Australasian Groundwater and
Environmental Consultants Pty Ltd

Report on

# Underground Water Investigation Report for ATP769 Paranui Pilot Project

Prepared for
Westside Corporation

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*Report on*

# Underground Water Investigation Report for ATP769 Paranui Pilot Project

## 1 Introduction

Westside Corporation (Westside) in joint venture with Mitsui E&P Australia, operate under an authority to prospect (ATP) for development of the Paranui Pilot Project (the Project) on ATP769. The Project is located 10 km south of Moura, and 5 km to the west of the Meridian Coal Seam Gas (CSG) fields. In this part of the tenement, the Project targets the Baralaba Coal Measures which occur between 550 m and 950 m depth and generally contain 21 m to 25 m of gas-bearing coal in up to 14 seams.

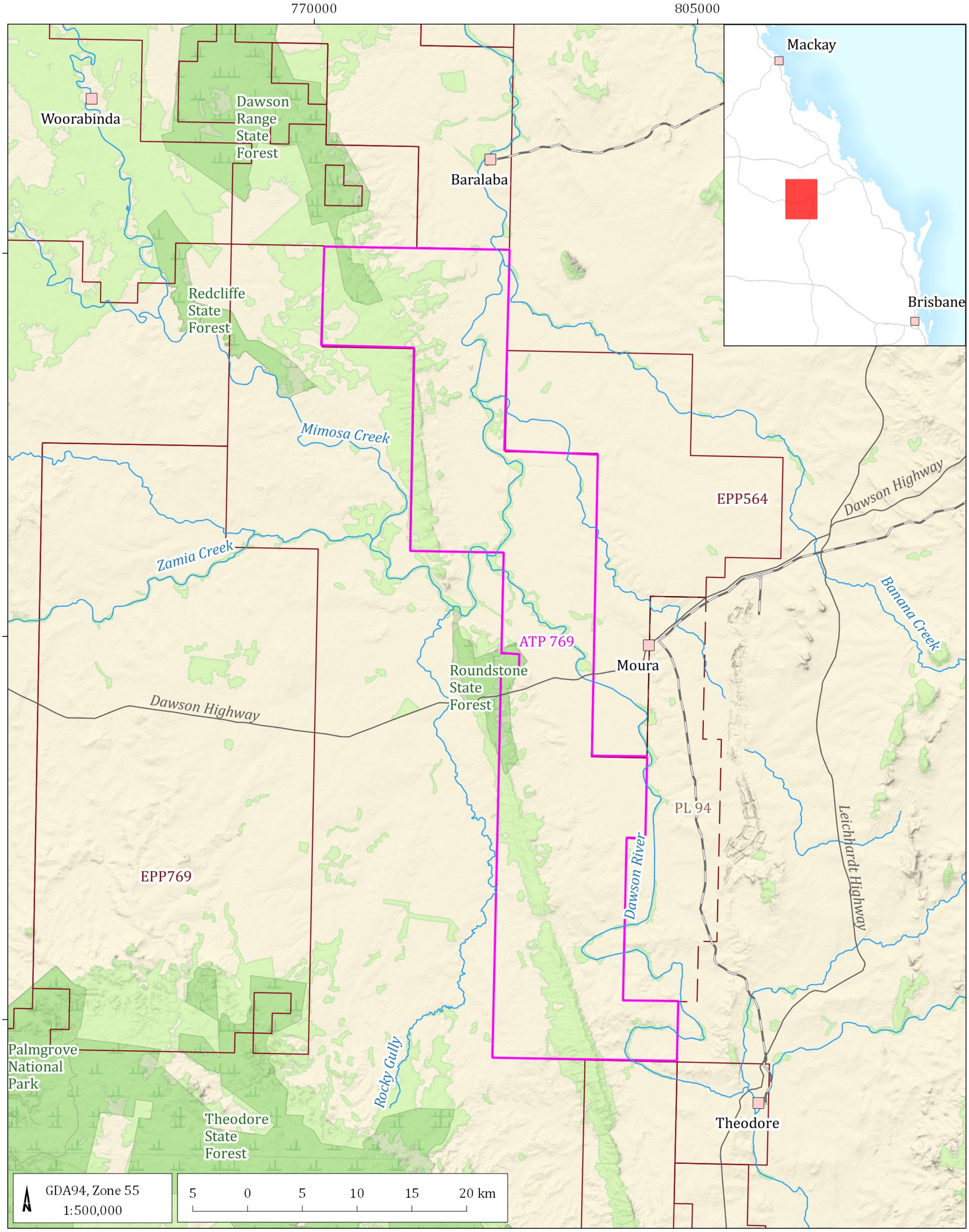
The Paranui Pilot Project initially included six appraisal wells (P-1, P-2, P-3, P-5R, P-6R and P-8), two observation wells (P-4 and P-7) and one core well (P-10). Three additional wells (P-11, P-12 and P-13) were completed in 2010. Pilot testing of these wells commenced in late 2010 but was subsequently suspended due to the protracted wet season. The pilot testing identified an initial reserve of 135 petajoules (PJ) of CSG, with an additional 183 billion cubic feet of CSG (estimated) available to a depth of 1,000 m within the remainder of the ATP769 tenement.

Prior to commencing operation, the Pilot Project must comply with the requirements of the Australian legislation, specifically Water Act (2000), which includes the requirement to prepare an Underground Water Impact Report (UWIR). The initial UWIR was prepared in October 2015 and took effect on 5th November 2015 for the period 2015 to 2018. This report presents the results of the UWIR for the period 2018 to 2021 within the ATP769 tenement. This UWIR has been undertaken by Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) at the request of Westside.

### 1.1 Project area

The Project is currently operating within the Paranui property which is located roughly centrally along the eastern side of ATP769. It is understood that up to six gas bores will be put into operation.

Following completion of prospecting, it is likely that the Paranui portion of the ATP769 area will be developed into a CSG production site. The ATP769 encompasses a number of adjoining and discrete properties, and extends north, south and west of the Paranui site. The combined area of ATP769 is 3,265 km$^2$ whilst the portion of ATP769 that Westside are focusing their exploration covers an area of approximately 910 km$^2$ as shown in Figure 1.1. The Paranui site which includes the Pilot Project has an area of 2.12 km$^2$ (2,121 ha).




LEGEND

- Populated place
- Road
- Watercourse/drainage
- Rail
- ATP769
- Petroleum lease (PL 94)
- Exploration Permit for Petroleum (EPP)
- Vegetation
- Reserve

Paranui UWIR update (G1631B)

**Site location**

AGE

DATE 05/12/2018

FIGURE No: **1.1**


Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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## 1.2 Legislation

The following sections summarise Queensland Government legislation and policy for groundwater that applies to the management of groundwater affected by petroleum or coal seam gas (CSG) projects.

## 1.3 Petroleum and Gas (Production and Safety) Act 2004 (QLD)

The authority to prospect ATP769 was granted under the *Petroleum and Gas (Production and Safety) Act 2004* (Qld).

Under the *Petroleum and Gas (Production and Safety) Act 2004* (Qld), the petroleum tenure holder may *take or interfere with underground water in the area of the tenure if taking or interference happens during the course of, or results from, the carrying out of another authorised activity for the tenure*. The Act requires tenure holders to comply with underground water obligations specified in the *Water Act 2000* (Qld).

## 1.4 Water Act 2000 (QLD)

Management of underground water as a result of the exercise of underground water rights by petroleum tenure holders for petroleum or CSG projects is detailed in Chapter 3 of the Water Act 2000. It provides a framework that requires the petroleum tenure holder to prepare an Underground Water Impact Report (UWIR) which establishes underground water obligations for monitoring and managing impacts on aquifers and springs. More specifically it provides for trigger levels for establishing impact on an aquifer in the event of a decline in water levels. The trigger levels are:

- a 5 m decline in water levels within a consolidated aquifer;
- a 2 m decline in water levels within an unconsolidated aquifer; and
- a 0.2 m decline in water levels associated with active springs.

The extent of declines in groundwater levels in aquifers greater than the trigger level, within the three-year period time structure are defined as Immediately Affected Areas or IAA. This includes those aquifers that are hosted in the coal seam measures. Predicted declines the water level by more than the bore trigger threshold at any time is defined as Long Term Affected Areas or LTAA.

## 1.5 Environmental Protection (Water) Policy (EPP Water)

The Environmental Protection (Water) Policy (EPP Water) provides a framework to protect and/or enhance the suitability of Queensland waters for various beneficial uses. Groundwater resources within the project site and its surrounds are located within the Dawson River Sub-basin as listed in Schedule 1 of the EPP Water. The EPP states that the environmental values for groundwaters within the Dawson River Sub-basin may include aquatic ecosystems, irrigation, farm supply/use, stock water, aquaculture, primary recreation, drinking water, and cultural and spiritual values.

The EPP Water provides water quality objectives (WQOs) to support and protect the various environmental values identified for waters within the Dawson River catchment. The WQOs for the Dawson River Sub-basin groundwaters are provided in the Dawson River Sub-basin Environmental Values and Water Quality Objectives (DES, 2011) according to their chemistry zone and depth category. Groundwater within the vicinity of the project site is classified as 'shallow' and 'deep' under chemistry zones 21 a moderately saline Na > Mg > Ca, Cl type water. Section 4.3 describes the groundwater quality relevant to the project setting.

The groundwater WQOs for aquatic ecosystems in Zone 21 are summarised in Table 1.1 below.

### Table 1.1 WQO (aquatic ecosystems) for groundwaters in the Dawson River sub-catchment (Zone 21)

| Depth | shallow < 30m | | | deep >30 m | | |
|---|---|---|---|---|---|---|
| **Percentile** | **20th** | **50th** | **80th** | **20th** | **50th** | **80th** |
| Electrical Conductivity (uS/cm) | 1,033 | 2,000 | 4,609 | 217 | 585 | 2,060 |
| Hardness (mg/L) - as $CaCO_3$ | 272 | 522. | 1566 | 21 | 84 | 428 |
| pH | 7.40 | 7.90 | 8.20 | 6.60 | 7.40 | 7.92 |
| Alkalinity | 223 | 345 | 478 | 47 | 143 | 317 |
| Calcium | 61 | 96 | 300 | 6 | 20 | 126 |
| Magnesium | 30 | 63 | 200 | 1 | 3 | 35 |
| Sodium | 103 | 237 | 715 | 42 | 145 | 324 |
| Chloride | 153 | 445 | 1765 | 55 | 170 | 572 |
| Sulfate | 16 | 45 | 125 | 0 | 5 | 112 |
| Bicarbonate Alkalinity as $CaCO_3$ | 269 | 416 | 570 | 27 | 168 | 242 |
| Nitrate | 0.00 | 1.00 | 5.88 | 0.00 | 0.00 | 1.00 |
| Silica | 29 | 37 | 44 | 11 | 13 | 16 |
| Fluorine | 0.157 | 0.210 | 0.400 | 0.100 | 0.200 | 0.400 |
| Iron | 0.000 | 0.020 | 0.060 | 0.000 | 0.020 | 0.495 |
| Manganese | 0.000 | 0.010 | 0.224 | 0.000 | 0.080 | 0.268 |
| Zinc | 0.020 | 0.020 | 0.040 | 0.100 | 0.125 | 0.150 |
| Copper | 0.030 | 0.050 | 0.050 | 0.030 | 0.045 | 0.060 |
| Sodium Absorption Ratio | 2.50 | 4.10 | 9.00 | 2.80 | 5.40 | 15.20 |
| Residual Alkali Hazard (meq/L) | 0.00 | 0.02 | 0.95 | 0.10 | 2.02 | 3.37 |
| Redox potential (mV) | ID | ID | ID | ID | ID | ID |

***Notes:*** *All values as milligrams per litre (mg/L) unless specified.*
*µS/cm = microsiemens per centimetre*
*meq/L = milliequivalents per litre*
*mV = millivolts*
*ID: insufficient data to perform statistical summaries, or the parameter was not tested*

## 1.6 Report structure

The structure of this UWIR is in accordance with requirements of the *Environmental Protection Act 1994* (section 126A and 227AA) and *Water Act 2000* (section 376). This proposed structure was detailed in the *Guideline: (Water Act 2000) Underground Water Impact Reports and Final Reports*, (DES, 2017), and include the following sections:

- Part A: Information about underground water extractions resulting from the exercise of underground water rights (Section 2);
- Part B: Information about aquifers affected, or likely to be affected; underground water flow description (Sections 3 & 4);
- Part C: Predicted changes to water levels in the affected aquifer(s) (Section 5);
- Part D: An assessment of the impacts to the environmental values from the exercise of underground water rights (Section 6)
- Part E: A water monitoring strategy (Section 7);
- Part F: A spring impact management strategy (Section 8); and
- Conclusion (Section 9).

# 2 Underground water extractions (Part A)

## 2.1 Quantity of water already produced

As detailed in Section 1, the Pilot Project by Westside has only included pilot testing of three appraisal wells (P-5R, P-6R and P-8) at the Paranui site. Whilst the three additional wells (P-11, P-12 and P-13) were completed in 2010, pilot testing of these wells was not completed and subsequently suspended as a result of the protracted wet season in late 2010.

An overall total of 5,670 kL of water was produced from the three wells between June 2008 and August 2010. No water production has occurred since that time.

Monthly totals for water production over the three-year period are shown in Table 2.1 and Figure 2.1. This historical production has been included in the transient groundwater model described in Section 4.

### Table 2.1 Historical water production by well at ATP769

| Date | Water production (kL/month) | | |
|---|---|---|---|
| | P-5R | P-6R | P-8 |
| June 2008 | 0 | 330 | 0 |
| July 2008 | 0 | 518 | 0 |
| August 2008 | 0 | 368 | 0 |
| September 2008 | 243 | 238 | 5 |
| October 2008 | 566 | 124 | 37 |
| November 2008 | 385 | 105 | 2 |
| December 2008 | 0 | 114 | 0 |
| January 2009 | 173 | 115 | 0 |
| February 2009 | 257 | 87 | 0 |
| March 2009 | 177 | 19 | 50 |
| April 2009 | 150 | 0 | 36 |
| May 2009 | 125 | 0 | 0 |
| June 2009 | 113 | 0 | 0 |
| July 2009 | 120 | 0 | 0 |
| August 2009 | 117 | 0 | 0 |
| September 2009 | 138 | 0 | 0 |
| October 2009 | 139 | 0 | 0 |
| November 2009 | 91 | 0 | 0 |
| December 2009 | 121 | 0 | 0 |
| January 2010 | 98 | 0 | 0 |
| February 2010 | 71 | 0 | 0 |
| March 2010 | 81 | 0 | 0 |
| April 2010 | 91 | 0 | 0 |
| May 2010 | 101 | 0 | 0 |
| June 2010 | 78 | 0 | 0 |
| July 2010 | 83 | 0 | 0 |
| August 2010 | 6 | 0 | 0 |
| **Total** | **3,524** | **2,017** | **129** |

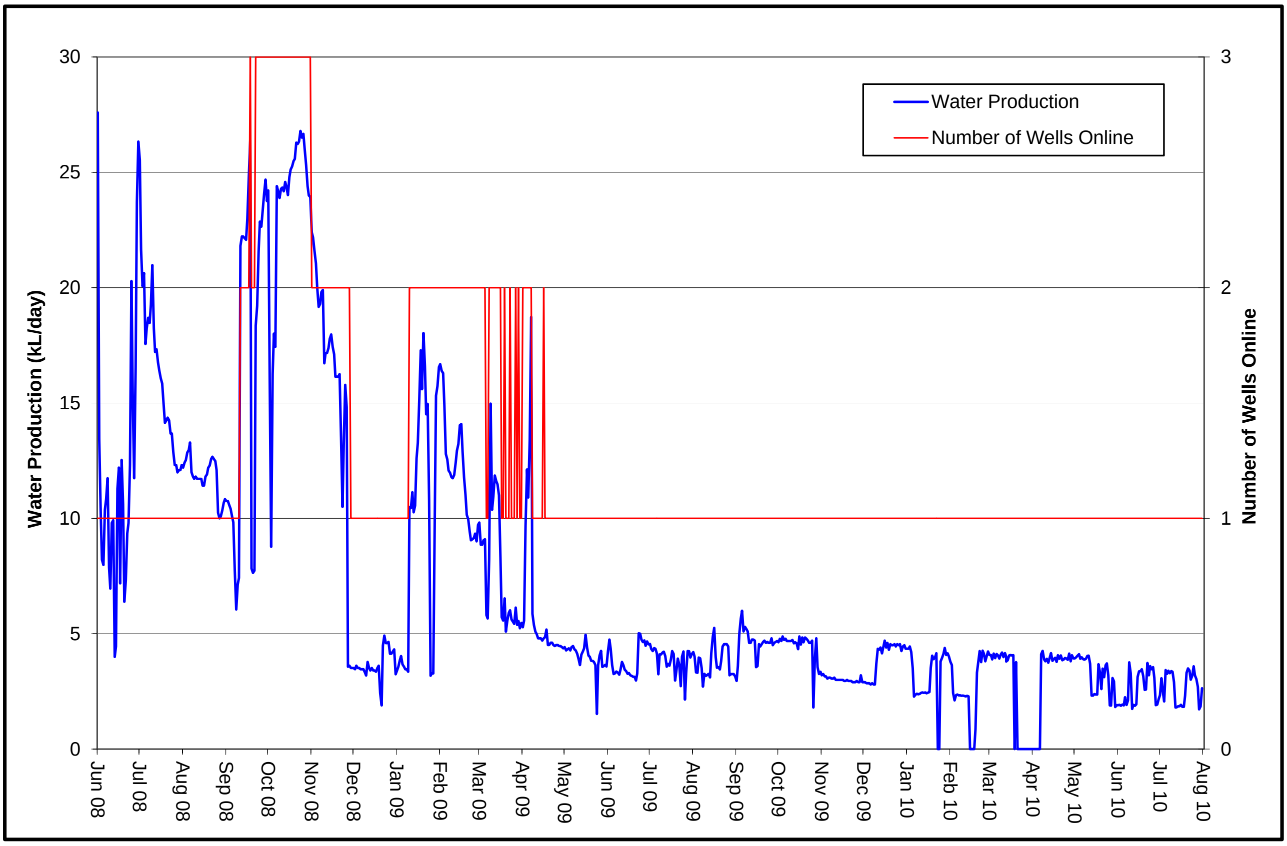



**Figure 2.1 Historical water production at ATP769**

## 2.2 Planned works for 2018 to 2021 UWIR reporting period

Westside have not undertaken any further pilot or production testing from the Paranui wells since 2010. Between April and May In 2017, Paranui wells PA4, PA7, PA8, PA11, PA12, and PA13 were plugged and abandoned. Westside have advised that there was no testing of the wells in the 2015 to 2018 UWIR reporting period, and there is no water extraction planned until 2022. That is, there will be no CSG production or groundwater extraction over the 2018 to 2021 UWIR reporting period.

The planned works over the next five years include an evaluation program which will include:

- re-evaluation of drilling data in 2018;
- re-evaluation of pilot production data and well performance, and infrastructure and market studies in 2019;
- infrastructure and market studies in 2020;
- design of pilot production testing, and infrastructure and market studies in 2021; and
- commencement of pilot production testing, book reserves and field development planning, and finalising gas sales agreements in 2022.

Since there has been no CSG production or groundwater extraction since the initial Pilot Project between 2008 and 2010, this UWIR assessment presents the modelled recovery of groundwater for the Pilot Project for the 2018 to 2021 reporting period.

