Bengal Energy

Underground Water Impact Report

Cooper Basin Tenements

15 September 2022 – Issued for Public Consultation

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On behalf of Bengal Energy

Executive Summary

The *Water Act 2000* requires that tenure holders adequately manage the impacts of underground water extraction necessarily associated with petroleum appraisal and production. This Underground Water Impact Report (UWIR) has been prepared to satisfy the requirements of the *Water Act 2000* which requires that a UWIR is prepared, publicly notified and approved as triggered by the commencement of water production associated with petroleum extraction. This UWIR has been prepared to satisfy all information requirements required by statute, including:

- Information about underground water extraction resulting from the exercising of the petroleum tenure holder's underground water rights;
- Information about the aquifers affected, or likely to be affected;
- Maps showing the area of the affected aquifer(s) where underground water levels are predicted to decline;
- A water monitoring strategy; and
- A spring impact management strategy.

This UWIR relates to Bengal Energy's activities which have occurred and continue to occur in the Queensland portion of the Cooper Basin.

Bengal Energy holds seven permits which were acquired from Santos Ltd (or its subsidiaries) in 2021. Santos had prepared an Underground Water Impact Report (UWIR) for its Cooper Basin permits in 2013 and updated the UWIR in 2016 and 2019 which included the permits now operated by Bengal Energy. Bengal Energy undertook a review of its proposed activities in relation to the Santos (2019) UWIR in 2021 and found that the predicted drawdowns in Santos (2019) accurately represented its planned activities. This is the first UWIR prepared by Bengal Energy for its Cooper Basin permits.

This UWIR accounts for potential groundwater impacts by water production associated with:

- Historical and future gas extraction from the Wareena 1 and Wareena 5 wells in PL1110 from the Toolachee Formation, and
- Historical oil extraction from the Caracal 1 well in ATP732 from the Wyandra Member of the Cadna-Owie Formation

A multi-layered analytical model was constructed to predict water level decline of affected aquifers. Forecast water rates for the future production were based a gas water ratio used by the Bengal Energy reservoir engineers.

The model predictions were used to identify those areas where the predicted drawdown exceeded the bore trigger threshold (5 m) and spring trigger threshold (0.2 m) as defined in the *Water Act 2000*. No areas were identified in any formation where the bore trigger threshold was predicted to be exceeded in the next three years therefore there is no Immediately Affected Area (IAA). The Long Term Affected Area (LTAA) occurred due to historical activities only and was only applicable to the Toolachee Formation in which no active water supply bores were identified. No springs were identified within the spatial extents of the predicted spring trigger threshold exceedances. The spring trigger threshold was adopted to assess potential impacts to terrestrial groundwater

dependent ecosystems (GDE). The predicted drawdown did not propagate to the shallowest modelled aquifer in exceedance of the spring trigger threshold therefore there are no predicted impacts to terrestrial GDEs.

This UWIR presents a Water Monitoring Strategy (WMS) that will assist with improving current understanding of the gas production zone and its connection to the overlying groundwater system. As required by the *Water Act 2000*, monitoring locations, schedules and the parameters to be tested have been detailed in the WMS. Monitoring data will be provided to OGIA twice yearly.

A Spring Impact Management Strategy is not required as drawdown at the closest springs is not predicted to exceed the springs trigger threshold.

Drawdown maps will be reviewed annually.

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1 Introduction

Bengal Energy Limited (Bengal) is the operator of the following petroleum permits in the Cooper Basin region of Queensland:

- PL1140– Wareena
- PL1109 – Ghina
- PL188 – Ramses
- PL411 – Karnak
- ATP732 - Tookoonooka
- ATP934 – Barrolka
- PCA115 - Nubba

Bengal acquired the permits from Santos Ltd (or its subsidiaries) in 2021 (Bengal Energy, 2021). Santos prepared an Underground Water Impact Report (UWIR) for its Cooper Basin acreage in 2013 and updated the UWIR in 2016 and 2019 which included the permits now operated by Bengal. Bengal undertook a review of its proposed activities in relation to the Santos (2019) UWIR in 2021 and found that the predicted drawdowns in Santos (2019) accurately represented its planned activities.

This is the first UWIR prepared by Bengal for its permits.

1.1 Project Description

Bengal's Cooper Basin tenements are shown on Figure 1.

Bengal's aim is to commercialise historically stranded gas resources through investment in pipeline infrastructure and exploration, appraisal and development drilling.

Historical and planned activities for each permit are summarised in Table 1.

1.2 Water production volumes

Bengal exercises its underground water rights through the extraction of underground water associated with oil and gas production. Bengal has estimated historical water extraction using a gas to water ratio, with monthly water production rates and cumulative volumes show on Figure 2. To 30 June 2022, 20.8 ML of water has been produced from Bengal's permits. The majority of the water was produced in the period June 2011 through July 2014 from Wareena 1 and Wareena 5. Caracal 1 was on production for April and May 2022 and produced less than 1 cubic meter of water during this time.

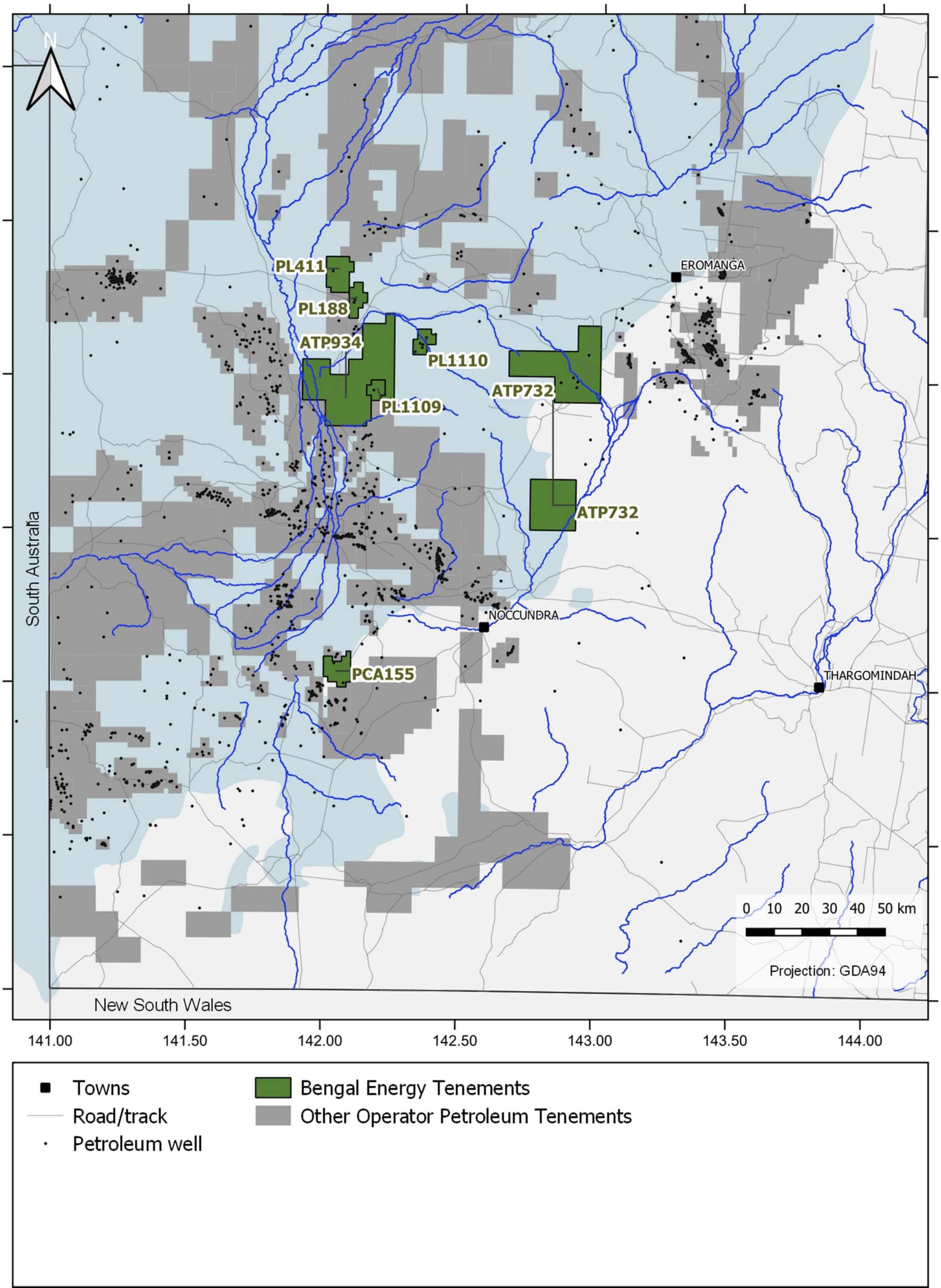
Bengal intends to continue to exercise its underground water rights through the extraction of water from the planned activities. Estimates of the future volume of underground water that will be produced is provided in Section 5.1

Table 1 Historical and future production activities

Tenement	Associated Wells	Historical production activities	Historic Water Production (ML)	Future production activities*	Target Formation
PL1110 (PL114[!])	Wareena 1 Wareena 5	Gas production from Wareena 1 and Wareena 5 wells. Production ceased in 2014	20.8	Recommence gas production from 2023	Toolachee Formation
PL1109 (PL157[!])	Ghina 1	No current or historical production	0	Potential extended production test on Ghina 1 (not expected to commence within current reporting period)	Toolachee Formation
PL188	Ramses 1	No current or historical production	0	No planned production	Toolachee Formation, Patchawarra Formation
	Ramses 2	No current or historical production	0	Potential future extended production test on Ramses 2, with commencement of commercial oil production if successful (not expected to commence within current reporting period)	Toolachee Formation, Patchawarra Formation Poolowanna Formation (oil)
PL411	Karnak 1	No current or historical production	0	No planned production	Toolachee Formation
PCA155	Nubba 1	No current or historical production	0	No planned production	Toolachee Formation
ATP732	Caracal 1	No current production	0.01	No planned production	Wyandra Member (Cadna-Owie Formation)
ATP934	No wells	-	-	-	-

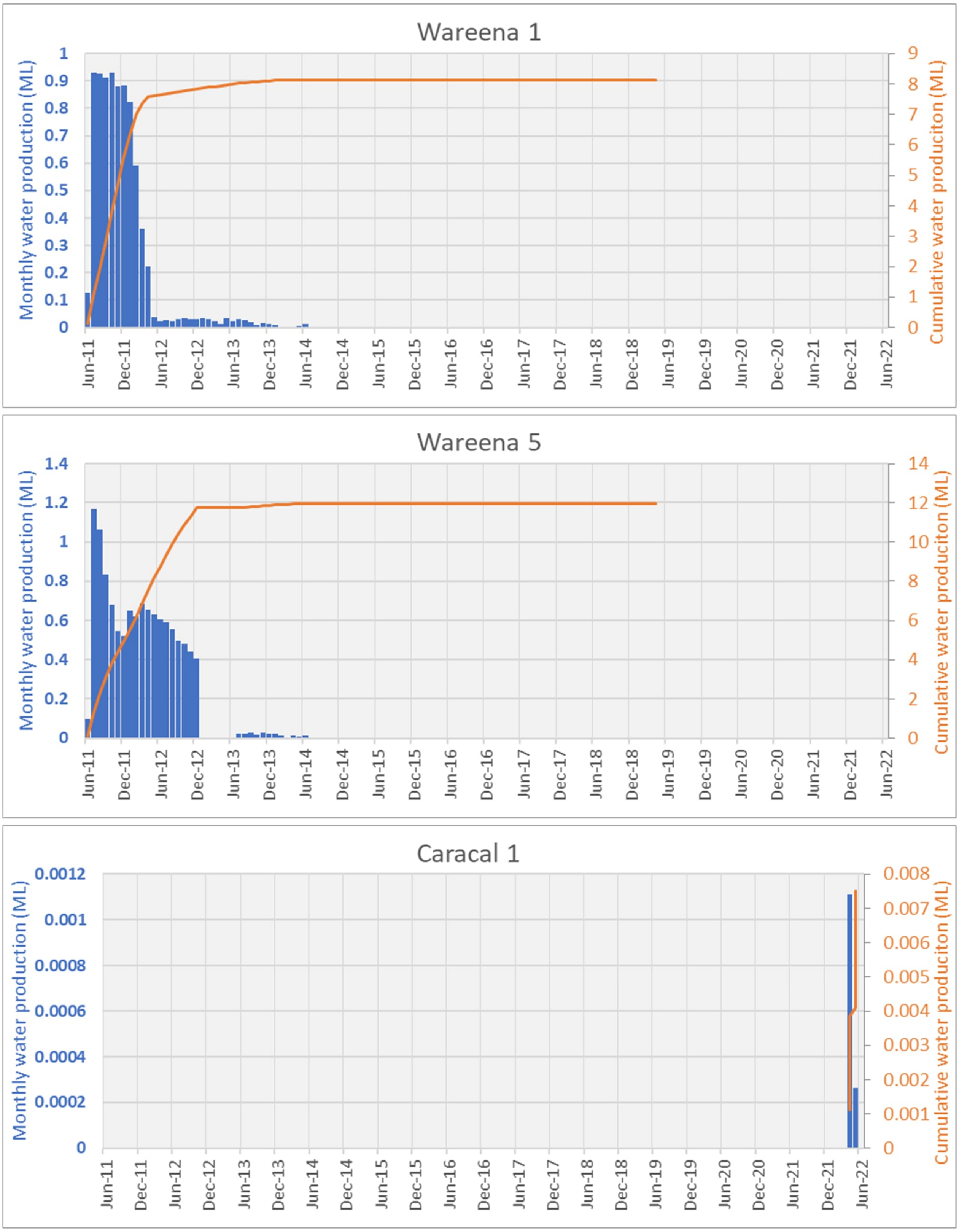
*for the period 16 December 2020 to 15 December 2025
[!] tenement number under the Petroleum Act 1923

Figure 1 Location of Bengal's Cooper Basin tenements



Data source: State of Queensland (2022)
QLD_Cooper_GDA94_Z54.qgz - BengalUWIR2022_LocationLayout

Figure 2 Historic water production volumes



2 Legislation and Regulation

Primary Queensland legislation that governs the management of resources, including groundwater, with respect to petroleum and gas extraction, is summarised below.

2.1 Petroleum and Gas (Production and Safety) Act 2004

The *Petroleum and Gas (Production and Safety) Act 2004* legislates for the safe and efficient exploration for, recovery of and transport of petroleum and fuel gas.

The Act establishes underground water rights for petroleum tenure holders. This allows the tenure holder to take or interfere with underground water in the spatial extent of the tenure if that interference or take occurs while undertaking another authorized activity for the tenure. There is no volumetric limit to the amount of water that may be taken, however the tenure holder is subject to the provisions of Chapter 3 of the *Water Act 2000*. The associated water can be used for any authorized purpose, within or off tenure.

2.2 Water Act 2000

The primary purpose of the *Water Act 2000* is to provide a framework for the sustainable management of Queensland's water resources, including the management of impacts on groundwater caused by the exercise of underground water rights by the resource sector. It is intended to:

- Sustain the health of ecosystems, water quality, water-dependent ecosystems and biological diversity;
- Recognise the interests of Aboriginal people and Torres Strait Islanders;
- Enable fair access to water resources in support of economic development; and
- Promote the efficient use of water.

The *Water Act 2000* vests all rights to the control of water in Queensland to the State, and the State may authorise the use of water through a number of instruments, including legislation, allocations, licenses, and permits. The sustainable use of water is managed through the preparation and implementation of water plans and water use plans, with processes for releasing unallocated water identified in a water management protocol.

Chapter 3 of the *Water Act 2000* provides for the management of impacts on underground water (groundwater) due to the exercise of underground water rights by resource tenure holders. It provides a regulatory framework that requires a resource tenure holder to:

- Monitor and assess the impacts of groundwater extraction associated with resources extraction on water bores and springs;
- Prepare underground water impact reports that establish obligations to monitor and manage impacts on aquifers and springs;
- Manage the cumulative impacts due to the exercise of two or more resource tenure holders' underground water rights; and

- Enter make good agreements with owners of bores impacted by the exercise of underground water rights.

With respect to petroleum and gas production, Chapter 3 of the Water Act 2000:

- Identifies the obligations of producers in relation to groundwater monitoring, reporting, impact assessment and management of impacts on other water users;
- Provides a framework and conditions for preparing a Baseline Assessment Plan and outlines the requirements of bore owners to provide information that the petroleum tenure holder reasonably requires to undertake a baseline assessment of the relevant bore;
- Sets out the process for assessing, reporting, monitoring, and negotiating with other water users regarding the impact of petroleum production on aquifers.
- The management of impacts on groundwater caused by the exercise of groundwater rights by petroleum tenure holders is achieved by providing a regulatory framework that requires:

    - Petroleum tenure holders to monitor and assess the impact of the exercise of underground water rights on water bores and to enter into "make good" agreements with the owners of the bores;
    - The preparation of UWIRs that establish underground water obligations, including obligations to monitor and manage impacts on aquifers and springs.

The Queensland Government's Office of Groundwater Impact Assessment (OGIA) is responsible for managing these requirements in a declared cumulative management area. Outside of the cumulative management areas, individual tenure holders are responsible. The requirements of a UWIR are specifically identified in the *Water Act 2000*. These requirements, and the conformance of this UWIR to those requirements, are identified in Table 2.

An UWIR will identify whether an Immediately Affected Area or Long Term Affected Area will result from the exercise of underground water rights. An Immediately Affected Area (IAA) is defined as an area where the predicted decline in water level within 3 years is greater than the bore trigger threshold. A Long Term Affected Area (LTAA) is defined as the area where bore trigger thresholds are exceeded at any time. The *Water Act 2000* defines the trigger thresholds as:

- Bore trigger threshold - 5 m for a consolidated aquifer;
- Bore trigger threshold - 2 m for an unconsolidated aquifer; and
- Spring trigger threshold - 0.2 m

UWIRs are published to enable the community, including bore owners and other stakeholders, within the relevant area, to make submissions on the UWIR. These submissions are then required to be summarised by the petroleum tenure holder and submitted with the UWIR to DES for approval. The UWIR must then remain available on the petroleum tenure holder's website.

