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Mount Pleasant Operation

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Appendix C

Groundwater Assessment

Australasian Groundwater and
Environmental Consultants Pty Ltd

Report on

Mount Pleasant Optimisation Project Groundwater Impact Assessment

Prepared for
MACH Energy Australia Pty Ltd (Mach Energy)

Project No. G1970A December 2020
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Table of contents

Page No.

Table of contents (continued)

Page No.

Table of contents (continued)

Page No.

Table of contents (continued)

List of figures

Table of contents (continued)

Page No.

Table of contents (continued)

Page No.

List of tables

List of appendices

Report on

Mount Pleasant Optimisation Project Groundwater Impact Assessment

1 Introduction

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) has been engaged by MACH Energy Australia Pty Ltd (MACH Energy)[1] to complete a groundwater impact assessment for the Mount Pleasant Optimisation Project (the Project). The purpose of the assessment is to form part of an Environmental Impact Statement being prepared to accompany an application for development consent under Divisions 4.1 and 4.7 in accordance with Part 4 of the New South Wale (NSW) Environmental Planning and Assessment Act 1979 (EP&A Act).

1.1 Project overview

The Mount Pleasant Operation (MPO) Development Consent DA 92/97 was granted on 22 December 1999. The MPO was also approved under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) in 2012 (EPBC 2011/5795).

MACH Energy acquired the MPO from Coal and Allied Operations Pty Ltd on 4 August 2016. MACH Energy commenced construction activities at the MPO in November 2016 and commenced mining operations in October 2017, in accordance with Development Consent DA 92/97 and EPBC 2011/5795.

MACH Mount Pleasant Operations Pty Ltd manages the MPO as agent for and on behalf of the unincorporated Mount Pleasant Joint Venture between MACH Energy (95% owner) and J.C.D. Australia Pty Ltd (5% owner)[1].

The approved MPO includes the construction and operation of an open cut coal mine and associated rail spur and product coal loading infrastructure located approximately three kilometres (km) north-west of Muswellbrook in the Upper Hunter Valley of NSW (Figure 1.1 and Figure 1.2).

The Project would include the following development:

- increased open cut coal extraction within MPO Mining Leases by mining of additional coal reserves, including lower coal seams in North Pit;
- staged increase in extraction, handling and processing of run-of-mine (ROM) coal up to 21 million tonnes per annum (Mtpa) (i.e. progressive increase in ROM coal mining rate from 10.5 Mtpa over the Project life);
- staged upgrades to the existing Coal Handling and Preparation Plant (CHPP) and coal handling infrastructure to facilitate the handling and processing of additional coal;
- rail transport of up to approximately 17 Mtpa of product coal to domestic and export customers;
- upgrades to workshops, electricity distribution and other ancillary infrastructure;

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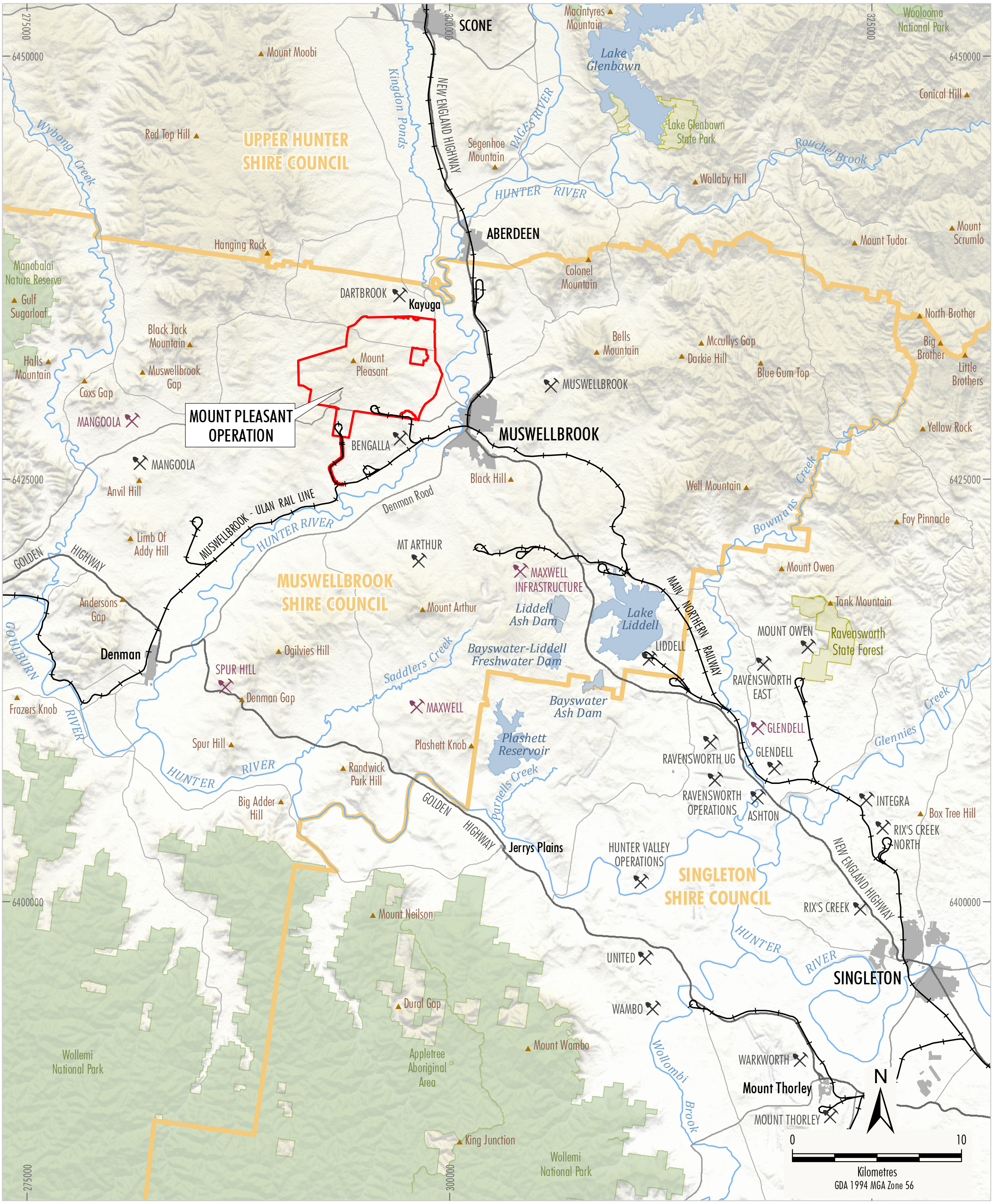
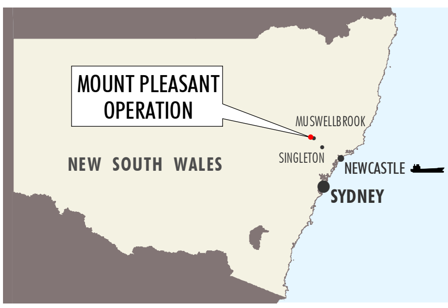
[1] Throughout this report, MACH Mount Pleasant Operations Pty Ltd and the unincorporated Mount Pleasant Joint Venture will be referred to as MACH.

- existing infrastructure relocations to facilitate mining extensions (e.g. local roads, powerlines and water pipelines);
- construction and operation of new water management and water storage infrastructure in support of the mine;
- additional reject dewatering facilities to allow co-disposal of fine rejects with waste rock as part of ROM waste rock operations;
- development of an integrated waste rock emplacement landform that incorporates geomorphic drainage design principles for hydrological stability, and varying topographic relief to be more natural in exterior appearance;
- construction and operation of new ancillary infrastructure in support of mining;
- extension to the time limit on mining operations to 22 December 2048;
- an average operational workforce of approximately 600 people, with a peak of approximately 830 people;
- ongoing exploration activities; and
- other associated infrastructure, plant, equipment and activities.

Figure 1.2 presents the key components of the Project.





LEGEND
- Mining Operation
- Proposed Mining Operations (Application Lodged)
- Railway
- Local Government Boundary
- State Forest/Reserve
- National Parks and Wildlife Estate
- Mining Lease Boundary (Mount Pleasant Operation)

Source: NSW Spatial Services (2020)

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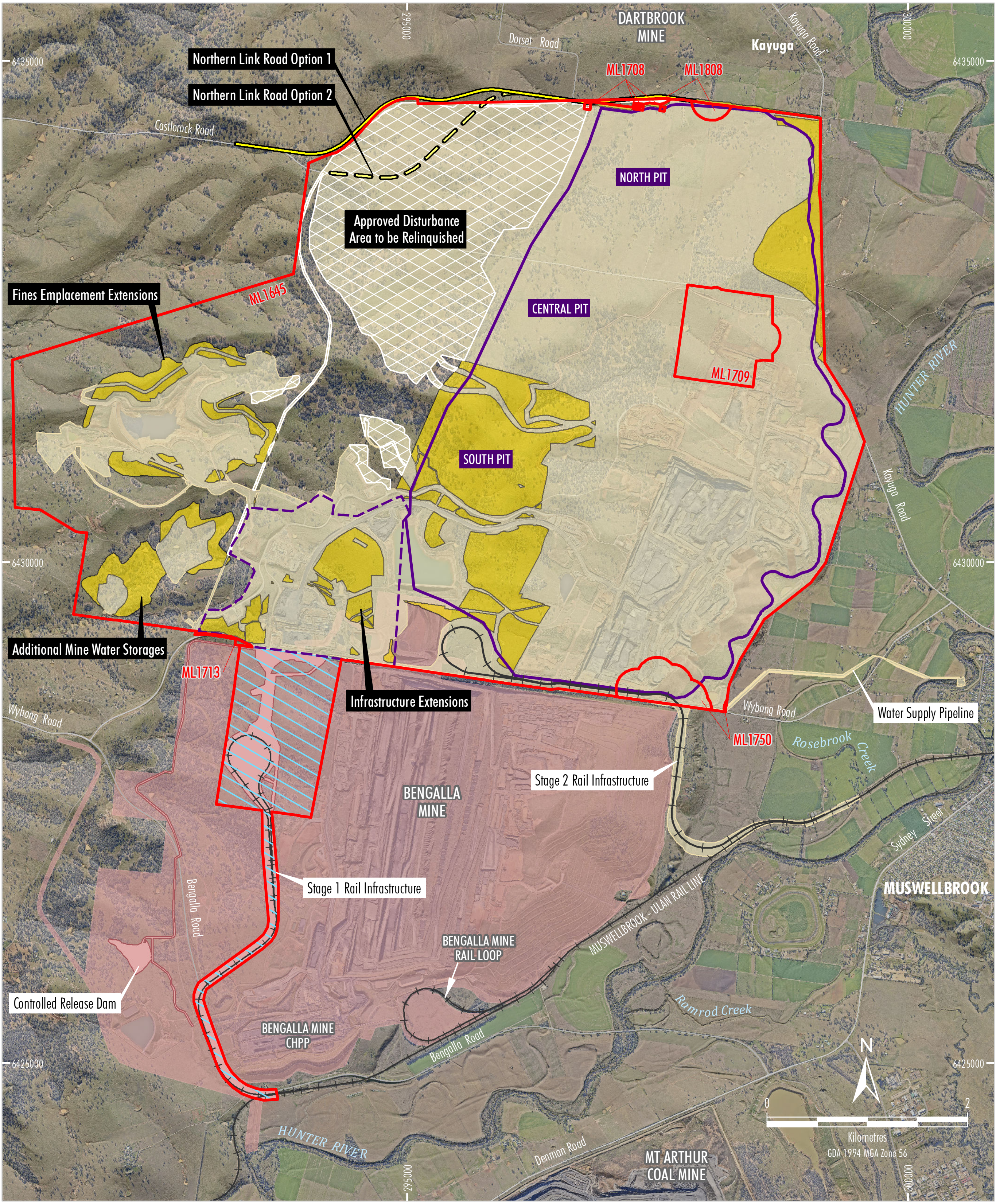
MOUNT PLEASANT OPTIMISATION PROJECT

Project location

Figure 1.1



LEGEND

Existing Mine Elements

- Mining Lease Boundary (Mount Pleasant Operation)
- Approximate Extent of Existing/Approved Surface Development (DA92/97) [1]
- Infrastructure to be removed under the Terms of Condition 37, Schedule 3 (DA92/97)
- Bengalla Mine Approved Disturbance Boundary (SSD-5170)
- Existing/Approved Mount Pleasant Operation Infrastructure within Bengalla Mine Approved Disturbance Boundary (SSD-5170) [1]

Additional/Revised Project Elements

- Approved Disturbance Area to be Relinquished [2]
- Approximate Additional Disturbance of Project Extensions [1]
- Northern Link Road Option 1 Centreline [3]
- Northern Link Road Option 2 Centreline
- Approximate Extent of Project Open Cut and Waste Rock Emplacement Landforms
- Revised Infrastructure Area Envelope

NOTES

1. Excludes some incidental Project components such as water management infrastructure, access tracks, topsoil stockpiles, power supply, temporary offices, other ancillary works and construction disturbance.
2. Subject to detailed design of Northern Link Road alignment.
3. Preferred alignment subject to landholder access.

Source: MACH (2020); NSW Spatial Services (2020); Department of Planning and Environment (2016) Orthophoto: MACH (July 2020)

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MOUNT PLEASANT OPTIMISATION PROJECT

Project layout

Figure 1.2

1.2 Objectives and scope of work

The objective of the groundwater impact assessment was to assess the impact of the Project on the groundwater regime, in consideration of the requirements of NSW and Federal Government legislation and policies. This included the Secretary's Environmental Assessment Requirements (SEARs) provided by the Department of Planning, Industry and Environment (DPIE).

The groundwater impact assessment comprises two parts, a description of the existing hydrogeological environment, and an assessment of the impacts of mining the Project on that environment.

The groundwater impact assessment includes:

- review of existing background data and previous hydrogeological investigations;
- modelling of the potential impacts resulting from the Project on:
    - regional groundwater levels in aquifers and aquitards during and post mining;
    - rates of baseflow to surface waters;
    - groundwater quality during and post mining; and
    - take of water under applicable water sharing plans.
- assessment of the potential for impacts upon water dependent assets via causal pathways including:
    - potential groundwater dependent ecosystems (GDE); and
    - third party water users (i.e. private bores).
- comparison of predicted impacts against the requirements of the NSW Aquifer Interference Policy (2012) (AIP); and
- assessment of risks to groundwater systems and consideration of appropriate mitigation, management and monitoring measures.

1.3 Mining operations

1.3.1 Approved Mount Pleasant Operation

As noted in Section 1.1, the MPO was granted project approval on 22 December 1999 (DA 92/97 [as modified]). The MPO is approved to produce up to 10.5 Mtpa of ROM coal. Under DA 92/97, the MPO currently extracts coal within its mining leases using open cut mining methods (i.e. truck and shovel operations).

The MPO includes a CHPP, a rail loop and spur, conveyor and load-out facility connecting the mine to the Muswellbrook–Ulan Rail Line. Transport of produced coal to the Port of Newcastle for export or to domestic customers is via rail with up to 9 trains per day despatched from the MPO. The principal use of coal produced at the MPO is for electricity generation.

1.3.2 Proposed Project operations

The Project would involve the continuation of the MPO with open cut mining optimised to recover an additional 247 million tonnes (Mt) of ROM coal. In total, approximately 406 Mt of ROM coal would be mined for the Project. Mining activities for the Project would be undertaken within currently held MPO mining leases. The optimised mining would target coal seams within the Wittingham Coal Measures, the same coal seams as the approved MPO. The additional coal being extracted would be accessed via the deepening of open cut pit floors in certain sections. Coal washing, handling and stockpiling would utilise existing and augmented infrastructure and processing facilities.

The outline of the proposed mining area is shown on Figure 1.2.

1.3.3 Adjacent mining operations

The Hunter Coalfield has a number of approved coal mining operations in addition to the approved operation at MPO. The nearest active mines within approximately 10 km of the Project are Bengalla Mine, Muswellbrook Coal Mine, Dartbrook Mine, Mt Arthur Coal Mine and Mangoola Coal. With the exception of the Muswellbrook and Mangoola Coal, each of these mines extract from the Wittingham Coal Measures. The AIP requires that an assessment of groundwater drawdown, including capture of groundwater via inflow, and any changes in water quality as the result of aquifer interference activities (such as open cut mining), considers the cumulative influence of nearby mines. A brief summary of these approved operations is provided below:

- Bengalla Mine (Bengalla Mining Company) extracts from the Wittingham Coal Measures using open cut methods. Mining operations commenced in 1998 and are approved to extract up to 15 Mtpa until 2039. The Bengalla Mine open cut progresses from east to west and is located immediately south of the MPO.
- Dartbrook Mine (Australian Pacific Coal) is located immediately north of the MPO and has previously extracted from the Wittingham Coal Measures using underground methods. Dartbrook Mine has been under care and maintenance since early 2006. In August 2019 the Independent Planning Commission (IPC) approved the recommencement of bord and pillar mining in the Kayuga Seam of the Wittingham Coal Measures until 2022, however the mine remains under care and maintenance.
- Muswellbrook Coal Mine (Muswellbrook Coal Company) is located approximately 6 km east of the MPO and extracts from the Greta Coal Measures to the Loder Seam using open cut methods. Coal has been extracted at Muswellbrook Coal Mine since 1907 with current open cut operations approved until 2022.
- Mt Arthur Coal Mine (BHP) is located approximately 8 km south of the MPO and currently extracts to the Ramrod Creek Seam of the Wittingham Coal Measures using open cut methods at two locations. Mining operations commenced in 2008 and are approved to 2026. Underground operations are approved at the Mt Arthur Coal Mine but have not yet commenced.
- Mangoola Coal (Glencore) is located approximately 15 km west of the MPO and extracts from the Newcastle Coal Measures to the Pilot Seam using open cut methods. Open cut operations are approved until 2029 however it is noted that an application to expand operations has been made and if approved, this would extend operations to 2030.

Mangoola Coal targets seams that are separated by a significant thickness of strata above the target seams of the Project. In addition, Mangoola Coal is on the western side of the Mt Ogilvie Thrust Fault. The Mt Ogilvie fault is a significant structural feature that offsets the coal seams against lower permeability interburden units, forming a barrier to the expansion of drawdown beyond the fault and limiting the potential for the groundwater impacts of the two operations to overlap.

Muswellbrook Coal Mine is closer to the Project, being 6 km east of MPO, and targets older seams in the Greta Coal Measures exposed in the Muswellbrook Anticline. Because of the stratigraphic separation, Mangoola Coal and Muswellbrook Coal Mine would not be considered in the cumulative impact assessment.

West Muswellbrook is a proposed open cut development about 3 km to the west of the Project. The West Muswellbrook Project proposes to target the shallow seams within the Jerrys Plains Subgroup of the Wittingham coal measures, being the Blakefield seam and above. These seams do not occur at the Project site and therefore cumulative impacts are unlikely.

Historically there has been an additional mining proposal, the Spur Hill Underground Coking Coal Project. However, it is noted that the Gateway Certificate for the Spur Hill Underground Coking Coal Project has lapsed and the proponent of the Spur Hill Underground Coking Coal Project has indicated that they do not anticipate it will proceed as proposed in previous documentation (Malabar Coal, 2019). It is noted that should any future development application be made for the Spur Hill Underground Coking Coal Project, then this would need to consider cumulative impacts with the Project at that time.

As a result, this assessment has considered the following approved mining operations as part of the cumulative assessment:

- Bengalla Mine;
- Mt Arthur Coal Mine; and
- Dartbrook Mine.

1.4 Report structure

This report is structured as follows:

- Section 1 – Introduction: provides an overview of the Project, scope of the report and objectives.
- Section 2 – Regulatory framework: describes the NSW and Commonwealth regulatory framework relating to groundwater and relevant to the Project.
- Section 3 – Environmental setting: describes the environmental setting of the Project Area including the climate, terrain, land uses and other environmental features.
- Section 4 – Geological setting: describes the regional geology and local stratigraphy.
- Section 5 – Hydrogeology: describes the existing local groundwater regime within the Project Area and surrounds.
- Section 6 – Numerical groundwater model: describes the application of modelling to assess the impacts associated with the Project.
- Section 7 – Groundwater model predictions: presents the numerical model predictions during mining and for the post mining recovery phase.
- Section 8 – Impact assessment: describes the predicted impacts of the Project on the groundwater regime and water dependent assets.
- Section 9 – Sensitivity and uncertainty analysis: summarises the uncertainty and sensitivity analysis undertaken on the numerical groundwater model, including details about the purpose and methodology of the assessment.
- Section 10 – Groundwater Monitoring and Management Plan: describes the proposed measures for mitigation, management and monitoring of the groundwater regime and potential impacts.

Appendix A provides a detailed description of the numerical modelling undertaken for the Project, including details on model construction, calibration and validation.

Appendix B tabulates the SEARs relevant to groundwater and cross references where these are addressed in this report.

2 Regulatory framework

The groundwater impact assessment was undertaken in accordance with the SEARs issued on 17 February 2020 and supporting agency comments. A tabulated summary of the SEARs relevant to this report, and the section in which they are addressed, is provided in Appendix B.

The Project has also considered the requirements of the following legislation, policies and guidelines relevant for groundwater:

- NSW Government:
    - *Water Management Act 2000* (WM Act) and the associated Water Sharing Plans;
    - AIP;
    - Strategic Regional Landuse Policy (2012); and
    - Protection of the Environment Operations Act (1997).
- Commonwealth Government:
    - EPBC Act guidelines including:
        - Significant impact guidelines (DoE, 2013).
        - Independent Expert Scientific Committee (IESC) information guidelines for coal seam gas (CSG) and large coal mining development proposals (IESC, 2018).
        - IESC Explanatory Note on Uncertainty Analysis in Groundwater Modelling (Middlemis & Peeters, 2018).

The following sections identify the relevant NSW Government legislative instruments, regulations and policies that are applicable to the management of groundwater at the MPO and the Project. This section also presents information on the licenses (water access and environmental) currently held by MACH.

2.1 Water Management Act 2000

The WM Act manages NSW water resources via the regulation of access rights through water licensing and approvals. The WM Act is administered by the NSW Department of Industry - Water (DoI – Water) and WaterNSW via the following means:

- water access licence (WAL): which allows the holder access to a maximum volume or share component that may be drawn from a particular water source. A WAL may also specify a category and the conditions under which water may be taken from a particular water source;
- water use approval: which authorises the particular use of water taken under a WAL; and
- water work approval: which states the nature, type and location of infrastructure by which water may be taken from a water source.

As the Project is considered a State Significant Development, under Section 4.4.1 of the EP&A Act it would not require a water use approval or a water work approval.

However, the Project would be required to obtain WALs to account for the maximum annual predicted inflows to the open cut (refer Section 2.1.2 and Section 2.3.1).

2.1.1 Water sharing plans

Under the WM Act, water sharing plans have been developed for certain river and aquifer systems to regulate access rights in a manner that protects dependent ecosystems.

Due to areal and geological heterogeneity, the management of water resources under a water sharing plan can be sub-divided to provide scope for further refinement in water resource allocation such as:

- extraction management units which assigns resource allocations via long-term, average annual extraction limits; and
- management areas or management zones which assign various rules on water trading and water access licence dealings.

Table 2.1 presents the Project-relevant surface water and groundwater water sharing plans, including the relevant sub-divisions (where applicable).

The boundaries of the respective water sharing plans and sub-divisions are shown in Figure 2.1.

Table 2.1 Water sharing plans relevant to the Project

Water sharing plan	Groundwater management area	Extraction management unit	Water source	Groundwater management zone
Hunter Unregulated and Alluvial Water Sources, 2009.	Hunter River Alluvium	Hunter Regulated River Alluvium	Hunter Regulated River Alluvial Water Source	Upstream (u/s) Glennies Creek
		Greater Hunter	Unnamed Upriver Alluvium in the Muswellbrook Water Source	-
			Dart Brook Water Source	Lower Dart Brook
	Not applicable (surface water)	-	Muswellbrook	-
Hunter Regulated River Water Source, 2016	Management Zone 1A	-	Hunter Regulated River Water Source	Glenbawn Dam water storage and Hunter River to Goulburn River junction
North Coast Fractured and Porous Rock Groundwater Sources, 2016	Sydney Basin – North Coast	-	Sydney Basin – North Coast Groundwater Source	-

Further information relating to the water sharing plans identified in Table 2.1 and its relevance to the Project is presented below.

The alluvial aquifers within the mine area are managed under the *Hunter Unregulated and Alluvial Water Sources Water Sharing Plan 2009*.

Within the vicinity of the Project, the Hunter River Alluvium groundwater management area is placed into sub-divisions, which are as follows:

- Unnamed Upriver Alluvium in the Muswellbrook Water Source– groundwater associated with alluvium along Sandy Creek, in the western section of the mine area.
- Hunter Regulated River Alluvial Water Source (Upstream Glennies Creek Management Zone) - groundwater associated with alluvium present to the north-east and south-east of the Project.
- Hunter Regulated River Water Source (Management Zone 1A) - Hunter River surface water and groundwater associated with alluvium located within 40 m of the top of the high bank of the Hunter River.

In the broader region, there are additional groundwater resources covered by the *Hunter Unregulated and Alluvial Water Sources Water Sharing Plan 2009* that may be marginally impacted by the Project. These are as follows:

- Dart Brook Water Source, situated to the north of the mine area and which falls within the bounds of the Lower Dart Brook Groundwater Management Zone; and
- Hunter Regulated River Alluvial Water Source (Upstream Glennies Creek Management Zone), situated east of the mine area.

No high priority GDEs listed in the *Hunter Unregulated and Alluvial Water Sources Water Sharing Plan 2009* are in the vicinity of the Project. Wappinguy Spring, approximately 40 km to the north-west of the mine area, is the closest high priority GDE listed in the *Hunter Unregulated and Alluvial Water Sources Water Sharing Plan 2009*.

The *Hunter Unregulated and Alluvial Water Sources Water Sharing Plan 2009* also addresses surface water within the catchment of the Hunter River, with the Project being situated within the boundaries of the Muswellbrook Water Source.

The proposed open cut development would intercept the groundwater resources managed under the *North Coast Fractured and Porous Rock Groundwater Sources Water Sharing Plan 2016*. The Project would continue extraction from Permian aged coal measures that form part of the Sydney Basin – North Coast Groundwater Source. This groundwater source is not sub-divided into groundwater management zones nor does it form part of an extraction management unit.

No high priority GDEs listed in the *North Coast Fractured and Porous Rock Groundwater Sources Water Sharing Plan 2016* are in the vicinity of the mine area. Parnell Spring, in the Wollemi National Park, 50 km to the south-southeast of the mine area, is the closest listed high priority GDE.

2.1.2 Water licensing

Where water sharing plans are in place, water access licences permit their holder to take water from a specified water source. Open cut mining could result in a direct take from a water source for (i.e. pumping for dewatering or consumptive uses) or an incidental (indirect) take (i.e. induced groundwater inflow to open cut voids from a connected water source or evaporative losses where the void intersects the water table).

Table 2.2 summarises the WALs held by MACH relevant to groundwater (including inflow to mine workings) at the MPO and which are subsequently applicable the Project.

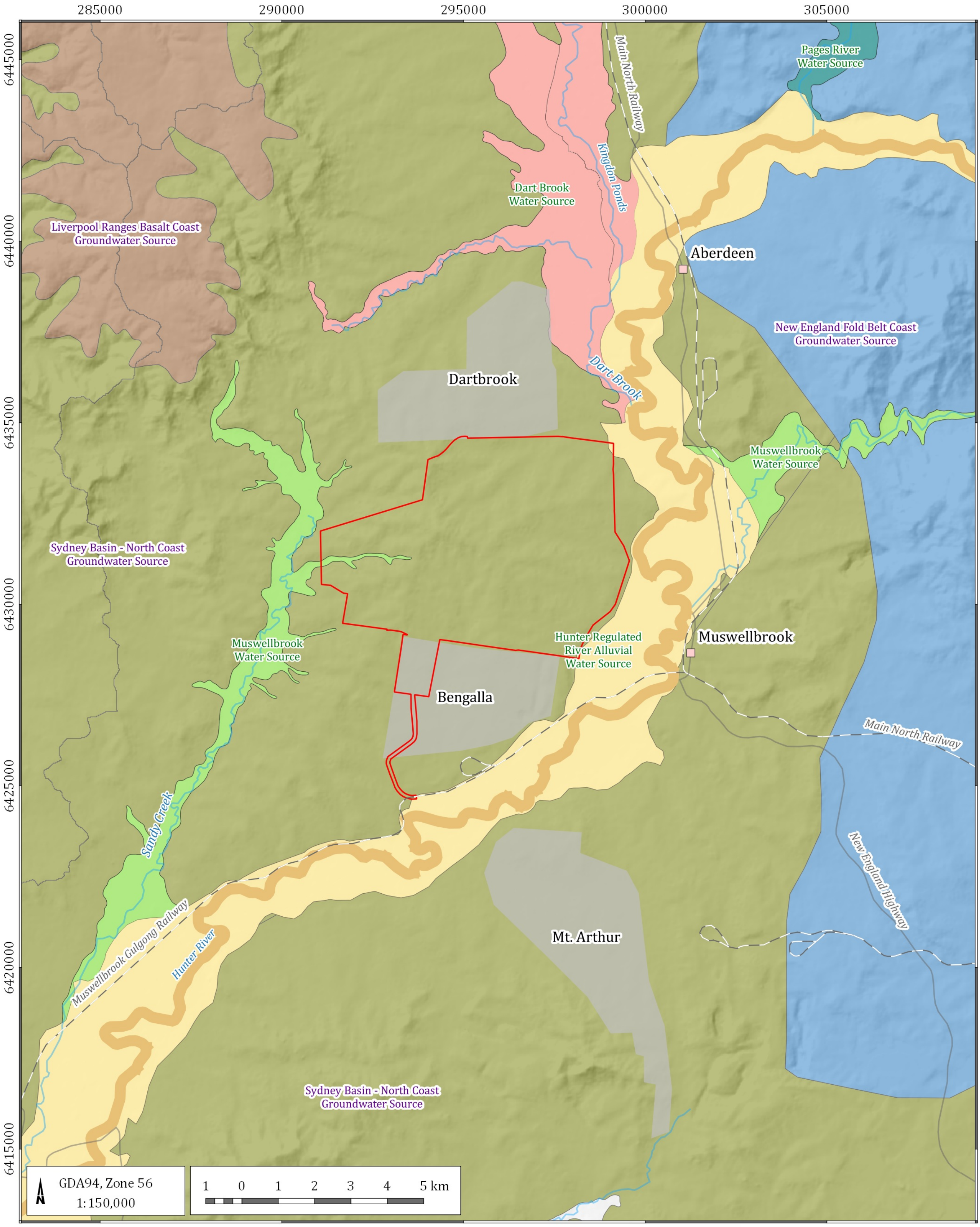
Table 2.2 Details of MACH held Water Access Licences – Groundwater Sources

WAL Number.	Licence category	Water source	Groundwater management Zone	Share components [Units]
18253, 18266, 18206, 18199, 18122, 18131, 21503, 18177	Aquifer	Hunter Regulated River Alluvial	Upstream Glennies Creek	285
Various	High Security	Hunter Regulated River	Management Zone 1A	961
Various	General Security	Hunter Regulated River	Management Zone 1A	2,937
23935	Aquifer	Muswellbrook	None	41
41437, 40298	Aquifer	Sydney Basin	None	730

2.2 Protection of the Environment Operations Act 1997

The POEO Act provides the framework for the regulation and reduction of pollution and waste in NSW. The POEO Act is administered by the NSW Environment Protection Authority (EPA), which issues environment protection licences (EPLs) for certain activities scheduled in the POEO Act, including those that may impact on groundwater quality.

MACH holds EPL 20850 which permits activities scheduled under the POEO Act (coal works and mining for coal) at MPO. The POEO Act also requires immediate reporting of pollution incidents which cause or threaten to cause material harm to the environment.



LEGEND

- Populated place
- Road
- Rail
- Drainage
- Project boundary
- Surrounding mines

Hunter Unregulated and Alluvial Water Sources

- Hunter Regulated River Alluvial Water Source
- Hunter Regulated River - management Zone 1 A (Hunter River from Glenbawn Dam to Goulburn River Junction)
- Dart Brook Water Source
- Muswellbrook Water Source
- Pages River Water Source

North Coast Fractured and Porous Rock Groundwater Sources

- Liverpool Ranges Basalt Coast Groundwater Source
- New England Fold Belt Coast Groundwater Source
- Sydney Basin - North Coast Groundwater Source

Mt Pleasant GIA (G1970A)

Water Sharing Plan areas and subordinate management units relevant to the Project

AGE

DATE 18/09/2020

FIGURE No: 2.1

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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2.3 State groundwater policy

2.3.1 Aquifer Interference Policy

Proponents of aquifer interference activities are required to provide predictions of the volume of water to be taken from a water source(s) as a result of the activity. These predictions need to occur prior to Project approval. After approval and during operations, these volumes need to be measured and reported in an annual returns or environmental management reports. The water user must hold sufficient share component and water allocation to account for the take of water from the relevant water source when the take occurs (refer Section 8.2).

The AIP states that a water licence is required for the aquifer interference activity regardless of whether water is taken directly for consumptive use or incidentally. In the case of the mining and the Project the take of water occurs incidentally during the mining process. This incidental take of groundwater can induce flow from adjacent groundwater sources or connected surface water, which constitutes take of water under the AIP. In all cases, separate access licences are required to account for the take from all individual water sources (refer Section 8.2 for predicted takes).

The AIP also describes minimal impact considerations for aquifer interference activities which are a series of acceptable thresholds for water level and quality changes. The minimal impact consideration thresholds depend upon whether the water source is highly productive or less productive and whether the water source is alluvial or porous/fractured rock in nature.

A "highly productive" groundwater source is defined by the AIP as a groundwater source which has been declared in regulations and datasets, based on the following criteria:

a) has a Total Dissolved Solids (TDS) concentration less than 1,500 milligrams per litre (mg/L); and

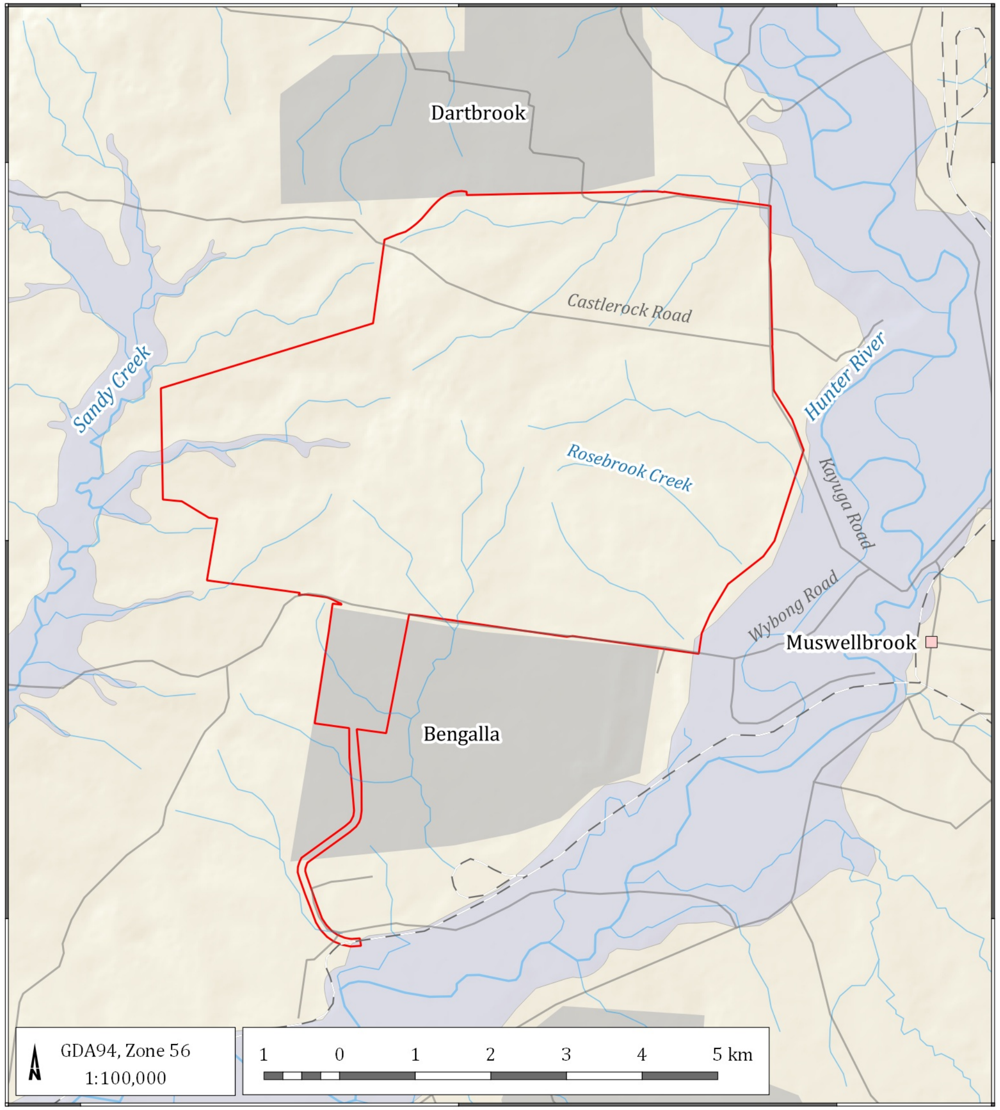
b) contains water supply works that can yield water at a rate greater than 5 litres per second.

Highly productive groundwater sources are further grouped by geology into alluvial, coastal sands, porous rock, and fractured rock. "Less productive" groundwater sources are all other aquifers that do not satisfy the "highly productive" criteria for yield and water quality.

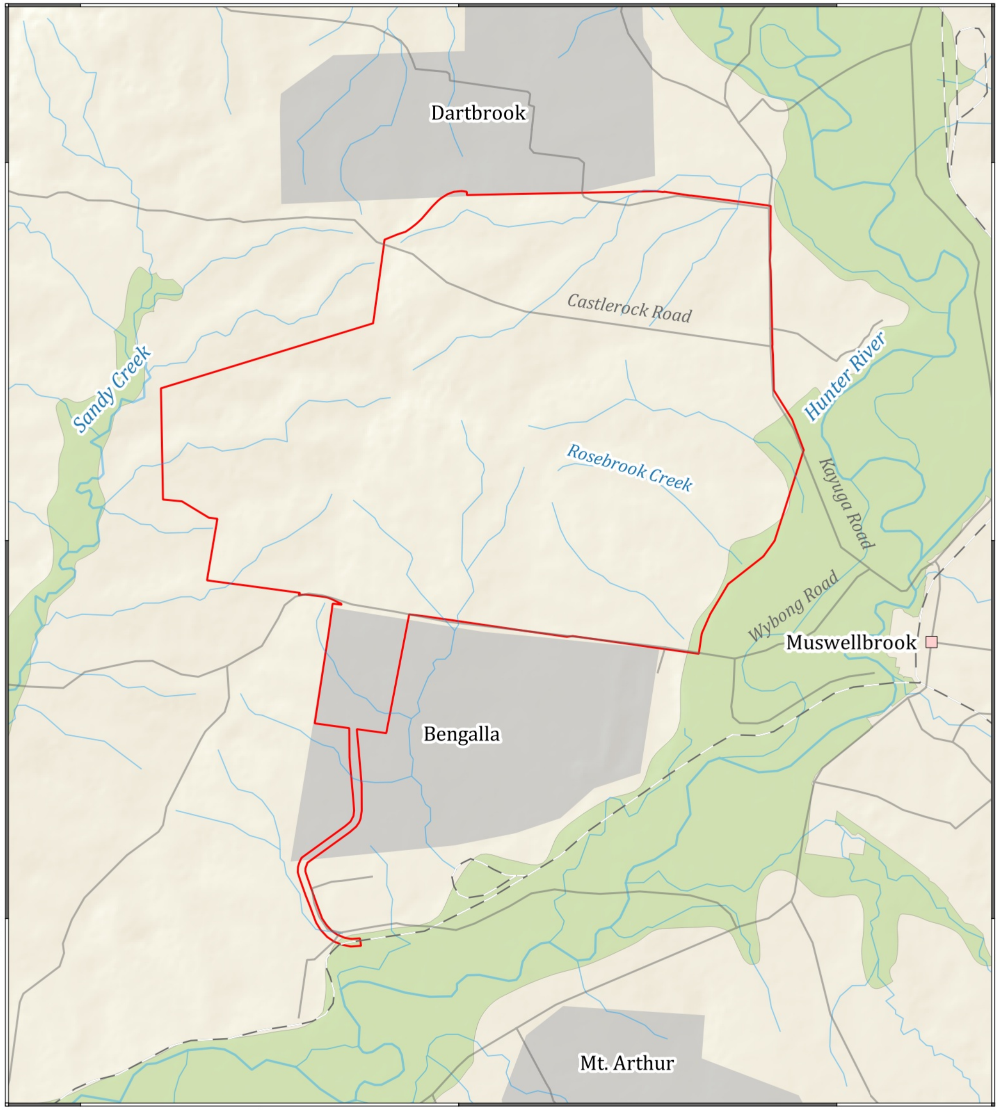
The AIP requires that impacts on highly and less productive water sources need to be assessed and accounted for. In 2012, the then NSW Crown Lands and Water Division produced a map of groundwater productivity across NSW, showing those areas classified as either highly or less productive. The groundwater productivity map has been produced based on regional scale geological maps. Figure 2.2 shows the groundwater productivity map, which indicates the alluvium along Sandy Creek and the Hunter River has been classified as highly productive. Neither of these classified highly productive groundwater areas would be intersected by the Project open cut. The extent and characteristics of the Quaternary alluvium is further discussed in Section 4.2.1. Section 5 provides further information on the properties of the alluvial and Permian aquifers. The Permian coal measures (porous and fractured rock) are categorised as "less productive" (DPI-Water, 2012).

The minimal impact considerations are a series of threshold levels defining minimal impact on groundwater sources, connected water sources, GDEs, culturally significant sites and water users. The thresholds specify water table and groundwater pressure drawdown as well as groundwater and surface water quality changes. Section 7 presents predicted Project impacts and compares these with the AIP thresholds. Appendix B notes where information required to address the AIP is presented within the report.

Productive groundwater



Biophysical strategic agricultural land



LEGEND

- Populated place
- Road
- Rail
- Drainage
- Project boundary
- Surrounding mines
- Highly productive groundwater (DPI Water)
- Biophysical Strategic Agricultural Land

Mt Pleasant GIA (G1970A)

Highly Productive groundwater (DPI Water) and Biophysical Strategic Agricultural Land

DATE
01/04/2020

FIGURE No:
2.2

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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2.3.2 NSW Strategic Regional Land Use Policy

Under the EP&A Act, the Strategic Regional Land Use Policy requires any State Significant mining development requiring a new mining lease to assess potential impacts on Biophysical Strategic Agricultural Land (BSAL). BSAL is land with high quality soil and water resources capable of sustaining high levels of productivity. BSAL is identified on regional mapping along parts of the Hunter River and Sandy Creek (Figure 2.2). The Project would be located wholly within existing mining leases, the Project will therefore not require an assessment of BSAL.

2.4 Commonwealth Environment Protection and Biodiversity Conservation Act 1999

The EPBC Act is administered by the Commonwealth Department of Agriculture, Water and the Environment (DAWE) to protect national environmental assets (Matters of National Environmental Significance [MNES]). As noted in Section 1.1, the MPO received approval under the EPBC in 2012 (EPBC 2011/5795) with this approval in effect until October 2035.

A 2013 amendment to the EPBC Act, identified impacts on water resources as the result of large coal mining development as being MNES (the 'water trigger'). The IESC is a statutory body established under the EPBC Act to provides scientific advice to the Commonwealth Environment Minister and relevant State ministers on the impacts on water resources. Guidelines have been developed in order to assist the IESC in reviewing CSG or large coal mining development proposals. A summary of the IESC guidelines and where they are addressed within the report is included in Appendix B.

The proposed action to increase open cut coal extraction to allow mining of additional coal reserves and increase processing operations at the MPO not already authorised by the Approval Decision EPBC 2011/5795 was referred to the Commonwealth Minister for the Environment and Energy in July 2020 (EPBC 2020/8735) (the proposed action).

A delegate of the Commonwealth Minister determined on 26 August 2020 that the proposed action is a "controlled action" and therefore the action requires approval under the EPBC Act, including an assessment of potential impacts on water resources.

3 Environmental setting

3.1 Location

The Project is situated in the Hunter Coalfields of the Sydney Basin and is entirely within the Muswellbrook Local Government area. The mine is situated approximately 3 km northwest of Muswellbrook.

3.2 Climate

3.2.1 Rainfall

The climate in the Muswellbrook area is temperate, and is characterised by hot summers with intermittent thunderstorms and mild dry winters. The Bureau of Meteorology (BoM) operates a number of rainfall stations in the vicinity of the Project. The nearest rainfall station, situated approximately 6 km northeast of the Project, is Muswellbrook (St Heliers), (BoM station 061374). This station commenced operation in 1992. The average (mean) annual rainfall at Muswellbrook (St Heliers) is approximately 580 millimetres (mm).

In order to obtain longer term climate information, data was sourced from the Scientific Information for Land Owners (SILO) database. SILO is operated by the Queensland Department of Environment and Science, with data contributions from BoM. SILO generates a climate dataset via interpolation between neighbouring BoM stations to produce a continuous daily time series. The SILO dataset obtained for this assessment (latitude -32.25, longitude 150.85) included long-term rainfall, temperature, and evaporation information from 1889 to present.

A comparison of SILO average monthly rainfall and that recorded at Muswellbrook (St Heliers) is shown in Table 3.1. This comparison of longer-term SILO climate data identifies similar annual average rainfall (~603 mm/a) to that recorded at Muswellbrook (St Heliers).

Table 3.1 Average monthly rainfall (mm)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Muswellbrook (St Heliers) 061374	59.7	60.7	62.8	35.6	41.8	50.6	35.9	38.9	45.9	44.9	74.3	64.0
	Average Annual 580.2 mm (1992 – 2019)											
SILO	71.8	63.3	56.2	40.2	40.8	47.5	40.1	37.1	38.5	48.6	63.6	66.1
	Average Annual 603.4 mm (1889-2019)											

Long-term rainfall trends are provided by the cumulative rainfall departure (CRD). A CRD is generated by cumulatively summing the residuals between actual monthly rainfall and the long-term average monthly rainfall with a rising CRD correlating with above average rainfall and a falling CRD indicating the reverse. CRD trends are relevant as groundwater hydrographs, particularly for shallow aquifers, tend to reflect similar trends, with declining groundwater levels during a period of below average rainfall and rising trends in periods of above average rainfall.

Figure 3.1 shows the CRD calculated using the SILO rainfall data for the period 1900 to 2019.

Figure 3.1 Cumulative Rainfall Departure and monthly rainfall (SILO)

Figure 3.1 indicates that the long-term rainfall trend in the upper Hunter catchment comprises a long period of lower than average rainfall between around 1900-1950, with multiple year droughts such as the 1937 – 1946 "WWII Drought". The period following 1946 was characterised by a (generally) sustained period of above average rainfall until the early 1990s. Whilst this period indicates that conditions were generally wetter, it was periodically interspersed with short-lived droughts, including the 1982-83 drought.

Figure 3.1 also indicates wetter episodes in the early- and mid-1950s, mid-1970s, early-1990s and 2010-12. Of note is the below average rainfall from early 2017 resulting in the steep decline in recent times as shown in Figure 3.1. Groundwater levels and the response to climate and mining activities are discussed further in Section 5.

3.2.2 Evaporation

Evaporation data was obtained from Scone SCS station 061089, located approximately 20 km northeast of the Project and SILO potential evaporation. Table 3.2 presents a summary of monthly averages from Scone SCS and SILO.

A summary of SILO average monthly rainfall and potential evaporation is shown on Figure 3.2.

Table 3.2 Average monthly evaporation (mm)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Scone SCS 061089	217.0	175.2	151.9	108.0	71.3	48.0	58.9	86.8	120.0	158.1	186.0	223.2
	Average Annual 1,606 mm (1992 – 2019)											
SILO	212.5	167.1	148.3	102.5	71.1	53.1	61.6	86.6	114.0	154.0	183.3	213.6
	Average Annual 1,568.9 mm (1889-2019)											

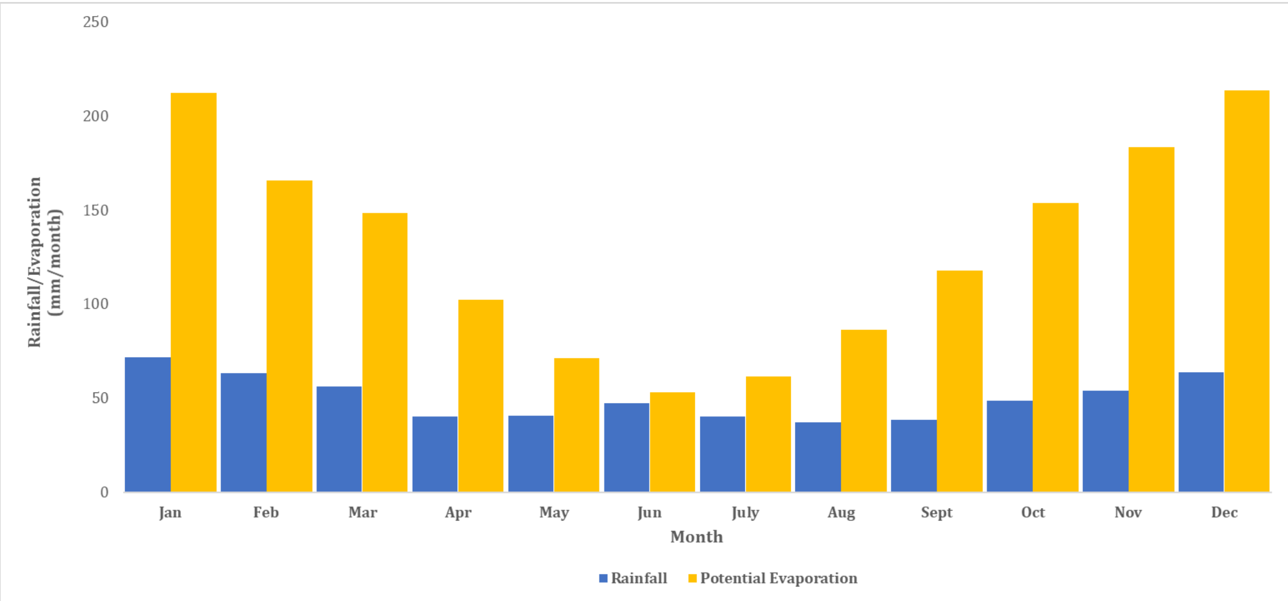


Figure 3.2 Monthly average SILO rainfall and potential evaporation

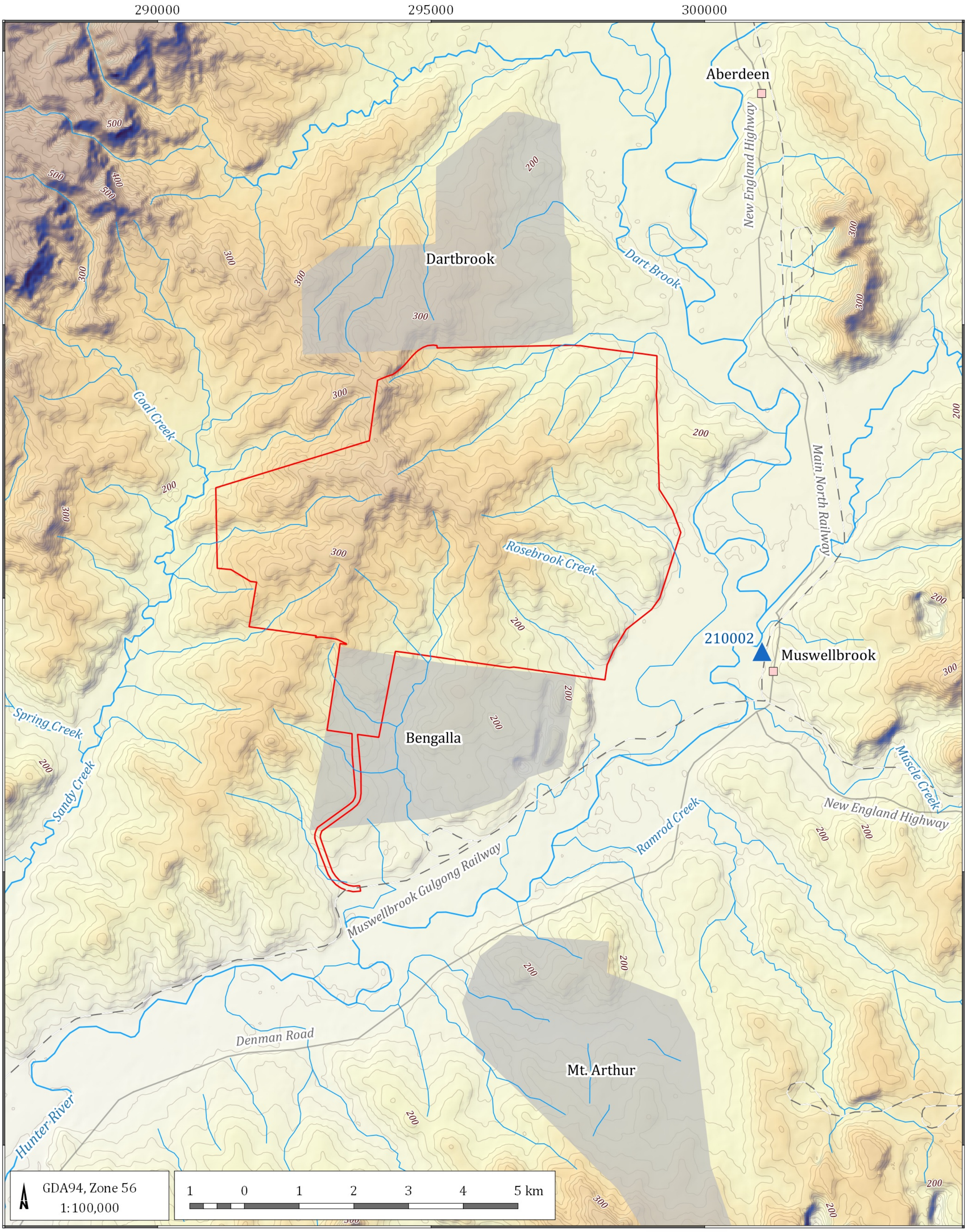
Figure 3.2 indicates that groundwater recharge is unlikely to be high due to the high evaporation rates relative to rainfall. Recharge rates depend on a range of factors including soil type, geology, topography, vegetation and dominant land use. Despite the high average evaporation rates recharge will occur sporadically when rainfall activity promotes saturation of the soil profile and evaporation is insufficient to remove the soil moisture. During these periods there is potential for deep drainage of water to underlying groundwater systems.

3.3 Topography

The Project area and much of its surrounds exhibits high topographic relief relative to the floodplain area of the Hunter River, which is relatively flat-lying with minor incised drainages.

Data from the NSW Spatial Services Unit of the Department of Finance, Services and Innovation has been combined with site-specific LiDAR data to generate the DEM shown on Figure 3.3.

As shown on Figure 3.3, ground elevation across the mine area ranges from approximately 150 metres above Australian Height Datum (mAHD) to 350 mAHD. Lower elevations are typically associated with the Hunter River floodplain (at about 140-160 mAHD) to the east of the mine area.



LEGEND

- Populated place
- Water NSW stream gauge
- Road
- Rail
- Drainage
- Project boundary
- Surrounding mines

Elevation (mAHD)

- 100
- 200
- 400
- 600
- 800
- Elevation contour (mAHD)

Mt Pleasant GIA (G1970A)

Terrain and drainage

AGE

DATE 01/04/2020

FIGURE No: **3.3**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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3.4 Drainage

Whilst drainage in the Project area is characterised by lower order, unnamed ephemeral watercourses, there are a number of local and regional drainage features present in the vicinity of the Project (refer Figure 3.3). A brief description of regional, local and Project area drainage is presented below.

3.4.1 Regional drainage

The Hunter River, with a catchment of 22,000 square kilometres (km^2) is the principal regional drainage feature. In the vicinity of the Project, it flows from the north-east to the south and then south-west before reaching its confluence with the Goulburn River, 20 km south of the Project. Glenbawn Dam is a major hydraulic control regulating the flow of the Hunter River and is situated 15 km upstream of the Project.

The Project is situated in the 'Upper Sector' of the Hunter River Salinity Trading Scheme, as managed by the NSW EPA.

3.4.2 Local drainage

In the vicinity of the Project, there are a number of local drainage features that are tributaries of the Hunter River (refer Figure 3.3).

The Project is located approximately 1 km south of the confluence of Dart Brook and the Hunter River. Dart Brook is a perennial watercourse that is characterised by a broad alluvial plain (1 to 2 km wide). Dart Brook is a major tributary of the Hunter River with headwaters approximately 50 km to the north of the Project.

Kingdon Ponds, another perennial watercourse is the main tributary to Dart Brook, with the confluence located 3 km upstream from where Dart Brook joins the Hunter River.

Sandy Creek, a non-perennial watercourse, originates 7 km north-west of the Project and flows south, within 1 km of the Project mining leases, before joining the Hunter River in the town of Denman, southwest of the Project. Sandy Creek is fed by several lower order watercourses including Coal Creek, and Spring Creek. A number of first and second order un-named watercourses occur within the Project area and subsequently drain west to Sandy Creek.

For clarity, 'Sandy Creek' will be used to refer to Sandy Creek within the Muswellbrook Water Source (refer Section 2.1.1), and which flows north to south up to 3 km west of the mine area. This distinction is considered necessary as there are two other watercourses also locally known as 'Sandy Creek' in the area. The first of which is the southernmost tributary of Dart Brook and which lies approximately 4 km to 5 km north of the Project. The second enters the Hunter River from the east of Muswellbrook, approximately 3 km east of the Project.

3.4.3 Project area drainage

There are a number of ephemerally discharging first and second order named and un-named watercourses occurring within the Project area (refer Figure 3.3). These watercourses drain either west to Sandy Creek or east to the Hunter River.

The small catchments in the south east of the Project area discharge directly east onto the alluvial plain. The eastward draining second order watercourse known a Rosebrook Creek connects with a secondary or relict channel of the Hunter River that is situated to the west of the main trunk of the river. Review of aerial photography indicates that drainage lines from the eastward draining catchments have been overprinted or altered by agricultural activities. In addition, drainage from two small catchments in the northern section of the mine area drain to the north before turning east and joining the Hunter River.

3.4.4 Streamflow and electrical conductivity

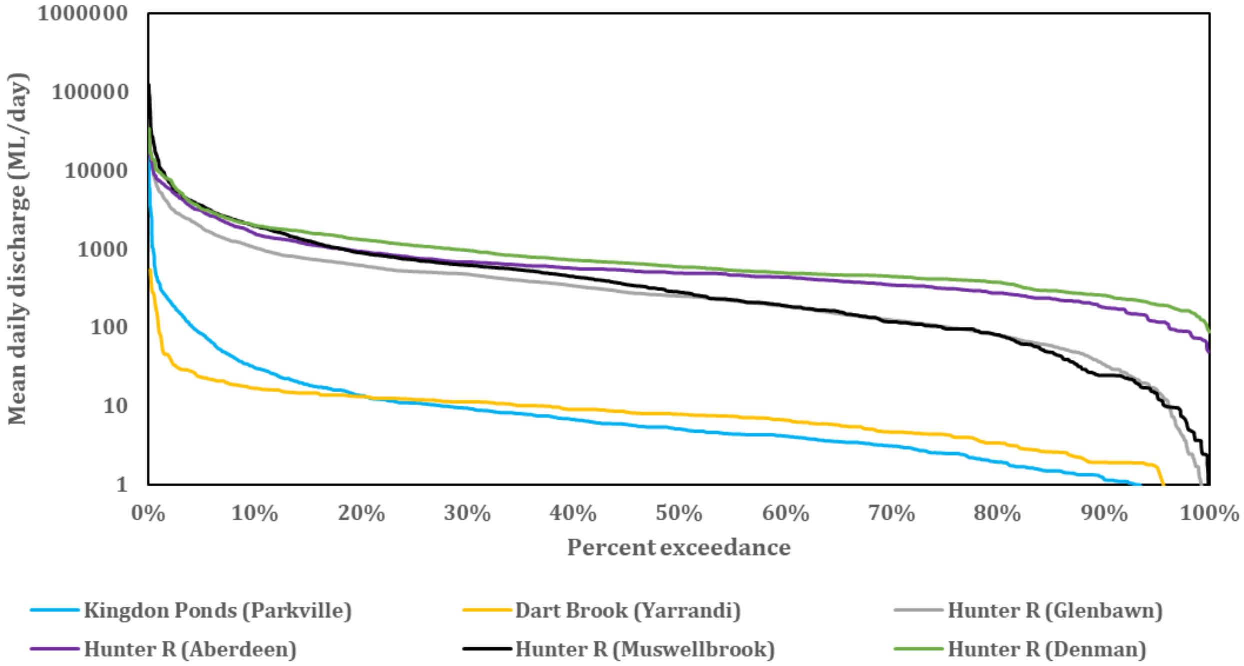
WaterNSW operates a number of stream gauges in the vicinity of the Project. These gauges measure streamflow and electrical conductivity (EC) and are listed in Table 3.3 from upstream to downstream (Kingdon Ponds Creek, Dart Brook and Hunter River).

Table 3.3 WaterNSW stream gauges in vicinity of the Project

Station	Name	Status	Monitoring period	Area (km²)
210093	Kingdon Ponds Creek (near Parkville)	Active	1972 - current	177
210124	Dart Brook at Yarrandi Bridge	Active	1991 - current	233
210015	Hunter D/S Glenbawn	Active	1940 - current	1,295
210056	Hunter River at Aberdeen	Active	1959 - current	3,090
210002	Hunter River at Muswellbrook Bridge	Active	1906 - current	4,220
210055	Hunter River Denman	Active	1908 - current	4,530

Figure 3.4 presents flow duration curves determined from streamflow measured at the stream gauges listed in Table 3.3. The flow duration curves on Figure 3.4 show that flow in the regulated Hunter River downstream of Glenbawn Dam is reliable as a result of this dam being in place. Flow in the Hunter River tributaries Dart Brook and Kingdon Ponds is lower as the result of smaller catchment size and no hydraulic controls to regulate discharge.

Available stream gauge EC data is also presented on Figure 3.4. Data is not recorded at all stream gauges (e.g. Dart Brook) or across the entire period shown at all gauging stations However, Figure 3.4 shows that EC is relatively fresh, generally between 100 and 1,000 microSiemens per centimetre (µS/cm), along the Hunter River, with the mean (at Muswellbrook) being 478 µS/cm. The summary shows that there is a slight increase in EC from upstream to downstream.



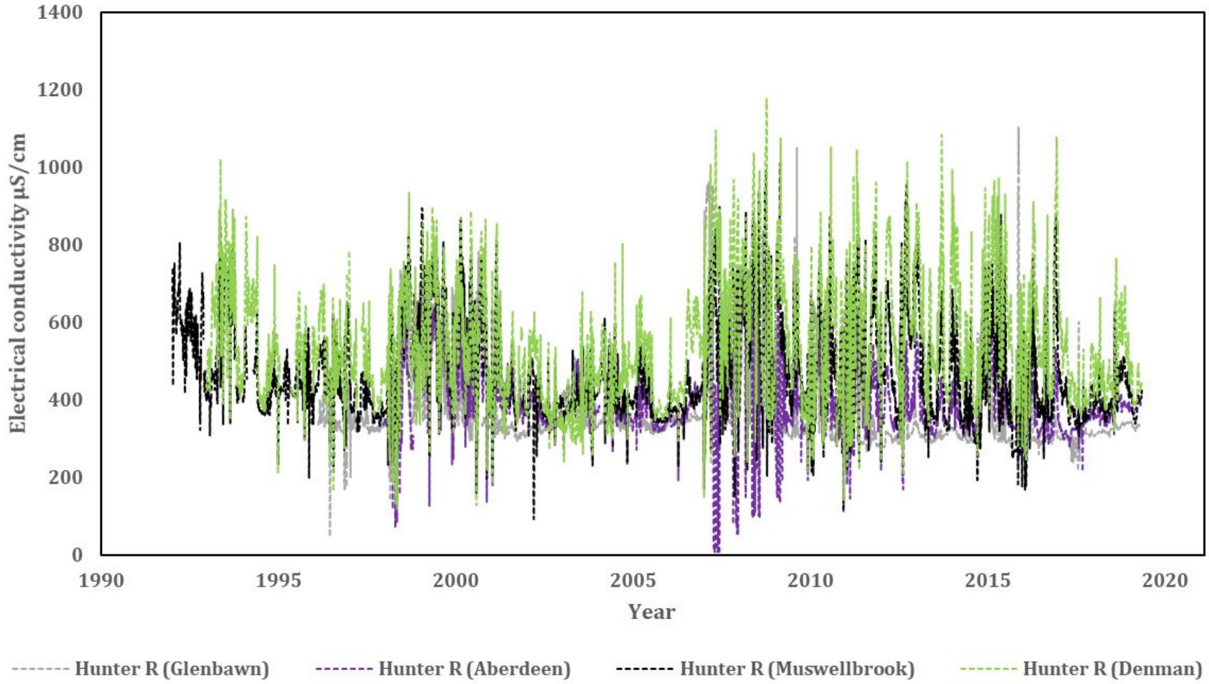


Figure 3.4 Flow duration and electrical conductivity at WaterNSW stream gauges

3.5 Land use

According to NSW Land Use Mapping, the Project area is predominantly cleared with unimproved agricultural land utilised primarily for grazing. Areas of grassy woodland also exist within the Project area. Areas of arable land exist to the east of the Project on the floodplain of the Hunter River. Residential and industrial land uses are present as part of the township of Muswellbrook (1 km east), the rural locality of Kayuga, as well as there being some improved pasture.

Mining is a major land use in the immediate Project area. As noted in Section 1.3.3, Bengalla Mine is situated immediately south of the Project and Dartbrook Mine immediately north. In addition, Mangoola Coal, Mt Arthur Coal Mine and Muswellbrook Coal Mine are also located in the vicinity of the Project.

MACH is the major landholder within the Project boundary and have historically leased most of the relevant landholdings for ongoing agricultural production.

4 Geological setting

The geological setting has been informed by the following data sources:

- publicly available geological maps (Hunter Coalfields map sheets) and reports;
- hydrogeological reports and geological datasets prepared for MPO and surrounding mines; and
- hydrogeological data held on the DPI-Water groundwater database.

The information provided was used to develop a 3D numerical groundwater model for the Project. Appendix A describes the approach to the groundwater modelling in detail.

4.1 Regional geology

The Project is located along the western outcrop of the Permian coal measures, as shown on the 1:100,000 scale Hunter Coalfield Regional Geology Map (Glen & Beckett, 1993) (Figure 4.1). The Hunter Coalfield forms part of the Permian and Triassic Sydney Basin that was formed during a period of crustal thinning and igneous rifting in the Late Carboniferous to Early Permian. The basin was subsequently infilled with Permian and Triassic aged sediments.

Regional geology is comprised of the Late Permian Wittingham coal measures, a sequence of coal seams interbedded with claystone, tuff, siltstone, sandstone, and conglomerate. The Wittingham coal measures are divided into two subgroups, the Jerrys Plains Subgroup and the Vane Subgroup. The Jerrys Plains Subgroup comprises a sequence of coal seams interbedded with claystone, tuff, siltstone, sandstone, and conglomerate. Within the Jerrys Plains Subgroup there are 15 main coal seams that are mined across the Hunter Valley. In stratigraphic order (youngest to oldest) these coal seams include Whybrow seam, Redbank Creek seam, Wambo seam, Whynot seam, Blakefield seam, Glen Munro seam, Woodlands Hill seam, Arrowfield seam, Bowfield seam, Warkworth seam, Mount Arthur seam, Piercefield seam, Vaux seam, Broonie seam and Bayswater seam. The Vane Subgroup includes the Wynn seam and Edderton seam.

The Wittingham coal measures conformably underlie the Newcastle coal measures. Together the Wittingham and Newcastle coal measures form the Singleton Supergroup. The Singleton Supergroup overlies the marine sequences of the Maitland Group (sandstones, siltstones and conglomerates) that in turn overlies the Early Permian Greta coal measures.

The Permian sediments are unconformably overlain by a thin capping of Quaternary alluvial sediments deposited along drainage lines and forming flood plains. The alluvial deposits near the Project comprise silt, sand, and gravel along the present-day alignments of the Hunter River and Sandy Creek. A weathering profile is typically present as a thin heterogeneous layer of unconsolidated weathered material (regolith) grading to fresh bedrock.

The coal measures are influenced by a series of fold structures and thrust faults (Hunter and Aberdeen) that trend in a northwest-southeast direction. The Hunter thrust fault and Aberdeen thrust fault, are located approximately 6 km to the east of the Project. In this vicinity, these faults generally trend parallel to each other with an approximately north to south/southeast trace. The Aberdeen fault is almost coincident with the Muswellbrook Anticline, the axis of which has been eroded away, exposing older units including the Maitland Group and the Greta coal measures. The Hunter thrust forms the boundary between the Carboniferous New England Block which has been thrust over Permian Sydney Basin sediments. Regionally, the Permian coal measures outcrop between older Carboniferous units to the east and younger Triassic sandstones and conglomerates of the Sydney Basin to the west.

The main structural feature west of the Project is the Mt Ogilvie thrust fault. This structure, approximately 10 km west of the Project trends north to south. Throw along the fault has forced the Wittingham Coal Measures up where they now lie adjacent to the younger Newcastle Coal Measures. Throw along the Mt Ogilvie fault has led to a maximum displacement of 100 to 200 m beneath Sandy Creek (HydroSimulations, 2013; MER, 2006). Further south this structure weakens, with the throw declining so that the fault/structure forms a roll-over or monocline (HydroSimulations, 2013 and 2015). Smaller, but similarly north-south oriented faults are mapped by Glenn and Beckett (1993) between the Project and Mt Ogilvie Fault. These are the Mirrabooka and Lyndale Faults, and are indicated to exhibit smaller throw.

Table 4.1 provides a summary of the regional geology shown on Figure 4.1, including the stratigraphic units and coal measures relevant to the Project and surrounding area. Figure 4.2 and Figure 4.3 provide conceptual geological cross-sections showing the occurrence of key stratigraphic units across the Project.

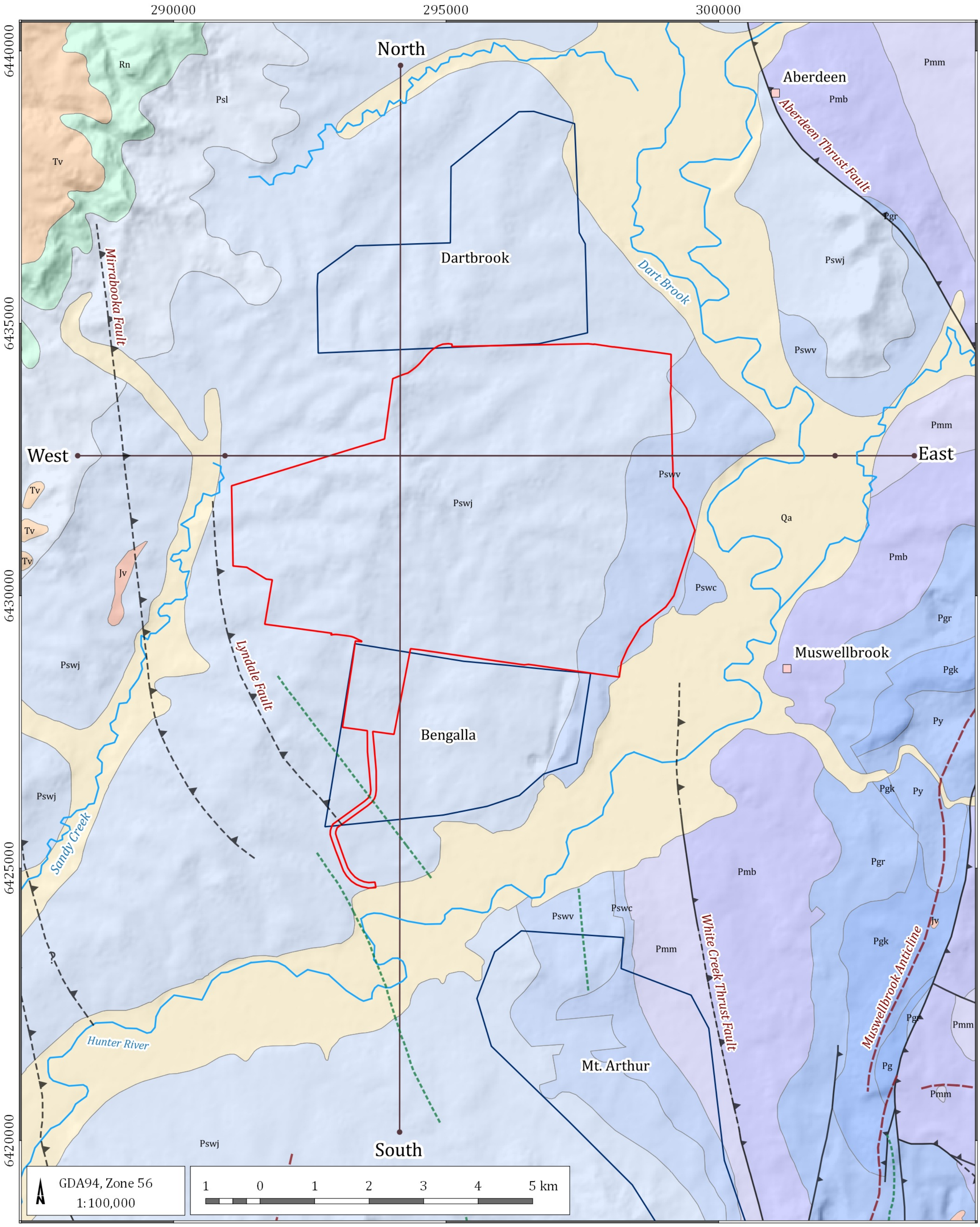
Table 4.1 Summary of regional geological units

<table>
<tr><th>Age</th><th colspan="3">Stratigraphic unit</th><th>Description*</th></tr>
<tr><td>Quaternary</td><td colspan="3">Quaternary sediments – alluvium (Qa)</td><td>Clay, silt, and sand overlying basal clayey sands and gravels in places.</td></tr>
<tr><td>Tertiary and Jurassic</td><td colspan="3">Basalt (Tv or Jv)</td><td>Flows, sills and dykes</td></tr>
<tr><td>Triassic</td><td colspan="3">Narrabeen Group (Rn)</td><td>Interbedded fine to medium-grained sandstone and siltstone, claystone and conglomerate.</td></tr>
<tr><td rowspan="17">Permian</td><td colspan="3">Newcastle Coal Measures</td><td>Numerous coal seams; claystone, tuff, siltstone, sandstone, conglomerate</td></tr>
<tr><td rowspan="16">Wittingham Coal Measures</td><td colspan="2">Watts Sandstone</td><td>Well-sorted quartz lithic sandstone</td></tr>
<tr><td colspan="2">Denman Formation</td><td>Dark grey striped sandstone-siltstone laminite with abundant burrows</td></tr>
<tr><td rowspan="7">Jerrys Plains Subgroup (Pswj)</td><td>Bowfield seam</td><td rowspan="7">Numerous coal seams; claystone, tuff, siltstone, sandstone, conglomerate</td></tr>
<tr><td>Warkworth seams (A and E)</td></tr>
<tr><td>Mt Arthur seams</td></tr>
<tr><td>Piercefield seam</td></tr>
<tr><td>Vaux seam</td></tr>
<tr><td>Broonie seams</td></tr>
<tr><td>Bayswater seam</td></tr>
<tr><td colspan="2">Archerfield Sandstone</td><td>Bronze-coloured, well-sorted quartz lithic sandstone</td></tr>
<tr><td rowspan="6">Vane Subgroup (Pswv)</td><td>Wynn seam</td><td rowspan="6">Coal bearing sequences with wedges of sandstone and siltstone.</td></tr>
<tr><td>Edderton seam</td></tr>
<tr><td>Clanricard</td></tr>
<tr><td>Bengalla</td></tr>
<tr><td>Edinglassie</td></tr>
<tr><td>Ramrod Creek</td></tr>
</table>

Age	Stratigraphic unit		Description*
		Saltwater Creek Formation (Pswc)	Sandstone and siltstone, minor coaly bands, siltstone towards base.
Permian	Maitland Group	Mulbring Siltstone (Pmm)	Fine-grained offshore sediments: siltstone, claystone, minor fine sandstone.
		Muree Sandstone (Pms)	Fine to coarse sandstone, conglomerate, and minor clay
		Branxton Formation (Pmb)	Conglomerate, sandstone, and siltstone

***Notes*:** * *Descriptions predominantly from the Australian Stratigraphic Units Database (Geoscience Australia, 2017).*
Seams highlighted in ***bold*** *are the Project target coal seams.*

TOC



LEGEND

- Populated place
- Drainage
- Cross section lines
- Thrust fault
- Thrust fault (approximate)
- Thrust fault (inferred)
- Anticline
- Syncline
- Project boundary
- Surrounding mines

Surface geology

- Qa - Quaternary Alluvium
- Tv - Tertiary Basalt
- Jv - Jurassic Volcanics
- Rn - Hawkesbury Sandstone, Narrabeen G.
- Psl - Wollombi Coal Measures
- Pswj - Denman Fmt, Jerrys Plains Subgroup
- Pswv - Archerfield Ss., Vane Subgroup
- Pswc - Saltwater Creek Formation
- Pmm - Mulbring Siltstone
- Pmb - Braxton Formation
- Pg - Greta Coal Measures
- Pgr - Greta Coal Measures
- Pgk - Greta Coal Measures
- Py - Gyarran Volcanics

Mt Pleasant GIA (G1970A)

Surface geology

DATE 30/11/2020

FIGURE No: **4.1**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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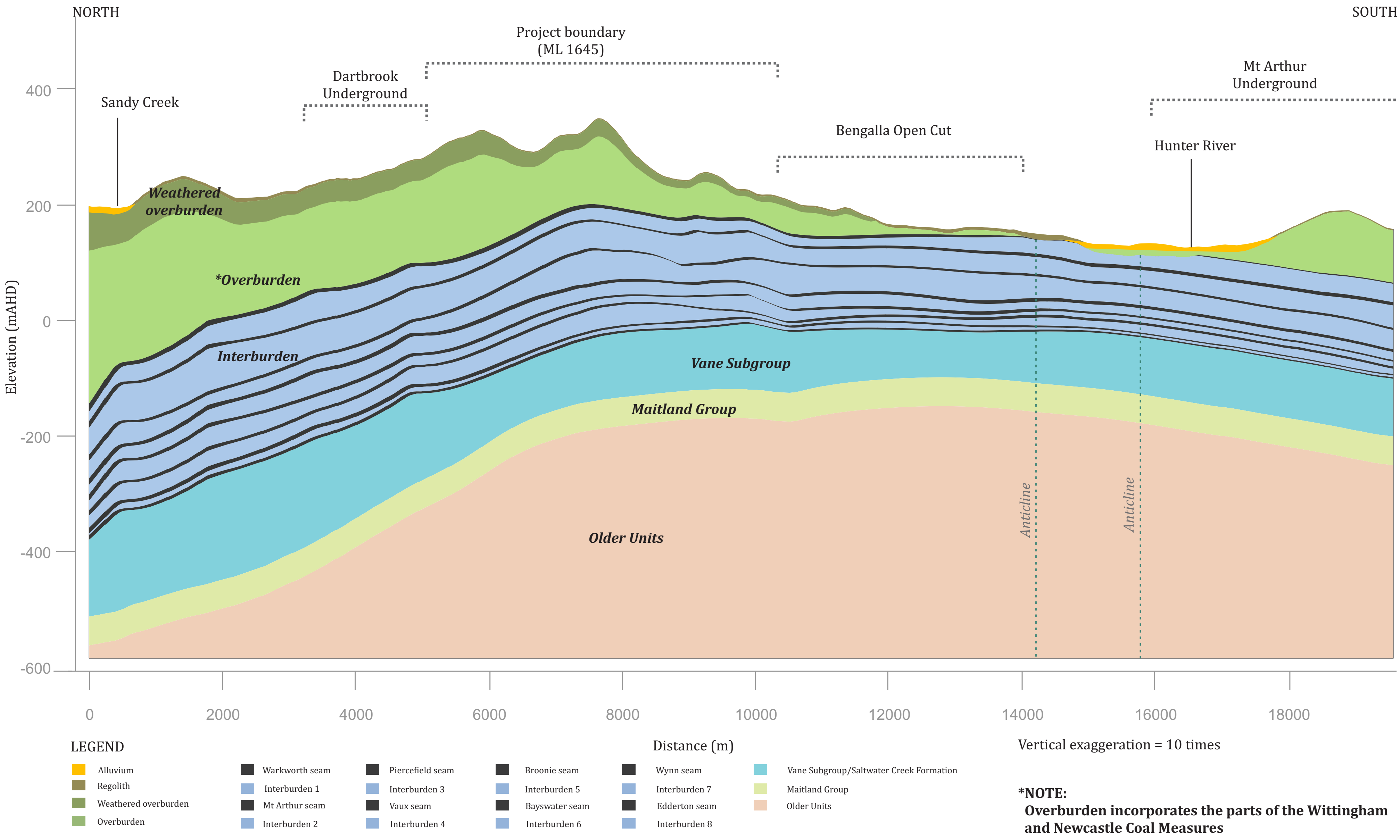
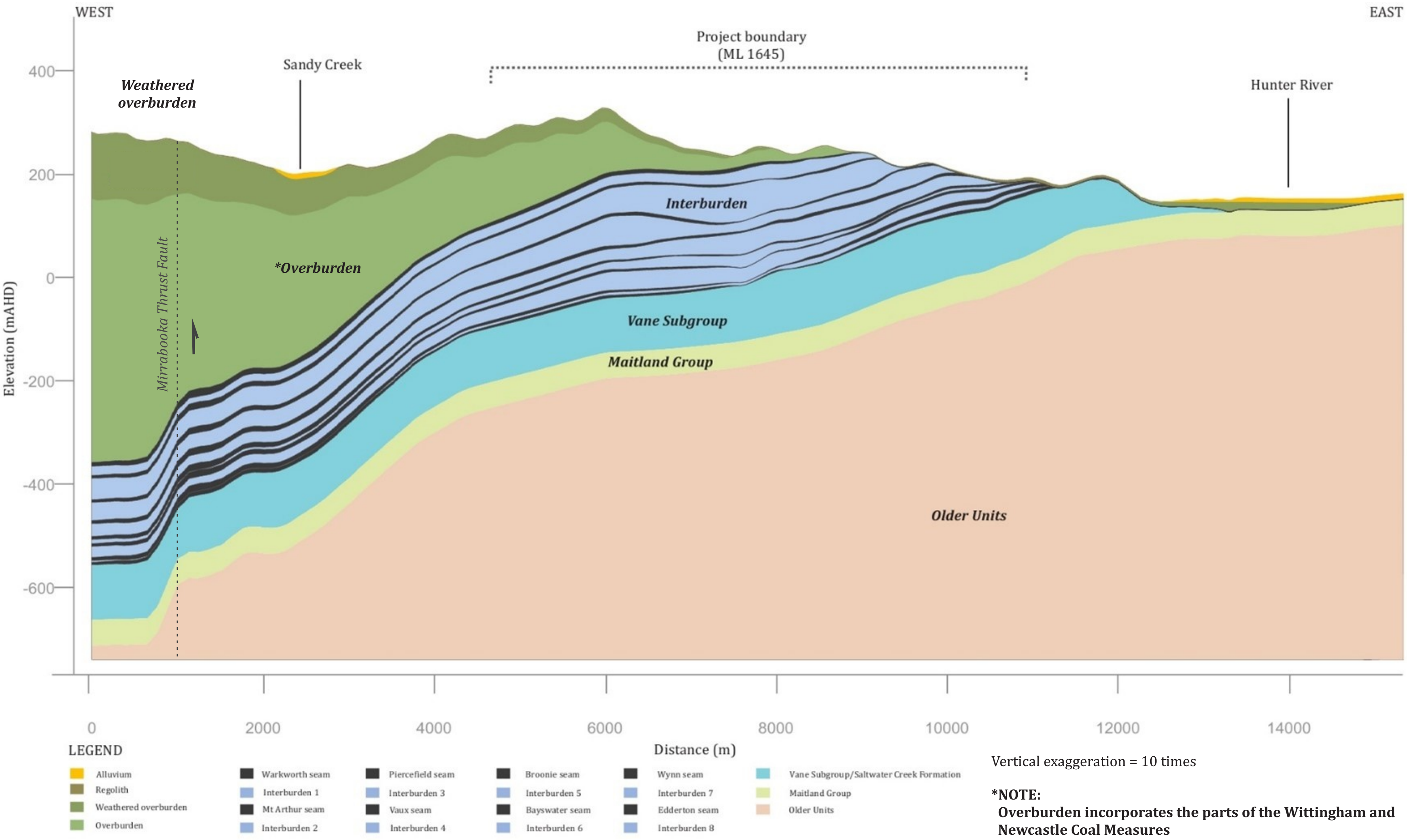


Conceptualised north - south geological cross section

Figure 4.2

Mt Pleasant GIA (G1970A)



Conceptualised west – east geological cross section

Figure - 4.3

Mt Pleasant GIA (G1970A)

4.2 Local geology

At a local scale, the following stratigraphic units occur within, or adjacent to the Project (from youngest to oldest):

- Quaternary alluvium;
- Permian sediments (Wittingham coal measures);
  - Jerrys Plains Subgroup;
  - Vane Subgroup (including Saltwater Creek Formation); and
- Maitland Group.

Each of the main stratigraphic units is discussed in further detail below in order of increasing depth from ground surface and increasing geologic age.

4.2.1 Quaternary alluvium

Figure 4.1 shows areas of alluvium as mapped by Glenn and Beckett (1993) for the Hunter Coalfield Map. Near the Project, alluvial sediments are mapped along the Hunter River floodplain to the north, east and south, as well as along Sandy Creek to the west.

The Hunter Alluvium near the Project is typical of that deposited by a partially confined meandering river system that is characterised by a sedimentary sequence which fines upward. These sequences are commonly less than 20 m thick. MPO monitors seven bores (MPBH1, MPBH2, MPBH3b, MPBH4, MPBH5, MPBH6 and MPBH7) located within the Hunter Alluvium along the eastern boundary of the Mount Pleasant Operation (i.e west of Hunter River main channel). Lithology logs for these bores are presented in Figure 4.4.

