Westside Corporation

Meridian Gas Project – PL94
Underground Water Impact Report

CDM Smith

Westside Corporation

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Underground Water Impact Report

11 June 2019

CDM Smith

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Document History and Status

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Section 1 Introduction

CDM Smith Australia Pty Ltd (CDM Smith) has been engaged by Westside Corporation Ltd (Westside) to prepare this revision to the Underground Water Impact Report (UWIR) for the operation of Petroleum Lease 94 (PL94). The requirements for an Underground Water Impact Report (UWIR) are set out within the Level 1 Environmental Authority issued by the Queensland Department of Environment and Heritage Protection (DEHP) and the operation of the associated Co-development Area, all of which comprise the Meridian Seam Gas Project (the Meridian Project).

The registered principal holder of PL94 is as follows:

Westside CSG A Pty Ltd
Level 8, 300 Queen Street
Brisbane Qld 4000
ACN: 117145516

This report represents a revision to the 2016 UWIR that was a revision of the inaugural UWIR issued in 2013. Much of the analysis presented in the 2013 and 2016 versions has been maintained, as it is still representative of relevance to current and proposed operations for PL94 over the next three years.

1.1 Legislation

1.1.1 Water Act 2000

The regulation of groundwater extractions associated with Petroleum Leases is set out within the *Water Act 200*0. Guidance on the content of UWIRs is provided in *Guideline – Underground Water Impact Reports and Final Reports* (the UWIR Guideline) produced by DEHP. This report has been prepared to meet the requirements set out within Part 2, Division 4 of the Water Act (2000) for UWIRs which are summarised as follows:

Part 2, Division 4 of the Water Act (2000)

Subdivision 1, 376 Content of underground water impact report

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

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

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

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

(c) a description of the methods and techniques used to obtain the information and predictions under paragraph (b);

(d) a summary of information about all water bores in the area shown on a map mentioned in paragraph (b)(iv), including the number of bores, and the location and authorised use or purpose of each bore;

(e) a program for—

- (i) conducting an annual review of the accuracy of each map prepared under paragraph (b)(iv) and (v); and
- (ii) giving the chief executive a summary of the outcome of each review, including a statement of whether there has been a material change in the information or predictions used to prepare the maps;

(f) a water monitoring strategy;

(g) a spring impact management strategy;

(h) if the responsible entity is the commission—

- (i) a proposed responsible tenure holder for each report obligation mentioned in the report; and
- (ii) for each immediately affected area—the proposed responsible tenure holder or holders who must comply with any make good obligations for water bores within the immediately affected area;

(i) other information or matters prescribed under a regulation.

1.2 Licence

The Meridian Project operates PL94 under an Environmental Authority, in accordance with DEHP Permit Number PPG00783713 (the DEHP Permit). This Permit sets out a number of conditions and requirements for the management and protection of underground water, surface water and springs:

The conditions relating to groundwater detailed within the DEHP Permit are set out below:

Groundwater Requirements under DEHP Permit Number PPG00783713

Authorised impacts to groundwater

(GB) The extraction of groundwater as part of the authorised resource activity(ies) from underground aquifers must not directly or indirectly cause environmental harm to a wetland.

Groundwater Impact Monitoring Program

(G9) A Groundwater Monitoring Program must be developed and implemented which is able to detect any changes to groundwater quality as a result of storing contaminants in a containment facility(ies) (e.g. surface dams, monocells).

(G10) The Groundwater Monitoring Program must be developed and implemented by a suitably qualified person in the fields of hydrogeology, groundwater sampling design and groundwater monitoring program design.

(G11) The Groundwater Monitoring Program, must include, but not necessarily be limited to:

a) locations of monitoring sites, monitoring methodology and trigger values for detecting impacts on groundwater quality
b) as a minimum, sampling of the parameters and at the frequency listed in Schedule G, Protecting Water Values, Table 1 - Minimum Groundwater Monitoring Parameters and Monitoring Frequency
c) procedures to establish background groundwater quality
d) sampling of groundwater in accordance with the requirements for baseline bore, well and stimulation impact monitoring as per conditions (114) to (116); and
e) a sufficient number of monitoring sites to provide information on the following:
   i. seepage to groundwater and surrounding soils from any regulated dam and its effect on groundwater and soils and
   ii. background monitoring sites (i.e. groundwater quality in representative bores that have not been affected by the authorised resource activity(ies) authorised under this environmental authority)
   iii. the conduct of a geodetic survey of all monitoring bores to determine the relative water surface elevations of each bore and reported in metres relative to the AHO and
   iv. the determination of groundwater flow direction, groundwater flow rate and hydraulic conductivity; and
   v. a rationale containing details on the program purpose, program conceptualisation and verification of assumptions.

(G12) All groundwater monitoring bores must be installed according to the standards outlined in The National Water Commission's Minimum Construction Requirements for Water Bores in Australia 2012, the Department of Natural Resources and Mines' Minimum standards for the construction and reconditioning of water bores that intersect the sediments of artesian basins in Queensland 2014 or Code of Practice for constructing and abandoning coal seam gas wells and associated bored in Queensland 2013 as amended from time to time.

(G13) Groundwater monitoring bores must be constructed by, or under the supervision of a licensed Queensland water bore driller who has the correct endorsements on their licence for the type of activity being performed.

(G14) Groundwater samples must be monitored for the water quality parameters at the minimum frequencies specified in Schedule G, Protecting Water Values, Table 1 – Groundwater Monitoring Parameters and Monitoring Frequency (reproduced .below as **Table 1-1**).

Table 1-1 DEHP Environmental Authority Requirements for Groundwater Monitoring Parameters and Monitoring Frequency (Reproduced from Schedule G, Table 1 of Environmental Authority No. PPG00783713)

Groundwater parameter	Monitoring Frequency
Water level [m]	Quarterly
Groundwater pressure in geological strata [kPa]	Biannually
pH	Biannually
Electrical conductivity [µS/m]	Biannually
Total dissolved solids [mg/L]	Biannually
Temperature [°C]	Biannually
Dissolved oxygen [mg/L]	Biannually
Alkalinity (bicarbonate, carbonate, hydroxide and total as CaC03) [mg/L]	Biannually
Sodium adsorption ratio (SAR)	Biannually
Anions (bicarbonate, carbonate, hydroxide, chloride, sulphate) [mg/L]	Biannually
Cations (aluminium, calcium, magnesium, potassium, sodium) [mg/L]	Biannually
Silica [mg/L]	Biannually
Dissolved and total metals (including but not necessarily being limited to: aluminium, arsenic, barium, borate (boron), cadmium, chromium Ill, copper, iron, fluoride, lead, manganese, mercury, nickel, selenium, silver, strontium, tin and zinc) [µg/L]	Biannually
Total phosphorus as phosphorus [mg/L]	Biannually
Ammonia, nitrate and nitrite as nitrogen [mg/L]	Biannually
Total petroleum hydrocarbons [mg/L]	Biannually
BTEX (as benzene, toluene, ethylbenzene, ortho-xylene, para-xylene, meta-xylene and total xylene) [µg/L];	Biannually
Polycyclic aromatic hydrocarbons (including but not necessarily being limited to: naphthalene, phenanthrene, benzo[a]pyrene) [µg/L]	Biannually
Gross alpha + gross beta or radionuclides by gamma spectroscopy [Bq/L]	Biannually

Stimulation Baseline Monitoring Requirements under DEHP Permit Number PPG00783713

(I11) Prior to undertaking any stimulation activity, a baseline bore assessment must be undertaken of the water quality of:

a) all landholders active groundwater bores (subject to access being permitted by the landholder) that are spatially located within a two (2) kilometre horizontal radius from the location of the stimulation initiation point within the target gas producing formation and
b) all landholders' active groundwater bores (subject to access being permitted by the landholder) in any aquifer that is within 200 metre above or below the target gas producing formation and is spatially located with a two (2) kilometre radius from the location of the stimulation initiation point; and
c) any other bore that could potentially be adversely impacted by the stimulation activities in accordance with the findings of the risk assessment required by conditions (I9) and (I10).

(I12) Prior to undertaking stimulation activities at a well, there must be sufficient water quality data to accurately represent the water quality in the well to be stimulated. The data must include as a minimum the results of analyses for the parameters in condition (I13).

(I13) Baseline bore and well assessments must include relevant analytes and physico-chemical parameters to be monitored in order to establish baseline water quality and must include, but not necessarily be limited to:

a) pH
b) electrical conductivity [µS/m]
c) turbidity [NTU]
d) total dissolved solids [mg/L]
e) temperature [°C]
f) dissolved oxygen [mg/L]
g) dissolved gases (methane, chlorine, carbon dioxide, hydrogen sulfide) [mg/L]
h) alkalinity (bicarbonate, carbonate, hydroxide and total as CaC03) [mg/L]
i) sodium adsorption ratio (SAR)
j) anions (bicarbonate, carbonate, hydroxide, chloride, sulphate) [mg/L]
k) cations (aluminium, calcium, magnesium, potassium, sodium) [mg/L]
l) dissolved and total metals and metalloids (including but not necessarily being limited to: aluminium, arsenic, barium, borate (boron), cadmium, total chromium, copper, iron, fluoride, lead, manganese, mercury, nickel, selenium, silver, strontium, tin and zinc)[µg/L]
m) total petroleum hydrocarbons [µg/L]
n) BTEX (as benzene, toluene, ethylbenzene, ortho-xylene, para- and meta-xylene, and total xylene) [µg/L]
o) polycyclic aromatic hydrocarbons (including but not necessarily being limited to: naphthalene, phenanthrene, benzo[a]pyrene) [µg/L]
p) sodium hypochlorite [mg/L]
q) sodium hydroxide [mg/L]
r) formaldehyde [mg/L]
s) ethanol [mg/L] and
t) gross alpha + gross beta or radionuclides by gamma spectroscopy [Bq/L].

(I14) A Stimulation Impact Monitoring Program must be developed prior to the carrying out of stimulation activities which must be able to detect adverse impacts to water quality from stimulation activities and must consider the findings of the risk assessment required by conditions (I9) and (110) that relate to stimulation activities and must include, as a minimum, monitoring of:

a) the stimulation fluids to be used in stimulation activities at sufficient frequency and which sufficiently represents the quantity and quality of the fluids used
b) flow back waters from stimulation activities at sufficient frequency and which sufficiently represents the quality of that flow back water
c) flow back waters from stimulation activities at sufficient frequency and accuracy to demonstrate that 150 percent of the volume used in stimulation activities has been extracted from the stimulated well and
d) all bores in accordance with condition (I11).

(I15) The Stimulation Impact Monitoring Program must provide for monitoring of:

a) analytes and physico-chemical parameters relevant to baseline bore and well assessments to enable data referencing and comparison including, but not necessarily being limited to the analytes and physico-chemical parameters in condition (I13) and
b) any other analyte or physico-chemical parameters that will enable detection of adverse water quality impacts and the inter-connection with a non-target aquifer as a result of stimulation

activities including chemical compounds that are actually or potentially formed by chemical reactions with each other or coal seam materials during stimulation activities.

(116) The Stimulation Impact Monitoring Program must provide for monitoring of the bores in condition (I14(d)) at the following minimum frequency:

a) monthly for the first six (6) months subsequent to stimulation activities being undertaken then
b) annually for the first five (5) years subsequent to stimulation being undertaken or until analytes and physico-chemical parameters listed in conditions (I13(a)) to (I13(t)) inclusive, are not detected in concentrations above baseline bore monitoring data on two (2) consecutive monitoring occasions.

(117) The results of the Stimulation Impact Monitoring Program must be made available to any potentially affected landholder upon request by that landholder.

Section 2 Project Description

2.1 History

The Meridian Project was first explored by various operators such as MIM in the early 1990s, Conoco in the mid-1990s and Oil Company of Australia (now Origin) at the beginning of the 2000s. Conoco undertook the initial development in the Moura field in 1996 and Oil Company of Australia undertook most of the development drilling in the other fields in the period 1999 to 2002, in the PL94 area. Anglo Coal undertook the operation of PL94 in 2006, and Westside took operatorship of PL94 on 1 July 2010.

2.2 Operation of the Meridian Project PL94

2.2.1 Licensed area

The Meridian Project comprises five gas fields distributed across the Site within the PL94 area, as shown on Figure F1. The gas fields within PL94 are listed below:

- Dawson River;
- Nipan;
- Moura; and
- Mungi.

The wells within these gas fields target seams within the Baralaba Coal Measures.

2.2.2 Current and future production

The production wells within PL94 consist of vertical wells associated with stimulation programs, and single lateral wells. In the Westside operated area of PL94 there are 192 production wells (**Table 2-1**) of which 120 are operational as of April 2019. The remaining 72 wells are potential gas producers that have been installed and may have historically produced.

The locations of all wells associated with CSG operations within PL94 are shown in Figure F2.

Table 2-1 Production Wells in Meridian Project PL94 in early-2019

Operator	Operational Production Wells	Potential Gas Producing Wells (i.e. installed but not currently operational)	2019 Proposed Gas Producing Wells (i.e. wells that have not yet been installed, as of May 2019)
Westside Corporation (PL94)	120	72	54

2.3 Summary of Current Groundwater Extraction (Part A)

2.3.1 Current and Historical Groundwater Extractions

Current and historical water production rates for the wells have been estimated on a regular basis by Westside using bucket-tests for vertical wells and by counting the surface separator dumps for horizontal wells. Production data from PL94 for the period July 2011 to April 2019 has been collated and presented in **Table 2-2** and **Figure 2-1**. Data prior to Westside's operation of PL94 is now available but is not presented here.

Table 2-2 Historical Water Production - Meridian Project PL94 - July 2011 to June 2016

Gas Field	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19
Dawson volume (ML)	6	16	4	13	19	53	97	81
Moura volume (ML)	31	7	1	5	12	17	26	24
Nipan volume (ML)	7	6	4	13	12	11	10	11
Mungi volume (ML)	8	1	0	0	0	0	12	18
Total volume (ML)	51	30	8	31	42	81	146	135
Average Total Production Rate (L/s)	1.6	1.0	0.3	1.0	1.3	2.6	4.6	4.3

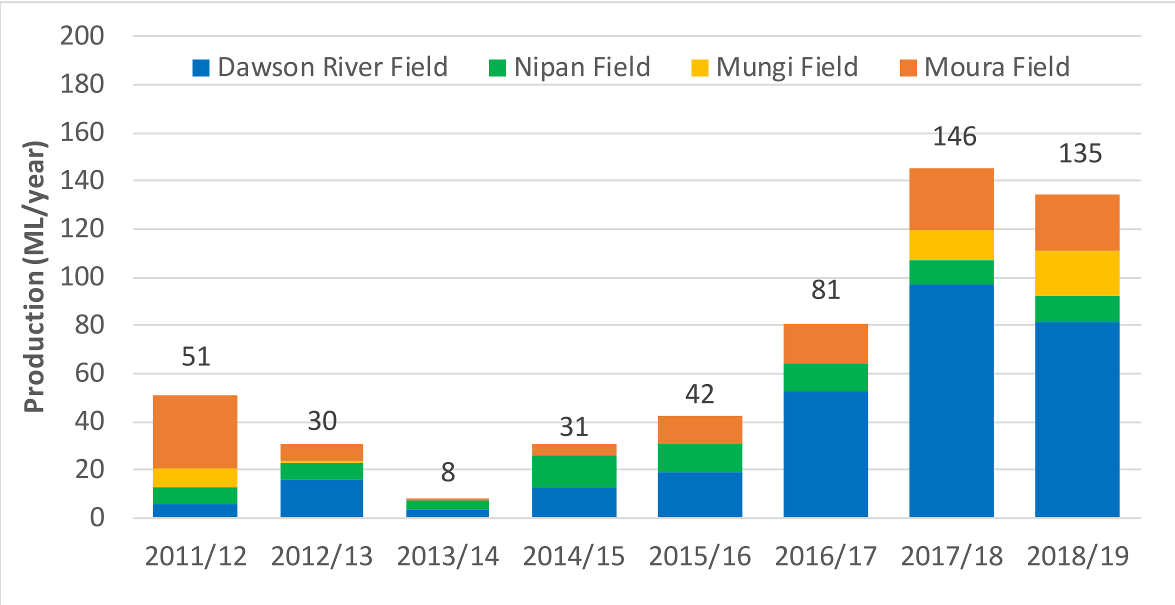


Figure 2-1 Yearly water production data for PL94

2.4 Estimated Future Water Production

2.4.1 PL 94 Estimated Future Water Production

The estimated future water extraction has been developed for existing and proposed gas wells within PL94 using the following assumptions:

- Water production rates in existing operational wells continue into the future at the same rate as most recent data record with a monthly decline factor of 0. 9674.
- Each new proposed well for 2019, 2020, 2021 have an extraction rate of 0.09 L/s with a decline factor of 0.9674 applied each month. Start dates for 2019 wells are on the expected drilling completion date and for the proposed 2020 and 2021 wells, on the first of January of that year.

The estimates developed are intended to represent the best estimate of production over the period of the predictions.

Estimates of planned locations and predicted extraction rates have been prepared by Westside Corporation; however, this information is commercially sensitive, therefore only a summary of predicted extractions is provided in this report (**Table 2-3**).

Table 2-3 Predicted Water Production - Meridian Project PL94

Gas Field	2019	2020	2021
Dawson volume (ML)	97.1	74.8	83.1
Moura volume (ML)	48.7	138.3	120.9
Nipan volume (ML)	14.4	72.2	87.7
Mungi volume (ML)	25.3	39.7	102.6
Total volume (ML)	185.6	325.0	394.2
Total Rate (L/s)	5.9	10.3	12.5

Section 3 Project Setting

3.1 Location and Topography

PL94 is located in Central Queensland, approximately 180 km south-west of Gladstone. The lease has an elongated shape extending about 27 km in a north-south direction and 7 km east-west, covering a total area of 169 km^2.

The lease is located to the west of, and roughly parallel to the Dawson Mine. The Dawson Mine leases occupy a 30 km long, north-south, strike length. The township of Moura is located in the northwest corner of PL94 and the township of Theodore is about 11 km to the south of the lease.

The lease is located in the catchment of the Dawson River in the Fitzroy Basin, between the Malakoff Range, a prominent north-south trending ridge to the east, and the Dawson Range to the west (**Figure F1**).

The Dawson River flows toward the north and then northwest through PL94. A number of westerly flowing ephemeral tributaries cross the Dawson Mine and PL94 and discharge to the Dawson River. Their courses have been significantly altered by mining activities.

The topography is undulating and grades to the west and the Dawson River with surface slopes generally less than 3°. The land within the lease area is predominantly used for grazing, with some smaller areas of cropping.

3.2 Climate

Climate monitoring data collected by the Bureau of Meteorology is available for the Moura Post Office (Station No. 039071) located in the northern area of PL94. It appears that this station has not been recording rainfall data after August 2016. The climate of the surrounding region is subtropical, with warm to hot summers and mild winters.

The average annual rainfall at the Moura Post Office Station since 1980 is 685 millimetres (mm), of which the majority falls in the warmer months of the year (November to February). Mean daily pan evaporation in the summer season reaches 8 mm/day in December and 3 mm/day in June. Average daily evaporation of 5.8 mm/day (2117 mm/year) exceeds mean rainfall throughout the year, the highest moisture deficit occurring during summer.

