UNDERGROUND WATER IMPACT REPORT

ATP 2019 – Galilee Basin

19 May 2022

Final

Copies of this document can be downloaded at www.galilee-energy.com.au

Contents

Document Revision History

Date	Version	Author	Comment
7/12/2021	RevA	Ryan Morris	Issued for internal review
15/12/2021	Rev0	Ryan Morris	Issued for Public Consultation
19/05/2022	Rev1	Ryan Morris	Issued for DES Assessment

The following document was prepared by RDM Hydro Pty Ltd

On behalf of Galilee Energy Ltd

Executive summary

The *Water Act 2000* requires that petroleum tenure holders adequately manage the impacts of underground water extraction necessarily associated with the extraction of coal seam gas (CSG) and other petroleum. 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. 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 pilot activities which have occurred and continue to occur on ATP 2019. ATP 2019 was granted by the Queensland Government for the purpose of petroleum and gas exploration, with a particular focus of this program being CSG exploration in the Betts Creek Beds of the Galilee Basin. The project area within ATP 2019 is located near Ilfracombe, approximately 60 km north-east of Longreach.

Since commencing in October 2009, pilot activities and production have not been continuous. This UWIR takes into account groundwater impacts associated with past pilot programs and future programs as follows:

- The completed Glenaras pilot, which comprised 5 pilot wells that tested the R2-R7 seams of the Permian coal measures (Betts Creek Beds);
- The Glenaras R1 pilot which used the same wells as the original Glenaras pilot, but recompleted to test the R1 seam only;
- The Glenaras Multi-lateral pilot comprising five horizontal wells targeting the R3 seam only;
- The extended Glenaras Multi-lateral pilot, comprising the original five horizontal wells, integrated with six more recently installed vertical wells; and
- The potential addition of a further six vertical wells around the extended multi-lateral pilot.

A multi-layered analytical model was constructed to predict water level decline of affected aquifers. A transient calibration of the model was achieved through history-matching to pilot water production and associated pressure monitoring. Forecast water rates for the extended Glenaras Multi-lateral pilot and potential additional wells was incorporated to predict future water level declines.

To satisfy the requirements of the *Water Act 2000,* the results of the calibrated model 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*.

The model predicts an Immediately Affected Area (IAA) and Long Term Affected Area (LTAA) for the Betts Creek Beds only. No registered water supply bores that access the Betts Creek Beds are located within either the IAA or LTAA. No IAA or LTAA applies to other formations. No springs were identified within the spatial extents of the predicted spring trigger threshold exceedances

This UWIR presents a Water Monitoring Strategy (WMS) for the Permian coal measures and the Hutton Sandstone that would ensure that any unexpected impacts are identified and improve current understanding of the relevant groundwater system. As required by the *Water Act 2000*, monitoring locations, schedules and the parameters to be tested have been detailed in the WMS.

Drawdown maps will be reviewed annually.

Glossary and units of measurement

Alluvial aquifer	Permeable zones that store and produce groundwater from unconsolidated alluvial sediments. Shallow alluvial aquifers are generally unconfined aquifers
Alluvium	Unconsolidated sediments (clays, sands, gravels and other materials) deposited by flowing water. Deposits can be made by streams on river beds, floodplains, and alluvial fans
Aquifer	Rock or sediment in a formation, group of formations, or part of a formation that is saturated and sufficiently permeable to transmit economic quantities of water.
Aquifer properties	The characteristics of an aquifer that determine its hydraulic behaviour and its response to abstraction
Aquifer, confined	An aquifer that is overlain by low permeability strata. The hydraulic conductivity of the confining bed is significantly lower than that of the aquifer
Aquifer, semi-confined	An aquifer overlain by a low-permeability layer that permits water to slowly flow through it. During pumping, recharge to the aquifer can occur across the confining layer – also known as a leaky artesian or leaky confined aquifer
Aquifer, unconfined	Also known as a water table aquifer. An aquifer in which there are no confining beds between the zone of saturation and the surface. The water table is the upper boundary of an unconfined aquifer
Aquitard	A low-permeability unit that can store groundwater and also transmit it slowly from one formation to another. Aquitards retard but do not prevent the movement of water to or from adjacent aquifers
ATP	Authority To Prospect
Australian Height Datum (AHD)	The reference point (very close to mean sea level) for all elevation measurements, and used for correlating depths of aquifers and water levels in bores
Baseline	Pre-development situation
Bore	A structure drilled below the surface to obtain water from an aquifer/reservoir or series of aquifers
Casing	Steel pipe cemented in place during the construction process to stabilize the wellbore
Coal	A sedimentary rock derived from the compaction and consolidation of vegetation or swamp deposits to form a fossilised carbonaceous rock
Coal seam	A layer of coal within a sedimentary rock sequence
Coal seam gas (CSG)	Coal seam gas is a form of natural gas (predominantly methane) that is extracted from coal seams
Confining layer	Low permeability strata that may be saturated but will not allow water to move through it under ordinary hydraulic gradients
CSG	coal seam gas
Cumulative departure from the mean	A method used to display rainfall data in a way that is comparable to groundwater level data in order to understand the recharge relationship
DES	Department of Environment and Science (Queensland)
DNRME	Department of Natural Resources, Mines and Energy (former)
Depressurisation	The process of removing formation water from a targeted coal seam to reduce pressure to enable the desorption of CSG from the coal seams
Dissolved oxygen	Gaseous oxygen dissolved in an aqueous solution

Drawdown	A lowering of the water table in an unconfined aquifer or the pressure surface of a confined aquifer caused by pumping of groundwater from bores and wells
EA	Environmental Authority; CSG operators in Queensland must obtain an EA before operations can commence
Eh	Reduction potential; also written as ORP
Electrical conductivity (EC)	A measure of a fluid's ability to conduct an electrical current and is an estimation of the total ions dissolved. It is often used as a measure of water salinity. Measured in µS/cm
Flow testing program	An exploration program designed to test the ability of pilot wells to flow, dewater and produce gas
Groundwater	The water contained in interconnected pores or fractures located below the water table in the saturated zone
Groundwater system	A system that is hydrogeologically more similar than different in regard to geological province, hydraulic characteristics and water quality, and may consist of one or more geological formations
Head (hydraulic head)	A specific measurement of water pressure above a geodetic datum
Hydraulic conductivity	The rate at which water of a specified density and kinematic viscosity can move through a permeable medium (notionally equivalent to the permeability of an aquifer to fresh water). Measured in metes per day (m/d)
Hydraulic fracturing	A fracture stimulation technique that increases a gas well's productivity by creating a pathway into the targeted coal seam by injecting sand and fluids through the perforated interval directly into the coal seam under high pressure
Hydrostratigraphic unit	A collection of stratigraphy considered, for the purpose of building a conceptual or numerical model, to contain the same hydraulic properties
km	kilometres
kPa	kilopascals
Logger	A device used to collect certain data at specified intervals
m	meters
Meteoric origin	Water that originates from precipitation
microSiemens per centimetre (µS/cm)	A measure of water salinity commonly referred to as EC (see also Electrical Conductivity). Most commonly measured in the field with calibrated field meters
ML	megalitres
Monitoring bore	A non-pumping bore generally of small diameter that is used to measure the elevation of the water table and/or water quality. Bores generally have a short well screen against a single aquifer through which water can enter
Groundwater flow model	A computational representation used to simulate and predict aquifer conditions within a defined groundwater system
OGIA	Office of Groundwater Impact Assessment, established under the Water Act 2000; and housed with the Department of Natural Resources and Mines
Permeability	A measure of the ability of a porous material (e.g. a rock or unconsolidated material) to allow fluids to pass through it
pH	Potential of Hydrogen; the logarithm of the reciprocal of hydrogen-ion concentration in gram atoms per litre; provides a measure on a scale from 0 to 14 of the acidity or alkalinity of a solution (where 7 is neutral, greater than 7 is alkaline and less than 7 is acidic)
Piezometer	See monitoring bore or vibrating wire piezometer (as appropriate)

Pilot well	An appraisal well which is tested by pumping to lower the water pressure in the coal seam, allowing gas to flow to surface once the hydrostatic head is low enough
Potentiometric surface	The potential level to which water will rise above the water level in an aquifer in a bore that penetrates a confined aquifer; if the potential level is higher than the land surface, the bore will overflow and is referred to as artesian
Pressure cement	Cement inserted around casings of a well built to withstand a required pressure to ensure no leakage occurs
Produced water	Groundwater generated from coal seams during flow testing and dewatering
Production well	A well used to retrieve gas from the underground reservoir for commercial purposes
QPED	Queensland Petroleum Exploration Data
Recharge	The process which replenishes groundwater, usually by rainfall infiltrating from the ground surface to the water table and by river water reaching the water table or exposed aquifers. The addition of water to an aquifer
Resistivity	The ability of a material to oppose the flow of electric current
RN	Registered number (within groundwater bore database)
RT	Rig Rotary Table (commonly used datum for depth measurements in wells)
Sandstone	Sandstone is a sedimentary rock composed mainly of sand-sized minerals or rock grains (predominantly quartz)
Sandstone aquifer	Permeable sandstone that allows percolation of water and other fluids, and is porous enough to store large quantities of groundwater
SCADA	Supervisory Control and Data Acquisition; a computer system that monitors infrastructure
Screen	A type of bore lining or casing of special construction, with apertures designed to permit the flow of water into a bore while preventing the entry of aquifer or filter pack material
Sedimentary rock aquifer	These occur in consolidated sediments such as porous sandstones and conglomerates, in which water is stored in the intergranular pores, and limestone, in which water is stored in solution cavities and joints. These aquifers are generally located in sedimentary basins that are continuous over large areas and may be tens or hundreds of metres thick. In terms of quantity, they contain the largest volumes of groundwater
Shut-in pressure	The surface force per unit area exerted at the top of a wellbore when it is not producing
Specific electrical conductivity	A measure of the electrical conductivity of a substance normalised to 25°C, measured in µS/cm
Stable isotope	Forms of a given chemical element with a different atomic mass and are not radioactive (i.e. stable nuclei). In hydrological studies, the stable isotopes of interest generally relate to H, C, N, O, S, B, and Li
Standing water level (SWL)	The height to which groundwater rises in a bore after it is drilled and completed, and after a period of pumping when levels return to natural atmospheric or confined pressure levels
Stratigraphic log	Visual representation of the downhole stratigraphy of a particular well/bore
Stratigraphy	The depositional order of sedimentary rocks in layers
Storativity	The volume of water released from storage per unit decline in hydraulic head in the aquifer, per unit area of the aquifer
TDS	Total Dissolved Solids, measured in milligrams/litre (mg/L)

Unconformity/ disconformity	An unconformity is a buried erosion surface separating two rock masses or strata of different ages, indicating that sediment deposition was not continuous. A disconformity is an unconformity between parallel layers of sedimentary rocks which represents a period of erosion or non-deposition
UWIR	Underground Water Impact Report
Vibrating wire piezometer (VWP)	A vibrating wire piezometer measures pore pressure and consists of a vibrating wire pressure transducer and signal cable. It can be installed in a borehole, embedded in fill or suspended in a standpipe
Water quality	Term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose
Water table	The top of an unconfined aquifer. It is at atmospheric pressure and indicates the level below which soil and rock are saturated with water
Well	Pertaining to a gas exploration well or gas appraisal or production well
Wellhead	The surface termination of a wellbore
Workover	The process of performing major maintenance or remedial treatments on an oil or gas well

1. Introduction

The *Water Act 2000* requires that petroleum tenure holders adequately manage the impacts of underground water extraction necessarily associated with the extraction of coal seam gas (CSG), other petroleum resources, and mineral resources. Since 1 December 2010, the *Water Act 2000* has been amended to include, among other requirements, provisions for the preparation, consultation and submission of an Underground Water Impact Report (UWIR) – a requirement that is triggered by the exercise of underground water rights, corresponding to the extraction of water associated with petroleum, gas or mineral production or testing. The key aspects of an UWIR include:

- 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.

A UWIR was submitted to the Department of Environment and Heritage Protection (DEHP) by AGL Energy (*AGL, 2013*), as the Operator of ATP 529. The initial UWIR was accepted on 15 January 2013 and took effect on 1 February 2013. Since then, AGL Energy has sold their 50% share of ATP 529 to Galilee Energy Limited (Galilee), who through its subsidiary companies, now holds 100% of ATP 529 and is the Operator. Galilee Energy submitted an updated final UWIR on 23 June 2016 (Galilee, 2016), was approved by the Department of Environment and Science (DES) on 27 July 2016 with annual reviews the 2016 UWIR to submitted DES. The UWIR was again updated in late 2020 and was approved by DES on 28 May 2021. This UWIR has been prepared as an amended UWIR, as per s392(1)(a) of the *Water Act 2000* after an annual review of the 2021 UWIR identified that the possible installation of an additional six pilot wells would result in a material change to the area where the underground water levels are predicted to decline as compared with the 2021 UWIR.

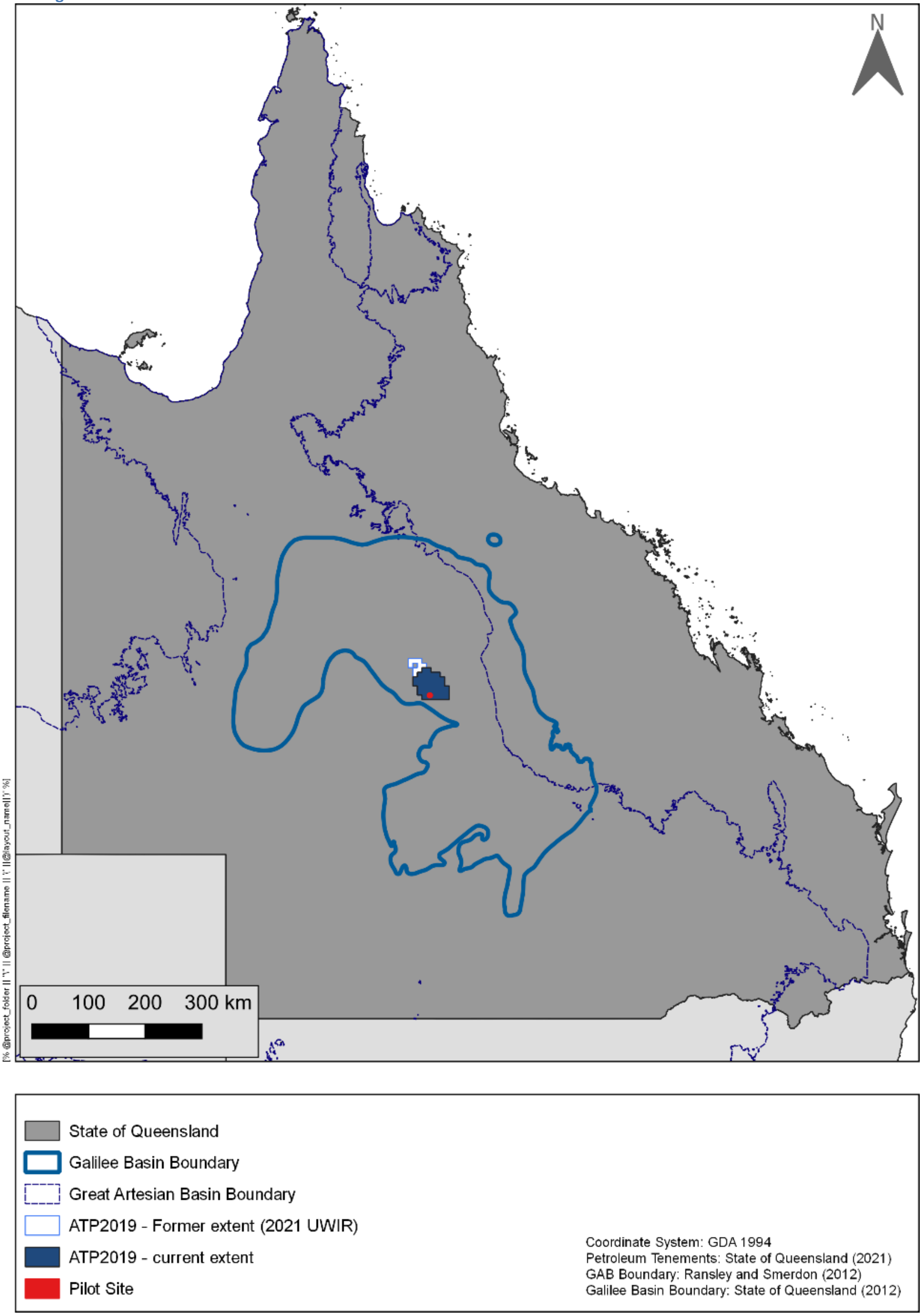
Galilee Energy publicly advertised the release of the amended UWIR on 16 December 2021 and provided letters to on-tenure landholders advising them of the opportunity to provide submissions. Galilee Energy received no submissions on the amended UWIR during the consultation period.

Since the preparation of the 2016 UWIR, Galilee Energy has transitioned the tenure to the *Petroleum & Gas (Production & Safety) Act 2004* from the *Petroleum Act 1923*. Resulting from this this transition, ATP 529 became ATP 2019, to which the tenure is now referred. Furthermore, two Potential Commercial Areas (PCA) have been declared over ATP 2019. PCA315 covers the southern portion of ATP 2019, while PCA314 covers the northern portion.

1.1 Project area

ATP 2019 was granted by the Queensland Government for the purpose of petroleum and gas exploration. The focus on ATP 2019 is CSG exploration in the Betts Creek Beds of the Galilee Basin. ATP 2019 currently covers an area of 1,025 graticular sub-blocks (approximately 3,245 km^2). The location of ATP 2019 within Queensland, the Galilee Basin and the Great Artesian Basin, is shown on Figure 1. The project (pilot) area within ATP 2019 is located close to the southern boundary of the tenement near Ilfracombe, approximately 60 km northeast of Longreach.

Figure 1 Location of ATP 2019



1.2 Project history

Pilot activities are summarised in Table 1, with locations shown on Figure 2. Past and future pilot programs and associated wells are discussed in further detail in Section 5

During October 2008, AGL drilled five pilot wells on Glenaras Station, (GA02, GA03, GA04, GA05 and GA06). Each well was constructed to isolate all aquifers behind fully pressure cemented steel casing. During November 2009, AGL installed a monitoring bore Gowing 1 (GW01) within the pilot area and piezometers for pressure monitoring were installed in the previously drilled Rodney Creek 8 well (RC08). A 357ML produced water holding pond (Glenaras Pond) was constructed and all produced water from the pilot production has been stored in this holding pond. Since 2020, produced water has been beneficially used for irrigation.

The Glenaras pilot (otherwise referred to as the original pilot) operated intermittently between October 2009 and February 2014 targeting the R2 to R7 seams of the Betts Creek Beds. In October 2015, the five Glenaras wells were plugged and recompleted so that only the R1 seam was perforated. The Glenaras R1 pilot operated from October 2015 to February 2018. Most of the original Glenaras pilot wells have now been plugged and abandoned across the Betts Creek Beds interval (except for Glenaras 3).

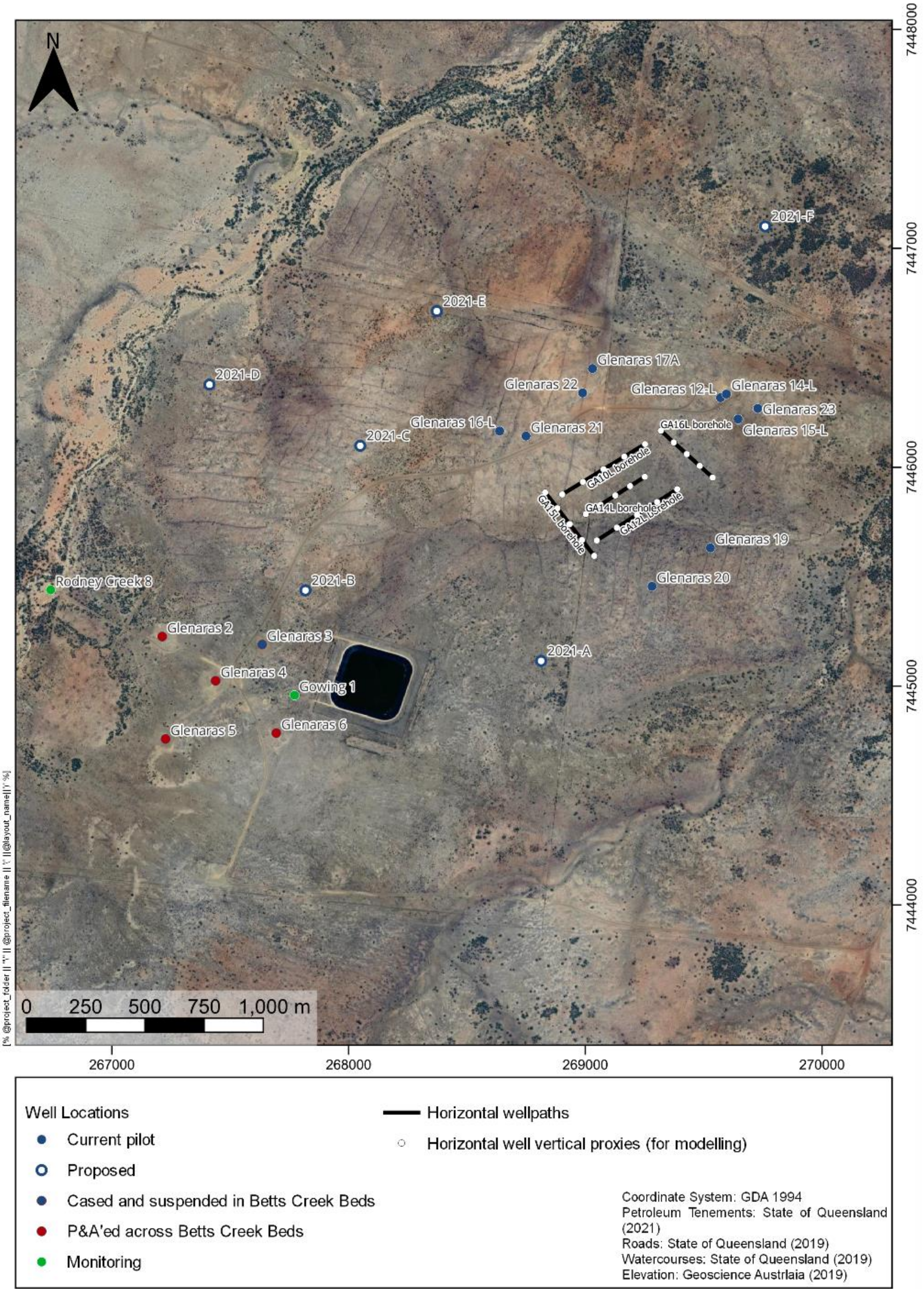
The first well of the proposed Summer Hill pilot (Glenaras 7) was drilled as part of a three well coring and exploration campaign in 2011. The well was left suspended following the coring program and while it was originally planned to complete the well to enable pilot testing, the Summer Hill pilot was deferred in lieu of an alternative depressurisation strategy, which culminated in the Glenaras Multi-lateral pilot.

The current pilot is referred to throughout this document as the Glenaras Multi-lateral pilot. It comprised five lateral wells which variously commenced production in June 2018. In September and October 2020, six vertical wells were installed to enhance depressurisation, with production from these wells commencing in late 2020. An additional six vertical wells may be installed during 2022 or 2023 to further enhance depressurisation.

Table 1 Summary of pilot programs on ATP 2019

Pilot program	Status	Wells	Test interval	Dates
Glenaras pilot	Original pilot, completed	GA02 GA03 GA04 GA05 GA06	R2 to R7 seams	October 2009 – April 2010 October 2010 – August 2012 March 2013 – February 2014 (not all wells producing throughout all test periods)
Glenaras R1 pilot	Historical pilot	GA02 GA03 GA04 GA05 GA06	R1 seam only	October 2015 – August 2017
Summer Hill pilot	Proposed	GA07	Did not proceed	Did not proceed
Glenaras Multi-lateral pilot	Current pilot	GA10-L GA12-L GA14-L GA15-L-ST1 GA16-L	R3 seam only	GA10L and GA12L commenced June 2018. Shut-in February to July 2019. All wells producing July 2019 to present.
		GA17A GA19 GA20 GA21 GA22 GA23	R1 to R7 seams	Commenced production in November 2020. All wells currently in production.
	Planned pilot extension	Up to 6 additional vertical wells (temporarily named 2021-A through F)	R1 to R7 seams	Potentially drilled and commissioned 2022.