These logs serve to classify the typical properties of the alluvial aquifer system in the vicinity of the Project and which are as follows:

- Poorly graded gravel beds 5-10 m thick, representing paleochannel deposits (from historical river meandering);
- Gravel beds progressively overlain by sediments of decreasing size (coarse sand to fine sands and clays), indicating a reduction in stream power at that location over time and
- Silty sand in the (approximately) upper 6 m, representing either overbank deposition or colluvial material transported from areas of higher topography.

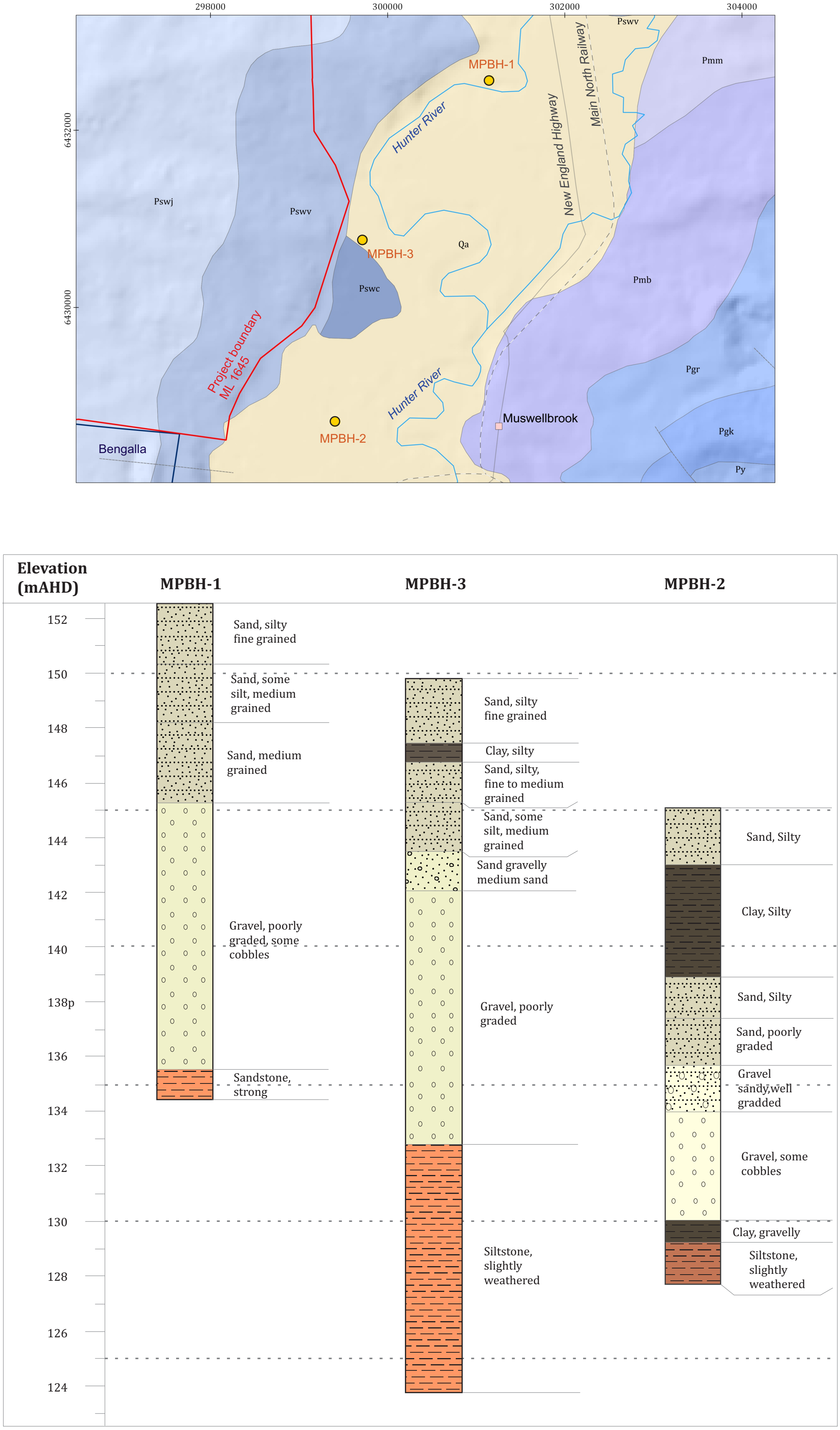
Similar stratigraphic sequences are described for the Hunter Alluvium in the groundwater assessments for Mt Arthur Coal Mine and Bengalla Mine (AGE, 2013a, b), with sand and silt overlying the basal gravels that exhibit higher groundwater productivity.

MPO has previously commissioned investigations to better understand the nature and extent of alluvium in the vicinity of the mine, these investigations included:

- Geophysical investigation (Groundwater Imaging, 2016) using transient electromagnetic (TEM) survey. The survey was undertaken along the eastern edge of the approved MPO boundary to assist in identifying unconsolidated sediments, including alluvium in this area.
- Investigative drilling (ENRS, 2018) in a number of locations selected based on the results of the geophysical survey and desktop analysis. Drilling was undertaken to confirm the presence or absence of alluvium in these locations to inform where MPO infrastructure and waste dumps might be situated.

Based on a review of topography data, geological mapping, MPO drilling data and registered groundwater works (bores) from the NSW government database to provide a refined understanding of the nature and extent of the alluvium in the vicinity of the MPO it was identified that:

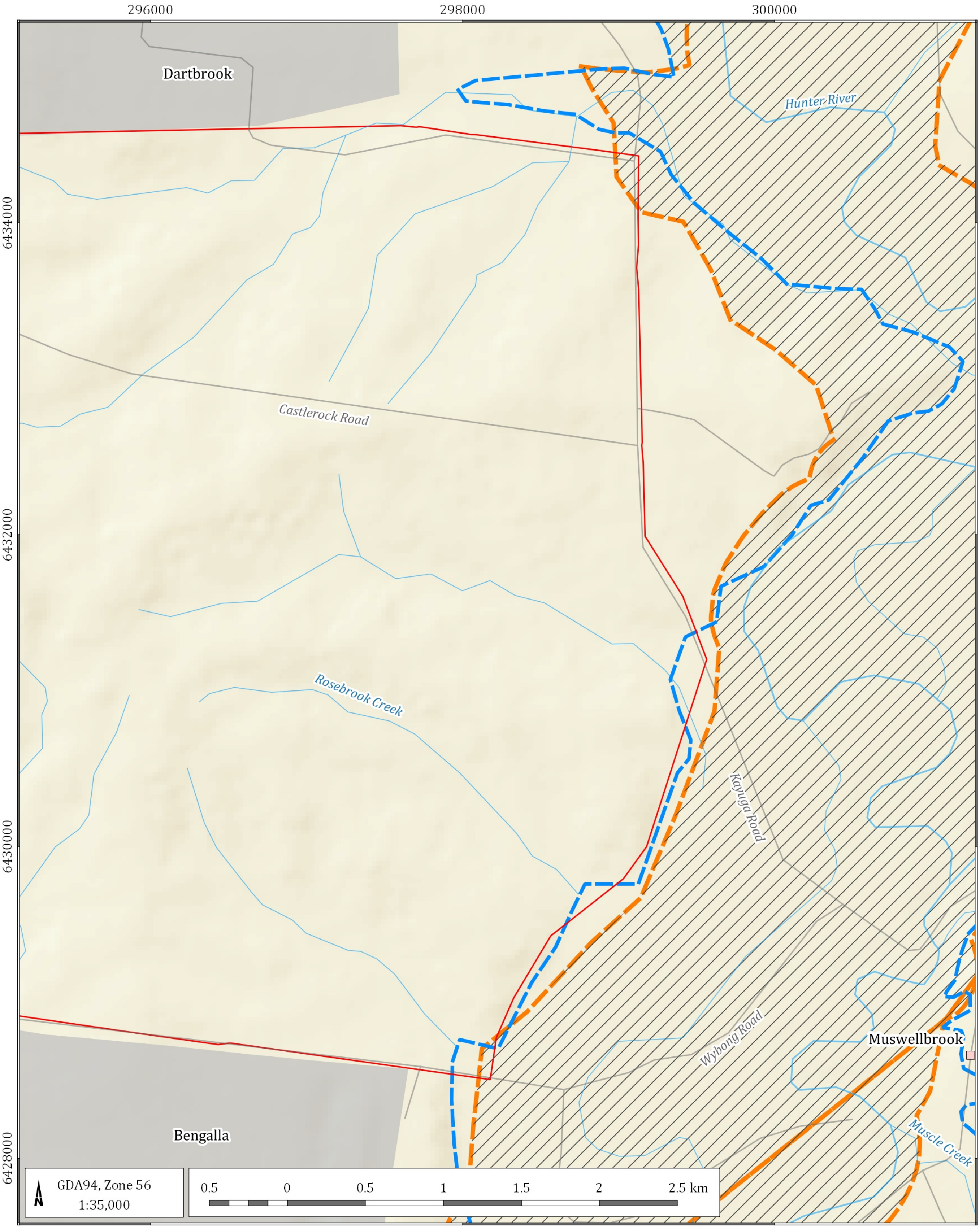
- Much of the unconsolidated material in many drillholes within the MPO boundary was weathered strata (regolith) dominated by fine-grained lithologies.
- Adjacent to the MPO boundary, alluvium broadly corresponds with mapped geology (Glenn and Beckett, 1993) (refer Figure 4.1), the Hunter Alluvium Water Source (refer Figure 2.1) and productive groundwater (refer Figure 2.2).
- Based on bore logs and the TEM survey, some local modification to mapped alluvial boundaries were required to either extend or reduce its extent (refer Figure 4.5).



Hunter alluvium thickness in bores

Figure 4.4

Mt Pleasant GIA (G1970A)



LEGEND

- Populated place
- Road
- Drainage
- Project boundary
- Surrounding mines
- Hunter Regulated River Alluvial Water Source
- Interpreted alluvial boundary
- Highly productive groundwater (DPI Water)

Mt Pleasant GIA (G1970A)

Interpreted extents of Hunter alluvium

AGE

DATE 01/04/2020

FIGURE No: 4.5

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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4.2.2 Wittingham Coal Measures

The Permian sediments of the Wittingham Coal Measures outcrop and subcrop beneath and to the west of the Hunter River. Further west, away from major drainage lines, the Wittingham Coal Measures are conformably overlain by the Newcastle Coal Measures, and to the north, unconformably by the Triassic sediments of the Narrabeen Group.

The target coal resources for both the approved MPO and the Project occur within the Permian sediments of the Wittingham Coal Measures; and include the Warkworth, Mt Arthur, Piercefield, Vaux, Broonie and Bayswater seams of the Jerrys Plains Subgroup; and the Wynn and Edderton seams of the Vane Subgroup. The target coal resource for the Project is approximately 120-180 m thick (from the top of Warkworth seam to the base of the Edderton Seam), with 25-30% of that thickness comprised of coal. Interburden between the coal seams of the Wittingham Coal Measures consists of interbedded lithic sandstone, siltstone, tuffaceous claystone and mudstone units which are a result of variable depositional environments. Figure 4.6 presents the typical stratigraphy at the Project whilst Figure 4.7 and Figure 4.8 provide imagery of stratigraphy in the MPO open cut face.

The youngest of the Permian sediments within the approved MPO, the Project area and surrounds are the Jerrys Plains Subgroup (Pswj on Figure 4.1). As shown on Figure 4.6, coal seams of the Jerrys Plains Subgroup above the Bowfield seam are not present at the Project.

The late Permian Vane Subgroup (Pswv on Figure 4.1) conformably underlies the Jerrys Plains Subgroup and is subdivided into the Foybrook Formation and the Archerfield Sandstone. The uppermost unit is the Archerfield Sandstone which comprises well-sorted quartz lithic sandstone deposited in a wave or current dominated lower deltaic plain depositional setting. The Archerfield Sandstone occurs at the base of the Bayswater seam, and is distinguishable as a massive, light brown or honey coloured sandstone.

The Foybrook Formation comprises coal bearing sequences with wedges of siltstone and sandstone. There are six main coal seams within the Foybrook Formation; in stratigraphic order (youngest to oldest) coal seams include Wynn, Edderton, Clanricard, Bengalla, Edinglassie and Ramrod Creek seams. Locally to the Project area, the Vane Subgroup outcrops east of the Jerrys Plains Subgroup, adjacent to the Hunter River alluvium. The Vane Subgroup, including the Saltwater Creek Formation are also inferred to subcrop beneath the veneer of the Hunter alluvium.

Generally, the Permian coal measures at the Project are stratified (layered) sequences that have undergone deformation resulting in strata dipping at an approximate 4% gradient to the west. This dip locally increases in proximity to some of the faults noted above.

The seams associated with the Wittingham Coal Measures occurring in the approved MPO and the Project vary in thickness with a summary (Project target seams in **bold**) presented in Table 4.2.

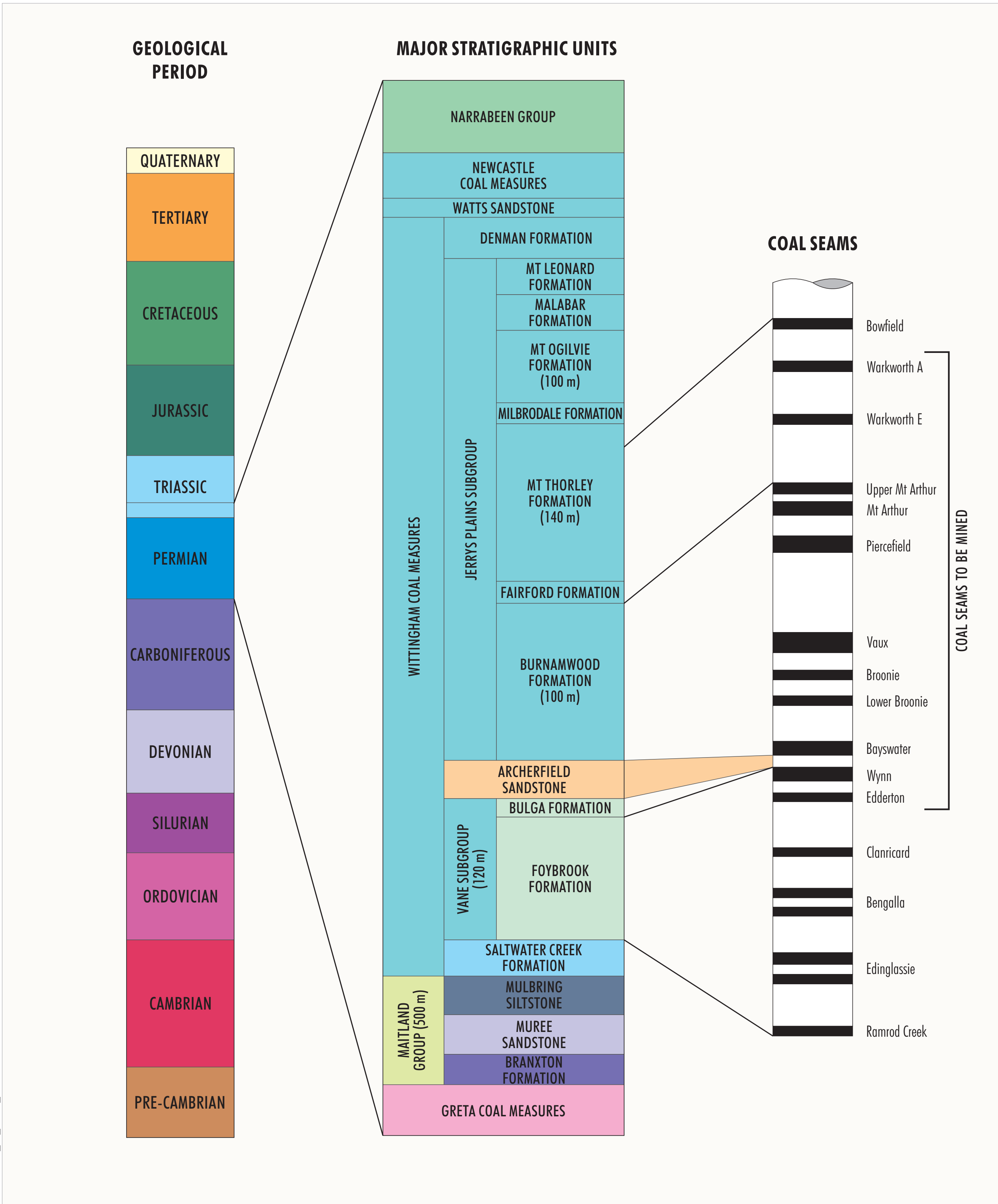
Table 4.2 Wittingham Coal Measures indicative thickness

Seam	10th percentile thickness (m)	90th percentile thickness (m)	Average thickness (m)
Bowfield	0.8	3.4	1.8
Warkworth	2.4	7.8	6.5
Mt Arthur	3.6	11.7	6.8
Piercefield	1.9	8.1	5.8
Vaux	3.7	37.1	17.0
Broonie	1.9	6.3	4.5
Bayswater	1.9	10.7	6.0
Wynn	3.2	7.7	5.1
Edderton	3.2	4.8	4.2
Clanricard	1.1	3.8	2.5
Bengalla	2.1	4.6	2.9
Edinglassie	3.7	6.3	5.8
Ramrod Creek	0.5 (20th percentile)	20.4 (80th percentile)	6.0

Figure 4.2 and Figure 4.3 show the surface and depth of the coal seams and interburden units in cross section. Figure 4.2 also indicates the Muswellbrook anticline and the strata dipping away from the fold axis and plunging to the west.

Locally there are two west-to-east trending faults within the MPO, as mapped by MACH. These are known as the 'North Fault' and 'South Fault' respectively, and have a small degree of displacement, up to 15 and 20 m respectively but generally much less. The orientations of these local faults are consistent with the group of faults mapped by Glenn and Beckett (1993) in the Bengalla area.

As noted in Section 4.2.1, a thin weathered profile occurs across the Permian sediments within the MPO. Figure 4.7 and Figure 4.8 show the MPO open cut face looking south west and north east respectively. Figure 4.7 provides an indication of coal seam dip and the depth of the weathered profile at the MPO whilst Figure 4.8 shows some local deformation above the coal seam. Of note in both figures is the absence of a saturated section in the exposed strata (i.e no seepage face).



MAC-18-02 SSD _EIS_App GW_001C

Source: MACH (2020)

MACHEnergy

MOUNT PLEASANT OPTIMISATION PROJECT

Mount Pleasant typical stratigraphic section

Figure 4.6

Figure 4.7 Mount Pleasant open cut pit face – looking south west

Figure 4.8 Mount Pleasant open cut pit face – looking north west

4.2.3 Maitland Group

The Maitland Group is a sedimentary sequence from the basal Branxton Formation (conglomerate), the Muree Sandstone, and the finer-grained Mulbring Siltstone. Review of cross-sections in Glenn and Beckett (1993), indicates that the thickness of the Branxton Formation is approximately 150 m near Muswellbrook (maximum reported thickness is >1000 m) whilst the Mulbring Siltstone is approximately 300 m (maximum reported thickness is 393 m).

The alluvial or deltaic Muree Sandstone is absent from this part of the Hunter Coalfield.

5 Hydrogeology

5.1 Hydrostratigraphic units

The geological units described previously can be grouped into the following 'hydrostratigraphic units' based on their ability to transmit groundwater:

- Quaternary alluvium – forms a relatively extensive alluvial aquifer system within the flood plains of the Hunter River and Sandy Creek; and
- Permian sediments that can be divided into:
    - thin, generally dry and variably permeable weathered rock (regolith);
    - non coal interburden such as conglomerates, claystones, siltstones and sandstones that forms aquitards; and
    - low to moderately permeable coal seams that act as the most transmissive strata within the coal measures sequence.

The sections below describe the hydrogeological properties of each of the hydrostratigraphic units and present a conceptual model for the groundwater regime.

5.2 Groundwater monitoring network

MPO currently monitors groundwater levels and quality using a network of monitoring bores. The monitoring network covers the Hunter alluvium, regolith and the Permian interburden/coal seams within the MPO. Monitoring bores within the Hunter alluvium are typically shallow (<20 m) owing to the shallow nature of the local alluvial deposits. The Permian strata are also monitored using bores installed in the shallow and deeper strata within the geological sequence. The locations of the MPO monitoring bores are shown on Figure 5.1. The adjacent Bengalla Mine also operates a groundwater monitoring network with both operations sharing the groundwater information collected. Summary details of the MPO groundwater monitoring network are provided in Table 5.1.

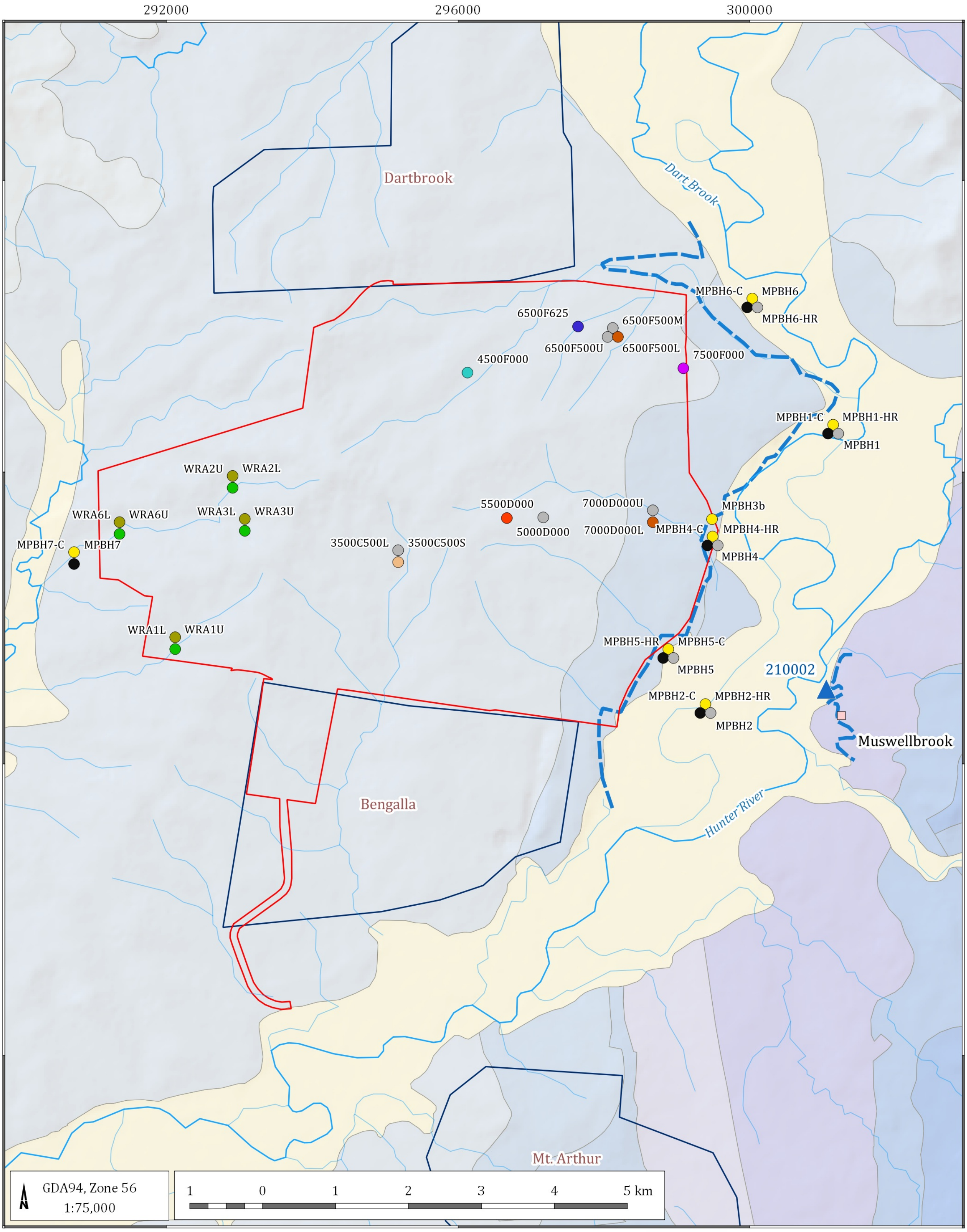
Table 5.1 MPO groundwater monitoring network

Bore ID	General Location	Easting (GDA94)	Northing (GDA94)	Elevation (mAHD)	Total Depth (m)	Aquifer/Unit
Melody	Central	297623	6434011	192.1	43.8	Interburden
MPBH1	Eastern	301151	6432563	152.54	18	Alluvium
MPBH1-C	Eastern	301140	6432567	153.57	77	Coal
MPBH1-HR	Eastern	301134	6432573	153.51	50	Interburden
MPBH2	Eastern	299403	6428716	145.03	17.4	Alluvium
MPBH2-C	Eastern	299383	6428748	146.15	80	Coal
MPBH2-HR	Eastern	299385	6428746	146.10	50.5	Interburden
MPBH3b	Eastern	299481	6431354	149.98	14	Alluvium
MPBH4	Eastern	299477	6431036	148.07	15	Alluvium
MPBH4-C	Eastern	299489	6431035	149.89	81	Coal
MPBH4-HR	Eastern	299500	6431033	149.62	50.5	Interburden
MPBH5	Eastern	298875	6429486	144.25	10	Alluvium
MPBH5-C	Eastern	298881	6429491	145.92	33.2	Coal
MPBH5-HR	Eastern	298889	6429495	146.02	22	Interburden
MPBH6	Eastern	300032	6434294	157.85	17	Alluvium
MPBH6-C	Eastern	300034	6434303	157.87	115	Coal
MPBH6-HR	Eastern	300033	6434298	157.83	65	Interburden
MPBH7	Western	290737	6430821	196.41	11	Alluvium
MPBH7-C	Western	290729	6430820	195.65	75	Coal
3500C500S	Central	295177	6430846	239.80	28.48	Interburden #1
3500C500L	Central	295177	6430846	239.80	86.77	Mt Arthur Seam
4500F000	Central	296128	6433364	217.20	121.24	Vaux Seam
5000D000	Central	296667	6431369	241.10	171.35	Wynn and Edderton Seams
6500F500U	Central	298120	6433894	189.00	35.1	Interburden #4/Broonie Seam
6500F500M	Central	298120	6433894	189.00	77.3	Interburden #6/Wynn Seam
6500F500L	Central	298120	6433894	189.00	115.2	Maitland Group
6500F625	Central	297644	6433996	194.10	36.3	Permian - unknown
7500F000	Central	299088	6433423	183.70	182.8	Edderton Seam
WRA1U	Western	292118	6429657	218.04	6.5	Regolith

Bore ID	General Location	Easting (GDA94)	Northing (GDA94)	Elevation (mAHD)	Total Depth (m)	Aquifer/Unit
WRA1L	Western	292121	6429650	217.80	19.4	Warkworth seam
WRA3U	Western	293075	6431276	258.07	6.75	Regolith
WRA3L	Western	293074	6431275	257.67	22.19	Warkworth seam
WRA6U	Western	291354	6431233	212.13	9.27	Regolith
WRA6L	Western	291359	6431231	211.67	18.98	Warkworth seam

In summary the key aspects of the MPO monitoring network (shown on Figure 5.1) are as follows:

- the network is comprised of three areas: Eastern, Western and Central;
- the eastern network monitors groundwater in the alluvial aquifer in the Hunter River via five bores (MPBH1 through MPBH5);
- the western network monitors groundwater in the alluvium/ regolith and underlying Permian strata in drainage lines that discharge to the west (i.e. Sandy Creek); and
- the central network monitors groundwater in the coal seams and interburden units proximal to open cut pits.



LEGEND

- Populated place
- Water NSW stream gauge
- Drainage
- Project boundary
- Surrounding mines

Surface geology

- Qa - Quaternary Alluvium
- Psl - Wollombi Coal Measures
- Pswj - Denman Fmt, Jerrys Plains Subgroup
- Pswv - Archerfield Ss., Vane Subgroup
- Pswc - Saltwater Creek Formation
- Pmm - Mulbring Siltstone
- Pmb - Braxton Formation
- Pgr - Greta Coal Measures
- Pgk - Greta Coal Measures
- Py - Gyarran Volcanics

- Interpreted alluvial boundary

Groundwater monitoring bores

- Alluvium
- Regolith
- Edderton Seam
- Interburden
- Maitland Group
- Mt Arthur Seam
- Permian - unknown
- Vaux Seam
- Warkworth seam
- Wynn and Edderton Seams
- Coal

Mt Pleasant GIA (G1970A)

Mount Pleasant groundwater monitoring network

AGE

DATE 18/09/2020

FIGURE No: **5.1**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\GIA_report\05.01_G1970A_Mount Pleasant groundwater monitoring network.qgs

5.3 Hydraulic properties

The hydraulic properties that govern groundwater storage and flow across the broader region vary considerably between the unconsolidated Quaternary alluvial systems and the confined hard rock Permian groundwater system associated with the coal measures. Details of the hydraulic properties in the aquifers associated with the Project are presented below.

5.3.1 Hydraulic conductivity

Hydraulic property data within the Project areas has historically been collected at the MPO, much of it during the original approvals process in the 1990s. Results of slug, packer and core testing were presented in the original Environmental Impact Statement (ERM Mitchell McCotter, 1997) and a supplementary submission to the Commission of Inquiry (ERM Mitchell McCotter, 1999).

The results of the packer testing program are presented in Table 5.2.

Table 5.2 Hydraulic conductivity packer test data

Bore ID	Test zone	Test depth	Hydraulic conductivity (m/day)
5750D750	Broonie seam	56-59	3.7×10^{-2}
	interburden	72-75	6.2×10^{-3}
	interburden/coal	83-86	5.3×10^{-3}
	interburden	87-90	1.0×10^{-4}
	Bayswater seam	91-94	1.1×10^{-1}
	Wynn seam	106-109	1.0×10^{-1}
	interburden	113-116	3.2×10^{-3}
	interburden	124-127	6.4×10^{-3}
	Wynn seam	133-136	8.0×10^{-2}
	Edderton seam	141-144	6.3×10^{-2}
4750C000	interburden	52–55	1.1×10^{-3}
	Piercefield seam	70.5-73.5	1.4×10^{-1}
	interburden	77-80	8.0×10^{-4}
	interburden	97.5–100.5	1.1×10^{-3}
	interburden	111–114	3.0×10^{-3}
	Broonie seam	135–138	3.4×10^{-2}
	interburden	153.5–156.5	3.3×10^{-3}
	interburden	164.5–167.5	1.7×10^{-3}
4250F250	Piercefield seam	86–89	1.5×10^{-2}
	Vaux seam	150-153	1.5×10^{-1}
	Bayswater seam	191.5–194.5	9.6×10^{-2}
	interburden	127–130	2.6×10^{-3}
	interburden/coal	173.5–176.5	3.0×10^{-3}
	interburden	211–214	2.4×10^{-3}

ERM Mitchell McCotter (1997) stated that testing (unknown method, assumed to be pumping tests) had been undertaken at three locations in the Hunter River alluvium. The results of these tests produced estimates of hydraulic conductivity of 8.8, 18.9 and 33.2 m/day (harmonic mean = 15.3 m/d). AGE (2013b) reported results in the range 5-40 m/day for Hunter River alluvium, as did Aquaterra (2006), who reported 50 m/day. These reported values for hydraulic conductivity are relatively high and likely associated with underlying gravel at the base of the alluvium, as observed in the bore logs shown on Figure 4.4.

To supplement the MPO data, horizontal hydraulic conductivity values for the coal seams and interburden units determined from field testing at other mine sites in the vicinity of the Project were compiled (AGE, 2013a, 2013b, 2014; MER, 2006, 2007). The results of this compilation are presented graphically in Figure 5.2 (coal) and Figure 5.3 (interburden).

As shown on Figure 5.2, testing results indicate that horizontal hydraulic conductivity values in the coal seams are in the range between 1 x 10^{-5} to 1 m/day. Similar testing conducted in the Permian interburden units returned lower values, ranging from predominantly between 1 x 10^{-6} to 1 x 10^{-2} m/day (i.e. hydraulic conductivity was generally two orders of magnitude lower than the coals).

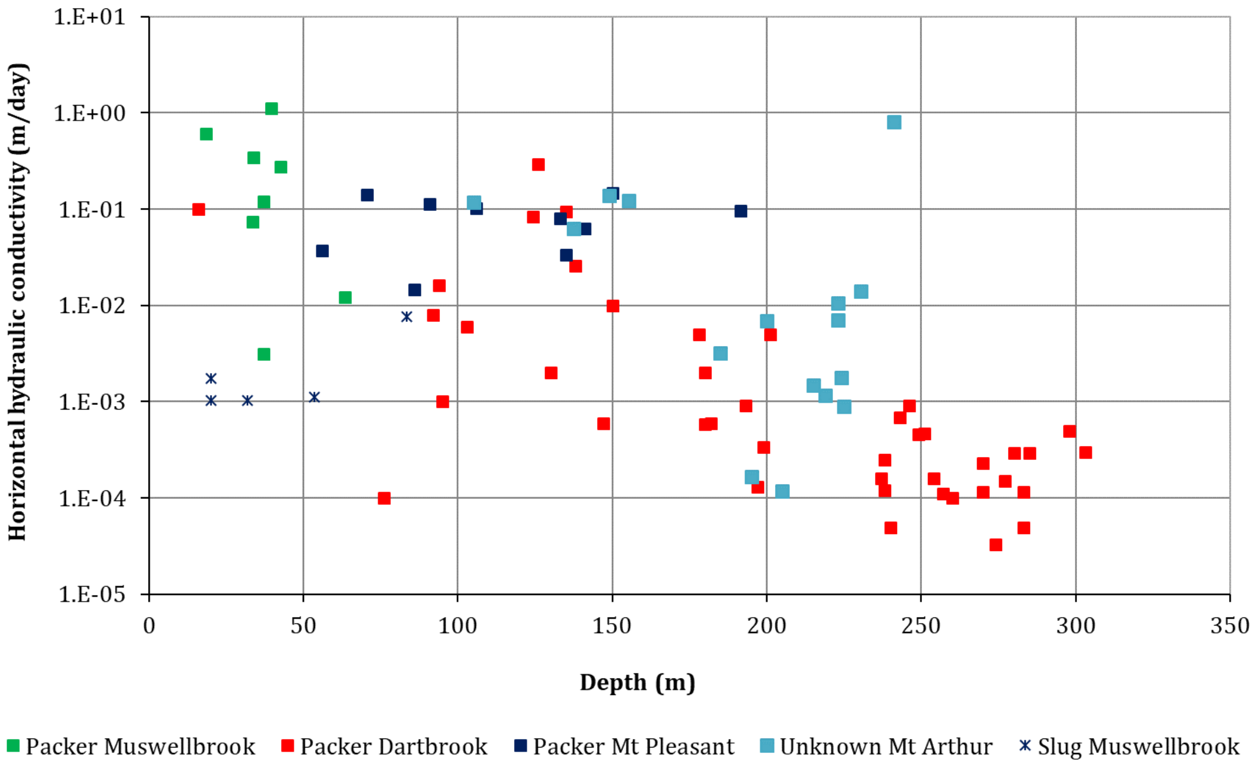


Figure 5.2 Hydraulic conductivity vs depth – Permian coal

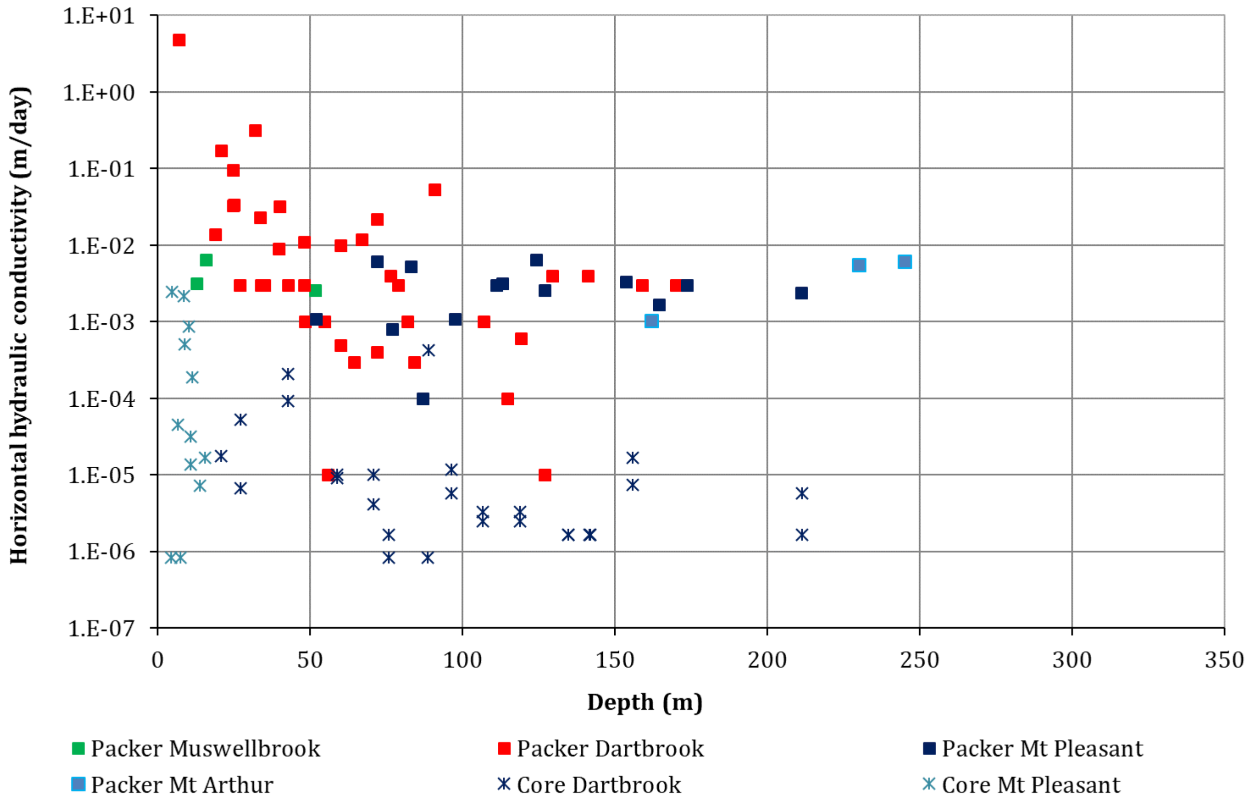


Figure 5.3 Hydraulic conductivity vs depth – Permian interburden

5.3.2 Storage properties.

A number of measurements of total porosity from Bulga exploration core samples vary between 4.3 to 10.7% for those interburden units that correspond with the target sequence at the Project (MER, 2013). Total porosity is a theoretical upper limit for the groundwater held in a volume of rock or soil and is significantly higher than the porosity that would be drained under gravity (Specific yield [Sy]). It is noted that Sy together with porosity(n) and specific storage (Ss), usually decreases with depth.

However, Rau *et al* (2018) concluded that based on poroelastic theory Ss can only theoretically occur between the range of 2.3 x 10^{-7} m^{-1} and 1.3 x 10^{-5} m^{-1}.

5.4 Saturation and productivity

5.4.1 Hunter River alluvium

As noted in Section 2.3.1, the Quaternary alluvium associated with the Hunter River is recognised as a highly productive groundwater system. The alluvial material typically offers significantly increased groundwater storage when compared to the underlying Permian coal seams, through higher interstitial porosity.

Figure 5.4 below shows the saturated thickness of the Hunter alluvium measured between 2003 and 2018 in the monitoring bores with extensive historical monitoring records. Review of the borehole logs for these bores (refer Figure 4.4) indicates that groundwater occurs within the gravels at the base of the alluvial sequence. This is further supported by water level observations, shown in Figure 5.5 which identifies that water levels in the monitoring bores correspond with the top of the gravels noted in the borehole logs.

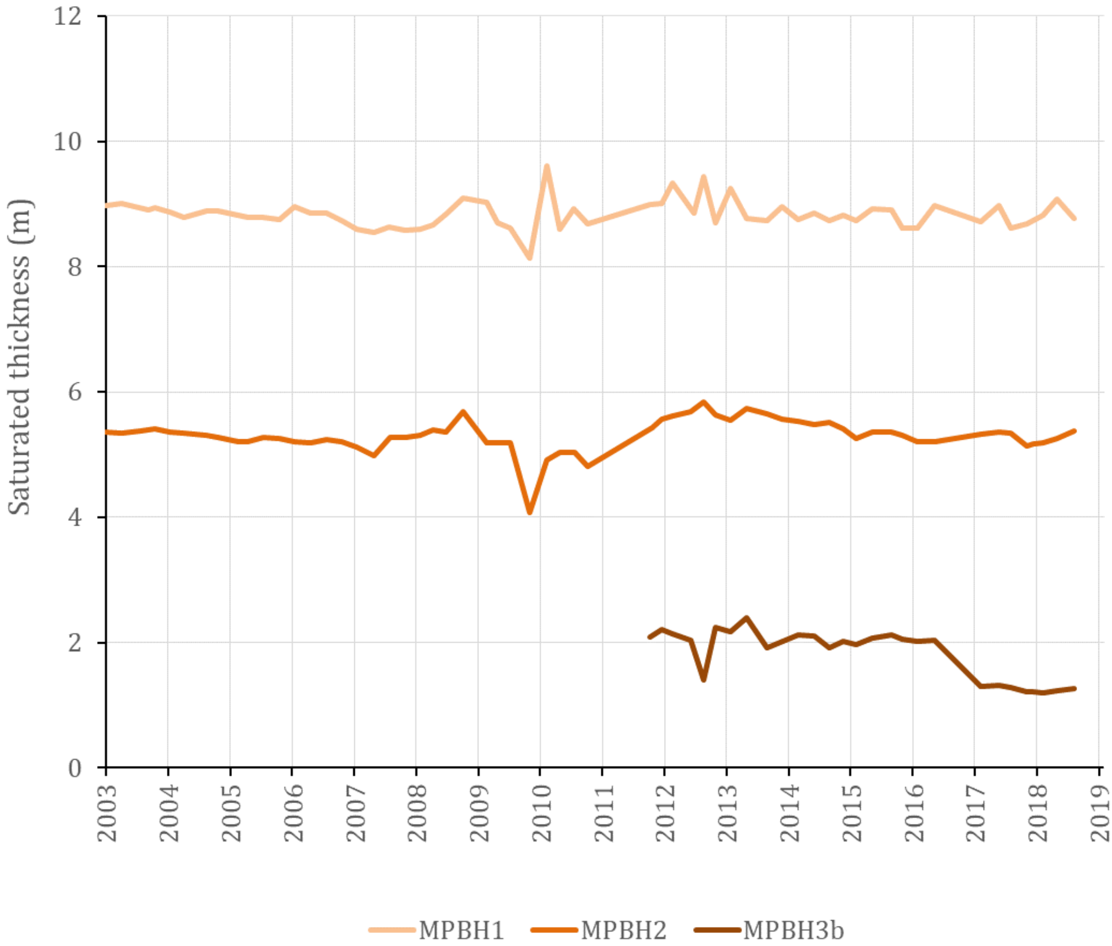


Figure 5.4 Saturated thickness – Hunter alluvium

5.4.2 Permian sediments

Saturation of the Permian strata occurs in both the coal seams and interburden. The ability to yield water is limited to the coal seams, as the interburden does not transmit significant volumes of groundwater, instead acting as an aquitard confining the coal seams. The coal seams are comprised of multiple plies with intervening non-coal interburden. When the plies and non-coal layers are combined each seam can range from 2.5 m to 10 m in thickness and is generally fully saturated with groundwater. The yield from the coal seams is also relatively low due to limited permeability and thickness, meaning they cannot be classified as 'highly productive", and are considered "less productive". Figure 4.7 and Figure 4.8 shows the coal seams intersected in MPO open cuts and illustrates the lack of significant seepage from the interburden rock units and the coal seams. This limited seepage from the coal seams is typical of Hunter Valley mines, which do not commonly need to remove significant volumes of groundwater from the mining face/pit as the volumes of seepage are low and readily evaporate from the pit face.

5.5 Water levels

5.5.1 Hunter River alluvium

Figure 5.5 presents water levels in the Hunter alluvium measured between 2003 and 2018 in three monitoring bores, MPBH1, MPBH2 and MPBH3b (refer Figure 4.4). This figure also presents water levels compared to the average monthly stream water level in the Hunter River and the CRD, as derived from SILO data (refer Section 3.2.1). The average monthly stream water level shown was calculated using the stage record for WaterNSW gauge 210002 (Hunter River at Muswellbrook). The water level was then adjusted using the zero gauge elevation.

Figure 5.5 shows a clear head separation between the nearest bore to the gauge (MPBH2, 980 m from the gauge). This separation suggests losing surface water conditions in this reach of the river. Review of LiDAR data and water levels at MPBH1 and MPBH3, both upstream of the gauge, indicate levels are below the invert of the river channel. This also suggests losing surface water conditions in the vicinity of these bores.

The conclusion drawn from the baseline monitoring conducted within the Hunter alluvium is that water levels in the alluvium are generally stable and do not exhibit a marked response to rainfall. This indicates that losses from the surface water system maintain the alluvial aquifer in this area.

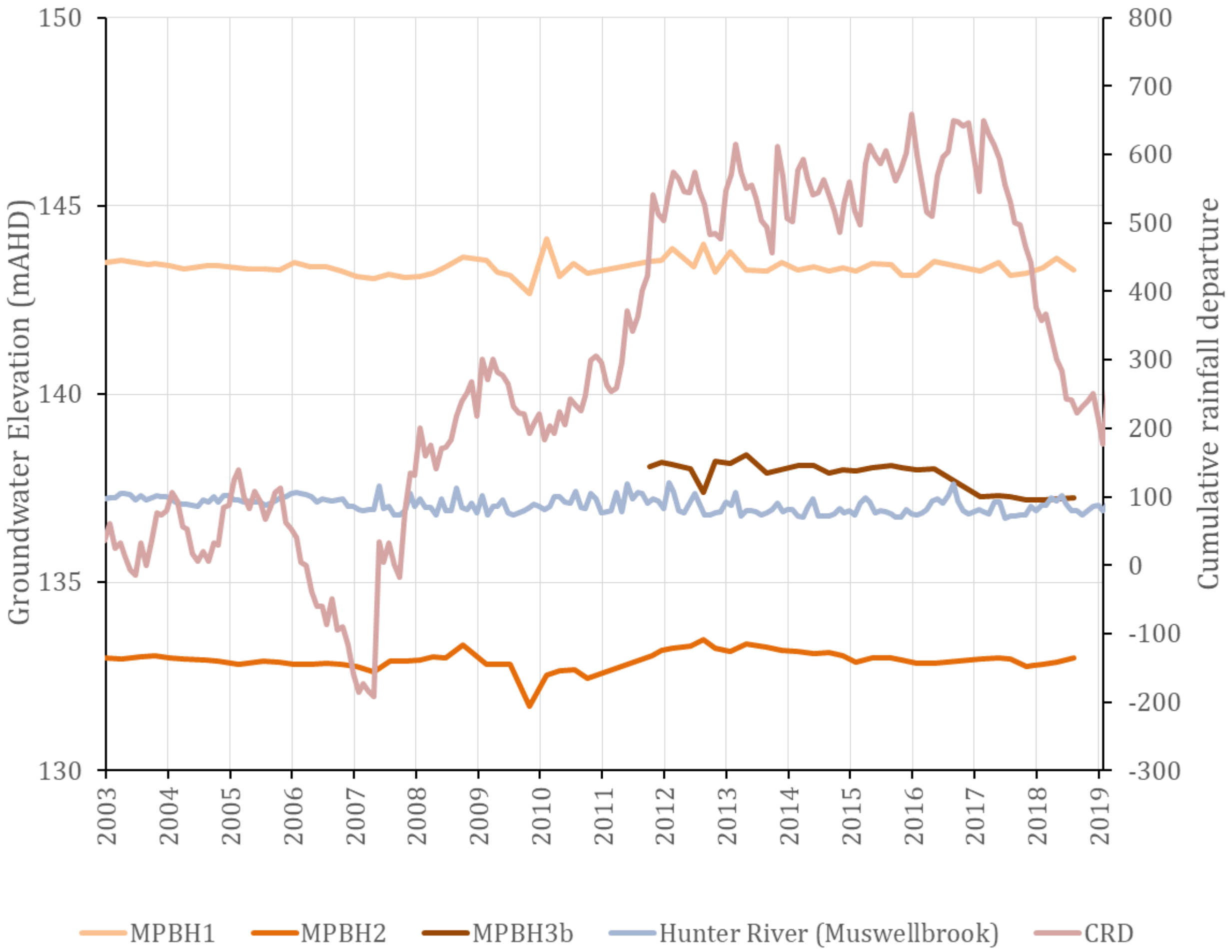


Figure 5.5 Water levels – Hunter alluvium and Hunter River

5.5.2 Permian sediments – Western area

Monitoring bores in the west of the MPO (WRA1, WRA2, WRA3, WRA5, WRA6 [see Figure 5.1]) are all located within shallow Permian sediments. These are nested monitoring bores with separate piezometers within the regolith and underlying unweathered Permian strata. The upper piezometer (U) is screened in regolith (i.e. weathered rock [WRA3, WRA5 and WRA6 only]), with the lower piezometer (L) screened in either Permian interburden or coal seams, below the depth of weathering (refer Table 5.1). The water levels recorded within the regolith and underlying strata and shown on Figure 5.6 are similar, indicating a degree of connectivity between these units and/or limited vertical gradients between the strata. Figure 5.6 also shows the CRD (refer Section 3.2.1) for the period shown. Comparison with the CRD indicates that water levels in the monitored strata do not exhibit a marked response to rainfall. Moderate groundwater flow is expected through the relatively permeable regolith and is expected to follow topography. Whilst the regolith has the potential to hydraulically connect the alluvium to the mine workings, this unit is typically dry, thin (refer Figure 4.7 and Figure 4.8) and topographically separated from the open cut pits (i.e. drainage divide).

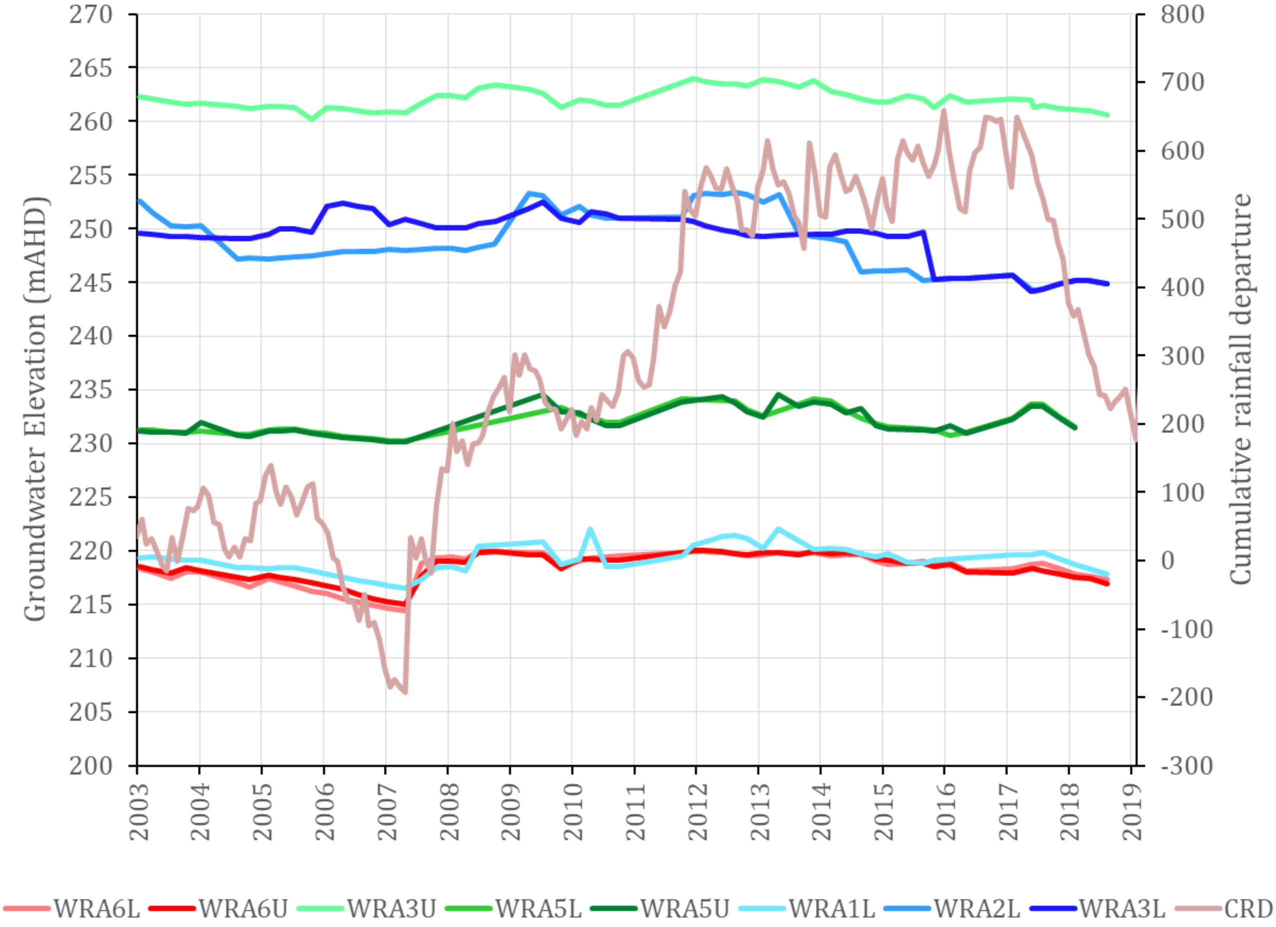


Figure 5.6 Water levels – Western area regolith and Permian sediments

5.5.3 Permian sediments – Central area

Groundwater in the central section of the MPO, north and west of the open cut pits, is monitored via a network of eleven monitoring bores (refer Figure 5.1). The monitoring bores of the central network target Permian sediments including interburden, coal seams and the underlying Maitland Group (6500F500L and 7000D000U). Table 5.1 presents information on the Permian strata in which these bores are screened. Three locations (6500F500, 3500C500 and 7000D000) are nested monitoring bores with an upper piezometer (U) and lower piezometer (L). Water level observations for these bores are presented on Figure 5.7.

Figure 5.7 show that, apart from a slight decline at 3500C500L, water levels within the upper interburden units (3500C500L and 3500C500S) are relatively stable and show no response to rainfall variation, as shown by the CRD. Mixed interburden and coal units (5500D000, 6500F00U, 6500F500M and 7000D000U) are also relatively stable and do not show drawdown influence from the nearby Dartbrook or Bengalla Mines.

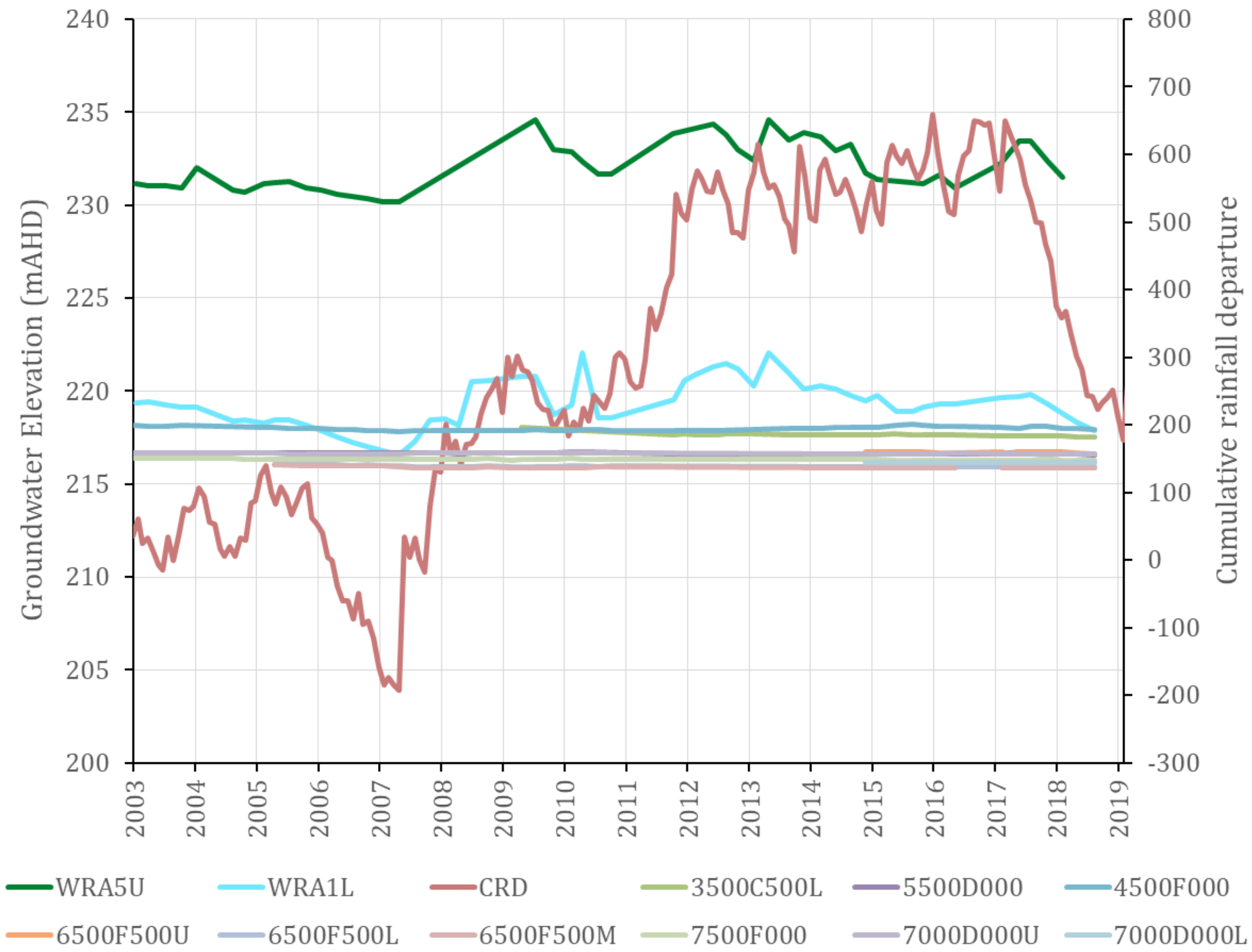


Figure 5.7 Water levels – Central area Permian sediments

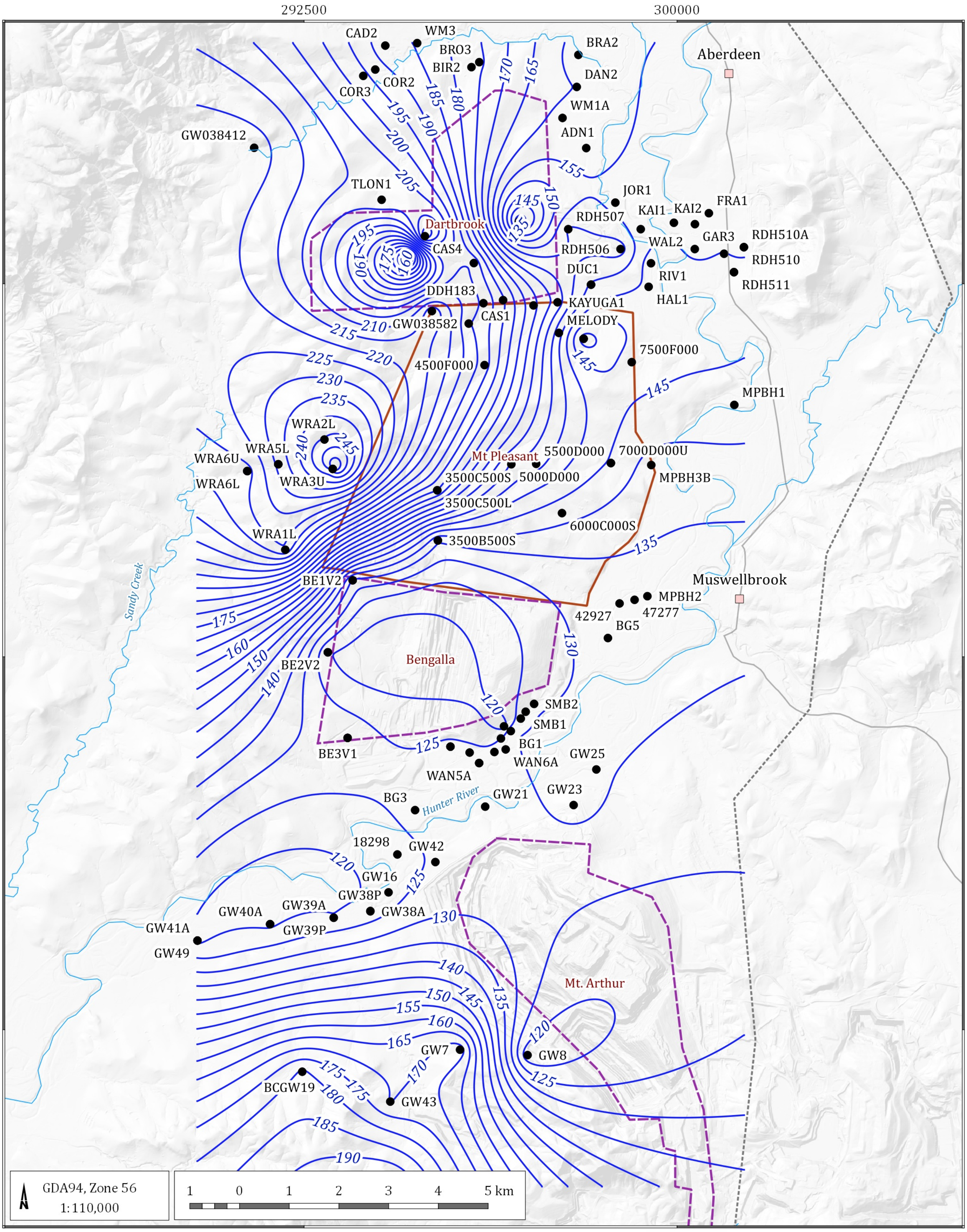
5.6 Groundwater flow

Regionally, groundwater tends to flow from elevated terrain toward the Hunter River floodplain. On the western side of the Project, the inferred groundwater gradient is generally steep. This gradient induces easterly flow from the elevated topography in the west. Gentler groundwater gradients from the Carboniferous volcanics and outcropping Permian strata associated with the Muswellbrook Anticline, induces flow in a westerly direction toward the Hunter River.

Groundwater flow within the Hunter River alluvium is in the direction of streamflow. As noted in Section 5.5.1 water levels in alluvial monitoring bores indicate a high degree of interaction between the alluvium and the Hunter River with surface water flow from the river to the adjacent alluvium. A map of water table contours based on 2016 monitoring data is presented in Figure 5.8. Drawdown from mine dewatering is indicated in the contours across the Dartbrook Mine, Bengalla Mine, and Mt Arthur Coal Mine mining areas.

Within the MPO, there is a groundwater divide associated with the topographic high in the western section of the MPO with:

- westward and then southerly groundwater flow toward Sandy Creek; and
- eastward and south-eastward groundwater flow toward the Hunter River.



LEGEND

- Populated place
- Regional monitoring bore
- Water table contour (mAHD)
- Drainage
- Road
- Mt Pleasant mine
- Surrounding mines
- Model boundary

Mt Pleasant GIA (G1970A)

Water table contours interpolated from 2016 observations

DATE 31/08/2020

FIGURE No: **5.8**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\GIA_report\05.08_G1970A - 2016 potentiometric surface.qgs

5.7 Groundwater quality and beneficial use

5.7.1 Salinity and pH

This section describes the water quality and beneficial use of groundwater within the Quaternary alluvium and Permian sediments. Salinity is the key constraint to groundwater use, and can be described by total dissolved solid (TDS) concentrations. TDS concentrations are commonly classified on a scale ranging from fresh to extremely saline. Food and Agriculture Organization of the United Nations ('FAO') (2013) provide a useful set of categories for assessing salinity based on TDS concentrations as follows:

- Fresh water: <500 mg/L (approximately 750 µS/cm).
- Brackish (slightly saline): 500 to 1,500 mg/L (approximately 750 to 2,250 µS/cm).
- Moderately saline: 1,500 to 7,000 mg/L (approximately 2,250 to 10,500 µS/cm).
- Saline: 7,000 to 15,000 mg/L (approximately 10,500 to 22,400 µS/cm).
- Highly saline: 15,000 to 35,000 mg/L (approximately 22,400 to 55,250 µS/cm).
- Brine: >35,000 mg/L (approximately 55,250 µS/cm).

As noted in Section 5.3.1, MACH operates a groundwater monitoring network at the MPO. as shown in Figure 5.1 and detailed in Table 5.1. Each of the monitoring bores identified in Table 5.1 is attended quarterly for measurement of field parameters (pH and electrical conductivity [EC]). As EC is proportional to the total dissolved ions in a water sample it can be used to estimate TDS concentrations by multiplying by 0.67 (ANZG 2019).

Figure 5.9, Figure 5.10 and Figure 5.11 shows the ranges in groundwater EC (µS/cm) collected across the MPO monitoring bore network. These figures also show the FAO classifications that have been derived from the 0.67 EC to TDS multiplier.

Figure 5.9 presents the EC measured at monitoring bores within the Hunter alluvium adjacent to the Project and the Hunter River, measured at WaterNSW gauge 210002. Measured EC at MPBH1 (median 540 µS/cm) is consistent with the Hunter River (median EC 433 µS/cm) and can be considered as fresh water. When compared to the Hunter River, measured EC at MPBH2 (median 879 µS/cm) is slightly higher and within lower bound of the "brackish" water category. Groundwater at MPBH3b (median 3,860 µS/cm) has notably higher EC than the other alluvial bores and considered to be "moderately saline". Application of the EC to TDS multiplier identifies that groundwater in MPBH1 and MPBH2 falls within the 'highly productive' category (TDS <1,500 mg/L) of the AIP whilst that in MPBH3b does not.

Measured groundwater EC in the western monitoring network is shown on Figure 5.10. This network is comprised of bores situated adjacent to minor drainage features which discharge into Sandy Creek. Notably, groundwater in this network exhibits the highest EC for all MPO monitoring bores. Groundwater in this network sits within the moderately saline to saline classification with calculated medians between 3,520 µS/cm (WRA1L) and 15,830 µS/cm (WRA3L). With the exception of WRA3L, the median EC is within the ANZG (2018) recommended range for livestock drinking water (EC 7463 µS/cm [TDS < 5,000 mg/L]). Groundwater in the shallow regolith near Sandy Creek (WRA3U and WRA6U) returned calculated median values of 5,305 and 7,189 µS/cm respectively.

Measurement of groundwater EC in the central monitoring bores has not been continuous, as shown on Figure 5.11. EC in these bores is variable with median EC in the coal seams 1,850 µS/cm (brackish); interburden 4,270 µS/cm (moderately saline); mixed interburden and coal 1,855 µS/cm (brackish) and the underlying Maitland Group 1,340 µS/cm (brackish).

Whilst not shown on figures, calculated median pH for groundwater in each of the networks (eastern, western and central) was 7. The range of pH in the eastern and western networks was between 6.3 and 8.1 whilst that for the central network was greater (pH 5.7 to 12.4) reflecting the heterogeneity of the units monitored in this network.

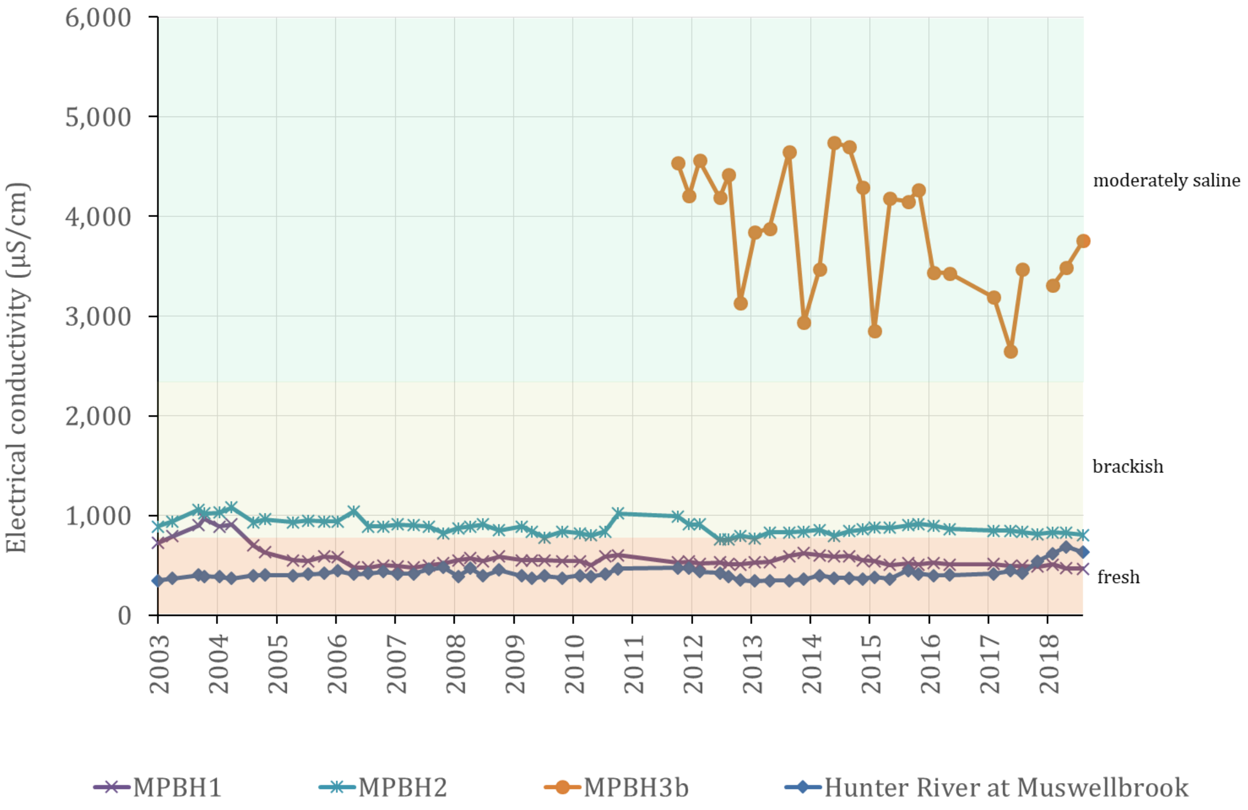


Figure 5.9 Electrical conductivity – Hunter alluvium and Hunter River

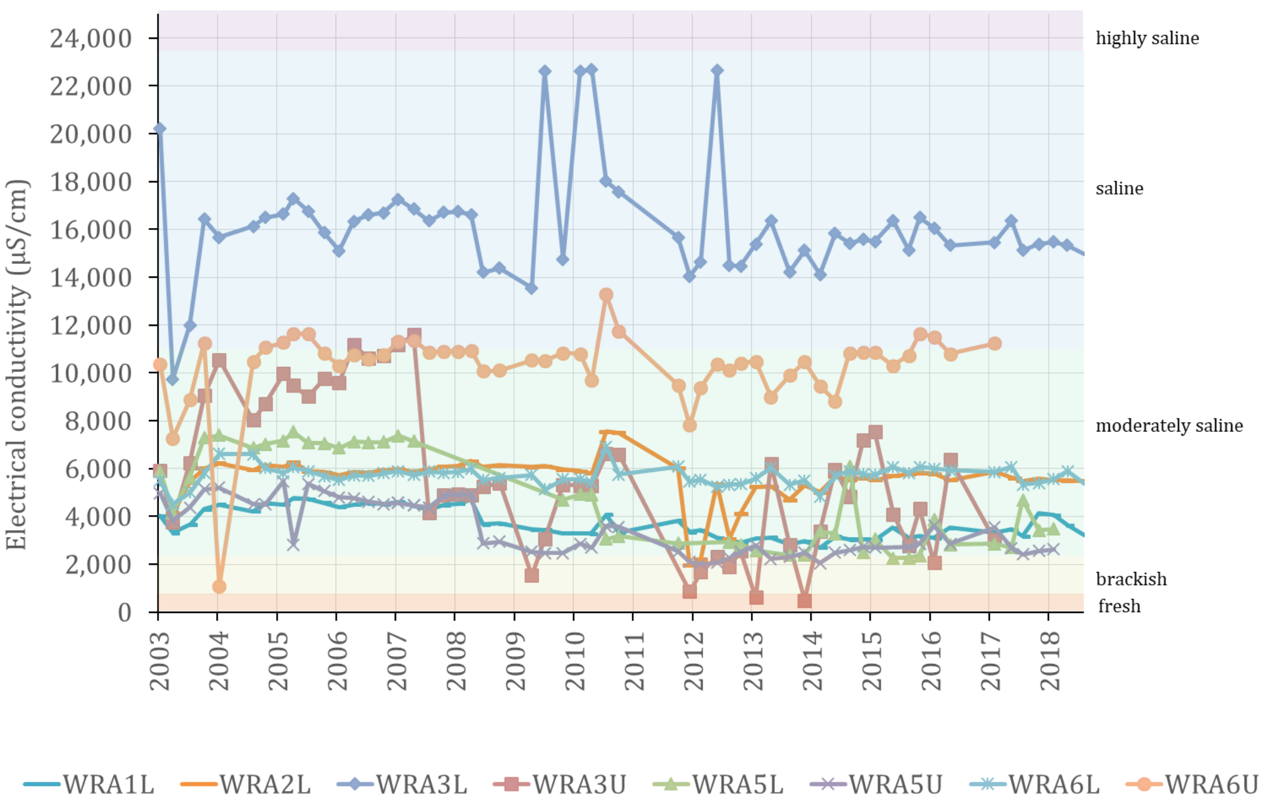


Figure 5.10 Electrical conductivity – Western area regolith and Permian sediments

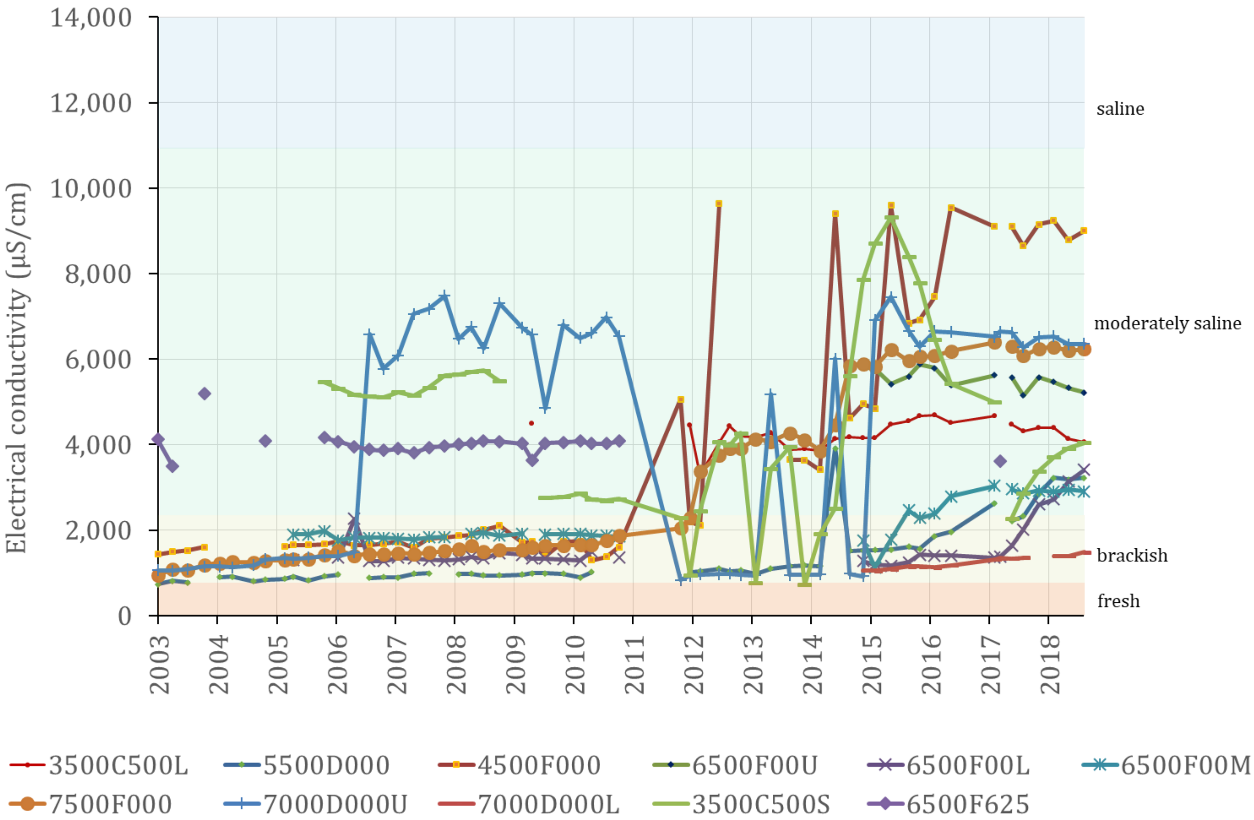


Figure 5.11 Electrical conductivity – Central area Permian sediments

5.7.2 Major ions

Analysis of the varying abundances and types of dissolved ions present in a sample can be used to classify groundwater. The chemical composition of a groundwater often reflects its origin and interactions with the host aquifer materials, including the dissolution and precipitation of minerals. Subsequently, the chemical classification of groundwater via major ion composition is a useful method to develop conceptual models of groundwater systems.

The major ion chemistry of 129 groundwater samples collected at the MPO is shown as a Piper plot on Figure 5.12. A Piper plot uses two tri-linear plots to represent the proportions of major cations (lower-left: $Na^+ + K^+$, Ca^{2+}, Mg^{2+}) and anions (lower-right: $HCO_3^- + CO_3^{2-}$, Cl, SO_4^{2-}) that are measured in a groundwater sample. Each analysis is then projected onto a third rhombohedral (upper) plot illustrating the overall water type.

Review of the Piper plot indicates that whilst the results for the Permian strata, including the coal measures, are variable, they are generally dominated by sodium, potassium and chloride resulting in classification as a sodium chloride type water. Groundwater in the alluvium could principally be classified as a magnesium carbonate type water with predominantly calcium and bicarbonate ions present in samples.

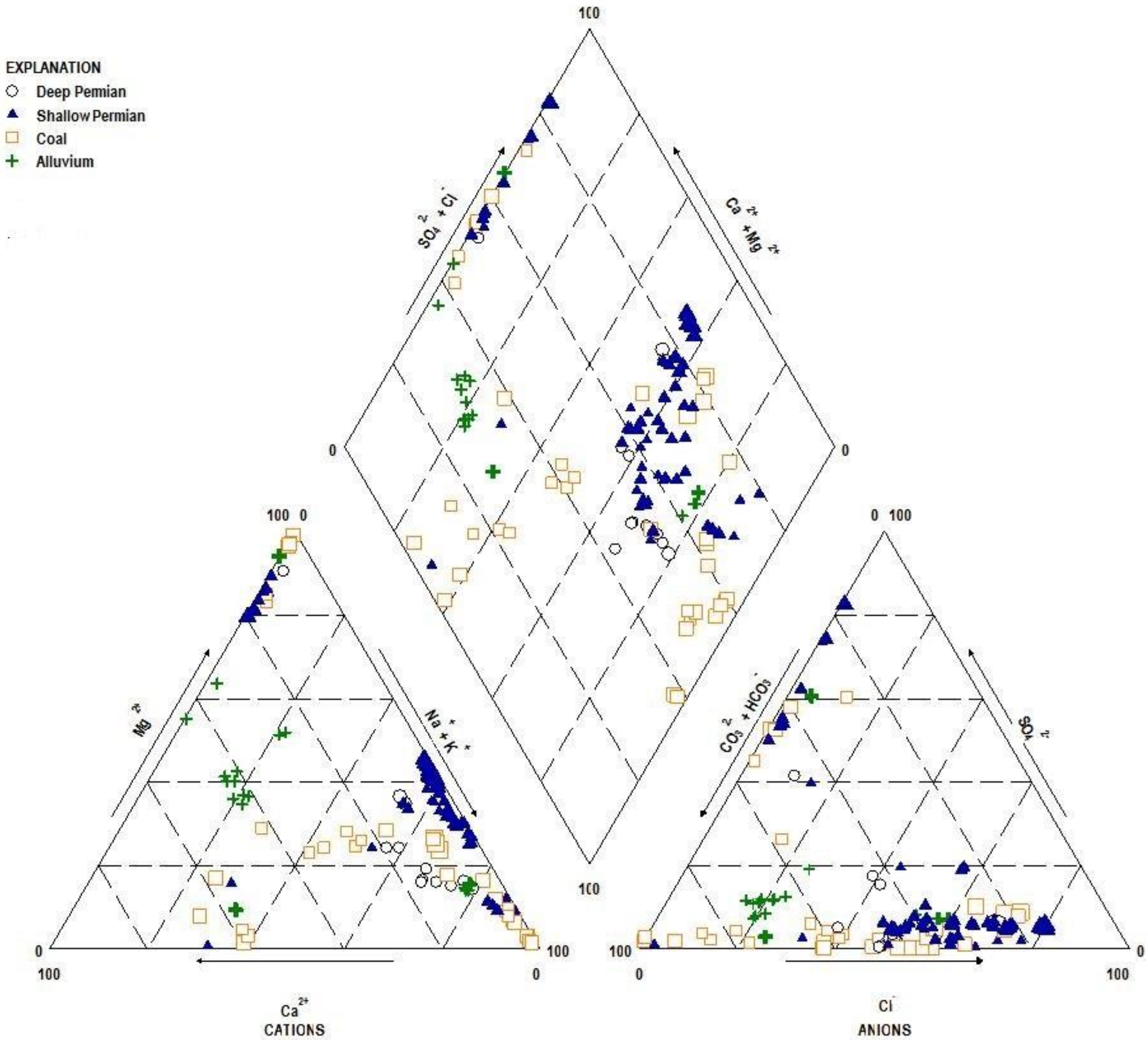


Figure 5.12 Piper plot of groundwater composition at the MPO

5.7.3 Metals

Metals and metalloids are trace elements that naturally occur in the Earth's crust. Trace elements are considered essential for many organisms in low quantities, however harmful if in high uptake. Inherently, the presence of trace elements in the subsurface results in the suspension and dissolution of these species in groundwater.

The Australian Drinking Water Guidelines (NHMRC, 2011) and ANZECC & ARMCANZ (2000) water quality guidelines outline standard concentrations that indicate when trace elements become harmful in water. The concentrations of trace metals in 131 groundwater samples from the Quaternary alluvium and Permian aquifers at the site are summarised in Figure 5.13. Comparison to the ANZECC & ARMCANZ framework illustrates that most trace element quantities measured at the site fall within acceptable limits for irrigation and livestock use in both the alluvial and Permian systems. Groundwater sourced from the alluvium demonstrates generally lower ion and trace concentrations and as such meets the stricter acceptable limits for human drinking water for more of the analytes (e.g. aluminium, arsenic, lead) than does the Permian sourced groundwater (NHMRC, 2011).

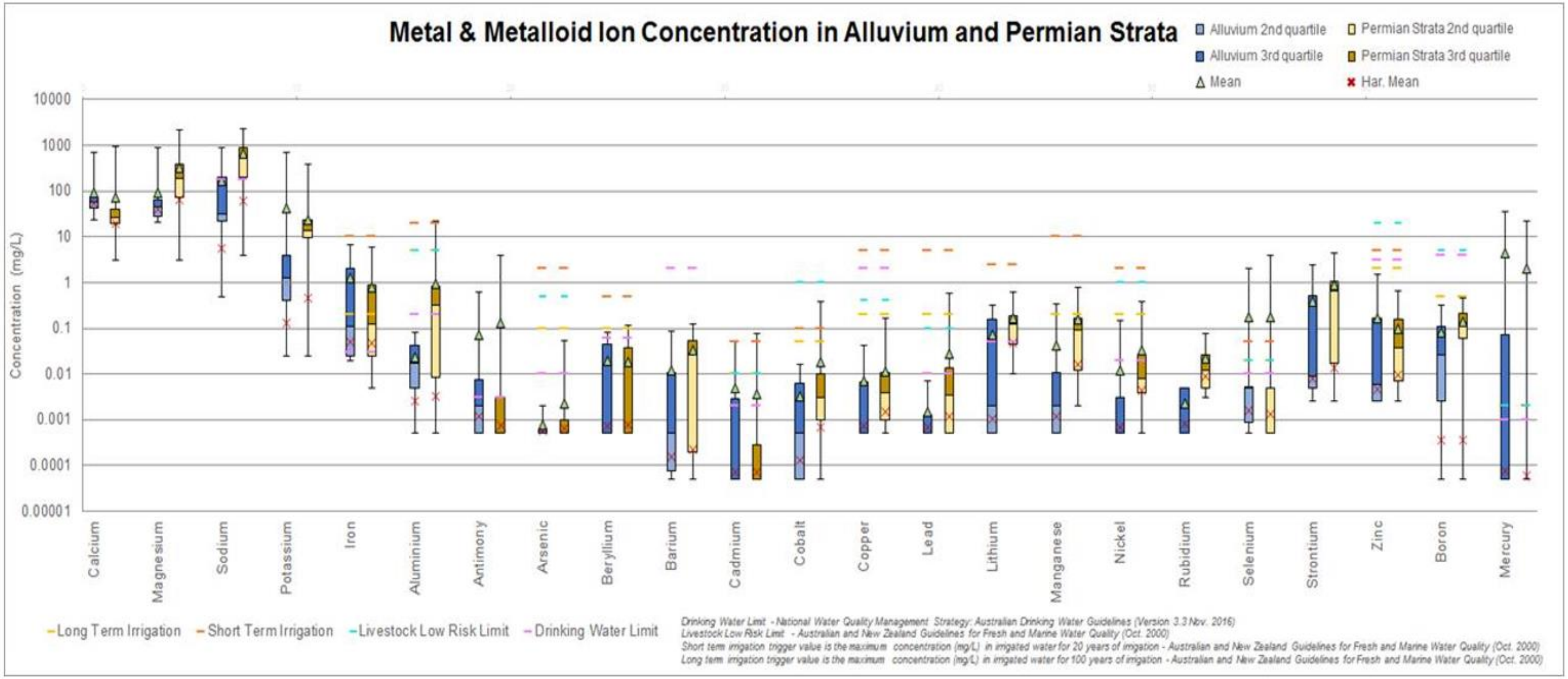


Figure 5.13 Metal and metalloid ion concentrations in Alluvium and Permian strata at the MPO

5.7.4 Beneficial Use

As noted above, salinity is the key restriction on beneficial use of groundwater at the MPO. Groundwater at the MPO falls between the brackish and moderately saline classification. This means that much of this groundwater (moderately saline to saline) is unsuitable for more sensitive uses such as human consumption and irrigation. The data does indicate that some MPO groundwater has salinity levels that could be tolerated by stock or used to irrigate salt tolerant crops.