# 3 Geology and hydrostratigraphic units (Part B)

A review of the geological and hydrogeological features that occur beneath ATP769 are described below and have been used to develop the hydrogeological conceptualisation of the groundwater regime beneath the Project area and surrounds. This understanding forms the basis for the numerical groundwater flow model. Geological information reviewed as part of this assessment has included:

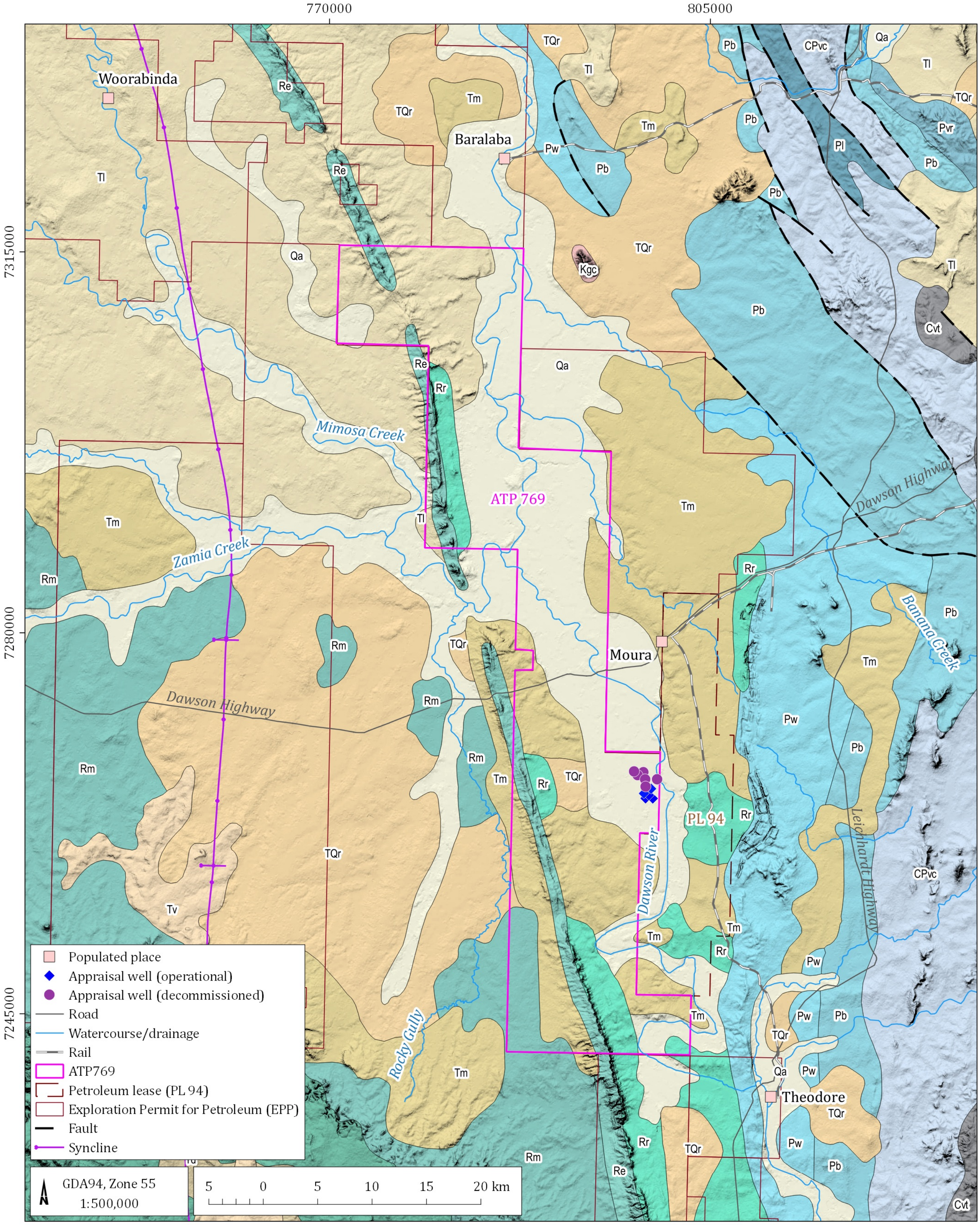
- 1:250,000 Geological Series – Baralaba sheet SG55-4 (GSQ, 1964);
- 1:250,000 Geological Series - Monto sheet SG56-1 (GSQ, 1981); and
- Bowen Basin Structural Geology 2008 (CSIRO & DEM, 2008).

The target for coal seam gas exploration at ATP769 is the Baralaba Sub-Group which comprises the Baralaba Coal Measures and Kaloola Formation.

## 3.1 Stratigraphy

The stratigraphic sequence across the site comprises two distinct units; a Permian sequence which is unconformably overlain by the Triassic Rewan Formation. Unconsolidated Tertiary sediments unconformably overlie both formations along the Dawson River. The Permian and Triassic rocks form a regular layered, westerly dipping sedimentary sequence while the Tertiary and Quaternary sediments are more complex and irregular. Localised linear deposits of Quaternary alluvium are associated with most of the creeks that traverse the site. These creeks enter a large flat alluvial plain associated with the Dawson River. The floodplain is up to 10 km wide around in the northern area of the lease and decreases to about 1 km at the southern extremity.

The surface geology is shown in Figure 3.1. The coal seam gas wells are shown on the geology map in Figure 3.2, and a general stratigraphic section as provided by Westside for the Paranui Project is given in Figure 3.3.

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**Generalised Surface Geology**

- Qa - Quaternary alluvium
- TQr - Tertiary/Quaternary regolith
- Td - Tertiary duricrust
- Tv - Tertiary volcanics
- Tl - Paleocene - Oligocene sediments
- Tm - Oligocene-Miocene sediments
- Kgc - Cretaceous intrusives
- Ji - Injune Creek Group, Wallloon Coal Measures
- RJb - Bundamba Froup
- Rm - Moolayember Formation
- Re - Clematis Group
- Rr - Rewan Group
- Pb - Back Creek Group
- Pl - Woolein Formation
- Pvr - Rookwood Volcanics
- CPga - Auburn Subprovience granitoids.
- CPvc - Camboon Volcanics
- Cvt - Torsdale Volcanics

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**Surface geology**

DATE 07/12/2018

FIGURE No: **3.1**


Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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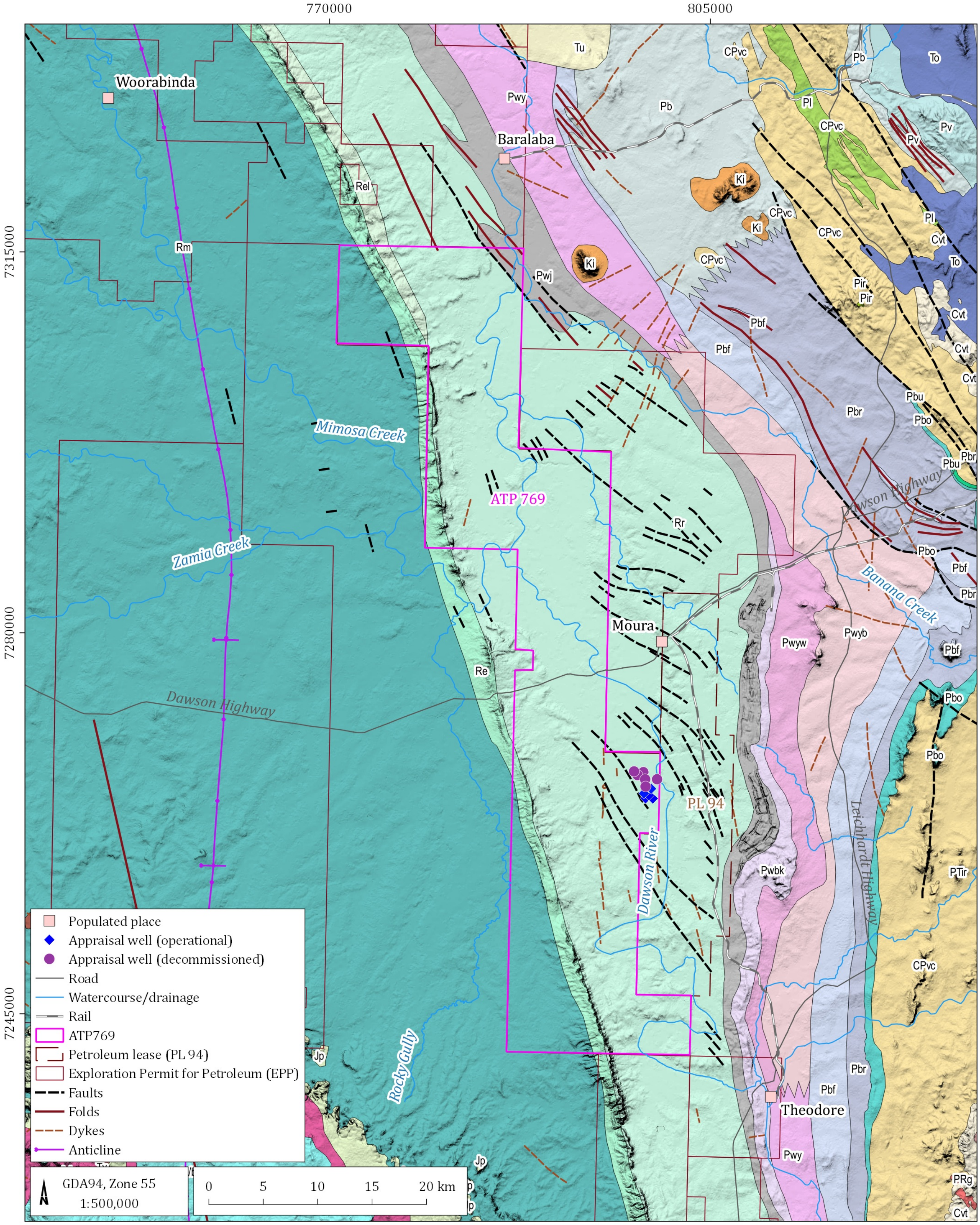


LEGEND

**Solid Geology**

- Tv - Undifferentiated volcanics
- Ki - Individed Intrusives
- Je - Evergreen Fm
- Jp - Precipice Sandstone
- Rm - Moolayember Fm
- Rr - Reewan Fm
- Re - Clematis Group
- Pwj - Rangal/Baralaba Coal meaures
- Pwbk - Kaloola Member
- Pwy - Gyranda Fm
- Pbr - Barfield Fm
- PRg - Granite,granodiorite
- Pl - Woolein Fm
- Pbf - Flat Top Fm
- CPvc - Camboon Volcanics
- CPg - Granodiorite, adamellite
- Cg - Carboniferous granodiorite
- Cvt - Torsdale Volcanics

Paranui UWIR update (G1631B)

**Basement geology**

AGE

| DATE | FIGURE No: |
|---|---|
| 07/12/2018 | **3.2** |


Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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| Paranui Well P-12 | | | | | | |
|---|---|---|---|---|---|---|
| **Age** | **Formation** | **Geology** | **Depth to Top (mRT[1])** | **Depth to Base (mRT[1])** | **Gross Thickness (m)** | **Net Coal Thickness (m)** |
| Quaternary | Alluvium | Clay, sand | 0 | 18.82 | 18.82 | - |
| Triassic | Rewan Formation | Dark grey-green sandstone, siltstone | 18.82 | 626.8 | 607.98 | - |
| Upper Permian | Baralaba Coal Measures | Dark grey-green sandstone, siltstone | 626.8 | 632 | 5.2 | - |
| | | Un-named - Stoney Coal | 632 | 634.58 | 2.58 | 0 |
| | | Dark grey siltstone, sandstone | 634.58 | 657.12 | 22.54 | - |
| | | PC1 - Coal | 657.12 | 661.42 | 4.3 | 2.2 |
| | | Grey-dark grey sandstone, siltstone | 661.42 | 676.61 | 15.19 | - |
| | | PC2 - Coal | 676.61 | 678.32 | 1.71 | 1.12 |
| | | Dark grey siltstone | 678.32 | 696.1 | 17.78 | - |
| | | PC3 - Coal | 696.1 | 699 | 2.9 | 1.72 |
| | | Dark grey siltstone, sandstone | 699 | 713.12 | 14.12 | - |
| | | PC4 - Coal | 713.12 | 715.44 | 2.32 | 2.11 |
| | | Dark grey siltstone | 715.44 | 726.98 | 11.54 | - |
| | | Un-named - Coal | 726.98 | 727.63 | 0.65 | 0 |
| | | Grey-dark grey sandstone, siltstone | 727.63 | 754.05 | 26.42 | - |
| | | PC5 - Coal | 754.05 | 757.28 | 3.23 | 3.11 |
| | | Dark grey siltstone | 757.28 | 792.4 | 35.12 | - |
| | | PC6-7 - Coal | 792.4 | 796.8 | 4.4 | 4.4 |
| | | Dark grey siltstone | 796.8 | 827.05 | 30.21 | - |
| | | PC8 - Coal | 827.05 | 830.37 | 3.32 | 3.12 |
| | | Dark grey siltstone | 830.37 | 854.11 | 23.74 | - |
| | | PC9 - Coal | 854.11 | 856.38 | 2.27 | 1.74 |
| | | Dark grey siltstone | 856.38 | 874.06 | 17.68 | - |
| | | PC10 - Coal | 874.06 | 876.12 | 2.06 | 2 |
| | | Dark grey siltstone | 876.12 | 883.46 | 7.34 | - |
| | | Un-named - Stoney Coal | 883.46 | 885.38 | 1.92 | 0 |
| | | Dark grey siltstone | 885.38 | 905 | 19.62 | - |
| | | PC11 - Coal | 905 | 908.74 | 3.74 | 1.63 |
| | | Dark grey siltstone | 908.74 | 916.62 | 7.88 | - |
| | | PC12 - Coal | 916.6 | 918.0 | 1.4 | 1.3 |
| | | Dark grey siltstone | 918 | 932.6 | 14.6 | - |
| | | PC13 - Coal | 932.6 | 933.21 | 0.61 | 0.52 |
| | | Dark grey siltstone | 933.21 | 941.83 | 8.62 | - |
| | | Un-named - Coal | 941.83 | 942.06 | 0.23 | 0 |
| | | Dark grey siltstone | 942.06 | 949.29 | 7.23 | - |
| | | PC14 - Coal | 949.29 | 949.62 | 0.33 | 0 |
| | Yarrabee Tuff Bed | Tuff, stoney at base | 949.62 | 955.06 | 5.44 | - |
| | Kaloola Member | Grey siltstone, mudstone | 955.06 | - | - | - |
| | | *End of hole* | - | 1045.82 | - | - |

Notes: 1 - mRT, metres below rotary table

Source: Westside Corporation Limited

## Figure 3.3 Generalised stratigraphy of the Paranui project site area

A typical east-west cross section through ATP769 in relation to the Paranui Project Site area is presented in Figure 3.4.

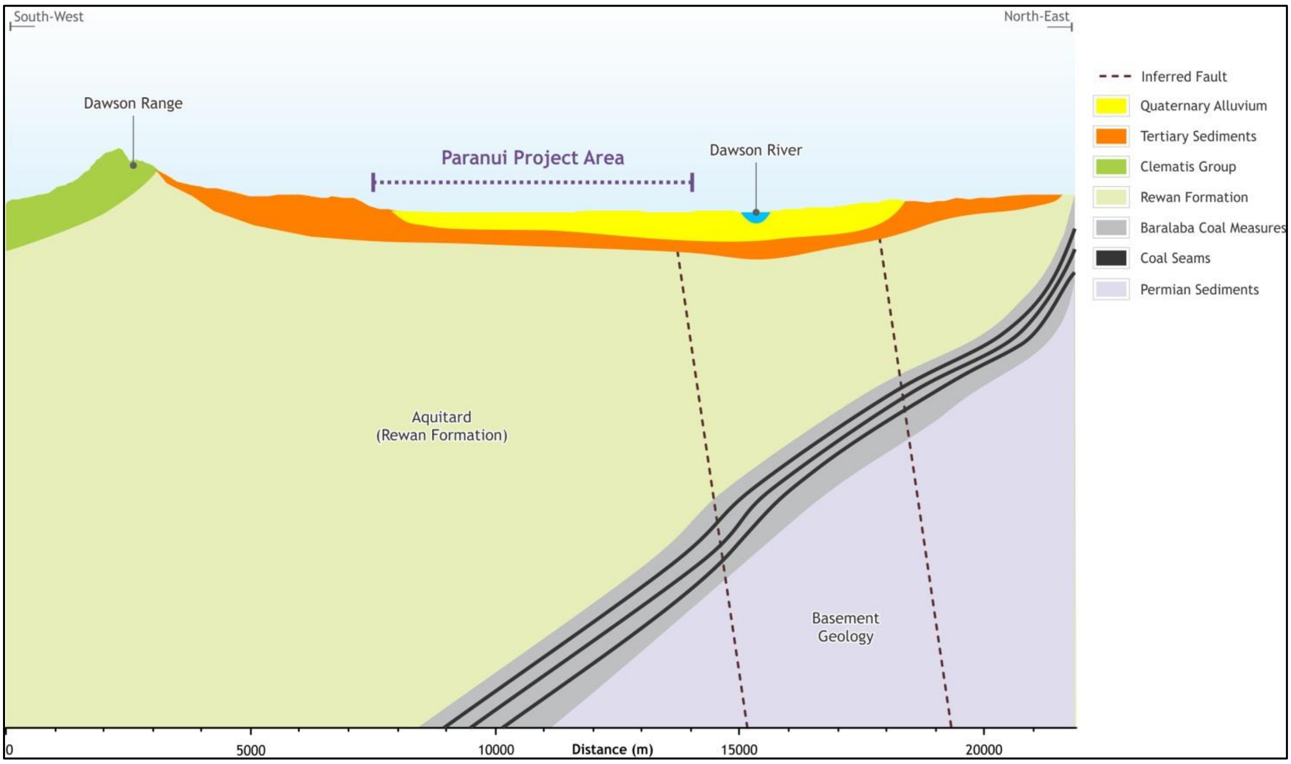



**Figure 3.4 Typical geological cross section**

## 3.2 Permian Strata – Baralaba coal measures

The gas resources targeted in ATP769 are contained within a sequence of coal seams denoted numerically from PC1 to PC14 in sequential order from top of the Upper Permian Baralaba Coal Measures. The Baralaba Coal Measures are up to 320 m thick striking north-south and dipping to the west at between 5° and 16°. The westerly dip of the sequence indicates the upper coal seams are about 650 m below ground level in the eastern area of ATP679, and up to 900 m below surface in the western areas.

The Baralaba Coal Measures consist of fine to medium grained, feldspathic and lithic sandstone and interbedded units of siltstone, mudstone, shale and coal seams. Sandstone occurs as thick beds of typically massive, channel sandstone that is extensively cross bedded. Carbonaceous mudstone and tuff are common towards the base of the production sequence. The coal beds are black, vitreous, thinly laminated to very thinly bedded.

## 3.3 Triassic Strata

Triassic aged sediment overlies the Permian strata within most of ATP769. These sediments include Rewan Formation which are the dominant Triassic sediments, and Great Artesian Basin [GAB] (Clematis Group and Moolayember Formation) outcropping along the western margins of the ATP769.

### 3.3.1 Rewan Formation

The Rewan Formation is typically comprised of brown/green siltstone and shale with minor interbedded lithic sandstones. The Rewan Formation has limited outcrop over much of ATP769, as it is obscured by a blanket of unconsolidated Tertiary and Quaternary sediments over much of the Project area, as is the case within the Paranui site (refer Figure 3.1).

### 3.3.2 Great Artesian Basin - Mimosa management area

The eastern boundary of the Great Artesian Basin (GAB) Mimosa Management Area occurs 8 km west of the Paranui Project area (Figure 3.2). The Mimosa Management Area is comprised largely of the Triassic Clematis Group and Moolayember Formation which are considered a recharge area for the GAB. These sediments dip towards the west and are separated from the Permian coal measures by the Rewan Formation.

## 3.4 Weathered strata and unconsolidated alluvium

The Baralaba Coal Measures are typically weathered to a depth of between 2 m and 25 m below surface (AGE, 2011). As the rocks which form the Coal Measures consist primarily of minerals that weather to clays, the residual soils developed over these rocks are therefore high in clay content.

Thin zones of alluvial deposits of sand, gravel and clay are associated with the creek systems that traverse ATP679. Extensive alluvial deposits up to 10 km wide occur adjacent to the Dawson River between Theodore and Baralaba. Six lines of investigation holes were drilled across the alluvium at a spacing of 20-25 km by the former Water Resources Commission 1991. The alluvium consists of soil, sandy clay and clay overlying widespread and generally thick deposits of fine to medium silty sand which is normally underlain by clay bound and silty sand and gravel. The alluvium varies between 10 m and 26 m in thickness. In places, the alluvial deposits are separated from the underlying bedrock by Tertiary sediments.

## 3.5 Structures

ATP769 is located on the eastern limb of the Mimosa Syncline in the south-eastern Bowen Basin. The area has been affected by a series of compression events, resulting in multiple north-westerly striking reverse faults. Extension is also evident in the form of sporadic north-easterly striking normal faults.

# 4 Hydrogeological regime (Part B)

The hydrogeology of the Project area and surrounds comprises two distinct aquifers that occur within the study area, these being:

- the Quaternary age alluvium; and
- the Permian to Triassic age fractured rocks.

These aquifers are described in more detail below.

## 4.1 Quaternary alluvial aquifers

Quaternary deposits within the ATP769 consist of unconsolidated alluvium comprising soil, silt, clay, sand, and gravel associated with the rivers and creeks that traverse the study area. More specifically these are dominated by the Dawson River alignment.

The nature of the alluvium associated with the Dawson River in the area of ATP769 was investigated by the Water Resources Commission in 1991. The investigation included drilling a line of bores across the floodplain known as the Moura Line. The line of bores was drilled adjacent to the Dawson Highway to the west of the township of Moura. The lithological units intersected in each borehole across the floodplain as prepared by Water Resources Commission are shown in Figure 4.1.

This data indicates the unconsolidated alluvial sediments are between 15 m and 20 m in thickness and are generally comprised of silty and clayey sediments in the upper 10 m, with the potential for clay bound or clean sands and gravels in the basal 5 m. The alluvial sediments were underlain by brown silty clays and chocolate shales.

Groundwater levels at the time these monitoring bores were drilled in 1991 were between 10 m and 11 m below ground level. Groundwater levels in the Moura area indicated the Dawson River was a gaining river, but further upstream as the elevation of the river bed rises, groundwater levels are close to the bed of the river indicating a losing stream in this area.

