Attachment 5

Additional Information - Groundwater

WINCHESTER SOUTH PROJECT

Environmental Impact Statement

Additional Information

WHITEHAVEN WHITEHAVEN COAL

Resource Strategies

WINCHESTER SOUTH PROJECT

Groundwater Impact Assessment

Prepared for:

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Level 22
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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Whitehaven Coal Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

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DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
620.13245.10000-R01-v5.0	12 October 2022	D Lyons	B Rask	D Lyons
620.13245.10000-R01-v5.0	12 October 2022	D Lyons	B Rask	D Lyons
620.13245.10000-R01-v5.0	June 2022	D Lyons	B Rask	D Lyons
620.13245.10000-R01-v4.0	May 2022	D Lyons	B Rask	D Lyons
620.13245.10000-R01-v3.4	May 2021	J Newton / M Veen	D Lyons	D Lyons

DOCUMENT REFERENCES

TABLES

FIGURES

APPENDICES

1 Introduction

SLR Consulting Australia Pty Ltd (SLR) has been engaged by Whitehaven Coal Limited (Whitehaven) to undertake a Groundwater Assessment for the Winchester South Project (the Project), for incorporation into a broader Environmental Impact Statement (EIS).

Whitehaven WS Pty Ltd (Whitehaven WS), a wholly owned subsidiary of Whitehaven, proposes to develop the Project, a metallurgical open cut coal mine and associated infrastructure within the Bowen Basin, located approximately 30 kilometres (km) south-east of Moranbah, within the Isaac Regional Council Local Government Area (LGA) (**Figure 1-1**). Products would include predominantly metallurgical coal for the steel industry and thermal coal for energy production.

In 2021, Whitehaven WS submitted the *Winchester South Project Environmental Impact Statement* (the EIS) for assessment under the *State Development and Public Works Organisation Act 1971* (SDPWO Act). The EIS was placed on public notification by the Office of the Coordinator-General (OCG) from 4 August 2021 until 15 September 2021. During and following this period, government advisory agencies, organisations and members of the public provided submissions on the Draft EIS to the OCG.

Subsequent to the public notification of the Draft EIS, Whitehaven WS reviewed the mine plan and mine schedule with the aim of reducing environmental impacts of the Project and challenging the Project final landform in response to comments raised in submissions. This review also considered new geological data, coal quality data and the outcomes of processing trials to further refine the mine plan.

On 3 December 2021, the Coordinator General formally requested (in accordance with section 34A of the SDPWO Act) Additional Information on the environmental effects of the Project and other matters relating to the Project.

This Groundwater Assessment forms part of the Additional Information and provides an assessment of the amended mine plan and mine schedule and responses to issues raised in submissions, as well as satisfying the requirements of the *Terms of reference for an environmental impact statement – Winchester South Project* (Terms of Reference) issued by the Coordinator-General on 4 September 2019.

1.1 Winchester South Project

The Project involves the development of an open cut coal mine in an existing mining precinct (**Figure 1-2**). The Project would include construction and operation of a mine infrastructure area (MIA), including a Coal Handling and Preparation Plant (CHPP), train load-out facility and rail spur, which would be used for the handling, processing and transport of coal. An infrastructure corridor would also form part of the Project, including a raw water supply pipeline connecting to the Eungella pipeline network, an electricity transmission line (ETL) and a mine access road (**Figure 1-3**).

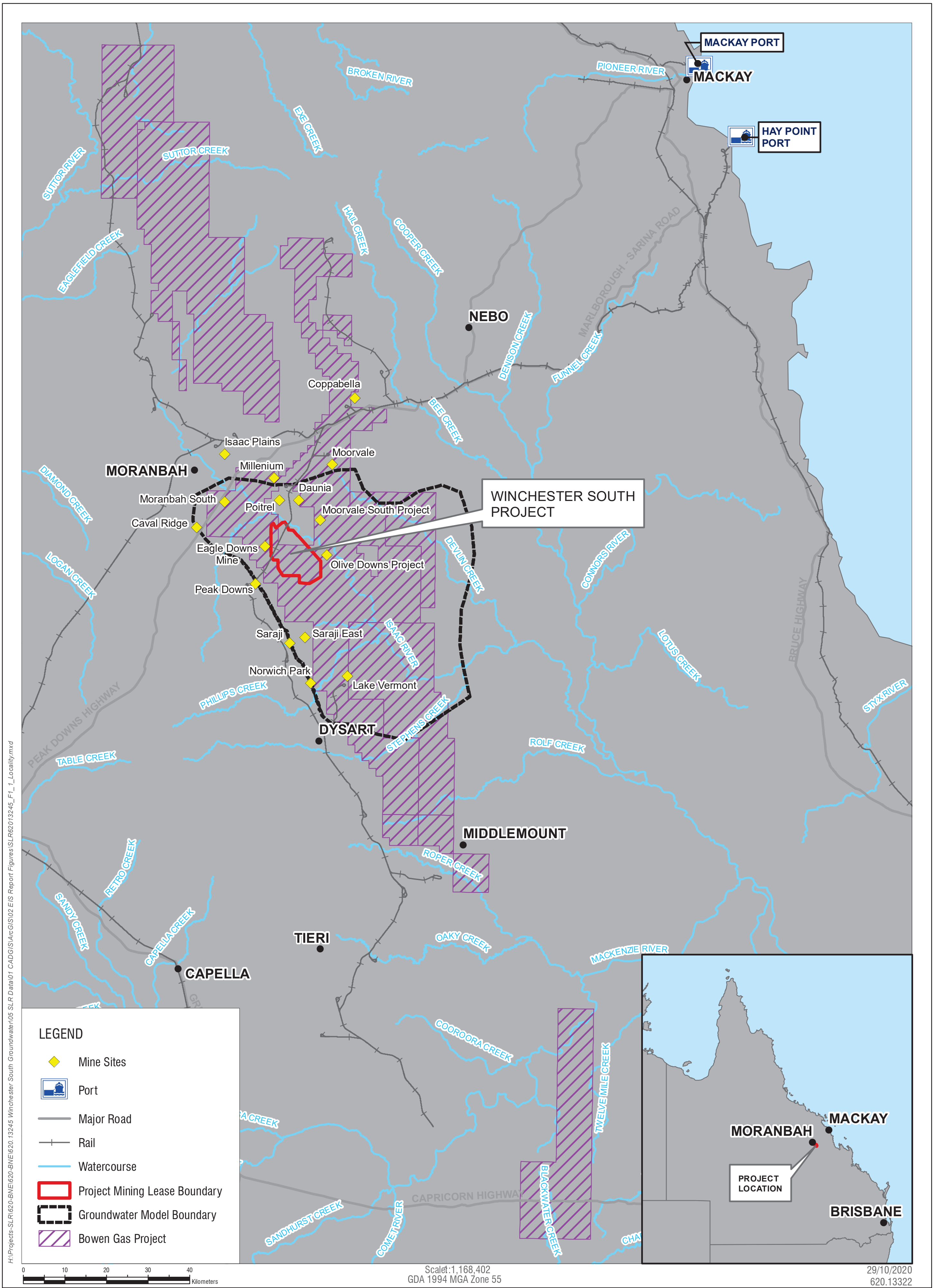
The Project is forecast to extract approximately 15 million tonnes per annum (Mtpa) of run-of-mine (ROM) coal, with a forecast peak extraction of up to 17 Mtpa, for approximately 30 years. The coal resource would be mined by open cut mining methods, with product coal to be transported by rail to port for export.

The Project will consist of a maximum of six open cut pits targeting the Rangal Coal Measures (targeting the Leichhardt and Vermont Upper Seams).

Located west and south-west of the Project are existing mine operations Peak Downs and Saraji. Located directly to the west is Eagle Downs Underground Mine and Caval Ridge. Located to the north and north-east of the Project is Daunia Mine, Poitrel Mine, and the proposed Moorvale South Project. Immediately to the south and south-east of the Project is the Olive Downs Project with Lake Vermont Mine further south (**Figure 1-1**).

Throughout this report, the terms “the Project Area” and “Study Area” are used as defined by:

- The Project Area is the areas within Mining Lease Application (MLA) 700049, MLA 700050, MLA 700051, and MLA 700065, that would involve mining activities including open cut mining and waste rock emplacement.
- The Study Area is the regional area surrounding the Project considered in detail within this assessment, as shown in **Figure 1-1**, and is synonymous with the groundwater model boundary. The selection of the groundwater model boundary is discussed in **Section 6**.



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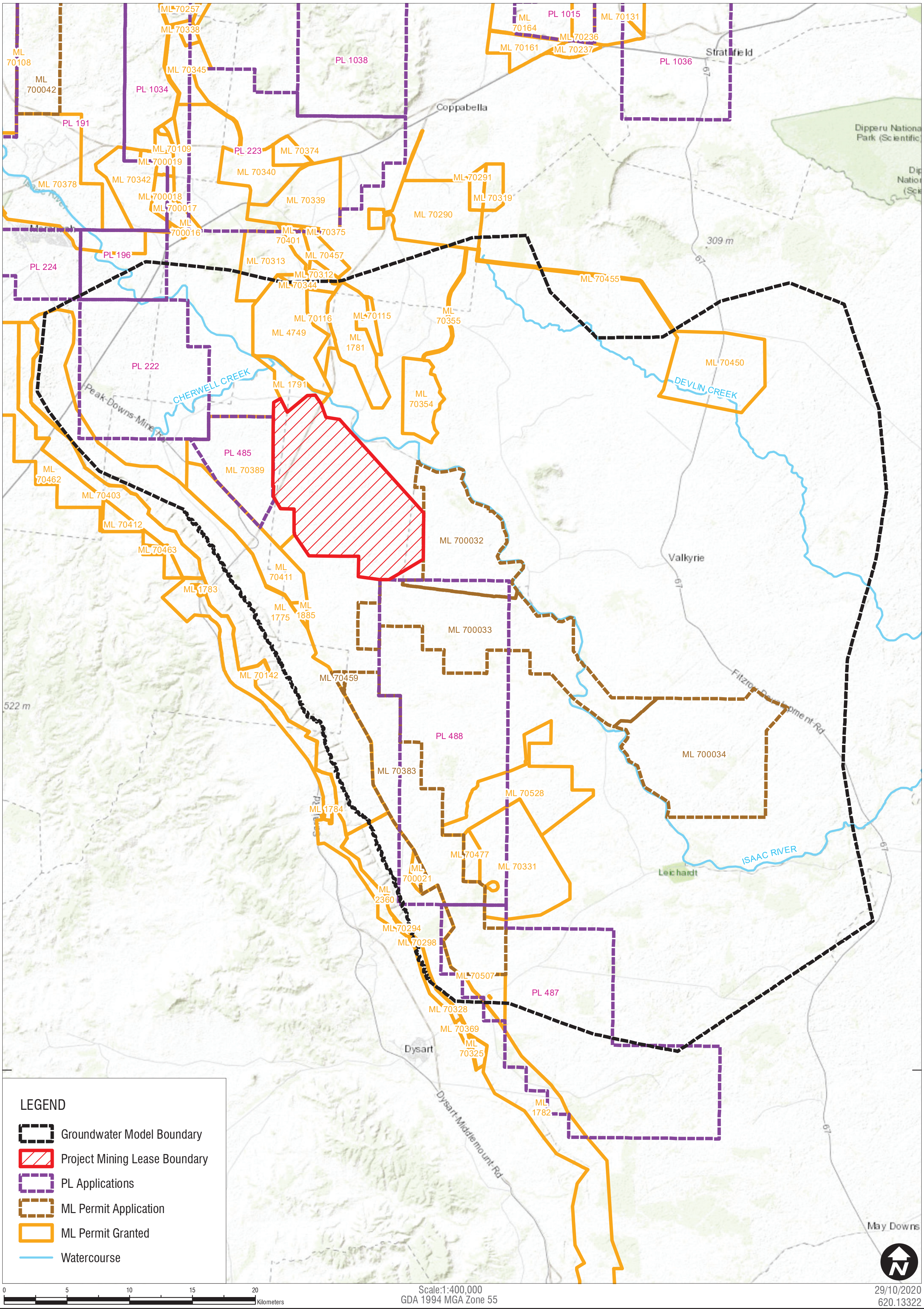
Project Location and Study Area

FIGURE 1-1



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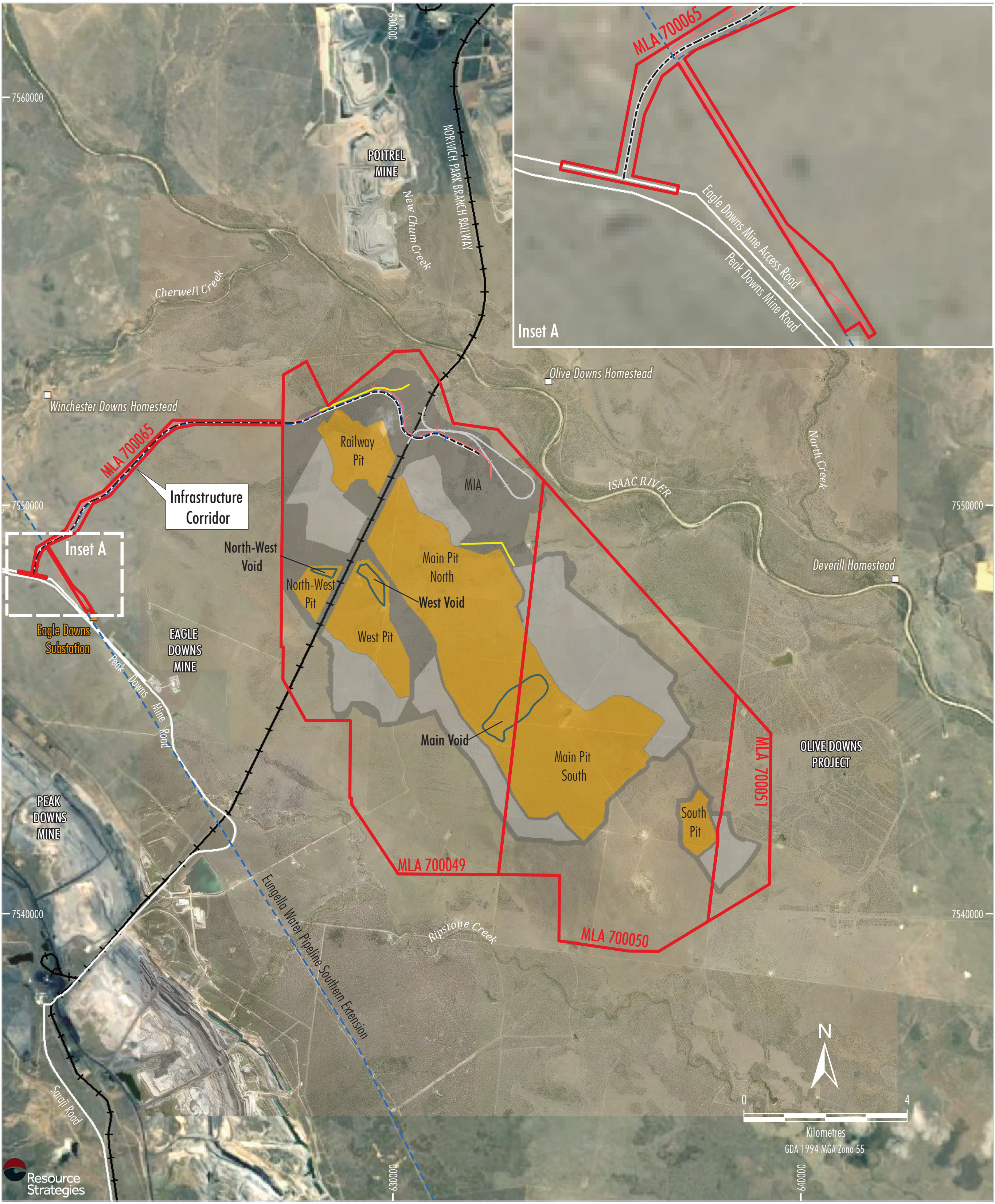
Project and Surrounding Mine Tenements

FIGURE 1-2



LEGEND

- Mining Lease Application Boundary
- Eungella Water Pipeline Southern Extension
- Railway
- Substation

Project Component*

- Indicative Infrastructure Area
- Indicative Out-of-pit Waste Rock Emplacement
- Indicative Open Cut Pit Including In-pit Waste Rock Emplacement
- Indicative Mine Access Road
- Indicative Rail Spur and Loop
- Indicative Electricity Transmission Line
- Indicative Raw Water Supply Pipeline
- Indicative Flood Levee
- Indicative Residual Void Waterbody

*Note: * Excludes some project components such as water management infrastructure, access tracks, topsoil stockpiles, explosives magazines, power reticulation, temporary offices, other ancillary works and construction disturbance.*

Source: The State of Queensland (2018 - 2020); Whitehaven (2020)
Orthophoto: Google Image (2019); Whitehaven (2017)

WHITEHAVEN COAL

WINCHESTER SOUTH PROJECT

Project General Arrangement

Figure 1-3

1.2 Project Design

The Project involves the development of an open cut coal mine in an existing mining precinct (**Figure 1-2**). The Project would include construction and operation of a MIA, including a CHPP, train load-out facility and rail spur, which would be used for the handling, processing and transport of coal. An infrastructure corridor would also form part of the Project, including a raw water supply pipeline connecting to the Eungella pipeline network, an ETL and a mine access road (**Figure 1-3**).

The Project involves activities and infrastructure relevant to this Groundwater Assessment, including:

- Open cut mining targeting the Rangal Coal Measures and Fort Cooper Coal Measures;
- Out-of-pit and in-pit emplacement of waste rock material;
- On-site CHPP to process ROM coal from the Project;
- Co-disposal of coal rejects on-site within the footprint of the open cut pits and/or out-of-pit emplacement areas;
- Progressive development of sediment dams and storage dams, pumps, pipelines and other water management equipment and structures (including levees);
- Other associated infrastructure, including workshops, offices, crib facilities, bathhouse, warehouse, an ETL, re-fuelling facilities (including diesel storage), communication facilities and other associated amenities; and
- Progressive development and rehabilitation of the optimised final landform with three residual voids.

The main water demands for the Project would be for the CHPP, dust suppression and evaporation losses from water bodies. The water for operations will be sourced (subject to detailed design) from several sources including; open cut dewatering, processing water re-use and recycling, treated wastewater, flood harvesting, and incident rainfall and runoff. Supplementary raw water supply can be sourced from existing off-site water supply networks such as the existing Eungella pipeline network (alignment subject to detailed design). Supply options from neighbouring mines are also being investigated to supplement the Project's raw water requirements.

The Project is being designed to backfill the open-cut voids so that the three residual voids are located outside the extent of the Isaac River Floodplain as defined by the Queensland Floodplain Assessment Overlay (Department of Natural Resources, Mines and Energy [DNRME], 2017a) (**Figure 1-3**).

1.3 Objectives

The Groundwater Assessment has been undertaken in accordance with the Queensland government requirements and the *Commonwealth Environment Protection and Biodiversity Conservation 1999* (EPBC Act). The Groundwater Assessment comprises two parts; (i) a description of the existing hydrogeological environment; and (ii) an assessment of the impacts of mining on that environment. To this end, the stated scope of work was to:

- Review relevant groundwater, geotechnical and environmental reports to characterise the geological and hydrogeological setting of the Project.
- Review publicly available hydrogeological data such as the Queensland Government's spatial data system (Queensland Globe) and the Bureau of Meteorology's (BoM) National Groundwater Information System (NGIS) (BoM, 2019).

- Review the existing census of groundwater supply bores in the vicinity of the Project to confirm locations, usage and groundwater quality.
- Characterisation of the existing groundwater resources, including properties and quality.
- Conceptualisation of the groundwater regime of the Project Area and Study Area.
- Assessment of the potential interaction between the Isaac River and associated alluvium and the Project.
- Development and calibration of a numerical groundwater flow model suitable for the assessment of potential impacts of the Project, in accordance with the *Australian Groundwater Modelling Guidelines* (Barnett et al., 2012) and *Murray Darling Basin Commission guidelines* (Middlemis et al., 2001).
- Undertake predictive modelling for the scale and extent of mining impacts upon groundwater levels, groundwater quality and groundwater users at various stages during mine operations and post-mining.
- Predictive modelling of the cumulative impacts of Project, surrounding mines and the other relevant developments (e.g. Bowen Gas Project).
- Assessment of the extent of groundwater impacts as a result of the Project, including long-term impacts on regional groundwater levels and water quality impacts on environmental flows and baseflows.
- Assessment of potential impacts on groundwater dependant ecosystems (GDEs) resulting from short and/or long-term changes in the quantity and quality of groundwater.
- Assessment of the potential third-party impacts (i.e. privately-owned bores) as a result of changes to the regional groundwater system.
- Development of reasonable and practicable mitigation and management strategies where potential adverse impacts are identified.
- Development of a groundwater monitoring program and management measures.

1.4 Information Sources

In addition to publicly available and Project-specific information and data, the Groundwater Assessment has been prepared utilising information and data collected and collated as part of recent groundwater assessments for the nearby Olive Downs Project (HydroSimulations, 2018), Moorvale South Project (SLR, 2019a), and Eagle Downs Mine (SLR, 2019b). Whitehaven has existing data sharing agreements with the owners of each of the projects/mines, which allows for the sharing of data, models and documentation. Under these agreements, data utilised as part of each project's groundwater assessment has been incorporated into this Groundwater Assessment.

2 Legislative Requirements and Relevant Guidelines

Legislative requirements and guidelines relevant to the Project and groundwater are outlined below.

2.1 Legislation

Relevant legislation in relation to taking or interfering with groundwater resources for the Project include:

- EPBC Act.
- Queensland Water Act 2000 (Water Act):
    - *Water Resource (Fitzroy Basin) Plan 2011.*
    - *Environmental Protection (Underground Water Management) and Other Legislation Amendment Act 2016*.
- Queensland Environmental Protection Act 1994 (EP Act):
    - *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* (EPP Water).

The following sections summarise Commonwealth and Queensland groundwater legislation and policy relevant to the Project.

2.1.1 Commonwealth Environment Protection and Biodiversity Act 1999

The EPBC Act is administered by the Commonwealth Department of Agriculture, Water and the Environment (DAWE). The EPBC Act is designed to protect national environmental assets, known as Matters of National Environmental Significance (MNES). Under the 2013 amendment to the EPBC Act, potentially significant impacts on groundwater resources were included where they pertain to a coal seam gas (CSG) or large coal mine development, known as the 'water trigger'.

The Project has been declared a Controlled Action by the DAWE, with water resources being one of the controlling provisions. Due to the Bilateral Agreement between the Commonwealth of Australia and the State of Queensland (2004), only one impact assessment is required for a project that triggers an assessment under both the EPBC Act and State legislation. However, the impact assessment is reviewed separately by the State and Commonwealth. The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) is a statutory committee established under the EPBC Act that provides scientific advice to the Commonwealth Environment Minister and relevant State ministers. Guidelines have been developed in order to assist the IESC in reviewing CSG or large coal mining development proposals that are likely to have significant impacts on water resources. This includes completion of an independent peer review of numerical groundwater modelling in accordance with the *Australian Groundwater Modelling Guidelines* (Barnett et al., 2012). The IESC information requirements checklist is presented in **Table 2-1**, with details on where aspects have been addressed and documented within the Groundwater Assessment.

Table 2-1 IESC Information Requirements Checklist

Assessment Item - Description of Proposal	
Context and Conceptualisation	**Section in Report**
Provide a regional overview of the proposed project area including a description of the geological basin; coal resource; surface water catchments; groundwater systems; water-dependent assets; and past, present and reasonably foreseeable coal mining and CSG developments.	Section 3, Section 4 and Section 5
Describe the proposal's location, purpose, scale, duration, disturbance area, and the means by which it is likely to have a significant impact on water resources and water-dependent assets.	Section 1 and Section 7
Describe the statutory context, including information on the proposal's status within the regulatory assessment process and any applicable water management policies or regulations	Section 2
Describe how impacted water resources are currently being regulated under state or Commonwealth law, including whether there are any applicable standard conditions.	Section 2
Assessment Item – Risk Assessment	**Section in Report**
Identify and assess all potential environmental risks to water resources and water-related assets, and their possible impacts. In selecting a risk assessment approach consideration should be given to the complexity of the project, and the probability and potential consequences of risks.	Section 7
Incorporate causal mechanisms and pathways identified in the risk assessment in conceptual and numerical modelling. Use the results of these models to update the risk assessment.	Section 5.7, Section 6
Assess risks following the implementation of any proposed mitigation and management options to determine if these will reduce risks to an acceptable level based on the identified environmental objectives.	Section 8
The risk assessment should include an assessment of: • all potential cumulative impacts which could affect water resources and water-related assets, and mitigation and • management options which the proponent could implement to reduce these impacts.	Section 7, Section 8
Assessment Item – Groundwater	
Context and Conceptualisation	**Section in Report**
Describe and map geology at an appropriate level of horizontal and vertical resolution including: Definition of the geological sequence(s) in the area, with names and descriptions of the formations and accompanying surface geology, cross-sections and any relevant field data. Geological maps appropriately annotated with symbols that denote fault type, throw and the parts of sequences the faults intersect or displace.	Section 4
Provide data to demonstrate the varying depths to the hydrogeological units and associated standing water levels or potentiometric heads, including direction of groundwater flow, contour maps, and hydrographs. All boreholes used to provide this data should have been surveyed.	Section 4 and Section 5.3 and Appendix A2 and A4
Define and describe or characterise significant geological structures (e.g. faults, folds, intrusives) and associated fracturing in the area and their influence on groundwater – particularly groundwater flow, discharge or recharge. Site-specific studies (e.g. geophysical, coring/ wireline logging etc.) should give consideration to characterising and detailing the local stress regime and fault structure (e.g. damage zone size, open/closed along fault plane, presence of clay/shale smear, fault jogs or splays). Discussion on how this fits into the fault's potential influence on regional-scale groundwater conditions should also be included.	Section 5.2

Context and Conceptualisation	Section in Report
Provide hydrochemical (e.g. acidity/alkalinity, electrical conductivity, metals, and major ions) and environmental tracer (e.g. stable isotopes of water, tritium, helium, strontium isotopes, etc.) characterisation to identify sources of water, recharge rates, transit times in aquifers, connectivity between geological units and groundwater discharge locations.	Section 5.4 and Appendix A3
Provide site-specific values for hydraulic parameters (e.g. vertical and horizontal hydraulic conductivity and specific yield or specific storage characteristics including the data from which these parameters were derived) for each relevant hydrogeological unit. In situ observations of these parameters should be sufficient to characterise the heterogeneity of these properties for modelling.	Section 5.2
Describe the likely recharge, discharge and flow pathways for all hydrogeological units likely to be impacted by the proposed development.	Section 5.3
Provide time series level and water quality data representative of seasonal and climatic cycles.	Appendix B
Assess the frequency (and time lags if any), location, volume and direction of interactions between water resources, including surface water/groundwater connectivity, inter-aquifer connectivity and connectivity with sea water.	Section 5.3.5 and Section 5.6
Analytical and Numerical Modelling	**Section in Report**
Provide a detailed description of all analytical and/or numerical models used, and any methods and evidence (e.g. expert opinion, analogue sites) employed in addition to modelling.	Appendix B
Provide an explanation of the model conceptualisation of the hydrogeological system or systems, including multiple conceptual models if appropriate. Key assumptions and model limitations and any consequences should also be described.	Section 5.7
Undertaken groundwater modelling in accordance with the *Australian Groundwater Modelling Guidelines* (Barnett et al. 2012), including independent peer review.	Appendix B and Section 6
Consider a variety of boundary conditions across the model domain, including constant head or general head boundaries, river cells and drains, to enable a comparison of groundwater model outputs to seasonal field observations.	Appendix B
Calibrate models with adequate monitoring data, ideally with calibration targets related to model prediction (e.g. use baseflow calibration targets where predicting changes to baseflow).	Appendix B
Undertake sensitivity analysis and uncertainty analysis of boundary conditions and hydraulic and storage parameters, and justify the conditions applied in the final groundwater model (see Middlemis and Peeters 2018).	Appendix B
Describe each hydrogeological unit as incorporated in the groundwater model, including the thickness, storage and hydraulic characteristics, and linkages between units, if any.	Appendix B
Provide an assessment of the quality of, and risks and uncertainty inherent in, the data used to establish baseline conditions and in modelling, particularly with respect to predicted potential impact scenarios.	Appendix B
Describe the existing recharge/discharge pathways of the units and the changes that are predicted to occur upon commencement, throughout, and after completion of the proposed project.	Section 5.3 and Section 6.6
Undertake an uncertainty analysis of model construction, data, conceptualisation and predictions (see Middlemis and Peeters 2018).	Appendix B

Analytical and Numerical Modelling	Section in Report
Describe the various stages of the proposed project (construction, operation and rehabilitation) and their incorporation into the groundwater model. Provide predictions of water level and/or pressure declines and recovery in each hydrogeological unit for the life of the project and beyond, including surface contour maps for all hydrogeological units.	Section 6 and Appendix B
Provide a program for review and update of models as more data and information become available, including reporting requirements.	Appendix B
Identify the volumes of water predicted to be taken annually with an indication of the proportion supplied from each hydrogeological unit.	Section 6.2 and Appendix B
Provide information on the magnitude and time for maximum drawdown and post-development drawdown equilibrium to be reached.	Section 6 and Appendix B
Undertake model verification with past and/or existing site monitoring data.	Appendix B
Impacts to Water Resources and Water-Dependent Assets	**Section in Report**
Provide an assessment of the potential impacts of the proposal, including how impacts are predicted to change over time and any residual long-term impacts. Consider and describe: • any hydrogeological units that will be directly or indirectly dewatered or depressurised, including the extent of impact on hydrological interactions between water resources, surface water/groundwater connectivity, inter-aquifer connectivity and connectivity with sea water. • the effects of dewatering and depressurisation (including lateral effects) on water resources, water-dependent assets, groundwater, flow direction and surface topography, including resultant impacts on the groundwater balance. • the potential impacts on hydraulic and storage properties of hydrogeological units, including changes in storage, potential for physical transmission of water within and between units, and estimates of likelihood of leakage of contaminants through hydrogeological units. • the possible fracturing of and other damage to confining layers. • For each relevant hydrogeological unit, the proportional increase in groundwater use and impacts as a consequence of the proposed project, including an assessment of any consequential increase in demand for groundwater from towns or other industries resulting from associated population or economic growth due to the proposal.	Section 7
Describe the water resources and water-dependent assets that will be directly impacted by mining or CSG operations, including hydrogeological units that will be exposed/partially removed by open cut mining and/or underground mining.	Section 7
For each potentially impacted water resource, provide a clear description of the impact to the resource, the resultant impact to any water-dependent assets dependent on the resource, and the consequence or significance of the impact.	Section 7
Describe existing water quality guidelines, environmental flow objectives and other requirements (e.g. water planning rules) for the groundwater basin(s) within which the development proposal is based.	Section 2 and Section 5.4
Provide an assessment of the cumulative impact of the proposal on groundwater when all developments (past, present and/or reasonably foreseeable) are considered in combination.	Section 6.5
Describe proposed mitigation and management actions for each significant impact identified, including any proposed mitigation or offset measures for long-term impacts post mining.	Section 8
Provide a description and assessment of the adequacy of proposed measures to prevent/minimise impacts on water resources and water-dependent assets.	Section 8

Data and Monitoring	Section in Report
Provide sufficient data on physical aquifer parameters and hydrogeochemistry to establish pre-development conditions, including fluctuations in groundwater levels at time intervals relevant to aquifer processes.	Section 5.2 and Section 5.3
Provide long-term groundwater monitoring data, including a comprehensive assessment of all relevant chemical parameters to inform changes in groundwater quality and detect potential contamination events.	Section 5.4
Develop and describe a robust groundwater monitoring program using dedicated groundwater monitoring wells – including nested arrays where there may be connectivity between hydrogeological units – and targeting specific aquifers, providing an understanding of the groundwater regime, recharge and discharge processes and identifying changes over time.	Section 5.1
Ensure water quality monitoring complies with relevant National Water Quality Management Strategy (NWQMS) guidelines (ANZG 2018) and relevant legislated state protocols (e.g. QLD Government 2013).	Section 8.2.1
Develop and describe proposed targeted field programs to address key areas of uncertainty, such as the hydraulic connectivity between geological formations, the sources of groundwater sustaining GDEs, the hydraulic properties of significant faults, fracture networks and aquitards in the impacted system, etc., where appropriate.	Section 5.1.1, Section 5.2, Section 5.5.1 and Section 5.6.1
Assessment Item – Water-dependent assets	
Context and conceptualisation	**Section in Report**
Identify water-dependent assets, including: water-dependent fauna and flora and provide surveys of habitat, flora and fauna (including stygofauna) (see Doody et al. 2019). public health, recreation, amenity, Indigenous, tourism or agricultural values for each water resource.	Section 5.5 and Section 5.6
Estimate the ecological water requirements of identified GDEs and other water-dependent assets (see Doody et al. 2019).	Section 5.6
Identify the hydrogeological units on which any identified GDEs are dependent (see Doody et al. 2019).	Section 5.6.1
Identify GDEs in accordance with the method outlined by Eamus et al. (2006). Information from the GDE Toolbox (Richardson et al. 2011) and GDE Atlas (CoA 2017a) may assist in identification of GDEs (see Doody et al. 2019).	Section 5.6
Provide an outline of the water-dependent assets and associated environmental objectives and the modelling approach to assess impacts to the assets.	Section 6 and Section 7
Describe the conceptualisation and rationale for likely water-dependence, impact pathways, tolerance and resilience of water-dependent assets. Examples of ecological conceptual models can be found in Commonwealth of Australia (2015).	Section 5.6
Describe the process employed to determine water quality and quantity triggers and impact thresholds for water-dependent assets (e.g. threshold at which a significant impact on an asset may occur).	Section 7
Impacts, risk assessment and management of risks	**Section in Report**
Provide an assessment of direct and indirect impacts on water-dependent assets, including ecological assets such as flora and fauna dependent on surface water and groundwater, springs and other GDEs (see Doody et al. 2019).	Section 7.2 and Terrestrial Ecology Assessment

Impacts, risk assessment and management of risks	Section in Report
Provide estimates of the volume, beneficial uses and impact of operational discharges of water (particularly saline water), including potential emergency discharges due to unusual events, on water-dependent assets and ecological processes.	Surface Water and Flooding Assessment
Describe the potential range of drawdown at each affected bore, and clearly articulate of the scale of impacts to other water users.	Section 7.2
Assess the overall level of risk to water-dependent assets through combining probability of occurrence with severity of impact.	Section 7
Indicate the vulnerability to contamination (e.g. from salt production and salinity) and the likely impacts of contamination on the identified water-dependent assets and ecological processes.	Section 7.4
Identify the proposed acceptable level of impact for each water-dependent asset based on leading-practice science and site-specific data, and ideally developed in conjunction with stakeholders.	Section 7.2
Identify and consider landscape modifications (e.g. voids, on-site earthworks, and roadway and pipeline networks) and their potential effects on surface water flow, erosion and habitat fragmentation of water-dependent species and communities.	Section 8
Propose mitigation actions for each identified impact, including a description of the adequacy of the proposed measures and how these will be assessed.	Section 8
Data and Monitoring	**Section in Report**
Identify an appropriate sampling frequency and spatial coverage of monitoring sites to establish pre-development (baseline) conditions, and test potential responses to impacts of the proposal (see Doody et al. 2019).	Section 8.2
Develop and describe a monitoring program that identifies impacts, evaluates the effectiveness of impact prevention or mitigation strategies, measures trends in ecological responses and detects whether ecological responses are within identified thresholds of acceptable change (see Doody et al. 2019).	Section 8.2.1
Consider concurrent baseline monitoring from unimpacted control and reference sites to distinguish impacts from background variation in the region (e.g. BACI design, see Doody et al. 2019).	Section 8.2
Describe the proposed process for regular reporting, review and revisions to the monitoring program.	Section 8.2.3
Ensure ecological monitoring complies with relevant state or national monitoring guidelines (e.g. the DSITI guideline for sampling stygofauna (QLD Government 2015)).	Terrestrial Ecology Assessment
Assessment Item – Water and salt balance, and water quality	**Section in Report**
Provide a quantitative site water balance model describing the total water supply and demand under a range of rainfall conditions and allocation of water for mining activities (e.g. dust suppression, coal washing etc.), including all sources and uses.	Surface Water and Flooding Assessment
Provide estimates of the quality and quantity of operational discharges under dry, median and wet conditions, potential emergency discharges due to unusual events and the likely impacts on water-dependent assets.	Surface Water and Flooding Assessment
Describe the water requirements and on-site water management infrastructure, including modelling to demonstrate adequacy under a range of potential climatic conditions.	Surface Water and Flooding Assessment
Provide salt balance modelling that includes stores and the movement of salt between stores, and takes into account seasonal and long-term variation.	N/A

Assessment Item – Cumulative Impacts	
Context and conceptualisation	**Section in Report**
Provide cumulative impact analysis with sufficient geographic and temporal boundaries to include all potentially significant water-related impacts.	Section 6
Consider all past, present and reasonably foreseeable actions, including development proposals, programs and policies that are likely to impact on the water resources of concern in the cumulative impact analysis. Where a proposed project is located within the area of a bioregional assessment consider the results of the bioregional assessment.	Appendix B
Impacts	**Section in Report**
Provide an assessment of the condition of affected water resources which includes: • identification of all water resources likely to be cumulatively impacted by the proposed development • a description of the current condition and quality of water resources and information on condition trends • identification of ecological characteristics, processes, conditions, trends and values of water resources • adequate water and salt balances, and • identification of potential thresholds for each water resource and its likely response to change and capacity to withstand adverse impacts (e.g. altered water quality, drawdown).	Section 5 and Section 7
Assess the cumulative impacts to water resources considering: • the full extent of potential impacts from the proposed project, (including whether there are alternative options for infrastructure and mine configurations which could reduce impacts), and encompassing all linkages, including both direct and indirect links, operating upstream, downstream, vertically and laterally • all stages of the development, including exploration, operations and post closure/decommissioning • appropriately robust, repeatable and transparent methods • the likely spatial magnitude and timeframe over which impacts will occur, and significance of cumulative impacts, and • opportunities to work with other water users to avoid, minimise or mitigate potential cumulative impacts.	Section 7
Mitigation, monitoring and management	Section in Report
Identify modifications or alternatives to avoid, minimise or mitigate potential cumulative impacts. Evidence of the likely success of these measures (e.g. case studies) should be provided.	Section 8
Identify cumulative impact environmental objectives.	Section 8
Identify measures to detect and monitor cumulative impacts, pre and post development, and assess the success of mitigation strategies.	Section 8
Describe appropriate reporting mechanisms.	Section 8
Propose adaptive management measures and management responses.	Section 8
Assessment Item – Final landform and voids – coal mines	**Section in Report**
Identify and consider landscape modifications (e.g. voids, on-site earthworks, and roadway and pipeline networks) and their potential effects on surface water flow, erosion, sedimentation and habitat fragmentation of water-dependent species and communities.	Surface Water and Flooding Assessment

Assessment Item – Final landform and voids – coal mines	Section in Report
Assess the adequacy of modelling, including surface water and groundwater quantity and quality, lake behaviour, timeframes and calibration.	Appendix B
Provide an evaluation of stability of void slopes where failure during extreme events or over the long term (for example due to aquifer recovery causing geological heave and landform failure) may have implications for water quality.	Section 6 of the EIS Main Text
Provide an assessment of the long-term impacts to water resources and water-dependent assets posed by various options for the final landform design, including complete or partial backfilling of mining voids. Assessment of the final landform for which approval is being sought should consider: • groundwater behaviour – sink or lateral flow from void. • water level recovery – rate, depth, and stabilisation point (e.g. timeframe and level in relation to existing groundwater level, surface elevation). • seepage – geochemistry and potential impacts. • long-term water quality, including salinity, pH, metals and toxicity. • measures to prevent migration of void water off-site. For other final landform options considered sufficient detail of potential impacts should be provided to clearly justify the proposed option.	Section 6.6 and Section 7.4
Evaluate mitigating inflows of saline groundwater by planning for partial backfilling of final voids.	Section 7.4.3
Assess the probability of overtopping of final voids with variable climate extremes, and management mitigations.	Section 6.6
Assessment Item – Acid-forming materials and other contaminants of concern	**Section in Report**
Identify the presence and potential exposure of acid-sulphate soils (including oxidation from groundwater drawdown).	Geochemistry Assessment
Describe handling and storage plans for acid-forming material (co-disposal, tailings dam, and encapsulation).	Geochemistry Assessment
Identify the presence and volume of potentially acid-forming waste rock, fine-grained amorphous sulphide minerals and coal reject/tailings material and exposure pathways.	Section 5.4.4
Assess the potential impact to water-dependent assets, taking into account dilution factors, and including solute transport modelling where relevant, representative and statistically valid sampling, and appropriate analytical techniques.	Section 5.4.4
Identify other sources of contaminants, such as high metal concentrations in groundwater, leachate generation potential and seepage paths.	Section 7.4
Describe proposed measures to prevent/minimise impacts on water resources, water users and water-dependent ecosystems and species.	Section 8

2.1.2 Queensland Water Act 2000

The Water Act, supported by the subordinate Water Regulation 2016, is the primary legislation regulating groundwater resources in Queensland. The purpose of the Water Act is to advance sustainable management and efficient use of water resources by establishing a system for planning, allocation and use of water.

Management framework relevant to the Project

The Water Act is enacted under a framework of catchment specific Water Resource Plans (WRPs). A WRP provides a management framework for water resources in a plan area, and includes outcomes, objectives and strategies for maintaining balanced and sustainable water use in that area. Resource Operations Plans (ROPs) implement the outcomes and strategies of WRPs. Groundwater Management Areas (GMAs) and their component groundwater units are defined under WRPs. Authorisation is required to take non-associated groundwater from a regulated GMA or groundwater unit for specified purposes. The specified purposes are defined under a WRP, the Water Regulation 2016 or a local water management policy.

Water resources within the Project Area are captured under the Water Plan (Fitzroy Basin) 2011. The plan covers surface water (zone WQ1301) associated with Isaac River, and groundwaters (zone WQ1310 – Fitzroy Basin groundwaters).

As part of the Project, Whitehaven is proposing to exercise underground water rights during the period in which resource activities would be carried out within the Project Area. The Project may interact with groundwater within the Isaac Connors Groundwater Management Area (GMA – Zone 34) of the Fitzroy Basin under the Water Plan (Fitzroy Basin) 2011. This relates to both Groundwater Unit 1 (containing aquifers of the Quaternary alluvium) and Groundwater Unit 2 (sub-artesian aquifers) as shown in **Figure 2-1**. The extent of Groundwater Unit 1 (Isaac Connors Alluvium Groundwater Sub-area) is based on the mapped extent of Quaternary alluvium, which is mapped within the vicinity of the Project. As discussed further in **Section 4.2**, the extent of alluvium has been refined based on information specific to the Study Area.

Water Act declared watercourses and drainage

The Water Act includes criteria for determining watercourses that require authorisation under the Water Act to take water, interfere with the flow of water, take quarry material or excavate and place fill in a watercourse. The Water Act also includes criteria for drainage features that may require authorisation to take or interfere with overland flow. In the vicinity of the Project Area, the Isaac River is defined as a watercourse under the Water Act criteria, and several small tributaries of the Isaac River that traverse the Project Area are defined as drainage features (with one defined as a watercourse).

These declared watercourses and drainage features may be relevant to the Groundwater Assessment for the Project if there is interaction between the surface water-groundwater systems.

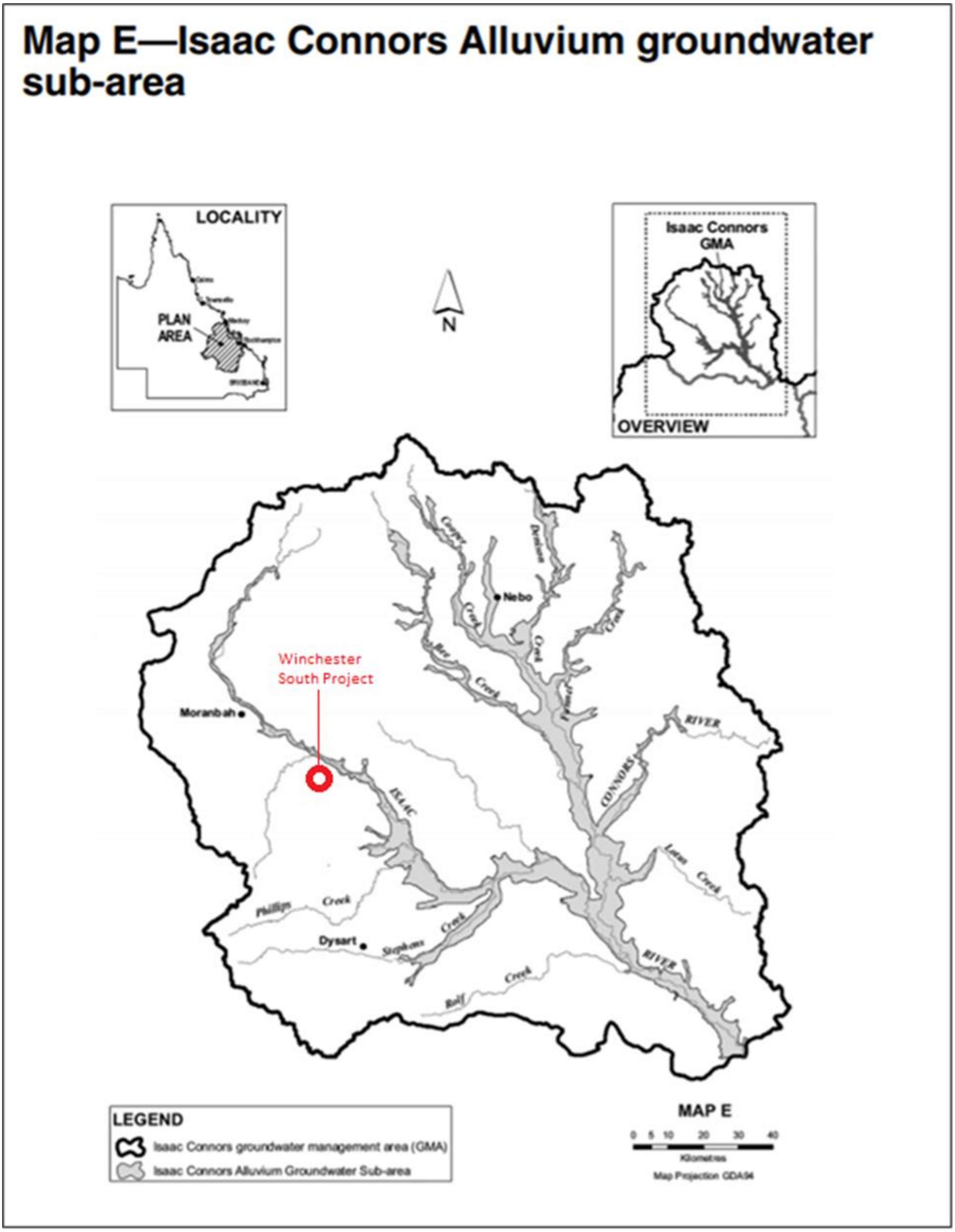


Figure 2-1 Location of the Project within the Isaac Connors GMA (Water Plan (Fitzroy Basin, Map E)

2.1.3 Environmental Protection (Water and Wetland Biodiversity) Policy 2019

The EPP Water aims to achieve objectives set out by the EP Act and applies to all waters of Queensland. EPP Water provides a framework to protect and/or enhance the suitability of Queensland waters for various beneficial uses by:

- Identifying environmental values and management goals for Queensland waters;
- Providing state water quality guidelines and water quality objectives (WQOs) to enhance or protect the environmental values;
- Providing a framework for making consistent, equitable and informed decisions; and
- Monitoring and reporting on the condition of Queensland waters.

Groundwater resources within the vicinity of the Project are scheduled under the EPP Water as Isaac Groundwaters of the Isaac River Sub-basin of the Fitzroy Basin water plan (WQ1301). The legislated environmental values (EVs) for these groundwaters are:

- Physical, chemical and biological integrity of the groundwaters to support aquatic ecosystems;
- Human use EVs:
    - Suitability of water supply for irrigation;
    - Farm water supply/use;
    - Stock watering;
    - Primary recreation;
    - Drinking water supply; and
    - Cultural and spiritual values.

The EPP Water also provides limited WQOs for underground aquatic ecosystem protection in Fitzroy Basin groundwaters. These WQOs provided in the EPP Water are classified by groundwater depth and regional chemistry zone.

Surface water resources within the vicinity of the Project are scheduled under the EPP Water as:

- Waters of the Isaac northern tributaries of the Isaac River Sub-basin of the Fitzroy Basin water plan (WQ1301); and
- Waters of the Isaac and lower Connors River main channel of the Isaac River Sub-basin of the Fitzroy Basin water plan (WQ1301).

The legislated environmental values (EVs) for these surface waters are:

- Physical, chemical and biological integrity of the groundwaters to support aquatic ecosystems;
- Human use EVs:
    - Suitability of water supply for irrigation;
    - Farm water supply/use;
    - Stock watering;
    - Human consumption;

- Primary recreation;
- Secondary recreation;
- Visual recreation;
- Drinking water supply;
- Industrial water supply; and
- Cultural and spiritual values.

The surface water WQOs for both the Isaac northern tributaries of the Isaac River Sub-basin of the Fitzroy Basin water plan and the Isaac and lower Connors River main channel of the Isaac River Sub-basin of the Fitzroy Basin water plan (WQ1301) may be relevant to the Groundwater Assessment for the Project if there is interaction between the surface water-groundwater systems.

2.1.4 Environmental Authority

Under the EP Act, an EIS assessment is required as part of the application for Environmental Authority (EA) to undertake an environmentally relevant activity. The EIS process assesses the potential environmental impact of the Project, and how impacts should be avoided, minimised and managed. The EIS also informs subsequent approval decisions under the EP Act and other relevant legislation. The Department of Environment and Science (DES) is responsible for the administration and delivery of EIS assessments.

In accordance with the EP Act, Project specific Terms of Reference (TOR) were issued by the Department of State Development in September 2019. Groundwater specific items are presented in **Table 2-2**, along with details on where the item has been addressed within the report.

