




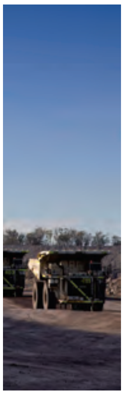

MTW / HVO
Lemington Underground Mine Water Storage Project

Modification Report

APPENDIX A

Groundwater Assessment

YANCOAL
兖煤澳大利亚有限公司

Australasian Groundwater & Environmental Consultants

Report on

Lemington Underground Water Storage Groundwater Assessment

Prepared for
Yancoal Australia Pty Ltd

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Table of contents

Table of contents

List of figures

Table of contents

Table of contents

List of tables

List of appendices

Table of contents

Lemington Underground Water Storage – Groundwater Assessment

1 Introduction

The Lemington Underground area was mined from 1971 until 1992 and is situated to the north of Mount Thorley Warkworth (MTW) and south of Hunter Valley Operations (HVO) South (Figure 1.1). Underground mining at Lemington occurred in the Mount Arthur coal seam (Rust, 1997) by utilising longwall and bord and pillar methods in different parts of the mine. Currently, the completed Lemington Underground workings sit within mining leases under the control of Hunter Valley operations, which is jointly owned by Yancoal Australia Ltd (Yancoal) and Glencore Coal Pty Ltd (Glencore).

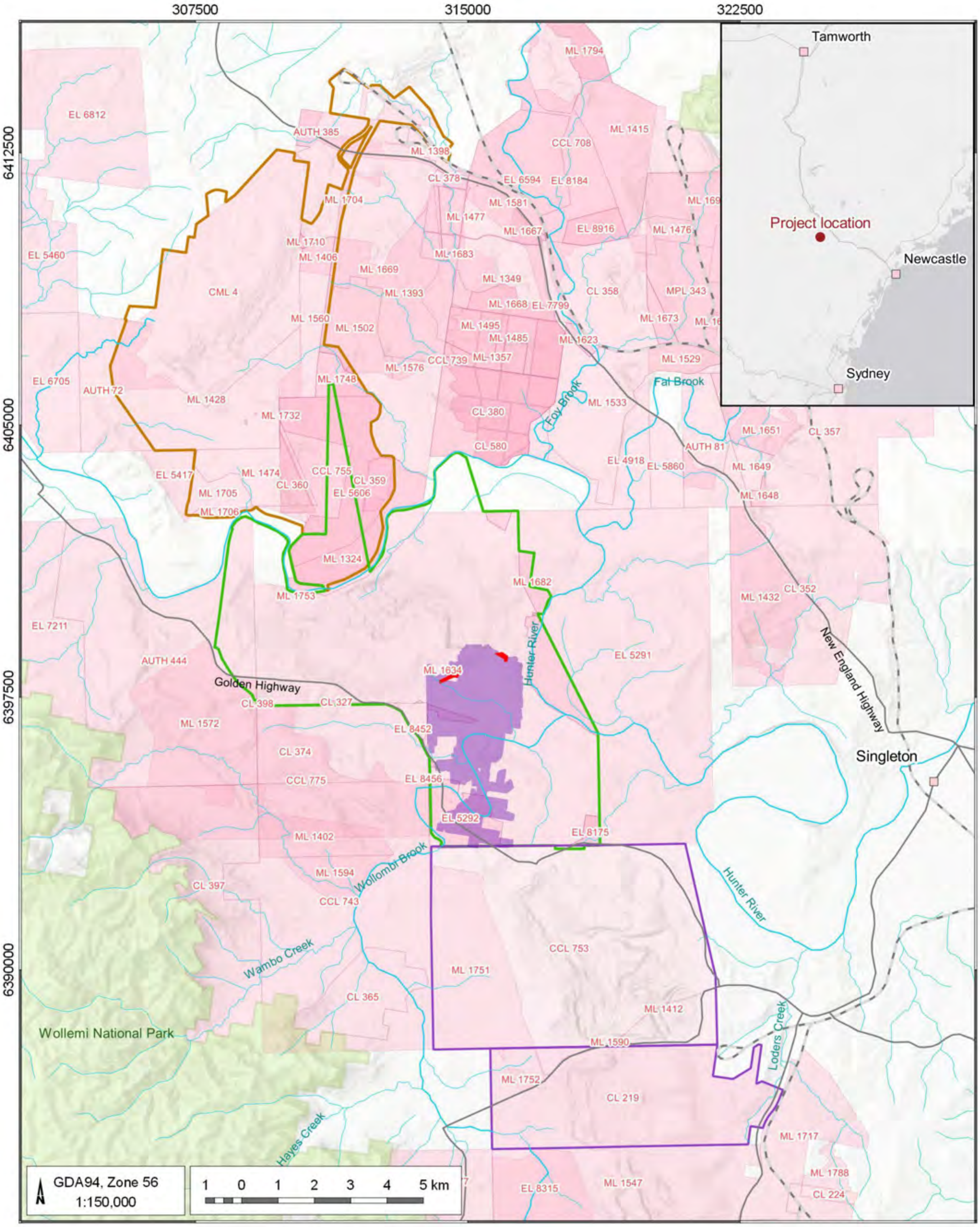
Glencore and Yancoal intend to prepare applications to modify the current HVO South Project Approval 06_0621 and the Warkworth State Significant Development (SSD) 6464 consent. The main purpose of the modification is to approve the use of the completed Lemington Underground workings as an additional water storage facility which would both receive and provide water to other parts of HVO South (and HVO North under existing water sharing arrangements) and MTW water management systems.

1.1 Objectives and scope of work

The objective of this groundwater assessment is to assess the impact of the proposed modification on the groundwater regime and address the requirements of the NSW government legislation and policies. The groundwater assessment comprises two parts: a description of the existing hydrogeological environment, and an assessment of the impacts of the modification on that environment.

Tasks completed in undertaking this assessment included:

- review of existing background data and previous hydrogeological investigations including:
  - Groundwater and Mine Water Management Study South Lemington Mine (Rust, 1997);
  - HVO South Modification 5 Groundwater Study (AGE, 2017);
  - MTW 2020 Annual Groundwater Review (SLR, 2021); and
- analysis of the existing water level, quality, and extraction data pertaining to the assessment area;
- determination of the groundwater storage capacity of the abandoned Lemington Underground workings;
- assessment of impacts resulting from the modification, including impacts on groundwater levels and baseflow;
- assessment of potential impacts at known and potential groundwater dependent ecosystem (GDE) locations resulting from short and/or long-term changes in groundwater levels and quality;
- assessment against the Aquifer Interference Policy (AIP) (DPI – Office of Water, 2012a); and
- recommendations for groundwater impact monitoring and management.



LEGEND

- Populated place
- Natural drainage feature
- Road
- Rail
- Lemington Underground workings
- Historic Boxcut
- HVO North development consent boundary
- HVO South development consent boundary
- MTW Leases
- Coal titles
- National Park

Lemington UG Water Storage (G1468J)

Project location

AGE

DATE 11/06/2021

FIGURE No: **1.1**

Source: LiDAR DEM - © Department Finance, Services and Innovation.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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1.2 Report structure

This report is structured as follows:

- Section 1 – Introduction: provides an overview of the modification and the assessment scope.
- Section 2 – Regulatory framework: provides an overview of the relevant regulatory framework.
- Section 3 – Existing HVO and MTW operations: describes the historical and current mining operations at HVO and MTW.
- Section 4 – Environmental setting: describes the climate, surface drainage, regional geology, and local stratigraphy.
- Section 5 – Hydrogeological setting and existing impact assessment describes the hydrostratigraphic units, water levels and flow directions, surface water flows, potential storage capacity of the Lemington Underground, groundwater inflows, water quality of existing surface water storage facilities and relevant groundwater sources, and GDE's.
- Section 6 – Impact assessment – proposed modification: provides an assessment of the anticipated incremental impacts of the modification on groundwater users and the receiving environment.
- Section 7 – References.
- Appendix A – Hydrographs.
- Appendix B – Time-series water quality graphs.

1.3 Modification description

The proposed modification seeks approval to more fully integrate the available water storage in the completed Lemington Underground workings into the mine water management systems of HVO South and MTW. As required to meet operational requirements, water would be transferred into and out of the workings from other existing surface water storages to assist with balancing inflows and outflows to these systems. Water is currently extracted from the workings via a single extraction bore (LUG Bore) and is used as a supplementary operational water supply. The modifications would include (Figure 1.2):

- construction of three new bore sites and duplication of the existing LUG bore to access the Lemington Underground Mine void;
- use of these four bore sites to transfer water from HVO and MTW into the former Lemington Underground Mine void and/or extract water from the void and transfer back to HVO and MTW; and
- development of supporting infrastructure (e.g. pipelines and powerlines).

To allow for ease of management between the HVO and MTW operations, duplicate bores and infrastructure may be constructed at each location.

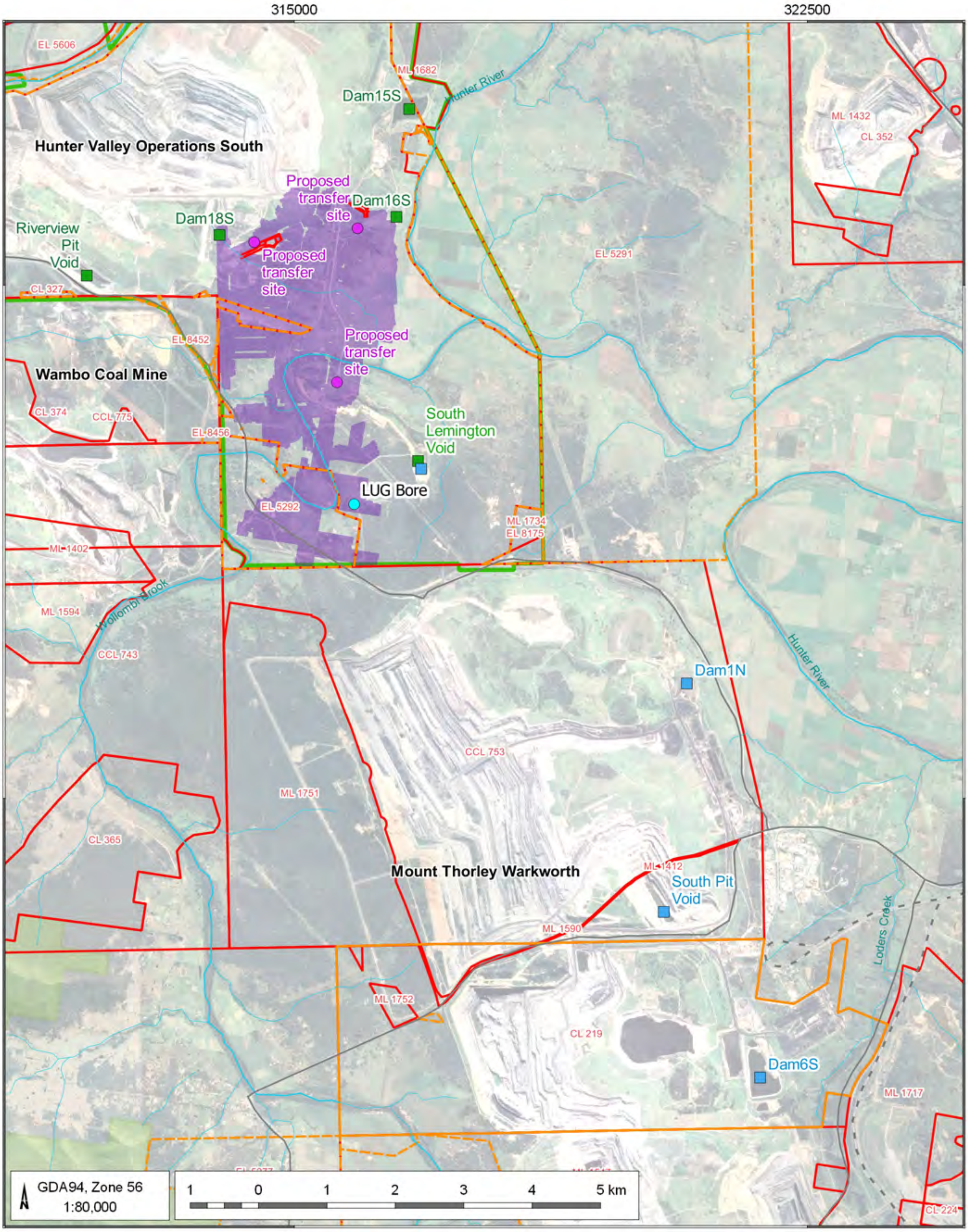
All water transfers into and out of the former Lemington Underground Mine void would be metered to enable full accounting of water transfers.

Figure 1.2 shows the locations of the main surface water storages which form part of the existing HVO South and MTW mine water management systems. The location of a further three potential water transfer locations proposed in the modification, and the existing LUG bore location are also shown. Each water transfer location will likely comprise two groundwater bores.

The intention of this modification is to use the former Lemington Underground workings as a water storage, similar to storing water in an open cut void, thereby supplementing existing pit water storages (i.e. Riverview Void and South Lemington Pit), which are planned to be mined through (or impacted by planned mining) in the progression of the approved HVO South mine plan (refer Table 3.1). The additional water storage provided by the modification is required to alleviate the current and upcoming water management constraints and to avoid major interruptions to mining operations.

The modification proposes to transfer site water into the former underground workings and then extract water as required to meet make-up water demands. Extraction of water over and above that transferred into the underground storage would be accounted for against a relevant Water Access Licence (WAL) in any relevant reporting period (i.e. only if the total annual extraction of water out of the underground mine water storage is greater than the total volume transferred in the void of storage).

Note, currently water is extracted from the Lemington Underground workings under licence from a single bore installed towards the south of the workings (referred to as the LUG bore). The extracted water is currently pumped either directly to MTW or to the South Lemington Pit 1 void, from where it is pumped and utilised by MTW. Other than natural groundwater inflows no water is currently transferred into the underground void for storage or other purposes.



LEGEND

- Populated place
- Natural drainage feature
- Road
- Rail
- Lemington Underground workings
- Historic Boxcut
- Exploration Licence Boundary
- Mining and Coal Lease Boundary
- HVO South development consent boundary
- National Park
- Current extraction bore
- Proposed water transfer bores
- MTW surface water storages
- HVO surface water storages

Lemington UG Water Storage (G1468J)

General Project Arrangement

AGE

DATE
14/09/2021

FIGURE No:
1.2

Source: LiDAR DEM - © Department Finance, Services and Innovation.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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2 Regulatory framework

This Section outlines the regulatory framework of relevance to this groundwater assessment report which has been prepared considering the following legislation, policy and guidelines relating to groundwater:

- NSW Government:
  - Legislation:
    - Water Management Act 2000, Water Management (General) Regulation 2018 and the associated Water Sharing Plans (WSPs): and
    - Environmental Planning and Assessment Act 1979 (EP&A Act).
  - Policy and Plans:
    - Aquifer Interference Policy (AIP)

The sections below summarise the intent of the key legislation and policy above and how they apply to the modification.

2.1 Water Management Act 2000

The NSW *Water Management Act 2000* provides for the “protection, conservation and ecologically sustainable development of the water sources of the State”. The *Water Management Act 2000* provides arrangements for controlling land-based activities that affect the quality and quantity of the State’s water resources.

The *Water Management Act 2000* includes the concept of “no more than minimal harm” for both the granting of water access licences (WALs) and the granting of approvals. Aquifer interference approvals are not to be granted unless the Minister is satisfied that adequate arrangements are in force such that no more than minimal harm will be done to any water source, or its dependent ecosystems, as a consequence of it being interfered with in the course of the activities to which the approval relates.

Under section 4.41 1(g) of the EPA&A Act, SSD developments are exempt from requiring a water use approval, a water management work approval or an activity approval under the *Water Management Act 2000*.

2.2 NSW Environmental Planning and Assessment Act 1979

The EP&A Act provides a system of environmental planning and assessment for the State of NSW. Section 4.12(8) of the EP&A Act requires that a development application for a SSD is to be accompanied by an EIS prepared by or on behalf of the applicant in the form prescribed by the regulations.

In this case given the proposal represents a relatively minor modification to two existing approvals preparation of an EIS is not required. Nevertheless, an assessment of the incremental impacts of operating the Lemington Underground workings as a water storage facility, rather than a source of water, on groundwater resources is required. In particular, the modification needs to be assessed against the various state groundwater policies as described below.

2.3 State groundwater policy

2.3.1 Aquifer Interference Policy

The *Water Management Act 2000* defines an aquifer interference activity as involving any of the following:

- penetration of an aquifer;
- interference with water in an aquifer;
- obstruction of the flow of water in an aquifer;
- taking of water from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations; and
- disposal of water taken from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations.

Examples of aquifer interference activities include mining, coal seam gas extraction, injection of water, and commercial, industrial, agricultural, and residential activities that intercept the water table or interfere with aquifers.

The AIP states that:

"*all water taken by aquifer interference activities, regardless of quality, needs to be accounted for within the extraction limits defined by the water sharing plans. A water licence is required under the WM Act (unless an exemption applies, or water is being taken under a basic landholder right) where any act by a person carrying out an aquifer interference activity causes:*

- *the removal of water from a water source; or*
- *the movement of water from one part of an aquifer to another part of an aquifer; or*
- *the movement of water from one water source to another water source, such as:*
  - *from an aquifer to an adjacent aquifer; or*
  - *from an aquifer to a river/lake; or*
  - *from a river/lake to an aquifer".*

In addition to volumetric water licensing considerations, the AIP requires details of potential:

- *"water level, quality or pressure drawdown impacts on nearby water users who are exercising their right to take water under a basic landholder right;*
- *water level, quality or pressure drawdown impacts on nearby licensed water users in connected groundwater and surface water sources;*
- *water level, quality or pressure drawdown impacts on groundwater dependent ecosystems;*
- *increased saline or contaminated water inflows to aquifers and highly connected river systems;*
- *to cause or enhance hydraulic connection between aquifers; and*
- *for river bank instability, or high wall instability or failure to occur."*

In particular, the AIP describes minimal impact considerations for aquifer interference activities based upon whether the water source is highly productive or less productive and whether the water source is alluvial or porous/fractured rock in nature. The AIP prescribes a maximum of 2 metres (m) cumulative decline at any water supply work. If this impact threshold is exceeded, make good provisions will apply for the impacted water supply work.

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 (L/s).

Highly productive groundwater sources are further grouped by geology into alluvium, 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.

In the vicinity of HVO South and MTW only the Quaternary Age alluvial strata associated with Wollombi Brook and the Hunter River are mapped as being “highly productive”. The geological strata present at, or close to, the surface in the remainder of the area, which predominantly comprise Permian Age coal measures (porous and fractured rock), are all categorised as “less productive”.

The minimal impact considerations are a series of threshold levels defining minimal impact on groundwater sources, connected water sources, groundwater dependent ecosystems, 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 6 presents the Project impacts and compares these with AIP thresholds where relevant.

2.4 Water sharing plans and licensing

NSW Water Sharing Plans (WSPs) establish rules for sharing water between the environmental needs of rivers and aquifers, and water users, as well as between different types of water use such as town supply, rural domestic supply, stock watering, industry, and irrigation.

The Department of Planning, Industry and Environment – Water has progressively developed WSPs for rivers and groundwater systems across NSW following the introduction of the *Water Management Act 2000*. The purposes of the WSPs are to protect the health of rivers and groundwater, while also providing water users with perpetual access licences, equitable conditions, and increased opportunities to trade water through separation of land and water.

Three WSPs apply to the aquifers and surface waters within the vicinity of the Project – these are the WSP for the:

- Hunter Regulated River Water Source 2016 (Hunter Regulated WSP) – Hunter River surface water;
- Hunter Unregulated and Alluvial Water Sources 2009 (Hunter Unregulated WSP) – alluvial groundwater; and
- North Coast Fractured and Porous Rock Groundwater Sources 2016 (North Coast Fractured and Porous Rock WSP) – groundwater from Permian interburden and coal.

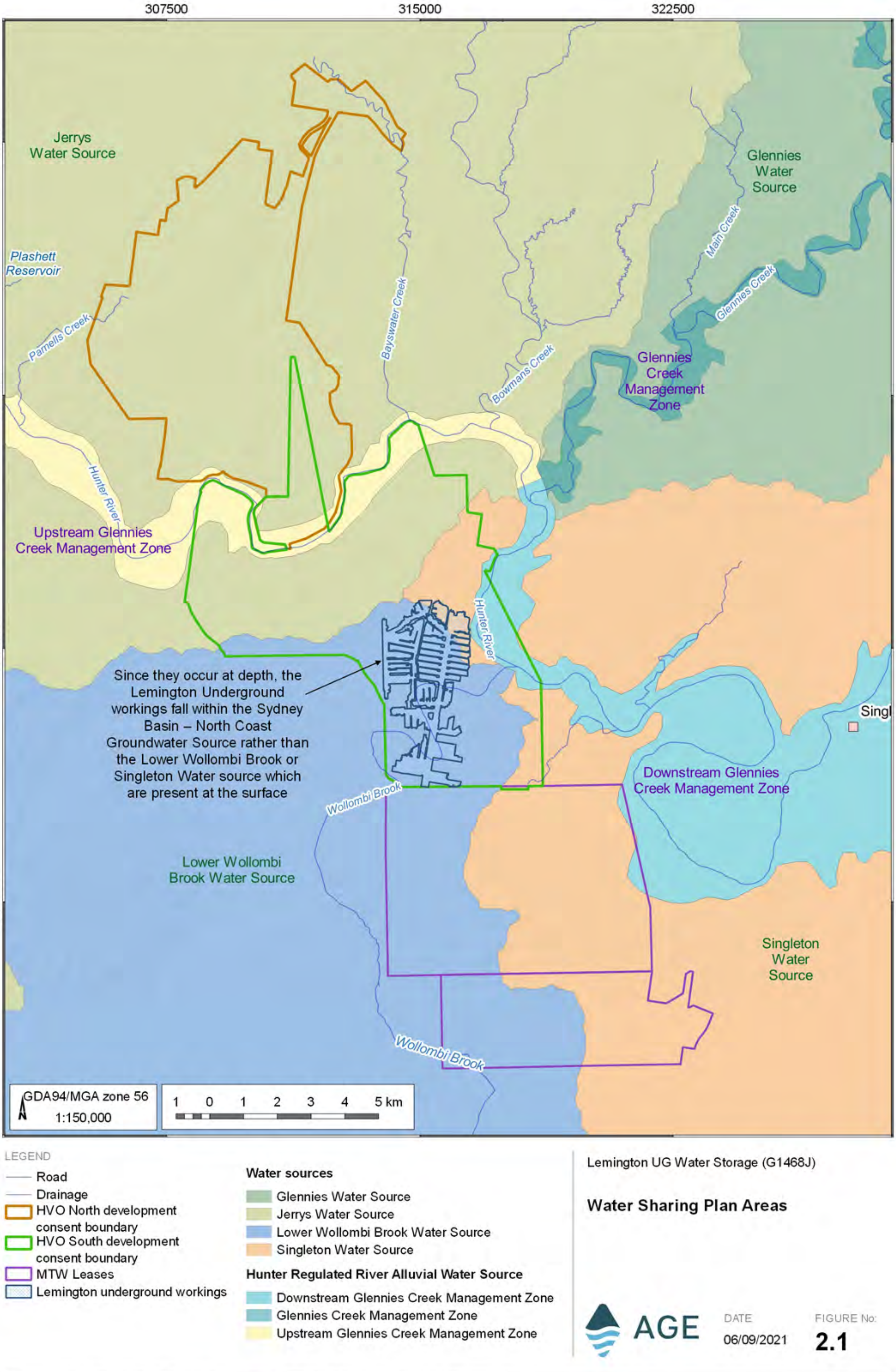
The boundaries of the respective WSP and water sources of the Hunter Regulated and Hunter Unregulated WSPs are shown in Figure 2.1. These WSPs are the main tool used to manage extraction from the Hunter River and associated near surface unconsolidated material. Groundwater resources in the underlying consolidated aquifers underlying the Hunter River Regulated and Hunter River Unregulated WSPs (not shown on the map) are wholly managed by the North Coast Fractured and Porous Rock WSP. The Lemington Underground workings are located in this water source and hence there is potential for the modification to directly affect groundwater resources in the North Coast Fractured and Porous Rock WSP.

The North Coast Fractured and Porous Rock WSP commenced on 1 July 2016 and establishes the management regime relevant for groundwater taken from the Permian bedrock. The Lemington Underground workings and the modification area falls within the Sydney Basin – North Coast Groundwater Source of the North Coast Fractured and Porous Rock WSP.

The Hunter Regulated River WSP is divided into three management zones (Zone 1, Zone 2, and Zone 3). The zones are defined from a single common point, which is the junction of Glennies Creek with the Hunter River. The Hunter River within the modification area is managed by Zone 1B up to the Glennies Creek junction, Zone 2A up to the Wollombi Brook junction, and Zone 2B for the remainder of the river until the downstream extent of the Hunter Regulated water source extends outside the modification area.

The Hunter Unregulated WSP includes the unregulated rivers and creeks within the Hunter River catchment, the highly connected alluvial groundwater (above the tidal limit) and the tidal pool areas. In total, there are 39 water sources covered by the Hunter Unregulated WSP and nine of these are further sub-divided into management zones. HVO South, MTW, and the Lemington Underground workings are located within or in close proximity to the Jerrys Water Source, Glennies Water Source, Singleton Water Source and the Lower Wollombi Brook Water Source.

As discussed above since the Lemington Underground workings are located in the North Coast Fractured and Porous Rock WSP no direct impacts on surface water resources or associated near surface unconsolidated strata are likely, although indirect impacts are possible as a result of the modification.



Lemington UG Water Storage (G1468J)

Water Sharing Plan Areas

AGE

DATE 06/09/2021

FIGURE No: 2.1

Source: ELVIS LiDAR DEM (accessed April 2019 ; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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3 Existing MTW and HVO Operations

3.1 Lemington Underground

Historic mining at the Lemington Underground commenced in 1971 via two box cuts (Figure 3.1) and targeted the Mount Arthur coal seam (Rust, 1997). Coal extraction ceased in 1992. As shown in Figure 3.1, both longwall, and bord and pillar mining techniques were utilised in different parts of the workings. Start and end dates for other approved mining activities in the HVO South and MTW mining lease areas are summarised in Table 3.1 and are discussed further in Sections 3.2 and 3.3.

Extraction of the Mount Arthur coal seam commenced from the north and generally progressed towards the south in line with the dip of the seam which is also from north to south. As shown in Figure 3.2, the depth of the workings from the surface therefore also increases from north to south. Towards the northern end of the workings, the Mount Arthur coal seam is present at around 30 m from surface, compared to around 270 m below surface at the southern end of the workings. The working section height across both the longwall and bord and pillar mining areas is understood to have been approximately 2 m. Figure 3.3 shows the floor elevation of the workings that ranges from 40 mAHD at the northern end of the workings to -200 mAHD at the southern end of the workings.

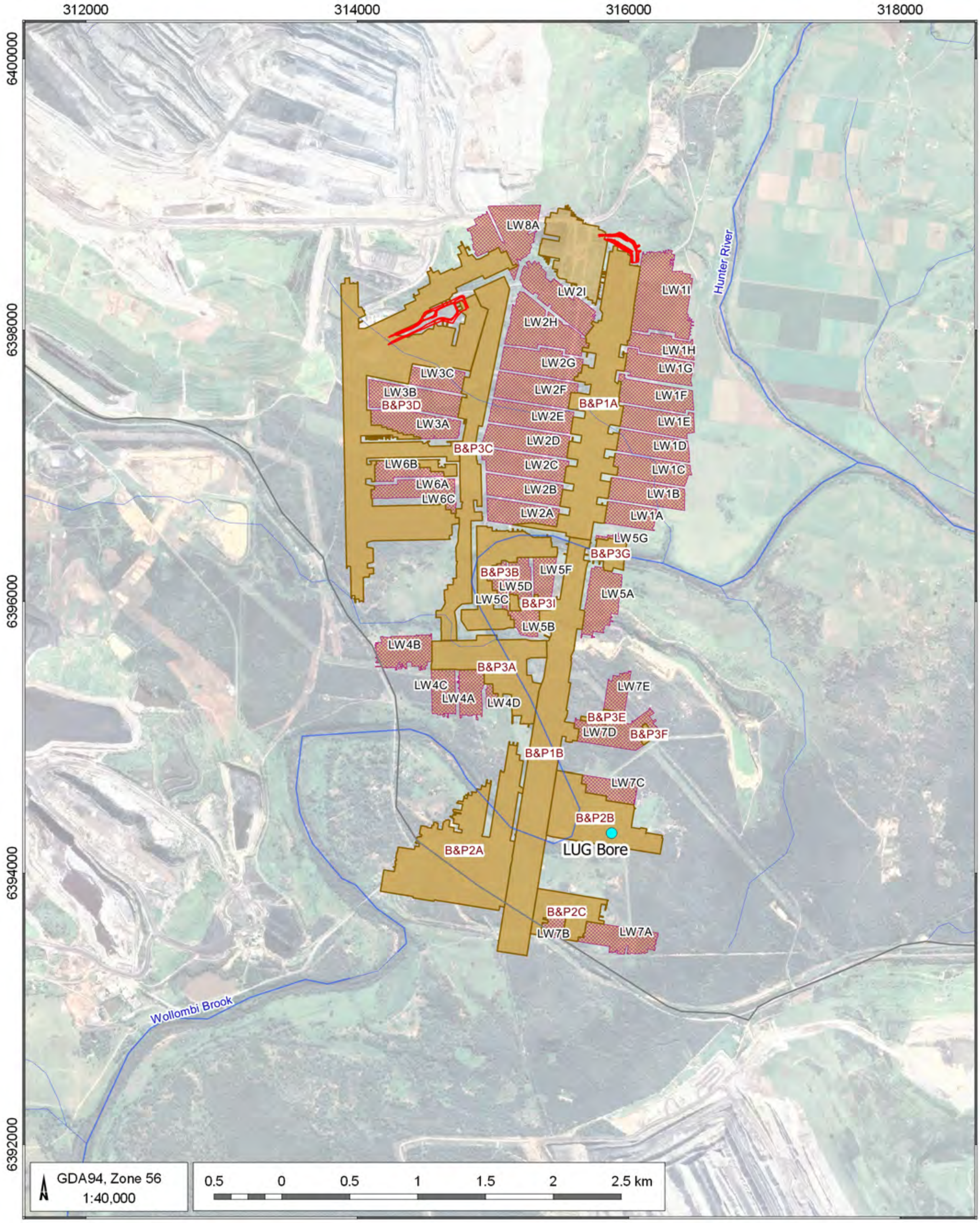
In total, the longwall mining sections of the mine cover an area of around 3.14 square kilometres (km^2) and the bord and pillar sections around 4.35 km^2, including the pillars. Based on the available mapping, pillar dimensions appear to range from 25 to 35 m with the intervening bord (room) width ranging from 5 to 8 m.

Table 3.1 Summary of approved HVO and MTW mine workings and target seams

Reference name	Mine area	Basal coal seam	Start date	End date
HVO South	Cheshunt Pit (open cut)	Bayswater	2002	2030
	Riverview Pit (open cut)	Bayswater	1997	2030
	South Lemington Pit 1 (open cut)	Bowfield	1998	2024
	South Lemington Pit 2 (not yet mined)	Vaux	2015	2030
	Lemington mine (underground)	Mount Arthur	1971	1992
MTW	Warkworth	Warkworth to Mount Arthur	1981	2037
	Mount Thorley	Woodlands Hill	1981	2020

An extraction bore was installed and screened into the Lemington Underground void in 2008 as a supplementary operational water source – the LUG Bore. Extraction from this bore commenced in October 2013.

From 2013 to 2020, a total of 5,520 ML was extracted via the LUG Bore at varying rates, depending on mine make-up water requirements, with a maximum of 1,730 ML extracted in 2019. Figure 3.4 shows the total annual and monthly extraction volumes (where monthly data is available) for the LUG Bore.



LEGEND

- Current extraction bore
- Natural drainage feature
- Road
- Historic Boxcut
- Longwall panels
- Bord & Pillar

Lemington UG Water Storage (G1468J)

Lemington Underground historical workings

AGE

DATE 16/08/2021

FIGURE No: **3.1**

Source: LiDAR DEM - © Department Finance, Services and Innovation.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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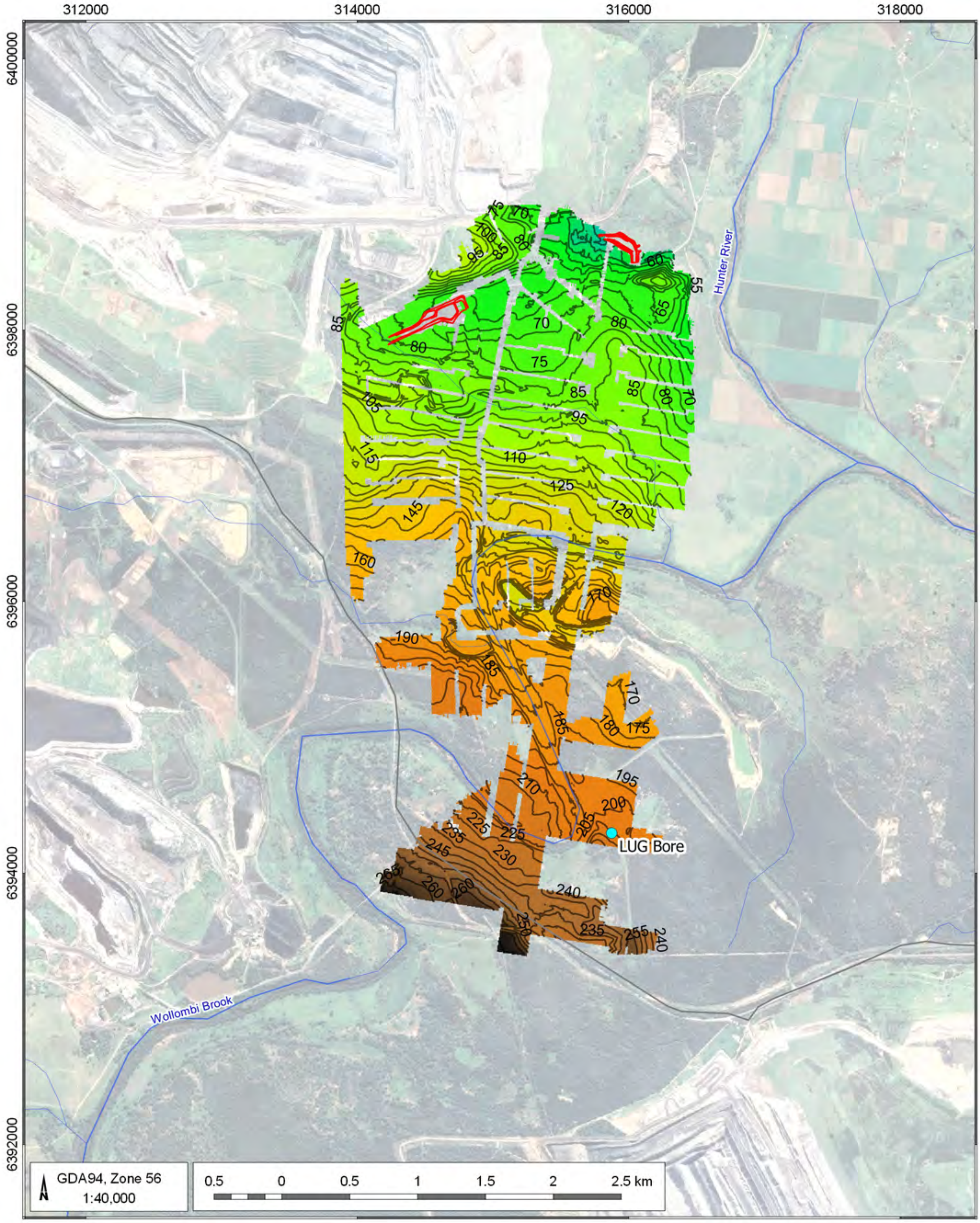


LEGEND

- Current extraction bore
- Natural drainage feature
- Road
- Historic Boxcut
- Contour line

Base depth below surface (m)

- 30
- 50
- 100
- 150
- 200
- 250
- 270

Lemington UG Water Storage (G1468J)

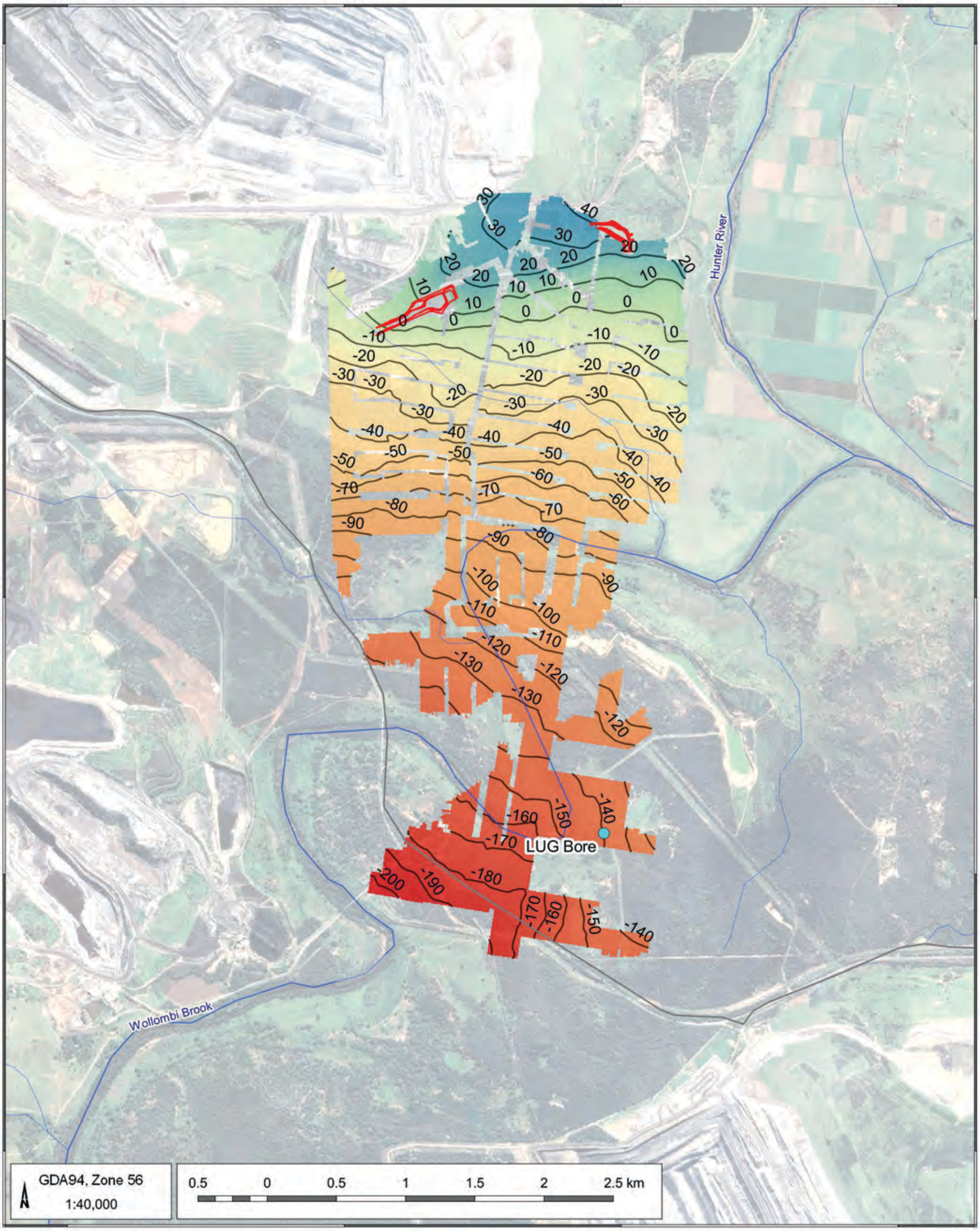
Depth to base of Lemington Underground workings below surface

AGE

DATE 16/08/2021

FIGURE No: **3.2**

Source: LiDAR DEM - © Department Finance, Services and Innovation.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1468J.Lemington_UG_Water_Storage\3_GIS\Workspaces\001_GIA\03.02_G1468J_Depth of Lemington Underground workings below surface.qgs



LEGEND

- Current extraction bore
- Natural drainage feature
- Road
- Historic Boxcut
- Contour line

Floor elevation (mAHD)

- -200
- -150
- -100
- -50
- -20
- -10
- 0
- 10
- 20
- 50

Lemington UG Water Storage (G1468J)

Floor elevation of the Lemington Underground workings

AGE

DATE 03/08/2021

FIGURE No: **3.3**

Source: LiDAR DEM - © Department Finance, Services and Innovation.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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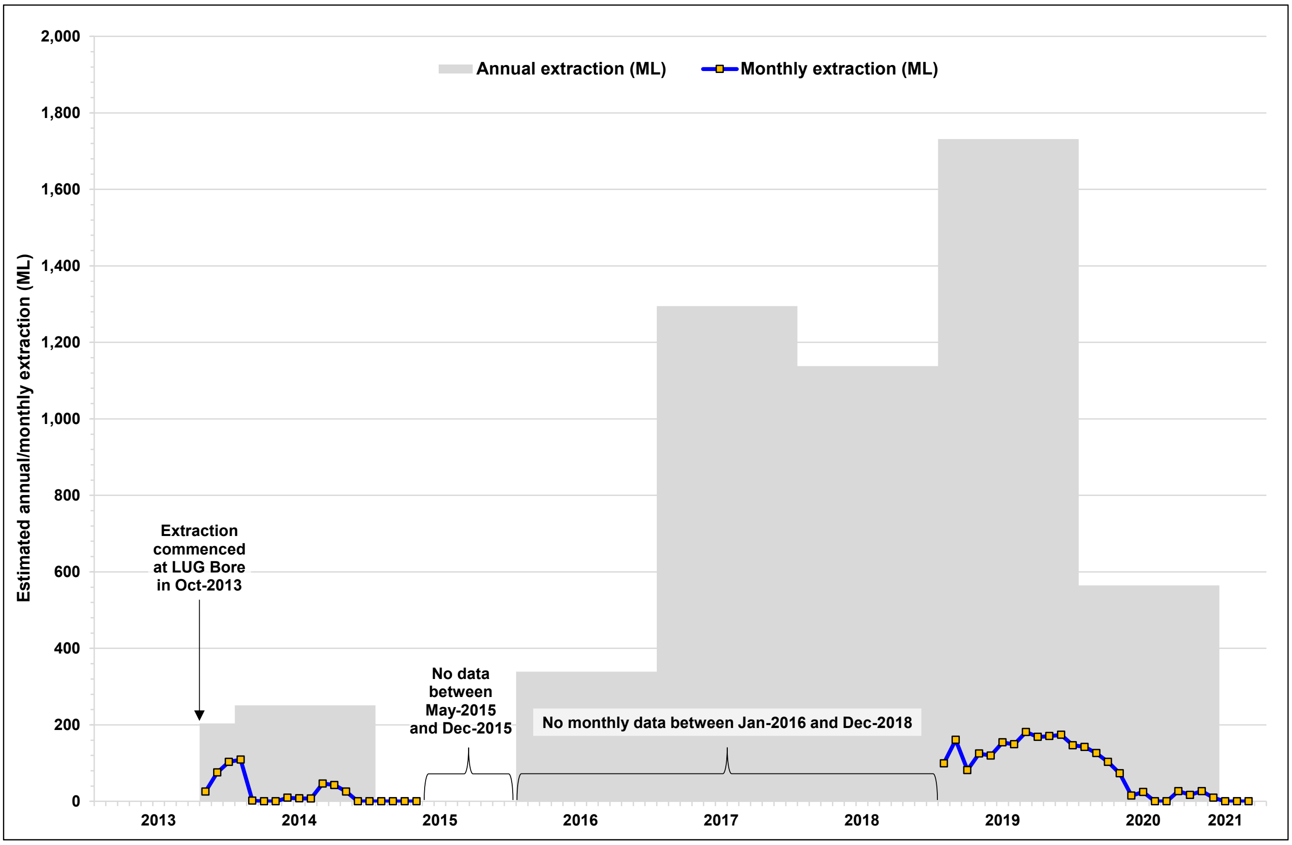


Figure 3.4 Total annual and monthly extraction at the LUG Bore

3.2 HVO South

The Cheshunt, Riverview, and South Lemington (Pit 1 and 2) open cut mines, situated south of the Hunter River, are located within HVO South development consent boundary. Mining from the collective HVO South areas commenced in 1971 and is currently approved to continue until 2030 (Table 3.1). Active mining currently occurs within the Cheshunt and Riverview Pits.

South Lemington Pit 1, located east of the Lemington Underground, ceased active mining in 2001 and South Lemington Pit 2 has never been mined. A groundwater assessment is currently ongoing as part of the HVO Continuation Project extending HVO South's life of mine to 2045.

The proposed modification seeks approval to utilise the Lemington Underground workings as a storage facility from which water can be transferred into and out of. The proposal includes installation of additional extraction bores (accessing the Lemington Underground workings that HVO and MTW will independently operate and manage). The Lemington Underground workings water storage facility would supplement existing open cut pit water storages that are planned to be remined as part of the HVO South approval.

Up until 2017, both MTW and HVO were previously majority owned and operated by Coal & Allied (Rio Tinto). A number of aspects of the operations, including water management, were integrated. This includes the use of available open cut voids at HVO for the storage and reuse of water across both mining complexes.

3.3 MTW

Mining at MTW commenced in the early 1980s with mining progressing west (down-dip) from sub-cropping coal seams of the Jerrys Plains Subgroup. Warkworth Mine's West and South Pits have been mined down to the Mount Arthur coal seam while the North Pit has been mined down to the shallower Warkworth coal seam. Loders Pit, located at Mt Thorley Mine, has been mined to the shallower Woodlands Hill coal seam.

MER (2002) previously described the MTW mining history indicating the site had been operating since 1981 and *"during this time coal has been progressively extracted through the development of four pits – the North, West, South and Woodlands Hill pits…..The different pit orientations have facilitated mining around a localised fold as indicated by the structure contours for the Woodlands Hill seam. During the 21 years of mining to date, operations have progressed without major groundwater influx – most observed seepage is through the floor and most is lost to evaporation in the pit".*

MTW currently manages the extraction of water from the Lemington Underground and pumps the extracted water to the MTW main water storages either directly or via the HVO Lemington South Void (South Lemington Pit 1 void).

4 Environmental setting

4.1 Climate

Climate data for the project area was sourced predominantly from the Scientific Information for Land Owners (SILO[1]) database, for the location nearest to the Lemington Underground. This database contains patched or infilled climatic data including rainfall, temperature, and evaporation from 1889 to the present day. From this data, monthly average rainfall values for the period from 2010 to 2020 have been calculated (Table 4.1). The area experiences a temperate climate characterised by relatively hot summers with regular thunderstorms and relatively mild dry winters. As shown in Table 4.1 long term annual average rainfall as extracted from SILO is 657 millimetres (mm) per year.

For comparison with the local estimate data from the nearest meteorological station situated at Bulga (Station 061191), located approximately 9 km south of Lemington Underground, are also shown in Table 4.1. Data for this station suggest a slightly higher long-term average annual rainfall of 690 mm per year.

Table 4.1 Summary of rainfall averages (2010 to 2020)

Month	Mean monthly rainfall (mm) – SILO	Mean monthly rainfall (mm) – Bulga rainfall station (061191)
January	82	91
February	67	81
March	90	99
April	48	47
May	29	27
June	49	46
July	29	28
August	30	30
September	35	37
October	48	50
November	76	70
December	75	84
Total	**657**	**690**

To place rainfall in the recent years into a historical context, cumulative rainfall departure (CRD) (also referred to as residual rainfall mass) was calculated. The CRD is calculated by subtracting long-term average monthly rainfall from actual monthly rainfall, providing a monthly departure from average conditions before then calculating cumulative totals. A rising slope in the CRD plot identifies periods of above average rainfall, while a falling slope indicates below average rainfall. A standard technique for assessing groundwater level trends is to compare the water level hydrographs with a CRD plot. A CRD can be used to assess if changes in groundwater levels are correlated with climatic conditions or whether other factors such as resource extraction, mining, irrigation, etc may be an influence.

[1] https://www.longpaddock.qld.gov.au/silo/point-data/

Figure 4.1 shows a CRD plot for the SILO patched rainfall data from 2010 to 2020. As shown the period from 2010 to 2016 was characterised by above average rainfall, while below average rainfall dominated from 2016 until 2019 (which coincided with higher extraction rates from the LUG Bore). More recently, above average rainfall during the second half of 2020 has led to a rising curve.

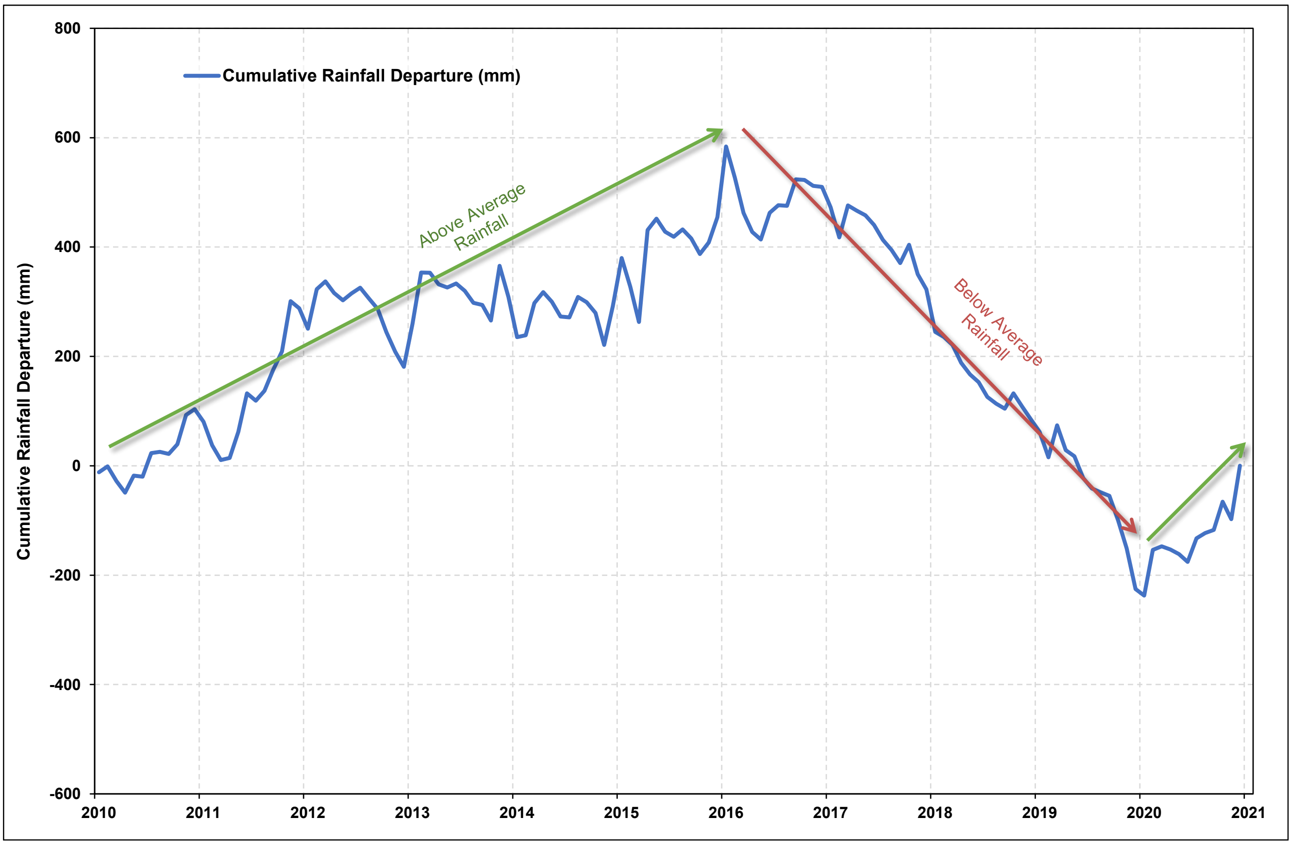


Figure 4.1 Cumulative rainfall departure (2010 – 2020)

4.2 Surface drainage

4.2.1 Wollombi Brook

As shown in Figure 4.2, the Lemington Underground workings extend beneath Wollombi Brook which flows from south-west to north-east over the workings reaching a confluence with the Hunter River around 1.5 km to the east. Flows in the brook are monitored at the following two gauging stations proximal to the area but more than 200 m above the Lemington Underground workings:

- Station 210028 (Wollombi Brook at Bulga); 13.5 km upstream of the workings; and
- Station 210004 (Wollombi Brook at Warkworth); immediately upstream of the workings but around 210 m vertically above the B&P 2A mining area

Summary data for gauging stations 210004 and 210028 is provided in Table 4.2, based on data available from the WaterNSW web portal for the period January 2010 to April 2021. The data suggest a long-term average flow of 258 ML/d at Warkworth (210004), approximately 20 ML/d higher than recorded at Bulga (210028) around 13.5 km upstream.

As shown in Table 4.2, periods of no observed flow are relatively common, occurring 21% of the time at the Bulga gauge and 26% of the time at Warkworth.

Table 4.2 Wollombi Brook flow gauging station data summary

Station number	Water Course and Station Name	Catchment Area (km2)	Long-term average flow (ML/d)	Number of no flow months (% of record)
210028	Wollombi Brook at Bulga	1,672	238	29 (21%)
210004	Wollombi Brook at Warkworth	1,848	258	35 (26%)

Note: Statistics based on monthly average flow data for the period January 2010 to April 2021 inclusive.

4.2.2 Hunter River

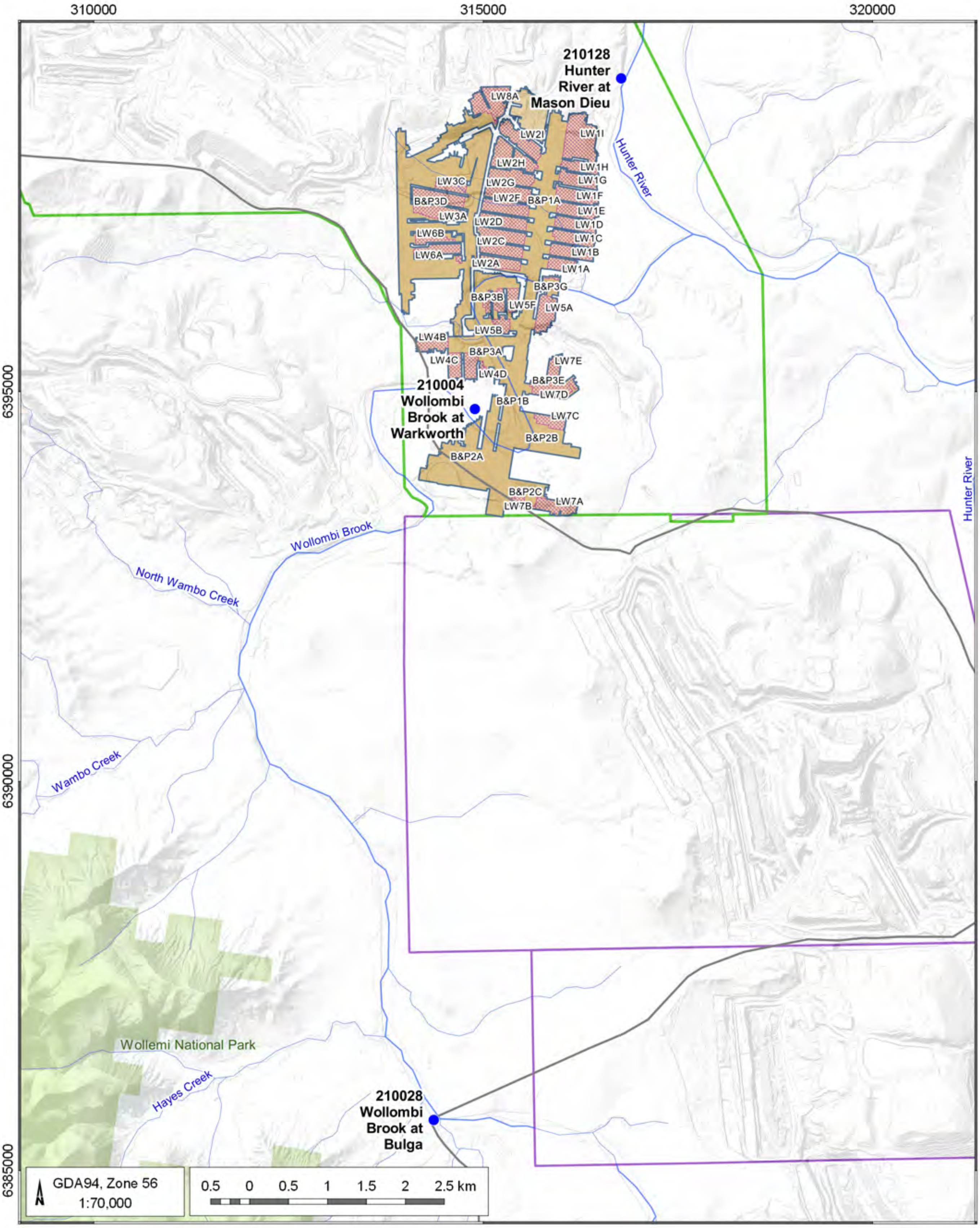
As shown in Figure 4.2, the Hunter River flows from northwest to southeast around 300 m east of the location of the Lemington Underground workings. The WaterNSW monitoring network includes one gauging station on the Hunter River at Mason Dieu (21028) around 600 m upstream of the location of the underground workings.

Summary data for the Mason Dieu gauge is provided in Table 4.3, based on data available from the WaterNSW web portal for the period January 2010 to April 2021. The data suggest a long-term average flow of 946 ML/d. As shown in Table 4.3, there are no periods during the period shown when the Hunter River ceased to flow, due in part to regulation of flows in the river by operation of a number of water storages upstream.

Table 4.3 Hunter River flow gauging station data summary

Station number	Water Course and Station Name	Catchment Area (km^2)	Long-term average flow (ML/d)	Number of no flow months (% of record)
210128	Hunter River at Mason Dieu	14,390	946	0 (0%)

Note: Statistics based on monthly average flow data for the period January 2010 to April 2021 inclusive.



LEGEND
- Populated place
- Gauging stations
- Natural drainage feature
- Road
- Rail
- Lemington underground workings
- Longwall panels
- Bord & Pillar
- National Park
- HVO North development consent boundary
- HVO South development consent boundary
- MTW Leases

Lemington UG Water Storage (G1468J)

Surface drainage

AGE

DATE 07/09/2021

FIGURE No: **4.2**

Source: LiDAR DEM - © Department Finance, Services and Innovation.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1468J.Lemington_UG_Water_Storage\3_GIS\Workspaces\001_GIA\04.02_G1468J_Surface drainage.qgs

4.3 Geology

4.3.1 Regional geology

The Lemington Underground workings are located within the Hunter Coalfield towards the north-eastern margin of the Permian and Triassic Sydney Basin. The basin formed during a period of crustal thinning and igneous rifting in the Late Carboniferous to Early Permian and subsequently infilled with Permian and Triassic aged sediments. The basin is structurally bound by the Hunter-Mooki Thrust Fault, where the New England Block is thrust over Permian Sydney Basin sediments. The regional geological sequence generally dips in a westerly or south-westerly direction.

4.3.2 Local geology

Figure 4.3 is a surface geology map of the area surrounding the Lemington Underground workings. As shown Quaternary Age alluvial deposits (Qav, Qal) associated with the Wollombi Brook are mapped at outcrop across the central part of the workings. Elsewhere the outcrop geology in the area is dominated by the Permian Age Jerry Plains Subgroup (Pwj), which forms part of the Wittingham Coal Measures (Table 4.4). Areas of Cenozoic Age high level sands (Cz_aths), known locally as the Warkworth Sands, are also mapped to the south of the workings.

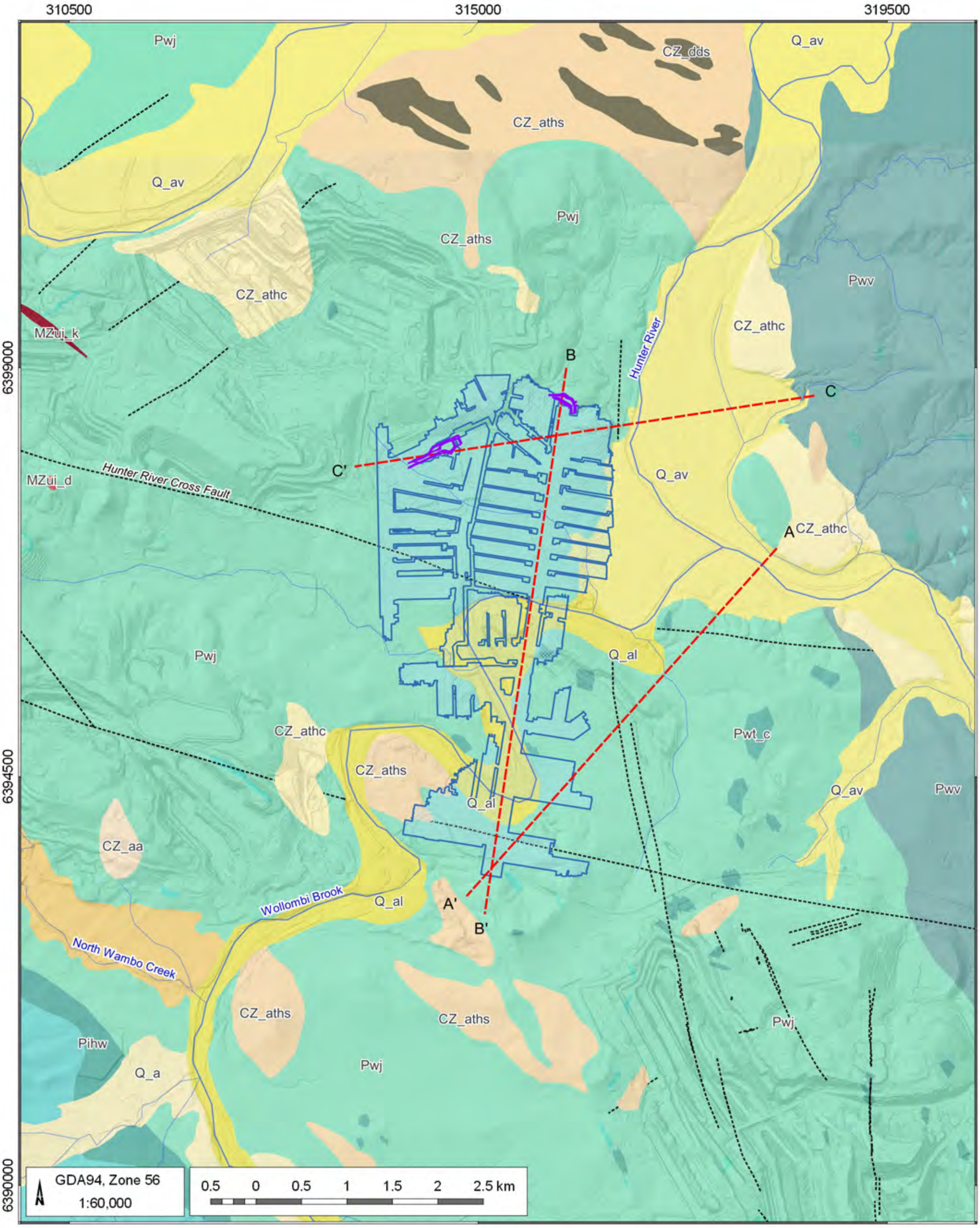
These main stratigraphic units occurring in the vicinity of the workings and the dominant lithology within each are as follows:

- Quaternary alluvium – unconsolidated clays, silts, sands, and gravels mainly associated with Wollombi Brook and the Hunter River;
- Warkworth Sands – aeolian sand dunes unconformably overlying the Wittingham Coal Measures towards the south of the Project area; and
- Permian age Wittingham Coal Measures including the Jerry Plains and Vane Subgroups comprising multiple coal seams with intervening claystones, siltstones, sandstones, and conglomerates.

Local mapped and inferred faults are also shown in Figure 4.3 as identified from the NSW Seamless Geology database and mapping from mine geologists. Generally, faults are orientated in a north-northwest to south-southeast with a secondary subset of faults orientated north-east to south-west. Figure 4.4, Figure 4.5, and Figure 4.6 provide cross-sections through the Lemington Underground workings and surrounds.

