Government
of South Australia

South Australia Strategic Hydrogeological Framework

BRAEMAR PROVINCE

Joint collaboration between
Department for Energy and Mining
Department for Environment and Water

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Foreword

Sustainable water sources are fundamental to our State's economic growth, environment, and quality of life. Access to water has been a longstanding constraint on the development of some of South Australia's most prospective mineral laden regions. Changing rainfall patterns leading to a drier climate, will exacerbate this situation unless South Australia can identify alternative secure sources of water.

To overcome this limitation, South Australia has invested in a strategic hydrogeological framework that deepens our existing knowledge of the water beneath us. By improving our knowledge of groundwater resources, we aim to minimise risks and create greater certainty to investors seeking to progress resource projects within the arid regions of South Australia.

This strategic hydrogeological framework covers the Braemar Province, a remote part of the State that straddles the Barrier Highway with limited social infrastructure but an identified potential for resource development. The White Dam gold mine and Honeymoon uranium mine are two operating resource projects in the province, however discoveries of numerous magnetite and copper deposits suggest the potential for future developments.

This strategic hydrogeological framework analyses projected water demand and the capacity of the groundwater resources to support it. It also includes a roadmap to help inform Government decision-making and guide further investment to address knowledge gaps and constraints.

The goal of this information is to ultimately unlock the development opportunities of this province and guide regional development of water infrastructure to underpin jobs, business activity and royalty revenue to support the delivery of government services for all South Australians.

The development of this strategic hydrogeological framework was a joint initiative between the Department for Energy and Mining and the Department for Environment and Water. Both departments have a long-standing history of collaboration to create and collate data to better inform the decisions the government and investors make to sustainably advance our State.

To find out more about the framework and the broader exploratory and analytic work carried out by South Australia's internationally recognised team of geoscientists, I encourage you to contact the Department for Energy and Mining. My thanks are extended to everyone involved in producing these important contributions to the state's hydrogeological knowledge.

Dr Paul Heithersay PSM FTSE FSEG FAusIMM
Chief Executive
Department for Energy and Mining

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Executive Summary

SCOPE AND OBJECTIVES

This report covers the development of the Strategic Hydrogeological Framework for the Braemar Iron Province.

The Braemar Province has a high concentration of known mineral resources, dominated by magnetite. Magnetite is a highly prospective and valuable source of iron ore for steel making and other uses. However, the mining and processing of magnetite requires a significant amount of water and there is little to no surface water available in the Braemar Province. The framework examines the potential for groundwater to alleviate this constraint and presents an action plan for the State to advance the investigation and development of groundwater resources to support mining.

WATER DEMAND FOR MINING

Defined mineral resources of magnetite in the Braemar Province are substantial (11,191 Mt). Six major magnetite projects are being considered for development, with various rates of production proposed (from 1.5 Mt/y to 20 Mt/y). In general, the development philosophy expressed in the feasibility studies is to start at lower rates of production and expand once the industry is established and efficiencies of scale are realised. Thus, much higher rates of production could be expected once the industry is established, and the size of the mineral deposits is such that long mine lives (in the order of 50 years) could be supported.

The water demand for magnetite mining and processing is directly related to production rates and is generally ~0.6 to 2.0 GL for every Mt of concentrate produced. Based on the production rates proposed across the various projects and an assumed water requirement of 2.0 GL/Mt, the cumulative regional water demand for mining development is in the order of 10 GL/y over the short-term (<5 years) and this could increase to 60 GL/y under an advanced development scenario in the longer term (>10 years). In terms of water quality, most projects can tolerate the use of highly saline water for processing with a small quantity of fresh water used to wash the final product and remove impurities.

GROUNDWATER RESOURCES AND THEIR CAPACITY

The geology of the study area has given rise to two main aquifer systems, as follows:

- In the Olary Ranges, fractured rock aquifers are hosted in the fracture networks of pre-Cenozoic rocks. These resources are close to the mineral deposits (within 5 km).
- In the Murray Basin, sedimentary aquifers are hosted in the more permeable units of the Cenozoic sediments. These resources are further away (generally >50 km).

The capacity of the fractured rock aquifers is limited due to low storage, low recharge, and generally low yields (some higher yields may be found in more heavily fractured zones). The development of these groundwater resources would also have to address any potential impacts to third-party users (existing stock and domestic wells) and groundwater dependent ecosystems. Despite these limitations, mining development in the Braemar would likely access these resources to some extent, given their proximity to the mine sites.

The Lower Renmark Aquifer offers the most prospective groundwater resource in the Murray Basin. It is an extensive, confined aquifer of considerable thickness (i.e. it has a high storage capacity) and currently supports stock and domestic groundwater supplies but is minimally developed.

While it is a prospective resource, it should be noted that insufficient data is currently available to understand potential interactions with the water table and therefore potential impacts on surface water ecosystems (i.e. groundwater dependent ecosystems) associated with larger developments.

The current knowledge of these aquifer systems is limited due to the paucity of groundwater drilling in the region. While acknowledging this uncertainty, a preliminary assessment of the capacity of these resources indicates:

- Fractured rock aquifers of the Olary Ranges are unlikely to provide sufficient water for significant mining development in the region, but they will likely provide a supplemental water supply.
- There is a reasonable probability of the Lower Renmark aquifer meeting low and moderate demand scenarios and possibly supporting higher levels of demand. The available hydrogeological data indicates that while prospective groundwater supplies are evident in South Australia, higher yielding and lower salinity groundwater could be obtained in New South Wales at similar distances from the mining projects.

OPPORTUNITIES, CONSTRAINTS AND ISSUES ARISING

The key opportunities in developing groundwater resources to assist mining development include:

- Economic growth and development associated with mining development.
- Water to communities as an extension of mining and groundwater resource development.

The constraints include:

- Limited capacity of local fractured rock groundwater resources to support large scale mining development.
- Costs of developing groundwater resources at distance.
- Management of salinity and other potential water quality considerations.
- Uncertainties related to:
  - Groundwater resource estimation and long-term sustainability of supply.
  - Mine planning: timing, demand quality and quantity, costs of developing resources.
- Land access issues for infrastructure and corridor planning.

The issues arising include:

- Competition for water resources (e.g. well interference).
- Potential impacts (and cumulative impacts) of groundwater resource extraction.

ACTION PLAN

An action plan has been formulated to address the above knowledge gaps, constraints and the issues arising. The action plan is designed as a means to prioritise government efforts in the short to medium-term (<5 years). The following actions have been identified:

1. Undertake fieldworks and desktop investigations (including groundwater flow modelling) to address knowledge gaps and better understand the capacity of the groundwater resources. Prior to undertaking this work, discuss the framework with the NSW government and consider assessing the NSW part of the Murray Basin.
2. Maintain dialogue with project proponents to better understand mine water demand projections.
3. Develop a regional water management framework to manage competing impacts (e.g. well interference) and cumulative impacts from water resource development.
4. Resolve land access issues associated with the development of an off-tenement water supply.
5. Develop a water data protocol (as a state-wide activity) that describes how groundwater data can be collected and collated as part of future mineral exploration.
6. Conduct an options assessment to consider prospects of importing seawater to the region as an alternative to developing groundwater resources.
7. Subject to agreement from mining industry stakeholders, explore and develop a framework for joint-water supply infrastructure.

1 Introduction

1.1 BACKGROUND

South Australia is the driest state within the driest inhabited continent on earth. Poor access to water is a critical constraint to resource and economic development, particularly for mining development in areas to the north of Goyder's Line.

In seeking to facilitate mining development and economic growth, the South Australian government is considering ways in which it could assist in improving access to water to unlock the mineral opportunities in this region. A suite of works has been initiated to target this objective and includes:

1. The Water and Infrastructure Corridors Program, which is focussed on the establishment of water and infrastructure corridors to support mining and resource development via:
    a. a transport and corridors study, informed by the development of an economic 'heat map', to: a) identify the need for possible infrastructure corridors to connect regional economic activity with access to transport, power and water, and; b) establish a process to provide for land access negotiations and agreements along such corridors
    b. the development of a Strategic Hydrogeological Framework to examine the potential for groundwater resources to mitigate water constraints to mining development. The framework is to cover the state's priority mineral provinces in the far north (or north of Goyder's Line), with the initial focus being on two study areas: the Stuart Shelf region of the Gawler Craton, and the Braemar Province (see Figure 1).
2. The Northern Water Supply project (being led by Infrastructure SA), which is considering a significant infrastructure investment involving the construction of a coastal desalination plant and pipeline to transfer treated seawater from the Spencer Gulf to support a) new and emerging industries in the Upper Spencer Gulf, b) growth of the mining sector in the State's northern region, and c) support growth in other sectors (e.g. horticulture, pastoral and agriculture).

This report covers the development of the Strategic Hydrogeological Framework for one of the key study areas, the Braemar Iron Province.

The framework is a joint initiative between the Department for Energy and Mining (DEM) and the Department for Environment and Water (DEW), with DEM acting as the lead agency. CDM Smith has been engaged in a secondment capacity to drive the delivery of the framework as part of the DEM-DEW team.

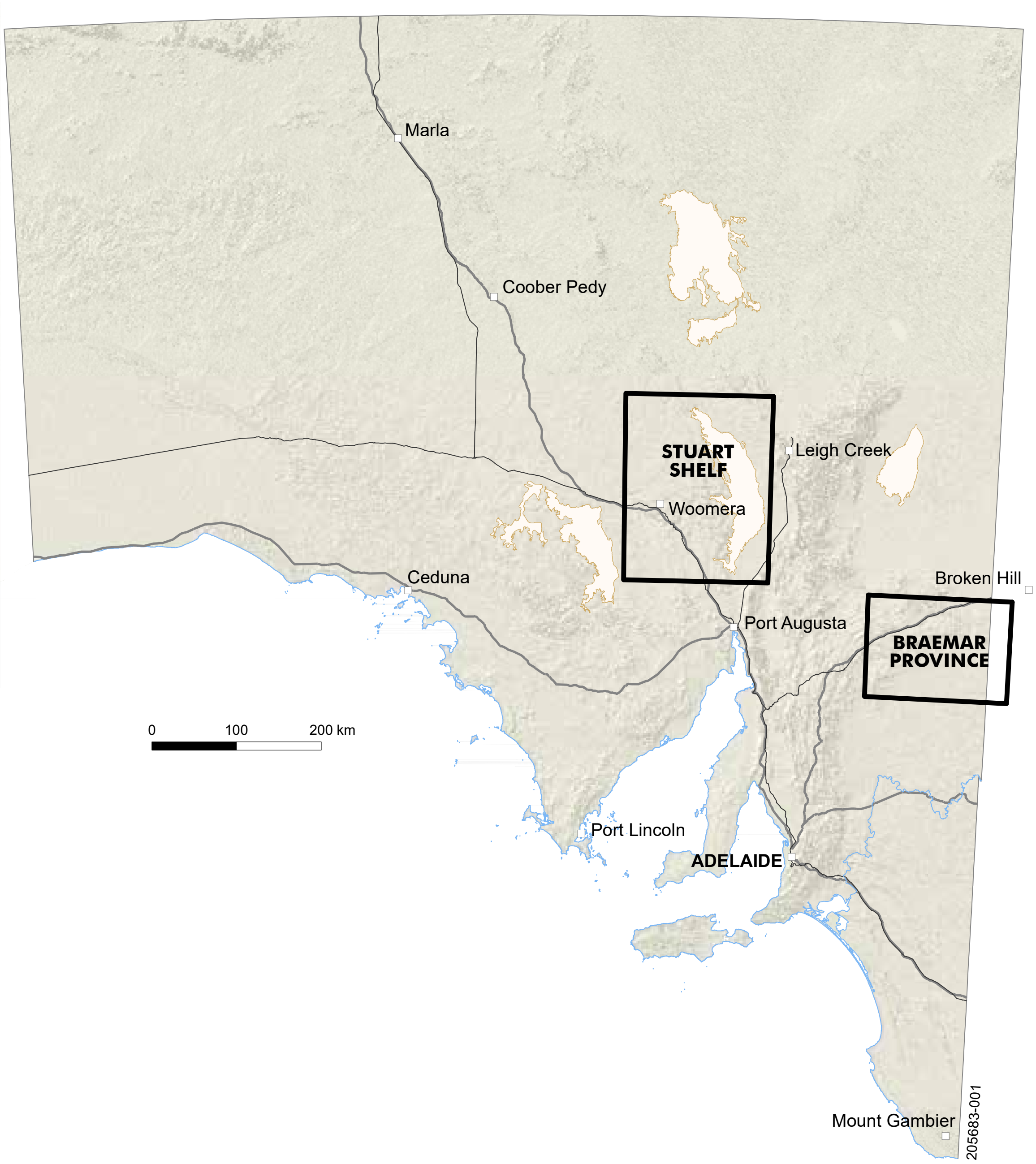

Figure 1 *Strategic Hydrogeological Framework Study Areas*

1.2 SCOPE AND OBJECTIVES

The objective of the Strategic Hydrogeological Framework is to present an up-to-date understanding of the water requirements to develop the mineral resources in the defined region of interest (the Braemar Province) and an up-to-date understanding of the groundwater resources that could potentially support this mining activity. Based on an analysis of likely mine water demand and the capacity of the groundwater resources to support this demand, a 'road map' is to be developed which is to inform where government efforts can best be directed in the short-to-intermediate term (over the next 5 years or so) to prove up these groundwater resources and instigate corridor planning for water delivery infrastructure.

1.3 STUDY AREA AND SCOPE

The framework is focussed on groundwater resources, but must also consider the linkages to other potential water supply options (e.g. piped seawater, which could be either desalinated or untreated).

The framework is driven by mining demand for water but must also cover the opportunities and benefits to local communities (and other industries) from the supply of water via the infrastructure investment.

The Braemar Province has been selected as an area of interest (study area) due to a high concentration of known mineral resources, dominated by magnetite, in what is a water-limited region. Magnetite is a highly prospective and valuable source of iron ore for steel making and other uses. The South Australian Government is working to guide and support the development of the state's iron ore resources for economic growth and the creation of jobs within the supply chain (DEM Magnetite Strategy 2022 [1]). As such, the government is seeking to unlock the state's magnetite resources and increase production to 50 million tonnes per annum by 2030. As one of only three geographic regions in the state where magnetite resources are concentrated, the Braemar Province is an area of focus for the government to guide and support mining development. Such development would require a significant amount of water, given the ore processing requirements of magnetite. The region has therefore been selected as an area of interest for this study.

The spatial boundaries of the Braemar Province study area have been determined by the location of the known magnetite deposits (see Figure 2). The study area extends into New South Wales to include the Hawsons deposit.

