations Plan 2006	Defines the maximum amount of water that can sustainably be extracted from the recognised aquifers within each groundwater management area. Requires monitoring for all licensed bores	Santos production wells are not licensed for water extraction with DERM as they are covered by the Petroleum Legislation.
Environmental Protection and Biodiversity Conservation (EPBC) Act 1999	Provides the regulatory framework for Matter of National and Environmental Significance (MNES).	The most significant groundwater related MNES in the GAB are GAB artesian discharge springs.
Water Resource (Cooper Creek) Plan 2000, Queensland	The Plan applies to watercourses and non-artesian groundwater systems.	Defines water rights for accessing non-GAB groundwater systems and surface water

3.0 METHODOLOGY FOR THIS UWIR

3.1 Sources of Data

Table 3: List of Available Data

Data	Source	Details & Comment
Bores names & locations, bore hydrogeological information	DERM	Extraction from DERM groundwater database.
Bore use, licensing	DERM	Extraction from DERM Water Entitlements System (WES) database (previously WERD database)
Oil and gas wells	Santos	Location, date of installation, initial pressure, depth, target formations, status
Geology	Santos	Some conceptual geological cross sections provided in power point presentations and reference papers
	Santos	Stratigraphy tables, reports, reference papers
	Santos	Review of regional petroleum potential: regional mapping of petroleum beds, geochemistry of oil and gas, migration pathway
	SA Government	Petroleum geology of southern Australia
Planning development	Santos	Petroleum Lease - Later Development Plan
Hydraulic parameters of oil and gas formations and other formations	Santos	Estimates of the reservoirs permeability and porosity values of specific formations
	Literature Review	Estimates of hydraulic conductivity for majority of formations
Regulatory / Licences	Santos	Environmental Authority
Groundwater production	Santos	Produced water volumes per field (for oil), produced oil volume also provided. Forecast volumes not provided.
	DERM	Groundwater licence data (licence register only, no allocation provided by DERM)
Water levels / formation pressures	Santos	Initial reservoir pressures (prior to testing and production) available for a number of production wells.
	DERM	Data available from groundwater database, no monitoring data available/provided
	Santos	Multi-levels formation pressure provided for Iliad oil field and Tickalara oil field
Well field estimates for future production and pressures	Santos	Not provided
Well completions information	Santos	Not provided
	DERM	Information available in groundwater database
Dam/ Ponds data	Santos	Ponds register available
	Santos	Santos Ponds water management engineering standards available
	Santos	Ponds water quality results for hazard category assessment
Environmental values	Santos	Environmental management plan for the south west Queensland
	DERM	GAB springs location (including discharge springs)

Water quality data	Santos	Chemistry data for selected environmental monitoring and production wells
	DERM	Information within the DERM Groundwater database
Weather data	BOM	Climate data obtained BOM website - http://ww.bom.gov.au/

3.2 Data Collation and Review

An extensive data request was provided to Santos with a full day meeting with Santos geologist, reservoir engineer, environmental team members and GIS operators at the start of the study to discuss data requirements and the context of use of the data.

In parallel, data was collated from literature review, governmental databases and websites.

The bores and wells located within the study area were assessed. Data was received in different formats. In some instances, the accuracy of the data provided was questionable. Data quality was thoroughly checked, and data were excluded from further analysis if found to be of poor quality.

Typically, poor quality information was attributed to contradictory information, lack of units for measurements, or the absence of key hydraulic parameters for some formations. All coordinates were converted to Geographic Datum GDA94 (latitude & longitude). Corrections and/or conversions were made when required. All elevations in the report are provided in metres, in relation to the Australian Height Datum (m AHD).

A hydrogeological conceptual model of the Cooper Basin study area was developed utilising bore or well hydrogeological information.

Note: In this report, the term ‘well’ refers to infrastructure used to extract gas or oil and produced water from the subsurface. A ‘bore’ refers to the structure that is used to extract groundwater for domestic, stock, irrigation, industrial or commercial purposes. Although wells and bores are defined differently; they are similar engineering structures.

3.3 Geology and Stratigraphy

Santos SWQ oil and gas operations are located within the Eromanga Basin and the Cooper Basin. While in QLD, the regulation relative to management of groundwater in the GAB includes the upper formations of the Cooper Basin in the definition of the GAB, Santos considers the Cooper Basin and Eromanga Basin as two different basins separated by the Basal Jurassic Unconformity and with the Cooper Basin not belonging to the GAB.

The geology of both basins is documented in the literature, the focus of those references being most often the oil and gas reservoirs.

Santos geologists and engineers were consulted to provide site specific information and documentation and also confirm and identify geological characteristics and features in the local geology of the study area. Stratigraphic information, made available by Santos, focused on the stratigraphy of the oil and gas formations and the adjoining formations.

The geology is described in Section 4.3.

3.4 Groundwater Level and Quality

Groundwater level and quality data were obtained primarily from the DERM groundwater database. The data was extracted from the “water level” table.

Water levels were assigned to targeted aquifers using an automated database function by relating the open section details of the bore (open, screen or perforation depths) to the stratigraphy and aquifer tables through common features ‘bore construction’ and the ‘formation tops and bottoms’. Where the automated query returned an error message, the assignment of a target aquifer to the bore was performed manually. Note that in the following circumstances it is *not* possible to assign a target formation to a bore:

- Absent or incomplete bore construction, aquifers or stratigraphy information.
- Bore open through several formations, in which case water levels or water chemistry results cannot be used to characterise a specific formation.
- Contradictory information.

This exercise reduces significantly the number of bores contributing to the definition of the hydrogeological conceptual model.

Water quality data were extracted from various sources that included databases and excel spreadsheets. The analytes selected for the groundwater water quality assessment were pH, electrical conductivity (EC) and major ions. Available water quality information for each bore was identified and assessed. The water chemistry data were also linked to their targeted aquifer.

Santos data predominantly represented the oil and gas formations. Initial bore pressures were provided. Water quality data were provided for some of the wells and water management ponds.

3.5 Bore Construction

DERM requires that a water bore driller undertaking the drilling of water bores be registered. The main intention of this requirement is to prevent adverse impacts potentially arising from inter-aquifer leakage. Under the Petroleum Legislation, gas and oil wells may be drilled by non-registered water drillers.

Oil and gas well construction practices and well integrity are further developed in Section 6.0.

3.6 Meta Data Summaries

Metadata is “data about data”. That is, information on the:

- data available;
- amount of data;
- coverage of data;
- quality of data; and
- source of the data.

As part of the data quality checking process, each bore of the study area from the DERM groundwater database was assigned a “data quality” score for each of the criteria presented in Table 3.
The assessment card in Table 3 allows for the update of the metadata based on the results of the groundwater baseline assessment to be carried out from later this year.

Table 4: Metadata Assessment Card

Information	Score	Criteria
Bore Stratigraphy	1	Good stratigraphy information
	2	Partial stratigraphy information available
	3	No information
Bore Construction	1	Good bore construction practices
	2	Bore construction practice in doubt
	3	No information / bad bore construction
Water Levels	1	Water level information and date of survey
	2	Water level but no date
	3	No data
Bore Chemistry	1	EC and pH measurements and date of sampling
	2	Partial information
	3	No data
Water Quality	1	Major ions chemistry available and date of sample
	2	Partial information
	3	No data
Bore Depth	1	Bore log (original hard copy available) *OR* DERM and Bore Inventory data* identical *OR* depth ground proofed.
	2	Depth available from DERM database only OR DERM database value when Bore Inventory depth and DERM bore depths are different.
	3	Depth from Bore Inventory only (oral information)
	4	No data

*bore depth bore inventory data is not yet available; the metadata scoring will need to be reviewed after completion of the baseline assessment program.

The data from DERM were compiled together into one main "metadata table". The metadata table identifies the data available for each bore and when available, provides general information for each bore or well. Secondary tables providing the water levels and water chemistry data were also created to assist with the development of the hydrogeological conceptual model.

The bore depth and target formation information is not readily available in the DERM database and was compiled directly from the DERM database where possible using the casing, stratigraphy and aquifer tables. The cross-referencing was automated. Due to poor data entry format and poor data consistency in the database many bores cannot be related to a formation target directly, a number of correlations have been performed manually. In addition the WES (previously WERD) database, which gathers information on water licensing was used to complete some of the empty fields as bores are licensed to withdraw water from a specific aquifer. Conflicts between databases were solved on a case to case basis.

Table 5: Metadata Summary

Field	Description
Bore Name	Unique name for each bore
Facility type	Represents the type of bore, for example sub-artesian, artesian - controlled flow
RN replaces	Identify bore replacement. Data from the DERM data base.
Facility status	Abandoned, suspended, producing, monitoring well, etc.
Target aquifer	Geological formation
Source for Target Aquifer	DERM or WES
WES database target aquifer	Geological formation
Bore Depth	Drilled depth (in metres)
Bore depth - DERM Table	Casing, strata log, stratigraphic table or no data
Source Bore Depth	DERM (table source)
Driller name	Driller name – where available
Driller licence number	Licence number – where available
Shire code	Number – where available
Parish	Number – where available
Drilling company	Drilling company – where available
LOT	LOT number – where available
PLAN	Number – where available
Description	Address
County	Address
Property name	Address
Original name number	Address
Coordinates	Geographic Datum GDA94, latitude and longitude
Elevation	Of surface or wellhead or reference point, in m AHD
Source elevation - DERM	Advanced Spaceborne Thermal Emission and Reflection Radiometer, Global Positioning System or Survey
Equipment - DERM	Windmill, Head work etc.

Field	Description
Bore Purpose (WES data)	Domestic Supply, Stock etc.
Interpreted stratigraphy	Score 1, 2 or 3 (refer to Table 3)
Construction details	Score 1, 2 or 3 (refer to Table 3)
Water level	Score 1, 2 or 3 (refer to Table 3)
Bore chemistry (Field)	Score 1, 2 or 3 (refer to Table 3)
Water Quality	Score 1, 2 or 3 (refer to Table 3)
Bore depth	Score 1, 2, 3 or 4

3.7 Development of the Hydrogeological Conceptual Model

A conceptual hydrogeological model (CHM) is a non-mathematical presentation of the hydrogeology of a region. The model provides information about the nature and extent of geological layers comprising the subsurface of:

- aquifers, aquitards and aquicludes - their characteristics and interactions between each other;
- groundwater flow; and
- geological and man-made influences on the groundwater systems.

The purpose of the conceptual model is to provide a visualisation of the hydrogeological system. It may also be used to define the baseline groundwater conditions that can be used to assess potential future impacts. The conceptual hydrogeological model is based on geological cross section and contours maps of the local interpreted hydrostratigraphy. The section and maps identify the locations, depth and thickness of each formation where possible (in these case, sedimentary layers), areas of outcrop at the surface, salinity and the direction of groundwater flow.

The hydrogeology of the Eromanga Basin is generally well documented in the literature on a regional scale. This is not so true for the hydrogeology of the Cooper Basin formations.

Hydrogeological maps illustrating the hydraulic heads and salinity data were created for each major formation provided sufficient water heads and salinity data were available. The maps are a representation of the current system even though a lot of the data is not recent, a number of bores have water heads values and salinity measurements from the last ten years and from much earlier times, these values are observed to be similar, confirming that the map would generally be acceptable for a current representation of the system.

To generate the maps, data that did not have spatial attributes (coordinates or depth) were excluded. Individual data points were assessed, and in most cases removed if the value for that point was significantly different to those from the local area. Areas with no information (i.e. formation too deep for the completion of private bores) or where the aquifer was non-existent (i.e. beyond the outcrop region), were not included.

3.8 Impact Estimation

The recent amendments (June 2011) to the QLD Water Act 2000 (Reprinted in June 2011 and discussed in Section 2.0) and the P&G Act 2004 do not require the UWIR to estimate impact through the use of a groundwater numerical model. Section 258 of the P&G Act, now repealed, provided exemption to the need to development of a *groundwater flow model* when:

- Existing Water Act bores in an aquifer other than the source aquifer for the exercise of the rights—the source aquifer is *not* hydraulically connected to that aquifer;
- Any existing Water Act bore in the source aquifer is *sufficiently separated in distance* from the place where the rights are to be exercised.

As mention previously, the requirements for the UWIR (refer to Section 2.0) are now contained in the Water Act 2000. This requires a description of the methods and techniques used to obtain the information and predictions of the area of an aquifer where the water level is predicted to decline of more than the bore trigger threshold (S376) (Section 2.2).

A groundwater numerical model was not developed for the Santos Cooper Basin activities. The approach to estimate water variation impact is a combination of:

- Assessment of risk to existing groundwater bores and environmental values associated to the producing aquifer;
- An analytical solution approach (using analytical equations to calculate groundwater flow) which uses the hydrogeological data from the conceptual hydrogeological model to establish **indicative estimated of the magnitude of potential drawdown** in the target beds and neighbouring formations; and
- The field pressure data and formation stratigraphy demonstrating the absence of impacts between formations.

4.0 SITE DESCRIPTION

4.1 Topography and Drainage

Santos Cooper Basin oil and gas field projects are situated across a very large generally flat drainage area of what is known as the Channel Country of far south-eastern Queensland (extending into South Australia).

Topography is limited to low undulating topography ('hills and ridges') between the drainage channel system. The Channel Country is characterised by vast flat lying braided, flood and alluvial plains of the Diamantina and Coopers Plains. Surrounding the floodplains are gravel or gibber plains, dunefields and low ranges. The low resistant hills and tablelands are remnants of the flat-lying Cretaceous (65-140 million years ago) sediments.

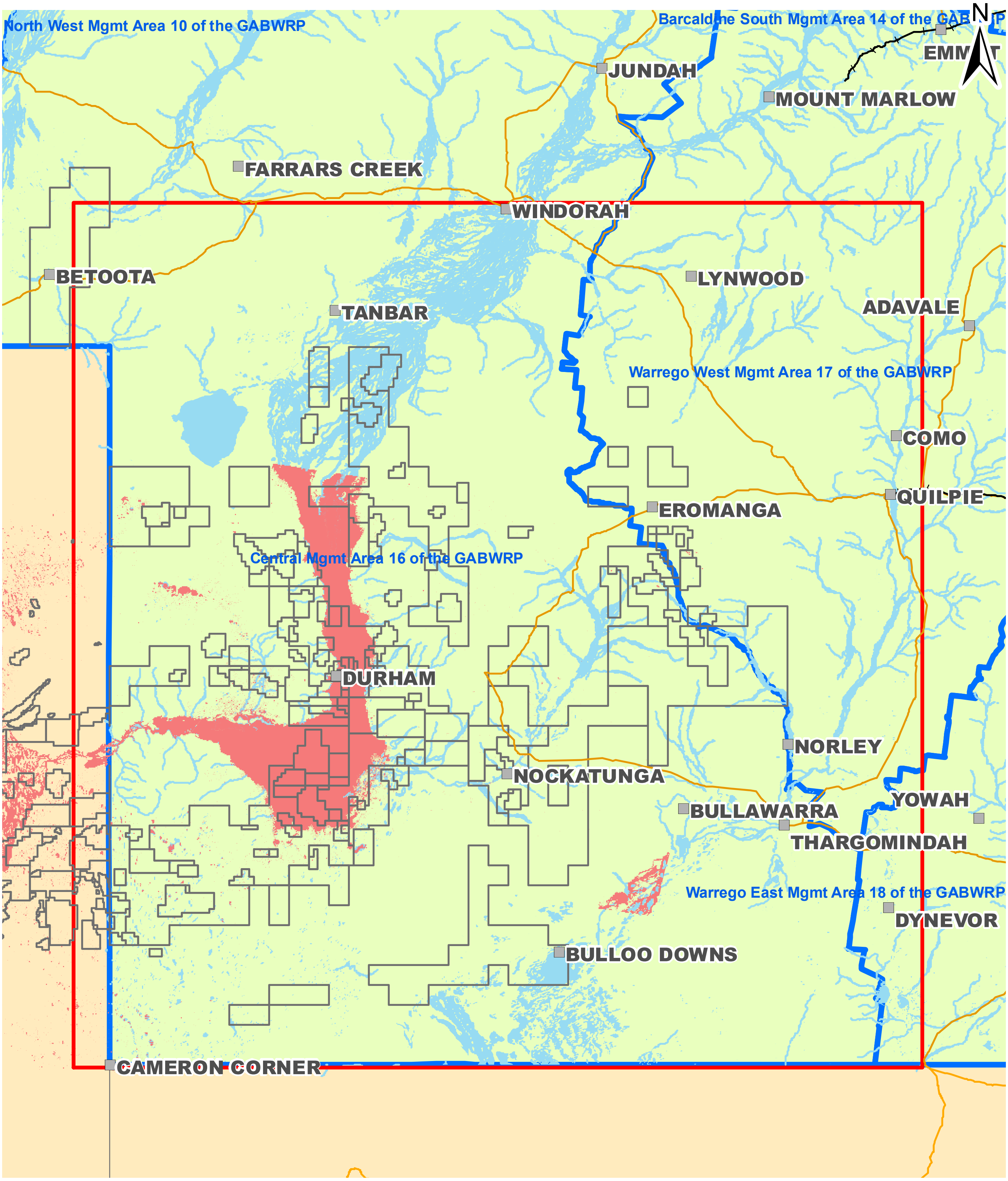
The drainage system is dominated by the Cooper Creek Basin and drains towards Lake Eyre (Figure 5). During period of high rainfall, the flat topography and drainage channel system becomes a very large flooded plain. The water flow bottlenecks where Cooper Creek crosses the Queensland-South Australia border.

The Cooper Creek is an internal river of 1,523 km length and covering a catchment area of 306,000 km^2. Water flows vary greatly over time. In most of the creek reaches, the braided channels of Cooper Creek and its main tributary, the Wilson River, are dry and little more than a string of waterholes.

Generally, Cooper Creek stream flows are confined to the main channels, but every 3-4 years flows are sufficient to inundate parts of the Cooper floodplain, via a network of tributary channels. During extended periods of no flow, the Cooper contracts to a series of semi-permanent and permanent waterholes, which provide drought refuges for a variety of flora and fauna.

Within the study area (largely confined to the Cooper Creek catchment basin), there are also intermittent surface water flows following storm events that cause ponding of surface water on interdune clay pans, predominantly in the dunefield regions and other areas.

The latest large flood event was observed in January and February 2010.



COOPER BASIN UWIR

SANTOS

STUDY AREA DURING FLOODS (2010)

LEGEND

- Town/Locality
- Railway
- Highway/Major Road
- River/Creek
- Santos Operated Permits
- Study Area
- Flood Area 2010 Extent
- Groundwater Management Area

0 5 10 20 30 40 50 Kilometres

SCALE (at A4) 1:2,500,000

Coordinate System: GCS GDA 1994

PROJECT: 117636010
DATE: 19/12/2011
DRAWN: AJW
CHECKED: FH

FIGURE 4

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1. Base information copyright MapInfo Australia Pty Ltd
2. ATP/PL tenure supplied by Santos, August 2011
3. Flood extents provided by Santos, 2011

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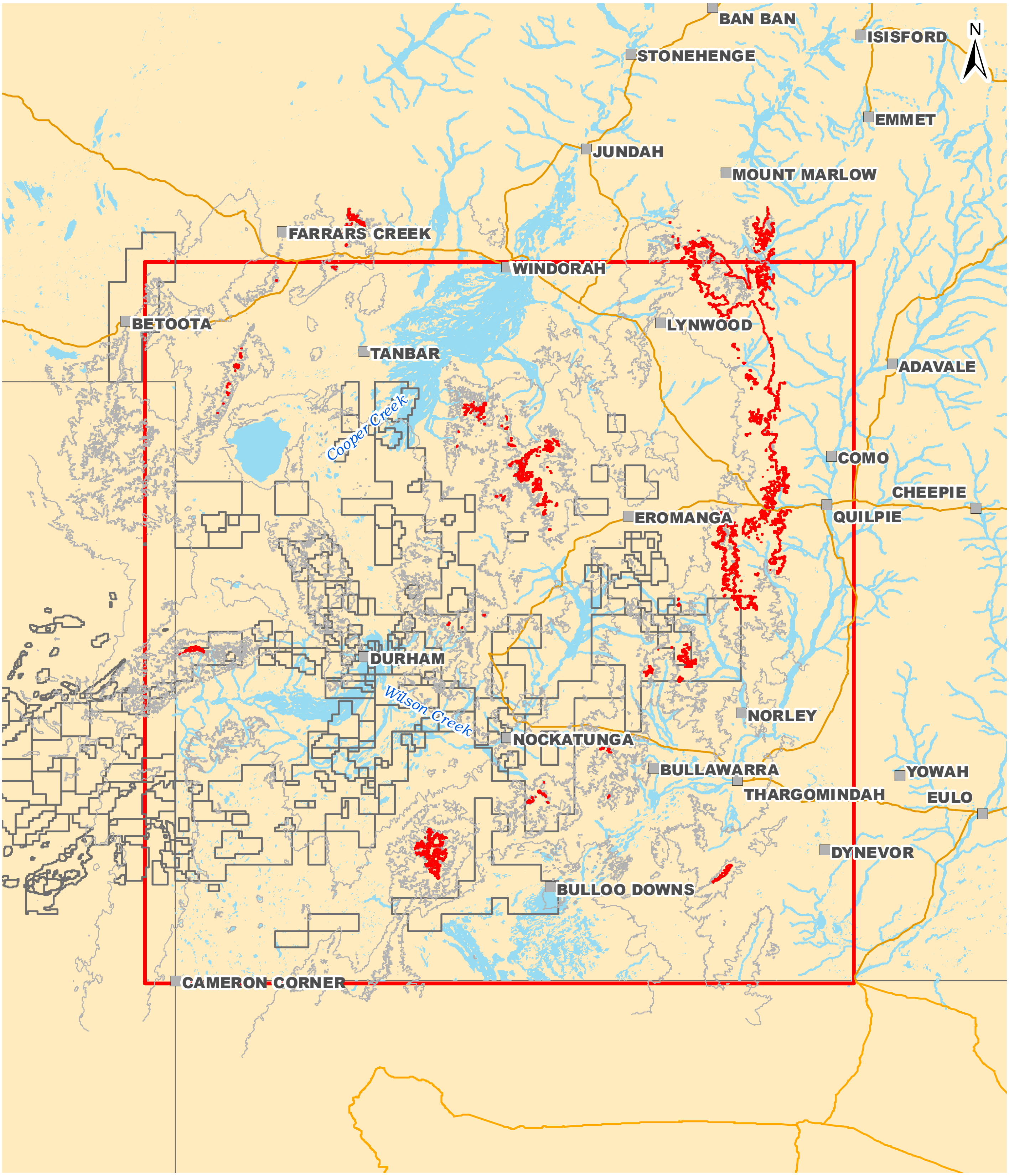
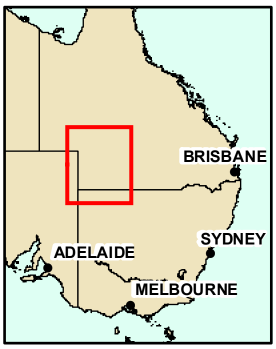


COOPER BASIN UWIR

SANTOS

TOPOGRAPHY AND DRAINAGE OF THE STUDY AREA



LEGEND

- Town/Locality
- Elevation Contour - 250m mAHD
- Elevation Contour - 50m Interval
- Highway/Major Road
- River/Creek
- Santos Operated Permits
- Area of Interest

0 10 20 40 60 80 100 Kilometres

SCALE (at A4) 1:3,000,000

Coordinate System: GCS GDA 1994

PROJECT: 117636010
DATE: 20/12/2011
DRAWN: AJW
CHECKED: FH

FIGURE 5

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COPYRIGHT
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File Location: J:\hyd\2011\117636010 Santos_Copper Basin O&G & Moonie Oil - official folder in BRISBANE\GIS\Projects\117636010_R_F0030_CooperBasinTopography.mxd

4.2 Climate

As note previously, the Cooper Basin is located within South West Queensland, which is an arid to semi-arid region of central Australia where the average rainfall is low. The seasons are generally characterised by hot mild dry summers and dry winters. December to February are the wettest and hottest months where temperature exceed 35°C. The Bureau of Meteorology (BOM) provides monthly average data for temperature and rainfall for anywhere in Australia. For more detailed description please refer to http://www.bom.gov.au/.

Table 6 presents the average minimum and maximum monthly temperatures, the average monthly total rainfall for the study area collected from *Windorah Post Office* as closest station to Durham. These data are averages for number of years. Maximum values are in red and minimum values in blue. Annual average values for temperature and rainfall are also presented in Figure 6.

Table 6: Mean Climate Characteristics within the Cooper Basin Operations Area - Windorah Station

Mean	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years
Temp (°C) - Max	38.1	36.6	34.5	30.2	25.3	21.7	21.4	24.1	28.4	32.5	35.4	37.8	30.5	1931-2012
Temp (°C) - Min	24.1	23.5	21.1	16	11.3	7.6	6.6	8.1	12.1	16.5	19.9	22.5	15.8	1931-2012
Rainfall (mm)	42.9	49.2	43.3	19.7	18.8	16.5	15.0	9.8	10.6	17.7	22.3	30.7	296.9	1887-2012
Evaporation (mm)	12	11	9.5	7.2	4.8	3.6	3.7	5.2	7.4	9.6	11.3	12.5	8.2	1969-2012

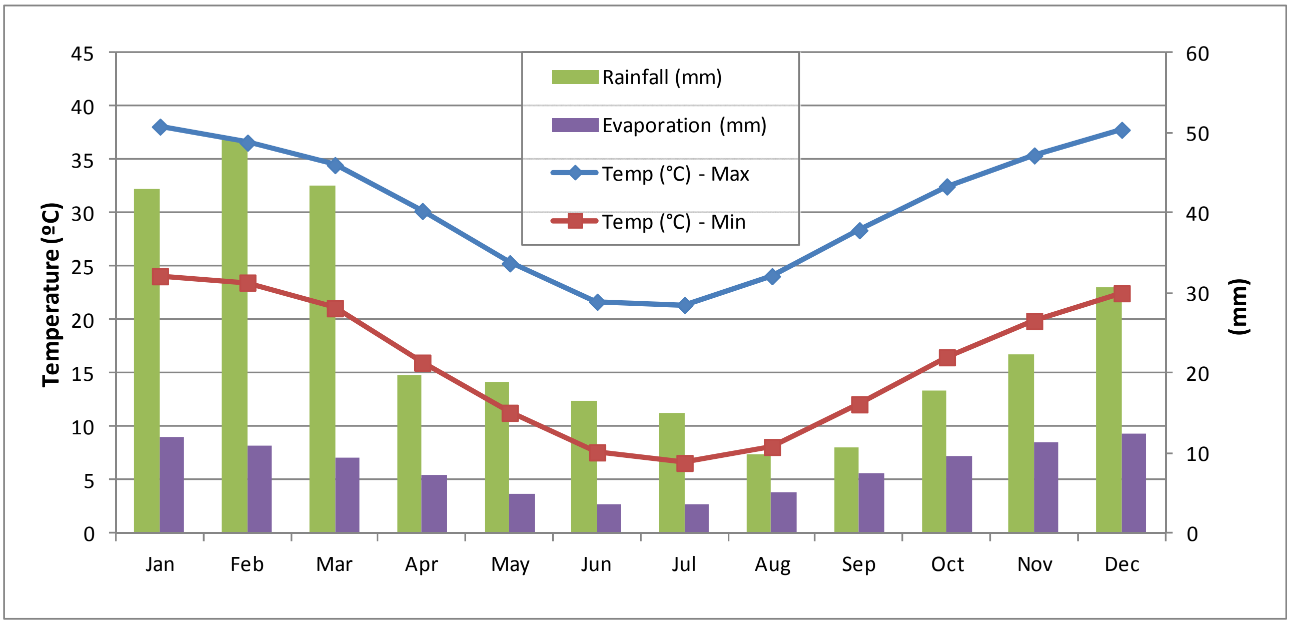


Figure 6: Rainfall and Temperature Diagram - Monthly Averages from 1931-2012 for Windorah Station (BOM, 2012)

4.3 Geology

4.3.1 Regional Settings

This section defines the regional geological setting of the Study Area.

Santos SWQ oil and gas operations are located within the Eromanga Basin and the Cooper Basin. While in QLD, the regulation relative to management of groundwater in the GAB includes the upper formations of the Cooper Basin in the definition of the GAB, geologists consider the Cooper Basin and Eromanga Basin as two separate basins with the Cooper Basin not belonging to the GAB.

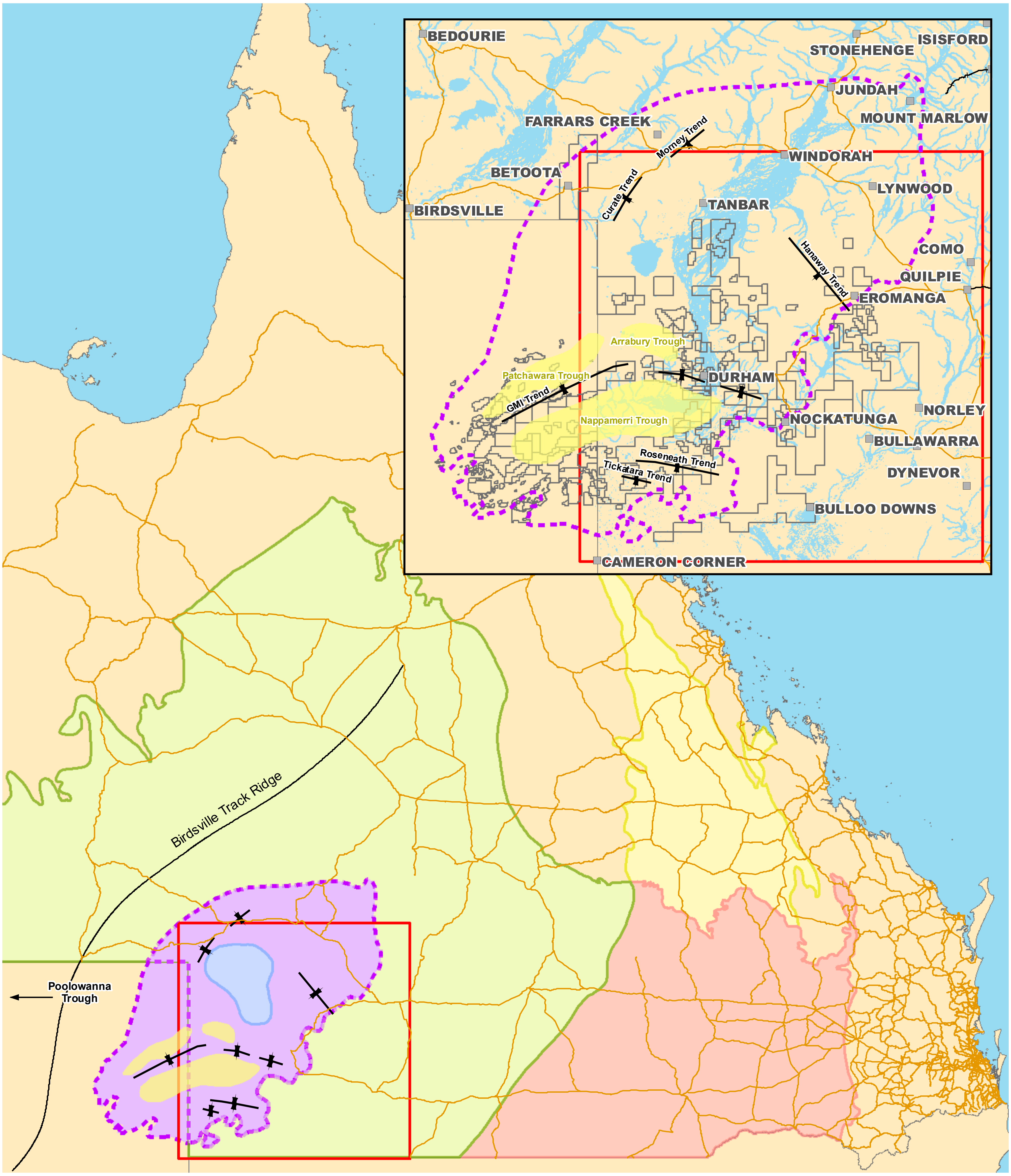
4.3.2 Depositional Configuration

At Surface, the geology is dominated by Quaternary alluvium deposits (Figure 9) associated with the flood plains, with consolidated sediments of the Glendower Formation (Tertiary) or Winton Formation (Cretaceous) on the higher ground.

The Great Artesian basin ("GAB") underlies approximately one-fifth of the Australian continental area and extends beneath a large portion of Queensland, South Australia, New South Wales and the Northern Territory; stretching between the Great Dividing Range and the Lake Eyre depression (Figure 7). The Eromanga Basin is the largest *sub-basin* within the Great Artesian Basin, and it contains two major centres of basin subsidence: the Central Eromanga depositional centre and the Poolowanna Trough, separated by the Birdsville Track Ridge (Figure 7). Total sedimentary thicknesses range between 100 m and 3000 m.

The GAB is underlain by several older sedimentary basins, of which the Permian-age Cooper Basin is one example, with the Cooper Basin being entirely overlain by the Eromanga Basin. A major unconformity at the base of the Jurassic succession separates the Jurassic-Cretaceous Eromanga basin from the underlying Carboniferous-Triassic Cooper Basin.

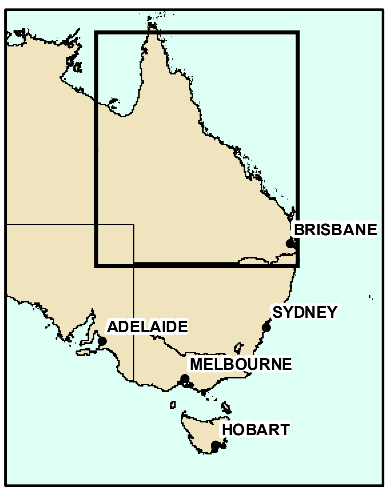
Note that the names of the formations within the Cooper Basin and the GAB vary from one area to another. Habermehl (Habermehl, 1986) and others have tried to provide basin wide correlations between nomenclatures for the GAB. This section aims at using the geological nomenclature defined for SWQ by Draper (2002) and reported in Figure 8. Reference to "equivalent naming" will be required in order to link with the nomenclature used in the QLD GAB regulation



COOPER BASIN UWIR

SANTOS

GAB STRUCTURAL GEOLOGY OF THE STUDY AREA



LEGEND

- Town/Locality
- Highway/Major Road
- Birdsville Ridge (Approximate Location)
- Structural Trend
- Geological/Structural Trough
- Santos Operated Permits
- Study Area
- Cooper Basin
- Barrolka Trough
- Bowen Basin
- Eromanga Basin
- Surat Basin
- River/Creek

0 30 60 120 180 240 300 Kilometres

SCALE (at A3) **1:6,500,000**

Coordinate System: GCS GDA 1994

PROJECT:	**117636010**
DATE:	**19/12/2011**
DRAWN:	**AJW**
CHECKED:	**FH**

FIGURE 7

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2. ATP/PL tenure supplied by Santos, August 2011
3. Structural geology of GAB, DERM
4. Structural elements of the Cooper and Eromanga Basins digitised from Lowe Young et al 1997

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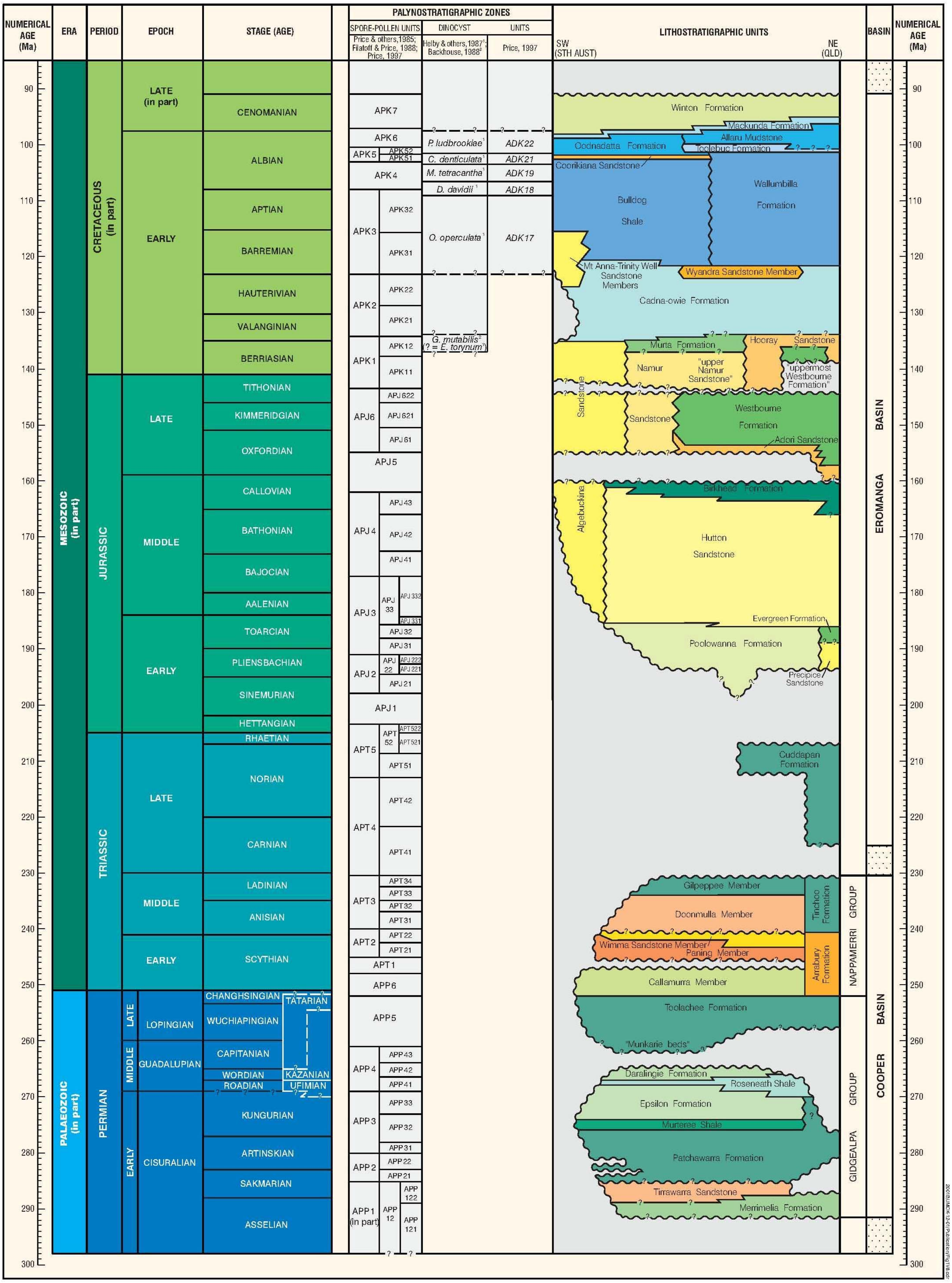
Figure 8: Chronology and stratigraphy of the Cooper and Eromanga Basins (Queensland and South Australia) (Draper, 2002)



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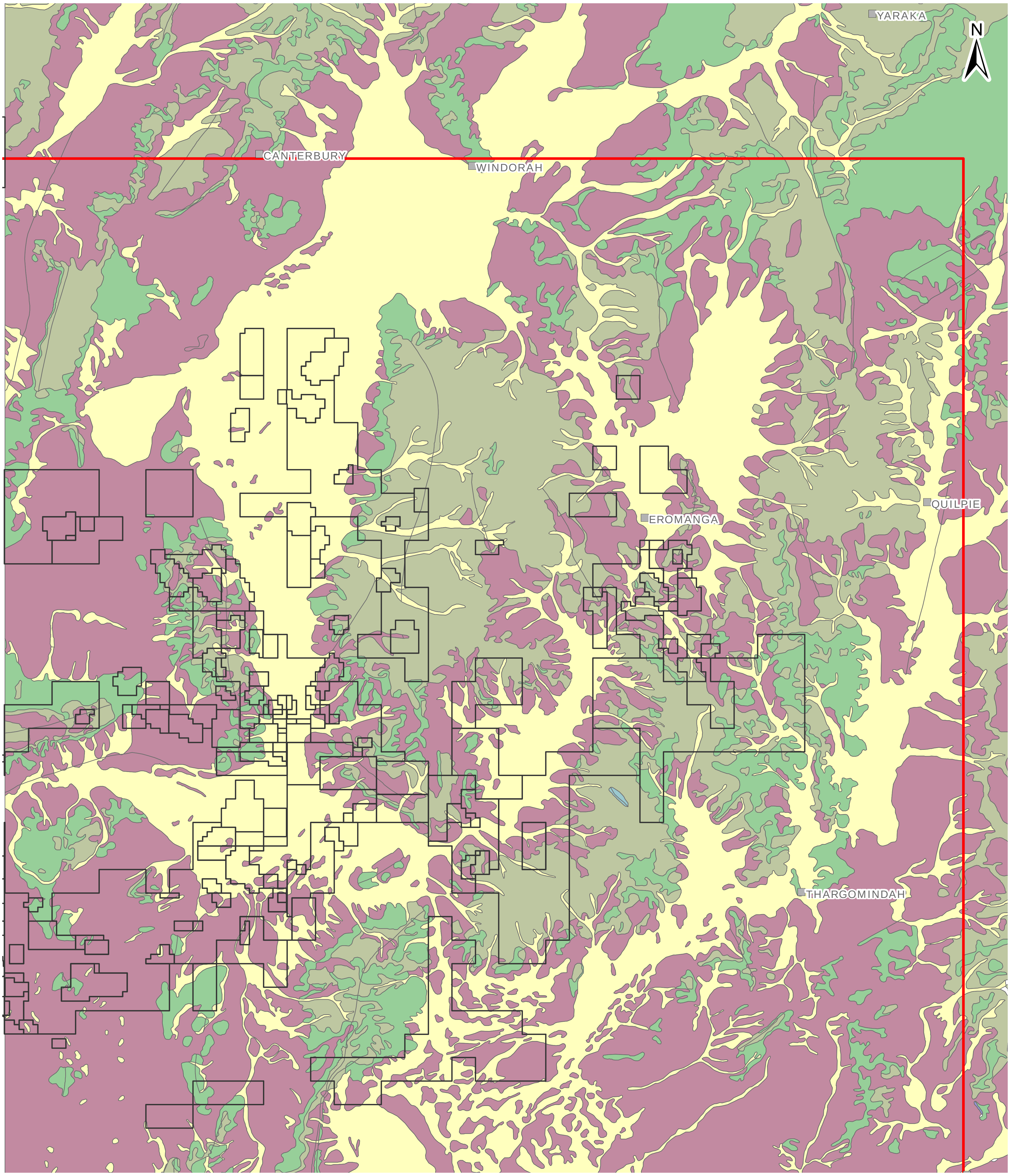

COOPER BASIN UWIR

SANTOS

SURFACE GEOLOGY

LEGEND

- Town
- Santos Operated Permits
- Study Area
- Doncaster Member
- Glendower Formation
- Mackunda Formation
- Q-CER
- Qa-CER
- Winton Formation

0 10 20 40 60 80 Kilometres

SCALE (at A3) **1:1,500,000**

Coordinate System: GCS GDA 1994

PROJECT: **117636010**
DATE: **29/11/2011**
DRAWN: **AJW**
CHECKED: **FH**

FIGURE 9

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3. Tenure boundaries supplied by Santos, August 2011

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4.3.3 Tectonic Setting and Basin Stress Regime

Introduction

The primary stresses within the Cooper-Eromanga basin are vertical overburden stress σv, maximum horizontal stress σH, and minimum horizontal stress σh. The stress regime within the basins are characterised on the assumption that σv is a principal stress and therefore, σH and σh are also principal stresses, where σh is the least principal stress. This assumption is considered valid given the relatively flat topography across the basin.

General stress orientation

The maximum horizontal stresses, σH, in the basin generally follow an east to west orientation, at approximately 101˚, as indicated by stress data from borehole breakout testing (Hills et al, 1998; Reynolds et a;, 2004). The east-west trending nature of σH predominates in the Nappamerri trough, however, regional variations across the basin have been observed. In the Patchawarra Trough σH is oriented southeast to north-west; north-east of Gigealpa σH was oriented west-northwest to east-southeast. This clockwise rotation of σH from the Nappamerri Trough to the Patchawarra Trough is accepted to be part of the larger stress rotation observed across the Australian continent. The orientation of σH does not exhibit significant variation with depth. (Reynolds et al, 2004).

The vertical overburden stress, σ_v is governed by overlying rock mass and the stress gradient does not exhibit significant variation with depth. The σ_v stress gradient is approx. 20.3 Mpa/km at 1,000m depth and approaches approximately 22.6 Mpa/km at 3,000m depth.

The magnitude of σ_h varies significantly across the basin; the σ_h stress gradient ranges from 13.6 Mpa/km to 22.6 MPa/km across the basin, with σ_h approaching σ_v in some local areas (Reynolds et al, 2004). σ_h decreases with depth up to approximately 1 km below the surface and then stabilises. At 1km to 4 km depth σh is between 0.6 σv to 0.7 σv, with σ_h generally approaching the higher end of this range (Hillis et al, 1998). At lower depths σ_h approaches, and may exceed, $\sigma_{v,}$ resulting in σ_v becoming the minimum principal stress. (Reynolds et al, 2004).

Stress Assumptions and principal stresses – general faulting regime

On the basis that σ_h is the minimum principal stress, the Cooper-Eromanga basin stress regime is primarily associated with strike-slip faulting σ_H > σv> σ_h, normal faulting $\sigma_v > \sigma_H > \sigma_h$, and transitional strike-slip/reverse faulting ($\sigma_H > \sigma_h \approx \sigma_v$) at depth where $\sigma_h \approx \sigma_v$. Reverse faulting ($\sigma_H > \sigma_h > \sigma_v$) is not associated with the stress regime in the basin however, at lower depths where $\sigma_h > \sigma_v$ may occur some reverse faulting may exist. (Reynolds et al, 2004).

Hydrostatic stress

Pore pressures within the basin are generally hydrostatic. Overpressures are thought to occur in deeper shalier strata within the basin and have been observed in the Nappamerri Trough from depths of 2.7 km (Hillis et al, 1998). Local under-pressures have also been observed and are attributed to extensive production within the basin (Reynolds et al, 2004). This is of particular importance when considering the impact of depressurising formations through oil and gas extraction. The implication is that impact translation though the depositional sequences are minimised or negated completely. This is further discussed in the succeeding sections.

Seismic activity

Major earthquake events within the immediate region surrounding the basin, bounded by the Simpson Desert, NSW-QLD border, and the NT-QLD border, include:

- Tennant Creek, NT (6.7 Mb) in January 1988
- Simpson Desert, NT (5.6 Mb) in August 1972
- Simpson Desert, NT/QLD/SA (4.7 Mb) in November 1978.

This region has experienced intermittent earthquakes of low to moderate magnitude (0 – 3.5Mb) each year since the establishment of seismic records.

4.3.4 Summary of the Cooper Basin Geology

The Cooper Basin comprises a thick late Carboniferous to Middle or late Triassic non-marine sedimentary pile within a broad basin shaped setting in the interior of central Australia.

Structurally, the Cooper Basin is one of a number of remnant Late Carboniferous to Early Permian depositional centres which lay in the Australian interior of the Gondwana Supercontinent. The Cooper Basin differs from these other depositional centres by containing an additional sequence which ranges in age from Late Permian to Middle Triassic and spans the Permo-Triassic boundary *without* a break in deposition. It also differs in being the only such basin with major oil and gas production (Petroleum Geology of South Australia, Volume 4 - Cooper Basin, PIRSA, 1998). Three major troughs (Patchawarra, Nappamerri and Tanapperra) are identified within the basin, each separated by structurally high ridges.

The Cooper Basin depositional episode was terminated by a period of gentle regional compressional deformation resulting in landmass uplift and sustained erosion within the basin. Sedimentary basin development re-initiated subsequently with the formation of the Eromanga Basin (Section 4.3.3) during the Early Jurassic to Late Cretaceous times.

The Cooper Basin contains a succession of fluvio-lacustrine sandstone, shales and coals to a thickness of up to 1,800 m to the south, in the north it is thinner (up to 600 m thick).

The description of the stratigraphy and lithology for the study area is provided in Figure 10. In addition, Figure 8 provides information on the lateral continuity of the various units and on discontinuities or major unconformities present in the stratigraphic sequence.

The Cooper Basin can be subdivided in two major geological groups: the late Carboniferous and Permian Gidgealpa Group and the Triassic Nappamerri group. The earliest sediments withinthe Cooper Basin were of glacial origin. The subsequent formations generally consist of a succession of interbedded sandstone and shale formations. The Tirrawarra Sandstone represents low sinuosity fluvial to proglacial outwash deposits overlain by peat swamp, floodplain and high sinuosity fluvial facies of the Patchawarra Formation. Two lacustrine shale units (Murteree and Roseneath Shales) with intervening fluvio-deltaic sediments (Epsilon and Daralingie Formations) were deposited during a phase of continued subsidence. Early Permian uplift led to erosion of the Daralingie Formation and underlying units from basement highs (SA DPI 1998).

The upper sequence of the Cooper Basin, the Gilpeppee Member of the Tinchoo Formation is dominated by siltstones and shales. Draper (2002) has mapped the thickness of shales of the Tinchoo Formation in SWQ. The mudstone (both shale and siltstone) thickness is 80 -160 m in the centre of the Cooper Basin with maximum thickness of 182 m.

The formations of interest for Santos are the Tirrawarra Sandstone, Patchawarra Formation, Epsilon Formation and Toolachee Formation, as these are the main hydrocarbon reservoirs within the Cooper Basin:

- The *Tirrawarra Sandstone* consists of fine to coarse-grained and pebbly sandstone with locally common interbeds of conglomerate and minor interbeds of carbonaceous siltstone, shale and coal. The Tirrawarra Sandstone is 30 to 40 m thick in average in SWQ.
- The *Patchawarra Formation* consists of interbedded variable size sandstone beds with siltstone, shale and coal beds, sandstone and mudrock beds being the dominant type of geology. The Patchawarra Formation is the thickest (up to 680 m in the Nappamerri Trough and up to 550 m in SWQ near the SA border - Figure 7) and in QLD the second most widespread Permian unit after the Toolachee Formation generally extending to the limits of the Cooper Basin (Draper, 2002).
- The early Permian *Epsilon Formation* is defined as series of sandstones and siltstone and shales with minor coals. The formation is widespread across the Cooper Basin. The maximum thickness (156 m) is observed in the Nappamerri Trough, in QLD the thickness is mostly 30 to 40 m with thicker areas (up to 92 m) encountered in the QLD part of the Nappamerri Trough. .

- The late Permian *Toolachee Formation* consists of interbedded sandstones, siltstones and shale with thin coal seams and some conglomerates. It spreads unconformably over older formations across the whole Cooper Basin and is observed at its thickest in the Patchawarra and Nappamerri Troughs. In Queensland, the thickness is mostly 25 - 50 m with the exception of an area north of the Jackson–Naccowlah– Pepita Trend where the Toolachee Formation is 100 - 130 m thick (Draper, 2002).

Geological contour maps for the following formations can be found in Appendix B:

- Depth to Toolachee Formation
- Depth to Patchawarra Formation
- Thickness of Patchawarra Formation
- Thickness of Toolachee Formation
- Thickness of shale within the Nappamerri Group

The top pre-Permian faults provide the basin's overall fabric, whereas the younger faults from the basal Toolachee Formation and basal Eromanga unconformity are generally reactivated Permian faults (refer to Section 4.3.7).

The Tirrawarra Sandstone, Patchawarra Formation, Epsilon Formation and Toolachee Formation (Figure 10) are the main gas reservoirs within the Cooper Basin. Minor gas reservoirs are also present in the Tirrawarra Sandstone, the Wimma Sandstone Member of the Arraburry Formation and the Tinchoo Formation. Some oil reservoirs are present in the Paning Member of the Arraburry Formation.

4.3.5 Summary of the Eromanga Basin Geology

The Jurassic – Cretaceous Eromanga Basin unconformably overlies the older Carboniferous - Permian Cooper Basin. The sedimentary sequences which comprise the Eromanga Basin reach a thickness of up to 2,500 m and were deposited during a period of subsidence subsequent to that which generated the Cooper Basin. There are two main sub-basin centres in the Eromanga Basin: the *Central Eromanga Depositional centre* and the *Poolowanna Trough* to the west separated by the Birdsville Track Ridge (Figure 7). The top of the Eromanga Basin is also delimited by an unconformity.

The study area for this UWIR is located in the *Central Eromanga Basin*.

The deposits of the Eromanga Basin follow three episodes (and three different origins) of deposition:

- Lower non-marine sediments from early Jurassic to Mid-Cretaceous corresponding to the Poolowanna Formation to the Cadna-Owie Formation. During that period the largest transgression over the Eromanga Basin was the "Birkhead Lake" transgression.
- Marine sediments from mid-cretaceous to late Cretaceous corresponding to the Wallumbilla Formation to the Mackunda Formation.
- Upper non marine sediments (fluviolacustrine) of the Winton Formation.

The formations of the Eromanga Basin are a succession of well identified sandstones and siltstones and mudstones with interbedded minor sandstones and occasional coal seams (Figure 10).

The formations of the Eromanga Basin often have their equivalent throughout the GAB (Figure 10), the nomenclature used in this section aims at using the SWQ nomenclature as illustrated on Figure 8.

The GAB is Australia's largest groundwater system with extended confined artesian or sub-artesian aquifers. However, some parts of the aquifers are also oil and/or gas reservoirs.

The major formations of the Eromanga Basin are (from top to bottom):

- The *Winton Formation*: The Winton Formation is composed of interbedded fine to coarse sandstone, shale, siltstone and coal seams deposited in fluvio-lacustrine environments. It directly underlies the quaternary and Tertiary sediments. The Winton Formation outcrops on higher relief surrounding the valleys and flood plains of the study area and show lateral facies changes from east to west.
- The *Wallumbilla Formation* or *Rolling Downs Group*: The confining beds of the Rolling Downs Group, and, in particular, the Lower Wallumbilla Formation and Upper Wallumbilla Formation, referred to as Doncaster and Coreena Members in other parts of the GAB, occur throughout the Eromanga Basin, Surat Basin and Carpentaria Basin. The fine-grained nature of the Rolling Downs Group sediments is reflected in the low to very low porosity and permeability of these units. The thickness is on average 500 m in the component basins but thins to less than 300 m over the Eulo-Nebine Ridge and Euroka Arch (Appendix B). Within the Eromanga Basin, the sequence attains a maximum thickness of 1,000 m (BRS, 2000).
- The *Cadna-Owie* and *Hooray Formations*: The Cadna-Owie and Hooray formations are thinnest (<50 m) on the existing erosional margins, and thickens toward the basin centre to reach a maximum interpreted thickness of 800 m in the Surat Basin (Appendix B). Aquifer thickness reaches a maximum of 350 m over the southwestern regions of the underlying Patchawarra, Nappamerri, Allunga and Tenappera Troughs within the Cooper Basin (BRS, 2000) described previously;
- The *Westbourne Formation, Adori Sandstone* and *Birkhead Formation*: This group is dominated by shale and mudstone beds which thicknesses up to 140 m for the Westbourne Formation and 110 m for the Birkhead Formation in SWQ. The Adori Sandstone contains the main sandstone beds of the group on thicknesses varying from 20 to 130 m in the Cooper region but limited to 55 m in SWQ, those sandstones are cemented in their lower section.
- The *Hutton* and *Poolowanna Formations*: these formations are major sandstone formations of the GAB and can reach just over 200 m in the Poolowanna Trough for the Poolowanna Formation and up to 360 m for the Hutton Sandstone in the Patchawarra Trough. In SWQ, the Hutton reaches 244 m and is typically 90 to 210 m thick, the Poolowanna Formation reaches 165 m thickness. The equivalent of the Poolowanna Formation in the eastern parts of the GAB is the Precipice Sandstone. In the study area, the Evergreen Formation which separates the two sandstone formations in the Surat Basin is absent.

Geological contour maps for the following formations can be found in Appendix B:

- Depth to Winton Formation
- Depth to Cadna-Owie Formation
- Depth to Hooray Sandstone
- Depth to the Hutton Formation
- Depth to the Poolowanna Formation;
- Thickness of the Cadna-Owie Formation
- Thickness of the Hooray Sandstone
- Thickness of the Hutton Sandstone
- Thickness of the Poolowanna Formation

Major faulting events and structural uplifts have occurred within the eastern part of the Eromanga Basin, however they did not structurally affect the part of the Eromanga Basin of covered by Santos tenements.

Within the study area, significant oil reservoirs are present with the Hutton Sandstone, the Birkhead Formation and the Murta Formation. The Wyandra Sandstone Member, McKinlay Member (which belongs to the Murta Formation) and Namur Sandstone, Westbourne Formation and Adori Sandstone and Lower Poolowanna hold minor oil reservoirs (Figure 10).

Figure 10: Stratigraphy Sequence in the Study Area

WRP Management Units		Litho-stratigraphy										
Central GMA16	Warrego West GMA 17			Unit name	Sub-unit	Equivalent Formation in other parts of the GAB **	Deposits environment *	Lithology Description*, ****	Geological Age	Thickness*, ****	Santos Current Production Reservoir (oil&Gas)	Hydrogeological Chracteristics
				Whitula Formation			Fluvial to lacustrine	Interbedded sandstone, siltstone, mudstone and claystone	Tertiary	Maximum of 160 m, confined to downwarps	No	
				Marion Formation			Fluvial deposits	Sandstone and quartz pebble conglomerate. Some clasts, silicification		About 8 m, limited geographical extend	No	
				Glendower Formation			Fluvial deposits	Sandstone, silty silstone, conglomerate and minor mudstone		in QLD, 70 m in average, maximimum 145 m ***	No	Aquifer
		Eromaga Basin		Winton Formation			Terrestrial deposition environment. Fluviolacustrine.	Interbedded fine to coarse-grained sandstone, shale, siltstone and coal seams with intraclast conglomerates.	Cretaceous	Over 400 m in the Cooper region, maximum thickness of 1100 m in the northern Patchawarra Trough	No	Aquifer (possibly limited)
				Mackunda Formation			Marine environment	Interbedded, partly calcareous very fine-grained sandstone, siltstone and shale in the basin centre.		60–120 m thick in the Cooper region	No	Aquifer
				Allaru Mudstone			Low-energy, shallow marine environment	Mudstone with thin calcareous siltstone and minor thin, very fine-grained sandstone interbeds		From 100 to over 300 m thick, generally being over 200 m in QLD, thinner in outcrop areas.	No	Water bearing
Central 1	Warrego West 1			Toolebuc Formation		Surat Silstone	Marine environment	Mudstone		in QLD, 20-45 m thick	No	Confining bed
				Wallumbilla Formation	Upper Wallumbilla	Coreena Member	Marine environment	Mudstone and siltstone with minor interbeds of fine grained sandstone		in QLD, 200 to over 350 m thick	No	Aquifer
					Lower Wallumbilla	Doncaster Member						
Central 2	Warrego West 2			Cadna-owie Formation	Upper Cadna-owie including the Wyandra Sandstone Member	Cadna-owie Formation, Bungil Formation, Gilbert River Formation	Lowstand system infilling fluvial channels then transgressive systems	Medium to coarse-grained, quartzose to labile sandstone with scattered pebbles		Mainly 60-90 m in QLD. Wyandra Sandstone Member from 3 to 18 m in Queensland. Lower Cadna-owie Formation typically 10–20 m thick around the basin margin, increasing to 75–100 m in the deeper parts of the basin. Maximum thickness of >115 m in the Nappamerri Trough.	Oil (not frequent)	Aquifer
					Lower Cadna-owie		Transition from terrestrial to marine deposition environment	Siltstone with very fine to fine-grained sandstone interbeds and minor carbonaceous claystone . Pebbly layers, diamictites and coarse breccia layers occur around the basin margin.			No	Confining bed
Central 3	Warrego West 3			Hooray Sandstone	Murta Formation (including the McKinlay Member)	Hooray Sandstone, Mooga Sandstone, Orallo Formation and Gubberamunda Sandstone	Meandering fluvial, floodplain and lacustrine environment	Thinly interbedded siltstone, shale, very fine to fine-grained sandstone and minor medium and coarse-grained sandstone. A basal siltstone is widespread in the Cooper region.		in QLD, typically between 60-85 m thick	Oil, some gas (not frequent) Seal	Aquifer
					Upper Namur Sandstone		Meandering braided fluvial systems	Fine to coarse-grained sandstone with minor interbedded siltstone and mudstone. The basal Namur Sandstone, like the Adori Sandstone, has been strongly cemented with diagenetic calcite in places.		in QLD, 50 to 70 m thick in average however can be less or thicker.	Oil (not frequent)	
Central 4	Warrego West 4			Westbourne Formation		Injune Creek Group	Lacustrine deposits (transgression)	Interbedded dark grey shale and siltstone with minor sandstone interbeds	Jurassic	In QLD, 70 to 140 m thick in the Cooper region	Oil (not frequent)	Confining bed
				Adori Sandstone			Amalgamated braided fluvial sandstone deposited in lowstand system tract.	Well-sorted, subrounded, cross-bedded, fine to coarse-grained sandstone. Calcite cemented zones up to 45 m thick are developed locally in the basal Adori and Namur Sandstones		20 to 130 m thick in the Cooper region (maximum 55 m in QLD)	Oil (not frequent)	Aquifer
				Birkhead Formation	Upper Birkhead		Meandering to lacustral deposition. Birkhead "lake", largest transgression of the Eromanga Basin.	Interbedded siltstone, mudstone and fine to medium grained sandstone with thin, lenticular coal seams (<0.3 m thick)		in QLD 40-100 m thick, maximum of 110 m. A maximum thickness of >150 m occurs in the Patchawarra and Nappamerri Troughs	oil - Basal Birkhead and Middle Birkhead (scattered)	Water bearing
					Middle Birkhead							
					Lower Birkhead							
Central 5	Warrego West 5			Hutton Sandstone			Erosion then lowstand system	Fine to coarse-grained quartzose sandstone with minor siltstone interbeds		in QLD, 90-210 m thick, maximum of 244 m.	Oil, some gas (not frequent) - moslty in upper part	Aquifer
Central 6	Warrego West 6			Poolowanna Formation	Upper Poolowanna	Precipice Sandstone	Transgression to highstand systems	Interbedded siltstone, sandstone and rare coal seams. Sandstone beds range from very fine to medium grained, and contain minor pebbles and granules of quartzite and reworked basement.		in QLD, maximum of 165 m		Aquifer
					Lower Poolowanna		Lowstand (fluvial) and early transgressive system				Oil (not frequent)	
		Cooper Basin		Cuddapan Formation			High sinuosity fluvial and coal swamp development	Sublabile to quartzrose sandstone in lower part, with interbedded siltston, mudstone and coal in upper part	Triassic	in QLD, mainly 20 m to over 50 m. Restricted geographically.		
MAJOR UNCONFORMITY			MAJOR UNCONFORMITY									
Central 7	Warrego West 7		Nappamerri Group	Tinchoo Formation	Gilpeppee Member	Moolayember Formation		Interbedded dense siltstones and light grey sandstone	Triassic	in QLD, from 125 - 200 m thick, maximum of 260 m. The Gilpeppee Member is generally 45 to 90 m thick.	Gas (not frequent)	Confining bed
					Doonmulla Member			Uniform dense siltstone, with minor coal seams (Gilpeppee Member) and intraclast conglomerate				
				Arraburry Formation	Wimma Sandstone Member	Clematis Sandstone		Fine to medium-grained quartzose sandstone with minor interbeds of siltstone and mudstone.		Maximum total thickness of 400 m in the Patchawarra Trough. Callamura Member: up to 150 m and more. Panning Member : up to 200 m and more. Wimma Sandstone : 115 m maximum	Gas (not frequent)	Aquifer
					Paning Member	Rewan Formation		Upward-fining cycles of fine to medium-grained sandstone grading into siliceous mudstone and siltstone units.			Oil (not frequent)	Confining bed
					Callamurra Member			Siltstone and mudstone, minor sandstone interbeds (Early Triassic).Siderite and cements have formed in siltstone and sandstone beds.				Confining bed
			Gilgealpa Group	Toolachee Formation			Channels deposits	Interbedded fine to coarse-grained sandstone, siltstone and carbonaceous shale, sometimes with thin coal seams (<3 m thick), and conglomerates.	Permian	Up to 190 m	Gas	Aquifer
				Daralingie Formation			Deltaic deposits	Siltstone and mudstone with interbedded fine to very fine-grained sandstone. Minor coal seams and carbonaceous partings and streaks occur.		in QLD, mostly 15-30 m thick, up to 96 m in Nappamerri Trough		Confining bed
				Roseneath Shale			Lacustrine deposits	Siltstone, mudstone and minor sandstone.		Up to 100 m, generally 50-80 m thick in QLD		Confining bed
				Epsilon Formation			Deltaic deposits	Thinly bedded, fine to medium-grained sandstone with carbonaceous siltstone and shale, and thin to occasionally thick (<2-20 m) coal seams.		Maximum thickness of 156 m in the Nappamerri Trough. In Nappamerri Trough, over 60 m thicl, elase msolty 30-40 m thick.	Gas	Aquifer
				Murteree Shale			Mainly lacustrine	Argillaceous siltstone and fine-grained sandstone.		In QLD, moslty less than 50 m thick.		Confining bed
				Patchawarra Formation			Individual and stacked channels	Interbedded fine to medium-grained, locally coarse-grained and pebbly sandstone, siltstone, shale and coal .		50 to 150 m with up to 550 m in QLD	Gas	Aquifer
				Tirrawarra Sandstone			Braided channel deposits	Fine to coarse-grained and pebbly sandstone with locally common interbeds of conglomerate and minor interbeds of carbonaceous siltstone, shale and coal.		30-40 m range in QLD, maximum 75 m total thickness	Gas (not frequent)	Aquifer
				Merrimelia Formation			Glacial sediments deposits, deep glacio-lacustrine sediments	Conglomerate, sandstone, conglomeratic mudstone, siltstone and shale	Late Carboniferous to Early Permian	Maximum 84 m in QLD		Water bearing

Data sources:
* : Petroleum Geology of South Australia, Volume 2 and 4, http://www.pir.sa.gov.au/petroleum/access_to_data/petroleum_publications/petroleum_geology_of_south_australia
**: GAB WRP, 2007
***: Australian Stratigraphy Database
****: Geology of the Cooper and Eromanga Basins, QLD, Draper,2002

4.3.6 Conceptual Geological Cross Sections

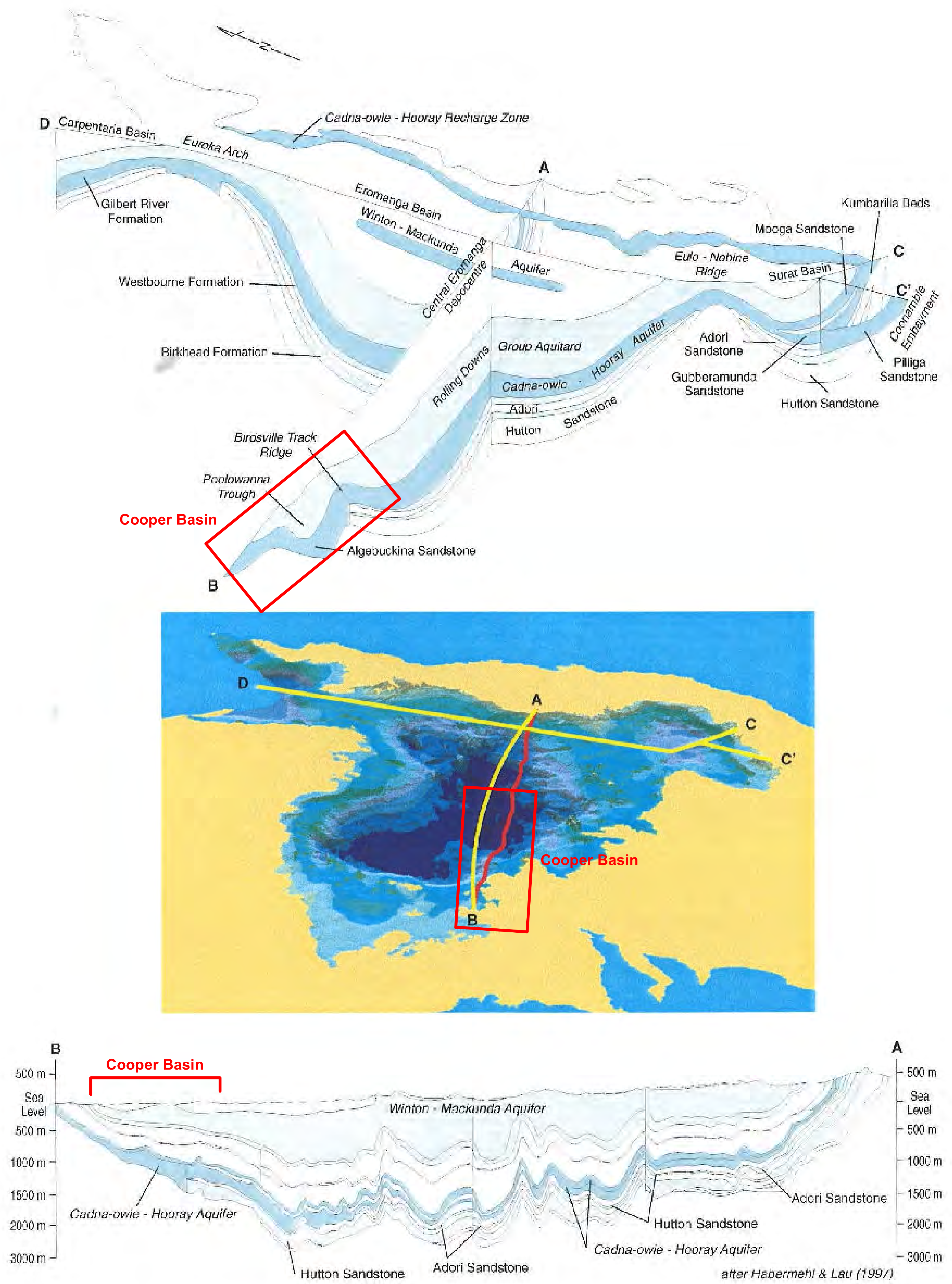
A schematic geological cross-section across the Eromanga Basin is presented in Figure 11. The “A-B” section cuts across the main depositional centre of the basin in SWQ. This corresponds generally to the location of the study area. As displayed, the upper formations of the Eromanga Basin (from Cadna-Owie and Hooray systems up) are continuous across the Basin. Older formations are restricted to areas within sub-basins (these formations or their equivalent may be present in several basins).

Abbreviations commonly used by Santos as stratigraphy markers or reservoir markers, and used in some of the geological figures are summarised in Table 7.

Table 7: Geological Abbreviations for Stratigraphical markers of the Eromanga and Cooper Basins Formations

Name of Marker	Definition
‘C’ Horizon	Top Cadna-Owie
‘E’ Horizon	Top Birkhead Formation
‘H’ Horizon	Top Hutton Sandstone
‘L*’ Horizon	Basal Eromanga Unconformity
‘PC00’ Horizon	Top Toolachee Formation (chrono-marker)
‘PU-70’ Horizon	Basal Toolachee Formation (chrono-marker and Daralingie Unconformity)
‘VC00’ Horizon	Top Patchawarra Formation (chrono-marker)
‘VC50’ Horizon	Lower Patchawarra Formation (chrono-marker)
‘VCxx’ - Horizon	Chrono-stratigraphic marker within the Patchawarra Formation
‘ZU00’ Horizon	Top Pre-Permian (Basement)

A geological conceptual cross section across both the Cooper and Eromanga Basins has been generated in a SW to NE axis across the study area passing through the Barrolka fields (Barrolka Trough). The conceptual geological cross-section is presented in Figure 12.



COOPER BASIN UWIR

SANTOS

GEOLOGICAL SCHEMATIC CROSS SECTION ACROSS THE GAB EROMANGA BASIN

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DATE: 28/11/2011
DRAWN: AJW
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FIGURE 11

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1. Figure taken from Hydrochemistry and implied hydrodynamics of the Cadna-owie-Hooray Aquifer Great Artesian Basin - B.M. Radke et al 2000

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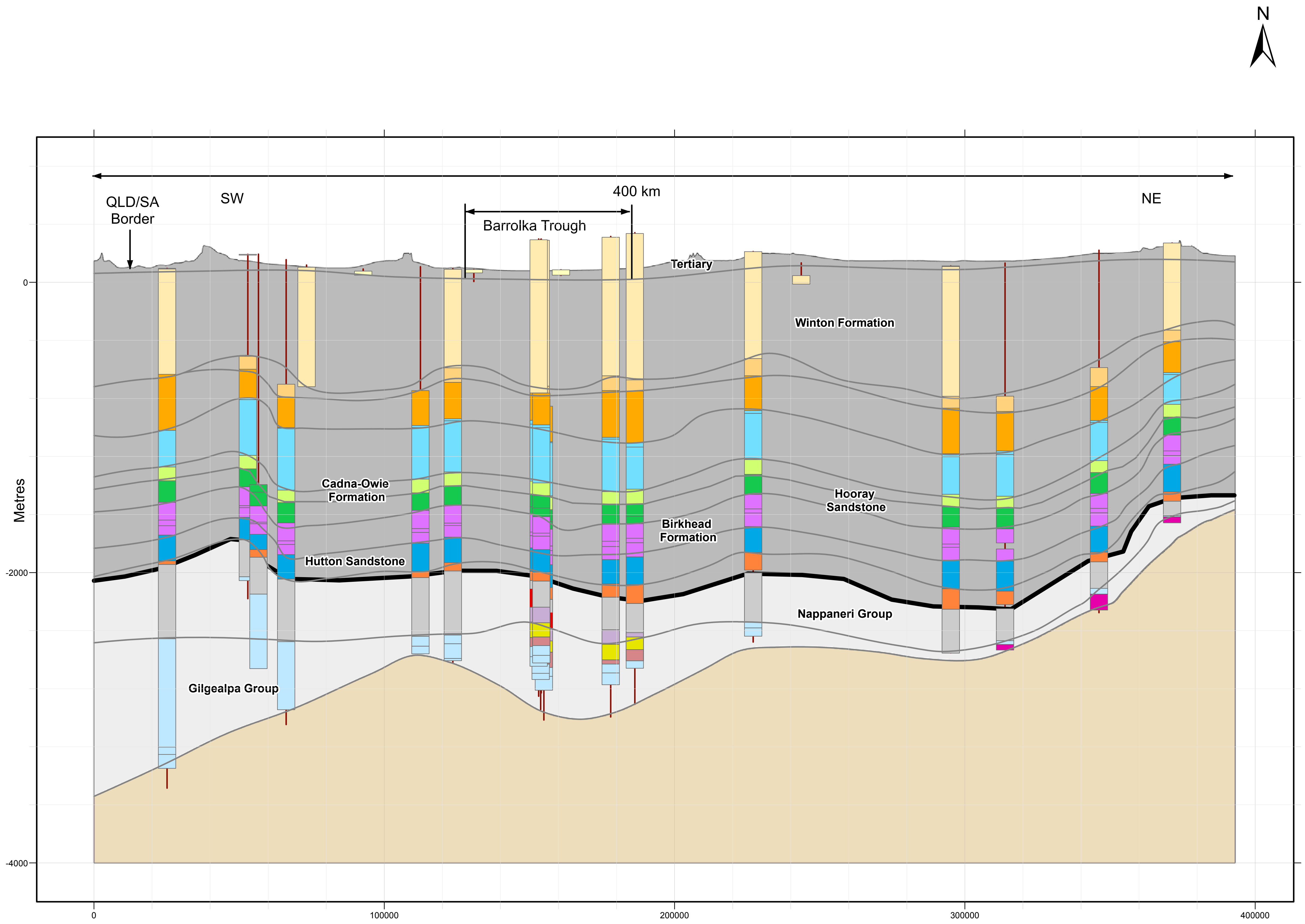
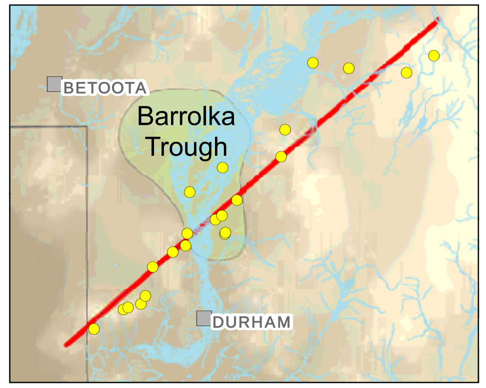


COOPER BASIN UWIR

SANTOS

GEOLOGICAL CONCEPTUAL CROSS SECTION ACROSS THE STUDY AREA



Legend

Litho-stratigraphy			
		Unit name	Sub-unit
		Tertiary sediments	
Eromaga Basin		Winton Formation	
		Mackunda Formation	
		Allaru Mudstone	
		Toolebuc Formation	
		Wallumbilla Formation	Coreena Member
			Doncaster Member
		Cadna-Owie Formation	Wyandra Sandstone member
			Lower Cadna-Owie
		Hooray Sandstone	Murta Formation
			McKinlay Member
			Namur Sandstone
		Westbourne Formation	
		Adori Sandstone	
		Birkhead Formation	Upper Birkhead
			Middle Birkhead
			Lower Birkhead
		Hutton Sandstone	
		Poolowanna Formation	Upper Poolowanna
			Lower Poolowanna
Cooper Basin	Nappamerri Group	Tinchoo Formation	Gilpepee Shale
			Doonmulla Member
		Arraburry Formation	Wimma Sandstone Member
			Panning Member
			Callamurra Member
	Gilgealpa Group	Toolachee Formation	
		Daralingie Formation	
		Roseneath Shale	
		Epsilon Formation	
		Murteree Shale	
		Patchawarra Formation	
		Tirrawarra Sandstone	
		Merrimelia Formation	

Geological Contact

Major Unconformity

Eromaga Basin

Cooper Basin

Basement

0 10 20 40 60 Kilometres

Vertical Exaggeration 1:50

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FIGURE 12

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4.3.7 Tectonics Controls and Trapping Mechanisms

Faults

The structural framework of the Cooper Basin, particularly with regard to faulting is complex in the study area. Santos has, however, undertaken an exercise of mapping (Santos, 2004) to simplify the tectonic features within the area. The primary purpose of this mapping was to identify likely fault conduits (likely to enhance vertical migration of petroleum fluids) and fault baffles (likely to prevent lateral migration of **petroleum fluid**).

Over the area of Santos SWQ activities, the major episodic faults occurred in the top pre-Permian (basement), the basal Toolachee Formation and the basal Eromanga unconformity (Figure 14). The top pre-Permian faults provide the basin's overall fabric, whereas the younger faults from the basal Toolachee Formation and basal Eromanga unconformity are generally reactivated Permian faults.

In the Eromanga Basin formations, very few regional faults are observed as very little fault movement occurred during deposition of Eromanga Basin sediments. Subsidence and compaction dominated the structural geology (PIRSA, 2006).

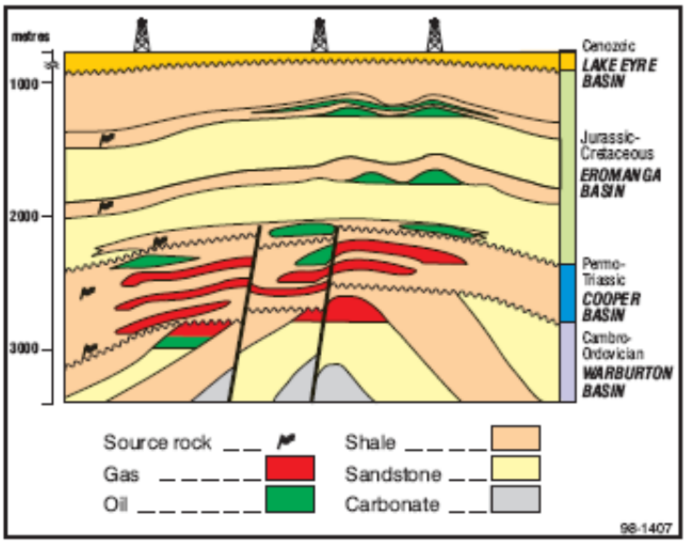
Hydrocarbon Trapping Mechanisms

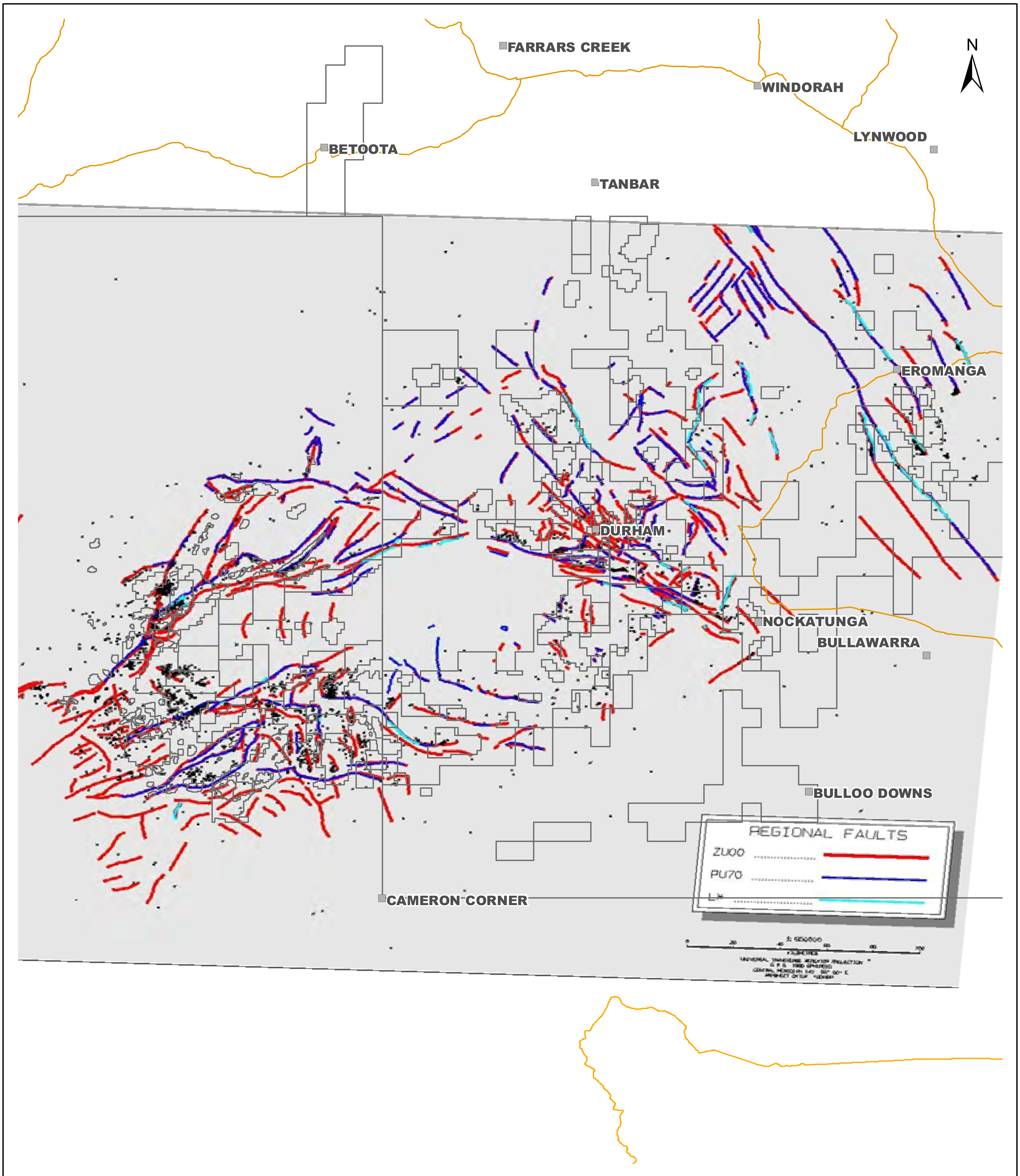
Eromanga Basin

Trapping mechanisms are dominantly structural with a stratigraphic component (e.g. Hutton–Birkhead transition, Poolowanna facies, McKinlay Member and Murta Formation). Seals consist of intraformational siltstones and shales of the Poolowanna, Birkhead and Murta Formations. Where these units are absent, potential seals higher in the sequence include the Bulldog Shale and Wallumbilla Formation (SA DPI, 1998).

Cooper Basin

Anticlinal and faulted anticlinal traps have been relied on as proven exploration targets but potential remains high for discoveries in stratigraphic and sub-unconformity traps, especially where the Permian sediments are truncated by the overlying Eromanga Basin succession. Minor amounts of hydrocarbons are reservoired in sands of the Nappamerri Group, but its mud-prone nature means that it also acts as regional seal to the Cooper Basin. The uppermost major sandstone reservoirs in the Cooper Basin are in the Toolachee Formation. Beneath the Daralingie Unconformity, which marks the base of the Toolachee, are two important early Permian regional seals - the Roseneath and Murteree Shales. The Roseneath Shale is the regional top seal for the reservoir sands in the Epsilon Formation and the Murteree Shale seals the Patchawarra Formation. The Toolachee and Patchawarra Formations, in particular, consist of a series of interbedded sands, shales and coals, and the shales and coals often act as intraformational seals.

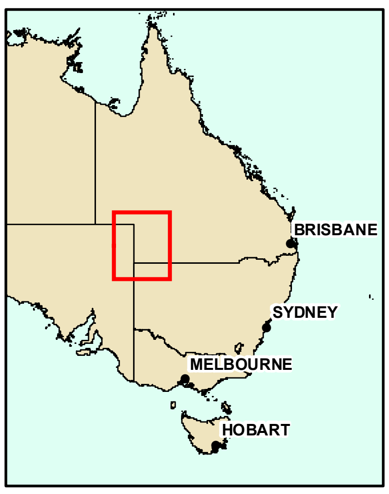




COOPER BASIN UWIR

SANTOS

SUMMARY OF REGIONAL MAJOR FAULTS (SANTOS 2004)



LEGEND

- Town/Locality
- Highway/Major Road
- Santos Operated Permits
- Basal Toolachee Formation (PU70 Horizon)
- Top Pre-Permian (ZU00 Horizon)
- Basal Eromanga Unconformity

0 5 10 20 30 40 50 Kilometres

SCALE (at A3) 1:1,825,287.36

Coordinate System: GCS GDA 1994

PROJECT: 117636010
DATE: 19/12/2011
DRAWN: AJW
CHECKED: FH

FIGURE 14

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2. ATP/PL tenure supplied by Santos, August 2011
3. Faults map supplied by Santos (2004)

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Tectonics and Uplifts

Tectonics and uplifts are discussed in the PIRSA reports on the Eromanga and Cooper Basins geology (PIRSA, 1998; see also Section 4.3.3).

Carboniferous-to-Triassic deposition within the Cooper Basin was terminated at the end of the Early Triassic by regional uplift, tilting and erosion.

Deposition in the Eromanga Basin commenced during the Early Jurassic and was controlled by the topography of the unconformity surface. No major depositional breaks occur in the Eromanga Basin, indicating a period of relative tectonic quiescence. With the large scale Early Cretaceous marine inundation of the Australian continent a rapid period of subsidence took place in the Eromanga Basin.

4.4 Environmental Values

The environmental values defined here are those of the surface water or groundwater resource within the study area and are defined as “those qualities of the waterway that make it suitable to support particular aquatic ecosystems or human use” (Environmental Protection (Water) Policy, 2009, referred to as EPP Water, 2009). The EPP 2009 provides guidelines on determining the environmental value that should be considered for a particular project site or area, which follow the framework set out in *Appendix H* of the *Queensland Water Quality Guidelines 2006* (QWQG 2006).

There are a number of environmental values associated to surface water bodies, however, these may/may not be related to groundwater systems. Environmental ecosystems depending on groundwater are referred to as Groundwater Dependant Ecosystems (GDE). Environmental values depending relevant to groundwater resources in the study area are:

- Groundwater Dependant Ecosystems (Incl. wetlands and springs);
- Drinking Water;
- Sandstone Aquifers of the Great Artesian Basin; and
- Groundwater Users.

The hydrogeology of the study area is described in Section 5.0.

4.4.1 Groundwater Dependant Ecosystems (Incl. springs)

Groundwater dependent ecosystems (GDEs) can be defined as those ecosystems whose ecological processes and biodiversity are wholly or partially reliant on groundwater. The extent of GDE dependency on groundwater can range from being marginally or episodically dependent to being entirely dependent on groundwater (SKM, 2001).

Examples of GDEs include:

- Terrestrial vegetation supported by shallow groundwater.
- Aquatic ecosystems in rivers and streams that receive groundwater baseflow. Baseflow typically accounts for a significant fraction of total flow volume in major rivers and streams. Baseflow can sustain streamflow volumes long after rainfall events, or throughout dry seasons, and is therefore critical to the maintenance of aquatic ecosystems in rivers and streams in many Australian environments. Baseflow can occur as springs discharging into a river or stream, or as diffuse influx of groundwater through banks and bed sediments.
- Wetlands, which are often established in areas of groundwater discharge.
- Springs and associated aquatic ecosystems in spring-fed pools.
- Aquifers and caves, where stygofauna (groundwater-inhabiting organisms) reside.

Potential GDEs in the Study Area are illustrated on Figure 15.

The nearest GAB spring is located at 95 km from Santos tenements.

Cooper Creek Basin has been announced as wild river area, the basin is the largest catchment in the Lake Eyre Basin region.

Note: DERM defines *wild river areas* some river ecosystems rare which are relatively untouched by development and are therefore in near natural condition, with all, or almost all, of their natural values intact. These areas may include threatened plants, birds and marine and estuarine species. .

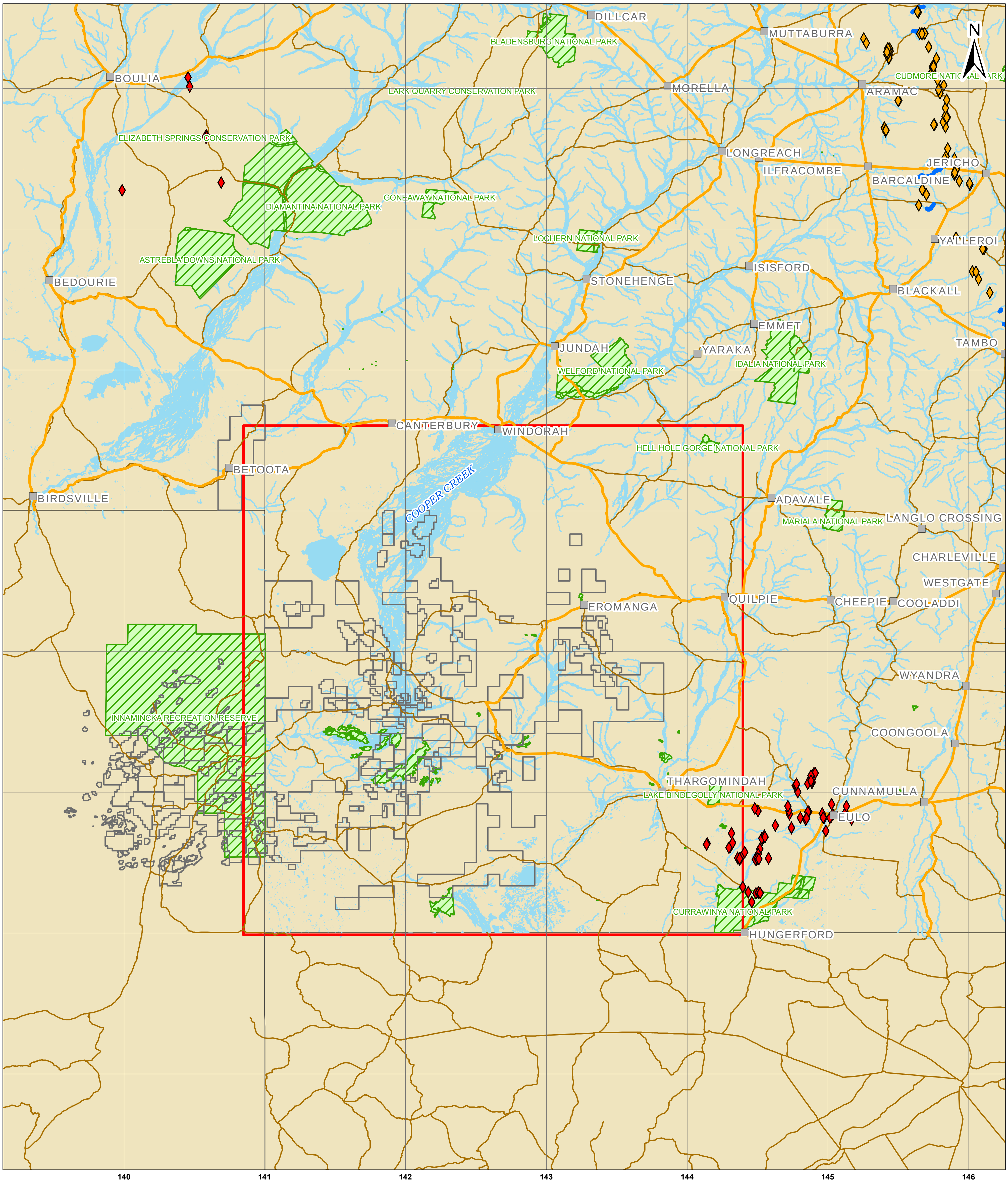
The Cooper Creek has been recognised as one of the Australia's most iconic inland rivers and largely intact natural values. The *Cooper Creek Basin Wild River Area Summary: Natural Values Assessment* (DERM, 2010) concludes that "the persistence of waterholes in the Cooper Creek is largely influenced by surface water flows and evaporation, with little inputs from groundwater". As a consequence the Cooper Creek system is not classified as a GDE.

As mentioned earlier, the study area lies within the Channel Country regional ecosystem. Within this region, there are no recognised endangered regional ecosystems (EREs) (Santos, 2011).

Within the study area, the only *wetland* listed of international significance under the EPBC Act Protected Matters database (Ramsar sites) is the Currawinya Lakes National Park located at the very south eastern corner of the study area. It consists of a mosaic of low dunefields, lakes, clay and saltpans, dissected tablelands and low hills and contains one of the richest and most diverse samples of wetlands in inland Australia. The Currawinya Lakes National Park lies more than 240 km east of the closest Santos Cooepr Basin activities petroleum lease in the study area. The wetland is underlain by the Eromanga Basin but not by the Cooper Basin.

Other nearby national parks include the Lake Bindegolly National Park, west of the town of Thargomindah and the large Innamincka Recreation Reserve in SA.

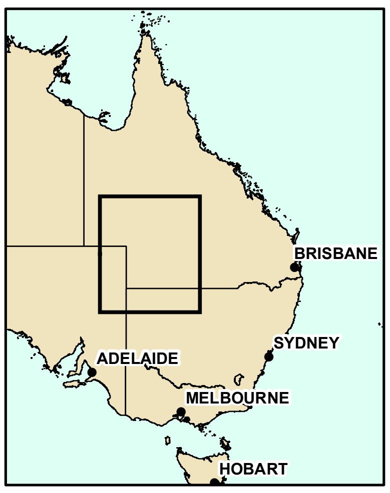
In summary, there are no known GDEs over the study area.



COOPER BASIN UWIR

SANTOS

GROUNDWATER DEPENDANT ECOSYSTEMS IN THE STUDY AREA



LEGEND

- Town/Locality
- GAB ROP Discharge Spring
- GAB ROP Recharge Spring
- Watercourse Spring
- Highway/Major Road
- Secondary Road/Track
- Study Area
- Santos Operated Permits
- National Park/ Nature Reserve
- River/Creek

0 20 40 80 120 160 Kilometres

SCALE (at A3) 1:3,000,000

Coordinate System: GCS GDA 1994

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FIGURE 15

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2. Geology supplied by the State of Queensland (Department of Mines and Energy), 2007
3. Tenure boundaries supplied by Santos, August 2011

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4.4.2 Drinking Water and Groundwater Users

Groundwater is a common drinking water source for many inland areas of Australia, especially where aquifers of good quality and yield are present at reasonably shallow depths.

Municipal water supply accounts for about all large licensed groundwater allocation across the study area. Licensed municipal water supply may represent approximately 5 -10% of the number of groundwater licences across the study area. This is consistent with the likelihood of numerous individual stock and domestic water supply bores of limited groundwater use. Municipal water supply bores found in the WES database are licensed in the Hooray Sandstone.

In addition to municipal water, individual properties in those remote arid areas are likely to access groundwater for water supply. These water supplies are not required to be licensed.

Groundwater as a drinking water supply and water resource for the rural community is considered to be an important environmental value in the study area.

It should be noted that groundwater use by the local communities is limited to the formations of the Eromanga Basin and overlying sediments and more generally, the shallower formations. A large proportion of the water supply bores target the Winton Formation aquifer (according to information from the DERM groundwater database).

Groundwater use is further discussed in Section 5.9.

4.4.3 Sandstone Aquifers of the Great Artesian Basin

The main GAB aquifers (i.e. in the Eromanga Basin stratigraphy) over the study area are the Winton Formation, Cadna-Owie Formation, Hooray Sandstone, Hutton Sandstone and Poolowanna Formation (Precipice Sandstone equivalent) within the Eromanga Basin.

The aquifers of the Cooper Basin (pre-GAB) are not considered by the regulator within the defined "*sandstone aquifers of the GAB*". Nevertheless, the major aquifers are presumed to be the Wimma Sandstone, Toolachee Formation, Epsilon Formation, Patchawarra Formation and Tirrawarra Formation.

The aquifers of the Eromanga Basin are considered highly productive aquifers over most of the GAB.

In the study area, only the upper aquifers within the stratigraphy sequence are of interest to the local community due to the significant depth of the deeper aquifers. As such, the Hutton and Poolowanna Sandstone aquifers are not used by the community (at the possible exception of a couple of exploration bores converted as groundwater bore).

4.5 Local Community Recreational, Aesthetical, Cultural and Spiritual Values

A number of stakeholders' values in the study area are related to the channel country flood area. Permanent water holes and floods have ensured the viability of aboriginal communities and non-aboriginal people. Aboriginal trade routes are found along Cooper Creek crossing the continent from north to south.

Santos draft *Environmental Management Plans* (EMP) discusses the cultural and spiritual values of the study area.

The EMPs identify ten sites of cultural heritage significance within or in close proximity to the study area. These sites are either listed in the Register of the National Estate (RNE) and/or the Queensland Heritage Register and are shown in Table 8.

Table 8: Significant Sites of Cultural Heritage (Aboriginal and European) (Santos 2011)

Historic site	Aboriginal significance	European significance	RNE*	Qld Heritage Register
Dig Tree Reserve (Nappamerry Station via Thargomindah, Qld)	✓	✓	✓	-
Cunnavalla Creek Area (Qld)	✓	-	✓	-
Durham Downs Area (Qld)	✓	-	✓	-
Johnson Channel Area (Qld)	✓	-	✓	-
Nappa Merrie Archaeological Area (Qld)	✓	-	✓	-
Nappapethera Waterhole Sites (Qld)	✓	-	✓	-
Orientos Area (Qld)	✓	-	✓	-
Noccundra Hotel	-	✓	✓	✓
Thargominda Historic House	-	✓	✓	-
Dr Ludwig Becker's Grave	-	✓	-	✓

* Register of the National Estate

There are also currently three native title claims over various portions of the study area (Boonthamurra People, Wongkumara People and Kullilli People).

The most populated regions within the study area are Eromanga (approx 80 inhabitants) and Thargomindah (approx. 250 inhabitants). Transient populations are growing with the development of tourism and the increase of caravan parks.

5.0 HYDROGEOLOGICAL CONCEPTUAL MODEL

5.1 Hydrogeological Setting

The Cooper and Eromanga basins are two chronologically successive stacked basins. The Cooper Basin is often considered by geologists as not being part of the GAB, however the upper formations of the Cooper Basin are included into the QLD GAB regulation (GAB ROP, GAB WRP). The Eromanga Basin is one of the main basins of the GAB, it is widely spread and covers the whole of the Cooper Basin. The connection between the two basins is geologically marked by a major discontinuity.

Both the Cooper Basin and Eromanga Basin are multi-layered systems comprising alternating layers of sandstone, shales, mudstones and siltstones formations (Section 4.3). The sandstone formations of the Eromanga Basin correspond generally to water bearing formations and aquifer formations, they may yield significant quantities of groundwater to water bores and springs.

The siltstones, shales and mudstones formations are generally low permeability rocks and generally do not qualify as aquifers. However, sandstone beds can be found amongst the mudstones and siltstones, some of them forming limited groundwater sources and able to supply low yield bores.

The formations may be expected to be laterally continuous and hydraulically connected however this may not always necessary be the case due to the variability in the nature of the deposits.

For management purposes, the GAB is subdivided in Groundwater Management Area (GMA) as defined in the *GAB Hydrogeological Framework for the GAB WRP Area* (DERM, 2005) [Section 2.0]. Each area is further divided in Groundwater Management Units (GMU) as represented on Figure 10. GMU groupings follow stratigraphy and hydrogeological characteristics as presented on Figure 10. The identification of GMUs allows for administration of access to water and water entitlements.

5.2 Hydrostratigraphy

Santos tenements are contained within the *Central Management Area* (GMA16) mostly, and the western part of *Warrego West Management Area* (GMA 17) as illustrated on Figure 16.

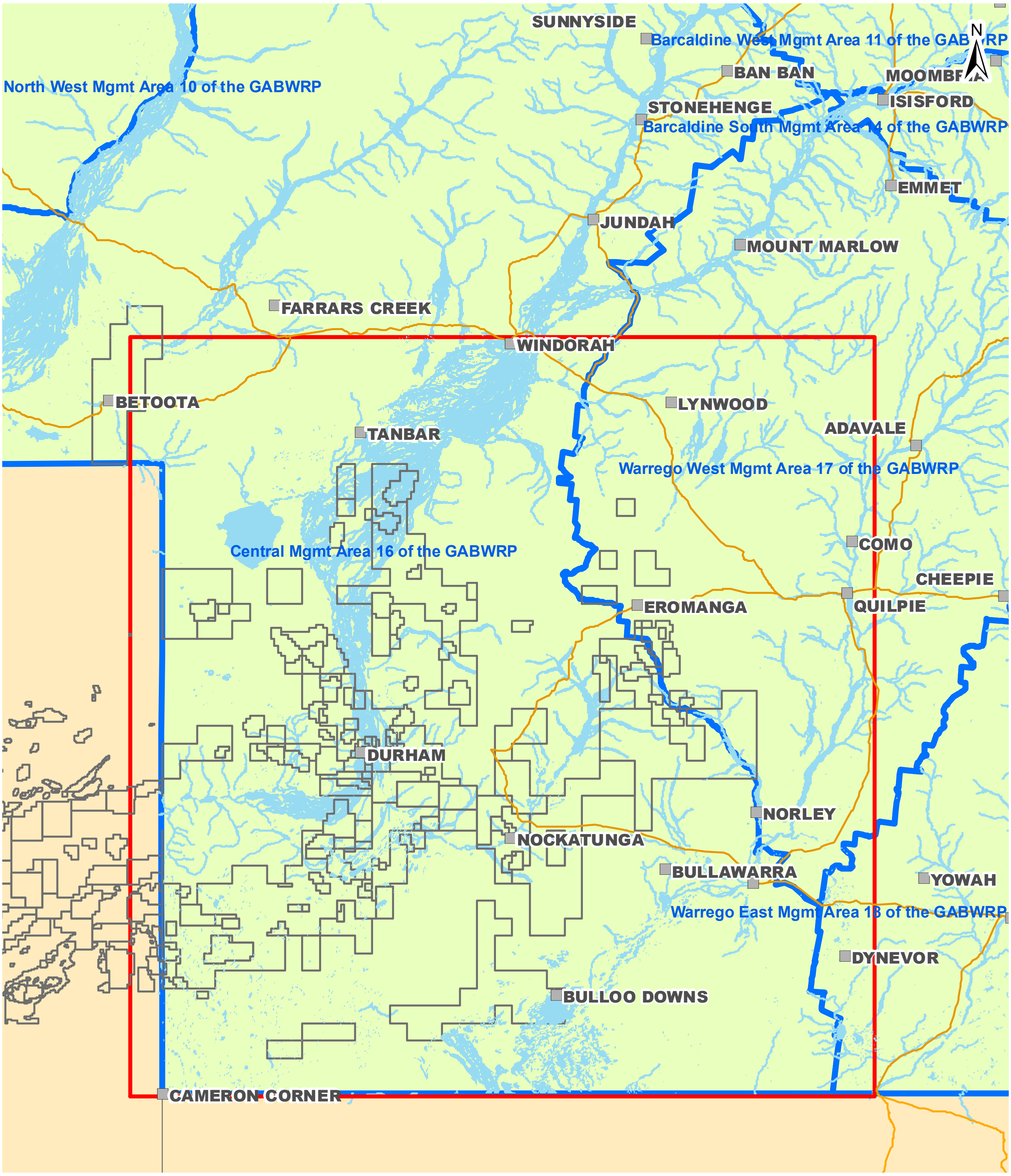
The main aquifer units and aquitard units are presented on Table 9. The main aquifer groupings, in term of production of groundwater, include:

- The aquifers of the Quaternary formations and Tertiary sediments;
- The GAB aquifers of the Eromanga Basin (water supply for agricultural and drinking water, and groundwater extraction associated with the production of oil);
- The older and deeper aquifers of the Cooper Basin (groundwater extraction associated with the production of gas).

