arris

agricultural & environmental

# Underground Water Impact Report ATP 688

**WestSide Corporation Ltd**

**24th August, 2017**

| Version | Date | Author | Reviewed | Issued by |
|---|---|---|---|---|
| Final | 24th August 2017 | R Martin | Jim Kelly<br>Dr G Ritchie | Jim Kelly |

| | | |
|---|---|---|
| **Created by** | Arris Pty Ltd | Bld 11b, Gate 2c<br>Hartley Grove<br>URRBRAE SA 5064<br><br>t 08 8313 6706<br>f 08 8313 6752<br>ACN 092 739 574 |
| **Client** | WestSide Corporation Ltd | |
| **Name of Organisation** | | |
| **Name of Project** | Underground Water Impact Report ATP688 | |
| **Name of Document** | | |
| **Project Number** | | |
| **Document Version** | Final | |
| **Cover** | | |
| **Sensitivity** | This document and the information, ideas, concepts, methodologies, technologies and other material it contains remain the intellectual property of Arris Pty Ltd. The document is not to be copied without the express permission of at least one of the above parties. | |
| **Disclaimer** | This report is presented “as is” without any warrantees or assurances. Whilst all reasonable efforts have been made to ensure the information provided in this review is current and reliable, Arris Pty Ltd does not accept any responsibility for errors or omissions in the contents. | |
| **Document Delivery** | Arris Pty Ltd provides this document in either printed format, electronic format or both. Arris considers the printed version to be binding. The electronic format is provided for the client’s convenience and Arris Pty Ltd requests that the client ensures the integrity of this electronic information is maintained. Storage of this electronic information should at a minimum comply with the requirements of the Commonwealth Electronic Transactions Act (ETA) 2000.<br><br>Where an electronic only version is provided to the client, a signed hard copy of this document can be provided by Arris Pty Ltd if requested by the client. | |

# Table of Contents

## List of Tables



## List of Figures

# Abbreviations

| Abbreviation | Explanation |
|---|---|
| ° | Degree |
| % | Percent |
| ATP | Authority to Prospect |
| BAP | Baseline Assessment Plan |
| BoM | Bureau of Meteorology |
| CDMR | Cumulative departure from mean rainfall |
| CSG | Coal Seam Gas |
| DEHP | Department of Environment and Heritage Protection |
| EIS | Environmental Impact Study |
| ERA | Endangered Regional Ecosystem |
| ESA | Environmentally sensitive area |
| ET | Evapotranspiration |
| FCCM | Fort Cooper Coal Measures |
| HSU | hydrostratigraphic unit |
| IAA | Immediately Affected Area |
| IESC | Independent Expert Scientific Committee |
| $K_h$ | Hydraulic Conductivity |
| kL | Kilolitre |
| kL/d | Kilolitre per day |
| kL/year | Kilolitre per year |
| km | Kilometre |
| $km^2$ | Kilometre squared |
| $K_v$ | Vertical Conductivity |
| L | Litre |
| L/s | Litres per second |
| LTAA | Long Term Affected Area |
| m | Metre |
| $m^3$ | Cubic metre |
| m/a | Metres per annum |
| m bgl | Metres below ground level |
| MCM | Moranbah Coal Measures |
| m/d | Metres per day |
| $m^2/d$ | Square metre per day |
| mm/a | Millimetre per annum |
| mg/L | Milligrams per litre |
| OGIA | Office of Groundwater Impact Assessment |
| PCG | Preconditioned conjugate gradient |
| RMS | Root mean square |
| RN | Registered Number |
| Ss | Specific Storage |
| Sy | Specific Yield |
| T | Transmissivity |
| TA | Tenement Area |
| µS/cm | MicroSiemens per centimetre |
| µg/L | Micrograms per litre |
| UWIR | Underground Water Impact Report |
| yr | Year |

# 1 Executive Summary

The registered holders of Authority to Prospect (ATP) 688 are WestSide Corporation (ABN 74 117 145 516) and BNG (Surat) Pty Ltd (ABN. 97 090 629 913). The Underground Water Impact Report (UWIR) for ATP 688 was approved (with conditions) by the Chief Executive of the department of Environment and Heritage Protection (DEHP) on 20 September 2013. Since that time, no new production or production testing has been undertaken. Activities on ATP 688 post approval of the 2013 UWIR have included the abandonment of several exploration bores. In the immediate short-term (next two to three years) no further production testing or drilling is programmed in ATP 688. However, events may occur that result in activities resuming across ATP 688.

Although no activity is planned, predictive modelling has been completed to define the extent of Immediately Affected Areas and Long Term Affected Areas above the trigger levels in accordance with the *Water Act* (Qld), 2000. By predicting drawdowns caused by underground water extractions this modelling presents a conservative estimate of potential impacts that may result in the unlikely event that activities in ATP 688 resume within the life of this Underground Water Impact Report.

Modelling has been carried out to provide estimates of declines in water level in response to the extraction of groundwater associated with pilot testing in ATP 688. For this model, future groundwater extraction has been estimated from historical pumping during production testing. Two additional wells MSM04L1 and MSM04L2 have been proposed in the Mount St Martin's however, there is no certainty that these wells will be constructed.

Under the applied assumptions predictive modelling identifies two consolidated aquifers (The Upper Goonyella Coal Seam and the Goonyella P Seam) are likely to be affected by the exercise of underground water rights. There are no reportable impacts in the overlying alluvium and basalt aquifer.

Pursuant to section 376 of the Water Act, 2000 (Qld), this report forms the UWIR for ATP 688. There is no production or production testing currently forecast in ATP 688. Based on this, where relevant the UWIR provides a summary of information presented in the previous UWIR for ATP 688 which was approved (with conditions) by DEHP on 20 September 2013.

# 2 Introduction

## 2.1 Background

The registered holders of Authority to Prospect (ATP) 688 are WestSide Corporation (ABN 74 117 145 516) and BNG (Surat) Pty Ltd (ABN. 97 090 629 913). ATP688 is located 110 km west of Mackay (Figure 1), with target coal seams located at depths of approximately 150 m below ground level (m bgl).

The Underground Water Impact Report (UWIR) for ATP 688 was approved (with conditions) by the Chief Executive of the Department of Environment and Heritage Protection (DEHP) on 20 September 2013. Since that time, no new production or production testing has been undertaken. Activities on ATP 688 post approval of the 2013 UWIR have included the abandonment of three exploration bores (Table 1).

**Table 1 Wells plugged and abandoned across ATP 688**

| Well Name | Easting | Northing | Latitude | Longitude |
|---|---|---|---|---|
| **MSM-1** | 594167.5996 | 7703290.599 | -20.767764 | 147.904658 |
| **BH-01** | 585243.6748 | 7679474.096 | -20.983373 | 147.8201 |
| **Mt Saint Martins -6** | 600282.3219 | 7694077.804 | -20.850678 | 147.963924 |
| **Mt Saint Martins -7** | 599125.265 | 7699441.212 | -20.802284 | 147.952499 |
| **Mt Leslie 8** | 598760.6173 | 7685138.953 | -20.931518 | 147.949807 |
| **Tilbrook 1** | 582536.2672 | 7671135.884 | -21.05883 | 147.794454 |
| **Tilbrook 2** | 587321.0916 | 7676500.462 | -21.010141 | 147.840235 |
| **Tilbrook 3** | 582838.5846 | 7675238.179 | -21.021753 | 147.797167 |
| **Tilbrook 4** | 584303.9454 | 7671319.916 | -21.057087 | 147.811459 |
| **Tilbrook 5** | 584822.4193 | 7674318.626 | -21.02997 | 147.816301 |
| **Tilbrook 6** | 585261.9476 | 7671801.368 | -21.052692 | 147.820655 |
| **Tilbrook 8A** | 584201.3093 | 7670902.491 | -21.060863 | 147.810491 |
| **Tilbrook 8LA** | 583857.9771 | 7670739.404 | -21.062352 | 147.807195 |
| **Tilbrook 8B** | 584665.8225 | 7670501.373 | -21.064465 | 147.814982 |
| **Tilbrook 8LB** | 584531.9017 | 7670137.537 | -21.067758 | 147.813711 |
| **Tillbrook 9A** | 584157.6064 | 7671089.813 | -21.059172 | 147.810062 |
| **Tilbrook 10B** | 585736.4052 | 7672988.416 | -21.041946 | 147.825163 |

### 2.1.1 Purpose of This Report

Pursuant to section 376 of the *Water Act*, 2000 (Qld), this report forms the UWIR for ATP 688. Under the Water Reform and Other Legislation Amendment (WROLA) Act 2014 (which commenced on 6 Dec 2016) additional matters are required to be addressed in the UWIR. Specifically, impacts on Environmental Values which is addressed in Section 5 of this Report.

There is no production or production testing currently forecast in ATP 688. Therefore, there are no changes to the predictions in the UWIR as approved 20 September 2013. Based on this, where relevant the UWIR provides a summary of information presented in the previous UWIR for ATP 688 which was approved (with conditions) by DEHP on 20 September 2013. The purpose of this report is to address chapter three, division four, section 376 of the Queensland *Water Act*, 2000 which stipulates that the UWIR must include:

- Part A: Information about underground water extractions resulting from the exercise of underground water rights.
    - Quantity of water already produced.
    - Quantity of water to be produced in the next three years.
- Part B: Information about aquifers affected, or likely to be affected.
    - Aquifer descriptions.
    - Underground water flow and aquifer interactions.
    - Underground water level trend analysis.
- Part C: Maps showing the area of the affected aquifer(s) where underground water levels are expected to decline.
    - Maps of affected areas.
    - Methods and techniques used in building a computer based hydrogeologic model, and the associated water level maps and predictions.
    - Water bores within Immediately Affected Areas.
    - Annual review of maps produced.
- Part D: Impacts on Environmental Values
    - Identification and description of environmental values
    - Nature and extend of any impacts on the environmental values
    - Impacts to formation integrity and surface subsidence
- Part E: A water monitoring strategy.
    - Rational behind water monitoring strategy.
    - Timetable for the water monitoring strategy.
    - Reporting program for the water monitoring strategy.
- Part F: A spring impact management strategy.
    - Spring inventory and values.
    - Connectivity between the spring and aquifer.
    - Management of impacts.
    - Timetable for strategy.
    - Reporting program.

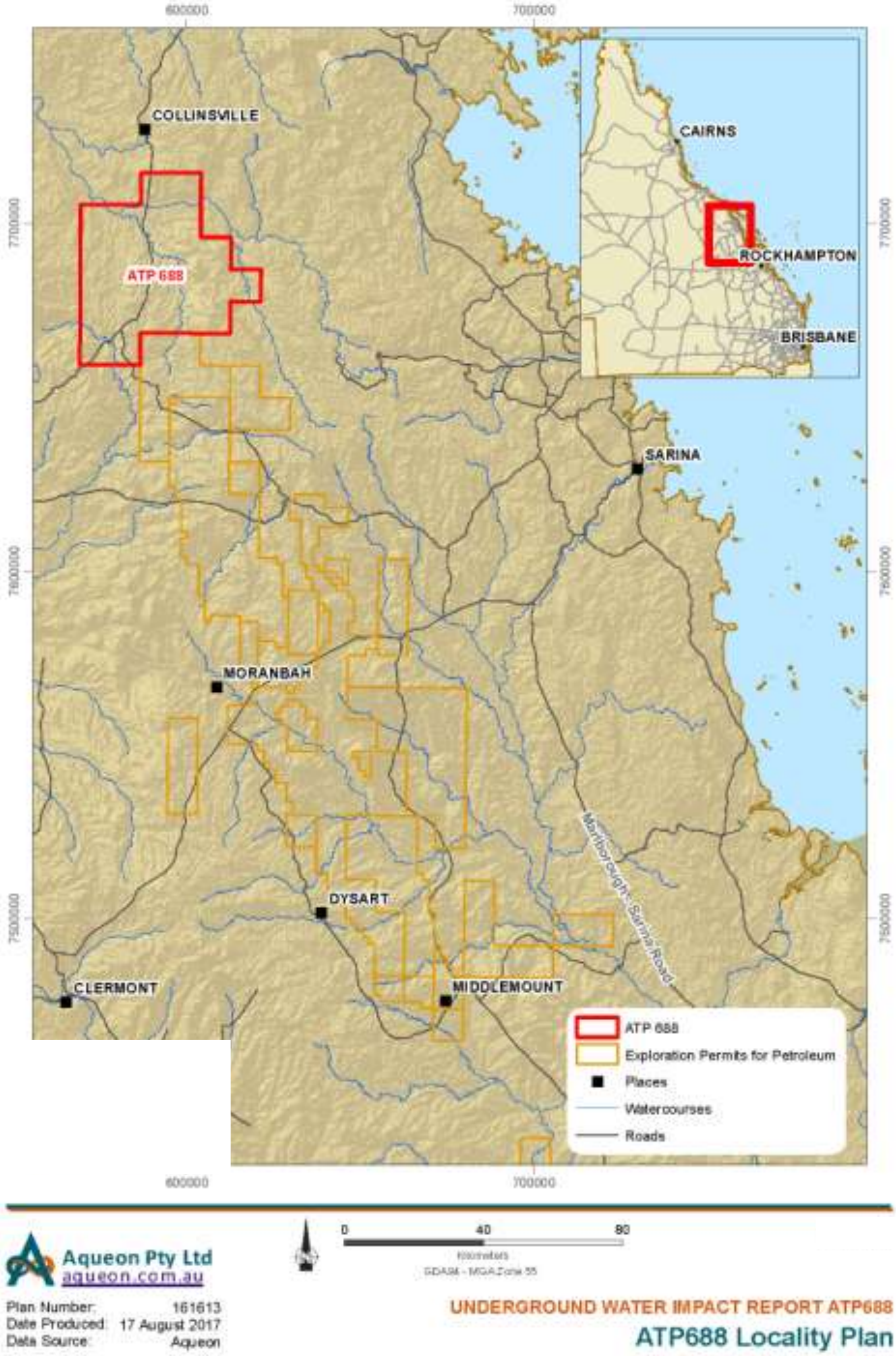


**Figure 1 ATP 688 Locality Plan**

## *2.2 Project Area*

ATP 688 is located within the Bowen Basin approximately 110 km west of Mackay covering an area of approximately 72 km$^2$ (Figure 1).

## 2.3 Legislative Requirements

### 2.3.1 Petroleum Act 1923 - Queensland

The authority to prospect ATP 688 was granted under the *Petroleum Act,* 1923 (Qld). Under the *Petroleum Act 1923* (Qld), the petroleum tenure holder may take or interfere with groundwater to the extent that it is necessary and unavoidable during an activity authorised under the petroleum tenure. The Act requires tenure holders to comply with underground water obligations specified in the *Water Act,* 2000 (Qld).

### 2.3.2 Petroleum and Gas (Production and Safety) Act 2004

The *Petroleum and Gas (Production and Safety) Act,* 2004 (P&G Act, 2004 (Qld)) regulates coal seam gas activities and governs groundwater management in relation to coal seam gas development. ATP 688P was granted under the P&G Act. Under the P&G Act, the petroleum tenure holder may take or interfere with groundwater to the extent that is necessary and unavoidable during an activity authorized under the petroleum tenure (Section 185 Underground water rights). The P&G Act, 2004 (Qld) requires tenure holders to comply with the underground water obligations specified in the Water Act, chapter three.

### 2.3.3 Water Act 2000 - Queensland

The *Water Act*, 2000 (Qld) provides a comprehensive regime for the planning and management of all water resources including vesting to the State

- The rights over the use, flow and control of all surface water, groundwater, rivers, and springs) in Queensland.
- Regulates water use and the obligations of coal seam gas production and pilot testing in relation to groundwater monitoring, reporting, impact assessment and management of impacts on other water users.
- Provides a framework and conditions for preparing a Baseline Assessment Plan (BAP) and outlines the requirement of bore owners to provide information the petroleum holder reasonably requires to undertake a baseline assessment of any bores.
- Sets out the process for assessing, reporting, monitoring, and negotiating with other water users regarding the impact of coal seam gas production, and pilot testing on aquifers.
- Provides a framework for the petroleum tenure holder to undertake an UWIR once they have started pilot testing.
- A UWIR will identify whether an "Immediately Affected Area" (IAA) will result from CSG activities. An IAA is defined as an area where the predicted decline in water levels within three years is at least:
    a. 5m for a consolidated aquifer.
    b. 2m for an unconsolidated aquifer.

UWIRs are published to enable comments from bore owners within the area. Submission made by bore owners will be submitted by Eureka Petroleum Pty Ltd (a 100% owned subsidiary of Blue Energy Limited) to DEHP. UWIRs are submitted for approval to DEHP two months after the consultation date. The OGIA may also advise DEHP about the adequacy of these reports. The OGIA will maintain a database of information collected under monitoring plans carried out by petroleum tenure holders in accordance with approved UWIRs. The database will also incorporate bore baseline data collected by petroleum tenure holders.

## 2.4 Summary of Methods

Production testing has not been undertaken since the previous UWIR. In addition to this, further production testing is currently not forecast for ATP 688. Based on no further programmed testing, the UWIR for the period 2016 to 2019 provides a summary of information presented in the previous UWIR for ATP 688 which was approved by the Department of Environment and Heritage Protection (DEHP) on 20 September 2013.

Whilst no extraction activities are planned in the near future, the model presented in Section 5 of this report has been updated to reflect past activities and a predicted future water demand if exploration activities should resume at ATP 688. The modelling has been completed to identify any potential impacts should extraction activities resume during the life of this UWIR. The modelling presents a conservative (worst case) outcome as it assumes extraction activities are continuous from 2016.

# 3 Part A: Underground Water Extractions

## *3.1 Quantity of Water Already Produced*

A total of seven pilot wells have been completed in the Mount St Martins area (refer inset Figure 2) and initial production testing from three wells (MSM2, MSM3, and MSM4) occurred from December 2007 through January 2008 (Table 2). A total of six kilolitres (kL) of water was produced from MSM4.

In the Tilbrook area (refer inset Figure 2) a total of 13 wells have been installed targeting the Moranbah Coal Measures and production testing occurred between December 2007 and August 2010 on two wells (T7 and T8). A total of 19,332 kL of water was produced (Table 2) from the two bores (T7 and T8) over the period of testing.

**Table 2 Historical Water Production (kL), ATP 688 (Data supplied by WestSide Corporation)**

| Month Ending | MSM4 | T7 | T8 |
|---|---|---|---|
| 12/2007 | 6 | 0 | 5 |
| 01/2008 | 0 | 0 | 49 |
| 02/2008 | 0 | 0 | 71 |
| 03/2008 | 0 | 0 | 0 |
| 04/2008 | 0 | 5 | 0 |
| 05/2008 | 0 | 10 | 11 |
| 06/2008 | 0 | 27 | 49 |
| 07/2008 | 0 | 34 | 9 |
| 08/2008 | 0 | 31 | 10 |
| 09/2008 | 0 | 30 | 7 |
| 10/2008 | 0 | 26 | 9 |
| 11/2008 | 0 | 32 | 8 |
| 12/2008 | 0 | 92 | 16 |
| 01/2009 | 0 | 113 | 13 |
| 02/2009 | 0 | 97 | 40 |
| 03/2009 | 0 | 103 | 42 |
| 04/2009 | 0 | 98 | 40 |
| 05/2009 | 0 | 100 | 6 |
| 06/2009 | 0 | 94 | 1 |
| 07/2009 | 0 | 98 | 992 |
| 08/2009 | 0 | 97 | 1,171 |
| 09/2009 | 0 | 94 | 1,920 |
| 10/2009 | 0 | 96 | 1,682 |
| 11/2009 | 0 | 93 | 1,484 |
| 12/2009 | 0 | 79 | 1,422 |
| 01/2010 | 0 | 48 | 1,290 |

| Month Ending | MSM4 | T7 | T8 |
|---|---|---|---|
| 02/2010 | 0 | 0 | 1,121 |
| 03/2010 | 0 | 66 | 1,090 |
| 04/2010 | 0 | 106 | 0 |
| 05/2010 | 0 | 103 | 801 |
| 06/2010 | 0 | 98 | 1,598 |
| 07/2010 | 0 | 0 | 1,299 |
| 08/2010 | 0 | 0 | 1,206 |
| **Total (kL)** | **6** | **1,870** | **17,462** |

## *3.2 Quantity of Water to be Produced in the Next Three Years*

ATP 688 is still in the exploration stage and with cessation of pilot testing in August 2010, Westside Corporation have no immediate plans to continue exploration in ATP 688. Therefore, the predicted water production for the next three years (2016 to 2019) will be zero (0) litres (Table 3). Whilst no testing activity is currently programmed over the period 2016 to 2019, this could change. In the unlikely event that it might change, modelling has been completed assuming that some activity will occur to present a conservative estimate of what impacts may occur should a testing programme resume.

**Table 3 Water produced during 2011 to 2016**

| Year | Estimated Produced water in litres per year per well | | |
|---|---|---|---|
| | MSM4 | T7 | T8 |
| Sept 2011 - Sept 2012 | 0 | 0 | 0 |
| Sept 2012 - Sept 2013 | 0 | 0 | 0 |
| Sept 2013 - Sept 2014 | 0 | 0 | 0 |
| Sept 2014 - Sept 2015 | 0 | 0 | 0 |
| Sept 2015 – Sept 2016 | 0 | 0 | 0 |
| Sept 2016 - Sept 2017 | 0 | 0 | 0 |
| Sept 2017 - Sept 2018 | 0 | 0 | 0 |
| Sept 2018 - Sept 2019 | 0 | 0 | 0 |
| Total per Well (litres) | 0 | 0 | 0 |

With minimal initial water production and cessation of pilot testing in August 2010 the Immediately Affected Area predicted by the groundwater numerical modelling in the UWIR prepared in 2013 for the period 2013 to 2016 did not eventuate. Current legislation under the *Water Act,* 2000 (Qld) requires Westside Corporation to publish an updated UWIR for public consultation advising the predicted water production for the next three years.

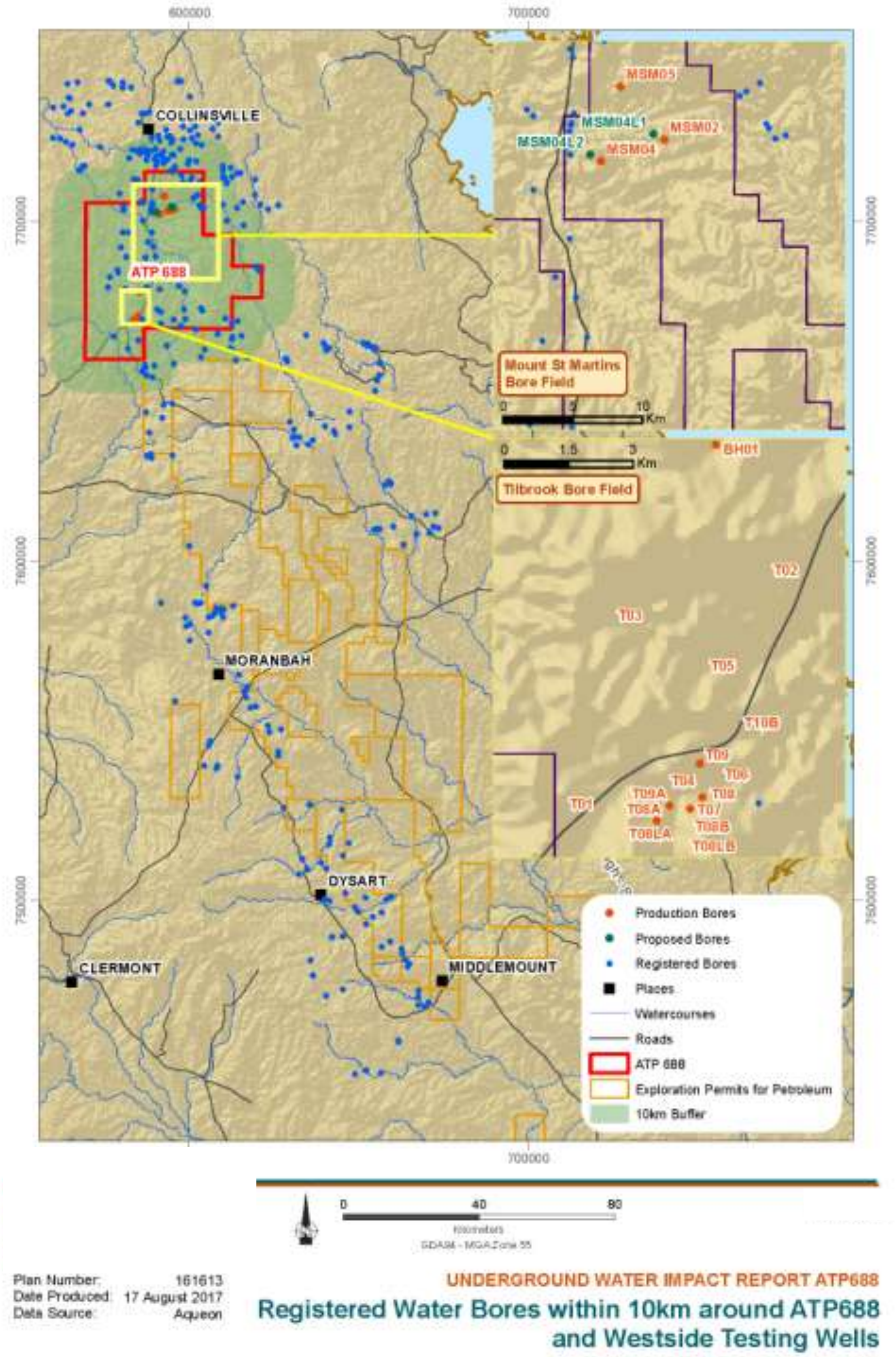


**Figure 2 Registered Water Bores within 10 km around ATP 688 and WestSide Testing Wells**

# 4 Part B: Geological and Hydrogeological Setting

## *4.1 Geological Setting*

Changes in the tectonic setting influenced the paleogeography and depositional environment of the Bowen Basin (Fielding et.al, 2000). Early Permian extensional subsidence and igneous activity resulted in a basin-and-range topography with infrabasins hosting thick accumulations of mainly non-marine, fluvial and lacustrine deposits with occasional marine incursions. Figure 3 presents a diagrammatic representation of the rock unit correlation across the Bowen Basin (after Satins and Koppe, 1980).

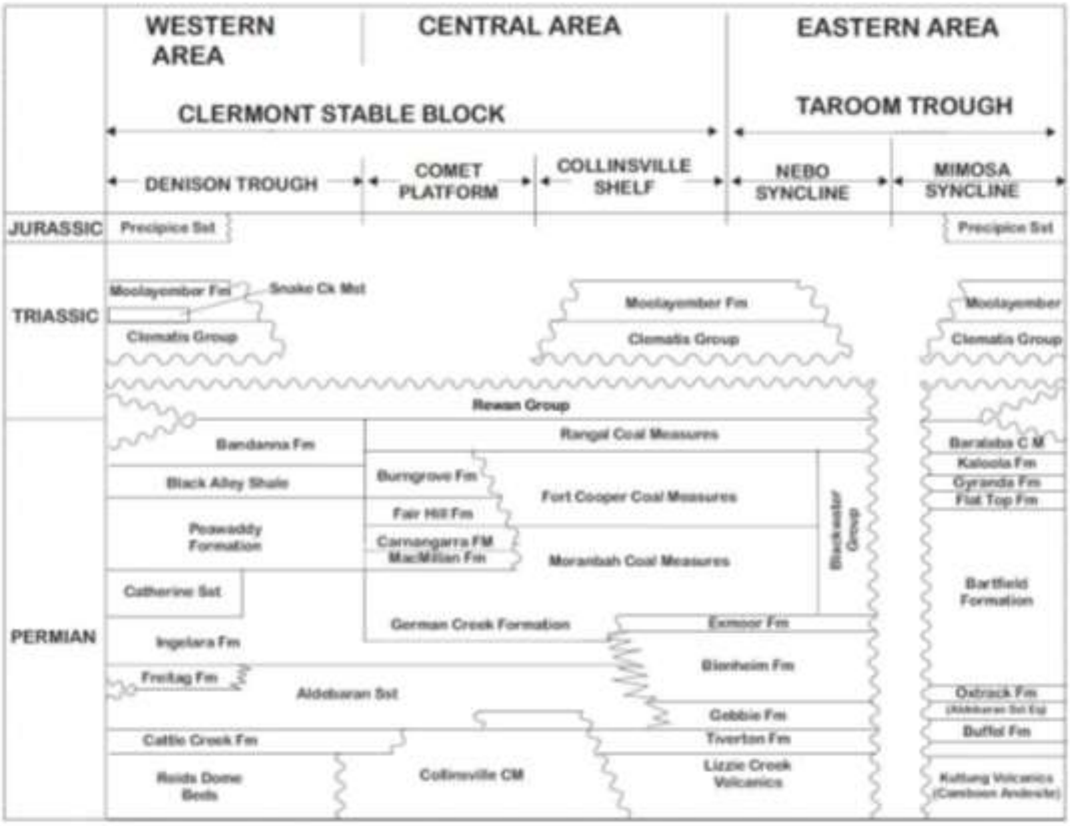


Figure 3 Diagrammatic representation of rock unit correlation Bowen Basin stratigraphic column (*source: Satins and Koppe, 1980*)

ATP 688 is located within the Collinsville Shelf and Nebo Syncliniorium of the eastern Bowen Basin and comprises Permian, Triassic, and young Tertiary and Quaternary sediments (Cadman et al., 1998). Figure 4a provides a geologic map of the area, Figure 4b presents the legend for the geological map and Figure 5 presents a cross-section through the northern tenement area.