In order to place recent rainfall years into a historical context, the Cumulative Rainfall Departure (CRD) which is a summation of the monthly departures of rainfall from the long-term average monthly rainfall, was calculated as follows:

$$CRD_n = CRD_{n-1} + (R_n - R_{av})$$

Where: CRD_n = CRD for a given month

CRD_{n-1} = CRD for a preceding month

R_{av} = long-term average rainfall for a given month

R_n = actual rainfall for given month

The CRD graph for the period 1980 to 2020 is shown in **Figure 3-1**. A rising trend in the CRD plot indicates periods of above average rainfall, whilst a falling slope indicates periods when rainfall is below average. The CRD shown on **Figure 3-1** indicates that the area experienced a period of generally below average rainfall from 1990 until 2009. Above average rainfall has been recorded from 2009 to 2012 followed by average – slightly below average rainfall to present. Rainfall data from this station is not available from the Bureau of Meteorology after August 2016 and so this figure was produced using patched data from SILO.

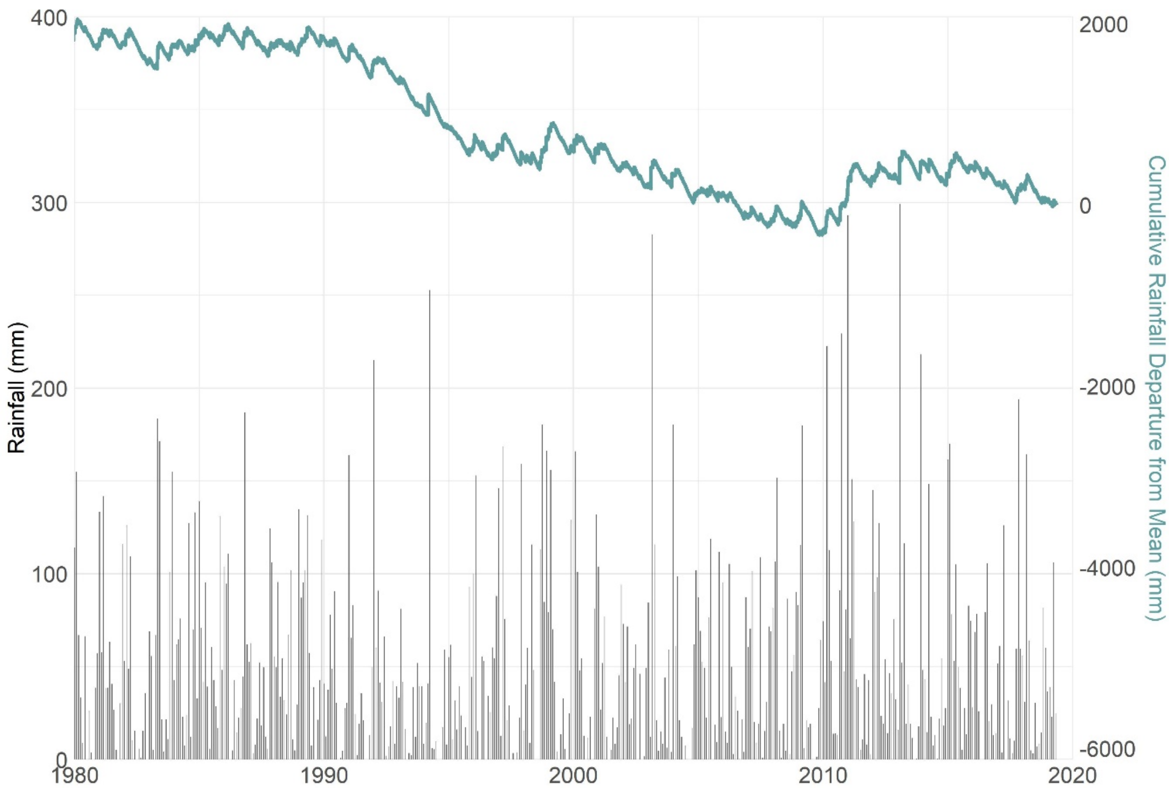


Figure 3-1 Monthly Rainfall Data - Moura Post Office (Station Number 039071) using SILO data

Section 4 Geology and Hydrogeology (Part B)

4.1 Information Sources

A number of sources of information have been reviewed during the preparation of this report, including:

- Geological Maps:
  - Geological Survey of Queensland – Australia 1:250,000 Geological Series - Monto sheet SG 56-1, 1981;
  - Geological Survey of Queensland – Australia 1:250,000 Geological Series – Baralaba sheet SG 55-4, 1964;
- Spatial Analysis of Coal Seam Water Chemistry Task 1: Literature Review (Prepared for Department of Environment and Resource Management). WorleyParsons, December 2010.
- Baseline Groundwater Study – Meridian Seam Gas Field. Australian Groundwater & Environmental Consultants Pty Ltd (AGE), March 2011.

4.2 Regional

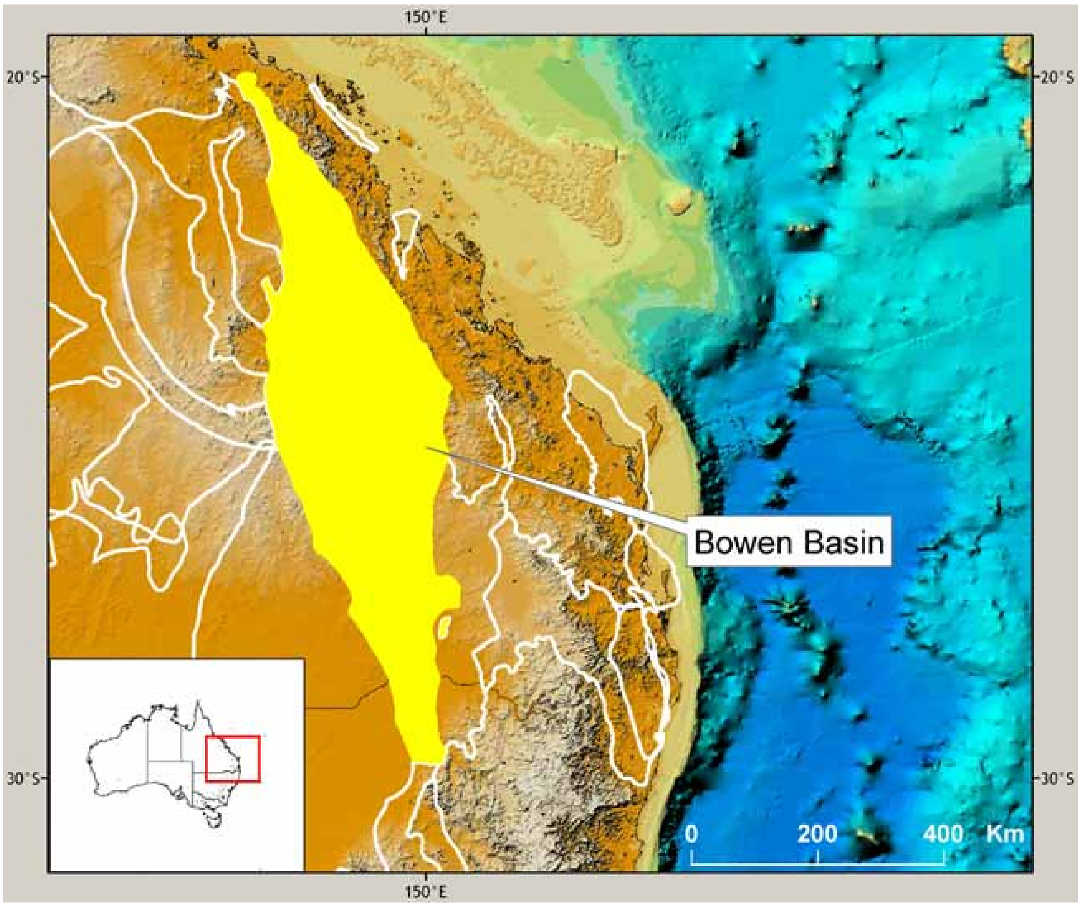
4.2.1 Regional Geology

The Meridian Project is located south of Moura Township in Central Queensland, which is dominated by sedimentary rocks of the Bowen Basin. The Bowen Basin is an elongated basin that extends from Townsville to the Queensland – New South Wales border (**Figure 4-1**). The basin extends approximately 600 km in length and 250 km in width.

The history of the Bowen Basin is complex and dominated by sedimentary transgressive and regressive cycles with minor volcanic, igneous and tectonic activity. The dominance of the sedimentary activity has resulted in the deposition of sedimentary rocks that can be stratigraphically correlated to adjoining basins to the south.

Regionally, the Bowen Basin comprises of clastic sediments, limestone, volcanoclastic sediments and coal, all of which were deposited in continental and marine environments between Permian to Middle Triassic. Unconsolidated Quaternary Alluvium and, in places, remnants of Tertiary sandstone and silts flows overlie Triassic rocks.

The Meridian Project is located on the eastern side of the Bowen basin within the central area as shown on **Figure 4-1**. PL94 is situated in the catchment of Dawson River in the Fitzroy Basin, between the topographic highs of Malakoff Range to the east and Dawson Range to the west.



Notes: sourced from Geoscience Australia (http://www.ga.gov.au accessed 4/4/2012)

Figure 4-1 The Bowen Basin (Geoscience Australia)

The central Bowen Basin stratigraphy comprises basal basement rocks consisting of volcanics (Lizzie Creek Volcanic, Camboon Volcanics) overlain by sedimentary rocks comprising (from oldest to youngest):

- Buffel Formation;
- Oxtrack Formation;
- Barfield Formation;
- Flat top formation;
- Gyranda Formation;
- Kaloola Formation;
- Baralaba Coal Measures;
- Rewan Formation;
- Clematis group (frequently absent);
- Moolayember Formation (frequently absent);
- Duaringa Formation;

- Tertiary volcanic (extent limited); and
- Quaternary Alluvium.

Structurally, the central Bowen Basin is affected by northwest-southeast aligned faulting extending into the Back Creek Group.

A generalised stratigraphy of the central Bowen Basin is presented in **Table 4-1** and an excerpt from the geological maps published by the Geological Survey of Queensland is presented in Figure F3.

Table 4-1 Generalised stratigraphy of the central Bowen Basin

	Geological Unit		Description	Thickness
Quaternary	Undefined alluvium		Alluvial sand, gravel and clay (AGE, 2011)	Locally deposited and frequently not present
		Unconformity		
Tertiary	Undefined alluvium		Sandstone, siltstone, claystone, conglomerate (1:250,000 Geological Sheet)	Locally eroded and frequently not present
		Unconformity		
Triassic	Moolayember Formation		Micaceous sandstone and siltstone	Locally eroded and frequently not present
	Clematis Group		Medium to coarse grained sandstone, siltstone, mudstone and conglomerate	Locally eroded and frequently not present
	Rewan Group		Sandstone, mudstone and conglomerate	Locally eroded
		Unconformity		
Permian	Blackwater Group	Baralaba Coal Measures	Calcareous mudstone and shale, coal and feldspathic sandstone	250m (AGE, 2011)
		Gyranda Subgroup	Siltstone and shale with rare coal	Up to 1500m
	Back Creek Group	Flat Top Formation	Siltstone, sandstone, mudstone and conglomerate	Not reported
		Barfield Formation	Calcareous mudstone	700m
		Oxtrack Formation	Fossiliferous limestone	Not reported
		Buffel Formation	Fossiliferous limestone	130m
	Camboon Volcanics		Basalt	3000m

Data sourced from the Geoscience Australia Stratigraphic Units Database (http://www.ga.gov.au/products-services/data-applications/reference-databases/stratigraphic-units.html accessed 4/4/2012) except where otherwise indicated.

4.2.2 Regional Hydrogeology

The regional hydrogeology of the Bowen Basin is poorly defined. The Worley Parsons (December 2010) study indicates that groundwater should conceptually flow in a south westerly direction, following the dipping of the strata away from the recharge zones. It is likely that on a local scale the direction of shallow groundwater flow direction will be topographically driven but also likely to be influenced by factors including contrasting aquifer properties, rainfall variability, surface water – groundwater interaction, irrigation or other groundwater extractions.

Hydraulic properties of the aquifers and aquitards comprising the Bowen Basin are also limited (Worley Parsons, 2010), with some information available on the Moolaymeber Formation, the Clematis Group and the Rewan Group as detailed in Table 4-2.

Table 4-2 Literature Reported Hydrogeological Characterisation of units within the Bowen Basin (Worley Parsons, 2010)

Unit	Horizontal Hydraulic Conductivity (m/d)	Porosity (%)	Source
Moolayember Formation	$1.2x10^{-4}$ – $8.9x10^{-2}$	18 – 27	Worley Parsons, 2010
	$8.3x10^{-6}$ – $1.0x10^{1}$	Not reported	Commonwealth of Australia, 2014
Clematis Group	$6.0x10^{-2}$ – $4.5x10^{2}$	12 – 20	Worley Parsons, 2010
	$8.3x10^{-6}$ – $5.5x10^{1}$	Not reported	Commonwealth of Australia, 2014
Rewan Group	$1.2x10^{-4}$ – $1.2x10^{-3}$	Not reported	Worley Parsons, 2010
	$8.3x10^{-6}$ – $1.9x10^{0}$	Not reported	Commonwealth of Australia, 2014

Testing completed in the development of the Meridian Project has identified the Baralaba Coal Measures to be a relatively productive water bearing formation. Measurement of coal seam permeability has been completed in a number of locations across the Meridian Project. The hydraulic conductivities calculated from the testing are reported in AGE (2011) and are presented in Table 4-3.

Table 4-3 Measured Hydraulic Conductivity of the Baralaba Coal Measures (AGE, 2011)

Depth (mbgl)	Hydraulic Conductivity (m/d)	Gas Field
254.3	$8.00X10^{-4}$	unknown
266.1	$1.52X10^{-4}$	unknown
303.4	$9.20X10^{-4}$	unknown
348.7	$5.20X10^{-5}$	unknown
386.4	$3.20X10^{-4}$	unknown
415.6	$2.40X10^{-6}$	unknown
193.7	$3.20X10^{-4}$	Hillview
240.2	$1.88X10^{-2}$	Hillview
277.2	$3.12X10^{-3}$	Hillview
315.6	$1.28X10^{-3}$	Hillview
342.5	$4.56X10^{-3}$	Hillview
312.0	$4.00X10^{-4}$	Hillview
351.7	$1.20X10^{-3}$	Hillview
388.2	$8.80X10^{-4}$	Hillview
488.3	$8.00X10^{-4}$	Hillview
317.5	$8.80X10^{-4}$	Hillview
359.4	$8.80X10^{-4}$	Hillview
253.6	$2.56X10^{-3}$	Hillview
294.0	$4.00X10^{-4}$	Hillview
440.7	$6.49X10^{-3}$	Moura
468.1	$3.76X10^{-4}$	Moura
502.0	$1.12X10^{-2}$	Moura
	$5.76X10^{-5}$	Dawson River /Nipan
	$4.50X10^{-5}$	Dawson River /Nipan

Depth (mbgl)	Hydraulic Conductivity (m/d)	Gas Field
	$2.87X10^{-5}$	Dawson River /Nipan
	$2.54X10^{-5}$	Dawson River /Nipan
	$3.11X10^{-5}$	Dawson River /Nipan
	$5.98X10^{-5}$	Dawson River /Nipan

The measured hydraulic conductivities indicate that the formation is variable, with markedly lower hydraulic conductivities in the south. The geometric mean and median values are $4.08x10^{-4}$ and $6x10^{-4}$ m/d respectively.

4.2.3 Groundwater quality

As with the hydrogeological information, groundwater quality across the Bowen Basin at a regional level is limited. Groundwater quality information available from the literature is detailed in **Table 4-4** below.

Table 4-4 Literature Reported groundwater chemistry of units within the Bowen Basin

Formation	Water type	Salinity	Source
Alluvium	Na+Ca, Cl	528 – 2,500 µS/cm	AGE, 2011
Moolayember Formation	Cl, HCO_3	2,000 µS/cm	Worley Parsons, 2010
Clematis Group	Na-HCO_3, Cl	131 – 900 µS/cm	Worley Parsons, 2010
Rewan Group	Na, Cl	25,000 µS/cm	Worley Parsons, 2010
Baralaba Coal Measures	--	4,800 – 19,000 µS/cm	Worley Parsons, 2010
	Na+K, Cl	5010 – 15,400 µS/cm	AGE, 2011
Gyranda Subgroup	--	--	
Back Creek Group		2,800 – 30,000 µS/cm	Worley Parsons, 2010

Water quality data from the AGE, 2011 report has been reproduced below in **Table 4-5** and **Table 4-6**, along with a piper trilinear plot (**Figure 4-2**) to demonstrate the typical water type. **Figure 4-2** indicates that the Baralaba Coal Measures are a Na+K, Cl dominated with relatively high salinity. The Quaternary Alluvium has a more mixed water type, ranging from a Na-Cl type to more calcareous chemistries. This is consistent with the lower salinity and shallower nature of these waters, which are more likely to be influenced by modern recharge and localised hydrological processes. This also demonstrates conceptually, that there is very low connectivity between the shallow alluvial waters and the deeper waters of the Baralaba Coal Measures.

Table 4-5 Groundwater quality in the Quaternary alluvium

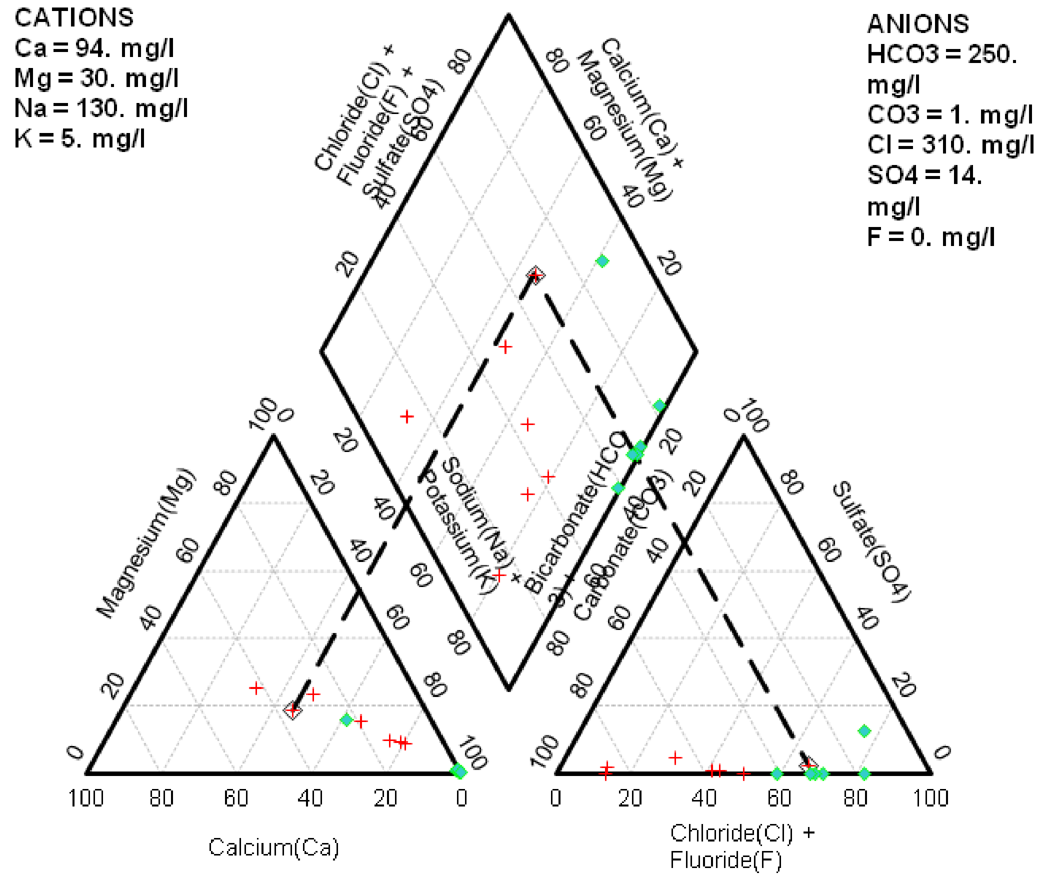
Analysis	Units	Bore Number (DNRM Reference)						
		13030637	13030638	13030639	13030640	13030641	13030647	Bore 1*
pH	-	7.0	7.5	7.4	7.7	7.2	7.0	7.3
EC	µS/cm	595	2500	777	1580	528	647	1430
TDS	mg/L	523	1921	685	1158	439	380	870
CO3	mg/L	0.2	2.3	0.7	2	0.3	0.1	<1
HCO3	mg/L	282.7	928.7	454.8	555	303	169	248

Analysis	Units	Bore Number (DNRM Reference)						
		13030637	13030638	13030639	13030640	13030641	13030647	Bore 1*
Hardness	mg/L	83	288	81	285	140		
SO4	mg/L	16.1	14.6	7.4	7.7	0	0	14
Cl	mg/L	72.6	382	39.2	250	27	98	305
Ca	mg/L	19.6	62.6	17.6	63	46	31	94
Mg	mg/L	8.2	32.1	9	31	17	16	30
Na	mg/L	113	489	147	244	37	55	134
K	mg/L	10.3	9.5	8.5	4.9	6.1	11	5
Fe	mg/L	0.15	0.05	0.02	0.1	0.1	0.4	
F	mg/L	0.28	0.29	0.47	0.4	0.2	0.2	
SiO2	mg/L	27	79	66	70	31	27	
NO3	mg/L	0.0	0.0	0.0	0.0	0.0	0.0	1.78

Notes:

Data collected in 1991, collated in AGE (2011)

*Bore 1 was collected by AGE in 2011.