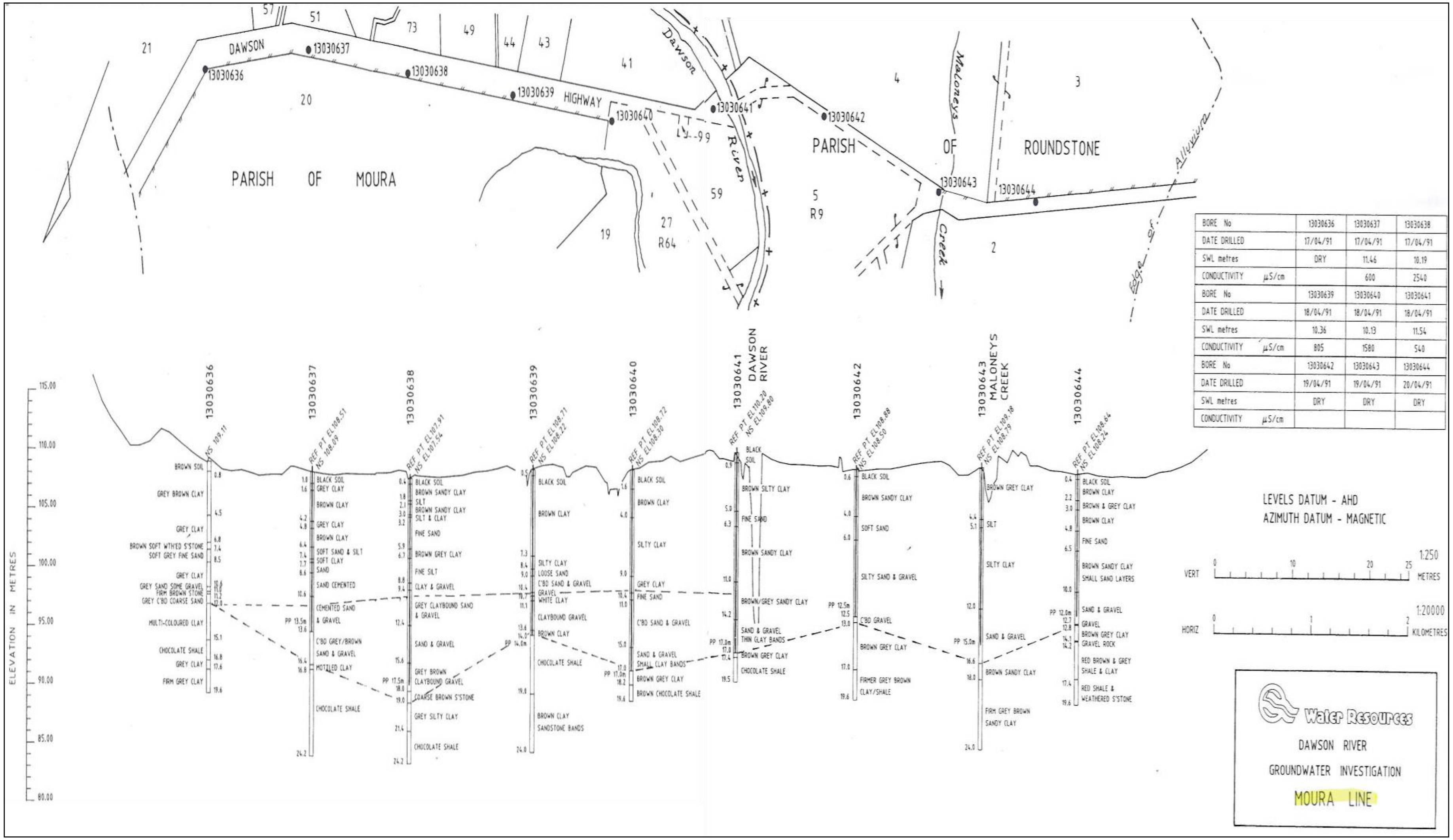



**Figure 4.1 Cross section – Moura Line**

### 4.1.1 Distribution and users

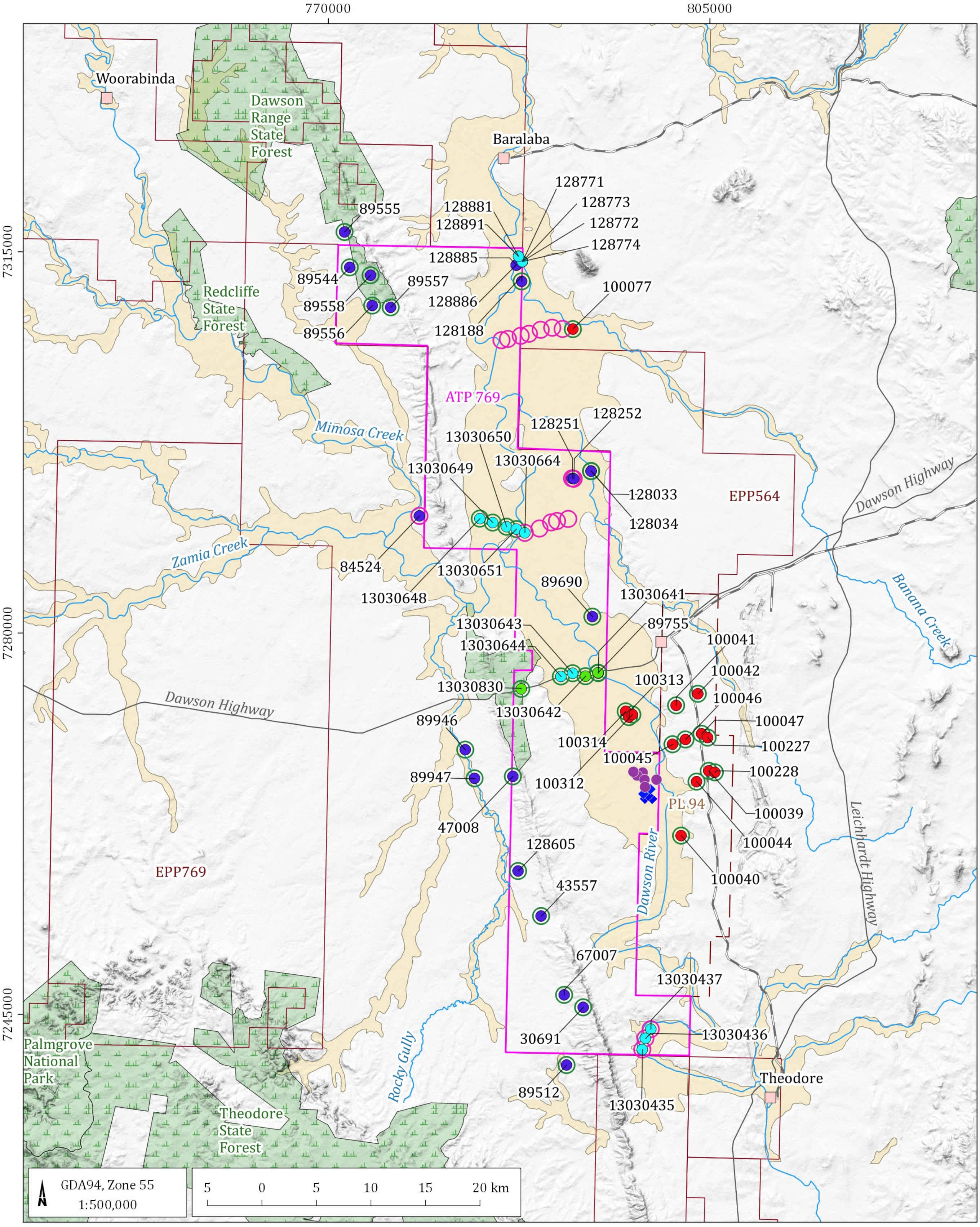
The Quaternary alluvium associated with the Dawson River covers an area of about 240 km2 which extends across much of the ATP769. Data from the Department of Natural Resources and Mining (DNRM) Groundwater Database was reviewed to assess groundwater usage in the alluvium within this portion of ATP769. The locations of the bores within the DNRM database are shown in Figure 4.2. Details of these registered bores and summarised in Table 4.1 and Appendix A.

**Table 4.1 Registered bores in Dawson river alluvium within ATP769**

| Registered number | Year drilled | Easting | Northing | Purpose | Status | Depth (m) | Screen |
|---|---|---|---|---|---|---|---|
| 89690 | - | 794221 | 7281500 | Water Supply | Existing | 19 | 14.2-18.9 |
| 89755 | 2001 | 794738 | 7276353 | Water Supply | Existing | 24 | 15.0-24.0 |
| 128033 | 2007 | 794105 | 7294871 | Water Supply | Existing | 18 | 14.5-17.5 |
| 128034 | - | 794104 | 7294843 | Water Supply | Existing | - | 16.5-22.5 |
| 128188 | 2006 | 787733 | 7312273 | Water Supply | Existing | 15.5 | 14.5-15.5 |
| 128771 | 2012 | 787806 | 7314088 | - | Existing | 23.5 | 11.0-23.5 |
| 128772 | 2012 | 787802 | 7314105 | - | Existing | 20.0 | 11.3-17.3 |
| 128881 | 2012 | 787440 | 7314586 | - | Existing | 29.0 | 9.5-21.5 |
| 128885 | 2012 | 787270 | 7313771 | - | Existing | 17.0 | 9.0-15.0 |
| 128886 | - | 787220 | 7313767 | - | Existing | 18.0 | 9.6-15.6 |
| 13030641 | 1991 | 794755 | 7276316 | WR Monitoring Bore | A/U | 17 | 4.0-17.0 |
| 13030642 | - | 793588 | 7276030 | WR Investigation Bore | A/U | 13 | 10.5-12.5 |
| 13030643 | - | 792407 | 7276301 | WR Investigation Bore | A/U | 16.6 | 13.0-15.0 |
| 13030644 | - | 791331 | 7276008 | WR Investigation Bore | A/U | 12.8 | 9.0-12.0 |
| 13030648 | - | 783892 | 7290497 | WR Investigation Bore | A/U | 16.6 | 14.0-16.0 |
| 13030649 | - | 785071 | 7290131 | WR Investigation Bore | A/U | 19.7 | 17.2-19.7 |
| 13030650 | - | 786338 | 7289754 | WR Investigation Bore | A/U | 23.9 | 21.0-23.0 |
| 13030651 | - | 787244 | 7289537 | WR Investigation Bore | A/U | 15.4 | 13.0-15.0 |

***Note:*** *Projection is MGA94, Zone 55*

A total of 18 registered bores are located in the alluvial aquifer. Ten of the registered boreholes appear to be designed for pumping groundwater from the alluvium. These bores were installed between 2001 and 2012 and are constructed with screens located in the basal sands and gravels.




LEGEND

- Populated place
- Road
- Watercourse/drainage
- Rail
- ATP769
- Petroleum lease (PL 94)
- Exploration Permit for Petroleum (EPP)
- Quaternary Alluvium
- Reserve
- Appraisal well (operational)
- Appraisal well (decommissioned)

**Registered bores**

- Water Supply
- Sub-artesian Monitoring
- Water Resource Investigation
- Petroleum or Gas Exploration
- Registered bore - Existing
- Registered bore - Destroyed

Paranui UWIR update (G1631B)

**Registered bores**

DATE 07/12/2018

FIGURE No: **4.2**


Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1631B.Paranui UWIR update\3_GIS\Workspaces\001_Deliverable1\04.02_G1631B_Registered bores.qgs

### *4.1.2 Groundwater levels*

Groundwater levels have been monitored intermittently in the monitoring bores along the Moura Line between 1991 and 2018. The groundwater levels are presented below in Figure 4.3.

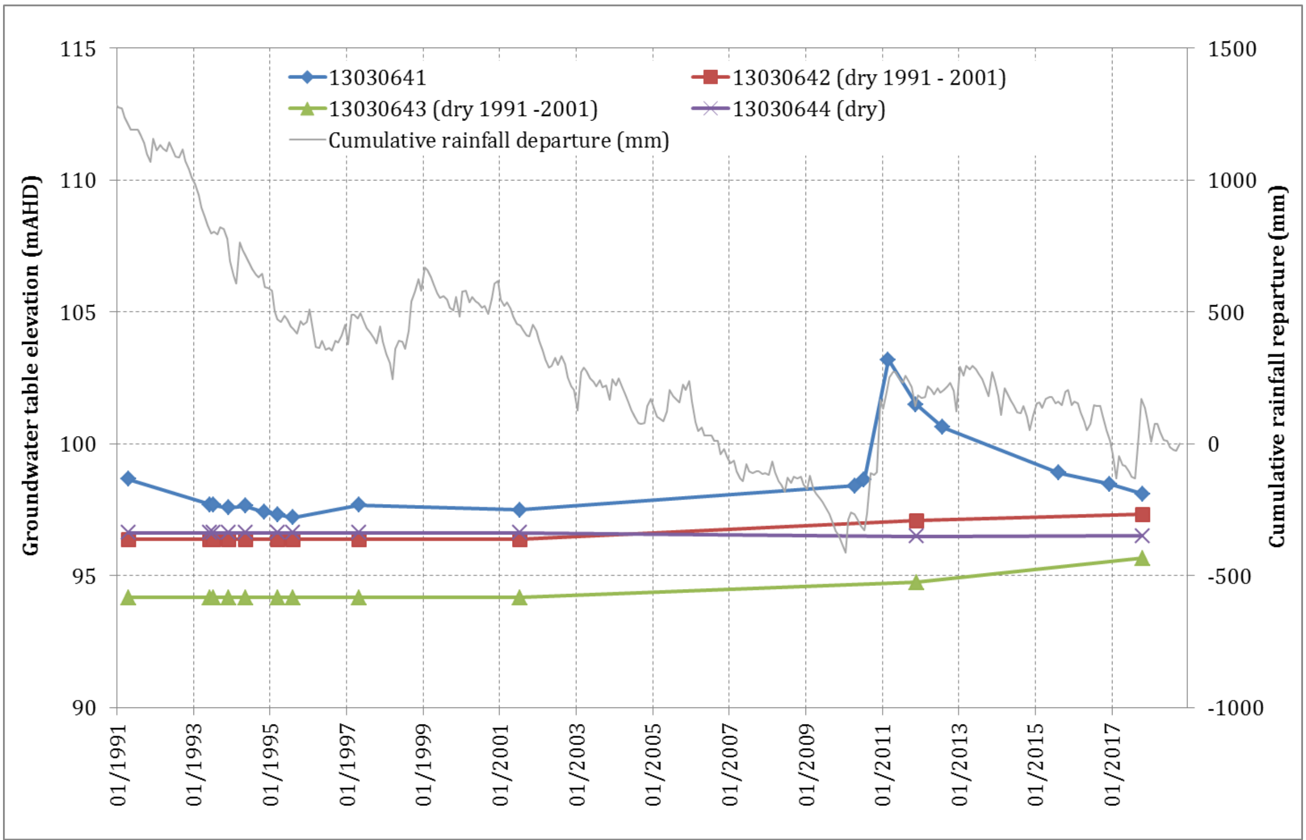



**Figure 4.3 Moura Line monitoring bore water level hydrographs**

Water level data is available for all bores, however bores RN13030642, RN13030643 and RN13030644 have historically been dry (between 1991 and 2001), with water table measurements recorded only after 2011. Water levels in bore RN13131641 remained generally static between 1991 and 2010 but responded to the above average rainfall observed by the rising Cumulative Rainfall Departure (CRD) value between 2010 and 2011. This response was not observed Bore RN 13030830 (Figure 4.4) which is constructed within Rewan Formation sediments. These sediments are typically tight and of low permeability (i.e. they are clay bound) and would not be expected to respond to recharge from rainfall.

### *4.1.3 Groundwater flow and yields*

Groundwater flow is from the alluvium to the Dawson River when the alluvium is recharged by good rainfall and water levels are high and above the river water level. Conversely when rainfall is low and water levels are below the bed of the river, groundwater flow is likely to remain within the alluvium and be to the north.

There is no information available on yields from bores constructed in the alluvial aquifer. Yields from bores are expected to be good where clean basal gravels are present and water levels and sufficiently high. When the basal gravels are clay bound, yields would be poor.

### 4.1.4 Hydraulic parameters

No testing of the hydraulic properties of the alluvium is known to have been undertaken. The drilling undertaken along the Moura Line suggests zones of clean basal sands would have a very high hydraulic conductivity. However, these zones are not likely to be laterally extensive with clay bound sand and gravel commonly encountered in the investigation. In the absence of any hydraulic parameters for this alluvial aquifer, typical values were sourced from relevant literature and other EIS coal projects in the Bowen Basin and are provided in Table 4.2.

**Table 4.2 Alluvium hydraulic parameters**

| Parameter | Value |
|---|---|
| Hydraulic Conductivity | 0.1 – 100 m/day (Bowen Basin alluvial aquifers)[a]<br>20 – 100 m/day (coarse sand)[b] |
| Specific Yield | 0.05 – 0.25[a]<br>0.27[b]<br>0.25[c] |
| Specific Storage | $1 \times 10^{-3}$ (c) |

***Source of data:*** *a – CDM Smith, 2013.*
*b – Kruseman & de Ridder, 1992.*
*c – AGE, 2006.*

### 4.1.5 Recharge and discharge processes

Recharge to the alluvial aquifer is expected to occur through direct diffuse rainfall infiltration, and also via seepage from the Dawson River into the alluvium during high flow and flood events.

The Dawson River alluvial floodplain covers an area of about 780 km$^2$ within the vicinity of ATP769. The average long term recharge to the aquifer from rainfall is estimated to be about 4 ML/day, assuming 0.25% of the rainfall infiltrates the aquifer. The estimated rainfall recharge rate is approximately 1.7 mm/year based on an average annual rainfall of 685 mm (Station Number 39071, Moura Post Office).

## 4.2 Bedrock Triassic/Permian Aquifers

### 4.2.1 Description

The Triassic sediments within the Mimosa Management Area are considered a recharge area for the GAB. The aquifers associated with these sediments are separated from the underlying Permian coal measures by a thick sequence (~600 m) of "tight", very low yielding, low permeability sediments that make up the Rewan Formation. Permeability testing elsewhere in the Bowen Basin indicates very low permeability values around $1 \times 10^{-5}$ m/day for the Rewan Formation (AGE, 2010).

The Permian coal seams comprise confined aquifers which generally exhibit relatively low permeability and recharge rates. Groundwater storage and movement occurs within the coal seam cleats and fissures, and within fractures associated with faults intersecting the seams. The sediments of the interburden and overburden sequence are typically relatively impermeable and form aquitards.

The Permian strata can be categorised into the following hydrogeological units:

- generally hydrogeologically “tight” and hence very low yielding sandstone, siltstone and shales that comprise the majority of the Permian interburden/overburden;
- low to moderately permeable coal seams which are the prime water bearing strata within the Permian sequence; and
- potentially higher yielding fracture zones associated with faulting and open joints.

### *4.2.2 Distribution and users*

Data from the DNRM Groundwater Database identifies there are 17 registered monitoring bores within these sediments in this portion of ATP769. Seven are recorded as being constructed within either the Clematis Group or Moolayember Formation sediments, and one with the Rewan Formation. The locations of these bores within the NRM database are shown in Figure 4.2. Details of these registered bores and summarised in Table 4.3 and Appendix A.

**Table 4.3 Registered bores in Triassic/Permian sediments within ATP769**

| Registered number | Year drilled | Easting | Northing | Purpose | status | Depth | Screen |
|---|---|---|---|---|---|---|---|
| 30691 | 1968 | 793380 | 7245647 | Water Supply | Existing | 64 | Open |
| 43557 | 1974 | 789514 | 7254015 | Water Supply | Existing | 538 | Open |
| 47008 | 1974 | 786935 | 7266841 | Water Supply | Existing | 525 | Open |
| 67007 | 1982 | 791626 | 7246771 | - | Existing | 365.0 | Open |
| 89512 | - | 791848 | 7240340 | Water Supply | Existing | - | 36-42 |
| 89544 | - | 771954 | 7313557 | Water Supply | Existing | - | - |
| 89556 | 1991 | 774018 | 7310055 | Water Supply | Existing | 54 | 42-48 |
| 89557 | 1991 | 775712 | 7309890 | Water Supply | Existing | 60 | 24-54 |
| 89558 | 1991 | 773869 | 7312837 | Water Supply | Existing | 54 | 42-54 |
| 89946 | - | 782567 | 7269271 | Water Supply | Existing | - | - |
| 89947 | - | 783414 | 7266667 | Water Supply | Existing | - | - |
| 100077 | - | 792431 | 7307891 | Petroleum/Gas Bore | Existing | - | - |
| 128605 | 2009 | 787401 | 7258147 | Water Supply | Existing | 560 | 290-560 |
| 128773 | 2012 | 787805 | 7314101 | - | Existing | 185.0 | 136-178 |
| 128774 | 2012 | 787789 | 7314089 | Monitoring bore | Existing | 252.0 | VWP |
| 128891 | - | 787442 | 7314568 | Monitoring bore | Existing | 147.2 | VWP |
| 13030830 | - | 787697 | 7274857 | WR Monitoring Bore | Existing | 48 | 46.5-47.5 |

The majority of these bores are located within the GAB sediments where more reliable yields and better water quality is available.

### 4.2.3 Aquifer properties

Measurement of coal seam permeability has only been undertaken in pilot well P-1 with estimates of permeability provided for wells P-5R and P-6R (IPT, 2010). These are summarised in Table 4.4. The intrinsic permeability of the coal seams, measured in millidarcies (md) was converted to a hydraulic conductivity, with the units of meter/day by a multiplication factor of $8\times10^{-4}$.