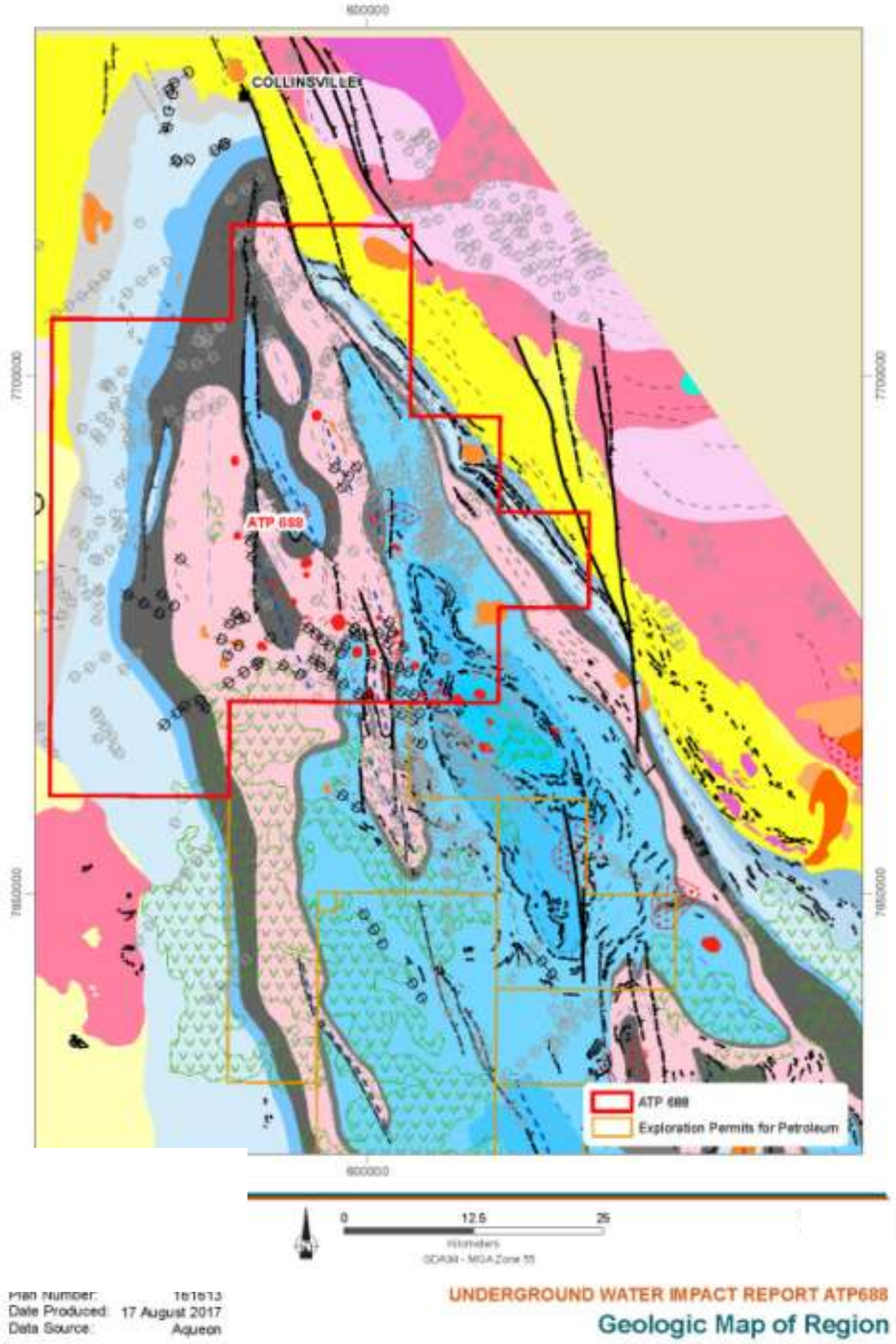


**Figure 4a Geological map of the study area**

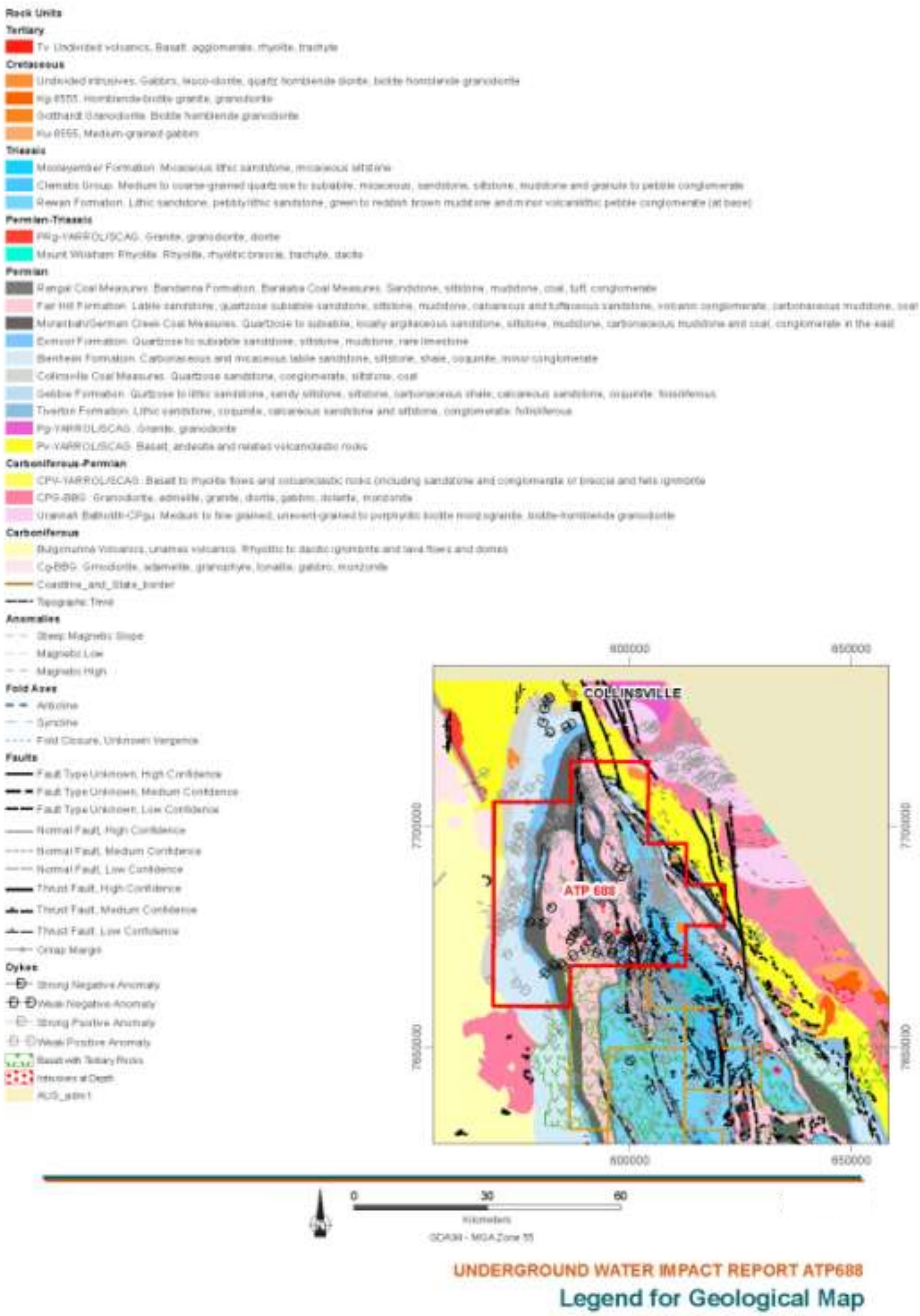


**Figure 4b Geological map legend**

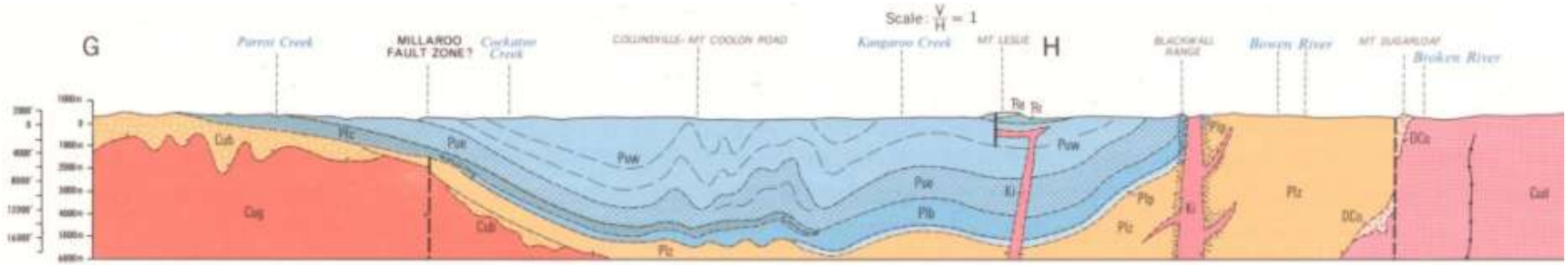


**Figure 5 Cross section through ATP688** ***(source Paine and Cameron (1972))***

The oldest outcropping rocks (in the north of the project area) are part of the middle to upper Permian Collinsville Coal Measures of the Back Creek Group. The freshwater sediments of the Blackwater Group overly the marine Back Creek Group. The Triassic Rewan Formation and Clematis Group conformably overlie the Blackwater Group. Superficial alluvium and basalt flows overlie these consolidated rocks.

The stratigraphic sequence within ATP 688 is shown in Table 4. In ATP 688 the primary target are the Moranbah Coal measures which are intersected in drill holes approximately 150 m bgl.

**Table 4 Generalised stratigraphic sequence of northern Bowen Basin (*after Reeves and O'Neil, 1989 and QCoal, 2010*)**

| Age | Formation | Sub Unit |
|---|---|---|
| Quaternary | | Alluvium |
| Tertiary | | Duaringa Formation, Sutton Formation, Basalt |
| Triassic | | Moolayember Formation |
| | Clematis Group | Expedition Sandstone |
| | | Glenidal Formation |
| | Rewan Group | Arcadia Formation |
| | | Sagittarius Formation |
| Late Permian | Backwater Group | Rangal Coal Measures |
| | | Fort Cooper Coal Measures |
| | | Moranbah Coal Measures |
| Middle Permian | Back Creek Group | Exmoor Formation |
| | | Blenheim Formation |

The most prominent structure in the project area is the steeply dipping eastern flank of the Bowen Syncline. It is outlined by the Back Creek Group, striking north-northwest, and dipping to the west- southwest at angles of 40° or more. The axis of the syncline is in the eastern part of the project area. Here, the syncline is characterised by great thickness of sediment and strong folding. Mesozoic granite intrusion just east of the Blackwall Range, separates this area from the older lower Permian volcanics which form the basement. Further to the south and southeast of the project area the Triassic Rewan and Clematis group outcrop.

The regional tectonic setting of the Bowen Basin is compressive, characterised by numerous folds and thrust faults developed during the Triassic Hunter-Bowen Orogeny (Gilliam, 2004). The Jellinbah thrust fault system is a major north to south striking fault system that runs along the length of the Bowen Basin, with maximum throw in the order of 600 to 800 m (Gilliam, 2004). A series of subsidiary thrust faults occur within the project area. The fold and fault axis in the project area generally trends north-northwest, which is parallel to the regional Bowen Basin trend and axis of Bowen Syncline to the east.

The geological cross section (Figure 5) indicates the dipping of the layers and the whole sedimentary sequence towards the axis of the syncline at around 10 to 30 degrees, and the presence of SW to NE trending faults in the area.

## 4.2 Hydrogeological Setting and Aquifer Descriptions

CDM Smith (2013) conceptually divides the sub-surface beneath ATP 688 into four distinct hydrostratigraphic units (HSUs). From the youngest to the oldest the units comprise:

1. Tertiary basalt and minor Quaternary alluvium;
2. Triassic Clematis Group and Rewan Formation;
3. Permian Blackwater Group including Rangal, Fort Cooper and Moranbah Coal Measures; and
4. Lower Permian Back Creek Group.

On a regional scale, the Triassic and Permian sediments are generally not regarded as a significant groundwater resource. The fractured sandstone interbeds and coal seams have generally higher competence and permeability than the interburden material. The most productive aquifers locally are the Quaternary alluvium and the Tertiary basalt.

Within ATP 688, the superficial unconsolidated alluvium and the Blackwater Group are the most significant formations. All formations except the Quaternary alluvium are consolidated.

### 4.2.1 Tertiary Basalt and Quaternary Alluvium

CDM Smith (2013) report the alluvium is typically associated with present day channels and flood plains, comprising layers of fine grained highly transmissive material. The oldest alluvial plains have been partially dissected to form gently rolling country. Monitoring data suggest the alluvial aquifer is unconfined and connected to surface water features such as streams and rivers. Based on the available data from well stratigraphic logs, the thickness of the alluvium is generally between 10 m to 30 m.

The basalt appears to be less weathered in the eastern part of the project area, but this may reflect greater erosion, such that the weathered upper parts have been removed. In this area, the basalt represents one of the major aquifers. Flow through the basalt occurs mainly via fractures therefore, this aquifer system has considerable local variability between vertical and horizontal conductance. Assigning a bulk unit average value is considered appropriate for this project. The primary source of water to the aquifer results from rainfall recharge and surface water features act primarily as discharge points, with localised variations due to topographic elevation. The thickness of this unit is typically around 20 m.

### 4.2.2 Triassic Clematis and Rewan Formations

The Lower to Middle Triassic Clematis sediments comprise mainly quartz sandstone with minor siltstone and mudstone. They form a major aquifer within the Great Artesian Basin but locally this is a less reliable source of water due to increasing depth of cover and small outcropping area. Flow via primary porosity is limited, with most flow occurring through fractures. Within a regional framework, a single horizontal and vertical hydraulic conductivity can be assigned to represent the flow domain. The average porosity of the sandstone is reported to be 21% (Gray, 1968). The thickness of this unit is about 150 m at the eastern edge of Bowen Basin, but does not appear in ATP 688 and is not represented in the numerical model.

The Lower Triassic Rewan Formation comprises argillaceous mudstone, siltstone and labile sandstone and is generally believed to have low permeability due to diagenesis (Bashari, 1998). Gray (1968) reports the average porosity of the sandstone in the Rewan Formation is 16 to 17%.

Although both formations are represented across ATP 688, neither outcrops significantly in the area.

### 4.2.3 Permian Blackwater Group

The Blackwater Group hosts the economically important Late Permian fluviatile to fluvio-deltaic coal-bearing sediments of the Bowen Basin: Rangal, Fort Cooper Coal Measures (FCCM) and Moranbah Coal Measures (MCM) in stratigraphic order from youngest to oldest. The thickness of the Blackwater Group exceeds 1500 m at the axis of the Bowen syncline, with FCCM approximately 400 m thick and MCM 250-300 m thick in the project area. The coal measures comprise consolidated, very low permeability interbedded layers of sandstone, siltstone, carbonaceous shale, coal, locally cherty mudstone, and minor conglomerate. These interbedded layers are very poor at transmitting and storing water, and therefore are not used in the area for stock or domestic purposes.

The coal seams within the MCM, from oldest to youngest, are referred to as A Seam, B Seam (Lower Goonyella), C Seam, E Seam (Middle Goonyella), P Seam, P Rider and Q Seam (Upper Goonyella) (QCoal, 2010). The coal seams of interest present within the project area are the A Seam, B seam, P Seam and Q Seam. The E seam is thin and/or discontinuous in the test areas and has been omitted from the model; the E seam thickness is incorporated into interburden thicknesses.

### 4.2.4 Lower Permian Back Creek Group

Two Lower Permian formations are significant in the ATP 688 region and form the Back Creek Group. The basal formation is the Lizzie Creek Volcanics comprising black shale and siltstone characterised by a hard-siliceous appearance, and form massive outcrops along the eastern margin of project boundary. This unit represents the low permeability basement within the project area.

Overlying the Lizzie Creek Volcanics is the Exmoor Formation. It consists of sandstone, siltstone, and mudstone with rare marine fossils (Draper, 1985a and b).

### 4.2.5 Hydrogeological Properties

A limited amount of permeability testing has been undertaken over the project area, and has mostly targeted the coal seams. For other HSUs, the data was obtained from literature and recent EIS studies in the Bowen Basin. A summary of values is provided in Table 5 along with the source of information. For this table, the relative conceptual behaviour of the hydrostratigraphic units in the lease area has been considered when identifying the formation type.

**Table 5 Summary of hydraulic properties for the major HSUs in the Bowen Basin (after CDM Smith 2013)**

| Formation | Type | $K_h$ [m/d] | $K_v$ [m/d] | T [$m^2$/d] | Sy [-] | Ss [-] | Data Source |
|---|---|---|---|---|---|---|---|
| Quaternary Alluvium | Aquifer | 1 to 40 | 0.2-2 | | 0.05-0.18 | 0.0005 | 2 |
| | | 100 | 10 | | 0.25 | 0.001 | 1 |
| | | 0.7-1.5 | | 6 to 15 | | | 3 |
| | | 10 | 1 | | 0.2 | 0.0001 | 7 |
| | | 0.088-0.38 | | | | | 5 |
| Tertiary Basalt | Aquifer | 0.005-0.19 | | | | | 5 |
| | | 0.05 | 0.005 | | 0.05 | 0.00005 | 2 |
| Clematis Sst | Aquifer | 5-438 | | | 0.2 | | 8 |

| Formation | Type | $K_h$ [m/d] | $K_v$ [m/d] | T [$m^2$/d] | Sy [-] | Ss [-] | Data Source |
|---|---|---|---|---|---|---|---|
| Rewan Formation | Aquitard | 0.00001 to 0.0001 | 0.000001 to 0.00001 | | 0.005 | 0.000001 | 1 |
| | | 0.00075 | 0.0000001 | | 0.05 | 0.00005 | 2 |
| | | 0.1 | | | 0.05 | 0.000005 | 6 |
| Fort Cooper Coal Measures, Moranbah Coal measures and Rangi Coal Measures | Coal Seams, Aquifers | 0.0028 to 0.47 | | 0.008 to 1.9 | | | 4 |
| | | | | 0.3 to 178.6 | | | 3 |
| | | 0.000001 to 1 | 0.000001 to 1 | | 0.01 | 0.000001 | 1 |
| | | 0.000041 to 0.16 | 0.0000083 to 0.082 | | 0.01 | 0.0000002 | 2 |
| | | 0.111-0.9 | | | 0.08 | 0.0004 | 7 |
| | | 5 | | | 0.05 | 0.000005 | 6 |
| | Interburden Aquitard | 0.0001 | 0.00000007 | | 0.05 | 0.00001 | 2 |
| | | 0.1 | | | 0.05 | 0.000005 | 6 |
| Back Creek Group | | 0.01-0.001 | 0.001 to 0.00001 | | 0.03--0.18 | 5E-4 to 5E-6 | 9 |

Source of data is 1: AGE (2006), 2: Ausenco-Norwest (2012), 3: JBT (2012), 4: Parsons Brinckerhoff (2011), 5: URS (2009), 6: BHP Billiton Mitsubishi Alliance (2009), 8: GSQ (1968), 9: URS (2012).

## 4.3 Conceptual Hydrological Model

### 4.3.1 Groundwater Flow Directions

There is a total of 403 DEHP registered bores within 10 km of the ATP 688 boundary, completed in different aquifers. The bore locations are shown on Figure 2. Bores located near the active area in ATP 688 are presented in Appendix A. Of the total number of registered bores within the 10 km of the ATP 688 boundary, only 64 bores have installation details and depth to water measurements. For these bores, the ground elevations were interpreted from a detailed topographic contour map, and the groundwater level calculated by subtraction from the elevation. The accuracy is within ± 2m which is considered acceptable for this project.

CDM Smith (2013) noted that the water levels used to provide the base conditions have been acquired over an extended period and depth to water is assumed to be measured from an interpolated ground surface. Therefore, the data may not reflect current conditions and cannot be considered to have high accuracy. Nevertheless, the general flow directions in some aquifers can be interpreted based on the available information.

Within the shallow alluvium, water level elevations from different alluvial systems were mapped. The contoured water table reflects topographic elevations and the flow is associated with the valley alluvium. Available water level time-series data for the Alluvial aquifer is shown in Figure 6.

Insufficient groundwater data are available to contour potentiometric surfaces for other deeper units, such as the Blackwater Group, within the project area. Data available from further south of the project area indicates a decline in potentiometric head within the Blackwater Group over the period 2007 to 2008, with a drop of over 5 m. Based on the available information in the deeper Tertiary and Permian units, the general groundwater flow direction is from the northwest to the southeast.

### 4.3.2 Aquifer Recharge and Discharge

Recharge to shallow alluvium occurs directly via rainfall recharge, with small volumes of leakage from the losing/ephemeral stream systems. Groundwater in the shallow alluvial aquifer is most likely connected to surface water drainage system. Vertical leakage and through-flow from the basalt aquifer may also contribute to groundwater recharge of the shallow alluvial aquifer.

Groundwater recharge to Triassic and Permian units occurs via direct recharge where these units crop out or are covered by a thin veneer (<5m) of surficial sediments over the central and southern regions of the project area. Where these are covered by younger basalt flows and Tertiary units, vertical leakage is possible.

The cumulative departure from mean rainfall (CDMR) method is often used to identify whether observed water level fluctuations are due to rainfall recharge or other processes. CDMR is the accumulated difference between the actual rainfall recorded (e.g. in a month or a year) and the long-term mean. If there is poor correlation between groundwater level hydrographs and the CDRM, it may be concluded that rainfall recharge is not significant, or that some other recharge processes are dominant (e.g. regional inflow, upward leakage from the deeper aquifer systems etc.).

The closest Bureau of Meteorology (BoM) rainfall station (Station number 033013) is located at Collinsville. The mean rainfall is 718.5 mm over the period of record from 1939 to 2013 (BoM, 2013b). The data from this station was used in the CDMR analysis, along with long term groundwater level data from four bores completed in the shallow volcanic and Back Creek group aquifers. These bores are located outside ATP 688, in the southern part of the ATP coverage.

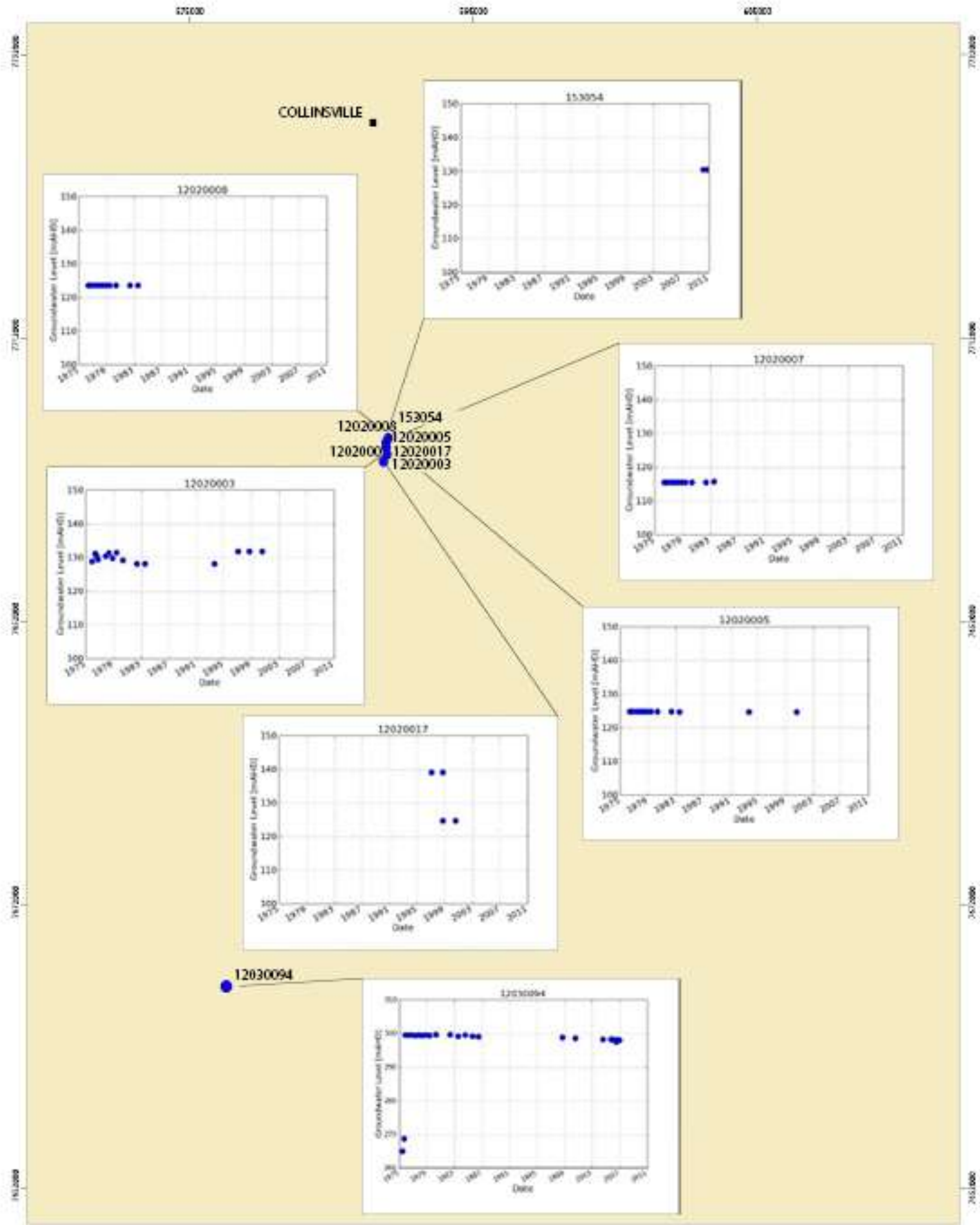


**Figure 6 Available water table hydrograph data (after CDM Smith 2013)**

The hydrographs available for the shallow volcanic and Back Creek Group bores have been plotted with yearly rainfall residual mass in Figure 7 to show the dependency of water levels on rainfall. The data for registered bores installed in the Back Creek Group indicate that the changes in shallow water levels are minor and the fluctuations over the past seven years have not exceeded 1-2 m on average. Bore 13040281, installed in basalt, shows a good correlation with rainfall trends exhibiting a rise in the standing water level of about 10 m following the period of higher than average rainfall during 2008 to 2013 and slight declines from 2013 to 2017 in response to a period of lower mean monthly rainfall. The water table in this unit is a subdued representation of topography and is controlled by evapotranspiration in low lying areas.

Trends in the observation bore 13040283 show a rising water level from 2013 to 2017, counter to the below average rainfall over the corresponding period. This trend may result from a greater thickness of the overburden therefore infiltration takes considerably longer (>4 years) to reach the aquifer. Alternatively, the recovery in groundwater levels recorded in bore 13040283 may be associated with a lower pumping demand from this aquifer in the immediate area.

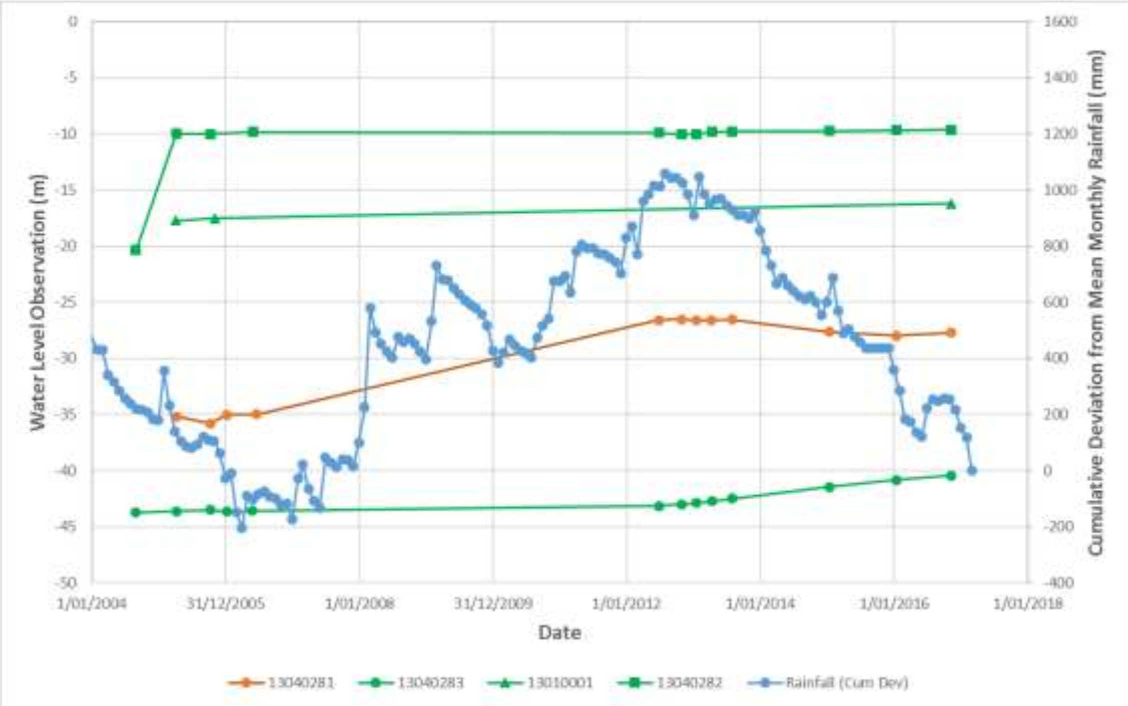


**Figure 7 Cumulative departure from mean rainfall analysis for four bores where aquifer is known (after CDM Smith 2013)**

The main groundwater discharge processes are regional lateral flow along hydraulic gradients, and evapotranspiration in addition to other minor discharge processes such as groundwater pumping.

### 4.3.3 Groundwater Level Trend Analysis

Limited data is available to enable analysis of the long-term groundwater trends within ATP 688 or nearby areas. Some analysis of trends has been provided in section 4.3.2. Around the lease area, temporal sequences of water level observations are available in a few cases, but the screened aquifer interval is not listed. For the most part, water level trends are stable over time and vary by less than 2 m.

### 4.3.4 Aquifer Connectivity

Northwest to southeast trending faults run through the project area resulting from tectonic activities after the Early Permian (Silwa et al. 2008). These faults exhibit significant throw and are thought to act as barriers to groundwater flow east-west across the faults. A review of groundwater levels in monitoring water bores on each side of the fault in the project area was inconclusive in determining whether the faults truly are sealing, as insufficient data exists.

Connectivity between underlying and overlying aquifers has not been assessed through pumping tests nor detailed isotopic analysis or hydrogeochemical characterisation. Generally, the shallow alluvial aquifer is separated from the Blackwater Group Coal Seams by low conductivity interburden and in some locations by the intervening Triassic formations. Review of water level observations was inconclusive, as many bores unfortunately do not list the screened interval or aquifer unit over which they have been completed.