The limitation of groundwater development to the main units from the Eromanga Basin is due to the access at shallower depths of suitable groundwater resources. The aquifers from the Cooper Basin are much deeper and are only accessed during the production of gas.

Hydrostratigraphy can only be thoroughly described for the formations of the Eromanga Basin - using information from the DERM database or from the literature. Insufficient information is available to provide a detailed description of the hydrostratigraphy of the Cooper Basin formations.

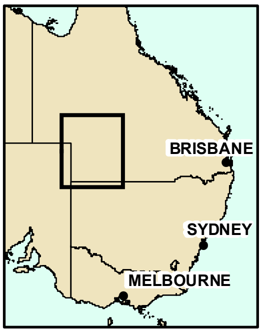
Note that the Quaternary and Tertiary sediment aquifers and the Winton Formation are not administered under the GAB Resource Operation Plan (GAB ROP, DERM 2007).



COOPER BASIN UWIR

SANTOS

GROUNDWATER MANAGEMENT AREA FOR THE STUDY AREA



LEGEND

- Town/Locality
- Highway/Major Road
- River/Creek
- Santos Operated Permits
- Study Area
- Groundwater Management Area

0 10 20 40 60 80 100 Kilometres

SCALE (at A4) 1:3,000,000

Coordinate System: GCS GDA 1994

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FIGURE 16

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3. Groundwater Management Area supplied by the State of Queensland (Department of Natural Resources & Water), 2008

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Table 9: Hydrostratigraphy of the Study Area

GMA Unit			Unit name	Sub-unit	Equivalent Formation other parts of the GAB
	Eromanga Basin		Glendower Formation		
	Eromanga Basin		Winton Formation		
	Eromanga Basin		Mackunda Formation		
	Eromanga Basin		Allulu Mudstone		
Central 1 - Warrego West 1	Eromanga Basin		Toolebuc Formation		Surat Siltstone
Central 1 - Warrego West 1	Eromanga Basin		Wallumbilla Formation	Coreena Member	Wallumbilla Formation
Central 1 - Warrego West 1	Eromanga Basin		Wallumbilla Formation	Doncaster Member	Wallumbilla Formation
Central 2 - Warrego West 2	Eromanga Basin		Cadna-Owie Formation	Wyandra Sandstone Member	Cadna-Owie Formation, Bungil formation, Gilbert River Formation
Central 2 - Warrego West 2	Eromanga Basin		Cadna-Owie Formation	Lower Cadna-Owie	Cadna-Owie Formation, Bungil formation, Gilbert River Formation
Central 3 - Warrego West 3	Eromanga Basin		Hooray Sandstone	Murta Formation	Hooray Sandstone, Mooga Sandstone, Orallo Formation and Gubberamunda Sandstone
Central 3 - Warrego West 3	Eromanga Basin		Hooray Sandstone	Namur Sandstone	Hooray Sandstone, Mooga Sandstone, Orallo Formation and Gubberamunda Sandstone
Central 4 - Warrego West 4	Eromanga Basin		Westbourne Formation		Injune Creek Group
Central 4 - Warrego West 4	Eromanga Basin		Adori Sandstone		Injune Creek Group
Central 4 - Warrego West 4	Eromanga Basin		Birkhead Formation	Upper Birkhead	Injune Creek Group
Central 4 - Warrego West 4	Eromanga Basin		Birkhead Formation	Middle Birkhead	Injune Creek Group
Central 4 - Warrego West 4	Eromanga Basin		Birkhead Formation	Lower Birkhead	Injune Creek Group
Central 5 - Warrego West 5	Eromanga Basin		Hutton Sandstone		
Central 6 - Warrego West 6	Eromanga Basin		Poolowanna Formation	Upper Poolowanna	Precipice Sandstone
Central 6 - Warrego West 6	Eromanga Basin		Poolowanna Formation	Lower Poolowanna	Precipice Sandstone
MAJOR UNCONFORMITY					
Central 7 - Warrego West 7	Cooper Basin	Nappamerri Group	Tinchoo Formation	Gilpepee Shale	Moolayember Formation
Central 7 - Warrego West 7	Cooper Basin	Nappamerri Group	Tinchoo Formation	Doonmulla Member	Moolayember Formation
Central 7 - Warrego West 7	Cooper Basin	Nappamerri Group	Arraburry Formation	Wimma Sandstone Member	Clematis Sandstone
Central 7 - Warrego West 7	Cooper Basin	Nappamerri Group	Arraburry Formation	Panning Member	Rewan Formation
	Cooper Basin	Nappamerri Group	Arraburry Formation	Callamurra Member	
	Cooper Basin	Gilgealpa Group	Toolachee Formation		
	Cooper Basin	Gilgealpa Group	Daralingie Formation		
	Cooper Basin	Gilgealpa Group	Roseneath Shale		
	Cooper Basin	Gilgealpa Group	Epsilon Formation		
	Cooper Basin	Gilgealpa Group	Murteree Shale		
	Cooper Basin	Gilgealpa Group	Patchawarra Formation		
	Cooper Basin	Gilgealpa Group	Tirrawarra Sandstone		
	Cooper Basin	Gilgealpa Group	Merrimelia Formation		

Major Aquifer
Water Bearing
Confining Bed

5.2.1 Quaternary and Tertiary Alluvium

The Quaternary and Tertiary alluvium formations cover a large proportion of the study area, they are often associated to the very flat structures of the flood plains and are absent where the Winton Formation outcrops.

The Quaternary and Tertiary sediments are expected to be unconfined and form the water table aquifer where present. Insufficient water level information is available for the Quaternary formations to define further the level of connectivity.

The Glendower Formation is the main formation of the Tertiary for the study area. The Australian Stratigraphic Database identifies the Whitula Formation overlying the Glendower Formation, however the significance of the Whitula Formation in the study area is unknown.

The Glendower Formation consists of consolidated sediments comprising sandstones, sandy siltstones and minor conglomerate and mudstones (Australian Stratigraphic Database, geosciences Australia).

Groundwater flow follows the topographical profile with the limitations imposed by the fluvial nature and the presence of the sediments. As illustrated on the hydrogeological map, the hydraulic gradient is small (Figure 19).

The salinity of these aquifers is brackish, with electrical conductivities (EC) ranging from 3,000 to 7,000 µS/cm (on the basis of data from the DERM database).

5.2.2 Winton Formation

According to the DERM database, the Winton Formation is a significant aquifer for the local community because it supplies a number of stock and domestic bores. The depth to the Winton Formation and thickness of the Winton Formation (based on DERM groundwater database) are illustrated in the maps of APPENDIX B. The top of the Winton Formation is (according to the DERM groundwater database) found in the first 50 m below ground and the thickness can reach up to 970 m.

Santos' geology team however dispute the role of the Winton Formation as a significant aquifer in SWQ, at best it would be water bearing. It appears (Pers. Comm. N. Lemon, Santos, November 2011) that although in a large area of QLD the Winton Formation is a significant aquifer, the quality of the Winton Formation as an aquifer appears to diminish westward from central Queensland to SW Queensland and into SA and that the top and bottom of the Winton are so poorly defined in the subsurface that one cannot be sure that water production currently assigned to the Winton Formation does not come from the overlying Tertiary (Eyre Formation in South Australia) or underlying Mackunda Formation. This situation is supported in SA by the findings of Gravestock and al. (1995).

The Winton Formation directly underlies the Tertiary sediments, some levels of hydraulic conductivity are expected however no data is available to sustain this affirmation.

The water quality in the Winton Formation is brackish to saline. The water is fresh to brackish with ECs ranging from 900 to 13,000 µS/cm. Water flows in this aquifer is generally to the south west (Figure 20).

5.2.3 Cadna-Owie Formation

The Cadna-Owie Formation is considered a major GAB unit. Its upper section, the Wyandra Sandstone is an aquifer however its thickness is quite limited over SWQ, the Lower Cadna-Owie is considered an aquitard.

The few data points available in the groundwater database seem to indicate fresh to slightly brackish water quality with the Wyandra Sandstone. Insufficient water level information is available to describe water flows and water levels and to create a hydrogeological map.

Habermehl defines this unit as non artesian (1986, 1997), however the DERM groundwater database identifies a few artesian bores in the Cadna-Owie Formation.

The proportion of aquifer sandstone and siltstones in this unit is much lower than that in the Hooray Sandstone and the spatial variability even greater. The Wyandra Sandstone is recognised as the productive layer of the formation. It is a highly permeable shallow marine sandstone, mostly extensive in the eastern regions of the Formation (BRS, 2000).

5.2.4 Hooray Sandstone

The Hooray Sandstone system is a major GAB unit, in the study area it is a major aquifer. Oil reservoirs and minor gas reservoir are also contained with this unit. Two sub-units are identified in the Hooray Sandstone:

- The Murta Formation, equivalent in other GAB basins are the Mooga and Gubberamunda Sandstones, however in the study area it is rather considered to be a confining bed, the main confining unit being a siltstone bed located at the base of the Murta Formation and found widespread over the Cooper region. Oil and some gas reservoirs can be found in the Murta Formation. The McKinlay Member, which belongs to the Murta Formation, is not always present in SWQ and contains minor oil reservoirs.
- The Namur Sandstone is the major water bearing unit of the Hooray Sandstone. Oil can also be found in this unit.

The water quality in the Hooray Sandstone is generally fresh and may be slightly brackish as EC values (DERM database) range from 675 to 3,930 µS/cm with a median value of 1,003 µS/cm. A few bores have several salinity values measured over a 40 year period. For those bores, the latest values are observed to be similar to earlier values.

A number of bores within the Hooray Sandstone may be artesian. Groundwater bores for that unit seem to be concentrated to the south east of the study area (Figure 21). No water level and salinity data are available for the main part of the area (i.e. within Santos tenements).

Figure 21 indicates that the groundwater flow direction is directed to the south east (for the available dataset) and that the generally the water salinity is fresh to slightly brackish.

The Hooray Sandstone seems to be an aquifer of higher yield than the overlying aquifers, town water supply bores are completed with the Hooray Sandstone. An analysis of bore yields from the DERM database would need to be undertaken to confirm this statement.

5.2.5 Westbourne Formation, Adori Sandstone and Birkhead Formation

Little hydrogeological information is available on the Westbourne Formation, Adori Sandstone and Birkhead Formation.

The Westbourne Formation is generally considered to be a confining bed of homogeneous characteristics (lacustrine deposits associated with a large transgression), however in the south east section of the study area, a number of private bores are completed in the Westbourne Formation, possibly in some of the minor sandstone beds of the formation.

The Adori Sandstone is an aquifer in the study area, insufficient information is available to characterise it further.

The Birkhead formation is a succession of non-continuous confining beds and water bearing sandstone units.

Salinity levels cannot be commented upon as salinity data are not available for those formations in the DERM database nor were made available from Santos produced water extracted from this formation.

5.2.6 Hutton Sandstone

The Hutton Sandstone is a significant GAB aquifer however its depth (about 2,000 m bgl – refer to Figure 12) in the study area prevents it from access other than for oil activities. The groundwater flow is expected to be to the south west i.e. consistent with the flow of the major GAB units as described in the literature.

Note: there is insufficient water level data in the Hutton Sandstone to characterise groundwater flow direction further.

Water quality of the Hutton Sandstone in the study area cannot be commented upon as no data was made available on produced water quality.

5.2.7 Poolowanna Formation

Also referred to as the Basal Jurassic Formation (older name in the nomenclature), the Poolowanna Formation is the equivalent of the Precipice Sandstone (in SE QLD). As for the Hutton Sandstone, groundwater flow is expected to be to the south west i.e. consistent with the flow of the major GAB units as described in the literature.

5.3 Observed Reservoir Pressure Data

Formation pressure data is collected by Santos as drilling operations are conducted. Santos notes that (per. comm. Owen Davies and Nick Lemon; Santos, 2012):

"Typically the water pressure in a number of water-bearing stratum in each well is monitored during drilling by:

- *Drill stem test (DST);*
- *Repeat formation tester (RFT); or*
- *Formation micro tester (FMT).*

*Pressure testing is undertaken to assess the likely thickness of the oil or gas column found at any particular level. This is done by comparing the pressure in the hydrocarbon-bearing zone with the expected water pressure, predicted by the water pressure-depth line (*Figure 17 and Figure 18).

Models for predicting the influence of gas and oil, and associated water production at depth require input data on the pressure transmissibility of the strata that separates the target formations (referred to as seals). In the case of SWQ:

- *Seals between the Glendower and Winton aquifers; and*
- *Seals between the Murta, Namur, (Hooray) and Hutton Sandstone, from which oil is produced.*

Numerous Santos wells have undergone pressure measurements in the Cadna-Owie to establish water pressure-depth lines and this data can be re-assessed to see if depletion from underlying hydrocarbon production zones has influenced the aquifers utilised for water supply. If no depletion is seen in the Cadna-Owie Formation, then production is assumed not to have had an influence on the overlying aquifers.

Where groundwater has been abstracted from the same aquifers as those associated with hydrocarbon production, observed pressure data may provide a direct indication of the groundwater pressure in that aquifer and aquitard. The extrapolation of the water pressure gradient to the surface provides an indication of the level to which water will now rise compared to what it would have been in the past.

With suitable interrogation of this historical pressure data, an assessment of the potential reduction in groundwater level may be possible. It should be noted that this would be a combined result of water resource abstraction and cumulative impact from the hydrocarbon industries.

Santos has a library of water pressures in many of the water-bearing levels in the Eromanga Basin that could be used to define changes to groundwater. Ongoing drilling will continue to add to that data base, tracking *the changes into the future. Additional pressure points can be added to the scope of each well if needed to ensure the database is sufficient to cover the needs of water monitoring."*

At the time of writing, this historical pressure data was not in a format suitable for analysis (per. comm. Owen Davies; Santos, 2012), Collation and analysis of this data will be an undertaking of the Water Monitoring Plan (APPENDIX H).

Two examples of this are available from Santos' existing data sets; those of Tickalara Field and Iliad Field in SWQ (Figure 17 and Figure 18).

These figures demonstrate how the pressure (plotted points from Tickalara 19, 20, 21 and 22 and Iliad 3, 4,5 and 6) are depleted below the predicted water pressure line (blue dashed line that increases in pressure with increasing depth) is confined within each target formation (shown as yellow layers) by the presence of an overlying aquitard (seal bed, shown as orange layers).

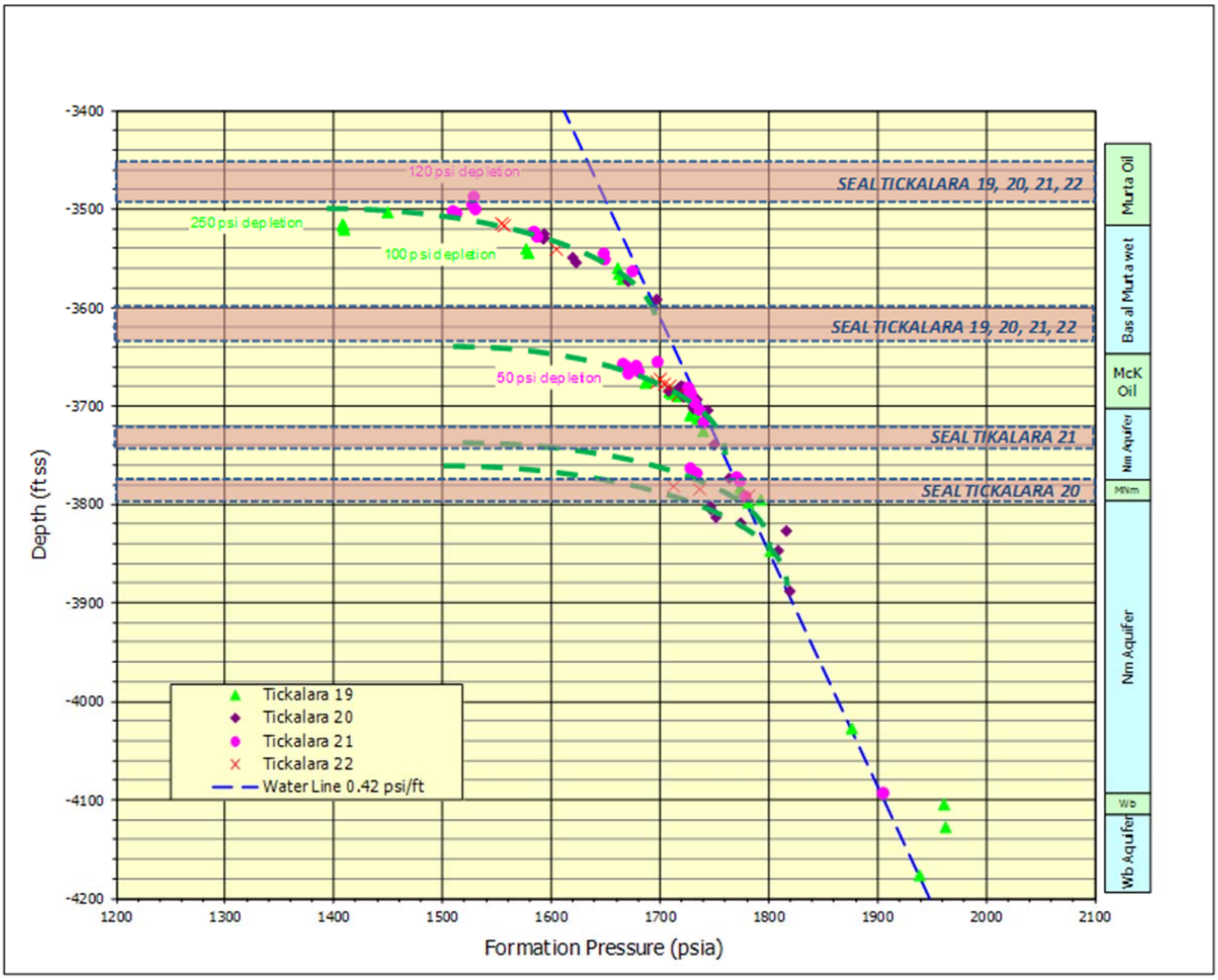


Figure 17: Observed Tickalara Oil Field Pressure with Depth Plots

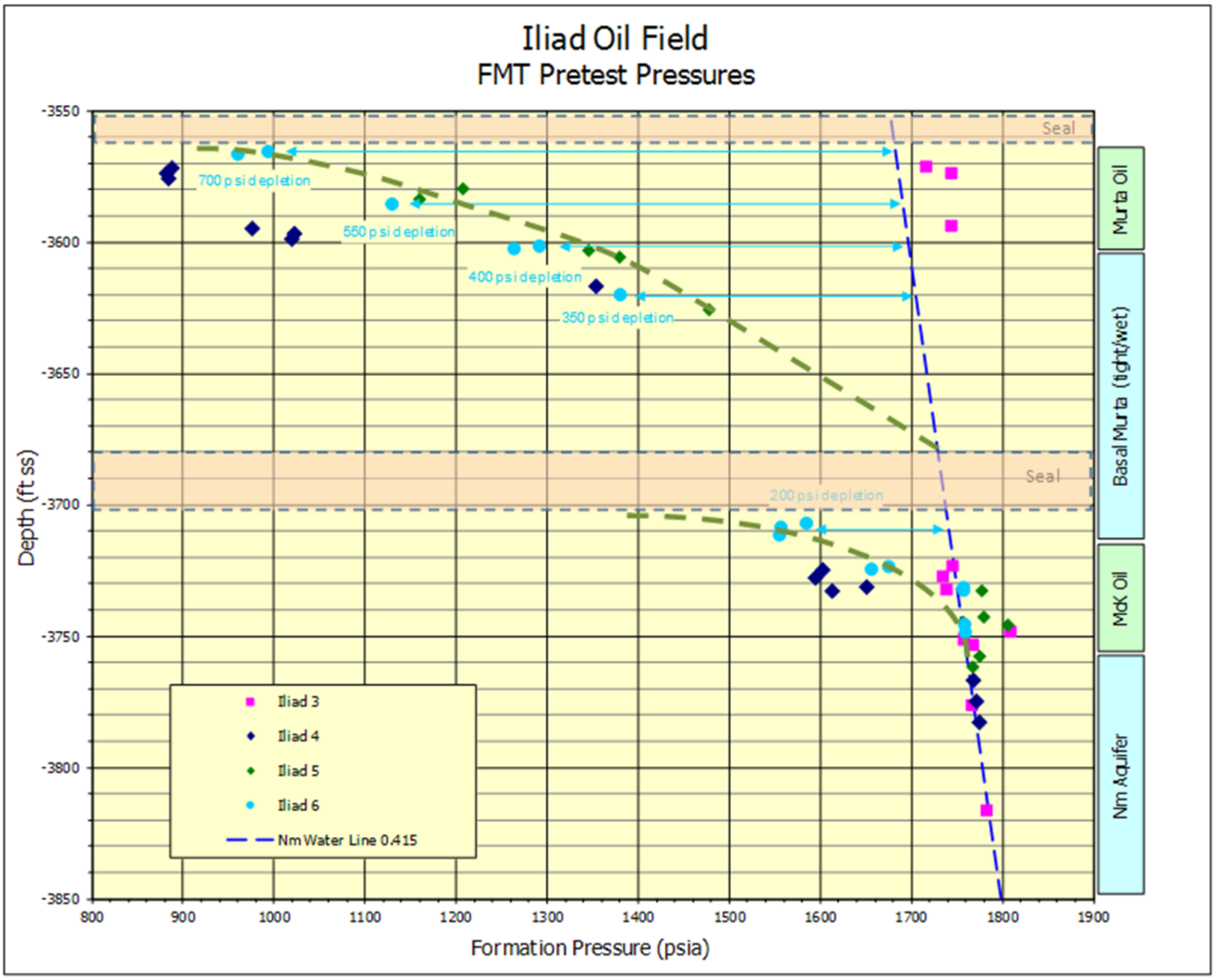
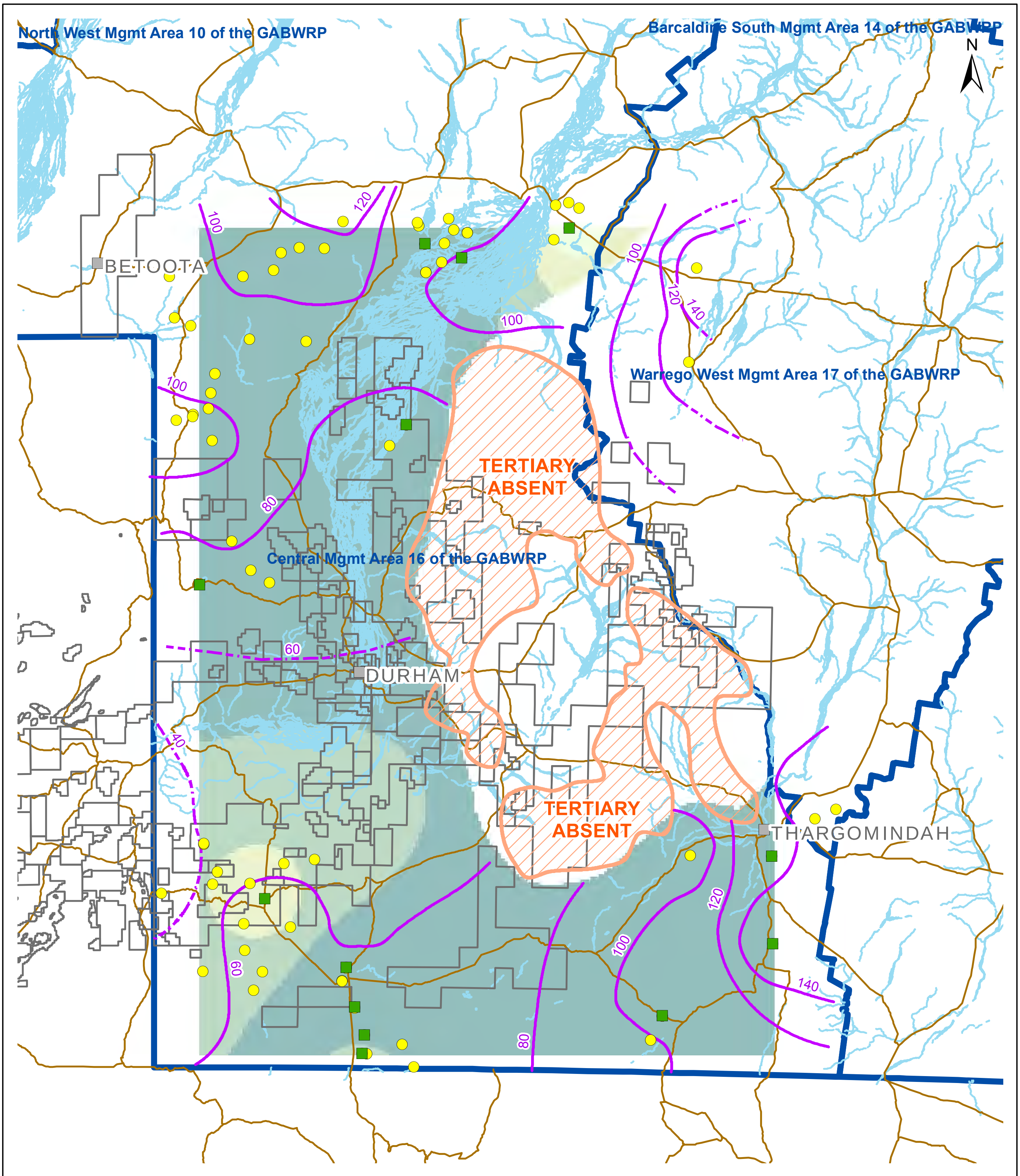


Figure 18: Observed Iliad Field Pressure with Depth Plots

5.4 Structural Influence on Groundwater Flow

Section 3.3.4 presented a narrative on the tectonic setting and basin stress regime within the Cooper-Eromanga Basins. The Cooper-Eromanga basin stress regime is primarily associated with strike-slip faulting, normal faulting, and transitional strike-slip/reverse faulting at depth. When taking the observed (and sustained) overpressures into account, this stress regime is predominantly more conducive to tight compressive (non-tensional) fault creation, and as such largely self-sealing fault systems. This would infer the faults are more likely not to readily form conduits for groundwater (or indeed, gas or oil) flow. This is supported by pressure measurement (and sustained overpressures) and profiles, such as are presented in Figures 17 and 18.



COOPER BASIN UWIR

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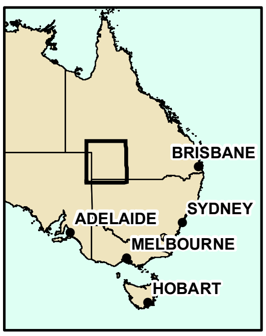
HYDROGEOLOGICAL MAP: TERTIARY FORMATION



LEGEND

- Town/Locality
- Water Level and Electrical Conductivity Data Point
- Water Level Data Point
- Piezometric Isoline (mAHD) 20 m Interval
- Inferred Piezometric Isoline (mAHD) 20 m Interval
- Highway / Major Road
- River/Creek
- Santos Operated Permits
- Groundwater Management Area

Electrical Conductivity (µS/cm)

- 0 - 3000
- 3,000 - 4,500
- 4,500 - 6,000
- 6,000 - 7,500
- 7,500 - 9000

0 5 10 20 30 40 50 Kilometres

SCALE (at A3) 1:2,500,000

Coordinate System: GCS GDA 1994

PROJECT:	**117636010**
DATE:	**28/11/2011**
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FIGURE 19

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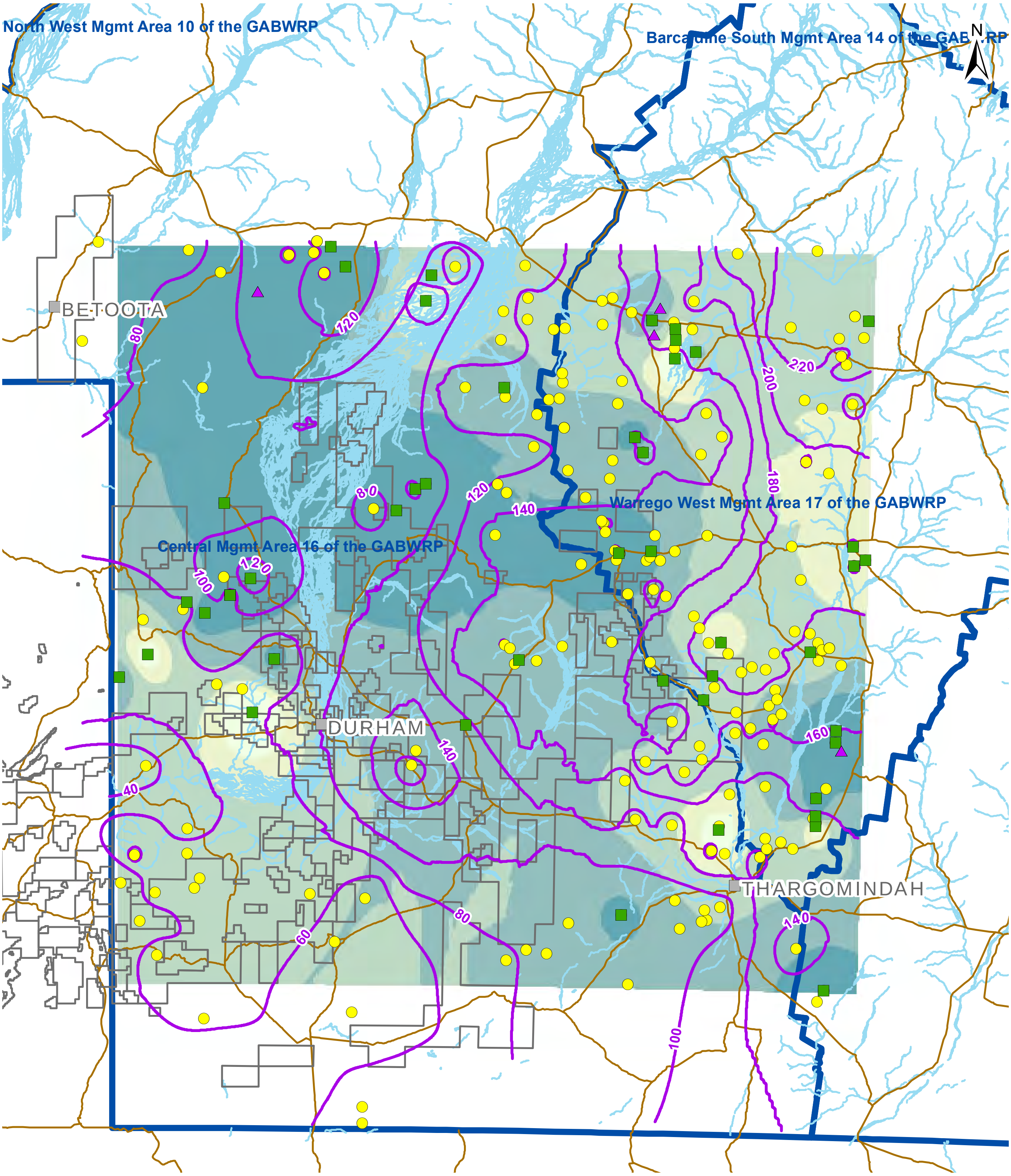

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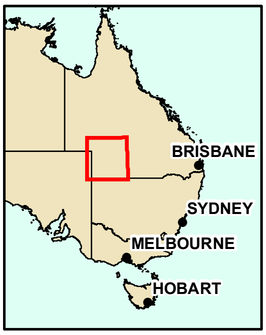
HYDROGEOLOGICAL MAP: WINTON FORMATION



LEGEND

- Town/Locality
- Water Level and Electrical Conductivity Data Point
- Electrical Conductivity Data Point
- Water Level Data Point
- Inferred Piezometric Isoline (m AHD) 20 m interval
- River/Creek
- Highway / Major Road
- Santos Operated Permits
- Groundwater Management Area

Electrical Conductivity (µS/cm)

- 0 - 3,000
- 3,000 - 4,500
- 4,500 - 6,000
- 6,000 - 7,500
- 7,500 - 15000

0 5 10 20 30 40 50 Kilometres

SCALE (at A3) 1:2,500,000

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FIGURE 20

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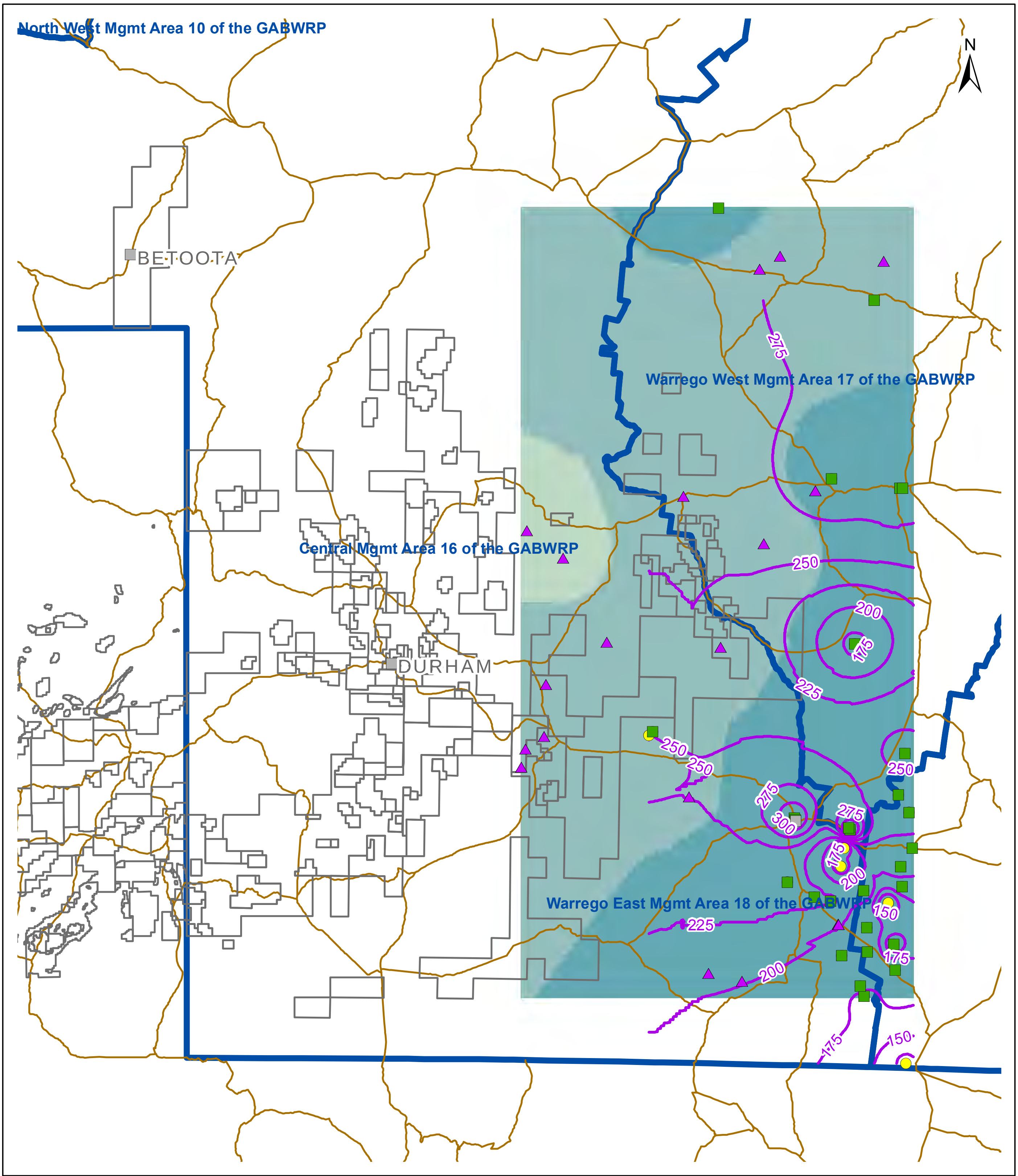

COOPER BASIN UWIR

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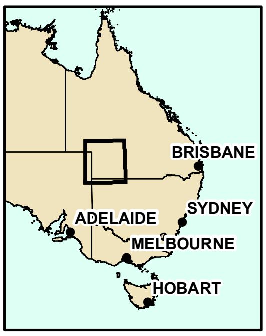
HYDROGEOLOGICAL MAP: HOORAY SANDSTONE



LEGEND

- Town/Locality
- Water Level and Electrical Conductivity Data Point
- Electrical Conductivity Data Point
- Water Level Data Point
- Inferred Piezometric Isoline (metres AHD - Interval 25 metres)
- Highway / Major Road
- Santos Operated Permits
- Groundwater Management Area

Electrical Conductivity (µS/cm)
- 0 - 1,500
- 1,500 - 3,000
- 3,000 - 4,500

0 5 10 20 30 40 50 Kilometres

SCALE (at A3) 1:2,500,000

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FIGURE 21

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5.5 Hydraulic Parameters

A review of hydraulic parameters was undertaken for the strata in the vicinity of the site. This is summarised in Table 10.

Table 10: Hydraulic Parameters

Basin	Formation	Hydraulic Conductivity (m/d) Min	Hydraulic Conductivity (m/d) Max	Porosity (fraction)
Eromanga Basin	Quaternary and Tertiary Alluvium	-	-	-
	Winton Formation	-	-	-
	Mackunda Formation Alluru Mudstone Toolebuc Formation Wallumbilla Formation	-	-	-
	Cana-Owie Formation	-	-	-
	Hooray Sandstone	4.3×10^{-4}	4.3×10^{-1}	-
	Westbourne Formation, Adori Sandstone and Birkhead Formation	8.0×10^{-7} [2]	2.5×10^{-4} [2]	0.2 [2]
	Hutton Sandstone	3.5×10^{-1}	9.8×10^{-3}	
	Poolowanna Formation	1×10^{-7} [2]	3.7×10^{-3} [2]	0.18 [2]
Cooper Basin	Tinchoo / Arrabury Formations			
	Toolachee Formation	2.0×10^{-3} [1]	4.3×10^{-3}	0.15 0.08 to 0.12[3]
	Daralingie, Roseneath Shale, Epsilon and Murteree Shale Formations	-	-	-
	Patchawarra Formation	3.3×10^{-4} [1]	3.5×10^{-3} [1]	0.13 0.08 to 0.12[3]

[1] Gov. of South Australia, Primary Industries and Resources, SA. Petroleum and Geothermal in South Australia – Cooper Basin, 2009.

[2] Alexander, E.M., Reservoirs and Seals of the Eromanga Basin (undated).

[3] Recent information provided by Santos (Santos, 2011).

5.6 Groundwater Level Variations

A network of groundwater monitoring bores has been selected by DERM to monitor groundwater pressures over the whole of the GAB as illustrated on Figure 23. Twenty four groundwater monitoring locations are within the study area, most of those groundwater monitoring bores are targeting the main GAB aquifers of the Eromanga Basin (refer to metadata table). Although water level data is available from 1974 to 2011, all of the bores shown within the study area have very limited water level records. Hydrographs for representative bores are presented in Figure 22; these have been selected as the closest wells to site with the greatest number of available water level records available.

Santos does not have any regional groundwater monitoring bores across its well fields.

Table 11: DERM GAB Monitoring Network - Target Aquifers

RN	LATITUDE	LONGITUDE	Formation*
326	-27.227627	144.3736947	Coreena Member
358	-26.6693889	143.2727374	Hooray Sandstone
3770	-25.845405	144.1222963	Hooray Sandstone
5994	-28.54135	144.33206	Cadna-Owie Formation
12900	-28.3065933	143.9151356	Hooray Sandstone
13488	-28.6094707	143.3081558	Wallumbilla Formation
15286	-28.6813277	143.9381618	Cadna-Owie Formation
16768	-27.4510425	141.0574634	Hutton Sandstone
17428	-28.2743291	144.1420228	Hooray Sandstone
18144	-28.3921154	144.3032971	Wallumbilla Formation
22945	-25.4831149	143.409366	Hooray Sandstone
23233	-25.7300197	143.5999248	Hooray Sandstone
23349	-27.9054058	143.3229819	Hooray Sandstone
23569	-27.7188708	142.5648591	Hooray Sandstone
50503	-27.2872927	143.4556593	Hooray Sandstone
50623	-27.274913	142.9318421	Hooray Sandstone
8 bores	Refer to map	Refer to map	unknown

*Target formation either provided in the DERM database or inferred from the DERM database information.

The water levels presented on Figure 22 have been converted to m AHD from the reported units in the DERM database as calculated static head relative ("CAL_STAT_HD") to the natural surface (m above ground level). In most subartesian bores this is the standing water level. In artesian bores a more complex procedure is required to account for previous use from the bore and temperature variation inside the bore's water column to obtain the true static head or water level.

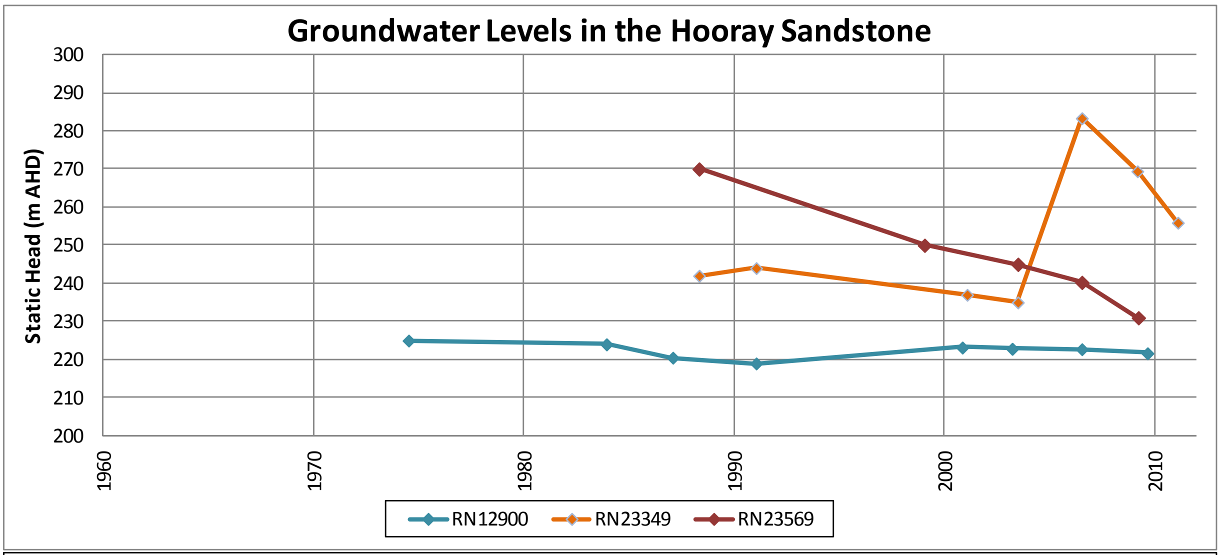
Groundwater levels for the Hutton and Hooray Sandstones, and Wallumbilla and Cadna-Owie Formations are shown in Figure 22. The recorded monitoring data is sporadic and seasonal trends cannot be interpreted.

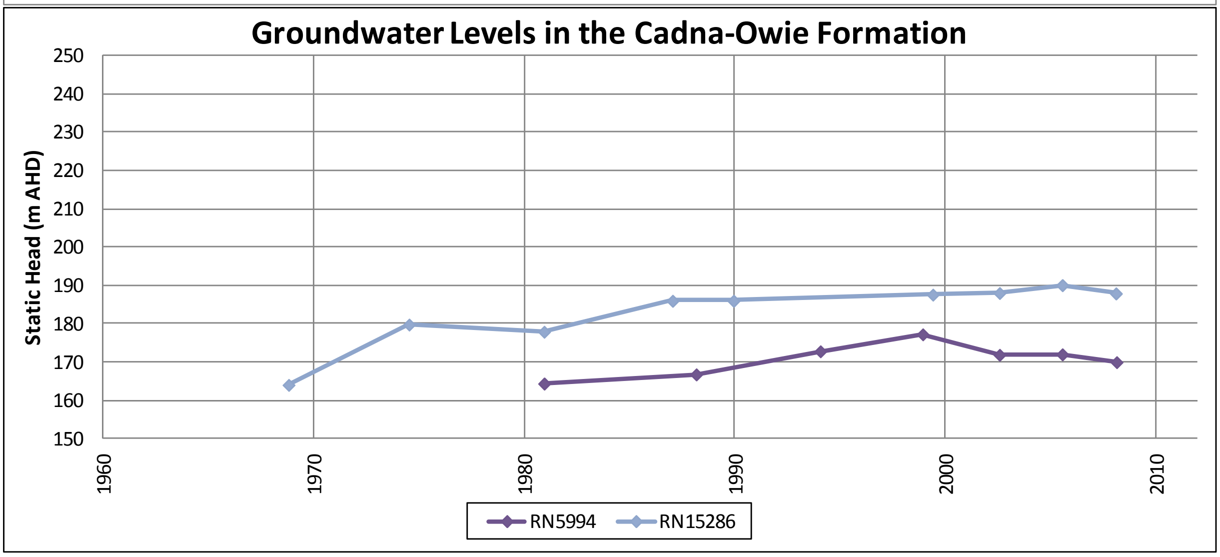
The limited data for the Hutton Sandstone and Wallumbilla Formation are combined on one graph (Figure 22). There are only three available groundwater level measurements for the Hutton Sandstone (RN 16768), located within the Santos tenements, which is significantly deeper than the Wallumbilla Formation. The available data does not indicate significant water level variations between the first and most recent measurements in these formations.

The most recent measurements in the Cadna-Owie Sandstone indicate rising static head of up to 25 m for the available data set.

The Hooray Sandstone shows significant variations in water level since 1970, with measurements between 220 to 290 m AHD between three selected monitoring bores (Figure 22). The static head in bore RN23569 indicates a 40 m decline between 1988 and 2009; RN23349 static head shows an increase over time; whereas RN12900 does not show a trend.

Based on the available data set, it is possible the decrease in static head in RN23569 may the result of extraction from the deeper Birkhead Formation and Hutton Sandstone, particularly given the location of the well within the predicted radius of influence of the Cooper oil and gas field activities (Figure 44). Due to the lack of data since 2009, the extent of the effects of the long-term drought cycle ending by 2010 is not known. However, overall the available static head data for the Hutton Sandstone do not indicate a particular trend.





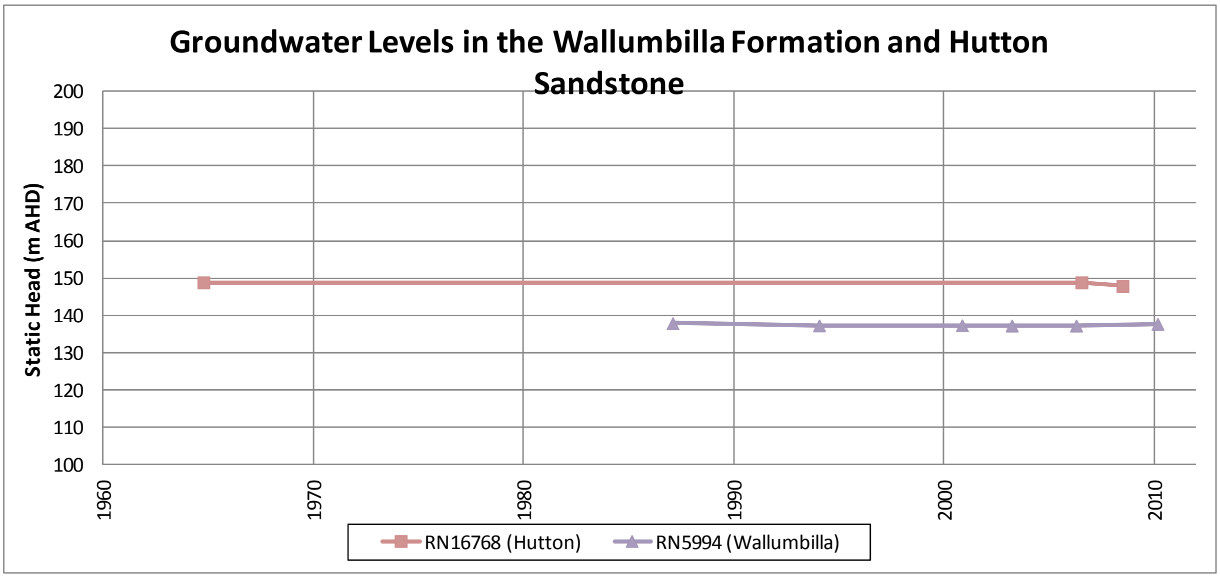
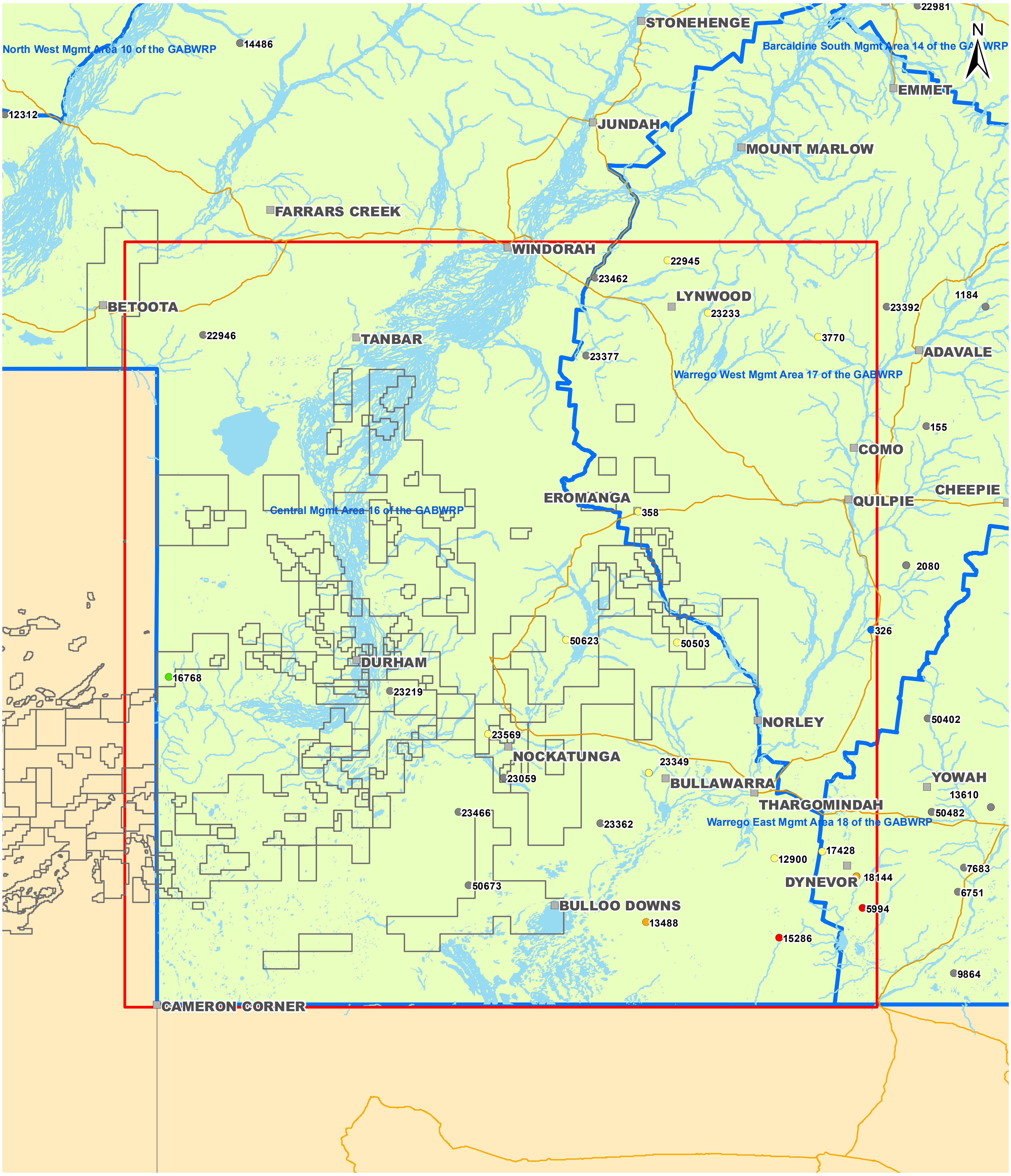


Figure 22: Available DERM Data for GAB Monitoring Bores



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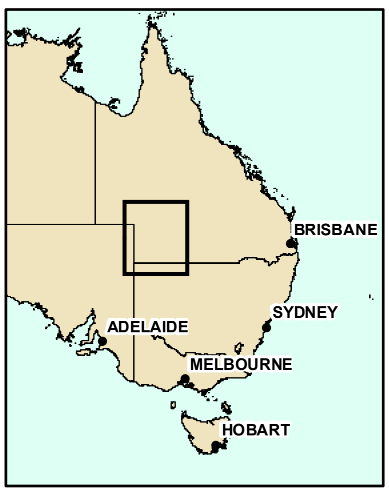
GAB GROUNDWATER MONITORING NETWORK OVER THE STUDY AREA



LEGEND

- Town/Locality
- Highway/Major Road
- River/Creek
- Santos Operated Permits
- Study Area
- Groundwater Management Area

Target Aquifer

- Wallumbilla Formation
- Coreena Member
- Cadna-owie Formation
- Hooray Sandstone
- Hutton Sandstone
- No data

0 10 20 40 60 80 100 Kilometres

SCALE (at A3) **1:2,000,000**

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FIGURE 23

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4. Groundwater monitoring network supplied by DERM, 2010

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5.7 Aquifer Recharge and Discharge

Recharge of the GAB aquifers occurs near the GAB boundaries through the GAB intake beds mostly (Figure 24). Recharge via infiltration of groundwater through the overlying formations is a minor recharge mechanism and is limited to the upper GAB formations.

Groundwater flows in the GAB are predominantly westward, south-westward and southward from the eastern margin of the GAB and eastwards from the WA recharge beds (Figure 24).

Discharge areas in the GAB usually manifest as springs, supply by leakage to alluvium aquifers (Tertiary-Recent), and discharge to inland lakes and artesian bores. In the study area there are no identified GDEs (Section 4.4.1). The only discharge of water is through artesian bores.

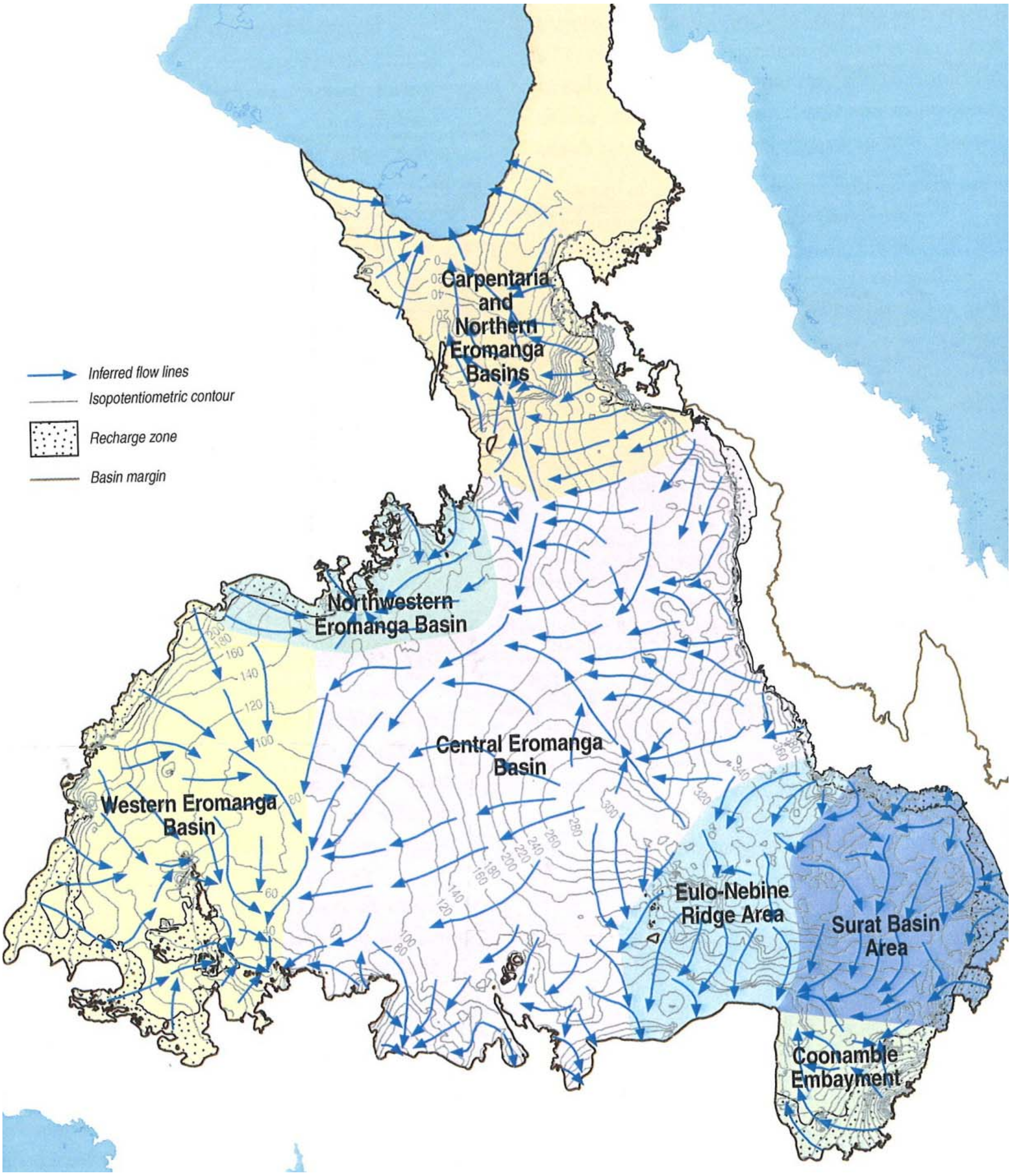


Figure 24: GAB Regional Groundwater Flow and Recharge Intake Beds (BRS, 2000)

In the study area, artificial discharge of the GAB aquifers occurs during oil and gas production as produced water production and during extraction by the local community. Artificial recharge of water only occurs where flooding techniques are used in association to oil production (Section 6.3.3).

5.8 Groundwater Quality

5.8.1 Data Quality Assessment

The groundwater chemistry data available within the study area was collected between 1950 and 2010 (DERM groundwater database). The quality of available data cannot be verified; however, data reliability and accuracy for major ions can be estimated from the electroneutrality of the ion balance, since positive and negative charges in the water should be equal. Ion balance error (IBE) is calculated as follows:

$$IBE(\%) = \frac{\sum Cations - \sum Anions}{\sum Cations + \sum Anions} \times 100$$

where cations and anions are expressed in milliequivalents per litre (meq/L). A milliequivalent is a measurement of the molar concentration of the ion divided (normalized) by the ionic charge of the ion. Approximately 90% (494 out of 546 samples) of the analytical data had IBE values within the ±20 % range, indicating that the major ion analyses were of good quality. Fifty two samples with IBE over the ±20 % range have been excluded from the assessment.

5.8.2 Water Quality Description

5.8.2.1 Physical Parameters

The groundwater quality assessment included analysis of pH, total dissolved solids (TDS) and major ion chemistry. Groundwater classification in terms of pH is presented in Table 12.

Table 12: Groundwater pH

Range	Description
pH < 5	Acid
pH 5 - 7	Slightly Acid
pH 7	Neutral
pH 7 - 9	Slightly Alkaline
pH >9	Alkaline

TDS and electrical conductivity (EC) are measures of the dissolved salt content. TDS is reported as a concentration (in mg/L) and is either measured by evaporating a known volume of water and weighing the residual solids, or calculated by adding the major ion concentrations.

A range of salinity classifications (based on TDS concentration) have been published in literature. Classifications are generally based on beneficial use applications (irrigation or livestock watering) and do not define the full range of TDS found in natural waters (e.g. seawater or brines). The water salinity classification adopted for this study is presented in Table 13, as adopted from Fetter (1994), with a further division of brackish water into slightly brackish and brackish (USDA, 2007).

Table 13: Groundwater classification based on TDS concentrations

Salinity Classes (modified from Fetter, 1994)	
Water type	TDS (mg/L)
Fresh	less than 1,000
Slightly brackish	1,000 to 3,000
Brackish	3,000 to 10,000
Saline	10,000 to 100,000
Brine	more than 100,000

EC is a measure of the conductance of a liquid and is reported in microSiemens per centimetre (µS/cm) at 25°C. There is a linear relationship between dissolved salt load and EC values for water samples.

5.8.2.2 Major Ion Chemistry

AQUACHEM software (Waterloo Hydrogeological Inc, 2003) was used for water quality assessment and graphical interpretations of the groundwater quality data, as follows:

5.8.2.2.1 Piper Diagram

Cation and anion concentrations for each groundwater sample are converted to meq/L and plotted as percentages of their respective totals in two triangles of the Piper diagram (Figure 25). The cation and anion relative percentages in each triangle are then projected into a quadrilateral polygon that describes the water type. The Piper diagram therefore is a convenient tool to differentiate groundwater types based on the relative major ion composition.

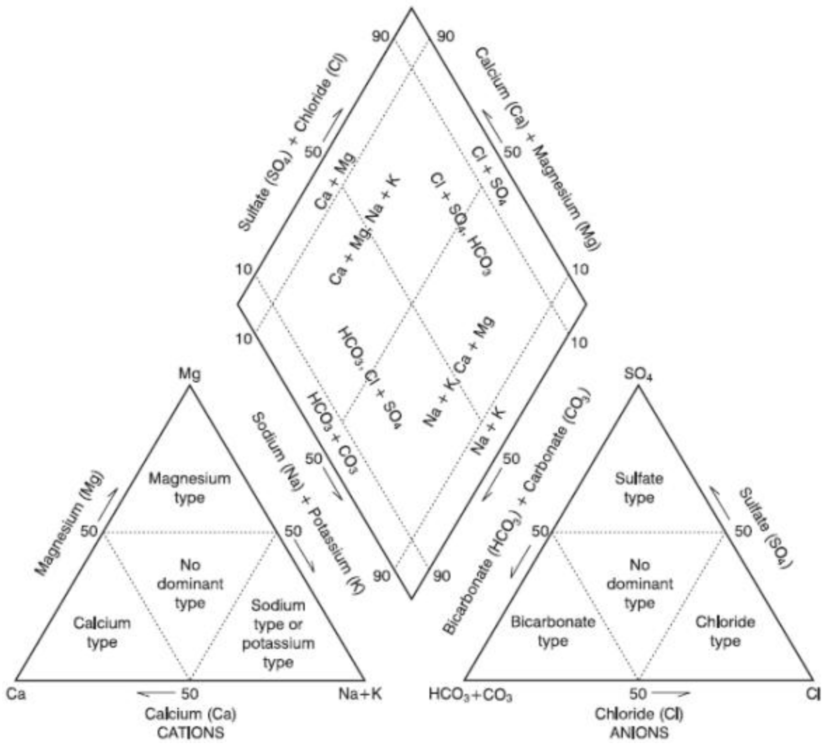


Figure 25: Classification of Hydrochemical Facies using Piper Plot

5.8.2.2.2 Wilcox Diagram

The Wilcox plot is also known as the U.S. Department of Agriculture diagram (Waterloo Hydrogeological Inc, 2003). A Wilcox plot is used to determine the suitability of water for irrigation purposes. The Wilcox plot is a simple semi-log scatter plot of sodium hazard (sodium absorption ratio (SAR)) on the Y-axis versus salinity hazard (EC) on the X-axis. The salinity and sodium hazard classes are presented in Table 14 and Table 15 and in detail described in Section 5.8.4.2).

Table 14: Salinity hazard classes

Salinity Hazard Class	Electrical Conductivity (µS/cm)	Characteristics
C1 – Low	0-250	Can be used for irrigation on most soil with minimal likelihood that soil salinity will develop
C2 – Medium	251-750	Can be used for irrigation if a moderate amount of drainage occurs
C3 – High	751-2250	Not suitable for use on soil with restricted drainage; some soils with adequate drainage may require special management control

Salinity Hazard Class	Electrical Conductivity (µS/cm)	Characteristics
		for salinity
C4 – Very High	> 2250	Not suitable for irrigation under normal conditions

Table 15: Sodium hazard classes

Sodium Hazard Class	Sodium Adsorption Ratio (SAR)	Characteristics
S1 – Low	0-10	Suitable for irrigation on most soil with minimal danger of harmful levels of exchangeable sodium
S2 – Medium	10-18	Appreciable sodium hazard in fine textured soil having high cation exchange capacity
S3 – High	18-26	Produces harmful levels of exchangeable sodium in most soils
S4 – Very High	>26	Unsatisfactory for irrigation purposes

5.8.3 Groundwater Quality in the Study Area

5.8.3.1 Available Data

Water quality data extracted from the DERM database included 772 samples collected from groundwater bores located within the study area. However, only 494 samples collected from the different locations passed the quality control and could be assigned to a particular aquifer formation.

Groundwater quality data in the study area was available for the aquifers associated to the following formations:

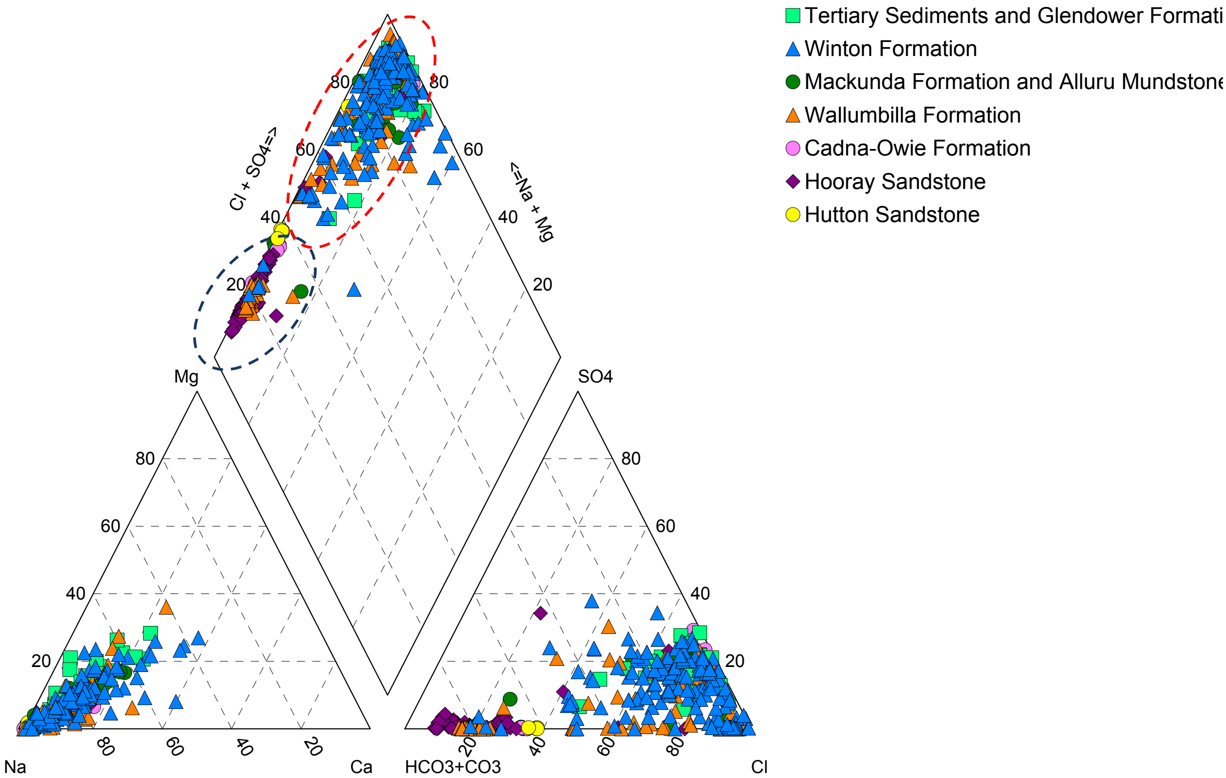
- Tertiary sediments (10 samples),
- Glendower Formation (31 samples),
- Winton Formation (160 samples),
- Mackunda Formation (16 samples),
- Alluru Mudstone (7 samples),
- Wallumbilla Formation (97 samples),
- Cadna-Owie Formation (20 samples),
- Hooray Sandstone (147 samples),
- Adori Sandstone (1 sample), and
- Hutton Sandstone (5 samples).

Groundwater pH values in the study area ranged from 6.2 to 9.9. The slightly acidic pH (6.2) was associated with groundwater from the *Winton Formation* aquifer. The most alkaline sample was collected from the *Wallumbilla Formation*. In the majority of samples the pH ranged between 7.5 and 8.5.

Based on TDS concentrations the majority of groundwater is slightly brackish (TDS<3,000 mg/L). Some samples from Winton Formation, Wallumbilla Formation, Glendower Formation and Hutton Sandstone are classified as brackish with TDS concentrations in the range 3,000-10,000 mg/L. The most saline sample was collected from the *Winton Formation* aquifer.

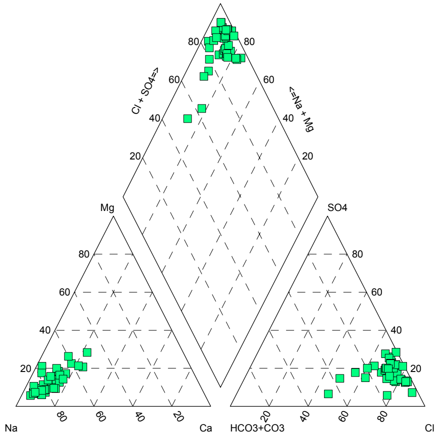
5.8.3.2 Water Types of the Study Area Formations

As shown on Figure 26 and Figure 27 the dominant ions are sodium, bicarbonate and chloride, and water types are either sodium-bicarbonate or sodium-bicarbonate-chloride types. Groundwater from the Winton Formation, Wallumbilla Formation, Hooray Sandstone and Tertiary Sediments/Glendower Formation appear to have higher proportion of sodium and magnesium.

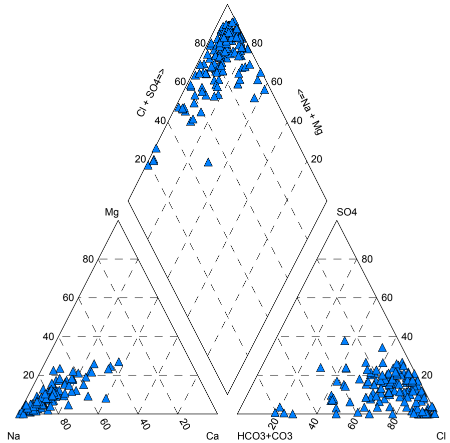


Note: the red grouping highlights a similar water type generally for the upper formations (late Cretaceous to Quaternary), whereas the blue grouping regroups the water samples for the deeper formations of the Eromanga Basin.

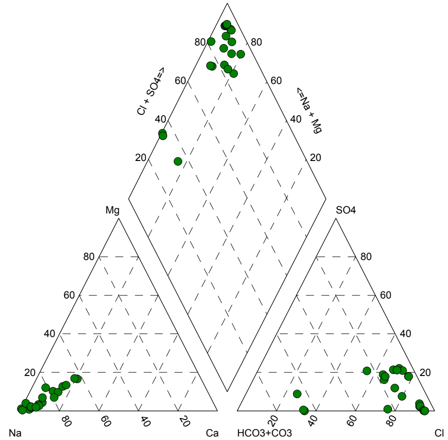
Figure 26: Piper Diagram



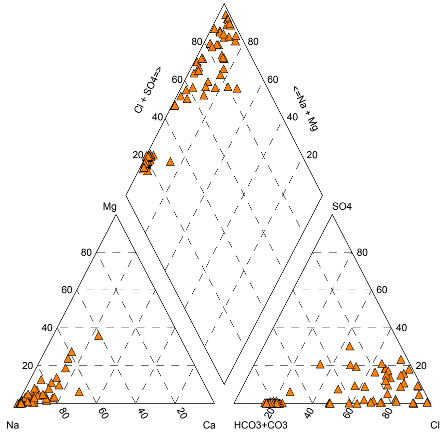
Tertiary Sediments and Glendower Formation



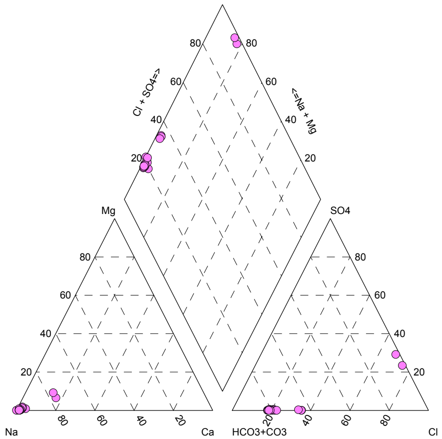
Winton Formation



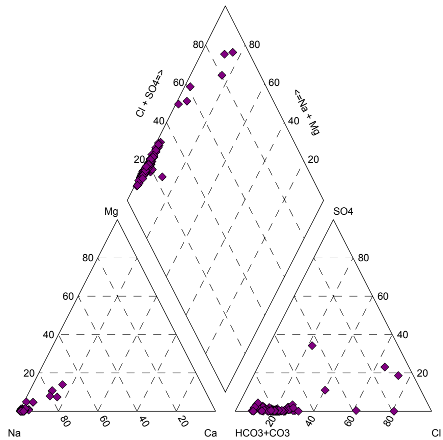
Mackunda Formation and Alluru Mudstone



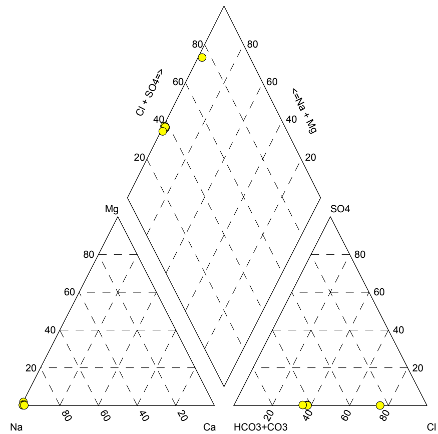
Wallumbilla Formation



Cadna-Owie Formation



Hooray Sandstone



Hutton Sandstone

Figure 27: Piper Diagrams of Individual Formations

5.8.4 Comparison of Groundwater Quality to Regulatory Guidelines

5.8.4.1 Public Supplies and Domestic Use

The Australian drinking water guidelines (ADWG, 2004) established drinking water regulations for public supplies of drinking water. The regulations specify:

- A health-related guideline value is the concentration that does not result in any significant risk to the health of the consumer over a lifetime of consumption; and
- An aesthetic guideline is the concentration associated with acceptability of water, based on appearance, taste and odour.

The assessment criteria for public supplies and domestic use are presented in Table 16.

Sodium and chloride appear to have the highest percentage of exceedances within the study area. Most of the analysed samples exceed the sodium drinking water standard. Fluoride concentrations exceed the drinking water criteria in 33% of samples where fluoride was included in the analytical suite. The pH standard was exceeded in 16% of samples, with samples being slightly alkaline to alkaline rather than acidic.

Table 16: Comparison of ground-water-quality samples with standards for drinking water (ADWG, 2004)

Analyte	Drinking water standard (mg/L; except pH)	No of samples exceeding standard***
pH	6.5 - 8.5	16% (66 out of 412 samples)
Chloride	250**	51% (253 out of 492 samples)
Sodium	180**	95% (469 out of 492 samples)
Sulphate	250** 500*	15% (55 out of 372 samples) 11% (41 out of 372 samples)
TDS	< 500 – good quality 500-1,000 – acceptable based on taste >1,000 – excessive scaling, corrosion, unsatisfactory taste	11% (37 out of 334 samples) – good quality 42% (139 out of 334 samples) – acceptable based on taste 47% (158 out of 334 samples) – excessive scaling, corrosion, unsatisfactory taste
Fluoride	1.5*	33% (152 out of 465 samples)
Copper	0.08	0% (0 out of 45 samples)
Iron	0.3	9% (13 out of 145 samples)
Manganese	0.05	14% (18 out of 130 samples)
Zinc	3	0% (0 out of 52 samples)
Nitrate	11.29	19% (28 out of 144 samples)

* - health value; ** aesthetic value; na-not available; ***TDS concentrations complying with standard

Total hardness is a commonly used measure to characterize the suitability of water for public-supply and domestic use. Total hardness can be characterized into four classes (Table 17; ADWG, 2004). Total hardness was calculated from the chemical composition and refers to the sum of calcium and magnesium (expressed in mg/L of CaCO3). Approximately 49% of samples represent soft groundwater, 16% moderately hard, and approximately 15% of groundwater samples would cause scaling.

Table 17: Groundwater hardness

Total Hardness as CaCO3 (mg/L)	Hardness Classes	Percent of Samples
<60	Soft, but possibly corrosive	49% (237 out of 485 samples)
60-200	Good quality (moderately hard)	16% (79 out of 485 samples)
200-500	Increasing scaling problem (hard)	19% (94 out of 485 samples)
>500	Severe scaling (very hard)	15% (75 out of 485 samples)

Groundwater suitability for livestock watering is assessed on the basis of TDS concentrations and the concentration of specific ions, particularly calcium and sulphate. The trigger values for both calcium and sulphate are 1,000 mg/L. Sulphate and calcium concentrations did not exceed 1,000 mg/L in groundwater from the study area, except calcium concentration exceeded 1,000 mg/L in 2 samples (Winton Formation) out of 489 (0.4%) and sulphate concentration exceeded 1,000 mg/L in 10 samples (various locations) out of 372 (2.7%).

Recommended TDS concentrations in drinking water for livestock watering are summarised in Table 18. As groundwater from the study area is generally fresh and slightly brackish with the TDS concentrations less than 3,000 mg/L it is suitable for watering of the majority of the majority of livestock listed in Table 18. The exception is 45 out of 334 (13%) groundwater samples where TDS is ranging from 3,102 to 32,300 mg/L that would not be suitable for livestock watering.

Table 18: Tolerances of Livestock to TDS in Drinking Water (ANZECC & ARMCANZ, 2000)

Livestock	TDS (mg/L)		
	No adverse effect on animals	Stock should adapt without loss of production	Stock may tolerate these levels for short periods if introduced gradually
Beef cattle	< 4,000	4,000 – 5,000	5,000 – 10,000
Dairy cattle	< 2,500	2,500 – 4,000	4,000 – 7,000
Sheep	< 5,000	5,000 – 10,000	10,000 – 13,000
Horses	< 4,000	4,000 – 6,000	6,000 – 7,000
Pigs	< 4,000	4,000 – 6,000	6,000 – 8,000
Poultry	< 2,000	2,000 – 3,000	3,000 – 4,000

5.8.4.2 Agricultural Use

Agricultural use of groundwater includes irrigation (limited in the study area) and livestock watering (dominant). Irrigating with water that has a high content of dissolved salts and excess sodium can adversely impact the soil structure or adversely affect plant growth. This can depend on the amount of salt present in the water, the soil type being irrigated, the climate and the specific plant species and the growth stage.

The irrigation water quality classification system is based on two characteristics:

- salinity hazard; and
- sodium (alkali) hazard of the water.

Both salinity hazard and sodium hazard are each divided into four classes based on EC values and sodium absorption ratio (SAR). The SAR indicates the tendency of sodium to replace calcium and magnesium in soil and is calculated as follows:

$$SAR = \frac{Na}{\sqrt{\frac{(Ca + Mg)}{2}}} \times 100$$

The characteristics of the salinity and sodium hazard classes are presented in Table 14 and Table 15, respectively. Salinity hazard and sodium hazard are combined into a single plot to evaluate the suitability of water for irrigation (Figure 28).

Figure 28 indicates that groundwater from the study area plot within a wide range of both sodium and salinity hazard classes. The groundwater from all of the formations from SWQ aquifers fall into high sodium hazard (S2-S4) and very high salinity hazard class (C4). Based on this classification groundwater from the study area would not be suitable for irrigation.

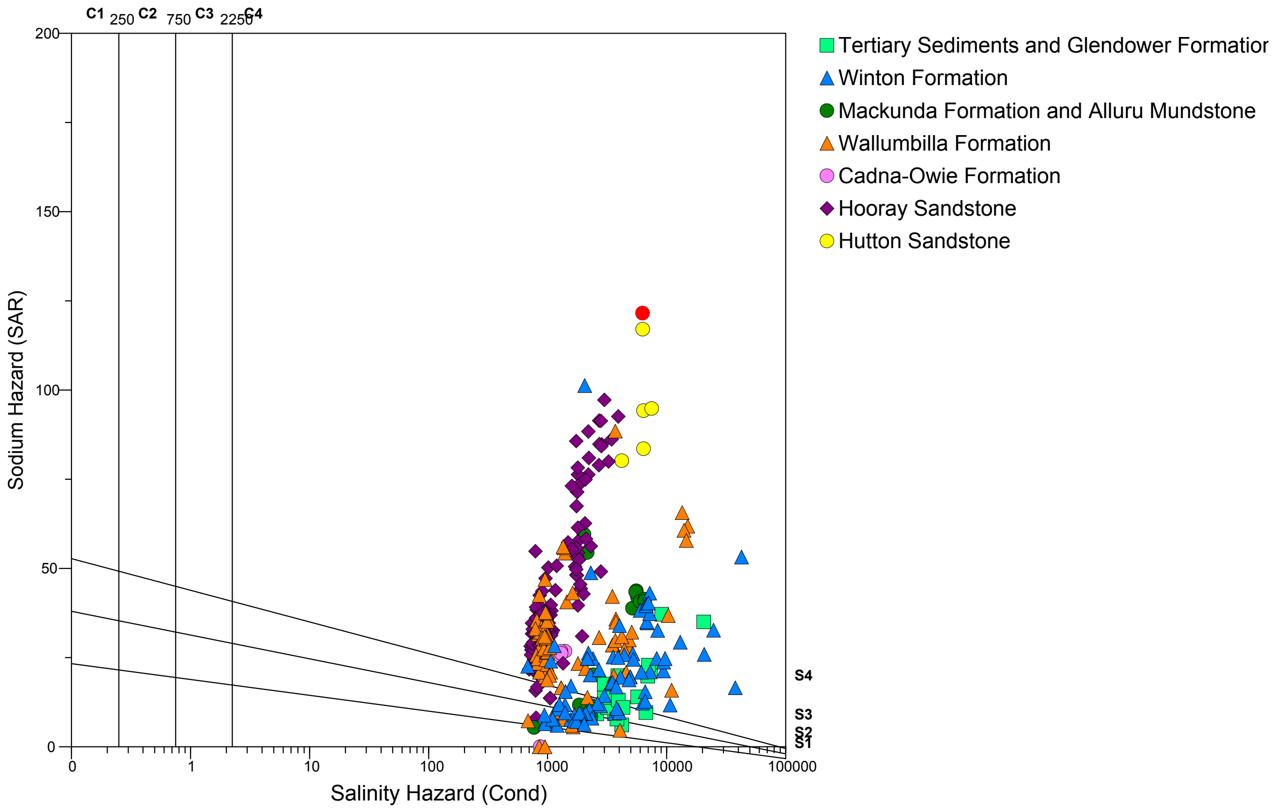


Figure 28: Wilcox Plot Showing Salinity and Sodicity Hazard Classes.

5.9 Groundwater Use (other than Produced Water)

Groundwater use is largely for stock and domestic purposes, town water supply is also sourced from groundwater.

There are no large groundwater users albeit for town water supply in the study area (on the basis of the DERM WES dataset). The bores for municipal supply licensed in the WES database are for the towns of Eromanga and Thargomindah.

No bores are registered for the facilities of Ballera and Jackson, however Santos own 104 water production bores.

Groundwater is primarily sourced from the Tertiary formations and the upper GAB formations of the Eromanga Basin. Figure 29 illustrates the distribution of groundwater sources over the study area. The geographical distribution of groundwater sources for private bores and Santos bores is provided on Figure 30 and tabulated in Table 19.

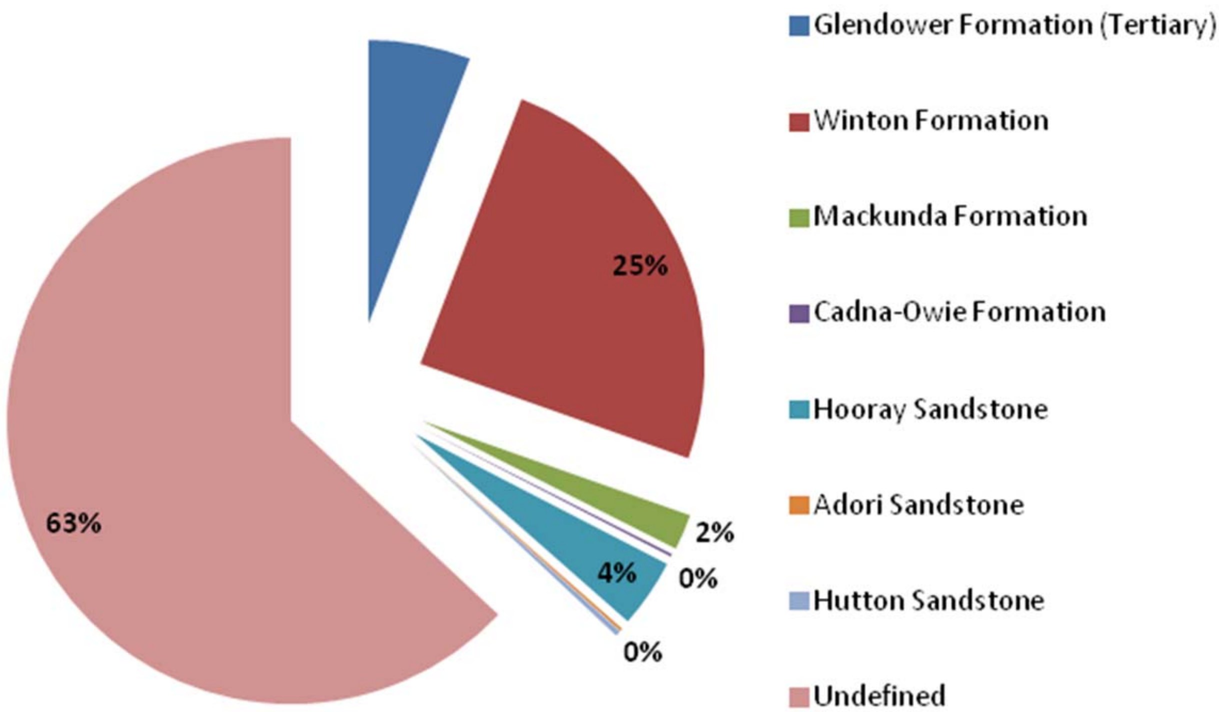


Figure 29: Target Groundwater Sources for Groundwater Usage in the Study Area

Note: the above chart (Figure 29) was drawn using the data from the metadata table. A total of 688 bores have information on the type of pump or are artesian bores and have been assumed used by the community for groundwater supply of various purposes. The data supplied in the DERM WES database only provides information for 138 licensed bores in the study area and assigns 63% of the bores to undefined aquifers.

Most properties are expected to have access to their own water supply through stock and domestic types of licences. Those licences are part of the basic landholder rights to access water, groundwater use is limited to domestic consumption and cattle farming (not including any industrial cattle operations). There is no groundwater entitlement associated to these licences however it is commonly assumed that those bores extract a maximum of 5 ML/year.

The total volumetric water entitlements in the study area is 2,390 ML/yr for urban and town supply from 7 bores; however four of the licensed bores totalling 900 ML were listed as “Lapsed/Never Constructed” and/or expired. The total nominal allowance for stock and domestic bores is 635 ML/yr for 127 bores. The total extraction volume for the 135 licensed bores listed in the DERM database is therefore 2,125 ML/yr (excluding lapsed/non-constructed bores entitlements; Table 19).

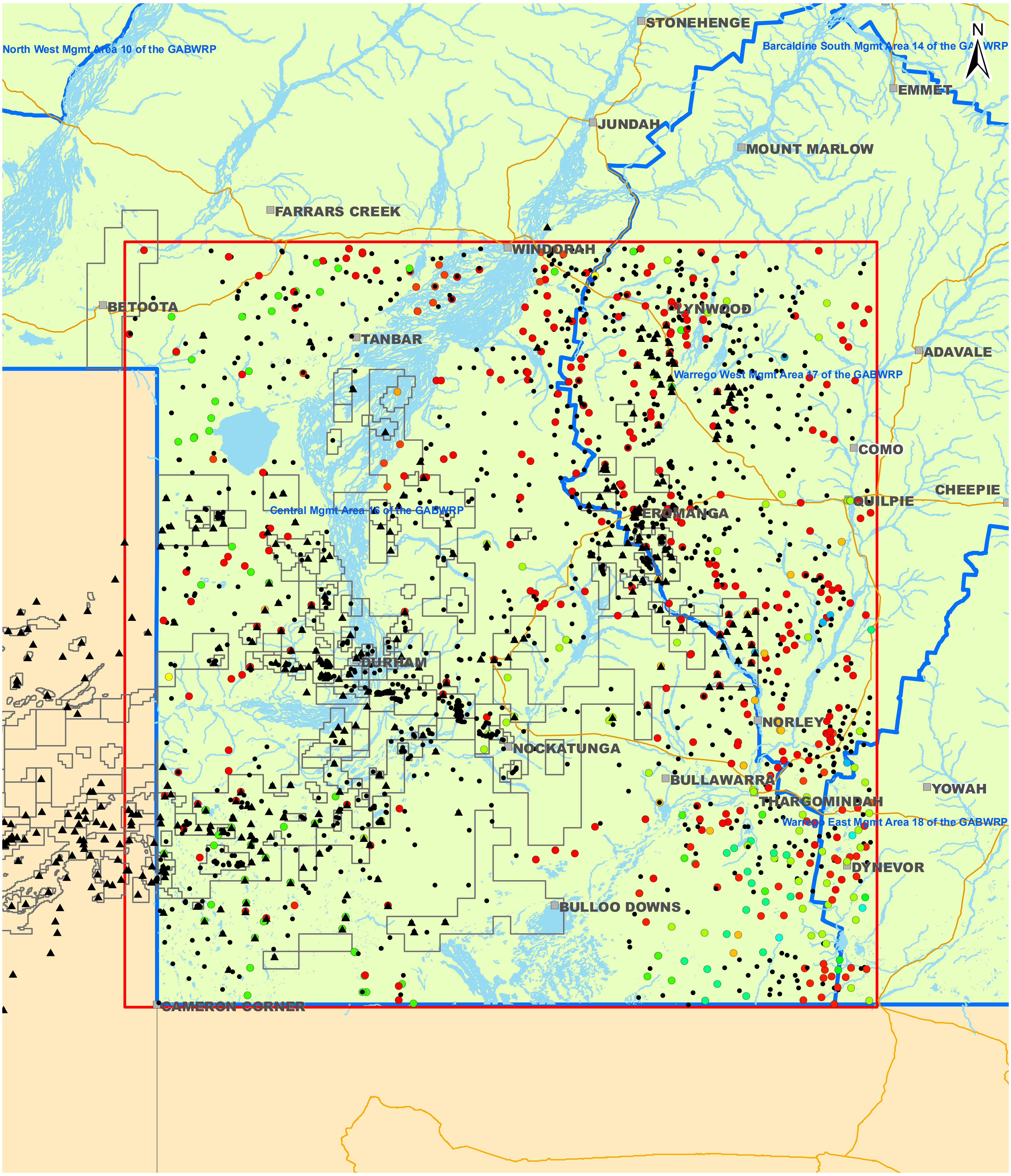
Table 19: Estimated Water Extraction from Bores in the Study Area

RN	Bore Status	Entitlement (ML/yr)	Purpose
Various (127 Bores)	Installed	635	Stock and Domestic (5ML/yr each)
358	Installed	70	Stock, Urban
390	Installed	600	Urban
390	Installed	600	Urban
50887	Installed	220	Domestic Supply, Stock, Urban
100219	*Lapsed(Never Constructed)*	*100*	*Irrigation*
116117	*Lapsed(Never Constructed)*	-	*Urban*
116117	*Lapsed(Never Constructed)*	*600*	*Urban*
116117	*Lapsed(Never Constructed)*	*200*	*Town Water Supply*
TOTAL		**2125**	

Note: Extraction data in italics have not been included in the total estimated water extraction for the study area (Lapsed/Never Constructed).

Santos water production associated to the oil and gas production as described in Section 6.5 is mostly from the Hutton Sandstone (82% of average annual production), the Birkhead Formation (7.8%) and the oil reservoirs of the Hooray Sandstone (8.6%).

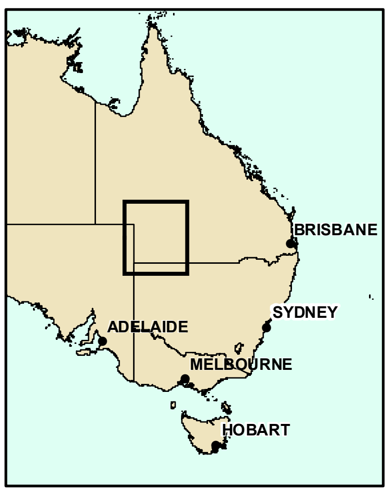
Figure 30 shows the geographical distribution of all known bores in the study area. Bores with known target formations shown in Figure 30 are tabulated in APPENDIX E.



COOPER BASIN UWIR

SANTOS

GEOGRAPHICAL DISTRIBUTION OF GROUNDWATER USE



LEGEND

- Town/Locality
- Highway/Major Road
- River/Creek
- Santos Operated Permits
- Study Area
- Groundwater Management Area

Santos bores

- Unknown

DERM

- Quaternary
- Tertiary Sediments
- Glendower Formation
- Winton Formation
- Mackunda Formation
- Allaru Mudstone
- Wallumbilla Formation
- Coreena Member
- Doncaster Member
- Cadna-Owie Formation
- Hooray Sandstone
- Adori Sandstone
- Hutton Sandstone
- Main Range Volcanics
- Unknown

0 10 20 40 60 80 100 Kilometres

SCALE (at A3) 1:2,000,000

Coordinate System: GCS GDA 1994

PROJECT:	117636010
DATE:	19/12/2011
DRAWN:	AJW
CHECKED:	FH

FIGURE 30

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File Location: J:\hyd\2011\117636010 Santos_Copper Basin O&G & Moonie Oil -official folder in BRISBANE\GIS\Projects\117636010_R_F0039_CooperBasinGroundwaterSources.mxd

6.0 SANTOS OPERATIONS

Santos activities are described in the SWQ study areas Environmental Management Plans (Santos, 2011) sourced from draft Project Area Environmental Authorities. The summary information on activities and infrastructure reported below has been extracted from these environmental management plans.

6.1 Gas and Oil Production Occurrence and Processes

Santos Cooper Basin gas and oil operations cover a large area in SA and SWQ (32,000 km^2). The operations are grouped in "processing satellites" or centres where Santos has developed all the facilities necessary to the operations of the fields.

As a summary, Santos has developed the following infrastructure:

- 33 Oil and Gas Processing Satellites, the main ones for SWQ are described in Sections 6.2.2 (gas) and 6.3.2 (oil);
- Approximately 820 gas producing wells, 400 oil producing wells; in SWQ there are 191 producing gas wells and 230 producing oil wells;
- Gas storage facilities at Moomba (SA) and Chookoo (QLD);
- Nine camps;
- 5600 km of pipelines, 2390 km roads.

In the Environmental Management Plans, Santos has divided the production fields into three Project areas:

- The **Western Study Area** comprising of following treatment plants and satellite facilities:
  - Ballera gas centre;
  - Jackson oil facility;
  - Chookoo, Naccowlah oil and gas;
  - Tickalara oil; and
  - Watson oil.
- The **Central Study Area** comprising the following Tarbat oil facilities and associated fields:
  - Tarbat Oil;
  - Ipunda/Ipunda Nth fields;
  - Endeavour/Monler fields;
  - Mulberry/Talgeberry/Chancett/Gimboola fields;
  - Tintaburra/Toobunyah fields;
  - Kooroopa/Kooroopa Nth/Takyah fields; and
  - Zenoni/Mugginullah/Aros fields.
- The **Eastern Study Area** comprising the Nockatunga oil facility and associated fields:
  - Nockatunga oil;
  - Winna/Koora/Kihee fields;

- Maxwell fields; and
- Muthero/Thungo/Dilkera/Currambar fields.

A consequence of the geological settings of Santos Cooper Basin operations is the location of *gas* production fields within the centre of Santos production area (Figure 2) and the *oil* production fields around the edges of study area.

Activities undertaken in the oil and gas fields can be classified in a successive logical order:

- Geophysical Operations – including Exploration surveying to provide detailed information on geology;
- Drilling and well operations for exploration drilling - to verify the presence or absence of a hydrocarbon reservoir and quantify the reserves;
- Drilling & Well Operations – Appraisal drilling to determine if the reservoir is economically feasible to develop; and
- Development, production and processing operations - to produce oil and gas from the respective reservoirs until economically feasible reserves are depleted.

Only activities related to potential groundwater impact are further developed in this report.

6.2 Gas Extraction

6.2.1 Areas of Production and Target Beds

Gas is primarily extracted from the formations of the Cooper Basin. The geology of the Cooper Basin has been presented in Section 3.3. The main consequence of the geological settings is the very deep location of the gas target beds at depth of 2,000 m or more. The gas fields are located in the centre of Santos tenements in SWQ and in SA (Figure 2).

There are 191 producing gas wells within Santos SWQ tenements.

The major gas reservoirs as illustrated in the stratigraphic column presented in 6.2.1 and are as follows:

- The Toolachee Formation;
- The Epsilon Formation; and
- The Patchawarra Formation.

These reservoirs are stacked porous sandstone formations separated by finer grained siltstones and mudstone formations (refer to detailed stratigraphy table Figure 10). The latter are typically referred to as the seal or cap rock beds where they are located over the reservoirs.

Table 20 provides the target gas reservoirs for each gas field in SWQ.

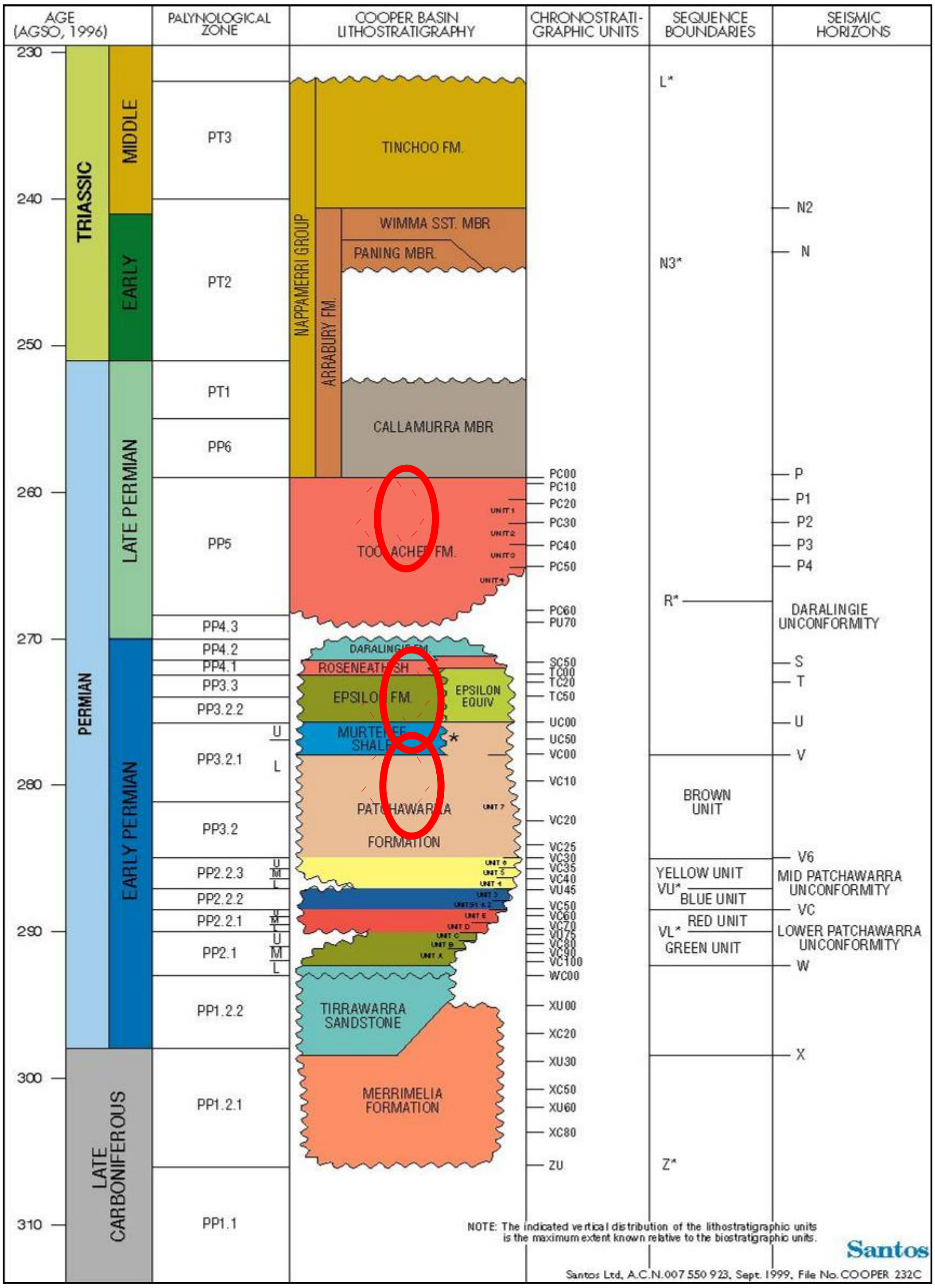


Figure 31: Gas Reservoirs Stratigraphical Distribution

Table 20: List of Gas Fields

PL Number	Target Formation	Gas Field Names
PL 107, 82, 83	Patchawarra Formation	Okotoko
PL 108	Toolachee Formation, Patchawarra Formation, Epsilon Formation	Costa
PL 109	Epsilon Formation, Patchawarra Formation, Toolachee Formation	Tudga
PL 110	Epsilon Formation, Patchawarra Formation	Stokes
PL 111	Toolachee Formation, Patchawarra Formation, Epsilon Formation	Yawa
PL 112	Toolachee Formation (mostly), Patchawarra Formation	Barrolka
PL 113	Toolachee Formation and Patchawarra Formation	Tartulla
PL 114	Toolachee Formation	Wareena
PL 117	Toolachee Formation	Vernon
PL 129	Toolachee Formation, Patchawarra Formation, Epsilon Formation	Ashby
PL 130	Patchawarra, Epsilon Formation	Chirron
Pl 131	Toolachee Formation and Patchawarra Formation	Baryulah, Vega, Tuno, Wellington Acrus
PL 132	Toolachee Formation, Patchawarra Formation, Epsilon Formation	Costa
PL 133	Toolachee Formation	Goora
PL 134	Toolachee Formation, Patchawarra Formation, Epsilon Formation	Kappa
PL 136	Patchawarra Formation	Keilor
PL 137	Epsilon Formation, Patchawarra Formation	Macadama
PL 138	Toolachee Formation	Marago
PL 139	Toolachee Formation and Patchawarra Formation	Monte
PL 140	Patchawarra Formation	Moon
PL 141	Toolachee Formation, Tinchoo Formation	Mt Howitt
PL 142	Toolachee Formation, Patchawarra Formation, Epsilon Formation	Raffle
PL 143	Toolachee Formation, Poolowanna (basal Hutton)	Ruby
PL 144	Toolachee Formation	Thoar
PL 145	Toolachee Formation	Toby
PL 146,147, 25,85,86	Birkhead Formation, Toolachee Formation, Hutton Sandstone, Murta Formation	Wackett
PL 148	Patchawarra Formation, Toolachee Formation	Whanto
PL 151	Toolachee Formation (mostly), Patchawarra Formation	Barrolka
PL 152	Toolachee Formation	Barrolba
PL 152	Toolachee Formation (mostly), Patchawarra Formation	Barrolka
PL 154	Toolachee Formation	Clinton
PL 155	Toolachee Formation (mostly), Patchawarra Formation	Barrolka
PL 158	Wimma Sandstone	Marama
PL 159	Toolachee Formation, Patchawarra Formation, Tirrawarra	Tallalia

PL Number	Target Formation	Gas Field Names
	Formation	
PL 177	Toolachee Formation	Winninia
PL 178	Toolachee Formation	Winninia
PL 181	Toolachee Formation, Patchawarra Formation, Tirrawarra Formation	Roti
PL 186	Patchawarra Formation	Quasar
PL 188	Toolachee Patchawarra Formation	Ramses
PL 207	Toolachee Formation	Chinook
PL 208	Toolachee Formation, Epsilon Formation	Hebe
PL 241	Toolachee Formation, Patchawarra Formation, Epsilon Formation	Theta
PL 25	Toolachee Formation, Patchawarra Formation	Naccowlah Chilla, Chookoo, Wackett
PL 254	Toolachee Formation, Patchawarra Formation	Lepard
PL 255	Toolachee Formation, Patchawarra Formation	Lepard
PL 26	Hutton, Patchawarra, Epsilon Formations	
PL 34	Murta Formation, McKinley/Namur for Oil. Toolachee for gas	Tickalara, Sigma, Mooliampah, Iliad, Rhiems
PL 61	Patchawarra Formation, Toolachee Formation	Ballera, Curri. Yanda, Galex
PL 62	Epsilon Formation, Patchawarra Formation, Toolachee Formation	Tudga
PL 79	Toolachee Formation and Patchawarra Formation	Costa
PL 80, 156	Toolachee Formation	Durham Downs
PL 81	Toolachee Formation and Patchawarra Formation	Karmona
PL 84	Epsilon Formation, Patchawarra Formation	Stokes
PL 86	Toolachee Formation	Wackett
PL 87	Toolachee Formation and Patchawarra Formation	Wippo
PL26	Hutton Sandstone, Patchawarra Formation, Epsilon	Bogala, Karri, Chookoo
PL34	Epsilon Formation	Wills Matrix
PL61	Hutton Sandstone, Namur, Toolachee Formation, Patchawarra Formation	Yanda, Cari, Ballera, Galex
PL75	Toolachee Formation	Patroclus
PL 98	Formation unknown	Challum
PL 59	Formation unknown	Challum

6.2.2 Activities and Infrastructures

Ballera Gas Centre

The Ballera Gas Centre accepts production from approximately 45 gas fields containing about 130 producing gas wells through approximately 500 kilometres of pipelines and flowlines. All field boost compression facilities are located at the main plant, being supplemented by additional nodal compression at strategic field locations.