In addition, minimum reporting requirements for groundwater impact assessments are outlined within the *Guideline Requirements for site-specific and amendment applications – underground water rights* (DES, 2016). A summary of the guideline requirements and where they have been addressed within this report is provided in **Table 2-3.**

Table 2-2 Project Terms of Reference (groundwater related)

Section in TOR	Detail	Section in Report
11.36	Describe the water related environmental values and describe the existing surface water and groundwater quality regime within the study area in terms of water body interaction and high/low freshwater flows. Describe the baseline condition of the existing waters in, upstream and downstream of the site and describe the water quality requirements of existing and potential water users in areas potentially affected by the proposed project.	**Section 5** and **Appendix A**
11.37	With reference to the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (EPP (Water and Wetland Biodiversity)), section 9 of the EP Act, Schedule 8 of the EP Regulation and SPP State Interest Guideline – Water Quality and other guidelines (see Appendix 1 of the project TOR), identify the environmental values of surface water (including wetlands) and groundwater within the project site and surrounding area, including immediately downstream that may be affected by the project, including any human uses of the water and any cultural values.	**Section 5** and **Appendix A**
11.38	At an appropriate scale, detail the chemical, physical and biological characteristics of surface waters and groundwater within the area that may be affected by the project, including within and adjacent to the site. Water quality parameters should be appropriate to the downstream, and upstream uses and environmental values that may be affected. Include a description of water quality variability within the study area associated with climatic and seasonal factors, variability of freshwater flows and extreme events using suitable reference locations and sufficient data to adequately establish baseline condition.	**Section 5**
11.39	The assessment of impacts on water is to be in accordance with DES guideline Application requirements for activities with impacts to water (ESR/2015/1837) and DES EIS information guideline for an environmental statement - water (or updates as they become available).	**Section 5**
11.40	State how any proposed exercise of underground water rights for the life of the project would be carried out on site and describe the aquifers affected or likely to be affected; movement of underground water to and from the aquifer; area where the water level is expected to decline; the predicted quantities of water to be taken or interfered with; the environmental values that will be affected; and assessment of cumulative impacts to the quality of the groundwater.	**Section 6**
11.41	Identify the predicted quantity and quality (including location, timing and duration) of all potential discharges of water and wastewater sewage by the Project, whether as point sources (such as controlled and uncontrolled discharges from regulated dams) or diffuse sources (such as seepage from waste rock dumps/waste management areas or irrigation to land of treated sewage effluent). Assess the potential impacts of any discharges on the quality and quantity of receiving waters (including groundwater) taking into consideration the assimilative capacity of the receiving environment and the practices and procedures that would be used to avoid or minimise impacts. Refer to DES Receiving environment monitoring program guideline for use with environmentally relevant activities under the EP Act.	**Section 7.4**
11.42	Describe the cumulative impacts of the proposed project, in conjunction with existing development and possible future development (as described by approved plans and existing project approvals), to water quality.	**Section 6.5**

Section in TOR	Detail	Section in Report
11.44	Describe how the achievement of the water quality objectives would be monitored, audited, reported, and how corrective/ preventative actions would be managed in accordance with EPP (Water and Wetland Biodiversity).	**Section 8.2.3**
11.45	Describe the proposed management of existing, altered and/or constructed waterbodies including any watercourse, waterway, lake or spring on the project site to maintain water quality. Describe all methods and management to avoid and minimise impacts occurring to groundwater.	**Section 7.4.2**
11.48	Describe the water related environmental values and describe the existing surface water and groundwater resources regime within the study area and the adjoining waterways in terms of water levels, discharges and flows. Describe existing and potential users of water in areas potentially affected by the proposed project, including municipal, agricultural, industrial, mining, recreational and environmental uses of water.	**Section 5**
11.50	Identify the location and source aquifer of all authorised groundwater extraction bores in areas potentially impacted by the project.	**Section 5.5**
11.51	The assessment of impacts on water is to be in accordance with DES guideline Application requirements for activities with impacts to water (ESR/2015/1837) (or updates as they become available) (see Appendix 1 of the Project TOR).	**Section 6 and Section 7**
11.52	Provide details of proposed monitoring, impoundment, extraction, discharge, injection, use or loss of surface water or groundwater (including volumes and rates).	**Section 8.2**
11.57	Develop hydrological models as necessary to describe the inputs, movements, exchanges and outputs of all significant quantities and resources of surface water and groundwater that may be affected by the project. The models should address the range of climatic conditions that may be experienced at the site throughout all phases of the project, and adequately assess the potential cumulative impacts of the project on water resources including to the post-decommissioning phase. The models should include a site water balance (including any voids) to determine the upper and lower bounds of future water levels after mine closure, and the calculated trends of water quality in the voids over time. This should enable a description of the project’s impacts at the local scale and in a regional context including proposed: (a) surface waters: i. changes in flow regimes from diversions, water take and discharges ii. alterations to riparian vegetation and bank and channel morphology iii. direct and indirect impacts arising from the project iv. management of mine affected water. (b) groundwaters: i. nature, type of geology and stratigraphy and depth to and thickness of the aquifers; their transmissivity; and value as water supply sources ii. aquifer types (confined, unconfined, karst) iii. flow directions iv. draw-down, recharge and discharge processes v. yields and aquifer/hydraulic parameters through field tests vi. groundwater-surface water interactions, and potential impacts to local streams, the Isaac River, the Great Barrier Reef and any other aquifers and surface water.	**Sections 4**, **5**, **6** and **7** and **Appendix B**

Section in TOR	Detail	Section in Report
	vii. quality, quantity and significance of groundwater in the proposed project area and any surrounding area including seasonal variations of groundwater levels.	
11.61	Describe the cumulative impacts of the proposed project, in conjunction with existing development and possible future development (as described by approved plans and existing project approvals), to water resources, including management of impacts on underground water rights under the Water Act 2000.	**Section 6.5**
11.63	Describe measures that would be used to avoid, minimise or mitigate any impacts on surface water and groundwater resources.	**Section 8**
11.64	Describe how the achievement of the water resources objectives would be monitored, audited, reported, and how corrective/ preventative actions would be managed.	**Section 8**
11.65	Provide a policy outline of compensation, mitigation and management measures where impacts are identified.	**Section 8.2**
11.179	The National Partnership Agreement on Coal Seam Gas and Large Coal Mining, to which Queensland is a signatory, specifies that all coal seam gas and large coal mining proposals that are likely to have a significant impact on water resources are to be referred to the Independent Expert Scientific Committee (IESC) for advice	Project referred to IESC
11.180	In relation to the proposed mine and access road (EPBC 2019/8460), the MNES chapter must provide details on the use and interference with the current state of groundwater and surface water in the region as well as any use of these resources.	**Section 5**
11.181	The MNES chapter is to describe and assess the impacts to water resources giving consideration to the Significant Impact Guidelines 1.3: Coal seam gas and large coal mining developments – impacts on water resources (see Appendix 1 of the Project TOR).	**Section 7**
11.182	The MNES chapter is to address the information requirements contained in the Information guidelines for proponents preparing coal seam gas and large coal mining development proposals and provide a cross-reference table to identify where each component of the guidelines has been addressed (see Appendix 1 of the Project TOR). Explanatory notes on the IESC information guidelines may assist in addressing the information requirements: (a) Information Guidelines explanatory note - Uncertainty analysis–Guidance for groundwater modelling within a risk management framework; (b) Information Guidelines explanatory note - Assessing groundwater-dependent ecosystems; and (c) Information Guidelines explanatory note - Deriving site-specific guideline values for physico-chemical parameters and toxicants.	**Section 5** and **Appendix B**

Table 2-3 Requirement for Site Specific and Amendment Applications – Underground Water Rights

	Detail	Section in Report
Part A	A statement that the applicant proposes to exercise underground water rights.	**Section 2**
Part B	A description of the area/s in which underground water rights are proposed to be exercised.	**Section 1**
Part C	A description of the aquifer/s affected or likely to be affected.	
	• Aquifer type (confined, unconfined, fractured etc)	**Section 5.3**
	• Geology/ stratigraphy for each aquifer	**Section 4**
	• Depth to and thickness of the aquifers	**Section 4**
	• Physical integrity of the aquifer, fluvial processes and morphology	**Section 5**
	• Depth to water level and seasonal changes in levels	**Section 5** and **Appendix A**
	• Hydrogeological cross sections	**Section 5.6.4**
	• Maps (spatial extent)	**Section 4** and **Section 5.3**
Part D	An analysis of the movement of underground water to and from the aquifer.	
	• Inputs (i.e. recharge) and outputs (i.e. baseflow and abstraction)	**Section 5.3**
	• Underground water elevations (i.e. mapped groundwater flow directions)	**Section 5.3**
	• Connectivity between aquifers and hydraulic properties	**Section 5.2**
	• Preferential flow pathways (i.e. faults)	**Section 5.3**
	• Springs	**Section 5.6**
Part E	A description of the area of the aquifer where the water level is predicted to decline because of the exercise of underground water rights.	**Section 6**
	Predictions should: • Be made for the life of the resource project and for post resource tenure closure; • Be made about the timing, spatial extent and magnitude of maximum water level declines in affected aquifers; • Be made about the timing and magnitude of groundwater level equilibrium in affected aquifers.	**Section 6** and **Appendix B**
	Produce potentiometric contour maps showing maximum predicted water level decline for each affected aquifer.	**Section 6**
	Modelling methodology, including: • Model type (e.g. numerical or analytical); • Modelling platform; • Model inputs; • Model boundary conditions; • Model assumptions and limitations;	**Appendix B**

	Detail	Section in Report
	• Sensitivity analysis and calibration results.	
Part F	The predicted quantities of water to be taken or interfered with because of the exercise of underground water rights.	**Section 6.2**
	Details on the methodology used for measuring extraction volumes and developing the extraction schedule.	**Appendix B**
Part G	Information on predicted impacts to the quality of groundwater that will, or may, happen because of the exercise of underground water rights.	**Section 7.4**
	Identify the quality of the groundwater prior to the resource activity commencing.	**Section 5.4**
	Explain the variation of chemical concentrations as a result of chemical reactions over the life of the project due to the exercise of underground water rights (i.e. changes in salinity and concentration of dissolved gas).	**Section 5.4.4**
	Estimate extent and likelihood of groundwater quality impacts, with justification based on potential sources of contamination.	**Section 7.4**
Part H	Identifying and describing environmental values: • Information on the environmental values that will, or may, be affected by the exercise of underground water rights; • Describe and define environmental value of aquifers, presenting available raw data used. Document groundwater use, including details on operating bores within the areas predicted to be affected by the exercise of underground water rights.	**Section 5** and **Appendix A**
	Nature and extent of the impacts on the environmental values (risk assessment): • The magnitude, relative size or actual extent of any impact in relation to the environmental value being affected; • The vulnerability or resilience of the environmental value (severity and duration) Uncertainty of impacts and any assumptions.	**Section 6** and **Appendix B**
	Surface subsidence impacts.	Not applicable
Part I	Information on strategies for avoiding, mitigating or managing the predicted impacts on the environmental values or predicted impacts on the quality of groundwater. Strategies for avoiding, mitigating and managing the predicted impacts on both environmental values and predicted changes in groundwater quality should include: • Objectives which define the outcomes that are intended to be achieved (i.e. avoiding, mitigating and managing the predicted impacts) and a description of unavoidable impacts to environmental values; • Measures (specific methods/procedures/tools) to be implemented to demonstrate how the objectives will be achieved; • Indicators relevant to protection of the environmental values (i.e. indicators are the values that are to be measured to gauge whether the objectives are being achieved and are used to are to be used in auditing the performance of measures); • A program for monitoring the indicators (see EP Act Guideline for requirements); • A reporting program which includes triggers for the review of the strategies, and identifies additional data, assessment, analysis and reporting requirements.	**Section 8**

2.1.5 Relevant Guidelines

There are several available guidelines designed to assist project proponents to meet the relevant legislative requirements in order to complete a Groundwater Assessment for coal mining proposals such as the Project. These guidelines are:

- DES (2016) - *Requirements for site-specific and amendment applications—underground water rights - EP Act;*
- DES (2017) - *Underground water impact reports and final reports - Water Act;*
- DES (2021a) – *Application requirements for activities with impacts to water (ESR/2015/1837) (Version 4.04);*
- IESC (2018a) - *Information guidelines for proponents preparing coal seam gas and large coal mining development proposals – EPBC Act;*
- IESC (2018b) - *Information Guidelines explanatory note. Uncertainty analysis—Guidance for groundwater modelling within a risk management framework – EPBC Act;*
- Doody et al. (2019) - *Information Guidelines Explanatory Note. Assessing groundwater-dependent ecosystems – EPBC Act;* and
- Barnett et al. (2012) - *Australian Groundwater Modelling Guidelines*.

3 Existing Conditions

3.1 Climate

The climate at the Study Area is sub-tropical with higher temperatures, higher rainfall and higher evaporation occurring over the summer months (December to February). The closest BoM weather station is located at Iffley (station 34100), 16 km to the south-east of the Project. The Iffley station has been in operation since 1998, however, there are several instances of data gaps in the monitoring record. Approximately 50 km south-east of the Project at Carfax (station 34016) a weather station has been operating since 1962. The Carfax station has a continuous record with only a few occasional months of missing data. A more recent station at Moranbah Airport (station 34035, 26 km north-west of the Project) has been open since 2012. **Table 3-1** provides the details of the nearby operational weather stations.

Table 3-1 Operational BoM Weather Stations near the Project

Name	Site Number	Date Commenced	Easting (GDA94 z55)	Northing (GDA94 z55)	Elevation (mAHD)	Operational Status	Distance from Project
Iffley	34100	1998	647356	7539801	173	Open	16 km southeast
Carfax	34016	1962	673063	7515595	128	Open	50 km southeast
Moranbah Airport	34035	2012	610999	7559653	232	Open	26 km northwest

mAHD = metres Australian Height Datum.

SILO Grid point data (Latitude: -22.20, Longitude: 148.30) was used to assess long-term rainfall trends in the vicinity of the Project. This dataset is interpolated from quality checked observational time-series data collected at nearby stations by the BoM. Data from January 1889 until December 2019 was used for assessing the long-term rainfall trends in the vicinity of the Project. From this data, the average annual site rainfall is 577 millimetres (mm). The two highest annual rainfalls were recorded for the years 1890 and 2010, with annual rainfalls of 1250 mm and 1122 mm, respectively. The minimum annual rainfall occurred in 1902 with 222.2 mm. Monthly averages for the three stations discussed as well as the SILO grid point are listed in **Table 3-2**.

Table 3-2 Average Monthly Rainfall

Rainfall (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Carfax	110.9	95.3	62.5	31.8	35.6	28.0	22.3	22.5	18.5	35.7	55.3	95.2	615.9
Iffley	112.5	87.3	62.0	40.3	15.8	40.6	18.9	39.1	13.8	33.9	55.8	90.9	560.7
Moranbah Airport	86.2	103.6	97.7	26.2	27.4	17.3	29.5	8.3	7.4	24.7	42.5	56.5	529.3
SILO Grid Point Data	108	96	65	30	27	30	21	19	16	31	50	84	577

Source: http://www.bom.gov.au/climate/data/index.shtml

Note: SILO Grid point data coordinates are Latitude: -22.20 and Longitude: 148.30.

Rainfall trends for Carfax over the past century are indicated by analysis of the residual mass curve (RMC, or cumulative deviation from the mean) (**Figure 3-1**). Positive gradients on this curve (rising limbs) confirm wetter conditions than normal, while negative gradients (falling limbs) indicate dry conditions. Average rainfall conditions are inferred during periods of stable residual mass. **Figure 3-1** shows that, over the past 50 years, the wettest periods occurred during 1973-1979, 2007-2008 and in 2010. The driest periods were 1963-1970, 1991 1998 and 2001-2006. As shown by the declining trend in the RMC, the Project Area is currently experiencing drier than average conditions.

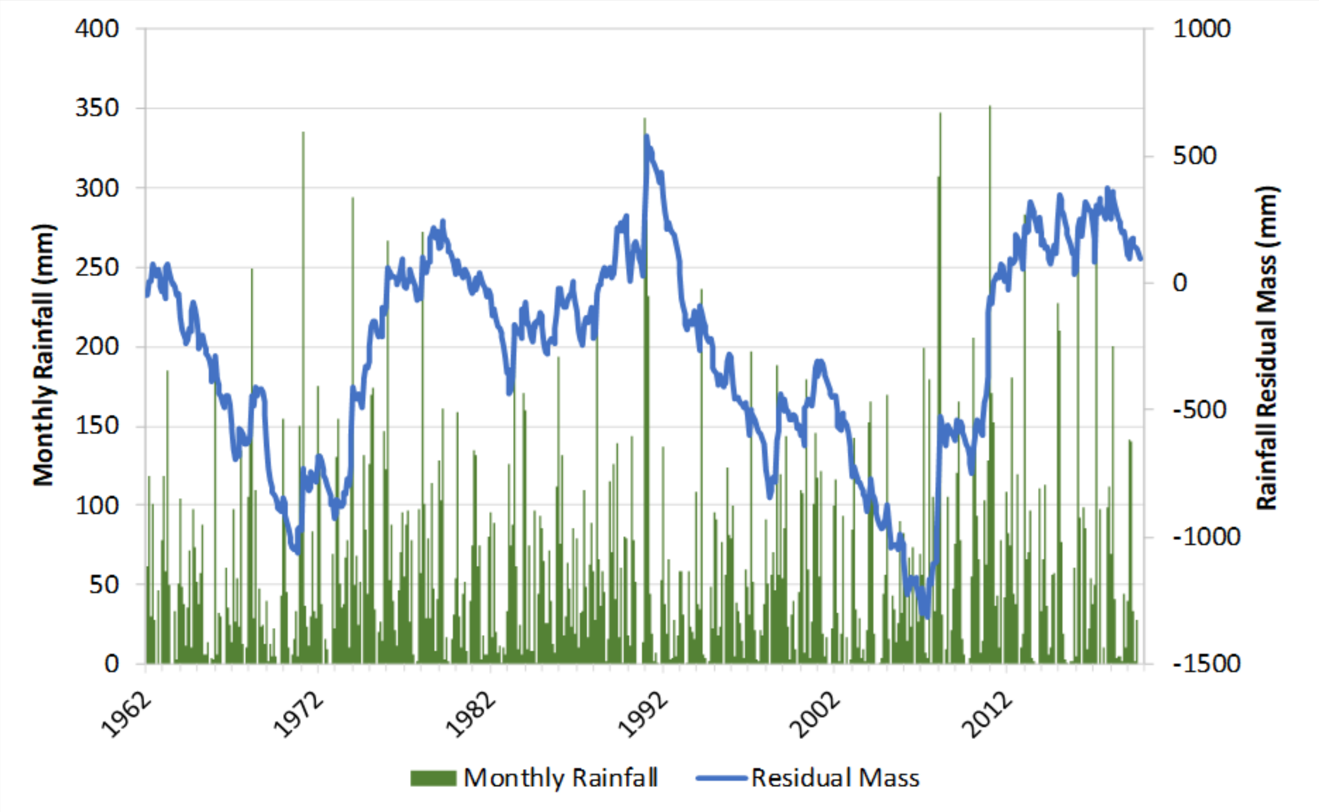


Figure 3-1 Long-term Monthly Rainfall and Rainfall Residual Mass Curve at Carfax (Station 34016)

The RMC performs an additional service: if rainfall recharge is a significant source of groundwater, the temporal variability in recorded groundwater levels can be expected to mimic the pattern of this curve. That is, natural fluctuations in the groundwater table result from temporal changes in rainfall recharge to groundwater systems. Typically, changes in groundwater elevation reflect the deviation between the long-term monthly (or yearly) average rainfall, and the actual rainfall, illustrated by the rainfall RMC. Groundwater hydrographs showing the relationship between rainfall and groundwater levels are assessed in **Section 5**.

Actual and potential evapotranspiration (ET) have been taken from BoM's Australia wide interpolation dataset at the locations of the weather stations (BoM, 2020a). The potential ET in the district is about 1600 mm/year according to BoM (2005) (**Table 3-3**). The definition of potential ET is: "… *the ET that would take place, under the condition of unlimited water supply, from an area so large that the effects of any upwind boundary transitions are negligible and local variations are integrated to an areal average"*. For example, this represents the ET which would occur over a very large wetland or large irrigated area, with a never-ending water inflow. Further to this, where the water table approaches the ground surface, ET can also approach the potential ET value.

Table 3-3 Average Monthly Potential Evapotranspiration

PE (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Carfax	187	155	170	124	96	80	81	100	126	172	189	188	1668
Iffley	181	151	167	122	96	80	81	99	125	172	188	184	1646
Moranbah Airport	175	147	163	120	95	80	81	98	124	171	186	179	1619

PE = Potential Evapotranspiration.

The actual ET in the district is about 600 mm/year according to BoM (2005) (**Table 3-4**). The definition for actual ET is: *"... the ET that actually takes place, under the condition of existing water supply, from an area so large that the effects of any upwind boundary transitions are negligible and local variations are integrated to an areal average"*. For example, this represents the predicted ET that is occurring over a large area of land under the existing (mean) rainfall conditions.

Table 3-4 Average Monthly Actual Evapotranspiration

AE (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Carfax	72	64	70	45	33	29	29	29	34	55	67	67	594
Iffley	70	65	71	46	35	31	30	29	33	54	67	66	597
Moranbah Airport	63	62	65	43	33	29	27	25	28	47	62	60	544

AE = Actual Evapotranspiration.

Figure 3-2 shows that the average potential monthly ET exceeds the average monthly rainfall over the entire year, often by more than double. Average actual ET is equal to or slightly less than average rainfall for all months except during the "wet" season between December and March, when the average rainfall exceeds the average actual ET.

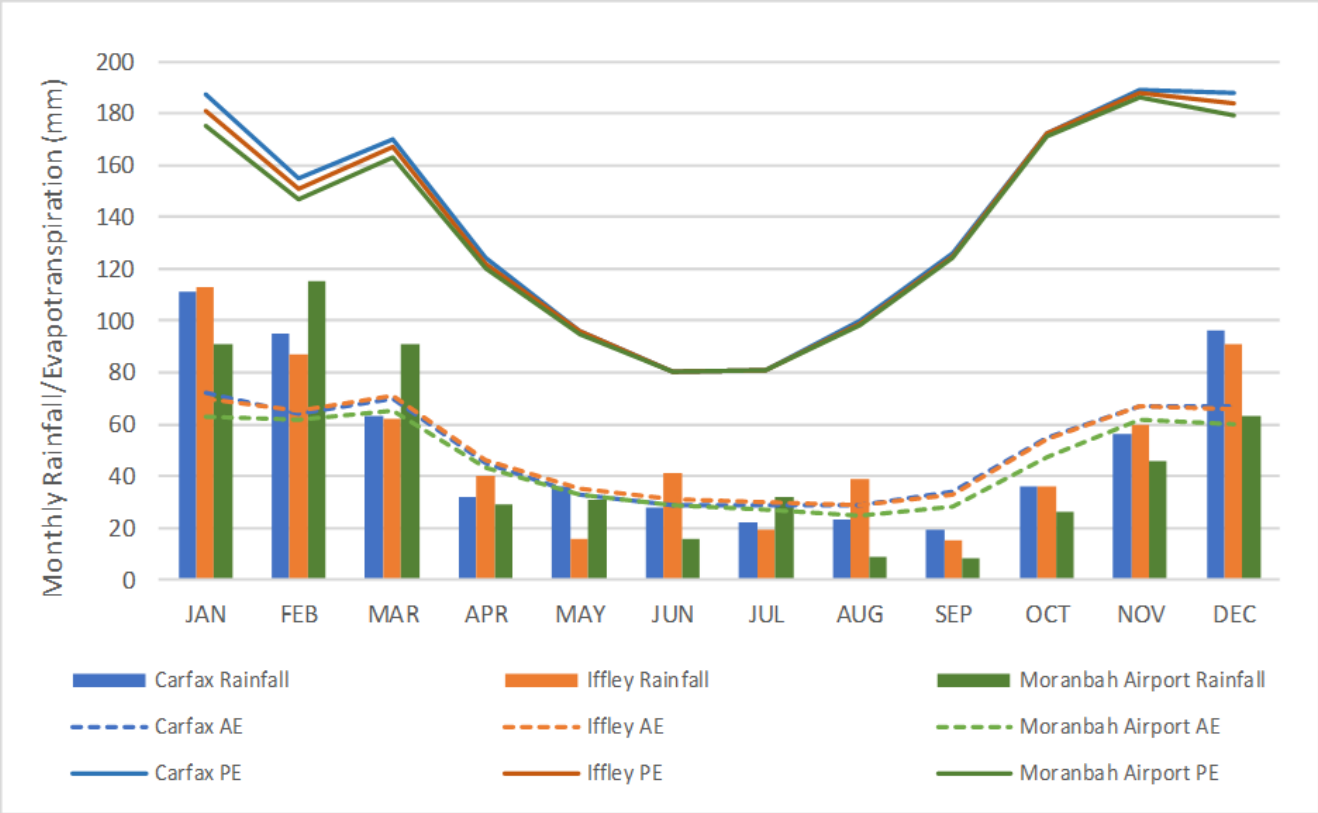


Figure 3-2 Average Monthly Rainfall and Evapotranspiration at Nearby Weather Stations

3.2 Topography and Drainage

The Project is located in the Isaac Connors surface water catchment, a sub-catchment of the upper Fitzroy Basin. The topography of the Project Area is relatively flat with gentle undulation and average elevations of approximately 200 mAHD (**Figure 3-3**). Elevations in general range between approximately 195 mAHD in the east of the Project Area towards the Isaac River to 205 mAHD in the west.

The Isaac River, directly east of the Project Area, is the major drainage feature of the region and flows from north-west to south-east (**Figure 3-3**). An unnamed minor watercourse traverses the northern section of the Project Area. The Project Area lies south-east of Cherwell Creek and J B Gully which flow south-west to north-east, and north of Ripstone Creek which flows north-west to south-east. The confluence of Cherwell Creek to the Isaac River is approximately 3 km north of the Project at an elevation of 185 mAHD. Ripstone Creek flows into Boomerang Creek approximately 15 km south-east of the Project Area. Ripstone Creek is used as a controlled release point by Peak Downs Mine (authorised under EA number EPML00318213) and the Eagle Downs Mine (EA number EPML00586713). The Isaac River, Cherwell Creek, J B Gully, and Ripstone Creek are all ephemeral and only flow briefly after rainfall. After significant rainfall, water remains in ponds that are used as livestock water sources.

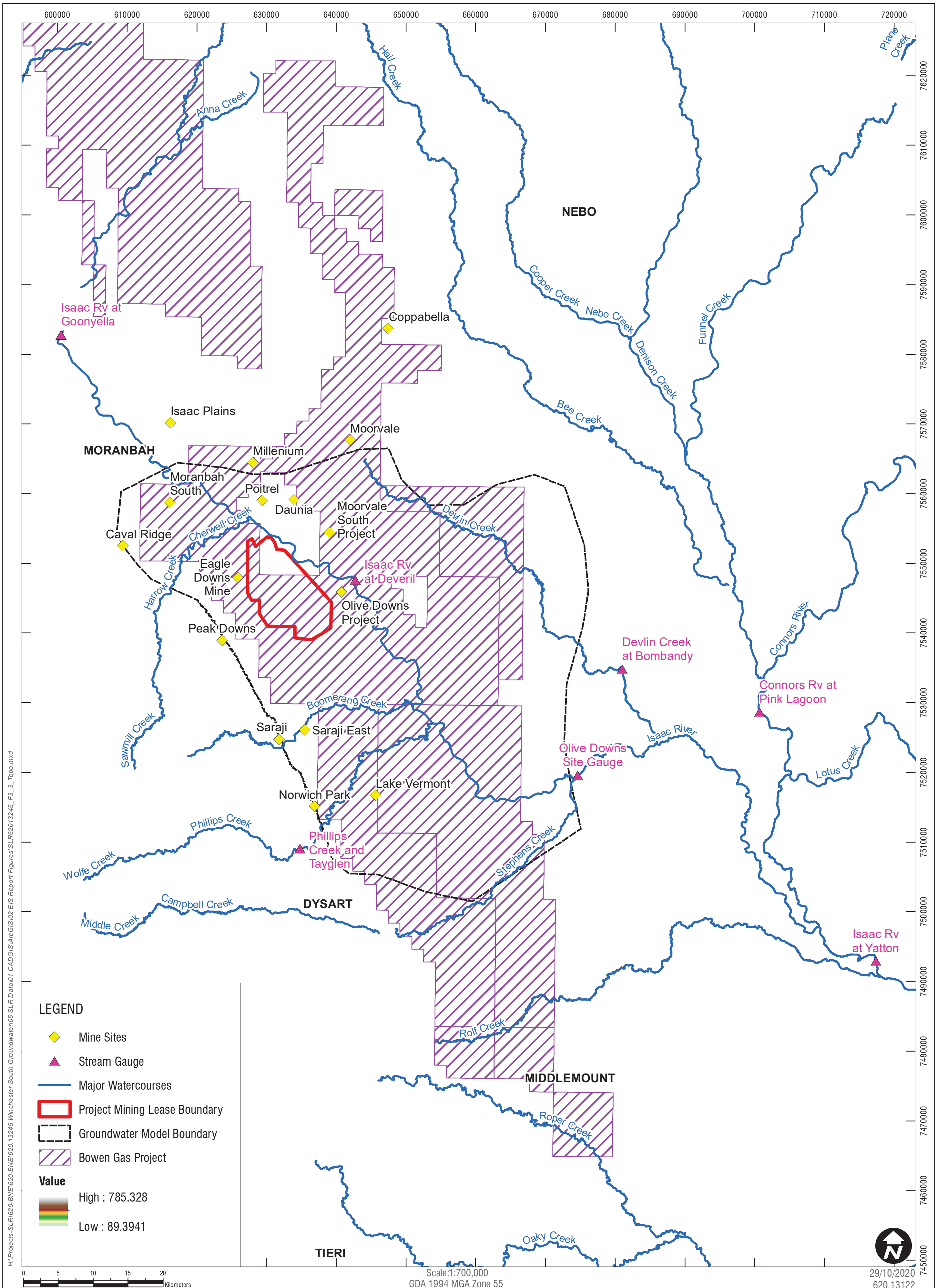
There is a Department of Natural Resources, Mines and Energy (DNRME) gauging station located at Isaac River at Deverill (station 130410A), located approximately 2 km downstream of the Isaac River and Cherwell Creek confluence. A gauging station referred to as 'ISDS' has also been installed downstream of the Study Area in the Isaac River at the bridge on Fitzroy Developmental Road, just downstream of the confluence with Stephens Creek. Data records are taken at 10 minute intervals, with logging commencing on 22 December 2016. As at 22 April 2018, five flow events (peak flow greater than 1 cubic metre per second [m^3/s]) have been recorded at this gauge. The greatest discharge was recorded in March 2018 at 804 m^3/s. **Figure 3-3** shows the relative locations of the stream gauging stations.

Table 3-5 presents a summary of stream gauge stations along the Isaac River near the Project, derived from the DNRME Water Monitoring Information Portal (WMIP) (DNRME, 2019).

Table 3-5 DNRME Stream Gauging Stations

Station Location	Number	Distance from Project	Zero-gauge Elevation (mAHD)	Mean Flow (ML/day)	Max Flow (GL/day)	Max Flow Date
Isaac River at Deverill	130410A	Directly east of the Project	169.30	445	228	Mar 1988
Isaac River at Goonyella	130414A	50 km upstream (along river channel)	230.06	147	150	Jan 1991
Isaac River at Yatton	130401A	116 km downstream (along river channel)	89.15	5420	2060	Mar 2017

ML/day = megalitres per day, GL/day = gigalitres per day.



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Topography and Drainage

FIGURE 3-3

Figure 3-4 presents daily mean stream discharge at the Isaac River at Deverill station (130410A) from 1968 to October 2019, compared against daily rainfall at Carfax station (34016). The graphs show that flows within the Isaac River are typically ephemeral, with short-duration flows generally occurring over the summer months.

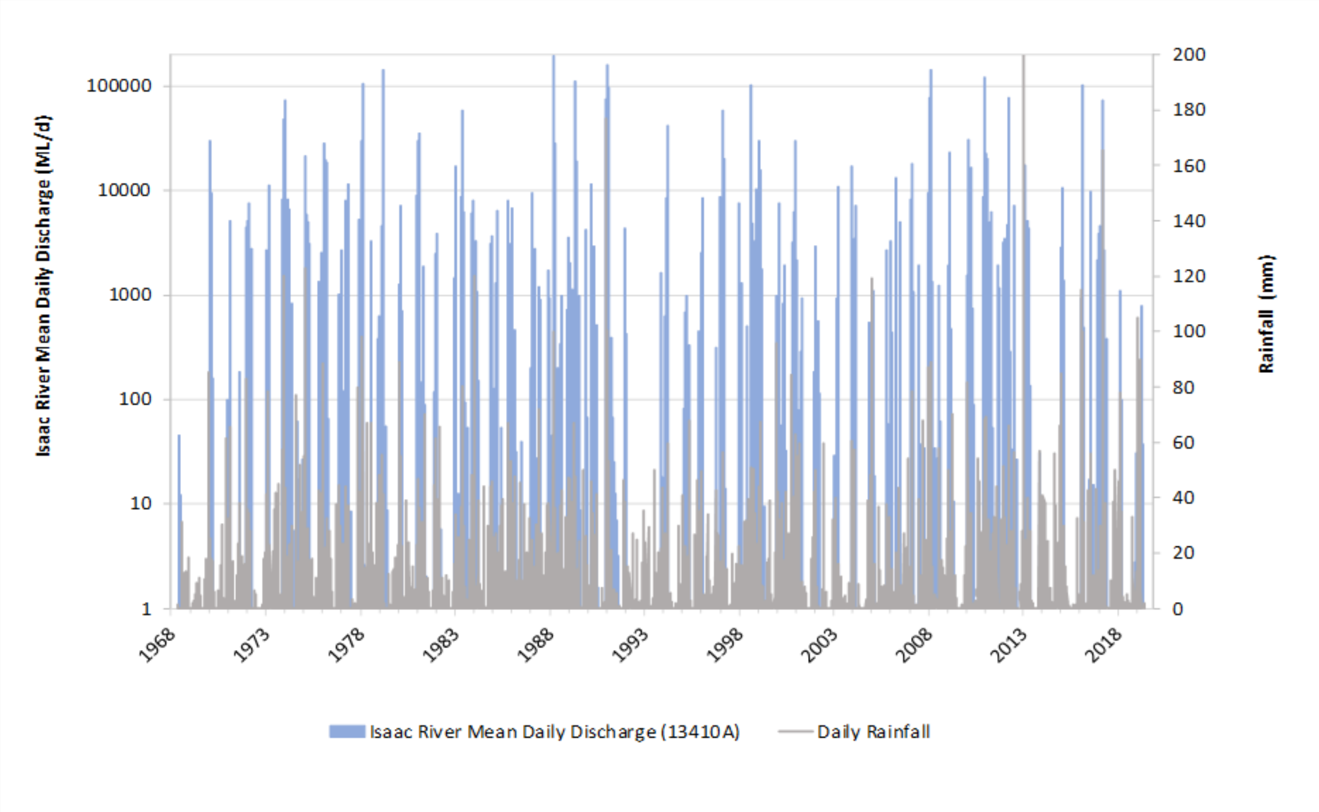


Figure 3-4 Isaac River (Station 130410A) Stream Flow and Rainfall at Carfax (Station 34016)

Based on daily flow data since 1968, **Figure 3-5** shows that the Isaac River flows only 27% of the time, with less than 11% probability of flows exceeding 100 ML/day. Less than 1% of readings exceed 10,000 ML/day, which includes high flow/flood events in 2008 (January and February), 2010 (December), 2012 (March), 2016 (February) and 2017 (March).

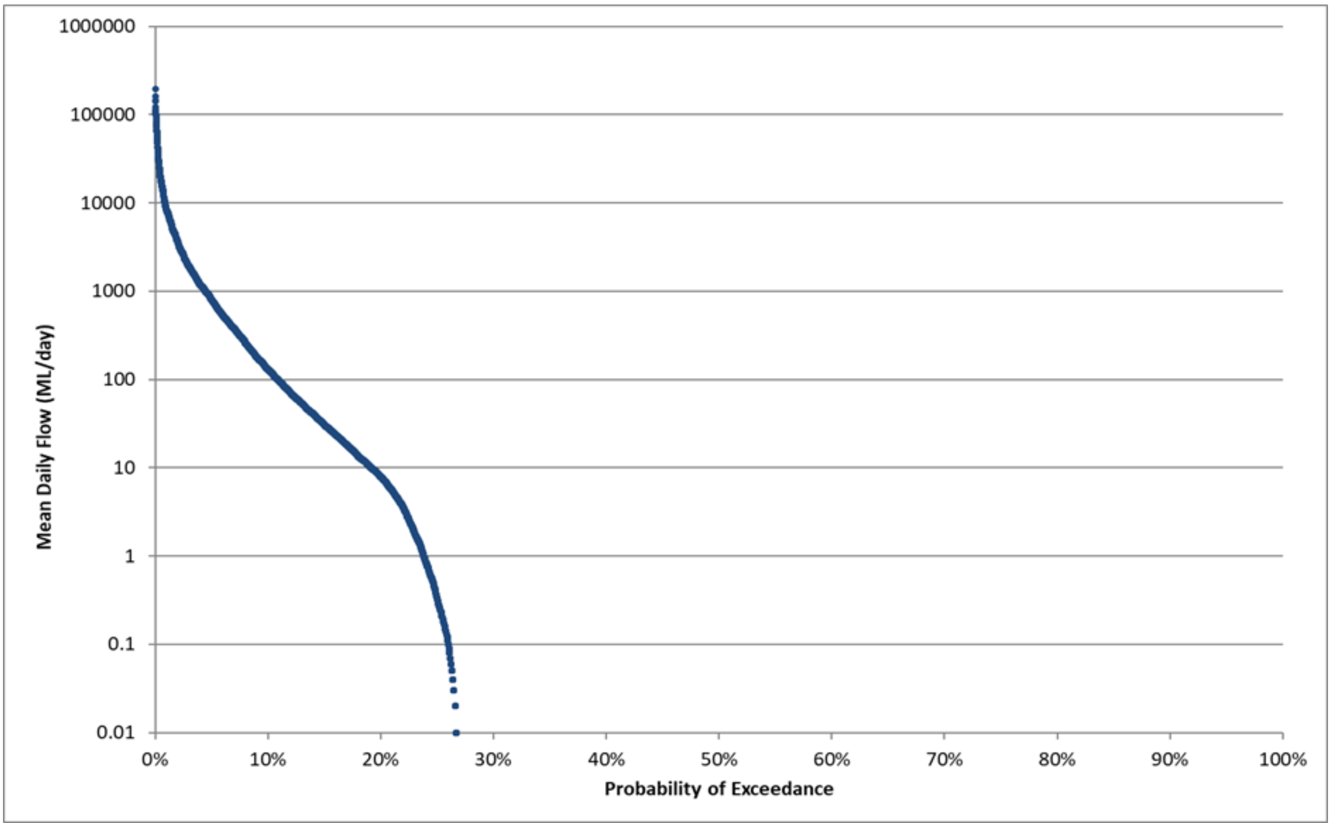


Figure 3-5 Isaac River (Station 130410A) Mean Daily Flow Duration Curve (1968 – 2019 data)

3.3 Land Use and Mining

The Project Area covers approximately 7,000 hectares (ha) of land adjacent to the Isaac River. The land is largely covered with native pasture used for grazing with remnant and regrowth woodland vegetation present in some small patches. There are no nature conservation areas, including National or State parks in or nearby the Project Area. There is no Strategic Cropping Land mapped within the Project Area.

The predominant surrounding land uses within the Study Area are mining and agriculture (grazing). There are several proposed and active coal mining operations near to the Project. There are also several proposed wellfields for extraction of CSG associated with the Bowen Gas Project. **Table 3-6** summarises the nearby resource extraction operations.

Table 3-6 Proposed and Current Operations near to the Project

Operation	Status	Type	Planned Start	Planned End	Distance from Project	Target Coal Resource
Bowen Gas Project[1]	Proposed	Coal Seam Gas	~2017[2] (On Hold)	2055	Proposed wells in and around Project	Rangal Coal Measures, Moranbah Coal Measures
Olive Downs Project[1]	Proposed	Open-cut	2020	2099	Adjacent, east and south-east	Rangal Coal Measures
Lake Vermont[1]	Operating	Open-cut	2014	2045	26 km south-east	Rangal Coal Measures

Operation	Status	Type	Planned Start	Planned End	Distance from Project	Target Coal Resource
Saraji[1]	Operating	Open-cut	1974	2040	19.5 km south-west	Moranbah Coal Measures
Saraji East[1]	Proposed	Underground - Longwall	TBD	TBD	11 km south	Moranbah Coal Measures
Peak Downs[1]	Operating	Open-cut	1972	2075	8 km west	Moranbah Coal Measures
Eagle Downs Mine[1]	Care and Maintenance	Underground - Longwall	~2017[2] (On Hold)	2064	Adjacent, west	Moranbah Coal Measures
Poitrel[1]	Operating	Open-cut	2006	2026	8 km north-west	Rangal Coal Measures
Daunia[1]	Operating	Open-cut	2011	2034	7.5 km north-west	Rangal Coal Measures
Millennium	Operating	Open-cut	2005	2027	10.5 km north-west	Rangal Coal Measures
Moorvale	Operating	Open-cut	2003	2017+	19 km north	Rangal Coal Measures
Moorvale South Project[1]	Proposed	Open-cut	2021	2031	4 km to the east	Rangal Coal Measures, Fort Cooper Coal Measures
Coppabella	Operating	Open-cut	1998	2035	35.5 km north-east	Rangal Coal Measures, Fort Cooper Coal Measures
Caval Ridge	Operating	Open-cut	2013	2043	8 km west	Moranbah Coal Measures
Isaac Plains	Operating	Open-cut	2006	2070	18 km north-west	Rangal Coal Measures
Norwich Park	Care and Maintenance	Open-cut	1979	2012	36.6 km south	German Creek Formation
Moranbah South	Proposed	Underground – Longwall and Bord and Pillar	2017[2] (On Hold)	2060	10km north-west	Moranbah Coal Measures

Note:

1. Cumulative impacts assessed as part of this Groundwater Assessment
2. On Hold – Projects approved and proposed to commence, but have not yet commenced

A brief summary of each of the surrounding mines included in the cumulative assessment is provided below. These mines are included largely based on their proximity to the Project. In areas with multiple mines in close proximity (e.g. to the west of the Project), only the closest mines to the Project are included in the cumulative assessment under the assumption that cumulative drawdown will be governed by these closest mines. **Figure 1-1** and **Figure 1-2** show the locations of the developments.

The potential for cumulative impacts due to the neighbouring mining and gas developments is discussed in **Section 6**.

3.3.1 Bowen Gas Project

The Bowen Gas Project is a CSG development by Arrow Energy Pty Ltd (Arrow), targeting gas within coal seams of the Rangal Coal Measures and Moranbah Coal Measures. The Bowen Gas Project proposes to extract approximately 270 gigalitres (GL) of associated water with the gas over a period of 55 years from 6,000+ extraction wells covering and area of 9,500 square kilometres (km^2). Arrow has identified an extraction wellfield targeting the Rangal Coal Measures and Moranbah Coal Measures in the vicinity of the Project. While the final well locations and relative timing of these activities are yet to be finalised, gas extraction has been considered for the purposes of cumulative assessment of the Project (**Section 6**).

3.3.2 Olive Downs Project

The Olive Downs Project is an approved metallurgical coal mine development proposed by Pembroke Olive Downs Pty Ltd. The Olive Downs Project is located adjacent to the east and south-east of the Project. The mine will consist of a series of open cut pits targeting the Leichhardt and Vermont Seams of the Rangal Coal Measures. The Olive Downs Project will extract up to 20 Mtpa over a mine life of approximately 79 years, commencing approximately in 2020. Based on the planned maximum production rate, approximately 400 million tonnes (Mt) of product coal would be produced during the life of the mine.

3.3.3 Lake Vermont Coal Mine

The Lake Vermont Coal Mine is a medium size open cut coal mine producing coking and pulverised coal injection (PCI) coal for the export market to be used in steel production, with a majority ownership held by Jellinbah Group. Mining operations commenced in September 2008, with first coal production in January 2009. The target production rate is 12 Mtpa, targeting the Rangal Coal Measures. The Lake Vermont Coal Mine gained approval to extend the existing mining operation into new mining areas to the north of the current operation.

3.3.4 Saraji Mine

The Saraji Mine is an open cut metallurgical coal mine operated by BHP Billiton Mitsubishi Alliance (BMA). The Saraji Mine targets the Moranbah Coal Measures where they shallow at the western limb of the Bowen Basin. Coal extraction commenced in 1974 and is expected to continue until approximately 2040. No details regarding mine progression have been obtained from BMA, therefore, for the purposes of this assessment it is assumed the Saraji Mine would continue to develop primarily in an easterly direction following the coal seam down-dip.

3.3.5 Saraji East Project

The proposed Saraji East Project includes an underground single-seam mine operation and associated project infrastructure. The Saraji East project has planned extraction of up to 7 Mtpa of metallurgical product coal for the export market over a life of 25 to 30 years and is located east and adjacent to the existing Saraji Open Cut Coal Mine. The Saraji East Project is currently undergoing the EIS process and is anticipated to commence in coal extraction in 2024, subject to approval (BMA, 2017).

3.3.6 Peak Downs Mine

The Peak Downs Mine is an open cut metallurgical coal mine operated by BMA and follows the strike of the Moranbah Coal Measures, north of Saraji. Coal extraction commenced in 1972 and is expected to continue until approximately 2075. As per the Saraji Mine, no details regarding mine progression have been obtained from BMA, therefore, for the purposes of this assessment it is assumed the Peak Downs Mine would continue to develop from its current extents in an easterly direction down dip.

3.3.7 Caval Ridge Mine

The Caval Ridge Mine is an open cut metallurgical coal mine operated by BMA and follows the strike of the Moranbah Coal Measures, north of Peak Downs. Coal extraction commenced in 2013 and is expected to continue until approximately 2045. As per the Saraji and Peak Downs mines, no details regarding mine progression have been obtained from BMA, therefore, for the purposes of this assessment it is assumed the Caval Ridge Mine would continue to develop from its current extents in an easterly direction down dip.

3.3.8 Eagle Downs Mine

Eagle Downs Mine is a multi-seam underground mine operated by Eagle Downs Coal Management Pty Ltd (a joint venture between South 32 and Aquila Resources). The Eagle Downs Mine targets the Moranbah Coal Measures using longwall extraction. The Eagle Downs Mine was approved in 2011 and development of a small box cut and drift commenced in 2013. However, no activities have been conducted at the Eagle Downs Mine since 2015. The Eagle Downs Mine proposes a production rate of up to 11 Mtpa with a mine life of 50 years, however, it is currently unknown when operations will recommence.

3.3.9 Poitrel Mine

The Poitrel Mine owned by BHP Mitsui Coal Pty Ltd (BMC) is located 25 km east south-east of Moranbah. The Poitrel Mine is an open cut mine targeting the Leichhardt and Vermont Seams within the Rangal Coal Measures, which consists of 79 Mt of resources. The Poitrel Mine is projected to produce up to 5 Mtpa of ROM coal for at least 20 years (Environmental Protection Agency [EPA], 2005).

3.3.10 Daunia Mine

Daunia Mine is located approximated 30 km south-east of Moranbah. As with Poitrel, Daunia Mine is an open cut mine targeting the Leichhardt and Vermont Seams within the Rangal Coal Measures. The Daunia Mine is located on the eastern limb of an anticline that separates it from adjacent Poitrel Mine. The Daunia Mine has a production rate of 4 Mtpa with a mine life of 21 years (Queensland Government Coordinator-General, 2009).

3.3.11 Moorvale South Project

Moorvale South Project operated by Peabody Energy Australia PCI (C & M Management) Pty Ltd, and owned by the Coppabella and Moorvale Joint Venture is located 23 km south of Coppabella. The Moorvale South Project initially targets the Leichhardt and Vermont Seams, and where economically viable also the Fort Cooper Coal Measures using conventional open cut mining and strip-mining methods. The Moorvale South Project is projected to extract between 1.5 and 2 Mtpa with a mine life of 10 years.

4 Geology

4.1 Regional Geology

The coal deposit for the Project is in the northern part of the Bowen Basin, a foreland sedimentary basin of approximately 200,000 km2 (**Figure 4-1**). The Bowen Basin is a north-northwest to south-southeast oriented basin and contains the largest coal reserves in Australia. The southern half of the Bowen Basin is covered by the Surat Basin, and the Galilee Basin exists to the west (Geoscience Australia, 2017).

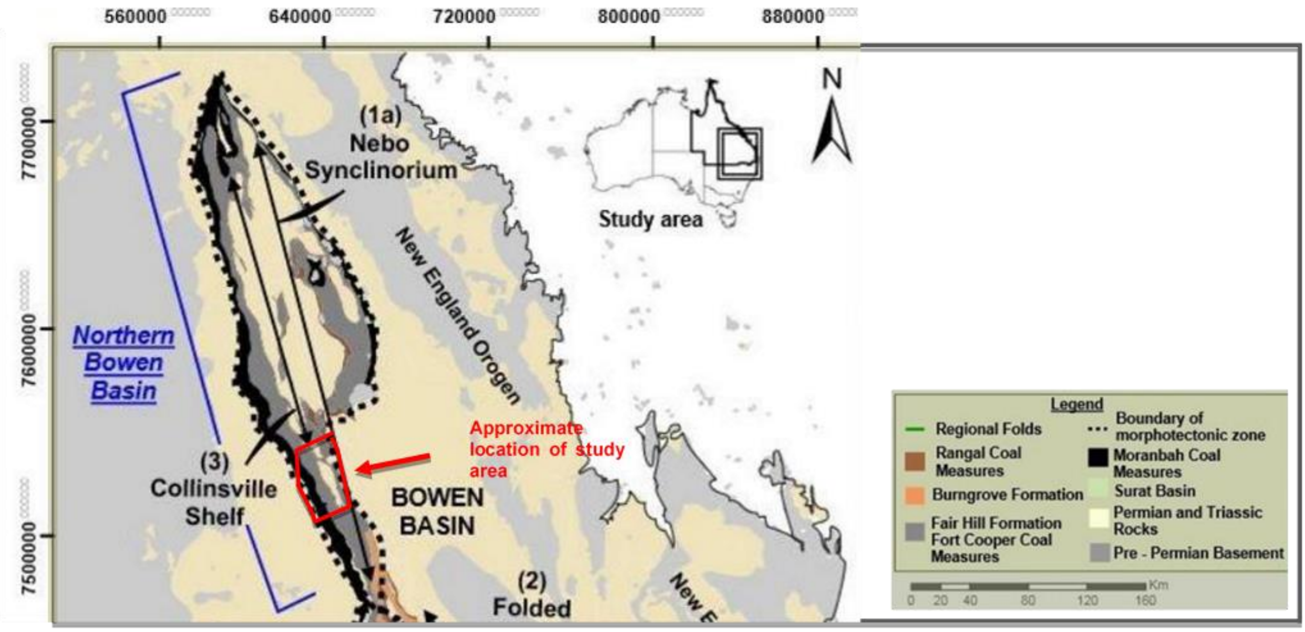


Figure 4-1 Structural Setting of the Bowen Basin (after Dickins and Malone, 1973)

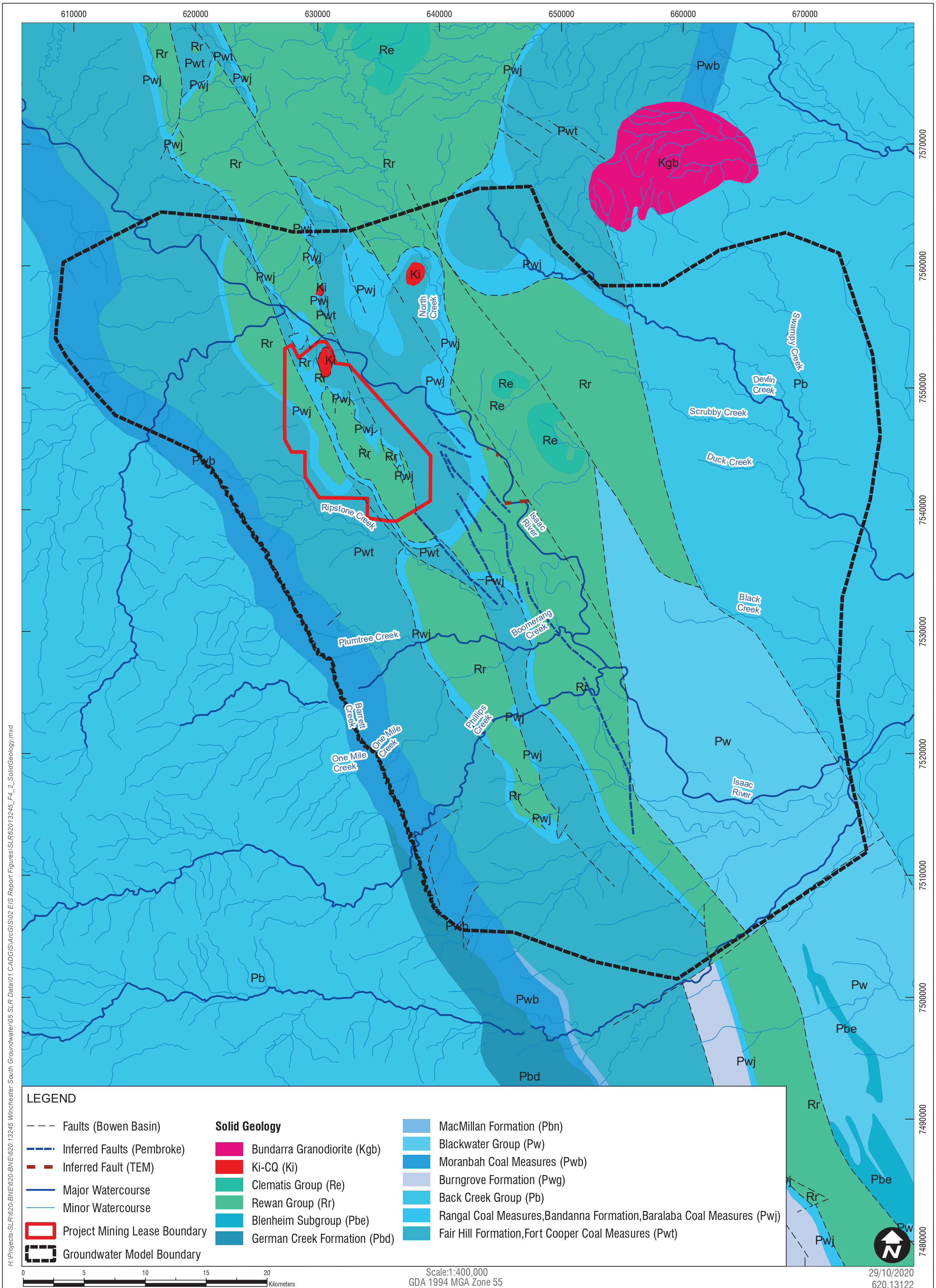
Basin geology within the Collinsville Shelf includes the basal Permian aged Back Creek Group, which is comprised of generally fine-grained clastic sedimentary rocks deposited in a fluvial to shallow marine environment. The Back Creek Group is conformably overlain by the Blackwater Group, which includes the Moranbah Coal Measures, Fort Cooper Coal Measures and Rangal Coal Measures. The economic seams of the Project are contained in the Late Permian Rangal Coal Measures. The Permian strata occur at outcrop on the eastern and western edges of the Bowen Basin and are unconformably overlain by the Triassic aged terrestrial sedimentary rocks of the Rewan Group. While not present at the Project, isolated pockets of remnant quartzose sandstones of the Middle Triassic Clematis Group are also mapped within the Study Area, on the eastern side of the Isaac River.