### 4.3.5 Summary

The hydrogeological characterisation for ATP 688 can be summarised by the following key points, with reference to Figure 4a, Figure 4b and Figure 5:

- The sedimentary sequence comprises four hydraulic units (superficial Quaternary/Tertiary, Triassic, Permian coal seam groups, and lower Permian) with various hydraulic conductivities.
- The older Permian units outcrop over the central and northern part of ATP 688, while the Triassic units occur to the south.
- The presence of the Bowen Syncline in the centre of ATP 688 results in the whole sedimentary sequence dipping relatively steeply towards the syncline axis at about 10 to 30 degrees.
- The project area is bound to the northeast by the Collinsville Fault which extends along a north south axis (like other structures in the Bowen Basin), and further south by Cretaceous granite intrusions.
- To the west, the basement Carboniferous Bulgonunna Volcanics outcrop. Formations are strongly offset across faults and it is considered that the major faults represent barriers to groundwater flow.
- Groundwater flow in the low permeability Triassic and Permian strata is relatively slow and has long residence times; therefore, the groundwater quality is generally poor as the water slowly flows through the rock dissolving soluble salts. Available groundwater data indicate that the groundwater in the Permian and Triassic strata is saline.
- Groundwater flow in the shallow basalt and alluvium follows the topography. The flow in the Blackwater group is in a south-easterly direction. This interpretation is based on data collected over different time periods and within the outcrop zone only, and may not be entirely accurate.
- Water level contouring of the heads in alluvium and basalt demonstrates that heads correlate with topography, indicating recharge at higher outcrop areas and discharge at low-lying areas.
- In areas where the Permian strata outcrops and are not overlain by alluvium or basalt, the aquifer is unconfined to semi-confined. With depth, underlying units such as the Rewan Formation and Coal Measures become confined.
- The shallow aquifer system is recharged mainly through rainfall infiltration. Groundwater recharge occurs in areas of high relief where strata outcrops, as well as through better drained soils in the mid and lower slopes and in the valley where Permian rocks subcrop. Deeper hydrogeology units are recharged where they crop out at surface.
- Where the water table is shallow (<5 m bgl), evapotranspiration is considered a major aquifer discharge process.
- The aquifers which are most likely to be affected by underground water extraction include the Permian coal seams where pumping occurs, and the overlying superficial alluvial and basalt aquifers.

# 5 Part C: Predicted Impacts for Affected Aquifers

## *5.1 Modelling Methodology*

Numerical groundwater modelling has been undertaken to provide estimates of decline in water level in response to the extraction of groundwater associated with pilot testing in ATP 688. The focus of the modelling is to identify aquifers likely to be affected by CSG pumping including impacts which occur above trigger drawdown levels in the Immediately Affected Area and Long Term Affected Area. The model developed by CDM Smith (2013) has been used to support this updated UWIR and the methodology and approach is largely reproduced from the UWIR for ATP 688, 2013.

### 5.1.1 Modflow-Surfact

The groundwater modelling package MODFLOW-SURFACT (Hydrogeologic Inc., USA) was selected to construct the required numerical model. SURFACT is an enhanced version of MODFLOW developed by the United States Geological Survey. MODFLOW is the most widely used code for groundwater modelling and is considered an industry standard.

The requirement of MODFLOW to retain laterally continuous model layers can result in numerous thin and mostly dry cells that can be problematic in areas where the water table extends across multiple layers, particularly in areas of steep topographic gradient. SURFACT is chosen in this study because it is better able to simulate these conditions and provides better numerical stability. SURFACT incorporates additional computational modules to enhance the simulation capabilities and robustness. The additional features include:

- The modelling of variable saturation conditions (allowing for complete desaturation conditions) thus avoiding dry-cell problems.
- Fracture porous media simulation with dual porosity.
- An adaptive time-stepping scheme automatically adjusts time-step size to the non-linearities of the system to optimize the solution stability.
- Prevents water table build-up beyond a specified recharge-ponding elevation.
- More robust and efficient PCG matrix solver.
- Comprehensive mass budget based on mass-conserving algorithm.
- Available time-varying properties for hydraulic conductivity and storativity.

For predictive simulation, a pseudo-steady state model was constructed and calibrated to verify model conceptualisation and attain reasonable parameter ranges aligned with field measurements. The outcome of the steady-state model was used as initial conditions for the transient predictive model. Uncertainty analysis was conducted for predictive simulations through several predictive simulations to further quantify impacts from parameter uncertainty.

### 5.1.2 Model Domain

Numerical groundwater modelling was completed in the region surrounding the active exploration areas within ATP 688, where current and planned activities are focused. The model has been constructed to focus on potentially affected aquifers and to present conservative (worst-case) results. As the Bowen Basin is a syncline, the model domain was selected to encompass the outcrop of the Moranbah Coal Measures and the overlying superficial sediments (refer Figure 4a).

Significant faulting occurs in the region and sediments to the east of the faults are upthrown. In the east of ATP 688, the large faults are conceptually assumed to act as no-flow barriers and bound the active model domain, as no Coal Seam Gas production or testing occurs east of the fault. In the centre of the model domain, a mid-Triassic thrust fault extends through the active region. The south-eastern boundary of the transfer zone between the middle and eastern bounding faults has been selected to act as a conservative no-flow barrier. This no-flow assumption will cause the model to predict the largest drawdown in the immediate area of the production testing bores, as additional extraction water cannot be obtained from surrounding formations on the opposite side of the faulting.

### 5.1.3 Model Grid

The model domain covers a total area of 3,149 $km^2$ and has an active area of 1,622 $km^2$. The model grid comprises 67 rows, 47 columns and 18 layers, giving a total of 56,682 cells (29,196 active cells). The grid and associated boundary conditions is shown in Figure 8. A uniform column and row spacing of 1 km is assigned. The model grid discretisation is coarse and is considered commensurate with the current understanding of the site hydrogeology. Refinement of the model grid is not considered warranted at this stage as it would not be expected to increase the confidence level of model predictions without additional site specific data.

### 5.1.4 Model Layers

The distribution of model layers is designed to approximate the presence of key geological structures and their control on the regional groundwater flow system. These include north-south striking, low angle thrust faults and associated duplication of stratigraphy.

A significant fault is aligned along a northwest - southeast axis through the model domain. Considerable geologic offset occurs across this unnamed mid-Triassic thrust fault. The presence of low angle thrust faults is simulated using separate model layers to represent the duplication of the same hydrostratigraphic units. Due to the requirement of SURFACT to maintain laterally continuous layers, a larger number of “dummy” layers with reduced thickness are generated in areas where the hydrostratigraphic units are interpreted to terminate against the faults or pinch out.

The hydrostratigraphic units represented by each of the 18 model layers are summarised in Table 6. The term “pinched out” refers to where the model layer is reduced to a minimum thickness.

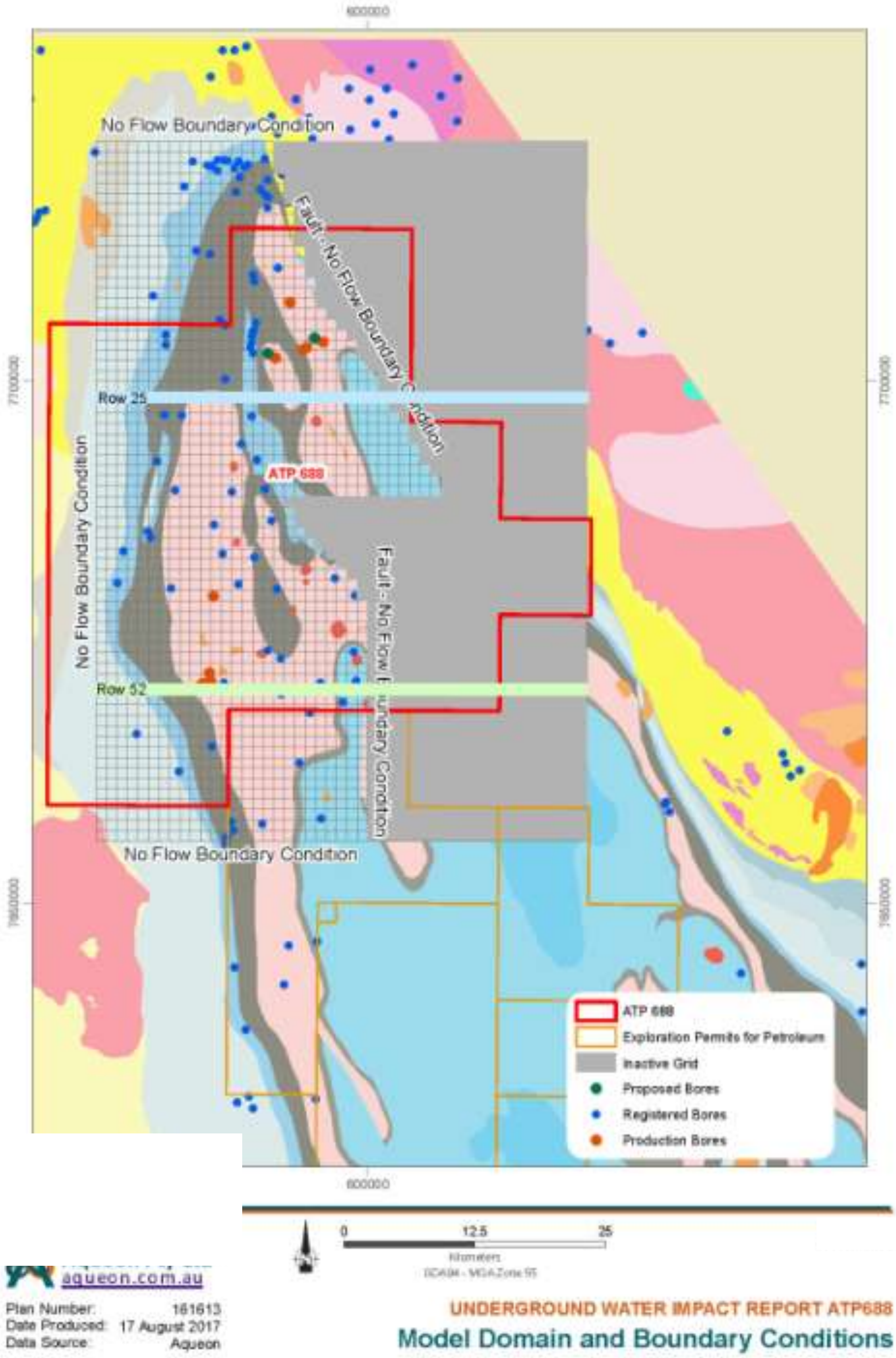


**Figure 8 Model Domain and Boundary Conditions**

Table 6 Stratigraphic representation in model layers

| Layer | Stratigraphic Unit | |
|---|---|---|
| | West of Fault | East of Fault |
| 1 | Alluvium/Basalt | Alluvium/Basalt |
| 2 | Pinched out | Rewan Formation<br>Blackwater Group (Moranbah / Fort Cooper / Rangal Coal Measures) above Upper Goonyella Coal Seam |
| 3 | Pinched out | Upper Goonyella Coal Seam |
| 4 | Pinched out | Interburden 1 |
| 5 | Pinched out | P Seam |
| 6 | Pinched out | Interburden 2 |
| 7 | Pinched out | Lower Goonyella A Coal Seam |
| 8 | Pinched out | Interburden 3 |
| 9 | Pinched out | Lower Goonyella B Coal Seam |
| 10 | Pinched out | Interburden 4 |
| 11 | Interburden 1 | Back Creek Group (Exmoor) |
| 12 | P Seam | Back Creek Group (Exmoor) |
| 13 | Interburden 2 | Back Creek Group (Exmoor) |
| 14 | Lower Goonyella A Coal Seam | Back Creek Group (Exmoor) |
| 15 | Interburden 3 | Back Creek Group (Exmoor) |
| 16 | Lower Goonyella B Coal Seam | Back Creek Group (Exmoor) |
| 17 | Interburden 4 | Back Creek Group (Exmoor) |
| 18 | Back Creek Group (Exmoor) | Back Creek Group (Exmoor) |

To determine the extent of the Goonyella aquifers, a combination of the geological map and available borehole logs from Mount St Martins and Tilbrook gas wells were used to infer the base of the Moranbah Coal Measures. The borehole logs were averaged to determine the thickness of the associated coal seams and the interburden, which were laid on top of the MCM base. The model includes four coal seams of interest to the project and their assumed thickness to the west and east of the faults is summarised below. The stratigraphic pile was then filled in with the overlying interburden and Rewan Formation. The horizontal extent of the coal seam aquifer is shown in maps of the predicted drawdown (refer Section 5.2).

The top layer of the model is intended to represent the water table aquifer, comprising alluvium and Tertiary basalt. A uniform thickness of 20 m is assumed for this layer, based on bore log stratigraphy. The unconsolidated aquifer extends across the entire model domain. Figure 9a and Figure 9b present model cross sections, where the locations of the cross sections are indicated in Figure 8. The cross section, Figure 9a shows numerical representation of the duplication of hydrostratigraphic units associated with thrust faulting.

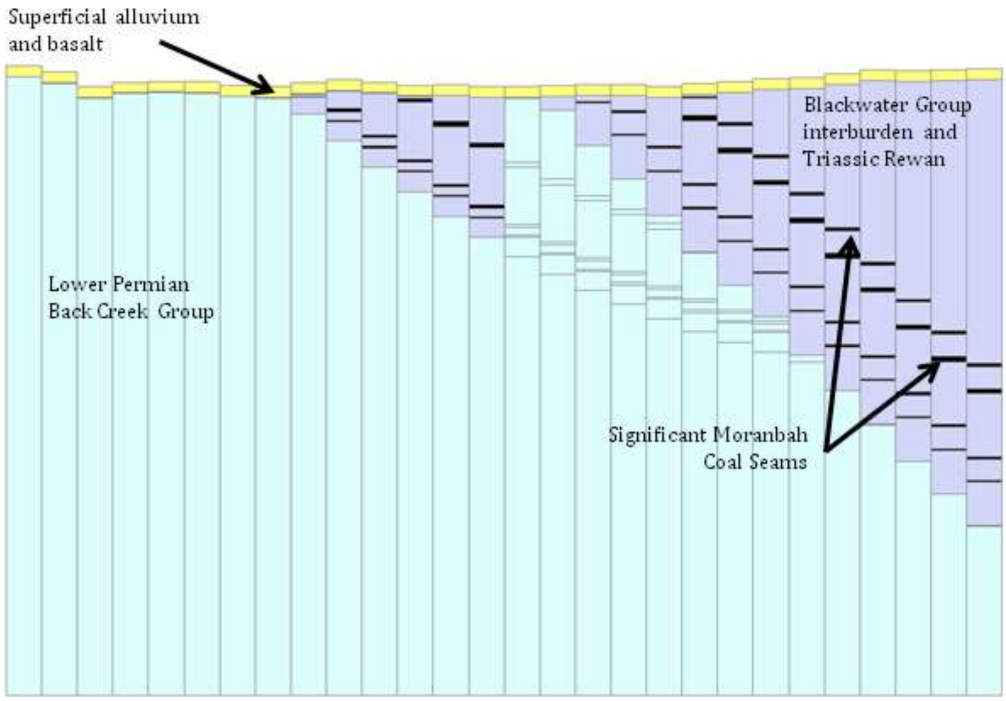


**Figure 9a Cross sections through the model domain Mt. St Martins gas field (row 25)**

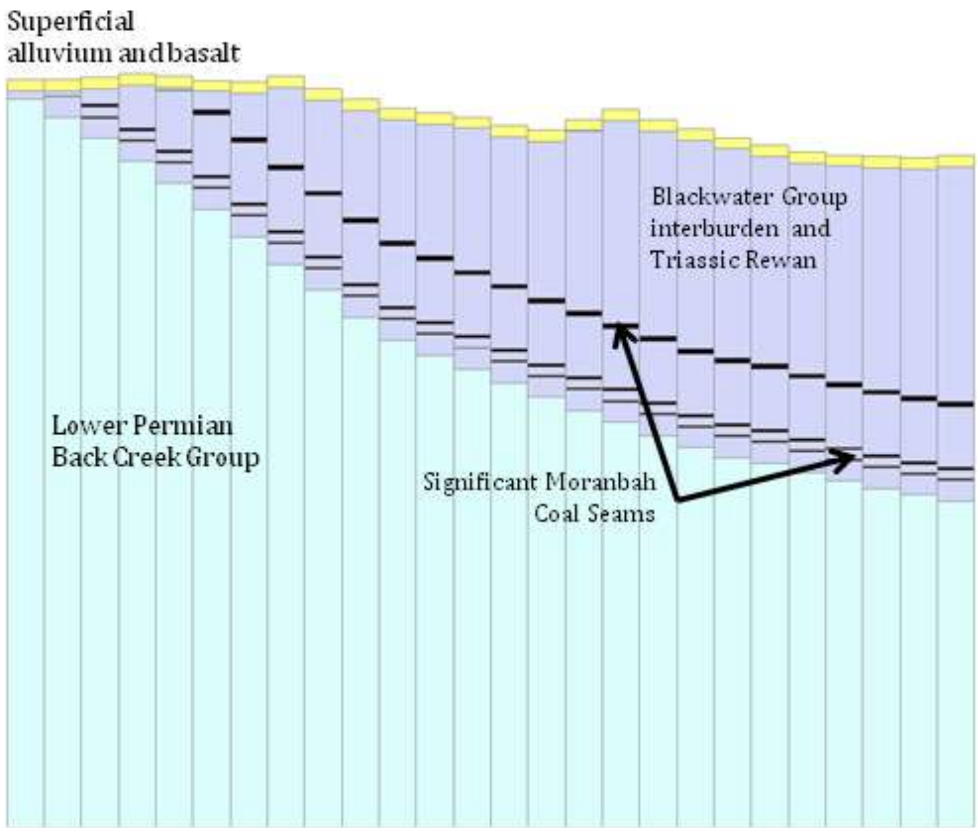


**Figure 9b Cross section through the model domain Tilbrook gas field (row 52)**

**Table 7 Coal seam and interburden thickness in Moranbah Coal Measures**

| Layer | Thickness | |
|---|---|---|
| | West | East |
| Upper Goonyella Coal Seam | Absent | 8 |
| Interburden 1 | Absent | 40 |
| P Seam | 10 | 10 |
| Interburden 2 | 107 | 117 |
| Lower Goonyella A Coal Seam | 6 | 6 |
| Interburden 3 | 15 | 40 |
| Lower Goonyella B Coal Seam | 4 | 4 |
| Interburden 4 | 36 | 81 |

### 5.1.5 Boundary Conditions

A no flow boundary condition is assigned around the perimeter of the model. It is assumed that there is limited hydraulic connection across the fault to the east of the Mount St Martins and Tilbrook gas field, as shown in Figure 8. The assumption of no flow boundary is conservative and is considered appropriate given the uncertainty in the site hydrogeology and broader hydrogeology beyond the model domain.

A uniform recharge rate of 36.5 mm/a is assigned to the uppermost active cells to represent the background rainfall derived recharge, which represents 5% of average annual rainfall (BoM, 2013a). Evapotranspiration is simulated using MODFLOW's Evapotranspiration (ET) Package. An ET rate of 2 m/a. was assigned to the top layer of the model with an extinction depth of 5 m. The evaporation rate is like the annual areal potential rate of 1.8 m/a. (BoM, 2013b).

The implication of the selected boundary conditions is that under baseline conditions, all the recharge into the model is balanced by ET. Any water removed from simulated production activities will derive from aquifer (and bounding aquitard) storage. The volume of water removed by ET will change if the simulated production activities result in drawdown at the water table where the water table lies within the specified ET extinction depth. Hence these boundary conditions create a conservative model where CSG production will directly impact water levels.

### 5.1.6 Calibration

The available groundwater level data indicate that the water table is a subdued reflection of topography, with recharge occurring in areas of topographic high and discharge in areas of topographic low. The interpreted groundwater flow direction is to the north. Few groundwater level data from deeper hydrostratigraphic units were available for calibration.

The groundwater table elevation as simulated in the model at the end of 2012 is shown in Figure 10. Calibration to 2012 groundwater levels has been used to be consistent with the initial 2013 UWIR. The topographical control on the baseline water table is simulated by ET.

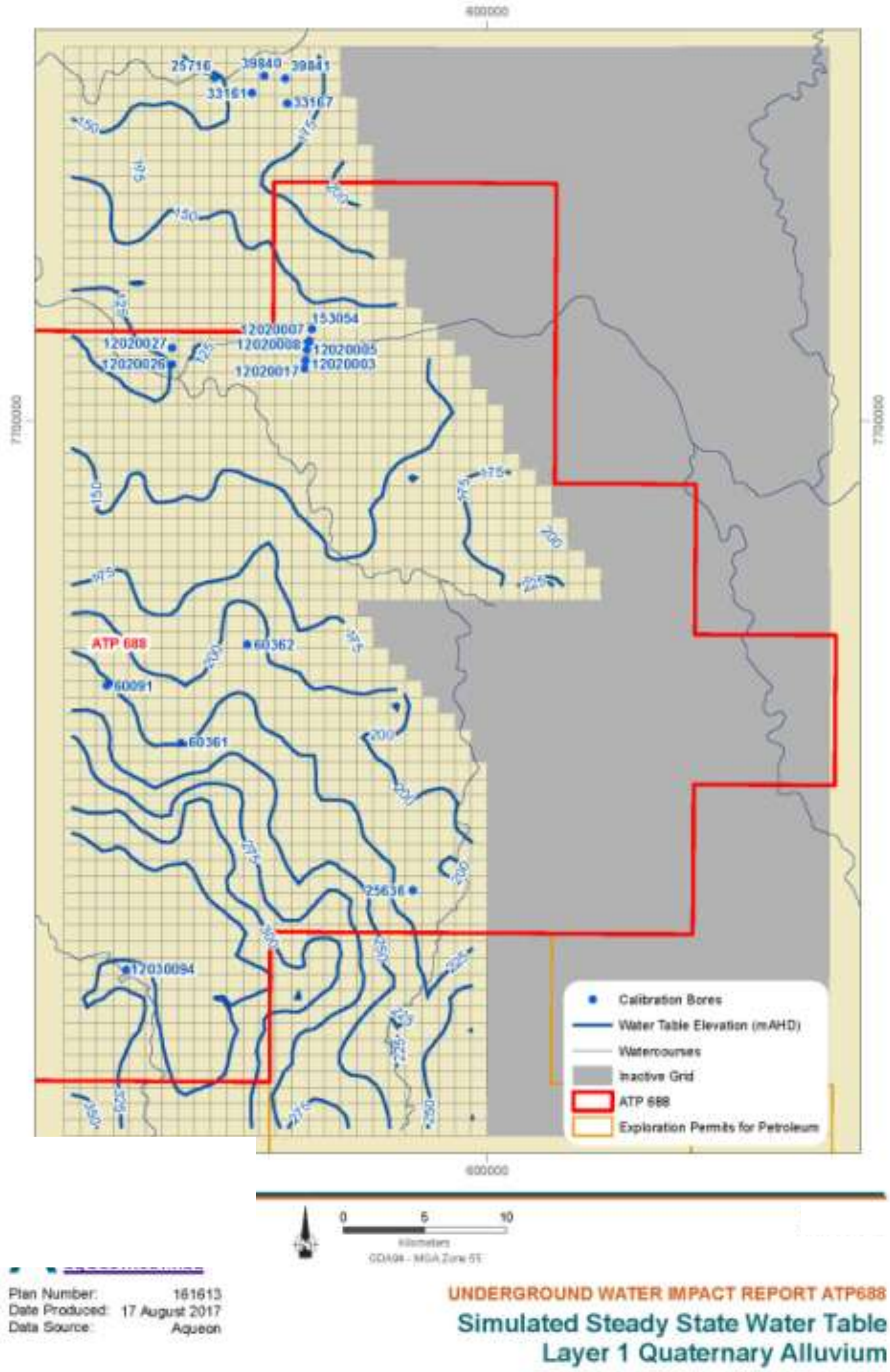


**Figure 10 Simulated Steady State Water Table Layer 1 Quaternary Alluvium**

Due to the choice of boundary conditions, the simulated water table is not strongly sensitive to the assumed hydraulic properties and does not assist in constraining the hydraulic properties. Rather, the objective of the steady state calibration presented here is to establish a set of initial conditions for predictive simulations that are consistent with the available hydraulic head information and assumed hydraulic properties.

Figure 11 presents the scatterplot of observed hydraulic head against simulated hydraulic head for the steady state model. No transient model calibration was undertaken as part of this assessment due to insufficient observed data.

The calibration statistics (RMS Error = 14.8% and residual mean = -13.46) result in a good fit between the observed and predicted water levels indicating that the model is fit for the intended purposes. The mass balance of the steady state calibration model reports total inflows from recharge of 162200 m3 and total outflows from evapotranspiration of 162209 m3 for the entire model domain. This is a very low discrepancy of 0.006% and is considered acceptable for this model.

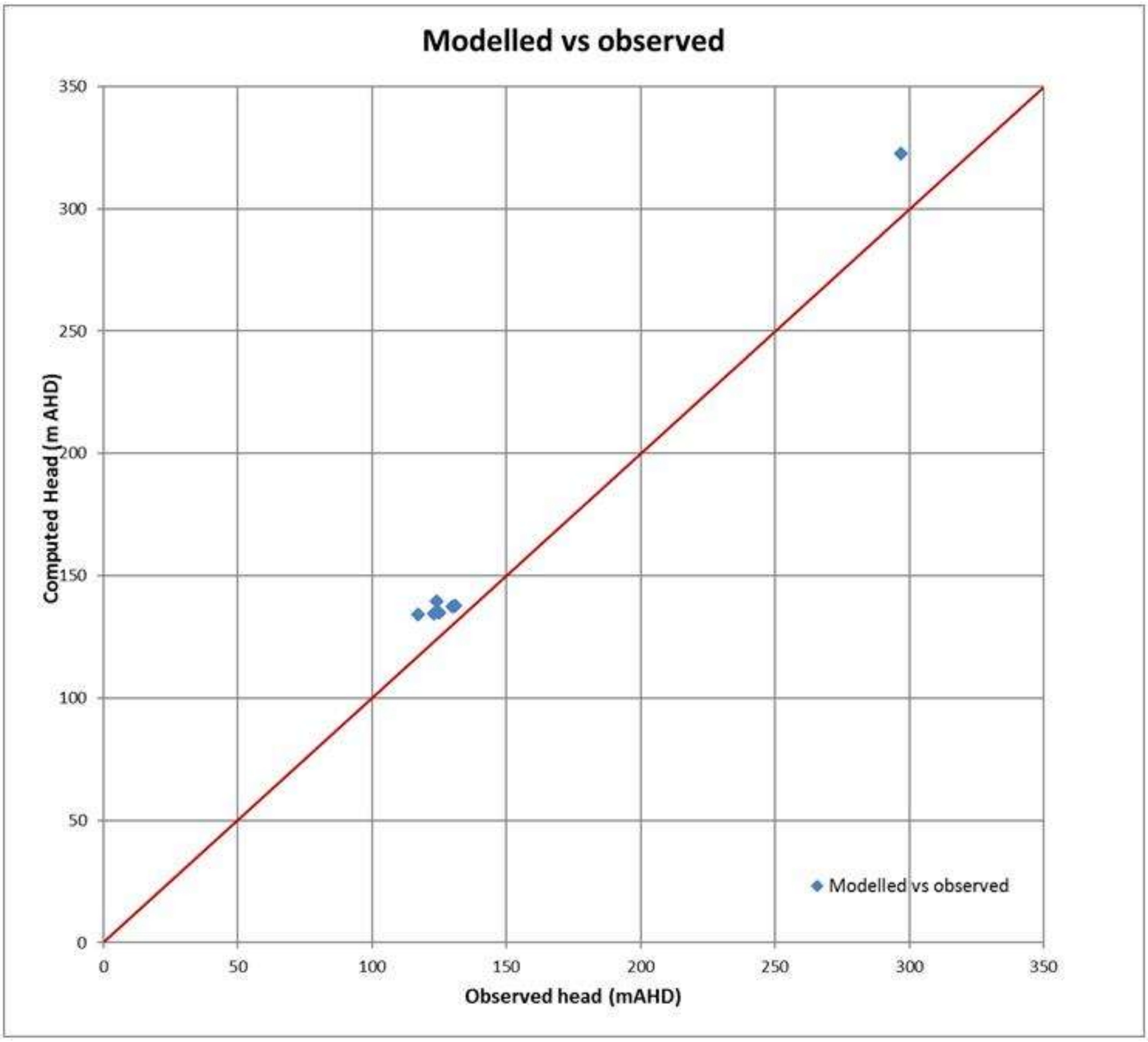


**Figure 11 Calibration scatterplot of simulated hydraulic head versus observed hydraulic head for steady state model**

The calibrated estimates of hydraulic properties are presented in Table 8. All values fall within the range presented in Table 5 Section 4.2.5.

**Table 8 Calibrated model hydraulic properties**

| Unit | $K_H$ (m/d) | $K_V$ (m/d) | $S_S$ | $S_y$ |
|---|---|---|---|---|
| Alluvium / Basalt | 1 | 0.1 | $1 \times 10^{-6}$ | 0.05 |
| Interburden | $1 \times 10^{-4}$ | $1 \times 10^{-5}$ | $1 \times 10^{-6}$ | 0.01 |

| | | | | |
|---|---|---|---|---|
| Coal Seams (Upper Goonyella Seam, P Seam, Lower Goonyella A and B Seams) | 0.05 | 0.005 | $1 \times 10^{-6}$ | 0.01 |
| Back Creek Group | $1 \times 10^{-4}$ | $1 \times 10^{-5}$ | $1 \times 10^{-6}$ | 0.01 |

### 5.1.7 Prediction Methodology

The predictive simulations consider the potential impacts to groundwater due to the proposed production testing program. The coal seams are interpreted to subcrop beneath the alluvium/basalt to the west, following the surface of fault planes. The production tests will drawdown the water levels within the targeted coal seams and bounding hydrostratigraphic units. Possible pathways of drawdown impacts to the water table include lateral flow via coal seams and vertical flow via overburden.