The Ballera centre ties into a moderate size underground storage for processed sales gas at Chookoo. Some natural gas liquids are recovered at Ballera with raw gas and condensate sent to Moomba via the 180 kilometre Ballera–Moomba pipeline to allow additional liquids recovery. Sales gas from Ballera is sent to Mt Isa via an 800 kilometre pipeline and to Wallumbilla in eastern Queensland for transportation on to Brisbane via a 1,100 kilometre pipeline. No crude oil is processed at Ballera.

The central processing plant comprises:

- Inlet separators;
- Two potassium carbonate CO_2 removal trains;
- One membrane CO_2 removal train;
- Glycol gas dehydration;
- Two Dew Point Control separation trains; and
- Export compression.

Water required by the processing facilities is provided by local groundwater bores. A membrane treatment plant is required to produce potable water.

Electrical power id supplies by a 45 MW electricity generation plant located on site and which is powered by natural gas (the electricity is produced for site use only and is not for sale).

Ballera Gas Centre is serviced by a jet-capable sealed airstrip and also includes associated services, a waste management facility and camp.

Chookoo Gas

The Chookoo facility consists of reciprocating gas compressors enabling either field re-injection into underground storage of sales gas from Ballera plant, or compression of withdrawal gas and discharge to the Ballera Plant sales export compressors.

6.3 Oil Production

6.3.1 Areas of Production and Target Beds

Oil production is extracted from the GAB formations within the Eromanga Basin at depth averaging 1,000 m below ground level. The major oil reservoirs are found within the following GAB formations:

- The Murta Formation and the Namur Formation, these are the upper and lower formations of the Hooray Sandstone. Oil reservoirs are not frequent in the Namur Formation (a sandstone) but more abundant in the Murta Formation (interbedded mudstones, siltstones and fine grained sandstones).
- The Birkhead Formation: the Birkhead formations are interbedded siltstone, mudstone and fine sandstone. Oil reservoirs are present in the basal Birkhead mostly, scattered oil reservoirs are found in the middle Birkhead Formation.
- The Hutton Sandstone: this is the main extraction unit for oil over the Santos tenements in SWQ.

Minor oil reservoirs are also found in other formations:

- The Wyandra Sandstone Member, this is the upper formation of the Cadna-Owie Formation, oil occurrence is not frequent; and
- The Westbourne Formation and the Adori Sandstone.

Figure 32 summarises the occurrence of oil reservoir through the stratigraphy profile.

There are 230 producing oil wells within Santos tenements in SWQ.

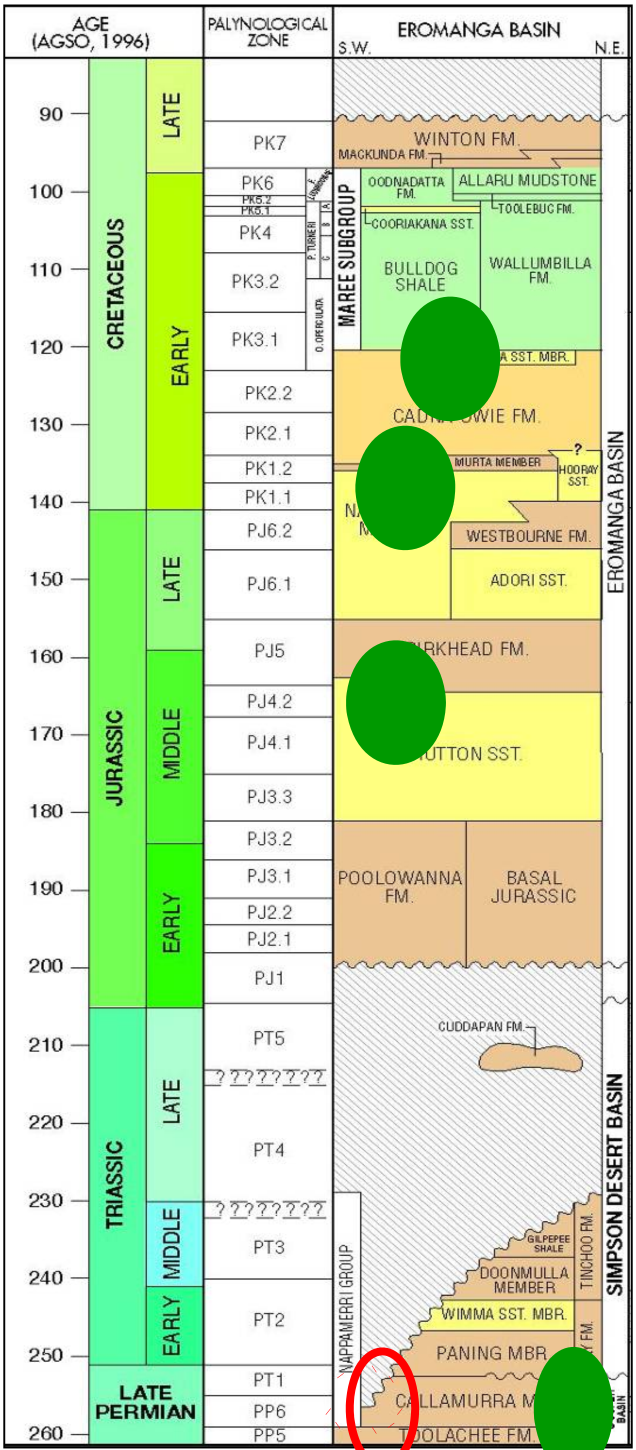


Diagram as provided by Santos

Figure 32: Oil Reservoirs Stratigraphical Distribution

Table 21: List of Oil Fields

PL Number	Field Type	Target Formation	Area Name
PL 23	Oil	Murta Formation, Namur Sandstone, Westbourne Formation, Birkhead Formation (mostly), Hutton Sandstone	Jackson, Gunna, Tinpilla, Tostada
PL 24	Oil	Westbourne Formation, Birkhead Formation, Hutton Sandstone	Jackson South
PL 25	Oil	Hutton Sandstone, Murta Formation, Basal Jurassic	Naccowlah Chilla, Chookoo, Wackett
PL 26	Oil	Hutton Sandstone, Murta Formation, Basal Jurassic, Birkhead	Bogala, Karri, Chookoo
PL 29	Oil	Wyandra, Birkhead, Hutton Sandstone	Tintaburra
PL 33	Oil	Murta Formation, Birkhead Formation, Adori Sandstone	Nockatunga, Winna, Kihee, Koora
PL 34	Oil and Gas	Murta Formation, McKinley Member/Namur Sandstone for Oil. Toolachee Formation for gas	Tickalara, Sigma, Mooliampah, Iliad, Rheims
PL 35	Oil	Hutton Sandstone	Watson, Watkins, Wandilo
PL 36	Oil	Birkhead Formation, Hutton Sandstone	Cooroo
PL 38	Oil	Birkhead Formation, Hutton Sandstone	Toobunyah
PL 39	Oil	Wyandra Sandstone, Murta Formation, Westbourne Formation, Birkhead, Adori Sandstone	Talgeberry, Mulbery
PL 50	Oil	Murta Formation	Maxwell
PL 51	Oil	Murta Formation, Birkhead formation	Thungo, Muthero, Kanel, Dilkera
PL 52	Oil	Wyandra Sandstone, Murta Formation, Hutton Sandstone	Ipundu, Tarbat
PL 55	Oil	Basal Birkhead Formation	Munro
PL 57	Oil	Birkhead Formation	Cranston, Endeavour, Minni Ritchi
PL 61	Oil	Cadna-Owie Formation, Murta Formation, Basal Birkhead/Hutton Sandstone	Yanda
PL 68	Oil	Basal Birkhead Formation, Hutton Sandstone	Genoa
PL 75	Oil	Hutton Sandstone, Namur (upper) Sandstone	Patroclus
PL 76	Oil	Birkhead Formation, Hutton Sandstone	Bolan, Corella, Echuburra, Natan
PL 77	Oil	NA	Jarrar
PL 78	Oil	Westbourne Formation, Namur Sandstone, Birkhead Formation	Bowen
PL 95	Oil	Westbourne Formation, Hutton Sandstone	Monler
PL 97	Oil	Hutton Sandstone, Namur Sandstone	Cook
PL 168	Oil	NA	Tennaform
PL 169	Oil	Birkhead Formation	Gimboola, Chancett
PL 170	Oil	Birkhead Formation, Murta Formation, Wyandra Sandstone	Kooroopa, Takyah
PL 244	Oil	Murta Formation	Currambar
PL 245	Oil	Murta Formation	Noccundra
PL 293	Oil	Wyandra Sandstone, Murta Formation	ZeoniZenoni
PL 294	Oil	Murta Formation	Mugginanullah

PL Number	Field Type	Target Formation	Area Name
PL 295	Oil	Birkhead Formation	Mulberry Endeavour
PL 298	Oil	Wyandra Sandstone	Aros
PL 301	Oil	Birkhead Formation	Zeus, Minos
PL 302	Oil	Murta Formation	Bogala
PL 303	Oil	Murta Formation	Cuisinier
PL 460	Oil	Birkhead Formation, Namur Sandstone, Murta Formation	Inca

6.3.2 Activities and Infrastructures

Jackson Oil facility

The Jackson Oil facility accepts production from a number of oil fields serviced by approximately 250 kilometres of pipelines and flow lines. Produced oil is dewatered and sent via the 250 kilometre, 300mm Jackson-Moomba pipeline to Moomba and on to the Port Bonython oil terminal in South Australia.

Jackson acts as the central collection and storage facility for several outlying satellite gathering areas such as Watson, Tickalara, Naccowlah and Tarbat.

The Jackson facility comprises:

- Oil processing inlet separators, dewatering tanks, evaporation ponds and skimming ponds;
- Centralised electrical power services totalling 8.5 MW supply beam pumps, progressive cavity pumps (PCPs) and electric submersible pumps (ESPs) at Jackson and Naccowlah facilities;
- Oil storage (two tanks, 63,000 barrels total or about 10 ML)
- Landfarm;
- Shipping pumps; and
- Associated services and camp.

Water is provided by bores and treated by a Reverse Osmosis Plant (ROP) to produce potable water.

Naccowlah Oil

The Naccowlah facility comprises oil storage tanks, wash and test tanks, a diesel storage (frac) tank, a crude storage (frac) tank and a landfarm. Oil is transferred from the Naccowlah field via artificial lift pumps. Power is distributed to the Plant and associated fields via a Ruston turbine and Waukesha generator packages, with Caterpillar diesel generators for back up. Produced formation water is separated through wash tanks to the on-site evaporation pond system. Oil is pumped to Jackson as required via pipeline.

Tickalara Oil

The Tickalara Oil satellite consists of oil storage tanks, wash tanks, a test tank and several crude fuel storage tanks. Oil is transferred from Tickalara and associated fields via artificial lift pumps including ESP, beam pumps and PCPs. The Tickalara facility has Caterpillar shipping pumps for the transfer of produced oil through the Tickalara-Watson-Cooroo (TWC) pipeline to the Jackson Oil facility or direct injection into the Jackson to Moomba oil flowline and transferred to Moomba . The Tickalara facility is equipped with a tanker unloading terminal for the receipt of crude oil from the Munro and Dulu fields. The facilities are complete with dewatering tanks, and a series of evaporation ponds and oil skimming facilities.

Watson Oil

The Watson Oil facility consists of oil storage tanks, wash tanks, vertical frac tanks and crude fuel storage tanks. Oil is transferred from Watson and associated fields via artificial lift pumps including ESP, beam and jet pumps. In winter months Watson Oil receives oil production from the Tickalara Oil facility as required. Watson oil is transferred to Jackson via shipping pumps and the TWC pipeline or direct injection into the Jackson to Moomba Oil pipeline to Moomba. The facilities are complete with dewatering tanks, and a series of evaporation ponds and oil skimming facilities.

Nockatunga Oil

The Nockatunga Oil facility consists of oil storage tanks, wash tanks, crude fuel storage tanks and associated services and camp. Oil is transferred to Nockatunga from associated fields via artificial lift beam pumps, Jet Pumps and progressive capacity pump (PCPs). The Nockatunga facility transfers produced oil to the Jackson Plant via road tankers. The loading terminal consists of a diesel powered loading pump. The facilities are complete with dewatering tanks, and a series of evaporation ponds and oil skimming facilities.

Tarbat Oil

The Tarbat Oil facility consists of oil storage tanks, wash tanks, crude fuel storage tanks, land farm and associated services and camp. Oil is transferred to Tarbat from the associated fields via artificial lift (beam) pumps and PCPs. Tarbat facility transfers produced oil to the Jackson Plant via a 250 mm trunkline. Mains power is supplied to the field and permanent camp by a 5MW gas turbine. The facilities are complete with dewatering tanks, and a series of evaporation ponds and oil skimming facilities.

6.3.3 Water Flooding

Water flooding is being undertaken in the Cranstoun, Mulberry, Gimboola, Talgeberry and Endeavour fields (all in ATP299P) with the objective of enhancing oil recovery by maintaining pressure in the Birkhead and Murta oil reservoirs and improving sweep efficiency (Table 20 and Figure 30). Significant and rapid pressure depletion in the reservoirs had occurred despite only modest fluid production - confirming the suitability for a Secondary Recovery pressure maintenance scheme. Water flooding was selected as the preferred Secondary Recovery scheme. Water is injected into the oil reservoir in order to restore and maintain pressure and enhance production.

The Birkhead Formation is located 1300 m below ground level at the Mulberry and Endeavour oil fields. In this area of the Eromanga Basin, the deposits were fluvial-lacustrine with frequent laterial facies variations resulting in a channelized geometry of the sandstone beds which restrict lateral continuity of the oil reservoirs.

The Murta Formation is found from 700 - 800 m depth. The Murta Formation was deposited during meandering fluvial conditions, floodplain and lacustrine environments.

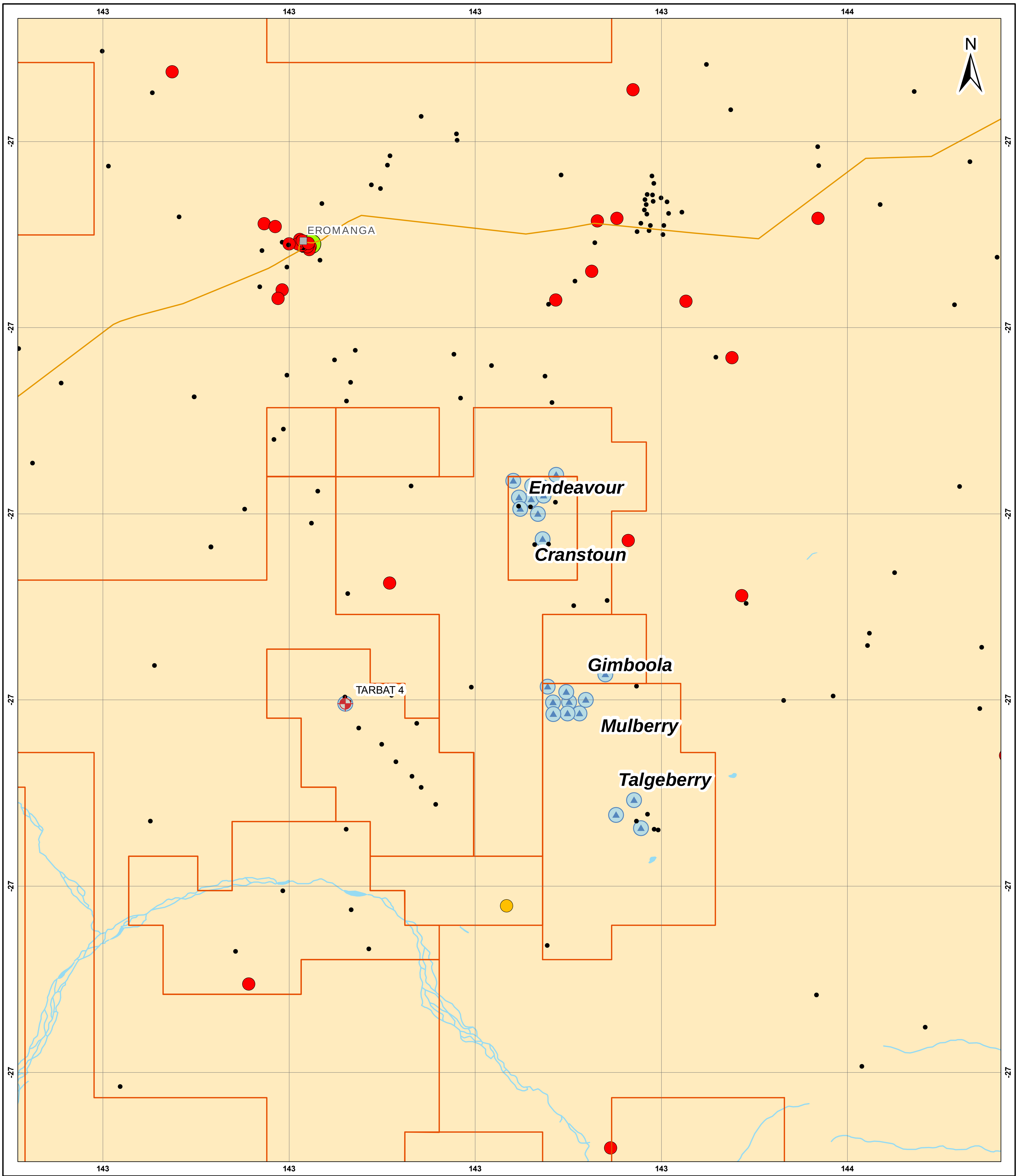
Water flooding is organised generally around one water injection well surrounded by a number of oil producing wells with an average distance between injection and production wells of 400 to 500 m. Santos has a number of injection wells for each field where water flooding is performed. At Endeavour 9, the average injection rate is of 0.10 ML/day (65 barrels of water per day).

Until early February 2009, the water has historically been sourced from the Namur Sandstone aquifer (from Tarbat 4). From that date, water was sourced mostly from treated produced water (from the Tarbat treatment plant) and supplemented by groundwater from Tarbat 4. Defects in the design which affected chemical injection resulted in the plant being shut down, redesigned and becoming operational again in February 2011. During that period, Santos reverted in using Tarbat 4 as primary source of water for water flooding.

Section 8.2 and 8.3 further discuss the potential risks and impacts related to these activities, and management measures implemented to control those risks.

Table 22: Summary of Water Flooding Activities

Field	Reservoir	Water Injection Commenced	No of Water Injectors	Water Injectors	Relevant PL
Cranstoun	Birkhead	Aug ‘07	1	Cranstoun 4	PL 57
Endeavour	Birkhead	Oct ’06 & Aug/Sep ‘07	9	Endeavour 4, 6, 9, 10, 11, 12, 14, 17 & 36	PL 57 (& PL 295)
Gimboola	Birkhead	Mar ‘07	1	Gimboola 5	PL 169
Mulberry	Birkhead	Jun ’06, Nov ’06 & Jul ‘07	8	Mulberry 2, 4, 7, 18, 25, 28, 30 & 41	PL 39 (& PL 295)
Talgeberry	Murta	May ’07 & Oct ‘07	3	Talgeberry 6, 8 & 17 (via annulus)	PL 39
	Birkhead	Oct ‘07	1	Talgeberry 17 (via tubing)	PL 39



COOPER BASIN UWIR

SANTOS

WATER FLOODING ACTIVITIES

LEGEND

- Town/Locality
- Highway/Major Road
- River/Creek
- Water Source Well
- Water Injection Wells
- Santos Operated Permits

Private Bores

Target Aquifer

- Hooray Sandstone
- Winton Formation
- Mackunda Formation
- Unknown

0 1 2 4 6 8 10 Kilometres

SCALE (at A4) **1:200,000**

Coordinate System: GCS GDA 1994

PROJECT:	117636010
DATE:	29/11/2011
DRAWN:	AJW
CHECKED:	FH

FIGURE 33

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File Location: J:\hyd\2011\117636010 Santos_Copper Basin O&G & Moonie Oil -official folder in BRISBANE\GIS\Projects\117636010_R_F0065_CooperBasinWaterFloodingActivities.mxd

6.3.4 Summary of Oil and Gas Production Wells

The numbers of oil and gas production wells in each tenure is given in Appendix E.

6.4 Hydraulic Fracturing

As mentioned previously, the gas wells within the Cooper Basin formations generally each intersect several reservoirs. Historically, hydraulic stimulation was not required but as tighter gas is being targeted there is a need to stimulate the target formation for the operations to remain economically viable.

In order to produce from all of the gas reservoirs intersected in a well, Santos uses methods to selectively isolate and individually fracture each hydrocarbon bearing zone. As a result, a typical gas well will have more than one fracturing treatment and the current average is about five treatments per well. The typical Santos oil well will rarely have more than one fracturing treatment due to the limited number of oil reservoirs and the fact that oil bearing formations are not as dependent on fracturing to be commercially viable.

Since 1987, a total of 275 hydraulic stimulations have been completed within 192 wells (not all producing) in the SWQ (Figure 34).

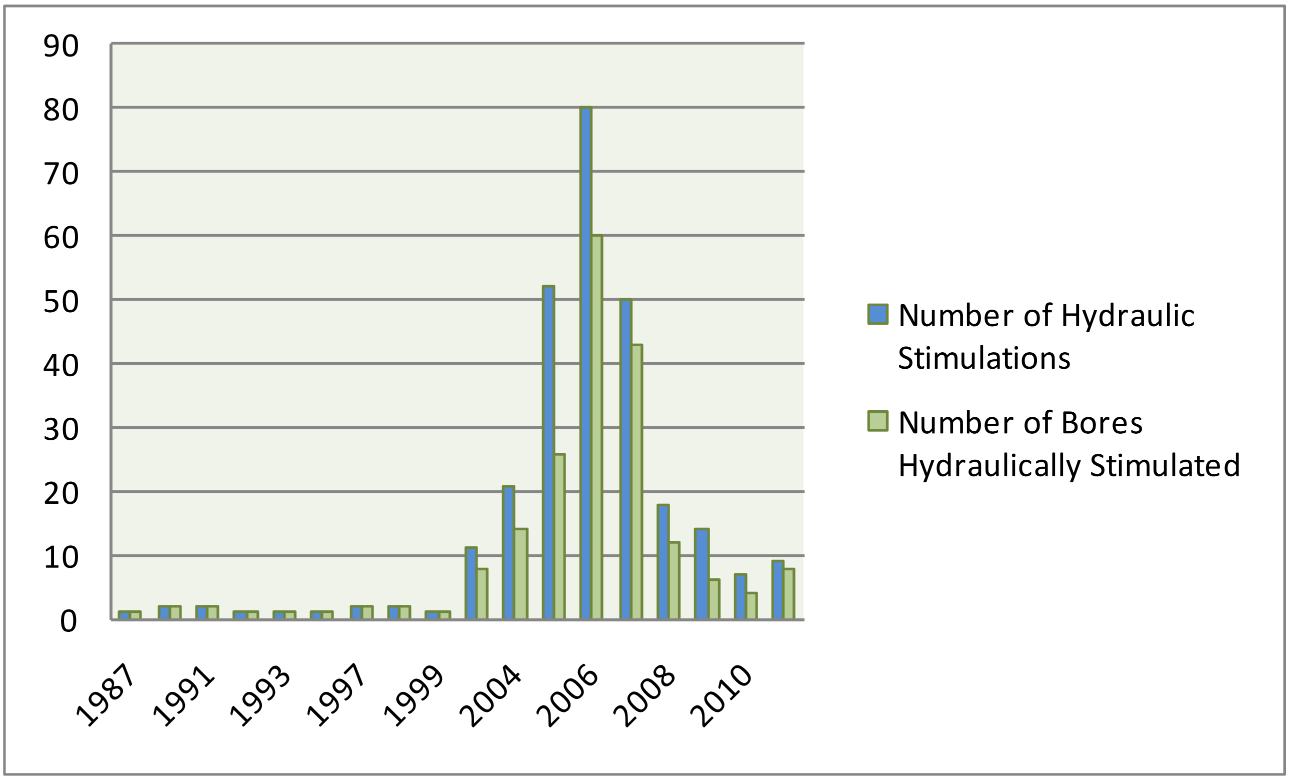


Figure 34: Historical Number of Hydraulically Stimulations in SWQ

The number of stimulation has recently been quite small in SWQ however this varies depending on the development activities. The locations of the stimulations carried out in the last five years are illustrated on Figure 35 Santos has performed few hydraulic stimulation in the last two years in SWQ, the last SWQ stimulation was undertaken in June 2010 on Patroclus 3 , a few locations at Challum gas fields are planned to be hydraulically stimulated in 2012.

The water source for hydraulic fluids is selected from a range of options:

- Specifically completed water bores;
- Water line of one of the nearby facility;

- Evaporation ponds;
- Water collection tanks; or
- Stage separator pond (see section 6.5), water used would be from the bottom section of the pond.

The suitable water source selected for hydraulic fracturing would have the lowest salinity level possible. Santos has sampled over 800 locations in SWQ to identify amongst them potential water sources or characterise the water source.

Chemistry of the fluid is strictly controlled to ensure the fluid is at the right conditions to mix, hydrate, crosslink during treatment and then break on flow back. Laboratory tests are performed for the entire duration of the stimulation.

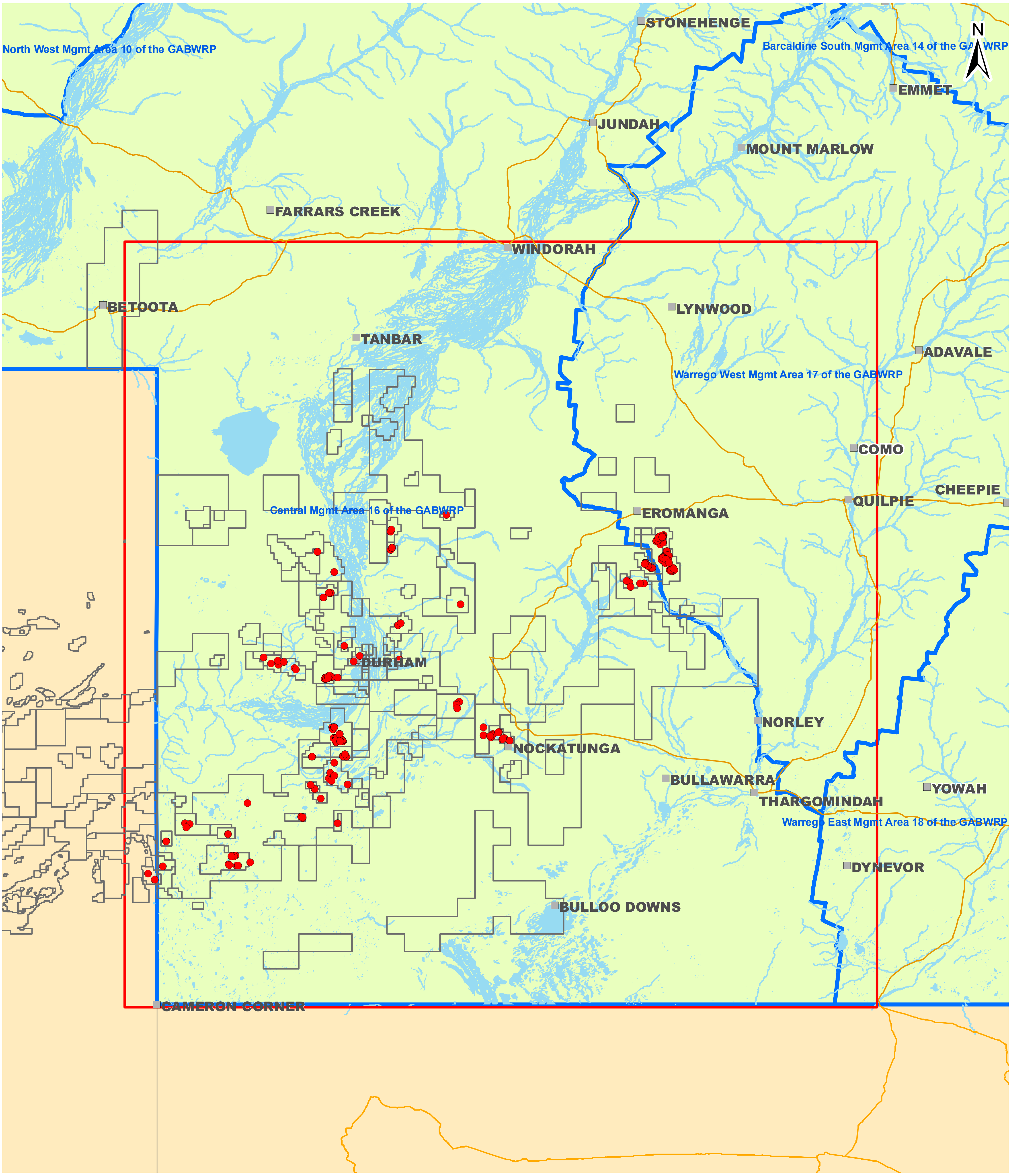
Flow back fracture fluid at present is not recycled. Once returned to the surface, the fracture fluids are discharged to the flow back pit. Where visible hydrocarbon is present on the surface of the water in the pit, a vacuum truck is used where practicable to remove the hydrocarbon.

Santos has provided DERM with information on hydraulic fracturing practices in 2010 (Santos, 2010), this includes information on the composition of hydraulic fracturing fluids, process of hydraulic fracturing for oil and gas wells followed by Santos and depth of the hydraulic fracturing in relation to depth of private bores (stock and domestic water waters). From this document and recent update on Santos practices, the following conclusions can be made:

- BTEX is being eliminated from the hydraulic fracturing process of oil operations. Small volumes of diesel (which contains some of the constituents of BTEX) *were* used in the past as a suspension agent in fracturing fluids. Santos now uses dry gel powder with water as a substitute. .
- BTEX is a natural component of hydrocarbon light crude (condensate) production.

In the last twelve months Santos has started a program of sampling flowback water for hydrocarbons for all hydraulically stimulated well. This will be applied to the 2012 hydraulic fracturing program.

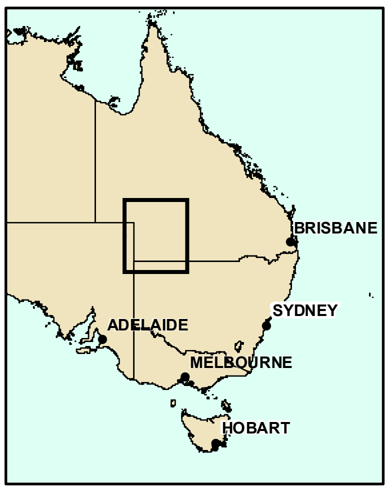
Santos is also investigating potential recycling of flow back fluid. Results of trials in other Santos operations will be applied to SWQ operations as appropriate.



COOPER BASIN UWIR

SANTOS

HYDRAULIC FRACTURING LOCATIONS IN SW QLD



LEGEND

- Historic Hydraulic Fracturing Locations
- Town/Locality
- Highway/Major Road
- River/Creek
- Santos Operated Permits
- Study Area
- Groundwater Management Area

0 10 20 40 60 80 100 Kilometres

SCALE (at A3) 1:2,000,000

Coordinate System: GCS GDA 1994

PROJECT:	117636010
DATE:	19/12/2011
DRAWN:	AJW
CHECKED:	FH

FIGURE 35

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6.4.1 Produced Water Production

Water is produced as a co-product of gas and oil production. The gas extraction generates only a limited volume of water oil production generated a larger volume of water. Approximately 191 gas producing wells and 230 oil producing wells concur to the water production figures provided in this section. Figure 37 illustrates the average annual rate water in Central and Warrego West. The highest average annual rates is in Central (Hutton Sandstone) – 4,998 ML/year (Table 23)

6.4.2 Produced Water Monitoring Methodology

The methodology for monitoring extracted water is different for the oil and gas wells. Generally gas wells produce significantly less water.

Gas water measurement methodology

Santos (per. comm. Owen Davies and Tom Paspaliaris; Santos, 2012) indicated that *the volume of produced water associated with gas production is not metered or measured directly. The total volume is estimated based on the average water content of the produced gas.*

Oil water measurement methodology

The methodology for monitoring produced water in *oil* production is summarised as:

Individual well water measurement can be by water-cut meters (Red-eye or DNOC), wellhead water-cut samples or via tank dips. Very few wells use this, due to flowing conditions rendering meter readings useless.

Monthly Allocation to any given well is done by:

- *Estimating the theoretical monthly oil and water production by well (using latest individual well test rates multiplied by the number of days the well was producing for the month [referred to as the "uptime"]);*
- *Summing all the wells' theoretical volumes that collect into some fixed, known gathering point to give the monthly total theoretical oil & water volumes;*
- *Comparing it to the actual monthly oil and water production at that fixed, known gathering point (where the monthly actual oil and water production is based on measurement of trucked oil loads, or oil piped through a fiscal metering point; and*
- *Allocating (pro-rating) the total theoretical volumes to the individual wells based on the ratio of "actual total"/"theoretical total".*

The monitoring methodology for the majority of the produced water (i.e. the approximately 5 GL/year abstracted through oil production) is likely to be a reasonable approximation of actual volumes. This is because the total volume for each well is recorded at a known gathering point and compared to the actual oil and water production volumes through a fiscal metering point. This provides a check that the monitoring equipment is operating properly and provides the opportunity to record this at two separate points.

There is likely to be more uncertainty with the produced water from gas production. However, as this required less produced water to be extracted (approximately 3% of the total from the Cooper and Eromanga Basins) this is not considered to be a significant source of error in the impact calculations.

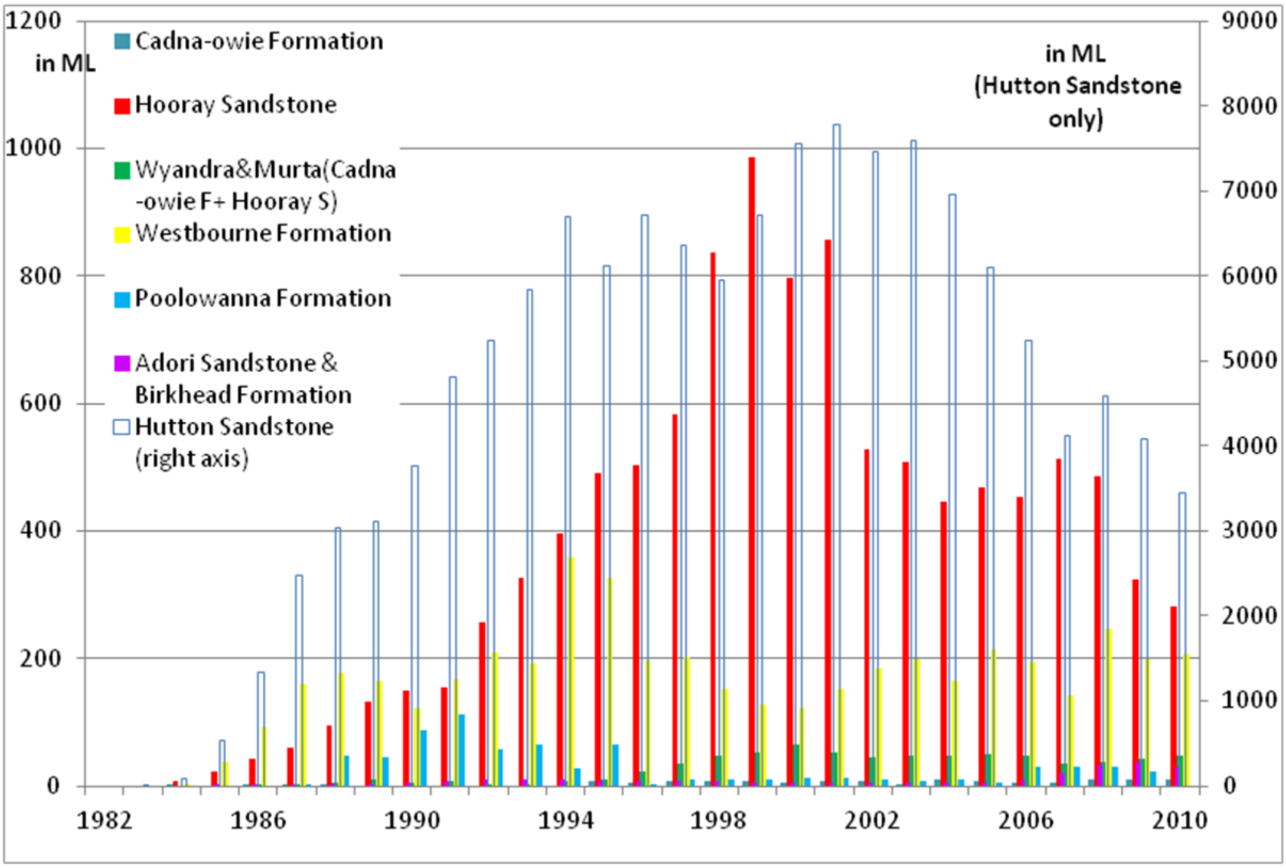
6.4.3 Methodology for Predicting Three Year Water Extraction

Santos does not estimate future produced water extraction for either oil or gas activities (per. comm. Owen Davies; Santos, 2012). For the purposes of 'immediately affected area' predictive modelling (the next three years of extraction), the last year of extraction data was taken to be representative of future extraction.

Considering the duration of extraction from these basins and the declining trend in extraction, (Figure 36) this was considered conservative and likely to be greater than actual extraction for the next three years.

To adopt a conservative approach to the long term affected area calculation, the last year of extraction data was extrapolated for a period of 20 years. This is considered highly conservative.

Water production varies over time (Figure 36), a water production peak has been observed in the late 1990s – early 2000s, the current trend is a decline of produced water associated with the decline of oil production.



Note: The Hutton Sandstone produced water volumes are displayed on the right axis

Figure 36: Variation over time of produced Water in Santos SWQ Oil and Gas Fields

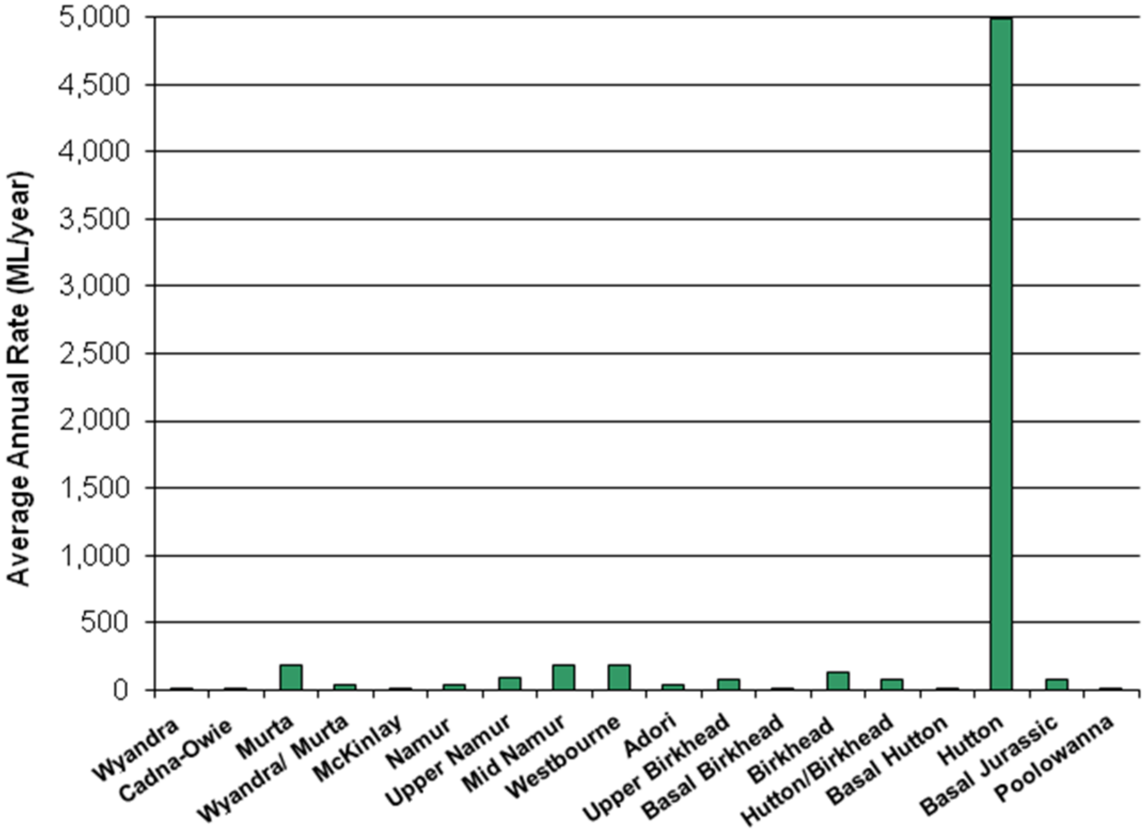
Table 23: Produced Water Production

Grouped by GMU	Formations	Total Water produced	Average Annual Water Production Rate [1]			General Reserve Central and Warrego West	Total S&D + Entitlement		Predicted Average Annual Rate [3]
		ML	*Total ML/year*	*Central - ML/year*	*Warrego West - ML/Year*	*ML/year*	*Central, ML/year*	*Warrego West, ML/year*	*ML/year*
Central 2 / Warrego West 2	Cadna-Owie Formation	125	8.89	8.89	0	0	214	1,007	5.8
Central 3 / Warrego West 3	Hooray Sandstone	11,615	523	522	1.14	1,000 + 1,000 ML	11,198	4,669	344
Central 4 / Warrego West 4	Westbourne/Adori/ Birkhead (Injune Ck Group equivalent)	8778	483	411	72	0	254	774	318
Central 5 / Warrego West 5	Hutton Sandstone	133,229	4,998	4,998	0.36	0	293	525	3,288
Central 6 / Warrego West 6	Poolowanna Formation	715	78	78	None	0	0	10	51
	Toolachee & Patchawarra	NA	150 [2]	150*	NA	NA	NA	NA	98
TOTAL ANNUAL ABSTRACTION (ML/year)			6,241	TOTAL ANNUAL ABSTRACTION (ML/year)					4,106

[1] The *average annual water production rate* is annual average established for all producing years at each field. Water production for each oil and gas fields are reported in Appendix DAPPENDIX D.

[2] Estimate provided by Santos gas reservoir Engineers, actual volumes are currently being compiled

[3] *Predicted Average Annual Rate* (discussed in Section 6.4.3) represents recent extraction extrapolated for the next three years. As extraction is declining, this is lower than the historical *average annual water production rate*.



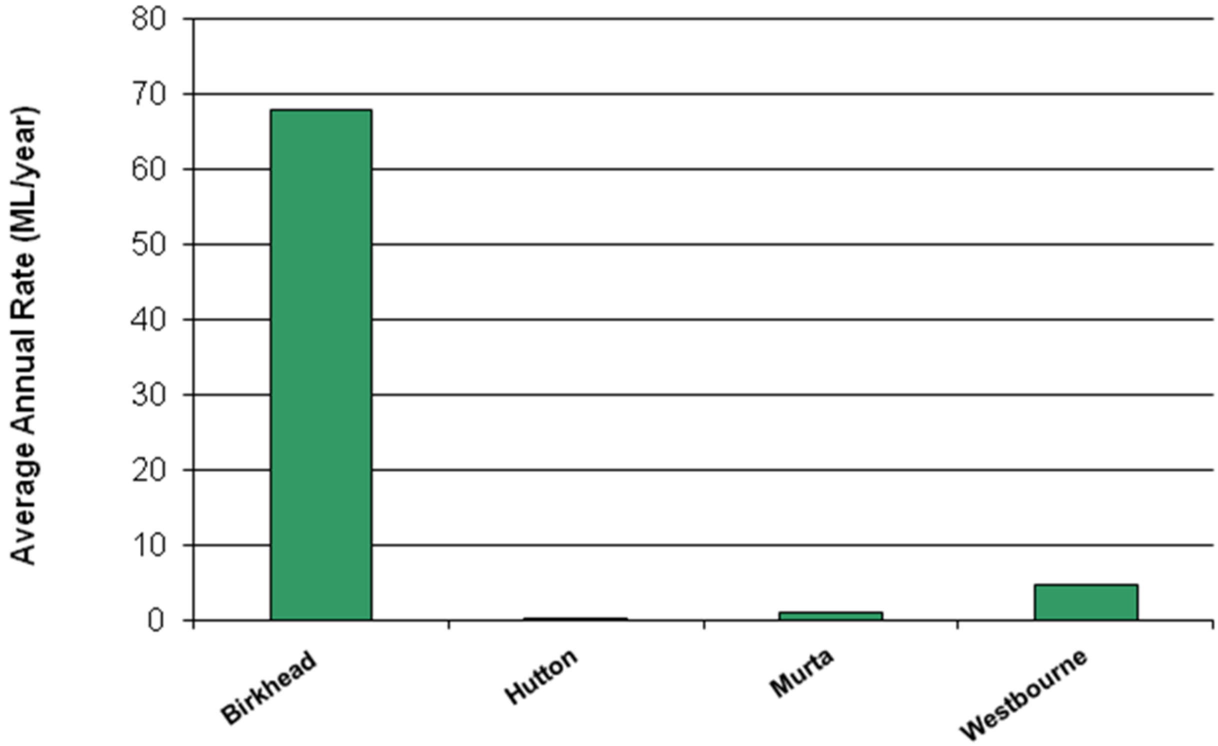


Figure 37: Average Annual Water Rate in Central and Warrego West (note: graphs scales are different)

6.5 Management of Produced Water

Produced water is either collected in tanks located at the well head and then transferred to interceptor ponds (oil wells) or directed to the separation facilities at the nearest satellite (gas wells).

The produced water is stored in ponds. Some of the water is re-used for drilling or hydraulic fracturing if located close enough to the activities, the rest eventually ends up in evaporation ponds.

There are three types of ponds:

- *Interceptor ponds*: those ponds are often located at individual well sites, or at the local oil and gas facility. The water is separated from the hydrocarbons using up to two levels of separations. Interceptor ponds allow for the collection from the water surface of dissolved hydrocarbons or suspended droplets to a dewatering or slops tank for later reprocessing or disposal.
- *Holding ponds*: these ponds are used downstream of secondary separation *if* evaporation is to take place in free-form evaporation ponds. This ensures an additional buffer to prevent hydrocarbon from reaching the free-form evaporation ponds, should there be a process upset.
- *Evaporation ponds*: water from the secondary separation or holding ponds flows to one or more ponds designed for evaporation. Water entering these ponds should contain only trace levels of hydrocarbons.

Facilities used for separation are lined. From the interceptor pond, water proceeds to the holding and evaporation ponds, which may have a synthetic liner, many of them using compacted clay or earthen surface. Table 24 provides a summary of water management ponds. The detailed list, pond size and coordinates of all ponds in SWQ are reported in Appendix A.

Where water flooding is undertaken, water for the water flooding is sourced from treated produced water at the Tarbat treatment plant (Section 6.3.3).

Table 24: Summary of Water Management Ponds

	Number of ponds	**Maximum surface area (ha)** **Average [Min – Max]**	**Maximum operating Volume (ML)** **Average [Min – Max]**
Interceptor ponds	35	0.068 [0.003 - 0.175]	0.947 [0.046 - 2.625]
Holding ponds	21	0.192 [0.038 - 0.63]	2.315 [0.375 - 7.5]
Evaporation ponds	65	3.658 [0.060 - 29.2]	33.201 [0.78 - 292]
Other (Airport and pump-out ponds)	2	0.545 [0.09 - 1.00]	5.675 [1.35 - 10]

7.0 GROUNDWATER IMPACT ESTIMATION

For the purposes of this UWIR, the affected area due to groundwater drawdown for consolidated rock aquifers was considered to be the area with greater than 5 m drawdown.

Impacts to groundwater dependant ecosystems (GAB springs) was considered to be a calculated drawdown of 0.2 m directly beneath the springs. As the source aquifers supplying the springs is uncertain, the 0.2 m drawdown assessment was considered for a range of potential source aquifers in the study area.

7.1 Approach and Limitations

The following sections discuss the approach used in the groundwater impact estimation.

7.1.1 Analytical Approach

An analytical approach was selected to provide an *indicative estimated of the magnitude of potential drawdown* in the target beds and neighbouring formations in the immediate and long term scenarios.

The analytical approach was considered as appropriate after consideration of:

- the depth of Santos groundwater extractions compared to the depth of extraction in private water bores: Santos is extracting at depths over 2,000 m for the Cooper Basin, and over 1,000 m for more than 90% of the extraction in the Eromanga Basin while most private bore target the upper formations;
- the stratigraphic settings: a number of confining beds are located between the upper aquifers of the stratigraphy profile which are the target aquifers for most private bores and Santos production activities; and
- the large area of Santos production activities resulting in the geographical distribution of the volumes of water produced.

In addition, the data (density and quality) and resources available to Golder were not sufficient for the preparation of a numerical model.

As a result of the above, an analytical approach was considered more appropriate to establish an indicative assessment of affected areas due to the extraction of produced groundwater during gas and oil production on neighbouring formations.

7.1.2 AnAqSim Analytical Software

The groundwater impact estimation was conducted using an analytical solution called AnAqSim (version 2011-2 and updated using the 64-bit version 2012-1). AnAqSim is analytical software capable of superimposing multiple analytical calculations (using flow equation calculations) to yield a composite solution consisting of equations for head and discharge as a function of location and time. Whilst the analytical equations are written in two-dimensions, three-dimensional flow may be simulated using simple planar multiple levels. In multi-level calculations, the resistance to vertical flow is accounted for in the vertical leakage between levels.

Note: AnAqSim *is not a high resolution numerical model, such as might be undertaken in MODFLOW or FeFlow. It is indicative in its level of complexity and output. However, AnAqSim is significantly better than many traditional analytical methods.*

It was necessary to simplify the conceptual hydrogeological model to comply with the capabilities of the analytical calculations (equations). Whilst this did not permit the analysis of basin structure and geometry, it did provide a representative vertical distribution of strata (‘layers’) and representative groundwater levels.

Up to five planar layers with corresponding initial groundwater levels are permitted in the software. To evaluate the potential impact in each basin, analysis was divided into two separate calculation exercises:

1) **Eromanga Basin**: containing the Early Jurassic to Late Cretaceous strata, namely the GAB aquifers; and

2) **Cooper Basin**: containing the Late Carboniferous, Permian and to Triassic strata, namely the older pre-GAB aquifers.

The separate calculation domains are shown in Table 25 and Table 26 respectively.

The division into two separate domains permitted the allocation of five layers in the Eromanga Basin as a separate hydraulic system, excluding the underlying Cooper Basin strata. It was anticipated that the impact from extraction in the Cooper Basin would not impact beyond the top of the Tinchoo Formation (i.e. the top of the Cooper Basin) due to the thickness of the low permeability layers and the small abstraction rate.

If no impact was predicted by the analysis at the top of the Cooper Basin, then it was considered reasonable to omit this form the overlying Eromanga Basin calculations.

7.1.3 Assumptions and Limitations

The following assumptions and limitations are inherent to the analytical modelling process:

- Calculations for both basins were undertaken in **steady state conditions** (i.e. not time varying) to investigate the ‘immediate affected area’ and the ‘long term affected area’ using recent extraction average and the long term extraction average respectively;
- Other abstractors (non Santos wells) were not considered in the calculation;
- Total recorded annual extraction was apportioned to each model layer to create a representative abstraction for modelling;
- Total annual extraction was divided between a representative number of wells. It was necessary to reduce the actual number of wells in the analysis to maintain stability in the software. Approximately 1/3 of the total number of wells was used, whilst maintaining the geographical distribution pattern. This had the effect of increasing the extraction from each well by approximately 2/3 in order to preserve the total extraction from the field. Given the resolution of the model, this approach was considered representative of the total extraction, both volumetrically and spatially. This was further refined for the immediately affected and long term calculations, as follows;
  - The immediate affected area calculation used an extraction rate for both basins that was calculated by extrapolating the last year of historical extraction data. This was considered conservative as the likely actual extraction was anticipated to decline over this period (Figure 36);
  - The long term affected area calculation used an extraction rate for both basins that was calculated by taking the long term historical extraction. As the fields are generally in decline (Figure 36) the long term extraction was larger than the immediate extraction rate.
- It was necessary to select adjacent strata to group together in the model to simplify the actual layering. This was because the model is capable of modelling only 5 layers. Grouping of stratum was carried out in such a way as to minimise the impact on the model results. The grouping process grouped adjacent stratum with similar hydrostratigraphical properties (e.g. adjacent aquifers and aquitards) and assigned a single representative hydraulic property. This is known as the equivalent porous medium approach. This was considered suitable given the available data in this area;
- The necessary combination of layers (considering these are in reality interbedded high and low permeability layered strata) as a single equivalent porous medium layer result in a **worst case scenario** as the selected value was conservative and potential very low permeability layers cannot be captured in the model;
- AnAqSim provides the calculated drawdown for the top of the each layer (no results are available for each subdivision). and
- The model calculates the drawdown as water head pressure. Where the formations are artesian, the calculated drawdown corresponds to a water pressure decline (unless the extent of the pressure

decline is such that the bore reaches sub-artesian conditions), in non-artesian formations (as in the upper formations targeted for water supply by the community), the drawdown corresponds to a decrease of water level.

7.2 Groundwater Impact Calculation Input Parameters

This section discusses the input parameters necessary for the groundwater impact calculation.

The simplified geological layering used in the calculation for the Eromanga Basin and Cooper Basin is shown in Table 25 and Table 26 respectively. These simplified layering grouped similar adjacent strata together where appropriate, to reduce the observed stratigraphy into no more than 5 layers.

Input parameters were sourced from Santos records of historical values, literature values and from Golder's experience in the area (as discussed in Section 5.5 and reference list). Likely values were selected for the predictive model calculations. The impact of the selected representative hydraulic property values was investigated through sensitivity analysis (Section 7.6).

DERM groundwater level monitoring data including artesian pressure data (Section 5.6) was used to establish a representative initial groundwater levels for each model layer as well as observed pressure data from Santos wells.

Table 25: Eromanga Basin Analytical Calculation Parameters

Layer	Top Elevation (mAHD)	Bottom Elevation (mAHD)	Average Head (mAHD)	Horizontal Hydraulic Conductivity (m/d)	Vertical Hydraulic Conductivity (m/d)	Porosity (Fraction)	Storativity	Representative number of Santos wells in QLD (QLD plus SA wells)	Hydraulic Properties
TOP OF MODEL – ground level									
1 – UPPER: Tertiary and Quaternary strata and Winton Formation (UNCONFINED)	Ground level [1&2]	-185 [1&2]	100 [1]	$5.0x10^{-2}$ [3]	$5.0x10^{-4}$ [3]	0.1 [3]	Sy: 0.05 [3]	0	Aquifer
2 – LOWER: Tertiary and Quaternary strata and Winton Formation (CONFINED)	-100 [1&2]	-185 [1&2]	100 [1]	$5.0x10^{-2}$ [3]	$5.0x10^{-4}$ [3]	0.1 [3]	0.08 [3]	0	Aquifer
3 – Alluru, Toolebuc and Wallumbilla Formations	-185 [1&2]	-500 [1&2]	150 [1]	$1.0x10^{-2}$ [3]	$1.0x10^{-4}$ [3]	0.15 [3]	0.01 [3]	0	Aquitard
4 – Cadna-Owie Formation and Hooray Sandstone	-500 [1&2]	-620 [1&2]	200 [1&2]	$1.0x10^{-3}$ [4]	$1.0x10^{-5}$ [4]	0.02 [4]	0.01 [4]	0*	Aquifer and Aquitard (part)
5 – Westbourne, Adori and Birkhead Formations and Hutton Sandstone and Poolowanna Formation	-620 [1&2]	-895 [1&2]	290 [2]	$1.0x10^{-2}$ [4]	$1.0x10^{-4}$ [4]	0.15 [4]	0.04 [4]	336 (404)	Aquifer and Aquitard (part)
BASE OF MODEL – major unconformity at base of Eromanga Basin									

Table 26: Cooper Basin Analytical Calculation Parameters

Layer	Top Elevation (mAHD)	Bottom Elevation (mAHD)	Average Head (mAHD)	Horizontal Hydraulic Conductivity (m/d)	Vertical Hydraulic Conductivity (m/d)	Porosity (Fraction)	Storativity	Representative number of Santos wells in QLD and SA	Hydraulic Properties
TOP OF MODEL – major unconformity at top of Cooper Basin									
1 – UPPER: Tinchoo and Arrabury Formations (UNCONFINED)	-895 [1&2]	-950 [1&2]	315 [3]	$1.0x10^{-4}$ [3]	$1.0x10^{-5}$ [3]	0.01 [3]	0.001 [3]	0	Aquitard
2 – LOWER Tinchoo and Arrabury Formations	-950 [1&2]	-1100 [1&2]	315 [3]	$1.0x10^{-4}$ [3]	$1.0x10^{-5}$ [3]	0.01 [3]	0.001 [3]	0	Aquitard
3 – Toolacheee to Patchawarra Formations	-1100 [1&2]	-1200 [1&2]	325 [2]	$3.9x10^{-3}$ [4]	$3.9x10^{-4}$ [4]	0.05 [4]	0.005 [4]	38	Interbedded aquitard / aquifer layers
BASE OF MODEL – major unconformity overlying Cambro-Ordivician Warburton Basin									

Notes for both tables:

Source
[1] DERM database
[2] Santos / Santos DST / Santos groundwater monitoring data
[3] Inferred value
[4] Literature value
* Abstraction from Layer 4 (Cadna-Owie Formation and Hooray Sandstone) was assigned to the underlying Layer 5 to maintain numerical stability in the model. Assigning extraction in the base layer of the model provided additional numerical stability. Layer 5 was selected as the majority of extraction is likely to be sourced from these stratum (Section 7.2.4). Concentrating extraction in this manner was considered suitable as drawdown was still able to propagate upwards through the Layer 4 to the overlying Layer.

7.2.1 Extent of Calculation and Boundary Conditions

The extent of the Cooper Basin and Santos tenements (Figure 39) was used in conjunction with the distribution of Santos extraction wells in Queensland only to form the extent of the calculation domain. This included a buffer of approximately 50 km from the nearest extraction well to limit the influence of the boundary conditions on the solution.

Boundary conditions were set as lines of zero flux (i.e. no flow boundaries) and located at sufficient distance from the area of interest to be far field boundaries.

The upper and lower extents of the model were assigned as head dependant flux conditions. This permitted the increasing groundwater level with depth conditions by mimicking recharge at the surface and a small flux at the base.

In the Eromanga Basin, the value assigned to the head dependant flux was 100 mAHD at the surface (to represent approximated observed groundwater levels in the upper layer). This is computed using the head difference between a specified head and the domain head. Vertical resistance to flow was created by the layer properties.

The flux at the base of the model was calibrated at $1x10^{-5}$ m/d (equivalent to 3.65 mm/year recharge to the base of the model). This was necessary to simulate the observed increasing hydraulic pressure with depth in both basins.

For the Cooper Basin, the upper model boundary had a head dependant flux set at 315 mAHD, to replicate observed heads and a flux at the base of $1x10^{-6}$ m/d (equivalent to 0.37 mm/year recharge to the base of the model). The value for the flux at the base of the model was achieved through the calibration process that matched modelled groundwater levels to the approximated observed groundwater levels.

The extent of the Eromanga Basin calculation domain can be seen in Figure 38 and the extent of the Cooper Basin calculation domain can be seen in Figure 39.

Santos bores shown in these figures have been tabulated and are given in Appendix E.

7.2.2 Water Production Volumes Used for the Calculation

The water extraction rates for the *immediately affected area* was calculated as the average recent extraction (last year of available data) and extrapolated over the next three years.

The *long term affected area* used average extraction for all years of operation for which data is available. The rate of groundwater extraction in the analytical model is representative of a steady state solution i.e. the rate used in the calculation cannot vary over time. A summary of the extraction rates used in the modelling is as follows:

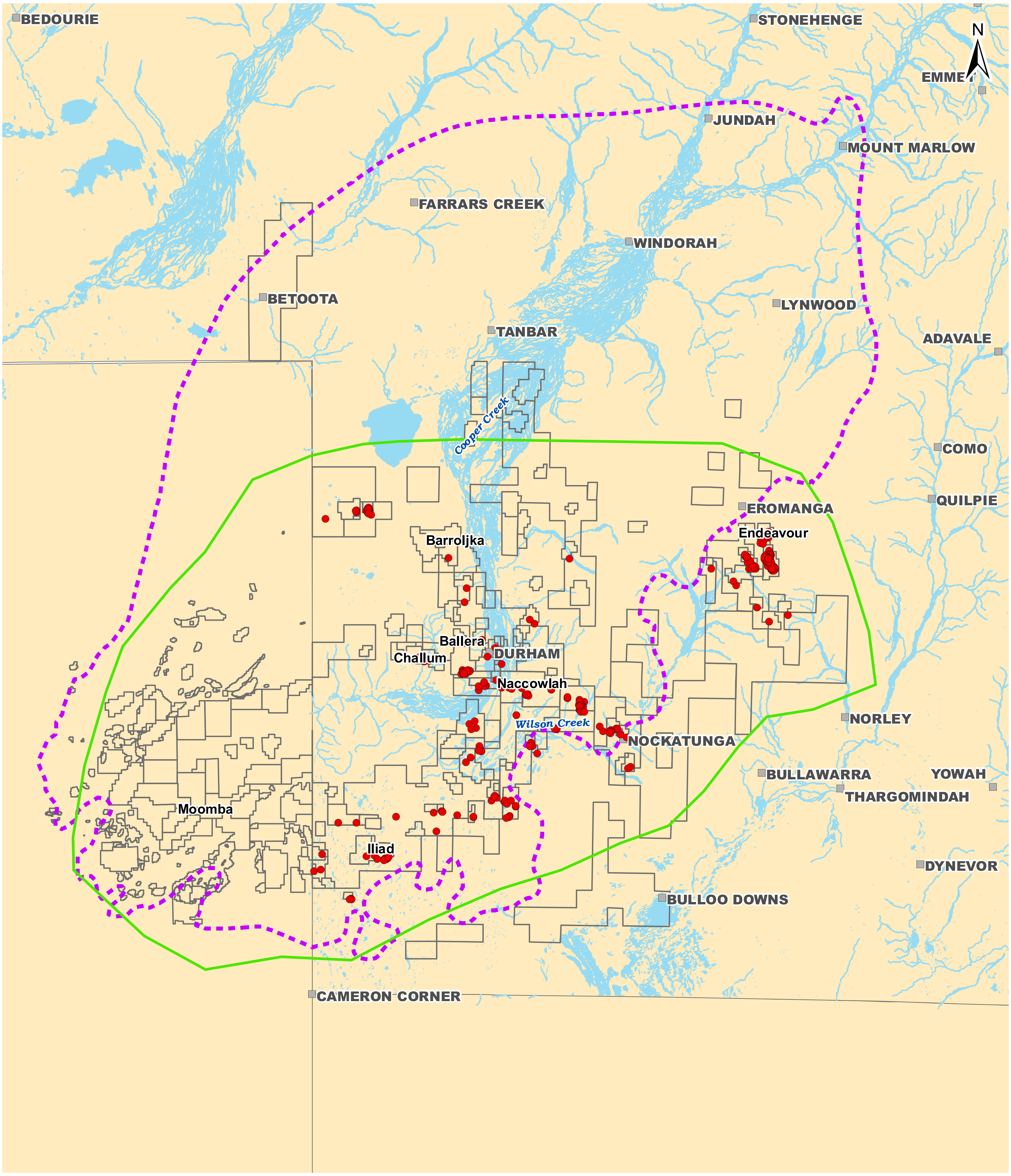
Eromanga Basin

- Eromanga Basin predictive model *immediate affected area* extraction rate (equivalent to the last 3 years average extraction) of 30.7 m^3/day for each representative well used in the model;
- Eromanga Basin predictive model *long term affected area* extraction rate (equivalent to the long term average extraction) of 34 m^3/day for each representative well used in the model;

Cooper Basin

- Cooper Basin predictive model *immediate affected area* extraction rate (equivalent to the last three years average extraction rate) of 3.5 m^3/day for each representative well used in the model;
- Cooper Basin predictive model *long term affected area* extraction rate (equivalent to the long term average extraction) of 4.5 m^3/day for each representative well used in the model.

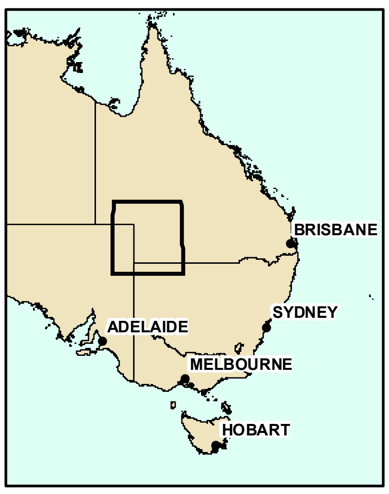
Variation over time of the water production for oil and gas fields is provided in Section 6.4.1.



COOPER BASIN UWIR

SANTOS

EXTENT OF THE EROMANGA BASIN CALCULATION



LEGEND

- Town/Locality
- River/Creek
- Extent of Analysis
- Cooper Basin
- Santos Operated Permits
- Representative Borehole Locations in Analytical Analysis

0 10 20 40 60 80 100 Kilometres

SCALE (at A3) 1:2,000,000

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FIGURE 38

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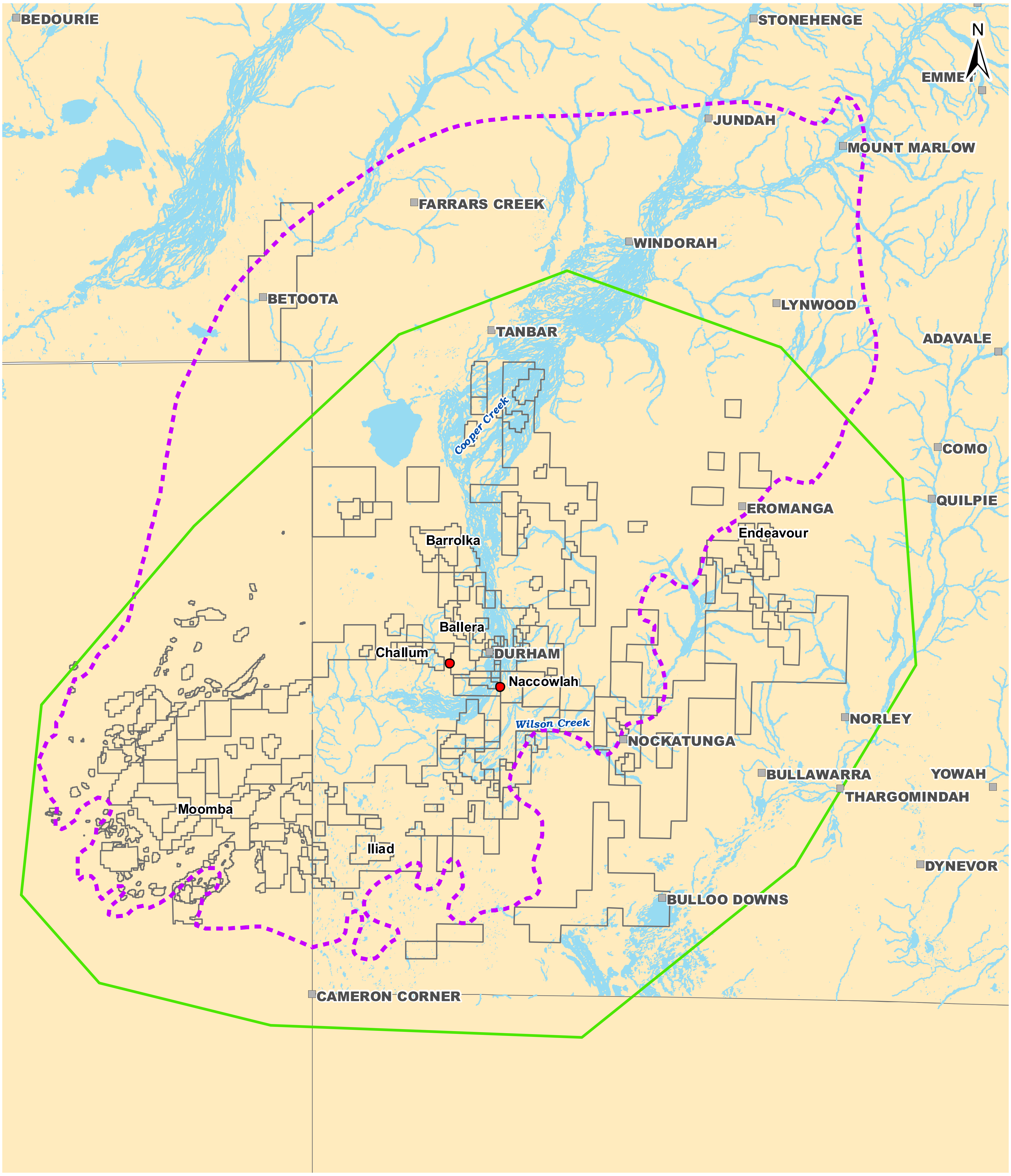
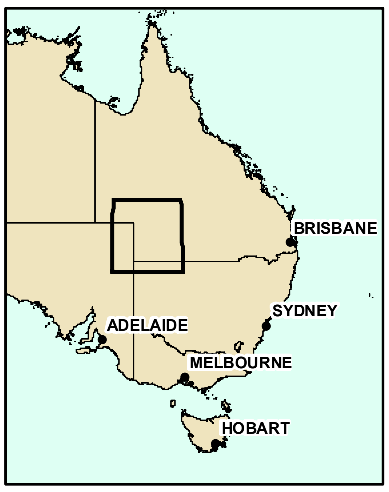


COOPER BASIN UWIR

SANTOS

EXTENT OF THE COOPER BASIN CALCULATION



LEGEND

- Town/Locality
- River/Creek
- Extent of Analysis
- Cooper Basin
- Santos Operated Permits
- Representative Borehole Locations in Analytical Analysis

0 10 20 40 60 80 100 Kilometres

SCALE (at A3) 1:2,000,000

Coordinate System: GCS GDA 1994

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FIGURE 39

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7.2.3 Justification for the Layering in AnAqSim

The *Eromanga Basin* was grouped into five layers according to the hydraulic properties of the strata and the most commonly observed multiple targets for oil and gas extraction.

- **Layer 1:** consisted of the upper half of the major aquifers in the area, exploited for groundwater abstraction. These were the unconfined shallow Quaternary, Tertiary and Winton Formation aquifers (Figure 29). These were grouped into two layers. No abstraction was assigned to this upper layer in the model. The upper portion contained the head dependant flux boundary;
- **Layer 2:** consisted of the lower half of the Quaternary, Tertiary and Winton Formation. These have been split into the upper two layers in order to investigate the potential impact of the deeper oil and gas extraction;
- **Layer 3:** consisted of the underlying Alluru, Toolebuc and Wallumbilla Formations. These are generally considered to be an aquitard with very little groundwater abstraction and no oil or gas extraction in the Eromanga Basin;
- **Layer 4:** combined the Cadna-Owie Formation and Hooray Sandstone. Oil and gas wells are often screened in both these formations and they exhibit similar geological characteristics, both being generally thinly interbedded sandstone and siltstone with occasional coarse grained, brecciaed or pebble beds;
- **Layer 5:** consisted of the Westbourne, Adori and Birkhead Formation aquifers and aquitards as well as the underlying Hutton Sandstone and Poolowanna Formation. Oil and gas extraction wells were often screened over a combination of these strata generally comprising interbedded siltstone, shale, fine sandstone and occasional coal seams. The Hutton Sandstone and Poolowanna Formation were considered to be more permeable and accounted for the highest extraction rate by an order of magnitude. The Hutton Sandstone and Poolowanna Formation are therefore the main targets for oil and gas extraction; and
- The **Base** of the model was formed by the base of the Eromanga Basin, which is marked by a major unconformity. Underlying the Eromanga Basin are the aquitards of the Tinchoo and Arrabury Formations. It was considered suitable to separate the Cooper Basin into a separate model due to the hydraulic separation of the two basins as well as the low average extraction from the underlying Cooper Basin.

The *Cooper Basin* was grouped into three layers, with the upper layer being split into two layers with identical properties. This was to permit the response of pumping to be observed in the Tinchoo and Arrabury Formations. The layers were configured as follows:

- **Layer 1:** the upper portion of the Tinchoo and Arrabury Formations comprise layer 1. This had the head dependant flux boundary condition to be applied to the top in order to replicate the observed groundwater levels. Layer 1 was assigned identical hydraulic properties to the underlying Layer 2 Tinchoo and Arrabury Formations;
- **Layer 2:** represented the lower half of the Tinchoo and Arrabury Formation aquitards. No oil or gas extraction was identified to target these strata. These are generally interbedded siltstone and fine sandstone with low permeabilities; and
- **Layer 3:** combined the strata between the Toolacheee to Patchawarra Formations at the base of the Cooper Basin. These were not utilised for water supply and only a limited extraction of oil and gas has been extracted from these strata. Often, wells are completed at multiple levels across this Early to Late Permian strata, making grouping of these suitable for analysis.

Note that although AnAquSim allows the division of a layer in two, the calculated results are provided for the full layer (no results available for each subdivision).

7.2.4 Assigning Abstraction in the Calculation

Historical abstraction data provide by Santos assigns oil and gas extraction to each field in the Cooper or Eromanga Basin

No complete data set for the abstraction target for each well or field was available. Many wells are likely to have perforated casing over multiple productive layers. This means assigning the historical abstraction to individual target formations unfeasible. It was considered reasonable therefore to assign all abstraction to a single layer in the analysis for both basins.

The grouping of the strata in the software (Section 7.2.3) and treating adjacent grouped strata as an EPM removed the necessity to establish the target formation beyond the defined layers within the software. This is because abstraction can only be assigned to defined software layers and not specific target depths or strata within an individual layer. This allowed a much more coarse definition of assigning the extraction target formation. Golder considers this an acceptable assumption as the software does not allow for further refinement, the EPM approach should already provide a bulk representative behaviour of the adjacent grouped strata. As the focus of impact is the strata generally overlying the extraction targets, this was deemed to be a suitable methodology.

The target of extraction was assigned to the layers, as defined in Table 25 and Table 26. The total annual abstraction was preserved for each basin and so this methodology was considered representative of the actual extraction.

For simplicity, the Hutton Sandstone and Poolowanna Formation were grouped together as the bottom layer of the model and therefore also combined the abstraction from these strata into the single layer. The total abstraction from each target layer was equally assigned to a representative number of wells. This was calculated to be proportional to the total number, required for ease of calculation. This scenario was also considered to represent the worst case scenario, as in reality, the abstraction is divided over a greater number of wells and over a spatially greater area.

It was necessary to further group the total abstraction in the Eromanga Basin model to Layer 5 (i.e including the Cadna-Owie Formation and Hooray Sandstone, Westbourne, Adori and Birkhead Formations and Hutton Sandstone and Poolowanna Formation). This will have the impact of increasing the drawdown in Layer 5, however it is considered not to reduce the impact above Layer 4 in the model.

The extraction well locations in the Eromanga Basin were filtered to reduce the number of wells in the calculation whilst maintaining the spatial distribution of extraction. This was achieved by accepting every tenth well from all Santos wells when ordered in an increasing easterly direction. The locations of the representative extraction wells are shown in Figure 38 and Figure 39.

In the Cooper Basin, the total extraction rates were considered low. The proportion of extraction from each field was also accounted for (Table 23) as follows:

- Eromanga Basin Layer 4 (Cadna-Owie Formation and Hooray Sandstone) accounting for 9% of the total annual extraction;
- Eromanga Basin Layer 5 (Late to Early Jurassic [Westbourne Formation, Adori Sandstone, Birkhead Formation, Hutton Sandstone and Poolowanna Formation]) accounting for 89% of the total annual extraction; and
- Cooper Basin Layer 3 (Early to Late Permian [Toolachee and Daralingie Formations, Roseneath Shale, Epsilon Formation, Murtree Shale and Patchwarra Formation]) accounting for 2% of the total annual extraction.

The relatively low extraction rate from the Cooper Basin is due to the Cooper Basin being a target for gas more than oil. As discussed, gas results in significantly less produced water than oil.

7.2.5 Observed Groundwater levels and Calibration Targets

Groundwater levels in the shallow aquifers and those that are utilised for groundwater abstraction or monitored by DERM were generally obtained from the DERM groundwater database.

Section 5.6 discusses the observation bore network and demonstrates the spread of available data both temporally and spatially in the study area. Strata that have been targeted for oil or gas extraction also has some hydrostatic pressure and groundwater level data. This was obtained from Santos, with representative groundwater levels given in Table 25 and Table 26. The selected value for groundwater level is derived from numerous spatially distributed values and from a range of elevations and depths across the basins. As the calculation required the layers to be horizontal and planar, the groundwater levels were also set at simplified representative levels.

Where no groundwater level data was available, it was necessary to extrapolate between adjacent layers to infer the level in the calculation.

Calibration was undertaken on both calculations using observed groundwater levels verses calculated groundwater levels in unpumped conditions. The bottom flux and hydraulic conductivity values were altered until a satisfactory fit was achieved. A plot of modelled verses observed groundwater level for the Eromanga Basin is given in Figure 40.

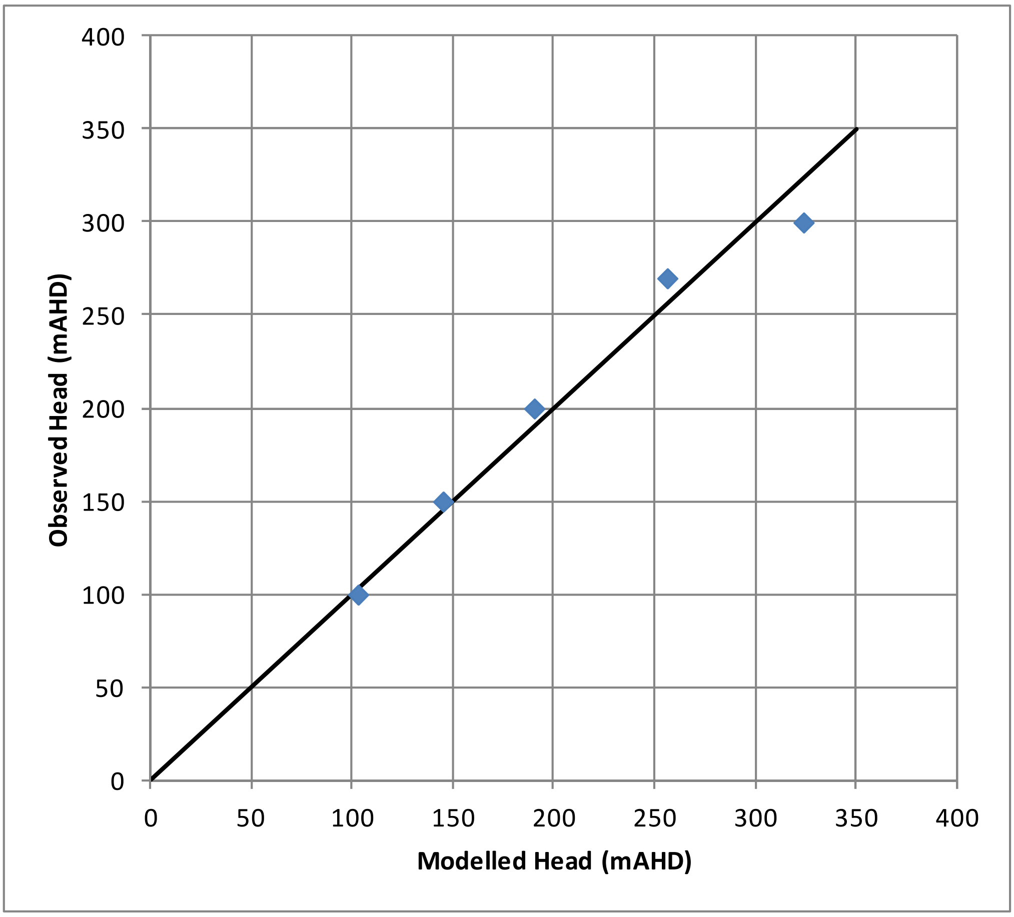

Figure 40: Eromanga Basin Model Initial Conditions: Observed verses Modelled Groundwater Level

A good fit for initial model conditions for the Eromanga Basin between modelled and observed groundwater head was achieved in using the parameters given in Table 25. The data shown in Figure 40 is tabulated in Table 27.

Table 27: Eromanga Basin: Observed verses Modelled Groundwater Level

Calibration Target	Modelled Groundwater Level (mAHD)	Observed Groundwater Level (mAHD)	Residual (m)
Level 1	102	100	2
Level 2	104	150	-46
Level 3	120	200	-80
Level 4	196	270	-74
Level 5	270	300	-30

The fit for initial groundwater conditions for the Cooper Basin are shown in Table 28.

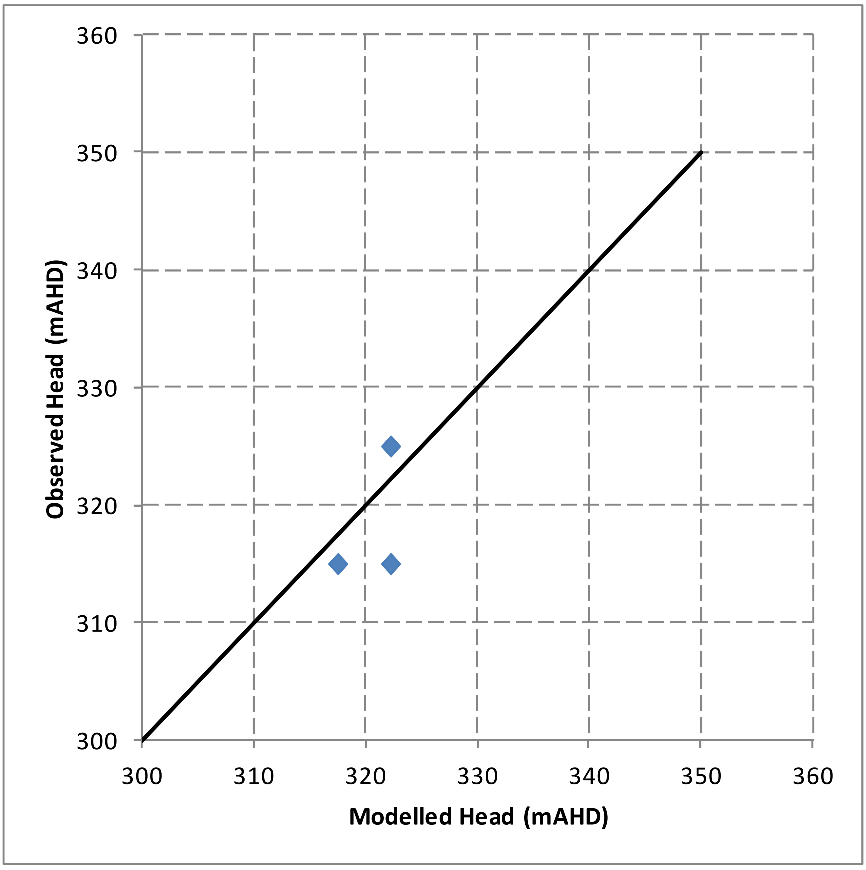

Figure 41: Cooper Basin Model Initial Conditions: Observed verses Modelled Groundwater Level

Table 28: Cooper Basin: Tabulated Observed verses Modelled Groundwater Level

Calibration Target	Modelled Groundwater Level (mAHD)	Observed Groundwater Level (mAHD)	Residual (m)
OBH Layer 1	317	315.0	2
OBH Layer 2	322	325.0	-3
OBH Layer 3	322	315.0	7

Both models were considered to be well calibrated and able to demonstrate the potential impact of pumping.

7.3 Calculated Impact of in the Eromanga Basin

The calibrated model was run in steady state to give a conservative, worst case scenario for the *immediately affected area* and *long term affected area*. The calculated drawdown for each layer is given in Figure 42 to Figure 45 (Note: the contours shown are one metre contours).

UNDERGROUND WATER IMPACT REPORT OIL AND GAS FIELDS SWQ

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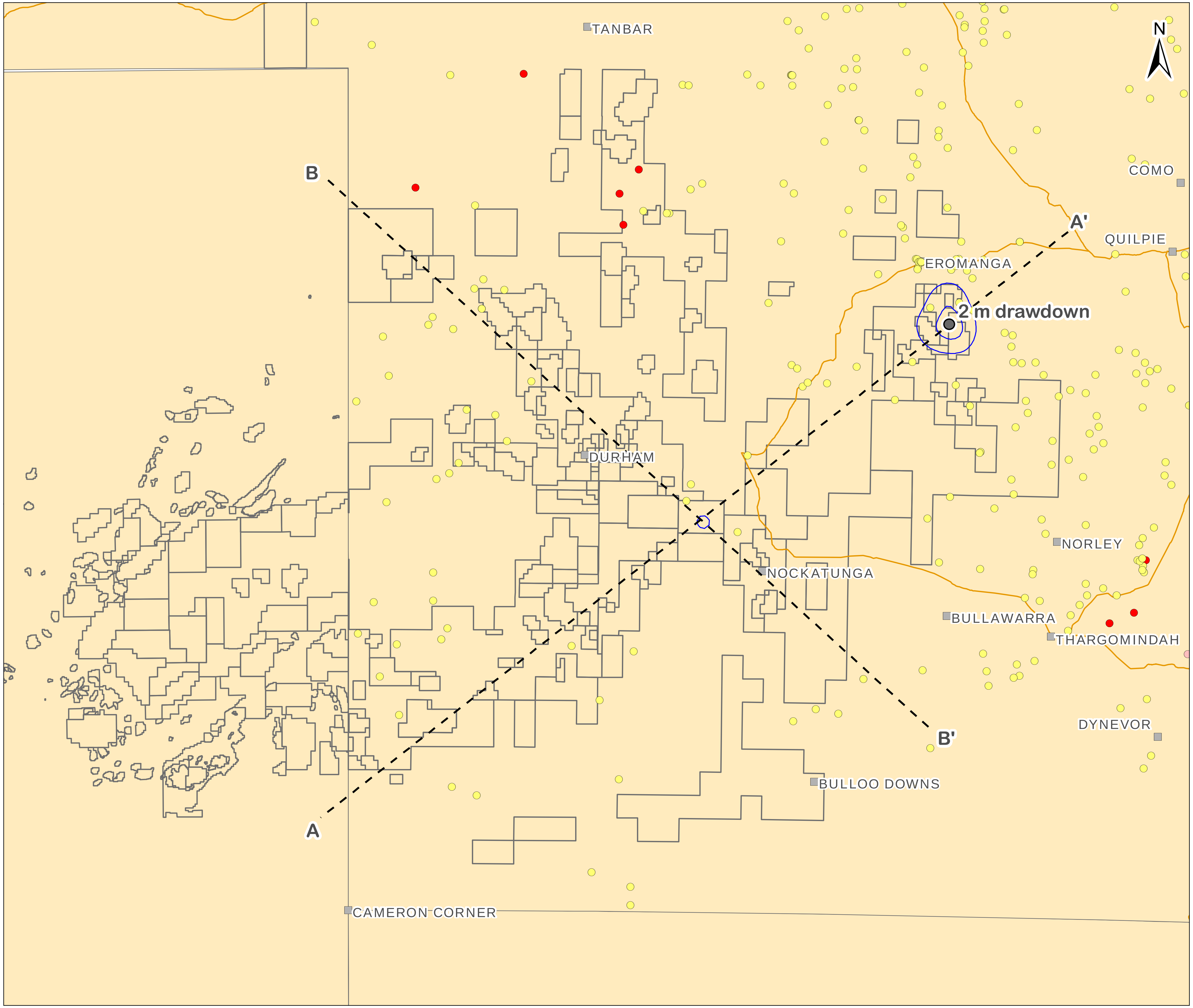
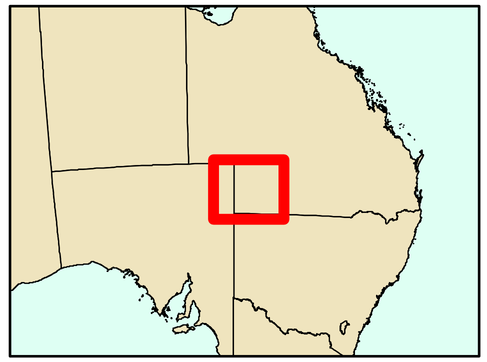
IMMEDIATELY AFFECTED AREA - EROMANGA BASIN MODELLED GROUNDWATER DRAWDOWN IN LAYER 2





LEGEND

Private Bores

- Quaternary
- Tertiary Sediments
- Winton Formation
- Maximum Drawdown
- 1 m Drawdown Contour
- Groundwater line of section A-A'
- Groundwater line of section B-B'
- Town/Locality
- Highway/Major Road
- Santos Operated Permits

NOTES

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0 5 10 20 30 40 50 Kilometers

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FIGURE 42

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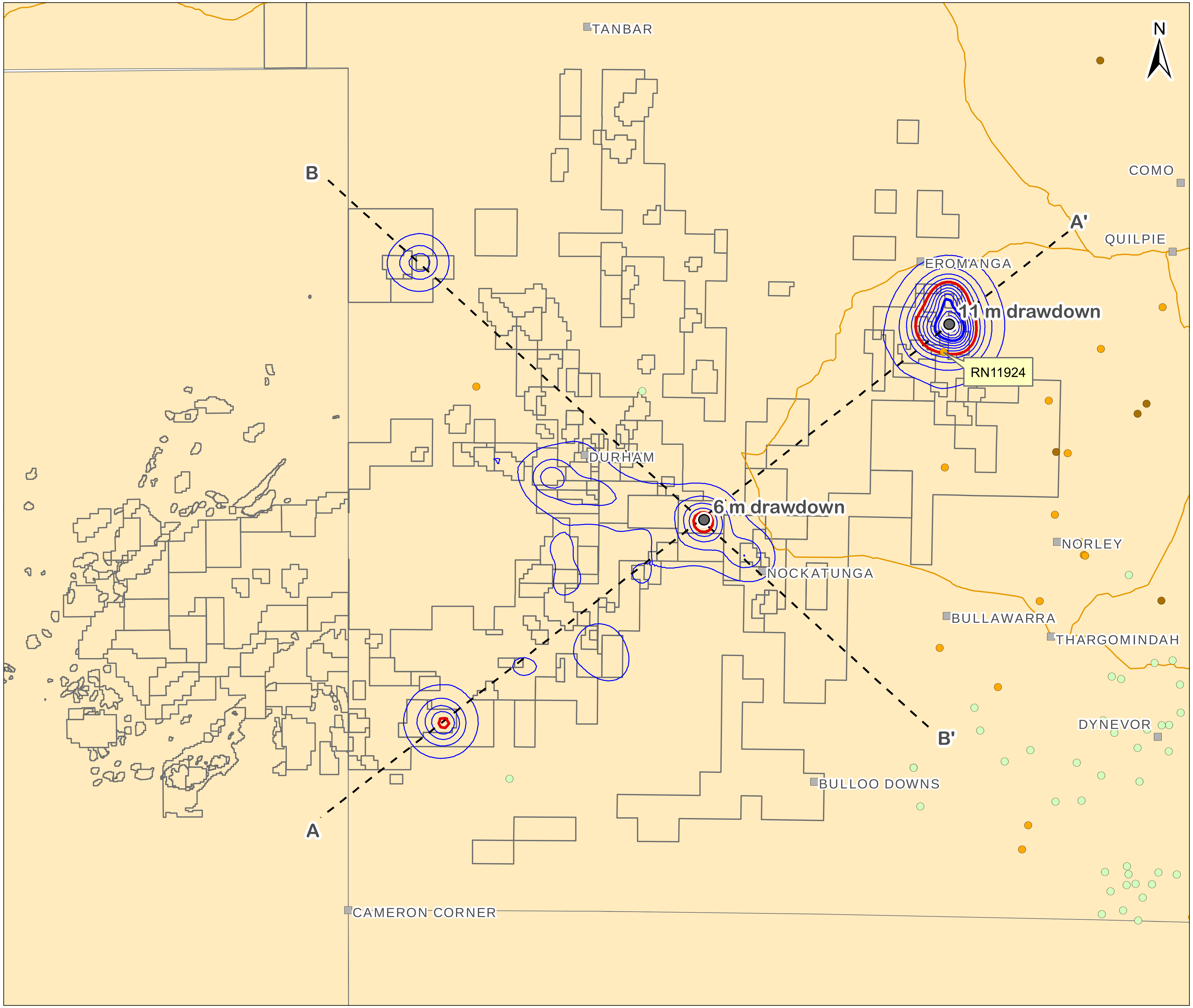
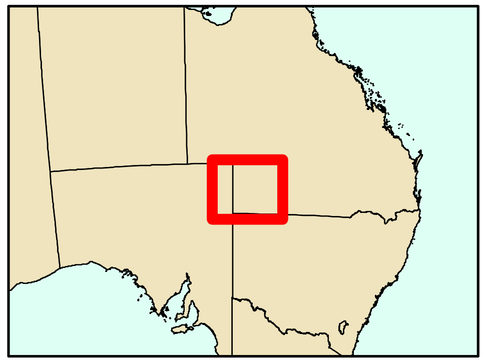


UNDERGROUND WATER IMPACT REPORT OIL AND GAS FIELDS SWQ

SANTOS

IMMEDIATELY AFFECTED AREA - EROMANGA BASIN MODELLED GROUNDWATER DRAWDOWN IN LAYER 3



LEGEND

Private Bores

- Mackunda Formation
- Allaru Mudstone
- Wallumbilla Formation
- Maximum Drawdown
- Affected Area (>5 m Drawdown)
- 1 m Drawdown Contour
- 5 m Drawdown Contour
- Groundwater line of section A-A'
- Groundwater line of section B-B'
- Town/Locality
- Highway/Major Road
- Santos Operated Permits

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FIGURE 43

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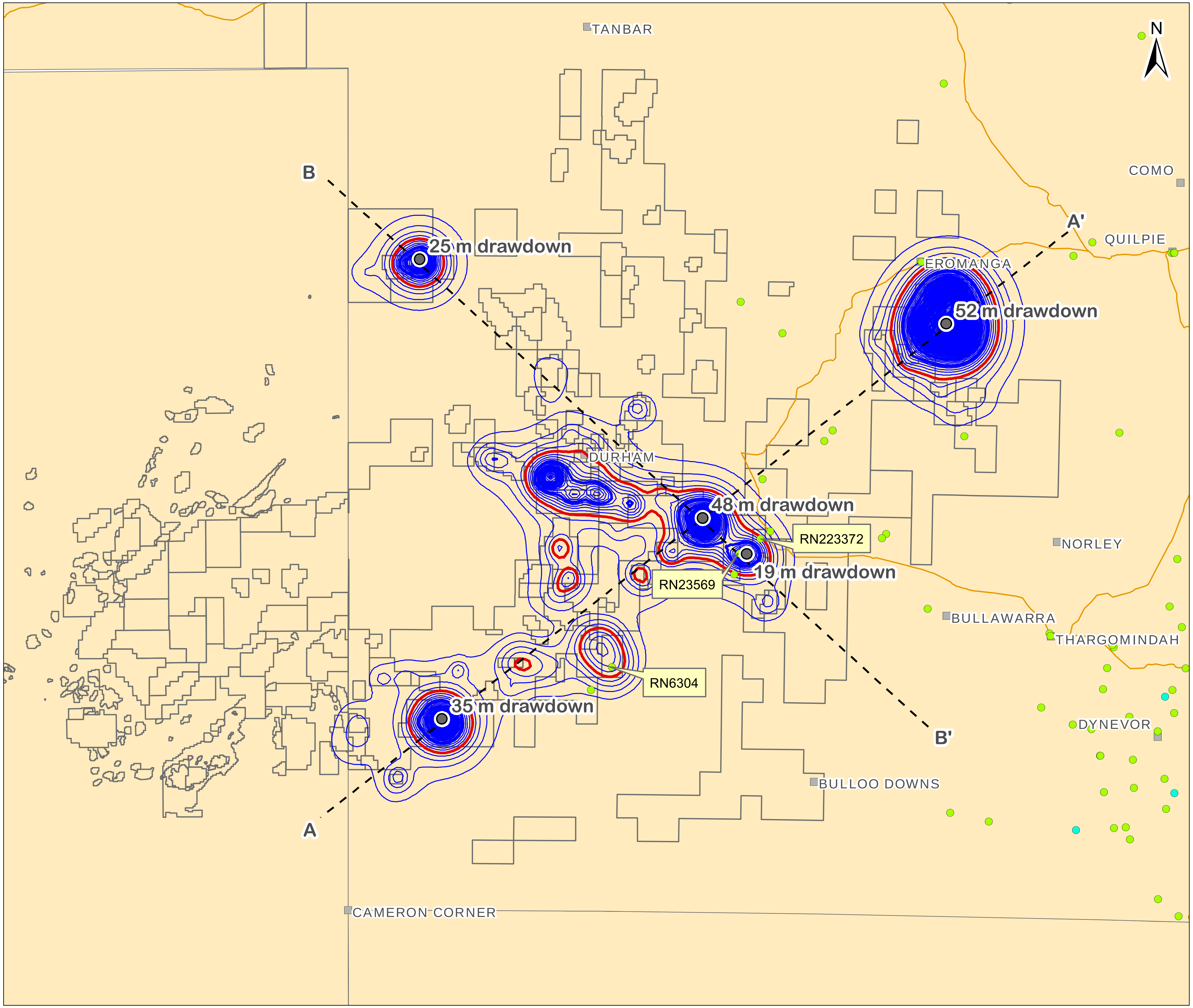
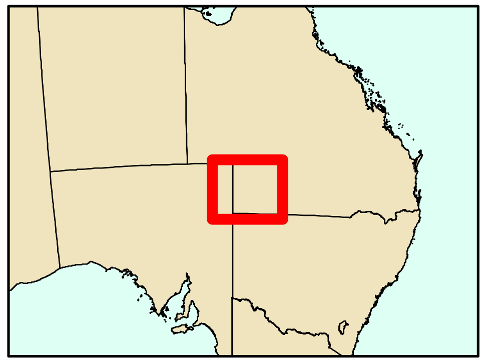
UNDERGROUND WATER IMPACT REPORT OIL AND GAS FIELDS SWQ

SANTOS

IMMEDIATELY AFFECTED AREA - EROMANGA BASIN MODELLED GROUNDWATER DRAWDOWN IN LAYER 4





LEGEND

Private Bores

- Cadna-Owie Formation
- Hooray Sandstone
- Maximum Drawdown
- Groundwater line of section A-A'
- Groundwater line of section B-B'
- Affected Area (>5 m Drawdown)
- 1 m Drawdown Contour
- 5 m Drawdown Contour
- Town/Locality
- Highway/Major Road
- Santos Operated Permits

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FIGURE 44

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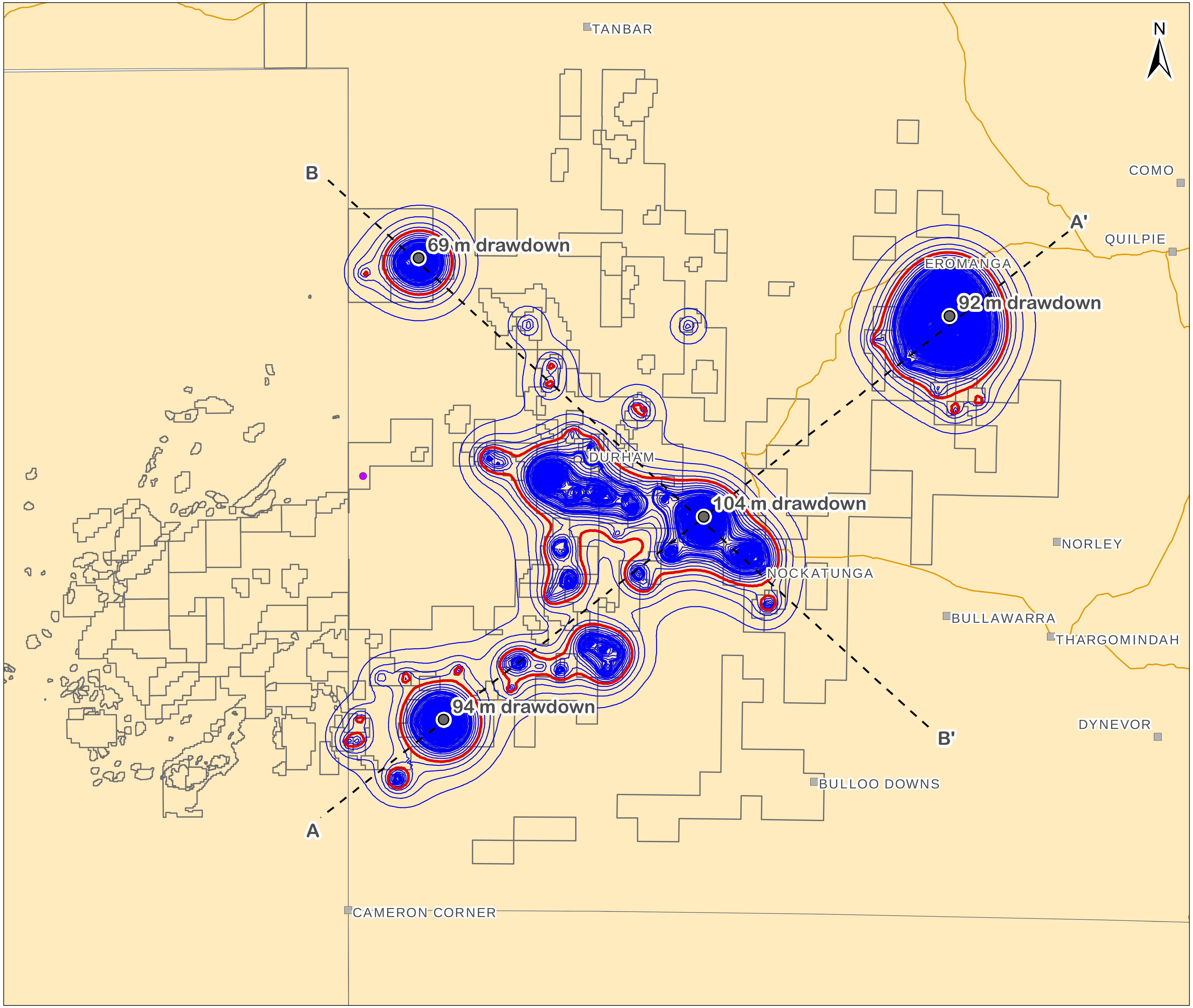

UNDERGROUND WATER IMPACT REPORT OIL AND GAS FIELDS SWQ

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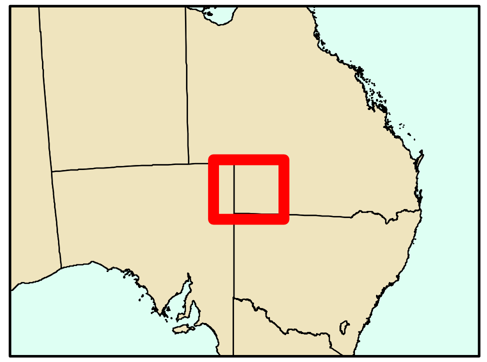
IMMEDIATELY AFFECTED AREA - EROMANGA BASIN MODELLED GROUNDWATER DRAWDOWN IN LAYER 5



LEGEND

Private Bores

- Adori Sandstone
- Hutton Sandstone
- Maximum Drawdown
- Affected Area (>5 m Drawdown)
- 1 m Drawdown Contour
- 5 m Drawdown Contour
- Groundwater line of section A-A'
- Groundwater line of section B-B'
- Town/Locality
- Highway/Major Road
- Santos Operated Permits

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0 5 10 20 30 40 50 Kilometers