**Table 4.4 Summary of permeability testing data**

| Well/Seam | Depth | Intrinsic permeability (md) | Hydraulic conductivity (m/day) | Field |
|---|---|---|---|---|
| P-1/Y | 688.95 | 0.13 | 0.0001 | unknown |
| P-1/B | 762.20 | 0.27 | 0.0002 | unknown |
| P-1/Bl+C | 786.21 | 1.01 | 0.0008 | unknown |
| P-5R | - | 0.065 | 0.00005 | unknown |
| P-6R | - | 0.305 | 0.0002 | unknown |

The test data indicates the hydraulic conductivity/permeability of the coal seams is relatively low for coal. The coal permeability ranges from $8\times10^{-4}$ m/day to $5\times10^{-5}$ m/day.

These are lower than the permeability values for the Meridian Seam Gas Fields (AGE, 2011) which is consistent with these coal seams being deeper. The permeability of coal seams typically decline with depth as overburden pressure closes the cleats.

The hydraulic conductivity of the interburden and overburden units has not been measured within ATP769. In the absence of any hydraulic parameters for the interburden and overburden units, typical values were sourced from relevant literature and other EIS coal projects in the Bowen Basin and are provided in Table 4.5.

**Table 4.5 Overburden, interburden and coal seam hydraulic parameters**

| Geological Unit | Parameter | Value |
|---|---|---|
| Rewan Formation/Interburden | Hydraulic Conductivity | $0.1 – 10^{-6}$ m/day [a]<br>$10^{-4}$ - $10^{-5}$ m/day [b, c] |
| | Specific Storage | $5\times10^{-5}$ - $5 \times 10^{-6}$ (a)<br>$1\times10^{-6}$ (b, d)<br>$1\times10^{-5}$ (c) |
| Bowen Basin Coal Seams | Hydraulic Conductivity | $5 – 10^{-6}$ m/day [a]<br>1 m/day for less than 100 m depth, declining to $10^{-6}$ m/day for greater than 400 m depth [b]<br>$5\times10^{-2}$ m/day for less than 100 m depth [c] |
| | Specific Storage | $4\times10^{-4}$ to $2\times10^{-7}$ (a)<br>$1\times10^{-6}$ (b)<br>$1\times10^{-4}$ to $1\times10^{-5}$ (c, d) |

***Source of data:*** *a – CDM Smith, 2013.* *b – AGE, 2006*
*c – AGE, 2010* *d – Rau et al, 2018*

The referenced data in Table 4.5 indicates that the hydraulic conductivity values for the overburden/interburden sediments in the Bowen Basin can be as much as one to two orders of magnitude lower than the coal seams. Based on the cyclic sequence of sandstones, siltstones and shales that comprise the overburden and interburden sediments, these sequences as a whole are considered to have a poor capacity to transmit water.

### *4.2.4 Water level fluctuations and piezometric elevation*

Monitoring of groundwater levels/pressures in the overburden and coal seams is not undertaken routinely on ATP769. Outside the lease DNRM constructed a monitoring bore into the consolidated bedrock in 2003 as part of the "National Action Plan for Salinity". This bore (RN13030830) is located north of the Paranui Project area within the Rewan Formation along the Dawson Highway and west of the Dawson River Alluvium. Groundwater levels have been monitored in these bores since installation, with hydrographs shown in Figure 4.4. The water levels in this monitoring bore are for groundwater associated with the overburden and show only very limited fluctuation with rainfall.

Groundwater level determined from water level measurements for the Moura Mine to the east, indicate a hydraulic gradient of 0.01 (1 in 100) in the Dawson South Stage 2 area grading from RL 150m in the east to RL 120m in the west (AGE, 2011). Based on this, it is considered that the potentiometric surface in the bedrock is expected to be a subdued reflection of the topography indicating groundwater flow from the east, towards the Dawson River in the west.

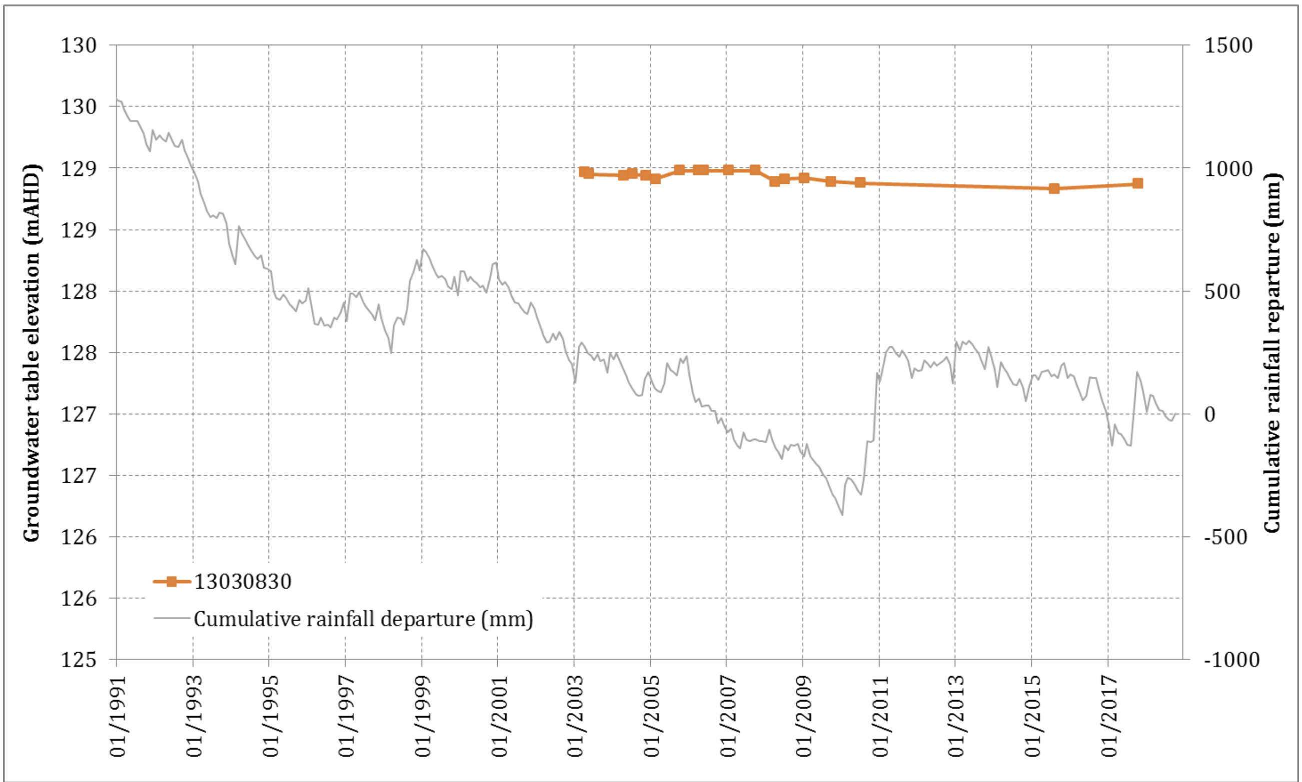



**Figure 4.4 Hydrograph - Rewan Formation**

### *4.2.5 Groundwater flow (Yield)*

The coal seam gas wells within the Paranui Project area (in ATP769) were drilled using the rotary mud method and therefore no observations of groundwater flows from different stratigraphic units can be made. There are 13 existing, registered landholder bores within ATP769 that have been constructed in the bedrock for stock and domestic purposes. These are mostly located towards the western side of the ATP769 into the GAB Triassic sediments.

It is understood that drilling undertaken at the adjacent Dawson Mine does not typically intersect large volumes of groundwater, with dry holes being common (AGE, 2011). The exception is where the hydraulic conductivity has been locally enhanced by closely spaced open joints or broken fault zones which can have higher yields. These zones do not generally produce high yields long-term as the fractures are readily drained of water due to the less transmissive surrounding rocks.

The coal seams are considered to be the only laterally extensive aquifer within the coal measures.

### *4.2.6 Recharge and discharge processes*

Recharge to the coal seams is expected to be primarily via the outcrop and subcrop areas which occur to the east of ATP769 particularly within the Dawson Mine lease. The recharge rates are expected to be relatively low in comparison to the alluvial aquifer.

The Triassic/Permian outcrop is recharged by diffuse areal recharge and potentially also from the overlying Quaternary/Tertiary unconsolidated sediments where these are present. Again, the rates of recharge are considered to be relatively low, compared to the alluvial aquifer.

## 4.3 Groundwater quality

Part of this review has included initiating the baseline groundwater monitoring of accessible registered bores listed in Table 4.1 and Table 4.3. Nine bores were sampled which included:

- RN89755, RN89947, RN128033, RN13030641, and unregistered bore next to RN89690 located within the Quaternary Alluvium;
- RN47008, RN43557, RN128605 located within the Clematis Sandstone (GAB); and
- RN13030830 located within the Rewan Formation.

Grab samples were collected from each bore using either a bailer or from an outlet for those bores equipped with pumps (RN47008, RN43557, RN89947, RN128605) between 29 May and 28 June 2013. The results of this sampling are provided in Appendix B.

The salinity of the water samples can be categorised based on the following total dissolved solids concentrations (FAO, 2013) for groundwater:

| | |
|---|---|
| Fresh water | <500 mg/L |
| Brackish (slightly saline) | 500 to 1,500 mg/L |
| Moderately saline | 1,500 to 7,000 mg/L |
| Saline | 7,000 to 15,000 mg/L |
| Highly saline | 15,000 to 35,000 mg/L |
| Brine | >35,000 mg/L[1] |

In summary, the analysis results indicate:

- Groundwater within the alluvial aquifer is neutral to slightly alkaline and fresh (286 mg/L) to brackish (1,290 mg/L) dominated by calcium, sodium and chloride ions.
- Groundwater within the GAB sediments is alkaline and fresh (365 mg/L) to slightly brackish (564 mg/L) also dominated by calcium, sodium and chloride ions.

[1] The Department of Environment and Heritage (DEHP) define a brine as saline water with a total dissolved solids concentrations greater than 40,000 mg/L.

- Groundwater within the Rewan Formation sediments is slightly alkaline and highly saline (17,700 mg/L) also dominated by calcium, sodium and chloride ions.
- Detectable levels of metals for barium, manganese, nickel, strontium, boron, iron, zinc in most bores, with detectable levels of arsenic in RN89755 and RN128033, and cobalt and copper in RN 89755.
- Detectable levels of nutrients in all bores sampled.
- Levels below the laboratory detection limits for all bores sampled for total petroleum hydrocarbons (TPH), benzene, toluene, ethyl benzene and xylenes (BTEX), and polycyclic aromatic hydrocarbons (PAH).
- No detectable levels for gross alpha and beta radionuclides for all bores sampled.
- Detectable levels for dissolved methane between 15 μg/L and 128 μg/L in four of the bores sampled.

## 4.4 Groundwater dependent ecosystems and springs

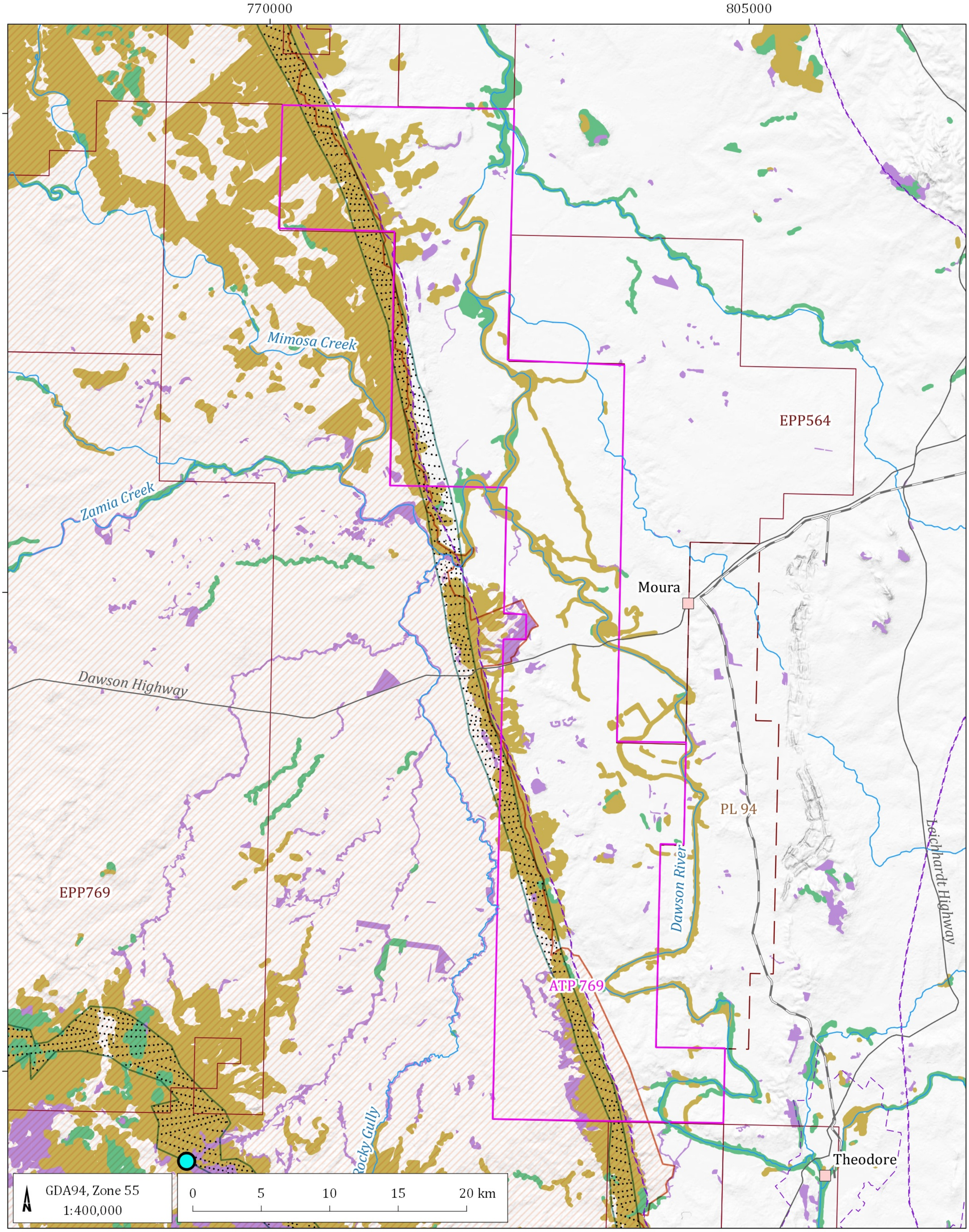
A Groundwater Dependent Ecosystem (GDE) is one in which the plant and animal community is dependent on the availability of groundwater to maintain its structure and function. The BoMs GDE Atlas shows ecosystems including springs, wetlands, rivers, and vegetation that interact with the subsurface presence of groundwater, or the surface expression of groundwater (BoM, 2017). The Atlas categorises GDEs into two classes in Queensland. These are ecosystems that potentially rely on the:

- surface expression of groundwater - this includes all the surface water ecosystems which may have a groundwater component, such as rivers, wetlands, and springs; and
- subsurface presence of groundwater - this includes all vegetation ecosystems.

Figure 4.5 shows the potential GDE's identified by the BoM GDE mapping within and around the Paranui Pilot Project. This shows much of the surrounding land that is still treed has been mapped as a "terrestrial" GDE and appears to be based heavily upon the extent of this existing treed vegetation associated with the Dawson River and associated flood plain. Within this area, the mapped GDEs include:

- Terrestrial vegetation associated with the watercourse located on the Paranui property which is mapped as a moderate potential GDE that is *"most likely to be accessing additional water sources"*;
- Terrestrial vegetation, located within the Paranui property which is mapped as a moderate to high potential GDE that range from being *"most likely to be accessing additional water sources"* to "*possibly likely to access an additional source of water than rely solely on rainfall"*; and
- Aquatic wetland/riverine habitat within watercourses associated with Dawson River, which is mapped as a moderate potential GDE that is "*most likely to be accessing additional water sources"*.

Any dependence on groundwater is assessed to be solely attributable to connection and access to the shallow alluvial aquifer and not the deeper (more saline) groundwater associated with the Baralaba Coal Measures.




LEGEND

- Populated place
- Spring
- Road
- Watercourse/drainage
- Rail
- ATP769
- Petroleum lease (PL 94)
- Exploration Permit for Petroleum (EPP)
- Groundwater Management Unit Boundary
- GAB Intake Area
- Mimosa GMU (Area 22 of the GABWRP)

**Terrestrial GDE**

- High potential GDE
- Moderate potential GDE
- Low potential GDE

Paranui UWIR update (G1631B)

**Groundwater dependent ecosystems & springs - terrestrial**

AGE

DATE 05/12/2018

FIGURE No: **4.5**


Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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## 4.5 Conceptual hydrogeological model

As standard practice, every numerical groundwater model has as its foundation a conceptual model. Details of the groundwater regime for this project described in this section form the basis of the numerical model. The conceptual model is an understanding of how the groundwater system operates and is an idealised and simplified representation of the natural system.

Figure 3.4 presents a generalised east-west section showing the location of the Paranui project area in relation to the regional geological setting. Hydrogeologically, the data used to develop this conceptualisation indicates the area supports two distinct aquifers that occur within the study area, these being:

- the Quaternary age alluvium; and
- the Permian to Triassic age fractured rocks.

Figure 4.6 shows the hydrogeological conceptualisation on a local scale.

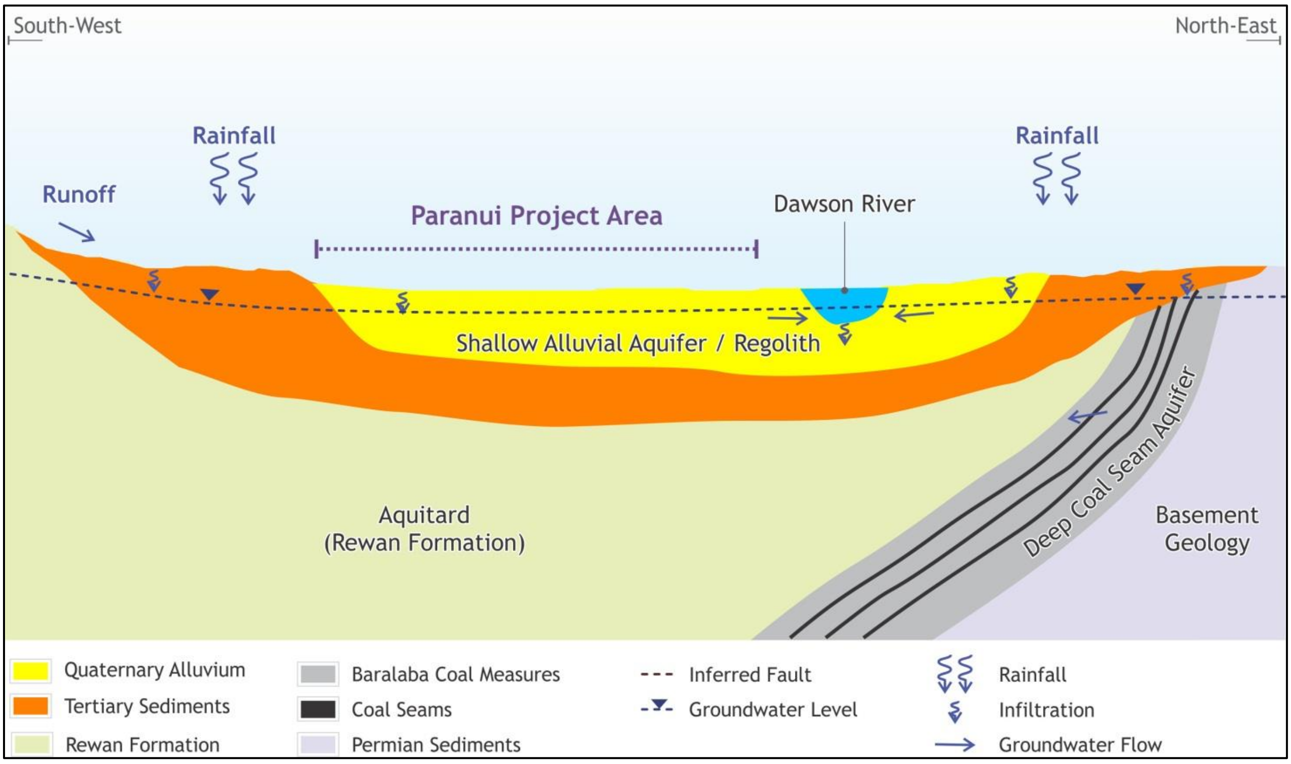



**Figure 4.6 Conceptual hydrogeological model**

This conceptualisation shows groundwater occurs:

- locally within the base of the Quaternary sediments where more permeable sediments occur; and
- regionally where it effectively includes the combined hydraulic heads of the deeper saline aquifers hosted within the Permian Baralaba Coal Measures, which include coal seams that will be targeted for this CSG project.

These aquifers are separated by a thick sequence of Triassic (Rewan Formation) sediments which comprise "tight", low permeability sediments or aquitards. As such, these aquifers are unlikely to be hydraulically interconnected.