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[1] www.energymining.sa.gov.au/home/events-and-initiatives/initiatives/magnetite_strategy

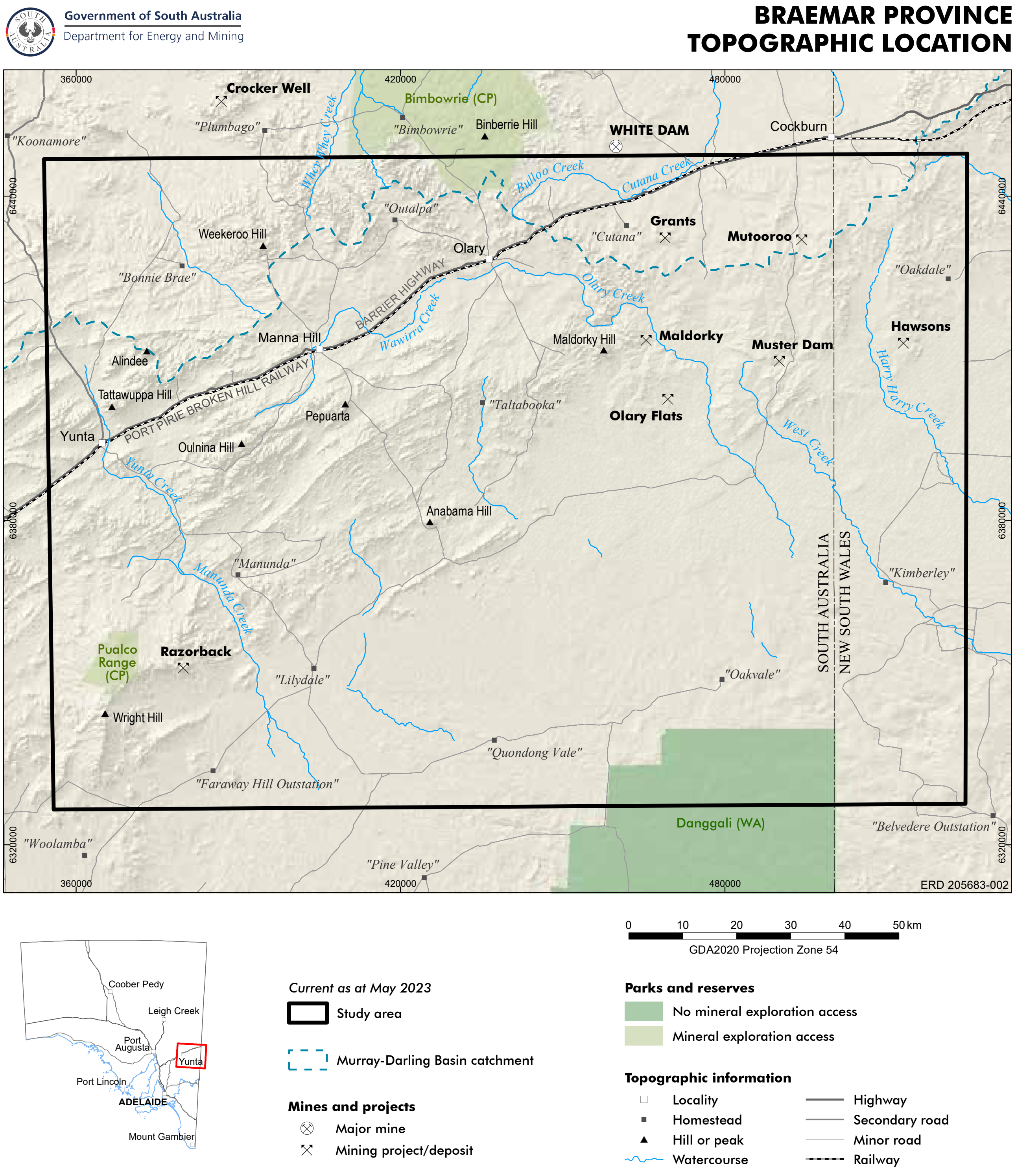

Figure 2 *Braemar Province study area*

1.4 THIS REPORT

This report is structured to present the Strategic Hydrogeological Framework as a logical review and analysis of the available information to arrive at a road map, as follows:

- Section 2 presents a summary of the known mineral resources contained within the study area and the status of mining activity (from exploration to feasibility studies), noting that no magnetite mining has commenced.
- Section 3 examines mine water requirements and presents an estimate of the projected water demand to develop the mineral resources. Water quality requirements are also described.
- Section 4 presents a summary of the regional hydrogeology and describes what is known about the potential groundwater resources within the study area and its immediate surrounds. The prospectivity of these groundwater resources is interrogated.
- Section 5 presents an analysis of whether the capacity of the potential groundwater resources in the region (described in Section 4) is sufficient to meet the projected mine water demands (described in Section 3). A SWOT Analysis (Strengths, Weaknesses, Opportunities and Threats) is undertaken to assess the groundwater resource potential.
- Section 6 presents a road map to guide government efforts in groundwater and corridor planning in helping to facilitate the mining investment and activity. It presents an action plan that is framed around addressing the key knowledge gaps, constraints and developing pathways to navigate the issues arising.

Mining industry stakeholders were engaged and consulted in the development of this framework. A draft version of this report was circulated for review and feedback, and a project workshop held to discuss the key findings and recommendations. The following parties have been consulted in the development of this framework:

- Havilah Resources
- Hawsons Iron
- Magnetite Mines
- Lodestone Mines
- Department for Energy and Mining
- Department for Environment and Water
- Department for Infrastructure and Transport

2 Study area, mineral resources and development

2.1 STUDY AREA

The Braemar Province study area is shown in Figure 2. It covers a section of the Olary Ranges—a lateral extension of the Adelaide Geosyncline that has formed a ridge system that arcs in a north-easterly direction from Peterborough in South Australia towards Broken Hill in New South Wales. The ranges rise to ~600 m AHD and feature linear ridge/valley landscapes flanked by plains of the Murray geological basin to the south-east and gently undulating broad alluvial plains to the north which slope gradually towards Lake Frome. The ranges create a drainage divide between the Murray-Darling Basin catchment to the south and the Lake Frome Basin to the north. The climate is arid, with hot, dry summers. Mean annual rainfall is ~200 mm[2]. The major land use is pastoral. Prior to European settlement the region was occupied by the Ngadjuri, Wiljakali and Danggali people (Tindale, 1974).

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[2] Yunta Airstrip (BOM Site 020062) has a mean annual rainfall of 197 mm.

2.2 MINERAL RESOURCES

The spatial boundaries of the Braemar Province study area have been determined by the location of the defined mineral resources, which are primarily magnetite but also include some copper-cobalt resources. The locations of the main deposits are shown in Figure 3. They occur to the south of the Barrier Highway, forming an arc which extends in a north-easterly direction from the Ironback Hill and Razorback Ridge deposits in the south-west to the Hawsons deposit in the north-east.

The known magnetite resources of the study area occur within the Nackara Arc, a tectonic subdivision of the Adelaide Geosyncline. They are found mostly as magnetite BIF (Braemar ironstone facies), which refers to ironstone facies within two separate formations, the Pualco Tillite and Benda Siltstone (Davies and Twining 2018), that were deposited during the Neoproterzoic Era. They tend to occur at shallow depths with gently dipping slabs and are often recognised by electromagnetic signatures (Figure 3).

Exploration since the mid-2000s has identified many BIF prospects within the Nackara Arc, with several deposits defined as JORC-compliant. Defined mineral resources of magnetite BIF total 11,191 Mt as listed in

Table 1, and there is potential for a significant expansion of the resource inventory based on exploration targets, which totalled 20,000–57,000 Bt in 2018 (Davies and Twining 2018). Current exploration leases are shown in Figure 4. A Section 15 Gazettal (pursuant to the *Mining Act 1971*) applies to a region of the Murray Basin. Under this gazettal, applications for mineral tenements are being withheld while DEM undertakes its own exploration studies.

While there are no operational magnetite mines in the Braemar, there are six major magnetite projects being considered for mining development which are undergoing feasibility assessment of various levels of advancement, as outlined in Table 2. The current datasets on SARIG indicate a contained final iron ore product of ~1,350 Mt across these six projects.

Various rates of production are currently proposed across the different projects, ranging from 1.5 to 2.0 Mtpa in the South Australian projects and up to 20 Mtpa for the Hawsons project in NSW; however, these are subject to change as feasibility studies advance. In general, the development philosophy expressed in the feasibility studies undertaken thus far is to start at lower rates of production and expand once the industry is established and efficiencies of scale are realised. Thus, much higher rates of production could be expected once the industry is established, and the size of the mineral deposits is such that long mine lives (in the order of 50 years) could be supported.

In addition to magnetite, the study area includes copper-cobalt resources in sulphide ore bodies hosted by metamorphic rocks of the Willyama Supergroup (late Paleoproterzoic Era) of the Curnamona Province. One major deposit of this type, Mutooroo, occurs within the study area and has been defined as a JORC resource comprising 195.0 Kt of Copper, 20.2 Kt of Cobalt and 82.1 Koz of Gold (Havilah Resources 2022[3]). Given the relatively small size of the copper-cobalt-gold resources compared to the total resource inventory for magnetite, they are not described further in this study explicitly; however the development of groundwater resources to support mining in the region, is just as relevant for mining these resources as well.

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[3] https://www.havilah-resources-projects.com/mutooroo

Table 1 *JORC-compliant magnetite resources in the study area.*

Deposit name	Owner	Total resource			Indicated / Inferred
		Mt	**% Fe**	**% DTR** (a)	
Maldorky	Havilah Resources	147	30.1	36	Indicated[b]
Razorback Ridge/Iron Peak	Magnetite Mines	3,000	18.2	15.8	Indicated & Inferred[c]
Muster Dam	Magnetite Mines	1,550	18.7	15.2	Inferred[c]
Ironback Hill	Magnetite Mines	1,187	23.2	?	Inferred[c]
Olary Flats	Lodestone Mines	510	26.4	26.9	Indicated & Inferred[d]
Red Dam	Lodestone Mines	472	0	19.7	[e]
Grants	Havilah Resources	304	24	–	Inferred[c]
Nippon Hill	Lodestone Mines	71	–	14.4	[e]
Hawsons (NSW)	Hawsons Iron	3,950		12.2	Indicated & Inferred[f]
	Total	**11,191**			

a *Davis Tube Recovery (DTR)*
b *Havilah Resources Limited (2020) Annual Report for the Financial Year Ended 31 July 2020*
c *Magnetite Mines (2022) ASX Announcement 2022*
d *Lodestone Mines (2022) Olary Flats Iron Ore Project - Mineral Resource Estimates, 31 October 2022*
e *Davies and Twining (2018)*
f *Hawsons Iron Limited (2022) ASX Release - Mineral Resource Upgrade, 26 July 2022*

Table 2 *Developing mining projects in the study area.*

Project	Commodities	Owner	Development Status
Maldorky	Fe_3O_4	Havilah Resources	Mining Lease Proposal
Grants	Fe_3O_4	Havilah Resources	Feasibility studies
Razorback	Fe_3O_4	Magnetite Mines	Advanced feasibility studies
Muster Dam	Fe_3O_4	Magnetite Mines	Scoping
Olary Flats	Fe_3O_4	Lodestone	Advanced feasibility studies
Hawsons (NSW)	Fe_3O_4	Hawsons	Advanced feasibility studies
Mutooroo	Cu-Co-Au	Havilah Resources	Feasibility studies

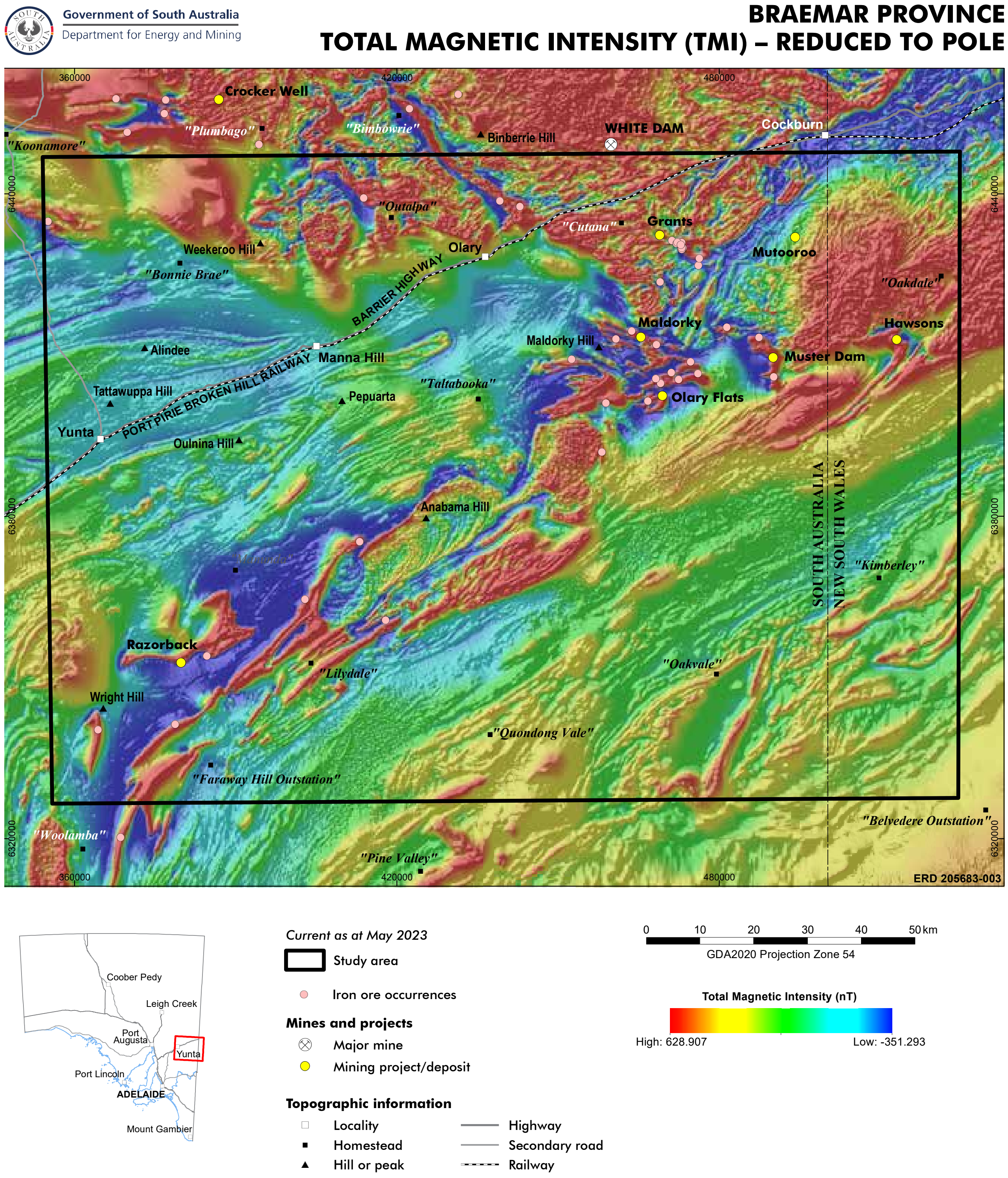

Figure 3 *Braemar iron region magnetite occurrences shown over TMI image*

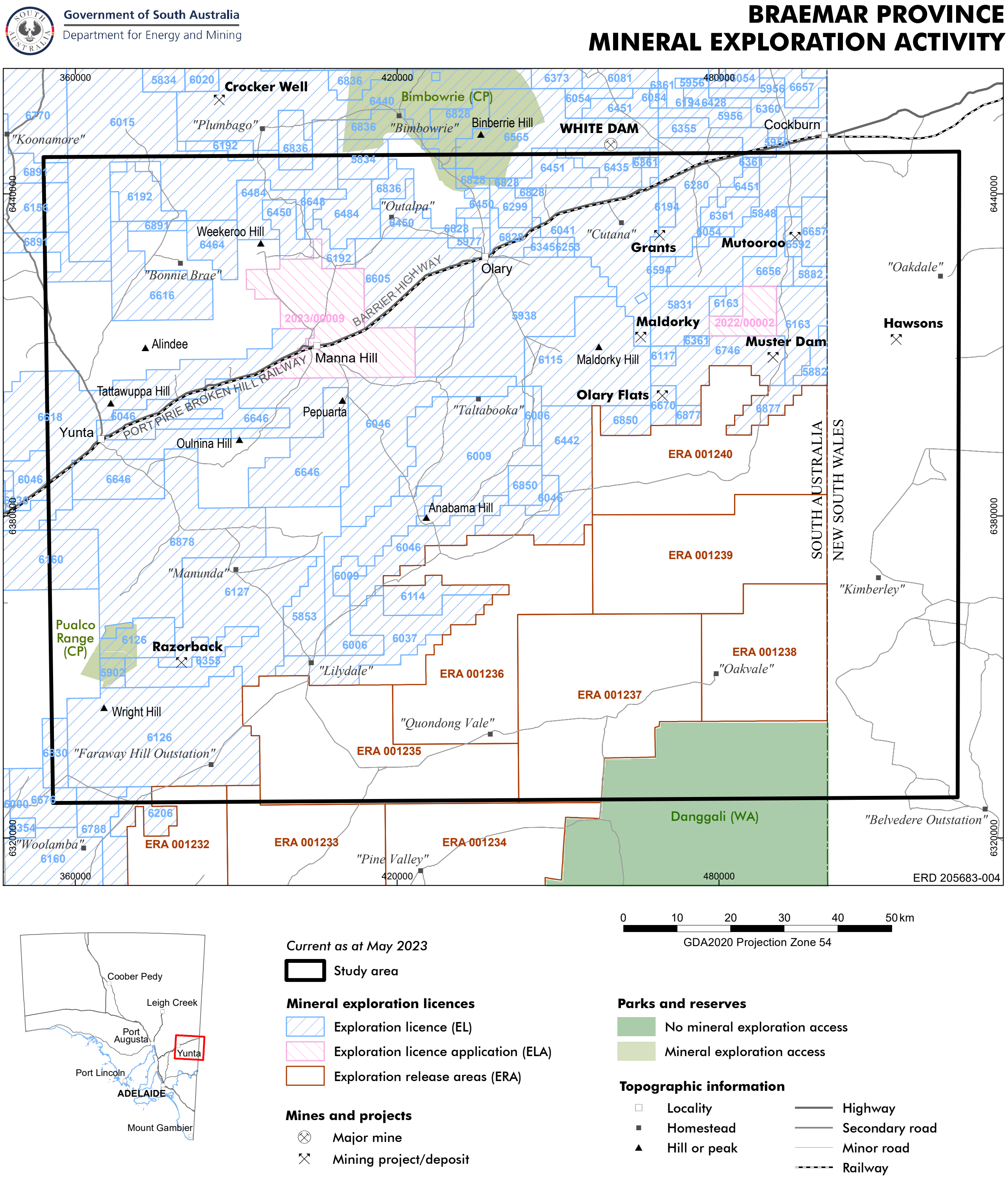

Figure 4 *Current exploration leases.*

3

Mine water demand

3.1 MINE WATER REQUIREMENTS

3.1.1 Quantity

Water is required for many aspects of a mining development which include but are not limited to:

- Construction requirements (e.g. mine plant, mine camp, haul roads, infrastructure)
- Dust suppression (in-pit and ex-pit)
- Potable water for workforce, mine camp and workshops
- Mineral processing and tailings
- Product export
- Exploration drilling

Of these requirements, mineral processing and tailings are typically the most substantial component of the mine water balance and this is particularly true for magnetite projects where beneficiation of the ore is required to increase the iron content and produce magnetite concentrate (the final product which is transported to market).