Table 4.4 Sequence stratigraphy of the Wittingham Coal Measures

<table>
<tr><th colspan="5">Regolith/ Quaternary alluvium/ Aeolian sands</th></tr>
<tr><td rowspan="28">Singleton Supergroup</td><td rowspan="28">Wittingham Coal Measures</td><td colspan="3">Denman Formation</td></tr>
<tr><td rowspan="18">Jerrys Plains Subgroup</td><td>Mount Leonard Formation</td><td>Whybrow Seam</td></tr>
<tr><td colspan="2">Althorpe Formation</td></tr>
<tr><td rowspan="4">Malabar Formation</td><td>Redbank Creek Seam</td></tr>
<tr><td>Wambo Seam</td></tr>
<tr><td>Whynot Seam</td></tr>
<tr><td>Blakefield Seam</td></tr>
<tr><td rowspan="2">Mount Ovilgie Formation</td><td>Glen Munro Seam</td></tr>
<tr><td>Woodlands Hill Seam</td></tr>
<tr><td colspan="2">Milbrodale Formation</td></tr>
<tr><td rowspan="3">Mount Thorley Formation</td><td>Arrowfield Seam</td></tr>
<tr><td>Bowfield Seam</td></tr>
<tr><td>Warkworth Seam</td></tr>
<tr><td colspan="2">Fairford Formation</td></tr>
<tr><td rowspan="5">Burnamwood Formation</td><td>Mount Arthur Seam</td></tr>
<tr><td>Piercefield Seam</td></tr>
<tr><td>Vaux Seam</td></tr>
<tr><td>Broonie Seam</td></tr>
<tr><td>Bayswater Seam</td></tr>
<tr><td colspan="3">Archerfield Sandstone</td></tr>
<tr><td rowspan="8">Vane Subgroup</td><td colspan="2">Bulga Formation</td></tr>
<tr><td rowspan="6">Foybrook Formation</td><td>Lemington Seam</td></tr>
<tr><td>Pikes Gully Seam</td></tr>
<tr><td>Arties Seam</td></tr>
<tr><td>Liddell Seam</td></tr>
<tr><td>Barrett Seam</td></tr>
<tr><td>Hebden Seam</td></tr>
<tr><td colspan="2">Saltwater Creek Formation</td></tr>
</table>



LEGEND

- Fault lines
- Natural drainage feature
- Cross section lines
- Historical Boxcut
- Lemington Underground workings

Cenozoic

- Q_a - Alluvium
- CZ_aa - polymictic gravel
- CZ_athc - Alluvial terrace deposits
- CZ_aths - High-level sand and sandstone
- Q_al - overbank deposits
- Q_av - Alluvial valley deposits
- QH_al - Fluvially deposit
- CZ_dds - -Aeolian deposits

Permian mesozoic igneous

- MZui__d - Dolorite
- MZui__k - Alkaline dolerite

Permian Triassic

- Pihw - Watts Sandstone
- Pne - Newcastle Coal Measures
- Pwj - Jerrys Plains Subgroup
- Pwj_s - Jerrys Plains Subgroup - sandstone
- Pwt__c - Wittingham Coal Measures - conglomerate
- Pwv - Vane Subgroup

Lemington UG Water Storage (G1468J)

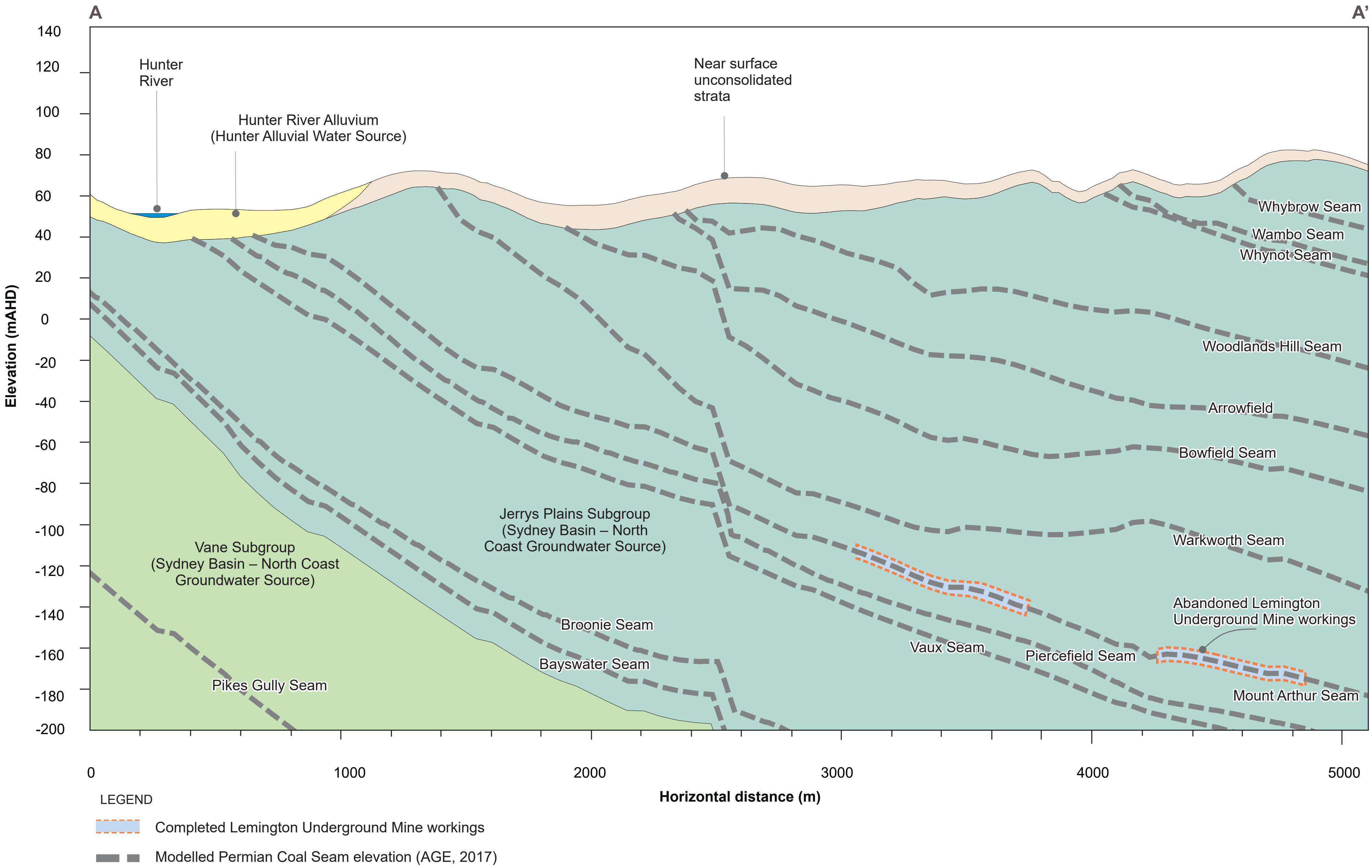
Surface geology

AGE

DATE 06/09/2021

FIGURE No: **4.3**

Source: ELVIS LiDAR DEM (accessed April 2019 ; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1468J.Lemington_UG_Water_Storage\3_GIS\Workspaces\001_GIA\04.03_G1468J_Solid geology_SEAMLESS.qgs

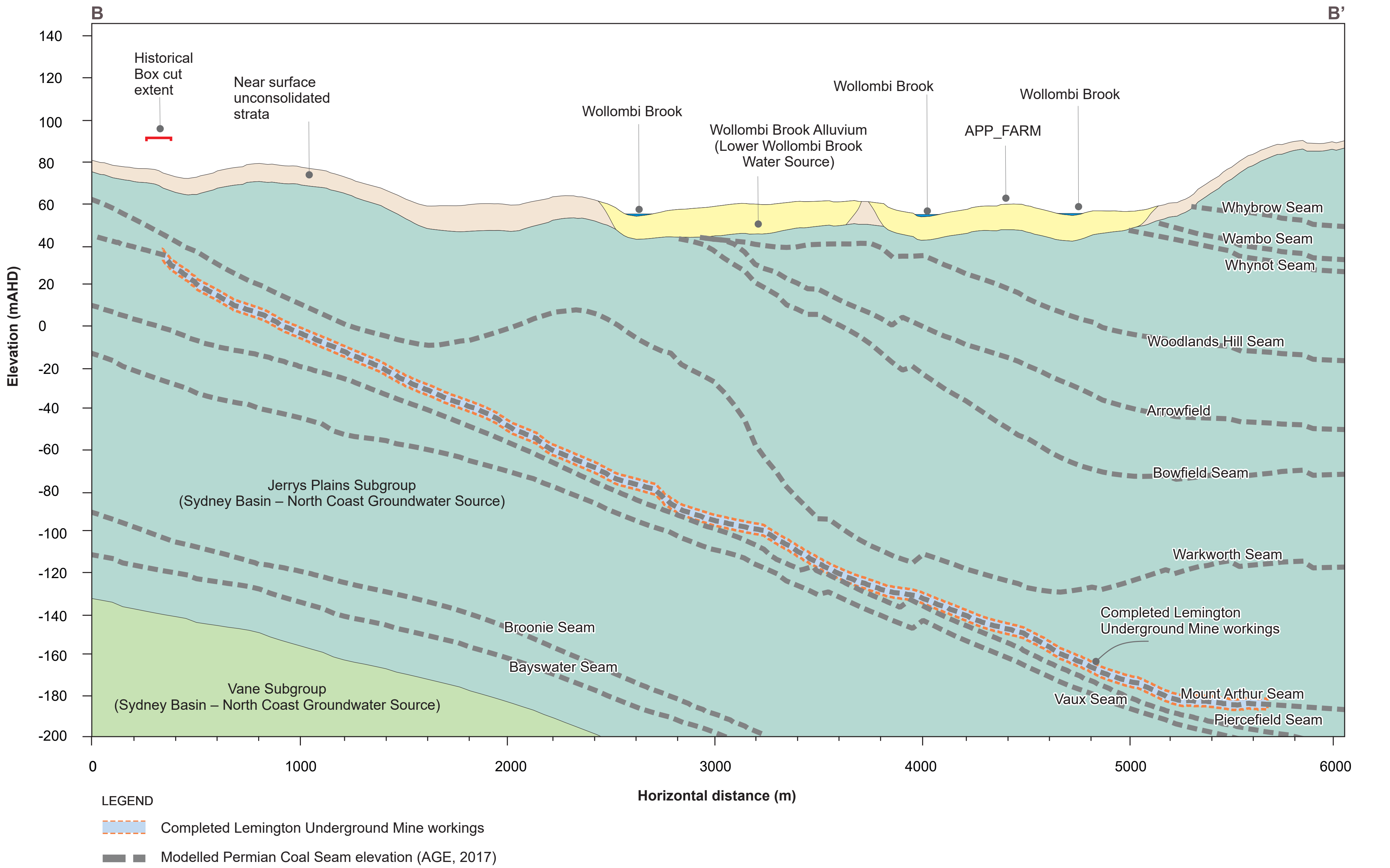


Conceptual geological cross section – A-A'

Figure - 4.4

Lemington UG Water Storage (G1468J)

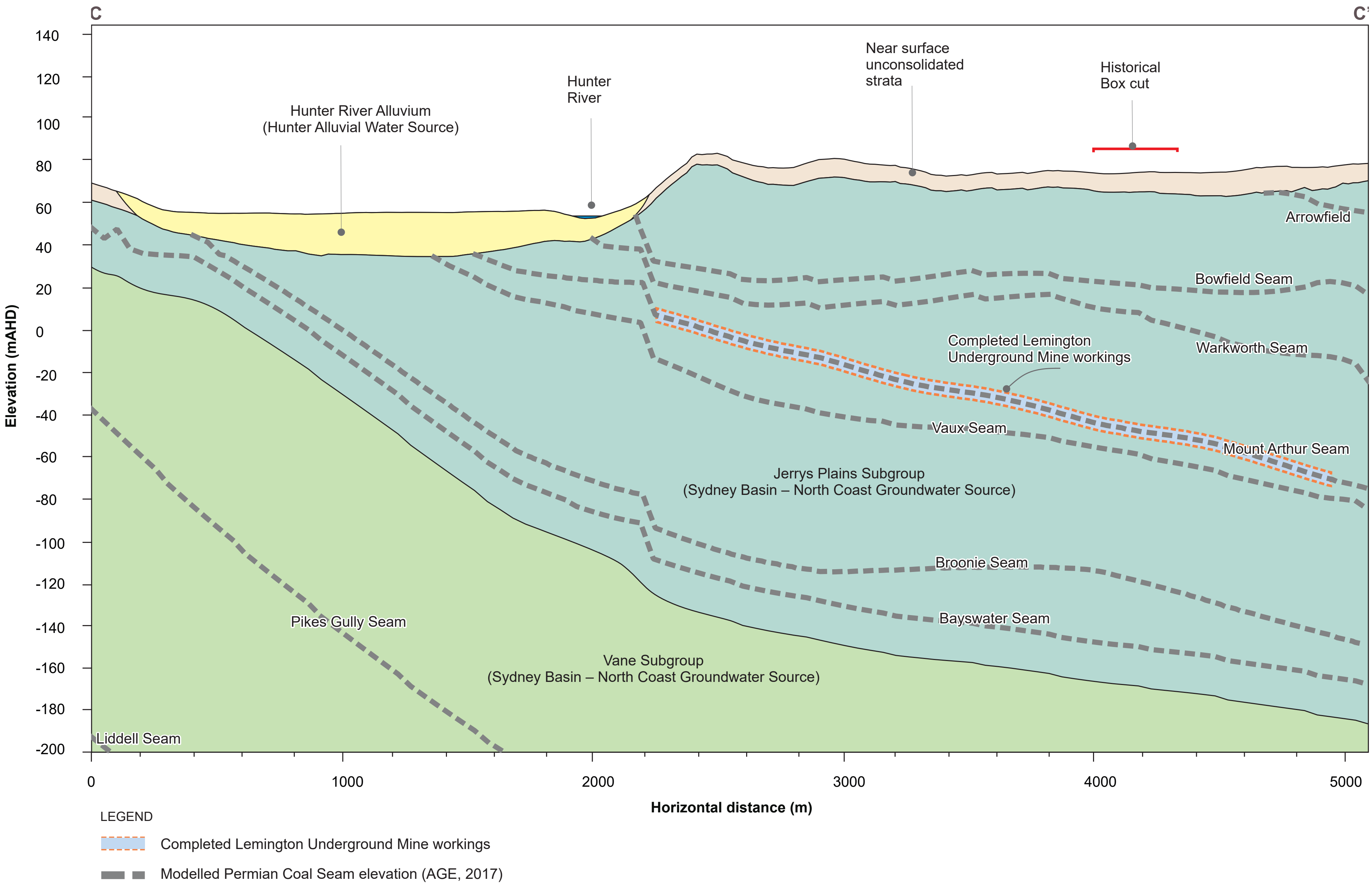
AGE



Conceptual geological cross section – B-B'

Figure - 4.5

Lemington UG Water Storage (G1468J)



Conceptual geological cross section – C-C'

Figure - 4.6

Lemington UG Water Storage (G1468J)

AGE

5 Hydrogeological setting and existing impact assessment

5.1 Introduction

This section presents a summary of the hydrogeological setting in the Project area and assesses the impacts of the current extraction from the Lemington Underground workings, which has operated since 2013, based on historic observations and other previous reports. The impacts of the proposed modification are assessed and summarised in Section 6.

5.2 Hydrostratigraphic units

The key hydrostratigraphic units of relevance to assessing the impacts of the proposed modification are as follows:

- Quaternary alluvium and regolith;
- Warkworth Sands; and
- Coal seams and intervening interburden units comprising the Jerrys Plains Subgroup.

A general hydrogeological description of each of the above units is provided below in Sections 5.2.1 to 5.2.3 with further details of the hydrogeological characteristics of each unit provided in subsequent sections.

5.2.1 Quaternary alluvium and regolith

The estimated extent and thickness of Quaternary alluvium present within the project area is shown in Figure 5.1. The extent of these deposits is based on the published geological mapping (Figure 4.3). The estimated thickness is based on a regolith thickness published by Commonwealth Scientific and Industrial Research Organisation (CSIRO; 2015) and adjusted where necessary to agree with borehole data from the state groundwater database and MTW drilling records.

As shown in Figure 5.1, the Wollombi Brook alluvial aquifer is estimated to be around 10 m thick in the vicinity of the Lemington Underground workings but is largely restricted to the main channel of Wollombi Brook and only extends a short distance up the associated tributaries. The Hunter River alluvium is both wider and thicker, between 10 and 25 m thick close to the main channel to the northeast of the workings.

As shown in Figure 5.1, the Wollombi Brook meanders across the southern half the Lemington Underground workings. However, as shown in cross section B-B' (Figure 4.5) the alluvium underlying the brook is separated from the workings below by between 105 and 230 m of coal seams and interburden units which comprise the Jerry's Plains subgroup. As shown in cross section C-C' (Figure 4.6) the eastern limit of the workings also lies close to the Hunter River and hence the workings are partially overlain by the Hunter River alluvium. The workings are relatively shallow in this area and are located between 40 and 100 m below the base of the alluvium.

The alluvial deposits present within the area typically comprise fine-grained clay, and silt rich surficial deposits underlain by sand and gravel rich lower horizons (SLR, 2020). Accordingly, most water supply bores target the lower sections of the alluvial strata. Recharge is likely to be predominantly via rainfall recharge, enhanced by downward leakage from surface water courses during wet periods and also possible by upward leakage from the underlying bedrock.

As shown in Figure 4.3, the Jerrys Plain subgroup and other Permian units are mapped at outcrop across the majority of the area surrounding the workings. However, weathering of these bedrock units typically results in the development of an unconfined regolith unit at the surface overlying fresher bedrock units at depth. Regolith thicknesses tend to be quite variable since it depends on a range of factors including the depth of weathering, and extent and frequency of fracturing. However, typical thicknesses in the area, based on the CSIRO (2015) regolith thickness dataset are thought to between 3 and 8 m. Recharge to the regolith is likely to occur predominantly from rainfall infiltration and the unit is likely to act as a water store during sustained wet periods providing a source for recharge to the underlying Permian strata (AGE, 2014).

LEGEND
- Natural drainage feature
- Contour line
- Lemington Underground workings

Alluvium thickenss (m)
- 0
- 5
- 10
- 20
- 30

Lemington UG Water Storage (G1468J)

Mapped alluvium extent and estimated thickness

AGE

DATE 07/09/2021

FIGURE No: **5.1**

Source: ELVIS LiDAR DEM (accessed April 2019 ; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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5.2.2 Warkworth Sands

As shown in Figure 4.3, areas of Cenozoic Age high level sands (Cz_aths), known locally as the Warkworth Sands, are also mapped at outcrop to the south of the workings and the Warkworth Sands Woodland ecological community is thought to be at least partially supported by groundwater in these sands (see also Section 5.8).

Previous investigations conducted by AGE (2010; 2011) suggest that the Warkworth Sands typically comprise around 3 m of relatively fine-grained sands overlying a low permeability base of weathered residual clay associated with the underlying strata. The low permeability clays limit the vertical flow of incident rainfall resulting in the formation of a thin ephemeral perched water table at the base of the sand mass.

This conceptual model is supported by a soil survey undertaken by Lockwood (2007) in the Warkworth Sands approximately three months after an extreme rain event. The findings indicated nearly all deep sand profiles were moist close to the clay boundary, and many were saturated. This implies that the water table formed at the base of the Warkworth Sands is perched and is not in direct hydraulic connection with the regional aquifer in the underlying Permian fractured rock.

A number of small seepages of groundwater occur from the Warkworth Sands at the break of slope created by the Wollombi Brook floodplain, although the majority of the perched water is likely to be removed from the aquifer by direct evapotranspiration through the vegetation (AGE, 2010). Furthermore, Cumberland Ecology (2014) noted species indicative of a persistent water table can be found in dune swales suggesting some groundwater permanence.

5.2.3 Jerrys Plains Subgroup

The generally western dipping Jerrys Plains Subgroup occur as a layered sedimentary sequence. Historically, only the Mount Arthur coal seam has been mined in the Lemington Underground workings although as discussed previously a number of other coal seams overly the workings and are targeted in other local coal mining developments. Groundwater usage from the Permian strata in the workings' vicinity is limited by the generally brackish to saline nature of the groundwater and the low and variable yields (AGE, 2014). Bore yields are typically less than 5 L/s and hence the hydrostratigraphic units present are classified as 'less productive aquifers' according to the criteria set out in the NSW AIP.

The overlying strata typically comprise (AGE, 2010):

- hydrogeologically "tight" and subsequently very low yielding to essentially dry sandstone, siltstone, and conglomerate that comprise most of the Permian interburden/overburden; and
- low to moderately permeable coal seams, typical ranging in thickness from 1 to 5 m which are the main water bearing strata within the Jerrys Plains Subgroup.

The shallow coal measures form unconfined aquifers that outcrop or subcrop above the Lemington Underground workings at surface, west of the Hunter River, and transform into semi-confined to confined aquifers deeper down dip (Figure 4.4; Figure 4.5; Figure 4.6). The coal measures that outcrop at surface, or subcrop below the regolith and alluvium serve as pathway for direct recharge to occur into the deeper coal seams.

The Mount Arthur coal seam as mined in the Lemington Underground workings ranges in depth from 30 m to 270 m below ground. Hydraulic properties, including permeability and storage, of the Project area have thus been affected by the historic mining. Directly above the historically mined workings, increased permeability and storage is expected to have occurred both within and above the workings, particularly in areas where longwall mining, rather than bord and pillar, techniques were adopted (leading to roof collapse into the mine goaf).

5.3 Water levels and flow directions

5.3.1 Groundwater monitoring network

Groundwater level monitoring is undertaken within each of three current mining areas to the north, south and west of the Lemington Underground workings and data are also available for a number of state monitoring bores in the area. The location of groundwater level monitoring points used for the current study are shown in Figure 5.2 and a summary of the number of monitoring bores in each hydrostratigraphic unit is presented in Table 5.1. Water level data for the HVO bores was downloaded from Glencore's Environmental Monitoring Database. Data relating to the MTW mine was received direct from MTW as part of the ongoing groundwater assessment and review at MTW. Water level data for the WaterNSW bores was accessed via the WaterNSW web portal[2]. Water level data for the United Wambo Wollombi Brook alluvium monitoring bores (GW15, P16, P20) was extracted from the Wambo 2019 Annual Review report (Wambo, 2019[3]). Hydrographs for each water level monitoring location are presented in Appendix A.

As shown in Table 5.1, data have been collated for 60 monitoring points in total and this data set includes multiple monitoring points in each of the main coal seams, the alluvium overlying the workings, and the Warkworth Sands. Monitoring locations for which the monitored formation is not known or with no water level data beyond 2012 have been excluded (pumping at LUG Bore commenced in October 2013.

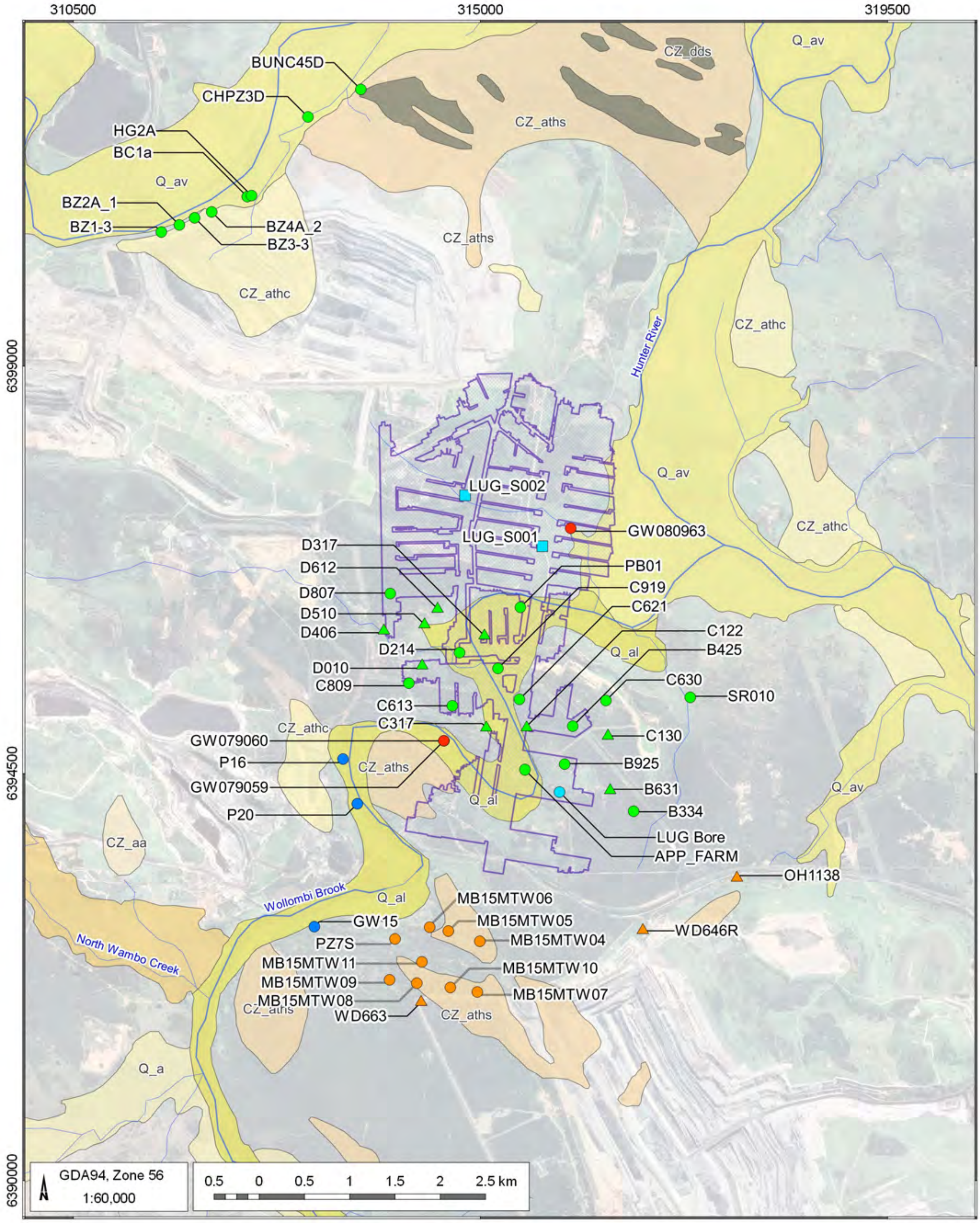
For the most part, the monitoring points considered comprise standpipe monitoring bores for shallow installations and vibrating wire piezometers (VWPs) for monitoring of deeper formations. As shown in Figure 5.2, a number of monitoring points comprise nested facilities with multiple VWPs installed in the same bore.

Table 5.1 Combined groundwater level monitoring locations

Geological Formation	Lithological Unit	HVO	MTW	WaterNSW	United Wambo	Total
Aeolian	Warkworth Sands	0	9	0	0	**9**
Quaternary	Wollombi Brook Alluvium	3	0	1	3	**7**
Jerrys Plains Subgroup	Glen Munro coal seam	1	0	0	0	**1**
	Woodlands Hill coal seam	7	0	0	0	**7**
	Arrowfield coal seam	4	0	1	0	**5**
	Bowfield coal seam	15	0	0	0	**15**
	Warkworth coal seam	1	3	0	0	**4**
	Mount Arthur coal seam	9	2	1	0	**12**
	Total	**40**	**14**	**3**	**3**	**60**

[2]https://realtimedata.waternsw.com.au/

[3]https://www.peabodyenergy.com/Peabody/media/MediaLibrary/Operations/Australia%20Mining/New%20South%20Wales%20Mining/Wambo%20Mine/Wambo-Coal-Mine-2019-Annual-Review.pdf



LEGEND

- Natural drainage feature
- Lemington Underground workings

Cenozoic

- Q_a - Alluvium
- CZ_aa - polymictic gravel
- CZ_athc - Alluvial terrace deposits
- CZ_aths - High-level sand and sandstone
- Q_al - overbank deposits
- Q_av - Alluvial valley deposits
- QH_al - Fluvially deposit
- CZ_dds - -Aeolian deposits

Monitoring network

- HVO - nested
- HVO - not nested
- NGIS - not nested
- United Wambo - not nested
- MTW - nested
- MTW - not nested
- Current extraction bore
- Recently drilled monitoring bore

Lemington UG Water Storage (G1468J)

Groundwater level monitoring locations

AGE

DATE 07/09/2021

FIGURE No: **5.2**

Source: ELVIS LiDAR DEM (accessed April 2019 ; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1468J.Lemington_UG_Water_Storage\3_GIS\Workspaces\001_GIA\05.02_G1468J_Groundwater level monitoring locations.qgs

5.3.2 Lemington Underground Workings / Mount Arthur coal seam

Available groundwater level data for the 12 monitoring locations in the Mount Arthur coal seam, which was targeted by the Lemington Underground workings, are shown on Figure 5.3. As discussed previously (Section 3.1) groundwater has been extracted from the LUG Bore towards the south of the workings from October 2013 onwards. The impact of this extraction can be clearly seen in both monitoring locations which are located within the footprint of the workings, i.e., the LUG Bore itself and GW080963. Data are available for the LUG Bore from February 2018 onwards and data ceased to be collected from GW080963 in September 2019. Nevertheless, collectively, data for these two monitoring points show a rapid decline in water levels in the workings from 2017 to 2019, due to increased extraction from the LUG Bore. Thereafter, groundwater levels in the workings appear to have recovered slowly to around -55.7 metres Australian Height Datum (mAHD) in the LUG Bore in March 2021 as the volume of water pumped has reduced during the recent period.

As shown in Figure 5.3 and Figure 5.4, the minimum level observed in the LUG Bore was around -58.7 mAHD in May 2018. It should be noted, however, that groundwater levels in the vicinity of the workings would have been as low as -205 mAHD (i.e., the minimum elevation of the base of the workings) during operation of the mine dewatering system from 1971 to 1992. The maximum level observed in the LUG Bore, immediately after completion in 2008, was 5 mAHD.

Data are also available for two Mount Arthur monitoring points located to the southeast (WD646R_P5), and southwest (WD663_P6) of the workings (Figure 5.3). WD646R_P5's observed water levels decreased from 9.8 to 7.6 mAHD during 2019 and remained stable during 2020. WD663_P6's observed water levels decreased from 43.2 to 41.1 mAHD during 2020. The observed drawdown at WD646R_P5 and WD663_P6 is likely resultant from mining of the Mount Arthur coal seam at MTW to the south of these bores.

As Figure 5.5 shows, the remaining nine Mount Arthur monitoring points are located north of the Lemington Underground workings towards the northern perimeter of the Cheshunt Pit at HVO. Data for these monitoring locations suggest relatively stable water levels that do not correlate with water levels observed at GW080963 and LUG Bore and hence are considered more likely to be affected by HVO operations at Cheshunt Pit, rather than varying water levels in the Lemington Underground Workings.

Current levels at GW080963 have been estimated based on the extrapolated levels shown Figure 5.4, which have been generated by assuming that the observed relatively static observed difference in levels in the LUG and GW080963 applies from the end of the data for this bore. The resulting extrapolated level of -31.9 mAHD for GW080963 has been used in preference to a recent dip of the bore which suggests an actual level of - 24.4mAHD, a level which is thought to be below the base of the screen. Post drilling levels for two additional monitoring bores (LUG_S001 and LUG_S002) recently completed into the workings has also been incorporated and used to develop the interpolated current groundwater level contours in the Mount Arthur coal seam shown in Figure 5.5. As shown, a level of -29.9 mAHD has been observed in the LUG_S001 whilst LUG_002 was observed to be dry. Intersection of the groundwater level contours shown in Figure 5.5 with the estimated workings floor elevation data (Figure 3.3) and taking into account data for LUG_S002 suggests that the workings are currently saturated to around -22 mAHD was shown on Figure 5.5.

Information on relative levels and hence potential flow directions between different strata is provided in the conceptual sections shown in Figure 5.6, Figure 5.7 and Figure 5.8 which have been created by adding current estimated groundwater levels at each monitoring point to the geological sections previously presented in Section 4.3. As shown in Cross Section A-A' (Figure 5.6) current groundwater levels within the Lemington Underground workings are well below observed levels in the overlying strata, due in part to extraction from the LUG Bore. Accordingly, water will be being drawn into the workings both vertically from overlying strata and horizontally within the coal seams. As shown in cross section B-B' (Figure 5.7) and cross section C-C' (Figure 5.8) the workings are understood to be unsaturated further north close to the Hunter River and hence some water may be being drawn from the alluvium in areas where the coal seams are present at subcrop.

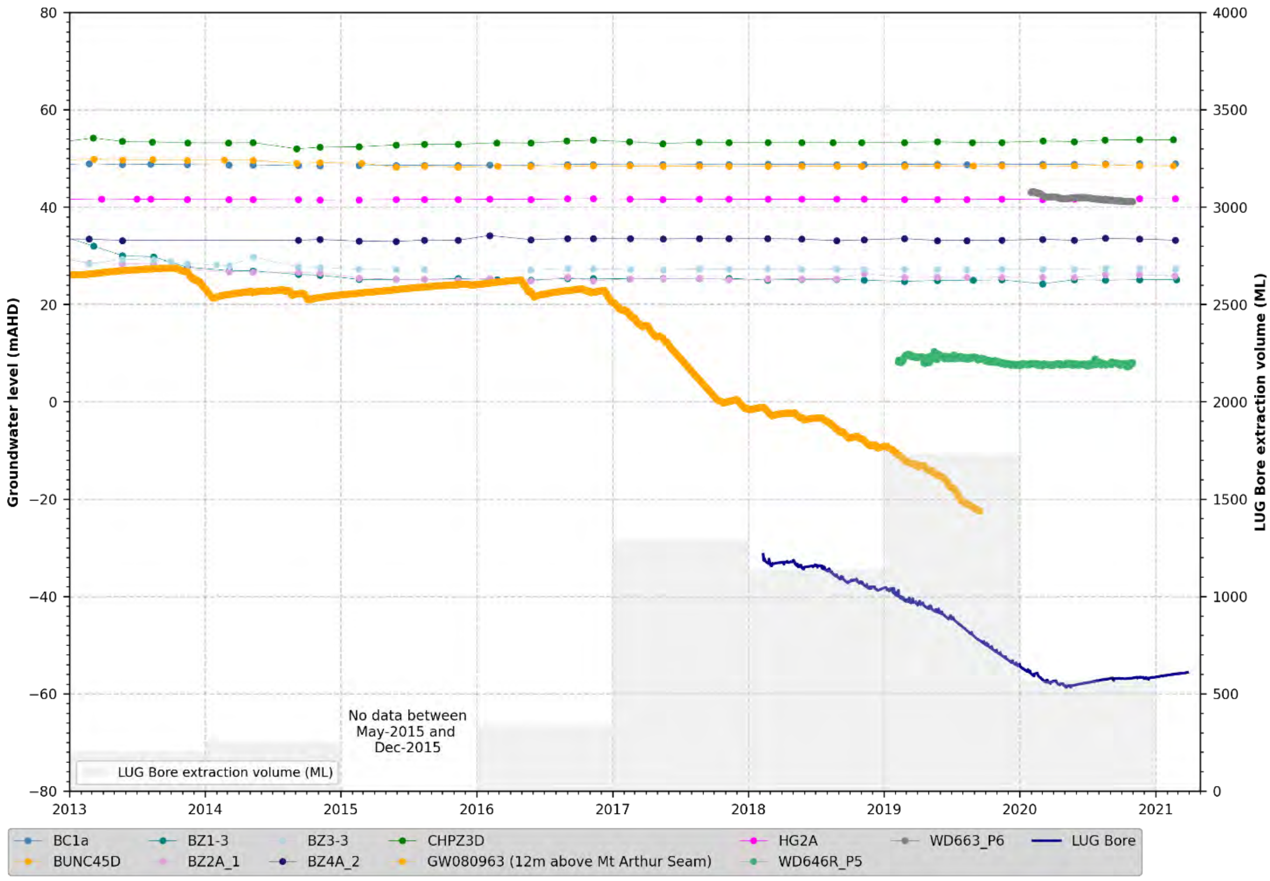


Figure 5.3 Mount Arthur coal seam groundwater levels

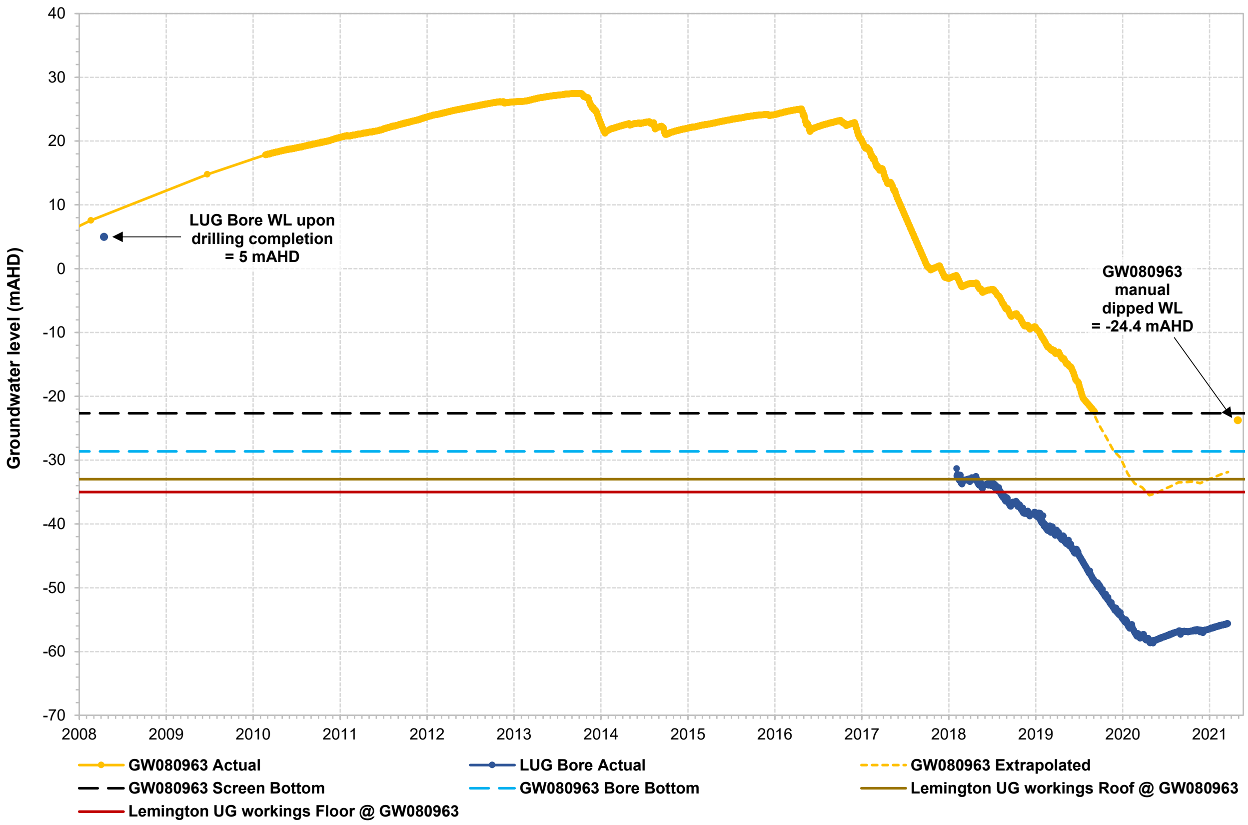
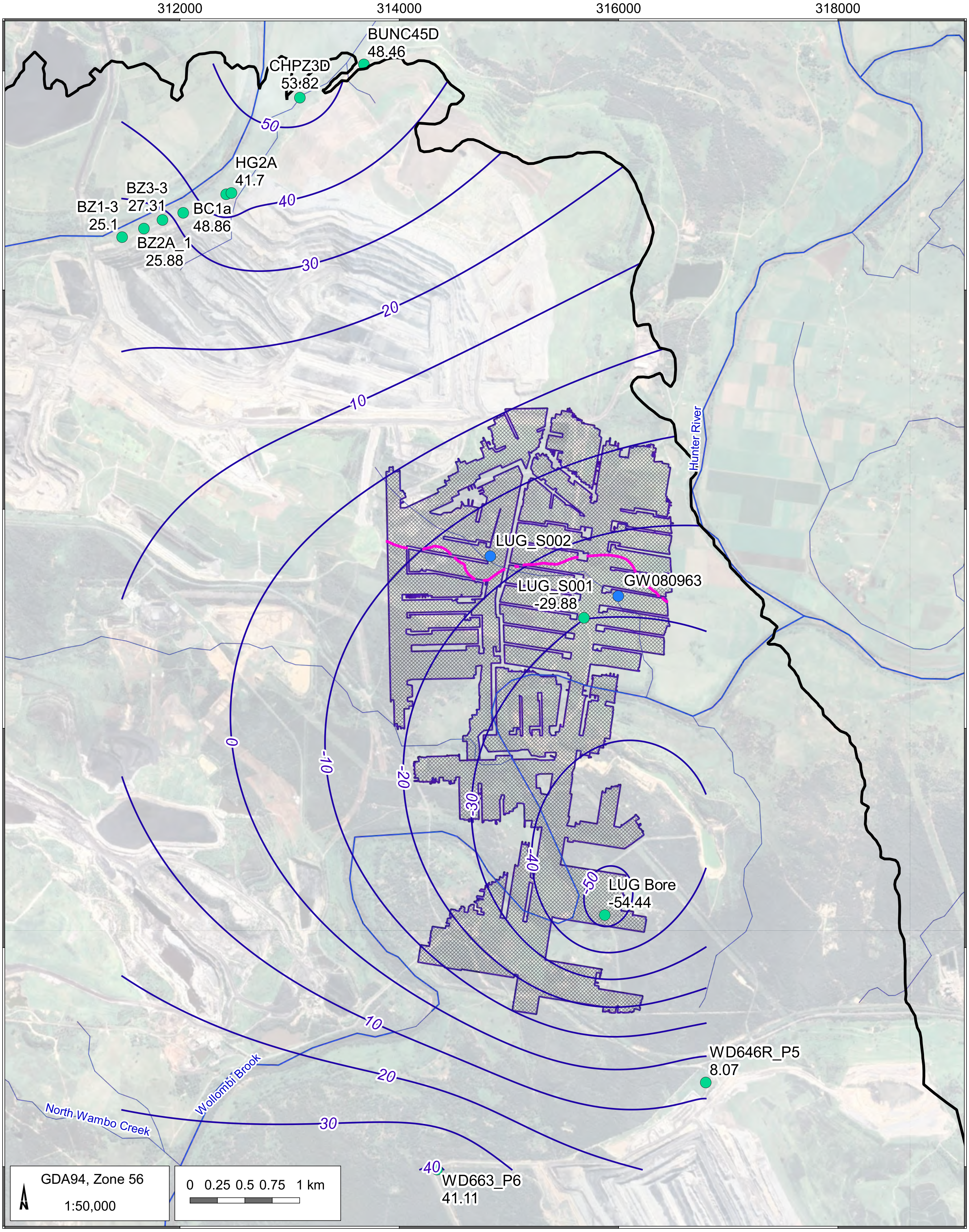


Figure 5.4 GW080963 extrapolated water levels with bore and workings' reference levels



LEGEND

- Mount Arthur seam groundwater level contour (mAHD)
- Current estimated saturation level (-22 mAHD)
- Natural drainage feature
- Lemington Underground workings

- Mount Arthur bore of interest
- Mount Arthur seam monitoring bore

WD663_P6 : BoreID
41.11 : Current water level (mAHD)

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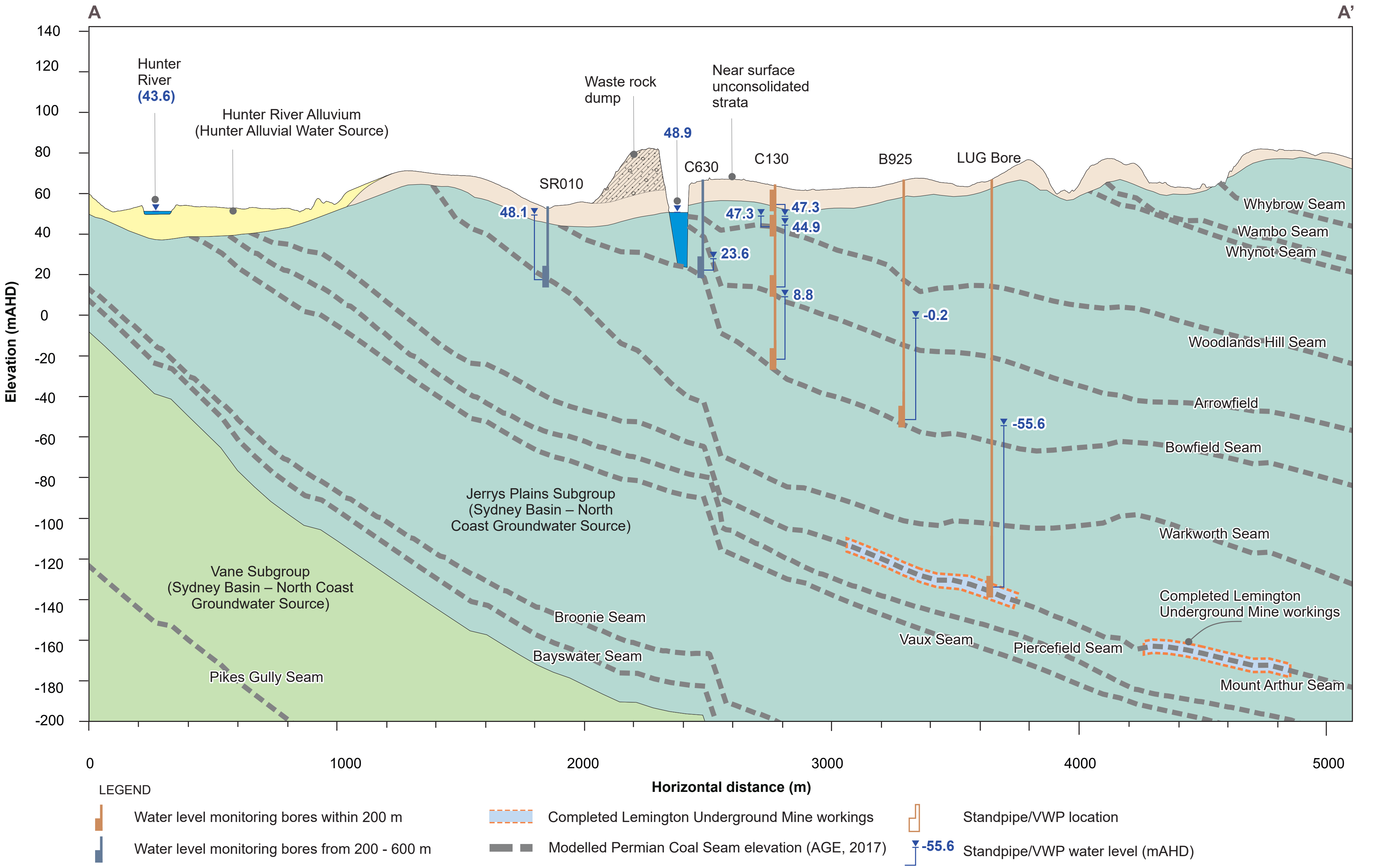
Current groundwater levels – Mount Arthur coal seam

AGE

DATE 06/09/2021

FIGURE No: **5.5**

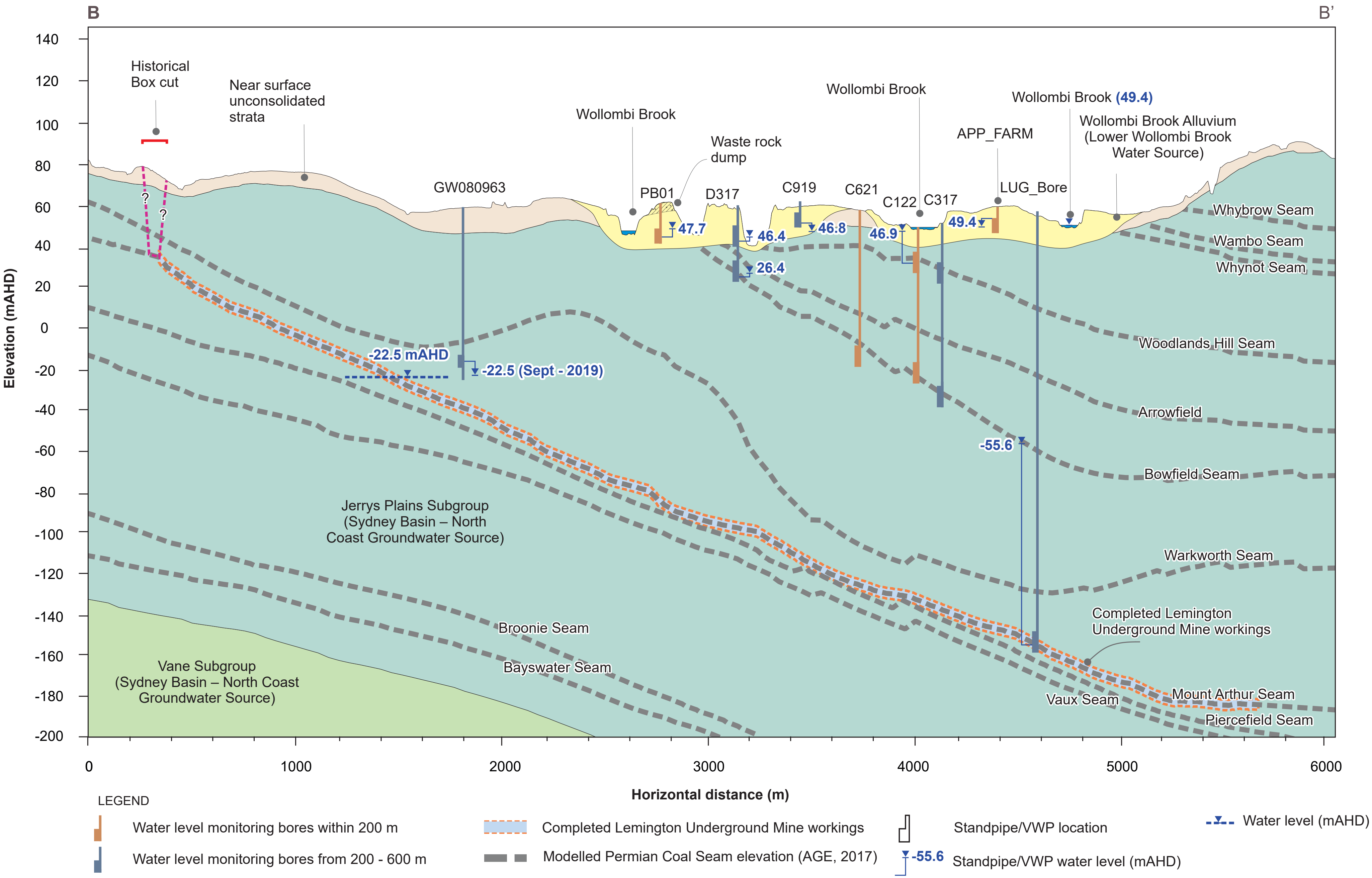
Source: ELVIS LiDAR DEM (accessed April 2019 ; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1468J.Lemington_UG_Water_Storage\3_GIS\Workspaces\001_GIA\05.05_G1468J_Current groundwater levels – Mt Arthur coal seam.qgs



Conceptual hydrogeological cross section – A-A'

Figure - 5.6

Lemington UG Water Storage (G1468J)

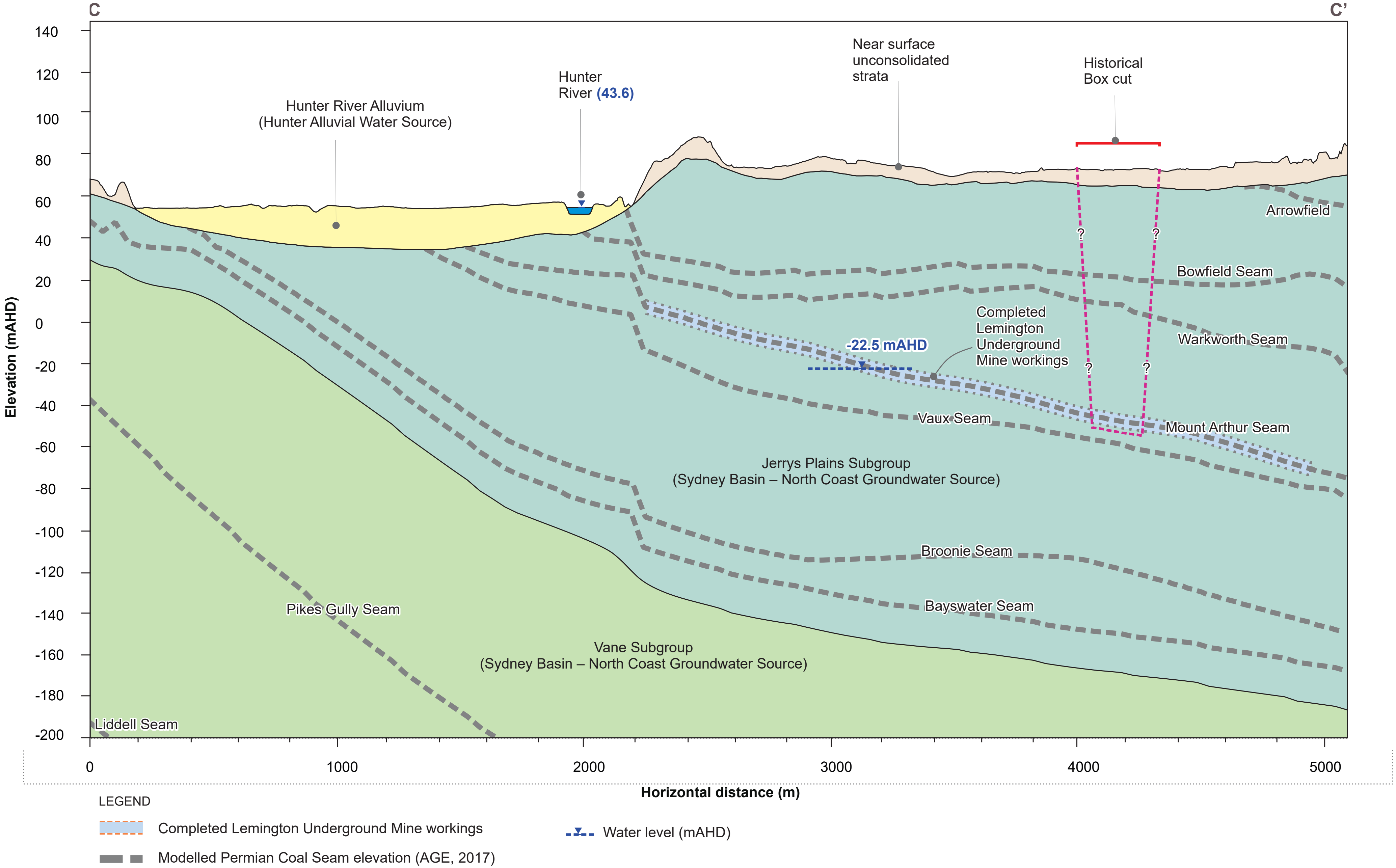


Conceptual hydrogeological cross section – B-B'

Figure - 5.7

Lemington UG Water Storage (G1468J)

AGE



Conceptual hydrogeological cross section – C-C'

Figure - 5.8

Lemington UG Water Storage (G1468J)

AGE

5.3.3 Warkworth coal seam

Data is available for four groundwater level monitoring points completed into the Warkworth coal seam located to the south and east of the LUG Bore. Hydrographs for these monitoring points are shown in Figure 5.9. Monitoring point locations and current groundwater levels are shown in Figure 5.10.

As shown in Figure 4.5, this seam is generally positioned between 15 and 70 m above the Mount Arthur coal seam and as such groundwater levels in the Warkworth coal seam are likely to respond to variations in groundwater levels in the underlying workings. However, none of the four monitoring locations are located in close proximity to the LUG Bore or the workings, the closest bore SR010 is located approximately 1.2 km to the east. Data for SR010 shows a gentle declining water trend since 2012, when water level monitoring commenced at the bore. From January 2012 until March 2021 observed levels declined from 49.1 mAHD to 48.1 mAHD (1 m of drawdown likely from regional mining and long-term declining CRD). Data for monitoring points OH1138_1 and OH1138_2 which are located around 1.6 km to the southeast of the workings, close the northern boundary of the MTW mining area also suggest minor drawdown of less than 2 m during 2013 to 2020 period when the LUG Bore has been in operation. However, these monitoring points are also located close to the Warkworth open cut which also targets the Warkworth coal seam and hence are thought to be primarily affected by ongoing mining operations, rather than extraction from the LUG Bore.

Since none of the monitoring points are located close to the Lemington Underground workings there is no reliable information of relative levels between the Warkworth coal seam and the underlying Mount Arthur coal seam. However, significantly lower groundwater levels and downward flow from the Warkworth coal seam towards the workings is anticipated.

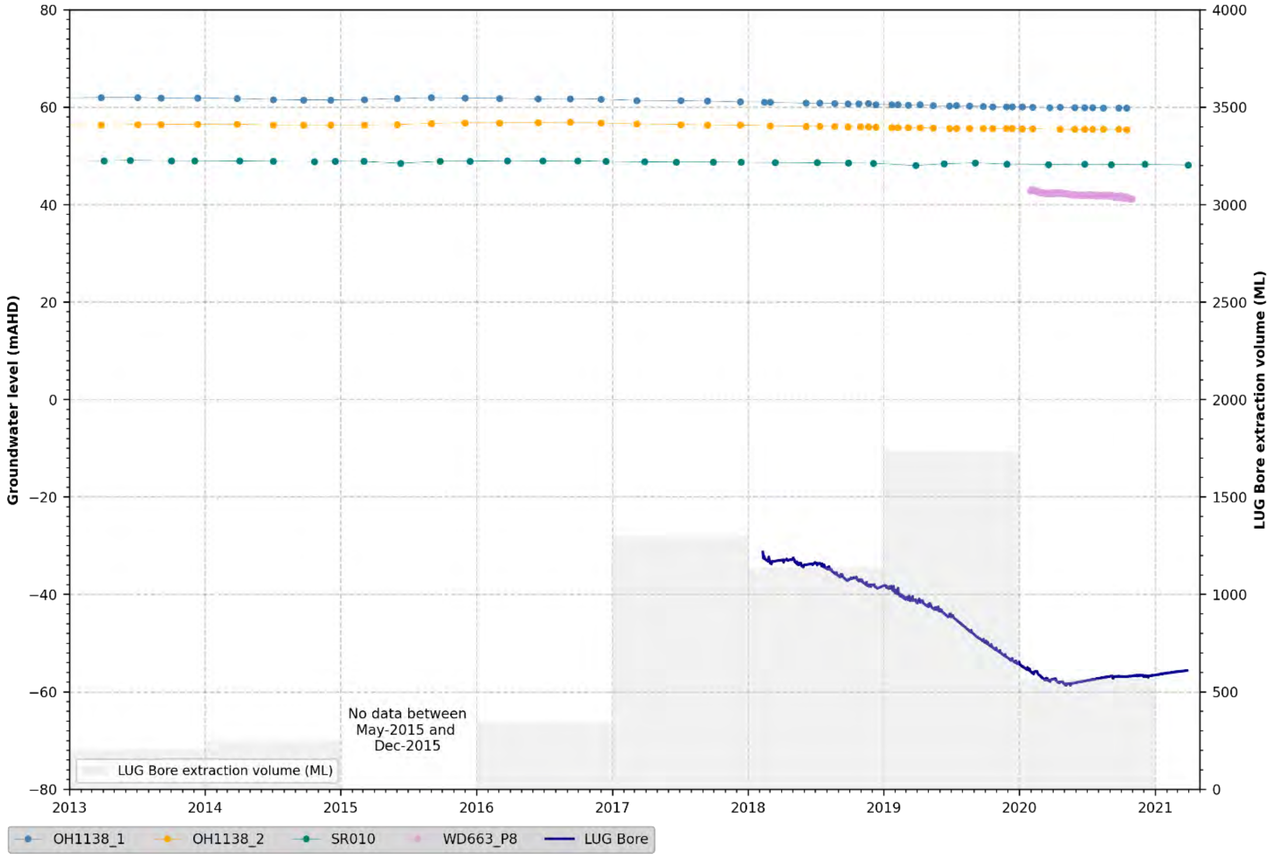
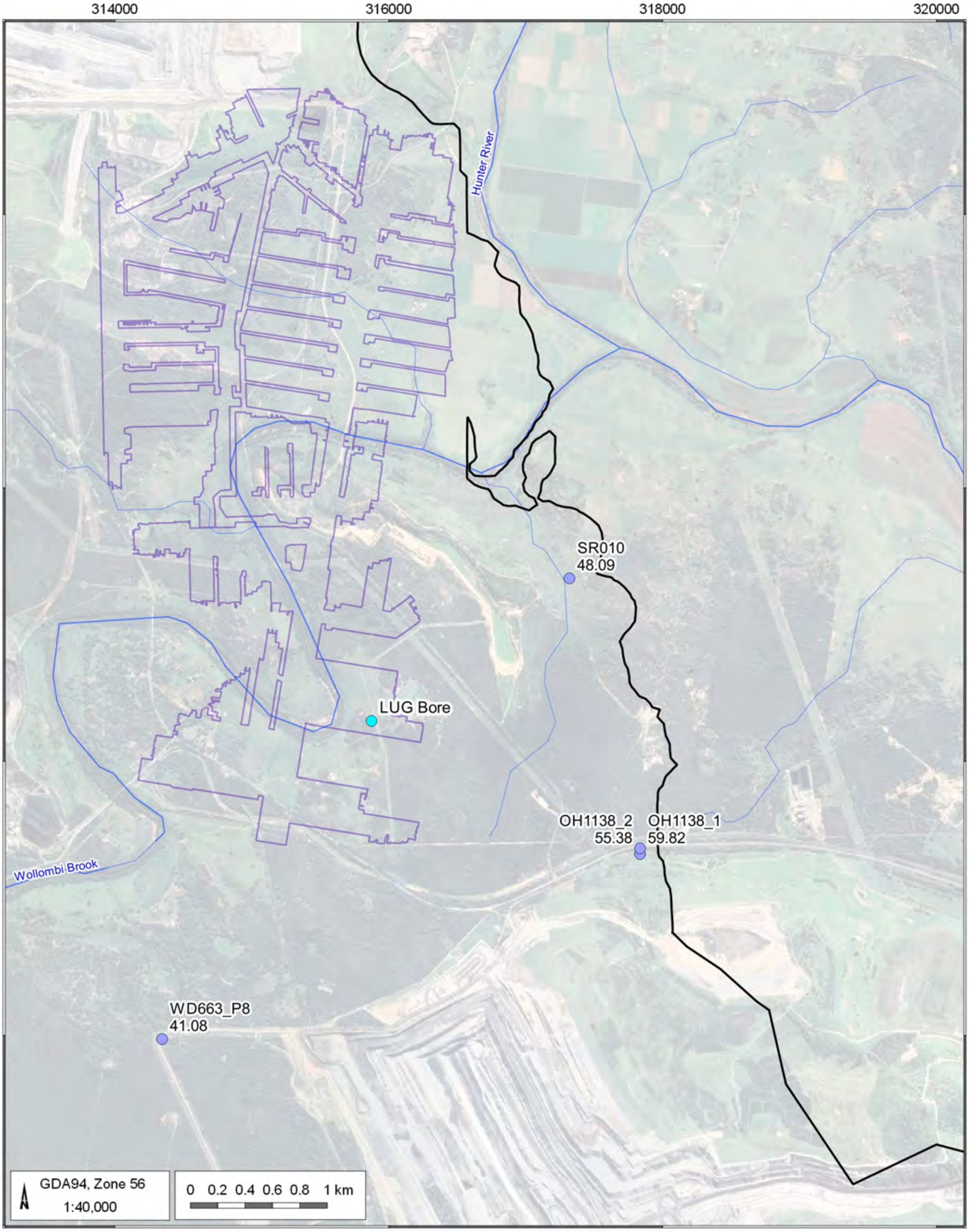


Figure 5.9 Groundwater levels Warkworth coal seam



LEGEND
- Current extraction bore
- Natural drainage feature
- Lemington Underground workings
- Warkworth subcrop
- Warkworth seam monitoring bore

WD663_P8 : BoreID
41.08 : Current groundwater level drawdown (m)

Lemington UG Water Storage (G1468J)

Current groundwater levels – Warkworth coal seam

AGE

DATE 06/09/2021

FIGURE No: **5.10**

Source: ELVIS LiDAR DEM (accessed April 2019 ; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1468J.Lemington_UG_Water_Storage\3_GIS\Workspaces\001_GIA\05.10_G1468J_Current groundwater levels – Warkworth coal seam_V01.qgs

5.3.4 Bowfield coal seam

The Bowfield coal seam overlies the Warkworth coal seam and ranges between 80 and 120 m above the Lemington Underground workings (Figure 4.5). Data is available for 15 groundwater level monitoring points in this seam located to the northwest and east to northeast of the LUG Bore (Figure 5.11 and Figure 5.12). As shown in Figure 5.12, the majority of the monitoring locations are located either directly above, or in close proximity to, the workings and hence show generally declining groundwater levels from 2017 onwards, which correlate with increased extraction from the LUG Bore over the same period. Estimated maximum groundwater level declines range from 2.6 to 31.6 m at the 11 monitoring locations within 2 km of the LUG Bore (B334_BFS, B631_BFS, B925_BFS, C130_BFS, C317_BFS, C613_BFS, C621_BFS, C630_BFS, D010_BFS, D241_BFS, D317_BFS). Conversely, data for the remaining four monitoring points located more than 2 km from the LUG Bore (D406_BFS, D510_BFS, D612_BFS, and D807_BFS) show slight increases of up to 12.4 m during the same period.

As shown in Figure 5.12, drawdown in the Bowfield coal seam generally decreases with distance away from LUG Bore. B925_BFS, located 300 m north of the LUG Bore and directly above the Lemington Underground workings, shows the most drawdown of 31.6 m. D010_BFS, located 2 km northwest of LUG Bore and directly above the Lemington Underground workings, shows the least drawdown of 2.6 m. Drawdowns of more than 2 m are not observed in the Bowfield coal seam in any monitoring point more than 2 km from the LUG Bore. Given that impacts will reduce with distance vertically above the workings then this also implies that drawdowns in the overlying units must also be less than 2 m at 2 km.

Information on relative levels between the Bowfield coal seam and workings in the Mount Arthur coal seam are shown in Cross Section A-A’ (Figure 5.6) and Cross Section B-B’ (Figure 5.7) which suggest head differences of around 50 to 100 m suggesting downward flow but limited connectivity between the two seams.

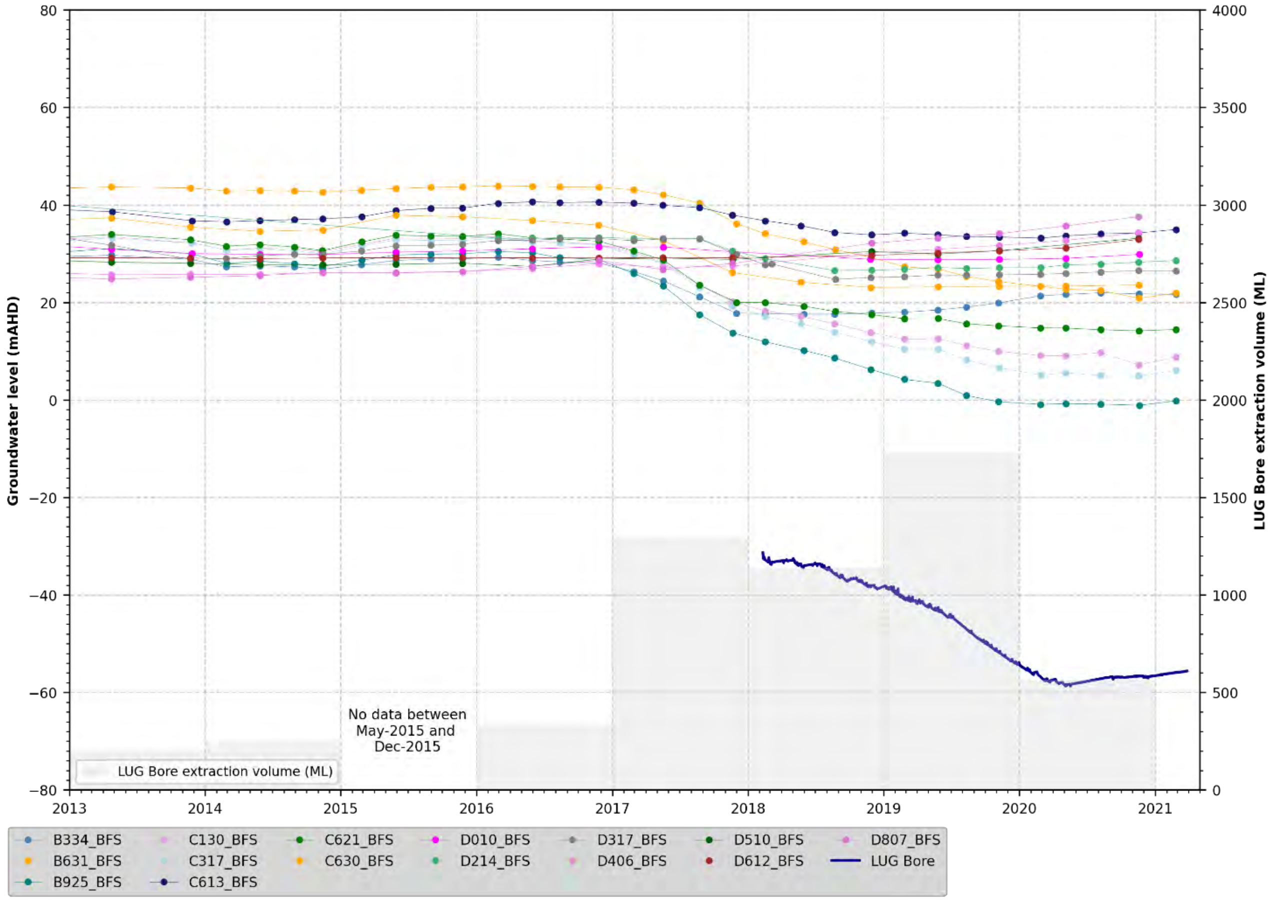
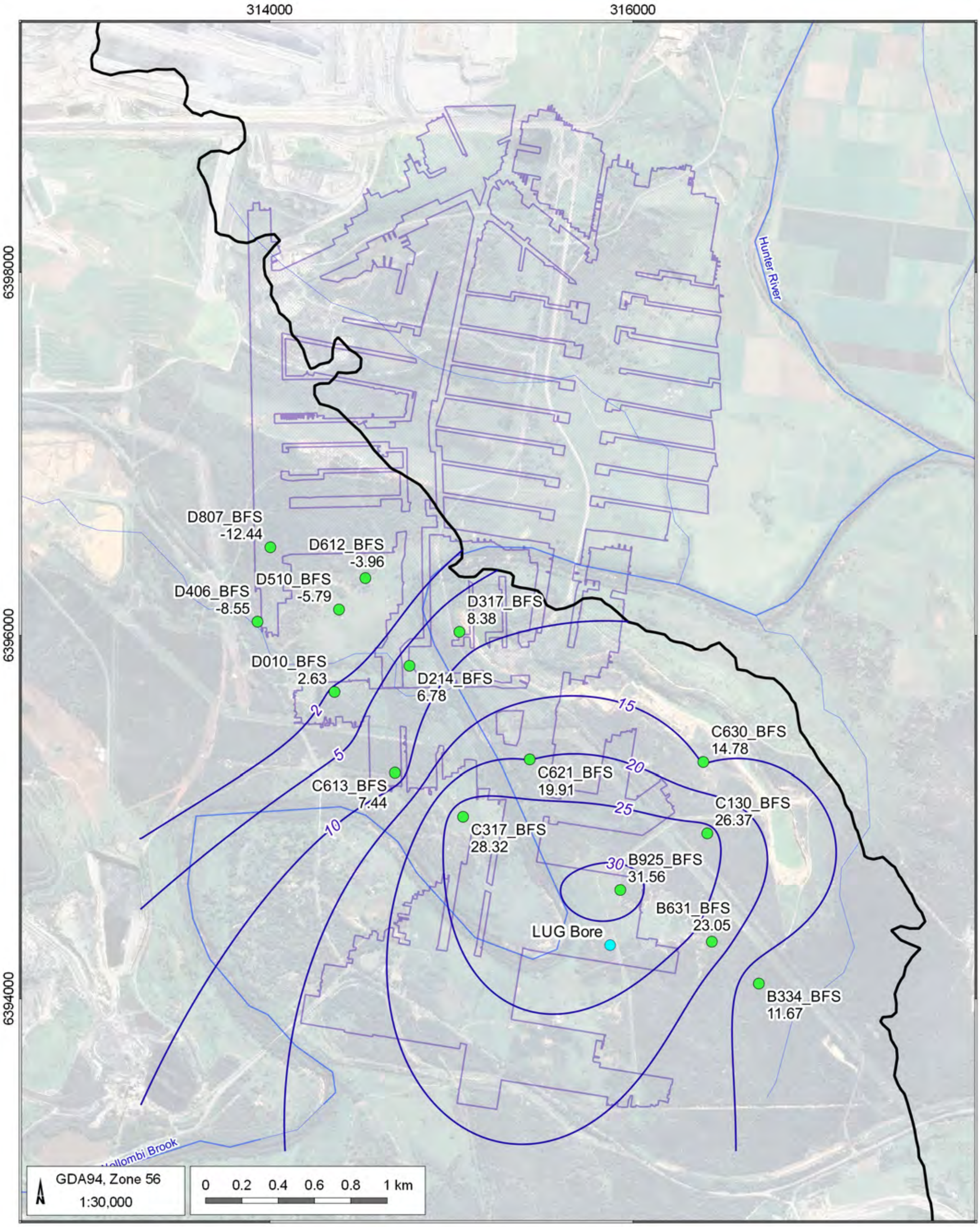


Figure 5.11 Groundwater levels Bowfield coal seam



LEGEND

- Current extraction bore
- Natural drainage feature
- Bowfield seam groundwater level drawdown contour (m)
- Bowfield subcrop
- Lemington Underground workings
- Bowfield seam monitoring bore

B334_BFS : BoreID
11.67 : Current groundwater level drawdown (m)

Lemington UG Water Storage (G1468J)

Groundwater level drawdown – Bowfield coal seam

AGE

DATE 12/08/2021

FIGURE No: **5.12**

Source: ELVIS LiDAR DEM (accessed April 2019 ; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1468J.Lemington_UG_Water_Storage\3_GIS\Workspaces\001_GIA\05.12_G1468J_Groundwater level drawdown – Bowfield coal seam.qgs

5.3.5 Arrowfield coal seam

The Arrowfield coal seam overlies the Bowfield coal seam and on average is positioned around 135 m above the Lemington Underground workings (Figure 4.5). Hydrographs for monitoring points completed into this seam are shown in Figure 5.13, and monitoring point locations are shown in Figure 5.14.