The Permian and Triassic units are covered by a thin veneer of unconsolidated to semi-consolidated Cainozoic sediments (Tertiary to Quaternary alluvium and colluvium). The alluvial sediments are localised along rivers and creeks (i.e. Isaac River). Volcanic intrusions and extrusions (i.e. basalt) are also present within the region.

The generalised regional stratigraphy is summarised in **Table 4-1** The solid geology is presented in **Figure 4-2**, based on the 1:500k solid geology outcrop mapping of the Bowen Basin. The surficial geology is shown in **Figure 4-3**, and is based on the Clermont (SF5511) and St Lawrence (SF5512) 1:250k geological maps, as compiled within the Queensland Geology Detailed Surface Mapping (DNRME, 2017b).

Table 4-1 Regional Stratigraphy

Period		Stratigraphic Unit		Description	Distribution	Max Thickness
Cainozoic		Isaac River Quaternary alluvium (Qa)		Flood plain alluvium comprising clay, silt, sand and gravel.	Surficial cover localised along Isaac River and North Creek.	~ 50 m
		Regolith - alluvium, colluvium and other sediments in floodplains, alluvial fans, and high terraces (Qr, Qr\b and TQa)		Colluvial and residual deposits comprising poorly sorted clay, silt, sand, gravel and black soils, silts and muds derived from weathered basalts.	Surficial cover throughout the Project.	~ 20 m
		Duaringa Formation (Tu)		Mudstone, sandstone, conglomerate, siltstone, oil shale, lignite and basalt.	Present to south and east of Study Area.	~ 100 m
Triassic		Mimosa Group	Clematis Group (Re)	Cross-bedded quartz sandstone, some quartz conglomerate and minor red-brown mudstone.	Isolated outcrop to the south-east of the Project.	~ 100 m
			Rewan Group (Rr) (Rewan Formation and Sagittarius Sandstone)	Rewan Formation: green lithic sandstone, pebbly lithic sandstone, green to reddish brown mudstone and minor volcanolithic pebble conglomerate (at base). Sagittarius Sandstone: lithic sandstone interbedded with mudstones and siltstones with scattered carbonaceous plant material.	Outcrops or subcrops within the Study Area, and central and northern zones of the Project.	~ 840 m
Permian	Late	Blackwater Group	Rangal Coal Measures (Pwj)	Coal seams, carbonaceous shale and mudstone, tuff, siltstone and mudstone.	Within Project Area; isolated Outcrops in the central and northern zones of the Project.	~ 200 m
			Fort Cooper Coal Measures (Pwt) (Fair Hill Formation)	Coal, brown and green sandstone, conglomerate, carbonaceous shale, tuff.	Within Project Area; Outcrops or subcrops in central and northern zones of the Project.	~ 350 m
			Moranbah Coal Measures (Pwb)	Quartzose to sublabile locally argillaceous sandstone, siltstone, mudstone, carbonaceous mudstone and coal.	Within/underlies the Project; Outcrops or subcrops in the west of the Study Area.	~ 400 m
	Early to Middle	Back Creek Group(Pb)		Quartzose to lithic sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite.	Within/underlies Project; Outcrops in the west of the Study Area.	~ 400 m



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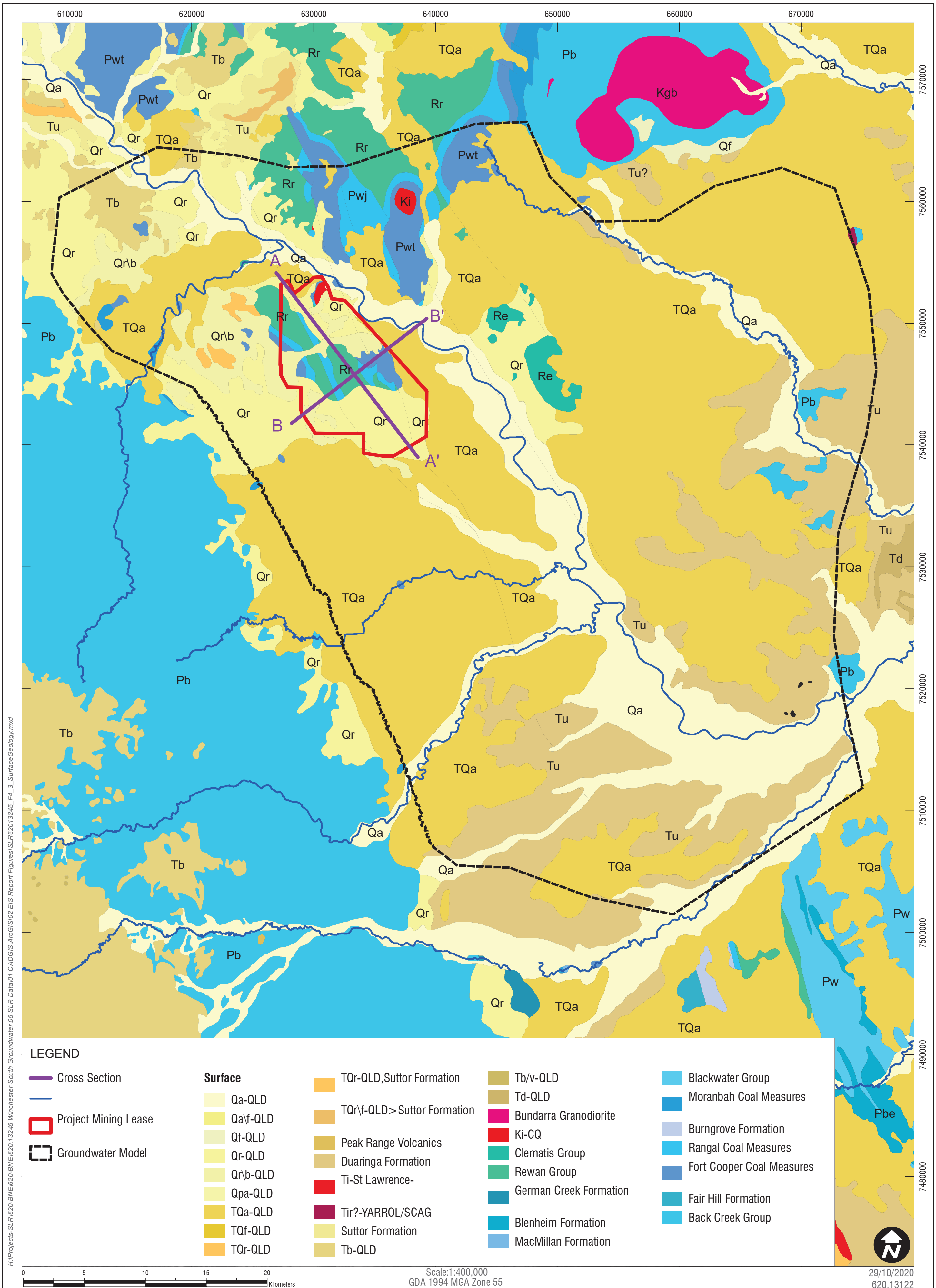
Solid Geology

FIGURE 4-2



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Surface Geology

FIGURE 4-3

4.2 Local Geology

The stratigraphic profile within the Study Area comprises three distinct units:

- Cainozoic sediments (alluvium and regolith);
- Early Triassic Rewan Group; and
- Permian coal measures.

Each of the main stratigraphic units are discussed in further detail below. The structural geology of the Study Area is also discussed in **Section 4.2.5**. Geological cross sections of the Project Area are presented in **Figure 4-6** and **Figure 4-7**.

4.2.1 Cainozoic Sediments

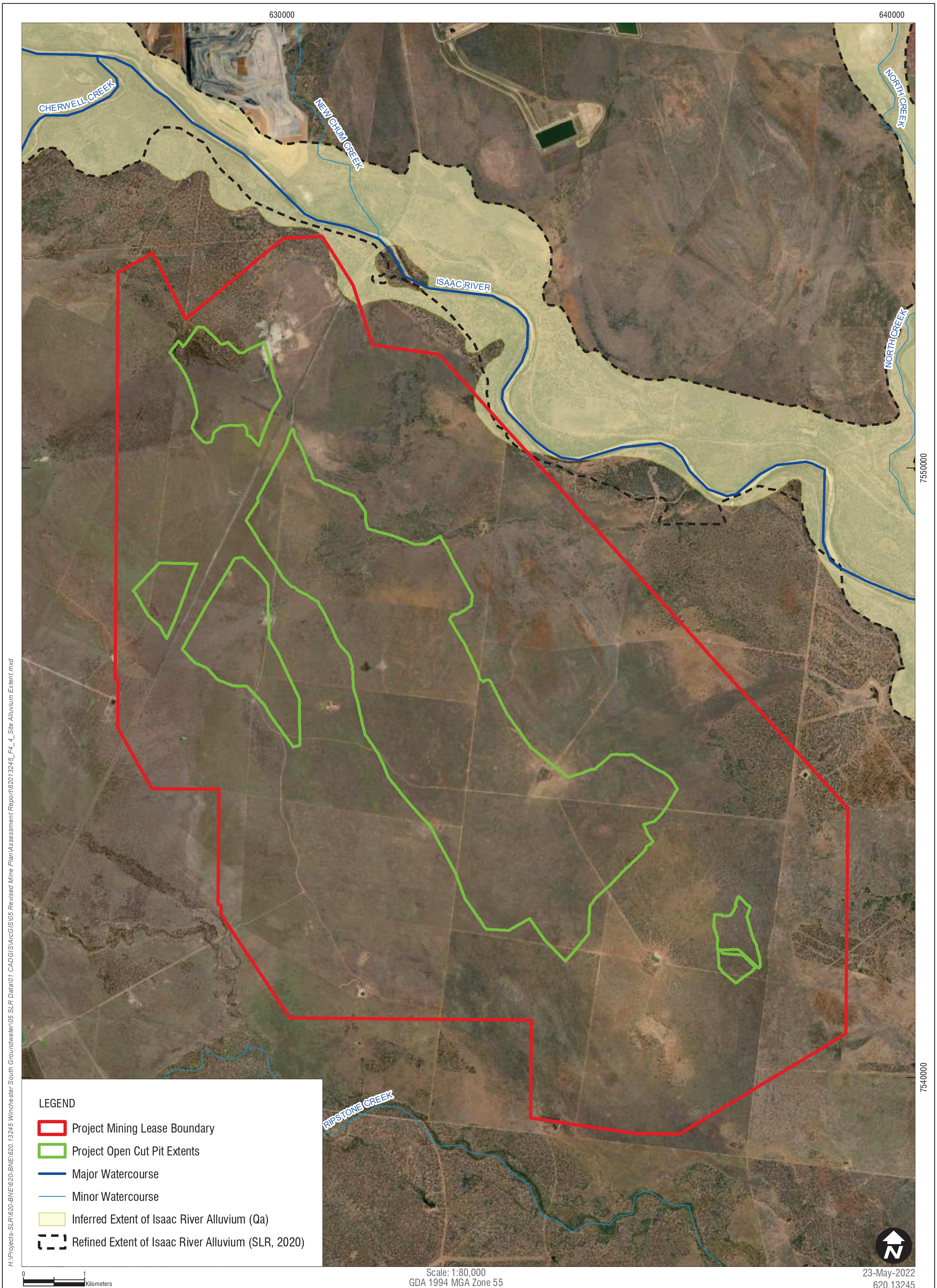
4.2.1.1 Isaac River Alluvium

State (Queensland Government) Detailed Surface Geology (SDSG) mapping (**Figure 4-3**) shows that alluvium is localised along the Isaac River, to the north and east of the Project. The extent and thickness of the unconsolidated sediments was assessed for the Project Area in March 2019 by Groundwater Imaging Pty Ltd (Groundwater Imaging). Groundwater Imaging undertook a geophysical survey which entailed Agricultural Transient Electromagnetic System (AgTEM) and DC – Electrical Resistivity Tomography (DC-ERT) transects adjacent to the Isaac River and surrounds to improve understanding of the extent, permeability, and depth of alluvium. Detailed subcrop geology information was also identified as part of the survey. Data from the geophysical surveys are included within **Appendix A1**. The results from the survey are summarised as follows:

- The rock weathering horizon is high in groundwater salinity, resulting in high electrical conductivity. This weathering horizon is absent within the alluvium, as it has been eroded and replaced with recent alluvium. The absence of the highly conductive weathering horizon allows for clear identification of alluvial extents within the geophysical data.
- A shallow 8 to 10 m embayment of flat layered alluvium covers coal measures to the east of the survey extent. This alluvium has been mapped in previous reports (Douglas Partners, 2012) as a Cainozoic Sand Plain with somewhat different extents.
- The Isaac River alluvium is limited in extent away from the modern river channel.

AgTEM surveys have also been conducted by Groundwater Imaging for the Moorvale South Project and Olive Downs Project Groundwater Assessments. Survey results from the Moorvale South Project and Olive Downs Project investigations have contributed to defining alluvial extents and thicknesses in the vicinity of their respective sites.

Additionally, slope break analysis has been performed for this assessment using 1 m Digital Elevation Model (DEM) topography data provided by Whitehaven. The slope break analysis has been used to define alluvial extents in the area west of the AgTEM survey. Alluvial extents identified from the slope break analysis do not differ dramatically from the extents previously identified by the SDSG mapping, giving credibility to the accuracy of the alluvium extents in areas within the Study Area where only SDSG mapping information is available. The mapped extents of the Isaac River alluvium as identified from the site-specific geology logs from exploration drill holes, AgTEM surveys performed for the Project, Moorvale South Project and Olive Downs Project, slope break analysis and SDSG mapping is presented in **Figure 4-4**.



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Isaac River Alluvium Extent

FIGURE 4-4

Site drillhole data was reviewed when mapping alluvial extents for **Figure 4-4**. The drillhole data revealed the possibility of at least one Project drill hole intercepting the Isaac River alluvium. Drill hole WSN206 occurs 3 km northeast of the Project boundary within mapped alluvial extents. The log for this hole shows sand present, occurring from the surface down to a depth of 22 m, where it overlies siltstone. Drillholes intercepting Isaac River alluvium around the Olive Downs Project indicate that it comprises a heterogeneous distribution of fine to coarse grained sands interspersed with lenses of clays and gravels. These sediments, while spatially variable, generally comprise four main stratigraphic sequences:

- Upper soil and clay layer (up to 13 m thick);
- Sand and sandy clay unit (up to 24 m thick);
- Sand and gravel unit (up to 8 m thick); and
- Basal clay unit (up to 10 m thick).

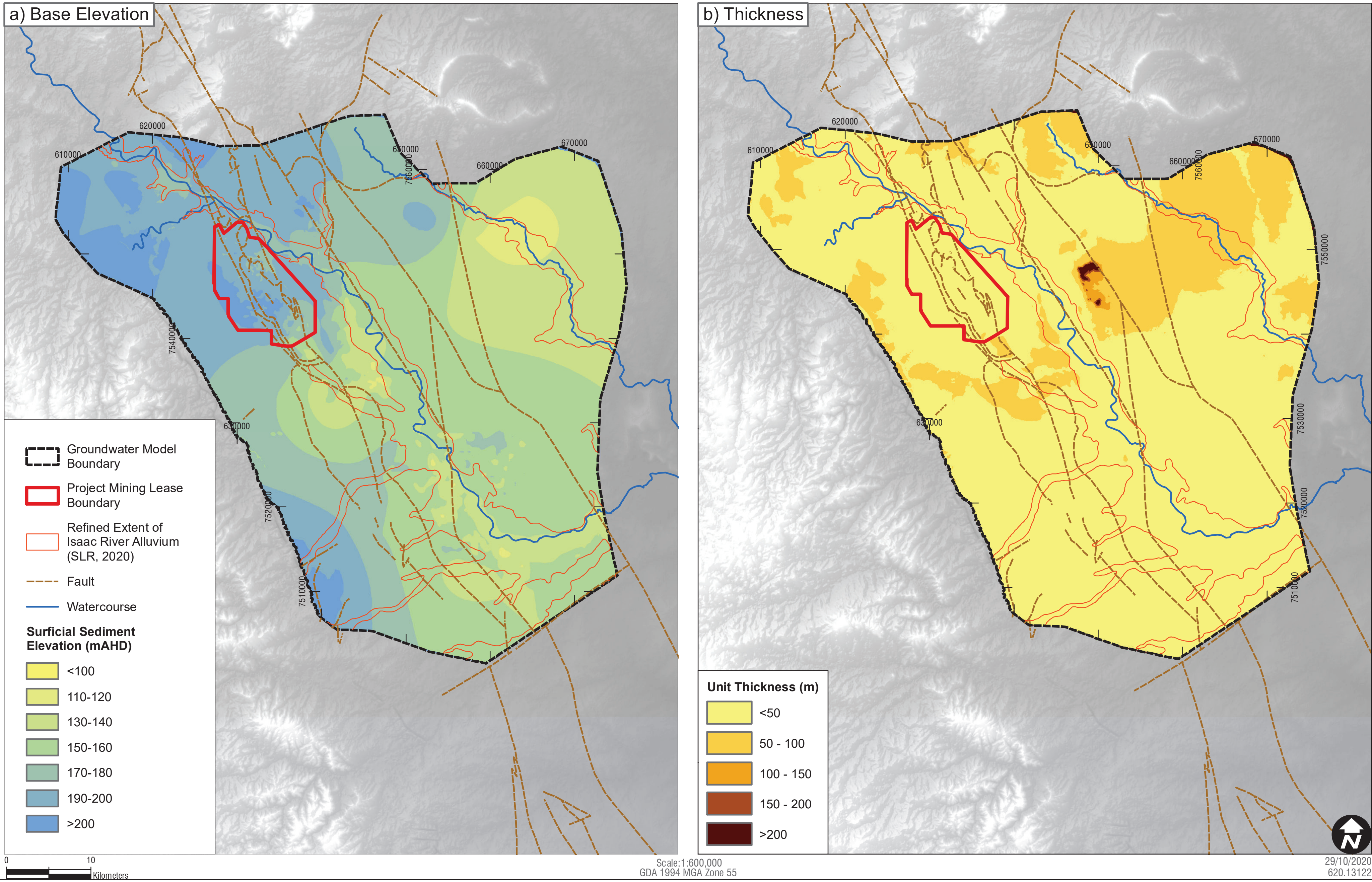
Figure 4-4 indicates that there would be no direct interception of the Isaac River alluvium by the proposed open cut pits (mining activity) for the Project. The minimum distance between the Project open cut pits and the Isaac River alluvium is approximately 1.8 km at its closest point. This minimum distance occurs at Main Pit, with distance to Isaac River alluvium generally increasing as the Project progresses south.

4.2.1.2 Regolith

The surficial regolith material covering much of the Study Area comprises Cainozoic (Quaternary to Tertiary) aged sediments, including alluvium and colluvium. Older alluvial (TQa) sediments are distributed extensively across the region with colluvium and residual deposits (Qr and Qr\b) abundant in the north-west of the Study Area and Project Area (**Figure 4-3**). The Cainozoic (Tertiary) aged Duaringa Formation (Tu) is also mapped at surface at the southern end of the Study Area. Drill logs in the Project Area indicate the sequences exhibit similar geological characteristics and have therefore been grouped as 'regolith' within this assessment.

Based on geological logs, the regolith in the Project Area comprises a heterogeneous distribution of fine to coarse grained sand, clay, sandstone and claystone. The regolith material is on average 25 m thick. The units are highly weathered, with the depth of weathering extending to a maximum of 100 mbgl, into the underlying coal measures. The extent and thickness of the regolith material is presented on **Figure 4-5**, interpolated based on geological data and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Soil and Landscape Grid of Australia (CSIRO, 2015) data.

Regolith deposits over the Project Area comprise colluvium, residual deposits (Qr) and weathered Permian units. Project drill logs indicate unconsolidated sediments in the area comprise clay, silt, sand, gravel and soil. Within the Project Area, Permian units are, on average, weathered to a depth of 22 metres below ground level (mbgl) and Tertiary to Quaternary aged deposits are on average weathered to 25 mbgl.



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Base Elevation and Thickness of Surficial Units

FIGURE 4-5

4.2.2 Tertiary Basalt & Early Cretaceous Granitoid

Tertiary aged basalt is present only as isolated patches in the north-west of the Study Area. There are no exploration drill hole logs available within this unit for the Study Area, however, a search of Queensland Globe bores in the Study Area in 2019 revealed 3 groundwater bores (RN162048, RN162043 and RN162044) have been logged as intersecting basalt. From these logs an average depth to base of basalt of 67 mbgl is observed.

An early-Cretaceous granitoid body has been identified in the Project AgTEM survey (Groundwater Imaging, 2019). SDSG mapping indicates three isolated occurrences of this intrusion in the Study Area. This porphyritic igneous rock is highly resistive with complicated extents. The origin of this unit in the Project Area is a matter of debate; its fine groundmass and irregular extent suggest it is a welded pyroclastic ash flow. The granitoid has a complicated relationship to the Permian coal measures, with many dipping and abrupt boundaries. Some horizontal lenses (sills) also extend into the coal measure strata.

4.2.3 Triassic Strata

The Triassic sedimentary rocks include an isolated pocket of Clematis Group approximately 7 km east of the Project Area, and the more regionally extensive Rewan Group. The outcrop of Clematis Group is approximately 300 m thick and forms a localised topographic high at an elevation of around 450 mAHD. The Clematis Group typically comprises cross-bedded quartzose sandstone with minor conglomerate and mudstone.

Regionally the Rewan Group unconformably overlies the Permian coal measures as in-fill material. The unit is largely absent where the Permian coal measures occur at outcrop and thickens towards the Isaac River. At the Project, the weathered Rewan Group unit occur at outcrop. Drill logs give an average weathered Triassic strata thickness of 25 m.

The Triassic aged Rewan Group includes two formations, the Rewan Formation that comprises green lithic sandstone, pebbly lithic sandstone, green to reddish brown mudstone and minor volcanolithic pebble conglomerate, and the underlying Sagittarius Sandstone unit that comprises lithic sandstone interbedded with mudstones and siltstones with scattered carbonaceous plant material.

The Rewan Group occurs beneath the alluvium and regolith in the Study Area and has an average thickness of 33 m with a maximum of around 74 m thickness where it occurs within the Project Area. The transition from the Rewan Group to the underlying Permian coal measures is generally difficult to define. The transition is often based on the change in colour (i.e. green-grey to blue-grey) and depth (15 m to 60 m) above the first major coal seam (Leichhardt Seam) of the Rangal Coal Measures (JB Mining Services, 2016). The relationship between the geological units in the Study Area is presented in **Figure 4-6** and **Figure 4-7**. Interpolated structure and thickness contours of the Rewan Group within the Study Area are presented in **Figure 4-8** based on previous geological models and drill hole logs.

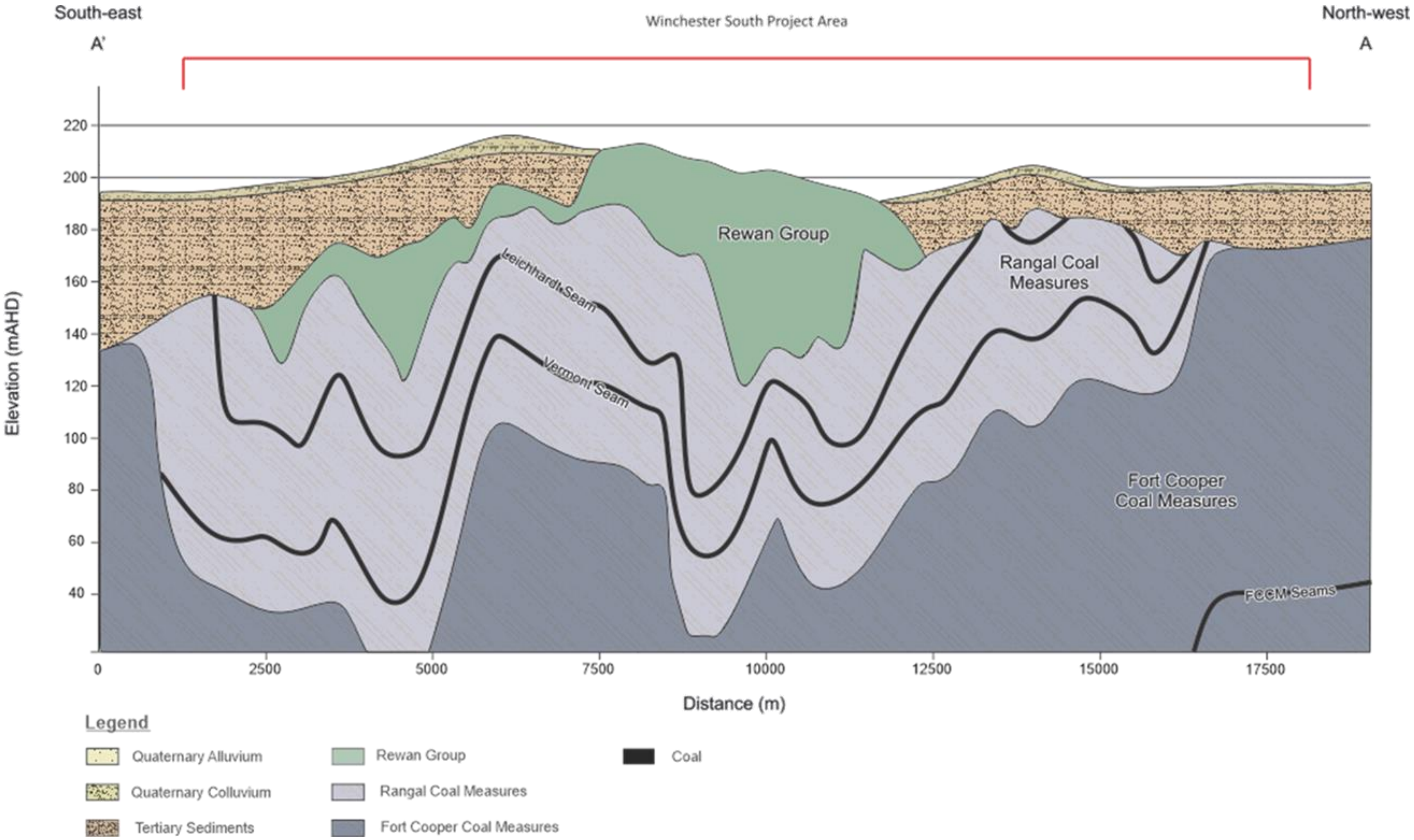


Figure 4-6 Geological Cross Section – Southeast–Northwest

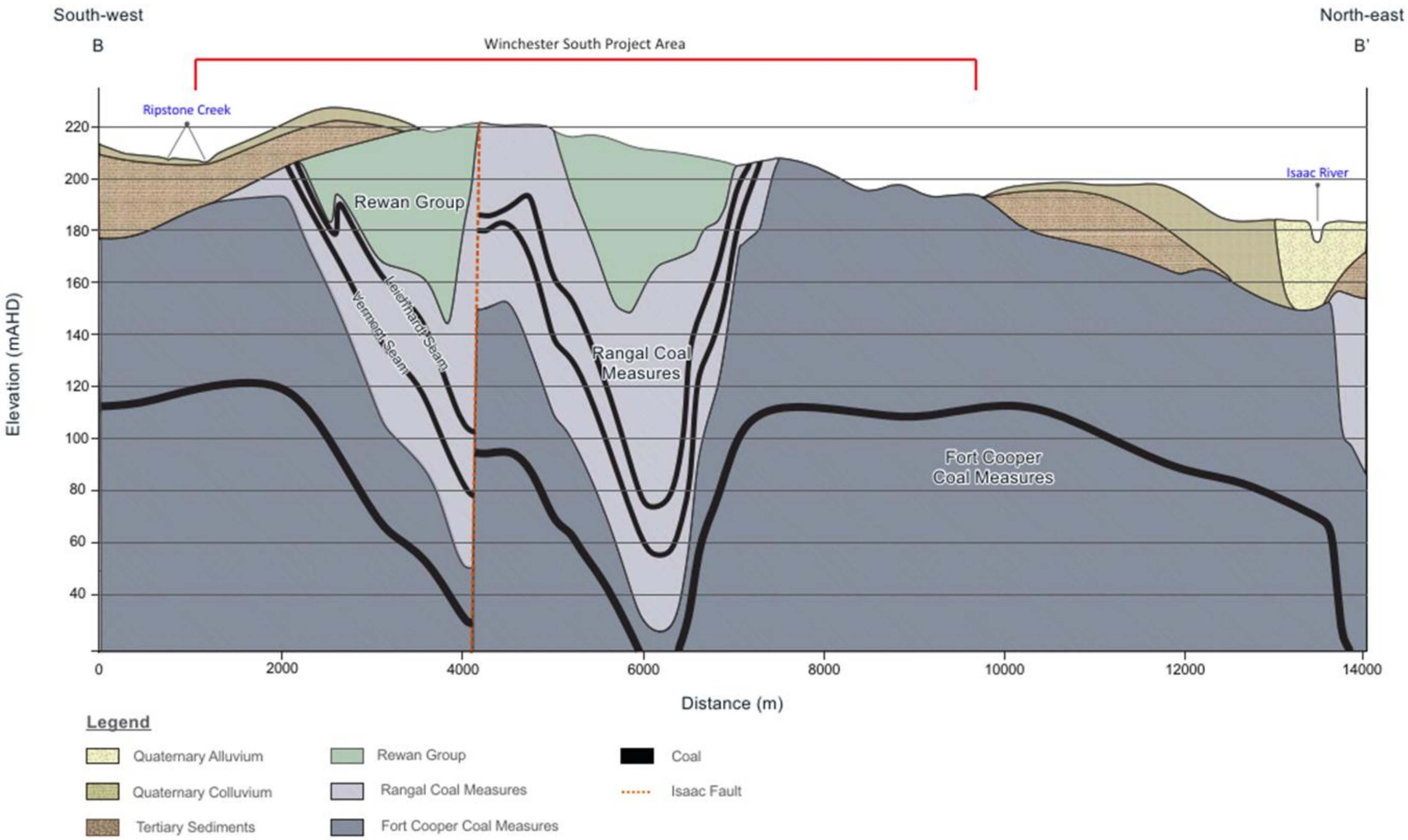
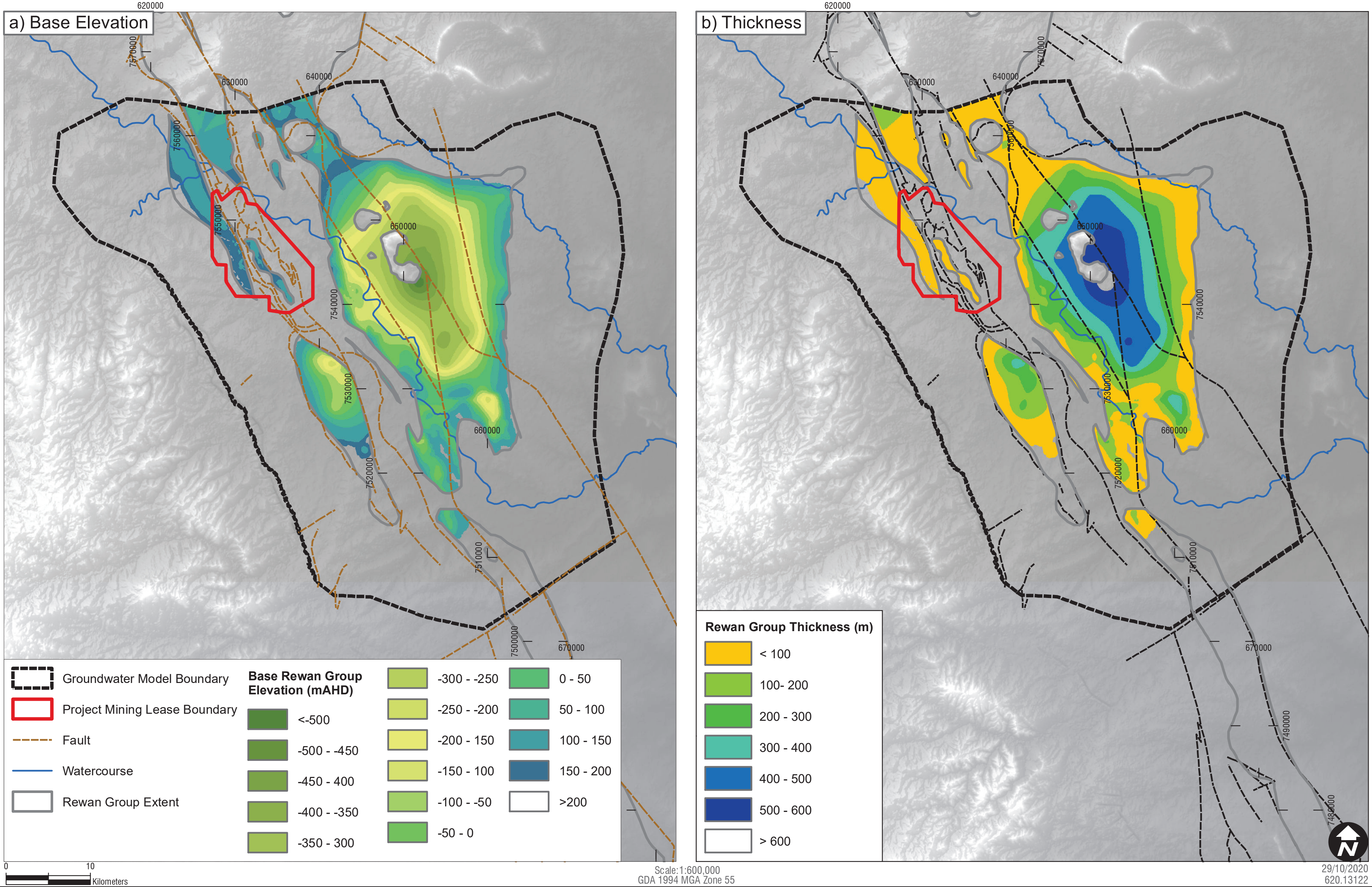


Figure 4-7 Geological Cross Section – Southwest–Northeast



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Structure and Thickness of Triassic Units

FIGURE 4-8

4.2.4 Permian Coal Measures (Blackwater Group)

Permian coal-bearing sedimentary rocks of the Blackwater Group form the main economic resource of the numerous mines in the Study Area. In increasing depth (age) order, the major coal measures in the Study Area include the:

- Rangal Coal Measures;
- Fort Cooper Coal Measures; and
- Moranbah Coal Measures.

Each of these units is discussed further below.

4.2.4.1 Rangal Coal Measures

The shallowest coal measures, the Rangal Coal Measures, has an average thickness of 60 m with a maximum of 195 m thickness at the Project and a depth ranging from 5 mbgl to 310 mbgl. The Rangal Coal Measures contain the target seams for the Project. The Rangal Coal Measures comprise light grey, cross-bedded, fine to medium grained labile and well cemented sandstones, grey siltstones, mudstones, shale and coal seams. The non-coal portions of the sequence being predominantly sandstones, siltstones, mudstone and shales are referred to as interburden in the mining context. Discontinuous vertical horizons in some drill logs at the Project Area indicate the local stratified Rangal Coal Measures sequences are displaced by faulting. Further details on the structural geology are outlined within **Section 4.2.5**.

The coal seams within the Rangal Coal Measures that are of economic interest to the Project are the Lower Leichhardt and Vermont Upper Seams. The average combined thicknesses of the constituent plies comprising each seam is given:

- Lower Leichhardt Seam combined average thickness equal to 4 m; and
- Vermont Upper Seams combined average thickness equal to 2 m.

The Leichhardt Seam is highly weathered where it occurs at subcrop near the surface. Project drill logs indicate that the Vermont Upper Seam is separated from the overlying Leichhardt Seam by interburden material ranging in thickness up to 90 m. The interburden between the Leichhardt and Vermont Seams consist primarily of sandstone, with some mudstone and siltstone. The interburden thickens to the south, where massive sandstone bands characterise the sequence (Golder, 1981). Interpolated structure and thickness contours of the Leichhardt Seam and Vermont Seams at the Project are presented in **Figure 4-9** and **Figure 4-10** respectively. These contours have been based on the Project geological model and drill hole data.

4.2.4.2 Fort Cooper Coal Measures

The Fort Cooper Coal Measures conformably underlie the Rangal Coal Measures and occur at subcrop within the Project Area. The Fort Cooper Coal Measures also contains target seams for the Project (e.g. Vermont Lower Seam). The transition between the Rangal Coal Measures and the Fort Cooper Coal Measures is marked by the Yarrabee Tuff which immediately overlies the Vermont Lower Seam. The Yarrabee Tuff is a basin-wide marker bed comprised of weak, brown tuffaceous claystone, and drill logs indicate the tuff has an average thickness of 0.7 m within the Project Area. Regionally, the formation has a maximum thickness of approximately 350 m (HydroSimulations, 2018) and drill logs indicate the Fort Cooper Coal Measures are comprised of lithic sandstone, conglomerate, mudstone, carbonaceous shale, coal, tuff and tuffaceous (cherty) mudstone.

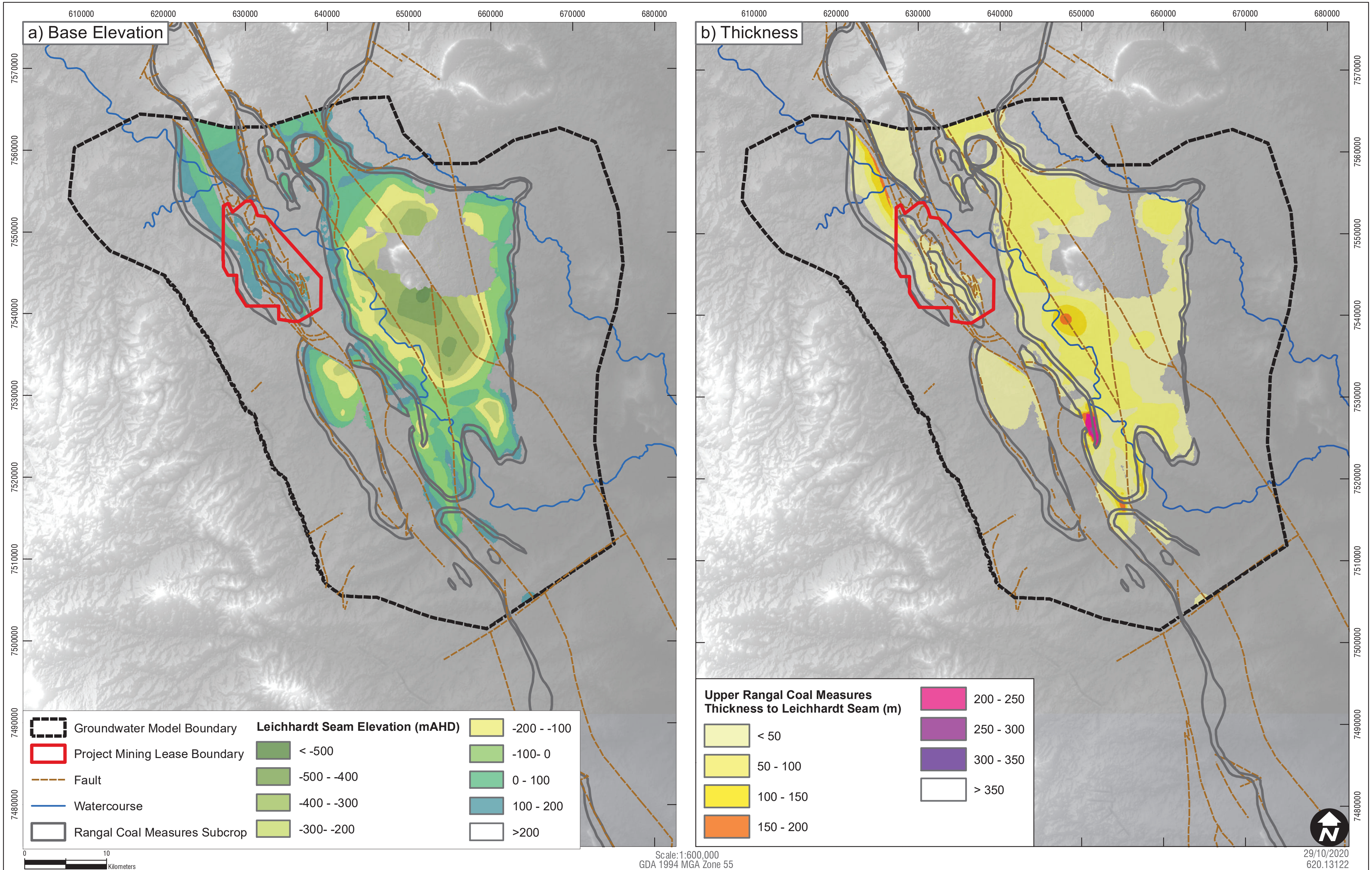
4.2.4.3 Moranbah Coal Measures

The Moranbah Coal Measures conformably underlie the Fort Cooper Coal Measures. These coal measures occur at subcrop west of the Study Area, where they are targeted as part of the Peak Downs and Saraji mines. The Moranbah Coal Measures comprise volcanic lithic sandstones, with lesser siltstone, mudstone, conglomerate and coal. Limited local geology data are available for this formation within the Project Area. The Moranbah Coal Measures were however identified at the Moorvale South Project site with a depth ranging from 236 mbgl to 617 mbgl (SLR, 2019a).

4.2.5 Structural Geology

The Project is located in a structurally complex setting, along the western margin of the Winchester South Syncline. The strike of the syncline is north-northwest to south-southeast and the structure has plunge to the south-southeast. The target seams at site dip towards the east at an angle typically less than 5°, however, dip can be up to 10° in areas (Golder, 1981).

The geology at the Project is heavily faulted, with the north-south oriented Isaac Thrust Fault occurring in the west of the Project Area, and a dense fault network covering the eastern portion, as shown in **Figure 4-2**. Large throws exceeding 80 m displacement have been observed in Project drill holes which intercept the Isaac Thrust Fault and within the eastern fault network.



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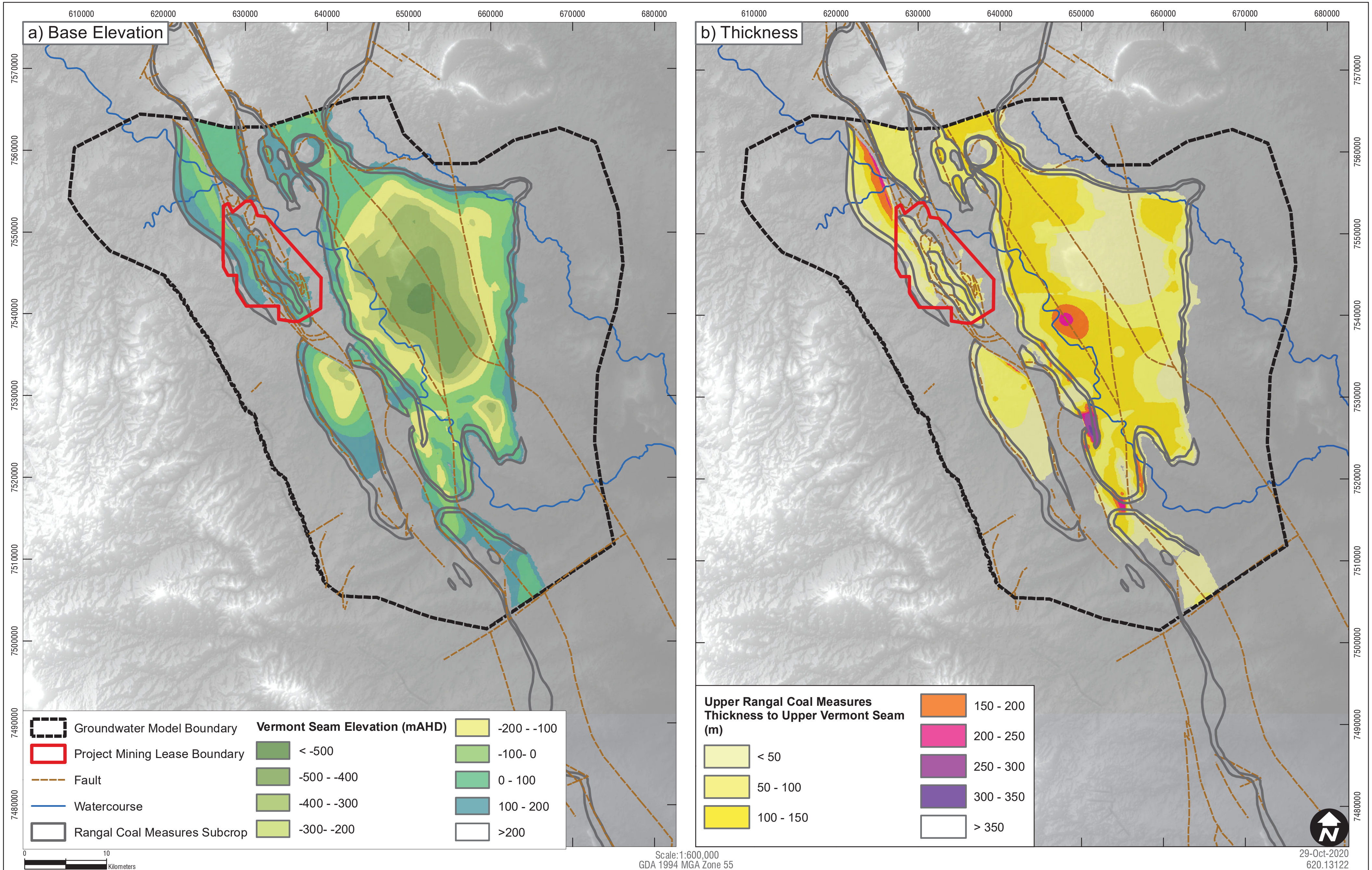
Base Elevation of Leichhardt Seam and Thickness of Rangal Coal Measures to Leichhardt Seam

FIGURE 4-9



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Base Elevation and Thickness of Permian Coal Measures to Upper Vermont Seam

FIGURE 4-10

5 Hydrogeology

Based on the understanding of the geological setting presented in **Section 4**, the hydrogeological regime relevant to the Project comprises the following key hydrogeological units:

- Cainozoic sediments:
  - Quaternary alluvium – unconfined aquifer (water-bearing strata of permeable rock, sand, or gravel) localised along Isaac River;
  - Quaternary to Tertiary colluvium and weathered units (regolith) – unconfined and largely unsaturated unit bordering alluvium;
  - Triassic Rewan Group – aquitard overlying Permian coal measures across much of the Project Area;
- Permian coal measures with:
  - Low permeability interburden units with aquitard properties; and
  - Coal sequences that exhibit water bearing properties associated with secondary porosity through cracks and fissures.

The sandstones of the Clematis Group are generally considered to form an aquifer and are included within the Great Artesian Basin (GAB) aquifers. However, at the Project this unit is not present, but does occur as a small isolated outcrop within the Study Area to the east of the Project. This outcrop is not regionally extensive or hydraulically connected to the GAB. Consequently, the Clematis Group is not considered in detail as part of this assessment.

The Tertiary basalt present in the north-west of the Study Area is not regionally extensive, occurring only as isolated outcrops. Its isolated occurrence and distance from the Project (11 km north-west) limits the hydrogeologic importance to the Project, hence, it is not considered in further detail as part of this assessment.

An Early Cretaceous Granitoid igneous body occurs within a small portion of the northern Project Area, outside of planned mining activity. The rock is solid in nature with a very fine groundmass and unlikely to have significant primary porosity that would facilitate storage and transmission of groundwater. However, regional Bowen Basin fault mapping suggests faulting that affects the Permian strata is also present within the igneous body; where fracturing associated with this faulting is present within the body, it may provide secondary porosity that facilitates groundwater storage and flow within the body.

The coal seams within the Rangal Coal Measures are the primary aquifer units within the Project Area. These seams can be characterised as confined fractured rock aquifers, with the Vermont Seam and immediate underlying strata being the main aquifer unit. The Leichhardt Seam overburden acts as an aquitard and is typically dry, or very low yielding.

As discussed further in **Section 4.2.5,** the Project Area is heavily faulted. Investigations into the hydraulic parameters of the faults within the Project Area was undertaken by Hydrogeologist.com.au in 2019. The findings of this investigation are further discussed in **Section 5.2.3**.

This section provides a discussion of each hydrogeological unit relevant to the Project, covering hydraulic properties, groundwater occurrence, hydraulic gradients, recharge, discharge, groundwater quality, and water use.

5.1 Groundwater Monitoring

5.1.1 Project Area

Whitehaven has installed a Project groundwater monitoring network that comprises a total of 14 monitoring sites consisting of 12 monitoring bores and two Vibrating Wire Piezometer (VWP) arrays (**Table 5-1** and **Table 5-2**). The monitoring network was established in 2012 and expanded further in 2019. Replacement of five monitoring bores in the network took place in October 2019, including bores C2105, C2304, R2009, R2010, and R2034 which were all replaced with bores drilled adjacent the original bore and installed to the same target aquifer. Replacement bores are denoted with an ‘R’ added to the original bore ID. Due to the recent installation of the replacement monitoring bores, baseline data collected from the original bores has been analysed throughout this report. Original bores included in this review are presented in **Table 5-3**. In addition to the 14 monitoring sites, two privately-owned bores and one Whitehaven-owned bore (Winnet) are included in the monitoring network. It is noted that Winnet Bore has been identified as being screened within the Isaac River alluvium, despite being located just outside the mapped extent of the unit in **Figure 5-1**. The network’s monitoring bores intersect a range of hydrostratigraphic units, including:

- The Isaac River alluvium (two privately-owned bores and one Whitehaven owned bore);
- The Vermont Seam of the Rangal Coal Measures (four bores);
- Interburden of the Rangal Coal Measures (three bores); and
- The Leichhardt Seam of the Rangal Coal Measures (five bores).

Baseline water monitoring from the groundwater monitoring network was undertaken during 2019 and 2020. The locations of the current monitoring network are shown in **Figure 5-1** and details provided in **Table 5-1**. Further details about the groundwater monitoring network are included within **Appendix A2**.

Table 5-1 Current Project Groundwater Monitoring Network

Bore ID	Easting (GDA94 z55)	Northing (GDA94 z55)	Elevation (mAHD)	Total Depth (mbgl)	Monitored Unit
C2105R	634650	7541857	209.09	60.00	Leichhardt Seam
C2136	631742	7547243	199.39	65.60	Leichhardt Seam
G2304R	633245	7543171	216.24	56.00	Vermont Seam
G2307	630881	7547844	194.42	81.00	Vermont Seam
R2008	630879	7542573	220.32	-#	Leichhardt Seam
R2009R	631332	7542812	220.24	83.00	Interburden
R2010R	631730	7543070	216.67	66.00	Leichhardt Seam
R2032	630495	7545853	205.31	81.10	Leichhardt Seam
R2034R	629598	7545346	221.60	39.50	Interburden
R2035	629190	7545103	223.54	37.40	Vermont Seam
R2054	629240	7548107	203.60	82.50	Interburden
R2055	628798	7547863	207.46	67.90	Vermont Seam
Knob Hill 1	631005	7553874	191*	Not accessible	Isaac River Alluvium
Knob Hill 2	630431	7554061	193*	24.30	Isaac River Alluvium
Winnet Bore	634791	7550023	187*	18.12	Isaac River Alluvium

Note: Coordinates in GDA 94 MGA Zone 55; * – estimated from DEM; mbgl – metres below ground level; mAHD – metres above Australian Height Datum; # - Depth unknown

Table 5-2 Project Groundwater Monitoring Network - VWPs

Bore ID	Easting (GDA94 z55)	Northing (GDA94 z55)	Elevation (mAHD)	Total Depth (mbgl)	Sensor Depth (mbgl)	Sensor Depth (mAHD)
VWP1	632312	7549767	192.81	155	50	142.81
					90	102.81
					150	42.81
VWP2	635711	7546357	201.68	155	50	151.68
					90	111.68
					150	51.68

Table 5-3 Replaced Project Monitoring Network Bores

Bore ID	Easting (GDA94 z55)	Northing (GDA94 z55)	Elevation (mAHD)	Total Depth (mbgl)	Monitored Unit
C2105	634668	7541867	208.28	-#	Leichhardt Seam
G2304	633262	7543161	215.55	58.00	Vermont Seam
R2009	631318	7542810	219.72	81.00	Interburen
R2010	631743	7543062	215.62	64.50	Leichhardt Seam
R2034	629614	7545329	220.73	39.00	Interburen

Note: Coordinates in GDA 94 MGA Zone 55; * – estimated from DEM; mbgl – metres below ground level; mAHD – metres above Australian Height Datum; # - Depth unknown

5.1.2 Other Projects

Groundwater monitoring data from bores installed at the adjacent Olive Downs Project, Moorvale South Project, and Eagle Downs Mine have been incorporated into this Groundwater Assessment. These bores are shown on **Figure 5-2** and a summary provided in **Figure 5-4**.