SCALE (at A3) 1:1,500,000

Coordinate System: GDA 1994 MGA Zone 54

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UNDERGROUND WATER IMPACT REPORT OIL AND GAS FIELDS SWQ

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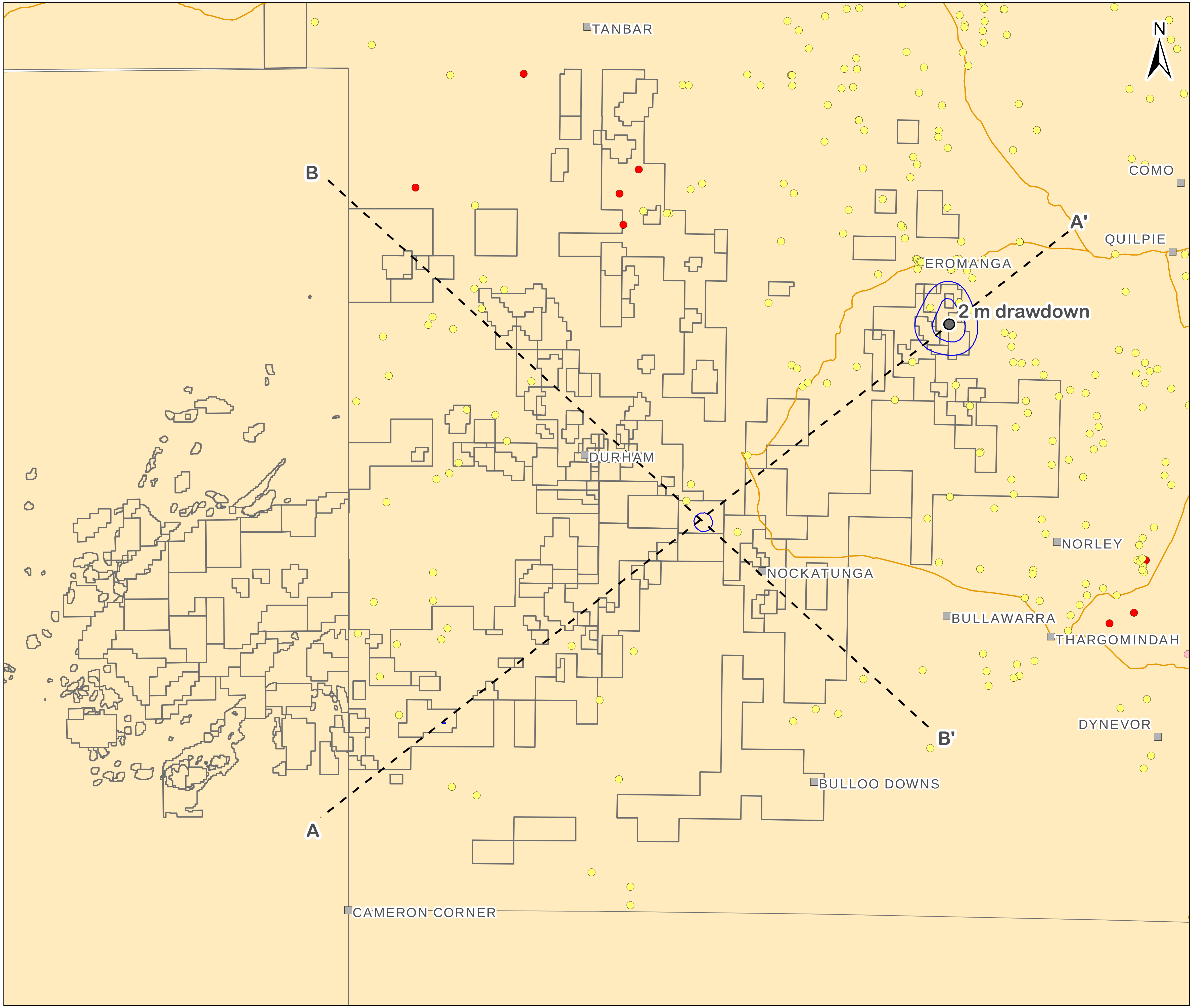
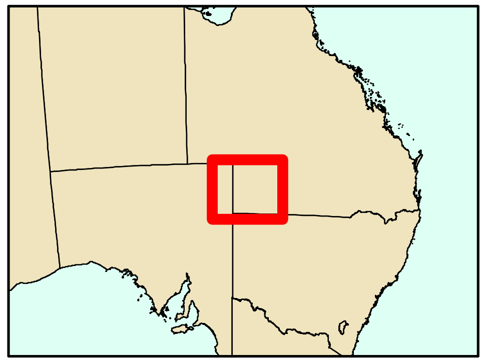
LONG TERM AFFECTED AREA - EROMANGA BASIN MODELLED GROUNDWATER DRAWDOWN IN LAYER 2





LEGEND

Private Bores

- Quaternary
- Tertiary Sediments
- Winton Formation
- Maximum Drawdown
- 1 m Drawdown Contour
- Groundwater line of section A-A'
- Groundwater line of section B-B'
- Town/Locality
- Highway/Major Road
- Santos Operated Permits

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0 5 10 20 30 40 50 Kilometers

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FIGURE 46

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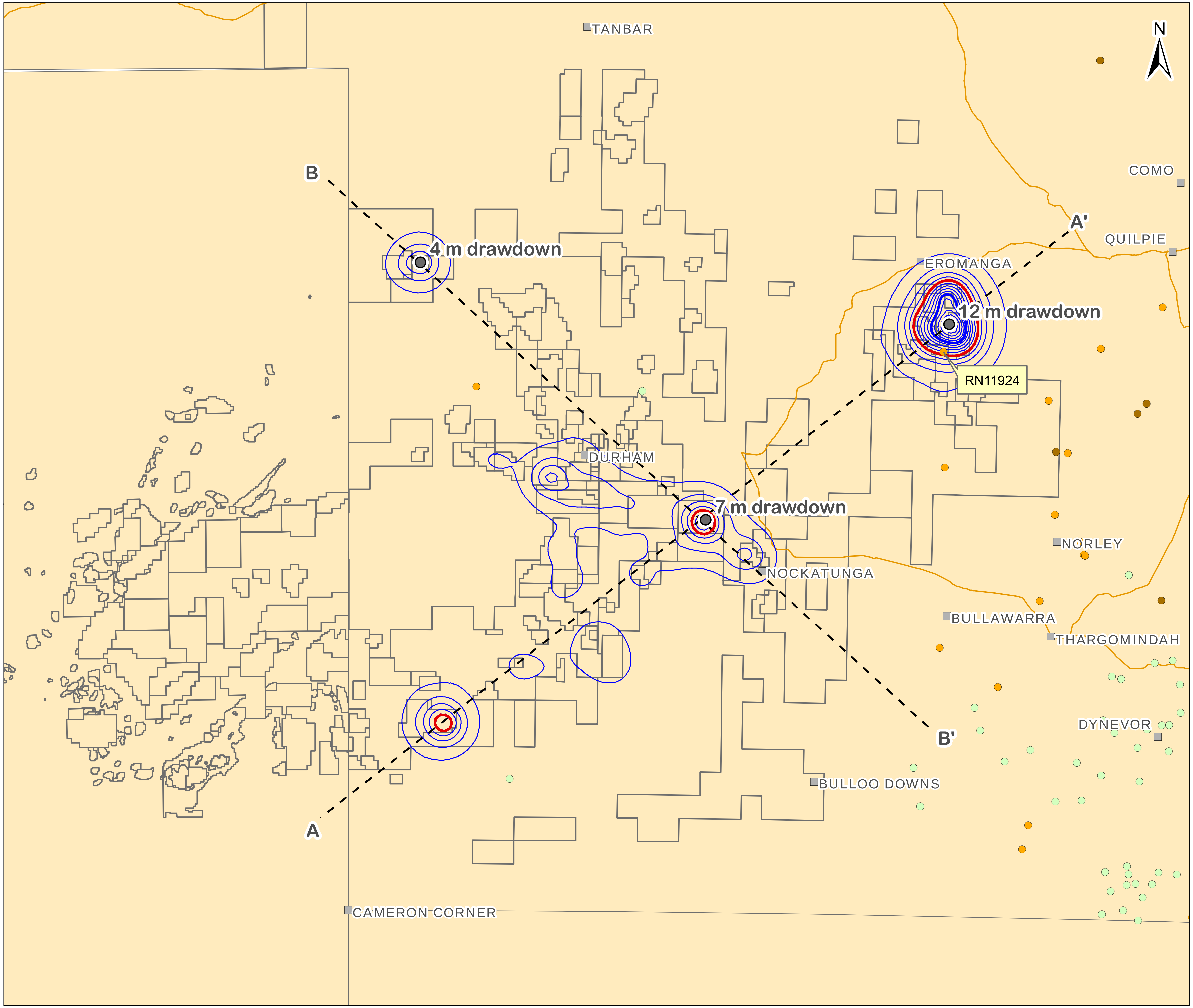
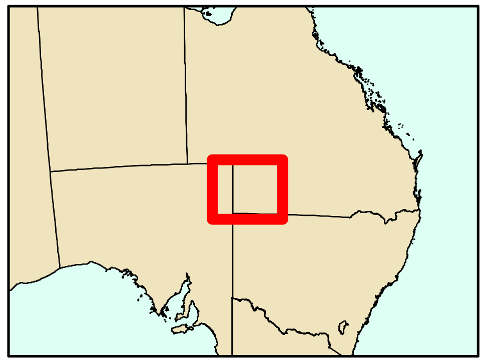
LONG TERM AFFECTED AREA - EROMANGA BASIN MODELLED GROUNDWATER DRAWDOWN IN LAYER 3





LEGEND

Private Bores

- Mackunda Formation
- Allaru Mudstone
- Wallumbilla Formation
- Maximum Drawdown
- Affected Area (>5 m Drawdown)
- 1 m Drawdown Contour
- 5 m Drawdown Contour
- Groundwater line of section A-A'
- Groundwater line of section B-B'
- Town/Locality
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FIGURE 47

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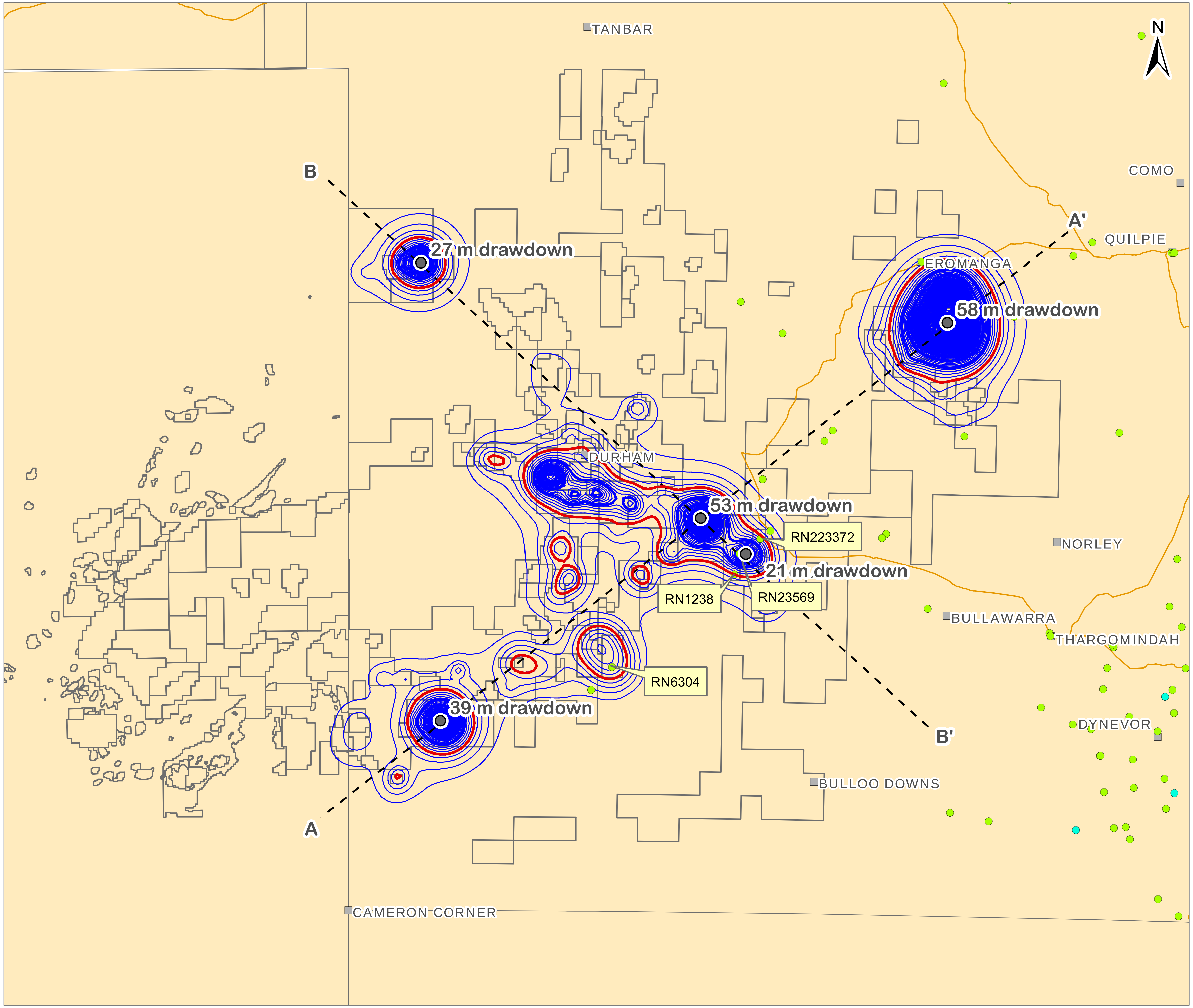

UNDERGROUND WATER IMPACT REPORT OIL AND GAS FIELDS SWQ

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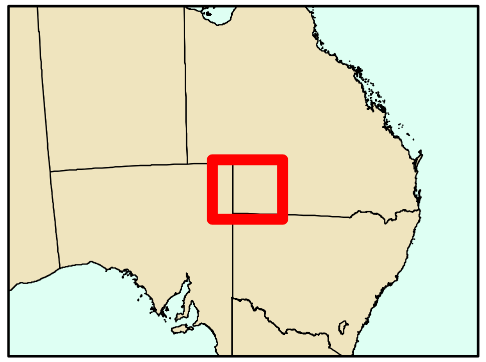
LONG TERM AFFECTED AREA - EROMANGA BASIN MODELLED GROUNDWATER DRAWDOWN IN LAYER 4



LEGEND

Private Bores

- Cadna-Owie Formation
- Hooray Sandstone
- Maximum Drawdown
- Affected Area (>5 m Drawdown)
- 1 m Drawdown Contour
- 5 m Drawdown Contour
- Groundwater line of section A-A'
- Groundwater line of section B-B'
- Town/Locality
- Highway/Major Road
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FIGURE 48

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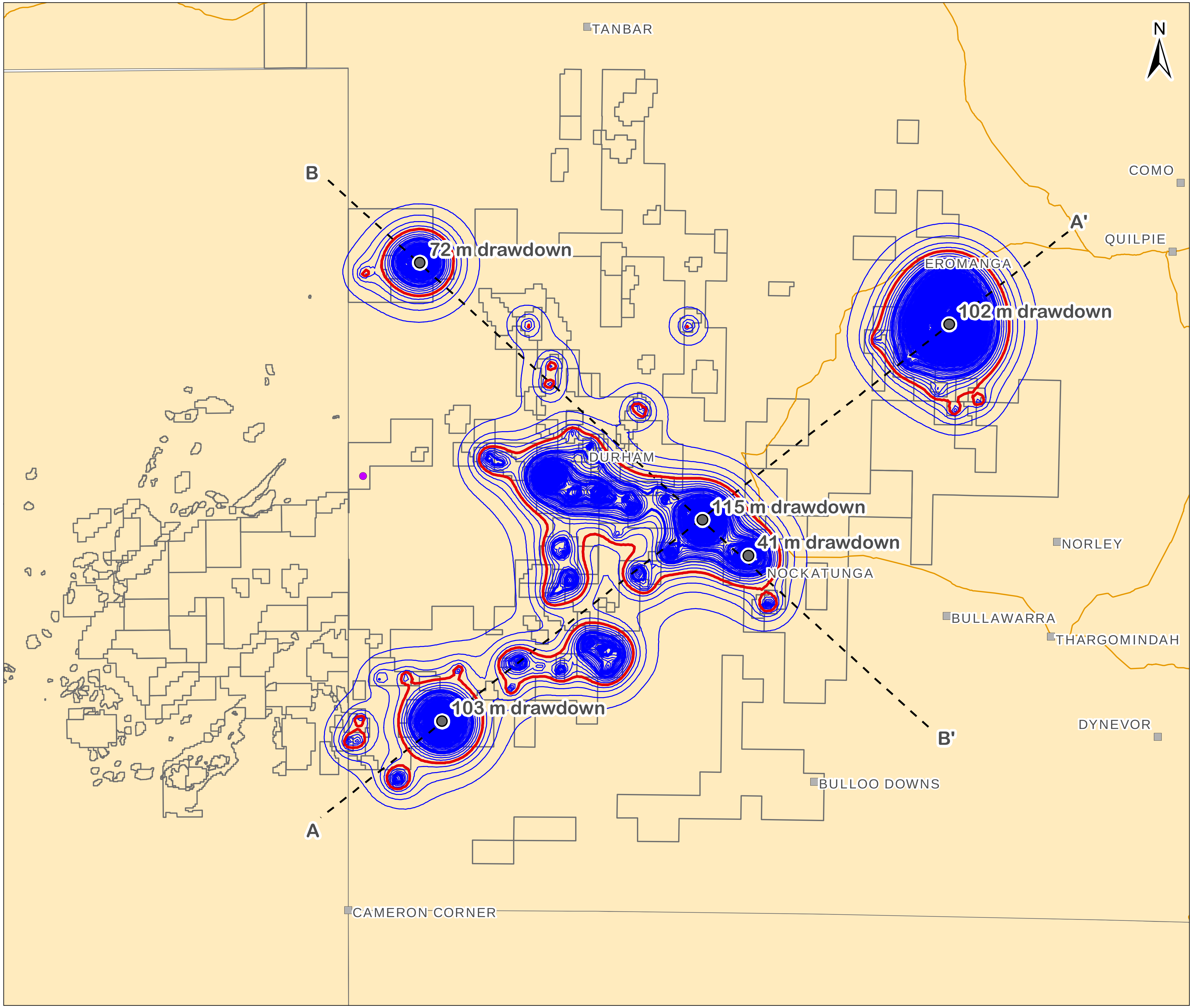

UNDERGROUND WATER IMPACT REPORT OIL AND GAS FIELDS SWQ

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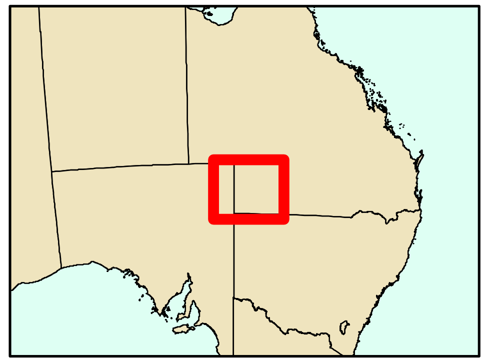
LONG TERM AFFECTED AREA - EROMANGA BASIN MODELLED GROUNDWATER DRAWDOWN IN LAYER 5



LEGEND

Private Bores

- Adori Sandstone
- Hutton Sandstone
- Maximum Drawdown
- Affected Area (>5 m Drawdown)
- 1 m Drawdown Contour
- 5 m Drawdown Contour
- Groundwater line of section A-A'
- Groundwater line of section B-B'
- Town/Locality
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FIGURE 49

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Groundwater level plots in cross section across the calculation area, are shown in Figure 50 and Figure 51.

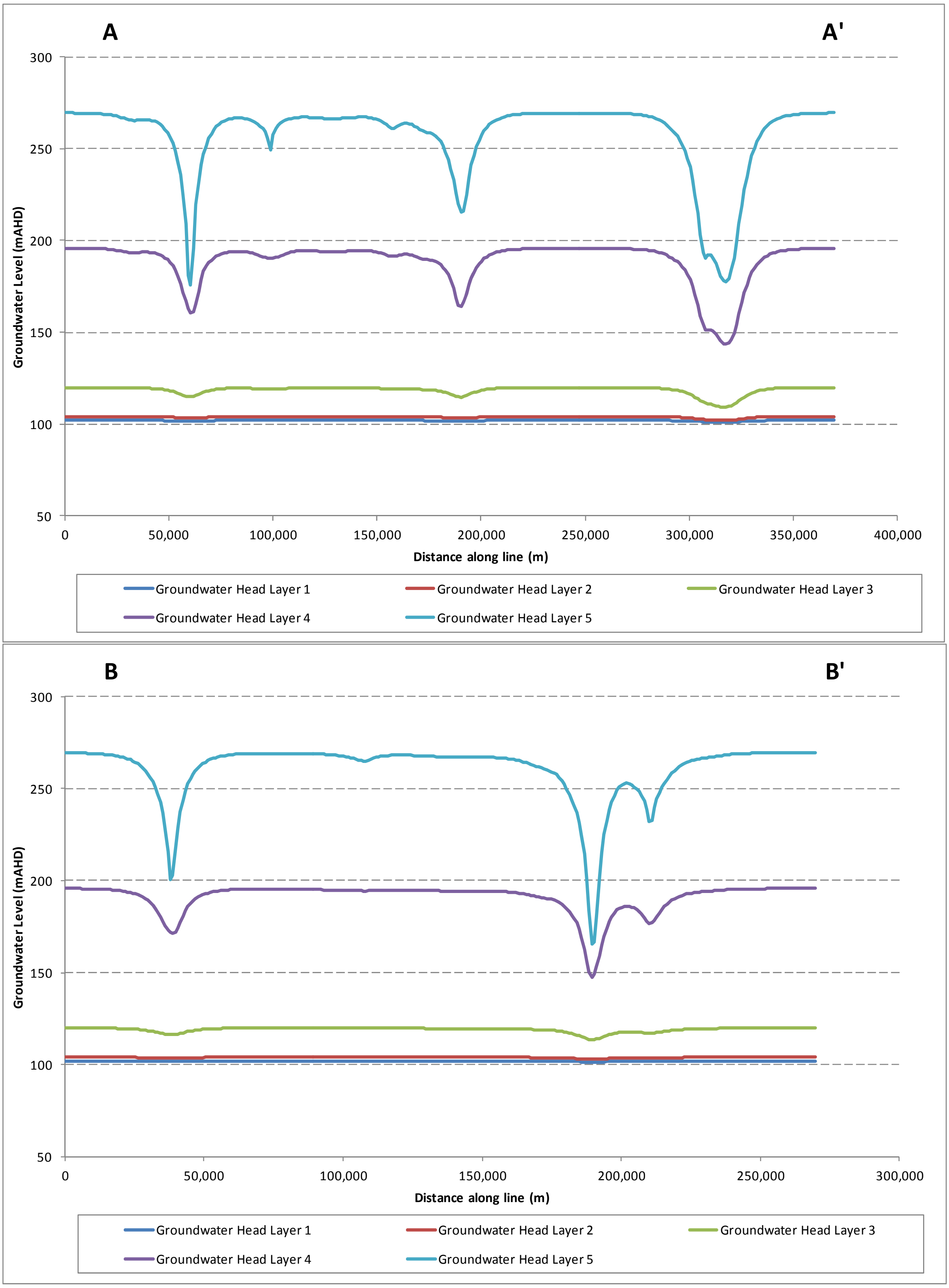
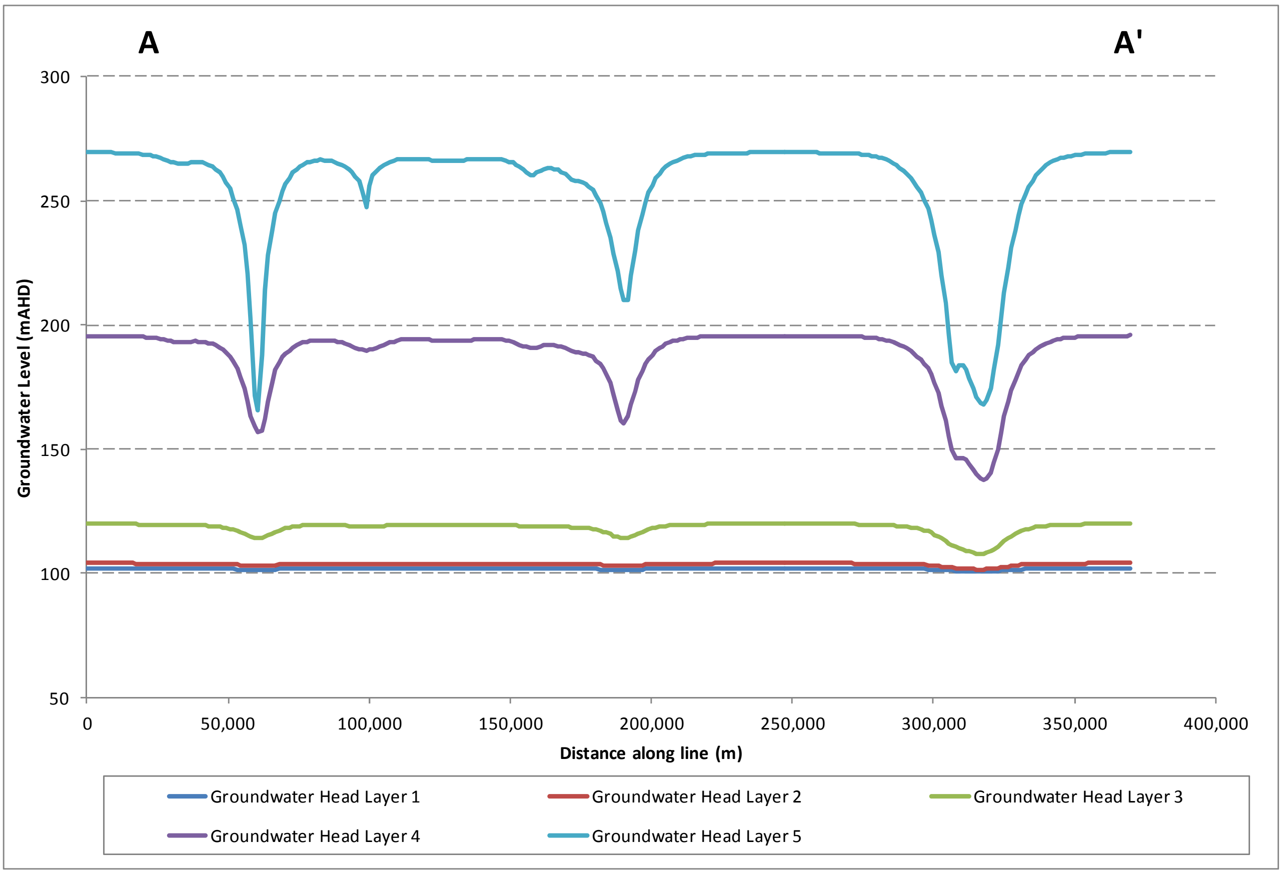


Figure 50: Eromanga Basin: Calculated Groundwater Levels in Immediately Affected Ares (Section A-A' and B-B')


A
A'
300
250
200
150
100
50
Groundwater Level (mAHD)
0
50,000
100,000
150,000
200,000
250,000
300,000
350,000
400,000
Distance along line (m)
Groundwater Head Layer 1
Groundwater Head Layer 2
Groundwater Head Layer 3
Groundwater Head Layer 4
Groundwater Head Layer 5

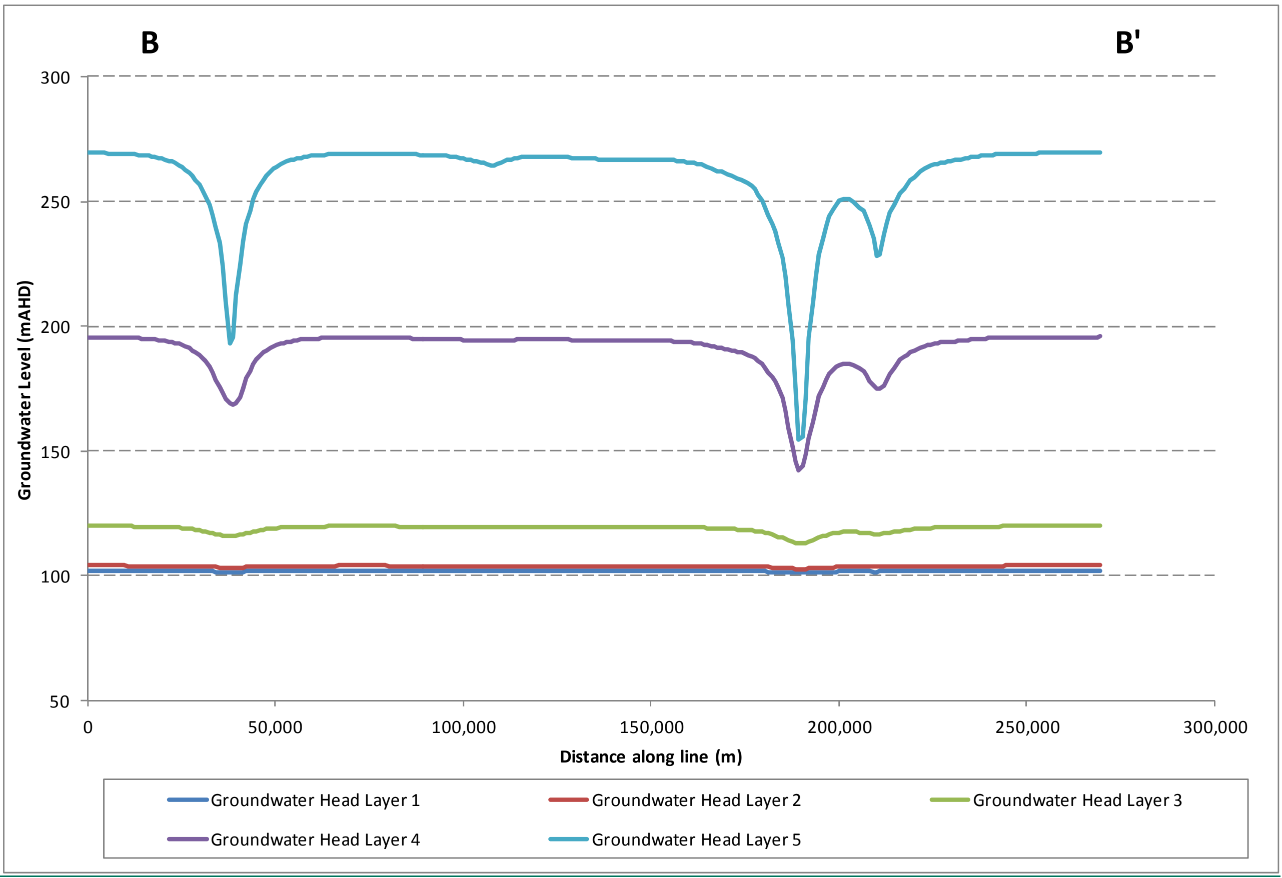

B
B'
300
250
200
150
100
50
Groundwater Level (mAHD)
0
50,000
100,000
150,000
200,000
250,000
300,000
Distance along line (m)
Groundwater Head Layer 1
Groundwater Head Layer 2
Groundwater Head Layer 3
Groundwater Head Layer 4
Groundwater Head Layer 5

Figure 51: Eromanga Basin: Calculated Groundwater Levels in Long Term Affected Ares (Section A-A' and B-B')

The maximum calculated drawdown in each layer along these lines of section is shown in Table 29.

Table 29: Calculated maximum drawdown along lines of section

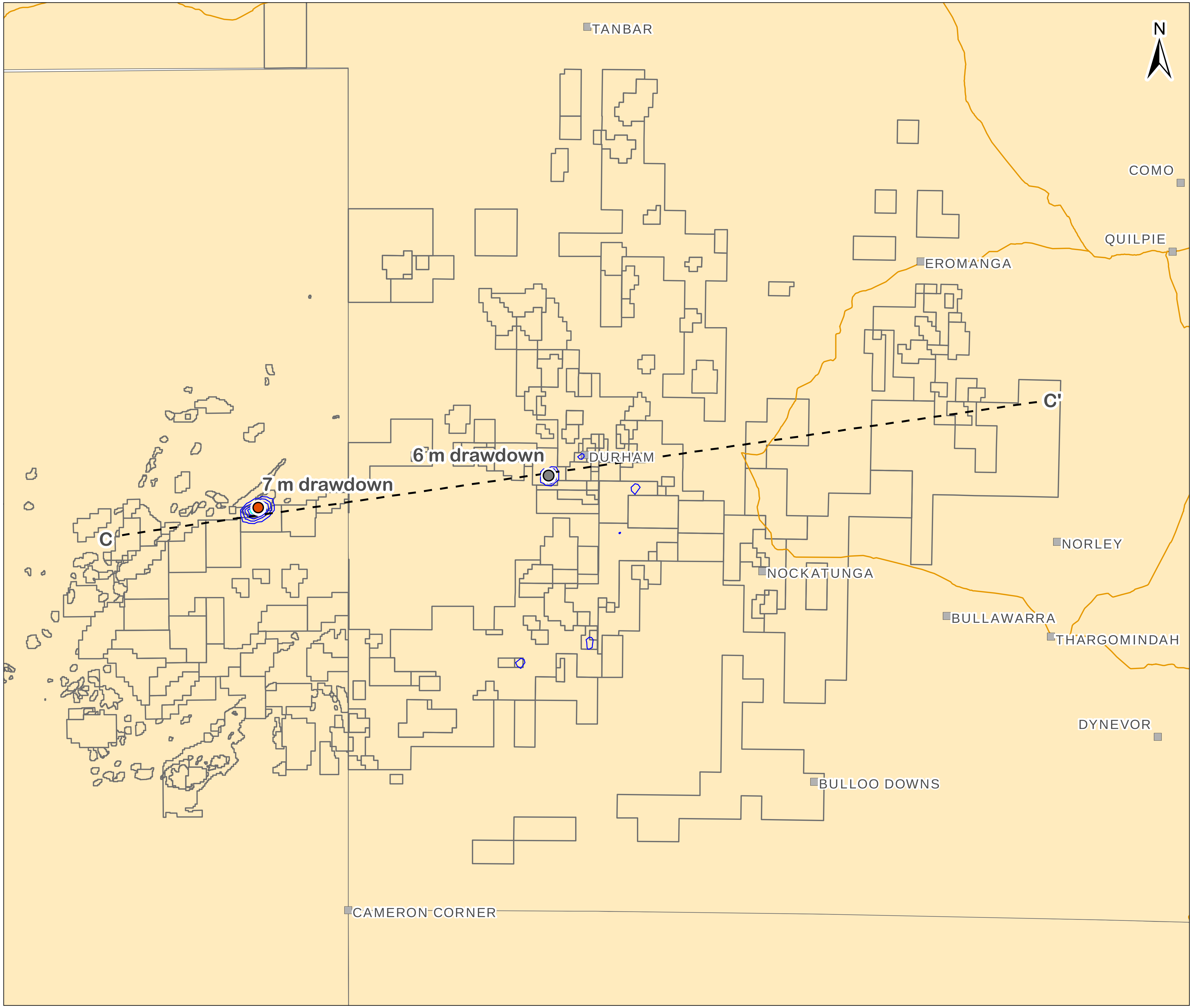
Layer Number	Layer Description	Maximum Drawdown in the Eromanga Basin (m)	
		Immediately Affected Area	Long Term Affected Area
2	Quaternary, Tertiary and Winton Formation	2	2
3	Alluru, Toolebuc and Wallumbilla Formations	11	12
4	Cadna-Owie Formation and Hooray Sandstone	52	58
5	Westbourne, Adori and Birkhead Formations / Hutton Sandstone and Poolowanna Formation	104	115

Groundwater level and pressure calculations from the software indicated limited propagation of drawdown (or pressure decline, in confined aquifers) up to Layer 2, even under steady state conditions. In reality, this would be anticipated to be less than that calculated due to the *intermittent and time-limited* operation of the extraction wells, as well as the increased spatial distribution of the extraction over a number of wells an order of magnitude higher than that used in this calculation.

Figure 42 to Figure 45 also show the spatial distribution of the greater than 5 m drawdown to be limited to the vicinity of the most clustered extraction wells.

7.4 Calculated Impact on the Cooper Basin

The calibrated model was run in steady state to give a conservative the worst case scenario. The calculated drawdown for each layer is given in Figure 52.



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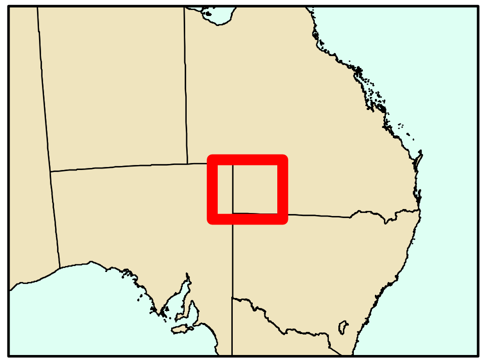
IMMEDIATE AFFECTED AREA - COOPER BASIN MODELLED GROUNDWATER DRAWDOWN IN LAYER 2



LEGEND

- Maximum Drawdown (QLD)
- Maximum Drawdown (SA)
- Affected Area (>5 m Drawdown)
- 1 m Drawdown Contour
- 5 m Drawdown Contour
- Groundwater line of section C-C'
- Town/Locality
- Highway/Major Road
- Santos Operated Permits

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FIGURE 52

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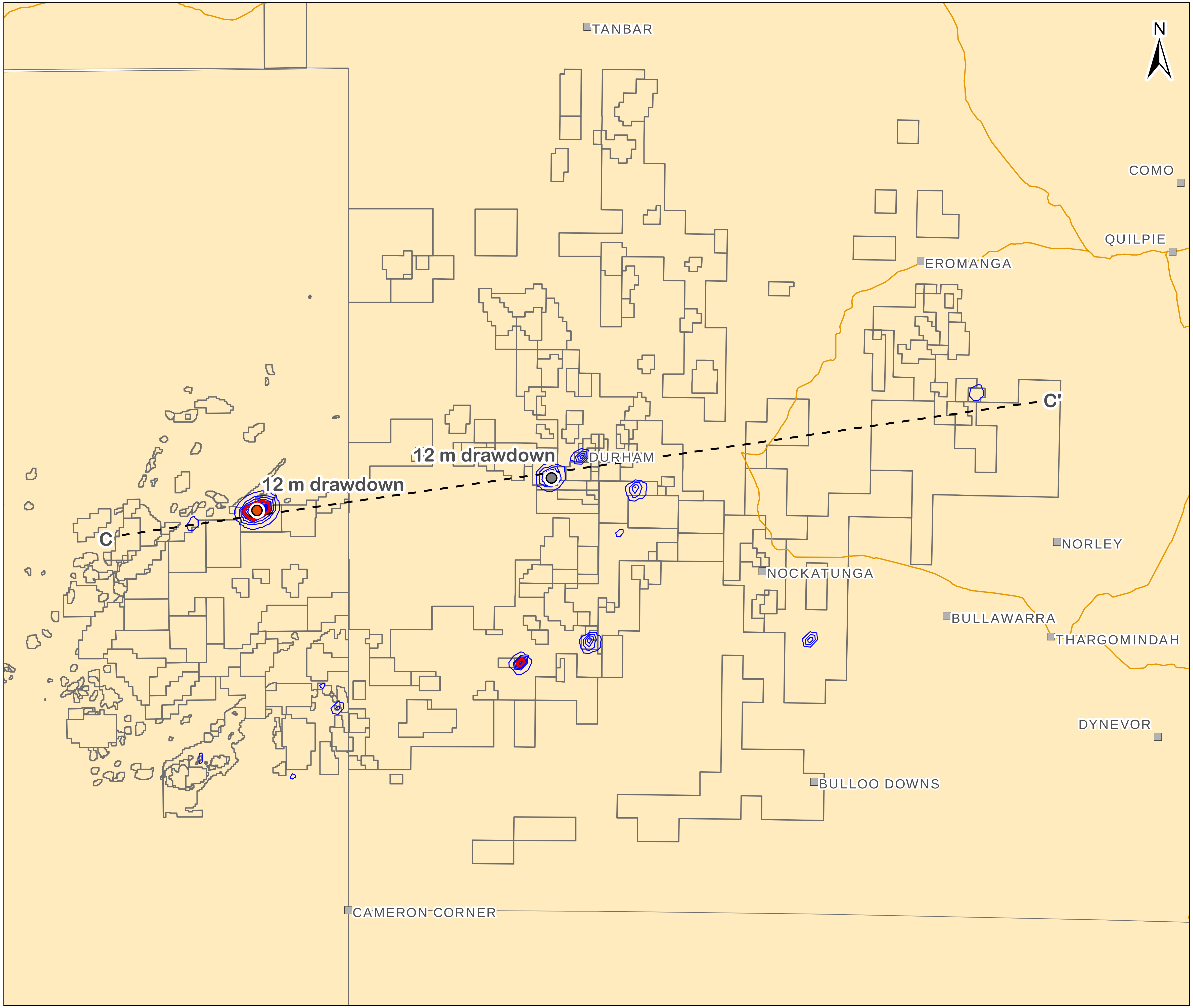
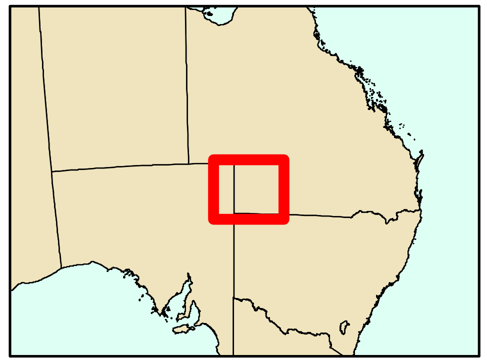
IMMEDIATE AFFECTED AREA - COOPER BASIN MODELLED GROUNDWATER DRAWDOWN IN LAYER 3





LEGEND

- Maximum Drawdown (QLD)
- Maximum Drawdown (SA)
- Affected Area (>5 m Drawdown)
- 1 m Drawdown Contour
- 5 m Drawdown Contour
- Groundwater line of section C-C'
- Town/Locality
- Highway/Major Road
- Santos Operated Permits

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SCALE (at A3) 1:1,500,000

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FIGURE 53

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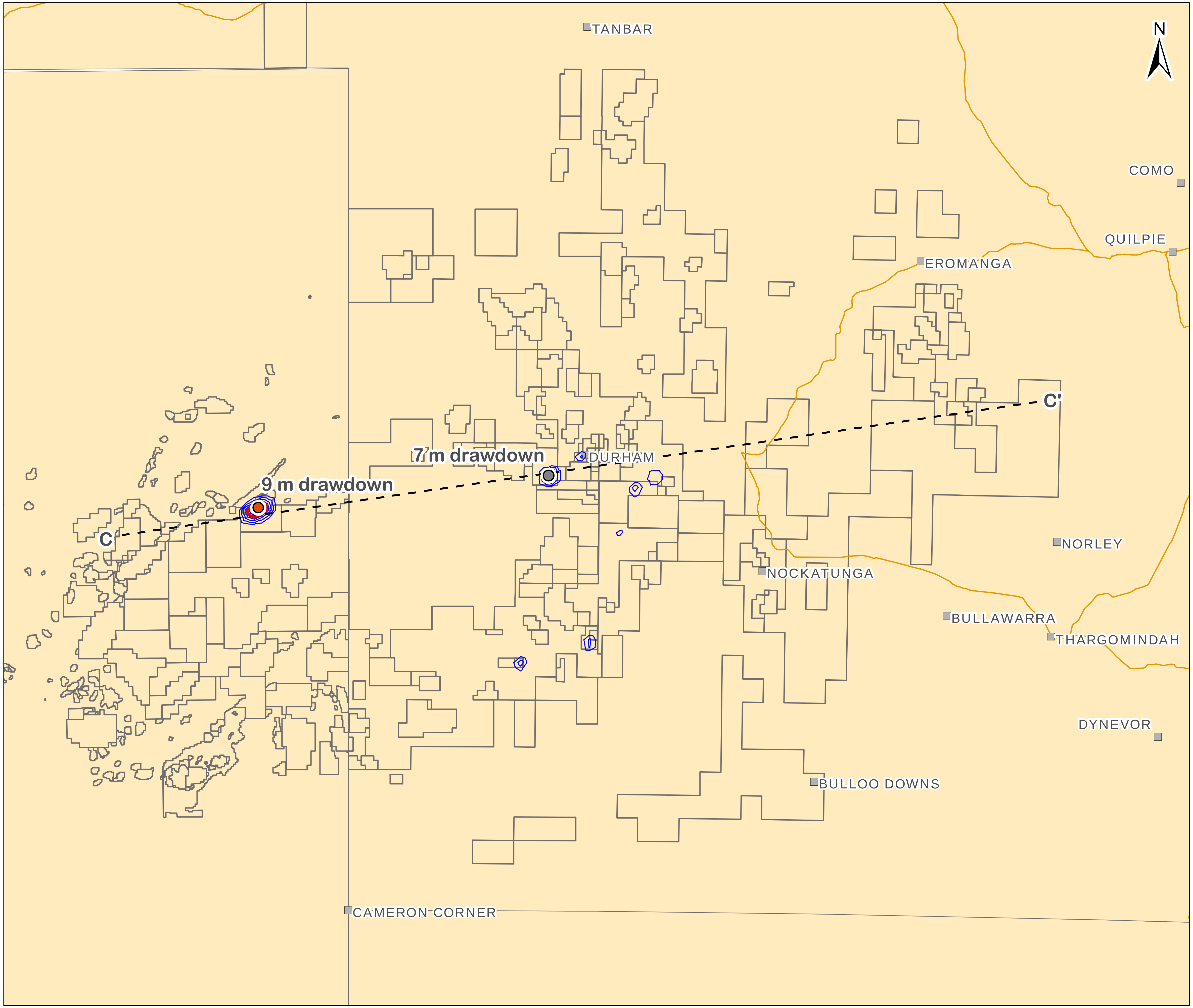

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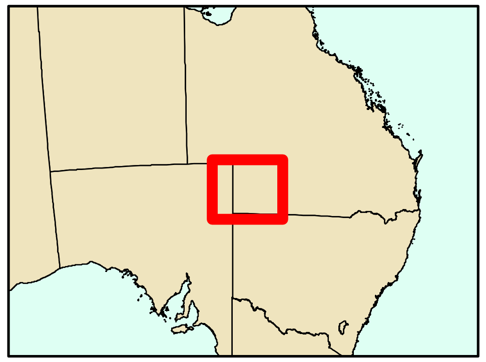
LONG TERM AFFECTED AREA - COOPER BASIN MODELLED GROUNDWATER DRAWDOWN IN LAYER 2



LEGEND

- Maximum Drawdown (QLD)
- Maximum Drawdown (SA)
- Affected Area (>5 m Drawdown)
- 1 m Drawdown Contour
- 5 m Drawdown Contour
- Groundwater line of section C-C'
- Town/Locality
- Highway/Major Road
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0 5 10 20 30 40 50 Kilometers

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FIGURE 54

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UNDERGROUND WATER IMPACT REPORT OIL AND GAS FIELDS SWQ

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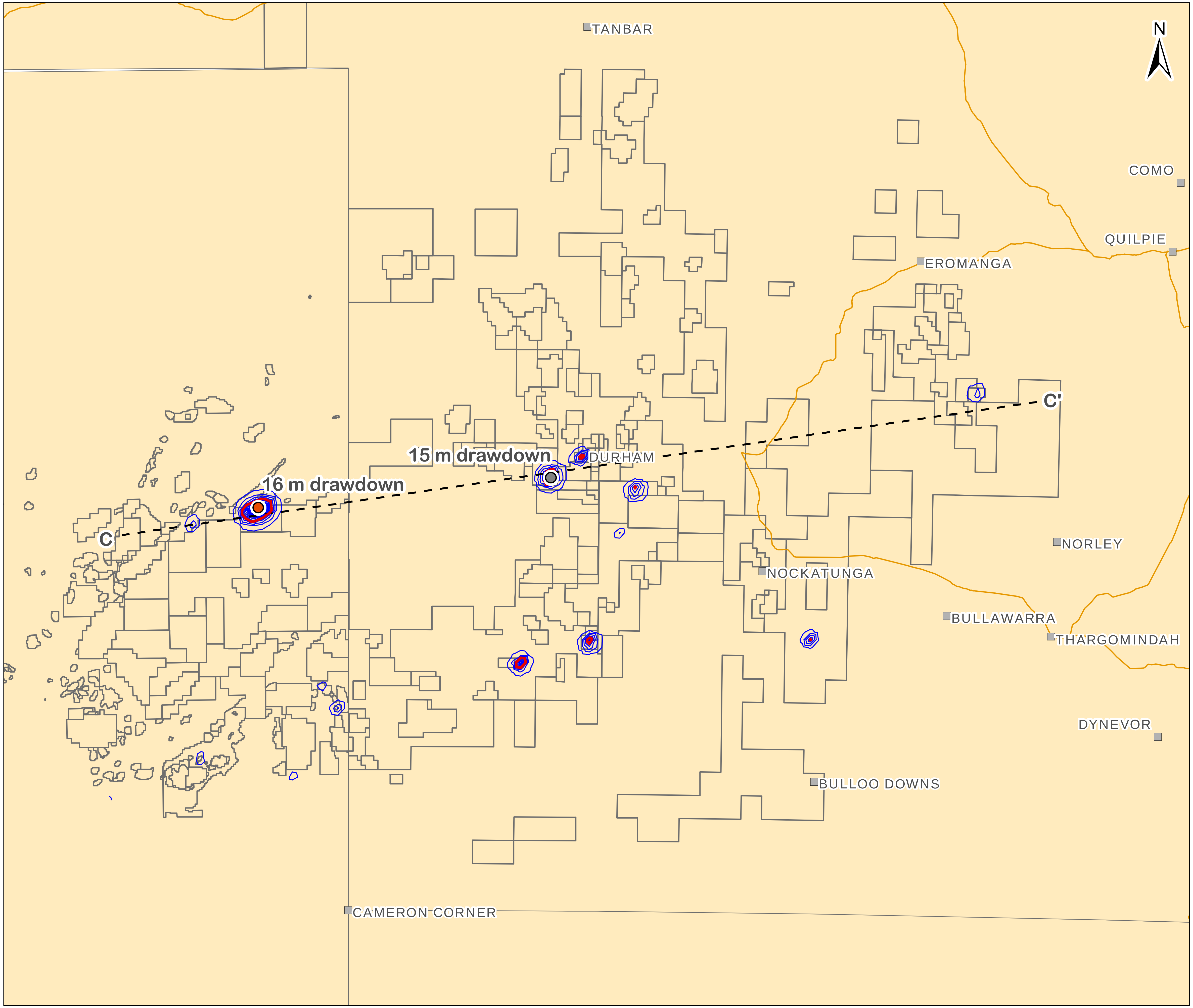
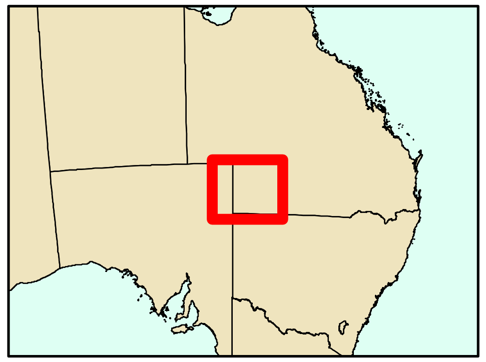
LONG TERM AFFECTED AREA - COOPER BASIN MODELLED GROUNDWATER DRAWDOWN IN LAYER 3





LEGEND

- Maximum Drawdown (QLD)
- Maximum Drawdown (SA)
- Affected Area (>5 m Drawdown)
- 1 m Drawdown Contour
- 5 m Drawdown Contour
- Groundwater line of section C-C'
- Town/Locality
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FIGURE 55

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Groundwater level plots in cross section across the calculation area, as shown in Figure 56.

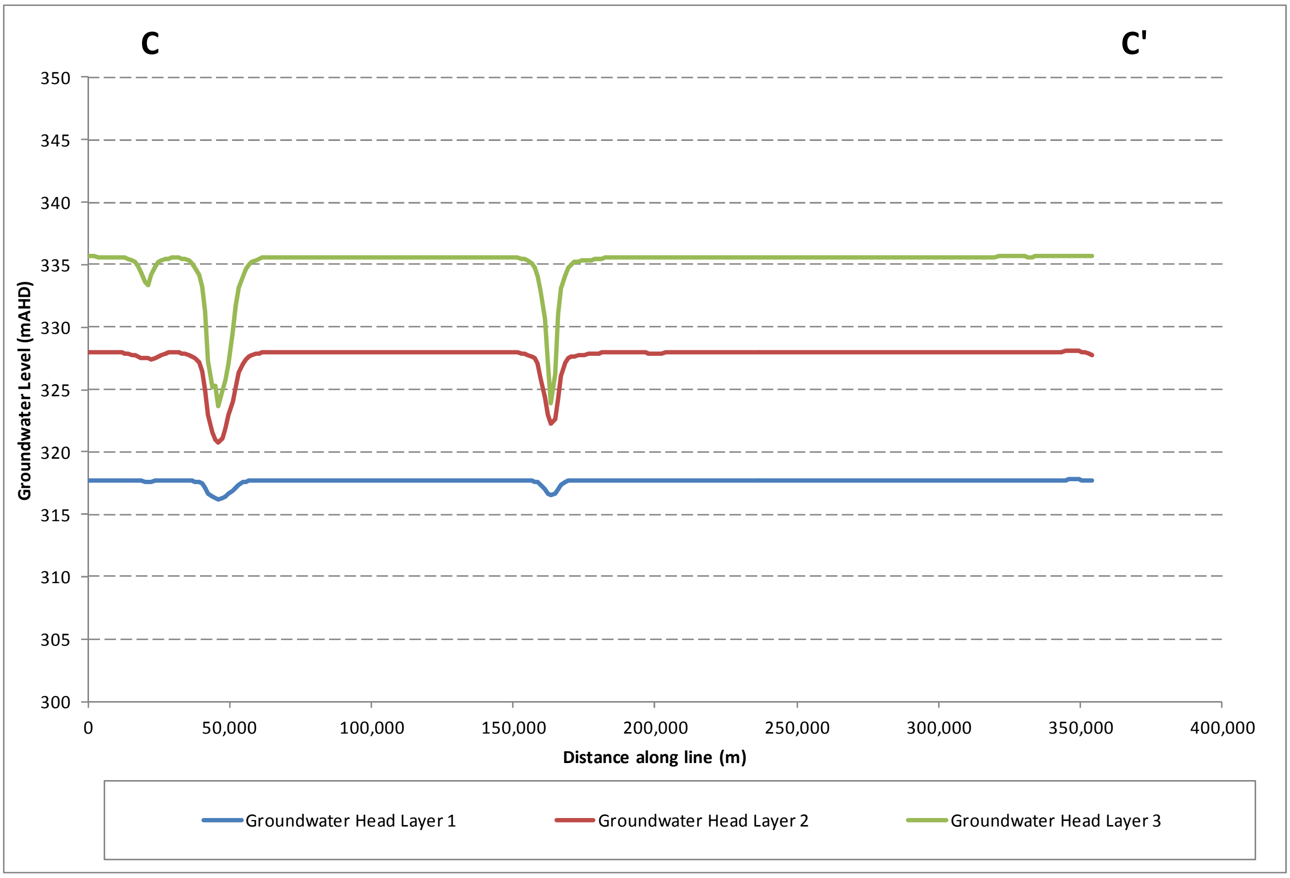

Figure 56: Cooper Basin: Modelled Immediate Affected Area Groundwater Levels in Cross Section C-C'

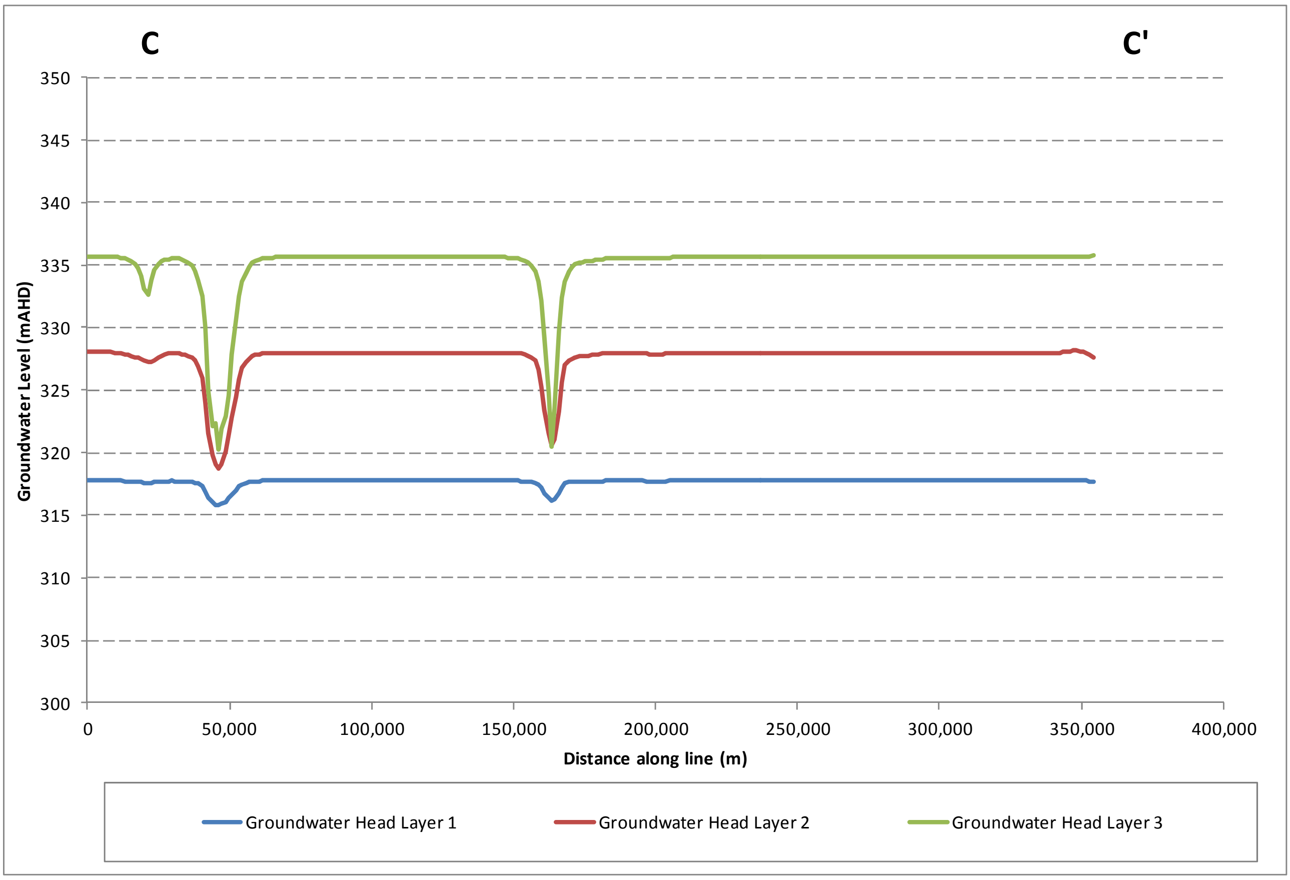

Figure 57: Cooper Basin: Modelled Long Term Affected Area Groundwater Levels in Cross Section C-C'

The maximum calculated pressure decline in each layer along these lines of section is shown in Table 30.

Table 30: Cooper Basin: Calculated maximum pressure decline along lines of section

Layer Number	Layer Description	Maximum Drawdown (m) along line C-C'	
		Immediately Affected Area	Long Term Affected Area
2	Layer 2 - Tinchoo and Arrabury Formations	7	9
3	Layer 3 – Toolachee to Patchawarra Formations	12	16

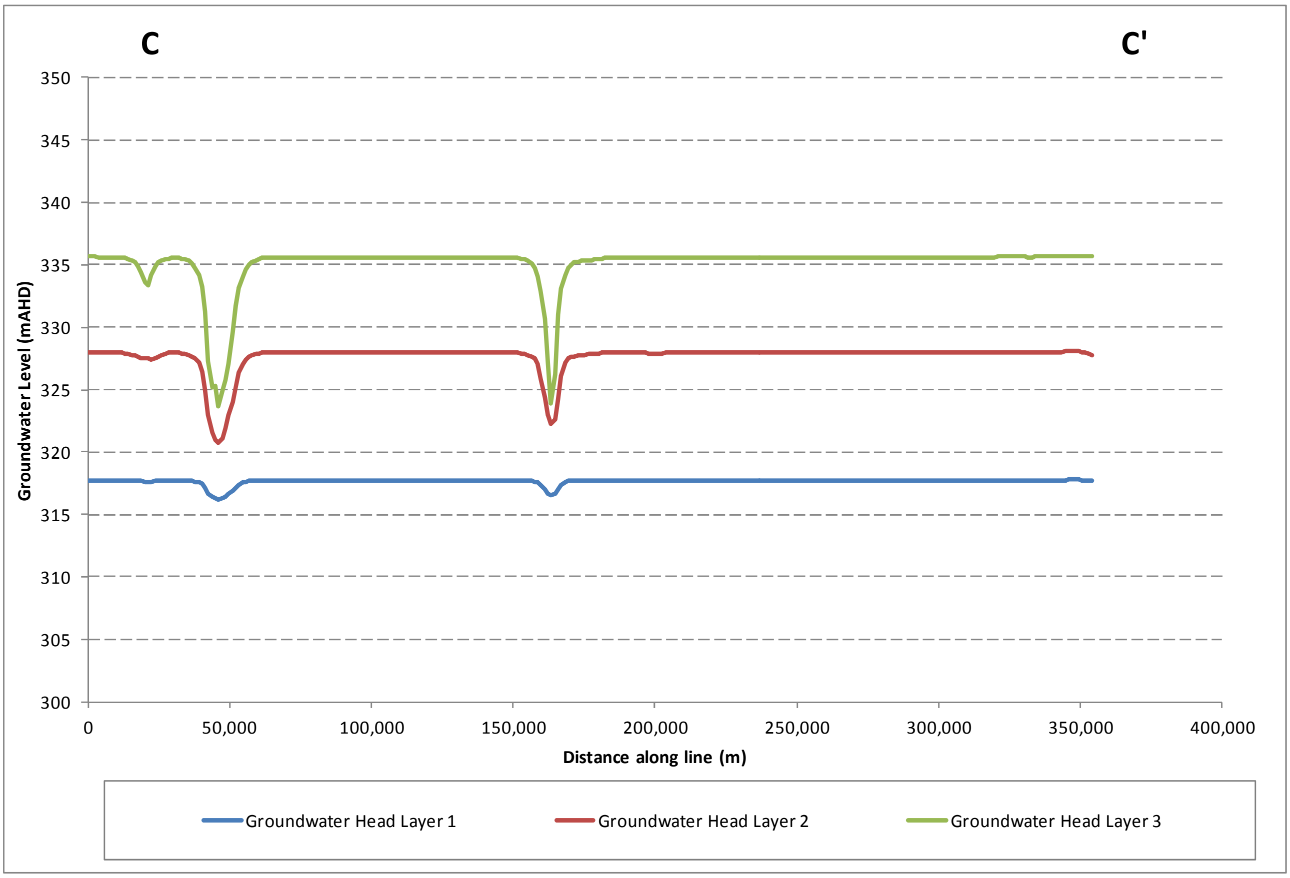

Figure 56 and Table 30 shows that the calculated pressure decline at the top of the Cooper Basin stratigraphy is very small in relation of the abstraction assigned at just 38 wells. No impact is likely to propagate above the top of the Tinchoo and Arraburry Formations due to extraction in the Toolachee to Patchawarra Formations.

The impact of extraction from the wells in Layer 3 of the model is also considered minimal, however, as this gives a worst case scenario, as actual extraction is geographically spread over a greater number of wells, the simulation was retained using this methodology.

7.5 Summary of Key Points from Analytical Calculations

Key points from the analytical calculation are:

- The calculated immediately affected area in the Eromanga Basin extends to include three private bores potentially extracting from the Cadna-Owie Formation or Hooray Sandstone (model layer 4). These are: RN223372, RN23569 and RN6304 (Figure 44);
- An additional single private bore was calculated as being within the long term affected area also potentially extracting from the Cadna-Owie Formation or Hooray Sandstone. This is bore: RN1238 (Figure 48);
- The calculated immediately affected area and long term affected area both included a single private bore potentially extracting form the Mackunda Formation (model layer 3) as shown in Figure 43 and Figure 47. This is private bore RN11924;
- The impact of extraction in the Cooper Basin does not affect areas beyond the assumed extraction well locations at the top of the Cooper Basin stratigraphy. These impacts can therefore be discounted from the analysis of the overlying Eromanga Basin; and
- The maximum predicted drawdown in the Eromanga Basin stratigraphy, in the strata directly underlying the unconfined Tertiary and Quaternary strata, is 2 m in steady state conditions. This is a worst case scenario due to the limited number of extraction well locations used in the calculation and the steady state analysis conditions applied in the computation. The impact on the Tertiary and Quaternary strata will therefore be less than 2 m.
- A maximum pressure decline of 52 m is estimated for the modelled unit containing the Cadna-Owie Formation and Hooray Sandstone, the 5 m contour line does not significantly extend outside of the tenements and only two private bores targeting the Cadna-Owie Formation and Hooray Sandstone have been identified within these 5 m (note that the target formation for those bores will need to be clarified).
- A maximum pressure decline of 115 m is estimated for the long term model unit comprising the Westbourne Formation, Adori Sandstone, Birkhead Formation, Hutton Sandstone and Poolowanna Formation. The 5 m drawdown contour line does not significantly extend outside of the tenements and no private bores targeting those formations.
- The Cooper Basin model was run to include extraction in South Australia. With the given hydraulic parameters in this model, no impact was observed in the Eromanga Basin due to extraction from the Cooper Basin in South Australia.

7.6 Sensitivity Analysis

Sensitivity analysis was undertaken on the calculations to investigate the confidence in the results. Two types of sensitivity analysis were undertaken:

- ***Hydraulic Parameter sensitivity analysis*** involving *increasing* the vertical hydraulic conductivity of the seal rock (underlying aquitard cap rock of the extraction targets) by an order to magnitude); and
- **Extraction scenario sensitivity *analysis*** involving the *addition of extraction* in South Australia, to investigate the potential for cumulative impacts form both states to influence the result for the QLD extractions alone).

All other input parameters to the model remained the same as the groundwater impact estimation scenario. Each is dealt with individually in the following sections.

7.6.1 Hydraulic Parameter Sensitivity Analysis

Analysis of the sensitivity of the groundwater impact estimation scenario result to changes in the vertical hydraulic conductivity of the seal layer was undertaken. To provide a conservative approach to sensitivity analysis, the vertical hydraulic conductivity was *increased* by an order of magnitude, as follows:

- ***HPSA1:*** Hydraulic Parameter Sensitivity Analysis on the Cooper Basin: Layer 2 (lower portion of the Tinchoo and Arraburry Formation) vertical hydraulic conductivity increased to 1×10^{-3} m/d; and
- ***HPSA2:*** Hydraulic Parameter Sensitivity Analysis on the Eromanga Basin: Layer 3 (the grouped layer consisting of the early to late Cretaceous Mackunda, Allura Mudstone, Toolebuc Formation and Wallumbilla Formation) vertical hydraulic conductivity increased to 1×10^{-1} m/d.

Recalibration of the steady state analysis was necessary in both cases. This involved altering the flux at the top of the model to achieve representative initial steady state groundwater levels in the model.

7.6.2 Extraction Sensitivity Analysis

In addition to the hydraulic parameter sensitivity analysis, the potential impact of extraction from Santos' SA operations was investigated. This was possible only for the Eromanga Basin as the deeper Cooper Basin extractions do not extend into South Australia.

The following scenario was calculated:

- **ESA1:** Extraction Sensitivity Analysis on the Eromanga Basin: inclusion of all Santos' oil and gas extraction within the Eromanga Basin included in the analysis,

The extraction rate was altered from the predictive model to allow for the addition of South Australia wells. The following extraction rates were used:

- *Eromanga Basin QLD plus SA* model *immediate affected area* extraction rate (equivalent to the last 3 years average extraction) of 25.5 m^3/day for each representative well used in the model; and
- *Eromanga Basin QLD plus SA* model *long term affected area* extraction rate (equivalent to the last 3 years average extraction) of 28.5 m^3/day for each representative well used in the model.

All other input parameters were the same as the predictive model.

7.6.3 Sensitivity Analysis Steady State Calibration

The same target initial groundwater conditions used in the groundwater impact estimation scenario to calibrate the sensitivity analysis steady state calculations. Results from the final calibrated steady state calculations for all sensitivity scenarios are tabulated in Table 31 and plotted in Figure 58.

Table 31: Sensitivity Analysis Calibration Results

Model Layer (and modelled groundwater level [mAHD])			Observed Groundwater Level (mAHD)		Sensitivity Analysis versus Observed Groundwater Level Residual (m)		
HPSA1	**HPSA2**	**ESA1**	**Eromanga Basin**	**Cooper Basin**	**HPSA1**	**HPSA2**	**ESA1**
Layer 1: 102	Layer 1: 315	Layer 1: 102	100	315	2	0	2
Layer 2:104	Layer 2: 318	Layer 2:104	150	325	-46	-7	-46
Layer 3:120	Layer 3: 318	Layer 3:120	200	315	-80	3	-80
Layer 4: 196	-	Layer 4: 196	270	-	-74	-	-74
Layer 5: 270	-	Layer 5: 270	300	-	-30	-	-30

The calibration plot of modelled groundwater level verses observed for all sensitivity models is show in Figure 58.

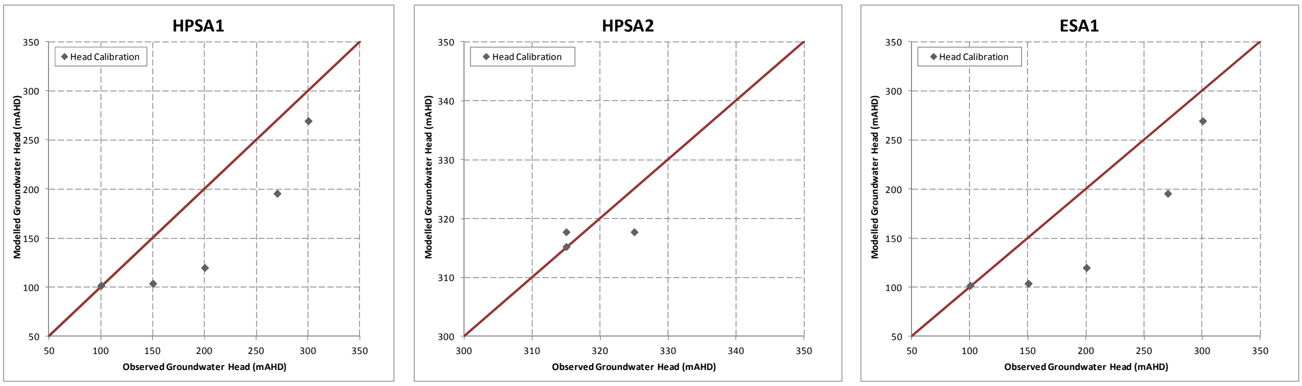

Figure 58: Plot of Sensitivity Analysis Steady State Calibration

These calibrations were considered suitable to conduct the sensitivity analysis modelling.

7.6.4 Results of Sensitivity Analysis Modelling

The calibrated models were run in steady state to give a conservative, worst case scenario. The calculated drawdown for each layer is given in Figure 59 to Figure 65 (Note: the contours shown are one metre contours).

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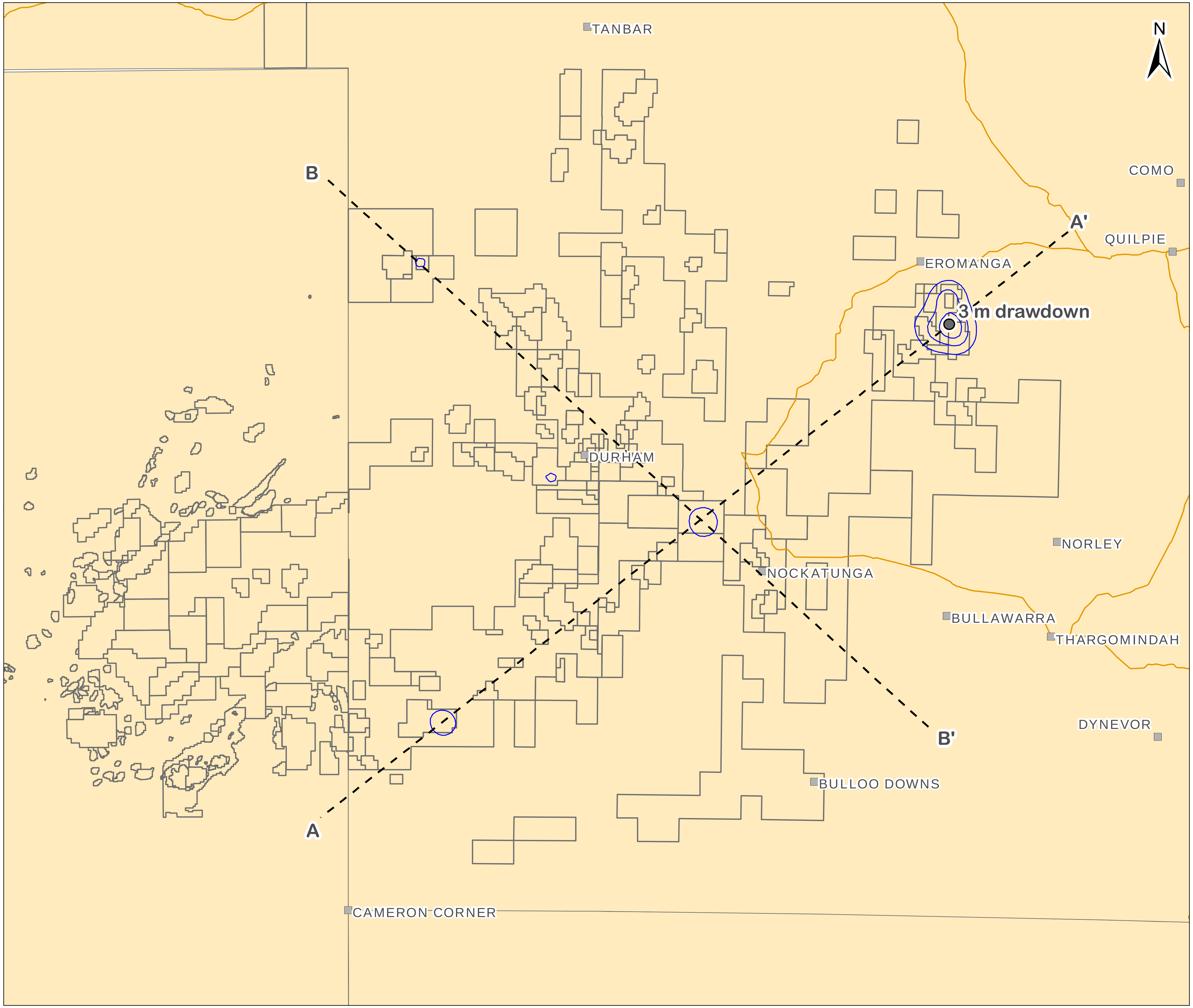
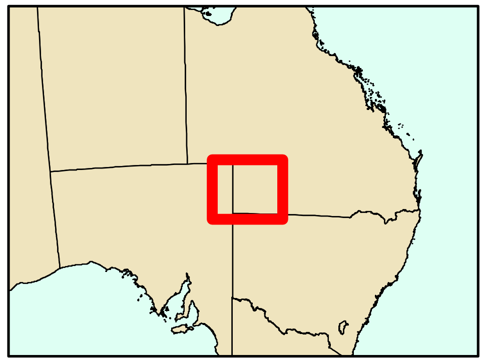
IMMEDIATE AFFECTED AREA - EROMANGA BASIN HPSA1 MODELLED GROUNDWATER DRAWDOWN IN LAYER 2





LEGEND

- Maximum Drawdown
- 1 m Drawdown Contour
- Groundwater line of section A-A'
- Groundwater line of section B-B'
- Town/Locality
- Highway/Major Road
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0 5 10 20 30 40 50 Kilometers

SCALE (at A3) 1:1,500,000

Coordinate System: GDA 1994 MGA Zone 54

PROJECT:	117636010-3000
DATE:	11/07/2012
DRAWN:	HW
CHECKED:	RH

FIGURE 59

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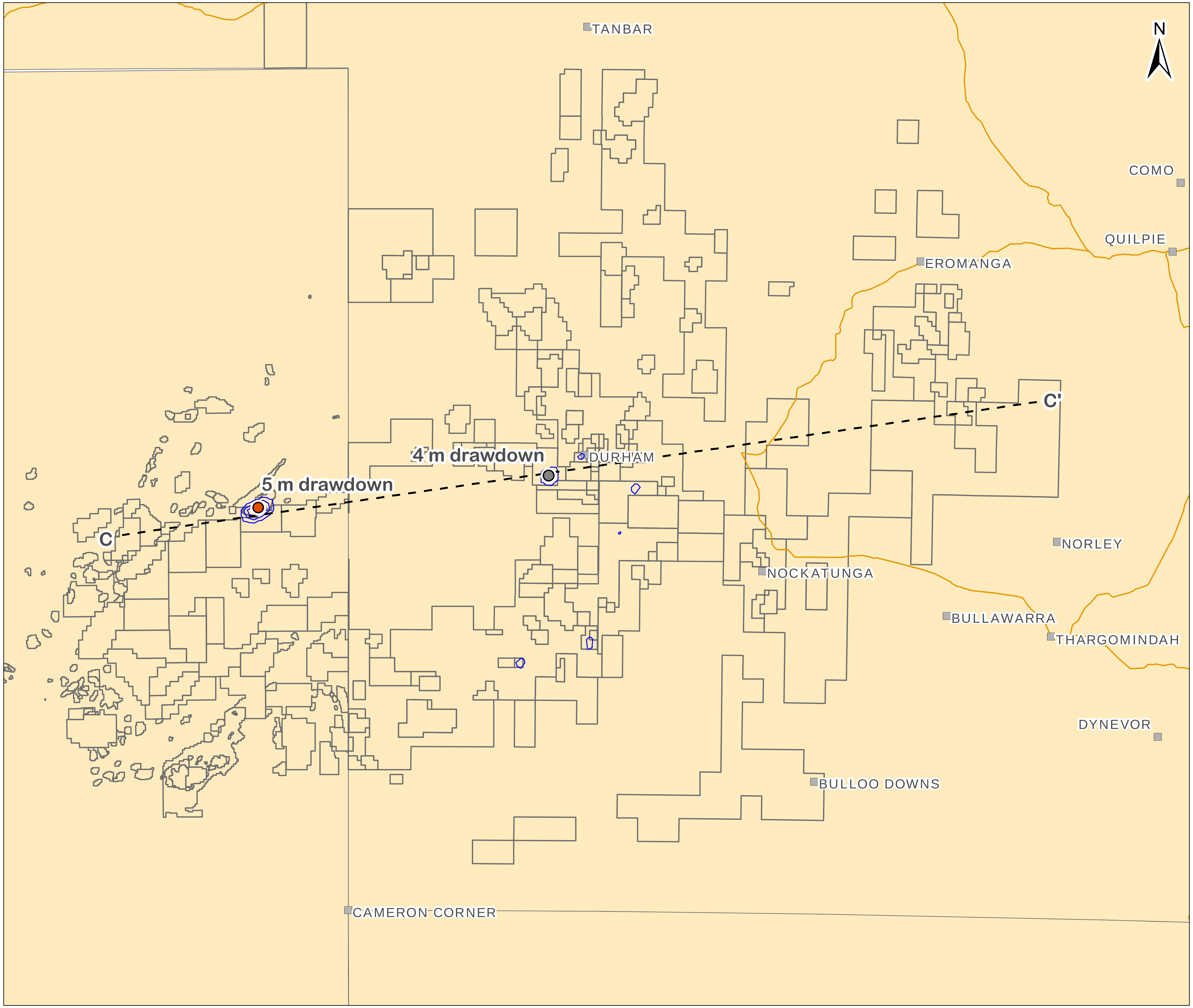
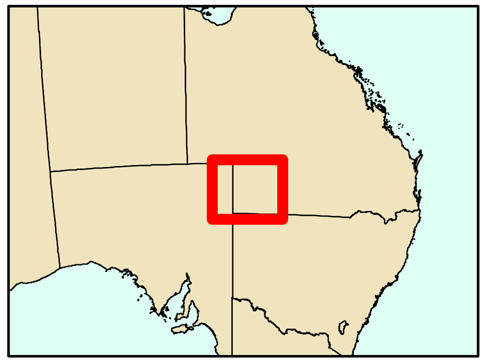
UNDERGROUND WATER IMPACT REPORT OIL AND GAS FIELDS SWQ

SANTOS

IMMEDIATE AFFECTED AREA - COOPER BASIN MODELLED HPSA2 GROUNDWATER DRAWDOWN IN LAYER 2





LEGEND

- Maximum Drawdown (QLD)
- Maximum Drawdown (SA)
- 1 m Drawdown Contour
- Groundwater line of section C-C'
- Town/Locality
- Highway/Major Road
- Santos Operated Permits

NOTES

Insert additional information here.

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0 5 10 20 30 40 50 Kilometers

SCALE (at A3) 1:1,500,000

Coordinate System: GDA 1994 MGA Zone 54

PROJECT:	117636010-3000
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FIGURE 60

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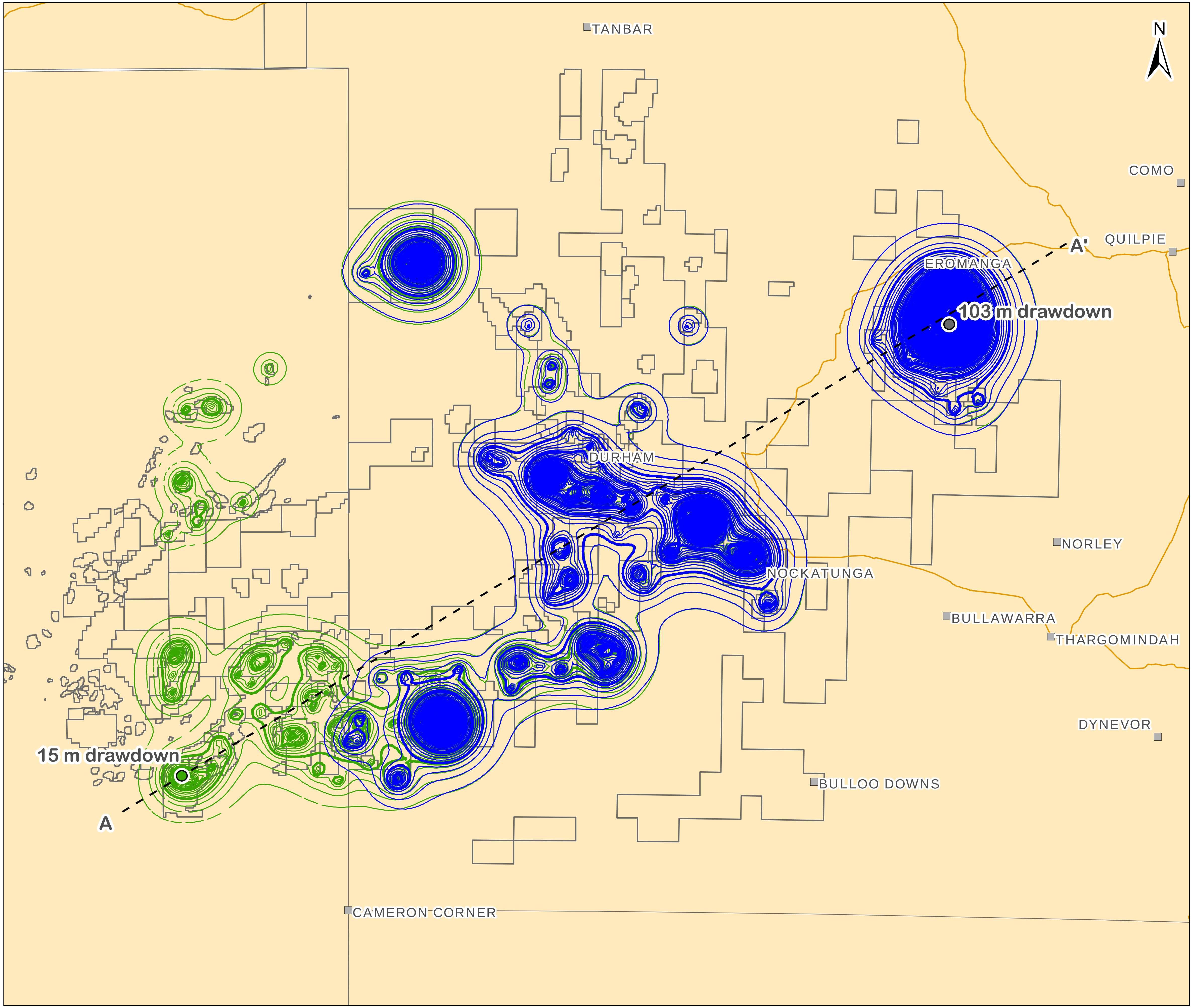
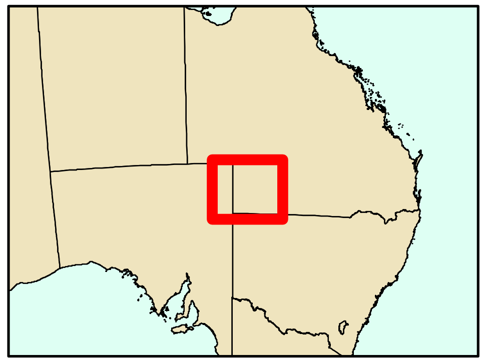
UNDERGROUND WATER IMPACT REPORT OIL AND GAS FIELDS SWQ

SANTOS

LONG TERM AFFECTED AREA - EROMANGA BASIN ESA1 AND PREDICTIVE MODEL: MODELLED GROUNDWATER DRAWDOWN IN LAYER 5





LEGEND

- Maximum Drawdown (SA)
- Maximum Drawdown (QLD)
- Groundwater line of section A-A'
- 1 m Drawdown Contour (QLD)
- 5 m Drawdown Contour (QLD)
- 1 m Drawdown Contour
- 5 m Drawdown Contour
- Town/Locality
- Highway/Major Road
- Santos Operated Permits

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0 5 10 20 30 40 50 Kilometers

SCALE (at A3) 1:1,500,000

Coordinate System: GDA 1994 MGA Zone 54

PROJECT: 117636010-3000
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FIGURE 61

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Groundwater level plots in cross section across the calculation area for the sensitivity analysis are shown in the following figures.

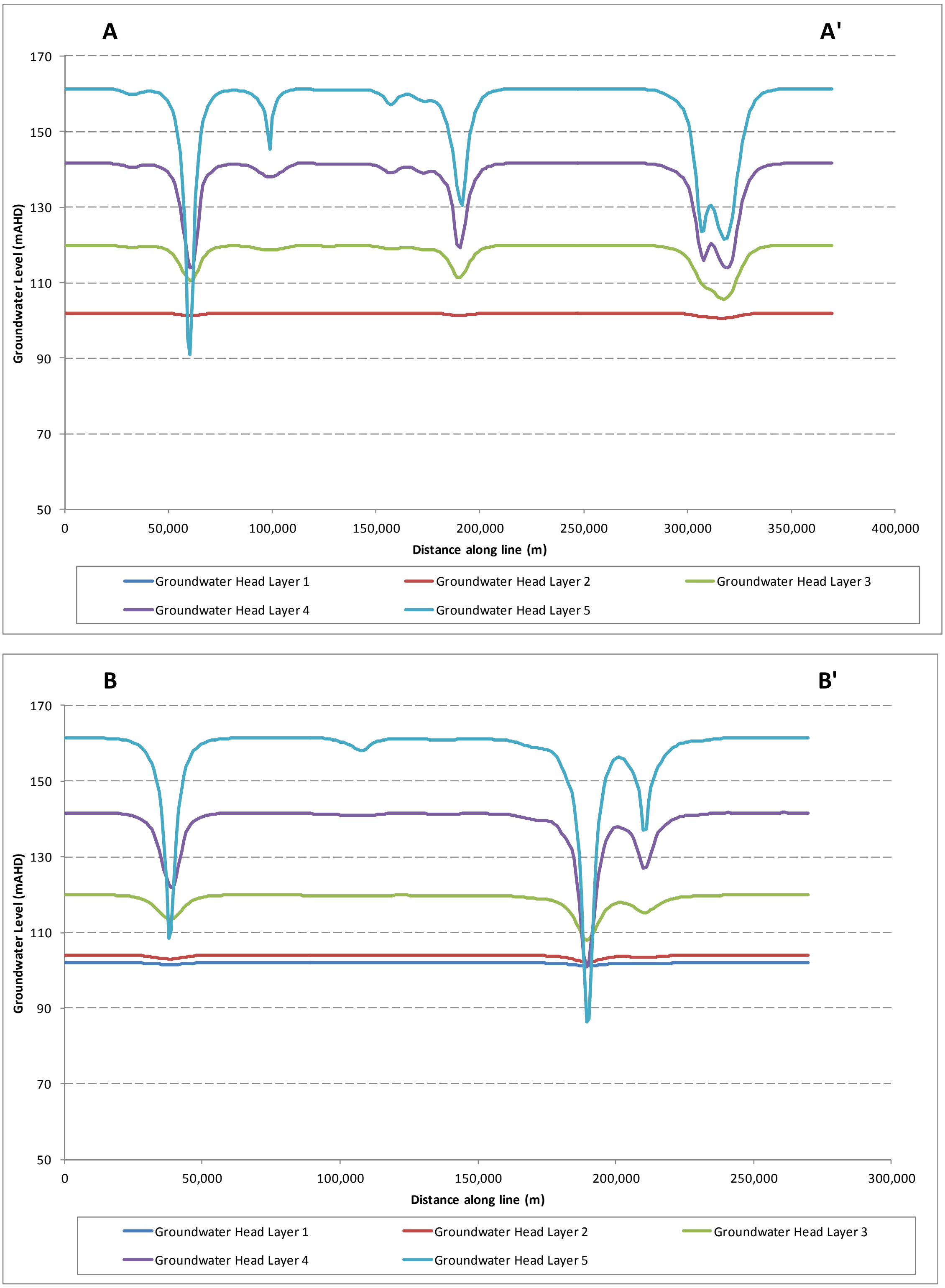
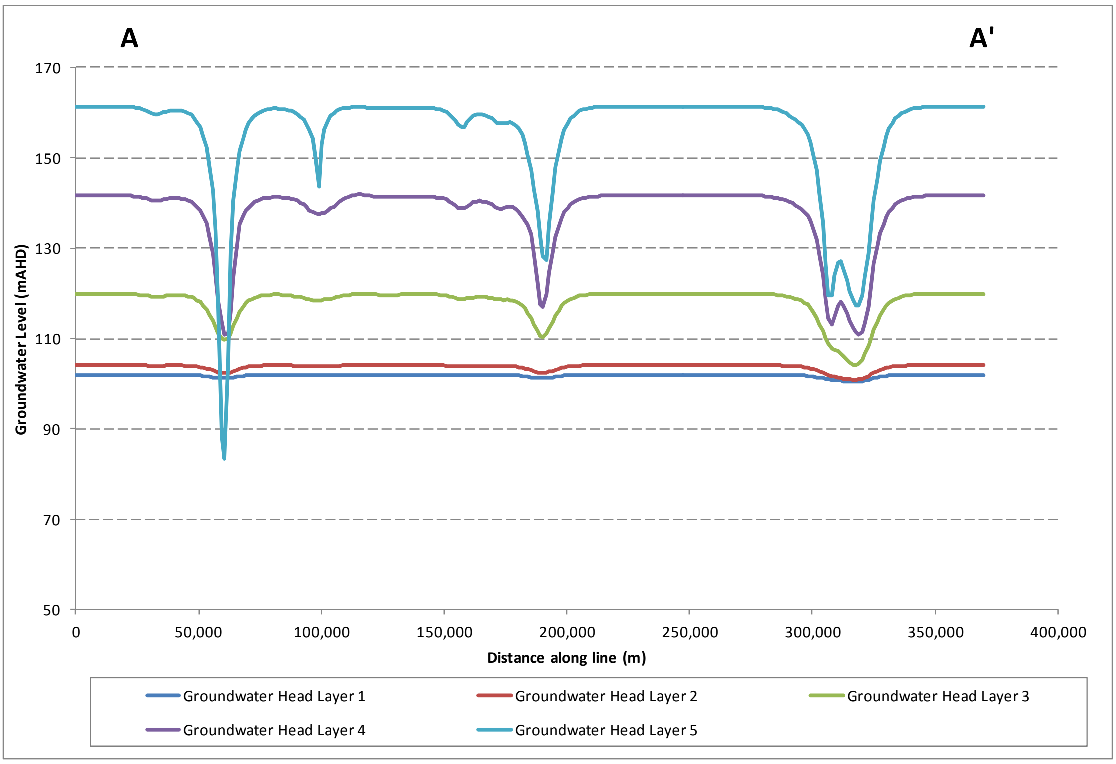


Figure 62: HPSA1: Immediately Affected Groundwater Cross Section A-A' and B-B'



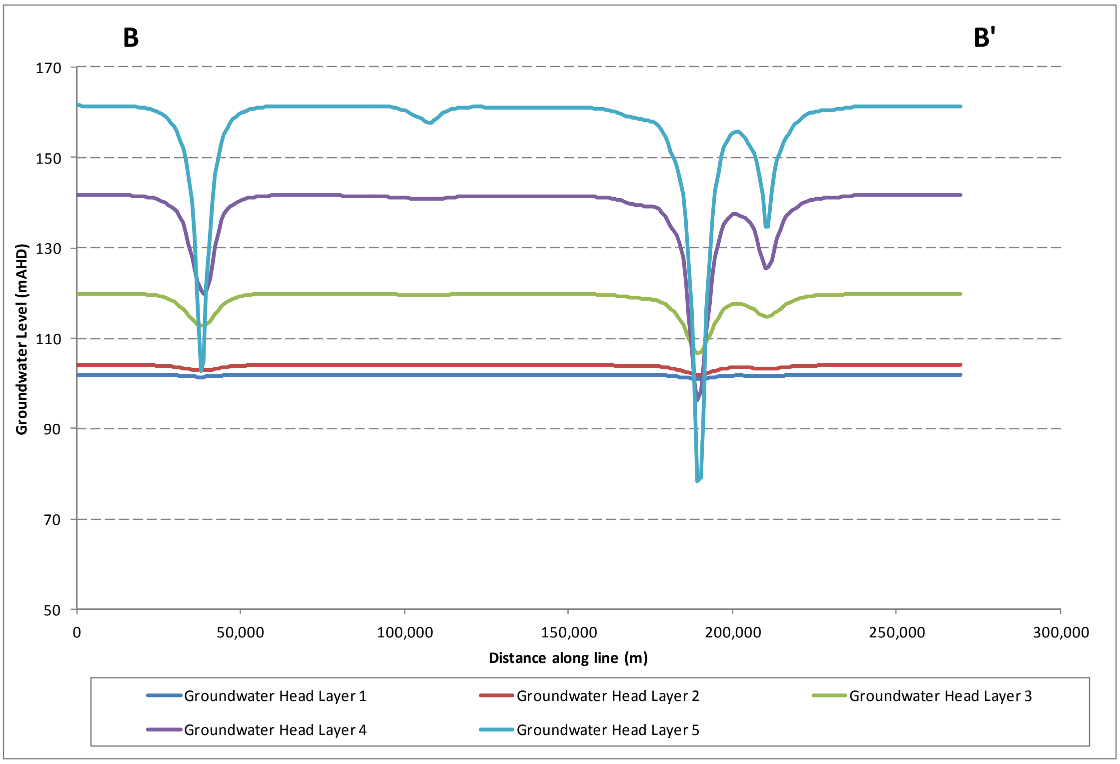
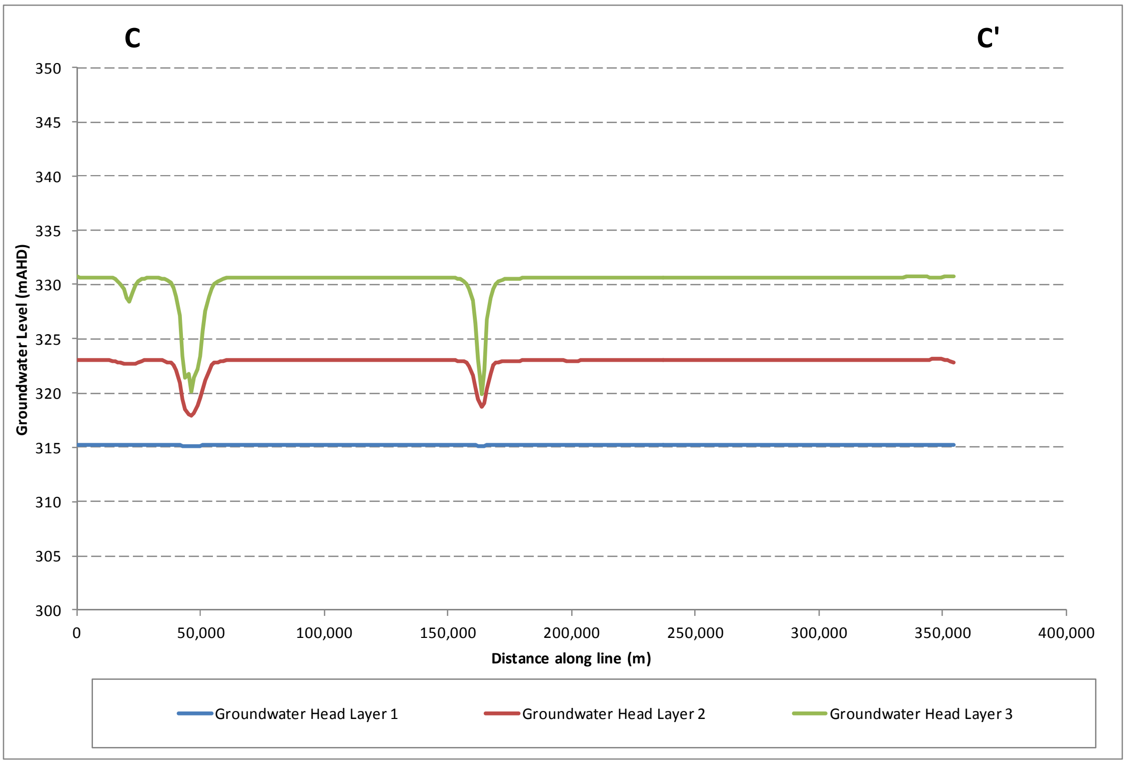


Figure 63: HPSA1: Long Term Affected Groundwater Cross Section A-A' and B-B'



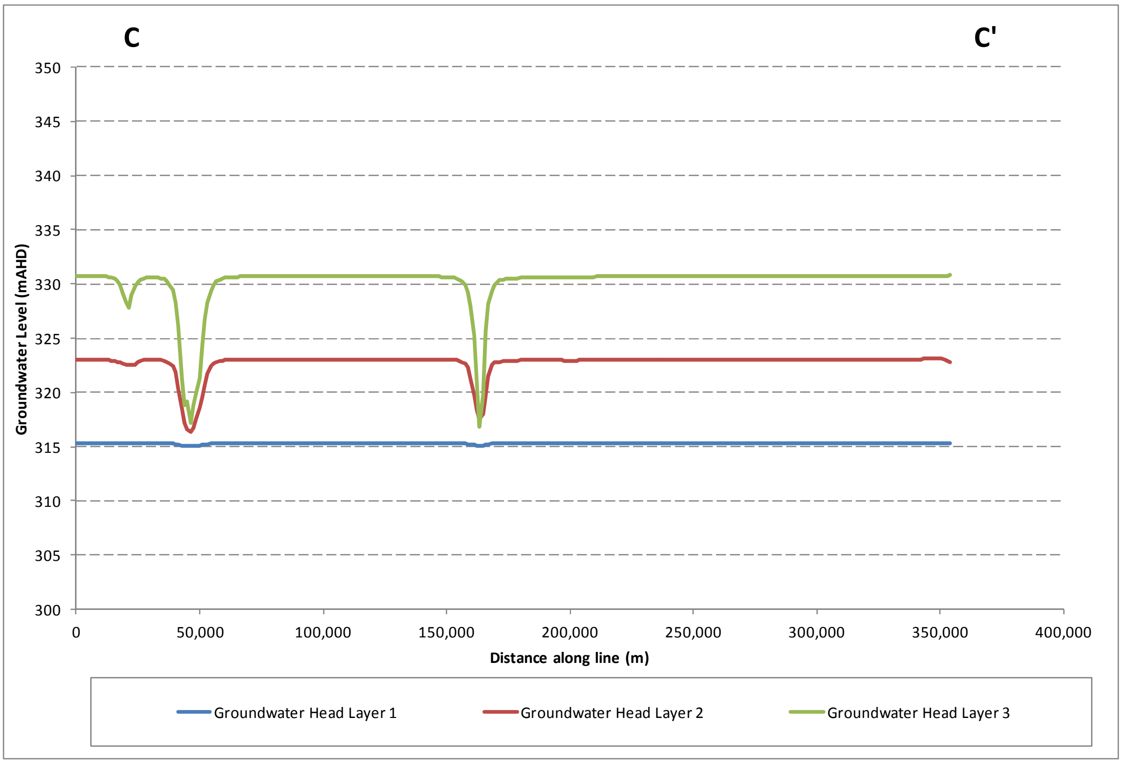


Figure 64: HPSA2: Immediately and Long Term Affected Groundwater Cross Section C-C'

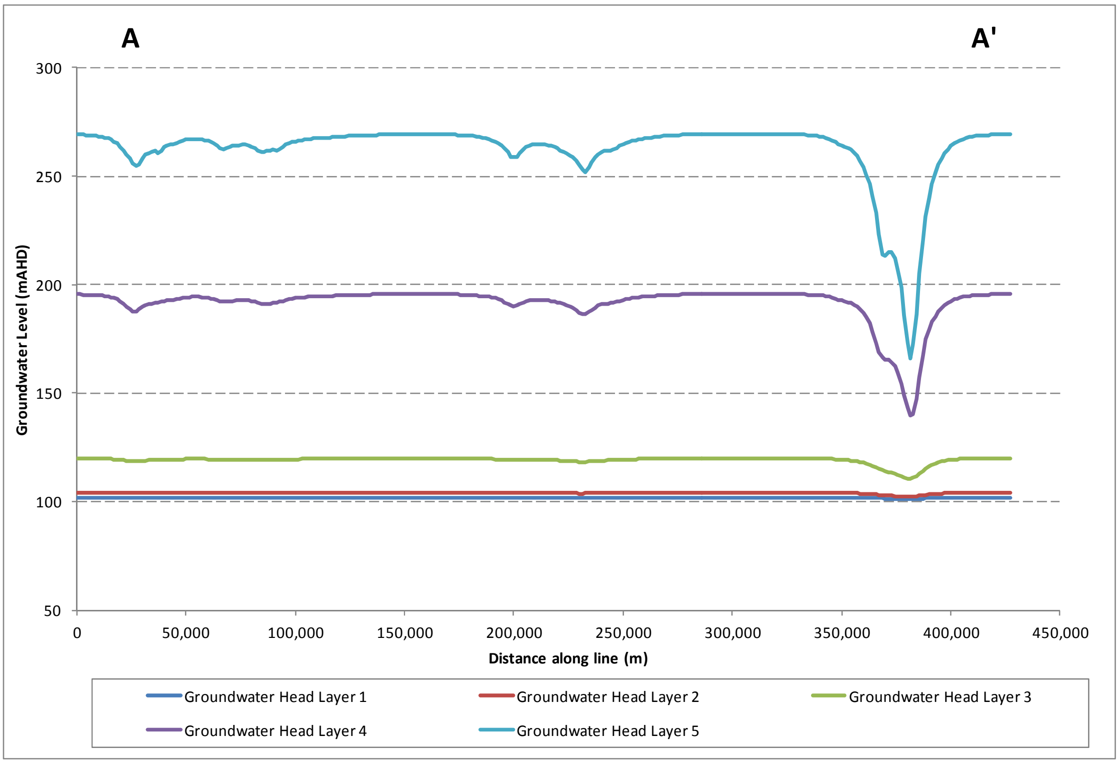


Figure 65: ESA1: Immediately and Long Term Affected Groundwater Cross Section A-A'

The maximum calculated pressure decline in each layer along these lines of section is shown in Table 32.

Table 32: Sensitivity Analysis Maximum Drawdown along lines of section

Model Layer	Maximum Calculated Drawdown along line(s) of section (m)					
	HPSA1		HPSA2		ESA2	
	Immediately Affected	Long Term Affected	Immediately Affected	Long Term Affected	Immediately Affected	Long Term Affected
Layer 1	1	2	0	0	1	1
Layer 2	3	3	5	7	2	2
Layer 3	14	16	11	14	8	9
Layer 4	41	45	-	-	50	56
Layer 5	75	83	-	-	92	103

7.7 Summary of Key Points from Analytical Calculations

A summary of the modelled drawdown for the predictive modelling and sensitivity analysis modelled is given in Table 33 and Table 34.

Table 33: Summary of Predictive and Sensitivity Analysis Drawdown for the Eromanga Basin

Model Layer	Maximum Immediate Drawdown (m)			Maximum Long Term Drawdown (m)		
	Predictive Model	HPSA1	ESA1	Predictive Model	HPSA1	ESA1
Layer 1	1	1	1	1	2	1
Layer 2	2	3	2	2	3	2
Layer 3	11	14	8	12	16	9
Layer 4	52	41	50	58	45	56
Layer 5	104	75	92	115	83	103

Table 34: Summary of Predictive and Sensitivity Analysis Drawdown for the Cooper Basin

Model Layer	Maximum Immediate Drawdown (m)		Maximum Long Term Drawdown (m)	
	Predictive Model	HPSA2	Predictive Model	HPSA2
Layer 1	2	0	2	0
Layer 2	7	5	9	7
Layer 3	12	11	15	14

Key points from the sensitivity analysis analytical calculation are:

- There is only limited variation between the sensitivity analysis results and the predictive model results. This gives confidence in the predictive model results in terms of potential impact from the Queensland extraction only model and the Queensland plus South Australia model run; and
- Eromanga Basin sensitivity analysis ***HPSA1*** (increasing the vertical hydraulic conductivity of the seal rock [Layer 3] above the target extraction zone) in the Eromanga Basin did not significantly alter the model estimated results:

In Layer 2 (the Tertiary Sediments and Winton Formation aquifers) drawdown in increased by 1 m in both the immediately and long term affected areas (from a maximum drawdown of 2 m to 3 m):

In Layer 3 (the over burden consisting of the Mackunda Formation to Wallumbilla Formation directly overlying the Cadna-Owie Formation) maximum drawdown was increased by 3 m (from a maximum drawdown of 11 to 14 m) in the immediately affected area and by 4 m (from a maximum drawdown of 12 to 16 m) in the long term affected area;

- Cooper Basin sensitivity analysis ***HPSA2*** (increasing the vertical hydraulic conductivity of the seal rock [Layer 2] above the target extraction zone) in the Cooper Basin did *not* significantly alter the model estimated results:
  - In both the immediate and long term affected areas, the maximum drawdown decreased by between 1 to 2 m from the predictive model.