Table 2 Requirements of a UWIR (*Water Act 2000*)

Reporting requirements	Underground Water Impact Report Guidelines (DES, 2021)	Section(s) of this UWIR
Section 376		
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; and	PART A UNDERGROUND WATER EXTRACTION	Section 1.2 Figure 2
(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 5.1 Figure 25
For each aquifer affected, or likely to be affected, by the exercise of the relevant underground water rights – (i) A description of the aquifer, and	PART B AQUIFER INFORMATION AND UNDERGROUND WATER FLOW	Section 3
(ii) an analysis of the movement of underground water to and from the aquifer, including how the aquifer interacts with other aquifers; and		
(iii) an analysis of the trends in water level change for the aquifer because of the exercise of the rights mentioned in paragraph (a)(i); and		
(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 mentioned in paragraph (a), by more than the bore trigger threshold within 3 years after the consultation day for the report; and	PART C PREDICTED WATER LEVEL DECLINES FOR AFFECTED AQUIFERS	Figure 29
(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		Figure 30
a description of the methods and techniques used to obtain the information and predictions under paragraph (b);		Section 5.1
a summary of information about all water bores in the area shown on a map mentioned in paragraph (b)(iv), including the number of bores, and the location and authorised use or purpose of each bore;		Table 7 Figure 23
(da) a description of the impacts on environmental values that have occurred, or are likely to occur, because of any previous exercise of underground water rights;		Section 5.3
(db) a description of the impacts on environmental values that have occurred, or are likely to occur, because of the exercise of underground water rights- (i) during the period mentioned in paragraph (a)(ii); (ii) over the projected life of the resource tenure;		Section 5.3
a program for – (i) conducting an annual review of the accuracy of each map prepared under paragraph (b)(iv) and (v); and		Section 6.4
(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;		Section 6.4
a water monitoring strategy;	PART D WATER MONITORING STRATEGY	Section 6.1
a spring impact management strategy;	PART SPRING IMPACT MANAGEMENT STRATEGY	Section 6.2
if the responsible entity is the office – (i) a proposed responsible tenure holder for each report obligation mentioned in the report; and		Not applicable
(ii) for each immediately affected area – the proposed responsible tenure holder or holders who must comply with any make good obligations for water bores within the immediately affected area;		Not applicable
other information or matters prescribed under a regulation		Not applicable
Section 378		

1) A responsible entity's water monitoring strategy must include the following for each immediately affected area and long-term affected area identified in its underground water impact report or final report— a) a strategy for monitoring— i) the quantity of water produced or taken from the area because of the exercise of relevant underground water rights; and ii) changes in the water level of, and the quality of water in, aquifers in the area because of the exercise of the rights;	PART D WATER MONITORING STRATEGY	Section 6.1
(b) the rationale for the strategy;		Section 6.1
(c) a timetable for implementing the strategy;		Section 6.1
(d) a program for reporting to the office about the implementation of the strategy.		Section 6.1
(2) The strategy for monitoring mentioned in subsection (1)(a) must include— (a) the parameters to be measured; and		Section 6.1
(b) the locations for taking the measurements; and		Section 6.1
(c) the frequency of the measurements.		Section 6.1
(3) If the strategy is prepared for an underground water impact report, the strategy must also include a program for the responsible tenure holder or holders under the report to undertake a baseline assessment for each water bore that is— (a) outside the area of a petroleum tenure; but		Not applicable
(b) within the area shown on the map prepared under section 376(b)(v).		Not applicable
(4) If the strategy is prepared for a final report, the strategy must also include a statement about any matters under a previous strategy that have not yet been complied with.		Not applicable

3 Hydrogeological Setting

3.1 Topography and drainage

The tenements are located within the Copper Creek drainage basin. The topography in the vicinity of the tenements is relatively flat, ranging in elevation from roughly 190 mAHD in the east, and around 80 mAHD in the vicinity of Cooper Creek (Figure 3). Cooper Creek is on the western extent of the tenement extent.

Cooper Creek flows to the south and discharges to Lake Eyre in South Australia. The channel system is highly anastomosing and reaches in excess of 40 km wide in parts. Cooper Creek and all of its tributaries are ephemeral with streamflow varying greatly between years from almost no flow to significant flooding.

3.2 Geology

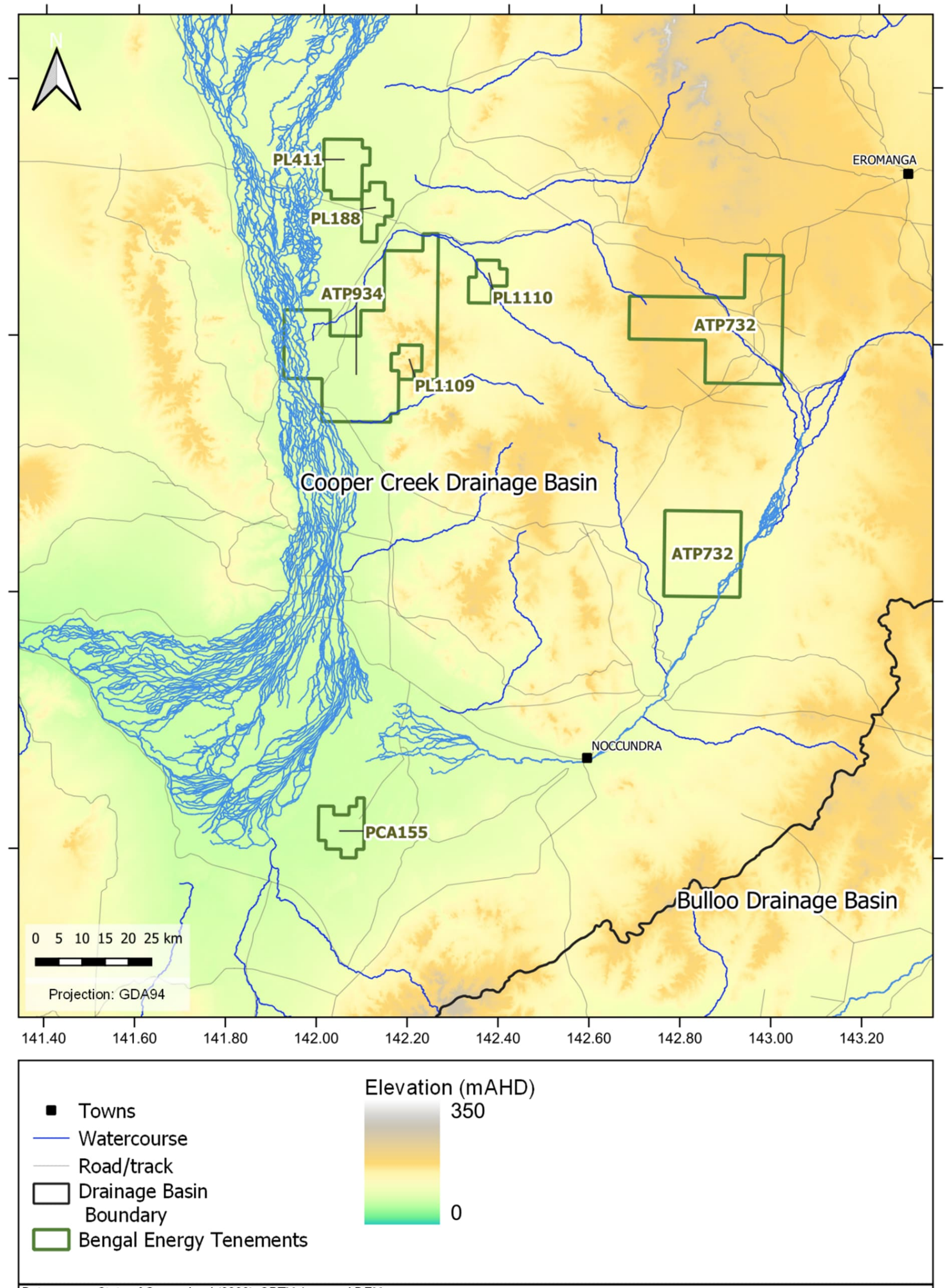
Bengal's tenements are located in the Queensland portion of the Cooper Basin. The Jurassic-Cretaceous aged Eromanga Basin unconformably overlies the Carboniferous-Permian Cooper Basin. Overlying the Eromanga Basin are Tertiary-aged, consolidated sediments of the Lake Eyre Basin and Quaternary-aged surficial deposits generally associated with drainage lines (Figure 4). The Eromanga Basin is a constituent basin of the Great Artesian Basin (GAB), which outcrops as the Winton Formation where not covered by the Tertiary or Quaternary sediments (Figure 4).

A regional stratigraphic column and associated lithologies presented in Table 4 and cross-sections based on well completion report stratigraphic interpretations are presented as Figure 5.

The Cooper Basin comprises non-marine sedimentary lithologies at depths of 1,000 m to 4,500 m below ground level (mGL). It is completely covered by the Eromanga Basin and therefore does not outcrop. The Tirrawarra Sandstone, Patchawarra Formation, Epsilon Formation and Toolachee Formation are the main gas producing formations in the Cooper Basin (Santos, 2019). The Cooper Basin is of lesser spatial extent that the Eromanga Basin, and pinches out within the northern to central portions of the northern block of ATP732.

The Eromanga Basin comprises a succession of alternating sandstones, siltstones and mudstones. The sandstone-dominated formations are generally considered as aquifers on a regional scale and the siltstone and mudstone dominated formations are generally considered to be aquitards. The major oil producing formations of the Eromanga Basin are the Hutton Sandstone, Birkhead Formation and Murta Formation (Namur Sandstone), with lesser oil production from the Cadna-Owie Formation (Wyandra Sandstone Member), Westbourne Formation, Adori Sandstone, and Lower Poolowanna Formation (Santos, 2019).

Figure 3 Topography and drainage



Data source: State of Queensland (2022); SRTM 1 second DEM
QLD_Cooper_GDA94_Z54.qgz - Bengal UWIR2022 Topography and Drainage

Table 3 Stratigraphic depths for relevant Bengal Energy wells

Unit	Depth (mRT)					Average Thickness (m)
	Karnak 1	Ramses 1	Ramses 2	Wareena 1	Wareena 5	
Winton Formation	0	0	0	0	0	169
Mackunda Formation	NA	NA	NA	NA	169	165
Allaru Mudstone	NA	NA	1061	NA	333	201
Toolebuc Formation	1386	1249	1280	NA	516	27
Wallumbilla Formation	1393	1275	1300	NA	572	368
Cadna-Owie Formation	1759	1668	1681	NA	902	232
Murta Formation	1855	1761	1768	978	992	57
Namur Sandstone	1908	1798	1854	1007	1072	84
Westbourne Formation	1989	1899	1913	1121	1136	119
Adori Sandstone	2105	2019	2026	1248	1253	24
Birkhead Formation	2136	2044	2047	1264	1279	84
Hutton Sandstone	2233	2132	2140	1333	1352	159
Poolowanna Formation	2393	2290	2296	1471	1533	459
Toolachee Formation	2941	2807	2801	1865	1866	54
Patchawarra Formation	2989	2854	2868	NP	NP	112
Basement	3099	2945	3004	1897	1911	-

mRT = meters below rotary table NA = not available NP = not present

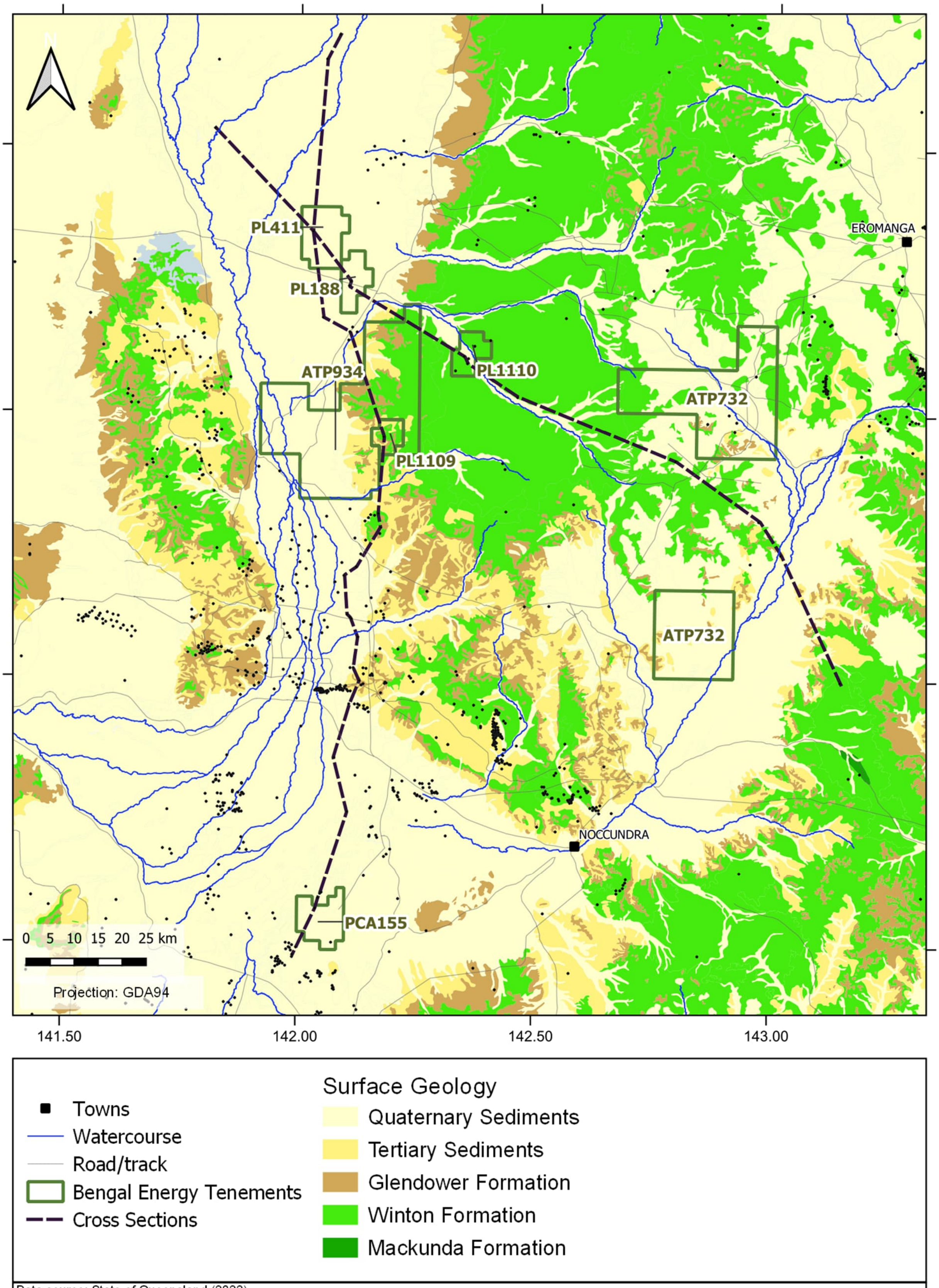
Table 4 Regional stratigraphic column with lithological descriptions

Basin	Age	Stratigraphic Unit	Lithological description	Depositional Environment
NA	Quaternary	Qa-QLD	Clay, silt, sand and gravel; flood-plain alluvium - undifferentiated	Fluvial
		Q-CER	Alluvium of older flood plains, sand, gravel, soil	Fluvial
Lake Eyre	Tertiary	Glendower Formation	Consolidated sandstones, sandy siltstones and minor conglomerate and mudstones (fluvial)	Fluvial
Eromanga	Late Cretaceous	Winton Formation	Interbedded, fine to coarse sandstone, carbonaceous and pyritic shale, siltstone and coal seams. Abundant fresh volcanogenic debris, lithics, felspar and traces of apatite, ferromagnesian minerals and mica	Fluvio-lacustrine
	Early Cretaceous	Mackunda Formation	Fine grained sandstone with calcareous matrix (white to light grey), argillaceous siltstone, occasionally pyritic near base	Cycles of deep-water marine to shoreface
		Allaru Mudstone /Oodnadatta Formation	Laminated claystone and siltstone with interbedded fine-grained sandstone. Lower section contains calcareous- ferruginous concretions, calcareous siltstone and fossiliferous concretionary limestone	Shallow marine
		Toolebuc Formation	Laminated calcareous and kerogenous mudstone, minor coquinite and limestone, labile sandstone and oil shale	Marine
		Coorikiana Sst	Fine grained sandstones with calcareous matrix (white to light green to grey) interbedded with brown-grey siltstones. Common accessory Glauconite	Regressive marine shoreface
		Bulldog Shale	Series of upward coarsening siltstones and fine-grained sandstones. Common basal glauconitic sandstones and disseminated pyrite in the upper half	Shallow to moderately deep open marine
		Cadna-Owie Formation	Wyandra Sst Member - Fine grained, clay rich sediments to fine calcareous sandstones with minor limestone and occasional bioturbation	Lowstand: shallow marine
			Lower Cadna-Owie - Pale grey sandstone, siltstone, calcareous sandstone and pebbly sandstone, some feldspathic intraformational conglomerate; thin coaly layers, dark mudstone, layers of kaolin-like material, possibly altered tuff	Transgressive: terrestrial to shallow marine
		Murta Formation	Interbedded and interlaminated sandstone, silty sandstone, siltstone and lesser mudstone, intraformational conglomerate and coal	Meandering: floodplain & lacustrine
	Mid to Late Jurassic	Namur Sst / Hooray Sst	Fine to medium grained sub labile quartzose sandstone and thin interbedded siltstone with disseminated fine carbonaceous fragments / medium- to coarse-grained, quartzose sandstone, commonly cross bedded and pebbly; minor siltstone, conglomerate, coal.	High energy, braided with intervening lower energy, distal floodplain
		Westbourne Formation	Interbedded siltstone, mudstone and minor lenses of fine grained quartzose sandstones. Occasional laterally discontinuous coal seams	Lacustrine
		Adori Sst	Fine- to medium-grained clayey sandstone and minor pebbly sandstone and siltstone	High energy braided fluvial

Basin	Age	Stratigraphic Unit	Lithological description	Depositional Environment
		Birkhead Formation	Carbonaceous and sideritic, bioturbated siltstone and mudstone interbedded with fine to coarse-grained volcanolithic sandstones and laterally discontinuous coal seams	Meandering fluvial
		Hutton Sst	Series of upward fining medium to coarse grained stacked channel sandstones, with conglomeratic bands. Minor siltstone and mudstone beds	High energy braided fluviatile system
	Early Jurassic	Poolowanna Formation	Fine to medium, quartz dominated sandstone and interbedded siltstone, with laterally discontinuous coals seams in the upper part	Meandering fluvial
Cooper	Late Permian	Toolachee Formation	Stacked, fining up sequences of fine to coarse grained well cemented sandstones, dark grey siltstone, carbonaceous shale and channel capping coal seams	Low energy meander belt to lacustrine facies
	Mid Permian	Epsilon Formation	Fine- to medium-grained sandstone interbedded with carbonaceous siltstone, shale and coal	Aggradational lacustrine delta
		Murteree Shale	Siltstone with minor fine-grained sandstone	Deep lacustrine
	Early Permian	Patchawarra Formation	Basal unit of carbonaceous siltstone with minor sandstone and thin coal seams, transitioning to more sandstone dominated with thicker coal seams and shale interbeds. Upper unit predominantly siltstone and shale with minor sandstone interval.	High-sinuosity fluvial system flowing over a floodplain with peat swamps, lakes, and gentle uplands
		Basement	Granodiorite and metasediments	