As shown in Figure 5.14, none of the five groundwater level monitoring locations completed into the Arrowfield coal seam are situated directly above the Lemington Underground workings but are mostly located towards the northwest and northeast of the LUG Bore. As shown in Figure 5.13 groundwater levels in the Arrowfield coal seam have remaining relatively static and suggest relatively minor drawdown (up to 3.9 m) during the monitoring period, compared to up to 31.6 m in the underlying Bowfield coal seam (Section 5.3.4).

Information on relative levels between the Arrowfield coal seam and workings in the Mount Arthur coal seam are shown in Cross Section A-A' (Figure 5.6) and suggest head differences of around 100 m suggesting downward flow but relatively limited connectivity between the two seams.

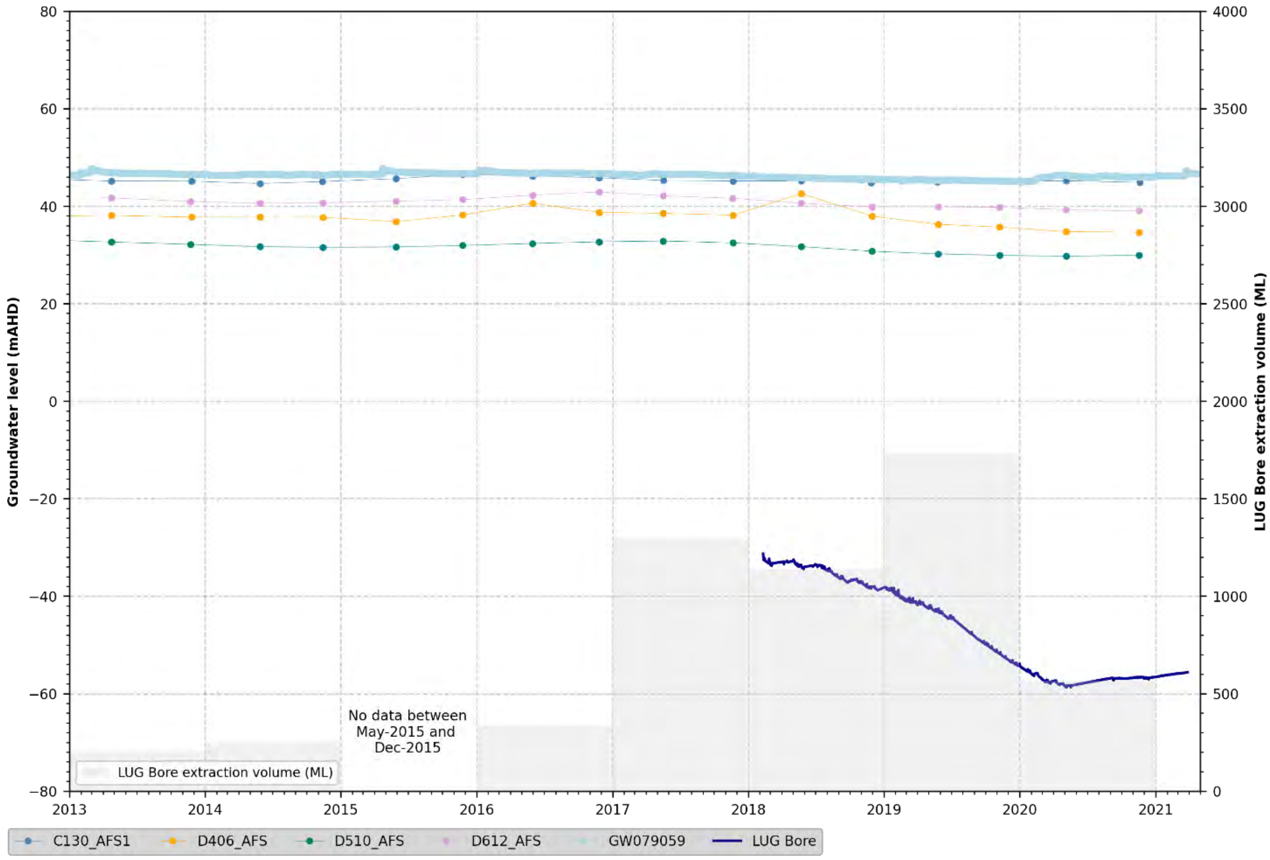
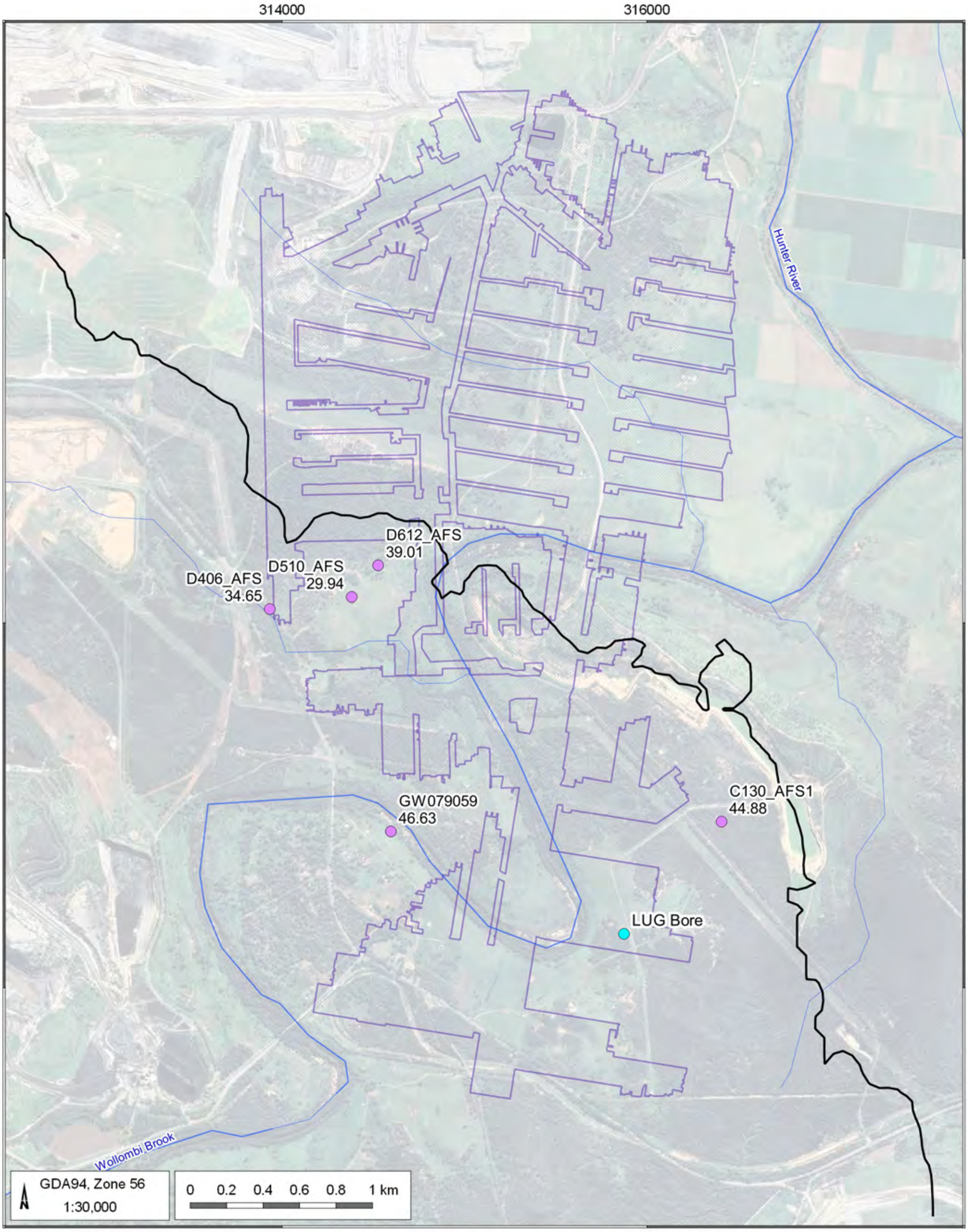


Figure 5.13 Groundwater levels Arrowfield coal seam



LEGEND
- Current extraction bore
- Natural drainage feature
- Lemington Underground workings
- Arrowfield subcrop
- Arrowfield coal seam monitoring location
  - C130_AFS : BoreID
  - 44.88 : Current groundwater level drawdown (m)

Lemington UG Water Storage (G1468J)

Current groundwater levels – Arrowfield coal seam

AGE

DATE 12/08/2021

FIGURE No: **5.14**

Source: ELVIS LiDAR DEM (accessed April 2019 ; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1468J.Lemington_UG_Water_Storage\3_GIS\Workspaces\001_GIA\05.14_G1468J_Current groundwater levels – Arrowfield coal seam.qgs

5.3.6 Woodlands Hill coal seam

The Woodlands Hill coal seam overlies the Arrowfield coal seam and is positioned around 170 m above the Lemington Underground workings (Figure 4.5). Hydrographs for monitoring points completed into the Woodlands Hill coal seam are shown in Figure 5.15, and monitoring point locations are shown in Figure 5.16.

As shown in Figure 5.16, six of the seven water level monitoring points completed into the Woodlands Hill coal seam are located between 800 to 2,000 m to the northwest and northeast of the LUG Bore. The remaining bore (B631_WDH) is situated about 600 east of the LUG Bore. Other than one monitoring point (B425_WDH) which shows around 11.3 m of drawdown, the majority of the available data shows relatively minor drawdowns of between 0.9 and 2.8 m during the monitoring period. This in turn suggests that the impacts of extraction from the LUG Bore on water levels in the Woodlands Hill coal seam are relatively minor.

Information on relative levels between the Woodlands Hill coal seam and workings in the Mount Arthur coal seam are shown in Cross Section A-A' (Figure 5.6) and Cross Section B-B' (Figure 5.7) which suggest head differences of around 100 m suggesting downward flow but relatively limited connectivity between the two seams.

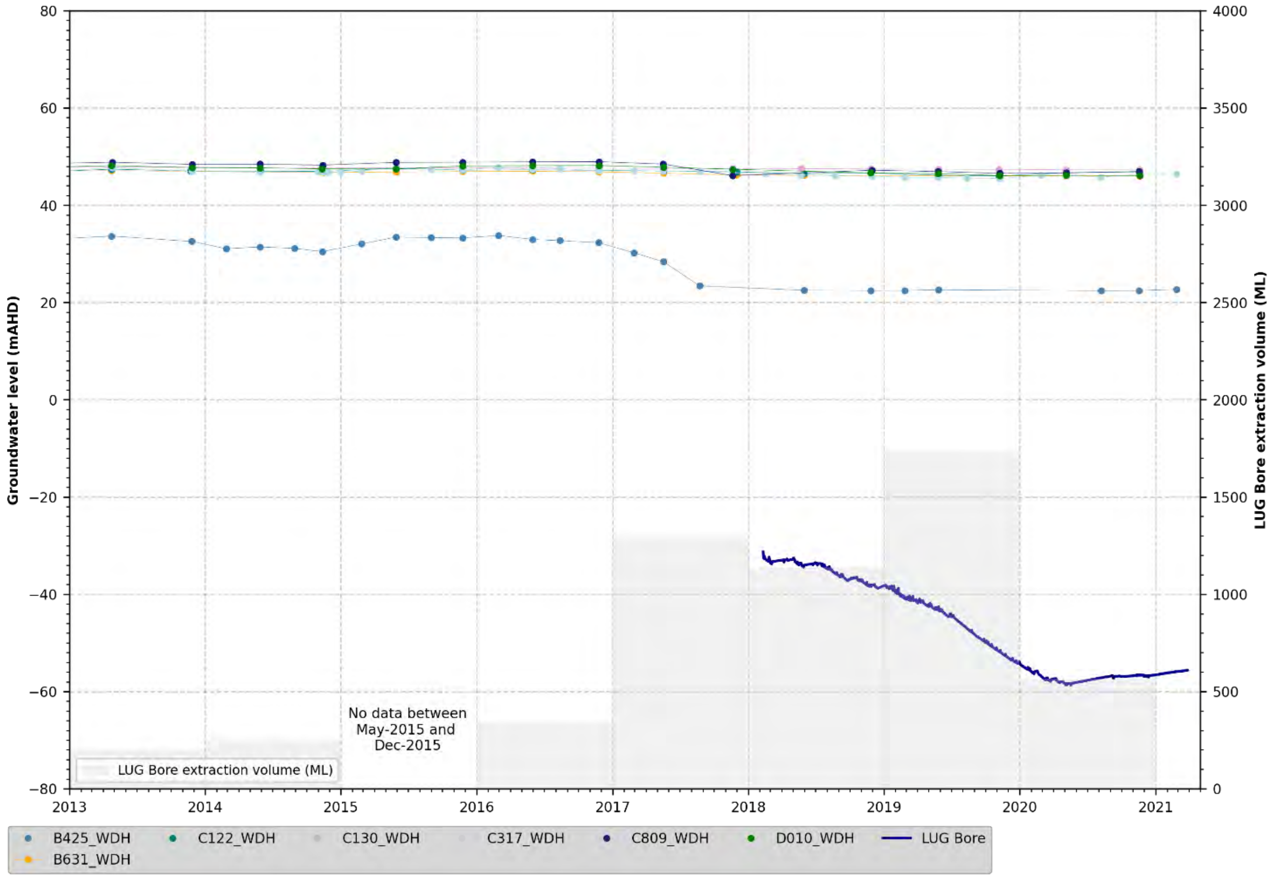
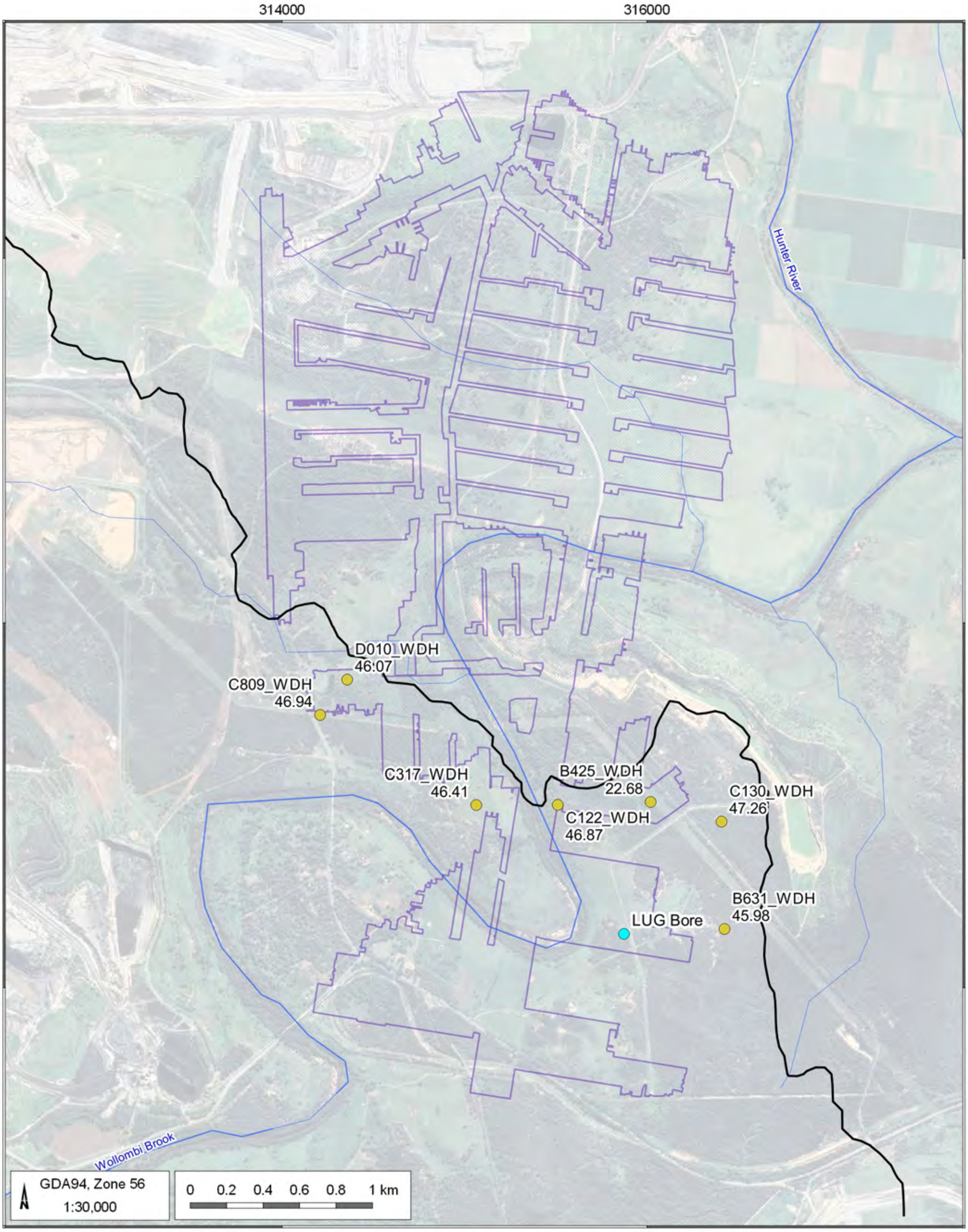


Figure 5.15 Groundwater levels Woodlands Hill coal seam



LEGEND
- Current extraction bore
- Natural drainage feature
- Woodlands Hill subcrop
- Lemington Underground workings
- Woodlands Hill seam monitoring bore

B631_WDH : BoreID
45.98 : Current groundwater level drawdown (m)

Lemington UG Water Storage (G1468J)

Current groundwater levels – Woodlands Hill coal seam

AGE

DATE 12/08/2021

FIGURE No: **5.16**

Source: ELVIS LiDAR DEM (accessed April 2019 ; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1468J.Lemington_UG_Water_Storage\3_GIS\Workspaces\001_GIA\05.16_G1468J_Current groundwater levels – Woodlands Hill coal seam.qgs

5.3.7 Glen Munro coal seam

The Glen Munro coal seam overlies the Woodlands Hill coal seam and is positioned around 200 m above the Lemington Underground workings (Figure 4.5). Data for the single monitoring point in the Glen Munro coal seam (D010_GM) are shown in Figure 5.17, and the monitoring point location is shown in Figure 5.18.

As shown in Figure 5.18 D010_GM is located approximately 2 km northwest of LUG Bore directly above the Lemington Underground workings. As shown in Figure 5.17 observed groundwater levels in D010_GM have declined slightly from 49.5 mAHD in May 2016 to 47.1 mAHD in November 2019 during the period when extraction from the LUG Bore was increasing, suggesting possible minor impacts of up 2.4 m at this location.

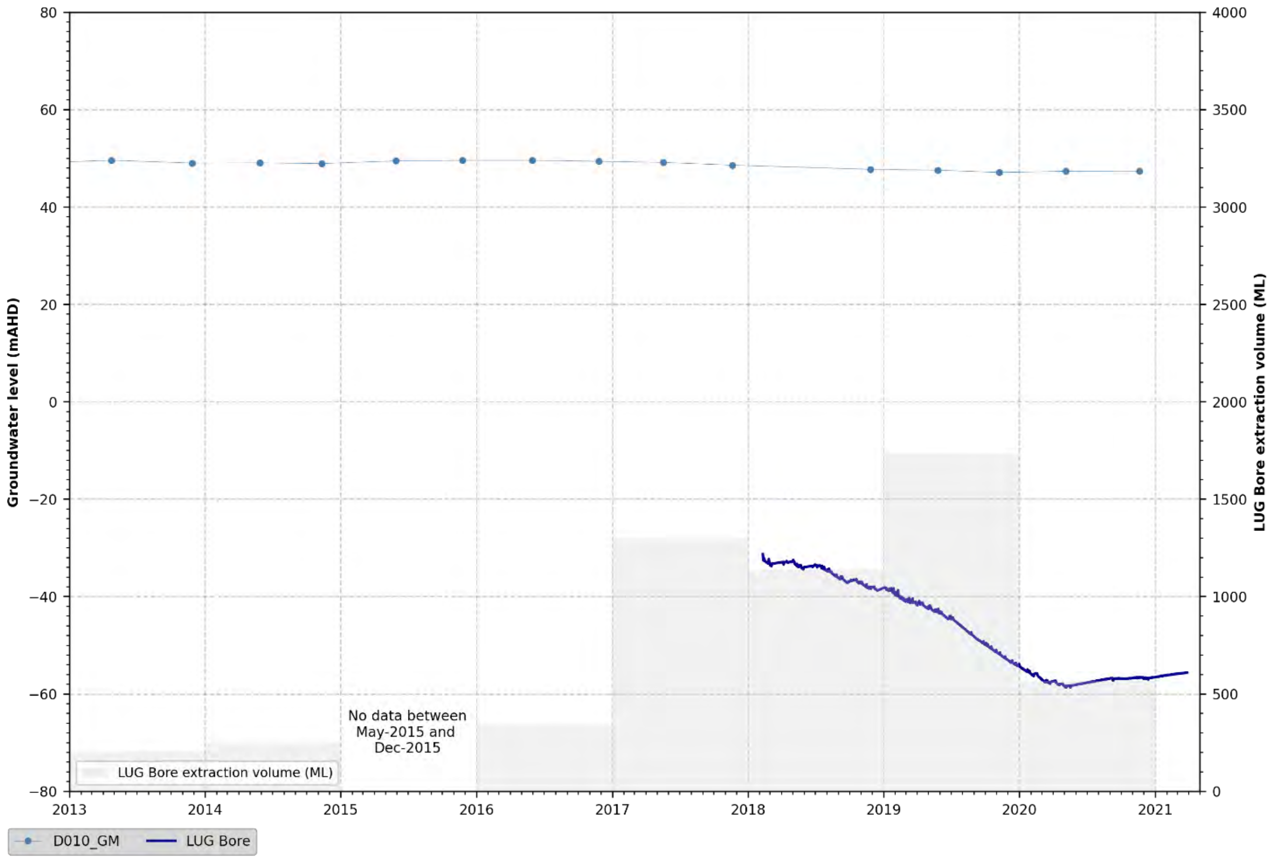
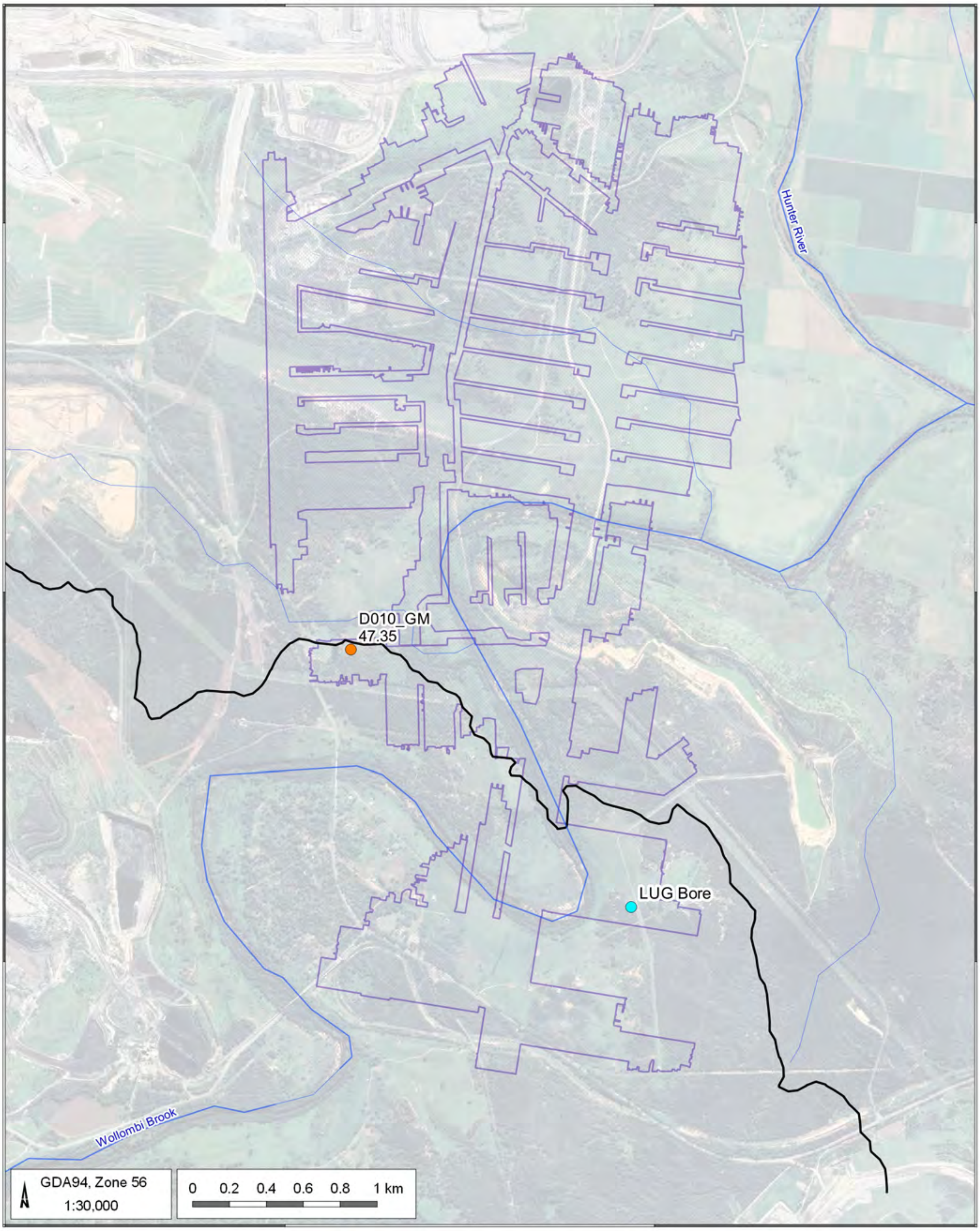


Figure 5.17 Groundwater levels Glen Munro coal seam



LEGEND

- Current extraction bore
- Natural drainage feature
- Lemington Underground workings
- Glen Munro subcrop
- Glen Munro seam monitoring bore

D010_GM : BoreID
47.35 : Current groundwater level drawdown (m)

Lemington UG Water Storage (G1468J)

Current groundwater levels – Glen Munro coal seam

AGE

DATE 12/08/2021

FIGURE No: **5.18**

Source: ELVIS LiDAR DEM (accessed April 2019 ; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1468J.Lemington_UG_Water_Storage\3_GIS\Workspaces\001_GIA\05.18_G1468J_Current groundwater levels – Glen Munro coal seam.qgs

5.3.8 Wollombi Brook alluvium

Groundwater level data for monitoring points completed into the Wollombi Brook alluvium are shown compared to cumulative departure from mean monthly rainfall in Figure 5.19 and to extraction from the LUG Bore in Figure 5.20. Monitoring point locations and current groundwater levels are shown in Figure 5.21.

As shown in Figure 5.21, groundwater level data are available for seven monitoring locations in the Wollombi Brook alluvium close to the Lemington Underground workings, three of which (APP_FARM, C919_ALL and PB01_ALL) are located directly above the workings.

As shown in Figure 5.19, groundwater levels in all of the alluvium monitoring points correlate well with the cumulative departure plot. In particular, groundwater levels at all locations decline gradually from 2016 to 2020 due to the relatively dry (i.e. below average) rainfall conditions which prevailed during this period resulting in the declining cumulative departure trace over this same period. Consequently groundwater levels at all seven monitoring points were already declining in 2016 prior to the increase in extraction from the LUG bore which occurred in 2017 and caused significant drawdown in the Mount Arthur and Bowfield coal seams in particular (Figure 5.3 and Figure 5.11). The observed rate of decline in alluvium levels during 2016 is similar to that during 2017, 2018 and 2019 when dry conditions continued but extraction from the workings increased. In particular, there is no evidence of any changes in drawdown rate in any of the three observations bores (APP_FARM, C919_ALL and PB01_ALL) which are located within the footprint of the workings and close to the LUG Bore. The rate of observed decline in these monitoring points before and after 2017 is no different from that seen in other monitoring points such as GW15 which is located close to the Wollombi Brook more than 1 km upstream of the workings.

Interpolated current groundwater level contours for the Wollombi Brook alluvium are shown in Figure 5.21 and suggests groundwater flows from southwest to northeast consistent with the surface water flow direction in the brook.

As shown in Cross Section B-B' (Figure 5.7) groundwater levels in the Wollombi Brook alluvium are generally slightly above those in the underlying Permian age strata in the vicinity of the workings and hence some downward leakage is expected. As shown the current groundwater level in the Bowfield coal seam close to the Wollombi Brook at monitoring point D317_BFS is around 26 m, i.e., around 20m below the current groundwater level in the alluvium. However, the lack of any significant observable responses in the alluvium groundwater level data (Figure 5.20) suggests that this downward flow component is relatively minor.

5.3.9 Hunter River alluvium

No groundwater level data is currently available for monitoring points installed into the Hunter River alluvium close to the Lemington Underground workings and the degree to which the operation of the Lemington underground mine and more recently extraction from the LUG Bore has historically affected groundwater levels in the alluvium are therefore not known. As shown in cross section B-B' (Figure 5.7) and cross section C-C' (Figure 5.8) the workings are understood to be unsaturated beneath the Hunter River alluvium and the coal seams are also thought to sub-crop beneath the alluvium. As such there is some potential for minor downward leakage in this area.

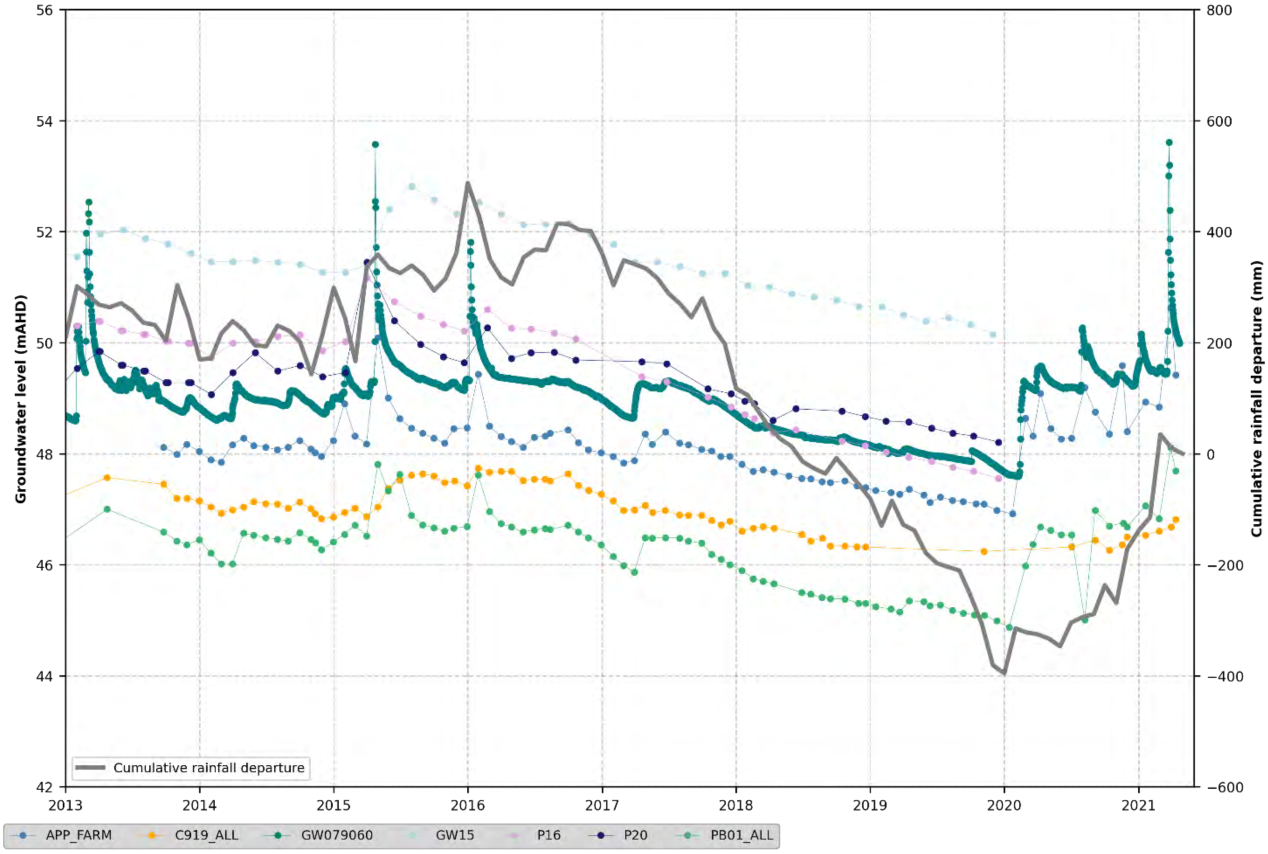


Figure 5.19 Wollombi Brook alluvium water levels compared to cumulative rainfall departure

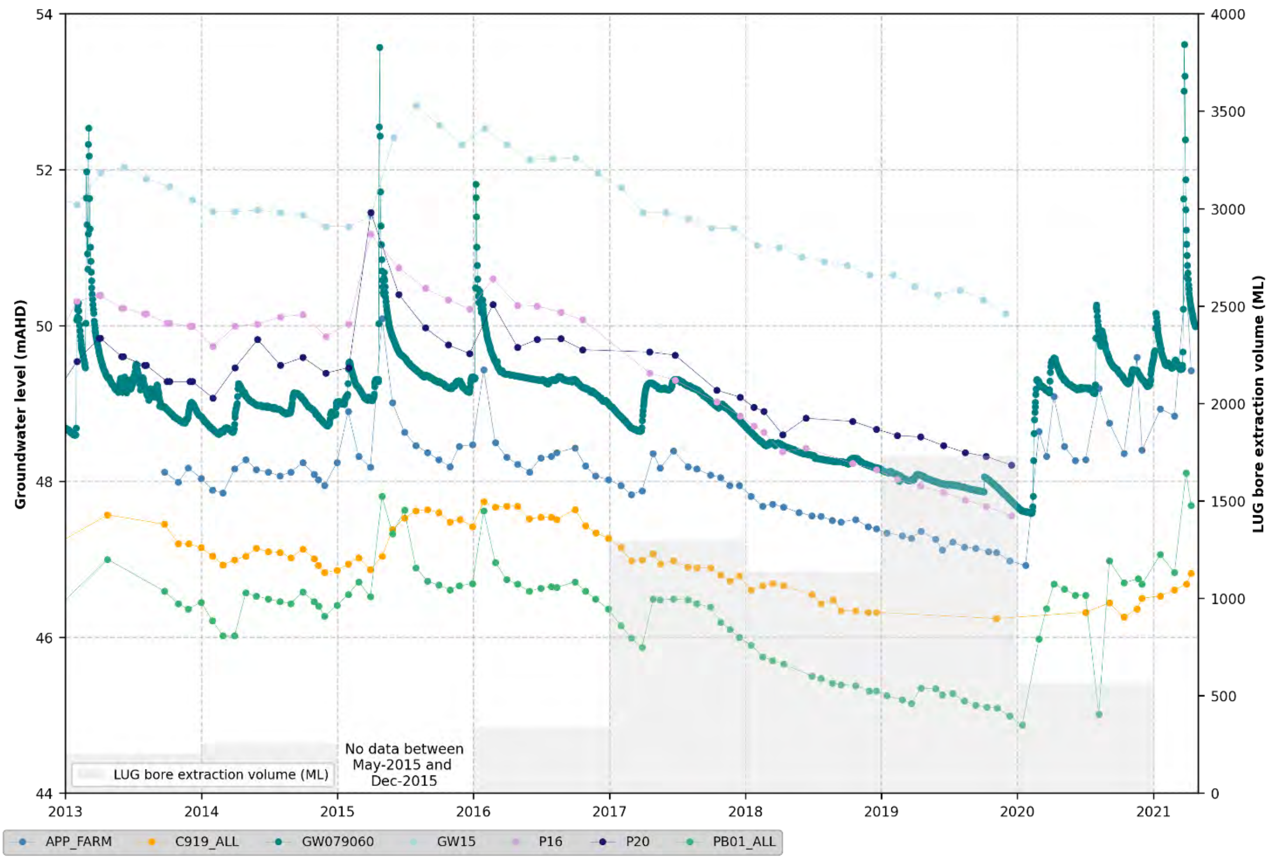
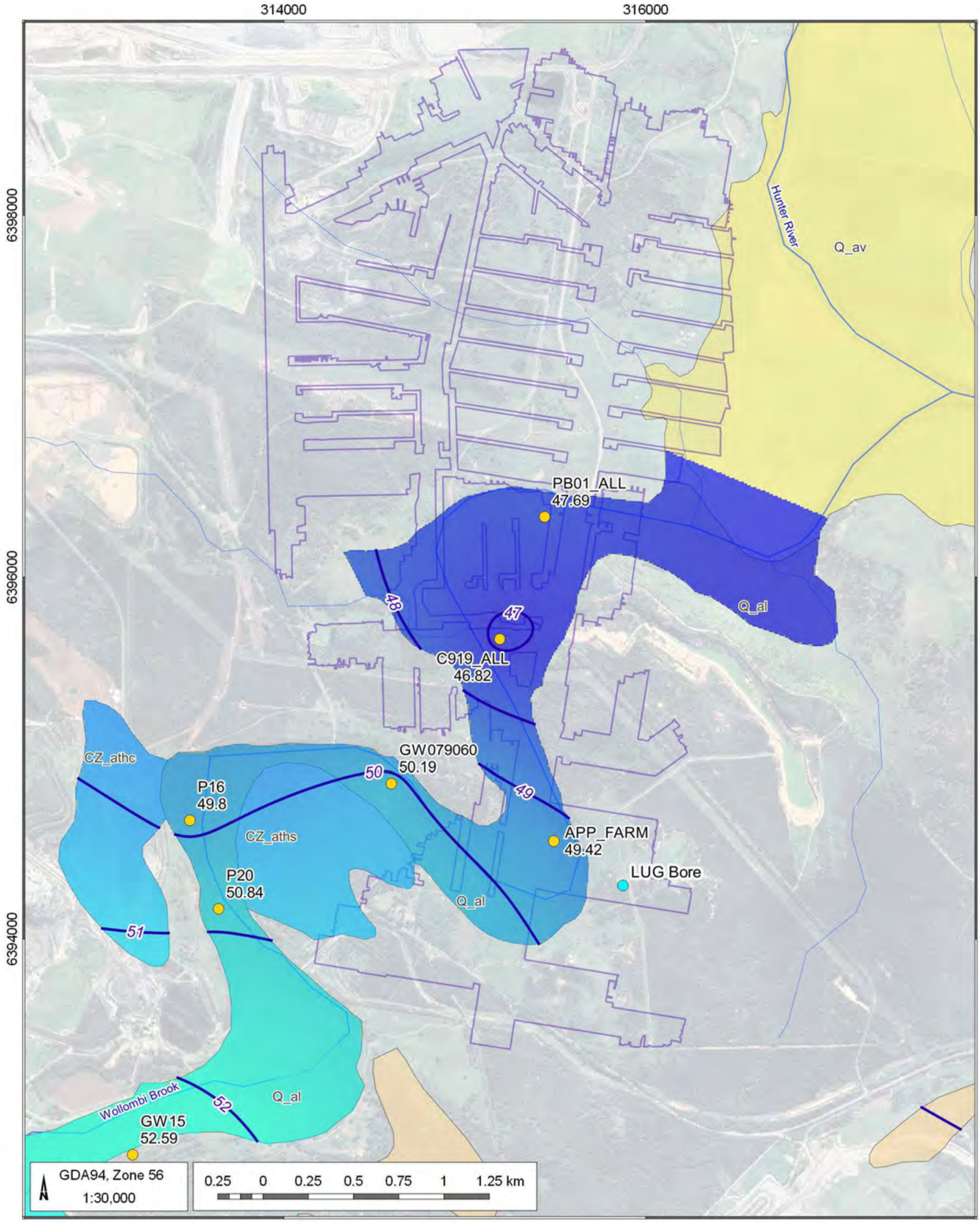


Figure 5.20 Wollombi Brook alluvium water levels compared to total annual extraction from LUG Bore



LEGEND

- Current extraction bore
- Natural drainage feature
- Alluvium groundwater level contour (mAHD)
- Lemington Underground workings

Cenozoic

- Q_al - overbank deposits
- Q_av - Alluvial valley deposits
- CZ_athc - Alluvial terrace deposits
- CZ_aths - High-level sand and sandstone

- Alluvium monitoring

GW15 : BoreID
52.59 : Current water level (mAHD)

Water level (mAHD)

47
48
49
50
51
52

Lemington UG Water Storage (G1468J)

Current groundwater level contours – Quaternary alluvium

AGE

DATE 03/08/2021

FIGURE No: **5.21**

Source: ELVIS LiDAR DEM (accessed April 2019 ; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1468J.Lemington_UG_Water_Storage\3_GIS\Workspaces\001_GIA\05.21_G1468J_Current groundwater level contours – Quaternary alluvium.qgs

5.3.10Warkworth Sands

Time series groundwater level data are currently available for only two Warkworth Sands monitoring bores PZ7S and MB15MTW06 (Figure 5.22). The remaining seven bores are understood to be predominantly dry. As the Warkworth Sands at PZ7S are saturated for prolonged periods, it is thought that this bore is located in a deeper trough of the sands where the perched water level persists above the confining basal clay bed. Lockwood (2007) found that the Warkworth Sands are underlain by a confining clay bed creating a perched aquifer system with limited hydraulic connection to the underlying Permian strata. Consistent with this conceptual model, as shown in Figure 5.22, observed groundwater levels at PZ7S show no significant response to the increasing extraction and declining levels in the workings which occurred from 2017 onwards.

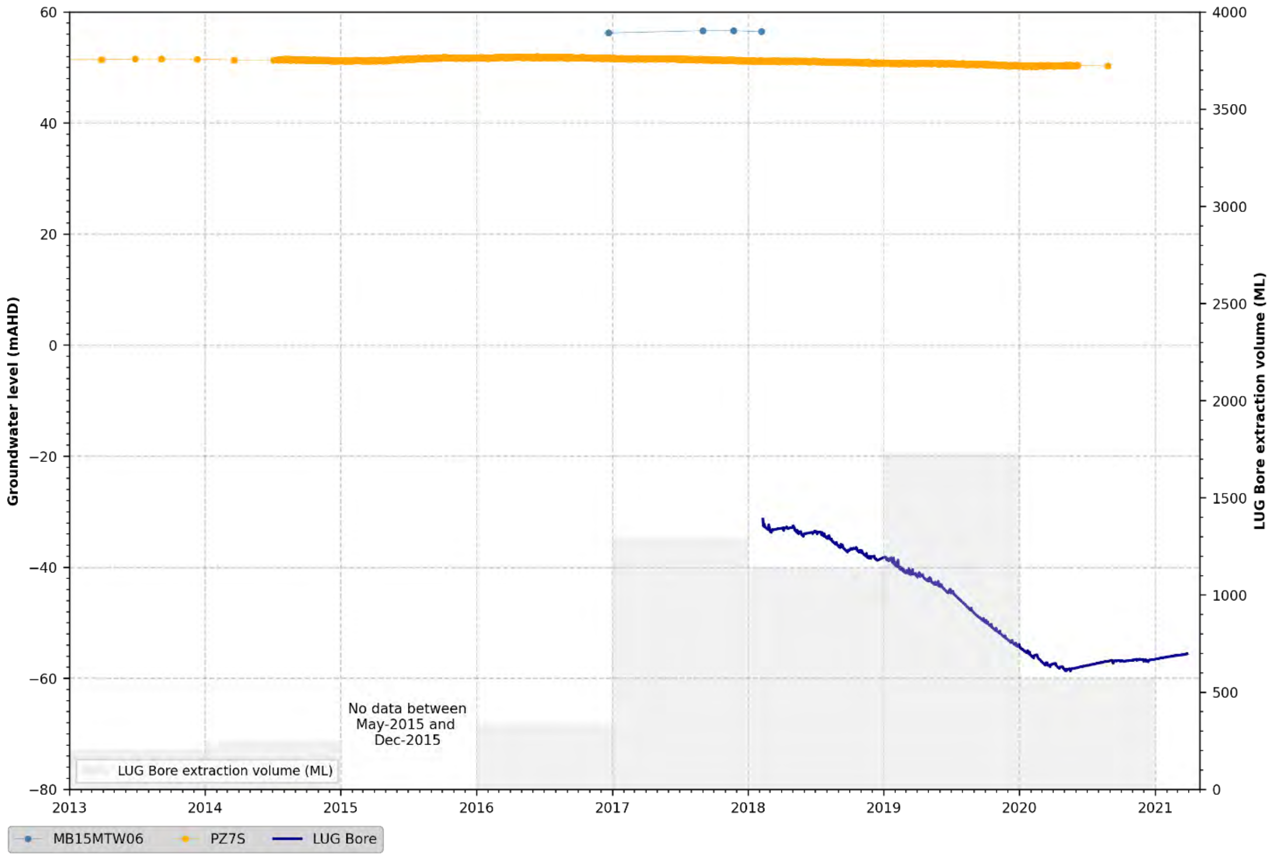
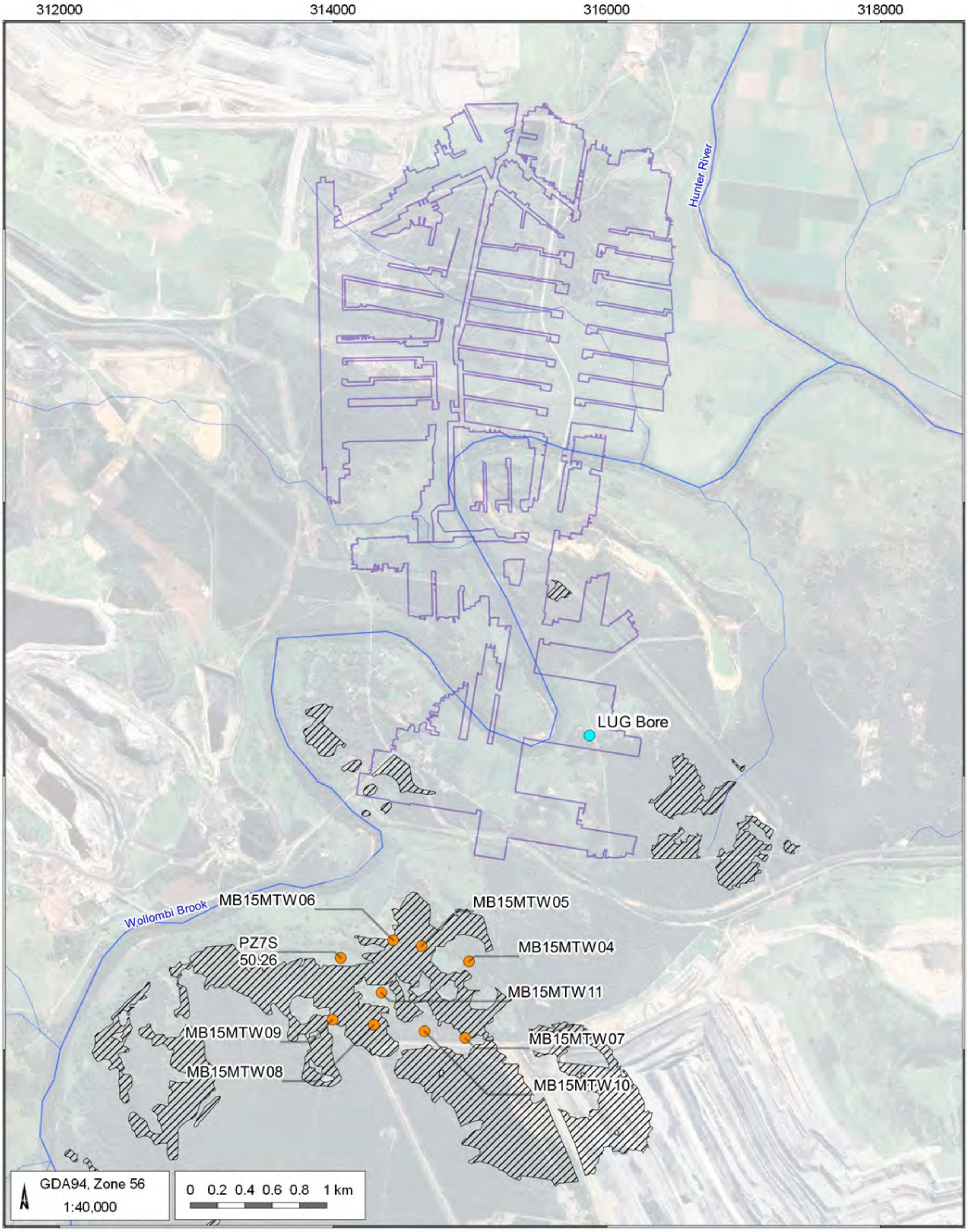


Figure 5.22 Groundwater levels Warkworth Sands



LEGEND
- Current extraction bore
- Natural drainage feature
- Lemington Underground workings
- Warkworth Sands Woodland
- Warkworth Sands monitoring bore

P27S : BoreID
50.28 : Current groundwater level drawdown (m)

Lemington UG Water Storage (G1468J)

Current groundwater levels and monitoring locations – Warkworth Sands

AGE

DATE 07/09/2021

FIGURE No: **5.23**

Source: ELVIS LiDAR DEM (accessed April 2019 ; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1468J.Lemington_UG_Water_Storage\3_GIS\Workspaces\001_GIA\05.23_G1468J_Current groundwater levels and monitoring locations – Warkworth Sands.qgs

5.3.11Nested monitoring facilities

Reliable groundwater level data are available for 10 of the 12 nested monitoring locations shown in Figure 5.2. Data for the remaining two nested monitoring locations, C122 and D317 contain missing or erroneous data. Hydrographs for the three nested monitoring locations within data closest to the LUG Bore (B631, C130, and C317) are shown in Figure 5.24, Figure 5.25 and Figure 5.26, respectively. Hydrographs for each of the remaining nested monitoring facilities not discussed below are presented in Appendix A C130, located approximately 800 m northeast of LUG Bore and 200 m east of the Lemington Underground workings, comprises four monitoring points completed into the Wollombi Brook alluvium, Woodlands Hill, Arrowfield, and Bowfield coal seams. As shown in Figure 5.24, substantial drawdown of around 26 m is observed in the lowermost monitoring point in the Bowfield coal seam during the 2017 to 2020 period, reflecting increased extraction from the LUG Bore over this period. However, data for the overlying Arrowfield coal seam (C130_AFS) shows around 1.6 m of drawdown over the same period and there is little or no response in the Woodlands Hill coal seam or in the Wollombi Brook alluvium.

Similarly, as shown in Figure 5.25 and Figure 5.26, data for the nested monitoring facilities B631 and C317 also show more than 20 m of drawdown in the Bowfield coal seam and little or no discernible drawdown in the overlying Woodland Hill coal seam.

Data for all three nested monitoring locations therefore reinforce observations made elsewhere in this report section that the major (>2 m) impacts of operating the LUG Bore extraction from 2013 onwards do not extend beyond the Bowfield coal seam.

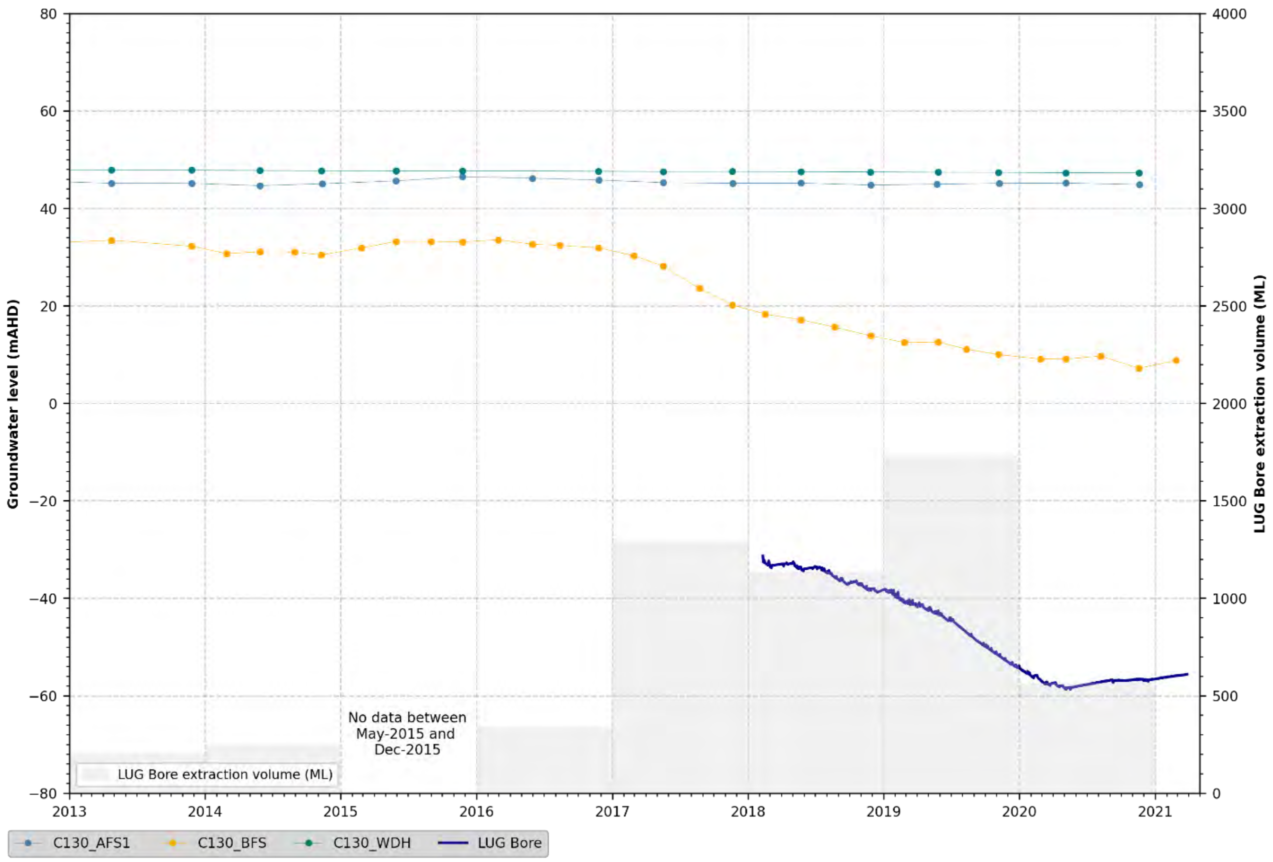


Figure 5.24 C130 nested facility water levels

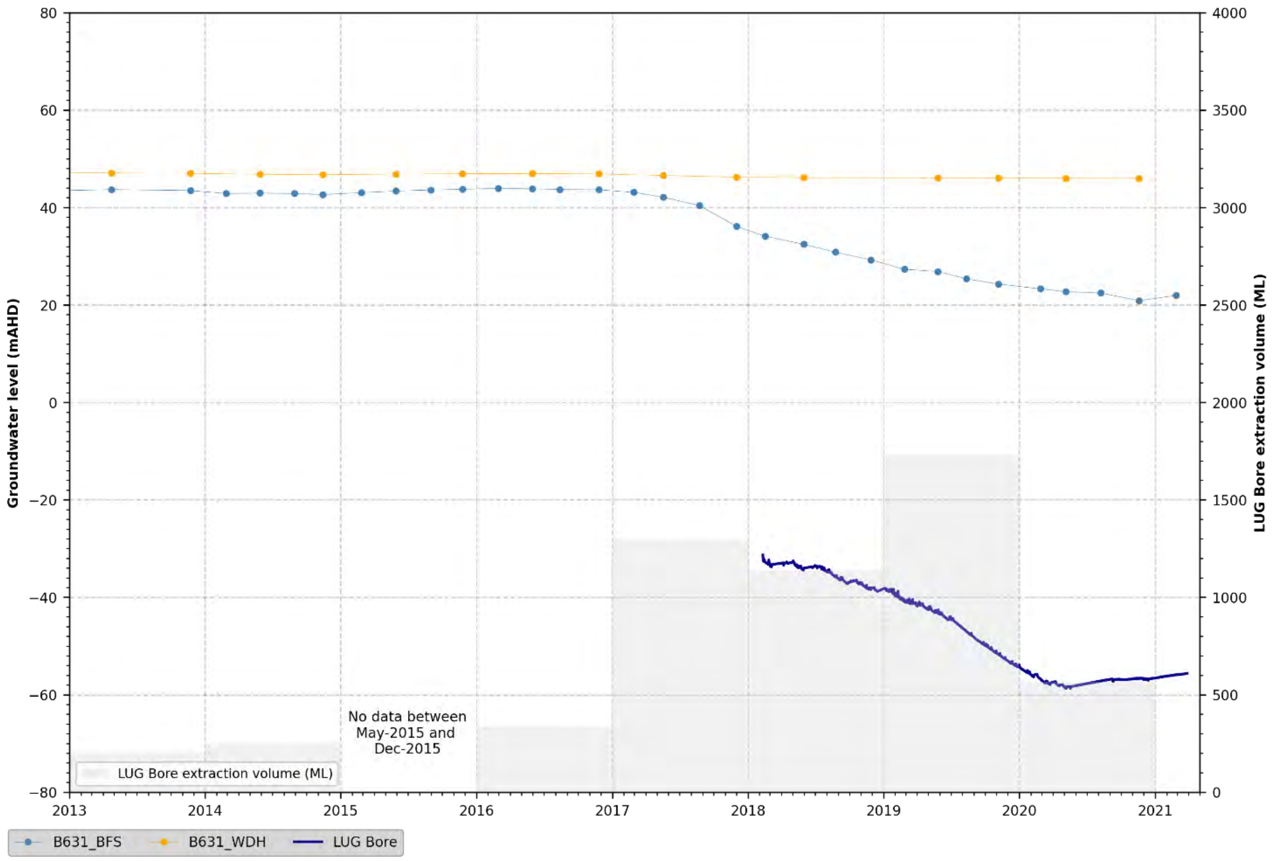


Figure 5.25 B631 nested facility water levels

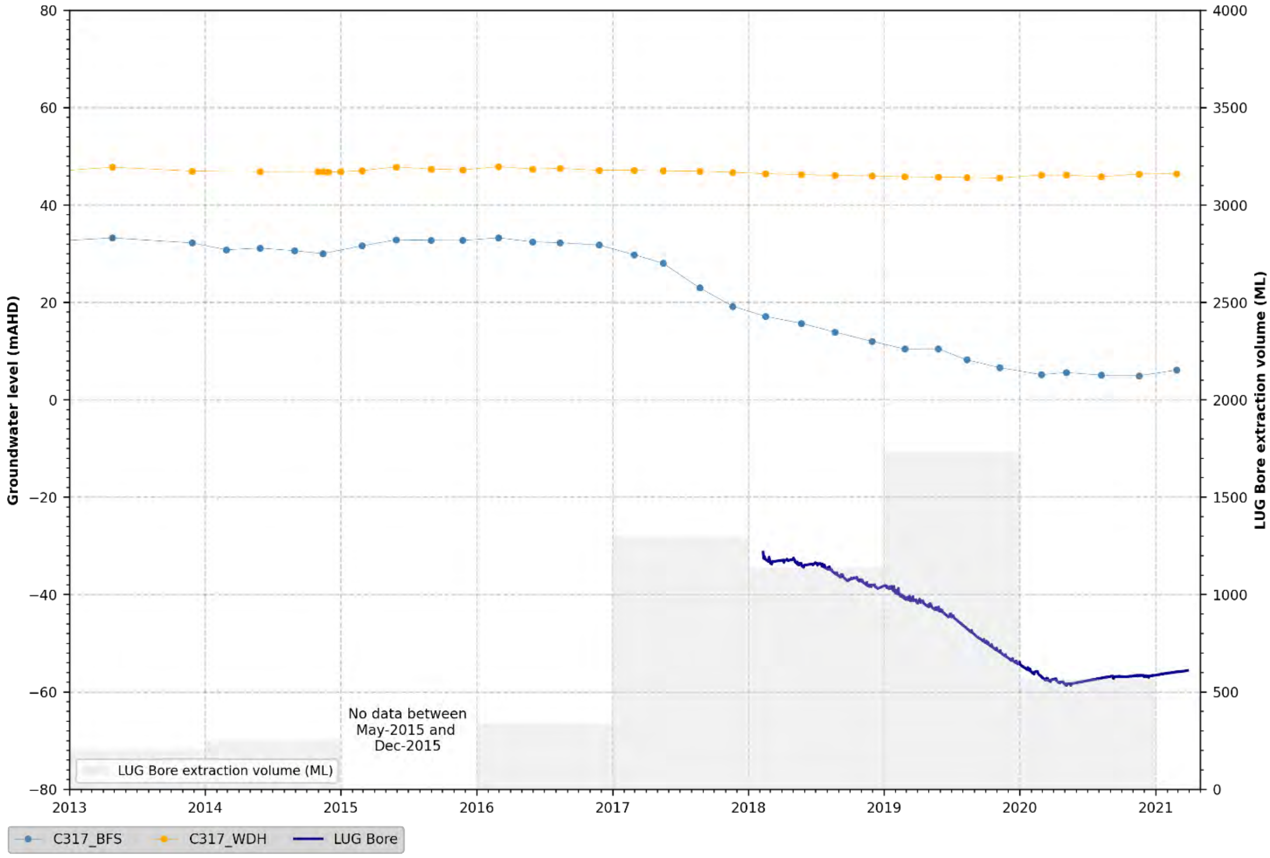


Figure 5.26 C317 nested facility water levels

5.4 Surface water flows

As discussed in Section 4.2 and shown in Figure 4.2, surface water flow data are available for the Wollombi Brook at Warkworth and on the Hunter River at Mason Dieu just upstream of the footprint of Lemington Underground workings. Consequently, flows at these gauges could be affected if there was any significant drawdown and/or leakage from the alluvium to the underlying strata. However, as described in Section 5.3 significant groundwater level impacts of more than 2 m do not appear to extend more than 2 km from the LUG Bore laterally and the Bowfield coal seam vertically. Furthermore, the average annual extraction from the workings (760 ML/year) represents only a small fraction of the long term average flow in the Wollombi Brook (94,170 ML/year) and in the Hunter River (345,290 ML/year) at these locations and hence any flow impacts would not be measurable.

5.5 Lemington underground storage curve development

In terms of understanding the potential impact of the modification on groundwater resources, a storage curve for the underground workings (i.e., a chart relating groundwater levels to the volume of water stored) is a key requirement. The geometry (length, width, height, and elevation) was spatially delineated for each section of the Lemington Underground workings from which the storage curve shown in Figure 5.27 has been derived. The storage curve is subject to some uncertainty as the geometry information has been estimated for each of the mine section polygons shown in Figure 3.1. The elevation of some sections of the mine varies significantly from north to south, for instance the base of the workings within section B&P1B (Figure 3.1) ranges from -186.4 to -72.9 mAHD. Upper bound, lower bound, and average storage curves were therefore developed (Figure 5.27), based on the minimum, maximum, and average of the elevation of the each of the mining sections. In practice, the actual storage curve will lie somewhere within the grey area shown, although for simplicity this report predominantly focusses on the average curve.

Further uncertainty in the storage curve results from the degree to which the mine goaf has been filled by the collapse of overlying material and the degree and extent of fracturing in the overlying material. The collapse of material into the goaf will tend to reduce the available storage in the workings, but this will also create additional void space in both the overlying caved and fractured zones. The storage curve shown in Figure 5.27 has been derived using a simpler, and likely more accurate, conservation of mass approach whereby the available storage in each part of the mine has been calculated based on the cutting height. Since mass can be neither created or destroyed then the total volume of void space initially available underground prior to any compaction and subsidence, will be equal to the volume of material removed and hence can be calculated from the geometry (length, width, and depth) of the void space created prior to collapse. As shown in Figure 5.27, using this approach then the total water storage volume available in the workings is estimated to be 9,200 ML.

As discussed previously in Section 5.3.2 and shown in Figure 5.5, the current groundwater level in the Mount Arthur coal seam is around -20 mAHD towards the north of the Lemington Underground workings. Intersecting these estimated groundwater level contours with the elevation of the base of the workings (Figure 3.2) suggests that the workings are at least partially saturated up to around -22 mAHD. As shown on Figure 5.27, this level equates to a current estimated storage volume of 6,800 ML, suggesting that there is currently around 2,400 ML of free storage available in the workings.