Recharge would principally be in the form of infiltration from rainfall and creek flow into the Quaternary, and to a lesser extent within the Permian aquifer sub-crop areas west of the Paranui site. However, this would be significantly reduced where predominantly clayey Tertiary sequences overlie the Permian coal measures.

Regionally, groundwater flow will be more pronounced within the more permeable Quaternary aquifer which is likely to be to the north. However, on a local scale, groundwater movement within the alluvium will be towards the Dawson River, particularly when groundwater levels are high and above the river water level. The regional groundwater levels within the bedrock are expected to be a subdued reflection of the topography indicating groundwater flow from the east towards the Dawson River.

## 4.6 Summary of hydrogeological investigation

The results of the hydrogeological investigation for ATP769 can be summarised with the following key points:

- The consolidated geology across the site comprises two distinct units which include a basement Permian sequence unconformably overlain by Triassic Rewan Formation. Unconsolidated Tertiary sediments unconformably overlie both formations along the Dawson River. The Permian and Triassic rocks form a regular layered, westerly dipping sedimentary sequence while the Tertiary and Quaternary sediments are more complex and irregular.
- The study area is bound to the east where the Permian geology outcrops roughly along the line of open cut coal mines. The eastern boundary of the GAB Mimosa Management Area is located along the western extents of ATP769, some 8 km west of the Paranui Project area.
- The hydrogeology of the Project area and surrounds comprises two distinct aquifers within the study area, which include the Quaternary age alluvium and the Permian to Triassic age fractured rocks.
- Groundwater associated with the unconsolidated alluvial sediments occurs within the sands and gravels in the basal 5 m. These are overlain by a thicker unit of clay sediments between 15 m and 20 m in thickness. Recharge to this aquifer is expected to occur from rainfall infiltration and seepage from the Dawson River into the alluvium during high flow and flood events.
- The Triassic sediments within the Mimosa Management Area are considered a recharge area for the GAB. Aquifers associated with these sediments are separated from the underlying Permian coal measures by a thick sequence (~600 m) of "tight", very low yielding and low permeability sediments that make up the Rewan Formation.
- The Permian coal seams comprise confined aquifers which generally exhibit relatively low permeability and recharge rates. The sediments of the interburden and overburden sequence are typically relatively impermeable and form aquitards. Recharge to the coal seams is expected to be relatively low, occurring where the coal seam sub-crop/outcrop, particularly within the Dawson Mine lease.
- Groundwater flow is typically from the alluvium to the Dawson River when water levels are high and above the river water level. When there is no rainfall and water levels are below the bed of the river, groundwater flow is likely to remain within the alluvium and be to the north.
- Groundwater levels within the bedrock are expected to be a subdued reflection of the topography indicating groundwater flow from the east towards the Dawson River.
- Groundwater usage is limited within the study area to shallow bores within the Dawson River alluvium and deeper bores into the GAB sediments in the west. Groundwater quality in these aquifers is typically neutral to alkaline and fresh. Groundwater in the deeper Rewan Formation is slightly alkaline and saline.

# 5 Predictions of groundwater impacts (Part C)

The predicted impact on the groundwater regime from groundwater abstraction in relation to CSG production in ATP769 has previously been assessed through development and simulation of a numerical groundwater model (AGE, 2015). This identified impact above the trigger drawdown levels in the Immediately Affected Area (IAA) and the Long Term Affected Area (LTAA).

Since there is no planned CSG production for the 2018-2021 UWIR reporting period, the numerical model has assessed the residual drawdown (extent of groundwater level recovery) from the 2008 to 2010 pilot testing (Section 2.1). As this is the most recent groundwater abstraction from the groundwater system, this review compares the residual drawdown from the pilot testing at the beginning (5th November 2018) to that at the end (5th November 2021) of the UWIR reporting period.

## 5.1 Model code

Simulation of groundwater flow for the Project site was undertaken using the MODFLOW-SURFACT code (referred to as SURFACT for the remainder of the report). SURFACT is a commercial derivative of the standard MODFLOW code, and is distributed by Hydrogeologic Inc. The advantage of SURFACT is its capacity to simulate unsaturated conditions using robust numerical solution schemes to handle the complex numerical problem resulting from the unsaturated flow formulation. Added to the more robust numerical solvers is an adaptive time-step function that aides the progression of the solution past difficult and complex numerical situations such as oscillations.

The model code has not changed since the previous iteration of the numerical groundwater model (AGE, 2015).

## 5.2 Model domain

The numerical groundwater model has focussed on the Paranui site where the CSG pilot testing historically took place. The extent of the model includes those aquifers that have been potentially affected from this CSG production testing.

The extents of the numerical model has been determined to minimise the size of the model on the basis that the predicted impacts are considered to be minimal. They extend from the Baralaba Coal Seam subcrop/outcrop to the east which is coincident with the location of the Moura Mine which is approximately 7 km to the west. Similarly, the northern and southern boundaries are located approximately 10 km from the Project site along the Dawson River alignment. The constructed model is three-dimensional, and includes a multi-layered geological system that vertically comprises 13 layers, these being:

- Layer 1 – regolith/topsoil and alluvium (two zones);
- Layers 2 to 11 – Rewan formation;
- Layer 12 – Baralaba Coal Seam; and
- Layer 13 – bedrock which include the model base with an arbitrary thickness of 150 m.

Layer 12 is the target layer for simulation of all pumping from the model and it represents a combined thickness of the individual coal seams.

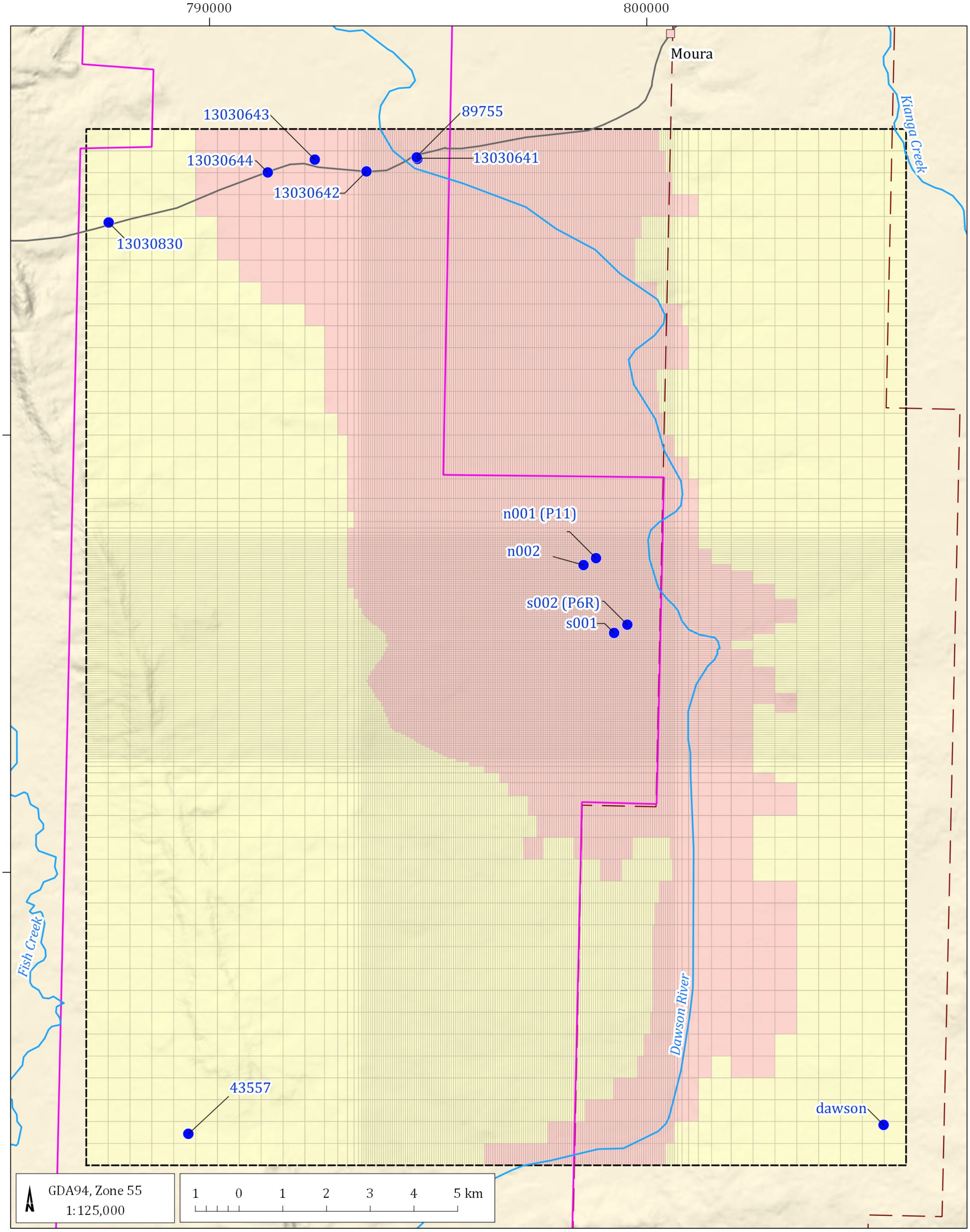
Where the geologic units subcrop or outcrop, the layer was ‘wrapped’ under the overlying layer, the thickness fixed at 0.5 m and the hydraulic properties of the underlying material adopted.

Figure 5.1 shows the model grid overlain on the regional surface geology. The model domain was discretised into 146 rows and 173 columns forming 25,258 rectangular cells. The dimensions of the model cells vary from 50 m by 50 m within the borefield CSG production area to up to 500 m by 500 m at the model extents.

The north-west corner of the model grid is located at 787180 mE and 7277000 mN (MGA 94, Zone 55). The model extent is about 18.8 km x 23.7 km covering an area of approximately 444 $km^2$.

The horizontal and vertical extents of the model domain have not changed since its previous iteration (AGE, 2015).

Publicly available SRTM digital elevation data was used to define the ground topographic surface in the model.




LEGEND

- Populated place
- Model Observation Bore
- Watercourse/drainage
- Road
- Model boundary
- Petroleum lease (PL 94)
- ATP769
- Model grid

**Model Recharge Zones**

- Alluvium (1.69 mm/year)
- Regolith (0.068 mm/year)

Paranui UWIR update (G1631B)

**Model domain**

DATE 05/12/2018

FIGURE No: **5.1**


Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1631B.Paranui UWIR update\3_GIS\Workspaces\001_Deliverable1\05.01_G1631B_Model domain.qgs

## 5.3 Model boundary conditions

The model domain is rectangular with all cells set as active and surrounded by "no flow" boundaries with the exception of the inlet and outlet points of the main Dawson River waterway. The base of the model was also assumed to be a "no flow" boundary. A "no flow" boundary does not allow any exchange of water between the model domain and the surrounding areas.

**Recharge**

The model distributed recharge across Layer 1 according to geology, with two zones of recharge. The zones represented the Quaternary alluvium and weathered regolith material Triassic/Permian Formations. The proportion of incident rainfall that infiltrates was calibrated for each recharge zone.

**Rivers**

Watercourses (including minor creeks) were incorporated into the model, using the SURFACT River (RIV) package. Within the model domain the Dawson River has been assumed to contain water for the duration of the simulation with a minimum water depth of 0.5 m. Conversely, the other "minor" creeks and gullies are considered ephemeral and are simulated as drains. All creeks and rivers were given high conductance and their parameters were not subject to calibration in PEST. Figure 5.2 shows the location of the river cells.

**Constant heads**

In order to simulate a hydraulic gradient in the Dawson River Alluvium, constant head boundaries were set in cells at the northern and southern edges of the model domain within the alluvium and were based on extrapolation of recorded groundwater head elevations to the model boundaries. Figure 5.2 shows the location of the constant head cells.

## 5.4 Hydraulic parameters

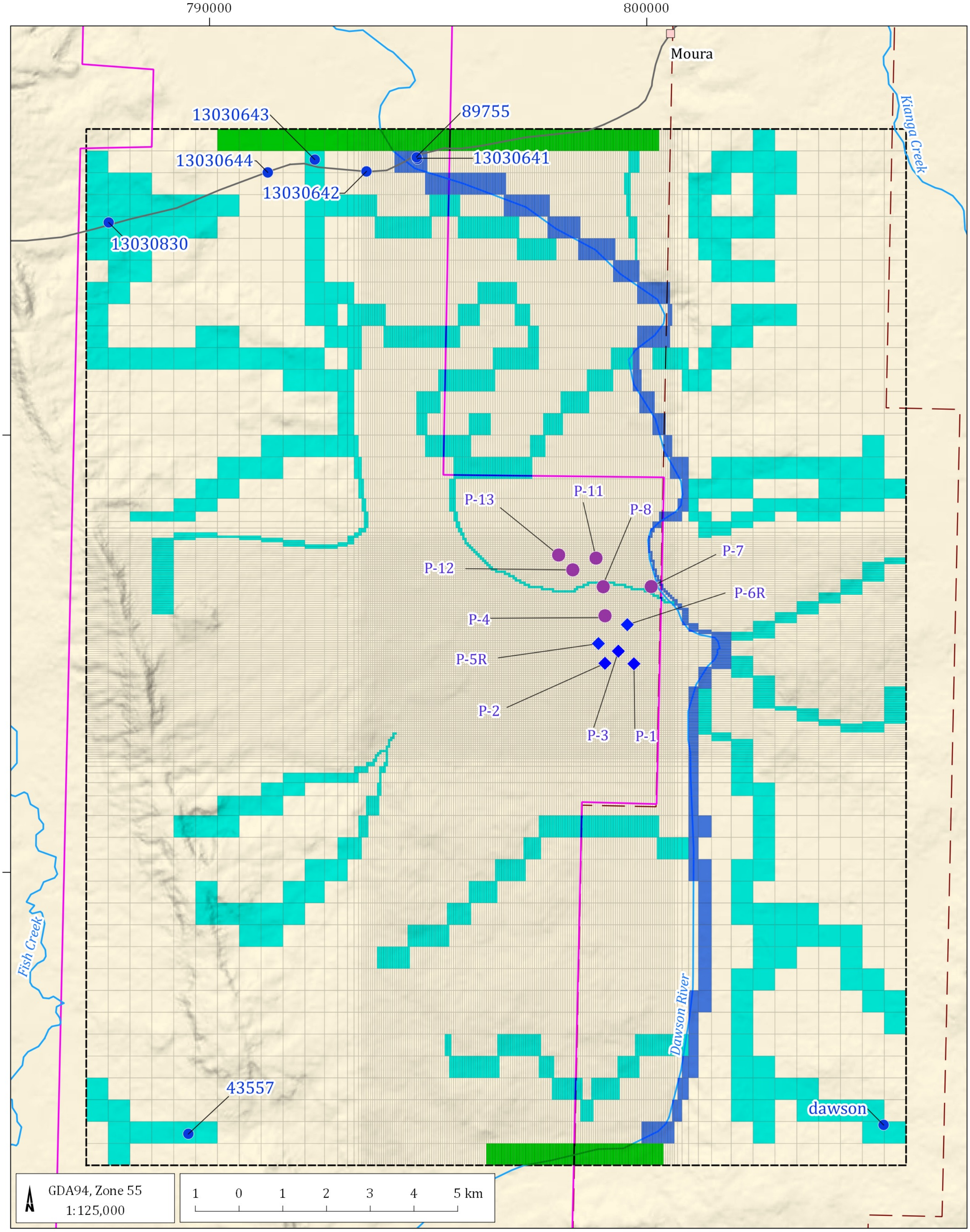
Hydraulic conductivity (Kh), specific yield ($S_y$) and specific storage ($S_s$) parameters have been based on typical values sourced from relevant literature and other EIS coal projects in the Bowen Basin (refer Section 4). Values for these parameters for the coal seams were not subject to calibration and have been based on available data for coal seams sourced from the CSG investigations and previous coal seam gas investigations (IPT, 2010 and AGE, 2011).

Although hydraulic conductivity and specific yield values were not changed from the 2015 model, the value of specific storage for the coal seams and overburden were revised in line with recent review by Rau *et al* (2018) of the theoretical upper and lower bounds in coal measures. The revised values for specific storage are $10^{-5}$ $m^{-1}$ for target coal seams and $10^{-6}$ $m^{-1}$ for the Rewan Formation layers. These fall within the range of values used by AGE for other projects in the area (refer Table 4.5).

## 5.5 Model calibration

During the previous AGE (2015) model calibration, hydraulic conductivity in the coal seam remained fixed. The recharge rates and permeability of other geologic units were altered to obtain a closer match between predicted and observed water levels. The main objective of model calibration was to reproduce and match the observed steady state water levels, reproduce the general pattern of the groundwater contours, and keep recharge rates within the expected low range.

Westside advised that since there has been no groundwater abstraction from the test wells since 2010, there has been no groundwater levels data collected to verify the water levels in the wells. As such, and given the minimal change for specific storage, the numerical model was not recalibrated.




LEGEND

- Populated place
- Appraisal well (operational)
- Appraisal well (decommissioned)
- Model Observation Bore
- Watercourse/drainage
- Model boundary
- ATP769
- River Cell - Dawson River
- Drain Cell
- Constant Head

Paranui UWIR update (G1631B)

**River cells and boundary conditions**

DATE 07/12/2018

FIGURE No: 5.2


Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1631B.Paranui UWIR update\3_GIS\Workspaces\001_Deliverable1\05.02_G1631B_River cells and boundary conditions.qgs

## 5.6 Hydraulic heads

Groundwater levels measured in registered water bores (details sourced from the DEHP Groundwater Database) were used as the calibration targets for the steady state model. The objective of the steady state modelling was to simulate current conditions prior to commencement of CSG operations. A total of eight data points were used to calibrate the model which include seven registered bores identified from the DEHP water bore data base. Table 5.1 shows the predicted and observed water levels for the monitoring bores within the Project site and from registered private bores.

**Table 5.1 Calibration targets and simulated water levels – steady state model**

| Bore ID | Easting (m) | Northing (m) | Measured water level (mAHD) | Modelled water level (mAHD) | Residual (m) | Source |
|---|---|---|---|---|---|---|
| 43557 | 789,514.0 | 7,254,015.0 | 139.70 | 111.36 | 28.34 | Registered bore |
| 89755 | 794,738.0 | 7,276,353.0 | 97.44 | 99.25 | -1.81 | Registered bore |
| 13030641 | 794,755.0 | 7,276,316.0 | 97.92 | 99.25 | -1.33 | Registered bore |
| 13030642 | 793,588.5 | 7,276,030.1 | 97.26 | 97.22 | 0.04 | Registered bore |
| 13030643 | 792,406.7 | 7,276,300.8 | 93.50 | 97.86 | -4.36 | Registered bore |
| 13030644 | 791,330.7 | 7,276,007.4 | 98.18 | 98.50 | -0.32 | Registered bore |
| 13030830 | 787,691.5 | 7,274,862.7 | 106.00 | 103.72 | 2.28 | Registered bore |
| Dawson | 805,418.7 | 7,254,218.7 | 132.79 | 125.13 | 7.66 | River |

Figure 5.3 compares the observed and simulated groundwater levels in the form of a scatter diagram.

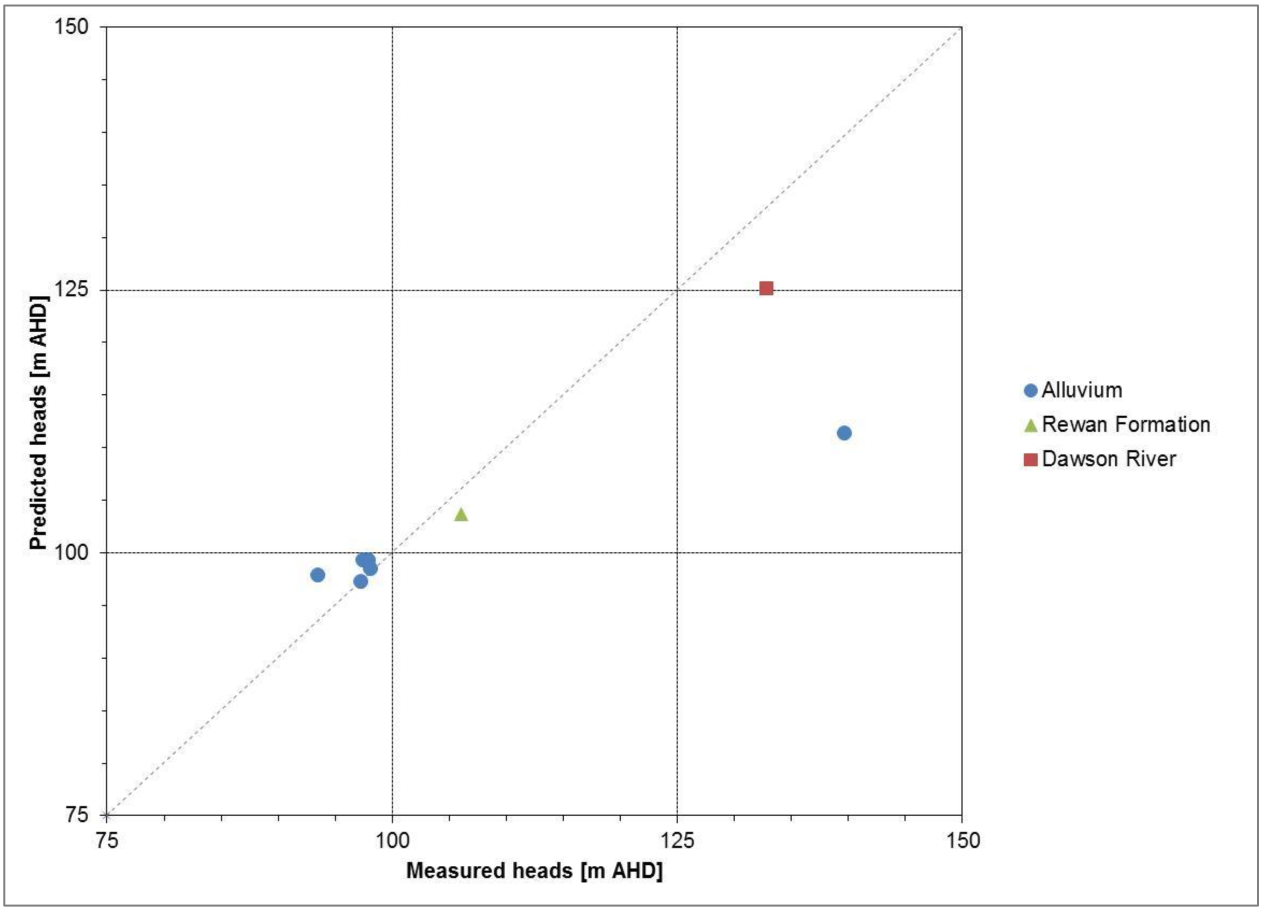



**Figure 5.3 Predicted versus observed groundwater levels from the steady state model**

The simulated steady state groundwater level elevations for selected layers are presented in Figure 5.4.

