Preliminary Assessment Extent (PAE) Arckaringa and Pedirka Basin Methodology and Assumptions

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Reference

Document
Rev 1.0 Preliminary Assessment Extent for Pedirka and Arckaringa Basins, provided to Office of Water Science, Department of the Environment

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1. INTRODUCTION

1.1 PURPOSE OF DOCUMENT

This document presents the approach taken to develop a Preliminary Assessment Extent (PAE) for the Arckaringa and Pedirka Basins. This document, together with associated mapping and geospatial data, represent draft information presented to the Bioregional Assessment Team, through the Department of the Environment's Office of Water Science (OWS), which will be amended as required to support the Bioregional Assessment Programme. It is understood that the Arckaringa and Pedirka PAEs will be subject to revisions as new ecological, hydrological and hydrogeological information and understandings become available.

1.2 BACKGROUND

A workshop was held on 6 December 2013 attended by ecological, hydrological and hydrogeological experts from SA Department of Environment, Water and Natural Resources (DEWNR), with support from Geoscience Australia (GA). The Northern Territory Department of Land Resource Management were consulted during the workshop relating to the Pedirka Basin. This comprised the following individuals:

- Kriton Glen, Geoscience Australia, Hydrogeology and Energy Section Leader.
- Lloyd Sampson, DEWNR Principal Hydrogeologist.
- Jeff Foulkes, DEWNR Principal Ecologist.
- Catherine Miles, Lake Eyre Basin expert Ecologist.
- Ben Plush, DEWNR GIS Consultant.
- Alex Osti, DEWNR Senior Hydrogeologist.
- Angus Duguid, Northern Territory Department of Land Resource Management, Wetland Scientist.
- Ryan Hooper, Senior Ecologist, DEWNR
- Andy Harrison, DEWNR Lake Eyre Basin Rivers Monitoring Project Manager/Senior Ecologist.

Additional workshop were subsequently held to reassess the PAEs based upon comments received through Geoscience Australia from the Bioregional Assessment team, with the inclusion of additional assumptions to refine the PAEs.

1.3 GENERAL ASSUMPTIONS

The following assumptions were applied to define the PAE for Arckaringa and Pedirka Basins:

- Extent of potential groundwater drawdown derived from DEWNR groundwater Stage 1 preliminary modelling for the Pedirka Basin. Further refinement of the model may alter the extent of PAEs. Summary details of the modelling is provided as Appendix 1 to this document.
- Due to the absence of short-term (7 year) viable CSG or coal developments in SA, potential specific mining locations are not considered other than known exploration activities occurring in SA.
- Exploration lease areas were included to determine known and potential mining activities, recognising these cover all mapped coal resources for the Pedirka and Arckaringa Basins.
- Exploration Lease areas do not specifically include potential mining related infrastructure corridors, such as pipelines and access roads outside of the mining lease boundaries.
- Influence of introduced weed and pests as a result of an increased mining related workforce into an area are excluded. For example, increased recreational fishing may lead to the increased risk of exotic species releases into aquatic environments which could feasibly extend the PAE into upstream areas, which would otherwise be excluded. In addition, established weeds and pests could be favoured by the mining activities. These factors may be considered within the Bioregional Assessment, but are not specifically used to define the current PAE.

- The PAE has been developed with the assumption that open cut coal mining has the potential to drawdown the GAB, where coal deposits lie below the Great Artesian Basin (GAB) as a result of dewatering activities.

1.4 PAE Methodology

The current PAE for the Arckaringa is presented in Figure 1, with Figure 2 presenting the current PAE for the Pedirka. These PAEs were derived utilising the assumptions identified below.

1.4.1 Arckaringa

The following methodology was followed to formulate the Arckaringa PAE:

- Extent of potential groundwater drawdown assumed at 210km around coal beds (refer Figure 3), based upon DEWNR conceptual modelling undertaken for the Pedirka Basin (refer Appendix A for summary of modelling methodology). Modelling of the Arckaringa basin is proposed be completed by late 2014 which may affect this assumption. This applied to the north and easterly direction from coal beds within the basin.
- Inferred 210km groundwater drawdown extent assumes potential for up to a 50 year Life of Mine (LOM) and large scale mining operations.
- Western and southern boundaries follow the Great Artesian Basin (GAB) and Arckaringa Basin boundaries taking the further boundary from coal beds to identify potential groundwater connectivity.
- 20km buffer boundary included as a contingency around known surface waters and groundwater drawdown extents.
- 10 km buffer included where PAE intersects with fractured rock aquifer (FRA) extents.
- Inclusion of springs in close proximity to 210km radius from coal beds in an easterly direction based upon knowledge of DEWNR groundwater system.
- Entire Lake Eyre (north and south) boundary incorporated (from SA Waterbodies mapping).
- Phreatic surface information (See Figure 5) was utilised to identify connectivity to shallow groundwater potentially utilised by vegetation, which was identified up to a 10m depth, based upon decisions made by the Bioregional Assessment team for other PAEs.
- Tertiary sediments were excluded from consideration as a buffer to the GAB where they intersect with coal deposits as it was assumed direct impact to the tertiary sediments would occur should open cut mining activities occur.