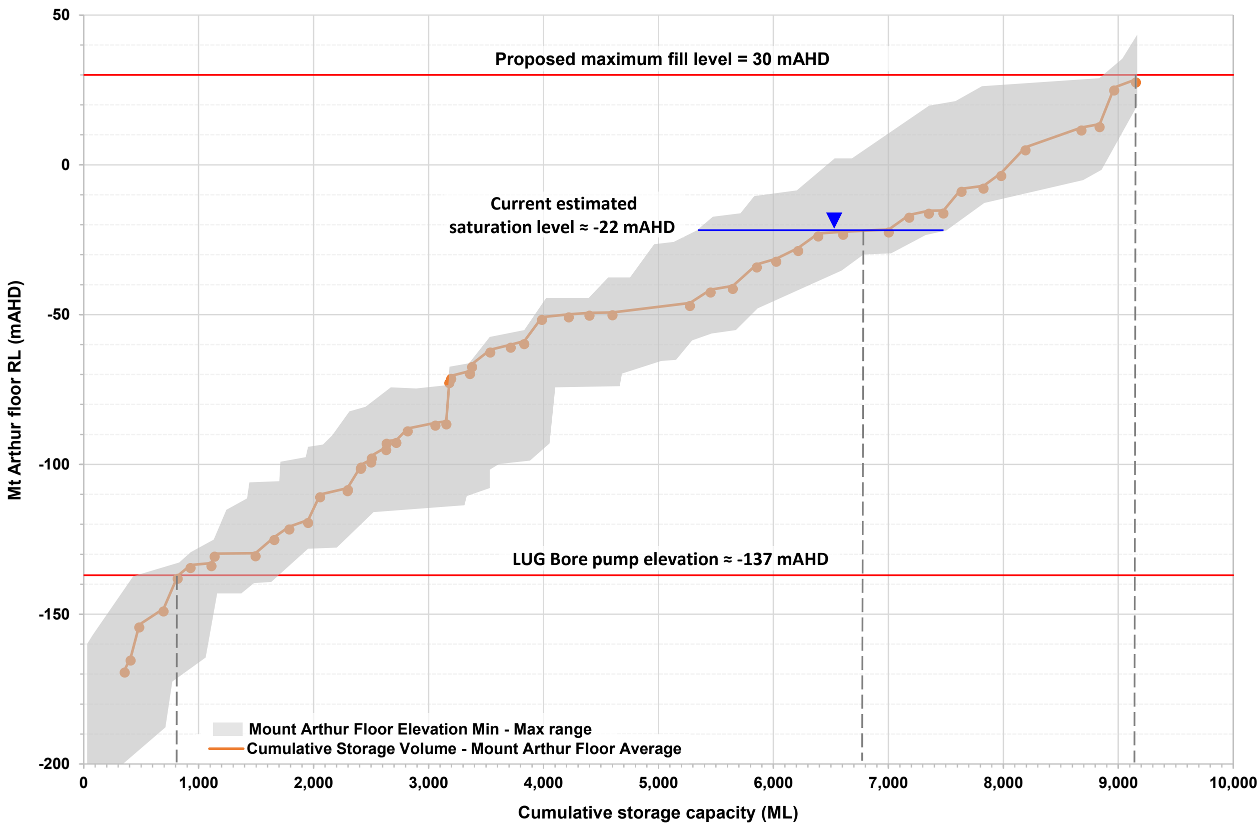


Figure 5.27 Estimated Lemington Underground storage curve

5.6 Groundwater use

5.6.1 Private groundwater users

Information on groundwater use within the study area has been extracted from two sources:

- Real-time water data via WaterNSW (2021); and
- the BoM NGIS (BoM, 2021).

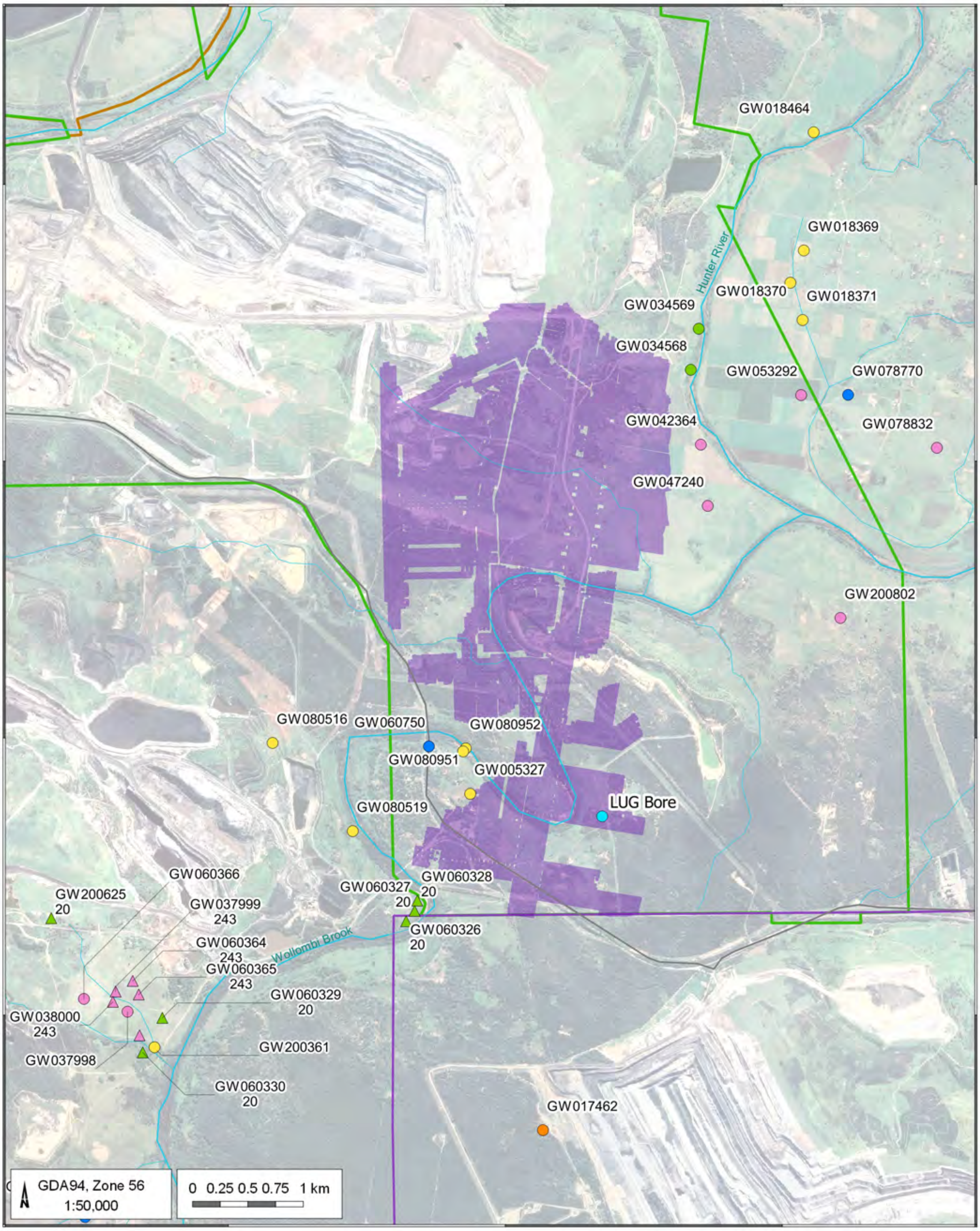
The WaterNSW dataset is considered to be the primary data source as this data feeds into the BoM NGIS dataset. However, both datasets were considered to ensure all registered bores are included in the dataset to be used. This combined dataset suggests the presence of 159 registered works within the vicinity of the Lemington Underground workings. This total includes 126 registered works which were drilled for other non-water supply purposes such as dewatering, exploration or groundwater monitoring and/or are no longer in use. Accordingly, there are 33 existing water supply bores within the project area as shown in Figure 5.28. It should be noted, however, that this total includes some 10 registered works for which the bore purpose is marked as "unknown" and hence which may not be water supply bores.

Registered water supply bores in the model domain are primarily identified as being used for irrigation or commercial and industrial purposes or for other undefined purposes. As shown in Table 5.2, 11 of the registered works are associated with groundwater licenses with stated volumes, which is a total of 1,335 ML/yr. Furthermore, information on the hydrostratigraphic unit (or aquifer) targeted by each bore is not typically provided in either the WaterNSW or NGIS systems. Accordingly, the licensed bores' screened depth was used as an indication of the stratigraphic unit intersected and subsequently targeted for extraction. Based on their reported depths, all but one of the bores shown extract water from alluvium associated with the Wollombi Brook. Only a single bore (GW200625 shown in Figure 5.30 is thought to be deep enough to penetrate into the underlying consolidated Permian strata. GW200625 is located approximately 3.3 km west of the Lemington Underground workings and is about 270 m deep, which is as deep as the deepest section of the Lemington Underground workings.

Overall, the Wollombi Brook alluvium, which is considered a highly productive aquifer, is the main water source utilised for licensed groundwater extraction. Of the 11 bores with licenced extraction, three are located near the Wollombi Brook approximately 400 m upstream of the Lemington Underground workings. These three bores are registered for commercial and industrial extraction with a total limit of 60 ML/yr. The remaining bores with licensed extraction are located more than 2.6 km southwest from the Lemington Underground workings.

Table 5.2 Registered water supply bores with licensed quantities

Hydrostratigraphic Unit	Commercial and Industrial (ML/yr)	Irrigation (ML/yr)	Stock and Domestic (ML/yr)	Other water supply (ML/yr)	Total volume (ML/yr)	No of bores
Hunter River alluvium	0	0	0	0	**0**	**0**
Wollombi Brook alluvium	100	1,215	0	0	**1,315**	**10**
Jerrys Plains subgroup	20	0	0	0	**20**	**1**
Total	**120**	**1,215**	**0**	**0**	**1,335**	**11**



LEGEND

- Current extraction bore
- Natural drainage feature
- Lemington Underground workings
- HVO North development consent boundary
- HVO South development consent boundary
- MTW Leases

Registered bores

- Commercial and Industrial
- Irrigation
- Stock and Domestic
- Water Supply
- Unknown

△ Bores with licensed volume
BoreID
Licensed volume

Lemington UG Water Storage (G1468J)

Registered water supply bores

AGE

DATE 06/09/2021

FIGURE No: **5.28**

Source: LiDAR DEM - © Department Finance, Services and Innovation.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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5.6.2 Groundwater inflows

In addition to developing a storage curve, the rate at which groundwater would naturally enter the workings represents a further key input in terms of understanding the impacts of the modification and also represents a constraint on the volume of water that could be transferred for storage into the underground workings.

As discussed previously (Section 5.3.2 and shown in Figure 5.3), extraction from the existing LUG Bore has significantly reduced during the recent period (due to increased onsite rainfall capture) leading to a gradual recovery in groundwater levels within the workings. Observed groundwater level and monthly extraction data for the period from April 2020 to April 2021 are shown in Figure 5.29 and show recovery rates of 0.011 to 0.013 metres per day during two discrete periods when there was little or no extraction from the LUG Bore. Extrapolating these rates over the course of a year suggests that natural inflow to the workings could cause levels to rise by around 4.0 to 4.75 metres per year, equivalent to around 500 ML of storage per year. As discussed above (Section 5.4), comparison of the current and maximum available storage in the workings suggest around 2,400 ML of available free storage which suggests that the workings could fill naturally within around five years if there were no further water transfers into or out of the workings.

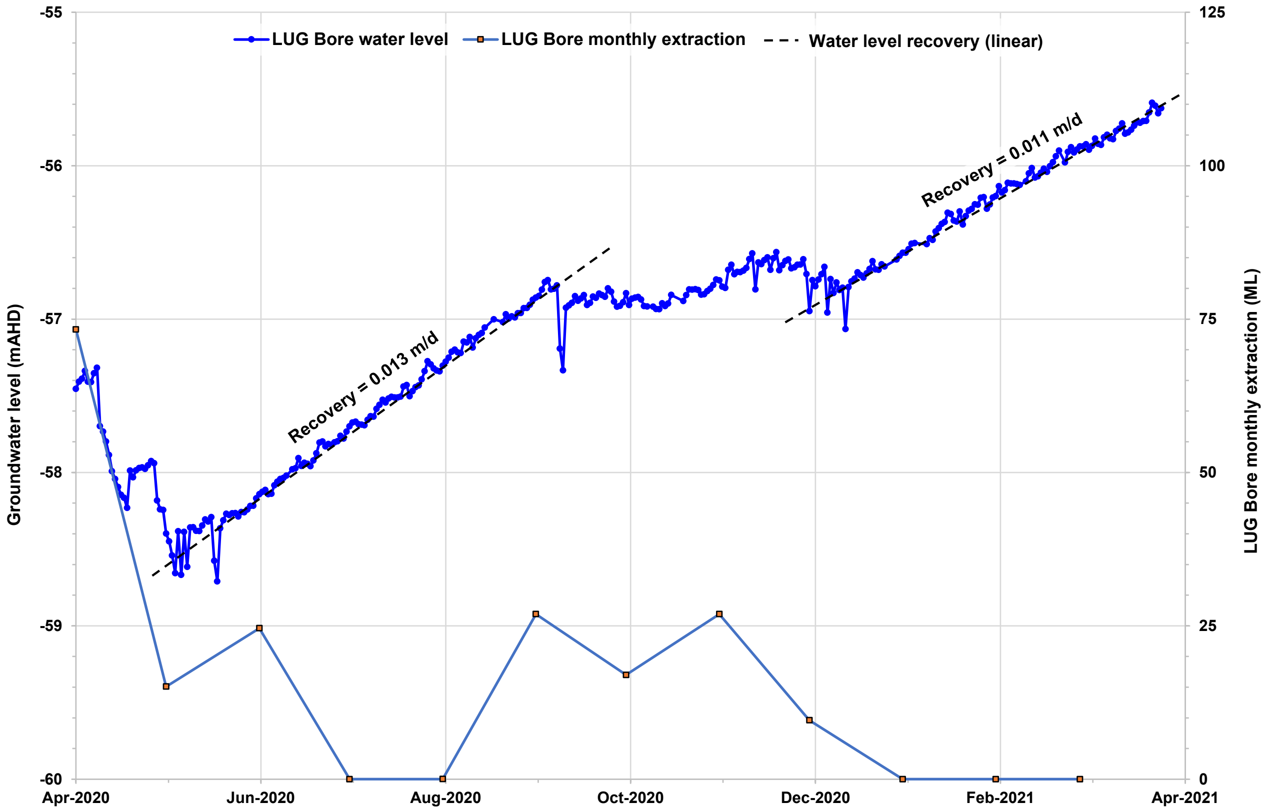


Figure 5.29 Estimated inflow- and recovery rates at the LUG Bore

5.7 Water quality

As discussed in Section 1.3, under the proposed modification, water would be transferred into and out of the workings from other existing surface water storages to assist with balancing inflows and outflows to the mine water management systems at HVO and MTW. Accordingly, water quality in existing surface water storages and in the Lemington Underground workings is a key consideration when assessing the impacts of the modification.

5.7.1 Surface water storage facilities

5.7.1.1 HVO

Under the modification, during wet periods when inflows to the HVO water management system exceed outflows, water would typically be transferred from the main HVO surface water storages (Dam 15S, Dam 16S, Dam18S, Riverview Pit Void, South Lemington Void in Figure 1.2) into the Lemington Underground workings. These storages are considered to be representative of the water quality that may be transferred to the Lemington Underground workings from HVO operations.

Time series electrical conductivity (EC), TDS, and pH data for Dam 15S and Dam 16S are shown alongside data for the LUG Bore in Figure 5.30, Figure 5.31, and Figure 5.32 respectively. Water quality data for Dam18S is currently limited to a single water quality measurement taken during August 2021. No data are currently available for the Riverview Pit Void, although water in this storage provides water into Dam 16S and Dam 18S for which there is at least some data.

As shown in Figure 5.30 and Figure 5.31, observed EC and TDS in the two HVO surface water storages for which time series data are available is quite variable, generally increasing during dry periods and decreasing during wet periods. However, during the entire period of record the EC and TDS concentrations are lower than that observed in the LUG Bore and hence in the Lemington Underground workings. The pH in the two surface water storages also fluctuates slightly but is consistently higher than in the LUG Bore, other than a single reading in mid 2015 (Figure 5.32).

These observations are reflected in the water quality summary statistics shown in Table 5.3 which indicate lower median TDS and EC and higher pH in the surface water storages compared to the LUG Bore. As shown in Table 5.3, the summary statistics also suggest similar water quality in Dam 18S compared to that in Dam 15S and Dam 16S, although as mentioned Dam 18S is limited to a single sample.

Table 5.3 Statistical summary (pH, EC and TDS) HVO water storages

Hydrochemical constituent	Statistical parameter	Dam 15S	Dam 16S	Dam 18S	LUG Bore
EC (µS/cm)	**Count**	219	104	1	28
	Minimum	914	369	4,800	7,530
	Median	4,430	1,642	4,800	8,470
	Maximum	15,490[1]	5,490	4,800	8,730
pH	**Count**	225	103	1	28
	Minimum	7.9	7.3	9.0	7.0
	Median	9.1	8.9	9.0	7.2
	Maximum	10.0	9.5	9.0	9.3
TDS (mg/L)	**Count**	107	78	1	7
	Minimum	497	224	2,850	2,360
	Median	1,790	1,870	2,850	4,870
	Maximum	4,690	4,020	2,850	5,150

Notes: µS/cm = microSiemens per centimetre.
No data currently available for the Riverview Pit Void.
[1] Outlying EC reading of 36,000 µS/cm taken in Dam 15S in 2010 when the dam was close to empty excluded.

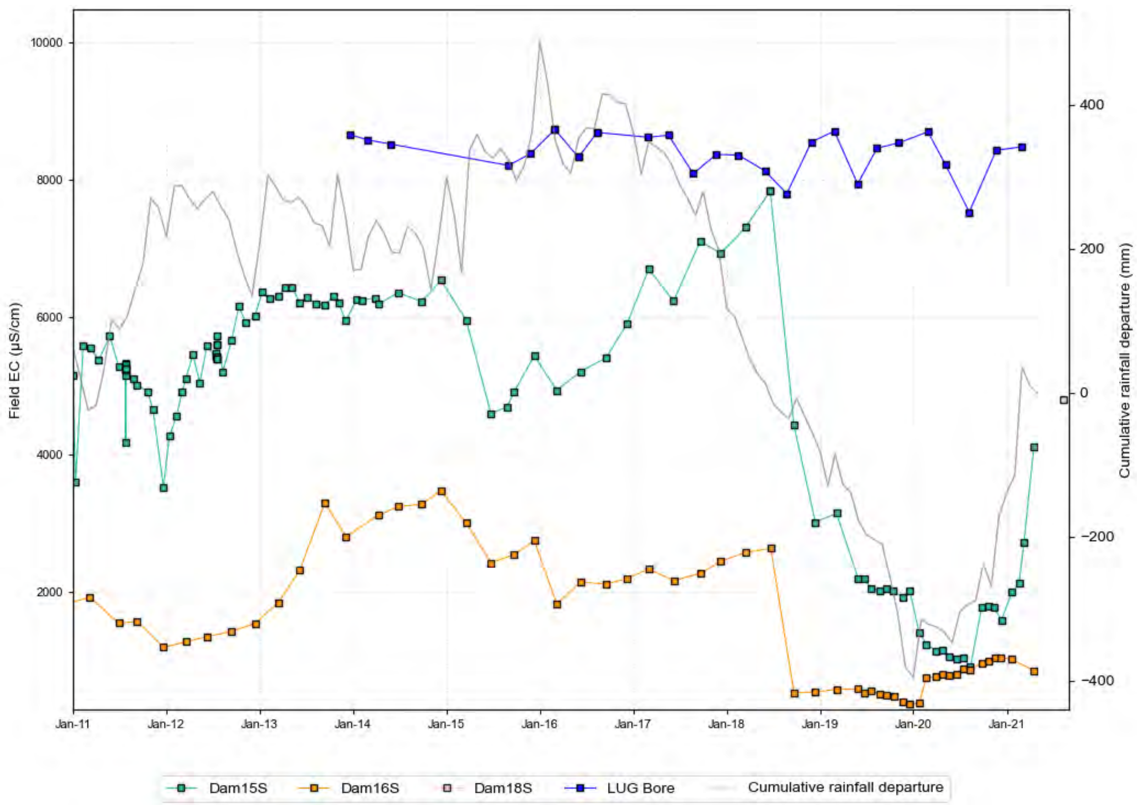


Figure 5.30 HVO main surface water stores and LUG Bore, electrical conductivity time series data

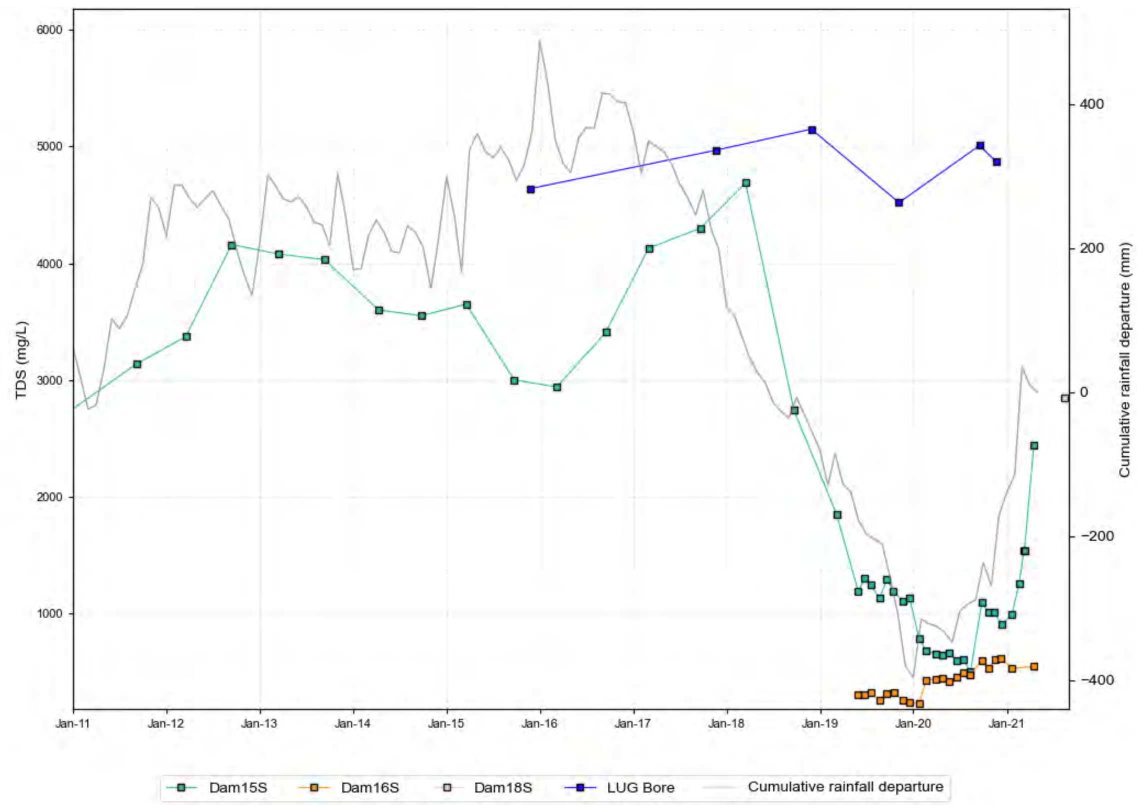


Figure 5.31 HVO main surface water stores and LUG Bore, TDS time series data

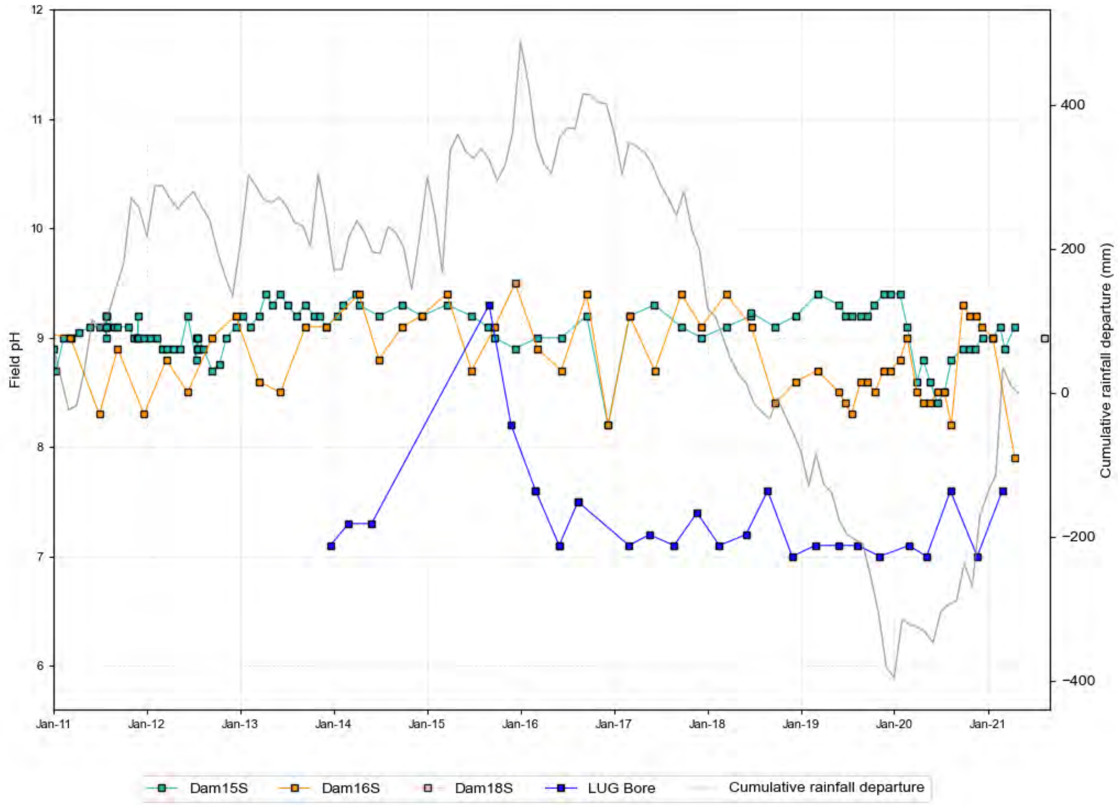


Figure 5.32 HVO main surface water stores and LUG Bore, pH time series data

Available major ion chemistry data for the HVO water storages, the LUG Bore, the Wollombi Brook alluvium, and the Hunter River and Wollombi Brooks' stream water are presented as both Piper and Durov plots (see Figure 5.33 and Figure 5.34 respectively). As shown, the data suggests that the major ion chemistry of the surface water storages sits somewhere in between that observed in the Hunter River and Wollombi Brook and associated alluvium and that observed in the LUG Bore. Reference to the Durov plot (Figure 5.34) also suggests that the most significant chemical differentiator between the surface water and groundwater samples is the observed differences between pH and EC described above.

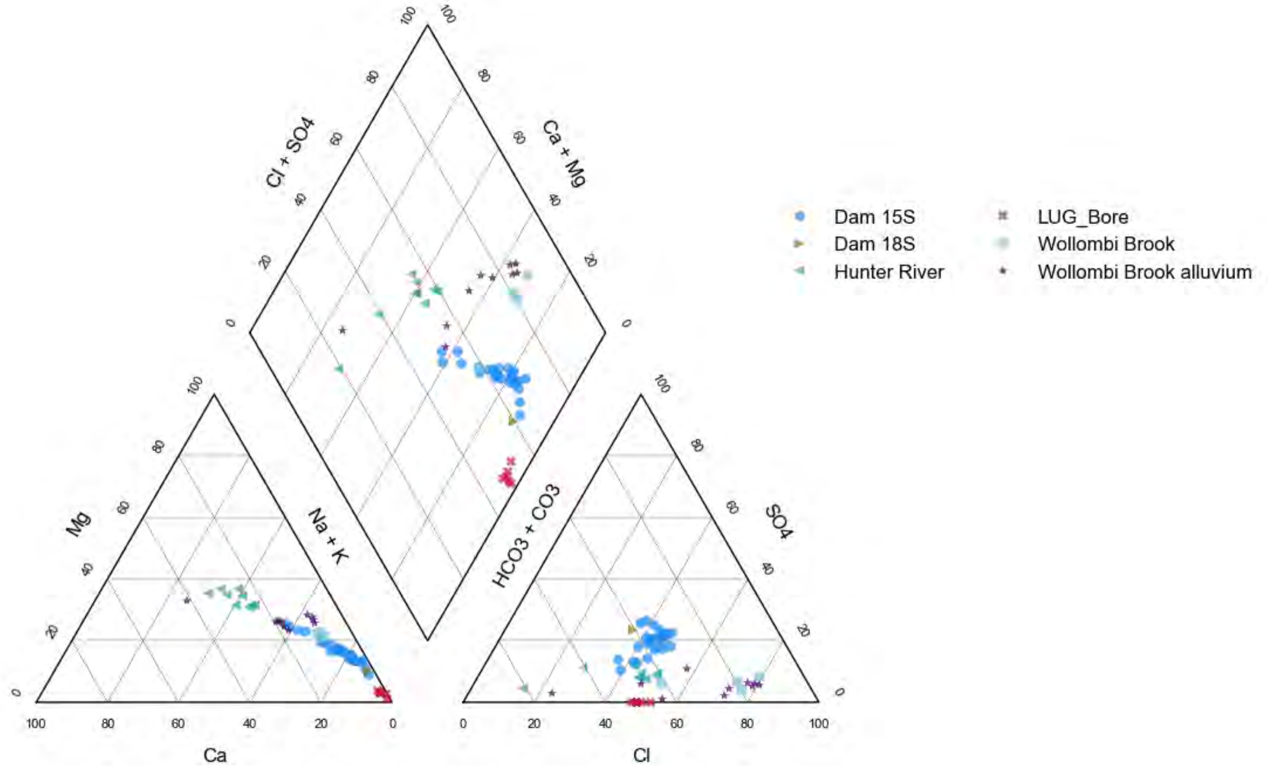


Figure 5.33 MTW main surface water stores, LUG Bore, surface water courses, and alluvium – Piper plot

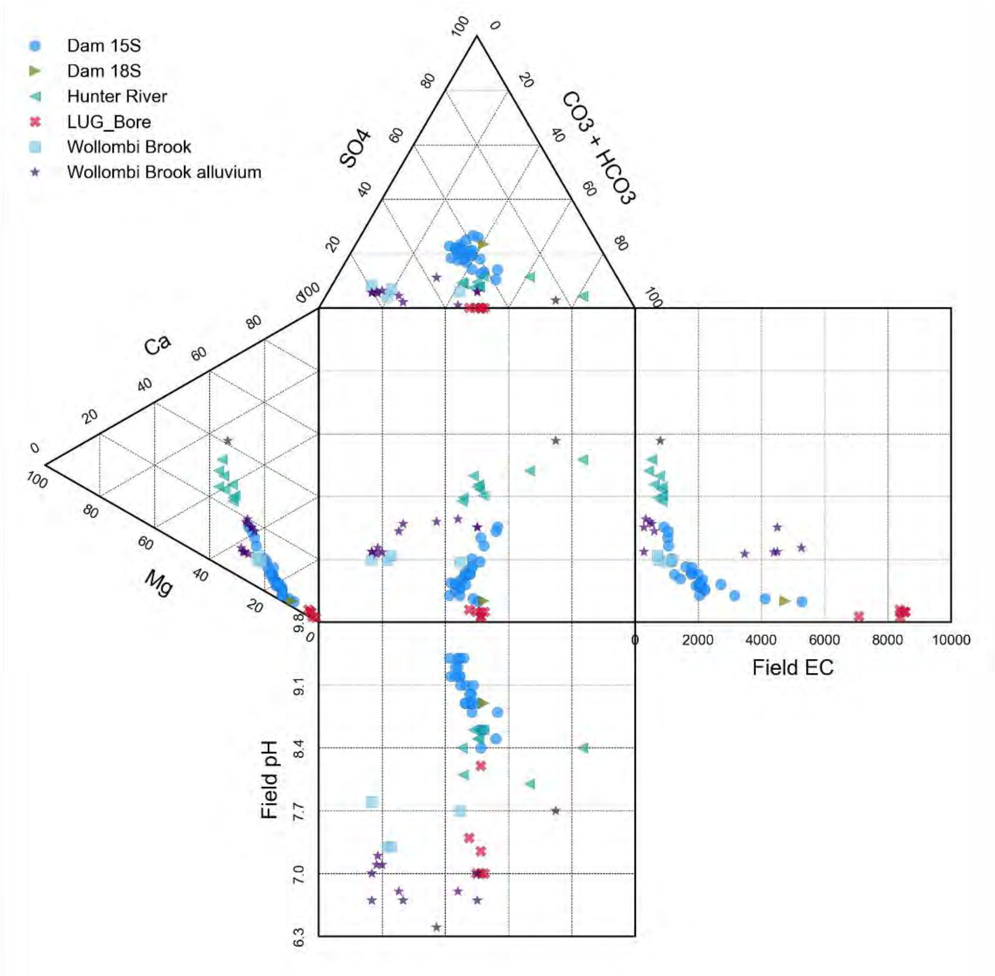


Figure 5.34 MTW main surface water stores, LUG Bore, surface water courses, and alluvium – Durov plot

5.7.1.2 MTW

Under the modification, during wet periods when inflows to the MTW water management system exceed outflows, water would typically be transferred from the main MTW surface water storages (e.g. Dam 1N, Dam 6S, South Pit Void, South Lemington Void shown in Figure 1.2) into the Lemington Underground workings. These storages are considered to be representative of the water quality that may be transferred to the Lemington Underground workings.

Time series electrical conductivity (EC), TDS, and pH data for Dam 1N and Dam 6S are shown alongside data for the LUG Bore in Figure 5.35, Figure 5.36, and Figure 5.37 respectively. Water quality data for the South Lemington Void and South Pit Void are currently limited to a single water quality sample taken during September 2020. All available major ion chemistry data for the surface water storages and the LUG Bore are also shown on Piper and expanded Durov plots, Figure 5.38 and Figure 5.39 respectively.

It should be noted that water extracted from the LUG Bore has historically been pumped into the South Lemington Void and this perhaps explains the similarity of the major ion chemistry in these two storages shown in Figure 5.38 and Figure 5.39. However, as shown in the lower section of the expanded Durov plot (Figure 5.39), observed pH in the South Lemington Void is consistently higher than observed in the LUG Bore suggesting some surface water contribution (as would be expected).

As shown in Figure 5.35 and Figure 5.36, observed EC and TDS in the two MTW surface water storages for which time series data are available is quite variable, generally increasing during dry periods and decreasing during wet periods. However, during most of the period of record EC and TDS concentrations in the two dams are lower than that observed in the LUG Bore and hence in the Lemington Underground workings. Conversely, pH in the two surface water storages is generally relatively static but consistently higher than in the LUG Bore (Figure 5.37). The LUG Bore's pH during May 2014 was 7.3 and was not sampled again until August 2015 when the pH increased to 9.3. The bore's pH then decreased to 7.6 by February 2016 and maintained a relatively stable trend for the remainder of the dataset.

The aforementioned observations are reflected in the water quality summary statistics shown in Table 5.4 which indicate lower median TDS and EC and higher pH in the surface water storages compared to the LUG Bore. As shown in Table 5.4, the summary statistics also suggest similar water quality in the South Lemington- and South Pit voids to that observed in the two dams, although as mentioned above the void data set is currently limited to one sample from each void.

Table 5.4 Statistical summary (pH, EC and TDS) MTW water storages

Hydrochemical constituent	Statistical parameter	Dam 1N	Dam 6S	LUG Bore	South Lemington Void	South Pit Void
EC (µS/cm)	**Count**	45	112	28	1	1
	Minimum	2,330	3,610	7,530		
	Median	5,540	6,955	8,470	6,700	6,650
	Maximum	9,520	9,540	8,730		
pH	**Count**	45	112	28	1	1
	Minimum	8.1	8.4	7.0		
	Median	8.9	9.0	7.2	9.1	8.6
	Maximum	9.2	9.2	9.3		
TDS (mg/L)	**Count**	25	15	7	1	1
	Minimum	1,490	3,710	2,360		
	Median	3,510	4,380	4,870	4,460	4,700
	Maximum	5,580	5,700	5,150		

Note: µS/cm = microSiemens per centimetre.

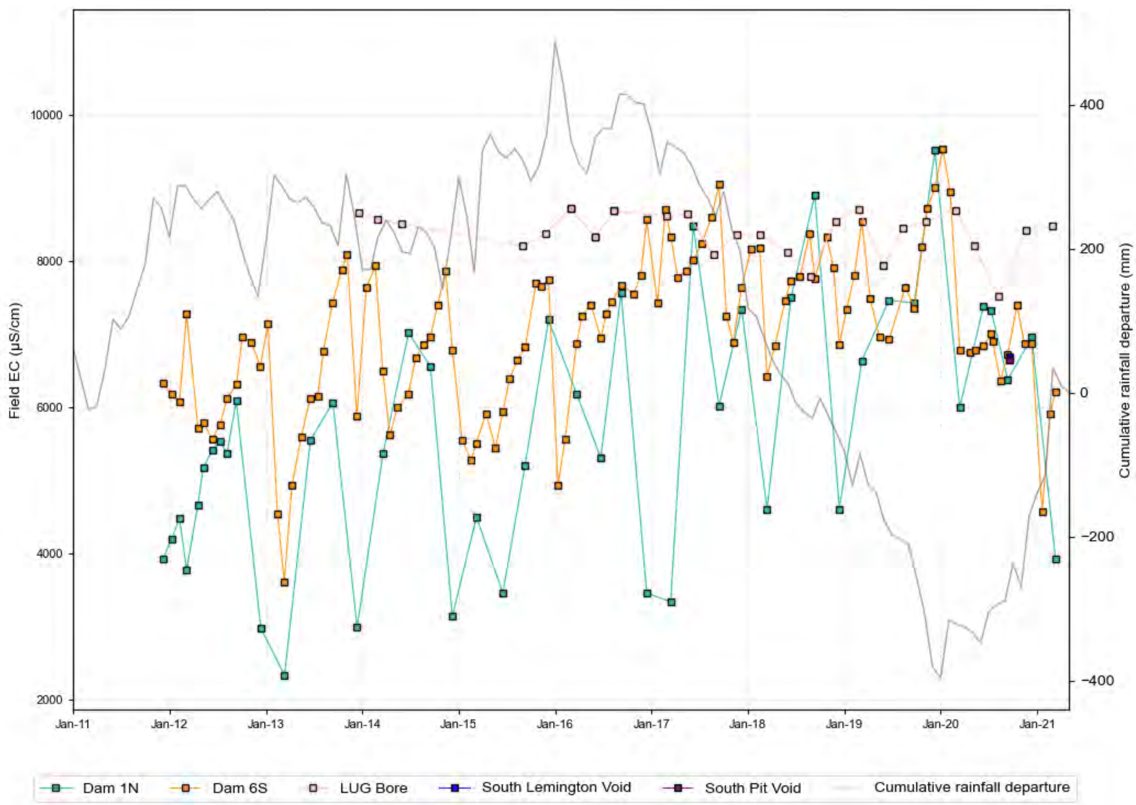


Figure 5.35 MTW main surface water stores and LUG Bore, electrical conductivity time series data

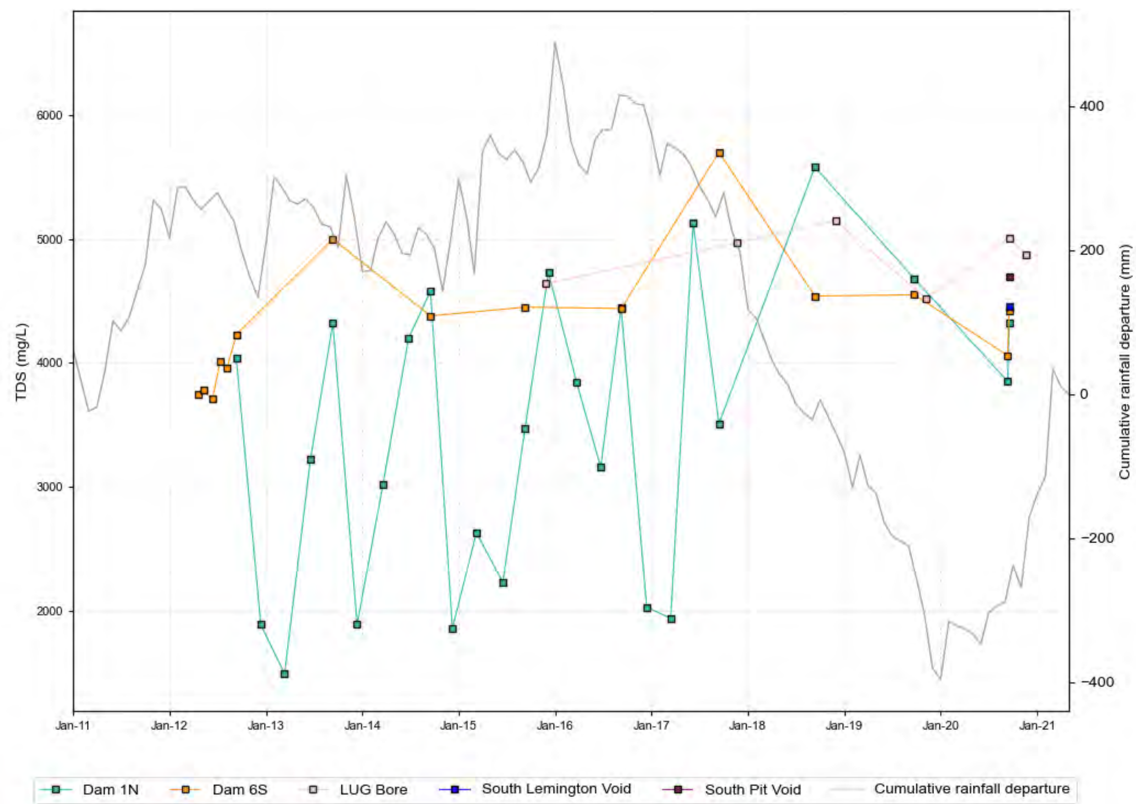


Figure 5.36 MTW main surface water stores and LUG Bore, TDS time series data

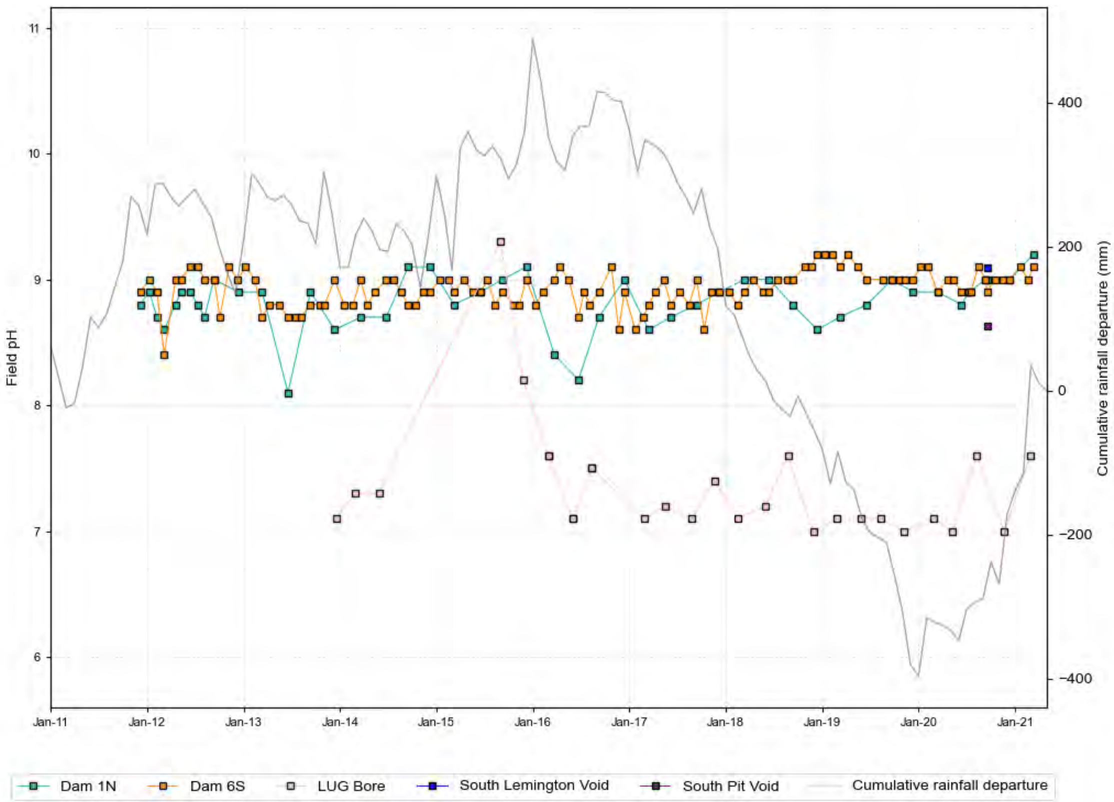


Figure 5.37 MTW main surface water stores and LUG Bore, pH time series data

Available major ion chemistry data for the MTW water storages, the LUG Bore, the Wollombi Brook alluvium, and the Hunter River and Wollombi Brooks' stream water are presented as both Piper and Durov plots (see Figure 5.38 and Figure 5.39 respectively). As shown, the data suggests only relatively subtle differences between the major ion chemistry of the surface water storage dams, voids and the LUG Bore. Conversely, MTW water storages and the LUG Bore's major ion chemistry does not correlate with that observed in the surface watercourses or underlying alluvium. As expected, given that water extracted via the LUG Bore is pumped into the South Lemington void, the major ion chemistry at these two sampling points is particularly similar.

As shown on the Durov plot (Figure 5.39), and as discussed previously in relation to the HVO stores, the most significant chemical differentiator between the surface water and groundwater samples is the observed differences between pH and EC described above.

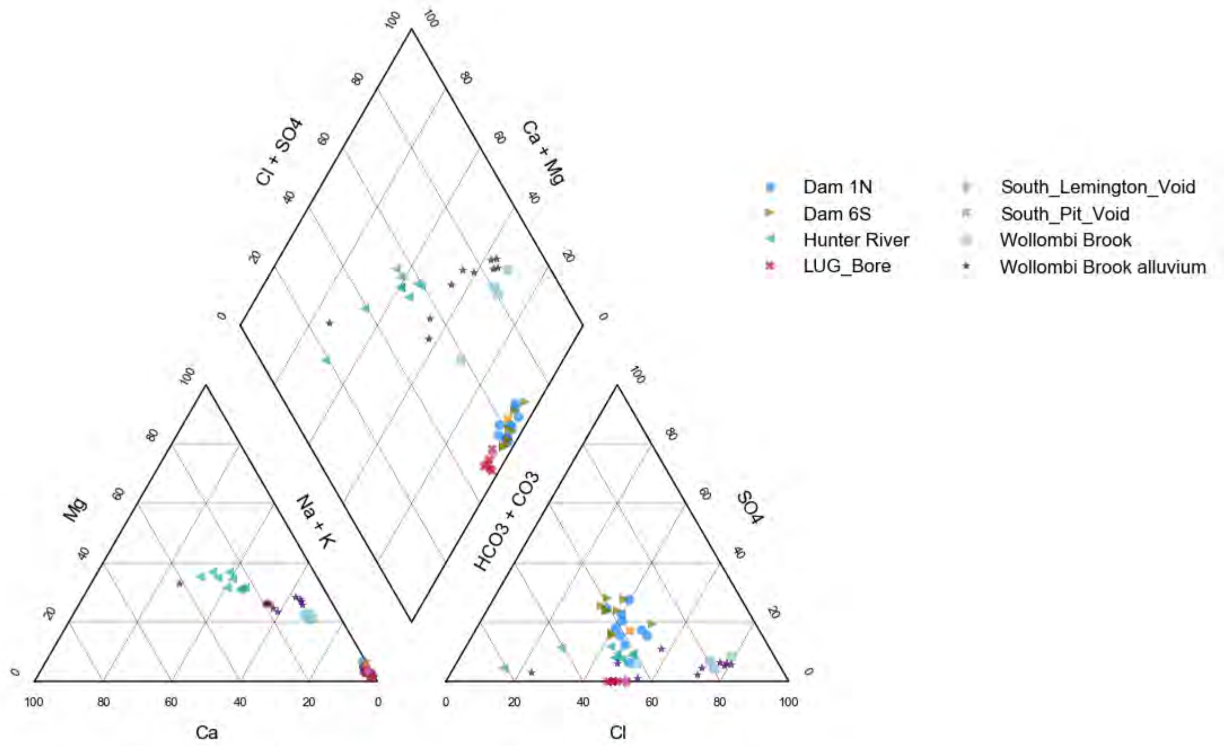


Figure 5.38 MTW main surface water stores, LUG Bore, surface drainages, and alluvium – Piper plot

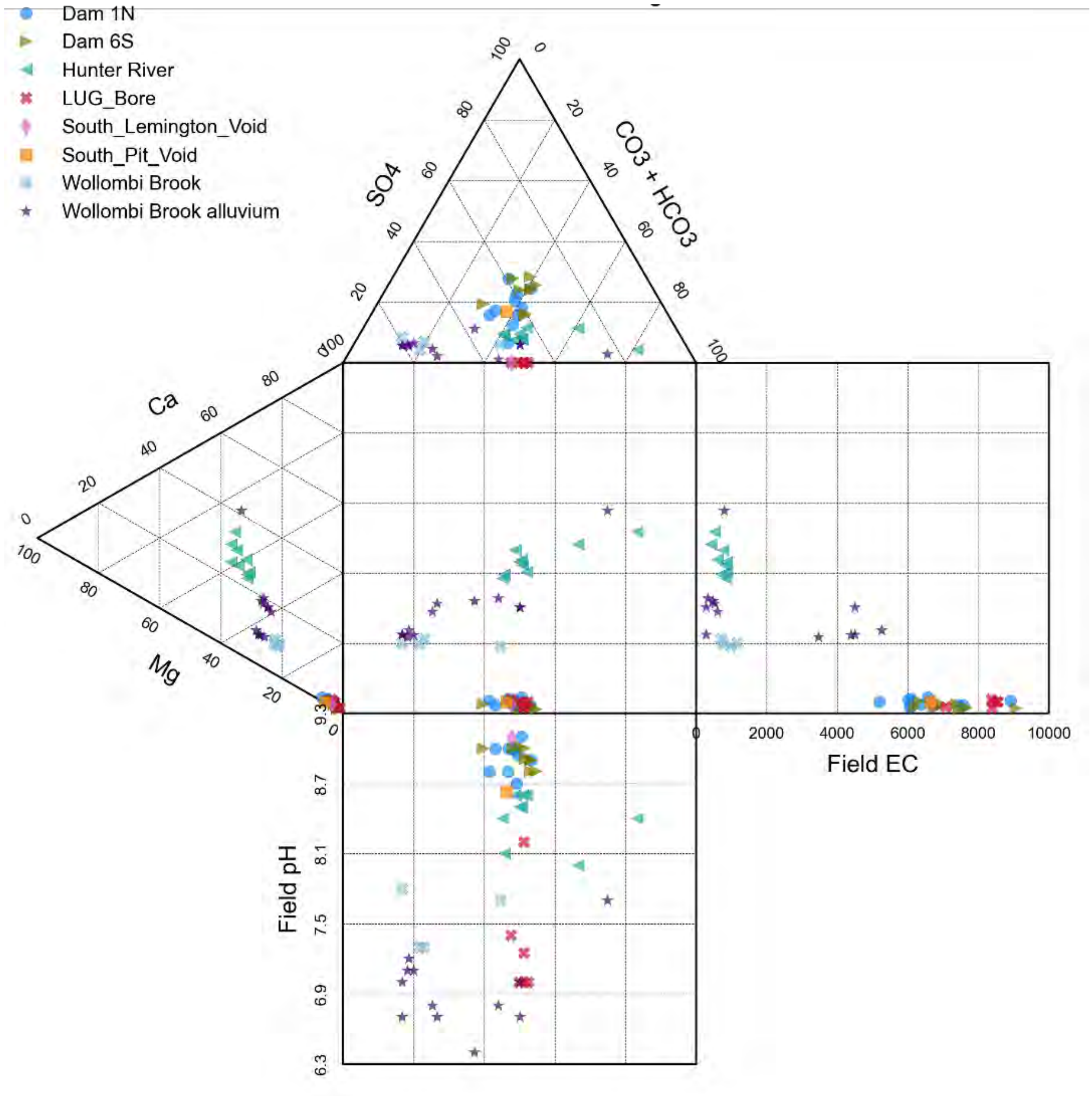


Figure 5.39 MTW main surface water stores, LUG Bore, surface drainages, and alluvium – Durov plot

5.7.2 Groundwater quality

5.7.2.1 Lemington Underground and Mount Arthur coal seam

Figure 5.40, Figure 5.41, and Figure 5.42 provide a comparison of observed EC, pH and TDS in the LUG Bore against other monitoring bores within the HVO and MTW monitoring networks which also monitor the Mount Arthur coal seam. This comparison was undertaken to understand potential variability within the Lemington Underground workings given that the LUG Bore represents the only location for which time series water chemistry data are available. It should be stressed, however, that all of the other sampling points for which Mount Arthur coal seams time-series data are available (i.e. excluding the LUG Bore and the recently completed LUG_S001 monitoring bore) are located some distance from the Lemington Underground workings in areas where the Mount Arthur Coal Seam subcrops beneath the Hunter River alluvium to the north of Cheshunt Pit. Accordingly, as shown in Figure 5.40, Figure 5.41, and Figure 5.42, the water chemistry in these bores is quite different from that observed from the LUG Bore. As shown in Figure 5.40 and Figure 5.42 the data suggests that the water pumped from the LUG Bore is characterised by relatively high EC and TDS, compared to other Mount Arthur coal seam samples. Conversely, however, as shown in Figure 5.41, observed pH at the LUG Bore is typically within the range observed elsewhere, other than two samples collected in 2015 during a relatively wet period. Data recently acquired for the LUG_S001 monitoring bore suggest that pH, EC and TDS values elsewhere within the workings are similar to those observed at the LUG Bore.

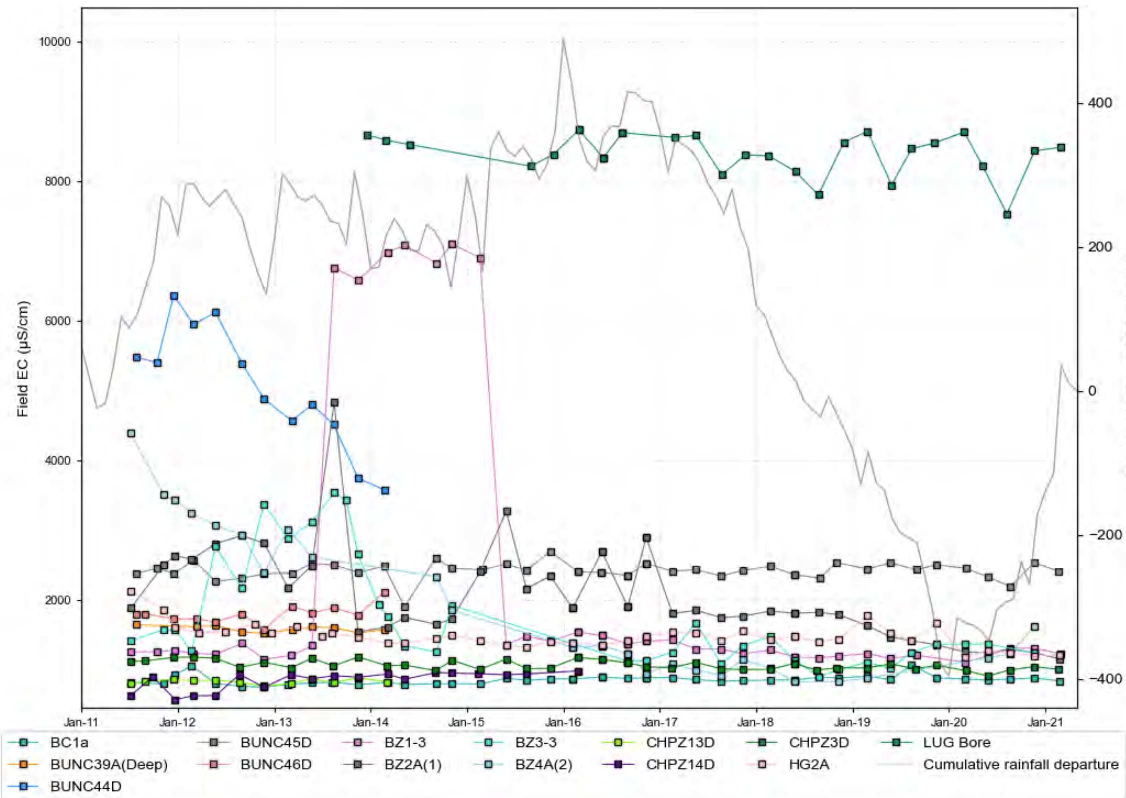


Figure 5.40 Mount Arthur coal seam electrical conductivity

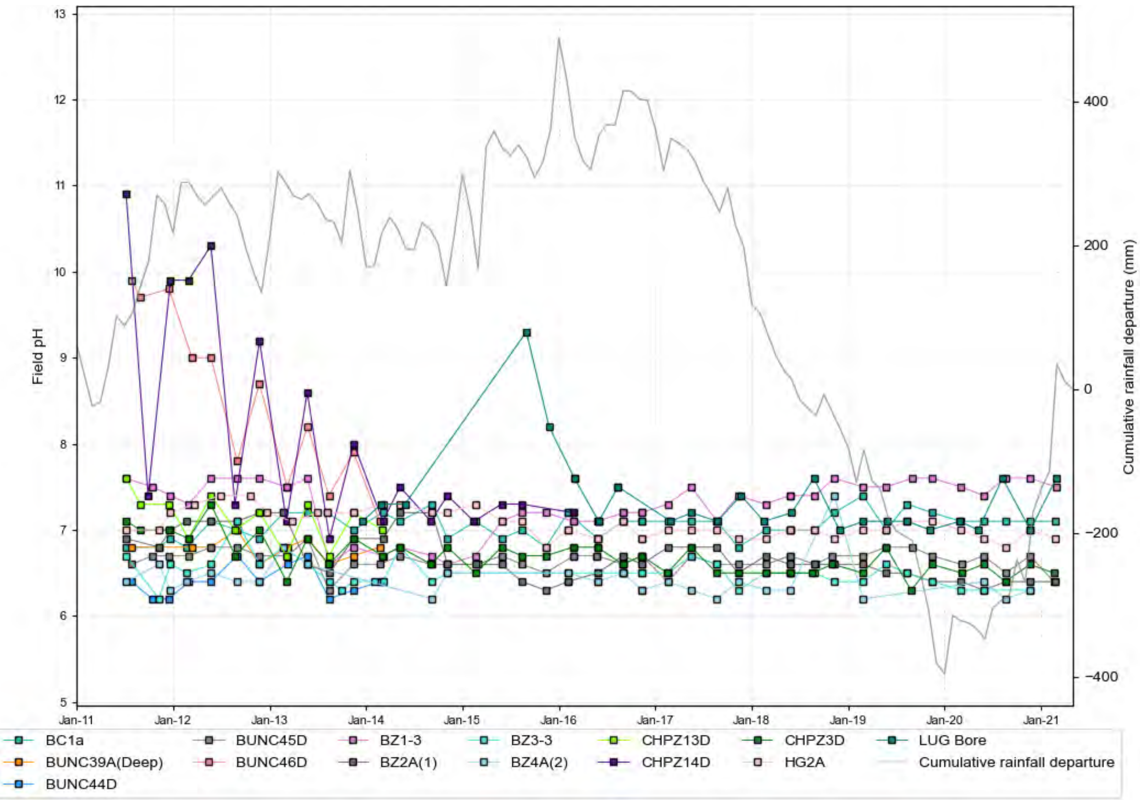


Figure 5.41 Mount Arthur coal seam pH

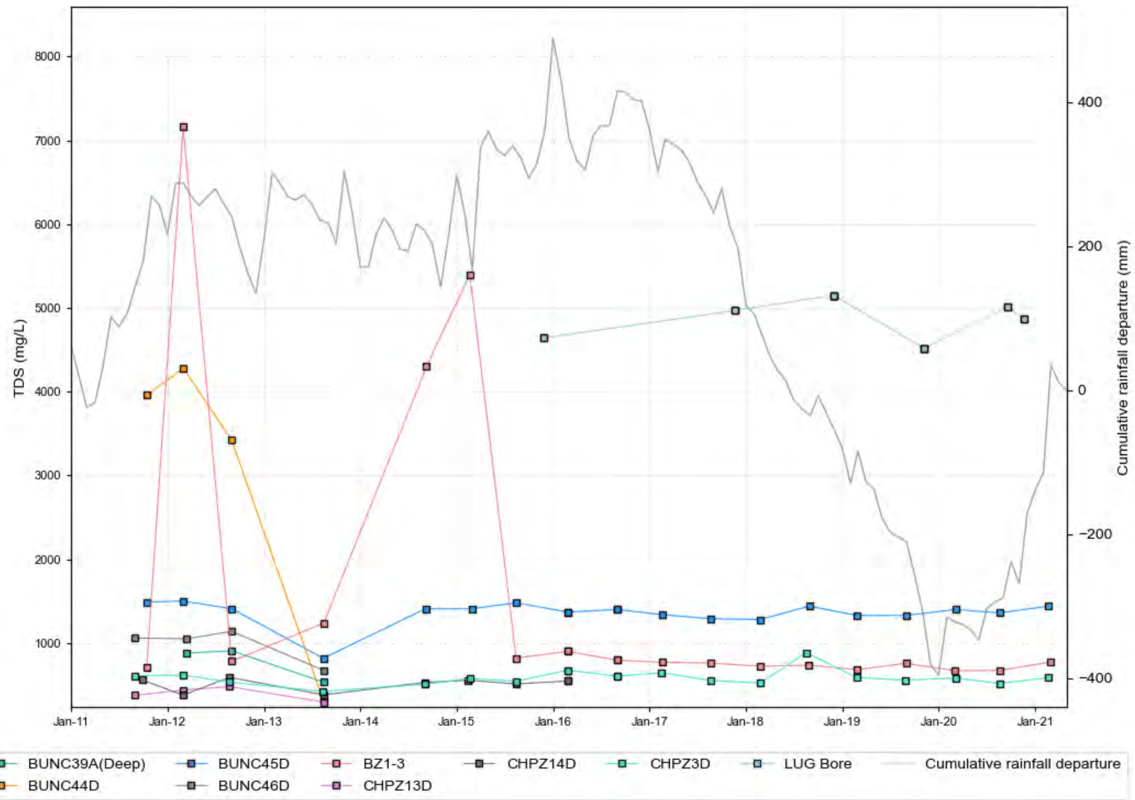


Figure 5.42 Mount Arthur coal seam TDS concentrations

Available major ion chemistry data for the Mount Arthur coal seam monitoring bores close to Cheshunt Pit as well as the LUG Bore and the recently completed LUG_S001 Lemington Underground monitoring bore are presented as both Piper and Durov plots (see Figure 5.43 and Figure 5.44 respectively). Consistent with the EC, and TDS data, these plots suggest that the major ion chemistry of LUG Bore and LUG_S001 are quite different to that observed in the Mount Arthur coal seam beneath the Hunter River alluvium to the north. Conversely, the major ion chemistry in the LUG Bore and LUG_S001 are very similar which suggests that the LUG Bore data is likely to be representative of the water chemistry elsewhere in the workings.

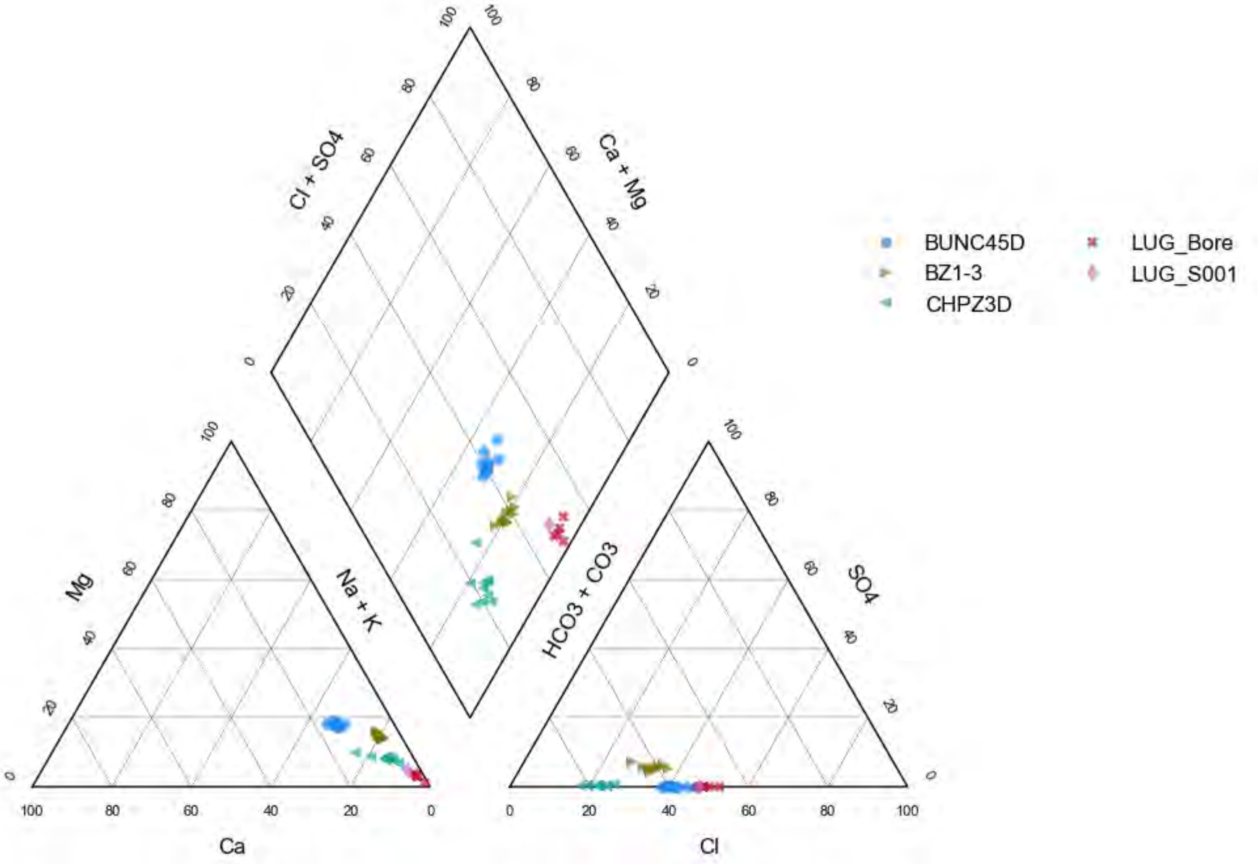


Figure 5.43 Piper plot of the Mount Arthur coal seam

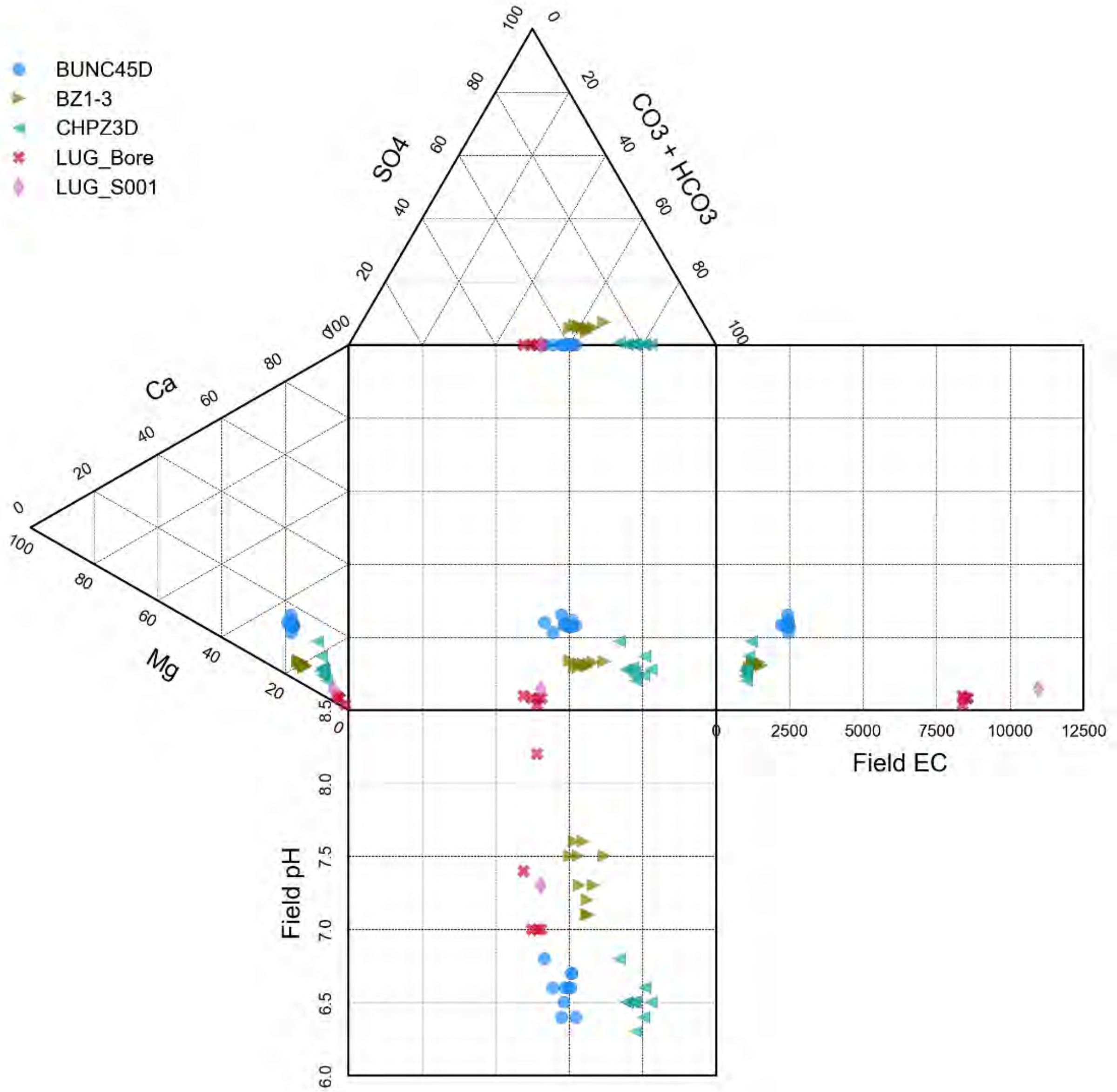


Figure 5.44 Durov plot of the Mount Arthur coal seam

5.7.2.2 Wollombi Brook alluvium and overlying coal seams

As shown in Figure 4.5, the Lemington Underground workings are overlain by a number of coal seams as well as the Wollombi Brook alluvium. Plots showing time-series EC, pH and TDS data available for each of these overlying formations are included in Appendix B. Summary EC and pH statistics in the form of box and whisker plots are presented in Figure 5.45 and Figure 5.46. Strata are listed in order of depth below ground. Samples taken from the Wollombi Brook alluvium are characterised by low EC (less than 2,000 µS/cm) and near neutral pH, whilst the coal seams are generally characterised by higher median EC values, up to around 20,000 µS/cm in the Warkworth coal seam which lies immediately above the Mount Arthur coal seam. Most of the coal seams are characterised by near neutral pH values, apart from the Warkworth seam which is more variable and more acidic than the other coal seams.