+ - Quaternary Alluvium

- Baralaba Coal Measures

Note: data from AGE, 2011

Figure 4-2 Piper trilinear plot of water quality in Baralaba Coal Measures and Quaternary Alluvium

Table 4-6 Groundwater quality in the Baralaba Coal Measures (collated from AGE, 2011)

Analysis	Units	Bore Number																	
		HV1	HV2	HV3	HV4	HV5	HV14	HV15	HV19	HV28	HV29	HV39	HV41	27502	MO29	NP40	HV40	DR28	PP4
Year sample collected		1993	1993	1993	1993	1993	2004	2004	2004	2004	2004	2004	2004	1993	2010	2010	2010	2010	2010
pH		8.5	8.1	8.4	8.3	8.6	8.2	8.8	8.0	7.5	8.2	8.2	8.1	7.3	8.3	8.2	8.5	8.2	8.6
EC	µS/cm	9010	12500	11500	14200	10600	14800	10900	13670	15400	14820	12130	12350	6385	6210	5010	8440	5820	8200
TDS	mg/L	6000	8700	7900	10000	7400	10064	7412	9296	10472	10078	8248	8398	9530	4161	3357	5655	3899	5494
SO4	mg/L	<1	<1	<1	<1	<1	2	2	1	1	2	<1	8	690	N/T	N/T	N/T	N/T	N/T
Cl	mg/L	2520	4150	3300	4200	2700	4392	1743	3846	6231	4008	2580	2692	2962	2331	1816	3622	1888	3897
Ca	mg/L	10	34	16	19	12	N/T	N/T	N/T	N/T	N/T	N/T	N/T	505	8	6.7	9.8	10	12.5
Mg	mg/L	7	22	10	36	7	N/T	N/T	N/T	N/T	N/T	N/T	N/T	216	2.6	1.5	11.1	2.3	4.3
Na	mg/L	2500	3550	3500	4400	3300	N/T	N/T	N/T	N/T	N/T	N/T	N/T	1550	1739	1230	2711	1163	2236
K	mg/L	12	150	75	120	80	N/T	N/T	N/T	N/T	N/T	N/T	N/T	15	11.5	9.5	22.1	61.4	24.5
CO3	mg/L	67	28	87	102	165	N/T	N/T	N/T	N/T	N/T	N/T	N/T	1.4	N/T	N/T	N/T	N/T	N/T
HCO3	mg/L	1630	1524	2391	3258	2924	N/T	N/T	N/T	N/T	N/T	N/T	N/T	771	N/T	N/T	N/T	N/T	N/T
Total Alkalinity	mg/L	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	N/T	620	980	580	720

Note: N/T Not tested

4.3 Local Geology

The Meridian Project PL94 area is presented on a geological map in **Figure F3**. The lease area is adjacent to the open cut Dawson Mine has a total area of approximately 240 km^2.

The PL94 area is characterised by undulating topography that grades further west of Dawson River. The Dawson River meanders to the north along the western border of the lease and acts as a major surface water receptor for a number of east-west trending ephemeral tributaries.

As detailed in **Section 4.2.1** the surficial geology of the PL94 area comprises Permian sedimentary rocks of the Baralaba Coal Measures unconformably overlain by the Triassic Rewan Group. The Triassic Clematis Group and Moolayember Formation are not present within the Site or in the surrounding area. The Quaternary Alluvium overlies the Rewan Group within the central, northern and western Site areas, and is associated with the Dawson River and its tributaries. A generalised stratigraphy of the Permian and Triassic sedimentary sequence is presented in **Table 4-1**.

The Site is largely situated over the Quaternary Alluvium as discussed above, which unconformably overlies either the Tertiary deposits or the Rewan Group. The Quaternary Alluvium varies in thickness between 10 and 26 m and are typically associated with tributaries of the Dawson River. On the south eastern site boundary, the Rewan Group is fully eroded and the Baralaba Coal Measures are exposed. To the east of the Site the Back Creek Group and underlying rocks are exposed at the surface.

A conceptualised cross section of the area is presented in **Figure 4-3**. The strata of the Baralaba Coal Measures and underlying formations are north-south trending and dipping to the west. Reported dips for the Baralaba Coal Measures range between 5^{o} and 16^{o} (AGE, 2011). Review of the geological maps of the areas indicates that the lower end of the range of these values is likely to be the more representative over the scale of the Site. Based on these dip measurements, the upper coal seams of the target Baralaba Coal Measures lie approximately 40 m below ground level in the eastern area of PL94 and greater than 1500 m below ground level in the western section.

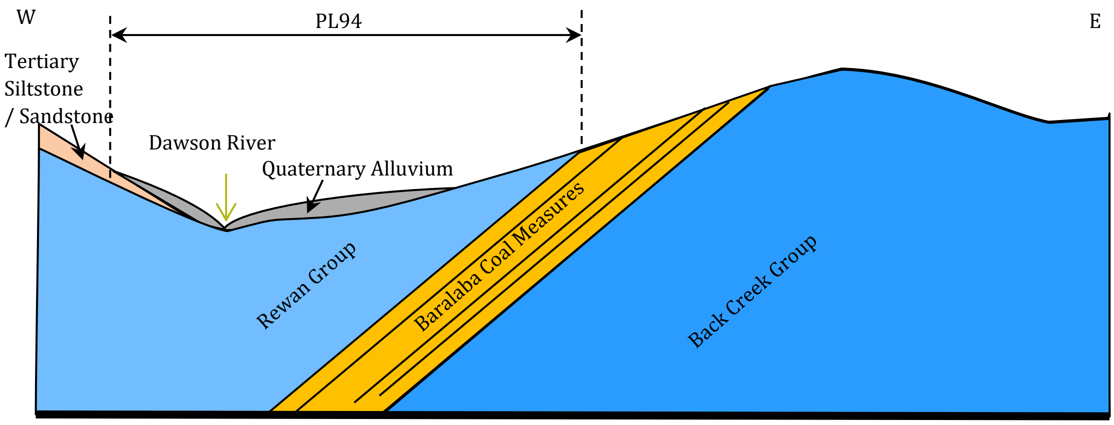


Figure 4-3 Conceptual geological cross-section

Structurally, the PL94 area is affected by a series of northwest-southeast striking faults. The faults are roughly parallel to each other, formed over multiple faulting periods.

4.4 Local Hydrogeology

As with the regional hydrogeology, only limited data is available on the local hydrogeology of the Site.

The Quaternary Alluvium, formed of soils, sandy clays and fine to medium silty sand (AGE, 2011), is considered a minor aquifer. The Quaternary Alluvium is regarded as an unconfined aquifer, where the major recharge mechanisms are expected to be through direct diffuse rainfall infiltration and seepage from the Dawson River during high flow periods following significant rainfall events. Insufficient data is available to characterize groundwater flow within this unit, but conceptually the shallow groundwater will follow a subdued expression of surface topography and flow towards and in alignment with the Dawson River, towards the north and northwest.

The Rewan Formation underlies the Quaternary Alluvium and is considered as a regional aquitard that is predominantly comprised of fine-grained rocks (siltstone and shale) with minor sandstone. Given the nature of the unit, conceptually it is expected to have minor hydraulic connection with the units directly above and below, and very low recharge rates. The Rewan Group is present as outcrops over the majority of the PL94 area but is overlain by alluvial sediments in the northern part of the area. Based on an estimated dip for the Baralaba Coal Measures of 5^{o}, the thickness of this unit within the PL94 area ranges from negligible at the eastern boundary of the Site to 600 m or more in the northwest of the Site and greater than 1500 m in the southwest.

The Baralaba Coal Measures is considered to be a confined aquifer and comprises the target coal seams interbedded with sandstone, siltstone and shales, which are termed interburden or overburden depending on their position relative to the coal seam. The fine-grained shale and siltstone rocks are typically of low permeability and function as aquitards, while the target seams are generally more permeable. Given the presence of both permeable and impermeable units, the Baralaba Coal Measures can be described as follows:

- the siltstone and shale that form interburden or overburden are hydrogeologically “tight” and low yielding; and
- the coal seams range in permeability from low to moderate and are the predominant water bearing strata. Groundwater storage and movement occurs within cleats, fissures and fractures of the coal seams.

The Baralaba Coal Measures outcrop to the east of PL94 and plunge to the west/northwest. Stratigraphic studies from the Dawson Mine show that the coal seams are generally up to 6 m in thickness, while the interburden is variable in thickness ranging from 15 to 60 m. The target coal seams occur at relatively shallow depths of less than 100 m in the southeast of PL94 but increase to depths of 600 m or more in the northwest of the Site and greater than 1500 m in the southwest. Considering the depth to the Baralaba Coal Measures and the presence of the Rewan Group aquitard overlaying the measures within PL94, any recharge for the Coal Measures is thought to occur primarily where it outcrops to the east. Conceptually, groundwater would flow down dip towards the northwest in alignment with regional groundwater flow patterns.

The Back Creek Group is the basement rock underlying the Bowen Basin. It is comprised predominantly of sandstone, siltstone and carbonaceous shale and contains the Flat Top and Barfield Formations which are unconfined aquifers where they outcrop to the East of PL94. These bedrock units are generally not considered as aquifers where they are confined beneath the Rewan Formation and Baralaba Coal Measures however.

4.5 Hydro census

Information from the DNRM groundwater database was collated and reviewed in 2019 to identify registered bores located within PL94 or a 1 km zone surrounding the area.

The information collated from the database is shown in **Figure F4**, summarised in **Table 4-7** and also below:

- 15 bores are registered with DNRM or interpreted as having been installed within the Quaternary Alluvium within 1km of PL94;
- 12 bores are registered with DNRM or interpreted as installed within the Rewan Group within 1 km of PL94;
- 12 bores are registered with DNRM or interpreted as installed within the Rewan Group within 1 km of PL94;
- Three and five bores are registered with DNRM or interpreted as being installed in the Tertiary siltstone/sandstone and Duaringa Formation respectively within 1 km of PL94;
- 15 and four monitoring and water resource investigation bores respectively are registered within 1km of PL94; and
- A total of 35 boreholes are registered with DNRM as having been installed in the Baralaba Coal Measures within 1 km of PL94.

Table 4-7 Boreholes registered with DNRM

Well ID	Installed Date	GIS References		Formation	Bore Use	Screened Interval (m BGL)	
		Latitude	Longitude			Top	Base
38343	1/10/1972	-24.78869169	150.0044221	Rewan Group*	NA		
47517	1/01/1967	-24.77674713	150.0238661	Rewan Group*	NA		
100039	19/05/1992	-24.67813592	150.0127548	BCS	PGE		
100040	1/06/1992	-24.73226688	149.9890067	BCS	PGE		
100041	13/06/1992	-24.62452482	149.9819218	BCS	PGE		
100042	24/06/1992	-24.61452479	150.0013659	BCS	PGE		
100043	19/07/1992	-24.58619147	150.0135877	BCS	PGE		
100044	3/06/1992	-24.68730261	150.0019216	BCS	PGE		
100045	6/07/1992	-24.65674707	149.9794219	BCS	PGE		
100046	14/07/1992	-24.65258039	149.9910884	BCS	PGE		
100047	14/08/1992	-24.64758036	150.0055325	BCS	PGE		
100048	13/09/1992	-24.60063591	149.9891438	BCS	PGE		
100049	1/10/1992	-24.60035813	149.9896993	BCS	PGE		
100097	8/11/1992	-24.81091391	150.0177553	BCS	PGE		
100098	17/11/1992	-24.79841388	150.0177552	BCS	PGE		
100099	15/11/1992	-24.79841388	150.0177552	BCS	PGE		
100156	26/09/1993	-24.80480278	150.0185885	BCS	PGE		
100157	8/10/1993	-24.80174721	150.0194218	BCS	PGE		
100158	1/10/1993	-24.80369167	150.0177553	BCS	PGE		
100159	18/10/1993	-24.80369167	150.0177553	BCS	PGE		
100160	12/10/1993	-24.80480279	150.0177553	BCS	PGE		

Well ID	Installed Date	GIS References		Formation	Bore Use	Screened Interval (m BGL)	
		Latitude	Longitude			Top	Base
100161	28/10/1993	-24.80424722	150.0185885	BCS	PGE		
100162	23/11/1994	-24.80508059	150.011922	BCS	PGE		
100163	4/05/1995	-24.80202521	149.9733119	BCS	PGE		
100192	12/03/1992	-24.55785815	150.026643	BCS	PGE		
100193	9/03/1992	-24.56258037	150.0274763	NA	PGE		
100227	12/07/1995	-24.65063591	150.011088	BCS	PGE		
100228	13/12/1994	-24.67924702	150.0183102	BCS	PGE		
100307	21/08/1995	-24.807303	149.9738675	BCS	PGE		
100308	1/08/1995	-24.804803	149.9710897	BCS	PGE		
100309	27/08/1995	-24.80202521	149.9733119	BCS	PGE		
100318	9/12/1993	-24.80424722	150.0180329	BCS	PGE		
100319	22/11/1994	-24.8064695	150.0091444	BCS	PGE		
100320	31/10/1994	-24.80285834	150.0158108	BCS	PGE		
100321	8/12/1994	-24.80424725	150.0116443	BCS	PGE		
100322	10/11/1994	-24.80202502	150.0144219	BCS	PGE		
100323	17/12/1994	-24.80591392	150.0133109	BCS	PGE		
111712	24/03/2002	-24.81878731	150.0403823	Rewan Group*	Water Supply	44.9 9	56.76
128139	12/04/2005	-24.5751766	149.9667555	Alluvium*	Water Supply	6	27
128254	16/07/2007	-24.54	150.0247222	Rewan Group	Water Supply	27	30
128576	27/01/2010	-24.5360401	149.9634466	Rewan Group*	Monitoring		
128768	17/10/2012	-24.56875509	149.9731558	Tertiary siltstone / sandstone*	Monitoring	6.5	8
128769	17/10/2012	-24.56895195	149.9727503	Tertiary siltstone / sandstone*	Monitoring	6.5	8
128770	17/10/2012	-24.56880724	149.9726337	Tertiary siltstone / sandstone*	Monitoring	7	8.5
128786	23/07/2013	-24.53555556	150.0247222	Rewan Group	Monitoring	27	30
128787	23/07/2013	-24.53747989	150.0212494	Rewan Group	Monitoring	21	30
128788	23/07/2013	-24.54012352	150.0230612	Rewan Group	Monitoring	16	20
170041	15/06/2016	-24.54020762	150.0232072	Duaringa Formation	Monitoring	36	45
170043	16/06/2016	-24.53460393	150.0190979	Duaringa Formation	Monitoring		
170052	2/06/2016	-24.55839597	150.0062026	Duaringa Formation	Monitoring		
170080	1/09/2016	-24.65057844	149.9893293	Alluvium	Monitoring		
170081	31/08/2016	-24.73214123	150.0057093	Alluvium	Monitoring		
170082	30/08/2016	-24.68070886	150.0134481	Alluvium	Monitoring		
170153	14/05/2018	-24.6029632	150.0234896	Duaringa Formation	Monitoring		
170154	13/05/2018	-24.65427172	150.0276246	Duaringa Formation	Monitoring		
13030636	17/04/1991	-24.58613734	149.9604424	Alluvium	WRI		
13030645	20/04/1991	-24.79783182	149.9561655	Alluvium	WRI		
13030646	20/04/1991	-24.79536704	149.9646709	Alluvium	WRI		
13030647	22/04/1991	-24.79826671	149.9707118	Alluvium	WRI		

Notes: database current as of 1 April 2019

* - Interpreted use from DNRM Database information

BCS – Baralaba Coal Seam; PGE – Petroleum or Gas Exploration; WRI – water resources investigation

4.5.1 Groundwater levels

A record of groundwater elevations between 1968 and present is held by DNRM for six monitoring bores targeting the Quaternary Alluvium in the Moura area near PL94. Groundwater elevation measurements from 1980 to 2012[1] are presented against the cumulative rainfall departure in **Figure 4-4**. It can be seen that in all monitored bores, with the exception of DNRM registered bore 13030385, the groundwater level slowly rose between 1980 and 1991 by approximately 2 m, then fell between 1991 and 2009 by approximately 2 m before starting to rise again in 2010 by 3–5 m. This aligns with the trends in the cumulative rainfall departure and indicates that groundwater levels are largely controlled by recharge from rainfall infiltration rather than by other controls such as extraction or changes in the groundwater level in the underlying formations.

In DNRM registered bore 13030385 (installed in the Quaternary Alluvium) the measured groundwater elevation variations are initially more subdued than the others but then show similar responses after the mid-1990s. This bore is located further away from the Meridian Project than the other Quaternary Alluvium bores and may be subject to different local recharge processes.