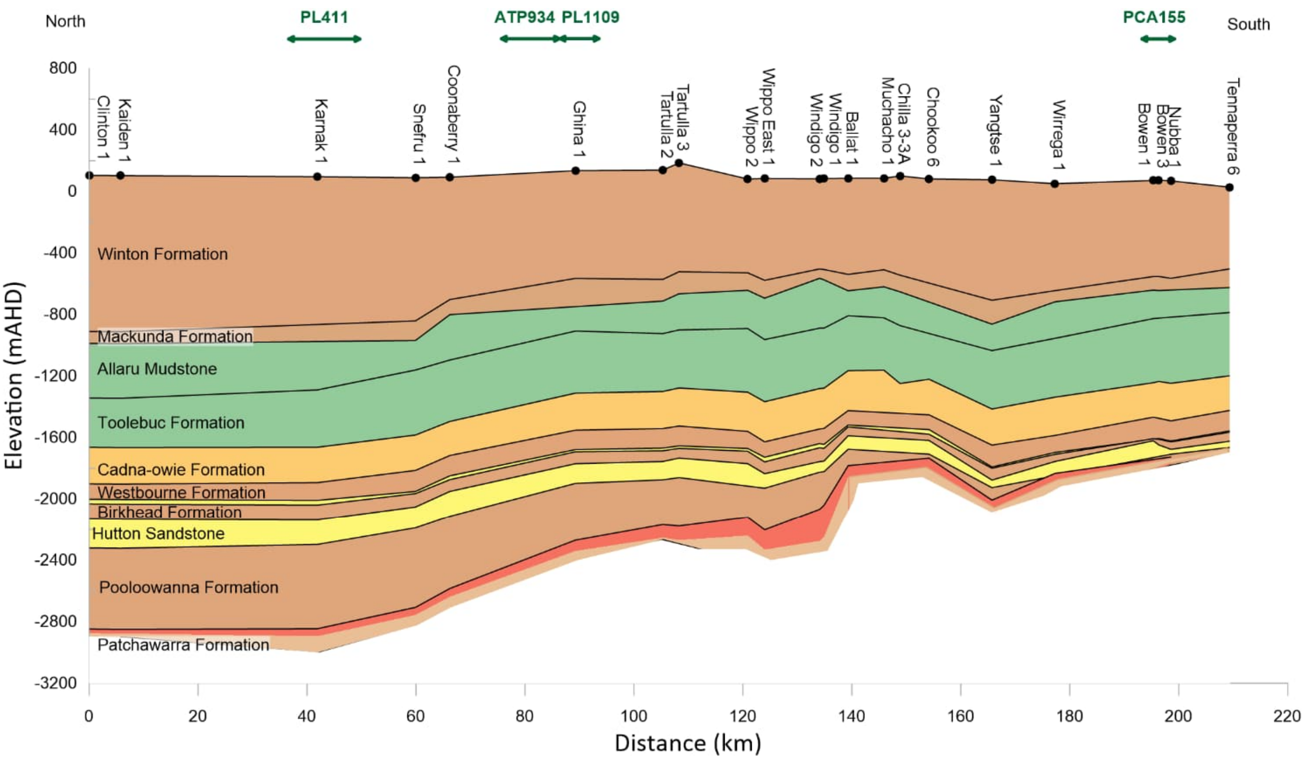
Aquifer　　Aquitard

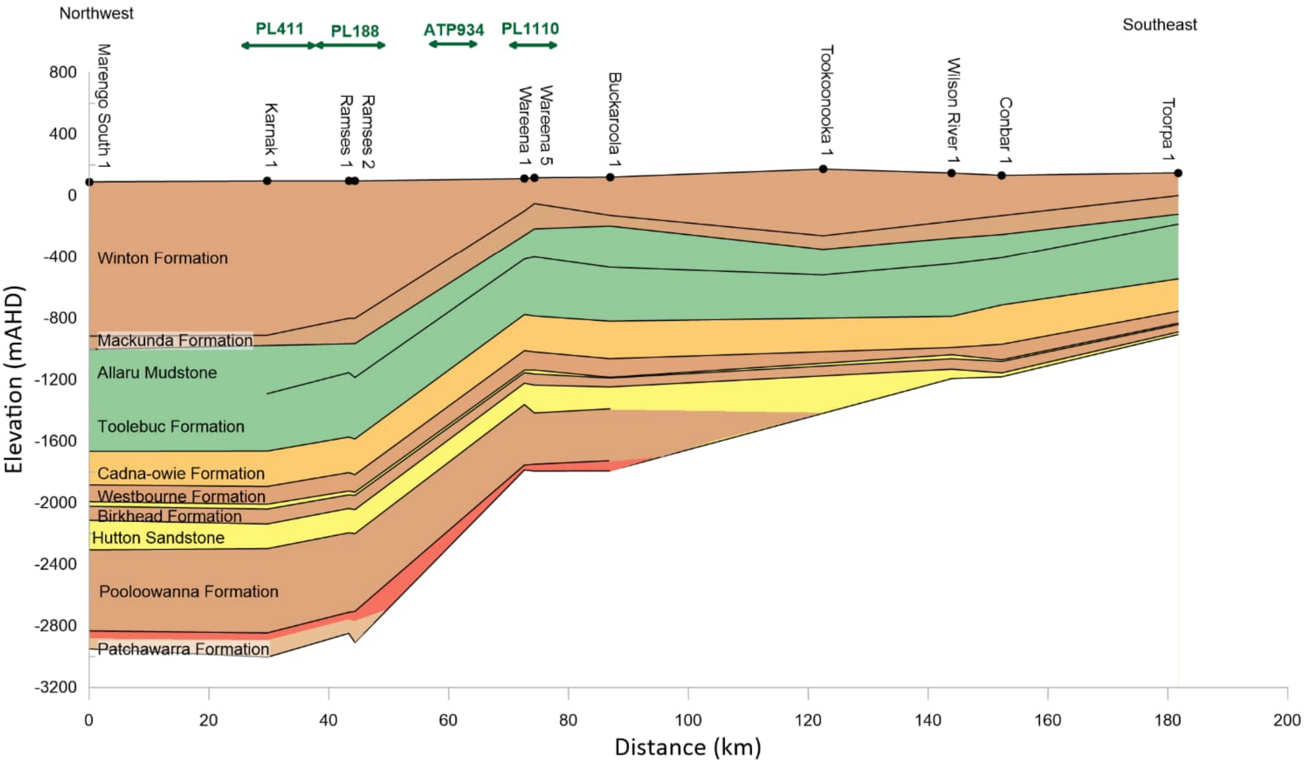
Figure 4 Surface Geology



Data source: State of Queensland (2022)
QLD_Cooper_GDA94_Z54.qgz - BengalUWIR2022 Surface Geology

Figure 5 Stratigraphic cross-sections (locations shown on Figure 4)





3.3 Hydrostratigraphy

Stratigraphic units form alternating layers of sandstone aquifers and siltstone/mudstone aquitards on a regional scale. GABORA divides the GAB formations into groundwater units to enable administration of access to water and water entitlements. Schedule 3 of GABORA identifies the geological formations associated with each groundwater unit. This subdivision is summarised in Table 5

The shallowest formation of the Eromanga Basin is the Winton Formation and is hydraulically contiguous with the underlying Mackunda Formation. The Winton Formation is the most economically significant aquifer due to its shallow depth and ease of access for landholder use. Claystones and shales within the Winton Formation form internal baffles, which separate the Winton Formation/Mackunda Formation aquifer system from overlying and undifferentiated, poorly consolidated Tertiary sediments of the Lake Eyre Basin. Evans et al. (2020) recognise the Winton-Mackunda to be more complex and compartmentalised than what has generally been conceptualised and they consider these formations a partial aquifer.

The Wyandra Sandstone Member is an aquifer within the Cadna-Owie Formation, sealed off from the Namur Sandstone (Hooray Sandstone equivalent) aquifer, by the regionally extensive Murta Formation. While the Murta Formation contains sandstone which are productive for oil, and therefore potentially water, these sandstones are unlikely to be laterally extensive and in a regional context, the Murta Formation is conceptualised as an aquitard. While the Cadna-Owie Formation is a significant aquifer elsewhere in the GAB, it is relatively poorly developed in the Cooper Basin region.

The Birkhead Formation, forms a low transmissivity partial aquifer to aquitard between the Hutton and Adori Sandstone aquifers, showing high variability in its hydraulic properties across the basin. These three aquifers are hydraulically separated from the Namur Sandstone by the overlying regionally extensive Westbourne Formation aquitard.

The Hutton Sandstone is a highly transmissive aquifer that is extensively exploited for the oil accumulations across the region.

The Early Jurassic Poolowanna Formation is conformable with the overlying Mid-Late Jurassic Hutton Sandstone and is considered an aquifer with lower hydraulic conductivity than the Hutton Sandstone, but intraformational siltstones and shales can form effective seals between the two formations.

The Toolachee Formation, the target of Bengal’s gas production, is part of the Permian-aged Cooper Basin and is not included in GABORA.

3.4 Recharge and Discharge

Recharge into the GAB aquifers occurs predominantly where they outcrop along the western slopes of the Great Dividing Range, located over 500 km to the northeast of the Cooper Basin region. Recharge via interformational flow is likely to be only a minor recharge mechanism as horizontal flow is expected to dominate.

In the southern Eromanga basin, gravity driven groundwater flow is to the south and south-west continuing to the western margins of the Eromanga Basin, where the groundwater discharges via springs.

Surficial Quaternary and Tertiary aged sediments are recharged from localised sources such as streamflow during flood events. Discharge is likely to be via baseflow to the creek lines after significant rainfall events and via evapotranspiration.

Table 5 Hydrostratigraphy and groundwater sub-areas (after GABORA)

Stratigraphic Unit	Groundwater Unit
Glendower Formation (Tertiary Sediments)	-
Winton Formation	Winton Mackunda South
Mackunda Formation	
Allaru Mudstone (Oodnadatta Formation)	
Wallumbilla Formation	Eromanga Wallumbilla (Rolling Downs)
Cadna-Owie Formation – Wyandra Sandstone	Eromanga Cadna-Owie
Cadna-Owie Formation – Lower	
Murta Formation	Eromanga South Hooray
Namur Sandstone (Hooray Sandstone equivalent)	
Westbourne Formation	Adori Injune Creek
Adori Sandstone	
Birkhead Formation	
Hutton Sandstone	Eromanga Hutton
Poolowanna Formation	

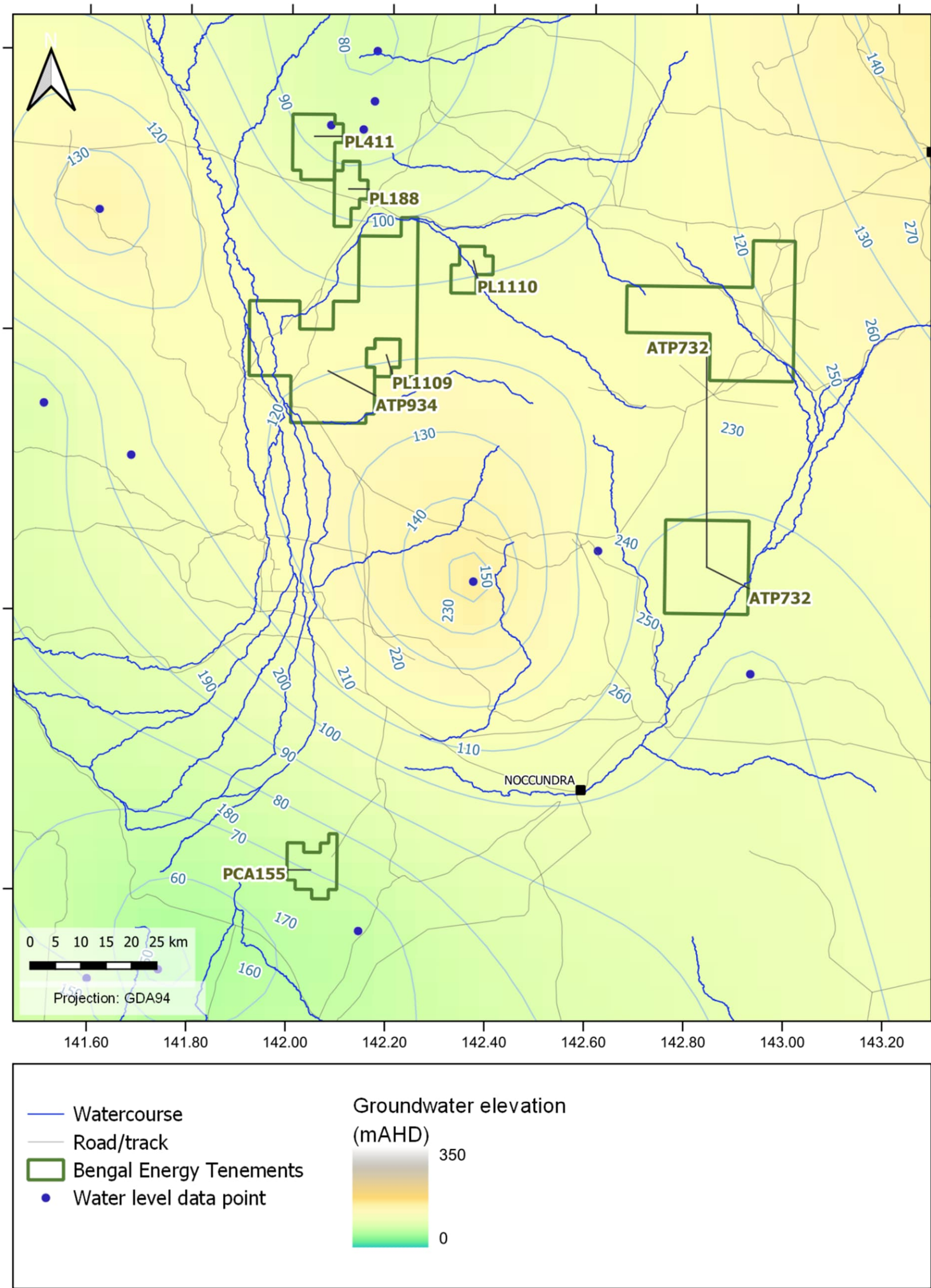
3.5 Groundwater levels

3.5.1 Spatial trends

Potentiometric surfaces have been prepared for the Tertiary Sediments (Figure 6), Winton Formation (Figure 7) and Namur/Hooray Sandstone (Figure 8) using water level data from the GWBD. There was insufficient data to generate potentiometric surfaces for any other formations.

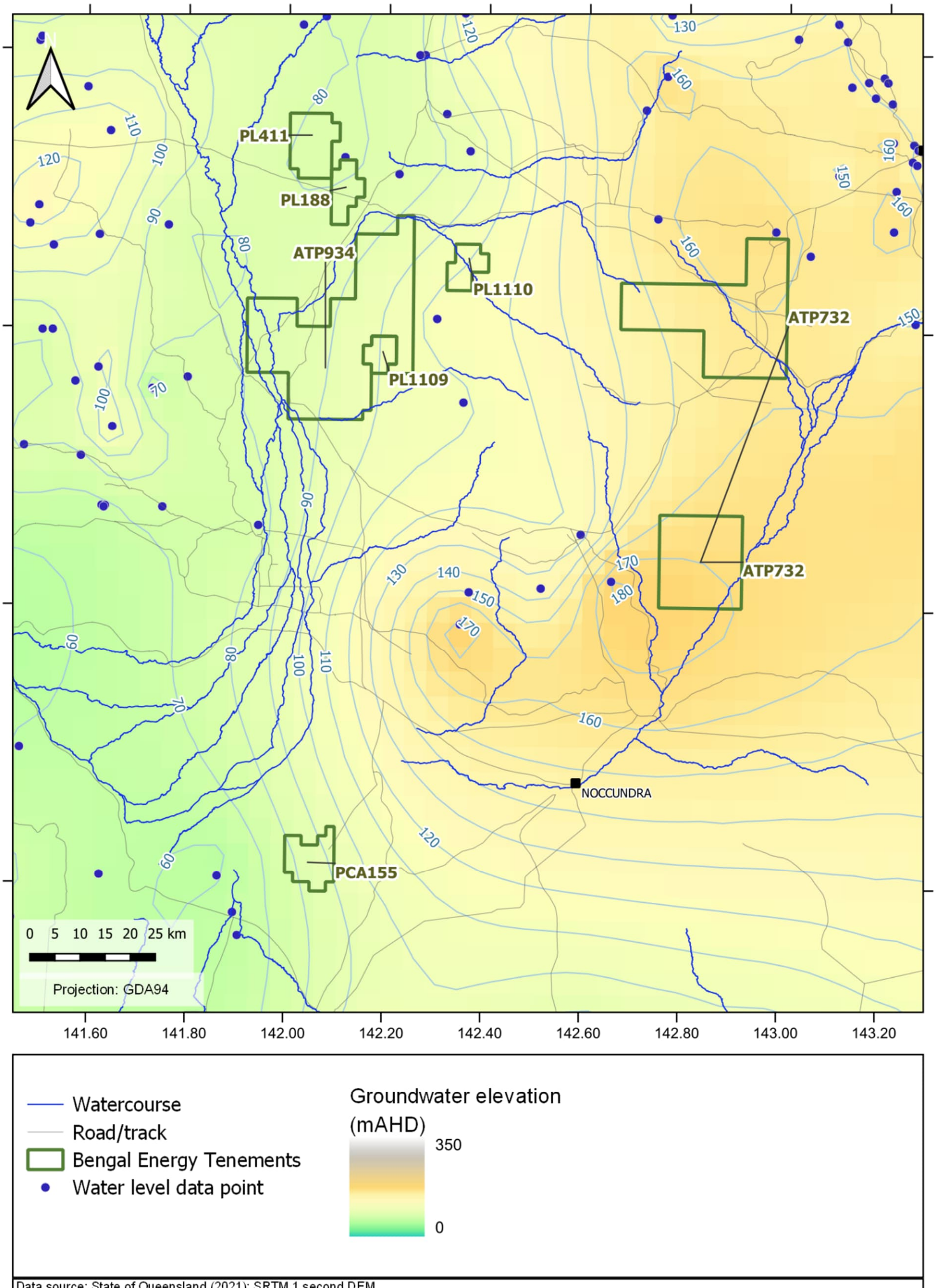
All three potentiometric surfaces suggest south to south westerly groundwater flow directions. The Tertiary Sediments and Winton Formations are sub-artesian as the potentiometric surface elevations are below ground level (refer Figure 3). The Namur Sandstone is artesian, with hydraulic head differences of well over 50 m between the deeper Namur Sandstone and the shallower Winton Formation and an upward hydraulic gradient. This significant head difference attests to the effectiveness of the intervening formations at providing hydraulic separation.