Additional data sets and assumptions used to derive the PAE and gain an understanding of ecological, hydrological, hydrogeological and mining related features and values include the following:

- Arckaringa basin boundary (DEWNR Dataset), including outlier basin formations excluded from the PAE where outside of the GAB.
- DMITRE Mapped areas of economic coal beds (Coal beds).
- Exploration Licences (EL) as lodged with DMITRE.
- Known watercourses (surface water data) (DEWNR dataset).
- Springs locations (DEWNR dataset + national springs database compiled for the Recovery Plan by Fensham et al. 2005)).
- GAB springs of the Lake Eyre supergroup included with a 5km buffer around the point location to accommodate the extensive wetland and terrestrial ecosystems the spring support. It is noted that the impacts of drawdown on pressures would reduce further from the coal resource but recognising that there may be ecological dependencies between the springs.

- PAE along south-western boundary of Arckaringa Basin based upon extent of drawn down from coal beds with limited groundwater knowledge. Western boundary excluded based on absence of GAB groundwater.
- A potentiometric surface has been generated for the GAB aquifer (Cadna-owie Formation – Algebuckina Sandstone and equivalents) for the SA and NT portions of the GAB.
- Coal Beds outside of Arckaringa Geological Basin are excluded.
- 5km buffer around GAB springs (GAB Springs Database) has been smoothed where appropriate.
- Dry areas of the GAB were excluded as these areas do not have surface water connections with lease areas.
- Potential for mining related water diversions excluded from the assessment.
- Upstream watercourses would be excluded where no direct link from mining, where outside the extent of drawdown.
- That the alluvial groundwater systems are not connected to the GAB (see data gaps below).

Data Gaps

The following data gaps existed when defining the Arckaringa PAE:

- Groundwater model (Class 1) of the Arckaringa Basin is being conceptualised. Modelling expected to be completed by June 2014.
- Information gaps exist to define relationships between alluvial groundwater and GAB (at the far extent of the drawdown zone of influence).
- Further refinement is required where overlaps with Stuart Shelf occurs, noting that BHP Billiton modelling undertaken as part of the proposed Olympic Dam expansion Project identified a large cone of depression and impact of groundwater flow to Stuart shelf.

1.4.2 PEDIRKA

The following methodology was followed to formulate the Pedirka PAE:

- Inferred 210km groundwater drawdown extent assumes potential for up to 50 year LOM and large scale mining operations from DEWNR modelling undertaken in the Pedirka subregion for the Eromanga Basin based upon around 400ML/day over 50 years to 1m drawdown.
- Westerly and southern boundaries follow the Great Artesian Basin (GAB) and Arckaringa Basin boundaries taking the further boundary from coal beds to identify potential groundwater connectivity.
- Pedirka basin boundary (DEWNR Dataset).
- 10 km buffer included where PAE intersects with fractured rock aquifer (FRA) extents.
- DMITRE Mapped areas of economic coal beds (Coal beds).
- Phreatic surface information was utilised to identify connectivity to shallow groundwater potentially utilised by vegetation, which was identified up to a 10m depth, based upon decisions made by the Bioregional Assessment team for other PAEs.
- Tertiary sediments were excluded from consideration as a buffer to the GAB where they intersect with coal deposits as it was assumed direct impact to the tertiary sediments would occur should open cut mining activities occur.
- Exploration Licences (EL) as lodged with DMITRE.
- Known watercourses (surface water data) (DEWNR dataset).
- Surface water basins – all of Macumba catchment surface waterbodies included (i.e. including sub catchments outside the Pedirka boundary) and downstream to the confluence with the Kallakoopah
- Upstream catchments of the Neales-Peake outside of the inferred 210km drawdown zone have been included on the basis that some of the springs support critical refuges for aquatic species that inhabit upstream reaches.

- 20km buffer boundary included as a contingency around known surface waters and groundwater drawdown extents, however all watercourse buffers are within the groundwater drawdown extent.
- Springs locations with SA (DEWNR dataset) + national springs database compiled for the Recovery Plan by Fensham et al. 2005).
- GAB springs of the Lake Eyre supergroup included with a 5km buffer around the point location to accommodate the extensive wetland and terrestrial ecosystems the spring support. It is noted that the impacts of drawdown on pressures would reduce further from the coal resource but recognising that there may be ecological dependencies between the springs.
- A potentiometric surface has been generated for the GAB aquifer (Cadna-owie Formation – Algebuckina Sandstone and equivalents) for the SA and NT portions of the GAB.
- Lower reaches of the Finke are within the 210km buffer around the Pedirka coal beds, which includes the Snake Gully/ Finke river floodout.
- Dalhousie springs complex is within the 210km drawdown extent.
- Water assets have been identified within northern areas of the Pedirka PAE based upon conservative assumptions that unknown vegetation dependency occurs from groundwater and shallow groundwater. This includes the Hale, Hay and Plenty Rivers together with wetlands of significance (Allitra tableland wetlands and Lower Plenty Lakes).
- Water assets have been identified within northern and eastern areas of the Pedirka PAE based on unknown terrestrial vegetation dependency on groundwater and shallow groundwater. Water assets include poorly studied floodout forest (dense riparian vegetation) of the Hale, Hay and Plenty Rivers together with wetlands of significance (Allitra tableland wetlands, Lower Plenty Lakes and Mulligan River salt lakes). It is however recognised that no GAB springs exist within the eastern areas of the Pedirka PAE.