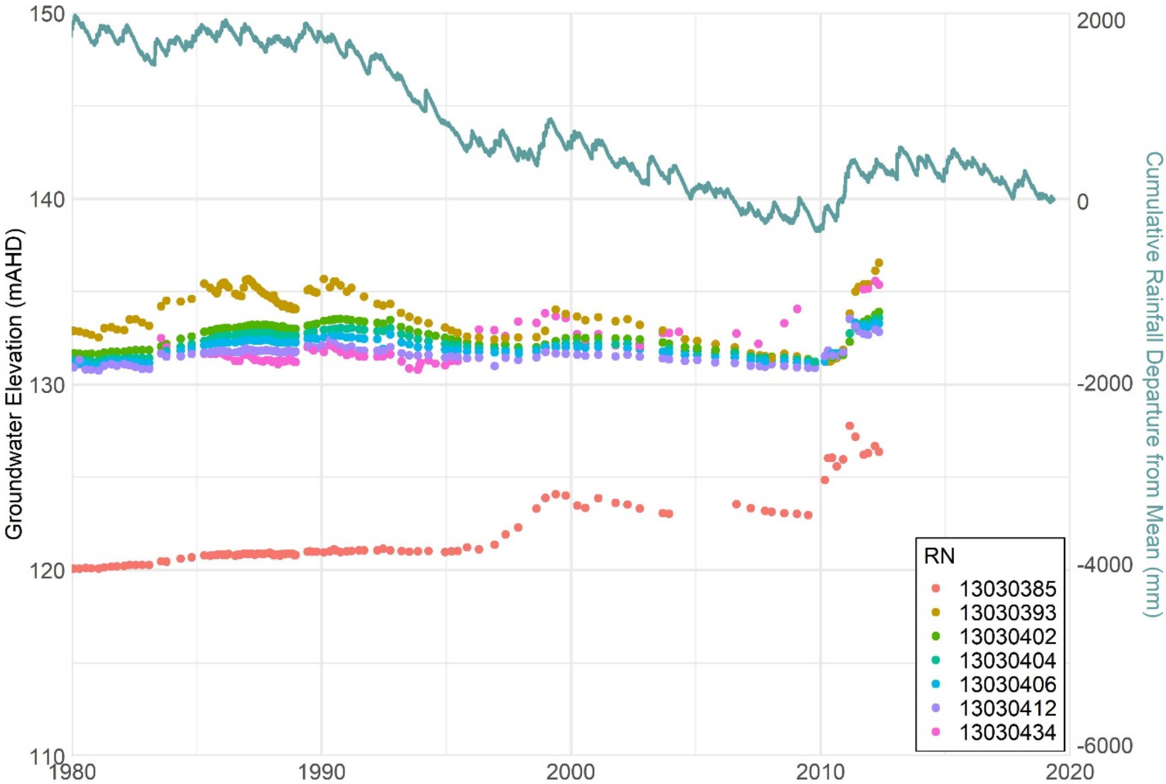


Figure 4-4 Recorded groundwater elevations in Quaternary Alluvium boreholes

Westside has undertaken regular groundwater level monitoring in a number of bores within PL94 that are installed in the Quaternary Alluvium **(Figure 4-5)**. This recent data shows relatively steady rising groundwater levels that is inconsistent with rainfall trends over this period. It is possible that groundwater levels are driven by the regulated water levels in the Dawson River, but this cannot be confirmed without further investigation.

[1] More recent groundwater level data was not available in the latest DNRM groundwater database dated 08/05/19.

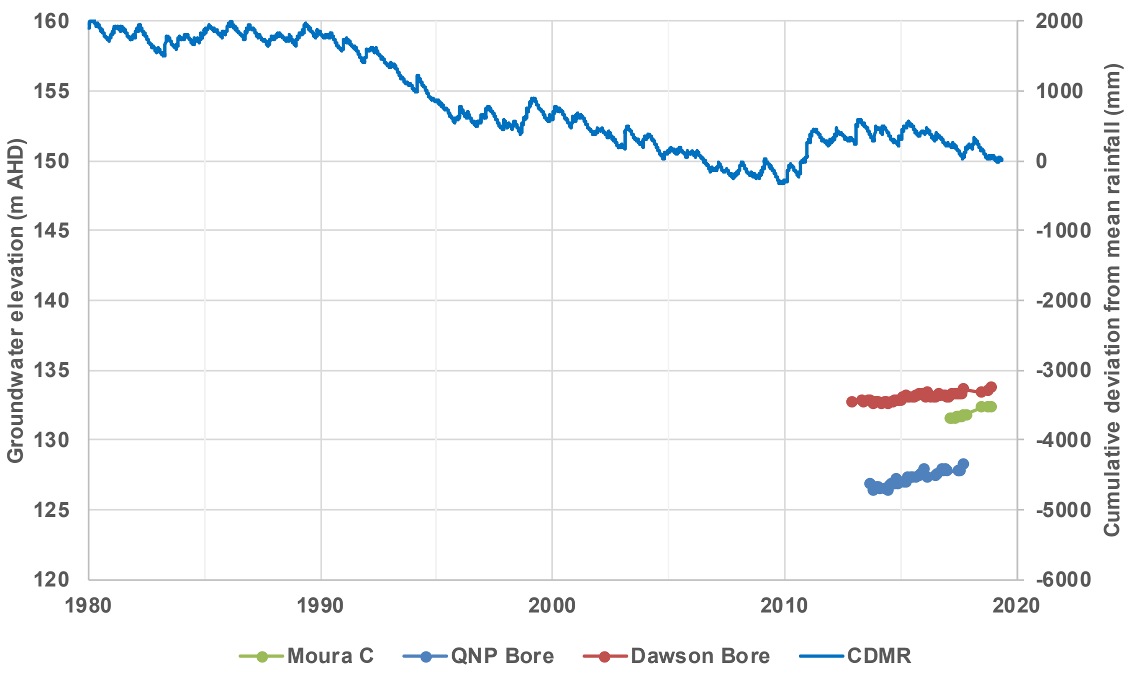


Figure 4-5 Time-series groundwater elevations in Quaternary Alluvium boreholes within PL94

Nearby groundwater elevations are measured by DNRM in bedrock formations as follows:

- One bore in the Rewan Group (1030830) located approximately 13 km to the west of PL94;
- Two bores in the Barfield Formation (103030822 and 103030827) respectively located approximately 13 km to the east and 13 km to the northeast of PL94;
- One bore in the Flat Top Formation (103030829) located approximately 18.5 km to the southeast of PL94.

Groundwater elevation variations are small in the Rewan Group bore (**Figure 4-6**), consistent with the conceptualisation that the Rewan Group acts as a regional aquitard. Groundwater level measurements from bores in the Barfield and Flat Top Formation are shown with the cumulative rainfall departure in **Figure 4-7** and **Figure 4-8**. It can be seen from these figures that the groundwater level in the monitoring bores broadly have similar trends to the cumulative rainfall departure (i.e. slight decline followed by an increase) suggesting rainfall-recharge as the dominant process influencing the groundwater variability in these wells.

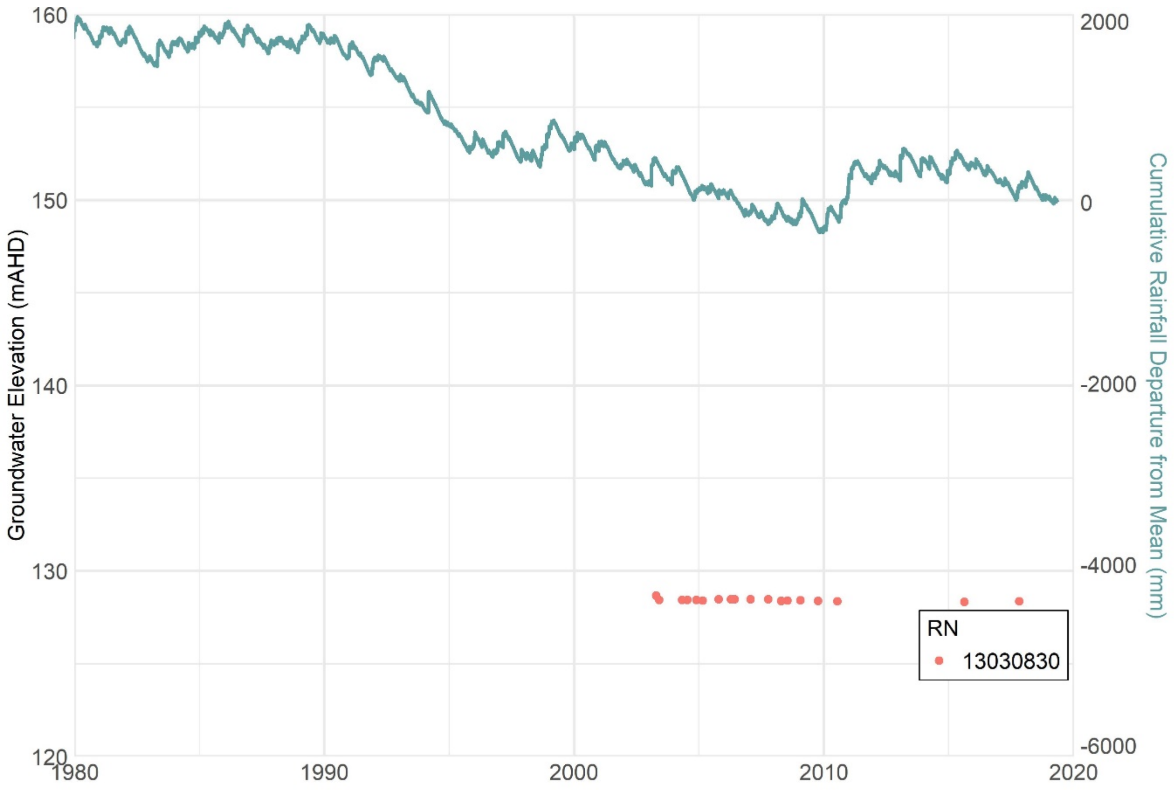


Figure 4-6 Recorded groundwater elevations in Rewan Group boreholes

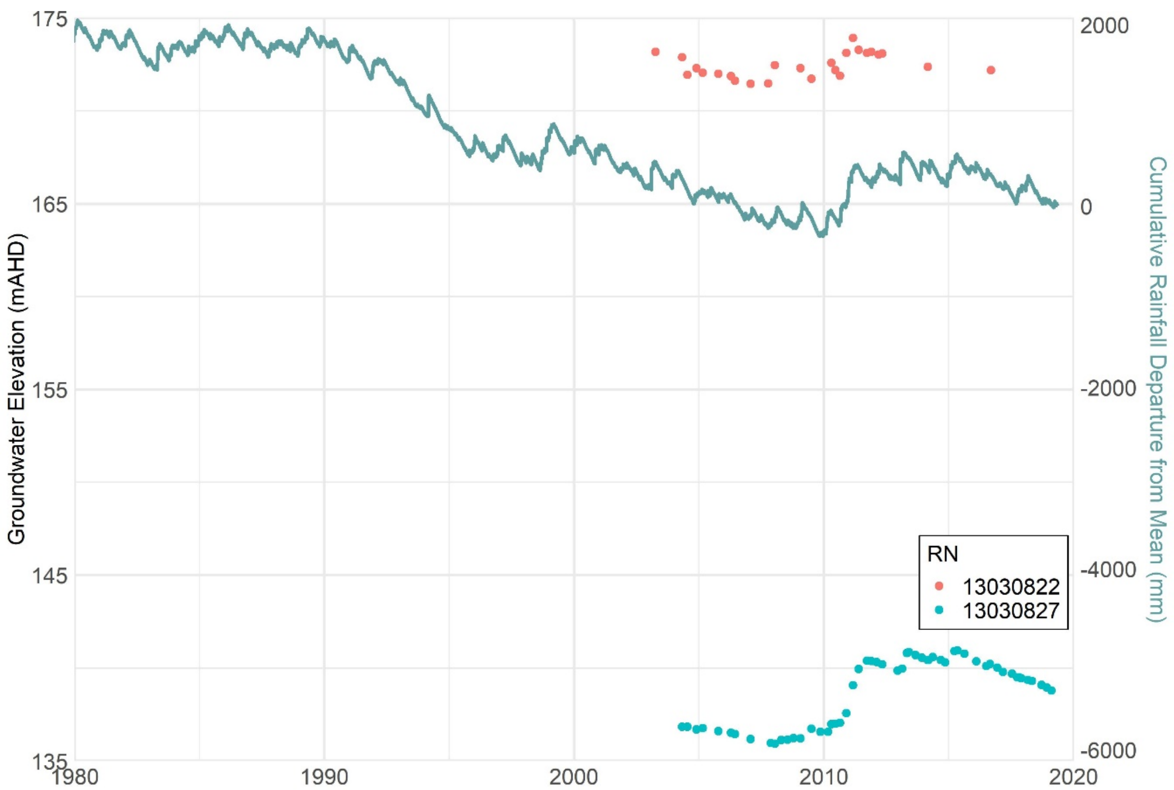


Figure 4-7 Recorded groundwater elevations in Barfield Formation boreholes

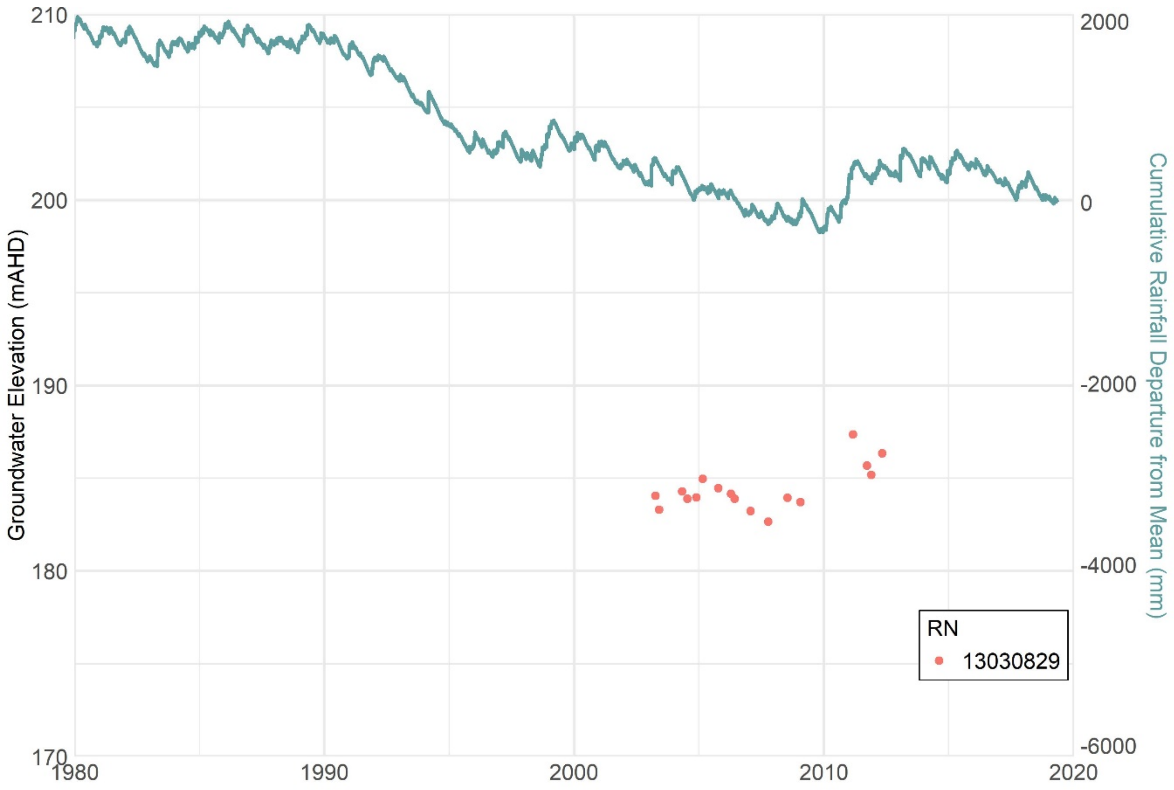


Figure 4-8 Recorded groundwater elevations in Flat Top Formation boreholes

Groundwater levels within the Baralaba Coal Measures were collated from information obtained by Westside for selected bores and is presented in **Figure 4-9**. Measurements of groundwater levels were not available; so instead the information presented shows the measured groundwater level relative to the highest measured groundwater elevation within the monitoring period. While this does not indicate actual groundwater levels, it demonstrates the pressure response to nearby operational gas production wells.

It can be inferred from **Figure 4-9** that operation of the gas wells induces drawdown in the bores installed in Baralaba Coal Measures by up to 350 m. In the absence of absolute groundwater elevation measurements, it has not been possible to assess the hydraulic connectivity between the confined Baralaba Coal Measures and the overlying Quaternary Alluvium in detail. However, hydrographs indicate no discernible evidence of drawdown in the shallow bores, suggesting that the effect of depressurisation has not yet propagated to the shallow aquifer and/or any depressurisation effects at the surface are masked by larger influences of rainfall and/or river recharge.

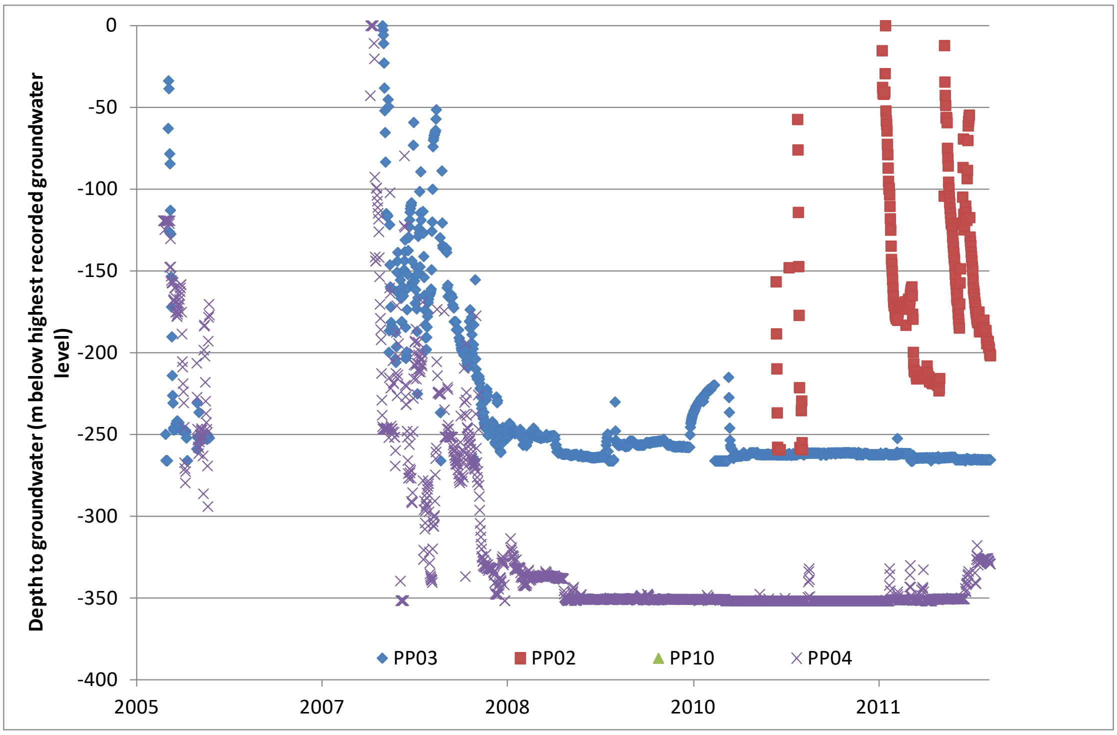


Figure 4-9 Relative groundwater levels in Baralaba Coal Measures wells

4.5.2 Groundwater chemistry

Groundwater sampling has occurred on a number of occasions for the shallow observation wells and gas wells before and after stimulation. These sampling events are summarised in Table 4-8. A range of hydrochemical species were analysed by NATA approved laboratories but these have not been assessed further in this report. It is recommended that these results be collated in future and presented on a Piper plot and/or spatially as Stiff plots.