The transient model covers the period from 2008 onwards. The initial conditions are the steady- state water levels described in Section 5.1.6. Historical produced water (Table 2), as described in Section 3.1, is included in the transient model. With the cessation of pumping, post 2010 zero values for water produced have been assigned to each production well in the model for the period 2011 to 2016 (Table 3). Table 1 lists those exploration wells that have been plugged and abandoned across ATP 688 and therefore these wells have not been included in the modelling as active.

There are no immediate plans to resurrect exploration activities in ATP 688 for the purposes of this model. However, a production testing program comprising seven gas wells in the Mount St Martins gas field and three gas wells in the Tilbrook gas field has been applied (Table 9). Testing is assumed to recommence in both the Mount St Martins and Tilbrook gas fields in 2017. Production testing at both gas fields is simulated to the end of 2019 at an average estimated water production rate of 13 $m^3$/d (kL/d) for each well except for Tilbrook 7 and 9. The water production rates are averaged derived from the historical pumping rates described in Table 2.

Water production from gas wells is simulated using MODFLOW's WELL package by prescribing the production rate. The wells are assumed to be fully screened across the thickness of the target coal seams. It is understood that some, if not all, of the proposed production wells will be completed as horizontal wells, extending some 600 to 700 m laterally into the target coal seams. This length is less than one cell discretisation. Whilst it is recognised that the lateral extensions may traverse across cell boundaries, the use of vertical well is considered sufficient for simulating the regional effect of water production due to the coarse grid discretisation adopted in this assessment.

**Table 9 Projected average water production rates in 2017 to 2019 (kL/year)**

| Well | Easting | Northing | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|
| Mount St Martins 2 | 595719 | 7703783 | 4,770.9 | 4,770.9 | 4,770.9 |
| Mount St Martins 4 | 591205 | 7702246 | 4,770.9 | 4,770.9 | 4,770.9 |
| Mount St Martins 3 | 593824 | 7703118 | 4,770.9 | 4,770.9 | 4,770.9 |
| Mount St Martins 1 | 594168 | 7703291 | 4,770.9 | 4,770.9 | 4,770.9 |
| Mount St Martins 5 | 592560 | 7707579 | 4,770.9 | 4,770.9 | 4,770.9 |
| Mount St Martins 04L2[1] | 590406.7 | 7702730.5 | 4,770.9 | 4,770.9 | 4,770.9 |
| Mount St Martins 04L1[1] | 594931 | 7704194.7 | 4,770.9 | 4,770.9 | 4,770.9 |
| Tilbrook8 | 584934 | 7671295 | 4,770.9 | 4,770.9 | 4,770.9 |

| Well | Easting | Northing | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|
| Tilbrook 7 | 584642 | 7671022 | 1,176.4 | 1,176.4 | 1,176.4 |
| Tilbrook 9 | 584874 | 7672065 | 1,176.4 | 1,176.4 | 1,176.4 |
| **Total (kL)** | | | **40,520.0** | **40,520.0** | **40,520.0** |

Note: [1] New production wells that may be installed in the future if exploration activities with ATP 688 resume within the next 3 years.

Several combinations of coal seams may be targeted depending on the thickness of seams encountered at the test locations. As there is some uncertainty in the coal seams proposed to be targeted at each location, pumping has been prescribed to the top two coal seams (Q/Upper Goonyella and P Seams) at Mount St Martins gas field and to the uppermost coal seam (P Seam) at the Tilbrook gas field. These coal seams are interpreted to be thicker than the underlying seams and pumping from these shallower seams would provide more conservative estimates of the potential groundwater impacts.

The transient model continues simulating in time to investigate any long-term effects of the proposed pumping.

It is acknowledged that the current generation of regional groundwater flow models, including this model, are not capable of simulating localised drawdown at production wells and the associated two-phase flow of water and gas in the near-area of the wells. The implication of neglecting two- phase flow is that drawdown at the wells is likely to be underestimated at the well bore, but may be more appropriate for the well grid cell. The assessment of localised two-phase flow effect is beyond the scope of this project and is not considered warranted for assessing the regional scale impact to groundwater due to the proposed production tests.

#### 5.1.8 Predicted Water Use Used in the Model

Modelling to predict the Immediately Affected Area and the Long Term Affected Area if exploration activities should resume within the next three years uses the same assumptions as the model constructed by CDM Smith (2013) with the addition of two new wells (Table 9).

The projected water production rates at each well have been derived by averaging historical water extraction measured during pilot tests in the high water-yielding Tilbrook wells. Note that coal seam gas wells normally produce less water after the first few years as the reservoir pressure decreases and gas production increases. The theoretical production rates for 2017 to 2019 are shown in Table 9 with extraction volumes listed in kilolitres per year. The maximum total extraction from 2017 to 2019 if exploration activities resume across both the Mount St Martins and Tilbrook gas fields is estimated to be 121,560 kL.

These extraction volumes are used in the numerical model. This model presents a very conservative estimate of the impacts as it assumes activities will commence late in 2017; however, under current plans for ATP 688 this is unlikely to be the case.

## *5.2 Underground Impact Affected Areas*

Model outputs of predicted water level decline for each affected aquifer are provided in Figure 11 to Figure 16. In Section 5.2.1, water level decline contours are presented for the Immediately Affected Area, associated to the pumping period (from 2016 to 2019). The effects remaining after the end of pumping in 2019 are then discussed.

#### 5.2.1 Predicted Water Level Decline Maps

The Water Act defines the trigger threshold in the water level decline as 5 metres for a consolidated aquifer and 2 metres for an unconsolidated aquifer. In the groundwater model, the Quaternary Alluvium in layer 1 is defined as unconsolidated. All other aquifer layers are classified as consolidated. The results from simulations are divided in two categories:

- the Immediately Affected Area and
- the Long Term Affected Area.

The Immediately Affected Area shows zones impacted in the next three years in this case 2016 to 2019. The Long Term Affected Area shows the zones impacted at any time following the three-year period.

#### *5.2.1.1 Immediately Affected Area*

The groundwater numerical modelling has been carried out to provide estimates of declines in water level in response to the extraction of groundwater associated with pilot testing in ATP 688. For this model, future groundwater extraction has been estimated from historical pumping during production testing. Two additional wells MSM04L1 and MSM04L2 have been proposed in the Mount St Martin's area (refer Figure 2); however, there is no certainty that these wells will be constructed now. For completeness, these additional two wells have been included in the modelling. Pumping is assumed to commence in 2017 at the same rates as Mount St Martins well 1 through 5 from 2017. If these new wells are not installed the present model results over-predict the affected area.

As expected, the addition of the two new wells in the Mount St Martins area pumping at annual rates of 4770.9 kL/a for the period 2017 to 2019 result in a larger Immediately Affected Area than the previous the previous modelling predictions (CDM Smith, 2013).

During CSG pumping, water level decline is observed in three different aquifers, all of which are coal seams: Upper Goonyella Coal Seam, Goonyella P Seam and Lower Goonyella A Coal Seam. No drawdown is present in the Quaternary Alluvium during that period. Water level declined caused by pumping in the impacted layers (where drawdown is greater than 5 m) at the end of years 2017, 2018 and 2019 is presented on Figure 12 to Figure 17.

Bores at Mount St Martins are pumping in the Upper Goonyella Coal Seam and Goonyella P Seam east of the fault. Maximum drawdown is observed at the end of pumping in 2019 in all impacted layers. In both the Upper Goonyella Coal Seam and the Goonyella P Seam (refer Figure 15 to Figure 17), the drawdown is predicted to be greater than 5 m for the first three years under the assumed pumping regime. Drawdown in aquifers caused by extraction at the Mount St Martins bores is localised in both coal seams. No registered water bores are located within these Immediately Affected Areas.

Tilbrook wells begin underground water extraction later than the Mount St Martins bores. Tilbrook 08 continues extraction during 2017 and Tilbrook 07 and 09 commence extraction in 2017. All wells are pumping from the Goonyella P Seam in the segment west of the fault. Again, maximum drawdown is observed at the end of pumping in 2019. In Figure 16, the water level decline exceeds 5 m in the Goonyella P Seam (layer 12). No significant drawdown (greater than 5 m) is observed in the underlying coal seams. Drawdown from the Tilbrook wells is greater than the 5 m trigger threshold only in the Goonyella P Seam at the end of pumping in 2019.

No registered water bores are situated within this Immediately Affected Area.

#### *5.2.1.2 Long Term Affected Area*

The modelled pumping in the Mount St Martins and Tilbrook bores is assumed to stop at the end of 2019 as part of this UWIR. After pumping, a recovery process starts whereby the water level drawdown decreases because of the removal of the pumping stress and lateral inflow from the regional aquifer system. At the end of 2020, almost all aquifers have fully recovered. A residual drawdown of approximately 2 m is visible in layers 3 and 5, corresponding to the Upper Goonyella Coal Seam and the Goonyella P Seam, east of the fault near the Mount. St.

Martins field. At the end of 2022 (three years after pumping), all aquifers have fully recovered. Therefore, there are no Long Term Affected Areas in ATP 688.

### 5.2.2 Water Bores in the Immediately Affected Area

Exploration activity in ATP 688 has been scaled back and no water has been produced from CSG activities post 2013. As no water has been produced, there is currently no Immediately Affected Area since September 2016. As discussed in Section 5.2.1, water level declines greater than the 5 m trigger threshold are observed in the Goonyella P Seam from the Tilbrook bores, and in the Upper Goonyella Coal Seam and Goonyella P Seam from the Mount St Martins bores. The impacted area is quite localised and no registered water bores are situated within the Immediate Affected Areas.

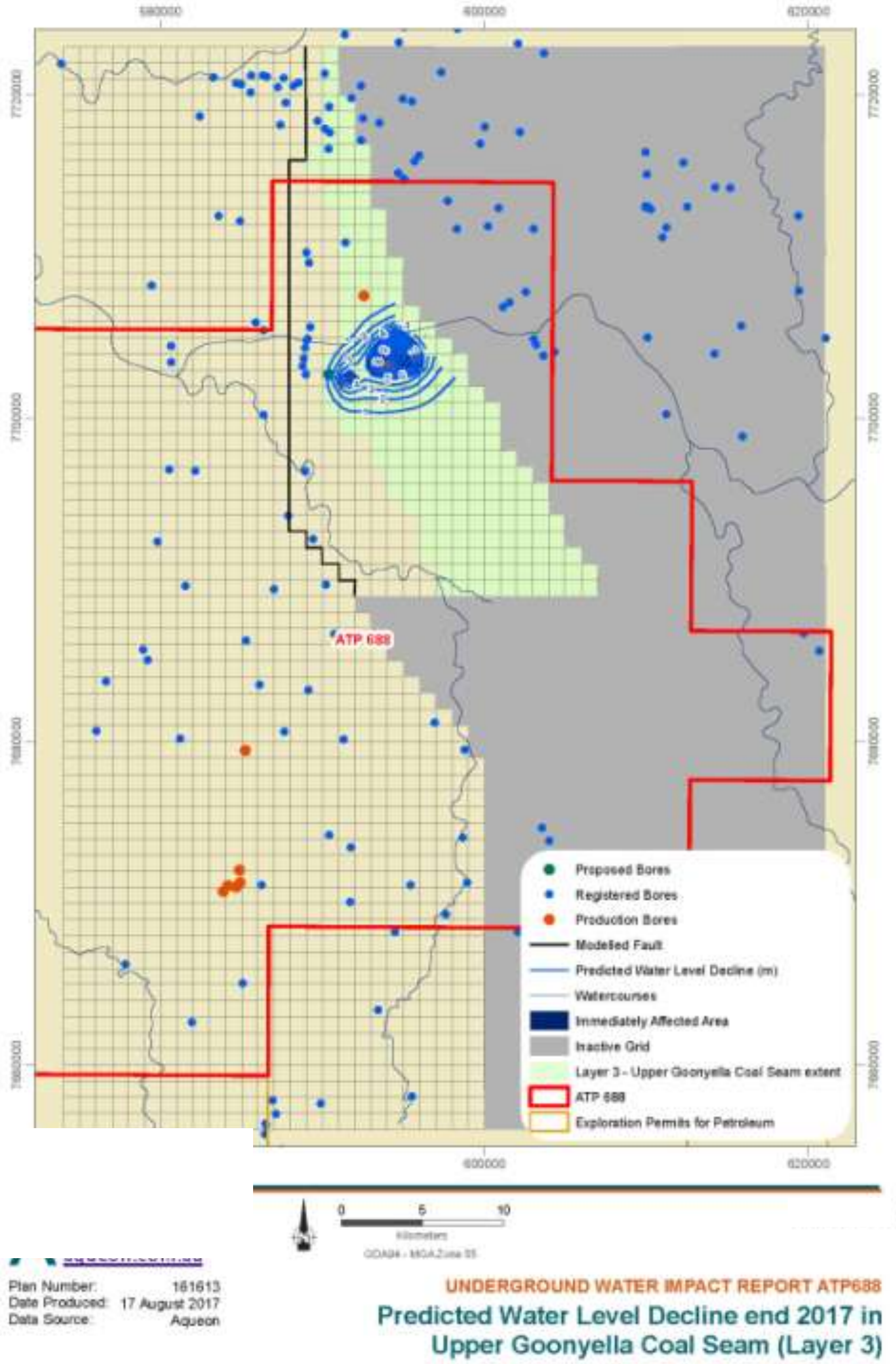


**Figure 12 Predicted water level decline end 2017 in Upper Goonyella Coal Seam (Layer 3)**

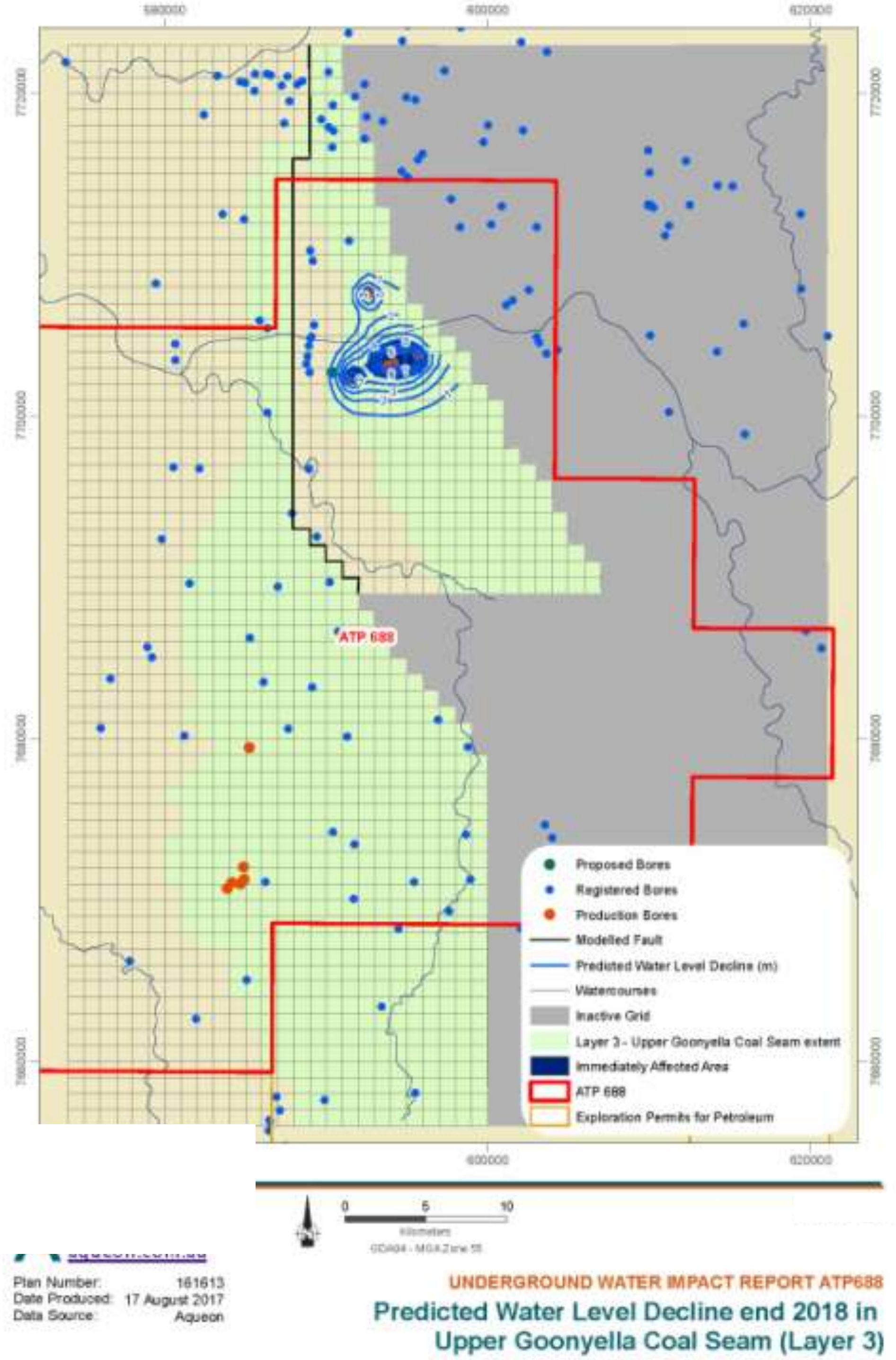


**Figure 13 Predicted water level decline end 2018 in Upper Goonyella Coal Seam (Layer 3)**

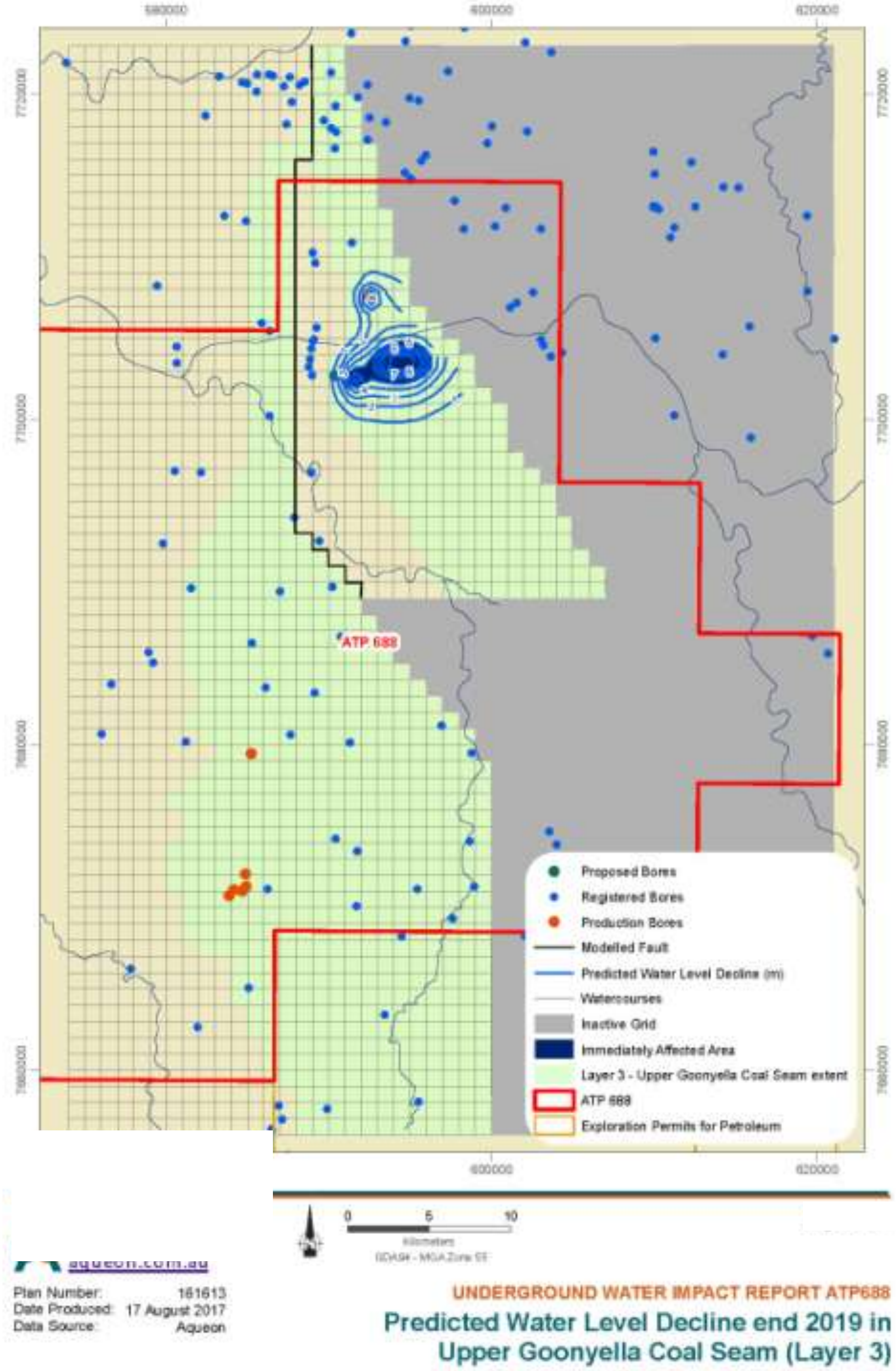


**Figure 14 Predicted water level decline end 2019 in Upper Goonyella Coal Seam (Layer 3)**

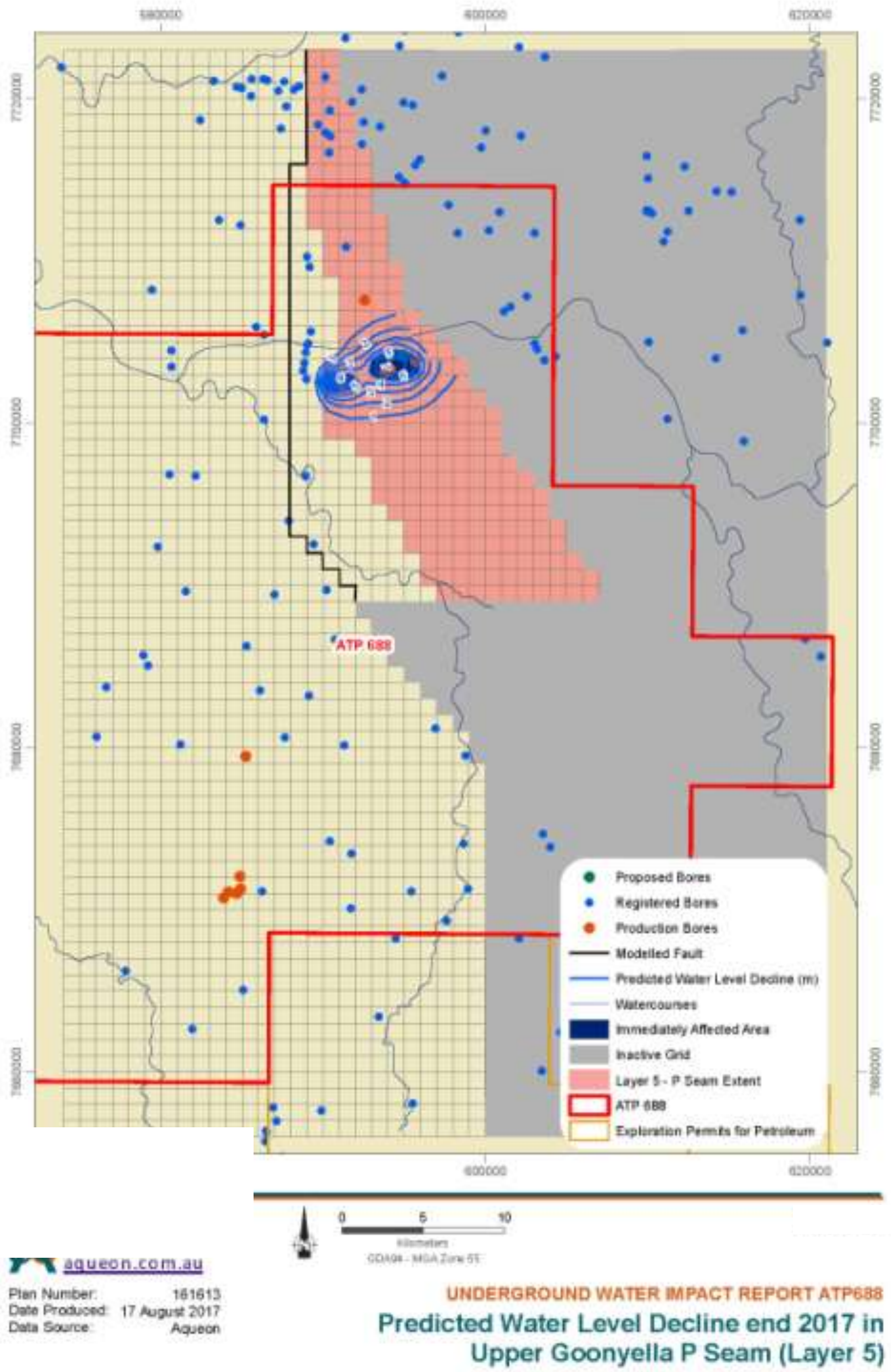


**Figure 15 Predicted water level decline end 2017 in Upper Goonyella P Seam (Layer 5)**

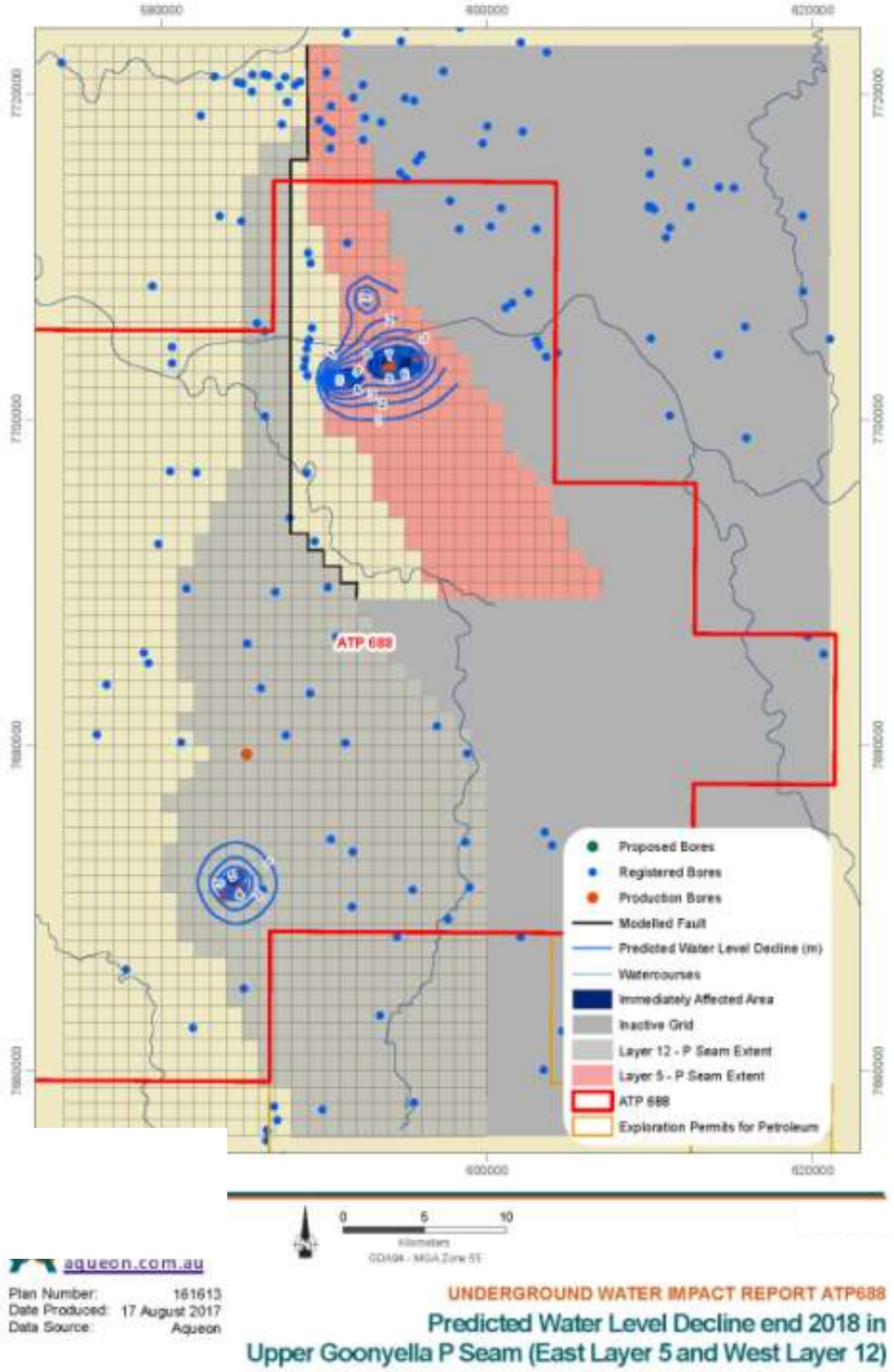


**Figure 16 Predicted water level decline end 2018 in Upper Goonyella Coal Seam (East Layer 5 and West Layer 12)**

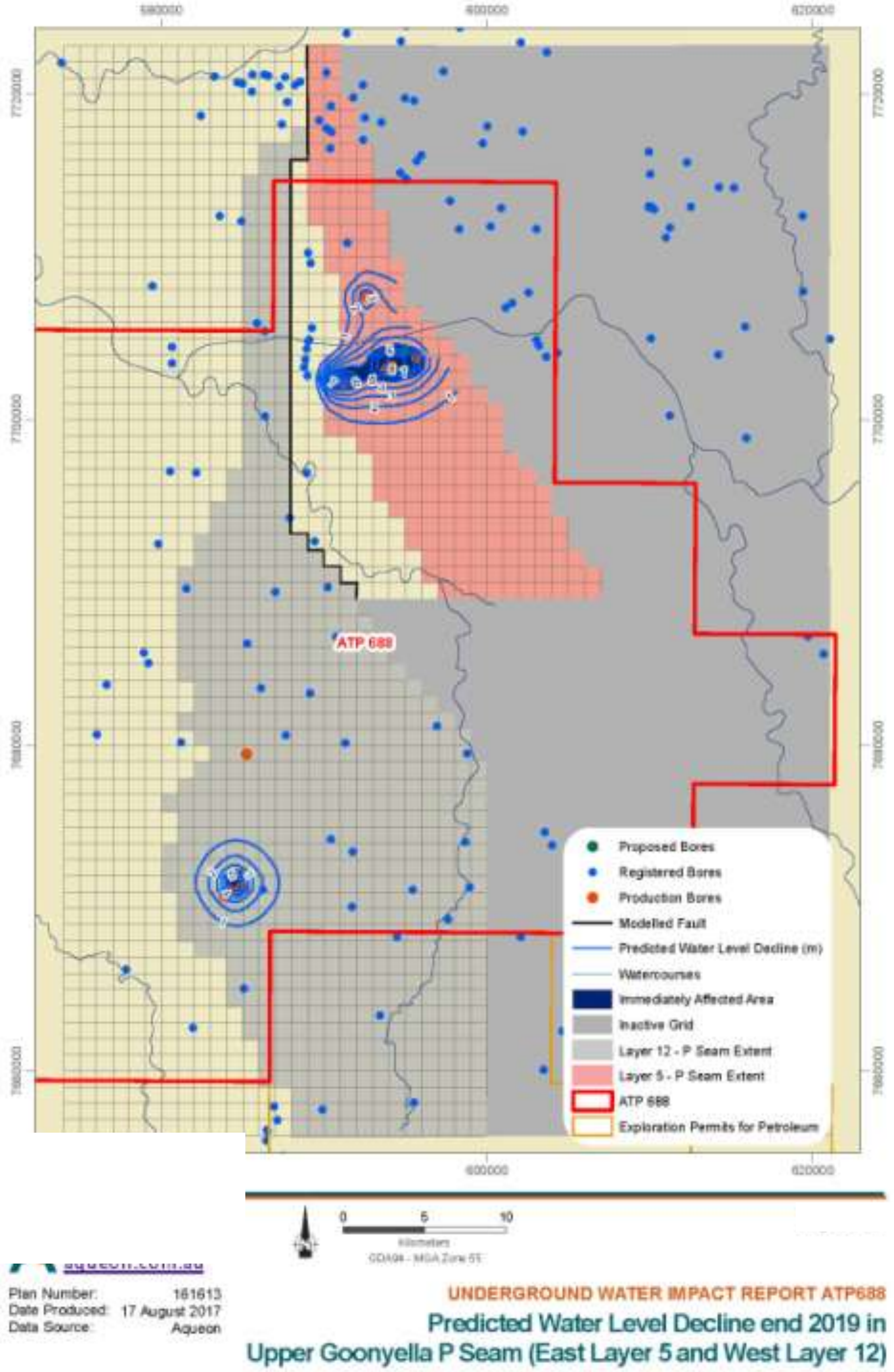


**Figure 17 Predicted water level decline end 2019 in Upper Goonyella Coal Seam (East Layer 5 and West Layer 12)**

## 5.3 Sensitivity to Model Parameters

Prediction uncertainty arises mainly because of ambiguities in model conceptualisation and model parameters due to lack of measured data. The effects of alternative conceptualisations on the calibrated model were not explored in this study because the alternatives were considered very limited and the current model has been built based on the best available information.