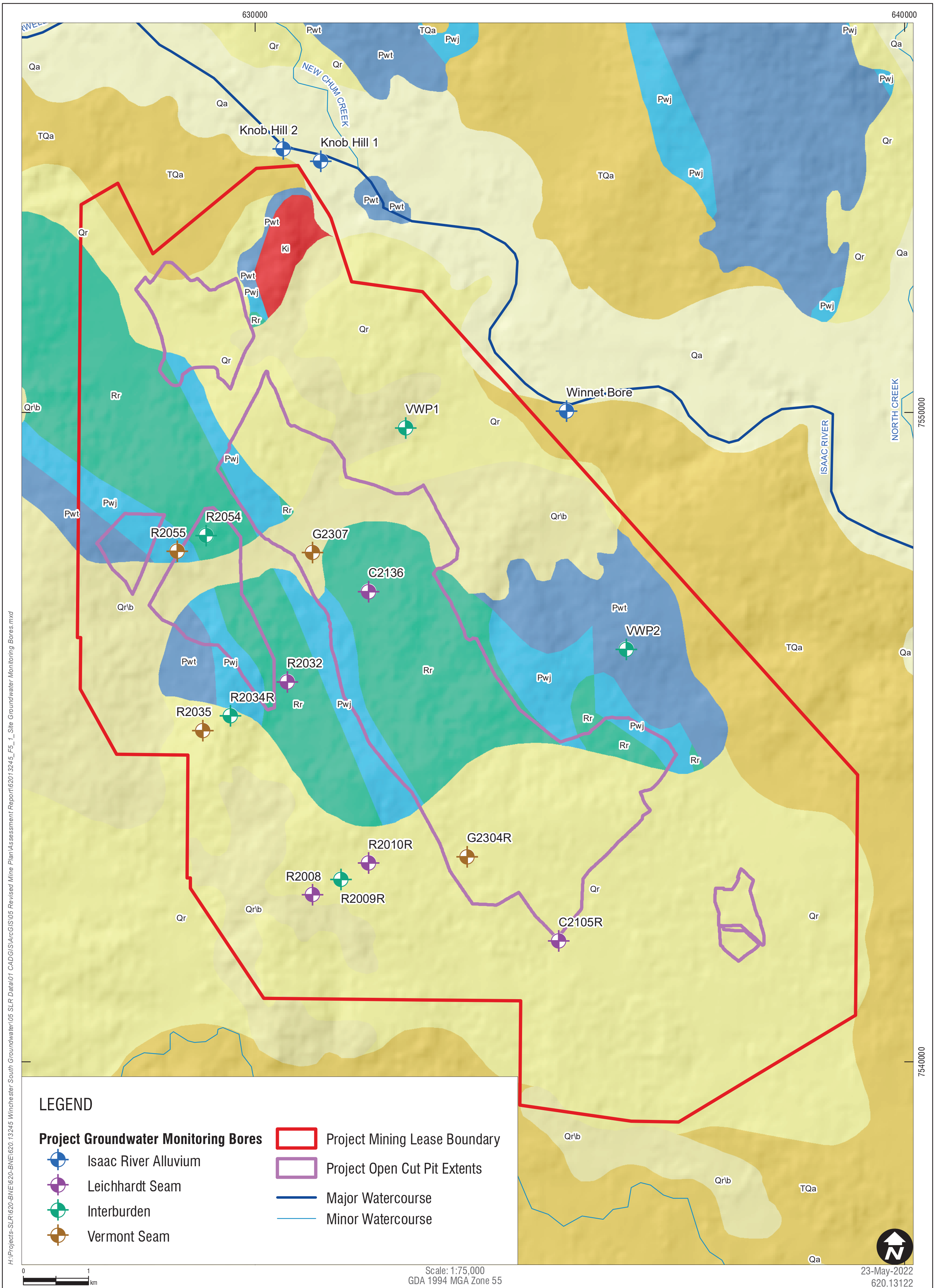
Table 5-4 Groundwater Monitoring Networks for Surrounding Operations

Bore ID	Site ID	Easting (GDA94 z55)	Northing (GDA94 z55)	Total Depth (mbgl)	Monitored Unit
Moorvale South Project					
MS0234	ODN18MB1	640275	7547943	43	Leichhardt Seam
MS0235	ODN18MB2	640263	7547944	20	Alluvium
MS0128	ODN18MB3	639750	7551426	45	Leichhardt Seam
-	ODN18MB4	640684	7549869	24.5	Alluvium
MS0135	ODN18MB5	640000	7551811	27	Alluvium
MS0163	ODN18MB6	639944	7551802	129	Leichhardt Seam
MS0117	ODN18MB7	640310	7554734	36	Alluvium
MS0129	ODN18MB8	638921	7550183	26	Alluvium
MS0113	ODN18MB9	640089	7557236	27	Rangal Overburden
MS0125	ODN18MB10	639451	7554580	135	Fort Cooper Coal Measures - Coal
MS0162	ODN18MB11	638599	7553465	122.8	Fort Cooper Coal Measures - Coal
MS0236	ODN18MB12	640277	7547944	124	Leichhardt Seam
MS0231	ODN18VWP1	640295	7547985	128	Alluvium Rangal Overburden Leichhardt Seam Vermont Lower Seam
MS0233	ODN18TB1	640318	7547935	57	Leichhardt Seam
MS0232	ODN18TB2	640303	7547935	21	Alluvium

Bore ID	Site ID		Easting (GDA94 z55)	Northing (GDA94 z55)	Total Depth (mbgl)	Monitored Unit
Olive Downs Project						
IF3839P	GW01s		642481	7547491	20	Alluvium
IF3837P	GW02s		641152	7546517	19	Alluvium
IF3838P	GW02d		641141	7546507	137	Vermont Upper Seam
IF3841P	GW04		643388	7544973	41	Alluvium
IF3835P	GW06s		639329	7542005	10	Regolith
VP3833P	GW08s		645312	7539839	13	Alluvium
VP3831P	GW12s		641504	7532788	42	Regolith
VE3827P	GW16s		660836	7525291	27	Regolith
VE3829P	GW18s		656889	7522809	15	Alluvium
VE3830P	GW18d		656868	7522804	183	Vermont Upper Seam
VE3825P	GW21s		661590	7521656	9	Regolith
VE3826P	GW21d		661585	7521655	157	Rangal Interburden
IF3856P	S7		641443	7545828	21	Alluvium
IF3857P	S9		641767	7545426	22	Alluvium
IF3858P	S11		642455	7545332	14	Alluvium
IF3859P	S10		642552	7546035	24	Alluvium
IF3860P	S8		642340	7546343	15	Alluvium
IF3861P	S6		642054	7546721	21	Alluvium
IF3862P	S4		641567	7546845	18	Alluvium
IF3863P	S5		642239	7547332	24	Alluvium
IF3864P	S2		641386	7547617	18	Alluvium
IF3840P	GW01d	VWP1	642479	7547491	413	Vermont Upper Seam
		VWP2				Leichhardt Seam
		VWP3				Rewan Group
		VWP4				Rewan Group
IF3836P	GW06d	VWP1	639334	7542008	203	Fort Cooper Coal Measures - siltstone
		VWP2				Fort Cooper Coal Measures - Coal
		VWP3				Fort Cooper Coal Measures - sandstone
		VWP4				Fort Cooper Coal Measures - sandstone

Bore ID	Site ID		Easting (GDA94 z55)	Northing (GDA94 z55)	Total Depth (mbgl)	Monitored Unit
VP3834P	GW08d	VWP1	645312	7539846	585	Leichhardt Seam
		VWP2				Rangal Overburden
		VWP3				Rewan Group
		VWP4				Rewan Group
VP3832P	GW12d	VWP1	641495	7532795	519	Leichhardt Seam
		VWP2				Leichhardt Seam
		VWP3				Rangal Overburden
		VWP4				Rewan Group
VE3828P	GW16d	VWP1	660835	7525287	339	Vermont Upper Seam
		VWP2				Leichhardt Seam
		VWP3				Rewan Group
		VWP4				Rewan Group
Eagle Downs Mine						
MB1	n/a		623254	7551541	50.5	Fort Cooper Coal Measures - siltstone
MB2	n/a		623684	7549391	50.5	Fort Cooper Coal Measures – sandstone and siltstone
MB3	n/a		627240	7549946	51.4	Rewan Group
MB4	n/a		626507	7544152	51.0	Fort Cooper Coal Measures – coal, sandstone and siltstone
MB5	n/a		628491	7542693	51.5	Fort Cooper Coal Measures – coal, sandstone and siltstone
LH8*	n/a		623797	7552173	>85.0	Fort Cooper Coal Measures
LH11*	n/a		627205	7546949	~30.0	Fort Cooper Coal Measures
LH13*	n/a		627200	7546952	~30.0	Fort Cooper Coal Measures

Note: * construction details not available



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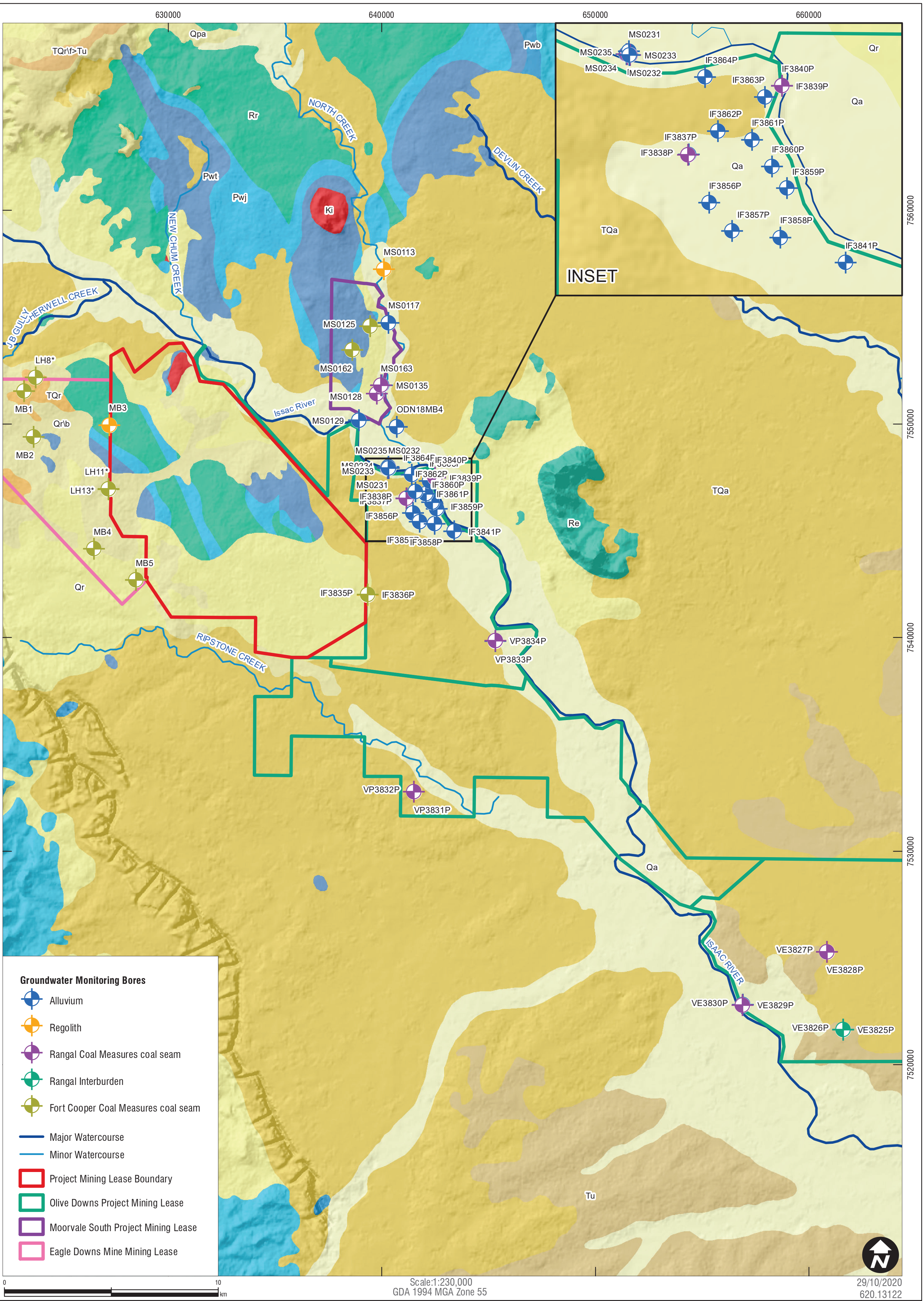
Project Groundwater Monitoring Bores

FIGURE 5-1



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Surrounding Groundwater Monitoring Bores

FIGURE 5-2

5.2 Hydraulic Properties

Hydraulic testing was conducted on major geological units within the Project Area for this Groundwater Assessment. Hydraulic testing was also conducted in 2017 and 2019 for the Olive Downs Project and Moorvale South Project Groundwater Assessments, respectively. The Project hydraulic testing included slug tests on the monitoring network, core sample from the overburden and underburden of the coal seams, as well as downhole packer tests targeting major faults in the Project Area. The Olive Downs Project and Moorvale South Project assessments included laboratory geotechnical testing of core samples for vertical (Kv) and horizontal (Kh) hydraulic conductivity, and field testing using methods such as monitoring bore slug testing, packer testing for horizontal hydraulic conductivity, pumping tests, as well as documenting airlift yields. Across July 2019 step and constant rate pumping tests were conducted at two bores as part of the Moorvale South Project assessment.

Two pumping tests have been carried out near the Moorvale South Project site, 3 km east of the Project Area. The purpose of these tests was to establish characteristics of the Isaac River alluvial aquifers and the coal seam aquifers of the Rangal Coal Measures (Golder Associates, 2019). This information contributes to the understanding of the connectivity between the deep and shallow aquifers, the interaction between the shallow aquifer and the Isaac River and the flow dynamics within the aquifers.

This section presents a summary of the available field hydraulic data and comparison to reported hydraulic properties within external sources. Full detail on the hydraulic testing conducted within the Project Area is included within **Appendix A2**.

5.2.1 Hydraulic Data

The database of available field results for horizontal and vertical hydraulic conductivity is presented graphically as **Figure 5-3**. Tests from the Project Area are provided as a separate classification on the plot. The data are also presented separately for each test method as results can vary based on the type of testing and analysis undertaken.

Figure 5-3 shows that the hydraulic conductivity of the alluvium is variable, ranging from 10^{-2} to almost 10^{1} metres per day (m/day), which reflects the heterogeneous nature of the alluvial sediments. Pumping tests conducted in 2019 as part of the Moorvale South Project assessment reported hydraulic conductivity values in the range of 2.1 – 2.7 m/day which is in the range of values provided by slug testing previously conducted across the Study Area.

The Rewan Group sediments exhibit a low hydraulic conductivity, typically less than 10^{-4} m/day, similar to the interburden/overburden material of the Rangal Coal Measures. Two interburden slug tests conducted within the Project Area in 2012 identified bores (R2034 & R2054) with an unusually elevated hydraulic conductivity of just under 1 m/day, which is thought to be associated with faulting and fracturing in the vicinity of these bores. Other results from this testing show an interburden hydraulic conductivity of at least an order of magnitude less than that of coal seams at similar depths. Hydraulic testing of core samples from overburden and underburden of the coal seams within the Project Area conducted in 2019 show results in the same range as those observed at Moorvale South Project, Olive Downs Project, and previous testing within the Project Area.

The coal seams of the Permian coal measures generally record higher hydraulic conductivity than the majority of the interburden/overburden for tests. This is due to the dual porosity of the coal seams, with a primary matrix porosity and a second (dominant) porosity provided by fractures (joints and cleats), and supports the concept of the coal seams themselves forming the dominant groundwater zones of the Permian units. Moorvale South Project site pumping tests in 2019, performed on the Leichhardt and Vermont Seams, reported hydraulic conductivity ranges between 0.5 – 1.5 m/day, and 0.5 – 1.2 m/day, respectively. These values generally align with previous testing of the Permian coal measures across the Study Area. **Figure 5-3** shows that the hydraulic conductivity of the Rewan Group as well as the Permian coal measures generally declines with depth, due to increasing overburden pressure reducing the aperture of secondary porosity features. Comparison of vertical and horizontal hydraulic conductivities indicates that within the Rewan Group the vertical hydraulic conductivity is around 10% to 40% of horizontal hydraulic conductivity. Anisotropy for the Rangal Coal Measures interburden material was more variable, with vertical hydraulic conductivity ranging between 11% and 76% of horizontal hydraulic conductivity. During the Olive Downs Project Groundwater Assessment, core samples were collected within the coal seam roof/ floor material and proximal to fault zones, where practicable (i.e. for competent samples). Results for these samples indicated a vertical hydraulic conductivity of between 50% to 160% of horizontal hydraulic conductivity.

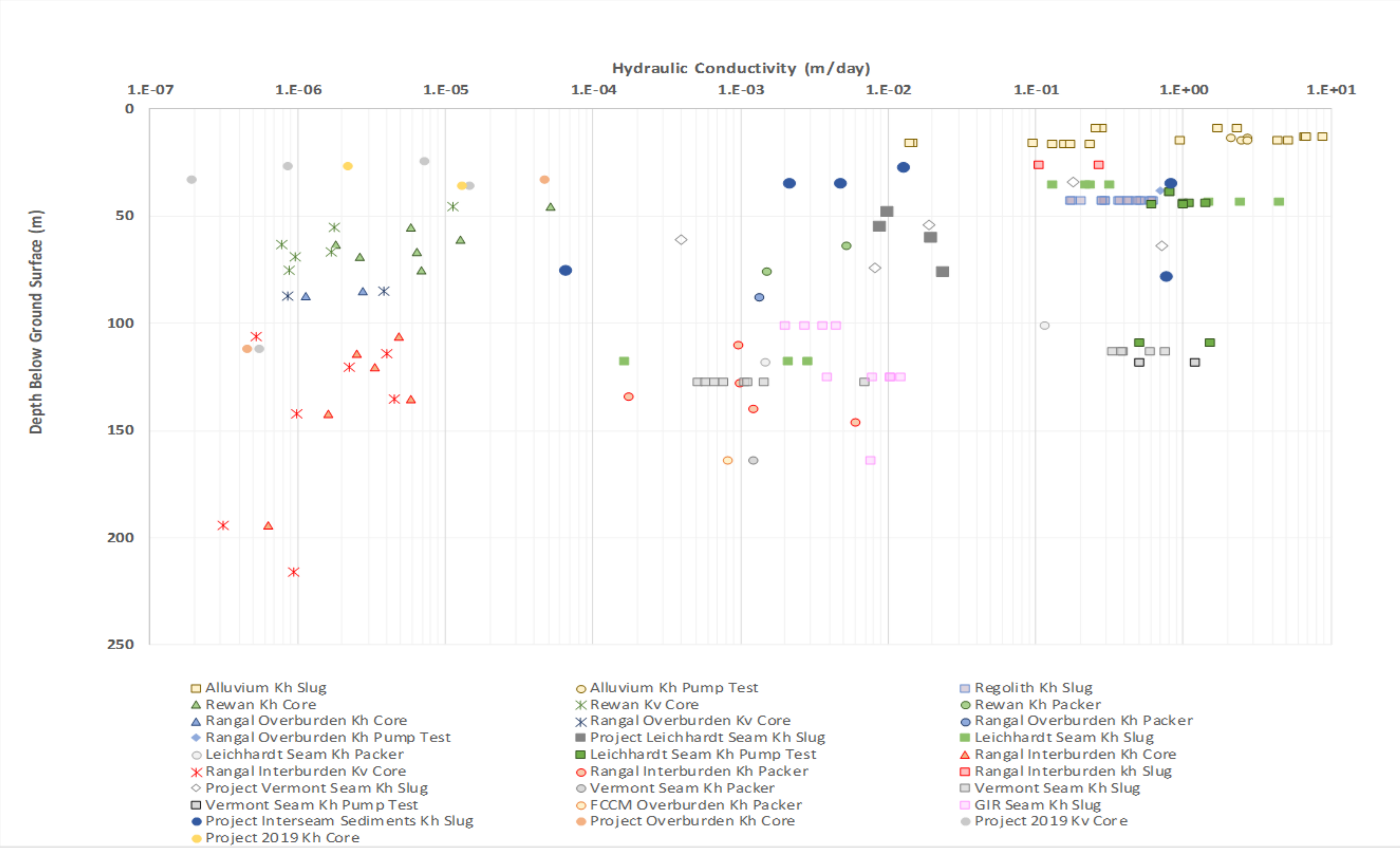
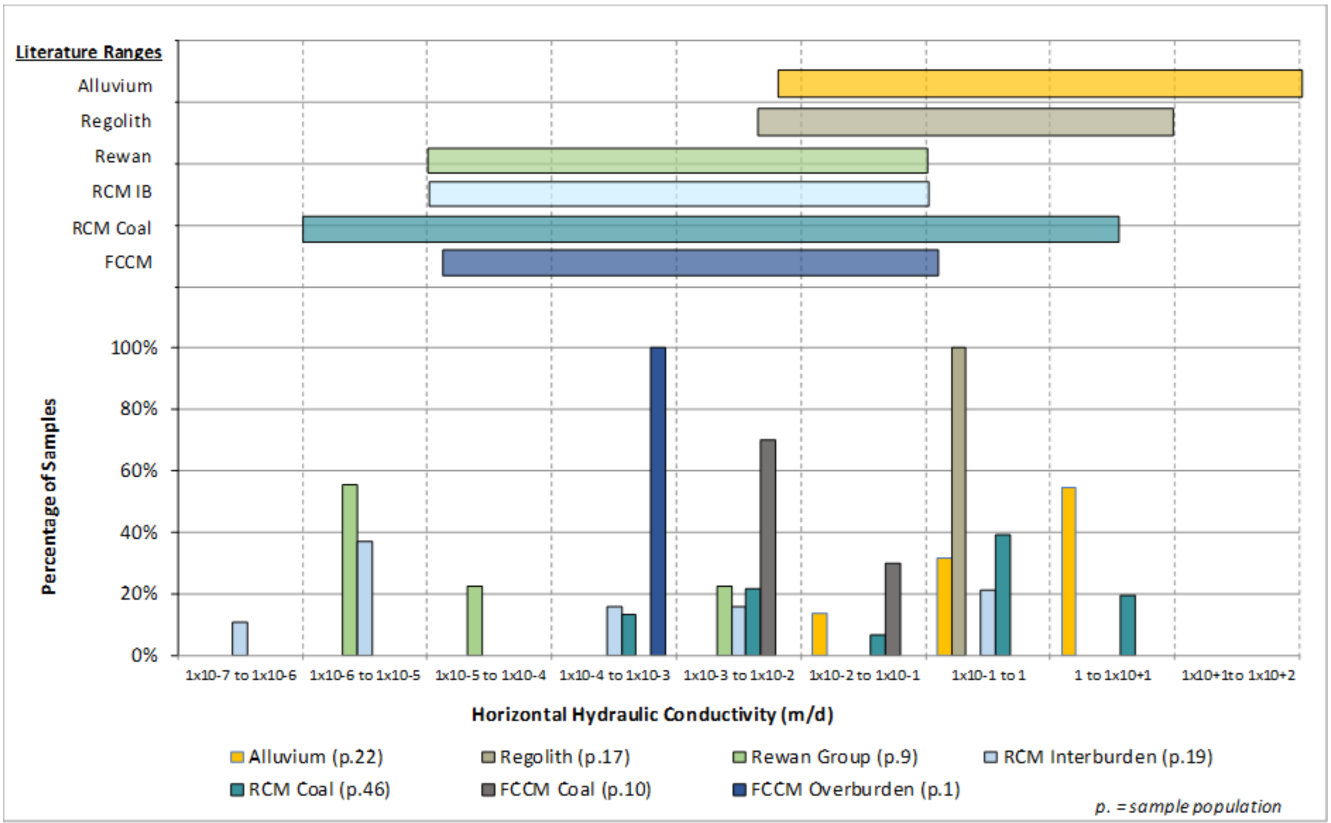


Figure 5-3 Summary of Results for All Hydraulic Testing

5.2.2 Hydraulic Conductivity Ranges

A histogram of the spread of horizontal hydraulic conductivity from the field testing at the Project, as well as at Olive Downs Project and Moorvale South Project, is presented in **Figure 5-4**. The results are compared to the range of documented values for the various units in literature.



RCM = Rangal Coal Measures, FCCM = Fort Cooper Coal Measures, RCM IB = Rangal Coal Measures Interburden.

Figure 5-4 Histogram of Horizontal Hydraulic Conductivity Distribution

The comparison shows that the field results for alluvium, regolith, Rangal Coal Measures and Fort Cooper Coal Measures within the Project Area and immediate surrounds fall within the range of field data collected through other studies across the Bowen Basin. Results from the Moorvale South Project site recorded some lower readings for the Rewan Group than previously identified in literature. A broader range of hydraulic conductivity for the Rangal Coal Measures coal was also observed at the Project Area and at the adjacent Moorvale South Project and Olive Downs Project sites than is observed in literature, with values of up to 1.5 m/day (Project Area) and 4.4 m/day (Moorvale South Project area) reported.

5.2.3 Faulting

As discussed in **Section 4.2.5**, extensive faulting has been mapped within the Permian coal measures within the Project Area (see **Figure 4-2**). As identified by Jourde et al. (2002), faulting can result in higher permeabilities within strata parallel with the fault plane, and lower permeabilities within strata perpendicular to the fault plane. However, this can also be dependent on whether faults are currently active (Paul et al., 2009). Faulting has been inactive within the Bowen Basin for over 140 million years (Clark et al., 2011), indicating that the fault zones are less likely to act as conduits to flow; this relates to filling of the fractured pore spaces over time through hydrothermal alteration and mineralisation (Uysal et al., 2000). Drill core logs from within the Study Area and the Project Area show that where fractures and faults have been geologically logged, many fractures are "healed" with calcite and siderite. This indicates that although the system contains a fracture network, many of the existing fractures are cemented and this cementation reduces the effective permeability of the fracture when compared to any open fracture network.

Within the Project Area, four existing drill holes were identified by Whitehaven as having a high likelihood of intersecting faults. Of these four, two drill holes were selected for further investigation based on their assessed moderate to high level of confidence of faulting intersection (**Table 5-5**). These drill holes were redrilled for the purpose of packer testing to characterise hydraulic properties of the faults downhole. Full details of the testing are presented in Hydrogeologist.com.au (2019). Results from the packer tests revealed lugeon values and hydraulic conductivities within the holes at various testing intervals as presented in **Table 5-6**.

Fault zones were confirmed to be intersected at these drill holes due to the presence of fracturing, calcite infills, and slickensides in core obtained from the drill holes, all of which are considered an indicative marker of faulting. Packer testing hydraulic conductivity results from bore WS3182 ranged from 9.48×10^{-4} to 1.02×10^{-3} m/day. Drill hole WS3189 reported hydraulic conductivity results ranging between 6.93×10^{-5} and 2.07×10^{-3} m/day. These results represent relatively low hydraulic conductivity values in line with those presented in **Figure 5-5**. These properties indicate that the faulting zones intercepted and tested within the Project Area are 'healed' and not pathways for preferential flow.

Table 5-5 Winchester South Packer Testing Hole Details

Bore ID	Easting	Northing	Elevation (mAHD)	Depth Chipped (m)	Depth Cored (m)
WS3182	629984	7548252	198.03	85	98.1
WS3189	632555	7548274	191.46	30	63.1

Table 5-6 Winchester South Packer Testing Results (Hydrogeologist, 2019)

Bore ID	Interval Tested (m)	Comments	Lugeon Pattern	Lugeon Value	Hydraulic Conductivity (m/s)	Hydraulic Conductivity (m/d)
WS3182	87 – 89	Mudstone and carbonaceous mudstone clasts, brecciated within sandstone matrix	Dilation – lowest lugeon recorded	0.38	1.10×10^{-8}	9.48×10^{-4}
	89 – 91	Mudstone, fractured and broken, slickensides	Turbulent – highest water pressure	0.40	1.14×10^{-8}	9.84×10^{-4}

Bore ID	Interval Tested (m)	Comments	Lugeon Pattern	Lugeon Value	Hydraulic Conductivity (m/s)	Hydraulic Conductivity (m/d)
	93 – 95	Mudstone and minor siltstone, unfractured, massive	Dilation – lowest lugeon recorded	0.54	1.18×10^{-8}	1.02×10^{-3}
WS3189	35 – 37	Coal	Wash out – highest value	0.52	2.39×10^{-8}	2.07×10^{-3}
	41 – 43	Mudstone, minor fracturing, calcite infill	Void filling – final value	0.04	1.19×10^{-9}	1.02×10^{-4}
	48 – 50	Mudstone, minor fracturing, calcite infill	Turbulent – highest water pressure	0.02	8.02×10^{-10}	6.93×10^{-5}
	54 – 56	Coal, sandstone, siltstone and mudstone, slickensides, calcite infill	Dilation – lowest lugeon recorded	0.04	9.95×10^{-10}	8.60×10^{-5}
	57 – 59	Siltstone and sandstone, relatively unfractured	Void filling – final value	0.08	2.57×10^{-9}	2.22×10^{-4}

RCM = Rangal Coal Measures, FCCM = Fort Cooper Coal Measures

As discussed in **Section 5.2.1**, laboratory geotechnical analysis of core samples of interburden immediately above and below coal seams proximal to a fault zone have previously been undertaken in support of groundwater assessments in the Study Area. The samples recorded vertical hydraulic conductivity of 50% to 160% of horizontal hydraulic conductivity; i.e. although some samples show a typical vertical hydraulic conductivity of somewhat less than horizontal hydraulic conductivity, some samples also suggest greater vertical hydraulic conductivity than horizontal hydraulic conductivity which may be indicative of preferential vertical flow pathways associated with faulting. However, it was also noted that these areas of increased vertical hydraulic conductivity are limited vertically, with samples collected from the same drill hole at horizons further above and below the fault zone (interburden and Rewan Group) returning a lower vertical hydraulic conductivity of between 11% and 76% of horizontal hydraulic conductivity.

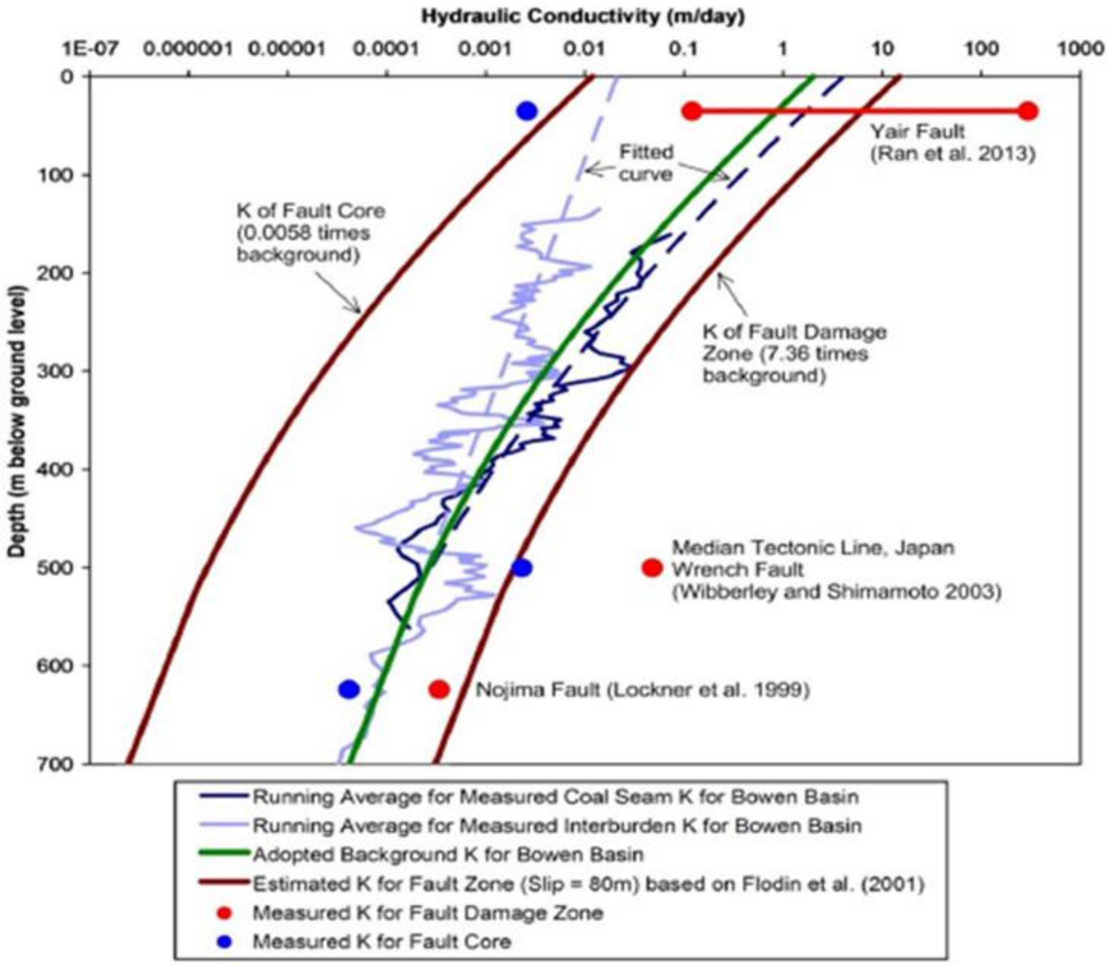


Figure 5-5 Faulting Conceptual Model Developed by Coffey (2014)

The impact of faults on groundwater flow within the Study Area was also assessed as part of the Bowen Gas Project. Kinnon (2010) assessed the movement of water and gas across a series of faults in the Bowen Basin using stable isotope and water quality analysis to assess zones of potential recharge, water mixing and flow pathways. Higher gas production rates were also observed on either side of a major fault, with differences in isotopic compositions of produced water for wells north and south of the major fault line at similar depths, implying little communication across the fault boundary, and suggesting that the fault acts as a horizontal permeability barrier to water and gas flow. The results of the study showed that compartmentalisation was evident and that this was due to the structural geology (faulting) in the basin.

Based on a detailed literature review of the effect of faulting on groundwater flow, Coffey (2014) has developed a conceptual model for fault zone hydraulic characterisation in the Bowen Basin (**Figure 5-5**), largely based on Jourde *et al*. (2002) and Flodin *et al*. (2001). This conceptualisation provides a means of inferring hydraulic conductivities of the fault core and the fault damage zone from regional hydraulic conductivity, with the fault core typically one to three orders of magnitude lower conductivity than the regional host rock, and the damage zone approximately an order of magnitude higher.

5.3 Groundwater Distribution, Flow, Recharge and Discharge

5.3.1 Alluvium

5.3.1.1 Distribution and Flow

Alluvial groundwater levels are currently monitored at three bores (refer to **Table 5-1** and **Figure 5-1**) as part of the Project. Water levels have been sporadically monitored at these sites between 2012 and the routine baseline monitoring in 2019. Knob Hill 1 was inaccessible throughout the 2019 baseline monitoring period, with data from 2012-2013 available. Recorded groundwater levels at all bores remained relatively stable over the monitoring period with a strong correlation between water level and rainfall observed at Knob Hill 1 and Knob Hill 2. Groundwater level trends for alluvial bores are presented in **Figure 5-6**. Current groundwater elevations within the alluvial monitoring network for the Project range between 171 mAHD (Winnet Bore) and 179 mAHD (Knob Hill 2), approximately 16 mbgl and 14 mbgl respectively. The higher elevations are recorded in bores positioned further upstream of the Isaac River. Anomalous values were reported during the final days of monitoring at Knob Hill 1 with the cause of this unknown but may be a result of groundwater level logger failure. These anomalous values have been removed from further analysis in this section.

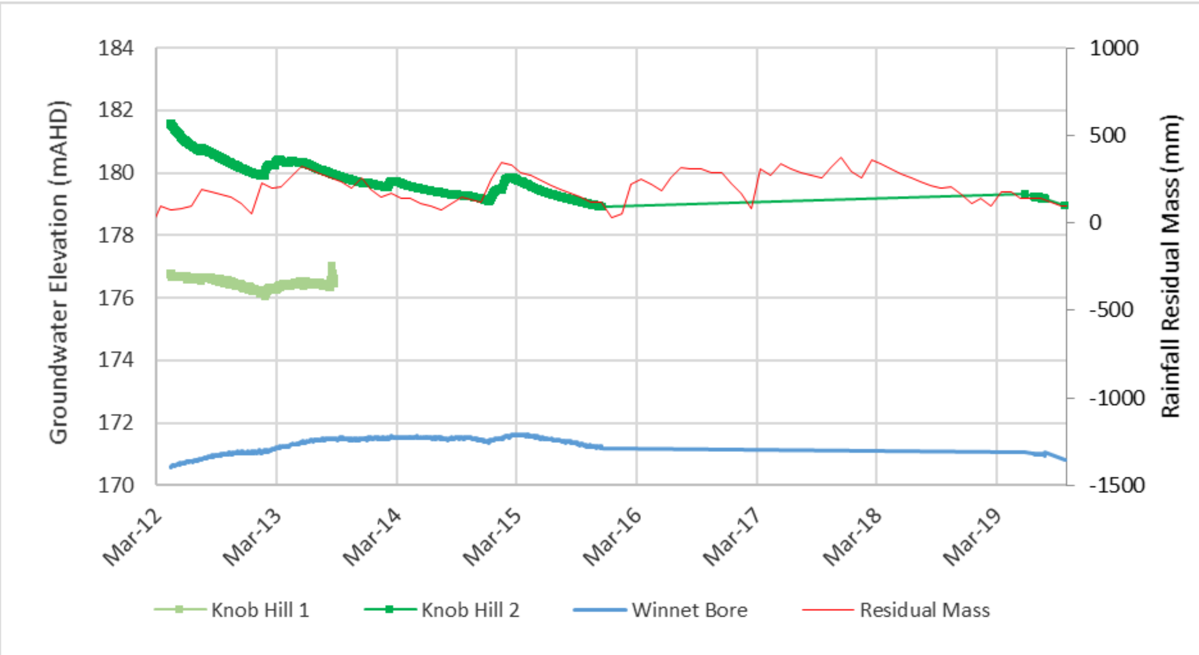


Figure 5-6 Hydrograph of Alluvial Groundwater Trends

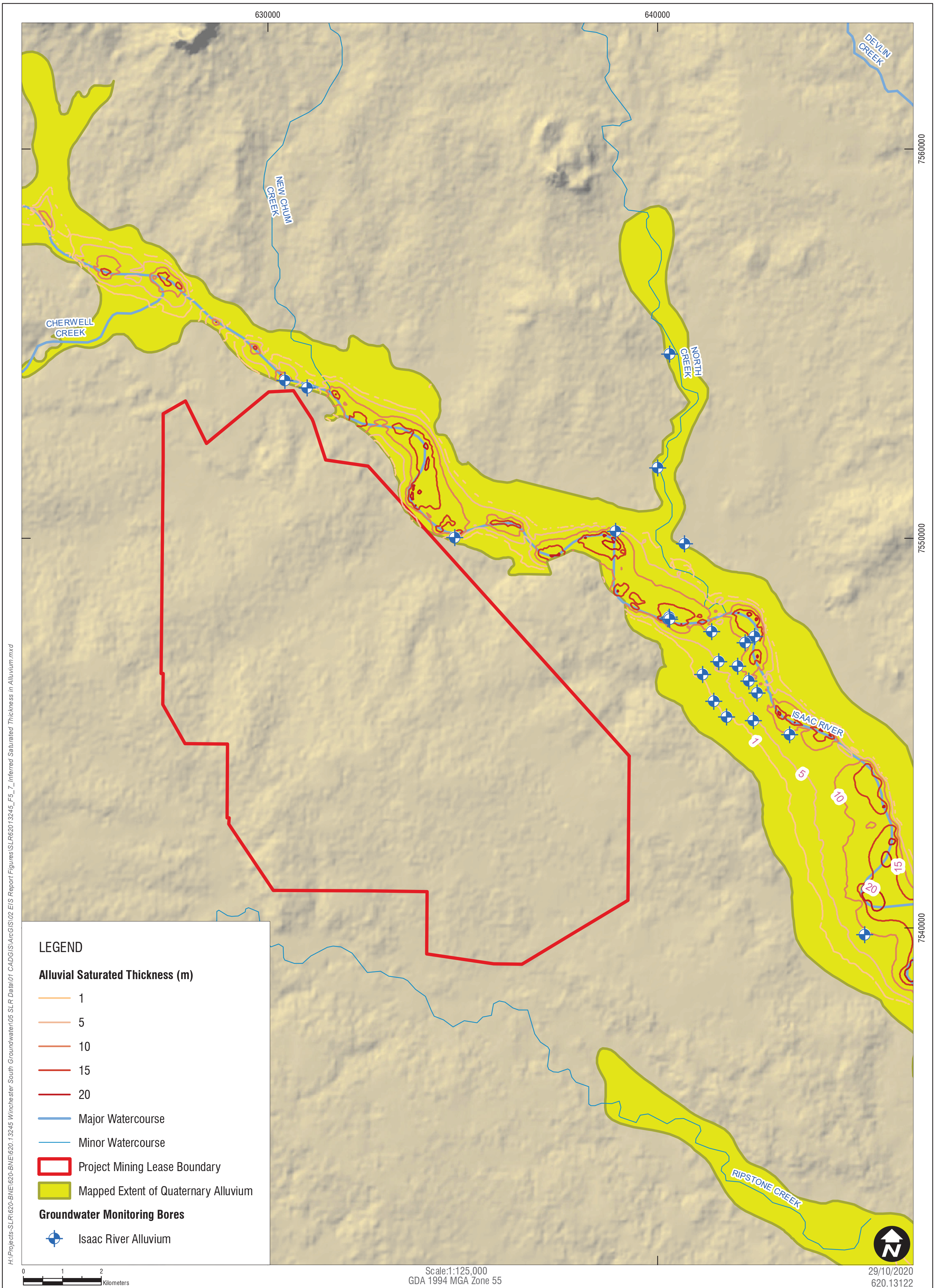
Figure 5-7 presents the mapped extent of alluvium and the calculated saturated thickness interpolated from available water level data. **Figure 5-7** shows that the surficial alluvium associated with the upper reaches of tributaries east of the Isaac River is largely dry. Alluvium of the Isaac River itself does appear saturated however, with the greatest saturated thickness along the alignment of the Isaac River.

A potentiometric surface for the Isaac River alluvium (**Figure 5-8**) has been developed using a combination of water levels obtained in the Project's alluvial monitoring bores and from water level observations collected during the Moorvale South Project and Olive Downs Project groundwater assessments. The water levels in the Isaac River alluvium clearly follow the flow direction of the Isaac River, with south-easterly flow gradients. Alluvial groundwater elevations range from just under 179 mAHD to the north of the Project, and between approximately 162 mAHD to 166 mAHD to the south-east, increasing with proximity to the Isaac River. This suggests losing stream conditions as discussed in **Section 5.3.5**.

5.3.1.2 Recharge and Discharge

Recharge to the alluvium is considered to be mostly from stream flow or flooding (losing streams), with direct infiltration of rainfall also occurring where there are no substantial clay barriers in the shallow subsurface. As shown in **Figure 5-6**, groundwater levels at Knob Hill 2 have generally shown trends similar to rainfall. Groundwater levels at Winnet Bore have remained relatively stable to slightly increasing from April 2012 to July 2019, recording an increase of approximately 0.5 m. The lack of response to rainfall trends observed at Winnet Bore may either relate to the presence of surficial clays restricting groundwater recharge, as discussed in **Section 4.2**, or that rainfall was not sufficient to wet the unsaturated zone within the Isaac River alluvium above the water table as well as providing vertical groundwater flow towards the water table.

Groundwater within the Isaac River alluvium is discharged as evapotranspiration from riparian vegetation growing along the Isaac River, as well as potential baseflow contributions after significant rainfall and flood events. Groundwater within the Isaac River alluvium is also discharged through the use of privately-owned bores in the region. Geological logs in the Study Area indicate the alluvium is underlain by low hydraulic conductivity stratigraphy (i.e. claystone, siltstone and sandstone), which restricts the rate of downward leakage to underlying formations. Localised perched water tables within the alluvium are evident where waterbodies continue to hold water throughout the dry period (e.g. pools in the Isaac River and floodplain wetlands) and occur where clay layers slow the percolation of surface water.



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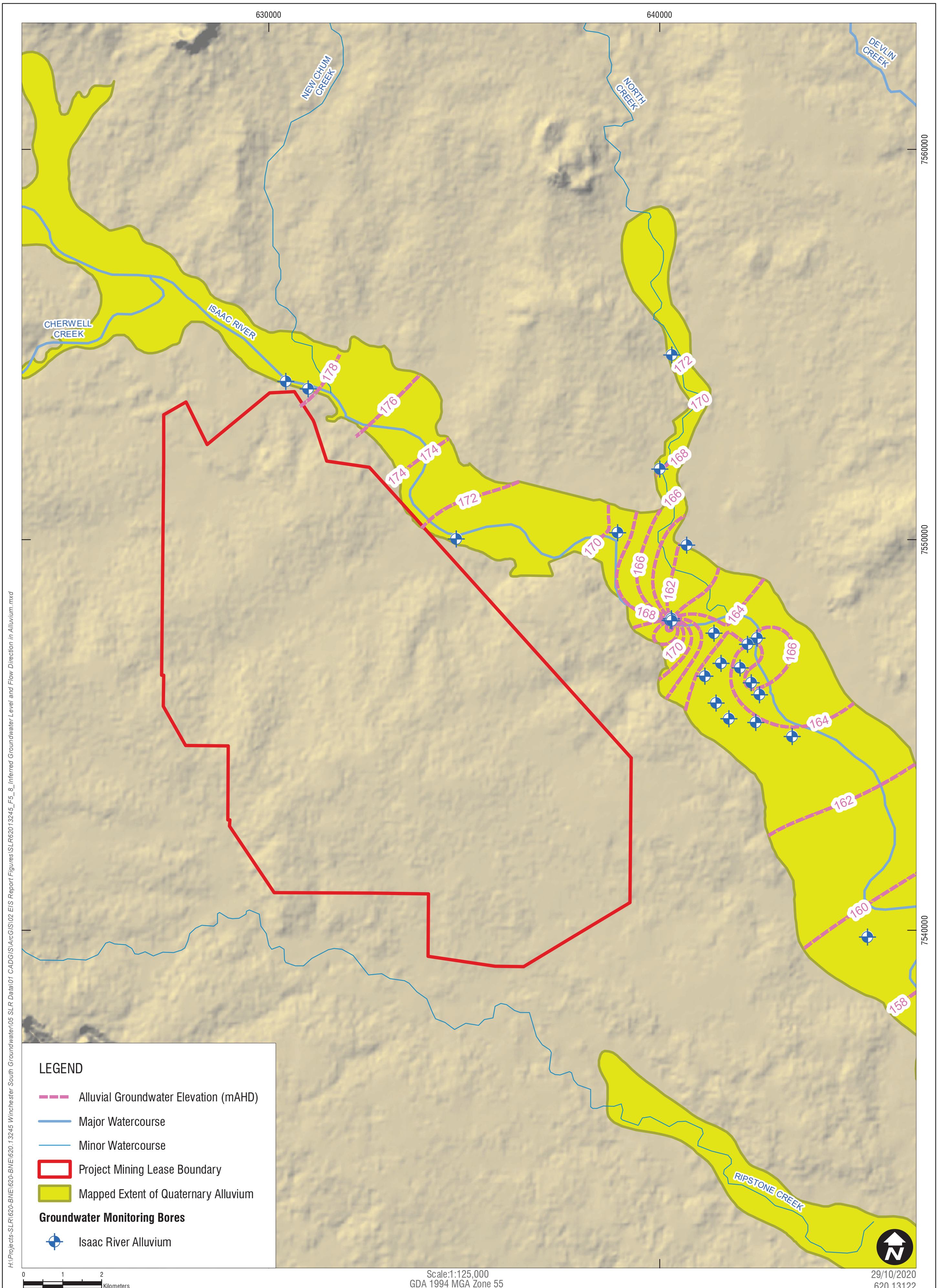
Inferred Saturated Thickness in Alluvium

FIGURE 5-7



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Inferred Groundwater Level and Flow Direction in Alluvium

FIGURE 5-8

5.3.2 Regolith

5.3.2.1 Distribution and Flow

Exploration drilling across the Project Area suggests that the regolith is not commonly saturated. Groundwater monitoring conducted within the Study Area includes four monitoring bores intersecting the regolith (GW06s, GW12s, GW16s and GW21s at the Olive Downs Project) with the location of these bores shown in **Figure 5-2**. Two of the regolith (GW06s and GW16s) bores have remained dry (unsaturated) between June 2017 and February 2019. However, bore GW12s which is located along Ripstone Creek, records a saturated thickness of around 23 m in the regolith, while bore GW21s has a saturated thickness of less than 1 m.

Overall, the regolith is considered to be largely unsaturated, with the presence of water restricted to lower elevation areas along the Isaac River and the lower reaches of its tributaries (i.e. Ripstone Creek). Flow within the regolith where it is saturated is a reflection of topography, flowing towards nearby drainage lines.

5.3.2.2 Recharge and Discharge

Water within the regolith, where it is saturated, occurs at depths of approximately 8 mbgl to 19 mbgl. Groundwater elevations at the two regolith monitoring bores containing water in the Study Area (GW12s and GW21s) are presented in **Figure 5-9**. Groundwater levels have remained relatively stable between June 2017 and February 2019, despite above average rainfall, although not substantial, from October to December 2017 and over February 2018. As discussed in **Section 4.2**, the regolith material comprises low hydraulic conductivity strata (i.e. clay and claystone), which restricts rainfall recharge. The lack of response may also be due to rainfall being insufficient to wet the unsaturated zone above the water table as well as providing vertical groundwater flow towards the water table.

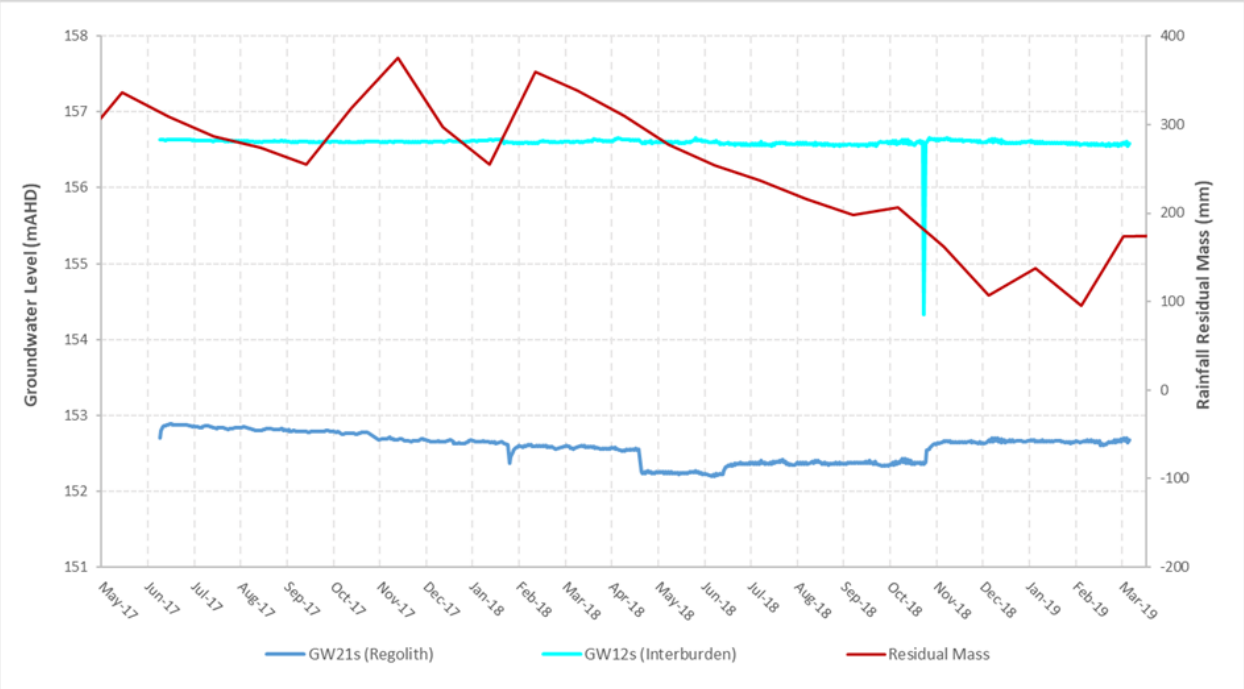


Figure 5-9 Hydrograph of Regolith Groundwater Trends

Groundwater discharge occurs primarily via evapotranspiration, with some short-term baseflow to streams from the regolith following wet climatic conditions. Vertical seepage through the regolith is limited by the underlying low hydraulic conductivity Rewan Group and other aquitards.