Figure 2 Layout of Pilot activities in ATP 2019



2. Legislation

Primary Queensland legislation that governs the management of resources, including groundwater, with respect to the CSG exploration and appraisal activities on ATP 2019 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 *Water Act 2000* provides the regime for the planning and management of all water resources in Queensland. With respect to petroleum and gas production, Chapter 3 of the *Water Act 2000:*

- Identifies the obligations of CSG 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 CSG 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 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.

A UWIR will identify whether an Immediately Affected Area or Long Term Affected Area will result from CSG activities. 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, Water Act	Underground Water Impact Report Guidelines (DES, 2017)	Section(s) of this UWIR
Section 376		
(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; and	PART A UNDERGROUND WATER EXTRACTION	1.1
(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		5.2
(b) 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	3
(ii) an analysis of the movement of underground water to and from the aquifer, including how the aquifer interacts with other aquifers; and		3.3, 3.7
(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		3.4, 5.3
(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 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 28 Figure 29 Figure 30 6.2
(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 28 Figure 29 Figure 30 6.2
(c) a description of the methods and techniques used to obtain the information and predictions under paragraph (b);		6.1
(d) 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 9
(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;		6.3 6.4
(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;		6.3 6.4
(e) a program for – (i) conducting an annual review of the accuracy of each map prepared under paragraph (b)(iv) and (v); and		7.3

Reporting requirements, Water Act	Underground Water Impact Report Guidelines (DES, 2017)	Section(s) of this UWIR
(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;		7.3
(f) a water monitoring strategy;	PART D WATER MONITORING STRATEGY	7.1
(g) a spring impact management strategy;	PART SPRING IMPACT MANAGEMENT STRATEGY	7.2
(h) 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
(i) 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	7.1
(b) the rationale for the strategy;		7.1
(c) a timetable for implementing the strategy;		7.1
(d) a program for reporting to the office about the implementation of the strategy.		7.1
(2) The strategy for monitoring mentioned in subsection (1)(a) must include— (a) the parameters to be measured; and		7.1 Table 11 Table 12
(b) the locations for taking the measurements; and		7.1 Table 11
(c) the frequency of the measurements.		7.1 Table 11
(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. Geological and hydrogeological regime

3.1 Geological summary

The Galilee Basin developed as a foreland basin in response to the Hunter-Bowen orogenesis over the Late Carboniferous to Middle Triassic. The Hunter-Bowen Orogeny climaxed in the Middle Triassic, resulting in tilting and uplift of the Galilee Basin. Following this uplift, the Eromanga Basin sediments were deposited during the Jurassic to Cretaceous within a large intra-cratonic setting. The Eromanga Basin is overlain by Tertiary sediments and Quaternary alluvium of the Lake Eyre/Cooper Creek catchments.

The Galilee Basin is underlain by the:

- Early Palaeozoic age Thomson Orogeny metasediments in the centre;
- Early Devonian to Early Carboniferous age Adavale Basin in the south; and
- Late Devonian to Early Carboniferous age Drummond Basin in the north-east.

The Galilee Basin extends over 247,000 km^2 and is divided into northern and southern regions by the east-west trending Barcaldine Ridge.

There are three depo-centres identified in the Galilee Basin (RPS, 2012):

- Lovelle Depression in the west;
- Koburra Trough in the east; and
- Powell Depression in the south.

Coal accumulations occur throughout the Permian sediments, including the Betts Creek Beds and the Aramac Coal Measures.

Deposition within the Galilee Basin ceased by the end of the Triassic, when a depositional hiatus and erosion occurred, resulting in an unconformity between the Galilee Basin sequence and the overlying Eromanga Basin sequence.

Sedimentary deposition recommenced in the Jurassic with the deposition of the Eromanga Basin sedimentary sequence. The contact between the two basins is referred to as the basal Jurassic unconformity.

The stratigraphy in the project area is shown in Table 3. Depths are based on the Glenaras and Rodney Creek wells.

3.1.1 Target geological formations

The principal targets for the current CSG exploration program are the Permian Betts Creek Beds. The Betts Creek Beds are composed of interbedded sandstone and conglomerate, siltstone, carbonaceous shale and high volatile bituminous coal seams (Figure 3). The Betts Creek beds are disconformable with the underlying Aramac Coal Measures and are unconformably overlain by the Rewan Formation.

Lesser possible targets include the deeper coal seams of the Aramac Coal Measures; however no testing of this formation has been undertaken to date.

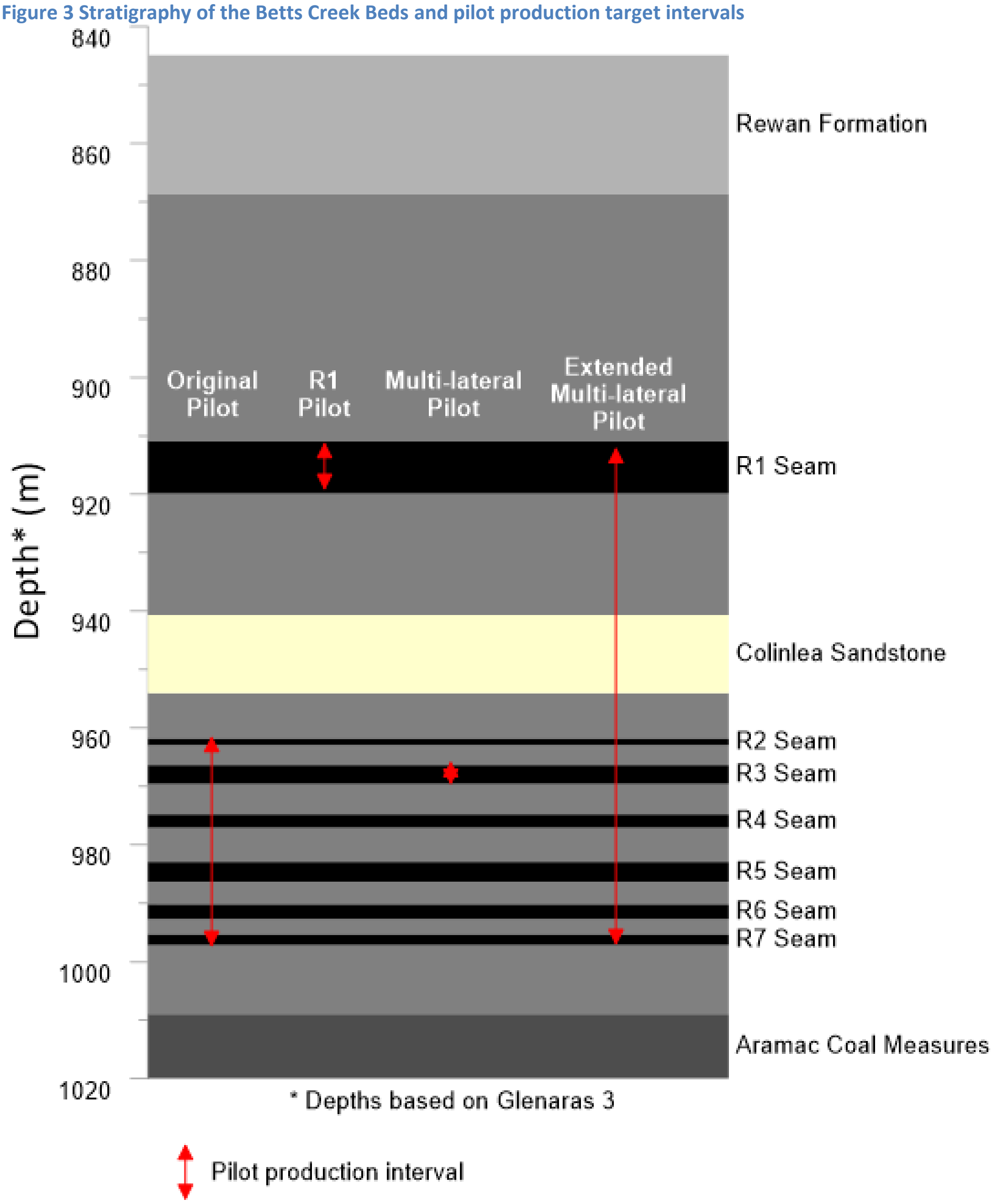
Table 3 Stratigraphic Table of the Galilee Basin and Eromanga Basin

Basin	Age	Formation/unit	Lithology	Depth to top (m)*		
				Minimum	Maximum	Average
	Quaternary	**Alluvium**		0		
	Tertiary	**Undifferentiated**		0		
Eromanga Basin	Cretaceous	**Winton Formation**	Lithic and felspathic sandstone, mudstone, siltstone, minor conglomerate, local coal, lignite and volcanic detritus	30		
		Mackunda Formation	Feldspathic sandstone, siltstone	‡		
		Allaru Mudstone	Primarily blue-grey mudstone (partly pyritic) and interbedded calcareous siltstone, cone-in-cone limestone and lesser sandstone	4	4	4
		Toolebuc Formation	Limestone, calcareous bituminous shale, coquinite	323	448	373
		Wallumbilla Formation	Mudstone and siltstone with calcareous concretions	331	457	384
		Cadna-owie Formation	Transitional, non-marine to marine sandstone, siltstone, calcareous sandstone and pebbly sandstone	504	627	552
		Hooray Sandstone	Fluvial, pale coloured, medium- to coarse-grained, quartzose sandstone, commonly cross	537	651	584
	Jurassic	**Westbourne Formation**	Fluvial-lacustrine sediments: fine-grained sandstone interbedded with siltstone,	587	727	644
		Adori Sandstone	Fine- to medium-grained clayey sandstone and minor pebbly sandstone and siltstone	617	770	674
		Birkhead Formation	Fine-grained sandstone, siltstone and carbonaceous mudstone, with some coal	630	778	689
		Hutton Sandstone	Poorly sorted, coarse to medium-grained, feldspathic sublabile sandstone (at base) and fine-grained, well-sorted quartzose sandstone (at top); minor carbonaceous siltstone, mudstone, coal and rare pebble conglomerate (at top); minor carbonaceous siltstone, mudstone, coal and rare pebble conglomerate	702	846	763
Galilee Basin	Triassic	**Moolayember Formation**	Micaceous lithic sandstone, micaceous siltstone.	Not present at pilot site		
		Clematis Sandstone	Medium to coarse-grained quartzose to sublabile, micaceous sandstone, siltstone, mudstone and granule to pebble conglomerate.	Not present at pilot site		
		Rewan Formation	Lithic sandstone, pebbly lithic sandstone, green to reddish brown mudstone and minor volcanolithic pebble conglomerate (at base); deposited in a fluvial-lacustrine environment	800	920	852
	Permian	**Betts Creek Beds**	Lithic sandstone, kaolinitic lithic sandstone, micaceous siltstone, conglomerate, mudstone, carbonaceous shale, coal, pebbly mudstone, tuff, breccia	863	992	899
	Early Permian	**Aramac Coal Measures**	Sandstone with coal and mudstone interbeds	997	1184	1049
		Jochmus Formation	Volcanic-lithic sandstones with interbedded	‡	‡	‡
		Jericho Formation	Diamictite, conglomerate, and sandstone with interbedded siltstone	‡	‡	‡
	Late Carbonifero	**Lake Galilee Sandstone**		‡	‡	‡
Base-ment	Early Palaeozoic		Metasediments	‡	‡	‡

Unconfined aquifer
Confined aquifer
Aquitard
CSG target

* based on the Glenaras and Rodney Creek wells, measured as true vertical depth; ‡not recorded in well logs

Figure 3 Stratigraphy of the Betts Creek Beds and pilot production target intervals

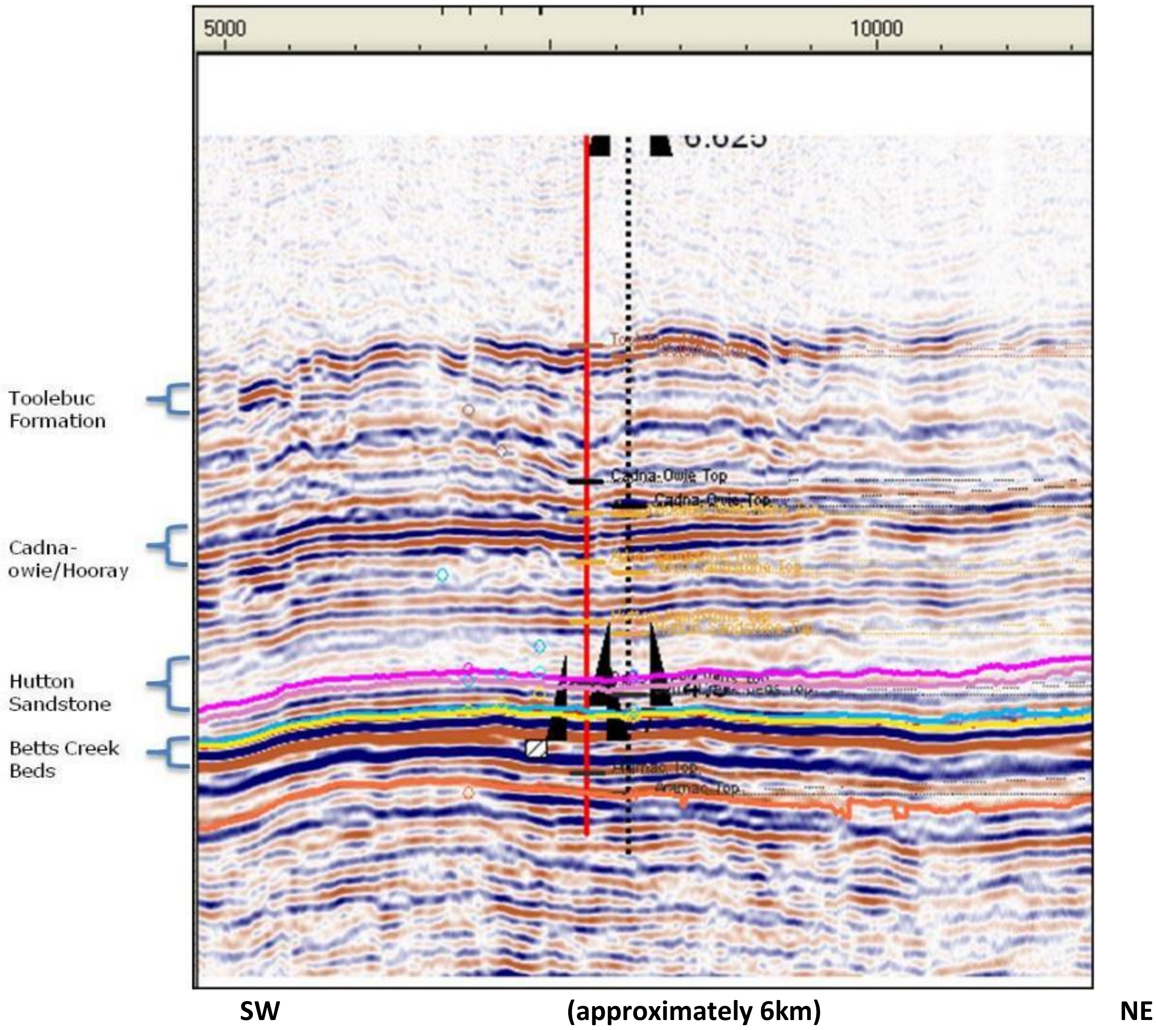


3.1.2 Geological structure

The Glenaras pilot is located on the Glenaras Anticline; with the wells located slightly off the crest of the anticline, as shown in Figure 4. Little structure is seen in the limb of the anticline, other than frequent faulting in the Toolebuc and Wallumbilla Formations. This faulting dies out at the Cadna-owie Formation and does not continue downward into the Jurassic sediments. The south-eastern limb dips more steeply than the north-western limb, which can be seen in Figure 5.

There are no observed large-scale structures that connect the Permian CSG targets with the shallower aquifers within the vicinity of the current CSG pilot exploration program.

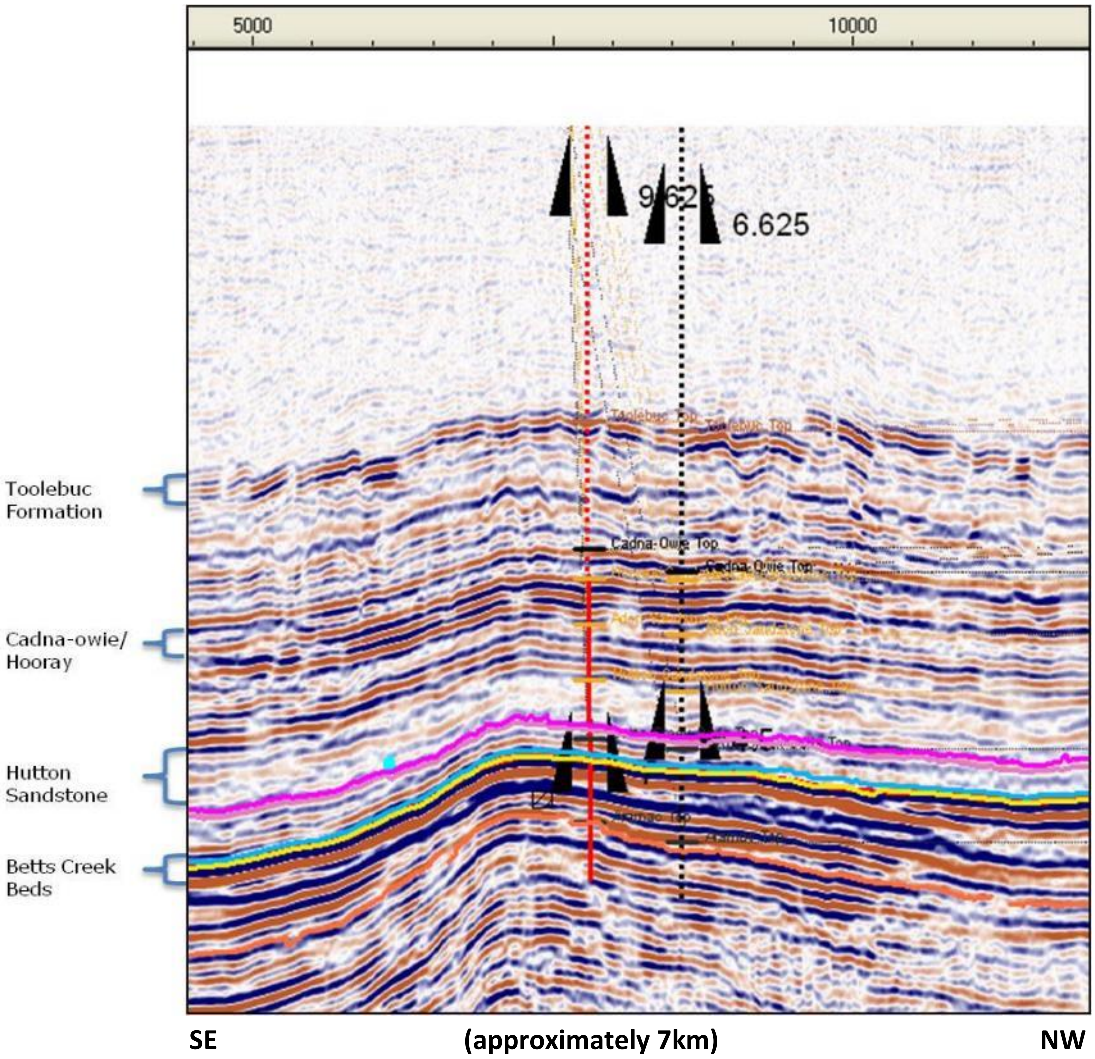
Figure 4 Northeast striking seismic line showing Glenaras Anticline (Sardine SS Line 9)



Note Minimal structure across the Glenaras Anticline.

Vertical axis shown in time not depth

Figure 5 Southeast striking seismic line, showing Glenaras Anticline (Sardine SS, Line 2)



Note steeper plunger south-eastern limb of Glenaras anticline with minimal faulting present at depth

Vertical axis shown in time not depth

3.2 Hydrostratigraphic summary

Table 4 identifies the hydrostratigraphic units for the area with a map of their outcrop areas presented as Figure 6. Figure 7 shows a northwest-southeast hydrogeological section based on stratigraphic picks from CSG and petroleum exploration wells.

The Tertiary sediments and Quaternary alluvium are associated with the Thomson River and its tributaries. These alluvial sediments are thin and are considered unlikely to form significant aquifers within ATP 2019.

The Jurassic-Cretaceous Eromanga Basin is a sub-basin of the Great Artesian Basin (GAB). On a large scale, the formations of the Eromanga Basin form a series of alternating aquifer and aquitards. The formations are grouped on similarities in the characteristics of their major lithological composition. It is recognised that at an intra-formational scale the lithology may differ such that an aquitard may locally behave as an aquifer and vice versa. General lithological descriptions of the formations are provided in Table 3.

The GAB is separated from the target CSG coal seams by the Rewan Formation and the Upper Betts Creek section, both of which are generally considered to be aquitards. The Triassic-aged Rewan Formation and Permian-aged Betts Creek Beds (the CSG reservoir) are part of the Galilee Basin sequence.

The hydrogeological section (Figure 7) identifies that the Moolayember Formation and Clematis Sandstone are present to the southeast of the pilot site, but pinch out approximately 8 km distant. The Rewan Formation is present at the pilot site but pinches out approximately 10 km to the northwest. The Rewan Formation ranges in thickness from 25m to 40m thick at the pilot location.