Due to its lower EC, (fresh water), groundwater measured in much of the Hunter alluvium (e.g. MPBH1 and MPBH2) could be applied to a broader range of beneficial uses. These may include a larger range of crops under irrigation, livestock fodder or, dependent on additional parameters, this groundwater may be utilised as potable water.

5.8 Groundwater dependent assets

The IESC Information Guidelines require the identification of water-dependent assets with potential to be impacted by CSG and large coal mines. Information on potentially groundwater dependent assets from a number of different sources is summarised below.

5.8.1 Bioregional Assessment - Hunter subregion water dependent assets

In the context of Bioregional Assessments water-dependent assets are defined as *'an asset potentially impacted by changes in groundwater and/or surface water due to coal or coal seam gas development. Some ecological assets solely depend on rainfall and will not be considered as water dependent if evidence does not support a linkage to groundwater or surface water'* (Macfarlane *et al.,* 2016). Assets can be classified for economic, ecological, or sociocultural.

In the Hunter sub-region ecological water dependent assets are classified into three subgroups:

- 'Surface water feature' – 205 assets;
- 'Groundwater feature (subsurface)' – 24 assets; and
- 'Vegetation' – 1,422 assets, of which;
    - Groundwater-dependent ecosystems – 587 assets; and
    - Habitat (potential species distribution) – 835 assets.

The Hunter River alluvium is noted as alluvial aquifer assets within the 'Groundwater feature (subsurface)' subgroup (refer Figure 5.14) The alluvium along Sandy Creek is not differentiated from the bedrock groundwater units in terms of the asset groupings. There are no groundwater springs identified close to the Project.

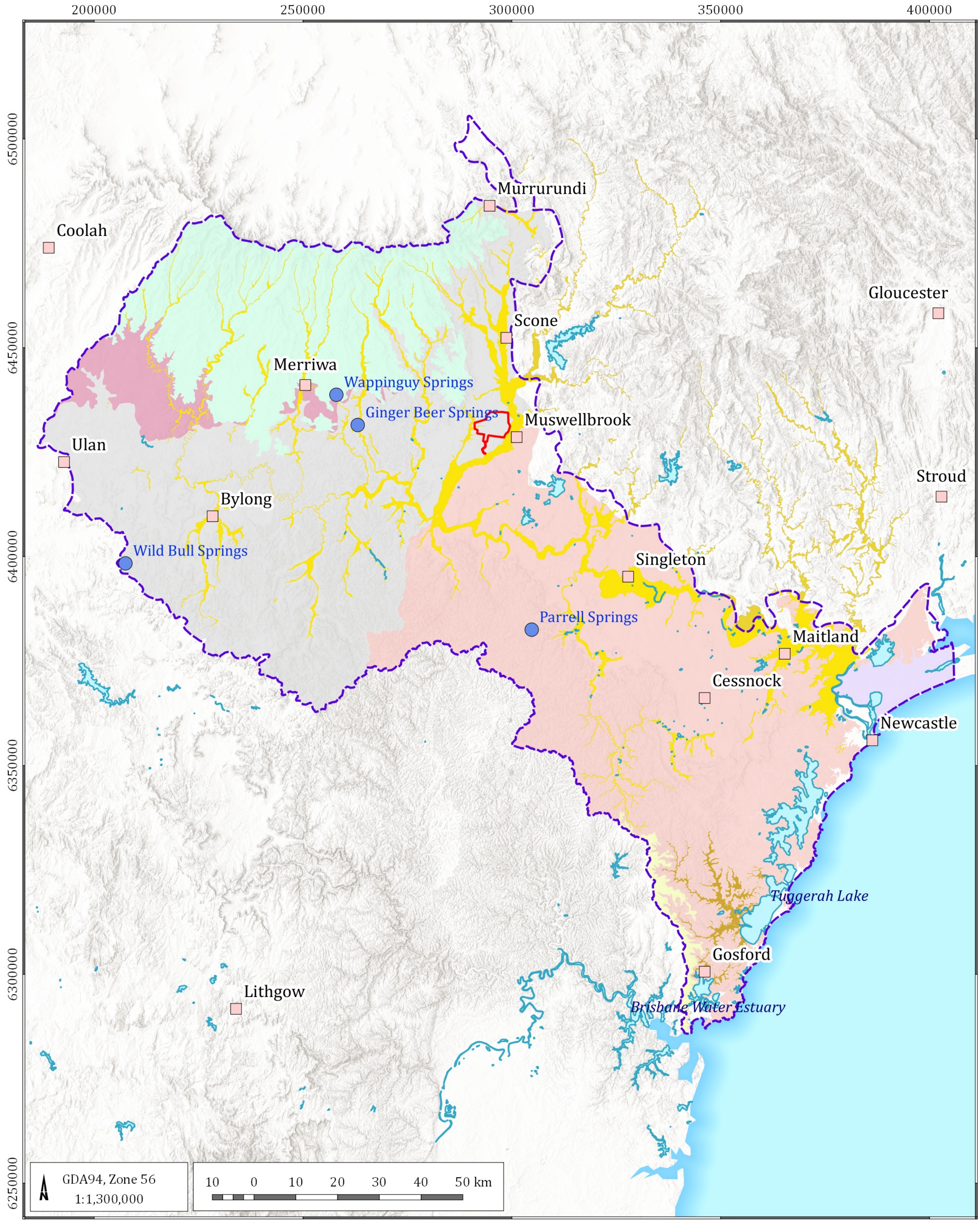
Assets within the 'Vegetation' subgroup and classified as 'Groundwater-dependent ecosystems' assets are shown on Figure 5.15. The closest assets to the Project are riverine forests located along the Hunter River. There are no vegetation assets identified along Sandy Creek.

Economic water dependent assets represent WALs, basic water rights, water source areas, water supply infrastructure, and regulated rivers. Within the Hunter subregion there are 108 surface water economic assets and 141 groundwater economic assets. The assets identified represent groups of smaller elements, e.g. in the Hunter region the 141 groundwater assets account for 5,463 individual elements as shown on Figure 5.16. The map identifies a number of potential groundwater elements with basic water rights (stock and domestic) or water access rights in the vicinity of the Project. Bores that are classified as exploratory or monitoring bores and which do not have associated water access rights are not included in the asset register (Macfarlane *et al*, 2016). Registered water bores within the vicinity of the Project are discussed further in Section 5.8.2.

There were 307 sociocultural water dependent assets identified within the Hunter subregion. These were judged to be water dependent based on their proximity to other surface water or groundwater features. The assets can be classified as:

- Cultural:
  - Heritage site – 275 assets; and
  - Indigenous site – 9 sites.
- Social:
  - Recreational – 23 sites.

There are no maps within the bioregional assessment showing the locations of the sociocultural water dependent assets within the Hunter subregion (Macfarlane *et al*, 2016).



LEGEND

- Locality
- Springs
- Project boundary
- Hunter subregion
- Hunter River Alluvium
- Liverpool Ranges Basalt
- Oxley Basin
- Sydney Basin - Mangrove Mountain Sandstone
- Sydney Basin - Upper Hunter
- Sydney Sandstone Central Coast
- Sydney Sandstone Central Coast Alluvium
- Tomago-Tomaree-Stockton Sandbeds

Mt Pleasant GIA (G1970A)

Bioregional assessment – Hydrogeological assets (Macfarlane et al., 2016)

AGE

DATE 20/11/2020

FIGURE No: **5.14**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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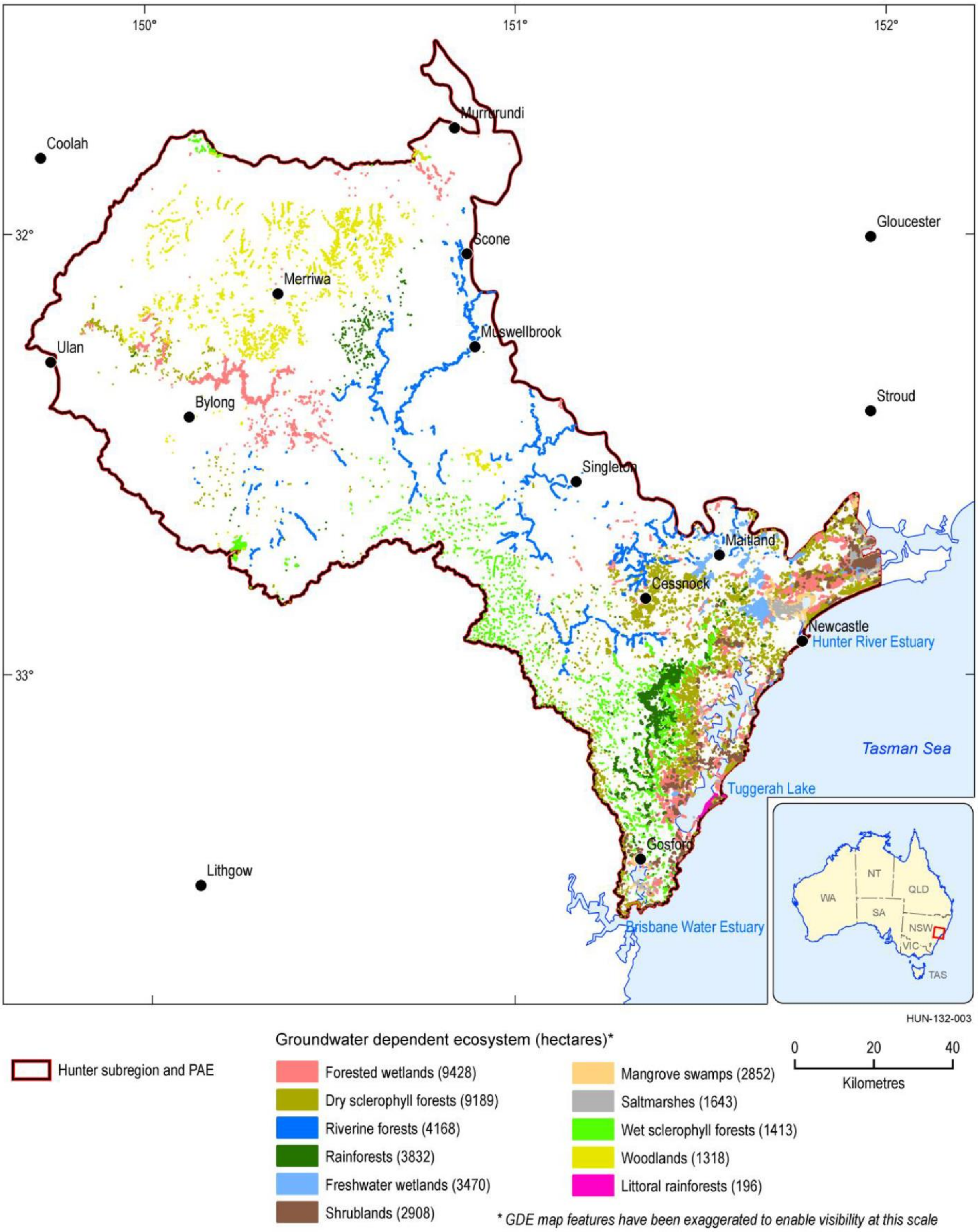


Figure 7 Location of assets in the 'Vegetation' subgroup in the 'Groundwater-dependent ecosystems' asset class of the Hunter subregion

Vegetation types are grouped according to vegetation formation (Keith 2006). Note that within this classification the formation 'Forested wetlands' includes Eastern riverine forests.
Data: NSW Department of Primary Industries (Office of Water) (Dataset 2)

Figure 5.15 Bioregional assessment – Ecological groundwater-dependent ecosystem assets (Macfarlane *et al.*, 2016)

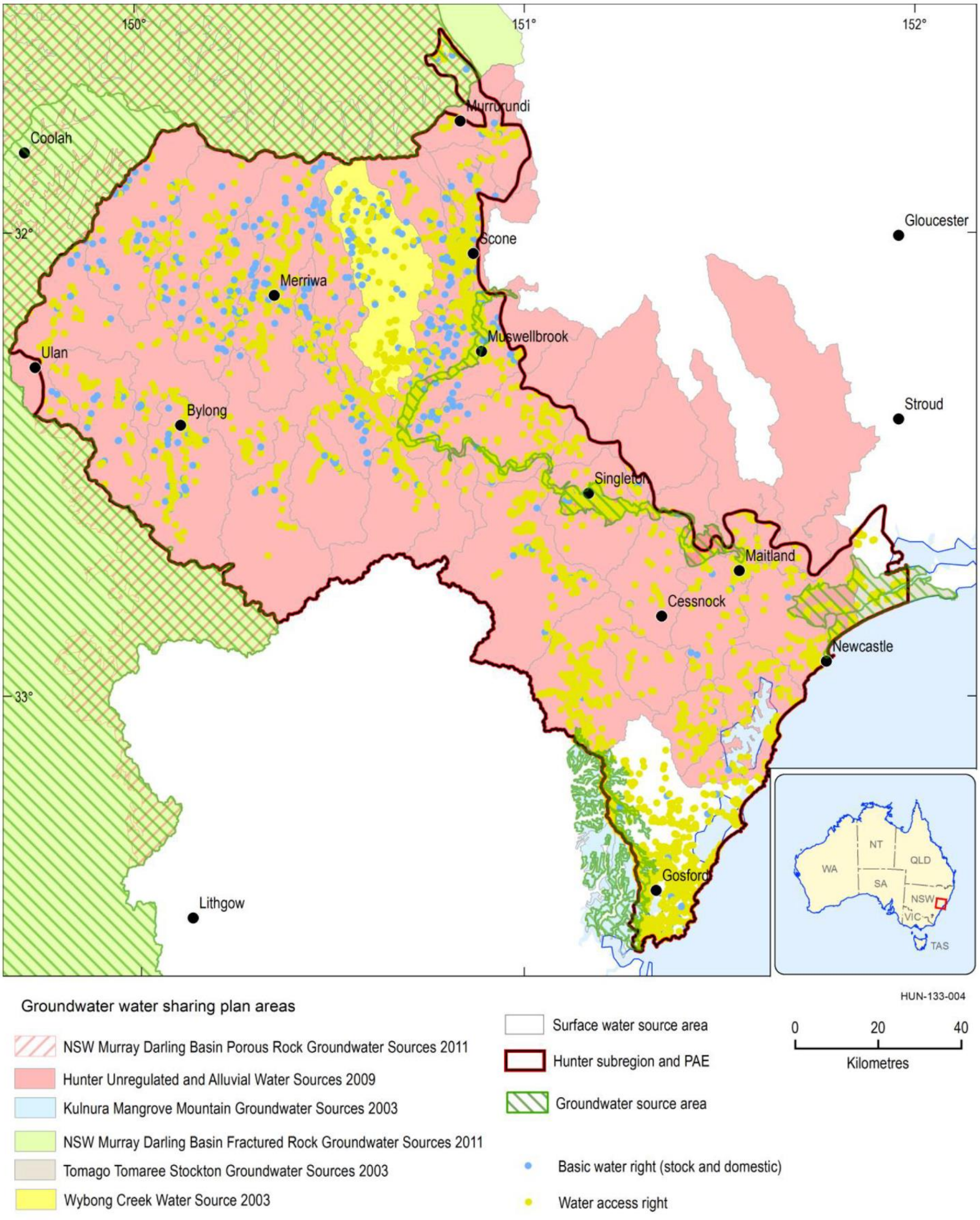


Figure 10 Location of groundwater elements within the preliminary assessment extent (PAE) of the Hunter subregion

Data: NSW Department of Primary Industries, NSW Office of Water (Dataset 2), NSW Office of Water (Dataset 4)

Figure 5.16 Bioregional assessment – Economic groundwater-dependent assets (Macfarlane *et al.,* 2016)

5.8.2 Private water users

In 2017, MACH commissioned a bore census of privately held bores and spring discharges at or near to the MPO (MACH, April 2017). MACH subsequently wrote to each landholder that participated in the bore census in May 2020 to confirm the outcomes of the bore census remained correct.

The census identifies seven bores on land within the approved MPO boundary, as shown on Figure 5.17. For completeness, Figure 5.17, shows all groundwater works in the vicinity of the Project, including monitoring bores for the MPO, Dartbrook and Bengalla Mines.

The census also identified 39 bores, wells and springs that are located on privately owned land and used for irrigation, stock watering and domestic purposes. Some bores also form part of the current and historic monitoring networks at surrounding coal mining operations. Details of the bores and their purpose are provided in Table 5.3.

Table 5.3 Private bores in the vicinity of the Project

Bore	Easting	Northing	Year drilled	Depth (mTOC)	Type
ADNUM1	300521	6429434	N/A	13	Well - Domestic
ASHFIELD1	289344	6428899	<50-60 (years)	5.75	Well - Stock
BARRY1	299564	6430431	N/A	13.56	Well - Stock & Domestic
BELGRAVE	295085	6434438	N/A	23.85	Well - Stock & Monitoring
COWTIME1	300330	6429753	N/A	-	Bore - Stock
CAS1 G	296503	6434654	1964	28.23	Bore - Not Used
CAS2 G	295914	6435419	<1950s	65	Bore- Monitoring
CAS3 G	295821	6435484	1957	76.7	Bore - Dry
CAS4 G	294928	6435957	NA	34.8	Bore - Monitoring
GRAY1	299882	6430334	N/A	-	Bore - Domestic
GRAY2	299856	6430316	N/A	-	Bore - Stock & Domestic
GW038412	291568	6437714	<1950s	7.7	Well - Stock & Domestic and Monitoring
HAYES1	299582	6430624	1930s	15.2	Well - Irrigation
HAYES2	299681	6430616	1950s-60s	15.5	Well - Stock & Domestic
JLON.1	292407	6434333	1971	57.9	Bore - Not in use (windmill not functioning)
JLON.2	292320	6434393	1965	37.4	Bore - Not Used
JLON1	298194	6434785	1979	6	Well & Bore - Monitoring
JLON2	300044	6434608	~1965-80s	82	Bore - Never used
JLON3	299887	6434455	<1961	12.83	Well - Domestic
JLON4	299404	6434623	1932	12.5	Well - Stock

Bore	Easting	Northing	Year drilled	Depth (mTOC)	Type
JLON5	299629	6434796	1954	11.7	Well - Irrigation
KELMAN1	300925	6429305	N/A	12.4	Well - Domestic
MATHER1	299814	6430440	>40 years	13.08	Well - Domestic
MITCHELL1	299860	6430413	N/A	-	Well - Domestic
MOORE1	299668	6430812	1958	52-56FT	Well - Domestic
MOORE1S	291441	6429318	N/A	NA	Spring - Stock
MOORE2	299720	6430762	2003	Blocked	Bore - Not Used (previously monitoring)
MOORE2S	291427	6429323	N/A	NA	Spring - Stock
MOORE3S	290851	6429236	N/A	NA	Spring - Stock
MOORE4	290139	6430000	< 60 years	4.5	Well - Stock
MP-BH1	301149	6432563	2003	18	Bore- Monitoring
MP-BH3	299481	6431354	N/A	14	Well - Stock
PARKINSON1	288944	6427796	N/A	4.7	Well - Stock
PITMAN1	300806	6429378	1991	-	Bore - Domestic
RDH76	296343	6435365	1982	49.4	Bore -Monitoring
SIMPSON1	299906	6429198	>50 years	11.6	Well - Stock & Domestic
SORMAZ1	300010	6429263	1992	11.61	Bore - Not Used
WALTON1	290331	6428144	N/A	90	Bore - Stock
WICKS1	300534	6429472	N/A	12.5	Well - Domestic

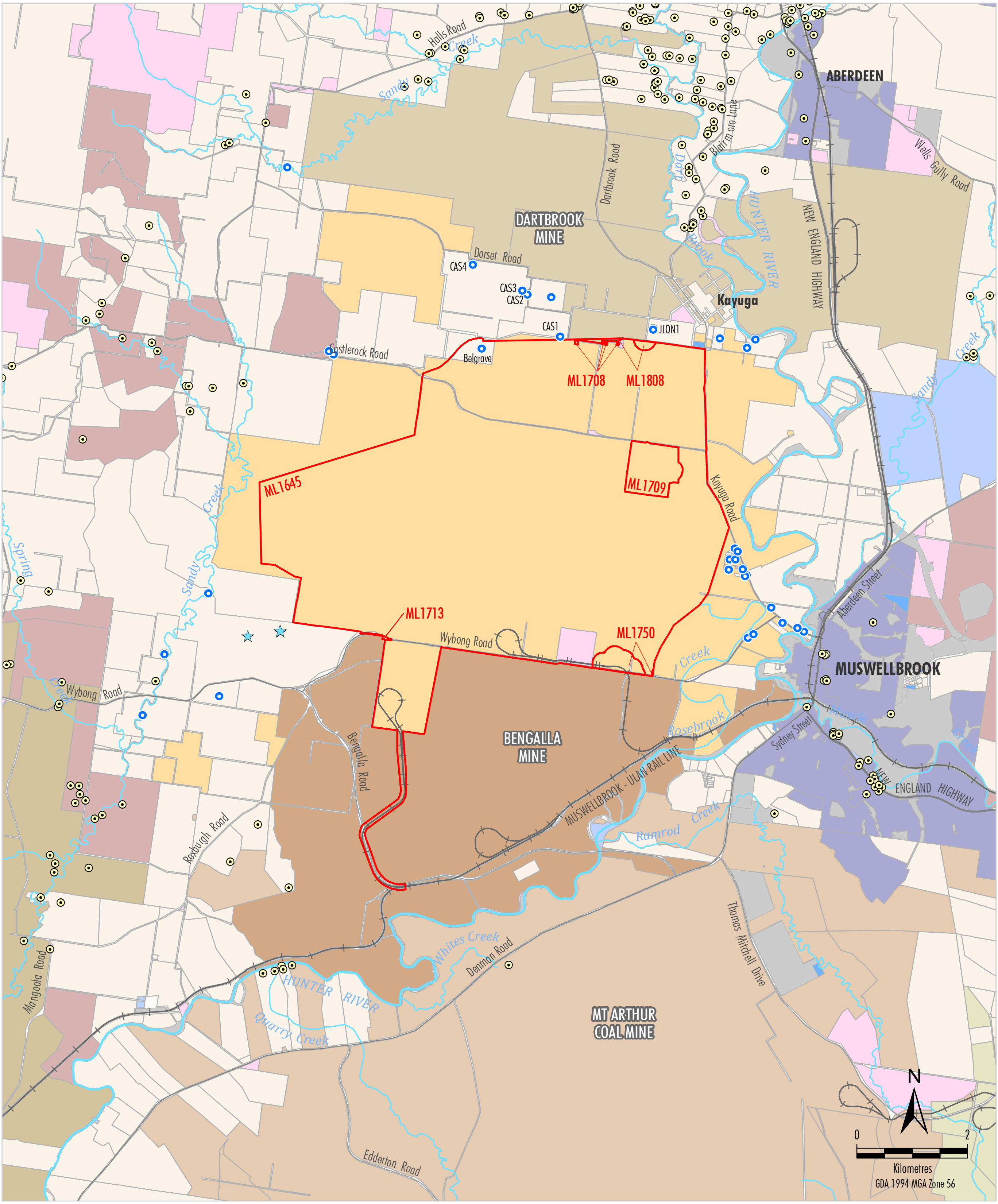
Note: mTOC = metres below top of casing.

With the exception of the Belgrave bore, that is located in the north western section of the MPO, none of the bores within the approved MPO boundary are privately operated. The Belgrave bore is also monitored as part of the Dartbrook Mine monitoring program.

Whilst the majority of the bores in Table 5.3 are authorised to take water under the basic landholder rights provisions of the WM Act, two of the bores identified in Table 5.3, JLON5 and HAYES1 are associated with WALs issued for the purpose of irrigation. Details of WALs issued in the vicinity of the Project and are presented in Table 5.4

Table 5.4 Water access licenses in the vicinity of the Project

Licence number	Water source	Share components
18131	Hunter Regulated Alluvial Water Source (U/S Glennies Creek Management Zone)	60
18224		22
18177		5



LEGEND

- Mining Lease Boundary (Mount Pleasant Operation)
- Mount Pleasant-controlled
- Bengalla-controlled
- Dartbrook-controlled
- Mangoola-controlled
- Muswellbrook Coal-controlled
- Mt Arthur-controlled
- Other Mining/Resource-controlled
- Crown
- The State of NSW
- Muswellbrook Shire Council
- Upper Hunter Shire Council
- Privately-owned Land
- Muswellbrook and Upper Hunter LEP Zones B2, B5, R1, R5
- Muswellbrook and Upper Hunter LEP Zones IN1, SP2, RE1, RE2, W1
- Bore/Well on Privately-Owned Land (Bore Census)
- Spring on Privately-owned Land (Bore Census)
- Water NSW Record

Source: MACH (2020); Water NSW (2020); NSW Spatial Services (2020)

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Groundwater Bores, Wells and Springs

Figure 5.17

5.8.3 Groundwater dependent ecosystems

GDEs are ecosystems that rely upon groundwater for their continued existence. GDEs may be completely dependent on groundwater, such as aquifer GDEs, or may utilise groundwater intermittently when it is available as a component of its lifecycle water requirements, such as riparian tree species in arid and semi-arid areas (Doody, Hancock and Pritchard, 2018).

The Australian Groundwater-Dependent Ecosystems Toolbox (Richardson et al., 2011) defines three main types of GDEs:

- Type 1: Subterranean ecosystems, including cave and aquifer ecosystems (refer Section 5.8.4).
- Type 2: Aquatic ecosystems that rely on the surface expression of groundwater, including surface water ecosystems which may have a groundwater component, such as rivers, wetlands and springs.
- Type 3: Terrestrial ecosystems that rely on the subsurface presence of groundwater.

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, Hancock and Pritchard, 2018).

No high priority GDEs listed in the *Hunter Unregulated and Alluvial Water Sources Water Sharing Plan 2009* are in the vicinity of the Project area. Wappinguy Spring, approximately 40 km to the north-west of the mine area, is the closest high priority GDE listed in the *Hunter Unregulated and Alluvial Water Sources Water Sharing Plan 2009*.

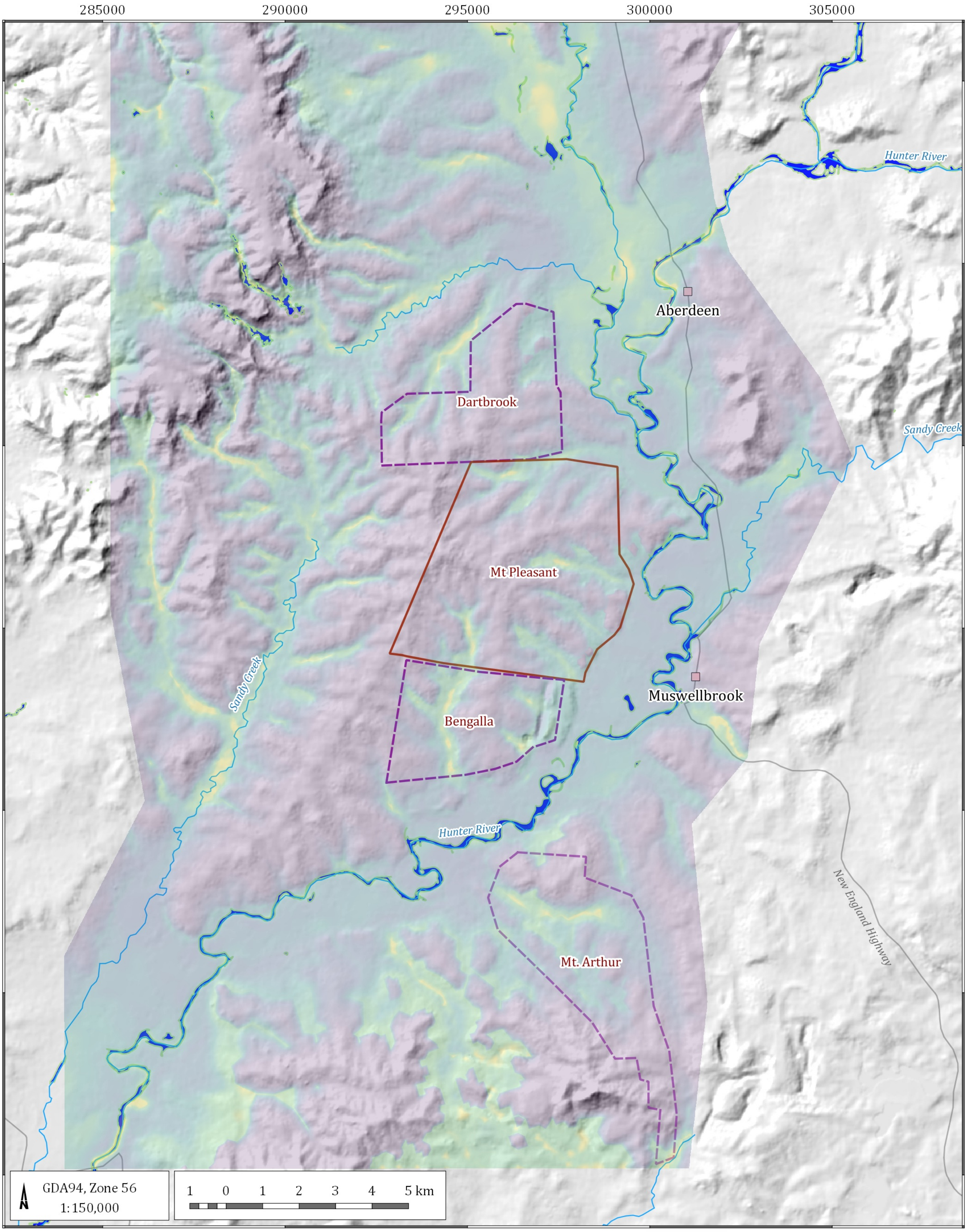
The *Groundwater Dependent Ecosystem Atlas* (GDE Atlas) was developed by the Commonwealth Bureau of Meteorology (BOM) as a national dataset of Australian GDEs to inform groundwater planning and management (BOM, 2018). The Atlas contains information about three types of ecosystems defined in the Australian Groundwater-Dependent Ecosystems Toolbox.

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 following potential GDEs in the vicinity of the Project (Figure 5.18):

- Aquatic habitat within the Hunter River is mapped as having high potential for groundwater interaction; and
- the majority of remnant terrestrial vegetation in the vicinity of the Project is mapped as having low potential for groundwater interaction.



LEGEND

- Populated place
- Drainage
- Road
- Mt Pleasant mine
- Surrounding mines
- High potential aquatic GDEs

Depth to water table (m)

- 1
- 2
- 5
- 10
- 30

Mt Pleasant GIA (G1970A)

Potential aquatic GDEs in the vicinity of the Project

DATE 20/11/2020

FIGURE No: **5.18**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\GIA_report\07.06_G1970A-Predicted drawdown in the vicinity of potential GDEs.qgs

Hunter River vegetation mapping was not undertaken for this Project. Notwithstanding, given the Hunter River is mapped as having high potential for groundwater interaction and groundwater levels in the Hunter alluvium are typically 5 to 10 m below land surface and 2 m below the stream bed, aquatic vegetation along the Hunter River has been assessed as a GDE (Section 8.4).

The Permian sediments within the Project area are not considered to be a significant aquifer. The regolith (weathered bedrock) directly below the ground surface may have a higher hydraulic conductivity, compared to the deeper interburden, owing to weathering effects. The depth to groundwater in the Permian sediments typically ranges from 50 m to greater than 100 metres below ground level (mbgl). There are isolated areas of shallower groundwater associated with regolith material present in ephemeral drainage lines, however these are a less significant water source than the Hunter River alluvial aquifer in terms of both water volume and quality.

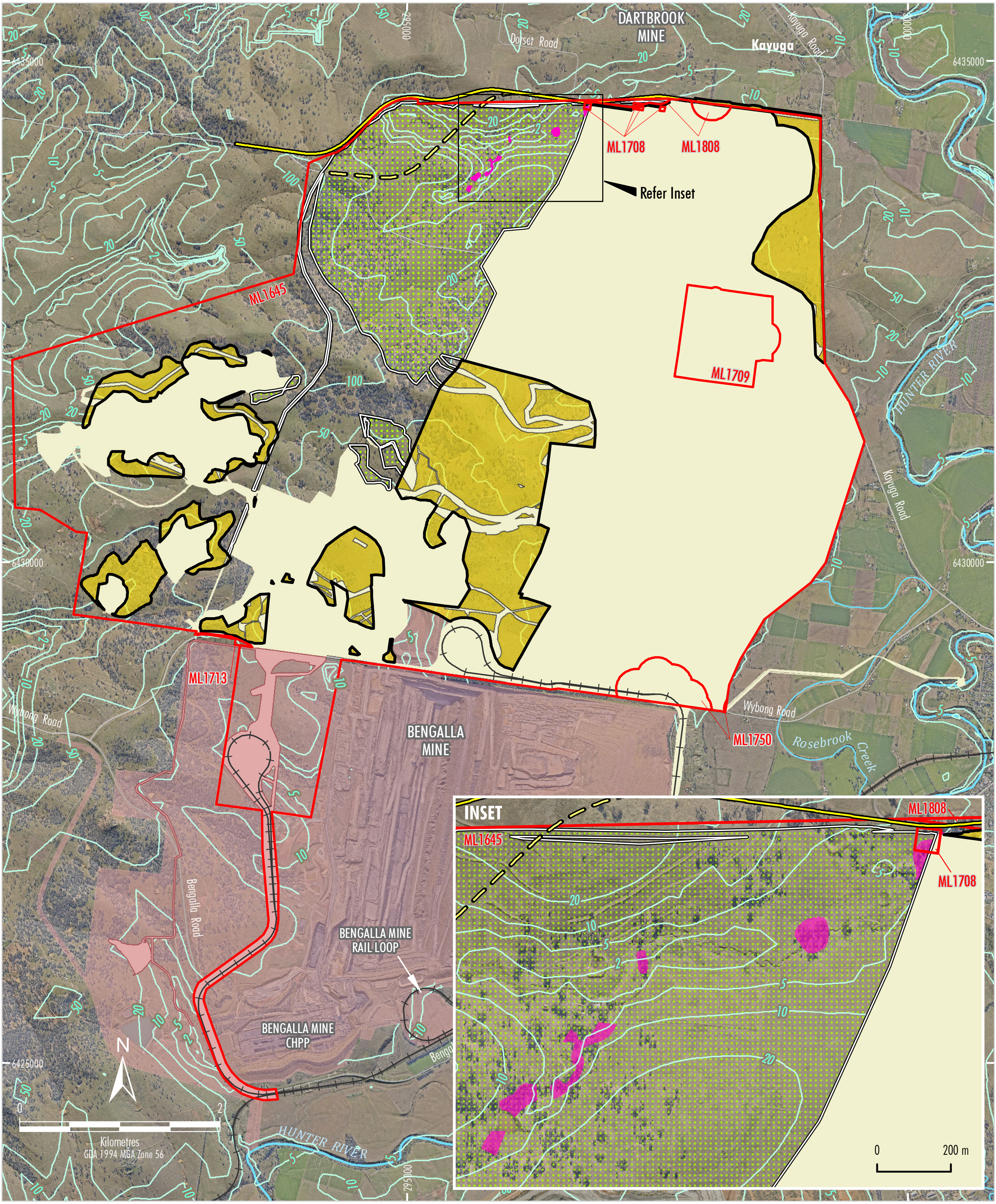
Vegetation mapping was conducted for the Project by Hunter Eco (2020). The mapping showed vegetation in the majority of the Project area is derived native grassland due to historical land clearing, with remnant and regrowth forest and woodland occurring in isolated areas. Remnant forest and woodland areas are primarily associated with grassy woodland communities, with some dry sclerophyll forests.

Hunter Eco (2020) reviewed mapped vegetation communities for species that could be potential Type 3 (terrestrial) GDEs. This review determined that approximately 3 hectares of Forest Red Gum Grassy Open Forest (Plant Community Type 618) could potentially be a facultative groundwater user on the basis that:

- Dominant tree species were Forest Red Gum (*Eucalyptus tereticornis*), Yellow Box (*Eucalyptus melliodora*) and Grey Box x White Box hybrid (*Eucalyptus moluccana* x *Eucalyptus albens*).
- This vegetation community is restricted to drainage lines, which suggests it favours areas of higher moisture content.
- The streamlines are ephemeral, but the eroded and incised stream beds indicate that there are periods of significant stormwater flow that could recharge aquifers and result in a temporarily elevated water level.

The location of the potentially groundwater dependent Forest Red Gum Grassy Open Forest vegetation community is shown on Figure 5.19

The depth to groundwater in the vicinity of this vegetation community typically ranges from 2 to 10 mbgl. Water levels at monitoring bore 4500F000, which is located approximately 100 m from an area of Forest Red Gum Grassy Open Forest, have historically fluctuated by approximately 10 m due to drawdown influence from the Dartbrook Mine (Section 5.9). The persistence of the Forest Red Gum Grassy Open Forest vegetation community supports Hunter Eco's observation that this community may access groundwater on a facultative basis. Accordingly, potential groundwater impacts on this vegetation community are assessed in Section 8.4.



LEGEND

- Mining Lease Boundary (Mount Pleasant Operation)
- Project Continuation of Existing/Approved Surface Development (DA92/97)
- Bengalla Mine Approved Disturbance Boundary (SSD-5170)
- Existing/Approved Mount Pleasant Operation Infrastructure within Bengalla Mine Approved Disturbance Boundary (SSD-5170)
- Approximate Additional Disturbance of Project Extensions
- Approved Disturbance Area to be Relinquished
- Northern Link Road Option 1 Centreline*
- Northern Link Road Option 2 Centreline
- Depth to Groundwater Contour (m)

Potential Groundwater Dependent Ecosystems

- Forest Red Gum Grassy Open Forest (PCT618)

Source: MACH (2020); Hunter Eco (2020); AGE (2020); NSW Spatial Services (2020); Department of Planning and Environment (2016)
Orthophoto: MACH (2020)

* Preferred alignment subject to landholder access.

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Groundwater Dependent Vegetation

Figure 5.19

5.8.4 Stygofauna

Stygofauna are small specialised subterranean aquatic invertebrates that are found in aquifers across Australia and the rest of the world. Stygofauna are predominantly found in aquifers with large (mm or greater) pore spaces, especially alluvial aquifers, and less frequently fractured rock aquifers (Hose *et al.*, 2015). Stygofauna have occasionally been recorded in coal seam aquifers, especially those which are hydraulically connected to a shallow alluvial aquifer.

The majority of stygofauna are found in locations where food supply and oxygen are more plentiful. The optimal conditions for stygofauna have been identified as:

- alluvial systems with large pore spaces;
- water levels within 20 metres of ground surface;
- EC of less than 5,000 µS/cm (TDS ~3,350 mg/L); and
- pH of approximately 6.5 to 7.5.

There is the potential for mining activities to impact on stygofauna habitats if they are present in the aquifer units near to the mines.

Several studies in eastern Australia have identified relatively diverse stygofauna in alluvial groundwater systems, including sites in the Hunter Region of NSW (Hancock and Boulton, 2008 and 2009; Tomlinson and Boulton, 2010). The greatest number of taxa appear to occur in boreholes with low conductivities (i.e. < 1,500 µs/cm) and where the water table was < 10 metres (m) deep, associated with the alluvium of larger river systems and trees with deep roots penetrating the saturated water of groundwater systems (Hancock and Boulton, 2008).

Between 2004 and 2008, 26 stygofauna taxa were identified in samples from 40 bores situated throughout the Hunter Valley, with this number expected to rise if samples were identified to species level (Hancock and Boulton, 2008 and 2009; Watts et al., 2007). Twenty taxa were recorded from the Hunter River alluvial aquifer near Denman and the Pages Creek alluvial aquifer. A total of 21 taxa were identified from bores sampled at Dart Brook, 18 taxa at Kingdon Ponds and eight taxa from the Hunter River alluvial aquifer near Muswellbrook (Hancock and Boulton, 2008 and 2009; Watts et al., 2007). None of the taxa collected were listed under the NSW *Threatened Species Conservation Act, 1995* or EPBC Act (ELA, 2013).

In 2012, ELA sampled thirteen bores and wells within the vicinity of the Bengalla Mine (ELA, 2013). Eight samples were collected from the Hunter River Alluvial Aquifer and five from the Permian rock aquifers in July 2012. Ten of the bores were re-sampled in September 2012. No new taxa were collected during the second round of sampling however, fauna were collected from three bores that did not yield any fauna in the first round, indicating that the distribution of stygofauna can vary temporally (ELA, 2013).

Six stygofauna taxa were collected from the two surveys (ELA, 2013). Cyclopoid crustaceans were the most numerous and frequently encountered taxon. Other taxa were *Notobathynella* sp. 1, *Bathynella* sp. 1, *Chillagoe* sp. 1, *Ostracoda* and *Oligochaeta* (ELA, 2013). All of the taxa collected at Bengalla Mine were known from other parts of the Hunter Valley (see Hancock and Boulton, 2009).

Bio-analysis (2020) undertook sampling for stygofauna in the vicinity of the Project. Sample sites were selected based on the likelihood of having suitable stygofauna habitat. Selection was based on available hydrogeological information and an attempt was made to choose bores or wells spread over the Study Area. Seven bores were visited on 27 and 28 November 2018 comprising five alluvial bores, one interburden bore (7000D000) and one Permian bore (WRA1L).

Six invertebrate taxa were collected from four of the alluvial bores, with three of those taxa considered likely to be stygofauna: *Cyclopidae*, *Ostracoda* and *Isotomidae*. All taxa were also present in bores sampled within the alluvial aquifer for the *Continuation of the Bengalla Mine – Stygofauna Assessment 2013* (Bio-analysis, 2020).

No stygofauna were collected from bore 18298, which is situated in the alluvial aquifer on the southern side of the Hunter River. Similarly, no stygofauna were collected from this bore by ELA (2013) in July 2012 and relatively low numbers (four *Cyclopidae* and six *Ostracods*) were collected in September 2012 (Bio-analysis, 2020).

No stygofauna were collected from the bore sampled within the interburden aquifer (7000D000) or the Permian aquifer (WRA1L), which is consistent with expectations given that EC in both bores was well above 1,500 µS/cm (Bio-analysis, 2020).

5.9 Conceptual model

Conceptual models are abstractions or simplifications of reality. During development of conceptual models, the essence of how the key system components operate and interact is distilled. This section describes the processes that control and influence the storage and movement of groundwater in the hydrogeological systems occurring in vicinity to the Project and the broader region around MPO.

The conceptual groundwater model for the Project is presented graphically in Figure 5.20. The conceptual groundwater model section graphically illustrates the main hydrogeological features and processes occurring at the Project, including recharge, discharge, and anthropogenic activities (i.e. landholder pumping and mine dewatering).

Two aquifer systems occur in the Project, namely:

- alluvium along the Hunter River;
- Permian sediments including:
    - weathered bedrock (regolith);
    - unweathered bedrock (overburden and interburden); and
    - the coal seams of the Wittingham coal measures.

Alluvial deposits are present along the Hunter River to the east and along Sandy Creek to the west of the Project. The main groundwater bearing units occur in the Hunter River flood plain due to greater saturated thickness and lower salinity. Groundwater levels in the Hunter alluvium are usually 5 to 10 m below land surface and 2 m below the stream bed, meaning the Hunter River is generally a recharge source (i.e. losing stream) to the alluvial groundwater system. While there is less data available for Sandy Creek west of the Project area, based on nearby groundwater levels and topography it is considered a gaining system.

The regolith (weathered bedrock) directly below the ground surface may have a higher hydraulic conductivity, compared to the deeper interburden, owing to weathering effects. The regolith aquifer represents a less significant water source than the alluvial aquifers in terms of both water volume and quality but is the most readily accessible unit for landholders outside the flood plain.

The Wittingham coal measures are not considered to be a significant aquifer. While some coal seams may show an elevated hydraulic conductivity, the dominant interburden sections are of very low hydraulic conductivity. Occurrence and flow of groundwater are governed by the presence of micro faults, joints, fractures, and bedding planes which are often locally discontinuous. The Wittingham coal measures are also relatively deep, which along with low yield volumes and variable salinity limits groundwater usage.

The generally lower salinity occurring within the Quaternary alluvium indicates more significant recharge rates that can occur via:

- diffuse rainfall and deep drainage through the flood plain soils;
- seepage of river and creek flows through the stream bed;
- runoff from the topographically higher bedrock hills and subsequent deep drainage through the soil profile at the fringes of the alluvium; and
- the Permian coal measures in places where higher heads in the coal seams cause upward discharge into the overlying alluvium.

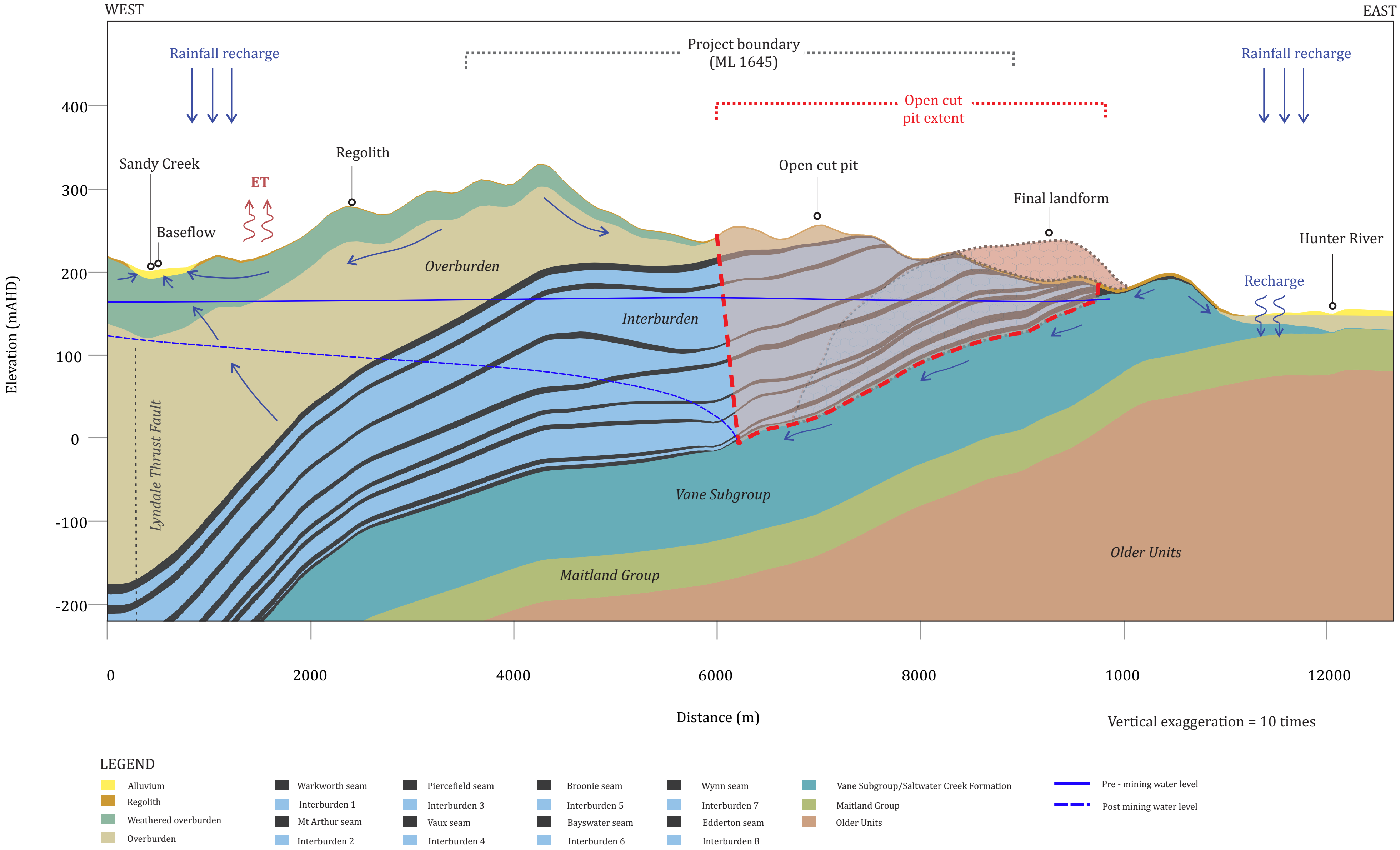
Recharge to the regolith is via direct infiltration of rainfall. The regolith in turn provides recharge to the Wittingham coal measures through areas of either coal seam or interburden sub crop.

The potentiometric surface and flow directions in both the regolith and the Wittingham coal measures reflect topography, with flow to the south-east towards the low lying alluvial flood plain. The flow within the alluvium is aligned with the direction of flow within the streams to the south and south-west.

In addition to natural groundwater systems, anthropogenic activities also influence groundwater flow in the vicinity of the Project and across the broader region, with nearby mining activities having the largest impact.

Landholders preferentially extract groundwater from the alluvial aquifers in the region, compared to the adjacent elevated hills (Permian sediments). Within the hills, most bores/wells are situated near drainages where recharge to regolith and shallow unweathered bedrock is expected to be enhanced. Evapotranspiration will also contribute to the discharge of groundwater in areas where the water table is sufficiently close to the land surface and where the vegetation can access it.

Groundwater quality across the hydrostratigraphic units is highly variable, ranging from fresh to saline. Groundwater quality is best within the alluvial aquifers, but still variable in quality based on location. Groundwater within the regolith, unweathered bedrock and coal seams is variable but can be suitable for stock and domestic purposes, where salinities are lowest.



Conceptual model

Figure - 5.20

Mt Pleasant GIA (G1970A)

5.10 Potential impact causal pathways

For the purposes of Bioregional Assessments causal pathways are defined as *'the logical chains of events – either planned or unplanned – that link coal resource development and potential impacts on water resources and water dependent assets'* (Dawes et al, 2018). Water dependent assets can be impacted by changes to quantity, quality or timing of surface water or groundwater or both. Water dependent assets in the vicinity of the Project were identified in Section 5.8.

The identification of causal pathways between the proposed development and the water-dependent assets is an important part of the impact assessment process. Causal pathways are initiated by an activity associated with the coal resource development. In the case of the Project this is the extension of mining of coal from within the existing approved MPO area, and it is the incremental increase in potential impacts that requires assessment. It is also important to note surrounding areas and water-dependent assets that are unlikely to be impacted by the proposed development.

There are four main causal pathway groups associated with coal mining, although there is commonly overlap or linkage between them:

- 'subsurface depressurisation and dewatering';
- 'subsurface physical flow paths';
- 'surface water drainage'; and
- 'operational water management'.

This report focusses on those causal groups primarily related to groundwater, that is 'subsurface depressurisation and dewatering', and 'subsurface physical flow paths'. 'Surface water drainage' is also briefly discussed in relation to groundwater-surface water interactions.

The 'subsurface depressurisation and dewatering' group of causal pathways occurs when coal mines intentionally dewater the subsurface so that open-cut and underground mining operations can occur safely. The pre-existing hydraulic gradients are disrupted, usually causing changes to groundwater levels and pressures, and occasionally altering groundwater quality. Pumping from conventional bores extracting groundwater to support mining activities is also part of this causal group. However, the scale of the effects from conventional bores is typically less than those associated with open cut mine dewatering. Groundwater extraction for open cut mine development can unintentionally affect non-target strata in situations where direct hydraulic connections exist. The connections could be diffuse, such as connections between adjacent geological layers, or more focussed via structures such as faults.

The region surrounding MPO has significant disturbance of groundwater levels from historical mining. Dartbrook Mine to the north and Bengalla Mine to the south both show mine related drawdown in their groundwater level monitoring data. These can be noted in the observation data points in the calibration hydrographs in Appendix A1. Notably, the bores responding to mining and subsequent care and maintenance at Dartbrook Mine are CAS2, CAS4, DDH193, and Kayuga1, and likewise at Bengalla Mine the bores showing direct influence from mining are BE2, REP21, WAN2, WAN4, WAN8, WAN10.

Subsurface depressurisation from historic and recent mining is evident in the groundwater level record of bores screened in the lower seams at MPO (Figure 5.21). The lower layers show the greatest drawdown response to adjacent mining, which is not reflected in the bores screened in the upper strata.

In the southern region of MPO, bore 3500B500L (Broonie seam) was drawn down 35 m from 2003-2017. The drawdown rate slowed between 2004 and 2008, during which Dartbrook Mine went into care and maintenance. Although the bore is some distance from Dartbrook Mine, the propagation of drawdown in the lower seams continues past the date of care and maintenance as the water level in the Wynn Seam is maintained at -66 mAHD. Drawdown continued to increase following the commencement of mining at Bengalla Mine in 1998 as the cone of depression generated by Bengalla Mine intercepted the bore.

Toward the centre of MPO, less significant drawdown was observed in bore 3500C500L (screened in the interburden between the Mount Arthur and Piercefield Seams seams) from 2011-2017, and in bore 5500D000 (screened in the interburden between the Bayswater and Wynn seams) from 2003-2017. In the northern region of MPO, 10 m of drawdown was observed bore 4500F000 (screened in the interburden between the Piercefield and Vaux seams) from 2003-2007, followed by six years of stable water levels and recovery from 2013. Similarly, a 5m drawdown was observed from 2004-2008 in bore 6500F625 (screened in the interburden between the Mount Arthur and Piercefield Seams seams) bordering Dartbrook Mine before recovering from 2007. To the north east of MPO, bore 7500F000 (Edderton seam) continued to gently depressurise from the beginning of record in 2004 through 2017.

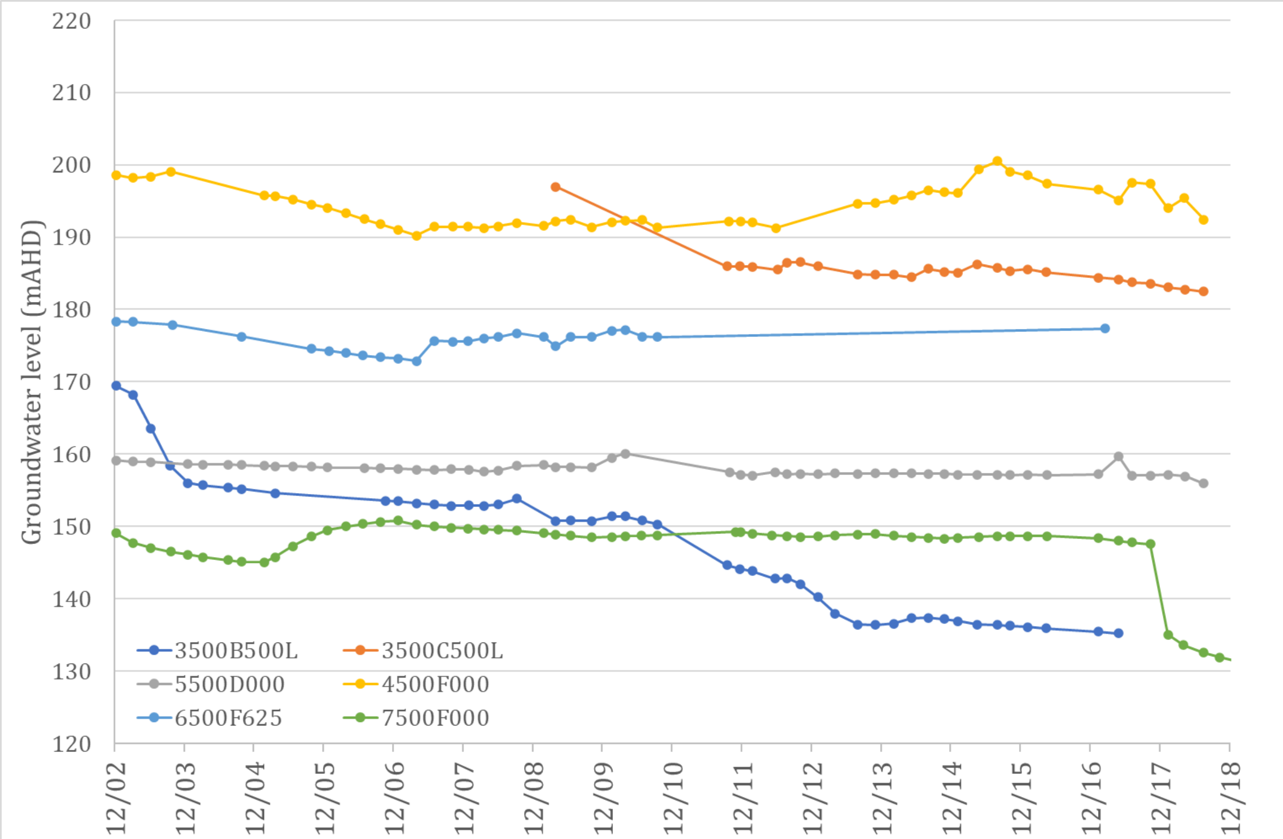


Figure 5.21 Subsurface depressurisation from historic mining

The 'subsurface physical flow paths' causal pathway group involves activities that physically modify the rock mass, creating new pathways that water may flow along. Long term the replacement of pre-mining bedrock by spoil or a final void lake would alter the physical properties of the subsurface compared to pre-mining conditions.

Example causal pathway diagrams for open cut coal mining developments are presented in Henderson et al. (2016). The groundwater components that are potentially relevant to mining at the Project are summarised in Table 5.5. The table outlines the most likely pathways, impact causes, impact modes and activities to generate the impacts. The potential hydrological effects on the groundwater system are noted in the final column. Those components that are most likely to produce the greatest changes to the groundwater system, or which have been identified as occurring within the Project area are highlighted bold.

Many of the smaller scale issues can be managed by following current best practices to reduce the likelihood of them occurring e.g. those activities caused by equipment failure or poor component design.

The potential activities that are most likely to produce impacts over a large area relate to the effects of open cut mining below the groundwater table, and backfilling of the resulting mining void with spoil.

Potential disruption to rivers has also been included as a high potential causal pathway, due to the proximity of the Hunter alluvium to the east and Sandy Creek to the west.

The most likely potential causal pathways identified have been considered when designing the numerical groundwater model to ensure that they are suitably represented.

Table 5.5 Causal pathways with a groundwater component

Pathway	Cause	Mode and activity	Hydrological effect
Aquifer outcrop areas – deep soil drainage	Coal characteristics	Fire in stockpiles, fire in the pit from excavation or blasting, fire in stockpiles	Quality
	Incomplete rehabilitation	Negligence during post-closure mine decontamination	Quality
	Consolidation of loose backfill	**Compaction or settlement of backfill over time**	**Direction**
	Diverting site drain line	Changes to natural surface drainage through diverting creeks or for rainfall and runoff diversion Disruption of natural surface drainage via dam construction, site preparation, topsoil and spoil preparation Disruption of natural surface drainage by excavation of the pit	Quality, Direction, Volume/ quantity
	Inevitable, deliberate	**Deliberate pit wall dewatering** **Leaching of spoil dumps or coal stockpiles** **Runoff changes via topsoil excavation and storage**	**Quality,** **Flow (reduction),** **Pressure,** **Volume/ quantity,**
	Poor handling/management	Excessive runoff during closure from water management structures	Quality
Aquifer outcrop areas – SW-GW interactions	Human error, accident	Equipment (pipe) failure leading to containment failure for dewatering water, waste streams, mine dewatering, treatment, re-use, disposal Substantial spillage from on-site mine equipment or on-site coal transport Treatment plant failure during mine water treatment, re-use, disposal	Quality
	Containment failure, leaching, flooding	Groundwater or surface water contamination from drill cutting disposal Increased inflow from natural events during dewatering, treatment, reuse and disposal processes Overflow and/or loss of containment of surface water Treatment plant failure during mine water treatment, re-use, disposal Leaching of fine rejects water decant dam	Quality
	Physical disruption of river boundary or channel	Linking aquifers via preferential drainage if mine expansion too close to river/lake	Flow (reduction), Pressure, Volume/ quantity

Pathway	Cause	Mode and activity	Hydrological effect
Aquifers – Groundwater conditions	Drilling control issues	Pressure imbalance and localised water table changes	Quality, Level
	Incomplete grouting	**Incomplete/compromised cementing leading to linking of aquifers within groundwater bores**	**Quality, Composition**
	Poor design, construction	Bore leakage between aquifers following abandonment Linking aquifers in groundwater supply bores with long screens	Quality, Composition
Aquifers – Groundwater conditions post mining	**Inevitable, deliberate**	**Artificial point of recharge, enhanced aquifer interconnectivity, groundwater source/sink – post closure water filling the pit** **Leaching from in-pit backfill/spoil dump**	**Quality, Direction, Pressure, Volume/ quantity**
		Groundwater extraction from groundwater supply bores	Pressure

Note: ***Bold*** *highlighting indicates those causes and activities that are likely to cause the greatest changes at the Project.*

Source: *After Henderson et al. (2016).*

6 Numerical groundwater model

A 3D numerical groundwater flow model was developed using MODFLOW-USG to assess the impacts from the Project. The objective of the modelling was to identify the impacts of the approved Mount Pleasant Operation and from the Project on the groundwater system and the identified water dependent assets. A detailed description of the numerical model development is provided in Appendix A.

The model simplifies the geology identified in the conceptual model into 20 key representative layers. The model domain covers an area of approximately 19 km from west to east, and 30 km from north to south, centred on the Project and encompassing adjacent mines to represent cumulative impacts. The model domain is discretised into 32,915 Voronoi cells per layer of varying sizes to represent different environmental and mining features throughout the model domain. The model mesh is shown in Figure 6.1. The specific features where cells were refined to smaller sizes are listed below:

- open cut and underground mines – 100 m x 100 m to 300 m x 100 m;
- streams and alluvial flood plains – from 100 m x 100 m to 200 m x 200 m cells;
- Dartbrook Mine Hunter Tunnel (under Hunter River) – 100 m x 100 m; and
- up to 700 m cell sizes in more peripheral areas.

The extent of the mines shown on figures in Sections 6 to 9 are based on the areas where drain cells were progressively applied. These areas are broadly representative of the mine extraction area at these sites but do not necessarily represent the full mine surface footprints or tenure.

The model layers represent the major hydrostratigraphic units including shallow geological units as well as the major coal seams and interburden. All model cells within each layer are active and assigned to one hydrostratigraphic unit.

The groundwater model was calibrated to a pre-mining steady state water level dataset and then to transient water level and Bengalla Mine, Dartbrook Mine and Mt Arthur Coal Mine inflow datasets (1991 to 2017). The calibration was achieved by adjusting aquifer parameters and stresses to produce the best match between the observed and simulated water levels and mine inflows (history matching). Manual testing, automated parameterisation software (PEST) (Doherty 2010) and pilot points were used to guide the model towards a set of hydraulic parameters and recharge rates that provided the best history matching result.

The dewatering of groundwater at mines is represented in the model by the drain boundary condition. In open cut pits the model layers within the pit shell have drain elevations set to dewater those model cells. Underground mining is represented by the drain package as well, but only applied in the coal seams being mined. The fracture zone above the longwall panels is simulated through hydraulic property changes representing the disturbance.

The match between the measured and modelled water levels is measured at the model scale by a Scaled Root Mean Square (SRMS) statistic of 4.1%, which indicates the model provides a good match to measured water levels and compares well to the range of <5% to <10% discussed in the modelling guidelines (Barnett et al., 2012). Mine inflow was also compared and shown to provide a reasonable match to four surrounding locations (Dartbrook Wynn Seam, Dartbrook Mine Hunter Tunnel, Bengalla Mine and Mt Arthur Coal Mine).

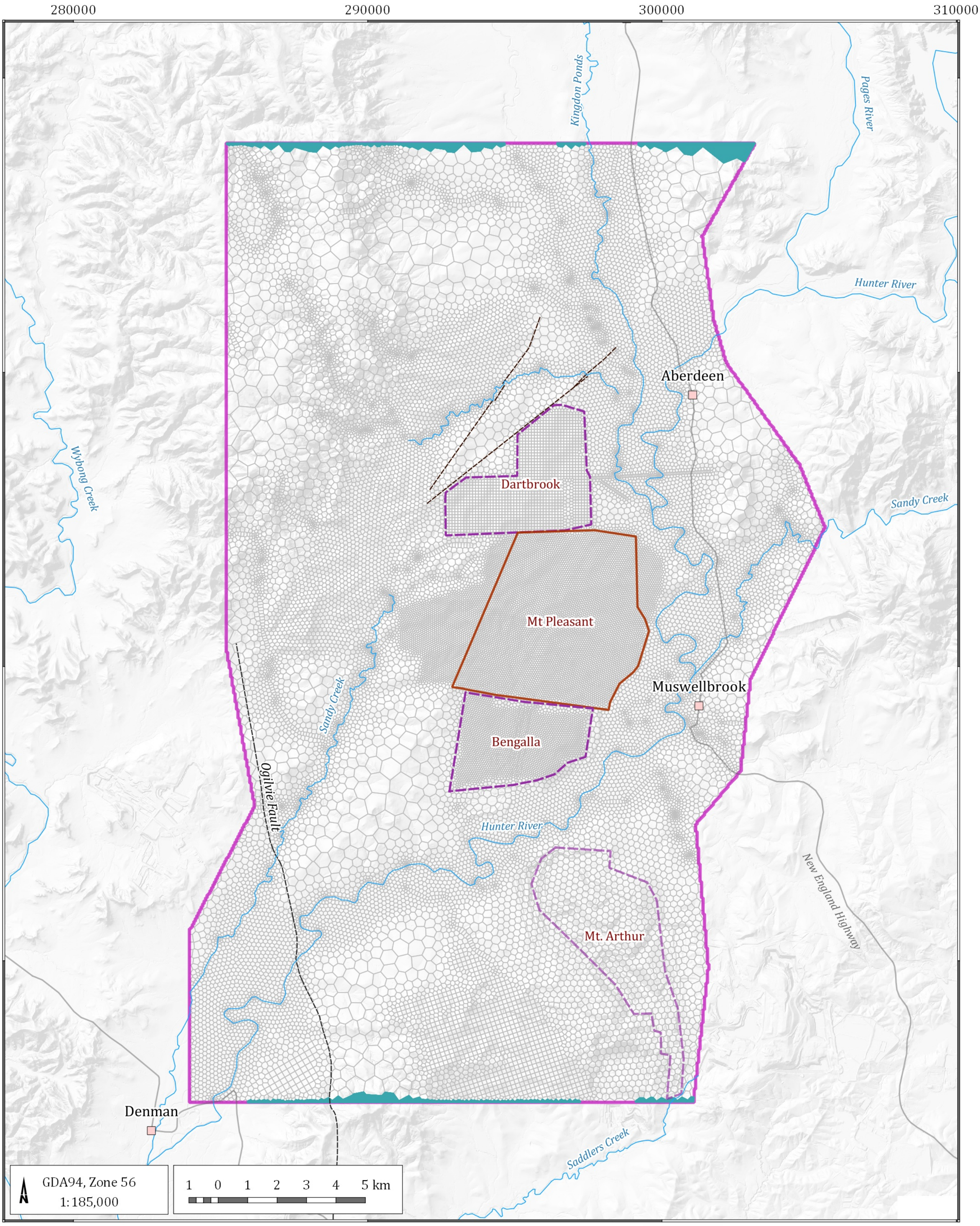
Following calibration, the model was used to estimate potential changes in the alluvial water table and the Permian groundwater pressure (drawdown), as well as the volume of groundwater intercepted by the Project, in accordance with the proposed mine plan. The impacts predicted by the model are derived from a differencing between two model simulations, with one model representing the MPO (incorporating the Project) and other approved mining operations (including those within their respective approval process), while the other model only represents the approved surrounding mines (excluding the approved MPO).

This approach provides an assessment of the overall cumulative impact of the MPO (incorporating the Project) and current approved mining.

The Mount Pleasant Operation is currently approved for mining operations until December 2026. The Project seeks to extend operations from 2026 to December 2048, incorporating an increase in the production rate and mining of additional coal reserves within the existing mining leases. To contextualise the incremental impact of the Project beyond the currently approved mine plan, a model iteration with mine progression ceasing at the end of 2026 was prepared for comparison against the full proposed mine life.

The residual impacts to the groundwater system post mining were also been assessed, with the water level in the void determined from interactions with the surface water models (refer Hydro Engineering Consultants [HEC], 2020).

The uncertainty of the model predictions, resulting from initial uncertainty in the assumptions and input parameters, was analysed. The analysis focussed on varying model parameters and design features that have the most influence on model predictions. The model parameters were adjusted to encompass the expected range of uncertainty. Appendix A provides a detailed discussion of the uncertainty analyses. Where possible the uncertainty analysis followed the process recommended in the IESC's draft explanatory note on uncertainty analysis (Middlemis and Peeters, 2018).



LEGEND

- Populated place
- Drainage
- Road
- Fault
- Mt Pleasant mine
- Surrounding mines
- Model grid
- General head boundary
- No-Flow Boundary

Mt Pleasant GIA (G1970A)

Model extent and mesh

DATE 02/10/2020

FIGURE No: **6.1**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\GIA_report\06.01_G1970A - Model extent and mesh.qgs

7 Groundwater model predictions

The following subsections describes the numerical model predictions during mining and for the post mining recovery phase.

7.1 During mining

7.1.1 Groundwater inflows to mining areas

The groundwater inflows to the MPO (incorporating the Project) were calculated based on the proposed mine schedule. Mining commenced in 2017 and would continue until the end of 2048. The total predicted groundwater inflows are shown in Figure 7.1.

The maximum predicted inflow is 303 megalitres (ML) in the 2034-35 water year. The peak inflow is well within the 730 ML of water access licence allocations currently held by MACH for the Sydney Basin - North Coast Groundwater Source.

The maximum predicted inflow for the MPO (incorporating the Project) is less than the maximum predicted inflow originally predicted for the approved MPO of 1.9 megalitres per day (ML/day) or 690 megalitres per year (ML/year) (PPK, 1997). This is considered to be due to material desaturation of the Permian strata by the neighbouring Dartbrook and Bengalla Mines, as well as improvements in groundwater modelling since the original water management study was prepared in 1997.

The maximum predicted inflow for the MPO (incorporating the Project) (approximately 300 ML) is only marginally higher than the maximum predicted inflow that would occur during the life of the approved MPO (approximately 270 ML in the 2024-25 water year).

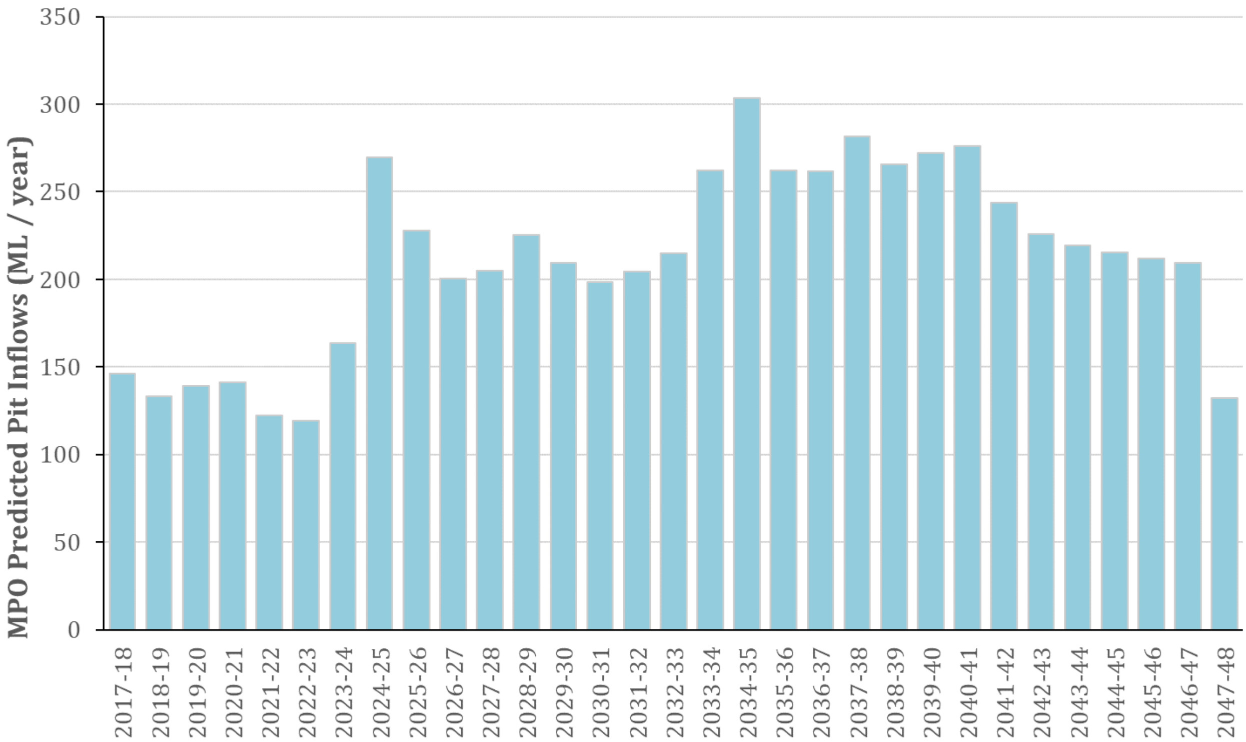


Figure 7.1 Predicted groundwater inflows

7.1.2 Drawdown during mining operations

Predictions of maximum groundwater drawdown during mining have been completed using the numerical groundwater model described in Section 6 and Appendix A. This model is termed the 'basecase' model as it represents the best match to historical data and is the basis of all later uncertainty analysis. The predicted drawdown contours are a composite of the maximum values predicted at each cell at any time over the operational period of mining. The actual duration and timing of the maximum predicted drawdown within each cell varies depending on the proximity of mining over the life of the Project.

Drawdown maps are presented for the alluvium and regolith (Layer 2) and Edderton seam (Layer 18) in Figure 7.2 and Figure 7.3. Each figure is split to show outputs for two different scenarios:

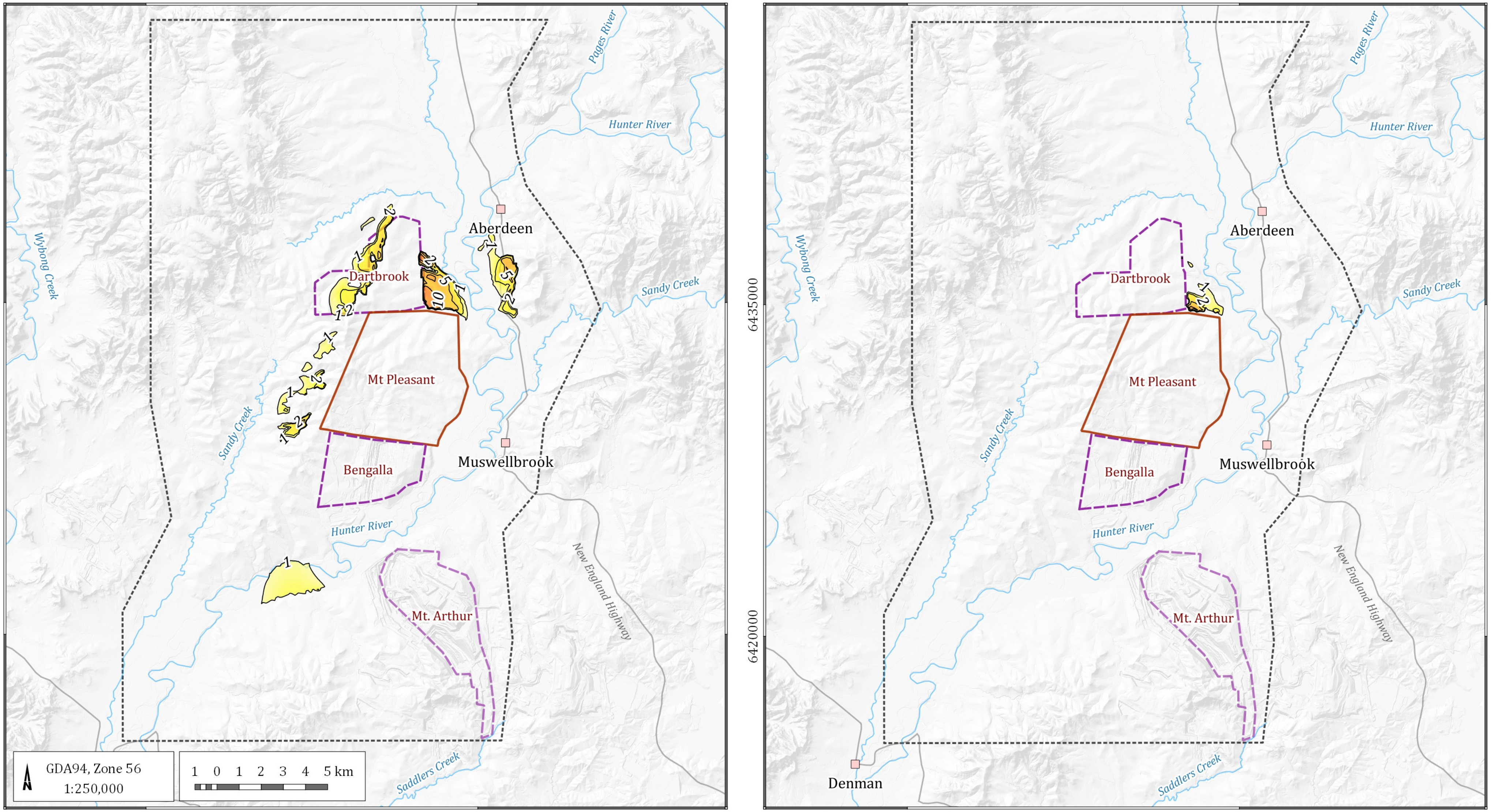
- maximum predicted cumulative drawdown – where drawdown occurs from the approved MPO and proposed Project extension/mining area as well as neighbouring mines (Dartbrook Mine, Bengalla Mine, and Mt Arthur Coal Mine); and
- maximum predicted drawdown attributed to the MPO (incorporating the Project) only.

The MPO (incorporating the Project) is predicted to result in only limited drawdown in the alluvium to the north of the Project, near the existing Dartbrook Mine (Figure 7.2b). Limited drawdown is predicted in the Hunter River alluvium as the majority of the target seams subcrop west of the alluvium extent. At the northern boundary of the Project, the Edderton seam subcrop extends closer to and then under the alluvium. This is the cause of the predicted drawdown in the alluvium to the north.

The maximum drawdown predicted in the Edderton seam is constrained to the north and south by the concurrent drawdowns occurring due to the neighbouring mines. Drawdown is constrained by the subcrop in the east (evident in the contours), and the subcrop extending under the alluvium to the north east of the Project can also be observed in the extent of the drawdown contours.

The incremental predicted drawdown attributed to the Project (i.e. compared to if mining at the MPO were to cease in 2026) is shown on Figure 7.4. The Project would result in an increase in drawdown in the alluvium immediately north of the MPO, due to the pit advancing further north. The proposed increase in depth of the Project open cut would also increase drawdowns in the basal Edderton Seam.

a) Maximum predicted cumulative drawdown **b) Maximum predicted drawdown attributed to MPO**



LEGEND

- Populated place
- Drainage
- Road
- Drawdown contour (m)
- Mt Pleasant mine
- Surrounding mines
- Model boundary

Drawdown (m)

0	20
1	50
2	100
5	200
10	500

Mt Pleasant GIA (G1970A)

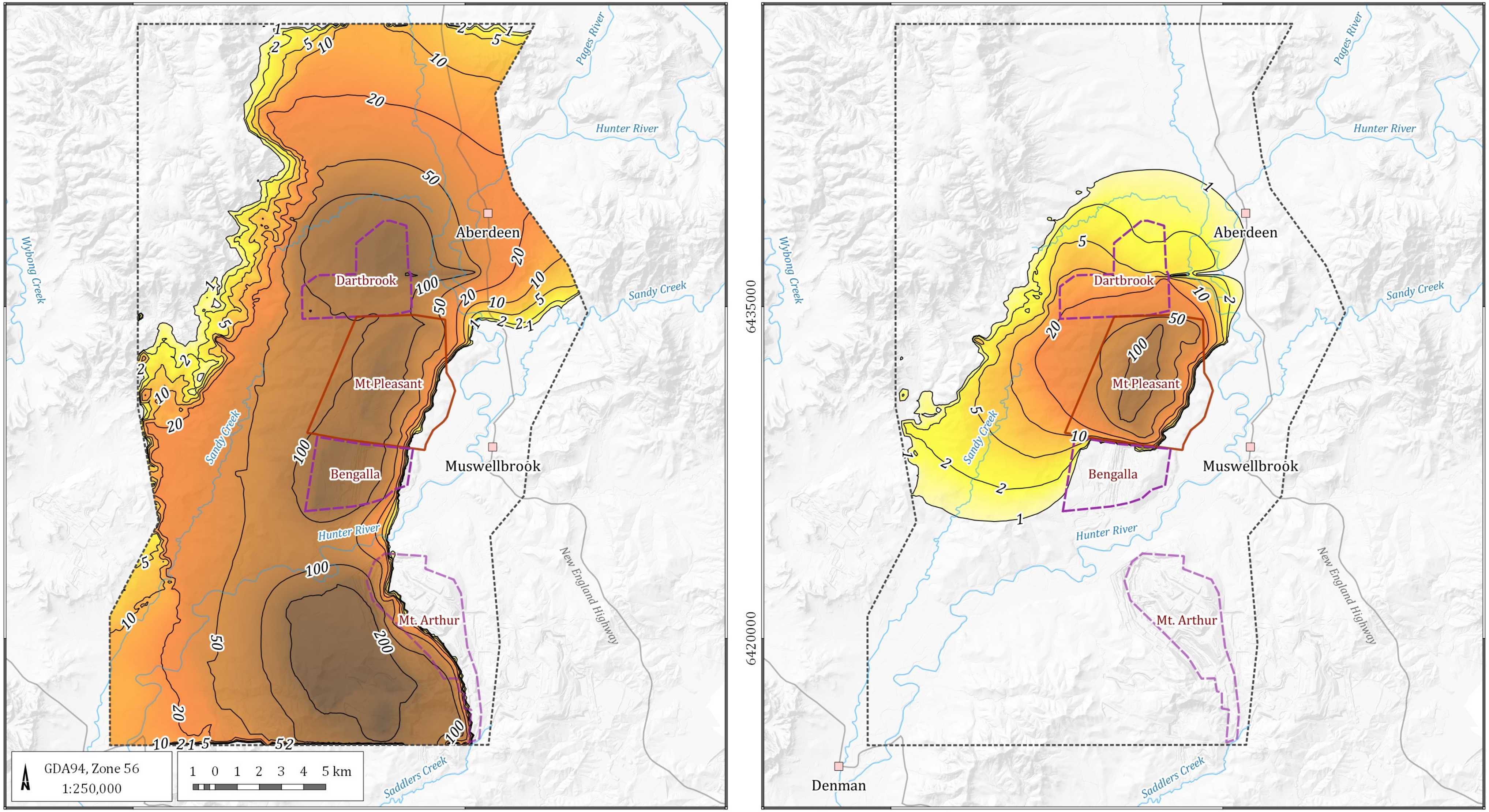
Predicted drawdown in alluvium (Layer 2) at end of mining

DATE
23/10/2020

FIGURE No:
7.2

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\GIA_report\07.02_G1970A - Predicted drawdown in alluvium (Layer 2) at end of mining.qgs

a) Maximum predicted cumulative drawdown **b) Maximum predicted drawdown attributed to MPO**



LEGEND

- Populated place
- Drainage
- Road
- Drawdown contour (m)
- Mt Pleasant mine
- Surrounding mines
- Model boundary

Drawdown (m)

0, 1, 2, 5, 10, 20, 50, 100, 200, 500

Mt Pleasant GIA (G1970A)

AGE

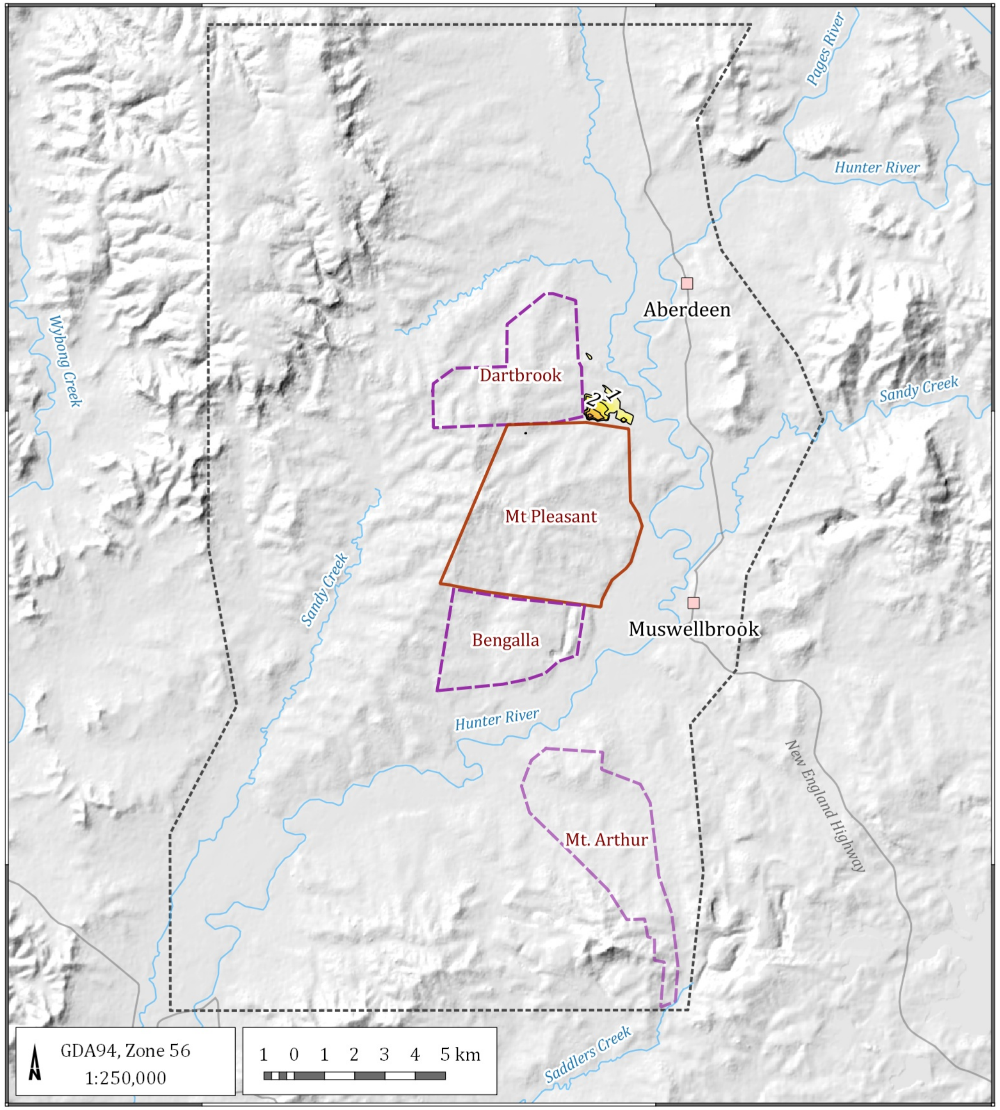
Predicted drawdown in Edderton seam (Layer 18) at end of mining

DATE
15/09/2020

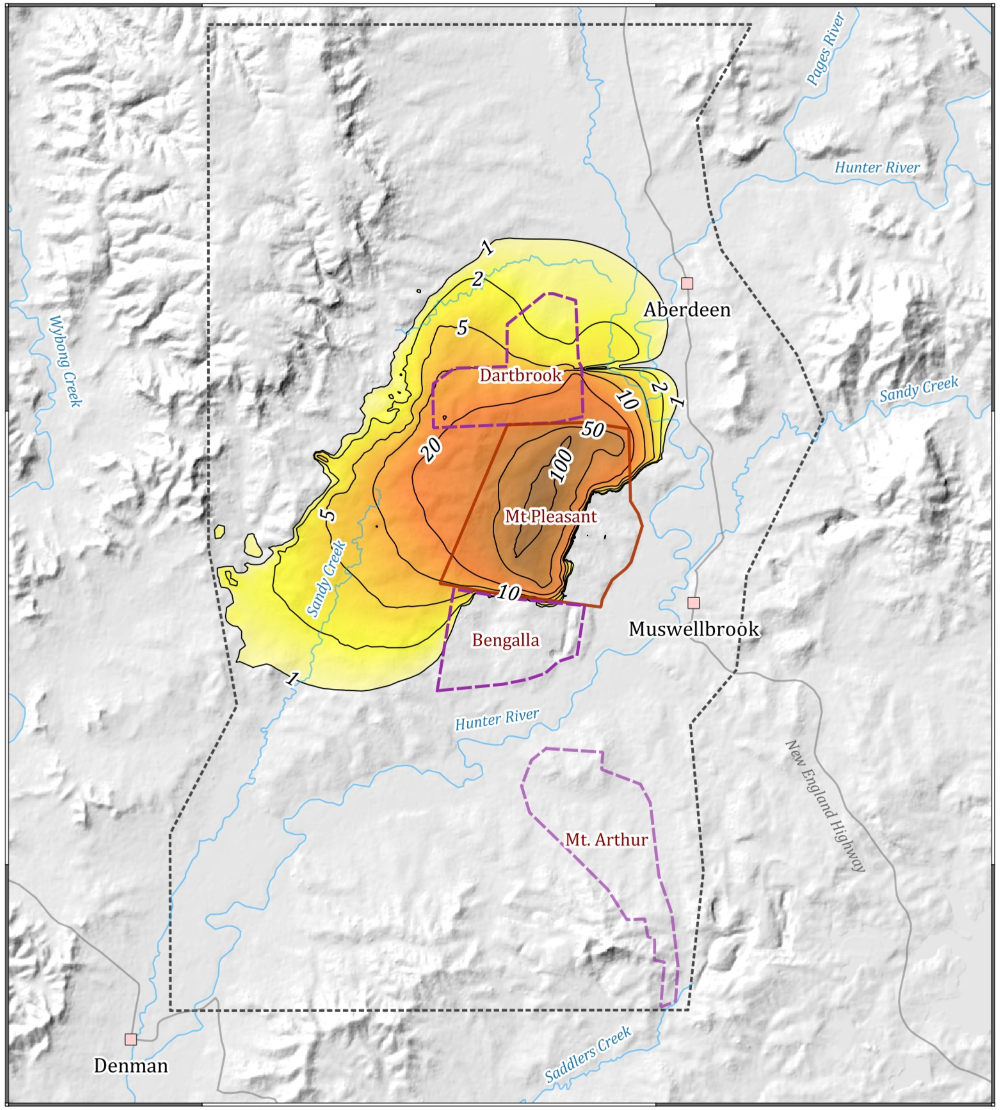
FIGURE No:
7.3

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\GIA_report\07.03_G1970A - Predicted drawdown in Edderton seam (Layer 18) at end of mining.qgs

a) Incremental increase in predicted drawdown due to the Project relative to the approved mine life (2026) in alluvium/regolith (Layer 2)



b) Incremental increase in predicted drawdown due to the Project relative to the approved mine life (2026) in Edderton Seam (Layer 18)



LEGEND

- Populated place
- Drainage
- Road
- Drawdown contour (m)
- Mt Pleasant mine
- Surrounding mines
- Model boundary

Drawdown (m)

0	20
1	50
2	100
5	200
10	500

AGE

Mt Pleasant GIA (G1970A)

Predicted incremental drawdown due to the Project only

DATE
23/10/2020

FIGURE No:
7.4

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\GIA_report\07.04_G1970A - Predicted incremental drawdown due to the Project only.qgs

7.2 Post mining recovery conditions

At the end of mining a large proportion of the open cut mining area would have been backfilled with spoil and recontoured to simulate more natural landforms in accordance with the proposed final landform. A final void would remain at the MPO, as well as at the neighbouring Bengalla Mine and Mt Arthur Coal Mine. The deepest areas of the void would be similar to the maximum depths mined.