An objective method to evaluate the calibration of a model is to examine the statistical parameters associated with the calibration. One such method is by measurement of the difference between the modelled and observed (measured) water levels. The root mean square (RMS) difference is expressed as follows:

$$RMS = \left[1/n \sum (h_o - h_m)_i^2\right]^{0.5}$$

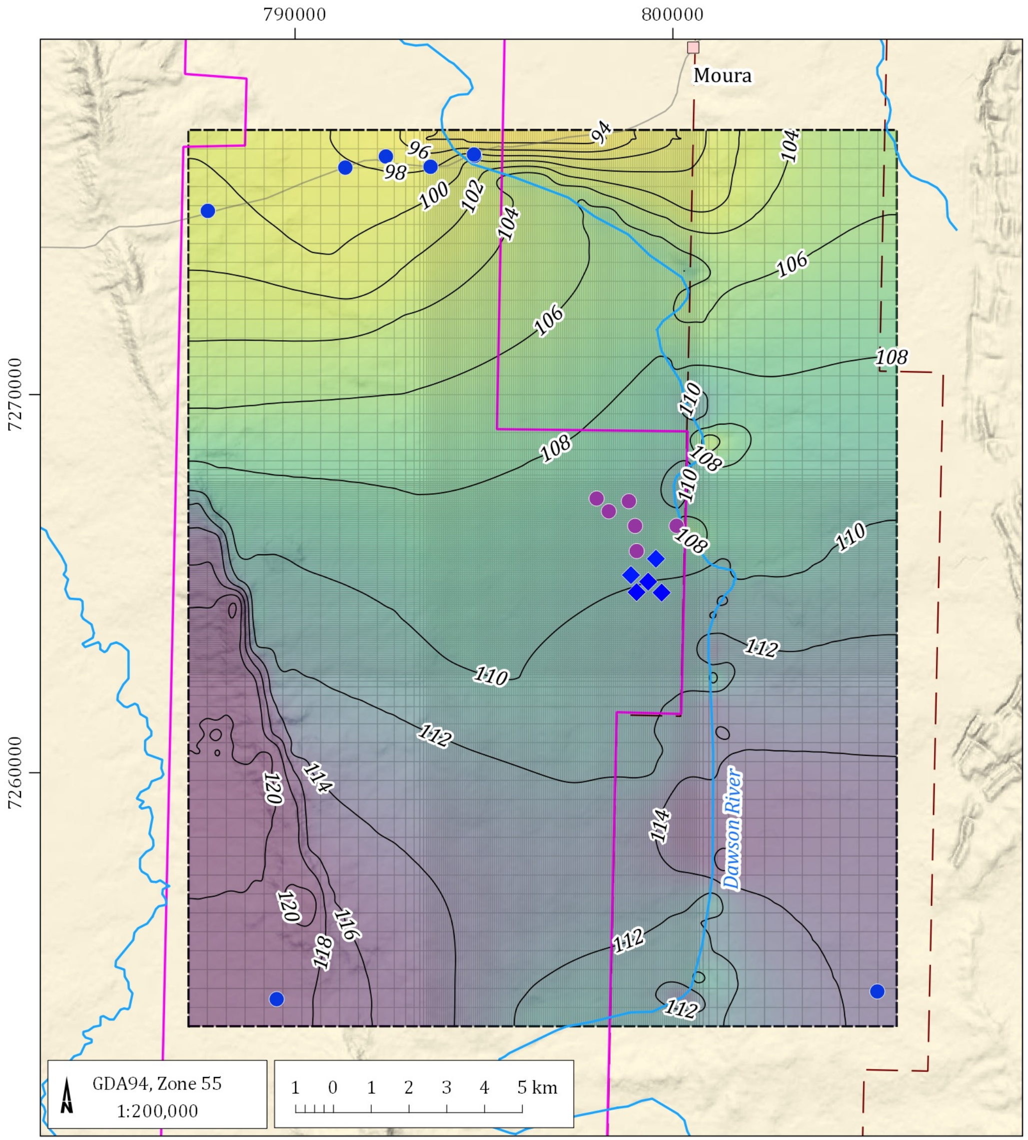
*where:* n = number of measurements

$h_o$ = observed water level

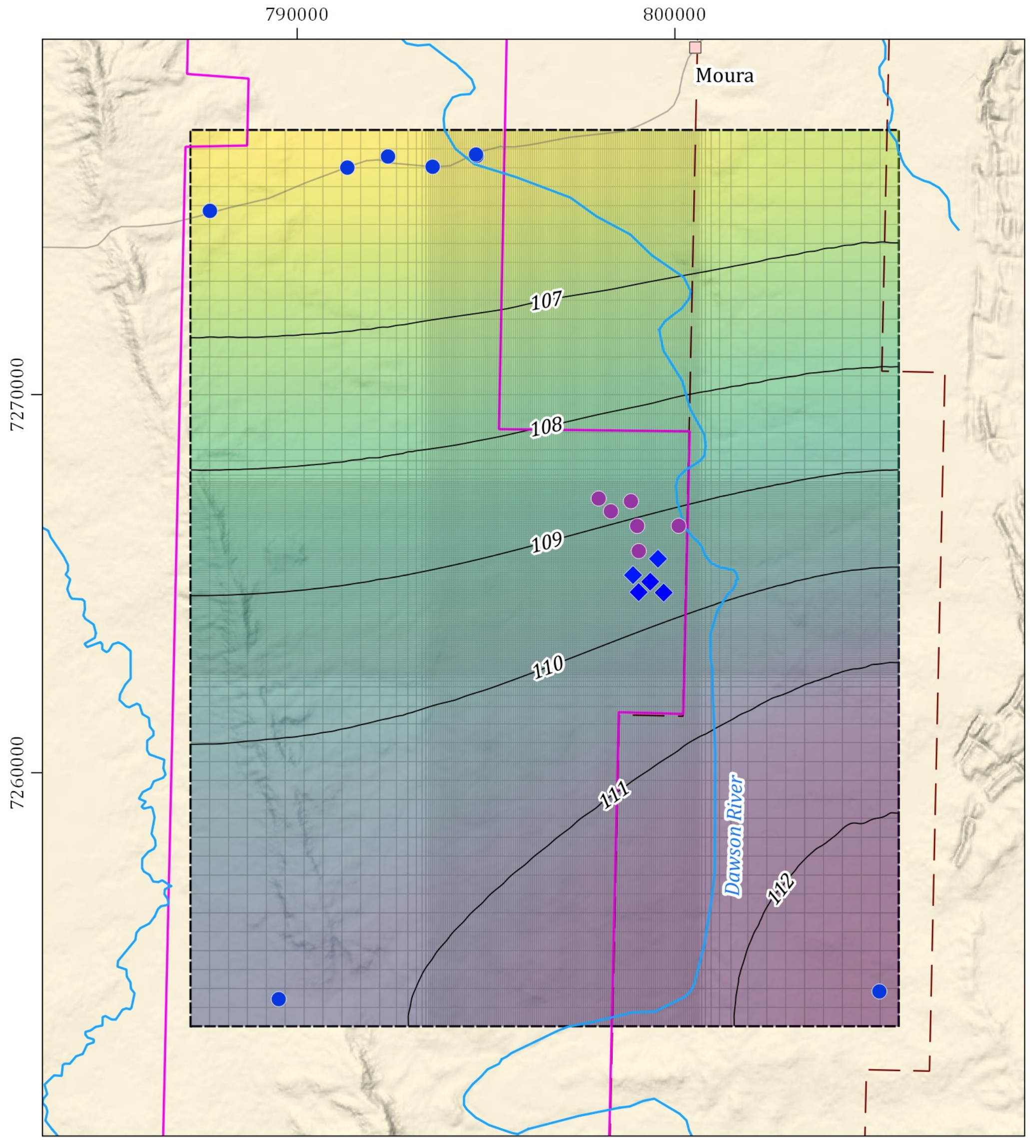
$h_m$ = simulated water level

The RMS calculated for the calibrated model was 10.55 m. The maximum acceptable value for the calibration criterion depends on the magnitude of the change in heads over the model domain. If the ratio of the RMS to the total change is small, known as the Scaled RMS (SRMS), the differences are only a small part of the overall model response (Anderson and Woessner, 1992).

**Steady State Heads _ Layer 1 (Unconsolidated)**




**Steady State Heads - Layer 12 (Coal Seams)**




LEGEND

- Populated place
- Appraisal well (operational)
- Appraisal well (decommissioned)
- Model Observation Bore
- Watercourse/drainage
- Road
- Model boundary
- Model grid
- Petroleum lease (PL 94)
- ATP769

**Head (mAHD)**

- 90
- 100
- 110
- 120
- Head contour

Paranui UWIR update (G1831B)

**Steady state heads Layer 1 and Layer 12**

DATE
07/12/2018

FIGURE No:
**5.4**


Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1631B.Paranui UWIR update\3_GIS\Workspaces\001_Deliverable1\05.04_G1631B_Steady state heads Layer1 and Layer 12.qgs

Scaled RMS was calculated by dividing the RMS by the range of observed values, as shown below:

$$RMS_{scaled} = [RMS / (\max h_o - \min h_o)] \left[ \frac{1}{100} \right]$$

The ratio of RMS (10.6 m) to the total head change across the calibration points (46.2 m) indicated a SRMS of 22.84% which is considered a poor calibration. The acceptable target for SRMS varies between models but is typically between 5% and 10% (Barnett *et al,* 2012). However, when the following points are taken into account, the calibration is considered to be the best achievable based on the available data:

- the steady state model used a simplified uniform representation of permeability based on limited data to represent a complex heterogeneous fractured rock system;
- the calibration points are mostly clustered along the northern model boundary with limited coverage across the remainder of the model domain; and
- the available observations are from different time periods, which may not be representative of steady state conditions.

## 5.7 Hydraulic properties

Table 5.2 presents the hydraulic parameters adopted for the model following calibration process.

### Table 5.2 Hydraulic parameters

| Layer | Parameter | Value |
|---|---|---|
| **Layer 1**<br>Alluvium<br>Weathered Material<br>(Regolith) | Horizontal Hydraulic Conductivity [kh] | Alluvium 20 m/day<br>Regolith 0.1 m/day |
| | Vertical Hydraulic Conductivity [kv] | Alluvium and Regolith 10% of $k_h$ |
| | Specific Yield [$S_y$] | Alluvium 0.1<br>Regolith $1{\times}10^{-3}$ |
| | Specific Storage [$S_s$] | Alluvium $1{\times}10^{-3}$<br>Regolith $1{\times}10^{-4}$ |
| **Layers 2 to 11**<br>Rewan Formation | Horizontal Hydraulic Conductivity [kh] | $1{\times}10^{-4}$ m/day |
| | Vertical Hydraulic Conductivity [kv] | 1% of $k_h$ |
| | Specific Yield [$S_y$] | $1{\times}10^{-3}$ |
| | Specific Storage [$S_s$] | $1{\times}10^{-6}$ |
| **Layer 12**<br>Baralaba Coal Seams (combined) | Horizontal Hydraulic Conductivity [kh] | $3.5{\times}10^{-4}$ m/day |
| | Vertical Hydraulic Conductivity [kv] | 10% of $k_h$ |
| | Specific Yield [$S_y$] | $5{\times}10^{-2}$ |
| | Specific Storage [$S_s$] | $1{\times}10^{-5}$ |
| **Layer 13**<br>Kaloola Formation (Model Base) | Horizontal Hydraulic Conductivity [kh] | $1{\times}10^{-4}$ m/day |
| | Vertical Hydraulic Conductivity [kv] | 1% of kh |
| | Specific Yield [$S_y$] | $1{\times}10^{-3}$ |
| | Specific Storage [$S_s$] | $1{\times}10^{-6}$ |

***Note:*** *See Section 4 for likely range and sources for aquifer storage parameters*

## 5.8 Water budgets

The differences between calculated model inflows and outflows at the completion of the calibration run, expressed as percent of discrepancy was 0.1%, indicating an accurate numerical solution and overall stability of the model. Table 5.3 presents the water budget inputs and outputs.

### Table 5.3 Groundwater budget – steady state model (ML/day)

| Parameter | Input | Output |
|---|---|---|
| Rainfall recharge | 0.7 | 0 |
| Constant heads | 24.7 | 53.0 |
| River leakage | 64.4 | 36.9 |
| **Totals** | **89.8** | **89.9** |

Table 5.4 presents the calibrated rates of recharge to Layer 1 for each geological zone defined in the model.

### Table 5.4 Rainfall recharge

| Geology | Recharge - Percentage of Rainfall (%) | Recharge (mm/year) |
|---|---|---|
| Alluvium | 0.25 | 1.69 |
| Weathered material (Regolith) | 0.01 | 0.07 |

## 5.9 Model Setup for Impact Assessment

The predictive simulation required the steady state model to be converted to transient flow conditions to predict the zone of depressurization induced by dewatering of the coal seams. This transient simulation includes the period from 2008 onwards with the initial starting conditions being those determined from the steady state analysis. The historical water production is as described in Section 2.1, with the predicted simulation as per that described in Section 2.2. Abstraction of groundwater from the numerical model is simulated using MODFLOW well package (WEL) in conjunction with the assigned well production rates. The wells are assumed to be fully penetrating across the entire depth of the coal seams assigned to Layer 12. No details of horizontal wells have been provided and hence have not been included in this simulation. Similarly, inclusion of any induced hydraulic (lateral) fracturing (or fracking) has not been specifically simulated as it is considered its impacts are on a much smaller scale than the resolution of the model grid.

The transient simulation therefore includes the two year period when the pilot testing occurred between 2008 and 2010 and water was abstracted from the three pilot wells. This is followed by a 100 year aquifer recovery simulation with no CSG production to investigate any long-term effect from the CSG pilot testing program. This part of the simulation therefore represents no groundwater abstraction and the period of groundwater recovery post CSG pilot testing within the Baralaba Coal Seams.

The extent of the drawdown responses from CSG production and groundwater abstraction are presented in terms of the trigger thresholds defined in the Water Act. These include a water decline in excess of 5 m for consolidated aquifers and 2 m for unconsolidated aquifers. As detailed in Section 5.7, the alluvium and regolith in Layer 1 represents the unconsolidated aquifers, whilst the other underlying layers 2 to 13 represent consolidated aquifers. More specifically the Baralaba Coal Seams are represented as a consolidated unit in Layer 12.

### 5.9.1 Immediately affected area

For the duration of the 2018 to 2021 UWIR reporting period, during which there is no groundwater abstraction or associated CSG production, residual groundwater drawdown is only observed in Baralaba Coal Seams (Layer 12). The extent of this residual drawdown defined by the 1 m drawdown contour is shown in Figure 5.5. As stated above, this predictive simulation is based on the pilot well testing in wells P-5R, P-6R and P-8 between 2008 and 2010. This shows the cumulative impact from groundwater abstraction from the three wells at the end of Year 3 in 2021 is contained within a 2.3 km to 2.75 km radius encompassing all three extraction wells.

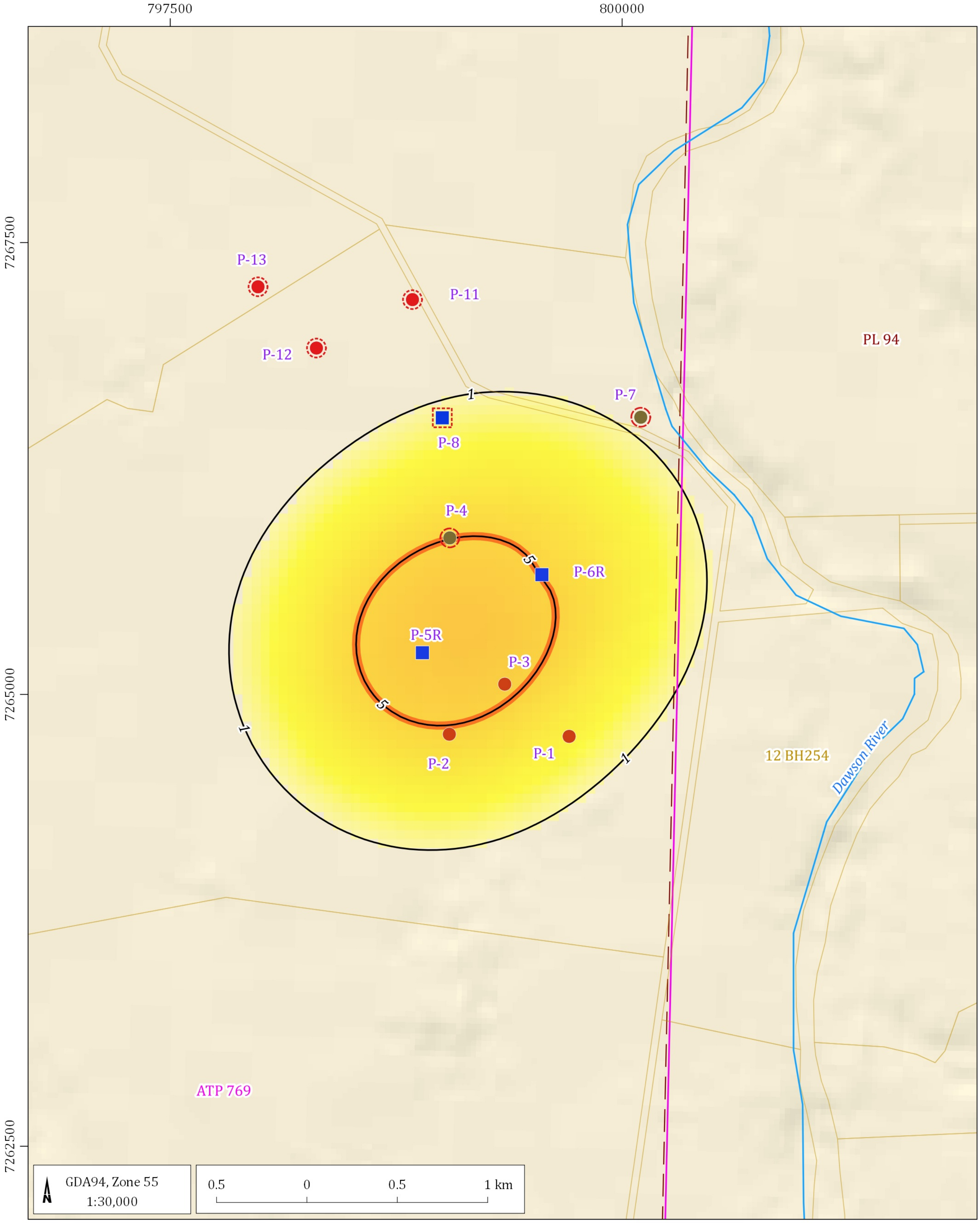
The extents of the IAA is defined by residual drawdown exceeding 5 m. The IAA is contained within a 980 m to 1,150 m radius of wells P-5R and P-6R. There is no groundwater drawdown predicted in the Quaternary Alluvium (i.e. Dawson River Alluvium). During this period, there are no impacted registered bores (Figure 5.5) within the IAA. The nearest registered bore is a petroleum or gas exploration bore (RN100045) located approximately 5 km northeast of the three pilot pumping wells. The nearest registered water supply is RN47008 which is located approximately 12 km west of the pilot wells.

### 5.9.2 Long term affected area

The LTAA assessed by the model showing the predicted residual drawdown water level decline by more than 5 m (water level trigger) at any time after the 2018 to 2021 UWIR reporting period is also shown in Figure 5.5. This shows the LTAA to be the same as that defined by the IAA. The IAA and LTAA extents are the same as the system is in recovery and the precited impacts at the end of the UWIR period (IAA) are also the maximum impact predicted for the future (LTAA) under current plans. As there is no CSG production or groundwater abstraction simulated after the 2008 to 2010 pilot testing period, the LTAA and IAA extents continues to decrease at the same rate.