8.0 POTENTIAL IMPACTS

8.1 Risk Assessment Process

Potential impacts related to water from pumping activities over the oil and gas fields have been systematically evaluated using a risk based assessment framework. This section provides the approach followed for the risk assessment performed for the water management activities associated with the oil and gas operations in the Cooper Basin.

Drivers for Risk Management:

Risk is to be managed to generally control two major elements:

- The impact of the activities on potential receptors; potential receptors being:
  - Environmental values described in Section 4.4 and particularly groundwater dependant ecosystems and river baseflow (watercourse springs),
  - The local community through town or individual domestic water supplies, recreational areas and activities, agricultural activities relying in groundwater and industrial groundwater users; and
  - Site workers (public health risks);
- The regulatory risks:
  - Adherence to the specific conditions for the operations (EAs); and
  - Adherence to the intent of the applicable legislation.

Risk Assessment Process

A risk is defined by the Australia/New Zealand Standard for Risk Management (AS/NZS 4360:2004) as *the chance of something happening that will have an impact on objectives*. It is measured in terms of a combination of the consequences of an event, and the likelihood of an event occurring.

The potential risks and their impacts to groundwater and environmental values associated to the current operations have been identified. The potential risks were evaluated and assigned a risk ranking according to the likelihood of the risk occurring, and the associated consequences (Table 35).

The matrix used to evaluate the risk consequences is the standard *Santos EHSMS risk assessment matrix* (developed in accordance with ANZ 4360:2004) presented in Appendix B, which includes a description of the categories of consequences considered, and a description of the relative magnitude of consequences for each category.

An analysis of the likelihood and consequence for each risk resulted in the risk issue being assigned a risk tolerance, *likelihood* and *consequence* are defined as:

- The likelihood is the *probability for an event to occur*;

- The consequence is the *effect that the event will have on different receptors or parameters*. The consequence can be to human health and safety, to the natural environment and to the Project reputation. Consequences can also be of financial matters.

Category between one (tolerable) and five (least tolerable), according to the matrix presented in

Table 36 and the hierarchy of risk analysis presented in Figure 66. A risk issue assessed as Category 1 is considered to be tolerable in its current state, without the need for mitigation actions to reduce the risk; these generally represent risk issues that are either very unlikely to occur, or that would result in a minor or negligible consequence if they do occur. Risk issues assessed as Category 2 to 5 may still be tolerable but require further evaluation of potential contingency actions or mitigation measures.

The development and implementation of management and mitigation measures by Santos have allowed the re-evaluation of the level of some of the risks.

Table 35: Risk Assessment Definitions (Santos)

	Consequences				
Consequence Type	**Negligible**	**Minor**	**Moderate**	**Major**	**Critical**
Health and Safety	Minor injury - first aid treatment	Injury requiring medical treatment with no lost time	Injury requiring medical treatment, time off work and rehabilitation	Permanent disabling injury and/or long term off work	Fatality
Natural Environment	Negligible impact. Reporting according to routine protocols	Impact on fauna, flora and/or habitat. Immediate regulator notification	Short term impact on sensitive environmental features. Triggers regulatory investigation.	Long term impact of regional significance on sensitive environmental features. Regulatory intervention/action.	Destruction of sensitive environmental features. Regulatory & high level Government intervention/action.
Reputation	Little public awareness and no concern. No media coverage	Some impact on business reputation. Adverse news in local media.	Moderate to small impact on business reputation. Qld media exposure.	Significant impact on business reputation and/or national media exposure.	Critical impact on business reputation /or international media exposure

Table 36: Santos Risk Matrix and Risk Tolerance Definition

			Consequence				
			I	II	III	IV	V
Likelihood	**Almost Certain** Is expected to occur in most circumstances	A	2	3	4	5	5
Likelihood	**Likely** Could occur in most circumstances	B	1	3	3	4	5
Likelihood	**Possible** Has occurred here or elsewhere	C	1	2	3	3	4

			Consequence				
	Unlikely Hasn't occurred yet but could	**D**	**1**	**1**	**2**	**2**	**3**
	Remote May occur in exceptional circumstances	**E**	**1**	**1**	**1**	**1**	**2**

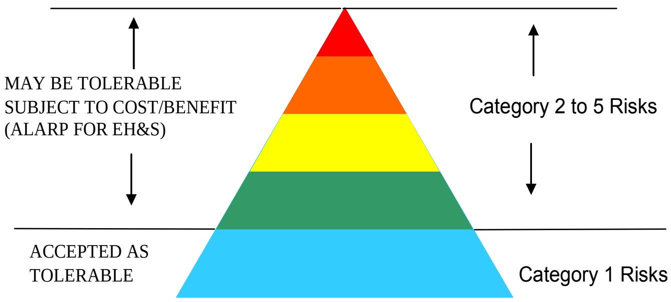


Figure 66: Hierarchy of Risk Tolerance (Santos EHSMS)

8.2 Identification of Risk to Environmental Values

The potential risk identification was undertaken following an operational approach (i.e. based on activities)

Operational risks include:

- Drilling, bore design, bore completion, hydraulic fracturing activities, and bore integrity of oil and gas exploration and production wells;
- Groundwater extraction associated with oil and gas operations;
- Produced water gathering, distribution, management, storage and disposal;
- Water treatment operations; and
- Other project infrastructures such as roads and camp services, irrigation and water supply.

Note: this section identifies generic risks and impacts *potentially* associated to oil and gas activities. The assessment against Santos specific operations is provided in Section 8.3.

8.2.1 Drilling, Well Installation and Well Integrity

Associated Risks

The primary risks associated with drilling, well installation and well integrity include:

- Creating an artificial connection between water-bearing formations that bypasses aquitards;
- Loss of drilling fluid into the formation (resulting in degradation of water quality);
- Contamination of deep aquifers, shallow aquifers, soil and surface water from the drilling fluids;

- Inappropriate control of artesian flows, if encountered; and
- Hydrocarbon and/or aquifer cross-flow or depletion from corrosion of un-cemented casing string sections by Permian oil or gas due to high levels of corrosive fluids.

The factors that traditionally contribute to these risks include inadequate design, construction and well head completion techniques for the wells, poor planning of drilling programmes, inappropriate drilling techniques and/or drilling and drilling fluid selection, and inappropriate abandonment methods.

Potential Impacts

The potential impacts associated with improper drilling, well installation, well integrity or borehole abandonment include depressurisation and/or cross-contamination of groundwater resources through leakage within the borehole, groundwater quality impacts resulting from loss of drilling fluid to the formation, and cross-contamination or depressurisation of water-bearing formations through inadequate control of flowing artesian conditions. In addition to groundwater impacts, mismanagement of flowing artesian conditions can result in water quality changes, erosion and surface water impacts from uncontrolled overland flow of artesian water into surface water courses.

The environmental values at risk from potential impacts related to drilling and well installation include:

- *Human consumptive uses* such as groundwater supply for drinking water and primary industry, which could be affected either through degradation of groundwater quality to a condition that is unsuitable for current uses, or depressurisation of water supply aquifers through inter-borehole leakage. Migration of saline water through leaky boreholes is a commonly observed impact from poor well completion or borehole abandonment techniques;
- *Aquatic ecosystems*, which could be affected by degradation of shallow aquifers that contribute baseflow to surface water features, or induced vertical leakage of water table aquifers resulting in reduced spring flow or baseflow contributions to aquatic ecosystems. Aquatic ecosystems would also be vulnerable to uncontrolled discharge of flowing artesian water, particularly where erosive scouring and increased sediment loads are involved.

8.2.2 Hydraulic Fracturing

Associated Risks

The risks associated with hydraulic fracturing processes are similar to those for drilling and well installations, as such:

- Loss of hydraulic fracturing fluid into the formation (resulting in potential degradation of water quality);
- Contamination of deep water table aquifer, soil and surface water from the storage and handling of hydraulic fracturing fluids at surface; and
- Health risks to aquatic and human receptors resulting from potential migration of hydraulic fracturing fluids components.

The factors that traditionally contribute to these risks include inadequate process design, constitution of the hydraulic fracturing fluids, and inappropriate management of hydraulic fracturing fluids and flowback at surface.

Potential Impacts

The potential impacts associated with hydraulic fracturing include contamination of the targeted aquifer from loss of hydraulic fracturing fluids to the formation and cross-contamination of groundwater resources through leakage within the borehole. In addition to groundwater impacts, mismanagement of fracturing fluids at surface during preparation or flowback can result in impacts to the water table aquifer and surface water system.

The environmental values potentially at risk from impacts related to drilling and well installation include:

- Human consumptive uses such as groundwater supply (deep aquifer or water table aquifer through uncontrolled release at surface) for drinking water and primary industry, which could be affected either through degradation of groundwater quality to a condition that is unsuitable for current uses;
- Soils and aquatic ecosystems, which could be affected by uncontrolled discharge of hydraulic fracturing fluids.

8.2.3 Groundwater Extraction

Associated Risks

The risk associated with extraction of groundwater during production of oil and gas is a risk of depressurisation of the target aquifer and potential induced leakage from overlying and underlying aquifers.

Potential Impacts

- Potential loss of available drawdown in bores and loss of artesian pressure

  The potential loss of drawdown in bores would affect Water Act bores in a region largely relying on groundwater for water supply and cattle farming. Groundwater usage has been discussed in Section 5.9. The risk analysis takes into account the target depth of these bores and the estimated impact from groundwater extraction (Section 6.0). The assessment and results of the potential impacts in view of these characteristics are discussed in Section 8.3.

- Subsidence

  Subsidence is a potential impact only if associated to extraction of sufficient volumes of water to depressurise one or several aquifers to the extent that the vertical effective stress (i.e. the stress that is carried on the rock skeleton due to the weight of the overburden to the surface) may increase sufficiently to cause settlement.

- Water quality changes

  Water quality changes may occur through inter-aquifer flow where higher salinity water is leaking into a low salinity aquifer thus contaminating the receiving aquifer. To enable water quality changes through induced leakage, both the volume of groundwater extracted and the hydrogeological characteristics of the aquifers are to be considered. The assessment and results of the potential impacts in view of these characteristics are discussed in Section 8.3.

- Loss of baseflow

  This potential impact would only be possible if groundwater extraction associated with the oil and gas production would result in a drawdown within the water table aquifer and if the water table aquifer was providing baseflow to streams.

- Impact on GAB springs

  Impact on GAB springs would result from a pressure drop in GAB aquifers due to extraction of large volumes of water. The depressurisation would need to propagate a certain distance. In the case of Santos operations, the nearest GAB spring is located at 90 km from Santos tenements. The results from the groundwater impact assessment will provide the basis of the risk assessment (Section 8.3).

8.2.4 Water flooding

Associated Risks

The risks associated with the water flooding activities are the risk of creating inter-formation connectivities, degrading adversely water quality of the receiving aquifer and over-pressurising the receiving aquifer.

The risk analysis for water flooding was carried by URS (URS, 2010).

Potential Impacts

The potential impact for migration of injection fluid out of the target formation into the aquifers would be due to wellbore integrity, fracture stimulation process of producing wells (see Section 8.2.2) and possible presence of conductive faults.

Degradation of the water quality in the receiving aquifer is dependent on the water quality used for water flooding and the potential for reactivity with the receiving aquifer.

Over-pressurisations may create fractures which could result in localised groundwater flows between formations.

8.2.5 Gathering and Water Disposal Systems

Gathering systems comprise the pipelines and associated infrastructure used to transport produced water from production wells. The water is transmitted to surface storage.

Associated Risk Issues

The primary risk issue associated with the gathering systems relevant to groundwater resources, is an uncontrolled release of produced water to the environment. This could result from a leak or break in the pipelines, or leakage from risers, drains and separators in the pipeline network.

The primary risk issue for water storages would be an uncontrolled discharge to the environment, either through vertical seepage through the base of unlined dams or ponds, or a catastrophic failure of the embankment. This could cause seepage into the groundwater aquifers and discharge to surface water courses.

Potential Impacts

An uncontrolled release of produced water from a gathering system could potentially impact shallow groundwater quality, depending on the size and location of the release, the nature of the soils, and the relative quality of the produced water compared to shallow groundwater quality. Related environmental impacts could include surface water contamination, soil contamination, and soil erosion.

The environmental values that would potentially be affected by an uncontrolled release are generally those that are associated with shallow groundwater systems. Potential contamination of a groundwater resource supporting municipal supply or primary industry uses would be the main concern for this scenario. It is likely that an uncontrolled release from a gathering system would be relatively limited in aerial extent, and as such any resulting impact to shallow groundwater should be localised. Aquatic ecosystems could also potentially be affected, either through direct overland runoff of produced water into a surface water body or via infiltration into shallow groundwater and subsequent discharge of a contaminant plume into a surface water body.

The groundwater values most likely to be affected by an uncontrolled release of poor quality water from a storage structure include human consumptive uses such as drinking water supply, and supply to primary industries and other industrial uses. Whilst municipal water supply bores often target deeper aquifer formations for security purposes, domestic water supply bores tend to preferentially access shallow groundwater resources to reduce the costs of well installation.

In the event of an impact to shallow groundwater that contributes to spring flow or baseflow, the aquatic ecosystem, and potentially the recreational and aesthetic amenity, associated with the receiving surface water body could be indirectly affected by impacts to shallow groundwater quality.

8.2.6 Project Infrastructure

In addition to water gathering and storage systems, oil and gas operations are supported by a range of additional infrastructure, including road networks, accommodation and related amenities for employees (possibly including STPs for sewage and grey water treatment), operations and maintenance facilities, gas and oil process facilities.

Associated Risk Issues

The groundwater risks related to surface infrastructure are limited to potential contamination of shallow groundwater resources by the various waste streams generated by the support infrastructure. The potential risk to groundwater quality would be commensurate with the volume and quality of any uncontrolled release to the environment.

Potential Impacts

The primary groundwater-related impact associated with a waste stream release would be contamination of shallow groundwater resources. Related impacts would include soil contamination, and potential surface water contamination depending on the location and nature of the release.

8.3 Assessment and Results of the Risk Analysis

The assessment of the risks and potential impacts considers initially the inherent risk of oil and gas productions (inherent risk rating) and then the site specific risks inclusive of current risk managements and controls (residual risk rating).

The assessment and results are discussed below and summarised in Table 37.

8.3.1 Drilling, Well Installation and Well Integrity

The potential impacts from drilling and well installation can result in high level consequences, however the likelihood of the risk is considered relatively low due to:

- The high level compliance of well drilling and installation now required by the petroleum industry licence conditions. The current industry standards for well completions are as a minimum consistent with good industry practice as set out in the *Minimum Construction Requirements for Water Bores in Australia, Ed.2, Revised Sept 2003* (Land and Water Biodiversity Committee, 2003), and as prescribed in DERM's *Water Act 2000 - Water Bore Drillers' Licensing Handbook*. Those standards have always required the casing (i.e. isolation) of the overburden formation from the opened interval as illustrated on Figure 67 for gas production wells.

- Well integrity is monitored through monitoring of well casing and testing of casings every one to three years dependant on risk level, number remaining un-cemented barriers for all Permian well;

- Upon completion of their service life the production wells and any other wells no longer required are decommissioned by pressure grouting. This provides for appropriate stewardship of the potential long-term risk of borehole degradation over time, which is so prevalent amongst old GAB bores that have never been reconditioned or appropriately decommissioned. Well suspension and abandonment are undertaken in accordance with the Statement of Environmental Objectives and Santos defined EHS Management Standards;

- Due to the depth of the formations targeted by Santos operations in SWQ, the drilling and completion of oil and gas wells encounter much higher pressures than water bores drilling and completion. High levels of operational standards are required to control those high pressures.

The gas and oil wells are targeting formations which are not targeted for groundwater extraction as their primary role due to their depth and the presence at shallower depth of good water supplies. The only exception is the Hooray Sandstone which supplies a limited number of groundwater users (Figure 29 and Figure 30) and within which localised minor oil accumulations are exploited. The groundwater users of the Hooray Sandstone are generally located at distance away of the oil production and are not considered to create any interference with water supply at such distances.

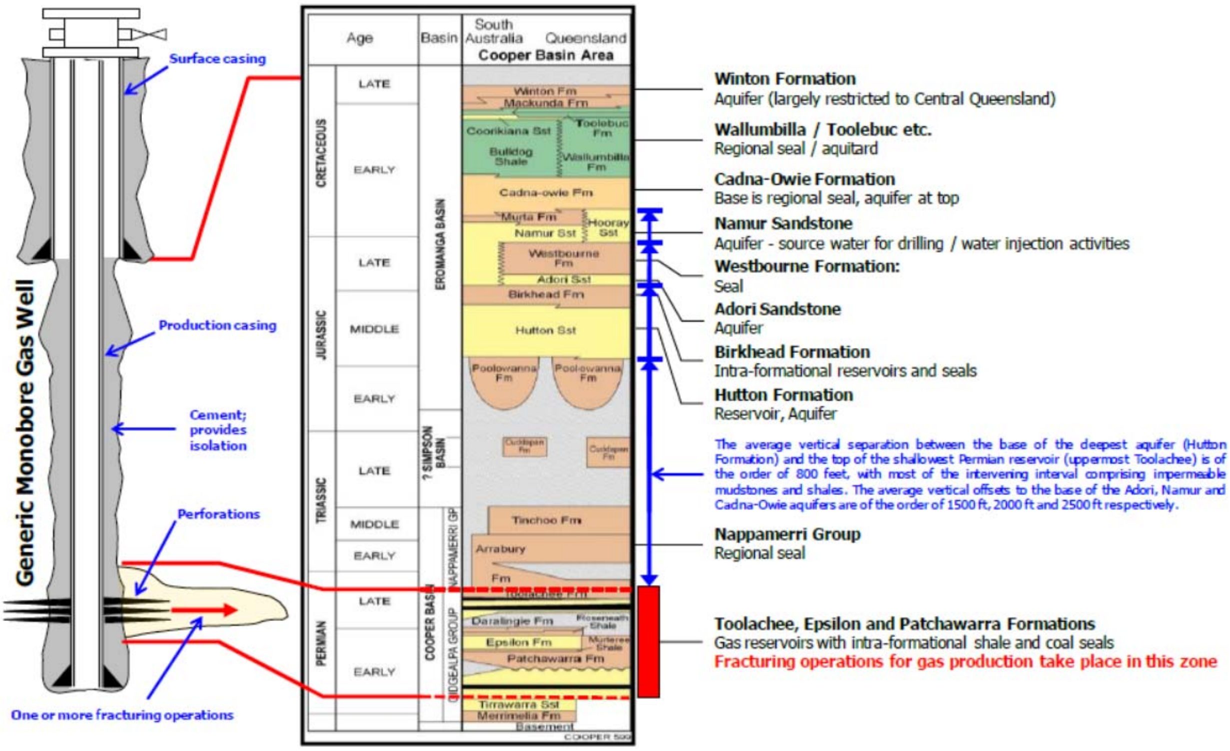


Figure 67: Typical Gas Well Construction Design (from Santos)

The risks to groundwater from drilling and well installation are classified in Table 37.

8.3.2 Hydraulic Fracturing

The use of hydraulic fracturing has recently been limited in the QLD part of Santos Cooper Basin activities mostly due to the remoteness of the sites and long travel distances making the processes logistically difficult and onerous.

The location of previous hydraulic fracturing and planned activities has been discussed in Section 6.3.4.

Although the consequence of contamination from hydraulic fracturing fluids will be major, the likelihood of the contamination occurring was classified as unlikely due to:

- the absence of potential receptors both at depth (i.e. private bores targeting the same geological units) and at surface (limited surface water network and absence of environmental values – Section 4.5);
- the geological and fracture (simulation) modelling undertaken prior to pumping the main treatments, - with the intention of identifying and constraining the physical limits of fracture zone growth (in or out of zone); and
- The monitoring and disposal practices in place in Santos Cooper Basin oil and gas fields for handling of hydraulic fluids.

8.3.3 Groundwater Extraction

The order of magnitude of groundwater extraction (Section 7.0) has been taken in consideration for the risk assessment rating. To summarise:

- Gas production in SWQ produces an average of 150 ML/year groundwater, over 191 wells (currently). The volume of groundwater associated to the production of gas is insignificant and will not result in any depressurisation;

- Oil production in SWQ produces an average 6,092 ML/year of groundwater, most of which (4,998 ML/year) is produced from the Hutton Sandstone. The production area is geographically large and extraction is from approximately 230 producing oil wells in Santos activities in SWQ.

The impacts from groundwater extraction associated with the oil and gas productions have been assessed and are reported in Section 6.0. The groundwater impact assessment concluded that:

- The impact of extraction in the Cooper Basin does not extend beyond the top of the Cooper Basin and can be discounted from the cumulative assessment. No dewatering was predicted above the Tinchoo Formation;
- There was predicted to be less than 2 m drawdown due to deeper extraction on the Quaternary, Tertiary and Winton Formation aquifers. This is considered within the margin of error of the analysis. Furthermore, as this is from steady state analysis, it is considered a worse case scenario. Actual observed drawdown is likely to be less; and
- The calculated drawdown in the combined layer of the Cadna-Owie Formation and Hooray Sandstone (Layer 4 in the analysis) was approximately 52 m in the immediate affected area and 58 m in the long term affected area. Actual drawdown is likely to be much less than this due to the transient nature of the extraction as well as the presence of low permeability layers within the strata that could not be captured in the analysis. Intermittent low permeability layers would be expected to retard the propagation of drawdown vertically upwards, limiting this impact.
- The effectiveness of the low permeability layers to retard the vertical propagation of drawdown is demonstrated in the Tickalara and Iliad Fields. Here, a survey of pressures in the target oil beds and the overlying formation demonstrated that depressurisation due to extraction is confined to the target beds by the overlying seal beds (Figure 17and Figure 18); and
- The effectiveness of the aquitards was investigated in the sensitivity analysis (HPSA1 and HPSA2). This demonstrated that even with an increase in the vertical hydraulic conductivity of the aquitard seal rock above the target formation) there was still minimal impact on the overlying strata

Section 5.3 provided an available example of the depletion of pressure in each target formation due to the overlying confining aquitard. The effect of these low permeability layers could not be captured in the analytical analysis due to the simplicity of the methodology. However, it is anticipated that the observed effectiveness of the aquitards (seal beds) at Tickalara and Iliad Fields would be observed in the remainder of the Eromanga Basin. It should also be noted that the presence of hydrocarbons is by its nature confined by a sealing trap mechanism. Cross-flows between multiple layers due to depletion or over-pressuring is further limited as a result.

These figures show trends in the observed pressure in each target formation are plotted with a green dashed line. The manner in which these repeat with each target formation demonstrates the effectiveness of the overlying seal in retarding the vertical impact of extraction.

As a result the risks of depressurisation of the groundwater systems and other risks associated to groundwater extraction were rated low.

8.3.4 Water Flooding

The risks from water flooding were rated low for the following reasons:

- Over-pressurisation of target zone from injection:
  - General operations do not result in exceeding fracturing pressures; however, fractures (if created) would be limited to the near-wellbore region, contained within the Birkhead and have no impact upon aquifers
  - No groundwater users in the area are targeting aquifers deeper than the Winton Formation

- Risk of reactivity of injected fluid with target zone:
  - Groundwater for water flooding is now sourced from treated produced water, the Namur aquifer which water quality has been demonstrated to be compatible with groundwater of the Birkhead Formation (URS, 2010) is only used as a complementary or backup water source.
  - Comprehensive analysis of waters was undertaken prior to project startup
- Potential for migration of injection fluid out of target formation into aquifers:
  - The Murta Formation oil reservoir lies from about 700 - 800 m below surface, the Birkhead Formation reservoir target lies 1,300 m below the surface. Both are overlain by thick regional impermeable seal rocks; stratigraphy provides natural isolation of target zone.
  - Groundwater bores in the area are targeting aquifers no deeper than the Winton Formation (note: for bores which target aquifer can be defined).
  - Wellbore casing isolates Birkhead Formation impact zone from groundwater.
  - A tracer program indicates a closed system with water injection and oil production contained within the Birkhead Formation zone (URS, 2010).
  - Local surface water bodies are not in connection with deeper aquifers (e.g. Namur Sandstone).
  - No major faulting is evident in the area.

8.3.5 Gathering and Water Disposal Systems

The potential risk issues associated with water storage activities were rated as Category 1 to 2 risks after assessment of water production volumes, pond sizes, operations and environmental settings.

Of the various scenarios considered, the highest risk rankings (Category 3) were related to potential seepage into the soil and shallow groundwater system.

8.3.6 Project Infrastructures

The potential risk issues associated with the Project infrastructure were rated as Category 1 risks. In all cases, either the likelihood or consequence related to various uncontrolled release scenarios was considered to be low, based on the control measures in place for managing each of the waste streams, or the relatively minor volumes or innocuous nature of certain waste streams, or the physical distance from the nearest sensitive receptor.

8.4 Risk Control and Mitigation to Reduce/Manage Impact Levels

The principal issues of concern with respect to potential risks to groundwater availability and quality arising from oil and gas activities have been identified as reduced access to groundwater resources supplying stock, domestic and other licensed uses, and potential impacts to groundwater quality (especially to shallow groundwater resources) associated with an uncontrolled release of poor quality water or hydrocarbons.

These issues are also amongst the primary concerns of local bore owners and the regulators (e.g. DERM). To address these high priority concerns, Santos has adopted a combination of preventative actions and management options to reduce the likelihood of adverse impacts occurring and to mitigate those risks.

8.4.1 Drilling, Well Installation and Well Integrity

Well construction design has been discussed in Section 8.3.1. The integrity of wells and risks of well failure are monitored by a dedicated well integrity team established in 2004. The well integrity management actions include:

- The monitoring of integrity of well by monitoring well casing.

  - All Permian well casings are tested every 1 to 3 years dependant on risk level and the number of remaining un-cemented. Well's casing strings are monitored by blowing down any trapped pressure, topping up with corrosion inhibited brine, pressure testing. The results are reviewed by field technician, database and well files are updated accordingly. Where issues have been flagged, further action is undertaken in liaison between Production operators & Petroleum Engineering staff.
  - Casing Pressure monitoring: Where Remote Operational Control telemetry is not connected to the casing, production operators monitor well casing pressures quarterly and notify Petroleum Engineering of abnormal pressures or changes.
  - Additional monitoring is advised on a case-by case basis by Petroleum Engineering.
- An annual surveillance maintenance programme across entire Cooper Basin well asset with capability to repair wells in event of sub-surface integrity problem and capability to suspend or plug and abandon wells in full compliance with Statement of Environmental Objectives

8.4.2 Hydraulic Fracturing

The hydraulic fracturing activities have been described in Section 8.4.3.

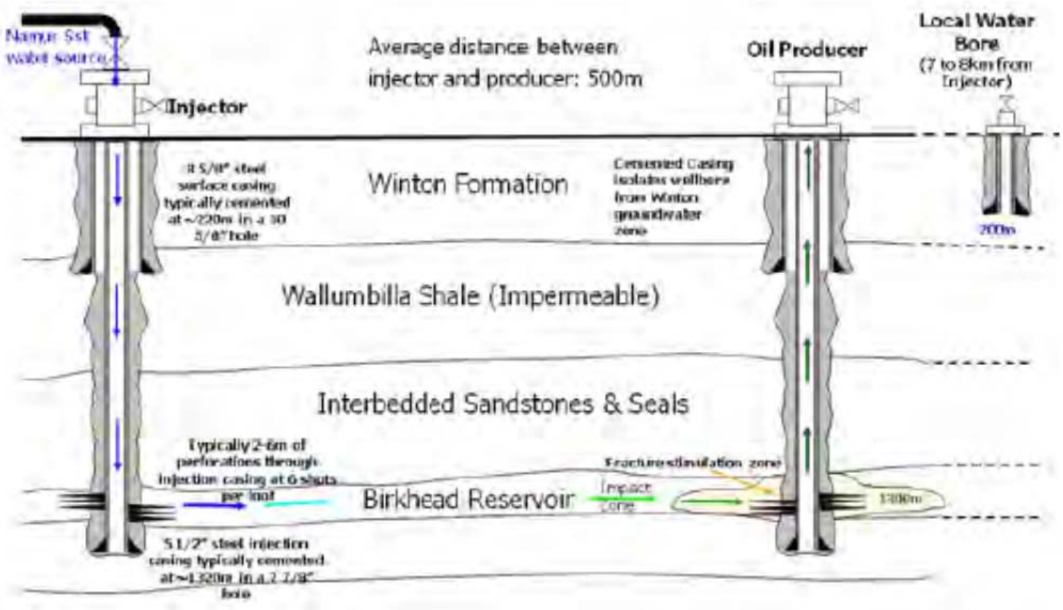
The risk associated with hydraulic fracturing is further controlled by:

- A process of both geological and fracture (simulation) modelling prior to pumping the main treatments, with the intention of identifying the physical limits of the fracture growth zone/s (in or out of zone) and to ensure the fluids pumped stay within the defined zone);
- Monitoring and control of the chemistry of the fluid to ensure the fluid is at the right conditions to mix, hydrate, crosslink during treatment and then break on flow back. Laboratory testings are performed for the entire duration of the stimulation.

8.4.3 Water flooding

Risk management procedures for water flooding include the following:

- Adherence to the flood well design illustrated on Figure 68. The design ensures the full integrity of the different formations is preserved. In addition well integrity is checked through regular mechanical integrity checks; and
- Effective management and monitoring of the waterflood program:
  - Metering, well testing and production allocation;
  - Chemical tracer program;
  - Regular produced water sampling (quarterly).
  - Reservoir and injection pressure monitoring.
  - Quarterly casing integrity checks.



Note: oil well design in this diagram is stylised and simplified; all oil well construction details are not shown.

Figure 68: Typical Water Flood Well Design

8.4.4 Pond and Dam Construction

Santos ponds are designed following the internal engineering standards defined in Santos EHSMS system (Santos Engineering Standard, DESIGN PRACTICE 1515-10-G008-0, Rev 2, 2005).

IN SWQ where a number of evaporation ponds are present, the ponds have been sited and designed to comply with the following requirements (Santos EHSMS):

- Operational / Engineering Criteria, evaporation ponds shall:
  - be contained within the field PPL boundary;
  - be located so as not to interfere with infrastructure or the requirements of other land users (e.g. landholders and tourists);
  - be located an appropriate distance from roads or other infrastructure (e.g. greater than 20m) so as not to create an unacceptable danger to humans or to stock and wildlife;
  - be readily accessible in all weather by 4WD cab utilities and 4WD vacuum trucks;
  - be optimally located (to minimise pipework lengths, etc.);
  - be downslope of separation facilities (to reduce pumping requirements, etc); and
  - be of sufficient area and allow room for expansion.
- Environmental Criteria, evaporation pond locations shall:
  - not overlie areas of shallow groundwater where that ground water is in use or may be used in the future;
  - not be located in natural watercourses, waterholes, drainage lines, salt lakes, salt pans and floodplains;

- not be located on gibber plains;
- be located in previously disturbed areas or in areas devoid of natural vegetation, or where this is not possible, contain vegetation of low conservation significance;
- avoid known sites of natural, scientific or cultural heritage (indigenous and non-indigenous) significance, and
- prevent significant seepage (ie. preference shall be given to sites with high clay content soils).

New pond designs will be in accordance with the relevant EA.

The relative magnitudes of the risks related to water management activities were used as a guide to developing appropriate risk control measures. The results of the risk assessment indicated that the majority of water management activities currently represent negligible or low risks to human health, the environment or the commercial viability of the Project. A summary table of risk analysis is presented in Table 37.

Table 37: Risk Assessment Results

Risk Issue	Cause	Impact	Inherent Risk Rating	Current Residual Risk Rating inclusive of Mitigation and Controls
Well Construction (Bore Drilling, Design, Completion, Integrity)				
Passage of water between aquifers	Poor design, Construction technique, Poor closure technique	Contamination, Pressure loss, Non-compliance	3	2
Leakage of introduced fluids including mud	Inappropriate muds or drilling technique	Contamination of aquifers and/or surface water	2	1
Artesian Flows	Over pressure/poor mud control/incorrect drilling assumptions	Erosion, loss of reputation	1	1
Hydraulic fracturing Fluids	Use of hydraulic fracturing fluids to increase horizontal connectivity and enhance the production of oil and gas reservoirs	Contamination of deep aquifers and/or surface water , soil and shallow groundwater	3	1
Oil and Gas Wells - Groundwater extraction from the wells				
Leakage between aquifers	Associated water production (limited volumes for gas production, larger volumes for oil production)	Loss of available drawdown in bores	3	2
		Subsidence	2	1
		Water quality changes	3	2
		Loss of baseflow (watercourse springs)	2	1
		Impacts on GAB discharge springs (incl. mound springs) and GAB recharge springs	1	1
		Oil flows well head splits/leaks and gas flows	3	1
Gathering Systems				
Discharge of associated water to environment	Leak of water pipe or controls	Soil/Shallow GW contamination	1	1
		Contamination of local SW	2	1
	Break in pipeline	Soil/Shallow GW contamination	3	1
		Contamination of local SW	3	1
	Leakage from low point drains/separators	Soil/Shallow GW contamination	3	2
Erosion	Design, construction of stream crossings, open areas	Stream water quality	2	1
Water Storage				
Uncontrolled discharge to environment	Seepage - vertical	Shallow groundwater and/or soil contamination	3	2
	Seepage - lateral	Vegetation loss, Discharge to water ways	3	2

Risk Issue	Cause	Impact	Inherent Risk Rating	Current Residual Risk Rating inclusive of Mitigation and Controls
	Dam Break	Damage to property, soil, water, surface infrastructure, loss of asset and associated income, fatality.	3	1
	Operational Failure Overflow, Operational Failure Accidental Release	Damage to property, soil, water, surface infrastructure, and associated income.	2	1
Surface Infrastructure (Road and Camp Services)				
Uncontrolled run-off from roads	Inadequate design and management of waterway crossings	Deterioration of water quality	2	1
Contaminant releases	Effluent release from sewage treatment	Soil and shallow GW contamination	1	1
	Kitchen Waste	Soil and shallow GW contamination	1	1
Workshop and maintenance areas	Chemical storage	Contamination of GW or SW	2	1
Compressor station hazards	Bulk Fuel and chemical storage	Contamination of GW or SW	2	1
Oil station hazards	Bulk Fuel and chemical storage	Contamination of GW or SW	2	1
	Washdown areas	Contamination of GW or SW, weeds	2	1
Water Flooding				
Potential for migration of injection fluid out of target formation into aquifers	Wellbore integrity	Migration of injection fluid out of the target formation into the aquifers	3	1
	Faults	Migration of injection fluid out of the target formation into the aquifers	2	1
Reactivity of injected fluid with target zone	Potential for reactivity with the receiving aquifer	Degradation of the water quality	3	1
Over pressurisation of target zone from injection	Create fractures	Localised groundwater flows between formations	2	1

Abbreviations:

GAB - Great Artesian Basin

SW - Surface Water

GW - Groundwater

9.0 VULNERABILITY ASSESSMENT OF THE ENVIRONMENTAL VALUES

9.1 Vulnerability of GDEs

No GAB discharge springs (including mound springs) are located within the Santos tenements or within 90 km of the tenement boundaries, and none of the predicted drawdown exceed the established triggers for impact to aquifers outside of Santos SWQ tenements (i.e. all modelled impacts are less than 5 m drawdown outside of Santos SWQ tenements) . Two maps indicating the 0.2m trigger threshold for model layers 3 and 4 are presented in Appendix I, using the base case scenario and showing the drawdown contours for the Long Term Affected Area (LTAA) and the Immediately Affected Area (IAA) in the Eromanga Basin model. The formations comprising these model layers are considered to be potential source aquifers for GAB discharge springs in the region. As indicated on the maps in Appendix I, the maximum modelled extent of the 0.2 m depressurisation contour for model layers 3 and 4 is still in excess of 50 km from the GAB discharge springs in the southeast corner of the study area. As such, Santos Cooper Basin operations in SWQ are expected to have no material impact on GAB mound springs.

As a consequence of this outcome, no spring impact management strategy has been developed.

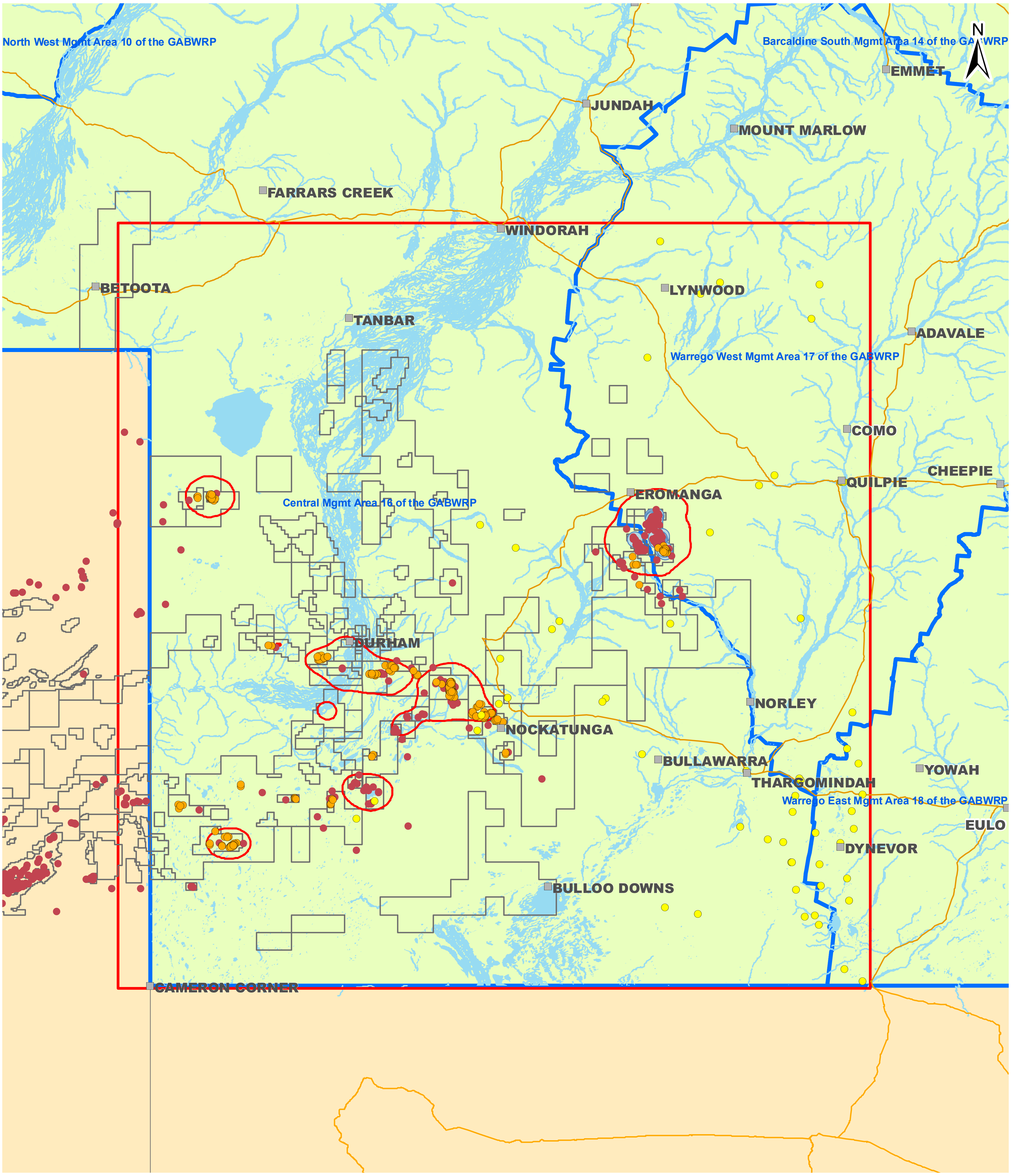
9.2 Vulnerability of Drinking Water and Groundwater Users

Private groundwater use and town water supply are typically sourced from the upper GAB (down to the Hooray Sandstone) and tertiary aquifers.

Potential vulnerability from aquifer depletion through extraction of produced water has been assessed in Section 6.0 and the result indicated no material impacts to any of the aquifers used by the community.

Vulnerability in terms of groundwater quality would potentially only affect bore owners or water supply sources from the Hooray Sandstone which also contains oil reservoirs exploited by Santos (within the Murta Formation mostly and to a lower extend within the Namur Sandstone – refer to Section 6.3.1). The location of Santos activities within the Hooray Sandstone and the groundwater users from the Hooray Sandstone is provided in Figure 69. Note that where no oil is produced from the Hooray Sandstone oil reservoirs, the modelled estimated 5 m drawdown contours are considered conservative as pressure measurements data at two oil fields have demonstrated that the depressurisation does not propagate to overlying layers (refer to Section 8.3.3).

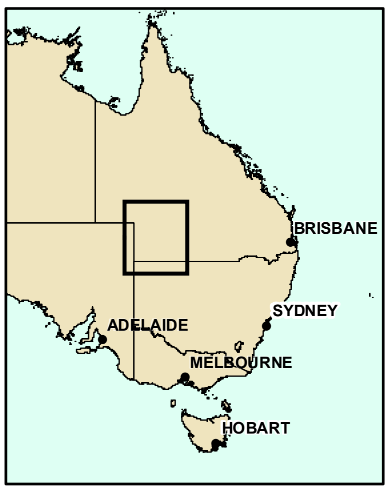
Figure 69 only identifies two private bores (RN23569 and RN6304) in PL33 and PL35 respectively as being within the 5 m drawdown contour. Generic information is available for these bores in the metadata table. These bores should be visited as part of the baseline assessment Santos is undertaking for SWQ and target aquifer should then be confirmed. Make good obligations would be developed as appropriate if necessary in view of the baseline assessment results.



COOPER BASIN UWIR

SANTOS

VULNERABILITY OF GROUNDWATER SOURCES OF THE HOORAY SANDSTONE



LEGEND

- Town/Locality
- Private Bore - Hooray Sandstone
- Producing Oil Well - Hooray Sandstone
- Producing Oil Well - Other Formations
- Water Injection Wells
- Highway/Major Road
- River/Creek
- Drawdown Contour (5 m)
- Santos Operated Permits
- Study Area
- Groundwater Management Area

0 10 20 40 60 80 100 Kilometres

SCALE (at A3) 1:2,000,000

Coordinate System: GCS GDA 1994

PROJECT:	117636010
DATE:	19/12/2011
DRAWN:	AJW
CHECKED:	FH

FIGURE 69

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COPYRIGHT

1. Base information copyright MapInfo Australia Pty Ltd
2. ATP/PL tenure supplied by Santos, August 2011
3. Groundwater Management Area supplied by the State of Queensland (Department of Natural Resources & Water), 2008
4. Drawdown estimated from analytical modelling. Results are considered conservative.

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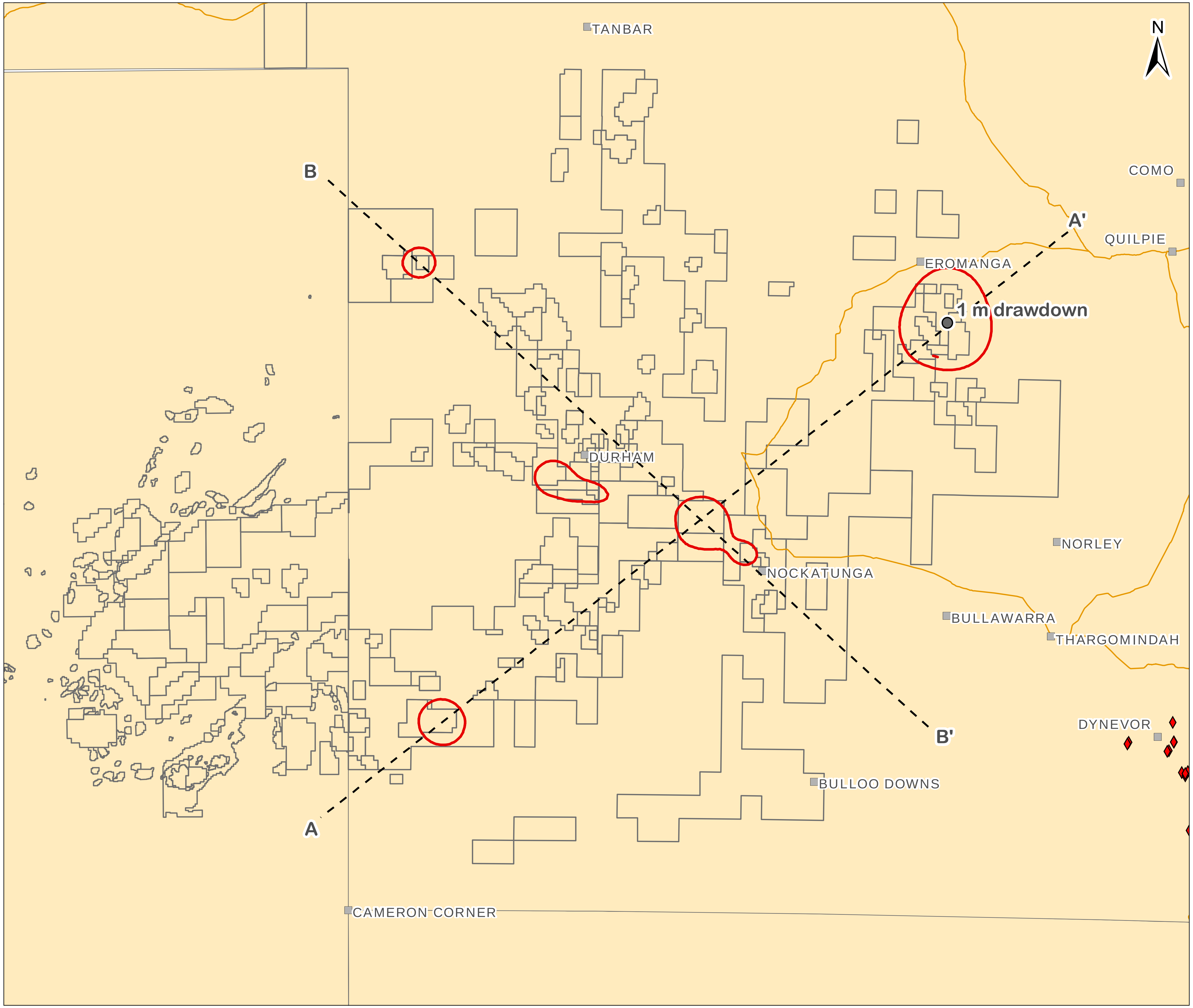
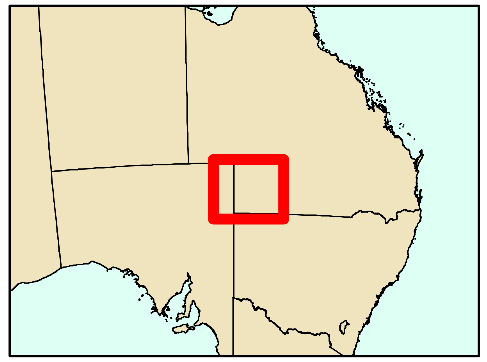
File Location: J:\hyd\2011\117636010 Santos_Copper Basin O&G & Moonie Oil -official folder in BRISBANE\GIS\Projects\117636010_R_F0039_CooperBasinVulnerabilityHooraySst.mxd



UNDERGROUND WATER IMPACT REPORT OIL AND GAS FIELDS SWQ

SANTOS

LONG TERM AFFECTED AREA - EROMANGA BASIN MODELLED GROUNDWATER DRAWDOWN IN LAYER 1 WITH GAB SPRINGS



LEGEND

- GAB ROP Discharge Spring
- GAB ROP Recharge Spring
- Maximum Drawdown
- Affected Area (>0.2 m Drawdown)
- Groundwater line of section A-A'
- Groundwater line of section B-B'
- Town/Locality
- Highway/Major Road
- Santos Operated Permits

NOTES

Insert additional information here.

COPYRIGHT

Insert COPYRIGHT information here.

0 5 10 20 30 40 50 Kilometers

SCALE (at A3) 1:1,500,000

Coordinate System: GDA 1994 MGA Zone 54

PROJECT: 117636010-3000
DATE: 30/07/2012
DRAWN: HW
CHECKED: RH

FIGURE 70

Golder Associates

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9.3 Vulnerability of GAB Aquifers

The volumes of produced water are not resulting in a basin wide depressurisation of the formations.

The result of the groundwater impact prediction concluded that:

- Groundwater extraction from gas production in the Cooper Basin will have negligible impact to groundwater.
- Groundwater production from oil production would have limited impacts on the Hutton Sandstone over the study area. The spatial extent of drawdown was limited to the direct vicinity of the extraction wells. Heavily utilised groundwater aquifers near the surface (the Quaternary, Tertiary and Winton Formations, show very small impact that is not considered significant and is much lower than the trigger levels defined under the Water Act 2000 (Section 2.2).

With regard to preservation of the water quality, operational procedures are in place to prevent any contamination of the GAB formation resulting either from aquifer cross contamination or contamination through injection of fluids during drilling, stimulation or water flooding.

As a consequence, on the basis of information provided to Golder and discussed in this report, there is negligible risk of impact from the Santos SWQ current level of activities on the GAB aquifers.

10.0 GROUNDWATER MONITORING

In view of the site activities, the result of the risk analysis and groundwater impact assessment, the groundwater resources most at risk from Santos activities are the shallow aquifers and the Hooray Sandstone aquifer where it is also a resource for the community.

This section highlights, for the purposes of a more detailed monitoring strategy, the possible basis for and rationale behind groundwater monitoring. A detailed groundwater monitoring program would provide the location, frequency and monitoring type.

10.1 Existing Monitoring

The current groundwater monitoring programs cover the following:

- Santos deep groundwater monitoring associated with the water flooding activities (refer to Section 8.4.3);
- Monitoring associated with the hydraulic fracturing activities (Section 8.4.1);
- Shallow groundwater monitoring associated with:
  - Ballera evaporation pond (8 monitoring bores); the QLD guidelines for the design of pond now require the establishment of shallow groundwater monitoring networks with all new pond.
  - Jackson refuelling station (3 monitoring bores);
  - Jackson landfarm activities (4 monitoring bores);
- DERM GAB monitoring network spread over the project area and targeting the formations of the Eromanga Basin (refer to Section 5.6).

10.2 Groundwater Monitoring Strategy

This section provides the basis for a water monitoring strategy i.e. describe the “why” behind the groundwater monitoring programs and the strategy developed to define the groundwater monitoring programs.

10.2.1 Rationale of Monitoring

A priority ranking to each monitoring activity is proposed. Five priority levels are defined (Table 38). These priorities are used to assist in the development of implementation and sampling schedules and to prioritise monitoring activities when required.

Prioritisation ranking is relevant where all monitoring activities are undertaken as part of a regulatory requirement. The proposed priority ranking is considered to be proactive and to address not only the regulatory requirements but also potential community concern and stakeholders’ requirements, and the need to establish a minimum of environmental baseline data.

Table 38: Monitoring Priority Ranking

Rank	Driver/Category	Description
1	Environmental Incident/Community Complaint Response	Response to an environmental incident (i.e. hydrocarbon spill), or response to a legitimate community complaint.
2	Compliance	Compliance with legislative conditions/monitoring requirements
3	Operational Monitoring	Monitoring of infrastructure facilities which are non-compliance or licence related.
4	Stakeholder Engagement and Relationship	Monitoring of environmental values which are non-compliance or licence related in relation to improving stakeholder relations.
5	Environmental Improvement and Performance	Monitoring of parameters and conditions which are non-compliance or licence related to improve environmental performance or lead to further environmental understanding

10.2.2 Development of Standard Monitoring Suites

Standard monitoring suites are proposed to streamline groundwater monitoring and assist with consistency of the monitoring activities and collected dataset.

The monitoring suites may include field measurements and laboratory analysis as monitoring activities vary from general site observation to in-situ measurements and sample collection for laboratory analysis. The following groundwater standard monitoring suites are defined:

- Groundwater field suite;
- Groundwater baseline suite;
- Hydrocarbon suite; and
- Potable water suite.

These suites apply to:

- The establishment of baseline conditions;
- Regional groundwater monitoring;
- Impact monitoring for groundwater in relation to general fields activities and specific programs.

Field Water Suite

The field suite comprises of a set of basic physical measurements taken with a calibrated multi-parameter water quality meter, and observations to be made during routine monitoring. The field suite is used in most locations and does not involve laboratory analysis. It is undertaken either on its own or in conjunction with the analytical suites defined in the following sections.

Groundwater Suite

This suite includes the field suite parameters and a range of basic water chemistry analyses. This monitoring will enable the definition of the basic characteristics of groundwater.

Hydrocarbon Suite

The Hydrocarbon Suite will address subsurface contamination due to the spill of oils and fuel from production areas, machinery and storage areas.

Potable Water Suite

This suite will be used to verify routinely the quality of the potable water supplied to camps and facilities and will identify variation to the water quality potentially resulting in short term health effect to individuals. This suite has a limited range of analytes inclusive of major ions, metals and microbiology. The suite has been defined according to the Australian Drinking Water Guidelines 2004 (ADWG, 2004) for facilities accommodating less than 1,000 workers or residents.

Table 39: Monitoring Suites Analytes

Analyte Group	Field Water Suite	Groundwater Baseline Suite	Hydrocarbon suite	Potable Water Suite
General Parameters				
Colour				X
Flow rate (where applicable)	X	X		
Water level/pressure (where applicable)	X	X		
Temperature (field)	X	X		
pH (field)	X	X		X
pH (lab)		X		X
Electrical Conductivity (field)	X	X		
Electrical Conductivity (lab)		X		
Turbidity (lab)				X
Hardness		X		X
Total Dissolved Solids - TDS (lab)		X		X
Oxygen Reduction Potential (field - manual)	X	X		
Major Ions				
Total Alkalinity as CaCO3		X		X
Hydroxide Alkalinity as CaCO3		X		X
Carbonate Alkalinity as CaCO3		X		X
Bicarbonate Alkalinity as CaCO3		X		X
Major Cations – Al, Ca, Mg, Na, K		X		X
Sulphate		X		X
Chloride		X		X
Minor Ions				
Ammonia as N		X		X
Nitrate		X		X
Nitrite		X		X
Total Nitrogen (TKN + NOx)		X		X
Fluoride		X		X
Total Phosphorus as P		X		
Reactive Phosphorus		X		
Hydrogen Sulfide				X

Analyte Group	Field Water Suite	Groundwater Baseline Suite	Hydrocarbon suite	Potable Water Suite
Boron				X
Total Cyanide				X
Other Analytes				
Total and Dissolved Organic Carbon		X		
Metals and Metalloids				
Dissolved/Total Metals (including digest where applicable) - Al, As, B, Ba, Be, Cd, Cr, Co, Cu, Fe, Li, Mn, Mo, Ni, Pb, Se, Sr, U, V, Zn		X		X
Mercury - Hg		X		X
Silver - Ag		X		
Strontium - Sr		X		
Tin - Sn		X		
Zinc - Zn		X		
Iron - Fe		X		
Copper - Cu		X		
Manganese - Mn		X		
Microbiology				
E.coli (MF)				X
Standard Plate Count				X
Total coliform				X
Thermo-tolerant (faecal) Coliform				X
Langeliers Index (calc – EC, Ca, Alky, pH, TDS)		X		
Calculated Parameters				
Sodium Absorption Ration – SAR		X		
Ionic Balance		X		
Organics				
TPH (C6-C9),		X	X	
BTEX		X	X	
TPH (C10-C36)		X	X	
PAH (including naphthalene and benzo(a)pyrene)		X	X	
Ethanol				
Formaldehyde				

10.2.3 Groundwater Monitoring Infrastructures

Several types of groundwater monitoring infrastructures are proposed in the groundwater monitoring program:

- Dedicated groundwater monitoring bores targeting specific aquifers, water level and water quality. This may include DERM GAB groundwater monitoring bores;
- Private bores identified from the baseline assessment program as suitable for groundwater quality and/or groundwater level monitoring. The selected bores target a single known aquifer; and
- Multi-level VWP measuring the pressure of the surrounding formation at their installed depth. Multi-level installations allow for monitoring of water levels in various units within the same borehole. The piezometers are cement grouted during installation therefore no water sample can be collected from VWPs.

10.3 Groundwater Monitoring Program

The groundwater monitoring program applies to the monitoring of:

- Regional groundwater; and
- Shallow groundwater associated with surface activities.

The groundwater monitoring program is designed to collect baseline groundwater information and monitor the potential impacts from the petroleum activities (exploration activities, extraction activities and produced water management activities) on identified groundwater environmental values. A copy of the proposed interim groundwater monitoring strategy is provided as Appendix H.

10.3.1 Shallow Groundwater Monitoring

Shallow monitoring programs are site specific and defined within the facility management or monitoring plans.

10.3.2 Hydraulic Fracturing Groundwater Monitoring

The monitoring regime for groundwater monitoring associated to hydraulic fracturing is being developed by the hydraulic fracturing team of Santos (Section 8.4.2). Golder recommends the exercise involve a review of the existing hydraulic fluid sample laboratory results dataset and assessment of hydraulic fluid mix.

10.3.3 Regional Groundwater Monitoring

Regional groundwater program will initially be defined for oil fields where the target reservoirs are within the Hooray Sandstone and where private bores targeting the Hooray Sandstone aquifers are identified within 5 km of the oil fields.

Regional groundwater monitoring should include:

- The monitoring of groundwater quality through the installation of dedicated groundwater monitoring bores or the use of suitable private bores as will be identified by the baseline assessment.
- The monitoring of groundwater levels / formation pressures using a combination of:
  - Equipment to allow measurement of water level/ formation pressure in different locations across the stratigraphy profile. It is recommended that multi-level Vibrating Wire Piezometers (VWP) are employed to monitor impacts from the extraction of oil from the following formations, the Namur Sandstone, the Murta Formation, the Lower Cadna-Owie and the Upper Cadna-Owie.
  - Dedicated groundwater monitoring bores; and

- Potentially, some private (landholder) groundwater bores identified suitable as a result of the water bore baseline assessment program.

The number of monitoring locations and types of installations selected has not yet been finalised. The following frequency for regional groundwater monitoring is proposed:

- Water levels (pressures) – daily where automated (monthly for two years then quarterly otherwise);
- Groundwater quality – quarterly using the Groundwater Baseline Suite

10.3.4 Monitoring Reporting

Monitoring data will be reviewed annually and reported internally and as required by regulatory requirements. In view of monitoring results the monitoring strategy and monitoring programs may be updated.

11.0 UWIR REVIEW SCHEDULE AND REPORTING PROTOCOL

It is proposed that the UWIR review schedule be linked to the development and review cycle of the water monitoring plan currently being developed by Santos.

A review period of no greater than three years will be undertaken. Site data including the following, will be reviewed:

- Groundwater level data from the water monitoring plan;
- Santos extraction volumes; and
- Santos pressure data.

It is intended that the above data will be reviewed and compared to the assumptions made in this UWIR. Any significant discrepancies between the assumptions in this UWIR and the additional data will trigger a review of the UWIR.

The review cycle will be incorporated in to the water monitoring plan (Appendix H).

In addition to the review schedule, the reporting will be undertaken to the regulator as required. The regulator will be engaged before reporting is undertaken to ensure appropriate procedures are being undertaken for reporting.

12.0 CONCLUSION

The impacts to groundwater from Santos oil and gas operations in the Cooper region of SWQ have been assessed in this UWIR through:

- A description of the geological settings of the gas and oil fields by the review of Santos data and literature information and the creation of a conceptual geological cross section and geological contour maps for the top and thicknesses of key formations;
- A review of the hydrogeological settings of the gas and oil fields by the analysis of large dataset of hydrogeological data, the creation of a hydrogeological conceptual model and hydrogeological maps;
- An identification of environmental values related to groundwater system and in particular groundwater dependant ecosystem including GAB artesian discharge springs;
- The description of Santos operations activities in relation to groundwater and the characterisation of produced water volumes;
- An assessment of impacts from groundwater extraction on the target petroleum reservoir and surrounding formations and on potential groundwater users;
- A risk analysis, assessment and discussion of the risk and management procedures and measures in place to reduce and manage the risks; and
- A review of the vulnerability of identified groundwater related environmental values assessed by combining the results of a risk analysis and the groundwater analytical model, and the management and mitigation measures implemented by Santos to manage the risks to groundwater systems.   .

Santos oil and gas fields in SWQ are located away from any major GDEs, also groundwater extractions associated with the oil and gas productions produce a limited volume of water which do not result in large scale depressurisation of the target aquifers. The groundwater impact assessment has demonstrated that aquifer drawdown is largely anticipated to be confined to the oil fields. **As a consequence: Santos current activities are not expected to have any material impact on GAB discharge springs and other GDEs.**

Santos oil and gas fields in SWQ are located within the Cooper and Eromanga GAB Basins, groundwater extraction for oil and gas production is carried out at great depths and does not generally compete with groundwater extraction for private use. Two private bores screened with the Hooray Sandstone and located in PL33 and PL35 have a potential for direct impact from groundwater extraction and groundwater contamination from drilling and hydraulic stimulation. The baseline assessment will need to confirm the aquifer targeted by these private bores. Groundwater monitoring at or near these bores is recommended. **As a consequence, Santos current activities are expected to have an insignificant material impact on groundwater resources used by the community with the possible exception of localised impacts to two bores screened within the Hooray Sandstone aquifer located within areas of oil production.**

The groundwater impact assessment has demonstrated that impacts to GAB aquifers are very local and even then depressurisation is limited and does not propagate across the production formations or though the stratigraphic profile. **As a consequence, Santos current activities in SWQ are expected to pose a negligible risk to the integrity of the GAB.**

This groundwater impact assessment has also highlighted the following:

- Groundwater extraction volumes from gas production in the formations of the Cooper Basin are relatively small (150 ML/year average over producing years for 191 gas wells);
- Impact of extraction in the Cooper Basin formations does not impact beyond the top of the Cooper Basin;

- The impact on the Tertiary and Quaternary strata is estimated to be less than 4.0 m. Considering the very conservative aspect of a steady state analytical model, this value is considered to be very conservative and to be in reality close to zero or null;
- Field data from two oils fields (Tickalara and Iliad) have demonstrated that depressurisation of oil reservoirs do not propagate to overlying formations; and
- Santos has implemented a combination of preventative actions and management options including industry best practices to reduce the likelihood of adverse impacts to groundwater occurring.

A water monitoring strategy has been developed in this UWIR and groundwater monitoring has been proposed to identify potential impacts or monitor to environmental values as mostly expected. The monitoring strategy will further be reviewed over time with the input of new information such as data from the completion of the baseline assessment program and the evolution of the activities of the oil and gas fields.

13.0 STANDARD DEFINITIONS

Abstraction	The removal of water from a resource e.g. the pumping of groundwater from an aquifer. Interchangeable with extraction.
Adsorption	The attraction and adhesion of ions from an aqueous solution to the surface of solids.
ADWG	Australian drinking water guidelines
Alluvial	Of, or pertaining to, material transported by water.
Alluvium	Sediments deposited by or in conjunction with running water in rivers or streams,
Analytical model	A mathematical model that provides an exact or approximate solution of a differential equation (and the associated initial and boundary conditions) for subsurface water movement or transport.
Anisotropy	The conditions under which one or more of the hydraulic properties of an aquifer vary with direction. (See also isotropy).
Anticline	A fold that is convex upward or had such an attitude at some stage of development. In simple anticlines the beds are oppositely inclined, whereas in more complex types the limbs may dip in the same direction. Some anticlines are of such complicated form that no simple definition can be given. Anticlines may also be defined as folds with older rocks toward the centre of curvature, providing the structural history has not been unusually complex.
Aquatic	Associated with and dependant on water e.g. aquatic vegetation.
Aquatic Ecosystems	The abiotic (physical and chemical) and biotic components, habitats and ecological processes contained within rivers and their riparian zones and reservoirs, lakes, wetlands and their fringing vegetation.
Aquiclude	A geologic formation which may contain water (sometimes in appreciable quantities), but is incapable of transmitting significant quantities under ordinary field conditions.
Aquifer	A saturated, permeable geological unit that is permeable enough to yield economic quantities of water to boreholes.
Aquifer system	Intercalated permeable and poorly permeable materials that comprise two or more permeable units separated by aquitards which impede vertical groundwater movement but do not affect the regional hydraulic continuity of the system.
Aquitard	A saturated geological unit with a relatively low permeability that retards and restricts the movement of water, but does not prevent the movement of water; while it may not readily yield water to boreholes and springs, it may act as a storage unit.
Artesian aquifer	A confined aquifer under hydrostatic pressure.
Artesian bore	A 'flowing' bore, where the piezometric head level is at an elevation higher than ground level, such that water freely flows out of the bore without mechanical assistance.
Attenuation	The breakdown or dilution of contaminated water as it passes through the ground.
Available drawdown	The height of water above the depth at which the pump is set in a borehole at the time of water level measurement.
Baseflow	Part of the discharge which enters a stream channel mainly from groundwater (but also from lakes and glaciers) during long periods when no precipitation (or snowmelt) occurs.
Basin	A depression of large size in which sediments have accumulated.

Bedrock	A general term for the solid rock that lies underneath the soil and other unconsolidated material. Also referred to basement. When exposed at the surface it is referred to as rock outcrop.
Bore	An artificially constructed or improved groundwater cavity which can be used for the purpose of intercepting, collecting or storing water from an aquifer; observing or collecting data and information on water in an aquifer; or recharging an aquifer. In this report, the term 'well' refers to infrastructure used to extract oil or gas and produced water from the subsurface. A 'bore' refers to the structure that is used to extract groundwater for domestic, stock, irrigation, industrial or commercial purposes.
Borehole	See definition for Bore.
Brackish	Water that contains between 3,000 and 10,000 mg/l of total dissolved solids.
Brine	Water that contains more than 35,000 mg/l of dissolved solids, saturated or nearly saturated with a salt – concentrate produced as a by-product of RO process. Also known as RO concentrate.
Brine Containment Ponds	Brine containment pond located downstream of the ROP
Catchment	(a) Area of land that collects rainfall and contributes to surface water (streams, rivers, wetlands) or to groundwater. (b) The total area of land potentially contributing to water flowing through a particular point.
Cone of depression	The piezometric groundwater surface which defines the area of influence of a borehole. The shape of a cone with large diameter at top.
Confined aquifer	An aquifer overlain by a confining layer of significantly lower hydraulic conductivity in which groundwater is under greater pressure than that of the atmosphere; the aquifer is bounded above and below by an aquiclude.
Contamination	The introduction of any substance into the environment by human activities.
DERM	Department of Environment and Resource Management recently created through a merger of the DNRW and the Environmental Protection Agency.
Discharge	Water that moves from a groundwater body to the ground surface (or into a surface water body such as a lake or the ocean). Discharge typically leaves aquifers directly through seepage (active discharge) or indirectly through capillary rise (passive discharge). The term is also used to describe the process of water movement from a body of groundwater.
Discharge area	Where significant amounts of groundwater come to the surface, either as liquid water or as vapour by evaporation.
Dissolved solids	Minerals and organic matter dissolved in water.
Drawdown	The lowering of a watertable resulting from the removal of water from an aquifer or reduction in hydraulic pressure.
Ecosystem	An organic community of plants, animals and bacteria and the physical and chemical environment they inhabit.
Elevation	A general term for a topographic feature of any size that rises above the adjacent land or the surrounding ocean bottom; a place or station that is elevated. The vertical distance from a datum (usually mean sea level) to a point or object on the Earth's surface; especially the height of a ground point above the level of the sea. The term is used synonymously with altitude in referring to distance above sea level, but in modern surveying practice the term elevation is preferred to indicate heights on the Earth's surface, whereas altitude is used to indicate the heights of points in space above the Earth's surface.
EMP	Environmental Management Plan
Epeirogenic	The slow movements of the Earth's crust leading to the formation of features.
EPP	Environmental Protection (Water) Policy

Equipotential (f)	A line connecting points of equal hydraulic potential or hydraulic head.
Evaporation	The conversion of a liquid into a vapour. In the hydrological cycle, evaporation involves heat from the sun transforming water (held in surface storages in soil) from a liquid into a gaseous state. This allows the water to move from water bodies or the soil and enter the atmosphere as water vapour.
Fault	A zone of displacement in rock formations resulting from forces of tension or compression in the earth's crust.
Field	A geographical area under which an oil or gas reservoir lies.
Flow rate	The amount of surface water or groundwater flowing past a given point or line over a defined period of time. Measured as volume, depth or area of water per unit time. Later groundwater flow through the aquifer can be estimated by $Q = K_h \times \frac{\partial h}{\partial x} \times A$ Where: Q = Lateral Groundwater flow (m^3/d) K_h = Horizontal hydraulic conductivity (m/d) A = Cross sectional area of the aquifer (m^2) $\frac{\partial h}{\partial x}$ = gradient
Formation	(a) A unit in stratigraphy defining a succession of rocks of the same type. (b) A body of rock strata that consists of a certain lithology or combination of lithologies.
Fresh water	Water that contains less than 1,000 mg/L total dissolved solids.
GAB	Great Artesian Basin
Gathering system	all infrastructures required to transfer produced water from oil and gas producing wells to the water management ponds and treatment plants.
GDE	Groundwater Dependant Ecosystem: ecosystems whose ecological processes and biodiversity are wholly or partially reliant on groundwater.
GLNG	Gladstone Liquefied Natural Gas
Groundwater	Water stored below the ground surface that saturates (in available openings) the soil or rock and is at greater than atmospheric pressure and will therefore flow freely into a bore or well. This term is most commonly applied to permanent bodies of water found under the ground.
Groundwater Dependent Ecosystems	Terrestrial or aquatic ecosystems whose ecological function and biodiversity are partially or entirely dependent on groundwater.
Groundwater flow	The movement of water through openings in sediment and rock that occurs in the zone of saturation. Lateral groundwater flow - movement of groundwater in a non-vertical direction. Lateral groundwater flows are usually, although not always, more or less parallel to the ground surface
Groundwater Management Areas (GMA)	The primary administrative boundaries defining the regions over which the Great Artesian Basin groundwater resources are regulated.
Groundwater Management Units (GMU)	The administrative subdivision of the aquifer formations that are regulated within each Groundwater Management Area.
Groundwater model	A simplified conceptual or mathematical image of a groundwater system, describing the features essential to the purpose for which the model was developed and including various assumptions pertinent to the system. Mathematical groundwater models can include numerical and analytical models.

Groundwater resource	All groundwater available for beneficial use, including both human and natural uses.
HDD	Horizontal directional drilling.
Head (hydraulic head, static head)	The energy contained within a column of water resulting from elevation or pressure. The static head is the height at which the surface of a column of water could be supported against the action of atmospheric pressure.
Hydraulic conductivity	A measure of the ease with which water will pass through earth material. It is defined as the rate of flow through a cross-section of one square metre under a unit hydraulic gradient at right angles to the direction of flow {m/day}.
Hydraulic gradient	(a) The slope of the water table or potentiometric surface. The hydraulic gradient is determined from the decline in groundwater level (δh) at two measuring points divided by the distance between them (δl). (b) The change in hydraulic head with direction.
Hydrology	The study of water and water movement in relation to the land. Deals with the properties, laws, geographical distribution and movement of water on the land or under the Earth's surface.
Infiltration	The process whereby water enters the soil through its surface. The downward movement of water into the soil profile.
Interstices	Openings or void space in a rock capable of holding water.
Isotropic	The condition of having properties that are uniform in all directions, opposite of anisotropic.
Km	Kilometres
L/s	Litres per second
Labile	Constantly undergoing or likely to undergo change; unstable.
Lithology	The physical and mineralogical characteristics of a rock. The characteristics, including grain size, of the strata of the subsurface media.
LSI	Langelier Saturation Index is a calculated number used to predict the calcium carbonate stability of water. It indicates whether the water will precipitate, dissolve, or be in equilibrium with calcium carbonate.
Maximum Drawdown Level	Maximum allowable drawdown defined for each aquifer in order to protect MNES (under the EPBC Act). If reached, it corresponds to an impact to MNES and triggers a series of make good actions. A threshold level has also been defined to provide an early impact warning prior to potentially reaching the Maximum Drawdown level
m AHD	Metres in Australian Height Datum
mg/L	Milligrams per litre
ML	Mega litre
Outcrop	(a) The part of a rock formation that appears at the surface of the ground. (b) A term used in connection with a vein or lode as an essential part of the definition of apex. It does not necessarily imply the visible presentation of the mineral on the surface of the earth, but includes those deposits that are so near to the surface as to be found easily by digging. (c) The part of a geologic formation or structure that appears at the surface of the earth; also, bedrock that is covered only by surficial deposits such as alluvium. (d) To appear exposed and visible at the earth's surface; to crop out.
Overburden	Designates material of any nature, consolidated or unconsolidated, that overlies a deposit of useful materials, ores, or coal--esp. those deposits that are mined from the surface by open cuts.

Perennial River	A river which may be dry for part of the year, due to seasonal variations in weather.
Period	A geologic timeframe smaller than Eras and subdivided into Epochs.
Permeability	A measure of the capacity of rock or stratum to allow water or other fluids such as oil to pass through it (ie. the relative ease with which a porous medium can transmit a fluid). Typically measured in darcies or millidarcies.
Permeable	Materials that liquids flow though with relative ease.
Petroleum Legislation	The *Petroleum and Gas (Production and Safety) Act 2004* (Qld) and the *Petroleum Act 1923* (Qld) and associated Regulations.
pH	A measure of the acidity or alkalinity of water. It is related to the free hydrogen ion concentration in solution pH = 7 is neutral; pH < 7 acidic; pH > 7 alkaline. (activity). Used as an indicator of acidity (pH < 7) or alkalinity (pH > 7).
Piezometer	A pressure measuring device (a tube or pipe, or other device), open to the atmosphere at the top and to water at the bottom, and sealed along its length, used to measure the hydraulic head in a geologic unit. This device typically is an instrument that measures fluid pressure at a given point rather than integrating pressures over a well. (b) a borehole cased and completed with a seal(s) adjacent to the slotted section to observe the groundwater pressure over the slotted interval rather than the elevation of the watertable.
Piezometric surface	A surface of equal hydraulic heads or potentials, typically depicted by a map of equipotential contours such as a map of water-table elevations. See potentiometric surface.
Piper diagram	A graphical means of displaying the ratios of the principal ionic constituents in water. (modified from Davis and DeWiest, 1966, and Freeze and Cherry, 1979). SMOW is standard mean ocean water.
Porosity	The volume of the voids divided by the total volume of porous medium (the percentage of a rock or soil that is represented by open voids or spaces): effective - the interconnected porosity which contributes to groundwater flow. Often used synonymously with specific yield although the two terms are not synonymous. fracture - the porosity of the fractures; intergranular - the porosity between the grains of a sediment or sedimentary rock; primary - intergranular porosity formed during the deposition of the sediment or from vesicles in igneous rocks; secondary - porosity formed after the rock is lithified by either dissolution or fracturing.
Potable water	Water that is safe and palatable for human use.
Preferential flow	The preferential movement of groundwater through more permeable zones in the subsurface.
Production bore (or well)	A bore from which abstraction of groundwater may take place, either through pumping or artesian flow.
QA/QC	Quality Assurance/Quality Control
Recharge	The water that moves into a groundwater body and therefore replenishes or increases sub-surface storage. Recharge typically enters an aquifer by rainfall infiltrating the soil surface and then percolating through the zone of aeration (unsaturated soil). Recharge can also come via irrigation, the leakage of surface water storage or leakage from other aquifers. Recharge rate is expressed in units of depth per unit time (e.g. mm/year).
Recovery	The rate at which the water level in a pumped bore rises once abstraction has ceased.
Rehabilitation	To restore to former condition or status.

Risk assessment	The overall process of using available information to predict how often hazards or specified events may occur (likelihood) and the magnitude of their consequences (adapted from AS/NZS 43601999).
Risk management	The systematic evaluation of the water supply system, the identification of hazards and hazardous events, the assessment of risks, and the development and implementation of preventive strategies to manage the risks.
River	A physical channel in which runoff will flow; generally larger than a stream, but often used interchangeably.
Runoff	(a) That portion of the rainfall that is not absorbed by the deep strata, is used by vegetation or lost by evaporation, or that may find its way into streams as surface flow. (b) Water flowing down slope over the ground surface, also known as overland flow. Precipitation that does not infiltrate into the soil and is not stored in depressions becomes run-off.
RO	Reverse Osmosis – water filtration/desalination method that employs a high pressure differential across a membrane to selectively remove contaminants in the CSG water. As the water is forced across the membrane all molecules larger than water are excluded leaving behind a concentrated waste stream (brine). RO is in widespread use for applications such as desalinisation of seawater, treatment of municipal water supplies and purification of industrial cooling water.
ROP	Reverse Osmosis Plant – Water treatment plant employing treatment using the RO process (located adjacent to Compression Facility, where required).
Saline water	Water that is generally considered unsuitable for human consumption or for irrigation because of its high content of dissolved solids.
Salinity	An accumulation of soluble salts in the soil root zone, at levels where plant growth or land use is adversely affected. Also used to indicate the amounts of various types of salt present in soil or water. (see Total Dissolved Solids).
Sanitation	The treatment and disposal of waste from the human body and grey water generated through household activity.
SAR	Sodium Adsorption Ratio the ratio of sodium to calcium and magnesium. For most irrigation schemes a SAR of between 10 and 20 is required to avoid the sodicity of the water degrading the physical structure of the soils
Screen, slotted section	A section of casing, usually steel or PVC, with apertures or slots cut into the tubing to allow groundwater to flow through. Screen usually refers to machined sections with openings that can be sized appropriate to the aquifer matrix and filter pack grading.
Sediment	a) Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the Earth's surface either above or below sea level. b) Solid material, whether mineral or organic, which has been moved from its position of origin and redeposited.
Sedimentary rock	Any rock that has formed from the consolidation of sediment.
Seep	Point at where seepage occurs.
Sorption	The general process by which solutes, ions, and colloids become attached (sorbed) to solid matter in a porous medium. Sorption includes absorption and adsorption.
Specific storage (Ss)	The amount of water absorbed, released or expelled from storage in a unit volume (i.e. 1 x 1 x 1) of aquifer under a unit change in hydraulic head (i.e. $\delta h = \pm 1$).
Standing water level (static water level, SWL)	The depth to groundwater measured at any given time when pumping or recovery is not occurring.

Storativity	The volume of water that a saturated confined aquifer releases from storage per unit surface area of the aquifer per unit decline in the water table. Quantifies the aquifers ability to release water.
Stratigraphy	The study of stratified rocks, especially their age, correlation and character.
Subsidence	(a) The vertical movement of the surface, although small-scale horizontal movements may be present. This sinking or settlement of the land surface can be caused by a number of processes, including production of fluids, solution, compaction, or cooling of magmatic bodies. (b) Lowering of the ground surface resulting from removal of hydrostatic pore space pressure (through buoyancy) or collapse of underground mine voids.
Threshold Level	Defined value (measurable criteria such as water level, water quality) that if reached for an environmental or operation monitoring aspect provides an early warning to a potentially upcoming impact
Total dissolved solids (TDS)	An expression of the total soluble mineral content of water determined by either measuring the residue on evaporation or the sum of analysed chemical constituents. Usually quoted in milligrams per litre (mg/L) or the equivalent parts per million (ppm), TDS may also be approximated from electrical conductivity (EC) measurements using the conversion EC (µS/cm) x 0.68 = TDS (mg/L) (see Electrical Conductivity).
Transmissivity (T)	The rate of horizontal groundwater flow through the full saturated thickness (b) of an aquifer across a unit width (i.e. an area of b x 1) (ie. through a 1 metre wide slice across the entire depth of an aquifer) under a unit hydraulic gradient (i.e. $\delta h / \delta l = 1$). Transmissivity may be quoted as m^3/day/m [L^3/T/L], but is more commonly expressed as m^2/day [L^2/T]. It provides a better comparison of the possible yield of an aquifer than saturated hydraulic conductivity because it takes into account the saturated thickness of an aquifer. Transmissivity is related to the hydraulic conductivity of the aquifer by the equation T=Kb.
Tremie pipe	A narrow diameter pipe, which keeps the sealing materials from becoming bridged inside the well casing and prevents dissolution of liquid grout.
Trigger level	Value of an operational or environmental measurable criteria (such as water level or water quality values) that if reached corresponds to the petroleum field activities having an impact on the environment.
Unconfined aquifer	An aquifer with no confining layer between the water table and the ground surface where the water table is free to fluctuate.
Vibrating Wire Piezometer (VWP)	The sensor of the VWP consists of a pressure transducer with an internal thin resonating wire connected to a sensitive perpendicular diaphragm. Water pressure exerted against the diaphragm wall causes it to deflect and alter the tension of the wire and this in turn causes the wire to resonate at different frequencies. An electromagnetic field induced from coils adjacent to the vibrating wire causes it to be plucked and resonate at a frequency signal which is sent through the signal cable to a readout unit or logger at the ground surface.
Watertable	(a) The upper surface of a body of groundwater occurring in an unconfined aquifer. At the watertable, pore water pressure equals the atmospheric pressure. (b) The surface of a body of groundwater within an unconfined aquifer at which the pressure is atmospheric.
Well field	A group of bores in a particular area usually used for groundwater abstraction purposes.

Wild Rivers	DERM defines Wild rivers some river systems which are relatively untouched by development and are therefore in near natural condition, with all, or almost all, of their natural values intact to preserve them these valuable river systems as a part of QLD natural heritage for the benefit of current and future generations Wild River areas include unique ecosystems, rare and threatened plants, birds and marine and estuarine species.
Yield	The quantity of water removed from a water resource e.g. yield of a borehole.

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HW,FH,IL/RKH;LJ/fh:hw/eo

A.B.N. [redacted]

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c:\users\eoakey\desktop\117636010-3000-001-rev3-cooper basin uwir_lbj.docx

APPENDIX A

DERM: Amend or Modify Notice

Queensland Government

8 May 2012

[redacted]
Santos Ltd
[redacted]

Dear Mr [redacted]

Please find attached an amend and resubmit notice for Santos Ltd's (Santos) Underground Water Impact Report (UWIR) for the Cooper Basin Oil and Gas Fields, South West Queensland.

According to section 384(2) of the *Water Act 2000*, Santos must modify the report in the way stated in the notice and give the amended report to the department no later than 40 business days after receiving this notice. Alternatively, Santos can make a submission to the chief executive as to why the report should not be modified by 8 June 2012.

The department would like to meet with Santos to discuss the notice at a mutually agreeable time. Should you have any questions in relation to this letter please contact [redacted] from the department on telephone [redacted]

Yours Sincerely

[redacted]

Manager – Energy Implementation
Energy Resources
Environment and Natural Resource Regulation

Queensland Government

Notice

Direction to amend or modify an Underground Water Impact Report or Final Report

This statutory notice is issued by the chief executive pursuant to section 384 of the Water Act 2000, to advise you of the need to modify the Underground Water Impact Report you submitted.

Santos Ltd

[redacted]

Your reference : UWIR- Cooper Basin Oil and Gas Fields, SWQ

Our reference : 489261

Attention: [redacted]

Dear Mr [redacted]

Re: Direction to amend an Underground Water Impact Report

The chief executive requires you to amend and resubmit the Underground Water Impact Report (UWIR) for the Santos Cooper Basin Oil and Gas Fields, SW QLD. The UWIR should be amended in the following ways:

Water quantity produced or taken (previous rights and 3 year forecast)

1. Provide a description of the methodology for measuring the quantity of water extraction because of the exercise of previous underground water rights. This description of methodology is necessary to assess whether the quantity of water estimated in the report is accurate.
2. Divide the estimate of water extraction into target formations and provide a description about the methodology for estimating the quantity of water to be extracted for a three year period, starting on the consultation day for the report. This description of methodology is necessary to assess whether the quantity of water estimated in the report is accurate.
3. Provide the following:
   - the quantity of water to be produced each year over the next three years for each formation and the methodology used to determine these estimates;
   - data in an appendix from Figures 33 and Figures 34 in tabular format (the data presented in these figures lack meaning if number values are not provided);
   - the number of production wells for each tenure;
   - clarification about which graph relates to both Central and Warrego West in Figure 34 of the report.

This information is necessary to ensure the accuracy of the information provided about previous and future water production and take.

Description of aquifer/s affected or likely to be affected

4. Accurately describe each affected aquifer affected or likely to be affected by:
   - discussing the influence of the faults identified in Figure 14 on the hydrogeology of the area;
   - clarifying if water level data can be derived from production wells e.g through reservoir pressure data;
   - amending symbols in Figure 27 to provide distinct colour for each formation;
   - providing a supporting table for Figure 27 indicating the number of bores for each formation within the report area;
   - clarifying the estimated water extraction of the bores identified including those with volumetric water entitlements;
   - amending Table 10 to remove the repeated listing of RN18144 and RN23349 and amend the first paragraph in section 5.4 accordingly.
   - including static head data from the groundwater database for artesian monitoring bores;
   - clarifying the extent of the data available to provide justification for not providing an analysis of the trends in water level change for aquifers because of the exercise of underground water rights.

This information is necessary to properly understand the structural framework of the affected aquifers, and to assess the accuracy of how they are described in the report.

Predicted impacts – Immediately and Long Term Affected Areas

8. Provide additional map or maps of the Cooper Basin Oil and Gas Fields' immediately affected area that clearly shows the areas of the aquifer where the water level is predicted to decline by more than the bore trigger threshold within three years after the consultation date. The maps should clearly demonstrate:
   a. detailed groundwater contours; and
   b. yearly drawdown predictions.
9. Provide additional map or maps at a smaller scale to clearly demonstrate the groundwater contours within the affected areas (Figures 39-41 and Figure 43) where the water level is predicted to decline by more than the bore trigger threshold at any time after the consultation date.
10. Indicate the tenure and lot and plan on which the bores in the immediately/long term affected area are located. This is necessary to properly understand the predicted impacts, and the bores which will be potentially impacted.

Modelling approach and methodology

11. Provide the following description of methods and techniques in relation to the information provided about affected aquifers.

    - Clarify the rationale for the selection of the hydraulic parameters (i.e. how were the parameters inferred or derived from supporting reports) and include comment on any uncertainties that are associated with the selection of these parameters.
    - Provide justification and explanation of the footnote on page 85 about the shifting of water extraction between model layers 4 & 5.
    - Amend Table 25 to clarify which column refers to observed groundwater level (both columns state modelled groundwater level).
    - Provide a sensitivity analysis for the aquifer parameters listed on page 49 to provide guidance on the uncertainty in the predicted impacts associated with the assumptions of the parameter values. Include details on the selection of sensitivity run parameters, the technique used and a discussion of the results or conclusions (relevant plots or lists of sensitive parameters).
    - Discuss the role data from departmental monitoring bores have in model development, calibration and review.
    - Include estimates of predictive uncertainty for the modelled results and detail the method used and reasons for reaching these conclusions. This should include discussion on:

        a. the potential for water extraction from Santos' South Australian operations to contribute to groundwater impacts in Queensland; and

        b. the relevance of the recognition of hydraulic interaction between the Cooper and Eromanga Basins in water resource models of the Great Artesian Basin, particularly in South Australia.

This information is necessary to ensure the accuracy of the information provided about affected aquifers.

Review & Reporting on UWIR

12. Provide a program for review of the report which includes milestones for updating model inputs, calibrating the model and producing updated maps.

13. Provide a program for giving the chief executive a summary of the outcome of each review, including a statement of whether there has been a material change in the information or predictions used to prepare maps.

Water Monitoring Strategy

14. Provide further detail on the monitoring network design; namely, the number of monitoring locations and types of installations, and demonstrate how this design fills critical data gaps and will improve the understanding of impacts of underground water extraction.

15. Amend the report to state monthly monitoring only. The report can later be amended to require quarterly monitoring once a review of the initial two years of data has been conducted.

16. A program for reporting to the Queensland Water Commission about the implementation of the monitoring strategy.

Spring Impact Management Strategy

17. Provide a map indicating the 0.2m trigger threshold and clarify whether or not this trigger is exceeded for the springs identified outside of the tenement boundaries (e.g. the GAB discharge springs in the vicinity of the Eulo). This information is necessary to ensure the accuracy of the information provided about potentially affected springs.

Conclusion

You must either:

1. submit the amended Underground Water Impact Report by no later than 40 business days after receiving this notice; or
2. make a submission to the chief executive by 8 June 2012 as to why the report should not be modified.

If you require more information, please contact Janet Menzies, on the telephone number listed below.

[redacted]

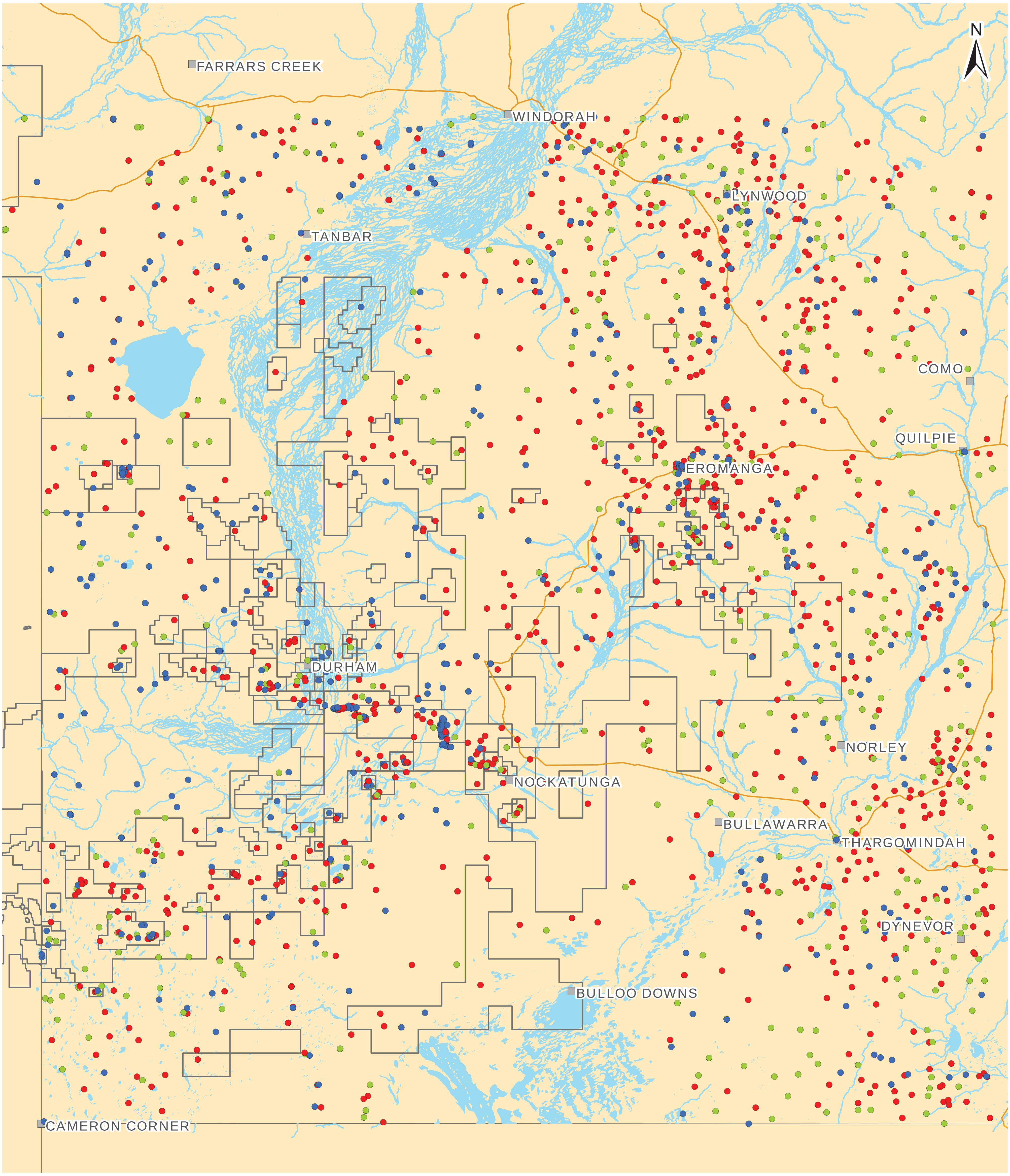
Delegate of the chief executive
Water Act 2000

8 May 2012

Date

Enquiries:
[redacted]
Ph: [redacted]
Fax: [redacted]
Email: [redacted]

APPENDIX B
Bore Metadata



COOPER BASIN UWIR

SANTOS

METADATA MAP: BORE STRATIGRAPHY

LEGEND

- Town/Locality
- Highway/Major Road
- River/Creek
- Santos Operated Permits

Stratigraphy Score

- 1 - Good stratigraphy information
- 2 - Partial stratigraphy information available
- 3 - No information

0 5 10 20 30 40 50 Kilometres

SCALE (at A3) **1:1,500,000**

Coordinate System: GCS GDA 1994

PROJECT: **117636010**
DATE: **31/07/2012**
DRAWN: **AJW**
CHECKED: **FH**

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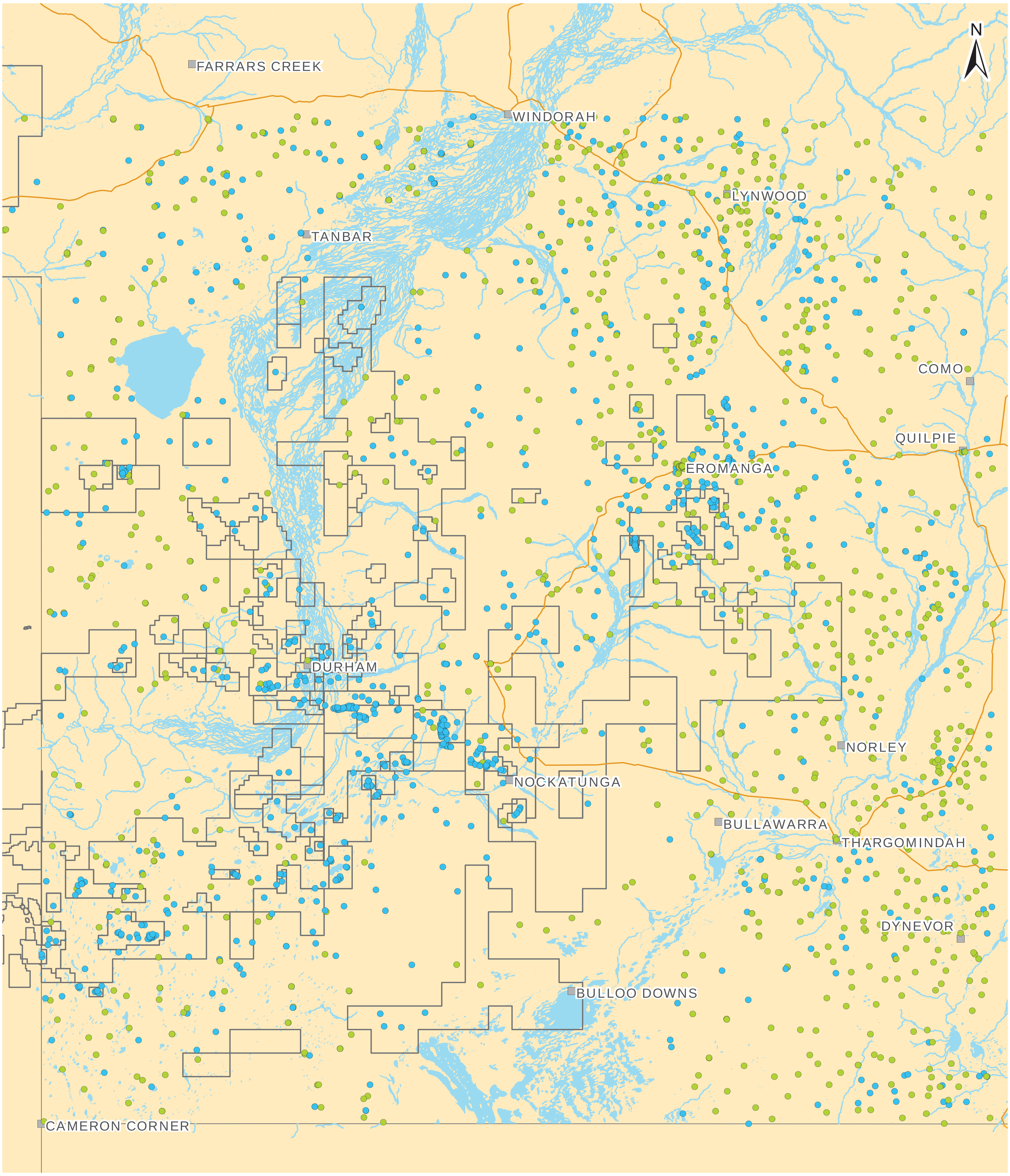

COOPER BASIN UWIR

SANTOS

METADATA MAP: BORE CONSTRUCTION

LEGEND

- Town/Locality
- Highway/Major Road
- River/Creek
- Santos Operated Permits

Bore Construction Score

- 1 - Good bore construction practises
- 2 - Bore construction practice in doubt
- 3 - No information/ bad bore construction

0 5 10 20 30 40 50 Kilometres

SCALE (at A3) **1:1,500,000**

Coordinate System: GCS GDA 1994

PROJECT: **117636010**
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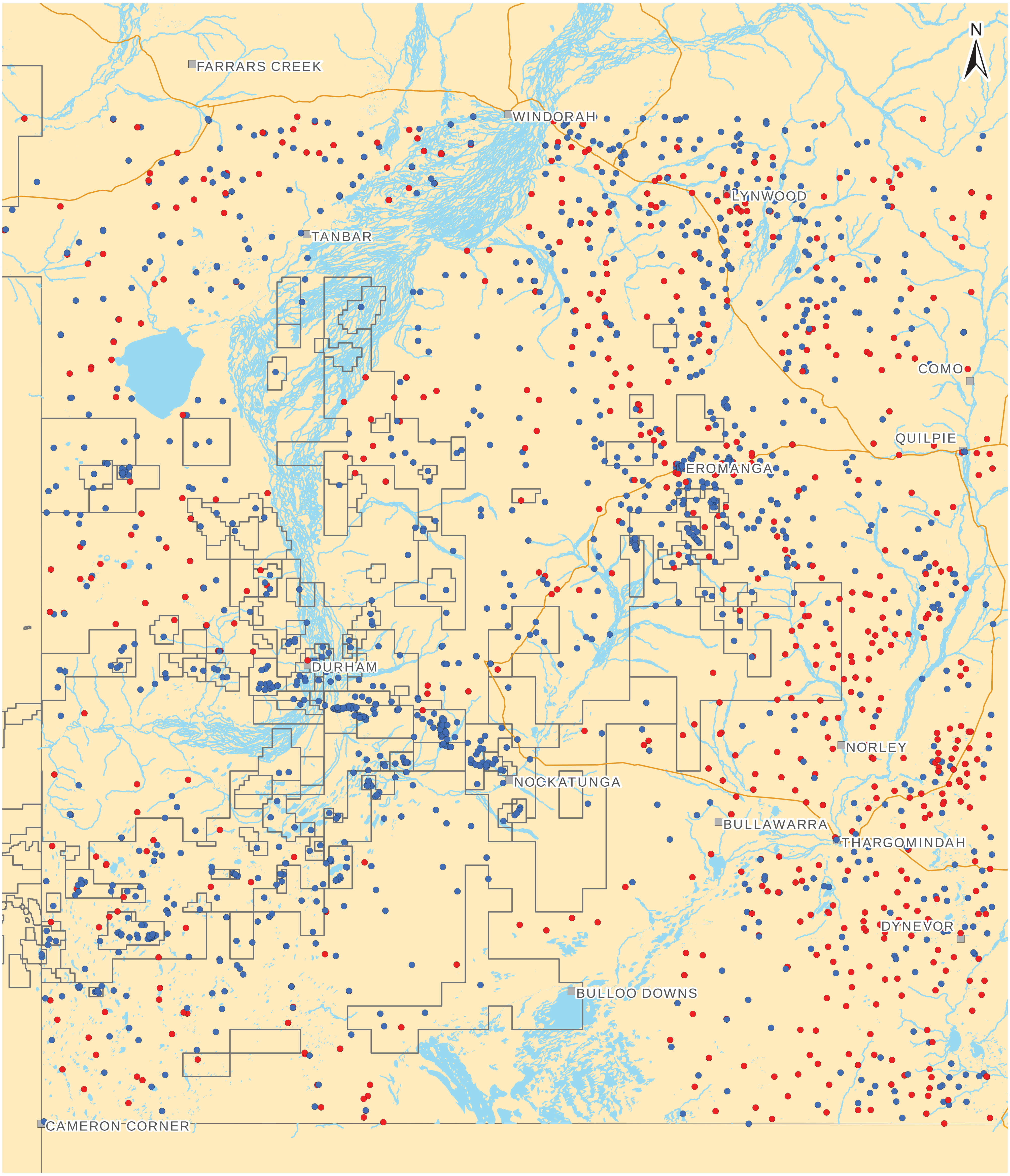

COOPER BASIN UWIR

SANTOS

METADATA MAP: WATER LEVEL

LEGEND

- Town/Locality
- Highway/Major Road
- River/Creek
- Santos Operated Permits

Water Level Score

- 1 - Water level information and date of survey
- 3 - No data

0 5 10 20 30 40 50 Kilometres

SCALE (at A3) **1:1,500,000**

Coordinate System: GCS GDA 1994

PROJECT: **117636010**
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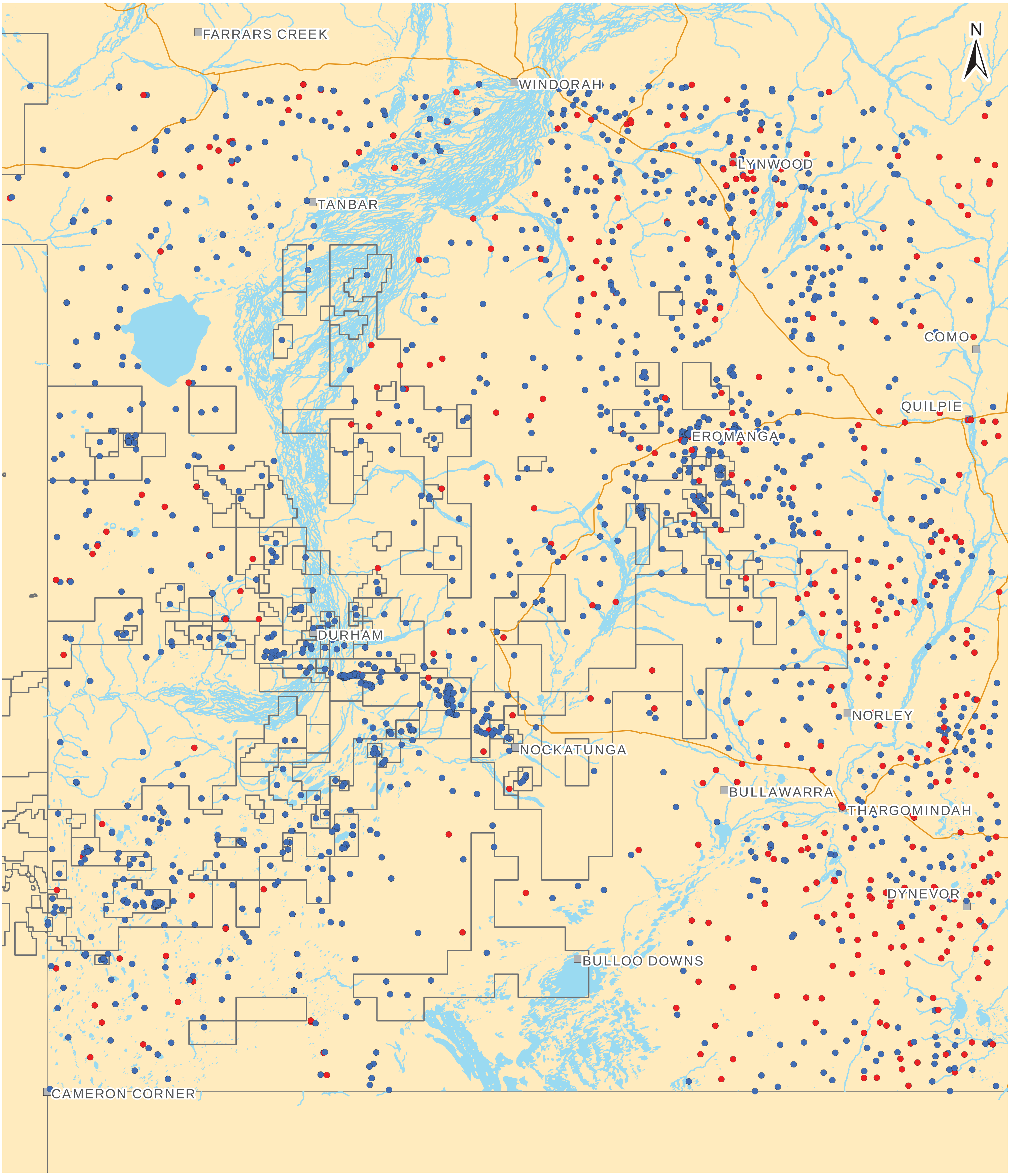