Figure 6 Potentiometric surface: Tertiary Sediments



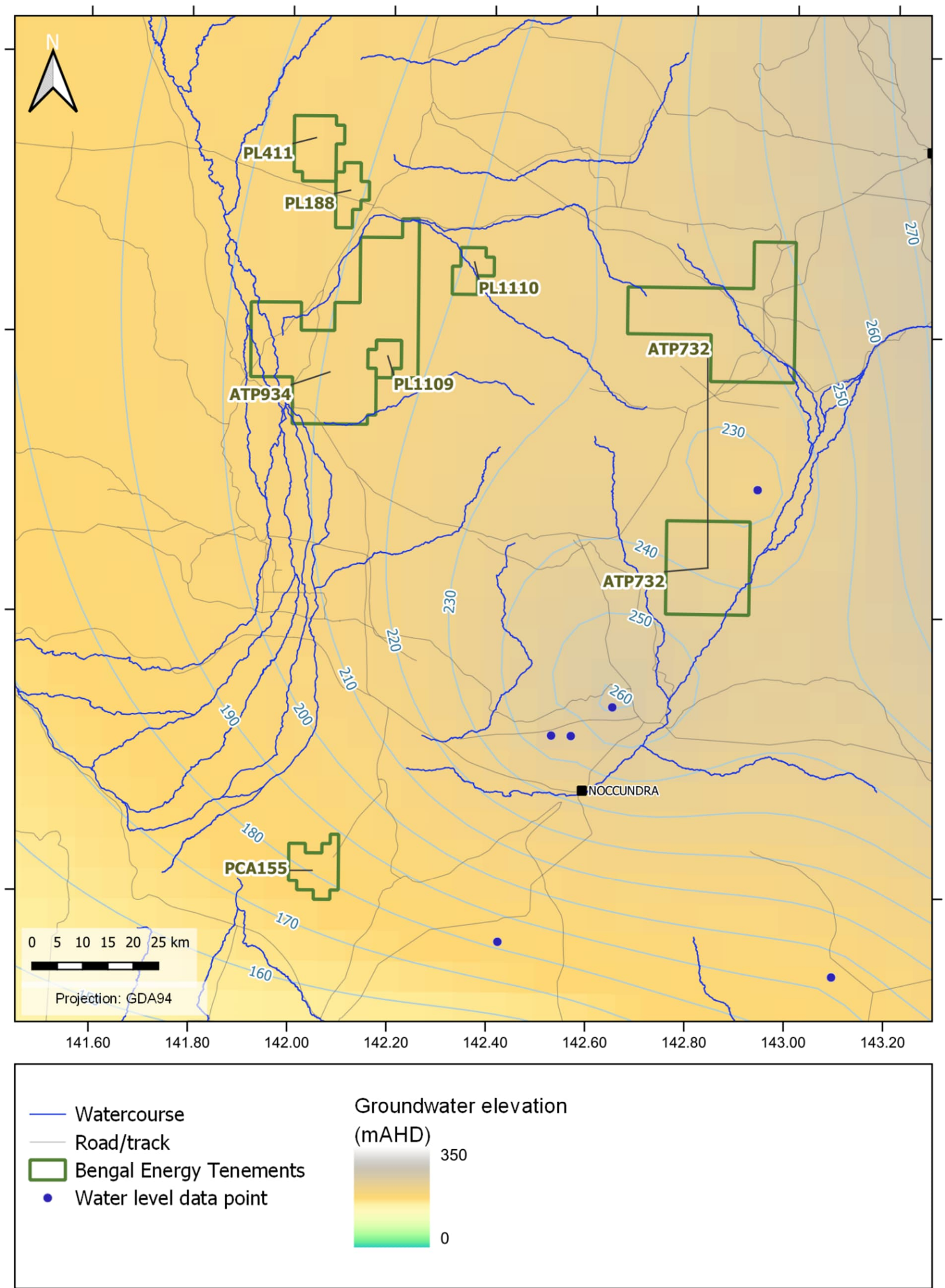
Data source: State of Queensland (2021); SRTM 1 second DEM
QLD_Cooper_GDA94_Z54.qgz - BengalUWIR2022 PotSurface - Tertiary

Figure 7 Potentiometric surface: Winton Formation



Data source: State of Queensland (2021); SRTM 1 second DEM
QLD_Cooper_GDA94_Z54.qgz - BengalUWIR2022 PotSurface - Winton

Figure 8 Potentiometric surface: Namur Sandstone



Data source: State of Queensland (2021); SRTM 1 second DEM
QLD_Cooper_GDA94_Z54.qgz - BengalUWIR2022 PotSurface - Hooray

3.5.2 Temporal trends

Figure 9 to Figure 13 present temporal water level trends for those bores from which more than two water level measurements were available from the GWBD for bores across the Cooper Basin region of Queensland. The locations of the bores with temporal water level data are shown on Figure 14. The data availability ranges from ~1910 to 2020, with most data available for the Namur Sandstone.

Temporal water level trends are summarised as follows:

Winton Formation (Figure 9) – Water level trends were available for only two bores, with two data points each. RN33326 shows a water level decline of roughly 20 m between 1969 and 2014, whereas RN50388 shows a relatively stable water level between 1980 and 1992. The former bore is over 130 km north of the tenements and the latter bore is within 20 km of ATP934.

Wallumbilla Formation (Figure 10) – Water level trends were only available for one bore in the Wallumbilla Formation. The graph shows a water level decline of roughly 5 m between 1960 and 1986, followed by a relatively stable water level up to the last reading in 2010. The bore is roughly 165 km southeast of ATP732.

Cadna-Owie Formation (Figure 11) – Water level trends were available for four bores in the Cadna-Owie Formation. The trends are variable, with three bores showing rising trends between 1962 and 2019, and one bore (RN6751) showing a declining trend from 1938 to 2000, and then a slowly rising trend from 2000 to 2019. The closest Cadna-Owie Formation bores with temporal water level data was approximately 175 km southeast of ATP732.

Namur Sandstone (Figure 12) –Water level trends were available for sixteen bores in the Namur Sandstone. All of the water level data show declining trends over the period 1908-2019. The greatest declines were in the earlier time, after which the trends flattened. Small rises in water levels have been observed in some bores post 2000. The closest bore is between the two non-contiguous areas of ATP732.

Hutton Sandstone (Figure 13) - Water level trends were only available for one bore in the Hutton Sandstone. The graph shows roughly stable water level between 1964 and 2011. One data point appears anomalous. The bore is close to the South Australia border. While there is no recent water level data, the stable water level during the period of peak oil production shows the limited impact of the petroleum industry on water levels in the Hutton Sandstone.

Figure 9 Temporal water level trends - Winton Formation

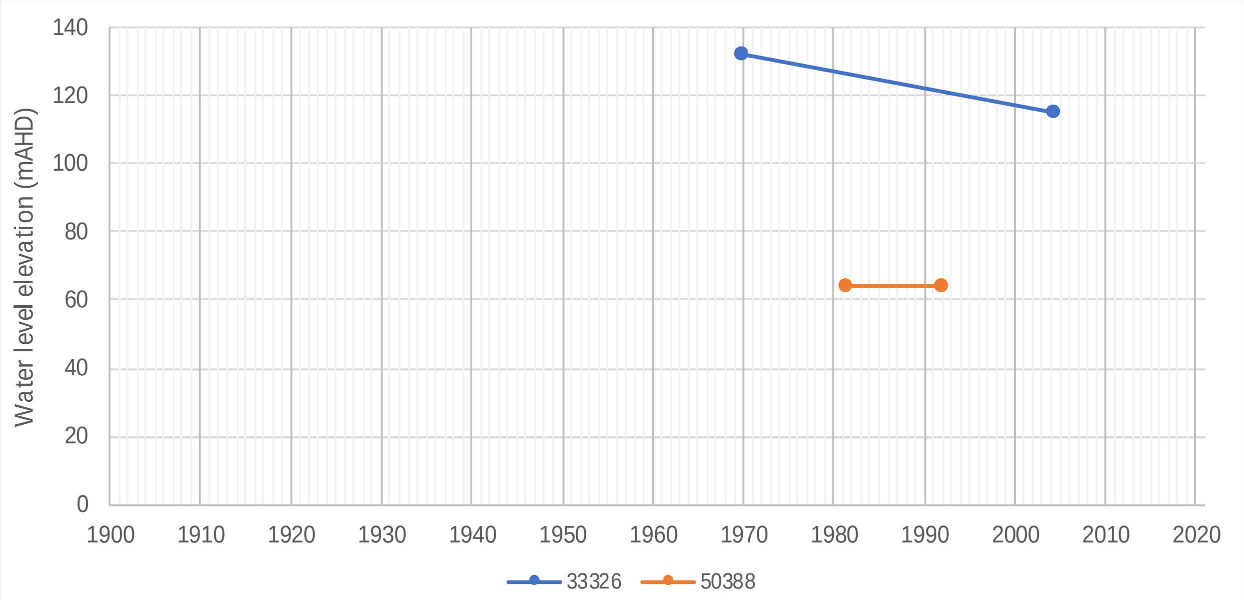


Figure 10 Temporal water level trends - Wallumbilla Formation

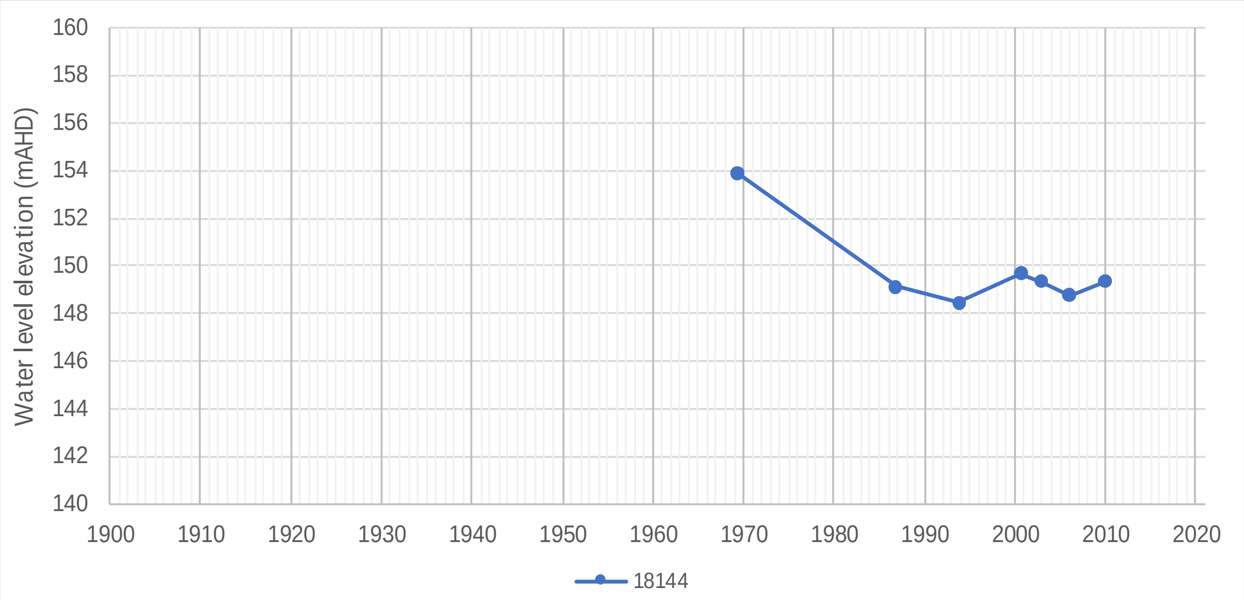


Figure 11 Temporal water level trends - Cadna-Owie Formation

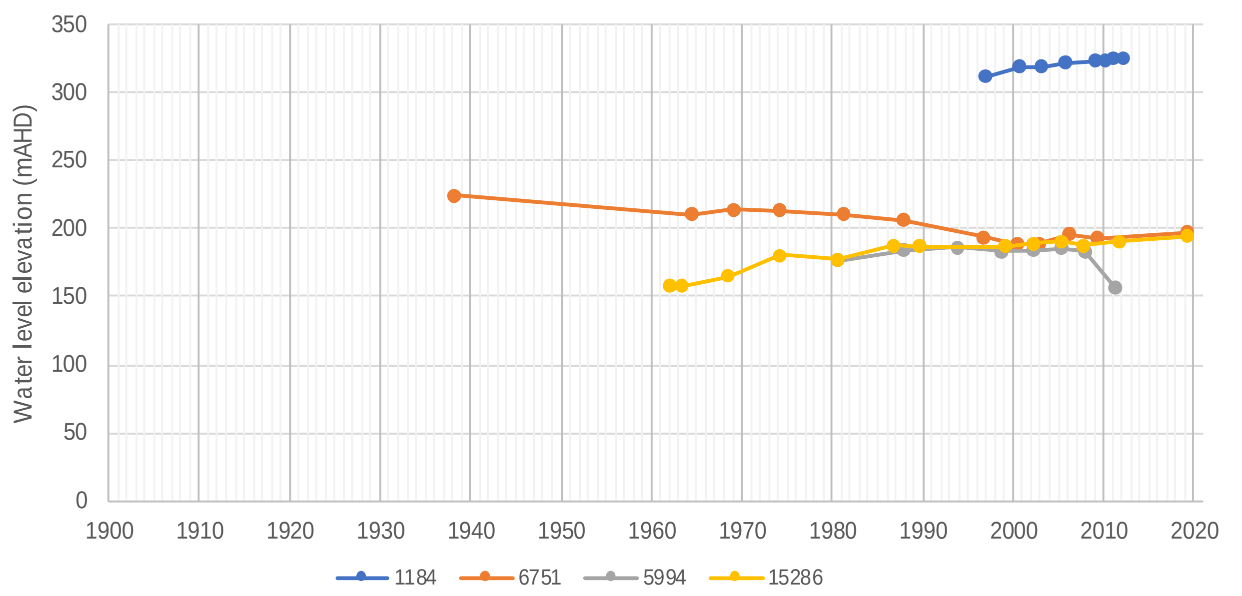


Figure 12 Temporal water level trends –Namur Sandstone

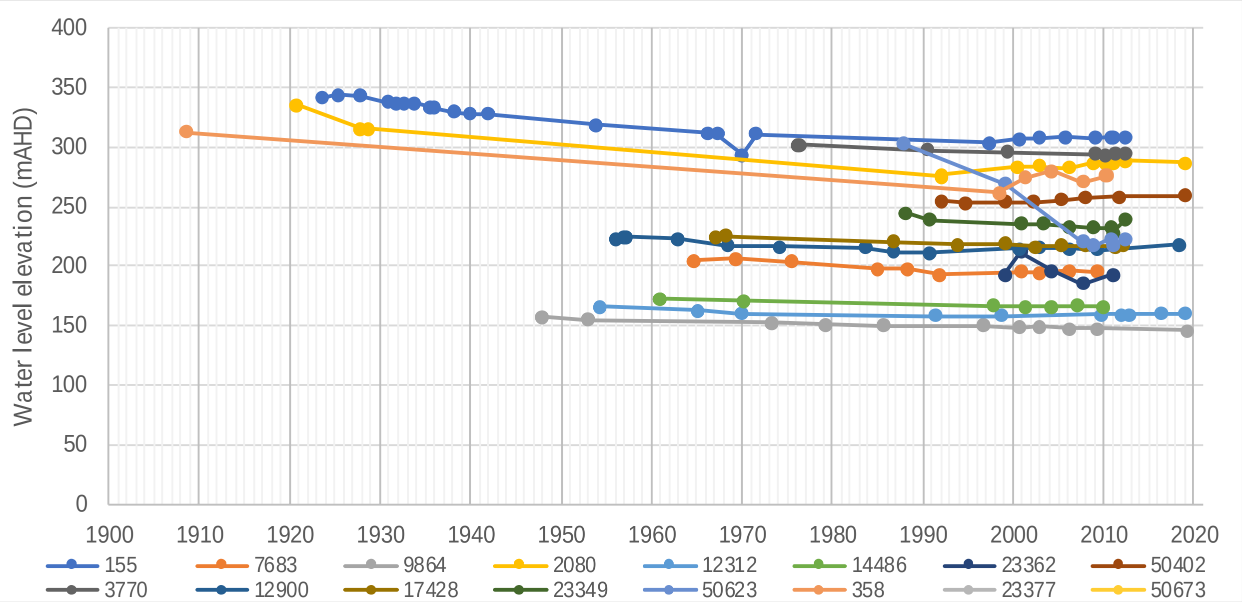


Figure 13 Temporal water level trends - Hutton Sandstone

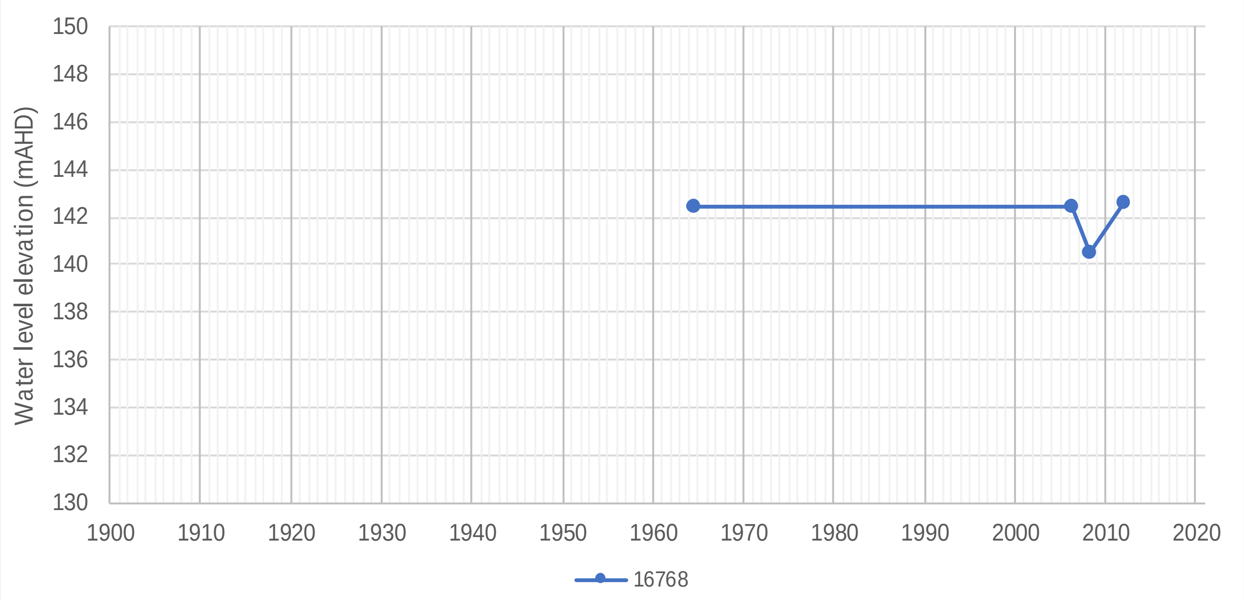
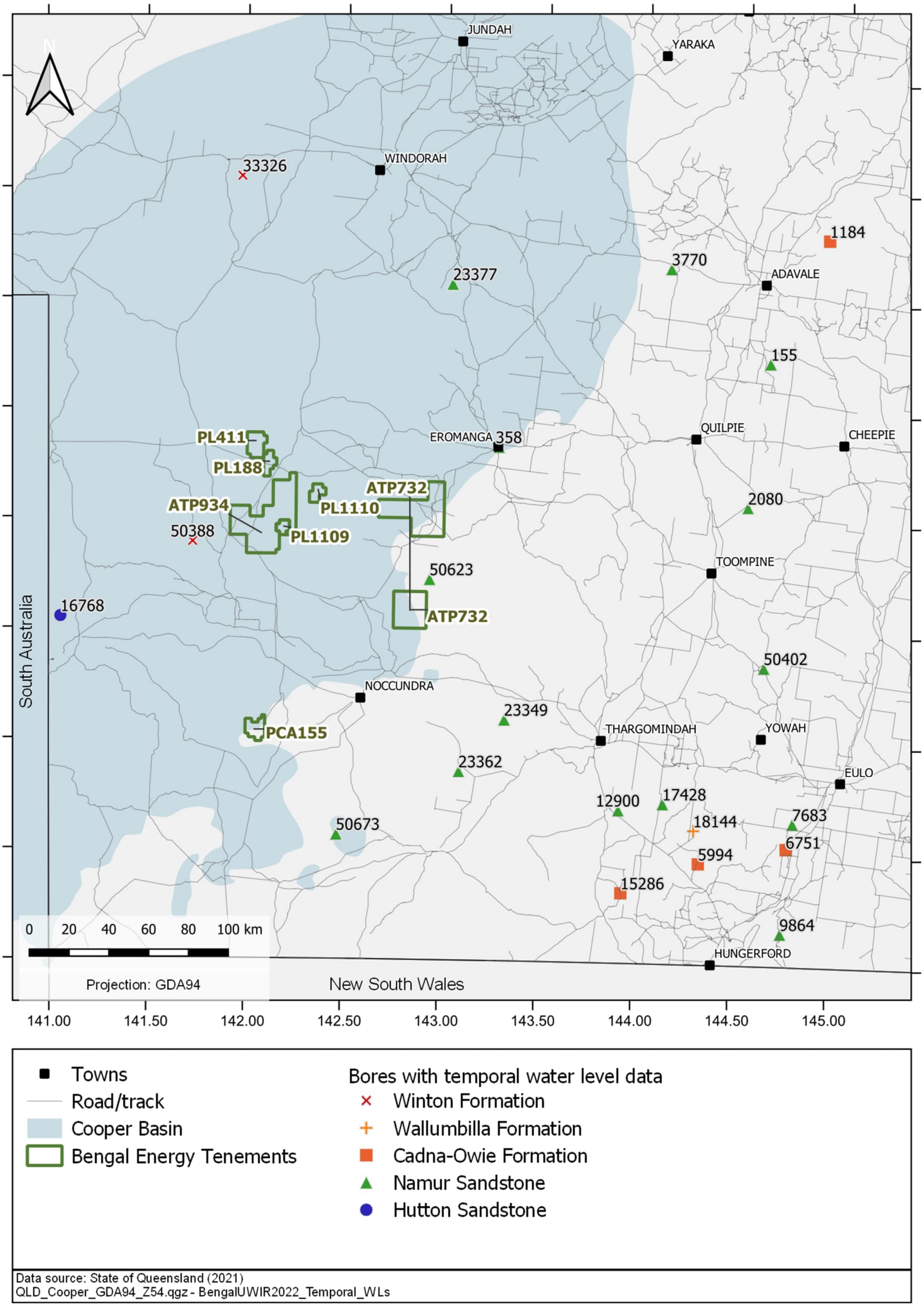


Figure 14 Temporal water level trends – Bore locations



3.6 Groundwater quality

Groundwater quality data has been compiled from the GWBD for the Cooper Basin region and has been grouped by formation for the calculation of statistics and for interpretation.