This drawdown was generated by identifying the maximum drawdown predicted at all the model cells within the coal seam layer. Similar to the IAA, there are no impacted registered bores (Figure 5.5) within the LTAA. That is, the nearest registered bores are the petroleum or gas exploration bore (RN100045) and water supply bore (RN47008) located approximately 5 km northeast and 12 km west respectively from the pilot wells.

The extent of groundwater recovery within each pilot bore during the UWIR 2018 to 2021 reporting period is presented on Figure 5.6. This shows that at the end of the UWIR reporting period (November 2021), the groundwater levels in the Baralaba Coal Seams (model layer 12) are predicted to recover to between 98.6% and 99.5% of the pre-testing groundwater levels. The numerical model predicts groundwater levels in the pilot wells will recover to less than 5 m by 2024, effectively removing the LTAA shown in Figure 5.5.




LEGEND

- Appraisal well (operational)
- Appraisal well (decommissioned)
- Appraisal well - pilot pumping 2008 - 2010
- Appraisal well – pilot pumping 2008 - 2010 (decommissioned)
- Observation well (decommissioned)
- Petroleum lease (PL 94)
- ATP769
- Cadastre
- Watercourse/drainage
- Road
- Drawdown contour
- Long Term Affected Areas (LTAA)

Paranui UWIR update (G1631B)

**Predicted groundwater drawdown end of 2021 – Combined Baralaba Coal Seam (Layer 12)**

AGE

DATE 07/12/2018

FIGURE No: **5.5**


Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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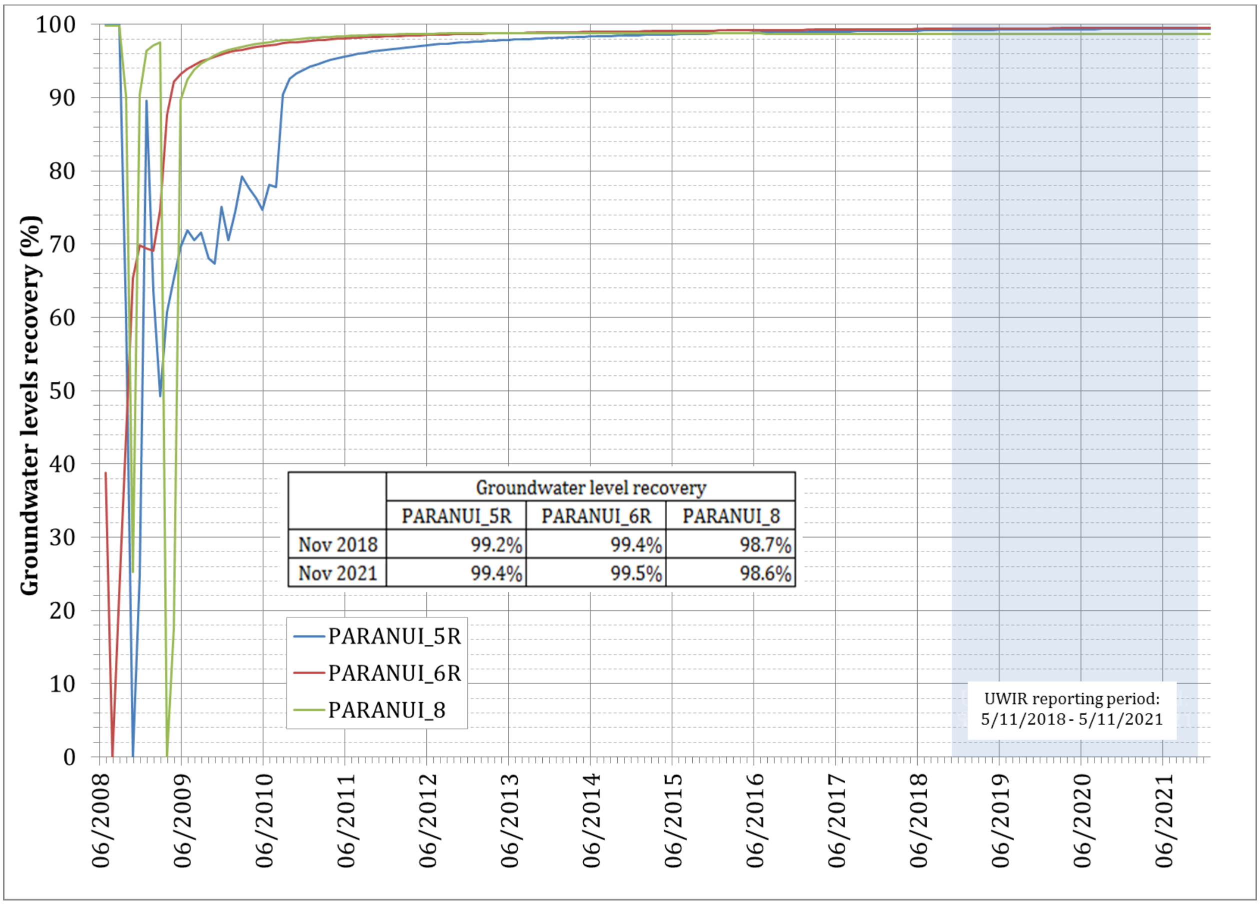


**Figure 5.6 Predicted recovery of groundwater levels in the CSG pilot wells**

## 5.10 Sensitivity

Since there is no groundwater abstraction or associated CSG production planned during the 2017 to 2021 UWIR reporting period, no sensitivity analysis of the predicted drawdown was undertaken for this numerical modelling.

## 5.11 Review of maps produced

This modelling has identified the areas defined as the IAA and LTAA are contained within the Permian coal sequences and do not propagate upwards into the overlying shallow alluvial aquifer. Neither do they extend laterally nor impact on other adjacent aquifers such as those within the GAB located along the western margins of ATP769. Following cessation of the CSG pilot testing between 2008 and 2010, groundwater levels have slowly recovered and there are no predicted long term affected areas beyond 2024. No registered or identified bores are assessed to be located within the predicted IAA and LTAA areas during the UWIR 2018 to 20121 reporting period.

Development, calibration and the results of predictive simulations from this groundwater model have been based on available data characterising the groundwater system under investigation. More specifically this model has used available data for aquifer parameters and groundwater levels to predict the impacts from the proposed CSG operations. The assumptions on the geology, hydrogeology and hydraulic properties of the model should be reviewed annually when CSG production recommences to determine the accuracy of predictions made. Where new data indicates substantial differences (previously unrecognised information) to those originally interpreted, these data will be incorporated into the model and revised predictions made and reported. The principal objective of this will be to validate the model predictions and identify if the data indicates significant divergence from the model predictions. Where identified, the groundwater model should be updated for revised simulation of CSG operations and assessment of the IAA and LTAA.

Based on the above, any future review should allow comparison of model predictions to field observations to ensure the model and its underlying assumptions are correct and 'fit for purpose'. Where commencement of pilot testing and associated water extraction has not occurred prior to the review period it is proposed that the model will not be reviewed or updated. The model will be updated at annual reviews where new data is available that would likely result in appreciable divergence from the original model predictions. Data that would likely result in such changes in model predictions include:

- geological and hydrogeological data such as structural features that behave as hydraulic barriers or modify the aquifer extents;
- changes to proposed CSG extraction and hence groundwater pump rates;
- significant variations in drawdown prediction of any well given the conservative nature of the model construction;
- changes in aquifer properties from further aquifer testing that produce aquifer parameter values that vary by more than an order on magnitude (for hydraulic conductivity) or are outside the variation observed in the sensitivity analysis; and
- variations in the model domain where drawdowns do not match those predicted.

# 6 Impact to environmental values (Part D)

The EPP Water (Section 1.5) provides a framework to protect and/or enhance the environmental values and hence suitability of Queensland waters (including groundwater) for various beneficial uses. Groundwater resources within the Project area lie within the Dawson River Sub-basin (DEHP, 2011), in which the environmental values for groundwaters that need to be considered include:

- aquatic ecosystems;
- irrigation and farm supply/use;
- stock water;
- aquaculture;
- primary recreation;
- drinking water; and
- cultural and spiritual values.

The Dawson River Sub-basin Environmental Values and Water Quality Objectives (DES, 2011) provides general WQO to support and protect the various environmental values identified for waters. The WQO are long-term goals for water quality management. Each of the environmental values listed above are discussed below to identify those that are relevant to the Project.

## 6.1 Aquatic ecosystem

As discussed in Section 4.4, any GDEs within the Paranui Pilot Project area are assessed to be solely attributable to connection and access to the shallow alluvial aquifer and not the deeper (more saline) groundwater associated with the Baralaba Coal Measures. There are no known springs or seeps within the Project area. The nearest mapped spring is associated with the Triassic Great Artesian Basin (GAB) Clematis Group and Moolayember Formation that outcrop along the western margins of the ATP769 approximately 30 to 40 km southwest of the Project site.

Regionally, groundwater flow within the underlying alluvial aquifer is towards the north. Groundwater levels are generally less than 10 mbgl and most likely in hydraulic connection with Dawson River surface waters. There are no springs from these deep confined aquifers within the Project area or surrounds that would support GDEs.

## 6.2 Irrigation and farm supply/use

Groundwater is not used for irrigation or farm supply within (and neighbouring) the Project area. There are no known irrigation bores located within 10 km of the Project area. Irrigation water supplies are understood to be sourced from the Dawson River (surface water licences) which is a more reliable water resource.

## 6.3 Stock water

As discussed in Section 4, there is no significant groundwater usage within (and neighbouring) the Project area. The primary agricultural purpose of land within and surrounding the Project area is cropping and cattle grazing.

The WQOs for Dawson River Sub-basin groundwaters are provided for tolerances of livestock to TDS (salinity) in drinking water and are adapted based on the guidelines presented in ANZECC (2000). Table 6.1 presents the tolerance of livestock to TDS in drinking water. The groundwater quality data from baseline data collected for the previous UWIR (AGE,2015) identifies only the alluvial water would be suitable for stock watering (refer Section 4.3).

### Table 6.1 Stock watering environmental values: Tolerance of livestock to TDS in drinking water[1]

| Livestock | No adverse effects on animals expected | Animals may have initial reluctance to drink or there may be some scouring, but stock should adapt without loss of production | Loss of production and decline in animal condition and health would be expected. Stock may tolerate these levels for short periods if introduced gradually |
|---|---|---|---|
| Beef cattle | 0 – 4,000 mg/L | 4,000 mg/L – 5,000 mg/L | 5,000 mg/L – 10,000 mg/L |
| Dairy cattle | 0 – 2,500 mg/L | 2,500 mg/L – 4,000 mg/L | 4,000 mg/L – 7,000 mg/L |
| Sheep | 0 – 5,000 mg/L | 5,000 mg/L – 10,000 mg/L | 10,000 mg/L – 13,000 mg/L[2] |
| Horses | 0 – 4,000 mg/L | 4,000 mg/L – 6,000 mg/L | 6,000 mg/L – 7,000 mg/L |
| Pigs | 0 – 4,000 mg/L | 4,000 mg/L – 6,000 mg/L | 6,000 mg/L – 8,000 mg/L |
| Poultry | 0 – 2,000 mg/L | 2,000 mg/L – 3,000 mg/L | 3,000 mg/L – 4,000 mg/L |

***Notes:*** *1 - From ANZECC (1992), adapted to incorporate more recent information.*

*2 - Sheep on lush green feed may tolerate up to 13 000 mg/L TDS without loss of condition or production.*

Water quality objectives are also provided for trace metal (heavy metals and metalloids) concentrations in livestock drinking water, these are summarised in Table 6.2. Water quality data for dissolved metals reported for the baseline groundwater monitoring conducted for the previous UWIR (AGE, 2015) was below these WQOs.

### Table 6.2 Stock watering environmental values: Low risk trigger values for heavy metals and metalloids in livestock drinking water

| Element | Trigger value (low risk)[1] (mg/L) |
|---|---|
| Aluminium | 5 |
| Arsenic | 0.5 (up to 5[2]) |
| Berylium | ND[3] |
| Boron | 5 |
| Cadmium | 0.01 |
| Chromium | 1 |
| Cobalt | 1 |
| Copper | 0.4 (sheep), 1 (cattle), 5 (pigs), 5 (poultry) |
| Fluoride | 2 |
| Iron | Not sufficiently toxic |
| Lead | 0.1 |
| Manganese | Not sufficiently toxic |
| Mercury | 0.002 |

| Element | Trigger value (low risk)[1] (mg/L) |
|---|---|
| Molybdenum | 0.15 |
| Nickel | 1 |
| Selenium | 0.02 |
| Uranium | 0.2 |
| Vanadium | ND[3] |
| Zinc | 20 |

***Notes:*** *1 - Higher concentrations may be tolerated in some situations (details provided in AWQG, Volume 3, Section 9.3.5).*

*2 - May be tolerated if not provided as a food additive and natural levels in the diet are low.*

*3 - ND – not determined, insufficient background data to calculate.*

*Metal values relate to the total concentration of the constituent.*

## 6.4 Aquaculture

There is no known use of groundwater for aquaculture purposes within (and neighbouring) the Project area.

## 6.5 Primary recreation

The only opportunity for primary recreational use of water would be that associated with the Dawson River. This surface water with Dawson River is hydraulically separated from the Baralaba Coal Measure by a hydrogeologically "tight" interburden and overburden sediments (refer Section 4.2) and is not assessed to have been impacted by pilot testing for the Paranui Project.

## 6.6 Drinking water

Data indicates that groundwater quality in the Project area that could potentially be suitable for human consumption is only available within the alluvial aquifer. This groundwater is not assessed to have been impacted by pilot testing for the Paranui Project.

## 6.7 Cultural and spiritual values

No specific WQOs are provided for cultural and spiritual values and would need to be such that they "protect or restore indigenous and non-indigenous cultural heritage consistent with relevant policies and plans" (DES, 2011). There are no defined environmental values in relation to cultural and spiritual values of groundwater within the Project area.

# 7 Water monitoring strategy (Part E)

The previous 2015 to 2018 UWIR identified the purpose for the Water Monitoring Strategy was to detect any changes in water levels and water quality as a result of the exercise of underground water rights at ATP769. The groundwater monitoring program recommended utilising existing observation wells P-4 and P-7 as Permian aquifer monitoring bores. Westside have advised these monitoring bores were plugged and abandoned between April and May 2017 and are no longer available for use as groundwater monitoring bores.

The UWIR report identified that water supplies near the Project area are mostly sourced from the Dawson River. As such, dependence on groundwater in this area is limited to a small number of water supply bores which mostly intersect the upper alluvial aquifer. Nearby registered bores that intersect the Baralaba Coal Seam aquifer are mainly CSG bores that are not used for water supply.

This update of the numerical modelling for the 2018 to 2021 UWIR reporting period, predicts the Baralaba Coal Seams are still impacted from groundwater abstraction from the CSG pilot testing between 2008 and 2010. The modelling predicts the IAA and LTAA are both contained within the Paranui Property boundary. The extent of this impact reduces on cessation of CSG pilot testing with no long term affected areas predicted after 2024.

The numerical modelling shows that there has been no impact on the shallower alluvial aquifer from the production testing for the Pilot Project between 2008 and 2010. On the basis that no CSG production or groundwater extraction is planned for the 2018 to 2021 UWIR reporting period, there will be no requirement for monitoring groundwater levels during this period.

Similarly, no springs have been identified within this portion of the ATP769 or the zone of likely influence for the proposed CSG operation. This being the case, there is no provision for monitoring springs in this monitoring strategy.

# 8 Spring impact management (Part F)

This part of the UWIR details the requirements for a spring management strategy for springs identified within areas where the source aquifer is predicted to decline by more than 0.2 m.

## 8.1 Spring inventory

A desktop review of the spring inventories has been undertaken as part of this assessment within 10 km of the ATP769 boundaries. This has included a review of the following publicly available data sources:

- Groundwater Dependent Ecosystems Atlas [2] (Queensland Wetland Data – Springs); and
- The Great Artesian Basin Springs Register[3].

No springs have been identified with the 10 km boundary of the ATP769, with the nearest spring approximately 30 km southwest of the Paranui well field. On this basis there is no information available regarding either potential connection between springs and aquifers or spring values as required for an UWIR.

## 8.2 Management of springs

On the basis there are no known springs within the Project area or likely to be affected from drawdown resulting from the any proposed CSG operation associated with ATP769, it is considered that there is no requirement for a spring management strategy for this Project.

[2] Bureau of Meteorology, (2018) Groundwater Dependent Ecosystems Atlas, data accessed 27 November 2018, http://www.bom.gov.au/water/groundwater/gde/index.shtml
[3] SA Department of Environment, Water and Natural Resources (2015) Great Artesian Basin Springs - PED. Bioregional Assessment Source Dataset. Viewed 28 November 2018, http://data.bioregionalassessments.gov.au/dataset/53482e4f-ddb1-45bb-92af-f8283b90c5a9.

# 9 Conclusions

Westside in joint venture with Mitsui E&P Australia, operate under an authority to prospect for development of the Paranui Pilot Project ATP769. This report presents the Underground Water Impact Report for Westside for the 2018 to 2021 reporting period and has been prepared in accordance with the requirements detailed in the Water Act 2000.

It includes a review of published and unpublished reports (in the public domain), registered bore operation, available groundwater level and (baseline) water quality data. Three aquifers have been identified within the study area, these include:

- a shallow alluvial aquifer mainly associated with the Dawson River;
- the eastern extents of the GAB Mimosa Management Area along the western margins of ATP769; and
- a deeper confined aquifer within the Permian coal sequences that host the CSG resource.

Numerical modelling was undertaken to assess the likely extents of impact on these aquifers from CSG production and groundwater abstraction within the Paranui Pilot Project ATP769. To date the only CSG production and groundwater abstraction was from pilot testing of three appraisal wells (P-5R, P-6R and P-8) between 2008 to 2010. This has identified that the Permian coal seam aquifer to be the only aquifer impacted by the proposed CSG operations for ATP769. Depressurisation of this aquifer does not extend upwards or laterally into either of the other two aquifers (GAB Mimosa Management Area or the alluvial aquifer).

As there has been no CSG production over the previous three years, nor is there any CSG production planned for the 2018 to 2021 reporting period, there are no impacted registered bores within either the IAA or the LTAA. The nearest registered bore is a petroleum or gas exploration bore located approximately 5 km to the northeast, and the nearest water supply bore is located approximately 12 km to the west.

The predicted extent of the IAA and LTAA as defined by drawdown exceeding 5 m is the same and is contained within a 980 m to 1,150 m radius of the pilot testing extraction wells. This will continue to decrease as there is no further CSG production and no groundwater abstraction planned for the 2018 to 2021 reporting period. The impacted area (IAA/LTAA) will completely disappear past the end of year 2024, 14 years after cessation of pilot pumping. On the basis that no CSG production or groundwater extraction is not planned for the 2018 to 2021 UWIR reporting period, there will be no requirement for monitoring groundwater levels during this period.

When Westside plan to recommence CSG production, the numerical model should be reviewed to confirm the predicted level and extents of impact on the aquifer(s). If identified necessary, this should include an update of the model to decrease the level of uncertainty with the current model parameters. The results and outcome of any model review will be presented to Westside and as part of an update of this UWIR in three years.