COOPER BASIN UWIR

SANTOS

METADATA MAP: BORE CHEMISTRY

LEGEND

Bore Chemistry Score

- 1 - EC and pH measurements and date of sampling
- 3 - No data
- Town/Locality
- Highway/Major Road
- River/Creek
- Santos Operated Permits

0 5 10 20 30 40 50 Kilometres

SCALE (at A3) 1:1,500,000

Coordinate System: GCS GDA 1994

PROJECT: 117636010
DATE: 31/07/2012
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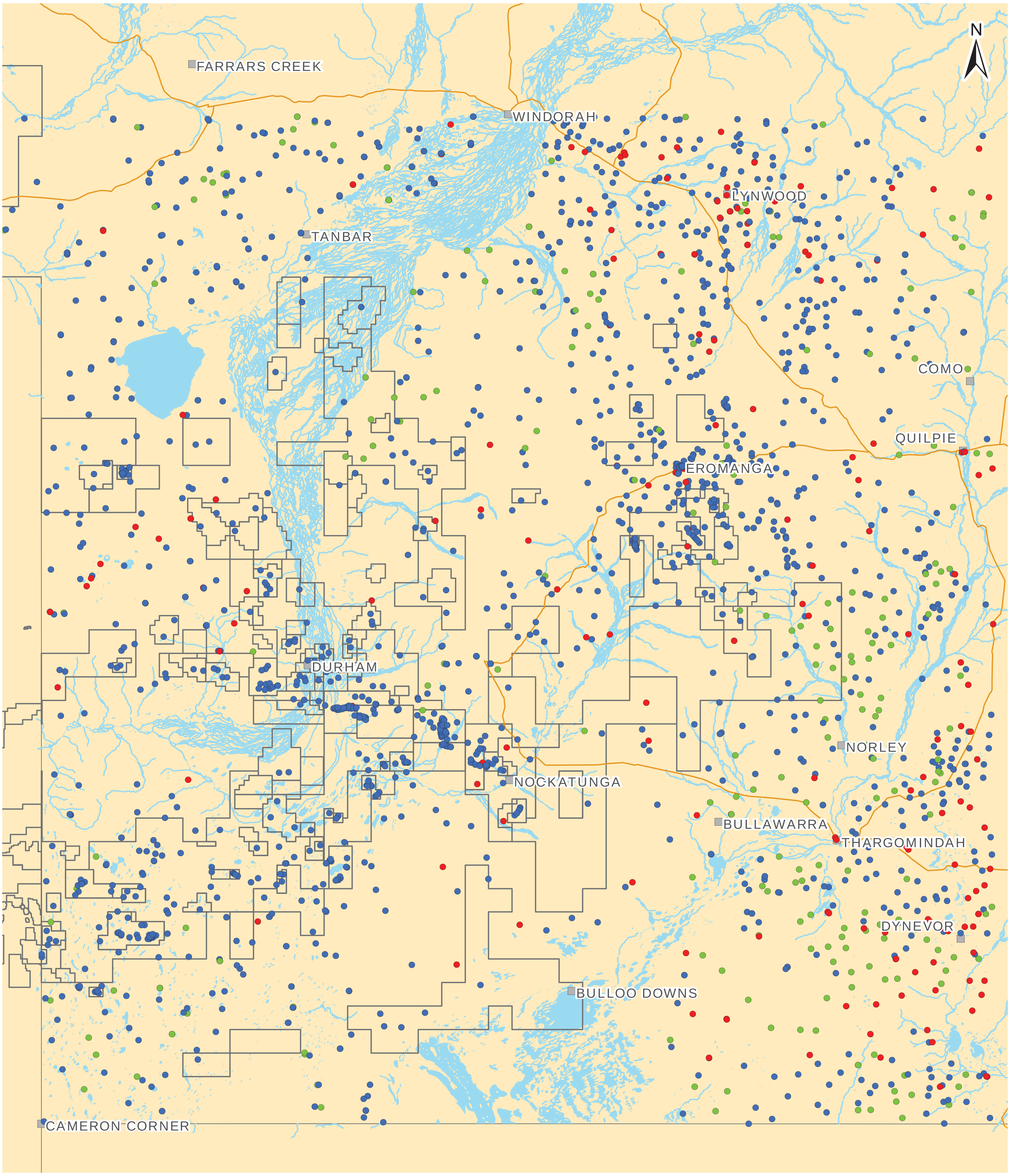

COOPER BASIN UWIR

SANTOS

METADATA MAP: WATER QUALITY

LEGEND

- Town/Locality
- Highway/Major Road
- River/Creek
- Santos Operated Permits

Water Quality

- 1 - Major ions chemistry available and date of sample
- 2 - Partial information
- 3 - No data

0 5 10 20 30 40 50 Kilometres

SCALE (at A3) **1:1,500,000**

Coordinate System: GCS GDA 1994

PROJECT:	**117636010**
DATE:	**31/07/2012**
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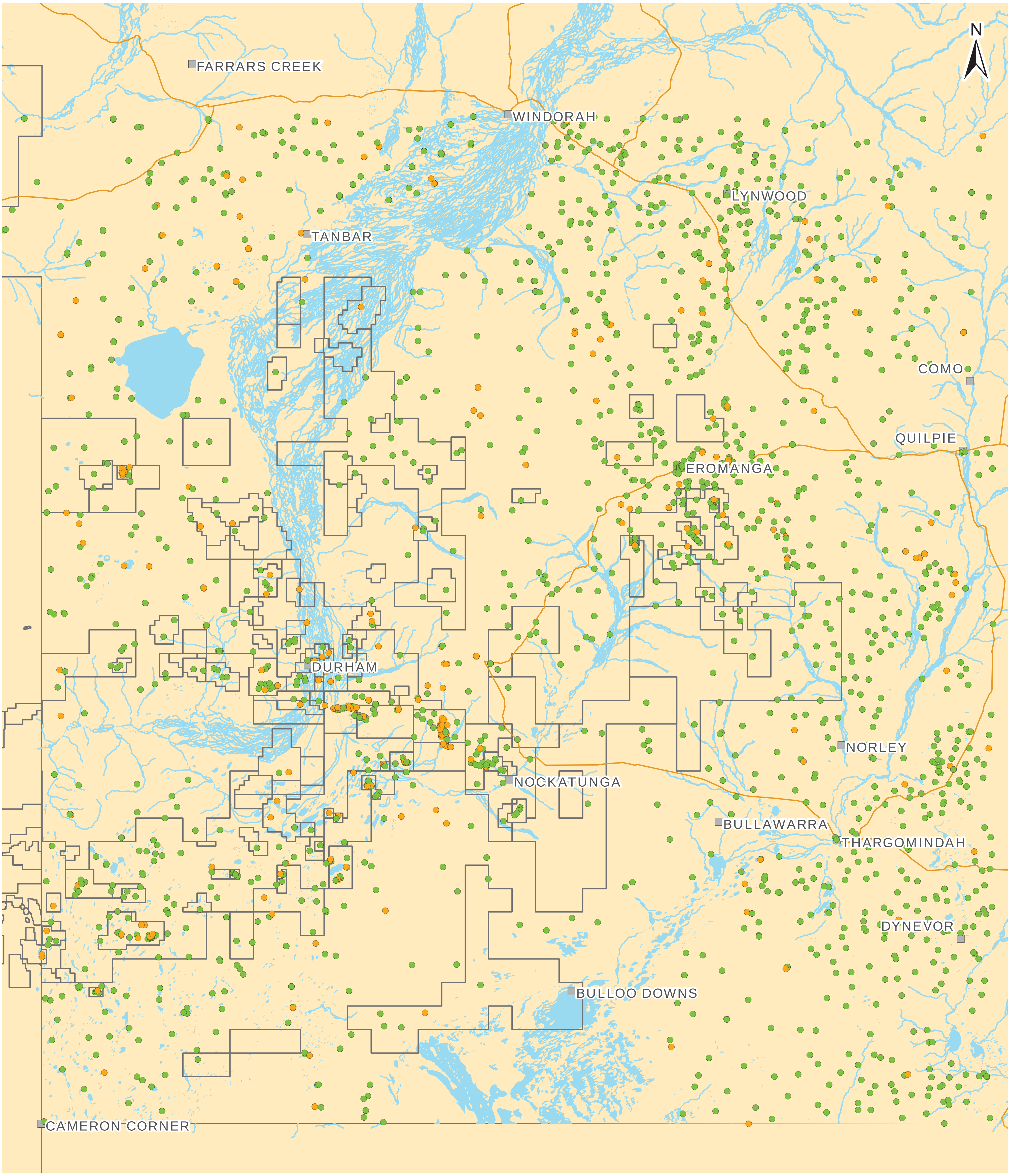

COOPER BASIN UWIR

SANTOS

METADATA MAP: BORE DEPTH

LEGEND

- Town/Locality
- Highway/Major Road
- River/Creek
- Santos Operated Permits

Bore Depth Score

- 2 - Depth available from DERM database only OR DERM database value when Bore Inventory depth and DERM bore depths are different
- 4 - No Data

0 5 10 20 30 40 50 Kilometres

SCALE (at A3) **1:1,500,000**

Coordinate System: GCS GDA 1994

PROJECT: **117636010**
DATE: **31/07/2012**
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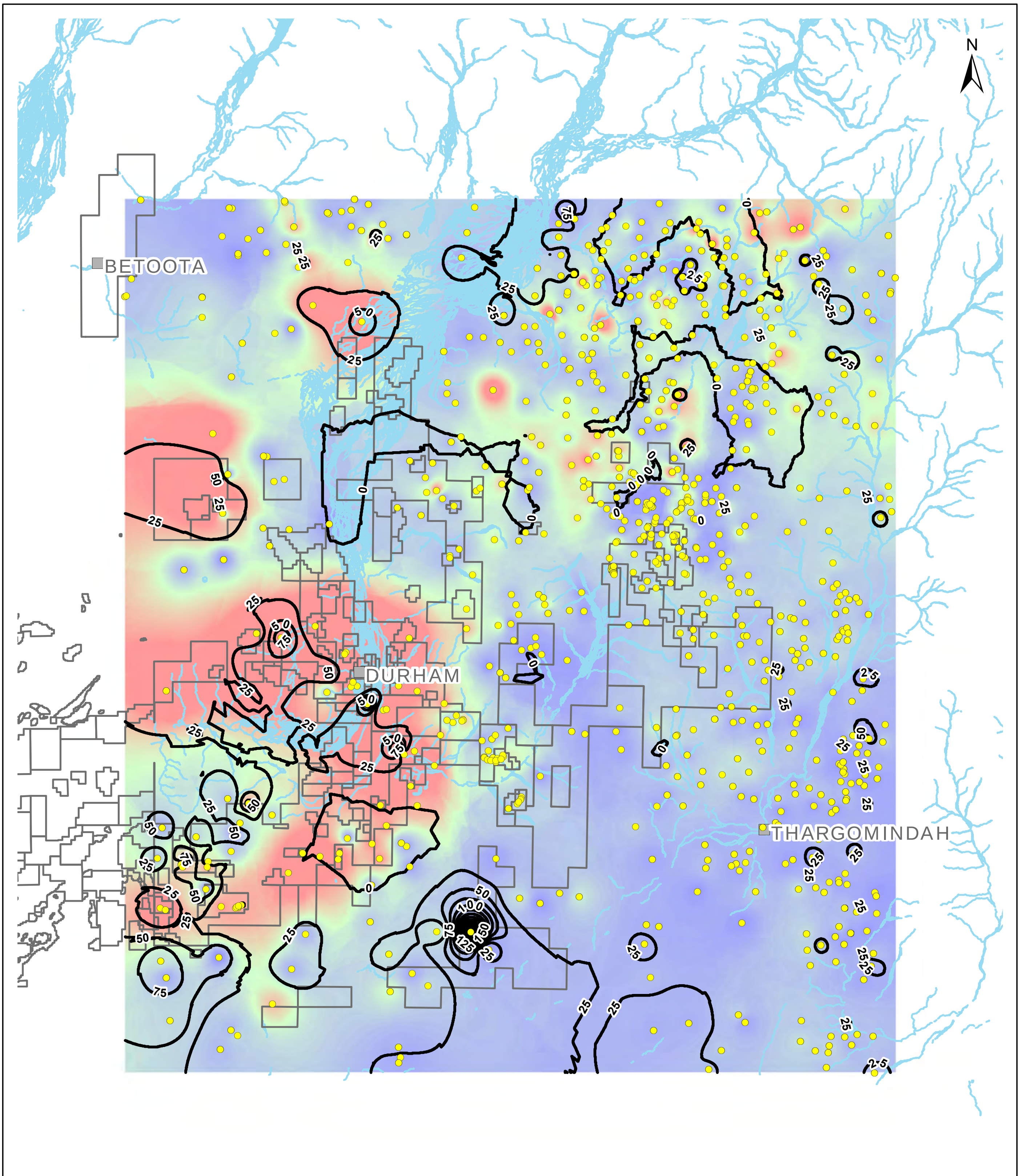
APPENDIX C

Geological Contour Maps



COOPER BASIN UWIR

SANTOS

GEOLOGICAL CONTOUR MAP: WINTON FORMATION

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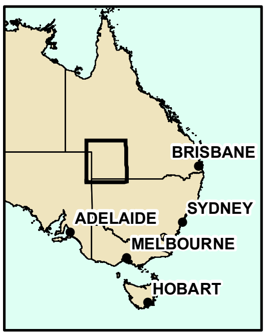

LEGEND

- Geology Data Point
- Town/Locality
- Depth to Winton Formation (m)
- River/Creek
- Santos Operated Permits

Thickness of Winton Formation (m)

High : 970

Low : 1

0 5 10 20 30 40 50 Kilometres

SCALE (at A3) 1:2,500,000

Coordinate System: GCS GDA 1994

PROJECT:	117636010
DATE:	31/07/2012
DRAWN:	AJW
CHECKED:	FH

APPENDIX C1

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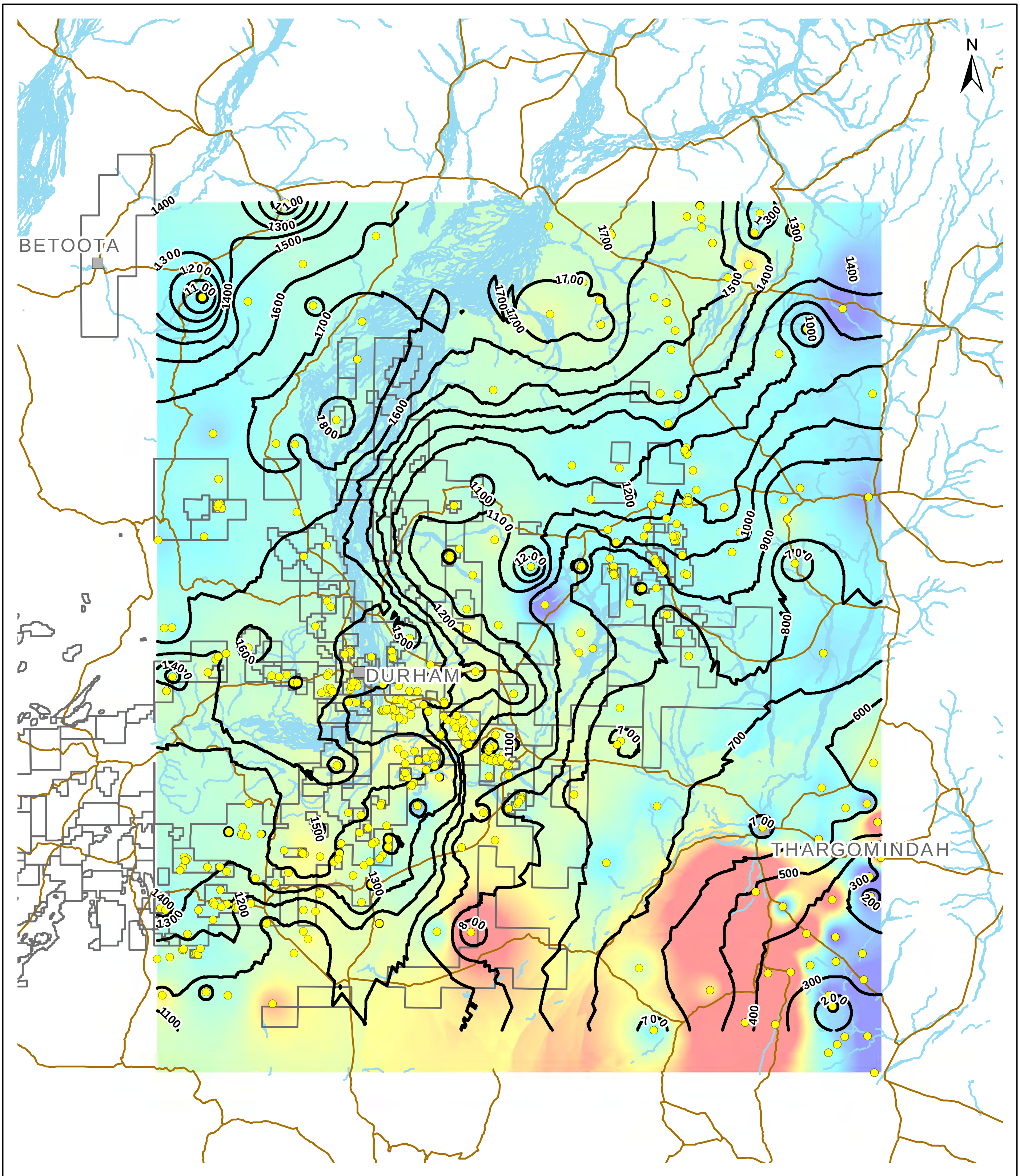
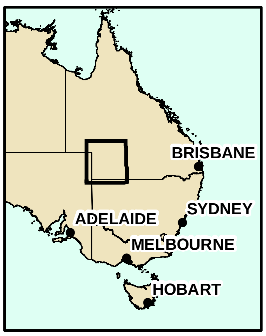


COOPER BASIN UWIR

SANTOS

GEOLOGICAL CONTOUR MAP: HOORAY FORMATION



LEGEND

- Geology Data Point
- Town/Locality
- Depth to Hooray Sandstone (m)
- Highway / Major Road
- River/Creek
- Santos Operated Permits

Thickness of Hooray Sandstone (m)

High : 595

Low : 1.8

0 5 10 20 30 40 50 Kilometres

SCALE (at A3) 1:2,500,000

Coordinate System: GCS GDA 1994

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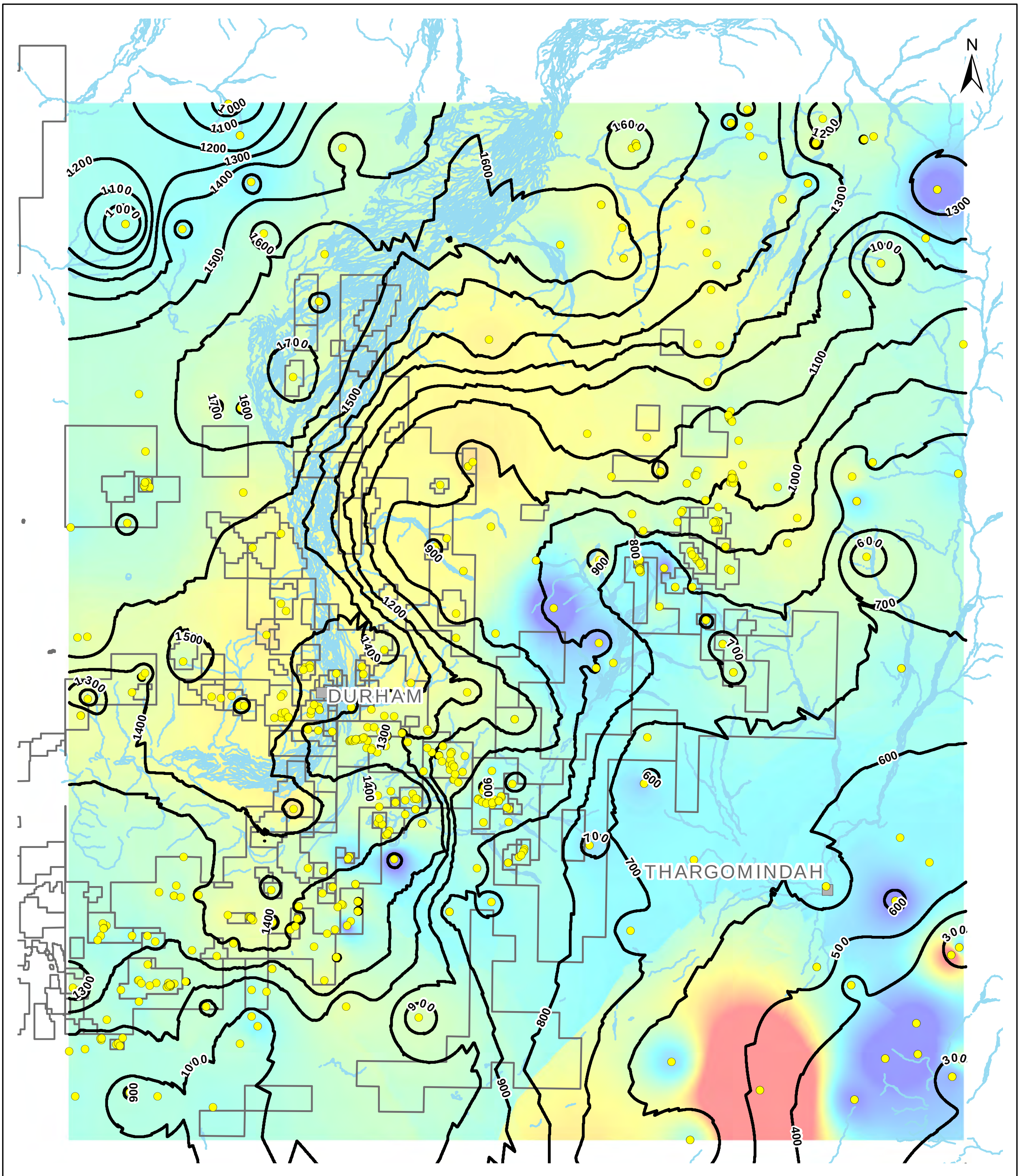
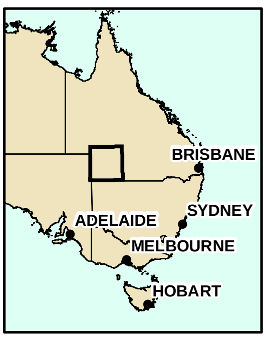


COOPER BASIN UWIR

SANTOS

GEOLOGICAL CONTOUR MAP: CADNA OWIE FORMATION



LEGEND

- Geology Data Point
- Town/Locality
- Depth to Cadna Owie (m)
- River/Creek
- Santos Operated Permits

Thickness of Cadna Owie Formation (m)

High : 390

Low : 18

0 5 10 20 30 40 50 Kilometres

SCALE (at A3) 1:2,000,000

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PROJECT:	117636010
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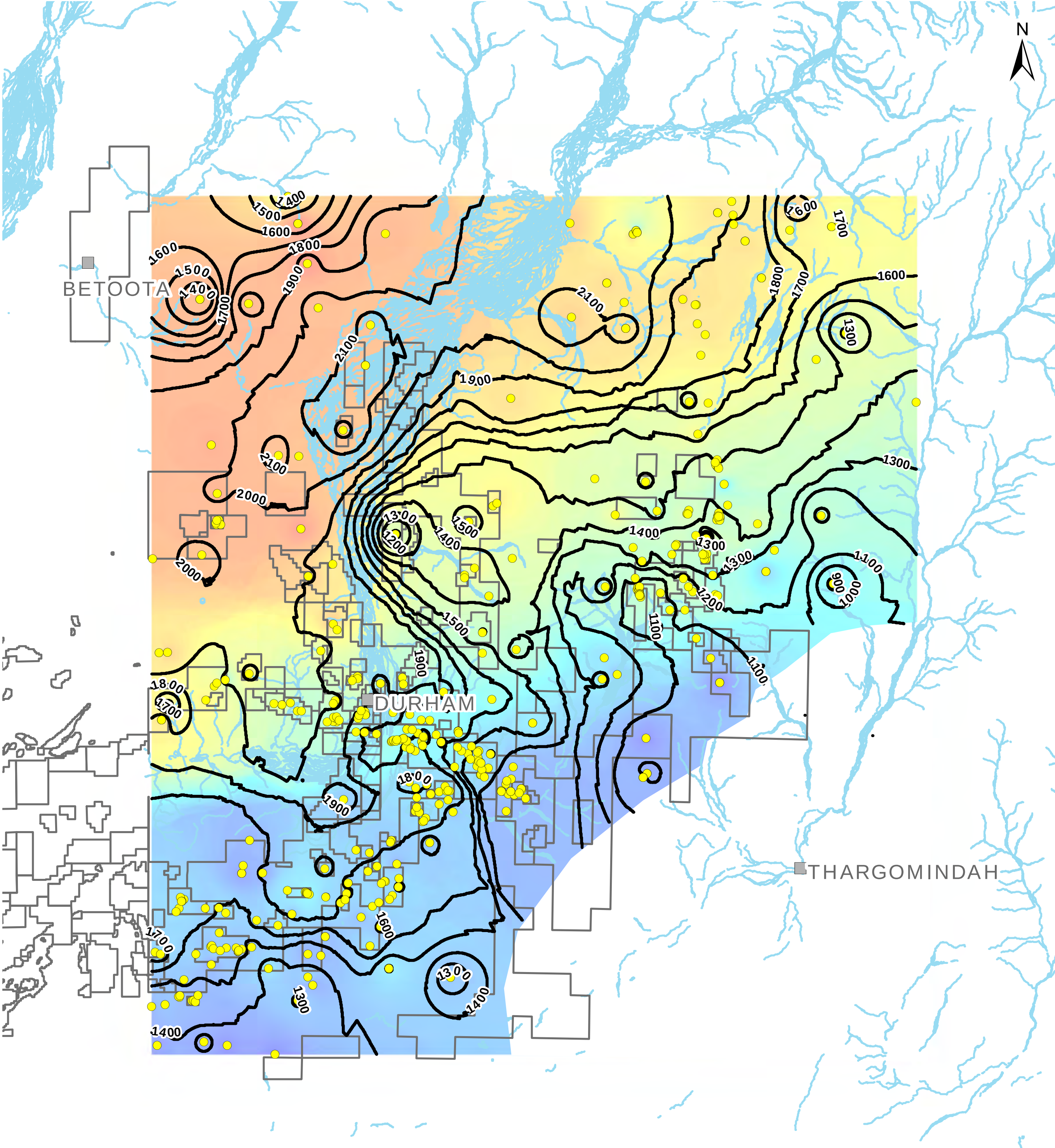
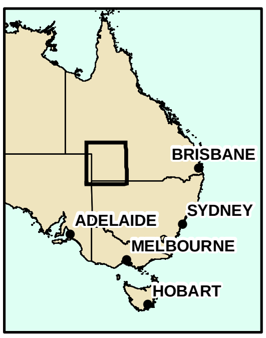


COOPER BASIN UWIR

SANTOS

GEOLOGICAL CONTOUR MAP: HUTTON SANDSTONE



LEGEND

- Geology Data Point
- Town/Locality
- Depth to Hutton Sandstone (m)
- Santos Operated Permits
- River/Creek

Thickness of Hutton Sandstone (m)

High : 241

Low : 2.

0 5 10 20 30 40 50 Kilometres

SCALE (at A3) 1:2,500,000

Coordinate System: GCS GDA 1994

PROJECT: 117636010
DATE: 31/07/2012
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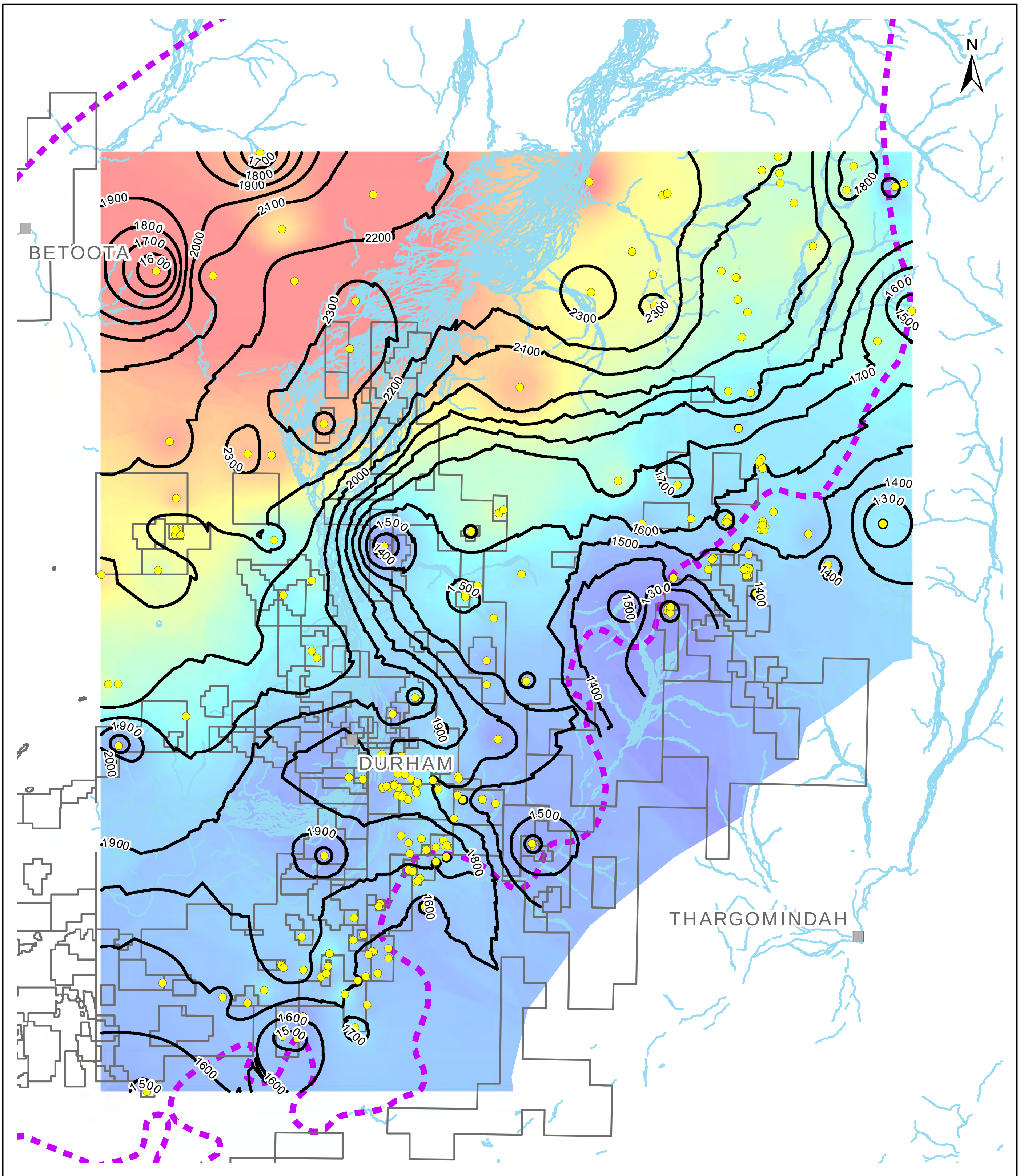
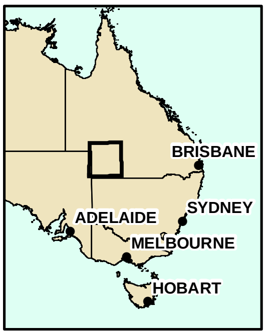


COOPER BASIN UWIR

SANTOS

GEOLOGICAL CONTOUR MAP: POOLOWANNA FORMATION



LEGEND

- Geological Data Point
- Town/Locality
- Depth to Poolowanna Formation (m)
- River/Creek
- Santos Operated Permits
- Cooper Basin

Thickness of Poolowanna Formation (m)

170

3

0 5 10 20 30 40 50 Kilometres

SCALE (at A3) 1:2,000,000

Coordinate System: GCS GDA 1994

PROJECT: 117636010
DATE: 31/07/2012
DRAWN: AJW
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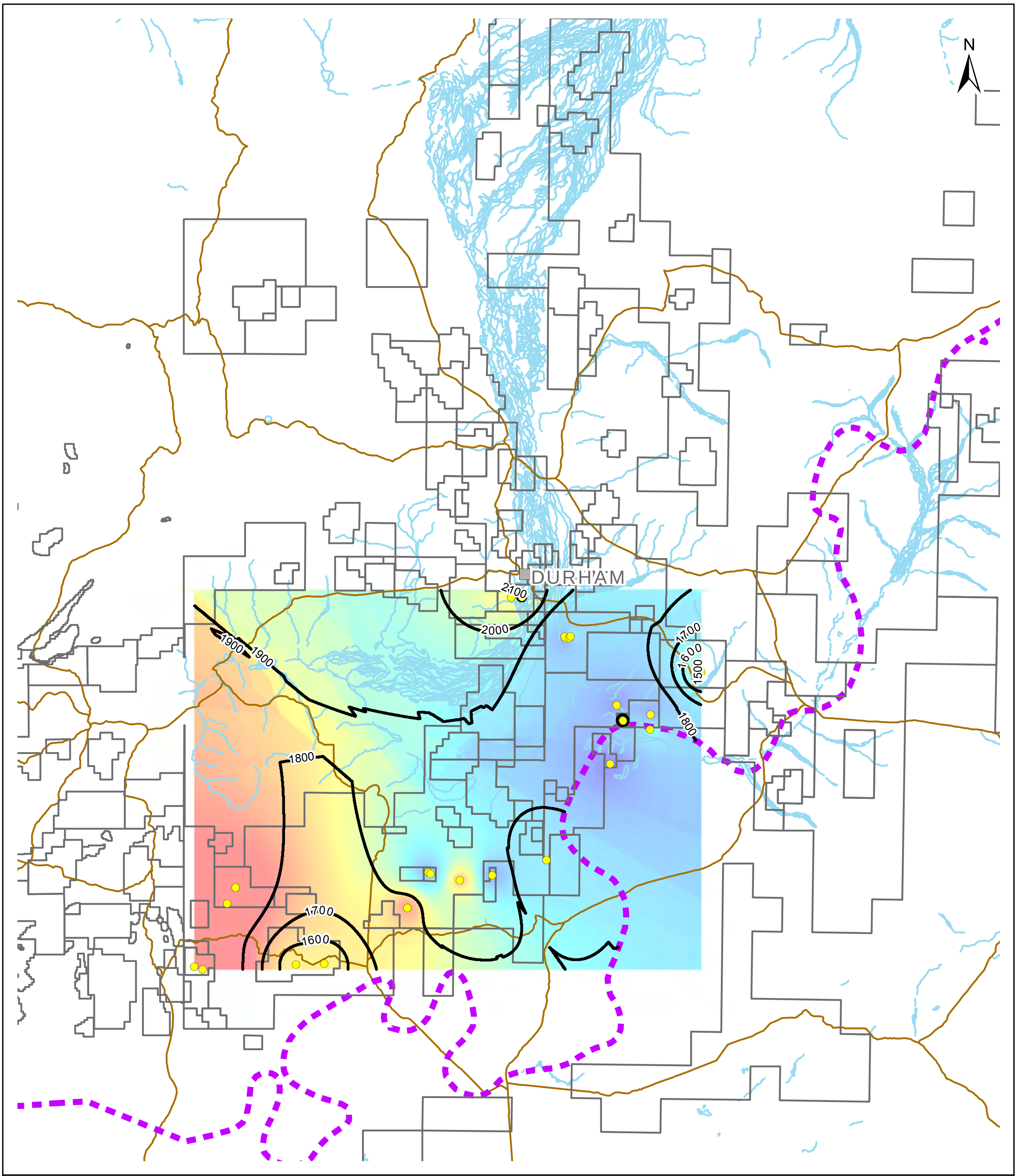

COOPER BASIN UWIR

SANTOS

GEOLOGICAL CONTOUR MAP: TOOLACHEE FORMATION

LEGEND

- Geology Data Point
- Town/Locality
- Depth to Toolachee Formation (m)
- Highway / Major Road
- River/Creek
- Santos Operated Permits
- Cooper Basin

Thickness of Toolachee Formation (m)

160

7

0 5 10 20 30 40 50 Kilometres

SCALE (at A3) 1:1,500,000

Coordinate System: GCS GDA 1994

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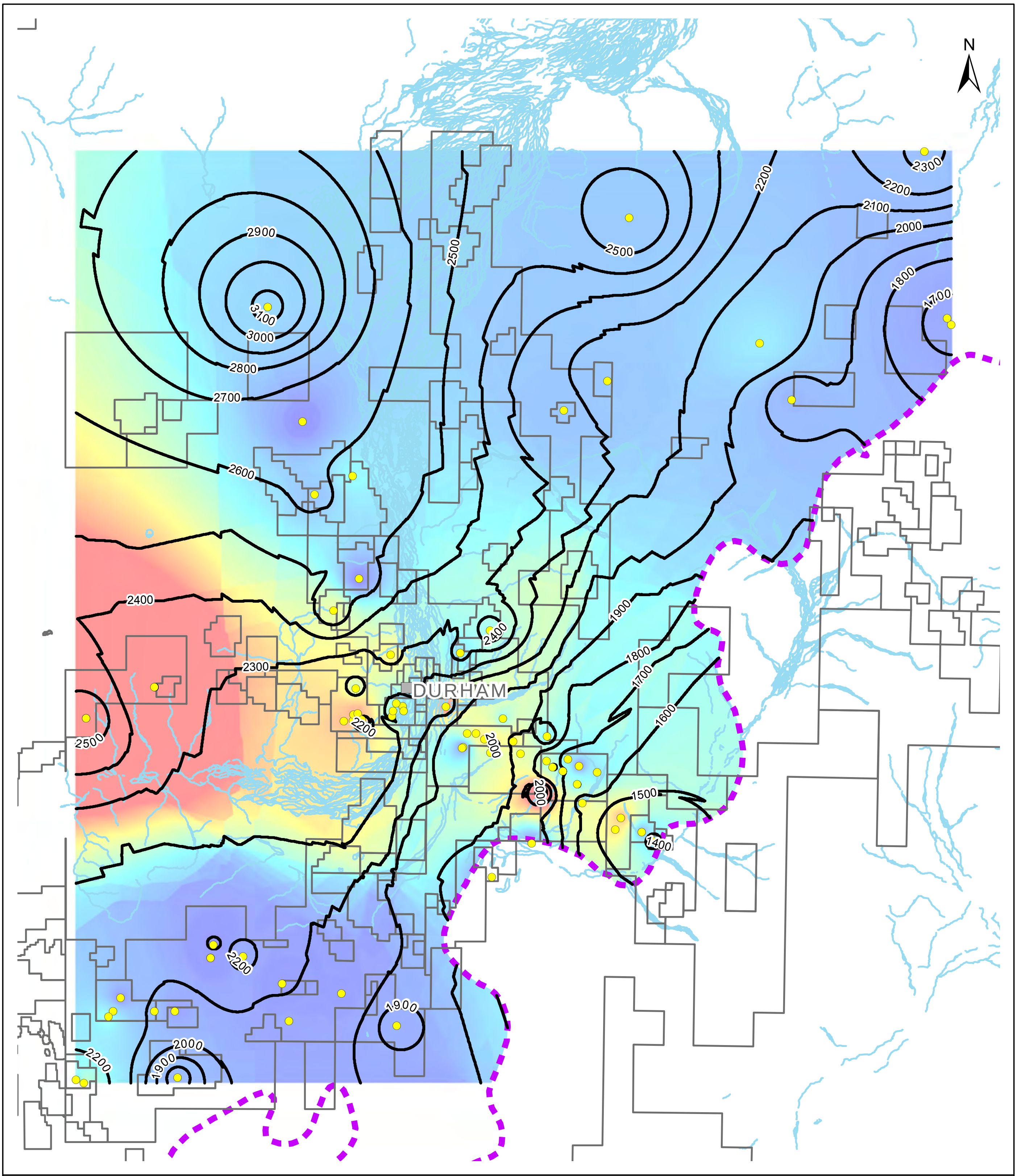

COOPER BASIN UWIR

SANTOS

GEOLOGICAL CONTOUR MAP: PATCHAWARRA FORMATION

LEGEND

- Geology Data Point
- Town/Locality
- Depth to Patchawarra Formation (m)
- River/Creek
- Santos Operated Permits
- Cooper Basin

Thickness of Patchawarra Formation (m)

745

Low : 7.5

0 5 10 20 30 40 50 Kilometres

SCALE (at A3) 1:1,500,000

Coordinate System: GCS GDA 1994

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DATE:	31/07/2012
DRAWN:	AJW
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APPENDIX D

Pond Register

ASSET REGISTER OF DAMS (INCLUDING PRODUCED FORMATION WATER EVAPORATION PONDS)

Data from Santos, 2011.

PL or ATP	Name of Dam/Pond	Latitude (WGS84)	Longitude (WGS84)	Max Surface Area (ha)	Max Operational Volume (ML)	Dam/Pond Purpose	Hazard Category
61	Ballera plant interceptor pond 1	-27.392833	141.809081	0.14	2.1	Separation	Low
61	Ballera plant holding pond 1	-27.3927528	141.80925	0.15	2.25	Secondary separation / Evaporation	Low
61	Ballera plant interceptor pond 2	-27.3931194	141.8083417	0.088	1.76	Separation	Low
61	Ballera plant holding pond 2	-27.3930611	141.8084694	0.1	2	Evaporation	Low
61	Ballera evaporation pond	-27.3917556	141.8103333	0.49	4.9	Evaporation	Significant
61	Ballera freeform evaporation pond	-27.3921083	141.8130167	29.2	292	Evaporation	Significant
61	Ballera airport pond	-27.39435	141.8074556	1	10	Evaporation	TBD
26	Bogala interceptor pond	-27.5175694	142.2575222	0.0625	0.94	Separation	Low
26	Bogala evaporation pond 1	-27.5171972	142.2572972	0.275	4.125	Evaporation	Significant
26	Bogala evaporation pond 2	-27.5307194	142.2577222	0.3	4.5	Evaporation	Significant
76	Bolan interceptor pond	-27.7817778	142.1605583	0.0576	0.864	Separation	Low
76	Bolan evaporation pond	-27.7813556	142.1604139	0.81	12.15	Evaporation	TBD
78	Bowen interceptor pond	-27.9124806	142.0543278	0.04	0.6	Separation	Low
78	Bowen evaporation pond	-27.9121278	142.0550417	2.1	21	Evaporation	TBD
97	Cook interceptor pond	-26.7001667	141.2874722	0.09	1.35	Separation	Low
97	Cook evaporation pond	-26.6999694	141.2866083	2.25	22.5	Evaporation	Low
36	Cooroo interceptor pond	-27.7141111	142.2875972	0.0484	0.726	Separation	Low
36	Cooroo evaporation pond	-27.7124111	142.287475	9	90	Evaporation	Significant
76	Echuburra interceptor pond 1	-27.8364778	142.1847194	0.0225	0.338	Separation	Low
76	Echuburra interceptor pond 2	-27.8362917	142.1847194	0.0324	0.338	Separation	Low
76	Echuburra evaporation pond	-27.8359194	142.1854278	2.25	33.75	Evaporation	Significant
63	Epsilon interceptor pond	-28.1595556	141.1331944	0.03	0.36	Separation	Low
63	Epsilon evaporation pond	-28.1599639	141.1330194	0.64	6.4	Evaporation	TBD
68	Genoa interceptor pond	-28.1416361	141.8502167	0.09	1.35	Separation	Low
68	Genoa holding pond	-28.1419528	141.8498	0.04	0.6	Evaporation	Low
68	Genoa evaporation pond	-28.1419528	141.8486417	5.4	54	Evaporation	TBD
68	Genoa freeform evaporation pond	-28.1441917	141.8495694	10	50	Evaporation	TBD
23	Jackson interceptor pond	-27.6155194	142.4108028	0.175	2.035	Separation	Low
23	Jackson evaporation pond 1	-27.6152667	142.4102528	1.35	13.5	Evaporation	Significant
23	Jackson evaporation pond 2	-27.6146	142.4094167	2.34	23.4	Evaporation	Significant
23	Jackson evaporation pond 3	-27.6207722	142.4079722	6	60	Evaporation	Significant
23	Gunna interceptor pond	-27.5740806	142.3782694	0.0025	0.34	Separation	Low
23	Gunna evaporation pond	-27.574975	142.3778556	0.2304	3.5	Evaporation	TBD
23	Tinpilla interceptor pond	-27.5648556	142.3497167	0.0324	0.49	Separation	Low
23	Tinpilla evaporation pond	-27.564775	142.3493833	0.2025	3	Evaporation	TBD
259P	Jarrah interceptor pond	-27.7114083	142.229175	0.04	0.6	Separation	Low
259P	Jarrah evaporation pond 1	-27.7109611	142.2282806	0.81	12.15	Evaporation	Significant
259P	Jarrah evaporation pond 2	-27.710275	142.2273583	1.12	20.25	Evaporation	Significant
259P	Jarrah pump-out pond	-27.7107167	142.2290389	0.09	1.35	Pump-out	Low
55	Munro interceptor pond	-28.5323806	141.1985611	0.0625	0.94	Separation	Low

PL or ATP	Name of Dam/Pond	Latitude (WGS84)	Longitude (WGS84)	Max Surface Area (ha)	Max Operational Volume (ML)	Dam/Pond Purpose	Hazard Category
55	Munro holding pond	-28.532125	141.1988222	0.5	7.5	Evaporation	TBD
55	Munro evaporation pond	-28.5324722	141.1969472	14.1	141	Evaporation	TBD
55	Munro freeform evaporation pond	-28.5314722	141.1993583	1.89	9.45	Evaporation	TBD
25	Naccowlah 2 interceptor pond	-27.484475	142.1368472	0.0576	0.864	Separation	Low
25	Naccowlah 2 evaporation pond	-27.4845444	142.1364194	0.59	8.9	Evaporation	TBD
25	Naccowlah interceptor pond	-27.5195194	142.1327639	0.175	2.625	Separation	Low
25	Naccowlah evaporation pond 1	-27.51975	142.1320028	1.08	10.8	Evaporation	Significant
25	Naccowlah evaporation pond 2	-27.5200222	142.1307667	2.7	40.5	Evaporation	Significant
25	Naccowlah freeform evaporation pond	-27.5414028	142.1037833	28.52	142.6	Evaporation	Significant
75	Patroclus interceptor pond	-28.1105278	141.6831972	0.09	1.35	Separation	Low
75	Patroclus holding pond	-28.1102056	141.683	0.0625	1.25	Evaporation	Low
75	Patroclus freeform evaporation pond	-28.1093528	141.6847833	12	60	Evaporation	TBD
25	Pitchery interceptor pond	-27.4982472	142.1569694	0.0625	0.5	Separation	Low
25	Pitchery holding pond	-27.4979056	142.1568333	0.095	0.95	Evaporation	Low
25	Pitchery evaporation pond 1	-27.4981167	142.1563556	0.35	3.5	Evaporation	Significant
25	Pitchery evaporation pond 2	-27.4979972	142.1555417	0.36	3.6	Evaporation	TBD
84	Stokes interceptor pond	-28.3457194	141.0318889	0.06	0.6	Separation	Low
84	Stokes evaporation pond	-28.3466639	141.0310417	5.18	51.8	Evaporation	TBD
34	Tickalara 2 interceptor pond	-28.3346944	141.3969722	0.09	0.9	Separation	TBD
34	Tickalara interceptor pond	-28.3424639	141.3841667	0.04	0.4	Separation	Low
34	Tickalara holding pond 1	-28.3421778	141.3836806	0.16	1.6	Evaporation	Low
34	Tickalara holding pond 2	-28.3427194	141.3834917	0.34	3.4	Evaporation	Significant
34	Tickalara evaporation pond	-28.3425194	141.3798	6	60	Evaporation	Significant
34	Tickalara freeform evaporation pond	-28.3421417	141.3694306	12	60	Evaporation	TBD
35	Watson interceptor pond	-28.0909639	142.0813472	0.175	2.625	Separation	Low
35	Watson holding pond 1	-28.0906917	142.0808472	0.176	1.76	Evaporation	Low
35	Watson holding pond 2	-28.0911	142.0806028	0.24	2.4	Evaporation	Low
35	Watson evaporation pond 1	-28.0939722	142.0745944	2.25	22.5	Evaporation	Significant
35	Watson evaporation pond 2	-28.0951083	142.0897167	11.0088	110.088	Evaporation	Significant
35	Watson evaporation pond 3	-28.0923556	142.0729222	9.338	93.38	Evaporation	Significant
35	Watson South interceptor pond	-28.1358611	142.0536444	0.04	0.4	Separation	Low
35	Watson South evaporation pond	-28.1355861	142.0549889	4	40	Evaporation	Significant
51	Muthero interceptor pond	-27.7112194	142.6114028	0.04	0.6	Separation	Low
51	Muthero holding pond 1	-27.7115389	142.6115361	0.2	2	Evaporation	Low
51	Muthero holding pond 2	-27.7123278	142.6102306	0.16	1.6	Evaporation	TBD
51	Muthero evaporation pond	-27.7137611	142.6094833	0.99	59.4	Evaporation	Significant
33	Nockatunga interceptor pond	-27.7169611	142.524275	0.0625	0.5	Separation	Low
33	Nockatunga holding pond 1	-27.7161528	142.5253444	0.04	0.4	Evaporation	Low
33	Nockatunga holding pond 2	-27.7160639	142.525475	0.0375	0.375	Evaporation	Low
33	Nockatunga evaporation pond 1	-27.7158167	142.5250361	0.36	3.6	Evaporation	Significant
33	Nockatunga evaporation pond 2	-27.7159222	142.5257389	0.15	1.5	Evaporation	Low
33	Nockatunga evaporation pond 3	-27.7164667	142.5255444	0.2	2	Evaporation	Low
51	Thungo interceptor pond	-27.5799472	142.5799472	0.054	0.54	Separation	Low

PL or ATP	Name of Dam/Pond	Latitude (WGS84)	Longitude (WGS84)	Max Surface Area (ha)	Max Operational Volume (ML)	Dam/Pond Purpose	Hazard Category
51	Thungo holding pond	-27.7287528	142.5807611	0.63	6.3	Evaporation	Significant
51	Thungo evaporation pond 1	-27.7275861	142.5817167	1.04	10.4	Evaporation	Significant
51	Thungo evaporation pond 2	-27.7267556	142.5828056	1.485	14.85	Evaporation	Significant
50	Maxwell interceptor pond	-27.8806611	142.6971028	0.08	1.2	Separation	Low
50	Maxwell holding pond	-27.880275	142.6969306	0.1	1.5	Evaporation	Low
50	Maxwell evaporation pond	-27.8798444	142.6967056	0.16	3.2	Evaporation	TBD
50	Maxwell South evaporation pond	-27.9042333	142.6770694	0.06	0.78	Evaporation	Low
33	Winna interceptor pond	-27.7270583	142.5541	0.04	0.32	Separation	Low
33	Winna holding pond	-27.7268833	142.5544694	0.06	0.48	Evaporation	Low
33	Winna evaporation pond 1	-27.7268917	142.554875	0.12	1.2	Evaporation	Low
33	Winna evaporation pond 2	-27.7268361	142.5554861	0.3	3	Evaporation	Significant
33	Winna evaporation pond 3	-27.7243556	142.5624861	0.6	6	Evaporation	TBD
170	Kooroopa evaporation pond	-27.0011861	143.2303278	0.09	0.9	Evaporation	Low
95	Monler interceptor pond	-26.7573639	143.2595361	0.0625	1.25	Separation	Low
95	Monler evaporation pond 1	-26.7571083	143.2600194	0.3	3	Evaporation	TBD
95	Monler evaporation pond 2	-26.7575056	143.2602972	0.25	2.5	Evaporation	TBD
170	Takyah interceptor pond	-27.0104861	143.3010944	0.0091	0.046	Separation	Low
170	Takyah evaporation pond	-27.0104639	143.3013111	0.168	1.68	Evaporation	Low
52	Tarbat interceptor pond	-26.8976167	143.3062889	0.0784	1.176	Separation	Low
52	Tarbat holding pond	-26.8979917	143.3069222	0.4	4	Evaporation	Low
52	Tarbat evaporation pond 1	-26.8982194	143.3080028	3.6	36	Evaporation	Significant
52	Tarbat evaporation pond 2	-26.8975861	143.3094	5.4	54	Evaporation	Significant
29	Tintaburra interceptor pond	-26.9320694	143.1020333	0.108	1.62	Separation	Low
29	Tintaburra holding pond 1a	-26.9318028	143.1021667	0.135	2.025	Evaporation	Low
29	Tintaburra holding pond 1b	-26.9315389	143.1022389	0.115	1.725	Evaporation	Low
29	Tintaburra holding pond 1c	-26.9311611	143.1023722	0.3	4.5	Evaporation	TBD
29	Tintaburra evaporation pond 2	-26.9312361	143.1017917	0.575	5.75	Evaporation	Low
29	Tintaburra evaporation pond 3	-26.9311139	143.1012333	0.6	6	Evaporation	Low
29	Tintaburra evaporation pond 4	-26.9308111	143.1001194	1.925	19.25	Evaporation	Significant
29	Tintaburra evaporation pond 5	-26.9304833	143.0983167	3.173	31.73	Evaporation	TBD
29	Tintaburra evaporation pond 6	-26.9300722	143.0961361	4.2	42	Evaporation	TBD
29	Tintaburra evaporation pond 7	-26.9314528	143.0958222	4.0015	40.015	Evaporation	TBD
29	Tintaburra evaporation pond 8	-26.9318639	143.0980139	2.9	29	Evaporation	TBD
29	Tintaburra evaporation pond 9	-26.9322889	143.0995139	2.225	22.25	Evaporation	TBD
29	Tintaburra evaporation pond 10	-26.9323972	143.1009556	2.1307	21.307	Evaporation	TBD
29	Tintaburra evaporation pond 11	-26.9342139	143.1012694	2	20	Evaporation	TBD
29	Tintaburra evaporation pond 12	-26.9345056	143.0997556	1.7	17	Evaporation	TBD
29	Tintaburra evaporation pond 13	-26.9338639	143.0966083	10.75	107.5	Evaporation	TBD
145	Toby interceptor pond	-26.6846333	142.3695472	0.0324	0.486	Separation	Low
145	Toby evaporation pond	-26.6841917	142.3683417	0.2	3	Evaporation	TBD

APPENDIX E

Produced Water and Well Oil/Gas Field Data

PRODUCED WATER PER OIL/GAS FIELD

Data from Santos, 2011

Field Name	RMU	Formation	PL Number	Production years		Total Water Produced	Average Annual Rate	Peak water production
				Years		*ML*	*ML/year*	*ML/day*
BOWEN	AD	Adori	PL78	1990-2007	17	215.07	1.000	0.150
MOOLIAMPAH	AD	Adori	PL 34	1985-2011	26	146.74	0.470	0.131
TALGEBERRY	AD	Adori	PL 39	2007-2011	4	43.08	1.026	0.056
ECHUBURRA	BBI	Basal Birkhead	PL 76	1991-2011	20	67.56	0.277	0.034
TOBY	BH	Basal Hutton	PL 145	1987-1988	1	0.07	0.012	0.001
BOGALA	BI	Birkhead	PL 26	1997-2011	14	105.44	0.606	0.039
BOWEN	BI	Birkhead	PL78	1990-2011	21	39.37	0.157	0.109
CHANCETT	BI	Birkhead	PL 169	2006-2011	5	0.32	0.006	0.005
CRANSTOUN	BI	Birkhead	PL 57	1987-2011	24	78.91	0.277	0.064
ENDEAVOUR	BI	Birkhead	PL 57	1989-2011	22	148.49	0.569	0.137
GIMBOOLA	BI	Birkhead	PL 169	1992-2011	19	0.15	0.037	34.084
JACKSON	BI	Birkhead	PL 23, PL24	2008-2011	3	32.98	0.804	0.035
JACKSON STH	BI	Birkhead	PL 23, PL24	1985-2011	26	119.41	0.375	0.062
KOORA	BI	Birkhead	PL 33	1985-2010	25	1.62	0.005	0.031
KOOROOPA	BI	Birkhead	PL 170	1985-2011	26	12.21	0.039	0.004
MINNI RITCHI	BI	Birkhead	PL 57	2006-2011	5	1.67	0.029	0.005
MINOS	BI	Birkhead	PL 301	2011	0	0.00	0.000	0.000

Field Name	RMU	Formation	PL Number	Production years		Total Water Produced	Average Annual Rate	Peak water production
MULBERRY	BI	Birkhead	PL 295, PL 39	2004-2011	7	414.78	4.660	0.423
MUTHERO	BI	Birkhead	PL 51	1989-2011	22	487.21	1.853	0.294
NOCKATUNGA	BI	Birkhead	PL 33	1985-2011	26	50.51	0.163	0.020
TAKYAH	BI	Birkhead	PL 170	1986-2011	25	23.41	0.076	0.017
TALGEBERRY	BI	Birkhead	PL 39	1985-2011	26	53.92	0.173	0.061
TENNAPERRA	BI	Birkhead	PL 78	1996-2011	15	3.43	0.019	0.044
TOOBUNYAH	BI	Birkhead	PL 38	1985-2011	26	71.33	0.232	0.038
ZEUS	BI	Birkhead	PL 301	2011	0	2.04	0.682	0.048
BOWEN	BJ	Basal Jurassic	PL78	1992-1996	4	74.60	1.865	0.167
CHOOKOO	BJ	Basal Jurassic	PL 25, PL 26	1987-1993	6	170.71	2.439	0.206
COOROO	BJ	Basal Jurassic	PL 36	1986-2011	25	363.31	1.227	0.097
KARRI	BJ	Basal Jurassic	PL 26	1990-2004	14	0.25	0.001	0.005
NACCOWLAH STH	BJ	Basal Jurassic	PL 25	1989-2008	19	81.10	0.356	0.107
TOBY	BJ	Basal Jurassic	PL 145	1987-2008	21	20.32	0.083	0.080
KERCUMMURRA	CD	Cadna-Owie		1985-2009	24	0.00	0.000	0.000
TOBY	CD	Cadna-Owie	PL 145	2007-2010	3	2.48	0.071	0.032
YANDA	CD	Cadna-Owie	PL 61	1995-2009	14	4.71	0.029	0.008
BOLAN	HU	Hutton	PL 76	1990-2010	20	231.80	0.978	0.103
CHOOKOO	HU	Hutton	PL 25, PL 26	1984-1997	13	165.10	0.995	0.320
COOK	HU	Hutton	PL 97	1985-2011	26	481.79	1.549	0.214

Field Name	RMU	Formation	PL Number	Production years		Total Water Produced	Average Annual Rate	Peak water production
CORELLA	HU	Hutton	PL 76	1989-1996	7	136.57	1.821	0.164
ECHUBURRA	HU	Hutton	PL 76	1992-2011	19	131.03	0.565	0.069
GENOA	HU	Hutton	PL 68	1992-2011	19	3524.44	15.126	1.333
GENOA NTH	HU	Hutton	PL 68	1993-1995	2	41.79	1.741	0.342
GRAHAM	HU	Hutton	PL23	2007-2011	4	53.88	1.122	0.124
IPUNDU NTH	HU	Hutton	PL 52	2007-2011	4	4.42	0.092	0.027
JACKSON #30	HU	Hutton	PL 23, PL24	1987-1989	2	1.43	0.060	0.006
JACKSON EAST	HU	Hutton	PL 23, PL24	2009-2011	2	49.79	1.844	0.074
JACKSON	HU	Hutton	PL 23, PL24	1982-2011	29	66799.57	193.622	11.020
JACKSON STH	HU	Hutton	PL 23, PL24	1987-2011	24	239.58	0.838	0.154
JARRAR	HU	Hutton	PL 77	1990-2011	21	1156.93	4.665	0.334
MARCOOLA	HU	Hutton	PL 38	2007-2011	4	2.15	0.049	0.004
MONLER	HU	Hutton	PL 95	1994-2011	17	5.17	0.025	0.020
MUNRO	HU	Hutton	PL 55	1988-2011	23	971.71	3.521	0.564
NACCOWLAH STH	HU	Hutton	PL 25	1984-2011	27	2609.92	7.933	0.680
NACCOWLAH WEST	HU	Hutton	PL 25	1984-2011	27	34467.77	107.043	8.634
NATAN	HU	Hutton	PL 76	1988-1992	4	4.13	0.084	0.011
PATROCLUS	HU	Hutton	PL 75	1991-2011	20	1133.70	4.784	0.617
PINAROO	HU	Hutton	PL 35	1989-1999	10	33.09	0.290	0.076
TARBAT	HU	Hutton	PL 52	1995-2011	16	620.13	3.230	0.403
TINTABURRA	HU	Hutton	PL 29	1983-2011	28	8500.80	25.682	2.404

Field Name	RMU	Formation	PL Number	Production years		Total Water Produced	Average Annual Rate	Peak water production
TOOBUNYAH	HU	Hutton	PL 38	1985-2011	26	3599.04	11.685	1.199
TOSTADA	HU	Hutton	PL 23	2007-2011	4	20.13	0.411	0.039
WATKINS	HU	Hutton	PL 35	2009-2011	2	0.70	0.024	0.006
WATSON	HU	Hutton	PL 35	1986-2011	25	1792.39	5.857	1.161
WATSON STH	HU	Hutton	PL 35	1985-2011	26	6400.12	20.448	1.756
WILSON	HU	Hutton	PL 23	1986-2011	25	30.66	0.102	0.049
YANDA	HU	Hutton	PL 61	2006-2011	5	19.27	0.332	0.030
COOROO	HU/BI	Hutton/Birkhead	PL 36	1986-2011	25	1254.69	4.239	0.347
WANDILO	HU/BI	Hutton/Birkhead	PL 35	1989-2011	22	494.35	1.887	0.577
ILIAD	MCK	McKinlay	PL 34	2009-2011	2	1.01	0.050	0.003
MOOLIAMPAH	MCK	McKinlay	PL 34	1990-2011	21	1.95	0.008	0.004
PATROCLUS	MCK	McKinlay	PL 75	1993-2011	18	3.53	0.017	0.004
TICKALARA	MCK	McKinlay	PL 34	2009	0	0.02	0.012	0.001
GENOA NTH	MNM	Mid Namur	PL 68	1994-1995	1	0.16	0.041	0.003
MOOLIAMPAH	MNM	Mid Namur	PL 34	1989-2011	22	32.30	0.122	0.013
PATROCLUS	MNM	Mid Namur	PL 75	1992-2011	19	113.56	0.505	0.133
TICKALARA	MNM	Mid Namur	PL 34	1988-2011	23	4069.66	14.483	2.234
BOGALA CENTRAL	MU	Murta	PL 26	2007-2010	3	0.30	0.008	0.001
BOGALA	MU	Murta	PL 26	1984-2011	27	594.86	1.830	0.125
CHALLUM 1	MU	Murta	PL58	1985-2011	26	4.80	0.015	0.010
CHALLUM 30	MU	Murta	PL58	2008-2011	3	4.52	0.116	0.026

Field Name	RMU	Formation	PL Number	Production years		Total Water Produced	Average Annual Rate	Peak water production
CHILLA	MU	Murta	PL 25	2007-2011	4	36.35	0.826	0.098
CUISINIER	MU	Murta	PL 303	2010-2011	1	0.02	0.001	0.000
CURRAMBAR	MU	Murta	PL 244	2006-2011	5	34.96	0.530	0.038
DILKERA	MU	Murta	PL 51	1989-2011	22	82.22	0.313	0.076
GUNNA	MU	Murta	PL 23	1984-2011	27	56.09	0.170	0.011
ILIAD	MU	Murta	PL 34	2005-2011	6	55.23	0.778	0.049
JACKSON	MU	Murta	PL 23, PL24	1983-2011	28	511.43	1.540	0.157
KAMEL	MU	Murta	PL 51	2007-2011	4	1.14	0.025	0.002
KIHEE	MU	Murta	PL 33	1988-2007	19	0.07	0.000	0.000
KOORA	MU	Murta	PL 33	1991-2010	19	84.35	0.360	0.037
MAXWELL/STH	MU	Murta	PL 50	1987-2011	24	90.66	0.312	0.021
MOOLIAMPAH	MU	Murta	PL 34	1989-2011	22	70.41	0.266	0.031
MUTHERO	MU	Murta	PL 51	1989-2011	22	121.11	0.461	0.113
NACCOWLAH	MU	Murta	PL 25	1989-2011	22	257.55	0.979	0.059
NACCOWLAH WEST	MU	Murta	PL 25	1984-1990	6	42.16	0.602	0.038
NOCKATUNGA	MU	Murta	PL 33	1985-2011	26	135.08	0.427	0.028
ORIENTOS	MU	Murta		1990-2010	20	1.72	0.007	0.013
PATROCLUS	MU	Murta	PL 75	1994-2011	17	11.82	0.057	0.042
PITCHERY	MU	Murta	PL 62	1988-2011	23	408.24	1.453	0.283
SIGMA	MU	Murta	PL 34	1985-2011	26	43.08	0.136	0.019
TAKYAH	MU	Murta	PL 170	1986-2011	25	29.20	0.095	0.024

Field Name	RMU	Formation	PL Number	Production years		Total Water Produced	Average Annual Rate	Peak water production
TALGEBERRY	MU	Murta	PL 39	1985-2011	26	39.43	0.127	0.036
THUNGO	MU	Murta	PL 51	1986-2011	25	649.34	2.143	0.276
TICKALARA	MU	Murta	PL 34	1988-2011	23	21.56	0.078	0.045
TINPILLA	MU	Murta	PL 23	1984-2011	27	24.66	0.075	0.018
WILSON	MU	Murta	PL 23	1988-2011	23	113.11	0.707	0.032
WINNA	MU	Murta	PL 33	1985-2011	26	219.70	0.709	0.081
YANDA	MU	Murta	PL 61	1985-2011	26	9.16	0.029	0.016
BOWEN	NM	Namur	PL78	1994-2011	17	1.34	0.006	0.001
COOK	NM	Namur	PL 97	2005-2010	5	0.03	0.0005	0.001
EPSILON	NM	Namur	PL 63	1988-1989	1	0.00	0.000	0.000
GENOA	NM	Namur	PL 68	1992-1996	4	0.31	0.006	0.009
GENOA NTH	NM	Namur	PL 68	1994-1995	1	0.10	0.020	0.002
ILIAD	NM	Namur	PL 34	1994-2011	17	393.44	1.929	0.179
RHEIMS	NM	Namur	PL 34	1990-1991	1	0.39	0.078	0.009
SIGMA	NM	Namur	PL 34	1985-2011	26	23.24	0.075	0.010
TENNAPERRA	NM	Namur	PL 78	1996-1997	1	0.67	0.042	0.005
WILSON	NM	Namur	PL 23	1984-2011	27	353.60	1.075	0.076
WALLAWANNY NTH	PO	Poolowanna	PL 77	1991	0	4.50	0.562	0.074
NACCOWLAH STH	TO	Toolachee	PL 25	1988-2010	22	101.22	0.382	0.059
YANDA	TO/UPA	Toolachee/Upper Patchawarra	PL 61	1990-2011	21	34.43	0.136	0.021

Field Name	RMU	Formation	PL Number	Production years		Total Water Produced	Average Annual Rate	Peak water production
ECHUBURRA	UBI	Upper Birkhead	PL 76	1991-2011	20	12.44	0.051	0.007
MUTHERO	UBI	Upper Birkhead	PL 51	2007-2008	1	67.68	5.640	0.252
PATROCLUS	UNM	Upper Namur	PL 75	1993-2011	18	418.17	1.927	0.168
TICKALARA	UNM	Upper Namur	PL 34	1985-2011	26	1700.80	5.365	1.060
BOWEN	WB	Westbourne	PL78	1992-2011	19	8.21	0.036	0.015
COOLUM	WB	Westbourne	PL 295	2005-2011	6	1.36	0.0183	0.002
COOROO NTH	WB	Westbourne	PL 36	1987-1988	1	0.24	0.017	0.003
DINGERA	WB	Westbourne	PL 51	1988-2005	17	0.33	0.002	0.007
ENDEAVOUR	WB	Westbourne	PL 57	2007-2011	4	0.25	0.005	0.003
JACKSON STH	WB	Westbourne	PL 23, PL24	1982-2011	29	438.62	1.275	0.273
JACKSON	WB	Westbourne	PL 23, PL24	1982-2011	29	3342.80	9.746	0.958
MONLER	WB	Westbourne	PL 95	1987-2011	24	104.10	0.363	0.054
MOOLIAMPAH	WB	Westbourne	PL 34	1990-2006	16	7.86	0.108	0.017
TALGEBERRY	WB	Westbourne	PL 39	1994-2011	17	0.00	0.000	0.000
TICKALARA	WB	Westbourne	PL 34	1987-2011	24	632.71	2.197	0.780
WILSON	WB	Westbourne	PL 23	1984-2011	27	292.90	0.890	0.065
KOOROOPA NTH	WY	Wyandra	PL 170	1995-2011	16	15.91	0.084	0.009
KOOROOPA	WY	Wyandra	PL 170	2007-2011	4	9.44	0.197	0.014
TALGEBERRY	WY	Wyandra	PL 39	1985-2011	26	91.77	0.295	0.042
TINTABURRA	WY	Wyandra	PL 29	1984-2011	27	0.84	0.003	0.013
IPUNDU NTH	WY/MU	Wyandra/ Murta	PL 52	1989-2011	22	176.86	0.678	0.101

Field Name	RMU	Formation	PL Number	Production years		Total Water Produced	Average Annual Rate	Peak water production
IPUNDU	WY/MU	Wyandra/ Murta	PL 52	1986-2011	25	258.43	0.847	0.099
TARBAT	WY/MU	Wyandra/ Murta	PL 52	1988-2011	23	311.33	1.120	0.127

TARGET FORMATIONS FOR KNOWN WELLS IN THE PROJECT AREA

Data from Santos, 2011

RN	Facility Type	Status	Target Aquifer	Drilled Depth (m)
5523	sub-artesian	Existing	Allaru Mudtone	258.47
13240	sub-artesian	Existing	Allaru Mudtone	188.10
13595	sub-artesian	Existing	Allaru Mudtone	185.93
5124	Artesian - cease to flow	Existing	Coreena Member	285.10
5174	sub-artesian	Existing	Coreena Member	242.40
5298	sub-artesian	Existing	Coreena Member	259.10
5299	sub-artesian	Existing	Coreena Member	170.80
6685	sub-artesian	Existing	Coreena Member	145.70
6968	sub-artesian	Existing	Coreena Member	81.84
8911	sub-artesian	Existing	Coreena Member	80.20
8912	sub-artesian	Existing	Coreena Member	230.50
13330	sub-artesian	Existing	Coreena Member	103.63
16017	sub-artesian	Existing	Coreena Member	265.30
33245	sub-artesian	Existing	Coreena Member	86.00
33395	sub-artesian	Existing	Coreena Member	243.80
5260	sub-artesian	Existing	Glendower Formation	36.00
12246	sub-artesian	Existing	Glendower Formation	24.10
12522	sub-artesian	Existing	Glendower Formation	29.60
13544	sub-artesian	Existing	Glendower Formation	31.70
13549	sub-artesian	Existing	Glendower Formation	31.70
13550	sub-artesian	Existing	Glendower Formation	31.70
13615	sub-artesian	Existing	Glendower Formation	36.60
13713	sub-artesian	Existing	Glendower Formation	42.70
13743	sub-artesian	Existing	Glendower Formation	36.90
13935	sub-artesian	Existing	Glendower Formation	30.50
14291	sub-artesian	Existing	Glendower Formation	63.40
14292	sub-artesian	Existing	Glendower Formation	84.40
14555	sub-artesian	Existing	Glendower Formation	61.90
14955	sub-artesian	Existing	Glendower Formation	94.80
16379	sub-artesian	Existing	Glendower Formation	25.00
16536	sub-artesian	Existing	Glendower Formation	30.50
16546	sub-artesian	Existing	Glendower Formation	32.00
16576	sub-artesian	Existing	Glendower Formation	22.90
16577	sub-artesian	Existing	Glendower Formation	22.90
24721	sub-artesian	Existing	Glendower Formation	38.71
26167	sub-artesian	Existing	Glendower Formation	13.70
32403	sub-artesian	Existing	Glendower Formation	53.30
35651	sub-artesian	Existing	Glendower Formation	86.30
36306	sub-artesian	Existing	Glendower Formation	37.80
36307	sub-artesian	Existing	Glendower Formation	37.50
36499	sub-artesian	Existing	Glendower Formation	52.40
50030	sub-artesian	Existing	Glendower Formation	49.50
50309	sub-artesian	Existing	Glendower Formation	38.70
50353	sub-artesian	Existing	Glendower Formation	26.21
51006	sub-artesian	Existing	Glendower Formation	42.06
116254	artesian - controlled flow	Existing	Hooray Sandstone	586.60
116266	artesian - controlled flow	Existing	Hooray Sandstone	966.30

RN	Facility Type	Status	Target Aquifer	Drilled Depth (m)
23426	artesian - controlled flow	Existing	Hutton Sandstone	2104.30
7677	sub-artesian	Existing	Mackunda Formation	182.90
9070	sub-artesian	Existing	Mackunda Formation	289.70
10283	sub-artesian	Existing	Mackunda Formation	234.80
11922	sub-artesian	Existing	Mackunda Formation	245.80
11924	sub-artesian	Existing	Mackunda Formation	217.10
13568	sub-artesian	Existing	Mackunda Formation	216.41
13629	sub-artesian	Existing	Mackunda Formation	197.90
13835	sub-artesian	Existing	Mackunda Formation	287.60
16304	sub-artesian	Existing	Mackunda Formation	192.02
16459	sub-artesian	Existing	Mackunda Formation	213.50
34797	sub-artesian	Existing	Mackunda Formation	264.30
6694	sub-artesian	Existing	Quaternary	21.30
10970	sub-artesian	Existing	Tertiary Sediments	51.82
14543	sub-artesian	Existing	Tertiary Sediments	122.80
15058	sub-artesian	Existing	Tertiary Sediments	25.60
15059	sub-artesian	Existing	Tertiary Sediments	31.70
15553	sub-artesian	Existing	Tertiary Sediments	32.90
15589	sub-artesian	Existing	Tertiary Sediments	125.00
16062	sub-artesian	Existing	Tertiary Sediments	29.30
16483	sub-artesian	Existing	Wallumbilla Formation	114.30
50001	sub-artesian	Existing	Wallumbilla Formation	600.00
1265	sub-artesian	Existing	Winton Formation	144.80
1954	sub-artesian	Existing	Winton Formation	56.40
5217	sub-artesian	Existing	Winton Formation	222.00
5222	sub-artesian	Existing	Winton Formation	139.00
5295	sub-artesian	Existing	Winton Formation	13.70
5323	sub-artesian	Existing	Winton Formation	137.20
5379	sub-artesian	Existing	Winton Formation	164.00
5519	sub-artesian	Existing	Winton Formation	73.20
5520	sub-artesian	Existing	Winton Formation	141.80
5521	sub-artesian	Existing	Winton Formation	197.60
5579	sub-artesian	Existing	Winton Formation	177.80
6112	sub-artesian	Existing	Winton Formation	186.30
6212	sub-artesian	Existing	Winton Formation	57.30
6267	sub-artesian	Existing	Winton Formation	160.02
6380	sub-artesian	Existing	Winton Formation	157.00
6680	sub-artesian	Existing	Winton Formation	62.80
6713	sub-artesian	Existing	Winton Formation	75.60
6733	sub-artesian	Existing	Winton Formation	96.00
6893	sub-artesian	Existing	Winton Formation	167.03
7128	sub-artesian	Existing	Winton Formation	115.80
7461	sub-artesian	Existing	Winton Formation	19.50
7896	sub-artesian	Existing	Winton Formation	128.02
7935	sub-artesian	Existing	Winton Formation	152.40
8065	sub-artesian	Existing	Winton Formation	80.20
8067	sub-artesian	Existing	Winton Formation	102.10
8245	sub-artesian	Existing	Winton Formation	144.20
9096	sub-artesian	Existing	Winton Formation	129.60
9183	sub-artesian	Existing	Winton Formation	191.20

RN	Facility Type	Status	Target Aquifer	Drilled Depth (m)
9345	sub-artesian	Existing	Winton Formation	143.30
9489	sub-artesian	Existing	Winton Formation	119.80
9689	sub-artesian	Existing	Winton Formation	118.90
9817	sub-artesian	Existing	Winton Formation	84.80
9894	sub-artesian	Existing	Winton Formation	149.70
10301	sub-artesian	Existing	Winton Formation	252.10
10424	sub-artesian	Existing	Winton Formation	61.00
10502	sub-artesian	Existing	Winton Formation	146.30
10508	sub-artesian	Existing	Winton Formation	124.40
10560	sub-artesian	Existing	Winton Formation	156.40
10629	sub-artesian	Existing	Winton Formation	215.00
10637	sub-artesian	Existing	Winton Formation	387.40
10784	sub-artesian	Existing	Winton Formation	253.00
11040	sub-artesian	Existing	Winton Formation	162.60
11452	sub-artesian	Existing	Winton Formation	89.00
11467	sub-artesian	Existing	Winton Formation	294.30
11469	sub-artesian	Existing	Winton Formation	176.80
11904	sub-artesian	Existing	Winton Formation	207.00
11993	sub-artesian	Existing	Winton Formation	304.80
12036	sub-artesian	Existing	Winton Formation	209.80
12055	sub-artesian	Existing	Winton Formation	113.10
12060	sub-artesian	Existing	Winton Formation	211.84
12066	sub-artesian	Existing	Winton Formation	3360.12
12087	sub-artesian	Existing	Winton Formation	177.20
12091	sub-artesian	Existing	Winton Formation	141.20
12092	sub-artesian	Existing	Winton Formation	136.90
12105	sub-artesian	Existing	Winton Formation	621.00
12137	sub-artesian	Existing	Winton Formation	294.30
12138	sub-artesian	Existing	Winton Formation	325.40
12154	sub-artesian	Existing	Winton Formation	822.00
12242	sub-artesian	Existing	Winton Formation	220.50
12252	sub-artesian	Existing	Winton Formation	72.54
12259	sub-artesian	Existing	Winton Formation	170.10
12377	sub-artesian	Existing	Winton Formation	243.84
12470	sub-artesian	Existing	Winton Formation	244.60
12525	sub-artesian	Existing	Winton Formation	114.91
12598	sub-artesian	Existing	Winton Formation	185.60
12685	sub-artesian	Existing	Winton Formation	152.10
12733	sub-artesian	Existing	Winton Formation	71.90
12734	sub-artesian	Existing	Winton Formation	111.30
12756	sub-artesian	Existing	Winton Formation	79.25
12844	sub-artesian	Existing	Winton Formation	229.82
12850	sub-artesian	Existing	Winton Formation	199.70
12860	sub-artesian	Existing	Winton Formation	304.00
12962	sub-artesian	Existing	Winton Formation	170.10
12968	sub-artesian	Existing	Winton Formation	195.70
12998	sub-artesian	Existing	Winton Formation	262.90
13021	sub-artesian	Existing	Winton Formation	61.90
13062	sub-artesian	Existing	Winton Formation	208.50
13074	sub-artesian	Existing	Winton Formation	73.20

RN	Facility Type	Status	Target Aquifer	Drilled Depth (m)
13075	sub-artesian	Existing	Winton Formation	182.00
13076	sub-artesian	Existing	Winton Formation	307.24
13142	sub-artesian	Existing	Winton Formation	122.00
13292	sub-artesian	Existing	Winton Formation	134.70
13339	sub-artesian	Existing	Winton Formation	98.50
13345	sub-artesian	Existing	Winton Formation	157.30
13346	sub-artesian	Existing	Winton Formation	74.70
13348	sub-artesian	Existing	Winton Formation	144.80
13565	sub-artesian	Existing	Winton Formation	143.60
13569	sub-artesian	Existing	Winton Formation	143.60
13575	sub-artesian	Existing	Winton Formation	78.60
13650	sub-artesian	Existing	Winton Formation	91.50
13657	sub-artesian	Existing	Winton Formation	154.80
13742	sub-artesian	Existing	Winton Formation	69.50
13804	sub-artesian	Existing	Winton Formation	281.80
14039	sub-artesian	Existing	Winton Formation	164.00
14147	sub-artesian	Existing	Winton Formation	97.50
14507	sub-artesian	Existing	Winton Formation	838.20
14559	sub-artesian	Existing	Winton Formation	74.70
14560	sub-artesian	Existing	Winton Formation	89.90
14566	sub-artesian	Existing	Winton Formation	131.10
14567	sub-artesian	Existing	Winton Formation	161.60
14587	sub-artesian	Existing	Winton Formation	168.60
14653	sub-artesian	Existing	Winton Formation	274.32
14791	sub-artesian	Existing	Winton Formation	133.20
14792	sub-artesian	Existing	Winton Formation	229.51
14877	sub-artesian	Existing	Winton Formation	353.30
14929	sub-artesian	Existing	Winton Formation	171.84
14941	sub-artesian	Existing	Winton Formation	203.30
15012	sub-artesian	Existing	Winton Formation	219.50
15013	sub-artesian	Existing	Winton Formation	39.10
15120	sub-artesian	Existing	Winton Formation	128.10
15186	sub-artesian	Existing	Winton Formation	150.90
15295	sub-artesian	Existing	Winton Formation	149.40
15477	sub-artesian	Existing	Winton Formation	281.80
15690	sub-artesian	Existing	Winton Formation	186.00
15808	sub-artesian	Existing	Winton Formation	32.00
15809	sub-artesian	Existing	Winton Formation	24.40
15968	sub-artesian	Existing	Winton Formation	161.50
16127	sub-artesian	Existing	Winton Formation	57.91
16146	sub-artesian	Existing	Winton Formation	62.50
16345	sub-artesian	Existing	Winton Formation	159.80
16489	sub-artesian	Existing	Winton Formation	122.30
16522	sub-artesian	Existing	Winton Formation	243.00
16526	sub-artesian	Existing	Winton Formation	224.40
16545	sub-artesian	Existing	Winton Formation	33.22
16700	sub-artesian	Existing	Winton Formation	154.20
16701	sub-artesian	Existing	Winton Formation	82.30
16847	sub-artesian	Existing	Winton Formation	35.70
16936	sub-artesian	Existing	Winton Formation	61.00

RN	Facility Type	Status	Target Aquifer	Drilled Depth (m)
16989	sub-artesian	Existing	Winton Formation	155.45
17059	sub-artesian	Existing	Winton Formation	86.90
17261	sub-artesian	Existing	Winton Formation	60.40
31989	sub-artesian	Existing	Winton Formation	183.00
32952	sub-artesian	Existing	Winton Formation	169.50
33326	sub-artesian	Existing	Winton Formation	70.10
33336	sub-artesian	Existing	Winton Formation	152.50
34039	sub-artesian	Existing	Winton Formation	144.50
34799	sub-artesian	Existing	Winton Formation	216.50
35973	sub-artesian	Existing	Winton Formation	67.10
35974	sub-artesian	Existing	Winton Formation	107.90
36475	sub-artesian	Existing	Winton Formation	107.90
50079	sub-artesian	Existing	Winton Formation	128.00
50106	sub-artesian	Existing	Winton Formation	18.30
50111	sub-artesian	Existing	Winton Formation	12.20
50182	sub-artesian	Existing	Winton Formation	15.42
50364	sub-artesian	Existing	Winton Formation	173.70
50384	sub-artesian	Existing	Winton Formation	161.50
50385	sub-artesian	Existing	Winton Formation	121.20
50386	sub-artesian	Existing	Winton Formation	179.80
50388	sub-artesian	Existing	Winton Formation	459.40
50389	sub-artesian	Existing	Winton Formation	140.20
50444	sub-artesian	Existing	Winton Formation	152.00
50469	sub-artesian	Existing	Winton Formation	61.00
69503	sub-artesian	Existing	Winton Formation	109.00
69504	sub-artesian	Existing	Winton Formation	128.10
116166	sub-artesian	Existing	Winton Formation	62.00
116209	sub-artesian	Existing	Winton Formation	149.00

NUMBER OF OIL AND GAS PRODUCTION WELLS IN THE COOPER AND EROMANGA BASINS

PL Reference	Total Number of Wells	Purpose		
		Gas	Oil	Oil and gas
PL 107	1	1	0	0
PL 108	3	3	0	0

PL 109	1	1	0	0
PL 110	1	1	0	0
PL 111	2	2	0	0
PL 112	10	10	0	0
PL 113	7	7	0	0
PL 114	3	3	0	0
PL 117	0	0	0	0
PL 129	4	4	0	0
PL 130	3	1	0	2
PL 131	32	32	0	0
PL 132	2	2	0	0
PL 133	0	0	0	0
PL 134	1	1	0	0
PL 135	0	0	0	0
PL 136	0	0	0	0
PL 137	2	2	0	0
PL 138	0	0	0	0
PL 139	1	1	0	0
PL 140	3	3	0	0
PL 141	0	0	0	0
PL 142	1	1	0	0
PL 143	0	0	0	0
PL 144	3	3	0	0
PL 145	0	0	0	0
PL 146	5	3	2	0
PL 147	1	1	0	0
PL 148	1	1	0	0
PL 149	1	1	0	0
PL 150	9	8	0	1
PL 151	4	4	0	0
PL 152	4	4	0	0
PL 153	1	1	0	0
PL 154	0	0	0	0
PL 155	3	3	0	0
PL 156	0	0	0	0
PL 157	1	1	0	0
PL 158	1	1	0	0
PL 159	1	1	0	0
PL 168	1	0	1	0
PL 169	8	0	8	0
PL 170	7	0	7	0
PL 175	2	2	0	0
PL 177	5	5	0	0

PL 178	0	0	0	0
PL 181	1	1	0	0
PL 182	2	2	0	0
PL 186	4	4	0	0
PL 187	2	2	0	0
PL 188	2	2	0	0
PL 189	1	1	0	0
PL 193	0	0	0	0
PL 205	2	2	0	0
PL 207	1	1	0	0
PL 208	1	1	0	0
PL 23	41	1	40	0
PL 24	9	0	9	0
PL 241	2	2	0	0
PL 244	1	0	1	0
PL 245	0	0	0	0
PL 249	0	0	0	0
PL 25	34	3	31	0
PL 254	1	0	0	1
PL 255	0	0	0	0
PL 26	8	3	4	1
PL 287	3	3	0	0
PL 288	2	2	0	0
PL 29	0	0	0	0
PL 293	2	0	2	0
PL 294	1	0	1	0
PL 295	19	0	19	0
PL 298	1	0	1	0
PL 301	4	0	4	0
PL 302	2	0	2	0
PL 303	4	0	4	0
PL 33	5	0	4	0
PL 34	32	0	31	1
PL 35	9	0	9	0
PL 36	5	0	5	0
PL 37	4	4	0	0
PL 38	1	0	1	0
PL 39	60	0	60	0
PL 409	1	1	0	0
PL 410	1	1	0	0
PL 411	1	1	0	0
PL 460	1	0	1	0
PL 50	2	0	2	0

PL 51	14	0	14	0
PL 52	38	0	38	0
PL 55	3	0	3	0
PL 57	31	0	31	0
PL 58	14	12	2	0
PL 59	18	17	1	0
PL 60	9	9	0	0
PL 61	24	10	12	1
PL 62	3	3	0	0
PL 63	8	7	1	0
PL 68	4	0	4	0
PL 75	4	0	3	1
PL 76	4	0	4	0
PL 77	2	0	2	0
PL 78	2	0	2	0
PL 79	1	1	0	0
PL 80	4	4	0	0
PL 81	5	5	0	0
PL 82	0	0	0	0
PL 83	2	2	0	0
PL 84	15	15	0	0
PL 85	2	2	0	0
PL 86	2	2	0	0
PL 87	0	0	0	0
PL 88	4	4	0	0
PL 95	0	0	0	0
PL 97	20	0	20	0
PPL 10	0	0	0	0
PPL 100	1	0	1	0
PPL 101	0	0	0	0
PPL 102	0	0	0	0
PPL 103	1	1	0	0
PPL 104	1	1	0	0
PPL 105	1	1	0	0
PPL 106	0	0	0	0
PPL 107	0	0	0	0
PPL 108	0	0	0	0
PPL 109	1	1	0	0
PPL 11	44	31	11	2
PPL 110	2	2	0	0
PPL 111	0	0	0	0
PPL 113	2	2	0	0
PPL 114	1	1	0	0

PPL 115	0	0	0	0
PPL 116	0	0	0	0
PPL 117	0	0	0	0
PPL 118	0	0	0	0
PPL 119	0	0	0	0
PPL 12	54	41	11	2
PPL 120	0	0	0	0
PPL 121	2	0	2	0
PPL 122	1	1	0	0
PPL 123	0	0	0	0
PPL 124	0	0	0	0
PPL 125	1	1	0	0
PPL 126	0	0	0	0
PPL 127	0	0	0	0
PPL 128	0	0	0	0
PPL 129	0	0	0	0
PPL 13	7	7	0	0
PPL 130	0	0	0	0
PPL 131	19	19	0	0
PPL 132	0	0	0	0
PPL 133	1	1	0	0
PPL 134	0	0	0	0
PPL 135	4	4	0	0
PPL 136	3	3	0	0
PPL 137	0	0	0	0
PPL 138	0	0	0	0
PPL 139	5	5	0	0
PPL 14	40	40	0	0
PPL 140	0	0	0	0
PPL 143	0	0	0	0
PPL 144	0	0	0	0
PPL 145	0	0	0	0
PPL 146	3	3	0	0
PPL 147	0	0	0	0
PPL 148	0	0	0	0
PPL 149	9	0	9	0
PPL 15	20	20	0	0
PPL 150	0	0	0	0
PPL 151	5	5	0	0
PPL 152	0	0	0	0
PPL 153	0	0	0	0
PPL 154	0	0	0	0
PPL 155	0	0	0	0

PPL 156	0	0	0	0
PPL 158	3	3	0	0
PPL 159	0	0	0	0
PPL 16	0	0	0	0
PPL 160	0	0	0	0
PPL 161	0	0	0	0
PPL 162	0	0	0	0
PPL 163	1	1	0	0
PPL 164	0	0	0	0
PPL 165	0	0	0	0
PPL 166	0	0	0	0
PPL 167	0	0	0	0
PPL 17	0	0	0	0
PPL 172	0	0	0	0
PPL 174	1	0	0	1
PPL 175	0	0	0	0
PPL 176	0	0	0	0
PPL 177	0	0	0	0
PPL 178	0	0	0	0
PPL 179	0	0	0	0
PPL 18	0	0	0	0
PPL 180	0	0	0	0
PPL 182	2	0	2	0
PPL 187	2	2	0	0
PPL 189	1	1	0	0
PPL 19	0	0	0	0
PPL 190	0	0	0	0
PPL 193	0	0	0	0
PPL 194	4	0	4	0
PPL 195	1	1	0	0
PPL 196	0	0	0	0
PPL 20	0	0	0	0
PPL 201	0	0	0	0
PPL 206	0	0	0	0
PPL 208	0	0	0	0
PPL 215	0	0	0	0
PPL 22	42	34	5	3
PPL 225	7	0	7	0
PPL 226	3	0	3	0
PPL 227	1	0	1	0
PPL 228	14	14	0	0
PPL 229	0	0	0	0
PPL 23	3	3	0	0

PPL 230	0	0	0	0
PPL 231	4	4	0	0
PPL 232	2	2	0	0
PPL 233	0	0	0	0
PPL 234	13	0	13	0
PPL 235	0	0	0	0
PPL 236	1	1	0	0
PPL 237	3	2	1	0
PPL 238	0	0	0	0
PPL 24	14	14	0	0
PPL 25	8	0	8	0
PPL 26	1	1	0	0
PPL 27	0	0	0	0
PPL 29	0	0	0	0
PPL 30	23	0	23	0
PPL 31	0	0	0	0
PPL 32	0	0	0	0
PPL 33	4	4	0	0
PPL 35	0	0	0	0
PPL 36	45	0	45	0
PPL 37	0	0	0	0
PPL 38	0	0	0	0
PPL 39	0	0	0	0
PPL 40	1	1	0	0
PPL 41	7	7	0	0
PPL 42	2	2	0	0
PPL 43	1	1	0	0
PPL 44	3	2	0	1
PPL 45	0	0	0	0
PPL 46	0	0	0	0
PPL 47	0	0	0	0
PPL 48	0	0	0	0
PPL 51	0	0	0	0
PPL 52	0	0	0	0
PPL 53	0	0	0	0
PPL 54	0	0	0	0
PPL 55	0	0	0	0
PPL 56	0	0	0	0
PPL 57	0	0	0	0
PPL 58	6	6	0	0
PPL 59	0	0	0	0
PPL 6	0	0	0	0
PPL 60	0	0	0	0

PPL 61	0	0	0	0
PPL 63	0	0	0	0
PPL 64	0	0	0	0
PPL 65	0	0	0	0
PPL 66	0	0	0	0
PPL 67	0	0	0	0
PPL 68	0	0	0	0
PPL 69	4	4	0	0
PPL 7	13	12	0	1
PPL 70	0	0	0	0
PPL 72	3	3	0	0
PPL 73	4	1	3	0
PPL 74	1	1	0	0
PPL 75	0	0	0	0
PPL 76	2	0	2	0
PPL 77	3	0	3	0
PPL 78	1	1	0	0
PPL 79	1	1	0	0
PPL 8	0	0	0	0
PPL 80	0	0	0	0
PPL 81	0	0	0	0
PPL 83	0	0	0	0
PPL 84	0	0	0	0
PPL 86	2	0	2	0
PPL 87	0	0	0	0
PPL 88	0	0	0	0
PPL 89	0	0	0	0
PPL 9	7	7	0	0
PPL 90	18	15	1	2
PPL 91	0	0	0	0
PPL 92	1	1	0	0
PPL 94	0	0	0	0
PPL 95	0	0	0	0
PPL 98	2	1	0	1
PPL 99	2	2	0	0

APPENDIX F

Risk Analysis

RISK ANALYSIS

Operational Area	Risk Issue	Cause	Impact	Consequence	Likelihood	Inherent Risk Rating	Control Measures /Mitigation/Site Operations	Consequence with mitigation & controls	Likelihood with mitigation & controls	Current Residual Rating inclusive of Mitigation and Controls
Bore Drilling, Design, Completion, Integrity	Passage of water between aquifers	Poor design, Construction technique, Poor closure technique	Contamination, Pressure Loss, Non-compliance	IV	C	3	Petroleum Licence conditions. Santos well completion procedures.	IV	D	2
	Leakage of introduced fluids including mud	Inappropriate muds or drilling technique	Contamination of aquifers and/or surface water	IV	D	2	Licence. Bore drilling techniques and design. Environmental assessment studies.	III	E	1
	Artesian Flows	Over pressure/poor mud control/incorrect drilling assumptions	Erosion, loss of reputation	I	D	1	Implement erosion controls. Licences.	I	D	1
	Hydraulic fracturing Fluids	Use of hydraulic fracturing fluids to increase connectivity and enhance the production of oil& gas reservoirs	Contamination of deep aquifers and/or surface water , soil and shallow groundwater	IV	C	3	Environmental assessment studies. Monitoring programs for hydraulic fracturing fluid. Disposal and treatment of backflow water. Mechanical integrity of wellbores regularly checked (quarterly).	III	E	1
Oil and Gas Wells - Groundwater extraction from the wells	Leakage between aquifers	Associated water production (limited volumes for gas production, larger volumes for oil production)	Loss of available drawdown in bores	IV	C	3	Bore Inventory. Groundwater Impact Assessment. No/limited groundwater usage from and below target beds. Stratigraphy	III	D	2
			Subsidence	IV	E	2	Groundwater impact assessment, no large scale depressurisation of formations.	III	E	1
			Water quality changes	IV	C	3	Abandonments of old/unused wells . Licence requirements. Monitoring of water quality parameters.	III	D	2
			Loss of baseflow (watercourse springs)	IV	D	2	Appropriate design. Collection systems. Groundwater Impact Assessment. No baseflow contributing to stream	I	E	1
			Impacts on GAB discharge springs (incl. mound springs) and GAB recharge springs	III	E	1	GAB discharge springs within 150 and 350 km of Oil&Gas fields. The closest springs are GAB recharge springs located 35 km away, however the gas well target is deep and will not affect a GAB recharge springs.	III	E	1
			Oil flows, well head splits/leaks and gas flows	IV	C	3	Monitoring and active leakage control. Storage leaks/splits. Appropriate design of the wells	IV	E	1
Gathering Systems	Discharge of associated water to environment	Leak of water pipe or controls, system failure	Soil/Shallow GW contamination	I	C	1	Monitoring program. Collection systems.	I	D	1
			Contamination of local SW	II	C	2	Pipeline maintenance and monitoring	II	D	1
		Break in pipeline	Soil/Shallow GW contamination	III	C	3	Monitoring program. Optimally located (to minimise pipework lengths, etc.)	III	E	1
			Contamination of local SW	III	C	3	Monitoring program.	III	E	1

Operational Area	Risk Issue	Cause	Impact	Consequence	Likelihood	Inherent Risk Rating	Control Measures /Mitigation/Site Operations	Consequence with mitigation & controls	Likelihood with mitigation & controls	Current Residual Rating inclusive of Mitigation and Controls
		Leakage from low point drains/separators	Soil/Shallow GW contamination	III	C	3	Appropriate design.	III	D	2
	Erosion	Design, construction of stream crossings, open areas	Stream water quality	II	C	2	Design to minimise impacts and accommodate high flows, few perennial streams	II	E	1
Water Storage	Uncontrolled discharge to environment	Seepage - vertical	Shallow groundwater and/or soil contamination	IV	C	3	Small water volumes production. Lined for separator and interceptor ponds. Monitoring program in high pond hazard.	III	D	2
		Seepage - lateral	Vegetation loss, Discharge to water ways	IV	C	3	Vegetation of low conservation significance.	III	D	2
		Dam Break	Damage to property, soil, water, surface infrastructure , loss of asset and associated income, fatality.	IV	D	3	Monitoring around infrastructure, treatment of water, dams located away from creeks and sensitive environment.	IV	E	1
		Operational Failure Overflow, Operational Failure Accidental Release	Damage to property, soil, water, surface infrastructure, and associated income.	IV	D	2	Water management model. Design of dams to accommodate large floods and operate at safe levels.	IV	E	1
Surface Infrastructure	Uncontrolled run-off from roads	Inadequate design and management of waterway crossings	Deterioration of water quality	III	D	2	Industry standard.	III	E	1
	Camp - Contaminant releases	Effluent release from sewage treatment	Soil and shallow GW contamination	II	D	1	Monitoring program.	II	E	1
		Kitchen Waste	Soil and shallow GW contamination	I	C	1	Site management procedures. Appropriate design.	I	E	1
	Workshop and maintenance areas	Chemical storage	Contamination of GW or SW	III	D	2	H&S and Environmental management procedures, specific to facilities handling chemicals. Response plans. Small quantities.	III	E	1
	Compressor station hazards	Bulk Fuel and chemical storage	Contamination of GW or SW	III	D	2	Monitoring. Environmental response plans specific to facilities	III	E	1
	Oil station hazards	Bulk Fuel and chemical storage	Contamination of GW or SW	III	D	2	Monitoring. Environmental response plans specific to facilities.	III	E	1
		Washdown areas	Contamination of GW or SW, weeds	II	C	2	Environmental response plans.	II	E	1
Water Flooding	Potential for migration of injection fluid out of target formation into aquifers	Wellbore integrity	Migration of injection fluid out of the target formation into the aquifers	III	D	3	Birkhead target hydraulically isolated. Flood well design. Well integrity is checked through regular mechanical integrity checks.	I	D	1
		Faults	Migration of injection fluid out of the target formation into the aquifers	III	D	2	No major faults identified in area based on seismic data. Chemical tracer program.	I	D	1
	Reactivity of injected fluid with target zone	Potential for reactivity with the receiving aquifer	Degradation of the water quality	II	C	3	Comprehensive analysis of waters taken prior to project start-up. Regular produced water sampling. Chemical tracer program.	I	D	1

Operational Area	Risk Issue	Cause	Impact	Consequence	Likelihood	Inherent Risk Rating	Control Measures /Mitigation/Site Operations	Consequence with mitigation & controls	Likelihood with mitigation & controls	Current Residual Rating inclusive of Mitigation and Controls
	Over pressurisation of target zone from injection	Create fractures	Localised groundwater flows between formations	II	D	2	General operations do not result in exceeding frac pressures; however, fractures (if created) would be limited to the near-wellbore region, contained within the Birkhead and have no impact upon aquifers. Reservoir and injection pressure monitoring.	I	D	1

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APPENDIX G

Santos Extraction Bores in the Cooper and Eromanga Basins

The following Table contains all Santos Oil and Gas wells located in Queensland, grouped by field name.