Table 4 Hydrostratigraphic units for ATP 2019

Age	Hydrostratigraphic unit	Formations	Unit type
Quaternary/ Tertiary	Alluvium	Alluvium & undifferentiated sediments	Unconfined aquifer
Cretaceous	Winton/Mackunda Formation	Winton Formation Mackunda Formation	Unconfined to semi-confined aquifer
	Allaru/Toolebuc/ Wallumbilla Formations	Allaru Mudstone Toolebuc Formation Wallumbilla Formation	Aquitard
	Cadna-owie Formation/Hooray Sandstone	Cadna-owie Formation Hooray Sandstone	Confined aquifer
Jurassic	Westbourne/Adori/Birkhead Formations	Westbourne Formation Adori Sandstone Birkhead Formation	Aquitard*
	Hutton Sandstone	Hutton Sandstone	Confined aquifer
Triassic	Rewan Formation	Moolayember Formation[!] Clematis Sandstone[!] Rewan Formation	Aquitard *
Permian	Coal measures	Betts Creek beds Aramac Coal Measures	Confined aquifer

*contains minor, discontinuous aquifers

[!] not present at the pilot site

Figure 6 Surface geology simplified into hydrostratigraphic units

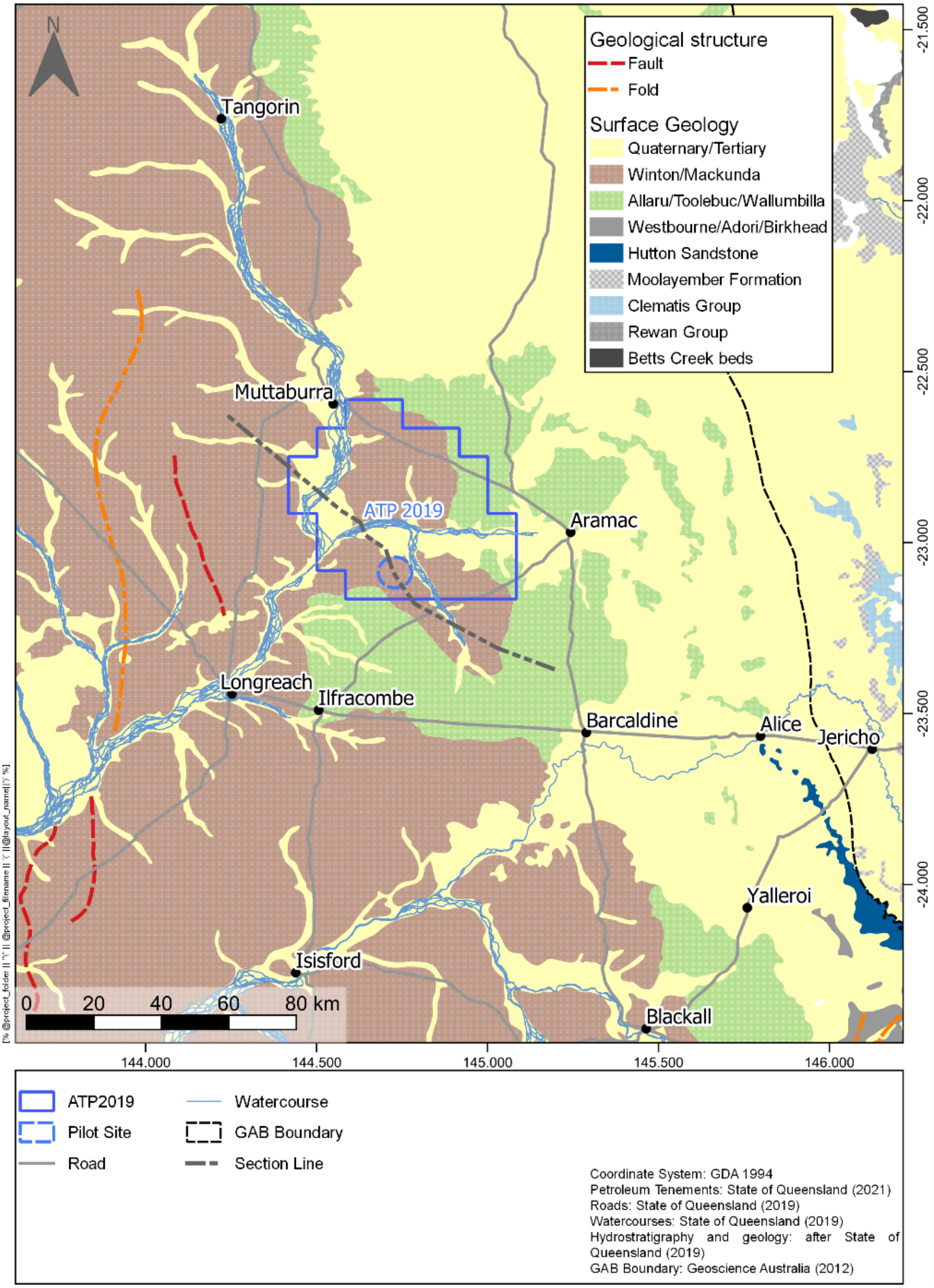
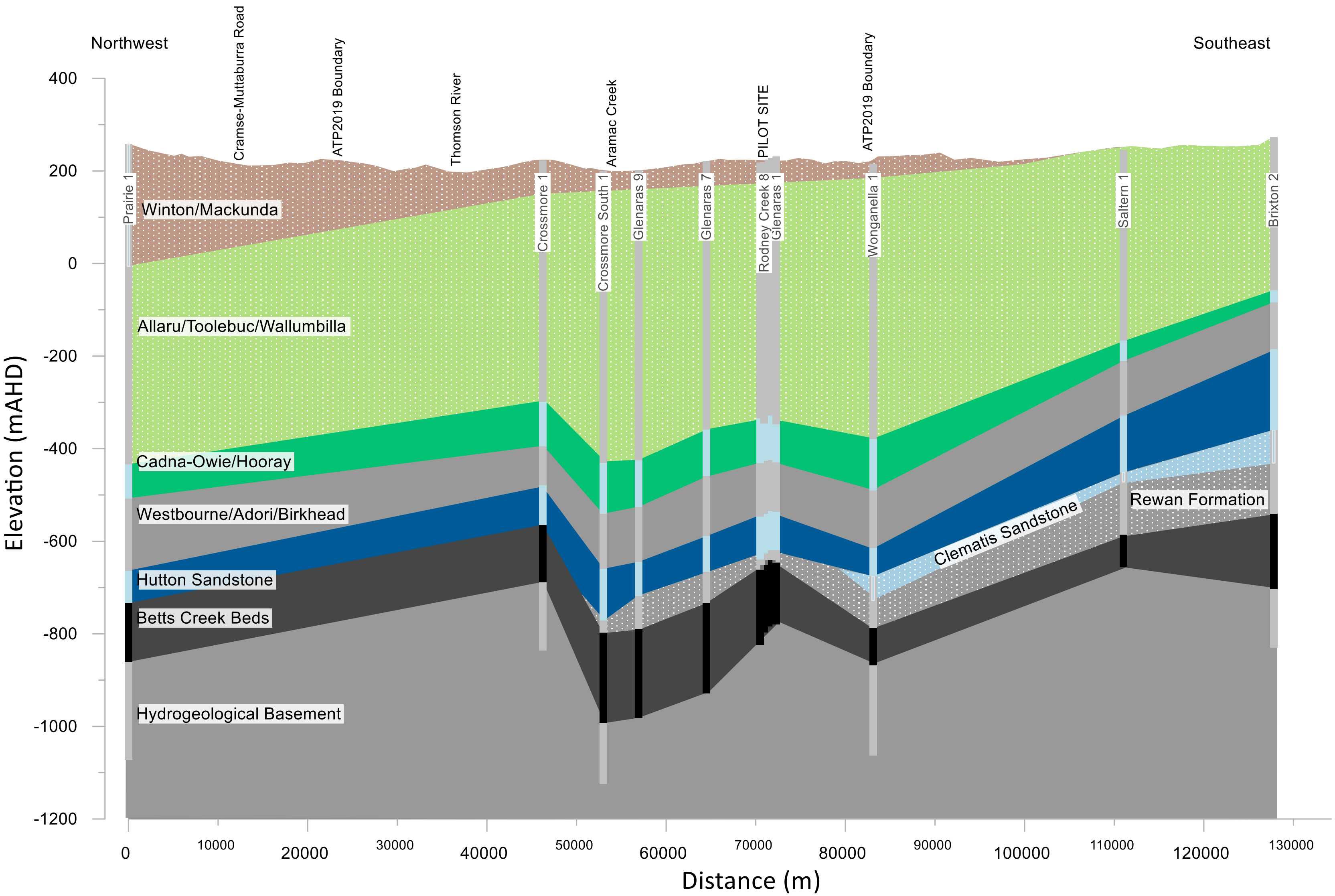


Figure 7 Hydrostratigraphic cross-section through the Pilot Site



3.3 Water levels – spatial trends

Potentiometric surfaces have been prepared for the Winton/Mackunda Formations (Figure 8), Cadna-owie/Hooray Sandstone (Figure 9) and the Hutton Sandstone (Figure 10) using the most recent available water level from the Queensland groundwater bore database (GWBD). The water level was converted to a common data (mAHD) using elevation data from the SRTM 1 second DEM. Contours were generated using the Kriging algorithm in Surfer© and the contours were clipped to the extent of the formation estimated from the surface geology mapping (Figure 6). There was insufficient data to prepare potentiometric surfaces for other formations.

The potentiometric surfaces show:

- In the Winton/Mackunda Formations, areas of relatively high (~240 mAHD) groundwater elevation are present to the northwest and the south of ATP2019, with a potentiometric low aligning with the Thompson River (~150-180 mAHD). The Winton-Mackunda Formations constitute the water table aquifer across much of the region, and the potentiometric surface suggests that the Thompson River is a groundwater sink, with groundwater flow potential towards the Thompson River.
- The Cadna-owie Formation/Hooray Sandstone extend further to the east where they outcrop in the Great Dividing Range. Similarly to the Winton/Mackunda Formations, the potentiometric highs are to the north and southeast of ATP 2019, with the lowest in the vicinity of the Thompson River. The highest groundwater elevation in the Cadna-owie Formation/Hooray Sandstones is in the vicinity of Yalleroi, where it reaches roughly 350mAHD. While the groundwater level elevation is lowest in the vicinity of the Thompson River, the pressures are still significantly artesian (>15 m). The groundwater elevation in the Cadna-owie Formation/Hooray Sandstones is generally greater than 30m higher than in the Winton/Mackunda Formations at an equivalent location, indicating an upward hydraulic gradient. It is recognised that there is a paucity of data to the west and southwest of ATP 2019 with which to constrain the potentiometric surface contours.
- Groundwater level elevations in the Hutton Sandstone exhibit a similar pattern to that of the Cadna-owie/Hooray Sandstones, but reach higher maximum elevations (roughly 400mAHD), and therefore there is an upward hydraulic gradient from the Hutton Sandstone to the Cadna-owie Formation/Hooray Sandstone. The head difference is not as great as between the Hutton Sandstone and the Cadna-owie-Hooray Sandstones as between the Cadna-owie/Hooray Sandstones and the Winton/Mackunda Formations, which is most likely due to the similarity of ground surface elevations in the outcrop areas of the deeper two formations.

While insufficient data was available to prepare a potentiometric surface for the Betts Creek Beds, drill stem test pressure data from Glenaras 1 indicates a pre-development pressure head of roughly 265 mAHD in 1966. This pressure head is approximately 15 m higher than the current potentiometric head for the Hutton Sandstone at the same location, indicating an upward hydraulic gradient and the effectiveness of the Rewan Formation as an aquitard. Pressures in the Hutton Sandstone have risen by about 10 m in the period since the Glenaras 1 DST.

Figure 8 Winton/Mackunda Formations - potentiometric surface

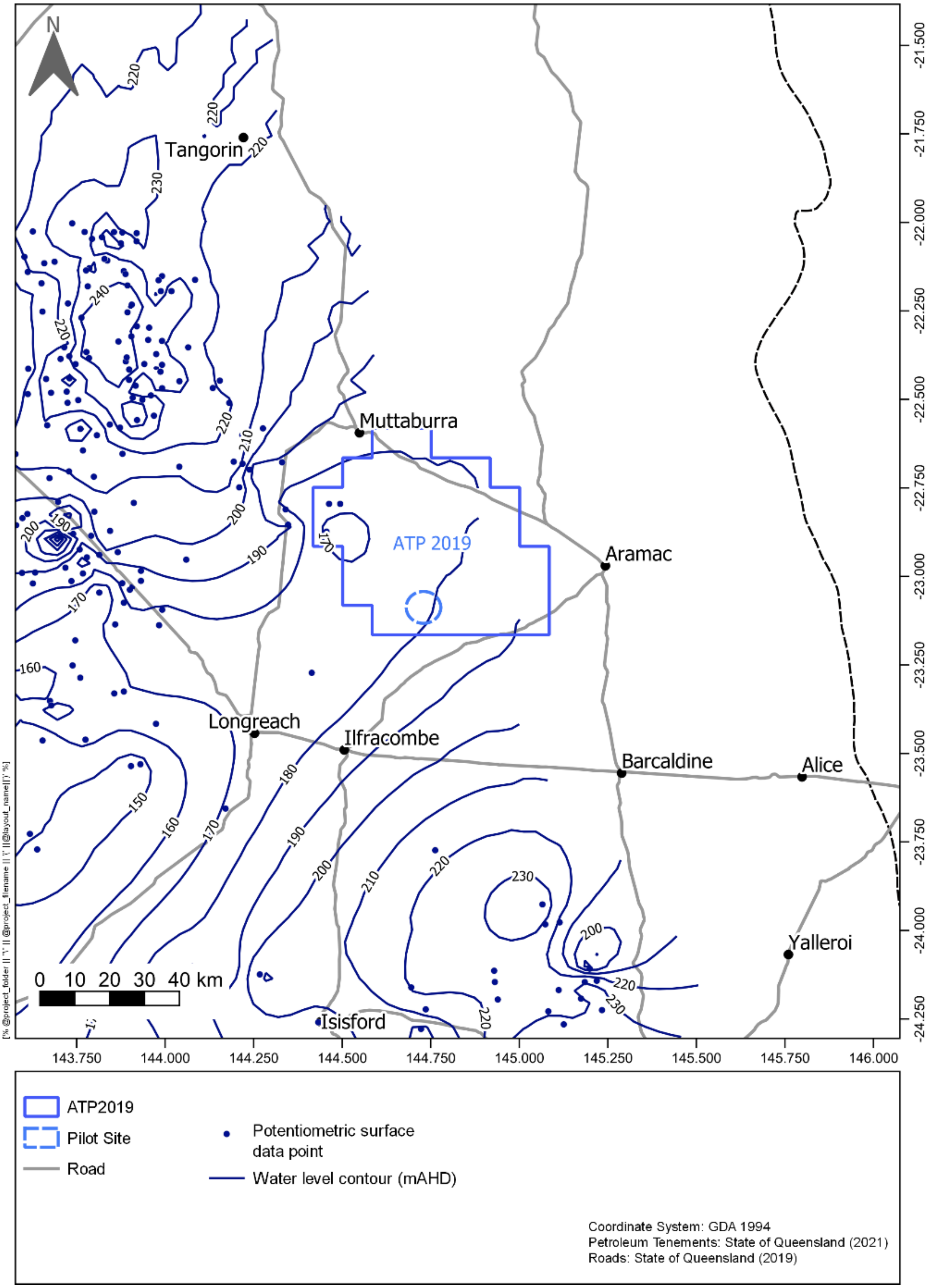


Figure 9 Cadna-owie Formation/Hooray Sandstones - potentiometric surface

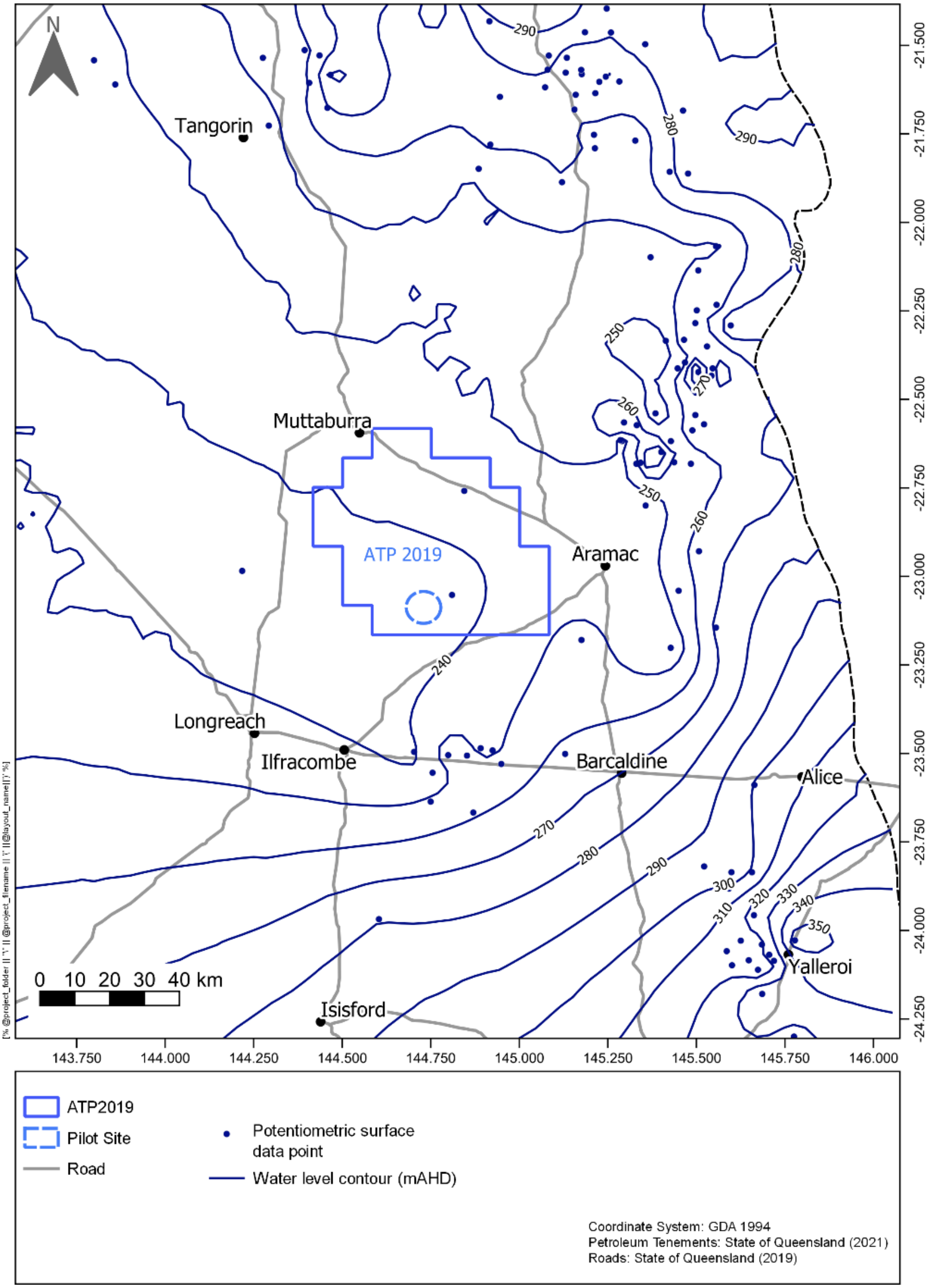
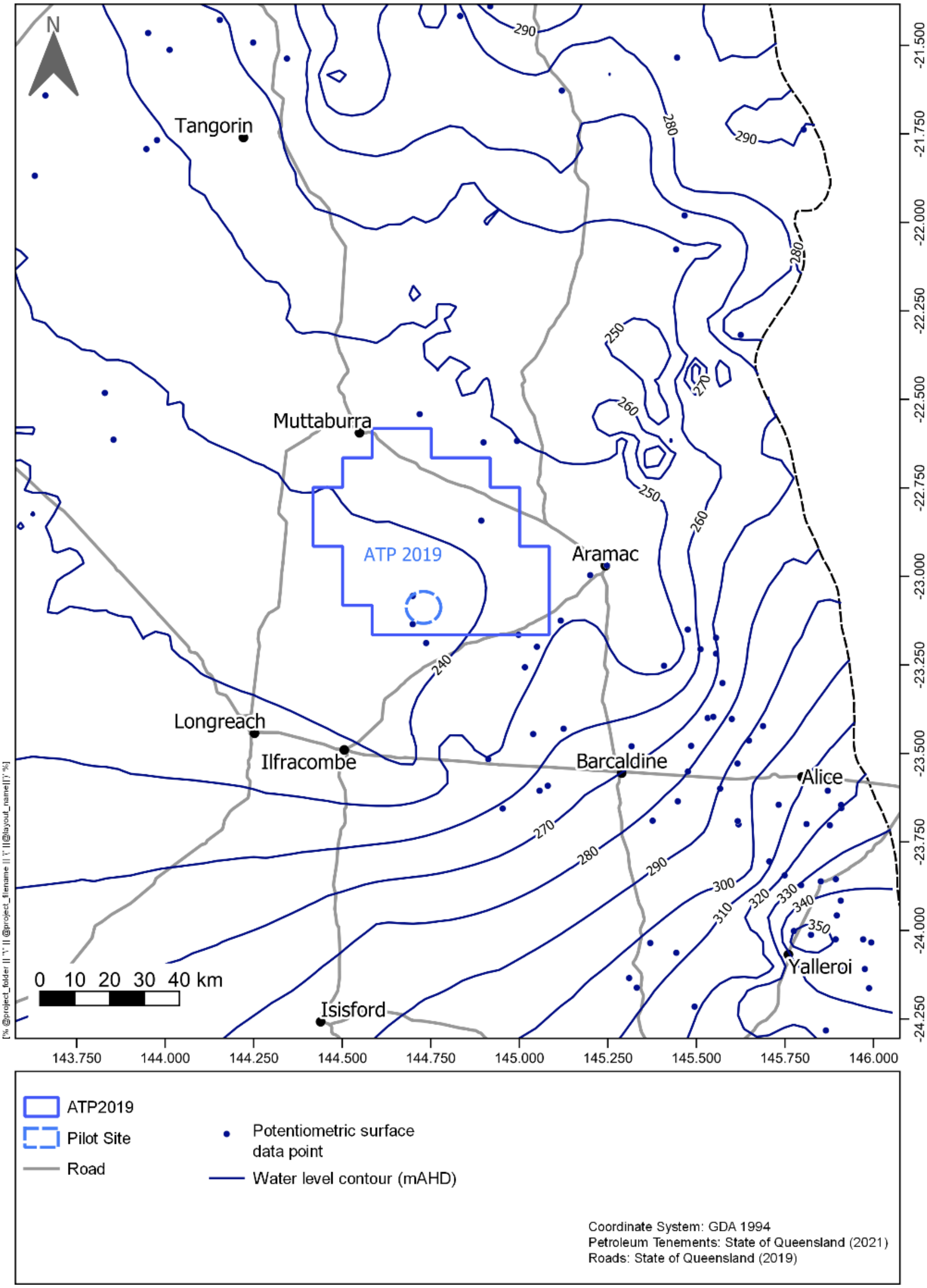


Figure 10 Hutton Sandstone - potentiometric surface



3.4 Water levels – temporal trends

Figure 11 to Figure 14 present timeseries water level trends compiled from GWBD data and data collected by Galilee during their annual monitoring of landholder bores surrounding the pilot site under the UWIR water monitoring strategy. The locations of the bores are shown on Figure 15. The water level data that is presented is only from bores on or near to ATP 2019. Insufficient data was available for the Westbourne Formation, Adori Sandstone and Birkhead Formation, Rewan Formation, Betts Creek Beds and underlying formations to assess water level trends, although water level trends associated with pilot production are discussed in Section 5.3. The regional temporal water level trends are summarised in Table 5. The only additional data since the ATP 2019 UWIR approved in 2021 was the Galilee monitoring data.

Table 5 Summary of water level trends over time

Formation	Figure	Description of trends
Wallumbilla Formation	Figure 11	Limited timeseries data available. Generally shows very slight decline in water level, although RN1628 indicates relative stability of the water level between ~1981-2005
Winton/Mackunda Formations	Figure 12	Water levels all from early 1950's. Insufficient data to identify trends
Cadna-owie/Hooray Sandstone	Figure 13	Water level data does not display consistent trends. RN146209 appears to show cyclicity, while RN93613 shows a significant increase in water level between ~2005 and ~2012
Hutton Sandstone	Figure 14 (Figure 24)	Timeseries data begins in the early 1900s and shows a general decline in water levels until the mid-1990s when water levels begin to rise. The rate of water level rise increases from the mid-2000s, likely corresponding to GABSI. The pressure sensor on Gowing 1 corroborates the spot measurements from the GWBD and other Galilee monitoring (Figure 24).