Two examples of water circuits for magnetite projects are provided in Figure 5 (for the Maldorky project) and Figure 6 (for the Karara Project) and the corresponding site water balances are provided in Table 3 and Table 4. While these projects have quite different set ups and associated water circuits, the bulk of the water used by both projects is for mineral processing and is ultimately lost via the tailings.

For the Maldorky project (Figure 5 and Table 3), which is located in the Braemar Province, 81 % of the total water consumption is via the tailings and the proposed water supply borefield has been scaled to meet this demand.

For the Karara project which is an operational magnetite mine in Western Australia (Figure 6 and Table 4), a dry stack tailings method has been implemented which dewaters the tails before deposition. This processing method lowers the proportion of water consumed by tailings deposition (48 % at Karara c.f. 81 % at Maldorky) but is a more complex and intensive processing option which may not be feasible for all projects.

Due to the water consumption by mineral processing, there is a direct relationship between the production rate (which controls water losses to tailings and via concentrate export) and the total water demand. This data has been collected across several projects using publicly available information, noting that the listed production rates may not necessarily be representative of the latest mine plans (Table 5). Based on this data, the water demand for magnetite projects could be reasonably expected to occur within the range of 0.6 to 2.0 GL for every Mt of concentrate produced.

Table 3 *Operational site water balance for the Maldorky project (Maldorky Iron 2014)*

Water input	GL/y	%	Water output	GL/y	%
Dewatering + water supply	2.3	81%	Tailings - all losses	2.2	81%
Pit inflows (sump pumping)	0.1	4%	Mine & construction	0.3	9%
Rainfall	0.2	9%	Other evaporation losses	0.2	7%
Ore Moisture	0.2	6%	Concentrate	0.1	4%
			Potable use	0.0	0%
Total IN	**2.8**	**100%**	**Total OUT**	**2.8**	**100%**

Table 4 *Operational site water balance for the Karara project, WA (Karara Mining Limited 2008)*

Water input	GL/y	%	Water output	GL/y	%
Dewatering + water supply	7.2	70%	Tailings - all losses	4.9	48%
Pit inflows (sump pumping)	0.5	5%	Other evaporation losses	2.4	23%
Rainfall	2	19%	Concentrate	1.2	12%
Ore moisture	0.6	6%	Dust suppression	1.0	10%
			Infiltration	0.6	6%
			Potable use	0.2	2%
Total IN	**10.3**	**100%**	**Total IN**	**10.3**	**100%**

Table 5 *Published estimates of production rate and water demand for various magnetite projects, noting that these production rates may not be representative of the latest mine plans*

Project	Production rate (Mt concentrate per annum)	Water Demand (GL per annum)	GL water per Mt concentrate	Source
Maldorky	2	3.7	1.9	Maldorky Iron (2014)
Razorback	2.7*	5	1.9	Magnetite Mines (2021)
Sino Iron	27.6	44	1.6	Strategen (2017)
Central Eyre Iron Project	21.5	15.6	0.7	Iron Road (2015)
Karara	12	6.6	0.6	Karara Mining Limited (2008)
Iron Bridge Magnetite Project	25	24.5	1.0	DER (2020)

*In September 2022, Magnetite Mines announced a project reconfiguration that would see a minimum production rate of 5 mtpa. This would nominally reflect in a water demand of ~10GL/year, and a 2.0GL water/1mtpa rate.

OPERATIONAL SITE WATER BALANCE FOR A MAGNETITE PROJECT

USING A STANDARD TAILINGS METHOD

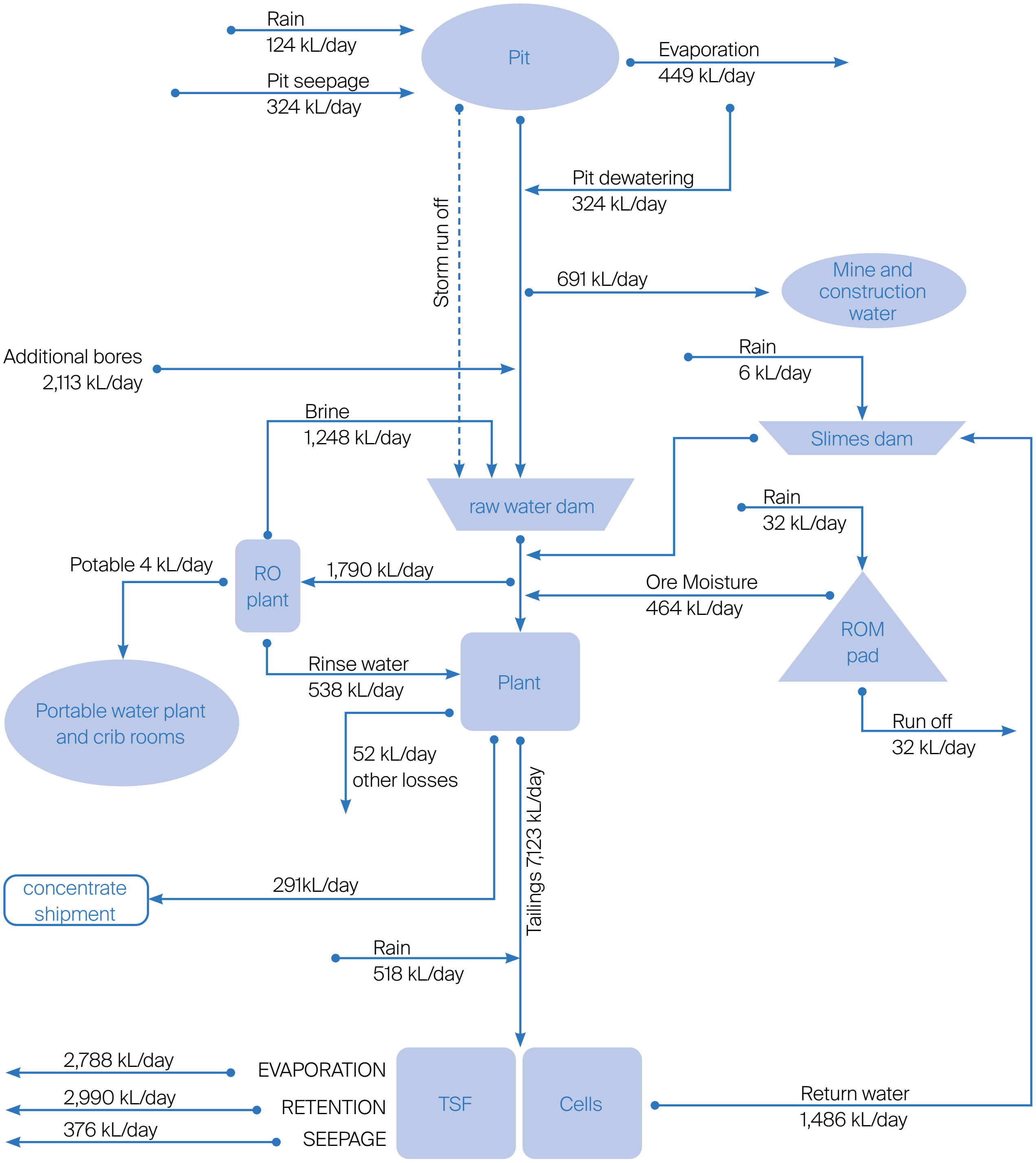

Figure 5 *Example of an operational site water balance for a magnetite project using a standard tailings method (Maldorky Iron 2014)*

OPERATIONAL SITE WATER BALANCE FOR A MAGNETITE PROJECT

USING A DRY STACKED TAILINGS METHOD

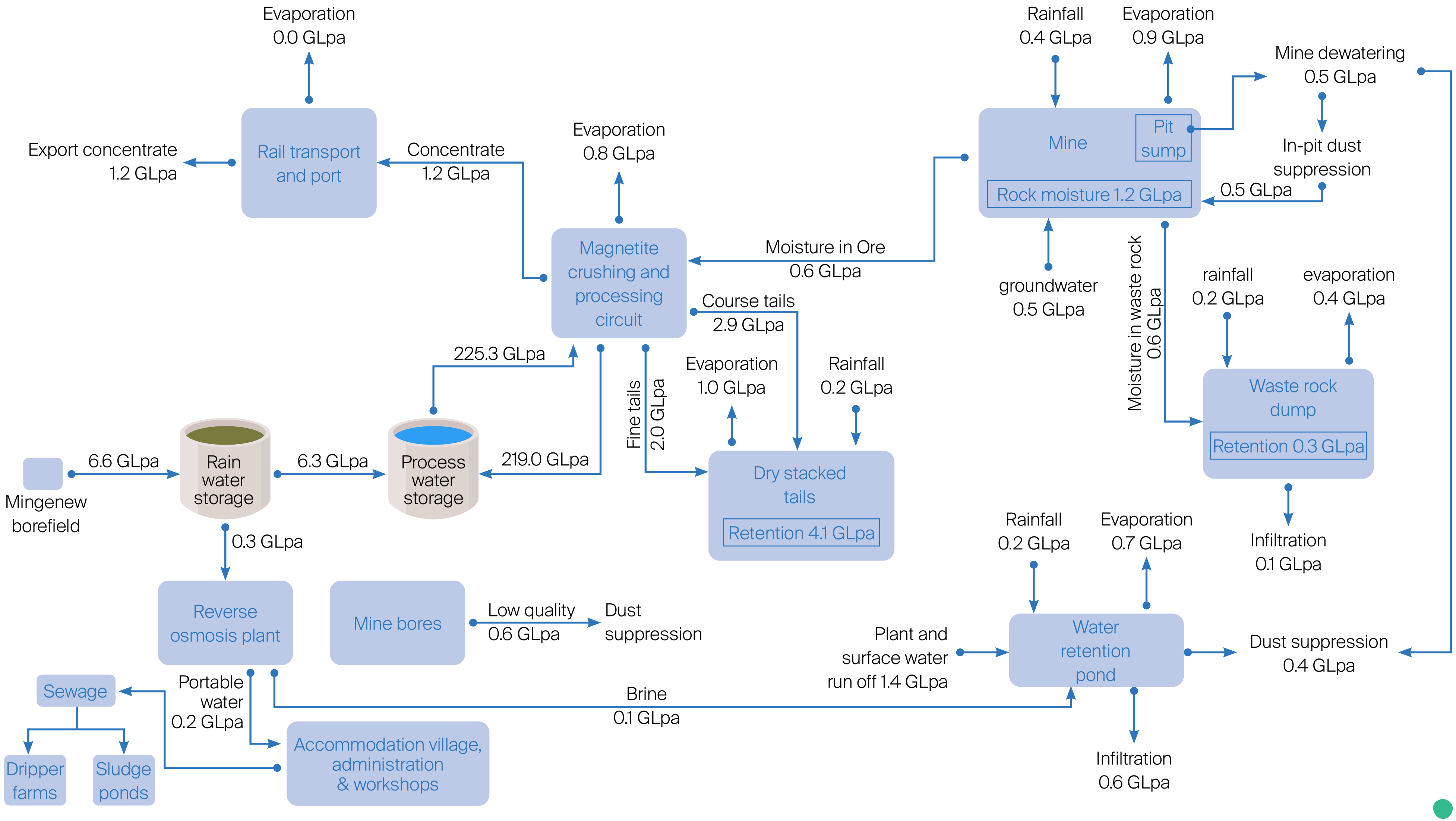

Figure 6 *Example of an operational water balance for a magnetite project using a dry stacked tailings method (Karara Mining Limited 2008)*

3.1.2 Quality

Processing water quality requirements vary from site to site based on the characteristics of the ore and the proposed metallurgical processes used to produce magnetite concentrate. While low salinity water is preferable, most projects can tolerate the use of highly saline water for the majority of processing requirements with a small quantity of fresh water used to wash the final product and remove impurities (e.g. sulfur, which is deleterious for steel production). Highly saline water is also corrosive. Water supply salinity limits are hard to define given the variables involved. However, to help frame the regional water requirements for developing magnetite deposits for the purposes of this study, it is reasonable to assume that raw water salinities are ideally less than 14,000 mg/L and no more than 35,000 mg/L (equivalent to seawater), noting that individual projects may be able to accommodate higher salinities. It is also assumed that each project would implement some level of desalination capacity (reverse osmosis (RO) treatment) to cover concentrate washing and potable needs.

3.2 Projected regional water demand

The estimated water demand is not provided for all the developing projects in the study area, mine plans are subject to change, and there is uncertainty as to the timing of development – noting that firm plans for water supply development would need to be in place over the next 12 months if mining is 5 years away (Magnetite Mines, pers. comm 2022). Nevertheless, the cumulative regional water demand for mining can be approximated by using proposed production rates (where stated), the total mineral resource inventory, the typical water requirements for magnetite mining and processing (Table 5), and by applying some assumptions on the scale and timing of mining development. Based on these considerations, the following water demand scenarios are presented for the purposes of this study:

Low demand scenario: 10 GL/y

(Initial development occurring in the short term, < 5 years from now)

Under this scenario, 1–2 magnetite mines are developed, and mining and production occurs at a scale consistent with initial development proposals resulting in a cumulative production rate of 5 Mt/y. The cumulative regional water demand would be in the order of 10 GL/y, assuming a water demand of ~2 GL/Mt based on the data presented in Table 5. This is the most likely scenario in the short-term.

Moderate demand scenario: 20 GL/y

(Intermediate development in the short-to-medium term, 5–10 years from now)

Under this scenario, 3–4 magnetite mines are developed, and mining and production occurs at a scale consistent with the initial development proposals, or 1–2 magnetite mines are developed at higher rates of production, resulting in a cumulative production rate of 10 Mt/y and a regional water demand of 20 GL/y (assuming a water demand of 2 GL/Mt). This scenario would most likely eventuate in the short-to-intermediate term after an initial period of lower production rates.

High demand scenario: 60 GL/y

(Advanced development in the long term, >10 years)

Under this scenario, >3 magnetite mines are developed at high rates of production, resulting in a cumulative production rate of 30 Mt/y and a regional water demand of 60 GL/y (assuming a water demand of 2 GL/Mt). This scenario would likely require a period of initial development at lower production rates before these higher rates of production are achieved, reducing the likelihood of this scenario eventuating in the short-term.

4 Hydrogeology and groundwater resources

4.1 REGULATORY CONTEXT

State legislation for land and water management is provided by the *Landscape South Australia Act 2019.* The study area occurs within two Landscape Regions administered under this legislation. The Olary Ranges fall within the South Australia Arid Lands Region. The plains of the Murray Basin fall within the Murraylands and Riverland Region. Mining operations in South Australia are regulated and controlled by the SA *Mining Act 1971.*

Both surface water and groundwater in the study area are non-prescribed water resources meaning they are not allocated nor managed in accordance with a Water Allocation Plan (WAP). They are, however, subject to several general protections provided by the *Landscape South Australia Act 2019*, Regional Landscape Plans (SA Arid Lands Landscape Board 2021; Murraylands and Riverland Landscape Board 2021), and Long-Term Environmental Watering plans (DEW 2020).

Most of the study area (i.e. south of the drainage divide) occurs within the Murray-Darling Basin catchment and both surface water and groundwater resources are managed in accordance with Commonwealth legislation provided by the *Water Act 2007* and the Basin Plan. The study area falls within the SA Murray Region Water Resource Plan (WRP) area for which a WRP has been prepared (DEW 2018). The WRP is a planning instrument that links Commonwealth and State legislation and documents how the State complies with the Basin Plan. The WRP area contains several surface water and groundwater resources which are split into separate management units for which a Sustainable Diversion Limit (SDL) is set (SDLs define how much water, on average, can be taken annually for consumptive use). Surface water in the study area is part of the SA Non-Prescribed Area (SS10) SDL Resource Unit which has an SDL of 55.2 GL. Groundwater is part of the SA Murray (GS6) SDL Resource Unit in the study area and has an SDL of 64.8 GL.

The SA Murray (GS6) SDL resource unit includes the area of the SA portion of the Murray-Darling Basin that is not covered by prescription or a water allocation plan. It extends from the Olary Ranges in the north to the Coorong and Lower Lakes in the south. It incorporates a range of fractured rock and sedimentary aquifers.