Figure 15 compares the salinity of five groups of formations, with the electrical conductivity (EC) to total dissolved solids (TDS) ratios shown on Figure 16.

The Cainozoic units comprising Quaternary and Tertiary Sediments shows the widest range in salinity, from extremely fresh to highly saline. The Winton and Mackunda Formations generally host the freshest water. There is a distinct increase in salinity from the Eromanga Basin units to the Poolowanna Formation and the Cooper Basin units beneath. The EC/TDS ratio is roughly 0.65 on average, with most of the data falling in the 0.5 – 0.75 range.

Piper tri-linear diagrams have been prepared to compare major ion chemistry within and between formations (Figure 17 to Figure 19). The piper diagrams presented herein were prepared using the most recent water quality analysis available for each bore. The piper diagrams have been prepared using the method described by Peeters (2014) in which the relative position on the piper diagram corresponds to a specific colour, thus allowing any spatial trends associated with the data to be assessed (Figure 20 to Figure 22). The piper diagrams and maps utilise the same symbol shapes for the different formation for ease of comparison.

The Tertiary Sediments, Winton and Mackunda Formations are predominantly sodium-chloride-bicarbonate waters, although there is a wide-spread in the relative proportions of ions, particularly of the anions. The water types of the three formations show significant overlap. Based on the piper diagrams alone (Figure 17, Figure 18), it appears that there may be an evolution in groundwater chemistry, however the corresponding maps (Figure 20, Figure 21) show no discernible spatial trends. The water quality variability in the shallow formations may be related to the proximity of the sampled bore to Cooper Creek.

Due to the paucity of data, a single piper diagram has been prepared for the Cadna-Owie Formation, Hooray Sandstone and Hutton Sandstone (Figure 22). Figure 22 shows no clear distinction between these formations, but does show that they are all dominated by sodium as the cation and are all rich in bicarbonate with variable amounts of chloride. There are no apparent spatial trends in the data.

Figure 15 Formation groundwater salinity ranges (after Evans et al., 2020)

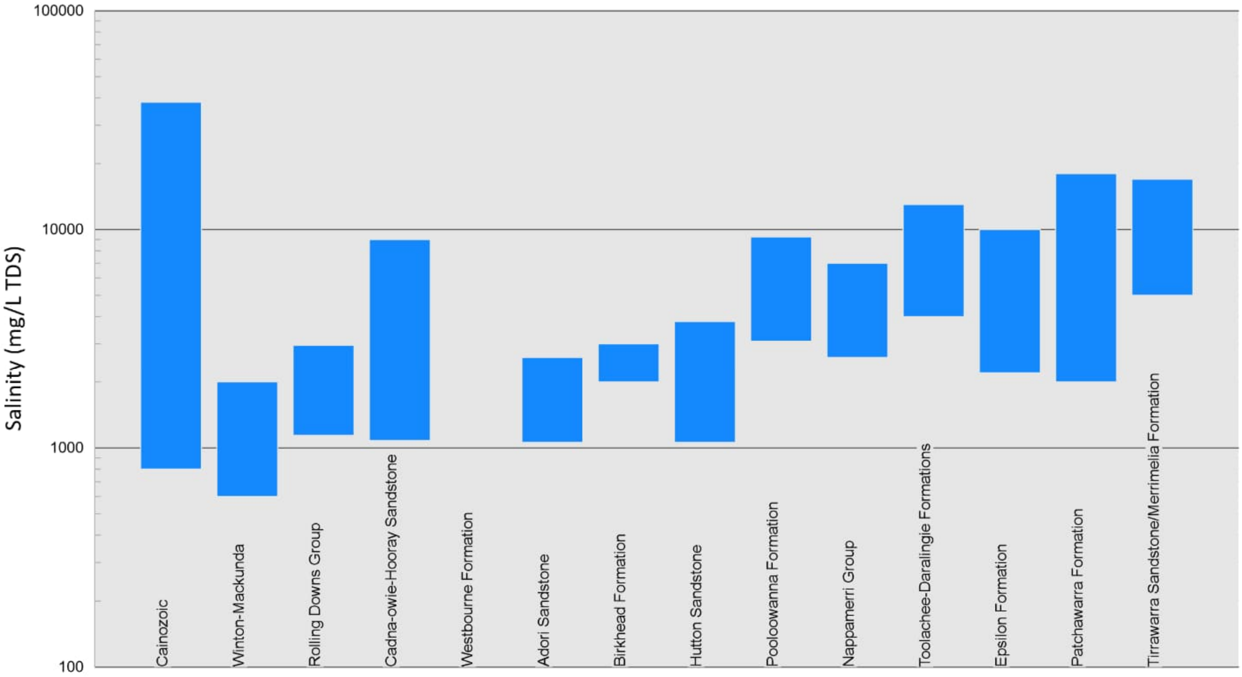


Figure 16 Total dissolved solids vs electrical conductivity

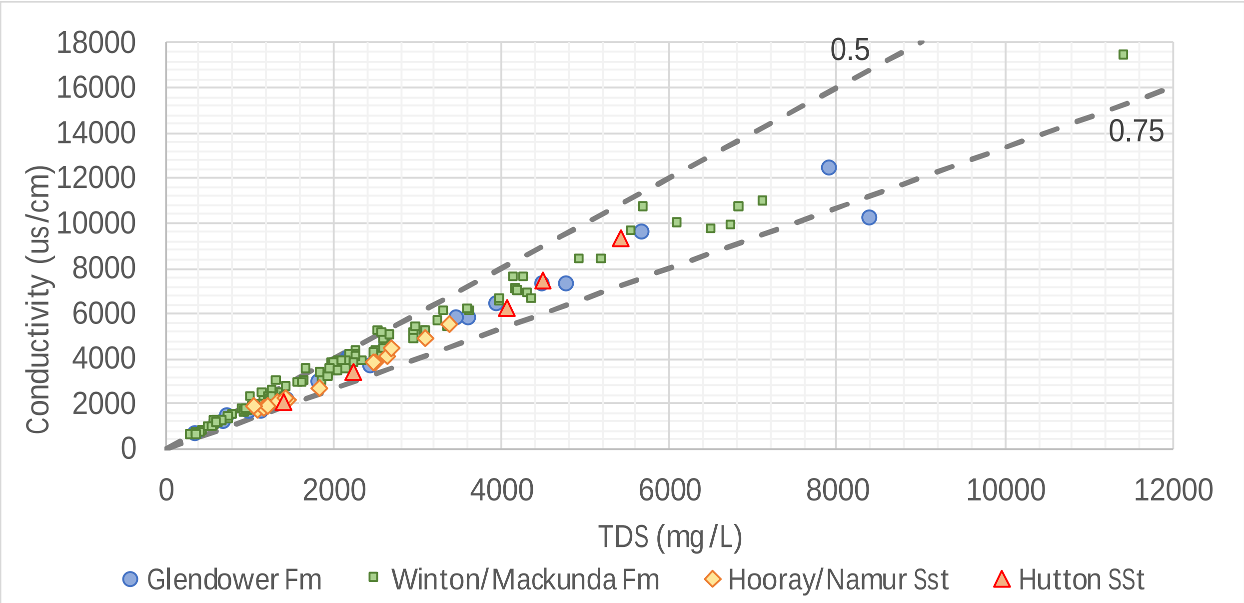


Figure 17 Piper diagram – Tertiary Sediments

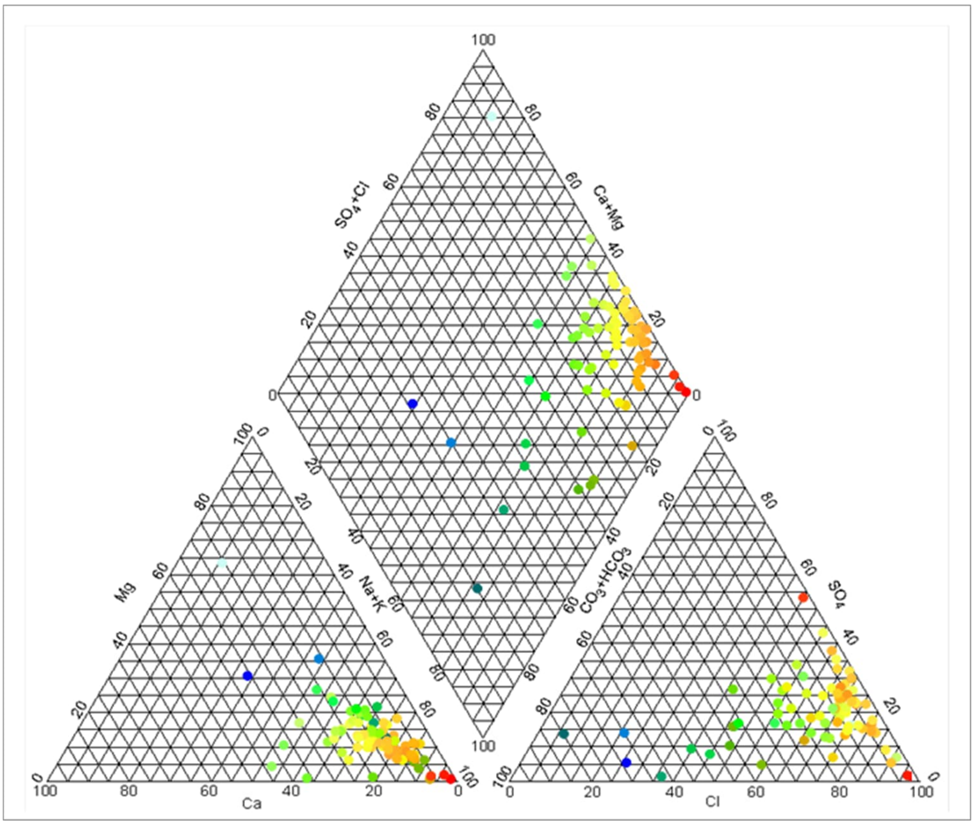


Figure 18 Piper diagram – Winton/Mackunda Formations

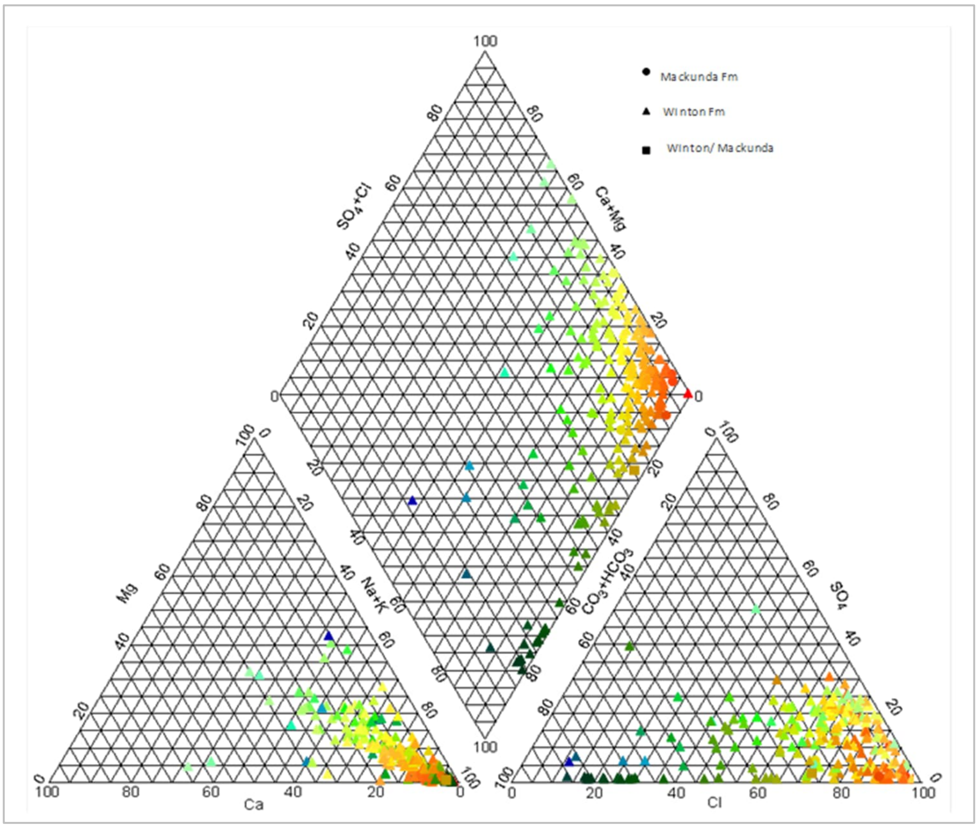


Figure 19 Piper diagram – Cadna-Owie Formation, Namur Sandstone and Hutton Sandstone