As discussed previously other than the LUG Bore and LUG_S001, all of the Mount Arthur coal seam bores with water quality data are located nearby or adjacent to the Hunter River, as shown in Figure 5.2. Data for the LUG Bore and other Mount Arthur coal seam monitoring points are therefore shown separately in the box and whisker plots (Figure 5.45 and Figure 5.46). Data for the LUG_S001 bore are not shown since only a single sample has been tested thus far. Based on results for this single sample, as would be expected, the water chemistry at the LUG_S001 monitoring bore which is completed into the workings appears to be very similar to that observed in the LUG Bore. Consistent with their location close the Hunter River data for the other Mount Arthur monitoring bores in the area (i.e. excluding the LUG Bore and the LUG_S001) show similar pH and EC values to that observed in the Wollombi Brook alluvium. Conversely, data for the Mount Arthur coal seam at the LUG Bore shows elevated EC values that are comparable to other coal seams.

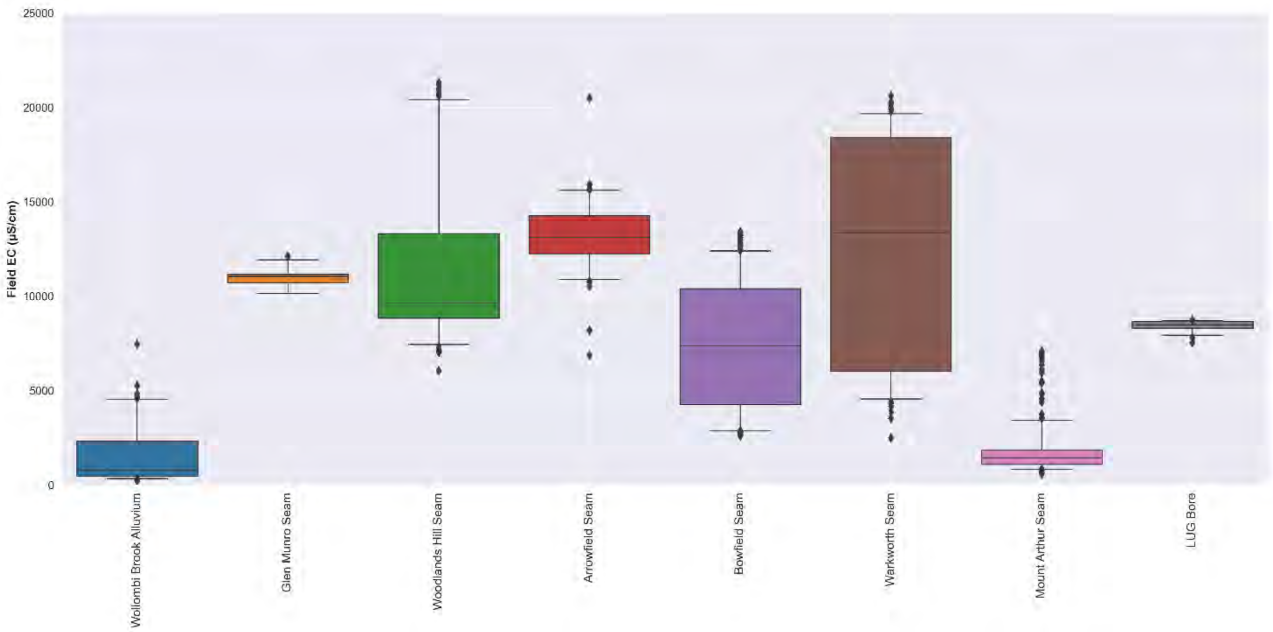


Figure 5.45 Box and whisker plot of EC for coal seams with data above Mount Arthur coal seam

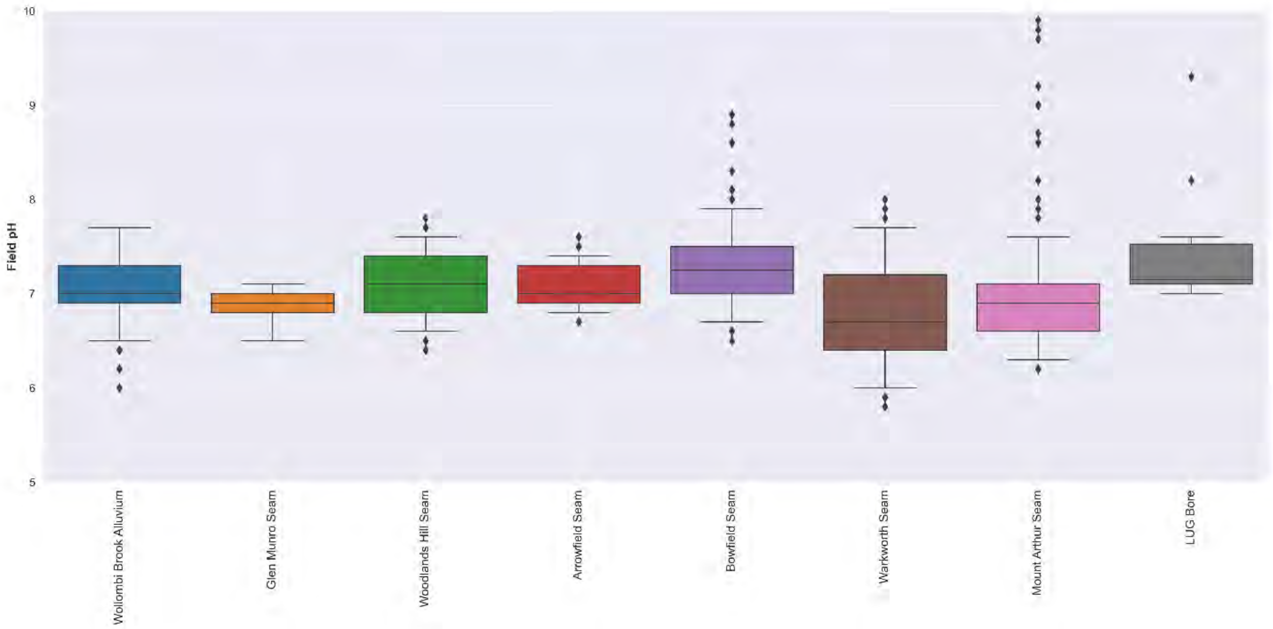


Figure 5.46 Box and whisker plot of pH for coal seams with data above Mount Arthur coal seam

5.8 Groundwater dependent ecosystems

GDEs are defined as ecosystems that are at least partially reliant on groundwater. Potential GDE occurrence at surface around the Lemington Underground workings is mapped in Figure 5.47. The map includes areas of low to high potential GDEs mapped in the National Atlas of Groundwater Dependent Ecosystems (the Atlas) (BoM, 2021). The Atlas shows known and potential GDEs and is the most comprehensive inventory of the location and characteristics of potential GDEs in Australia. As shown in Figure 5.47, the majority of the areas identified as having moderate and high potential GDE potential are largely associated the Hunter River and Wollombi Brook.

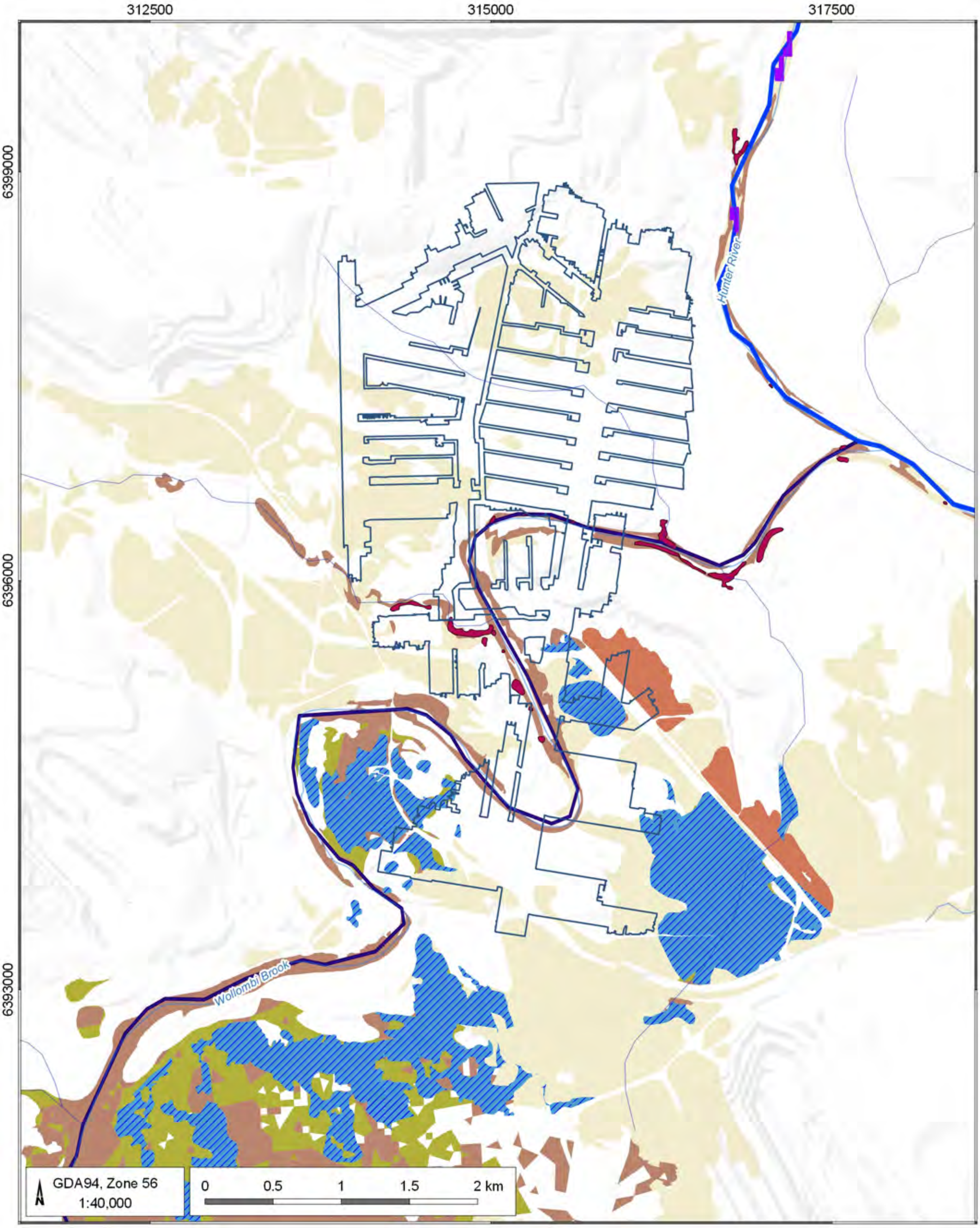
The Water Sharing Plans for the Hunter Regulated and Hunter Unregulated and Alluvial Water Sources show no high priority GDEs mapped within the project area. River Red Gums along the Hunter River and Wollombi Brook (Umwelt), 2016) have been identified as a potential GDE in the Project area. Other potential GDEs include Warkworth Sands Woodlands and Stygofauna in alluvium along the Hunter River and Wollombi Brook.

The River Red Gum communities identified by Umwelt (2016) along the Hunter River are likely to be predominantly supported by the relatively high storage and permeability surficial alluvial aquifers directly underlying the river, rather than the underlying generally lower storage and permeability Permian age strata.

As shown in Figure 5.47, areas of Warkworth Sands Woodlands are mapped south of the Wollombi Brook predominantly within areas where unconsolidated aeolian sediments known as the Warkworth Sands are mapped at outcrop. The Warkworth Sands Woodland in the Sydney Basin Bioregion are classified as an endangered ecological community under the Biodiversity Conservation Act 2016 (BC Act) and critically endangered ecological community under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). As discussed previously (Sections 5.2.2 and 5.3.10) the majority of monitoring bores installed into the Warkworth Sands are dry. However, data for a single monitoring point (PZ7S) suggest a relatively persistent water table at this location and work undertaken by Cumberland Ecology (2014) noted species indicative of a persistent water table found in dune swales in the area. AGE (2010) also noted some small seepages of groundwater from the Warkworth Sands at the break of slope created by the Wollombi Brook floodplain suggesting that the water table formed at the base of the Warkworth Sands is perched and there is no direct hydraulic connection with the underlying Permian fractured rock aquifer.

Stygofauna are known to occur in alluvial sediments in the area and may also occur in the shallow fractured rock up to 35 m (Stygoecologia, 2016). However, stygofauna are likely to become increasingly uncommon in the deeper, unweathered rock where increasing groundwater salinity, and low dissolved oxygen levels tend to limit their occurrence (Stygoecologia, 2016).

As discussed in Sections 5.3.8 and 5.3.10, there is no evidence that historic operation of the LUG Bore has had any significant impact on groundwater levels in the Wollombi Brook alluvium or in the Warkworth Sands. Significant impacts of more than 2 m do not appear to extend more than 2 km from the bore laterally and above the Bowfield coal seam vertically. This suggests that these potential GDEs, which are likely to mostly rely on surface water sources supplemented by groundwater sourced from near surface Quaternary age aquifers, are therefore also not impacted by groundwater extraction from the bore.



LEGEND

Drainage

Lemington Underground workings

Aquatic GDE

Known GDE - from regional studies

High potential GDE - from national assessment

Moderate potential GDE - from national assessment

Terrestrial GDE

High potential GDE - from regional studies

Moderate potential GDE - from regional studies

Low potential GDE - from regional studies

Potential GDE - mapped from current and historical studies

Potential Warkworth Sands

River Red Gum Area

Warkworth Sands Woodland (EPBC Act)

Warkworth Sands Woodland (TSC Act)

Lemington UG Water Storage (G1468J)

Groundwater dependent ecosystems

AGE

DATE 17/09/2021

FIGURE No: **5.47**

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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6 Impact assessment – proposed modification

6.1 Introduction

The modification seeks approval for the transfer and storage of water associated with the HVO South and MTW operations into the Lemington Underground workings additional to surface water storages. Since any impacts on local groundwater resources will be related to the long term extraction, rather than short term fluctuations in the pumping rates, the impacts of the modification are considered to be limited to the transfer of water into the workings as summarised below.

6.2 Groundwater level impacts

Historic mining at Lemington Underground occurred from 1971 to 1992. Groundwater levels in the vicinity of the workings would have been as low as -205 mAHD (i.e., the minimum elevation of the base of the workings) during operation of the mine dewatering system. Since 2013, groundwater has been extracted from the Lemington Underground via the LUG Bore, with recent groundwater levels in the workings estimated at -22 mAHD.

The additional transfer of water into the workings is not expected to materially change the groundwater impacts that have occurred due to the approved operations, and would act to mitigate some of the extraction impacts associated with the existing licensed extraction form the LUG Bore by increasing the average water levels in the workings. Extraction of the temporarily transferred and stored water from the additional proposed transfer points is not expected to materially change the groundwater impacts that have occurred due to the historical extraction from the LUG Bore (i.e. drawdown effects).

Monitoring of groundwater levels at a number of locations and depths above the Lemington Underground workings during operation of the LUG Bore also indicates that the impacts of extraction from the workings are largely limited to the two coal seams immediately overlying the workings (i.e. the Warkworth and Bowfield coal seams). Impacts also appear to reduce rapidly with distance from the LUG Bore, such that drawdowns in excess of 2 m are only observed in the Bowfield seam within around 2 km of the extraction bore (Figure 5.12). As shown in Figure 5.28 10 existing water supply bores are located within around 2 km of the LUG extraction bore. However, all of these bores are relatively shallow and target the Wollombi Brook alluvium, rather than the underlying Permian units. As discussed in Section 5.3.8 no significant historic impacts have been observed in the Wollombi Brook alluvium and hence no additional drawdown is expected either due to the modification or continued extraction from the workings.

6.3 Potential interactions with surface water

Groundwater level and surface water flow data collected during nine years of operating the LUG Bore indicates there have been no impacts on either groundwater levels in the Wollombi Brook alluvium or flows in the Wollombi Brook. Similarly, no significant historic impacts on the levels in the Hunter River alluvium or flows in the Hunter River are likely to have occurred due to operation of the LUG Bore extraction, although there is limited actual data to confirm this.

As shown in conceptual cross section C-C' (Figure 5.8), whilst current groundwater levels in the Lemington Underground workings are estimated to be at around -22 mAHD the Mount Arthur coal seams dip towards the south and the roof of the workings is at around 42 mAHD at its closet point to the Hunter River (Figure 3.3). The Hunter River is at around 43 mAHD at this location. Whilst this means that there should be no seepage from the workings towards the Hunter River, it is recommended that the transfer of water into and management of the water storage in the workings should be limited to a storage water level of approximately 30 mAHD. This will prevent seepage from the Lemington Underground water storage to the Hunter River alluvium. As such the modification is not expected to lead to any significant impacts on the Hunter River or the Wollombi Brook.

6.4 Water quality impacts

Since the proposed modification will involve the periodic transfer of water from surface water storages into and out of the workings there is potential for water quality impacts to occur. This has been assessed using a mass balance mixing modelling approach and conservatively assuming that all of the available free storage in the workings is filled using water transferred from existing surface water storages. For the purposes of the impact assessment it has been assumed that each surface water store contributes equally to the 2,400 ML of free storage currently available and that this water mixes completely with the estimated 6,800 ML of groundwater currently stored within the workings (Section 5.5). The modelling also assumes chemically conservative behaviour during mixing (e.g., no chemical reactions). Input surface water quality data used for the calculation are based on a weighted average of median observed concentrations for each surface water storage. The existing groundwater quality in the workings used for the calculations is based on the median of concentrations observed in water extracted from the LUG Bore.

Modelling results are summarised in Table 6.1 and suggest that the water derived from surface water storages will be basic (pH ~ 8.9) and be characterised by moderately elevated salinity (EC ~ 5,370 µS/cm), as well as low concentrations of metals/metalloids: aluminium (0.32 mg/L), copper (0.002 mg/L), cadmium (0.0001 mg/L), lead (0.001 mg/L), nickel (0.007 mg/L), and selenium (0.009 mg/L). No observed data are currently available for antimony, barium, cobalt, manganese, molybdenum, strontium, and vanadium and hence changes in these metals concentrations have not currently been assessed.

As shown in Table 6.1, results suggest that following mixing of the water currently stored in surface storage facilities with the groundwater currently stored in the workings the water within the void will have a lower salinity (EC ~ 7,760 µS/cm) and slightly higher pH (~ 7.3) compared to median water quality observations in LUG Bore. Conversely, the presence of generally slightly higher metals concentrations in the mixed surface water storages, than in the current underground workings, suggests that the proposed transfer could lead to slightly higher concentrations of aluminium, copper, cadmium, lead, nickel, and selenium than currently observed at the LUG Bore. However, as shown in Table 6.1, the predicted metals concentrations in the workings post-transfer would in most cases remain several orders of magnitude below ANZECC (2000) livestock (cattle) drinking water quality guideline values. Furthermore, water quality in the surface water stores is also relatively good. Hence even a worst case scenario in which the workings are pumped dry before being filled with water from surface water storages then this would also not result in any exceedances of these guideline values. It should also be noted that groundwater within the Permian strata is also not generally accessed and or used for non-mining related purposes. The modification is therefore not expected to result in any impact to the beneficial use or environmental values of groundwater in the surrounding strata.

Table 6.1 Predicted water quality impacts

Parameter (units)	Expected concentration in surface water storages transferred into the underground workings	Existing concentration in underground workings	Predicted concentration in underground workings post transfer	ANZECC (2000) livestock (cattle) drinking water quality guidelines
pH	8.9	7.2	7.3	NA
Electrical Conductivity, EC (µS/cm)	5,370	8,470	7,760	5,970
Aluminium, Al (mg/L)	0.32	0.01	0.09	5
Copper, Cu (mg/L)	0.002	0.001	0.0012	1
Cadmium, Cd (mg/L)	0.0001	0.0001	0.0001	0.01
Lead, Pb (mg/L)	0.001	0.001	0.001	0.1
Nickel, Ni (mg/L)	0.007	0.001	0.003	1
Selenium, Se (mg/L)	0.009	0.006	0.006	0.02

Note: NA – Not applicable

6.5 Groundwater dependent ecosystems

As discussed in Section 5.8, no impacts on groundwater levels in shallow Quaternary strata which support local GDEs have been observed relating to extraction from the Lemington Underground workings (via the LUG Bore). Additionally, as discussed in Section 6.2, as no additional groundwater level drawdown impacts are expected from the modification, then no impacts are expected on GDEs following the modification.

6.6 AIP considerations

As outlined in Section 2.3.1 under the NSW AIP proponents are required to provide details of potential:

- *"water level, quality or pressure drawdown impacts on nearby water users who are exercising their right to take water under a basic landholder right;*
- *water level, quality or pressure drawdown impacts on nearby licensed water users in connected groundwater and surface water sources;*
- *water level, quality or pressure drawdown impacts on groundwater dependent ecosystems;*
- *increased saline or contaminated water inflows to aquifers and highly connected river systems;*
- *to cause or enhance hydraulic connection between aquifers; and*
- *for river bank instability, or high wall instability or failure to occur."*

As described above drawdowns (or water level impacts) of more than the 2 m minimal impact threshold identified in the AIP are not anticipated at any other existing water users (Section 6.2) or at any local GDEs (Section 6.5). As detailed in Section 6.4, depending on the volume of water transferred from surface water storages, into the workings there is potential for the concentrations of some metals to increase in the workings, compared to those currently observed. However, the ongoing extraction of the temporarily stored water from the workings and the management of water levels in the underground workings to at or below 30 mAHD should ensure that hydraulic gradients towards the workings are maintained and prevent seepage of stored water to overlying alluvial and or surface water sources. No impacts on water quality in the surrounding strata, on nearby water users or on GDEs are therefore anticipated. Furthermore, the potential minor increase in metals concentrations is not predicted to affect potential groundwater usage in either the short or long term. Local water users predominantly extract groundwater for stock & domestic purposes from the Wollombi Brook Alluvium more than 100 m above the workings and the predicted metals concentrations in the workings themselves would, in most cases, remain several orders of magnitude below ANZECC (2000) livestock (cattle) drinking water quality guideline values. Finally, since transferring water into and out of the workings will not lead to any physical disturbance of the surrounding strata no impacts on the hydraulic connection between aquifers are anticipated.

The NSW AIP also requires that proponents of aquifer interference activities provide predictions of the volume of water to be taken from a water source because of the proposed activity. In this case, as discussed in Section 6.1, since extraction of the temporarily stored water from the underground workings will generally match the volume of water transferred into the workings no increase to the current approved long term extraction volumes should be necessary. Where extraction volumes from this storage exceed the volume of water transferred into the underground workings, then that amount of additional extracted water would be accounted for under existing WAL entitlements and may be replaced with water transferred into the workings.

No additional indirect take is expected from local groundwater sources, including the highly productive Wollombi Brook and Hunter River alluvium or the low productivity underlying Permian units.

6.7 Monitoring and management

As mentioned previously (Section 1.3), all water transfers in and out of the former Lemington Underground Mine void would be metered to enable full accounting of water transfers. Further, as described in Section 6.3, it is recommended that the underground workings water storage level be managed to not exceed approximately 30 mAHD. This will prevent seepage of the stored water into the surface water system (including into connected alluvial groundwater systems).

It is also recommended that additional monitoring points be installed:

- at two further locations within the workings to monitor operational groundwater levels and water quality; and
- into the Hunter River alluvium and into one or more underlying coal seams close to the northeast corner of the workings and to the west of the Hunter River since there is currently no monitoring in this area.