5.3.3 Rewan Group

5.3.3.1 Distribution and Flow

The closest bores to the Project Area screened within the Rewan Group is bore RN141383 (MB3), which is part of the Eagle Downs Mine monitoring network and is located directly west of the Project. VWP GW01d (at the Olive Downs Project) is approximately 5 km to the east of the Project, on the western side of the Isaac River. The location of both bores is shown in **Figure 5-2**. The Rewan Group thickens towards the Isaac River, and can be up to 300 m thick within the Study Area. In general, the occurrence of the Rewan Group can vary regionally based on the structural setting. The Rewan Group comprises low hydraulic conductivity lithologies and is typically considered an aquitard.

5.3.3.2 Recharge and Discharge

Groundwater elevations for bore RN141383 are shown in **Figure 5-10**. **Figure 5-10** shows water levels have remained stable to slightly increasing from 2012 to 2018. Groundwater elevations for VWP's GW01d (logger P3 and P4) are shown in **Figure 5-11**. Excluding recovery/stabilisation trends following construction and data considered to be erroneous, the graph shows that groundwater elevations within the Rewan Group have remained stable to slightly declining from 2017 to 2019. Groundwater elevations within the Rewan Group are above those recorded within the deeper Permian coal measures, indicating a downward hydraulic gradient. **Figure 5-11** also presents trends for nested alluvial bore GW01s (at the Olive Downs Project), which show alluvial groundwater levels above the Rewan Group groundwater elevation. This indicates a downward gradient from the overlying alluvium. However, as outlined above, due to the low hydraulic conductivity of the Rewan Group stratigraphy (**Section 5.2**), the unit is considered an aquitard, restricting groundwater flow.

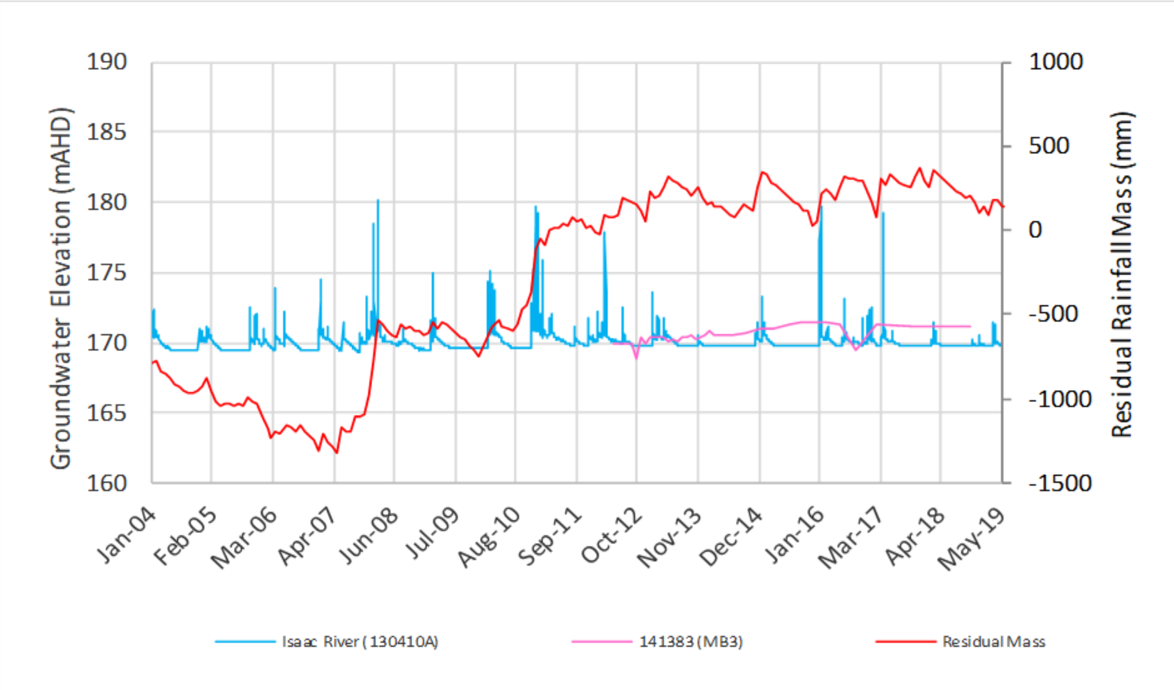


Figure 5-10 Hydrograph for Bore RN141383

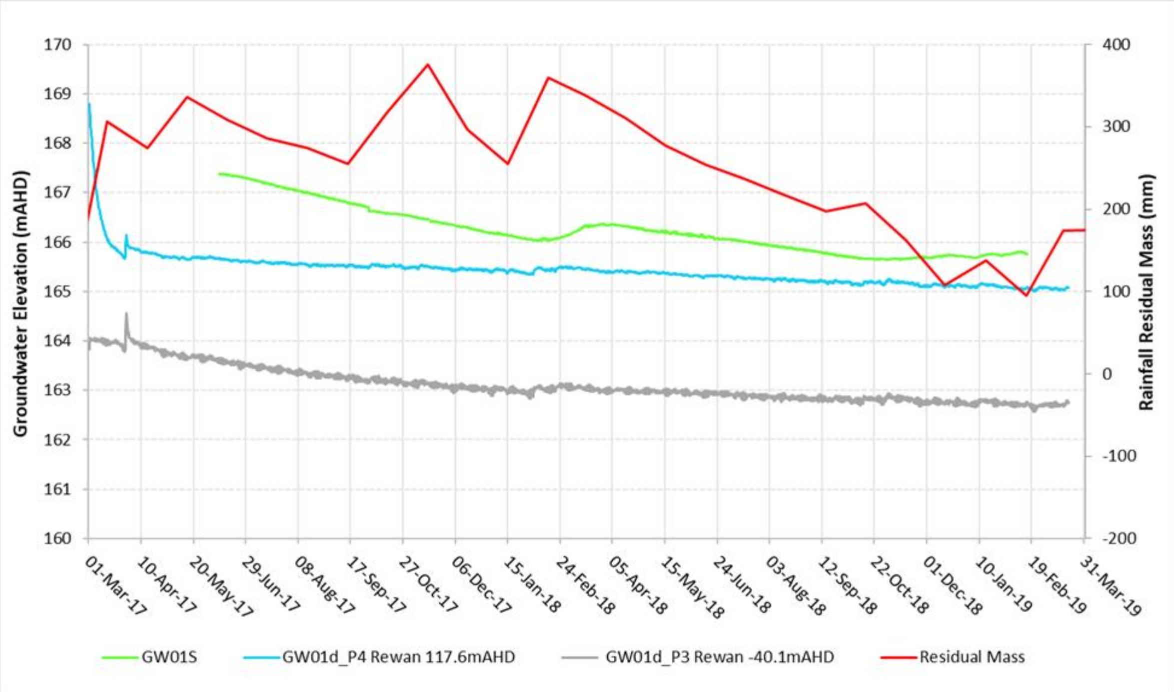


Figure 5-11 Hydrograph for VWP GW01d (P3 and P4) and Bore GW01s

5.3.4 Permian Coal Measures

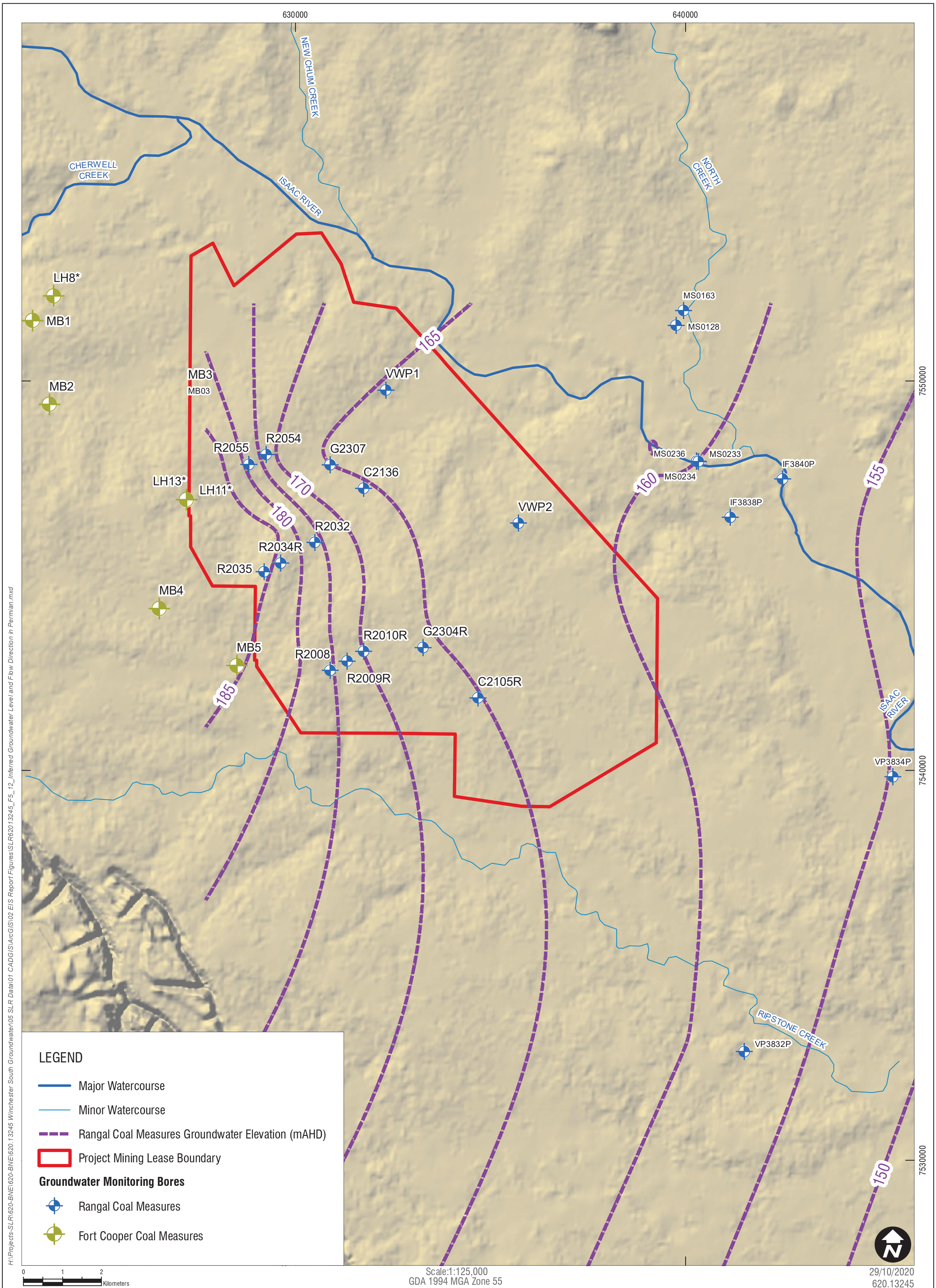
5.3.4.1 Distribution and Flow

The Permian coal measures outcrop towards the centre and north of the Project Area, and underlie the Rewan Group and surficial cover throughout the remainder of the Project Area. Within the Study Area the Permian coal measures generally, underlie the Rewan Group and surficial cover, and outcrop along the ridgelines to the east and west of the Study Area. Groundwater occurrence within the Permian coal measures is largely restricted to the more permeable coal seams that exhibit secondary porosity through fractures and cleats (**Section 5.2**).

Within the Project Area, there are 12 Project groundwater monitoring bores that intersect the Permian coal measures. The location of these bores is shown on **Figure 5-1**. All bores target the Rangal Coal Measures, with five of the bores within the Leichhardt Seam (C2105R, C2136, R2008, R2010R, R2032), four within the Vermont Seam (G2304R, G2307, R2035, R2055), and three within the interburden (R2009R, R2034R, R2054). In the Project Area, groundwater levels within the Rangal Coal Measures coal range from 190 mAHD to 166 mAHD. Bore R2304 screened in the Vermont Seam remained dry across the 2019 monitoring period. Replacement bore R2304R however provided an initial water level of 167 mAHD.

Groundwater levels in the Fort Cooper Coal Measures range from 31.9 mbgl to 32.7 mbgl (165.5 mAHD to 168 mAHD) within the Study Area. Seven monitoring bores located directly to the west of the Project Area, as part of the Eagle Downs Mine monitoring network are screened within the Fort Cooper Coal Measures. Groundwater levels within this unit to the west of the Project Area range from approximately 187 mAHD (MB1) to 196.74 mAHD (MB4).

A potentiometric surface map for the Rangal Coal Measures (**Figure 5-12**) has been developed using all available monitoring bore data. The water levels in the coal measures within the Project Area generally follow the downstream flow gradient of the Isaac River, with south-easterly trending hydraulic gradients. Groundwater elevations range from around 188 mAHD in the north-west, down to 155 mAHD in the south-east.



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Inferred Groundwater Level in the Rangal Coal Measures

FIGURE 5-12

5.3.4.2 Recharge and Discharge

Groundwater level trends for Project monitoring network bores intersecting the coal seams in the Rangal Coal Measures within the Project Area are presented in **Figure 5-13**. Trends for the underlying Fort Cooper Coal Measures unit in monitoring bores close to the Project for Eagle Downs Mine and Daunia Mine are presented in **Figure 5-14**, with their location shown in **Figure 5-12**. Groundwater levels at these bores can be seen to be relatively stable since 2015. Bore R2032 recorded a 3 m water level drop from approximately 188 mAHD to 185 mAHD in March 2019. This change coincides with the routine monitoring event in March and is likely a result of the logger being set at a different level. Groundwater levels have been relatively stable since, with a slight increase observed towards the end of 2019.

Groundwater within the Permian coal measures is confined and sub-artesian. For the shallower coal measures, groundwater elevations are generally at or below groundwater elevations within the overlying unconfined sediments, indicating a downward hydraulic gradient. However, with increased depth of cover and pressure the hydraulic gradient within the Permian coal measures reverses. This coincides with a decrease in hydraulic conductivity with depth as discussed in **Section 5.2**.

Recharge to the Permian coal measures occurs where the unit occurs at subcrop. Due to the low hydraulic conductivity of the interburden material, groundwater largely flows horizontally within the coal measures, along the bedding plane of the coal seams. Groundwater discharge occurs via evaporation and abstraction from mining operations.

Figure 5-13 Hydrograph for Monitoring Bores within the Rangal Coal Measures

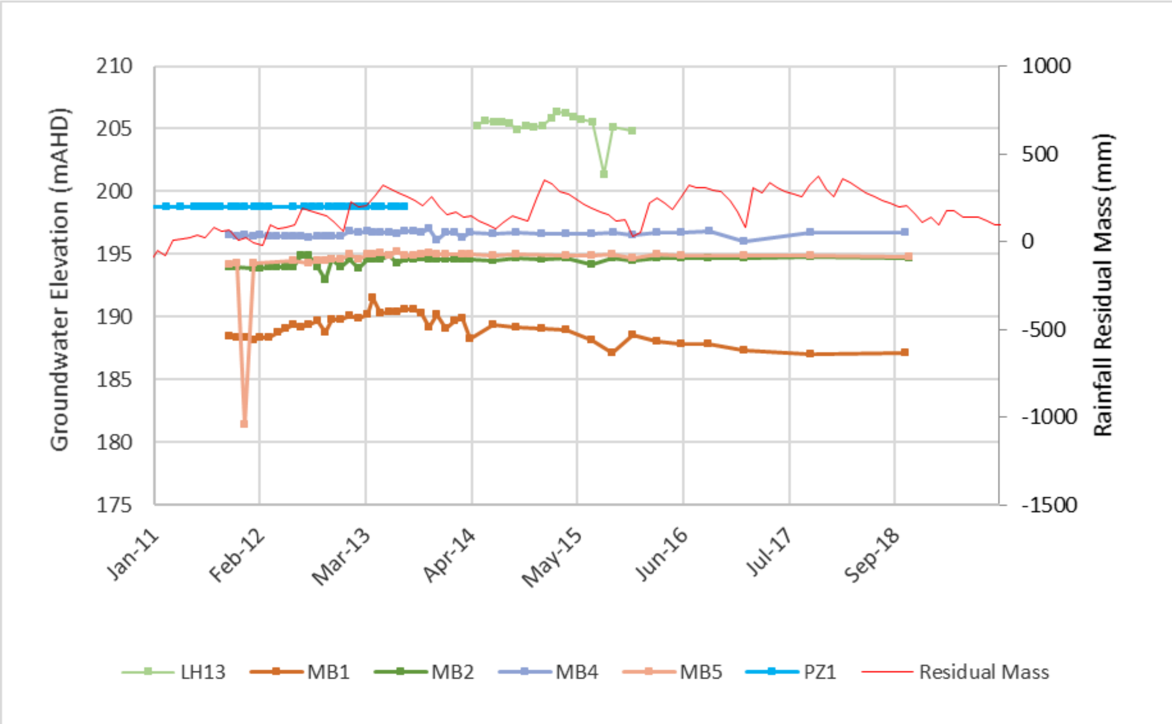


Figure 5-14 Hydrograph for Monitoring Bores within the Fort Cooper Coal Measures

5.3.5 Groundwater Interaction with Watercourses

In central Queensland, highly seasonal rainfall results in intermittent stream flow, limited groundwater recharge and deep water tables. In this environment, the most appropriate way to assess surface water and groundwater interaction is by comparing stream stage elevation data to the underlying groundwater elevation in a nearby monitoring bore. The Isaac River at Deverill (130410A) stream gauge provides a long-term record of stream stage for the Isaac River adjacent to the Project. The location of the stream gauges is shown in **Figure 3-3**. The WMIP data indicate that at Station 130410A surface water (flowing and ponded) elevations generally remain around 170 mAHD. The gauge has recorded a maximum stream elevation of 180 mAHD, which has been recorded five times since 1968, in March 1979, March 1988, April 1989, January 1991 and February 2008.

The closest bore to the Project with long-term groundwater level monitoring in the Isaac River alluvium is registered bore RN13040180, which is approximately 40 km downstream of the stream gauge (**Section 5.4.2**). RN13040180is located approximately 80 m from the Isaac River, along Carfax Road. Water levels in this bore clearly follow the rainfall residual mass curve, indicating that rainfall derived recharge (including from stream flow) is a key source of water to this aquifer (**Figure 5-15**). From 1970 to present, water levels within the alluvium at RN13040180 were recorded between 12 mbgl to 18 mbgl.

Sharp peaks have been recorded occasionally in the dataset and appear to correlate with times of high flow in the Isaac River, however, there does not appear to be a definitive relationship between river level/magnitude of discharge and magnitude of fluctuation in groundwater level. This is in part a reflection of the intermittent water level data (where data at times corresponding to high river levels is often not recorded due to flooding).

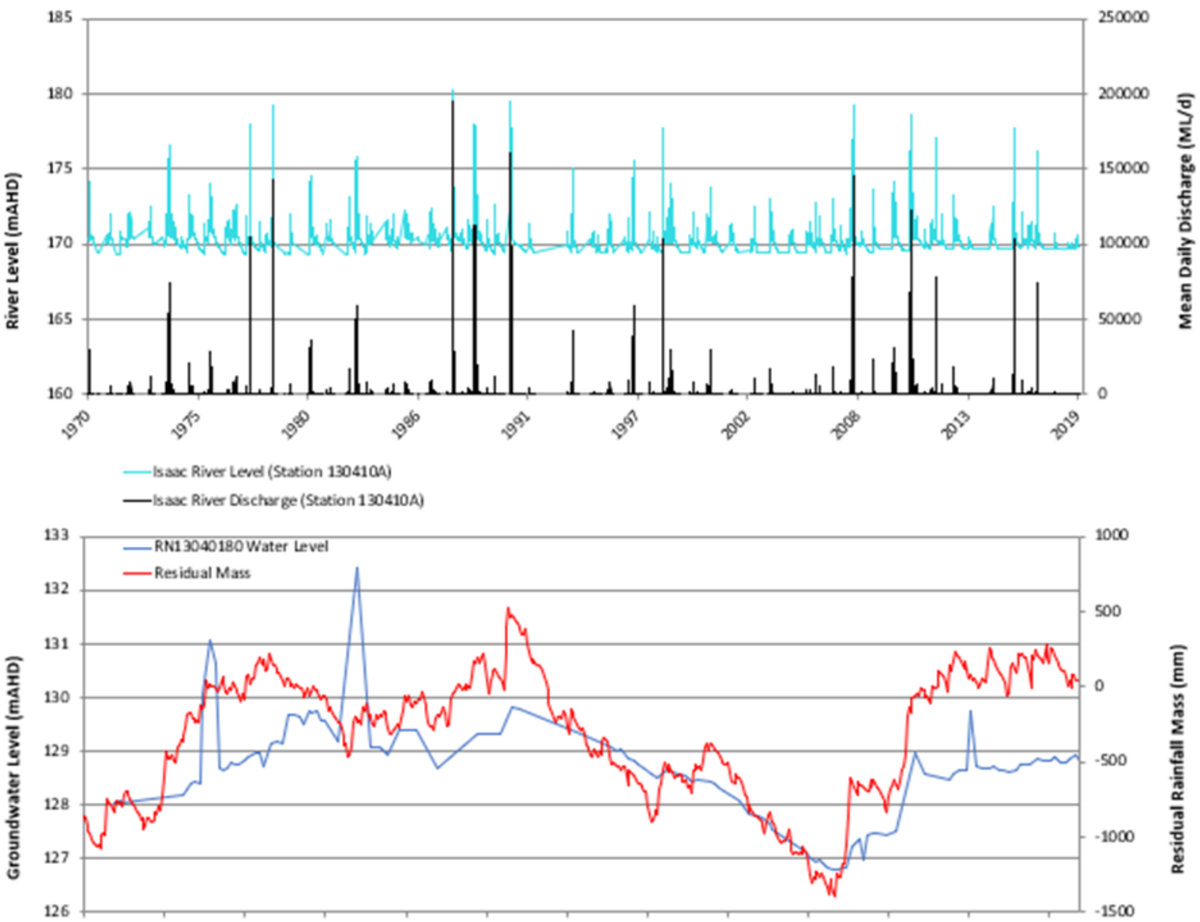


Figure 5-15 Groundwater Level in RN13040180 with Rainfall Residual Mass and Isaac River Levels Discharge for Stream Gauge 130410A

Currently the closest groundwater monitoring bores to the Project Area installed within the Isaac River alluvium are the privately-owned Knob Hill 2 bore and Whitehaven-owned Winnet Bore. Knob Hill 2 is 500 m upstream of the surface water monitoring point SW4. As presented in **Figure 5-6**, water levels within Knob Hill 2 are relatively stable at approximately 179 mAHD. In comparison, the elevation of SW4 is 187 mAHD.

The Isaac River is largely a losing system with stream-stage above that of the local groundwater levels, resulting in the water draining through the alluvial sediments to the local groundwater system. Occasional periods of baseflow to the Isaac River from the underlying alluvium may occur after prolonged rainfall events or following flood events. Under these conditions, recharged alluvial sediments will drain to the Isaac River as the hydraulic gradient reverses and sustains stream-flow for a short period after the rainfall event.

5.4 Baseline Water Quality

This section reports on the chemical characteristics and resulting possible beneficial uses of groundwater within the various geological units across the wider Study Area. Water quality results for surface water (Isaac River) and leachate analysis of potential spoil and rejects materials at the Project are also discussed below. **Appendix A3** presents the groundwater quality data collected at site, water quality time series graphs, as well as other publicly available data.

5.4.1 Water Type

The proportions of the major anions and cations were used to determine the hydrochemical facies of groundwaters sampled. The anion-cation balance from the Project monitoring bores is shown on the Piper diagram in **Figure 5-16**. The results for these monitoring bores generally indicate that the dominant water type across the Project Area is Sodium (Na) – Chloride (Cl) type. Alluvial bore Knob Hill 2 displays a mixed water type which differs from the two nearby alluvial monitoring bores which are both Na-Cl type; this suggests some degree of compartmentalisation in the alluvial aquifer. Bore R2010, R2032, R2035, and R2054, screened in the Rangal Coal Measures (Leichhardt Seam, Vermont Seam and interburden) all reported three consecutive readings of sodium (Na) at or close to limit of reporting (LOR) resulting in the water type plotting as HCO3-Cl type. Sodium levels have since returned to average with the cause of the low concentrations unknown but should be considered anomalous, with the Rangal Coal Measures being classified as an Na-Cl water type as is consistent with other samples in the Study Area.

Major ion data collected from the Eagle Downs Mine monitoring network is presented in **Figure 5-17**, with data from the Moorvale South Project and Olive Downs Project groundwater assessments, and publicly available sources presented in **Figure 5-18**, along with data for the Isaac River at Deverill (Station 130410A).

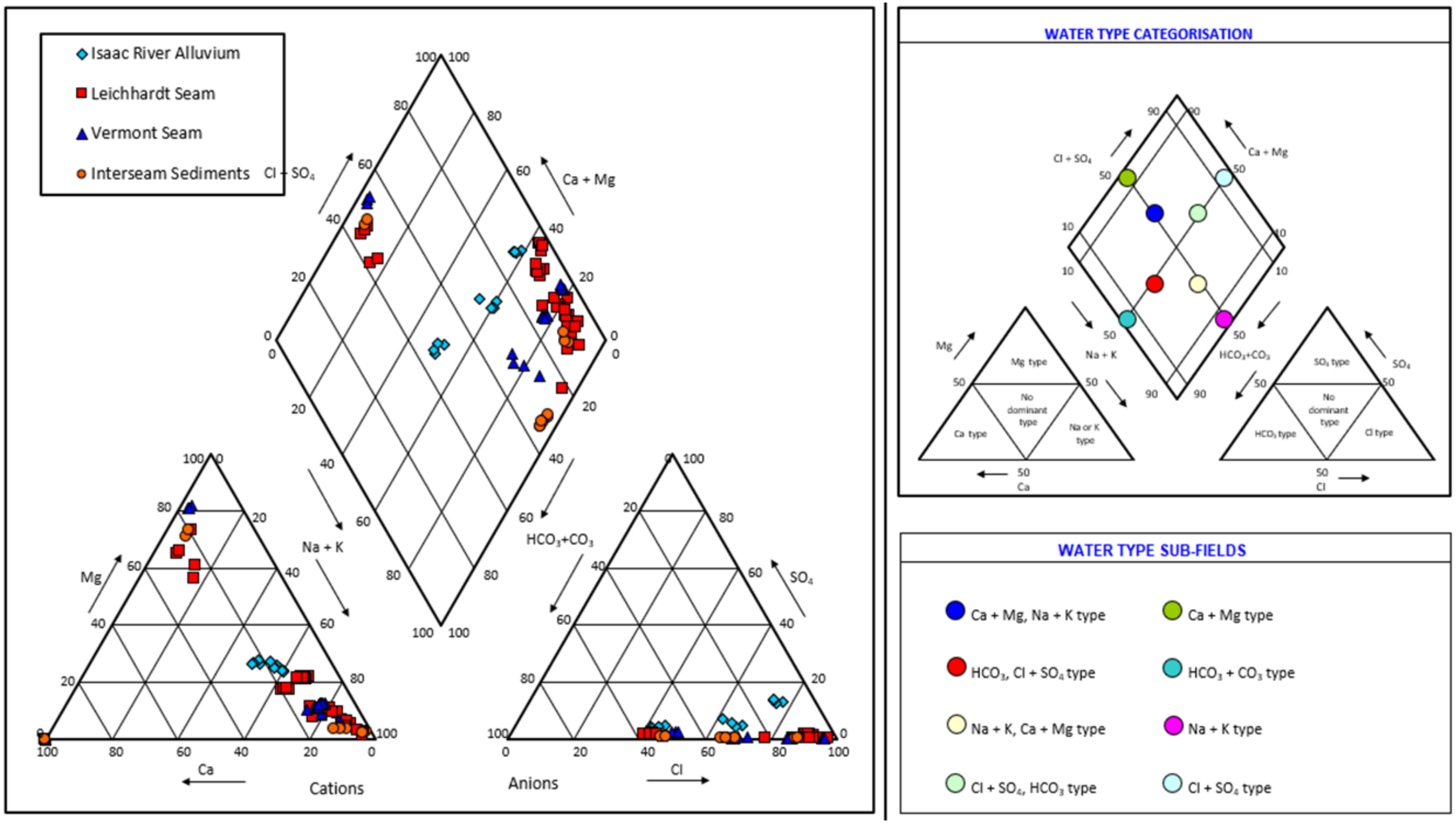


Figure 5-16 Piper Diagram of Project Bores

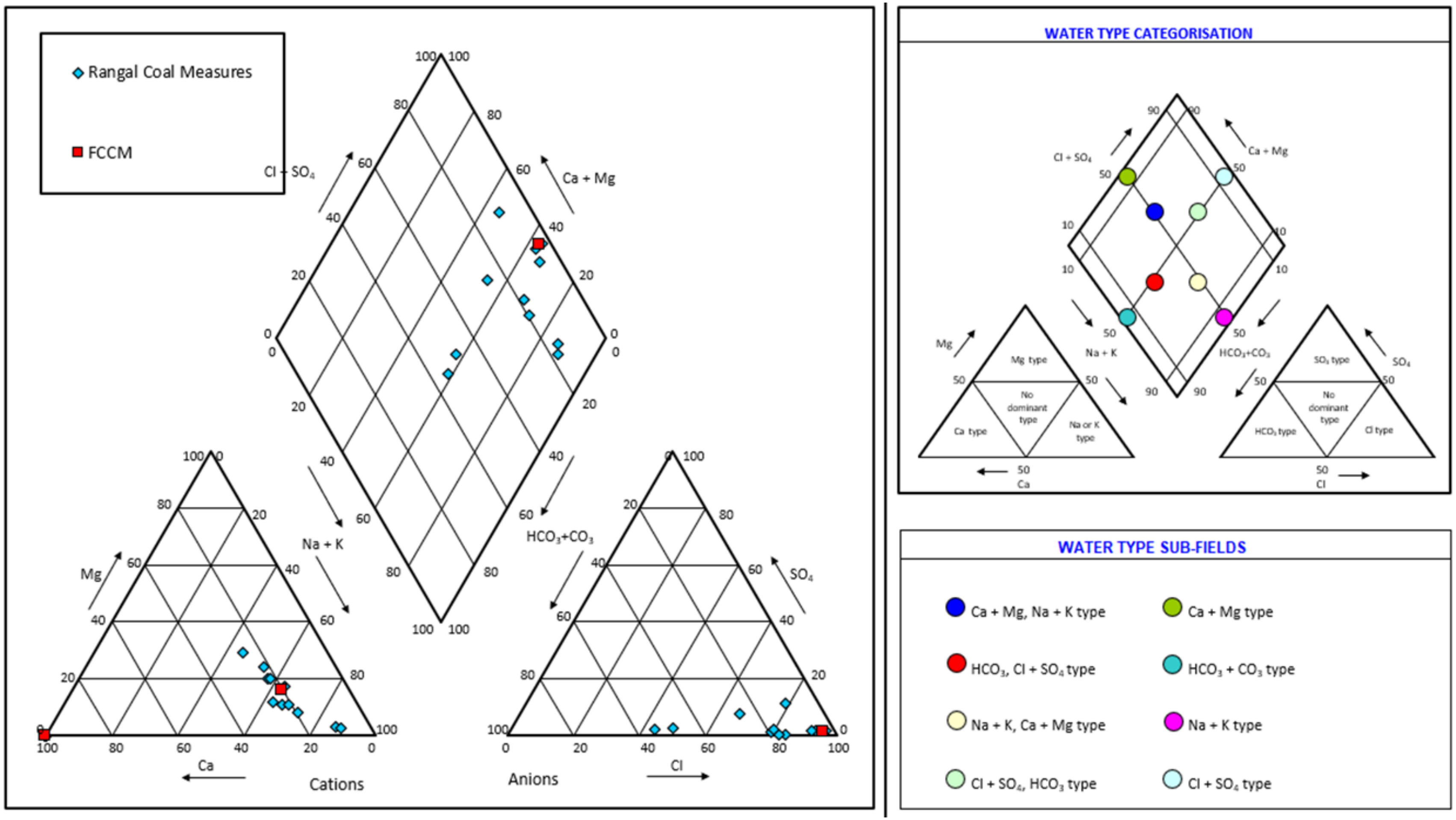


Figure 5-17 Piper Diagram of Eagle Downs Mine Monitoring Bores

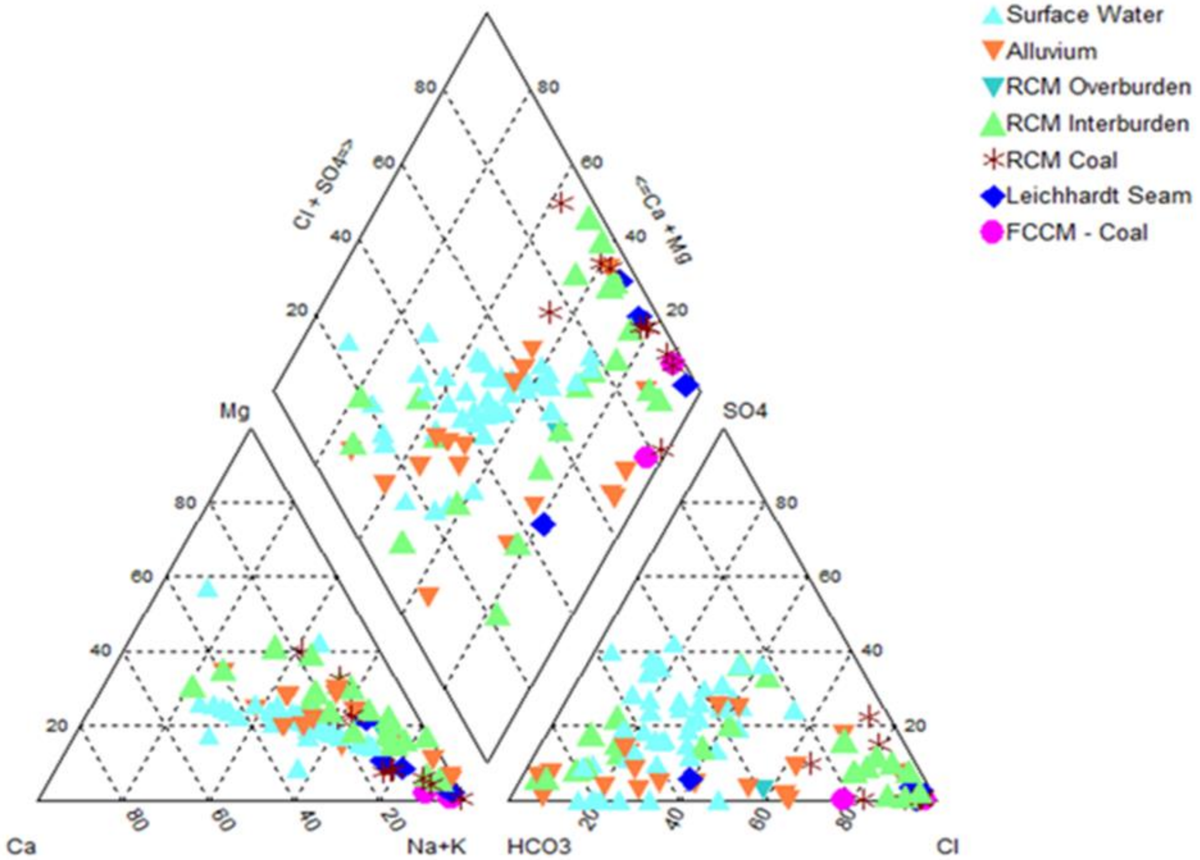


Figure 5-18 Piper Diagram of All Data

5.4.2 Salinity

Salinity is a key constraint to water management and groundwater use and can be described by total dissolved solid (TDS) concentrations.

Figure 5-19 presents the TDS data associated with waters screened in the various geological horizons for Study Area monitoring bores (collected as part of the Project monitoring network, Eagle Downs Mine monitoring network), registered bores and publicly available data. Salinity ranges represented on **Figure 5-19** are defined by the Food and Agriculture Organization of the United Nations (FAO, 2013).

The graph shows that surface water within the Isaac River is largely fresh, while water within the alluvium is fresh to saline with an average TDS of 863 milligrams per litre (mg/L) (marginal) and ranging between 10 mg/L and 3,430 mg/L. Where water is present within the regolith material, it is generally highly saline, but can be brackish to moderately saline with an average TDS of 10,510 mg/L and ranging between 1,460 mg/L and 18,600 mg/L. Water within the Permian coal measures is generally saline within the coal seams and saline interburden units but can range between fresh and highly saline. Coal seam units of the Permian coal measures record an average TDS of 6,212 mg/L, ranging between 923 mg/L and 16,400 mg/L. The interburden units of the Permian coal measures record an average TDS of 3,436 mg/L, ranging between 421 mg/L and 18,400 mg/L.

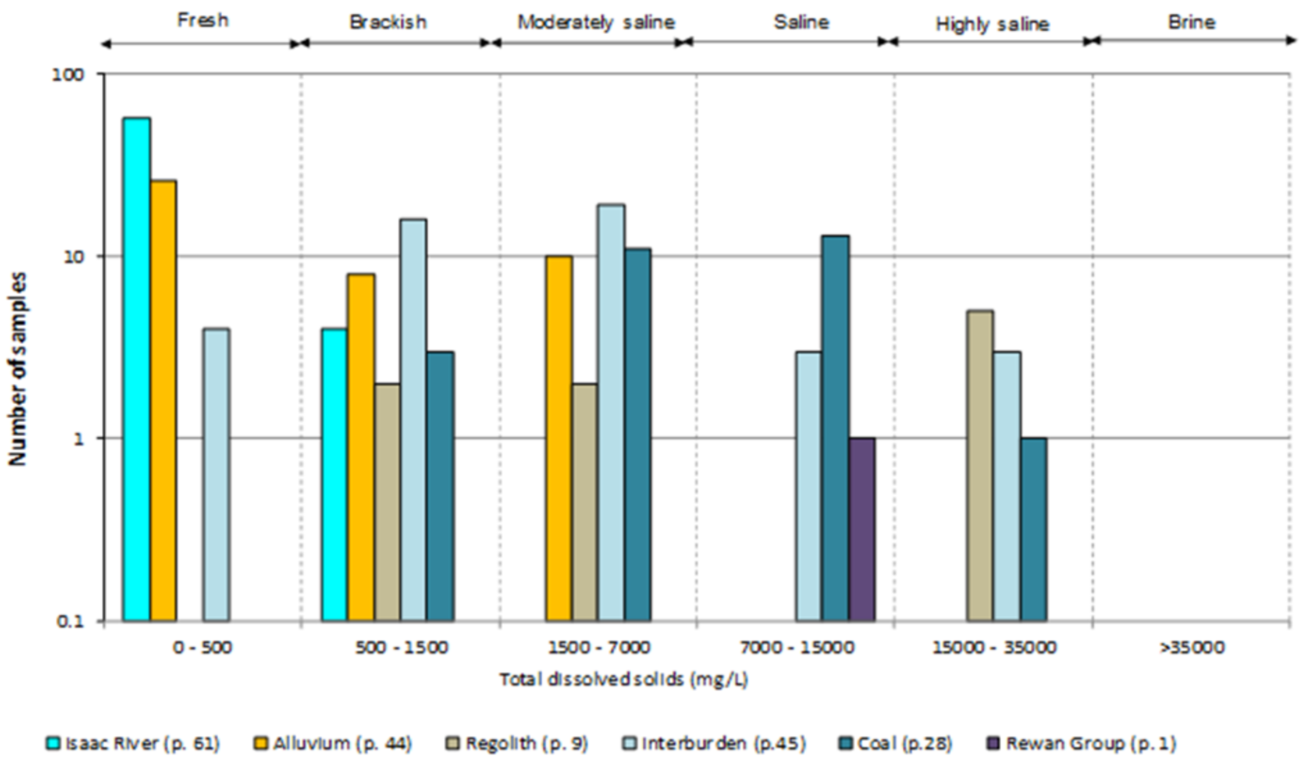


Figure 5-19 FAO (2013) Salinity Ranking by Unit – Study Area

Figure 5-20 presents the TDS data associated with waters screened in the various geological horizons from the Project monitoring bores.

The graph shows that water within the alluvium is generally saline with an average TDS of 2,505 mg/L, ranging between 593 mg/L and 5,190 mg/L. Water within the Rangal Coal Measures ranges between fresh and highly saline, but is generally saline across the interburden, Leichhardt Seam, and Vermont Seam. The Leichhardt Seam records an average TDS of 8,705 mg/L, ranging between 246 mg/L and 18,500 mg/L. The Vermont Seam records an average TDS of 5,794 mg/L, ranging between 571 mg/L and 10,500 mg/L. The interburden of the Rangal Coal Measures records an average TDS of 3,037 mg/L, ranging between 465 mg/L and 5,470 mg/L.

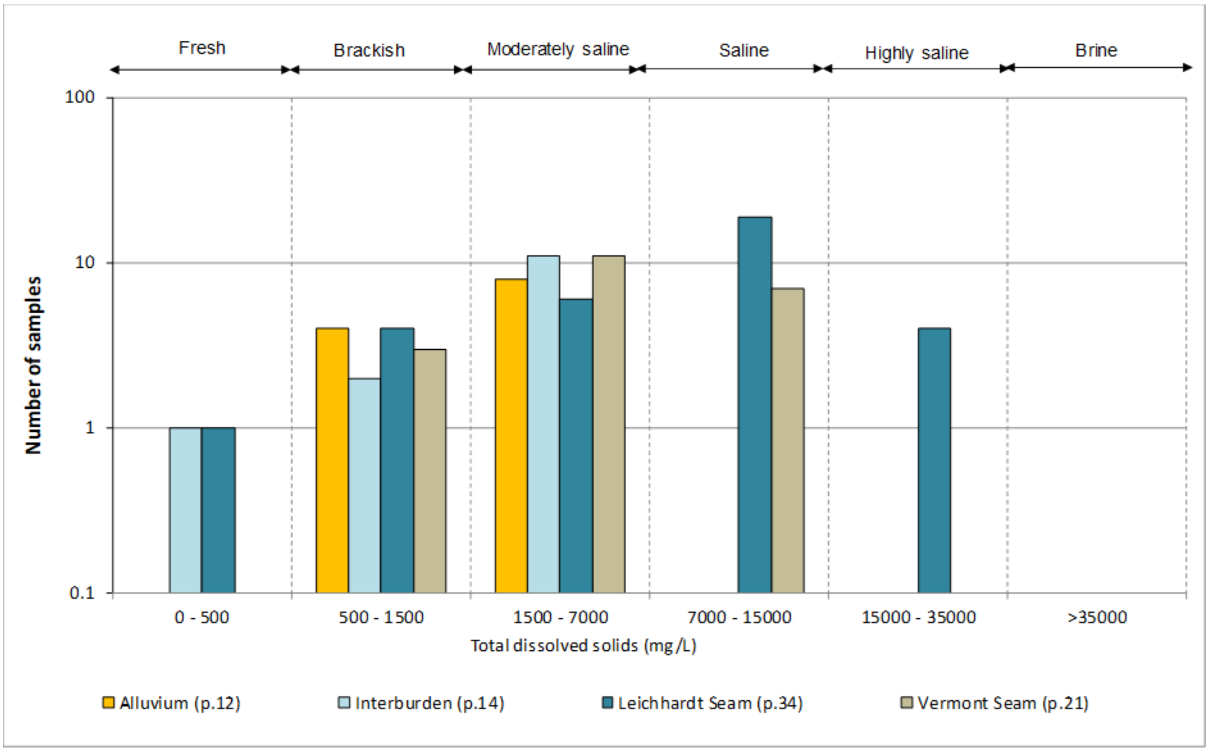


Figure 5-20 FAO (2013) Salinity Ranking by Unit – Project Bores

Available long-term trends in salinity within the alluvium and Isaac River inside the Study Area are presented in **Figure 5-21**. The salinity in the alluvium and Isaac River has been described by electrical conductivity (EC) rather than TDS. As discussed above, salinity within the alluvium can be highly variable spatially. As demonstrated by **Figure 5-21**, salinity can also vary at one location temporally. Results for alluvial bore RN13040180 indicates EC can range between 199 MicroSiemens per centimetre (µS/cm) and 7,400 µS/cm (fresh to saline). **Figure 5-21** also presents EC as recorded at Isaac River station 130410A since 2011, which ranges between 49 µS/cm and 1,773 µS/cm (fresh to brackish).

The water quality data for the alluvium occasionally shows an inverse correlation in EC to rainfall residual mass curve, with rising EC recorded during periods of declining/below average rainfall and vice versa. However, due to the lack of temporal readings, there is no clear correlation between groundwater salinity in the alluvium at RN13040180 and stream flow and salinity of the Isaac River.

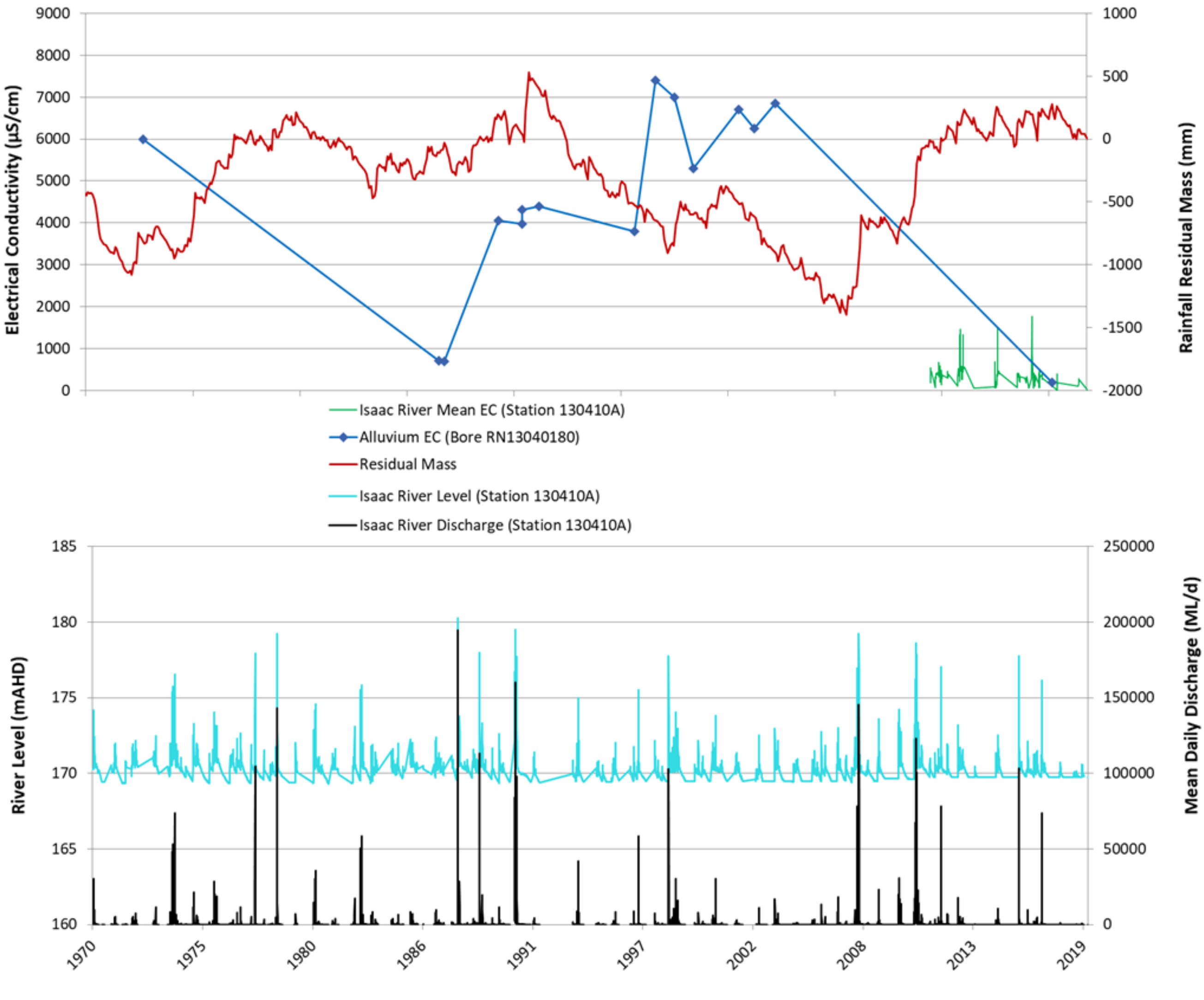


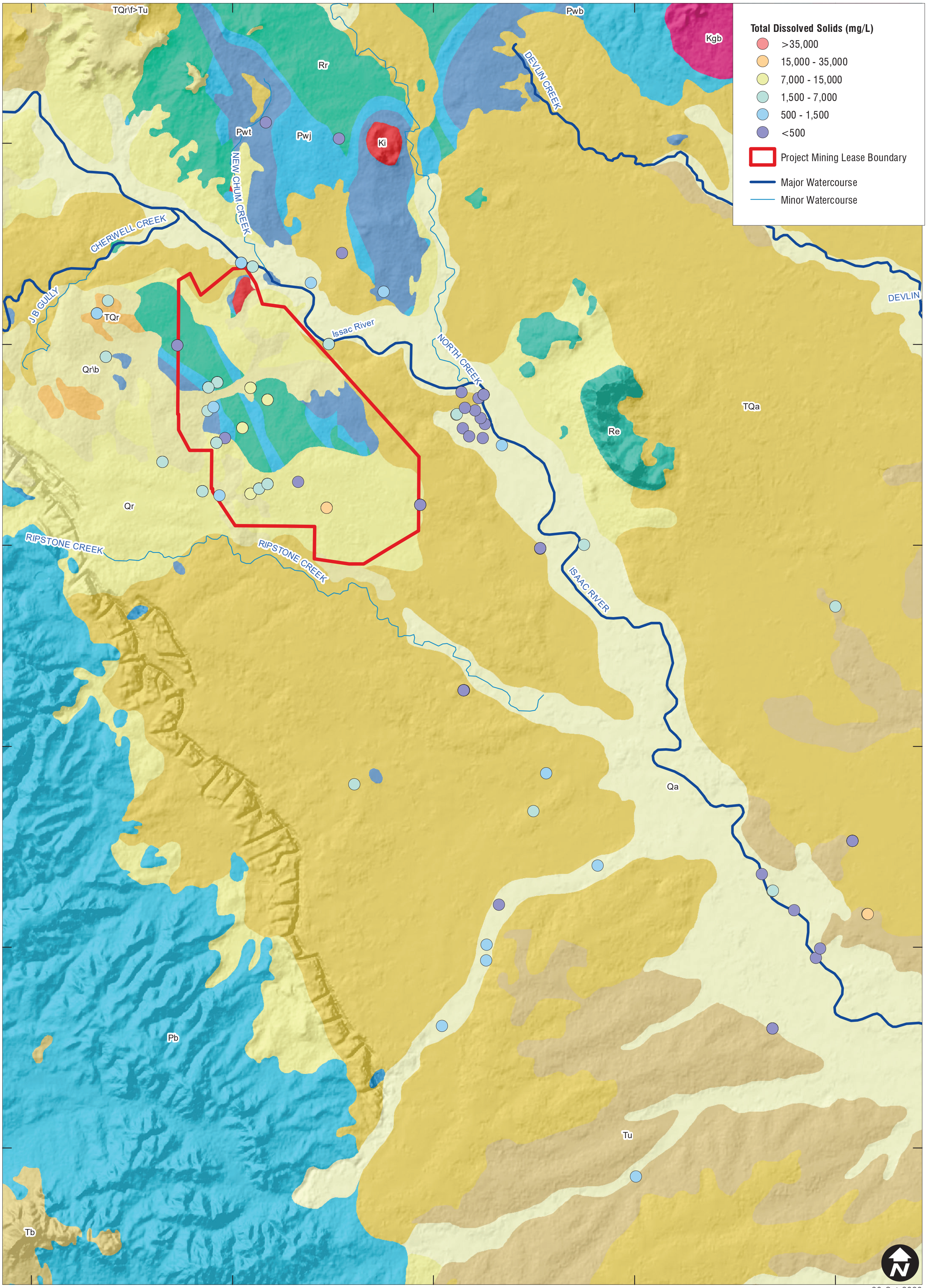
Figure 5-21 Isaac River Salinity Versus Alluvium Salinity

Spatial distribution of TDS is shown in **Figure 5-22** for the Study Area, which is based on measured TDS and calculated from available EC data from the Project monitoring network, Eagle Downs Mine monitoring network, and from the Moorvale South Project and Olive Downs Project groundwater assessments. Full details of the sampling are contained in **Appendix A3**. **Figure 5-22** depicts mostly fresh water quality localised along the Isaac River, with brackish to moderately saline water along the river and tributaries. Alluvial monitoring bores for the Project show marginal to saline water along the Isaac River, further outlining the spatial variability of salinity within the alluvium. As expected, the salinity within the coal measures appears to increase with depth. Bores within the Permian coal measures near the subcrop areas in the west generally record moderately saline water quality, which increases to saline quality where the Permian coal measures are deepest near the Isaac River. This corresponds with the Permian coal measures being largely recharged by rainfall where they occur at subcrop.