Table 4-8 Summary of hydrochemical sampling

Bore ID	Number of Samples	Year Range	Aquifer
Dawson	4	2012-2015	Alluvium
QNP	50	2012-2017	Alluvium
Moura C	4	2018-2019	Alluvium
56 gas wells	162	2017-2019	Baralaba Coal Measure

Section 5 Conceptual Hydrogeological Model

A conceptual hydrogeological model has been developed based on the understanding of the local geological and hydrogeological conditions present within and adjacent to PL94. This acts as the basis for development of a numerical groundwater model, which represents a simplified version of the complex groundwater processes that are likely to occur. The numerical model is ultimately designed to be used as a tool to run predictive scenarios that inform possible future changes in groundwater pressures and levels as a result of a stress to the system (i.e. groundwater extraction from the Baralaba Coal Measures).

The geology within and surrounding the Site has been simplified to a series of sub-horizontal, laterally extensive hydrostratigraphic units shown conceptually in **Figure 4-3**. The Baralaba Coal Measures are a water bearing formation and are considered to include transmissive sections that act as aquifers (coal seams) although it should be noted that groundwater within this formation is relatively saline and consequently of low value for other purposes. The Baralaba Coal Measures are overlain by the Rewan Formation, which is considered to act as an aquitard (i.e. low hydraulic conductivity). As such, any extraction from the Baralaba Coal Measures will induce a slow 'leakage' of groundwater from the Rewan Formation into the Baralaba Coal Measures.

Overlying the Rewan Formation is an alluvium body. This is an aquifer that is in hydraulic connection with the Dawson River, variably discharging to the river or being recharged by the river depending on the direction of the hydraulic gradient between the river and alluvial groundwater system.

Groundwater extraction from the Baralaba Coal Measures has the potential to result in some reduction in the groundwater pressure within the Rewan Formation. If this pressure response is transmitted vertically to a significant extent (i.e. towards the surface) then the potential exists for groundwater levels in the alluvial aquifer to be affected, although the magnitude and timing of the potential change is not well constrained. Extraction from the Baralaba Coal Measures therefore has the potential to impact surface water – groundwater exchange fluxes and ecosystems that depend on the shallow groundwater as a source of water.

A simple numerical model has been developed to address the potential for impacts to the alluvial aquifer and characterise the extend of drawdown in the Baralaba Coal Measures.

Section 6 Predictive Groundwater Modelling (Part C)

6.1 Modelling Requirement

As advised by the UWIR Guideline, predictive groundwater modelling is required to develop maps indicating:

- Water level declines by more than the applicable bore trigger threshold within three years following the report consultation day (Immediately Affected Area); and
- Water level declines by more than the applicable bore trigger threshold, at any time (Long Term Affected Area).

The Water Act 2000 provides bore trigger thresholds as follows:

- Consolidated aquifer – 5 m;
- Unconsolidated aquifer – 2 m.

6.2 Methodology

6.2.1 Overview

A numerical groundwater model was developed by AGE (2015) for the adjacent site ATP769 and update by AGE in 2018). These models, referred to here as the AGE-2015 and AGE-2018 models have been adapted for use as a tool for PL94, which is referred to as the PL94 model. The PL94 model domain is extended to the north, south and east such that the PL94 historical and planned future extraction wells are captured and not located too close to the model boundaries. Details of the AGE-2015 model development are found in AGE (2015) and are only briefly summarised here where changes to the model have been made. The PL94 model is run using MODFLOW-USG, the WEL Package (to represent water production from the gas field) and the SMS solver.

Key changes to the PL94 model to adapt it for the PL94 requirements are as follows:

- **Grid resolution and time stepping** – Due to the vertical discretisation (13 layers) a regular horizontal grid resolution of 300 m is chosen for the PL94 model. This facilitates moderate runtimes for future sensitivity scenarios with monthly time-steps. The PL94 model domain extends 30 km east to west and 40 km south to north. The layering of the PL94 model is based on the AGE-2018 model layering, which is extrapolated to the extended model boundary. The top of layer 1 is based on the 1 second shuttle radar topography mission (SRTM) digital elevation model (DEM). The top of Layer 12 (Baralaba Coal Measures) is defined through interpolation of the top of Layer 12 in the AGE-2018 model and the line of sub-cropping of the unit digitised from the basement geology map (shown in Figure 3.2 of AGE, 2015). The resulting surface and guiding points are illustrated in Figure 6-1. Other layer interfaces in the PL94 model are based on layer thicknesses as summarised in Table 6-1. Apart from layer 1, all layers are dipping downwards towards the west. Where layers outcrop on the eastern side, their thickness is pinched to a residual 1 m thickness. MODFLOW USG can have discontinuous layers but it was preferred to use a residual thickness to simplify the node and cell numbering for post-processing convenience.

- **Boundary conditions** – The boundary conditions imposed on the PL94 model are adopted from the AGE-2018 model, including no flow boundaries along the perimeter of the model domain, with the exception of constant heads placed along the southern and northern areas of the Dawson Alluvium. The constant head values are specified as 125.3 and 99.5 m AHD in the southern and northern areas, respectively, which correspond to the estimated river stage elevations in the model. Recharge to the PL94 model is unchanged from the AGE-2018 steady state model and is applied at constant rates of 1.7 mm/y in the alluvium and 0.7 mm/y across the rest of the model domain. The AGE-2018 model did not represent groundwater evapotranspiration, which is also not represented in the PL94 model.

  The Dawson river is represented using river cells with a stage elevation of 0.5 m above the river bed elevation (defined as being 2.5 m below the DEM topographic elevation to account for incision of the river bed relative to the average elevation provided by the DEM at the model grid scale). Only Dawson River and one tributary in the southeast corner of the model domain are represented in the PL94 model. This is considered appropriate given there is currently only limited information available for river level and flow. This approach is also considered to be conservative in the sense it will tend to overestimate Alluvial heads by underestimating drainage of the alluvium.

- **Model parameters** –Hydraulic parameters for all layers of the PL94 model are adopted from the AGE-2018 model. The calibration achieved for the AGE-2018 model is considered adequate for the purposes of this report, although some layers in the PL94 model are made homogenous according to the parameter values reported in AGE (Chapter 5.5 in AGE 2018). A scaled root mean square (SRMS) of 22.8% was achieved for the PL94 model using the AGE (2018) reported parameter values. This was a poor calibration performance but was considered the best achievable based on available data. On this basis the PL94 model is considered adequate for the purposes of this UWIR without recalibration.

- **Predictive scenarios** – Planned production well locations and rates have been provided by Westside and are implemented in the PL94 model along with the historical production information also provided by Westside. Transient scenarios are run using the historical water production data for 21 years until the start of 2019 and estimated future water production is appended to the historical data for the predictive modelling. A decay rate of 0.9674 is applied to monthly extraction rates to account for decline in well productivity over time rather than continuing constant production rates into the future. Predicted drawdown outputs are presented for three years' time (2021) and 50 years later (2071), which in this modelling are the timeframes for the IAA and the LTAA impacts, respectively.

  The base scenario uses the water production rates described above and the parameter values from AGE (2018). There were also six sensitivity scenarios to capture some of the uncertainty of model drawdown predictions due to parameter values. These are described the model predictive uncertainty section.

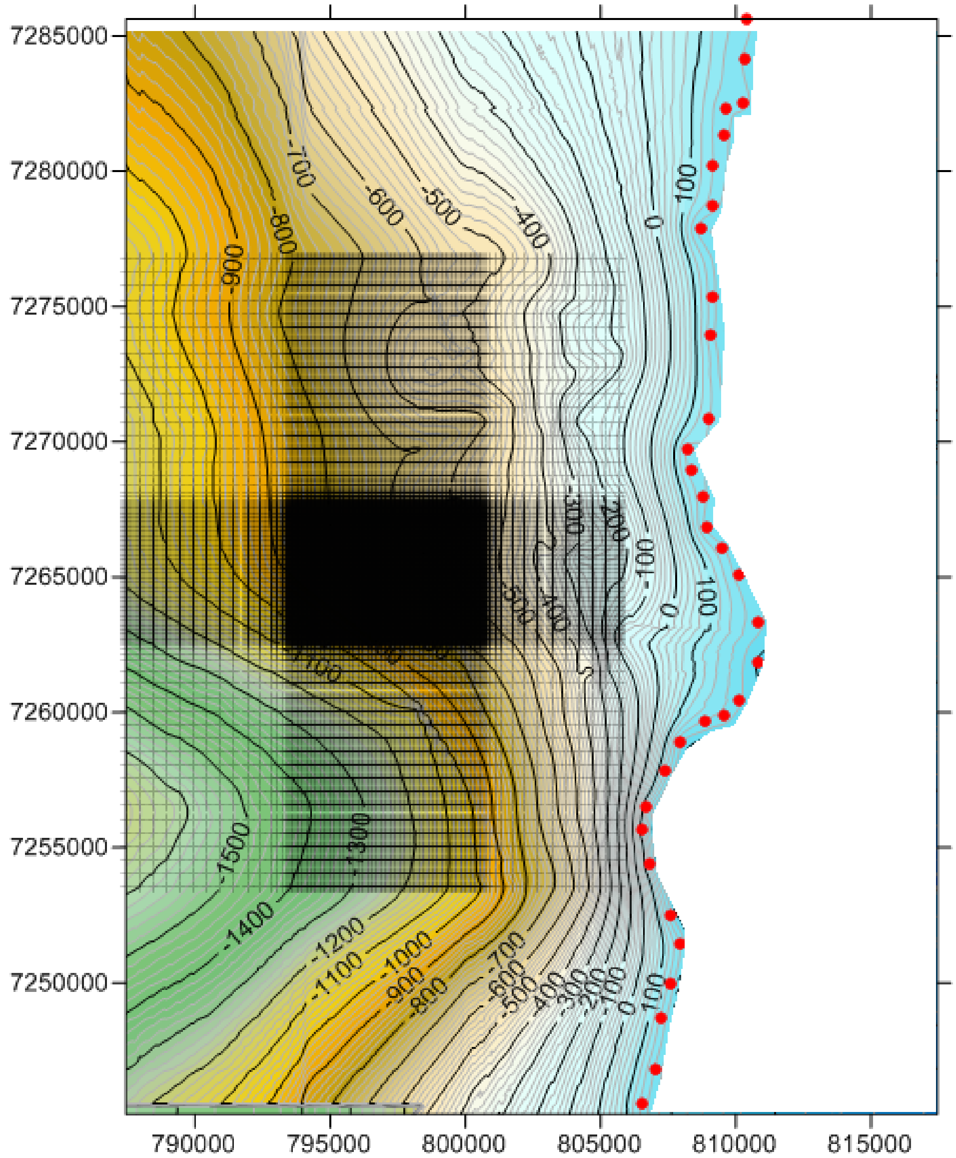


Figure 6-1 Top of layer 12 - interpolation of the existing grid (grey) (AGE, 2018) and the digitised sub-cropping location of the Baralaba coal measures (red dots) (after AGE, 2015).

Table 6-1 Layer thickness

Layer	Thickness (m)
1	15
2	Layer 2 thickness is the residual thickness between the base of layer 1 and the top of layer 3*
3-11	120
12	15
13	300

*Layers 3 to 11 are built by piling up 120 m thick layer on top of layer 12. When those layers are intersecting the base of Layer 1 (15 m below the DEM) their thicknesses are reduced to a minimal thickness of 1 m. The layer 2 thickness is defined by the difference between the base of layer 1 and the top of layer 3, which varies from 500 m (in the Southwest) to the minimal thickness of 1 m (in the North and East).

6.3 Model Parameters

6.3.1 Aquifer & confining unit parameters

The parameter values used with the PL94 model are presented in **Table 6-2** and adopted directly from the AGE-2018 model. Re-calibration is considered unlikely to significantly improve confidence in drawdown predictions and has not been undertaken.

Table 6-2 Model parameter values adopted from the AGE-2108 model (after AGE, 2018)

Layer(s)	Parameter	Value
Layer 1 Alluvium and Regolith (weathered material)	Horizontal Hydraulic Conductivity [kh]	Alluvium 20 m/day Regolith 0.1 m/day
	Vertical Hydraulic Conductivity [kv]	Alluvium and Regolith 10% of kh
	Specific Yield [Sy]	Alluvium 0.1 Regolith 1×10^{-3}
	Specific Storage [Ss]	Alluvium 1×10^{-3} Regolith 1×10^{-4}
Layers 2 to 11 Rewan Formation	Horizontal Hydraulic Conductivity [kh]	1×10^{-4} m/day
	Vertical Hydraulic Conductivity [kv]	1% of kh
	Specific Yield [Sy]	1×10^{-3}
	Specific Storage [Ss]	1×10^{-6}
Layer 12 Baralaba Coal Measures (combined)	Horizontal Hydraulic Conductivity [kh]	3.5×10^{-4} m/day
	Vertical Hydraulic Conductivity [kv]	10% of kh
	Specific Yield [Sy]	5×10^{-2}
	Specific Storage [Ss]	1×10^{-5}
Layer 13 Kaloola Formation (Model Base)	Horizontal Hydraulic Conductivity [kh]	1×10^{-4} m/day
	Vertical Hydraulic Conductivity [kv]	1% of kh
	Specific Yield [Sy]	1×10^{-3}
	Specific Storage [Ss]	1×10^{-6}

Both the Baralaba Coal Measures (Layer 12) and the Rewan Formation (Layers 2 – 11) are consolidated aquifers and therefore a drawdown trigger threshold of 5 m is applicable, as defined within the DEHP Guideline – Underground Water Impact Reports and Final Reports. The alluvium (Layer 1) is an unconsolidated aquifer and has a drawdown trigger threshold of 2 m.

6.3.2 Operational Parameters

A comprehensive set of predicted water extractions has been prepared by Westside Corporation; however, this information is commercially sensitive, therefore a summary of the predicted future water extraction is set out in **Section 2** of this report.

The proposed operational plans for PL94 provide details of the predicted water extraction and planned production well drilling until 2022. This data has been reviewed to define the expected location and volume of water extraction associated with current operations and the proposed developments during the next three years. The predicted water extraction rates are provided in **Table 6-3**.

Table 6-3 Summary of operational parameters

Operational parameter	April 2019	2019	2020	2021
Number of production gas wells in PL94	70	124	176	251
Average water extraction rate per gas well (L/s/well)	0.05	0.047	0.059	0.050
Total water extraction (L/s)	3.5	5.9	10.3	12.5

6.4 Predicted Drawdown

6.4.1 Baralaba Coal Measures

Predicted groundwater drawdown at the end of 2021 in the Baralaba Coal Measures resulting from operation of the existing and future gas wells within PL94 is presented in **Figure F6**. This result represents the IAA drawdown. The LTAA is defined to be the drawdown or depressurisation predicted 50 years after 2021 and is shown in **Figure F7**. Comparing the IAA and TTAA, the extent of the 5 m drawdown contour expands in area while the magnitude of the drawdown is reduced after 50 years.

No registered bores associated with third party use are currently located within the Baralaba Coal Measures IAA or LTAA areas.

6.4.2 Rewan Formation

Three registered bores associated with third party use (38343, 47517 and 128787) are located within the LTAA (**Table 6-4**). These bores are inferred or known to be installed in the Rewan Formation and have unknown or monitoring uses. Note that predicted drawdown in the Rewan Formation is not equivalent to that predicted for the Baralaba Coal Measures (Figure F7) and does not exceed the 5 m trigger at the relatively shallow depths that these wells are presumed or known to be screened within this unit. The depths of bores 38343 and 47517 should be checked to confirm that they are unlikely to be impacted in addition to identifying their purpose.

Table 6-4 Registered Rewan Formation bores within the area of > 5 m drawdown in the Baralaba Coal Measures

RN	GIS Reference		Aquifer (from DNRM Database)	Aquifer (inferred by CDM Smith)	Drilled Date	Original Name	Screen depths (m bgl)
	Latitude	Longitude					
38343	-24.788692	150.004422	Unknown	Rewan Group	1/10/1972	CANCELLED **********	NA
47517	-24.776747	150.023866	Unknown	Rewan Group	1/01/1967	NIPAN SALEYARDS BORE	NA
128787	-24.53747989	150.0212494	Rewan Group		23/07/2013	GW8	21-30

6.4.3 Alluvial aquifer

In the Base scenario, the maximum drawdown in the alluvial aquifer is predicted to be 0.0005 m in 2021 and 0.02 m in 2071. Drawdown of this magnitude is considered negligible.

6.4.4 Model predictive sensitivity

Six sensitivity scenarios have been performed to assess the predictive uncertainty derived from a selection of model parameter values. The details of the parameters varied are described below and summarised in Table 6-5 and Table 6-6.

- Sensitivity runs 1 to 3 focus on the hydraulic parameters of the Rewan Formation aquitard and assess how the propagation of the depressurisation within the Baralaba Coal Measures vertically toward the alluvial aquifer is controlled by the hydraulic parameter values of the Rewan Formation.

- Sensitivity scenario 4 to 6 focus on the model features that are controlling the representation of the alluvium aquifer. There is limited information to construct and constrain the alluvium aquifer representation in the model. These sensitivity runs aim to assess whether an incomplete and imprecise representation of the alluvium is detrimental to the prediction on the drawdown propagation from the Baralaba aquifer to the alluvium. The sensitivity scenarios look at the sensitivity to diffuse rainfall recharge, the river elevation and the alluvial aquifer constant head boundary conditions.

Table 6-5 Summary of drawdown sensitivity to the hydraulic properties of the Rewan Formation

Layers 2 to 11 hydraulic property	Base case	Sen 1	Sen 2	Sen 3
Horizontal Hydraulic Conductivity [kh]	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Vertical Hydraulic Conductivity [kv]	1.00E-06	**1.00E-05**	**1.00E-04**	1.00E-06
Specific Yield [Sy]	1.00E-03	1.00E-03	1.00E-03	**1.00E-02**
Specific Storage [Ss]	1.00E-06	1.00E-06	1.00E-06	**1.00E-05**

Table 6-6 Summary of drawdown sensitivity to representation of the alluvial aquifer

Layers 2 to 11 hydraulic property	Base case	Sen 4	Sen 5	Sen 6
Recharge of alluvium [mm/year]	1.7	**0.17**	As base case	As base case
Recharge of regolith [mm/year]	0.07	**0.007**	As base case	As base case
River stage	River bottom 2.5m below DEM elevation (river stage 0.5m)	As base case	**River bottom 5.5m below DEM elevation (river stage 0.5m)**	As base case
Constant Head	Set at 125.3 mAHD at the upstream end of the model domain across the alluvium aquifer, and at 99.5m at the downstream end	As base case	As base case	**Remove the constant head BC**

6.4.4.1 Baralaba coal measures

The predicted 5 m drawdown contours are shown in the Baralaba Coal Measures for the IAA and LTAA under each sensitivity scenario in **Figure F8** and **Figure F9** respectively. Sensitivity scenarios 1, 2, and 3 show the predicted drawdown extent is reduced if the vertical hydraulic conductivity and storage coefficients are increased (i.e., greater leakage occurs from the aquitard). Sensitivity scenarios 4, 5 and 6 are essentially identical to the Base scenario because changes to the representation of the alluvium have negligible effect in the coal measures.

6.4.4.2 Rewan formation

The predicted drawdown within the aquitard is highest in the layers just above the Baralaba Coal Measures but this pressure response is significantly attenuated above the first few layers. In layer 2, just below the Alluvial aquifer the predicted drawdown in the aquitard is negligible at the IAA and LTAA time periods.

6.4.4.3 Alluvium

Drawdown in the alluvium is most sensitive to the vertical hydraulic conductivity of the Rewan Formation (Scenario 1 and 2) and relatively insensitive to the differences in the design of scenarios 3 to 6. The predicted maximum drawdown in the alluvium is summarised in Table 6-7. This result indicates that an accurate representation of the Rewan Formation is the most critical factor for a reliable estimation of the drawdown in the alluvium. An inaccurate representation of the alluvium recharge and interaction with the Dawson river is less relevant for influencing the drawdown.