Current extraction in the SA Murray SDL resource unit is relatively small (1.8 GL/y) (DEW 2018) due to the high salinity of the groundwater in the region. The SDL has been estimated (CSIRO and SKM, 2010) as 64.8 GL/y using a method based on recharge rates, groundwater salinity and risk ranking of extraction to the resource.

The SA Murray SDL resource unit is ranked:

- low risk for key environmental assets;
- low risk for key environmental function;
- low risk for the productive base;
- as having no risk to the key environmental outcomes; and
- as having a high level of uncertainty in relation to knowledge of risks.

The SDL for the SA Murray indicates availability of a large (saline) water resource where groundwater extraction poses low risk to the environment and productive base of the aquifer.

There are not expected to be regulatory impediments to the development of groundwater resources in the study area (under State or Commonwealth legislation). However, there will need to be a clear picture of possible impacts and risk mitigation prior to development of the resource.

The conditions of use of groundwater for mining could be managed as a Program for Environment Protection and Rehabilitation, PEPR (under Part 10A, ***Mining Act 1971***), which requires proponents to manage the environmental impacts associated with mining operations. The PEPR would require that a proponent associated with exploration or mineral lease development outlines an understanding of the groundwater resource, likely impacts, monitoring approach and strategies for mitigation of risks.

In this case the Minister could request a PEPR for development of a groundwater resource with an emphasis on:

- benchmarking the understanding of the groundwater resource (e.g. recharge mechanisms);
- describing a conceptual design for a wellfield with estimated extraction rates during the life-of-mine;
- quantifying the cumulative impact of extraction on the resource and other users (consumptive and environmental) assuming multiple operators;
- approach to monitoring and reporting of wellfield cumulative impacts; and
- approach to mitigation of risks

4.2 CLIMATE AND HYDROLOGY

The study area is arid with potential evaporation (~2,000 mm/y) exceeding rainfall (~200 mm/y) by a factor of 10. The rainfall is very irregular and sporadic. In the rare events that it does rain, it can be localised and very heavy.

Surface water is highly ephemeral. Watercourses drain the Olary Ranges, yet only flow ephemerally and terminate as they fan out across the plains. The main watercourses (Olary Creek, Wiawera Creek, Yunta Creek and Manunda Creek) are shown in Figure 2.

Olary Creek and Wiawera Creek are ephemeral creeks that provide water to wetlands and River Red Gums (South Australian Arid Lands Natural Resources Management Board, 2014) during flow events. Flows in Yunta Creek are irregular and water is diverted for Yunta township.

Manunda Creek provides water to a drainage line that supports River Red Gums (South Australian Arid Lands Natural Resources Management Board, 2014).

A series of small, farm dams have been constructed throughout the region to capture a portion of surface runoff for stock and domestic use.

Plant communities along watercourses reliant on surface flows are Coolabah (*Eucalyptus coolabah*), River Red Gum (*Eucalyptus camaldulensis*), Elegant Wattle (*Acacia victoriae*) and *Acacia salicina* woodlands. The presence of River Red Gum also indicates that shallow groundwater persists.

4.3 GEOLOGY

The study area corresponds roughly to the Olary 1:250,000 geology map sheet (Figure 7), which is described by Forbes (1991). The surface geology is shown in Figure 8. The major stratigraphic groupings are as follows:

- The oldest rocks are Early Proterozoic metamorphics and amphibolite of the Willyama Supergroup and Middle Proterozoic granitoid, which outcrop to the north and northeast as part of the Curnamona Province. These form a series of inliers, referred to collectively as Willyama Inliers, and are generally surrounded by the younger Proterozoic sediments of the Adelaide Geosyncline.
- Neoproterozoic sedimentary rocks of the Adelaide Geosyncline (termed Adelaidean rocks) are widely exposed along the Olary Ranges. These were formed in a fault-controlled basin during prolonged periods of continental to marine deposition interspersed with periods of glaciation.
- The Ordovician Anabama Granite which outcrops intermittently through the centre of the study area at Anabama Hill and surrounds. It intrudes and is flanked by units of the Adelaide Geosyncline.
- The thickest sequence of younger material is the Tertiary sediments of the Murray Basin in the southeast. Quaternary sediments are present in low-lying areas as Holocene alluvium along modern watercourses and as broader Pleistocene floodplain deposits (Pooraka Formation), which occur extensively in areas of low relief.

The three main tectonic zones (as shown in Figure 7) are the Willyama Inliers, the Adelaide Geosyncline and Murray Basin, which correspond to three major structural and metamorphic events as follows:

- The Olarian Orogeny occurred during the Early to Middle Proterozoic, so only affects the rocks of the Willyama Supergroup. The event caused deformation and metamorphism of the basal sediments and volcaniclastic rocks to amphibolite grade and was accompanied by local melting and by intrusion of felsic granitoid.
- The Delamarian Orogeny occurred from the late Cambrian to the Ordovician and affected both the Willyama Supergroup and the Adelaidean rocks. Rocks were folded, metamorphosed and intruded by the Anabama Granite and associated dykes. Deformation gave rise to north-south orientated folds and a second main phase produced major northeast-southwest folds. The Adelaidean rocks were affected by broad, steeply dipping folds striking east-northeast, and northwesterly directed faults.
- In the Tertiary, downwarping and downfaulting occurred in the Murray Basin, allowing for the deposition of continental sand and shallow marine to estuarine clay and limestone. This is evident along the Anabama fault (see Figure 8 and Figure 9), a northeast to southwest striking fault along the edge of the Murray Basin with an offset of up to 70 m (deeper on the basin side).

Throughout much of the early to middle Cenozoic, a network of extensive rivers drained the continent in a much wetter period. These rivers formed large paleovalleys in which fluviatile sediment was subsequently deposited. While such paleovalleys occur in the study area and were recently mapped using geophysical techniques (Mulè et al. 2022), the location of the study area being at the top of a drainage divide limits the presence of deep, highly incised and infilled paleovalley systems. Deeper paleovalleys occur further to the north in the Curnamona Province, where they are linked to Uranium deposits, and further to the south within the Murray Basin, where they comprise ancestral tributaries and channels of the Murray-Darling catchment. The paleovalleys that do occur in the study area are shown in Figure 9 where they are plotted over a regolith thickness that has been derived from inverted Airborne Electromagnetic (AEM) data. Substantially thicker sedimentary packages are not evident along these paleovalleys, with the thicker areas of sediments being more apparent to the south of the Anabama fault.

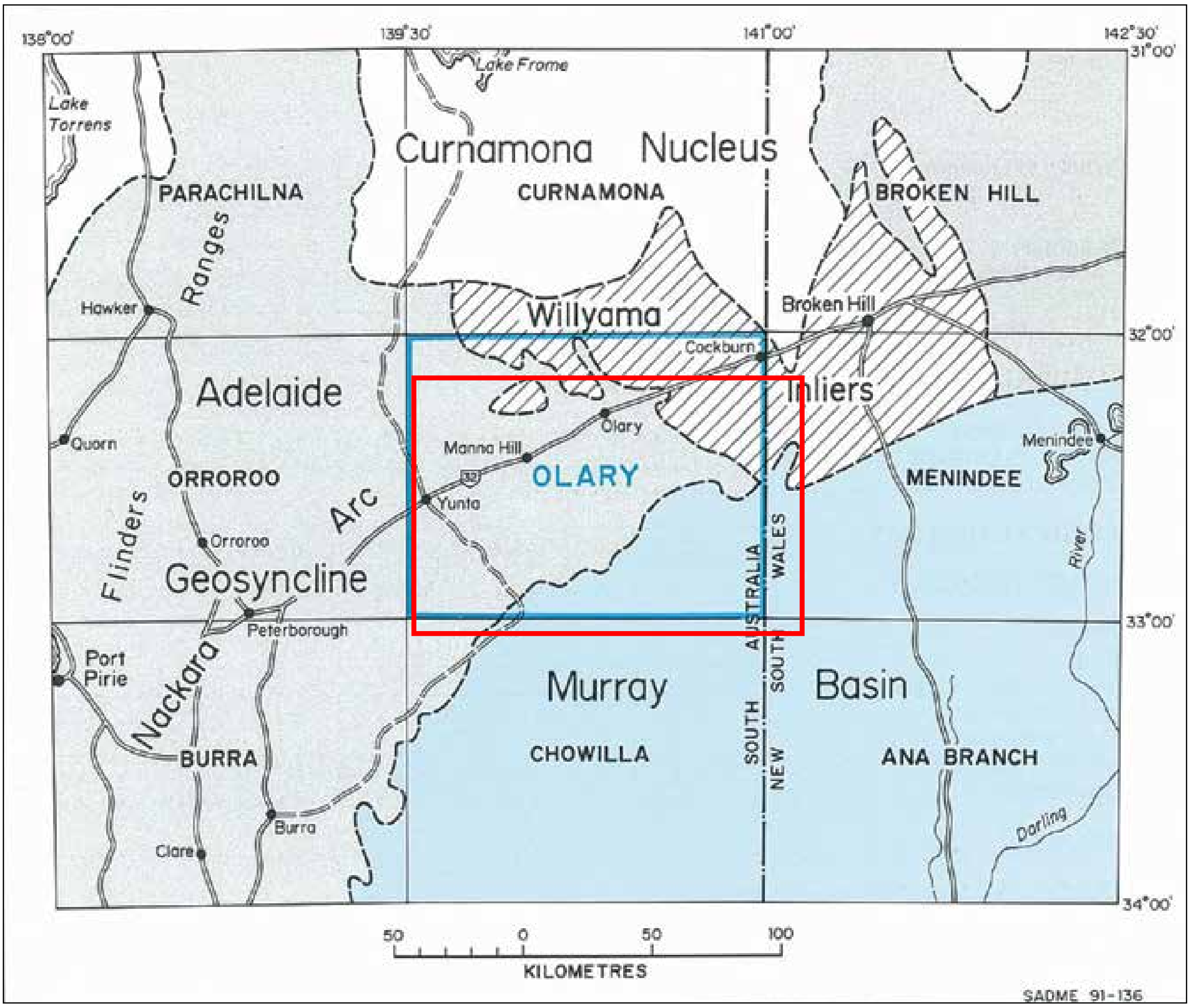

Figure 7 *Location map of Olary 1:250,000 map sheet (blue) showing the main tectonic groupings of the study area: Willyama Inliers, Adelaide Geosyncline and Murray Basin. The study area boundary is shown in red. (After Forbes 1991).*

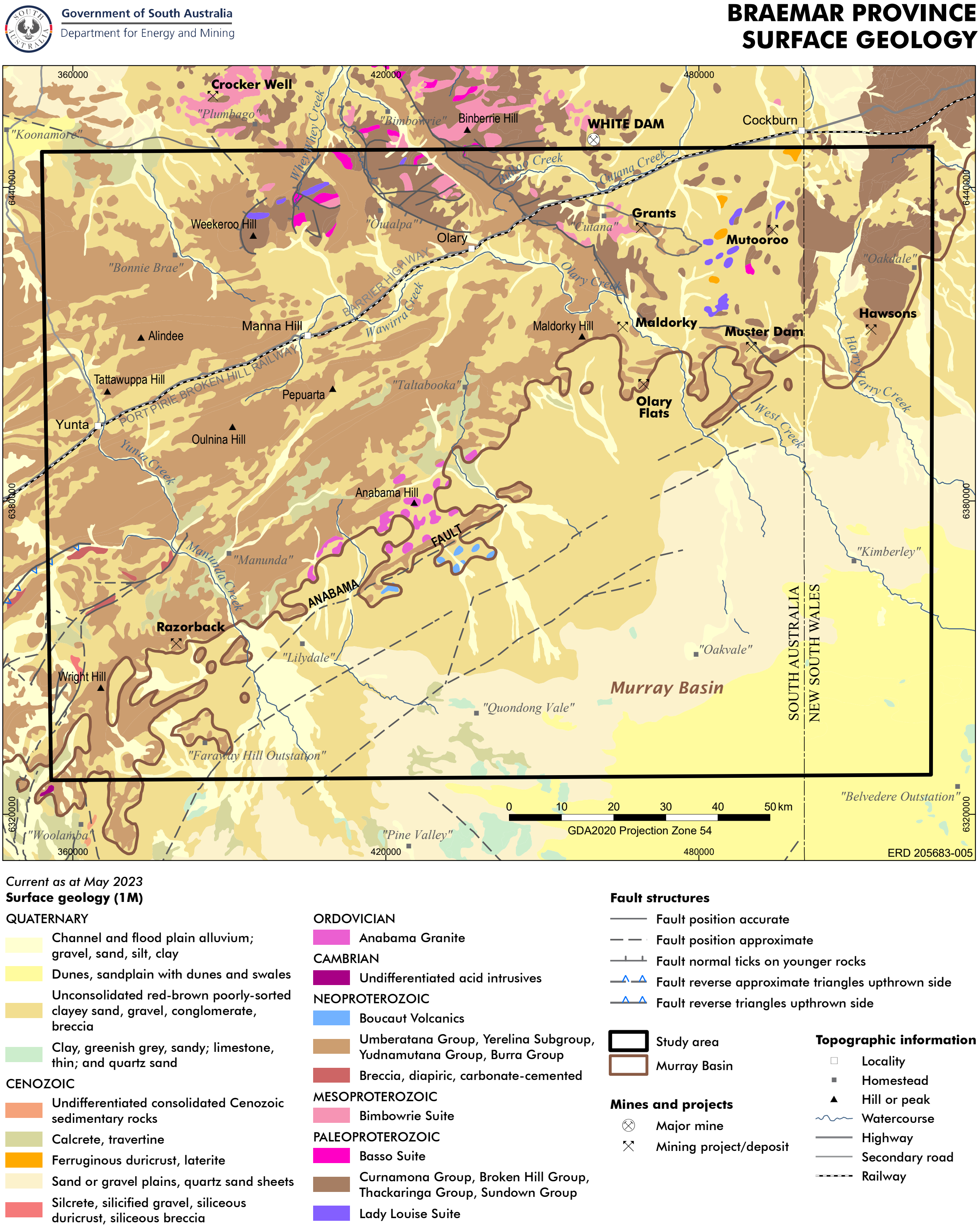

Figure 8 *Surface geology*

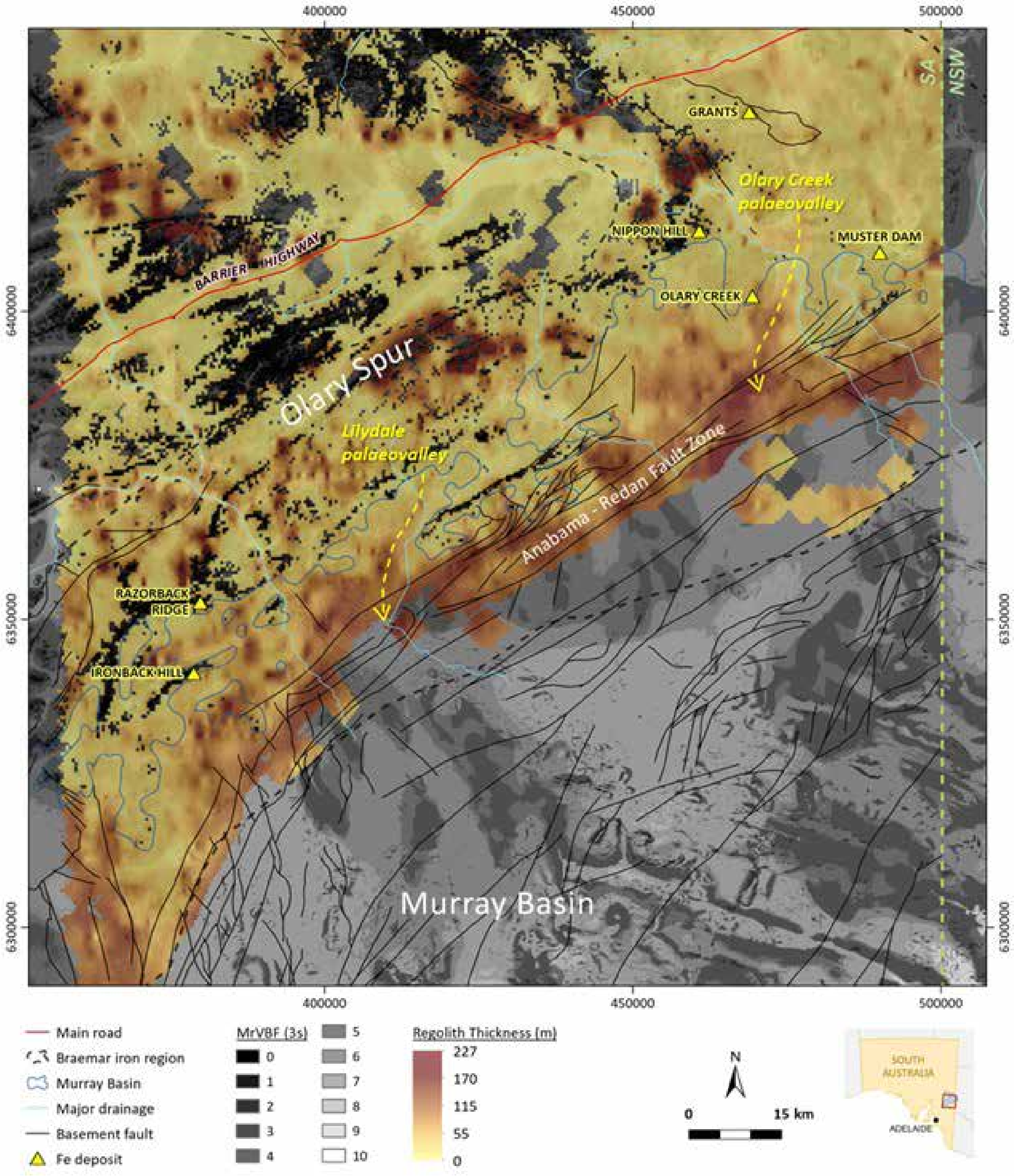

Figure 9 *Derived map of "regolith thickness" (can also be interpreted as sediment thickness) generated from the inverted AEM data. Areas of interpreted outcrop have been clipped in the map. The map is overlain on a MrVBF terrain index (panchromatic background image). Thicker areas of regolith are shown on the margins of the Olary Spur where the Murray Basin sediments onlap. The thalwegs of the Olary Creek and Lilydale Palaeovalleys are indicated with their indicative drainage directions shown. (Mulè et al. 2022)*

4.4 GROUNDWATER RESOURCES

4.4.1 Existing datasets and knowledge base

The latest publicly available groundwater data has been obtained from WaterConnect[4] (for SA data) and the Bureau of Meteorology[5] (for NSW data) (see Figure 12, Figure 13, Figure 14). Broadscale hydrogeological reviews have been undertaken for the non-prescribed areas of South Australian Arid Lands (Watt et al. 2012) and the South Australian Murray-Darling Basin (Barnett 2015). The study area is also covered by the Burra-Chowilla-Olary hydrogeological map 1:250,000 scale by Barnett (1994), which details the hydrostratigraphy and maps the yields and salinities of the main aquifers.