Surface water quality sampling was conducted as part of the Project at nine locations throughout 2019. The locations of the monitoring sites are shown in **Figure 5-23**. The surface monitoring network monitors the Isaac River, Ripstone Creek, and several un-named drainage features. The range of pH and EC for each site, from February 2019 until June 2020 is shown in **Table 5-7** with all data shown in **Appendix A3**. Over the monitoring period, the data indicates that the EC is higher at the upstream site compared to the downstream sites for both the Isaac River and the un-named drainage feature that traverses centre of the Project Area.

Table 5-7 Project Surface Water Monitoring Sites

Site	Monitoring Events	Dry readings		EC (µS/cm)	pH
SW1	4	3	Range	257 – 488	8.08 – 8.70
			Average	389	8.38
SW2	4	2	Range	197 – 309	6.94 – 9.05
			Average	279	8.02
SW3	4	2	Range	369 – 756	7.35 – 8.31
			Average	479	7.88
SW4	4	0	Range	192 - 861	7.44 – 8.50
			Average	441	7.96
SW5	4	1	Range	230 – 538	6.92 – 7.47
			Average	389	7.31
SW6	4	4	Range	-	-
			Average	-	-
SW7	4	3	Range	255	7.40
			Average	255	7.40
SW8	4	3	Range	408	8.10
			Average	408	8.10
SW9	4	0	Range	598 – 978	7.19 – 8.88
			Average	750	8.02



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Groundwater Salinity Figures

FIGURE 5-22

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Surface Water Monitoring

FIGURE 5-23

5.4.3 Beneficial Groundwater Use

The Project lies within the Isaac Connors Groundwater Management Area (GMA – Zone 34) of the Fitzroy Basin under the *Water Plan (Fitzroy Basin) 2011*. Groundwater at the Project includes alluvial groundwater under GMA Groundwater Unit 1 and water within the hard rock aquifers in GMA Groundwater Unit 2 (sub-artesian aquifers). The management objective of the *Environmental Protection (Water) Policy 2009 Isaac River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130, including all waters of the Isaac River Sub-basin (including Connors River)* is to maintain the 20th, 50th and 80th percentiles water quality results in order to preserve or enhance groundwater quality for its recognised uses. In the case of Isaac groundwaters, these values include aquatic ecosystems, irrigation, farm supply/use, stock watering, primary recreation, drinking water as well as being of cultural and spiritual value.

In order to understand the groundwater resources within the Project and Study Area, available water quality data have been compared to the:

- Fitzroy Basin Zone 34 groundwater quality objectives for deep and shallow water;
- *Australian Drinking Water Guidelines* (National Health and Medical Research Council, 2011); and
- Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) (2000) guidelines for aquatic ecosystems, irrigation (long-term and short-term) and stock water supply.

Comparing the data to relevant guideline levels, the summary results indicate that water within the Quaternary alluvium at the Project is generally suitable for stock water supply and short-term irrigation (**Appendix A3**). However, the alluvial groundwater generally exceeds guidelines levels for drinking water (i.e. TDS, chloride and Na), freshwater aquatic systems, and long-term irrigation (chromium [Cr], iron [Fe], and manganese [Mn]). The alluvial groundwater also records concentrations of total and dissolved iron and manganese above the Fitzroy Plan WQOs for Zone 34 (shallow).

Results from the Moorvale South Project and Olive Downs Project groundwater assessments however show that, where water is present within the regolith material, it exhibits poorer quality compared to the alluvium and is not considered a suitable groundwater resource for livestock, irrigation, drinking water or aquatic ecosystems. The water within regolith material was found to exceed the Fitzroy Plan WQO (Zone 34 –shallow) for EC, Cl, calcium (Ca), Na, hardness, magnesium (Mg), sulfate (SO_4^{2-}), copper (Cu) and Mn.

Water within the interburden of the Permian coal measures is generally suitable for stock water supply, with the exception of R2034 which displays total and dissolved nickel (Ni), and total aluminium (Al) concentrations above the guidelines for three of the six available measurements. In contrast, groundwater within the coal seams generally exhibit a higher TDS, which is on average higher than the guideline level for beef cattle but below the guideline level for sheep. Comparison of results to the guideline levels indicates the Rangal Coal Measures (interburden and coal) are not considered a suitable groundwater resource for irrigation, drinking water or aquatic ecosystems. Groundwater within the coal measures (coal and interburden) record concentrations of bicarbonate above the Fitzroy Plan WQO (Zone 34 – deep), and fluoride above the Fitzroy Plan WQO (Zone 34 – shallow and deep).

Groundwater chemistry results from the Eagle Downs Mine monitoring network suggest that water within the Fort Cooper Coal Measures could be suitable for stock water supply and short-term irrigation. It is noted however that not all analytes are available for a complete assessment of the suitability for this unit.

5.4.4 Leachate Analysis

Leachate analysis was undertaken within the Project Area by EGi (2012) and Terrenus Earth Sciences (2020). Further, leachate analysis was also conducted within the Study Area by Terrenus Earth Sciences for the Olive Downs Project EIS and is considered relevant to the Project given the similar geological setting. The analysis was conducted on weathered overburden (clay), overburden (sandstone and siltstone), and interburden (claystone, sandstone, coal with some claystone, mudstone, and siltstone) material representative of future spoil material. Some of the overburden and interburden samples were also noted to be carbonaceous.

Analysis was also conducted on material representative of waste rock material, and carbonaceous claystone and siltstone (coal seam roof and floor) representative of potential rejects material, as well as composite samples representing coarse rejects. It is important to note that the results from the geochemistry studies prepared by Terrenus Earth Sciences represent an 'assumed worst case' scenario as the samples are pulverised prior to testing, and therefore have a very high surface area compared to materials in the field and do not account for mixing during emplacement.

Analysis by EGi (2012) and Terrenus Earth Sciences (2020) tested 38 samples for the total metals analysis (365 samples tested in total for Terrenus Earth Sciences [2020]) and found the following:

- 36 samples were identified as Non Acid Forming (NAF), of which, 29 were identified as having very low Sulfur (S) content (<0.1 %).
- 2 samples were identified as 'uncertain classification' with one likely to be NAF, and one likely to be potentially acid forming (PAF).
- pH is generally 8.7 and ranges between 6.3 and 10.1.
- EC is generally fresh, averaging 601 µS/cm and ranges between 110 µS/cm and 2,410 µS/cm.
- S content is generally 37 mg/L and ranges between 2 mg/L and 319 mg/L.
- Al concentrations are all below the LOR of <0.2 mg/L in the 2019 sampling, with values between <0.01 mg/L and 0.15 mg/L observed in 2012.
- Arsenic concentrations between <0.001 mg/L and 0.4 mg/L.
- Metals concentrations were all below the laboratory limit of reporting for beryllium (Be), cadmium (Cd), cobalt (Co), mercury (Hg), Ni, lead (Pb), and vanadium (V).
- Metals concentrations above the LOR were identified for the following:
  - Barium (Ba) with all 2019 values below LOR of <0.2, and 2012 values between 0.06 mg/L and 0.94 mg/L.
  - Boron (B) with a majority of samples below LOR ranging between <0.05 mg/L and 0.4 mg/L.
  - Cr with all values below with the exception of one 2012 sample with a concentration of 0.08 mg/L.
  - Cu with all 2019 values below LOR of <0.02, and 2012 values between the LOR of <0.01 mg/L and 0.012 mg/L.
  - Fe with all 2019 values below LOR of <0.2, and 2012 values between 0.001 mg/L and 0.1 mg/L.
  - Mn with values between <0.001 mg/L and 0.07 mg/L.
  - Selenium (Se) with a majority below LOR, and 10 samples between 0.01 mg/L and 0.02 mg/L.

Terrenus Earth Sciences (2018) performed an analysis of 27 representative samples of waste rock material (as a bulk material) for the total metals analysis (166 samples tested in total for Terrenus Earth Sciences [2018]) that found:

- All samples were identified as NAF with most showing very low S content (<0.1%).
- One sample returned 'uncertain' results, due to conflicting results.
- pH is generally 9.0 and ranges between 5.4 and 9.7, with only one reading below pH 7.
- EC is generally 400 µS/cm and ranges between 158 µS/cm and 1,050 µS/cm.
- S content is generally 27 mg/L and ranges between 4 mg/L and 92 mg/L.
- Al concentrations are around 0.3 mg/L and range between <0.2 mg/L and 0.5 mg/L.
- As concentrations are around 0.12 mg/L and range between <0.02 mg/L and 0.5 mg/L.
- Metals concentrations were all below the laboratory limit of reporting for Ba, Be, B, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb and Zn.

Overall, the geochemical assessment found that the potential spoil material is expected to be overwhelmingly NAF, with excess acid neutralising capacity (ANC) and has a negligible risk of developing acid conditions. Furthermore, spoil is predicted to generate low to moderate salinity surface run-off and seepage with low soluble metal/metalloid concentrations. However; some spoil materials may be sodic (to varying degrees) with potential for dispersion and erosion (to varying degrees).

Analysis of the eight samples tested as being representative of potential reject material found:

- Six of the eight samples were identified as NAF, with five classified as having very low S content (<0.1%).
- One sample returned 'uncertain' results, due to conflicting results.
- One sample was classified as PAF – derived from carbonaceous claystone of the Lower Leichhardt Seam roof at a depth of 104 mbgl.
- pH is generally 8.9 and ranges between 6.9 and 9.6.
- EC is generally 293 µS/cm and ranges between 120 µS/cm and 554 µS/cm.
- S content is generally 49 mg/L and ranges between 6 mg/L and 206 mg/L.
- Al concentrations are around 0.4 mg/L and range between <0.2 mg/L and 1.0 mg/L.
- As concentrations are around 0.07 mg/L and range between <0.02 mg/L and 0.22 mg/L.
- Metals concentrations were all below the laboratory limit of reporting for Ba, Be, B, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb and Zn.

Overall, the geochemical assessment found that 30% of potential reject material has a relatively low degree of risk associated with potential acid generation. The material has a low S (and sulphide) concentration and low metals/metalloids concentrations. The magnitude of any localised acid, saline or metalliferous drainage would be buffered by the presence of the alkaline NAF spoil. As a bulk material (of relatively small total quantity), coal reject is regarded as posing a generally low risk of environmental harm and health-risk.

5.5 Groundwater Usage - Anthropogenic

A search of the Queensland Government's Groundwater Bore Database (GWBD) and BoM's NGIS was carried out for registered bores within the Study Area. The search indicated that there are 310 registered bores, of which 177 bores (57%) are used for groundwater monitoring and investigations, and 83 bores (27%) are used for water supply. The remainder of bores have an unknown use or resulted from exploration activities (**Table 5-8**).

Table 5-8 Registered Use of Groundwater Bores within the Study Area

Use	Count	Percent of Total
Groundwater monitoring (mine monitoring, water resource investigation, etc.)	177	57
Water Supply	83	27
Unknown	33	11
Exploration (petroleum, gas, coal, stratigraphic etc)	17	5
Total	310	100

5.5.1 Field Bore Censuses

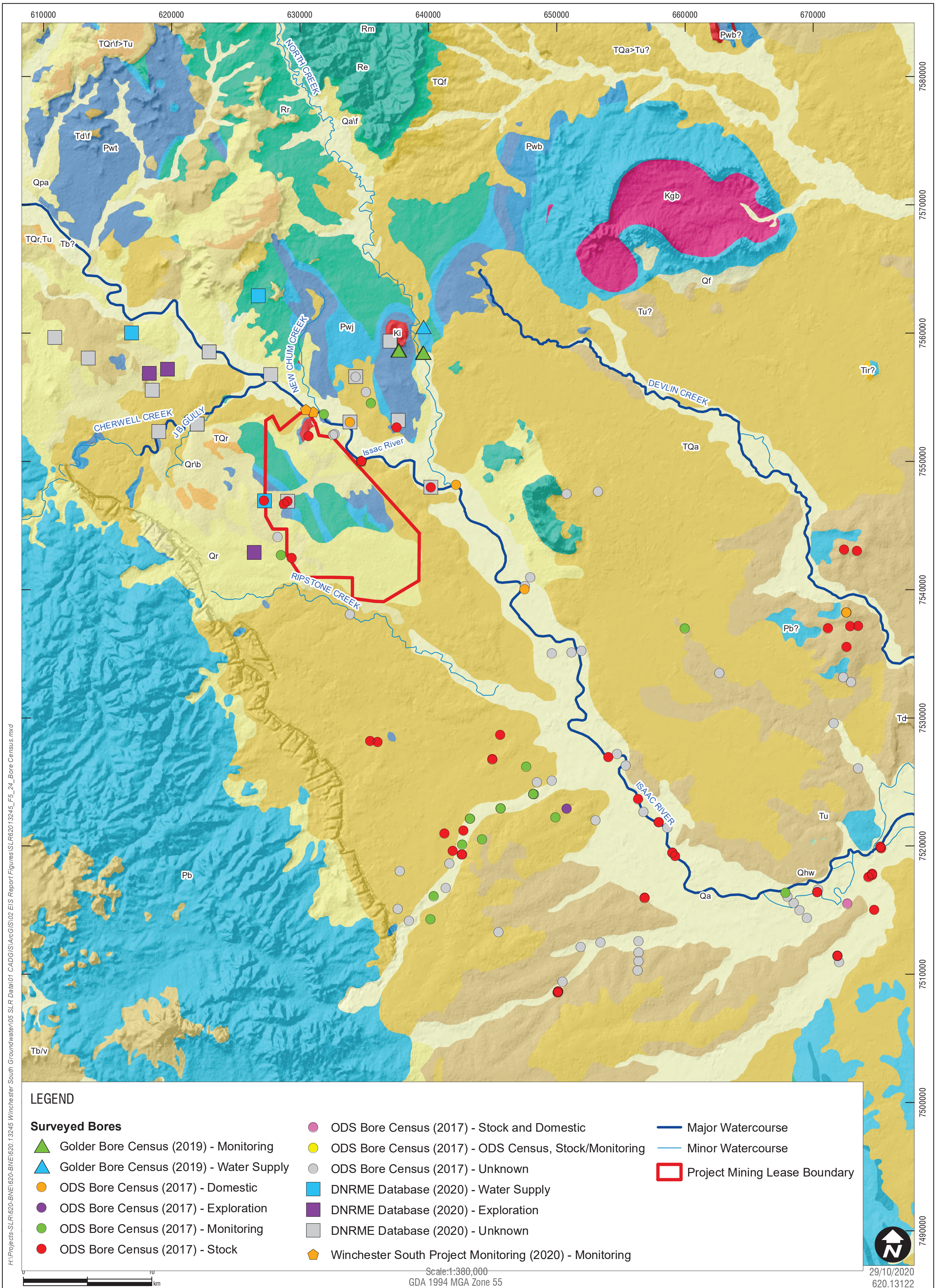
Two field bore censuses have been carried out within the Study Area. The earlier survey, a field bore census of groundwater bores and wells within 20 km of the Study Area was conducted from September to November 2017 as part of the Olive Downs Project Groundwater Assessment. A field bore census of groundwater bores and wells was also conducted for the Moorvale South Project (Golder Associates, 2019).

Across the two bore census, a total of 131 bore locations were assessed. Of the 131 bores:

- 47 bores were found to be existing and in use;
- 37 bores are existing but not in use;
- 8 bores were of unknown status (could not access); and
- 39 bores were abandoned and destroyed.

Of the existing and unknown bores with water use information available, 52 are used for stock water supply, 19 are used of groundwater monitoring and 6 are used for domestic water supply. For the existing and unknown bores with geological information available, 22 intersect alluvium, 10 are within regolith material and 30 intersect Permian coal measures (Rangal Coal Measures, Blackwater Group and Back Creek Group).

Figure 5-24 shows the locations and uses of bores detailed in the combined bore censuses as well as bores identified from the DNRME bore database (as of August 2020). Full results of the Olive Downs Project and Moorvale South Project bore census surveys are provided in **Appendix A4**.



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Private Bores - Groundwater Use Surrounding the Project

FIGURE 5-24

5.6 Groundwater Usage – Environmental

5.6.1 Groundwater Dependent Ecosystems

A Groundwater Dependent Ecosystem (GDE) is one in which the plant and/or animal community is dependent on the availability of groundwater to maintain its structure and function.

5.6.1.1 National Atlas of Groundwater Dependent Ecosystems

GDEs are ecosystems that require access to groundwater to meet all or some of their water requirements on a permanent or intermittent basis for maintenance of the ecosystem (Richardson *et al*., 2011). GDEs are classified by Doody *et al*. (2019) into three broad types:

- Aquifer and cave ecosystems (i.e. subterranean GDEs);
- Ecosystems dependent on the sub-surface presence of groundwater (i.e. terrestrial GDEs, including some riparian vegetation communities); and
- Ecosystems dependent on the surface expression of groundwater (i.e. aquatic GDEs).

GDEs can require access to groundwater on a permanent (obligate) or intermittent (facultative) basis to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services (Doody *et al*., 2019).

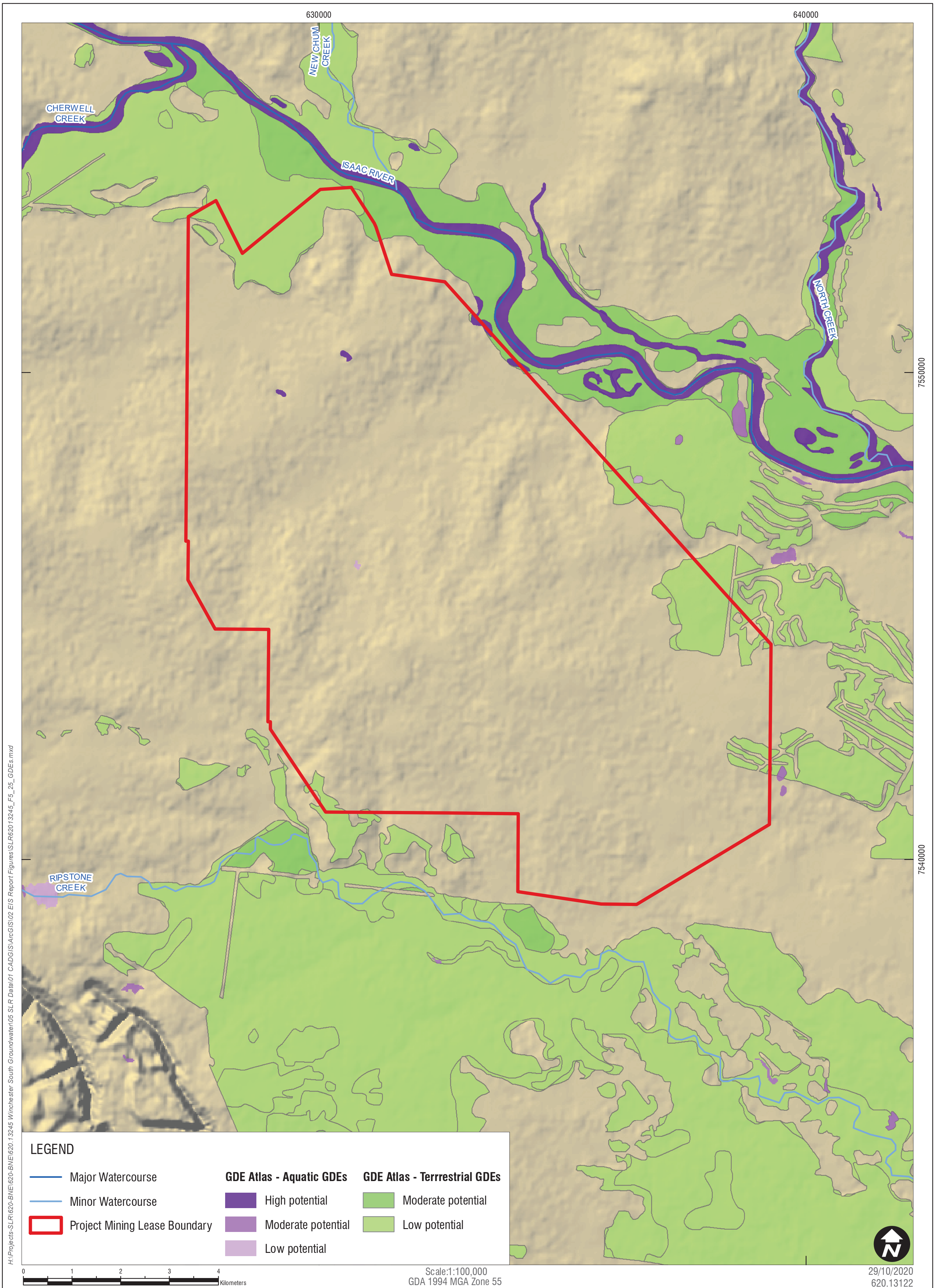
The *Groundwater Dependent Ecosystem Atlas* (GDE Atlas) was developed by BoM as a national dataset of Australian GDEs to inform groundwater planning and management (BoM, 2020b). The GDE Atlas contains information about three types of ecosystems defined in the *Australian Groundwater-Dependent Ecosystems Toolbox* (Richardson *et al*., 2011).

GDEs derived in the GDE Atlas are mapped according to the following classifications:

- High potential for groundwater interaction;
- Moderate potential for groundwater interaction; and
- Low potential for groundwater interaction.

The GDE Atlas identifies the potential aquatic GDEs in the vicinity of the Project (**Figure 5-25**), including:

- The Isaac River and Cherwell Creek are mapped as having high potential for groundwater interaction;
- Wetlands on the Isaac River floodplain or its tributaries are mapped as having high or moderate potential for groundwater interaction;
- Wetlands to the east of the Project area are mapped as having moderate potential for groundwater interaction; and
- Three farm dams within the Project area are mapped as having high or moderate potential for groundwater interaction.



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Potential Groundwater Dependent Ecosystems (BoM, 2020)

FIGURE 5-25

The GDE Atlas also identifies the potential terrestrial GDEs in the vicinity of the Project (**Figure 5-25**), including:

- The riparian vegetation along the Isaac River and Cherwell Creek is mapped as having high potential for groundwater interaction;
- The terrestrial vegetation associated with wetlands on the Isaac River floodplain and its tributaries is mapped as having high potential for groundwater interaction;
- Terrestrial vegetation on the Isaac River and Ripstone Creek floodplains (outside of wetlands) mapped as having moderate potential for groundwater interaction; and
- Some areas of terrestrial vegetation in the vicinity of the Project are mapped as having low potential for groundwater interaction, including areas in the north and south-west of the Project area.

5.6.1.1.1 Potential Aquatic Groundwater Dependent Ecosystems

The Isaac River and Cherwell Creek are largely a losing system (i.e. not fed by groundwater) resulting in the water draining through the alluvial sediments to the underlying, local groundwater table. The occasional periods of baseflow to the Isaac River from the underlying alluvium may occur after prolonged rainfall events or following flood events. Under these conditions, recharged alluvial sediments would drain to the Isaac River as the hydraulic gradient reverses and sustains stream-flow for a short period after the rainfall event.

The aquatic in-stream ecosystems associated with the Isaac River and Cherwell Creek are largely not dependent on the surface expression of groundwater, but would be for a short period after rainfall events. However, these waterways are ephemeral and will inevitably dry out (Ecological Service Professionals, 2022).

Given the understanding of the groundwater regime, the riparian vegetation along the Isaac River and Cherwell Creek may access the surface expression of groundwater for short periods of time after rainfall events, however monitoring data within the Isaac River indicates that these events would occur infrequently (Ecological Service Professionals, 2022).

The depth to groundwater beneath the palustrine wetlands ranges from 10 m to 20 m, meaning that the aquatic ecosystem associated with the wetlands do not receive groundwater discharge, and therefore are not aquatic GDEs. Rather, the clay-rich substrates of these wetlands are likely to hold surface water run-off for extended periods creating the above ground conditions for the aquatic ecosystem. This conclusion is supported by alluvial drillholes and logs and the transient electromagnetic (TEM) survey undertaken in the vicinity of PW2 (the most proximal Palustrine Wetland to the Project), which confirm the presence of clay-rich sediments near the surface.

In the context of GDEs, the term ‘groundwater’ includes water occurring naturally below ground level (e.g. in an aquifer), and includes water in the soil capillary zone (capillary fringe above a saturated groundwater zone), but not the water held in the soil above this zone in the unsaturated or vadose zone (Doody *et al*., 2019). Therefore, these wetlands do not fit the definition of an aquatic GDE. Further, the farm dams in the locality are not likely to be aquatic GDEs.

5.6.1.1.2 Potential Terrestrial Groundwater Dependent Ecosystems

E2M (2021) concluded the following regarding the potential terrestrial GDEs in the vicinity of the Project:

- The riparian vegetation along the Isaac River and Cherwell Creek has a moderate to high potential to meet the definition of a terrestrial GDE, and any dependency on groundwater in the Quaternary alluvium is likely to be facultative, during dry times.

- The terrestrial vegetation associated with wetlands on the Isaac River floodplain and its tributaries has a moderate potential to meet the definition of a terrestrial GDE, and any dependency on groundwater is likely to be facultative, during dry times.
- Terrestrial vegetation on the Isaac River and Ripstone Creek floodplains (outside of wetlands) has a moderate potential to meet the definition of a terrestrial GDE, and any dependency on groundwater is likely to be facultative, during dry times.
- Some areas of terrestrial vegetation in the vicinity of the Project have a low potential to meet the definition of a terrestrial GDE, and any dependency on groundwater in the regolith is likely to be facultative, during dry times (if at all). It is unlikely that these Regional Ecosystems would be dependent on the groundwater due to the poor quality (high salinity) of the groundwater source.

5.6.2 Stygofauna

Stygofauna are subterranean aquatic fauna that live part of or all of their lives in groundwater systems (Ecological Service Professionals, 2022).

Sampling for stygofauna was undertaken in May and October 2019, and January 2020 as per the *Guideline for the Environmental Assessment of Subterranean Aquatic Fauna* (DES 2019). A total of eleven bores were sampled as part of the stygofauna assessment with sampling completed; seven bores were sampled during the late wet season in May 2019 (i.e. C2136, R2009, R2010, R2032, R2035, R2054 and R2055), an additional two bores were sampled during the early wet season in October 2019 (i.e. Winnet Bore and Knob Hill 2) and sampling also was undertaken in January 2020 using the pumping method at all previously sampled bores, as well as two additional bores (i.e. Knob Hill 1 and R2008) (Ecological Service Professionals, 2021).

No stygofauna species were recorded from bores sampled during the Project field survey undertaken by Ecological Service Professionals (2022) for the Aquatic Ecology and Stygofauna Assessment.

Regolith is considered to be largely unsaturated throughout the region, with the presence of highly saline water occurring in the lower elevation areas along the Isaac River (DPM Envirosciences, 2018b). High EC of the regolith throughout the broader region suggests that the groundwater environment is not ideal for stygofauna; however, stygofauna are likely to occur in the alluvium associated with the Isaac River (DPM Envirosciences, 2018b).

Two bores in the Isaac River alluvium were sampled recently as part of the Olive Downs Coking Coal Project Aquatic Ecology Assessment (DPM Envirosciences, 2018b). Although stygofauna were considered likely to occur in these unconsolidated sediments, none were recorded during the study (Ecological Service Professionals, 2022).

A recent stygofauna pilot study prepared for the Vulcan Complex Project (FRC Environmental, 2020) in the Fitzroy Basin (located 10 km south-west of the Project) found one stygofauna taxon in two bores, namely a stygoxenic fauna of the Order Ostracoda. These stygofauna, however, are not obligate inhabitants of groundwater ecosystems and are unable to establish populations in such environments (Ecological Service Professionals, 2022).

5.6.3 Springs

A spring vent is a point where there is a surface expression of groundwater, with groundwater flow occurring intermittently or continuously. The Queensland Government maintains an inventory of identified springs in the Queensland Springs Database (DES, 2019). No springs have been identified within the Project Area.

5.6.4 Internationally and Nationally Important Wetlands

A search of the EPBC Act 'Protected Matters' database (DAWE, 2022) found that there are no Internationally or Nationally Important Wetlands within the Project Area. The closest wetlands of international importance are located approximately 190 km south-east of the Project and include those of the Shoalwater and Corio Bays Area. Lake Elphinstone is the closest nationally important wetland, located 70 km north (upstream) of the Project. Due to their distance from site, no internationally or nationally important wetlands will be impacted by the Project.

5.7 Conceptual Model

A conceptual model of the groundwater regime has been developed based on the review of the hydrogeological data for the Project and surrounds.

The Project is located within the northern part of the Bowen Basin, which comprises Permian coal measures that have been folded into a syncline structure that strikes in a north-west to south-east direction. The geology of the Project comprises the stratified sequences of the Moranbah Coal Measures, Fort Cooper Coal Measures and Rangal Coal Measures that dip towards the east. The Project targets mainly the Leichhardt Seam and Vermont Upper Seam of the Rangal Coal Measures, that occur at subcrop at the central zone, portions of the northern area, and underlie the Rewan Group and surficial cover throughout the remainder, with depth increasing toward the Isaac River. The Triassic Rewan Group sediments unconformably overlie the coal measures and can reach a maximum of 74 m thick within the Project Area and up to 300 m thick within the Study Area. Surficial cover includes the alluvium along the Isaac River and surrounding creeks, as well as regolith material comprising Quaternary to Tertiary sediments. The main hydrogeological features at the Project include:

- Cainozoic sediments:
  - Quaternary alluvium – unconfined aquifer (water-bearing strata of permeable rock, sand, or gravel) localised along Isaac River;
  - Quaternary to Tertiary colluvium and weathered units (regolith) – unconfined and largely unsaturated unit bordering alluvium;
- Triassic Rewan Group – aquitard overlying Permian coal measures across much of the Project Area;
- Permian coal measures with:
  - Hydrogeologically 'tight' interburden units with aquitard properties; and
  - Coal sequences that exhibit water bearing properties associated with secondary porosity through cracks and fissures.

The Isaac River alluvium comprises of a heterogeneous distribution of fine to coarse grained sands interspersed with lenses of clays and gravels. The hydraulic properties of the Isaac River alluvium vary due to the variable lithologic composition, with field tests from the Moorvale South Project and Olive Downs Project groundwater assessments indicating horizontal hydraulic conductivity can range between 1.4 x10^{-2} m/day and 8.7 m/day. Groundwater occurs within the alluvium at depths of around 11 mbgl to 17 mbgl and is approximately 8 m below the base of the Isaac River at the closest monitoring point. Regionally, groundwater flow within the Isaac River alluvium is a subdued reflection of topography, with groundwater flowing in a south-eastern direction consistent with the alignment of the Isaac River. However, local groundwater levels within the alluvium are highest close to the Isaac River, indicating a potential local flow direction away from the Isaac River. This also indicates potential losing conditions from the Isaac River to the underlying alluvium during flow periods. Spatially, the alluvium is variably saturated, with the two site alluvial monitoring bores showing saturation in proximity to the Isaac River, and two alluvial bores (Olive Downs Project bores GW04 and GW08s, west of the Project) being recorded as dry since July 2017. Localised perched water tables are also evident where waterbodies continue to hold water throughout the dry period (e.g. pools in the Isaac River and wetlands) occurring where clay layers slow the percolation of surface water.

Recharge to the alluvium is considered to be mostly from stream flow or flooding (losing streams), with direct infiltration of rainfall also occurring rapidly where there are no substantial clay barriers in the shallow sub-surface. On a regional scale, discharge is via evapotranspiration from vegetation growing along creek beds and minor short duration baseflow events after significant rainfall/flooding. Infiltration to underlying formations is limited to areas with relatively high hydraulic conductivity units (e.g. coal seams). General downwards recharge to deeper units is limited by the low hydraulic conductivity (confining) Rewan Group and coal measure interburden sequences.

Water quality data for the alluvium within the Study Area indicates it can be fresh to saline and highly spatially and temporally variable. The alluvium across the Study Area is mostly suitable for stock water supply and irrigation but is not suitable for drinking water and freshwater aquatic ecosystems. Alluvial bores within the Project monitoring network were found to be on average, not be suitable for long-term irrigation, with concentrations of iron, chromium, and manganese exceeding guideline levels. Review of the Queensland GWBD and two bore censuses indicate alluvial groundwater associated with the Isaac River is used by local landholders, predominantly for stock water supply. It should be noted that the surface alluvium extent is minor within the Project Area and there is no direct interception of the Isaac River alluvium by the proposed open cut pit extents.

Tertiary-Quaternary aged sediments (regolith) present across the Project Area form the base of the unconfined shallow groundwater system. The groundwater flow processes are similar to those of the Isaac River alluvium; however, the fluxes are expected to be significantly lower due to the dominance of clay within the Tertiary sediments. Within the Study Area, near the Isaac River and creeks (i.e. Ripstone Creek), water has been detected within the regolith material at depths of around 8 mbgl to 19 mbgl. Outside of these areas the regolith material was found to be largely unsaturated. Water quality data for the regolith indicates it is generally highly saline but can be brackish to moderately saline. Water within the regolith is generally of poor quality and not considered suitable for stock, irrigation, aquatic ecosystems or drinking water.

In the Permian strata, groundwater is encountered in the coal seams and in the sandstone/siltstone units of lower hydraulic conductivity. As with the rest of the Bowen Basin, the coal seams are the main groundwater bearing units within the Permian sequences, with low hydraulic conductivity interburden generally confining the individual seams. The coal seams are dual porosity in nature with a primary matrix porosity and a secondary (dominant) porosity provided by fractures (joints and cleats). Hydraulic conductivity of the coal decreases with depth due to increasing overburden pressure reducing the aperture of fractures. Vertical movement of groundwater (including recharge) is limited by the confining interburden layers, meaning that groundwater flow is primarily horizontal through the seams with recharge only occurring at subcrop. Review of fault behaviour within the Study Area and from external studies has identified that faults can increase vertical hydraulic conductivity parallel to the fault trace and reduce it perpendicular to the fault trace. However, any increases in vertical hydraulic conductivity is limited to small vertical horizons (<20 m) and is variable between faults dependent on localised hydrothermal activity and mineralisation in-filling pore spaces. Hydraulic testing of faults within the Project Area indicate that faulting zones intercepted are not pathways for preferential flow.

Regionally, groundwater within the Permian coal measures flows in a south-easterly direction. Review of water quality data indicates water within the Permian coal measures is generally saline within the Project Area but can range between fresh to highly saline. Groundwater within the coal measures of the Project Area is only considered suitable for some stock, with the type of stock dependent on the TDS range (i.e. beef cattle or sheep). Some bores screened within the interburden and the coal seams display highly variable concentrations of aluminium and nickel, exceeding the guidelines for stock watering. Further monitoring of this unit is required within the Project Area to determine the overall suitability for stock.

A conceptual cross-section, made from the south-west north-east section (see **Figure 4-3**) through the Project Area, of the hydrogeological system is presented in **Figure 5-26** illustrating the conceptual model of the area prior to any mining.

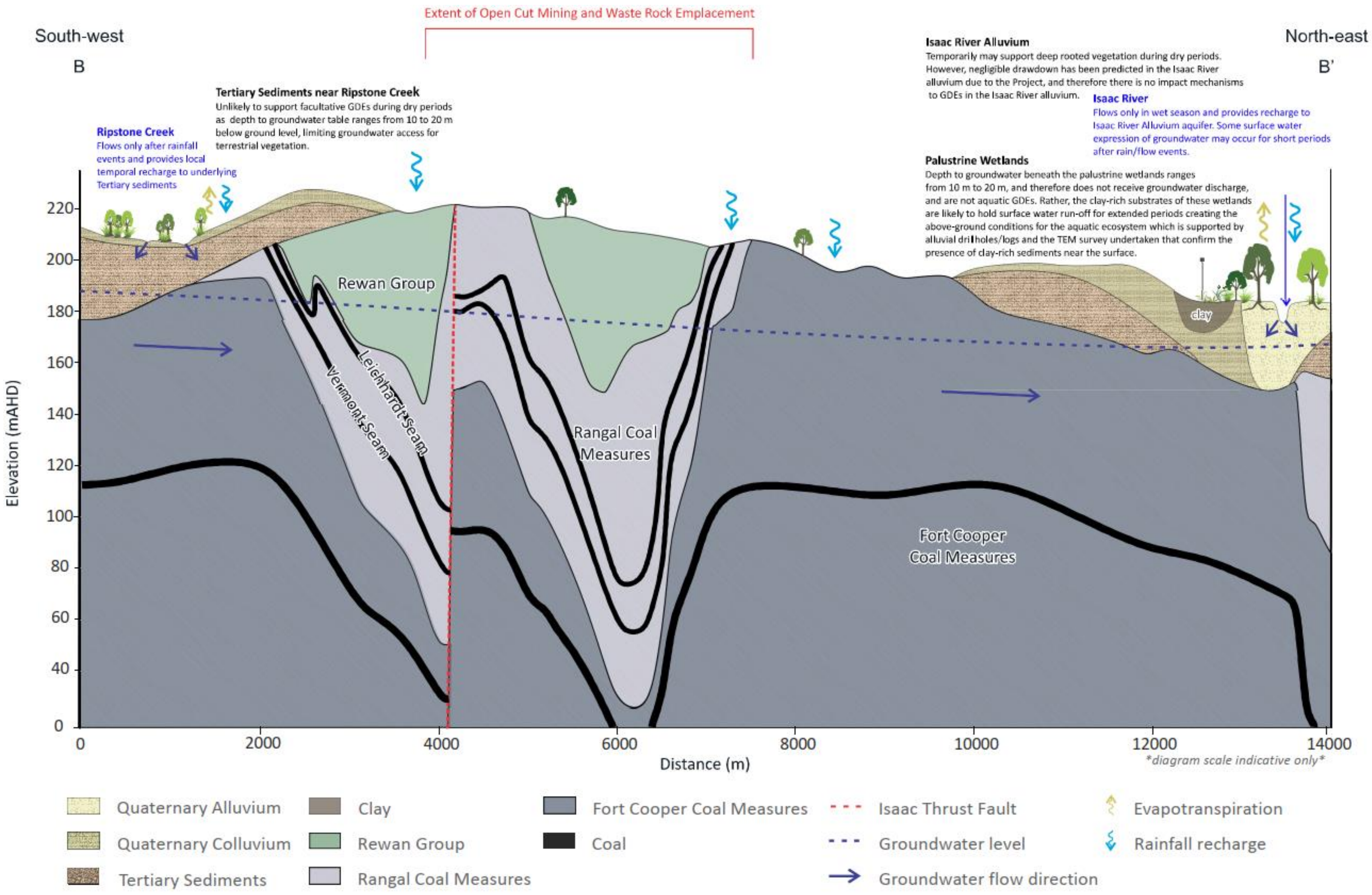


Figure 5-26 Conceptual Model of the Groundwater System Pre-Mining

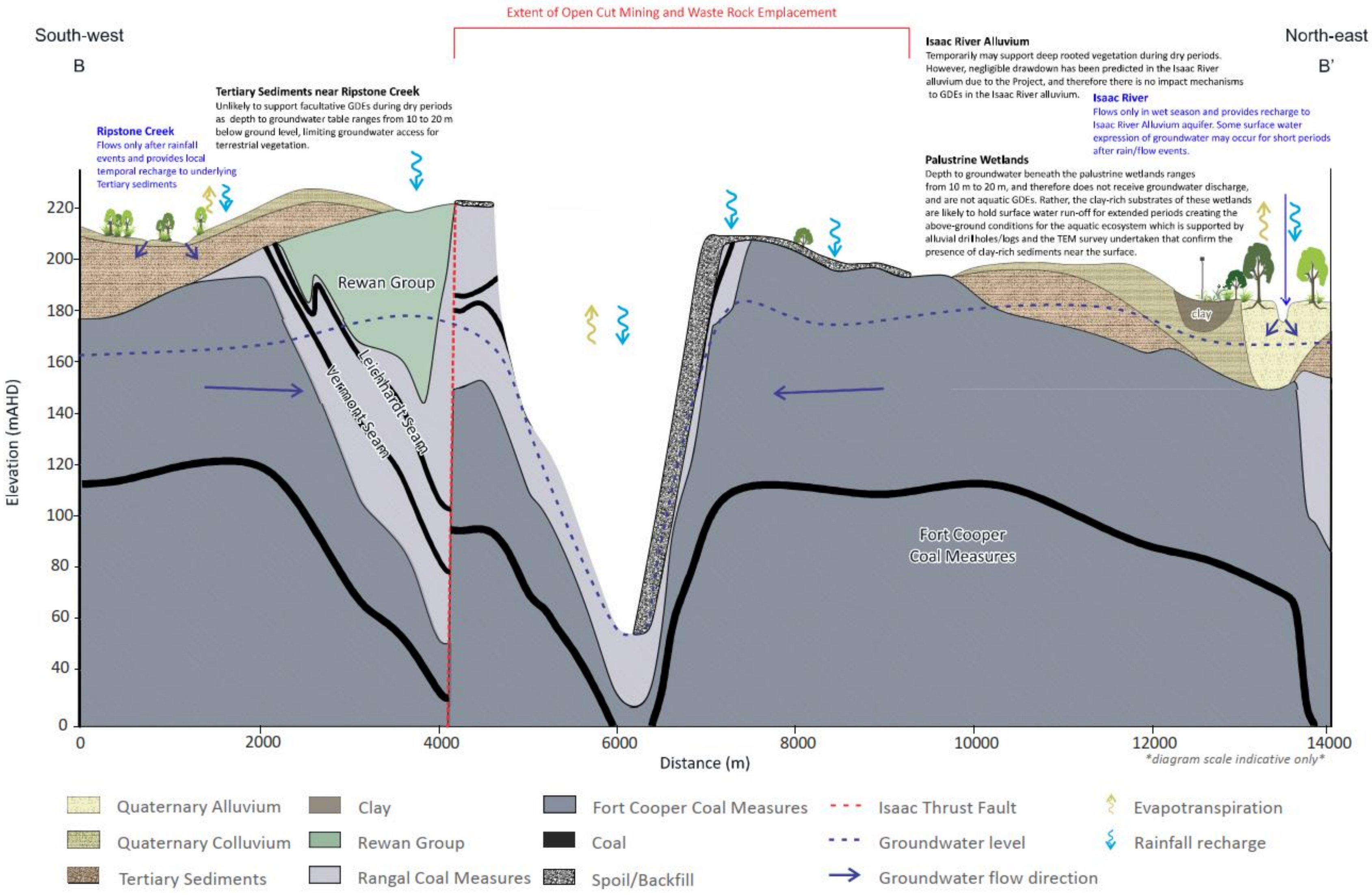


Figure 5-27 Conceptual Model of the Groundwater System During-Mining

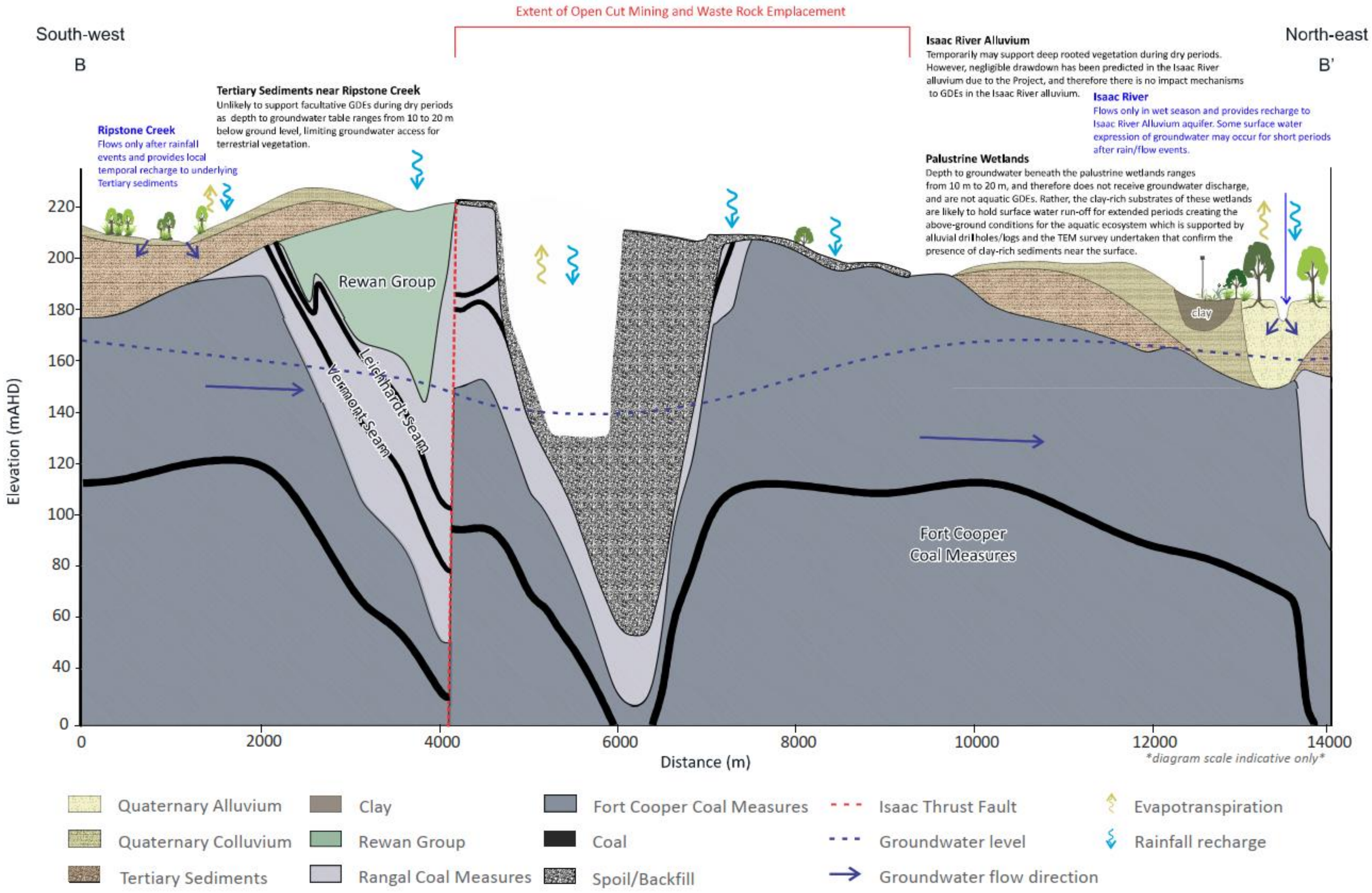


Figure 5-28 Conceptual Model of the Groundwater System Post-Mining

6 Groundwater Simulation Model

6.1 Model Details

This section provides a summary of the design and development of the numerical groundwater model used to support this Groundwater Assessment. Full details on the design of the numerical groundwater model are included within **Appendix B**.

6.1.1 Model Objectives

Numerical modelling was undertaken in support of the Groundwater Assessment for the Project to evaluate the potential impacts of the Project on the local groundwater regime. The objectives of the predictive modelling were to:

- Assess the groundwater inflow to the mine workings as a function of mine position and timing;
- Simulate and predict the extent and area of influence of dewatering and the level and rate of drawdown at specific locations; and
- Identify areas of potential risk, where groundwater impact mitigation/control measures may be necessary.

6.1.2 Model Design

The numerical groundwater model was developed based on the conceptual groundwater model, presented within **Section 5.6.4**. The model was developed using Geographic Information Systems (GIS) in conjunction with MODFLOW-USG, which is distributed by the USGS. MODFLOW-USG is a relatively new version of the popular MODFLOW code (McDonald and Harbaugh, 1988) developed by the United States Geological Survey (USGS). MODFLOW is the most widely used code for groundwater modelling and has long been considered an industry standard.

Model geometry has been adopted from the numerical groundwater model for the Olive Downs Project (HydroSimulations, 2018) as updated for the Moorvale South Project (SLR, 2019a). Further revisions were incorporated into the numerical groundwater model for the Project, including the expansion of the model domain to the north-west. The model is roughly 65 km x 70 km at its widest extents and comprises a maximum of 72,700 cells per layer. The model domain is discretised into 14 layers representing key geological units within the alluvium, regolith, Rewan Group, Rangal Coal Measures, Fort Cooper Coal Measures and Moranbah Coal Measures. Over the 14 model layers, with pinch out areas (where a layer is not present) in Layers 3 to 14, the total cell count for the model is 787,789. The model grid has been developed as a Voronoi mesh, with cells aligned and variably sized to focus on key features such as rivers, mine areas and faults.

6.1.3 Model Calibration

The numerical model includes a steady-state calibration (pre-2006) and transient calibration (2006 to 2021). Both the steady-state and transient calibrations capture historical mining at Peak Downs, Caval Ridge, Saraji, Lake Vermont, Eagle Downs, Poitrel and Daunia Mines. Mining was represented in the model using the MODFLOW drain package, with the drain cells set to the base of the target coal seam for each pit and within the target coal seam for underground mines. Calibration of the model was carried out with the objective being to replicate the groundwater levels measured in the Olive Downs Project, Moorvale South Project, Eagle Downs Mine and the Project monitoring networks and available privately-owned bores, in accordance with *Australian Groundwater Modelling Guidelines* (Barnett *et al*., 2012).

Steady-state calibration for the model achieved a 5.3% scaled root mean square (SRMS) error, which is within the acceptable limits (i.e. 10%) recommended by the *Australian groundwater modelling guidelines* (Barnett et al., 2012). Observations from recently installed Project site bores have been included in the transient calibration statistics. Project site bore residuals were calculated as the difference between the observed water level and simulated head for the corresponding time period in the predictive model. With the Project monitoring network bore residuals included, the transient calibration achieved an 2.4% SRMS error, which is also within the acceptable limit of 10%. A detailed description of the calibration procedure is provided in **Appendix B**.

6.1.4 Model Performance and Limitations

Under the earlier *Murray-Darling Basin Commission – Groundwater Flow Modelling Guideline* (Middlemis *et al*., 2001), the numerical groundwater model is best categorised as an Impact Assessment Model of medium complexity. Middlemis et al. (2001) describe this model type as follows:

> *Impact Assessment model - a moderate complexity model, requiring more data and a better understanding of the groundwater system dynamics, and suitable for predicting the impacts of proposed developments or management policies.*

Barnett et al. (2012) also developed a system within the modelling guidelines to classify the confidence level for groundwater models. Models are classified as Class 1, Class 2 or Class 3 in order of increasing confidence based on key indicators such as available data, calibration procedures, consistency between calibration and predictive analysis and level of stresses. The numerical groundwater model for the Project would be classified as a Confidence Level 2 (Class 2) groundwater model, with the following key indicators (based on Table 2-1 of Barnett et al., 2012):

- Groundwater head observations and bore logs are available and with a reasonable spatial coverage around the site and regionally;
- Seasonal fluctuations are not accurately replicated in all parts of the model domain (Level 2);
- SRMS error and other calibration statistics are acceptable (Level 3); and
- Suggested model use is for prediction of impacts of proposed developments in medium value aquifers (Level 2).