Table 6-7 Predicted maximum drawdown in the alluvial aquifer under all sensitivity scenarios

Time frame	Base	Sen 1	Sen 2	Sen 3	Sen 4	Sen 5	Sen 6
End of 2021 (IAA)	0.0005	0.14	0.31	0.00002	0.0002	0.0005	0.0005
End of 2071 (LTAA)	0.02	0.18	0.24	0.00002	0.006	0.02	0.02

6.5 Future modelling efforts

Future numerical modelling could be improved by developing and calibrating a transient model. This would allow more confidence to be placed in the predictions of future impacts, as potentially important transient processes can only be represented in a highly simplified way within the steady-state modelling. A transient model would incorporate time-series inputs and observations that would be used to further constrain the parameter values, and could include the following processes:

- Rainfall recharge;
- Surface water levels and exchange fluxes with the alluvial aquifer;
- Groundwater evapotranspiration;
- Groundwater levels in the unconfined aquifer; and
- Groundwater pressures in confined aquifers and the aquitard.

Additionally, future modelling work should include a critical review of the model boundary conditions and the potential influence of adjacent mining operations.

A full model update is planned in future to be commensurate with the magnitude of gas production and in accordance with UWIR guidelines.

Maps of predicted drawdown are to be updated on a yearly basis in future. This will require an additional model scenario run with updated historical and future production data, enabling maps to be produced that show the revised predicted drawdown impacts at the IAA and LTAA time periods.

6.6 Comparison with previous assessment

The spatial extent and magnitude of predicted drawdown impacts using the PL94 model are similar to those of the previous assessment, which used an analytical approach (CDM Smith, 2016). There are differences in the hydraulic property values used and conceptual assumptions, but each is considered to result in conservative estimates of future drawdown, while the numerical approach gives greater flexibility and in future revisions, could be used to improve the confidence in model predictions.

Section 7 Impacts on environmental values (Part D)

The findings of the modelling completed in **Section 6.4** show that the predicted impact of the water production from the Baralaba Coal Measures is limited both in vertical and lateral extent to the Baralaba Coal Measures themselves. As there are only negligible drawdown impacts predicted for the Alluvial aquifer under sensitivity scenarios, it follows that the likelihood of any impact on environmental values related to the shallow groundwater system are also negligible. Hence an assessment of the potential environmental impact due to the previous or current planned water extraction, is not required.

Section 8 Water Monitoring Strategy (Part E)

8.1 Rationale

The underground water monitoring strategy has been developed to address the findings of this UWIR, and to monitor over time water level and water quality changes caused by the exercise of underground water rights within PL94.

Where present, local registered (and to an unknown extent unregistered) bores primarily draw water from the shallow Quaternary alluvial and Tertiary basalt aquifers. These superficial aquifers are separated from the coal seams targeted by Westside's gas production wells by the lower permeability interburden and Rewan Formation. In addition, the production wellbores are sealed and cased in accordance with relevant guidance and best practice to avoid aquifer cross-contamination. Modelling results show no anticipated impact in the shallow aquifers.

There are no springs identified in PL94 or within 10 km of is boundary. Therefore, this monitoring strategy does not make provisions for monitoring of springs.

The modelling predicts an Immediately Affected Area in the Baralaba Coal Measures, the extent of the area in which modelling predicts a drawdown of greater than 5 m is shown in **Figures F5 – F8**. The extraction of gas from the targeted seams within the Baralaba Coal Measures will by its nature result in a depressurisation and therefore a reduction in water levels (drawdown). This drawdown will be in excess of the monitoring threshold criteria (defined below).

8.1.1 Monitoring threshold criteria

In order 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 impact triggers:** Compare concentrations of following 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 impact triggers:** Compare measured groundwater levels 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 A**.

8.2 Monitoring strategy and timetable

Based on the results of modelling, the monitoring strategy is designed to quantify changes predicted to occur as a result of water extraction during gas operations. The strategy covers the following:

- quantification of water extracted from the coal measures;
- measurement of water levels within the Immediately Affected Area in Baralaba Coal Measures and in the shallow Quaternary alluvial and Tertiary basalt aquifers (as a precaution); and

- water quality monitoring in Baralaba Coal Measures and in the shallow Quaternary alluvial and Tertiary basalt aquifers (as a precaution and to further establish baseline understanding).

As no Immediately Affected Area is predicted outside of the Baralaba Coal Measures, baseline sampling within or without PL94 is not warranted. However, monitoring of selected locations in overlying aquifers is recommended to improve understanding of seasonal trends in groundwater level and quality and to support greater confidence in future model predictions.

8.2.1 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. Results will be included in annual reports.

8.2.2 Existing monitoring points

Groundwater bores

Since the approval of the UWIR in 2013, Westside has been undertaking regular groundwater level monitoring at a limited number of locations. There is time-series data presented for three of these wells shown in Figure 4-5, while others shown in **Table 8-1** have been dry when monitored. If wells are noted to be consistently dry, then they should be re-drilled such that the watertable is intersected by the well.

Table 8-1 Proposed monitoring bore details (after CDM Smith, 2016b)

Bore ID	Registered Number	Latitude	Longitude	Total Depth (m bgs)	Geology	Recent groundwater level
QNP Bore	128524	-24.5399	150.0247	30	Rewan	N
Dawson Bore		-24.80231389	150.0135111	34	Unknown	Y
Moura C		-24.68091667	150.0136528	21.24	Alluvium	Y
GW14		-24.53460	150.01910	54	n/a	n/a
Nipan		-24.73192222	150.0052278	20.8	Alluvium	N
Mungi		-24.5584	150.0062	30.5	Tertiary siltstone	N

Gas Wells

Samples have been collected from nine gas production wells within the Dawson field and these samples submitted for laboratory analysis. Of these wells two were sampled on two occasions during 2013, therefore it is recommended that these wells (DR27 and DR31) be retained within the monitoring network.

8.2.3 Additional monitoring points

Groundwater bores

Given there is only recent groundwater level data available for 2 of the 6 shallow monitoring wells, it is not currently possible to observe any potential impacts in the unconfined aquifer across each of the PL94 gas fields. It is therefore recommended that monitoring wells be re-drilled to target the upper most aquifer (Quaternary Alluvium or Tertiary deposits – location dependant) in locations where existing monitoring bores are dry. It is expected that these bores will be installed prior to the next scheduled annual review of the UWIR.

Gas Wells

Westside has provided an updated list of gas monitoring wells screened across the Baralaba Coal Measures, as listed in **Table 8-2** below with their locations included in **Figure F10**.

Table 8-2 Gas wells identified for Monitoring

Well ID	Type	Easting	Northing	Water level / pressure	Water quality sampling
DR25V	Gas well	804571.52	7255514.27	Y	Y
DR39L	Gas well	805091.37	7254179.58	Y	Y
DR28V	Gas well	804657.39	7256844.39	Y	
DR35V	Gas well	804008.44	7256396.34	Y	Y
DR33V	Gas well	805163.18	7255541.23	Y	
MER34L	Gas well	805207.8	7271047.77	Y	Y
MR14V	Gas well	804812.94	7269782.9	Y	Y
MR31V	Gas well	805997.81	7266082.92	Y	
MN10V	Gas well	804688.7	7278096.26	Y	Y
MN21V	Gas well	803463.62	7282854.62	Y	
MN17V	Gas well	805053.64	7282547.87	Y	Y
NP05V	Gas well	804032.62	7261526.1	Y	
NP01V	Gas well	803228.18	7261160.18	Y	Y
NP14V	Gas well	805365.66	7260402.44	Y	Y
NP19V	Gas well	805194.27	7259423.58	Y	Y
NP10V	Gas well	803459.31	7259908.78	Y	Y

Note: should Westside determine that any of the gas wells identified here are unsuitable for level or quality monitoring (now or at any time in the future) alternatives close to the proposed well will be identified, though whilst operational requirements will take precedence the value of a continuous data set should be emphasised.

When monitored, these gas wells are expected to provide a reasonably good representation of the effect of gas extraction on BCM groundwater pressure across PL94. The distribution of monitoring wells could be improved in the Moura and Mungi gas fields, while to coverage is considered reasonable for the Dawson River and Nipan gas fields. These monitoring locations and others can in the future be used to compare observed drawdown in the BCM with the modelled predictions and further constrain hydraulic parameters in future numerical models.

8.2.4 Water level monitoring schedule

Water level monitoring is designed to verify the model predictions and to provide early notification of unexpected reductions in water levels.

In shallow groundwater monitoring bores groundwater levels will be measured using an electronic dip meter. The reference point below which the depth to water is measured will be recorded and photographed such that consistency with historical and future measurements can be maintained. Where applicable casing collar height above ground level will be measured and recorded. Depth to water measurements will be used in conjunction with surveyed elevation data to calculate groundwater elevation relative to the Australian Height Datum (AHD) at each location.

The gas wells selected as groundwater level monitoring locations have been chosen as they are currently active and are assumed to be suitable for taking measurements. Groundwater levels will be measured in gas wells using ultrasonic level transmitter with groundwater elevations calculated to AHD using survey data.

The threshold criteria included in **Section 8.1.1** will be used to determine if groundwater level changes are significant.

UWIR approval conditions dictate that groundwater levels within the gas wells must be measured on a monthly basis. It is recommended that groundwater levels in the overlying shallow aquifers be measured at least quarterly for the first 12 months. On completion of one year of monitoring to establish seasonal and/or annual natural water level variation it may be possible to reduce groundwater level monitoring frequencies, based on a review of the results.

8.2.5 Water quality monitoring schedule and parameters

The water quality monitoring defined herein is designed to assess whether gas operations are affecting the groundwater quality within the monitored aquifers by establishing a baseline dataset. The analytical suite described in **Table 8-3** includes parameters defined as representing the minimum requirement within the Meridian Project EA. The EA defines two suites depending on the objective of monitoring; the first suite (defined in schedule B, Table 1 of the EA) is appropriate for general and ongoing monitoring and includes parameters suitable to establish water type and general quality as well as to assess concentrations of potential contaminants that may be present due to gas activities. The second suite (defined in Schedule J of the EA) includes additional parameters to assess dissolved gases and is intended to detect the effect of stimulation fluids used. The two suites have been combined in **Table 8-3** and it is recommended that all parameters be analysed during the first round of monitoring in order to establish baseline conditions.

Subject to initial results not showing concentrations of stimulation suite analytes indicative of impact it is recommended that ongoing monitoring be reduced to the general suite defined in schedule B (as indicated in **Table 8-3**). Should specific chemicals be known or suspected to have been used in a field or particular well, the analytical suites should be augmented to include relevant indicator parameters. Water quality monitoring should be synchronous with water level monitoring such that relationships between level and quality could be better understood. Therefore, it is recommended that samples for water quality analysis be collected every 3 months for the first year with the monitoring frequency to be re-evaluated based on a review of the first year's data.

Table 8-3 Groundwater Analytical Suite

Groundwater parameter		Monitoring Scenario			
		First Round	Ongoing Gas wells	Ongoing Shallow bores	Following Stimulation
Field Parameters	Temperature	X	X	X	
	pH	X	X	X	
	Electrical conductivity (EC)	X	X	X	
	Dissolved oxygen (DO)	X	X	X	
	Oxidation-Reduction Potential (ORP)	X	X	X	
	Turbidity	X	X	X	
pH		X	X	X	X
Electrical conductivity		X	X	X	X
Turbidity		X			X
Total dissolved solids		X	X	X	X
Temperature		X	X	X	X
Dissolved oxygen		X	X	X	X
dissolved gases (methane, chlorine, carbon dioxide, hydrogen sulphide)		X			X
Alkalinity (bicarbonate, carbonate, hydroxide and total as CaC0$_3$)		X	X	X	X
Sodium adsorption ratio (SAR)		X	X	X	X

Groundwater parameter	Monitoring Scenario			
	First Round	Ongoing Gas wells	Ongoing Shallow bores	Following Stimulation
Anions (bicarbonate, carbonate, hydroxide, chloride, sulphate)	X	X	X	X
Cations (aluminium, calcium, magnesium, potassium, sodium)	X	X	X	X
Silica	X	X	X	X
Dissolved and total metals (including but not necessarily limited to: aluminium, arsenic, barium, borate (boron), cadmium, chromium III, copper, iron, fluoride, lead, manganese, mercury, nickel, selenium, silver, strontium, tin and zinc)	X	X	X	X
Total phosphorus as phosphorus	X	X	X	
Ammonia, nitrate and nitrite as nitrogen	X	X	X	
Total petroleum hydrocarbons	X	X	X	X
BTEX (as benzene, toluene, ethylbenzene, o, p, m and total xylene)	X	X	X	X
Polycyclic aromatic hydrocarbons (including but not necessarily limited to: naphthalene, phenanthrene, benzo[a]pyrene)	X	X	X	X
sodium hypochlorite	X			X
sodium hydroxide	X			X
Formaldehyde	X			X
Ethanol	X			X
Gross alpha + gross beta or radionuclides by gamma spectroscopy	X	X	X	X

All water quality analysis will be performed by a NATA accredited laboratory.

8.3 Reporting Program

Westside will prepare an annual report of the results of the water monitoring strategy outlined herein. The report will include details of the monitoring undertaken such as dates of fieldwork, measurements, sampling methods and details of QA/QC procedures adopted.

The results of all monitoring will be collated into a **single consolidated database** such that temporal trends can be identified, tracked, exported and communicated efficiently. The results will be reviewed with respect to the threshold criteria defined in **Section 8.1.1.** The annual report will include a review of the Immediately Affected Area and the Long Term Affected Area where measured groundwater elevation and pressure data will be compared to the predicted groundwater drawdown presented in the UWIR. When appropriate, the new information collected through the monitoring strategy will be critical for integration within future updates and improvements to the numerical model.

A summary of the outcomes of the annual review will be submitted to the Chief Executive 20 business days after each anniversary day or another date agreed to in writing by the Chief Executive.

The monitoring strategy and data described by the annual review will also be submitted to the Office of Groundwater Impact Assessment (OGIA) within 20 business days after each anniversary day or another date agreed to in writing.

Section 9 Spring Impact Management Strategy (Part F)

9.1 Spring Inventory

In accordance with the UWIR Guideline, a desktop-based spring inventory has been completed.

Springs and watercourses were identified using the sources of information reviewed in **Table 9-1**.

Table 9-1 Spring and Wetland Data Sources

Source & Data Set	Comment
Queensland Government Information Service (Queensland Wetland Data – Springs)	No springs identified
Wetland Info Website	No wetland points identified (springs and rock holes)
Great Artesian Basin Resource Operation Plan Spring Register	No springs identified

The review of available information identified that there are no springs within PL94.

9.2 Spring Impact Management Strategy

The finding of the modelling completed in **Section 6.4** of the report was that any impact of the water production from the Baralaba Coal Measures is limited both in lateral extent and to the Baralaba Coal Measures. As no springs were identified on Site a Spring Impact Management Strategy is not required.

Section 10 References

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Figures

Figure F1: Location of Gas Fields

Figure F2: Existing Gas Production Wells 2016

Figure F3: Geological Map of the Meridian Project Area

Figure F4: DNRM Registered boreholes located within 1 km of the Meridian Project

Figure F5: Groundwater model domain and boundary conditions

Figure F6: Predicted drawdown in Baralaba Coal Measures IAA: Base scenario

Figure F7: Predicted drawdown in Baralaba Coal Measures LTAA: Base scenario

Figure F8: Predicted 5 m drawdown contour in Baralaba Coal Measures IAA: All scenarios

Figure F9: Predicted 5 m drawdown contour in Baralaba Coal Measures LTAA: All scenarios

Figure F10: Proposed groundwater level and quality monitoring locations

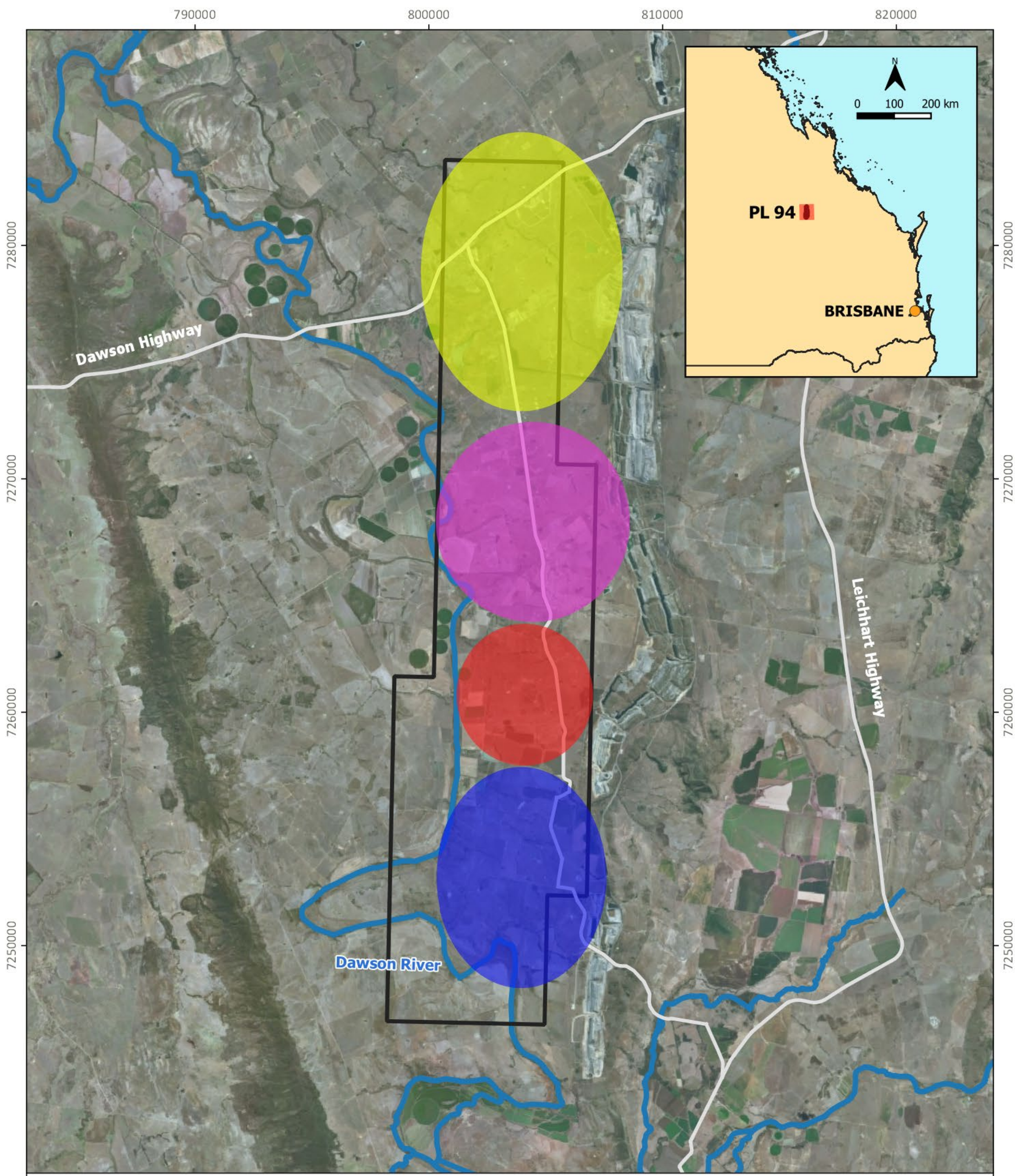

Figure F1

Location of gas fields

Legend

Well fields

- Mungi
- Moura
- Nipan
- Dawson River
- Road
- Watercourse
- PL94

DATA SOURCES
Westside
ESRI Satellite
DNRME

DISCLAIMER
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Datum/Projection: GDA94 / MGA zone 55