Post mining conditions were simulated using the numerical model to determine how the changes to the groundwater system caused during mining affect the system in the long term. Appendix A (Section A4.2) provides details of the model set up and the representation of post mining conditions.

Post mining conditions were simulated by extending the model run to cover a period of 1000 years after mining ceases. Groundwater levels from the end of mining become the starting heads of the recovery period. Removal of all remaining mine 'drain cells' in the model and switching to the final landform in the backfilled mining areas also occurs at the start of this recovery period.

When interpreting the post mining results it is important to note that the long modelling period (1000 years) reduces the confidence in the forecast of post mining predictions. The post mining predictions should therefore be considered an early indicator of potential post mining impacts that should be reviewed and updated as part of post closure planning for the Project (e.g. as part of a mine closure plan).

The model results indicate that groundwater levels would gradually recover in some places close to the mine, however the drawdown extent would continue to grow with time until an equilibrium state is reached. In all mining areas, the long-term groundwater levels are predicted to equilibrate at a lower level than under pre-mining conditions, with the final void acting as a long-term groundwater sink.

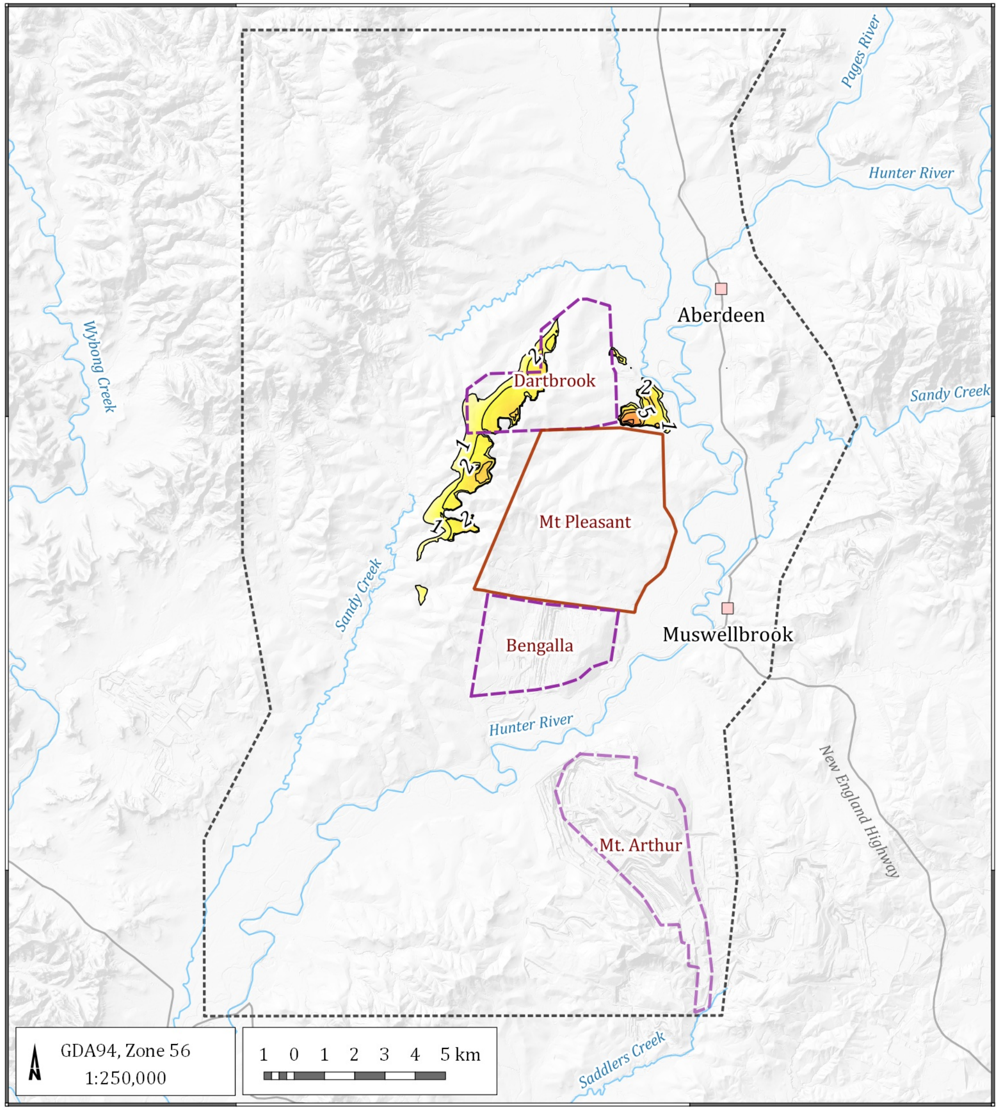
The predicted long-term residual drawdown due to the Project final void is presented in Figure 7.5 for layer 2 (representing alluvium and regolith) and layer 18 (representing the Edderton seam). These drawdowns are determined by the same differencing approach to determine the maximum drawdown due to the MPO (incorporating the Project).

Predicted flow paths for water originating from the out-of-pit waste emplacement and fines emplacement area were simulated using the groundwater model outputs and the semi-analytical particle tracking software MODPATH (Pollock, 2016). Particles were placed in selected model cells within indicative out of pit emplacement zones (to the east and north), on the western disturbance boundary and at the location of the fines emplacement area to gauge potential seepage paths around the Project. Expressions of particle movement were computed by tracking each of the particles from one model cell to the next over time.

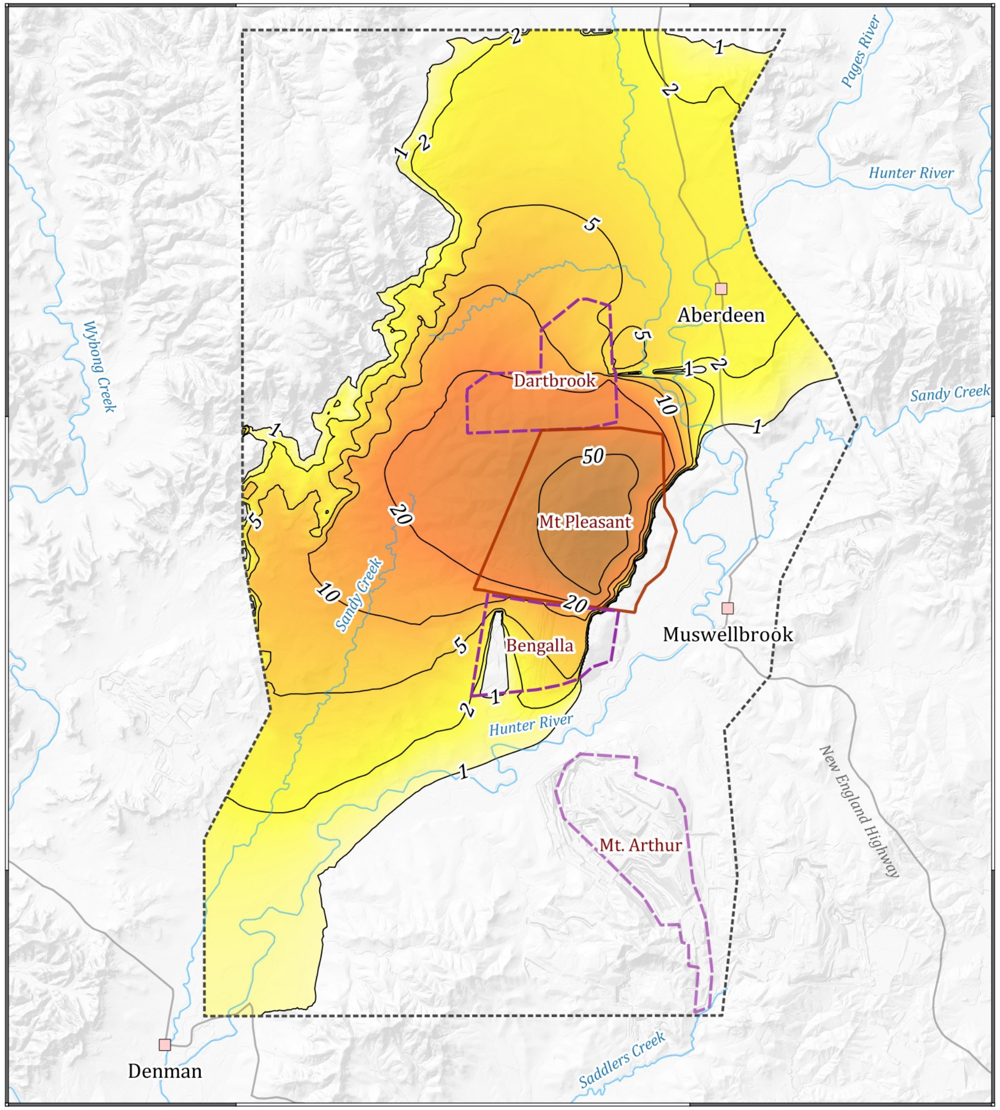
The particle tracking (Figure 7.6) using MODPATH demonstrates flow migration from the out-of-pit emplacement and fines emplacement area would be directed predominantly towards the MPO and Bengalla Mine final voids. All eastern origin points tracked down towards the MPO void or over Dartbrook, while the western particles terminated either in the MPO or Bengalla Mine final voids. One northern-based particle was directed towards the Dartbrook Mine (i.e. the underground workings). The particles in the spoil to the east of the void are predicted to take a shorter period of time to reach the void lake due to the higher hydraulic conductivity of the emplaced spoil.

Particle tracking from the fines emplacement area indicated the MPO and Bengalla Mine final voids act to largely constrain potential seepage from this structure and restrict the potential for seepage downstream in the Sandy Creek catchment.

a) Maximum predicted drawdown attributed to MPO in alluvium/regolith (Layer 2)



b) Maximum predicted drawdown attributed to MPO in Edderton Seam (Layer 18)



LEGEND

- Populated place
- Drainage
- Road
- Drawdown contour (m)
- Mt Pleasant mine
- Surrounding mines
- Model boundary

Drawdown (m)

0, 1, 2, 5, 10, 20, 50, 100, 200, 500

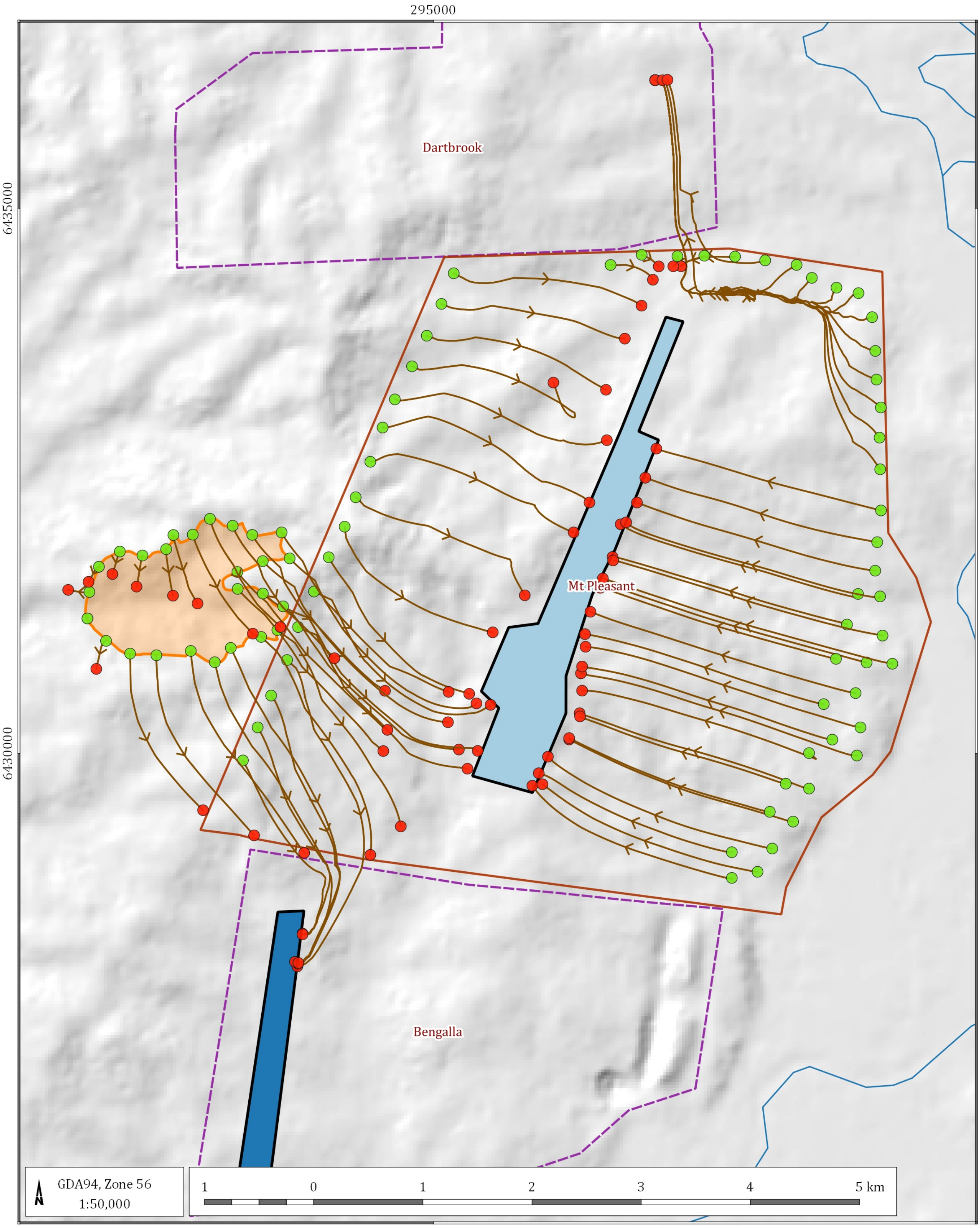
Mt Pleasant GIA (G1970A)

Post recovery drawdown attributed to MPO

DATE 18/11/2020

FIGURE No: **7.5**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\GIA_report\07.05_G1970A - Post recovery drawdown attributed to MPO.qgs



LEGEND

- Bengalla
- Dartbrook
- Mt Pleasant
- Mt. Arthur
- Model boundary
- MPO final void
- Bengalla final void
- Final Western Tailings Dam
- Populated place
- Drainage
- Road
- Particle start point
- Particle pathlines
- Particle termination point

Mt Pleasant GIA (G1970A)

Predicted particle pathlines post-mining

DATE 20/11/2020

FIGURE No: 7.6

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\GIA_report\03_G1970B_Predicted particle pathlines post mining.qgs

8 Groundwater Impact assessment

8.1 Incidental take of water from the alluvium and stream flow effects

The model was used to determine the potential for mining to interfere with the alluvial groundwater systems and to provide estimates of indirect 'water take' in accordance with the AIP. Mining would not directly intercept alluvial aquifers, however, an indirect impact or 'water take' occurs as the Permian strata become depressurised and the volume of groundwater flowing from the Permian to the Quaternary alluvium progressively reduces. The change in alluvial water resources was determined by comparing water budgets for alluvial zones using versions of the numerical model that contained and excluded MPO.

8.1.1 Indirect take from alluvium

The indirect take from the Hunter River, Sandy Creek and Dart Brook alluvium is presented in Figure 8.1. In accordance with the AIP, the predicted change in baseflow has been subtracted from the change in alluvial flow to prevent double accounting.

The unadjusted indirect take from the Hunter River alluvium due to the MPO (incorporating the Project) peaks at 27 ML/year by the end of mining. The incremental change in indirect take from the alluvium due to the Project (i.e. relative to the approved MPO) is predicted to be 20 ML/year.

The indirect take from the Sandy Creek alluvium increases over time, with peak take of 2 ML/year by the end of mining. Similarly, indirect take from the Dart Brook alluvium increases to a maximum of 6 ML/year by the end of mining.

8.1.2 Indirect take from surface water

Baseflow to the streams in the vicinity of MPO is reduced as mining draws down the water table, influencing the magnitude and direction of surface water-groundwater exchange.

The predicted reduction of baseflow due to the MPO (incorporating the Project) in each of the Hunter River, Sandy Creek and Dart Brook is shown on Figure 8.2.

The predicted reduction in baseflow to the Hunter River due to the Project is 27 ML/year at the end of 2048, rising to a peak of 32 ML/year in the post-mining phase. Potential impacts to baseflow in Sandy Creek and Dart Brook are predicted to be negligible (i.e. peak reduction in baseflow of 2 ML/year and 6 ML/year, respectively).

8.1.3 Post mining changes in alluvial and surface water fluxes

The equilibrium water level in the final void is predicted to be significantly lower than the pre-mining water level. 'Water take' from the groundwater systems would continue post mining due to the continued flow of groundwater to the final void.

The long-term peak indirect take from each water source is considered in the Project water licensing requirements (Section 1.1).

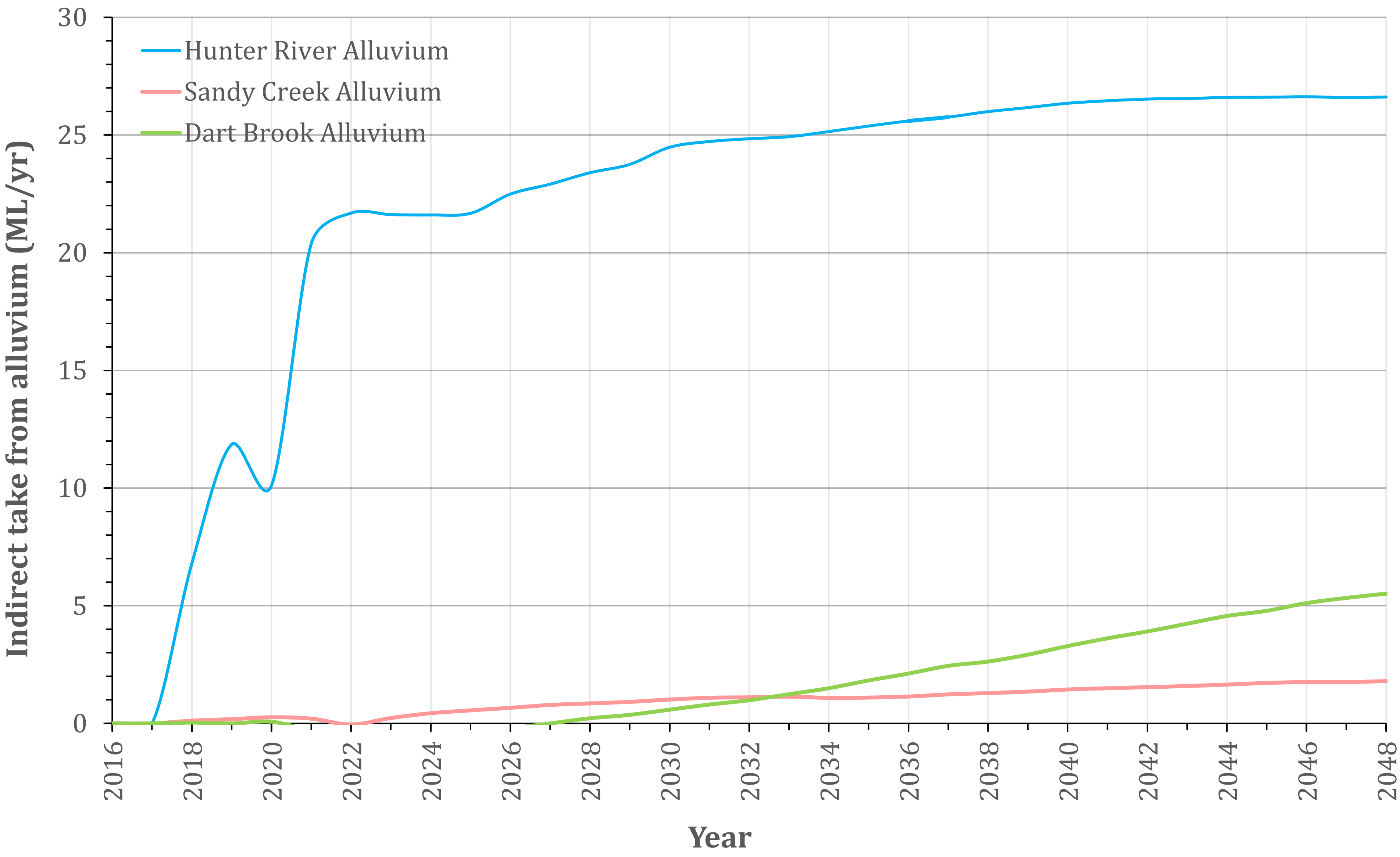


Figure 8.1 Indirect take from alluvium bodies surrounding MPO

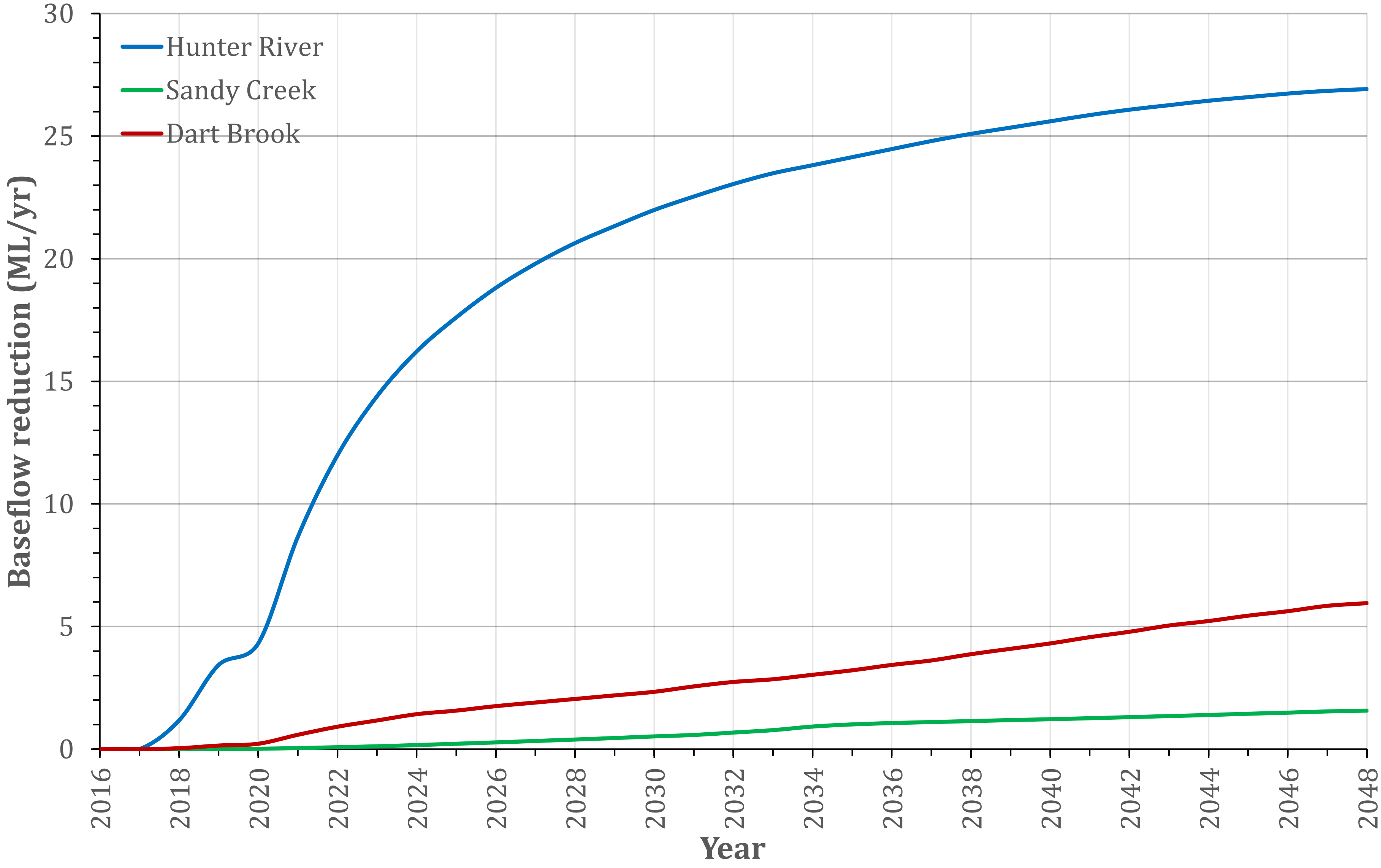


Figure 8.2 Reduction in baseflow induced by MPO

8.2 Water licensing requirements

The *Water Management Act, 2000* and AIP require that all groundwater taken, either directly or indirectly, is accounted for via WALs. Groundwater intercepted from the mining area is considered a direct take from the Permian groundwater system, whilst the changes in flow occurring within the Quaternary alluvium and rivers resulting from depressurisation of the underlying Permian is considered an indirect take.

A summary of the water licensing requirements for the MPO (incorporating the Project) is provided in Table 8.1. MACH holds sufficient licences to account for the take from each water source, with the exception of 13 ML/year of predicted take from the Dart Brook Water Source, which is regulated under the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources, 2009*. MACH would be readily able to acquire this entitlement given:

- the modest license deficit of 13 ML/year represents a very small fraction of the overall entitlement available in the Dart Brook Water Source (approximately 30,000 units); and
- WALs in the Dart Brook Water Source are actively traded, with 2,697 units permanently transferred in the 2019-2020 water year.

The proportion of inflows from the various water sources is summarised in Table 8.1. The post mining take from the North Coast fractured Rock Water Sharing Plan is 44 ML/year from the perspective of flow from host rock into the mined area to the pit void. Within the mined area, the additional recharge on the spoil also flows to the void, which increases the total groundwater inflows to the void to 547 ML/year.

Table 8.1 Water Licensing Requirements for the MPO (incorporating the Project)

Water Sharing Plan	Water source	Share components [Units]	During Mining Water Licensing Requirements (ML/year)	Post-mining Water Licensing Requirements (ML/year)
Hunter Regulated River Water Source, 2016	Hunter Regulated River (Management Zone 1A)	961 (High) 2,937 (General)	27	32
Hunter Unregulated and Alluvial Water Sources, 2009	Hunter Regulated River Alluvial	285	27	34
	Muswellbrook	41	2	6
	Dart Brook	Nil	6	13
North Coast Fractured and Porous Rock Groundwater Sources, 2016	Sydney Basin	730	247	44 (547 if spoil is included)

8.3 Water supply bores

Section 5.8.2 described groundwater usage in private bores in proximity of the MPO Project. The bore census identified 39 bores, wells and springs that exist on privately owned land used for irrigation, stock watering and domestic purposes in the proximity of the Project. Several bores also form part of the current and historic monitoring networks at surrounding coal mining operations.

An assessment of drawdown in private bores was conducted, considering both the impacts of the MPO (incorporating the Project) and cumulative regional mining (future active mining at Dartbrook Mine, Bengalla Mine and Mt Arthur Coal Mine) on private bores. Of the 39 locations identified in the census, 35 of the locations were included in this assessment as the remainder were abandoned. Where bores lacked a record of depth, it was assumed that the bore accessed the most productive layer in that location (e.g. bores located within the extent of the Hunter River alluvium were assumed to access the alluvial layers).

A total of six bores on private property were predicted to experience drawdown exceeding 2 m due to cumulative impacts from the MPO (incorporating the Project) and neighbouring mines. Details of the bores and the predicted drawdown at each location are summarised in Table 8.2.

Two of the private bores, CAS3_G and JLON1, are understood to already be dry. A further three bores: CAS1_G, CAS2_G and CAS4_G that are projected to experience more than 2 m drawdown due to MPO are not currently in use. Therefore, the BELGRAVE bore is the only location that is active and not dry, and predicted to experience more than 2 m drawdown due to MPO.

Existing monitoring undertaken at CAS1_G and CAS4_G as part of the Dartbrook Mine groundwater monitoring programme indicates these bores have already experienced approximately 15 m drawdown due to the operation of the Dartbrook Mine.

The BELGRAVE bore has been monitored by Dartbrook Mine since 2000. Monitoring data collected from the BELGRAVE bore indicates (AQC Dartbrook Management, 2020):

- the BELGRAVE bore recorded a decline in groundwater levels in response to mining between 2004 and 2006;
- pH has fluctuated between 6.6 and 9.2; and
- EC has ranged from approximately 5,000 µS/cm to 12,500 µS/cm.

The BELGRAVE bore is accessing regolith material associated with the 'less productive' Sydney Basin-North Coast Groundwater Source.

Table 8.2 Drawdown in private bores

Bore ID	Depth (mTOC)	Groundwater level (mBGL)	Electrical Conductivity (µS/cm)	Max drawdown: All mining (m)	Max drawdown: MPO (m)	Type
BELGRAVE	23.85	7.16	6,280	7.74	3.31	Well - Stock & Monitoring
CAS1_G	28.23	11.73	8,040	12.03	7.15	Bore - Not in Use
CAS2_G	65	39.71	13,045	13.80	3.44	Bore - Monitoring (Not in Use)
CAS3_G	76.7	Dry	Dry	15.94	3.43	Bore - Not in Use*
CAS4_G	34.8	27.89	10,585	33.51	2.10	Bore - Monitoring (Not in Use)
JLON1	52	Dry	Dry	12.11	9.34	Well & Bore - Monitoring*

Notes: *Groundwater level & EC data for all bores is sourced from regional monitoring/Mt Pleasant census data from 2016-2020.*

** Bore observed to be dry.*

8.4 Groundwater dependent ecosystems

The following potential GDEs have been identified in the vicinity of the Project (Sections 5.8.3 and 5.8.4):

- the Hunter River is identified as a potential Type 2 aquatic GDE based on the BoM GDE Atlas;
- approximately 3 ha of Forest Red Gum Grassy Open Forest (PCT 618) has been identified as a potential Type 3 terrestrial GDE (Hunter Eco, 2020); and
- Stygofauna collected from bores accessing the Hunter River alluvium.

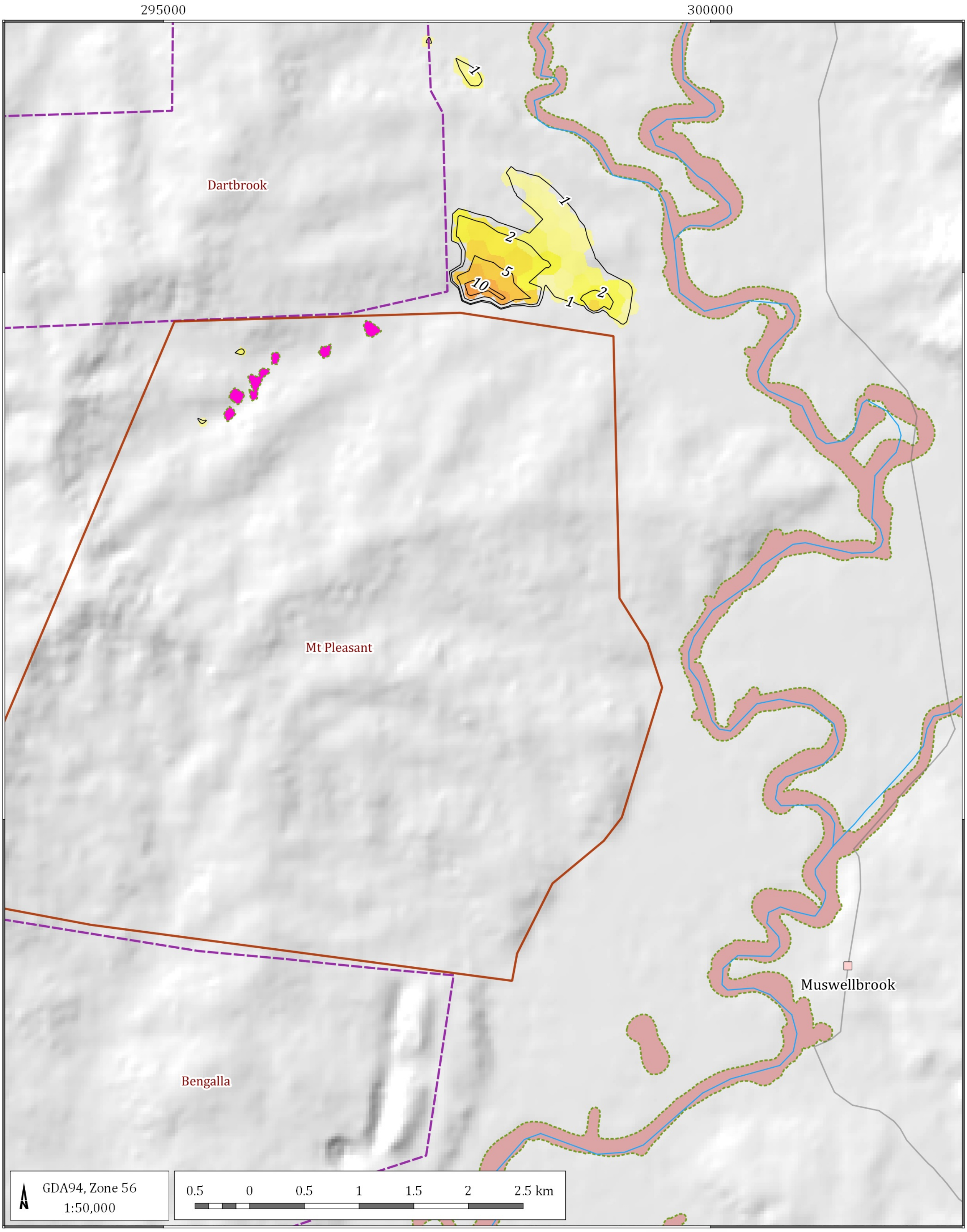
No high priority GDEs listed in the *Hunter Unregulated and Alluvial Water Sources Water Sharing Plan 2009* are in the vicinity of the Project area. Wappinguy Spring, approximately 40 km to the north-west of the mine area, is the closest high priority GDE listed in the *Hunter Unregulated and Alluvial Water Sources Water Sharing Plan 2009*.

The impacts to the Hunter River were evaluated through assessment of the drawdown extent in the nearby alluvium. The alluvium area predicted to experience drawdown due to the Project is limited, being located primarily to the north of Mt Pleasant and due east of Dartbrook Mine as shown in Figure 8.3. The predicted peak reduction in baseflow to the Hunter River due to the Project is 29 ML/year, which is negligible relative to the total flows in the Hunter River (greater than 100,000 ML/year on average).

During-mining, the predicted drawdown in the vicinity of the Forest Red Gum Grassy Open Forest (PCT 618) is negligible (Figure 8.3). Larger drawdowns are predicted during the post-mining recovery period. However, these are not anticipated to impact the condition of the vegetation community on the basis that the community only accesses groundwater on a facultative basis and has persisted despite being subject to groundwater drawdowns from previous mining activities.

Groundwater monitoring would be undertaken in the vicinity of the Forest Red Gum Grassy Open Forest (PCT 618) to confirm any impact to the vegetation community remains negligible and to increase confidence in future post-mining recovery groundwater modelling.

All of the stygofauna taxa collected in the vicinity of the Project are prevalent elsewhere in the Hunter Valley (Section 5.8.4). There is no significant drawdown predicted along the Hunter River alluvium and therefore potential impacts to these stygofauna populations are predicted to be negligible.



LEGEND

- Populated place
- Drainage
- Road
- Drawdown contour (m)
- Mt Pleasant mine
- Surrounding mines
- High potential terrestrial GDE 40 m buffer zone
- Forest Red Gum Grassy Open Forest (PCT 618)

Drawdown (m)

- 0
- 1
- 2
- 5
- 10
- 20
- 50

Mt Pleasant GIA (G1970A)

Predicted drawdown in the vicinity of potential GDEs

AGE

DATE 20/11/2020

FIGURE No: **8.3**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\GIA_report\08.03_G1970A - Predicted drawdown in the vicinity of potential GDEs.qgs

8.5 Groundwater quality

Key components of the Project that could affect groundwater quality are as follows:

- continuation of open cut mining;
- co-disposal of coarse and dewatered fine rejects with waste rock as part of ROM waste rock operations;
- continued development of the out-of-pit waste rock emplacement; and
- continued development of the fines emplacement area, including the construction of additional downstream embankment raises (lifts).

As mining progresses the void would act as a groundwater sink, preventing interaction between the final void water and the surrounding natural groundwater systems. Therefore, there would be no groundwater quality impact associated with the Project open cut.

The original water management study prepared for the MPO (PPK, 1997) predicted some seepage of water from the approved final landform to the surrounding natural groundwater system, including:

- seepage from the fines emplacement area towards the Sandy Creek alluvium; and
- seepage from the out-of-pit emplacement eastwards to the adjacent Hunter River alluvium.

During operations, the fines emplacement area would be managed in accordance with the *Mount Pleasant Operation Fines Emplacement Plan* (ATC Williams, 2017). The plan provides for the management of seepage from the fines emplacement area as follows:

- establishment of a foundation drain to manage potential seepage through the embankment;
- a clay fill cut-off key is constructed into the bedrock underlying the embankment footprint to minimise the potential for shallow seepage beneath the fines emplacement area;
- seepage water is collected, tested and recovered using a pump back system as required; and
- prioritising the return of decant water to the water management system, thereby minimising the decant pond volume and seepage potential of the fines emplacement area.

With the implementation of the above measures, the potential impacts on groundwater quality during the operation of the fines emplacement area is predicted to be negligible.

The Project involves the deepening and continued operation of the open cut pit in a westerly direction. As a result, the final void would be located closer to the fines emplacement area, drawing seepage towards the voids as opposed to the Sandy Creek alluvium. The increased depth of the final void would also increase the hydraulic gradient from the out-of-pit spoil towards the final void, reducing the potential for seepage towards the Hunter River alluvium.

The potential for seepage from the proposed final landform has been assessed using groundwater model outputs and the semi-analytical particle tracking software MODPATH (Pollock, 2016) (Section 7.2). The MODPATH analysis demonstrates that seepage from the fines emplacement area and out-of-pit waste emplacement area is predicted to primarily report to the Project and Bengalla Mine final voids.

Based on the above, the Project is considered to have a negligible impact on groundwater quality.

9 Sensitivity and uncertainty analysis

9.1 Overview

Middlemis and Peeters (2018) outline three general approaches to analysing parameter uncertainty in increasing order of complexity and of the level of resources required, they are:

1. deterministic scenario analysis with subjective probability assessment;
2. deterministic modelling with linear probability quantification; and
3. stochastic modelling with Bayesian probability quantification.

In this case a Monte Carlo (MC) uncertainty analysis was undertaken (option 3) to quantify the magnitude of uncertainty in the future impacts predicted by the model. This type of analysis produces probability distributions for predictive impacts by assessing a composite likelihood of an impact occurring through assessing and ranking the predictions from hundreds of model 'realisations'. Each model realisation is informed by the observation dataset by using the relationship between the observation statistics to perturbations of each parameter in the groundwater model.

This uncertainty analysis was essentially undertaken as a three-part process. Firstly, a valid range for each parameter (i.e. pre-calibration range) was determined, and then 300 model realisations were created, each with varied values of model parameters. The pre-calibration range used was identical to that used previously in the basecase model calibration (Appendix A).

The constrained realisations were tested and the models that failed to converge or could not achieve adequate calibration were rejected, leaving the output from 201 successful models. Models were considered to have an acceptable calibration if SRMS (heads) ≤10%. The outputs were analysed to provide a statistical distribution of the predictive impacts.

Outputs from the uncertainty modelling were processed in accordance with the risk-based calibrated language proposed in Middlemis & Peeters (2018). The ranges adopted are shown in Table 9.1.

Table 9.1 Calibrated uncertainty modelling language

Narrative descriptor	Probability class	Description	Colour code
Very likely	0-10%	Likely to occur even in extreme conditions	
Likely	10-33%	Expected to occur in normal conditions	
About as likely as not	33-67%	About an equal chance of occurring as not	
Unlikely	67-90%	Not expected to occur in normal conditions	
Very unlikely	90-100%	Not likely to occur even in extreme conditions	

9.2 Mine inflow rate

The range of possible inflow volumes from the basecase parameter set (Figure 9.1) indicate that despite calibration, uncertainty in model parameters results in variation in the simulated inflows. The predicted peak inflows range from 140 ML/year (1%) to 595 ML/year (98%), compared to the predicted inflow for the basecase of 247 ML/yr. The 98th percentile model case (595 ML/yr) remains within MACH's existing water licensing entitlement (730 units).

9.3 Baseflow reduction in Hunter River, Sandy Creek and Dart Brook

Figure 9.2 shows the variability of take from the Hunter River resulting from the uncertainty in model parameters. Despite the range of inflows, even the extremely unlikely upper take of 77 ML/yr is well within the MACH share components for the Hunter Regulated River source.

The extremely unlikely upper estimates of baseflow reduction for Sandy Creek and Dart Brook remain negligible (less than 20 ML/yr) (Figure 9.3 and Figure 9.4).

9.4 Indirect take from the Hunter River alluvium, Sandy Creek alluvium and Dart Brook alluvium

The range of predicted volumes of indirect take for the Hunter River alluvium, can be seen in Figure 9.5. Current MACH licensing for the Hunter River Regulated Alluvial Source exceeds even the *very unlikely* scenario (29.6 ML/yr), indicating that MPO would remain well within its licencing limits.

The extremely unlikely upper estimates of alluvial take for Sandy Creek and Dart Brook remain negligible (less than 10 ML/yr) (Figure 9.6 and Figure 9.7).

9.5 Zone of 2 m drawdown

The extent of the zone of 2 m drawdown at the end of mining (December 2048) was assessed for each of the 201 model runs. The total number of times a model cell had drawdown >2 m was tallied and converted to a percentile. The resulting contours for each percentile are shown on Figure 9.8 and Figure 9.9. The greater the extent of the drawdown away from the mine, the less likely it is to occur.

Please note that the colour ramp for Figure 9.8 and Figure 9.9 is reversed compared to the calibrated model language presented in Table 9.1. It is logical for the drawdown regions that fewer occurrences of 2 m drawdown in a model cell results in less chance of that drawdown being exceeded, whereas for the inflows there was greater chance of the inflow rate being exceeded if the percentile was low.

In the alluvium (Layer 2), it is *very unlikely (0.1-10%)* that the Sandy Creek alluvium would incur 2 m drawdown as a result of MPO.

The predicted zones of 2 m drawdown in the Hunter River and Dart Brook alluvium can be summarised as follows:

- the greatest likelihood zone intersecting the Hunter River Alluvium is *likely (67-90%);* and
- the highest probability zone crossing the Dart Brook Alluvium is *about as likely as not (33-67%).*

In the Edderton Seam (Layer 18), it is *unlikely (10-33%)* that the majority of the predicted basecase model extent of 2 m drawdown would be exceeded. Minor reaches to the west and to the north of MPO demonstrate areas *about as likely as not (33-67%)* to experience 2 m drawdown outside the predicted range of the basecase model.

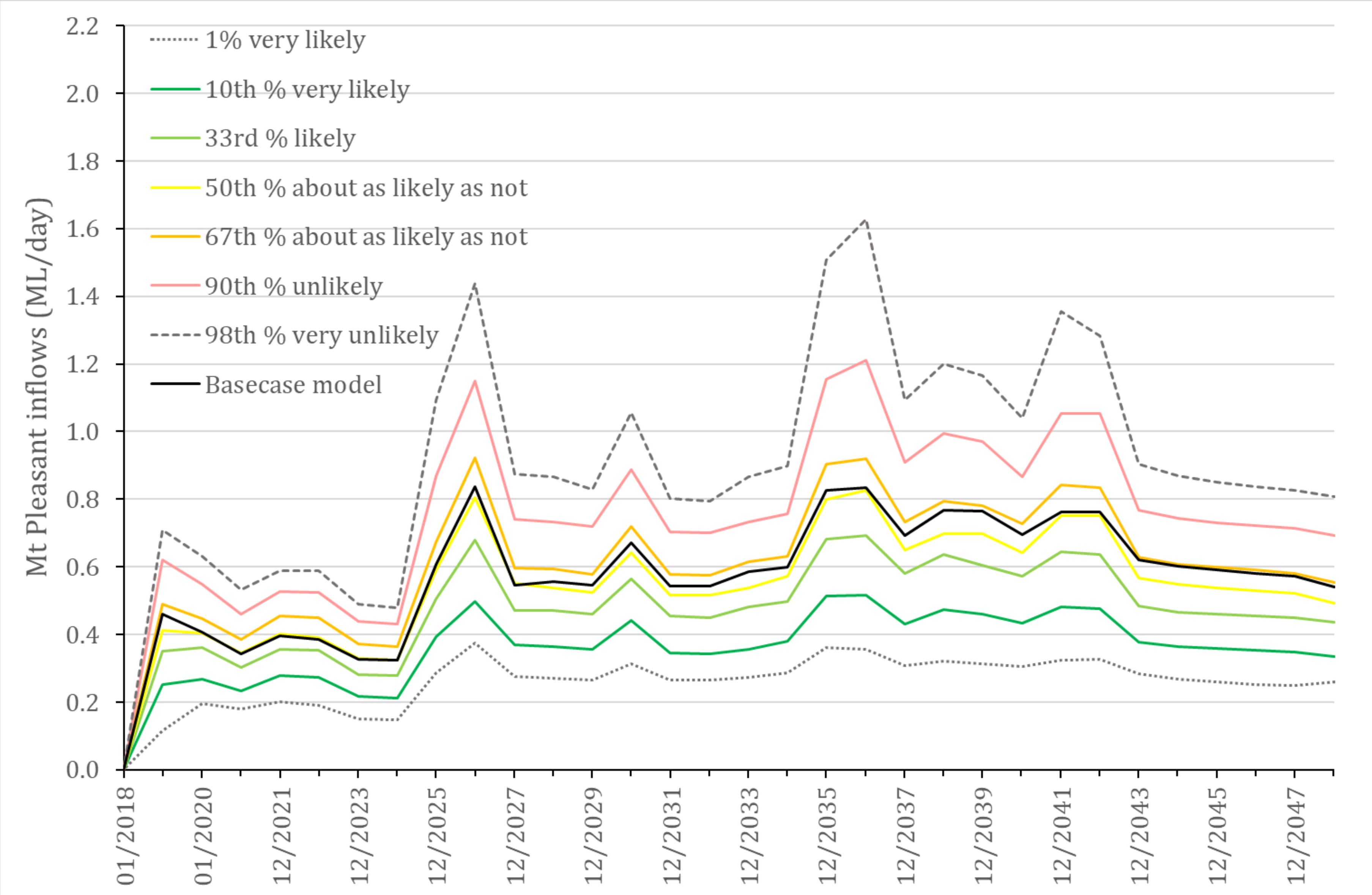


Figure 9.1 Probability distribution for MPO mine inflow rate

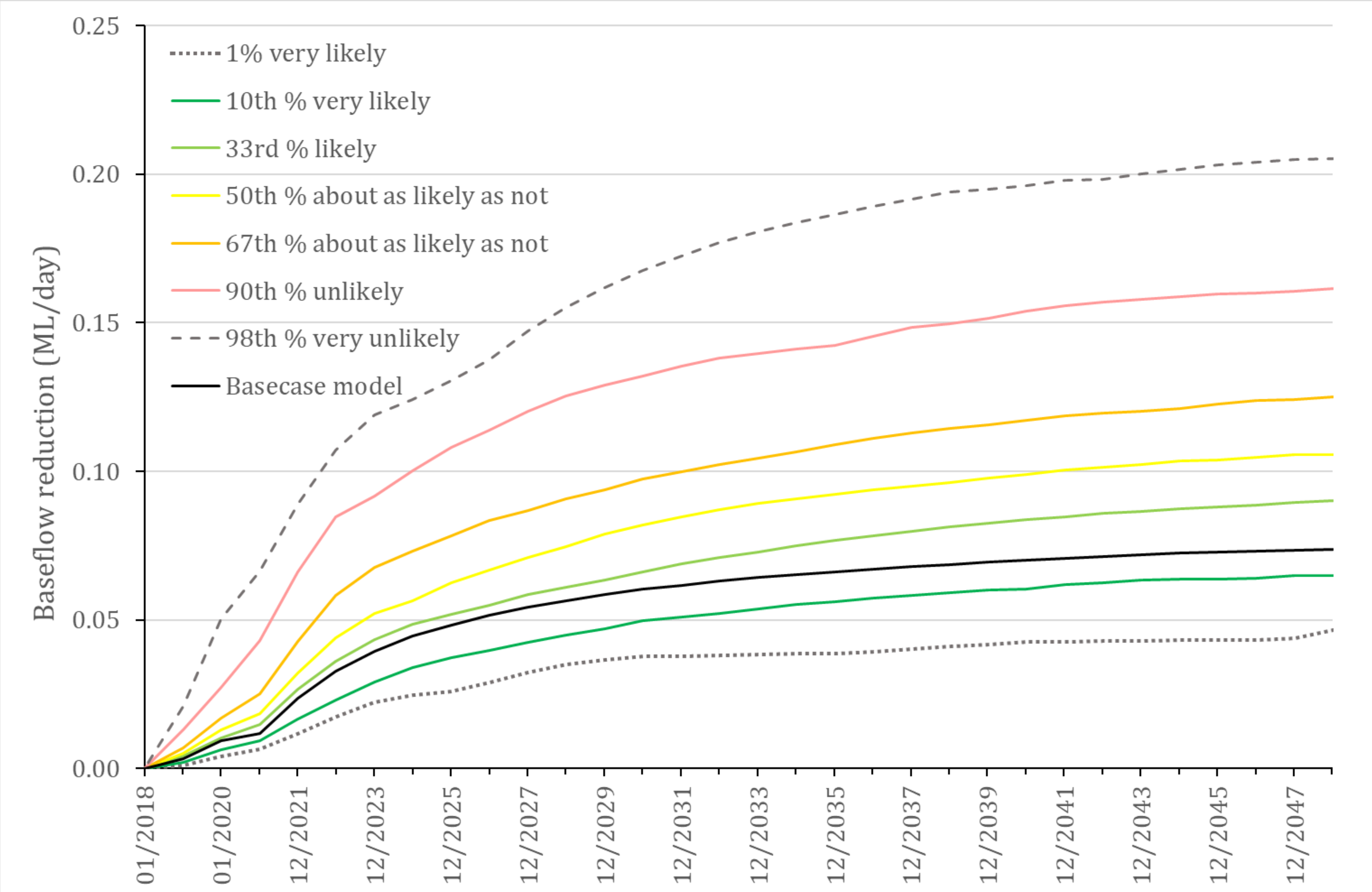


Figure 9.2 Probability distribution for rate of baseflow decline in Hunter River

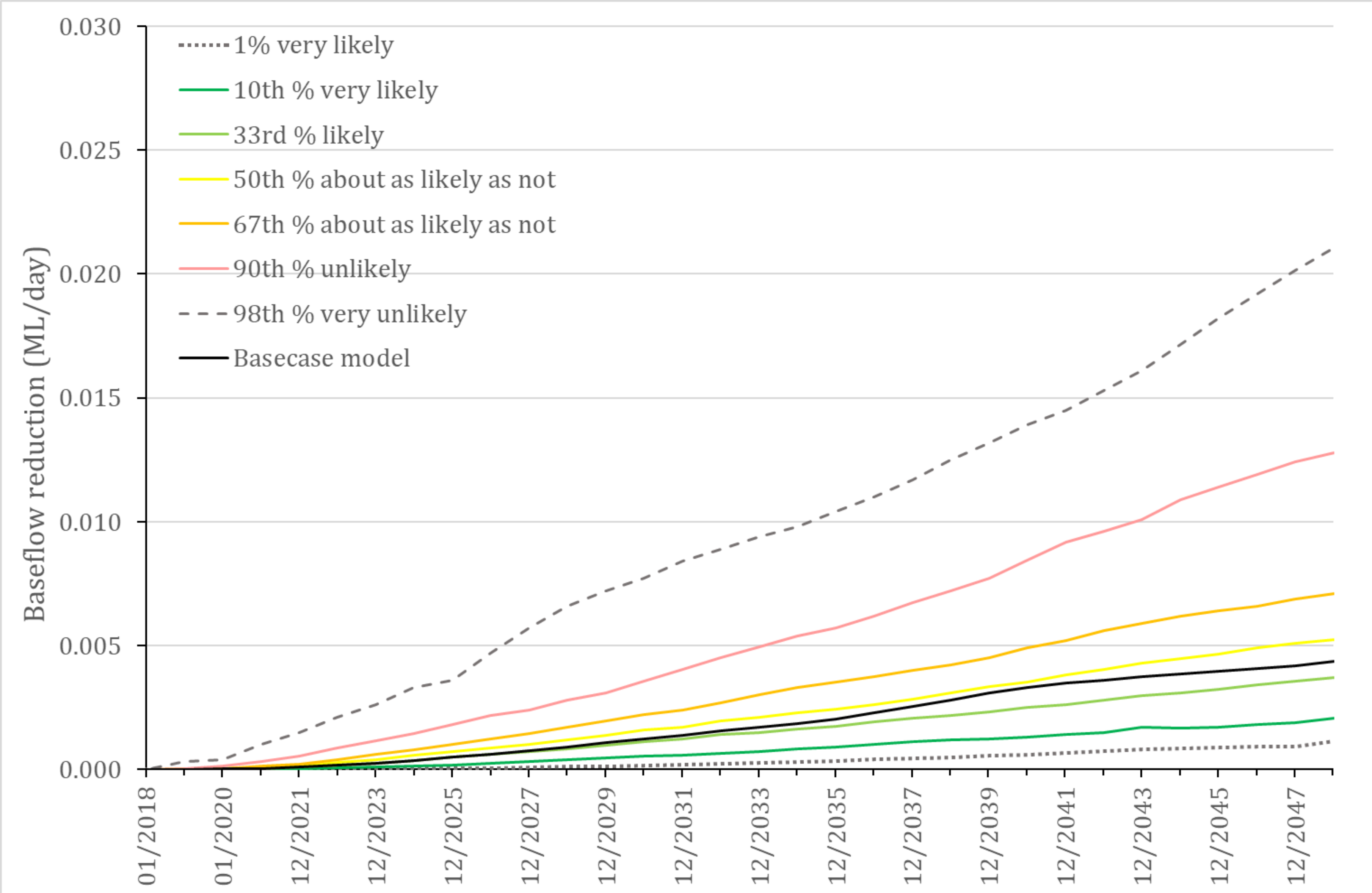


Figure 9.3 Probability distribution for rate of baseflow decline in Sandy Creek

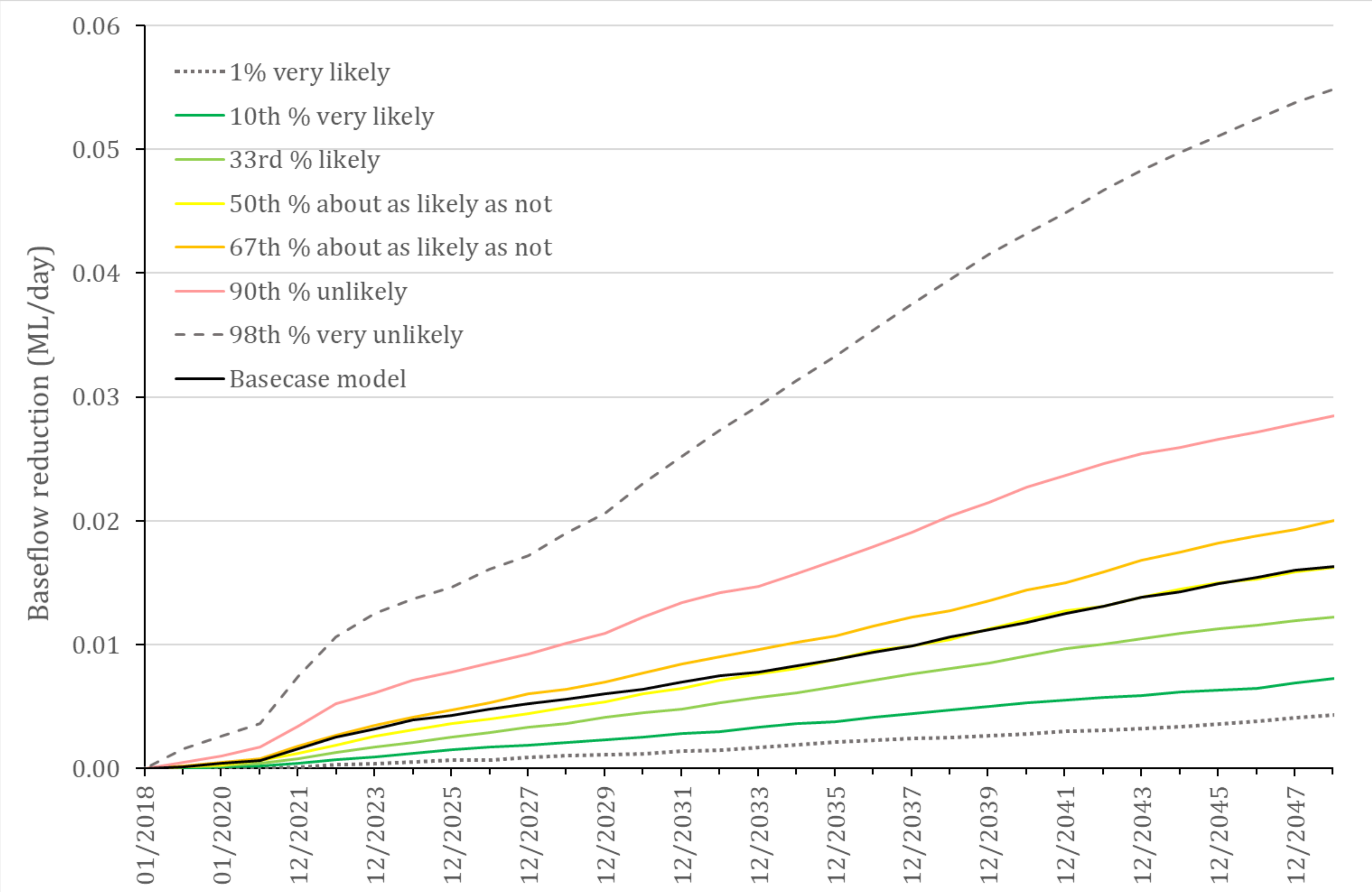


Figure 9.4 Probability distribution for rate of baseflow decline in Dart Brook

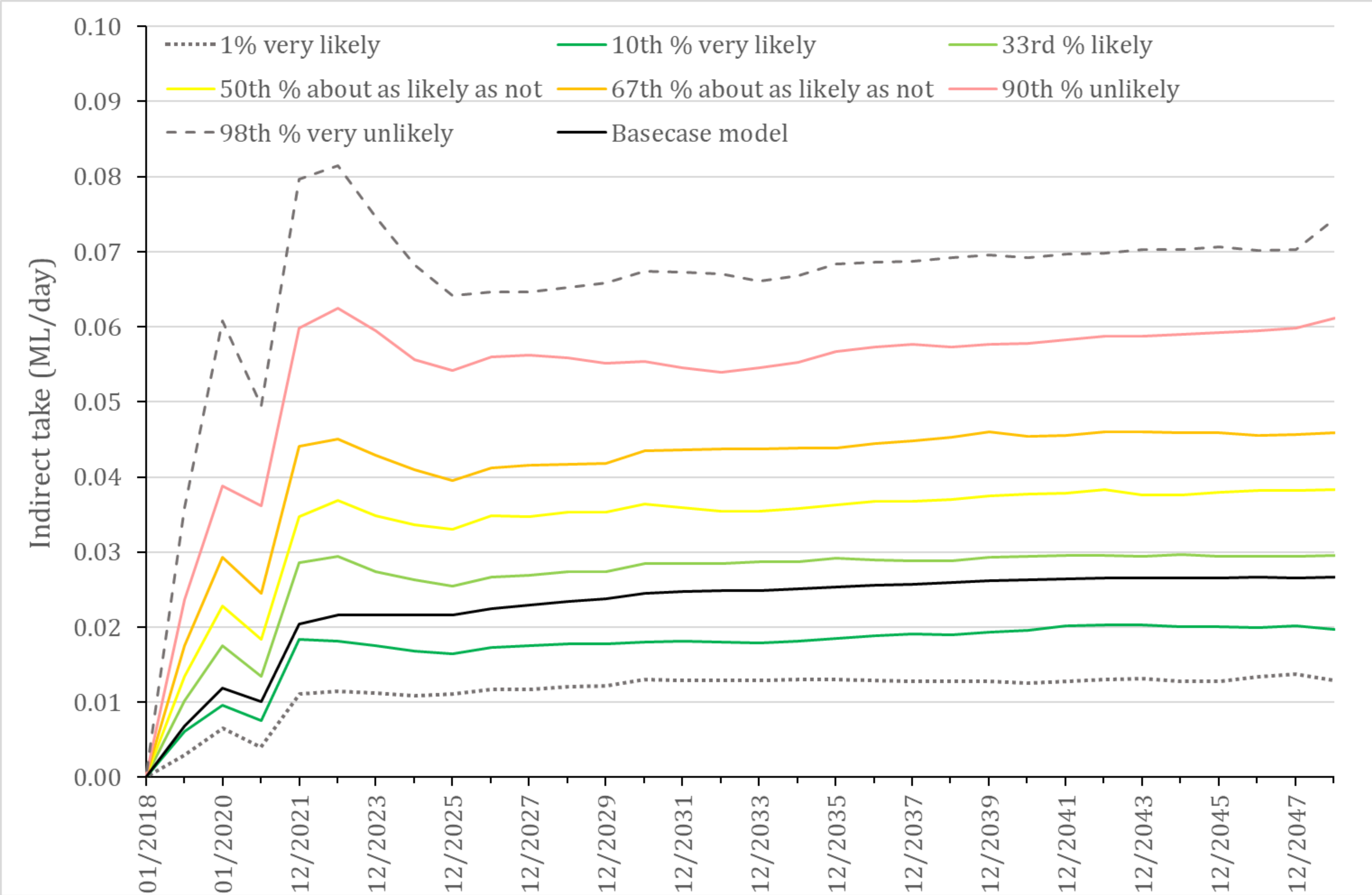


Figure 9.5 Probability distribution for indirect alluvial take from Hunter River alluvium

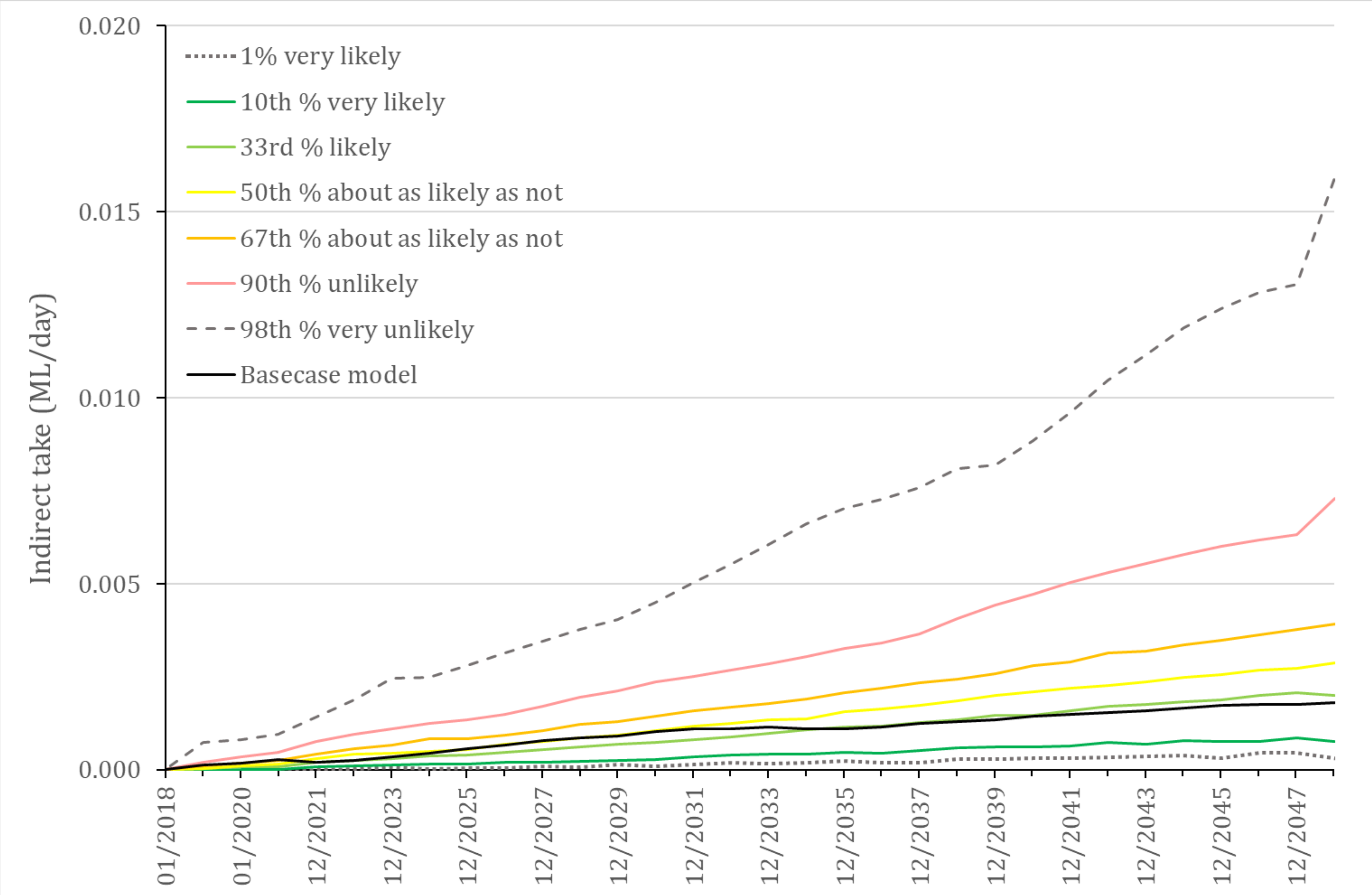


Figure 9.6 Probability distribution for indirect take from Sandy Creek alluvium

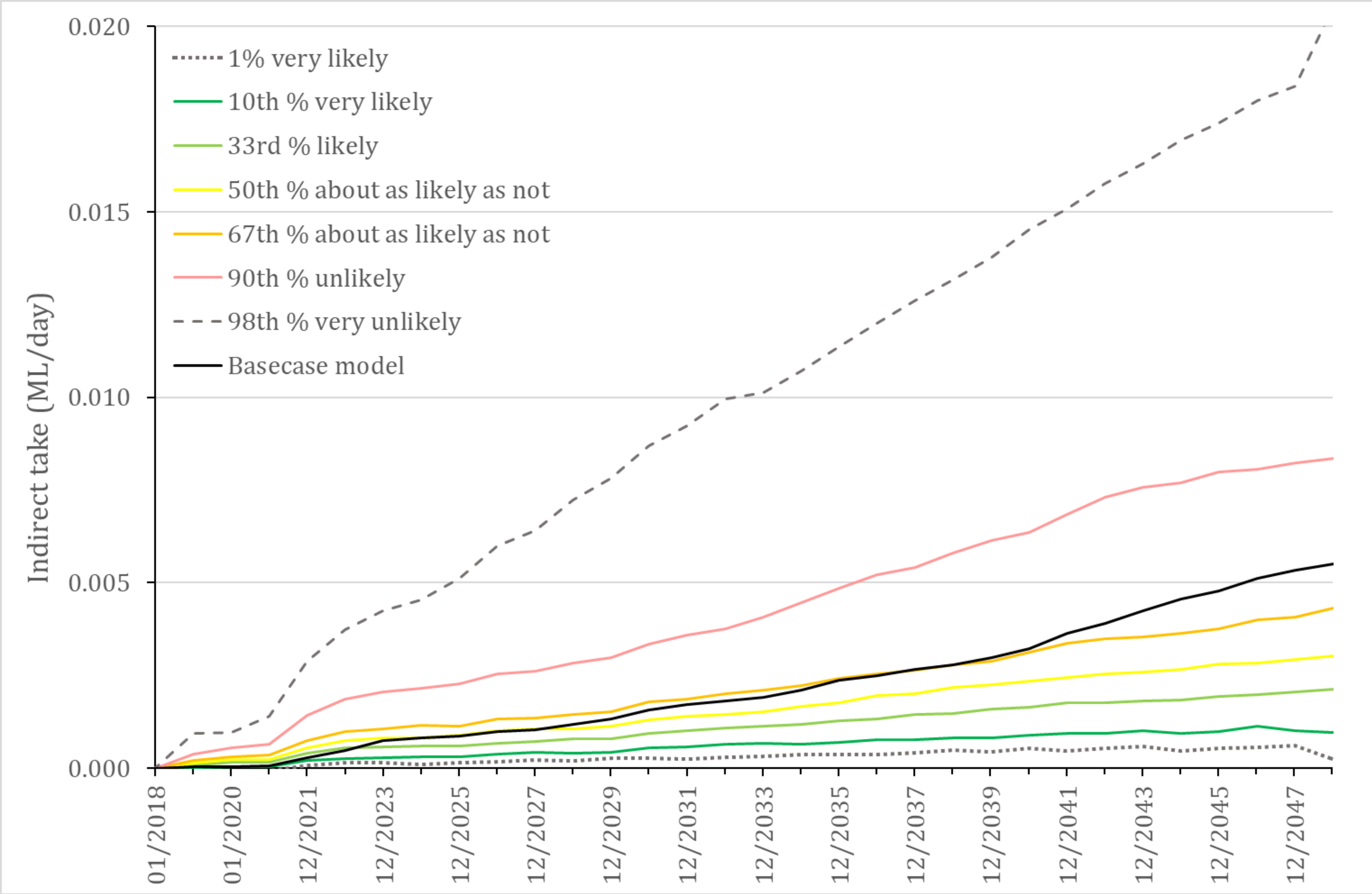
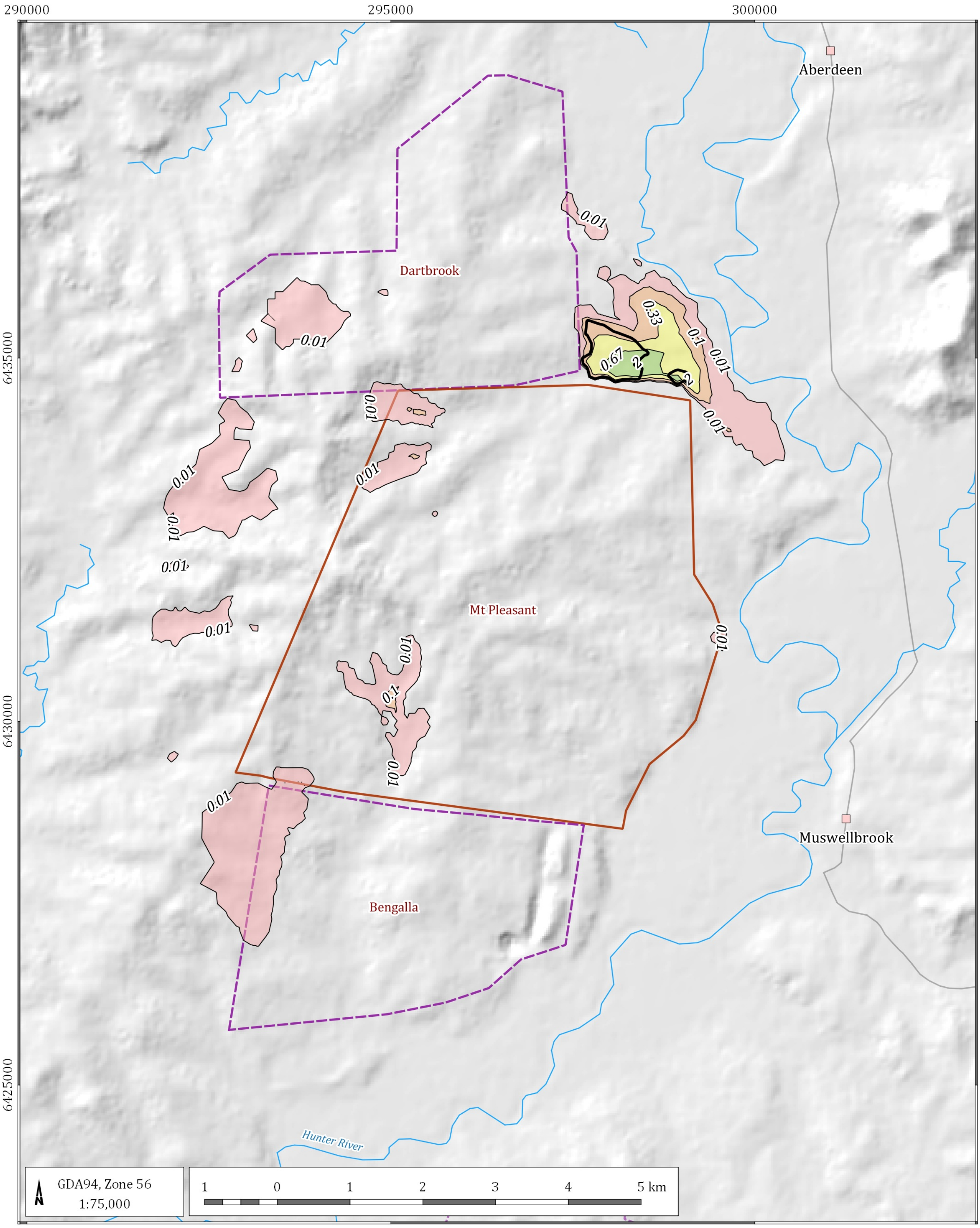


Figure 9.7 Probability distribution for indirect take from Dart Brook alluvium



LEGEND

- Populated place
- Drainage
- Road
- Drawdown contour
- Mt Pleasant mine
- Surrounding mines
- Base case 2 m drawdown zone

Likelihood of 2 m drawdown

- Very unlikely
- Unlikely
- About as likely as not
- Likely
- Very likely

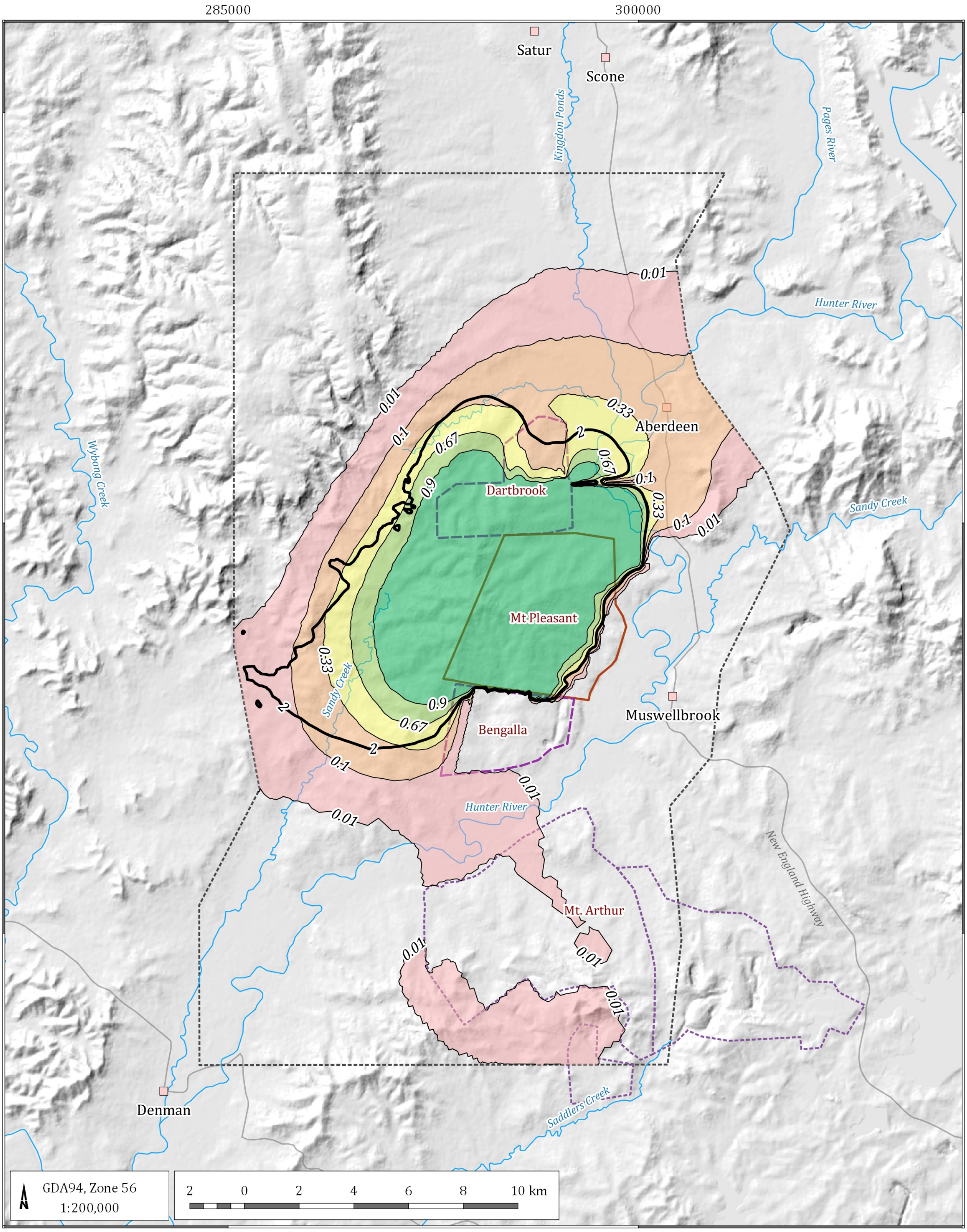
Mt Pleasant GIA (G1970A)

Likelihood of 2 m drawdown at end of mining (December 2048) - Alluvium (Layer 2)

DATE 02/10/2020

FIGURE No: **9.8**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\GIA_report\09.08_G1970A_Likelihood of 2 m drawdown at end of mining (December 2048) – Alluvium (Layer 2).qgs



LEGEND

- Populated place
- Drainage
- Road
- Mt Pleasant mine
- Surrounding mines
- Model boundary
- Base case 2 m drawdown zone

Likelihood of 2 m drawdown

- Very unlikely
- Unlikely
- About as likely as not
- Likely
- Very likely

Mt Pleasant GIA (G1970A)

Likelihood of 2 m drawdown at end of mining (December 2048) – Edderton Seam (Layer 18)

AGE

DATE 02/10/2020

FIGURE No: **9.9**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\GIA_report\09.09_G1970A - Likelihood of 2 m drawdown at end of mining (December 2048) – Edderton Seam (Layer 18).qgs

10 Groundwater monitoring and management

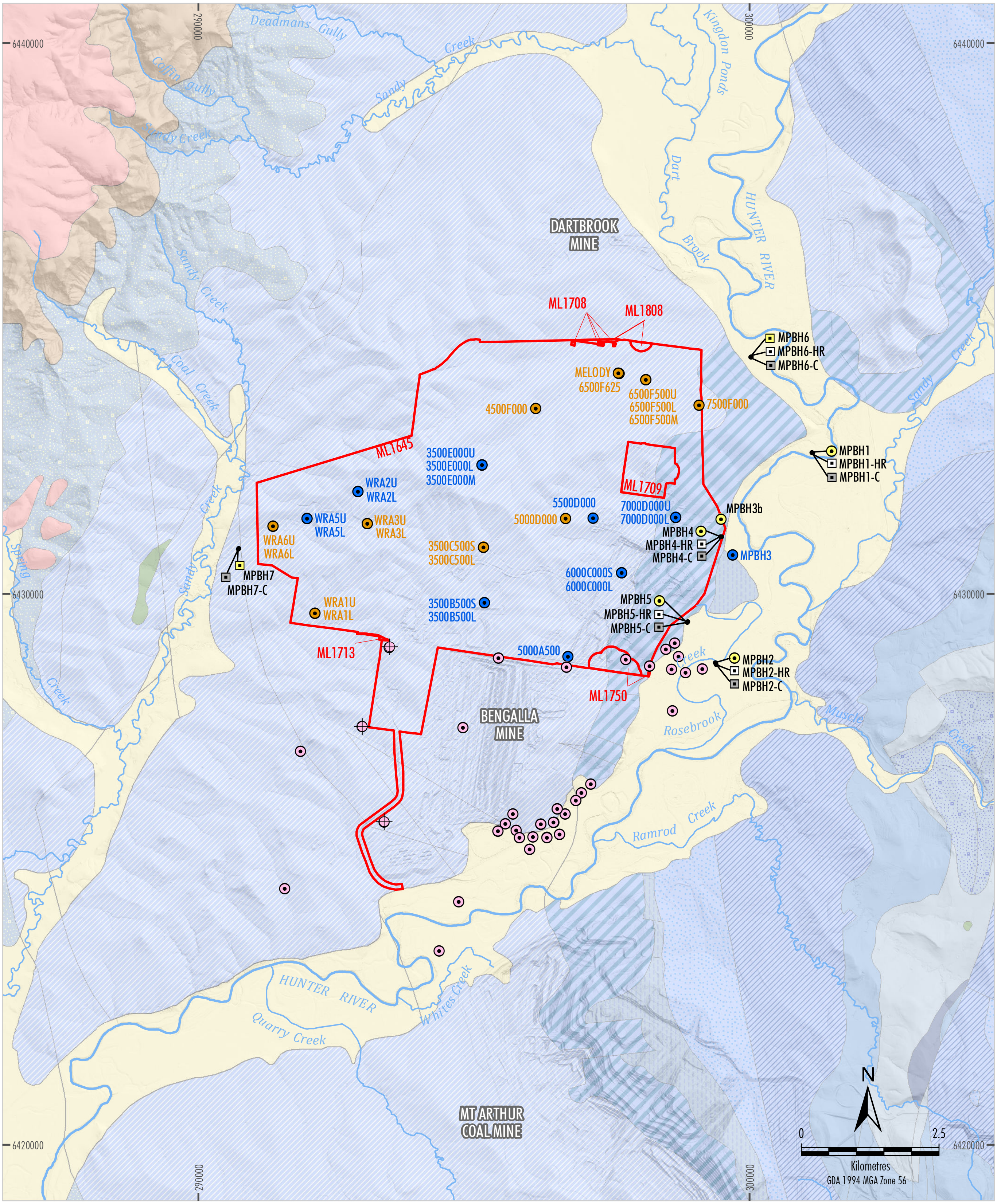
MACH currently operates the MPO in accordance with a Water Management Plan (WMP), which was prepared in consultation with NSW government agencies and approved in October 2019 (MACH, 2019). The WMP describes the management of environmental and community aspects, impacts and performance relevant to the site's water management system. The existing groundwater monitoring program would be continued so that the impact of the Project is monitored and managed. The sections below outline aspects of the current WMP, and recommended updates (should the Project be approved) to monitor the cumulative impacts of the MPO (incorporating the Project).