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Appendix A

Hydrographs

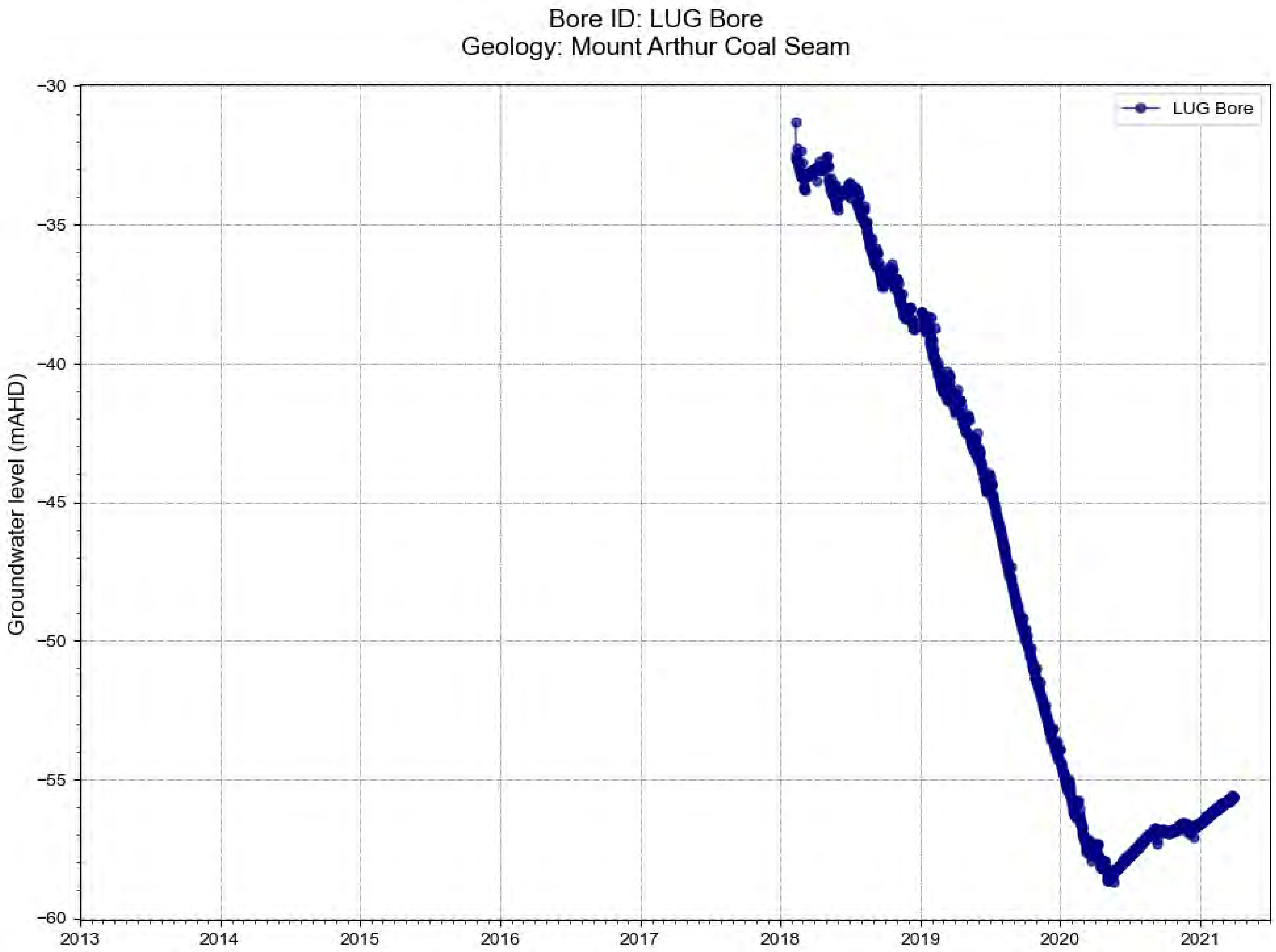


Figure A 1 LUG Bore water levels

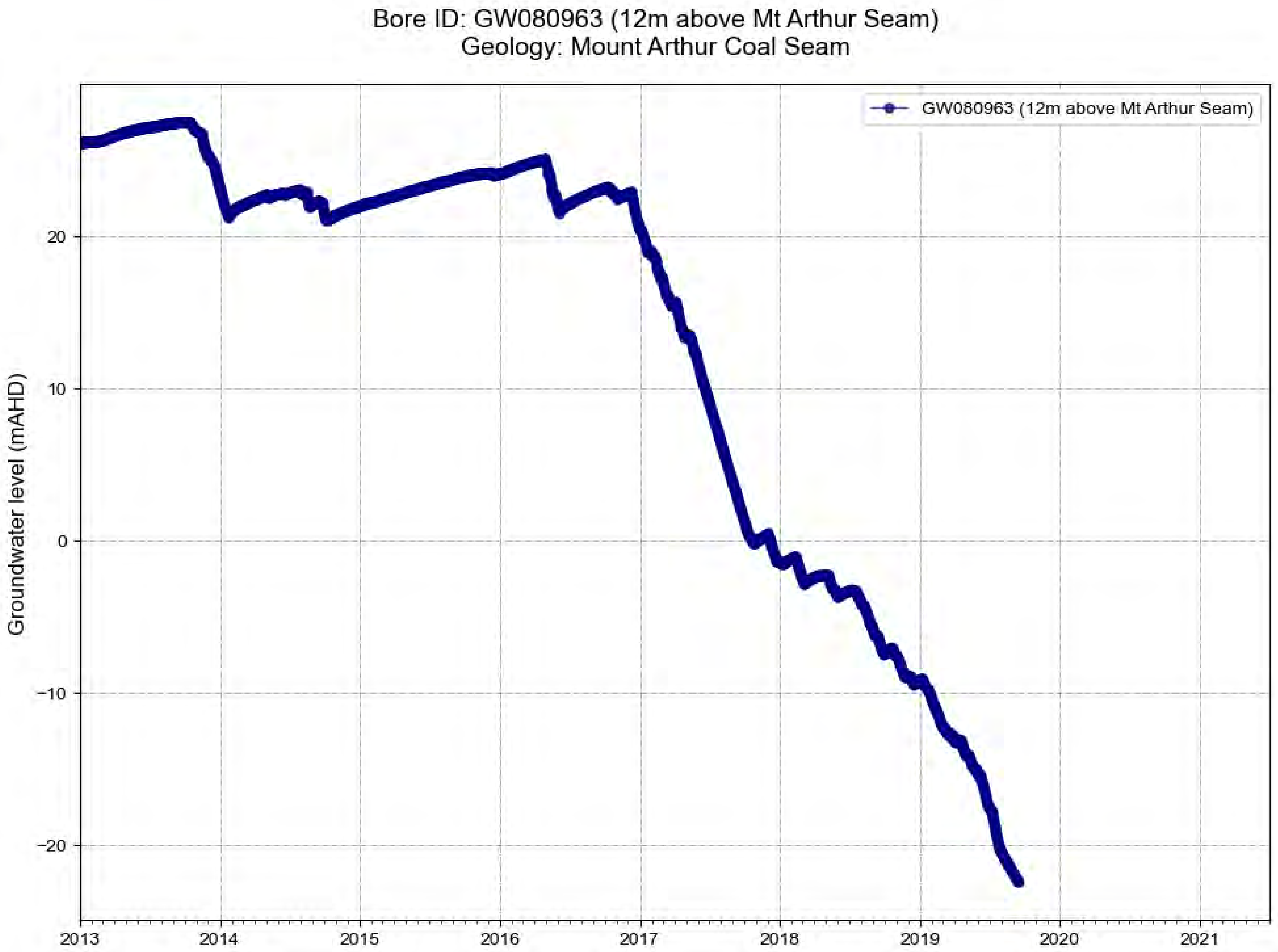


Figure A 2 GW080963 water levels

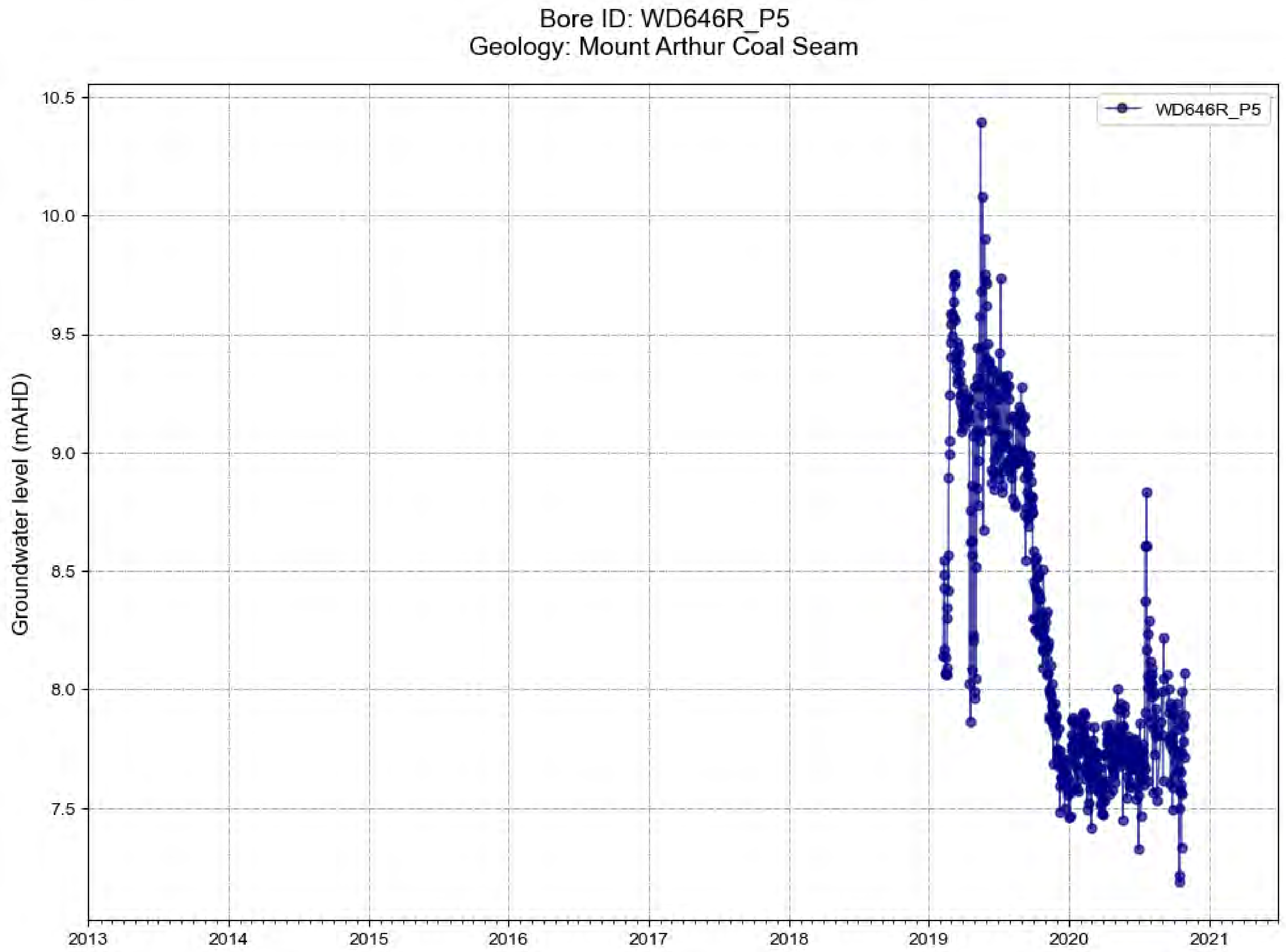


Figure A 3 WD646R_P5 water levels

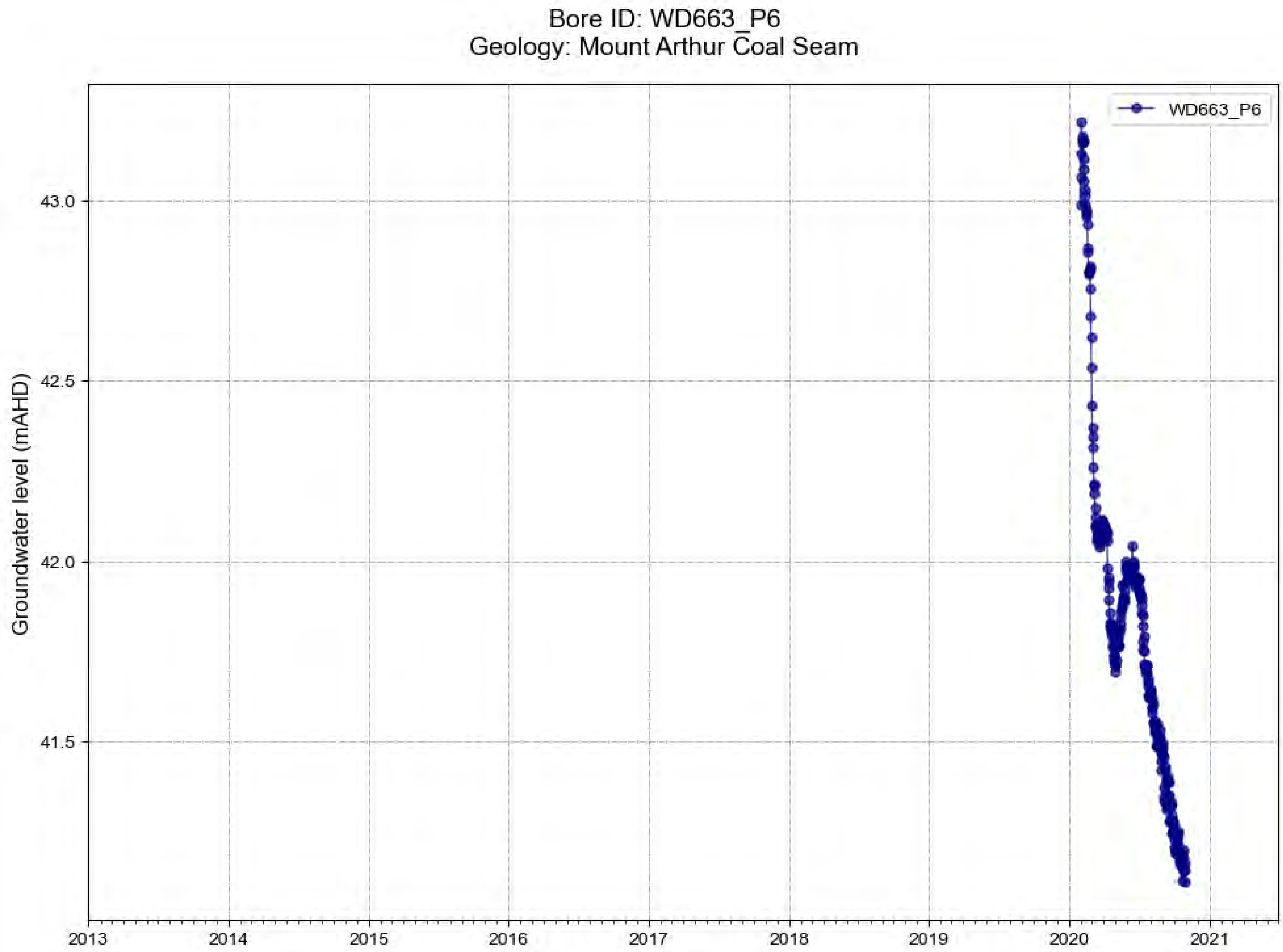


Figure A 4 WD663_P6 water levels

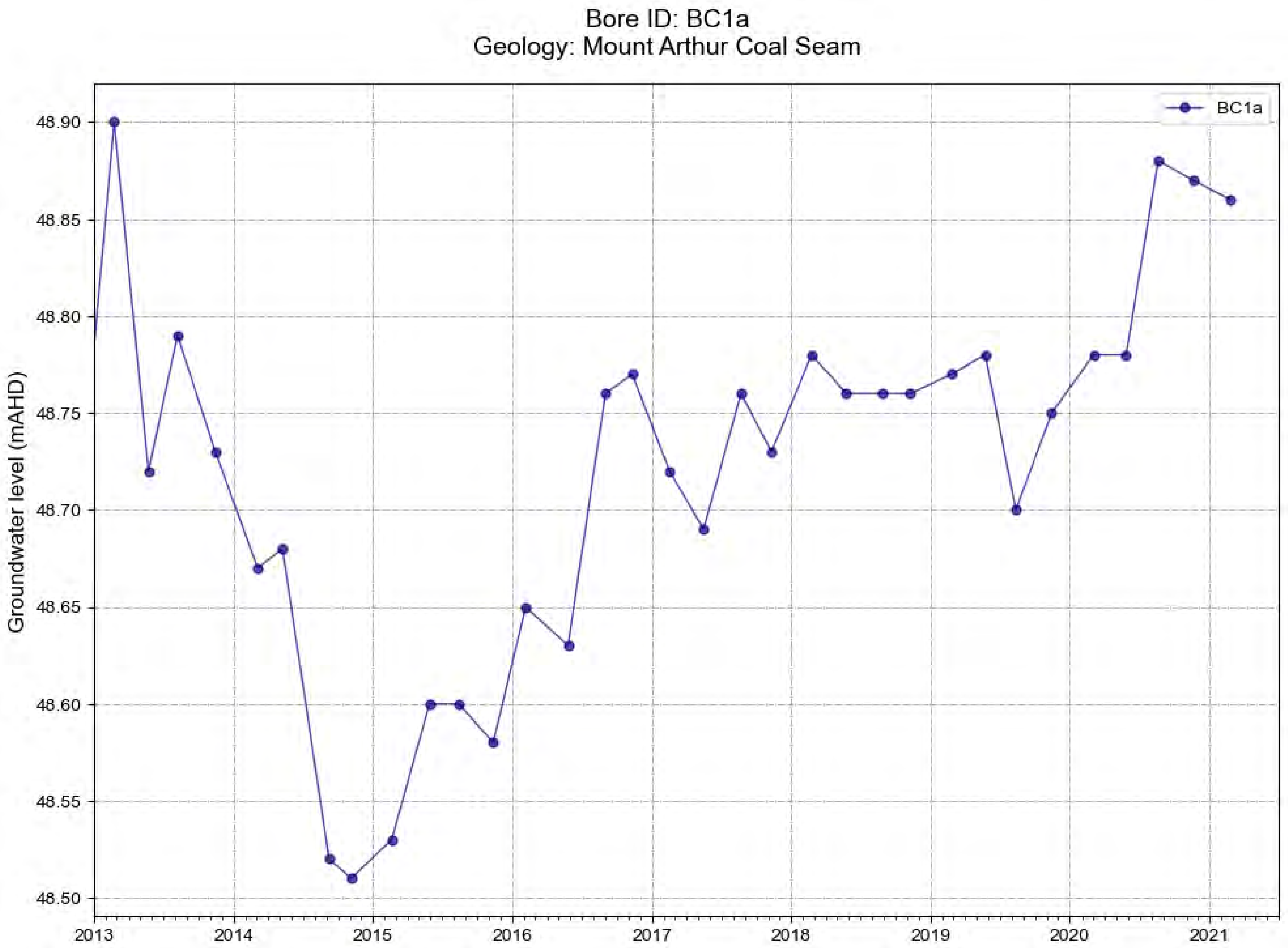


Figure A 5 BC1a water levels

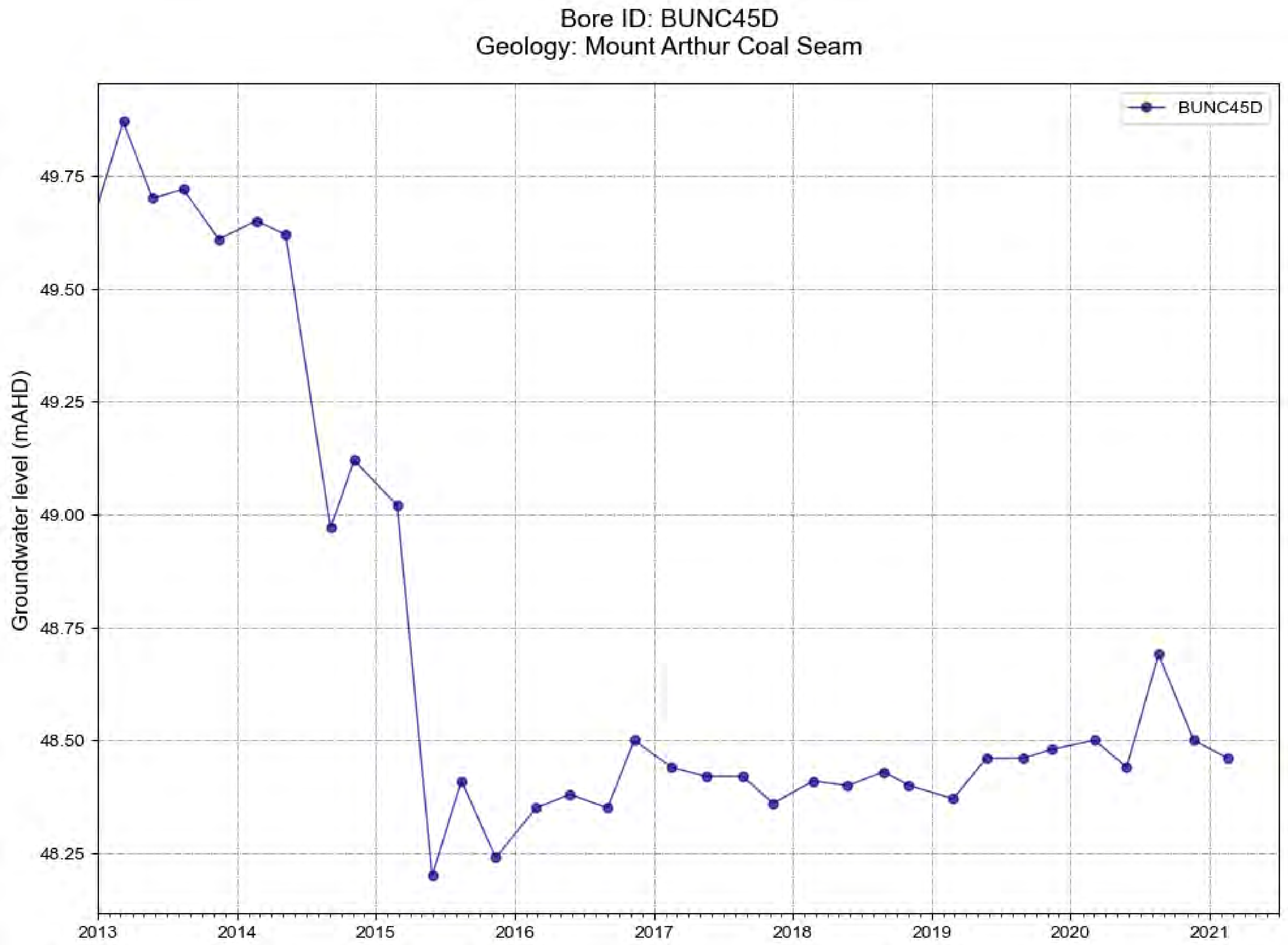


Figure A 6 BUC45D water levels

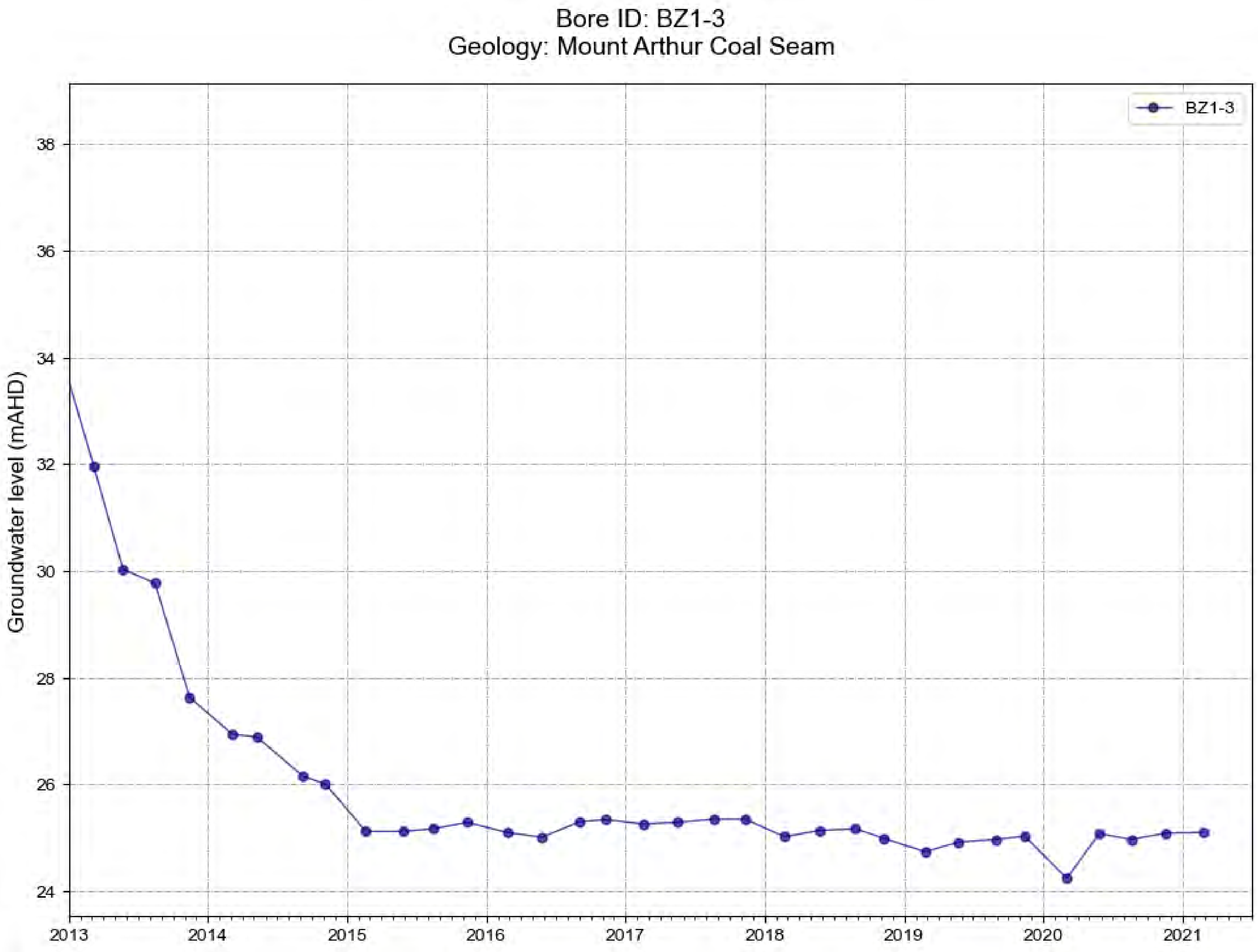


Figure A 7 BZ1-3 water levels

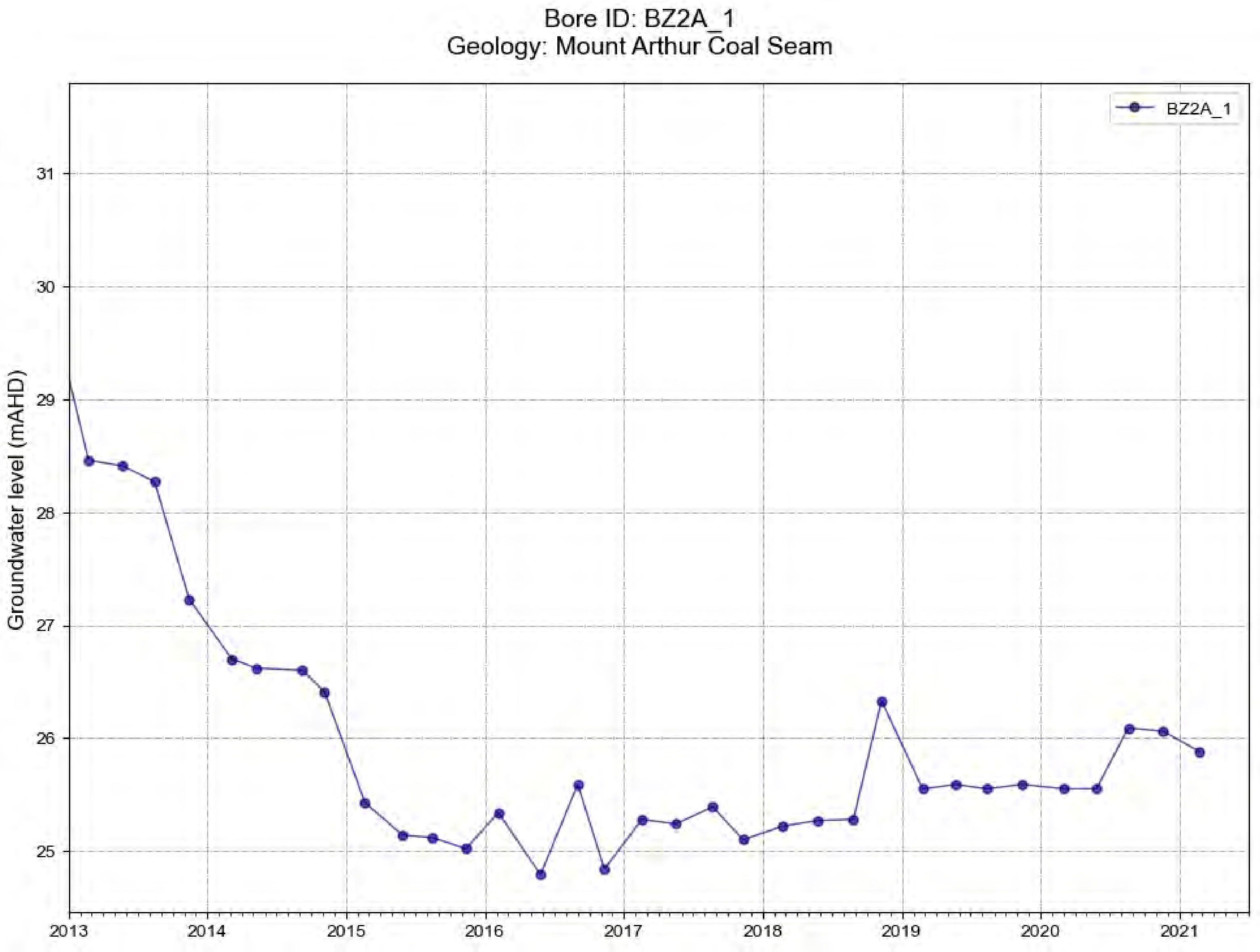


Figure A 8 BZ2A_1 water levels

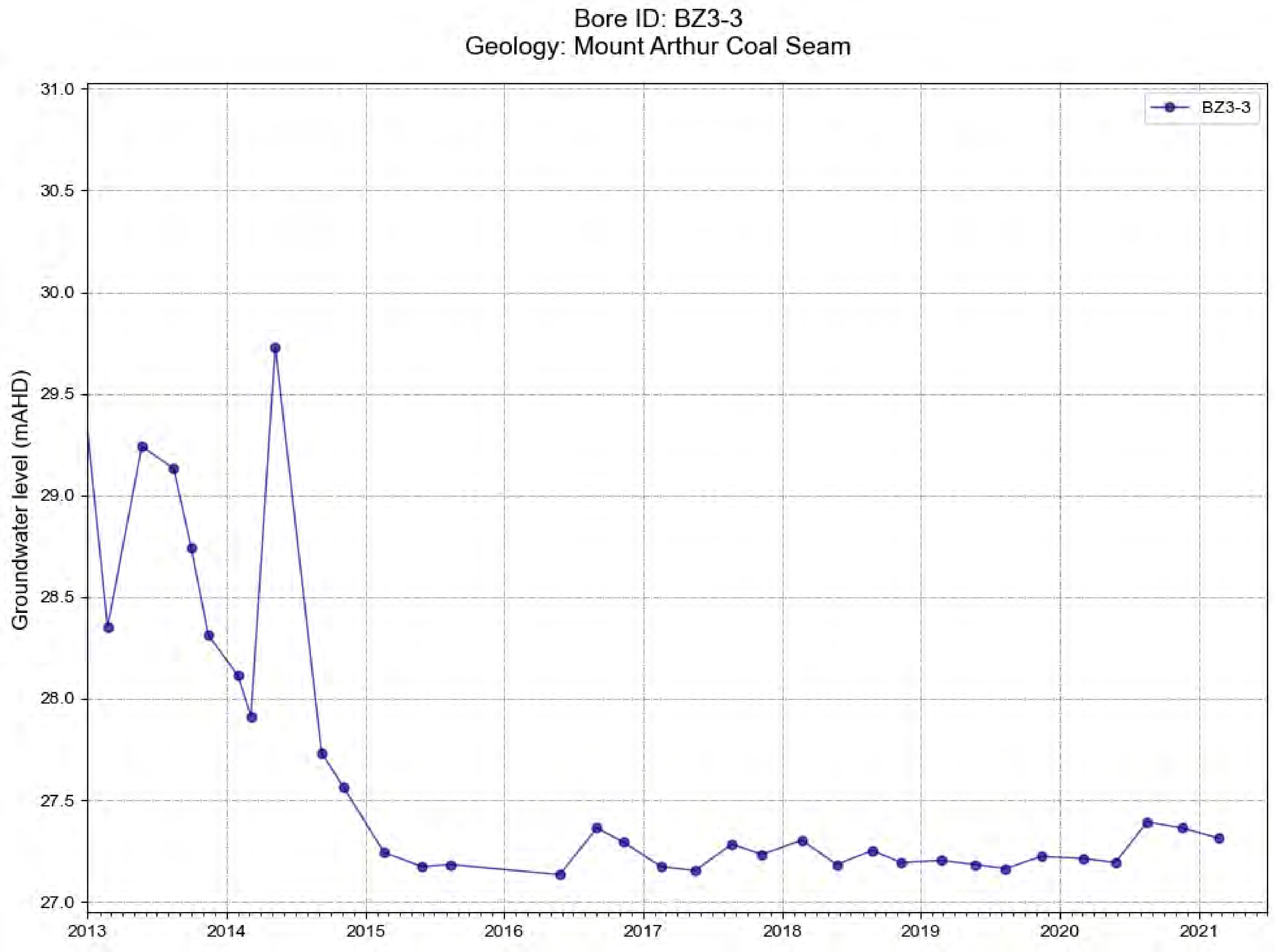


Figure A 9 BZ3-3 water levels

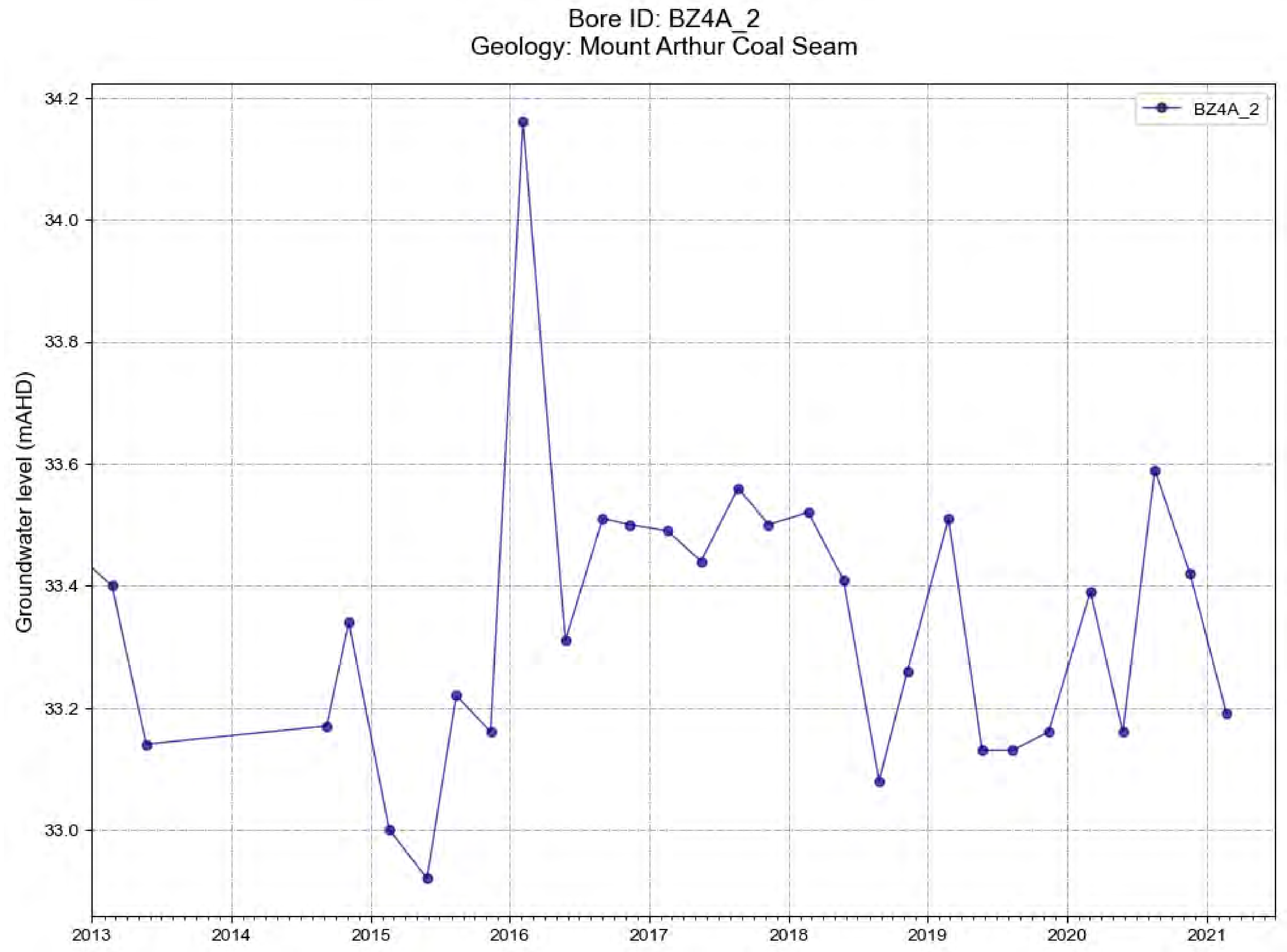


Figure A 10 BZ4A_2 water levels

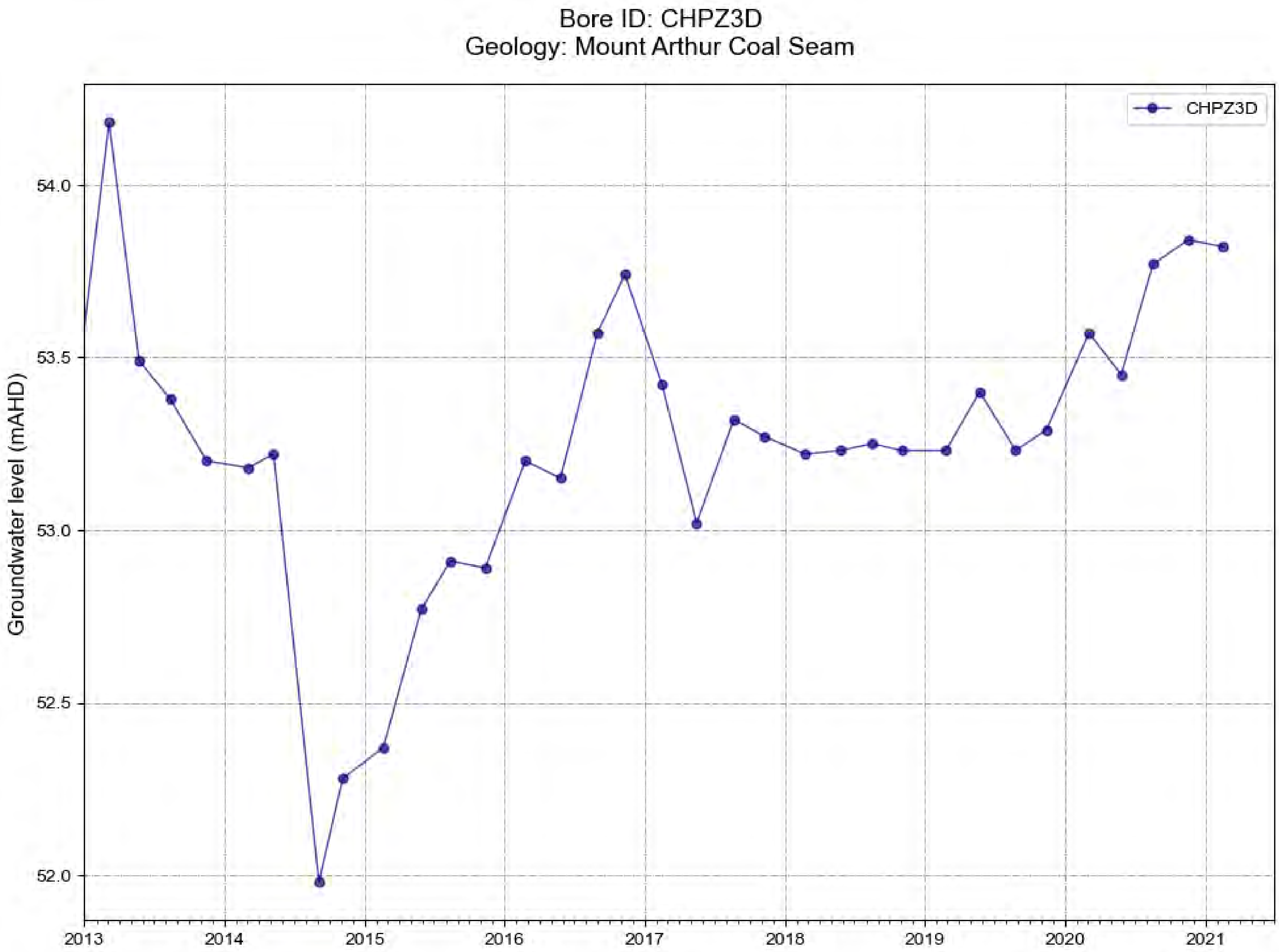


Figure A 11 CHPZ3D water levels

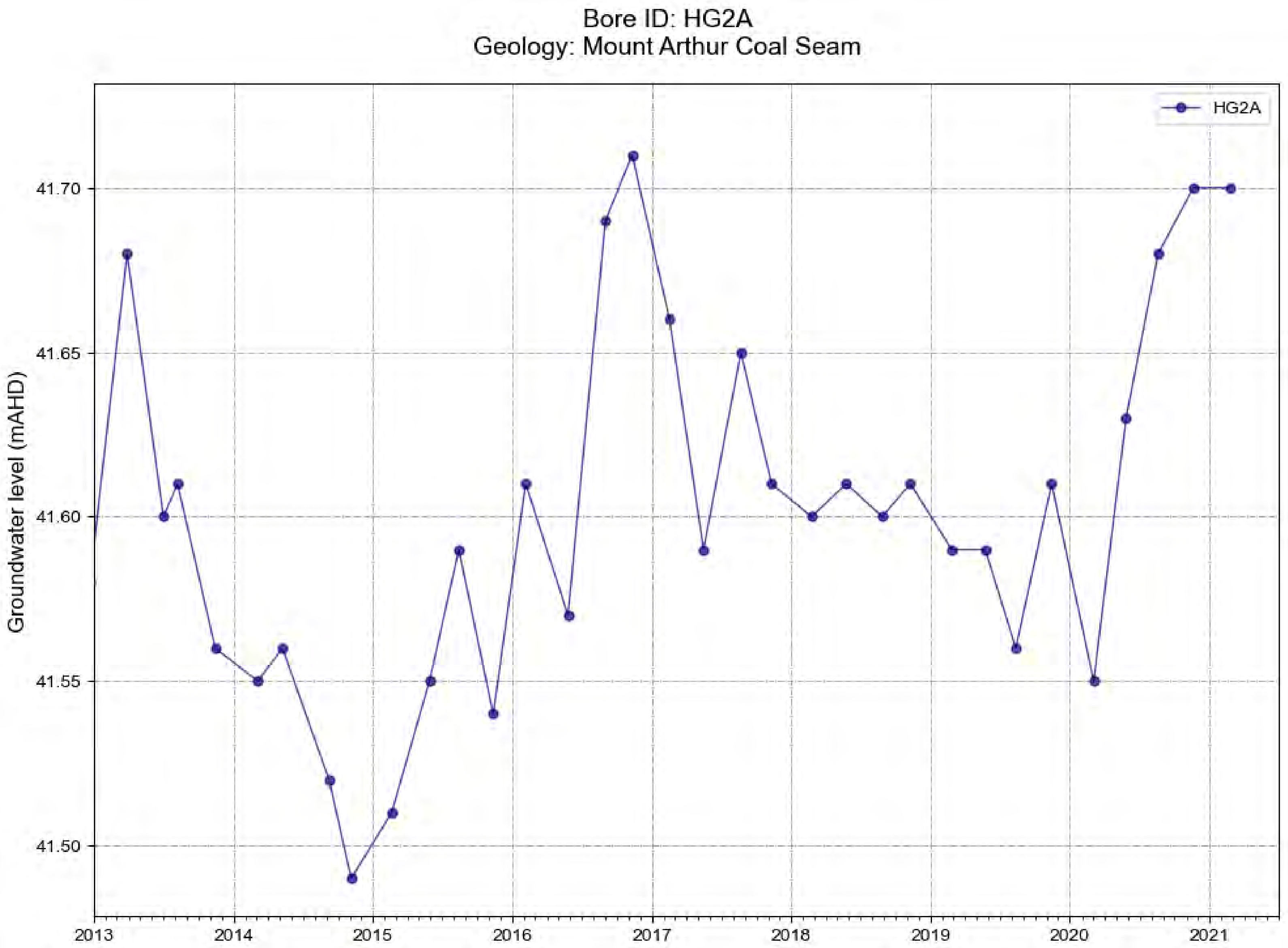


Figure A 12 HG2A water levels

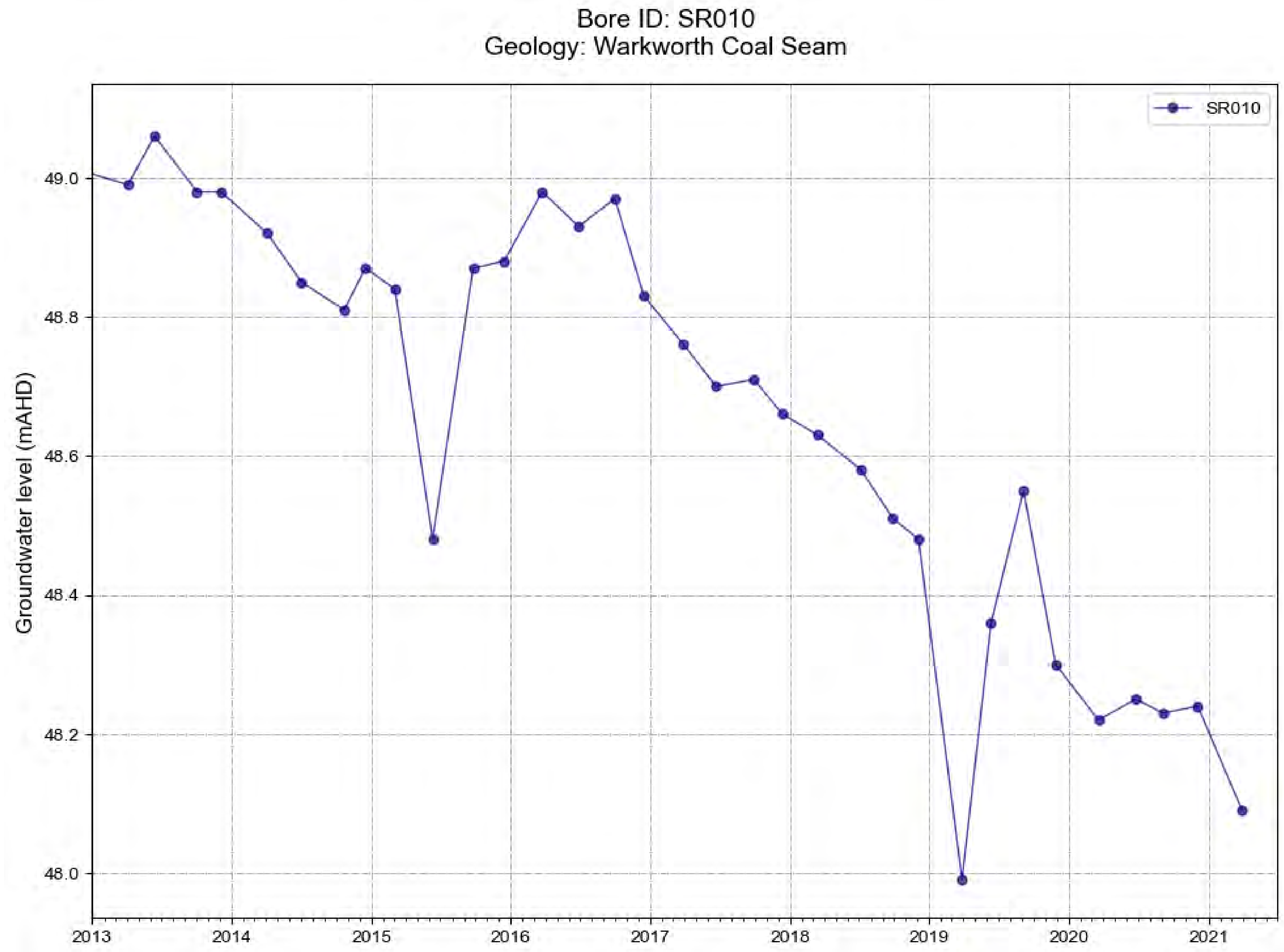


Figure A 13 SR010 water levels

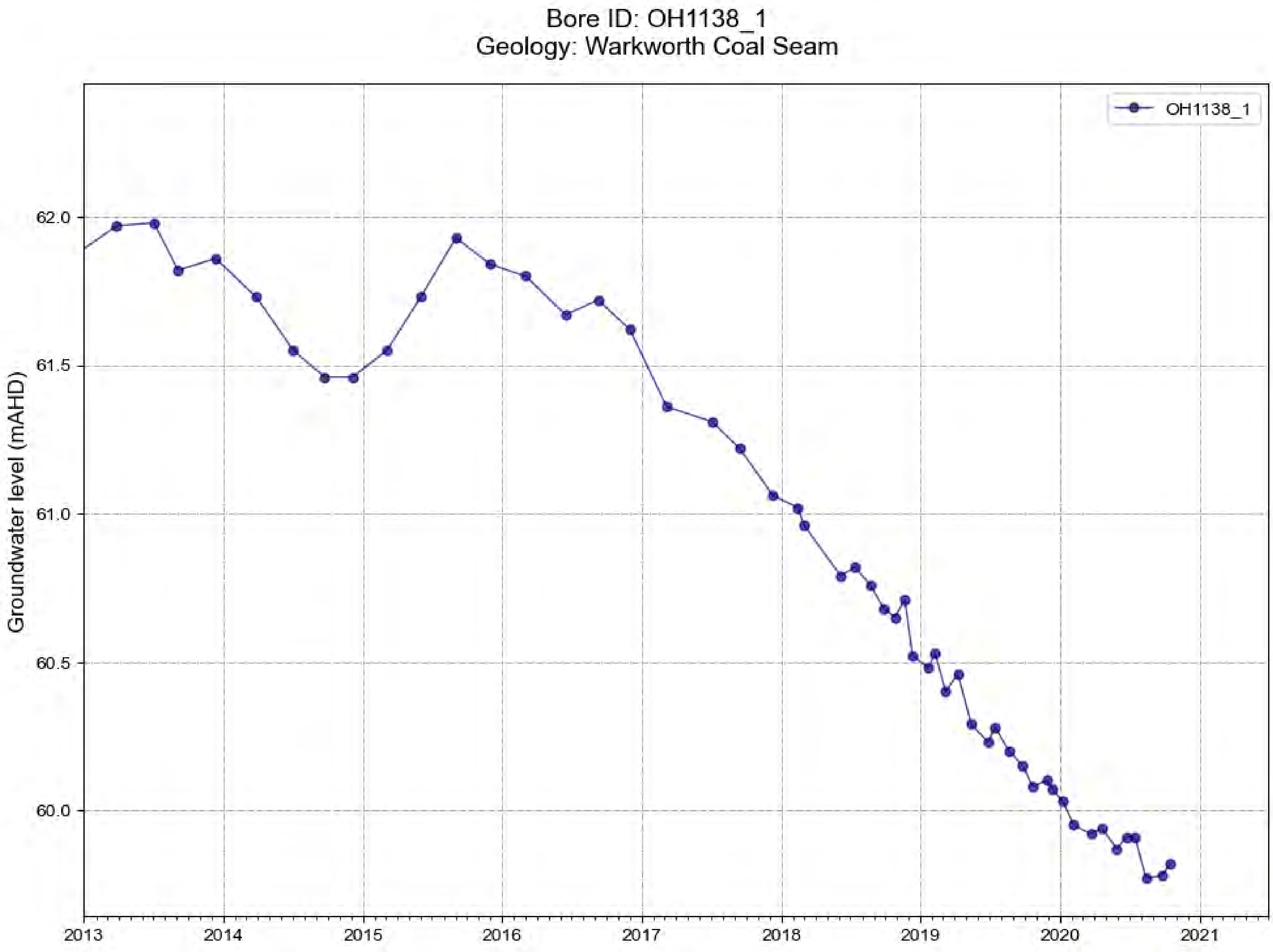


Figure A 14 OH1138_1 water levels

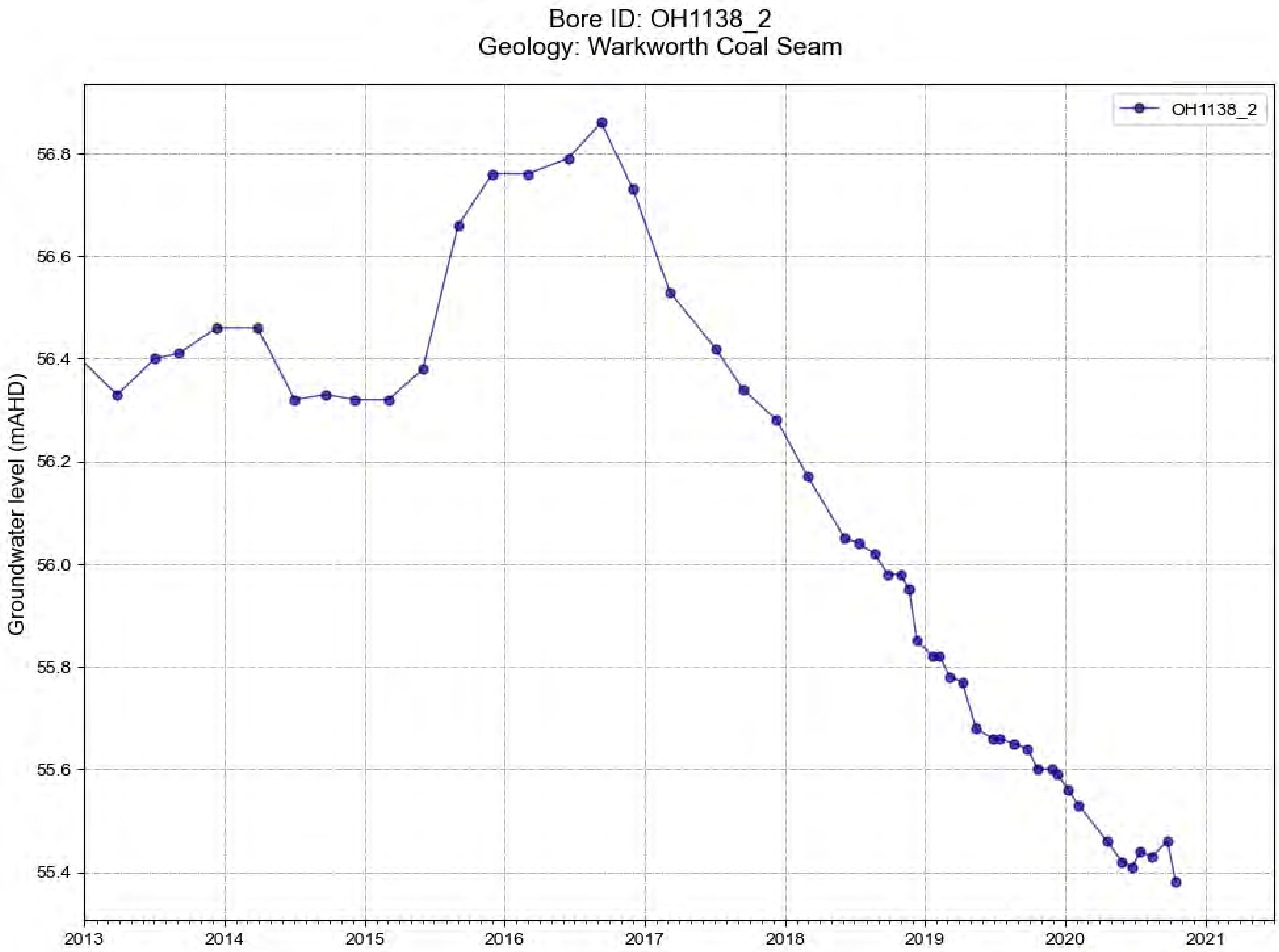


Figure A 15 OH1138_2 water levels

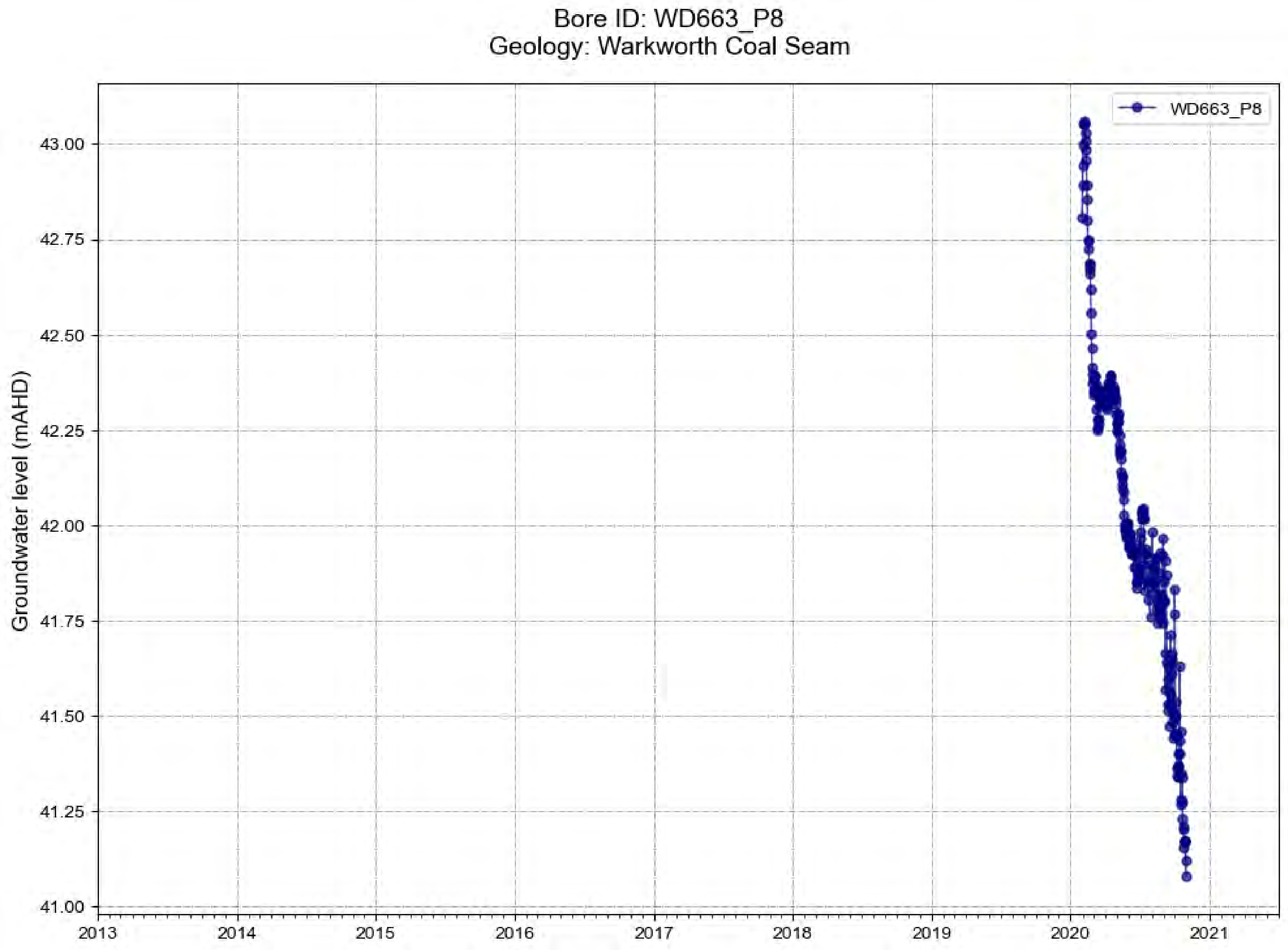


Figure A 16 WD663_P8 water levels

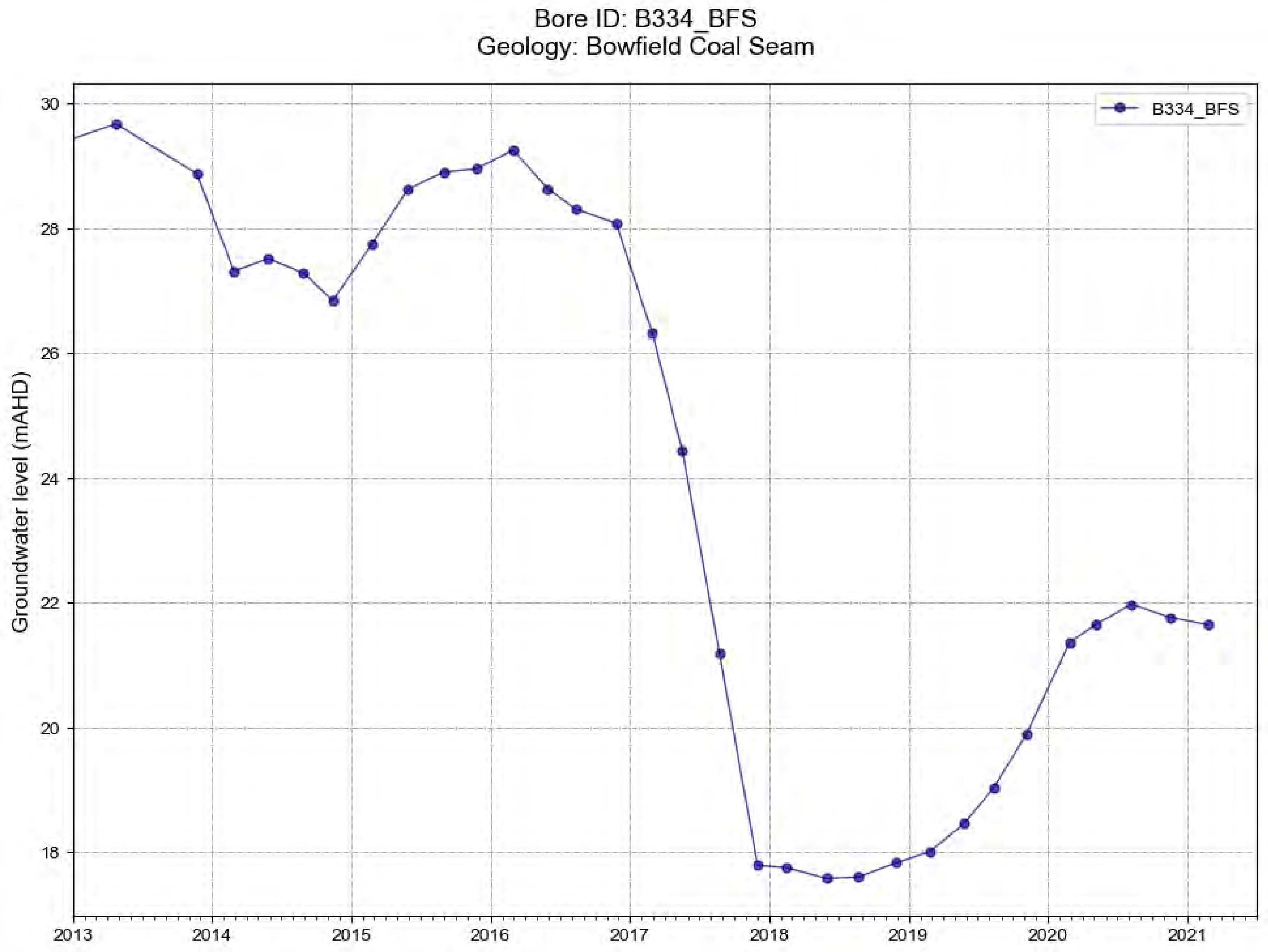


Figure A 17 B334_BFS water levels

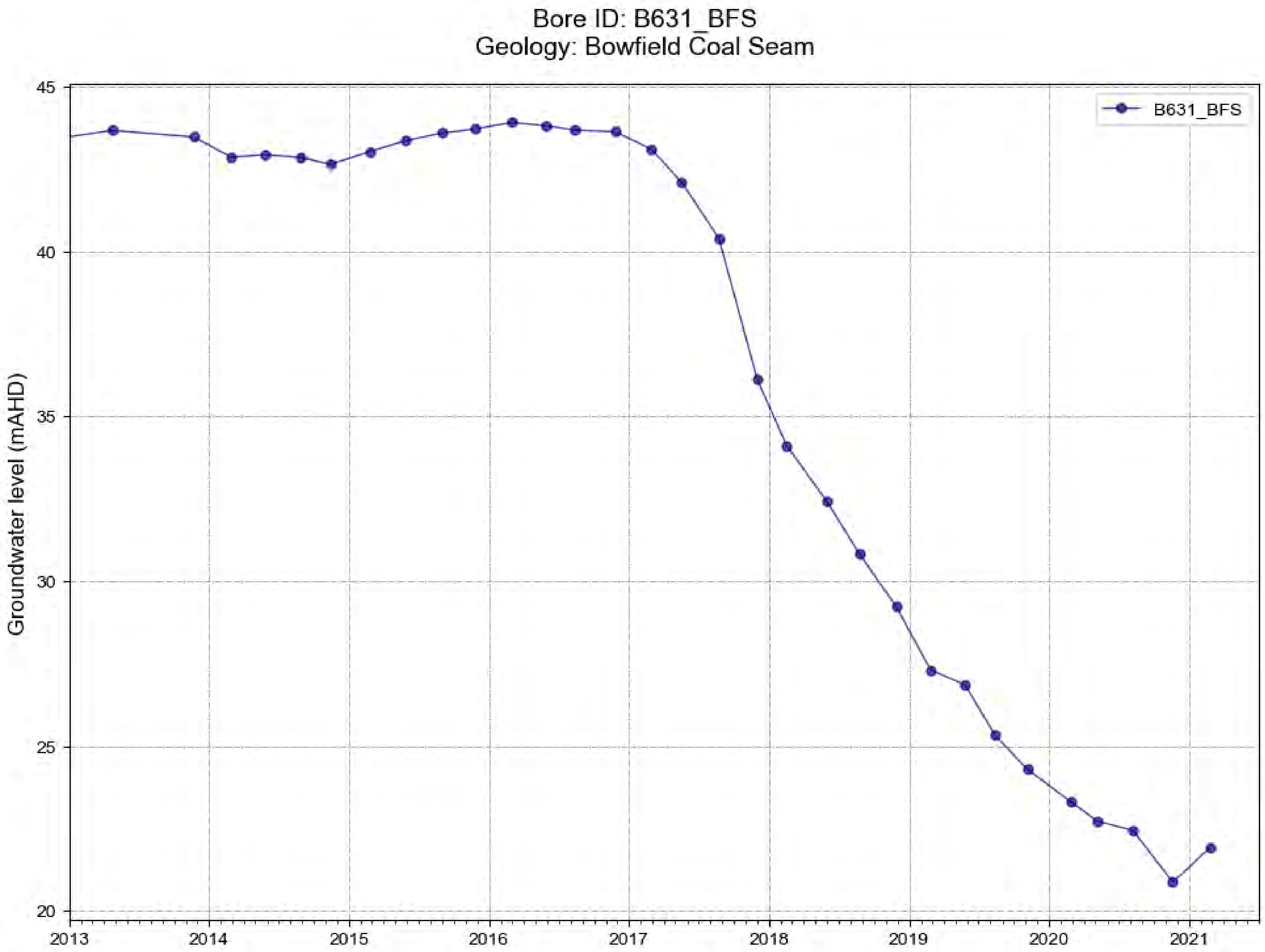


Figure A 18 B631_BFS water levels

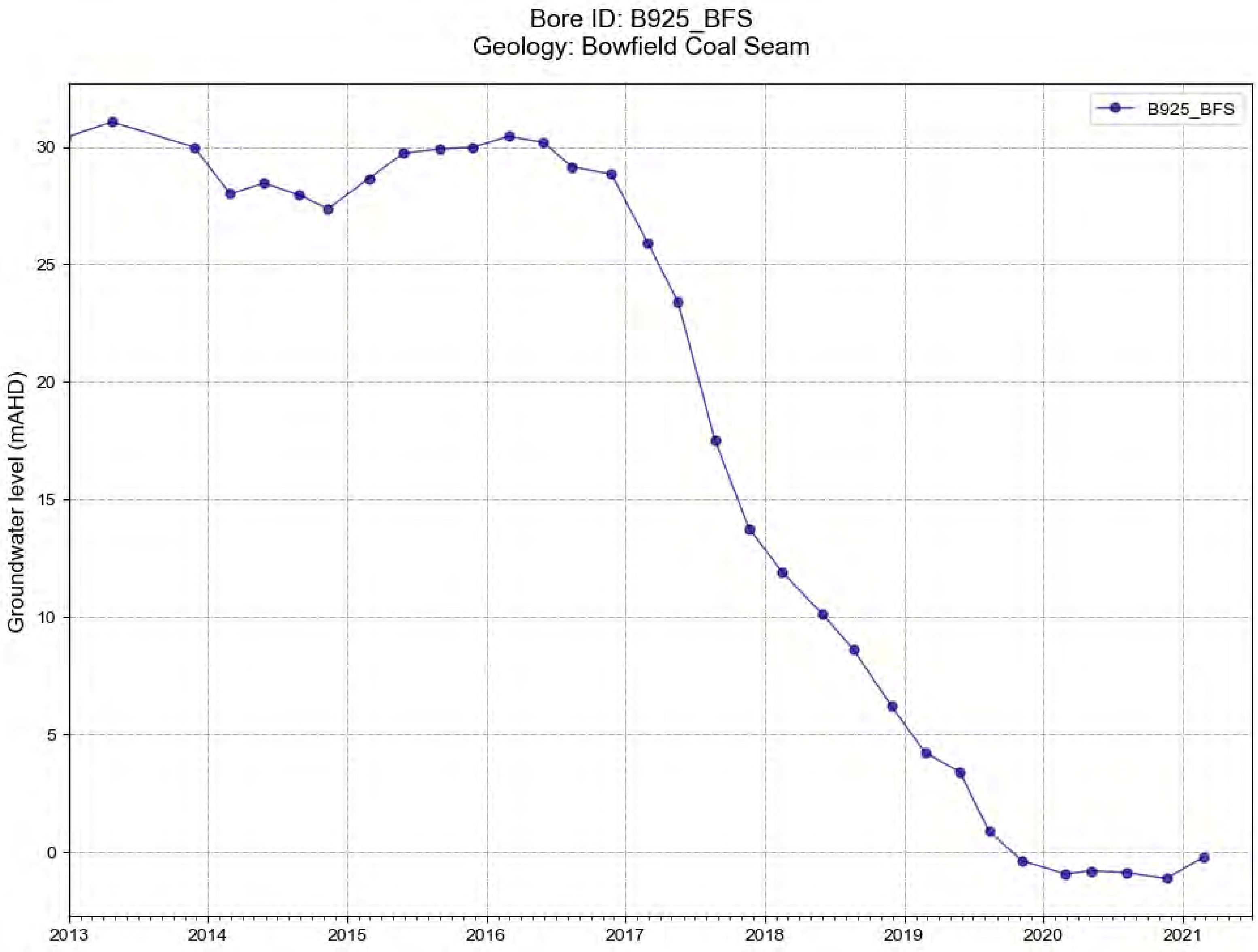


Figure A 19 B925_BFS water levels

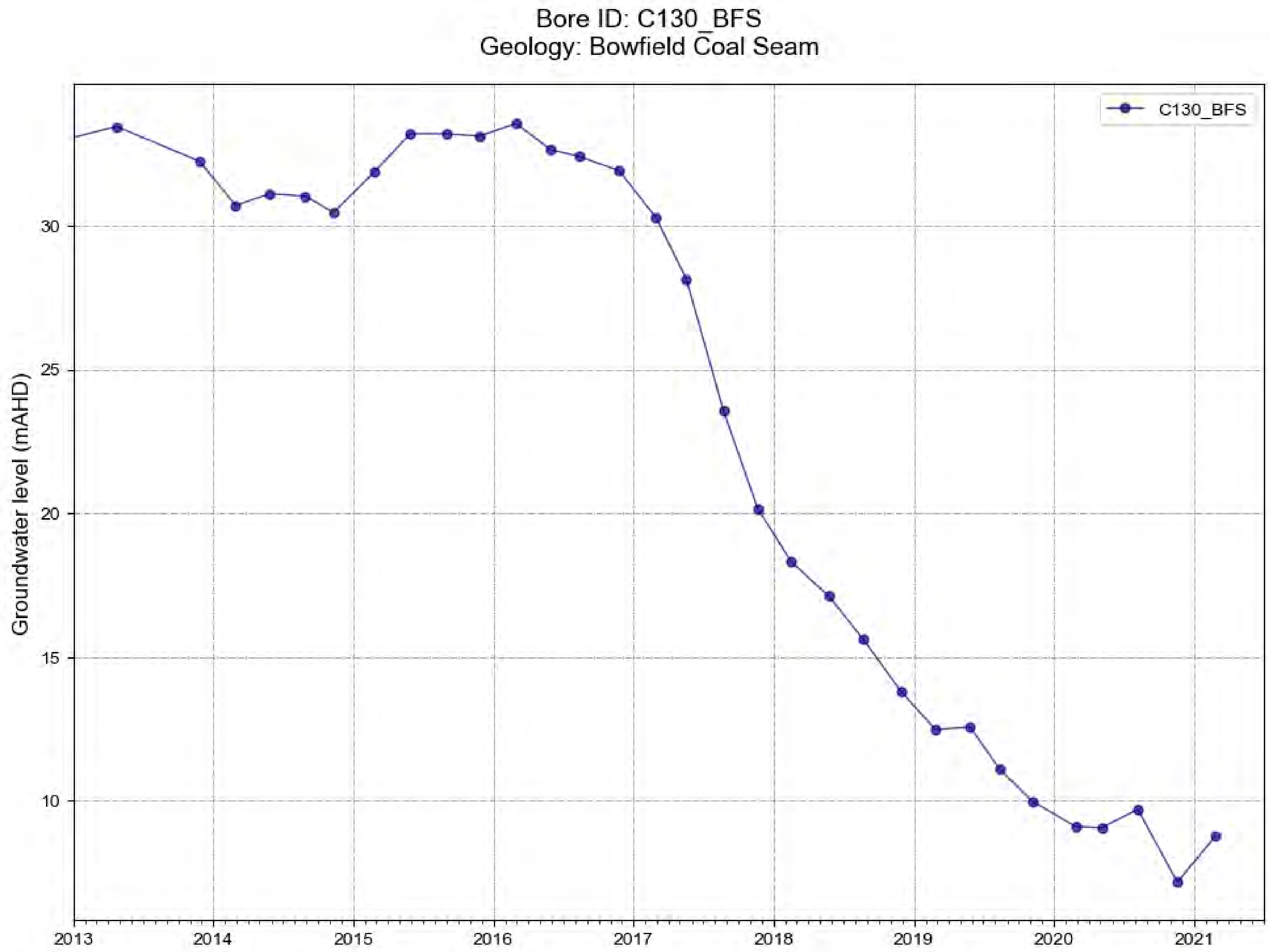


Figure A 20 C130_BFS water levels

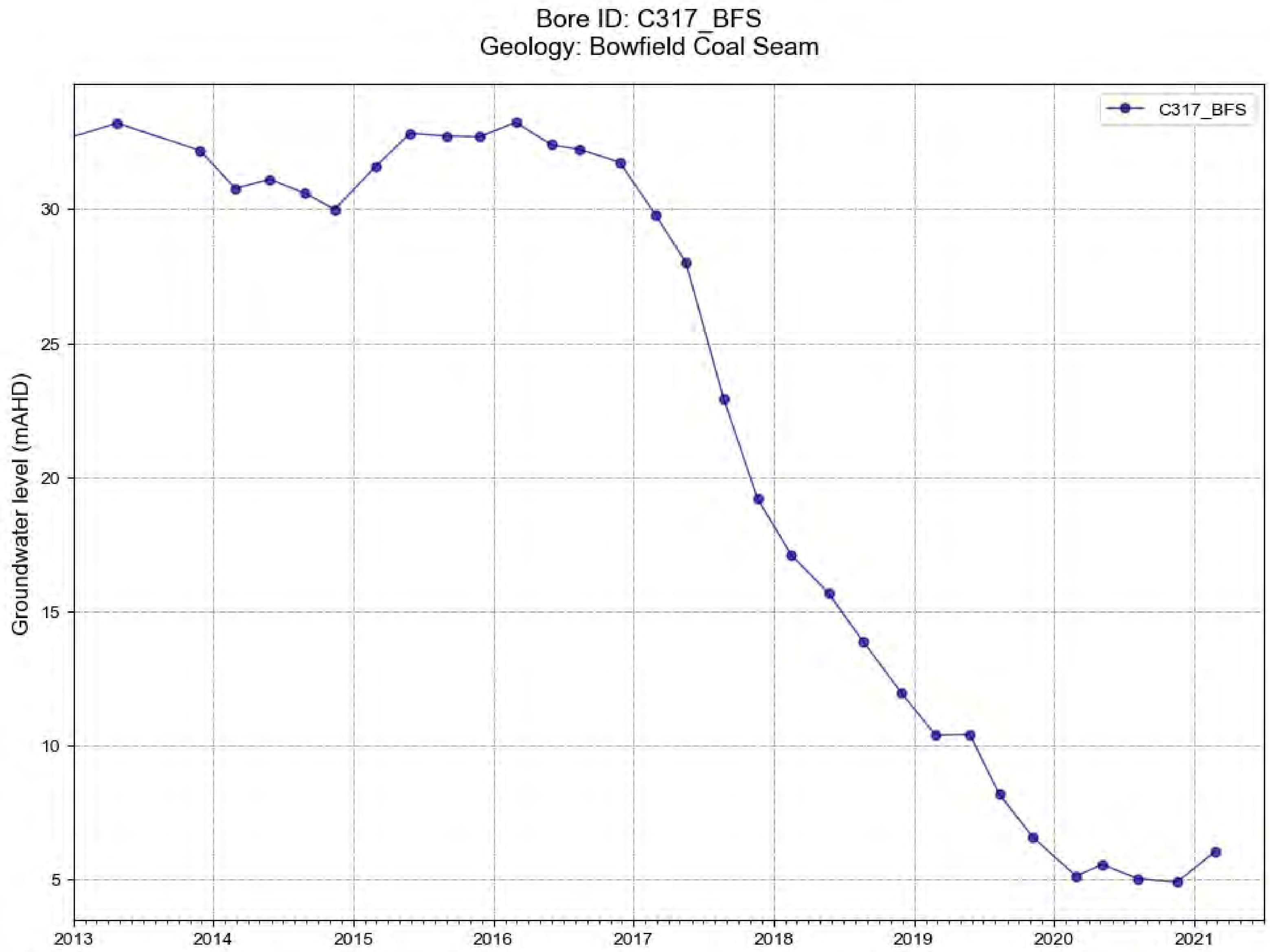


Figure A 21 C317_BFS water levels

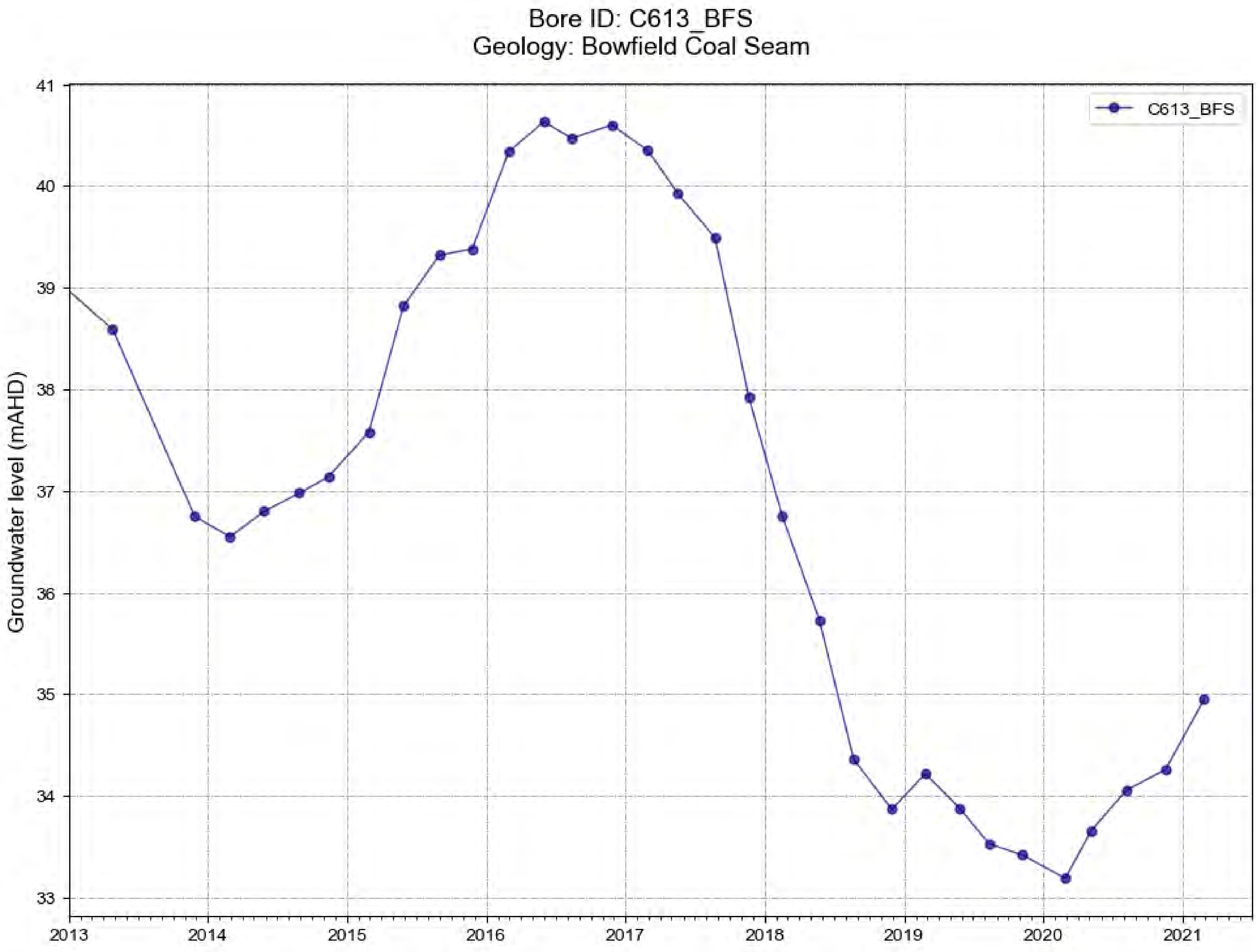
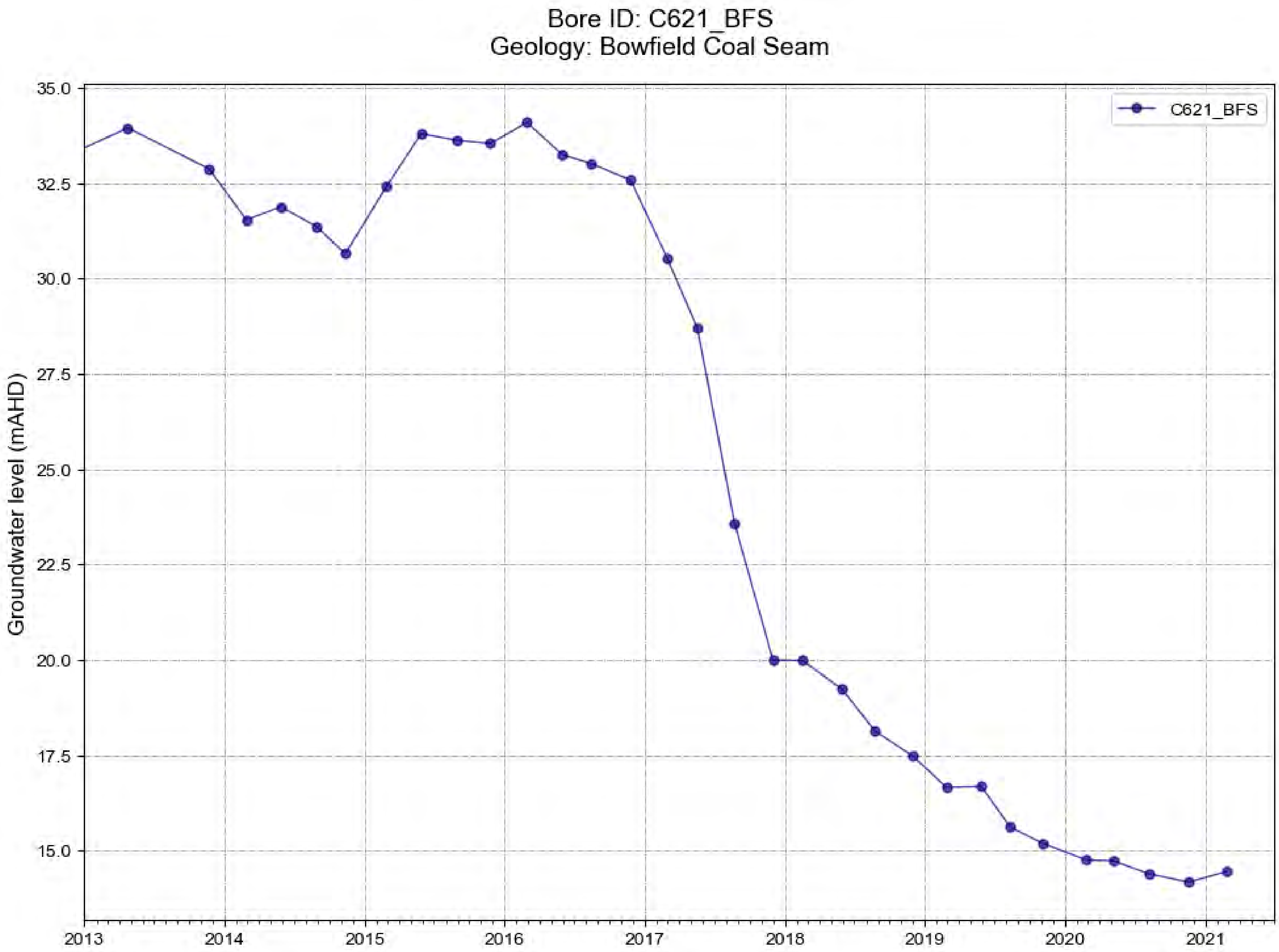


Figure A 22 C613_BFS water levels



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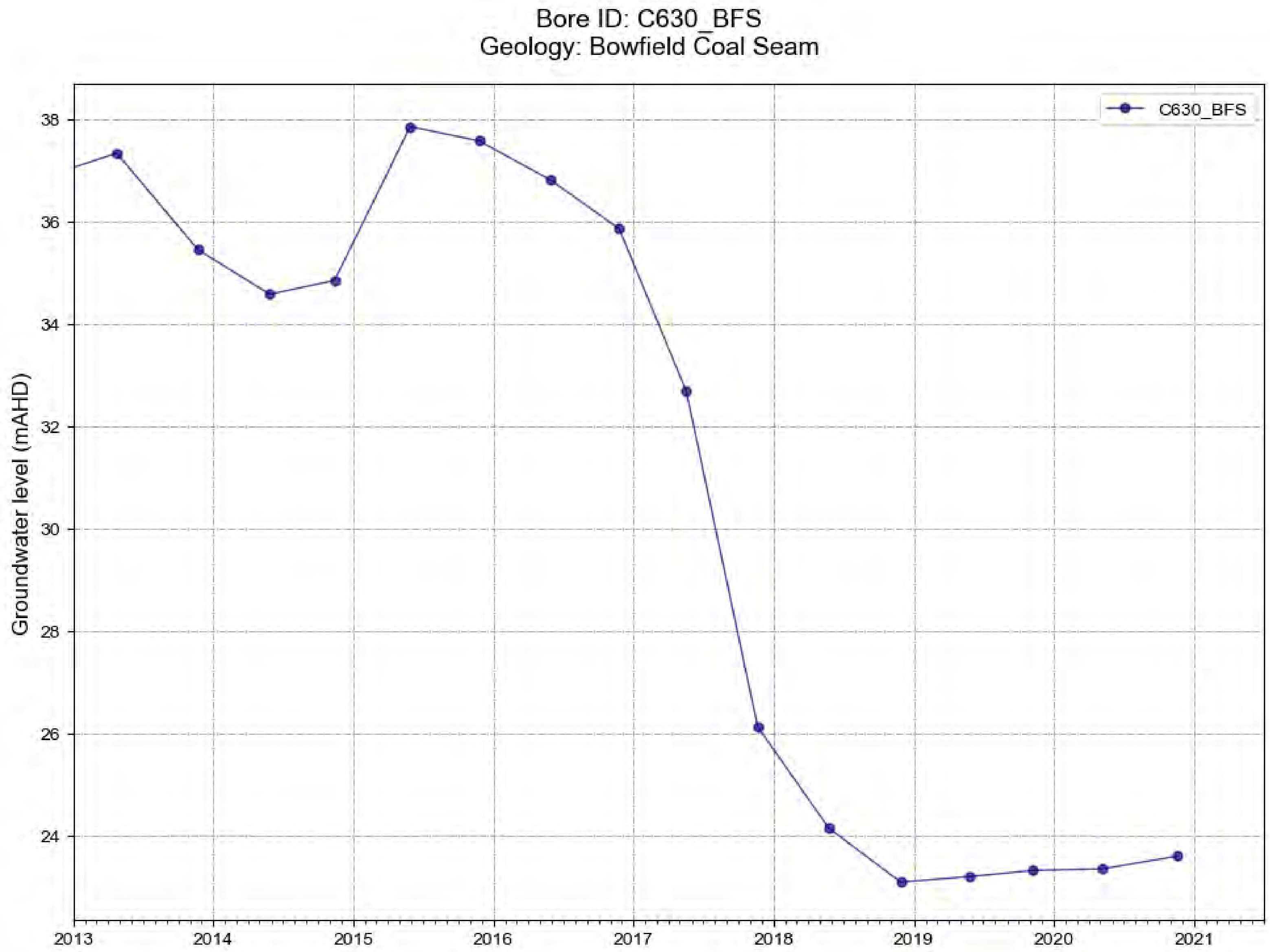


Figure A 24 C630_BFS water levels

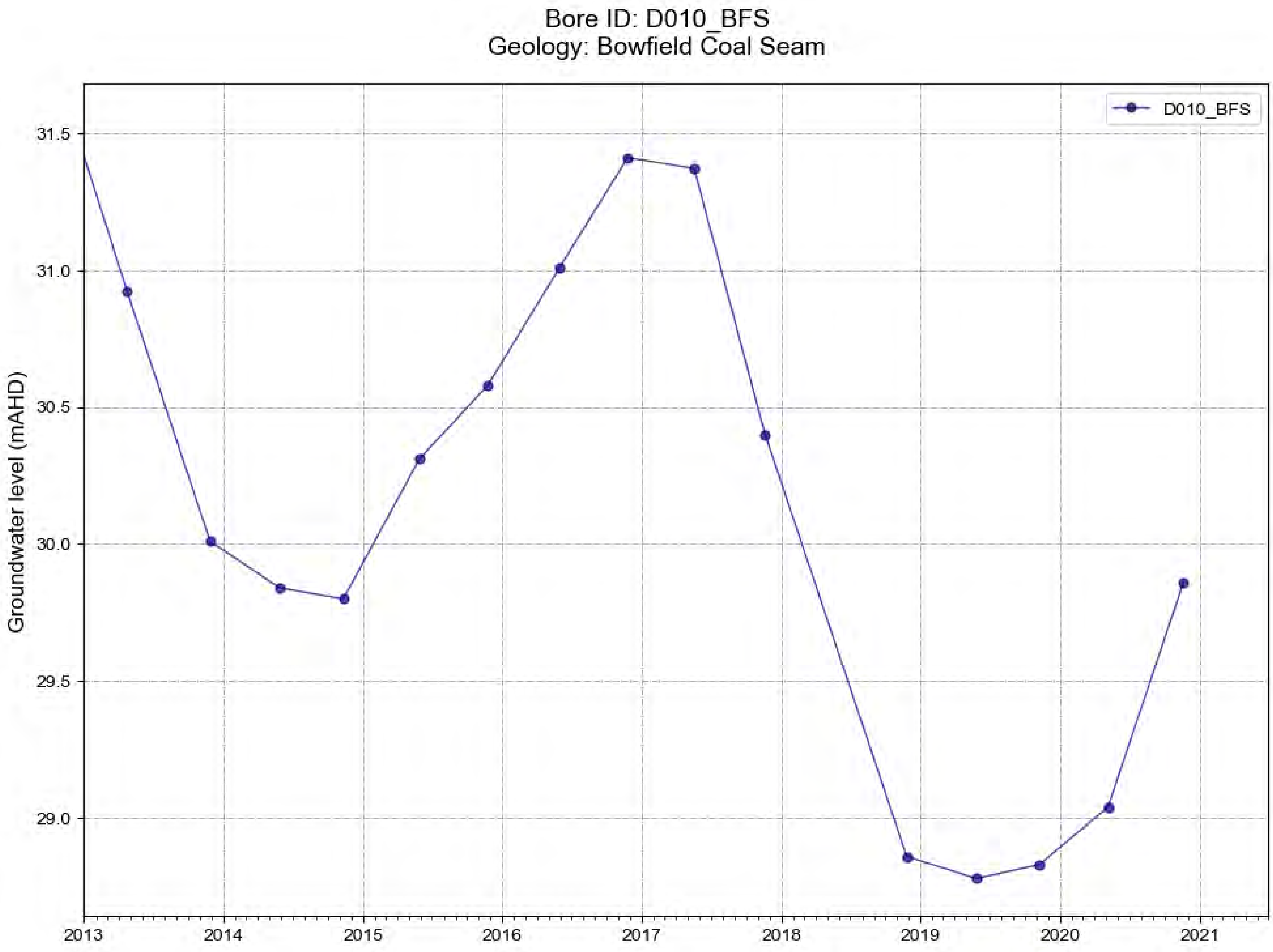
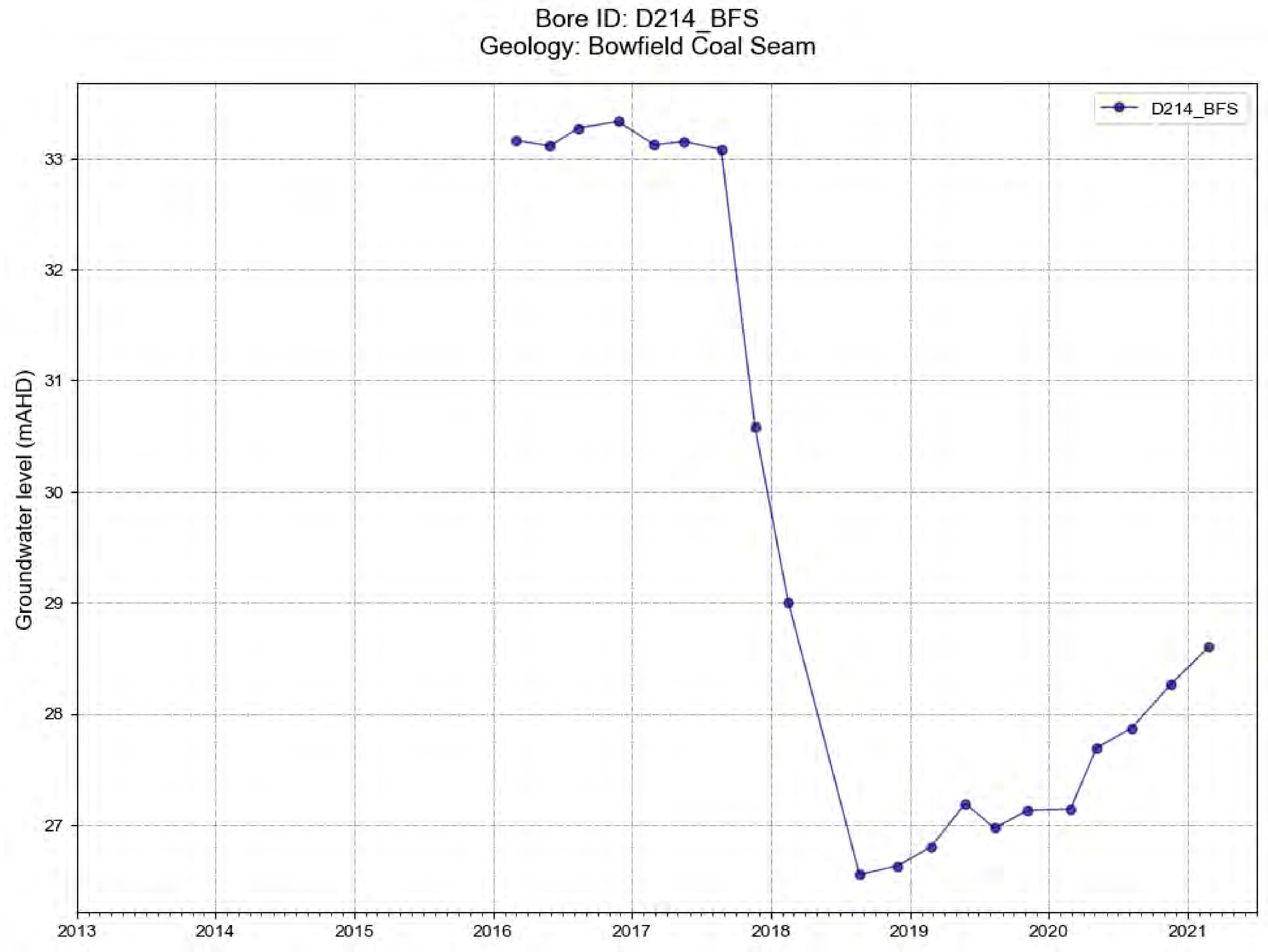


Figure A 25 D010_BFS



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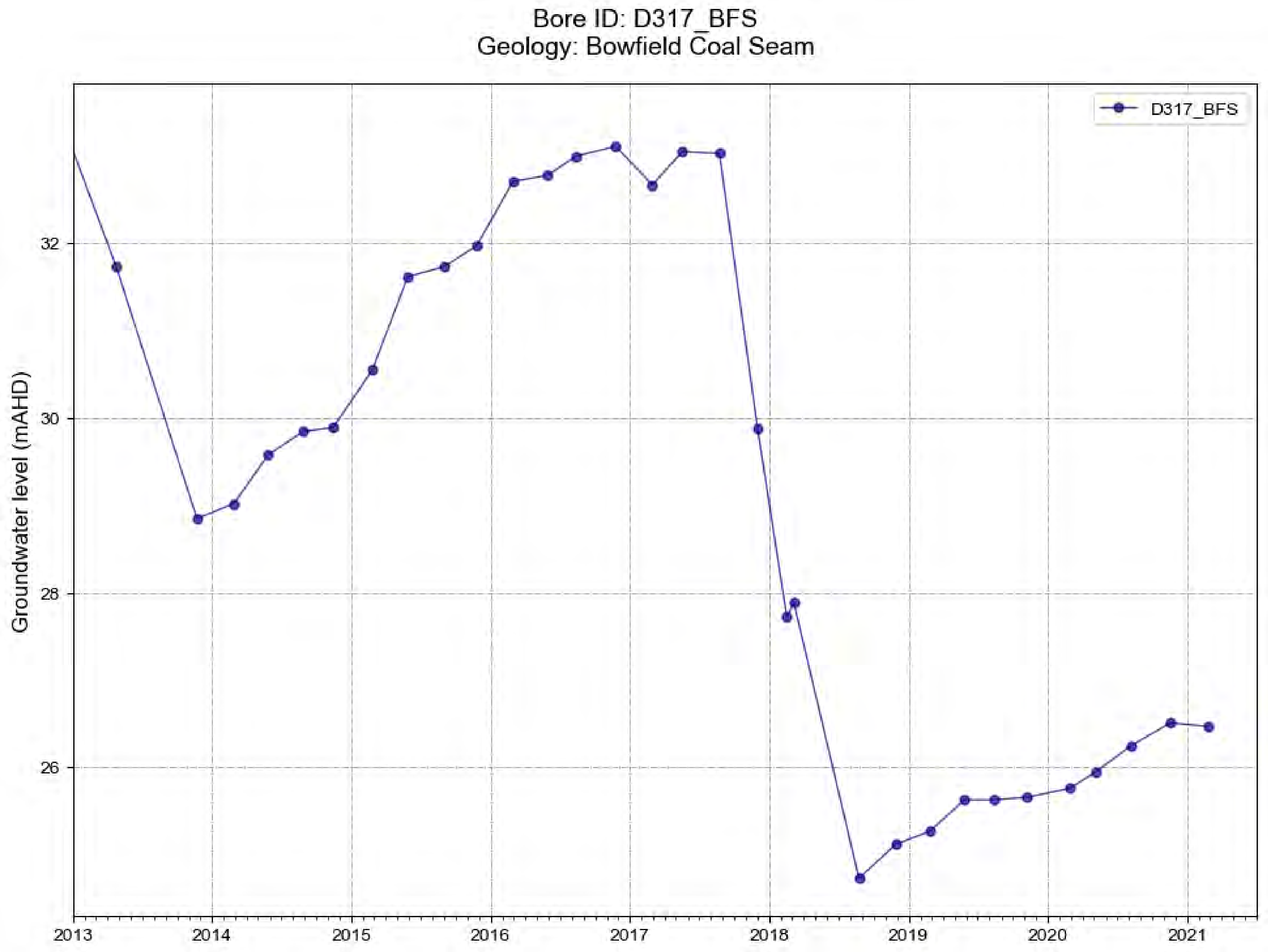

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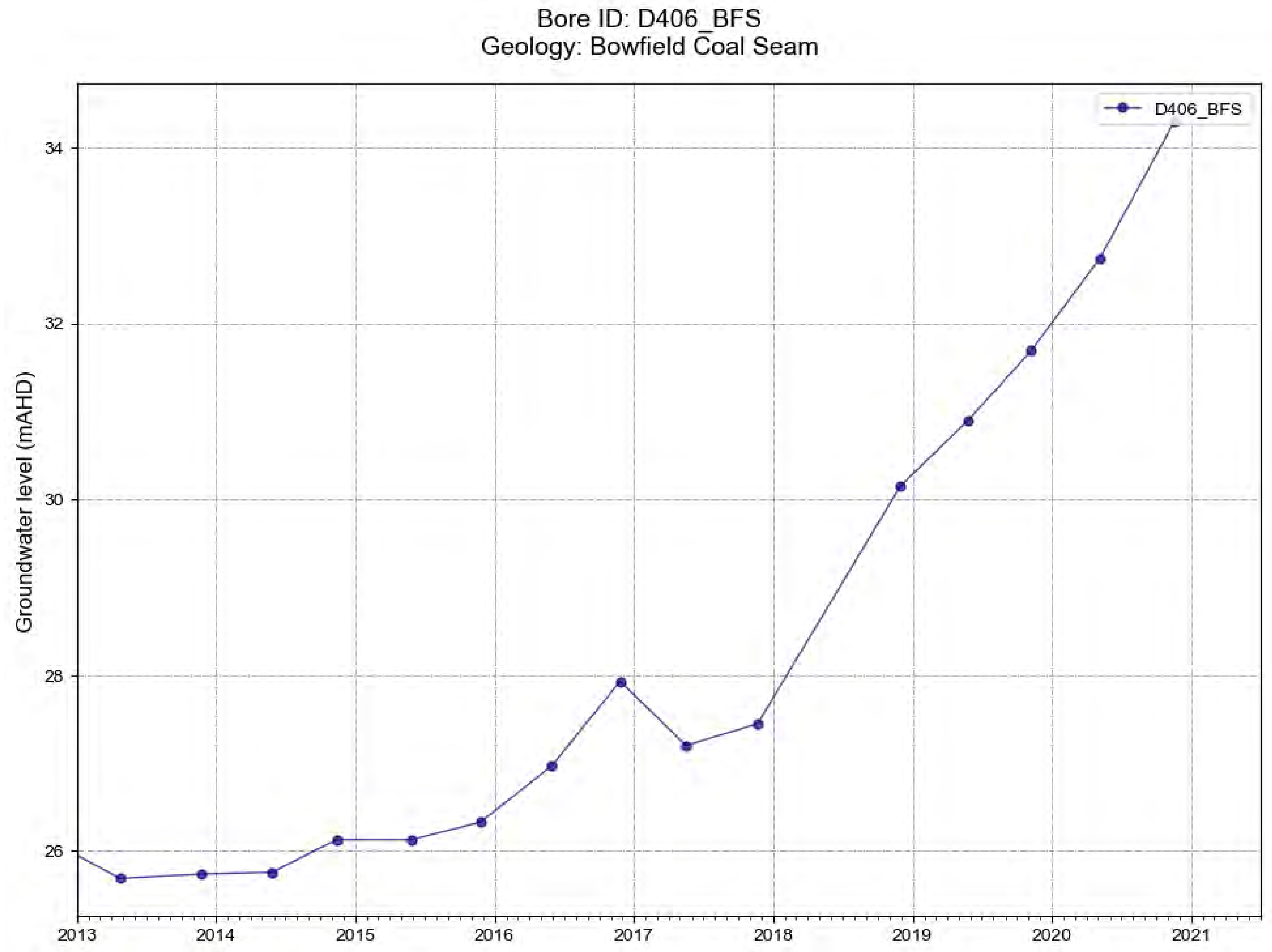

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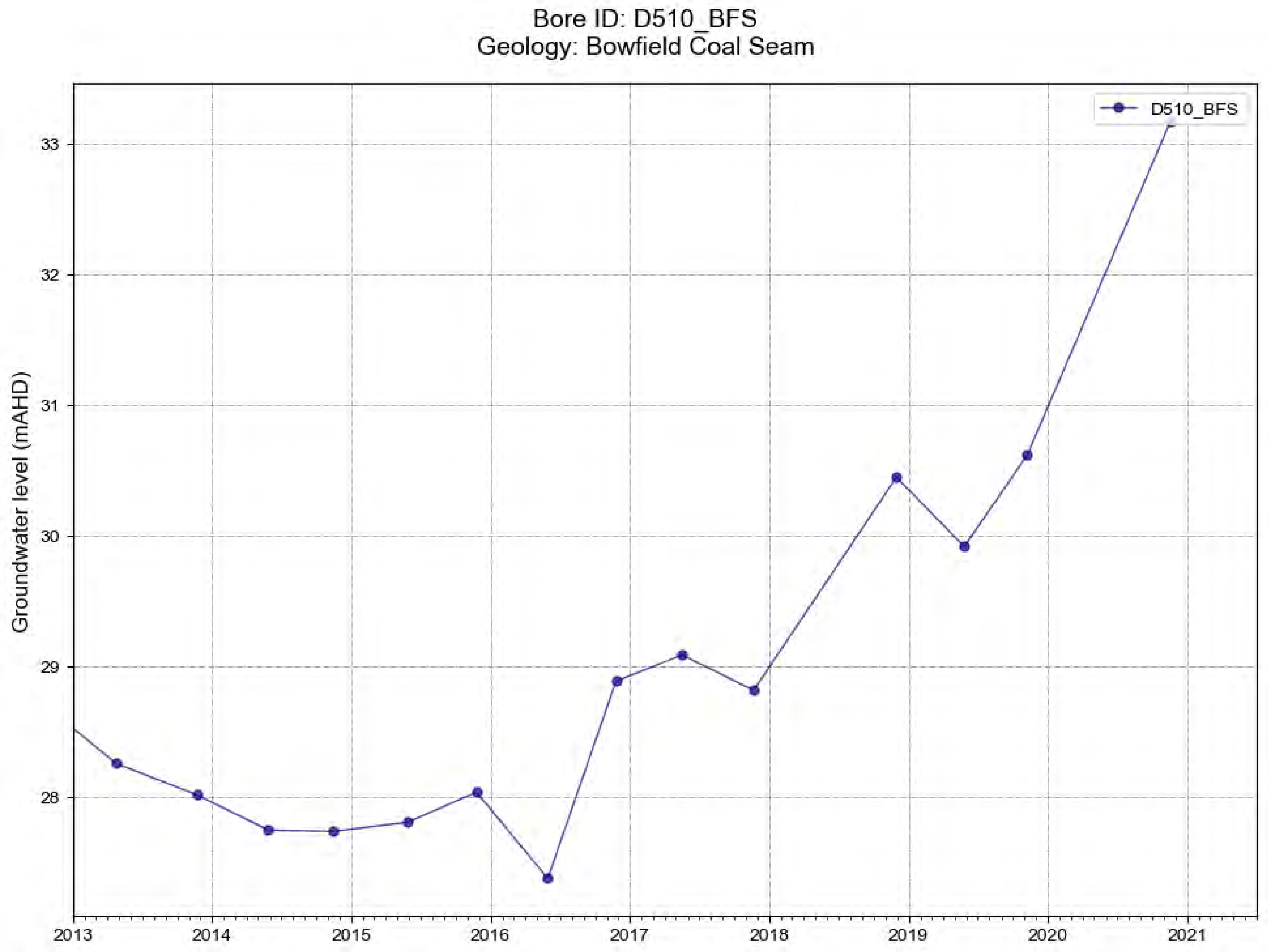