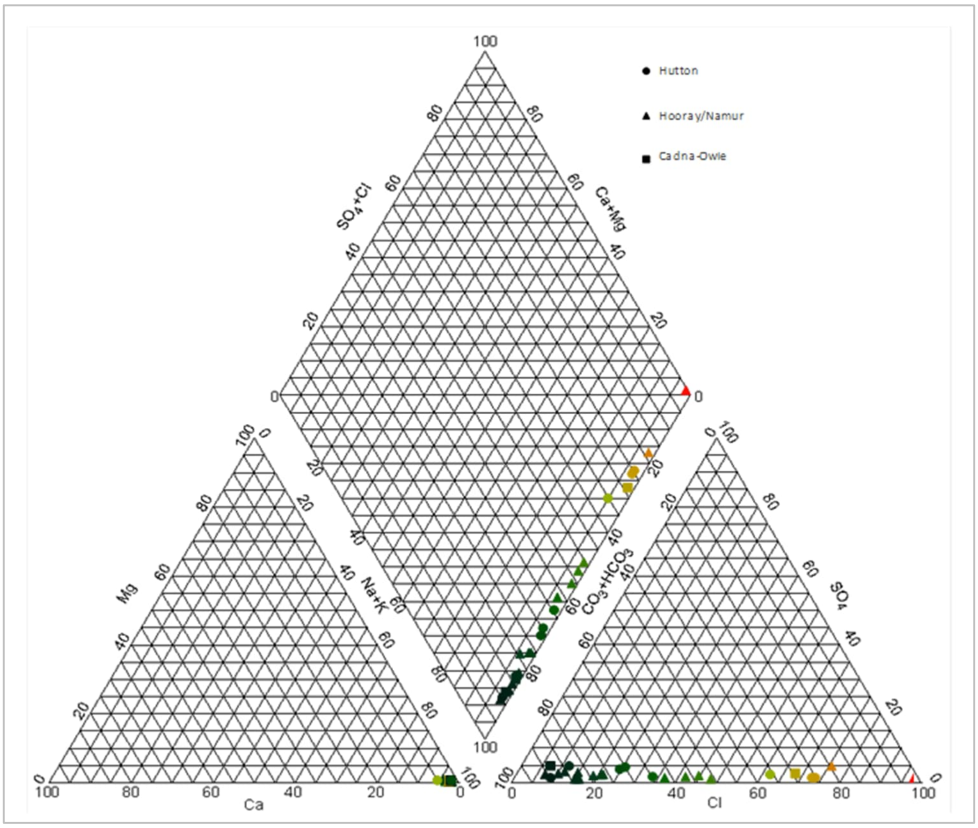


Figure 20 Piper diagram spatial representation – Tertiary Sediments

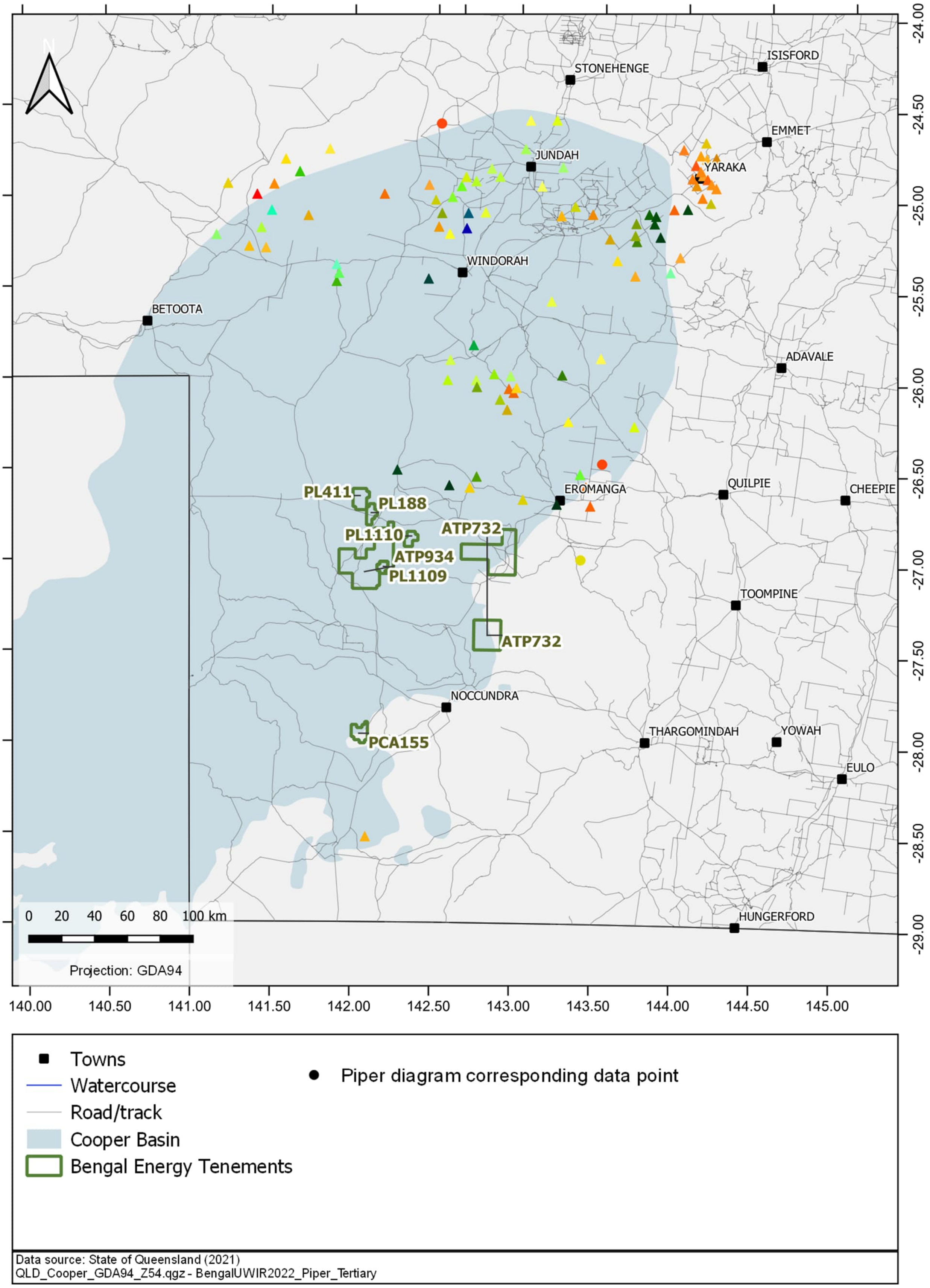
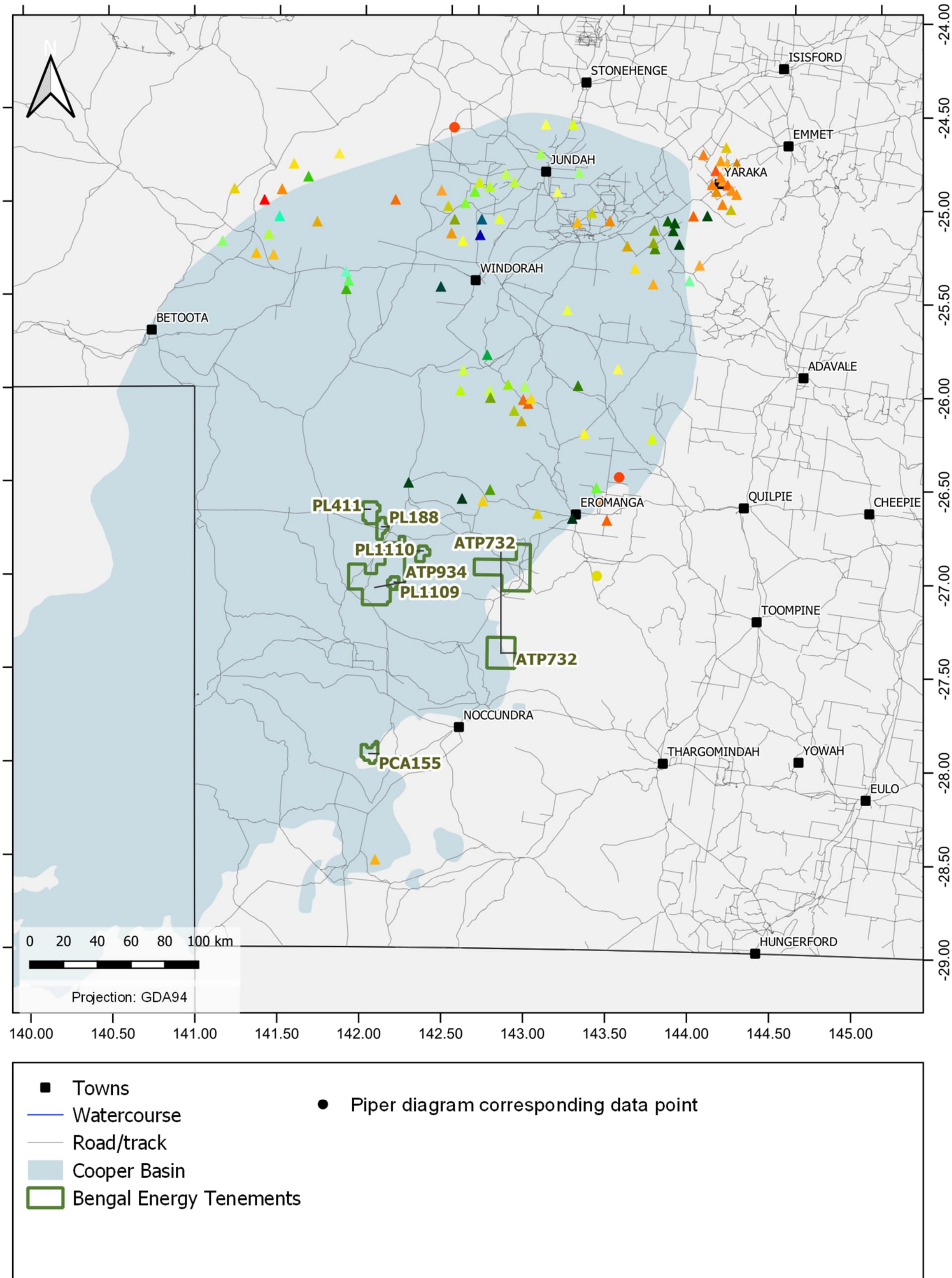
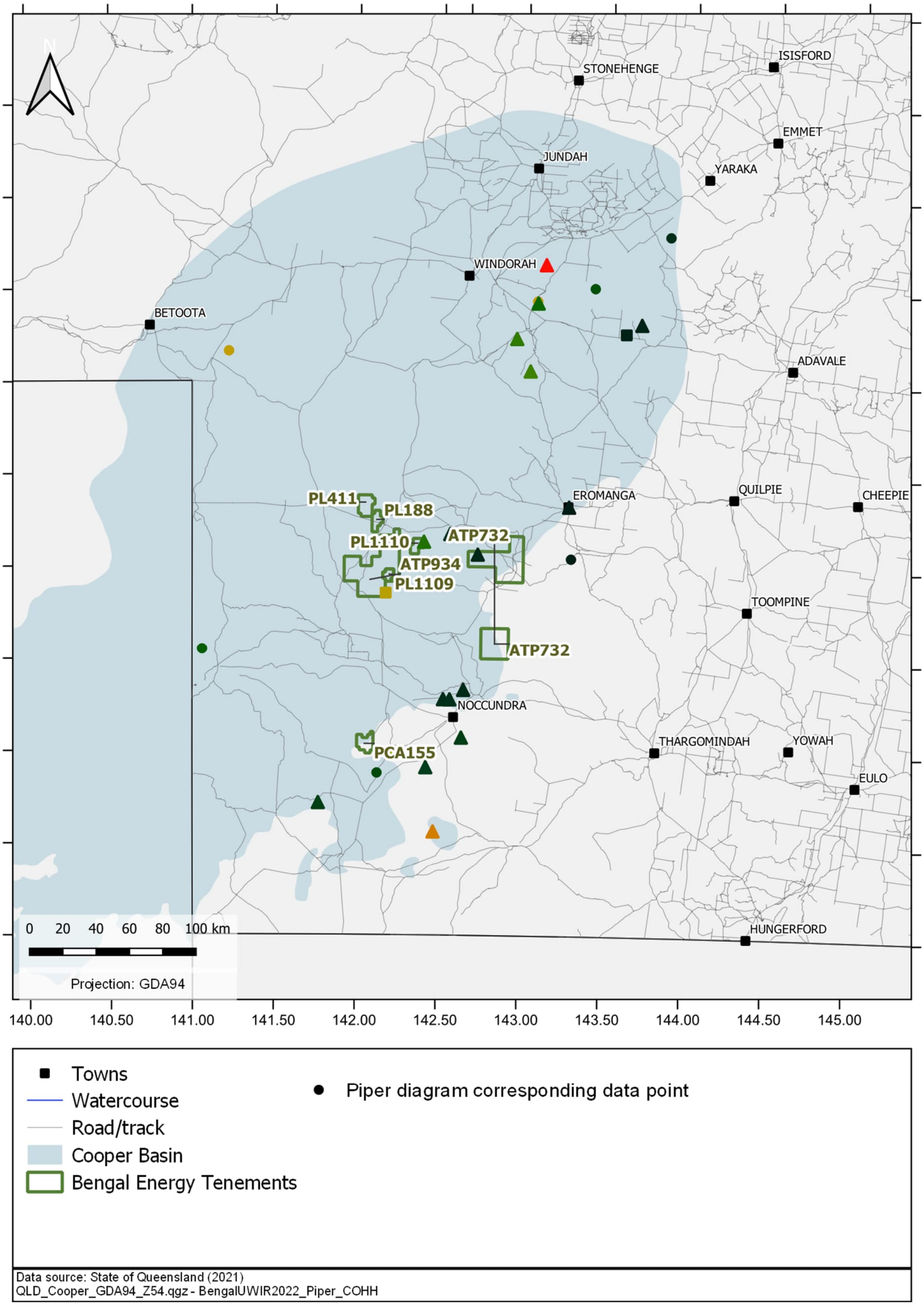


Figure 21 Piper diagram spatial representation – Winton/Mackunda Formations



Data source: State of Queensland (2021)
QLD_Cooper_GDA94_Z54.qgz - BengalUWIR2022_Piper_WintonMackunda

Figure 22 Piper diagram spatial representation – Cadna-Owie Formation, Namur Sandstone and Hutton Sandstone



3.7 Hydraulic parameters

Hydraulic parameters of a formation control the magnitude, extent and speed of propagation of pressure changes and water movement within and between formations.

Ranges in available horizontal hydraulic conductivities are summarised in Table 6. These have been obtained from Santos (2019, 2022), Bridgeport (2018) and have been calculated from GWBD flow test data (RDM Hydro, 2022).

The flow test data were analysed using the Theis (1935) solution for recovery tests. Transmissivities (T=K*b) were converted to hydraulic conductivities (K), using aquifer thicknesses (b) from either pumping, screened or open intervals in the bore construction details. Where no construction details were available, the full aquifer thickness was used. Several bores reported large open hole intervals, which are likely to exceed the true aquifer thickness. Therefore, it is likely that the assumed aquifer thickness will skew the hydraulic conductivities to lower values (Table 6).

No direct measurements of vertical hydraulic conductivities have been identified. Santos (2022) modelling used a vertical hydraulic conductivity value of 1×10^{-4} m/day for aquitards. This is greater than the upper limit used by OGIA (2019) in calibrating the Surat Cumulative Management Area UWIR model for most of the deeper formations and is therefore conservative as it will allow more leakage. Evans et al. (2020) report hydraulic conductivity as low as 3.5×10^{-9} for the Rolling Downs Group (Allaru Mudstone, Toolebuc Formation, Bulldog Shale).

A monitoring bore is required to calculate a storage coefficient from a pumping test. No direct measurements of storage co-efficients have been identified for the Cooper Basin region. OGIA (2019) identified specific storage to range from 3×10^{-7} to 1×10^{-5}. Hazel (1975) indicates that the storativity for a confined aquifer is about 5×10^{-6} per meter of aquifer thickness, which lies in the middle of the OGIA (2019) range.

Table 6 Horizontal hydraulic conductivities

Unit	RDM Hydro (2022)		Santos (2019)		Bridgeport (2018)		Santos (2022)
	Min	Max	Min	Max	Min	Max	Calibrated model equivalent
Winton Formation	4.1×10^{-4}	61.7	-	-	-	-	0.5
Hooray Sandstone/ Namur Sandstone	2.0×10^{-3}	2.6	4.3×10^{-4}	0.43	4.3×10^{-4}	1.96	0.5
Westbourne Formation, Adori Sandstone, Birkhead Formation	1.6×10^{-3}	0.007	8×10^{-7}	2.5×10^{-4}	2.8×10^{-5}	23	0.001
Hutton Sandstone	4.0×10^{-3}	0.008	3.5×10^{-1}	9.8×10^{-3}	5.7×10^{-5}	23	0.25
Poolowanna Formation	-		1.7×10^{-7}	3.7×10^{-3}	1×10^{-7}	1.59	0.001
Toolachee Formation	-		2.0×10^{-3}	4.3×10^{-4}	-	-	0.01
Patchawarra Formation	-		3.3×10^{-4}	3.5×10^{-3}	-	-	0.001

3.8 Conceptual model and aquifer interactions

The Cooper and Eromanga Basins comprises a series of alternating aquifers and aquitards. Evidence of the effectiveness of the aquitards at limiting the connection between the aquifers is provided by:

- The presence of recognised aquitards between each of the major aquifers, except for the Hutton Sandstone and Poolowanna Formation. Both of these are hydrocarbon reservoirs that are not locally utilised for water supplies. It is likely that thinner layers of low permeability rock result in the formations being locally hydraulically isolated.
- The significant hydraulic head difference between the deeper formations and the shallower formations. The Namur/Hooray Sandstone is heavily artesian (more than 100 m in some places), yet the Winton/Mackunda Formations are sub-artesian.
- The differences in water level trends between the formations.
- The differences in the distribution of salinities and major ion chemistries between the formations
- The accumulation of oil and gas in the deeper formations and the absence of oil in the shallow formations. If the formations were connected across the aquitards, the oil would have migrated vertically to eventually reach the shallower formations including the Winton and Mackunda Formations.

4 Environmental values

4.1 Registered water supply bores

The locations and attributed formations of registered bores in the vicinity of the Bengal tenements are shown on Figure 23.

Many of the registered bores are former petroleum wells. The GWBD records have been cross-referenced to QPED to identify the status of the petroleum wells. Those wells which the QPED status is listed as "producing hydrocarbons" or "suspended/capped/shut-in" were identified as petroleum wells. Those listed as "water bore" or "unknown" identified as water bores.

Seventy registered groundwater bores were identified within 10 km of Bengal tenement boundaries. The status and formations of these bores are summarised in Table 7.

Table 7 Registered water bores within 10 km of Project tenements

Status / Formation	Number of bores
Abandoned / destroyed	15
Petroleum Wells	27
Tertiary Sediments (Glendower Formation)	2
Winton/ Mackunda Formations	18
Wallumbilla Formation	1
Namur/Hooray Sandstone	2
Basement	1
Insufficient data to identify formation	4
Total	**70**

4.2 Springs and groundwater dependent ecosystems

Doody et al. (2019) define groundwater dependent ecosystems (GDEs) as natural ecosystems which require access to groundwater on a permanent or intermittent basis to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services (Richardson et al., 2011). The broad types of GDEs are (Eamus et al., 2006):

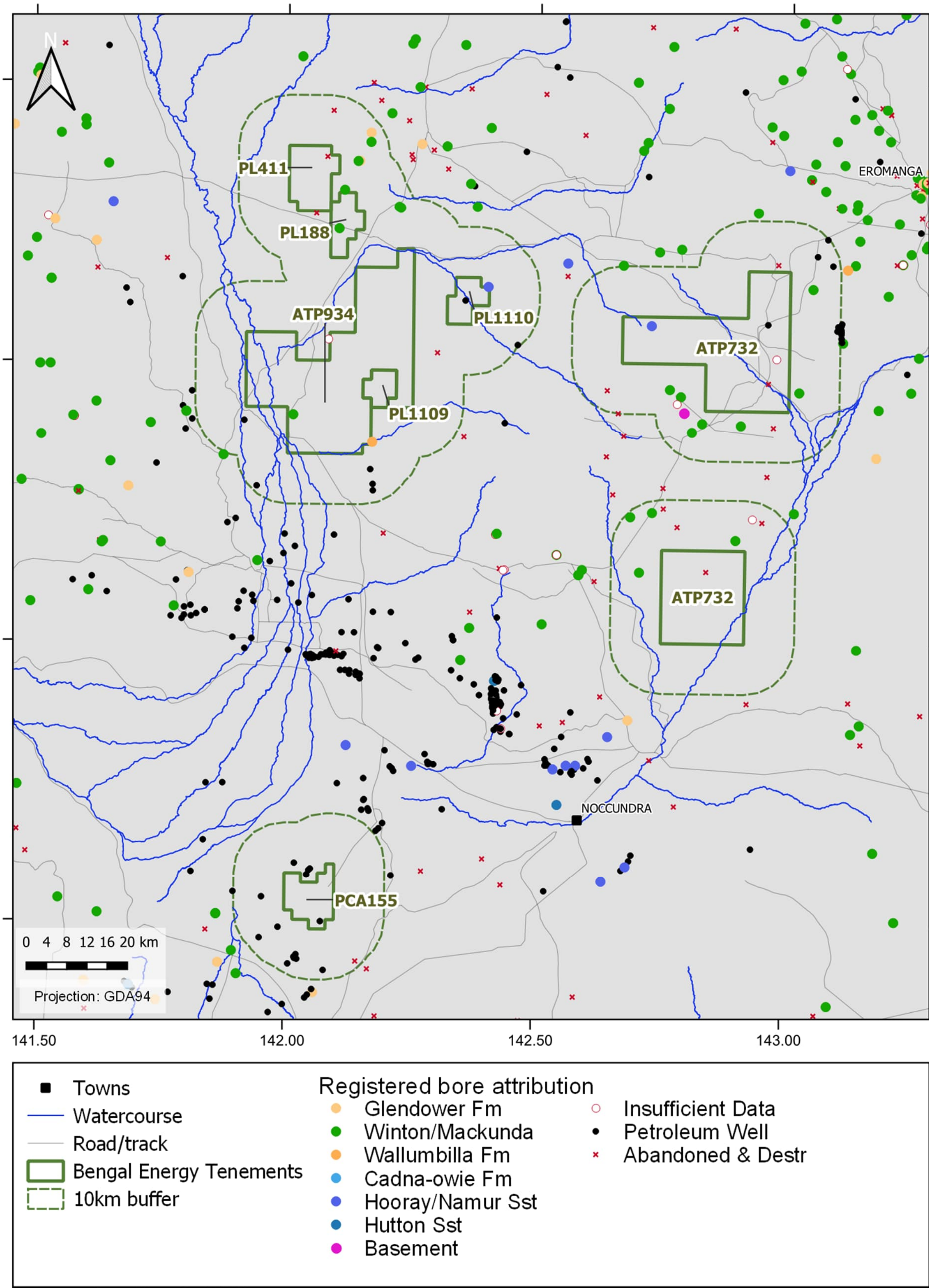
- **Springs** - Ecosystems dependent of surface expression of groundwater. It includes drainage lines that are fed by groundwater (baseflow reaches or watercourse springs).
- **Terrestrial GDEs** - Ecosystems dependent on sub-surface expression of groundwater.
- **Stygofauna** - Subterranean ecosystems.

There are no springs present in the vicinity of the tenements or surrounding regions. The nearest mapped springs are located over 150 km the east of the nearest project tenement boundary, in the vicinity of Eulo. Evans et al. (2020) identify the absence of springs in the Cooper Basin region to be indicative of the effectiveness of the Rolling Downs Group formations as a regional aquitard.