Results presented in the previous section are based on calibrated parameters which lie within the range of previously measured or estimated values. The predicted results depend upon the conceptual hydrogeological model, associated parameter values, and a projected water extraction scenario. Some level of uncertainty exists within all these factors. To address the sensitivity of model results to one of these factors, two alternative parameter sets were used in additional predictive runs.

The model is particularly sensitive to hydraulic conductivity and only moderately sensitive to changes in storativity. Parameter uncertainty was explored through adjusting selected parameters, which were likely to impact on predictive drawdown.

As the projected CSG extraction occurs in the Goonyella Coal Seams, the hydraulic parameters associated with this formation will impact the projected drawdown. A factor was applied to previous calibrated horizontal and vertical hydraulic conductivity parameters in each coal seam (refer Table 8) to generate a “best case” and “worst case” scenario.

For the best-case scenario, hydraulic conductivity in the coal seams was increased by an order of magnitude. For the worst-case scenario, hydraulic conductivity in the coal seam was decreased by an order of magnitude. None of these new parameter values have been calibrated against observed data and may not adequately represent the actual state of the system, but can inform the process provided by the UWIR.

Maps of predicted water level decline for each affected aquifer are provided as part of this report. Results are first presented for the Immediately Affected Area associated with the pumping period (from 2016 to 2019). The longer-term effects remaining after the end of pumping in 2019 are next discussed for each sensitivity scenario.

### 5.3.1 Best Case Scenario

For the best-case scenario, hydraulic conductivity values are greater than the calibrated ones by a factor of 10. Increasing the conductivity creates smaller maximum drawdown, but the total affected area is expected to be greater.

Simulation results have shown that at the end of 2019, maximum drawdown is less than 5 m in every model layer. One year after the end of pumping (end of 2020), all layers have fully recovered.

### 5.3.2 Worst Case Scenario

The worst-case scenario is designed to illustrate what impacts might be predicted if calibrated hydraulic conductivity values are divided by 10. By decreasing the hydraulic conductivity, it is expected that the maximum drawdown will be greater, and spread further around the groundwater extraction bores.

Simulation results from this scenario show that all coal seams present in the model exhibit drawdown caused by the proposed CSG pumping and have Immediately Affected Areas. Also, Long Term Affected Areas are simulated for this worst-case scenario.

#### *5.3.2.1 Immediately Affected Area, Worst-Case*

During water extraction for CSG operations, water level decline has been predicted in three different seams of the Goonyella Coal Seam aquifer in the base case scenario. For the worst-case scenario, increased drawdown is expected in four different coal seams: Upper Goonyella Coal Seam, Goonyella P Seam, Lower Goonyella A Seam and Lower Goonyella B Seam. As in the base case, no drawdown is observed in the Quaternary Alluvium during the pumping period (2016 to 2019). Immediately Affected Areas, where water level decline greater than 5 m at the end of years 2017, 2018 and 2019 are mapped in Figure 12 to Figure 17.

Bores at Mount St Martins are pumping in the Upper Goonyella Coal Seam and Goonyella P Seam east of the north-south trending thrust fault. As expected, maximum drawdown is observed at the end of pumping in 2019 in impacted layers. Maximum drawdown is greater than in the base case by up to three times. However, the worst case Immediately Affected Area does not change greatly from the calibrated predictions (see dark blue area on figures in Section 5.2.1.2 and this section). Again, no registered water bores are situated within the predicted Immediately Affected Area.

Tilbrook pumping wells are pumping from the Goonyella P Seam in the segment west of the fault from 2017. Again, maximum drawdown is observed at the end of pumping in 2019. Water level decline exceeding 5 m (Immediately Affected Area) is observed in the Goonyella P Seam (layer 12), and in the Lower Goonyella A and B Seams (Figure 18 to Figure 22). No registered water bores are situated within this Immediately Affected Area.

No steady state calibration has been performed using these best case/worst case parameters. The sensitivity parameters allow an estimate of how a change in parameters can provide information on the uncertainty in predictions.

#### *5.3.2.2 Long-Term Affected Area – Worst Case*

Following the end of proposed underground water extraction in 2019, the worst-case model was run for a long period to track the groundwater system recovery. In the calibrated base case scenario, no Long Term Affected Areas were predicted. For the worst case sensitivity run, significant effects are still visible years after the end of pumping. Simulated results indicate that it takes up to 5 years before all coal seams have water level declines less 5 m. Hence the worst-case scenario does predict Long Term Affected Areas.

Figure 23 to Figure 25 present the Long Term Affected Area at the end of 2020, a year after CSG pumping stops, and the date when the predicted drawdown is the greatest. These figures show that four coal seams are still strongly affected by the pumping. All model layers begin to recover in 2020, showing decreasing drawdown. No registered bores are situated within the Long Term Affected Areas suggested by the worst-case scenario.

The sensitivity runs of this section demonstrate that changing model parameters can produce either no reportable drawdown and no Immediately Affected Area, or can slightly increase the area of the Immediately Affected Area and generate Long Term Affected Areas. The Water Monitoring Strategy in Appendix B addresses this uncertainty with additional data collection.