Figure 11 Wallumbilla Formation - timeseries water level measurements

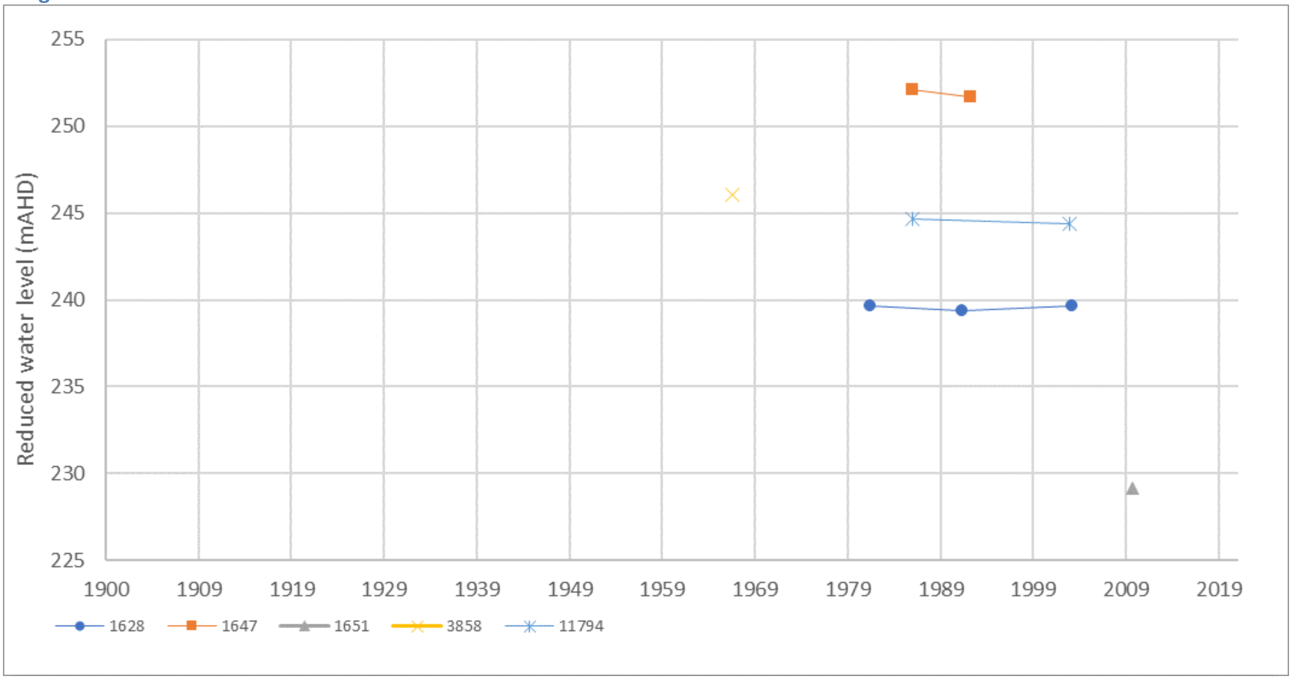


Figure 12 Winton/Mackunda Formations - timeseries water level measurements

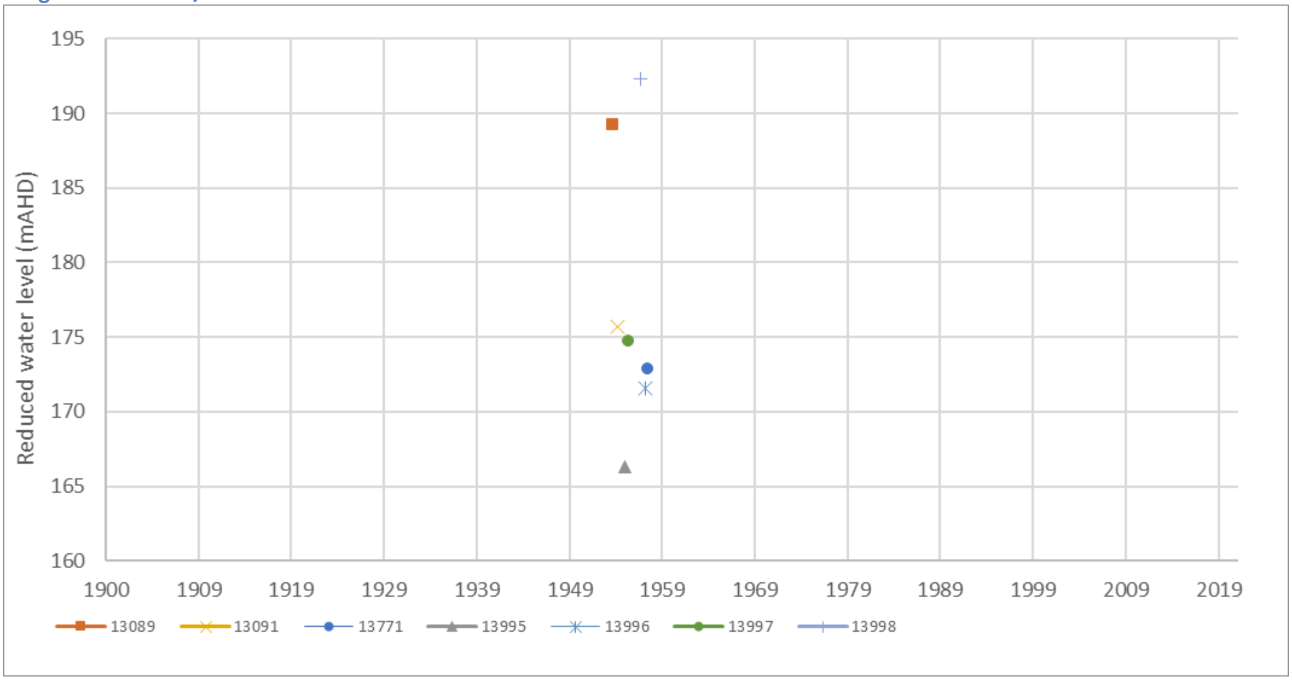


Figure 13 Cadna-owie Formation/Hooray Sandstone - timeseries water level measurements

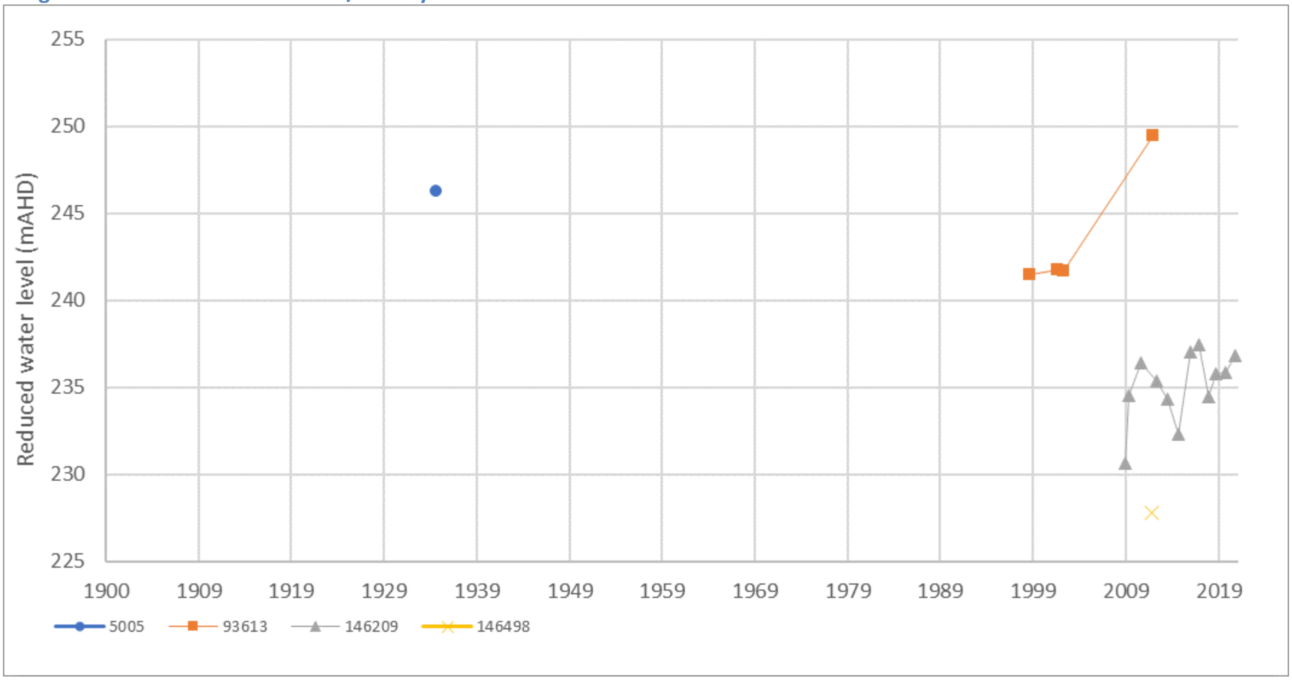


Figure 14 Hutton Sandstone - timeseries water level measurements

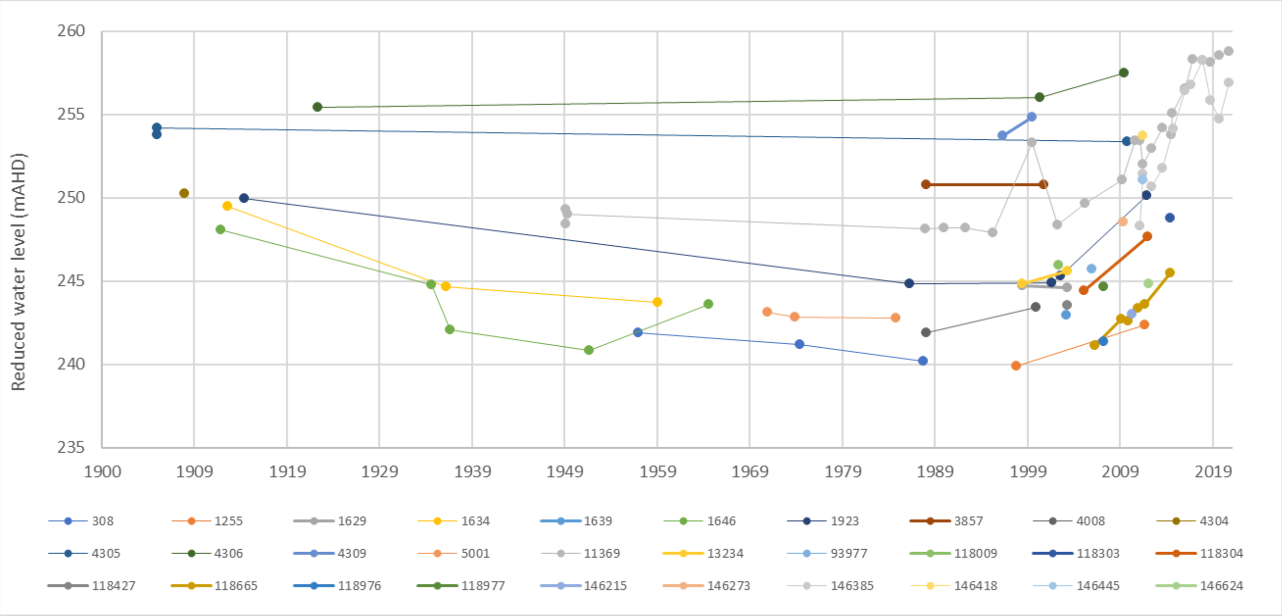
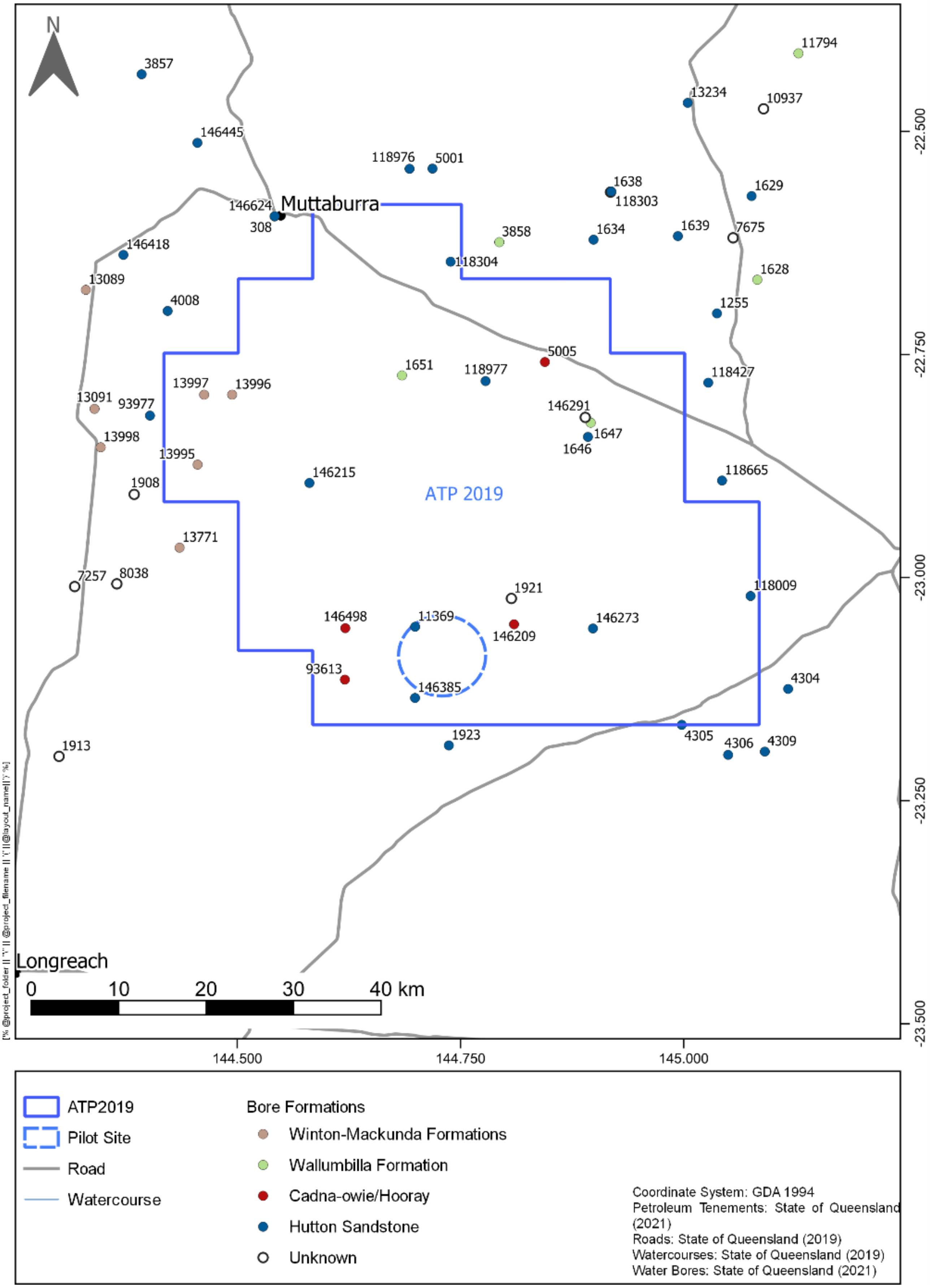


Figure 15 Locations of bores (and associated formations) with timeseries water level data



3.5 Groundwater quality

Groundwater quality data was obtained from the GWBD and from Galilee monitoring activities.

Major ion chemistry data from bores within ATP 2019 are presented as a Piper tri-linear diagram in Figure 16 with average electrical conductivities and pHs provided in Table 6. Where multiple analyses were available for a bore, the most recent was used. The piper diagram indicates that, except for the Winton/Mackunda Formations, the dominant water type is sodium bicarbonate. Despite having similar water-types, some differentiation between the Betts Creek Beds and the GAB aquifers can be observed on Figure 16. Salinities of all the aquifers are fresh, although there does appear to be some stratification on an aquifer scale. All formation pHs are circum-neutral.

The Winton/Mackunda appears to be a sodium chloride water type, however only two samples were available, and these were from relatively shallow bores. The dominances of the chloride ion and the significantly high salinity may be due to evaporation process that are affecting the shallow groundwater.

Galilee monitoring data collected under the UWIR water monitoring strategy (WMS) is presented as Figure 17, showing timeseries field water quality measurements, Figure 18 which presents a Piper tri-linear diagram generated from major ion analyses of the produced water, and Figure 19 which presents a comparison of minor ion and trace element concentrations. It is noted that a sample was not collected from Glenaras-10L in 2021 because the pump had failed immediately prior to the monitoring campaign and the well was shut-in at that time.

The timeseries field data identifies that the R1 seam is slightly fresher (~1,600 µS/cm to 2000 µS/cm) when compared with the deeper R3 seam targeted by the lateral pilot wells (~2,000 µS/cm to 2,400 µS/cm). The vertical pilot wells installed in 2020 initially reported ECs similar to the lateral wells, but tended to become fresher over time, to more resemble the salinity of the R1 seam, however the most recent measurements suggests that this may have been due to instrument drift. All pHs were circum-neutral, with the initially higher pHs likely to be due to residual drilling and completions fluid in the pilot well. This can also be seen in the temperature data of the R1 pilot. Gowing 1, the Hutton Sandstone bore was significantly fresher, more alkaline and cooler that the Betts Creek Beds pilot wells.

The Piper diagram (Figure 18) shows the produced water to be strongly sodium-bicarbonate, with negligible concentrations of other cations (Ca, Mg, K) but with 20-40% chloride. The samples from Gowing 1 (Hutton Sandstone) had lower concentrations of chloride than the Betts Creek Beds samples, but was also dominated by sodium as the cation and bicarbonate as the anion.

The majority of trace element concentrations are less than the limit of reporting. Figure 19 shows that the fluoride, boron and strontium content of the Betts Creek Beds is approximately three times higher than that of the Hutton Sandstone. Barium concentrations are also significantly greater in the Betts Creek Beds than the Hutton Sandstone, however there is also a significant difference between barium concentration in the R1 and R3 seams within the Betts Creek Beds. Furthermore, the barium concentrations of the fully penetrating vertical wells installed across the entire Betts Creek Beds sequence (GA17A and GA19-GA23) suggests that the majority of the water is produced from the lower Betts Creek Beds. This is consistent with the lower hydraulic conductivity of the R1 seam in the calibrated groundwater flow model compared with the R2-R7 seams of the lower Betts Creek Beds (Table 10).

Individual sample water chemistry results are attached as Appendix A.

Table 6 Aquifer water quality parameters (average) and water types

Formation	pH	Electrical Conductivity (µS/cm)	Dominant Water Type
Winton/Mackunda Formations	6.4	6789	Sodium chloride
Wallumbilla Formation	8.4	811	Sodium bicarbonate
Hooray Sandstone	8.6	1608	Sodium bicarbonate
Hutton Sandstone	8.2	706	Sodium bicarbonate
Betts Creek Beds	8.4	1934	Sodium bicarbonate

Figure 16 Trilinear plot for water quality data from bores within ATP 2019

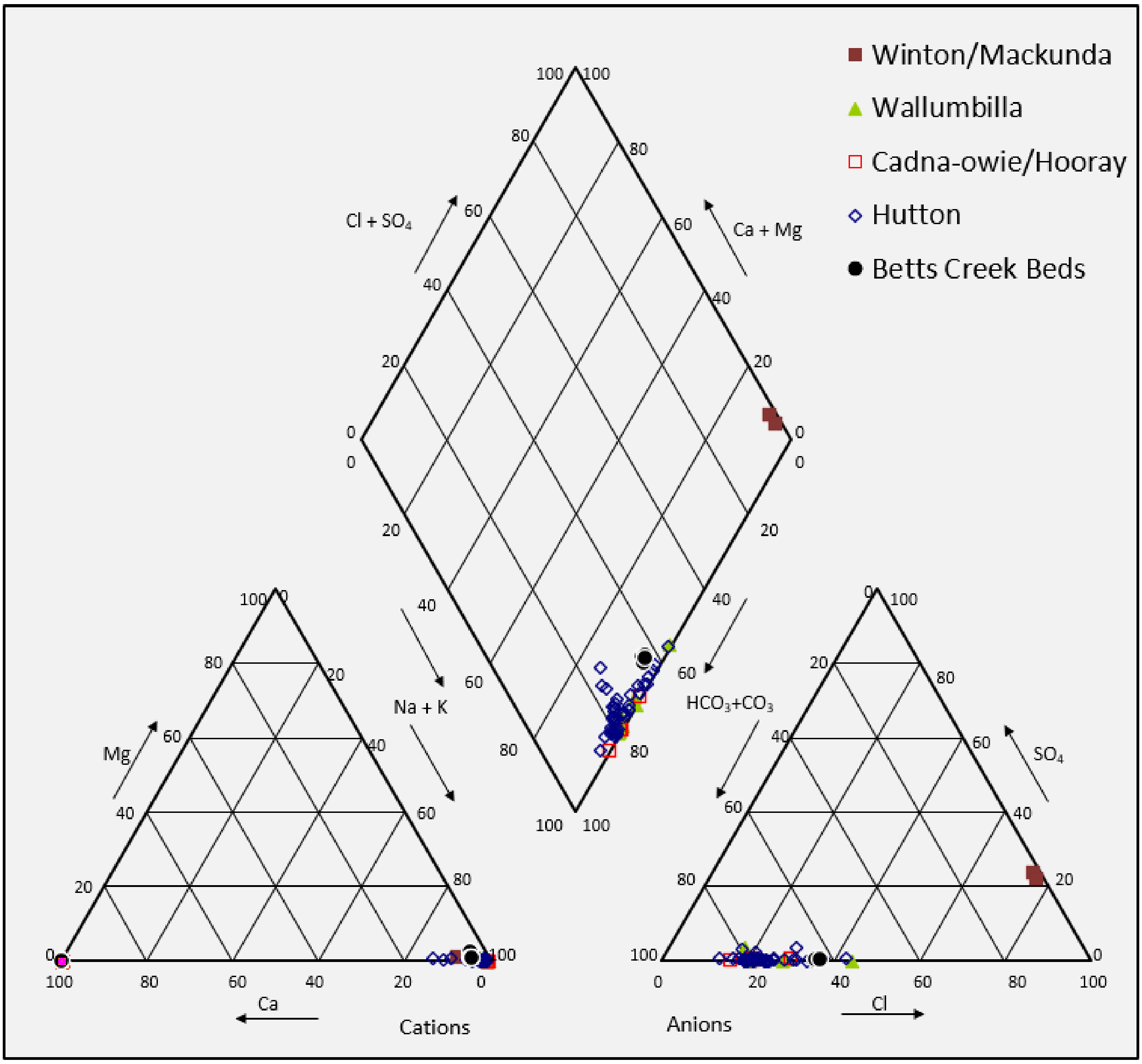


Figure 17 Timeseries field water quality parameters from pilot wells during production