Figure A 29 D510_BFS water levels

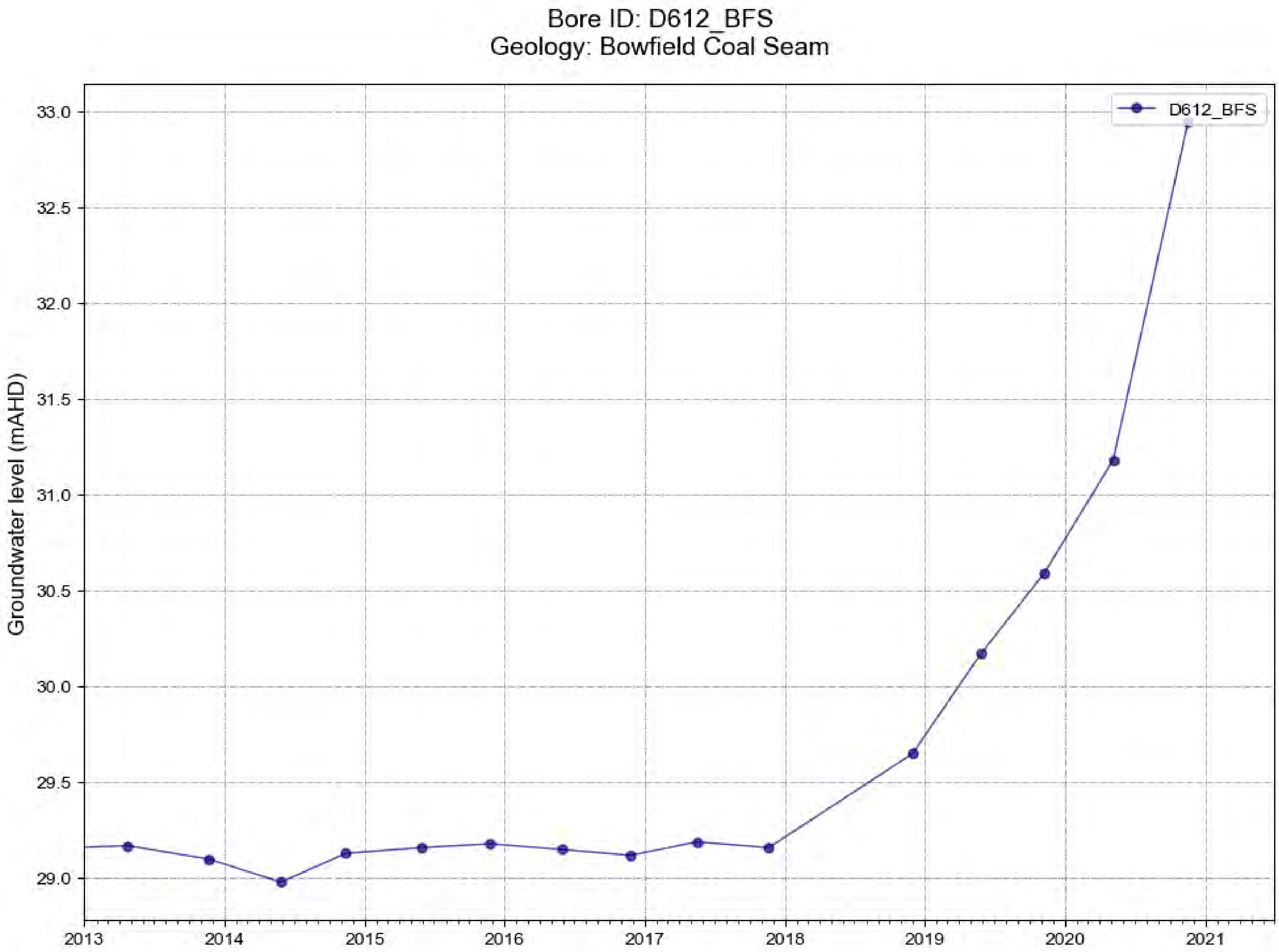
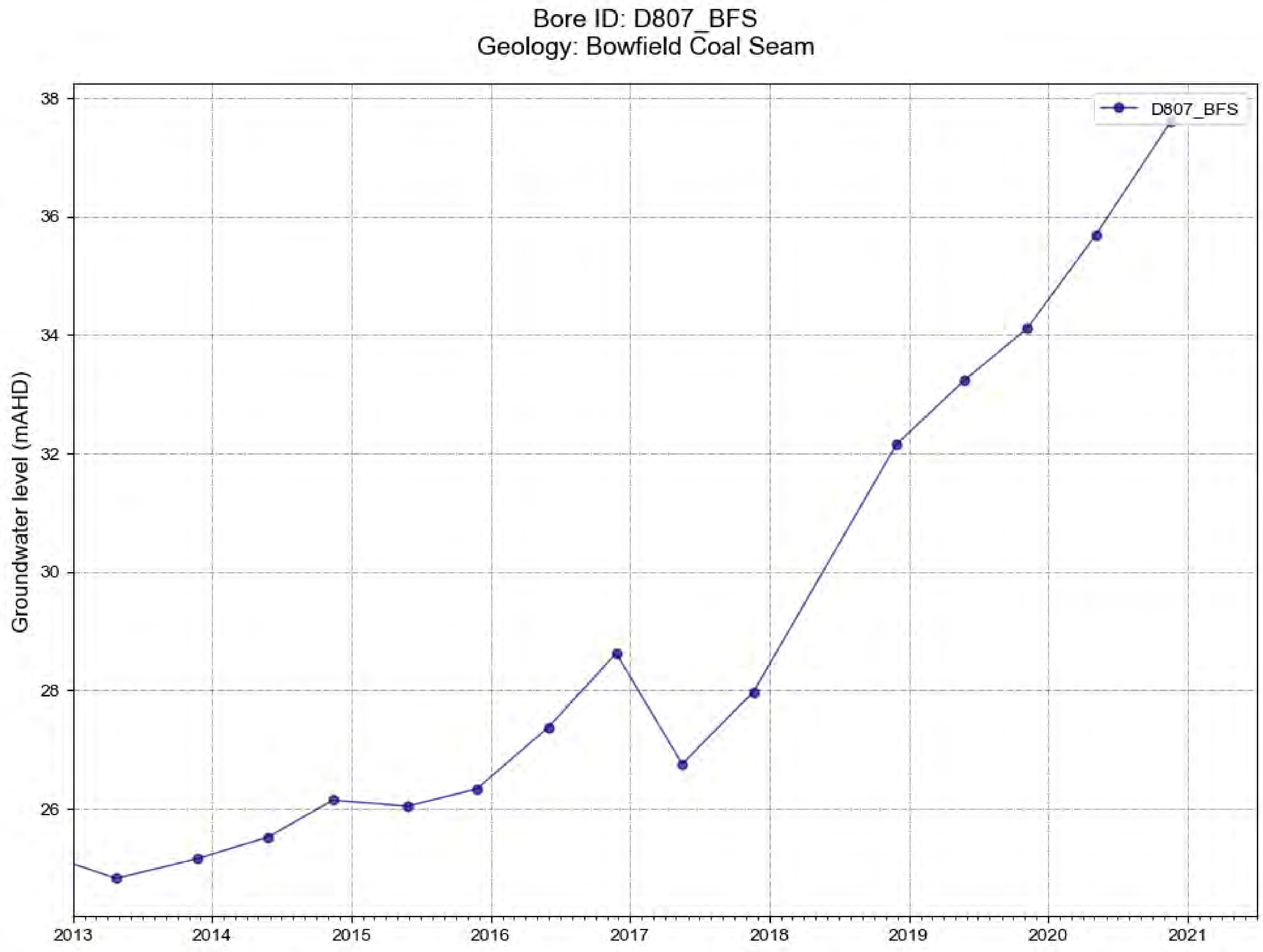


Figure A 30 D612_BFS water levels



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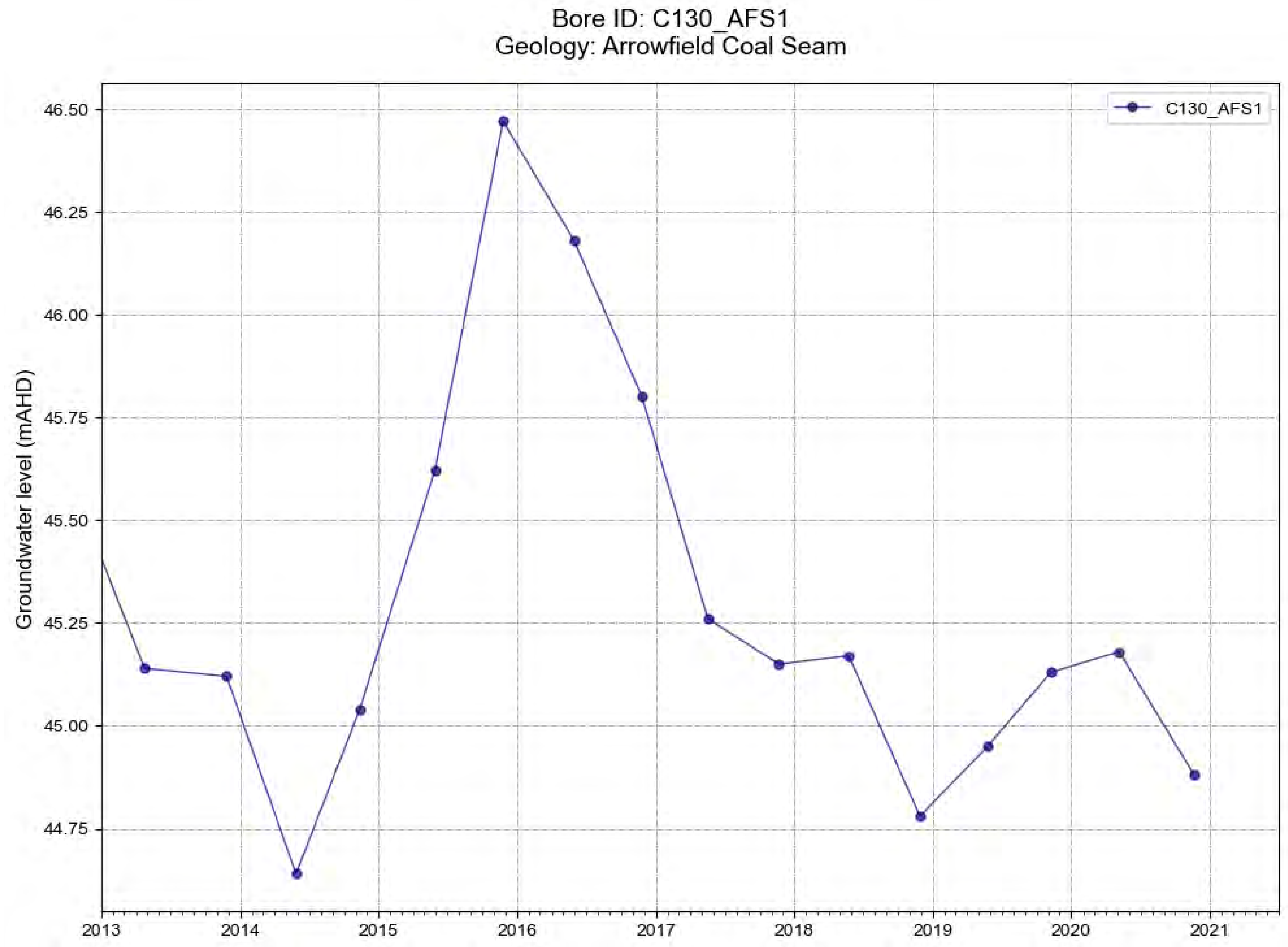

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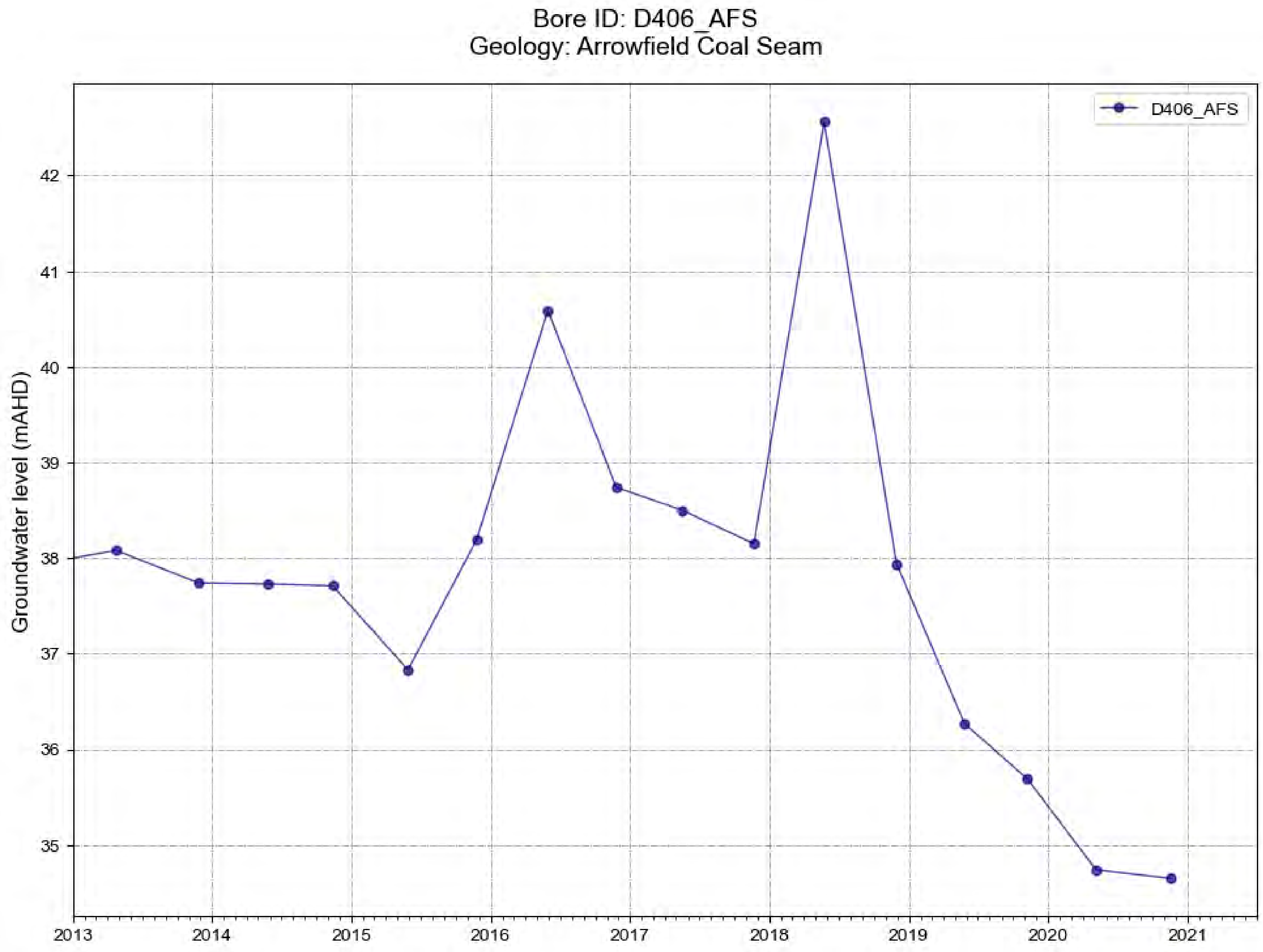

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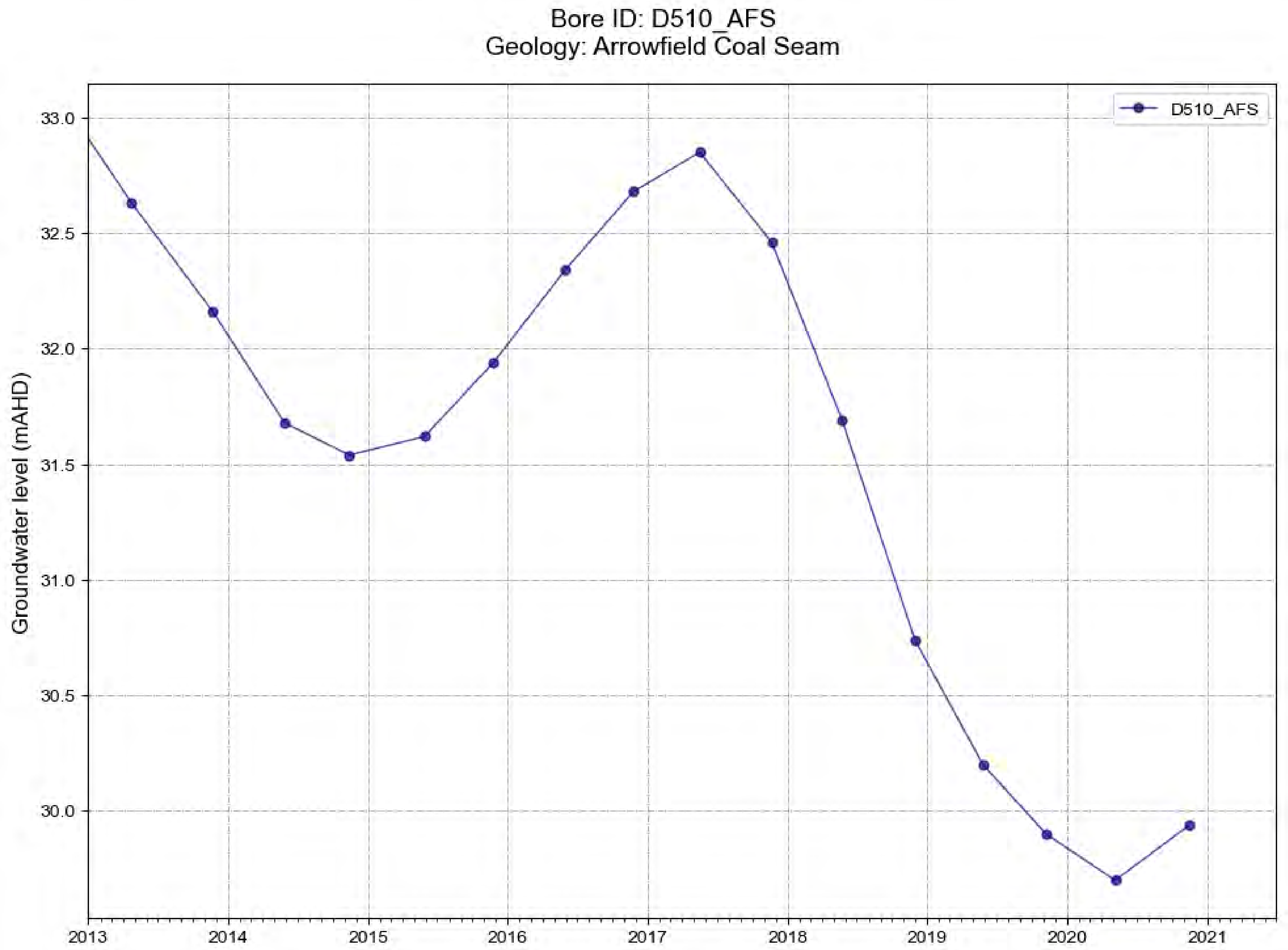

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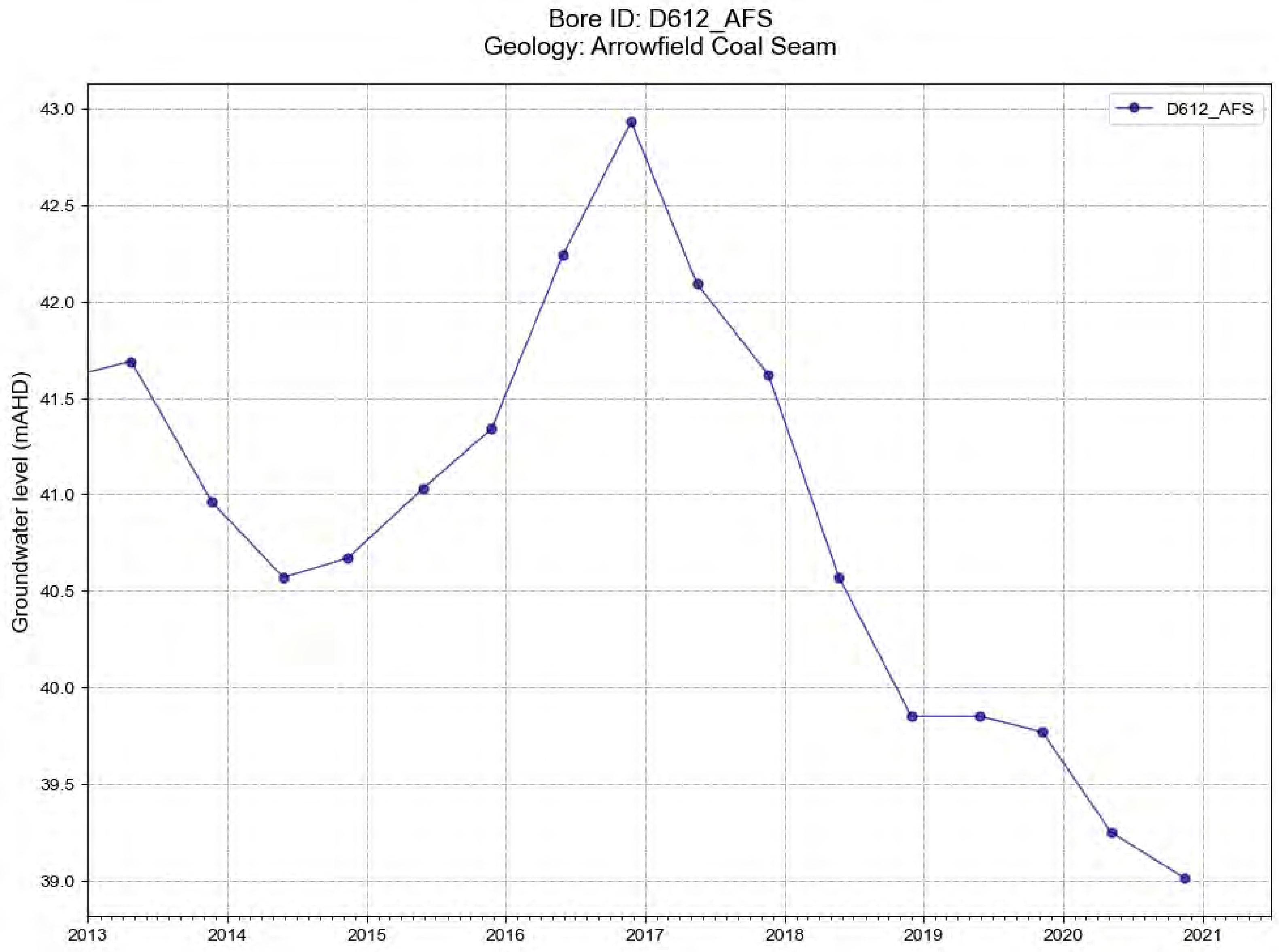

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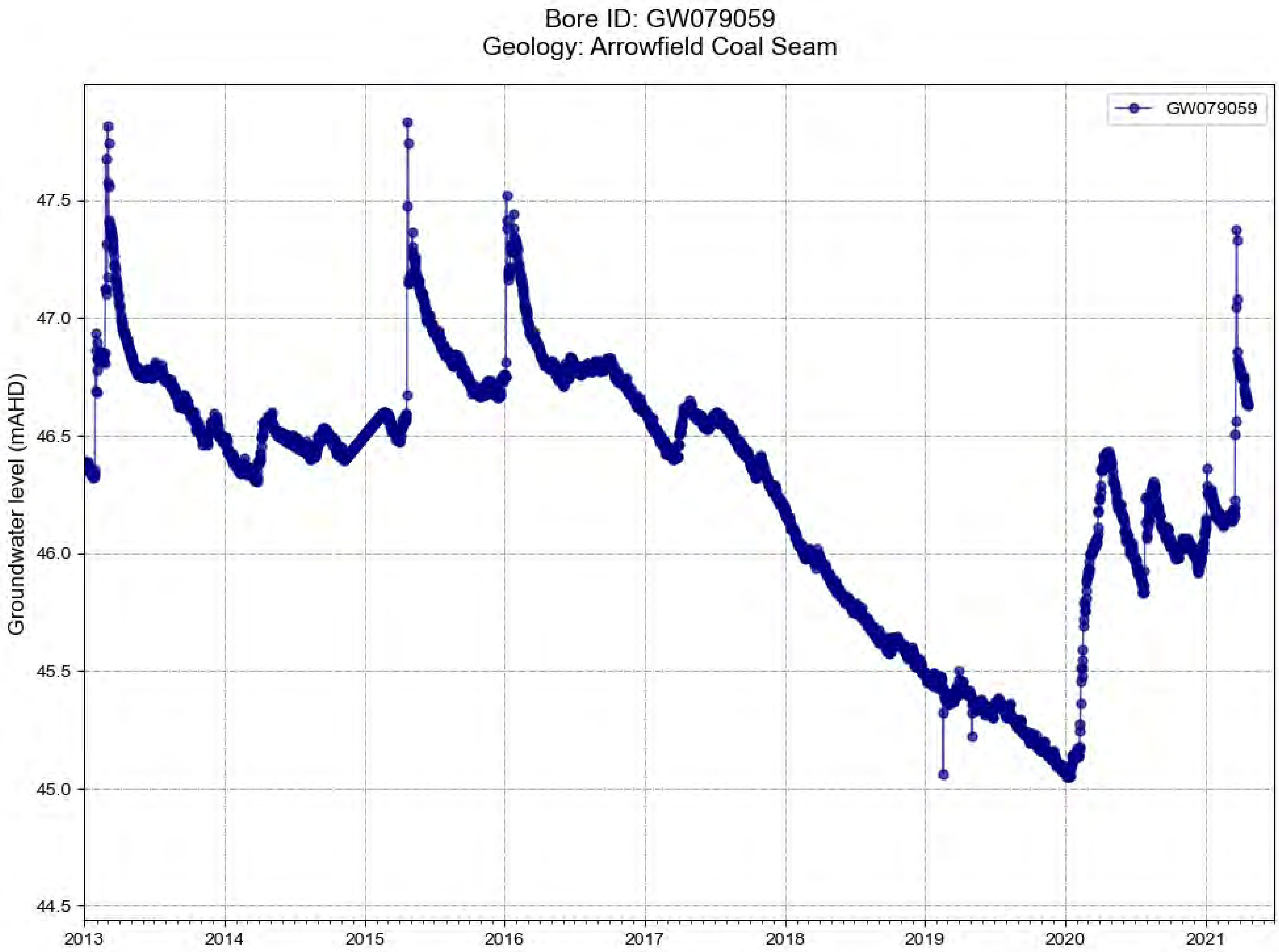


Figure A 36 GW079059 water levels

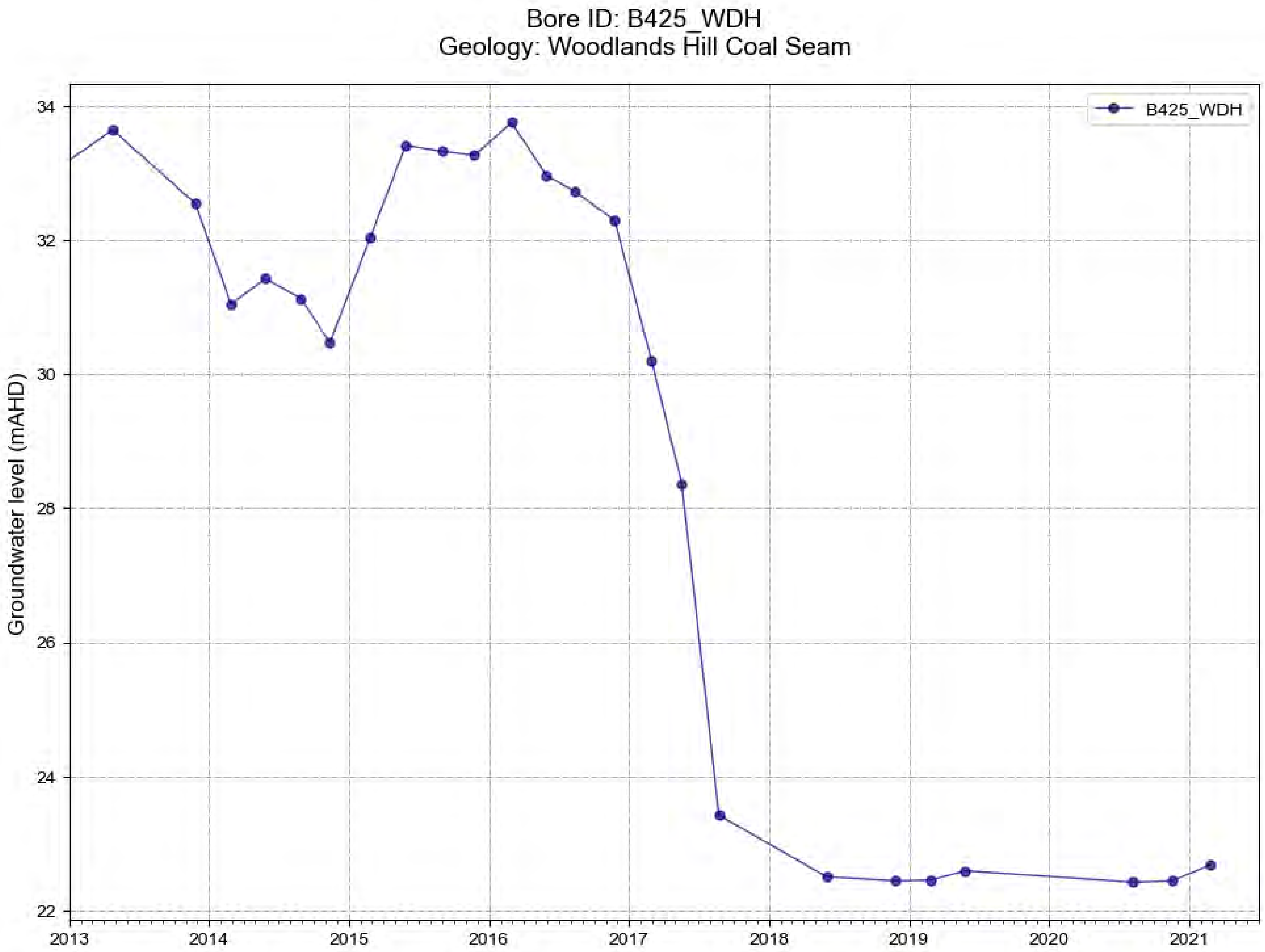
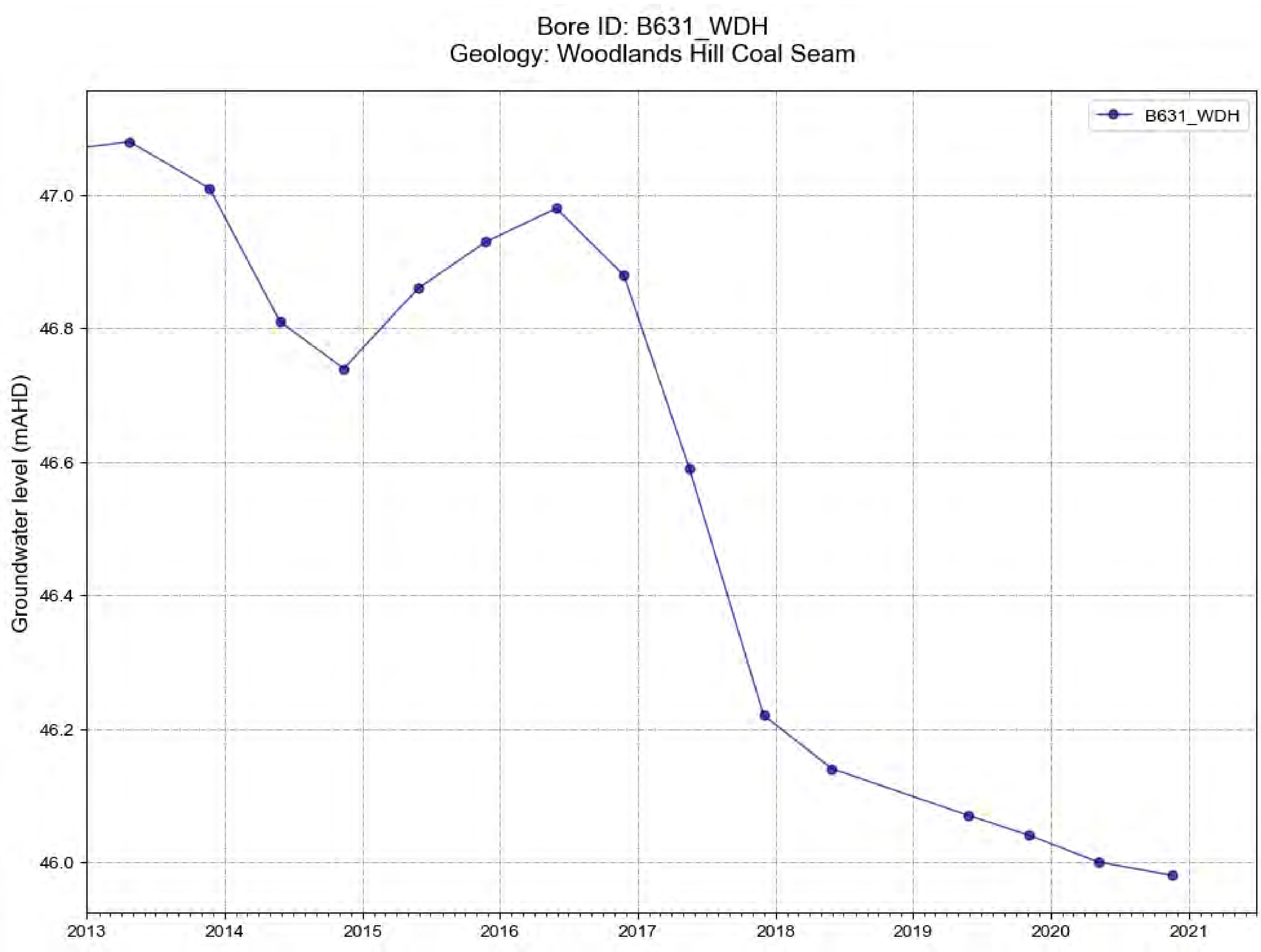


Figure A 37 B425_WDH water levels



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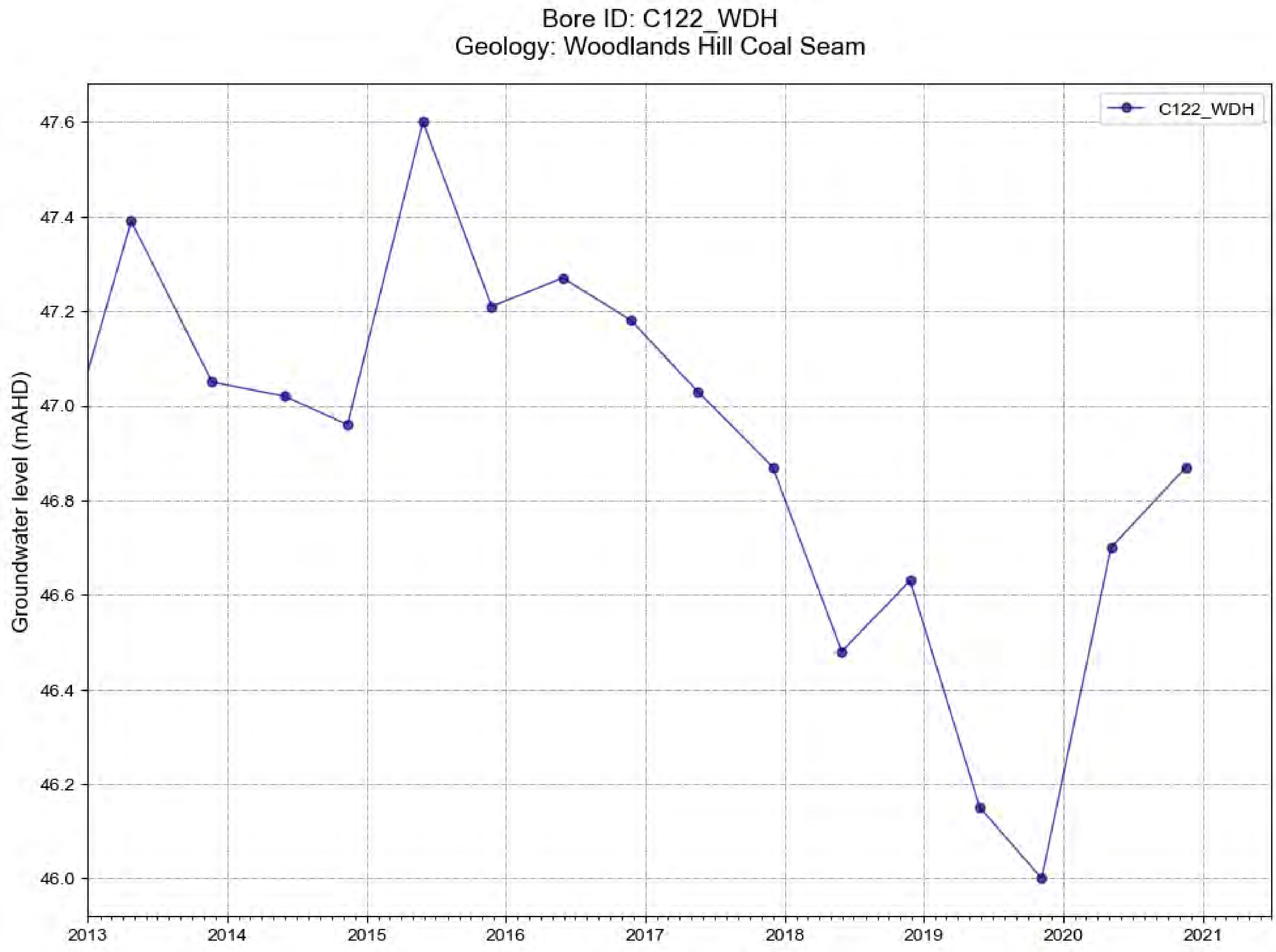

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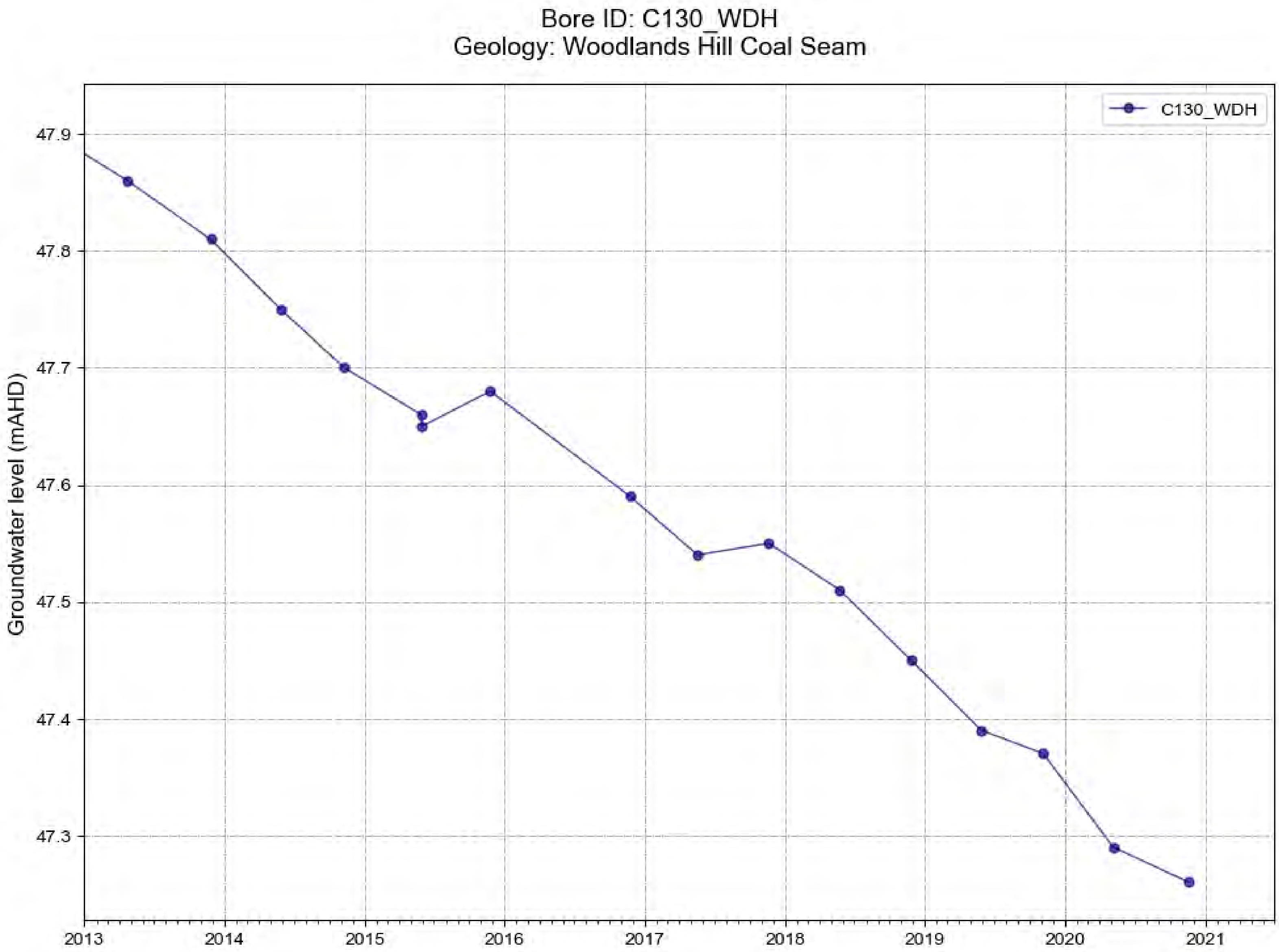

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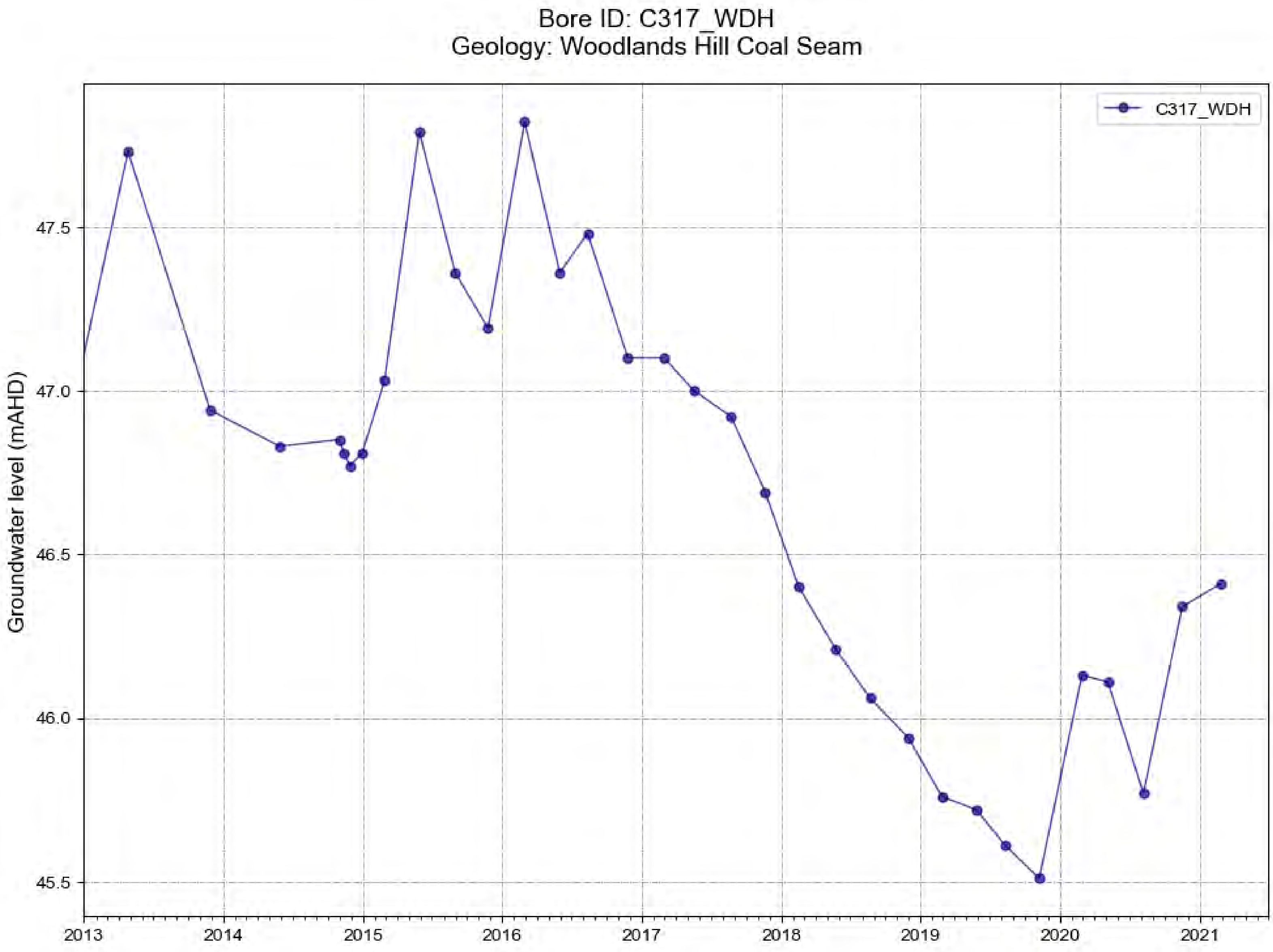