10.1 Groundwater Monitoring Plan

The currently approved *Mount Pleasant Operation Groundwater Management Plan* (GWMP) outlines a monitoring program to collect groundwater levels and quality measurements and allow actual impacts to the local groundwater system to be compared against those identified in the environmental assessments. The groundwater monitoring program focusses on collecting information on potential impacts to:

- groundwater levels on neighbouring properties and any beneficial groundwater users;
- groundwater quality; and
- Water licence compliance.

The Mount Pleasant Operation GWMP identifies 34 active monitoring bores as shown in Figure 10.1. These 34 locations comprise alluvial, Permian, coal seam and older formation (Maitland Group) monitoring bores that are visited on a quarterly basis for measurement of manual water levels and in-situ pH and EC (MACH, 2019). Groundwater samples are collected annually for laboratory analysis of various parameters including physicochemical parameters, major ions, alkalinity, select nutrients and dissolved and total metals.



LEGEND

- Mining Lease Boundary (Mount Pleasant Operation)

Newly Established Mount Pleasant Monitoring

- Standpipe - Coal Seam
- Standpipe - Interburden
- Standpipe - Alluvium

Mount Pleasant Monitoring

- Standpipe
- Standpipe - Alluvium
- Standpipe - Historical

Bengalla Monitoring

- Bengalla Standpipe
- Bengalla Vibrating Wire Piezometer

Source: MACH (2020); Bengalla Mining Company (2015); NSW Spatial Services (2020)

Note: Refer to Figure 3-2 for regional geology legend.

MACHEnergy

MOUNT PLEASANT OPTIMISATION PROJECT

Mount Pleasant Groundwater Monitoring Network

Figure 10.1

10.2 Proposed Groundwater Monitoring Program

As the cumulative groundwater impacts from the Project are predicted to effect a larger area than for the currently approved MPO, the GWMP monitoring network would need to be expanded to ensure that any impacts from the cumulative MPO Project are identified in a timely manner.

A number of groundwater monitoring sites already exist around the Project area due to the proximity of surrounding mines. Based on the data reviewed as part of this document, and predicted impacts of the Project, it is also recommended that a number of new monitoring bores are installed to assess the impacts on groundwater elevation and quality in Permian units as well as nearby alluvial systems.

10.2.1 Water level monitoring

The monitoring network has evolved over time, with sites being destroyed as mining has progressed. Within the current WMP, four sites have been destroyed: 6000C000S, 6000C000L, WRA5U and WRA5L. The prior locations of these bores are shown in Figure 10.1 alongside the sites that remain active. To add to the active monitoring network, it is recommended that the following sites are added to the water level monitoring locations in the revised monitoring GWMP:

- replacement bores for those that have been destroyed;
- additional alluvial bores: one to the north-east of the MPO pit (where >2 m alluvial drawdown is predicted as a result of MPO) and one to the east of the MPO pit area to monitor for drawdown and potential emplacement seepage;
- an additional shallow groundwater bore in the vicinity of the potential Type 3 terrestrial GDE;
- a VWP to the west of the MPO pit to capture pressure changes in relevant Permian units; and
- private bores in the potential areas of impact (dependent on landowner agreement).

Currently groundwater levels are measured in the monitoring bores on a quarterly basis, with a few exceptions made for private bores to the north and west of the mining tenements that are monitored bi-annually. The current monitoring along with the additional proposed locations are considered sufficient to monitor the predicted impacts of the cumulative MPO Project in the areas surrounding the MPO Project. It is proposed that monitoring is continued at the same frequencies as already prescribed in existing bores, and a minimum of quarterly at new sites.

Data from bores monitored at the Dartbrook and Bengalla Mines should also be reviewed and considered as part of the implementation of the GWMP.

Ongoing monitoring would enable natural groundwater level fluctuations (such as responses to rainfall) to be distinguished from potential groundwater level impacts due to depressurisation resulting from approved and proposed mining activities. Ongoing monitoring of groundwater levels would also be used to assess the extent and rate of depressurisation against model predictions.

Yearly reporting of the water level results from the monitoring network would be included in the annual review. As part of the review, water levels are compared against predictions of impacts made in the project approval documents, and also location specific water level trigger values. When water levels fall within the approved drawdowns and triggers then there is a low risk of unexpected environmental harm occurring to surrounding groundwater dependent assets. If water level responses are not consistent with predictions, then a review is required to determine the cause of the discrepancies.

The methodology used to generate water level triggers would be consistent with the methodology in the approved GWMP.

The annual review would also identify if any additional monitoring sites are required to better understand any changes being observed, or if optimisation of the existing monitoring sites should be undertaken.

10.2.2 Water quality monitoring

Currently groundwater monitoring is conducted at Mount Pleasant Operation on a quarterly basis for field water quality (EC and pH), with samples being collected for laboratory analysis on an annual basis to test for the parameters outlined in Table 10.1.

Table 10.1 Parameters for annual groundwater laboratory analysis

Parameters			
EC	Total Dissolved Solids (TDS)	Total Hardness as CaCO3	Carbonate alkalinity as CaCO3
Total alkalinity as CaCO3	pH	Calcium	Magnesium
Sodium	Potassium	Chloride	Sulfate as SO4
Aluminium	Arsenic	Boron	Nitrite as N
Cadmium	Copper	Ionic Balance	Lead
Zinc	Mercury	Nickel	Selenium
Total Cations	Ammonia as N	Beryllium	Reactive Silica
Antimony	Hydroxide Alkalinity as CaCO3	Nitrate as N	Total Phosphorous as P
Nitrate & Nitrite as N	Total Anions	Bicarbonate Alkalinity as CaCO3	Acidity as CaCO3

Groundwater quality analysis would continue in order to detect any changes in groundwater quality during mining. The current monitoring quarterly frequency for pH and EC monitoring is considered adequate to monitor the larger predicted impacts of the Project on groundwater quality. In addition, the locations for full annual groundwater quality suites would be adjusted to account for mined out sites and provide adequate spatial coverage to detect the cumulative mining impacts.

A number of additional parameters are proposed to be included in the annual water quality sampling suite. The revised full suite is shown in Table 10.2, with newly proposed parameters shown in bold.

Yearly reporting of the water quality results would be included in the annual review. Trends in water quality would be compared against defined trigger levels to identify parameters and sites that are varying from baseline conditions. If changing trends are identified in water quality then a review would be completed to identify the cause of the discrepancy. The differences could be from a number of influences, again such as mining, climate, third party activities etc.

The methodology used to generate water quality triggers would be consistent with the methodology in the approved Mount Pleasant Operation GWMP i.e. statistical percentiles for pH and EC, and interim triggers based on ANZECC (2000) recreational water use guideline values for other parameters.

The annual review should also consider if any additional monitoring sites are required to better understand any changes being observed, or if optimisation of the existing monitoring sites, frequency of sampling and analytical suite should be undertaken. The WMP updates would consider the optimal sites for monitoring of groundwater quality during the life of the project.

Table 10.2 Revised parameters for annual groundwater laboratory analysis

Parameters			
EC	Total Dissolved Solids (TDS)	Total Hardness as CaCO3	Carbonate alkalinity as CaCO3
Total alkalinity as CaCO3	pH	Calcium	Magnesium
Sodium	Potassium	Chloride	Sulfate as SO4
Aluminium	Arsenic	Boron	Nitrite as N
Cadmium	Copper	Ionic Balance	Lead
Zinc	Mercury	Nickel	Selenium
Total Cations	Ammonia as N	Beryllium	Reactive Silica
Antimony	Hydroxide Alkalinity as CaCO3	Nitrate as N	Total Phosphorous as P
Nitrate & Nitrite as N	Total Anions	Bicarbonate Alkalinity as CaCO3	Acidity as CaCO3
Fluoride	**Barium**	**Chromium**	**Cobalt**
Iron	**Molybdenum**	**Strontium**	**Silver**
Vanadium			

10.2.3 Mine water seepage monitoring

Regular monitoring of groundwater seepage into the different mining areas (where possible) is a key component in accurately calculating and reporting of licensable groundwater take from surrounding bedrock strata.

The results of this monitoring would be reviewed quarterly. If inflows above the approved predicted volumes are identified, then the data would be reviewed to identify the causes.

Groundwater inflows would also be utilised when calibrating and validating any future updates of the numerical groundwater model for the Project. However, the difficulty in measuring groundwater seepages entering the mine area should be noted as the volumes are relatively small, and total pumped flows are subject to several other uncertainties.

10.2.4 Future model iterations

Every three years, or if significant changes to mining occur, or monitoring results identify a need (e.g. where groundwater extraction from the pit or water level changes are inconsistent with predictions) the validity of the model predictions would be assessed by comparing the extraction volumes and groundwater level data against model predictions. The predictions would be validated against historical monitoring data collected as part of the groundwater monitoring program. It is considered this remains appropriate to track the impacts of the Project on the groundwater regime.

10.2.5 Data management and reporting

The WMP outlines the data management and reporting requirements for groundwater data. For reporting, this includes:

- Publishing monthly groundwater level and groundwater quality monitoring results to the company website as a regular measure of performance.
- All hazards, near misses and incidents are reported to the supervisor of the relevant work area immediately. MPO will notify the Secretary and any other relevant agencies as soon as practicable of the incident and soon as practicable of the incident and provide within seven days a detailed report on the incident. All incidents resulting or having the potential to result in material harm to the environment, as defined by Section 147 of the NSW *Protection of the Environment Operations Act 1997* are managed in accordance with the MPO Pollution Incident Response Management Plan.
- The Annual Review is prepared in accordance with Condition 3, Schedule 5 of Development Consent DA 92/97.
- MPO maintains a centralised location to record details of relevant external stakeholder communications. Complaints are recorded and investigated. Follow up communication with the complainant is undertaken to communicate the outcome of complaint investigations.
- The WMP and supporting plans (including the GWMP) are reviewed and resubmitted to DPIE every three years, or earlier if required, for approval by the Secretary. Any changes to the WMP as a result of the review are made in consultation with EPA and DPIE Water. The WMP will reflect changes in environmental requirements, technology and operational procedures. Updated versions of the approved WMP are made publicly available on the MPO website once approved by the Secretary.

The Annual Review must:

- describe the development that was carried out in the previous calendar year, and the development that is proposed to be carried out over the next year;
- include a comprehensive review of monitoring results and complaints records of the project over the previous calendar year, which includes a comparison of these results against the:
  - relevant statutory requirements, limits or performance measures/criteria;
  - monitoring results of previous years; and
  - relevant predictions in the documents listed in Condition 3, Schedule 5 of Development Consent DA 92/97;
- identify any non-compliance over the last year, and describe what actions were (or are being) taken to ensure compliance;
- identify any trends in monitoring data over the life of the project;
- identify any discrepancies between the predicted and actual impacts of the project;
- analyse the potential cause of any significant discrepancies; and
- describe what measures will be implemented over the next year to improve the environmental performance of the project.

These procedures remain appropriate to report the impacts of the Project on the groundwater regime. However, they would be updated to reflect contemporary Development Consent conditions as necessary.

10.2.6 Management and mitigation strategies

The WMP includes a Surface and Ground Water Response Plan (SGWRP) containing a Trigger Action Response Plan (TARP) to implement in the case of groundwater monitoring results being detected outside the groundwater trigger value range. The actions to be implemented in the event of groundwater levels in relevant alluvial monitoring bores falling below the trigger values specified within Table 10 of the GWMP, three consecutive water quality results outside of the adopted trigger values, or landholder complaints are reproduced in Table 10.3 to Table 10.5.

Table 10.3 Groundwater level response protocol

Response Protocol	
Trigger	A groundwater level measurement at a relevant alluvial monitoring bore falls below the trigger value specified within Table 10 of the GWMP.
Investigation	1. Notify the MACH Energy Environmental Superintendent within 24 hours of becoming aware of the trigger event. 2. Check and validate the data which indicates an exceedance of the trigger conditions. 3. Undertake supplementary water level measurements to check if the exceedance is ongoing. 4. Conduct a preliminary investigation, including a review of site activities being undertaken at the time, baseline groundwater monitoring results, groundwater results at nearby locations, the prevailing and preceding meteorological and streamflow conditions and changes to the landuse/activities being undertaken in the area, including mining/pastoral activities. If necessary, engage a suitably qualified hydrogeologist to assist with the preliminary investigation (e.g. interpretation of monitoring results). 5. Identify plausible and possible causative mechanisms and assess/quantify these against all relevant data and information to identify most likely causes. 6. Determine if private groundwater supply bores in the vicinity of the monitoring bore have experienced cumulative drawdowns in excess of 2 metres (m) and an associated reduction in groundwater yield (The minimal impact consideration for privately owned groundwater bores under the *NSW Aquifer Interference Policy* is drawdowns greater than 2 m). 7. Determine if there has been an effect on potential GDEs located along the Hunter River. 8. Provide a preliminary investigation report to the DPIE, EPA and DPIE Water within seven days of identifying the trigger exceedance.
Response	• Implement appropriate contingency and remedial measures (including the privately-owned groundwater bores response protocol, if required). • Communicate results of investigation, contingency and remedial measures to government agencies as required and summarise in the Annual Review. • Review and update the WMP and resubmit to the DPIE (if required).

Table 10.4 Groundwater quality response protocol

Response Protocol	
Trigger	A monitoring bore records an EC or pH value above (or outside the range of) the trigger values specified in Table 12 of the GWMP at three successive monitoring rounds.
Investigation	1. Notify the MACH Energy Environmental Superintendent within 24 hours of becoming aware of the trigger event. 2. Check and validate the data which indicates an exceedance of the trigger conditions. 3. In the event of an apparently anomalous groundwater monitoring result, conduct a resample/retest. 4. Conduct a preliminary investigation, including a review of site activities being undertaken at the time, baseline groundwater monitoring results, groundwater results at nearby locations, the prevailing and preceding meteorological and streamflow conditions and changes to the landuse/activities being undertaken in the area, including mining/pastoral activities. If necessary, engage a suitably qualified hydrogeologist to assist with the preliminary investigation (e.g. interpretation of monitoring results). 5. Provide a preliminary investigation report to the DPIE, EPA and DPIE Water within seven days of identifying the trigger exceedance.
Response	• Subject to the outcomes of the investigation, develop/design contingency and remedial measures. Contingency and remedial measures considered practical for implementation may include: – notification to local groundwater users; – providing an alternative water source for the duration of the water quality impact; – reviewing and refining the Ground Water Monitoring Program including undertaking additional specific monitoring of private landholder bores; – reviewing mine plan impacts on the alluvial groundwater source; and – repairing, replacing, or constructing new water management infrastructure. • Communicate results of investigation, contingency and remedial measures to government agencies as required and summarise in the Annual Review. • Review and update the WMP and resubmit to the DPIE (if required).

Table 10.5 Privately-owned groundwater bores response protocol

Response Protocol	
Trigger	Complaint by local landholder regarding water supply from groundwater bore.
Investigation	1. Notify the MACH Energy Environmental Superintendent within 24 hours of receiving the complaint. 2. Check and validate the information provided with the complaint. 3. Conduct a preliminary investigation, including a review of site activities being undertaken at the time, baseline groundwater monitoring results, groundwater results at nearby locations, the prevailing and preceding meteorological and streamflow conditions and changes to the landuse/activities being undertaken in the area, including mining/pastoral activities. If necessary, engage a suitably qualified hydrogeologist to assist with the preliminary investigation (e.g. interpretation of monitoring results). 4. Where a preliminary investigation indicates a potential mining effect at the complainant's bore, conduct a detailed investigation to determine whether the MPO has contributed to a greater than 2 m cumulative drawdown or a detrimental water quality effect.
Response	• In the event that a detailed investigation conclusively attributes greater than 2 m drawdown, or a detrimental water quality effect, for an existing groundwater supply user to the MPO, investigate appropriate contingency and remedial measures which may include: – deepening the affected groundwater supply bore; – construction of a new groundwater supply bore; or – provision of an alternative water supply. • Determine the exact nature of contingency/remedial measures in consultation with the affected landholder (and relevant regulatory agencies as required). • Communicate results of investigation, contingency and remedial measures to government agencies as required and summarise in the Annual Review. • Review and update the WMP and resubmit to the DPIE (if required).

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Glossary and acronyms

AGE	Australasian Groundwater and Environmental Consultants Pty Ltd
AHD	Australian Height Datum
AIP	Aquifer Interference Policy
ALUM	Australian Land Use Mapping
BSAL	Biophysical Strategic Agricultural Land
CSG	Coal seam gas
CRD	Cumulative Rainfall Departure
EMD	Environmental Monitoring Database
DoEE	Department of the Environment and Energy
DPI	Department of Primary Industries
GDE	Groundwater Dependent Ecosystem
IESC	Independent Expert Scientific Committee
MPO	Existing approved Mount Pleasant Operation
MACH Energy Australia Pty Ltd	The proponent
Mount Pleasant Optimisation Project	The continuation of mining at Mount Pleasant Operations
Project Area	Includes the existing approved MPO
ML	Megalitres
MNES	Matters of National Environmental Significance
Mtpa	Million tonnes per annum
SILO	SILO is a database of historical climate records for Australia
SRLU Policy	Strategic Regional Landuse Policy
TARP	Trigger Action Response Plan
TDS	Total Dissolved Solids
VWP	Vibrating wire piezometer

Appendix A Numerical modelling report

A1 Model Objectives

The model has been developed to address the following objectives of the groundwater impact assessment:

- replicate the historical behaviour of the groundwater regime;
- predict the changes in groundwater levels and flows due to the proposed mining at the MPO (incorporating the Project);
- predict the cumulative changes to groundwater levels and flows due to the MPO (incorporating the Project) and surrounding mines;
- predict potential impacts to existing users including GDEs; and
- predict take from various water sources for estimating licence requirements.

A2 Model Details

A2.1 Model software and complexity

Groundwater modelling has taken into account the Murray-Darling Basin Commission (MDBC) Groundwater Flow Modelling Guideline (MDBC, 2001) as well as the Australian Groundwater Modelling Guidelines (Barnett et al., 2012). Under the earlier MDBC modelling guideline, the model is best categorised as an Impact Assessment Model of medium complexity. That earlier guide (MDBC, 2001) describes 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."*

Under the more recent (Barnett et al., 2012) guidelines, this model would be classified as a Confidence Level 2 groundwater model, with the following key indicators (based on Table 2-1 of Barnett et al., 2012):

- rainfall and evaporation data are available for the site (Level 3);
- groundwater head observations and bore logs are available and with a good coverage around the MPO and relevant nearby mines, but without spatial coverage throughout the model domain (Level 2);
- streamflow data and baseflow estimates available at a few points (Level 2);
- seasonal fluctuations reasonably replicated in many parts of the model domain (Level 2, possibly 3);
- scaled RMS error and other calibration statistics, e.g. mean residual, are acceptable (Level 3); and
- suggested use is for prediction of impacts of proposed developments in aquifers with a medium to high value (Level 2).

Numerical modelling has been undertaken using the MODFLOW-USG code (Panday et. al. 2015). MODFLOW-USG is widely used code for groundwater modelling and is presently considered an industry standard.

A2.2 Model grid

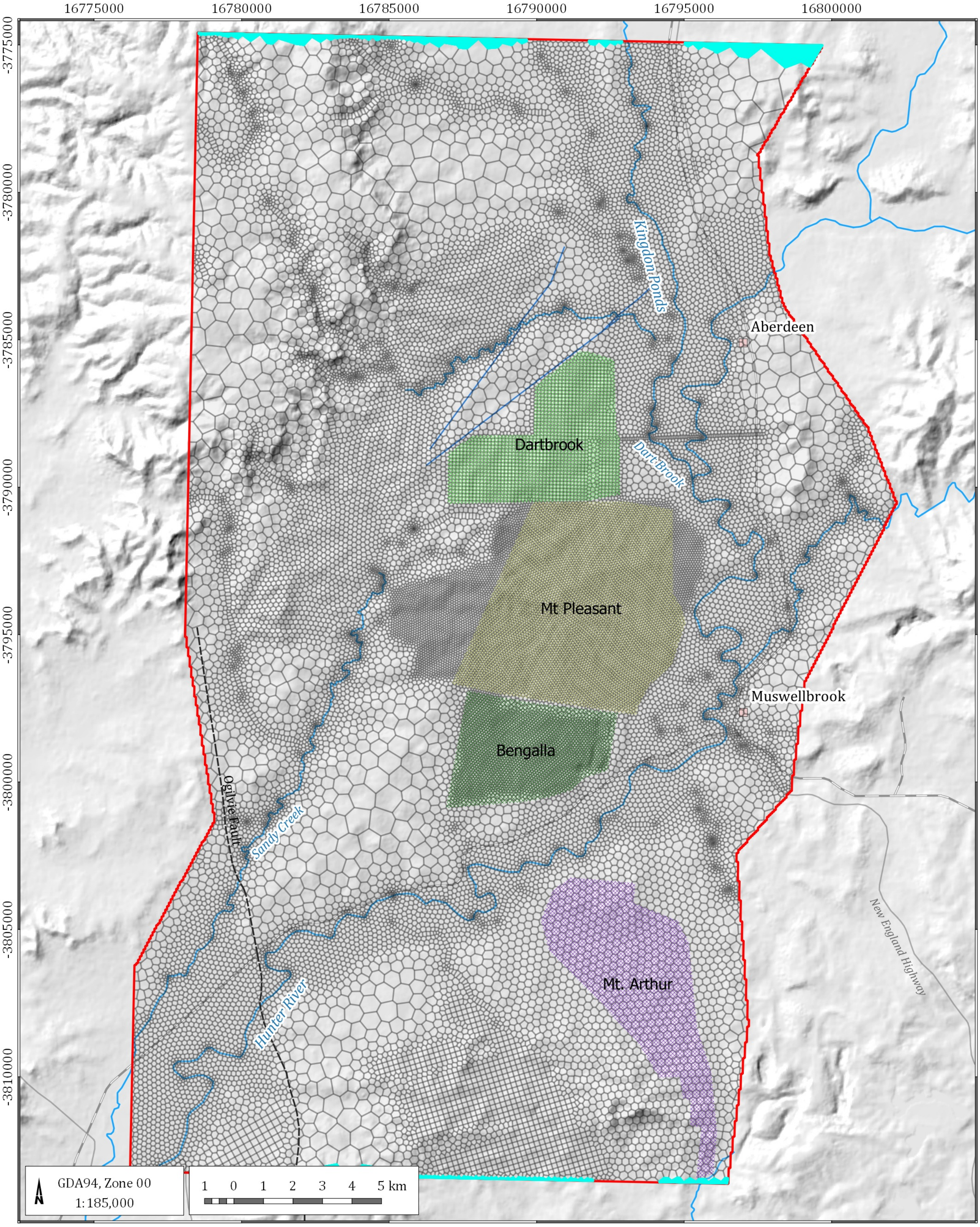
The model grid covers the proposed Project area and surrounding mines. The model domain is approximately 19 km wide (west to east direction) and 30 km long (north to south direction) as shown in Figure A 2.1. The active model extent is limited by the outcrop of Maitland Group units to the east. The Maitland Group is the unit below the deepest seam at the MPO. The Mount Ogilvie fault is used as a model boundary in the south-west of the model domain and is simulated as a no-flow boundary. The nearest model edge to the proposed mine is 9 km which is considered sufficient to avoid the boundary condition assigned at the model extent affecting the key predicted impacts.

The boundary conditions assigned at the model extents are also presented in Figure A 2.1. The General Head Boundary (GHB) is assigned to model layers representing coal seams at the northern and southern model extents and allows for the transfer of water into and out of the model domain. The remaining model extents are considered no flow boundaries.

The model domain is discretised and arranged into 20 layers comprising 32,915 cell nodes in each layer. The dimensions of the cells have been varied to represent different levels of detail throughout the model domain. The specific features where cells were refined to smaller sizes are listed below:

- open cut and underground mines – 100 m x 100 m to 300 m x 100 m;
- streams and alluvial flood plains – from 100 m x 100 m to 200 m x 200 m cells;
- Dartbrook Mine Hunter Tunnel – 100 m x 100 m; and
- up to 700 m cell sizes in more peripheral areas.

The model layers represent the major hydrostratigraphic units including shallow geological units as well as the major coal seams and interburden.



LEGEND

- Grid
- Road
- Rail
- Olgilvie Fault
- Drainage
- Populated place
- Bengalla
- Dartbrook
- Mt Pleasant
- Mt. Arthur
- General head boundary
- No-Flow Boundary

MT Pleasant GIA (G1970A)

Model grid extent

AGE

DATE 07/09/2020

FIGURE No: **A 2.1**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\002_Deliverable2\02.01_G1970_Grid layout.qgs

A2.2.1 Model layers

The model uses 20 layers to represent the key hydrostratigraphic horizons from the Quaternary alluvium down to deeper Permian formations. The layers were based on horizons in available from the MPO geological model and extrapolated beyond the limit of geological model using publicly available data and experience. AGE considers this to be adequate to meet the model objectives. The model layering is summarised in Table A 2.1.

It should be noted that all model cells within each layer are active and assigned to one hydrostratigraphic unit. Where the hydrostratigraphic unit sub-crops and effectively disappears, the assigned thickness is reduced to 5 cm. To make the model more representative of the geology, hydraulic properties have been assigned from the major unit beneath these areas where the hydrostratigraphic unit being represented by the model layer does not exist.

Table A 2.1 Model layers

Layer	Represents
1	Surficial alluvium and weathered zone/regolith
2	Weathered overburden
3	Overburden
4	Warkworth Seam
5	Interburden 1
6	Mount Arthur Seam
7	Interburden 2
8	Piercefield Seam
9	Interburden 3
10	Vaux Seam
11	Interburden 4
12	Broonie Seam
13	Interburden 5
14	Bayswater Seam
15	Interburden 6
16	Wynn Seam
17	Interburden 7
18	Edderton Seam
19	Vane Subgroup/Saltwater Creek Formation
20	Maitland Group and older units

A2.2.2 Timing

The numerical groundwater model simulates groundwater flow from 1990 to 3049 as follows:

- Last day of 1990 – steady state stress period;
- 1991 to the end of 2010 – 21 x annual stress periods;
- 2011 to the end of 2017 – 24 x quarterly stress periods;
- 2018 to the end of 2048 – 31 x annual stress periods; and
- 2049 to 3049 – recovery stress period.

Quarterly stress periods are introduced to the model so that seasonal variability in recharge and mine progression in Bengalla Mine and Mt Arthur Coal Mine could be better represented.

A2.3 System stresses

A2.3.1 Recharge

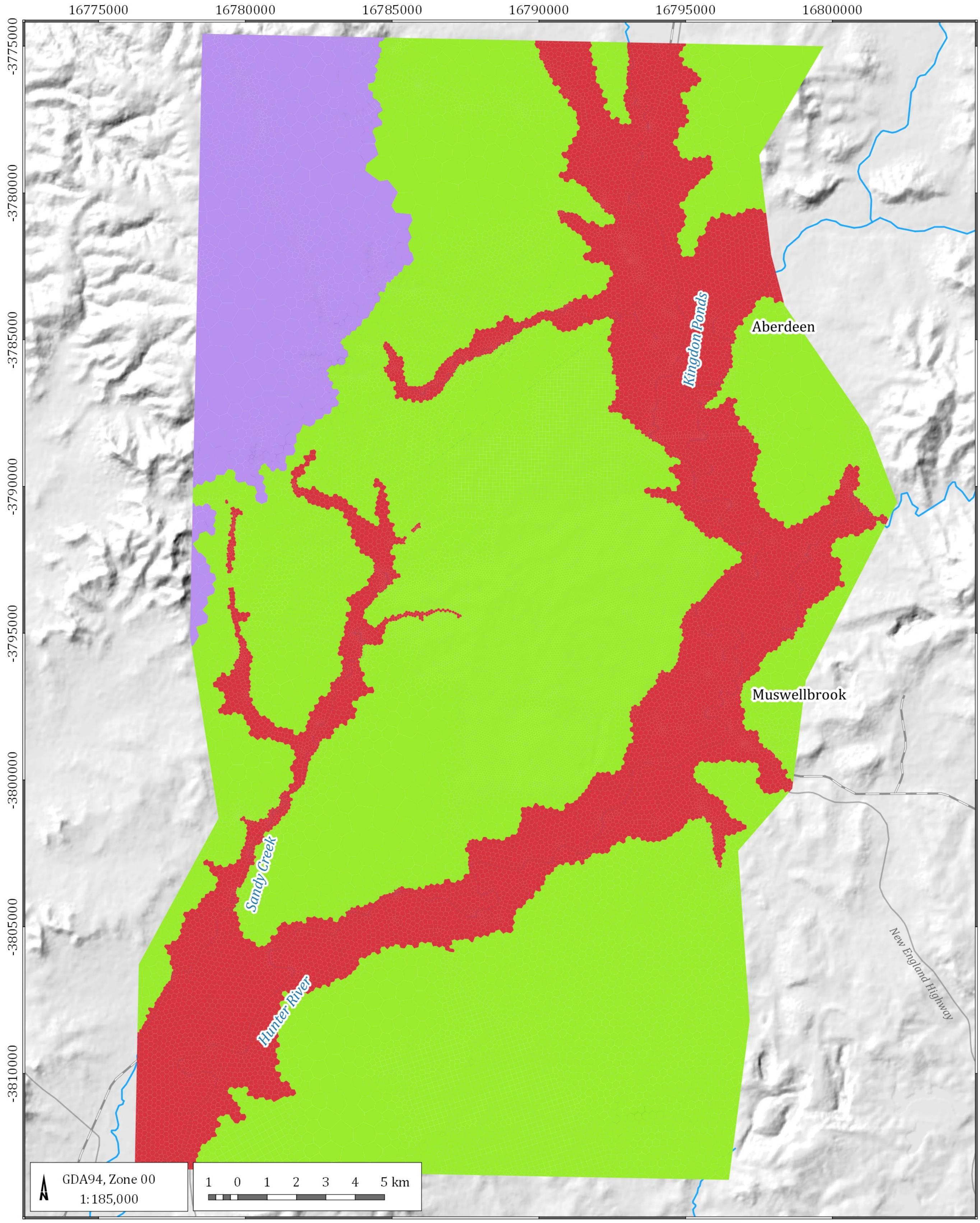
The MODFLOW USG recharge package (RCH) was used to represent deep drainage from diffuse rainfall. The dominant mechanism for recharge to the groundwater system is through diffuse infiltration of rainfall through the soil profile and subsequent deep drainage to underlying groundwater systems. Options within MODFLOW USG were selected to ensure flow through the vadose zone was not represented, due to a lack of available parameters to represent unsaturated flow. The closest Bureau of Meteorology (BoM) meteorological station to the MPO is Muswellbrook (St Heliers), station number 061374, located approximately 5 km east of the proposed operations. Climatic data from this station was obtained for the period between 01 January 1991 to 1 June 2020 and used to calculate the annual rainfall for the calibration period. Average annual rainfall at Muswellbrook is approximately 580 mm. The long-term average rainfall was applied for all time beyond June 2020.

The model domain was divided into three zones within which the factors affecting recharge were thought to be consistent. This was largely driven by the locations where various geologies outcrop and the recharge could be received. Figure A 2.2 shows the recharge distribution zones. Table A 2.2 represents the calibrated rate of recharge for each geological unit.

Table A 2.2 Recharge rate and percentage for each zone

Zone	Diffuse recharge rate - transient			
	% of annual rainfall	Min (mm/year)	Mean (mm/year)	Max (mm/year)
Alluvium	3.20%	12.4	23.9	28.4
Triassic Sandstone	2.80%	10.9	20.9	24.8
Permian	0.5%	1.9	3.7	4.4

Notes: mm/year = millimetres per year



LEGEND

- Grid
- Road
- Rail
- Drainage
- Populated place

Recharge zones

- Alluvium
- Triassic
- Permian

MT Pleasant GIA (G1970)

Recharge zones

AGE

DATE 21/01/2020

FIGURE No: A 2.2

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\002_Deliverable2\02.02_G1970_Recharge zones.qgs

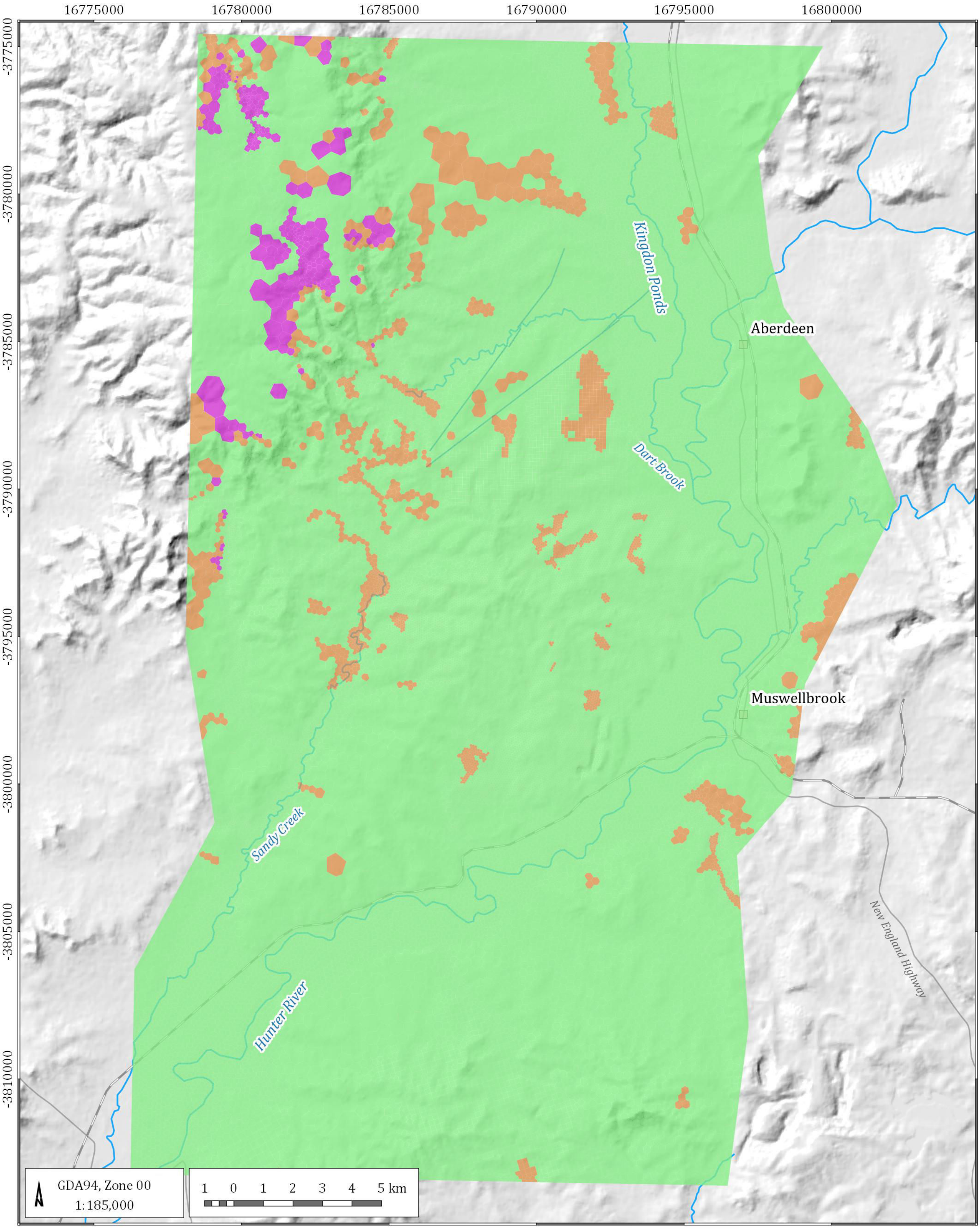
A2.3.2 Evapotranspiration

Evapotranspiration from shallow water tables was represented with the evapotranspiration package (EVT). The evapotranspiration boundary condition was assigned to the uppermost model cells across the model domain (i.e. layer 1 where alluvium is present, layer 2 everywhere else). Evapotranspiration will only occur when the water table depth is close enough to the natural surface to be within the extinction depth (below which no evapotranspiration takes place). Actual potential evaporation rate (600 mm/year) is assigned at the surface to represent the maximum rate of evapotranspiration. Below ground this rate decreases linearly until reaching zero at the extinction depth. Extinction depths have been derived from the plant rooting depths of the dominant species in the various vegetation communities across the model domain. Table A 2.3 shows the extinction depth for each vegetation zone and Figure A 2.3 shows the evapotranspiration zones.

Table A 2.3 Evapotranspiration rooting zones

Vegetation zone	Rooting depth (m)
Open grassland	1
Open/grassy woodland	2.5
Forest	5

Note: m = metres.



LEGEND

- Grid
- Road
- Rail
- Drainage
- Populated place

Evapotranspiration zones

- Open grassland
- Open/grassy woodland
- Forest

MT Pleasant GIA (G1970)

Evapotranspiration zones within the model area

DATE 09/04/2020

FIGURE No: A 2.3

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\002_Deliverable2\02.03_G1970_Evapotranspiration zones within the model area.qgs

A2.3.3 Water courses and surface drainage

Groundwater interaction with surface drainage was modelled using the river package (RIV) of the MODFLOW USG. The major streams in the area are the Hunter River, Dart Brook, and Sandy Creek. For the major watercourses, river stage elevations are interpolated between gauging stations to assign a depth or water in the river. This replicates the generally consistent flow in these streams and provides opportunity for recharge from the stream. Minor watercourses are ephemeral and only flow for short periods after rainfall events, and are therefore simulated with a river depth set to zero. This means that groundwater is only removed from these features as baseflow when groundwater levels are high enough (i.e. above the bed of the river). The location of the river cells in the groundwater model were assigned to either layer 1 where alluvium exists or layer 2 where layer 1 is not present. Table A 2.4 summarises the river cell parameters in the model.

Table A 2.4 River (RIV) bed parameters

River No	River name	Vertical hydraulic conductivity Kv (m/day)	Width (m)	Water depth (m)	Bed thickness (m)
1	Hunter River	0.05	20	Steady state (1 – 2 m) Transient (historical monthly average)	1
2	Dartbrook	0.05	10	Steady state (0.7 m) Transient (historical monthly average)	1
3	Sandy Creek	1	5	0	1
4	Other creeks	1	5	0	1

A2.3.4 Mining

The Hunter region has a number of coal mining operations. The MPO is situated between a number of mines, therefore cumulative impacts must be considered. The neighbouring mines include Bengalla Mine and Mt Arthur Coal Mine to the south and Dartbrook Mine to the north. Mangoola Coal is located on the western side of the Mount Ogilvie Thrust Fault. The Mt. Ogilvie Fault is a significant structural feature in the region which fully offsets the coal seams against lower permeability interburden in the vicinity of the MPO. This means potential cumulative impacts between the Project and Mangoola Coal are significantly reduced.

A2.3.4.1 Bengalla Mine and Mt Arthur Coal Mine open cut

The model represented open cut mining using the drain (DRN) package. For the other open cut mines (i.e. Bengalla Mine and Mt Arthur Coal Mine), publicly available data (AGE, 2013a/2013b/2014, and HydroSimulations 2015) was used to represent the progression of mining and the drain cells were set for all model cells within the pit shell extent (i.e. all layers from the lower most mined seam to the surface). The reference elevations for each drain cell was set to the bottom of the corresponding layer assuming that the layer becomes dry and the water stored in each layer is removed by the drain. The volume of water removed via the DRN package is a function of the head difference (between the predicted groundwater level in the model cell and the reference level assigned to the drain) and a conductance term. Initial estimates of drain conductance were calculated layer-by-layer using model cell dimensions and vertical hydraulic conductivity values.

Open-cut mining is followed by the progression of backfilling with spoil. The higher permeability of mining spoil was simulated by changing the permeability and storage properties of model cells containing spoil using the MODFLOW-USG Time-Variant Materials package (TVM). The higher recharge within the spoil was simulated using the MODLFOW USG RCH package.

Table A 2.5 shows the hydraulic properties and recharge rate applied to simulate the spoil in the groundwater model.

Table A 2.5 Hydraulic properties applied to spoil

Kh (m/day)	Kv (m/day)	Sy	Ss (m^{-1})	Recharge
0.3	0.1	0.1	1e-05	2% rainfall

Notes: Kh = Horizontal Hydraulic Conductivity
Kv = Vertical Hydraulic Conductivity
Sy = Specific Yield
Ss = Specific Storage

A2.3.4.2 Dartbrook Mine

Like the open cut mines, the underground mining at Dartbrook Mine was simulated using the MODFLOW USG DRN package. The drain boundary condition was set within the Dartbrook Mine target coal seams (i.e. Wynn and Kayuga seams). The drain cells were gradually added to the model to replicate the development of the roadways and the extraction of panels over time. The model also simulated the gradual changes to aquifer properties in response to longwall mining such as goaf and fracture zone development, using the MODFLOW USG Time Varying Materials (TVM) package. This was achieved by changing the parameters within the coal seam and overlying strata as the longwall panel was developed. In doing so, a series of multipliers were used to enhance hydraulic conductivities within the deformation zone overlying coal extraction areas. The multipliers are dependent on height above the coal seam, with the highest values applied to the units closest to the mined seam and then a gradual reduction as the units near the maximum height of connective cracking. The maximum height of connective cracking was derived using the Ditton/Merrick equation (Ditton and Merrick, 2014). Changes to hydraulic parameters used a logarithmic stepping function across stress periods. The fractured zone multipliers are presented in Table A 2.6 and Table A 2.7 for Wynn Seam longwall mining and for Kayuga Seam longwall mining, respectively.

Table A 2.6 Fracture zone multipliers for Wynn seam longwall mining at Dartbrook Mine

<table>
<tr><th>Lithology</th><th>Layer</th><th>Median height above seam (m)</th><th>Kh multiplier</th><th>Kv multiplier</th></tr>
<tr><td>Alluvium and Regolith</td><td>1</td><td>285</td><td rowspan="10">2</td><td rowspan="2">3</td></tr>
<tr><td>Alluvium</td><td>2</td><td>283</td></tr>
<tr><td>Overburden</td><td>3</td><td>283</td><td rowspan="4">3</td></tr>
<tr><td>Warkworth Seam</td><td>4</td><td>283</td></tr>
<tr><td>Interburden 1</td><td>5</td><td>260</td></tr>
<tr><td>Mount Arthur Seam</td><td>6</td><td>234</td></tr>
<tr><td>Interburden 2</td><td>7</td><td>190</td><td rowspan="4">5</td></tr>
<tr><td>Piercefield Seam</td><td>8</td><td>145</td></tr>
<tr><td>Interburden 3</td><td>9</td><td>127</td></tr>
<tr><td>Vaux Seam</td><td>10</td><td>109</td></tr>
</table>

<table>
<tr><th>Lithology</th><th>Layer</th><th>Median height above seam (m)</th><th>Kh multiplier</th><th>Kv multiplier</th></tr>
<tr><td>Interburden 4</td><td>11</td><td>82</td><td rowspan="3">6</td><td rowspan="3">20</td></tr>
<tr><td>Broonie Seam</td><td>12</td><td>56</td></tr>
<tr><td>Interburden 5</td><td>13</td><td>48</td></tr>
<tr><td>Bayswater Seam</td><td>14</td><td>39</td><td rowspan="2">68</td><td>75</td></tr>
<tr><td>Interburden 6</td><td>15</td><td>19</td><td>118</td></tr>
<tr><td>Wynn Seam</td><td>16</td><td>0</td><td>83</td><td>152</td></tr>
</table>

Table A 2.7 Fracture zone multipliers for Kayuga seam longwall mining at Dartbrook Mine

<table>
<tr><th>Lithology</th><th>Layer</th><th>Median height above seam (m)</th><th>Kh multiplier</th><th>Kv multiplier</th></tr>
<tr><td>Alluvium and Regolith</td><td>1</td><td>285</td><td rowspan="4">2</td><td rowspan="3">3</td></tr>
<tr><td>Alluvium</td><td>2</td><td>283</td></tr>
<tr><td>Overburden</td><td>3</td><td>283</td></tr>
<tr><td>Warkworth Seam</td><td>4</td><td>283</td><td>47</td></tr>
<tr><td>Interburden 1</td><td>5</td><td>260</td><td>3</td><td>73</td></tr>
<tr><td>Mount Arthur Seam</td><td>6</td><td>234</td><td>10</td><td>115</td></tr>
</table>

A2.3.5 Depth dependence of hydraulic conductivity

Figure A 2.4 and Figure A 2.5 summarise the available hydraulic conductivity measurements derived from different tests in the Project area against depth. There are two types of hydraulic tests shown in the figures, known as the packer and core permeability tests. The core test values are generally lower than the packet test. This is expected given that the core test represents the centimetre-scale sample and does not consider the joints/fractures and hydraulically conductive structures within the formations.

Figure A 2.4 and Figure A 2.5 show that the Kh declines with depth as overburden pressure increases. To reflect this, an exponential equation that fits the packer test data was adopted in the model, simulating the reduced Kh with depth. The equation is as follows:

- Coal and interburden: $Kh = HC_0 \times \exp(slope \times depth)$

Where: *Kh* is horizontal hydraulic conductivity at specific depth.

HC_0 is horizontal hydraulic conductivity at depth of 0m (intercept of the curve).

depth is depth of the floor of the layer (thickness of the cover material).

slope is a term representing slope of the formula (steepness of the curve).

Values of 'slope' and HC_0 were derived such that the equations provided the line of best fit for the measured hydraulic test data. Given that this project focuses mainly on the MPO, the lines of best fit were weighted more towards the MPO test data. With regards to the type of hydraulic test, the packer test data was preferred over the core permeability test. As mentioned, this is mainly because the packer test generally provides the bulk representative value of interburden and coal seam hydraulic properties.

The fit of equations are shown as the black lines in Figure A 2.4 and Figure A 2.5 for the coal and interburden. These equations have been used to assign the initial permeability values in the model. During the calibration, the slope is fixed and the HC0 can vary based on the upper and lower ranges specified as dash blue and yellow lines in Figure A 2.4 and Figure A 2.5. The horizontal and vertical conductivity were capped to ensure maximum and minimum values did not exceed literature ranges for their respective units. Table A 2.8 presents the additional parameter constraints applied to coal and Permian units.

Table A 2.8 Additional parameter constraints

Unit	Min Kh (m/day)	Max Kh (m/day)	Min Kv (m/day)	Max Kv (m/day)
Coal and interburden	1.0E-06	1.0E-01	1.0E-09	1.0E-01

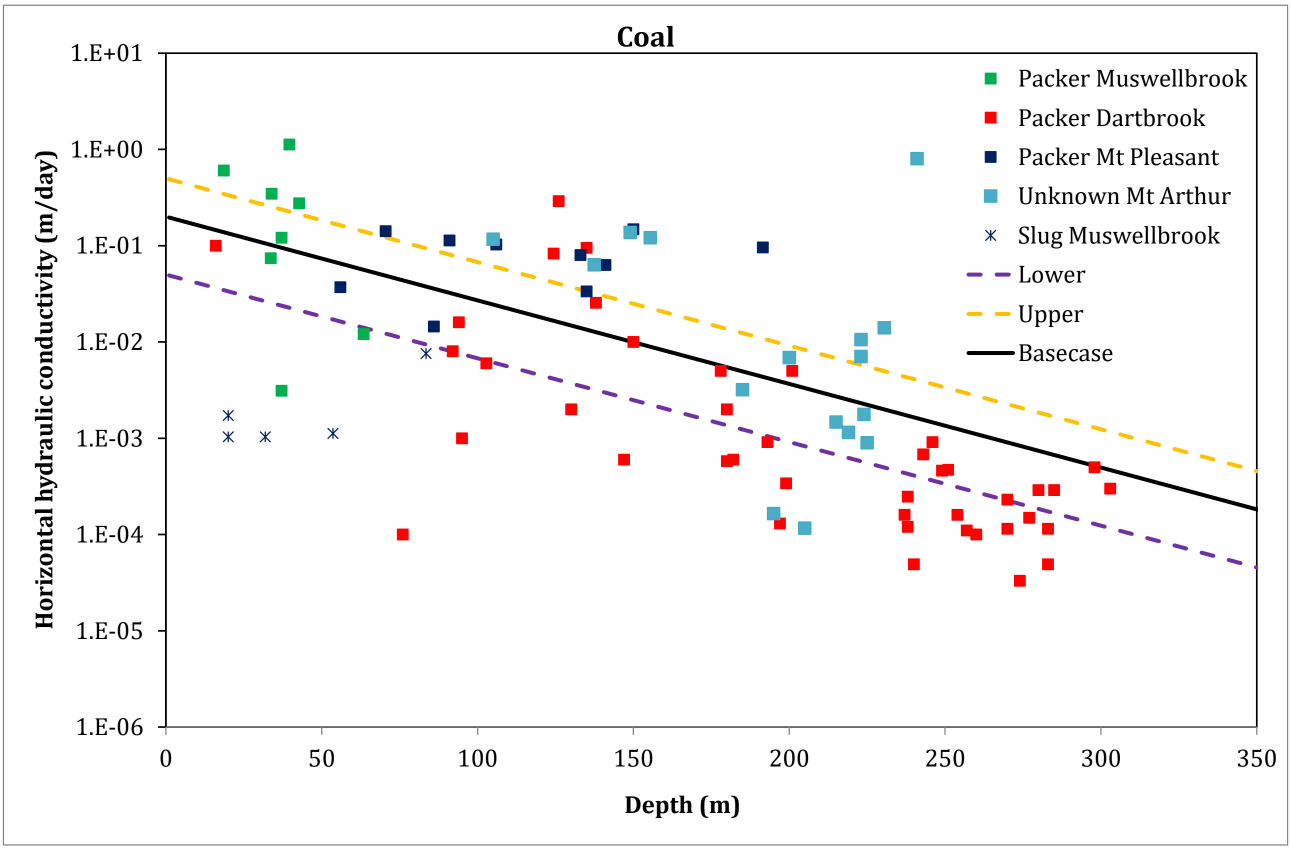


Figure A 2.4 Horizontal hydraulic conductivity for coal seam measures

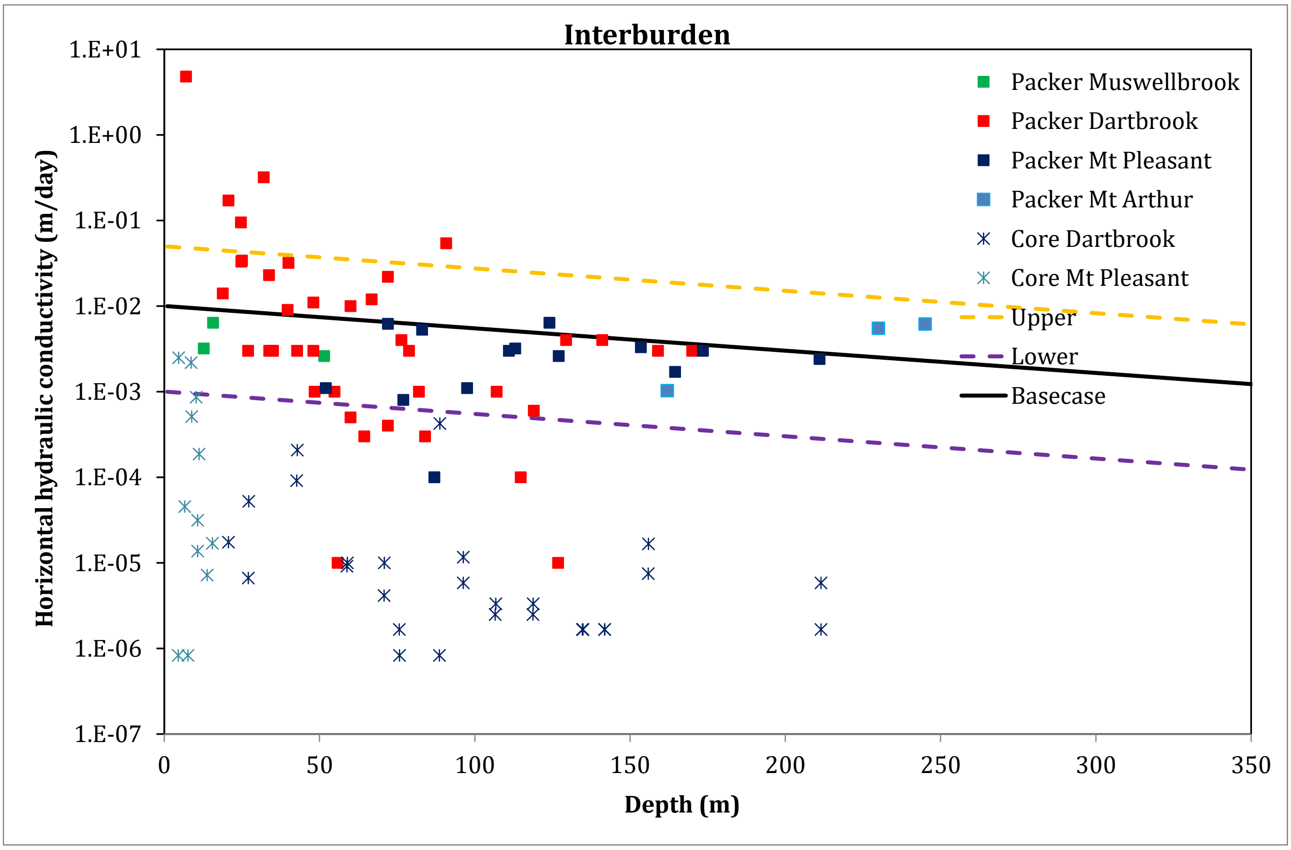


Figure A 2.5 Horizontal hydraulic conductivity for interburden

A3 Model calibration

The groundwater model was calibrated to a pre-mining steady state water level set and then to transient water level and mine inflow datasets (1991 to 2017) using available groundwater level data and documented mine inflows. The model was calibrated by adjusting aquifer parameters and stresses to produce the best match between the observed and simulated water levels and mine inflows. Manual testing, automated parameterisation software (PEST) (Doherty 2010) and pilot points were used to determine optimal hydraulic parameters and recharge rates to achieve the most representative calibration of the groundwater model.

A3.1 Calibration targets

A3.1.1 Heads

The steady state and transient model simulated water levels at all available monitoring bores with reliable datasets. A total of 114 monitoring sites were available to calibrate the model, comprising:

- 87 monitoring bores; and
- 27 monitoring points with vibrating wire piezometers.

Figure A 3.1 shows the locations of the monitoring bores. Because the frequency and amount of data varies from monitoring location to monitoring location, the bore water level records were weighted as follows:

- obviously anomalous results were removed;
- datalogger data was reduced to a monthly frequency; and
- datapoints for each location were weighted according to the formula:

Weight of datapoint = 1/ √ (number of points for that site).

Using this method, bores with longer records have a lower weighting per datapoint, but the overall weighting of each bore in the combined dataset is equal to 1. The model was calibrated to the observed water level datasets, with the 'best calibrated' model returning the lowest objective function (phi) value (i.e. the lowest statistical difference between the observed and modelled values across the chosen dataset).

A3.1.2 Fluxes

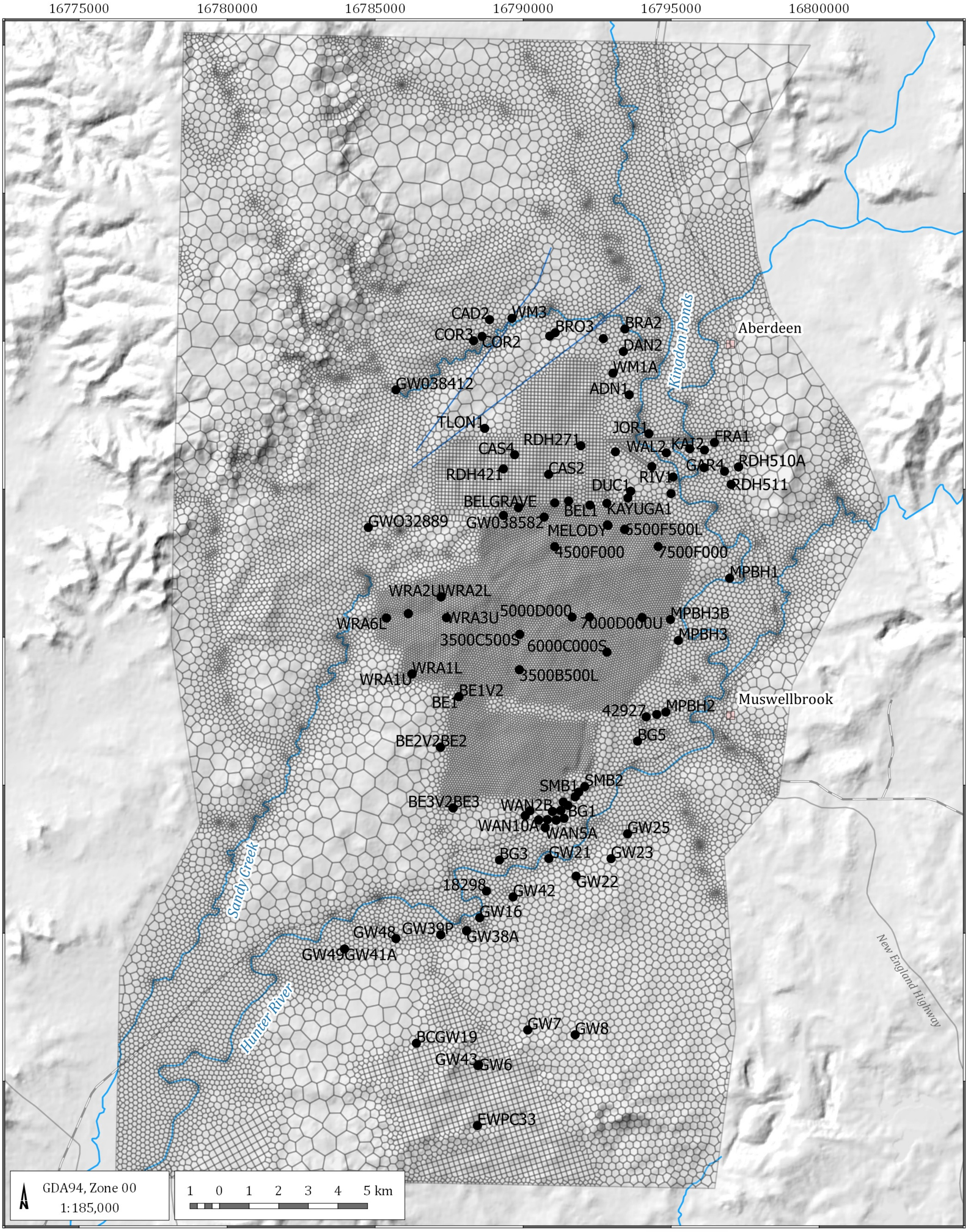
The MPO started operations in October 2017 and so mining at the MPO is not simulated during the calibration period. However, groundwater inflows to other mines in this area are available. As mentioned in Section A2.3.4, the neighbouring mines include the Bengalla Mine, Mt Arthur Coal Mine open-cuts, and the underground extraction at Dartbrook Mine. Data and records for inflow has been derived from the Annual Environmental Management Reports (AEMR) and used for calibration.

Responses of observation bore water levels to advancing mining suggested that there was a degree of heterogeneity present within several geological layers. This became more apparent during initial model calibration, when not all bores within a layer would calibrate using uniform hydraulic parameters.

To explore the heterogeneity within the model domain and provide a degree of flexibility during the calibration, a series of pilot points were added to the top three model layers. The locations of the pilot points in each model layer are consistent between the layers and are shown in Figure A 3.2. The pilot points were interpolated across the model domain in each layer of the model using ordinary automatic Kriging through PLPROC[2] (Watermark Numerical Computing, 2015). Horizontal and vertical conductivity were then derived based on the interpolated values at each cell centre.

To calibrate the model, the pilot point multipliers were allowed to vary ± two orders of magnitude from the starting point. The starting point for all multipliers was assumed to be 1. For Permian units (coal and interburden) there was additional constraints applied to cap the upper and lower values (as presented in Table A 2.8).

[2] A parameter list processor.



LEGEND

- Grid
- Road
- Rail
- Drainage
- Populated place
- Observations

MT Pleasant GIA (G1970)

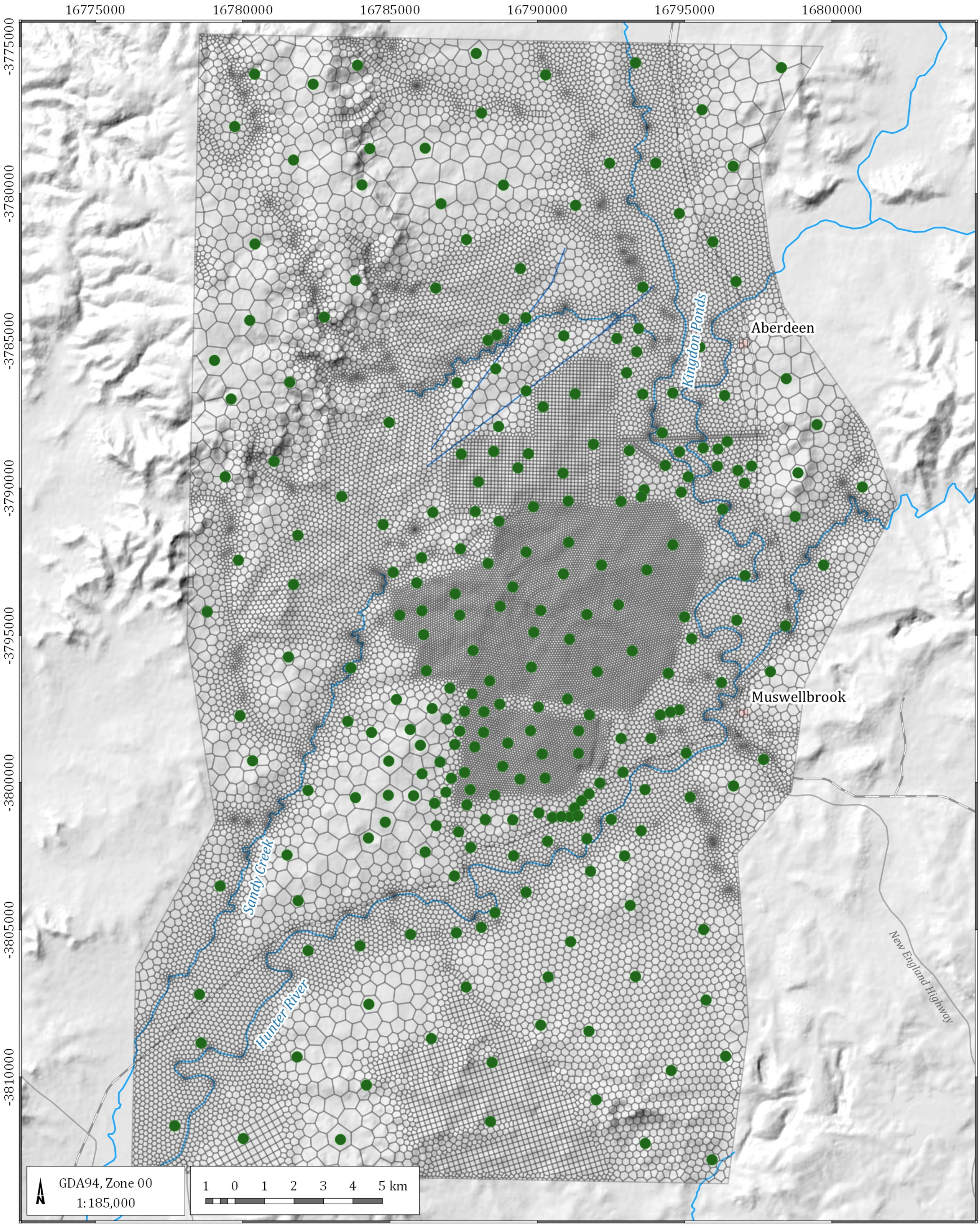
Observation target locations

AGE

DATE 21/01/2020

FIGURE No: A 3.1

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\002_Deliverable2\03.01_G1970_Observation target locations.qgs



LEGEND

- Grid
- Road
- Rail
- Drainage
- Populated place
- Pilot points

MT Pleasant GIA (G1970)

Location of pilot points

DATE 21/01/2020

FIGURE No: A 3.2

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\002_Deliverable2\03.02_G1970_Location of pilot points.qgs

A3.2 Calibration results

Figure A 3.3 presents the observed and simulated groundwater levels graphically as a scattergram for the historical transient calibration. The points in the scatter are grouped by the various mines the data is sourced from. Overall, there is a good fit between the modelled and observe datasets in all mines, particularly in the MPO. It appears that there is some variability in the Mt Arthur Coal Mine monitoring bores, which may be due to not replicating all the interburden and target coal seams within Mt Arthur Coal Mine. Appendix A 1 shows the simulated hydrographs for each observation bore.

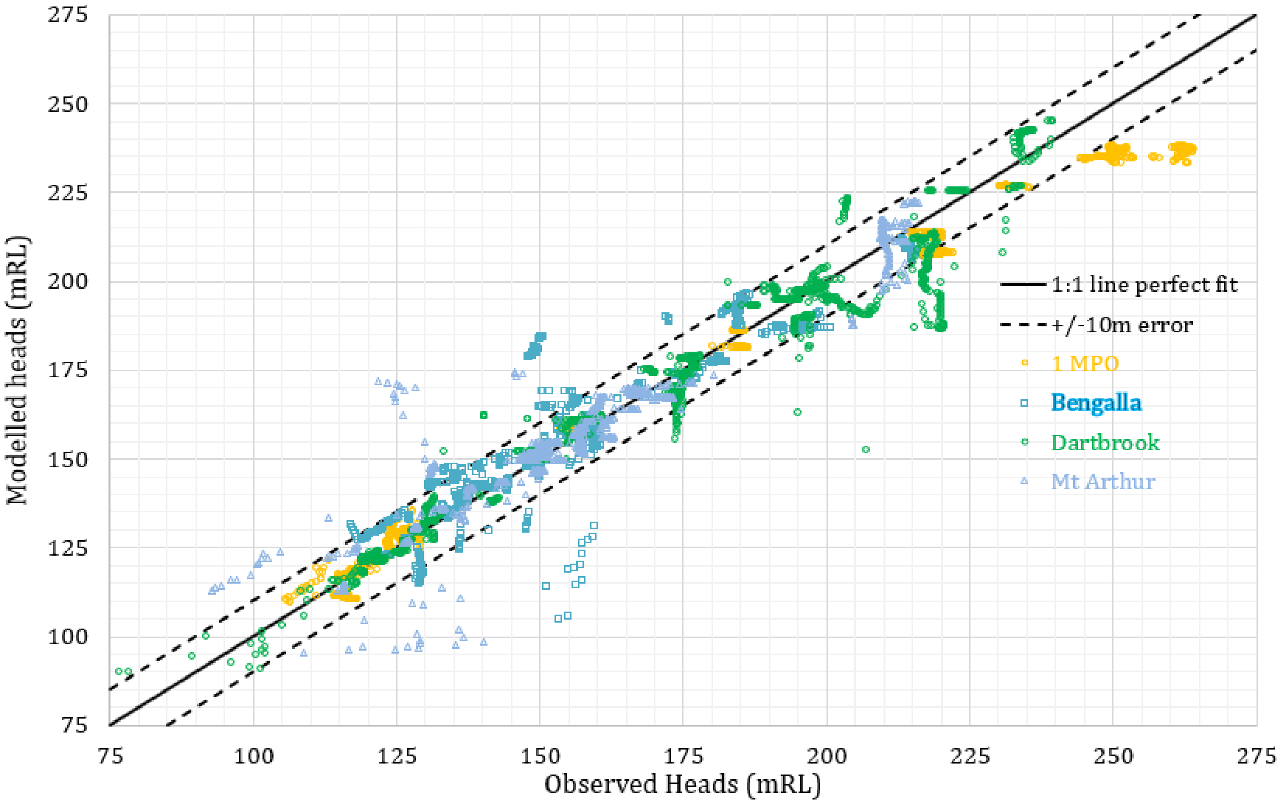
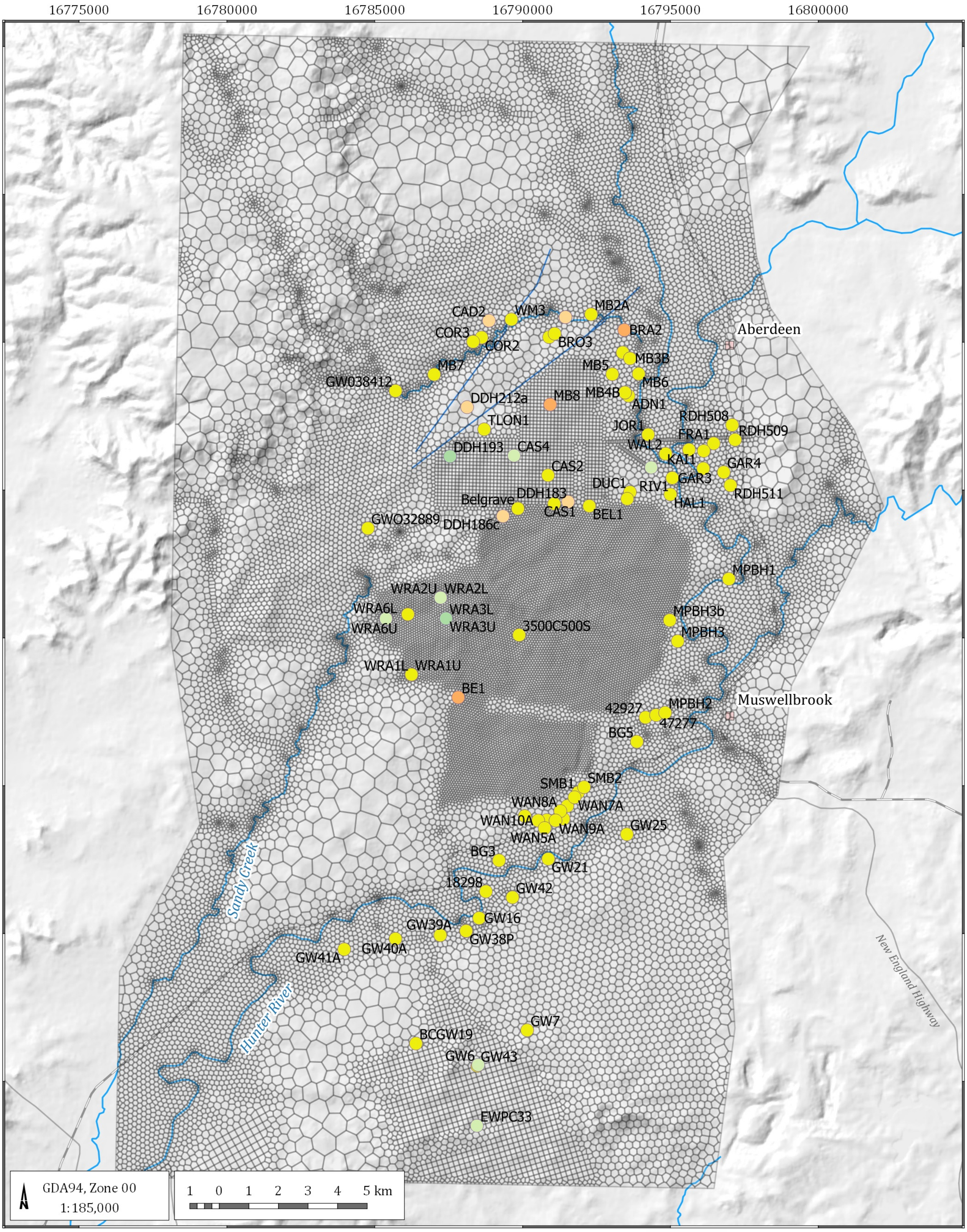


Figure A 3.3 Transient calibration – modelled vs observed groundwater levels

Figure A 3.4 shows the spatial distribution of residuals at shallow groundwater observation sites (i.e. layers 1 to 3). This figure indicates that the shallow bores are replicated reasonably well across the model domain. Figure A 3.5 shows the spatial distribution of residuals within deeper units (i.e. layers 4 to 20) and indicates the deep bores are generally well represented across the model domain. The largest residuals are shown as dark orange points in Figure A 3.5 and includes the nested piezometer BE1 located west of Bengalla Mine. Further inspection of hydrographs for BE1 and surrounding nested bores (i.e. BE2 and BE3) in Appendix A 1 indicates that the model has been able to simulate the pressure difference from shallow to deep piezometers, but the heads appear to be overestimated in V1 and V2 piezometers in BE1 and BE2. This overestimation does not appear to be significant and may be due to heterogeneity and assumed thickness of the interburden units.



LEGEND

- Grid
- Road
- Rail
- Drainage
- Populated place

Average residuals (m)

- -40.0 - -30.0
- -30.0 - -20.0
- -20.0 - -10.0
- -10.0 - -5.0
- -5.0 - 5.0
- 5.0 - 10.0
- 10.0 - 20.0
- 20.0 - 30.0
- 30.0 - 40.0

MT Pleasant GIA (G1970)

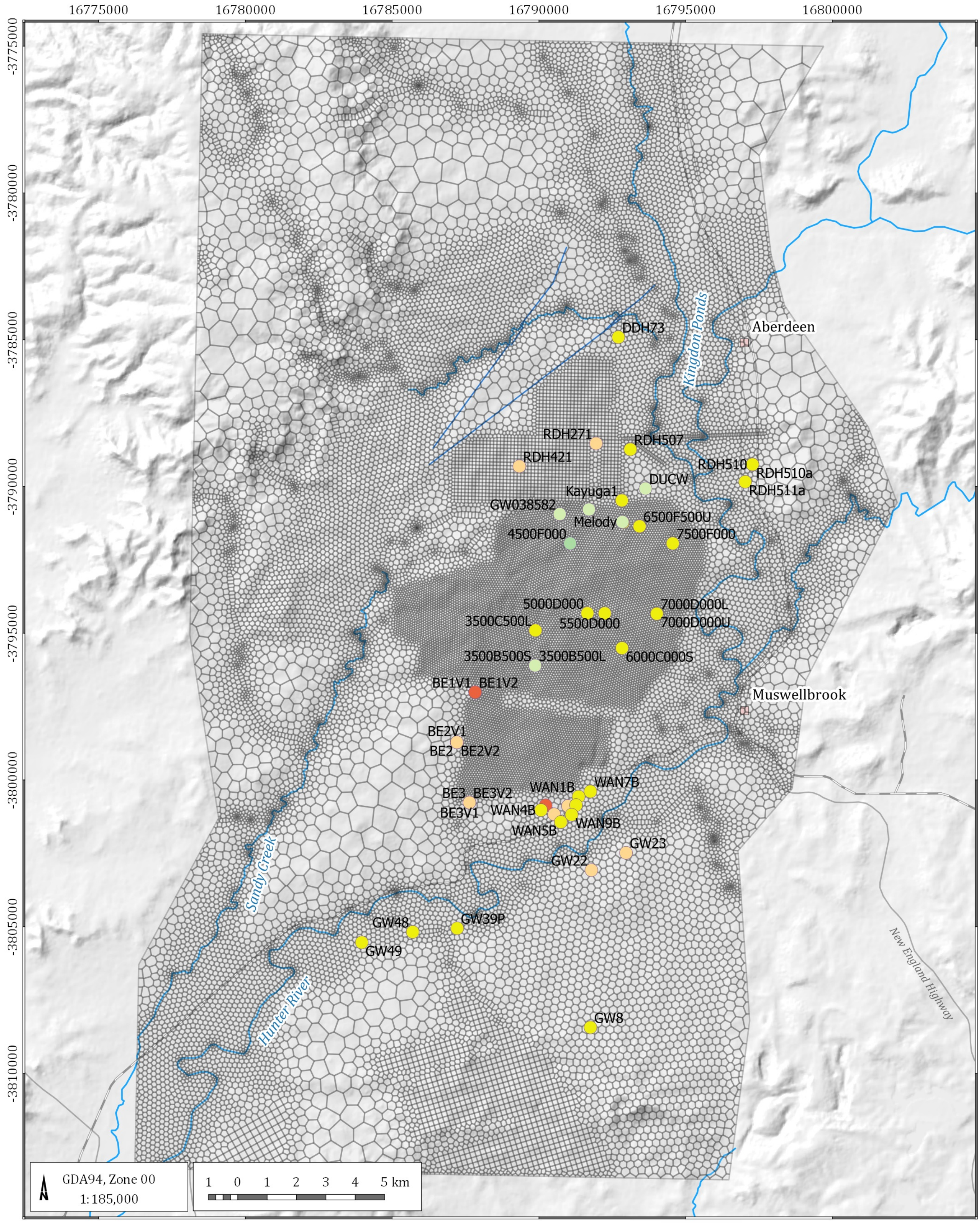
Average residuals for shallow bores in layers 1 to 3

AGE

DATE 21/01/2020

FIGURE No: A 3.4

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\002_Deliverable2\03.04_G1970_Average residuals for shallow bores in layers 1 to 3.qgs



LEGEND

- Grid
- Road
- Rail
- Drainage
- Populated place

Average residuals (m)

- -40.0 - -30.0
- -30.0 - -20.0
- -20.0 - -10.0
- -10.0 - -5.0
- -5.0 - 5.0
- 5.0 - 10.0
- 10.0 - 20.0
- 20.0 - 30.0
- 30.0 - 40.0

MT Pleasant GIA (G1970)

Average residuals for shallow bores in layers 4 to 20

AGE

DATE 21/01/2020

FIGURE No: A 3.5

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\002_Deliverable2\03.05_G1970_Average residuals for shallow bores in layers 4 to 20.qgs

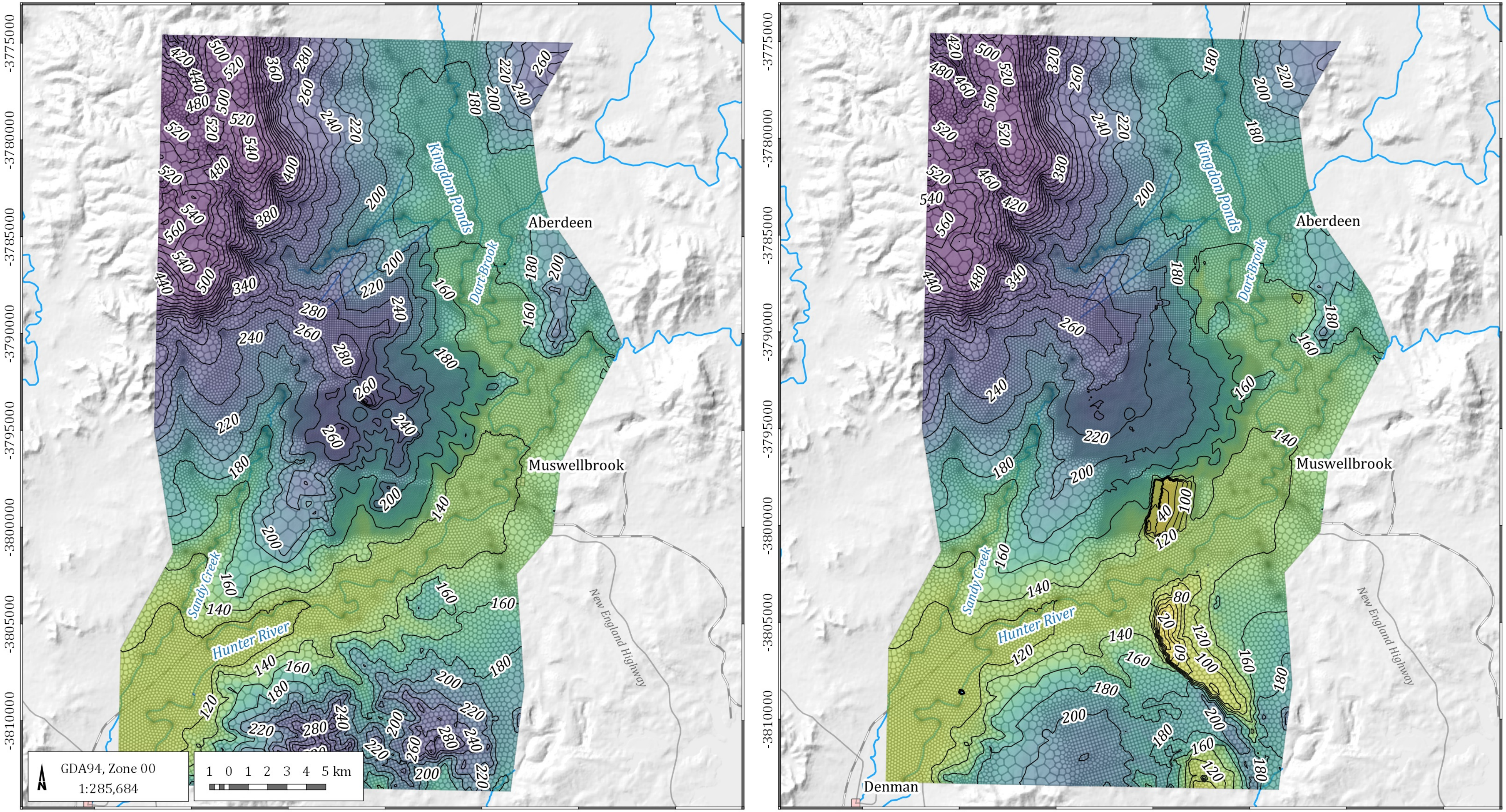
The root mean square (RMS) error calculated for the calibrated model was 5 m. The total measured head change across the model domain was 190.2 m, with a standardised unweighted RMS (SRMS) of 4.1%. This is well below the SRMS target of < 10% suggested in the Australian Modelling Guidelines (Barnett et al., 2012) and therefore the model as a whole can be considered calibrated.

A3.2.1 Calibration heads

The calibrated heads from the pre-mining steady state model are presented for Layer 1 (alluvium and regolith) and Layer 16 (Wynn seam) in Figure A 3.6(a) and Figure A 3.7(a), respectively. The calibrated heads at the end of the transient model (2017) are presented for Layer 1 (alluvium and regolith) and Layer 16 (Wynn seam) in Figure A 3.6(b) and Figure A 3.7(b), respectively. Groundwater levels representing 2017 conditions show the depressurised zones within the potentiometric surface caused by the advancement of mining at Bengalla Mine, and Mt Arthur Coal Mine and Dartbrook Mine.