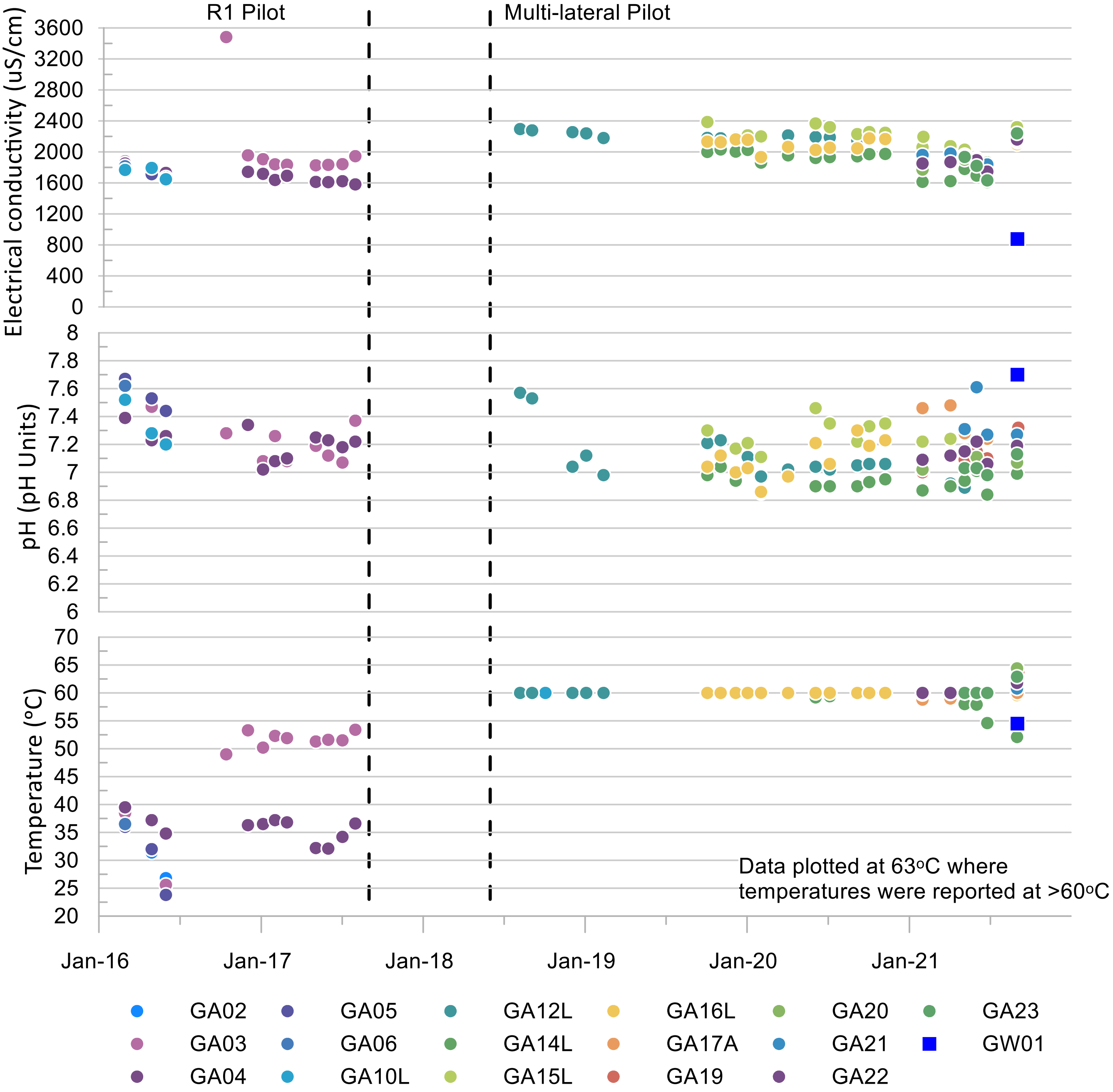


Figure 18 Trilinear plot for water quality data from pilot wells and Gowing 1

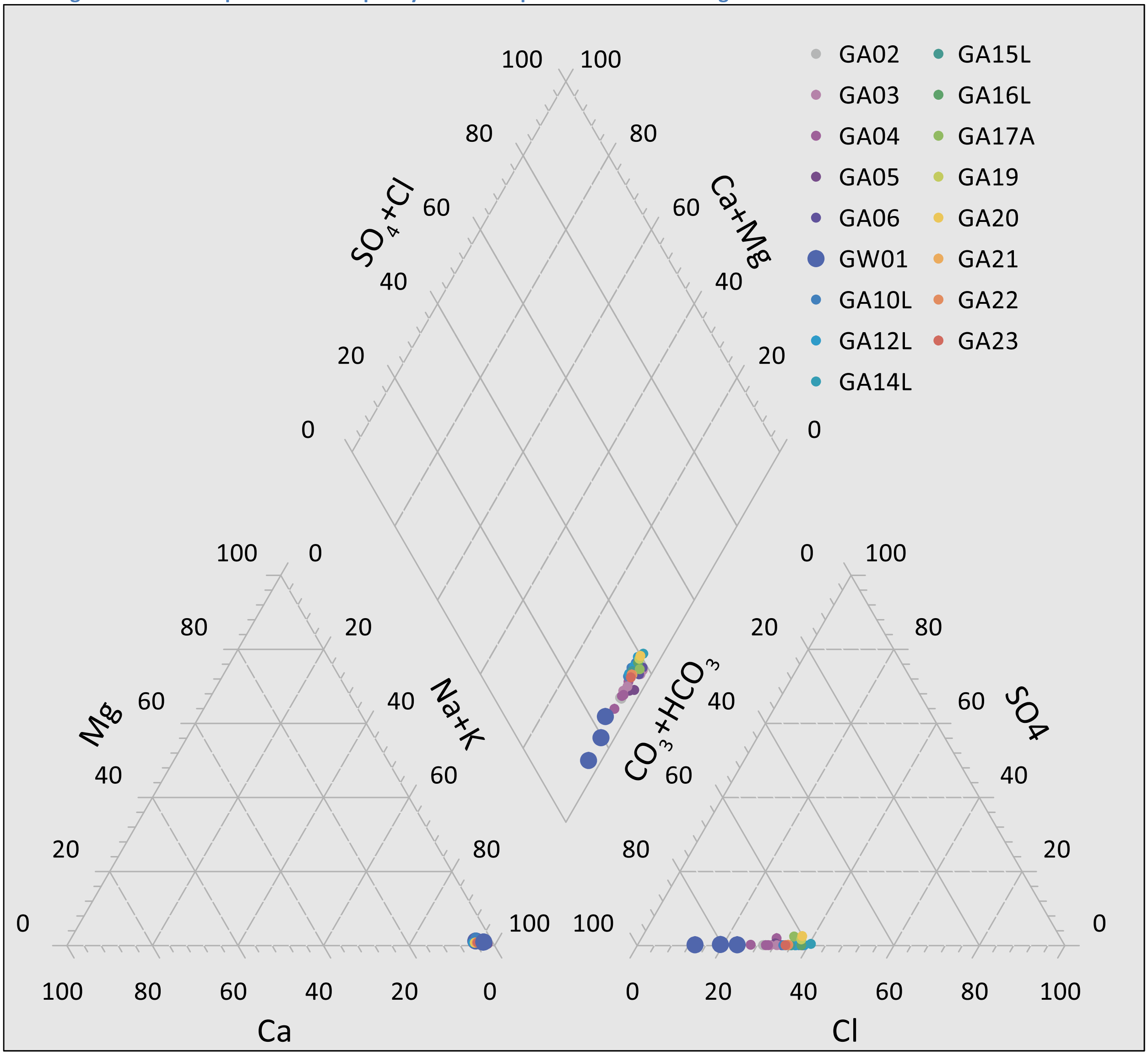
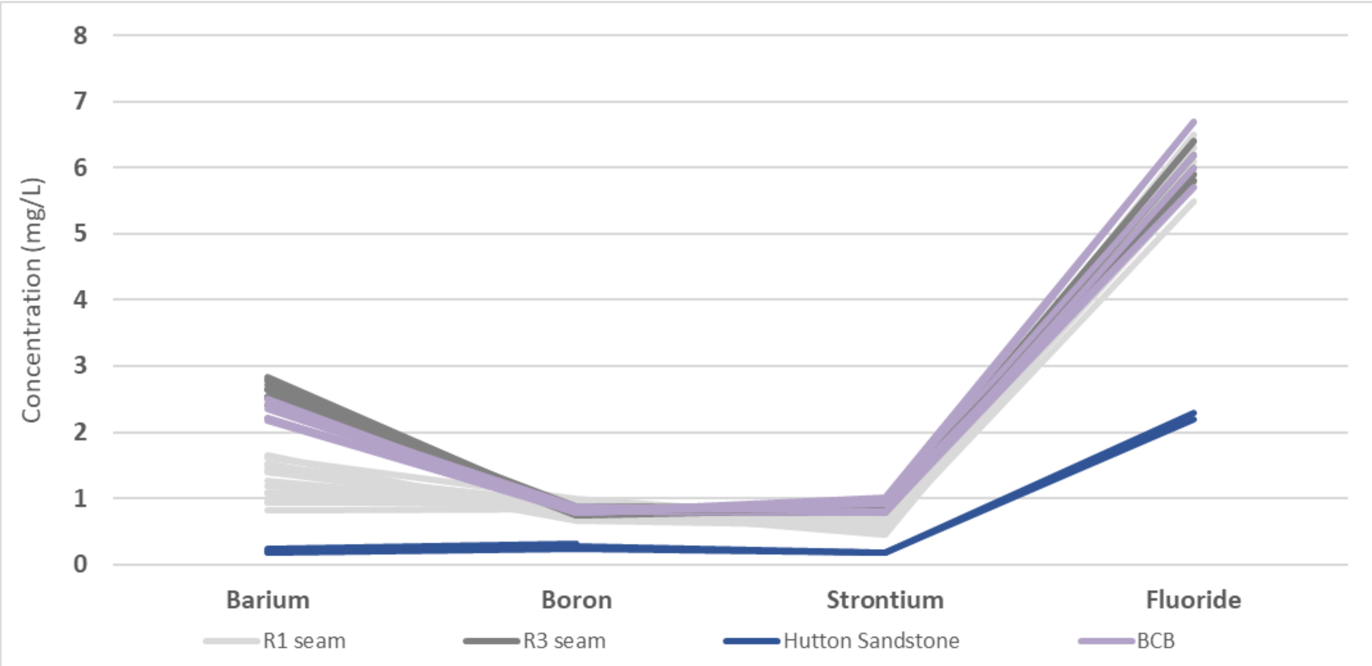


Figure 19 Pilot well water quality trace element comparison



3.6 Hydraulic parameters

Hydraulic parameters of the formations control the ability to transmit water through the rock, and therefore control the propagation of pressure reduction (drawdown) for a given volume (and rate) of extracted water. The key hydraulic parameters are hydraulic conductivity (or permeability) and the storage co-efficient. Transmissivity is hydraulic conductivity multiplied by aquifer thickness.

Galilee obtained estimates of the permeability of the Betts Creek Beds using MDT testing of Glenaras 10 and Glenaras 17A. The results of this testing are comparable to the values obtained from the calibration of the model to historical production (Table 10).

Galilee performs annual monitoring on three landholder bores in the immediate vicinity of the site. Flow and shut-in tests were previously incorporated in these monitoring activities. The data from the 2019 tests have been analysed and a summary of the derived hydraulic properties are provided in Table 7. The data shows that the Hutton Sandstone is an order of magnitude more transmissive that the Cadna-owie Formation/Hooray Sandstone.

Flow test data for Cadna-owie Formation/Hooray Sandstone and Hutton Sandstone bores were downloaded from the GWBD for a radius of approximately 150 km from the pilot site and were analysed to obtain aquifer transmissivities. One hundred and fifty-six (156) tests were analysed with the statistical distribution of the results provided in Table 8. The GWBD data analyses indicate a similar aquifer hydraulic regime to the Galilee test analyses, i.e. the Hutton Sandstone appears to be an order of magnitude more transmissive than Cadna-owie Formation/Hooray Sandstone.

A monitoring bore is required to calculate a storage coefficient and all the flow tests available from the GWBD were single bore tests. In highly confined aquifers such as the Hutton Sandstone at the site, the storativity is primarily related to the specific storage/compressibility of water and the aquifer thickness. The compressibility of water was used as the specific storage value in the numerical model for the approved UWIR for ATP 2019 (Galilee, 2016). For the Betts Creek Beds, the storativity was obtained through the model calibration as there was interference between the production wells and the RC08 monitoring from which the storage coefficient could be calculated.

Table 7 Transmissivity statistics from Galilee Energy flow tests on landholder bores

Registered Number	Aquifer	Aquifer thickness (m)	Transmissivity (m2/day)	Average hydraulic conductivity[!] (m/day)
RN11369	Hutton	123	3,190	25.9
RN146385	Hutton	135	2,350	17.4
RN146209	Cadna-Owie/Hooray	34	147	4.3

[!] $Hydraulic\ conductivity = \frac{Transmissivity}{Aquifer\ thickness}$

Table 8 Transmissivity statistics from GWBD flow test analysis

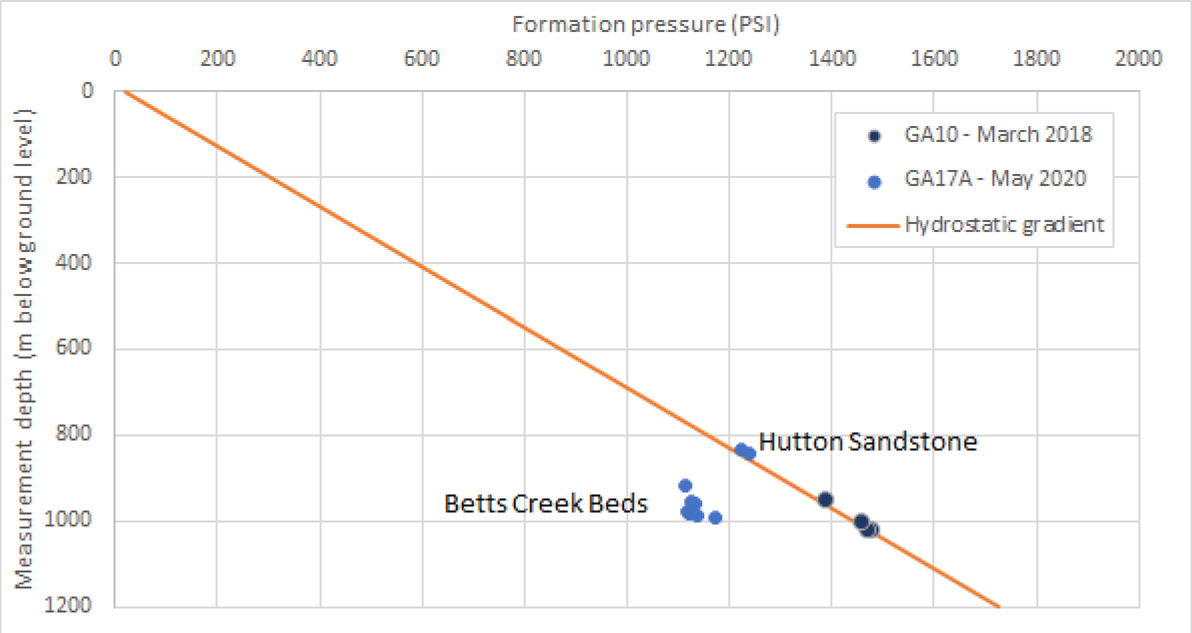
Statistic	Cadna-owie Formation/Hooray Sandstone		Hutton Sandstone	
	All	50km radius	All	50km radius
Number of tests	35	2	119	29
Average	686	133	3,055	4,464
Standard Deviation	1,020	185	3,506	3,649
Median	289	133	1,481	3,105

3.7 Aquifer interactions

Multiple lines of evidence provide evidence of the effectiveness of the aquitards and the interaction between the aquifer units in the vicinity of ATP 2019 and the pilot site. These include:

- Different potentiometric heads between the Hutton Sandstone and the overlying Cadna-owie Formation/Hooray Sandstone (separated by the Westbourne/Adori/Birkhead Formations), and between the Cadna-owie Formation/Hooray Sandstone and the overlying Winton/Mackunda Formations (separated by the Allaru/Toolebuc/Wallumbilla Formations). Comparison of a pre-development pressure head from the Betts Creek Beds and the Hutton Sandstone shows that the Rewan Formation is effective as an aquitard as there was an estimated hydraulic head difference of 25 m between the two formations at the time of measurement.
- Formation pressure measurements obtained via MDT testing prior to (March 2018) the operation of the multi-lateral pilot show pressures in the Betts Creek Beds that follow a normal hydrostatic gradient (Figure 20). MDTs performed during the operation of the pilot (May 2020) show significant pressure depletion within the Betts Creek Beds (roughly 140 m). Despite this pressure depletion, the Hutton Sandstone had remained normally pressured, providing further evidence of the effectiveness of the Rewan Formation at providing hydraulic separation.
- Results from stable isotope samples from two of the Glenaras pilot wells (GA02 and GA04) indicate that the water within the Permian coal measures is of meteoric origin (PB, 2012). The isotopic signature of groundwater form the Hutton Sandstone (Gowing 1) is more enriched than the deeper Permian formations (Betts Creek beds and Aramac Coal Measures); but still plots on the global meteoric water line, indicating that groundwater in this aquifer is also of meteoric origin but younger than the deeper water held in the Permian coal measures (PB, 2012). The different ages of the water indicate that there is limited mixing occurring along the flow path from the recharge area to the sample sites.
- While the general chemical composition of the deeper formations is a sodium-bicarbonate water type (Figure 16, Table 6) there is variability in the average salinity of the groundwaters and overall ratios of major and minor ions between the aquifers. This indicates that significant mixing has not occurred over geological time and horizontal flow is likely to dominate.

Figure 20 MDT Pressure measurements before and during the multi-lateral pilot operation



4. Environmental Values

The environmental values (EVs) of water are the qualities that make it capable of supporting aquatic ecosystems and human uses. The Queensland Government's *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* (EPP Water and Wetland Biodiversity) is the primary vehicle through which the EVs of waterways in Queensland are protected. For certain catchments, the EPP Water and Wetland Biodiversity and its supporting documents identify specific EVs alongside water quality objectives (WQOs) to ensure their protection. No such EVs or WQOs have been defined for the Cooper Creek catchment. The following EVs are listed under Section 6(2) of the EPP Water and Wetland Biodiversity:

- Aquatic ecosystems associated with high ecological value, slightly disturbed, moderately disturbed and highly disturbed waters
- Aquaculture
- Agriculture
- Recreation (primary, secondary and visual)
- Drinking water
- Industrial use
- Cultural and spiritual values

The exercise of underground water rights has the potential to impact on these EVs through the degradation of water quality or the reduction in water availability through depressurisation. The EVs are supported by either groundwater supply bores (aquaculture, agriculture, drinking water and industrial use) or through the surface expression of groundwater via springs and baseflow to surface water bodies and their associated wetlands (all identified EVs). Aquatic ecosystems also include terrestrial groundwater dependent ecosystems, for which there may not be a surface expression of the groundwater.

The environmental values within the vicinity of ATP 2019 and the pilot activities are described in the following sections.

4.1 Groundwater bores

A search of the GWBD identified 52 registered water bores within the current extent of ATP 2019 and the LTAA (based on the Lower Betts Creek Beds – refer to Figure 28). Of the 54 bores, 18 are recorded as being abandoned and destroyed, and one is recorded as abandoned but still useable. Seven of the registered bores were wells drilled for petroleum or CSG exploration. They are recorded as plugged and abandoned in the QPED database, with the exception of Rodney Creek 3 and EEA Crossmore 1. Rodney Creek 3 was reported as shut-in, however it was plugged and abandoned by Galilee in 2020. Crossmore 1 is identified as being suspended as a water bore. The GWBD identifies it as abandoned but still useable and is therefore not considered to be an active supply bore. It has not been in operation as a landowner water supply bore. One registered bore is the Gowing 1 monitoring bore (RN146279), installed by the Operator for monitoring of CSG pilot activities.

Three additional registered water bores were identified outside of ATP2019, but within the maximum spatial extent of the predicted long-term affected areas (LTAA). One of these bores was abandoned and destroyed.

The remaining 26 bores that are considered to be actively used for water supplies within ATP 2019 and the LTAA are identified in Table 9. All of the bores are believed to be used for stock and/or domestic purposes (agriculture and drinking water). No industrial or aquaculture use of the bores has been identified. The closest town water supply bore to the pilot site is the Muttaburra town bore. The locations of the relevant bores are shown on Figure 28 to Figure 30.

Table 9 Active water supply bores within ATP 2019 and the predicted LTAA (excludes abandoned bores and non-water supply bores)

Registered Number	Original Name	Type	Drilled Year	Use
1631	Highbury	Artesian - Ceased to Flow	1894	Stock/Domestic
1632	Highbury (4)	Sub-Artesian Facility	1914	Stock/Domestic
1646	No1 Bore	Artesian - Ceased to Flow	1905	Stock/Domestic
1648	-	Artesian - Ceased to Flow	1912	Stock/Domestic
1649	-	Artesian - Ceased to Flow	1911	Stock/Domestic
1650	No. 1	Artesian - Controlled Flow	1908	Stock/Domestic
1651	No. 2 Or Ewen Bore	Artesian - Controlled Flow	1926	Stock/Domestic
1653	-	Artesian - Controlled Flow	1924	Stock/Domestic
1923	Marchmont No.2 Bore	Artesian - Controlled Flow	1915	Stock/Domestic
3859	Acacia Bore	Artesian - Ceased to Flow	1914	Stock/Domestic
4305	Willoughby No. 1	Artesian - Controlled Flow	1906	Stock/Domestic
5005	Srf Job No 194	Sub-Artesian Facility	1935	Stock/Domestic
11369	Glenaras Bore	Artesian - Controlled Flow	1950	Stock/Domestic
93613	Rand Bore	Artesian - Controlled Flow	1999	Stock/Domestic
118009	Powella Bore	Artesian - Controlled Flow	2003	Stock/Domestic
118304	Mt Cornish No 6	Artesian - Controlled Flow	2005	Stock/Domestic
118977	Aviemore Bore	Artesian - Controlled Flow	2007	Stock/Domestic
118980	Daunton Bore	Artesian - Controlled Flow	2007	Stock/Domestic
146120	Highbury	Sub-Artesian Facility	2008	Stock/Domestic
146209	Summer Hill Bore	Artesian - Controlled Flow	2009	Stock/Domestic
146215	Crossmoor	Artesian - Controlled Flow	2009	Stock/Domestic
146273	Nikko Bore	Artesian - Controlled Flow	2010	Stock/Domestic
146291	No 2	Artesian - Controlled Flow	2010	Stock/Domestic
146385	Stewarts Creek Bore	Artesian - Controlled Flow	2011	Stock/Domestic
146498	-	Artesian - Controlled Flow	2012	Stock/Domestic
163092	-	Artesian - Controlled Flow	2013	Stock/Domestic

4.2 Surface expression of groundwater and terrestrial GDEs

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):

- Ecosystems dependent on surface expression of groundwater - Springs
- Ecosystems dependent on sub-surface expression of groundwater – terrestrial GDEs
- Subterranean ecosystems - stygofauna

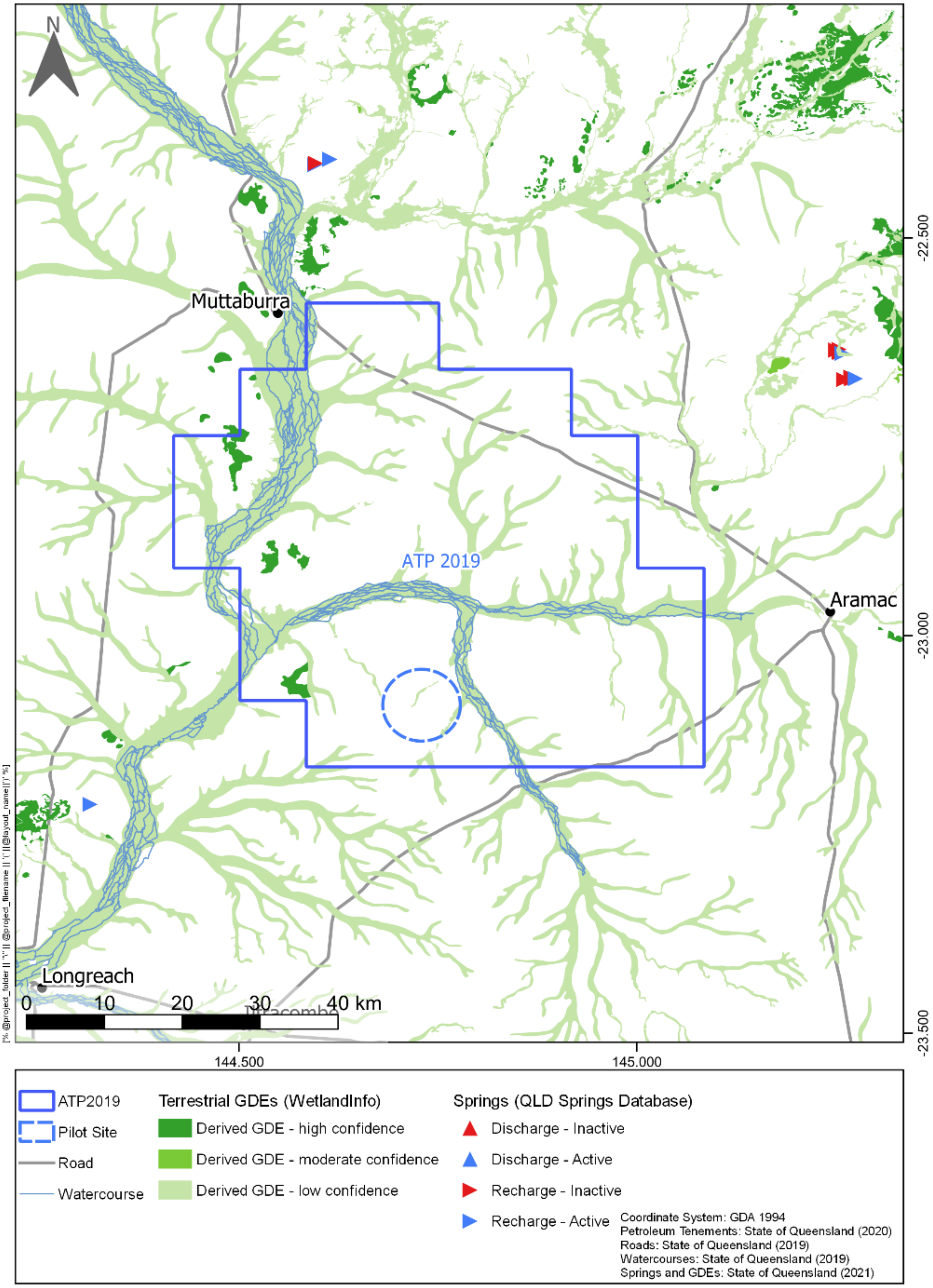
Figure 21 presents the location of springs and terrestrial GDEs in the vicinity of ATP 2019 and the pilot site. These sites may support recreational use and cultural and spiritual values.