Field Name and Well Reference Number	Oil or Gas Well	Easting (GDA 54)	Northing (GDA 54)	Ground Level (mAHD)	Datum Height (Kelly Bushing) (m)	Well Datum Elevation (mAHD)	Date Drilled
ACRUS 1	GAS	582730.4326	6933263.87	225.55	16.6	242.15	12/05/2002
APOLLOSA 1	OIL	584523.1632	6893652.827	232.38	13.2	245.58	20/01/2004
AROS 2	OIL	739261.6165	6989838.13	206.82	4.86	211.68	30/11/2006
ARRABURY 3	OIL	507157.4131	6991681.243	425.75	15.6	441.35	2/11/2005
ASHBY 2	GAS	552952.3636	6876554.974	341.07	16.6	357.67	21/03/2005
ASHBY 3	GAS	557246.1567	6876717.857	327.46	16.6	344.06	7/03/2005
ASHBY 4	GAS	554825.4051	6877295.269	337.14	16.6	353.74	11/12/2005
ASHBY NORTH 1	GAS	555466.7254	6879970.608	326.21	17.25	343.46	22/04/1997
BALLERA SOUTH 1	UNAS	580274.8461	6970185.783	372.11	17.25	389.36	10/01/1998
BALLERA WEST 1	GAS	577148.0921	6969878.76	334.16	20.1	354.26	1/09/1994
BALLERA WEST 2	GAS	576687.6086	6971703.561	335.1	26.2	361.3	2/02/1999
BALLERA WEST 3	GAS	576687.5162	6970116.371	329.75	16.6	346.35	2/03/2002
BARROLKA 10	GAS	570053.5206	7030766.204	336.64	19.3	355.94	16/02/2006
BARROLKA 2	GAS	567379.6079	7027638.162	361.68	20.1	381.78	12/07/1994
BARROLKA 3	GAS	572951.0088	7025918.48	315.35	19.3	334.65	22/10/1996
BARROLKA 4	GAS	569980.5235	7025909.211	332.69	26.2	358.89	27/10/2000
BARROLKA 4ST1	GAS	569980.4241	7025909.211	332.69	26.2	358.89	27/10/2000
BARROLKA 5DW1	GAS	570782.9835	7023304.485	363.14	26.2	389.34	5/02/2001
BARROLKA 5DW2	GAS	570782.9835	7023304.485	363.14	26.2	389.34	5/02/2001
BARROLKA 6	GAS	570516.8565	7023410.877	370.6	16.6	387.2	12/12/2001
BARROLKA 7DW1	GAS	572175.6898	7024515.331	343.6	26.2	369.8	12/06/2001
BARROLKA 7DW2	GAS	572175.6898	7024515.331	343.6	26.2	369.8	12/06/2001
BARROLKA 8	GAS	569065.7388	7025740.695	342.02	16.6	358.62	6/01/2002
BARROLKA 9	GAS	575274.826	7028668.76	299.27	19.3	318.57	24/01/2006
BARROLKA EAST 2	GAS	579088.4257	7029304.792	299.97	26.21	326.18	14/01/1998
BARROLKA NORTHEAST 1	GAS	575356.371	7033953.048	356.36	16.6	372.96	11/09/1997
BARROLKA NORTHEAST 2	GAS	570631.704	7034654.485	395.47	16.6	412.07	14/12/1997
BARTA 1	OIL	506272.6497	7043815.387	335.46	16.6	352.06	13/04/1998
BARTA NORTH 1	OIL	518344.4493	7046197.415	105.61	5.1	110.71	12/11/2010
BARYULAH 10	GAS	586556.3517	6929540.666	222.54	19.3	241.84	31/12/2005
BARYULAH 11	GAS	583031.0412	6929897.341	222.86	16.6	239.46	20/10/2006
BARYULAH 12	GAS	583506.0176	6931276.099	223.65	16.6	240.25	2/10/2006
BARYULAH 2	GAS	581987.4025	6930608.135	222.5	17.9	240.4	20/10/1995
BARYULAH 3	GAS	583227.6812	6930733.07	223.59	16.5	240.09	9/11/2000
BARYULAH 4	GAS	586064.586	6929988.19	222.44	16.6	239.04	6/06/2001
BARYULAH 5	GAS	585254.2416	6929652.036	223.13	16.6	239.73	29/07/2001
BARYULAH 6	GAS	585627.399	6929879.061	223.59	16.6	240.19	9/09/2004
BARYULAH 7	GAS	584471.1489	6930179.419	223.32	18.5	241.82	<Null>

BARYULAH 7ST1	GAS	584471.1489	6930179.419	223	18.5	241.5	12/09/2005
BARYULAH 8	GAS	582229.6393	6931534.412	223.78	18.5	242.28	3/10/2005
BARYULAH 9	GAS	583442.8082	6929180.958	221.91	18.5	240.41	20/10/2005
BARYULAH EAST 1	GAS	586370.0215	6929781.067	222.3	17	239.3	23/11/1994
BEEREE 1	GAS	560963.9003	7023433.368	522.73	16.6	539.33	9/07/1997
BEEREE 2	GAS	555613.7061	7033662.493	458.75	16.6	475.35	22/10/1997
BEEREE 2ST1	GAS	555613.7061	7033662.493	458.75	16.6	475.35	11/11/1997
BEEREE 3	GAS	558334.9427	7027075.337	548.65	16.6	565.25	24/01/1998
BILBERRY 1	OIL	736865.4569	7028130.128	164.24	4.07	168.31	14/07/2006
BINGILBERRY 1	OIL	737587.2495	7012768.004	169.34	4.1	173.44	20/11/2006
BOGALA 2	OIL	624694.1221	6954106.557	367.52	17	384.52	27/05/1988
BOGALA 3	OIL	624870.9704	6954314.931	372.09	16.5	388.59	29/08/1990
BOGALA CENTRAL 1	OIL	622841.6413	6956520.871	375.64	13.1	388.74	23/05/2007
BOLAN 2	OIL	614003.305	6926220.255	230.5	17.9	248.4	4/05/1991
BOWEN 2	OIL	603635.3187	6912631.47	217.85	16.5	234.35	24/02/1990
BOWEN 3	OIL	602909.8154	6911465.175	223.75	17.9	241.65	25/11/1992
BRUMBY 10	GAS	500113.3177	6856550.929	270.64	17	287.64	6/01/1997
BRUMBY 11	GAS	500185.4485	6859493.4	254.98	17	271.98	22/01/1997
BRUMBY 6	GAS	500152.5083	6857650.106	260.62	20.1	280.72	1/01/1993
BRUMBY 8	GAS	500182.693	6858687.132	254.98	17	271.98	13/11/1995
BURUNDI 1	OIL	648574.7743	6926217.932	102.84	3.95	106.79	11/10/2007
CALLISTO 1	OG	651130.8541	6972258.046	140.6	4.02	144.62	15/11/2003
CARNEY SOUTH 1	OIL	615029.1657	6961860.792	319.58	13.15	332.73	12/08/2007
CHALLUM 10	GAS	560275.251	6968159.036	245.23	26.2	271.43	28/10/1998
CHALLUM 11	GAS	552989.6608	6969425.224	276.54	26.2	302.74	24/11/1998
CHALLUM 12	GAS	564106.711	6966117.842	244.78	26.2	270.98	17/12/1998
CHALLUM 13	GAS	556414.7756	6972103.617	268.53	26.2	294.73	11/01/1999
CHALLUM 14DW	GAS	554738.1037	6970326.557	269.73	26.2	295.93	4/05/1999
CHALLUM 15	GAS	554023.9427	6969226.88	269.67	26.2	295.87	19/03/1999
CHALLUM 16DW1	GAS	561071.077	6969156.048	249.75	26.2	275.95	13/05/2000
CHALLUM 16DW2	GAS	561071.077	6969156.048	249.75	26.2	275.95	13/05/2000
CHALLUM 17DW1	GAS	562435.7239	6968390.411	250.6	26.2	276.8	22/08/2000
CHALLUM 17DW2	GAS	562435.7239	6968390.411	250.6	26.2	276.8	22/08/2000
CHALLUM 18DW1	GAS	557583.6498	6970873.748	259.59	26.2	285.79	9/07/2000
CHALLUM 18DW2	GAS	557583.5514	6970873.86	259.59	26.2	285.79	9/07/2000
CHALLUM 19	GAS	557314.8118	6970410.429	258.56	16.6	275.16	3/02/2001
CHALLUM 20DW1	GAS	559899.1196	6969465.1	253.41	26.2	279.61	25/04/2001
CHALLUM 20DW2	GAS	559899.1196	6969465.1	253.41	26.2	279.61	25/04/2001
CHALLUM 20DW3	GAS	559899.1196	6969465.1	253.41	26.2	279.61	25/04/2001
CHALLUM 21DW1	GAS	554633.1116	6970619.457	268.8	26.2	295.01	12/03/2001
CHALLUM 21DW2	GAS	554633.1116	6970619.457	268.8	26.2	295.01	12/03/2001
CHALLUM 22	GAS	564223.3506	6968162.988	251.21	16.6	267.81	17/03/2001

CHALLUM 23	GAS	558188.3191	6968763.483	247.28	16.6	263.88	23/04/2001
CHALLUM 24	GAS	559087.2604	6971188.196	258.64	16.6	275.24	26/02/2001
CHALLUM 25	GAS	561368.806	6970472.753	261.02	16.6	277.62	6/04/2001
CHALLUM 26	GAS	555923.6205	6971370.339	265.55	16.6	282.15	14/02/2004
CHALLUM 27	GAS	553827.0052	6969861.239	267.29	16.6	283.89	5/03/2004
CHALLUM 28	OIL	558744.0019	6969191.633	249.57	13.18	262.75	30/08/2006
CHALLUM 29	OIL	556967.323	6969761.815	254.95	13.35	268.3	10/09/2006
CHALLUM 30	OIL	555121.2514	6970261.044	270.53	13.12	283.65	21/09/2006
CHALLUM 6	GAS	555395.4521	6971034.654	267.48	17.25	284.73	2/12/1997
CHALLUM 7	GAS	554336.9488	6970300.641	273.85	26.2	300.05	1/03/1998
CHALLUM 8	GAS	561860.2908	6967769.669	252	26.2	278.2	15/09/1998
CHALLUM 9	GAS	558107.8724	6969691.019	255.94	26.2	282.14	1/05/1998
CHALLUM WEST 1	GAS	549725.3341	6973834.729	309.58	26.2	335.78	30/03/1998
CHANCETT 1	OIL	739070.9312	7027229.01	163.64	3.98	167.62	28/06/2006
CHI 1	OG	545629.5099	6864677.128	417.91	16.6	434.51	30/01/2010
CHILLA 1	GAS	611982.706	6955831.479	331	16.6	347.6	1/05/1998
CHILLA 2	OIL	612398.0411	6956098	346.09	12.9	358.99	1/10/2007
CHILLA 3	OIL	611579.4118	6956743.741	344.13	13	357.12	15/02/2009
CHILLA 3A	OIL	611584.3648	6956745.246	344.13	13	357.13	25/02/2009
CHINOOK 1	GAS	590326.0398	6985561.761	252.1	16.6	268.7	19/12/2003
CHIRON 1	OG	508292.0786	6849874.033	325.59	16.6	342.19	23/09/1996
CHIRON 2	OG	506431.148	6851435.02	329.75	17.25	347	30/12/1996
CHIRON 3	GAS	508261.9667	6850484.025	315.65	19.3	334.95	23/05/2005
CHOOKOO 10	GAS	611592.9023	6951637.341	261.71	17.25	278.96	23/02/1998
CHOOKOO 7	OG	612500.9145	6951526.539	268.44	17.9	286.34	11/01/1989
CHOOKOO 8	OIL	611218.7034	6951142.198	257.18	16.5	273.68	7/12/1989
CHOOKOO 9	GAS	612812.0539	6950766.975	267.39	17.25	284.64	10/02/1998
CLASSIC 1	OIL	737752.9759	7039110.917	164.1	4.87	168.97	2/07/2006
CLINTON 1	GAS	607775.1062	7091642.557	323.13	18.78	341.91	13/12/1997
COOK 10	OIL	530043.0967	7045844.933	403.51	15.75	419.26	5/04/2008
COOK 11	OIL	528254.9224	7047015.082	394.65	15.75	410.4	23/03/2008
COOK 12	OIL	528672.9187	7048194.911	392.38	15.4	407.78	4/03/2008
COOK 13	OIL	528677.1169	7048820.118	390.19	15.7	405.89	19/04/2008
COOK 14	OIL	528725.2604	7046441.75	394.88	15.75	410.63	14/05/2008
COOK 15	OIL	528300.0767	7048170.496	388.19	16.6	404.79	16/12/2010
COOK 16	OIL	527779.3851	7048050.48	396.56	16.6	413.16	3/02/2011
COOK 17	OIL	528860.366	7049555.562	398.75	16.6	415.35	18/02/2011
COOK 18	OIL	528984.541	7048160.423	400.46	16.6	417.06	11/01/2011
COOK 19	OIL	528142.9662	7047490.03	389.27	16.6	405.87	30/12/2010
COOK 1DW1	OIL	528928.6341	7046723.161	395.03	17.9	412.93	5/12/1993
COOK 3	OIL	528639.1448	7047380.601	390.13	17	407.13	29/12/1992
COOK 3A	OIL	528612.5829	7047380.661	389.8	17	406.8	15/01/1993

COOK 4	OIL	529036.0136	7048480.833	399.32	17.9	417.22	14/09/1993
COOK 5	OIL	528297.4524	7047707.432	387.78	17	404.78	24/05/1994
COOK 6	OIL	528482.3029	7049306.33	385.39	17	402.39	7/06/1994
COOK 7	OIL	529369.8966	7047916.761	402.71	20.1	422.81	5/11/1994
COOK 8	OIL	528945.8616	7046818.151	395.24	20.1	415.34	24/01/1996
COOK 9	OIL	529085.1913	7049014.451	397.27	16.6	413.87	23/01/2002
COOK NORTH 2	OIL	531122.3032	7049756.005	401.65	20.1	421.75	19/09/1994
COOLAH 1	GAS	579408.2415	7018409.359	348.98	16.6	365.58	8/08/1997
COOLAH 2	GAS	582907.5788	7018112.012	311.12	19.3	330.42	12/10/1997
COONABERRY 1	GAS	609668.718	7029627.718	287.82	16.6	304.42	9/01/2001
COONABERRY 2	GAS	610236.3792	7030603.812	289.24	16.6	305.84	24/02/2007
COOROO 3	OIL	627371.4111	6933379.273	284.83	17	301.83	7/07/1988
COOROO 4	OIL	627194.3834	6933394.647	265.04	17	282.04	16/07/1989
COOROO 5	OIL	626695.5856	6933728.49	252.01	17.9	269.91	13/11/1989
COOROO 6	OIL	627616.564	6933560.071	271.94	17	288.94	3/12/1991
CORELLA 2	OIL	615052.6638	6924543.199	233.54	16.5	250.04	23/03/1990
CORRIDOR 1	GAS	595020.5132	7000559.389	257.28	20.1	277.38	18/02/1996
CORSAIR 1	GAS	614096.8174	6974088.768	270.34	16.6	286.94	27/01/2004
COSMO WEST 1	GAS	582268.6796	6925786.718	221.19	16.6	237.79	23/11/2004
COSTA 1	GAS	599960.6119	6969071.474	241.78	17.9	259.68	11/07/1993
COSTA CENTRAL 1	GAS	598745.5519	6967501.966	240.84	17.25	258.09	30/10/1997
COSTA SOUTH 1	GAS	597173.9243	6965830.481	242.1	20.1	262.2	16/08/1995
COSTA SOUTH 2	GAS	596638.6586	6966775.905	241.4	19.3	260.7	13/09/1996
COSTA SOUTH 3	GAS	597010.7451	6966121.798	241.99	16.6	258.59	22/10/2005
COSTA WEST 1	GAS	595932.4262	6968654.531	242.94	16.6	259.54	5/10/2005
CRANBERRY 1	OIL	743393.252	7018559.164	174.49	4.04	178.53	21/08/2006
CRANSTOUN 3	OIL	737562.4105	7031598.358	173.87	4.86	178.73	20/08/2006
CRANSTOUN 4	OIL	737014.4084	7032161.377	175.3	4.86	180.16	27/08/2006
CUISINIER 1	OIL	522097.8648	7047963.847	107.51	4.8	112.31	4/05/2008
CUISINIER 2	OIL	522437.5759	7048280.122	108.84	5.1	113.94	1/12/2010
CUISINIER 3	OIL	522489.9876	7047314.908	108.6	5.1	113.7	7/03/2011
CURRAMBAR 1	OIL	664143.1832	6929032.049	92.42	4.08	96.5	7/01/2006
CURRAWINYA 1	OIL	728979.6097	6999911.087	235.37	4.86	240.23	31/12/2006
CURRI 1	GAS	581175.7967	6972863.772	333.49	16.6	350.09	24/02/1998
DARTMOOR 1	CSG	651880.5587	6936481.685	117.9	5.06	122.96	29/07/2002
DILKERA 3	OIL	661046.7801	6930331.345	99.33	5.1	104.43	8/09/2010
DILKERA NORTH 1	OIL	661753.7476	6930629.453	109.67	4.02	113.69	7/01/2007
DINGERA 2	OG	588654.5941	6907257.407	227.92	17.9	245.82	15/12/1995
DINOJUE 1	OIL	657164.0453	6927437.057	117.76	5.18	122.94	14/06/2011
DULULU 1	OIL	543178.545	6866644.987	404.13	16.6	420.73	5/05/2005
DURHAM DOWNS 3	GAS	579069.7787	6999800.491	309.6	20.1	329.7	9/06/1994
DURHAM DOWNS	GAS	577899.9437	7004742.389	357.97	19.3	377.27	7/03/2006

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DURHAM DOWNS NORTH 1	GAS	580377.003	7007364.589	311.52	20.1	331.62	2/05/1994
DURHAM DOWNS NORTH 2	GAS	581444.725	7007344.713	305.44	19.3	324.74	6/12/2005
ECHUBURRA 2	OIL	617207.4326	6920591.361	249.02	17.9	266.92	19/05/1992
ENDEAVOUR 10	OIL	736555.0337	7035015.569	182.32	4.86	187.18	6/08/2006
ENDEAVOUR 11	OIL	737099.064	7034492.345	185.27	4.87	190.14	27/05/2006
ENDEAVOUR 12	OIL	735662.0595	7035305.064	177.84	4.86	182.7	28/10/2006
ENDEAVOUR 13	OIL	735643.4144	7034721.559	184.96	4.86	189.82	19/10/2006
ENDEAVOUR 14	OIL	735912.4027	7034400.944	186.98	4.86	191.84	19/09/2006
ENDEAVOUR 15	OIL	736194.8624	7034093.926	183.56	4.86	188.42	12/11/2006
ENDEAVOUR 16	OIL	735593.5081	7034104.827	182.77	4.86	187.63	12/10/2006
ENDEAVOUR 17	OIL	735968.8454	7033801.291	182.34	4	186.34	20/01/2007
ENDEAVOUR 18	OIL	735596.8803	7033501.845	183.55	4.86	188.41	11/09/2006
ENDEAVOUR 19	OIL	735614.1678	7032903.811	183.8	4.86	188.66	6/10/2006
ENDEAVOUR 20	OIL	738809.8008	7035875.937	183.37	3.96	187.33	9/12/2006
ENDEAVOUR 21	OIL	737388.8223	7035914.461	177.34	4.1	181.44	27/11/2006
ENDEAVOUR 25	OIL	736761.086	7035334.732	180.39	4.2	184.59	13/02/2007
ENDEAVOUR 26	OIL	737378.1493	7035330.469	184.17	4.86	189.03	10/01/2007
ENDEAVOUR 27	OIL	738058.5863	7035331.19	185.22	4.1	189.32	19/12/2006
ENDEAVOUR 28	OIL	737424.1428	7034702.068	187.96	4.1	192.06	24/12/2006
ENDEAVOUR 29	OIL	735350.9772	7034350.451	181.4	4	185.4	9/04/2007
ENDEAVOUR 31	OIL	738073.4731	7034685.19	185.9	4.06	189.96	3/04/2007
ENDEAVOUR 33	OIL	735301.7572	7033204.06	184.19	4.1	188.29	15/01/2007
ENDEAVOUR 34	OIL	735891.3586	7033189.398	183.24	4.39	187.63	10/01/2007
ENDEAVOUR 35	OIL	735944.794	7034995.278	179.56	4	183.56	6/02/2007
ENDEAVOUR 36	OIL	736811.9221	7033520.016	182.28	4	186.28	31/01/2007
ENDEAVOUR 37	OIL	734377.0416	7031125.301	177.1	4.08	181.18	15/04/2007
ENDEAVOUR 38	OIL	735584.9455	7032313.519	180.16	4.04	184.2	30/12/2006
ENDEAVOUR 39	OIL	735004.3043	7032913.962	184.52	4.86	189.38	20/01/2007
ENDEAVOUR 4	OIL	737045.4635	7034949.398	189.62	4.35	193.97	19/09/1994
ENDEAVOUR 40	OIL	736197.8774	7032909.862	180.66	4.05	184.71	5/01/2007
ENDEAVOUR 41	OIL	738617.9634	7037103.602	173.19	4.11	177.3	3/12/2006
ENDEAVOUR 5	OIL	736265.9684	7034672.35	183.24	4.87	188.11	15/05/2006
ENDEAVOUR 6	OIL	736503.3395	7034289.792	183.73	4.86	188.59	27/07/2006
ENDEAVOUR 7	OIL	736845.1207	7034080.749	182.99	4.86	187.85	21/07/2006
ENDEAVOUR 8	OIL	736241.954	7033511.074	180.12	4.87	184.99	16/06/2006
ENDEAVOUR 9	OIL	737725.6239	7035581.668	181.29	4.6	185.89	11/07/2006
ENOGGARA 1	OIL	723520.2136	7029097.429	162.56	3.96	166.52	4/06/2007
EPSILON 10	GAS	512267.9888	6884487.721	366.16	19.3	385.46	24/12/1999
EPSILON 11	GAS	512823.9472	6884130.43	375.06	16.6	391.66	19/03/2007
EPSILON 6	GAS	511588.8706	6881903.834	354.71	20.1	374.81	7/09/1991

EPSILON 7	GAS	514071.7606	6886193.481	395.67	17.9	413.57	11/11/1992
EPSILON 8	GAS	514233.3094	6884575.709	382.64	16.3	398.94	16/05/1997
EPSILON 9	GAS	514567.5487	6887274.853	407.67	16	423.67	15/07/1997
EULO 1	OIL	732729.7505	7031339.924	172.39	4.86	177.25	29/09/2006
FAJITA 1	OIL	641308.0184	6938326.98	357.15	13.14	370.29	22/04/2007
FERAL 1	OG	575497.8601	6888219.293	234.53	17.9	252.43	28/09/1992
GALEX 1	GAS	585022.4575	6962664.963	278.28	16.6	294.88	3/11/2004
GALEX 2	GAS	584171.1716	6963092.785	280.54	16.6	297.14	21/09/2008
GALIBA 1	GAS	586150.0726	6961250.205	323.95	16.6	340.55	17/11/1996
GENOA 2	OIL	583768.2178	6886901.104	242.07	17.9	259.97	16/02/1993
GENOA 3	OIL	583787.4239	6887244.639	236.71	16.6	253.31	31/05/2010
GENOA NORTH 1	OIL	584377.0816	6889636.421	238.2	17.9	256.1	19/12/1992
GENOA NORTH 2	OIL	584817.5179	6889122.228	236.3	16.6	252.9	13/06/2010
GHINA 1	GAS	616726.8825	7007686.232	431.56	12.4	443.96	31/05/1997
GIMBOOLA 2	OIL	740159.6211	7024557.614	170.12	4.05	174.17	22/06/2006
GIMBOOLA 3	OIL	739553.6592	7024611.625	171.1	4.09	175.19	12/05/2006
GIMBOOLA 4	OIL	739582.1959	7025154.94	170.54	4.06	174.6	30/06/2006
GIMBOOLA 4A	OIL	739582.1959	7025154.94	170.54	4.06	174.6	5/07/2006
GIMBOOLA 5	OIL	739877.8569	7024857.978	170.32	4.03	174.35	17/06/2006
GIMBOOLA 7	OIL	739902.5111	7025457.683	168.8	4.09	172.89	27/06/2006
GIMBOOLA WEST 1	OIL	738709.3644	7025533.026	170.22	5.26	175.48	26/11/1996
GRAHAM 2	OIL	636902.0322	6947212.257	448.39	15.7	464.09	19/04/2007
GUNNA NORTH 1	OIL	637276.2748	6950673.358	468.86	16	484.86	20/03/2007
HAKHEEM 1	OIL	738731.6794	6993667.475	192.24	4.86	197.1	22/11/2006
HEBE 1	GAS	594445.9558	6932348.371	226.93	19.3	246.23	22/01/2004
HECTOR 1	GAS	560893.8058	6911075.105	241.93	19.3	261.23	25/12/2004
HELIOSE 1	GAS	584885.5885	6903731.775	214.56	19.3	233.86	29/12/2003
HERA 1	GAS	584839.8134	6937143	225.82	26.2	252.02	10/07/1998
HERA 2	GAS	584468.5079	6937481.367	227.82	16.6	244.42	18/09/2001
HOVELL 1	OIL	595355.427	6862569.679	345.74	17	362.74	4/06/1995
HUCKLEBERRY 1	OIL	736254.2931	7023265.843	172.76	4.02	176.78	1/06/2006
HUCKLEBERRY 2	OIL	735645.2773	7023826.99	168.4	4.1	172.5	20/03/2007
HUDSON 1	OIL	505967.2789	7035074.592	97.44	4.79	102.23	21/07/2008
HURRICANE 1	GAS	622253.4391	6968370.125	301.77	16.6	318.37	5/01/2004
ILIAD 1	OIL	535935.3408	6870123.499	423.32	17	440.32	13/08/1994
ILIAD 2	OIL	534811.5962	6870148.677	415.81	17	432.81	6/09/1994
ILIAD 3	OIL	535709.1215	6870284.817	417.53	16.6	434.13	29/05/2005
ILIAD 4	OIL	536305.8777	6870182.081	436.02	15.75	451.77	14/09/2008
ILIAD 5	OIL	534579.3784	6869939.757	410.83	15.75	426.58	30/09/2008
ILIAD 6	OIL	535748.8803	6869812.322	422.21	15.9	438.11	9/10/2008
INCA 1	OIL	562891.7654	6889467.803	247.04	16.6	263.64	30/06/2010
INSPECTOR 1	OIL	727015.3691	7004167.397	183.36	4.02	187.38	25/05/2007

IPUNDU 10	OIL	730041.6324	7017644.048	201.47	5.26	206.73	10/08/1997
IPUNDU 11	OIL	728582.3929	7017569.957	188.48	5.26	193.74	23/08/1997
IPUNDU 12	OIL	731584.2259	7018507.684	173.32	5.26	178.58	28/08/1997
IPUNDU 12DW1	OIL	731584.2259	7018507.684	173.32	4.08	177.4	4/05/2005
IPUNDU 13	OIL	731374.2245	7018795.112	172.37	5.26	177.63	14/03/1998
IPUNDU 14	OIL	731994.4953	7018353.784	171.15	5.26	176.41	20/03/1998
IPUNDU 15	OIL	731007.7914	7018168.464	176.37	5.26	181.63	26/03/1998
IPUNDU 16	OIL	730341.7312	7019423.773	173.38	5.06	178.44	13/11/2009
IPUNDU 4	OIL	731613.8712	7018515.118	173.58	5.26	178.84	18/10/1996
IPUNDU 4A	OIL	731613.8712	7018515.118	173.58	5.26	178.84	14/04/1998
IPUNDU 5	OIL	730092.7104	7019780.284	172.94	5.26	178.2	31/10/1996
IPUNDU 6	OIL	731016.039	7018449.206	175.51	5.27	180.78	23/06/1997
IPUNDU 7	OIL	730747.0807	7019313.461	172.29	5.27	177.56	29/06/1997
IPUNDU 8	OIL	731902.4352	7017683.952	173.16	5.27	178.43	4/07/1997
IPUNDU 9	OIL	730985.9289	7017731.009	180.16	5.27	185.43	25/07/1997
IPUNDU NORTH 10	OIL	728494.9501	7020330.776	198.3	5.26	203.55	16/08/1997
IPUNDU NORTH 11	OIL	729358.4949	7020698.35	174.98	5.27	180.25	1/04/1998
IPUNDU NORTH 12	OIL	729096.6867	7021800.856	171.3	4.08	175.38	23/04/2007
IPUNDU NORTH 13	OIL	728641.4896	7020798.88	181.02	5.1	186.12	24/11/2009
IPUNDU NORTH 4	OIL	729007.2581	7020994.515	174.53	5.26	179.79	24/10/1996
IPUNDU NORTH 4DW1	OIL	729006.9661	7020994.853	174.55	3.93	178.48	29/04/2005
IPUNDU NORTH 5	OIL	728347.9887	7020822.73	181.41	5.26	186.67	7/11/1996
IPUNDU NORTH 6	OIL	727959.57	7020971.447	181.54	5.27	186.81	9/07/1997
IPUNDU NORTH 7	OIL	728602.6079	7021938.88	174.84	5.26	180.1	15/07/1997
IPUNDU NORTH 8	OIL	729503.414	7021015.944	171.96	5.25	177.21	20/07/1997
IPUNDU NORTH 9	OIL	728916.374	7020598.671	181.04	5.3	186.34	3/08/1997
IPUNDU NORTH 9DW1	OIL	728916.374	7020598.671	181.04	4.08	185.12	21/04/2005
IRTALIE EAST 1	OIL	624662.3336	6932199.362	248.72	16.6	265.32	20/10/2010
JACKSON 31	OIL	639952.3312	6943963.938	371.58	16.5	388.08	18/09/1987
JACKSON 32	OIL	641424.7676	6944653.652	348	16.5	364.5	27/09/1987
JACKSON 33	OIL	640516.6597	6945719.329	363.35	17	380.35	7/02/1988
JACKSON 33DW	OIL	640516.6597	6945719.329	363.35	16.6	379.95	14/06/1998
JACKSON 34	OIL	639716.305	6946096.608	385.37	17	402.37	12/03/1988
JACKSON 35	OIL	639751.9498	6945166.897	384.81	17	401.81	21/06/1988
JACKSON 36	OIL	640219.6221	6945185.02	368.51	17	385.51	29/05/1989
JACKSON 37	OIL	640208.515	6943712.684	356.79	16.5	373.29	13/07/1990
JACKSON 38	OIL	639625.2711	6947440.799	434.07	16.5	450.57	4/08/1990
JACKSON 39	OIL	640912.7382	6945228.666	358.6	16.5	375.1	24/07/1990
JACKSON 40	OIL	639306.7709	6946107.052	405.15	16.5	421.65	18/11/1990
JACKSON 41	OIL	640222.6973	6947789.406	393.56	16.5	410.06	28/11/1990
JACKSON 42	OIL	641231.9244	6945115.501	353.82	16.5	370.32	9/07/1991

JACKSON 43	OIL	639579.2732	6943559.462	374.63	17.9	392.53	23/01/1996
JACKSON 44	OIL	639693.8077	6945356.039	387.27	12.9	400.17	14/03/2005
JACKSON 45	OIL	639606.1445	6948798.789	405.44	12.9	418.34	6/06/2005
JACKSON 46	OIL	640165.0909	6942451.354	347.4	13.1	360.5	12/10/2007
JACKSON 47	OIL	641895.0625	6942303.905	331.1	13.1	344.2	5/10/2007
JACKSON 48	OIL	641296.9463	6944857.794	349.84	13.1	362.94	25/11/2007
JACKSON 49	OIL	640057.1567	6946320.179	391.96	12.92	404.88	18/11/2007
JACKSON 50	OIL	639897.119	6946946.831	419.16	12.87	432.02	11/11/2007
JACKSON 51	OIL	639727.0345	6947784.119	429.05	13.05	442.1	3/11/2007
JACKSON 52	OIL	640674.0848	6945555.299	365.05	13.1	378.15	9/12/2007
JACKSON 53	OIL	639909.7279	6945894.06	383.26	13	396.26	17/12/2007
JACKSON 54	OIL	640352.9596	6945887.418	373.75	13.2	386.95	24/12/2007
JACKSON 55	OIL	639927.5233	6945319.897	372.6	12.95	385.56	31/12/2007
JACKSON 56	OIL	639575.1446	6945294.018	393.93	13.04	406.97	3/12/2007
JACKSON 57	OIL	640037.4751	6942956.312	353.84	13	366.84	23/09/2008
JACKSON 58	OIL	639445.5505	6943335.509	366.54	12.98	379.52	23/01/2009
JACKSON EAST 1	OIL	642056.6035	6947846.101	385.46	17	402.46	11/01/1995
JACKSON EAST 2	OIL	641674.7159	6948304.61	405.84	13.1	418.94	9/02/2009
JACKSON SOUTH 10	OIL	641469.254	6940010.887	325.95	13.05	339	8/04/2007
JACKSON SOUTH 11	OIL	640449.0056	6940346.802	320.17	12.93	333.1	15/04/2007
JACKSON SOUTH 12	OIL	641511.4688	6941164.313	326.35	13.5	339.85	20/09/2007
JACKSON SOUTH 12A	OIL	641507.2813	6941160.595	327.36	13.3	340.65	28/09/2007
JACKSON SOUTH 13	OIL	642396.7475	6939501.118	355.84	13.2	369.04	14/09/2007
JACKSON SOUTH 14	OIL	641343.7229	6939889.241	325.92	13.03	338.95	22/10/2008
JACKSON SOUTH 15	OIL	640300.4066	6939892.336	318.24	13.1	331.34	9/10/2008
JACKSON SOUTH 16	OIL	641350.1111	6939895.594	325.98	13.2	339.18	2/11/2008
JACKSON SOUTH 8	OIL	640362.0602	6940576.061	321.83	17.9	339.73	11/02/1989
JACKSON SOUTH 9	OIL	643124.9408	6939197.723	373.24	17.9	391.14	2/08/1992
JALAPENO 1	OIL	622014.5465	6957657.01	389.14	13.17	402.31	12/06/2007
JARRAR 2	OIL	619620.5024	6932518.451	238.53	17.9	256.43	22/04/1991
JARRAR 3	OIL	619909.6945	6931941.896	240.87	17	257.87	17/01/1992
JUDGA 2	GAS	601379.7916	6965277.161	238.39	17.9	256.29	7/08/1993
JUDGA 3	GAS	600471.1059	6965764.759	238.71	19.3	258.01	19/10/2004
JUDGA NORTH 1	GAS	604316.377	6969411.331	241.6	12.4	254	16/01/1997
JUNO 1	GAS	581726.6777	6936257.133	224.6	16.6	241.2	16/02/1997
JUNO 2	GAS	581723.6669	6937070.734	224.08	26.2	250.28	6/06/1998
JUNO 3	GAS	582327.7603	6935873.98	225.65	16.6	242.25	18/10/2001
JUNO 4	GAS	582562.8289	6937136.187	225.29	16.6	241.89	21/11/2005

JUNO 5	GAS	581732.7587	6936105.653	225.12	16.6	241.72	9/06/2002
JUNO NORTH 1	GAS	583988.5879	6941290.942	225.37	19.3	244.67	4/12/1999
KAMEL 1	OIL	655542.9655	6934542.702	111.97	3.92	115.89	24/03/2007
KANANDA 1	GAS	581360.7204	6996499.773	325.03	26.2	351.25	17/09/2000
KANOOK 1	GAS	590687.1144	7001523.967	259.81	20.1	279.91	18/12/1993
KAPPA 1	GAS	510769.9413	6898506.111	382.11	26.2	408.31	21/07/1997
KARMONA 3	GAS	587401.3476	6979589.386	366.73	16.6	383.33	6/07/2002
KARMONA 4	GAS	588397.7145	6980191.021	443.33	16.6	459.93	14/12/2004
KARMONA 4A	GAS	588401.0854	6980191.884	443.33	16.6	459.93	31/12/2004
KARMONA 5	GAS	588096.3706	6978747.527	439.07	19.3	458.37	16/11/2005
KARMONA EAST 3	GAS	589318.1852	6981753.68	389.76	16.6	406.36	20/01/2005
KARNAK 1	GAS	602071.2436	7050573.189	287.79	26.2	313.99	2/08/2001
KARWIN 1DW1	GAS	630076.0295	6943419.601	352.27	19.3	371.57	13/11/1996
KERCUMMURRA 2	OIL	641485.7756	7002073.011	422.54	16.6	439.14	1/11/2009
KEREN 1	OG	561137.0548	6880718.979	426.96	17.9	444.86	13/09/1992
KINTA 1	GAS	504924.1145	6906931.956	314.56	19.3	333.86	8/11/2003
KOOROOPA 2	OIL	720346.778	7010760.165	158.34	4	162.34	17/05/2007
KOOROOPA 3	OIL	721834.644	7008890.425	159.84	4.02	163.86	10/05/2007
KOOROOPA NORTH 1	OIL	721287.0261	7011452.638	170.69	5.46	176.15	24/09/1995
KOOROOPA NORTH 2	OIL	720140.9167	7012084.035	163.1	5.26	168.36	7/03/1998
KOOYONG 1	OIL	734126.2434	7032590.08	177.78	4.86	182.64	3/09/2006
LEPARD 1	OG	572097.9481	6921694.723	216.73	16.6	233.33	12/11/2006
LOGANBERRY 1	OIL	731878.962	7025523.932	160.8	4.09	164.89	12/07/2006
MACADAMA 2	GAS	542934.3588	6985273.589	482.02	20.1	502.12	7/01/1996
MACADAMA 3	GAS	542926.1266	6983099.492	525.52	26.2	551.72	20/09/1997
MARAMA 1ST	GAS	613329.7175	7112304.17	339.09	20	359.09	25/12/1994
MARENGO SOUTH 1	GAS	581694.8658	7072200.975	296	18.78	314.78	28/07/1998
MARRACOONDA 1	OIL	577612.9547	6880584.926	251.36	17	268.36	17/07/1993
MATRIX 1	OG	525576.665	6874984.737	389.3	16.6	405.9	15/06/2005
MAXWELL 5	OIL	666451.832	6913336.397	126.65	3.92	130.57	18/10/2007
MAXWELL SOUTH 2	OIL	665109.9288	6912885.087	114.81	5.18	119.99	28/05/2011
MAYA 1	GAS	602461.7038	6986836.134	251.57	16.6	268.17	17/10/2004
MERULA 1	OIL	734053.9404	7028529.082	167.6	4.02	171.62	28/12/2003
MIMOSA 1	OIL	735069.5093	7033776.83	181.56	4.87	186.43	6/06/2006
MINNI RITCHI 1	OIL	736071.4878	7030689.978	175.92	4.07	179.99	29/07/2006
MINOS 1	OIL	593522.1478	6895991.344	235.5	13.05	248.55	1/01/2009
MIRANDA 1	GAS	517283.4697	6865714.536	374.59	17	391.59	27/06/1994
MITONGA 1	OIL	599180.5158	6893838.503	248.39	17.9	266.29	6/12/1992
MONTE 1	GAS	576843.9781	6981321.152	444.09	17.9	461.99	15/06/1996
MONTEGUE 1	GAS	501659.2365	6893181.841	285.33	16.6	301.93	12/11/2007
MOOKOO 1	GAS	618137.6772	6979511.377	289.5	12.4	301.9	6/03/1997

MOOLIAMPAH 3	OIL	527647.2364	6866567.045	439.41	17.9	457.31	7/01/1990
MOON 1	GAS	504164.8076	6877626.824	288.77	20.1	308.87	9/07/1995
MOON 2	GAS	503934.183	6879838.82	294.98	16.6	311.58	5/09/1996
MOON 3	GAS	503237.8446	6877746.532	294.81	16.6	311.41	16/03/2003
MUCHACHO 1	OIL	610342.585	6959448.869	268.3	13.2	281.5	4/09/2007
MUGGINANULLAH 2	OIL	732696.1005	6997221.194	180.73	4.86	185.59	23/12/2006
MULBERRY 1	OIL	738556.0982	7023280.585	176.5	4.02	180.52	18/12/2003
MULBERRY 10	OIL	739739.027	7022112.609	178.36	4.03	182.39	9/04/2006
MULBERRY 10A	OIL	739739.027	7022112.609	178.36	4.15	182.51	15/04/2006
MULBERRY 11	OIL	737732.0272	7023092.995	176.93	4.04	180.97	30/04/2006
MULBERRY 12	OIL	737584.353	7024194.132	172.62	4.09	176.71	20/05/2006
MULBERRY 13	OIL	737407.0358	7021337.102	185.58	4.04	189.62	23/04/2006
MULBERRY 14	OIL	739504.8179	7022480.461	176.87	4.03	180.9	6/04/2006
MULBERRY 15	OIL	737742.8682	7023682.204	174.75	4.02	178.77	6/06/2006
MULBERRY 16	OIL	738331.6039	7023671.061	174.8	4.09	178.89	5/05/2006
MULBERRY 17	OIL	737132.5806	7022518.893	178.26	4.03	182.29	12/06/2006
MULBERRY 18	OIL	738025.0031	7022802	177.83	4.1	181.93	26/10/2006
MULBERRY 19	OIL	737718.461	7022506.941	179.05	4.04	183.09	21/09/2006
MULBERRY 2	OIL	738119.9523	7023412.344	176.65	4.08	180.73	27/03/2005
MULBERRY 20	OIL	738553.0959	7022247.58	178.23	4.1	182.33	31/10/2006
MULBERRY 21	OIL	738325.1233	7021903.043	179.29	4.1	183.39	1/10/2006
MULBERRY 22	OIL	738896.267	7021885.659	180.67	4.1	184.77	7/10/2006
MULBERRY 23	OIL	738286.2496	7021304.829	182.39	4.05	186.44	14/10/2006
MULBERRY 24	OIL	740077.0962	7021266.97	181.59	4.1	185.69	20/10/2006
MULBERRY 25	OIL	737990.4123	7023952.109	173.85	4.4	178.25	16/09/2006
MULBERRY 26	OIL	737324.9799	7023950.271	173.15	4.2	177.35	20/02/2007
MULBERRY 27	OIL	737134.0752	7023683.831	173.69	4.1	177.79	26/02/2007
MULBERRY 28	OIL	737340.8304	7023415.433	175.47	4.1	179.57	3/03/2007
MULBERRY 29	OIL	737145.9693	7023144.412	176.69	4.86	181.55	5/02/2007
MULBERRY 3	OIL	739226.6628	7022937.162	176	4.08	180.08	4/04/2005
MULBERRY 30	OIL	737340.1269	7022793.664	178.03	4.1	182.13	8/03/2007
MULBERRY 31	OIL	738587.7356	7022821.154	176.87	4.06	180.93	21/08/2007
MULBERRY 32	OIL	738593.3365	7022812.512	176.89	4.06	180.95	15/08/2007
MULBERRY 33	OIL	738582.6231	7022829.344	176.92	4.06	180.98	29/08/2007
MULBERRY 34	OIL	738577.0181	7022837.764	176.95	4.3	181.25	4/09/2007
MULBERRY 35	OIL	738599.7891	7020985.047	185.66	4.87	190.53	17/02/2007
MULBERRY 4	OIL	738926.5109	7023518.986	175.08	4.08	179.16	15/04/2005
MULBERRY 41	OIL	737106.1051	7024251.266	171.85	4.86	176.71	28/02/2007
MULBERRY 42	OIL	736535.9131	7023706.181	171.81	4.1	175.91	13/03/2007
MULBERRY 44	OIL	736546.9505	7022549.326	176.08	4.04	180.12	26/03/2007
MULBERRY 45	OIL	737256.8798	7021721.832	182.05	4.87	186.92	10/03/2007
MULBERRY 5	OIL	738908.9953	7023088.867	176.4	4.08	180.48	26/05/2005

MULBERRY 6	OIL	738317.6846	7023083.46	176.51	4.3	180.81	7/03/2006
MULBERRY 7	OIL	738609.7584	7022787.479	176.94	4.3	181.24	16/03/2006
MULBERRY 8	OIL	738309.9235	7022495.742	178.25	4.3	182.55	24/03/2006
MULBERRY 9	OIL	738923.1873	7022444.415	176.68	4.03	180.71	31/03/2006
MUNKAH 10	GAS	589555.1867	6966056.84	291.66	16.6	308.26	18/04/2002
MUNKAH 11	GAS	588327.5369	6964155.992	243.14	16.6	259.74	4/04/2002
MUNKAH 12	GAS	592811.1228	6966012.64	238.12	16.8	254.92	9/10/2008
MUNKAH 3	GAS	592491.9981	6965640.606	238.86	17.9	256.76	11/07/1992
MUNKAH 4	GAS	589557.7237	6965536.71	241.13	17.9	259.03	28/05/1993
MUNKAH 5	GAS	590544.5626	6967637.736	297.33	17.9	315.23	21/06/1993
MUNKAH 6	GAS	588112.8021	6964257.236	241.17	16.6	257.77	7/08/1996
MUNKAH 7	GAS	588827.0734	6965307.602	243.44	26.2	269.63	22/05/1999
MUNKAH 9	GAS	590328.6393	6966950.605	299.83	16.6	316.43	22/03/2002
MUNRO 5	OIL	519507.7653	6844287.128	392.54	17	409.54	24/08/1994
MUNRO 6	OIL	519798.6355	6843818.909	394.13	17	411.13	<Null>
MUNRO 7	OIL	518897.9254	6843980.034	391.44	17	408.44	<Null>
MUTHERO 3	OIL	659000.7278	6933620.618	118.92	4.08	123	24/12/2005
MUTHERO 4	OIL	659232.9417	6933549.867	115.59	4.02	119.61	22/02/2007
MUTHERO 5	OIL	659036.0028	6933362.179	120.09	3.96	124.05	3/03/2007
MUTHERO 6	OIL	659265.8093	6933672.219	116.14	3.96	120.1	14/03/2007
MUTHERO 7	OIL	658954.9245	6933639.945	119.28	4.02	123.3	12/02/2007
NACCOWLAH 3	OIL	613017.0786	6959288.796	313.97	12.75	326.72	23/08/2007
NACCOWLAH SOUTH 12	OIL	608205.2378	6954707.041	249.24	17.9	267.14	30/01/1989
NACCOWLAH SOUTH 13	OIL	608981.7887	6954900.9	273.71	17	290.71	3/07/1989
NACCOWLAH SOUTH 14	OIL	607677.2425	6955404.452	247.01	17	264.01	18/06/1989
NACCOWLAH SOUTH 15	OIL	607259.323	6955492.873	239.63	13.15	252.78	8/07/2007
NACCOWLAH SOUTH 16	OIL	609210.1627	6954582.232	254.79	13.18	267.97	27/06/2007
NACCOWLAH SOUTH 17	OIL	607019.1431	6955135.248	240.09	13	253.09	3/08/2008
NACCOWLAH SOUTH 18	OIL	607925.7333	6954842.011	248.92	13	261.92	20/08/2008
NACCOWLAH WEST 10	OIL	603176.498	6955000.947	235.54	16.5	252.04	8/03/1990
NACCOWLAH WEST 11	OIL	602681.9437	6954809.125	234.07	16.5	250.57	13/10/1990
NACCOWLAH WEST 12	OIL	603844.7534	6954278.842	232.27	16.5	248.77	24/10/1990
NACCOWLAH WEST 13	OIL	602609.6678	6955058.999	236.51	16.5	253.01	6/11/1990
NACCOWLAH WEST 14	OIL	603473.9988	6954874.134	233.32	16.5	249.82	8/12/1990
NACCOWLAH WEST 15	OIL	604221.1424	6954337.905	232.3	17	249.3	14/12/1991
NACCOWLAH WEST 16	OIL	603941.5316	6954917.59	232.22	16.5	248.72	20/07/1991
NACCOWLAH WEST 17	OIL	605143.6705	6954497.746	234.05	17	251.05	25/12/1991

NACCOWLAH WEST 18	OIL	605588.4962	6955046.632	234.69	17	251.69	5/01/1992
NACCOWLAH WEST 19	OIL	603746.2964	6955095.507	231.38	17.9	249.28	24/07/1992
NACCOWLAH WEST 20	OIL	604842.0372	6954173.845	233.66	13.15	246.82	19/07/2007
NACCOWLAH WEST 21	OIL	605874.7434	6954820.149	236.05	13.15	249.2	27/07/2007
NACCOWLAH WEST 22	OIL	602983.8829	6955174.731	233.89	13	246.88	4/09/2008
NACCOWLAH WEST 7	OIL	604977.3391	6954703.464	233.51	17	250.51	19/02/1988
NACCOWLAH WEST 8	OIL	603426.8901	6954593.911	234.16	17	251.16	10/06/1988
NACCOWLAH WEST 9	OIL	603478.7071	6955174.103	234.39	16.5	250.89	19/11/1989
NATAN 2	OIL	613601.4968	6924291.889	241.05	16.5	257.55	17/08/1990
NOCKATUNGA 6	OIL	650094.3744	6934556.392	122.84	5.18	128.02	15/06/1995
NOCKATUNGA NORTH 1	OIL	649677.9416	6934576.933	126.11	5.1	131.21	27/08/2010
NUATA EAST 1	OIL	627662.8505	6944866.867	368.96	13.1	382.06	11/05/2007
OBERONE 1	OIL	583260.6974	6889815.981	241.59	17	258.59	5/08/1993
OKOTOKO 2	GAS	598423.2029	6975108.845	243.67	20	263.67	10/01/1994
OKOTOKO 3	GAS	598733.3605	6977201.685	247.11	16.8	263.91	18/12/2008
OKOTOKO EAST 1	GAS	600702.4368	6976497.051	245.04	20.1	265.14	29/09/1995
OKOTOKO WEST 1	GAS	595724.8069	6973492.407	244.03	20.1	264.13	8/09/1995
OKOTOKO WEST 2	GAS	594571.9767	6974369.045	244.42	16.65	261.07	13/09/2009
OLYMPUS 1	GAS	564359.2913	6879597.898	269.98	16.6	286.58	30/07/2004
OMEGA 1	GAS	543387.5057	6887191.33	429.75	17.25	447	28/02/1997
PATROCLUS 2	OIL	567118.0402	6890134.761	224.05	17	241.05	14/02/1992
PATROCLUS 3	OIL	567431.7392	6889971.359	226.95	17.9	244.85	13/10/1992
PATROCLUS 4	OIL	567650.2236	6889768.605	227.96	17.9	245.86	27/01/1993
PATROCLUS EAST 1	OG	568408.8434	6889122.947	226.89	17.9	244.79	25/08/1992
PINIATA 1	OIL	612461.6214	6958150.007	301.8	13.14	314.96	12/09/2007
PITCHERY 2	OIL	614222.3638	6958149.126	348.7	17	365.7	26/03/1988
PITCHERY 3	OIL	613879.784	6957845.869	335.56	13	348.56	22/09/2007
PITTEROO 1	OIL	681983.611	6899116.477	626.44	16.6	643.04	25/06/1998
PSYCHE 1	GAS	580021.3045	6912181.12	214.04	17.9	231.94	7/11/1995
PSYCHE 2	GAS	582277.3574	6911772.408	215.71	17.25	232.96	25/12/1997
PSYCHE 3	GAS	581056.2339	6909000.86	214.99	16.6	231.59	26/07/2005
PSYCHE 4	GAS	579680.9138	6910354.539	214.73	16.6	231.33	12/07/2005
PSYCHE 5	GAS	581306.7524	6911990.933	215.02	16.6	231.62	12/12/2006
PSYCHE 6	GAS	580534.0383	6913227.722	215.81	16.65	232.46	19/07/2009
PYTHON 1	GAS	519448.6272	6855212.589	392.4	13.29	405.69	5/08/2006
QUASAR 1	GAS	503874.7755	6859337.45	308.72	16.5	325.22	24/03/2001
QUASAR SOUTH 1	GAS	504199.7332	6856340.361	336.31	16.5	352.81	14/04/2001
QUASAR SOUTHEAST 1	GAS	505080.2883	6855619.045	326.44	16.5	342.94	22/12/2001

RAFFLE 1	GAS	557844.1138	6901415.91	304.92	17.25	322.17	27/01/1997
RAMSES 1	GAS	609597.5279	7039240.993	298.26	16.6	314.86	8/12/2000
RAMSES 2	GAS	609948.9665	7040204.132	298.06	16.6	314.66	7/01/2007
RANGER SOUTH 1	GAS	507473.0807	6858536.209	334.61	16.5	351.11	21/05/2001
RAWORTH 1	GAS	626337.5093	6961281.504	435.59	16.5	452.09	3/02/2001
RELIANCE 1	OIL	738580.3986	7033928.916	180	4.86	184.86	14/08/2006
RHEIMS 2	OIL	530279.9918	6873045.422	428.15	17	445.15	<Null>
ROSA 1	GAS	581946.3949	6984565.786	314.79	16.6	331.39	23/03/1998
ROSENEATH 2	GAS	522222.5496	6883987.329	438.18	16.6	454.78	20/02/2003
ROSENEATH 3	OIL	522598.3871	6884167.302	441.76	16.6	458.36	13/04/2003
ROTI 1	GAS	615114.8743	6971231.171	290.78	16.6	307.38	13/07/1996
ROTI 2	GAS	616640.7174	6970612.023	319.89	16.5	336.39	27/02/2001
ROTI 3	GAS	616724.9938	6969914.584	293.63	16.6	310.23	15/05/2001
ROTI WEST 1	GAS	613052.0759	6972373.767	266.15	16.6	282.75	27/08/2000
SAMPDORIA 1	OIL	585624.6063	6890654.008	238.35	17	255.35	<Null>
SARAH 1	GAS	504242.053	6885142.217	302.72	16.5	319.23	13/09/2000
SARATOGA 1	OG	524086.2267	7024924.555	356	15.6	371.6	14/10/2005
SEAGOON 1	OIL	744588.2897	7014538.163	180.17	4.1	184.27	8/11/2006
SHILLINGLAW 1	OIL	619556.3566	6875177.237	476.47	17	493.47	25/05/1995
SIGMA 2	OIL	533401.8438	6865039.137	399.41	17.9	417.31	21/12/1987
STILTON 1	OG	586816.8139	6953855.244	235.04	19.3	254.34	29/11/2004
STOKES 1	GAS	502818.8076	6864624.999	270.12	17	287.12	23/06/1993
STOKES 10	GAS	502437.3542	6865545.892	275.39	16.5	291.89	9/06/2001
STOKES 11	GAS	504131.5907	6865369.392	288.74	16.5	305.24	17/03/2002
STOKES 12	GAS	504908.666	6864233.925	303.67	16.5	320.17	1/02/2002
STOKES 2	GAS	505071.5624	6863806.021	289.3	17	306.3	4/09/1993
STOKES 3	GAS	501823.6525	6867922.796	290.68	17	307.68	1/04/1994
STOKES 4	GAS	504339.0663	6865848.333	289.89	17.25	307.14	5/04/1997
STOKES 5ST1	GAS	504017.3448	6864906.036	297.62	16	313.62	7/03/1999
STOKES 6	GAS	505003.5265	6864678.116	307.2	26.2	333.4	8/06/1999
STOKES 7	GAS	505960.9243	6865557.492	298.34	18.8	317.14	15/07/2000
STOKES 8	GAS	502296.1968	6866479.468	294.47	18.8	313.27	1/08/2000
STOKES 9	GAS	502845.8626	6863830.473	277.28	18.8	296.08	15/08/2000
STOKES CENTRAL 1	GAS	504365.9476	6867508.922	285.66	16.5	302.16	24/02/2002
STOKES NORTH 1	GAS	503826.8818	6869365.562	274.7	16.6	291.3	26/10/1996
STOKES SOUTH 1	GAS	503923.412	6862426.016	283.2	26.2	309.4	20/08/1998
SURLOW 1	GAS	595390.9155	6975838.223	245.21	16.6	261.81	29/11/2003
SURLOW 2	GAS	595616.2854	6976477.232	244.42	16.65	261.07	29/09/2009
TAKYAH 2	OIL	726393.5166	7010328.878	171.02	4.07	175.09	15/06/2007
TAKYAH 4	OIL	726130.3874	7014528.313	155	3.96	158.96	1/05/2007
TAKYAH 5	OIL	727677.9416	7010512.746	157.17	4.05	161.22	4/08/2007
TALGEBERRY 10	OIL	740959.6529	7016661.222	181.9	4.04	185.94	4/08/2006

TALGEBERRY 11	OIL	741802.7948	7016964.048	190.11	4.04	194.15	11/08/2006
TALGEBERRY 12	OIL	741552.928	7017805.18	184.99	4.06	189.05	18/07/2006
TALGEBERRY 13	OIL	740936.9769	7017854.935	182.08	4.04	186.12	23/07/2006
TALGEBERRY 14	OIL	742339.7803	7017179.728	182.25	4.04	186.29	16/08/2006
TALGEBERRY 15	OIL	740648.8331	7020010.771	179.84	4.04	183.88	2/09/2006
TALGEBERRY 16	OIL	738294.669	7019119.263	191.03	4.04	195.07	9/09/2006
TALGEBERRY 17	OIL	741130.4207	7018108.078	182.19	4.05	186.24	4/07/2007
TALGEBERRY 18	OIL	740945.8953	7017325.971	183.4	4.04	187.44	17/07/2007
TALGEBERRY 19	OIL	741394.0859	7018633.245	181.14	4.03	185.17	27/06/2007
TALGEBERRY 20	OIL	740414.1248	7017598.905	181.9	4.06	185.96	27/07/2007
TALGEBERRY 22	OIL	742049.9794	7017849.812	183.12	4.05	187.17	11/07/2007
TALGEBERRY 4	OIL	741771.7659	7017333.585	188.33	5.46	193.79	11/09/1995
TALGEBERRY 5	OIL	741785.2625	7018374.399	186.79	5.26	192.05	16/11/1996
TALGEBERRY 6	OIL	740249.2853	7017323.367	181.65	5.26	186.91	3/12/1996
TALGEBERRY 7	OIL	741294.0208	7017403.089	192.24	5.26	197.5	9/04/1998
TALGEBERRY 8	OIL	741437.5706	7016602.145	187.4	4.02	191.42	26/11/2003
TALGEBERRY 9	OIL	740623.7945	7016978.959	180.53	4.04	184.57	29/07/2006
TALGEBERRY NORTH 1	OIL	738922.0229	7020423.091	190.8	4.02	194.82	6/12/2003
TALLALIA 2	GAS	529318.2641	6973442.008	461.02	26.2	487.22	18/11/1997
TANU 1	GAS	593159.2514	6988472.736	254.62	20.1	274.72	18/10/1995
TARBAT 10	OIL	726744.5492	7024005.676	183.14	5.26	188.4	11/10/1996
TARBAT 11	OIL	726534.2114	7024804.783	181.72	5.25	186.97	30/07/1997
TARBAT 12	OIL	727472.28	7023635.943	182.15	3.93	186.08	14/05/2005
TARBAT 2	OIL	727369.0626	7023897.079	181.73	5.46	187.19	30/08/1995
TARBAT 3	OIL	727159.79	7023916.268	184.87	5.46	190.33	8/01/1996
TARBAT 4	OIL	727373.578	7023520.12	183.57	5.46	189.03	27/12/1995
TARBAT 5	OIL	726983.4756	7024225.164	178.73	5.46	184.19	20/04/1996
TARBAT 6	OIL	726728.7122	7024367.762	182.97	5.46	188.43	2/05/1996
TARBAT 7	OIL	727588.7207	7023589.497	178.72	5.46	184.18	12/05/1996
TARBAT 8	OIL	726733.4982	7024004.656	183.14	5.26	188.4	13/09/1996
TARBAT 9	OIL	726779.3795	7024008.041	183.14	5.26	188.4	29/09/1996
TARTULLA 2	GAS	615595.7084	6991688.993	437.91	17.9	455.81	30/12/1993
TARTULLA 3	GAS	616095.3767	6988764.241	588.25	20.1	608.35	5/08/1994
TARTULLA 4	GAS	613525.7373	6990801.541	327.42	20.1	347.52	8/03/1996
TARTULLA 5	GAS	612929.4583	6986119.567	325.23	12.4	337.63	9/07/1997
TARTULLA 6	GAS	612814.7858	6990113.737	314.14	16.6	330.74	5/02/2005
TARTULLA 7	GAS	614803.2289	6991297.852	419.81	16.6	436.41	19/02/2005
TARTULLA 8	GAS	613988.8427	6991428.105	356.26	16.31	372.57	27/12/2007
TEEGAL 1	OG	521289.5914	6870372.108	374.83	16.6	391.43	27/11/2006
TELLUS 1	GAS	505204.3434	6862446.237	312.07	16.5	328.58	1/05/2001
TELLUS SOUTH 1	GAS	505936.7977	6860845.104	307.64	16.5	324.14	15/01/2002
TENNAPERRA 2	OIL	596915.9684	6902042.178	221.29	13	234.29	11/01/2009

TEQUILA 1	OIL	635448.9195	6951614.27	500.58	15.4	515.98	2/04/2007
THETA 1	GAS	573225.723	6904854.253	211.91	16.6	228.51	30/12/2005
THETA 2	GAS	571447.5855	6907023.914	211.58	16.65	228.23	4/07/2009
THOAR 2	GAS	576517.0205	6899106.457	225.42	17.25	242.67	10/06/1997
THOAR 3	GAS	576172.922	6899734.811	223.66	16.6	240.26	11/08/2005
THOAR 4	GAS	575918.5875	6901099.419	212.14	16.6	228.74	23/01/2006
THUNGO 10	OIL	656018.2867	6931936.158	107.76	4.02	111.78	19/01/2007
THUNGO 11	OIL	655033.8352	6931784.106	114.75	3.96	118.71	1/04/2007
THUNGO 13	OIL	655796.5649	6931263.711	110.67	4.02	114.69	6/02/2007
THUNGO 7	OIL	655994.911	6932610.867	106.53	5.06	111.59	15/07/2002
THUNGO 8	OIL	656282.7453	6932908.577	106.46	4.02	110.48	3/11/2003
THUNGO 9	OIL	656088.2365	6932307.147	108.22	4.02	112.24	14/01/2007
THURRA 2	OIL	631990.3344	6957866.852	660.5	17.9	678.4	9/01/1993
TICKALARA 10	OIL	537032.8746	6864667.396	408.35	17.9	426.25	12/06/1992
TICKALARA 11	OIL	538335.6505	6865276.32	429.28	17.9	447.18	23/10/1992
TICKALARA 12	OIL	537662.9274	6865202.705	420.85	17.9	438.75	6/02/1993
TICKALARA 13	OIL	538256.1613	6865610.367	433.93	17	450.93	16/08/1993
TICKALARA 14	OIL	537666.2046	6865554.763	417.53	17	434.53	25/12/1994
TICKALARA 15	OIL	538736.7839	6866549.573	419.45	17	436.45	14/05/1995
TICKALARA 16	OIL	537157.9118	6864940.306	420.73	17.25	437.98	10/03/1997
TICKALARA 17	OIL	537396.8025	6865043.578	411.35	16.6	427.95	21/05/1998
TICKALARA 18	OIL	538030.706	6865454.224	426.54	16.6	443.14	12/05/1998
TICKALARA 19	OIL	536777.9896	6864491.603	417.45	15.75	433.2	21/10/2008
TICKALARA 20	OIL	539201.7528	6866054.836	418.99	15.4	434.39	2/11/2008
TICKALARA 21	OIL	537910.6099	6865293.642	432.97	16.6	449.57	20/12/2009
TICKALARA 22	OIL	538579.6694	6865894.915	431.27	16.6	447.87	29/12/2009
TICKALARA 23	OIL	538827.957	6865476.561	433.63	16.6	450.23	7/01/2010
TICKALARA 24	OIL	537303.7792	6865227.55	416.6	16.6	433.2	16/01/2010
TICKALARA 4	OIL	538138.2257	6865087.629	428.06	17.9	445.96	6/01/1988
TICKALARA 5	OIL	538577.9354	6865333.029	438.41	17.9	456.31	18/03/1988
TICKALARA 6	OIL	537270.8499	6864668.864	405.92	17	422.92	12/08/1988
TICKALARA 7	OIL	537936.981	6864989.458	424.8	20.1	444.9	21/09/1991
TICKALARA 8	OIL	537465.3257	6864861.455	414.59	17	431.59	27/01/1992
TICKALARA 9	OIL	538618.357	6865645.194	437.92	17.9	455.82	1/06/1992
TOGAR 1	OIL	619595.0185	6911256.045	263.59	17.9	281.49	20/08/1993
TOOBUNYAH 6	OIL	708862.8459	7017432.594	165.76	4.44	170.2	26/07/1994
TOOTEN 1	OIL	738162.3694	7032483.741	175.2	4.07	179.27	13/08/2006
TOOTEN 1A	OIL	738162.3694	7032483.741	175.4	4.07	179.47	14/08/2006
TOSCA 1	GAS	555313.2823	6892470.735	333.79	17.9	351.69	28/11/1995
TOSTADA 1	OIL	633120.7985	6949573.772	481.98	15.98	497.96	11/04/2007
TOSTADA 2	OIL	633407.9409	6950072.671	488.18	13.19	501.37	27/10/2007
TURANDOT 1	OIL	552166.6945	6893066.595	368.83	13.2	382.03	9/02/2004

TUROL 1	OIL	514625.9532	7020138.739	368.36	20.1	388.46	17/11/1995
UPSILON 1	OIL	532016.4559	6866935.019	395.83	16.6	412.43	18/05/2005
VEGA 1	GAS	587438.332	6933180.026	224.37	19.3	243.67	17/11/1997
VEGA 2	GAS	587006.0671	6933459.205	225.52	16.6	242.12	2/07/2001
VEGA 3	GAS	585144.0243	6933608.447	224.34	16.8	241.14	22/11/2008
VEGA NORTH 1	GAS	587059.4775	6935491.703	225.06	16.6	241.66	13/11/2001
WACKETT 10	GAS	597813.3255	6956474.308	236.28	19.3	255.58	15/09/1999
WACKETT 11	GAS	595767.6117	6959109.495	237.38	16.6	253.98	3/10/2000
WACKETT 12	GAS	598561.0675	6955922.038	236.09	16.6	252.69	7/02/2002
WACKETT 13	OIL	589545.6568	6957910.227	289.5	13.12	302.62	27/12/2006
WACKETT 14	GAS	598821.9405	6955275.17	236.28	16.65	252.93	16/08/2009
WACKETT 15	GAS	600225.2692	6956148.491	236.98	16.6	253.58	4/08/2009
WACKETT 16	GAS	598354.3163	6958134.395	238.16	16.65	254.81	29/08/2009
WACKETT 5	GAS	590684.0026	6956327.32	273.63	20.1	293.73	27/07/1995
WACKETT 6	GAS	589715.2519	6955776.448	231.99	17.9	249.89	7/02/1996
WACKETT 7	OIL	589582.7737	6957730.934	280.74	17.9	298.64	23/03/1996
WACKETT 8	GAS	586686.8558	6955835.483	278.7	17.25	295.95	23/09/1997
WACKETT 9	GAS	599064.2801	6957175.823	237.96	26.2	264.16	8/06/1999
WACKETT SOUTHEAST 1	GAS	599426.0028	6947275.02	231.1	16.6	247.7	27/10/2000
WANDILO 3	OIL	600178.1565	6895202.814	241.03	16.5	257.53	5/02/1990
WANDILO 4	OIL	600567.362	6895684.605	243.26	16.5	259.76	6/04/1990
WANDILO SOUTH 1	OIL	601476.3581	6894059.003	260.2	17	277.2	3/07/2011
WAREENA 3	GAS	631678.6536	7021479.26	373.16	12.4	385.56	14/12/1996
WAREENA 4	GAS	635716.6116	7026593.856	364.66	12.4	377.06	12/04/1997
WAREENA 5	GAS	634190.0594	7022970.933	367.72	16.65	384.37	14/10/2009
WARNIE 1	GAS	534927.5256	6911681.263	430.77	16.5	447.27	11/10/2000
WATKINS 1	OIL	603660.0036	6895677.607	269.55	13	282.55	8/12/2008
WATSON 3	OIL	606126.8846	6892778.391	270.18	13	283.18	14/11/2008
WATSON 4	OIL	605949.8528	6893159.438	264.11	13	277.11	23/11/2008
WATSON SOUTH 3	OIL	602820.3546	6887706.374	265.52	16.5	282.02	18/12/1989
WATSON SOUTH 4	OIL	602507.7547	6887104.008	269.17	17	286.17	26/07/1993
WATSON WEST 1	OIL	601127.2052	6886807.005	271.45	16.6	288.05	15/07/2010
WELLINGTON 1	GAS	582002.3038	6933353.116	224.64	16.6	241.24	21/08/2001
WELLINGTON 2	GAS	585170.865	6933921.222	224.08	16.6	240.68	8/11/2003
WELLINGTON 3	GAS	579475.7261	6933087.093	224.64	16.6	241.24	19/08/2004
WELLINGTON 4	GAS	579694.4119	6931605.835	223.88	16.6	240.48	24/09/2004
WELLINGTON 5	GAS	585299.2174	6931408.639	223.85	16.6	240.45	6/12/2004
WELLINGTON 6	GAS	586010.1387	6931191.247	223.68	16.6	240.28	3/12/2007
WHANTO 1	GAS	619139.8423	7066010.373	316.04	18.78	334.82	1/11/1997
WHYNOTT 1	OIL	738930.9582	7030844.31	171.46	4.07	175.53	9/08/2006
WILSON 8	OIL	640097.1903	6950335.314	433.56	17.9	451.46	7/04/1996
WILSON 9	OIL	640469.926	6949645.39	399.11	13.29	412.4	30/04/2007

WINDIGO 1	GAS	609640.6418	6970047.948	255.1	19.3	274.4	5/10/1999
WINDIGO 2	GAS	609076.916	6970634.027	252.08	16.6	268.68	18/09/2000
WINDULA 1	OG	539819.0918	7044227.083	449.37	15.6	464.97	21/09/2005
WINNA 4	OIL	651833.0327	6932261.947	133.75	4.08	137.83	11/12/2005
WINNINIA 1	GAS	582274.8256	6918469.497	217.95	17	234.95	13/12/1994
WINNINIA NORTH 1	GAS	587452.2159	6923074.252	219.52	19.3	238.82	29/10/1999
WINNINIA NORTH 2	GAS	588019.0933	6921571.761	219.89	16.5	236.39	12/12/2000
WINNINIA NORTH 3	GAS	586560.153	6921763.875	217.91	19.3	237.21	2/10/2004
WINNINIA NORTH 4	GAS	586916.0249	6924233.718	219.65	16.6	236.25	14/09/2005
WINNINIA SOUTH 1	GAS	580108.9386	6915949.432	215.81	16.6	232.41	28/08/2005
WIPPO EAST 1	GAS	610978.3089	6980537.915	259.1	16.6	275.7	31/07/2000
WIPPO EAST 2	GAS	611925.8222	6983231.538	262.41	16.5	278.91	9/01/2001
WIPPO SOUTH 1	GAS	607178.6539	6975209.71	244.84	12.4	257.24	9/08/1997
WOLGOLLA 3	GAS	532031.0911	6882361.791	425.09	16.6	441.69	3/02/2003
WOLGOLLA 4	GAS	528629.3468	6883815.796	436.71	16.6	453.31	3/04/2005
WOLGOLLA 5	GAS	533382.1216	6882292.831	430.18	16.6	446.78	23/04/2005
WOLGOLLA 6	GAS	532611.9607	6882927.63	422.07	16.6	438.67	7/02/2006
WOLGOLLA EAST 1	GAS	539388.3426	6880253.389	413.64	17.25	430.89	15/05/1997
WOMPI EAST 1	OIL	580207.0851	6874285.592	254.63	17	271.63	5/07/1993
YANDA 10	GAS	577481.8955	6962067.152	402.49	16.6	419.09	16/03/1997
YANDA 11	OIL	579266.0981	6962922.925	392.48	16.6	409.08	3/04/1997
YANDA 12	GAS	582101.1315	6963928.107	330.99	16.6	347.59	30/04/1997
YANDA 13	GAS	580835.8781	6964436.548	413.8	26.2	440	29/06/1999
YANDA 14	GAS	578093.695	6963735.121	425.25	26.2	451.45	25/02/1999
YANDA 15	OIL	579719.6021	6963213.217	380.54	12.9	393.44	12/02/2006
YANDA 16	OIL	581588.5567	6963506.246	389.17	12.9	402.07	25/01/2006
YANDA 17	OIL	580176.0897	6963381.95	390.97	13.12	404.09	5/10/2006
YANDA 18	OIL	580260.7358	6962845.345	399.57	13.12	412.69	15/10/2006
YANDA 19	OIL	578373.4398	6962490.199	421.09	13.12	434.21	25/10/2006
YANDA 20	OIL	578639.8401	6963151.276	429.59	13.12	442.71	4/11/2006
YANDA 21	OIL	579429.1049	6963587.422	420.3	13.12	433.42	30/11/2006
YANDA 22	OIL	580408.0312	6963954.926	371.78	13.12	384.9	10/12/2006
YANDA 23	OIL	580758.0505	6963167.106	395.63	13.12	408.75	13/11/2006
YANDA 24	OIL	579868.2791	6962612.28	424.24	13.12	437.36	21/11/2006
YANDA 25	OIL	578948.8636	6962382.825	430.64	13.21	443.85	18/12/2006
YANDA 7	OG	578103.427	6964131.086	406.44	17.89	424.33	28/09/1990
YANGTSE 1	GAS	606326.2709	6940773.498	230.18	19.3	249.48	2/11/2004
YAWA 1	GAS	591099.6953	6971433.939	243.13	17.9	261.03	2/03/1996
YAWA 2	GAS	591881.0324	6971549.108	307.12	16.8	323.92	2/11/2008
ZENONI 1	OIL	747750.2578	6996620.234	206.39	4.86	211.25	7/12/2006
ZEUS 1	OIL	594884.4078	6897771.349	236.75	13.02	249.77	18/12/2008
ZEUS 2	OIL	596056.0495	6897393.959	234.38	17	251.38	21/07/2011

ZEUS 3	OIL	595077.8542	6898241.344	236.35	17	253.35	7/08/2011
ZIEGFREID 1	OIL	748983.8077	6993387.526	197.43	4.87	202.3	16/12/2006

The following Table contains all Santos Oil and Gas wells located in South Australia, grouped by field name.

Field Name and Well Reference Number	Oil or Gas Well	Easting (GDA 54)	Northing (GDA 54)	Ground Level (mAHD)	Datum Height (Kelly Bushing) (m)	Well Datum Elevation (mAHD)	Date Drilled
ALISMA 1	GAS	494453.9034	6874933.997	248.8	20	268.8	1/08/1990
ALISMA 2	GAS	494593.2556	6875880.337	247.36	19.3	266.66	5/05/2005
ALLAMBI 1	GAS	485904.384	6872280.508	229.12	17	246.12	21/10/1994
ALLUNGA 1	GAS	435936.8763	6867499.053	106.94	18.78	125.72	1/08/1996
ALLUNGA TROUGH 1	GAS	433138.4037	6865003.806	133.21	18.8	152.01	10/07/1998
ALWYN 3	OIL	434132.0221	6848065.563	99.38	17	116.38	5/09/1989
ALWYN 4	OIL	433521.8125	6847846.418	101.25	17	118.25	23/09/1990
ALWYN 5	OIL	433629.9226	6849015.872	107.64	14.5	122.14	19/12/1990
ALWYN 6	OIL	434023.9034	6847535.82	100.5	13.2	113.7	10/07/2003
ALWYN 7	OIL	433430.0299	6848031.917	106.86	15.52	122.38	20/07/2007
ALWYN EAST 1	OIL	435746.379	6847358.903	99.55	13.2	112.75	18/07/2003
ALWYN NORTH 1	OIL	435881.5001	6849861.175	103.48	17	120.48	23/04/1991
AMYEMA 1	GAS	494195.3622	6860667.365	279.39	17.8	297.19	5/06/1989
ANGELICA 1	OIL	440155.1925	6997853.406	113.89	19.3	133.19	5/03/1998
APACHIRIE 1	OIL	443652.5918	7003270.928	104.41	20.1	124.51	7/06/1995
ARABURG 1	OIL	495230.6396	7076980.251	575.34	17.8	593.14	6/03/1989
ARAGORN 1	OIL	442692.4948	6853897.341	103.5	17	120.5	25/05/1997
AZOLLA 1	GAS	487853.7376	6847347.927	270.68	14.5	285.18	25/12/1988
BAGUNDI 3	GAS	477661.2647	6879412.268	236.13	17	253.13	3/01/1989
BAGUNDI 4	GAS	475920.7716	6878751.949	202.72	20.1	222.82	23/07/1992
BAGUNDI 5	GAS	474319.6757	6879194.487	197.61	19.3	216.91	31/01/2005
BAGUNDI 6	GAS	476622.3066	6878984.656	190.42	19.3	209.72	13/02/2005
BALCAMINGA 1	GAS	436581.8679	6949867.086	127.69	16.2	143.89	1/04/1987
BARATTA 2	GAS	467473.6475	6869701.185	156.48	17	173.48	4/08/1995
BARATTA SOUTH 1	GAS	468072.9877	6867937.727	162.12	17	179.12	14/04/1992
BARATTA WEST 1	GAS	465260.551	6870290.025	157.56	17	174.56	14/10/1996
BATTUNGA 1	GAS	454667.9684	6842209.66	128.95	20	148.95	26/09/1987
BAUHAUS 1	GAS	429833.166	6859573.694	111.7	18.78	130.48	20/08/1997
BAUHINIA 1	GAS	491117.8228	6958246.094	321.69	14.5	336.19	1/07/1991
BAUHINIA 2	GAS	490907.1117	6958549.663	332.82	16	348.82	29/12/1997
BECKLER 1	GAS	495918.2278	6897343.676	277.12	17	294.12	9/12/1996
BECKLER 2	GAS	495570.6409	6896753.338	275.03	18.8	293.83	19/04/2000
BECKLER 3	GAS	496301.4499	6898178.94	275.99	17.3	293.29	8/11/2000
BECKLER 4	GAS	494766.7908	6898499.95	262.16	18.8	280.96	10/12/2001

BECKLER 5	GAS	496955.6166	6895150.618	285.92	18.8	304.72	2/01/2002
BIALA 10	OIL	439516.5887	6843258.411	164.09	13.2	177.29	26/07/2003
BIALA 11	OIL	439153.8843	6844696.809	111.89	13.2	125.09	16/10/2003
BIALA 12	OIL	436554.1286	6842630.978	153.66	13.2	166.86	11/10/2003
BIALA 13	OIL	438232.9674	6845693.101	117.18	13.4	130.58	16/09/2006
BIALA 14	OIL	437629.9191	6844081.015	165.8	13.4	179.2	14/12/2006
BIALA 15	OIL	436882.9701	6843426.458	160.63	13.3	173.93	24/12/2006
BIALA 4	OIL	438088.8584	6845463.56	136.26	16.5	152.76	22/07/1987
BIALA 5	OIL	438503.4284	6843791.254	108.63	17	125.63	21/03/1990
BIALA 6	OIL	438982.5339	6845773.243	109.37	17	126.37	8/10/1991
BIALA 7	OIL	438221.8064	6843277.036	122.48	17	139.48	25/04/1992
BIALA 8	OIL	439373.2656	6844847.843	141.39	16.3	157.69	7/05/2002
BIALA 9	OIL	436450.7079	6842398.311	138.89	16.3	155.19	26/05/2002
BIG LAKE 17DW1	GAS	429022.5175	6876818.035	106.65	19.36	126.01	28/07/2007
BIG LAKE 44	GAS	429518.5685	6875649.851	107.39	20	127.39	30/12/1988
BIG LAKE 46	GAS	436596.4549	6881962.427	117.74	16.2	133.94	13/09/1989
BIG LAKE 48	GAS	429817.2263	6874053.948	107.56	20	127.56	29/04/1990
BIG LAKE 50	GAS	432790.877	6876567.743	115.31	20.3	135.61	3/11/1991
BIG LAKE 52	GAS	432073.9267	6879611.19	108.26	20	128.26	10/05/1992
BIG LAKE 54	GAS	435295.3988	6877786.446	135.08	20	155.08	6/06/1994
BIG LAKE 55	OIL	430814.9958	6877533.324	107.67	17	124.67	10/09/1995
BIG LAKE 56H	GAS	430533.5762	6877180.82	107.53	18.78	126.31	20/05/1996
BIG LAKE 57	OIL	430547.8571	6877205.276	107.59	18.78	126.37	18/06/1996
BIG LAKE 58DW	OIL	430905.1223	6877406.776	107.6	18.8	126.4	14/02/1997
BIG LAKE 59DW	OIL	430944.4179	6877449.436	107.67	18.8	126.47	27/02/1997
BIG LAKE 60	GAS	433421.9608	6880123.997	112.99	18.8	131.79	28/01/1997
BIG LAKE 61	GAS	429816.4244	6877510.519	107.72	20	127.72	1/07/1998
BIG LAKE 63	OIL	430672.1081	6877822.644	108.57	26.2	134.77	13/07/1999
BIG LAKE 64	GAS	431946.393	6877390.848	110.14	18.8	128.94	2/02/2000
BIG LAKE 65	GAS	431449.1092	6877935.167	109.16	18.8	127.96	8/10/2000
BIG LAKE 66	GAS	434044.2605	6879068.237	101.88	18.8	120.68	9/11/2000
BIG LAKE 67	GAS	432643.4476	6880059.901	113.21	18.8	132.01	9/09/2000
BIG LAKE 69	OG	430308.7592	6876983.742	107.35	16.3	123.65	16/07/2001
BIG LAKE 70	GAS	433393.5819	6879408.048	101.66	19.3	120.96	5/10/2001
BIG LAKE 71	GAS	432231.232	6878821.403	111.89	19.3	131.19	26/03/2003
BIG LAKE 71ST1	GAS	432231.232	6878821.403	111.89	19.3	131.19	26/03/2003
BIG LAKE 71ST2	GAS	432231.232	6878821.403	111.89	19.3	131.19	26/03/2003
BIG LAKE 72	GAS	432893.8774	6878483.163	147.77	19.3	167.07	29/05/2003
BIG LAKE 73	OIL	430727.6645	6877600.839	108.21	16.6	124.81	14/11/2002
BIG LAKE 74	OIL	430665.446	6877148.021	101.84	16.6	118.44	2/12/2002
BIG LAKE 74ST1	OIL	430665.446	6877148.021	101.84	16.6	118.44	2/12/2002

BIG LAKE 76	GAS	433589.8737	6878720.055	101.84	19.3	121.14	9/03/2004
BIG LAKE 77	GAS	429754.5456	6877421.192	108.97	19.3	128.27	3/04/2004
BIG LAKE 81	GAS	435455.8952	6881464.632	125.65	15.4	141.05	8/04/2005
BIG LAKE 82	GAS	436145.643	6880712.242	115.73	15.6	131.33	4/05/2005
BIG LAKE 83	GAS	431319.7935	6877813.552	107.62	19.3	126.92	18/12/2006
BIG LAKE 84	GAS	433323.0243	6880703.187	117.27	19.3	136.57	11/07/2007
BIG LAKE 85	GAS	431051.1676	6878821.378	109.82	19.3	129.12	16/06/2007
BIG LAKE 86	OIL	430176.0408	6876610.052	109.05	15.7	124.75	23/09/2007
BIG LAKE 87	OIL	431512.2418	6878559.04	108.72	19.1	127.82	24/06/2008
BIG LAKE 88	OIL	432479.2612	6879124.708	117.04	19.1	136.14	13/07/2008
BIG LAKE 89	GAS	431695.2733	6877873.214	107.98	19.1	127.08	14/09/2008
BIG LAKE 8DW1	GAS	431378.9142	6879420.525	109.24	18.5	127.74	7/08/2005
BIG LAKE 90	GAS	431675.1013	6877882.958	107.93	19.3	127.23	12/10/2008
BIG LAKE 91		431654.8332	6877892.369	107.9	19.1	127	8/11/2008
BIMBAYA 1	GAS	442291.4726	6952254.984	160.06	16.2	176.26	31/05/1986
BIMBAYA 2	GAS	442905.3362	6952941.56	132.5	20	152.5	2/10/1986
BIMBAYA 3	OG	441866.8837	6951683.042	157.44	16.2	173.64	13/02/1988
BOOKABOURDIE 10	GAS	444987.6617	6956813.751	135.35	20.3	155.65	10/12/1988
BOOKABOURDIE 11	GAS	445315.1417	6956710.316	130.71	20	150.71	13/12/1992
BOOKABOURDIE 6	GAS	448282.9947	6956141.431	147.77	16.2	163.97	1/05/1986
BOOKABOURDIE 7	GAS	450474.1308	6953962.745	147.07	16.2	163.27	21/12/1987
BOOKABOURDIE 8	GAS	447703.8794	6955442.879	140.94	16.2	157.14	18/03/1988
BOOKABOURDIE 9	GAS	448423.8233	6954361.03	135.39	16.2	151.59	29/04/1988
BOONGALA 1	GAS	486790.3165	6877172.001	260.43	20.3	280.73	22/01/1992
BOONGALA 2	GAS	486913.0235	6876844.009	228.44	16.31	244.75	22/05/2007
BOW 1	GAS	497582.7154	6900971.477	274.38	16.3	290.68	29/11/2000
BOW 2	GAS	497323.5543	6899750.676	263.88	18.8	282.68	14/11/2001
BRONZEWING 1	OIL	438907.5911	6842931.194	120.98	15.32	136.3	21/09/2007
BRUMBY 12	GAS	499327.3155	6858720.127	258.23	16.6	274.83	13/04/2006
BRUMBY 4	GAS	496570.1054	6860935.166	263.38	17.8	281.18	15/04/1988
BRUMBY 5	GAS	496850.4739	6858525.083	267.37	17	284.37	5/08/1989
BRUMBY 7	GAS	499878.7611	6855381.514	312.19	17	329.19	19/03/1993
BRUMBY 9	GAS	498714.5997	6859456.663	290.28	16.3	306.58	9/07/1996
BUCKINNA 2	OIL	448693.8048	6858466.148	133.27	17	150.27	19/10/1989
BUGITO 1	OIL	430415.7488	6841510.406	93.93	13.4	107.33	21/08/2005
BUGITO 2	OIL	430898.0452	6841606.767	94.19	15.7	109.89	6/11/2007
BULYEROO 1	GAS	458494.7061	6920680.224	151.91	20	171.91	16/10/1994
BURKE 10	OIL	494155.8689	6888784.567	268.18	15.7	283.88	23/05/2007
BURKE 11	GAS	493800.3961	6888710.5	270.92	19.1	290.02	21/12/2009
BURKE 3	GAS	493314.837	6889279.522	277.42	22	299.42	16/04/1982

BURKE 4	GAS	494456.7151	6888917.311	270.76	16.2	286.96	27/02/1982
BURKE 5	GAS	495181.7875	6889651.746	257.7	16.2	273.9	26/03/1982
BURKE 6	GAS	495903.2211	6887797.716	297.75	20	317.75	9/07/1994
BURKE 7	GAS	494310.9579	6888332.006	279.36	16.6	295.96	7/03/2006
BURKE 8	GAS	495187.5214	6888097.323	271.07	16.6	287.67	6/05/2006
BURKE 9	OIL	495097.922	6888432.055	268.77	15.7	284.47	4/05/2007
BURKE EAST 1	GAS	497968.5514	6888366.977	264.83	17.25	282.08	18/10/2000
BURLEY 3	GAS	466833.754	6924555.84	158.83	19.3	178.13	2/02/1997
BURLEY 3U	GAS	466833.754	6924555.84	158.84	18.78	177.62	16/11/1996
CALVIN 1	OIL	448309.8306	6850800.458	155.64	15.7	171.34	21/07/2007
CARAKA 1	GAS	474557.8564	6872315.548	190.39	17	207.39	21/04/1990
CARAWAY 1	OIL	467891.6474	7008937.408	140.36	20.1	160.46	18/05/1995
CARMINA 1	OIL	437713.8121	6852201.146	111.77	16.3	128.07	17/09/1996
CARMINA 2	OIL	437513.6001	6852621.971	97.53	12.9	110.43	21/06/2005
CAROOWINNIE 1	OIL	470550.0806	6847851.838	165.45	13.4	178.85	26/04/2007
CARTMAN 1	OIL	448041.8786	6856684.508	47.45	7.07	54.52	19/11/2009
CHILCARRIE 1	OG	463690.7927	6863596.816	160.31	14.5	174.81	13/04/1988
COBBLER 1	GAS	436061.5298	6947985.732	134.23	26.2	160.43	24/10/1998
COBBLER 1ST1	GAS	436061.5298	6947985.732	134.23	26.2	160.43	9/11/1998
COOBOWIE 1	OIL	495798.5441	6843075.102	298.8	17.8	316.6	25/04/1988
COOLOON 1	GAS	455870.5987	6876998.256	166.52	20	186.52	1/07/1990
COOLOON SOUTH 1	GAS	457767.0324	6874297.187	180.92	20.1	201.02	9/07/1991
COONATIE 10	GAS	434146.5833	6960465.123	129.62	19.36	148.98	5/01/2008
COONATIE 11	GAS	434394.9081	6960992.964	139.84	19.3	159.14	2/02/2008
COONATIE 12	GAS	433623.7617	6959858.253	131.34	19.3	150.64	2/05/2008
COONATIE 13	GAS	435092.656	6961852.403	133.51	19.3	152.81	5/04/2008
COONATIE 14	GAS	434038.9126	6961508.925	135.83	23.2	159.03	23/11/2010
COONATIE 15	GAS	434627.3409	6962338.225	130.48	23.4	153.88	21/01/2011
COONATIE 16	GAS	435286.0962	6960565.346	163.79	23.2	186.99	2/07/2010
COONATIE 17	GAS	433583.9753	6960473.5	152.94	19.1	172.04	23/06/2010
COONATIE 18	GAS	433431.5594	6959175.393	138.21	23.2	161.41	24/10/2010
COONATIE 19	GAS	434079.5975	6959086.619	137.02	19.1	156.12	24/08/2010
COONATIE 20	GAS	435616.387	6962466.854	143.95	23.2	167.15	13/09/2010
COONATIE 3	GAS	432901.1505	6960531.707	146.16	16.2	162.36	18/11/1987
COONATIE 4	GAS	435904.1038	6961980.956	132.6	19.3	151.9	3/07/1997
COONATIE 5	GAS	434936.6036	6961205.986	160.45	19.3	179.75	29/06/2004
COONATIE 6	GAS	434395.7261	6961764.067	127.9	19.3	147.2	29/09/2005
COONATIE 7	GAS	434652.9944	6960452.766	164.31	19.3	183.61	26/10/2005
COONATIE 8	GAS	433724.5252	6960920.127	137.01	19.36	156.37	5/12/2007
COONATIE 8ST1	GAS	433724.5252	6960920.127	137.01	19.36	156.37	5/12/2007

COONATIE 9	GAS	435653.3938	6961062.659	154.28	19.3	173.58	8/03/2008
CORUNA 1	GAS	432594.3156	6995585.85	122.87	18.8	141.67	28/11/1996
CROWSNEST 1	GAS	492624.2845	6900319.2	284.43	18.8	303.23	19/10/2001
CROWSNEST 2	GAS	493945.4073	6901411.411	283.53	16.6	300.13	22/09/2002
CROWSNEST 3	GAS	490927.5122	6900287.019	279.14	16.6	295.74	21/01/2003
CRUMPA 1	OIL	469963.7671	7014290.766	139.81	20.3	160.11	1/01/1994
CURLINGTON 1	OIL	431830.8483	6835081.325	45.8	4.8	50.6	9/01/2008
CUTTAPIRRIE 2	GAS	437584.9772	6987804.569	106.84	20	126.84	9/09/1995
CUTTAPIRRIE 3	GAS	439559.7067	6988774.057	132.82	18.8	151.62	28/07/1996
CUTTAPIRRIE 4	GAS	444043.3163	6987833.63	105.53	18.8	124.33	14/08/1997
CUTTAPIRRIE 5	GAS	441909.8315	6989942.486	149	18.8	167.8	22/10/1997
CUTTAPIRRIE 6	GAS	432653.2787	6986128.607	114.19	16.3	130.49	26/02/2000
CUTTAPIRRIE 7	GAS	436777.8599	6986198.415	110.09	16.3	126.39	21/04/2000
DARMODY 1	GAS	468367.5852	6943532.81	189.18	20.1	209.28	20/05/1996
DELLA 10	GAS	463900.7533	6891397.09	159.23	13.5	172.73	28/07/1980
DELLA 11	GAS	465728.2109	6892951.823	183.95	13.5	197.45	23/08/1980
DELLA 12	GAS	462354.1647	6889319.191	173.73	13.5	187.23	21/02/1981
DELLA 13	GAS	466148.9709	6891432.363	174.26	13.5	187.76	16/03/1981
DELLA 14	GAS	462865.4901	6892345.953	168.84	13.5	182.34	12/04/1981
DELLA 15	GAS	468066.9411	6892239.568	181.38	13.5	194.88	5/05/1981
DELLA 16	GAS	464425.34	6890133.345	170.59	13.5	184.09	28/05/1981
DELLA 18	GAS	462818.4711	6890723.889	164.74	17	181.74	26/07/1997
DELLA 18R	GAS	462818.4711	6890723.889	164.74	20	184.74	20/05/1998
DELLA 19	GAS	466233.9278	6892340.989	172.82	16.3	189.12	27/12/1999
DELLA 20	GAS	463469.588	6890988.445	182.06	18.8	200.86	13/05/2000
DELLA 21	GAS	462859.1626	6890968.284	168.21	18.8	187.01	7/06/2000
DELLA 22	GAS	466560.5448	6891683.66	205.25	18.8	224.05	27/05/2000
DELLA 23	GAS	467270.324	6891022.504	174.7	15.6	190.3	1/03/2003
DELLA 24	GAS	465620.2688	6892224.805	184.51	15.6	200.11	16/03/2003
DELLA 24DW1	GAS	465620.2688	6892224.805	184.51	15.6	200.11	13/11/2004
DELLA 25	GAS	462717.3183	6889427.565	157.04	13.29	170.33	20/05/2006
DELLA 7	GAS	461113.8133	6890947.664	171.64	13.5	185.14	29/02/1980
DELLA 8	GAS	466922.6964	6892264.151	185.83	13.5	199.33	24/04/1980
DELLA 9	GAS	463703.0919	6888753.741	164.58	16.2	180.78	25/03/1980
DEPARANIE 2	OG	428609.9371	6940238.938	137.83	16.8	154.63	10/07/2008
DERAMOOKOO 1	OIL	455902.9909	6995046.587	110.88	14.5	125.38	25/10/1989
DILCHEE 2	GAS	491682.9063	6878657.767	252	20	272	29/05/1990
DILCHEE 3	GAS	491456.822	6878120.33	240.86	16.3	257.16	23/02/1997
DIPTERA 1	OIL	436023.8337	6842100.289	158.81	13.4	172.21	8/10/2006
DULLINGARI 16	GAS	486565.5226	6887454.202	271.44	13.5	284.94	4/10/1981
DULLINGARI 17	GAS	490283.1369	6886752.156	289.52	13.5	303.02	1/12/1981

DULLINGARI 18	GAS	488858.8167	6886711.917	299.14	13.5	312.64	22/02/1982
DULLINGARI 19	GAS	489751.4529	6888672.483	287.15	20	307.15	6/04/1982
DULLINGARI 22	GAS	487582.0047	6888069.787	279.01	13.5	292.51	9/04/1982
DULLINGARI 23	GAS	487783.8325	6886800.705	293.2	20	313.2	25/05/1982
DULLINGARI 24	GAS	489376.5036	6890654.846	285.45	22	307.45	1/06/1982
DULLINGARI 25	GAS	487072.2503	6889328.453	268.59	20	288.59	26/06/1982
DULLINGARI 36DW1	GAS	489587.3358	6887787.783	292.4	19.1	311.5	3/12/2009
DULLINGARI 43	OIL	488169.5308	6887590.385	293.63	16.5	310.13	9/08/1987
DULLINGARI 44	GAS	488292.033	6890343.545	274.22	20	294.22	3/01/1988
DULLINGARI 45	GAS	486153.843	6886641.288	272.12	16.2	288.32	13/06/1989
DULLINGARI 46	GAS	485003.0513	6891020.373	233.18	20	253.18	24/04/1990
DULLINGARI 47	OIL	489228.6759	6890657.15	281.62	17	298.62	21/07/1991
DULLINGARI 48	OIL	488899.799	6886988.9	302.03	17	319.03	25/09/1996
DULLINGARI 49	GAS	489062.8224	6892646.665	270.04	17	287.04	24/10/1997
DULLINGARI 50DW	OIL	488077.2502	6886877.217	303.22	19.3	322.52	26/04/1998
DULLINGARI 51	GAS	488458.9058	6892381.451	266.34	26.2	292.54	22/04/1999
DULLINGARI 52	GAS	490083.6018	6891258.081	271.75	18.8	290.55	21/05/2001
DULLINGARI 53	GAS	489443.8553	6889021.606	281.79	18.8	300.59	9/06/2001
DULLINGARI 54	GAS	486946.2312	6888352.367	264.42	18.8	283.22	1/07/2001
DULLINGARI 55	GAS	486217.8271	6888202.33	254.37	19.3	273.67	27/04/2002
DULLINGARI 57	GAS	491138.6539	6893265.188	273.53	16.6	290.13	16/10/2003
DULLINGARI 58	OIL	488199.9991	6887265.283	304.82	13.4	318.22	10/02/2007
DULLINGARI 59	OIL	485484.1559	6893210.365	244.65	13.4	258.05	28/02/2007
DULLINGARI 60	OIL	486509.0109	6894106.752	250.55	13.3	263.85	24/03/2007
DULLINGARI NORTH 10	GAS	487622.5126	6896465.058	272.45	18.8	291.25	8/02/2001
DULLINGARI NORTH 11	GAS	485973.1457	6895364.669	243.97	18.8	262.77	2/03/2001
DULLINGARI NORTH 12	GAS	486455.1888	6893655.608	251.18	18.8	269.98	24/03/2001
DULLINGARI NORTH 13	GAS	488328.7717	6894464.038	266.8	18.8	285.6	27/04/2001
DULLINGARI NORTH 13ST1	GAS	488328.7717	6894464.038	266.8	18.8	285.6	27/04/2001
DULLINGARI NORTH 14	GAS	488272.7206	6895914.601	265.2	19.3	284.5	4/02/2002
DULLINGARI NORTH 15	GAS	488901.5213	6897192.451	277.49	19.3	296.79	23/02/2002
DULLINGARI NORTH 16	GAS	487121.8834	6896956.488	270.97	19.3	290.27	21/03/2002
DULLINGARI NORTH 17	GAS	485267.0525	6893994.51	255.77	19.3	275.07	7/04/2002
DULLINGARI NORTH 18	GAS	491543.3797	6899444.023	288.1	16.6	304.7	25/08/2002
DULLINGARI NORTH 19	GAS	488725.8067	6898023.107	293.6	16.6	310.2	18/09/2003
DULLINGARI NORTH 2	GAS	485829.0586	6893652.557	269.86	13.5	283.36	7/06/1982

DULLINGARI NORTH 3	OG	487394.2046	6895648.841	275.01	13.5	288.51	9/07/1982
DULLINGARI NORTH 5	GAS	488058.6456	6896950.812	271.88	20	291.88	16/06/1991
DULLINGARI NORTH 6	OG	485033.6567	6892857.317	230.42	20.3	250.72	12/10/1993
DULLINGARI NORTH 7	GAS	484803.0339	6891815.168	242.49	17	259.49	19/09/1997
DULLINGARI NORTH 8	GAS	486013.7362	6893004.951	256.26	18.78	275.04	17/09/1997
DULLINGARI NORTH 9	GAS	486801.0699	6896372.569	264.28	17	281.28	30/11/1997
FANGORN 1	OIL	431450.3291	6848619.809	109.59	17	126.59	8/06/1997
FROSTILLICUS 1	OIL	440090.8216	6850085.668	31.14	4.05	35.19	3/06/2006
FULCIA 1	OIL	460806.8504	7000480.596	123.47	18.78	142.25	6/02/1996
GAHNIA 1	GAS	493274.0907	6877264.29	259.18	20	279.18	9/08/1995
GAMBERO 1	OIL	450356.1185	6850168.92	149.67	15.7	165.37	8/07/2007
GOLAH SING 1	OIL	498082.203	6888794.706	266.52	15.7	282.22	5/06/2007
GOYDER 2	GAS	444760.9628	6859543.633	109.84	17	126.84	13/05/1997
GOYDER 3	GAS	443883.5787	6860646.145	109.63	16	125.63	29/03/1998
GOYDER 4	GAS	444882.1164	6860391.164	123.43	15.6	139.03	16/07/2003
GOYDER 5	GAS	445149.399	6859906.719	109.34	16.31	125.65	2/05/2007
GRANCHIO 1	OIL	446329.2755	6849742.541	129.52	15.7	145.22	31/08/2007
GRANCHIO 2	OIL	446810.0864	6849791.145	136.64	12.9	149.54	19/04/2008
GRANCHIO 3	OIL	446906.1191	6849421.99	155.28	13.2	168.48	26/06/2008
GRYSTES 1	GAS	468379.6861	6858983.215	152.38	20.1	172.48	22/05/1991
GUDI 1	GAS	429956.1183	6987573.509	150.17	18.8	168.97	28/10/1996
GUDNUKI 1	GAS	486778.716	6897838.779	268.11	19.3	287.41	3/08/1997
GUDNUKI 2	GAS	478662.4343	6893385.799	232.4	18.8	251.2	2/04/1998
GUDNUKI 3	GAS	491856.1355	6894127.208	264.9	19.3	284.2	30/07/1998
HALORAGIS 1	GAS	433208.219	6941364.281	135.01	20.3	155.31	25/08/1991
HAMLYN 1	OIL	447760.4303	7001918.753	103.74	20	123.74	1/06/1997
HAWKINS 1	OIL	441232.1701	6844038.67	128.54	15	143.54	11/09/2007
HOBBES 1	OIL	448349.7595	6851561.964	132.67	13	145.67	17/05/2008
HOBBES 2	OIL	447139	6851381.212	131.23	23.16	154.39	4/11/2009
HOEK 1ST1	OIL	445870.1925	6849099.971	42.54	4.05	46.59	13/07/2006
HOEK 2	OIL	445451.0093	6848961.099	41.63	4.05	45.68	15/06/2007
HOEK 3	OIL	446192.1611	6849030.101	43.94	3.99	47.93	25/05/2008
IKARUMBA 1	OIL	435622.8805	6851200.433	107.23	15.75	122.98	5/12/2007
ITCHY 1	OIL	442481.5777	6845806.965	124.29	13.4	137.69	6/01/2007
JAMES 1	OIL	484778.8471	7034342.148	217.65	14.5	232.15	16/09/1988
JAMES 2	OIL	484503.7223	7033647.59	231.93	15.75	247.68	22/08/2008
JAMES 3	OIL	484517.1605	7034196.184	224.4	15.4	239.8	<Null>
JENA 10	OIL	430659.252	6847056.442	128.18	17	145.18	11/07/1991
JENA 11	OIL	431958.4366	6845933.631	99.84	17	116.84	11/08/1992

JENA 12	OIL	432706.0909	6846908.692	94.84	17	111.84	23/08/1992
JENA 13	OIL	435101.4705	6845981.775	98.78	17	115.78	26/07/1996
JENA 14	OIL	429917.9929	6846003.398	101.65	16.3	117.95	5/06/2002
JENA 15	OIL	430198.3734	6846216.791	99.39	13.2	112.59	21/06/2003
JENA 16	OIL	430972.7305	6845308.331	97.96	13.2	111.16	2/07/2003
JENA 17	OIL	430885.2252	6844696.909	97.42	13.2	110.62	16/09/2003
JENA 18	OIL	432773.3146	6846483.306	104.61	13.2	117.81	25/09/2003
JENA 19	OIL	432999.5572	6846006.977	95.64	13.2	108.84	4/10/2003
JENA 2	OIL	432661.1248	6845653.058	104.54	17	121.54	16/09/1988
JENA 20	OIL	430893.6949	6845020.14	97.12	13.4	110.52	31/10/2005
JENA 21	OIL	433026.9341	6844672.983	97.17	15.5	112.67	15/11/2007
JENA 22	OIL	432657.1041	6845227.927	97.18	15.52	112.7	13/08/2007
JENA 25	OIL	429615.5943	6845334.399	139.63	15.7	155.33	25/11/2007
JENA 26	OIL	432365.5011	6847385.466	127.03	13.4	140.43	4/12/2006
JENA 27	OIL	430896.225	6847268.232	104.63	13.4	118.03	16/11/2006
JENA 28	OIL	433354.0553	6845464.898	98.34	15.52	113.86	3/08/2007
JENA 3	OIL	433834.1653	6844766.304	113.86	17	130.86	19/08/1989
JENA 4	OIL	431724.5163	6846141.005	103.86	17	120.86	27/08/1989
JENA 5	OIL	432068.8501	6845590.816	102.02	17	119.02	17/09/1989
JENA 6	OIL	432337.2905	6846607.659	108.64	17	125.64	5/01/1990
JENA 7	OIL	431618.6913	6845642.713	97.46	17	114.46	29/03/1990
JENA 8	OIL	432300.3599	6846223.111	96.24	17	113.24	7/09/1990
JENA 9	OIL	431517.0604	6846474.277	112.13	17	129.13	15/09/1990
KAPINKA 1	GAS	473030.2538	6857278.619	142.63	20.1	162.73	27/03/1991
KATINGAWA 1	GAS	479619.9537	6882282.304	229.79	20	249.79	13/07/1992
KEETO 2	GAS	473262.6994	6853300.808	174.19	20.1	194.29	12/04/1991
KELBROOK 1	GAS	485332.3202	6867615.41	227.59	19.3	246.89	28/12/1998
KELEARY 1	OIL	468710.9915	7005447.72	147.82	20	167.82	21/10/1991
KELEARY 2	OIL	468391.607	7006471.464	143.43	20.3	163.73	23/03/1994
KELEARY 3	OIL	468620.6187	7006096.67	130.24	20.1	150.34	24/04/1995
KERINNA SOUTH 1	OIL	452945.1162	6860536.497	133.1	13.39	146.49	3/10/2005
KERNA 5	GAS	498206.3947	6875383.147	242.76	20	262.76	16/09/1990
KERNA 6	GAS	497679.4455	6876245.028	267.98	16.3	284.28	3/01/1997
KERNA 7	GAS	497928.5978	6877555.367	269.35	26.2	295.55	31/03/1999
KERNA NORTH 1	GAS	496518.0258	6879810.602	285.63	19.3	304.93	5/07/1998
KIDMAN 10	GAS	477598.0654	6877382.778	212.27	17	229.27	23/12/1996
KIDMAN 6	GAS	483693.1827	6876905.608	251.31	17.8	269.11	3/01/1989
KIDMAN 7	GAS	479269.4389	6875698.858	195.39	17	212.39	7/05/1990
KIDMAN 8	GAS	481006.3736	6873816.733	213.07	20	233.07	3/04/1991
KIDMAN 9	GAS	482128.3214	6877104.643	236.68	17.4	254.08	27/02/1997
KIDMAN NORTH 3	GAS	480899.5078	6880380.136	247.21	19.3	266.51	23/04/2004

KIDMAN NORTH 4	GAS	481820.9486	6878251.851	226.33	19.3	245.63	14/02/2011
KIRBY 2	GAS	485467.8573	6941921.706	251.96	20.1	272.06	30/05/1992
KORMA 1	GAS	460523.9973	6953512.236	180.07	19.3	199.37	10/12/2003
KULTARR 1	GAS	499705.5395	6854625.091	301.61	16.3	317.91	11/11/1996
KYLE 1	OIL	443222.7095	6855350.786	32.4	7.1	39.5	6/12/2009
LAMDINA 2	GAS	440420.531	6974966.443	174.26	20	194.26	8/08/1997
LAMDINA 2A	GAS	440341.1637	6975015.241	170.91	18.8	189.71	16/09/1997
LEPENA 2	GAS	469364.4192	6880104.224	205.25	20	225.25	26/08/1994
LIMESTONE CREEK 10	OIL	441530.7182	6844602.751	142.5	16.3	158.8	17/05/2002
LIMESTONE CREEK 11	OIL	438796.2994	6846507.587	123.21	13.29	136.5	28/09/2006
LIMESTONE CREEK 7	OIL	440910.0274	6845466.13	120.63	16.5	137.13	29/07/1987
LIMESTONE CREEK 8	OIL	441094.2436	6844831.566	140.58	17.8	158.38	4/03/1988
LIMESTONE CREEK 9	OIL	439374.4117	6845175.455	120.78	17.8	138.58	18/03/1988
MARABOOKA 10	GAS	461525.4082	6882145.525	182.18	13.4	195.58	19/03/2006
MARABOOKA 11	GAS	462971.9158	6881770.023	164.41	13.4	177.81	26/03/2006
MARABOOKA 12	GAS	463645.4974	6881268.048	177.56	13.4	190.96	3/04/2006
MARABOOKA 13	GAS	465801.7172	6880138.275	191.84	16.8	208.64	8/08/2008
MARABOOKA 14	GAS	461253.4134	6883203.152	176.02	16.6	192.62	15/08/2008
MARABOOKA 15	GAS	464133.2117	6880383.283	171.88	16.8	188.68	3/09/2008
MARABOOKA 3	GAS	462034.5864	6882346.786	179.39	15.5	194.89	14/07/1984
MARABOOKA 4	GAS	461873.5217	6880627.286	169.71	15.5	185.21	10/02/1986
MARABOOKA 5	GAS	460457.3982	6882404.909	187.58	17	204.58	7/04/1995
MARABOOKA 6	GAS	461456.0994	6881815.396	181.67	16.6	198.27	24/10/2002
MARABOOKA 7	GAS	462672.5022	6882223.953	179.04	16.6	195.64	10/10/2002
MARABOOKA 8	GAS	462379.4048	6881510.6	163	16.6	179.6	16/07/2004
MARABOOKA 9	GAS	462292.7936	6882949.81	164.67	13.4	178.07	12/03/2006
MARABOOKA EAST 1	GAS	464651.9428	6880925.555	170.54	16.6	187.14	30/03/2003
MARSILEA 1	GAS	493884.6545	6863562.03	275.51	17.8	293.31	11/05/1989
MATARANKA 1	GAS	475828.0752	6850251.162	182.16	20	202.16	5/10/1990
MCKINLAY 5	OIL	449494.9801	6850665.016	116.09	15.7	131.79	15/08/2007
MCKINLAY 6	OIL	449789.0071	6849577.125	119.93	15.7	135.63	23/08/2007
MCKINLAY 7	OIL	450036.5135	6850511.229	138.99	12.95	151.94	10/04/2008
MCKINLAY 8	OIL	450697.8769	6851216.63	148.42	12.9	161.32	1/04/2008
MCKINLAY 9	OIL	448952.1524	6848858.056	143.99	13	156.99	26/04/2008
MERINDAL 1	GAS	453777.2623	6950936.759	160.83	16.3	177.13	23/01/1997
MERINDAL 2	GAS	453035.6596	6949249.974	147.29	20	167.29	31/08/1997
MERUPA 1	OG	446269.6078	6949923.502	130.72	20	150.72	8/11/1986
MERUPA 2	GAS	445072.3224	6949026.45	184.94	20.3	205.24	11/08/1988
METTIKA 1	GAS	495992.1442	6866116.428	275.39	20	295.39	3/02/1989