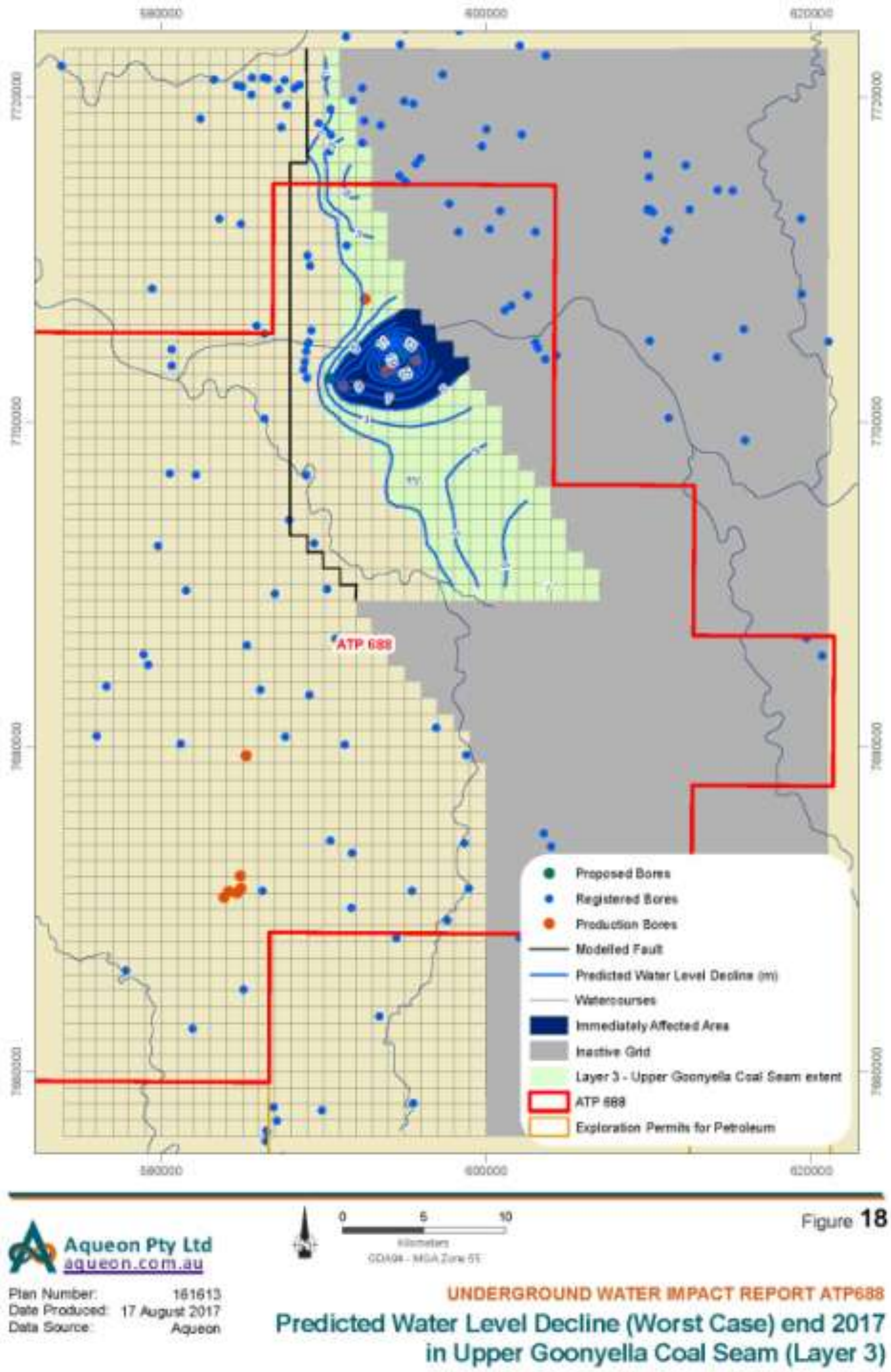


**Figure 18 Predicted Water Level Decline (Worst Case) end 2017 in Upper Goonyella Coal Seam (Layer 3)**

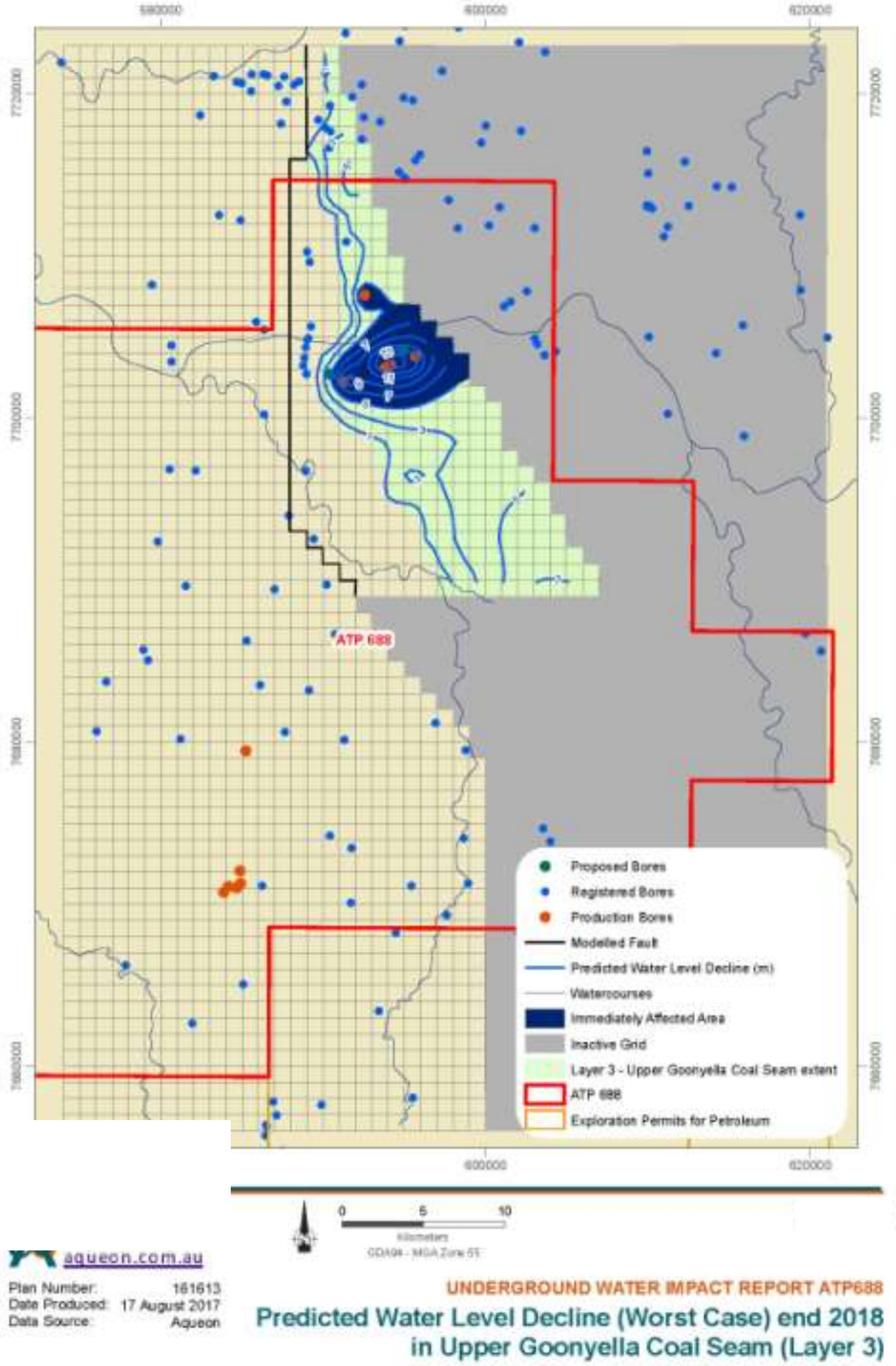


**Figure 19 Predicted Water Level Decline (Worst Case) end 2018 in Upper Goonyella Coal Seam (Layer 3)**

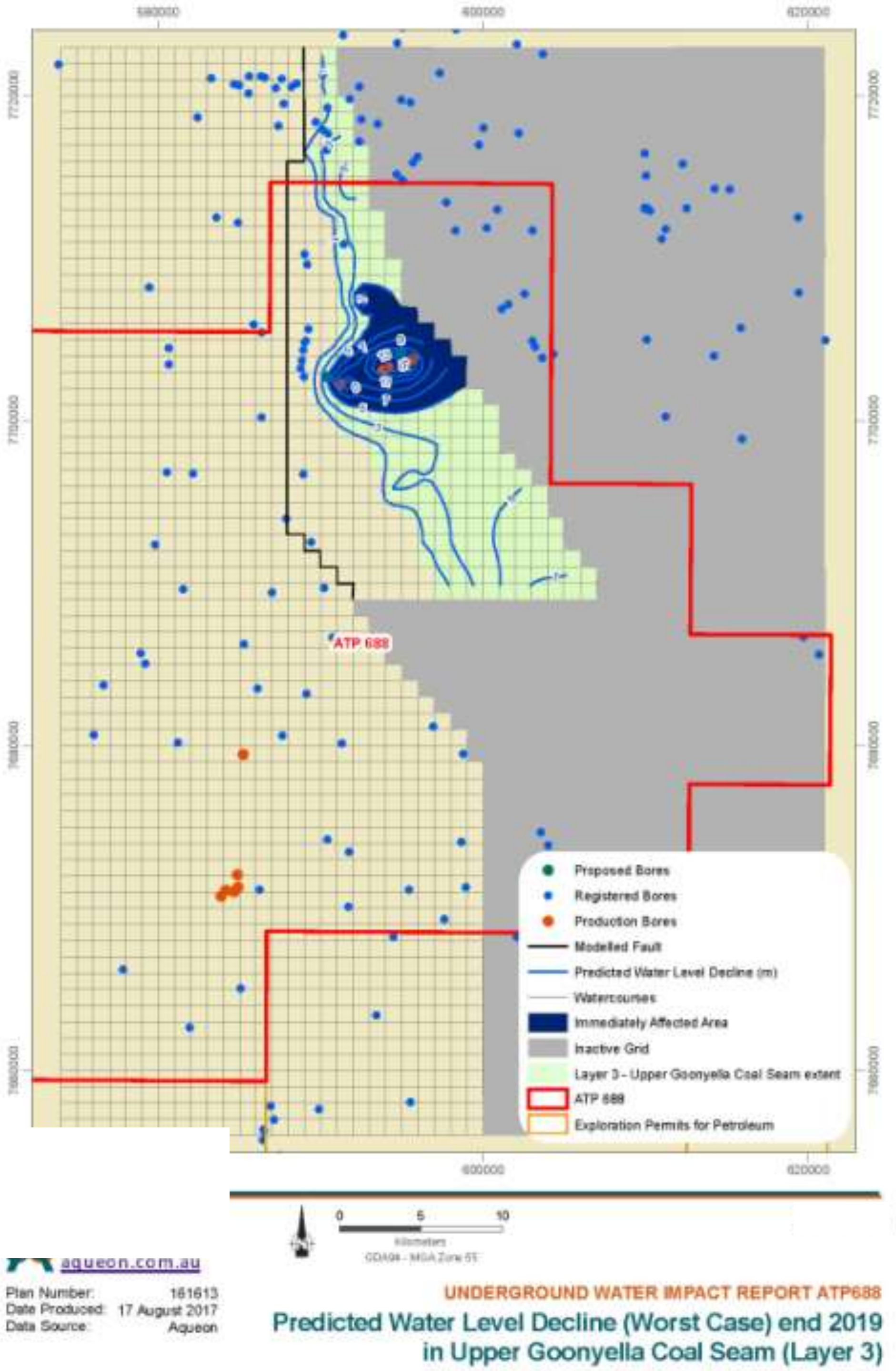


**Figure 20 Predicted Water Level Decline (Worst Case) end 2019 in Upper Goonyella Coal Seam (Layer 3)**

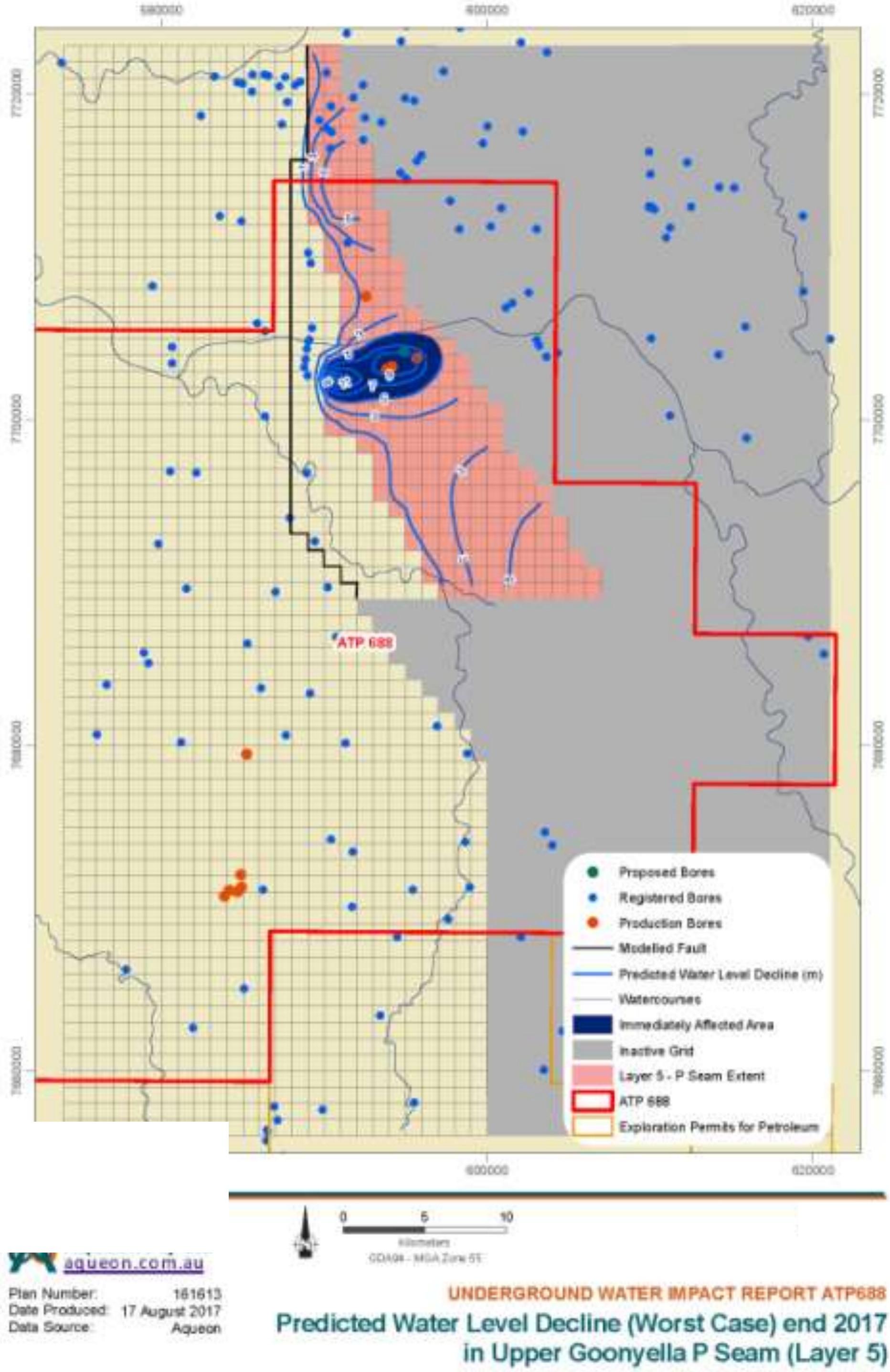


**Figure 21 Predicted Water Level Decline (Worst Case) end 2017 in Upper Goonyella P Seam (Layer 5)**

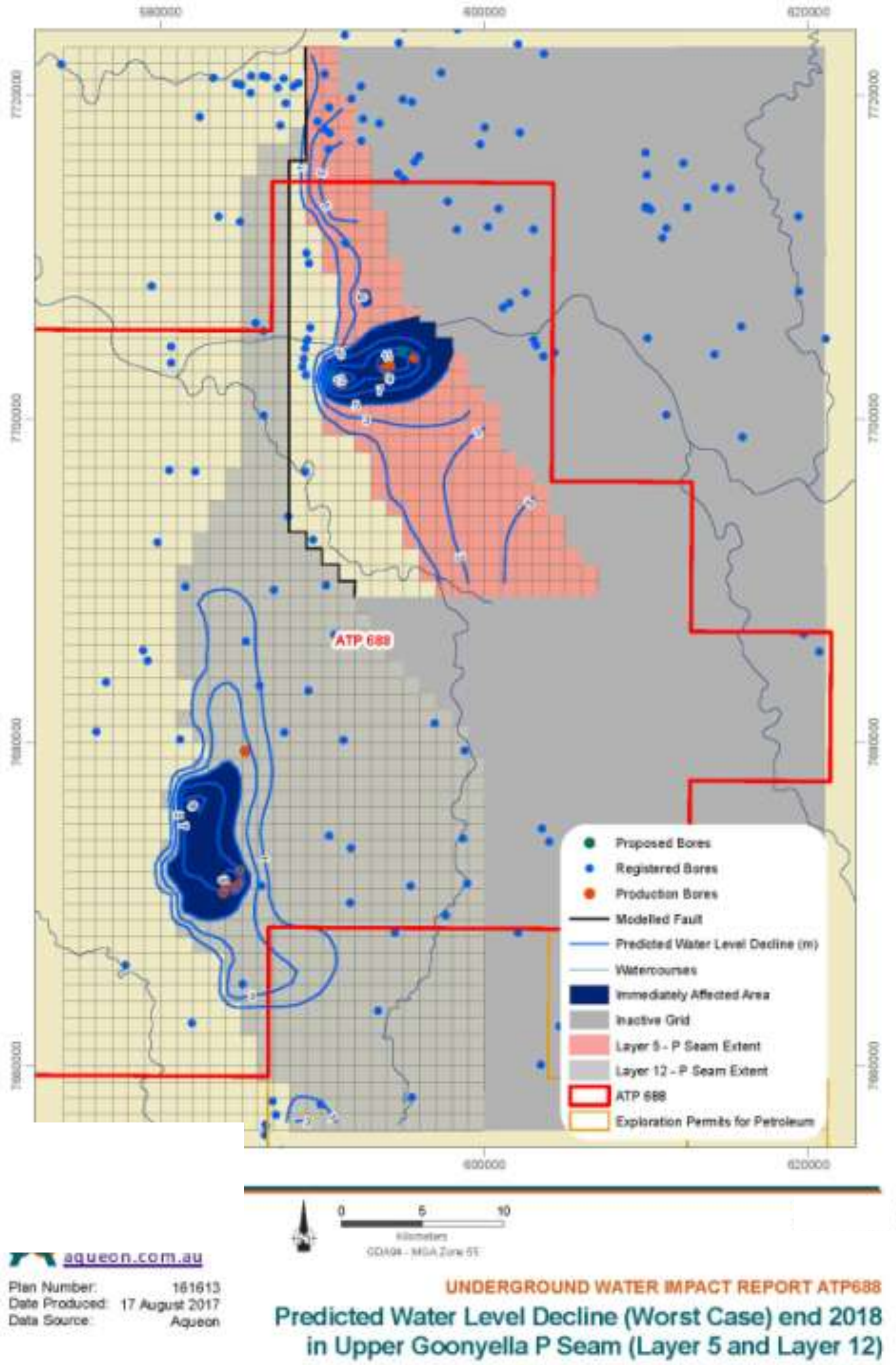


**Figure 22 Predicted Water Level Decline (Worst Case) end 2018 in Upper Goonyella P Seam (Layer 5 and Layer 12)**

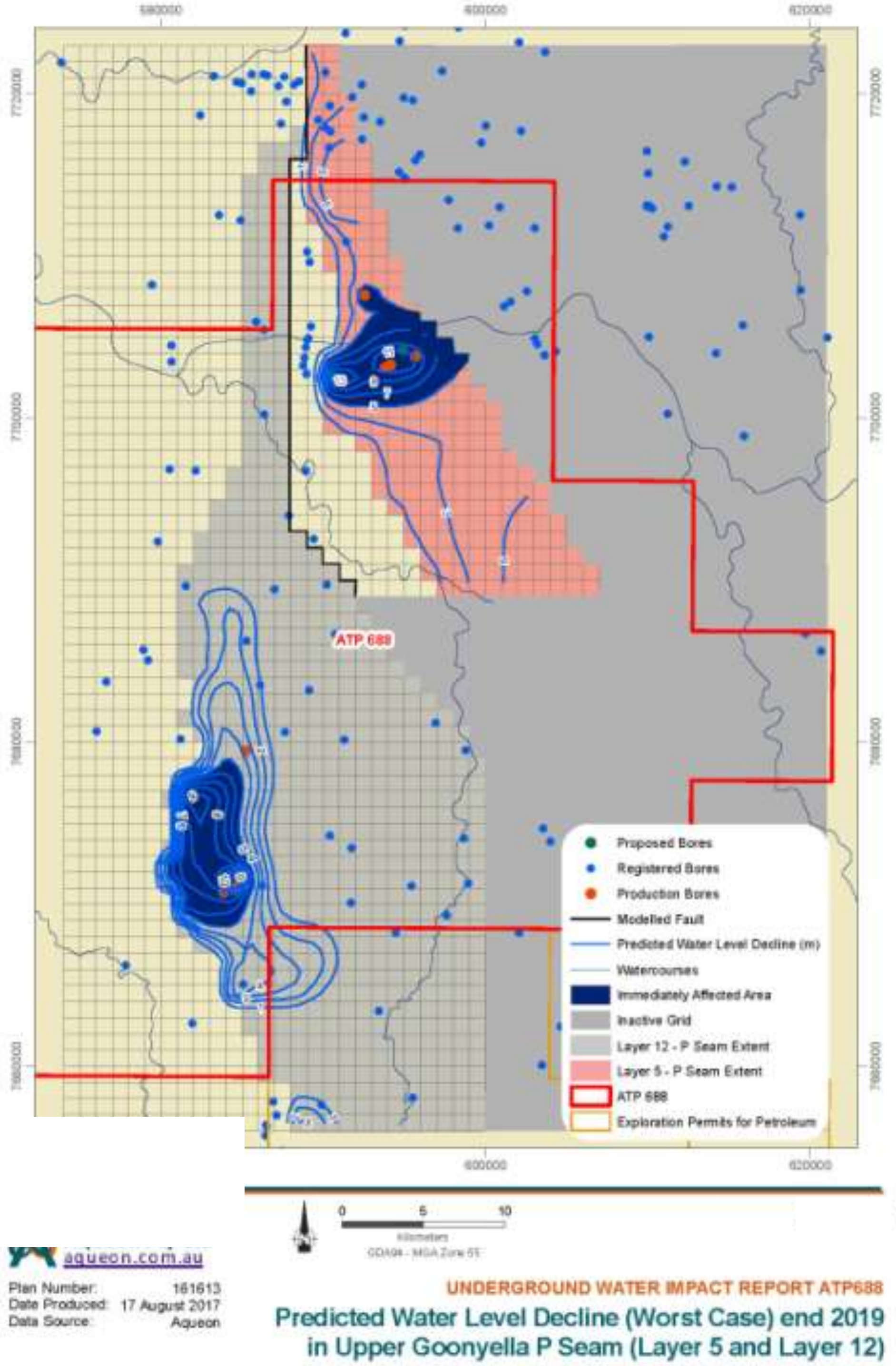


**Figure 23 Predicted Water Level Decline (Worst Case) end 2019 in Upper Goonyella P Seam (Layer 5 and Layer 12)**

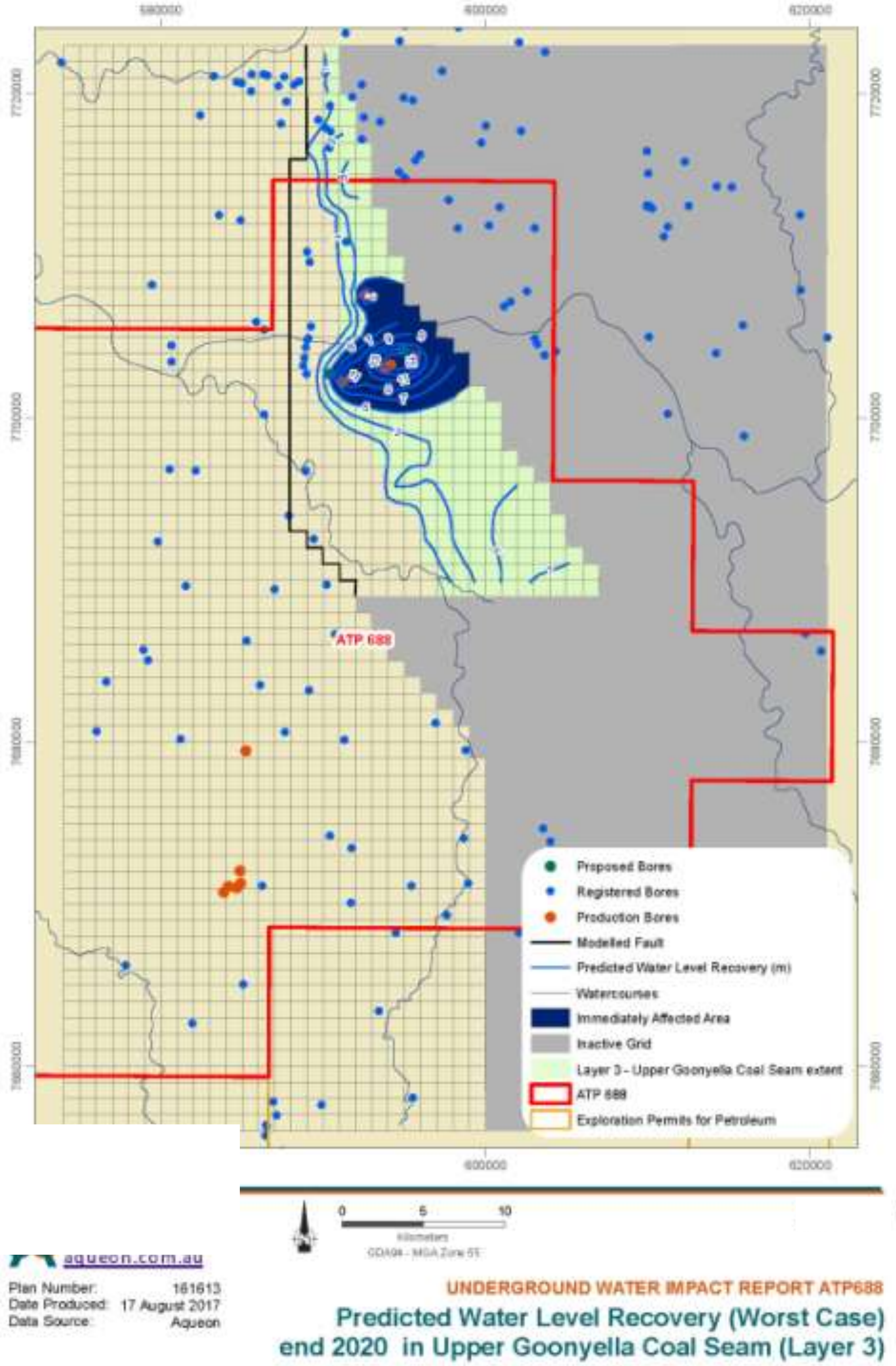


**Figure 24 Predicted Water Level Recovery (Worst Case) end 2020 in Upper Goonyella Coal Seam (Layer 3)**

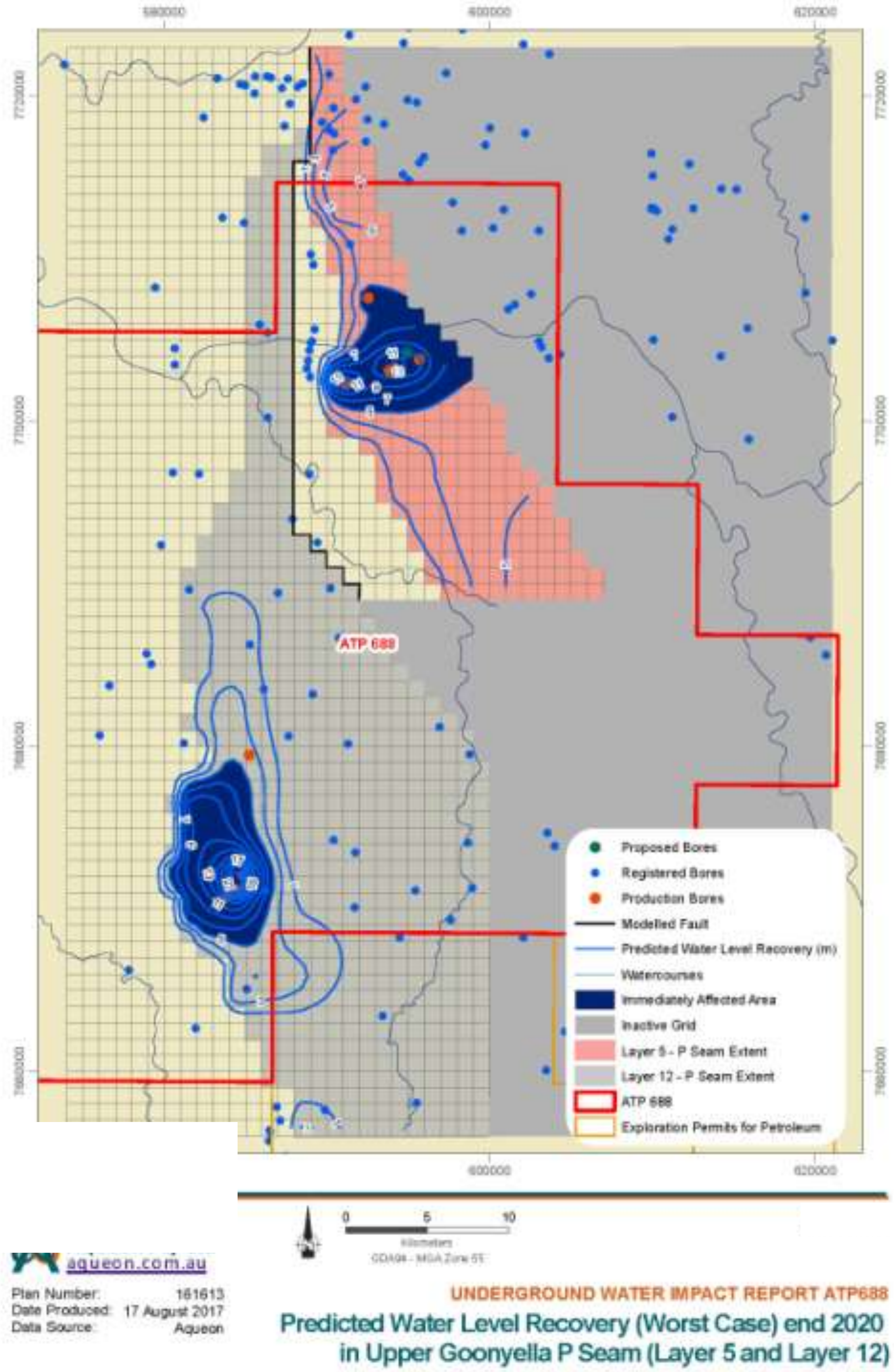


**Figure 25 Predicted Water Level Recovery (Worst Case) end 2020 in Upper Goonyella P Seam (Layer 5 and Layer 12)**

## 5.4 Model Limitations

All results presented within this report need to be considered with the assumptions and limitations inherent with numerical modelling of complex hydrogeological systems. A few of the more noteworthy limitations of this model are listed below:

- The model uses porous media flow methodology where mixed porous media and fracture flow is believed to occur. This is a problem with all models in which specific properties are not assigned to specific fractures or fracture zones.
- Applied stresses/timing are generalised because the observed data such as extraction pumping rates are somewhat erratic and are assumed from initial, but limited production testing.
- Whilst near-field geology is well understood, the properties of the basement rocks outside a radius of ~1 km are assumed.
- An average of volumes pumped during previous testing has been applied as the pumping regime to predict the immediate area and long-term impacts. This results in a likely overestimation of the affected areas.
- The current generation of regional groundwater flow models, including this model, are not capable of simulating localised drawdown at production wells and the associated two-phase flow of water and gas in the near-area of the wells.
- In the absence of any other information pumping associated with the possible installation of two new wells is assumed to commence in 2017. If pumping does not commence from these wells in early 2017 the model results presented here overpredict the affected areas.
- Data of depth to water used in calibration is spread over several years (2006 to 2012) and no new water level data is available post 2012.
- The exact extent of aquifer interconnection vertically or latterly is not accurately known.
- The model assumes test pumping takes place at rates similar to historical rates from the active wells. This provides a conservative case and is likely to overpredict any immediately affected or long-term affected area

## 5.5 Key Findings

The report identifies the extent of Immediately Affected Areas and Long Term Affected Areas above the trigger levels by predicting drawdowns caused by underground water extraction. The pumping rates used in the simulations have been based on historical rates plus assumptions that two new bores will be established in the Mount St Martins area. It should be noted that if modelled underground extraction rates are not reached, the predictions in this model over-estimate both the Immediately Affected Area and the Long Term Affected Area.

Groundwater modelling, using the best available parameters, leads to the prediction that there will be Immediately Affected Areas at ATP 688 only in the coal seams where extraction takes place. There are no reportable impacts in the overlying alluvium and basalt aquifer. After pumping ceases, groundwater elevations recover and there are no Long Term Affected Areas.

These findings depend upon several assumptions, documents, and data sources, which should be reviewed regularly to maintain accuracy of the maps. Reviews are particularly important whenever the modelling assumptions or data change significantly. For example, if regional faults are found to be permeable to groundwater flow, the model results should reflect the propagation of underground water decline along and across the faults. This modification to an underlying assumption may change (decrease or increase) the extent of the simulated Immediately Affected Area.

# 6 Part D: Impacts on Environmental Values

To meet the requirements of the Water Act, an UWIR must include the following:

1. A description of the impacts on environmental values that have occurred, or are likely to occur, because of any previous exercise of underground water rights (section 376(da) of the Water Act);
2. An assessment of the likely impacts on environmental values that will occur, or are likely to occur, because of the exercise of underground water rights (section 376 (db) of the Water Act) —
   a. for a three-year period starting on the consultation day for the report; and
   b. over the projected life of the resource tenure.

The DEHP guidelines for preparing the UWIR identifies the following considerations are required:

- Identification and description of the Environmental values within the Tenement Area.
- Nature and extent of any predicted impacts on the environmental values associated with exercising underground water rights.
- Impacts to formation integrity and issues that may cause surface subsidence.

DERM defines an Environmentally sensitive area (ESA) as a location, however large or small that has environmental values that contribute to maintaining biological diversity and integrity, has intrinsic or attributed scientific, historical, or cultural heritage value, or is important in providing amenity, harmony or sense of community. ESAs are divided into three categories (A. B. and C). Category A areas that have significant ecological values include national parks, marine parks, conservation parks, forest reserves, The Wet Tropics World Heritage Area and the Great Barrier Reef Region. Category B areas include Endangered regional ecosystems (REs), RAMSAR wetlands, state forest parks, wilderness areas, areas seaward of the highest astronomical tide, fish habitat areas and areas containing marine plants. Category C areas typically include Of Concern Res, essential habitat, referable wetlands, nature refuges, state forests, timber reserves. Declared water catchment areas, Koala habitat areas and resources reserves. For the purposes of ESAs, the biodiversity status of the RE is considered, not the status under the *Vegetation Management Act*, 1999 (AECOM, 2012)

The Directory of Important Wetlands in Australia (DIWA) and the Queensland Government Interactive wetlands map tool was used to identify areas of significant wetlands or identified GDEs occur within the boundary of ATP 688.

## *6.1 Identifying and describing environmental values*

When identifying environmental values, consideration must be given to the interconnectivity between groundwater and surface water systems (i.e. baseflow to watercourses) that may support groundwater dependent ecosystems (GDEs). For this UWIR a GDE is defined as an ecosystem which requires access to groundwater on a permanent or intermittent basis to meet all or some of their water quality requirements to maintain their communities of plants and animals, ecological processes, and ecosystem services. Ecosystem dependency on groundwater may vary temporally (over time) and spatially (depending on its location in the landscape). GDEs include aquifers, caves, lakes, palustrine wetlands (billabongs, swamps, bogs, springs, soaks etc. and have more than 30% emergent vegetation), lacustrine wetlands, rivers, and vegetation.

Two tributaries (Figure 1), Little Bowen River to the south and Broken River to the north, drain through ATP 688 from the south east and exit as the Bowen River in the upper north west portion of ATP 688. Ponding on the Bowen River after the confluence of the two tributaries occurs behind the Collinsville Weir located 21 km south of Collinsville. It is inferred that this water body will have been present for a suitable period to enable establishment of an ecosystem adapted to periods of almost permanent water supply.

The shallow alluvium aquifer is typically associated with present day channels and flood plains, comprising layers of fine grained highly transmissive material and monitoring data suggests the alluvial aquifer is unconfined and connected to surface water features such as streams and rivers. Connectivity between surface water features and the basalt aquifer is also considered to be high with surface water features receiving discharge from the basalt. Due to the level of connectivity the shallow groundwater system therefore supports baseflow and associated GDEs within the watercourses. During extended periods of drought or late summer where the watercourses are sufficiently incised to intersect the shallow water table pools will be maintained providing a refuge habitat for aquatic species.

Westside Corporation have completed two environmental assessments (AECOM 2010 and 2012) in the Mount Saint Martin area associated with the drilling of exploration wells in the area. The studies identified that most of the land has been cleared for grazing (Figure 26) but environmentally sensitive areas (ESA) under the Queensland classification system Category B (Endangered Regional Ecosystems, ERE’s) occur within the Mount Saint Martin locality of the Tenement Area (refer Figure 27 and Figure 28).

**Figure 26  Mount Saint Martin (MSM4L) showing cleared grazing land (Source: AECOM, 2012)**

**Figure 27 Mount St Martin (MSM2L) showing renant woodland with heavy under grazing (Source: AECOM, 2012)**

**Figure 28 Mount Saint Martin (MSM5L) showing lands cleared for grazing and non remnant vegetation regrowth (after AECOM, 2010)**

Generally, the two studies identified the ESA's to lie adjacent to watercourses or drainage lines. The studies did not identify any category A or C ESA's within the areas studied.
In the areas investigated one Referrable Wetland was identified within 400 m of the Bowen River. It is inferred that this wetland would most likely be supported by discharge of groundwater from the shallow water table aquifer.

Terrestrial vegetation such as illustrated in Figure 27 is likely to be supported to some degree by the shallow water table aquifer where tree roots penetrate sufficiently deep enough to intersect the water table.

## 6.2 Nature and extent of the impacts on the environmental values

Extractive testing ceased from the exploration wells in ATP 688 in 2010 and to date no further water has been discharged. However, in order to asses potential impacts the Groundwater Numerical modelling completed to support this UWIR assumes a level of continuous pumping (refer Table 2) from 2007 to 2019 plus given the uncertainties in aquifer parameters aquifer properties are modified to present a worst case simulation. Under these simulations no impacts associated with the extraction of water from the target coal seams were predicted on the shallow water table that supports base flow to the water courses, terrestrial vegetation and localised wetlands.

Therefore it is concluded that within the bounds of the available information over the period that this UWIR has been prepared, 2016 to 2019, any impact on the environmental values within ATP688 is unlikely.

## 6.3 Impacts to formation integrity and surface subsidence

Land subsidence associated with long-term (>60 years) extraction of groundwater has been well documented e.g. Mexico City and Bangkok. Land subsidence in these cases is associated with the over extraction and dewatering of the shallow aquifer systems. Currently there is little international information available describing observed subsidence associated with coal seam gas extraction

The Independent Expert Scientific Committee (IESC) on Coal Seam Gas and Large Coal Mining Development (2014) identify that there is no documented evidence of subsidence occurring from coal seam gas developments in Australia. Coffey Geotechnics (2013) modelled predictions of surface subsidence for individual coal seam gas fields in Queensland and identified that subsidence may range from 30 to 850 millimetres.

However, in the current environment of limited information, it is important that predictions of groundwater drawdown, compaction and subsidence are well documented, and monitoring is undertaken to:

- establish robust baseline datasets; and
- provide sufficient history and both spatial and temporal resolution to detect change and understand cause and effect relationships.

Monitoring and collection of data to establish the relevant baseline datasets are presented under Section 6, Water Monitoring Strategy. Once the additional baseline information has been collected if it becomes apparent during the extraction phase that land subsidence presents an operational risk additional measures for monitoring and management that may be considered could include:

- borehole extensometers; these are located within boreholes and measure change in height between the bottom of the bore and land surface to an accuracy of about 3 mm. Multiple readings over time measure changes in bore height above a reference point, and therefore infer subsidence at a single location.
- Recharge of associate water to underlying or overlying aquifer systems to maintain the balance in hydrostatic pressures.

# 7 Part E: Water Monitoring Strategy

The monitoring program described in this section will only be implemented if exploration /extraction activities are resumed at ATP 688.

## 7.1 Water monitoring strategy

Numerical modelling of the underground formations and associated water have predicted that only the target P coal seam and the Lower Goonyella A and B Seams have an Immediately Affected Area during the exploration phase in ATP 688. This is fully expected as the P coal seam and the Lower Goonyella A and B Seams are the primary target formations for pressure depletion. These coal seams are not a source of bore water in the area due to:

- Having high gas content and low water content.
- Having water quality that exceeds the Australian Drinking Water Guidelines 2004 (ADWG), published by the National Health and Medical Research Council.
- Uneconomic for large scale water demands due to depth, high drilling and completion costs, and low water productivity.

The water monitoring strategy for the target coal seams will be based on industry standard reservoir evaluation practices. This practice is performed by Reservoir Engineers, who are a subset of the Petroleum Engineering community. They are supported by Geophysicists, Geologists, and Petrophysicists. Reservoir evaluation methods specific to coal reservoirs are evolving over time and currently include seismic interpretations, core evaluation, well logging, transient through steady state pressure testing, and pilot testing analysis.

Initial exploration drilling has established the presence of gas bearing coals at depths. Mapping with limited well control, surface outcrops, seismic, and magnetic surveys have provided estimate of lateral extent of the coals. Future exploration efforts and pilot testing if it progresses aims to improve the knowledge of coal seam gas reservoir unknowns of:

- Initial reservoir pressure
- Effective gas saturation and volumes available to long term pilot testing
- Gas productivity
- Gas quality
- Effective water saturation and volume for long term pilot testing
- Water productivity
- Water quality
- Effective well drainage volume, both laterally and vertically
- Range of variance on all the above parameters

Coals seams are very complex, and are characterized by a high degree of heterogeneity vertically and laterally. This heterogeneity results in large variability in well to well productivity for water and gas. Some wells simply will not produce water or gas because of very low productivity of the target formation.

WestSide would commence any water monitoring strategy 3 months before any water / gas production.

## 7.2 Water monitoring rationale

The underground water monitoring strategy has been developed to address the findings of this UWIR, and to keep track of water level and water quality changes caused by the exercise of underground water rights at ATP 688.

Local registered bores are primarily drawing a water supply from the shallow Quaternary alluvial and Tertiary basalt aquifers. These superficial aquifers are separated from the perforated and exposed intervals of the coal seam production wells by lower permeability interburden and Rewan formations. In addition, the production wellbores are cemented and cased to best practice to avoid aquifer cross-contamination. Modelling results show no anticipated significant impact in the shallow aquifers. Therefore, the underground water monitoring strategy will not address this aquifer.

There are no springs identified within ATP688 or the surrounding 10 km, as discussed in Section 6. Therefore, this monitoring strategy also does not include provisions for monitoring springs.

However, the modelling predicts that there will be an Immediately Affected Area in the Goonyella coal seams, with maximum drawdown occurring in 2019 being the assumed end of production from these wells. If production were to continue beyond 2019 the model would need to be rerun to assess Immediately Impacted Areas and Long Term Affected Areas. After simulated pumping ceases, the impact reduces rapidly (within three years) and there are no Long Term Affected Areas.

### 7.2.1 Monitoring Threshold criteria

To identify adverse impacts, the monitoring strategy requires the development of criteria that detect significant changes against baseline or ongoing measurements. The following criteria will be used to identify significant changes in water quality and quantity:

- **Adverse chemical impacts**: Compare concentrations of selected analytes to previous monitoring rounds – if either (a) value exceeds highest previous measurement by >25% or (b) three subsequent monitoring events record an increase in one or more analyte concentrations then a potential adverse impact has been identified.
- **Adverse water level impacts**: Compare measured water level to previous monitoring rounds – if either (a) water level is lower than previous lowest measurement by >5 m or (b) three subsequent monitoring events record a fall in water level >1 m then a potential adverse impact has been identified.

These criteria are included in the Groundwater Monitoring Checklist included in Appendix B.

### 7.2.2 Critical data gaps

As discussed in Section 4.3, the predicted impacts depend upon some model inputs and assumptions which are not certain. This uncertainty can affect the impact conclusions and future data gathering should be designed to improve model certainty. To this aim, the following program will be implemented at ATP 688, with the projected model certainty improvement noted:

- Westside will determine if nearby geophysical surveys exist e.g. seismic, which can improve the geologic structure and the conceptual hydrogeologic model.
- Westside will measure horizontal and vertical hydraulic conductivity in the coal seams and surrounding interburden. Suggested methodology includes core testing of previously drilled or new CSG wells or laterals drilled within ATP 688. Both coal seam aquifer and interburden formations should be targeted with laboratory testing. These measurements will provide additional certainty in the hydraulic conductivity parameters utilised in the model.
- If possible, Westside will perform drill stem testing on new CSG wells or laterals drilled within ATP 688. Analysis of results will provide more certainty on hydraulic conductivity of the coal seams. Monitoring of pressure at nearby wells in the coal

seams and overlying aquifer may assist in determining aquifer connectivity and hydrogeologic parameters such as permeability and specific storativity.
- Regular groundwater level monitoring will be implemented at boreholes previously identified as suitable, thereby providing calibration data, and extending knowledge about the impact of CSG operations on aquifers. Refer to Section 5.3.2. for more detail on this strategy.

## *7.3 Monitoring strategy and frequency*

The monitoring strategy is designed to quantify changes that occur because of water extraction during coal seam gas extraction. The strategy covers the water extracted from the coal seams, regional impacts in the Immediately Affected Area and, as a precaution, in the alluvial aquifer. As there is no projected Long Term Affected area, baseline sampling outside the borders of ATP 688 is not proposed.

### 7.3.1 Extracted underground water

As in the past, Westside will maintain records of underground water extracted while exercising water rights. These quantities will be tabulated on a daily and monthly basis and graphed each year, similar to Figure 7. Results will be included in annual reports.

### 7.3.2 Water level monitoring

No registered bores were identified in the Immediately Affected Area in the Moranbah target Coal Seams. The DEHP registered database does indicate some bores further away from the Immediately Affected Area, although it is impossible to determine from the available records in which aquifer the bores are completed.

The numerical modelling predicts no Immediately Affected Area for the Quaternary alluvium or the Tertiary basalt. Furthermore, there have been no CSG exploration wells on test post 2013.

Although no monitoring is required under the Water Act, 2000, should exploration activities resume in ATP 688, monitoring is suggested to verify model predictions, and to provide early notification of any unexpected water level decline.

A suggested monitoring regime should comprise measurement of groundwater levels monthly for the first 12 months. All recorded groundwater level data should be referenced to a surveyed datum (i.e. Australian Height Datum). On completion of one year of monthly monitoring, aimed at establishing seasonal variations, the frequency of groundwater level monitoring could be reduced to quarterly or bi- annual as appropriate.

Previous scouting over ATP 688 identified three bores which were accessible and are shown in Table 11. In addition to the bores identified in Table 11, bores located near to CSG testing in the Moranbah Coal Seams should be identified. During initial monitoring, investigation into the existence of unregistered bores within the area will also be conducted to ascertain if more appropriate monitoring locations exist. Should this not be the case, a total of six monitoring bores (a combination of standpipe piezometers and vibrating wire piezometers) will be installed in the Blackwater Group formation and Alluvium aquifer (actual number of each to be confirmed following field investigation). Vibrating wire piezometers allow for monitoring water level pressures across multiple intervals in the same bore hole which can be extremely cost effective compared to single monitoring bores where aquifer systems are deep.

**Table 10 Existing bores identified to be suitable monitoring locations**

| Bore RN | Construction Date | Lattitude | Longitude | Aquifer | Purpose |
|---|---|---|---|---|---|
| Unregistered, may be 256636 | Unknown | -21.05427442 | 147.9191497 | Alluvium assumed | East of Tilbrook field |
| 12030094 4 | Unknown | -21.1031606 | 147.7493108 | Unknown | West of Tilbrook field |
| 70060 3 | 13/07/1984 | -20.50119999 | 147.8483000 | Unknown | Regional water levels, fluctuations and recharge analysis |

If exploration activities continue in ATP 688 any associated future monitoring bores will be sited to maximise early detection of any potential impact, especially with relation to exceeding the mandated trigger levels. The monitoring network design and supervision of installation of any new monitoring bores in ATP 688 should be carried out by a suitably qualified hydrogeologist. After the monitoring bores are located or installed, full details of the bores including the registered number or other unique identifier and the tenure and location of the bore will be provided in the annual reporting for ATP 688.

### 7.3.3 Water quality monitoring

Water quality monitoring is designed to assess whether CSG operations are contributing to decreased water quality within the affected aquifer.

If exploration activities resume in ATP 688, the suite of analytical parameters described in Table 12 focuses on parameters which may help distinguish aquifer water sources, and on hydrocarbon occurrence.

A suggested monitoring program should comprise collection of groundwater samples from relevant bores on a quarterly basis for the first 12 months. Samples will be scheduled for laboratory analysis for the suite included in Table 12. On completion of one year of quarterly monitoring to establish any seasonal or annual natural variations it may be possible to reduce groundwater quality sampling to bi-annual or annual as appropriate and based on the results of monitoring. All water quality analysis should be carried out by a National Association of Testing Authorities (NATA) accredited laboratory.

Sampling will conform to detailed quality management guidelines. The guidelines should include procedures for sample preservation/packaging/shipping, chain of custody protocol, sample documentation, decontamination procedures. All measured data will be subjected to quality assurance and quality control objectives on data completeness, comparability, representativeness, precision and accuracy, and laboratory procedures.

**Table 11 Water monitoring analytical suite**

| General | Units |
|---|---|
| Conductivity | µS/cm |
| Total Dissolved Solids (calculated) | Mg/L |
| pH | |
| Total Suspended Solids | ° |
| **Major ions** | |
| Bicarbonate alkalinity ($HCO_3$) | mg/L |
| Carbonate Alkalinity as $CaCO_3$ | mg/L |
| Total Alkalinity as $CaCO_3$ | mg/L |
| Sulphate (SO4) | mg/L |
| Chloride (Cl) | mg/L |
| Fluoride (F) | mg/L |
| Calcium (Ca) | mg/L |
| Magnesium (Mg) | mg/L |
| Potassium (K) | mg/L |
| Sodium (Na) | mg/L |
| **Nutrients** | |
| Ammonia (Total as N) | mg/L |
| Nitrate + Nitrite as N | mg/L |
| TKN as N | mg/L |
| Nitrogen - Total (as N) | mg/L |
| Phosphorus - Total (as P) | mg/L |
| **Hydrocarbons** | |
| Phenol compounds | µg/L |
| Polyaromatic Hydrocarbons (PAH) | µg/L |
| Total petroleum Hydrocarbons | µg/L |
| Methane (dissolved) | µg/L |

## *7.4 Reporting*

Westside will prepare an annual report on the findings of the Water Monitoring Strategy discussed in Section 5.3 and the review of the maps of Immediately Affected Areas shown in Figure 12 to Figure 17 as discussed in Section 4.2. Information relating to the completion of the monitoring requirements associated with this Underground Water Impact Report should be collated annually. The checklist provided in Appendix B should be completed and attached to any relevant documentation which should then be attached to this report. Any indicated actions prompted by a material change in the information or predictions should be implemented.

This UWIR will be updated in three years, incorporating the annual reviews and an updated groundwater model consistent with the monitoring data collected and other relevant new information on the hydrogeological regime or the quantity of water produced.

# 8 Part F: Spring Impact Management Strategy

## 8.1 Spring Inventory

Pursuant to the Water Act, 2000 a DEHP spring database review was completed for ATP 688. For any identified springs where predicted water levels within the source aquifer would decline more than 0.2 m, a spring impact management strategy is required.