Some targeted investigations have occurred in proximity to mining projects, but much of the data (aside from well locations) and associated reporting are not available in the public domain, except for the investigations undertaken for the Maldorky Mining Lease Proposal (Maldorky Iron Pty Ltd 2014).

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[4] https://www.waterconnect.sa.gov.au/Water-Resources/Groundwater/SitePages/Home.aspx

[5] http://www.bom.gov.au/water/groundwater/explorer/map.shtml

4.4.2 Aquifer systems

Groundwater can be hosted in either the pore spaces of porous rocks or sediments (primary porosity) or in the factures of otherwise impermeable basement and metasedimentary rocks (secondary porosity). The geology of study area has given rise to several aquifer systems, which are split into the two main physiographic zones, as follows:

- In the Olary Ranges, fractured rock aquifers are hosted in the fracture networks of pre-Cenozoic rocks (Adelaide Geosyncline or Willyama Inliers).
- In the Murray Basin, sedimentary aquifers occur which include,
  - Pliocene sands aquifer: an unconfined aquifer hosted in the Loxton-Parilla Sand featuring unconsolidated- to weakly-cemented fine to coarse sand.
  - Murray Group Limestone Aquifer: a mostly unconfined aquifer hosted in consolidated, fine to coarse limestone.
  - Renmark Group Aquifer: a confined aquifer hosted in unconsolidated carbonaceous sands, silt and clay.

These aquifer systems (shown in Figure 11 and Figure 11) are potential groundwater resources to support mining development and are described in the following sections.

4.4.3 Existing wells

Figure 12 shows the distribution of groundwater wells in the study area, classified by purpose. Most wells have been drilled for stock and domestic purposes with a greater concentration occurring in the ranges, and most installed along drainage lines where they likely intersect shallow alluvium and underlying fractured rock aquifers to obtain stock and domestic supplies.

Figure 13 shows the distribution of well yields. The data has some uncertainty attached to it. No yield data was available for NSW. Many of the wells in the SA database do not have yields recorded and the intersecting aquifer is mostly not listed. And yields are not always directly comparable given variability in borehole diameters and depths. Nevertheless, it is apparent that yields of less than 5 L/s are common throughout the study area, with higher yields occurring sporadically throughout the Olary Ranges and presumably associated with more highly fractured zones. There are only a few wells in the Murray Basin where yield data is available.

Figure 14 shows the distribution of groundwater salinity measured in wells. Groundwater salinity is generally high throughout the study area. It is highly variable in the Olary Ranges, ranging from <1,000 to >35,000 mg/L over relatively short distances. In the Murray Basin it is generally in the range of 7,000–14,000 mg/L.

4.4.4 Groundwater resources in the Olary Ranges

Potential groundwater resources in the Olary Ranges are contained in fractured rock aquifers within the pre-Cenozoic basement rocks.

These aquifer systems are spatially constrained. The fracture networks which host groundwater may only be interconnected over short distances, perhaps several kilometres at most, and may only occur at certain depths and orientations. As such, the available groundwater storage is low and sustained pumping at high rates may deplete this storage quite rapidly.

As evident in Figure 13, yields are variable and will depend heavily on whether fractures are intersected during drilling, which is not guaranteed and results in low success rates for groundwater exploration drilling. Low yields (<2 L/s) are common, but some higher yields may be found in more heavily fractured zones, most probably linked to areas of major faulting.

Salinities are variable (Figure 14) and likely depend on whether the wells intersect low salinity zones associated with surface drainage, but most commonly in the range of 3,000 to 14,000 mg/L.

Water table depths depend heavily on the topography, but with most wells being installed at low points in the landscape the depth to water is commonly within 10 m of the land surface (Maldorky 2014).

Groundwater recharge is likely to be very low regionally (<1 mm/y) based on the low rainfall and generally high salinity of the groundwater. However, zones of enhanced recharge are likely to occur along drainage lines. Such recharge would be episodic in response to infrequent large rainfall events and periods of surface runoff and constrained to drainage lines.

These groundwater resources support stock and domestic use. Potential groundwater dependent ecosystems (GDEs) are indicated along drainage lines (GDE Atlas; BOM 2022) where deep-rooted vegetation (e.g. River Red Gums) may access shallow groundwater to support transpiration requirements.

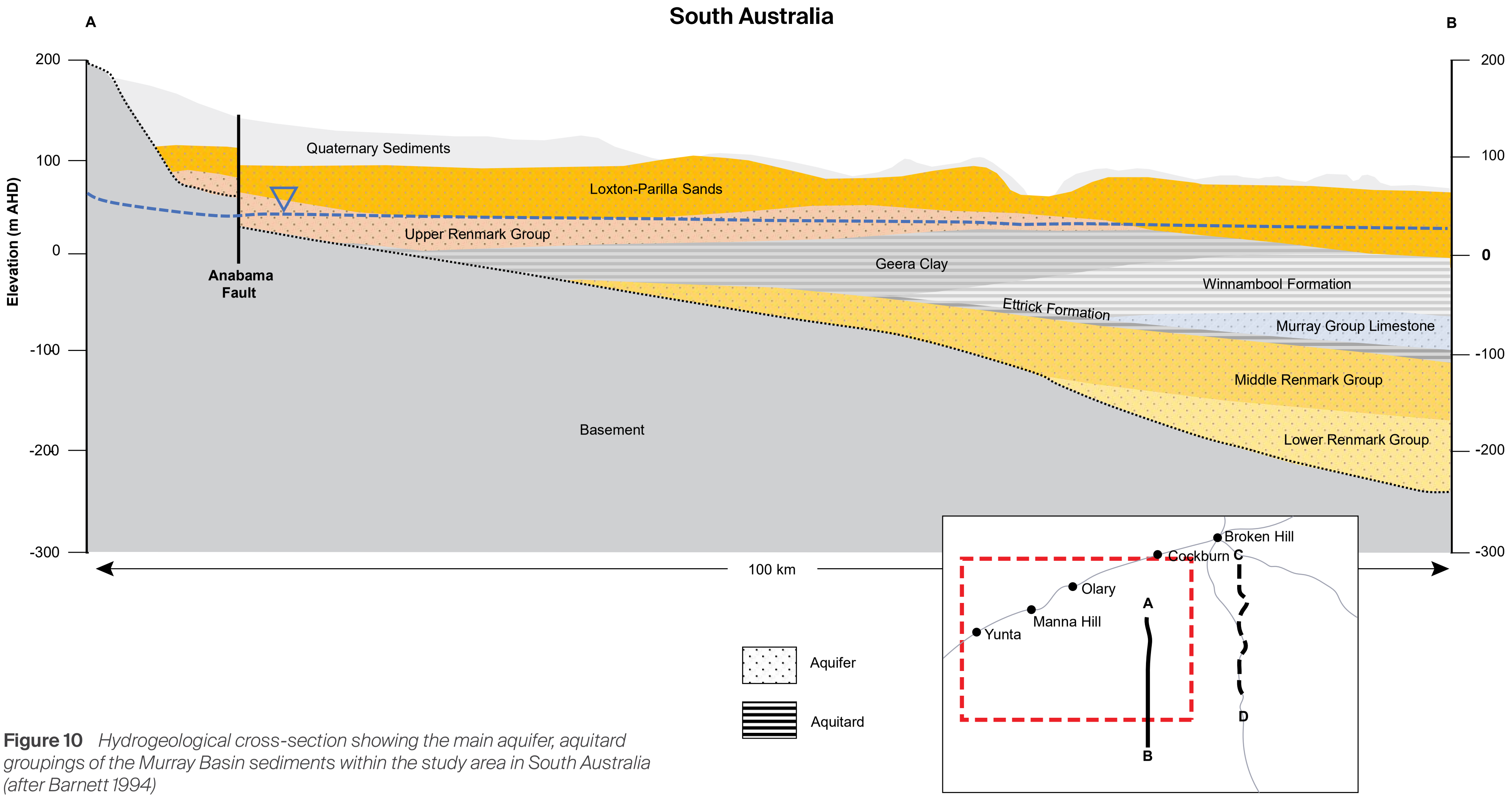


Figure 10 *Hydrogeological cross-section showing the main aquifer, aquitard groupings of the Murray Basin sediments within the study area in South Australia (after Barnett 1994)*

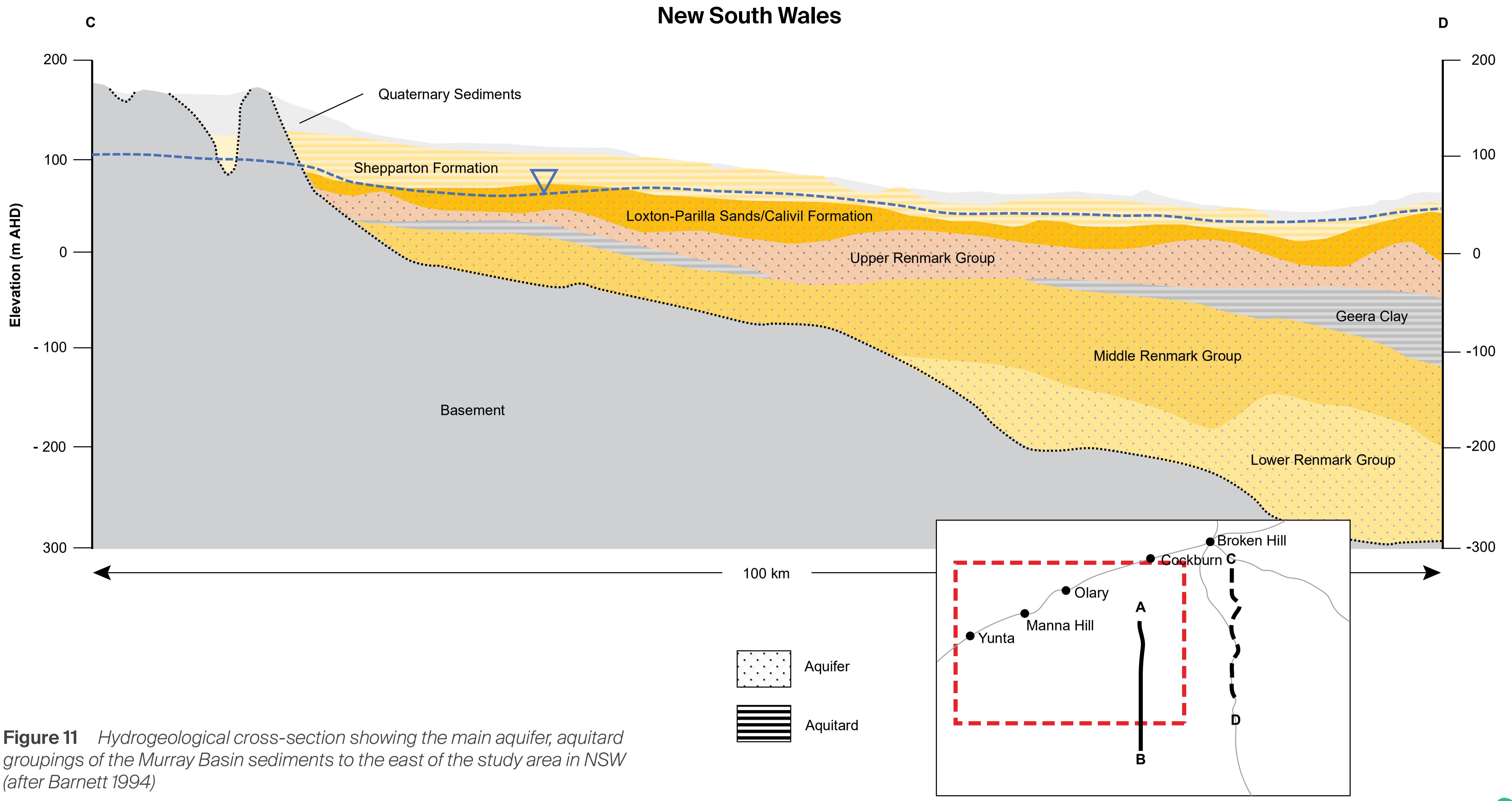


Figure 11 *Hydrogeological cross-section showing the main aquifer, aquitard groupings of the Murray Basin sediments to the east of the study area in NSW (after Barnett 1994)*

Government of South Australia
Department for Energy and Mining

BRAEMAR PROVINCE WELL NETWORK

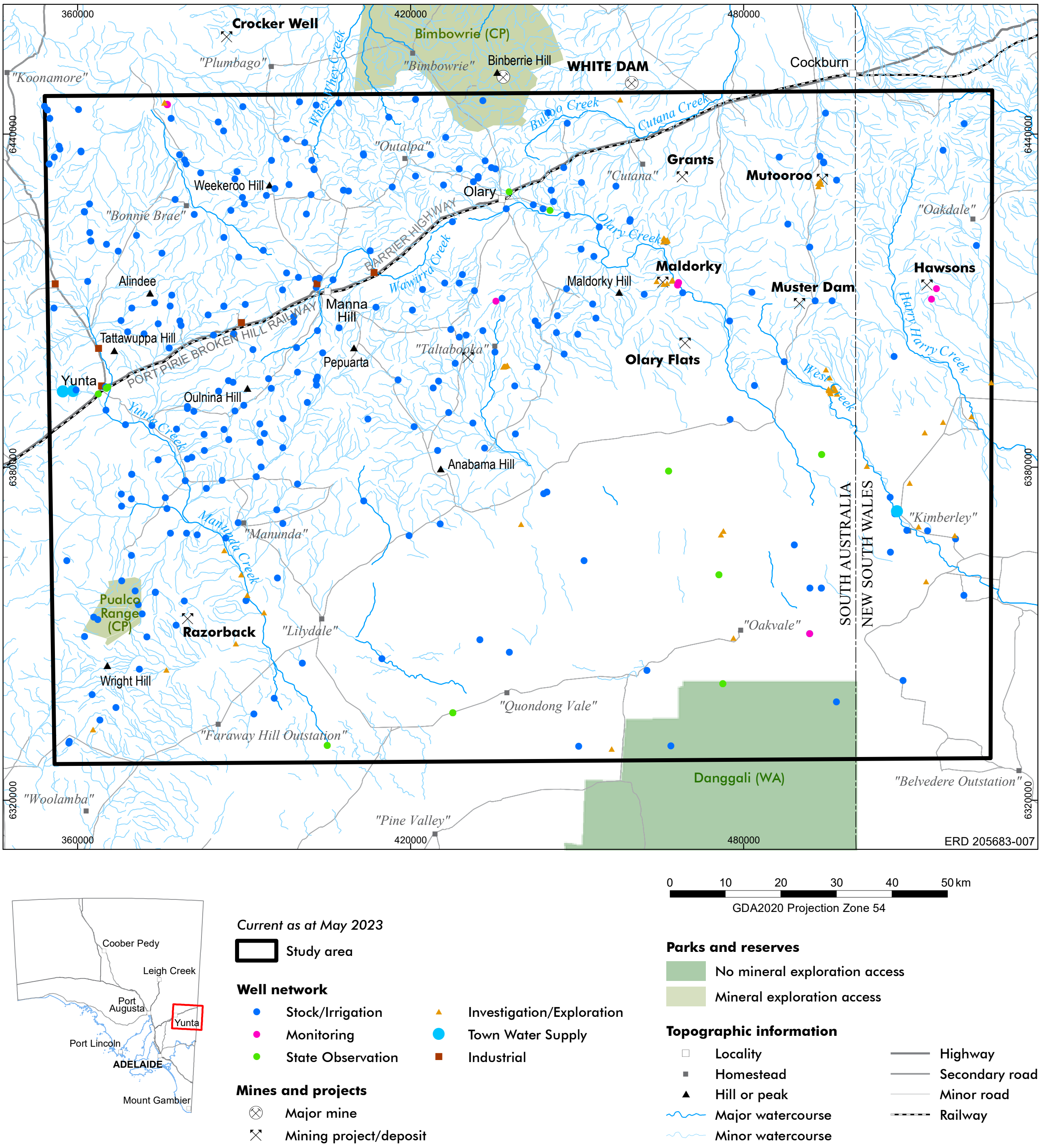


Figure 12 Existing wells in study area.