6.1.5 Model Predictions

Transient predictive modelling was undertaken to simulate both the proposed mining at the Project and surrounding mines from 31 December 2021 to 30 December 2053. The model timing used monthly followed by yearly stress period durations as mining progressed into the future. Three numerical model scenarios were run:

- Null Run – No future mining within the Study Area;
- Approved – Approved and foreseeable mining within the Study Area; and
- Cumulative – Approved and foreseeable mining plus the Project.

6.2 Predicted Groundwater Interception

The total annual volumes of groundwater predicted to be intercepted by the Project are shown in **Figure 6-1**. This total volume includes water removed in rock material with mining, as well as water evaporated from the pit surface.

Figure 6-1 shows total groundwater inflows to the open cut operations are predicted to reach a maximum peak in Year 2032. At this time, inflow due to the Project are predicted to be about 0.77 ML/day (280 ML/year). The average inflows over the duration of mining are predicted to be approximately 0.42 ML/day (155 ML/year).

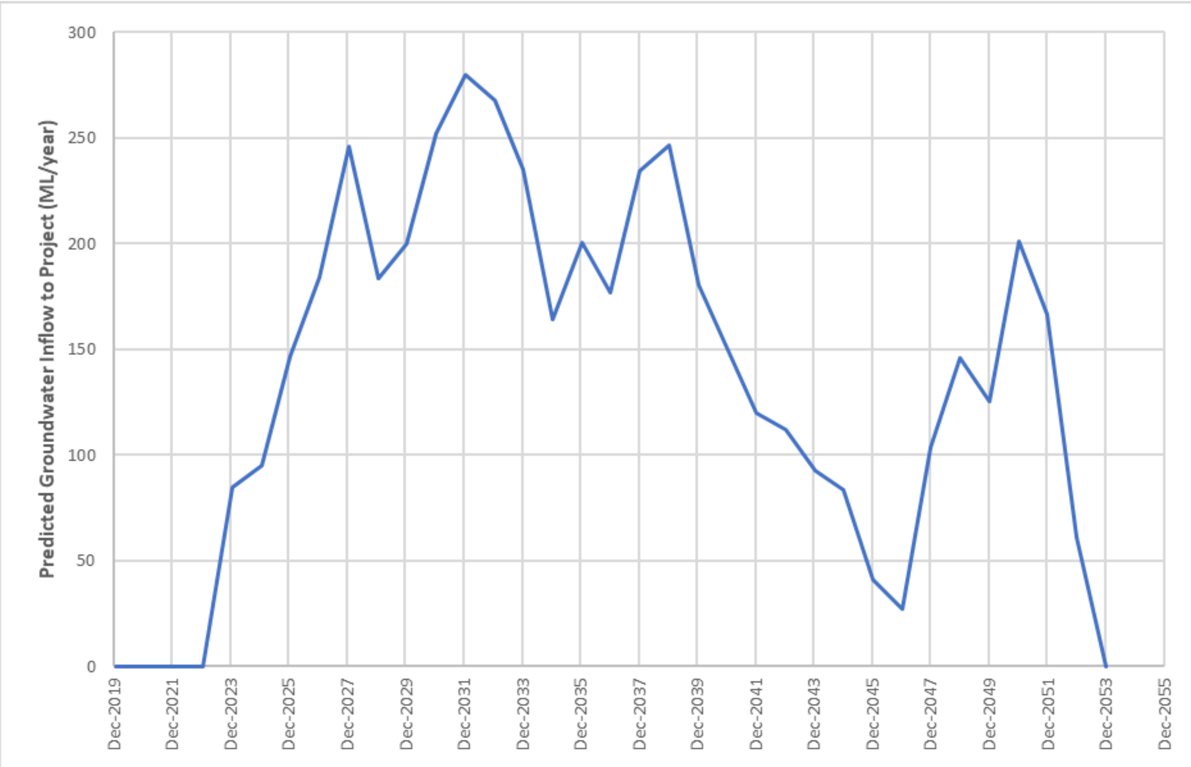


Figure 6-1 Predicted Project Mine Inflows

The *Water Plan (Fitzroy Basin)* 2011 groundwater area consists of the following:

- Isaac Connors Groundwater Unit 1 (containing aquifers of the Quaternary alluvium); and
- Isaac Connors Groundwater Unit 2 (sub-artesian aquifers).

Planned mining operations for the Project do not include any open cut pits that intercept the Isaac River alluvium, and therefore no direct take from Groundwater Unit 1 would occur from the mining operations. All direct groundwater take predicted by the model is, therefore, from Groundwater Unit 2.

6.3 Predicted Maximum Drawdowns

The process of mining reduces water levels in surrounding groundwater units. The extent of the zone affected is dependent on the properties of the aquifers/aquitards and is referred to as the zone of drawdown. Aquifer drawdown is greatest at the working coal-face, and generally, gradually decreases with distance from the mining operations.

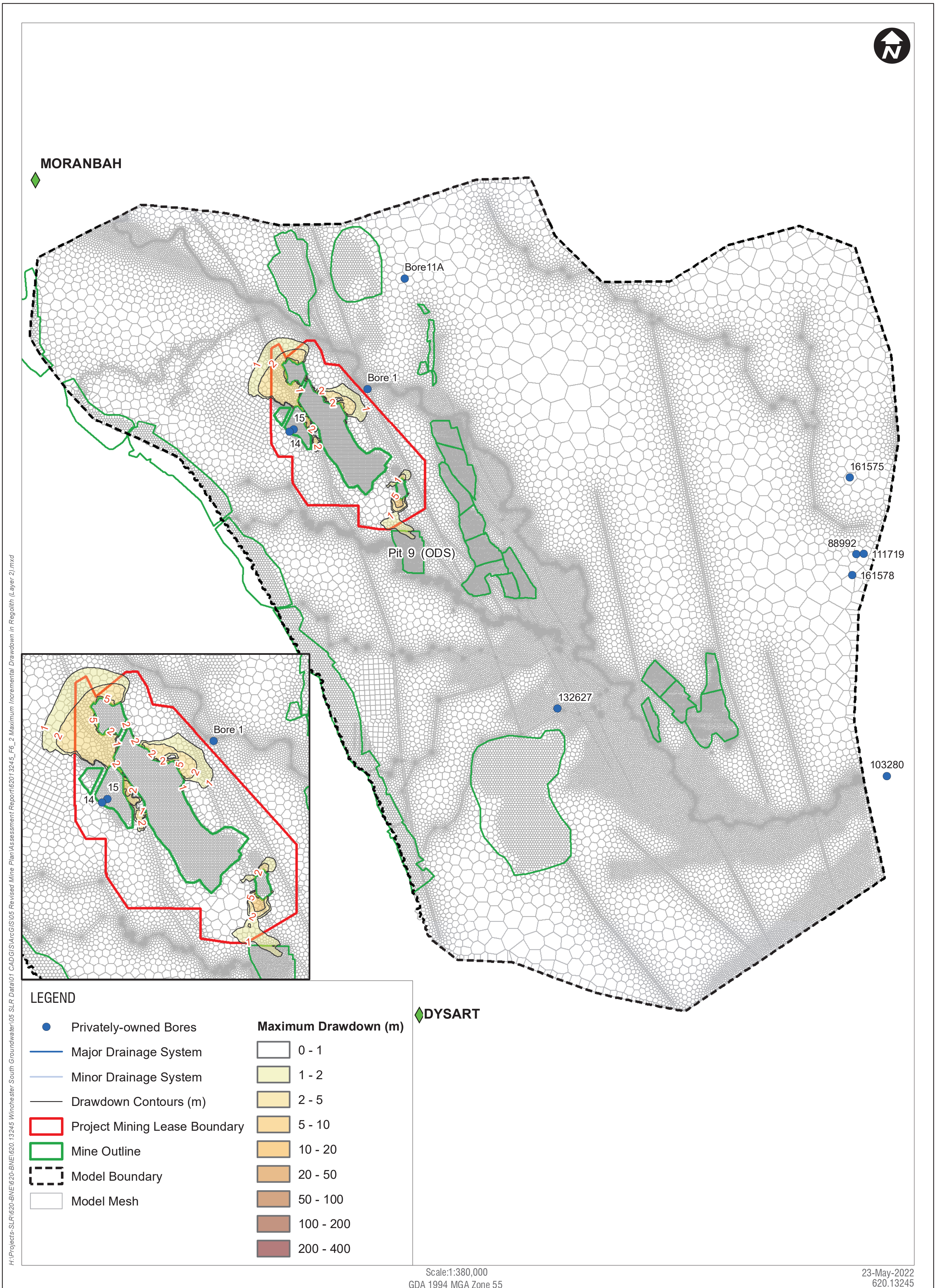
Maximum drawdown due to the Project is obtained by comparing the difference in groundwater levels for different aquifers in the Approved model run and the Cumulative model run. The maximum drawdown is a combination of the maximum drawdown values recorded at each model cell at any time over the duration of the predictive model. Figures showing predicted drawdowns feature the locations of privately-owned bores within the model domain. Discussion on the maximum predicted groundwater level drawdown at the privately-owned bores is included in **Section 7.2**.

The Project would result in negligible drawdowns within the alluvium (Layer 1) (i.e. maximum predicted drawdowns do not exceed 0.3 m). The maximum predicted drawdowns associated with the Project within the regolith (Layer 2), where the unit is predicted to be saturated, is shown in **Figure 6-2**. As shown, predicted effects of drawdown in the regolith are largely constrained to the Project Area, extending only up to approximately 1.8 km to the north-west and 1.6 km to the south-east away from the Project Area.

Figure 6-3 and **Figure 6-4** show the maximum Project-only drawdown within the Leichhardt seam and Vermont seam (Layer 5 and Layer 7), respectively, where predicted drawdown is greater than 1 m. It should be noted that no privately-owned bores intercept the Leichhardt seam or Vermont seam, but have been determined to intercept the interburden units. Discussion on the maximum predicted groundwater level drawdown at the privately-owned bores is included in **Section 7.2**.

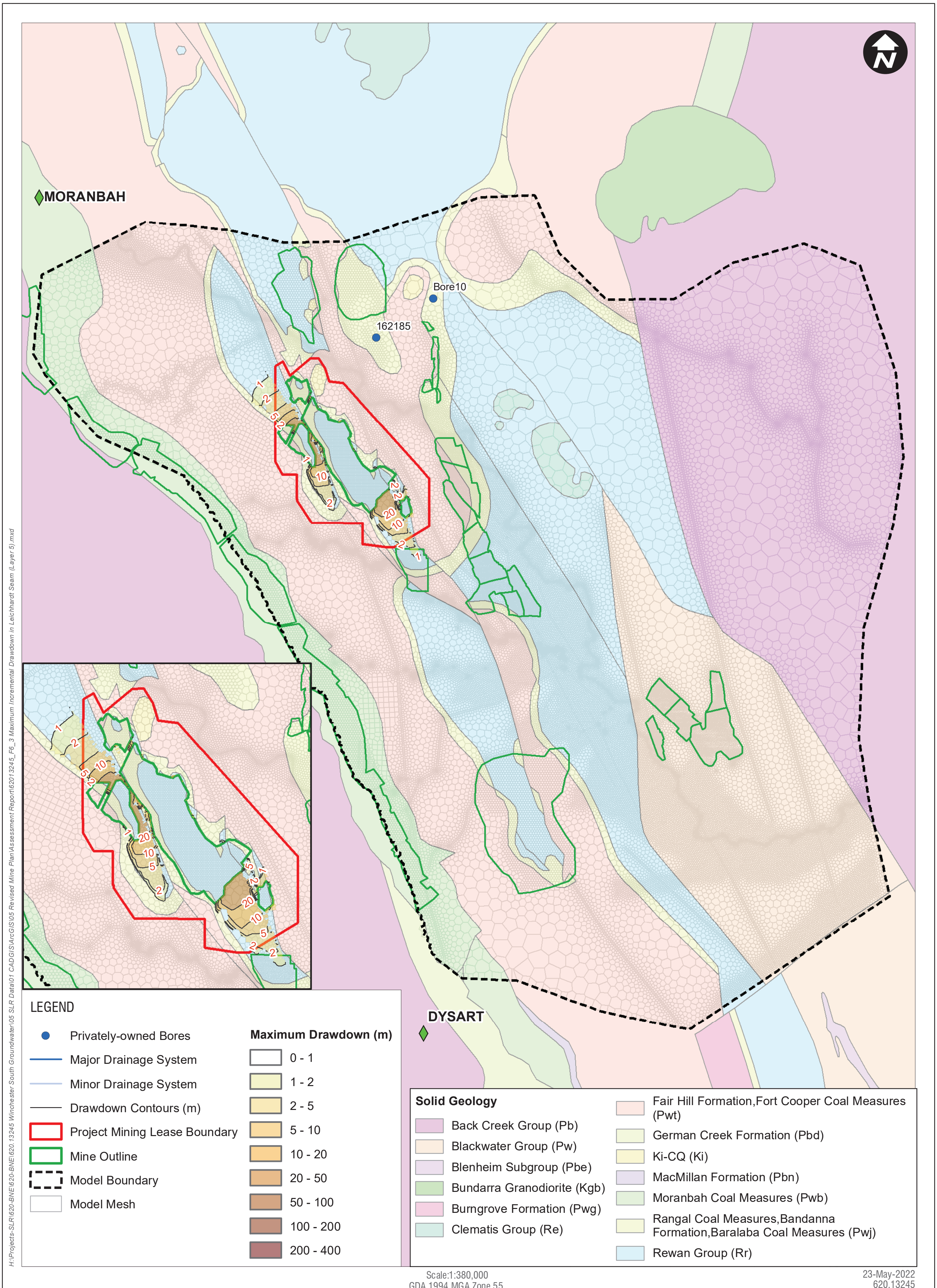
Groundwater level drawdown within the mined coal seams is influenced by the structure of the unit, particularly the northwest-southeast structural geological boundaries. Coal seams subcrop at the Project Area and dip east-northeast, and therefore the targeted seams generally do not occur to the west or south-west of the Project, limiting potential propagation of drawdown in the coal seam. Furthermore, the significant north-west to south-east strike of structural faulting at the Project Area exerts a dominant control on drawdown propagation away from the open cut pits. As shown in **Figure 6-3** maximum predicted Project-only drawdown within the Leichhardt seam is largely limited to the Project Area, only extending 1.7 km north-west and 1.6 km south-east of the Project. **Figure 6-4** shows maximum predicted groundwater level drawdown within the deeper Vermont seam has slightly reduced lateral drawdown extents as is observed in the Leichhardt seam.

It should be noted that underground workings have been left off drawdown prediction maps for model layers that are not intersected by those underground workings, so that underground mines are only shown for model layers that are directly impacted by those mines.



Maximum Incremental Drawdown in Regolith (Layer 2)

FIGURE 6-2



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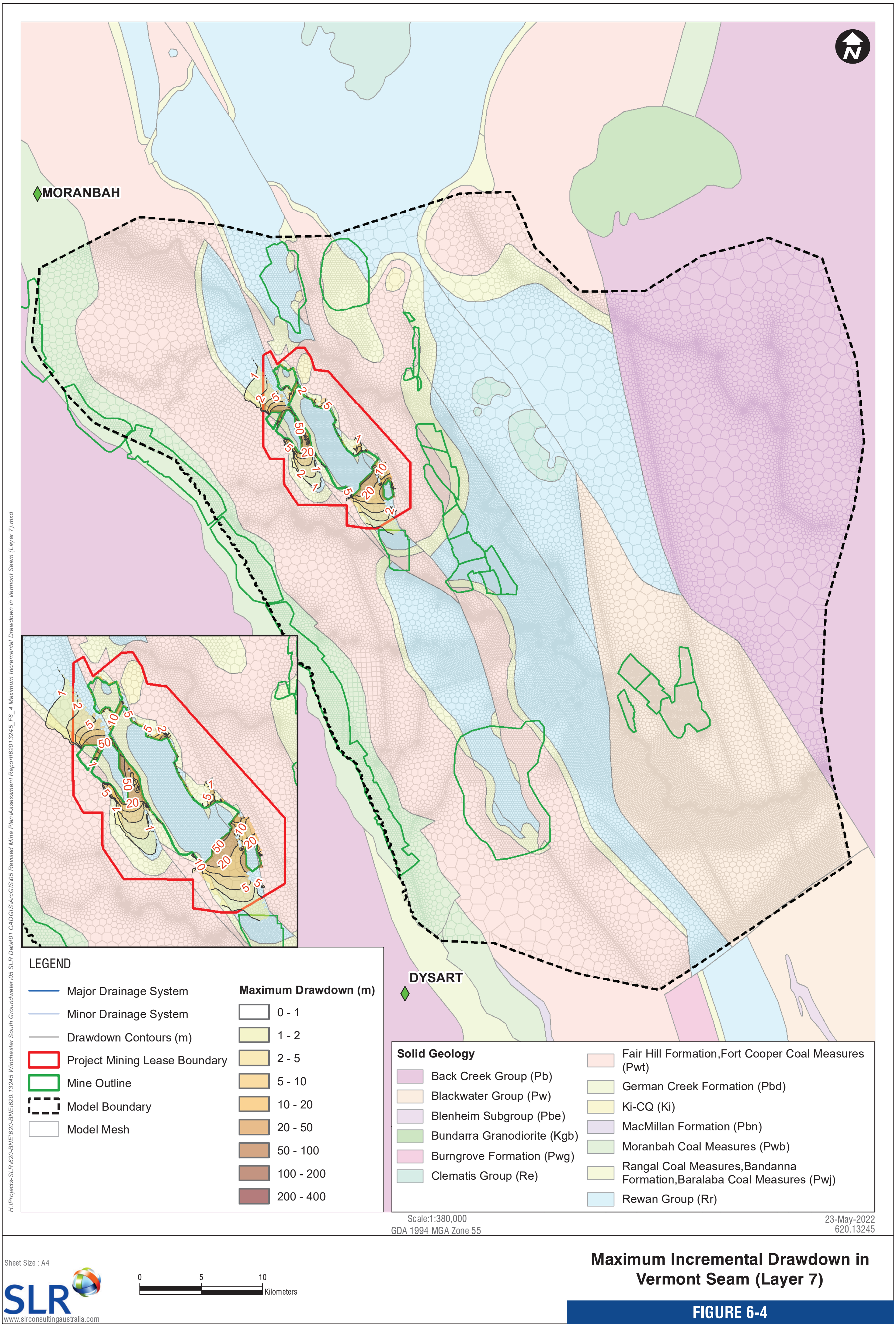
Maximum Incremental Drawdown in Leichhardt Seam (Layer 5)

FIGURE 6-3



Maximum Incremental Drawdown in Vermont Seam (Layer 7)

FIGURE 6-4

6.4 Incidental Water Impacts

6.4.1 Influence on Alluvium

As discussed previously, there would be no direct interception of the alluvium associated with the Isaac River with the proposed open cut pits for the Project (refer **Section 6.2**). Interference of the alluvial groundwater largely relates to increased leakage to the underlying Permian coal measures that are predicted to be depressurised as a result mining at the Project. Over the extent of Quaternary alluvium, the predicted indirect take from the Groundwater Unit 1 (alluvium) during Project mining is less than 0.01 ML/year and therefore considered negligible. The model predicts that for the long-term equilibrium condition post mining, there is negligible groundwater take from Groundwater Unit 1 (see **Section 3.6.1** of **Appendix B**).

6.4.2 Influence on Baseflow

The predicted change in water levels induced by mining could increase the hydraulic gradient between the Isaac River and the alluvium. As outlined within the conceptual model (**Section 5.6.4**), the Isaac River is largely a losing system in the Study Area, with seepage of surface water into the underlying alluvium. The model predicts that over the life of the Project, the change in the average rate of seepage from the river to the alluvium is insignificant and considered within the error threshold of predictions (less than 3.65 ML/year).

The Isaac River is ephemeral in nature, with flows following rainfall events that generate runoff. On average, when the Isaac River flows, 161,863 ML/year of surface water is discharged downstream. An estimate of less than 0.01% increased seepage from the Isaac River to the alluvium as a result of mining at the Project, therefore, represents an insignificant potential for flow rate reduction. The number of days that the Isaac River runs dry is not predicted to increase with the addition of the Project.

6.5 Cumulative Impacts

Cumulative impacts associated with approved and foreseeable open cut and underground coal mines surrounding the Project were modelled. The surrounding mines included within the model are the Olive Downs Project (Olive Downs South and Willunga), Moorvale South Project, Poitrel Mine, Daunia Mine, Peak Downs Mine, Caval Ridge Mine, Lake Vermont Coal Mine, Eagle Downs Mine, Saraji Mine and Saraji East Project.

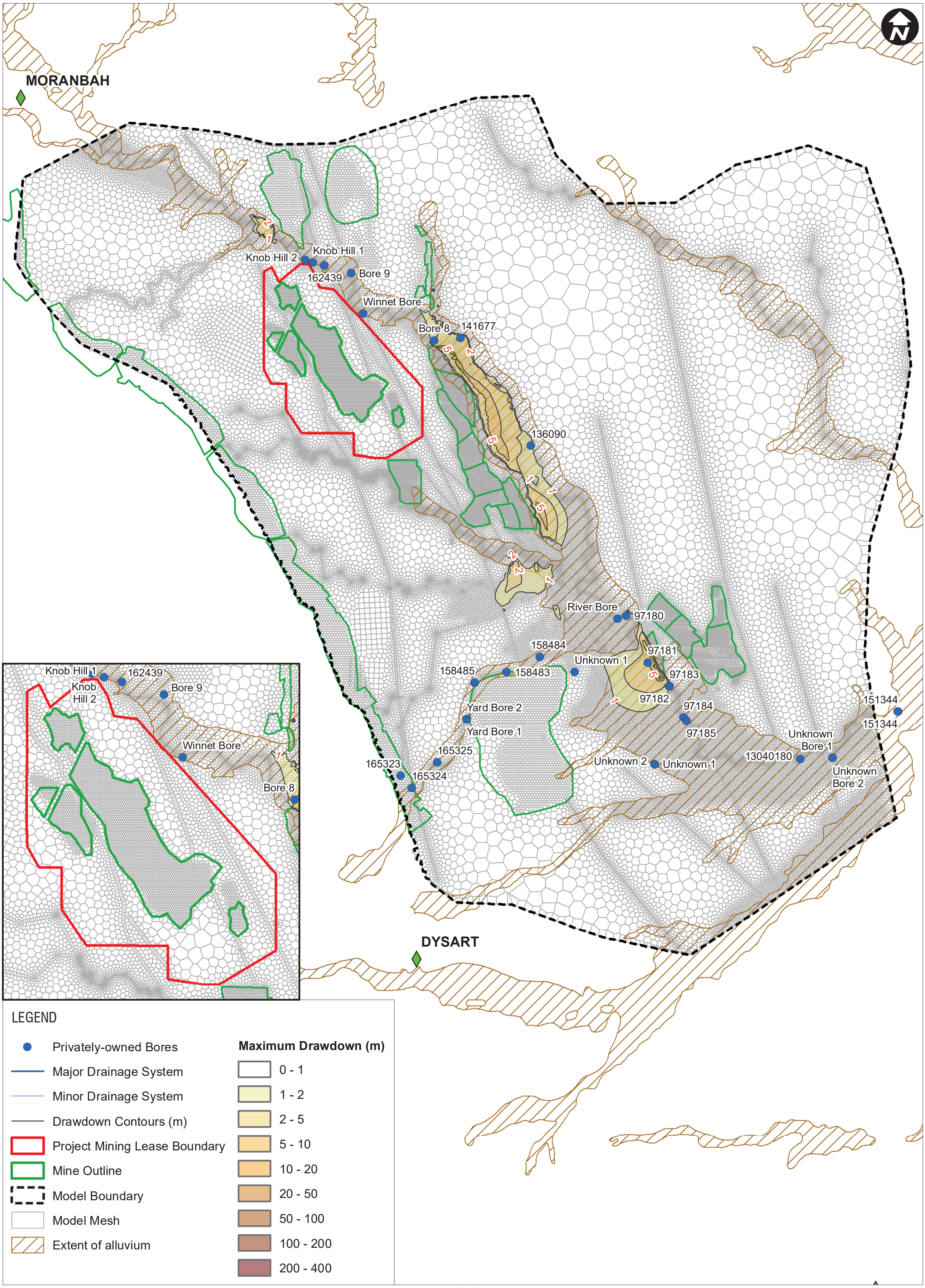
Figure 6-5 through **Figure 6-8** show the maximum cumulative drawdown of approved and foreseeable mining, plus the Project. The maximum drawdowns are obtained by calculating the maximum difference in heads between the Cumulative and Null Run scenarios at each cell at any time over the duration of the predictive model.

Figure 6-5 shows maximum cumulative drawdown within Quaternary alluvium (Layer 1) with drawdown close to surrounding mines (Poitrel to the north and Olive Downs Project to the east/south-east) are predicted, with only a small area of the Quaternary alluvium within the very north of the Project Area subject to predicted cumulative drawdowns. The magnitude of drawdowns are greatest in or closely around these other mining areas, and generally, gradually reduces with distance from mining operations. As discussed in **Section 6.3**, the Project's contribution to these cumulative drawdowns would be negligible.

Figure 6-6 shows maximum cumulative drawdown within the regolith (Layer 2), with the zone of drawdown from surrounding mines (Peak Downs Mine to the west and Pit 9 of the Olive Downs Project to the south) are predicted to reach the zone of impact from mining at the Project.

Figure 6-7 and **Figure 6-8** show the cumulative maximum drawdown within the Leichhardt seam and Vermont seam, respectively. The zone of drawdown from the Project only interacts with the zone of drawdown from Pit 9 mining at the Olive Downs Project located immediately south of the Project, with most of that drawdown interaction being within the Project Area. Elsewhere, the zone of drawdown from the Project does not interact with the zone of drawdown from any other mines and is similar in extent to the incremental (Project-only) predicted drawdown extent.

Assessment of cumulative impacts associated with the approved Bowen Gas Project was undertaken as a sensitivity analysis for the Olive Downs Project numerical groundwater model (HydroSimulations, 2018) (**Figure 6-9**). The Bowen Gas Project targets coal seams within the Rangal Coal Measures and Moranbah Coal Measures. As the Project shares much the same Study Area as the Olive Downs Project, results from the Olive Downs Project sensitivity analysis are equally applicable to the Project. Results of the assessment were presented in HydroSimulations (2018) and indicate that the assessment of cumulative impacts in the model is sensitive to the inclusion of the Bowen Gas Project, with cumulative drawdown extents in the Rangal Coal Measures extending significantly to the east across the model domain with the inclusion CSG extraction. Cumulative drawdown extents from the Bowen Gas Project are considered conservative and were predicted to be greater than the impacts produced by the Olive Downs Project alone (HydroSimulations, 2018).



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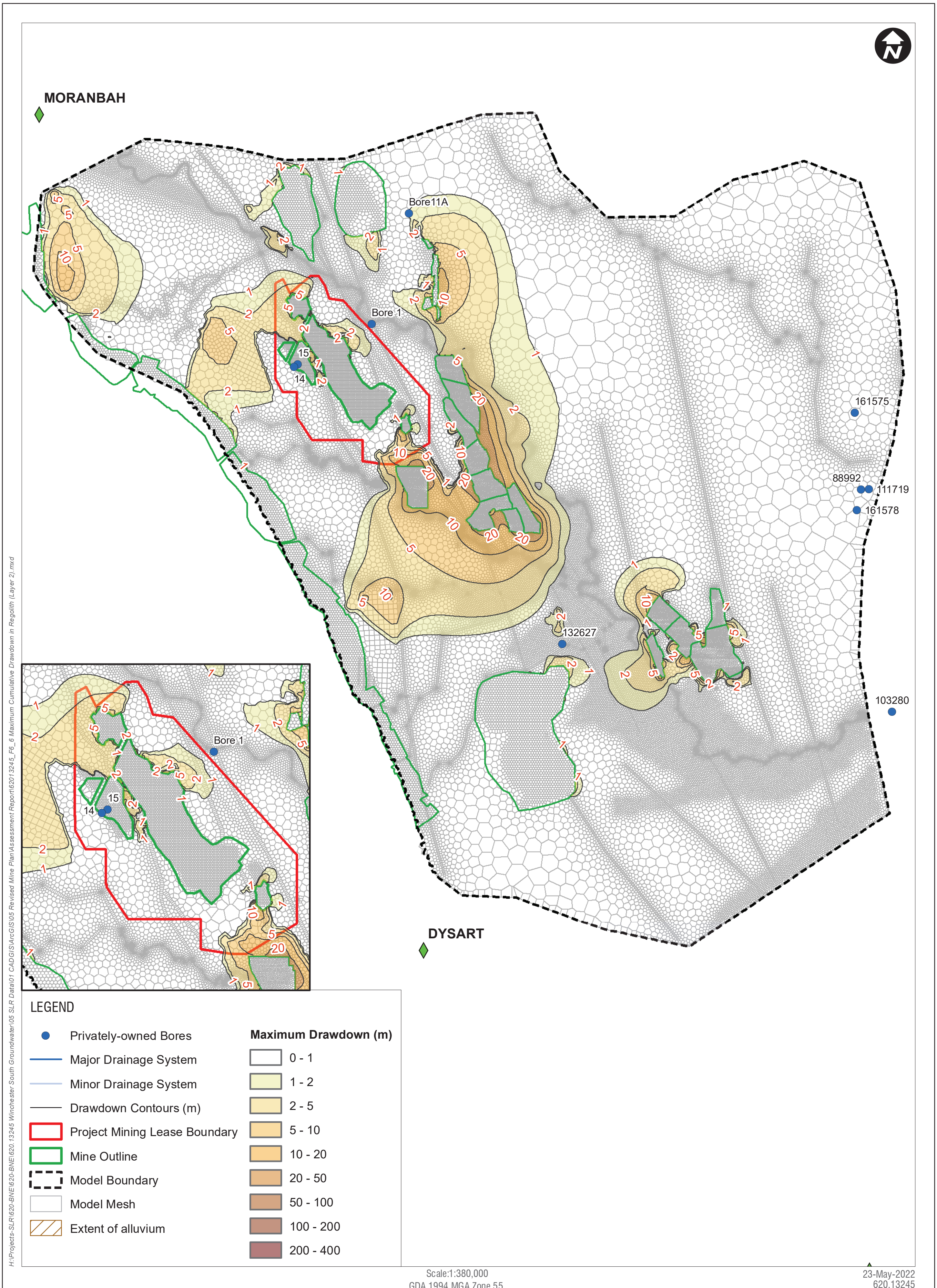
Maximum Cumulative Drawdown in Quaternary Alluvium (Layer 1)

FIGURE 6-5



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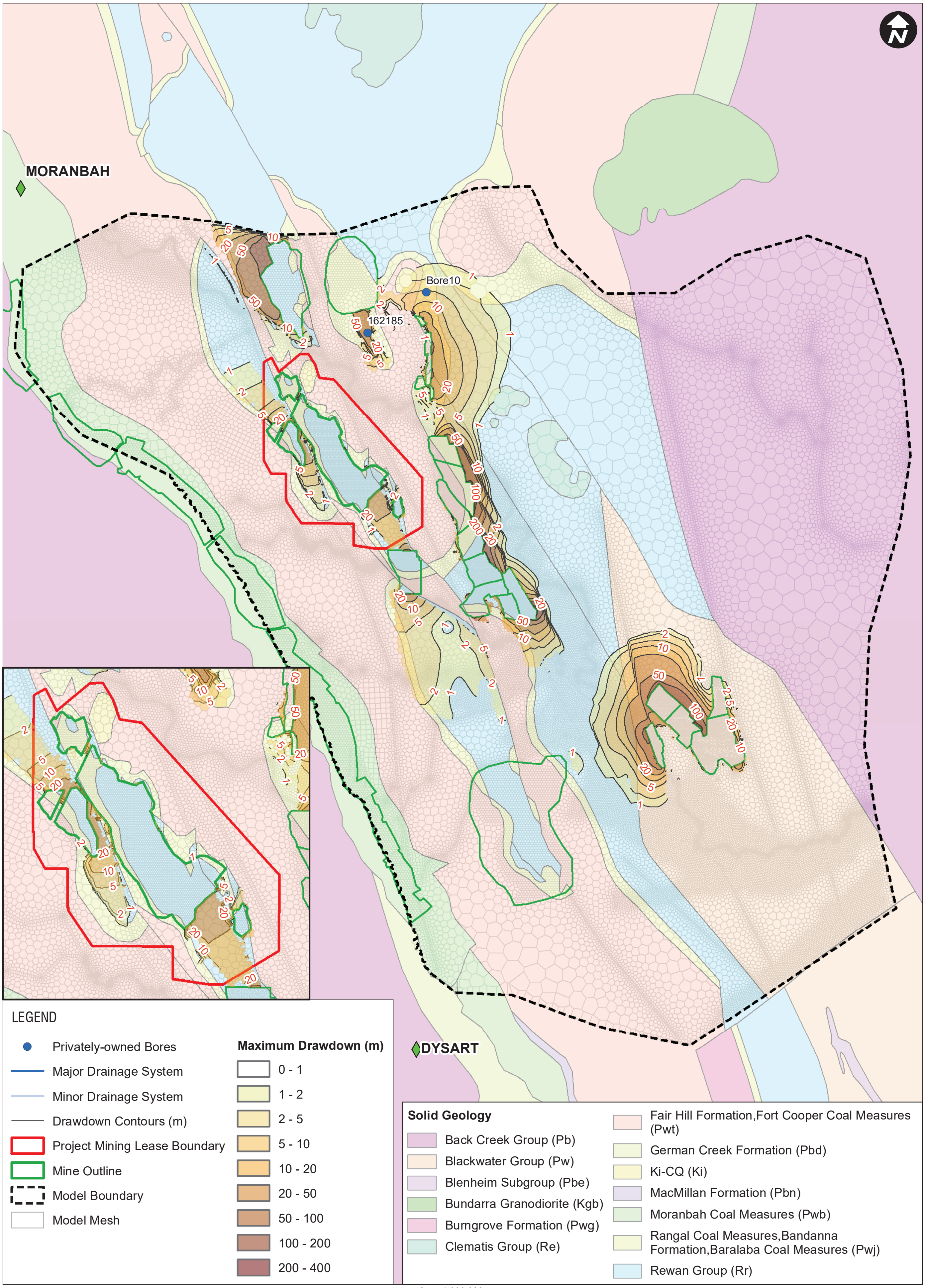
Maximum Cumulative Drawdown in Regolith (Layer 2)

FIGURE 6-6



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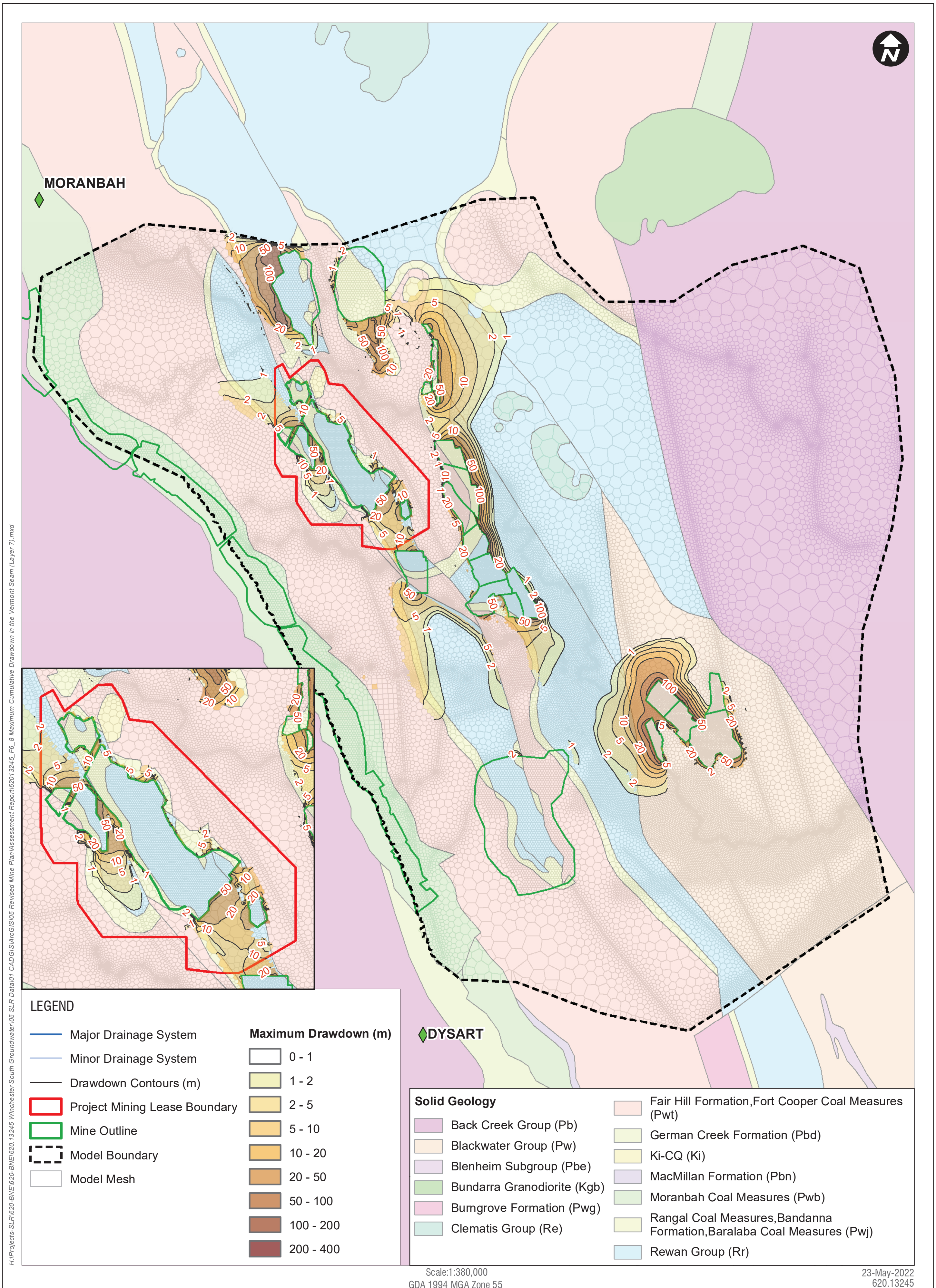
Maximum Cumulative Drawdown in the Leichhardt Seam (Layer 5)

FIGURE 6-7



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Maximum Cumulative Drawdown in the Vermont Seam (Layer 7)

FIGURE 6-8

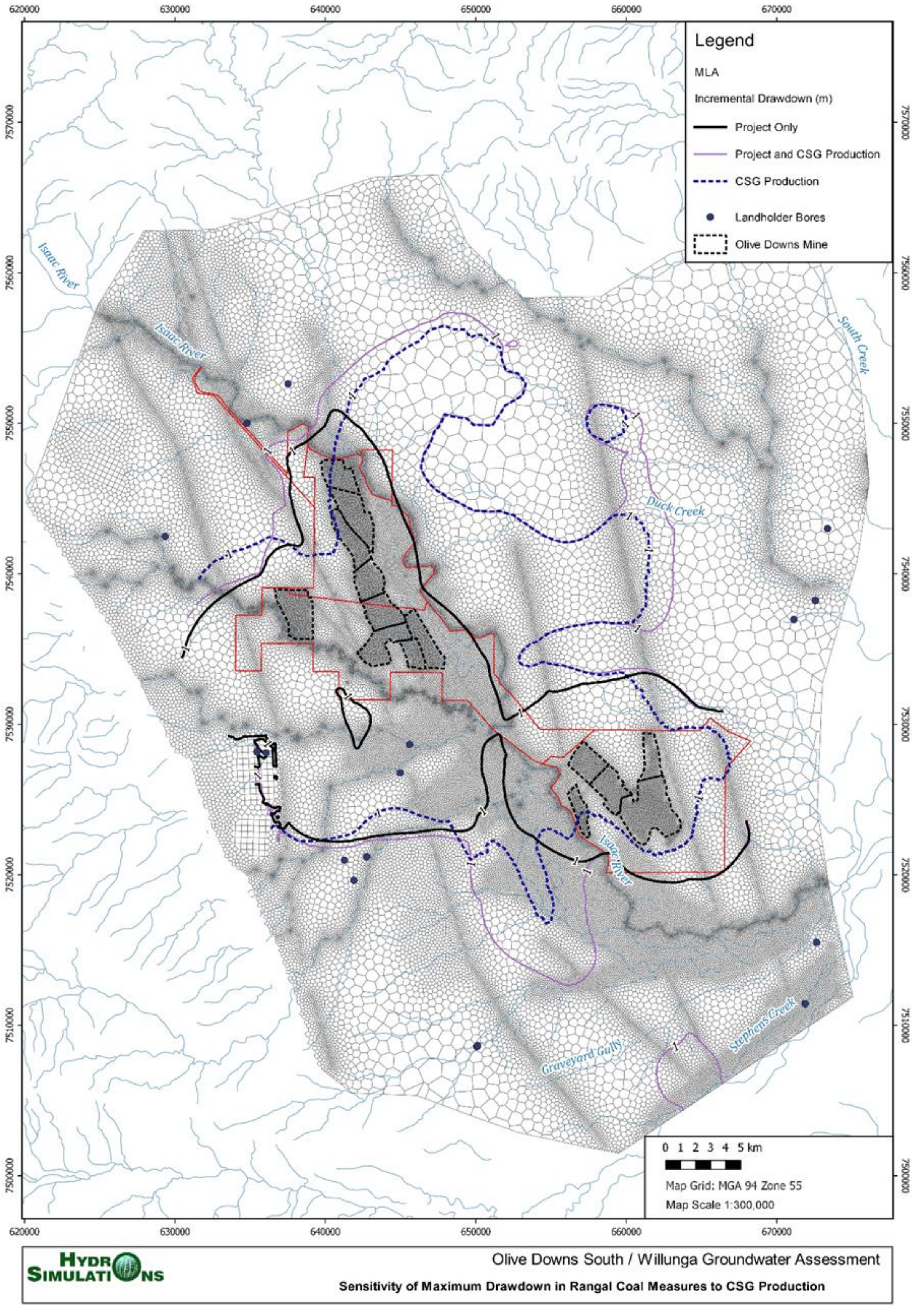


Figure 6-9 Sensitivity of Maximum Drawdown in Rangal Coal Measures to CSG Production (HydroSimulations, 2018)

6.6 Post-Mining Equilibrium

In response to feedback from regulatory and community stakeholders, Whitehaven WS has reviewed the Project mine plan and sequence with the aim of reducing the number of residual voids in the final landform; reducing the impacts of the Project on threatened species habitat and investigating uses for the residual void water bodies. The Project's optimised final landform would involve backfilling of the Railway and South Pits, and therefore there would be three residual voids for the Project (North-west Pit Void, West Pit Void, and Main Pit Void) to remain in perpetuity. The location of the residual voids for the Project are shown on **Figure 6-10**. The three residual voids would contain minimal spoil emplacement compared to the surrounding backfilled and rehabilitated pits.

SLR (2022) prepared the *Winchester South Project – Final Landform Scenario Groundwater Analysis Memo*, which considers the potential implications of three alternative final landforms for the Project:

- Scenario 1: Full backfill of the open cut pits to pre-mining levels.
- Scenario 2: Final landform with partial backfill of the open cut pits to 5 m above pre mining groundwater levels.
- Scenario 3: Final landform with covering of exposed coal seams.

Analysis of the above scenarios is presented in SLR (2022) and is not repeated in this report for brevity.

6.6.1 Recovery Model

Post-mining impacts were investigated with a Project recovery model for the optimised final landform (i.e. three residual voids), commencing from the end of mining at the Project and were run for 2,000 years, followed by a steady-state (long-term equilibrium) timestep. The model used post-mining predicted groundwater levels as the starting heads, and removed all drain cells simulating the proposed mining areas to allow groundwater levels to equilibrate. At the end of mining, the properties of the residual void cells were converted to values representative of void values.

The residual voids would accumulate water over time due to rainfall, surface water runoff and groundwater inflows from recovered groundwater levels. The equilibrated residual void water levels were estimated by the balance between groundwater inflow and the direct rainfall and rainfall runoff from the surrounding catchment against the evaporation loss from the lake surface. This was achieved through iterative surface water balance modelling (WRM Water & Environment [WRM], 2022). The predicted residual void water levels at equilibrium obtained from the residual void water balance model prepared by WRM (2022) was then implemented into the groundwater recovery model using a time variant constant head boundary condition for the final recovery simulation. **Figure 6-11** provides the simulated recovery of groundwater levels in the residual voids based on the surface water balance modelling.

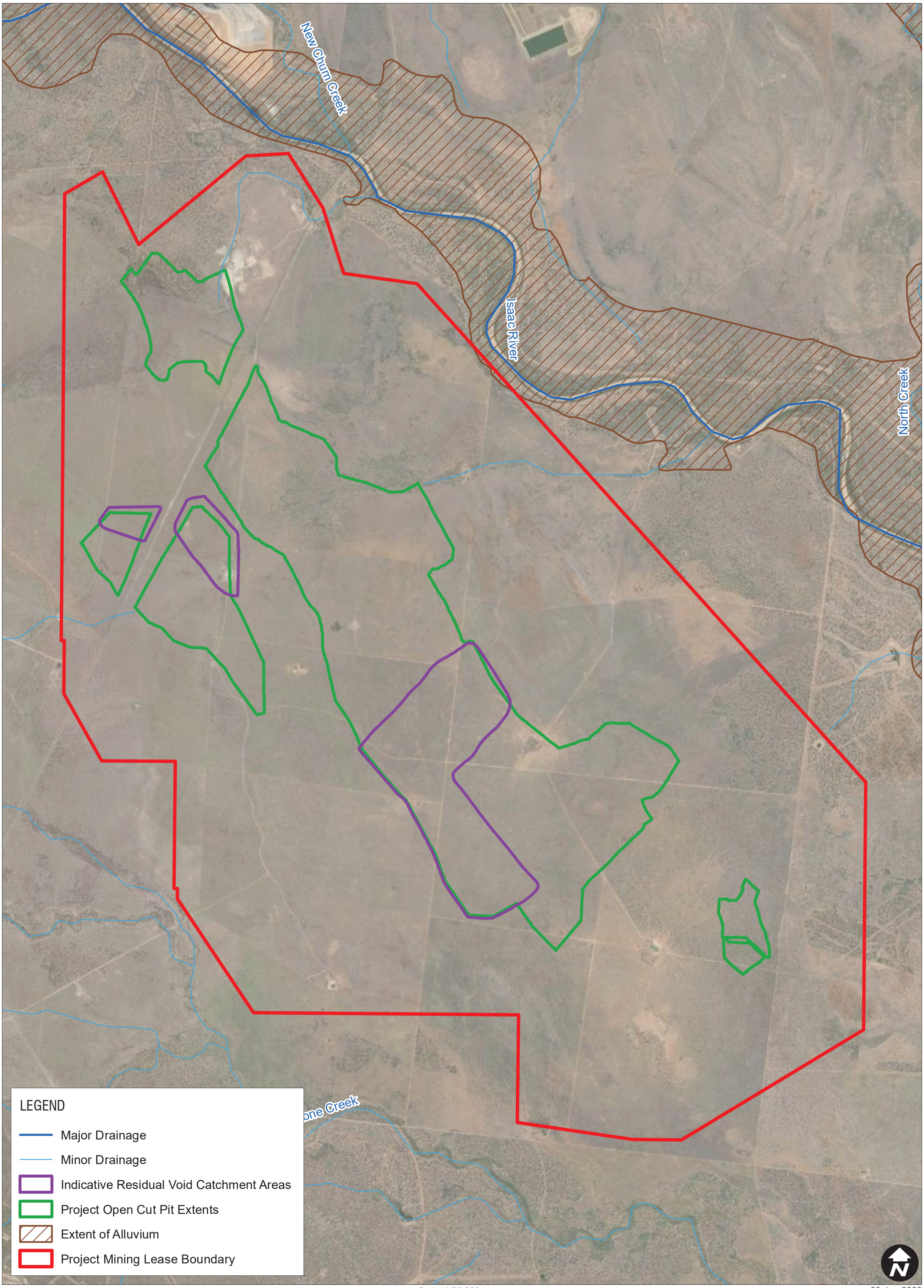
Figure 6-11 supports that the groundwater recovery is a slow process with the recovery rate declining as it reaches equilibrium conditions. Most groundwater recovery in the vicinity of the voids is achieved after 250 years, and the equilibrated water levels in the residual voids is predicted to be:

- North-west Pit Void – 128 mAHD;
- West Pit Void – 104 mAHD; and
- Main Pit Void – 141 mAHD.

The freeboard, for each of the residual voids (i.e. the difference in elevation between the long-term water levels in the residual voids and the pit crest elevation) is as follows:

- North-west Pit Void – approximately 62 m;
- West Pit Void – approximately 89 m; and
- Main Pit Void – approximately 49 m.

The long-term equilibrated water levels predicted as part of the numerical groundwater modelling is generally consistent with the results of the residual void modelling undertaken for the Surface Water and Flooding Assessment (WRM, 2022).