CDM Smith (2013) completed a desktop review of spring inventories, searching for springs within 10 km of ATP 688 boundaries. Cross checking against project maps and the following sources of information were used to identify spring locations:

- Queensland Government Information Service (Queensland Wetland Data – Springs);
- WetlandInfo Website; and
- Great Artesian Basin Resource Operation Plan Spring Register.

CDM Smith (2013) report no springs were located within or near the ATP 688 boundaries. An additional field check during sampling operations confirmed the negative search results.

Therefore, no information is available about the connectivity between springs and aquifers, nor spring values.

## 8.2 Management of Impacts to Springs

As no springs exist within the project or drawdown area of CSG activities associated with ATP 688, therefore no spring impact management strategy is required.

# 9 Conclusions

This Underground Water Impact Report was prepared for WestSide Corporation for ATP 688 in Queensland. This report conforms to the reporting requirements laid out in the Water Act (Qld) of 2000.

Following a review of the previous UWIR (CDM Smith, 2013) various published reports, registered bore extraction and water level data, and projected CSG operations at ATP 688 the following conclusions are drawn:

- With minimal initial water production and cessation of pilot testing in August 2010 the Immediately Affected Areas predicted by the groundwater numerical modelling in the UWIR prepared in 2013 for the period 2013 to 2016 did not eventuate.
- With cessation of pilot testing in August 2010 WestSide Corporation have no immediate plans to continue exploration in ATP 688. Therefore, the likely water production for the next three years will be zero (0) litres.
- Activities post 2013 approval have included the plugging and abandonment of three exploration wells wells (MSM-1, BH-01 and Tilbrook 9A) in addition to the 14 wells plugged and abandoned pre-2013.
- Whilst there are no immediate plans by WestSide Corporation to resume exploration activities in ATP 688, predictive modelling has been completed, inclusive of two new exploration wells, to evaluate the potential effects of pumping and identify any Immediately Affected Areas and Long-Term Affected Areas in the Mount St Martins exploration area if activities should resume.
- Modelling predictions have been completed to define the extent of Immediately Affected Areas and Long Term Affected Areas above the trigger levels in accordance with the Water Act (Qld), 2000, by predicting drawdowns caused by underground water extraction.
- The pumping rates used in the simulations have been based on historical rates plus assumptions that two new bores will be established in the Mount St Martins area.
- It should be noted that if modelled underground extraction rates are not reached the predictions in this model over-estimate both the Immediately Affected Area and the Long Term Affected Area.
- Under the applied assumptions predictive modelling identifies two consolidated aquifers (The Upper Goonyella Coal Seam and the Goonyella P Seam) are likely to be affected by the exercise of underground water rights.
- There are no reportable impacts in the overlying alluvium and basalt aquifer. After pumping ceases, groundwater elevations recover and there are no Long Term Affected Areas.
- All modelling results presented within this report need to be considered with the assumptions and limitations inherent with numerical modelling of complex hydrogeological systems.
- Local registered bores are primarily drawing a water supply from the shallow Quaternary alluvial and Tertiary basalt aquifers. These surficial aquifers are separated from the perforated and exposed intervals of the coal seam production wells by lower permeability interburden and Rewan formations and because of this separation modelling results show no significant impact in the shallow aquifers.
- This model is considered conservative because it assumes pumping commences in 2017 from the existing and new exploration bores. If pumping activities do not resume in 2017 the model predictions presented in this report significantly overestimate the Immediately Affected Area and the Long-Term Affected Area.
- The model is very sensitive to hydraulic conductivity and due to regional uncertainties sensitivity analysis was carried out by varying the hydraulic conductivity by an order of magnitude to present a worst case scenario.

- Under the worst case prediction modelled the Immediately Affected Area extends along a north south axis approximately 5 km around the pumped wells.
- A monitoring strategy has been prepared, if exploration activities resume, designed to quantify changes that occur because of water extraction during coal seam gas production.
- The monitoring strategy covers the water extracted from the coal seams, regional impacts in the Immediately Affected Area and, as a precaution, groundwater in the alluvial aquifer.
- Several, environmentally sensitive areas have been identified from previous surveys comprising minor wetlands adjacent to the Bowen River and also terrestrial vegetation that is most likely sustained by the shallow groundwater systems.
- The predictive simulations that model continued extractive pumping from 2007 to 2019 show no impacts on the shallow water table aquifers that support both terrestrial GDEs and discharges to water courses and drainage lines.
- Therefore within the bounds of the available information over the period that this UWIR has been prepared, 2016 to 2019, no impact on the environmental values within ATP688 is likely.
- Annual reports on the results of the Water Monitoring Strategy discussed in Section 5.3 will be submitted should exploration activities resume in ATP 688.
- Pursuant to the Water Act, (Qld) 2000 a DEHP spring database review was completed for ATP 688. No springs exist within the project or drawdown area of CSG activities associated with ATP 688, therefore no spring impact management strategy is required.

# 10 References

AECOM, 2010 Collinsville Vegetation Assessment, Prepared for Westside Corporation Ltd. Environmental Approval Amendment Application.

AECOM, 2012 Mount Saint Martin Vegetation Assessments. Prepared for Westside Corporation Ltd

AGE, 2006. Ensham Central Project EIA - Groundwater Impact Assessment. Prepared for Hansen Consulting. http://www.ensham.com.au/updated/eis/pdf/Volume-2_Appendices/APPENDIX%20C%20-%20GROUNDWATER.pdf

Ausenco-Norwest, 2012, *Groundwater Model, Northern Bowen Basin Regional Model Impact Predictions, Queensland, Australia*. Prepared for Arrow Energy Pty Ltd. http://www.arrowenergy.com.au/ data/assets/pdf_file/0018/3870/Appendix-M_Groundwater-Model-Technical-Report.pdf

Barnett, B., Townley, L.R., Post, V., Evans, R.E., Hunt, R.J., Peeters, L., Richardson, S., Werner, A.D., Knapton, A. and Boronkay, A., 2012. *Australian groundwater modelling guidelines*. Waterlines Report Series No. 82, National Water Commission, Canberra, 191 pp. June.

Bashari, A, 1998, *Diagenesis and reservoir development of sandstones in the Triassic Rewan Group, Bowen Basin, Australia,* Journal of Petroleum Geology, 21(4), 445-465.

Bureau of Meteorology, 2013a, *Evapotranspiration map*, http://www.bom.gov.au/jsp/ncc/climate_averages/evapotranspiration/index.jsp.

Bureau of Meteorology, 2013b, *Climate statistics for Collinsville, QLD*. http://www.bom.gov.au/climate/averages/tables/cw_033013.shtml, viewed 11 April 2013.

BHP Billiton Mitsubishi Alliance, 2009. *Daunia Coal Mine Project - Environmental Impact Statement. Appendix H Technical Report: Groundwater Modelling Assessment of Impact of Daunia Coal Mine on Regional Groundwater Aquifers*. http://www.bhpbilliton.com/home/aboutus/regulatory/Documents/dauniaMineEisAppendixH.pdf

Cadman, SJ, L Pain, and V Vuckovic, 1998, *Bowen and Surat Basins, Clarence-Moreton basin, Sydney Basin, Gunnedah Basin and other minor onshore basins, Qld, NSW and NT, Australian Petroleum Accumulations Report 11*, Department of Primary Industries and Energy, Bureau of Resource Sciences.

CDM Smith, 2013 *Underground water impact report ATP 688*. A report prepared for WestSide Corporation

Draper, JJ, 1985a*, Stratigraphy of the Northern Bowen Basin*, Bowen Basin Coal Symposium, Geological Society of Australia Abstracts, Volume 17.

Draper, JJ, 1985b, *Summary of the Permian stratigraphy of the Bowen Basin*, Bowen Basin Coal Symposium, Geological Society of Australia Abstracts, Volume 17.

Fielding, C.R., Silwa, R., Holcombe, R.J., & Kassan, J. 2000: *A new palaeogeographic synthesis of the Bowen Basin of central Queensland*. In: Beeston, J.W. (Editor.), Bowen Basin Symposium 2000, Geological Society of Australia Coal Geology Group & Bowen Basin Geologists Group, Brisbane, 287-302.

Gray, ARG, 1968, *Stratigraphic drilling in the Surat and Bowen Basins, 1965-1966*, Queensland Department of Mines, Report No. 22.

IESC, 2014 *Fact sheet - Subsidence from coal seam gas extraction* Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development, http://www.iesc.environment.gov.au/publications/subsidence-coal-seam-gas-extraction

JBT, 2012. *Foxleigh Plains Project - Environmental Impact Statement Groundwater Report*.

Prepared for Hansen Bailey. http://www.hansenbailey.com.au/assets/pdfs/foxleigh_eis/Appendix%20F%20-%20Groundwater.pdf

Paine, AGL and RL Cameron, 1972. 1:350,000 *Geological Series Explanatory Notes Bowen Queensland, Sheet SF/55-3*, Department of Mines, State of Queensland, Geological Survey of Queensland

Parsons Brinckerhoff, 2011. Middlemount Coal Project Stage 2 Environmental Impact Statement - Chapter 10 Groundwater. Prepared for Middlemount Coal. http://www.pb.com.au/middlemountcoal/09%20EIS%20for%20Public%20Consultation/Volume%202%20Main%20Text/10_Groundwater_110107.pdf

QCoal, 2010. Drake Coal Project Initial Advice Statement. http://www.ehp.qld.gov.au/management/impact-assessment/eis-processes/documents/drake-coal-ias.pdf

Reeves, S, R and O'Neill, P, J, 1989. Preliminary Results from the Broadmeadow Pilot, Project Bowen Basin, Australia. Proceedings of the 1989 Coalbed Methane Symposium.

Silwa, R, S Hamilton, J Hodgkinson, and J Draper, 2008, Bowen Basin Structural Geology, poster produced by CSIRO and the Queensland Government Department of Mines and Energy.

URS, 2009, Caval Ridge Groundwater Impact Assessment. Prepared for BM Alliance Coal Operations Pty Ltd. http://www.bhpbilliton.com/home/aboutus/regulatory/Documents/creisAppJGroundwater.pdf

URS, 2012. Report Groundwater Impact Assessment, Bowen Gas Project. Prepared for Arrow Energy Pty Ltd.

http://www.arrowenergy.com.au/ data/assets/pdf_file/0008/3869/Appendix-L_Groundwater-and-Geology-Technical-Report.pdf

# Appendix A
# Summary of Bores 10 km Surrounding ATP 688

As discussed in Section 4.3.1 bores registered with the Queensland DEHP within, and extending 10 km from the northern border of ATP 688 are listed below. No bores are located within simulated Immediately Affected Area or Long Term Affected Areas.

In the Table below, Queensland Bore Baseline Assessment Database Data Dictionary (November 2011) defines the registered number (RN), the status of the bore, the hydraulic unit (stratigraphic formation) accessed by the screen, the water quality measurement, the yield from the aquifer, the screen top and bottom, and the static water level as drilled (in metres below ground level). The facility and code is defined as Status: EX: existing; AD: abandoned.

The table illustrates that registered bore records are incomplete and field surveys are required to identify suitable pre-existing monitoring bores.

Table A-1: Registered bores within 10 km of ATP 688. RN is registered number

| Bore ID (RN) | Easting | Northing | Zone | Status | Formation | Quality | Yield (L/s) | Standing Water Level (m bgl) | Top Screen (m bgl) | Bottom Screen (m bgl) |
|---|---|---|---|---|---|---|---|---|---|---|
| **8606** | 614390 | 7536451 | 55 | EX | Unknown | | | | | |
| **22209** | 642194 | 7489229 | 55 | EX | Unknown | | | | | |
| **22742** | 589398 | 7692539 | 55 | EX | Unknown | | | | | |
| **23683** | 610002 | 7583535 | 55 | EX | Unknown | | | | | |
| **23686** | 609746 | 7585353 | 55 | EX | Unknown | | | | | |
| **23688** | 609488 | 7585355 | 55 | EX | Unknown | | | | | |
| **23693** | 609230 | 7585357 | 55 | EX | Unknown | | | | | |
| **23745** | 609749 | 7585722 | 55 | EX | Unknown | | | | | |
| **23748** | 609347 | 7585694 | 55 | EX | Unknown | | | | | |
| **23755** | 610038 | 7585966 | 55 | EX | Unknown | | | | | |
| **23758** | 609636 | 7585969 | 55 | EX | Unknown | | | | | |
| **23761** | 609400 | 7585110 | 55 | EX | Unknown | | | | | |
| **23839** | 606894 | 7583897 | 55 | EX | Unknown | | | | | |
| **23843** | 610179 | 7585719 | 55 | EX | Unknown | | | | | |
| **23846** | 605744 | 7583597 | 55 | EX | Unknown | | | | | |
| **24603** | 600263 | 7729920 | 55 | EX | BULGONUNNA | | | | 3 | 10 |
| **24604** | 608590 | 7724949 | 55 | EX | ALLUVIUM | | | | 2.7 | 8.2 |
| **25008** | 592391 | 7720564 | 55 | EX | Unknown | | | | | |
| **25191** | 576438 | 7741420 | 55 | EX | Unknown | | | | | |
| **25192** | 576273 | 7741465 | 55 | EX | ALLUVIUM | | | | 13 | 15 |
| **25319** | 597304 | 7721420 | 55 | EX | Unknown | | | | | |
| **25348** | 591794 | 7719800 | 55 | EX | Unknown | | | | | |
| **25349** | 585005 | 7720630 | 55 | EX | Unknown | | | | | |

| Bore ID (RN) | Easting | Northing | Zone | Status | Formation | Quality | Yield (L/s) | Standing Water Level (m bgl) | Top Screen (m bgl) | Bottom Screen (m bgl) |
|---|---|---|---|---|---|---|---|---|---|---|
| **25410** | 612544 | 7713080 | 55 | EX | UPPER CARB | | | | 17 | 19 |
| **25411** | 612304 | 7715810 | 55 | EX | UPPER CARB | | | | 14 | 20 |
| **25460** | 602534 | 7725620 | 55 | EX | BULGONUNNA | | | | 10 | 17 |
| **25461** | 601824 | 7728050 | 55 | EX | ALLUVIUM | | | | 10 | 13 |
| **25463** | 600224 | 7727010 | 55 | EX | Unknown | | | | | |
| **25464** | 603674 | 7722570 | 55 | EX | Unknown | | | | | |
| **25530** | 596835 | 7741629 | 55 | AD | ALLUVIUM | | | | 11 | 13 |
| **25621** | 586229 | 7671152 | 55 | EX | Unknown | | | | | |
| **25624** | 579195 | 7685070 | 55 | EX | Unknown | | | | | |
| **25625** | 578915 | 7685690 | 55 | EX | Unknown | | | | | |
| **25626** | 576005 | 7680680 | 55 | EX | Unknown | | | | | |
| **25628** | 602085 | 7668240 | 55 | EX | Unknown | | | | | |
| **25630** | 603568 | 7674694 | 55 | EX | Unknown | | | | | |
| **25631** | 598794 | 7679490 | 55 | EX | Unknown | | | | | |
| **25632** | 596924 | 7681170 | 55 | EX | Unknown | | | | | |
| **25633** | 597618 | 7669314 | 55 | EX | Unknown | | | | | |
| **25635** | 598929 | 7671312 | 55 | EX | Unknown | | | | | |
| **25636** | 595464 | 7671126 | 55 | EX | BLACKWATER GROUP | | | | 19 | 50 |
| **25638** | 591706 | 7670079 | 55 | EX | Unknown | | | | | |
| **25639** | 598657 | 7674078 | 55 | EX | Unknown | | | | | |
| **25641** | 603996 | 7673865 | 55 | EX | Unknown | | | | | |
| **25645** | 582395 | 7718680 | 55 | EX | Unknown | | | | | |
| **25646** | 579445 | 7708210 | 55 | EX | Unknown | | | | | |
| **25655** | 619399 | 7712507 | 55 | EX | UPPER CARB | | | | 9 | 15 |

| Bore ID (RN) | Easting | Northing | Zone | Status | Formation | Quality | Yield (L/s) | Standing Water Level (m bgl) | Top Screen (m bgl) | Bottom Screen (m bgl) |
|---|---|---|---|---|---|---|---|---|---|---|
| **25656** | 619454 | 7707920 | 55 | EX | UPPER CARB | | | | 6 | 10 |
| **25661** | 592514 | 7718580 | 55 | EX | Unknown | | | | | |
| **25666** | 590194 | 7689720 | 55 | EX | Unknown | | | | | |
| **25667** | 587014 | 7689440 | 55 | EX | Unknown | | | | | |
| **25668** | 591294 | 7680140 | 55 | EX | Unknown | | | | | |
| **25669** | 582145 | 7696770 | 55 | EX | Unknown | | | | | |
| **25670** | 587904 | 7693990 | 55 | EX | Unknown | | | | | |
| **25671** | 589144 | 7683190 | 55 | EX | Unknown | | | | | |
| **25672** | 588924 | 7696720 | 55 | AD | Unknown | | | | | |
| **25673** | 590754 | 7686680 | 55 | AD | Unknown | | | | | |
| **25674** | 586114 | 7683510 | 55 | AD | Unknown | | | | | |
| **25675** | 581525 | 7689630 | 55 | EX | Unknown | | | | | |
| **25676** | 579805 | 7692380 | 55 | EX | Unknown | | | | | |
| **25677** | 586345 | 7700240 | 55 | EX | Unknown | | | | | |
| **25691** | 593554 | 7724950 | 55 | EX | ALLUVIUM | | | | 16 | 18 |
| **25714** | 598324 | 7724140 | 55 | EX | GRANITE | | | | 6 | 9 |
| **25715** | 594974 | 7719770 | 55 | EX | GRANITE | | | | 7 | 10 |
| **25716** | 583265 | 7721110 | 55 | EX | ALLUVIUM | | | | 12 | 14 |
| **30166** | 595767 | 7558845 | 55 | AD | Unknown | | | | | |
| **30797** | 611254 | 7700260 | 55 | AD | Unknown | | | | | |
| **33142** | 576245 | 7734490 | 55 | EX | Unknown | | | | | |
| **33143** | 567145 | 7741090 | 55 | EX | Unknown | | | | | |
| **33161** | 593134 | 7727080 | 55 | EX | GRANITE | | | | 8 | 9 |
| **33162** | 594424 | 7725250 | 55 | EX | BASALT | | | | 14 | 21 |

| Bore ID (RN) | Easting | Northing | Zone | Status | Formation | Quality | Yield (L/s) | Standing Water Level (m bgl) | Top Screen (m bgl) | Bottom Screen (m bgl) |
|---|---|---|---|---|---|---|---|---|---|---|
| **33163** | 595034 | 7724240 | 55 | EX | GRANITE | | | | 6 | 9 |
| **33164** | 594734 | 7723270 | 55 | EX | BASALT | | | | 9 | 15 |
| **33165** | 591384 | 7723760 | 55 | AD | BASALT | | | | 5 | 18 |
| **33166** | 595554 | 7719610 | 55 | AD | BASALT | | | | 11 | 15 |
| **33167** | 587745 | 7719540 | 55 | EX | BASALT | | | | 12 | 15 |
| **33168** | 585585 | 7721240 | 55 | EX | Unknown | | | | | |
| **33215** | 590431 | 7674227 | 55 | EX | Unknown | | | | | |
| **33340** | 598204 | 7728090 | 55 | EX | BULGONUNNA | | | | 7 | 15 |
| **33341** | 607024 | 7727390 | 55 | EX | BULGONUNNA CREEK ALLUVIUM | | | | 0.6 | 6.4 |
| **33342** | 600024 | 7718050 | 55 | EX | BULGONUNNA | | | | 27 | 27 |
| **33343** | 599734 | 7716990 | 55 | EX | BULGONUNNA | | | | 6 | 10 |
| **33344** | 602194 | 7717730 | 55 | EX | BULGONUNNA | | | | 9 | 21 |
| **33345** | 602084 | 7723190 | 55 | EX | ALLUVIUM | | | | 5 | 11 |
| **34504** | 647324 | 7644144 | 55 | EX | Unknown | | | | | |
| **34569** | 604294 | 7730390 | 55 | EX | THUNDERBOLT GRANITE | | | | 13 | 14 |
| **36420** | 593524 | 7718270 | 55 | EX | THUNDERBOLT GRANITE | | | | 8 | 9 |
| **36421** | 600794 | 7724720 | 55 | EX | THUNDERBOLT GRANITE | | | | 6 | 21 |
| **36422** | 600285 | 7736789 | 55 | AD | THUNDERBOLT GRANITE | | | | 4 | 6 |
| **37147** | 652385 | 7493059 | 55 | EX | BACK CREEK GROUP | COND 11,000 | 0.61 | -27.4 | 34 | 36 |
| **38418** | 608380 | 7539621 | 55 | EX | BLENHEIM FORMATION | | | | 12 | 14 |
| **38419** | 604433 | 7539695 | 55 | EX | Unknown | | | | | |
| **38514** | 576035 | 7734460 | 55 | EX | Unknown | | | | | |
| **38516** | 570565 | 7734520 | 55 | EX | Unknown | | | | | |
| **38517** | 565355 | 7732570 | 55 | EX | Unknown | | | | | |

| Bore ID (RN) | Easting | Northing | Zone | Status | Formation | Quality | Yield (L/s) | Standing Water Level (m bgl) | Top Screen (m bgl) | Bottom Screen (m bgl) |
|---|---|---|---|---|---|---|---|---|---|---|
| **38518** | 563065 | 7733970 | 55 | EX | LIZZIE CREEK VOLCANIC GROUP | | | | 18.3 | 50.3 |
| **38518** | | | | | LIZZIE CREEK VOLCANIC GROUP | | | | 64.1 | 70.1 |
| **38519** | 564335 | 7731970 | 55 | EX | Unknown | | | | | |
| **38520** | 567700 | 7727030 | 55 | EX | Unknown | | | | | |
| **38521** | 564525 | 7736450 | 55 | EX | Unknown | | | | | |
| **38522** | 564105 | 7740610 | 55 | EX | Unknown | | | | | |
| **38547** | 654098 | 7495068 | 55 | EX | BLENHEIM FORMATION | COND 750 6/73 | 1.3 | -12.2 | 32 | 34 |
| **38754** | 642607 | 7505004 | 55 | EX | Unknown | | | | | |
| **38997** | 665032 | 7481405 | 55 | AD | BLACKWATER GROUP | | 0.3 | -99.99 | 40.5 | 76.5 |
| **39371** | 585575 | 7720170 | 55 | EX | ALLUVIUM | | | | 18 | 19 |
| **39376** | 573875 | 7721960 | 55 | AD | Unknown | | | | 15 | 36 |
| **39762** | 597645 | 7741279 | 55 | EX | EURI CREEK ALLUVIUM | | | | 0 | 2 |
| **39840** | 586305 | 7721230 | 55 | EX | ALLUVIUM | | | | 12 | 14 |
| **39841** | 587605 | 7721060 | 55 | EX | ALLUVIUM | | | | 10 | 11 |
| **39842** | 588925 | 7724550 | 55 | EX | BASALT | | | | 6 | 8 |
| **43060** | 663778 | 7482641 | 55 | EX | Unknown | | | | | |
| **43061** | 656767 | 7486480 | 55 | EX | Unknown | | | | | |
| **43062** | 659303 | 7487862 | 55 | EX | Unknown | | | | | |
| **43064** | 663042 | 7484421 | 55 | EX | BACK CREEK GROUP | 8500 US/CM | 0.5 | -24.4 | 67 | 73 |
| **43305** | 647075 | 7516837 | 55 | EX | BLACKWATER GROUP | VERY GOOD | 0.39 | -45.7 | 82 | 91 |
| **43639** | 638939 | 7511033 | 55 | AD | BLACKWATER GROUP | COND 7300 | 0.75 | -29.5 | 40 | 41 |
| **43794** | 645495 | 7489501 | 55 | EX | BLENHEIM FORMATION | 3850 | 2.4 | -11 | 53 | 57 |
| **44080** | 664487 | 7480492 | 55 | AD | BLACKWATER GROUP | | 0.01 | | 43 | 52.7 |
| **44336** | 634975 | 7509310 | 55 | EX | Unknown | | | | | |

| Bore ID (RN) | Easting | Northing | Zone | Status | Formation | Quality | Yield (L/s) | Standing Water Level (m bgl) | Top Screen (m bgl) | Bottom Screen (m bgl) |
|---|---|---|---|---|---|---|---|---|---|---|
| **44480** | 595049 | 7631253 | 55 | AD | Unknown | | | | | |
| **47546** | 636631 | 7477884 | 55 | EX | Unknown | | | | | |
| **47547** | 635859 | 7482382 | 55 | EX | Unknown | | | | | |
| **54108** | 591725 | 7673460 | 55 | EX | Unknown | | | | | |
| **54280** | 609944 | 7713130 | 55 | AD | Unknown | | | | | |
| **54281** | 609964 | 7716470 | 55 | AD | Unknown | | | | | |
| **54282** | 610044 | 7715100 | 55 | AD | Unknown | | | | | |
| **54283** | 609944 | 7713040 | 55 | AD | Unknown | | | | | |
| **54284** | 610264 | 7712950 | 55 | AD | GRANITE | | | | 17 | 17 |
| **54285** | 610124 | 7713100 | 55 | AD | Unknown | | | | | |
| **54948** | 582925 | 7739519 | 55 | EX | BULGONNUNA | | | | 8 | 23 |
| **54949** | 580465 | 7739550 | 55 | EX | BULGONUNNA | | | | 15 | 27 |
| **54950** | 580475 | 7740919 | 55 | EX | BULGONUNNA | | | | 23 | 26 |
| **57747** | 640392 | 7509441 | 55 | EX | BACK CREEK GROUP | | 4.42 | -99.99 | 70.1 | |
| **57748** | 632375 | 7507835 | 55 | EX | BLENHEIM FORMATION | | 1 | -18 | 36 | 38 |
| **60091** | 576595 | 7683720 | 55 | EX | ALLUV | | | | 19 | 25 |
| **60104** | 590815 | 7725440 | 55 | EX | LIZZIE CREEK VOLCANIC GROUP | | | | 11 | 21 |
| **60105** | 588185 | 7720600 | 55 | EX | ALLUVIUM | | | | 14 | 19 |
| **60275** | 604644 | 7662460 | 55 | EX | Unknown | | | | | |
| **60361** | 581195 | 7680190 | 55 | EX | ALLUV | | | | 27 | 44 |
| **60362** | 585264 | 7686260 | 55 | EX | ALLUV | | | | 51 | 74 |
| **60458** | 589906 | 7657632 | 55 | EX | BLACKWATER GROUP | | | | 40 | 56 |
| **60459** | 595533 | 7658096 | 55 | EX | BLACKWATER GROUP | | | | 20 | 45 |
| **60465** | 603477 | 7660098 | 55 | EX | Unknown | | | | 40 | 55 |

| Bore ID (RN) | Easting | Northing | Zone | Status | Formation | Quality | Yield (L/s) | Standing Water Level (m bgl) | Top Screen (m bgl) | Bottom Screen (m bgl) |
|---|---|---|---|---|---|---|---|---|---|---|
| **60661** | 564955 | 7736540 | 55 | EX | FORMATION UNKNOWN | | | | 31 | 34.5 |
| **60769** | 584985 | 7729210 | 55 | EX | Unknown | | | | | |
| **60814** | 608643 | 7729083 | 55 | EX | Unknown | POTABLE | 0.25 | -16.2 | 13 | 17.5 |
| **60881** | 596635 | 7741169 | 55 | EX | Unknown | | | | | |
| **62571** | 645502 | 7473754 | 55 | EX | BACK CREEK GROUP | | | -12.2 | 50 | 57 |
| **62719** | 608044 | 7538841 | 55 | EX | Unknown | | | | | |
| **63590** | 673546 | 7609705 | 55 | AD | Unknown | | | | | |
| **63591** | 672055 | 7610172 | 55 | AD | Unknown | | | | | |
| **63592** | 669965 | 7613804 | 55 | AD | Unknown | | | | | |
| **63963** | 629679 | 7641111 | 55 | AD | EXEVALE FORMATION | | | | 24 | 60 |
| **63964** | 631142 | 7636671 | 55 | AD | Unknown | | | | | |
| **63965** | 630678 | 7636264 | 55 | AD | EXEVALE FORMATION | | | | 12 | 60 |
| **63966** | 631812 | 7634082 | 55 | AD | Unknown | | | | | |
| **63967** | 635041 | 7634425 | 55 | AD | EXEVALE FORMATION | | | | 23.5 | 27.5 |
| **63968** | 632485 | 7636537 | 55 | AD | Unknown | | | | | |
| **63969** | 643170 | 7637431 | 55 | AD | Unknown | | | | | |
| **63970** | 647377 | 7639649 | 55 | AD | Unknown | | | | | |
| **63971** | 635806 | 7643316 | 55 | AD | Unknown | | | | | |
| **63972** | 640196 | 7639744 | 55 | AD | Unknown | | | | | |
| **63973** | 642680 | 7638501 | 55 | AD | Unknown | | | | | |
| **67067** | 661782 | 7458818 | 55 | EX | Unknown | | | | | |
| **67068** | 661813 | 7458411 | 55 | EX | Unknown | | | | | |
| **67130** | 642432 | 7504723 | 55 | EX | BLENHEIM FORMATION | | | | 45 | 47 |
| **67248** | 659733 | 7501055 | 55 | EX | BLACKWATER GROUP | 700 US/CM | 3.52 | -19 | 31 | 36 |