(a) Pre mining

(b) 2017



LEGEND

- Road
- Rail
- Populated place
- Drainage

Heads (m)

- 40
- 120.0
- 150.0
- 160.0
- 170.0
- 185.0
- 200.0
- 225.0
- 250.0
- 350.0
- 550.0

MT Pleasant GIA (G1970A)

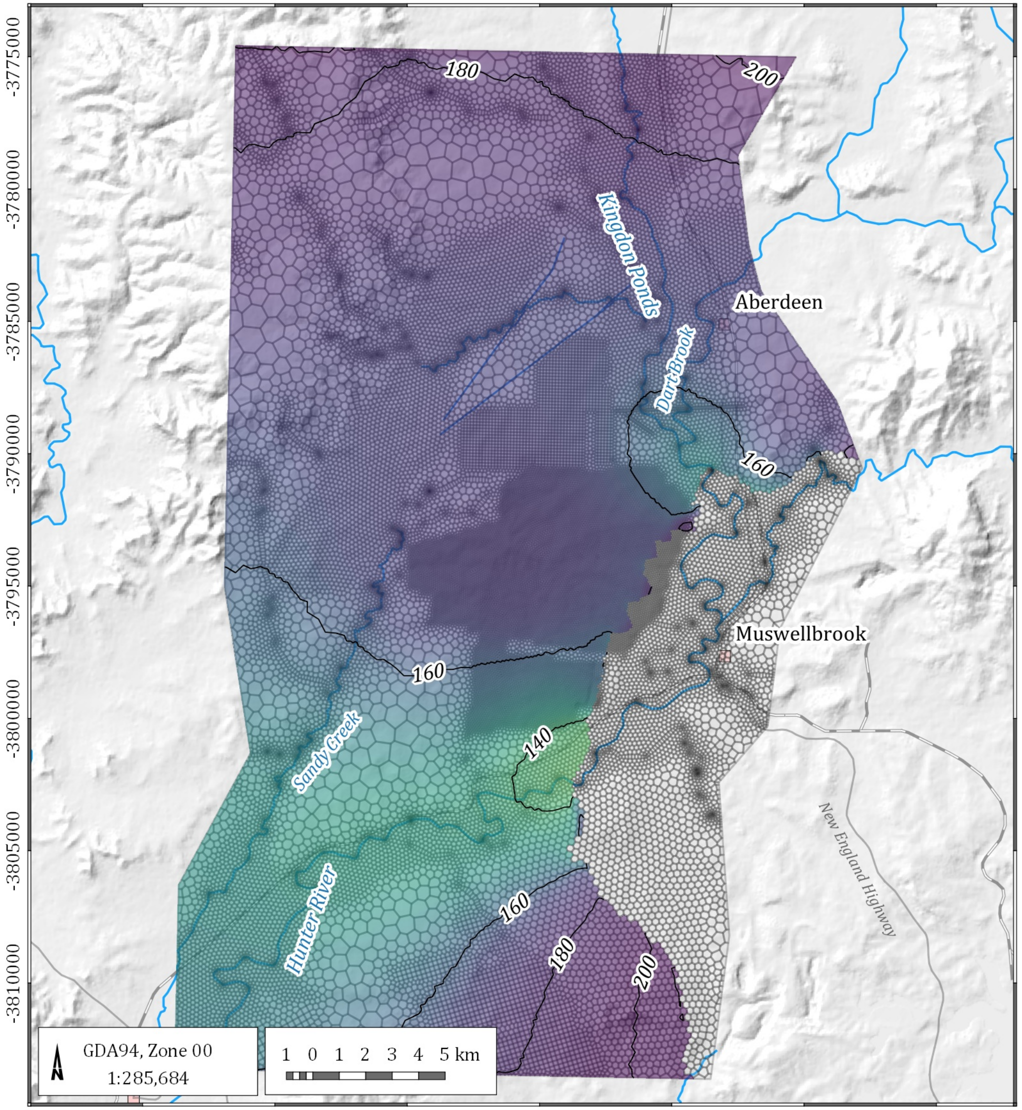
Modelled groundwater levels – layer 1 (Alluvium and Regolith)

DATE
07/09/2020

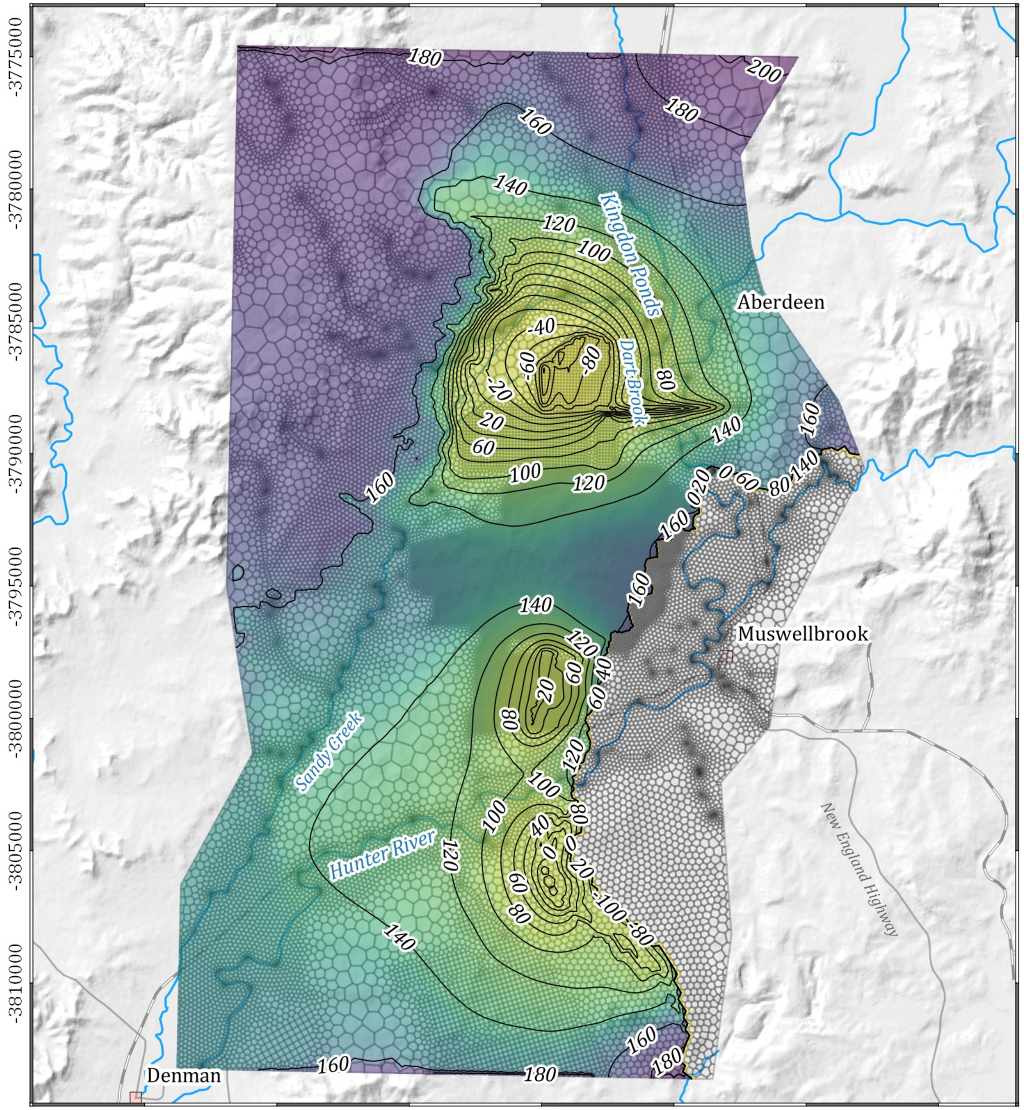
FIGURE No:
A 3.6

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\002_Deliverable2\03.06_G1970_Modelled groundwater levels layer 1 (Alluvium and Regolith).qgs

(a) Pre mining



(b) 2017



LEGEND

Road

Rail

Populated place

Drainage

Heads (m)	
-170.0	150.0
85.0	155.0
120.0	160.0
140.0	165.0
145.0	175.0
	200.0

MT Pleasant GIA (G1970A)

Modelled groundwater levels – layer 16 (Wynn Seam)

DATE
07/09/2020

FIGURE No:
A 3.7

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\002_Deliverable2\03.06_G1970_Modelled groundwater levels layer 1 (Alluvium and Regolith).qgs

A3.2.2 Hydraulic parameters

Table A 3.1 summarises the calibrated hydraulic conductivity (or in many cases HC_0) for each of the hydrostratigraphic units within the model domain. The values presented are the basecase value for each layer. It should be noted that hydraulic properties in layers 1 to 3 are adjusted based on the pilot points shown in Figure A 3.2 Appendix A 2 shows the resulting hydraulic conductivity from this pilot point adjustment process for model layers 1 to 3. The HC_0 that is listed in Table A 3.1 refers to the calibrated hydraulic conductivity at a depth of zero metres as utilised in the equation presented in Section A2.3.5.

The values in Table A 3.1 are further refined by the constraints listed in Table A 2.8 before being written to model input files. Percentile plots of the calibrated ranges in hydraulic conductivity that are written to model files are shown in Figure A 3.8 and Figure A 3.9. The plots use data from a regularised 200 m grid covering the model domain rather than model cell centres. This approach has been used to remove the effect of different cell sizes, which could bias the outputs. The notable steps in values in layer 1 and layer 2 represent the different stratigraphic zones present within that layer (e.g. alluvium and regolith).

Table A 3.1 Calibrated base hydraulic conductivity values (HC_0)

Model layer	Lithology	Horizontal hydraulic conductivity Kh (m/day)	Vertical hydraulic conductivity factor (Kv:Kh)
1 and 2	Alluvium and regolith	4.61	0.2
2	Weathered overburden (HC_0 in Kh-depth equation)	0.01	0.6
3	Overburden (HC_0 in Kh-depth equation)	0.01	0.003
4	Warkworth Seam (HC_0 in Kh-depth equation)	0.28	0.005
5	Interburden 1 (HC_0 in Kh-depth equation)	0.03	0.001
6	Mount Arthur Seam (HC_0 in Kh-depth equation)	0.05	0.006
7	Interburden 2 (HC_0 in Kh-depth equation)	0.02	0.008
8	Piercefield Seam (HC_0 in Kh-depth equation)	0.05	0.003
9	Interburden 3 (HC_0 in Kh-depth equation)	0.01	0.008
10	Vaux Seam (HC_0 in Kh-depth equation)	0.05	0.008
11	Interburden 4 (HC_0 in Kh-depth equation)	0.003	0.003
12	Broonie Seam (HC_0 in Kh-depth equation)	0.14	0.005
13	Interburden 5 (HC_0 in Kh-depth equation)	0.02	0.005
14	Bayswater Seam (HC_0 in Kh-depth equation)	0.05	0.002
15	Interburden 6 (HC_0 in Kh-depth equation)	0.03	0.003
16	Wynn Seam (HC_0 in Kh-depth equation)	0.14	0.002
17	Interburden 7 (HC_0 in Kh-depth equation)	0.05	0.001
18	Edderton Seam (HC_0 in Kh-depth equation)	0.06	0.001
19	Saltwater Creek Formation (HC_0 in Kh-depth equation)	0.02	0.001
20	Older units (HC_0 in Kh-depth equation)	0.06	0.03

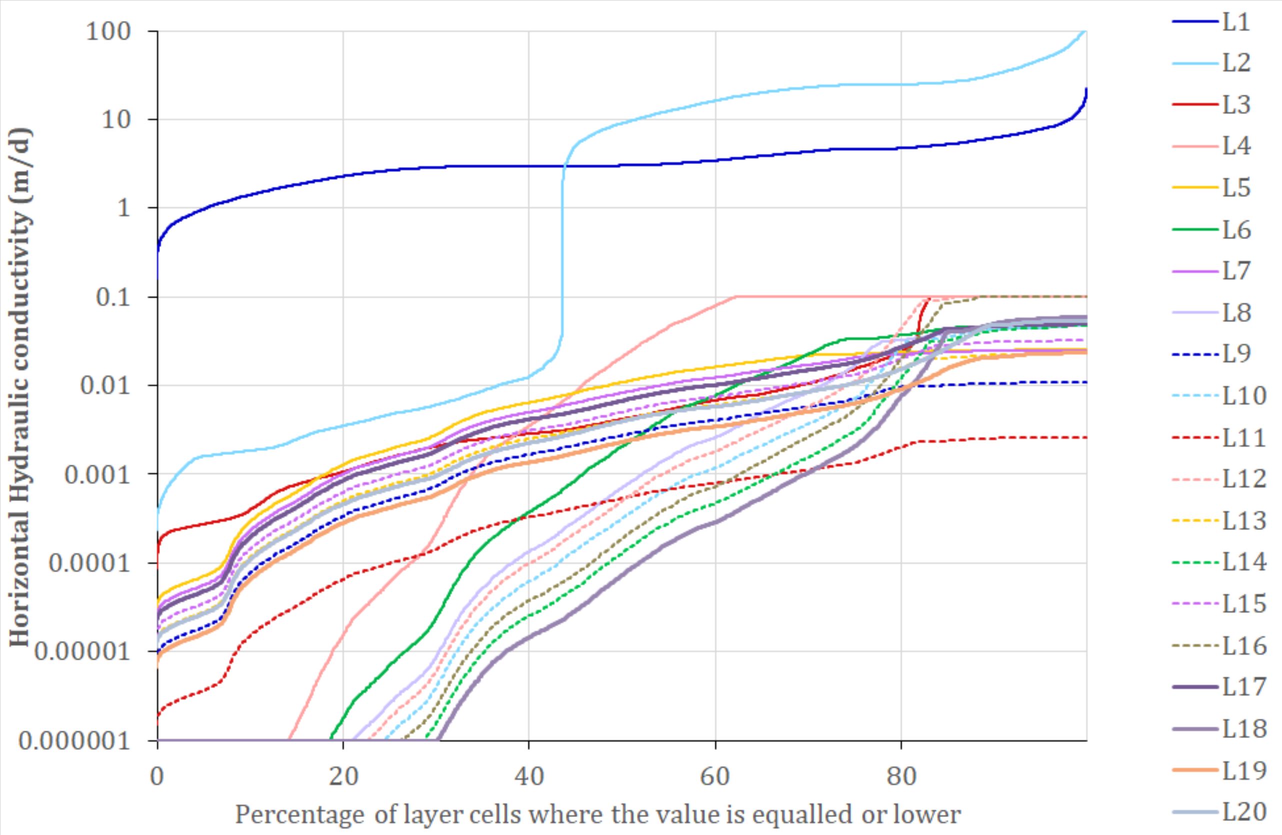


Figure A 3.8 Horizontal hydraulic conductivity ranges in each model layer

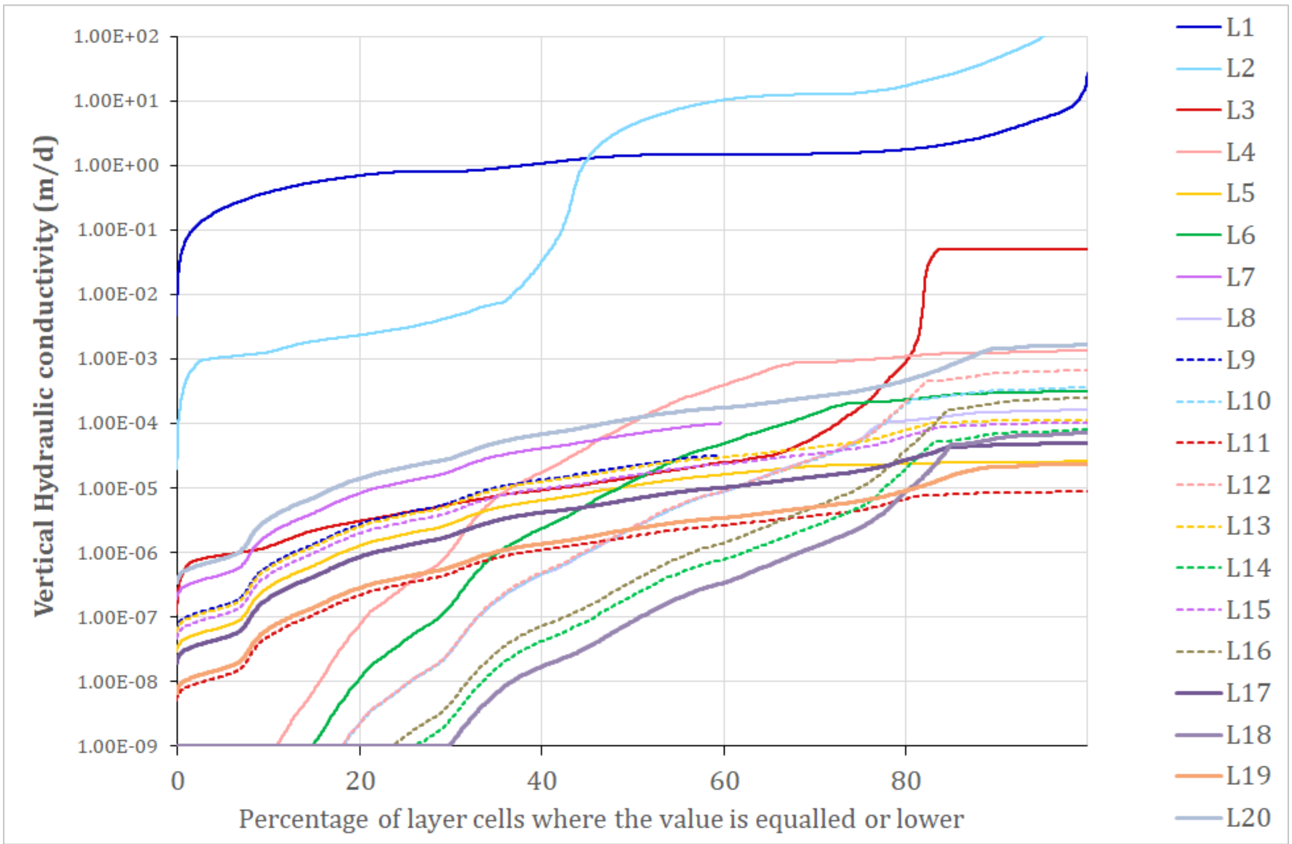


Figure A 3.9 Vertical hydraulic conductivity ranges in each model layer

A3.2.3 Storage properties

Table A 3.2 summarises the calibrated values for specific storage and specific yield. Unlike hydraulic conductivities, the storage parameters are uniform across the whole model domain at each layer. Specific yield is only relevant in the model where the layers become unconfined, so the parameter is not necessarily utilised in the deeper model layers. Specific storage is only applied where the model layers are confined.

Table A 3.2 Calibrated base storage values

Model layer	Lithology	Specific yield Sy (-)	Specific storage Ss (m^{-1})
1 and 2	Alluvium and regolith	7.0E-02	1.3E-05
2	Weathered overburden	3.2E-02	3.3E-06
3	Overburden	1.7E-03	2.3E-07
4	Warkworth Seam	3.8E-03	5.0E-06
5	Interburden 1	1.1E-02	7.6E-07
6	Mount Arthur Seam	1.1E-03	5.0E-06
7	Interburden 2	1.3E-03	6.7E-07
8	Piercefield Seam	1.6E-04	2.3E-07
9	Interburden 3	1.3E-04	3.0E-06
10	Vaux Seam	1.3E-04	2.2E-06
11	Interburden 4	1.6E-04	1.1E-06
12	Broonie Seam	1.0E-04	1.8E-06
13	Interburden 5	2.1E-04	2.8E-07
14	Bayswater Seam	1.2E-04	2.3E-07
15	Interburden 6	1.0E-04	2.3E-07
16	Wynn Seam	2.4E-03	3.1E-07
17	Interburden 7	1.0E-04	2.3E-07
18	Edderton Seam	6.3E-03	2.3E-07
19	Saltwater Creek Formation	1.0E-04	2.5E-06
20	Older units	4.6E-04	2.7E-06

A3.2.4 Water budget

The mass balance error (i.e. the difference between calculated model inflows and outflows at the completion of the steady state calibration) was 0.00%. The maximum percent discrepancy at any time step in the simulation was also 0.01%. This value indicates that the model is stable and achieves an accurate numerical solution. Table A 3.3 shows the water budget for the steady state (pre-mining) model.

Table A 3.3 Model budgets – steady state

Parameter	In (ML/day)	Out (ML/day)	In - Out (ML/day)
Rainfall	15.6	-	15.6
River	5.6	17.9	-12.3
Evapotranspiration	-	3.4	-3.4
General head boundary	0.1	0.02	0.08
Total	**21.3**	**21.32**	**-0.02**

The water budget indicates that recharge (rainfall and river leakage) to the groundwater system within the model averages 21.3 ML/day, with approximately 17.9 ML/day being discharged via surface drainage, and 3.4 ML/day lost to evapotranspiration in areas where the water table is close to the land surface. The measured difference between the discharge flows at Aberdeen (i.e. Hunter upstream) and Denman (i.e. Hunter downstream) indicates that Hunter river is losing on average 140 ML/day. The model indicates that Hunter river is losing on average 6 ML/day to seepage to the groundwater system which is around 4.3% of total loss. This seems plausible given the measured losses include surface water take and the losses to evaporation. Regional through flow from the general head boundary is negligible and contributes only 0.5% of the total input to the groundwater model.

Table A 3.4 shows the average component water budget for the transient calibration (1991 to 2017). The model converged to a satisfactory level with 0.0 percent discrepancy reported. This is confirmed by the numerical accounting terms of 'storage in' (3.46 ML/day) and 'storage out' (1.49 ML/day) providing the balance to the table below.

Table A 3.4 Model budgets – transient calibration

Parameter	In (ML/day)	Out (ML/day)
Rainfall	13.28	-
River	6.76	17.36
Evapotranspiration	-	2.97
General head boundary	0.1	0
Drains	-	1.78
Total	**20.14**	**22.11**

The transient water budget indicates that the groundwater system varies slightly from steady state conditions due to expanding mining represented in the model. Recharge (rainfall and river leakage) within the model averages 20.14 ML/day, with approximately 17.36 ML/day being discharged via surface drainage. The differences between the steady state and transient recharge rates are due to different climatic conditions during the transient calibration period (1991 to 2017) when compared to the annual average that was adopted for the steady state simulation. The transient budget also shows that, on average, drains (mining) take out an average of 1.78 ML/day, which is relatively small component of the overall water budget.

A3.2.5 Mine inflow

Figure A 3.10 to Figure A 3.13 show the simulated versus observed annual groundwater inflows to open cut pits and underground workings at mines within the model domain. Figure A 3.10 to Figure A 3.13 shows generally a good match between observed and simulated inflows.

The model slightly overestimates the inflows, particularly for Bengalla Mine. This is acceptable given that the model predicted inflows have not been adjusted for evaporative loss, nor for moisture that has been removed with the mined coal.

The key aspect of the level of match to the measured mine inflows is that the modelled inflows are in the same order of magnitude. Because of the simplified mine plans that have been adopted for the neighbouring mines, there is no expectation that all nuances in the inflow observations would be recreated.

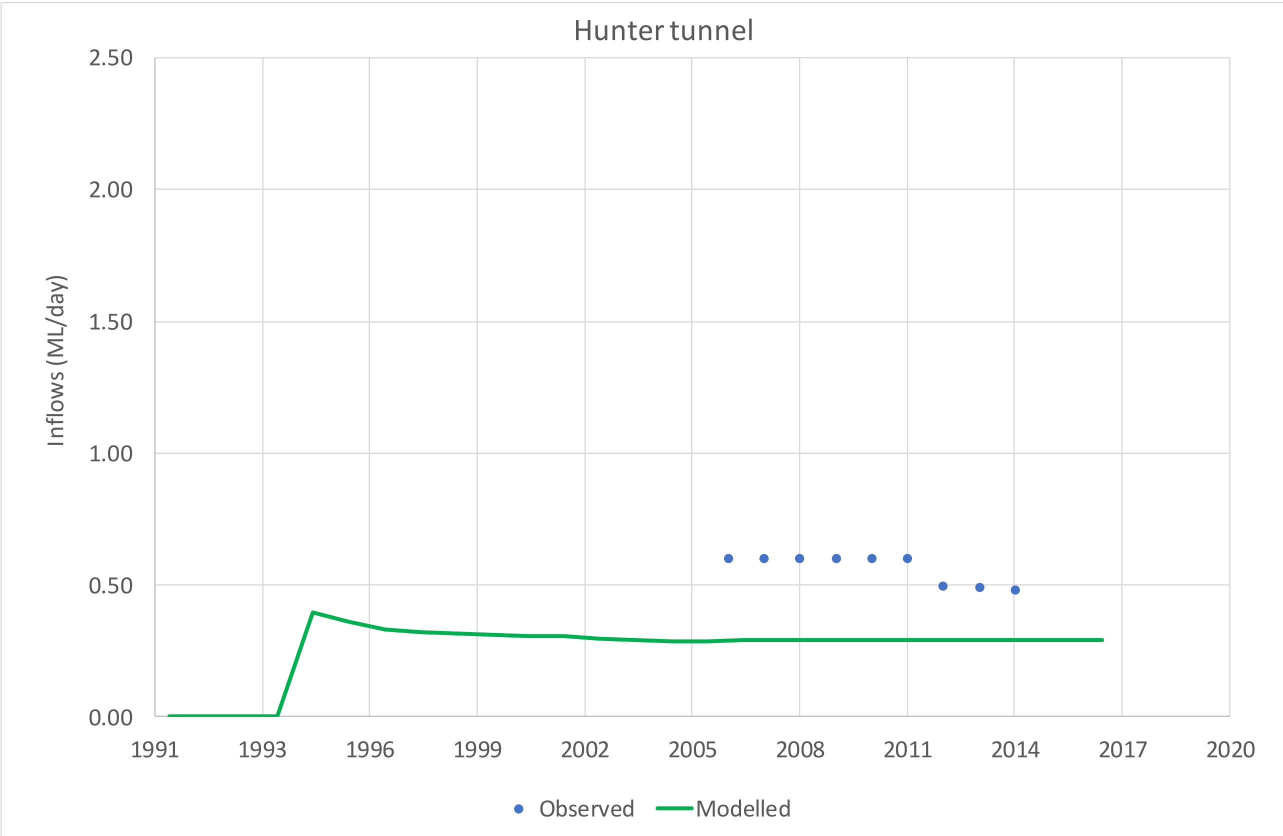


Figure A 3.10 Simulated and observed inflows – Dartbrook Mine Hunter Tunnel

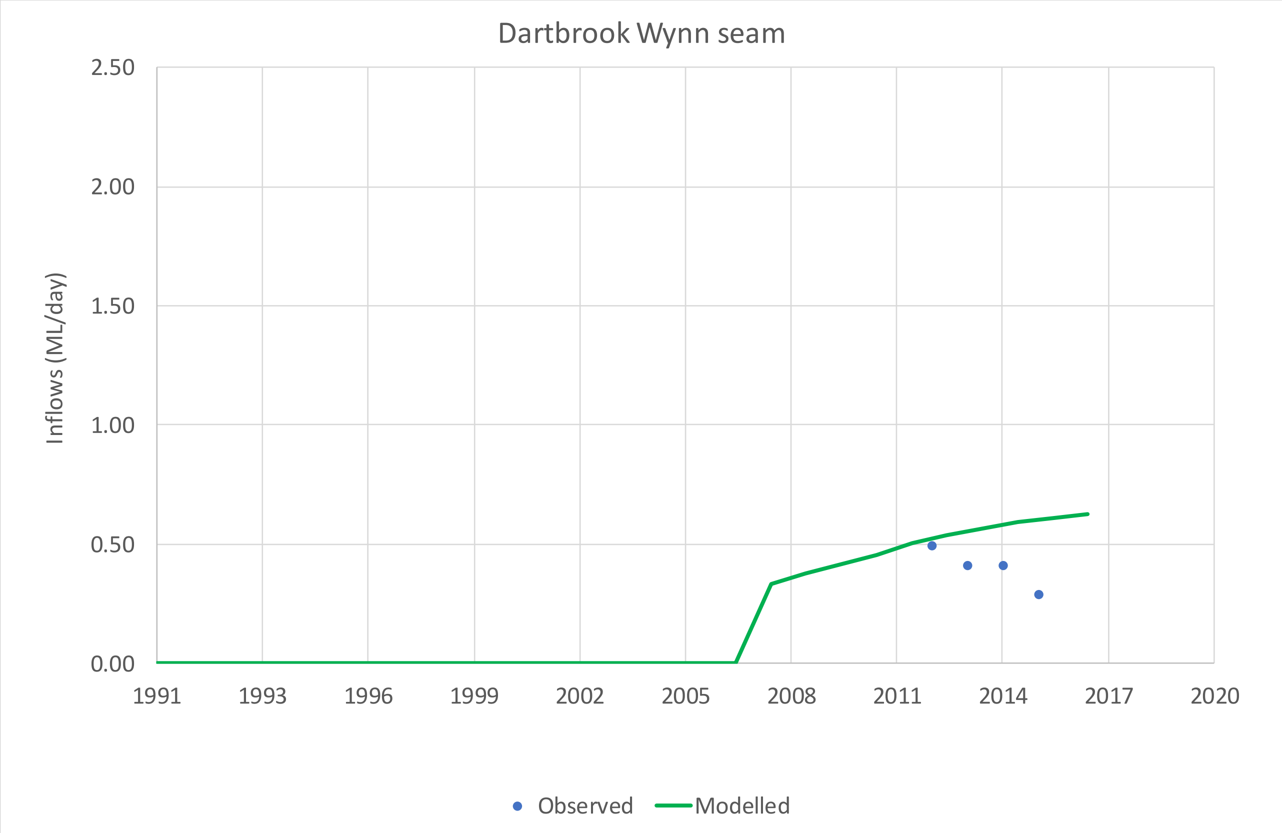


Figure A 3.11 Simulated and observed inflows – Dartbrook Wynn Seam

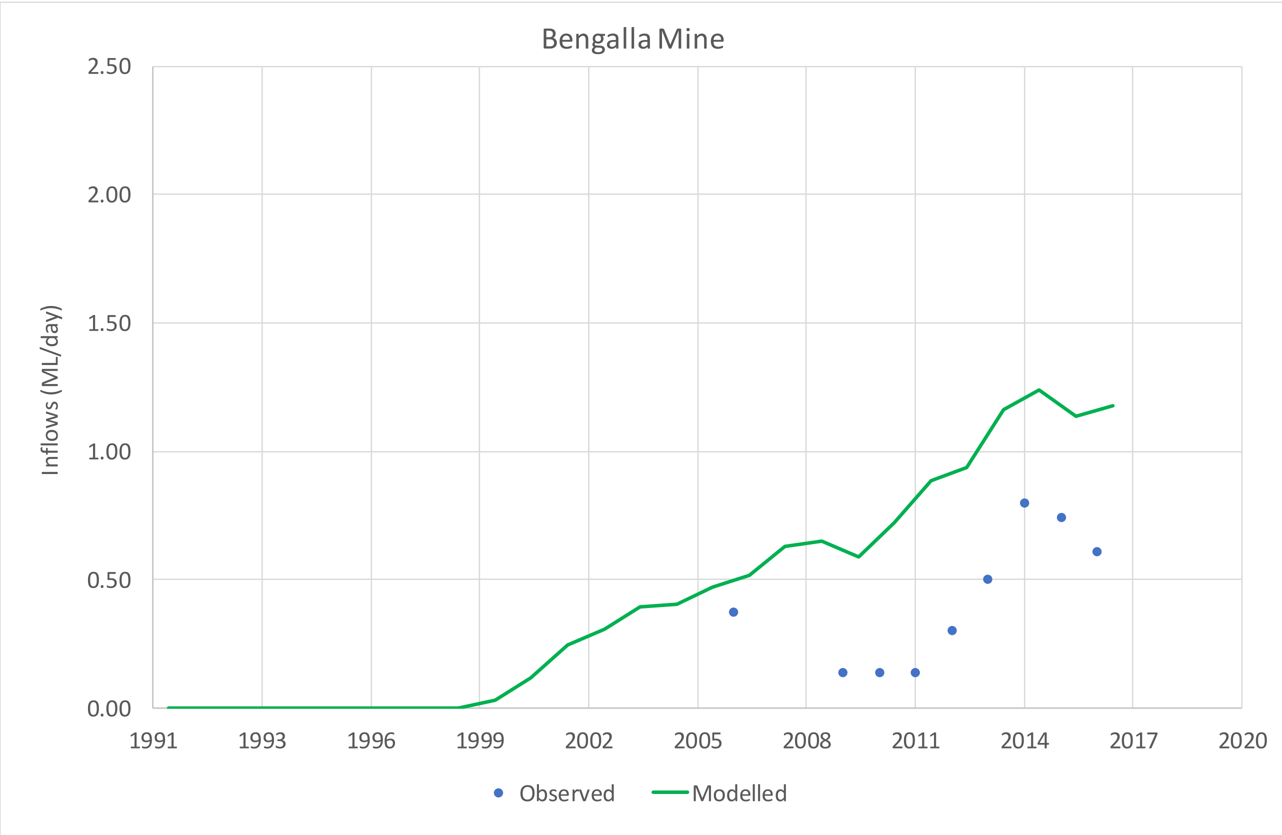


Figure A 3.12 Simulated and observed inflows – Bengalla Mine

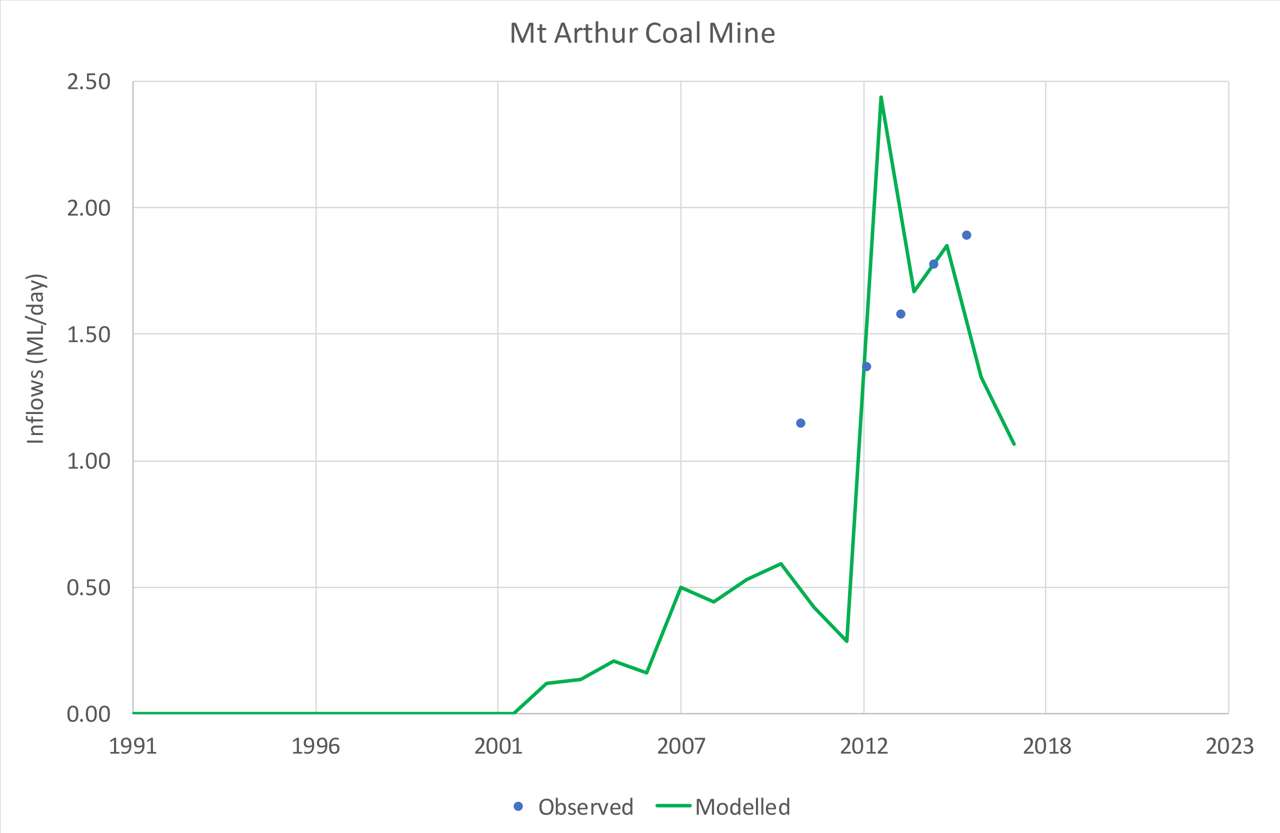


Figure A 3.13 Simulated and observed inflows – Mt Arthur Coal Mine

A3.2.6 Verification

As the model was calibrated to observations available up to 2017, new observed data is available to verify the calibration. Observed data for MPO monitoring locations have been added to their respective hydrographs to verify that the model calibration is still valid. The hydrographs are provided in Appendix A 3.

A4 Predictive and recovery simulations

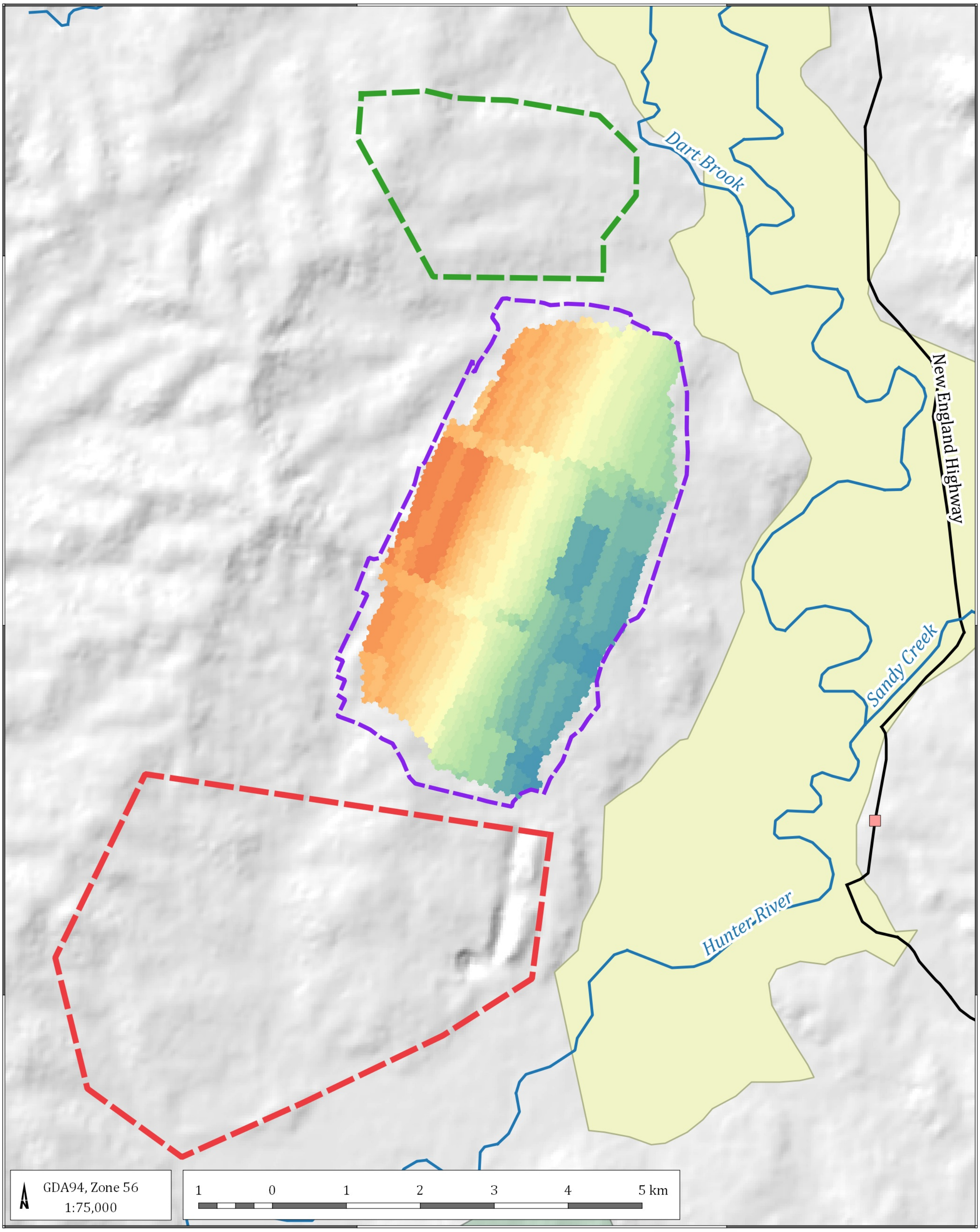
A4.1 Predictive simulations

Three models were run for the predictive simulations. These were:

- no mining – the model is run without any mining to provide a baseline output against which the simulations with mining can be compared;
- mining from neighbouring mines only (excluding the approved MPO and the Project); and
- mining from neighbouring mines and the MPO (incorporating the Project).

By comparing the outputs from these three model simulations the cumulative impacts from all mining areas, and the impacts from just the MPO (incorporating the Project) can be predicted. The mine plan for the approved and proposed mining at MPO combined is presented in Figure A 4.1. This mine plan was provided by MACH and indicates when mining begins at the locations shown. Outputs from the predictive models are presented in Sections 7 and 8 of the main report.

Further to the above model runs, and in recognition that the current impact assessment is about an extension of the existing approved mining, a model run was also undertaken that simulates the approved mining up to 2026. This was then used to isolate the approved mining impacts from the proposed extension and to add context to the overall MPO impacts being reported.



LEGEND

- Bengalla
- Dartbrook
- MPO
- Alluvium
- Populated place
- Road
- Drainage

Mining progression (years)

- 2018
- 2023
- 2028
- 2033
- 2038
- 2043
- 2048

Mt Pleasant GIA (G1970A)

MPO Simulated Mine Plan

AGE

DATE 28/08/2020

FIGURE No: **A 4.1**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\999_Working\model-inspection-workspace-20190924.qgs

A4.2 Recovery simulations

The transient model was extended by one stress period to simulate recovery of the groundwater system once all mining is complete. At the completion of mining, any remaining boundary conditions representing dewatering were removed, and the model was adjusted to simulate post-mining conditions. This included an increase in permeability in the mining areas to represent the more permeable spoil, and enhanced recharge rates to the spoil to simulate their enhanced recharge capacity. In addition, an evaporative boundary condition was applied over the final landform with the exception of the pit lake areas. Final voids are expected to remain for Mt Arthur Coal Mine and Bengalla Mine, as well as that proposed for MPO.

The water level for the MPO void post mining has been determined by HEC, and their predicted water level recovery in presented in Figure A 4.2. This assessment has used groundwater inflow predictions linked to stage elevation in the void within the overall void water balance to determine the predicted void water level.

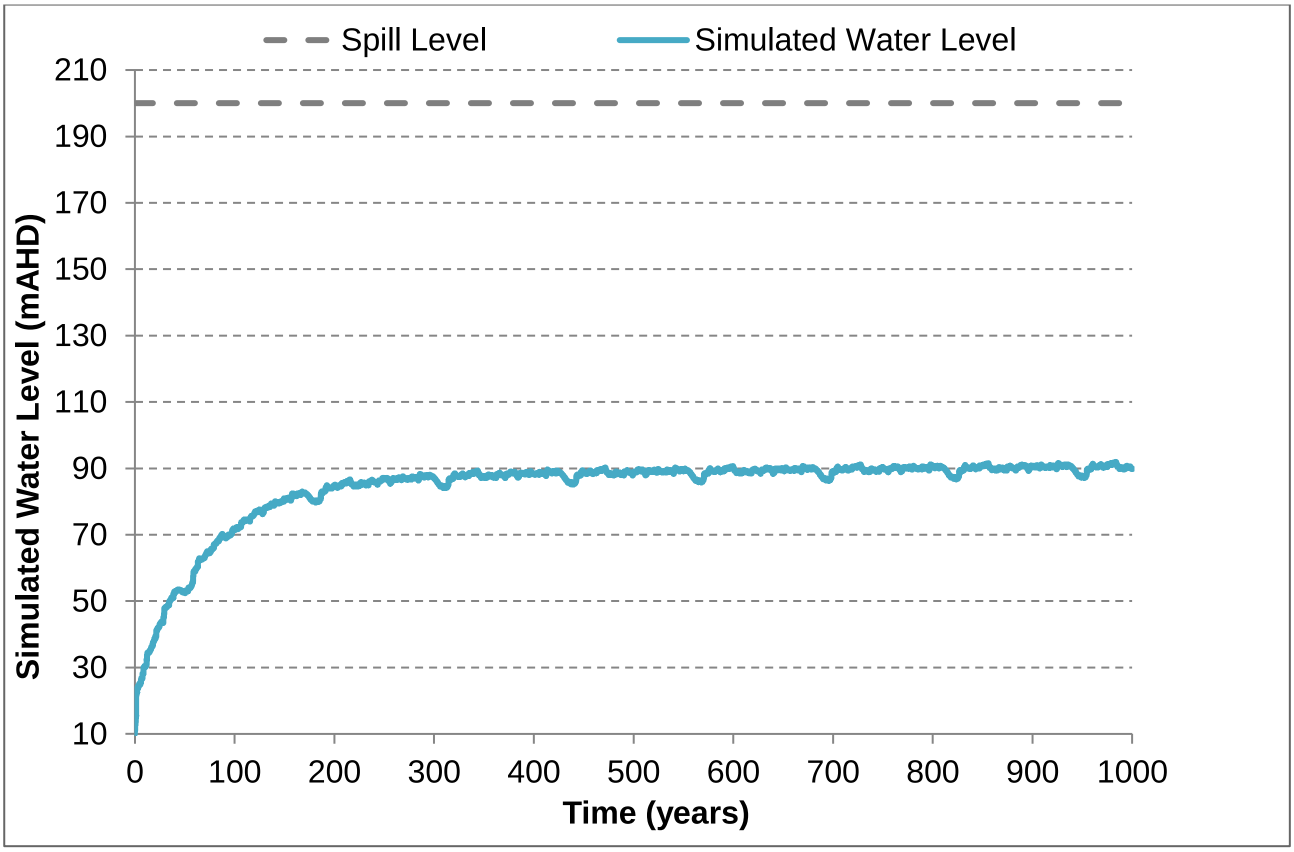


Figure A 4.2 MPO simulated void water level (HEC, 2020).

The void footprints for all the mines are presented in Figure A 4.3. Equilibrium void levels in the neighbouring mines have been sourced from corresponding assessments in the public domain.

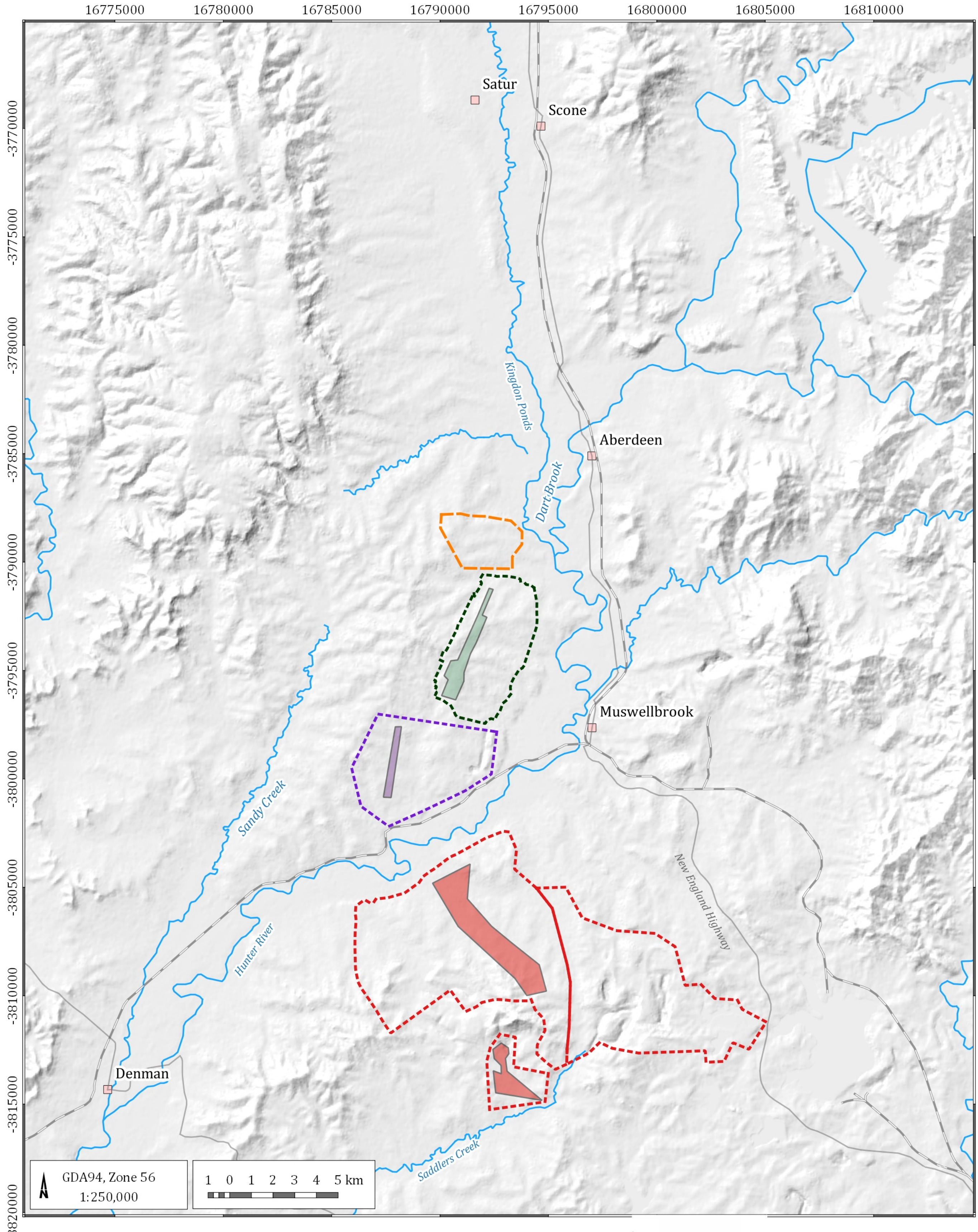
The recovery simulation was run for 1000 years, thus allowing the groundwater levels in the backfilled spoil, final void lake, unmined coal seams, and the overlying water-bearing strata to recover to a long term post mining equilibrium.

The general head boundary (GHB) package was used to simulate the pit water level in the MPO void with the reference general head value assigned to the target water level. Voids at the neighbouring mine sites (Bengalla and Mt Arthur) were simulated using the time variant constant head package (CHD).

Model cells representing backfilled spoil were assigned a higher horizontal (0.3 m/day) and vertical (0.1 m/day) conductivity than the bedrock units, and a porosity (specific yield) of 0.1. There are few reported measurements of hydraulic properties of backfilled mining spoil, therefore these parameters are estimated based on experience. Recharge rates to the spoil were also increased to 6% of average annual rainfall.

Despite the void lake being represented by the general head boundary condition, the model cells located within the final voids were also assigned a high Kh and Kv (1,000 m/day) and storage parameters (Sy of 1.0, Ss of 5.0×10^{-6} m^{-1}), to simulate free water movement within the void. This approach is often referred to as a 'high-k' lake. This allowed free movement of seepage into the upper parts of the void space to migrate down to the boundary condition (GHB) representing the pit lake.

Outputs from the recovery modelling are presented in Section 7.2 of the main report.



LEGEND

Road
- Minor Road
- Principal Road
- Secondary Road
- Track
- Rail

Drainage
- Major drainage
- Minor drainage
- Drainage

- Populated place
- Dartbrook Project Extent
- MPO Pit Extent
- MPO final void
- Bengalla Project Extent
- Bengalla final void
- Mt Arthur Project Extent
- Mt Arthur final voids

Mt Pleasant GIA (G1970A)

Simulated void footprint for MPO and neighbouring mines

AGE

DATE 20/11/2020

FIGURE No: **A 4.3**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\002_Deliverable2\03.05_G1970_Average residuals for shallow bores in layers 4 to 20.qgs

A5 Uncertainty analysis

Groundwater models represent complex environmental systems and processes in a simplified manner. This means that predictions from groundwater models, like so many other environmental models, are inherently uncertain. When considered in a risk management context, a single calibrated model is insufficient to fully predict the range of potential impacts and their likelihood. A robust uncertainty analysis is therefore important for regulatory decision-making to ensure management options and approaches are appropriate to the level of risk and its likelihood for any particular impact.

The sections below describe the methodology and results of the uncertainty analysis completed for the MPO Project numerical model.

A5.1 Methodology

A calibration constrained uncertainty analysis was undertaken to quantify the magnitude of uncertainty in the future impacts predicted by the model. This type of analysis produces probability distributions for predictive impacts by assessing a composite likelihood of an impact occurring through assessing and ranking the predictions from hundreds of models 'realisations'. Each model realisation is informed by the observation dataset by using the relationship between the observations statistics to perturbations of each parameter in the groundwater model.

This uncertainty analysis was essentially a three-part process. Firstly, the valid range for the parameters (i.e. pre-calibration range) was determined, and then 300 model realisations were created, each having differing values of key parameters. Realisations were then constrained using calibration datasets.

The constrained realisations were tested and the models that failed to converge or could not achieve adequate calibration were rejected, leaving only the output from 201 successful models. Models were considered to have an acceptable calibration of SRMS (heads) ≤10%. This output was analysed to provide a statistical distribution of the predictive impacts.

Outputs from the uncertainty modelling were processed in accordance with the risk-based calibrated language proposed in Middlemis & Peeters (2018). The ranges adopted are shown in Table A 5.1.

It is important to note that the ranges include outputs from all model runs that are deemed to be within an acceptable calibration. There may be one outlier model run within the dataset that produces the extremities of the ranges on the charts.

Table A 5.1 Calibrated uncertainty modelling language

Narrative descriptor	Probability class	Description	Colour code
Very likely	90 – 100 %	Likely to occur even in extreme conditions	
Likely	67 – 90 %	Expected to occur in normal conditions	
About as likely as not	33 – 67 %	About an equal chance of occurring as not	
Unlikely	10 – 33 %	Not expected to occur in normal conditions	
Very unlikely	0 – 10 %	Not likely to occur even in extreme conditions	

A6 Climate sensitivity analysis

In addition to the uncertainty analysis, the predictions have also looked at the potential impacts from long-term climate change. The potential change to rainfall volume and distribution resulting from climate change will have impacts on recharge rates to the groundwater system.

A climate change scenario was selected upon the basis of representing a situation where the natural contribution to groundwater is negatively impacted. This entailed running a simulation with a 20% reduction in rainfall recharge and an 8% increase in the evapotranspiration rate as compared to the base case of the MPO model. The changes were applied in the model from the beginning of mining at MPO. The two climate models that are the source of the adopted extremes of recharge (-20% - GFDL-ESM2M) and evaporation (+8% - ACCESS1-0) are documented in Whetton et. al. (2012).

Impacts to the groundwater system considering a long-term drier climate were shown to be minimal to MPO and the surrounding environment. Peak total inflows to the MPO pit only decrease by 19 ML/yr to 284 ML/yr, and a <5% reduction is evident for peak indirect take from the Hunter River, Sandy Creek and Dart Brook alluvium systems. A comparison of the base case and climate change predicted maximum drawdown on the alluvium (and regolith) and the deeper Edderton Seam is barely perceptible.

A7 References

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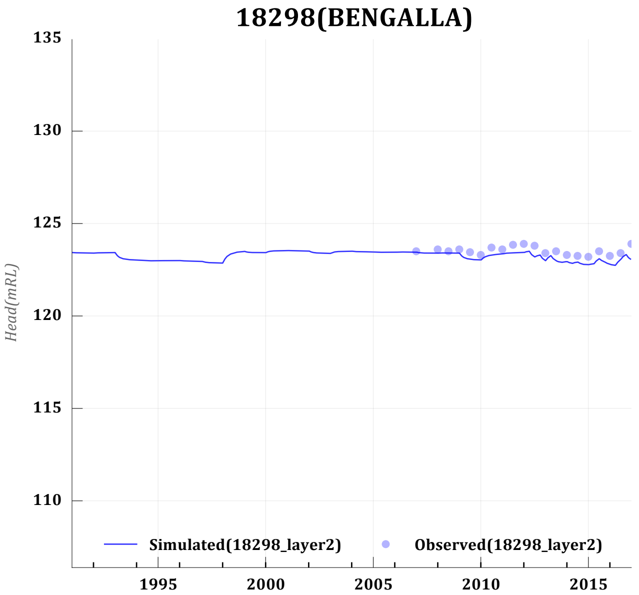
Whetton P, Hennessy K, Clarke J, McInnes K, Kent D, 2012, *'Use of Representative Climate Futures in impact and adaptation assessment.'* Climatic Change 115, 433-442. 10.1007/s10584-012-0471-z.

Appendix A 1 Calibration details and hydrographs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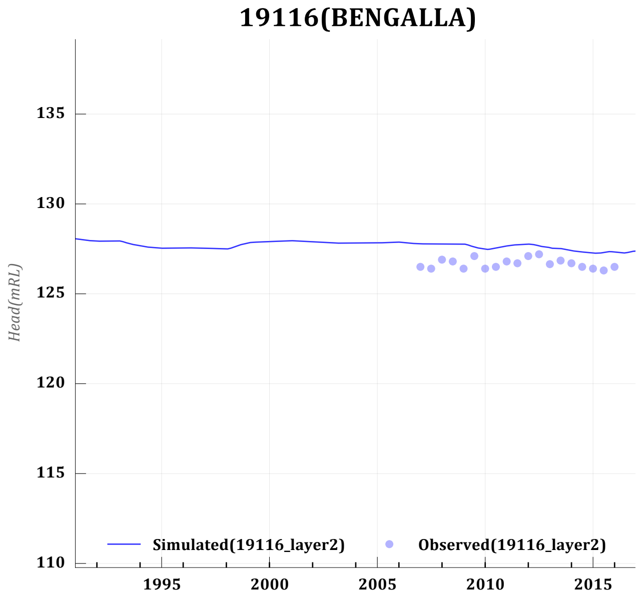
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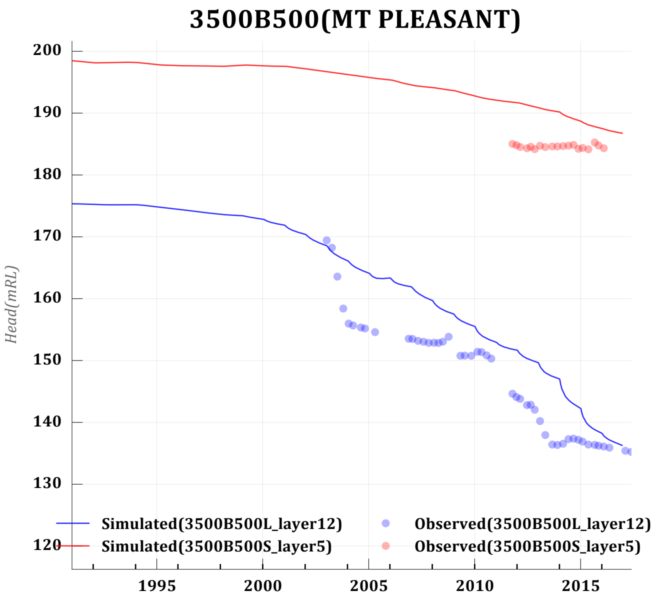
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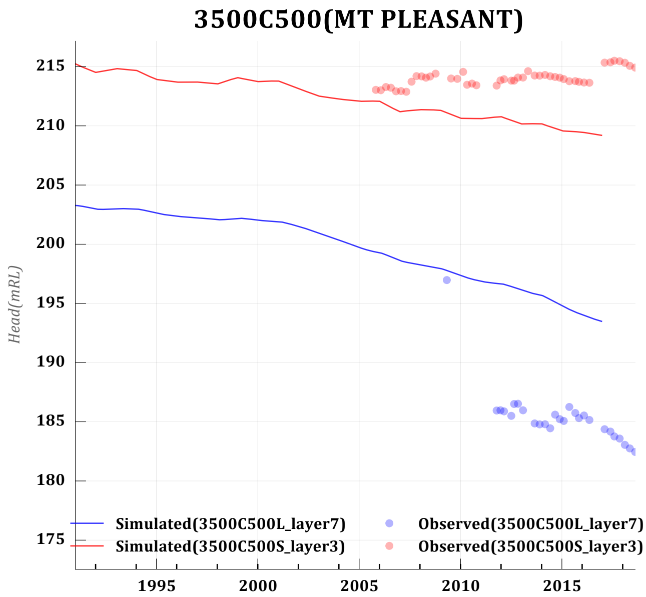
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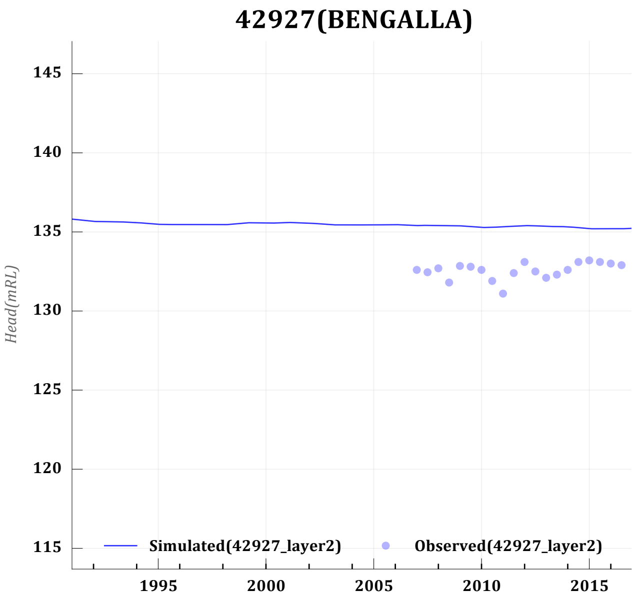
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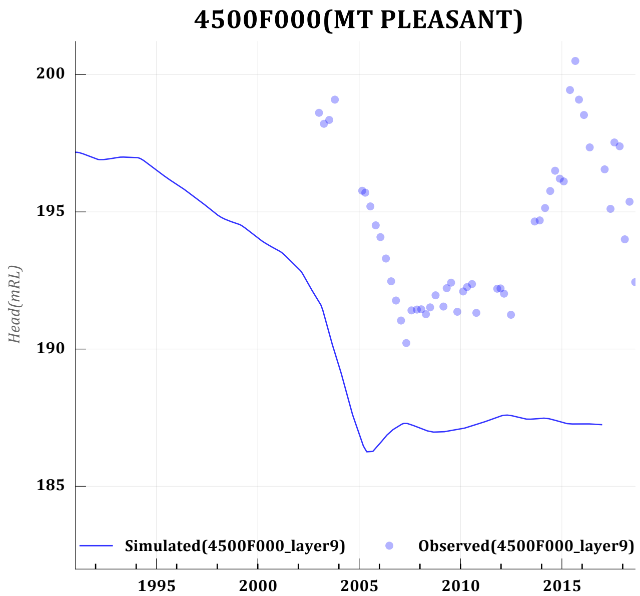
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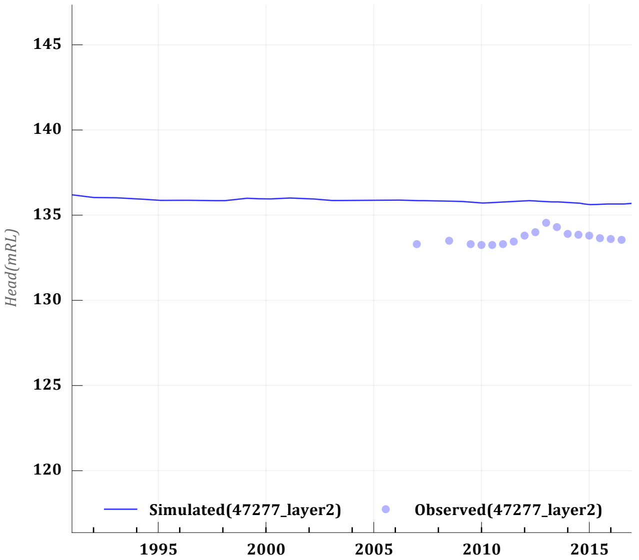

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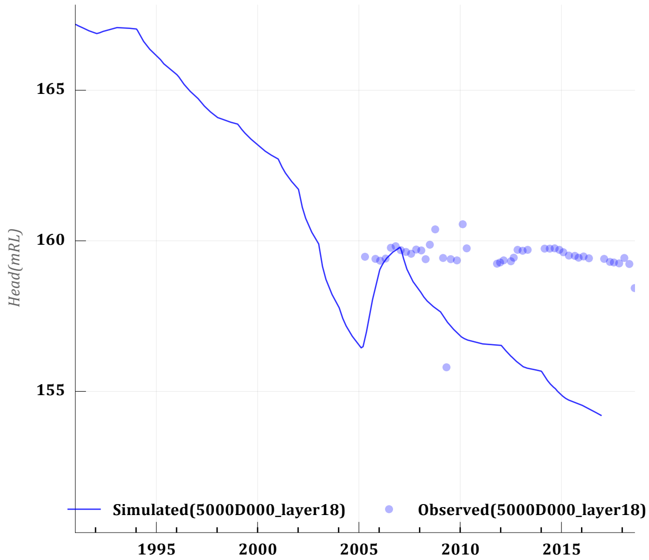

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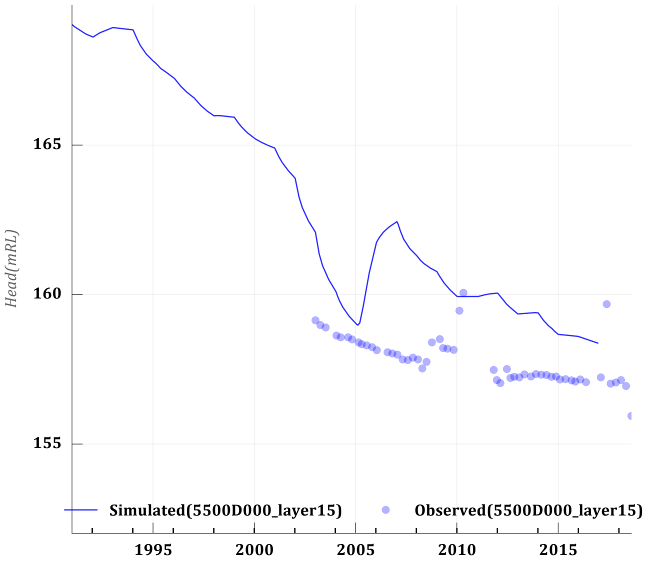

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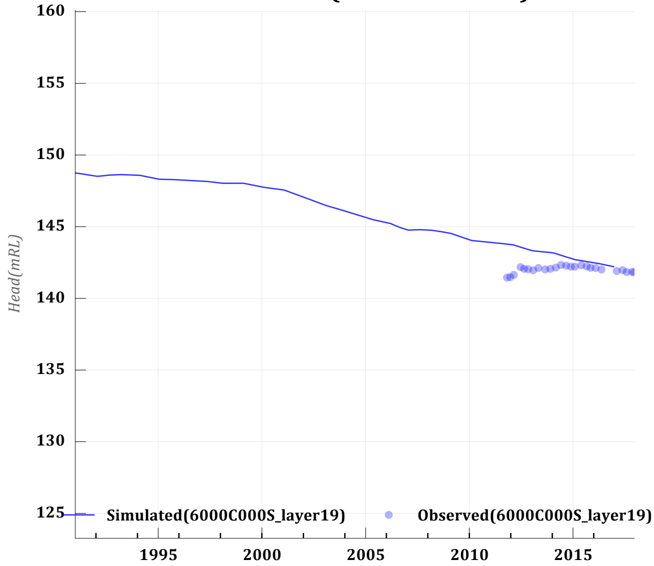

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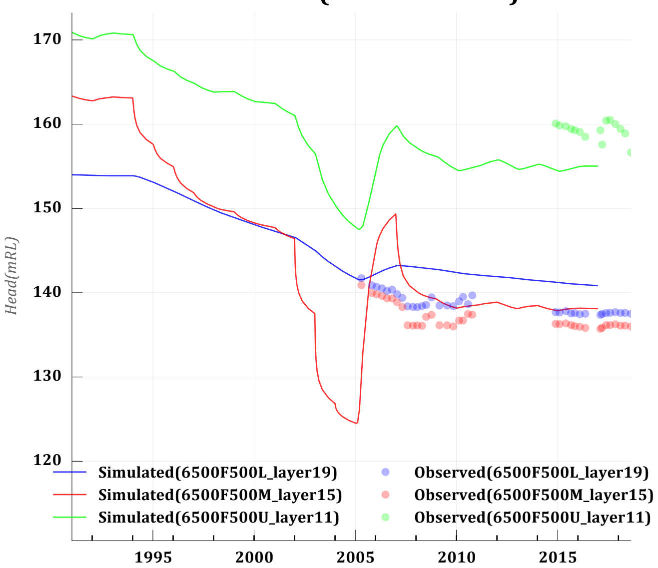

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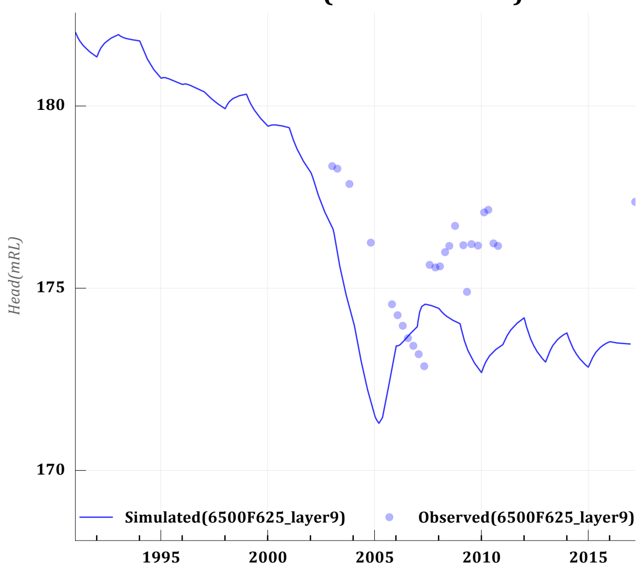

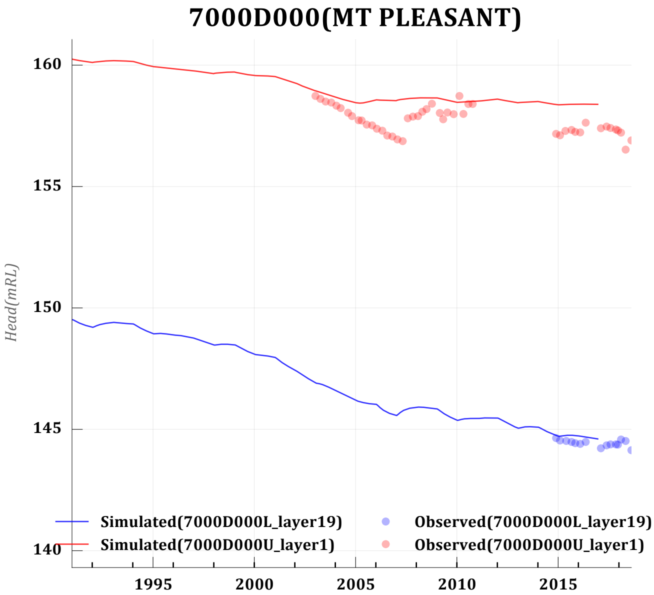
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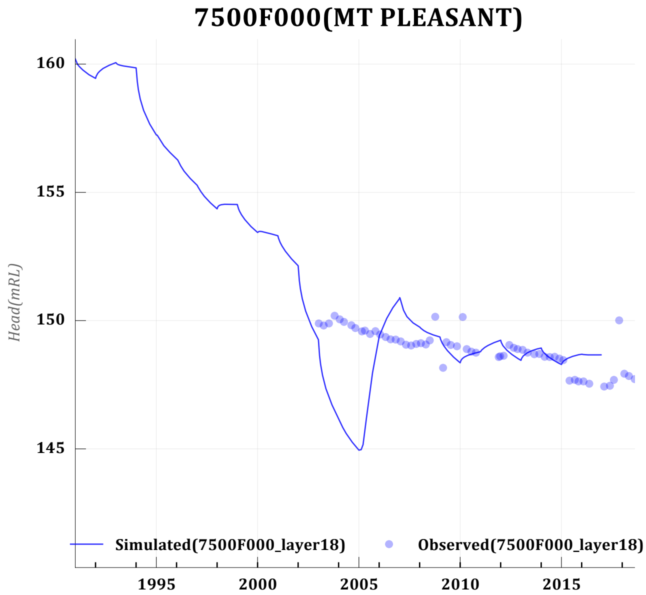
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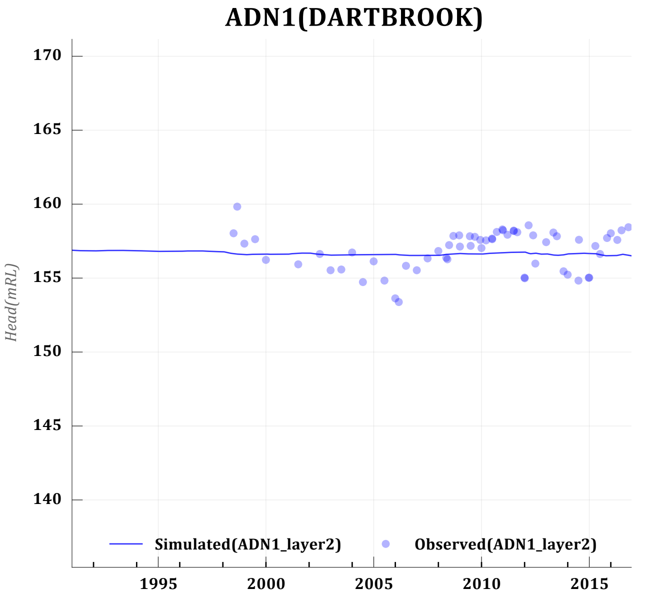
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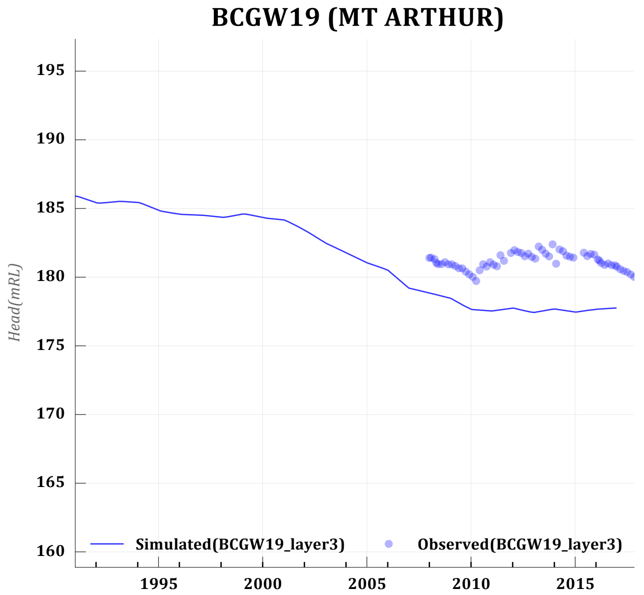
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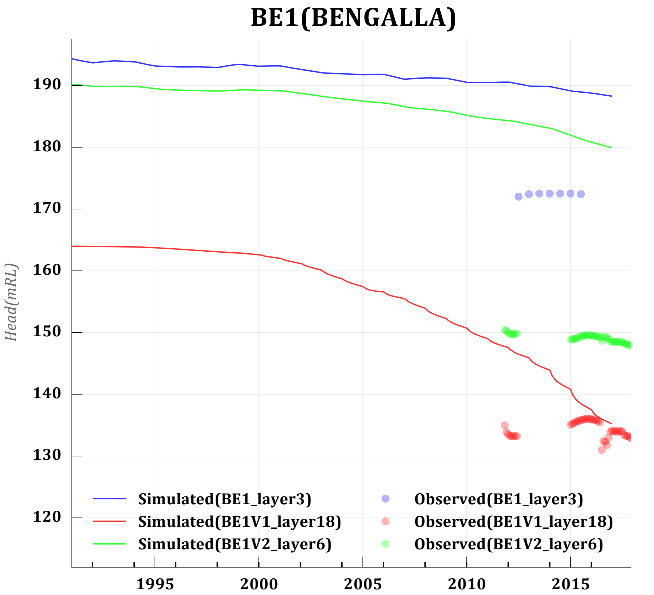
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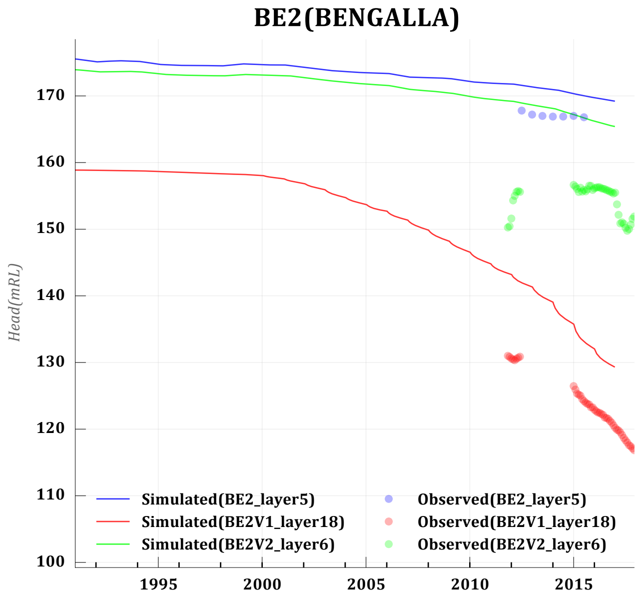
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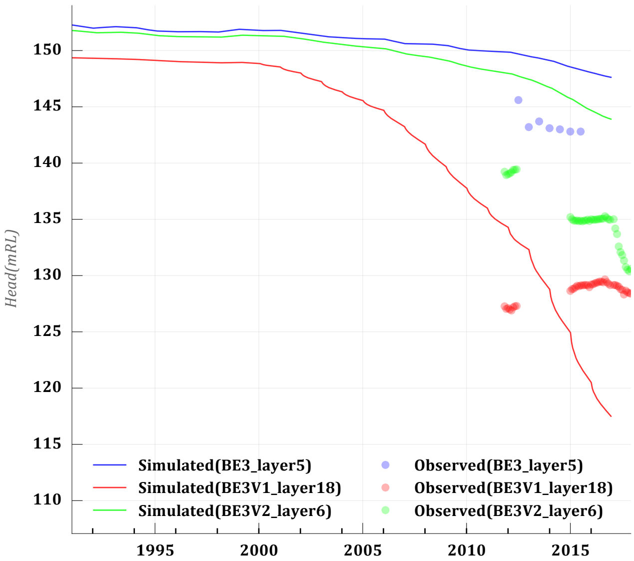

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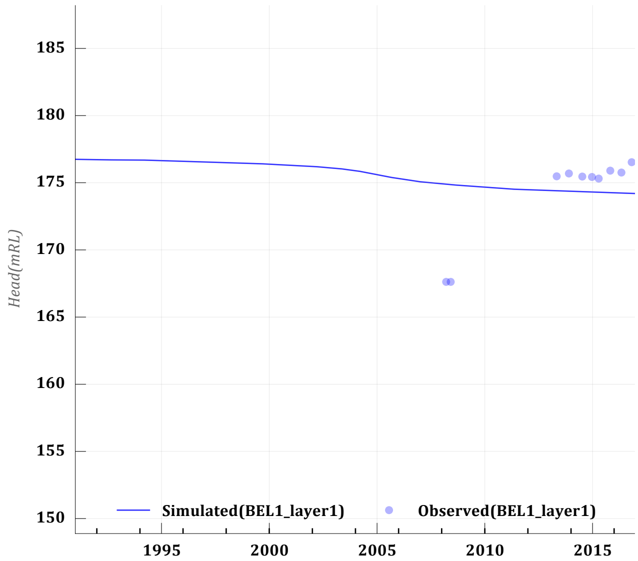

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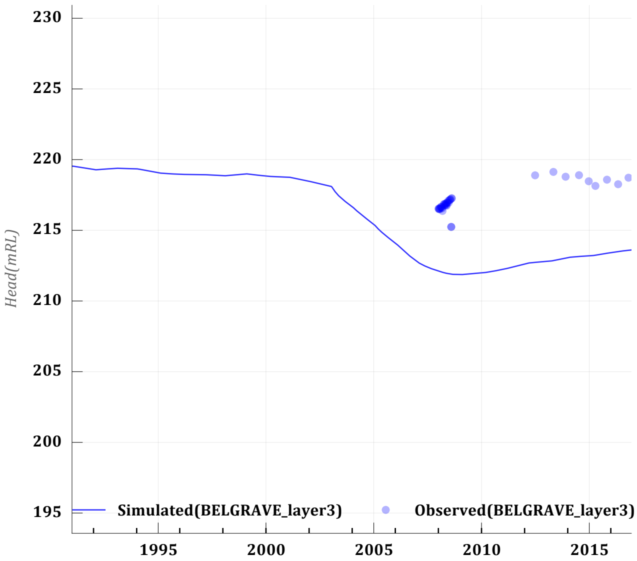

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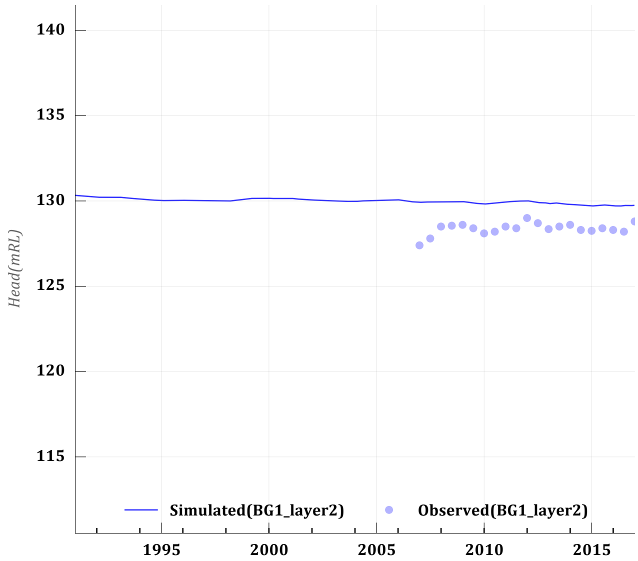

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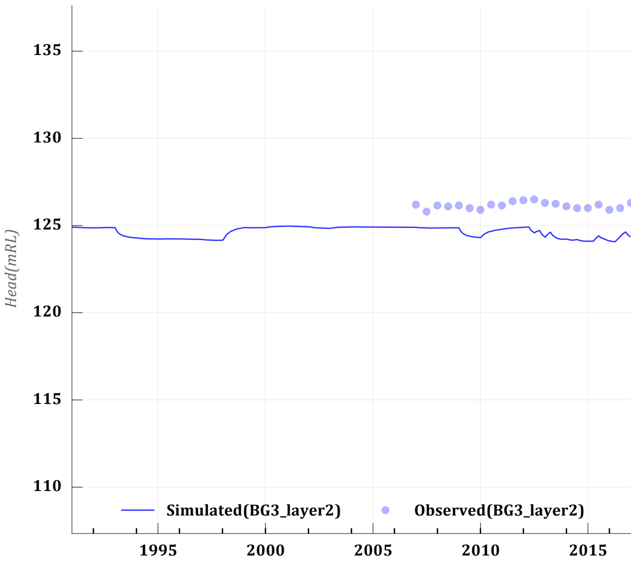

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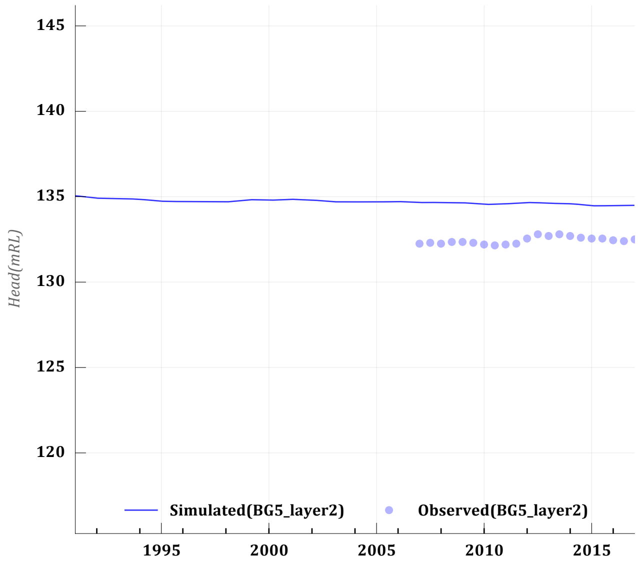
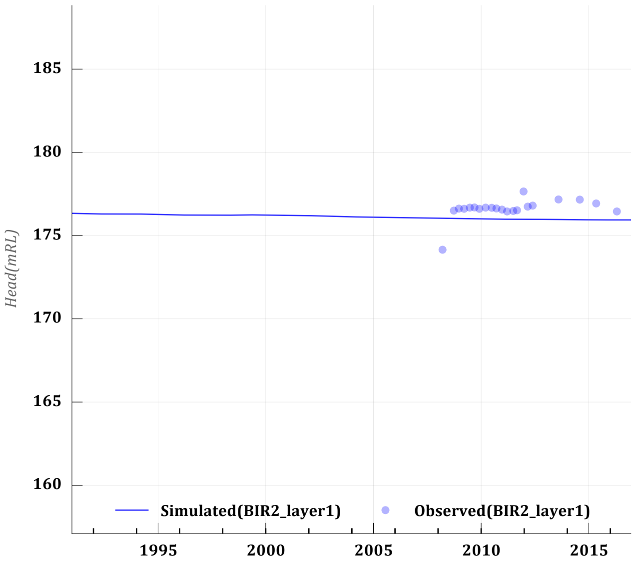
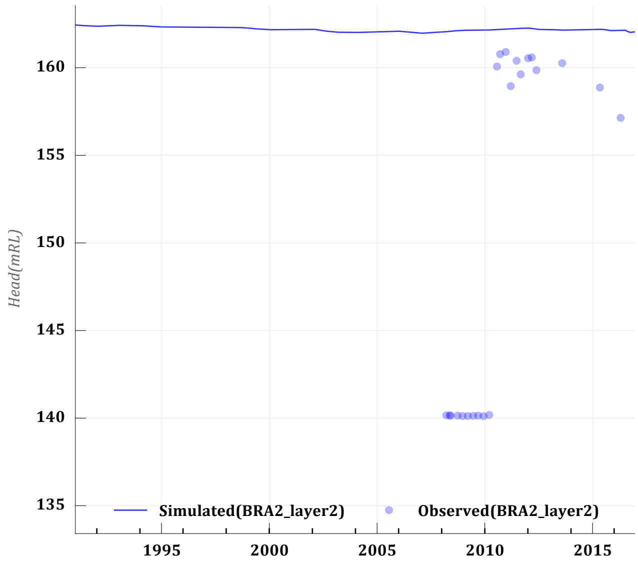


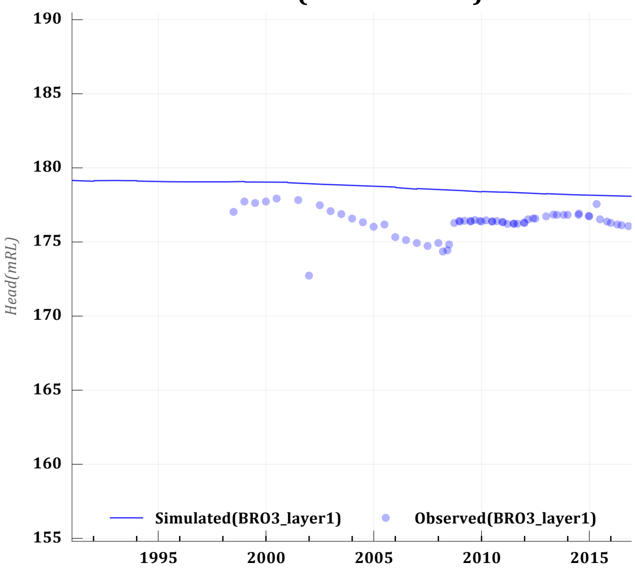
BIR2(DARTBROOK)



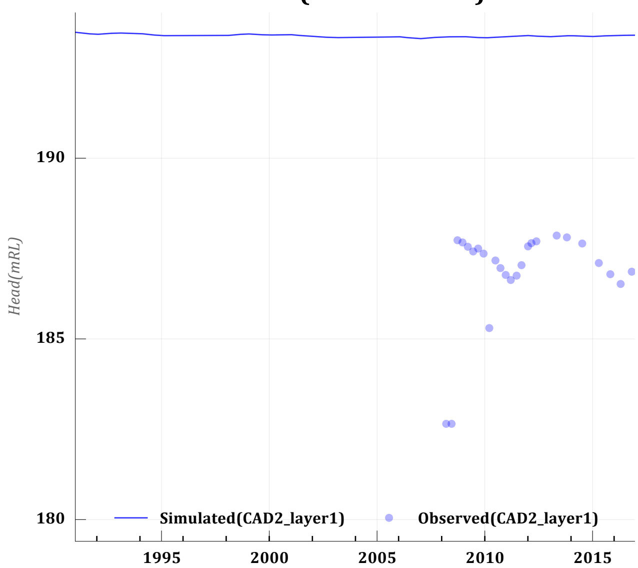
BRA2(DARTBROOK)



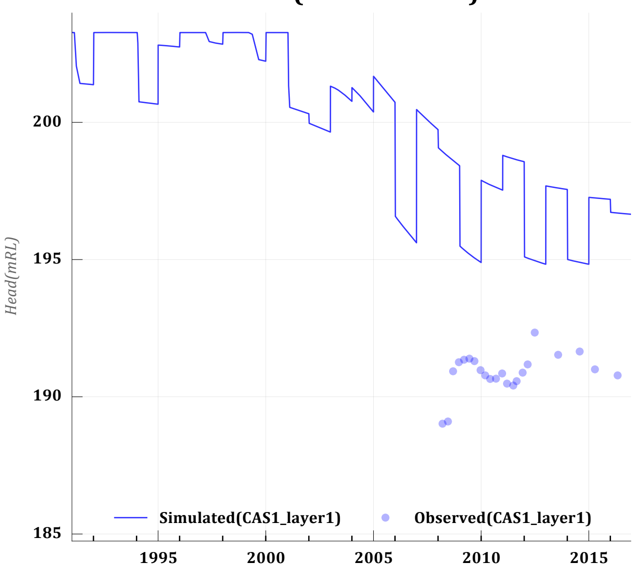
BRO3(DARTBROOK)