Assumptions

- No surface water connectivity to the isolated dune lake systems in the south and east of the Pedirka in the Simpson Desert.
- Absence of fish in Hale River.
- McDills Anticline has been excluded from the modelling assessment due to poorly characterised geological structure. Further investigations are required to understand the influence on water availability and transmission extent.
- Northern boundary extent based upon GAB basin boundary and extent of drawdown within the basin boundary.
- Groundwater flows from recharge areas in the GAB towards critical springs supergroup but drawdown would not be sufficient to impact the Mulligan springs as these are outside of the GAB (see data gaps below).
- Surface water features of the Finke River catchment within the Pedirka boundary included, but upstream connections of the tablelands excluded as frequency of connectivity is considered too infrequent for upstream refuge ecosystems to be reliant on these lower reaches.
- The Neales River catchment was derived from the 1 second national DEM and smoothed manually using heads up digitising. Where possible it follows existing basin boundaries.

Data gaps

The following data gaps existed when defining the Pedirka PAE:

- The aquatic ecosystems of the Pedirka region would be amongst the most poorly studied in the LEB, which itself is poorly studied by comparison with coastal catchments.

- Further investigations are required to gain a greater understanding of the dependency of riparian vegetation in particular floodout forests of Hale, Hay Plenty and Finke rivers upon shallow groundwater systems and the potential impacts of drawdown from mining related activities.
- Further modelling information proposed to be undertaken to understand zone of GW drawdown influence to 0.1 (surface level) which may extend the zone of influence further south and east to encompass springs in the Lake Eyre and Mulligan River supergroups.
- Exploration Licences not available for NT.
- Further relationship information required to clarify ecological relationships between the Macumba and greater Diamantina-Georgina connectivity (e.g. for fish recruitment, biomass production and genetic resilience).
- The influence of the Macumba River on Lake Eyre is unclear, with further research required. However, for the purpose of this PAE, Lake Eyre has been excluded.
- Based on current level of knowledge, there is flow in the GAB in the north east portion of the Pedirka PAE towards the Mulligan River supergroup of Springs, which are EPBC listed GAB springs. These are assumed to be recharged from flow in rivers in this region. There is potential that a reduction in pressure within the PAE could reverse the flow paths away from the Mulligan River springs or reduce pressure to them. However, due to the depths of tertiary sediments and distance from the coal beds, these have been excluded due to an unlikely hydrological connectivity. Further research on hydrogeology in this region should inform future decision to include or exclude these springs.

1.4.3 PAE Database Location

Below is an image of the geodatabases as they appear in Arc GIS:

2. FIGURES

Figure 1. Arckaringa PAE Revision 1.0

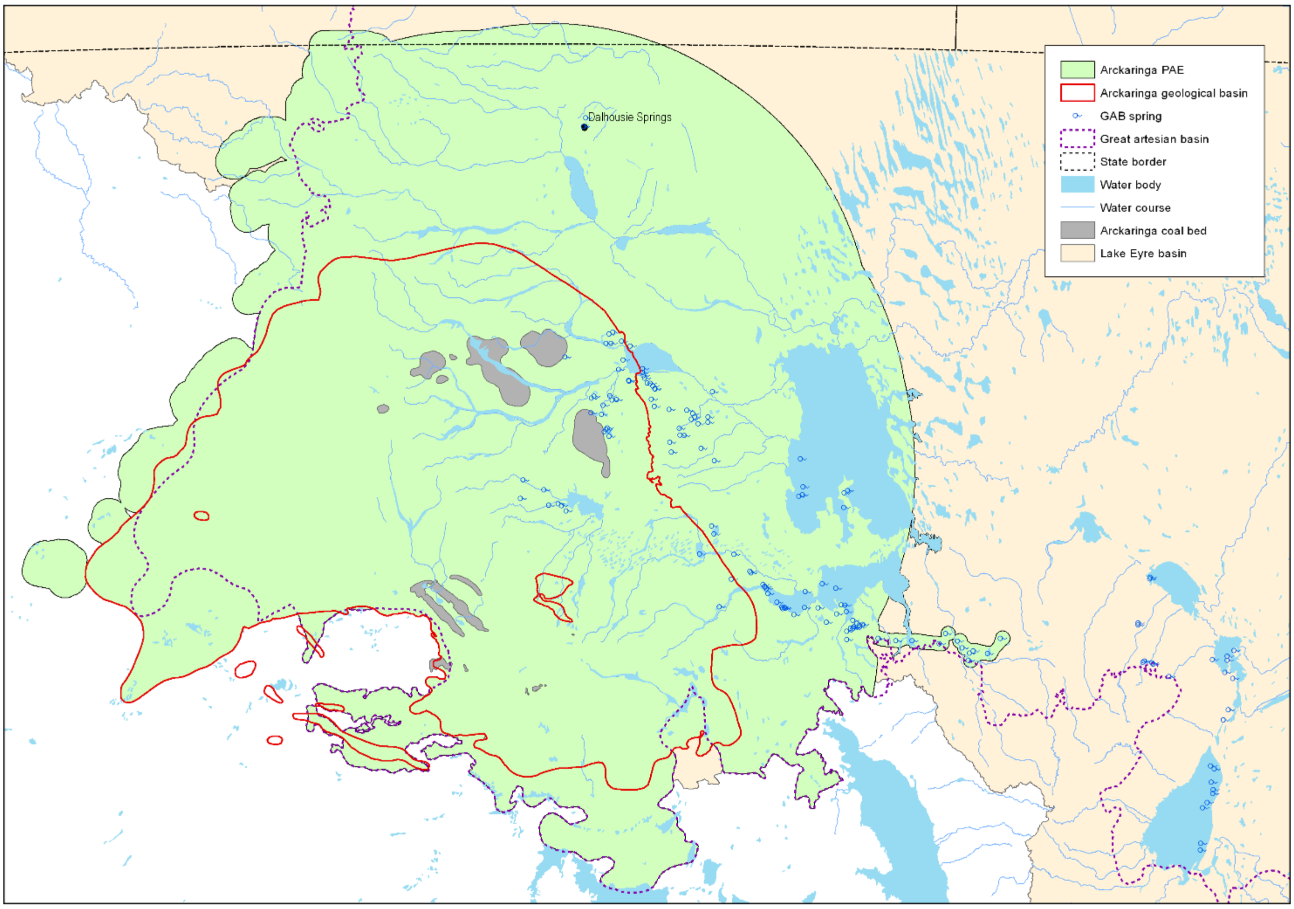


Figure 2. Pedirka PAE Revision 1.0

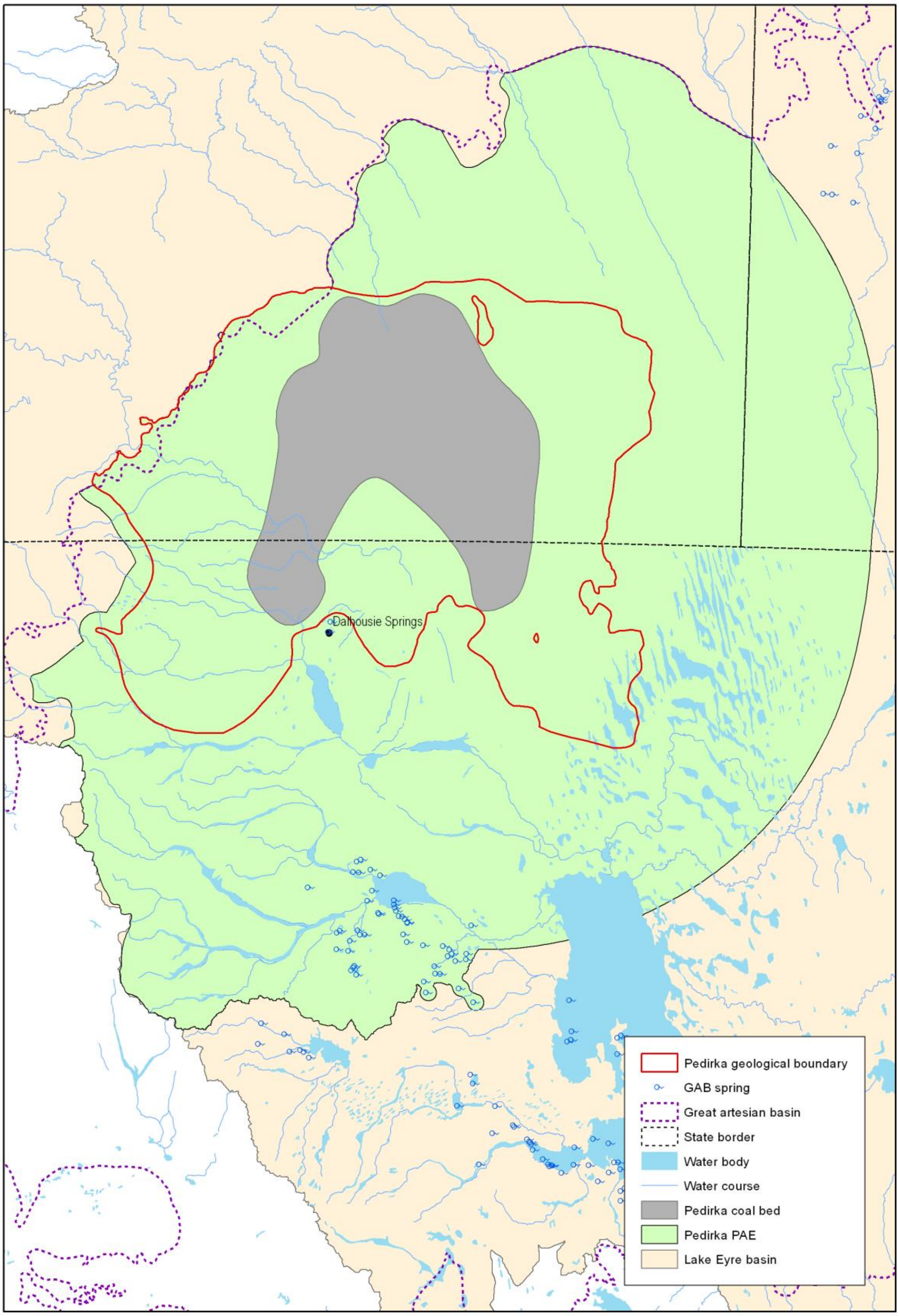


Figure 3. Modelled draw down extent

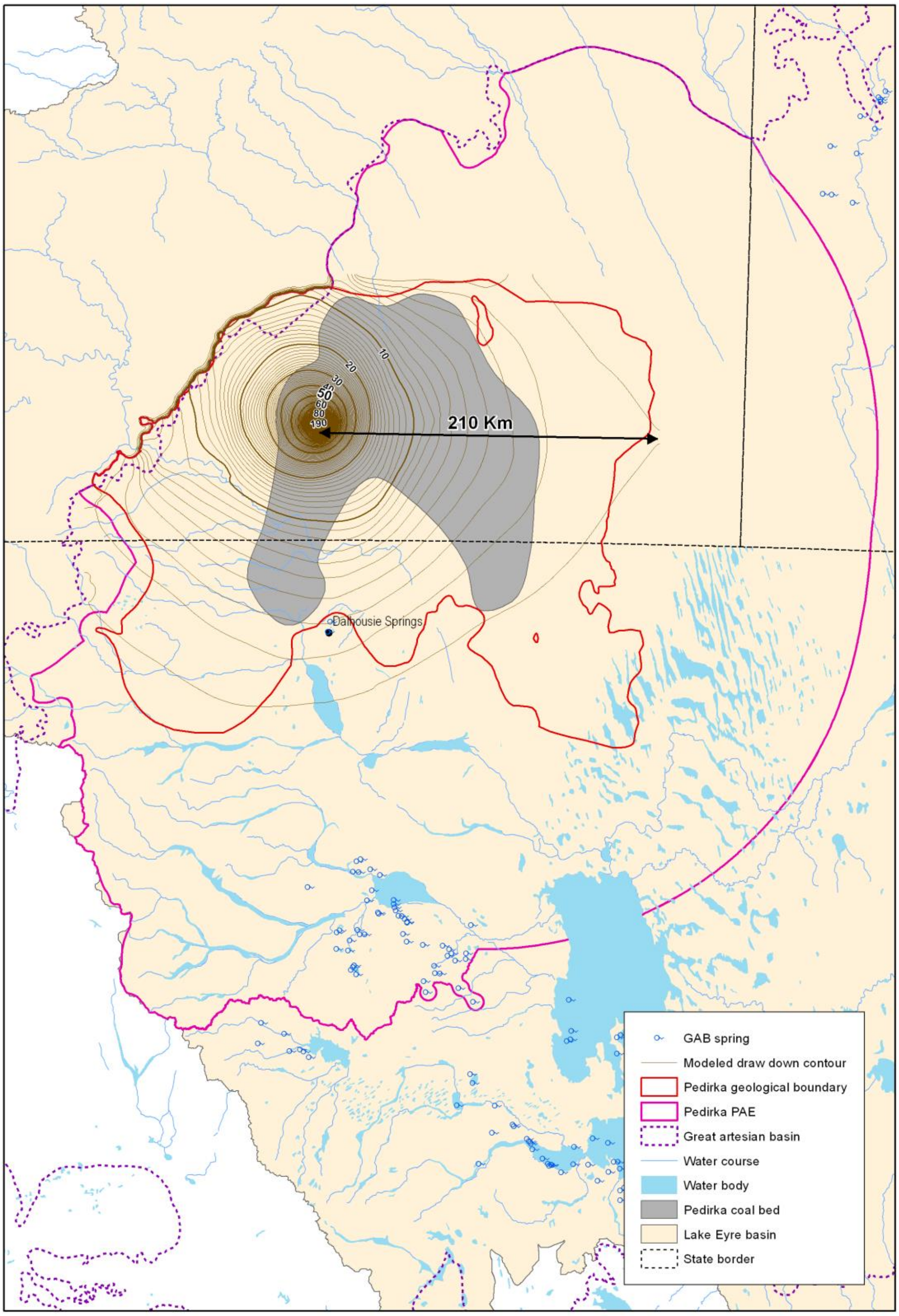


Figure 4. Phreatic Surface - Arckaringa

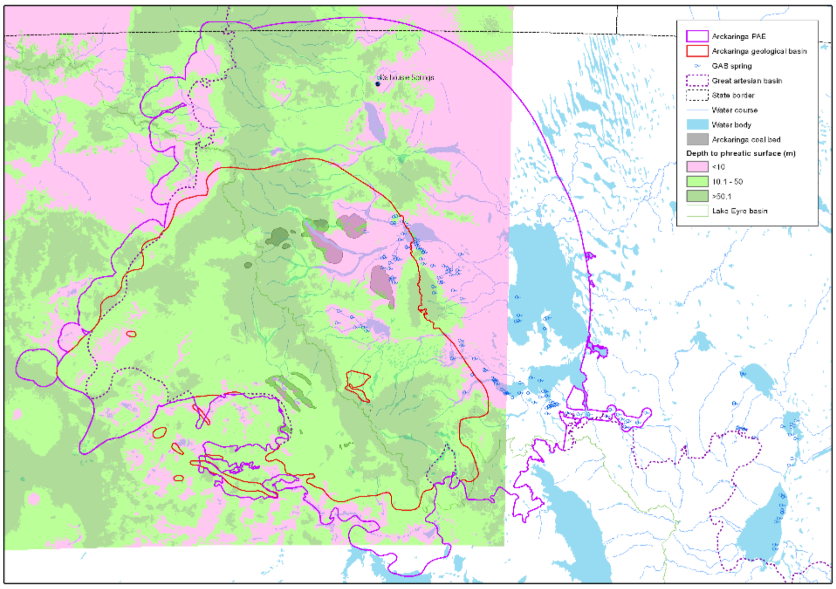
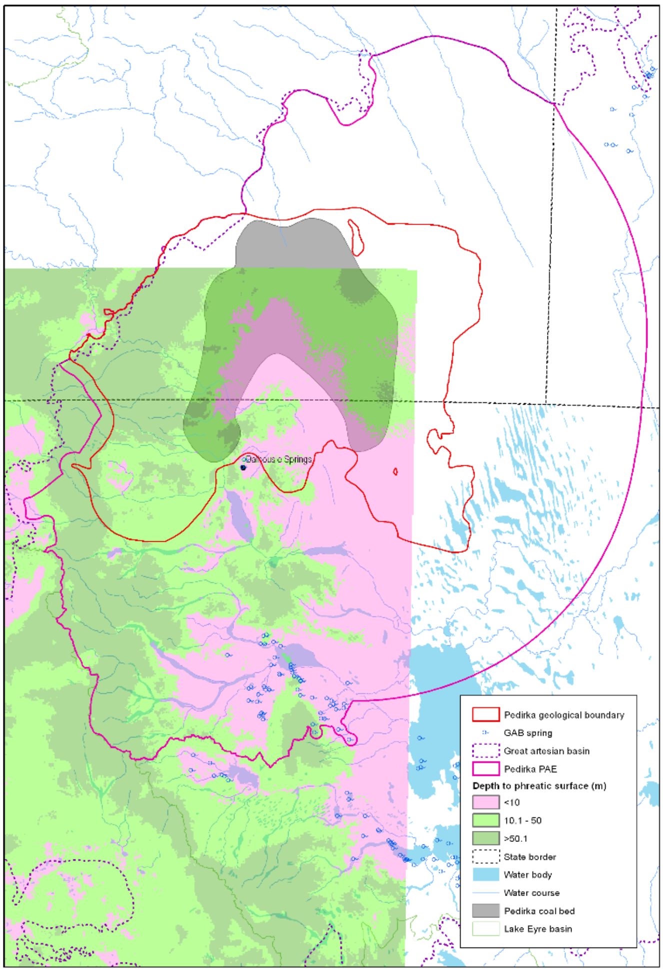


Figure 5. Phreatic Surface – Pedirka



APPENDIX 1. SUMMARY METHODOLOGY OF DEWNR PRELIMINARY STAGE 1 GROUNDWATER MODELLING FOR THE PEDIRKA BASIN.

Extracts from the Pedirka Modelling report (Peat et al. 2014 – in prep) are presented below to support the development of the Arckaringa and Pedirka Preliminary Assessment Extents.

Overview

The Australian Government, through the Department of the Environment Office for Water Science (OWS) funded the South Australian Government to undertake groundwater assessment projects in the Arckaringa Basin and the Pedirka Basin in recognition of coal mining and CSG development potential. A numerical groundwater model of the Pedirka Basin was developed as part of the Pedirka Basin groundwater assessment project. The following text is an extract of sections from the Pedirka modelling report which is in final draft stage (Peat et al. 2014 – in prep.).

The purpose of the modelling exercise was to improve our understanding of the regional groundwater system:

- By testing our current conceptual model,
- Providing an estimation of regional scale water balance,
- Conduct sensitivity testing and
- Define data and knowledge gaps.