METTIKA 2	GAS	496397.9579	6864797.937	244.9	17.8	262.7	4/07/1989
METTIKA 3	GAS	496224.8714	6867876.694	257.9	17.8	275.7	5/08/1989
METTIKA 4	GAS	495755.4789	6867606.674	255.06	17	272.06	22/03/1992
METTIKA 5	GAS	496601.3785	6865302.714	248.28	20.1	268.38	23/01/1993
METTIKA 6	GAS	495586.2221	6865644.026	256.38	19.1	275.48	8/01/2010
MILLUNA 1	GAS	447263.474	6864016.097	113.46	17	130.46	19/08/1997
MILLUNA 2	GAS	446816.2339	6864654.436	113.81	17.3	131.11	28/09/2000
MILLUNA 3	GAS	448002.0101	6865120.686	116.75	16.3	133.05	14/12/2000
MILLUNA 4	GAS	446337.0036	6864490.746	112.47	19.3	131.77	15/01/2005
MILLUNA NORTHEAST 1	GAS	449823.4337	6866560.447	136.05	16.3	152.35	5/04/2001
MOOLION EAST 1	GAS	428856.5851	6970653.121	166.78	26.2	192.98	8/02/1999
MOOMBA 120DW	GAS	432629.5053	6891843.746	125.26	19.3	144.56	11/10/2000
MOOMBA 133	GAS	436926.4789	6895210.974	128.36	19.3	147.66	29/03/2001
MOOMBA 134	GAS	430525.5281	6898755.74	147.52	19.3	166.82	22/12/2000
MOOMBA 139	GAS	433606.3676	6890402.81	116.97	18.8	135.77	21/07/2001
MOOMBA 149	OG	433199.3093	6891368.355	118.96	19.3	138.26	28/11/2001
MOOMBA 150	GAS	432696.4271	6890776.491	117.59	18.8	136.39	28/05/2002
MOOMBA 151	GAS	431037.8854	6892492.508	132.56	19.3	151.86	12/12/2001
MOOMBA 152	GAS	433613.3761	6890856.18	118.32	18.8	137.12	19/06/2002
MOOMBA 155	GAS	431917.285	6893287.555	131.5	19.3	150.8	27/06/2002
MOOMBA 162	GAS	430026.1107	6892362.66	118.94	19.3	138.24	16/07/2002
MOOMBA 163	GAS	431105.3099	6891669.765	120.1	19.3	139.4	4/08/2002
MOOMBA 164	GAS	431592.3442	6891162.066	118.81	19.3	138.11	22/08/2002
MOOMBA 175	GAS	438924.9564	6886486.404	159.98	16.6	176.58	19/08/2006
MOOMBA 178	GAS	437870.8312	6887823.884	120.28	16.31	136.59	14/06/2007
MOOMBA 179	GAS	439232.1558	6887113.902	136.36	16.31	152.67	12/09/2007
MOOMBA 180	GAS	438278.2071	6886397.77	148.17	16.31	164.48	4/10/2007
MOOMBA 181	GAS	438856.715	6887730.823	119.39	16.31	135.7	24/10/2007
MOOMBA 44	GAS	429232.4716	6884380.066	115.47	16.2	131.67	17/04/1979
MOOMBA 57	GAS	429010.3905	6880098.602	110.46	16.2	126.66	15/06/1988
MOOMBA 61	GAS	429665.7289	6891463.737	115.44	20.3	135.74	24/09/1988
MOOMBA 70	GAS	429600.3017	6878928.206	107.58	20	127.58	27/04/1991
MOOMBA 75	GAS	432422.2783	6893640.277	129.41	20	149.41	27/04/1994
MOOMBA 78	GAS	433595.4102	6894568.462	120.52	20	140.52	9/07/1995
MOOMBA 82	GAS	430236.7789	6884678.907	135.25	18.8	154.05	6/05/1997
MOONA 1	GAS	458886.4518	6882668.121	156.62	16.3	172.92	18/03/2001
MOONDIE 1ST1	GAS	458766.6874	6985885.038	128.25	18.8	147.05	12/10/1996
MOOTANNA 1	GAS	445635.5334	6911872.843	138.09	19.3	157.39	16/06/2001
MUDERA 10	GAS	456274.0531	6882522.111	126.11	13.29	139.4	26/04/2006
MUDERA 11	GAS	456832.3022	6883303.052	124.96	13.29	138.25	3/05/2006

MUDERA 12	GAS	457713.2104	6882123.29	128.89	15.6	144.49	3/04/2008
MUDERA 13		457073.1041	6884883.217	126.07	15.7	141.77	10/04/2008
MUDERA 14		455612.9878	6883723.195	140.14	12.85	152.99	19/07/2008
MUDERA 15		456852.8832	6882743.348	125.55	16.8	142.35	23/07/2008
MUDERA 16	GAS	455948.4586	6882150.458	129.03	16.8	145.83	31/07/2008
MUDERA 4	GAS	457633.8586	6883597.505	126.71	20	146.71	15/03/1989
MUDERA 5	GAS	456094.5175	6883507.848	124.92	12.4	137.32	15/11/1996
MUDERA 6	GAS	455993.1429	6881719.351	130.76	17	147.76	19/04/1997
MUDERA 7	GAS	457173.3666	6884303.417	126.08	13.2	139.28	22/10/2003
MUDERA 8	GAS	455743.5208	6884683.49	130.15	13.3	143.45	10/04/2006
MUDERA 9	GAS	455304.8246	6883149.968	149.34	13.3	162.64	18/04/2006
MUDERA NORTH 1	OIL	456399.8445	6884949.679	125.79	15.7	141.49	23/01/2008
MUDLALEE 3	GAS	455496.9851	6869412.775	155.02	20.1	175.12	5/08/1993
MUDLALEE 4	OIL	455080.7195	6870224.577	162.93	13.4	176.33	13/07/2007
MUDLALEE 5	OIL	455401.2952	6870374.68	211.26	12.9	224.16	8/03/2008
MUDLALEE 6	OIL	455516.9386	6869687.039	158.66	13	171.66	9/02/2008
MUDLALEE WEST 1	OIL	453683.7958	6868665.458	48	4.05	52.05	29/06/2007
MULGA NORTH EAST 1	OIL	456892.1416	6831029.001	48.99	3.93	52.92	6/05/2008
MUNDI 2	GAS	472118.1123	6859743.857	193.68	20.1	213.78	1/05/1991
MUNDI 3	GAS	472330.5336	6860736.858	163.55	20.3	183.85	24/12/1991
MUNDI 4	GAS	472612.7405	6858400.222	142.84	20.1	162.94	11/04/1992
MUNDI 5	GAS	472186.5418	6861221.416	156.26	20.1	176.36	28/04/1992
MUNDI 6	GAS	471754.06	6860357.946	170.53	19.3	189.83	27/02/2005
MUNDI 7	GAS	472204.6367	6858779.474	149.13	19.3	168.43	7/06/2005
MUNKARIE 7	GAS	492147.996	6849756.019	292.33	20.1	312.43	31/08/1992
MUNKARIE 8	GAS	492010.9304	6851381.666	275.76	17	292.76	22/09/1993
MUNKARIE 9	GAS	491453.9177	6850804.207	264.3	16.3	280.6	14/03/1997
MURTEREE SOUTH 1	OIL	457333.0235	6856130.081	35.62	3.9	39.52	22/01/2008
NAPOWIE 1	GAS	465251.2139	6959374.649	200.05	20.3	220.35	26/06/1993
NAPOWIE 2	GAS	461448.0445	6956158.601	168.23	26.2	194.43	10/06/1998
NAPPACOONGEE EAST 1	OIL	478612.8582	6900020.688	297.99	17	314.99	24/12/1993
NARCOONOWIE 10	OIL	473070.1729	6848093.631	169.88	23.2	193.08	20/01/2010
NARCOONOWIE 4	OIL	473061.9377	6848484.127	166.68	17	183.68	24/10/1991
NARCOONOWIE 5	OIL	474049.106	6849238.684	199.96	13.3	213.26	25/05/2007
NARCOONOWIE 6	OIL	473526.0069	6847552.71	199.7	13.4	213.1	10/05/2007
NARCOONOWIE 7	OIL	473589.1252	6849210.96	175.59	13	188.59	9/07/2008
NARCOONOWIE 8	OIL	472816.3312	6848542.61	169.88	23.2	193.08	22/12/2009
NARCOONOWIE 9	OIL	473373.5838	6849170.703	170.04	23.2	193.24	5/01/2010
NARDU 1	GAS	461916.4125	6953919.742	214.7	14.5	229.2	29/01/1991

ODONATA 1	OIL	431979.9239	6844640.152	103.57	13.4	116.97	26/11/2006
PACKSADDLE 6	OIL	468903.9658	6955169.256	437.35	19.3	456.65	29/08/2003
PASTICCIO 1	OIL	431359.0266	6842789.08	102.76	13.4	116.16	2/11/2006
PIRA 3	GAS	488745.9842	6880074.426	251.38	19.3	270.68	16/04/2005
PIRRAMINTA 1	OG	438346.3814	6945095.28	137.97	20.3	158.27	5/08/1987
PLANTAGO 1	GAS	495056.1753	6872159.459	234.28	17	251.28	8/12/1995
PLOTOSUS 1	GAS	478553.7308	6845521.762	231.56	16.3	247.86	25/07/1996
PONDRINIE 10	GAS	463216.9821	6950324.571	326.12	14.5	340.62	18/07/1991
PONDRINIE 11	GAS	468348.8802	6952196.331	422.12	17	439.12	5/11/1996
PONDRINIE 12	GAS	466332.5246	6950643.82	369.37	20	389.37	16/04/1997
PONDRINIE 12ST	GAS	466332.5246	6950643.82	369.37	20	389.37	26/04/1997
PONDRINIE 13	GAS	464818.8114	6950620.836	357.59	16	373.59	9/03/1998
PONDRINIE 14DW	GAS	463390.2469	6949327.824	295.65	19.3	314.95	9/12/1998
PONDRINIE 15DW	GAS	462086.2223	6948103.814	298.14	19.3	317.44	24/03/1999
PONDRINIE 16	GAS	459925.3254	6948972.67	231.18	16.3	247.48	25/03/2000
PONDRINIE 17DW	GAS	461217.7323	6948564.442	230.94	16.3	247.24	8/07/2000
PONDRINIE 3	GAS	459985.9408	6949601.495	228.46	17.8	246.26	28/10/1987
PONDRINIE 4	OG	466976.8714	6951286.161	386.11	17.8	403.91	10/02/1989
PONDRINIE 5	GAS	465691.0834	6951065.067	364.87	14.5	379.37	29/09/1989
PONDRINIE 6	GAS	464140.2395	6950187.634	338.35	17	355.35	18/10/1990
PONDRINIE 7	GAS	466476.4741	6951966.699	366.85	17	383.85	6/11/1990
PONDRINIE 8	GAS	462882.188	6949402.944	293.75	17	310.75	30/11/1990
PONDRINIE 9	OG	465419.6403	6951368.588	363.51	14.5	378.01	10/03/1991
PONDRINIE NORTH 1	GAS	470181.8553	6955467.413	448.83	19.3	468.13	31/07/1999
PONDRINIE NORTH 2	GAS	470542.0061	6956123.815	452.97	16.3	469.27	11/06/2000
POTHOS 1	OG	467143.9334	7031312.331	182.06	20	202.06	30/06/1997
POTIRON 1	OIL	487936.2159	7081577.693	459.4	14.3	473.7	7/04/1988
RAGNO 1	OIL	429264.8697	6844539.239	105.79	15.5	121.29	12/10/2007
REG SPRIGG 1	OIL	495922.4064	6987064.497	410.81	20.1	430.91	19/06/1996
REG SPRIGG 2	OIL	495604.9491	6987203.507	410.75	18.8	429.55	23/09/2001
REG SPRIGG 3	OIL	495373.7226	6987068.624	407.64	15.6	423.24	18/03/2004
REG SPRIGG NORTH 1	OIL	495272.2331	6987873.501	381.18	15.75	396.93	6/06/2008
REG SPRIGG WEST 1	OIL	493905.1168	6986612.975	398.54	15.6	414.14	8/06/2004
REN 1	OIL	450779.493	6854269.81	38.61	4.08	42.69	27/07/2005
RIEKE 1	GAS	446705.316	6858521.37	157.19	17	174.19	28/09/1995
RISSIKIA 1	OIL	437577.9514	6843531.439	143.34	13.4	156.74	3/09/2006
RUTHERFORD 1	OIL	482749.378	7039537.114	283.28	16.3	299.58	28/11/1998
SCRATCHY 1	OIL	443663.5418	6845452.408	176.66	15.45	192.11	26/08/2007
SCRUBBY CREEK 1	GAS	439687.167	6951288.317	143.22	26.2	169.42	11/07/1998

SECCANTE 1	OIL	430215.8558	6843637.985	94.89	15.36	110.25	21/10/2007
SHAZLICK 1	OIL	432900.2954	6850625.178	29.65	4.05	33.7	11/04/2007
SQUALO 1	OIL	447125.1032	6850356.032	162.79	12.9	175.69	21/03/2008
STIMPEE 1	OIL	446297.2589	6848479.411	37.26	4.08	41.34	9/08/2005
STIMPEE 2	OIL	445895.2931	6848197.495	45.79	4.08	49.87	19/09/2005
STIMPEE 3	OIL	445492.6657	6847851.304	38.4	4.79	43.2	9/09/2007
STIMPEE 4	OIL	446509.2762	6848778.286	40.56	7.07	47.63	26/10/2009
STIMPSON JAY 1	OIL	443726.3525	6850115.697	41.68	4.05	45.73	17/06/2006
STRATHMOUNT 1	GAS	499299.9984	6905230.67	301.29	20.3	321.59	15/07/1987
STREETON 1	GAS	485250.2918	6987330.863	266.49	18.8	285.29	22/11/1997
STRZELECKI 14DEEP	GAS	465317.9972	6877478.802	200.5	19.3	219.8	15/05/2004
STRZELECKI 14DW1	GAS	465317.9972	6877478.802	200.24	0	200.24	22/10/2004
STRZELECKI 15	GAS	466545.1346	6875111.828	184.47	15.5	199.97	29/03/1983
STRZELECKI 16	GAS	464189.4072	6876193.938	200.69	20.3	220.99	2/07/1983
STRZELECKI 24	OIL	463500.5343	6877334.44	201.53	15.5	217.03	24/05/1984
STRZELECKI 25	GAS	465203.8942	6874763.666	171.75	15.5	187.25	17/06/1985
STRZELECKI 26	OIL	464985.9875	6877206.636	231.58	14.5	246.08	6/11/1990
STRZELECKI 27	OIL	464628.7664	6877268.059	210.62	17	227.62	4/05/1991
STRZELECKI 28	OIL	465488.7811	6876849.62	191.2	17	208.2	29/06/1991
STRZELECKI 29	GAS	466994.2742	6876752.422	195.1	19.3	214.4	6/05/2004
STRZELECKI NORTHEAST 1	GAS	465866.4327	6877833.005	196.14	19.1	215.24	23/10/2010
TALLERANGIE 1	GAS	431032.8742	6951038.615	124.67	20	144.67	2/06/1995
TARRAGON 1	OIL	436062.2864	6997560.118	103.99	17.4	121.39	27/01/1997
TARRAGON 2	OIL	437017.8047	6997611.181	95.98	19.3	115.28	20/09/1998
TARWONGA 2	GAS	471741.2791	6862916.328	166.81	14.5	181.31	31/08/1987
TARWONGA 3	GAS	471819.6717	6867114.49	155.77	17	172.77	23/06/1990
TARWONGA 4	GAS	471334.1957	6862718.709	158.65	20.1	178.75	10/06/1991
TARWONGA 5	GAS	471457.0075	6863479.195	153.14	16.6	169.74	26/03/2006
TAYLOR SOUTH 1	GAS	448955.6769	6951402.757	143.47	16.2	159.67	13/02/1987
TELOPEA 1	OIL	467840.7459	7001019.884	130.2	20.1	150.3	19/10/1994
TELOPEA 2	OIL	467854.2058	7000528.243	149.88	20	169.88	10/01/1996
TERINGIE 1	OIL	440624.0132	6851392.911	31.05	4.08	35.13	12/07/2005
TERRACE 1	GAS	435784.9555	6989731.965	105.46	16.3	121.76	6/01/1999
THIELE 1	GAS	440082.4453	6945236.753	141.58	26.2	167.78	12/01/1999
TONNO 1	OIL	452043.794	6851007.376	147.41	15.7	163.11	6/08/2007
TOOLACHEE 10	GAS	480953.975	6854055.566	197.74	13.5	211.24	7/11/1982
TOOLACHEE 11	GAS	482441.7399	6859348.402	202.15	22	224.15	6/11/1982
TOOLACHEE 12	GAS	476895.3946	6855726.337	158.06	22	180.06	2/12/1982
TOOLACHEE 13	GAS	484105.1725	6856374.154	231.36	22	253.36	25/12/1982
TOOLACHEE 14	GAS	478756.7899	6859021.077	213.66	22	235.66	4/02/1983

TOOLACHEE 15	GAS	477791.1643	6853774.622	184.54	15.5	200.04	16/02/1983
TOOLACHEE 17	GAS	484319.5157	6853980.874	227.12	15.5	242.62	7/04/1983
TOOLACHEE 18	GAS	479635.9718	6853537.999	186.63	20.3	206.93	5/06/1983
TOOLACHEE 19	GAS	483101.1479	6855378.153	246.28	15.5	261.78	11/06/1983
TOOLACHEE 23	GAS	478086.8347	6861761.379	184.33	20.3	204.63	18/01/1984
TOOLACHEE 24	GAS	481395.5818	6860151.188	202.19	20.3	222.49	18/02/1984
TOOLACHEE 25	GAS	480870.4384	6852916.25	213.91	15.5	229.41	17/03/1984
TOOLACHEE 26	GAS	477496.6779	6854874.471	172.87	15.5	188.37	2/03/1984
TOOLACHEE 27	GAS	477488.3292	6856682.432	188.56	15.5	204.06	27/04/1984
TOOLACHEE 28	GAS	478196.5263	6852675.855	193.67	15.5	209.17	6/04/1984
TOOLACHEE 29	GAS	478079.5429	6858089.599	193.47	15.5	208.97	15/06/1984
TOOLACHEE 32	GAS	479504.0864	6855052.949	176.8	15.5	192.3	1/05/1985
TOOLACHEE 33	GAS	479523.7879	6860290.889	201.91	15.5	217.41	20/05/1985
TOOLACHEE 34	GAS	480026.9517	6857758.272	185.05	15.5	200.55	10/08/1985
TOOLACHEE 35	GAS	484009.7674	6859490.326	208.75	15.5	224.25	23/02/1986
TOOLACHEE 38	GAS	482049.0733	6857947.082	193.68	16.5	210.18	12/03/1987
TOOLACHEE 39	GAS	485192.5411	6855563.424	240.1	14.5	254.6	26/09/1987
TOOLACHEE 40	GAS	483953.5954	6864352.12	218.97	17.8	236.77	7/10/1987
TOOLACHEE 41	GAS	480859.8565	6864759.846	197.53	17	214.53	17/07/1990
TOOLACHEE 42	GAS	483685.0868	6857238.901	217	20	237	23/04/1991
TOOLACHEE 43	GAS	476701.3033	6865551.453	217.63	20	237.63	13/05/1991
TOOLACHEE 44	GAS	477610.0403	6863312.317	191.05	20	211.05	2/07/1991
TOOLACHEE 45	GAS	481354.071	6850475.806	191.15	20	211.15	20/07/1991
TOOLACHEE 46	GAS	477207.6266	6860688.231	192.42	20	212.42	9/08/1991
TOOLACHEE 46A	GAS	477207.6266	6860688.231	192.42	20	212.42	23/08/1991
TOOLACHEE 47	GAS	482088.6747	6849878.385	204.11	17	221.11	29/02/1992
TOOLACHEE 48	GAS	484020.9757	6854328.22	223.84	20.1	243.94	17/06/1992
TOOLACHEE 49	GAS	477639.2288	6861714.676	189.73	20.1	209.83	2/07/1992
TOOLACHEE 50	GAS	484769.555	6863317.949	236.91	20.1	257.01	13/08/1992
TOOLACHEE 51	GAS	479671.3184	6859503.926	217.35	17	234.35	9/07/1995
TOOLACHEE 52	GAS	480305.9136	6862930.71	202.92	16.3	219.22	31/12/2000
TOOLACHEE NORTH 1	GAS	475984.4952	6868311.578	172.05	17	189.05	23/05/1990
TOOLACHEE WEST 1	GAS	476689.5412	6859093.505	179.69	18.8	198.49	25/06/2000
TURBAN 1	GAS	492294.7239	6965772.377	524.38	14.5	538.88	13/10/1988
ULANDI 10	OIL	433222.4469	6842952.173	123.02	13.2	136.22	4/09/2003
ULANDI 12	OIL	433672.9413	6843149.944	144.98	13.2	158.18	22/08/2003
ULANDI 13	OIL	433203.2622	6843641.189	106.37	13.2	119.57	28/08/2003
ULANDI 14	OIL	433442.1423	6842684.198	127.01	13.2	140.21	9/09/2003
ULANDI 15	OIL	433465.889	6843775.963	122.46	13.4	135.86	19/10/2006
ULANDI 16	OIL	432268.0966	6841792.36	98.34	15.7	114.04	30/10/2007

ULANDI 2	OIL	432438.3422	6843418.439	97.4	17	114.4	5/11/1988
ULANDI 3	OIL	432557.4446	6841932.628	100.5	17	117.5	21/11/1988
ULANDI 4	OIL	434556.2978	6840489.147	108.63	17	125.63	3/11/1991
ULANDI 5	OIL	432865.2502	6842951.464	105.77	17	122.77	28/07/1992
ULANDI 6	OIL	432918.5747	6842574.412	118.19	16.3	134.49	11/06/2002
ULANDI 7	OIL	433111.726	6842243.472	111.56	13.2	124.76	2/08/2003
ULANDI 8	OIL	432527.2929	6842939.665	98.1	13.2	111.3	7/08/2003
ULANDI 9	OIL	432872.8063	6843392.127	103.68	13.2	116.88	15/08/2003
UNGARI 1	GAS	443276.6289	6836677.098	141.75	17.8	159.55	16/07/1989
VERBENA 1	GAS	486470.3311	6864663.238	236.81	20	256.81	21/08/1990
VERONA 1	GAS	445812.795	6989950.398	103.35	19.3	122.65	7/11/1998
VERONA 2	GAS	447232.9483	6990247.504	115.64	19.3	134.94	2/02/2003
VERONA 3	GAS	445265.2988	6991419.653	117.24	19.3	136.54	13/01/2003
WANTANA 2	GAS	444437.1155	6943077.771	136.46	20	156.46	17/01/1991
WHEELS 1	OIL	492207.6113	6888207.745	269.62	15.7	285.32	23/06/2007
WILPINNIE 2	GAS	476848.1351	6897441.52	259.2	17.8	277	26/08/1989
WILPINNIE 3	GAS	475214.97	6897228.993	259.15	17	276.15	3/01/1996
WILPINNIE 4	OIL	475097.3312	6897370.765	254.76	13.3	268.06	26/01/2007
WIRHA 1	OIL	482251.65	6843016.233	209.13	17.8	226.93	10/02/1988
WITCHETTY 1	GAS	480840.123	6869687.13	222.48	17	239.48	31/08/1988
WOMA 1	GAS	442159.9009	6980909.558	152.65	18.8	171.45	24/09/1996
WUROOPIE 1	OG	469836.14	6832831.229	175.09	17.8	192.89	13/09/1987
YALCHIRRIE 1	GAS	458321.6146	6953318.393	150.96	20	170.96	23/09/1991
YILKI 1	OIL	441594.9489	6852356.977	104.64	17	121.64	29/09/1988

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APPENDIX H

Groundwater Monitoring Program

REPORT

10 April 2013

SANTOS COOPER BASIN OIL & GAS FIELDS, SOUTHWEST QUEENSLAND

Interim Groundwater Monitoring Plan

Submitted to:
Santos Ltd
Ground Floor Santos Centre
60 Flinders Street
Adelaide, SA 5000

Report Number. 127666003 002 R Rev3

Distribution:

Santos Ltd - 1 Copy
Golder Associates - 1 Copy

Golder Associates

Executive Summary

This Groundwater Monitoring Plan (GWMP) has been prepared for Santos Ltd (Santos) by Golder Associates Pty Ltd (Golder), for monitoring of groundwater within Santos' petroleum tenements in Southwest Queensland (SWQ).

This GWMP is based on the findings of the *Underground Water Impact Report for Santos Cooper Basin Oil and Gas Fields, SW QLD* [UWIR] (Reference: 117636010-3000-001), in revision, and addresses the groundwater monitoring strategy requirements outlined therein. *This GWMP should be read in conjunction with the UWIR*.

Compilation and analysis of existing formation pressure data collected by Santos is a key objective of this GWMP. Since interpretation of these data is not complete, the approach and strategy behind this current GWMP version is considered *interim* only and subject to revision pursuant to this data review. Thus, both the water monitoring strategy and *proposed* water monitoring activities are also *interim*.

The period of applicability of this *interim* GWMP will be approximately 18 months from the time of Queensland Department of Environment and Heritage Protection (DEHP)'s acceptance of the Plan.

The *interim* groundwater monitoring strategy for Santos petroleum tenements is summarised as follows:

- **Compilation and analysis of existing formation pressure data**: Santos and Golder will compile and review existing formation pressure data across the area of interest to estimate groundwater elevations and pressure trends, hydraulic gradients, and potential zones of impact (i.e. where evidence of depressurisation is observed in formations that underlie aquifers accessed for water supply. Santos has a database of formation pressures in many of the water-bearing formations in the Eromanga Basin, collected during exploratory drilling within its tenements that will be used to define the potential changes to water levels required by the Water Act. This task will include the tracking, collection, and analysis of ongoing well drilling data for an 18- month period.
- **Undertake interim water monitoring activities**: Collection, laboratory analysis, and reporting of baseline data by undertaking groundwater monitoring activities at 15 existing bores (subject to landholder consent).
- **Revise the interim GWMP and strategy, if required**: Based on the results of previous tasks (bullet points 1 and 2), the GWMP may be revised after the interim period, if warranted. During this task the groundwater monitoring strategy will also be revisited, which will include consideration of verification of bore construction, and may include engineering or construction fieldworks required to further develop the monitoring network, if required.
- **Revise the UWIR and GWMP**: Revise the UWIR and GWMP on a 3 yearly cycle, as required by the Water Act,

Interim groundwater monitoring activities are summarised in the table below (subject to landholder agreement):

WBBA ID	Bore Name	Manually Measure Water Level	Install Bladder Pump	Field Measure Water Quality	Collect Sample for Laboratory Testing	Install Automated Water Level Device	Comment
5011	Palara	No	No	Quarterly	Quarterly	No	Windmill
5014	Ballera 2	No	No	No	No	No	Further inspection only
5016	Ballera 1	Quarterly	Yes	Quarterly	Quarterly	Yes	-
5025	Fork Tree	Quarterly	No	Quarterly	Quarterly	No	-
5028	Irtalie 1	No	No	Quarterly	Quarterly	No	-
5029	Keegan's	Quarterly	Yes	Quarterly	Quarterly	Yes	Repair head works
5033	Coothero Water	No	No	Quarterly	Quarterly	Yes	Install pressure gauge, data logger and fittings
5037	Jackson 6A	No	No	No	No	No	Further inspection only
5043	Naccowlah West 4	Quarterly	Yes	Quarterly	Quarterly	Yes	Fieldwork to modify head works
5048	Barrolka 2	Quarterly	Yes	Quarterly	Quarterly	Yes	-
5063	Durham Downs R2	Quarterly	Yes	Quarterly	Quarterly	No	Fieldworks to modify head works
5074	Cherry Cherry 1	No	No	Quarterly	Quarterly	No	Windmill
5076	Tarbat Job No 1947	Quarterly	No	Quarterly	Quarterly	No	Windmill
5077	Walla Wallan Bore 5	Quarterly	No	Quarterly	Quarterly	No	Windmill
5087	Grahams Bore	Quarterly	No	Quarterly	Quarterly	No	-

WBBA = Water Bore Baseline Assessment

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APPENDICES

1.0 INTRODUCTION

This Groundwater Monitoring Plan (GWMP) has been prepared for Santos Ltd (Santos) by Golder Associates Pty Ltd (Golder), for monitoring of groundwater within Santos' petroleum tenements in Southwest Queensland (SWQ). The GWMP is also designed to be adaptable to changes in Santos' operations, environmental data and conceptual understanding of the area of interest.

This GWMP has been prepared based on Golder's *Proposal and Cost Estimate – Groundwater Monitoring Plan, Southwest Queensland* (reference: P27666002 001 L Rev0), dated 31 January 2012, and follows previous works (Section 1.4). This GWMP is based on the findings of the *Underground Water Impact Report for Santos Cooper Basin Oil and Gas Fields, SW QLD* [UWIR] (Reference: 117636010-3000-001), in revision, and addresses the groundwater monitoring strategy requirements outlined therein. This GWMP should be read in conjunction with the UWIR.

This GWMP provides an interim water monitoring strategy that is designed to ensure that the proposed scope of monitoring program is specific and targeted in relation to the potential impacts identified in the Golder UWIR and provides measureable goals within its period of applicability. The GWMP summarises background technical information, outlines actions, responsibilities, monitoring network design and timeframes that will deliver an interim *water monitoring program* to meet the monitoring objectives.

Compilation and review of the existing, formation pressure data collected by Santos is a key objective of this GWMP. Since interpretation of these data is not yet complete, the approach and strategy behind this current GWMP version is considered to be *interim* only. The Water Bore Baseline Assessment (WBBA) is currently underway and monitoring data collected during interim water monitoring activities within this petroleum producing field may require revision to better achieve useful monitoring outcomes. Therefore, the period of applicability of the plan will be approximately 18 months from the time of Queensland Department of Environment and Heritage Protection (DEHP) acceptance, half that deemed appropriate for the associated UWIR revision cycle.

Finally, the GWMP provides a structure for engagement with private landowners during monitoring works and outlines the reporting and provision of monitoring data.

1.1 Legislative Framework

Santos is required to monitor and assess the impact of its petroleum production operations on underground water, as regulated by the *Water Act 2000* and relevant amendments in the *Water and Other Legislation Amendment Act 2010)*, collectively referred to as the "Water Act" herein. The amendments transfer the regulatory framework for underground water from the *Petroleum Act 1923* and the *Petroleum and Gas (Production and Safety) Act 2004* (P&G Act) to the Water Act.

Santos' activities in the Cooper Basin are subject to Queensland and/or Commonwealth regulation, and to site and activities-specific Environmental Authorities (EAs) determined by the DEHP under the *Environmental Protection Act 1994*.

The Water Act regulates access to water resources. Under this Act, a water licence is required to take water for any purpose other than domestic use and stock watering. When a water licence is required, there may be a requirement under Section 214(e) of the Act to carry out and report on a monitoring program. The groundwater management requirements that were previously regulated under the P&G Act and the *Petroleum Act 1923*, and were transferred to the Water Act in 2010 included the obligations to:

- Prepare Underground Water Impact Reports;
- Establish groundwater baseline conditions through WBBA monitoring of private bores; and
- Define "make good" provisions as a contingency to address losses incurred by private bore owners resulting from petroleum activities.

The Water Act also defines the drawdown thresholds which, if reached, will trigger investigations and make good actions.

1.2 Cooper Basin Oil and Gas Fields Operations

Santos currently operates conventional gas and oil fields within the Eromanga and Cooper Basins of SWQ. The locations of Santos oil and gas production wells are illustrated in Figure 1. The oil and gas fields encompass an area in excess of 8,160 km² of largely semi-arid agricultural land, which was first developed for petroleum production in the early 1970s. Santos' petroleum tenements include approximately 191 producing gas wells and 230 producing oil wells.

Santos Cooper Basin petroleum fields produce both conventional oil and gas:

- *Conventional oil* is produced from the Great Artesian Basin (GAB) formations of the Eromanga Basin. The oil is present in discontinuous oil reservoirs within interbedded sandstone units or larger sandstone formations. There are several types of oil reservoirs resulting from the process of "trapping" of the oil. In many cases, the oil exists with the groundwater, and as a consequence of the oil being lighter than water it generally migrates to the upper part of a formation where further migration is prevented by a hydraulic barrier (structural or stratigraphic trap).

- *Conventional gas production* is undertaken from porous sandstone formations and as such does not require the depressurisation of the target beds (with respect to groundwater, and the need to remove groundwater to release the gas). Some water is produced as a by-product; however, the volumes are quite limited. In the area of interest, gas production is typically associated with the deep formations of the Cooper Basin (underlying the GAB system).

Note: "Santos", in this document, refers to Santos and its various companies who operate the oil and gas tenements on behalf of the various joint venture parties.

Based on Santos' Environmental Management Plans and as described in the UWIR (Golder, 2012, in revision), Santos has divided their Cooper Basin production fields into three 'Project Areas'. To reduce confusion the terms "Production Fields", "Project Areas", and "Study Areas"; used in previous documents are referred to in this GWMP as the area of interest (see Figure-1) or sub-areas to the area of interest and are as follows:

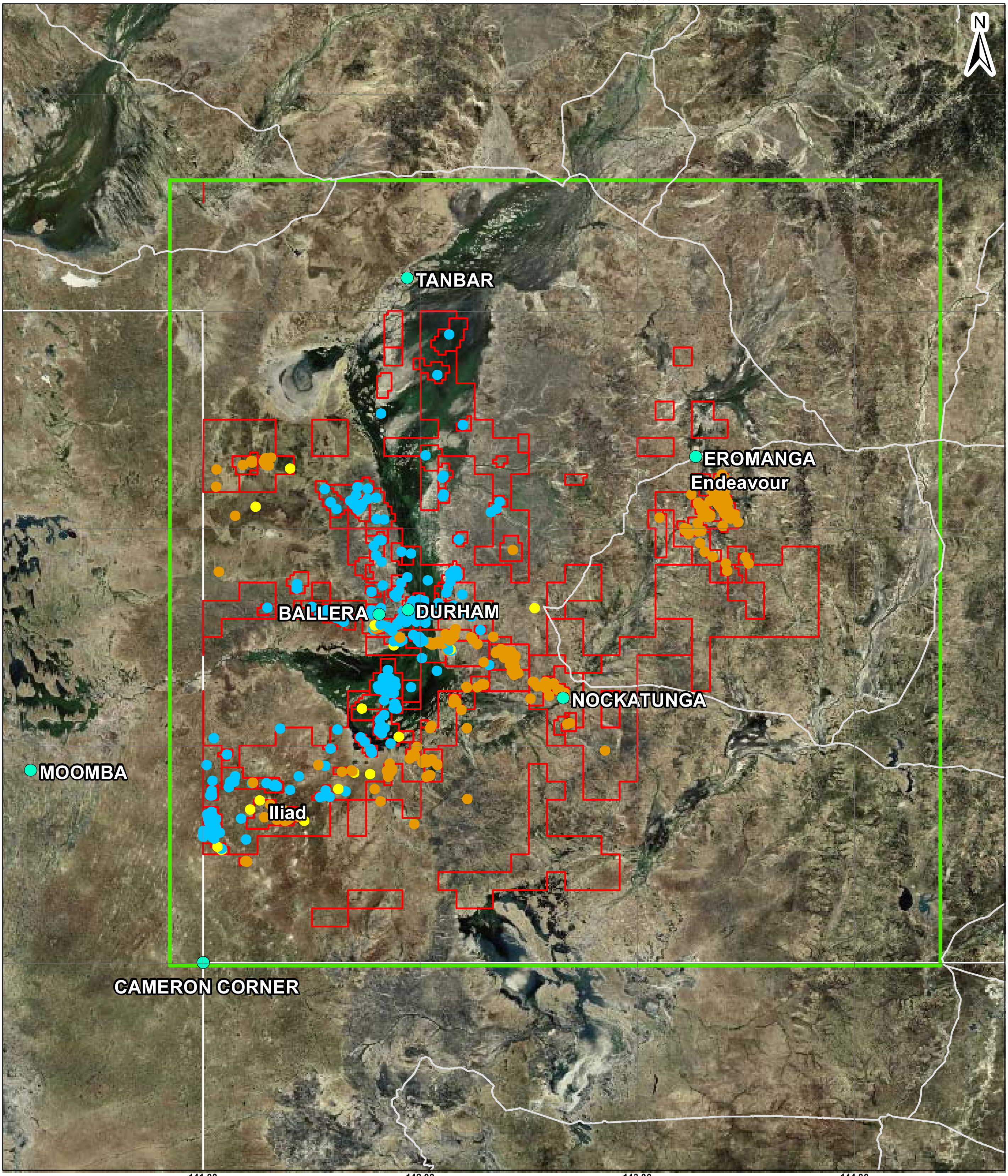
- The **Western Study Area (Western Sub-Area of Interest)**.
- The **Central Study Area** (**Central Sub-Area of Interest**).
- The **Eastern Study Area (Eastern Sub-Area of Interest)**.

1.3 Historic Monitoring by Santos

Prior to the implementation of the GWMP, Golder understands the previous Santos groundwater monitoring efforts included the following:

- Santos' deep groundwater monitoring associated with the water flooding activities as described in the UWIR;
- Shallow groundwater monitoring associated with:
  - Ballera evaporation pond (8 monitoring wells);
  - Jackson refuelling station (3 monitoring wells);
  - Jackson landfarm activities (4 monitoring wells);
- DEHP GAB monitoring network spread over the area of interest and targeting the formations of the Eromanga Basin; however, few exist within the area of interest.

These ongoing existing monitoring programs are considered separate from the monitoring requirements of this GWMP.



INTERIM GROUNDWATER MONITORING PLAN
SANTOS COOPER BASIN OIL & GAS FIELDS, SOUTHWEST QUEENSLAND

SANTOS LTD

AREA OF INTEREST PLAN

LEGEND

- Oil Production Well
- Oil and Gas Production Well
- Gas Production Well
- Santos Tenement Boundary
- Area of Interest
- Highway/Major Road
- Township

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Township and road data sourced from MapInfo Street Pro.

0 5 10 20 30 40 50 kilometres

SCALE (at A4) 1:2,750,000

Coordinate System: GCS GDA 1994

PROJECT:	127666003
DATE:	17 JUL 2012
DRAWN:	KB
CHECKED:	BC / DG

FIGURE 1

Golder Associates

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File Location: S:\Santos\Project\Deliverable\Production Fig\127666003 - GWMP\002 - GWMP\REV 1 Figures - 17072012\127666003-002-R-F0001-Rev1.mxd

1.4 Previous Groundwater Studies

Previous groundwater reports prepared for Santos' SWQ tenements include:

- URS (2010), *Water Flooding Impact Assessment: Further Information to Support Assessment of Potential Impacts of Water Flooding in PL295*
- Santos (2010), *Response to DEHP Re: Use of fracture fluids containing BTEX*
- Golder (2012, in revision), *Underground Water Impact Report for Santos Cooper Basin Oil and Gas Fields, SW QLD* (Golder reference: 117636010-3000-001-Rev2) [UWIR], dated 30 July 2012..
- Golder (2012), Santos South West Queensland, *Regional Water Bore Baseline Assessment Report (Priority 1 and 2 Bores)* [WBBA] (Reference 117666006-019-R-Rev0), dated 29 May 2012.

Golder has undertaken two of the previous investigations in relation to this GWMP. A summary of the Golder studies is presented below.

1.4.1 Underground Water Impact Report

Under the Water Act, Santos is required to prepare an UWIR for its SWQ oil and gas production fields. In compliance with this requirement, a UWIR was prepared for Santos by Golder.

The UWIR identified the quantity of water produced during the production of gas and oil, and the potential impact of this groundwater extraction on the various aquifers accessed for water supply in the area of interest. It also identified environmental values of groundwater within the area of interest and the existing or proposed groundwater monitoring program required to assess potential impacts based on a groundwater monitoring strategy. Potential impacts to private bores and springs are specifically required to be addressed.

The risk assessment and groundwater modelling presented in the UWIR assessed the potential for environmental values of groundwater to be affected by drawdown/depressurisation associated with petroleum activities, defined as follows:

Immediately Affected Area (IAA)

- The IAA of an aquifer is the area within which water levels are predicted to decline, due to water extraction by petroleum tenure holders, by more than the trigger threshold within three years. The trigger thresholds, as specified in the Water Act, are 5 m for consolidated aquifers (such as sandstone) and 2 m for unconsolidated aquifers (such as alluvial deposits).

Long-term Affected Area (LAA)

- The LAA of an aquifer is the area within which water levels are predicted to fall, due to water extraction by petroleum tenure holders, by more than the trigger thresholds at any time in the future. The trigger thresholds, as specified in the Water Act, are 5 m for consolidated aquifers (such as sandstone) and 2 m for unconsolidated aquifers (such as alluvial deposits).

Note: A decline of the water level in a bore of more than the trigger threshold is considered to increase the potential risk of impairment to the water supply from the ongoing petroleum production activities.

The UWIR concluded that the groundwater extraction associated with oil and gas production is limited in volume and current activities are not expected to have significant impacts on the groundwater resources used by the community, with the possible exception of two areas of localised impact (Production Lease (PL) 33 and PL35).

Section 10.0 of the UWIR summarised the existing monitoring programs and proposed a basis for a groundwater monitoring strategy and an early monitoring program. The groundwater monitoring strategy outlined the rationale and ranking for groundwater monitoring options, and also outlined standard monitoring analyte suites and groundwater monitoring infrastructure. The UWIR was considered when undertaking the WBBA and also while preparing this GWMP, as it is the primary regulatory compliance document for groundwater management.

This GWMP should be read in conjunction with the UWIR.

1.4.2 Water Bore Baseline Assessment Report

The objective of the WBBA is to collect baseline data with regards to the existence, construction, condition and accessibility of water bores (so-called "Water Act", 'private' or 'farmers' bores) and, when possible, aquifer data including water level, water quality, and water extraction (pumping rate and scheduled use). These assessments are intended to characterise groundwater conditions prior to production. In the case of the Cooper-Eromanga Basins, where operations have been ongoing for 40+ years, this aspect is less relevant as current "baseline" conditions may reflect the influence of historical petroleum production. However, it still provides a basis for future comparison of groundwater conditions, particularly with regard to potential impacts from petroleum production.

Water bores have been identified within Santos' SWQ tenements for assessment and classified as one of three priorities:

- **Priority 1** – bores within leased areas *inside* a 2 km radius of production wells,
- **Priority 2** – bores within leased areas but *outside* a 2 km radius of a production well; and,
- **Priority 3** – bores *outside* of the established lease but within Santos' tenement boundaries.

(It should be noted that fieldwork for the Priority 1 and 2 bores is complete; fieldwork to identify Priority 3 bores is currently in progress with WBBA data scheduled to be compiled by September 2013.)

The WBBA (Priority 1 and 2 bores) report concluded the numbers of bores that *actually* exist within the area of interest is less than what is indicated in the DEHP groundwater database and in the project brief.

The observations indicate significant data gaps between the DEHP database (used in preparing the UWIR), Santos' records and the actual existence of bores. Many historical records reviewed were not relevant, while data quality contained in other records is considered questionable. In general, reliable historic and bore construction records are limited and records indicating the aquifer in which bores are screened are absent.

Criteria have been established in an effort to assign potential bore suitability for future groundwater monitoring. In general, baseline data is limited and 76 bores were considered not suitable or 'poor' for on-going monitoring purposes. Fifteen (15) bores were considered 'fair' for monitoring and their details are summarised in Table 1. However, even 'fair' bores are generally absent of reliable screened interval data.

Two bores highlighted in the UWIR as being within potential impact zones, were visited as part of the WBBA (Priority 1), with observations summarised below:

- **5032: Whim Well**
  Location was visited; however, the bore was not found.

- **5033: Coothero Water Bore**
  The bore was visited and a groundwater sample collected. The bore is artesian and completed with a valve head; however, a pressure gauge is not installed so the piezometric level of the screened aquifer(s) is unknown. Bore construction records have not been received by Golder (including the well depth or screened aquifer) and therefore the bore's suitability as a monitoring point is of limited value. However, it is included in the interim monitoring network due to being potentially impacted and has potential to be valuable upon further field investigation.

Eight other bores were observed to be currently used by private landowners (Table 2). Based on WBBA criteria, these bores are not considered to be suitable for ongoing monitoring. However, some of these may be considered appropriate for monitoring use as part of the GWMP network and are discussed further (see Section 4.3).

Due to the uncertain and unverified quality of historic bore construction records, bores considered to be 'fair' for monitoring purposes would benefit from further field verification works prior to the commencement of monitoring.

Based on the data collected, Golder recommended the following strategy:

- Priority 3 WBBA should be completed, as planned.
- Investigation works should be undertaken to verify bore construction records and confirm the actual suitability of bores for monitoring.

Table 1: Water Bores assessed as potentially suitable for ongoing monitoring during WBBA works

Suitability for Ongoing Monitoring	Santos Priority	Bore ID	Name	DEHP RN	Santos Permit	Measured Water Depth (m btoc**)	Reported Bore Depth (m)*	Target Aquifer (from DEHP)*
Fair	1	5029	Keegan's Bore	0	PL 78	-	48.0	(not in DEHP database)
Fair	1	5057	Wolgolla 1 Road Bore	0	PL 88	-	68.6	-
Fair	3	5025	Fork Tree Bore	0	ATP 259P	-	123.4	-
Fair	(not in initial list)	5058	Wolgolla 1 Road Bore B	0	PL 88	-	39.2	-
Fair	1	5014	Ballera 2 Bore	23565	PL 61	-	2613.4	(no data)
Fair	1	5016	Ballera 1 Bore	0	PL 61	31.86	89.0	-
Fair	1	5026	Vega North 1 Supply Bore	0	PL 131	9.21	116.5	-
Fair	1	5037	Jackson 6A	23321	PL 23	-	1265.2	(no data)
Fair	1	5039	Jackson Land Sludge Farm Water Bore	0	PL 23	19.44	<50.0	-
Fair	1	5042	Naccowlah South 2	23219	PL 25	-	1749.0	(no data)
Fair	1	5048	Barrolka Bore 2	0	PL 112	17.50	114.0	-
Fair	2	5028	Irtalie 1	23570	PL 36	-	1914.6	(no data)
Fair	3	5063	Durham Downs Bore R2	0	ATP 259P	-	60.0	-
Fair	(not in initial list)	5040	Jackson Bioremediation Area Monitoring Bore 1	0	PL 23	20.19	<50.0	-
Fair	(not in initial list)	5041	Jackson Bioremediation Area Monitoring Bore 2	0	PL 23	-	<50.0	-

*Reported data from records including DEHP database and historic documents and has not been measured in the field.

** btoc = below top of casing

- Data not obtained

Table 2: Priority 1 and 2 bores observed to be used by third parties (private users) during WBBA works

Priority	WBBA ID	Bore Name	DEHP RN	Santos' Permit	Latitude D.DDD	Longitude D.DDD	Measured Water Depth (m btoc*)	Head Type	Bore Depth (m) (source: DEHP database)
1	5011	Palara Bore	6057	PL 59	141.6050278	-27.4107500	- (not measured)	Windmill	243.80
1	5075	Mt Margaret No 14	9096	PL 170	143.2446600	-27.0444600	-	Windmill	129.60
1	5077	Walla Wallan Bore 5	6373	PL 295	143.4021900	-26.8459600	15.40	Windmill	156.70
2	5069	Mt Margaret No 20	10565	PL 295	143.3630310	-26.8817580	-	Windmill	-
2	5074	Cherry Cherry Bore 1	6369	PL 39	143.4002100	-26.9949200	-	Windmill	285.40
2	5076	Tarbat Job No 1947	12036	PL 295	143.3123900	-26.8317400	30.40	Windmill	209.80
2	5087	Grahams Bore	14955	PL 110	141.0342850	-28.2851030	-	Mono Pump	94.80
-	5086	Moon Field Road Bore	0	ATP 259P	141.0346780	-28.1448710	-	Mono Pump	-

* btoc = below top of casing

2.0 OBJECTIVES OF THE GWMP

2.1 Preamble

Based on decades of field measurements of formation pressures and the ongoing nature of operations in the Cooper and Eromanga Basins, Santos engineers are confident that water pressure gradients through the Cadna-owie Formation, Hooray Sandstone, and Hutton Sandstone are not indicative of large scale reduction in formation pressures throughout the area of interest (Pers.Comm., N. Lemon et al., Santos, 2012).

The database of formation pressure will, as part of this interim GWMP, be compiled, reviewed, and analysed. It is anticipated to provide strong evidence that hydrostatic pressure in the major production zones in the Hutton Sandstone, Cadna-owie Formation and Hooray Sandstone is higher than in the overlying hydrostratigraphic units. If formation pressure gradient data analysis results are as expected, then Santos anticipates there is little risk to the current local private bores.

2.2 Objectives

The primary objective of groundwater monitoring activities (and this GWMP) is to assess potential impacts to groundwater in order to:

- protect the environment from potentially adverse impacts; and
- protect local private bore production from reduced yield y and assess whether private bores have potentially been impacted from petroleum production activities (Water Act). The Water Act defines water level drawdown *bore trigger threshold* as follows:
  - 5 m decline for consolidated aquifers such as sandstone;
  - 2 m decline for unconsolidated aquifers such as shallow alluvium; and
  - 0.2 m for active springs.

Other objectives of this GWMP are as follows:

- Describe the area of interest to be monitored by the network, including:
  - a hydrogeological conceptual model (HCM); and
  - a hydrostratigraphic summary of relevant aquifers and formations.
- Present the interim groundwater monitoring strategy;
- Present interim water monitoring activities including the interim groundwater monitoring network;
- Present a schedule for reporting of results (in line with "Annual Reporting" obligations).
- Present the response actions - if trigger threshold levels are exceeded (including a verification investigation to assess whether the threshold exceedance is the result of petroleum activities).

This GWMP is *not* designed to meet obligations or conditions outlined in specific Environmental Authorities (EAs) or Management Plans.

2.3 Limited Period of Applicability

This interim version of the GWMP has a limited applicability period of 18 months from the date of acceptance of the plan by DEHP. During this time, the monitoring requirements outlined in this interim GWMP will be completed in order to better assess an ongoing groundwater monitoring strategy. The relevant results of other works and tasks underway by Santos with regard to groundwater management will be incorporated into the next revision of this plan.

3.0 SITE DESCRIPTION AND HYDROGEOLOGY

Information regarding topography and drainage, aquifer recharge and discharge, groundwater quality and climate is contained within the UWIR, which should be read in conjunction with this GWMP.

3.1 Hydrogeological Conceptual Model (HCM)

The Cooper and Eromanga basins are two chronologically successive stacked basins. The Cooper Basin is often considered by geologists as not being part of the GAB. However, the upper Formations of the Cooper Basin are included in the Queensland GAB regulation (GAB Resource Operations Plan [ROP], GAB Water Resource Plan [WRP]). The Eromanga Basin is one of the main basins of the GAB; it is laterally extensive and covers the whole of the Cooper Basin. The connection between the two basins is geologically marked by a major discontinuity.

Both the Cooper Basin and Eromanga Basin are multi-layered sedimentary systems comprising alternating layers of sandstone, shale, mudstone and siltstone. The sandstone formations of the Eromanga Basin are generally recognized as water bearing units and where they are of appreciable extent and thickness are defined as aquifers, which yield significant quantities of groundwater to water bores and springs.

The siltstones, shales and mudstones are low permeability rocks and are regionally considered to be aquitards. However, transmissive sandstone beds can be found amongst the mudstones and siltstones, some of them forming water-bearing zones that can yield limited groundwater sources to low yield bores.

The formations can be laterally continuous and are hydraulically connected; however, this may not always be the case due to the variability in the composition of these sedimentary units.

For management purposes, the GAB is subdivided into Groundwater Management Areas (GMA) as defined in the *GAB Hydrogeological Framework for the GAB WRP Area* (DEHP, 2005). Each area is further divided into Groundwater Management Units (GMUs). The identification of GMUs allows for administration of access to water and water entitlements.

3.2 Hydrostratigraphy

Santos' tenements are contained mainly within the *Central Management Area* (GMA16) extending into the western part of *Warrego West Management Area* (GMA 17).

The main aquifers and aquitards units are presented on Table 3**Error! Reference source not found.**. The main aquifer groupings, in terms of production of groundwater, include:

- The shallow aquifers of the Quaternary and Tertiary alluvium formations;
- The deeper GAB aquifers of the Eromanga Basin (water supply for irrigation, stock watering and drinking water, and groundwater extraction associated with the production of oil);
- The deeper aquifers of the Cooper Basin (groundwater extraction associated with the production of gas; no known water supply bores installed to these depths).

Access to suitable groundwater resources at shallower depths has resulted in limited water supply development of the main aquifers of the Eromanga Basin. The aquifers of the Cooper Basin are much deeper and are only accessed for the production of gas.

Hydrostratigraphy can only be described in detail for the formations of the Eromanga Basin using information from the DEHP database or from the literature. Insufficient information is available to provide a detailed description of the hydrostratigraphy of the Cooper Basin formations. The descriptions in this report are partially based on information provided by Santos' engineers and geologists based on their experience in the area of interest. Santos' interpretations of formation hydraulic properties occasionally differ from regional interpretations in published literature; however, the technical opinions of Santos staff are important as they have conducted much of the significant investigation of the Cooper Basin.

Table 3: Hydrostratigraphy of the Area of Interest (UWIR, 2012)

GMA Unit	Basin	Group	Unit	Sub-unit	Equivalent Formation other parts of the GAB
	Eromanga Basin		Glendower Formation		
	Eromanga Basin		Winton Formation		
	Eromanga Basin		Mackunda Formation		
	Eromanga Basin		Alluru Mudstone		
Central 1 - Warrego West 1	Eromanga Basin		Toolebuc Formation		Surat Siltstone
Central 1 - Warrego West 1	Eromanga Basin		Wallumbilla Formation	Coreena Member	Wallumbilla Formation
				Doncaster Member	
Central 2 - Warrego West 2	Eromanga Basin		Cadna-owie Formation	Wyandra Sandstone Member	Cadna-owie Formation, Bungil formation, Gilbert River Formation
				Lower Cadna-owie	
Central 3 - Warrego West 3	Eromanga Basin		Hooray Sandstone	Murta Formation	Hooray Sandstone, Mooga Sandstone, Orallo Formation and Gubberamunda Sandstone
				Namur Sandstone	
Central 4 - Warrego West 4	Eromanga Basin		Westbourne Formation		Injune Creek Group
			Adori Sandstone		
			Birkhead Formation	Upper Birkhead	
				Middle Birkhead	
				Lower Birkhead	
Central 5 - Warrego West 5	Eromanga Basin		Hutton Sandstone		
Central 6 - Warrego West 6	Eromanga Basin		Poolowanna Formation	Upper Poolowanna	Precipice Sandstone
				Lower Poolowanna	
MAJOR UNCONFORMITY					
Central 7 - Warrego West 7	Cooper Basin	Nappamerri Group	Tinchoo Formation	Gilpepee Shale	Moolayember Formation
				Doonmulla Member	
			Arraburry Formation	Wimma Sandstone Member	Clematis Sandstone
				Panning Member	Rewan Formation
				Callamurra Member	
	Cooper Basin	Gilgealpa Group	Toolachee Formation		
			Daralingie Formation		
			Roseneath Shale		
			Epsilon Formation		
			Murteree Shale		
			Patchawarra Formation		
			Tirrawarra Sandstone		
			Merrimelia Formation		

Major Aquifer

Water Bearing Unit (in places)

Aquitard (Confining Bed)

3.2.1 Quaternary and Tertiary Alluvium

The Quaternary and Tertiary alluvium formations cover a large portion of the area of interest; they are often associated with the flat topography of the flood plains and are absent where the Winton Formation outcrops.

The shallow, and often surficial, Quaternary and Tertiary sediments are typically unconfined and form the water table aquifer where they are present. Insufficient groundwater elevation data is available for the Quaternary formations to define the level of connectivity.

The Glendower Formation is the primary aquifer for the Tertiary sediments within the area of interest. The Glendower Formation consists of consolidated sediments comprising sandstones, sandy siltstones and minor conglomerate and mudstones (Australian Stratigraphic Database, Geosciences Australia). The Australian Stratigraphic Database identifies the Whitula Formation as overlying the Glendower Formation; however, the significance of the Whitula Formation in the area of interest is unknown.

Groundwater flow generally follows the topographical profile with the limitations imposed by the fluvial nature of the sediments. As previously reported in the UWIR, the hydraulic gradient is very low. Groundwater quality is variable. Salinity of these aquifers is brackish, with electrical conductivity (EC) values ranging from 3,000 to 7,000 µS/cm (based on data from the DEHP database).

3.2.2 Winton Formation (Water-Bearing Unit)

The Winton Formation is considered to be an aquifer since it supplies a number of stock and domestic bores. The depth to the Winton Formation and its hickness (based on DEHP groundwater database) is illustrated in the maps presented in the UWIR (Golder, 2012). The top of the Winton Formation is (according to the DEHP groundwater database) typically encountered in the first 50 m below ground surface (bgs) and its thickness can reach up to 970 m.

Santos' geology team do not consider the Winton Formation to be a significant aquifer in SWQ; at best, they consider it a water bearing unit. Although in much of Queensland the Winton Formation is a significant aquifer, the quality of the Winton Formation as an aquifer appears to diminish westward from central Queensland to SWQ and into South Australia (SA) where it is more appropriately defined as a water-bearing unit (Pers. Comm. N. Lemon, Santos, November 2011). The top and bottom of the Winton are so poorly defined that it is difficult to be confident that water production currently assigned to the Winton Formation comes from the overlying Tertiary (Eyre Formation in SA) or the underlying Mackunda Formation. This is further supported in SA by the findings of Gravestock and al. (1995).

Whether or not the Winton Formation is continuously present in the area of interest, water quality from this unit, based on information from the DEHP database, is of fair to poor and is quite variable. The water quality reported for the Winton Formation is typically brackish to saline with EC values ranging from 900 to 13,000 µS/cm. The direction of groundwater flow in this aquifer is generally to the south west.

3.2.3 Upper Cadna-owie Formation (Aquifer)

The Cadna-owie Formation is considered to be a major GAB unit. Its upper section, the Wyandra Sandstone, is an aquifer; however, its thickness is limited across SWQ. The Lower Cadna-owie is considered an aquitard.

The proportion of productive sandstone aquifers in this unit is much lower than that in the underlying Hooray Sandstone and the spatial variability even greater. The Wyandra Sandstone is recognised as the productive layer of the formation. It consists of permeable shallow marine sandstone, which is most extensive in the eastern part of the Cadna-owie Formation (BRS, 2000).

The few data points available in the DEHP groundwater database seem to indicate fresh to slightly brackish water quality within the Wyandra Sandstone. Insufficient water level information is available to describe water flow patterns and groundwater elevations in order to create a hydrogeological map.

Historically, this unit has been described as non-artesian; however the DEHP groundwater database identifies a few artesian bores in the Wyandra Sandstone. As described in the objectives section of this GWMP, formation pressure data will be reviewed to help better define artesian or non-artesian zones, hydraulic gradients, water levels, and other hydrogeological conditions, if possible.

3.2.4 Hooray Sandstone (Aquifer)

The Hooray Sandstone is a major GAB formation; in the area of interest it is also considered to be a major aquifer. Oil reservoirs and a minor gas reservoir are also contained with this unit.

Two sub-units are identified in the *Hooray Sandstone:*

- The *Murta Formation*, equivalent in other GAB basins to the Mooga and Gubberamunda Sandstones (significant aquifer formations); however in the area of interest it is considered to be an aquitard. The main confining unit is a siltstone bed at the base of the Murta Formation which is laterally extensive across the Cooper Basin. Oil and some gas reservoirs are found in the Murta Formation. The McKinlay Member, which belongs to the Murta Formation, is not always present in SWQ and contains minor oil reservoirs.
- The *Namur Sandstone* is an aquifer and the major water bearing unit of the Hooray Sandstone. Oil is also found in this unit.

The water quality in the Hooray Sandstone is generally fresh to slightly brackish, with EC values (DEHP database) ranging from 675 to 3,930 µS/cm. The EC values are generally consistent over time as a few bores have several salinity measurements recorded over a 40 year period.

A number of water-bearing zones within the Hooray Sandstone may be artesian. Groundwater bores completed in this unit are generally concentrated to the south east of the area of interest. No water level and salinity data are available within Santos' tenements.

The UWIR findings indicate that the groundwater flow direction is to the south east and that generally the water salinity is fresh to slightly brackish.

The Hooray Sandstone seems to be an aquifer of higher yield than the overlying aquifers and a number of town water supply bores are completed within the Hooray Sandstone.

3.2.5 Westbourne Formation, Adori Sandstone and Birkhead Formation

Little hydrogeological information is available on the Westbourne Formation, Adori Sandstone and Birkhead Formation in the area of interest.

The Westbourne Formation is generally considered to be an aquitard (confining bed) of homogeneous character (lacustrine deposits associated with a large transgression). However, in the south east section of the area of interest, a number of private bores are completed in the Westbourne Formation, possibly in some of the minor sandstone beds of the formation.

The Adori Sandstone is an aquifer in the area of interest; however, insufficient information is available to characterise it further.

The Birkhead Formation is a succession of non-continuous confining beds and water bearing sandstone units.

Water quality data for these formations is not available in the DEHP database. Santos operations include produced water from these formations, but water quality data has not been recorded for the produced water.

3.2.6 Hutton Sandstone

The Hutton Sandstone is a significant GAB aquifer. Its depth, however, of approximately 2,000 mbgs in the area of interest, precludes access other than for petroleum activities. The groundwater flow direction is expected to be towards the south west (i.e. consistent with the flow of the major GAB units as described in the literature). Note: there is insufficient water level data on the Hutton Sandstone in the area of interest to characterise groundwater flow further.

No water quality data are available for this formation in the area of interest.

3.2.7 Poolowanna Formation

Also referred to as the Basal Jurassic Formation (older name in the geologic literature), the Poolowanna Formation is the equivalent of the Precipice Sandstone (in SE Queensland). Groundwater flow is expected to be to the south west (i.e. consistent with flow of the major GAB units as described in the literature).

No water quality data are available for this formation in the area of interest.

4.0 GROUNDWATER MONITORING STRATEGY

This GWMP provides the location, frequency and monitoring type for each monitoring bore. A standard method for the design of this GWMP has been followed using guidelines referenced in Section 7.0. The strategy and monitoring actions presented herein are considered a reasonable starting proposal for this interim GWMP.

Development of the monitoring strategy will be carried out within the three year revision cycle of the UWIR with consideration of the intervening WBBA results. The interim GWMP as proposed here, will apply for an approximate 18 month period, following approval from DEHP. If warranted, a revised GWMP may follow and again the duration of applicability of that revision would be approximately 18 months, thus bringing it in line with the revision cycle of the UWIR.

4.1 Interim Strategy

The interim groundwater monitoring strategy for Santos petroleum tenements is summarised as follows:

- **Compilation and analysis of existing formation pressure data**: Compile and review existing formation pressure data across the area of interest to estimate groundwater elevation and pressure trends, hydraulic gradients, and potential zones of impact or evidence of depressurisation in formations that underlie aquifers accessed for water supply. Santos has a database of formation pressures in many of the water-bearing levels within the Eromanga Basin that will be used to define the potential changes to water levels required by the Water Act. This task will include tracking, collection, and analysis of ongoing production well drilling data and will assist in filling data gaps related to formation pressures.
- **Undertake interim water monitoring activities**: Collection and reporting of baseline data by undertaking water monitoring activities using 15 existing bores.
- **Revise the interim GWMP and strategy**: Based on the results of previous tasks (bullet points 1 and 2), the GWMP will be reviewed and amended after the interim period, if warranted. During this task the groundwater monitoring strategy will also be revisited, which will include consideration of verification of bore construction along with engineering or construction fieldworks required to further develop the monitoring network, if necessary.
- **Revise the UWIR and GWMP**: As required by the Water Act, revise the UWIR and GWMP on a three year cycle.

Strategic tasks 1 and 2 are discussed in the following sections.

4.2 Existing Formation Pressure Data

Most oil and gas companies, such as Santos, measure formation pressure in a number of water-bearing formations in each well drilled, either by drill stem test (DST), repeat formation tester (RFT) or Formation Micro Tester (FMT). This is performed to assess the likely thickness of the oil or gas column found at any particular level. The assessment is done by comparing the pressure in the hydrocarbon-bearing zone with the expected water pressure, predicted by the water pressure-depth line or gradient. Models for predicting the influence of oil and gas and associated water production at depth require input data on the pressure transmissibility of the formations between oil and gas production zones and aquifers used by private bores. In the case of SWQ, between the main Glendower and Winton aquifers, which account for the majority of groundwater supply in the area of interest, and the petroleum reserves in the Murta, Namur, (Hooray) and Hutton from which oil is produced.

Many wells have had formation pressures measured over many years in the Cadna-owie Formation to establish water pressure-depth lines and this data will be evaluated to assess if depletion from underlying hydrocarbon production zones has influenced the aquifers used by private bore users.

If no depletion is observed at the Cadna-owie Formation level, then it will be inferred that oil and gas production has not influenced the aquifers above that level. Where water supply bores access the same aquifers as those associated with hydrocarbon production, Santos' formation pressure data will provide a direct indication of the water pressures in that area. The extrapolation of the water gradient to the surface provides an indication of the level to which water will now rise compared to what it would have been in the past. In other words, measured formation pressure can be used to assess the fall in water level in a water supply bore induced by the combined extraction by agricultural and petroleum industries.

Figure 2 below illustrates how each aquifer will have its own natural pressure-depth line, controlled by the level of water recharge to the basin and the salinity of the water. Salinity controls the slope of the line. The surface aquifers (red line for the Tertiary Sediments and Glendower Formation) and the Winton-Mackunda aquifer (brown line) each have their own pressure-depth line.

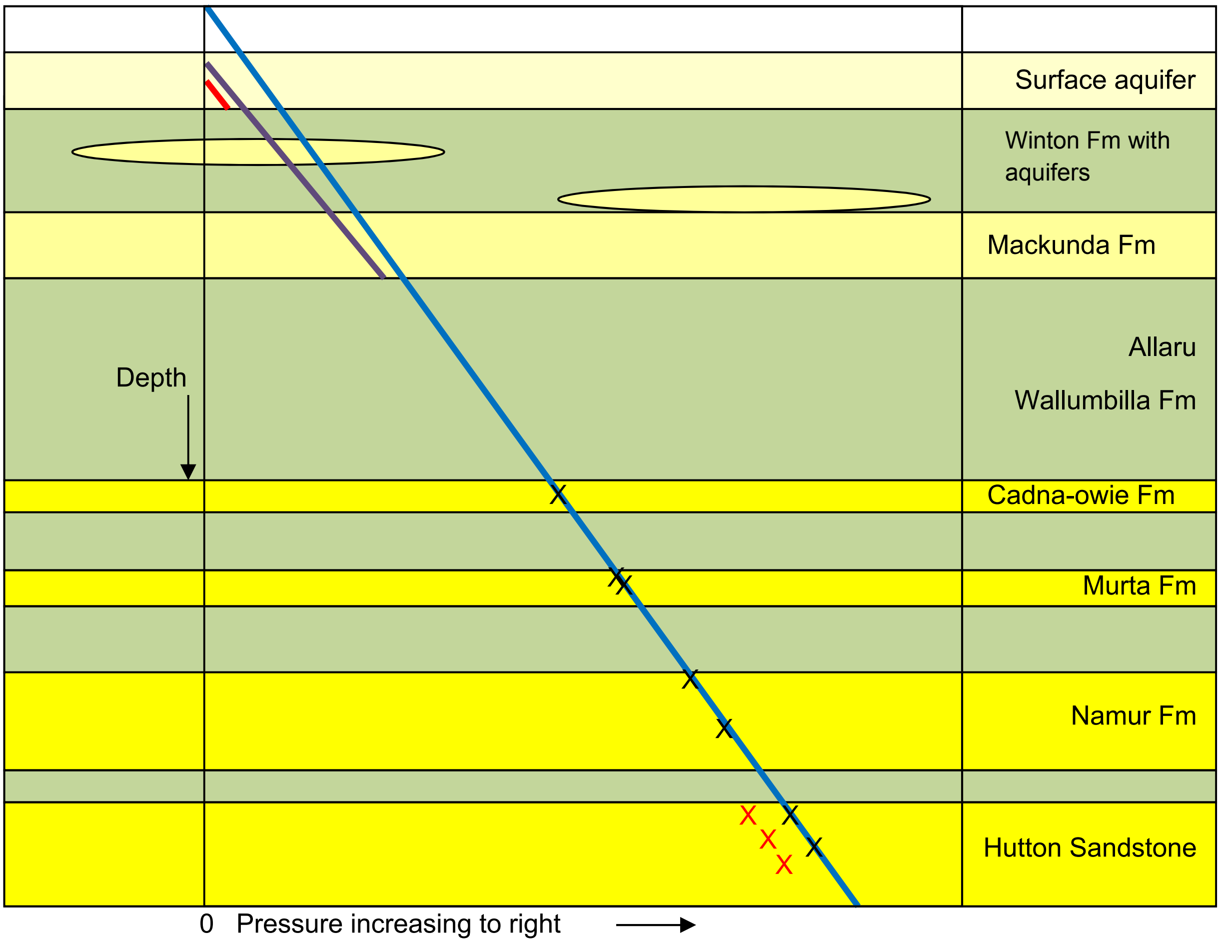


Figure 2: General Schematic of Observed Aquifer and Oil Field Pressure Trends (from Pers. Comm. with Dr. N. Lemon, Santos Principal Geologist, 2012)

The aquifers in the Cadna-owie, Murta, Namur and Hutton Sandstone are connected close to the recharge area in eastern Queensland and have similar salinities and the pressures lie on the same pressure –depth line (black Xs in Figure 2). The Murta Formation and Namur Sandstone combine in places and are called the Hooray Sandstone. Extrapolation of the pressures measured, using the FMT tool, to the surface defines the pressure line and determines whether the water will flow to the surface or to what level it will rise in a bore accessing this formation. Pumping for water and oil production can reduce the pressure in the vicinity of that production, as indicated by the theoretical red crosses in the Hutton Formation, thus establishing a new depleted pressure-depth line. If any of the aquitards (shown as green) allow for inter-aquifer water transfer, pressure depletion at depth should register in the overlying aquifers.

Santos will compile and review historical formation pressure data across the area of interest to assess groundwater elevation and pressure trends, hydraulic gradients, and potential zones of impact or evidence of depressurisation in formations that underlie aquifers used for the majority of private and public bores. In addition, Santos will capture, store, assess and report pressure data collected during oil and gas well drilling undertaken during the interim period, in order to assess pressure trends across the oil and gas fields.

4.3 Interim Water Monitoring Activities

4.3.1 Aquifers to be Monitored

The UWIR modelling estimates that the aquifers most likely to be impacted by Santos' activities include the shallow Quaternary and Tertiary aquifers, as well as the Cadna-owie Formation-Hooray Sandstone aquifers. Aquifers that are accessed for water supply within the area of interest should be targeted for monitoring. Monitoring of water quality and water levels (or pressures) should focus on the following aquifers:

- **Tertiary and Quaternary sedimentary formations to include the Glendower and Winton-Mackunda Formations**. The groundwater in these water-bearing units varies from semi-confined to confined. Approximate depths to the tops of these layers are 25 to 50 mbgs with base of the units ranging to over 600 mbgs. (Assumed as applicable to the **2 meter drawdown trigger level** until confined aquifer conditions are encountered d in a specific water monitoring bore.)

- **Cadna-owie Formation and Hooray Sandstone**: Approximate depth to the top of this layer range from 700 to 1,200 mbgs. (Applicable to the **5 meter drawdown trigger level**.)

As previously discussed, pressures in the Westbourne Formation, Birkhead Formation and Hutton Sandstone will be recorded during the drilling of oil and gas wells, as described in Section 4.2. Herein, this is considered a separate task and is not discussed further in the context of a 'Water Monitoring Activity'.

The UWIR concluded that the impact of water extraction in the underlying Hutton Sandstone and Cooper Basin does not extend beyond the location of the extraction wells.

4.3.2 Interim Monitoring Network

The interim monitoring network consists of the 15 bores (presented in Table 1) classified as 'fair' for monitoring purposes during the WBBA (Priority 1 and 2 Bores). However, the following amendments were made to create the interim monitoring network:

- Certain bores classified as 'fair' have been excluded from the interim monitoring network as follows:
  - Three bores (5039, 5040 and 5041), as they may be influenced by local impacts and are not considered to be regionally representative.
  - A single bore (5026) has been excluded based on geographical location.
  - Two bores (5057 and 5058) have been excluded as they were observed to be dry during WBBA works.
  - A single bore (5042) has been excluded from the interim monitoring network based on the condition of head works.
- A single bore (5033) was included as this was identified in the UWIR as a bore potentially impacted by petroleum activities.
- A single bore (5043) has been included based on geographical location.
- Three additional private bores (5077, 5076 and 5087) which were classified 'poor' have been included as they target single known aquifers (Winton and Glendower Formations), based on DEHP data.

- Two additional private bores (5011 and 5074) which were classified ‘poor’ have been included as they target active private users.

The interim proposed groundwater monitoring network is presented in Table 4. However, undertaking water monitoring activities at these bores is subject to landowner agreement.

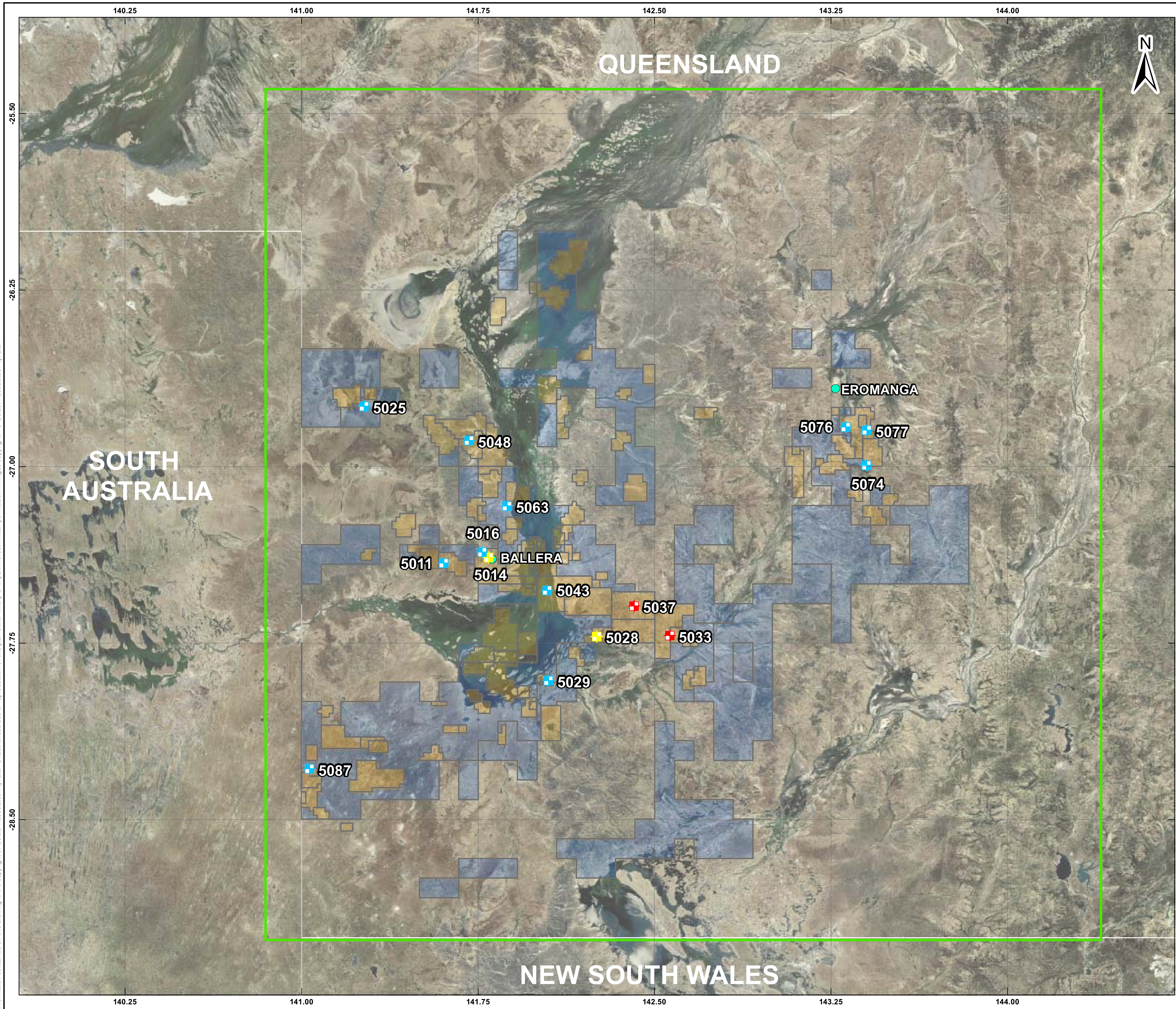
The 15 existing bores considered as network candidates meet certain minimal criteria, as follows:

- Criteria described in the WBBA.
- Contained water during WBBA fieldworks.
- Geographical location and proximity to production zones modelled in the UWIR to include the estimated IAA and LAA.
- Despite paucity of bore construction data, a bore’s potential to be screened in target aquifers or aquifers of interest.
- Ease of access and safety for monitoring and sampling purposes.
- Potential for network boreholes to undergo headwork improvement to provide future access for water level and/or water sampling equipment.

Table 4: Interim Santos Groundwater Monitoring Network

WBBA ID	Bore Name	DEHP RN	Santos Permit	Last Water Depth (m btoc) [1]	*Screen Interval (m)	*Depth (m)	Comments/ Possible Target Aquifer from DEHP [2]
5029	Keegan's Bore	-	PL 78	-	-	48	No DEHP data
5011	Palara Bore	6057	PL 59	-	No screen (open hole)	243.80	No DEHP data
5025	Fork Tree Bore	-	ATP 259P	-	-	123.4	No DEHP data
5074	Cherry Cherry Bore 1	6369	PL 39	-	No screen (open hole)	285.40	No DEHP data
5014	Ballera 2 Bore	23565	PL 61	-	No data	1518.5	Multiple to include Hutton SS (Hot bore water noted)
5016	Ballera 1 Bore	-	PL 61	31.86	-	89	No DEHP data
5037	Jackson 6A	23321	PL 23	-	No data	1265.2	No DEHP data
5043	Naccowlah West 4	50727	PL 25	-	Inconsistent data	92	Winton / Glendower Fm
5048	Barrolka Bore 2	-	PL 112	17.5	-	114	No DEHP data
5028	Irtalie 1	23570	PL 36	-	No data	1914.6	Hutton SS
5063	Durham Downs Bore R2	-	ATP 259P	-	-	60	No DEHP data
5077	Walla Wallan Bore 5	6373	PL 295	15.4	No screen (open hole)	156.7	Winton / Glendower Fm
5076	Tarbat Job No 1947	12036	PL 295	30.4	No data	209.8	Winton / Glendower Fm
5087	Grahams Bore	14955	PL 110	-	86.6 – 89.6	94.8	Winton / Glendower Fm
5033	Coothero Water Bore	-	PL 33	9.2	-	No Data	TBD

Footnotes:
1) btoc = below top of casing
2) From the DEHP Stratigraphy database and does not imply the bore is actually screened in this aquifer interval.
*Reported data from records including DEHP database, Queensland Digital Exploration Reports (QDEX) and historic documents and has not been measured in the field.



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INTERIM GROUNDWATER MONITORING PLAN
SANTOS COOPER BASIN OIL & GAS FIELDS, SOUTHWEST QUEENSLAND

SANTOS LTD

INTERIM GROUNDWATER MONITORING NETWORK

LEGEND

- Existing Water Bore - Possibly Screened In Tertiary Sediments - Winton Formation
- Existing Water Bore - Possibly Screened In Hooray Sandstone - Canda-Owie Formation
- Existing Water Bore - Possibly Screened In Hutton Sandstone
- Production Licence
- Exploration Permit
- Area of Interest
- Township

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Township data sourced from MapInfo Street Pro.

0 5 10 20 30 40 50 kilometres

SCALE (at A3) 1:1,750,000

Coordinate System: GCS GDA 1994

PROJECT: 127666003
DATE: 17 JUL 2012
DRAWN: KB
CHECKED: BC / DG

FIGURE 3

Golder Associates

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4.3.3 Monitoring Equipment and Methods

Monitoring requirements are to collect baseline data as a reference as to whether impacts similar to those predicted in the UWIR (Golder, 2012) (or otherwise) to the groundwater systems are occurring. Impacts will be assessed by comparing their magnitude with the background conditions and drawdown trigger thresholds. This GWMP is the second step in acquiring data to establish background conditions. The parameters considered for routine measurement are:

- Water level or piezometric head values; and
- Water quality parameters to include field measurements and laboratory analysis (see Table 5).

Where accessible with existing infrastructure, water level loggers (data loggers with pressure transducers) will be installed in the interim monitoring network bores. Data loggers will be installed at ground surface to record atmospheric pressure data. The data will be downloaded from each data logger during the scheduled quarterly groundwater monitoring event (GME). Where water level data loggers are not practical, a pressure gauge will be installed at the surface.

Where accessible, the interim groundwater network will have dedicated pumps installed in order to expedite GMEs and ensure better quality control of samples. Low flow bladder pumps (or similar) and accessories specified for saline and corrosive water environments will be installed.

The remaining bores will have water levels measured using manual water level probes during the scheduled quarterly GME.

A summary of monitoring methods is contained in Table 6, while further detail on sampling methods will be explained in a Work Plan, as described in Section 6.0.

4.3.4 Groundwater Quality Monitoring Suite

The UWIR defined standard monitoring suites including “Gases” and “Groundwater Base”. The purpose of these suites is to streamline groundwater monitoring and assist with consistency of the monitoring activities and collected dataset. During interim water monitoring activities, the groundwater baseline suite will be used to establish baseline conditions, consistent with the UWIR. Once a robust baseline is established and upon subsequent reviews of this GWMP, it may be considered reasonable to reduce the number of parameters measured, or conversely, expand the number of parameters measured, based on field observations or new information.

The groundwater baseline suite consists of a set of field water quality measurements taken with calibrated multi-parameter water quality meters, along with field observations to be made during routine monitoring. Field measurements will be used in conjunction with the laboratory analytical suite which includes a range of water chemistry analytes. This monitoring will enable the definition of the basic groundwater quality characteristics. Table 5 below lists the baseline monitoring suite:

Table 5: Monitoring Suites Analytes

Analytes
Colour
Gases (C1 – C4) (inc Methane)
Unionised Hydrogen Sulphide (not NATA Accredited)
Free and Total CO2
Free Chlorine
Bromide
Temperature
pH
Conductivity
Total Dissolved Solids
Alkalinity Total Alkalinity as CaCO3 Bicarbonate as CaCO3 Carbonate as CaCO3 Hydroxide as CaCO3
Chloride
Fluoride
Silica
Residual Alkali (calc)
Ionic Balance
Major Cations – Ca, Mg, Na, K
Major Anions – Cl, SO_4,
Sodium Absorption Ration (SAR)
Total Hardness (calc)
Reactive Phosphorus
Nitrite
Nitrate
Ammonia as N
Total Nitrogen (inc TKN/NOx)
Total Phosphorus as P
Total Organic Carbon
Dissolved Organic Carbon
Standard Plate Count (21°C & 36oC)
Sulfate reducing bacteria**
Hg
Total Metals (including digest) As, Ba, Be, Cd, Cr, Co, Cu, Mn, Ni, Pb, V, Zn
Additional Metals – Fe, Se, B, Sr, Al, Mo, Sn, U, Li
Ethanol
TPH(C6-C9) & TRH (C6-C10)/BTEX
TPH (C10-C36) & TRH (C10-C40)/PAH

The fieldwork methodology for gas and groundwater sample collection and a quality assurance and quality control will be included in a Detailed Work Plan, which will be developed prior to monitoring works.

Groundwater samples will be tested at a National Association of Testing Authority (NATA) approved laboratory.

4.3.5 Monitoring Frequency and Period

Starting after the GWMP has received approval by DEHP and during the interim 18 month period of its applicability, groundwater monitoring activities will be undertaken quarterly to collect a baseline dataset, with the monitoring frequency subject to later adjustment.

In a letter from Queensland Government, Energy Resources, Environment and Natural Resource Regulation Manager, Josh Lean, dated 8 May 2012; (*Direction to amend or modify an Underground Water Impact Report of Final Report*) to Santos, monthly 'monitoring' was requested. This interim GWMP proposes that quarterly groundwater quality, manual water level monitoring and download of automated recording will be more efficient and just as effective. This is based on outcomes of the predictive impact modelling conducted as part of the UWIR.

The Cooper-Eromanga Basin groundwater system is a slow acting hydrogeological system. In that regard, it has been modelled that groundwater level/pressure changes over a period of anything less than 3 months will not be meaningfully to measure. Potential impacts are calculated to be minimal, local, and slow in propagating through the aquifer systems, both laterally and vertically. The findings from the UWIR and historical monitoring data support this position.

Monitoring dates may vary, to capture potential seasonal influences. The following interim frequencies for water monitoring activities are as follows:

- Water levels (pressures):
  - Daily recording where automated recording is undertaken;
  - Quarterly for the interim period when manual recording and data collection is undertaken;
  - Longer Term: To be determined thereafter.
- Groundwater quality:
  - Quarterly for the interim period; and
  - Longer Term: To be determined thereafter.

If a trigger level for drawdown is exceeded a detailed response plan will be prepared that conforms to regulatory requirements with regards to verification and reporting, as outlined in Section 5.0.

NOTE: As impacts to underground water may continue over the life of Santos' petroleum activities, groundwater monitoring should be undertaken until after Santos provides a notice of closure for the petroleum tenements. The period of time for which groundwater monitoring will continue after tenement closure will depend on the outcomes from the future relevant UWIR.

4.3.6 Summary of Interim Water Monitoring Activity

The interim strategy includes interim water monitoring activities, as summarised in Table 6 below:

Table 6: Summary of Interim Water Monitoring Activities

WBBA ID	Bore Name	Manually Measure Water Level	Install Bladder Pump	Field Measure Water Quality	Collect Sample for Laboratory Testing	Install Automated Water Level Device	Comment
5011	Palara Bore	No	No	Quarterly	Quarterly	No	Windmill
5014	Ballera 2 Bore	No	No	No	No	No	Further inspection only. Hazard assessment of artesian hot water
5016	Ballera 1 Bore	Quarterly	Yes	Quarterly	Quarterly	Yes	-
5025	Fork Tree Bore	Quarterly	No	Quarterly	Quarterly	No	-
5028	Irtalie 1	No	No	Quarterly	Quarterly	No	-
5029	Keegan's Bore	Quarterly	Yes	Quarterly	Quarterly	Yes	Repair head works
5033	Coothero Water Bore	No	No	Quarterly	Quarterly	Yes	Install pressure gauge, data logger and fittings.
5037	Jackson 6A	No	No	No	No	No	Further inspection only.
5043	Naccowlah West 4 Bore	Quarterly	Yes	Quarterly	Quarterly	Yes	Fieldwork to modify head works
5048	Barrolka Bore 2	Quarterly	Yes	Quarterly	Quarterly	Yes	-
5063	Durham Downs Bore R2	Quarterly	Yes	Quarterly	Quarterly	No	Fieldworks to modify head works
5074	Cherry Cherry Bore 1	No	No	Quarterly	Quarterly	No	Windmill
5076	Tarbat Job No 1947	Quarterly	No	Quarterly	Quarterly	No	Windmill
5077	Walla Wallan Bore 5	Quarterly	No	Quarterly	Quarterly	No	Windmill
5087	Grahams Bore	Quarterly	No	Quarterly	Quarterly	No	-

- = no comment

5.0 REPORTING REQUIREMENTS

Water monitoring analytical data will be reviewed and analysed following each monitoring event on a quarterly basis. Groundwater Monitoring Assessment Reports will be submitted to Santos and DEHP annually as part of the “Annual Returns” obligations for monitoring data reporting.

Quarterly factual updates, which compare water level to drawdown trigger thresholds, will be prepared by qualified environmental and groundwater technical staff and submitted to Santos.

The **Annual Report** will also be prepared by qualified environmental and groundwater technical staff and peer reviewed by senior authorised, technical personnel. The Annual Report will address, at a minimum:

- A summary of the previous 12 months monitoring data with a comparison of the current data to previous results and drawdown trigger threshold levels and water quality guidelines;
- An evaluation/explanation of data from each monitoring location;
- Proposed changes to monitoring strategy, goals and changes to site conditions; and
- Action(s) proposed or taken to minimise the environmental risk from any trigger exceedance identified by the monitoring program.

Reporting of historical and recent formation pressure data and assessment of trends, as discussed in Section 4.2, will be undertaken by appropriately qualified staff and peer reviewed by senior authorised, technical personnel. This report will accompany the Annual Report.

5.1 Response Actions if Private Bore Impacts Occur

The Annual Report will, if applicable, also contain the response actions taken by Santos if the drawdown trigger threshold levels are exceeded that are determined to be the result of petroleum activities. If trigger thresholds are exceeded, the following actions will be implemented:

- Repeat sampling and/or field measurement to confirm the extent of drawdown or available water column;
- Identify the specific extent of the impact and the bore(s)s impacted;
- Establish whether the trigger level that has been exceeded has resulted in impairment of the bore function such that it is unfit for its intended purpose;
- Establish the primary and secondary factors contributing to the decrease in water levels;
- Provide written notification to each landowner and lessee/ occupier that is, has been or is reasonably likely to be affected by the event; and
- Provide written notification to DEHP.

5.2 Private Bore Impacts Confirmation

In the event that further assessment indicates a bore owner has been unduly impacted as a result of petroleum activities, either in terms of a significantly reduced bore yield (quantity), or degradation of water quality such that it is unsuitable for its intended use, the following “make good” actions will be considered in consultation with the bore owner and regulatory authorities, in order of preference:

- Re-setting the pump at a deeper level within the bore to access further available water column or replace the pump with a more efficient type;

- Installation of a replacement bore, if the condition of the original bore is such that reconditioning and/or deepening of the bore is not possible, or if an alternative location on a bore owner's property is less affected by operations;
- Provision of a replacement water supply of suitable quality to the bore owner to compensate for loss of yield in their water supply bore (this may be treated associated water); or
- Provide financial compensation to the bore owner, equivalent to the loss incurred due to the diminished bore yield or water quality (e.g. loss of agricultural productivity).

Alternative options may be available on a site-by-site basis, such as capping and piping of flowing artesian bores to increase water pressure. In general, Santos will negotiate with the bore operator and/ or the bore owner to establish a suitable course of action.

6.0 ADDITIONAL DOCUMENTS

Prior to groundwater sampling and monitoring field works, a Sampling and Analysis Plan (SAP) will be developed for the area of interest. The method of water sampling required will comply with that set out in the most recent version of the Department of Environment and Resource Management's (now DEHP) '*Monitoring and Sampling Manual 2009 – Environmental Protection (Water) Policy,* Version 2, September 2010" as amended from time to time.

Further guidance on groundwater and surface-water sampling protocols are contained in *Groundwater Sampling and Analysis – A Field Guide* (Geoscience Australia, 2009) and the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC 2000). The SAP will address the following topics:

- field methods procedure and QA/QC program;
- parameters to be measured;
- location of sampling points;
- field sampling procedures;
- sampling event logistics;
- site access requirements;
- laboratory data quality assurance and control plan; and
- Santos data management procedure for sample results.

To coordinate with the SAP, a Detailed Work Plan will be developed for fieldworks and will include the following elements:

- Health and Safety, Environment Plan

The health and safety, environment plan (HaSEP) for activities at the site will be developed in consultation with the Santos employees and contractors undertaking the work and forms part of the work plan. The HaSEP is a working document and is subject to continual review and update. The HaSEP will present general requirements for works at the site.

- Land Access Agreement

Santos previously compiled known bore ownership information during WBBA works. For future works, contact (by phone and email or letter) with land owners (if applicable) will be made indicating their borehole has been included in the groundwater monitoring network. If private bore owners agree to the use of their bores, then they will be notified when works are scheduled to be undertaken. Land access will be formally handled by Santos and activities will not be undertaken without prior landowner agreement. At a minimum, the plan will address the following items:

- Technical Specification (if required); when installing and operating field equipment.
- Completion of applicable permits to allow field works to lawfully proceed.
- Sampling team and training requirements.
- Logistics Plan to include mobilisation of staff, subcontractors, equipment and samples personnel.

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8.0 LIMITATIONS

This Document has been provided by Golder Associates Pty Ltd ("Golder") subject to the limitations in Appendix A.

Report Signature Page

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DG;BMC/MP;RKH;LJ/kp

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APPENDIX A

Limitations (LEG04 RL1)

LIMITATIONS

This Document has been provided by Golder Associates Pty Ltd ("Golder") subject to the following limitations:

This Document has been prepared for the particular purpose outlined in Golder's proposal and no responsibility is accepted for the use of this Document, in whole or in part, in other contexts or for any other purpose.

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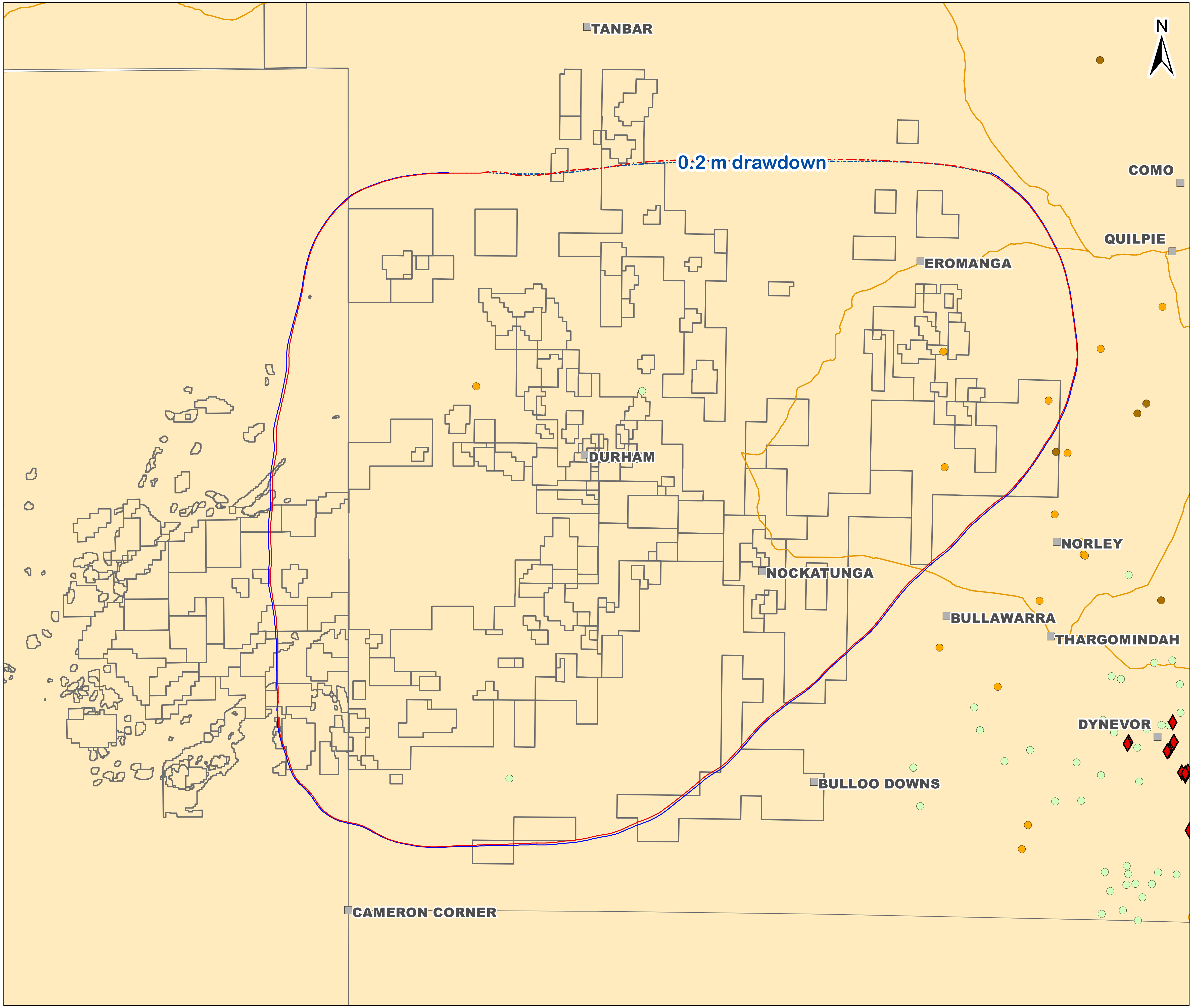
APPENDIX I

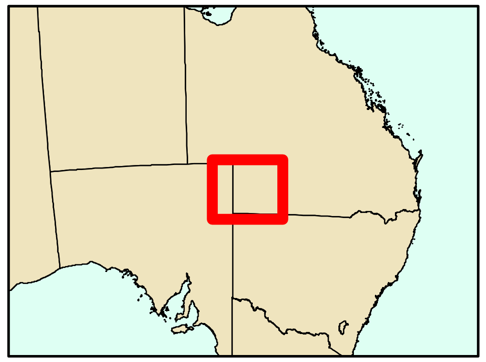
Maps Indicating the 0.2m Drawdown Trigger Threshold for Model Layers 3 and 4



UNDERGROUND WATER IMPACT REPORT OIL AND GAS FIELDS SWQ

SANTOS

IMMEDIATELY AND LONG TERM AFFECTED AREA - EROMANGA BASIN 0.2 M MODELLED GROUNDWATER DRAWDOWN IN LAYER 3



LEGEND

- GAB ROP Discharge Spring
- GAB ROP Recharge Spring

Long Term Affected Area

- 0.2 m drawdown contour

Immediately Affected Area

- 0.2 m drawdown contour

Private Bores

- Mackunda Formation
- Allaru Mudstone
- Wallumbilla Formation
- Town/Locality
- Highway/Major Road
- Santos Operated Permits

NOTES

Insert additional information here.

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0 5 10 20 30 40 50 Kilometers

SCALE (at A3) 1:1,500,000

Coordinate System: GDA 1994 MGA Zone 54

PROJECT: 117666006-033
DATE: 26/03/2013
DRAWN: HW
CHECKED: LJ

FIGURE 1

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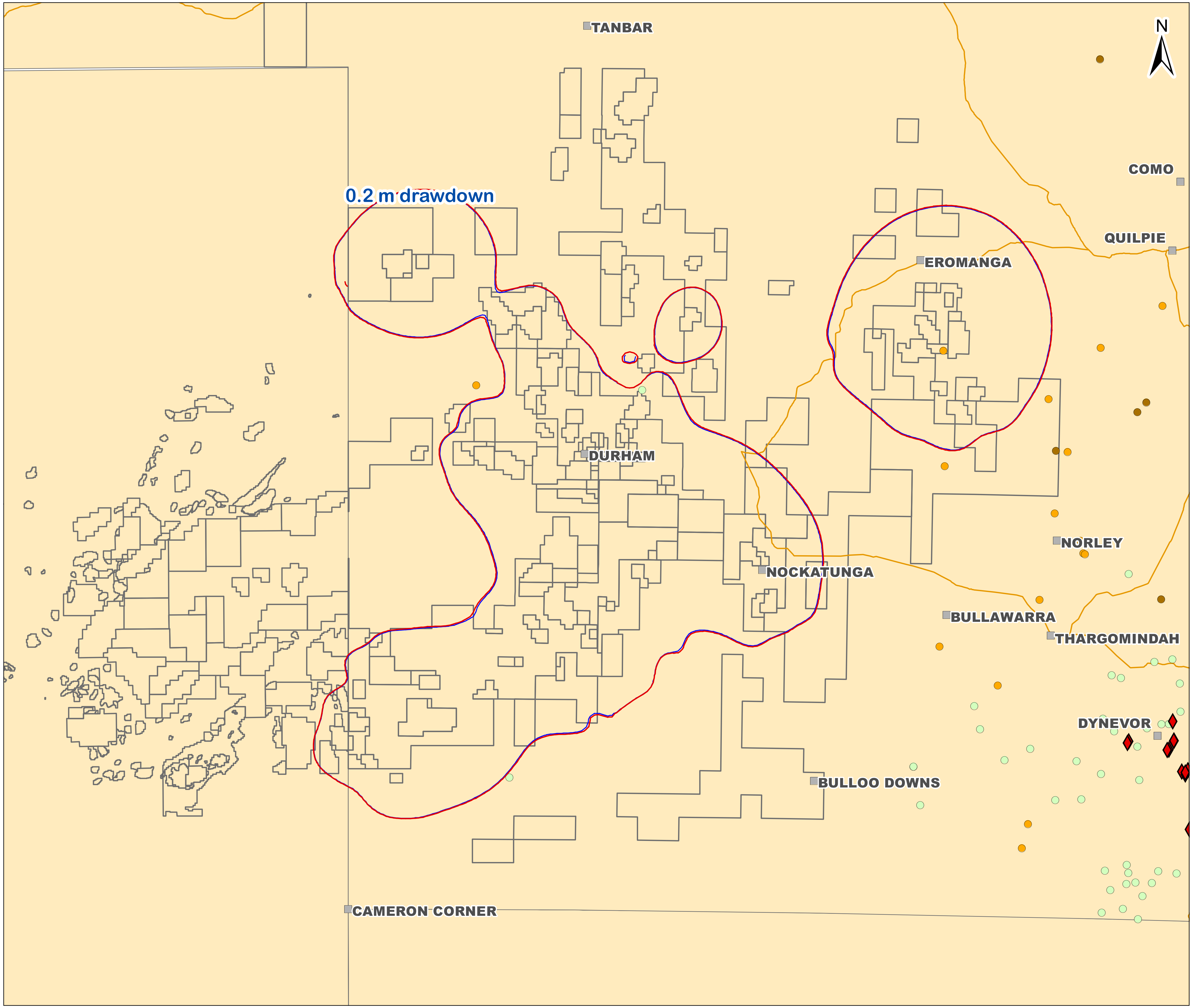

UNDERGROUND WATER IMPACT REPORT OIL AND GAS FIELDS SWQ

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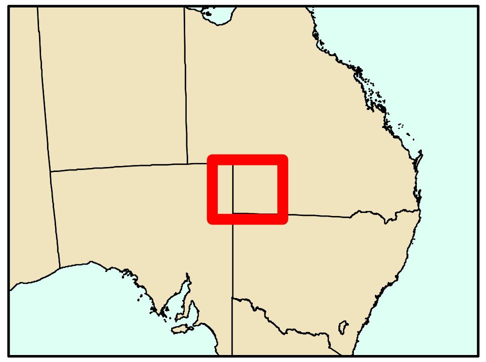
IMMEDIATELY AND LONG TERM AFFECTED AREA - EROMANGA BASIN 0.2 M MODELLED GROUNDWATER DRAWDOWN IN LAYER 4



LEGEND

GAB ROP Discharge Spring

GAB ROP Recharge Spring

Long Term Affected Area

0.2 m drawdown contour

Immediately Affected Area

0.2 m drawdown contour

Private Bores

Mackunda Formation

Allaru Mudstone

Wallumbilla Formation

Town/Locality

Highway/Major Road

Santos Operated Permits

NOTES

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0 5 10 20 30 40 50 Kilometers

SCALE (at A3) **1:1,500,000**

Coordinate System: GDA 1994 MGA Zone 54

PROJECT: **117666006-033**
DATE: **9/04/2013**
DRAWN: **HW**
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FIGURE 2

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Appendix B: South-West Queensland UWIR 2018 Annual Groundwater Monitoring Report, LBWCo (2019)

Appendix C: Underground Water Impact Reports for Santos' Cooper Basin Oil and Gas Fields, SW QLD (Santos, 2016)