The locations of the springs were obtained from the Queensland Springs Database (State of Queensland, 2021). The springs have been mapped into four categories, based on whether they are currently active or inactive (flowing or ceased to flow) and whether they are recharge or discharge springs. Recharge springs occur where the aquifer outcrops and rainfall infiltration is discharged again locally in a relatively short period of time and distance from the point of recharge, without necessarily reaching the regional water table. Discharge springs occur downdip from the outcrop areas and the rainfall recharge has entered the confined flow system, i.e. the aquifer is sealed above by an aquitard, and the aquifer is artesian, i.e. the potentiometric (pressure) surface is above ground level. Discharge springs also only occur where there is a geological conduit for groundwater flow to surface, such as a fault or where the aquitard is thin and possibly fractured. Since recharge springs are not connected to the regional hydrogeological system, there is negligible potential for them to be impacted by CSG production.

The closest identified springs are more than 40 km to the east of the pilot site. The Queensland Springs Database identifies the source aquifer for the discharge springs mapped to the east of the site as the Hooray Sandstone. There are no springs identified within ATP 2019.

The terrestrial GDE mapping from WetlandInfo (DES, 2020) shows that there are no known terrestrial GDEs within more than 150 km of the site. Within the immediate vicinity of the pilot site (Figure 21), derived terrestrial GDEs of low confidence are associated with the Thompson River and its tributaries (including Rodney Creek and Aramac Creek). There are intermittent patches of high confidence derived GDEs on the floodplain of the Thompson River to the west and northwest of the pilot site, which WetlandInfo identifies as being associated with shallow, local alluvial aquifers. Larger swathes of high confidence terrestrial GDEs are mapped along the Dividing Range, roughly 80 km to the east of the site. WetlandInfo identifies these to be sandy plain aquifers with intermittent groundwater connectivity related to the intermittent flow in the Barcoo and Thompson rivers.

Figure 21 Location of springs and terrestrial GDEs within the vicinity of ATP 2019



5. Water Production

5.1 Actual water production

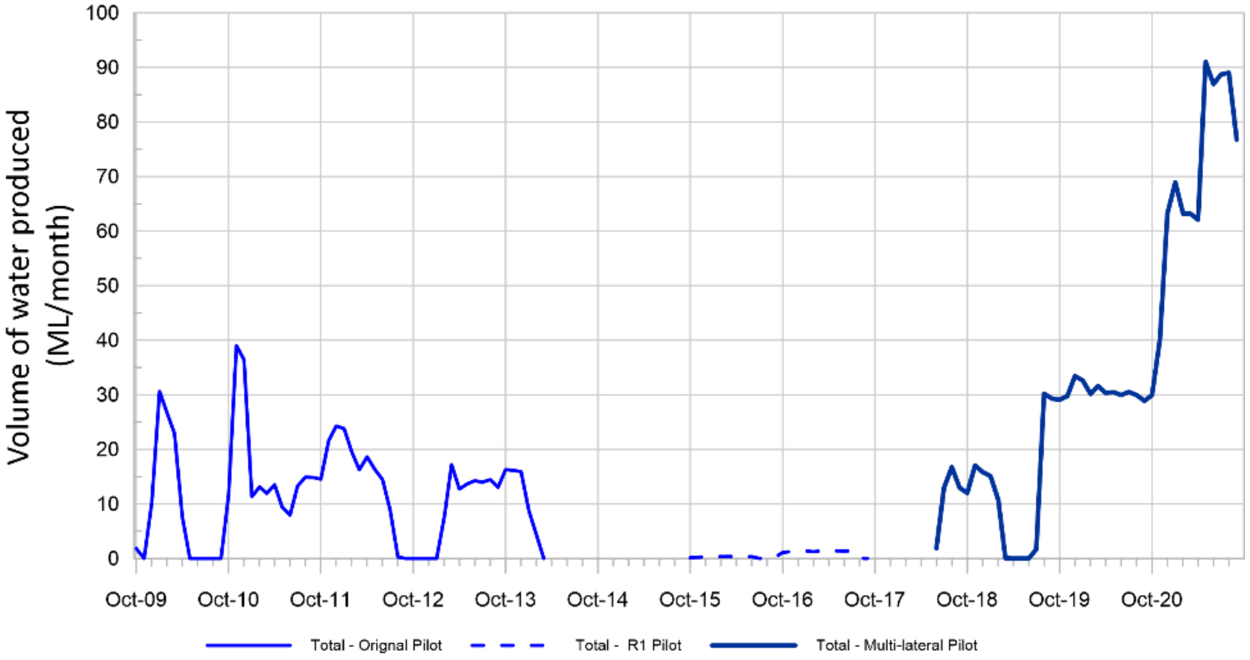
The volume of water produced at each well is measured by individual flow meters and a SCADA system calculates the total volume produced from each well on an hourly and daily basis. The daily data has been aggregated on a well-by-well basis to present monthly production totals. These data are presented as Figure 22.

Pilot production commenced from the original five-well Glenaras pilot in October 2009. The wells were fracture stimulated prior to the commencement of production. Technical pump issues resulted in sporadic operation of the wells until major well workovers were performed in late 2011. By the end of October 2011, all wells were fully operational and continued to operate until 19 February 2014. A total of roughly 640 ML was produced from the original pilot between October 2009 and the end of the pilot in February 2014.

As discussed in Section 1.2, the original five pilot wells were recompleted to isolate and test the R1 seam only. The wells went back on production as the Glenaras R1 pilot in October 2015, and the Glenaras R1 pilot ran until August 2017. The pilot produced a total of 16.25 ML at an average rate of 0.71 ML/month. As this pilot was restricted to the R1 seam, and no hydraulic stimulation was performed, water production rates are significantly lower than the Glenaras pilot.

Following the R1 pilot, an alternative depressurisation strategy was pursued with the installation and operation of the Glenaras Multi-lateral pilot. Production of the Glenaras Multi-lateral pilot commenced in June 2018 with Glenaras 10L and Glenaras 12L, at a rate of approximately 15 ML/month. Three additional wells were drilled and completed (Glenaras 14L, Glenaras 15L-ST1 and Glenaras 16L), with production recommencing from all five lateral wells in July 2019 at a rate of approximately 30 ML/month. Six vertical wells, Glenaras 17A, Glenaras 19, Glenaras 20, Glenaras 21, Glenaras 22 and Glenaras 23 were drilled in October and November 2020 and commenced production in November and December 2020, where the water production rate increased to a peak of 91 ML/month in May 2021. The monthly water rates declined following the peak due to pump failures relating to gas ingress. The extended multi-lateral pilot produced a total of 1,365.5 ML to 30 September 2021.

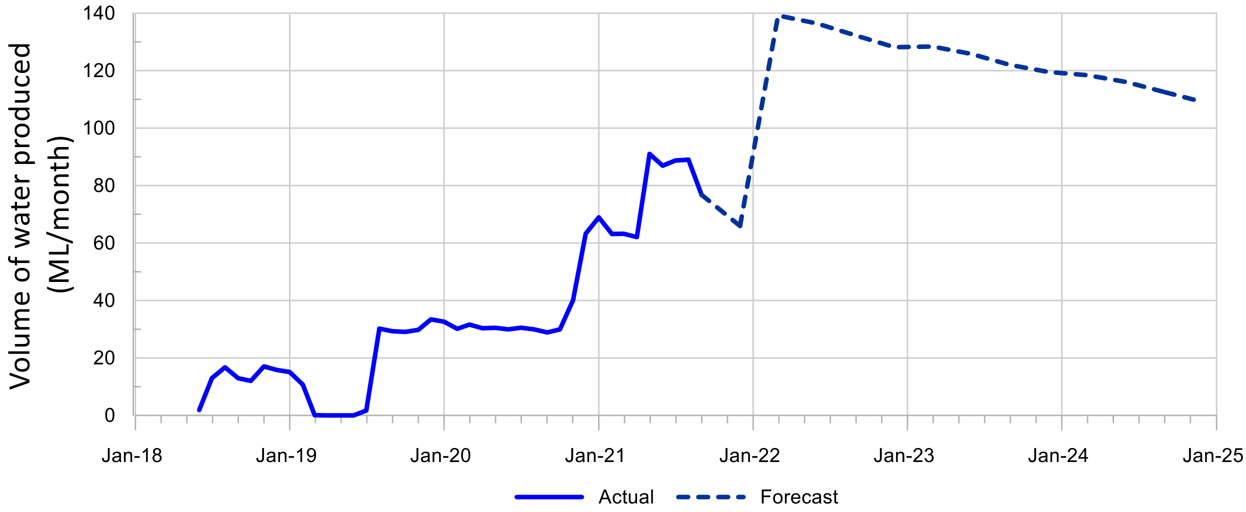
Figure 22 Monthly water production totals



5.2 Forecast water production

The forecast water production rates for the period from October 2021 to December 2024 are shown on Figure 23. The water production from the extended Glenaras Multi-lateral pilot is based on Galilee's reservoir engineering planning. It has been assumed (based on reservoir engineering) that the existing well rates would decline by 8% per year. The inclusion of the additional wells would initially result in an additional 70 ML/month of water being produced, and are also assumed to reduce by 8% per year thereafter. If the critical desorption pressure is reached in the reservoir and gas breakthrough occurs, it is expected that the water rates would decline much more rapidly than forecast.

Figure 23 multi-lateral pilot actual and forecast water production



5.3 Underground water level trend analysis

During November 2009, a water monitoring bore (Gowing 1 – GW01) was drilled within the pilot well area. The previously drilled Rodney Creek 8 (RC08) was fitted with a piezometer for remote pressure level sensing within the Colinlea Sandstone and the R3 coal seam. The sensor in the R3 seam failed in 2013. The locations of these monitoring bores relative to the pilot wells are shown on Figure 2.

RN 11369, RN 146209 and RN 146385 are the closest three landholder water supply bores to the pilot wells. These bores have been subject to annual monitoring since 2011.

Pressure measurements from these monitoring activities are plotted on Figure 24. These data show:

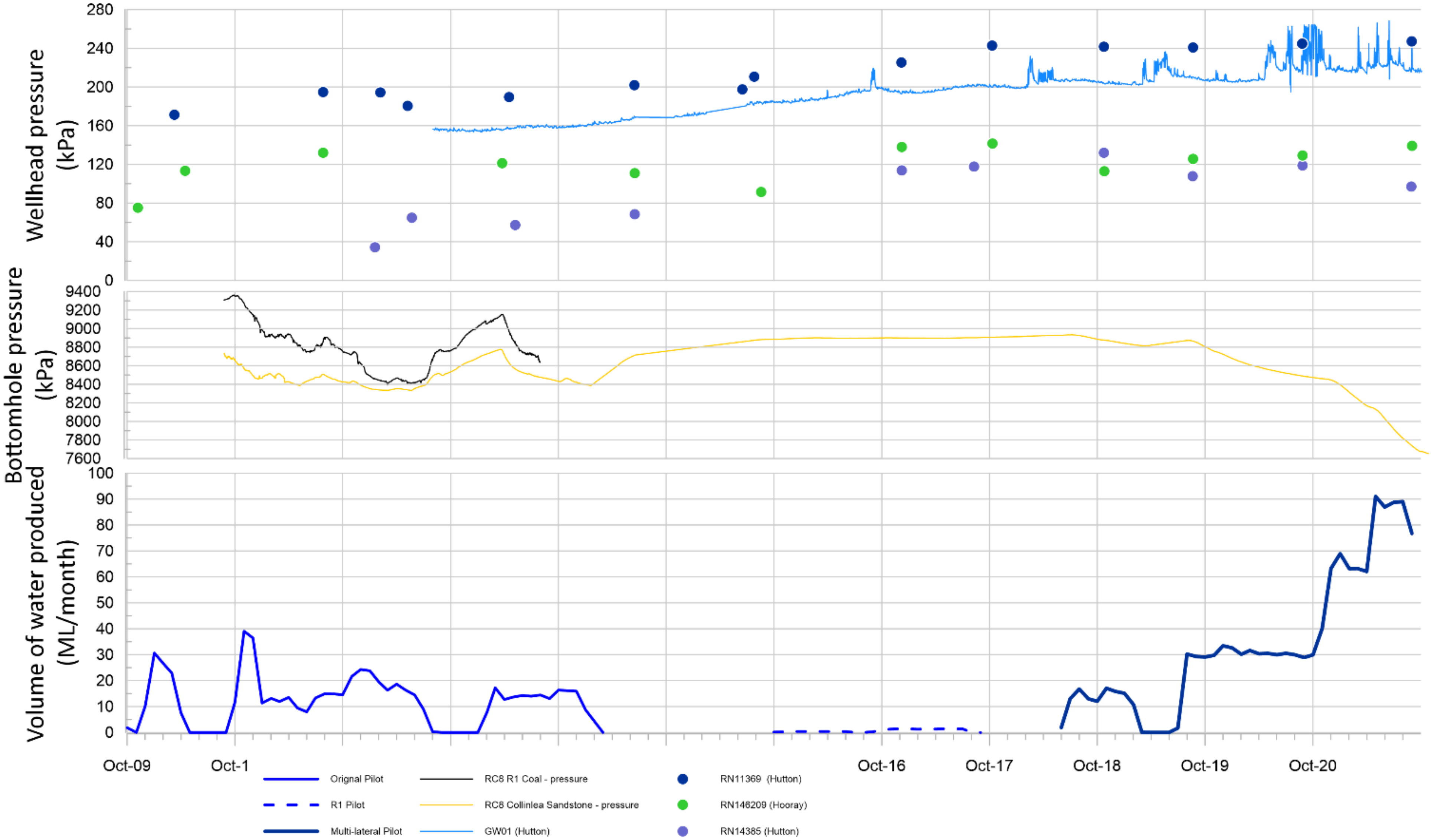
- Declining and recovering pressures in the Colinlea Sandstone that are consistent with water production from the pilot. A maximum drawdown of 130.5 m was observed in the Colinlea Sandstone corresponding to the end of the monitored period available for the preparation of this UWIR (30 September 2021).
- Generally rising pressures in the Hutton Sandstone until 2018 followed by relatively stable pressures. The continuous telemetered data from Gowing 1 (GW01) shows the same overall trend as the data from the two annually monitored landholder bores (RN11369 and RN14385) in the Hutton Sandstone, and are consistent with the observed regional trends (Figure 14). The short -term perturbations in the continuous pressure record from Gowing 1 relate to density changes due to water extraction from that bore for project purposes (non-associated water).
- A cyclical trend in the pressure of the Cadna-owie Formation/Hooray Sandstone as measured in RN146209. There is insufficient data from other bores in the region with which to compare these trends (Figure 13).

Bottomhole pressures are measured continuously in the operating pilot wells. These data have been aggregated to daily averages and the calculated pressure changes in the pilot wells are shown on Figure 25 and Figure 26. These data show:

- Significant drawdowns within the production wells sometimes in excess of 1,000 m. Since pressure recovery on the cessation of groundwater extraction is rapid, much of this drawdown can be attributed to wellbore skin effects, and the large magnitude of drawdown is not actually experienced outside of the wellbore and in the formation.
- Relatively small amounts of drawdown due to interference between the production bores. The small magnitudes of drawdown are consistent with the relatively low hydraulic conductivities obtained from Galilee's MDT testing and determined from the flow model calibration (Table 10).

Based on the available monitoring data, there is no measurable change of water level/pressure in aquifers outside of the Betts Creek Beds (the CSG target reservoir) due to pilot activities.

Figure 24 ATP2019 water production history and pressure responses



6. Predictions of groundwater impacts

6.1 Method

Predictions of water level declines due to the exercise of underground water rights by Galilee within ATP 2019 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. Only groundwater flow resulting from pumping from bores can be simulated, i.e. it does not consider recharge, non-bore discharge and cross- or through-flow, however these are not relevant within the area predicted to be potentially impacted. Over the spatial and temporal scale of the Galilee pilot activities within ATP 2019, the effectively layer-cake geology and the intraformational consistency in the lithologies, at the scale of the pilot activities and the predicted extent of the pressure changes, these limitations are considered appropriate for the purposes of predicting water level declines associated with the pilot activities.

The model was discretised into eleven layers representing the hydrostratigaphic units identified in Table 10. To allow the various vertical intervals tested during the Galilee pilot activities to be incorporated, the Betts Creek Beds was discretised into the R1 seam, the Colinlea Sandstone and the lower Betts Creek Beds, inclusive of the R2 to R7 seams and their interburden. It was necessary to incorporate aquitards above and below the Colinlea Sandstone. These were represented by the thicknesses of the non-coal interburden. Layer thicknesses were based primarily on the Glenaras 3 stratigraphy. It is recognised that the Clematis Sandstone has not been incorporated in the model, however it is not present at the pilot site and is estimated to pinch out at a distance and vertical separation where it would not be affected by the pilot activities (refer Figure 7). Similarly, the pinch-out of the Rewan Formation to the northwest of the site is not represented in the model, however this pinch out is understood to occur beyond the extent of hydraulic impact from the pilot activities.

The pilot wells identified in Table 1 were individually incorporated in the model to the layer from which pilot production occurred. The lateral wells were represented by five vertical wells spaced evenly along the length of the horizontal section of the wellbore, with total flow rates from the horizontals equally divided between the five assumed verticals. The locations of the wells, including the positions of the assumed vertical wells are shown on Figure 2. For the purposes of calibration, the pressure measurements from the lateral wells were assumed to correspond to the central vertical proxy-well.

A transient model calibration was performed to achieve the best overall match to the pressure responses in each of the production wells in the R1 and Multi-lateral pilots and Rodney Creek 8 (monitoring the Colinlea Sandstone). The original Glenaras pilot was not incorporated as pressure monitoring showed effectively full recovery following the cessation of that pilot and the commencement of the R1 pilot. The calibration was undertaken in the following stepwise manner:

1. History matching of the recovery (non-pumping) periods within the multi-lateral pilot to calibrate hydraulic parameters for the R1 Seam and the Lower Betts Creek Beds
2. History match of the Colinlea Sandstone response within Rodney Creek 8 monitoring to production from the multi-lateral pilot and the R1 pilot

3. Adjustment of the skin factors on each of the production wells to match the drawdown during the pumping phases.

The actual and predicted drawdown associated with each production well for the multi-lateral pilot are show on Figure 25 and Figure 26.

Since no response to the pilot activities could be observed in Gowing 1, the vertical hydraulic conductivity of the Rewan Formation could not be uniquely determined. The same value of vertical hydraulic conductivity was used as in the previous UWIR. This was conservatively estimated by increasing the vertical hydraulic conductivity of the Rewan Formation until the model predicted 0.2 m of drawdown within the Hutton Sandstone at the location of Gowing 1. Any additional increase in the vertical hydraulic conductivity of the Rewan Formation would not allow the pressure within the R1 seam to be reduced due to cross flow from the Hutton Sandstone. The MDT measurements performed by Galilee (Figure 20) show that the R1 seam had been depressurised.

For the Hutton Sandstone and the Cadna-owie Formation/Hooray Sandstone, the hydraulic conductivity was adjusted to match the transmissivity calculated from the flow tests performed during the baseline assessments (Table 7) on RN11369 and RN146209, being the closest tested bores to the pilot site.

Predictions were performed by adding the water forecast (Section 5.2 and Figure 23) and the planned wells from the multi-lateral pilot into the calibrated model. The predictions incorporate the full history of and future exercise of underground water rights within ATP 2019.

Table 10 Calibrated model hydraulic properties

Hydrostratigraphic unit	Thickness (m)	Horizontal hydraulic conductivity (m/day)	Vertical hydraulic conductivity (m/day)	Storativity (-)
Allaru/Toolebuc/Wallumbilla Formations	545.6	-	3.0×10^{-6}	0
Cadna-owie Formation/Hooray Sandstone	91.8	1.6	-	3.0×10^{-5}
Westbourne/Adori/Birkhead Formations	123.7	-	3.0×10^{-6}	0
Hutton Sandstone	83.1	3.4		3.0×10^{-5}
Rewan Formation, including upper non-productive Betts Creek Beds	76.2	-	2.7×10^{-5}	0
R1 Seam	11.1	0.014	-	4.3×10^{-5}
Colinlea upper aquitard*	21.3	-	4.75×10^{-21}	0
Colinlea Sandstone	9.7	0.003	-	8.1×10^{-5}
Colinlea lower aquitard*	13.4	-	105	0
Lower Betts Creek Beds* (between R2 and R7 seam)	25.7	0.097	-	2.1×10^{-5}
Hydrogeological basement*	100	-	1.9×10^{-11}	0

* Informal name used for modelling purposes only.