A regional scale MODFLOW model has been developed for the Pedirka Basin using available data and current information, and is defined as Class 1 (Barnett et al., 2012). A steady state model was developed that simulates a long term average condition and assumes a higher rate of diffuse recharge occurring in the past. The steady state model result for water level is used as initial conditions to run the transient model, which simulates the main processes occurring in the basin in the past, present and into the future and therefore includes simulation of the current condition. The transient model simulates a period of 100 000 years to represent changing conditions in the hydrogeological system and includes representation of the past, current and future conditions. The transient model stress periods vary to capture important trends in aquifer head and water balance.

Conceptual Model

Flow direction

According to current water level data, groundwater flow direction is predominantly occurring from the north-west to the south-east, with some lateral inflow from the north via the J aquifer.

Current groundwater flow direction is highlighted by diffuse recharge that is occurring, or has occurred in the past, along the north-west margin of the basin and discharge which mainly occurs along the southern edge of the basin through lateral outflow via the GAB aquifers.

Aquifer interaction

Insufficient lithological data and knowledge is available to develop a regional understanding of whether the Purni Formation and Crown Point Formation behave as a single aquifer, or whether multiple aquifers and aquitards exist within these formations. Within the eastern portion of the basin, Triassic sediments of the Simpson Basin unconformably overly Permian sediments. It is postulated that the Triassic may limit the hydraulic connectivity between the Permian aquifer and the overlying J aquifer, however faulting may enable vertical localised connectivity between overlying and underlying aquifers, particularly in the location of the Dalhousie-McDills Ridge.

Recharge

Recharge occurs on the north-west margin of the basin and include lateral inflow from GAB and recharge from rainfall and streams. It is presumed that diffuse recharge has been declining over the recent climate cycle (last

10 000 years) due to reduced rainfall. Based on current understanding, modern diffuse recharge is approximately 0.1 mm/y, which is negligible. Recharge from surface water features occurs where the Finke River and Goyder Creek intersect outcropping J aquifer and Permian aquifer, and is thought to be the primary mechanism for modern-day recharge to the basin.

Discharge

Discharge mechanisms are uncertain, as the South Australian portion of the Pedirka Basin is data poor.

In the northwest of the Pedirka Basin localised discharge may occur via evapotranspiration where the watertable is relatively shallow near Finke River. Local discharge to waterholes may also occur. These processes are assumed to be minor components of the overall basin water balance.

The Rollings Down Group controls the rate of vertical discharge from the J aquifer to shallower aquifers within the Cainozoic. Estimated rates of diffuse discharge through the Rollings Down Group range between 3 x 10-4 to 5 x 10-4, but can be higher where preferential flow paths occur along fractures and major faults such as the Dalhousie-McDills Ridge (Love et al., 2013b). This may influence groundwater flow direction and vertical discharge.

Model Structure

The groundwater model for the Pedirka Basin represents six key hydrogeological units with five active model layers (Layers 2 to 6). Model layers 2 to 6 represent the major stratigraphic units and each has been assumed to be a single hydrogeological unit. Insufficient data exists to discretise these units beyond the major stratigraphic units.

Table 1: Model layer aquifers and aquitards within the Pedirka model

Layer	Hydrogeological Group or Unit	Aquifer / Aquitard	MODFLOW Layer Type
1	Cainozoic and Rollings Down Group	Aquitard	Inactive
2	J Aquifer (GAB aquifer)	Aquifer	Type 0 (confined)
3	Triassic	Aquitard	Type 0 (confined)
4	Purni Formation	Aquifer	Type 0 (confined)
5	Crown Point Formation	Aquifer	Type 0 (confined)
6	Basement	Aquitard	Type 0 (confined)

Layer 1 (Rollings Down Group and Cainozoic) is included in the model for completeness, but it is assigned as inactive, or no-flow. Due to the low permeability of the Rollings Down Group it is assumed that there is very minor interactions between the underlying J aquifer and shallower interbedded aquifers in the Cainozoic & Rollings Down Group. This assumption/simplification reduces model complexity associated with shallower aquifers and ensures stability of the model.

All five active model layers (Layers 2 to 6) are modelled as confined (type 0) which represents the aquifer layer conditions across most of the basin area, improves model stability and reduces computation time. Modelling the aquifer system as confined is considered suitable over most of the basin, but the aquifers are unconfined/confined in a small area along the north-west margin of the model domain. The model may slightly overestimate aquifer transmissivity and underestimate aquifer storage in this area. The impact of this simplification/assumption is addressed through an uncertainty analysis discussed in a later section.

The structure of model layers consider topographic variation, drillhole data, seismic data and hydrogeological understanding of faulting and deposition (Wohling et al., 2013). Surfaces were modified to prevent negative model layer thickness and very thin model layers in the north-west of the Pedirka Basin. Surface elevations for individual layers were adjusted so that a minimum thickness of 10 m is obtained for each layer. The thickness

of each hydrogeological unit is overestimated by approximately
10 m, which is negligible in comparison to the overall thickness of these units across most of the basin, which are at least 200 m thick.