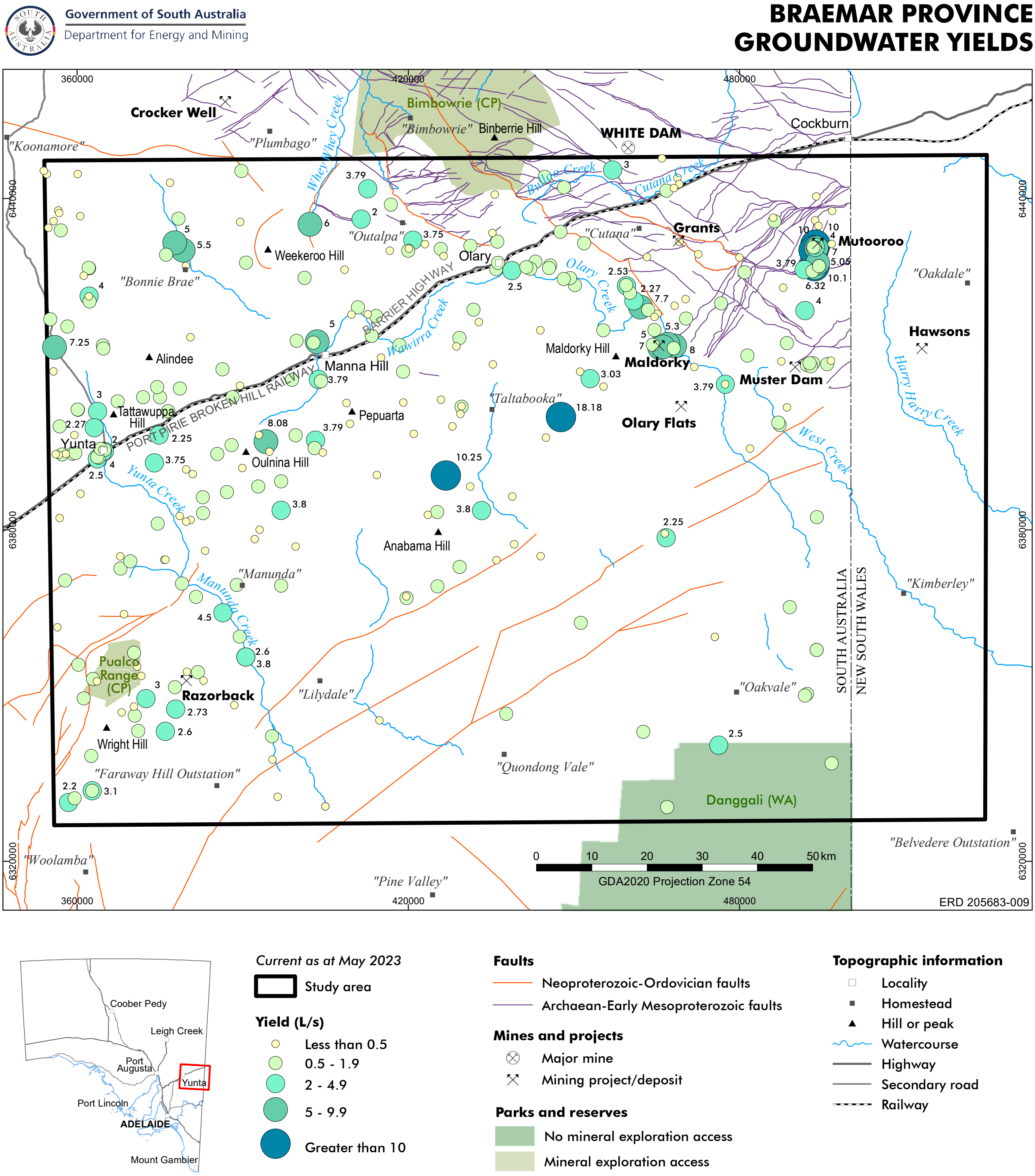


Figure 13 *Well yields in study area.*

Government of South Australia
Department for Energy and Mining

BRAEMAR PROVINCE
SALINITY (ELECTRICAL CONDUCTIVITY)

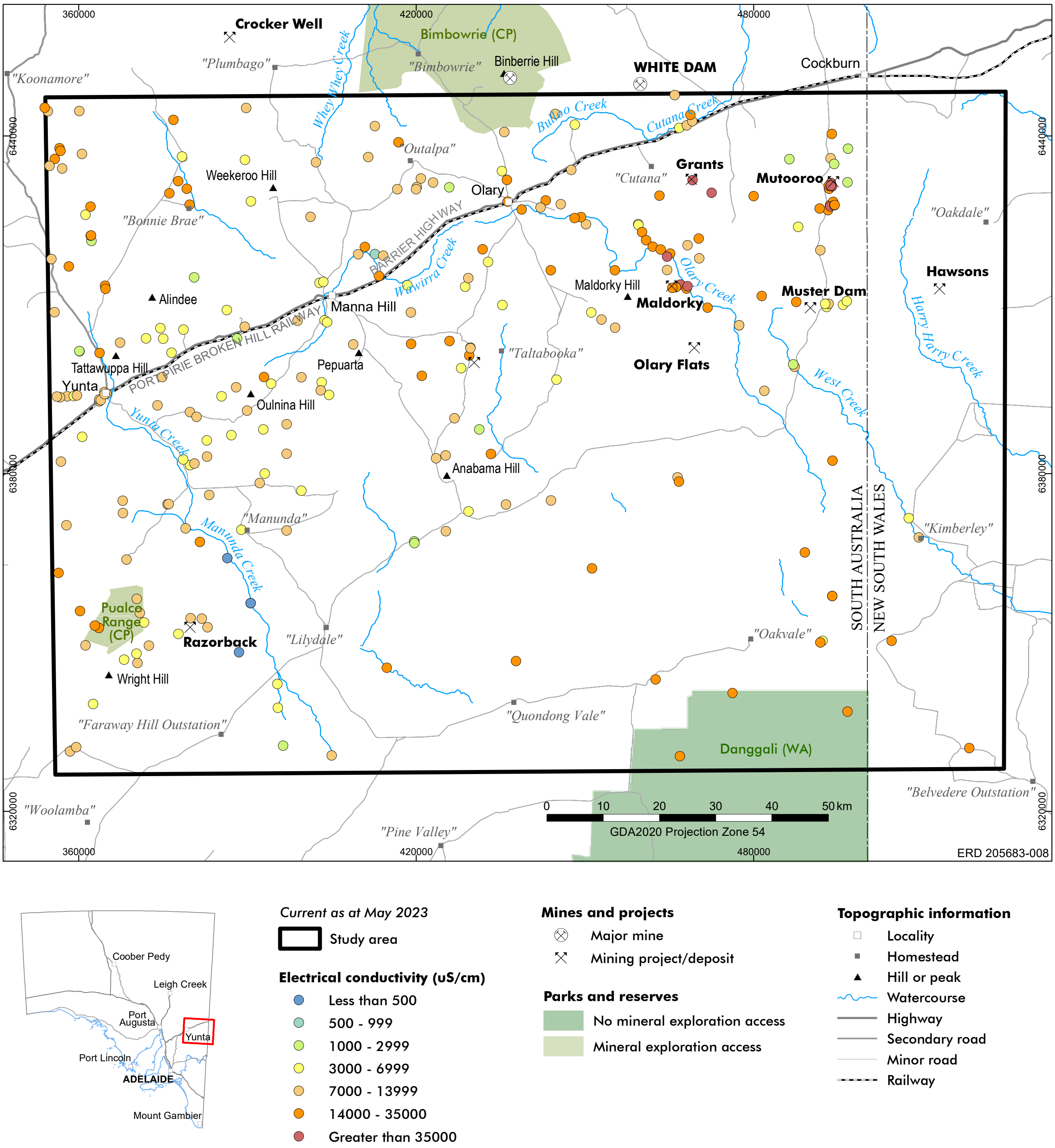


Figure 14 *Groundwater salinity.*

The potential for fractured rock aquifers to support mining development is limited. Several limiting factors are apparent:

- Generally low yields with low success rates for groundwater exploration drilling.
- Available groundwater storage being constrained by local fracture networks.
- Low recharge rates indicate that the rate of groundwater pumping would likely exceed recharge and the water would be drawn predominately from storage (i.e. groundwater levels would decline in response to pumping).
- Development of the groundwater resources would have to address any potential impacts to third party users (existing stock and domestic wells) and groundwater dependent ecosystems (e.g. deep-rooted vegetation along drainage lines).

Despite these limitations, mining development in the study area would likely access groundwater in the fractured rock aquifers to some extent, given the proximity to the mine sites and pit dewatering requirements. Maldorky Iron (2014) estimated pit dewatering rates of up to 4 ML/d (~1.5 GL/y or 46 L/s) for the Maldorky project. However, it is unclear if such rates could be sustained for long periods and support mine lives extending more than 5 years (this rate of pumping was only simulated for one year at Maldorky).

4.4.5 Groundwater resources in the Murray Basin

The Murray Basin is an extensive Cenozoic sedimentary basin extending from the riverine plains of NSW and Victoria to the mouth of the Murray River. A simplified representation of the regional Murray Basin hydro-stratigraphy is shown in Figure 15, with the part of the basin relevant to the study area highlighted. The depth and thickness of these units is shown in Figure 10 (within the study area) and in Figure 11 (to the east of the study area in NSW). Three main aquifer systems are of relevance: the Pliocene Sands / Loxton-Parilla Sands aquifer, the Murray Group Limestone aquifer and the Renmark Group (or Onley Formation) aquifer. These aquifers are part of a regional groundwater flow system that broadly flows from east to west. Modern-day recharge occurs largely in the higher rainfall zones to the east.

Regional hydrogeological mapping (Barnett 1994) is shown in Figure 16, 17 and 18. These yield and salinity maps are acknowledged by Barnett (1994) to have a high degree of uncertainty given the paucity of drilling and aquifer testing data over the region, but remain a valid product given there has been little additional drilling undertaken since 1994.

The Pliocene Sands are unsaturated or have minimal saturated thickness over much of the study area. At lower elevations to the southeast, the water table intersects this unit yet the aquifer system is mapped (see Figure 16) as being low yielding (<5 L/s) and therefore not being overly prospective as a groundwater resource.

The Murray Group Limestone (Figure 17) is absent from the study area, occurring at some distance to the south.

The Lower Renmark Aquifer (Figure 18) is mapped over the southern portion of the study area, with reasonably high yields indicated (>5 L/s) in SA and even higher yields indicated (>50 L/s) to the east of the study area within NSW, linked to the Menindee and Tarrara troughs (Brodie 1994). Indicative salinities for the Lower Renmark are 7,000–14,000 mg/L in SA and 3,000–7,000 mg/L in NSW. The aquifer is comparatively thicker in NSW (compare Figure 10 and Figure 11) giving rise to a resource with high yields and storage.

Based on this information, the Lower Renmark Aquifer offers the most prospective groundwater resource in the Murray Basin, being closer than the alternative aquifer systems and as high or higher yielding. It is an extensive aquifer of considerable thickness (up to 140 m in the Menindee-Tarrara trough area of NSW) yet would be thinner towards its outer extent (i.e. towards the Olary Ranges) where the basal sediments which make up the Lower Renmark Group are constrained by basement highs. And while it supports stock and domestic groundwater supplies, it is a minimally developed groundwater source.

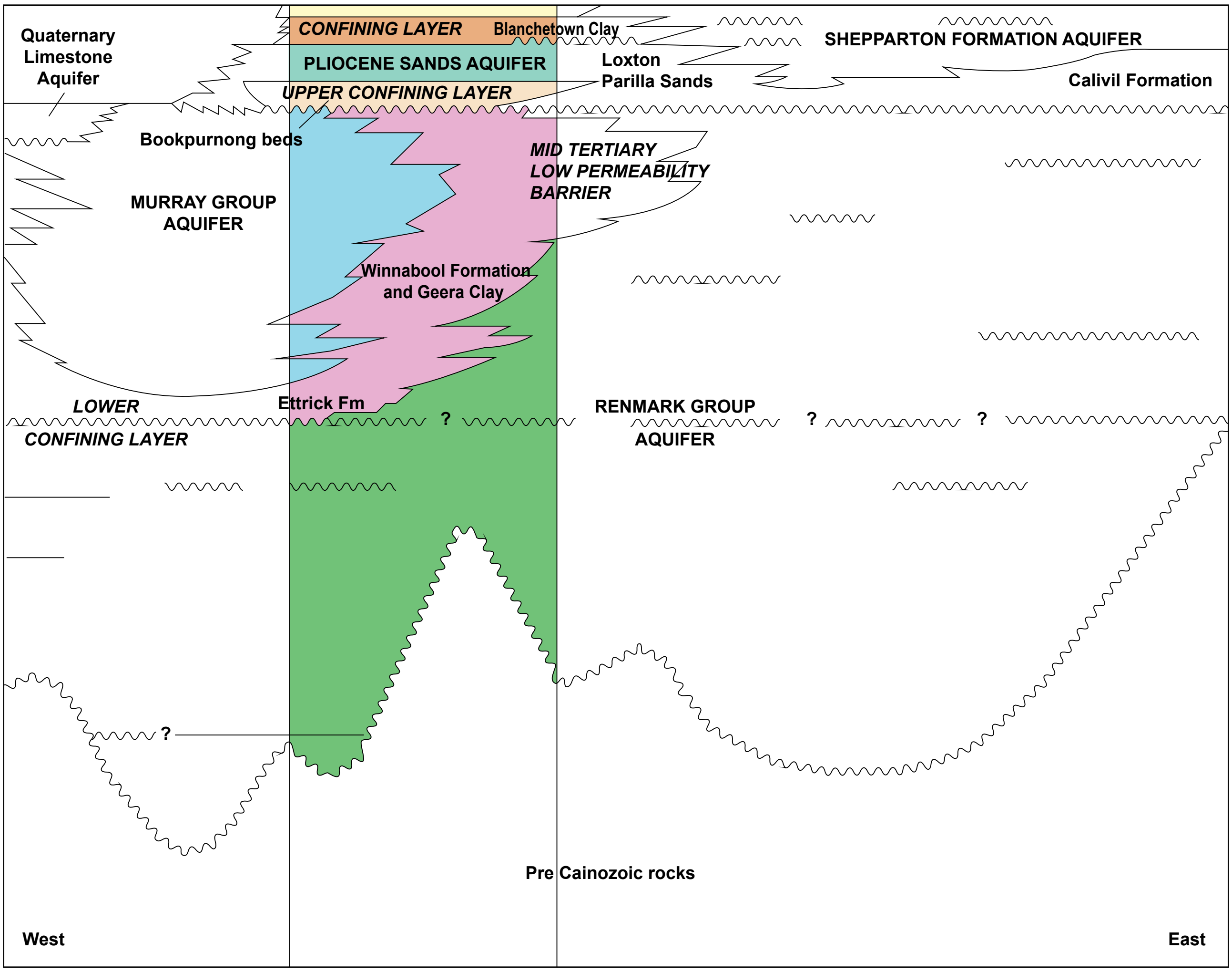
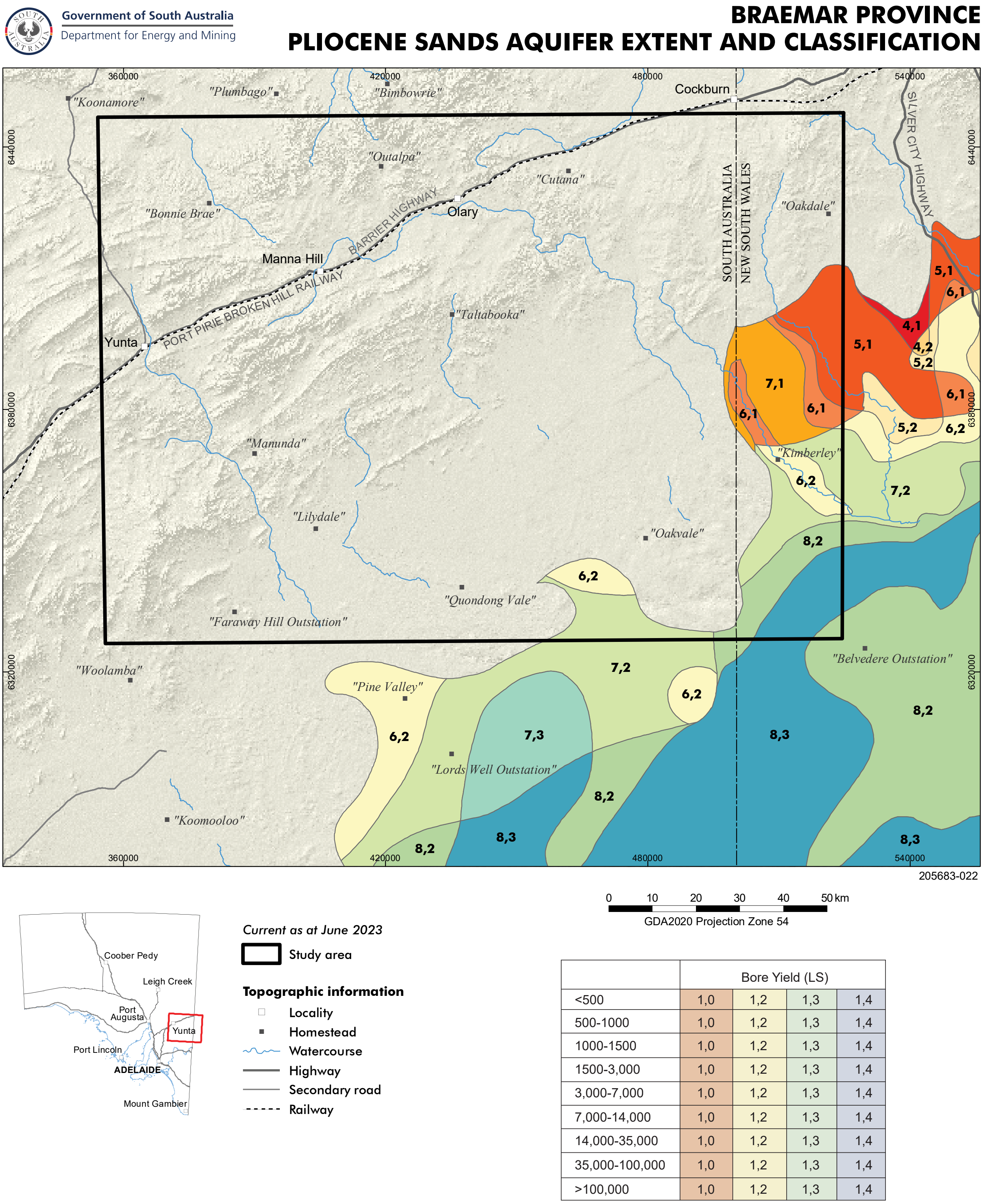