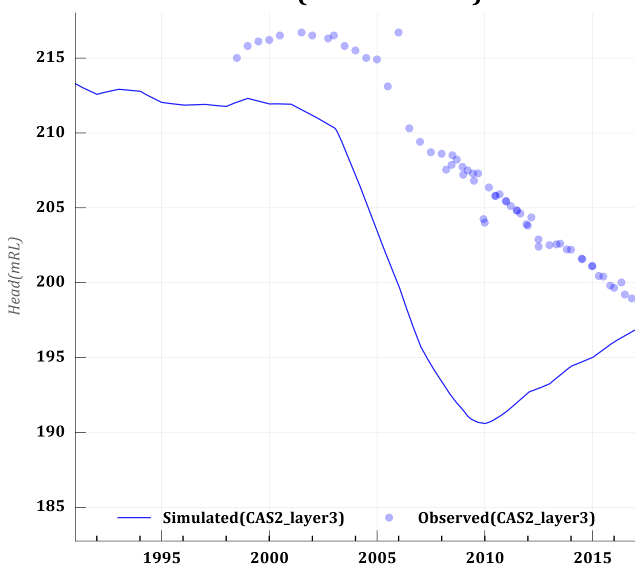
CAD2(DARTBROOK)



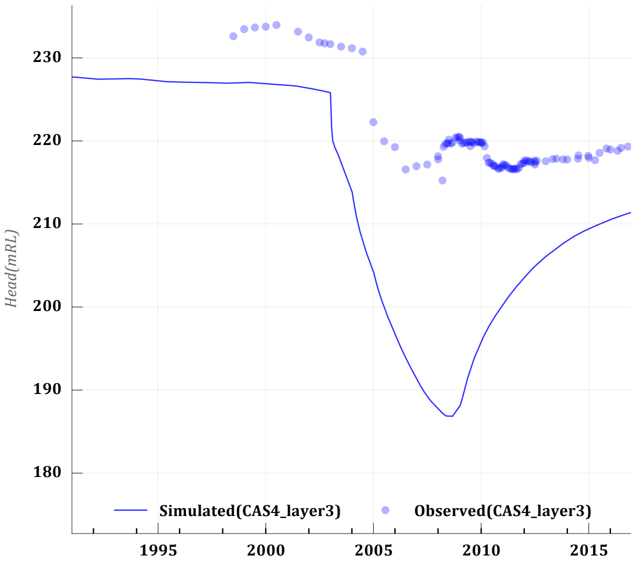
CAS1(DARTBROOK)



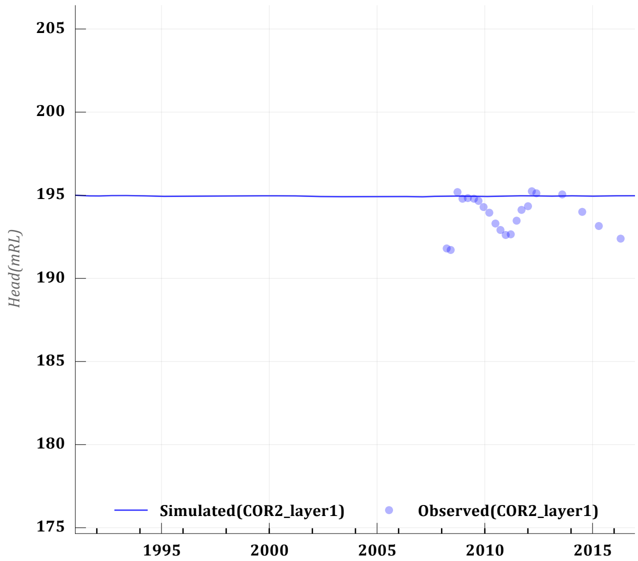
CAS2(DARTBROOK)



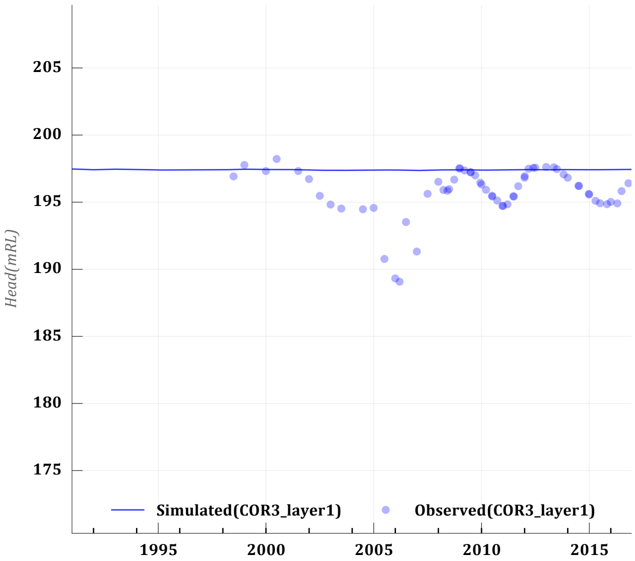
CAS4(DARTBROOK)



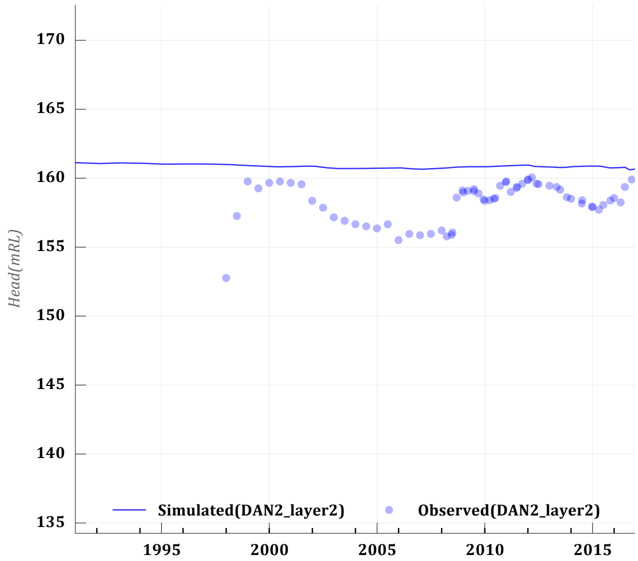
COR2(DARTBROOK)



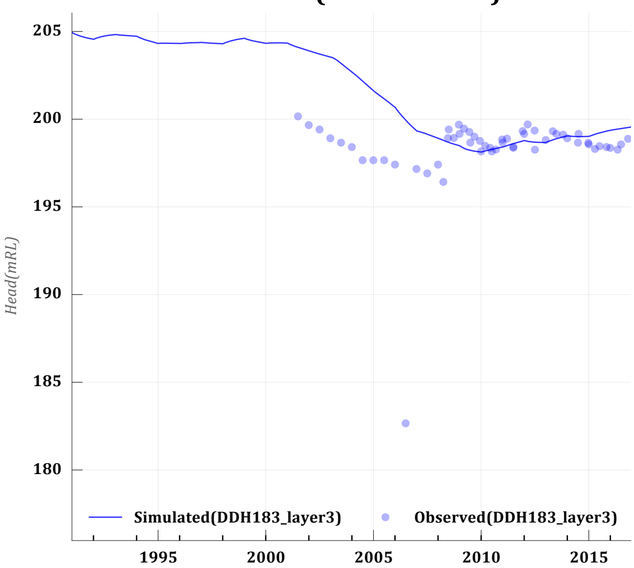
COR3(DARTBROOK)



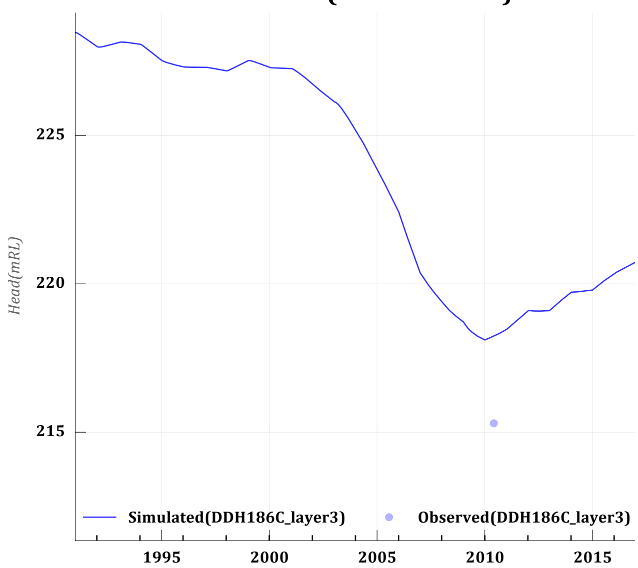
DAN2(DARTBROOK)



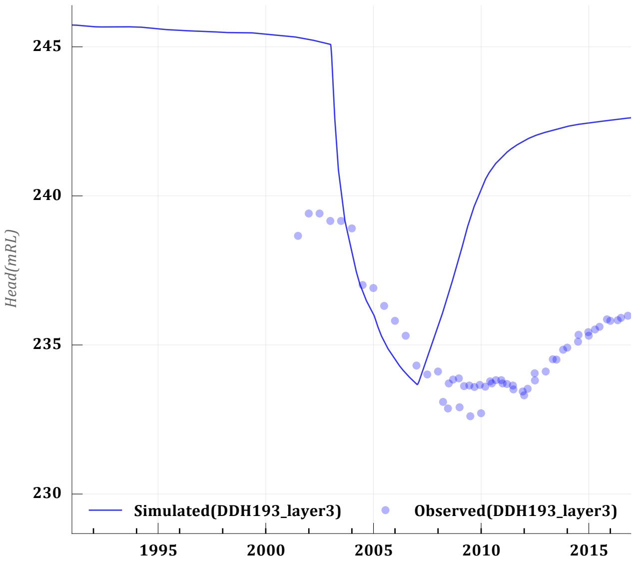
DDH183(DARTBROOK)



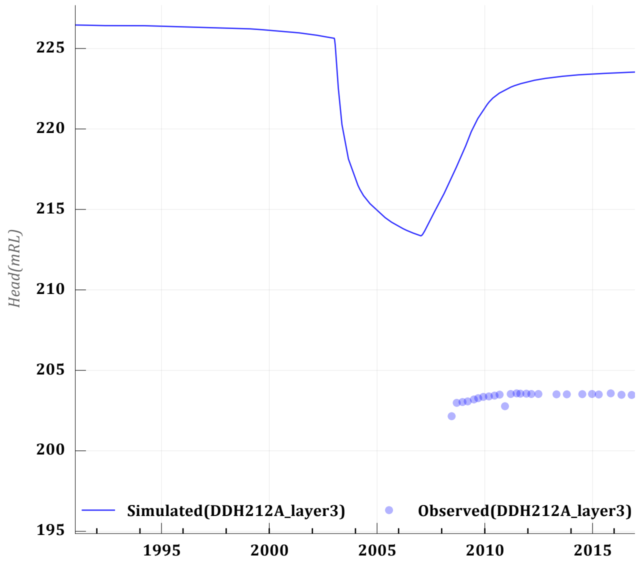
DDH186C(DARTBROOK)



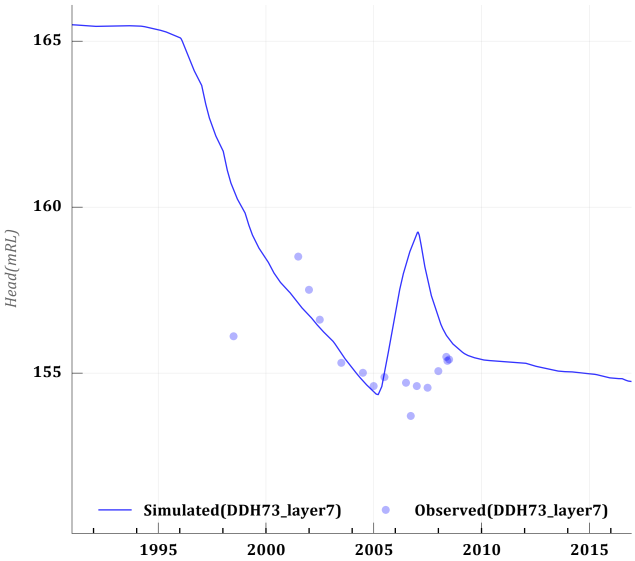
DDH193(DARTBROOK)



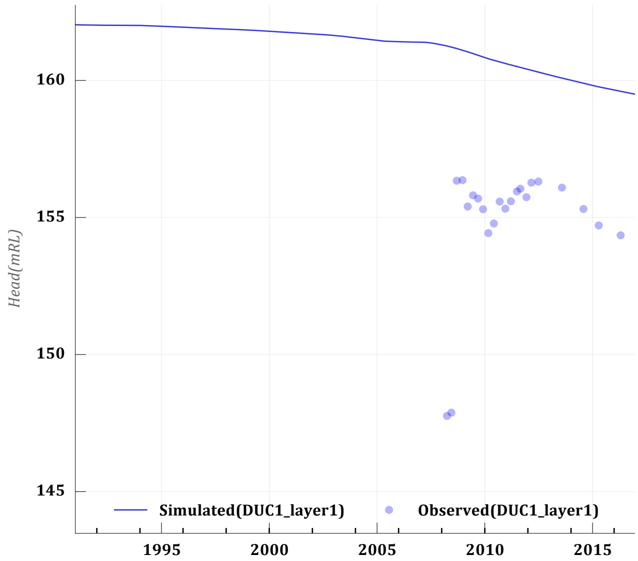
DDH212A(DARTBROOK)



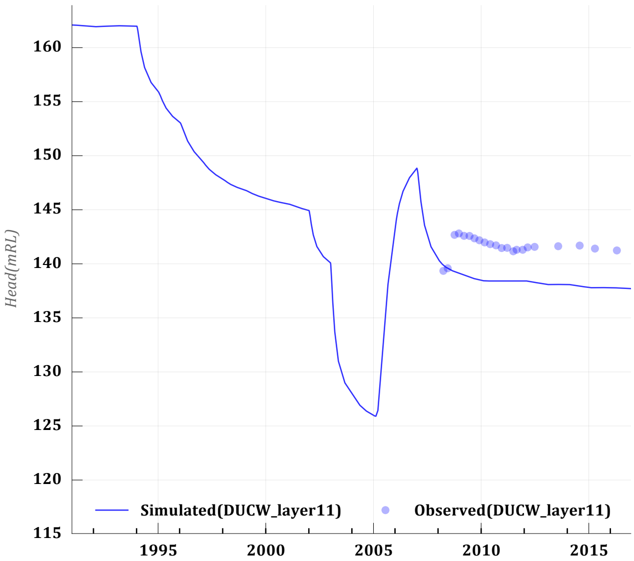
DDH73(DARTBROOK)



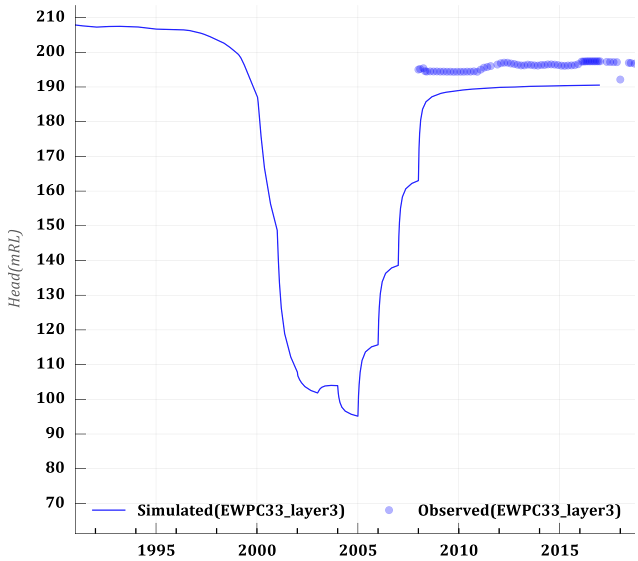
DUC1(DARTBROOK)

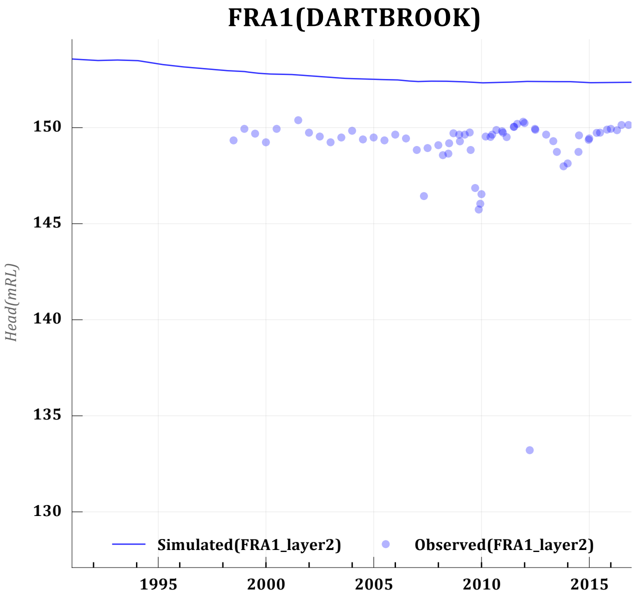


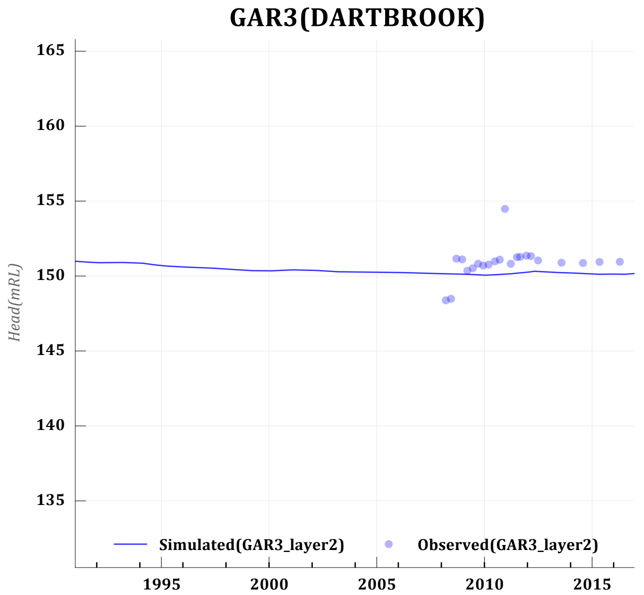
DUCW(DARTBROOK)

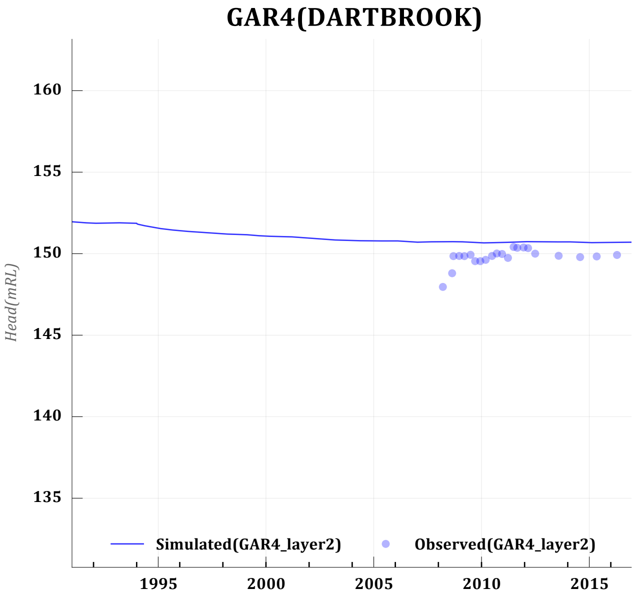


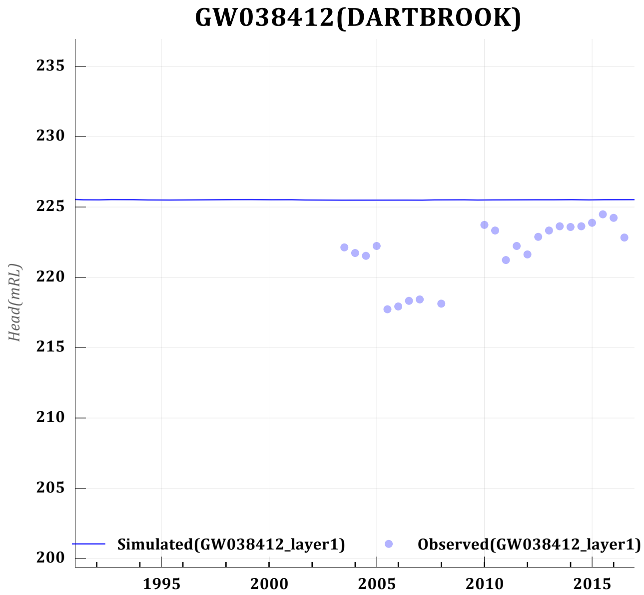
EWPC33 (MT ARTHUR)

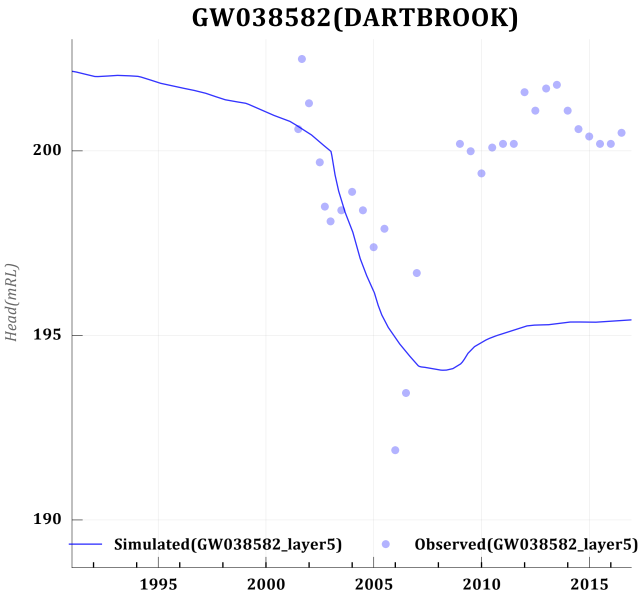


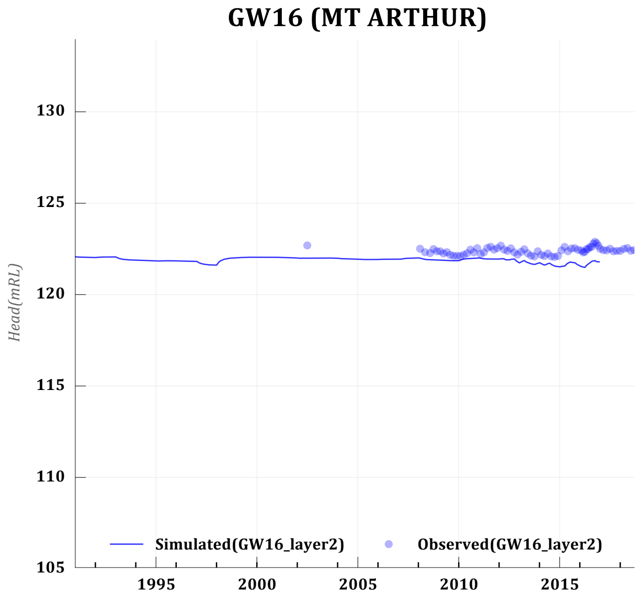

FRA1(DARTBROOK)
Head(mRL)
150
145
140
135
130
1995
2000
2005
2010
2015
Simulated(FRA1_layer2)
Observed(FRA1_layer2)

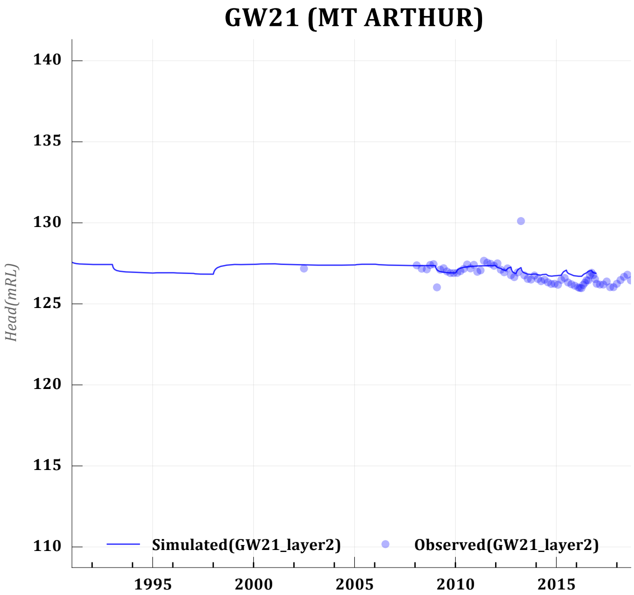

GAR3(DARTBROOK)
Head(mRL)
165
160
155
150
145
140
135
1995
2000
2005
2010
2015
Simulated(GAR3_layer2)
Observed(GAR3_layer2)

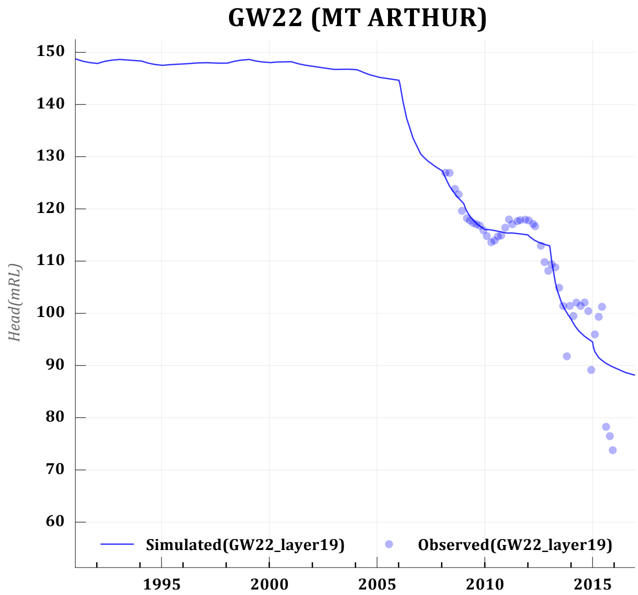

GAR4(DARTBROOK)
Head(mRL)
160
155
150
145
140
135
1995
2000
2005
2010
2015
Simulated(GAR4_layer2)
Observed(GAR4_layer2)

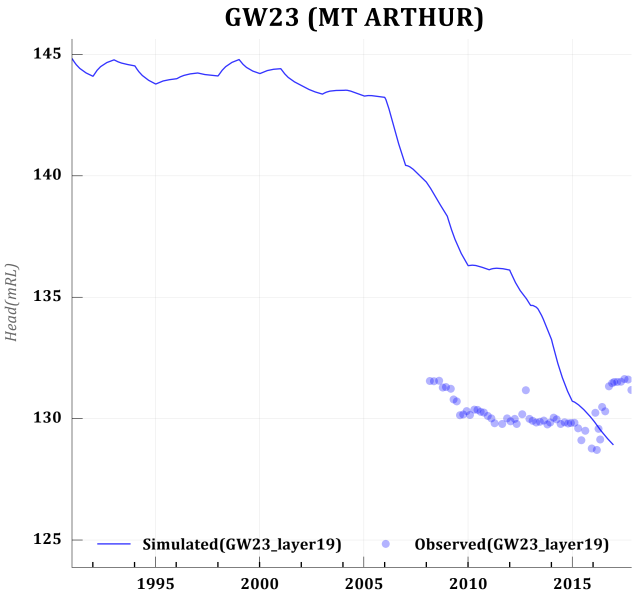

GW038412(DARTBROOK)
Head(mRL)
235
230
225
220
215
210
205
200
1995
2000
2005
2010
2015
Simulated(GW038412_layer1)
Observed(GW038412_layer1)

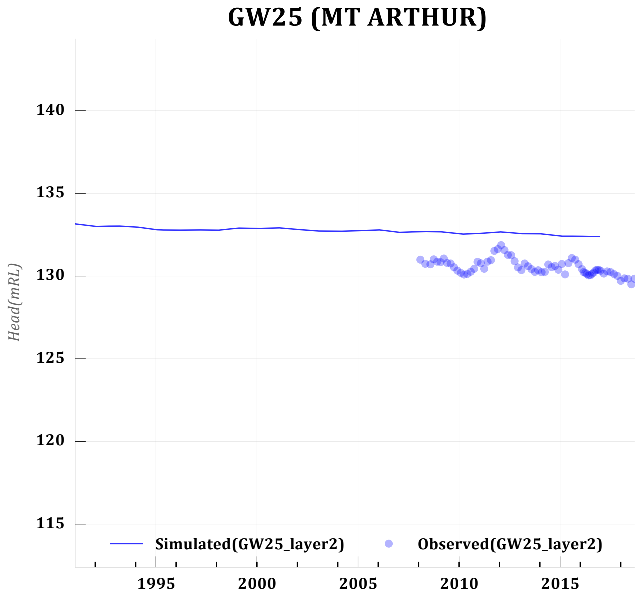

GW038582(DARTBROOK)
Head(mRL)
200
195
190
1995
2000
2005
2010
2015
Simulated(GW038582_layer5)
Observed(GW038582_layer5)

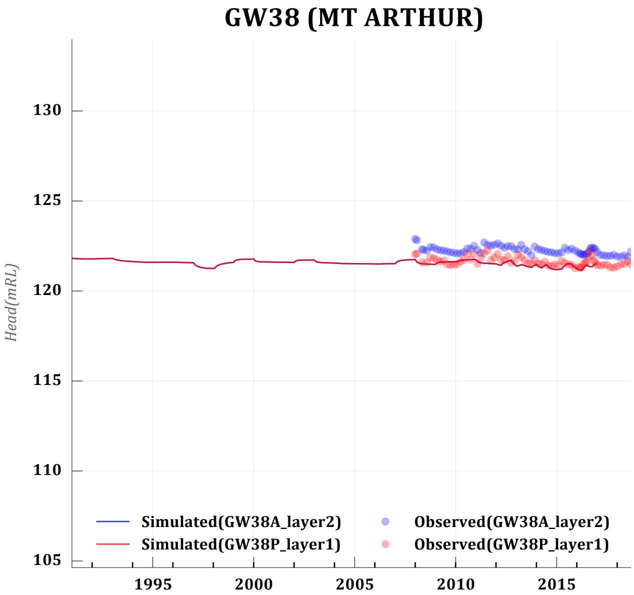

GW16 (MT ARTHUR)
Head(mRL)
130
125
120
115
110
105
1995
2000
2005
2010
2015
Simulated(GW16_layer2)
Observed(GW16_layer2)

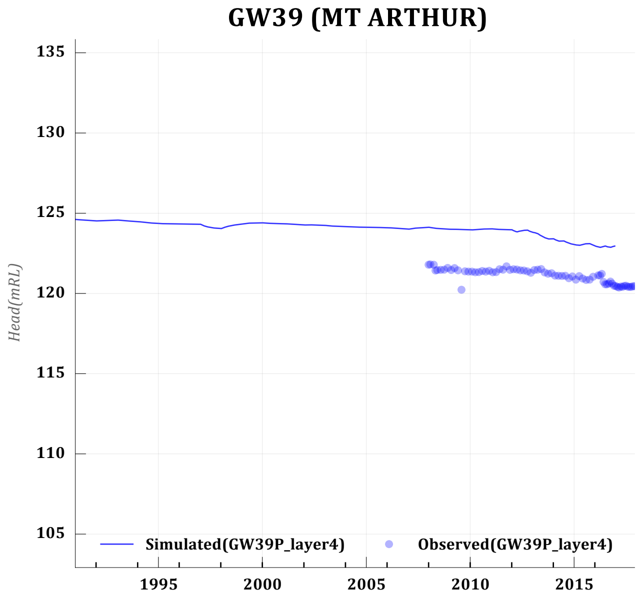

GW21 (MT ARTHUR)
Head(mRL)
Simulated(GW21_layer2)
Observed(GW21_layer2)


GW22 (MT ARTHUR)
Head(mRL)
Simulated(GW22_layer19)
Observed(GW22_layer19)

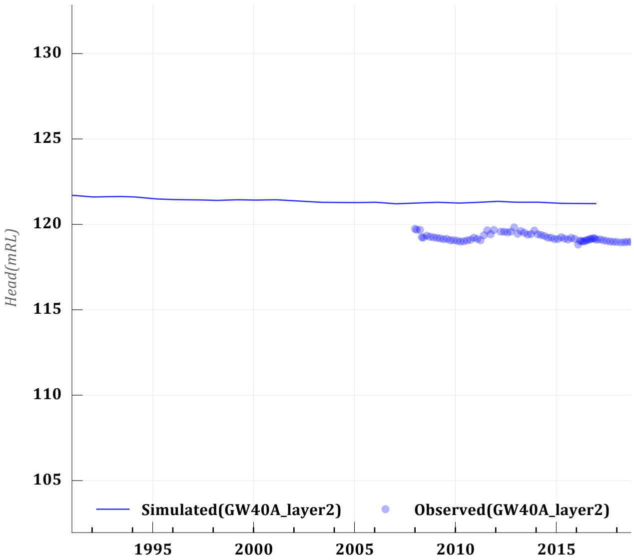

GW23 (MT ARTHUR)
Head(mRL)
Simulated(GW23_layer19)
Observed(GW23_layer19)


GW25 (MT ARTHUR)
Head(mRL)
Simulated(GW25_layer2)
Observed(GW25_layer2)

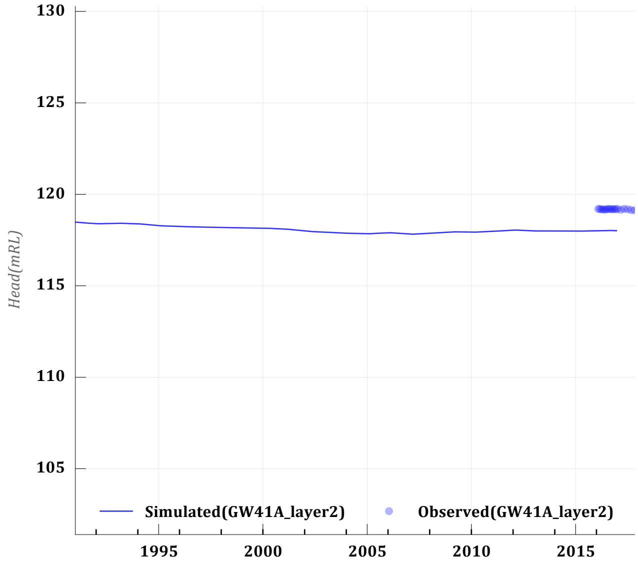

GW38 (MT ARTHUR)
Head(mRL)
Simulated(GW38A_layer2)
Simulated(GW38P_layer1)
Observed(GW38A_layer2)
Observed(GW38P_layer1)


GW39 (MT ARTHUR)
Head(mRL)
Simulated(GW39P_layer4)
Observed(GW39P_layer4)

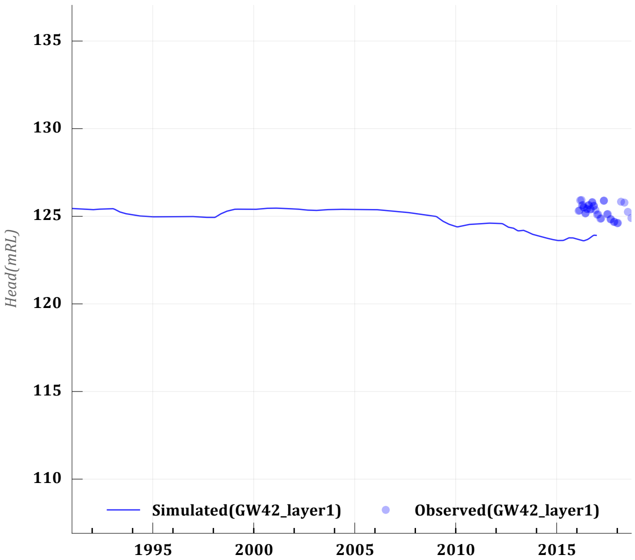
GW40A (MT ARTHUR)



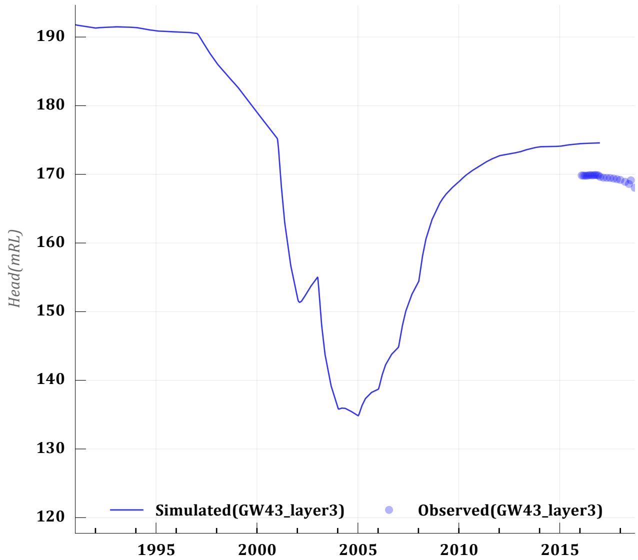
GW41A (MT ARTHUR)



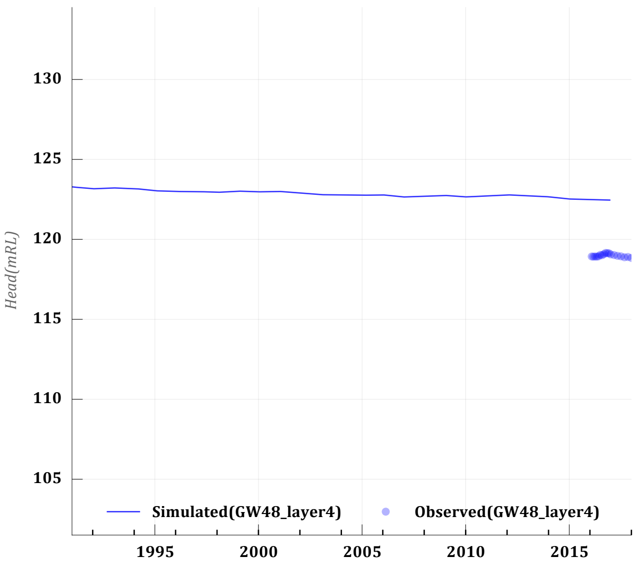
GW42 (MT ARTHUR)



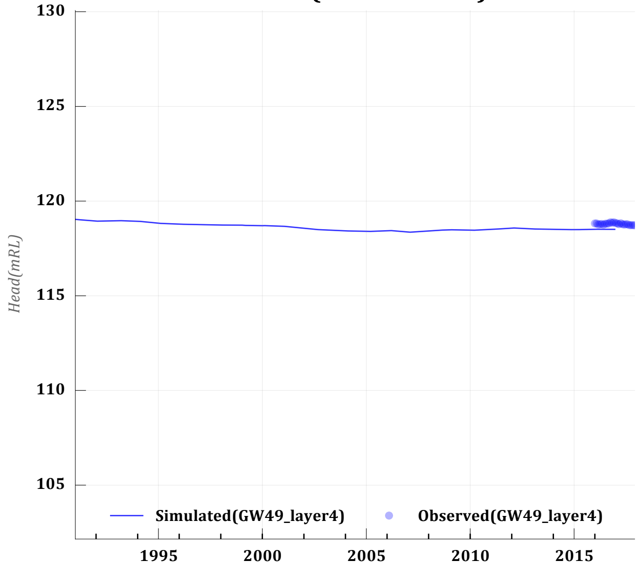
GW43 (MT ARTHUR)



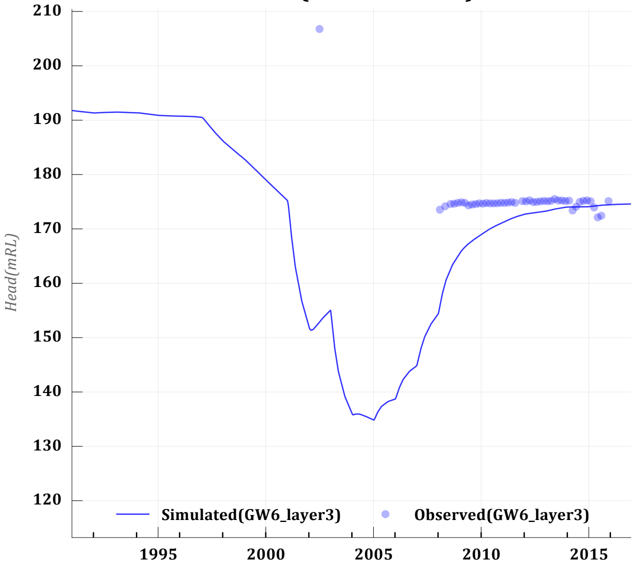
GW48 (MT ARTHUR)



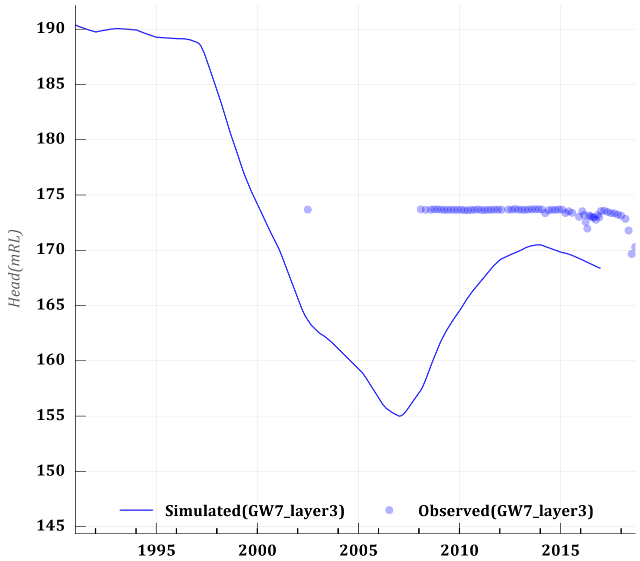
GW49 (MT ARTHUR)



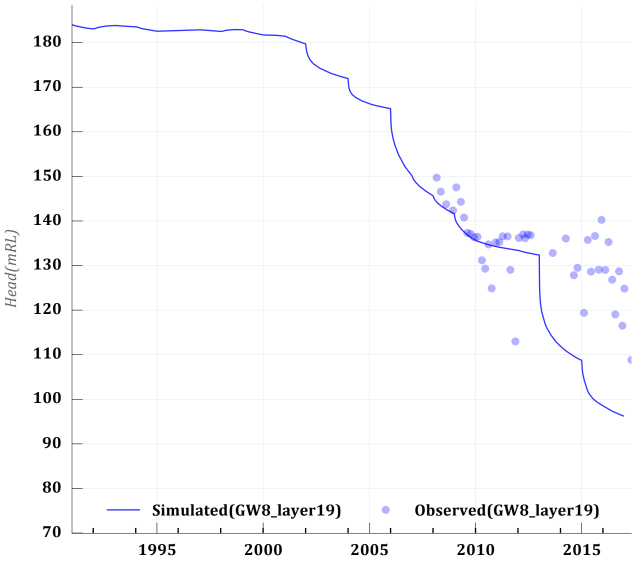
GW6 (MT ARTHUR)



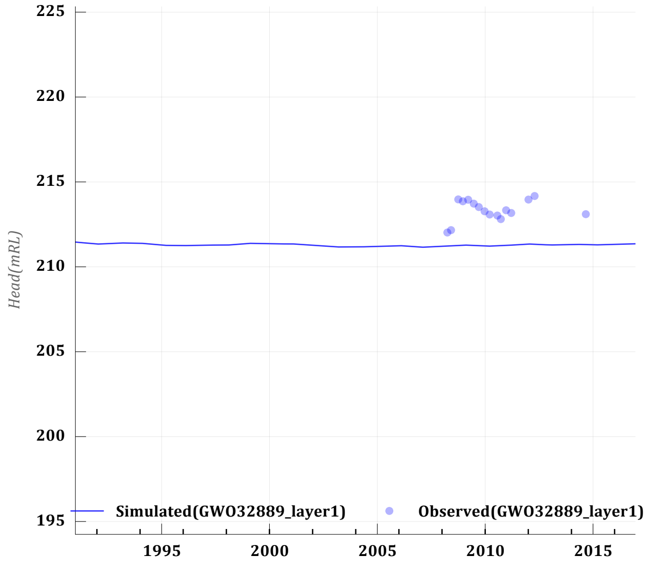
GW7 (MT ARTHUR)



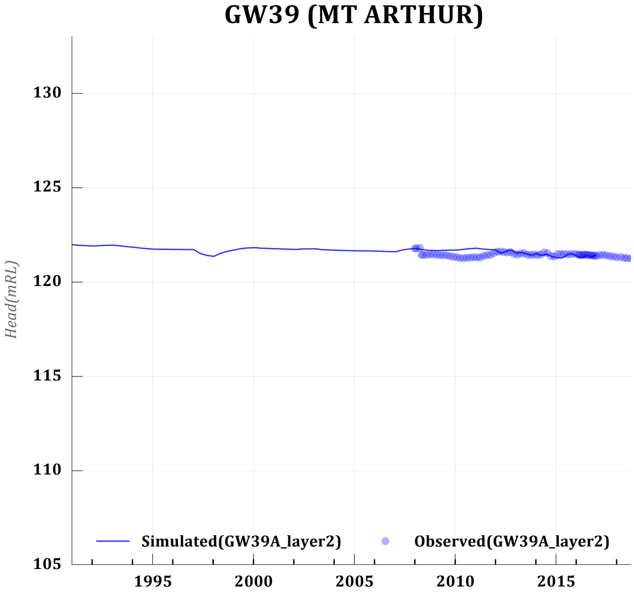
GW8 (MT ARTHUR)



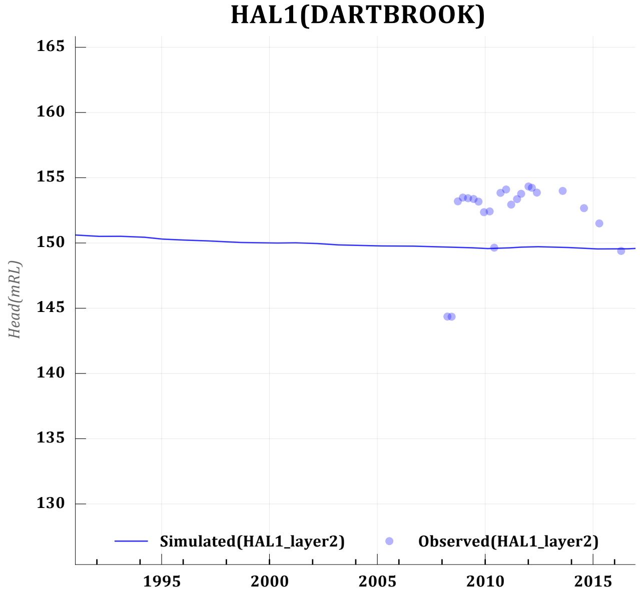
GW032889(DARTBROOK)

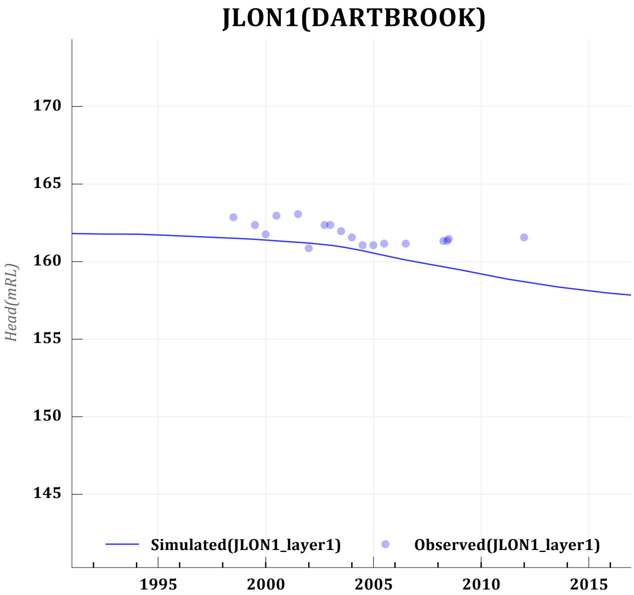


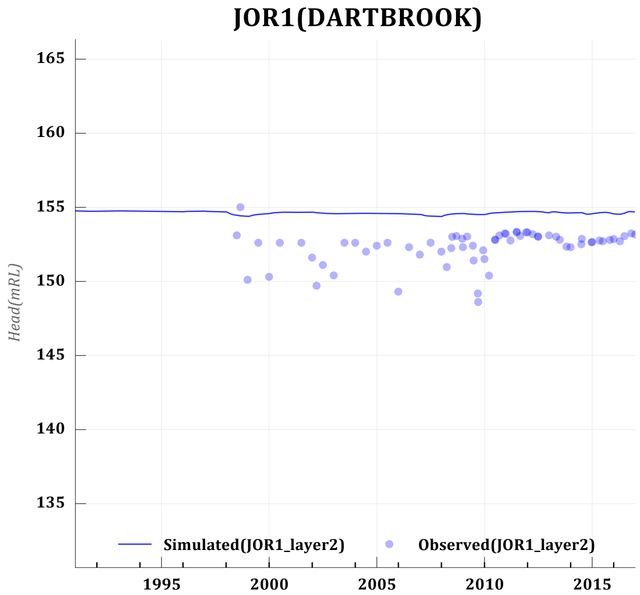
GW39 (MT ARTHUR)

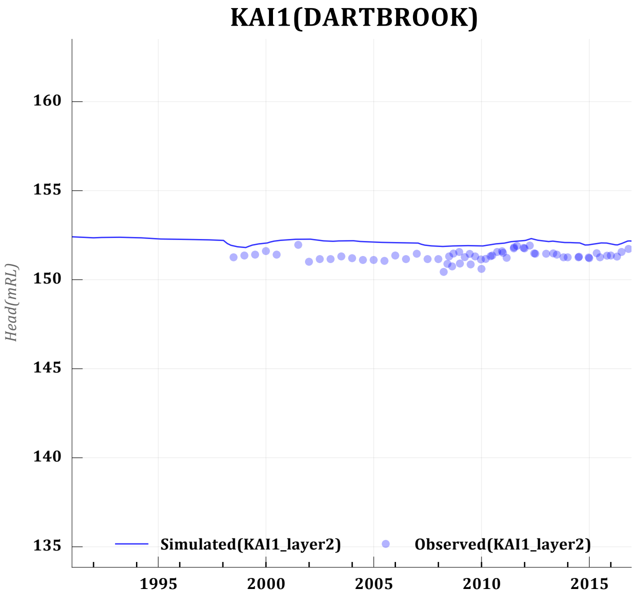


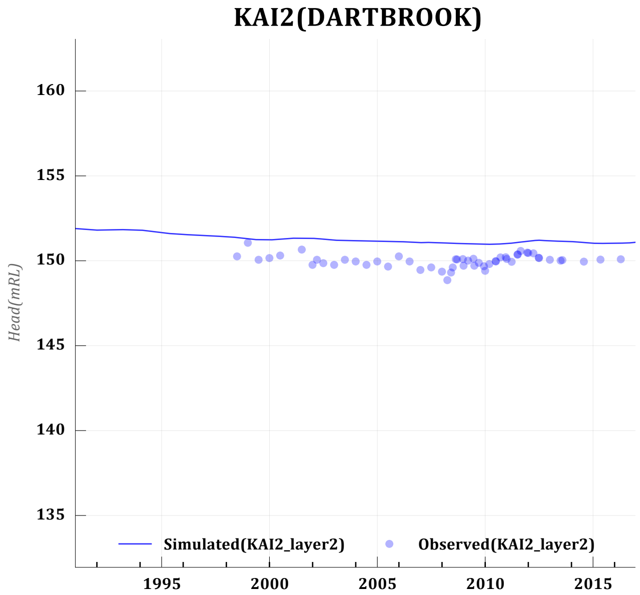
HAL1(DARTBROOK)

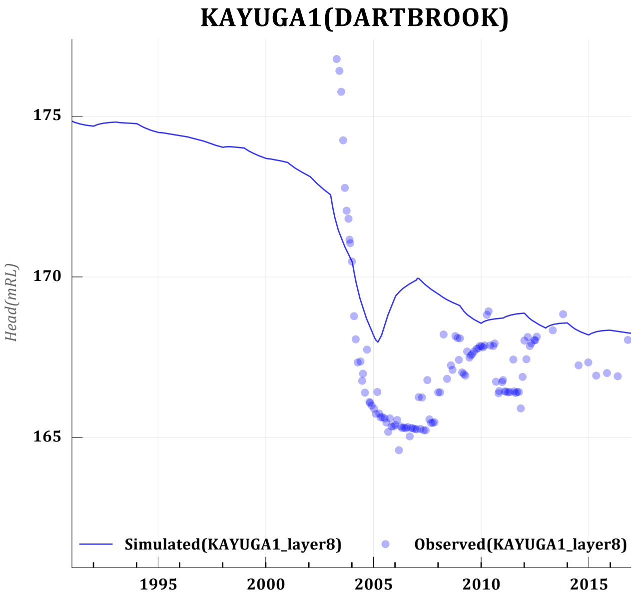


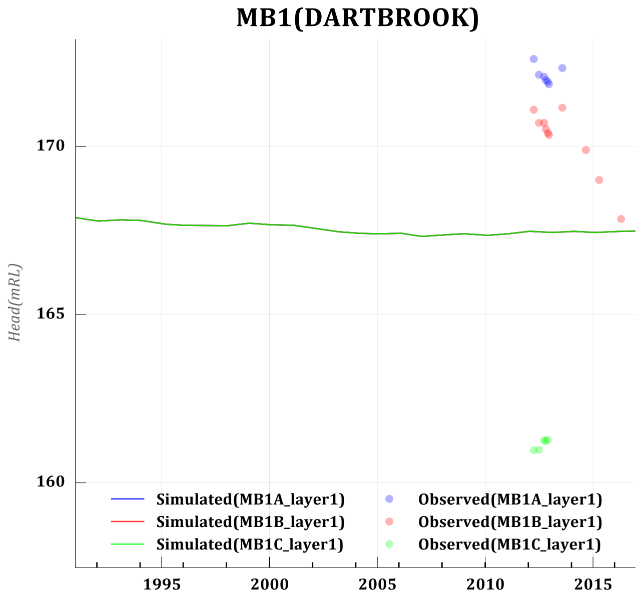

JLON1(DARTBROOK)
Head(mRL)
Simulated(JLON1_layer1)
Observed(JLON1_layer1)

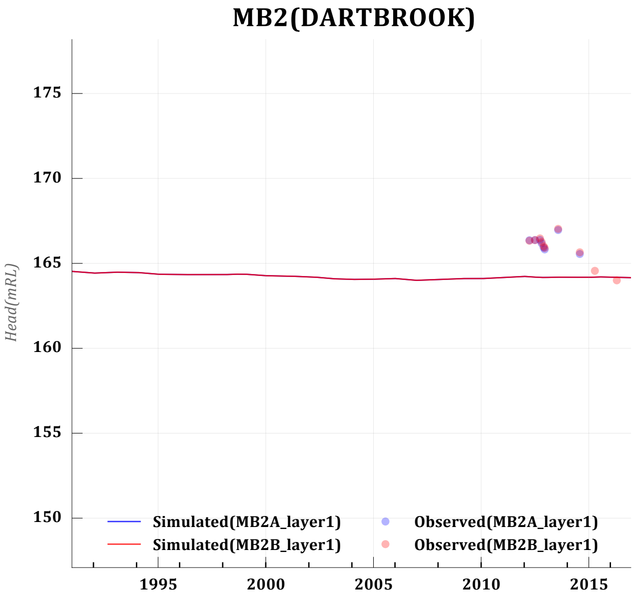

JOR1(DARTBROOK)
Head(mRL)
Simulated(JOR1_layer2)
Observed(JOR1_layer2)

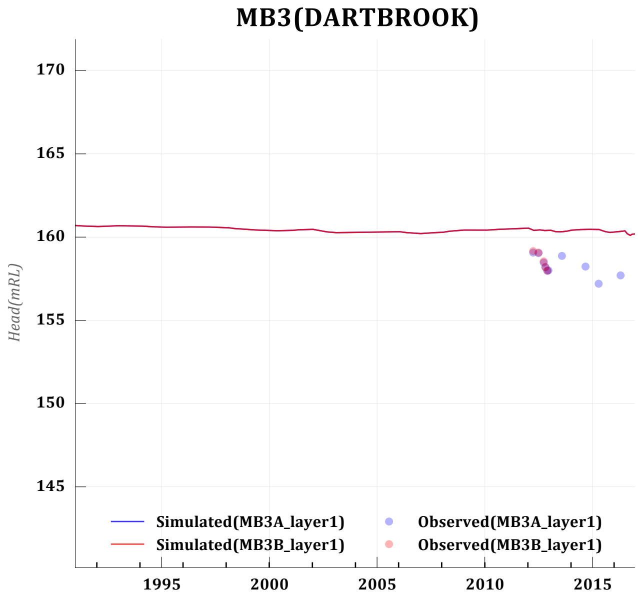

KAI1(DARTBROOK)
Head(mRL)
Simulated(KAI1_layer2)
Observed(KAI1_layer2)

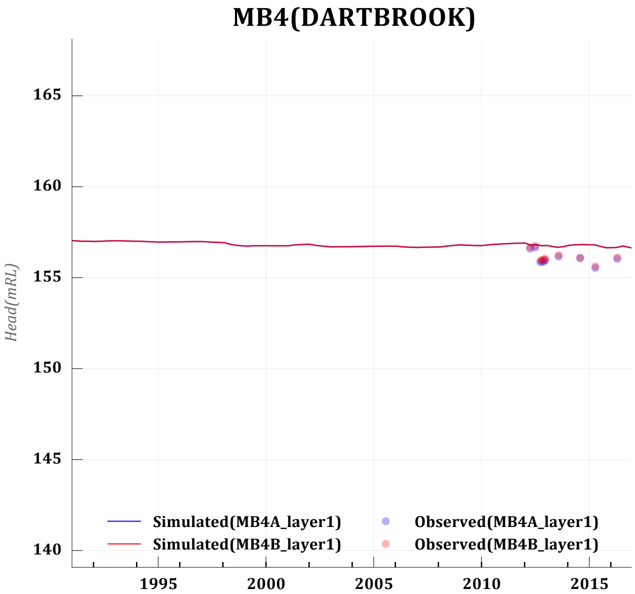

KAI2(DARTBROOK)
Head(mRL)
Simulated(KAI2_layer2)
Observed(KAI2_layer2)

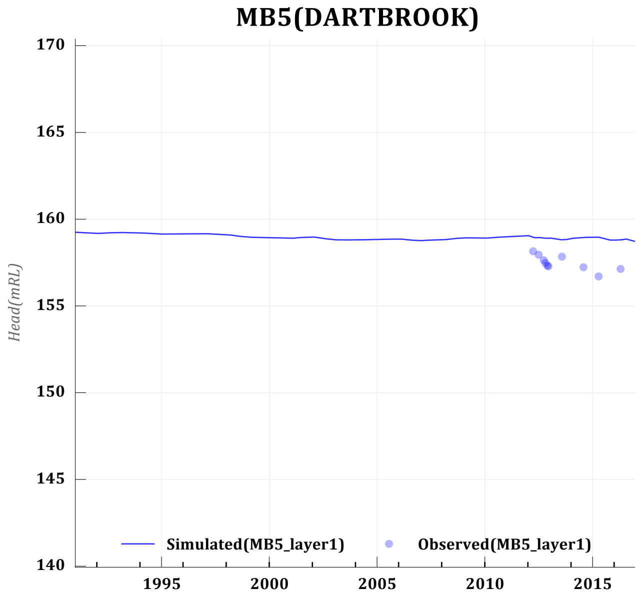

KAYUGA1(DARTBROOK)
Head(mRL)
Simulated(KAYUGA1_layer8)
Observed(KAYUGA1_layer8)

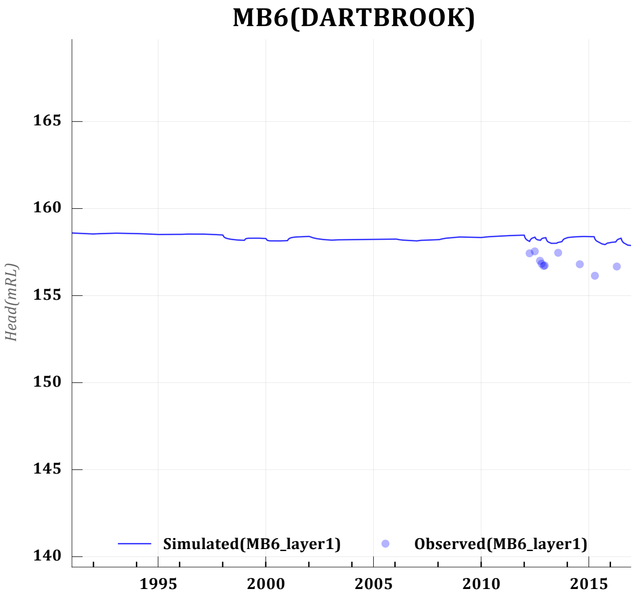

MB1(DARTBROOK)
Head(mRL)
Simulated(MB1A_layer1)
Simulated(MB1B_layer1)
Simulated(MB1C_layer1)
Observed(MB1A_layer1)
Observed(MB1B_layer1)
Observed(MB1C_layer1)

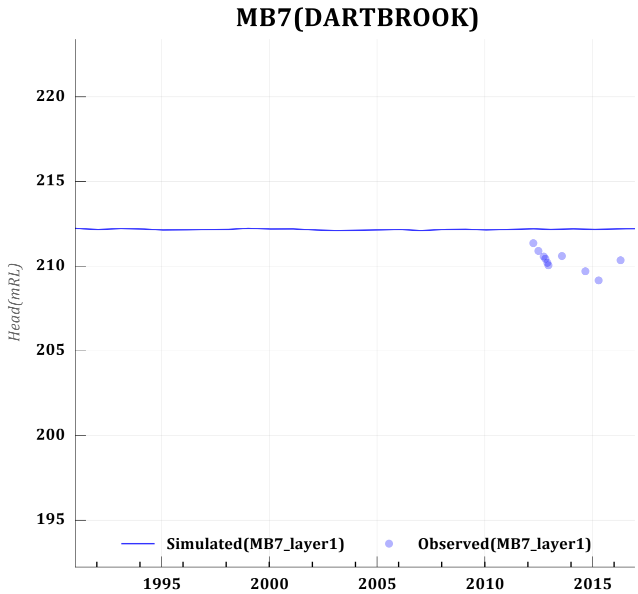

MB2(DARTBROOK)
Head(mRL)
175
170
165
160
155
150
Simulated(MB2A_layer1)
Simulated(MB2B_layer1)
Observed(MB2A_layer1)
Observed(MB2B_layer1)
1995
2000
2005
2010
2015

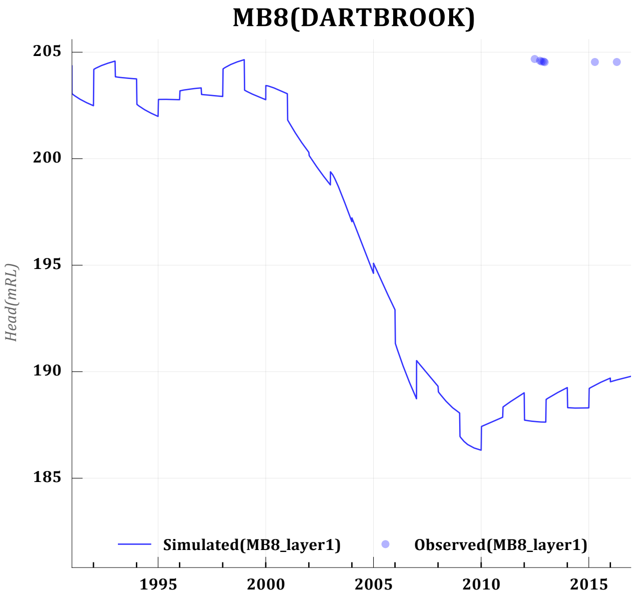

MB3(DARTBROOK)
Head(mRL)
170
165
160
155
150
145
Simulated(MB3A_layer1)
Simulated(MB3B_layer1)
Observed(MB3A_layer1)
Observed(MB3B_layer1)
1995
2000
2005
2010
2015

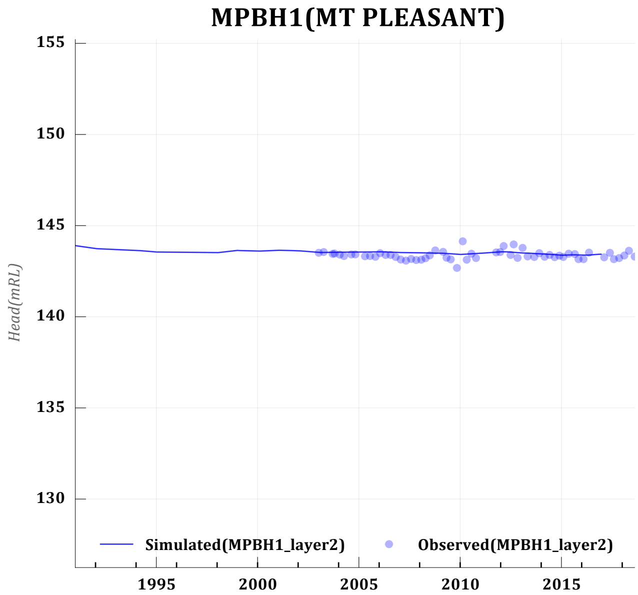

MB4(DARTBROOK)
Head(mRL)
165
160
155
150
145
140
Simulated(MB4A_layer1)
Simulated(MB4B_layer1)
Observed(MB4A_layer1)
Observed(MB4B_layer1)
1995
2000
2005
2010
2015

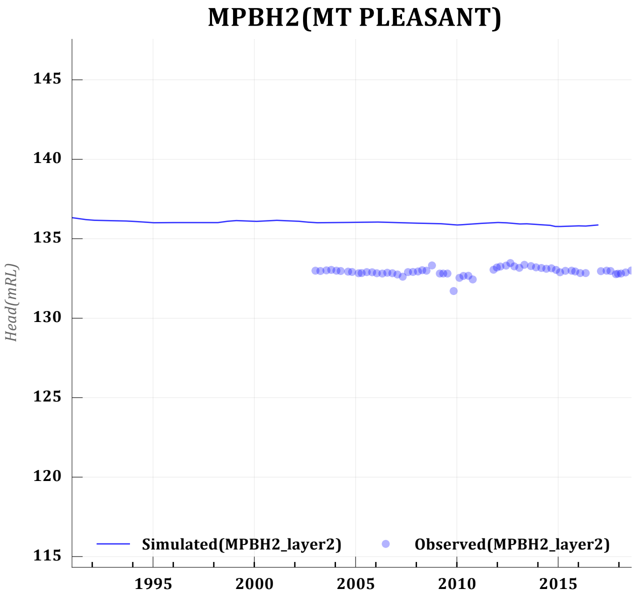

MB5(DARTBROOK)
Head(mRL)
170
165
160
155
150
145
140
Simulated(MB5_layer1)
Observed(MB5_layer1)
1995
2000
2005
2010
2015

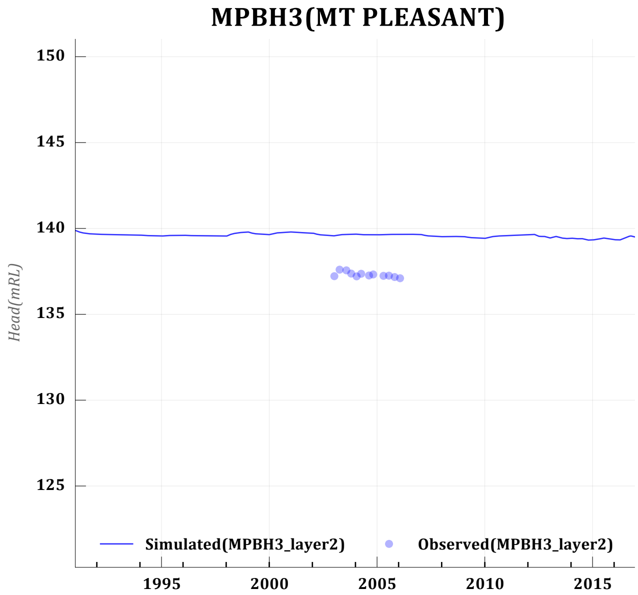

MB6(DARTBROOK)
Head(mRL)
165
160
155
150
145
140
Simulated(MB6_layer1)
Observed(MB6_layer1)
1995
2000
2005
2010
2015

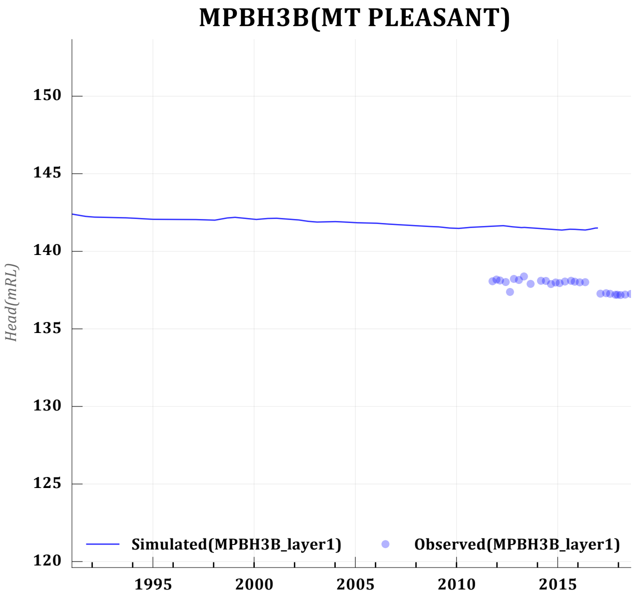

MB7(DARTBROOK)
Head(mRL)
220
215
210
205
200
195
Simulated(MB7_layer1)
Observed(MB7_layer1)
1995
2000
2005
2010
2015

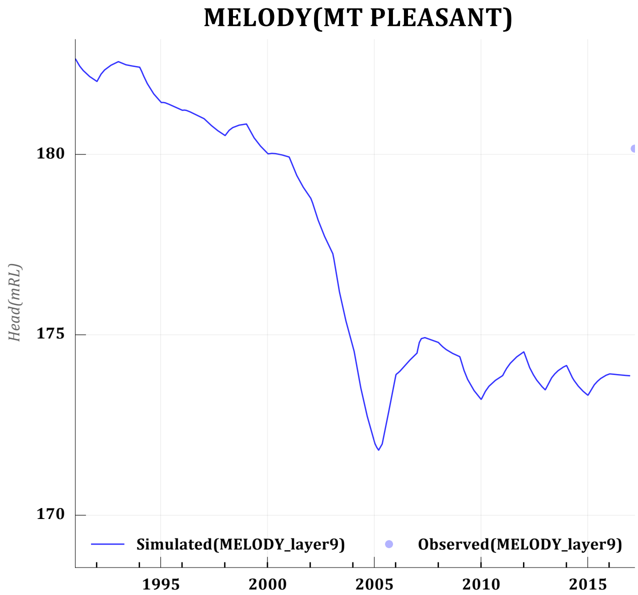

MB8(DARTBROOK)
205
200
195
190
185
Head(mRL)
Simulated(MB8_layer1)
Observed(MB8_layer1)
1995
2000
2005
2010
2015


MPBH1(MT PLEASANT)
155
150
145
140
135
130
Head(mRL)
Simulated(MPBH1_layer2)
Observed(MPBH1_layer2)
1995
2000
2005
2010
2015

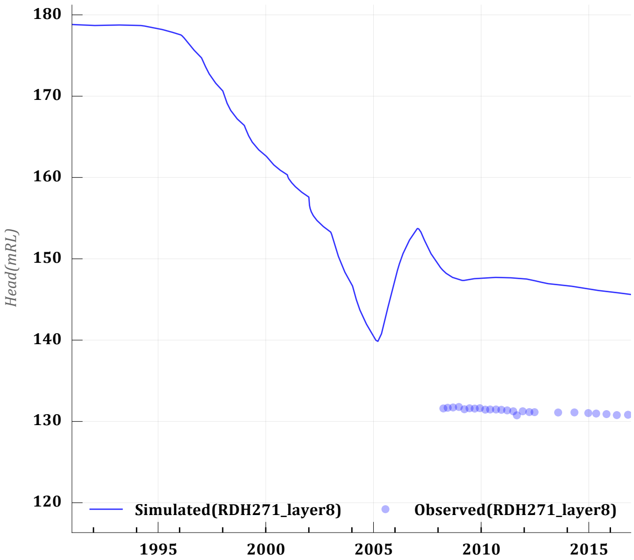

MPBH2(MT PLEASANT)
145
140
135
130
125
120
115
Head(mRL)
Simulated(MPBH2_layer2)
Observed(MPBH2_layer2)
1995
2000
2005
2010
2015


MPBH3(MT PLEASANT)
150
145
140
135
130
125
Head(mRL)
Simulated(MPBH3_layer2)
Observed(MPBH3_layer2)
1995
2000
2005
2010
2015

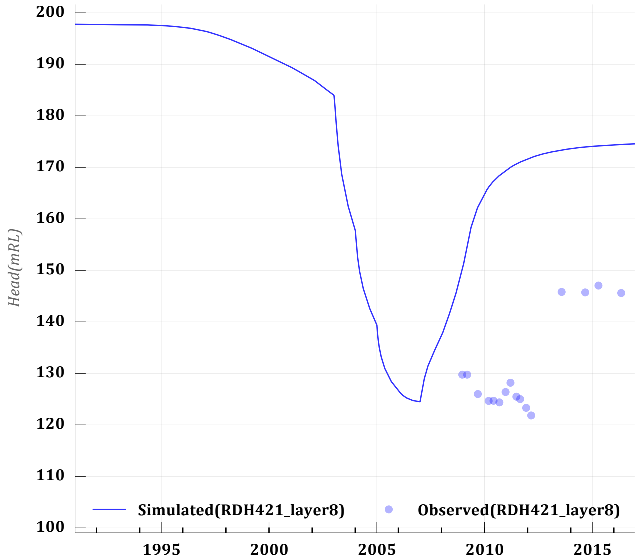

MPBH3B(MT PLEASANT)
150
145
140
135
130
125
120
Head(mRL)
Simulated(MPBH3B_layer1)
Observed(MPBH3B_layer1)
1995
2000
2005
2010
2015


MELODY(MT PLEASANT)
180
175
170
Head(mRL)
Simulated(MELODY_layer9)
Observed(MELODY_layer9)
1995
2000
2005
2010
2015

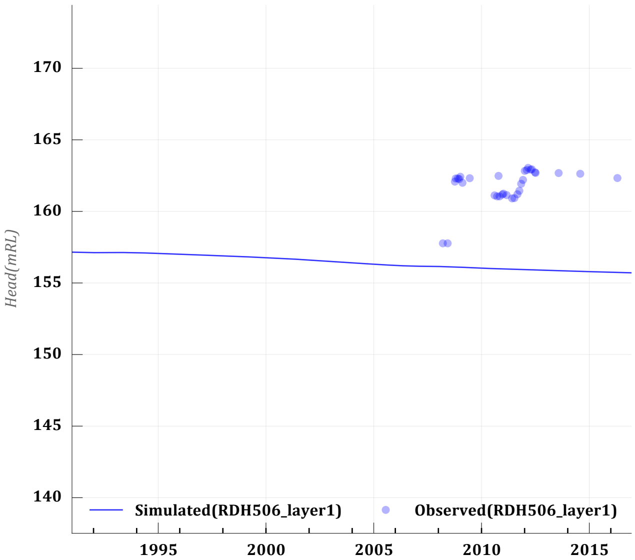
RDH271(DARTBROOK)



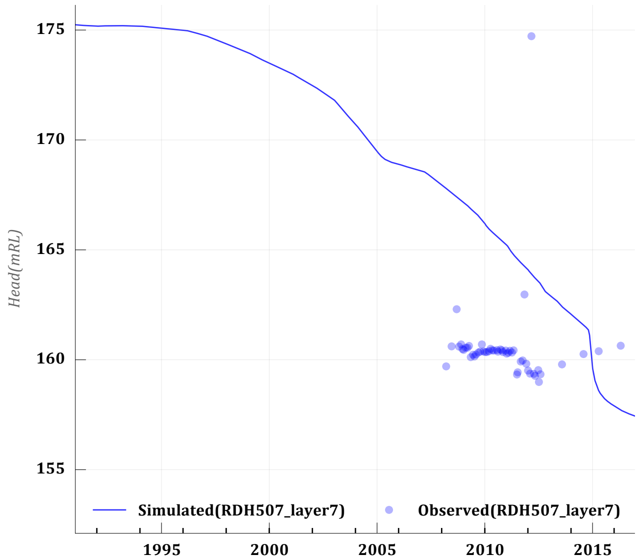
RDH421(DARTBROOK)



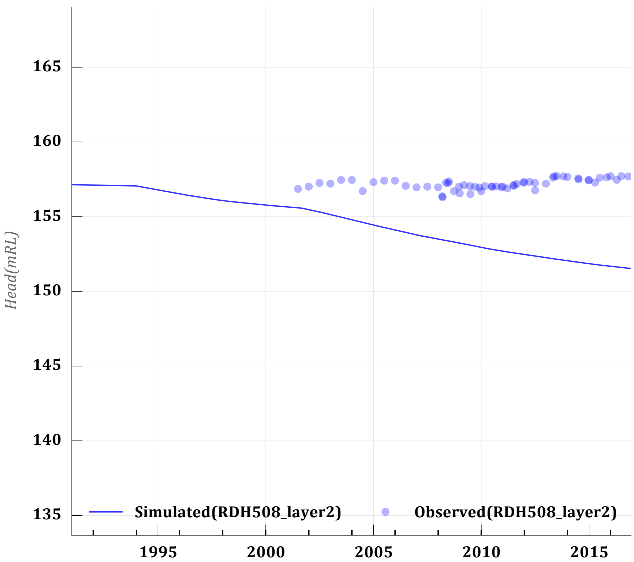
RDH506(DARTBROOK)



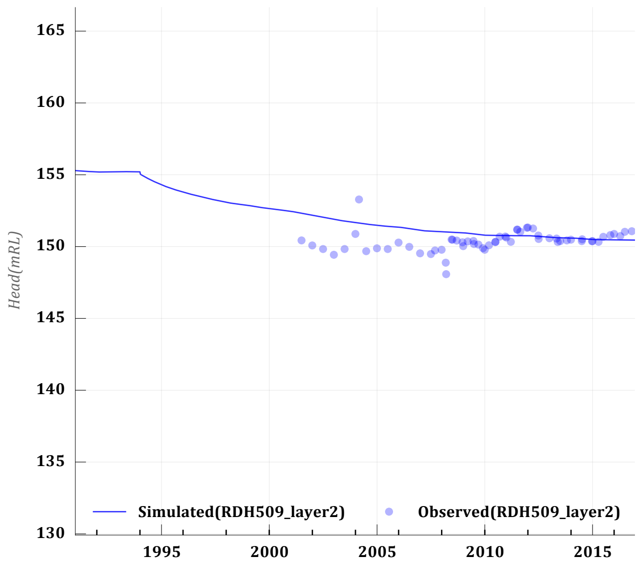
RDH507(DARTBROOK)

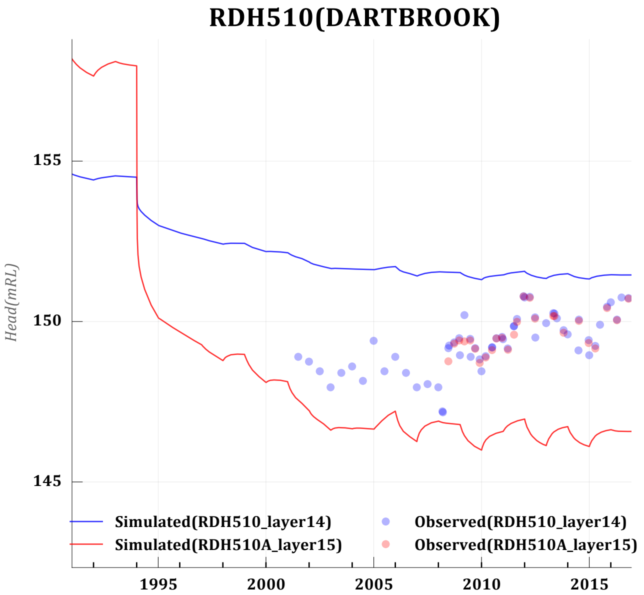


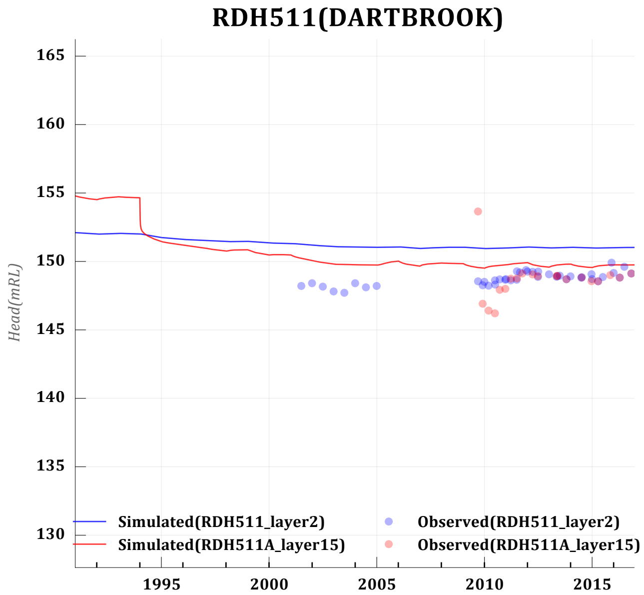
RDH508(DARTBROOK)

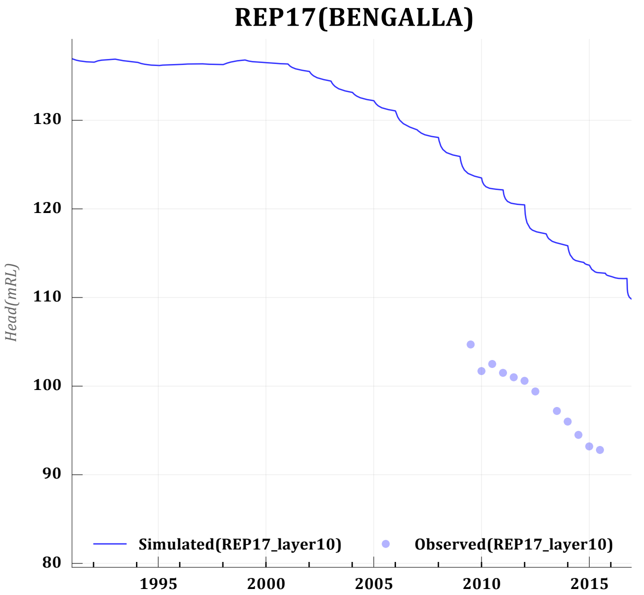


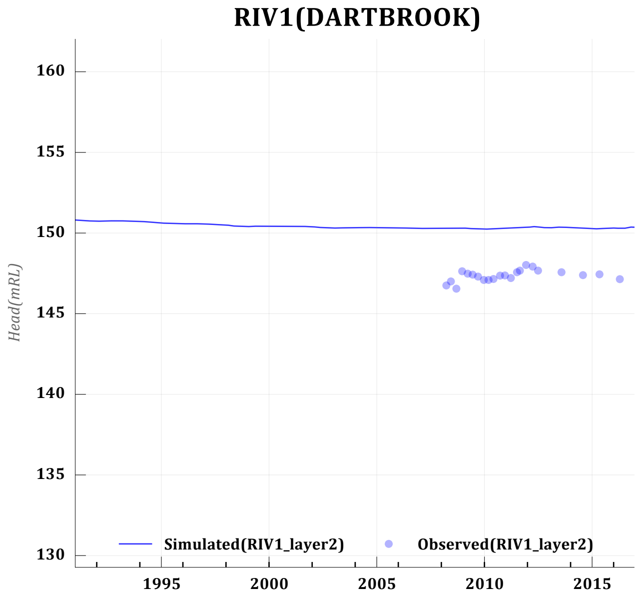
RDH509(DARTBROOK)

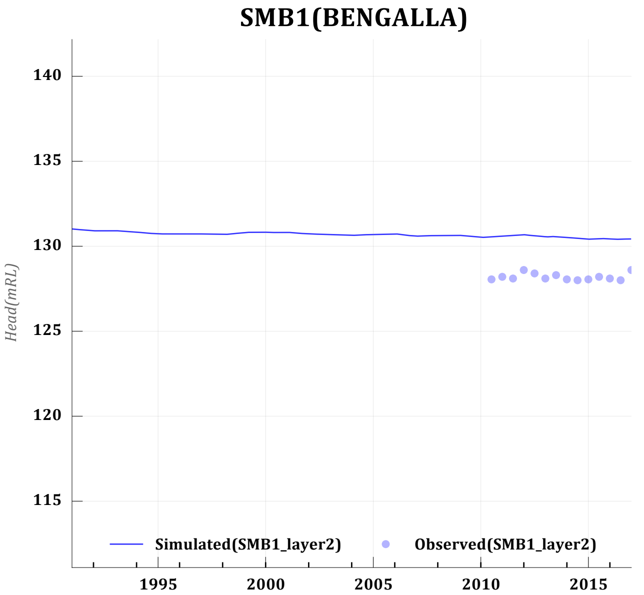


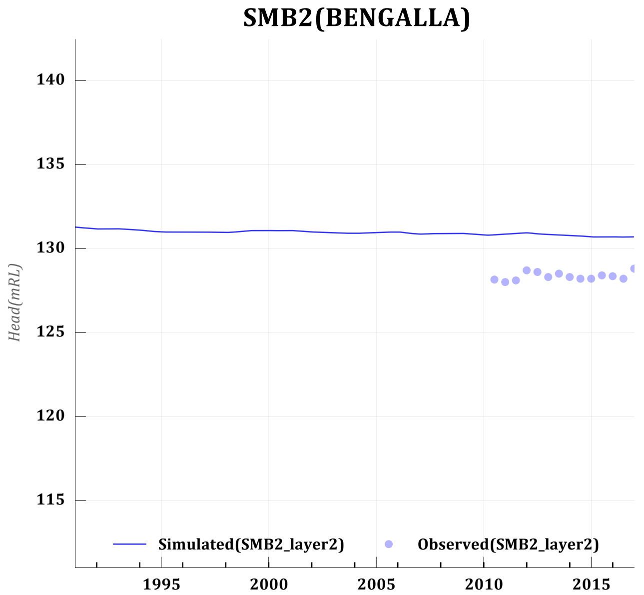

RDH510(DARTBROOK)
Head(mRL)
155
150
145
1995
2000
2005
2010
2015
Simulated(RDH510_layer14)
Simulated(RDH510A_layer15)
Observed(RDH510_layer14)
Observed(RDH510A_layer15)