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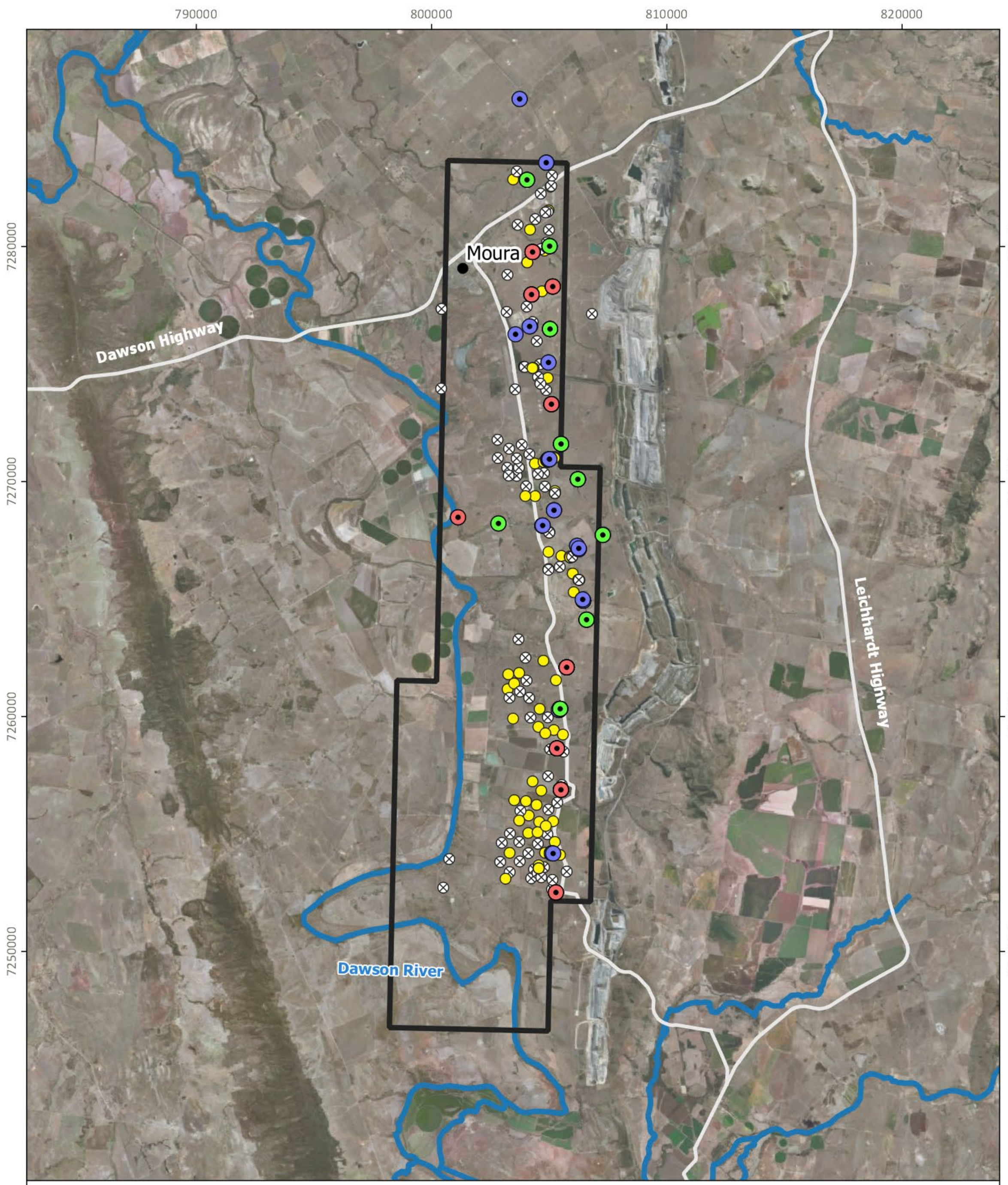

Figure F2

Location of gas wells

Legend

PL94

Road

Watercourse

Proposed wells

2019 Proposed well

2020 Proposed well

2021 Proposed well

Existing wells

Active

Inactive

DATA SOURCES
Westside
ESRI Satellite
DNRME

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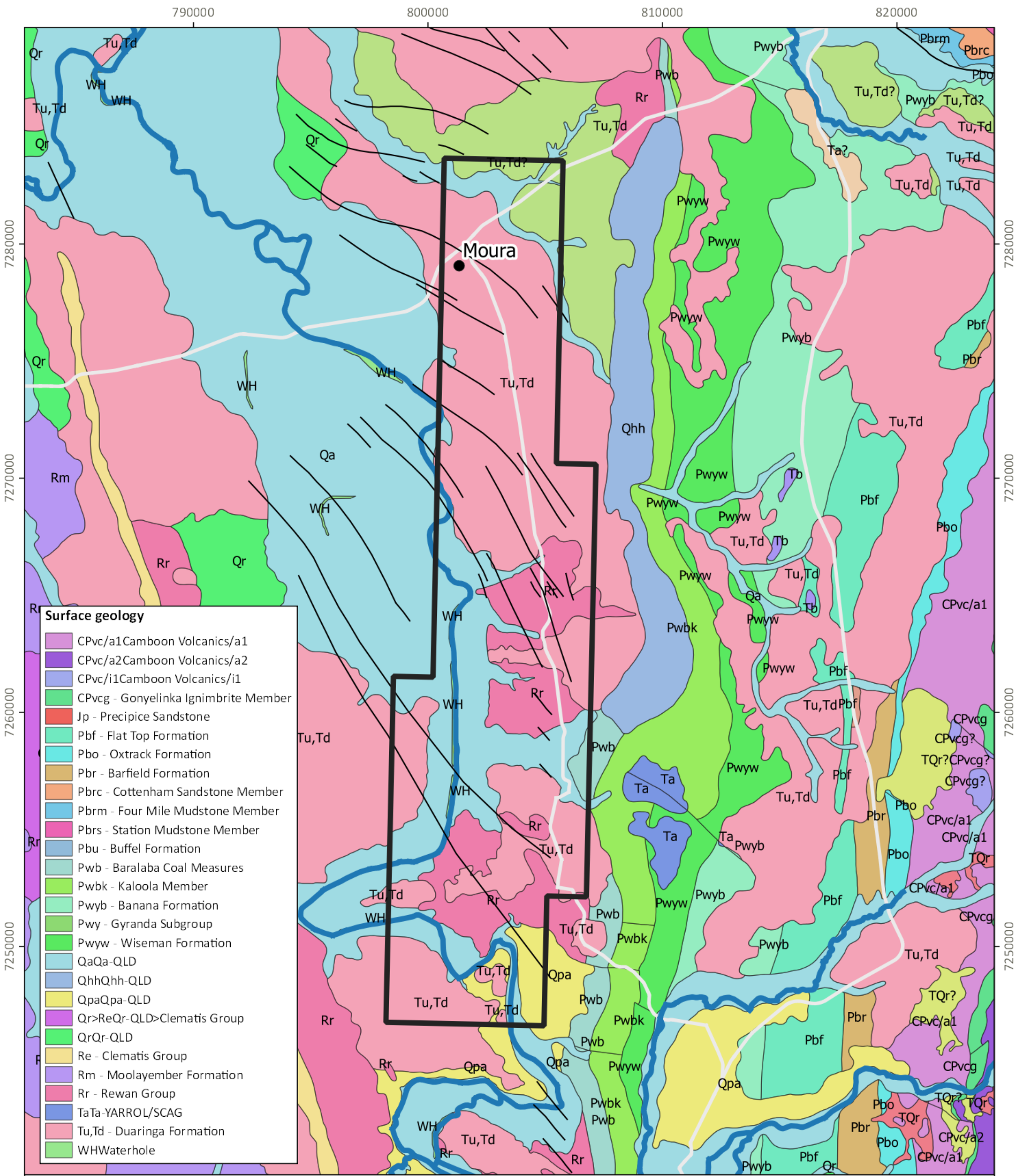

Figure F3

Regional geology

Legend

PL94

Watercourse

Road

Fault

DATA SOURCES
Westside
DNRME

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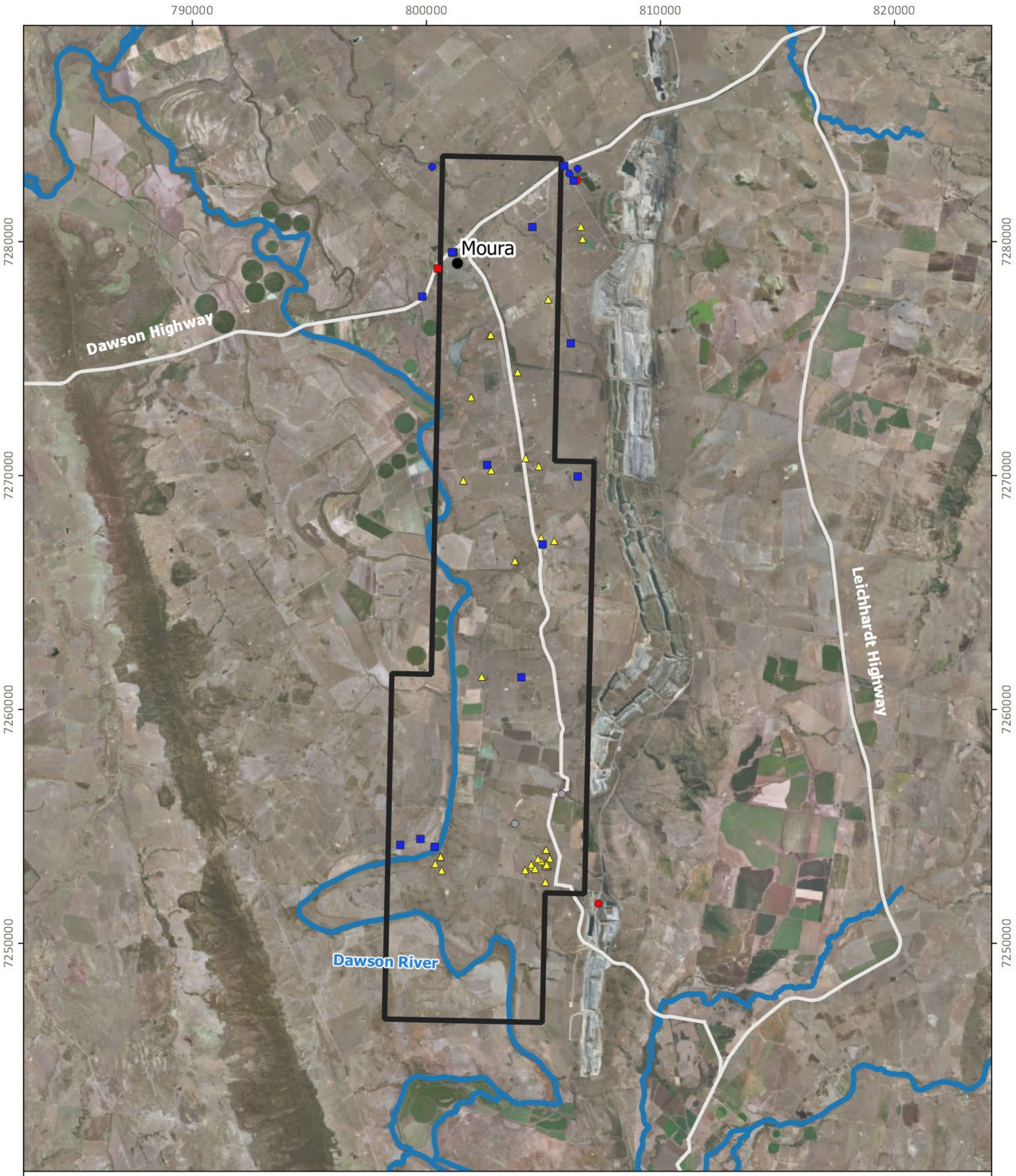

Figure F4

Registered bores within 1 km of PL 94

Legend

Registered bores

- Monitoring - Alluvium and shallow units
- Water supply - Alluvium and shallow units
- Monitoring - Rewan Group
- Water Supply - Rewan Group
- PGE - Baralaba Coal Seam
- Unknown use - Rewan Group

PL94
Watercourse
Road

DATA SOURCES
Westside
ESRI Satellite
DNRME

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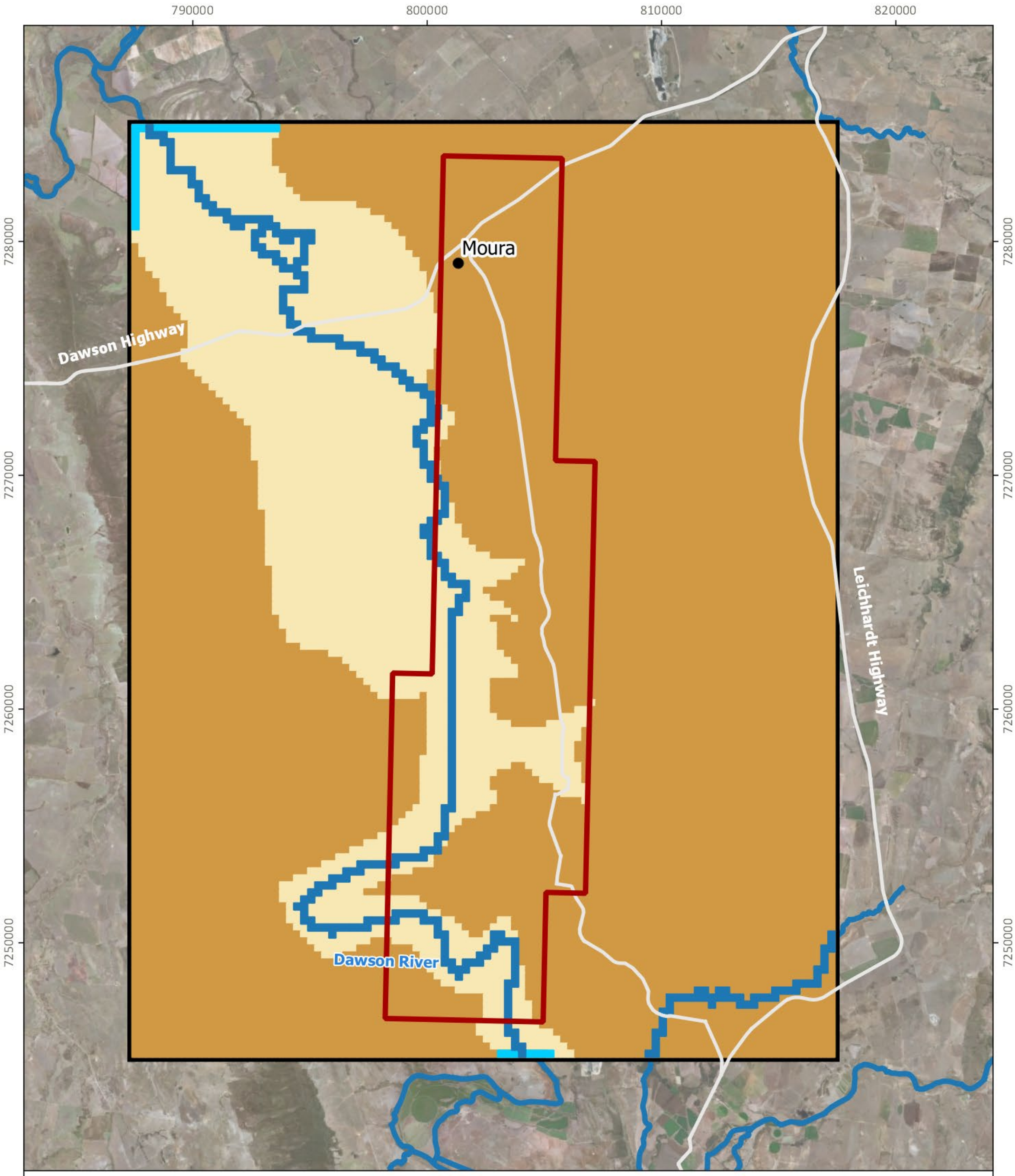

Figure F5

Groundwater model details

Legend

Model details

- Regolith
- Alluvium
- River
- Constant head
- PL94
- PL94 Model boundary
- Watercourse
- Road

DATA SOURCES
Westside
ESRI Satellite
DNRME

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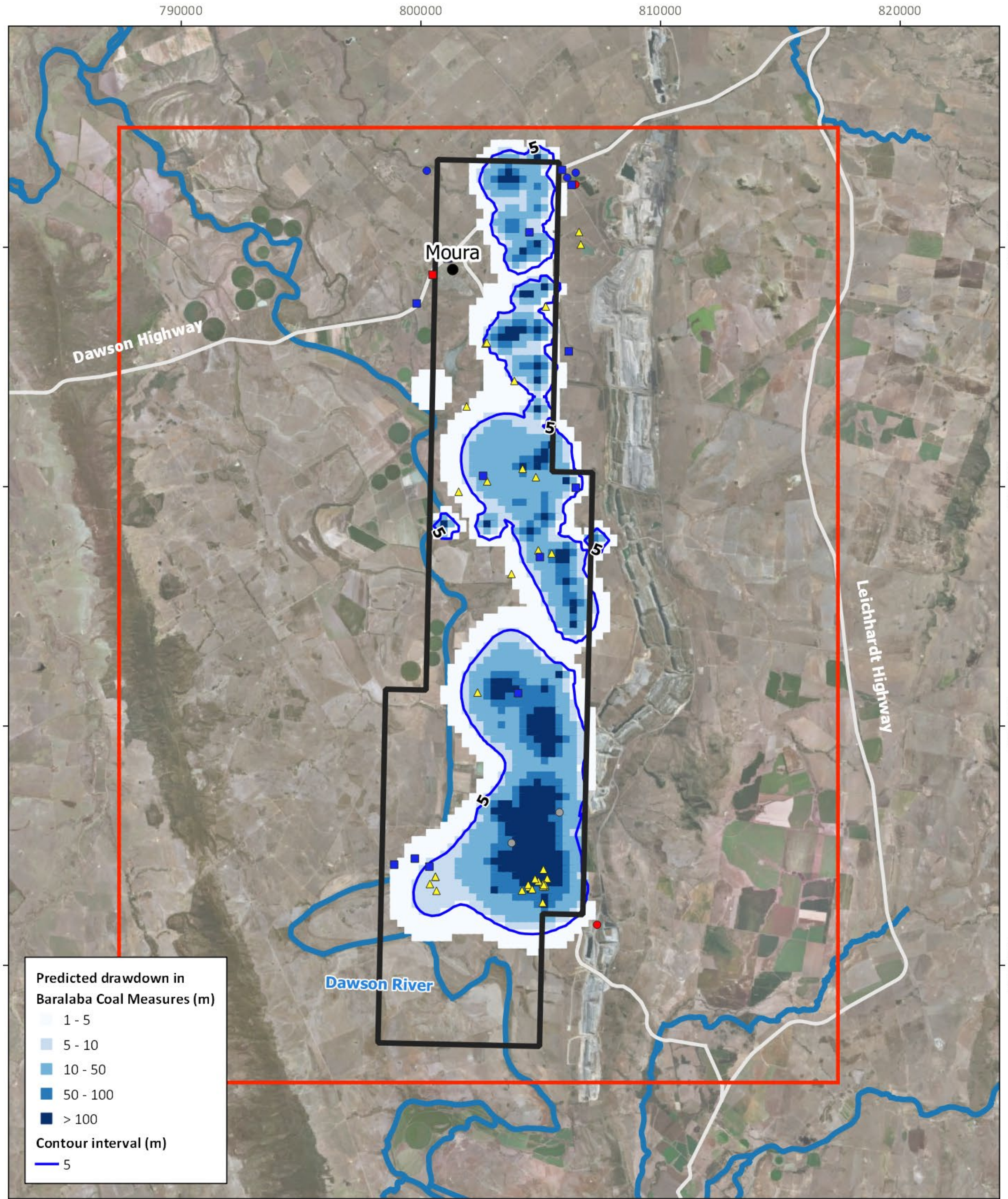