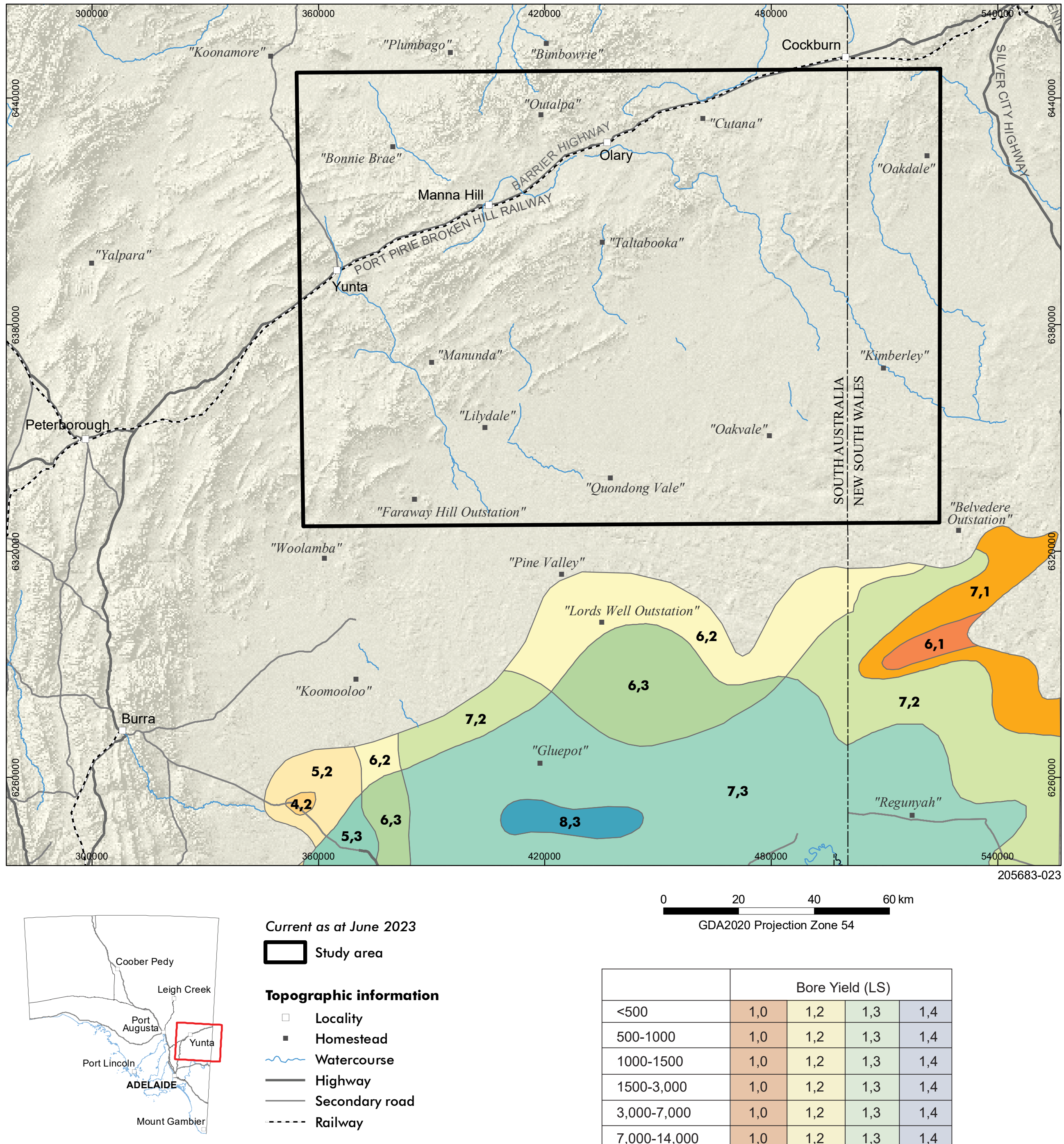
Figure 15 *Murray Basin hydro-stratigraphy with the shaded area highlighting the part of the Basin that occurs in the study area or its general vicinity (Barnett 1994)*



	Bore Yield (LS)			
<500	1,0	1,2	1,3	1,4
500-1000	1,0	1,2	1,3	1,4
1000-1500	1,0	1,2	1,3	1,4
1500-3,000	1,0	1,2	1,3	1,4
3,000-7,000	1,0	1,2	1,3	1,4
7,000-14,000	1,0	1,2	1,3	1,4
14,000-35,000	1,0	1,2	1,3	1,4
35,000-100,000	1,0	1,2	1,3	1,4
>100,000	1,0	1,2	1,3	1,4

Figure 16 *Pliocene sands aquifer extent and classification (after Barnett 1994)*

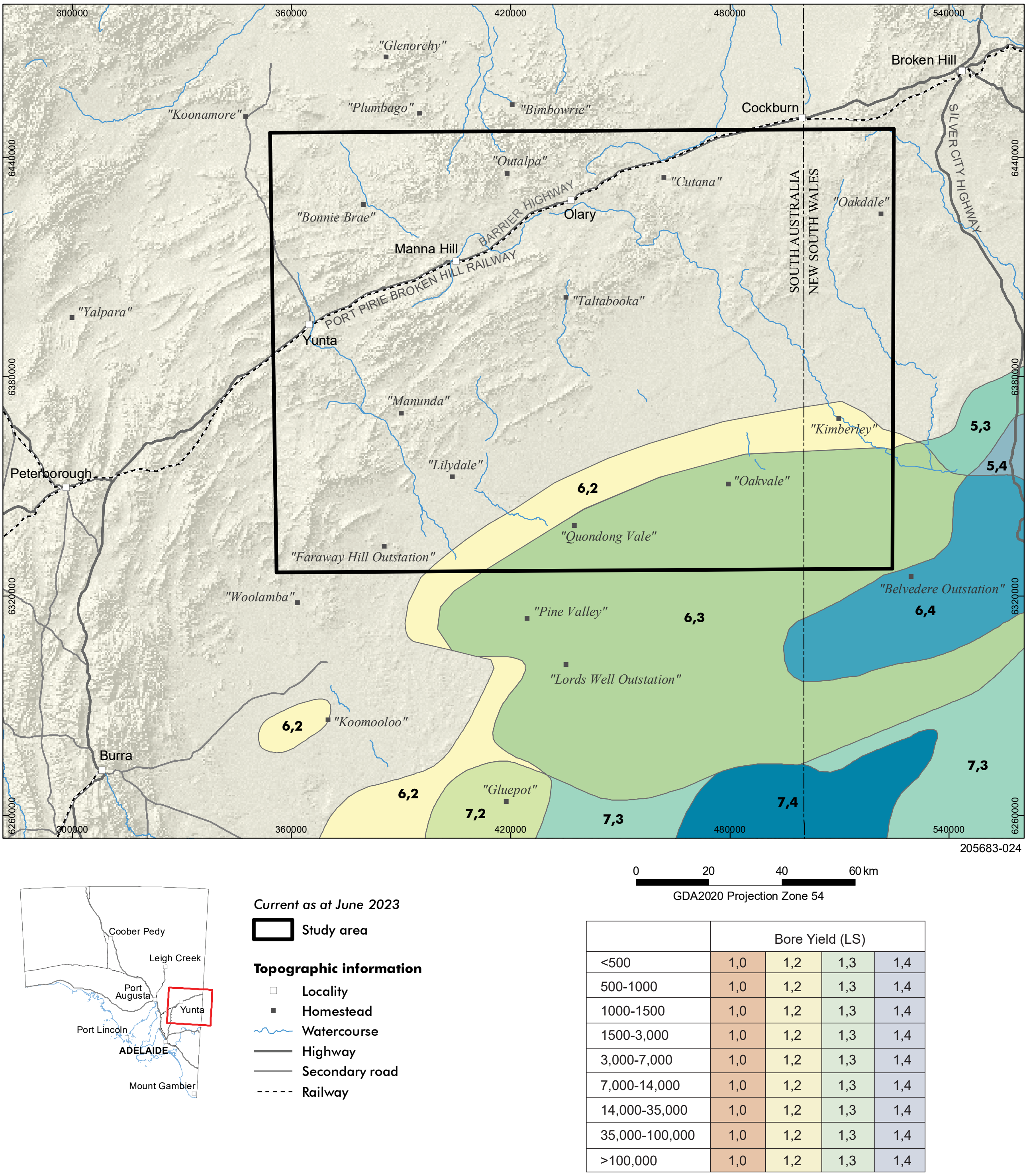
BRAEMAR PROVINCE
MURRAY GROUP LIMESTONE
AQUIFER EXTENT AND CLASSIFICATION



	Bore Yield (LS)			
<500	1,0	1,2	1,3	1,4
500-1000	1,0	1,2	1,3	1,4
1000-1500	1,0	1,2	1,3	1,4
1500-3,000	1,0	1,2	1,3	1,4
3,000-7,000	1,0	1,2	1,3	1,4
7,000-14,000	1,0	1,2	1,3	1,4
14,000-35,000	1,0	1,2	1,3	1,4
35,000-100,000	1,0	1,2	1,3	1,4
>100,000	1,0	1,2	1,3	1,4

Figure 17 *Murray Group Limestone aquifer extent and classification (after Barnett 1994).*

BRAEMAR PROVINCE LOWER RENMARK GROUP LIMESTONE AQUIFER EXTENT AND CLASSIFICATION



	Bore Yield (LS)			
<500	1,0	1,2	1,3	1,4
500-1000	1,0	1,2	1,3	1,4
1000-1500	1,0	1,2	1,3	1,4
1500-3,000	1,0	1,2	1,3	1,4
3,000-7,000	1,0	1,2	1,3	1,4
7,000-14,000	1,0	1,2	1,3	1,4
14,000-35,000	1,0	1,2	1,3	1,4
35,000-100,000	1,0	1,2	1,3	1,4
>100,000	1,0	1,2	1,3	1,4

Figure 18 *Lower Renmark Group Limestone aquifer extent and classification (after Barnett 1994).*

4.5 KNOWLEDGE GAPS AND UNCERTAINTIES

Several knowledge gaps and uncertainties constrain the current understanding of groundwater resources in the study area. These include:

- Well yields and salinities, particularly in the Murray Basin where there has been limited drilling.
- Aquifer extents and thicknesses as they are important determinants of the overall capacity of the groundwater resources.
- Groundwater levels and potentiometric surfaces.
- Hydraulic parameters (conductivity and storage) as they control the responsiveness of the aquifer to pumping and support estimates of sustainable rates of extraction.
- Status of existing stock and domestic users.
- Location and characterisation of potential GDEs.
- Recharge and discharge processes in the fractured rock aquifers as these will be important determinants of the sensitivity of potential GDEs to changes in groundwater conditions.

The focus of investigations to address these knowledge gaps should be on the following target areas:

- The Lower Renmark Aquifer in SA and NSW
- Fractured rock aquifers in close proximity to proposed mining developments
- The Anabama Fault Zone which Mulè (2022) identified as having some potential for hosting sedimentary aquifers close to mining developments.

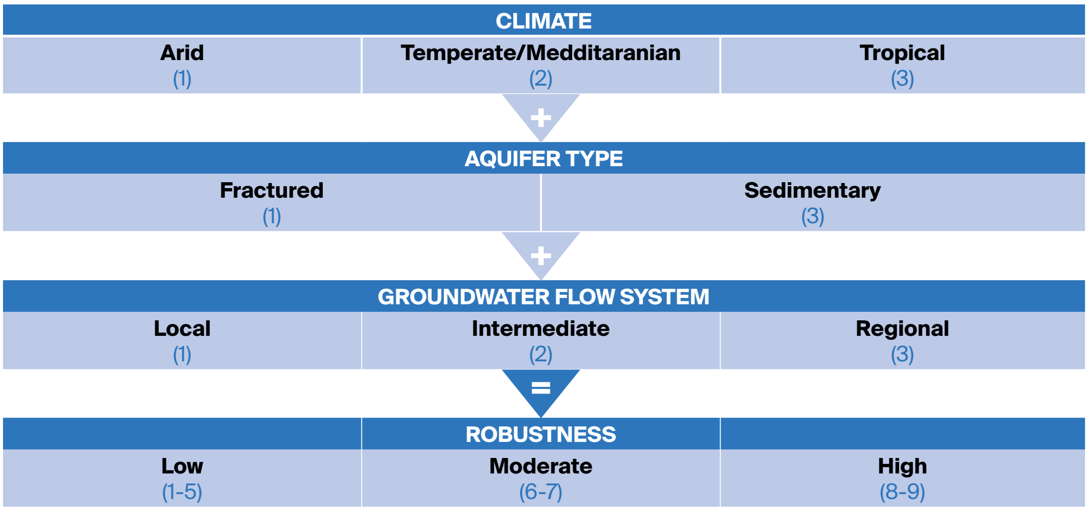
5

Groundwater resource assessment to support mining

5.1 CAPACITY OF GROUNDWATER RESOURCES TO MEET WATER DEMAND

The capacity of groundwater resources is related to several factors which include recharge, responsiveness to pumping, aquifer storage and the requirements of other water users (including GDEs). While the concept of groundwater resource capacity is relatively simple, it is challenging to quantify and relies on robust modelling approaches supported by data, which may not be available. Qualititative approaches can, however, provide some initial guidance.