Figure 24 presents GDE mapping from WetlandInfo (DES, 2022) in the vicinity of Bengal's tenements. Derived terrestrial GDEs of medium confidence are mapped that are linked to Quaternary-aged alluvial aquifers with a brackish, ephemeral groundwater connectivity regime.

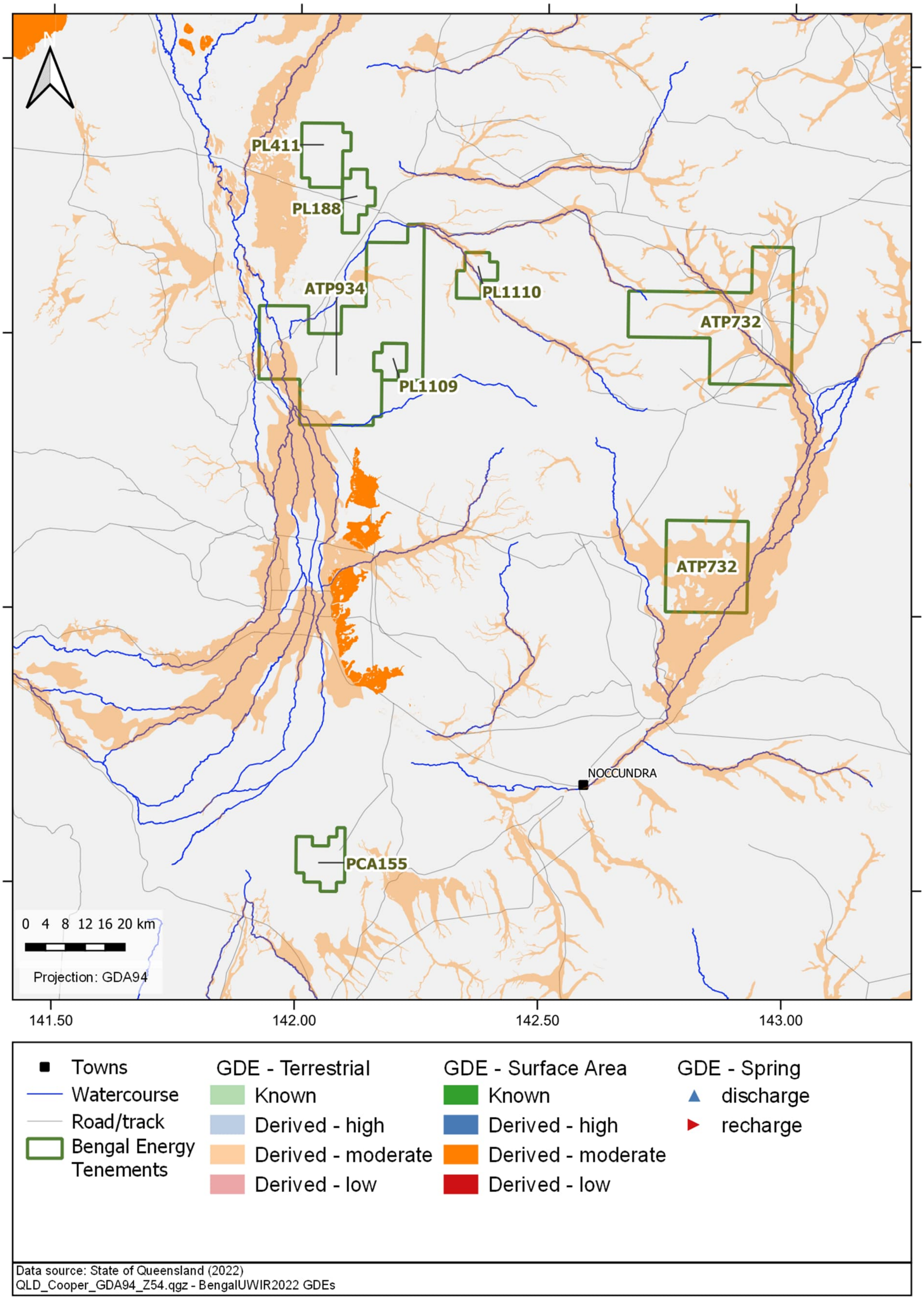
There is a moderate confidence of GDE presence (derived) to the south south of ATP934 boundary. This area of potential GDEs is associated with ephemeral groundwater discharge from unconsolidated Quaternary-aged sand dunes (DES, 2022). It occurs at the break of slope where the higher ground underlain by consolidated formations is drained by minor tributaries to Cooper Creek.

Figure 23 Registered water bores (by formation)



Data source: State of Queensland (2022)
QLD_Cooper_GDA94_Z54.qgz - BengalUWIR2022_RegisteredBores

Figure 24 Groundwater dependent ecosystems (GDEs)



5 Prediction of impacts

5.1 Method

Predictions of water level declines due to the exercise of underground water rights by Bengal Energy have been undertaken using the analytical modelling platform MLU for Windows Version 2.25.77 (Hemker and Post, 2008). MLU is a single-phase (water only) groundwater flow simulator.

MLU can perform transient drawdown calculations in layered aquifer systems. It assumes all layers are homogeneous, isotropic and of infinite extent, however the hydraulic characteristics of individual layers can be independently parameterised. It assumes lateral flow through aquifers and vertical flow through aquitards. Over the spatial and temporal scale of the tenements and the proposed gas extraction, the effectively layer-cake geology and the intraformational consistency in the lithologies, at the scale of the predicted extent of the pressure changes, these limitations are considered appropriate for the purposes of predicting water level declines associated with the historical and planned gas production activities.

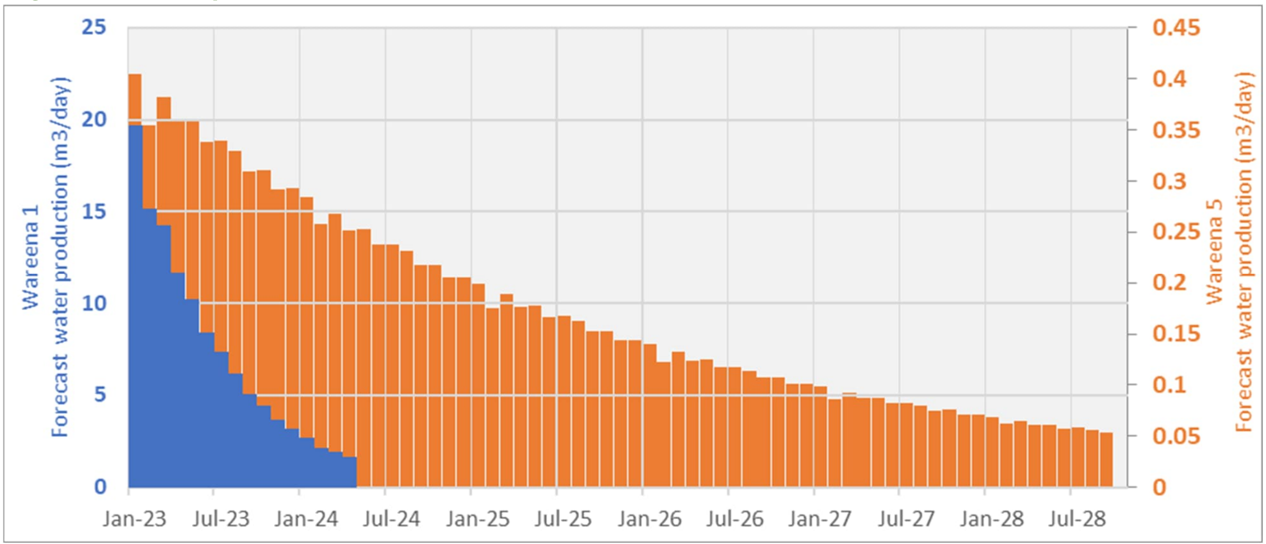
Table 8 summarises the base case model input parameters. The MLU model was discretised into eleven layers representing the hydrostratigraphic units and thicknesses based on Table 3. The hydraulic parameters were based on the distributions identified in Section 3.7. The shallower formations were combined to reduced computation times, which also provides a degree of conservativeness when assuming the Winton/Mackunda Formations as the surficial aquifer (usually overlain by Tertiary Sediments).
The wells identified in Table 1 with historical and/or future production ((Wareena 1, Wareena 5 and Caracal 1) were individually incorporated in the model to the layer from which production has historically occurred or is anticipated to occur. Historical water production was incorporated as per Figure 2. The forecast water production is based on the Bengal Energy's reservoir engineering assumption of 20 barrels of water per one million standard cubic feet of gas. The forecast water production for Wareena 1 and Wareena 5 is presented Figure 25. There is no other forecast production over the period of this UWIR (Table 1).

Table 8 Model layering and hydraulic parameters

Aquifer Layer	Formation	Model Hydrostratigraphic designation	Bottom Elevation (mAHD)	Thickness (m)	Kh (m/day)	Kv (m/day)	Ss
1	Winton/Mackunda	Aquifer	-224	334	0.1		5e-6
	Rolling Downs Group	Aquitard	-820	596		0.0001	
2	Cadna-Owie	Aquifer	-1052	232	0.5		5e-6
	Murta	Aquitard	-1109	57		0.0001	
3	Namur	Aquifer	-1193	84	0.5		5e-6
	Westbourne	Aquitard	-1312	119		0.0001	
4	Adori	Aquifer	-1336	24	0.001		5e-6
	Birkhead	Aquitard	-1420	84		0.0001	
5	Hutton	Aquifer	-1579	159	0.25		5e-6
	Poolowanna	Aquitard	-2038	459		0.0001	
6	Toolachee	Aquifer	-2092	54	0.01		5e-6

Kh = horizontal hydraulic conductivity; Kv = vertical hydraulic conductivity; Ss = specific storage

Figure 25 Water production forecast



5.2 Predicted magnitude and extent of groundwater level declines

Predictions of groundwater impacts are primarily influenced by the construction and parameterisation of the groundwater flow model, the development footprint and the water production history and forecast. Predictions were made of water level declines (drawdown) resulting from the total water extraction associated with the historical production from Wareena 1, Wareena 5 and Caracal 1 (Figure 2) and future water extraction associated with Wareena 1 and Wareena 5 (Figure 25).

The *Water Act 2000* identifies the bore trigger threshold for water level decline as 5 m for a consolidated aquifer and 2 m for an unconsolidated aquifer. Only the consolidated aquifer bore trigger threshold is relevant to this UWIR. The area in which the water level is predicted to decline by more than the bore trigger threshold within 3 years is termed the Immediately Affected Area (IAA), and the area in which the bore trigger threshold is exceeded at any time is termed the Long Term Affect Area (LTAA) (DES, 2021). For spring impacts, the trigger threshold is defined as a water level decline of 0.2 m. Since the *Water Act 2000* does not define a trigger threshold for terrestrial GDEs, the spring trigger threshold has been utilised.

The MLU model described above was used to predict water level drawdown due to the exercise of underground water rights by the Bengal. A timeseries model prediction was used to identify the timing of the maximum predicted drawdown for each model layer. The timeseries predictions for Wareena 1 and Wareena 5 are for a location halfway between the wells to represent the influence of production from both wells (Figure 24). The distance between Wareena 1 and Wareena 5 is approximately 1,680 m. For the Cadna-Owie Formation, the timeseries predictions are at the Caracal 1 well location (Figure 27).

The LTAA was generated by extracting the drawdown grid from the time with the maximum predicted drawdown as shown in Table 9 for the Toolachee Formation (September 2011) as this was the only layer in which the maximum predicted drawdown in any model time was predicted to exceed the 5 m bore trigger threshold. The predicted extent of drawdown for the LTAA is shown on Figure 29.

The IAA was assumed to be December 2026 (three years from the present).

The modelled drawdown predictions show:

- The maximum magnitudes of predicted drawdown for all model layers are provided in Table 9. Predicted drawdown exceeds the *Water Act 2000* bore trigger threshold for a consolidated aquifer (5 m) in the Toolachee Formation only. There are no registered water supply bores that access the Toolachee Formation within the mapped extent of 5 m drawdown (Figure 29);
- The IAA corresponds to the December 2026 (Figure 30). No trigger thresholds are predicted to be exceeded at this time. Drawdown is not predicted to exceed the bore trigger threshold during the period 2023 to 2026. The maximum predicted drawdown during the current reporting period is 4.6 m in the Toolachee Formation. Predicted drawdown in overlying formations is less than 0.2 m.
- The maximum predicted drawdown associated with production from Caracal 1 in the Cadna-Owie Formation is less than 0.01 m.
- Predicted drawdown only exceeds 0.2 m in the Toolachee Formation, Hutton Sandstone and Adori Sandstone associated with production from the Wareena wells.
- There are no mapped springs within the maximum predicted extent of 0.2 m drawdown in any model layer;
- The adopted trigger threshold for terrestrial GDEs (0.2 m) is not predicted to be exceeded in the model water table aquifer (Winton/Mackunda);
-

Figure 26 Timeseries predicted drawdown for Toolachee Formation (Wareena 1 and Wareena 5) production

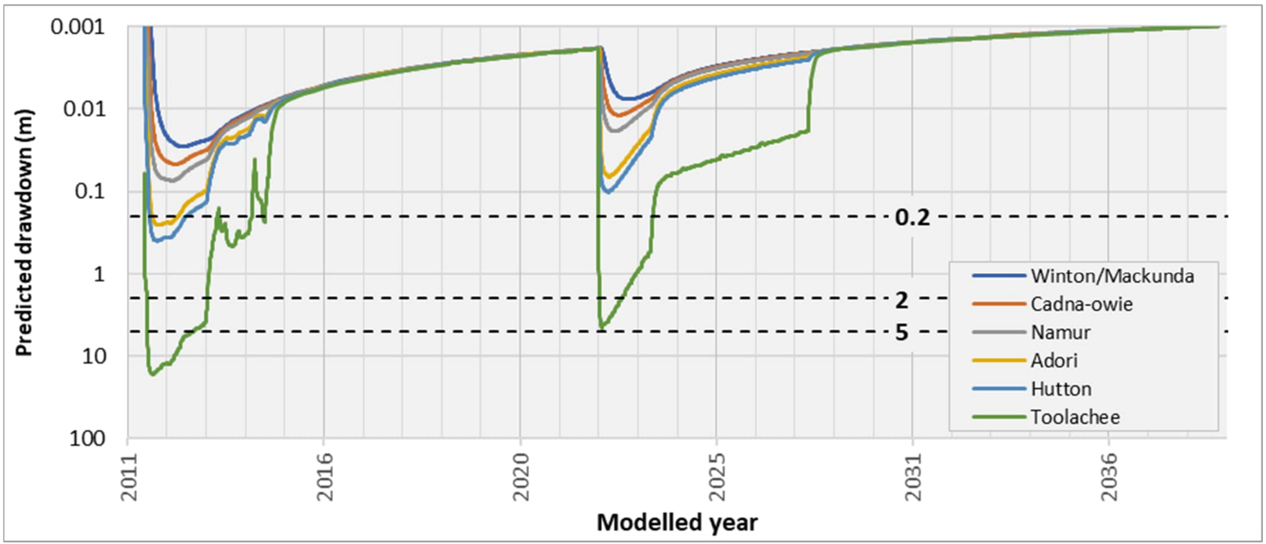


Figure 27 Timeseries predicted drawdown for Cadna-Owie Formation (Caracal 1) production

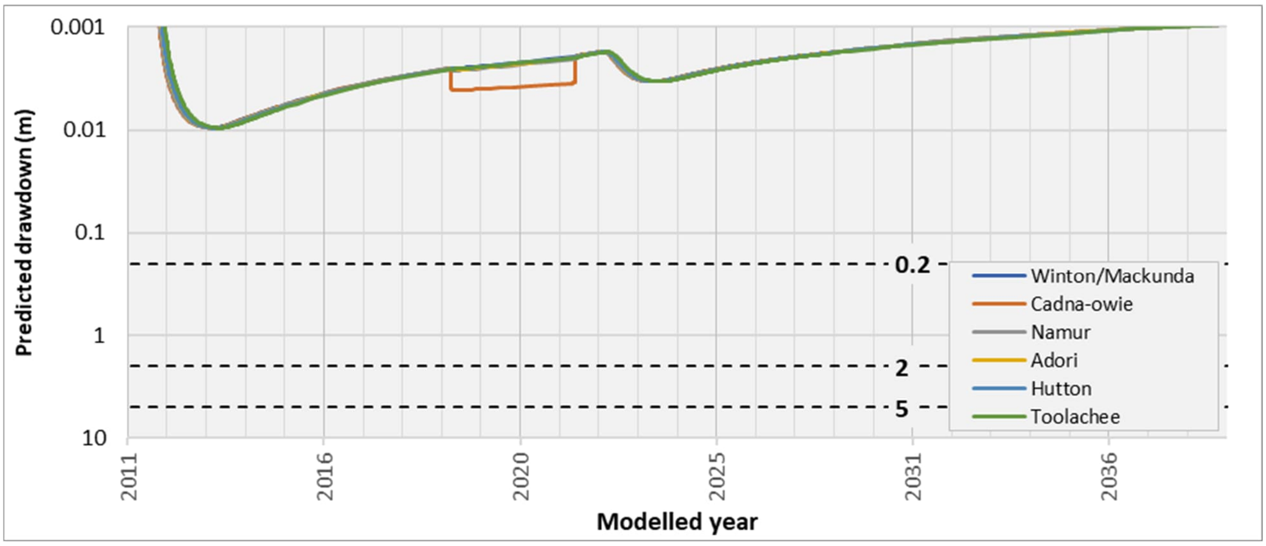


Table 9 Maximum magnitude of predicted drawdown

Layer	Formation	Maximum predicted drawdown (m)	Timing of maximum predicted drawdown
1	Winton Mackunda	0.03	May 2012
2	Cadna-Owie	0.05	March 2012
3	Namur Sandstone	0.07	February 2012
4	Adori Sandstone	0.26	October 2011
5	Hutton Sandstone	0.4	October 2011
6	Toolachee Formation	16.7	September 2011

Table 10 Model output dates

Layer	Aquifer	Model time (days)	Equivalent date	Reason chosen
6	Toolachee	92	September 2011	Maximum magnitude of drawdown in Toolachee Formation associated with production from Wareena 1 and Wareena 5 (long term affected area - LTAA)
All	All	5690	December 2026	3 years from assessment date (immediately affected area - IAA)

5.2.1 Sensitivity analysis

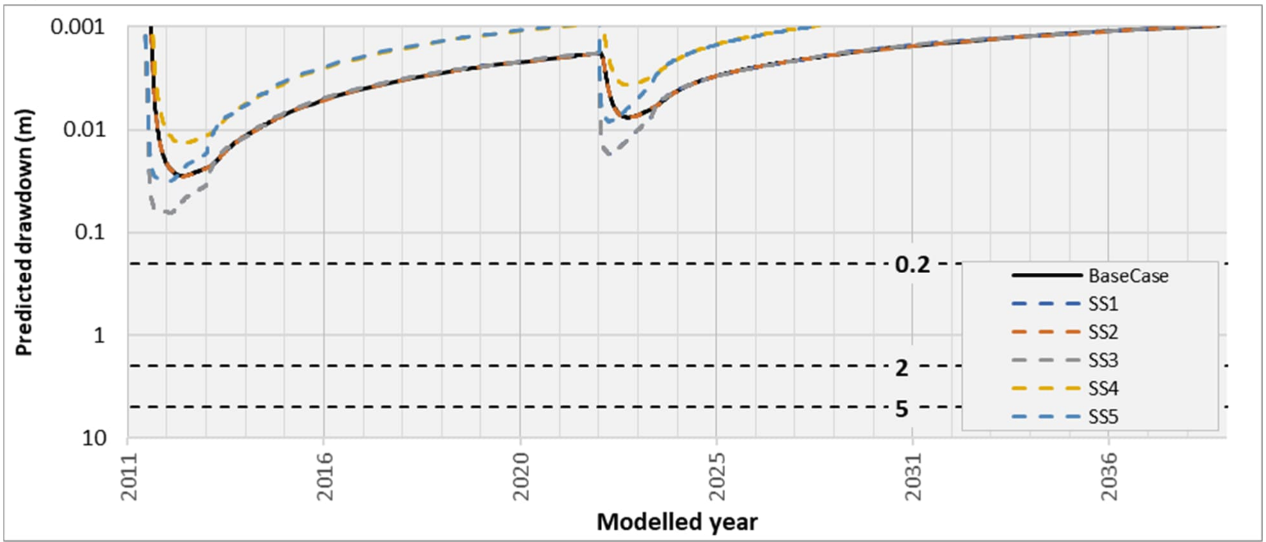
To assess the potential for propagation of impacts to Layer 1, with which terrestrial GDEs would be associated, a sensitivity of the predicted drawdown has been undertaken using MLU. To assess the potential changes to the maximum magnitude of predicted drawdown, a dummy bore was assumed in model Layer 1 between the Wareena 1 and Wareena 5 locations (the same location as for Figure 26). Each sensitivity scenario was assessed against the base case (described above). These are plotted on Figure 28, and are described as follows:

- Scenario 1 (SS1) – Increase of all aquitard Kv's by one order of magnitude (from 10^{-4} to 10^{-3}) – allow it to propagate more easily through the subsurface to the surface.
- **Scenario 2 (SS2) - Halve the hydraulic conductivity in the Toolachee Formation (with base case Kv)** – this increases the drawdown in the production formation providing a greater potential to increase in drawdown propagation through the overlying layers.