A summary of the aquifer parameters used in the model is presented in table 2.

Table 2: Adopted aquifer and aquitard hydraulic parameters and ranges in field estimates

Hydro-geological unit	Model layer	Modelled hydraulic parameters			Estimates of hydraulic parameters		Data sources
		Kh (m/d)	Kv (m/d)	Ss (-/m)	Kh (m/d)	S (-)	
J Aquifer	2	7 (20 in a small zone)	0.7 - 2	1×10^{-5}	Lower value 0.1 to 1.6 ; higher value 7 to 20	7×10^{-6} to 7×10^{-3}	Keppel et al (2013)
Triassic	3	1×10^{-7}	1×10^{-7}	1×10^{-5}	No data	No data	
Purni Formation	4	0.5	0.05	1×10^{-5}	1.7×10^{-4} -2.44	No data	Wohling et al (2013)
Crown Point Formation	5	1 (20 in a small zone)	0.1 - 2	1×10^{-5}	0.08 - 1.66	No data	Wohling et al (2013)
Basement	6	0.01	0.001	1×10^{-5}	No data	No data	

The regional hydraulic conductivity of the J aquifer of 7 m/d is based on a representative value from literature review (Keppel et al., 2013). There are no estimates of the hydraulic properties of the Triassic, and yet it is considered critical to understanding the connectivity between the J aquifer and Permian aquifer.

Regional modelled hydraulic conductivity of the Purni Formation and Crown Point Formation are estimated from a mid-range derived hydraulic conductivities from permeability measurements. Where outcropping Crown Point Formation intersects the Finke River, the hydraulic conductivity is assumed to be higher locally and assigned the same value as J aquifer. There are no available estimates of the hydraulic properties of basement.

Storativity estimates are available for the J aquifer however there are no estimates available for the remaining units. A uniform value of specific storage of 10-5 /m, an average value from J aquifer and text book value for general confined aquifer, has been adopted for all layers.

Model simplifications, limitations, calibration and not presented here but are available in detail in (Peat et al. 2014 – in prep.).

Dewatering Scenario

A hypothetical mine dewatering scenario was included in the sensitivity testing. The estimated impact of drawdown is regionally widespread and is related to the horizontal and vertical connectivity between the modelled aquifers. The test indicates that drawdown may occur in the GAB aquifer near Dalhousie Springs, but the aquifer remains artesian over the period of testing (50 years).

The objective of this stress test is to sense the potential impact of dewatering at a hypothetical mine location on the regional groundwater systems. The test is purely hypothetical and the result is considered to be of low confidence, given that the model is not calibrated for that purpose and there is limited data to constrain the regional model.

The hypothetical location is situated in the vicinity of where Stage 2drilling investigations have encountered coal beds at approximately 40 m below the top of the Purni Formation. MODFLOW Drain Package is used to simulate the effects of mine dewatering. As the model simulates dewatering using drain cells, the model test does not consider the construction time taken to dewater the aquifer to the top of the coal.

The drain cells are simulated over an area of 1 km2. The transient model water levels at the end of the model simulation period were used as initial conditions, and is assumed as a system in equilibrium and the estimations are not mixed with system changes due to other factors. The bed of the drain cells is situated at an elevation of -313 m AHD (depth of approximately 475 m bgl), which is approximately 40 m below the top of model layer 4. The conductance applied to the drain cells is 125 000 m2/d which minimises resistance so that target drawdown can be achieved.

The dewatering activity is simulated over a period of 50 years, with yearly stress periods. The model was run for 50 years and does not evaluate the recovery in the system after mining has ceased.

The test result indicates that approximately 7191 GL discharged from the drain cells over a period of 50 years (an average of 394 ML/day) to achieve maintaining the target level.

The estimated drawdown at 50 years is widespread across the basin and occurs at considerable distance from the mine site. Drawdown contours in the Permian aquifer at distance from the mine site are influenced by the presence of the Triassic sediments.

The maximum distance to the Eromanga Basin 1m drawdown contour is approximately 210 km. This distance was then added as a buffer to the Pedirka Basin extent of coal and clipped to the Eromanga Basin extent as a variable for defining the Pedirka PAE.

References

Barnett B, Townley LR, Post V, Evans RE, Hunt RJ, Peeters L, Richardson S, Werner AD, Knapton A and Boronkay A, 2012 *Australian Groundwater Modelling Guidelines*, Waterlines report, National Water Commission, Canberra

Peat, V & Yan, W 2014 (in prep.), *Pedirka Basin Numerical Groundwater Model 2014,* DEWNR Technical Report 2013/XX, Government of South Australia, through Department of Environment, Water and Natural Resources, Adelaide

Wohling, D., Keppel, M., Fulton, S., Costar, A., Sampson, L. and Berens, V. 2013, *Australian Government Initiative on Coal Seam Gas and Large Coal Mining – Arckaringa Basin and Pedirka Basin Groundwater Assessment Projects*, DEWNR Technical Report 2013/11, Government of South Australia, through Department of Environment, Water and Natural Resources, Adelaide