Howe (2011) developed a framework for the National Water Commission to qualitatively assess the capacity of aquifer systems (termed robustness) in relation to mining development (Figure 18). The framework measures robustness using three factors. Climate provides an indicator of recharge rates. Aquifer type provides an indicator of aquifer storage, with sedimentary aquifers typically having much higher storage volumes than fracture rock aquifers. The scale of the groundwater flow system provides an indicator of the spatial extent of the aquifer system (Walker et al 2003) and its total storage volume, with regional flow systems (>50 km) having substantially higher volumes than local flow systems (<5 km).



CLIMATE		
Arid (1)	**Temperate/Medditaranian** (2)	**Tropical** (3)

+

AQUIFER TYPE	
Fractured (1)	**Sedimentary** (3)

+

GROUNDWATER FLOW SYSTEM		
Local (1)	**Intermediate** (2)	**Regional** (3)

=

	ROBUSTNESS	
Low (1-5)	**Moderate** (6-7)	**High** (8-9)

Figure 18 *Qualitative aquifer robustness calculation (Howe 2011)*

This framework can be applied to the groundwater resources in the study area as follows:

- Fractured rock aquifers of the Olary Ranges are classified as having a low level of robustness (total score of 3) based on:
  - arid climate (1) of where recharge occurs
  - aquifer type is fractured (1)
  - local groundwater flow systems (1).
- The Lower Renmark aquifer is classified as having a high level of robustness (total score of 8) based on:
  - temperate/Mediterranean climate (2) of where recharge occurs (within the eastern extent of the Murray Basin in higher rainfall zones)
  - aquifer type is sedimentary (3).
  - regional groundwater flow system (3).

Based on this assessment, the Lower Renmark aquifer is clearly a more robust aquifer system to support mining development.

In the absence of a thorough modelling assessment, it is difficult to quantify the capacity of the resources in terms of a sustainable rate of groundwater extraction and the period over which this could apply, but the following sources provide some guidance:

- Modelling studies undertaken for the Maldorky Iron Project indicate a supply in the order of 2 GL/y could be obtainable from fractured rock sources for short periods of time (<5 years) (Maldorky Iron 2014).
- A sustainable diversion limit of 64.8 GL/y has been set for the SA Murray Region SDL unit, noting this applies to a region much larger than the study area and extends south of the Murray River (DEW 2018).

Using the current information, Table 6 has been prepared which outlines the likelihood of groundwater resource capacity meeting the regional mine water demand scenarios outlined in Section 3.2. The assessment indicates that fractured rock aquifers of the Olary Ranges are unlikely to provide sufficient water for significant mining development in the region, but they could possibly provide a supplemental water supply. Meanwhile, there is reasonable probability of the Lower Renmark aquifer meeting low and moderate water demand scenarios and possibly supporting higher levels of demand.

Table 6 *Likelihood of groundwater resources meeting mine water demand.*

Water demand scenario	Likelihood of groundwater resource capacity meeting cumulative water demand*	
	Fractured Rock Aquifers of Olary Ranges	Lower Renmark
Low (10 GL/y)	Unlikely	Probable
Moderate (20 GL/y)	Unlikely	Likely
High (60 GL/y)	Remote	Possible

*Probable: high probability of meeting demand (>80%);
Likely: reasonable probability of meeting demand (60-80%);
Possible: intermediate probability of meeting demand (10-60%);
Unlikely: low probability of meeting demand 1-10%;
Remote: very low probability of meeting demand (<1%)

5.2 GROUNDWATER SUPPLY OPTIONS

Three potential groundwater sources are evident from the hydrogeological analysis undertaken, as follows:

- Fractured rock aquifers in close proximity to the mining projects providing supplementary water supplies of less than 2 GL/y at each site
- Lower Renmark Aquifer in South Australia targeting areas of reasonable aquifer thickness and yield (5-50 L/s)
- Lower Renmark Aquifer in NSW targeting the Tarrara and Medindie troughs where higher yields (>50 L/s), aquifer thicknesses, and lower salinities are mapped.

A concept map for these groundwater sources is shown in Figure 19 with the approximate location of possible wellfields indicated, noting these may need to be relocated for land access issues or for hydrogeological reasons based on further investigations.

5.3 SWOT ANALYSIS

The assessment of groundwater resources to support mining is framed around strengths, weaknesses, opportunities and threats (SWOT). Groundwater resources in both the fractured rock aquifers and Murray Basin (Lower Renmark) are considered.

Strengths

- Well yields in Murray Basin resource appears to be reasonably high and consistent to minimise drilling requirements and number of production wells (subject to further drilling investigations and assessment).
- Capacity of the resource in Murray Basin appears to be high, with existing use being low relative to its capacity (subject to further investigations and assessment).
- Development of resource in Murray Basin unlikely to affect the River Murray given the distances involved and role of confining layers. It is also unlikely to be contentious from a basin-wide management perspective given the groundwater is saline and there is a broader need to limit the ingress of saline groundwater to the river as part of Basin Salinity Management practices (MDBA 2015).
- Resource in fractured rock is close to the proposed mining operations (within tenements) and would likely be developed to some extent via pit-dewatering.

Weaknesses

- Yields in fractured rock are variable and often low, increasing drilling requirements and number of production wells.
- Capacity of resource in fractured rock appears to be low.
- Development of resource in fractured rock systems would draw down the water table locally and could potentially impact GDEs and existing stock and domestic users.
- Salinity of groundwater (Murray Basin or Fractured Rock aquifer) means that it will require some form of desalination (as part of final concentrate washing and potable needs) and management of associated brine stream.

- Distance of groundwater resource in Murray Basin requires pipelines to transfer the water of up to around 100 km.
- There are substantial knowledge gaps given limited groundwater investigations undertaken in the study area. Knowledge gaps concern yields, salinity and other water quality characteristics, aquifer extents, inter-aquifer connectivity and leakage, hydraulic parameters, recharge processes and rates, groundwater dependent ecosystems and status of existing wells and use.
- Land access issues associated with developing groundwater resources in Murray Basin which concern obtaining water off-tenement in an area subject to the Mining Act Section 15 gazettal[6] and subject to agreement from pastoral lease holders, or interstate in NSW. Access to Danggali Conservation Park is also restricted.

Opportunities

- Development of a resource to support mining and associated infrastructure generating economic development, employment opportunities, and mining royalties for the state.
- Water resource development for mining could be extended to local landholders and communities as additional water for stock and domestic supplies.
- There is an opportunity for a coordinated approach to developing a water supply within the Murray Basin. The location of the resource relative to the mineral deposits is such that a common wellfield and pipeline could be considered (see Figure 19).

Threats

- Competition for groundwater resources (e.g. well interference) from multiple mining developments.
- Impacts to existing users (stock and domestic users and GDEs) via groundwater development and associated drawdown. Such impacts (if uncontrolled) could limit the capacity of the aquifer to supply water.
- Cumulative impacts to existing users (stock and domestic users and GDEs) via groundwater development and associated drawdown from incremental development of multiple mining projects leading to overlapping impacts. These cumulative impacts (if uncontrolled) could limit the capacity the aquifer to supply water.
- Land access issues associated with developing groundwater resources off-tenement. Such issues include: i) developing and accessing water resources from interstate in NSW; ii) developing and accessing water resources in areas subject to the Section 15 gazettal area (while it is in place); iii) remaining outside conservation areas; iv) cultural and native title considerations; v) agreements with pastoral lease holders.
- Management of salinity and other water quality considerations.

Uncertainty related to:

  - Projected mine water demand leading to under- or over-investment in infrastructure
  - Infrastructure and corridor planning
  - Hydrogeological knowledge base leading to overestimation in capacity of groundwater resources
  - Existing users and GDEs leading to unexpected impacts from groundwater resource development

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[6] A Section 15 Gazettal (pursuant to the *Mining Act 1971*) applies to region of the Murray Basin. Under this gazettal, applications for mineral tenements are being withheld while DEM undertakes its own exploration studies.

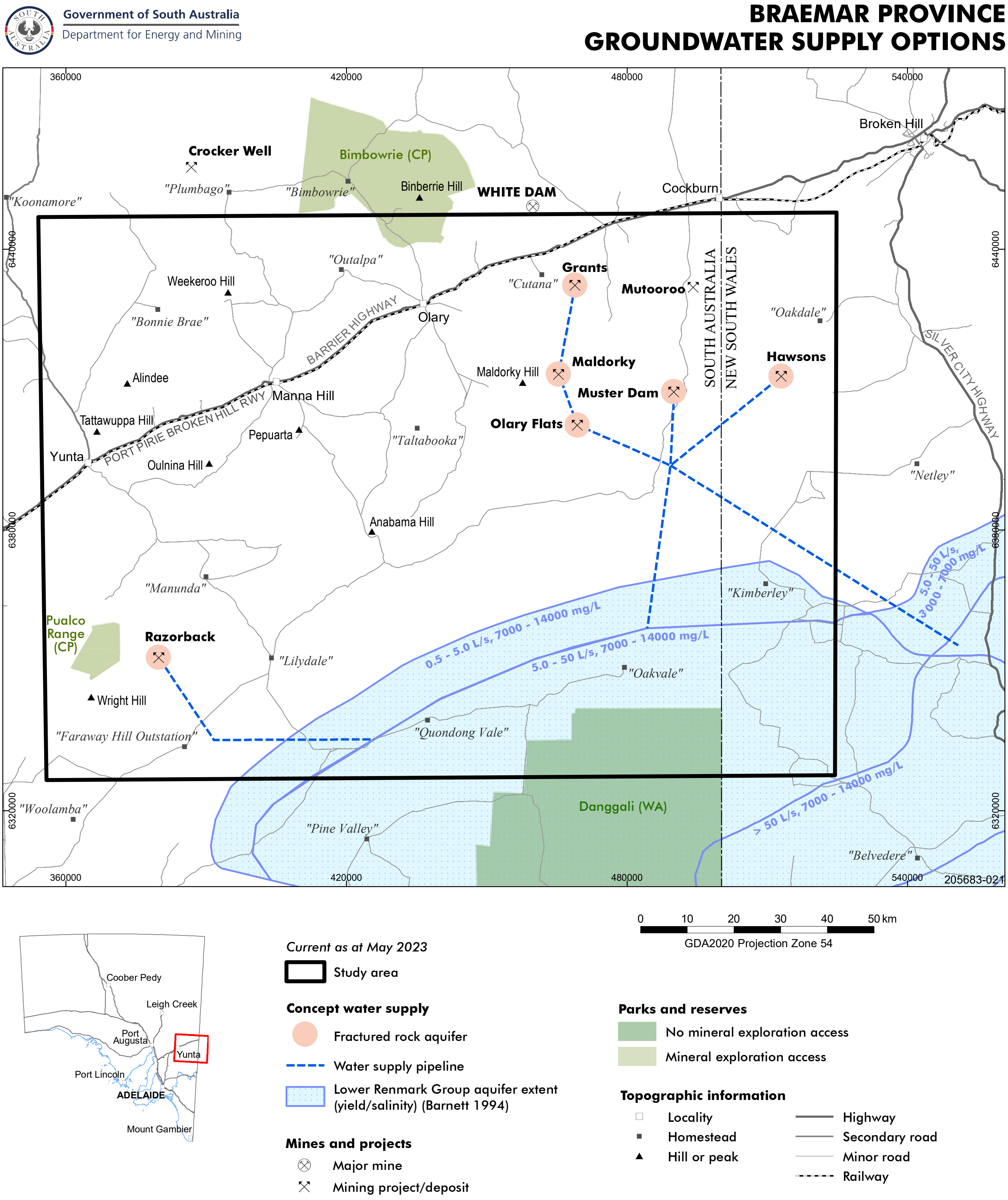

Figure 19 *Concept map of groundwater supply options (NOTE: Pipeline and wellfield locations indicative only)*

6 Road map

6.1 OBJECTIVES, CONSTRAINTS, AND ISSUES ARISING

The SWOT analysis undertaken in Section 5.3 has revealed several opportunities and threats in relation to developing groundwater resources for mining development. The overall objective of the road map is to realise these opportunities by addressing the threats and their inherent challenges, constraints and knowledge gaps.

The key opportunities in developing groundwater resources to assist mining development include:

- Economic growth and development associated with mining development.
- Water to communities as an extension of mining and groundwater resource development.

The constraints include:

- Limited capacity of local fractured rock groundwater resources to support large scale mining development
- Costs of developing groundwater resources at distance
- Management of salinity and other potential water quality considerations
- Uncertainties related to
  - Groundwater resource estimation and long-term sustainability of supply
  - Mine planning: timing, demand quality and quantity, costs of developing resources
  - Land access issues for infrastructure and corridor planning

The issues arising include:

- Competition for water resources (e.g. well interference)
- Potential impacts (and cumulative impacts) of groundwater resource extraction

6.2 ACTION PLAN

The action plan is framed around addressing the above knowledge gaps, constraints and developing pathways to navigate the issues arising. The objective is to the realise the opportunities presented in an efficient manner. The effort entailed will be a mix of industry and government-led initiatives, with the government led actions highlighted as a means to prioritise government investment in the short to medium-term (<5 years).

6.2.1 Better understanding the capacity of the resource

Objective: Quantify the capacity of the Murray Basin and fractured rock aquifers to meet demand

1. Discuss this project (Strategic Hydrogeological Framework) with NSW and consider assessing NSW part of the Murray Basin.
2. In consultation with existing project proponents design and implement a regional-scale pilot drilling and testing program to confirm well yields in target areas and to provide input data to a regional conceptual and numerical model (including aquifer extent and water balance).
3. Liaise with existing groundwater users in the target area (stock and domestic) to better understand their water requirements so that future operators of the water supply are aware of the need to maintain these requirements.
4. Identify and characterise potential GDEs to assess their sensitivity to changes in groundwater quantity (e.g. level and flux) and quantity.
5. Develop a regional-scale numerical groundwater flow model to quantify the cumulative impact of groundwater extraction and to determine the capacity of the resource to meet demand for a range of development scenarios (refer below).
6. Use the model to assess impacts to other environmental and consumptive users

6.2.2 Better understand demand scenarios

Objective: Quantify required volume and quality of water supply over life of mine

1. Maintain dialogue with project proponents to update demand scenarios for mine construction and operations.
2. Liaise with local groundwater users (stock and domestic) to determine current water requirements and potential opportunities for the provision of additional water.

6.2.3 Develop water resource management framework

Objective: Develop regional water management framework to manage competing impacts (e.g. well interference) and cumulative impacts from water resource development

1. Define preferred regulatory pathway, for example:
   a. On a case-by-case basis using the PEPR process under the Mining Act
   b. Resource prescription and the development of a water allocation plan
   c. The development of a third-party entity, such as an OGIA-type body [7] to manage competing and cumulative impacts

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[7] OGIA is the Office of Groundwater Impact Assessment. It is an independent office established to manage the cumulative impacts of groundwater extraction from resource operations (petroleum and gas, and mining) in the Surat Basin, Queensland. For more information, see: https://www.business.qld.gov.au/industries/mining-energy-water/resources/landholders/csg/ogia

2. Explore possible cross-border sharing arrangements with NSW
3. Establish stakeholder group
4. Establish resource condition limits
5. Define groundwater extraction limits
6. Develop management framework and policies

6.2.4 Land access and approvals

Objective: Resolve future land access issues associated with off-tenement water supply

1. Secure access to infrastructure corridors for wellfield and delivery pipeline off-tenement in an area subject to the Section 15 gazettal and subject to agreement from pastoral lease holders, or in NSW.

6.2.5 Data sharing with mineral exploration

Objective: Develop water data protocol for future mineral exploration in the Murray Basin

1. Develop a protocol that describes how water data can be collected and collated as part of future mineral exploration in the Murray Basin.

6.2.6 Options assessment to consider prospects of importing seawater

Objective: compare imported seawater against groundwater as a water supply option and develop imported water supply strategy

1. Identify and outline options for seawater supply integrated with a slurry transfer system to the coast via an infrastructure corridor
2. Compare these options to groundwater supply options
3. Develop imported water supply strategy

6.2.7 Explore joint-water supply development for mining

Objective: Develop framework for joint water supply development

1. Subject to agreement by industry stakeholders, work with industry to develop an approach to joint development, ownership and operation of a sustainable water supply for mine construction and operation. This framework would recognise:
   - A water supply would be developed incrementally in line with mining demand.
   - Competing impacts (e.g. well interference) would need to be managed.
   - Joint responsibility of cumulative impacts of the wellfield.
   - Access to shared infrastructure (delivery pipeline).

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As guests here on Kaurna land, the Department for Energy and Mining (DEM) acknowledges everything this department does impacts on Aboriginal country, the sea, the sky, its people, and the spiritual and cultural connections which have existed since the first sunrise. Our responsibility is to share our collective knowledge, recognise a difficult history, respect the relationships made over time, and create a stronger future.
We are ready to walk, learn and work together.

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