Figure F6

Predicted drawdown in Baralaba Coal Measures IAA: Base scenario

Legend

Registered bores
- Monitoring - Alluvium and shallow units
- Water supply - Alluvium and shallow units
- Monitoring - Rewan group
- Water Supply - Rewan group
- PGE - Baralaba Coal Seam
- Unknown use - Rewan group

PL94
PL94 Model boundary
Watercourse
Road

DATA SOURCES
Westside
ESRI Satellite
DNRME

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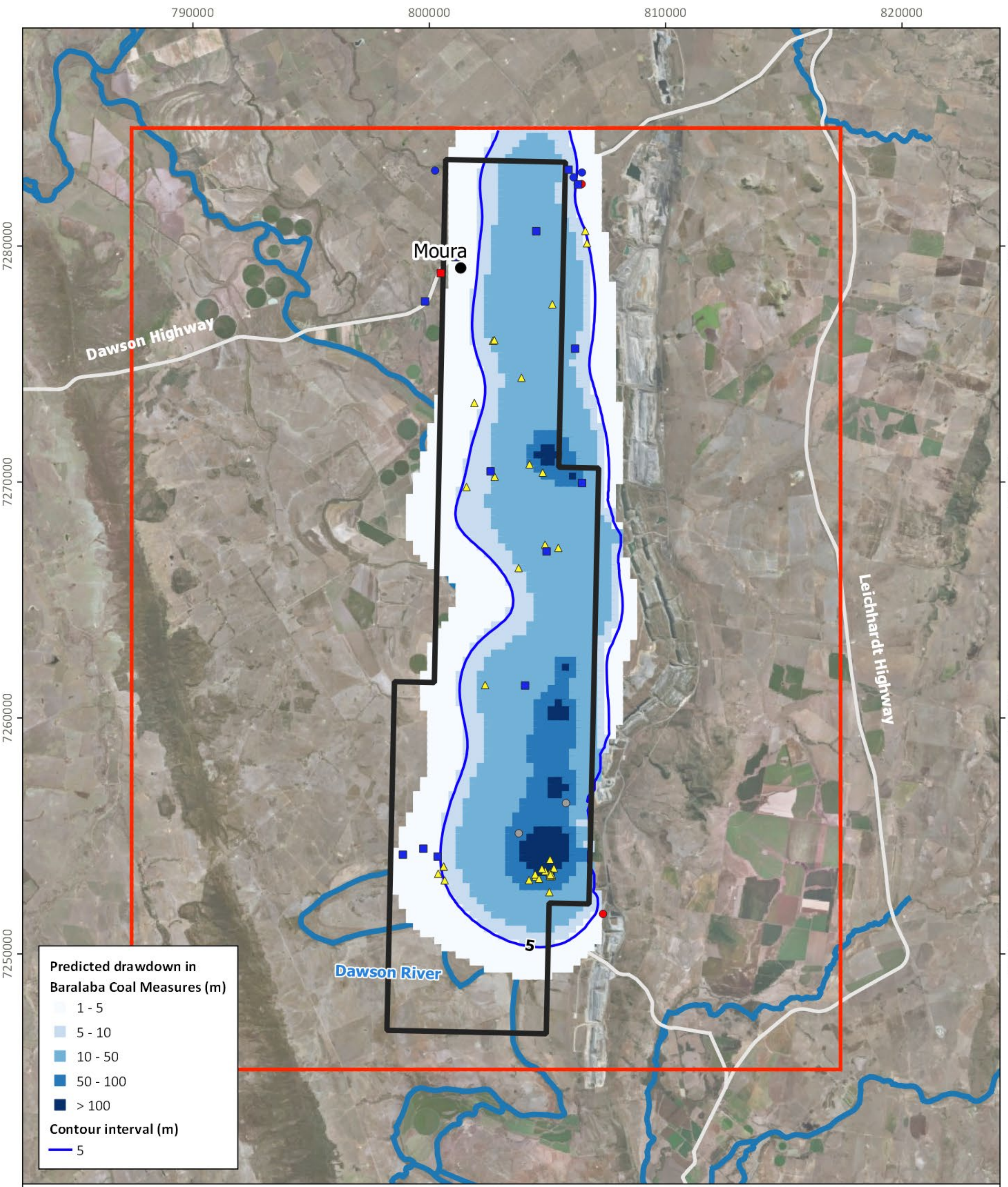

Figure F7

Predicted drawdown in Baralaba Coal Measures LTAA: Base scenario

Legend

Registered bores
- Monitoring - Alluvium and shallow units
- Water supply - Alluvium and shallow units
- Monitoring - Rewan group
- Water Supply - Rewan group
- PGE - Baralaba Coal Seam
- Unknown use - Rewan group

- PL94
- PL94 Model boundary
- Watercourse
- Road

DATA SOURCES
Westside
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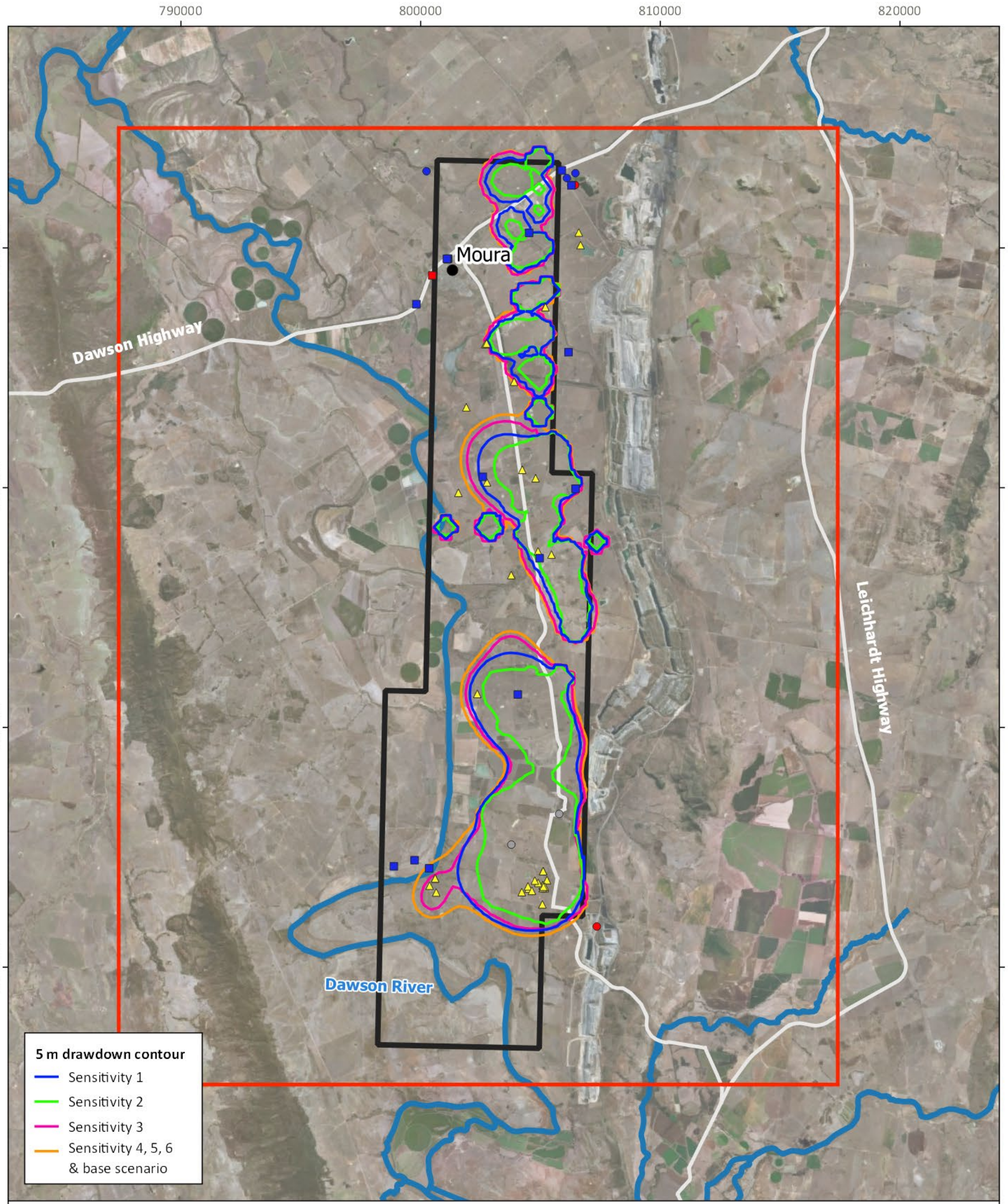

Figure F8

Predicted 5 m drawdown contour in Baralaba Coal Measures IAA: All scenarios

Legend

Registered bores

- Monitoring - Alluvium and shallow units
- Water supply - Alluvium and shallow units
- Monitoring - Rewan group
- Water Supply - Rewan group
- PGE - Baralaba Coal Seam
- Unknown use - Rewan group

- PL94
- PL94 Model boundary
- Watercourse
- Road

DATA SOURCES
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ESRI Satellite
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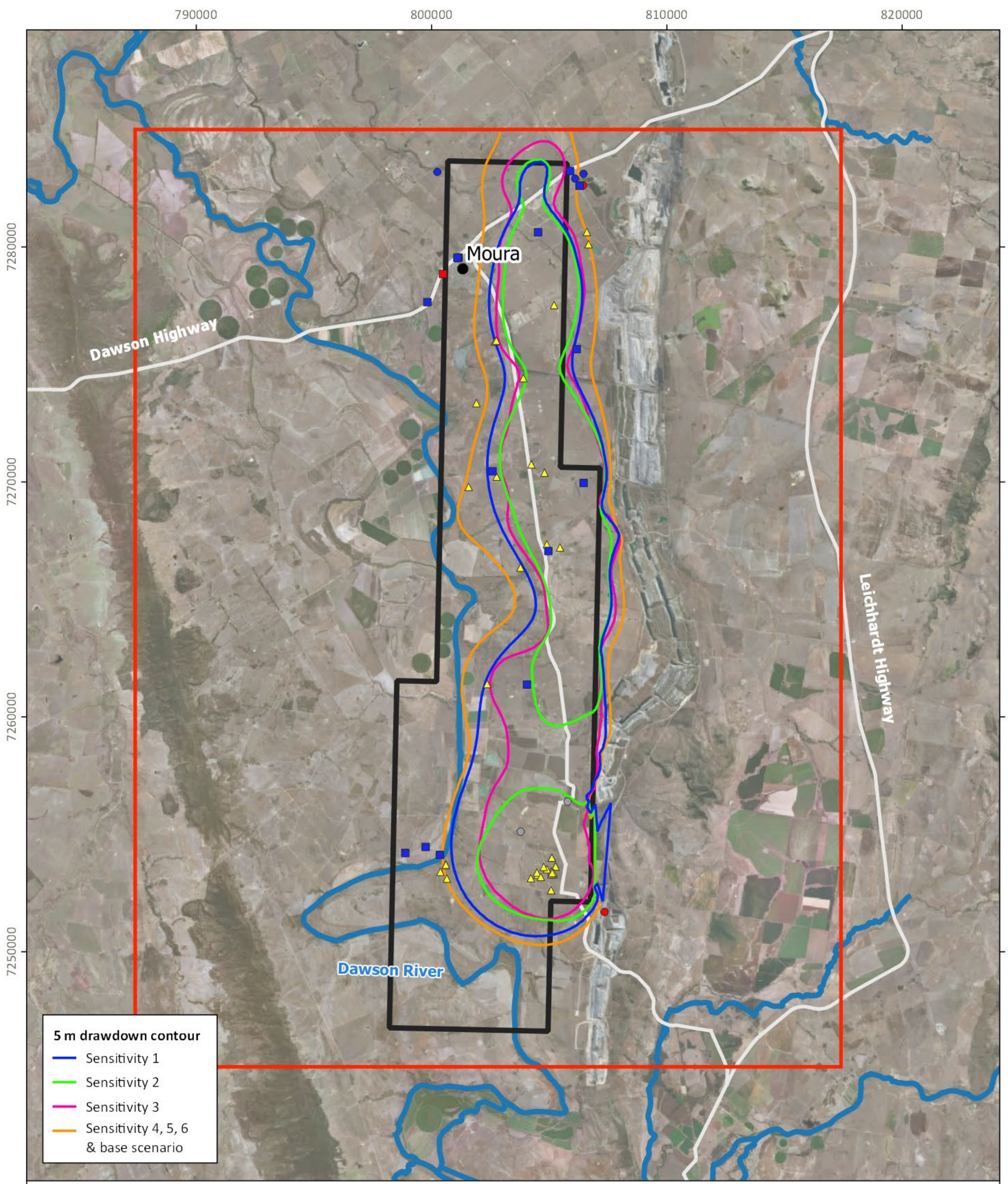

Figure F9

Predicted 5 m drawdown contour in Baralaba Coal Measures LTAA: All scenarios

Legend

Registered bores

- Monitoring - Alluvium and shallow units
- Water supply - Alluvium and shallow units
- Monitoring - Rewan group
- Water Supply - Rewan group
- PGE - Baralaba Coal Seam
- Unknown use - Rewan group

- PL94
- PL94 Model boundary
- Watercourse
- Road

DATA SOURCES
Westside
ESRI Satellite
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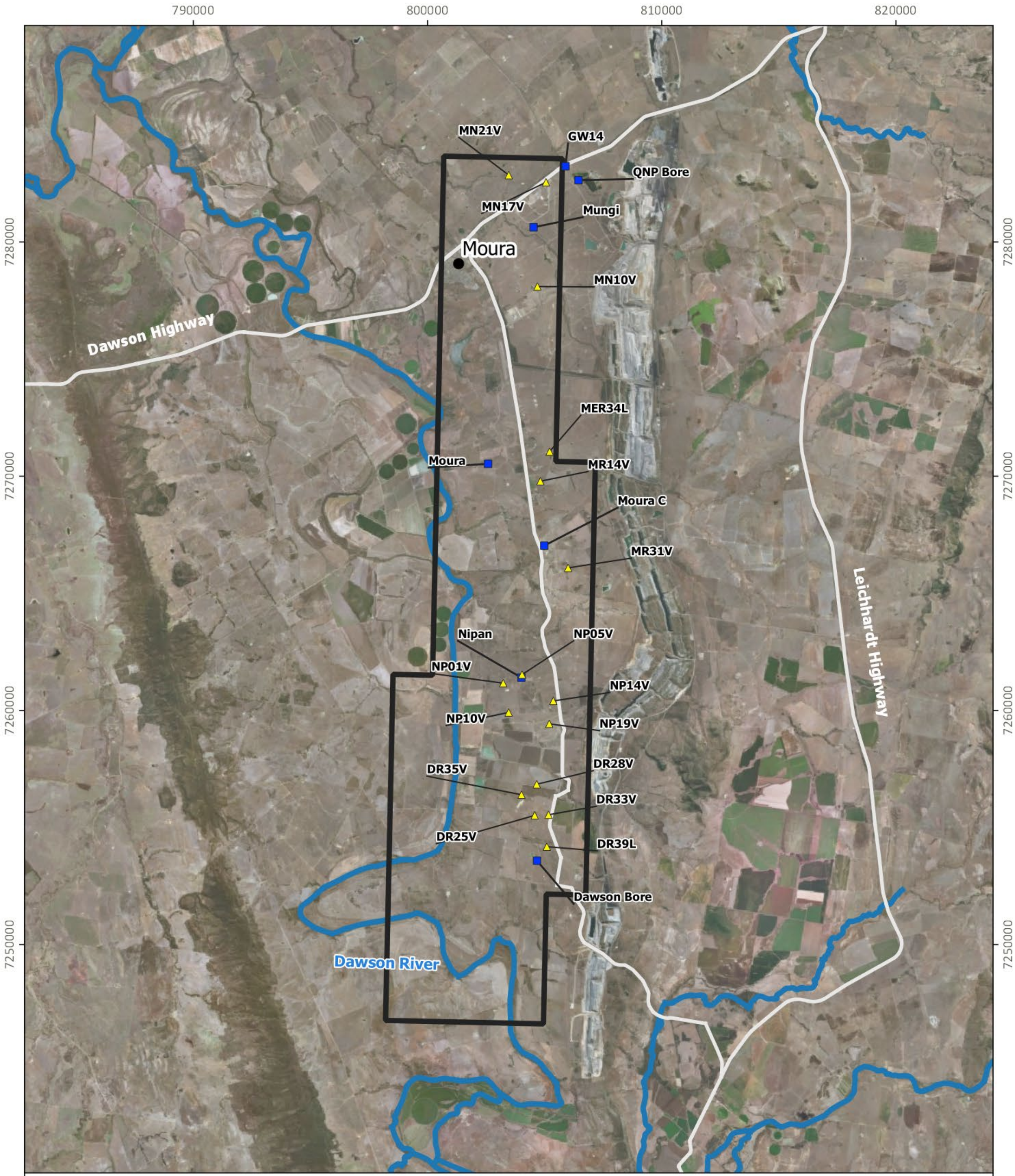

Figure F10

Observation well locations

Legend

- PL94
- Watercourse
- Road
- Shallow observation well
- Gas observation well

DATA SOURCES
Westside
ESRI Satellite
DNRME

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Appendix A - Underground Water Impact Report - Groundwater Monitoring Checklist

Groundwater Monitoring Checklist

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?** Compare measured water level to previous monitoring rounds – if either (a) water level is lower than previous lowest measurement by >5m or (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: ▪ Advise Environment Manager; ▪ Review operational activities; ▪ If appropriate commission review of data; ▪ Identify any requirement for and implement changes in operation to mitigate adverse impacts.	
Checklist Reviewed by	Name -	
	Date -	

Appendix B - Disclaimer and Limitations

This report has been prepared by CDM Smith Australia Pty Ltd (CDM Smith) for the sole benefit of Westside Corporation Ltd for the sole purpose of providing an Underground Water Impact Report (UWIR) to meet requirements for the operation of Petroleum Lease 94 (PL94).

This report should not be used or relied upon for any other purpose without CDM Smith's prior written consent. CDM Smith, nor any officer or employee of CDM Smith, accepts no responsibility or liability in any way whatsoever for the use or reliance of this report for any purpose other than that for which it has been prepared.

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(a) has relied upon and presumed the accuracy of this information;

(b) has not verified the accuracy or reliability of this information (other than as expressly stated in this report);

(c) has not made any independent investigations or enquiries in respect of those matters of which it has no actual knowledge at the time of giving this report to Westside Corporation Ltd; and

(d) makes no warranty or guarantee, expressed or implied, as to the accuracy or reliability of this information.

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If further information becomes available, or additional assumptions need to be made, CDM Smith reserves its right to amend this report.