- **Scenario 3 (SS3) – Halve the hydraulic conductivity in the Toolachee Formation (with SS1 case Kv).** The purposes of this sensitivity case was to induce a greater magnitude of drawdown in the Toolachee Formation and allow it to propagate more easily through the subsurface to the surface.
- **Scenario 4 (SS4) – Increase the hydraulic conductivities of all aquifers (with base case Kv)** – The intent of this sensitivity case was to increase the extent of propagation in the aquifer layers. Hydraulic conductivities were doubled for all model aquifers where the base case hydraulic conductivity was greater than 0.1 m/day or increased by an order of magnitude if less than 0.1 m/day.
- Scenario 5 (SS5) – Increase the hydraulic conductivities of all aquifers per SS4 with SS1 case Kv

While some of the sensitivity cases increased the predicted drawdown relative to the base case, there was no exceedance of the adopted trigger threshold (Figure 28).

Figure 28 Modelled drawdown in Layer 1 - sensitivity analysis



5.3 Predicted impacts to environmental values

Water level drawdown associated with the exercise of underground water rights is not predicted to result in the exceedance of the *Water Act 2000* bore trigger threshold in any existing registered water supply bores.

Water level drawdown associated with the exercise of underground water rights is not predicted to result in the exceedance of the *Water Act 2000* spring trigger threshold at any mapped springs or other groundwater dependent ecosystems. Sensitivity analyses performed indicate that regardless of the uncertainties in model parameters, the predicted drawdown does not exceed the spring trigger threshold in the uppermost model aquifer that would be relevant to terrestrial GDEs.

There are therefore no predicted impacts to environmental values.

Figure 29 Predicted Drawdown – Toolachee Formation September 2011

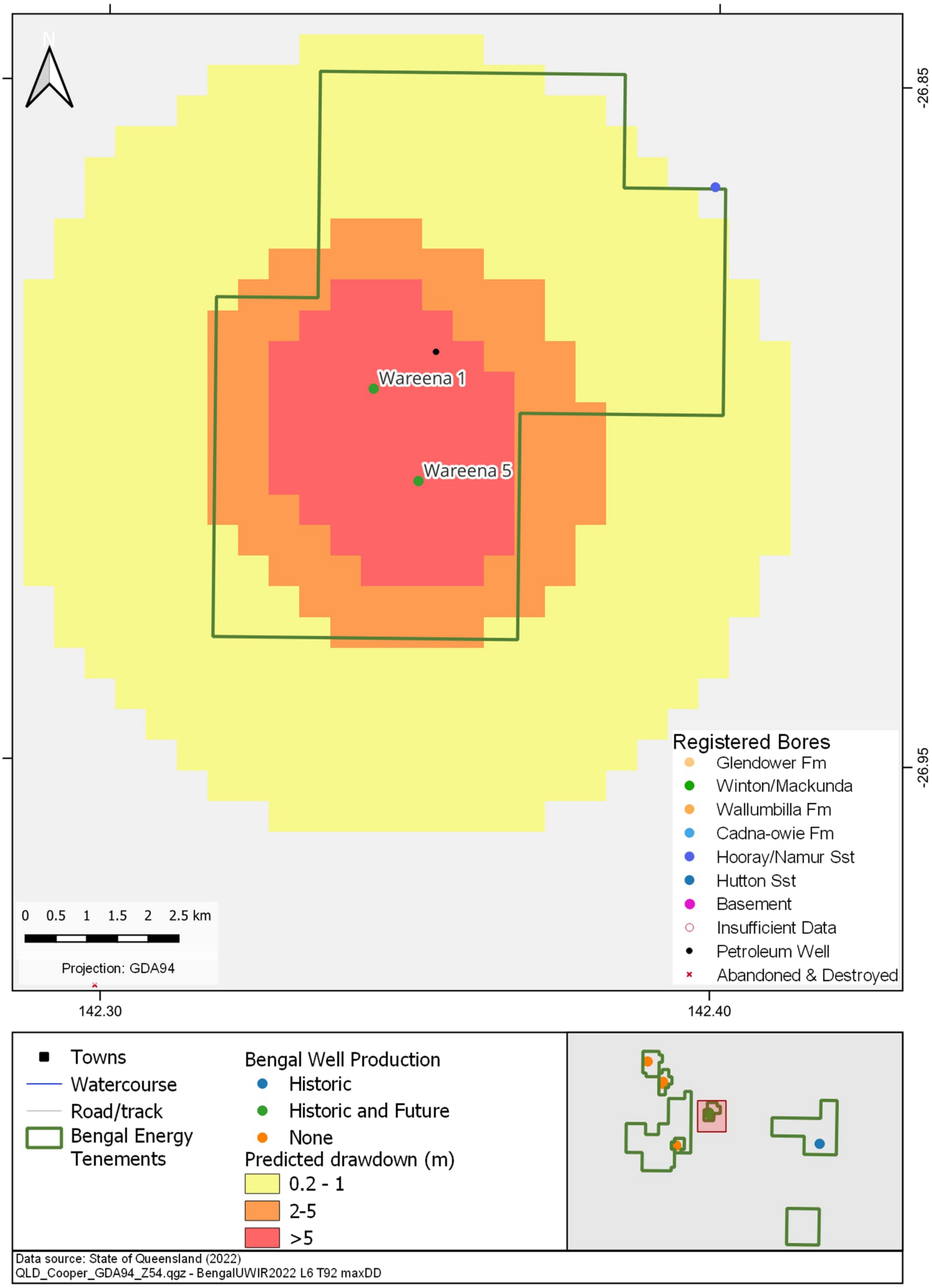
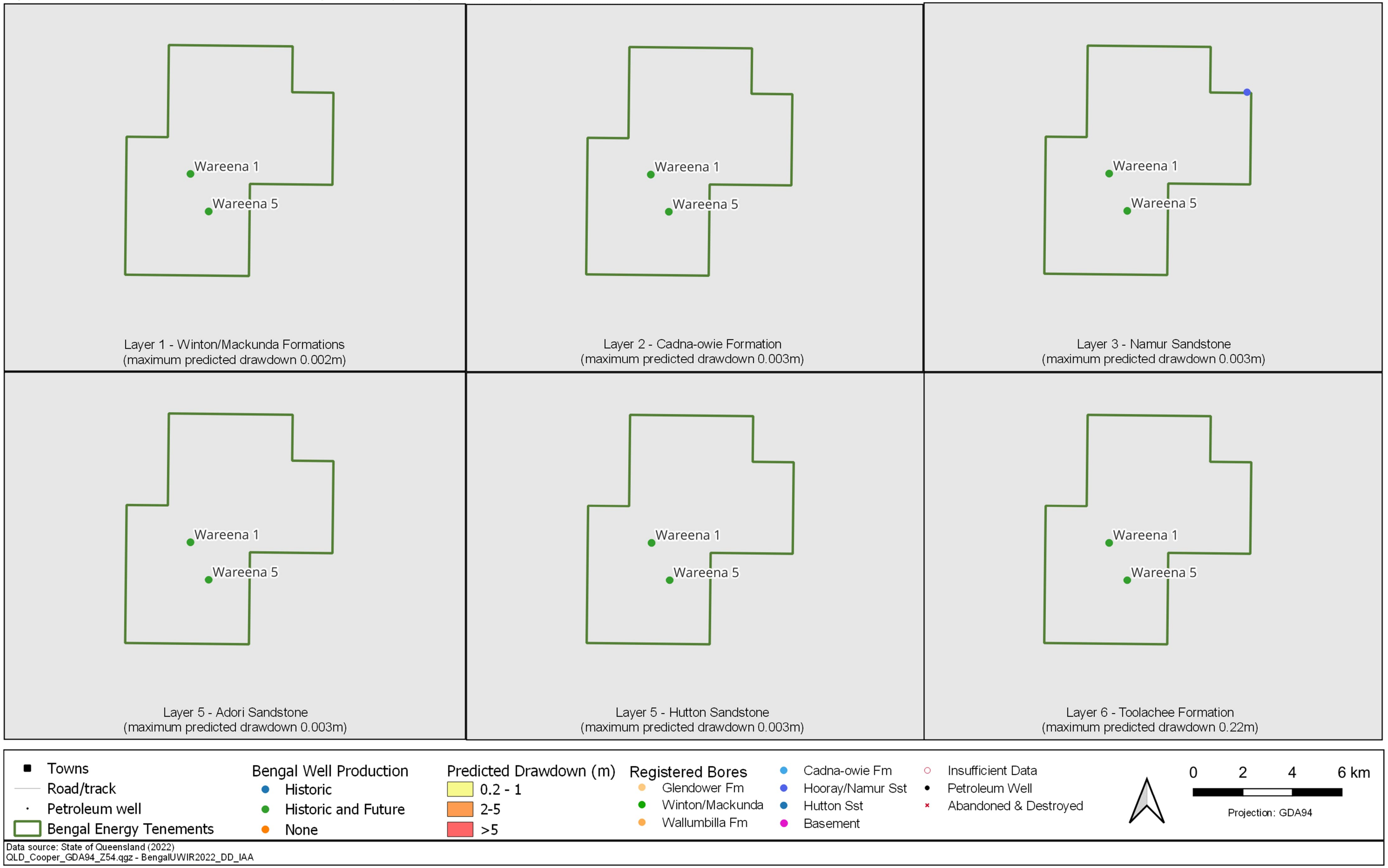


Figure 30 Predicted Drawdown for December 2026 (Immediately Impacted Area – IAA)



5.4 Potential impacts to formation integrity and surface subsidence

The extraction of water from the subsurface results in compaction of the strata from which it is produced. This compaction can be translated through the overlying rock and result in subsidence of the land surface. For the UWIR for the Surat Cumulative Management Area, OGIA (2019) used three risk categories of likelihood of a potential impact, for which low risk was less than 0.1 m of subsidence.

Simple elastic theory can be used to estimate the magnitude of compaction, which for the purposes of this assessment are assumed to translate to the surface and hence result in subsidence. Elastic theory is based on:

- drawdown resulting from the exercise of underground water rights as predicted by the modelling described above. Since MLU does not predict drawdown in the aquitards, the conservative assumption was made that the drawdown in the overlying aquitard was equal to the drawdown in the immediately underlying aquifer. The maximum predicted drawdowns from Table 9 were used;
- the thickness of the formation with which the predicted drawdown is associated (Table 8); and
- the formation compressibility. The specific storage of an aquifer is related to its compressibility, thus $5x10^{-6}$, the value used in the MLU model (Table 8), was also used in the subsidence calculation.

The maximum predicted magnitude of subsidence was less than 0.05 m. Based on the OGIA (2019) risk categories, the risk associated with subsidence is low.

6 Monitoring and Management Strategies

6.1 Water monitoring strategy

There is no predicted exceedance of the *Water Act 2000* bore trigger threshold in the next three years (no IAA) nor are there any springs or GDEs within the spatial extents of the *Water Act 2000* springs trigger threshold. The LTAA is associated with historical production.

The rationale for the water monitoring strategy (WMS) has therefore been developed to monitor and assess changes in water volumes and water chemistry of the produced water to further improve the understanding on the hydrogeological system and hence the future prediction of potential for impacts to environmental values.

The scope of the WMS is outlined in Table 11.

In implementing the WMS, water samples will be:

- Collected in accordance with the Monitoring and Sampling Manual: Environmental Protection (Water) Policy (DES, 2018).
- Collected in new, laboratory supplied sample containers, with appropriate preservatives;
- Stored in a chilled esky or refrigerator prior to delivery to the laboratory;
- Submitted under Chain-of-Custody protocols; and
- Submitted to a laboratory accredited with the National Association of Testing Authorities (NATA) for the analyses to be conducted.

Section 378(1)(d) of the *Water Act 2000* requires a program for reporting to the office (OGIA) about the implementation of the WMS. Data collected under the WMS will be compiled and provided to OGIA every 6 months in a format that complies with the OGIA data dictionary. Data provision to OGIA will align with data submissions for tenure holders in the Surat CMA, i.e. by 1 April and 1 October each year.

Table 11 Scope of water management strategy

Item	Location	Frequency	Monitoring suite
Water production	Wareena 1 Wareena 5	Monthly	Total volume of water produced (by well)
Water quality	Wareena 1 Wareena 5	Annually	• Total dissolved solids, electrical conductivity, pH • Major cations and major anions

6.2 Spring impact management strategy

Since there are no springs or groundwater dependent ecosystems located within the predicted extents of the exceedance of the *Water Act 2000* spring trigger threshold (0.2 m) a spring impact management strategy is not required.

6.3 Potential impacts to groundwater bores

The predictions of water level declines due to the exercise of underground water rights do not identify any bores for which the *Water Act* 2000 bore trigger threshold will be exceeded. However, Chapter 3 of the *Water Act 2000* identifies the make good obligations for resource tenure holders. If future UWIRs identify the exceedance of the bore trigger threshold at an active water supply bore, Bengal will comply with all make good obligations under the *Water Act 2000*.

Bengal will undertake the required bore assessments in accordance with the Bore Assessment Guideline (DES, 2017), and enter into make good agreements as necessary.

6.4 Reporting

An annual report will be prepared to provide an update on changes to circumstances that would impact on predictions reported in the UWIR, and to provide updates on the implementation of the WMS. An annual review will not be prepared when a revised UWIR is issued.

The review will include:

- A summary of changes to the mapped predictions of water level drawdown, and
- A statement of whether there has been a material change in the information or predictions used to prepare the maps.

The annual reviews will be provided to the Chief Executive (DES) within 20 business days of the anniversary date of the approval of this UWIR.

7 References

ANZECC (2000) Australia and New Zealand Guidelines for Fresh and Marine Waters. National Water Quality Management Strategy. October 2000.

ANZG (2018) Australia and New Zealand guidelines for fresh and marine water quality. https://www.waterquality.gov.au/anz-guidelines

Bridgeport Energy (2018) UWIR 2018-2021, Greater Kenmore & Bodalla Area, GKBA PL31, 32 & 47

DES (2021) Underground water impact reports and final reports. Guideline ESR/2016/2000 Version 3.03. Department of Environment and Science. 8 June 2021.

DES (2017) Bore Assessments: Guideline. ESR/2016/2005 Version 5.02. State of Queensland, Department of Environment and Science.

DES (2018) Monitoring and Sampling Manual: Environmental Protection (Water) Policy. Brisbane: Department of Environment and Science.

DES (2022) WetlandInfo. https://wetlandinfo.des.qld.gov.au/wetlands/. Accessed 22 August

Doody, T.M., Hancock, P.J. and Pritchard, J.L. (2019) Information Guidelines Explanatory Note: Assessing groundwater-dependent ecosystems. Report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of the Environment and Energy, Commonwealth of Australia 2019.

Eamus D., Froend R., Loomes R., Hose, G. and Murray, B. (2006) A functional methodology for determining the groundwater regime needed to maintain the health of groundwater-dependent vegetation. Australian Journal of Botany, 54: 91–114.

Evans TJ, Martinez J, Lai ÉCS, Raiber M, Radke BM, Sundaram B, Ransley TR, Dehelean A, Skeers N, Woods M, Evenden C and Dunn B (2020) Hydrogeology of the Cooper GBA region. Technical appendix for the Geological and Bioregional Assessment Program: Stage 2. Department of the Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia.

Hazel, C.P. (1975) Groundwater Hydraulics. Lectures presented to the Australia Water Resources Council's Groundwater School, Adelaide, August 1975.

Hemker, C.J. and Post, V.E.A. (2008) MLU for Windows, Version 2.25.77.

GWBD (2021) Groundwater Database – Queensland. Department of Natural Resources &Mines http://qldspatial.information.qld.gov.au/catalogue/custom/detail.page?fid={E314CC59-7466-4A9E-AFE2-A36645B1C29E}. Downloaded 11 August 2022.

OGIA (2019) Underground Water Impact Report for the Surat Cumulative Management Area, July 2019. Office of Groundwater Impact Assessment. Department of Natural Resources, Mines and Energy.

Peeters, L (2014) A Background Color Scheme for Piper Plots to Spatially Visualise Hydrochemical Patterns. Groundwater, Vol 52, No1, January-February 2014, pp1-6.

QPED (2016) Queensland Petroleum Exploration Data Available from Queensland Government http://qldspatial.information.qld.gov.au/catalogue/custom/detail.page?fid={840912C6-50F8-4234-8198-E035056664B0}

RDM Hydro (2022) PL1089 Environmental Authority Application Groundwater Assessment. 11 April 2022 – Final. Prepared for Texas Tickalara Holdings. https://www.tthandromedae.com/environment

Richardson, S., Ervine, E., Froend R, Boon, P., Barber, S. and Bonneville, B., (2011) Australian groundwater-dependent ecosystem toolbox part 1: Assessment framework. Waterlines Report. National Water Commission, Canberra.

Santos (2019) Underground Water Impact Report Santos Cooper Basin Oil and Gas Fields, South-West Queensland December 2019, Document Number: 0007-650-REP-0025

Santos (2022) SWQ Cooper Basin Underground Water Impact Report. Final.