Figure 25 Multi-lateral Pilot - flow rates with measured and modelled drawdowns (Colinlea Sandstone and lateral wells)

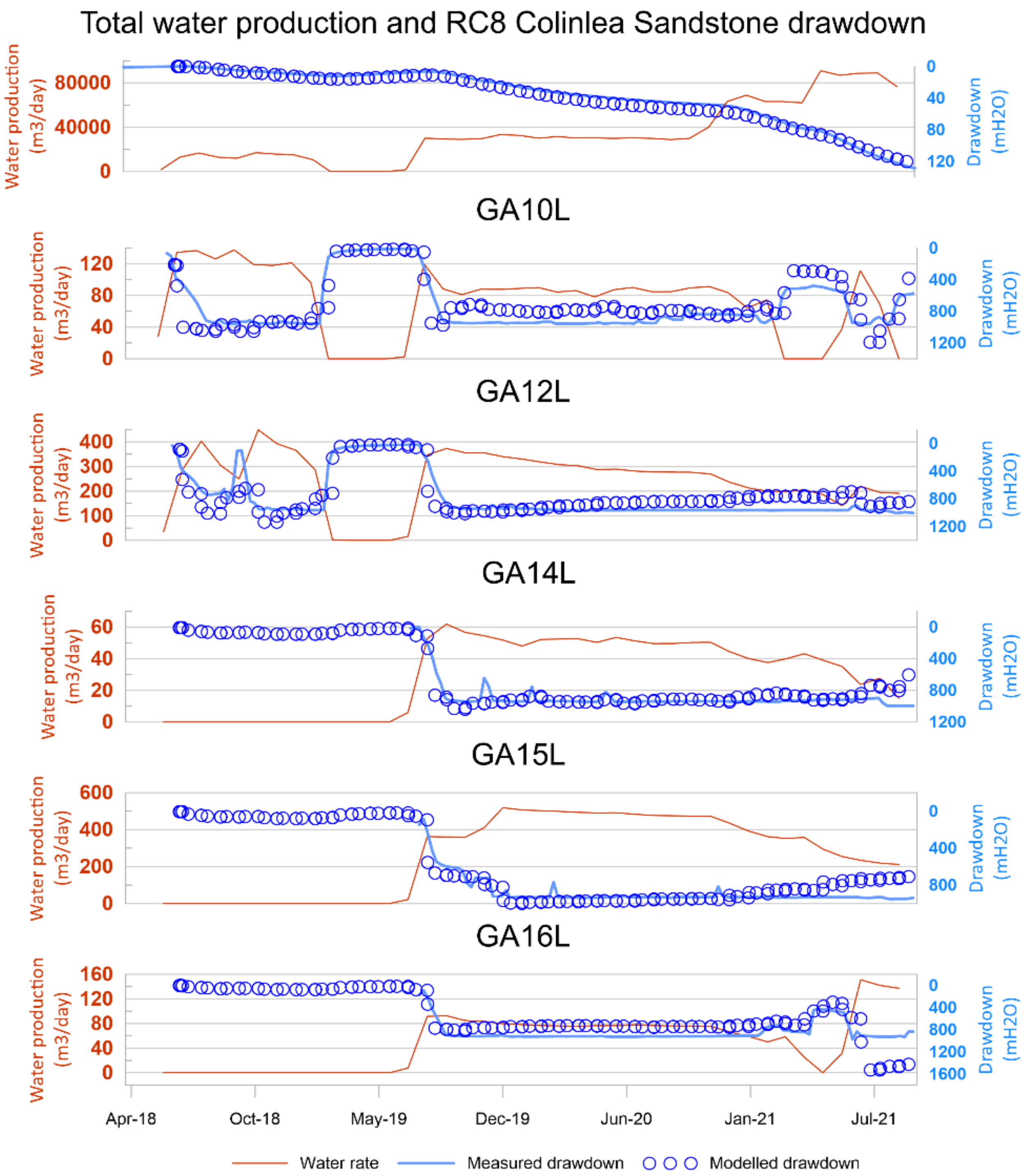
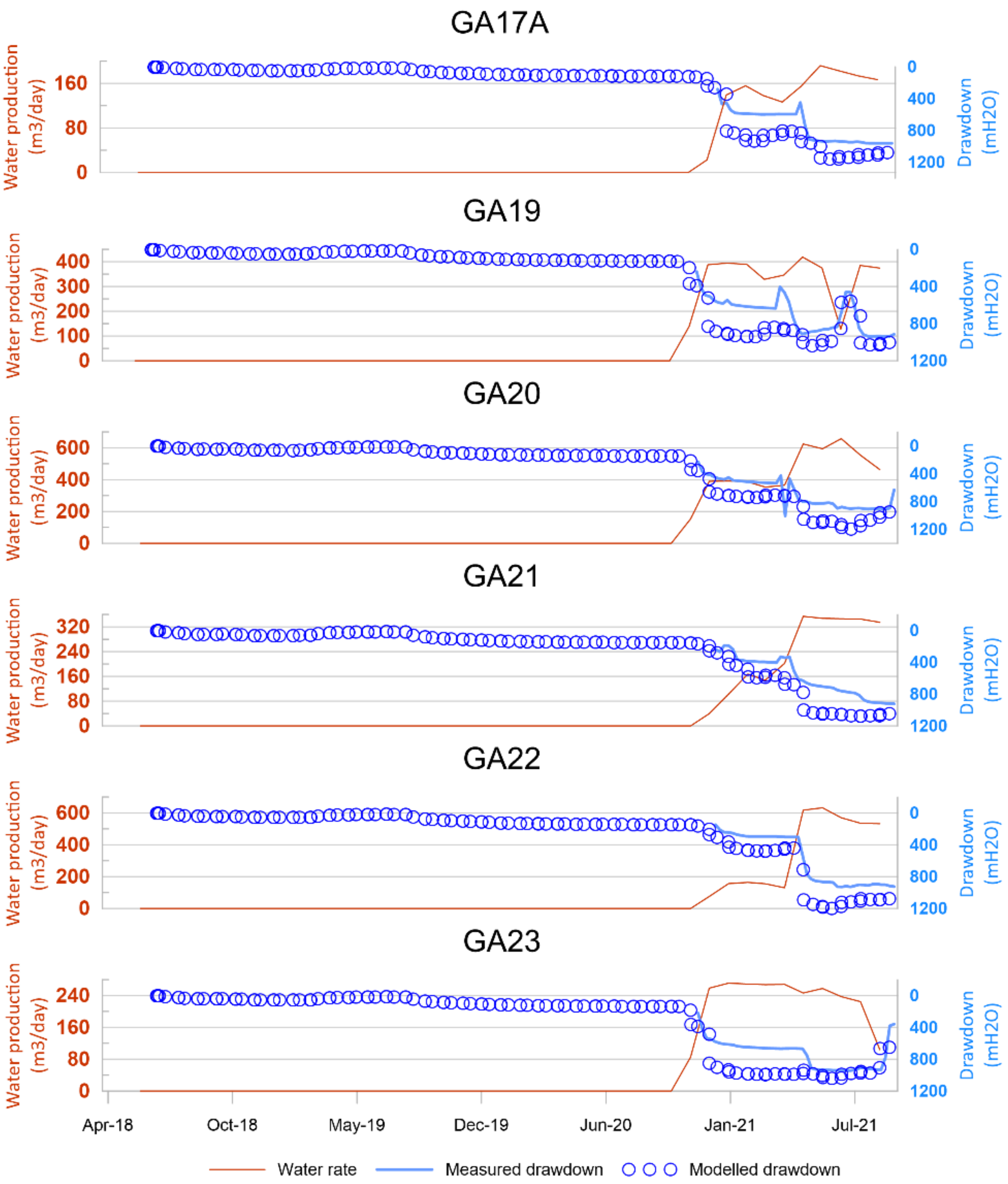


Figure 26 Multi-lateral Pilot - flow rates with measured and modelled drawdowns (vertical wells)



6.2 Predicted magnitude and extent of groundwater drawdown

Predictions of groundwater impacts are primarily influenced by the construction and parameterisation of the groundwater flow model and the footprint and water production history and forecast associated with the pilot production. Predictions were made of water level declines (drawdown) resulting from the total predicted water extraction associated with the historical Glenaras pilots and the forecast water production from the extended multi-lateral pilot through to the end of 2024, using the calibrated multi-layered analytical groundwater flow model as described in Section 6.1. The predictions therefore consider potential impacts to environmental values from the past, the current three-year period of the UWIR and the projected life of the resource tenure. Galilee is currently authorised to continue pilot production until 30 August 2022.

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. The area in which the water level is predicted to decline by more than the bore trigger threshold within 3 years is termed the IAA, and the area in which the bore trigger threshold is exceed at any time is termed the LTAA (DES, 2017). 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 predicted extents of the bore and springs trigger thresholds are shown on Figure 28 to Figure 30 for December 2022, December 2023 and December 2024. All of the mapped formations are consolidated therefore the 5 m bore trigger threshold applies. Maps are not provided for the Cadna-owie Formation/Hooray Sandstone as drawdown is not predicted to exceed 0.2 m at any time.

The drawdown maps identify:

- The maximum extent of and magnitude of drawdown is predicted to occur in the lower Betts Creek Beds (R2 to R7 seams). This is due to the higher hydraulic conductivity in this formation in the calibrated model relative to the upper Betts Creek Beds and therefore the extraction of a greater proportion of the forecast water and hence the larger area of influence. The LTAA (and IAA) is reached at the end of the forecast production period (December 2024) when the maximum extent of the predicted exceedance of the bore trigger threshold is roughly 18 km from the centre of the pilot area. The predicted extent of the spring trigger threshold is approximately 28 km at this time.
- There is no significant difference between the extent of the predicted extent of the exceedance of the bore trigger threshold in the Upper Betts Creek beds between the three years presented. The IAA and LTAA in the upper Betts Creek Beds is predicted to extend approximately 2.5 km from the centre of the multi-well pilot. The maximum extent of the exceedance of the spring trigger threshold is predicted to occur in the upper Betts Creek Beds in December 2024 and extends approximately 21 km from the centre of the multi-well pilot.
- The bore trigger threshold is not predicted to be exceeded in the Hutton Sandstone therefore there is no IAA or LTAA within the Hutton Sandstone. The maximum extent of the exceedance of the spring trigger threshold is predicted to occur in the Hutton Sandstone in December 2024 and extends approximately 21.6 km from the centre of the multi-well pilot.

6.3 Predicted impacts to environmental values

There are no active water supply bores identified that access the Betts Creek Beds within the IAA or the LTAA.

Since the predicted drawdown is not predicted to exceed the bore trigger threshold, there is no IAA or LTAA for either the Hutton Sandstone or Cadna-Owie Formation/ Hooray Sandstone aquifers.

There are no mapped springs (Figure 21) within the maximum predicted extents of the exceedances of the spring trigger threshold.

Drawdown would need to propagate to the water table aquifer for potential impacts to terrestrial GDEs or impacts to baseflow reaches that could support other environmental values to occur. The modelling does not predict drawdown in the Cadna-owie Formation/Hooray Sandstone, which underlies the Winton/Mackunda Formations that outcrops in the vicinity of the pilot site and would form the water table aquifer. The Winton/Mackunda Formations overlie the Cadna-Owie/Hooray Sandstone and therefore there is no drawdown predicted to occur to the water table, thus there are no predicted impacts to terrestrial GDEs or environmental values associated with baseflow reaches.

The greatest drawdown occurs in the Betts Creek Beds where the potential for groundwater flow will be towards this formation from the overlying formations. As the Hutton Sandstone water quality is better (lower salinity) than the Betts Creek Beds, there is no potential for the degradation of the water quality within the Betts Creek Beds and therefore no potential for impact to current or future human or environmental users / values. Since the drawdowns predicted in the Hutton Sandstone and Cadna-owie Formation/Hooray Sandstone are less than the current hydraulic head differences, there will be negligible change to inter-aquifer transfers due to the exercise of underground water rights on ATP 2019.

6.4 Predicted impacts to formation integrity and surface subsidence

The extraction of water and gas from the subsurface will result in compaction of the strata from which they are produced. This compaction can be translated through the overlying rock and result in subsidence of the land surface.

APLNG (2018) describes a simple elastic theory model to estimate compaction based on the drawdown resulting from CSG production, the thickness of the formation and the formation compressibility. The model assumes that all the compaction occurs within the coal and that all the compaction is translated into subsidence. The model is shown diagrammatically as Figure 27.

The potential magnitude of subsidence associated with the Galilee pilot activities has been calculated using the APLNG (2018) model. The model was parameterised with:

- Site-specific coal seam thicknesses from the Betts Creek Beds as represented by the Glenaras 3 well,
- Site-specific compressibility coefficients for the coals derived from storativity values from the calibrated MLU groundwater flow model, and
- Predicted groundwater level drawdowns from December 2023.

The predicted maximum magnitude of subsidence was 28 cm, which is predicted to occur centred on the active pilot wells.

The potential magnitude of subsidence reduces as predicted drawdown decreases with increasing distance from the pilot wells. At the closest point of Rodney Creek to the pilot production, the predicted subsidence is less than 0.07 m. For the UWIR for the Surat Cumulative Management Area, OGIA (2019) used three risk categories of likelihood for which low risk was less than 0.1 m of subsidence. Based on the OGIA (2019) categories, the risk associated with subsidence and the pilot activities on ATP 2019 is low.

Figure 27 Diagrammatic (not to scale) representation of linear elastic theory to estimate the magnitude of subsidence (APLNG, 2018)

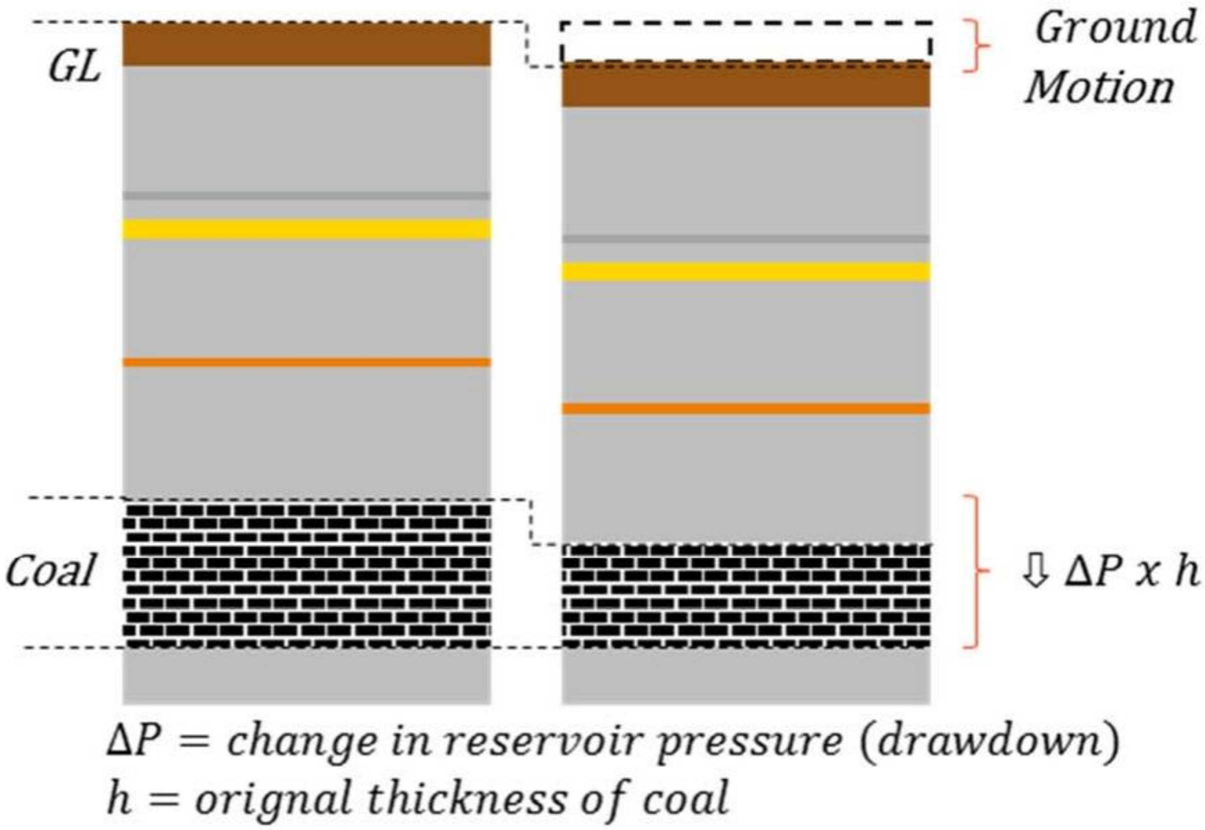


Figure 28 Lower Betts Creek Beds drawdown contours

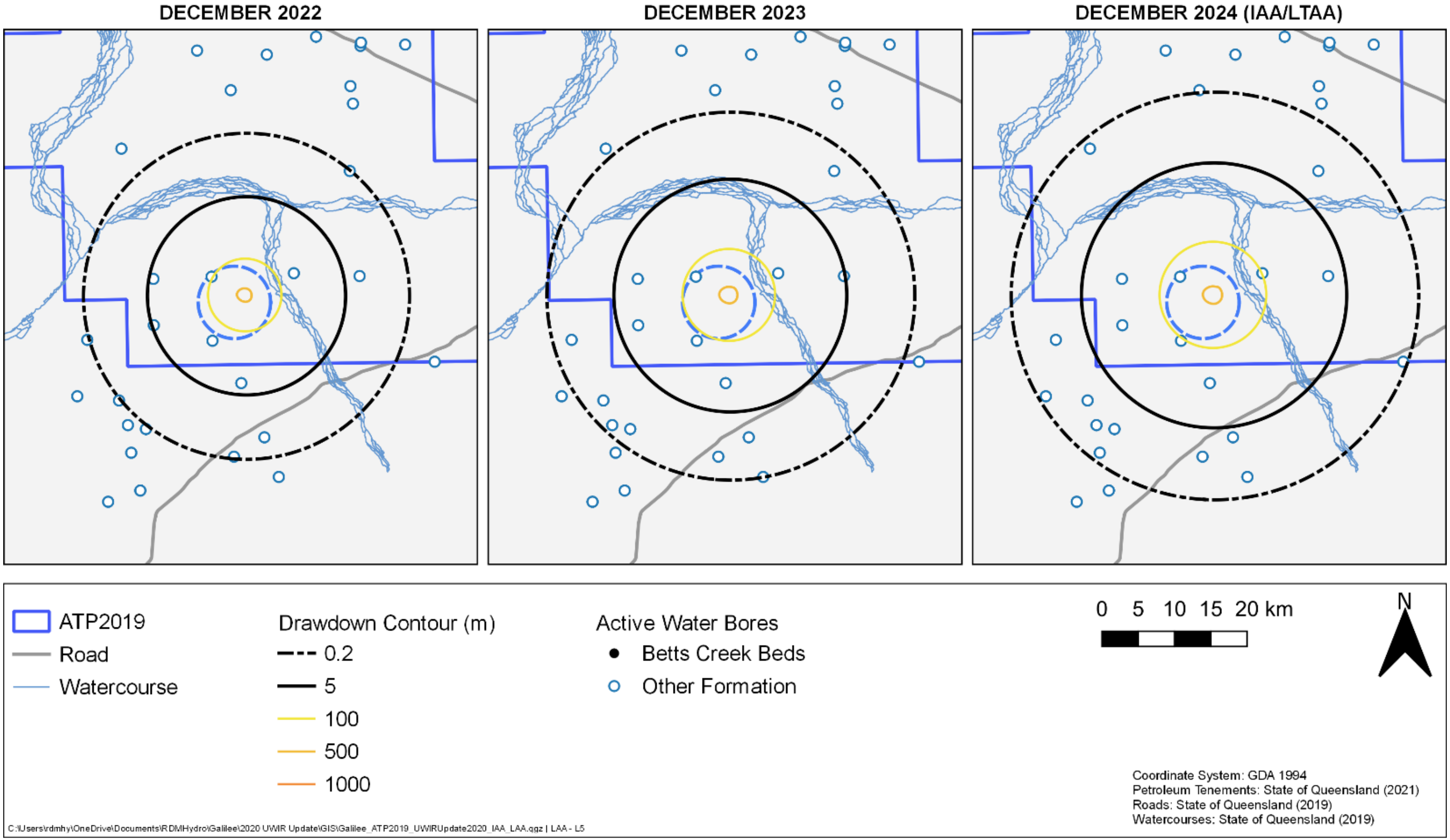


Figure 29 Upper Betts Creek Beds drawdown contours

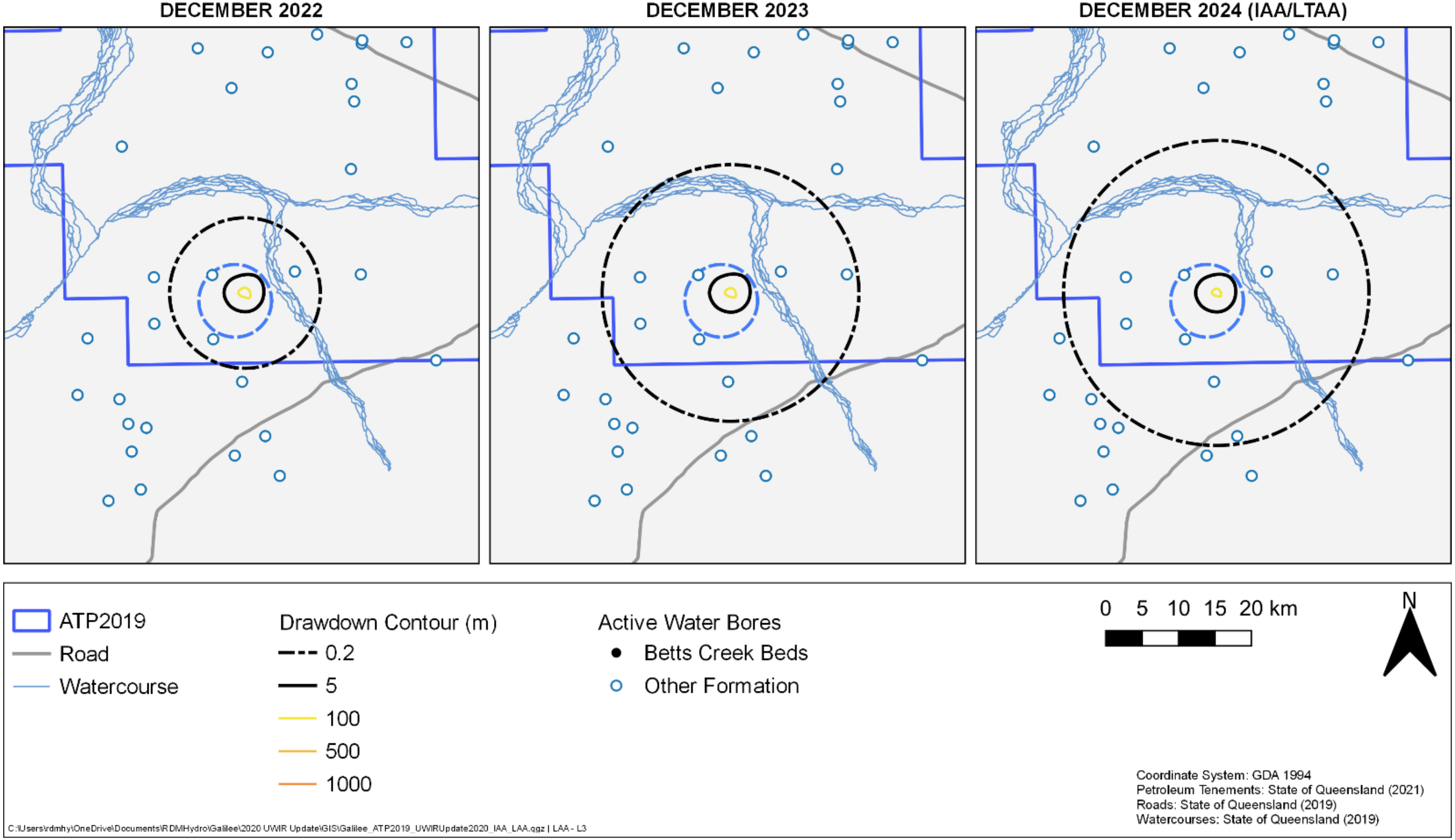
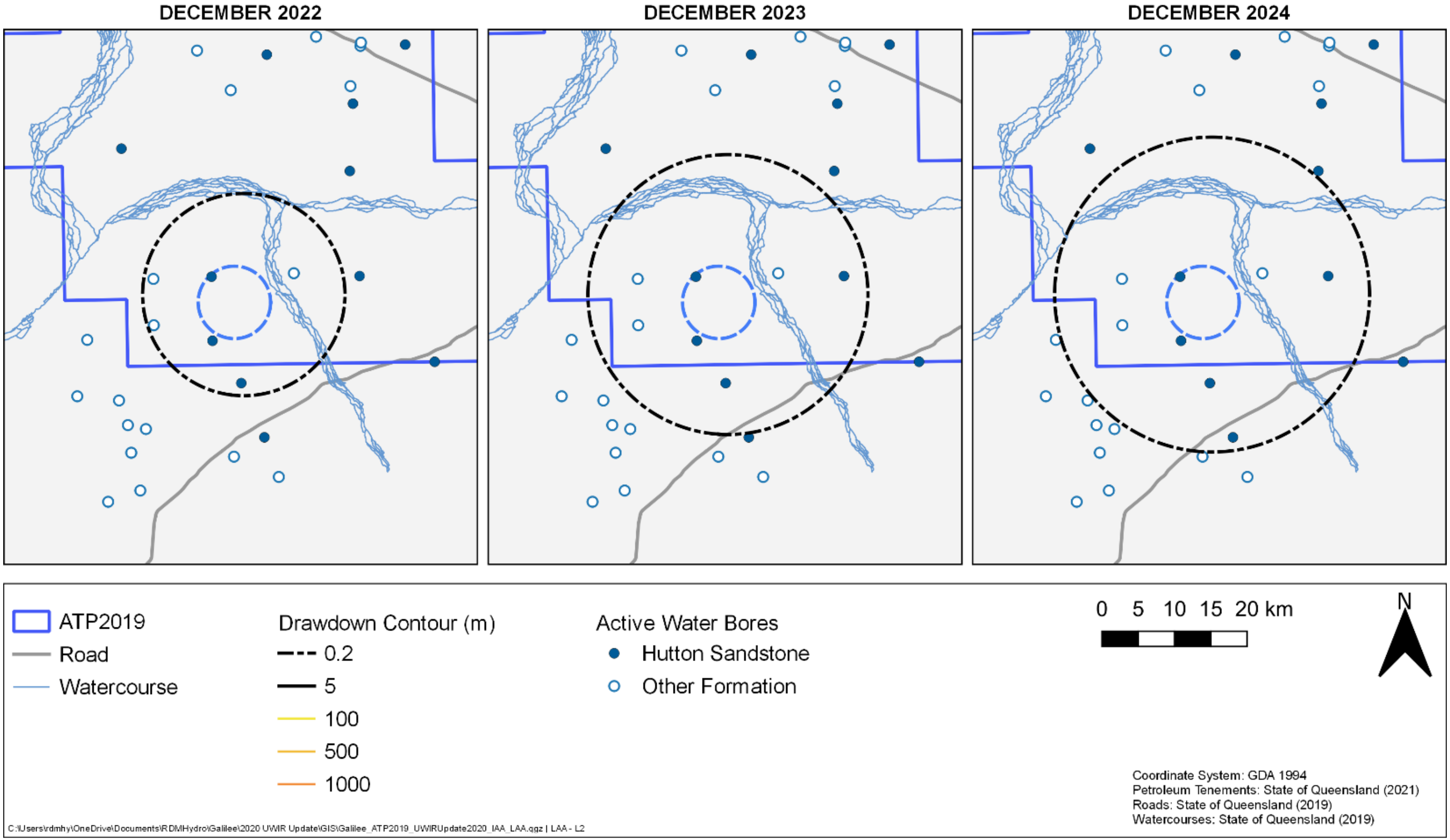


Figure 30 Hutton Sandstone drawdown contours



7. Monitoring, management and reporting

This section describes the water monitoring strategy (WMS), spring impact management strategy (SIMS) planned under this UWIR and the program for annual review of the accuracy of each map of the IAA and LTAA.