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Residual Void Locations

FIGURE 6-10

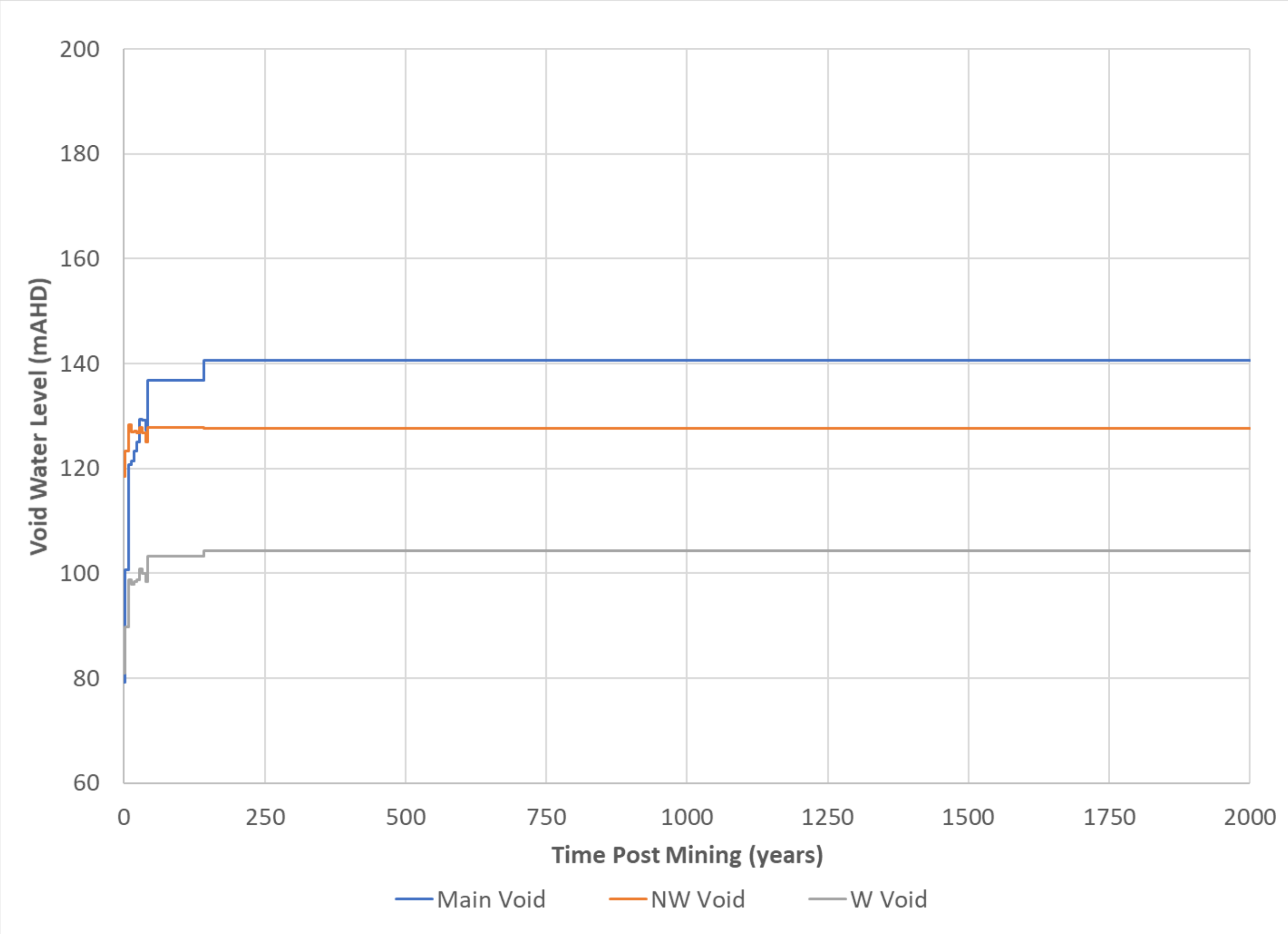


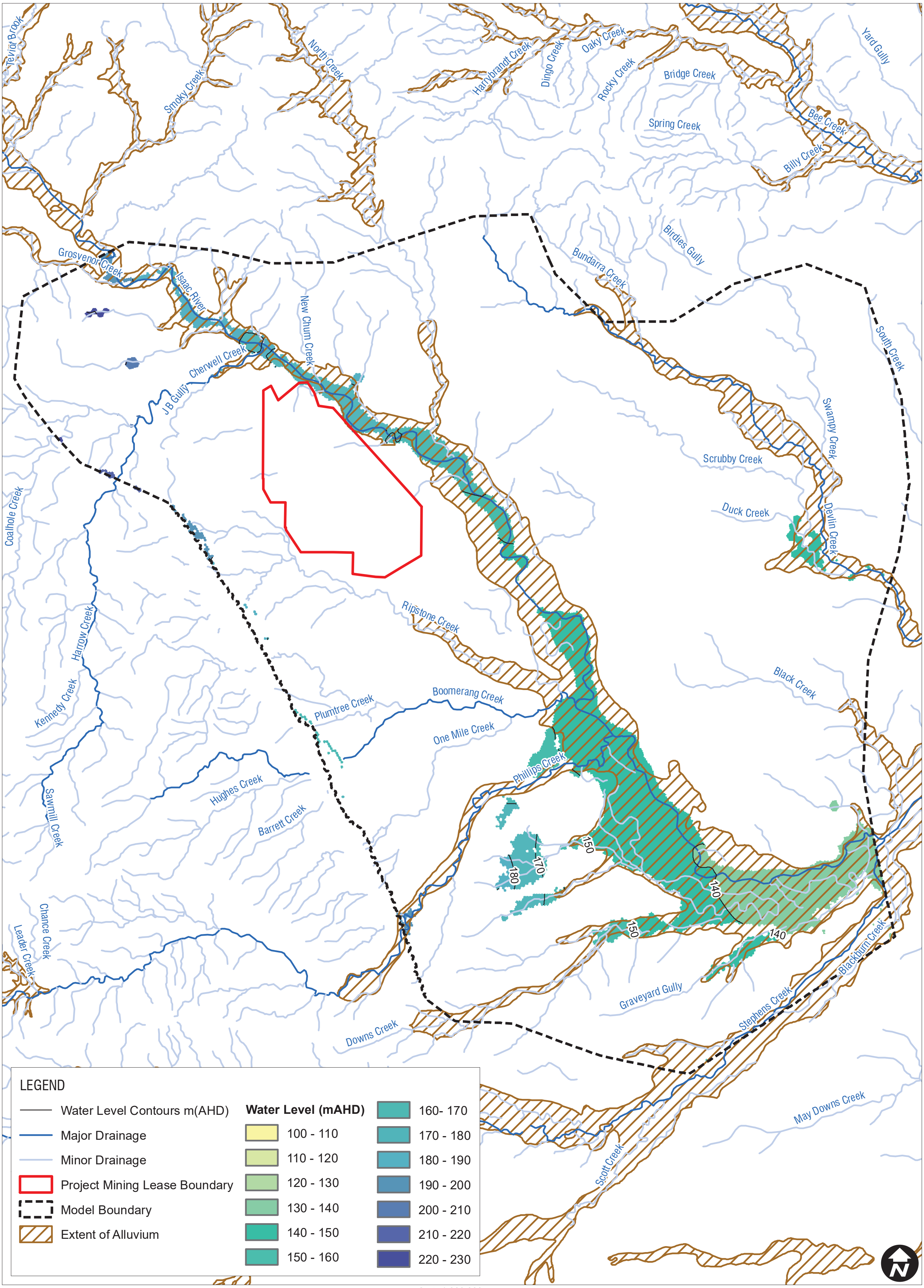
Figure 6-11 Simulated Residual Voids Water Level Recovery over Time

The predicted equilibrium water levels (long-term steady state) for the Quaternary Alluvium (Layer 1), the Regolith (Layer 2) and the Leichhardt and Vermont Seams (Layer 7 and 9) are shown in **Figure 6-12** through to **Figure 6-15**.

Adjacent to the backfilled open cut pits, groundwater levels in unconsolidated lithologies (model Layers 1 and 2) are predicted to recover back to pre-mining elevations (**Figure 6-12** and **Figure 6-13**). In the unconsolidated lithologies, recovered groundwater levels are predicted to be between approximately 162 mAHD at the backfilled and rehabilitated South Pit, and 179 mAHD proximal to the West and North-west Voids. Alluvium groundwater levels near to the Isaac River are predicted to remain close to the pre-mining elevation, at approximately 170 mAHD.

Figure 6-14 and **Figure 6-15** present the predicted recovered groundwater levels within the Permian coal measures (Leichardt seam and Vermont seam, respectively) in relation to the residual voids and spoil material within the backfilled open cut pits. Groundwater levels in the Permian coal measures very close to the residual voids range from approximately 120 mAHD proximal to the West and North-west Voids to 150 mAHD proximal to the Main Pit Void. Groundwater levels in the Permian coal measures then approximate 160 mAHD within 100-200 m of the residual voids. As such the West and Main Voids are predicted to behave as groundwater sinks with no risk of groundwater escaping far, and therefore the residual unlikely to impact on water quality within the surrounding strata (e.g. no mechanism for loss of residual void water to surrounding environment). It should be noted that the North-west Void pit lake levels are predicted above the surrounding groundwater levels. However, a hydraulic gradient exists between the West Void and North-west Void that drives flow from the North-west Void pit lake towards West Void. As the West Void is well below the surrounding groundwater levels, it is predicted to behave as a groundwater sink, which limits flow of groundwater flow off-site and potential impacts to water quality in the surrounding environment.

Figure 6-14 and **Figure 6-15** show a general flow direction towards the mined areas from the surrounding Permian coal measures, and a general inwards flow towards the residual voids themselves can also be observed. Outside the residual voids but within the backfilled and rehabilitated open cut pits, Vermont seam groundwater levels are predicted to recover to generally within approximately 25 m of the pre-mining heads.



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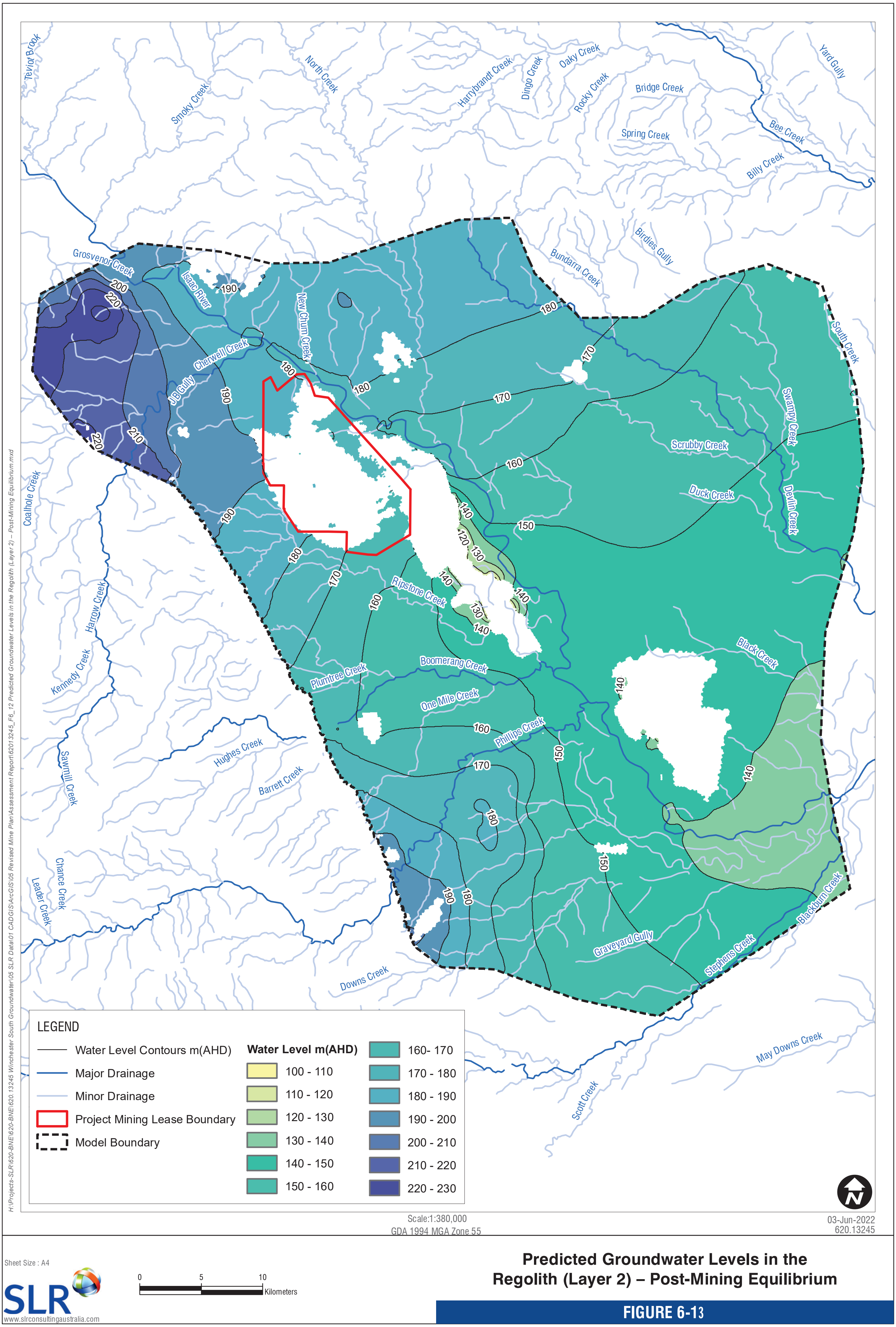
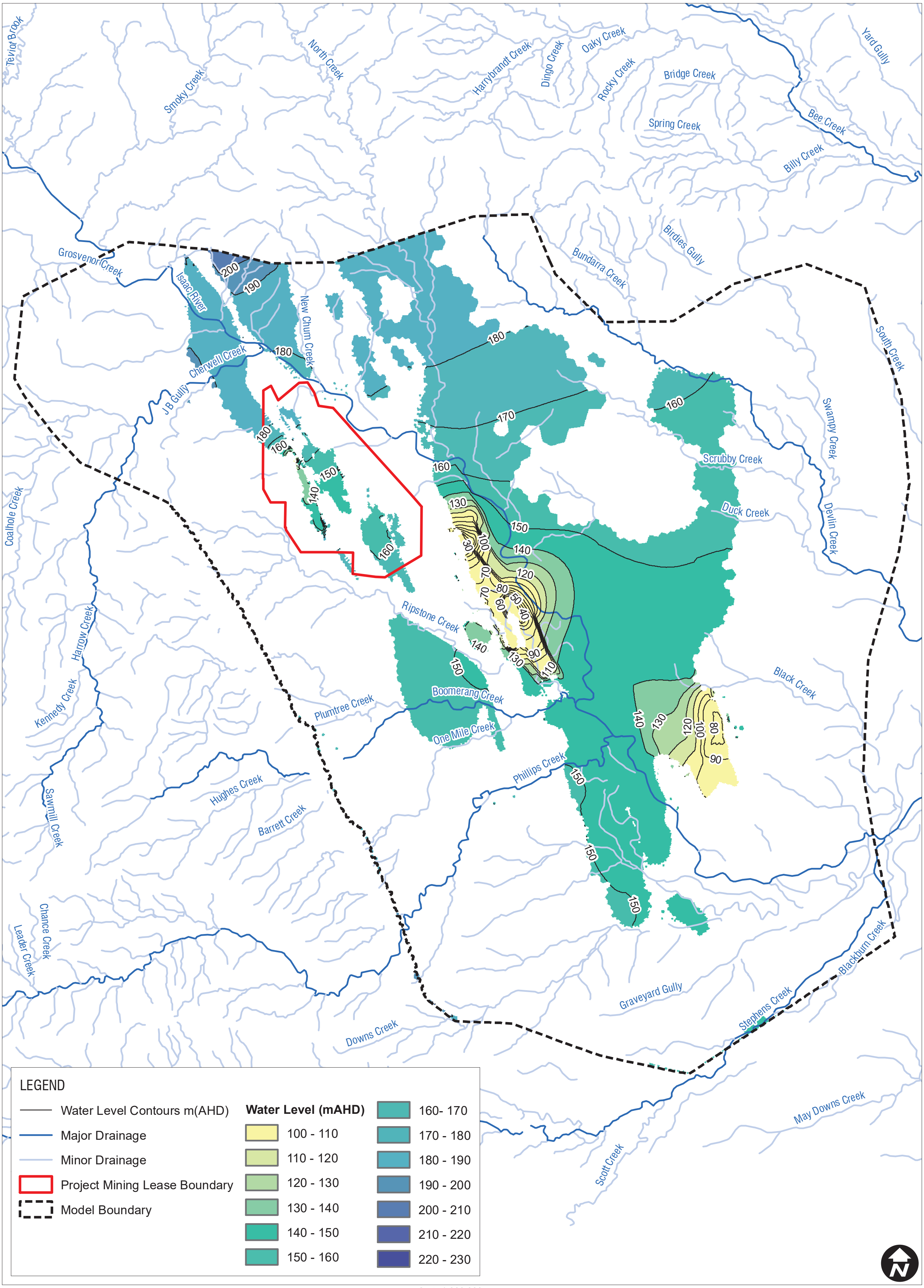
Predicted Groundwater Levels in Alluvium (Layer 1) – Post-Mining Equilibrium

FIGURE 6-12



Predicted Groundwater Levels in the Regolith (Layer 2) – Post-Mining Equilibrium

FIGURE 6-13



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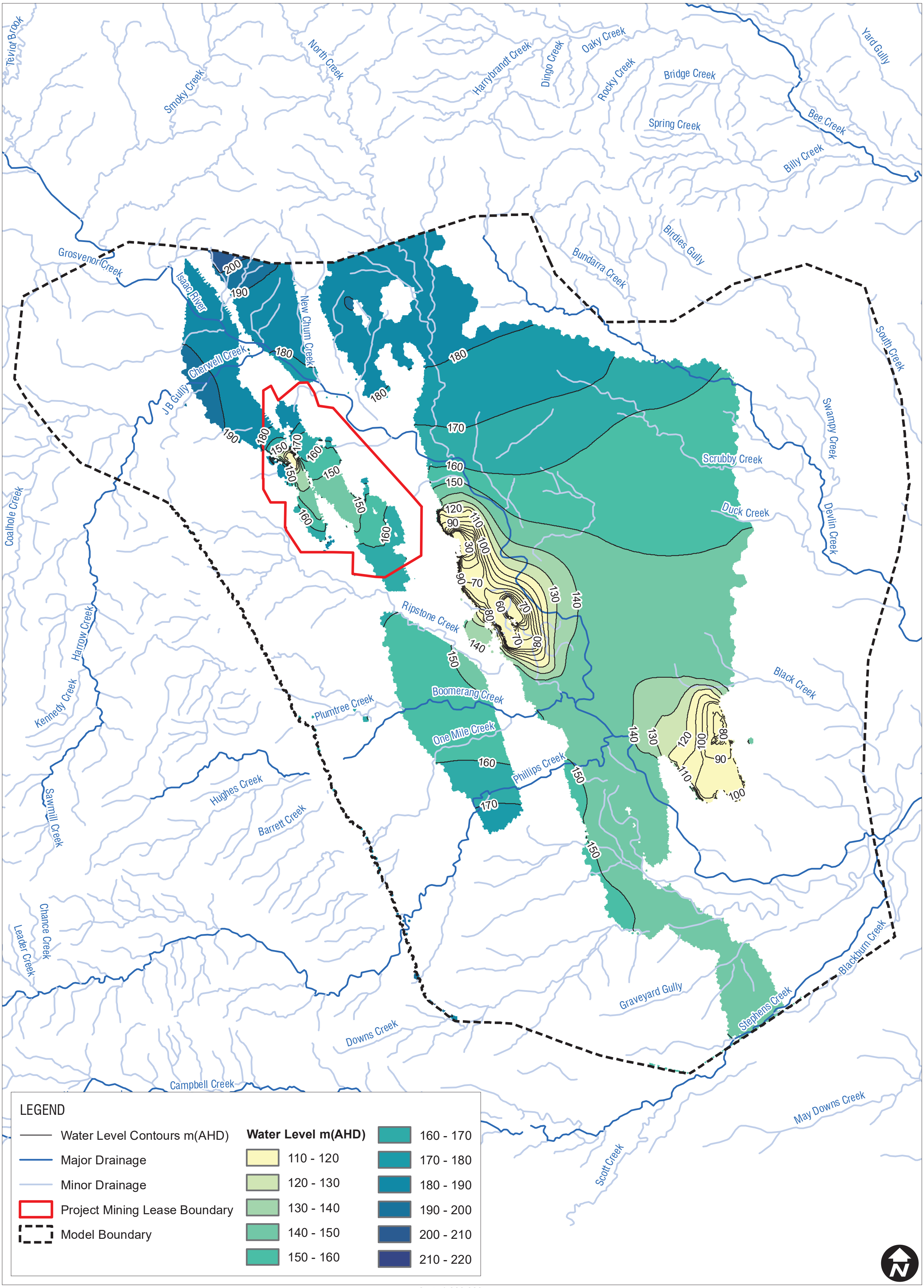
Predicted Groundwater Levels in the Leichardt Seam (Layer 5) – Post-Mining Equilibrium

FIGURE 6-14



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Predicted Groundwater Levels in the Vermont Seam (Layer 7) – Post-Mining Equilibrium

FIGURE 6-15

6.6.2 Flow Path Simulation

An analysis of the water movement within the residual voids and spoil within the open cut pits of the optimised final landform was undertaken to simulate and assess the movement and fate of water particles through the groundwater system post-mining. A number of particles were placed within the residual voids in the recovery groundwater model and the mod-PATH3DU code (S.S. Papadopulos & Associates, Inc., 2018) was used to simulate particle pathways along the groundwater flow field during recovery (i.e., 2,000 years and then steady state equilibrium). To run the mod-Path3DU code, the groundwater flow model was first simulated, and the transient head outputs from the groundwater flow model were used by mod-PATH3DU to simulate particle flowpath lines.

Figure 6-16 shows the initial location of particles within optimised final landform (e.g. within backfilled spoil and out-of-pit waste rock emplacements). The particles were released at the start of recovery and the movement of particles was recorded during the recovery simulation.

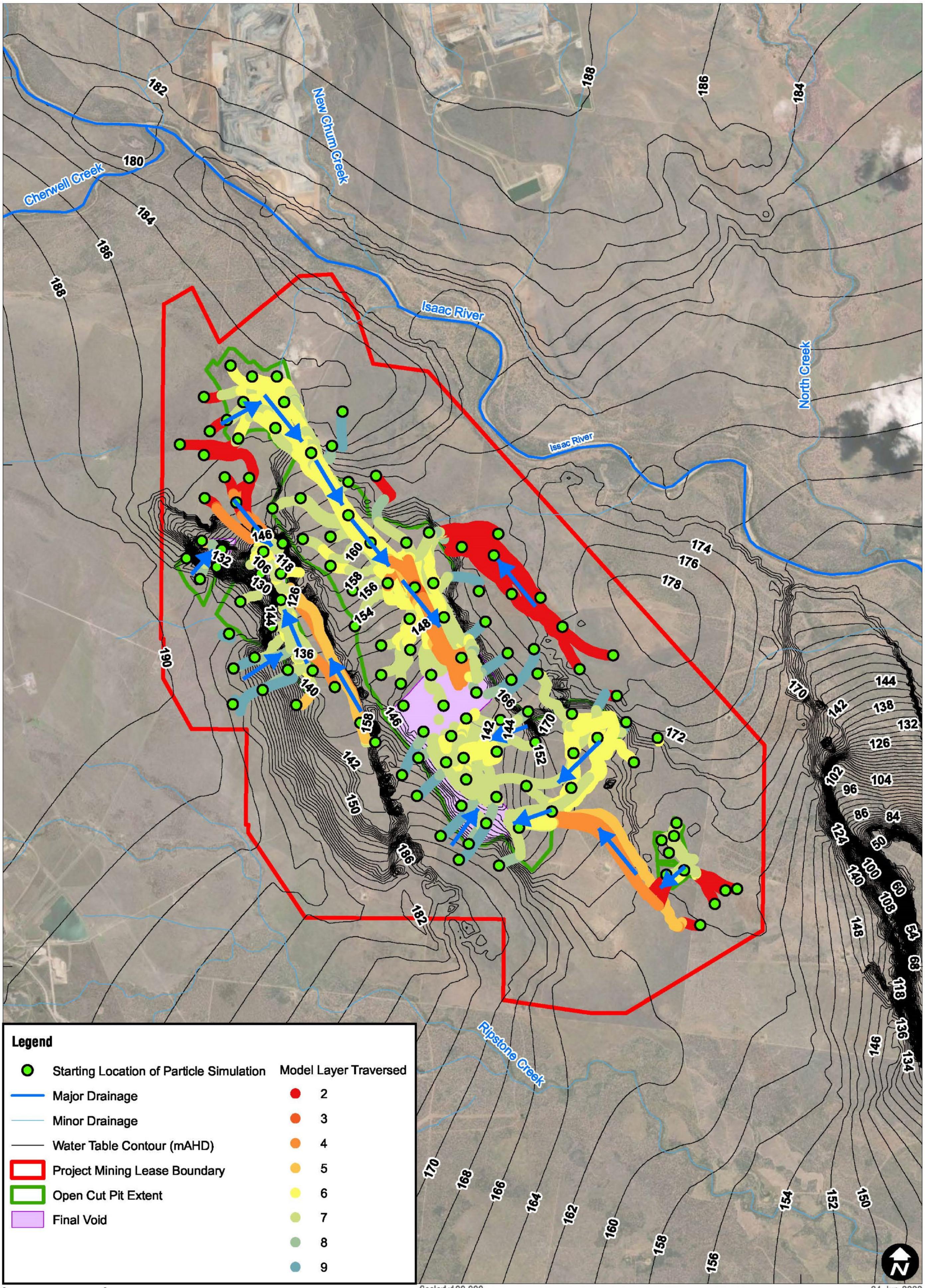
Figure 6-16 shows the predicted movement of water particles in the recovery simulation for the optimised final landform. The colours along the predicted particle flow paths provides the model layer the particle was simulated to be moving through:

- Red – Layer 2 (Regolith)
- Dark Orange – Layer 3 (Rewan Group)
- Orange – Layer 4 (Rangal Coal Measures overburden)
- Light Orange – Layer 5 (Leichhardt Seam)
- Yellow – Layer 6 (Rangal Coal Measures interburden)
- Light Green – Layer 7 (Vermont Seam)
- Pale Green – Layer 8 (Rangal Coal Measures underburden)
- Green – Layer 9 (Fort Cooper Coal Measures overburden)

The blue arrows on **Figure 6-16** show the general direction of particle movements. The particle movement simulation indicates that water flowing through backfill spoil of the optimised final landform would remain within the optimised final landform (e.g. backfilled spoil and residual voids) in the long-term with no water predicted to flow to the receiving environment (i.e. residual voids would remain groundwater sinks and groundwater would not flow from the residual voids off-site).

The colour changes along the paths on **Figure 6-16** indicate that particles situated within the shallower layers at the beginning of the recovery model move progressively toward Layers 6 and 7 (Rangal Coal Measures interburden and immediately underlying Vermont Seam, respectively) over the recovery period. The flow path analysis indicates the particles generally move toward the residual void water bodies, confirming that the simulation for the optimised final landform predicts the residual voids are acting as sinks with no potential for off-site migration.

Given that the particle pathlines are simulated from the start of recovery, they generally follow predicted head gradients. However, the particle directions at times appear to be in opposition to the head contours/gradients shown on **Figure 6-16**. It should be noted that the contours shown on **Figure 6-16** only represents the final head pattern when the aquifer has reached an equilibrium and hence does not necessarily show the transient head changes occurring during the 2,000 years recovery simulation. For example, the residual voids are generally dry at the start of the recovery when the head gradient is towards residual voids, which generally reduces as the backfilled spoil and residual void reach saturation.



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Location and Predicted Movement of Particles

FIGURE 6-16

7 Impacts on Groundwater Resources

7.1 Isaac Connors Groundwater Management Area

The Project does not directly intercept groundwater from Isaac Connors Groundwater Unit 1 (Quaternary alluvium) under the *Water Plan (Fitzroy Basin) 2011*, meaning, all direct groundwater take by the open cut pits for the Project is from Isaac Connors Groundwater Unit 2 (sub-artesian aquifers). The predicted direct take over time is presented in **Section 6.2**, which indicates the Project groundwater take would be in the order of up to 280 ML/year (average 155 ML/year) from Groundwater Unit 2. The predicted indirect take from the Groundwater Unit 1 (alluvium) during Project mining is less than 0.01 ML/year and therefore considered negligible. The model predicts that for the long-term equilibrium condition post-mining, there is negligible groundwater take from Groundwater Unit 1, and there would be 13 ML/year groundwater take from Groundwater Unit 2 to the residual voids. For context, the 13 ML/year predicted take from Groundwater Unit 2 approximates a take that could be compared to a typical single windmill-driven stock watering bore, i.e. a negligible take within the context of the regional groundwater system.

7.2 Potential Impact on Groundwater Users

7.2.1 Privately-owned Supply Bores

Chapter 3 of the Water Act 2000 provides bore drawdown threshold triggers of 2 m for unconsolidated aquifers, and 5 m for consolidated aquifers. As shown in **Figure 6-2** through **Figure 6-4**, there are no known privately-owned bores within the unconsolidated (Alluvium and Regolith) or consolidated (Permian coal measures) aquifers that lie within the predicted extent of Project-only drawdown greater than 1 m.

7.2.2 Ecological Sites

The aquatic in-stream ecosystems associated with the Isaac River and Cherwell Creek are largely not dependent on the surface expression of groundwater. The wetlands and farm dams in the locality are not likely to be aquatic GDEs. Modelling has shown that the Project would result in negligible increased leakage from surface flows of the Isaac River to the underlying alluvium. Modelling has also shown that the Project's contribution to cumulative groundwater impacts associated with the surface water systems would also be negligible. Therefore, impacts to surface flows and subsequently aquatic ecosystems downstream of the Project area are not expected (Ecological Service Professionals, 2022).

Any dependency on groundwater for riparian vegetation associated with the Isaac River and Cherwell Creek is likely to be facultative (i.e. intermittent), during dry times (E2M, 2021). However, there would be negligible drawdown in the alluvium along the Isaac River and Cherwell Creek as a result of the Project, as well as no impacts to groundwater quality. Modelling has also shown that the Project's contribution to cumulative groundwater impacts associated with the alluvium would also be negligible. Therefore, there would be no adverse impacts to riparian vegetation associated with the Isaac River and Cherwell Creek as a result of the Project.

Any dependency on groundwater for riparian vegetation surrounding ephemeral wetlands is likely to be facultative. These ephemeral wetlands are not likely to be aquatic GDEs as these wetlands do not receive groundwater discharge, rather, the clay-rich substrates of these wetlands are likely to hold surface water run-off for extended periods (E2M, 2021). Further, as there would be no impacts on groundwater quality and resources, there would be no adverse impacts to riparian vegetation surrounding these ephemeral wetlands.

Any dependency on groundwater that the woodland dominated by Regional Ecosystem 11.3.2 on the floodplains on the Isaac River, Ripstone Creek and Cherwell Creek is likely to be facultative (E2M, 2021). There would be no impacts to vegetation on the Isaac River, Ripstone Creek and Cherwell Creek floodplains (outside of wetlands) that may access water from the alluvium, as there would be negligible drawdown to the alluvium and no changes to groundwater quality within the alluvium.

The Project would result in a predicted maximum cumulative drawdown of up to 5 m below the woodland mapped as a low potential terrestrial GDE to the north of Project. Outside the alluvium, it is unlikely that these woodland patches would be dependent on groundwater due to the poor quality (high salinity) of the groundwater source (i.e. associated with the regolith) (E2M, 2021). Therefore, a predicted cumulative drawdown of up to 5 m below the woodland to the north of Project is unlikely to have any material impacts on this woodland.

In summary, the Project (including the associated cumulative interactions) is not predicted to have any material impacts on potential or actual GDEs due to changes in groundwater quality or resources.

7.3 Potential Impacts on Surface Drainage

The Isaac River is the major drainage feature of the region. It is located to the east of the Project and flows north-west to south-east in the vicinity of the Project.

A natural hydraulic gradient exists between the Isaac River and the associated alluvium that results in seepage from the Isaac River to the alluvium (i.e. a losing system). The change in water levels induced by mining increases the hydraulic gradient between the Isaac River and associated alluvium. The model predicts that the average rate of seepage from the Isaac River to the alluvium will increase by an insignificant amount, considered within the error threshold of predictions (less than 3.65 ML/year) over the life of the Project. This insignificant volume is itself considered a conservative over-estimate as the groundwater model does not represent an unsaturated zone that can form between the bed of the river and the underlying groundwater unit, which would serve to limit the hydraulic gradient and interconnectivity.

The Isaac River is ephemeral in nature, with flows only occurring after rainfall events that generate runoff. On average, when the Isaac River flows, 161,863 ML/year of surface water is discharged downstream. The conservative estimate of less than 3.65 ML/year increased seepage from the Isaac River to the alluvium as a result of the Project therefore represents an insignificant potential reduction in flow (including shallow sub-surface flow). The number of days that the Isaac River runs dry is not predicted to increase with the addition of the Project.

7.4 Potential Impacts on Groundwater Quality

This section describes the potential sources and pathways of groundwater contamination associated with the Project.

7.4.1 Out-of-Pit Waste Rock Emplacement Areas

As the mining operations progress, waste rock material would be placed within selected out-of-pit waste rock emplacement areas (refer **Figure 1-3**). The out-of-pit waste rock emplacement areas would be rehabilitated progressively as the mining operations progress.

The-out-of pit waste rock emplacement areas may produce seepage as a result of rainfall inundation, that theoretically could alter the existing groundwater quality. Runoff from disturbed areas outside the open cut pit and infrastructure areas, such as waste rock emplacement areas (both active and under rehabilitation) would be captured and managed as part of the sediment and mine-affected water systems, as described in WRM (2022). The systems would be designed to capture and reuse water, and operated to minimise off-site discharges.

As outlined in **Section 5.4.4**, a geochemical assessment has been prepared by Terrenus Earth Sciences (2020) for the Project that included leachate analysis of waste rock material within the Project Area and built upon previous geochemical studies (EGi, 2012). The analysis found that waste rock material is generally non-acid forming, with the leachate generally averaging an EC of 601 µS/cm (i.e. generally fresh as described in **Section 5.4.4**) and low in S content (<0.1%). It is important to note that the results presented in Terrenus Earth Sciences (2020) represent an 'assumed worst case' scenario as the samples analysed had a long equilibration period or had a very high surface area compared to likely materials in the field.

Modelling shows that the inward hydraulic flow gradients from the out-of-pit waste rock emplacement areas to the open cut pits during mining and residual voids post-mining would inhibit seepage from the mine landform to the Isaac River alluvium. Also, the in-situ Cainozoic sediments present between the alluvium and regolith and the out-of-pit waste rock emplacements generally comprise surficial soil and clays, up to 10 m in thickness (**Section 4.2**). Though not explicitly represented in the groundwater model, the surficial clays would inhibit potential seepage from the out-of-pit waste rock emplacements to the underlying regolith and alluvium. The flow path modelling is therefore conservative in this regard. Therefore, there would be no mechanism for groundwater seepage from the out-of-pit waste rock emplacements to impact on groundwater quality in the alluvium and regolith.

Notwithstanding, any seepage from the mine landform (i.e. leachate from the out-of-pit waste rock emplacement) would generally be fresh and low in S content, minimising the potential for impacts to groundwater quality.In-Pit Waste Rock Emplacement Areas

The in-pit waste rock emplacement areas would be rehabilitated progressively as the mining operations progress. The Project would involve progressively backfilling the open cut pits as space becomes available with water levels within backfilled areas predicted to recover back towards pre-mining levels post-mining.

As described above, leachate from the waste rock material generally exhibits poorer water quality compared to the alluvium, however, remains generally fresh and low in S content. Groundwater levels within the in-pit waste rock emplacement areas would remain below the base of alluvium. Therefore, a hydraulic gradient would not exist to enable interaction between water in-pit waste rock material and the surrounding alluvium.

Notwithstanding, any leachate from the mine landform (i.e. leachate from the in-pit waste rock emplacement) would generally be fresh and low in S content as described above, minimising the potential for impacts to groundwater quality.

7.4.2 Residual Voids

The optimised final landform would involve backfilling of the Railway and South Pits, and therefore there would be three residual voids for the Project to remain in perpetuity. Modelling predicted that the residual void water levels would equilibrate to:

- 128 mAHD in the North-west Void;
- 104 mAHD in the West Void; and
- 141 mAHD in the Main Void.

The equilibrated residual void water levels are predicted to be between approximately 24 m to 71 m below the pre-mining groundwater levels in the Permian Coal Measures, therefore, the residual voids would act as sinks to groundwater flow. Furthermore, the particle tracking simulation demonstrates that there would be no migration of water away from the optimised final landform and all flow would be towards the residual voids (Section 6.6). The predicted residual void equilibrated water levels are generally consistent with the results of the residual void modelling undertaken for the Surface Water and Flooding Assessment (WRM, 2022).

It is likely that water within the residual void would evaporate from the residual void water body surface and draw in groundwater from the surrounding strata and runoff from the residual void catchment areas. As the residual voids would act as sinks, evaporation from the residual void water body would overtime concentrate salts in the residual void water body. However, the gradual increase in salinity of the residual void water body would not pose a risk to the surrounding groundwater regime as the residual voids would remain as groundwater sinks in perpetuity and the hydraulic gradient between equivalent freshwater heads would always be towards the residual voids.

Additional modelling undertaken by WRM (2022) for the optimised final landform, identified an opportunity to beneficially re-use the residual void water bodies (the three residual voids) for agricultural or other purposes (e.g. water for cattle consumption). Given the predicted water quality, the re-use of residual void water would slow down the accumulation of salt in the residual voids, which may allow for a sustained final land use without potential impacts to the surrounding environment.

Progressing this re-use opportunity would be subject to further feasibility assessment and design, in addition to identification, negotiation and agreement with the final water user/s. The Surface Water and Flooding Assessment prepared by WRM (2022) for the Project has modelled the equilibrated water levels as well as the potential accumulation of salt in the residual voids.

7.4.3 Workshops and Storage

All workshop and fuel/chemical storage areas at the Project would be developed in accordance with current Australian Standards. This includes refuelling areas and chemical storage areas to be designed with adequate bunding and equipped for immediate spill clean-up. These controls represent standard practice and a legislated requirement at mining operations for preventing the contamination of the groundwater regime. Therefore, there is considered to be limited potential for groundwater contamination to occur with relation to workshops and fuel/chemical storage.

Sewage effluent would be contained within the mine water system or, if required the sewage effluent irrigation areas for the Project would be located outside the mapped extent of the Isaac River alluvium and contained to areas where potential seepage would not report off-site, to limit the potential impacts of the sewage effluent irrigation on the surrounding groundwater regime.

7.4.4 Cumulative Impacts

SLR has undertaken a review of the groundwater impact assessments for surrounding operations (Moorvale South Project and Olive Downs Project) to assess a likelihood for cumulative water quality impacts. The groundwater assessments for Olive Downs Project (HydroSimulations, 2018) and Moorvale South Project (SLR, 2019a) each identified no water quality impacts as a result of each project. Therefore, given no groundwater quality impacts are identified for the Project, it is unlikely there would be cumulative impacts to the water quality of the surrounding groundwater systems.

8 Management and Mitigation Measures

8.1 Mitigation Measures

8.1.1 Mine-Affected Water

The mine plan for the Project includes strategies to manage mine-affected water for the life of the Project.

Waste rock material would be emplaced in-pit as the space becomes available and will in some areas form the walls of the residual voids. As outlined in **Section 7.4.2**, groundwater within the residual voids is predicted to remain below pre-mining levels. Therefore, it is anticipated the residual voids would act as a groundwater sink, capturing water associated with in-pit rejects.

Groundwater inflows to the open cut pits would be pumped via in-pit sumps where necessary to ensure safe operating conditions. The groundwater inflows would be collected and contained within mine water management system.

A up-catchment diversion system would also be developed to divert surface water flows away from the disturbed areas associated with the Project. Temporary flood levees designed to an 0.1% Annual Exceedance Probability (AEP) flood event would also be developed to prevent inundation of the open cut pits.

8.1.2 Groundwater Use

The potential impacts on groundwater users (privately-owned bores) are described in **Section 7.2**. No privately-owned bores are predicted to exceed relevant bore trigger thresholds in the Chapter 3 of the Water Act and therefore there are no existing privately-owned bores that would be impacted by the Project.

It remains possible that in the future, privately-owned bores may be installed within the extent of drawdown related to the Project. In accordance with Chapter 3 of the Water Act, any impacts on such bore users that exceed the magnitude of impacts predicted in this groundwater assessment would require “make good provisions” for the additional impacts to ensure the bore user has access to a similar quantity and quality of water for the authorised purpose. This may include deepening a bore to increase its pumping capacity, constructing a new water supply bore, providing water from an alternative source or financial compensation.

8.2 Management

8.2.1 Groundwater Monitoring Program

A groundwater monitoring program would be established and would continue throughout the life of the Project. Recording of groundwater levels from existing monitoring bores and VWPs would continue and would allow natural groundwater level fluctuations (such as responses to rainfall) to be distinguished from potential groundwater level impacts due to depressurisation resulting from proposed mining activities. Groundwater quality sampling of existing monitoring bores would continue in order to provide longer term baseline groundwater quality at the Project, and to detect any changes in groundwater quality during and post-mining.

Table 8-1 summarises the Project's groundwater monitoring program, and **Figure 8-1** shows the bore locations. The current groundwater monitoring network is largely considered sufficient, however additional monitoring bores are proposed as follows to address the potential groundwater risks documented within this report:

- A bore installed into the regolith between the Project and the Isaac River. This additional bore will be sited within the extent of predicted Project-related drawdown in the regolith (refer **Figure 6-2**).
- A bore installed into the Permian coal measures (Leichhardt Seam) between Railway Pit and North-west Pit. This additional bore will be sited within the extent of predicted Project-related drawdown extending northwest towards the western ML boundary (refer **Figure 6-3**).
- A bore installed into the Permian coal measures (Leichhardt Seam) southeast of Main Pit. This additional bore will be sited within the extent of predicted Project-related drawdown extending southeast towards the southeastern ML boundary (refer **Figure 6-3**).

Groundwater monitoring data from bores installed at the adjacent Olive Downs Project, Moorvale South Project, and Eagle Downs Mine (**Figure 8-1**) would also be shared where practicable, but would not form part of the Project groundwater monitoring program.

For the purpose of obtaining a continual baseline dataset that covers the potential area of impact, the monitoring network presented in **Table 8-1** includes bores located in areas that would be directly subject to future mining disturbance.

It is also proposed that quarterly groundwater level and quality monitoring continue to be conducted on accessible privately-owned bores near to the Project (refer **Table 8-1**).

Groundwater quality monitoring would continue to be undertaken on a quarterly basis as outlined within **Table 8-1**. As part of the water quality monitoring, in addition to collecting field parameters (EC and pH), water samples would be submitted to a National Association of Testing Authorities (NATA) accredited laboratory for analysis of:

- Physio-chemical indicators (TDS and total suspended solids (TSS));
- Major Ions (Ca, fluoride [F], Mg, potassium [K], Na, Cl, SO4), hardness and ionic balance (total anions/cations);
- Total alkalinity as calcium carbonate ($CaCO_3$), HCO_3, carbonate (CO_3);
- Total and dissolved metals (silver [Ag], Al, As, B, Ba, Be, Cd, Co, Cr, Cu, Fe, Hg, Pb, Mn, molybdenum [Mo], Ni, Se, uranium [U], V and zinc [Zn]);
- Nutrients (Total nitrogen, nitrogen oxides, ammonia, phosphate); and
- Organics (total petroleum hydrocarbons C_6-$C_4$0).

Groundwater monitoring relevant to the Project and its potential impacts would continue to be conducted on adjacent leases by the relevant tenure holders, including Pembroke (Olive Downs Project), South32 (Eagle Downs Mine) and Peabody (Moorvale South Project) (refer **Figure 8-1**) in accordance with their relevant respective environmental approval conditions. Monitoring data would continue to be shared under the existing agreement in place between the surrounding operations and Whitehaven, enabling the ability to obtain long-term monitoring data in adjacent tenure areas outside of the Project Area.

Table 8-1 Proposed Project Monitoring Program

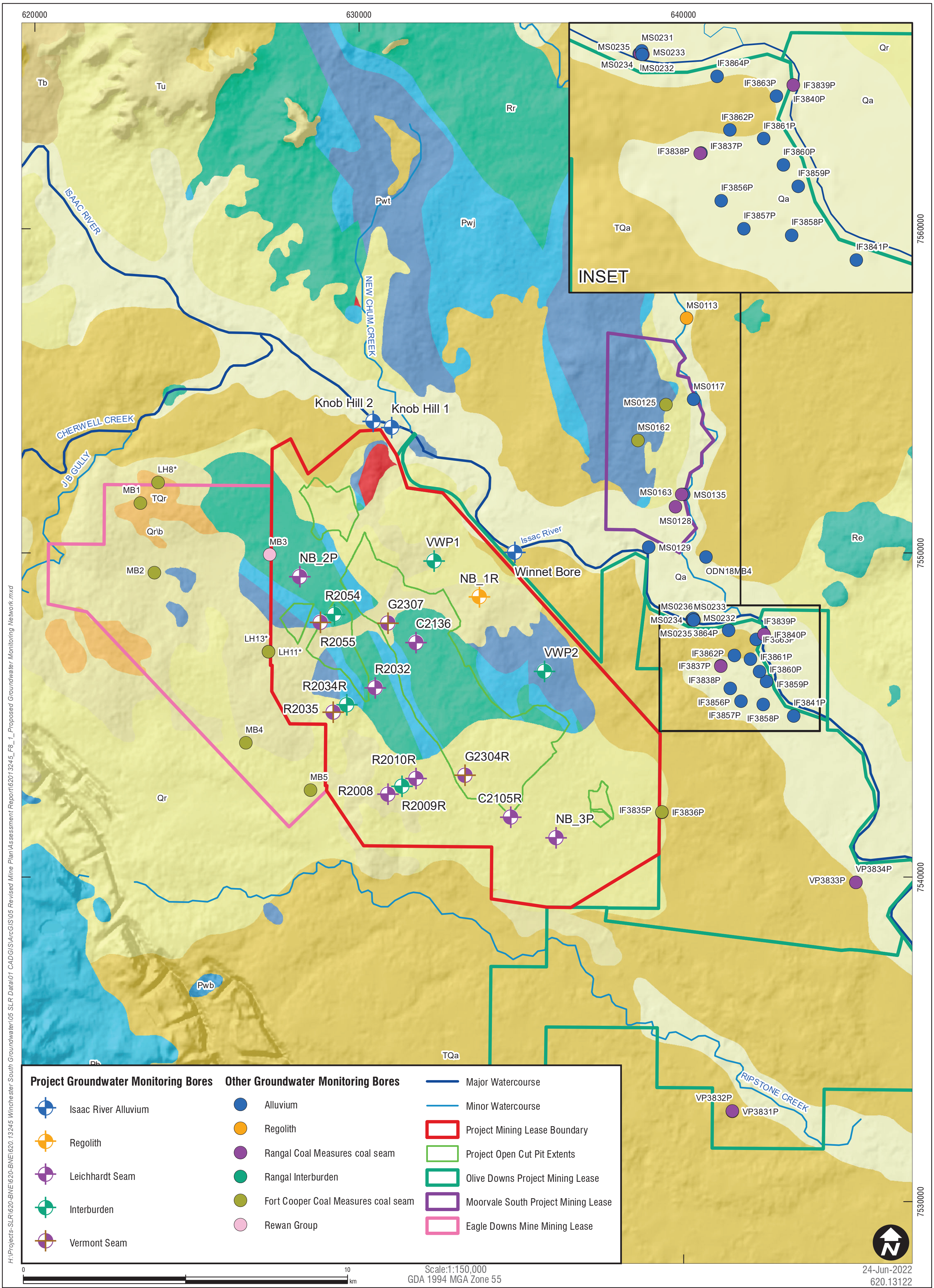
Bore ID	Type	Easting (GDA94 z55)	Northing (GDA94 z55)	Surface Elevation (mAHD)	Screen (MB/PB) or Sensor (VWP) Depth (mbgl)	TD (mbgl)	Monitored Unit	SWL	WQ	Location Description
C2105R	MB	634650	7541857	209.09	57.0 – 60.0	60.0	Leichhardt Seam	D/Q	Q	South-east corner of Main Pit
C2136	MB	631742	7547243	199.39	62.6 – 65.6	65.6	Leichhardt Seam	D/Q	Q	Central part of Main Pit
G2304R	MB	633245	7543171	216.24	53.0 – 56.0	56.0	Vermont Seam	D/Q	Q	South-east part of Main Pit
G2307	MB	630881	7547844	194.42	78.0 – 81.0	81.0	Vermont Seam	D/Q	Q	North-west part of Main Pit
R2008	MB	630879	7542573	220.32	31.5 – 33.0	-*	Leichhardt Seam	D/Q	Q	West-southwest of Main Pit
R2009R	MB	631332	7542812	220.24	77.0 – 83.0	83.0	Interburden	D/Q	Q	West-southwest of Main Pit
R2010R	MB	631730	7543070	216.67	60.0 – 63.0	66.0	Leichhardt Seam	D/Q	Q	West-southwest of Main Pit
R2032	MB	630495	7545853	205.31	78.1 – 81.1	81.1	Leichhardt Seam	D/Q	Q	South-east of West Pit
R2034R	MB	629598	7545346	221.60	36.0 – 39.0	39.5	Interburden	D/Q	Q	South-west of West Pit
R2035	MB	629190	7545103	223.54	34.4 – 37.4	37.4	Vermont Seam	D/Q	Q	South-west of West Pit
R2054	MB	629240	7548107	203.60	79.5 – 82.5	82.5	Interburden	D/Q	Q	Northern part of West Pit
R2055	MB	628798	7547863	207.46	64.9 – 67.9	67.9	Vermont Seam	D/Q	Q	Northern part of West Pit
NB_1R#	MB	633700#	7548650#	200#	22 – 25#	25#	Regolith	D/Q	Q	Between Main Pit and Isaac River alluvium
NB_2P#	MB	628164#	7549281#	207#	122 – 125#	125#	Leichhardt Seam	D/Q	Q	Between Railway Pit and North-west Pit
NB_3P#	MB	636064#	7541231#	202#	82 – 85#	85#	Leichhardt Seam	D/Q	Q	Southeast of Main Pit
Knob Hill 1‡	PB	631005	7553874	191*	-	-*	Isaac River Alluvium	n/a+	Q	Isaac River alluvium north of the Project
Knob Hill 2‡	PB	630431	7554061	193*	-	24.3	Isaac River Alluvium	D/Q	Q	Isaac River alluvium north of the Project

Bore ID	Type	Easting (GDA94 z55)	Northing (GDA94 z55)	Surface Elevation (mAHD)	Screen (MB/PB) or Sensor (VWP) Depth (mbgl)	TD (mbgl)	Monitored Unit	SWL	WQ	Location Description
Winnet Bore‡	PB	634791	7550023	187*	-	18.1	Isaac River Alluvium	D/Q	Q	Isaac River alluvium north-east of the Project
VWP1	VWP	632312	7549767	192.81	50.0	155.0	Fort Cooper Coal Measures overburden	D	n/a	Between Main Pit and Isaac River alluvium
					90.0		Fort Cooper Coal Measures coal seam	D		
					150.0		Fort Cooper Coal Measures underburden	D		
VWP2	VWP	635711	7546357	201.68	50.0	155.0	Fort Cooper Coal Measures overburden	D	n/a	Between Main Pit and Isaac River alluvium
					90.0		Fort Cooper Coal Measures overburden	D		
					150.0		Fort Cooper Coal Measures coal seam	D		

MB – Monitoring bore
VWP – Vibrating Wire Piezometer
PB – Privately-owned bore
n/a – Not Applicable

SWL – Standing water level (purpose of monitoring location)
WQ – Water quality monitoring (purpose of monitoring location)
Q – Quarterly monitoring frequency
TD – total depth.
– location co-ords and depth data nominal; to be confirmed after drilling/bore installation

D – Daily monitoring frequency using automatic logger
‡ - Inclusion in monitoring network dependent on continued approval to access the bore from bore owner
D/Q – Daily monitoring frequency using automatic logger and manually dipped on a quarterly basis
+ - Unable to monitoring SWL due to pump installed, but can still sample for water quality



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Proposed Groundwater Monitoring Network

FIGURE 8-1

8.2.2 Impact Assessment Criteria

Groundwater monitoring criteria would be established to monitor predicted impacts on both environmental values and predicted changes in groundwater quality. Impact assessment criteria for the site would be documented in a Water Management Plan (WMP) for the Project.

Groundwater quality trigger levels would be developed in consideration of the Department of Environment and Science (DES) guideline on *Using monitoring data to assess groundwater quality and potential environmental impacts* (DES, 2021b). The trigger levels would be established once 12 to 24 months of data have been collected from all bores in the site monitoring network such that a statistically significant baseline dataset exists for the entire network. As per the DES (2021b) guidelines, the triggers would be established in consideration of the *Environmental Protection (Water) Policy 2009 Isaac River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130, including all waters of the Isaac River Sub-basin (including Connors River)* WQOs, ANZECC and ARMCANZ (2000) criteria and site specific conditions. Trigger criteria would be established for each groundwater unit potentially impacted by the Project, being alluvium, regolith and the Permian coal measures.

8.2.3 Data Management and Reporting

Routine groundwater monitoring would be conducted on a quarterly basis, as outlined in **Section 8.2.1**. Data would be stored within a consolidated groundwater database. Quality assurance and quality control procedures would be put in place to help ensure the accuracy of data entered within the database. Prior to commencement of Project coal extraction, groundwater quality triggers would be established as outlined in **Section 8.2.2**.

When coal extraction commences at the Project, findings from the quarterly monitoring events would be stored in a groundwater monitoring database managed by the site environment department. The database would include automated identification of any groundwater quality trigger exceedances. Investigation into the cause of any exceedance would be conducted by suitably qualified personnel as required. The groundwater database would be available for provision to the regulator upon request.

Each year an annual review of groundwater level and quality trends would be conducted by a suitably qualified person. The review would assess the change in groundwater level and quality over the year, compared to historical trends and impact assessment predictions. The annual review would discuss any groundwater trigger exceedances or where data trends show potential for environmental harm.

8.2.4 Future Modelling

Every five years the validity of the model predictions would be assessed and if the data indicate significant divergence from the model predictions, the groundwater model would be updated.

9 Limitations

The model geology away from the Project Area, Olive Downs Project and Moorvale South Project (i.e. beyond the limits of the respective site geological models) is interpolated and estimated from publicly available data and regional scale mapping (e.g. Queensland Government mapping and EIS documentation [including the Bowen Gas Project]). Consequently, the depths, thickness and extents of the model layers away from the Project may not closely replicate reality. This is of particular note when simulating the cumulative impacts of surrounding mines. The coal seams of the Fort Cooper Coal Measures and Moranbah Coal Measures are simplified to single seams with aggregated seam thickness; as mining is applied conservatively to the base of this simplified seam, the depths of the surrounding mines may not be accurate and the stresses exaggerated.

Similarly, the timing and extent of surrounding mine activities have been largely inferred from publicly available data, and therefore an over- or under-estimation of impacts, or timing of impacts, may result due to this.

The inaccuracies involved in the modelling of surrounding mines, as noted above, combined with the large scale and complexity of the groundwater model has resulted in obvious model inaccuracies, which manifested as isolated drawdown areas at Poitrel Mine seemingly caused by mining at the Project. However, the lateral separation of the isolated drawdowns at Poitrel Mine from the drawdowns at the Project indicated that these were not true impacts. The model was subjected to thorough quality control processing and the conclusion was made that the drawdowns at Poitrel Mine likely resulted from inaccuracies surrounding how the mining and geology at Poitrel Mine has been simulated. The decision was, therefore, to exclude Poitrel Mine mining activities from the calibration and predictive simulation periods, for the impact assessment results relating to the direct impacts of the Project (i.e. incremental drawdowns, pit inflows, indirect alluvial take and changes in baseflow). Poitrel Mine is, however, included in the prediction of cumulative impacts.

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