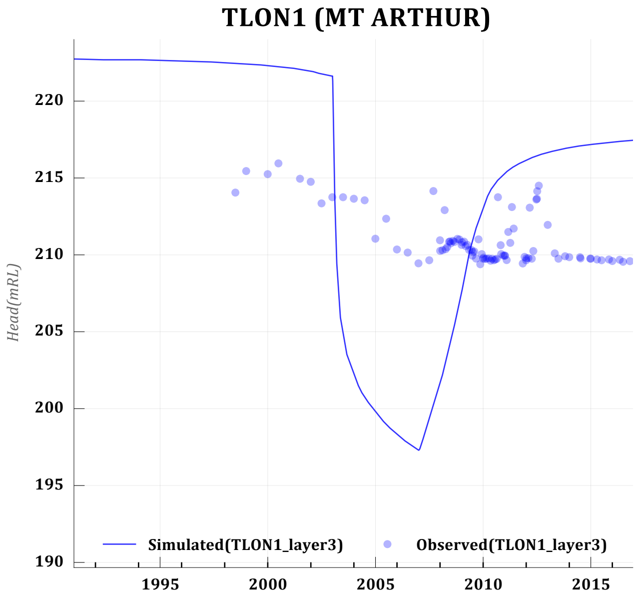

RDH511(DARTBROOK)
Head(mRL)
165
160
155
150
145
140
135
130
1995
2000
2005
2010
2015
Simulated(RDH511_layer2)
Simulated(RDH511A_layer15)
Observed(RDH511_layer2)
Observed(RDH511A_layer15)

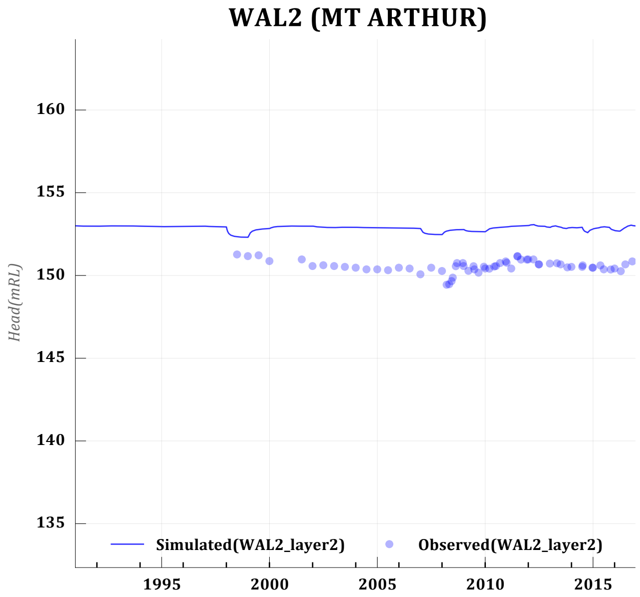

REP17(BENGALLA)
Head(mRL)
130
120
110
100
90
80
1995
2000
2005
2010
2015
Simulated(REP17_layer10)
Observed(REP17_layer10)

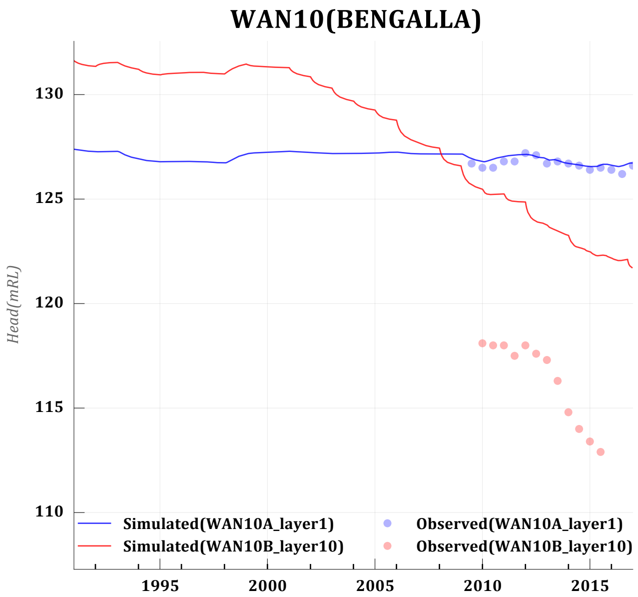

RIV1(DARTBROOK)
Head(mRL)
160
155
150
145
140
135
130
1995
2000
2005
2010
2015
Simulated(RIV1_layer2)
Observed(RIV1_layer2)

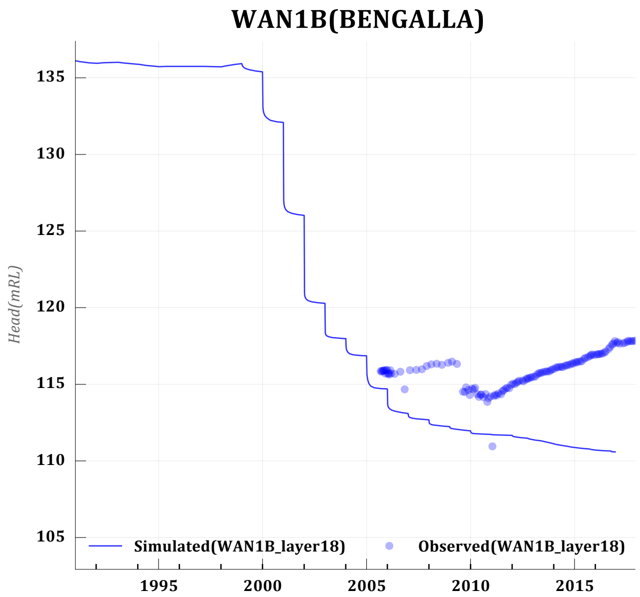

SMB1(BENGALLA)
Head(mRL)
140
135
130
125
120
115
1995
2000
2005
2010
2015
Simulated(SMB1_layer2)
Observed(SMB1_layer2)

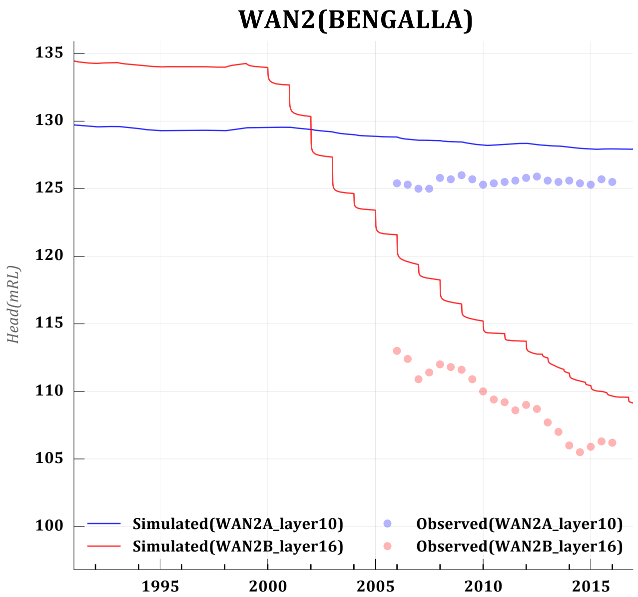

SMB2(BENGALLA)
Head(mRL)
140
135
130
125
120
115
1995
2000
2005
2010
2015
Simulated(SMB2_layer2)
Observed(SMB2_layer2)

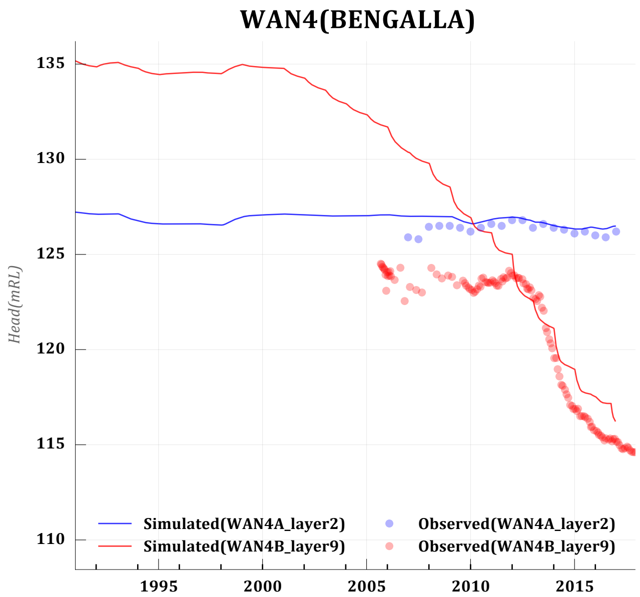

TLON1 (MT ARTHUR)
Head(mRL)
220
215
210
205
200
195
190
1995
2000
2005
2010
2015
Simulated(TLON1_layer3)
Observed(TLON1_layer3)


WAL2 (MT ARTHUR)
Head(mRL)
160
155
150
145
140
135
1995
2000
2005
2010
2015
Simulated(WAL2_layer2)
Observed(WAL2_layer2)

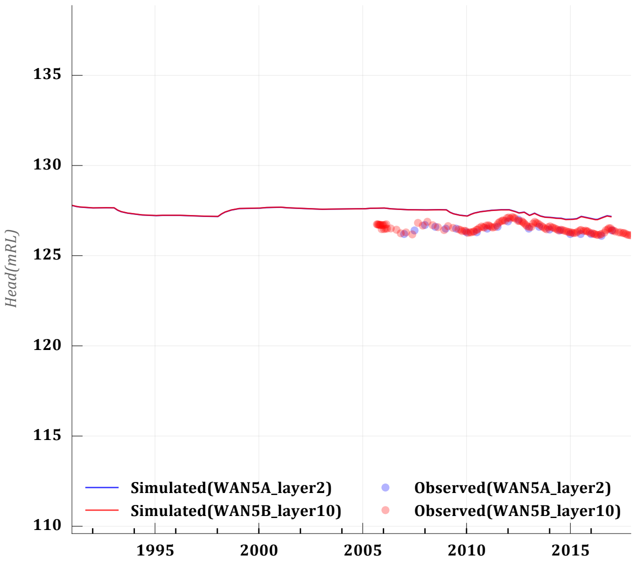

WAN10(BENGALLA)
Head(mRL)
130
125
120
115
110
1995
2000
2005
2010
2015
Simulated(WAN10A_layer1)
Simulated(WAN10B_layer10)
Observed(WAN10A_layer1)
Observed(WAN10B_layer10)


WAN1B(BENGALLA)
Head(mRL)
135
130
125
120
115
110
105
1995
2000
2005
2010
2015
Simulated(WAN1B_layer18)
Observed(WAN1B_layer18)

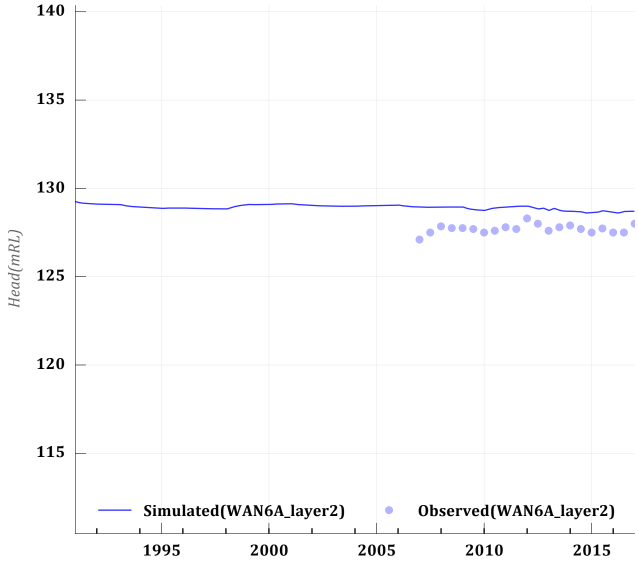

WAN2(BENGALLA)
Head(mRL)
135
130
125
120
115
110
105
100
1995
2000
2005
2010
2015
Simulated(WAN2A_layer10)
Simulated(WAN2B_layer16)
Observed(WAN2A_layer10)
Observed(WAN2B_layer16)


WAN4(BENGALLA)
Head(mRL)
135
130
125
120
115
110
1995
2000
2005
2010
2015
Simulated(WAN4A_layer2)
Simulated(WAN4B_layer9)
Observed(WAN4A_layer2)
Observed(WAN4B_layer9)

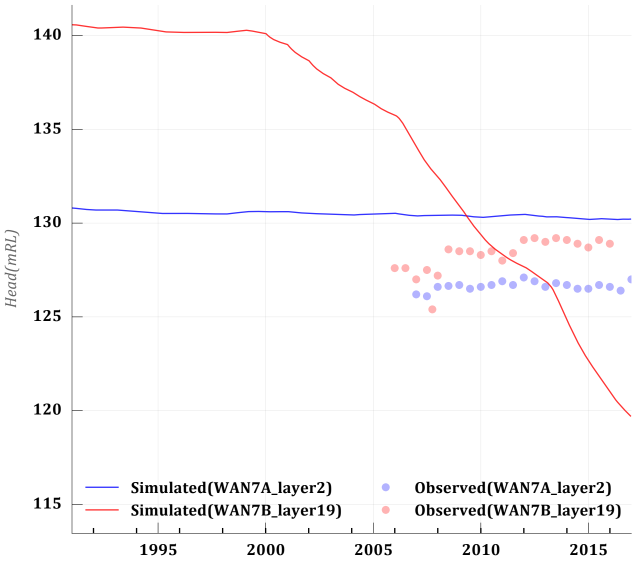
WAN5(BENGALLA)



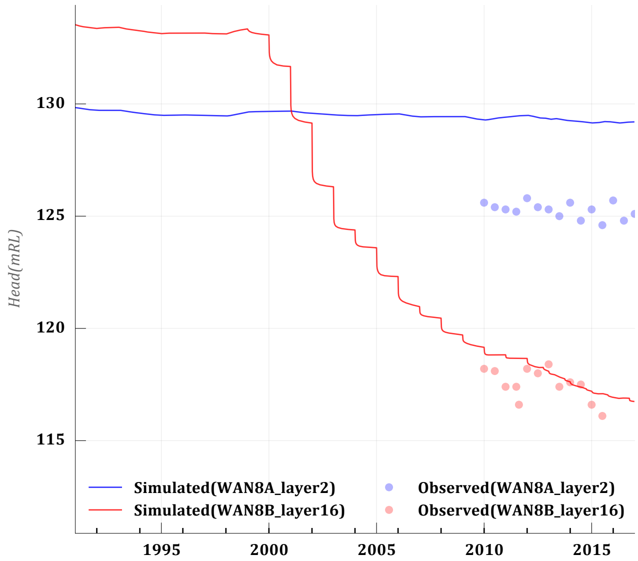
WAN6(BENGALLA)



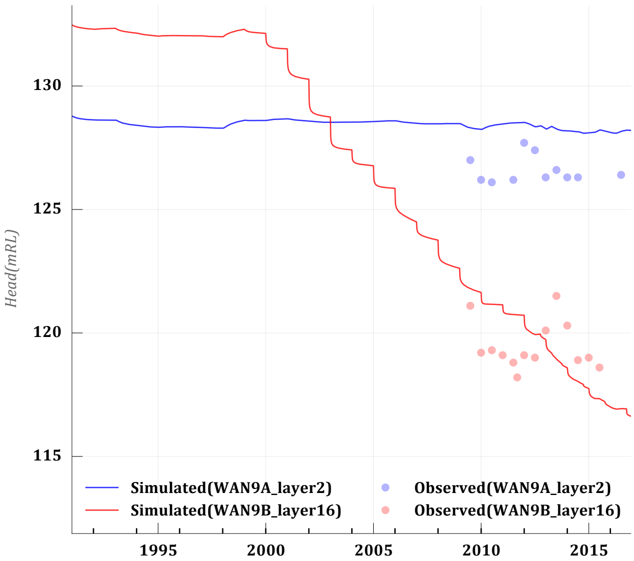
WAN7(BENGALLA)



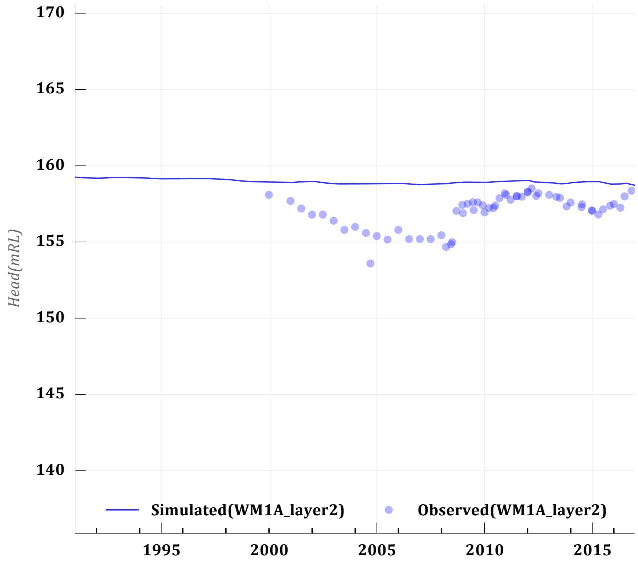
WAN8(BENGALLA)



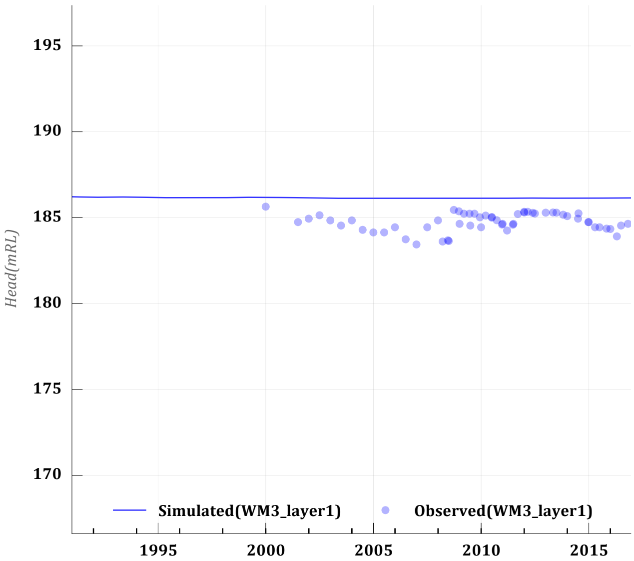
WAN9(BENGALLA)



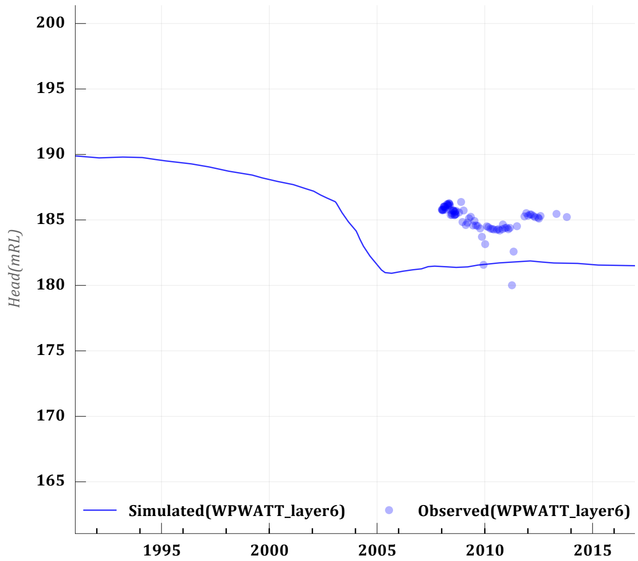
WM1 (MT ARTHUR)



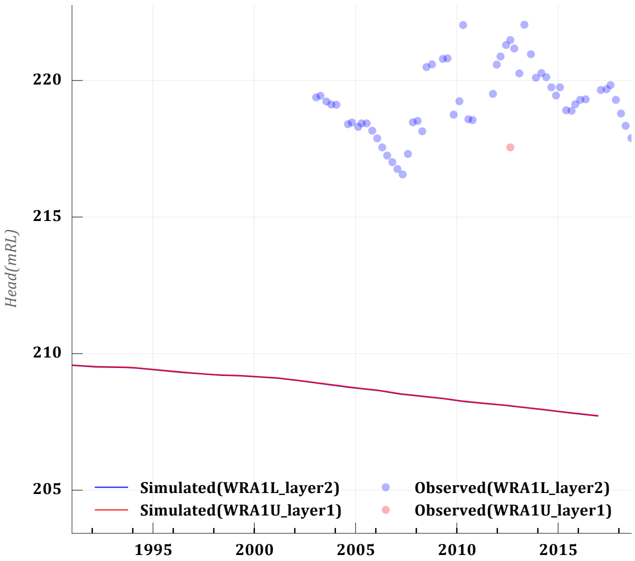
WM3 (MT ARTHUR)



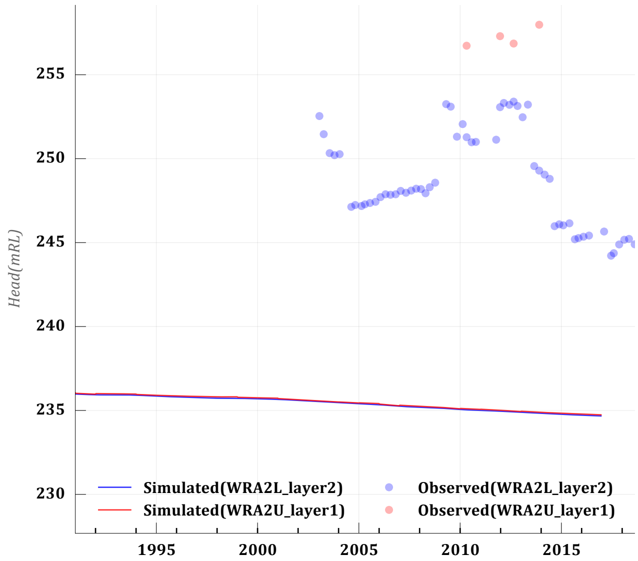
WPWATT(DARTBROOK)



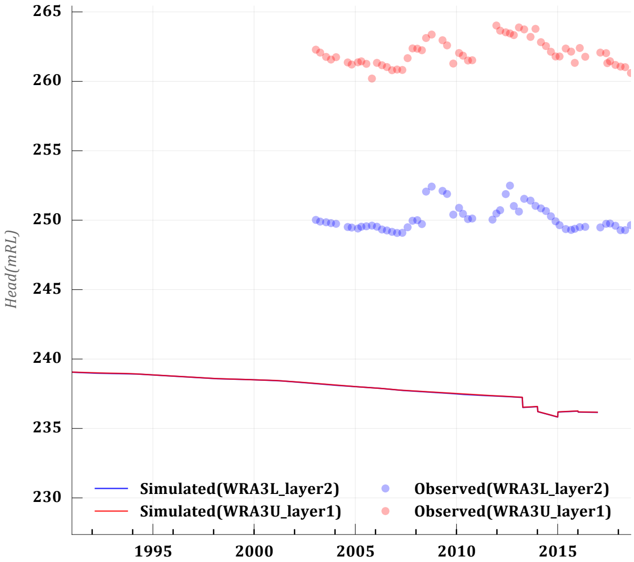
WRA1(MT PLEASANT)



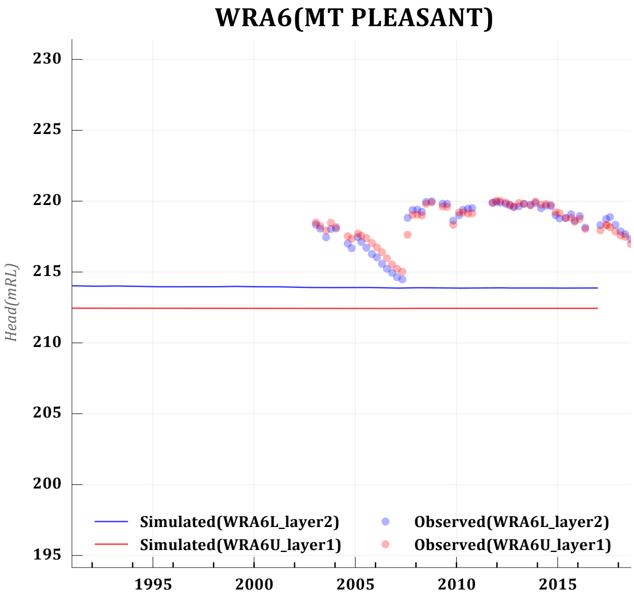
WRA2(MT PLEASANT)



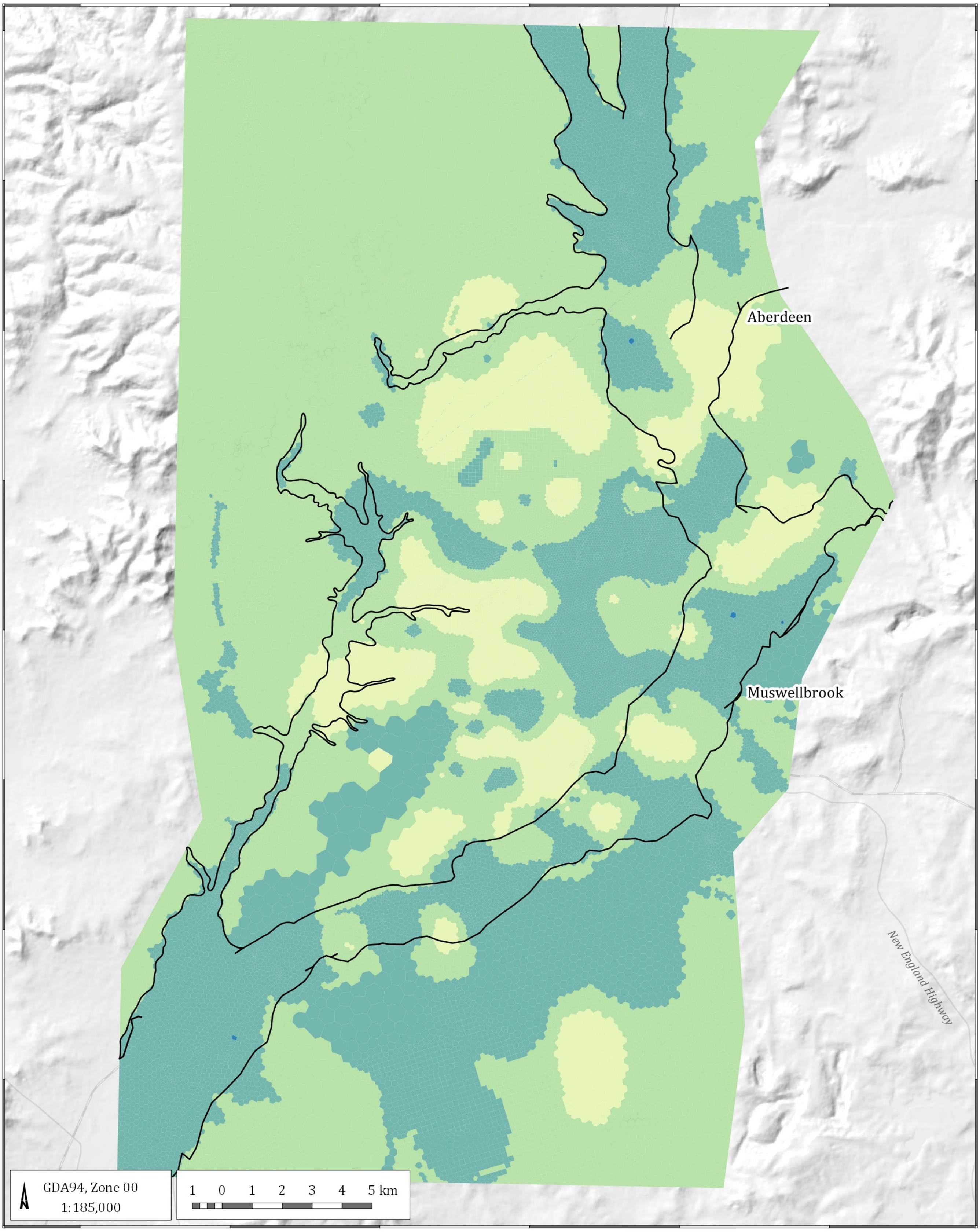
WRA3(MT PLEASANT)



WRA5(MT PLEASANT)


WRA6(MT PLEASANT)
Head(mRL)
230
225
220
215
210
205
200
195
1995
2000
2005
2010
2015
Simulated(WRA6L_layer2)
Simulated(WRA6U_layer1)
Observed(WRA6L_layer2)
Observed(WRA6U_layer1)

Appendix A 2 Spatial distribution of hydraulic parameters layers 1 to 3



LEGEND

- Grid
- Road
- Rail
- Drainage
- Populated place
- Alluvium extent
- Cells with thickness of less than 0.1m

Horizental Hydraulic conductivity (m/day)

- 0.0001 - 0.002
- 0.002 - 0.005
- 0.005 - 0.02
- 0.02 - 0.05
- 0.05 - 1.5
- 1.5 - 4.0
- 4.0- 20.0
- 20.0 - 120.0

MT Pleasant GIA (G1970)

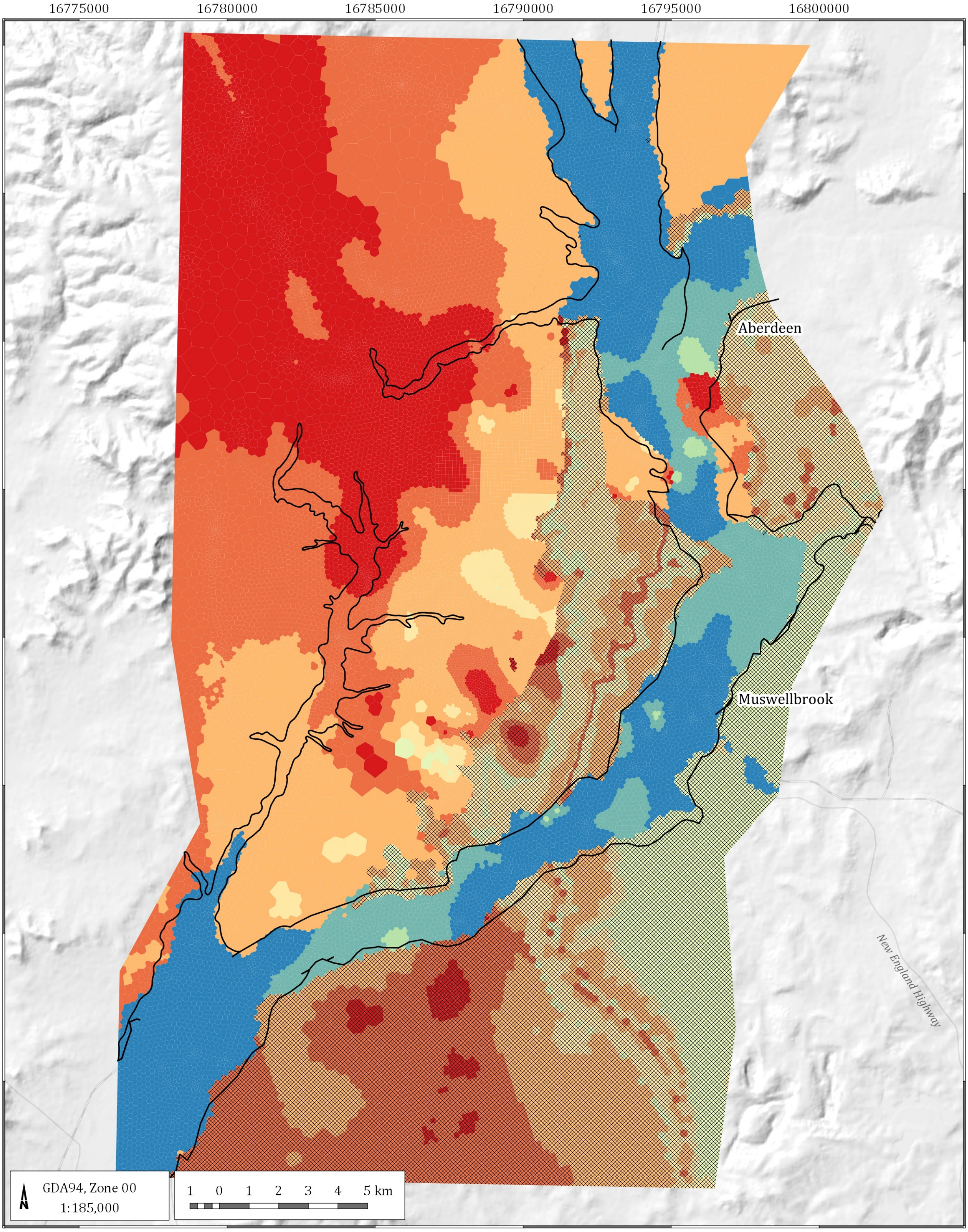
Spatial distribution of horizontal hydraulic conductivity (HK) layer 1

AGE

DATE 23/01/2020

FIGURE No: **A-2-1**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\002_Deliverable2\Appendix A-2.qgs



LEGEND

- Grid
- Road
- Rail
- Drainage
- Populated place
- Alluvium extent
- Cells with thickness of less than 0.1m

Horizontal Hydraulic conductivity (m/day)

- 0.0001 - 0.002
- 0.002 - 0.005
- 0.005 - 0.02
- 0.02 - 0.05
- 0.05 - 1.5
- 1.5 - 4.0
- 4.0 - 20.0
- 20.0 - 120.0

MT Pleasant GIA (G1970)

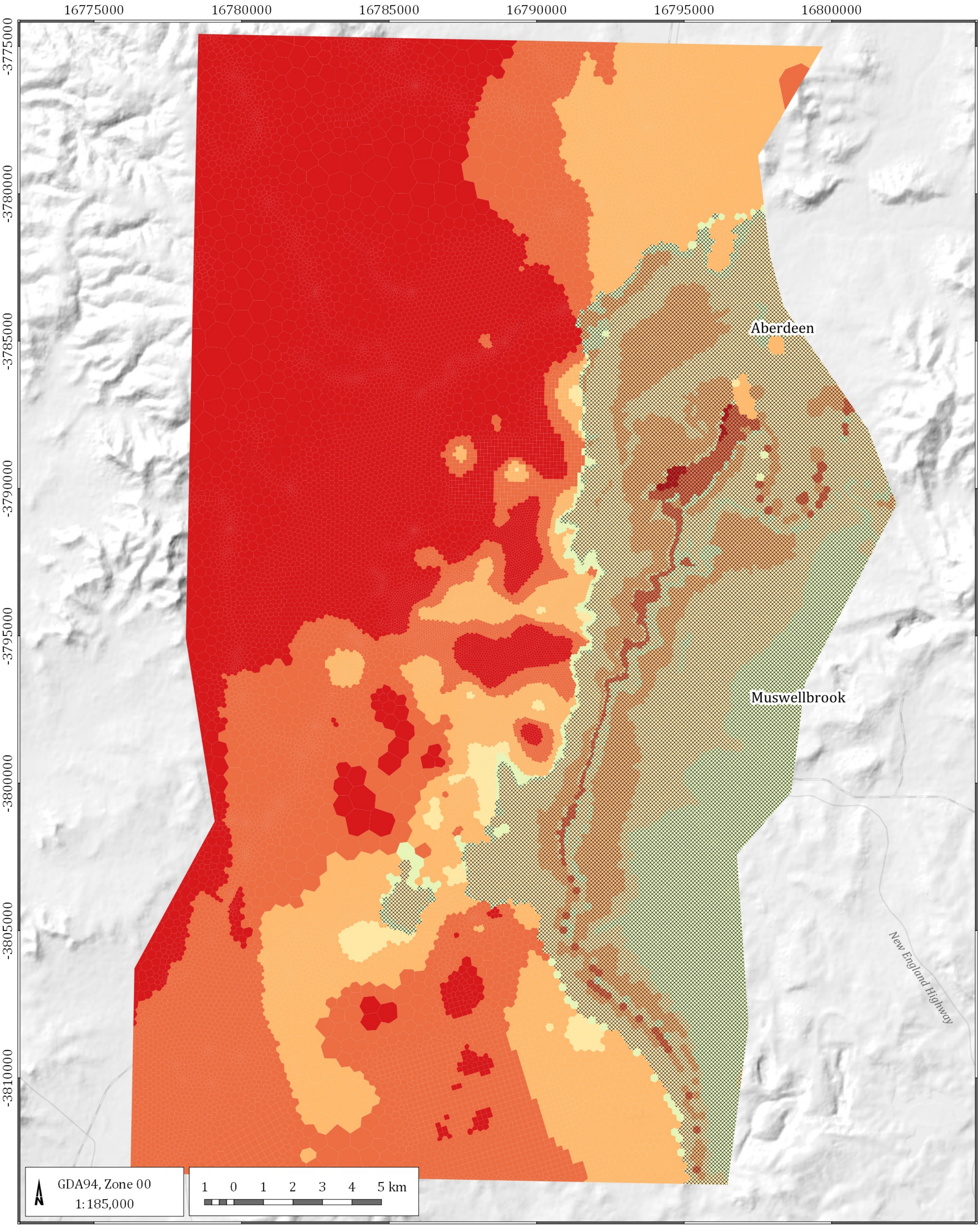
Spatial distribution of horizontal hydraulic conductivity (HK) layer 2

AGE

DATE 23/01/2020

FIGURE No: **A-2-2**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\002_Deliverable2\Appendix A-2.qgs



LEGEND

- Grid
- Road
- Rail
- Drainage
- Populated place
- Cells with thickness of less than 0.1m

Horizental Hydraulic conductivity (m/day)

- 0.0001 - 0.002
- 0.002 - 0.005
- 0.005 - 0.02
- 0.02 - 0.05
- 0.05 - 1.5
- 1.5 - 4.0
- 4.0 - 20.0
- 20.0 - 120.0

MT Pleasant GIA (G1970)

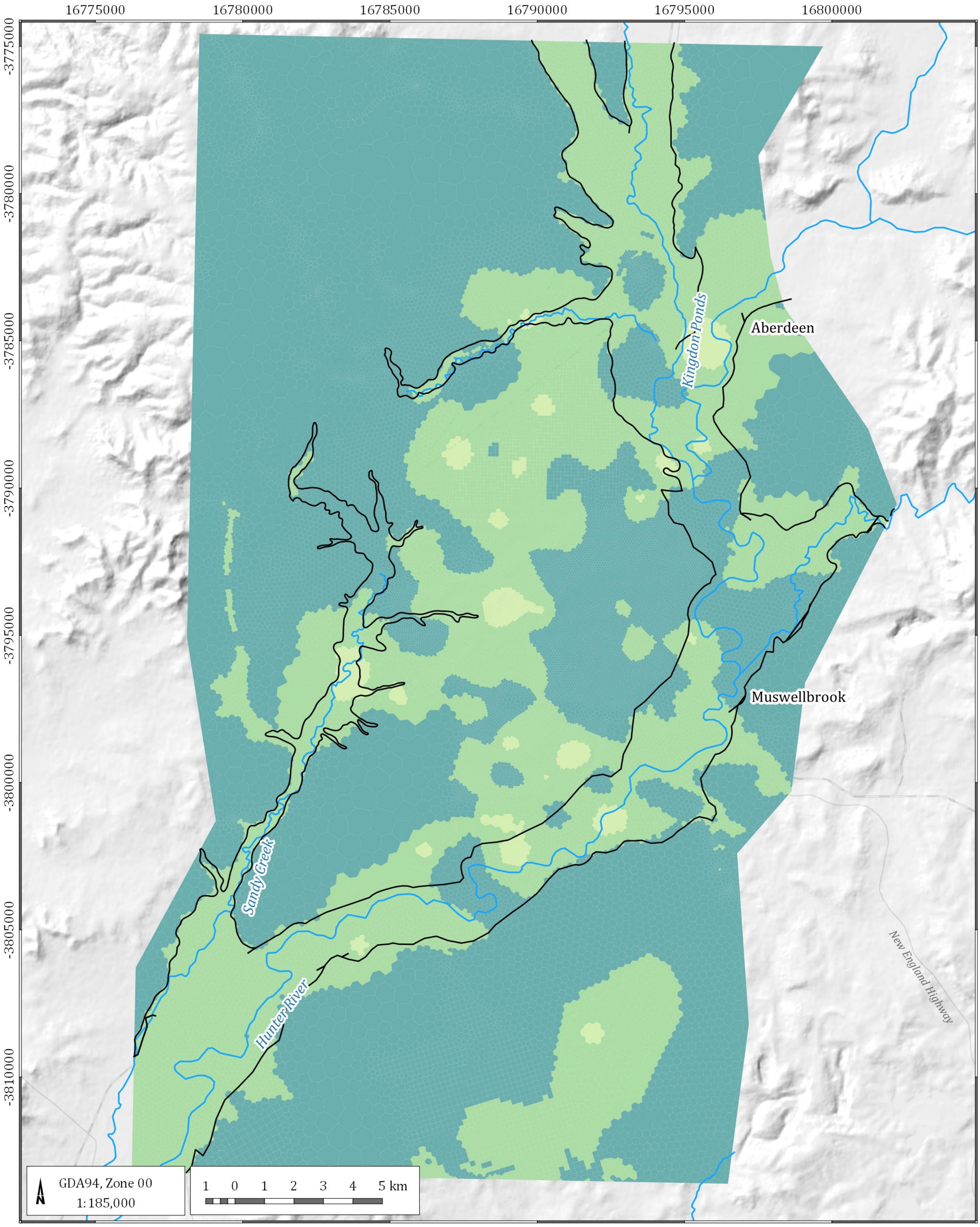
Spatial distribution of horizontal hydraulic conductivity (HK) layer 3

AGE

DATE 23/01/2020

FIGURE No: **A-2-3**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\002_Deliverable2\Appendix A-2.qgs



LEGEND

- Grid
- Road
- Rail
- Drainage
- Populated place
- Alluvium extent
- Cells with thickness of less than 0.1m

Vertical hydrualic conductivity (m/day)

- 0.000000085 - 0.000008
- 0.000008 - 0.00001
- 0.00001 - 0.00002
- 0.00002 - 0.0001
- 0.0001 - 0.001
- 0.001 - 0.1
- 0.1 - 1.0
- 1.0 - 20.0
- 20.0 - 120.0

MT Pleasant GIA (G1970)

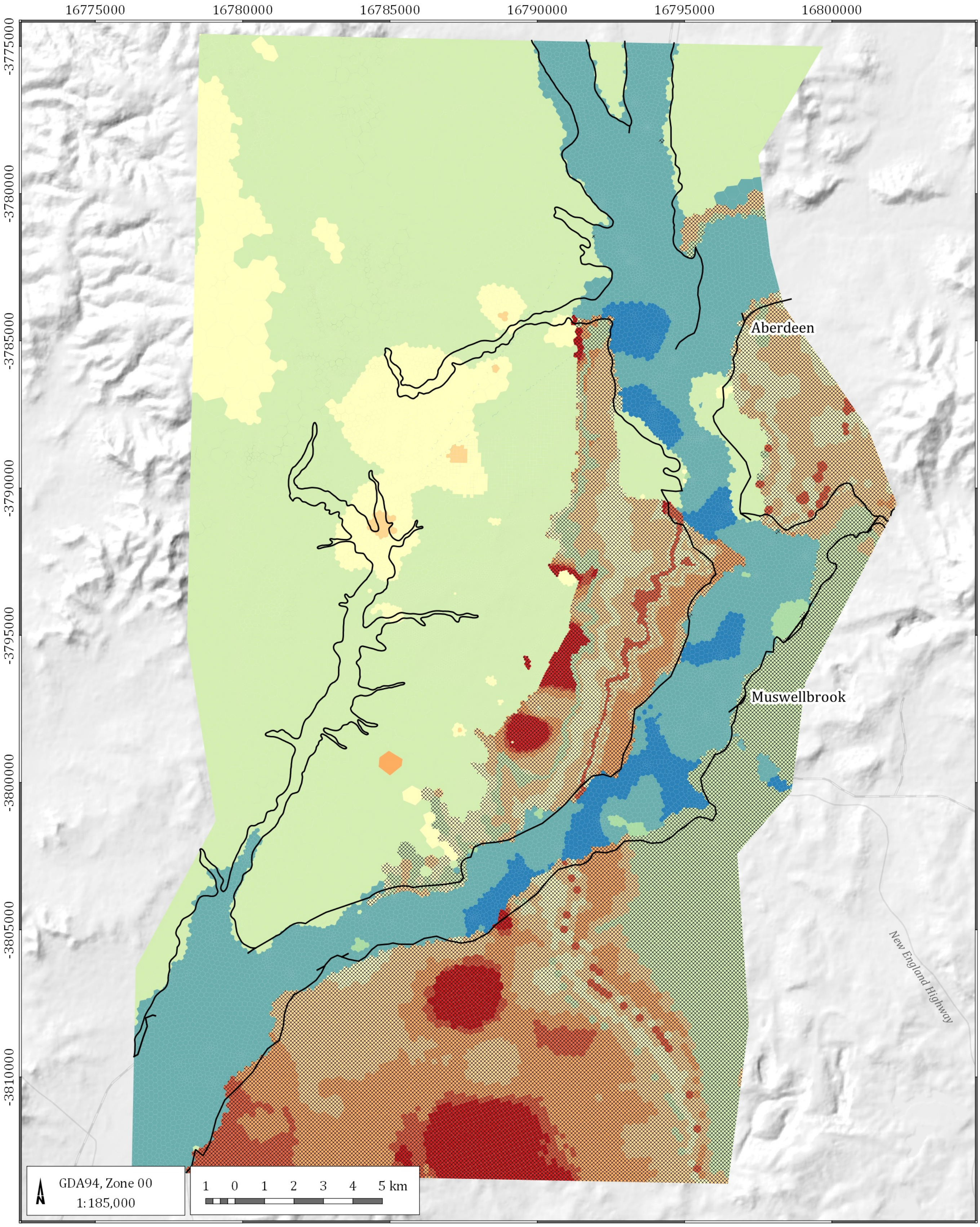
Spatial distribution of Vertical hydraulic conductivity (VK) layer 1

AGE

DATE
23/01/2020

FIGURE No:
A-2-4

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\002_Deliverable2\Appendix A-2.qgs



LEGEND

- Grid
- Road
- Rail
- Drainage
- Populated place
- Alluvium extent
- Cells with thickness of less than 0.1m

Vertical hydrualic conductivity (m/day)

- 0.000000085 - 0.000008
- 0.000008 - 0.00001
- 0.00001 - 0.00002
- 0.00002 - 0.0001
- 0.0001 - 0.001
- 0.001 - 0.1
- 0.1 - 1.0
- 1.0 - 20.0
- 20.0 - 120.0

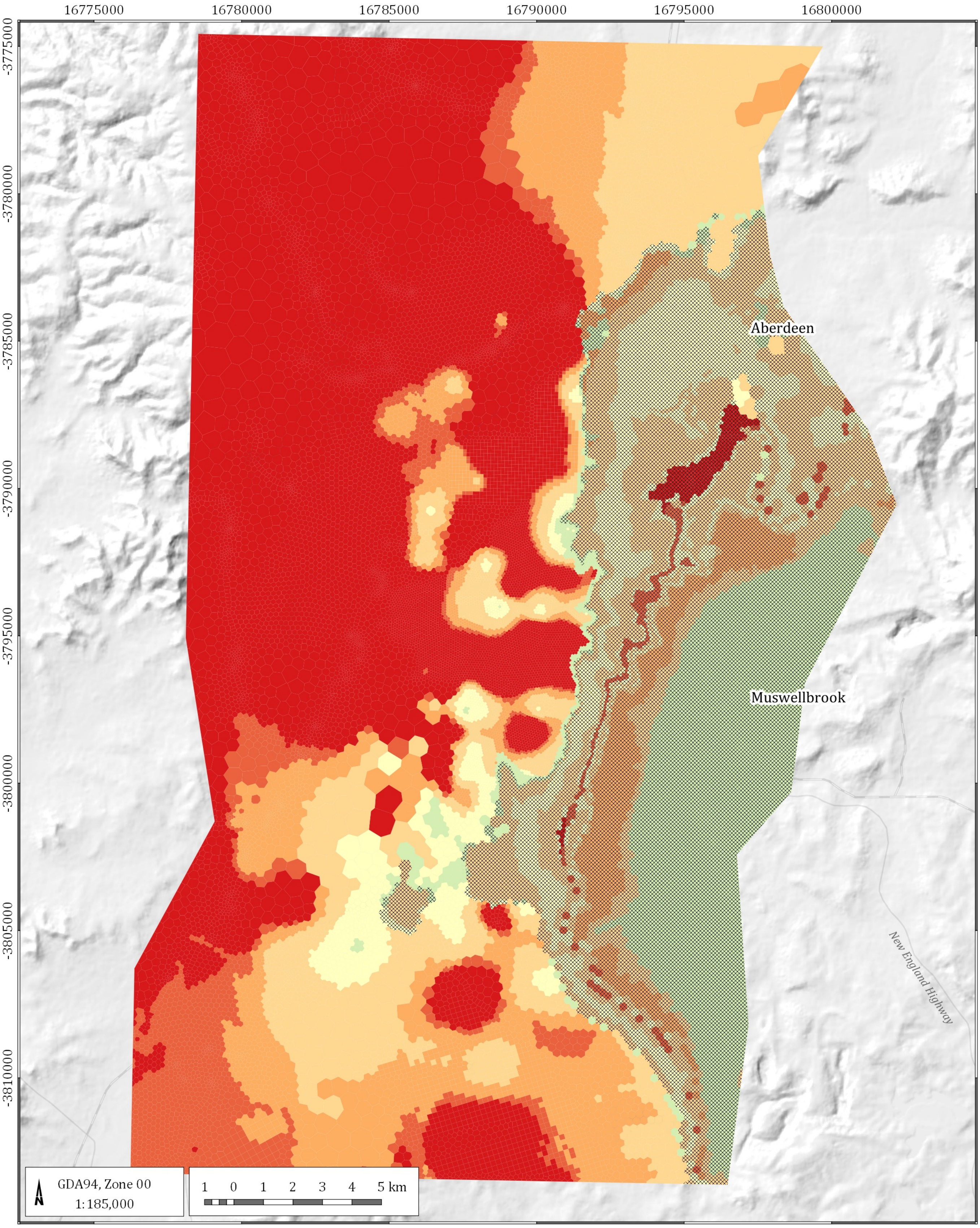
MT Pleasant GIA (G1970)

Spatial distribution of Vertical hydraulic conductivity (VK) layer 2

DATE 23/01/2020

FIGURE No: **A-2-5**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\002_Deliverable2\Appendix A-2.qgs



LEGEND

- Grid
- Road
- Rail
- Drainage
- Populated place
- Cells with thickness of less than 0.1m

Vertical hydraulic conductivity (m/day)

- 0.000000085 - 0.000008
- 0.000008 - 0.00001
- 0.00001 - 0.00002
- 0.00002 - 0.0001
- 0.0001 - 0.001
- 0.001 - 0.1
- 0.1 - 1.0
- 1.0 - 20.0
- 20.0 - 120.0

MT Pleasant GIA (G1970)

Spatial distribution of Vertical hydraulic conductivity (VK) layer 3

AGE

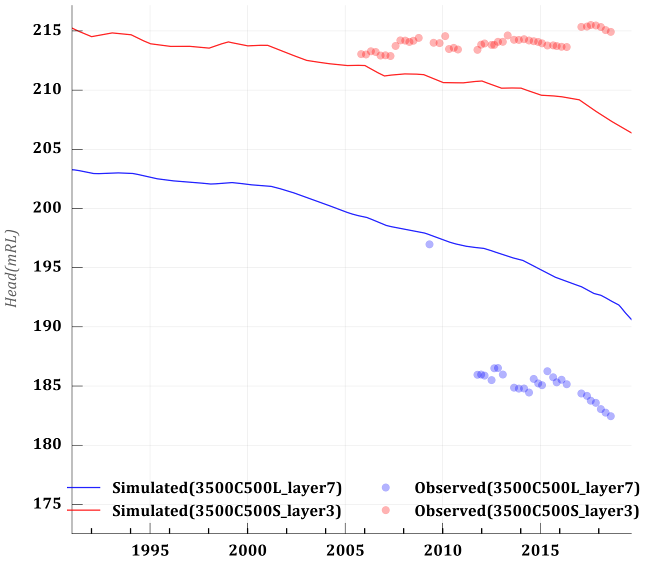
DATE 23/01/2020

FIGURE No: **A-2-6**

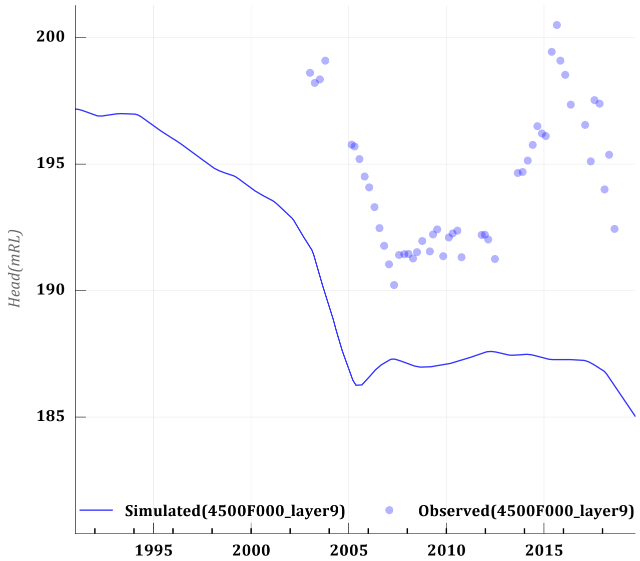
Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1970.Mt Pleasant GIA\3_GIS\Workspaces\002_Deliverable2\Appendix A-2.qgs

Appendix A 3 **Verification Hydrographs**

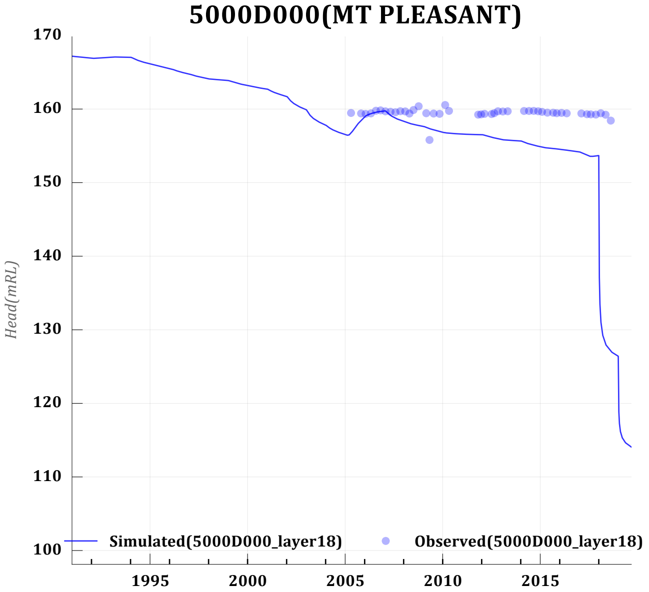
3500C500(MT PLEASANT)



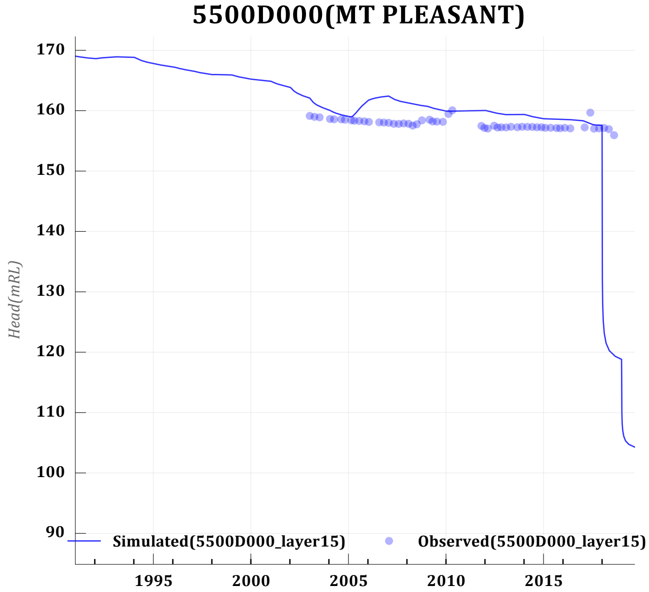
4500F000(MT PLEASANT)



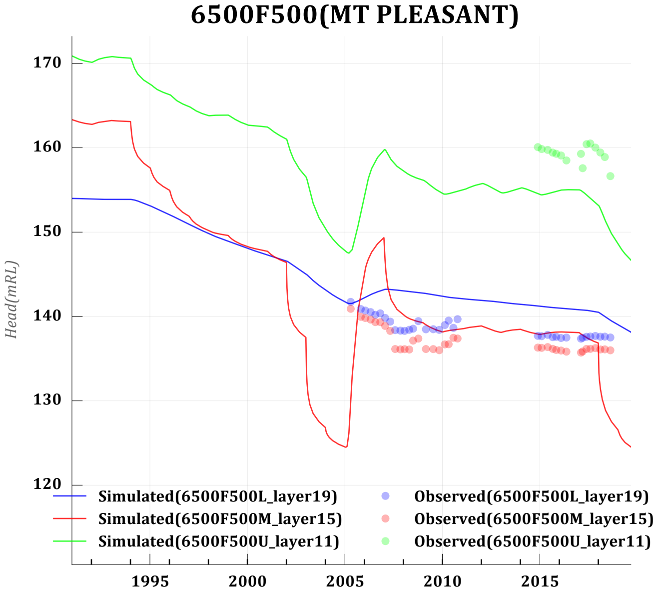
5000D000(MT PLEASANT)



5500D000(MT PLEASANT)



6500F500(MT PLEASANT)



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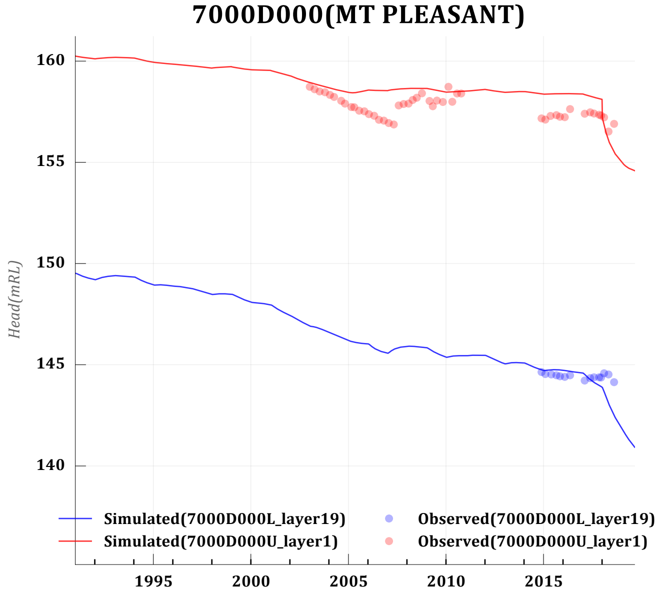

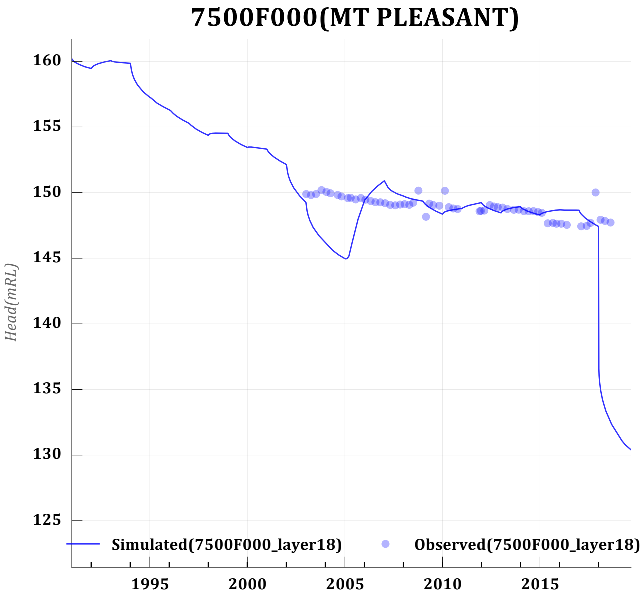
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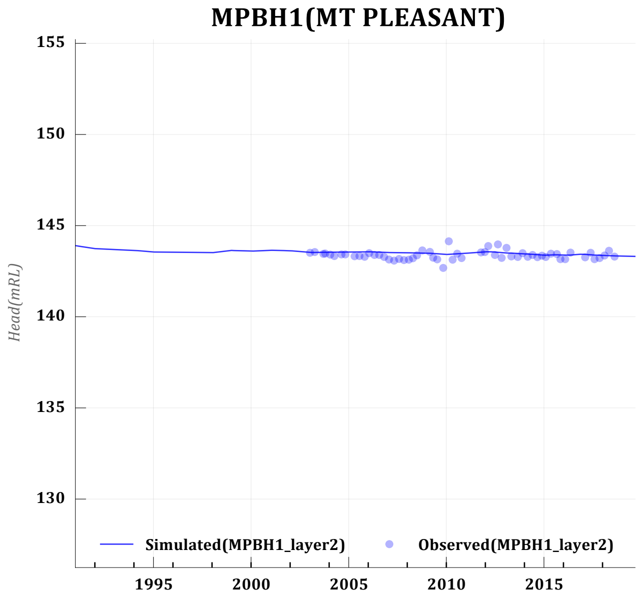
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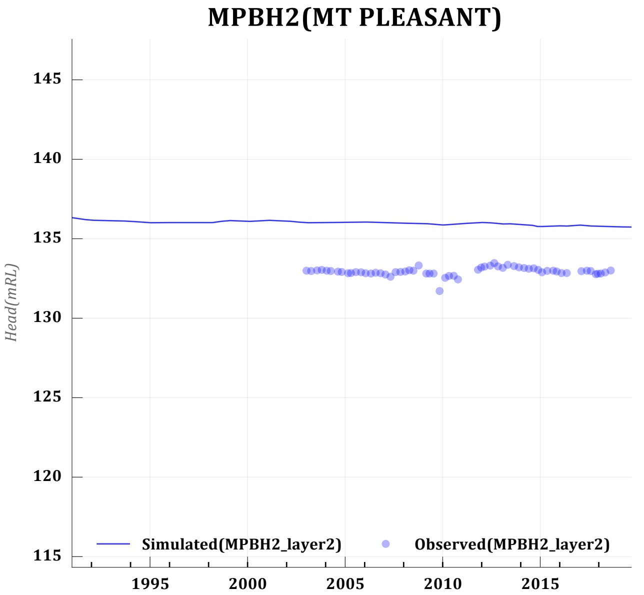
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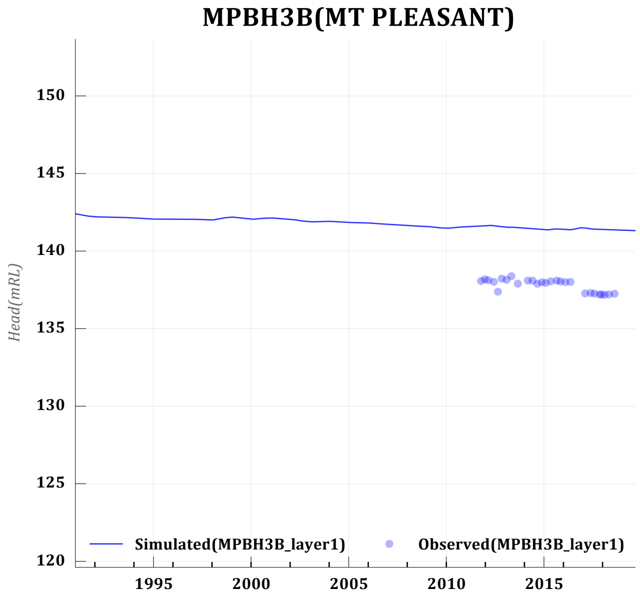
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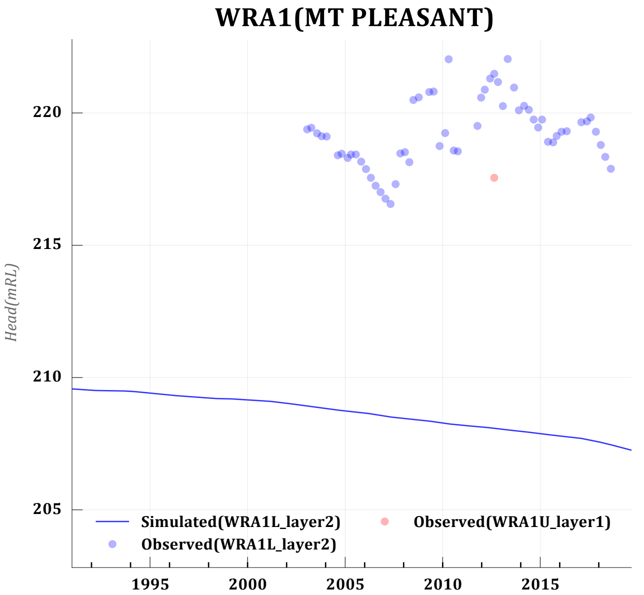
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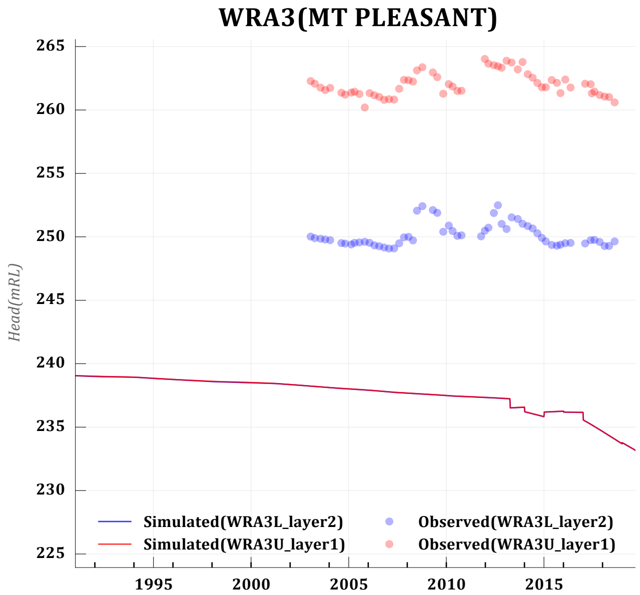
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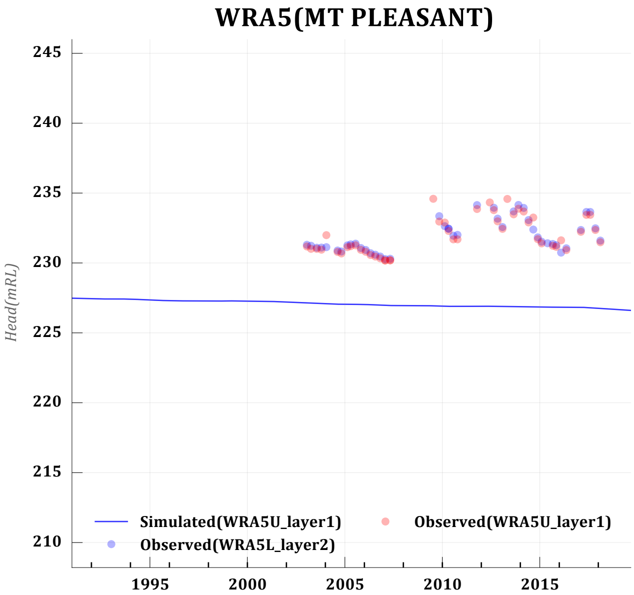
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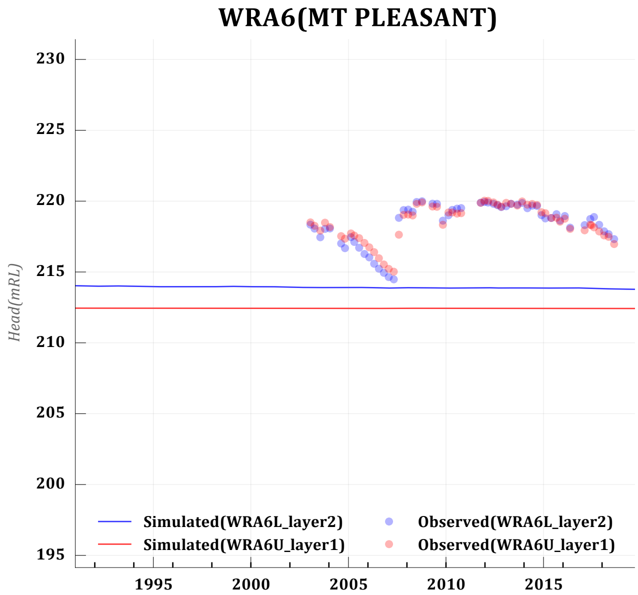
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Appendix B Compliance with government policy

B1 Compliance with New South Wales Policy

B1.1 Aquifer interference policy

This section discusses the ability of the MPO (incorporating the Project) to comply with the AIP. Table B1.1 to Table B1.2 below compare the groundwater impact predictions for the MPO against the requirements under the AIP.

Table B1.1 Accounting for or preventing the take of water

AIP requirement		Proponent response
1	Described the water source (s) the activity will take water from?	Section 2.1.1 describes the water sharing plans that the MPO will take water from, namely: • Sydney Basin North Coast Fractured and Porous Rock Groundwater Sources Water Sharing Plan; and • Hunter Regulated River Water Source Water Sharing Plan • Hunter Unregulated and Alluvial Water Sources Water Sharing Plan.
2	Predict the total amount of water that will be taken from each connected groundwater or surface water source on an annual basis as a result of the activity?	Section 7.1.1 and Section 8.1 summarise the peak take of groundwater and surface water from each water source due to the approved mining and the additional incremental effect of the proposed MPO Additional Mining Area.
3	Predicted the total amount of water that will be taken from each connected groundwater or surface water source after the closure of the activity?	Section 8.1.3 describes post mining impacts.
4	Made these predictions in accordance with Section 3.2.3 of the AIP? (page 27)	Based on 3D numerical modelling.
5	Described how and in what proportions this take will be assigned to the affected aquifers and connected surface water sources?	Table 8.1 summarises the peak take of surface water and groundwater from each water source due to mining at MPO (incorporating the Project).
6	Described how any licence exemptions might apply?	Refer to the Surface Water Assessment (HEC, 2020).
7	Described the characteristics of the water requirements?	Refer to the Surface Water Assessment (HEC, 2020).
8	Determined if there are sufficient water entitlements and water allocations that are able to be obtained for the activity?	Section 2.1.2 describes the entitlements held by the proponent and indicates these are sufficient to account for water taken from the potentially affected water sources. The proponent will ensure all necessary water licences are obtained for the development.
9	Considered the rules of the relevant water sharing plan and if it can meet these rules?	Refer to Section 8.2.

AIP requirement		Proponent response
10	Determined how it will obtain the required water?	Via seepage to the mine face (refer to Section 7.1.1). MPO also hold licences to take water from the regulated sections of the Hunter River. Refer to Section 8.2 for discussion regarding available of water access licences.
11	Considered the effect that activation of existing entitlement may have on future available water determinations?	Not applicable.
12	Considered actions required both during and post-closure to minimise the risk of inflows to a mine void as a result of flooding?	Refer to the Surface Water Assessment (HEC, 2020).
13	Developed a strategy to account for any water taken beyond the life of the operation of the Project?	Refer to Section 8.2.
	Will uncertainty in the predicted inflows have a significant impact on the environment or other authorised water users? Items 14-16 must be addressed if so.	Refer to Section 9.
14	Considered any potential for causing or enhancing hydraulic connections, and quantified the risk?	Open cut mining is not expected to generate significant changes in hydraulic connections beyond the pit shell.
15	Quantified any other uncertainties in the groundwater or surface water impact modelling conducted for the activity?	Refer to Section 9.
16	Considered strategies for monitoring actual and reassessing any predicted take of water throughout the life of the Project, and how these requirements will be accounted for?	Refer to Sections 8.2 and 10.

Table B1.2 Determining water predictions

AIP requirement		Proponent response
1	Establishment of baseline groundwater conditions?	Refer to Section 5. Water quality and level data has been collected at MPO since 2003 for some of the key groundwater units and tested for a selection of water quality analytes. The monitoring network has been adapted over time to ensure that good spatial coverage is maintained.
2	A strategy for complying with any water access rules?	Refer to Section 8.2.
3	Potential water level, quality or pressure drawdown impacts on nearby basic landholder rights water users?	See Table 8.2
4	Potential water level, quality or pressure drawdown impacts on nearby licensed water users in connected groundwater and surface water sources?	Refer to Section 8.1.
5	Potential water level, quality or pressure drawdown impacts on groundwater dependent ecosystems?	There are no high priority GDEs, as defined within WSPs, within the predicted area of drawdown.
6	Potential for increased saline or contaminated water inflows to aquifers and highly connected river systems?	The final void at MPO a will act as a 'groundwater sink' therefore no saline or contaminated water inflows to aquifers and highly connected river systems will occur. There is the potential for water from the MPO void to migrate to neighbouring voids that are predicted to have lower final void water levels,.
7	Potential to cause or enhance hydraulic connection between aquifers?	Only open cut mining is proposed which is not expected to generate significant changes in hydraulic connection beyond the pit shell.
8	Potential for river bank instability, or high wall instability or failure to occur?	Refer to surface water report (HEC, 2020).
9	Details of the method for disposing of extracted activities (for CSG activities)?	N/A

There are two levels of minimal impact considerations specified in the AIP. If the predicted impacts are less than the Level 1 minimal impact considerations, then these impacts will be considered as acceptable. Where the predicted impacts are greater than the Level 1 minimal impact considerations then the AIP requires additional studies to fully assess these predicted impacts. If this assessment shows that the predicted impacts do not prevent the long-term viability of the relevant water-dependent asset, then the impacts will be considered to be acceptable. The modelling indicates the Level 1 minimal impact consideration thresholds could be exceeded for MPO (incorporating the Project) in the form of > 2 m drawdown at six private bores. However, of these six bores there is only one bore that is active and not dry where the drawdown of >2 m can be directly attributed to MPO

B1.2 Planning Environmental Assessment Requirements (SEARs)

Table B1.3 Key SEARs Issues - Water

Requirement	Comment relating to MPO Project
A detailed site water balance, including a description of site water demands, water disposal methods (inclusive of volume and frequency of any water discharges), water supply infrastructure and water storage structure.	Refer to surface water report (HEC, 2020).
Identification of any licensing requirements or other approvals under the NSW *Water Act 1912* and/or Water Management Act 2000.	Section 2.1 discusses the requirements of the Water Management Act.
Demonstration that water for the construction and operation of the proposed development can be obtained from an appropriately authorised and reliable supply in accordance with the operating rules of any relevant Water Sharing Plan (WSP) or water source embargo.	Section 7 and Section 8 discuss the potential mining and post mining takes from the proposed development in relation to the relevant WSPs.
An assessment of any likely flooding impacts of the development.	Refer to surface water report (HEC, 2020).
The measures which would be put in place to control sediment runoff and avoid erosion.	Refer to surface water report (HEC, 2020).
An assessment of the likely impacts of the development on the quantity and quality of existing surface and groundwater resources including a detailed assessment of proposed water discharge quantities and quality against receiving water quality and flow objectives.	Section 7 and Section 8 discuss the likely impacts on groundwater resources. Refer to surface water report (HEC, 2020) for surface water components.
An assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure, and other water users.	Section 7 and Section 8 discuss the likely impacts on aquifers and other groundwater users.
An assessment of the likely impacts of the development on a water resource, in relation to coal seam gas development and large coal mining development under the Environment Protection and Biodiversity Conservation Act 1999 (see Attachment 3).	See Table B1.4 for responses to this requirement.

Table B1.4 SEARs Attachment 3 – Commonwealth Department of Environment and Energy assessment requirements.

Assessment Requirement 15	Comment relating to MPO Project
a) Hydrogeological assessment:	---
i. Provision of hydrogeological conceptualisations.	Section 5.9 presents the site conceptualisation Sections 3, 4, & 5 present the supporting datasets.
ii. Descriptions of geology and hydrogeology.	Sections 4 and 5 present the geological and hydrogeological information.
iii. Predictions of groundwater changes over the life of the proposed project (e.g. using numerical groundwater models).	Section 7 presents the predicted groundwater changes over the life of the mine generated using the numerical groundwater model.
iv. Predictions of groundwater recovery beyond the life of the proposed project (e.g. using numerical groundwater models).	Section 7.2 presents the predicted post mining groundwater changes generated using the numerical groundwater model.
v. Reference all of the above to analysis on groundwater quality and quantity data gathered from the existing project.	Refer to Section 7.
b) Surface water assessment:	Refer to surface water report (HEC, 2020).
c) Ecological and ecohydrological assessment:	Refer to ecology report.
d) Cumulative impact assessment:	---
i. Identify all surrounding existing and known future operations that could contribute cumulatively to surface water and groundwater impacts.	Section 1.3.3 discusses surrounding mining operations.
e) Final landform and rehabilitation assessment:	---
i. Provision of a rehabilitation strategy.	
ii. Predictions of final void water quality and quantity.	Refer to surface water assessment (HEC, 2020).
iii. Discussion on re-equilibration of groundwater and eventual discharges to the environment.	Section 7.2 discusses post mining recovery and potential long term impacts.
iv. Comprehensive risk assessment.	Risks are identified in Section 5.10 and Section 7, with a management plan discussed in Section 10. Numerical model uncertainty analysis is presented in Appendix A.

B2 Compliance with Commonwealth government policy

B2.1 Commonwealth Assessment Requirements

Table B2.1 Summary of impacts to the water quality of the water resource compared to the DoEE guidelines

Is there a substantial change in water quality of the water resource:	Comment
Create risks to human or animal health or the condition of the natural environment?	No
Substantially reduce the amount of water available for human consumptive uses or for other uses dependent on water quality?	No
Cause persistent organic chemicals, heavy metals, salt or other potentially harmful substances to accumulate in the environment?	Evaporation will concentrate salt in the final void lakes.
Results in worsening of local water quality where local water quality is superior to local or regional water quality objectives (i.e. ANZECC guidelines for Fresh and Marine Water Quality)?	No
Salt concentration/generation?	Evaporation will concentrate salt in the final void lakes.
Cumulative impact?	Cumulative impacts have been predicted using a numerical model. The cumulative impacts are not predicted to result in a substantial changed in water quality.
If significant impact on hydrology or water quality above, the likelihood of significant impacts to function and ecosystem integrity are to be assessed. The ecosystem function and integrity of a water resource includes the ecosystem components, processes and benefits/services that characterise the water resource.	No

B2.2 IESC Information Guidelines for Coal Seam Gas and Large Coal Mining Development

The Independent Expert Scientific Committee (IESC) on Coal Seam Gas and Large Coal Mining Development has information guidelines for advice on coal seam gas and large coal mining development proposals (IESC, 2018). The following tables specify where the IESC information requirements for individual proposals have been addressed within this report.

Table B2.2 Description of the proposal

Project Information	Addressed in section
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.	Sections 1,3,4 & 5
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 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 1.1
Describe how impacted water resources are currently being regulated under state or Commonwealth law, including whether there are any applicable standard conditions.	Section 2

Table B2.3 Risk Assessment

Project Information	Addressed in section
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.	Sections 5.10, 7, 10 & Appendix A
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 10
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 6 & Appendix A
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.	Sections 7 & 10

Table B2.4 Groundwater – Context and conceptualisation

Project Information	Addressed in section
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
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.	Sections 4, & 5
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 5.3
Provide time series level and water quality data representative of seasonal and climatic cycles.	Section 5.5 & Appendix A
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 5
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
Describe the likely recharge, discharge and flow pathways for all hydrogeological units likely to be impacted by the proposed development.	Section 5
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

Table B2.5 Groundwater – Numerical modelling

Project Information	Addressed in section
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.	Section 6 & Appendix A
Undertaken groundwater modelling in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al. 2012), including independent peer review.	Section 6 & Appendix A
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 A
Describe each hydrogeological unit as incorporated in the groundwater model, including the thickness, storage and hydraulic characteristics, and linkages between units, if any.	Appendix A
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 5.10 & Appendix A
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 & Appendix A
Identify the volumes of water predicted to be taken annually with an indication of the proportion supplied from each hydrogeological unit.	Sections 7 & 8
Undertake model verification with past and/or existing site monitoring data.	Appendix A
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 5.9
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 A2
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).	Section 9
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.	Section 5
Undertake an uncertainty analysis of model construction, data, conceptualisation and predictions (see Middlemis and Peeters).	Section 9
Provide a program for review and update of models as more data and information become available, including reporting requirements.	Section 10
Provide information on the magnitude and time for maximum drawdown and post-development drawdown equilibrium to be reached.	Section 7.2

Table B2.6 Groundwater – Impacts on water resources and water dependent assets

Project Information	Addressed in section
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 8
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.	Sections 5 and 8
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 8
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 5.7
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 8
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 10
Provide a description and assessment of the adequacy of proposed measures to prevent/minimise impacts on water resources and water-dependent assets.	Section 10

Table B2.7 Groundwater – Data and monitoring

Project Information	Addressed in section
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
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
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
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
Ensure water quality monitoring complies with relevant National Water Quality Management Strategy (NWQMS) guidelines (ANZECC/ARMCANZ 2000) and relevant legislated state protocols (e.g. QLD Government 2013).	Section 5

Table B2.8 Water dependent assets – Context and conceptualisation

Project Information	Addressed in section
Identify water-dependent assets, including: • water-dependent fauna and flora and provide surveys of habitat, flora and fauna (including stygofauna) (see Doody et al. [in press]). • public health, recreation, amenity, Indigenous, tourism or agricultural values for each water resource.	Section 5.8
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*. [in press]).	Section 5.8
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 5.8
Estimate the ecological water requirements of identified GDEs and other water-dependent assets (see Doody *et al*. [in press]).	Section 5.8
Identify the hydrogeological units on which any identified GDEs are dependent (see Doody *et al*. [in press]).	Section 5.8
Provide an outline of the water-dependent assets and associated environmental objectives and the modelling approach to assess impacts to the assets.	Section 5.8
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) triggers and impact thresholds for water-dependent assets (e.g. threshold at which a significant impact on an asset may occur).	Section 5.8

Table B2.9 Water dependent assets – Impacts, risk assessment and management of risks

Project Information	Addressed in section
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*. [in press]).	Section 8.4
Describe the potential range of drawdown at each affected bore, and clearly articulate of the scale of impacts to other water users.	Section 8.3
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 8.5
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.	Refer to ecology 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.	Refer to surface water assessment and ecology report
Assess the overall level of risk to water-dependent assets through combining probability of occurrence with severity of impact.	Refer to ecology report
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.	Refer to ecology report
Propose mitigation actions for each identified impact, including a description of the adequacy of the proposed measures and how these will be assessed.	Refer to ecology report

Table B2.10 Water dependent assets – Data and monitoring

Project Information	Addressed in section
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*. [in press]).	Refer to Biodiversity Development Assessment Report
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*. [in press]).	Refer to Biodiversity Development Assessment Report
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*. [in press]).	Refer to Biodiversity Development Assessment Report
Describe the proposed process for regular reporting, review and revisions to the monitoring program.	Refer to Biodiversity Development Assessment Report
Ensure ecological monitoring complies with relevant state or national monitoring guidelines (e.g. the DSITI guideline for sampling stygofauna [QLD Government 2015]).	Refer to Biodiversity Development Assessment Report

Table B2.11 Water and salt balance and water management strategy

Project Information	Addressed in section
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.	Refer to surface water assessment
Describe the water requirements and on-site water management infrastructure, including modelling to demonstrate adequacy under a range of potential climatic conditions.	Refer to surface water 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.	Refer to surface water assessment
Provide salt balance modelling that includes stores and the movement of salt between stores, and takes into account seasonal and long-term variation.	Refer to surface water assessment

Table B2.12 Cumulative Impacts – Context and conceptualisation

Project Information	Addressed in section
Provide cumulative impact analysis with sufficient geographic and temporal boundaries to include all potentially significant water-related impacts.	Section 8.5
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.	Section 8

Table B2.13 Cumulative Impacts – Impacts

Project Information	Addressed in section
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 8
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 8

Table B2.14 Cumulative Impacts – Mitigation, monitoring and management

Project Information	Addressed in section
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.	Refer to EIS Main Text
Identify measures to detect and monitor cumulative impacts, pre and post development, and assess the success of mitigation strategies.	Refer to EIS Main Text
Identify cumulative impact environmental objectives.	Refer to EIS Main Text
Describe appropriate reporting mechanisms.	Refer to EIS Main Text
Propose adaptive management measures and management responses.	Refer to EIS Main Text

Table B2.15 Final landform and voids – coal mines

Project Information	Addressed in section
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.	Preliminary Rehabilitation and Mine Closure Strategy
Assess the adequacy of modelling, including surface water and groundwater quantity and quality, lake behaviour, timeframes and calibration.	Preliminary Rehabilitation and Mine Closure Strategy
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.	Preliminary Rehabilitation and Mine Closure Strategy
Evaluate mitigating inflows of saline groundwater by planning for partial backfilling of final voids.	Preliminary Rehabilitation and Mine Closure Strategy
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.	Preliminary Rehabilitation and Mine Closure Strategy

Project Information	Addressed in section
For other final landform options considered sufficient detail of potential impacts should be provided to clearly justify the proposed option.	
Assess the probability of overtopping of final voids with variable climate extremes, and management mitigations.	Surface Water Assessment

Table B2.16 Acid-forming materials and other contaminants of concern

Project Information	Addressed in section
Identify the presence and potential exposure of acid-sulphate soils (including oxidation from groundwater drawdown).	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.	Geochemistry Assessment
Identify other sources of contaminants, such as high metal concentrations in groundwater, leachate generation potential and seepage paths.	Geochemistry Assessment
Describe handling and storage plans for acid-forming material (co-disposal, tailings dam, and encapsulation).	Geochemistry Assessment
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.	Geochemistry Assessment
Describe proposed measures to prevent/minimise impacts on water resources, water users and water-dependent ecosystems and species.	Geochemistry Assessment