7.1 Water monitoring strategy (WMS)

An underground water monitoring strategy is required for the IAA and the LTAA. IAAs and LTAAs have only been defined for the Betts Creek Beds as water levels are not predicted to decline in excess of the bore trigger threshold in the overlying aquifers.

The primary purpose of the monitoring is to enable assessment of changes in water levels and water quality because of the exercise of underground water rights. A secondary purpose is to provide supplementary information to improve the understanding of the groundwater system.

The groundwater flow model is based on a conceptualisation of the hydrogeology of the groundwater flow system. Monitoring of flow rates and pressures has enabled a transient calibration of the groundwater flow model used to identify the IAA and LTAA.

Continued monitoring of the pressures in the monitoring bore (GW01) and the surrounding landholder bores will validate the model predictions that the drawdown in the Hutton Sandstone is not expected to exceed the bore trigger threshold.

Monitoring of water quality of the production bores may provide indications of water leakage from other units. Because the water types are similar, salinity (measured in the field as electrical conductivity) will be measured at a higher frequency than laboratory analysis of water samples. Contrasts in minor ion ratios will be assessed through laboratory analysis of groundwater samples.

Monitoring associated with the Glenaras pilots commenced in 2010 and will continue for the life of the pilot program. The parameters to be measures, locations and frequency of measurements are provided in Table 11.

Table 11 Groundwater monitoring program - site list and schedule

Item	Sites		Frequency - During pilot production	Frequency – During shut-in
Downhole groundwater level/pressure monitoring	RC08 (Colinlea Sandstone) GW01 (Hutton Sandstone)		Daily	Daily
	GA10-L GA12-L GA14-L GA15-L GA16-L New pilot wells	GA17A GA19 GA20 GA21 GA22 GA23	Daily	Daily for at least one week following production
Volume of produced water	GA10-L GA12-L GA14-L GA15-L GA16-L New pilot wells	GA17A GA19 GA20 GA21 GA22 GA23	Daily	-
Shut in pressure	RN 11369 RN 146385 RN 146209		Annual	Annual
Water quality sampling and laboratory analysis	GA10-L GA12-L GA14-L GA15-L GA16-L GW01	GA17A GA19 GA20 GA21 GA22 GA23 New pilot wells	Annual	-
Field water quality measurements	GA10-L GA12-L GA14-L GA15-L GA16-L	GA17A GA19 GA20 GA21 GA22 GA23 New pilot wells	Quarterly	-

Note: sampling not possible for shut-in gas wells after cessation of flow testing program

7.1.1 Monitoring methodology

All water monitoring will continue to be undertaken in accordance with the *Queensland Monitoring and Sampling Manual* (DES, 2018). The methodology is summarised below.

Water level/pressure monitoring

Electronic pressure transducers are installed downhole in all gas wells and in one of the monitoring bores, (RC08), with a wellhead pressure sensor installed in the Hutton Sandstone monitoring bore (GW01). These continuously measure water levels in the Betts Creek Beds, Colinlea Sandstone and the Hutton Sandstone and are recorded and downloaded monthly.

Shut-in pressures on RN11369, RN146385 and RN146209 are measured using a pressure gauge.

Produced water volume monitoring

The volume of water produced at each well is constantly measured by individual electronic water flow meters installed in accordance with the manufacturer's specifications. The SCADA system continuously records the data and calculates the total daily volume produced from each well. Daily data is aggregated for reporting purposes.

Water quality monitoring

Water samples for water quality monitoring are collected from a valve on the wellhead, directly into laboratory supplied bottles.

Field parameters are measured at the time of sampling using a calibrated field water meter and include:

- Electrical conductivity (EC);
- pH;
- Temperature.

Samples are:

- 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.

The analytical suite shown in Table 12 has been adopted based on the historical monitoring and the suite identified in the UWIR for the Surat CMA (OGIA, 2019) and is considered appropriate to meet the purpose of the monitoring.

Table 12 Laboratory analytical suite

Category	Parameters	
Physiochemical parameters	Electrical conductivity Total dissolved solids pH	
Major ions	*Cations*	*Anions*
	Calcium	Chloride
	Magnesium	Carbonate
	Sodium	Bicarbonate
	Potassium	Sulphate
Dissolved metals and minor/trace elements	Arsenic	Lead
	Barium	Manganese
	Boron	Mercury
	Cadmium	Nickel
	Chromium	Selenium
	Cobalt	Strontium
	Copper	Zinc
	Iron	
Other analytes	Fluoride	Dissolved methane

7.1.2 Implementation of strategy and reporting

Section 378(1)(d) 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.

A review of the data collected under the WMS will be incorporated into the annual review of the accuracy of the IAA and LTAA (Section 7.3). This review will consist of a review of the collection of water level/pressure and water quality data from the monitoring points, as shown in Table 11 and a compilation of the water level and water quality data to monitor the groundwater trends within the Immediately Affected Area.

7.2 Spring Impact Management Strategy

Since there are no springs located within the predicted extents of the exceedance of the spring trigger thresholds (0.2 m) a spring impact management strategy is not required.

7.3 Annual review of the UWIR

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 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.

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.

8. References

AGL, 2010: Water Level and Water Sampling Protocol – Galilee Gas Project Exploration Program, AGL Unpublished Internal Report

AGL, 2013: Underground Water Impact Report – ATP 529P. Dated 4 January 2013

APLNG, 2018: 2017-2018 Groundwater Assessment Report. Origin Energy Report QLD 1000 E75 RPT CDN/ID 20305638. 20 November 2018. https://www.aplng.com.au/content/dam/aplng/compliance/management-plans/2017-2018%20Groundwater%20Assessment%20report.pdf

Coffey Geotechnics, 2013: Coal Seam Gas Monitoring and Management of Subsidence. Unpublished report for the Independent Expert Scientific Committee (IESC), Canberra

DES, 2017: Underground water impact reports and final reports. Guideline ESR/2016/2000 Version 3.02. Department of Environment and Science. 5 July 2017.

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

DES (2020) *WetlandInfo*. https://wetlandinfo.des.qld.gov.au/wetlands/. Accessed 28 July 2020.

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.

Galilee, 2016: Underground Water Impact Report ATP529 – Galilee Basin. Final for Submission Version C. Submitted 23 June 2016.

Hemker and Post, 2008: MLU for Windows. Version 2.25.78

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.

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 September 2021.

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}

RPS, 2012: Galilee Basin, Report on the Hydrogeological Investigations, RPS Australia East Pty Ltd report prepared for RLMS. December 2012 https://www.rlms.com.au/galilee-basin-operators-forum/

Parsons Brinckerhoff (PB), 2012: AGL Galilee Project – 'Glenaras' hydrogeochemical and isotope study. Unpublished PB report for AGL Energy Limited

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.

State of Queensland, 2021: Queensland Springs Database. Downloaded from QSpatial

Appendix A – Laboratory water quality data (2016-2019)

		Units	LOR	GA02	GA02	GA03	GA03	GA03	GA03	GA04	GA04	GA04	GA04	GA05	GA05	GA06	GA06
	Analyte	**Sample date**		14/12/2015	30/03/2016	14/12/2015	30/03/2016	6/12/2016	24/07/2017	14/12/2015	30/03/2016	6/12/2016	24/07/2017	14/12/2015	30/03/2016	14/12/2015	30/03/2016
Lab physi	Electrical conductivity	µS/cm	1	1720	1770	1840	1920	1900	1830	1730	1780	1770	1780	1790	1810	1870	1880
	TDS	mg/L	10	1070	999	1130	1120	1060	1040	1070	1040	998	1040	1070	1090	1120	1110
	TSS	mg/L	5	16	10	<5	52	<5	<5	27	18	5	63	<5	25	<5	25
Major/minor ions	Bicarbonate Alkalinity-mg CaCO3/L	mg/L	1	742	728	667	699	640	733	714	723	639	725	671	712	663	681
	Carbonate Alkalinity-mg CaCO3/L	mg/L	1	<1	<1	32	<1	85	<1	<1	<1	92	<1	43	<1	33	<1
	Alkalinity (Hydroxide) as CaCO3	mg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Alkalinity (total) as CaCO3	mg/L	1	742	728	699	699	725	733	714	723	732	725	714	712	696	681
	Chloride	mg/L	1	180	178	265	240	212	207	198	181	172	186	224	197	268	230
	Sulfate as SO4 - Turbidimetric	mg/L	1	1	<1	<1	<5	1	<1	17	<1	2	<1	<1	<5	<1	<5
	Calcium	mg/L	1	13	13	8	9	14	13	14	14	12	12	5	10	9	10
	Magnesium	mg/L	1	1	1	1	1	1	1	1	1	1	1	<1	1	1	1
	Potassium	mg/L	1	18	16	25	21	28	15	21	14	14	12	18	15	40	28
	Sodium	mg/L	1	378	428	408	456	381	402	384	428	372	399	390	439	383	436
	Fluoride	mg/L	0.1	6.5	6	5.9	5.5	6.3	6.4	6.2	5.8	6.2	6.2	6.1	5.7	6.3	5.8
	Silicon as SiO2	mg/L	0.05	34.5	36.1	36.1	41.3	38.4	36.7	38.6	37.9	37.3	37.4	34.6	37.2	32.2	39.6
	Bromine	mg/L	0.1	0.4	0.4	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5
Nutrients	Ammonia as N	mg/L	0.01	0.92	0.92	1.32	0.95	1.24	0.93	0.93	0.88	0.99	0.76	1	0.88	1.06	0.95
	Nitrate as N	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.04	<0.01	<0.01	<0.01	<0.01
	Nitrite as N	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Nitrite + Nitrate as N	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.04	<0.01	<0.01	<0.01	<0.01
	Methane	mg/L	0.01	12.5	13.5	15.4	10.1	4200	6.85	14.4	13.4	11,200	>13.9	14.5	12.7	13.7	13.7
Dissolved metals	Aluminium	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	0.04	0.03	0.06	0.04	<0.01	0.03	0.02	<0.01	<0.01	<0.01
	Arsenic	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	0.002
	Barium	mg/L	0.001	1.45	1.52	1.08	1.06	1.61	1.65	0.929	1.39	1.39	1.51	0.812	1.26	0.957	1.18
	Beryllium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Boron	mg/L	0.05	0.89	0.79	0.91	0.83	1	0.68	0.95	0.8	0.93	0.66	0.84	0.83	0.89	0.87
	Cadmium	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	Chromium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Cobalt	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Copper	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Iron	mg/L	0.05	8.46	4.2	2.42	3.78	0.57	1.07	7.74	5	1.54	3.4	2.2	3.25	1.12	1.02
	Lead	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Manganese	mg/L	0.001	0.096	0.053	0.057	0.073	0.019	0.029	0.118	0.076	0.049	0.073	0.045	0.042	0.051	0.055
	Mercury	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	Molybdenum	mg/L	0.001	<0.001	0.002	<0.001	0.006	0.001	0.001	<0.001	0.001	0.001	0.002	<0.001	0.004	<0.001	0.019
	Nickel	mg/L	0.001	<0.001	0.002	<0.001	0.002	<0.001	0.001	<0.001	0.001	0.002	0.004	<0.001	0.002	<0.001	0.008
	Selenium	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Strontium	mg/L	0.001	0.643	0.674	0.526	0.551	0.656	0.7	0.509	0.587	0.523	0.574	0.456	0.623	0.469	0.56
	Vanadium	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Uranium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Zinc	mg/L	0.005	<0.005	<0.005	<0.005	<0.005	0.005	0.005	<0.005	<0.005	0.005	0.008	<0.005	<0.005	<0.005	<0.005
Organics	C6-C10 Fraction	µg/L	20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	30	<20
	C6 - C10 Fraction minus BTEX (F1)	µg/L	20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
	C10 - C16 Fraction	µg/L	100	<100	<100	140	100	120	<100	<100	<100	<100	<100	<100	<100	190	<100
	C16 - C34 Fraction	µg/L	100	1030	340	4210	2130	6330	<100	1340	250	270	200	480	1190	1400	840
	C34 - C40 Fraction	µg/L	100	260	110	860	410	<100	<100	530	<100	<100	<100	210	320	430	240
	C10 - C40 Fraction (Sum)	µg/L	100	1290	450	5210	2640	6450	<100	1870	250	270	200	690	1510	2020	1080
	C6 - C9 Fraction	µg/L	20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	20	<20
	C10 - C14 Fraction	µg/L	50	<50	<50	110	90	<50	<50	<50	<50	60	<50	<50	<50	170	<50
	C15 - C28 Fraction	µg/L	100	660	210	3050	1510	6480	<100	850	160	240	140	280	750	910	500
	C29-C36 Fraction	µg/L	50	480	170	1540	780	<50	<50	680	120	100	100	280	570	690	440
	+C10 - C36 (Sum of total)	µg/L	50	1140	380	4700	2380	6480	<50	1530	280	400	240	560	1320	1770	940
	Sum of BTEX	µg/L	1	1	<1	4	<1	<1	<1	2	<1	<1	<1	5	<1	17	5
	Sum of Phenols	µg/L	1	<1	<1	<1	<1	<4.8	<1	<1	<1	<1.0	<1	<1	<1	<1	<1
	Sum of PAHs	ug/L	0.5	2.2	<0.5	3.2	<0.5	<4.8	<0.5	<0.5	<0.5	<0.5	<0.5	2.5	<0.5	6.5	<0.5

		Units	LOR	Glenaras 10L	Glenaras 10L	Glenaras 10L	Glenaras 12L	Glenaras 12L	Glenaras 12L	Glenaras 14L	Glenaras 15L	Glenaras 16L	GW01	GW01
	Analyte	**Sample date**		29/10/2018	21/08/2019	04/03/2020	29/10/2018	21/08/2019	04/03/2020	04/03/2020	04/03/2020	04/03/2020	30/03/2016	23/10/2018
Lab phys	Electrical conductivity	µS/cm	1	1980	1930	1920	1970	1920	1950	1950	1920	1930	767	1060
	TDS	mg/L	10	1160	1150	1250	1140	1150	1270	1270	1250	1250	452	601
	TSS	mg/L	5	<5	<5	-	11	<5	-	-	-	-	<5	
Major/minor ions	Bicarbonate Alkalinity-mg CaCO3/L	mg/L	1	696	725	662	666	701	656	668	662	663	342	397
	Carbonate Alkalinity-mg CaCO3/L	mg/L	1	<1	31	24	<1	46	20	8	18	8	<1	28
	Alkalinity (Hydroxide) as CaCO3	mg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Alkalinity (total) as CaCO3	mg/L	1	696	756	686	666	748	676	677	680	671	342	425
	Chloride	mg/L	1	246	237	233	249	245	238	234	228	230	48	80
	Sulfate as SO4 - Turbidimetric	mg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Calcium	mg/L	1	17	18	15	18	18	18	17	15	16	4	5
	Magnesium	mg/L	1	2	2	6	2	2	2	2	2	2	<1	<1
	Potassium	mg/L	1	26	20	21	18	17	18	23	18	20	3	238
	Sodium	mg/L	1	413	437	476	410	428	451	448	432	461	194	4
	Fluoride	mg/L	0.1	5.9	6.4	-	5.9	6.2	-	-	-	-	2.3	3.3
	Silicon as SiO2	mg/L	0.05	38.8	36.5	35.3	37.5	35.7	35.4	35.3	35.5	35.6	32.3	
	Bromine	mg/L	0.1	0.4	0.9	-	0.5	0.7	-	-	-	-	0.2	
Nutrients	Ammonia as N	mg/L	0.01	1.81	1.81	1.92	1.81	1.86	2.06	2.04	1.91	2.01	0.36	
	Nitrate as N	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
	Nitrite as N	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
	Nitrite + Nitrate as N	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
	Methane	mg/L	0.01	8050	3610	-	4770	6620	-	-	-	-	0.974	
Dissolved metals	Aluminium	mg/L	0.01	<0.01	<0.01	-	0.01	<0.01	-	-	-	-	<0.01	<0.01
	Arsenic	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
	Barium	mg/L	0.001	2.5	2.64	2.71	2.5	2.65	2.66	2.83	2.77	2.8	0.167	0.233
	Beryllium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Boron	mg/L	0.05	0.78	0.87	0.75	0.78	0.82	0.77	0.79	0.8	0.81	0.24	0.32
	Cadmium	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	Chromium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Cobalt	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Copper	mg/L	0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Iron	mg/L	0.05	0.28	0.07	-	0.16	0.14	-	-	-	-	0.12	<0.05
	Lead	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Manganese	mg/L	0.001	0.01	0.012	0.01	0.008	0.01	0.008	0.014	0.016	0.014	0.013	0.015
	Mercury	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	Molybdenum	mg/L	0.001	<0.001	<0.001	-	<0.001	<0.001	-	-	-	-	<0.001	<0.001
	Nickel	mg/L	0.001	<0.001	<0.001	0.002	<0.001	0.002	<0.001	<0.001	0.003	<0.001	<0.001	<0.001
	Selenium	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Strontium	mg/L	0.001	0.794	0.851	-	0.787	0.856	-	-	-	-	0.177	
	Vanadium	mg/L	0.01	<0.001	<0.001	-	<0.001	<0.001	-	-	-	-	<0.01	<0.001
	Uranium	mg/L	0.001	-	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.001	<0.01
	Zinc	mg/L	0.005	0.005	<0.005	0.01	<0.005	<0.005	<0.005	0.032	0.026	0.024	<0.005	<0.005
Organics	C6-C10 Fraction	µg/L	20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	
	C6 - C10 Fraction minus BTEX (F1)	µg/L	20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	
	C10 - C16 Fraction	µg/L	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	
	C16 - C34 Fraction	µg/L	100	<100	<100	<100	130	<100	<100	<100	<100	<100	<100	
	C34 - C40 Fraction	µg/L	100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	
	C10 - C40 Fraction (Sum)	µg/L	100	<100	<100	<100	130	<100	<100	<100	<100	<100	<100	
	C6 - C9 Fraction	µg/L	20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	
	C10 - C14 Fraction	µg/L	50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	
	C15 - C28 Fraction	µg/L	100	<100	<100	<100	110	<100	<100	<100	<100	<100	<100	
	C29-C36 Fraction	µg/L	50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	
	+C10 - C36 (Sum of total)	µg/L	50	<50	<50	<50	110	<50	<50	<50	<50	<50	<50	
	Sum of BTEX	µg/L	1										<1	
	Sum of Phenols	µg/L	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1	
	Sum of PAHs	ug/L	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	

		Units	LOR	GA10L	GA12L	GA14L	GA15L	GA16L	GA17A	GA19	GA20	GA21	GA22	GA23	GW01
	Analyte	**Sample date**		-	31/08/2021	31/08/2021	31/08/2021	31/08/2021	1/09/2021	3/09/2021	31/08/2021	31/08/2021	31/08/2021	31/08/2021	1/09/2021
Field parameters	Electrical conductivity	uS/cm	1	-	7.26	6.99	7.2	7.17	7.26	7.32	7.07	7.27	7.19	7.13	7.7
	pH	pH units	0.1	-	2200	2100	2320	2100	2130	2230	2200	2150	2160	2240	876
	Temperature	°C	0.1	-	64.5	52.1	62.9	59.6	60	63.7	64.4	60.8	61.8	62.9	54.5
Laboratory physical parameters	Electrical conductivity	µS/cm	1	-	1940	1930	1920	1930	1910	1930	1910	1890	1930	1900	766
	pH	mg/L	10	-	8.3	8.26	8.28	8.28	8.27	8.36	8.23	8.32	8.36	8.34	8.58
	Total Suspended Solids	mg/L	5	-	9	<5	<5	<5	<5	<5	<5	<5	<5	<5	-
Major/minor ions	Bicarbonate Alkalinity-mg CaCO3/L	mg/L	1	-	650	645	661	649	640	616	622	650	655	654	284
	Carbonate Alkalinity-mg CaCO3/L	mg/L	1	-	5	<1	<1	<1	<1	15	<1	11	20	12	30
	Alkalinity (Hydroxide) as CaCO3	mg/L	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
	Alkalinity (total) as CaCO3	mg/L	1	-	655	645	661	649	640	631	622	662	676	667	315
	Chloride	mg/L	1	-	229	222	222	228	213	232	225	213	220	209	46
	Sulfate as SO4 - Turbidimetric	mg/L	1	-	<1	11	1	<1	20	14	21	2	<1	<1	<1
	Calcium	mg/L	1	-	14	10	16	12	10	16	18	14	15	14	3
	Magnesium	mg/L	1	-	2	2	2	2	2	2	2	2	2	2	<1
	Potassium	mg/L	1	-	16	19	16	18	16	16	17	15	15	16	3
	Sodium	mg/L	1	-	438	439	439	445	434	430	460	434	438	434	183
	Fluoride	mg/L	0.1	-	5.8	6	6.4	5.8	6.7	6	5.7	6.2	6.7	5.7	2.2
Gases	Methane	mg/L	0.01	-	7760	9770	7640	7910	7780	5010	7940	7330	8160	8640	1060
Dissolved metals	Arsenic	mg/L	0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Barium	mg/L	0.001	-	2.5	2.53	2.54	2.4	2.21	2.42	2.51	2.22	2.18	2.34	0.186
	Boron	mg/L	0.05	-	0.82	0.83	0.73	0.81	0.82	0.88	0.77	0.78	0.8	0.8	0.27
	Cadmium	mg/L	0.0001	-	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	Chromium	mg/L	0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Cobalt	mg/L	0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Copper	mg/L	0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Iron	mg/L	0.05	-	0.07	0.1	<0.05	0.09	0.07	0.08	<0.05	0.1	0.05	0.08	0.12
	Lead	mg/L	0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Manganese	mg/L	0.001	-	0.004	0.002	0.006	0.003	0.002	0.005	0.005	0.006	0.005	0.004	0.006
	Mercury	mg/L	0.0001	-	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	Nickel	mg/L	0.001	-	0.02	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Selenium	mg/L	0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Strontium	mg/L	0.001	-	0.861	0.813	0.836	0.931	0.905	0.802	0.933	0.937	1.02	0.779	0.181
	Zinc	mg/L	0.005	-	0.006	<0.005	0.006	<0.005	0.007	<0.005	0.006	<0.005	<0.005	0.005	<0.005