| Bore ID (RN) | Easting | Northing | Zone | Status | Formation | Quality | Yield (L/s) | Standing Water Level (m bgl) | Top Screen (m bgl) | Bottom Screen (m bgl) |
|---|---|---|---|---|---|---|---|---|---|---|
| **67250** | 659241 | 7500795 | 55 | EX | BLACKWATER GROUP | 3600 US/CM | | | 30.5 | 35 |
| **67421** | 658156 | 7500245 | 55 | EX | Unknown | | | | | |
| **67422** | 656734 | 7496511 | 55 | EX | Unknown | | | | | |
| **67423** | 650064 | 7496776 | 55 | EX | Unknown | | | | | |
| **70019** | 587634 | 7680610 | 55 | EX | Unknown | | | | | |
| **70020** | 580525 | 7696850 | 55 | EX | Unknown | | | | | |
| **70060** | 588385 | 7732150 | 55 | EX | Unknown | | | | | |
| **70176** | 611004 | 7711210 | 55 | EX | Unknown | | | | | |
| **70177** | 615184 | 7714260 | 55 | EX | Unknown | | | | | |
| **70324** | 615954 | 7698890 | 55 | EX | Unknown | | | | | |
| **76237** | 615884 | 7705740 | 55 | EX | COLLINSVILLE GRANITE | | | | 6.1 | 19.8 |
| **76238** | 614224 | 7704000 | 55 | EX | COLLINSVILLE GRANITE | | | | 5.5 | 25.9 |
| **76239** | 610094 | 7705000 | 55 | EX | COLLINSVILLE GRANITE | | | | 5.5 | 12.2 |
| **76240** | 611234 | 7711780 | 55 | EX | COLLINSVILLE GRANITE | | | | 5.5 | 14.6 |
| **81135** | 641429 | 7662745 | 55 | AD | Unknown | | | | | |
| **81151** | 600066 | 7604543 | 55 | AD | Unknown | | | | | |
| **81696** | 608182 | 7586081 | 55 | EX | Unknown | | | | | |
| **81700** | 591815 | 7587788 | 55 | EX | Unknown | | | | | |
| **81701** | 600253 | 7576669 | 55 | EX | Unknown | | | | | |
| **81702** | 599074 | 7580862 | 55 | AD | Unknown | | | | | |
| **84538** | 641354 | 7516737 | 55 | EX | Unknown | | | | | |
| **85051** | 615465 | 7666406 | 55 | EX | UPPER BOWEN COAL | | | | 43 | 45 |
| **85052** | 612686 | 7669883 | 55 | EX | Unknown | | | | | |
| **85053** | 610676 | 7671548 | 55 | EX | Unknown | | | | | |

| Bore ID (RN) | Easting | Northing | Zone | Status | Formation | Quality | Yield (L/s) | Standing Water Level (m bgl) | Top Screen (m bgl) | Bottom Screen (m bgl) |
|---|---|---|---|---|---|---|---|---|---|---|
| **85054** | 608500 | 7667003 | 55 | EX | Unknown | | | | | |
| **85055** | 612730 | 7665442 | 55 | EX | Unknown | | | | | |
| **85056** | 612807 | 7665992 | 55 | EX | Unknown | | | | | |
| **85057** | 617447 | 7659908 | 55 | EX | Unknown | | | | | |
| **85058** | 612270 | 7662852 | 55 | EX | Unknown | | | | | |
| **85059** | 612561 | 7662379 | 55 | EX | EXEVALE FORMATION | | | | 42.5 | 44.5 |
| **85060** | 613755 | 7659148 | 55 | EX | EXEVALE FORMATION | | | | 94 | 97.5 |
| **85441** | 589056 | 7630385 | 55 | AD | BLACKWATER GROUP | | 0.88 | -54 | 80 | 81 |
| **85442** | 587485 | 7630927 | 55 | AD | BASALT | | 1 | -40 | 48 | 62 |
| **85443** | 588640 | 7631494 | 55 | AD | BLACKWATER GROUP | | 3.5 | -30 | 55 | 61.5 |
| **85499** | 606359 | 7546888 | 55 | EX | BLENHEIM FORMATION | | | | 47 | 53.6 |
| **85581** | 614260 | 7714295 | 55 | EX | Unknown | | | | | |
| **89035** | 636430 | 7478056 | 55 | EX | BLENHEIM FORMATION | | | | 22.5 | 24 |
| **89468** | 652072 | 7500792 | 55 | AD | Unknown | | | | | |
| **89484** | 640378 | 7471934 | 55 | EX | UNDIFF. | | | | 15 | 24 |
| **90013** | 646295 | 7502266 | 55 | AD | UNDIFF. | | | | 23 | |
| **90014** | 645217 | 7505537 | 55 | AD | Unknown | | | | | |
| **90016** | 641460 | 7499975 | 55 | AD | Unknown | | | | | |
| **90017** | 640107 | 7500530 | 55 | EX | UNDIFF | | | | 23 | |
| **90264** | 662740 | 7485824 | 55 | EX | PERMIAN COAL MEASURE | | | | 24 | 29 |
| **90437** | 649085 | 7498072 | 55 | AU | BLENHEIM FORMATION | | | | 30 | 36 |
| **90475** | 645463 | 7513291 | 55 | AD | BLACKWATER GROUP | | 0.01 | -304.5 | 56.69 | 60.96 |
| **100089** | 612943 | 7586807 | 55 | EX | Unknown | | | | | |
| **100137** | 609489 | 7585509 | 55 | EX | Unknown | | | | | |

| Bore ID (RN) | Easting | Northing | Zone | Status | Formation | Quality | Yield (L/s) | Standing Water Level (m bgl) | Top Screen (m bgl) | Bottom Screen (m bgl) |
|---|---|---|---|---|---|---|---|---|---|---|
| **100225** | 614778 | 7566528 | 55 | EX | Unknown | | | | | |
| **100235** | 605771 | 7579015 | 55 | EX | Unknown | | | | | |
| **100248** | 641645 | 7518640 | 55 | EX | Unknown | | | | | |
| **100253** | 618233 | 7556847 | 55 | EX | Unknown | | | | | |
| **100254** | 619668 | 7557174 | 55 | EX | Unknown | | | | | |
| **100290** | 607704 | 7584844 | 55 | EX | Unknown | | | | | |
| **100291** | 626431 | 7542882 | 55 | EX | Unknown | | | | | |
| **103210** | 616869 | 7560018 | 55 | EX | BLACKWATER GROUP | POTABLE | 0.38 | -19.81 | 25.91 | 27.43 |
| **105460** | 654242 | 7662979 | 55 | EX | URANNAH IGNEOUS COMPLEX | POTABLE | 1.01 | -2.3 | 8 | 9.2 |
| **105461** | 654960 | 7650098 | 55 | AD | URANNAH IGNEOUS COMPLEX | | | | 0 | |
| **105462** | 640561 | 7662220 | 55 | AD | LIZZIE CREEK VOLCANIC GROUP | | | | 0 | |
| **105463** | 639771 | 7664318 | 55 | AD | LIZZIE CREEK VOLCANIC GROUP | | | | 0 | |
| **105464** | 640052 | 7663424 | 55 | EX | LIZZIE CREEK VOLCANIC GROUP | POTABLE | 0.56 | -7 | 10 | 13.7 |
| **105502** | 652954 | 7663832 | 55 | EX | URANNAH IGNEOUS COMPLEX | POTABLE | 0.1 | -4.3 | 7 | 9 |
| **105503** | 652954 | 7663925 | 55 | AU | Unknown | | | | | |
| **105504** | 653065 | 7663432 | 55 | AU | Unknown | | | | | |
| **105505** | 652461 | 7663622 | 55 | AU | Unknown | | | | | |
| **105506** | 651629 | 7664121 | 55 | AU | Unknown | | | | 3 | 4 |
| **105507** | 651601 | 7664183 | 55 | AU | Unknown | | | | 2 | 3 |
| **105508** | 652781 | 7663895 | 55 | AU | Unknown | | | | 2 | 3 |
| **105509** | 652696 | 7664081 | 55 | AU | Unknown | | | | 5 | |
| **105510** | 651629 | 7664121 | 55 | EX | URANNAH IGNEOUS COMPLEX | | 0.38 | | 3.65 | 6.7 |
| **105511** | 654530 | 7662649 | 55 | EX | URANNAH IGNEOUS COMPLEX | | 0.63 | | 21.33 | 22.86 |
| **105512** | 654992 | 7662706 | 55 | AU | Unknown | | | | 3.65 | 5.02 |

| Bore ID (RN) | Easting | Northing | Zone | Status | Formation | Quality | Yield (L/s) | Standing Water Level (m bgl) | Top Screen (m bgl) | Bottom Screen (m bgl) |
|---|---|---|---|---|---|---|---|---|---|---|
| **105513** | 654992 | 7662706 | 55 | AD | Unknown | | | | | |
| **105514** | 654994 | 7662921 | 55 | EX | URANNAH IGNEOUS COMPLEX | | 0.44 | | 3.65 | 9 |
| **105515** | 654389 | 7663019 | 55 | EX | URANNAH IGNEOUS COMPLEX | | 0.5 | | 6.7 | 8.53 |
| **105516** | 654360 | 7663020 | 55 | EX | URANNAH IGNEOUS COMPLEX | | 1.57 | -1.58 | 4.57 | 7.31 |
| **105517** | 654331 | 7662958 | 55 | EX | URANNAH IGNEOUS COMPLEX | | 1 | | 5.18 | 7.13 |
| **105518** | 654388 | 7662927 | 55 | EX | URANNAH IGNEOUS COMPLEX | | 1 | | 8.23 | 9 |
| **105519** | 654530 | 7662649 | 55 | EX | URANNAH IGNEOUS COMPLEX | | 0.63 | | 18.9 | 22.5 |
| **105520** | 654530 | 7662680 | 55 | EX | URANNAH IGNEOUS COMPLEX | | 0.38 | | 10.05 | 13.56 |
| **105521** | 654472 | 7662680 | 55 | EX | URANNAH IGNEOUS COMPLEX | | | -1.05 | 9.14 | 11.58 |
| **105521** | | | | | Unknown | | | | 14 | 15.84 |
| **105521** | | | | | Unknown | | | | 17.37 | 18.3 |
| **105522** | 654471 | 7662557 | 55 | EX | URANNAH IGNEOUS COMPLEX | | | | 18.3 | 20.3 |
| **105523** | 654470 | 7662465 | 55 | EX | URANNAH IGNEOUS COMPLEX | | 0.19 | -8.8 | 9.14 | 9.3 |
| **105831** | 628592 | 7659696 | 55 | AD | Unknown | | | | | |
| **105832** | 628590 | 7659506 | 55 | AD | Unknown | | | | | |
| **105833** | 628501 | 7659507 | 55 | EX | QUATERNARY - UNDEFINED | POT | 1.87 | -5 | 14 | 16.1 |
| **105835** | 672489 | 7614196 | 55 | EX | NEBO CREEK ALLUVIUM | | 0 | -9.14 | 9.14 | 13.72 |
| **105836** | 614397 | 7670776 | 55 | EX | EXEVALE FORMATION | | 0 | -14.63 | 19.51 | 21.34 |
| **105837** | 634508 | 7666465 | 55 | EX | TERTIARY - UNDEFINED | | 0 | -17.37 | 17.98 | 21.34 |
| **122458** | 644983 | 7526770 | 55 | EX | BACK CREEK GROUP | COND 4000 | 1.88 | -26 | 35 | 50.5 |
| **125371** | 626349 | 7704725 | 55 | EX | Unknown | POTABLE | 1.25 | -9 | 7 | 20 |
| **125372** | 623254 | 7703666 | 55 | AD | Unknown | | | | | |
| **125375** | 621105 | 7704970 | 55 | EX | Unknown | POTABLE | 0.62 | -14 | 14 | 25 |
| **125401** | 563712 | 7723375 | 55 | AD | Unknown | | | | | |

| Bore ID (RN) | Easting | Northing | Zone | Status | Formation | Quality | Yield (L/s) | Standing Water Level (m bgl) | Top Screen (m bgl) | Bottom Screen (m bgl) |
|---|---|---|---|---|---|---|---|---|---|---|
| **125402** | 563689 | 7723357 | 55 | AD | Unknown | | | | | |
| **125403** | 562068 | 7724432 | 55 | EX | Unknown | | | | | |
| **125404** | 565675 | 7722743 | 55 | AD | Unknown | | | | | |
| **125665** | 568688 | 7731772 | 55 | EX | Unknown | POTABLE | 4 | -10 | 22 | 24 |
| **125696** | 597736 | 7713445 | 55 | EX | Unknown | POTABLE | 2.6 | -5 | 8 | 26 |
| **125697** | 595070 | 7714811 | 55 | AD | Unknown | | | | | |
| **125698** | 595687 | 7715912 | 55 | EX | Unknown | POTABLE | 5.6 | -25 | 8 | 37.27 |
| **125731** | 619729 | 7686702 | 55 | EX | Unknown | | | | | |
| **125885** | 620676 | 7685624 | 55 | EX | Unknown | POTABLE | 0.5 | -11 | 15 | 22.8 |
| **125971** | 586429 | 7655735 | 55 | AD | Unknown | | | | | |
| **125972** | 586916 | 7657821 | 55 | EX | Unknown | TDS 1300 | | -21.9 | 33 | 43 |
| **125973** | 587448 | 7654774 | 55 | AD | Unknown | | | | | |
| **125974** | 586506 | 7656354 | 55 | EX | Unknown | | | -27.4 | 34 | 65 |
| **125975** | 586517 | 7656307 | 55 | AD | Unknown | | | | | |
| **125976** | 581927 | 7662636 | 55 | AD | Unknown | | | | | |
| **125977** | 586466 | 7656364 | 55 | EX | Unknown | TDS 1200 | 12 | -27.4 | 66 | 71.5 |
| **125978** | 586932 | 7657823 | 55 | EX | Unknown | TDS 1500 | 5 | -22 | 47 | 51 |
| **131217** | 659445 | 7623045 | 55 | AD | Unknown | | | | | |
| **131218** | 657953 | 7622609 | 55 | EX | BLENHEIM FORMATION | POT | 2.13 | -10 | 11 | 17 |
| **131219** | 659597 | 7622711 | 55 | AD | Unknown | | | | | |
| **131220** | 657997 | 7622608 | 55 | AD | Unknown | | | | | |
| **131221** | 657931 | 7622609 | 55 | AD | Unknown | | | | | |
| **131459** | 628969 | 7658745 | 55 | EX | BLACKWATER GROUP | POT | 3.75 | -11 | 54 | 57 |
| **131460** | 655966 | 7654762 | 55 | AD | Unknown | | | | | |

| Bore ID (RN) | Easting | Northing | Zone | Status | Formation | Quality | Yield (L/s) | Standing Water Level (m bgl) | Top Screen (m bgl) | Bottom Screen (m bgl) |
|---|---|---|---|---|---|---|---|---|---|---|
| **132459** | 669458 | 7468660 | 55 | EX | Unknown | | | | | |
| **132465** | 652154 | 7450105 | 55 | EX | Unknown | | | | | |
| **132466** | 656691 | 7449411 | 55 | EX | Unknown | | | | | |
| **132631** | 635440 | 7528179 | 55 | EX | BACK CREEK GROUP | 7290 US/CM | 15 | -31 | 321 | 328 |
| **132731** | 644569 | 7507274 | 55 | EX | BLACKWATER GROUP | SALTY | 0.1 | -26 | 23 | 28 |
| **132732** | 645138 | 7506836 | 55 | EX | BLACKWATER GROUP | SALTY | 0.5 | -28 | 30 | 35 |
| **132733** | 645138 | 7506836 | 55 | EX | BLACKWATER GROUP | SALTY | 0.5 | -28 | 30 | 35 |
| **132734** | 645001 | 7506729 | 55 | EX | Unknown | | | | | |
| **132735** | 645118 | 7506800 | 55 | EX | Unknown | | | | | |
| **132736** | 645120 | 7506786 | 55 | EX | BLACKWATER GROUP | SALTY | 0.1 | -26 | 23 | 28 |
| **136092** | 633416 | 7512196 | 55 | EX | BACK CREEK GROUP | | 1.1 | -12 | 18 | |
| **136689** | 635868 | 7528234 | 55 | EX | DUARINGA FORMATION | 7290 US/CM | 15 | -31 | 321 | 328 |
| **140015** | 595975 | 7716281 | 55 | AD | Unknown | | | | | |
| **140016** | 603058 | 7711711 | 55 | EX | Unknown | POTABLE | 0.74 | -11.5 | 21 | 27 |
| **140017** | 600890 | 7713033 | 55 | AD | Unknown | POTABLE | 0.12 | -33 | 33 | 42 |
| **140018** | 598298 | 7711717 | 55 | AD | Unknown | | | | | |
| **140019** | 595077 | 7714752 | 55 | AD | Unknown | | | | | |
| **140020** | 594690 | 7715181 | 55 | EX | Unknown | POTABLE | 0.74 | -8.3 | 9 | 15 |
| **140021** | 602565 | 7707836 | 55 | AD | Unknown | | | | | |
| **140022** | 601558 | 7707200 | 55 | AD | Unknown | | | | | |
| **140023** | 601142 | 7706913 | 55 | AD | Unknown | | | | | |
| **140024** | 600240 | 7711878 | 55 | AD | Unknown | | | | | |
| **140025** | 592385 | 7717168 | 55 | AD | Unknown | | | | | |
| **140119** | 576644 | 7741286 | 55 | EX | Unknown | 850 PPM | 0.3 | -6.3 | 16 | 44 |

| Bore ID (RN) | Easting | Northing | Zone | Status | Formation | Quality | Yield (L/s) | Standing Water Level (m bgl) | Top Screen (m bgl) | Bottom Screen (m bgl) |
|---|---|---|---|---|---|---|---|---|---|---|
| **140127** | 577589 | 7740103 | 55 | EX | Unknown | 1100 PPM | 3.8 | -8 | 13 | 25 |
| **140400** | 587252 | 7720490 | 55 | EX | Unknown | | | | | |
| **140401** | 590426 | 7719297 | 55 | EX | Unknown | | | | | |
| **140402** | 587389 | 7718142 | 55 | EX | Unknown | | | | | |
| **140403** | 589700 | 7718421 | 55 | EX | Unknown | | | | | |
| **140404** | 590426 | 7719297 | 55 | EX | Unknown | | | | | |
| **140405** | 588530 | 7720770 | 55 | EX | Unknown | | | | | |
| **140406** | 586560 | 7721140 | 55 | EX | Unknown | | | | | |
| **140407** | 584660 | 7720720 | 55 | EX | Unknown | | | | | |
| **140408** | 590160 | 7721340 | 55 | EX | Unknown | | | -18.7 | 15 | 21 |
| **140408** | | | | | Unknown | | 0.02 | -18.7 | 21 | 25 |
| **140529** | 590383 | 7716667 | 55 | EX | Unknown | | | | | |
| **140530** | 590479 | 7717653 | 55 | EX | Unknown | | | | | |
| **140531** | 590132 | 7717898 | 55 | EX | Unknown | | | | | |
| **140877** | 559884 | 7724637 | 55 | EX | Unknown | | | | | |
| **141047** | 600220 | 7581503 | 55 | EX | ISAAC RIVER ALLUVIUM | | | -11.93 | 12 | 19 |
| **141123** | 663307 | 7604980 | 55 | EX | Unknown | 1800 US/CM | 0.6 | -10 | 21 | 25 |
| **141124** | 667132 | 7607940 | 55 | AD | Unknown | | | | | |
| **141125** | 667213 | 7608062 | 55 | AD | Unknown | | | | | |
| **141243** | 654381 | 7662721 | 55 | EX | Unknown | OK WATER | 0.88 | -6 | 16 | 18 |
| **141247** | 636485 | 7635612 | 55 | EX | Unknown | POTABLE | 1 | -35.5 | 56 | 63.6 |
| **141248** | 631014 | 7638701 | 55 | AD | Unknown | MOIST | | | 35 | 41 |
| **141367** | 656328 | 7658433 | 55 | EX | Unknown | | 0.1 | | 8 | |
| **141368** | 656378 | 7658481 | 55 | EX | Unknown | | 0.1 | | 6 | 10 |

| Bore ID (RN) | Easting | Northing | Zone | Status | Formation | Quality | Yield (L/s) | Standing Water Level (m bgl) | Top Screen (m bgl) | Bottom Screen (m bgl) |
|---|---|---|---|---|---|---|---|---|---|---|
| **141382** | 623251 | 7551535 | 55 | EX | Unknown | | 0.02 | -18.36 | 25 | |
| **141383** | 627054 | 7550393 | 55 | EX | Unknown | | | | | |
| **141384** | 623784 | 7549605 | 55 | EX | Unknown | | 0.03 | -23.87 | 42.2 | |
| **141385** | 623251 | 7551535 | 55 | EX | Unknown | | 0.01 | -30.53 | 42.2 | |
| **141386** | 626447 | 7543989 | 55 | EX | Unknown | TRACE ONLY | | -17.97 | 22 | |
| **141454** | 655567 | 7653368 | 55 | AD | Unknown | | | | | |
| **141545** | 660325 | 7610110 | 55 | EX | Unknown | POTABLE | 1.23 | -6 | 12 | |
| **141547** | 658909 | 7623526 | 55 | EX | Unknown | POTABLE | 3.87 | -10 | 19 | |
| **141718** | 670868 | 7608326 | 55 | EX | Unknown | SALT | 0.91 | -12 | 15 | 18 |
| **141787** | 605120 | 7592687 | 55 | EX | ISAAC RIVER ALLUVIUM | NOT TESTED | 0.01 | -10.48 | 13 | 15 |
| **141935** | 591997 | 7642215 | 55 | EX | Unknown | | | | 24 | |
| **141935** | | | | | Unknown | | 0.1 | -78.5 | 102 | 119 |
| **141936** | 592422 | 7645985 | 55 | EX | Unknown | | 0.1 | -36.5 | 38 | |
| **141936** | | | | | Unknown | | 0.5 | -36.5 | 54 | 67 |
| **141937** | 588323 | 7637881 | 55 | EX | Unknown | | 0 | -94.7 | 90 | 101 |
| **151043** | 667610 | 7471634 | 55 | EX | TERTIARY - UNDEFINED | | | | 21 | 30 |
| **151334** | 667716 | 7473509 | 55 | EX | TERTIARY - UNDEFINED | | | -25 | 25 | 30 |
| **151335** | 667641 | 7469327 | 55 | EX | Unknown | | | | | |
| **151336** | 670646 | 7469943 | 55 | EX | TERTIARY - UNDEFINED | | | -42 | 42 | 48 |
| **153054** | 589260 | 7705640 | 55 | AD | Unknown | | | | | |
| **153055** | 589001 | 7710264 | 55 | EX | Unknown | | | | 41 | |
| **153056** | 589167 | 7709631 | 55 | EX | Unknown | | | | 37 | |
| **153057** | 584890 | 7712200 | 55 | EX | Unknown | | | | 33 | |
| **153058** | 583592 | 7712534 | 55 | EX | Unknown | | | | | |

| Bore ID (RN) | Easting | Northing | Zone | Status | Formation | Quality | Yield (L/s) | Standing Water Level (m bgl) | Top Screen (m bgl) | Bottom Screen (m bgl) |
|---|---|---|---|---|---|---|---|---|---|---|
| **153059** | 586335 | 7705463 | 55 | EX | Unknown | | | | | |
| **153060** | 585881 | 7705931 | 55 | EX | Unknown | | | | | |
| **153061** | 591450 | 7710883 | 55 | EX | Unknown | | | -7 | 12 | |
| **153175** | 586079 | 7731773 | 55 | EX | Unknown | | 0.25 | -5.3 | 7 | 13 |
| **153175** | | | | | Unknown | | 0.25 | -5.3 | 30 | 32 |
| **153176** | 587209 | 7731782 | 55 | AD | Unknown | POTABLE | 0.06 | | 17 | 20 |
| **153229** | 589229 | 7654175 | 55 | EX | Unknown | | 0.4 | -33.7 | 46 | |
| **153230** | 587122 | 7656990 | 55 | EX | Unknown | POOR? NOT STATED | 8.5 | | 36 | |
| **153230** | | | | | Unknown | | 2.5 | -61 | 61 | |
| **153231** | 587115 | 7656973 | 55 | EX | Unknown | | | | 27 | 28 |
| **153231** | | | | | Unknown | | 1.5 | -22.8 | 35 | 52 |
| **153232** | 587279 | 7643867 | 55 | EX | Unknown | | | | 47 | |
| **153232** | | | | | Unknown | | 0.7 | -43.3 | 55 | 59 |
| **153233** | 585076 | 7665061 | 55 | AD | Unknown | | 4 | -72 | 89 | 96 |
| **153234** | 585089 | 7665060 | 55 | EX | Unknown | | 4 | -71.5 | 92 | 95 |
| **153235** | 595167 | 7646339 | 55 | EX | Unknown | | 0.1 | -55.8 | 112 | 120 |
| **153237** | 593438 | 7663430 | 55 | EX | Unknown | | 0.8 | -11.2 | 44 | |
| **153238** | 594512 | 7668243 | 55 | EX | Unknown | | 0.5 | -43 | 33 | 52 |
| **12020001** | 603199 | 7704582 | 55 | AU | Unknown | | | | | |
| **12020002** | 603027 | 7704911 | 55 | AU | Unknown | | | | | |
| **12020003** | 588851 | 7703750 | 55 | AU | Unknown | | | | | |
| **12020004** | 588856 | 7038255 | 55 | AU | Unknown | | | | | |
| **12020005** | 588919 | 7704352 | 55 | AU | Unknown | | | | | |
| **12020007** | 589023 | 7704833 | 55 | AU | Unknown | | | | | |

| Bore ID (RN) | Easting | Northing | Zone | Status | Formation | Quality | Yield (L/s) | Standing Water Level (m bgl) | Top Screen (m bgl) | Bottom Screen (m bgl) |
|---|---|---|---|---|---|---|---|---|---|---|
| **12020008** | 589075 | 7704956 | 55 | AU | Unknown | | | | | |
| **12020011** | 567597 | 7714971 | 55 | AU | Unknown | | | | | |
| **12020012** | 568010 | 7715295 | 55 | AU | Unknown | | | | | |
| **12020013** | 568008 | 7715295 | 55 | AU | Unknown | | | | | |
| **12020017** | 588754 | 7703253 | 55 | EX | Unknown | | | | | |
| **12020018** | 588980 | 7702715 | 55 | EX | Unknown | | | | | |
| **12020019** | 603641 | 7703870 | 55 | AD | Unknown | | | | | |
| **12020020** | 604355 | 7704114 | 55 | AD | Unknown | | | | | |
| **12020021** | 568330 | 7715664 | 55 | EX | Unknown | | | | | |
| **12020022** | 569104 | 7716381 | 55 | AD | Unknown | | | | | |
| **12020023** | 568515 | 7716220 | 55 | AD | Unknown | | | | | |
| **12020025** | 560038 | 7733536 | 55 | AD | Unknown | | | | | |
| **12020026** | 580663 | 7703507 | 55 | EX | Unknown | | | | | |
| **12020027** | 580641 | 7704484 | 55 | EX | Unknown | | | | | |
| **12030094** | 577823 | 7666252 | 55 | AU | Unknown | | | | | |
| **13010001** | 649066 | 7449003 | 55 | AU | BACK CREEK GROUP | | | -41 | 2 | 52 |
| **13040108** | 656270 | 7609520 | 55 | AD | Unknown | | | | | |
| **13040109** | 655636 | 7609403 | 55 | AD | Unknown | | | | | |
| **13040110** | 654975 | 7609409 | 55 | AD | Unknown | | | | | |
| **13040111** | 654484 | 7609260 | 55 | AD | Unknown | | | | | |
| **13040171** | 603448 | 7587837 | 55 | AD | Unknown | | | | | |
| **13040172** | 602585 | 7587596 | 55 | AD | Unknown | | | | | |
| **13040173** | 601809 | 7587601 | 55 | AD | Unknown | | | | | |
| **13040174** | 617190 | 7562863 | 55 | AD | Unknown | | | | | |
| **13040175** | 616813 | 7562251 | 55 | AD | Unknown | | | | | |

| Bore ID (RN) | Easting | Northing | Zone | Status | Formation | Quality | Yield (L/s) | Standing Water Level (m bgl) | Top Screen (m bgl) | Bottom Screen (m bgl) |
|---|---|---|---|---|---|---|---|---|---|---|
| **13040176** | 616291 | 7561486 | 55 | AD | Unknown | | | | | |
| **13040281** | 598875 | 7583323 | 55 | EX | BASALT | COND 13840 | | -35.18 | 42 | 59.5 |
| **13040282** | 605910 | 7545740 | 55 | EX | BACK CREEK GROUP | | | | 10 | 30.4 |
| **13040283** | 627834 | 7527375 | 55 | EX | BACK CREEK GROUP | | | | 47.5 | 52 |
| **13040316** | 665675 | 7613373 | 55 | AD | LEURA VOLCANICS | 800US/CM | 0.1 | | 22 | |
| **13040316** | | | | | LEURA VOLCANICS | 819US/CM | 1.15 | | 120 | 123 |
| **13040316** | | | | | LEURA VOLCANICS | 1056US/CM | 1.55 | | 172 | 182 |

# Appendix B

## UWIR Groundwater Monitoring Checklist

The following checklist (CDM Smith, 2013) would be completed at each monitoring episode

| Task | | |
|---|---|---|
| Verify monitoring completed as required | | |
| 1 | **All monitored bores intact?** | **Y/N** |
| | If boreholes damaged amend registered details | |
| 2 | **All monitoring completed according to schedule** | **Y/N** |
| | If monitoring incomplete commission additional monitoring as required | |
| Review monitoring data | | |
| 3 | **Potentially adverse impacts identified?**<br><br>Compare measured water level to previous monitoring rounds – if either<br><br>a) water level is lower than previous lowest measurement by >5m or<br><br>b) three subsequent monitoring events record a fall in water level >1m then a potential adverse impact has been identified. | **Y/N** |
| | If potentially adverse impacts identified, then:<br><br>• Advise Environment Manager;<br><br>• Review operational activities;<br><br>• If appropriate commission review of data;<br><br>• Identify any requirement for and implement changes in operation to mitigate adverse impacts. | |
| Checklist Reviewed by | Name - | |
| | Date - | |

arris
agricultural & environmental

**Arris Pty Ltd** ABN 91 092 739 574

**South Australian Office:**
The Waite Campus
Bld 11b Gate 2c
Hartley Grove
URRBRAE SA 5064 Australia
Tel +61 8 8313 6706
Fax +61 8 8313 6752

**Western Australian Office:**
6/14 Halley Road
BALCATTA WA 6021 Australia
Tel +61 8 9344 4600
Fax +61 8 8313 6752

**Queensland Office:**
44 Wentworth Terrace
ROCKHAMPTON Qld 4700 Australia
Tel +61 407 268 069
Fax +61 8 8313 6752

**Northern Territory Office:**
16 Willes Road
BERRIMAH NT 0828 Australia
Tel +61 8 8947 0181
Fax +61 8 8313 6752

info@arris.com.au

www.arris.com.au