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# *Appendix A* Summary details of Registered Bores in ATP769

# Appendix A – Registered Water Bores (Project No. G1631B)

| RN | Easting | Northing | Facility Type | Status | Lot | Plan | Formation Type | Top | Bottom | Flow | Quality | Yield | Water Level | Registered Date | Formation Name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 30691 | 793380 | 7245647 | Water Supply | Existing | - | - | Consolidated | 47.2 | 64 | N | | 0.2 | 33.8 | 29/08/1968 | Moolayemba Formation |
| 43557 | 789514 | 7254015 | Water Supply | Existing | 21 | BH148 | Consolidated | 61 | 538 | Y | 570 mS/cm | 0.4 | 27.6 | 10/03/1974 | Clematis Group |
| 47008 | 786935 | 7266841 | Water Supply | Existing | 18 | BH147 | Consolidated | 49.8 | 525 | Y | 900 mS/cm | 0.1 | 5.9 | 3/06/1974 | Clematis Group |
| 67007 | 791626 | 7246771 | Water Supply | Existing | | | Consolidated | 39.6 | 365.8 | Y | 950 mS/cm | 1.9 | 18.3 | 10/12/1982 | Clematis Group |
| 89512 | 791848 | 7240340 | Water Supply | Existing | 70 | LE275 | - | - | - | - | - | - | - | - | - |
| 89544 | 771954 | 7313557 | Water Supply | Existing | 1 | KM291 | - | - | - | - | - | - | - | - | - |
| 89556 | 774018 | 7310055 | Water Supply | Existing | 2 | KM292 | Fractured | 42 | 54 | N | SALTY | 0.5 | 20.0 | 18/09/1991 | Moolayemba Formation |
| 89557 | 775712 | 7309890 | Water Supply | Existing | 2 | KM292 | Consolidated | 42 | 60 | N | POTABLE | 1.9 | 8.0 | 24/09/1991 | Clematis Group |
| 89558 | 773869 | 7312837 | Water Supply | Existing | 212 | FTY1332 | Consolidated | 26 | 54 | N | POTABLE | 4.6 | 22.0 | 2/10/1991 | Clematis Group |
| 89690 | 794221 | 7281500 | Water Supply | Existing | 11 | FN200 | Unconsolidated | 8.23 | 15.2 | N | | 0.0 | 0.0 | | Dawson River Alluvium |
| 89755 | 794738 | 7276353 | Water Supply | Existing | - | - | Unconsolidated | 14.6 | 16.7 | N | POTABLE | 0.5 | 12.3 | 24/06/2001 | Dawson River Alluvium |
| 89946 | 782567 | 7269271 | Water Supply | Existing | 18 | BH147 | - | - | - | - | - | - | - | - | - |
| 89947 | 783414 | 7266667 | Water Supply | Existing | 18 | BH147 | - | - | - | - | - | - | - | - | - |
| 100077 | 792431 | 7307891 | Petroleum/Gas Bore | Existing | 35 | FN141 | - | - | - | - | - | - | - | - | - |
| 128033 | 794105 | 7294871 | Water Supply | Existing | 38 | FN506 | Unconsolidated | 14 | 18 | N | POTABLE | 0.2 | 11.6 | 3/06/2007 | Tertiary - undefined |
| 128034 | 794104 | 7294843 | Water Supply | Existing | 38 | FN506 | - | - | - | - | - | - | - | - | - |
| 128188 | 787733 | 7312273 | Water Supply | Existing | 4 | FN514 | Unconsolidated | 14.5 | 15.5 | N | 350 mg/L | 2.0 | 12.5 | 1/05/2006 | Dawson River Alluvium |
| 128605 | 787401 | 7258147 | Water Supply | Existing | 20 | BH150 | Consolidated | 315 | 457 | N | POTABLE | 1.4 | 0.0 | 20/07/2009 | Clematis Group |
| 128771 | 787806 | 7314088 | Mine Monitoring Bore | Existing | 11 | FN153 | Unconsolidated | 11.5 | 23.5 | N | - | - | 13.0 | 25/07/2012 | Dawson River Alluvium |
| 128772 | 787802 | 7314105 | Mine Monitoring Bore | Existing | 11 | FN153 | Unconsolidated | 6 | 18 | N | - | - | 12.9 | 25/07/2012 | Dawson River Alluvium |
| 128773 | 787805 | 7314101 | Mine Monitoring Bore | Existing | 11 | FN153 | Consolidated | 136 | 178 | N | - | - | 15.5 | 25/07/2012 | Blackwater Group |
| 128774 | 787789 | 7314089 | Mine Monitoring Bore | Existing | 11 | FN153 | Consolidated | 29 | 29.2 | N | - | - | - | - | Rewan Formation |
| 128881 | 787440 | 7314586 | Mine Monitoring Bore | Existing | 79 | FN106 | Unconsolidated | 10 | 22 | N | - | - | - | - | Dawson River Alluvium |
| 128885 | 787270 | 7313771 | Mine Monitoring Bore | Existing | 4 | FN514 | Unconsolidated | 1 | 17 | N | - | - | - | - | Dawson River Alluvium |
| 128886 | 787220 | 7313767 | Mine Monitoring Bore | Existing | 4 | FN514 | Unconsolidated | 1 | 16 | N | - | - | - | - | Dawson River Alluvium |
| 128891 | 787442 | 7314568 | Mine Monitoring Bore | Existing | 79 | FN106 | Consolidated | 33 | 33.2 | N | - | - | - | - | Blackwater Group |
| 13030641 | 794755 | 7276316 | Sub-artesian Monitoring Bore | Abandoned/Usable | - | - | Unconsolidated | 14.2 | 17 | N | 528 mS/cm | 0.0 | 11.5 | 18/04/1991 | Dawson River Alluvium |
| 13030642 | 793588 | 7276030 | WR Investigation Bore | Abandoned/Usable | - | - | Unconsolidated | 4 | 13 | N | - | 0.0 | 0.0 | - | Dawson River Alluvium |
| 13030643 | 792407 | 7276301 | WR Investigation Bore | Abandoned/Usable | - | - | Unconsolidated | 12 | 16.6 | N | - | 0.0 | 0.0 | - | Dawson River Alluvium |
| 13030644 | 791331 | 7276008 | WR Investigation Bore | Abandoned/Usable | - | - | Unconsolidated | 10 | 12.8 | N | - | 0.0 | 0.0 | - | Dawson River Alluvium |
| 13030648 | 783892 | 7290497 | WR Investigation Bore | Abandoned/Usable | - | - | Unconsolidated | 10.4 | 16.6 | N | - | 0.0 | 0.0 | - | Dawson River Alluvium |
| 13030649 | 785071 | 7290131 | WR Investigation Bore | Abandoned/Usable | 8 | KM87 | Unconsolidated | 17.4 | 19.7 | N | - | 0.0 | 0.0 | - | Dawson River Alluvium |
| 13030650 | 786338 | 7289754 | WR Investigation Bore | Abandoned/Usable | 8 | KM87 | Unconsolidated | 5.9 | 23.9 | N | - | 0.0 | 0.0 | - | Dawson River Alluvium |
| 13030651 | 787244 | 7289537 | WR Investigation Bore | Abandoned/Usable | 12 | KM87 | Unconsolidated | 11.2 | 15.4 | N | - | 0.0 | 0.0 | - | Dawson River Alluvium |
| 13030830 | 787697 | 7274857 | Sub-artesian Monitoring Bore | Existing | - | - | Consolidated | 44 | 47 | N | - | 0.0 | 0.0 | - | Rewan Formation |

Datum: MGA94 Zone 55

# *Appendix B* Baseline assessment laboratory analysis results

Appendix B – Water Quality – Laboratory Analyses (Project No. G1631)

| Sample ID / Sample date | | | 47008 | 43557 | 89755 | 89947 | 128033 | 128605 | 13030641.00 | 13030830 | Beaufoy Standpipe |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Analyte | Units | LOR | 12/06/2013 | 27/06/2013 | 29/05/2013 | 12/06/2013 | 30/05/2013 | 27/06/2013 | 29/05/2013 | 30/05/2013 | 28/06/2013 |
| Water Quality Indicators | | | | | | | | | | | |
| pH Value | pH Unit | 0.01 | 7.88 | 8.41 | 7.59 | 7.98 | 8.14 | 8.13 | 7.66 | 7.71 | 7.41 |
| Electrical Conductivity @ 25°C | µS/cm | 1 | 868 | 562 | 440 | 1320 | 1980 | 573 | 440 | 27200 | 988 |
| Total Dissolved Solids (Calc.) | mg/L | 1 | 564 | 365 | 286 | 858 | 1290 | 372 | 286 | 17700 | 642 |
| Total Hardness as $CaCO_3$ | mg/L | 1 | 109 | 10 | 167 | 262 | 345 | 99 | 152 | 4730 | 132 |
| Sodium Adsorption Ratio | - | 0.01 | 5.63 | 18.7 | 1.04 | 5.1 | 6.98 | 3.37 | 1.34 | 34.9 | 6.61 |
| Alkalinity | | | | | | | | | | | |
| Hydroxide Alkalinity as $CaCO_3$ | mg/L | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Carbonate Alkalinity as $CaCO_3$ | mg/L | 1 | <1 | 9 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Bicarbonate Alkalinity as $CaCO_3$ | mg/L | 1 | 127 | 185 | 197 | 470 | 821 | 116 | 191 | 439 | 231 |
| Total Alkalinity as $CaCO_3$ | mg/L | 1 | 127 | 194 | 197 | 470 | 821 | 116 | 191 | 439 | 231 |
| Dissolved Major Ions | | | | | | | | | | | |
| Calcium | mg/L | 1 | 32 | 4 | 42 | 39 | 82 | 23 | 38 | 537 | 30 |
| Magnesium | mg/L | 1 | 7 | <1 | 15 | 40 | 34 | 10 | 14 | 823 | 14 |
| Sodium | mg/L | 1 | 135 | 136 | 31 | 190 | 298 | 77 | 38 | 5520 | 175 |
| Potassium | mg/L | 1 | 10 | <1 | 4 | <1 | 11 | 8 | 4 | 87 | 3 |
| Chloride | mg/L | 1 | 194 | 70 | 24 | 174 | 193 | 111 | 31 | 11600 | 194 |
| Sulfate as $SO_4$ - Turbidimetric | mg/L | 1 | 30 | 4 | 1 | 15 | 9 | 1 | 4 | 118 | 11 |
| Ionic Balance | | | | | | | | | | | |
| Total Anions | meq/L | 0.01 | 8.63 | 5.93 | 4.63 | 14.6 | 22 | 5.47 | 4.77 | 338 | 10.3 |
| Total Cations | meq/L | 0.01 | 8.3 | 6.12 | 4.78 | 13.5 | 20.1 | 5.52 | 4.8 | 337 | 10.3 |
| Ionic Balance | % | 0.01 | 1.98 | 1.45 | 1.56 | 3.97 | 4.54 | 0.49 | 0.3 | 0.24 | 0.08 |
| Dissolved Metals | | | | | | | | | | | |
| Aluminium | mg/L | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.05 | <0.01 |
| Arsenic | mg/L | 0.001 | 0.001 | <0.001 | <0.001 | <0.001 | 0.007 | <0.001 | 0.002 | <0.005 | 0.002 |
| Beryllium | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.005 | <0.001 |
| Barium | mg/L | 0.001 | 0.111 | 0.022 | 0.068 | 0.059 | 0.085 | 0.088 | 0.025 | 0.574 | 0.103 |
| Cadmium | mg/L | 0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0005 | <0.0001 |
| Chromium | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.005 | <0.001 |
| Cobalt | mg/L | 0.001 | <0.001 | <0.001 | 0.004 | <0.001 | 0.001 | <0.001 | <0.001 | 0.008 | <0.001 |
| Copper | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.005 | <0.001 |
| Lead | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.036 | <0.001 |
| Manganese | mg/L | 0.001 | 0.177 | 0.001 | 2.74 | 0.106 | 1.09 | 0.229 | 0.002 | 0.88 | <0.001 |
| Molybdenum | mg/L | 0.001 | <0.001 | <0.001 | 0.002 | <0.001 | <0.001 | <0.001 | 0.004 | <0.005 | <0.001 |
| Nickel | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 | <0.001 | 0.003 | 0.019 | <0.001 |
| Selenium | mg/L | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.05 | <0.01 |
| Silver | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.005 | <0.001 |
| Strontium | mg/L | 0.001 | 0.249 | 0.166 | 0.584 | 0.818 | 1.49 | 0.169 | 0.16 | 23.8 | 0.632 |
| Tin | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.005 | <0.001 |
| Uranium | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.005 | <0.001 |
| Vanadium | mg/L | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.01 | <0.01 | <0.01 | <0.05 | <0.01 |
| Zinc | mg/L | 0.005 | 0.011 | <0.005 | 0.013 | <0.005 | 0.005 | <0.005 | <0.005 | 0.148 | <0.005 |
| Boron | mg/L | 0.05 | 0.16 | 0.26 | <0.05 | 0.06 | 0.13 | 0.18 | 0.05 | 1.5 | 0.05 |
| Iron | mg/L | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.07 | 0.05 | <0.05 | <0.25 | <0.05 |

| Sample ID / Sample date | | | 47008 | 43557 | 89755 | 89947 | 128033 | 128605 | 13030641.00 | 13030830 | Beaufoy Standpipe |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Analyte | Units | LOR | 12/06/2013 | 27/06/2013 | 29/05/2013 | 12/06/2013 | 30/05/2013 | 27/06/2013 | 29/05/2013 | 30/05/2013 | 28/06/2013 |
| Total Metals | | | | | | | | | | | |
| Aluminium | mg/L | 0.01 | <0.01 | <0.01 | 0.04 | <0.01 | 0.07 | 0.01 | 0.38 | 1 | 0.14 |
| Arsenic | mg/L | 0.001 | <0.001 | <0.001 | 0.042 | <0.001 | 0.006 | <0.001 | 0.003 | <0.005 | 0.002 |
| Beryllium | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.005 | <0.001 |
| Barium | mg/L | 0.001 | 0.115 | 0.024 | 0.123 | 0.061 | 0.107 | 0.099 | 0.192 | 0.612 | 0.105 |
| Cadmium | mg/L | 0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0005 | <0.0001 |
| Chromium | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 | <0.005 | <0.001 |
| Cobalt | mg/L | 0.001 | <0.001 | <0.001 | 0.004 | <0.001 | <0.001 | <0.001 | 0.001 | 0.009 | <0.001 |
| Copper | mg/L | 0.001 | <0.001 | <0.001 | 0.002 | <0.001 | 0.001 | <0.001 | 0.008 | 0.006 | <0.001 |
| Lead | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 | 0.001 | 0.042 | 0.113 | <0.001 |
| Manganese | mg/L | 0.001 | 0.179 | 0.001 | 3.58 | 0.119 | 0.954 | 0.24 | 0.638 | 0.89 | 0.005 |
| Molybdenum | mg/L | 0.001 | <0.001 | <0.001 | 0.003 | <0.001 | <0.001 | <0.001 | 0.004 | <0.005 | <0.001 |
| Nickel | mg/L | 0.001 | <0.001 | <0.001 | 0.001 | <0.001 | 0.002 | <0.001 | 0.028 | 0.021 | <0.001 |
| Selenium | mg/L | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.05 | <0.01 |
| Silver | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.005 | <0.001 |
| Strontium | mg/L | 0.001 | 0.252 | 0.168 | 0.632 | 0.825 | 1.52 | 0.173 | 0.539 | 25.2 | 0.635 |
| Tin | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.005 | <0.001 |
| Uranium | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | 0.002 | <0.001 | <0.001 | <0.001 | 0.007 | <0.001 |
| Vanadium | mg/L | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.05 | <0.01 |
| Zinc | mg/L | 0.005 | 0.02 | 0.006 | 0.03 | 0.008 | 0.009 | 0.013 | 0.06 | 0.169 | <0.005 |
| Boron | mg/L | 0.05 | 0.18 | 0.24 | <0.05 | 0.07 | 0.08 | 0.14 | 0.05 | 1.66 | <0.05 |
| Iron | mg/L | 0.05 | 0.2 | <0.05 | 7.03 | <0.05 | 0.43 | 1.94 | 2.71 | 0.78 | 0.1 |
| Mercury / Chromium | | | | | | | | | | | |
| Mercury, dissolved | mg/L | 0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Mercury, total recoverable | mg/L | 0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Trivalent Chromium | mg/L | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Hexavalent Chromium | mg/L | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Nutrients - N and P | | | | | | | | | | | |
| Ammonia as N | mg/L | 0.01 | 0.09 | 0.06 | 1.6 | 0.05 | 46.5 | 0.11 | 0.2 | 0.15 | 0.03 |
| Nitrite as N | mg/L | 0.01 | <0.01 | <0.01 | 0.37 | 0.01 | 0.08 | <0.01 | <0.01 | 0.02 | <0.01 |
| Nitrate as N | mg/L | 0.01 | <0.01 | 0.07 | 1.46 | 3.57 | 0.25 | 0.01 | 0.12 | 0.1 | 0.14 |
| Nitrite + Nitrate as N | mg/L | 0.01 | <0.01 | 0.07 | 1.83 | 3.58 | 0.33 | 0.01 | 0.12 | 0.12 | 0.14 |
| Total Kjeldahl Nitrogen as N | mg/L | 0.1 | <0.1 | 0.3 | 1.7 | 0.5 | 47.3 | 0.3 | 1.4 | 0.4 | <0.1 |
| Total Nitrogen as N | mg/L | 0.1 | <0.1 | 0.4 | 3.5 | 4.1 | 47.6 | 0.3 | 1.5 | 0.5 | 0.1 |
| Total Phosphorus as P | mg/L | 0.01 | <0.01 | 0.14 | 0.86 | <0.01 | 6.54 | 0.01 | 0.17 | 0.09 | 0.76 |
| PAH | | | | | | | | | | | |
| Naphthalene | µg/L | 1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| Acenaphthylene | µg/L | 1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| Acenaphthene | µg/L | 1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| Fluorene | µg/L | 1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| Phenanthrene | µg/L | 1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| Anthracene | µg/L | 1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| Fluoranthene | µg/L | 1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| Pyrene | µg/L | 1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| Benz(a)anthracene | µg/L | 1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| Chrysene | µg/L | 1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |

Appendix B – Water Quality – Laboratory Analyses (Project No. G1631)

| Sample ID / Sample date | | | 47008 | 43557 | 89755 | 89947 | 128033 | 128605 | 13030641.00 | 13030830 | Beaufoy Standpipe |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Analyte | Units | LOR | 12/06/2013 | 27/06/2013 | 29/05/2013 | 12/06/2013 | 30/05/2013 | 27/06/2013 | 29/05/2013 | 30/05/2013 | 28/06/2013 |
| Benzo(b)fluoranthene | µg/L | 1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| Benzo(k)fluoranthene | µg/L | 1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| Benzo(a)pyrene | µg/L | 0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Indeno(1.2.3.cd)pyrene | µg/L | 1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| Dibenz(a.h)anthracene | µg/L | 1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| Benzo(g.h.i)perylene | µg/L | 1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| Sum of PAH | µg/L | 0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Benzo(a)pyrene TEQ (WHO) | µg/L | 0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |

Appendix B – Water Quality – Laboratory Analyses (Project No. G1631)

| Sample ID / Sample date | | | 47008 | 43557 | 89755 | 89947 | 128033 | 128605 | 13030641.00 | 13030830 | Beaufoy Standpipe |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Analyte | Units | LOR | 12/06/2013 | 27/06/2013 | 29/05/2013 | 12/06/2013 | 30/05/2013 | 27/06/2013 | 29/05/2013 | 30/05/2013 | 28/06/2013 |
| BTEXN | | | | | | | | | | | |
| Benzene | µg/L | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Toluene | µg/L | 2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 |
| Ethylbenzene | µg/L | 2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 |
| meta- & para-Xylene | µg/L | 2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 |
| ortho-Xylene | µg/L | 2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 |
| Total Xylenes | µg/L | 2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 | <2 |
| Sum of BTEX | µg/L | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Naphthalene | µg/L | 5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Total Petroleum Hydrocarbons | | | | | | | | | | | |
| C6 - C9 Fraction | µg/L | 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 |
| C15 - C28 Fraction | µg/L | 100 | <100 | <100 | <100 | <100 | <100 | <100 | <100 | <100 | <100 |
| C29 - C36 Fraction | µg/L | 50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 |
| C10 - C36 Fraction (sum) | µg/L | 50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 | <50 |
| Total Recoverable Hydro- carbons / NEPM 2010 Draft | | | | | | | | | | | |
| C6 - C10 Fraction | µg/L | 20 | <20 | <20 | <20 | <20 | <20 | <20 | <20 | <20 | <20 |
| C6 - C10 Fraction minus BTEX | µg/L | 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 |
| >C16 - C34 Fraction | µg/L | 100 | <100 | <100 | <100 | <100 | <100 | <100 | <100 | <100 | <100 |
| >C34 - C40 Fraction | µg/L | 100 | <100 | <100 | <100 | <100 | <100 | <100 | <100 | <100 | <100 |
| >C10 - C40 Fraction (sum) | µg/L | 100 | <100 | <100 | <100 | <100 | <100 | <100 | <100 | <100 | <100 |
| Gases | | | | | | | | | | | |
| Dissolved Oxygen | mg/L | 0.1 | 8.8 | 13.8 | 5.3 | 8.4 | 5.4 | 16.2 | 6.1 | 6 | 13 |
| Free Carbon Dioxide as $CO_2$ | mg/L | 1 | 3 | 1 | 10 | 10 | 12 | 2 | 8 | 17 | 18 |
| Total Carbon Dioxide as $CO_2$ | mg/L | 1 | 115 | 168 | 183 | 423 | 734 | 104 | 176 | 403 | 221 |
| Methane | µg/L | 10 | <10 | <10 | 126 | <10 | 1420 | 88 | 23 | 15 | <10 |
| Miscellaneous | | | | | | | | | | | |
| Silicon as $SiO_2$ | mg/L | 0.1 | 21.2 | 20.5 | 35.4 | 39 | 27.4 | 10.6 | 34.1 | 17.2 | 82.3 |
| Fluoride | mg/L | 0.1 | 0.4 | <0.1 | 0.4 | 0.5 | 0.3 | 0.2 | 0.2 | 0.1 | 0.5 |
| Bromide | mg/L | 0.010 | 0.468 | 0.248 | 0.161 | 0.595 | 0.59 | 0.35 | 0.182 | 22.3 | 0.705 |
| Unionized Hydrogen Sulfide | mg/L | 0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Sulfide as $S^{2-}$ | mg/L | 0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Gross Alpha and Beta Activity | | | | | | | | | | | |
| Gross alpha | Bq/L | 0.05 | <0.25 | - | <0.14 | <0.40 | <0.50 | - | <0.12 | <10.0 | - |
| Gross beta activity - 40K | Bq/L | 0.10 | <0.50 | - | <0.29 | <0.80 | <1.00 | - | <0.25 | <20.0 | - |