Figure A 41 C317_WDH water levels

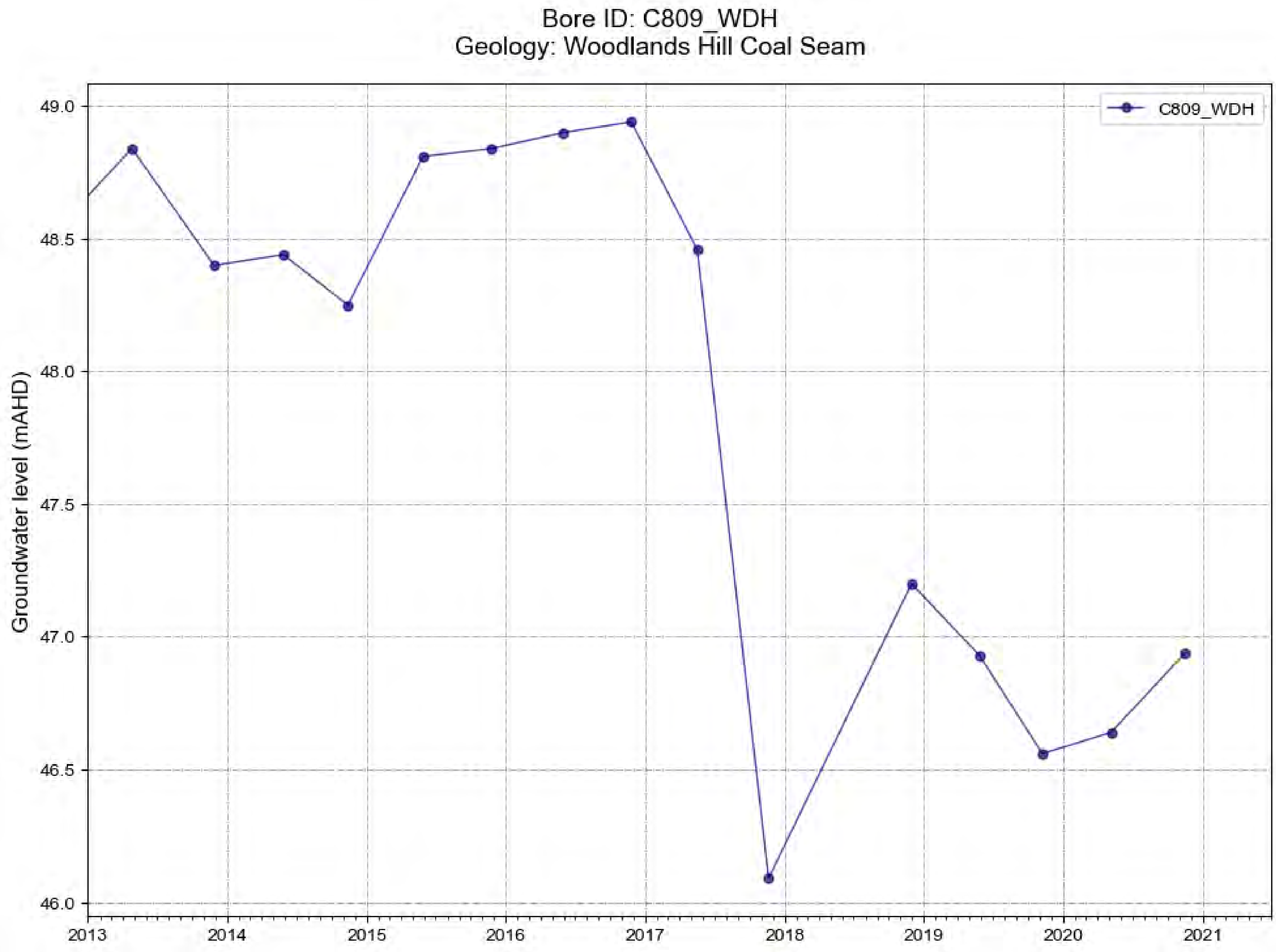

Figure A 42 C809_WDH water levels

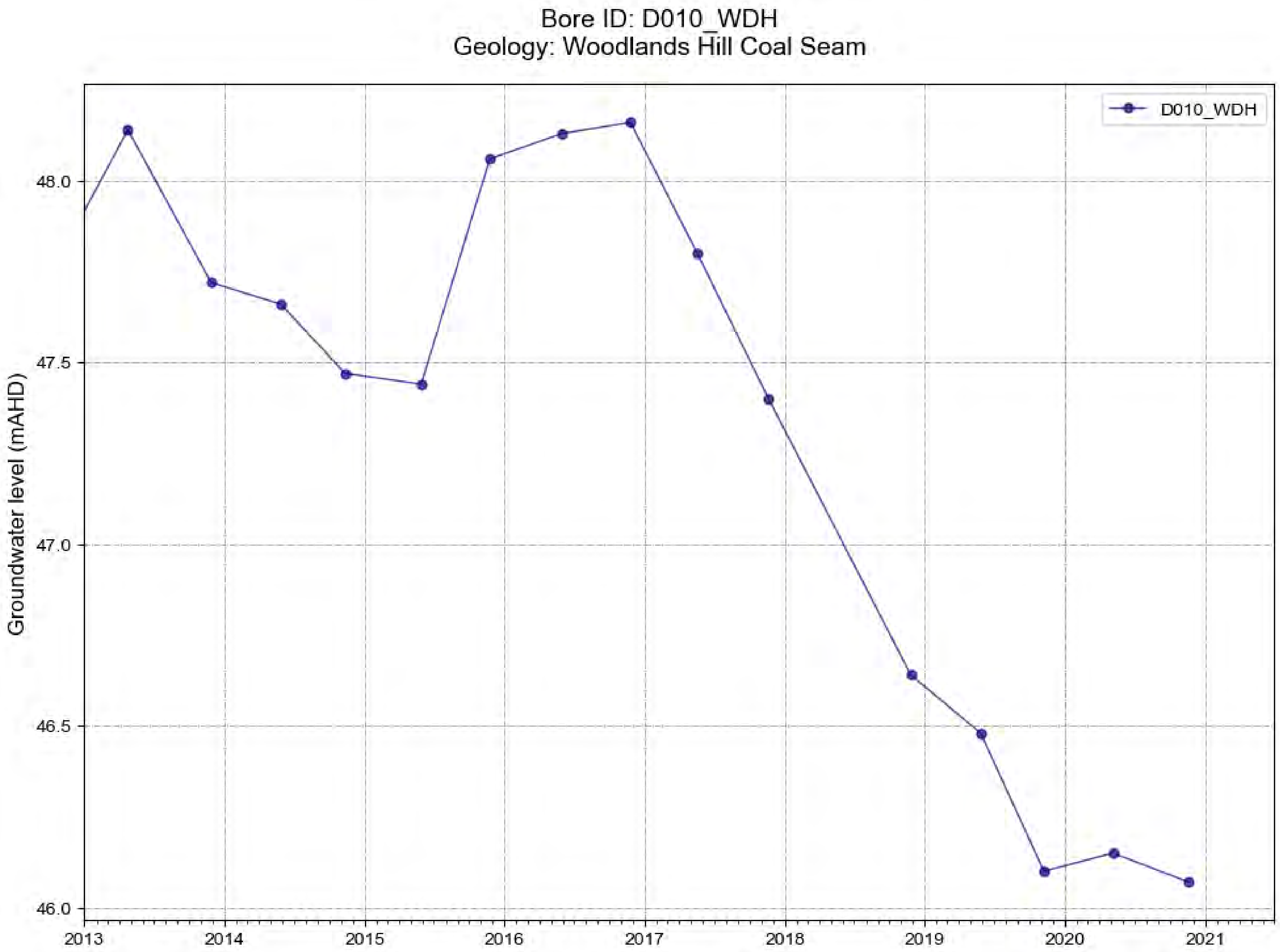

Figure A 43 D010_WDH water levels

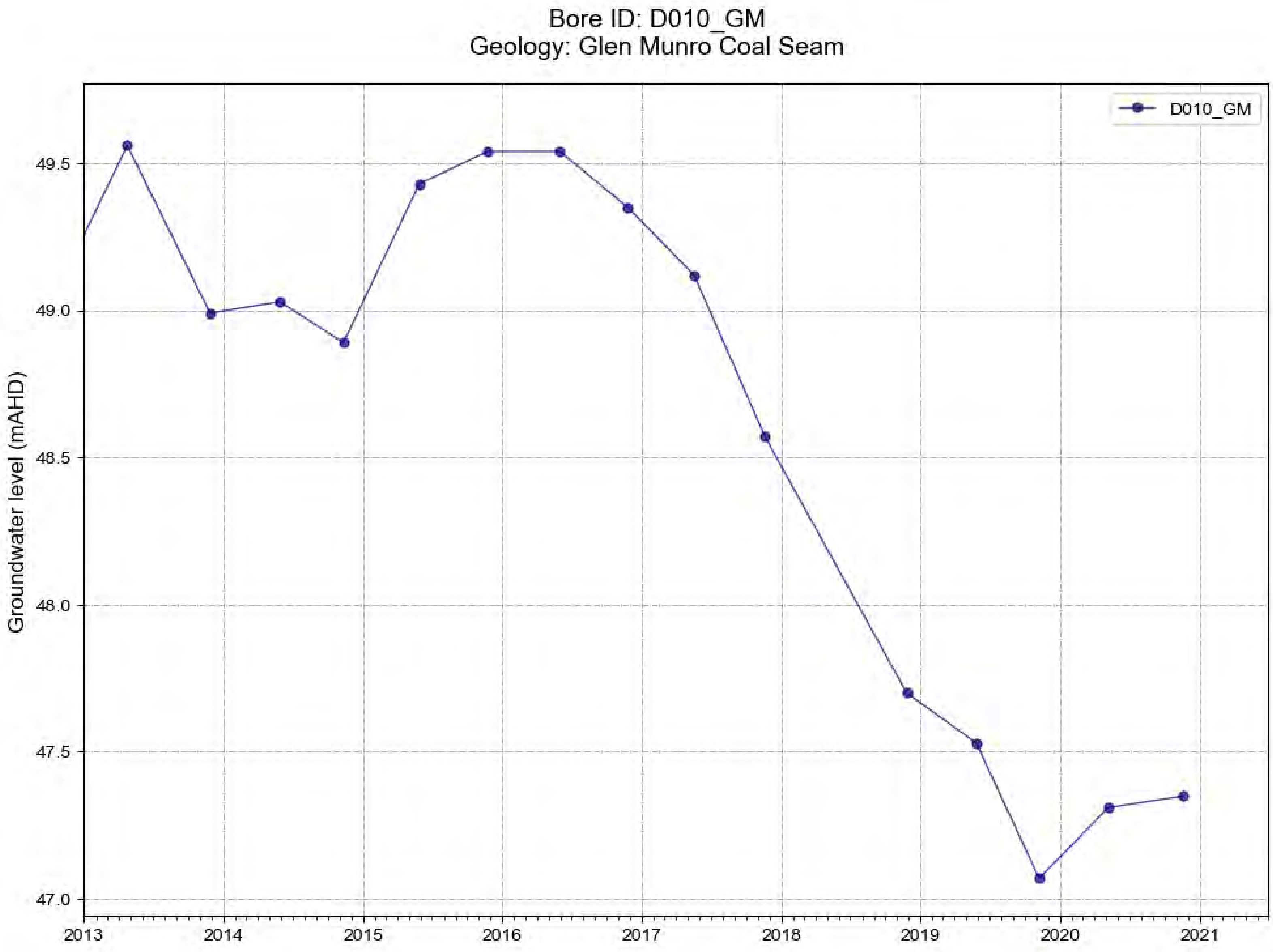

Figure A 44 D010_GM water levels

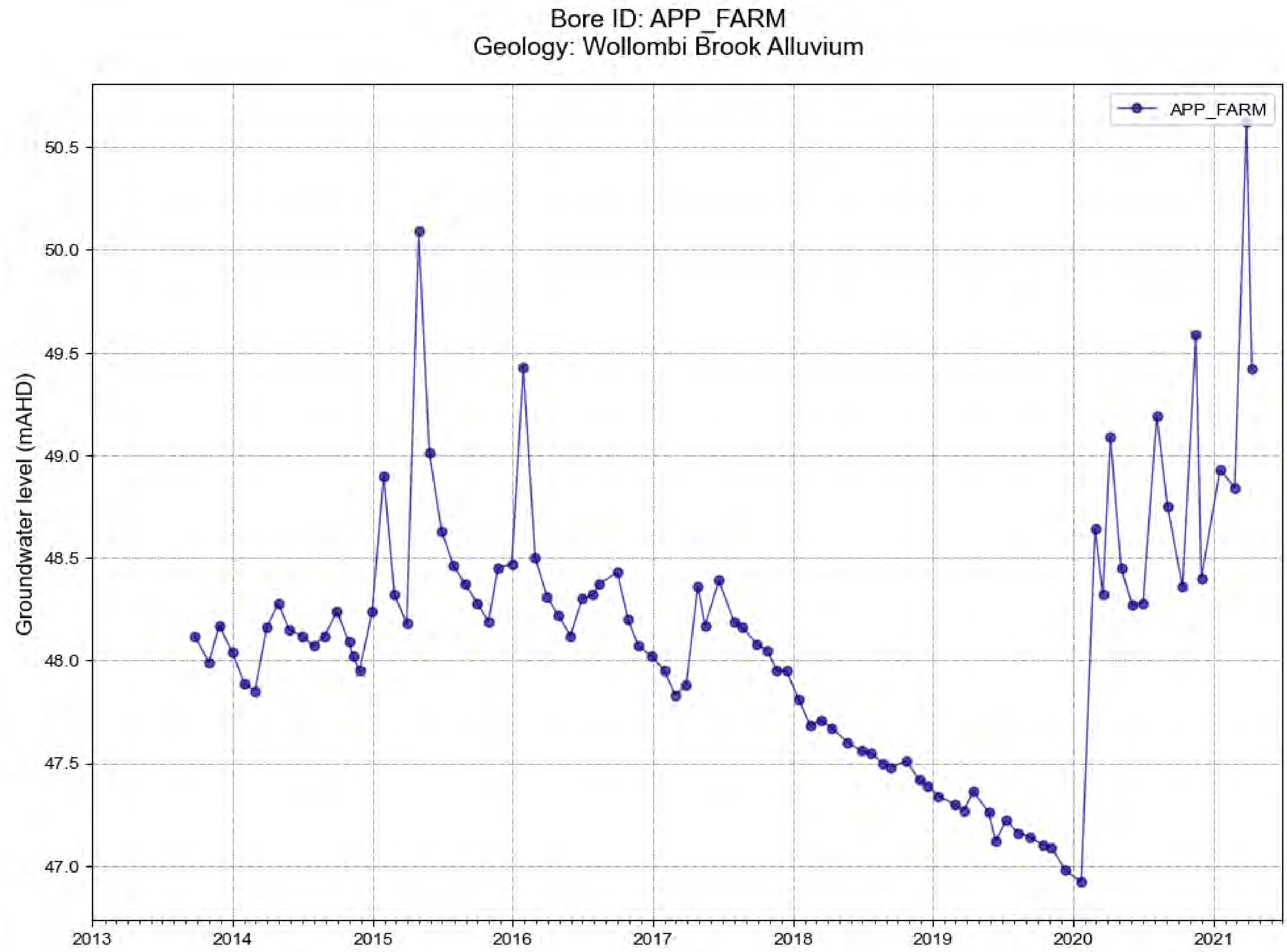

Figure A 45 APP_FARM water levels

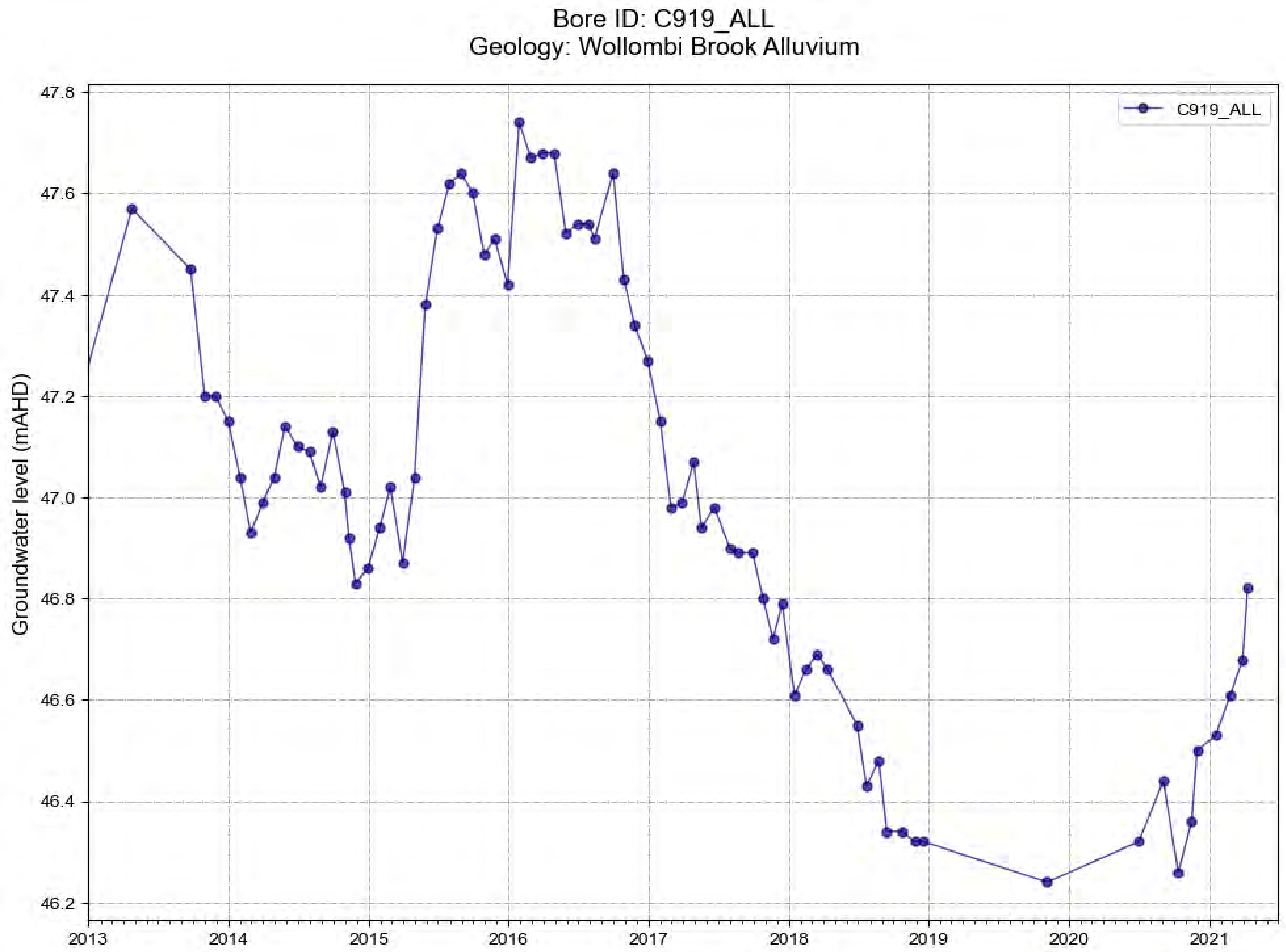

Figure A 46 C919_ALL water levels

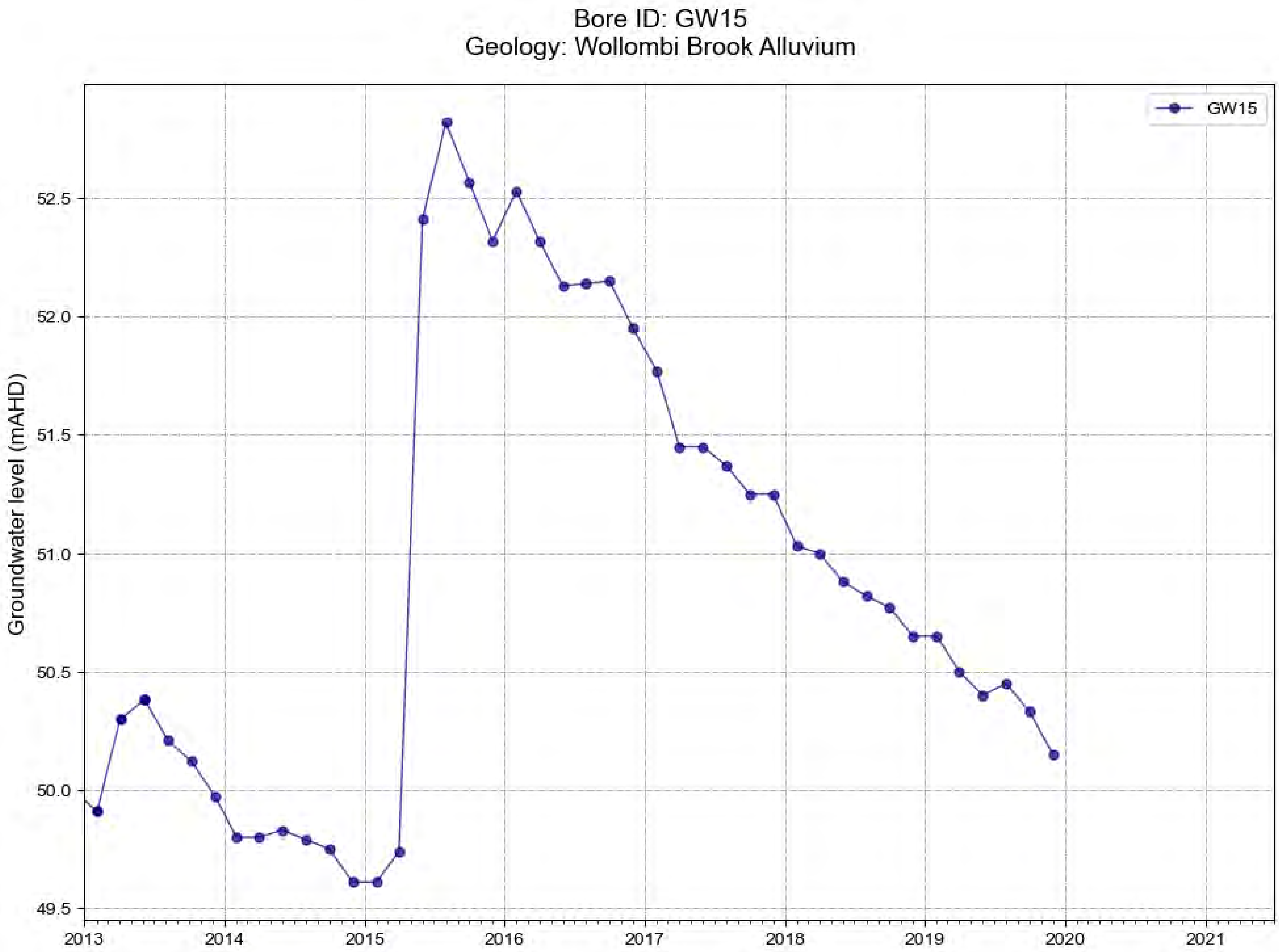

Figure A 47 GW15 water levels

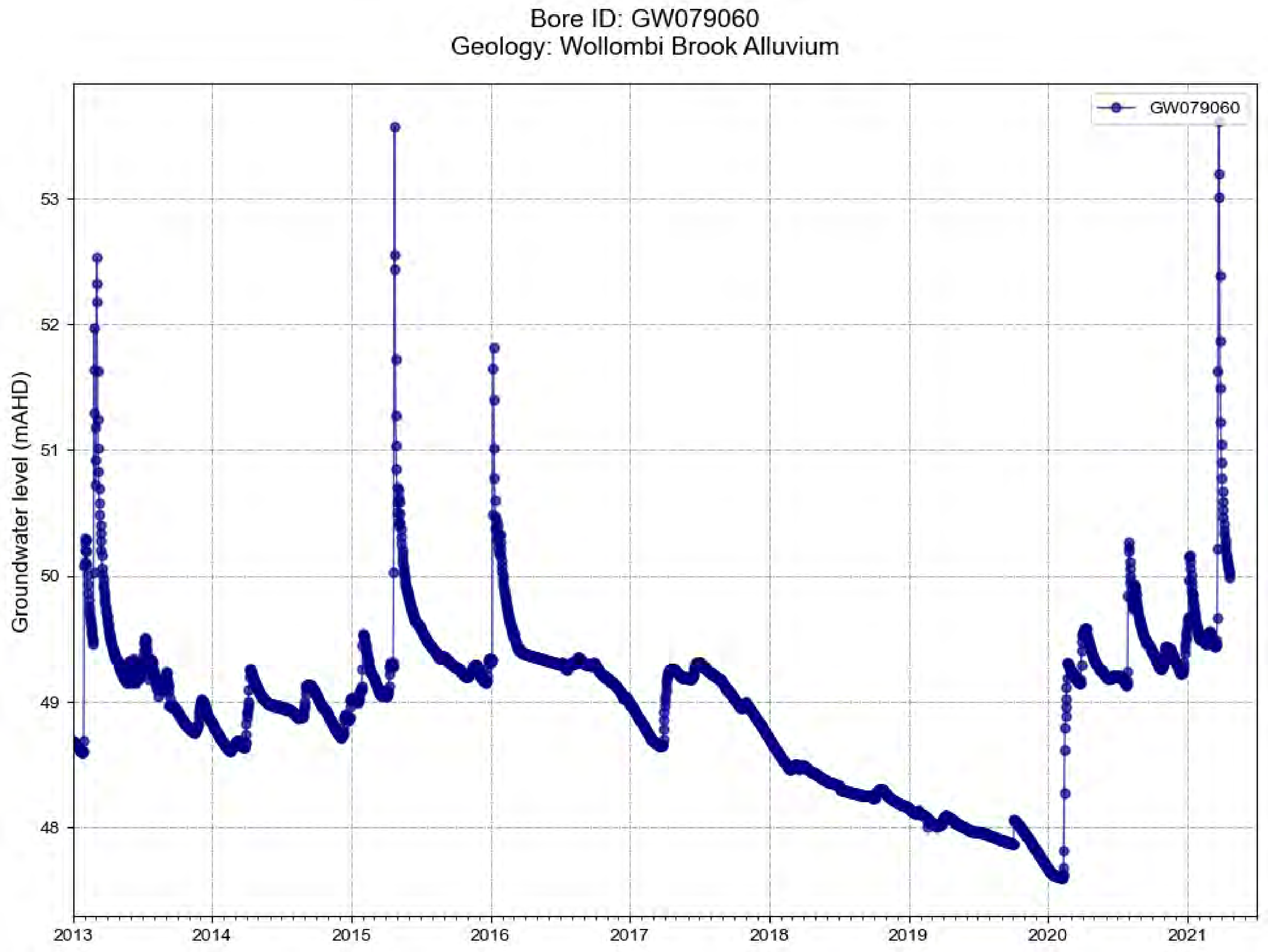

Figure A 48 GW079060 water levels

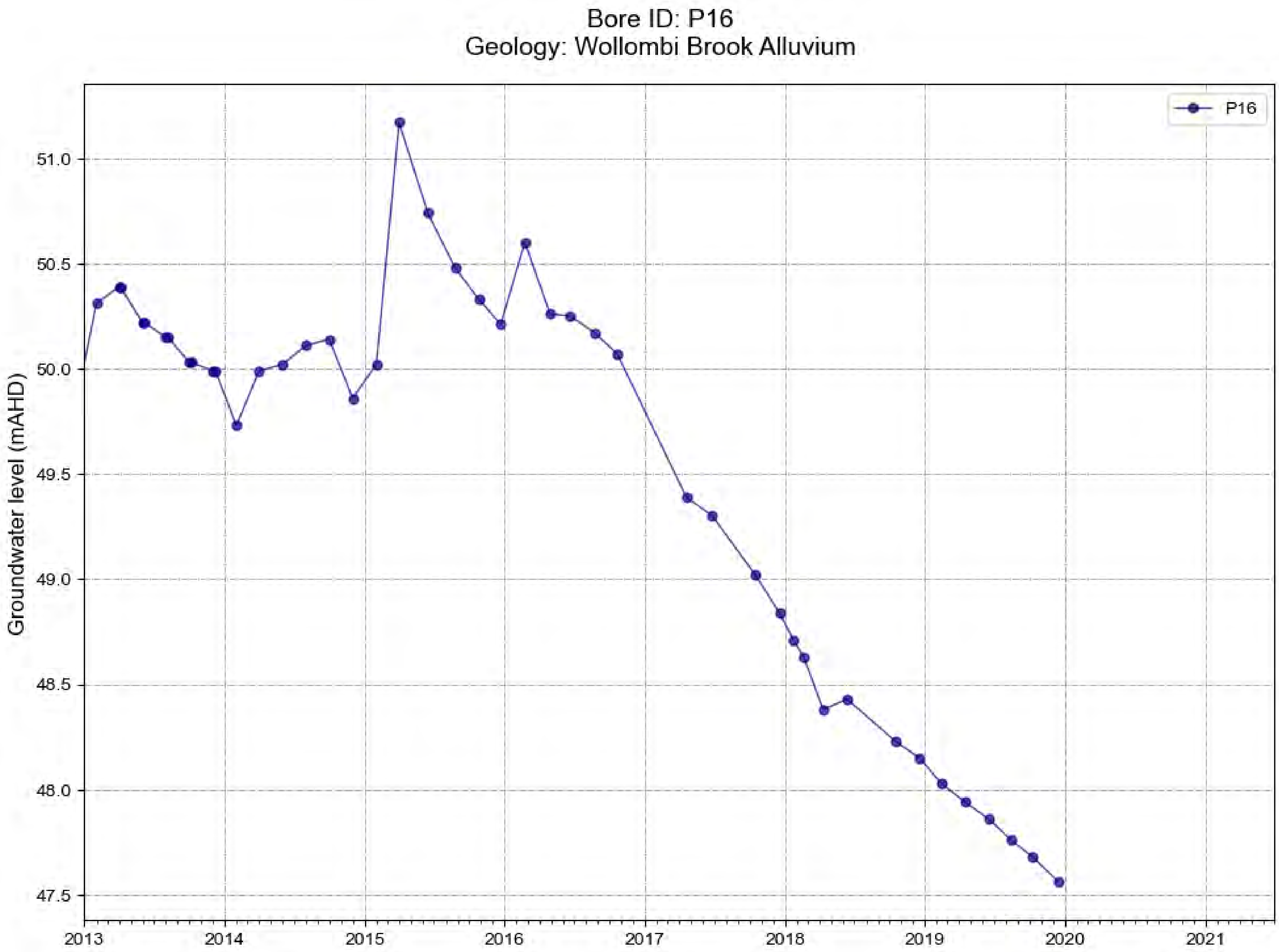

Figure A 49 P16 water levels

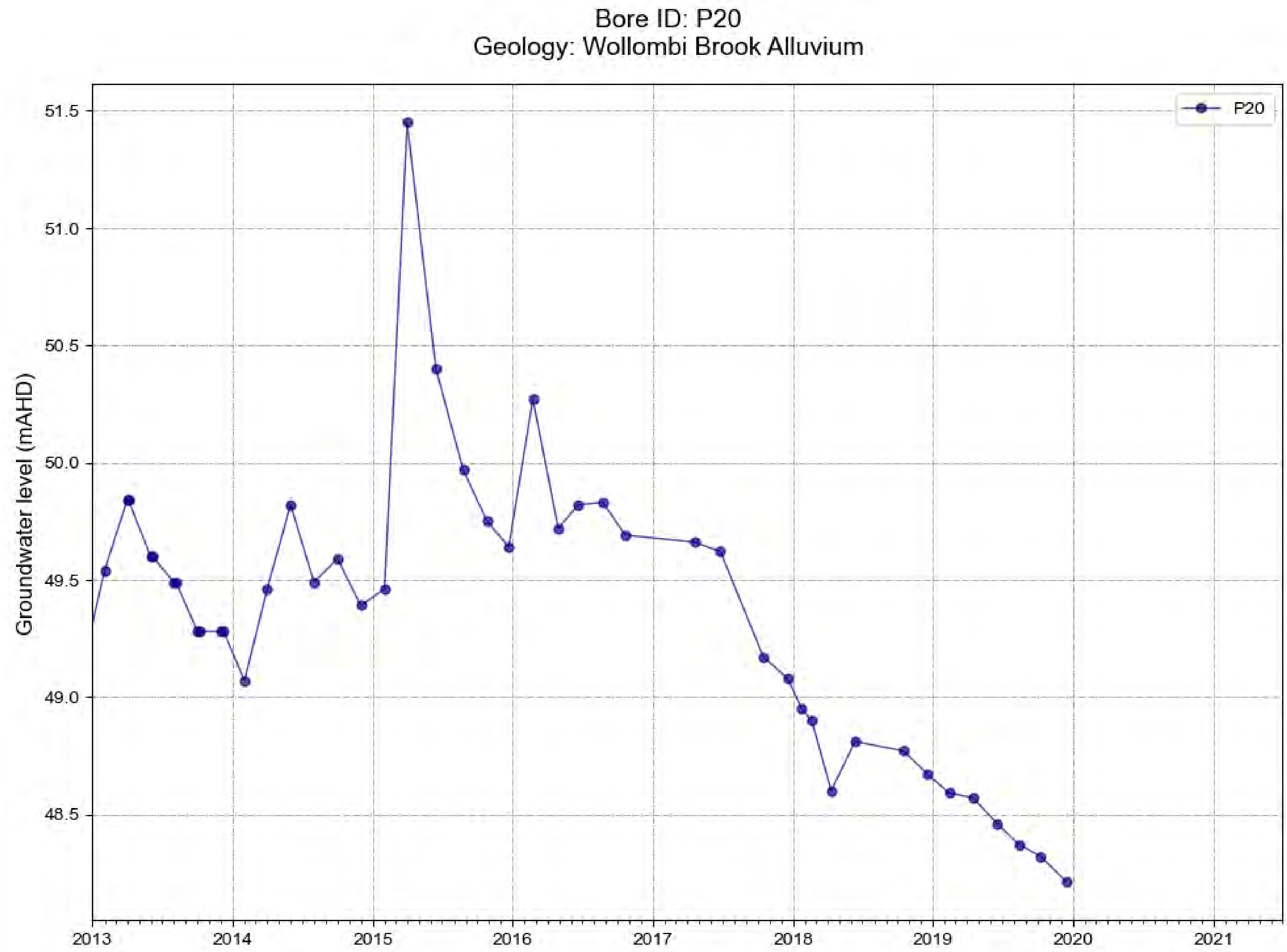

Figure A 50 P20 water levels

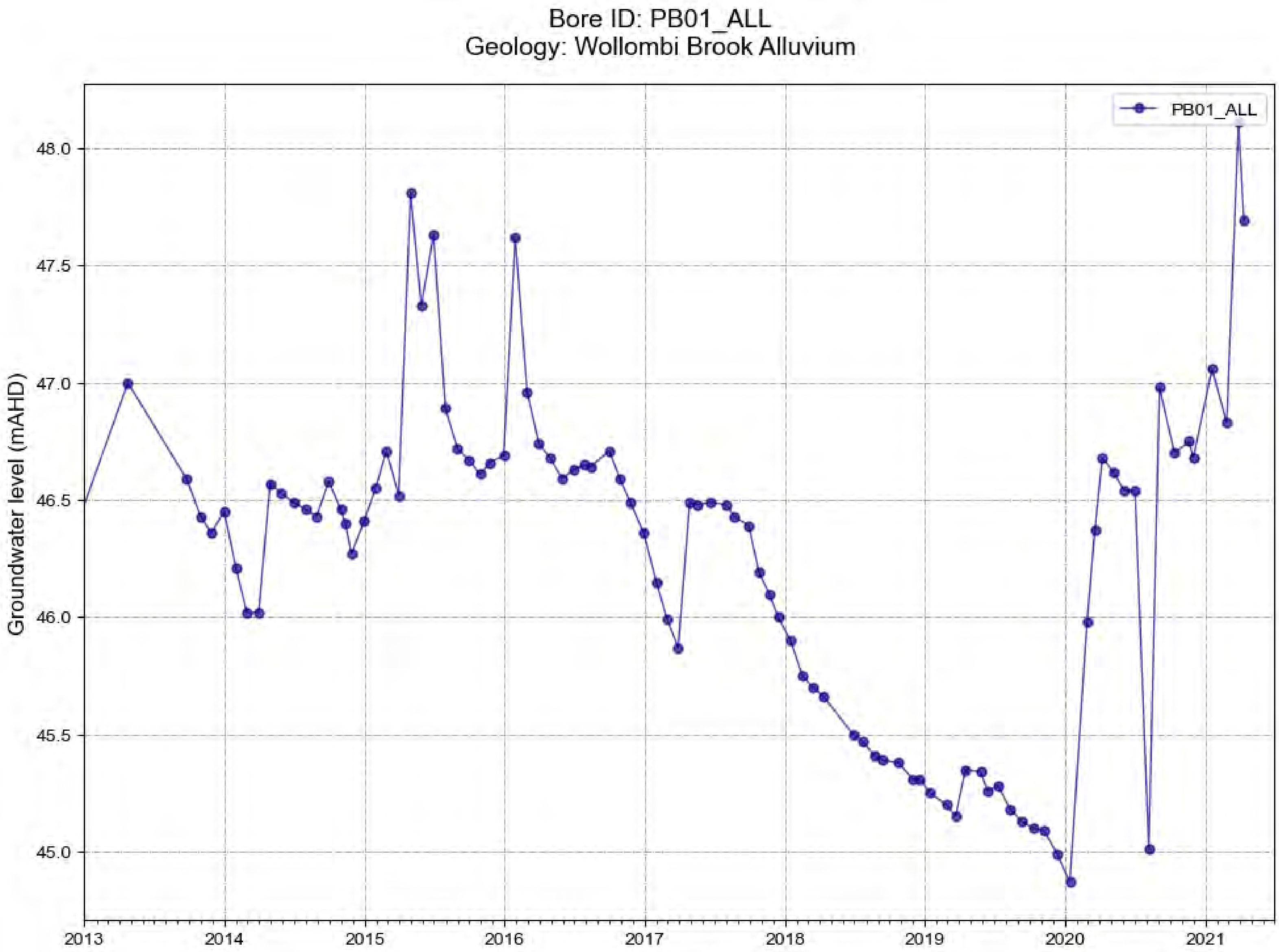

Figure A 51 PB01_ALL water levels

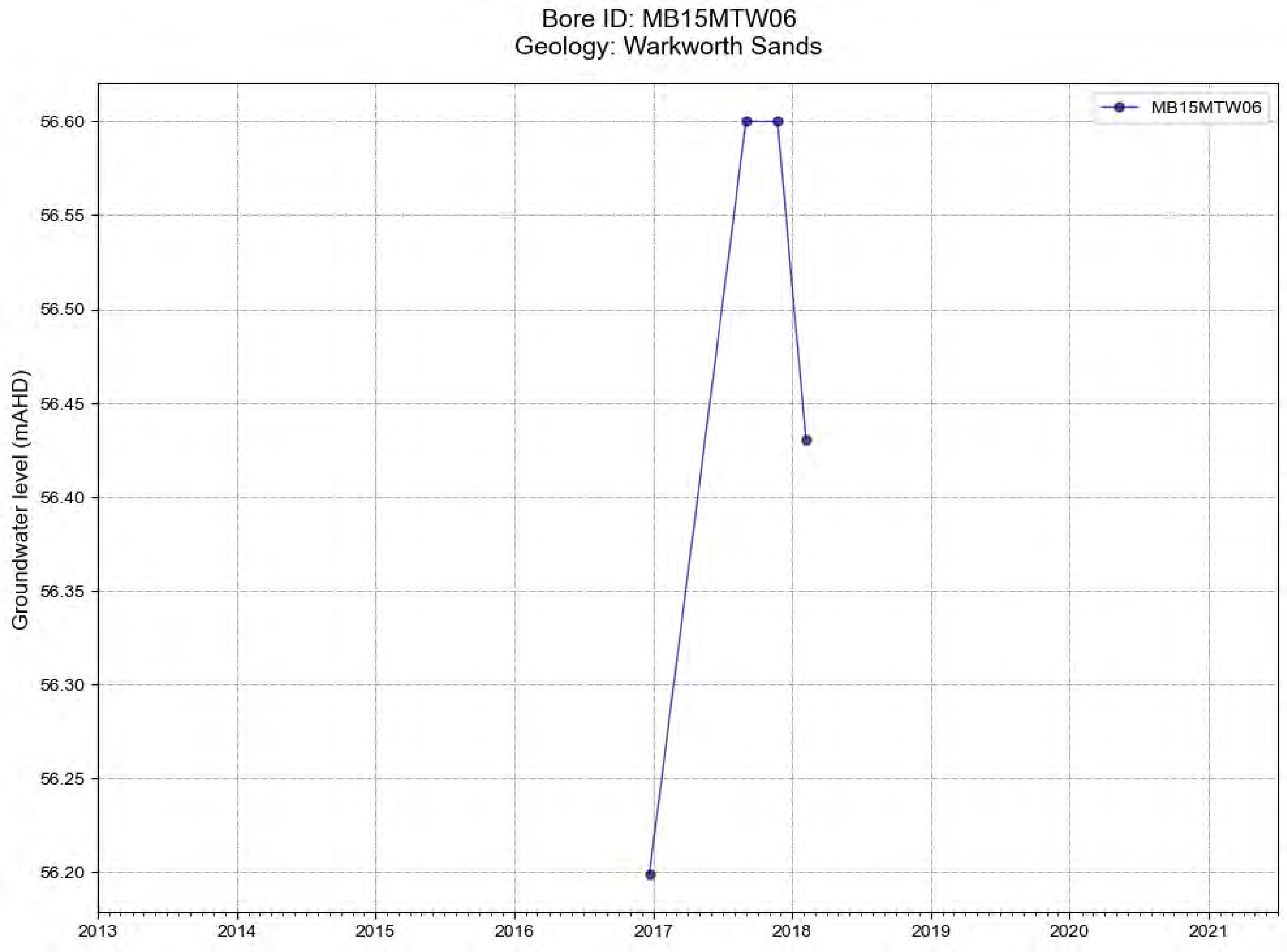

Figure A 52 MB15MTW06 water levels

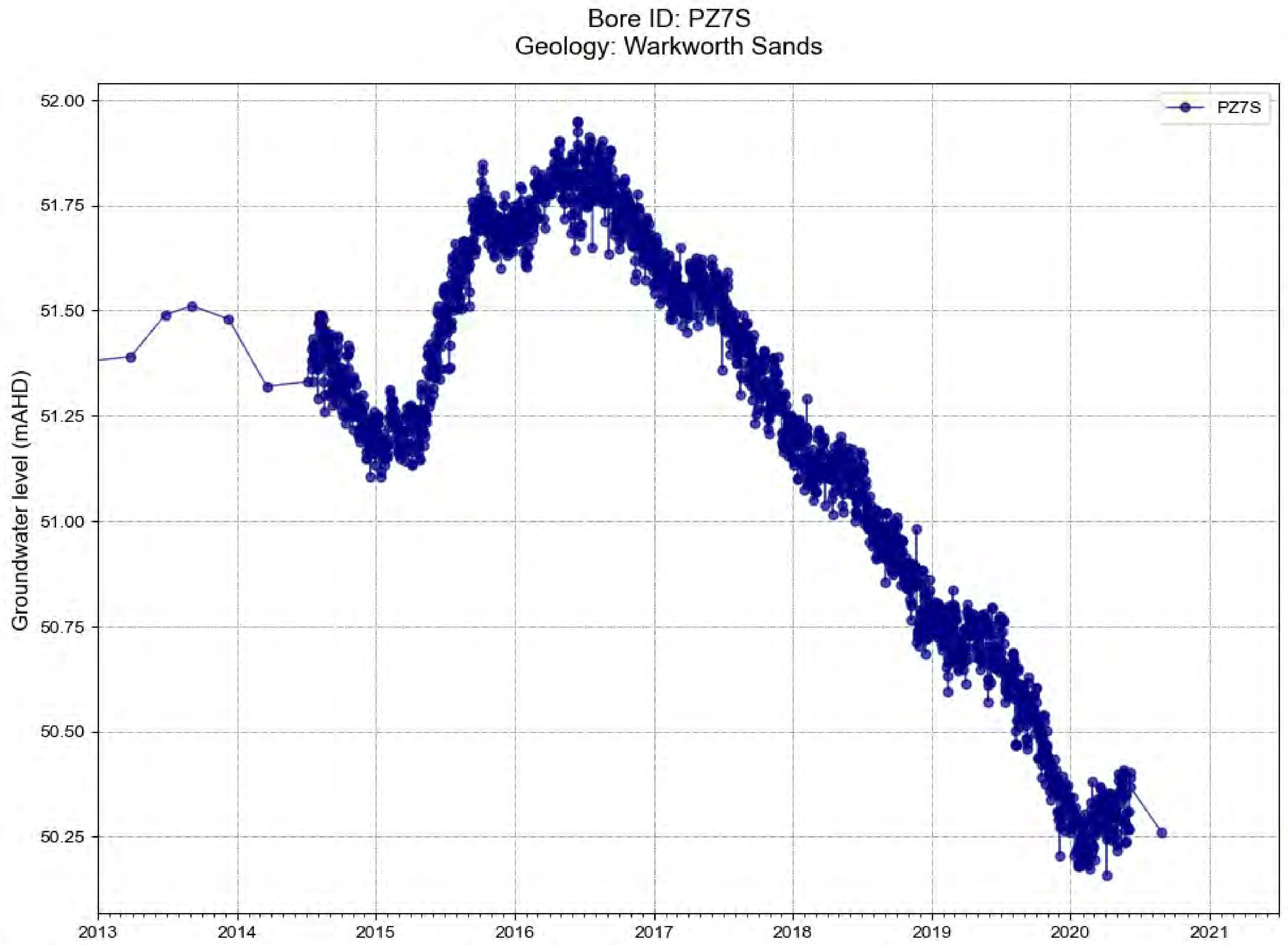

Figure A 53 PZ7S water levels

Appendix B

Time-series water quality graphs

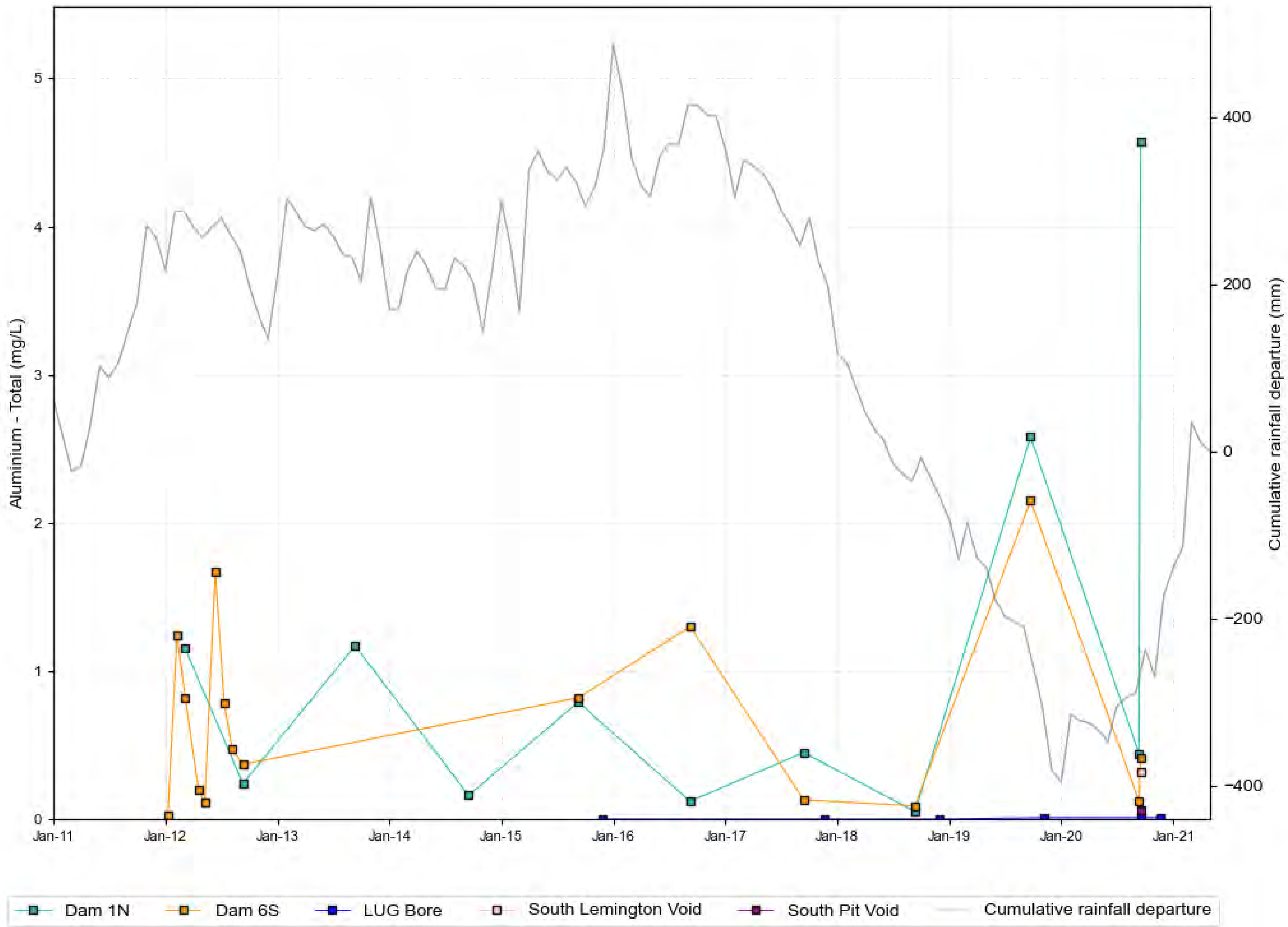

Figure B 1 MTW main surface water stores and LUG Bore, aluminium time series data

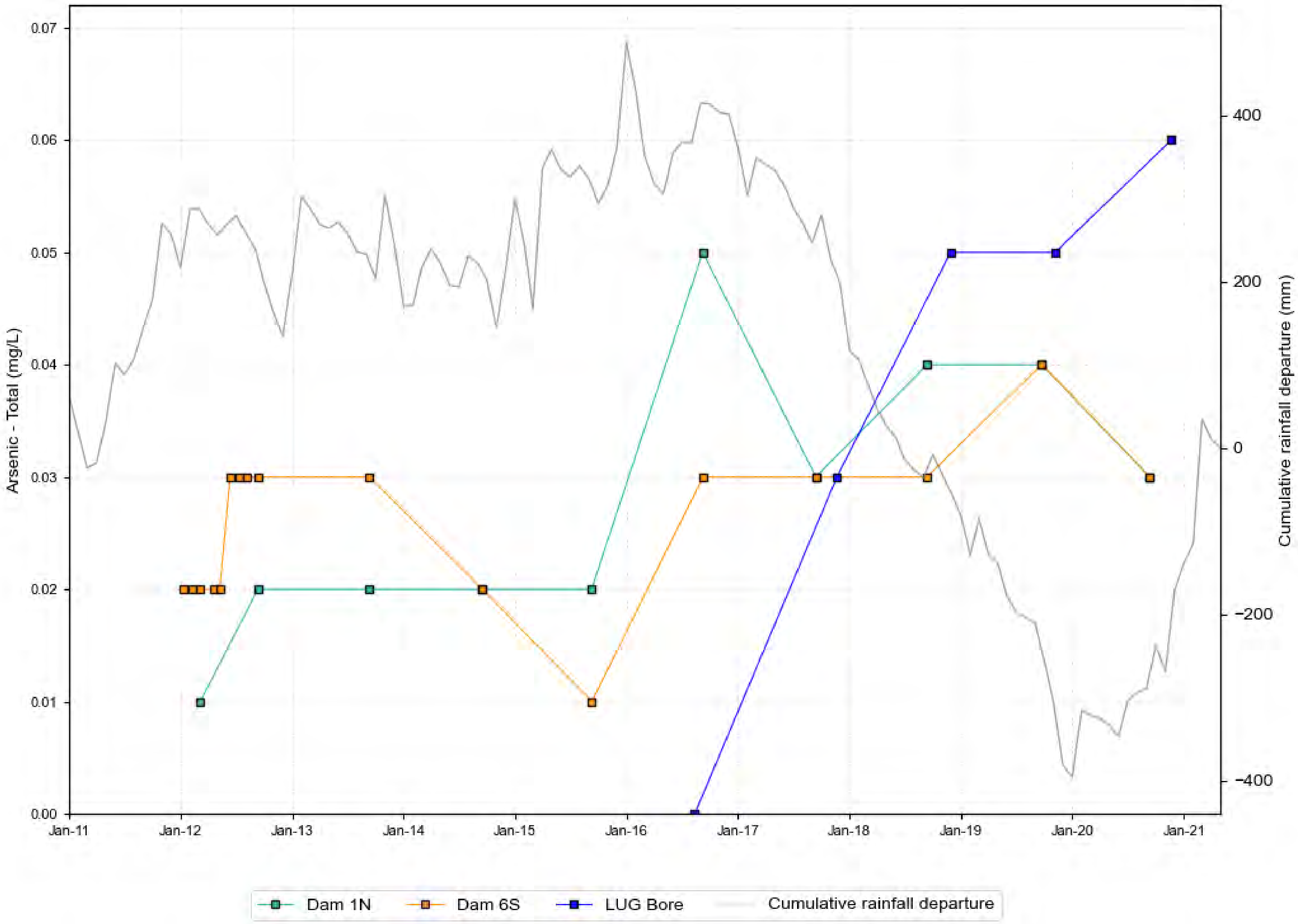

Figure B 2 MTW main surface water stores and LUG Bore, arsenic time series data

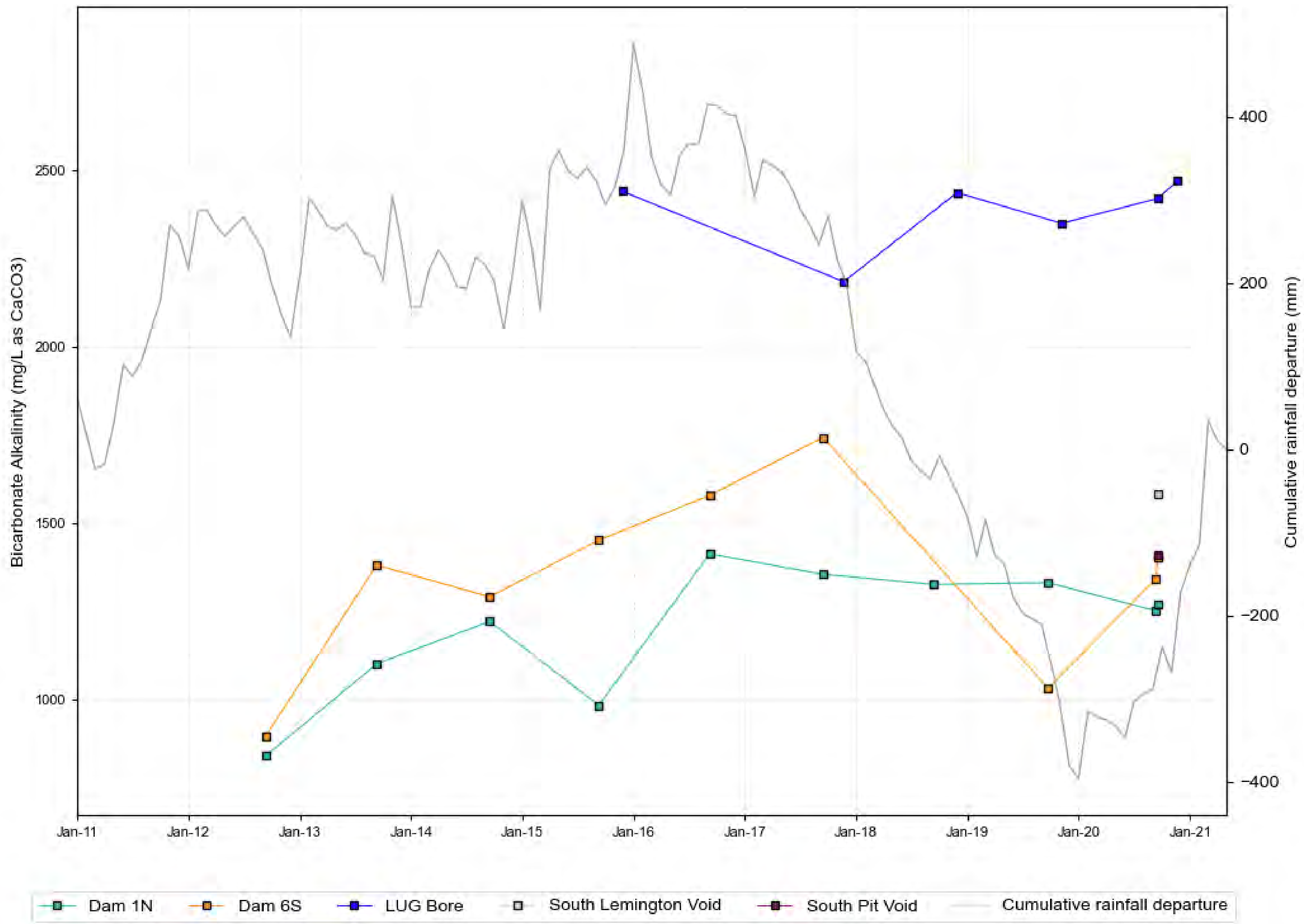

Figure B 3 MTW main surface water stores and LUG Bore, bicarbonate alkalinity time series data

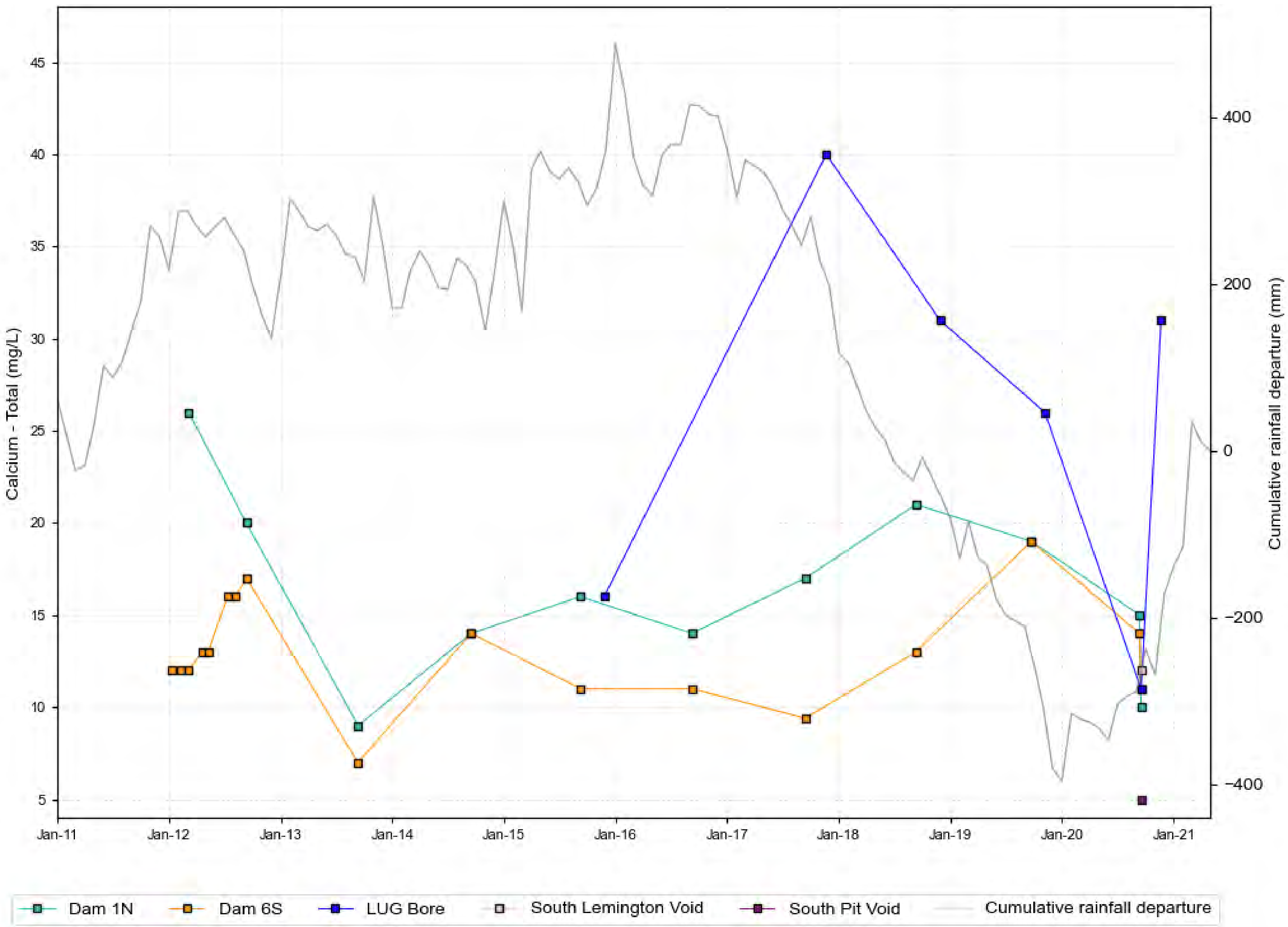

Figure B 4 MTW main surface water stores and LUG Bore, calcium time series data

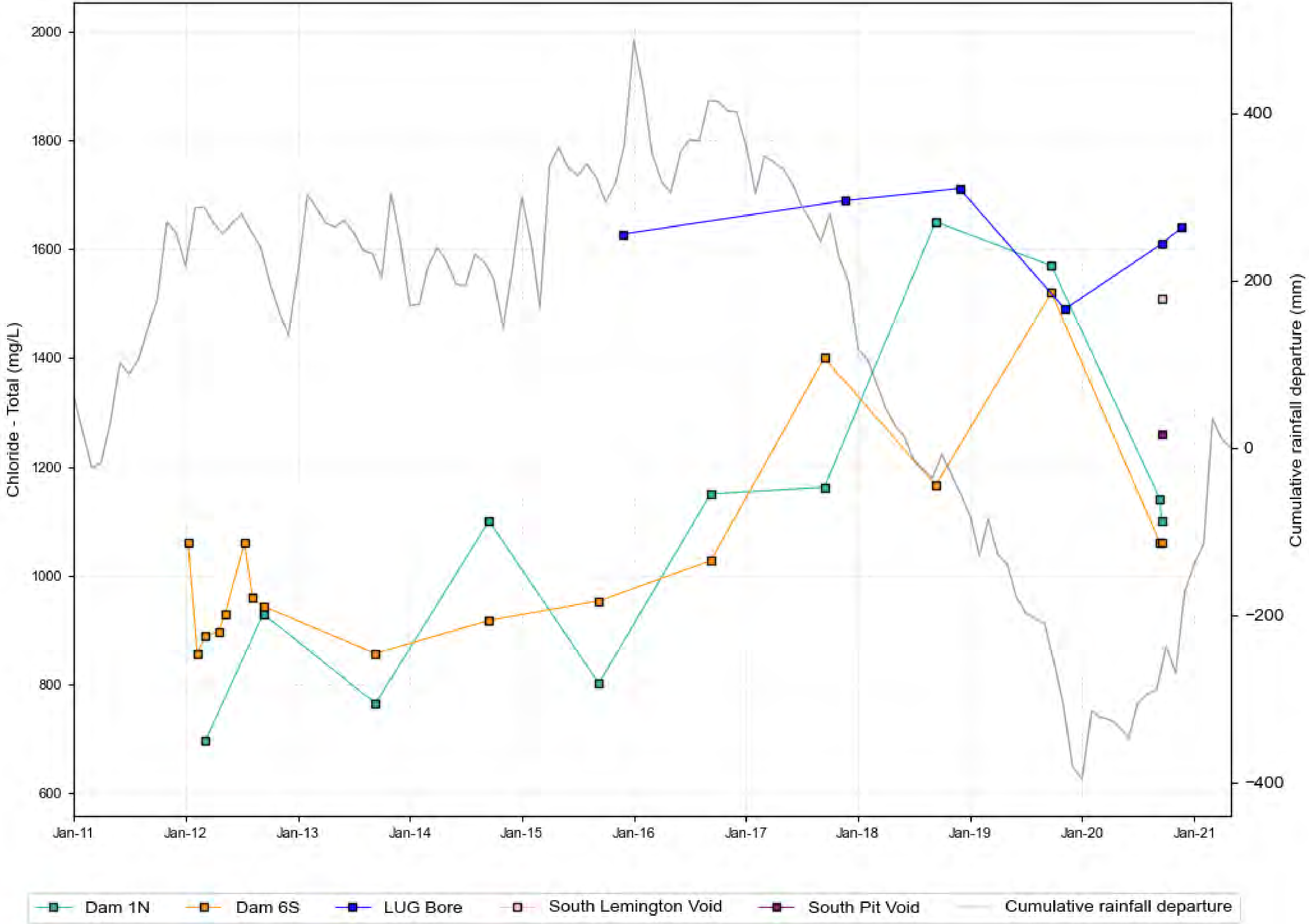

Figure B 5 MTW main surface water stores and LUG Bore, chloride time series data

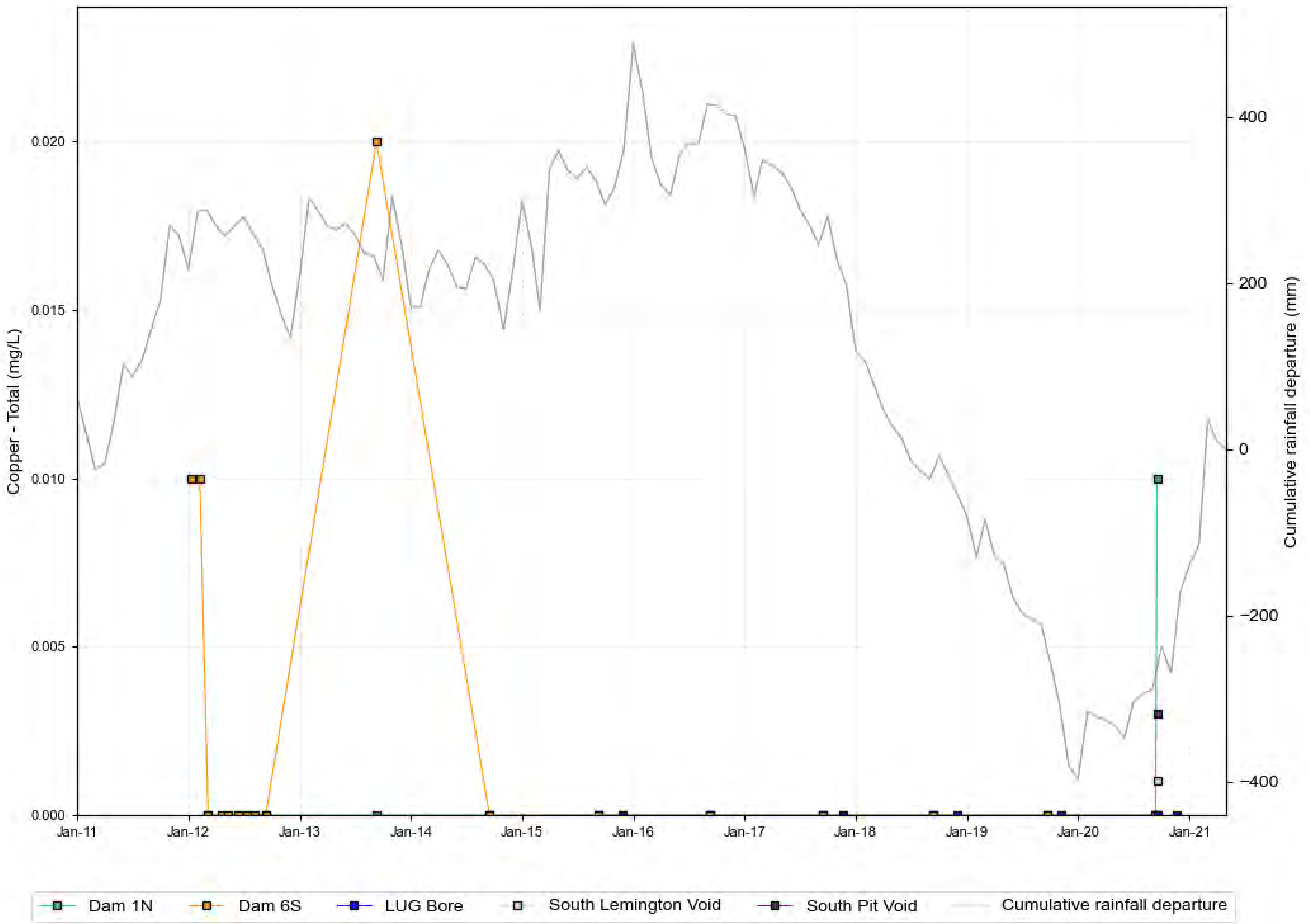

Figure B 6 MTW main surface water stores and LUG Bore, copper time series data

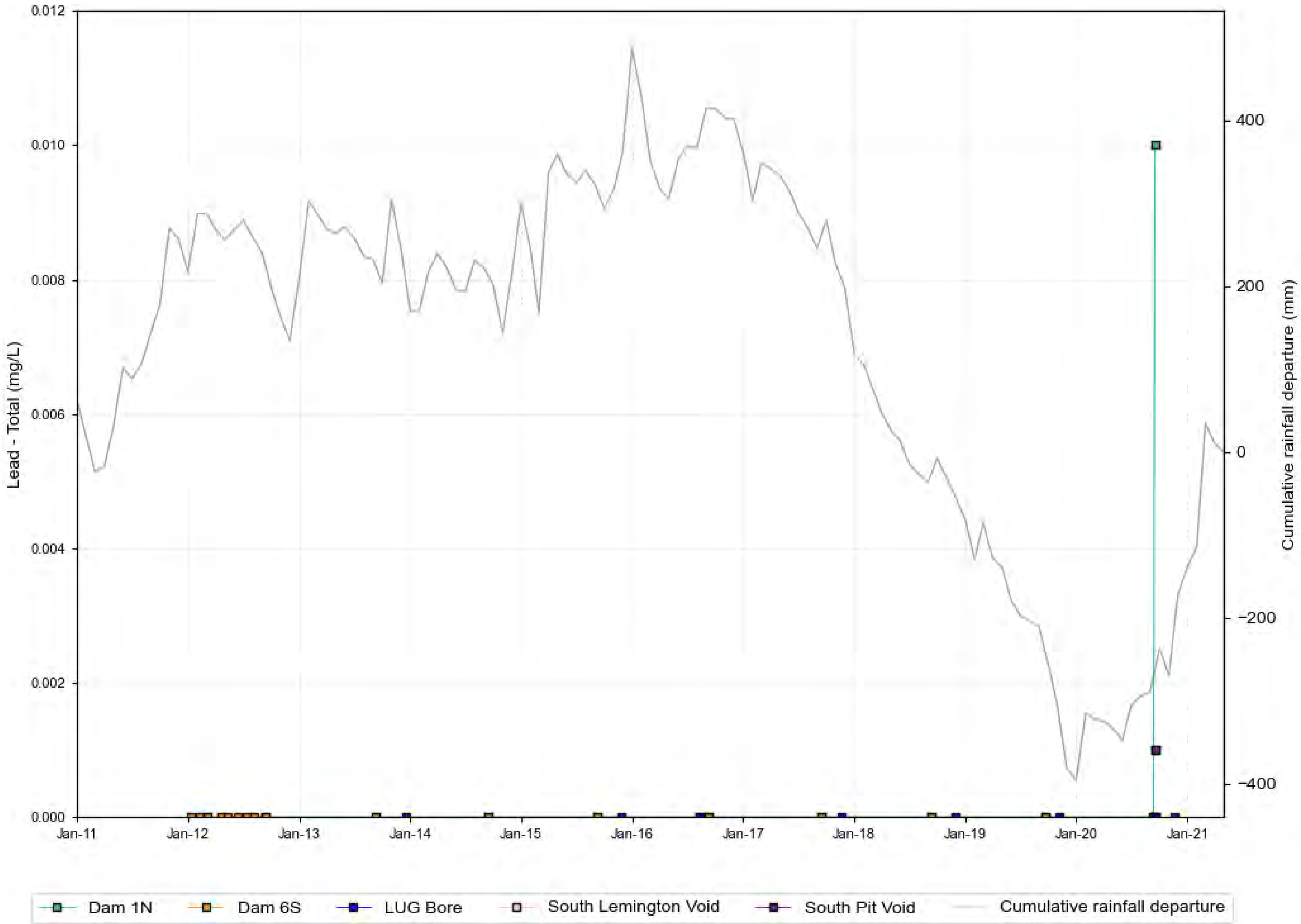

Figure B 7 MTW main surface water stores and LUG Bore, lead time series data

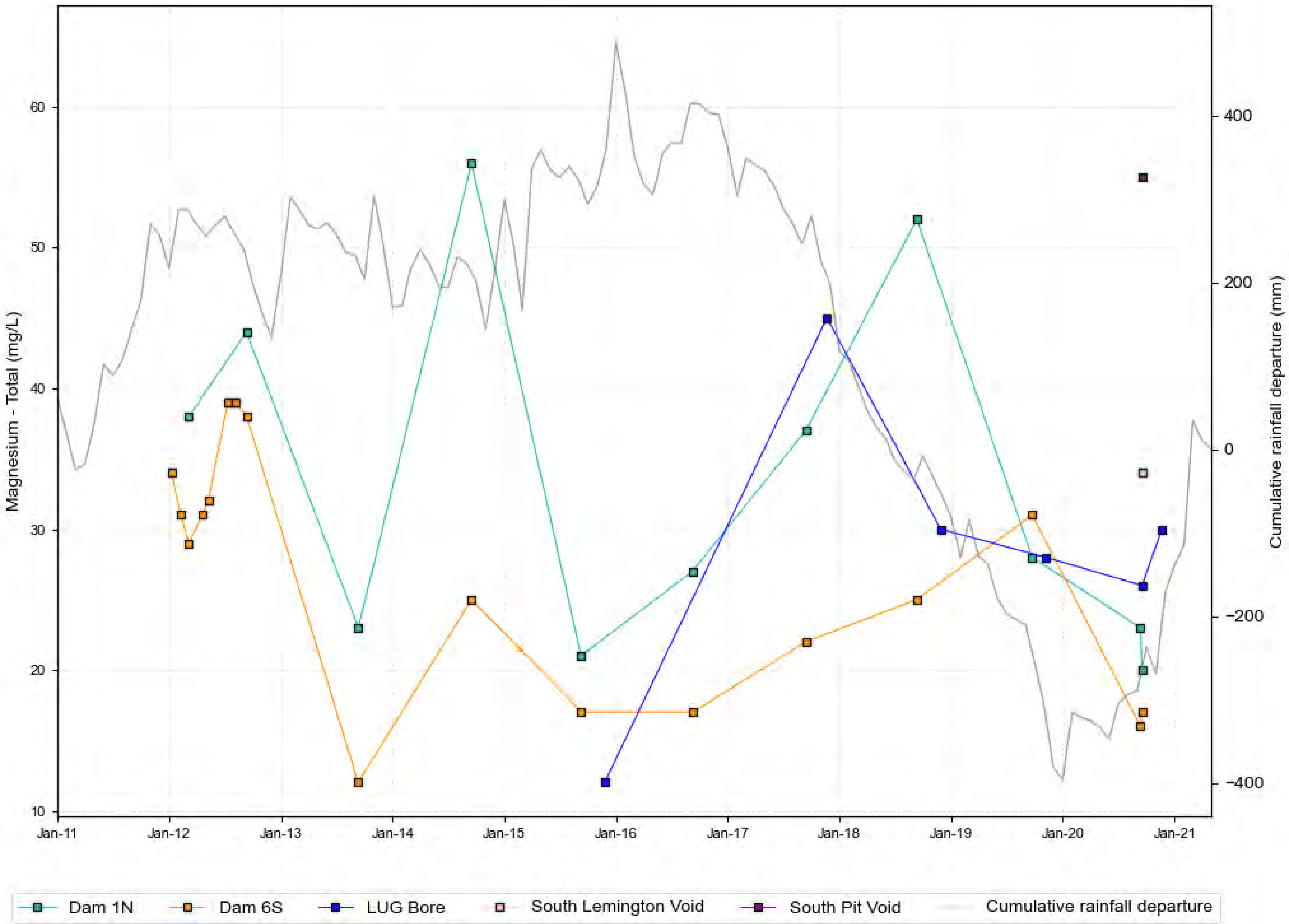

Figure B 8 MTW main surface water stores and LUG Bore, magnesium time series data

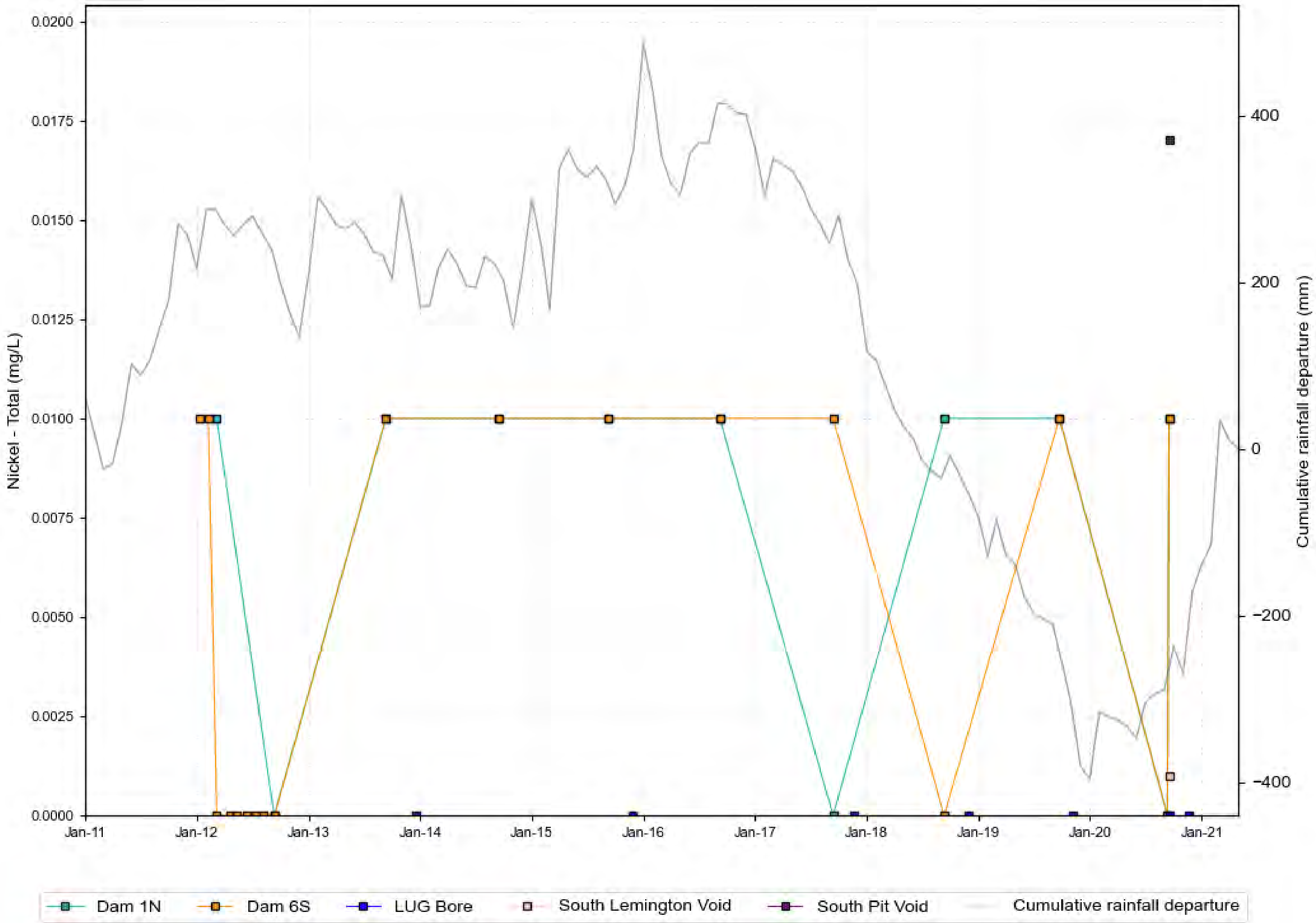

Figure B 9 MTW main surface water stores and LUG Bore, nickel time series data

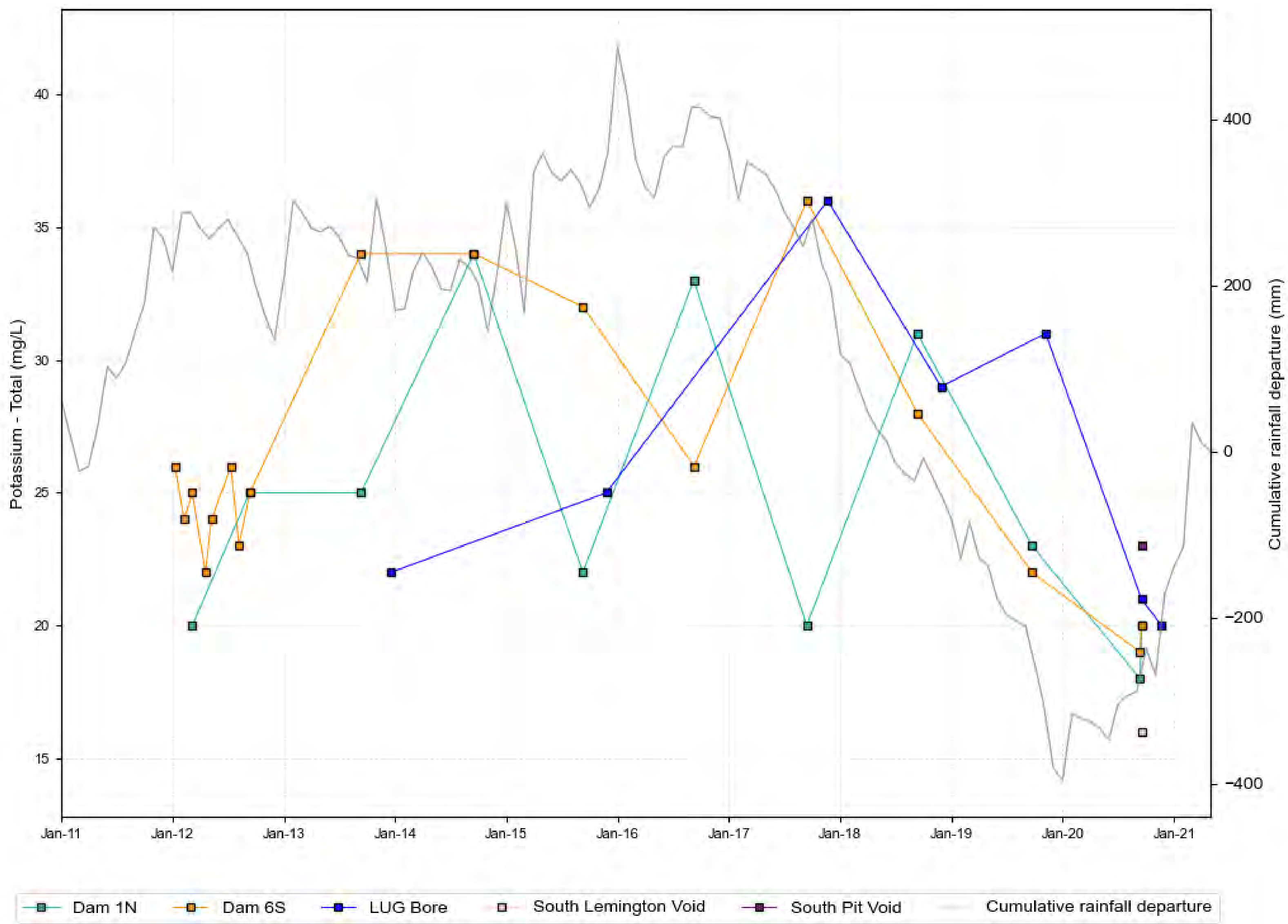

Figure B 10 MTW main surface water stores and LUG Bore, potassium time series data

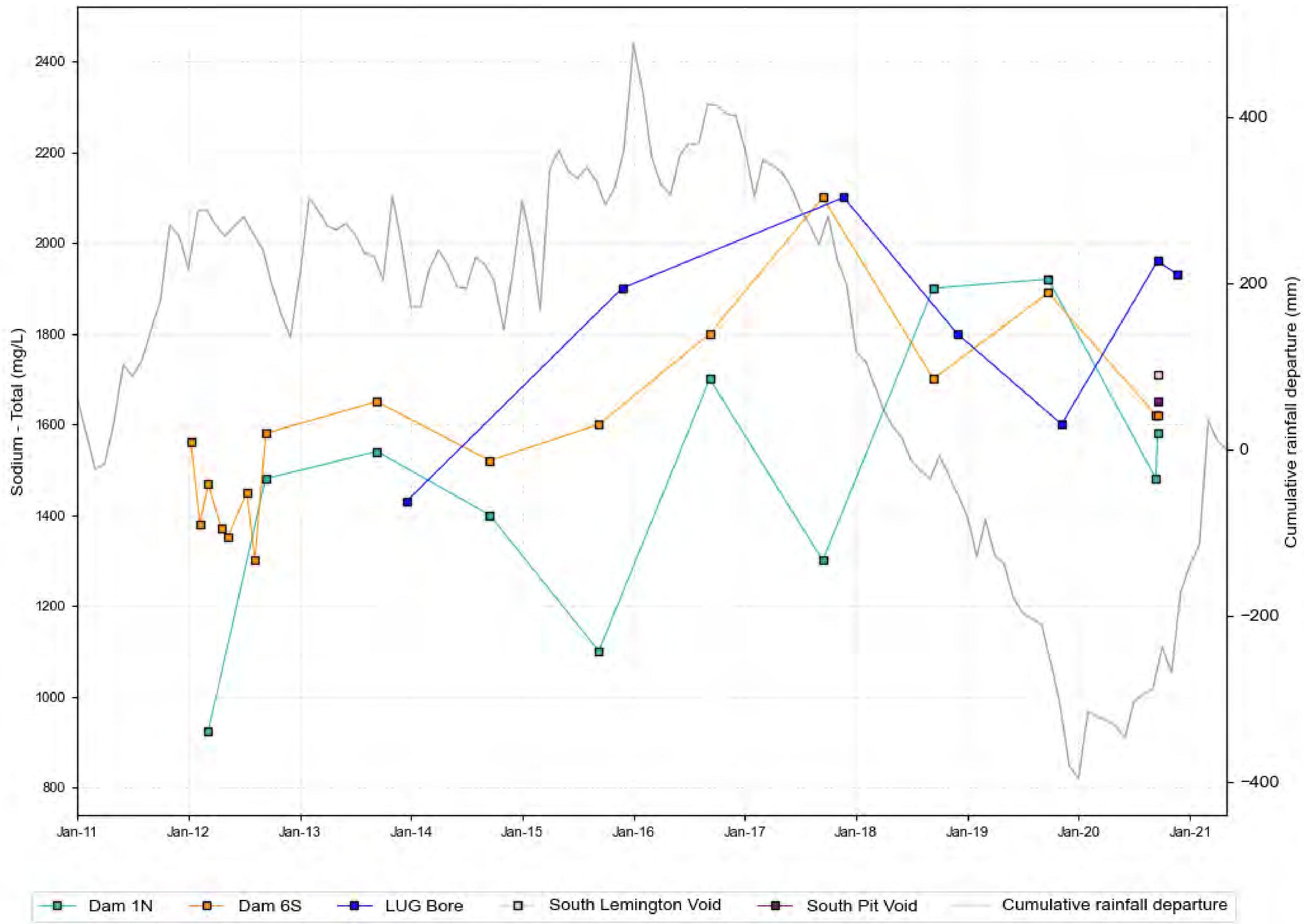

Figure B 11 MTW main surface water stores and LUG Bore, sodium time series data

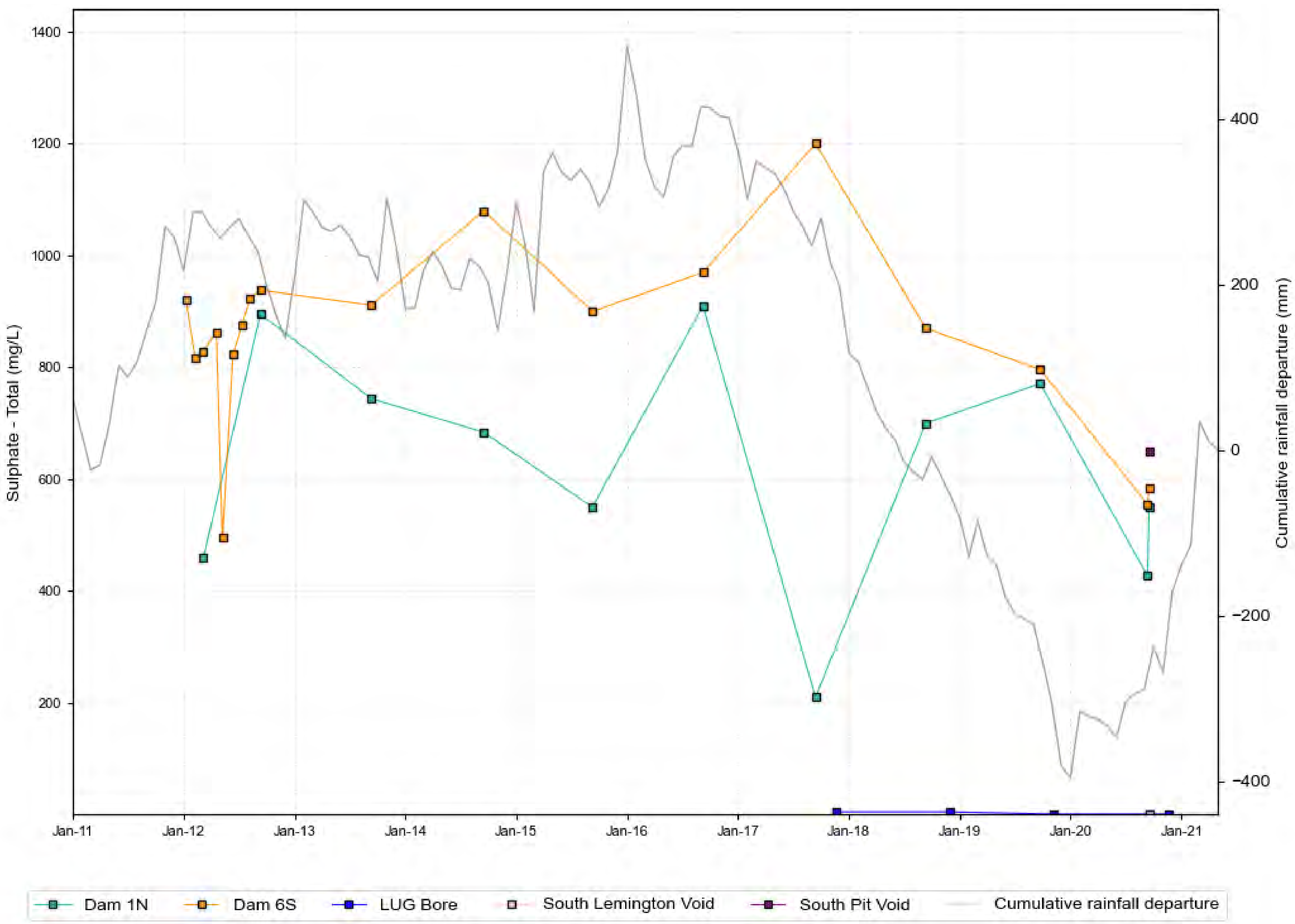

Figure B 12 MTW main surface water stores and LUG Bore, sulphate time series data

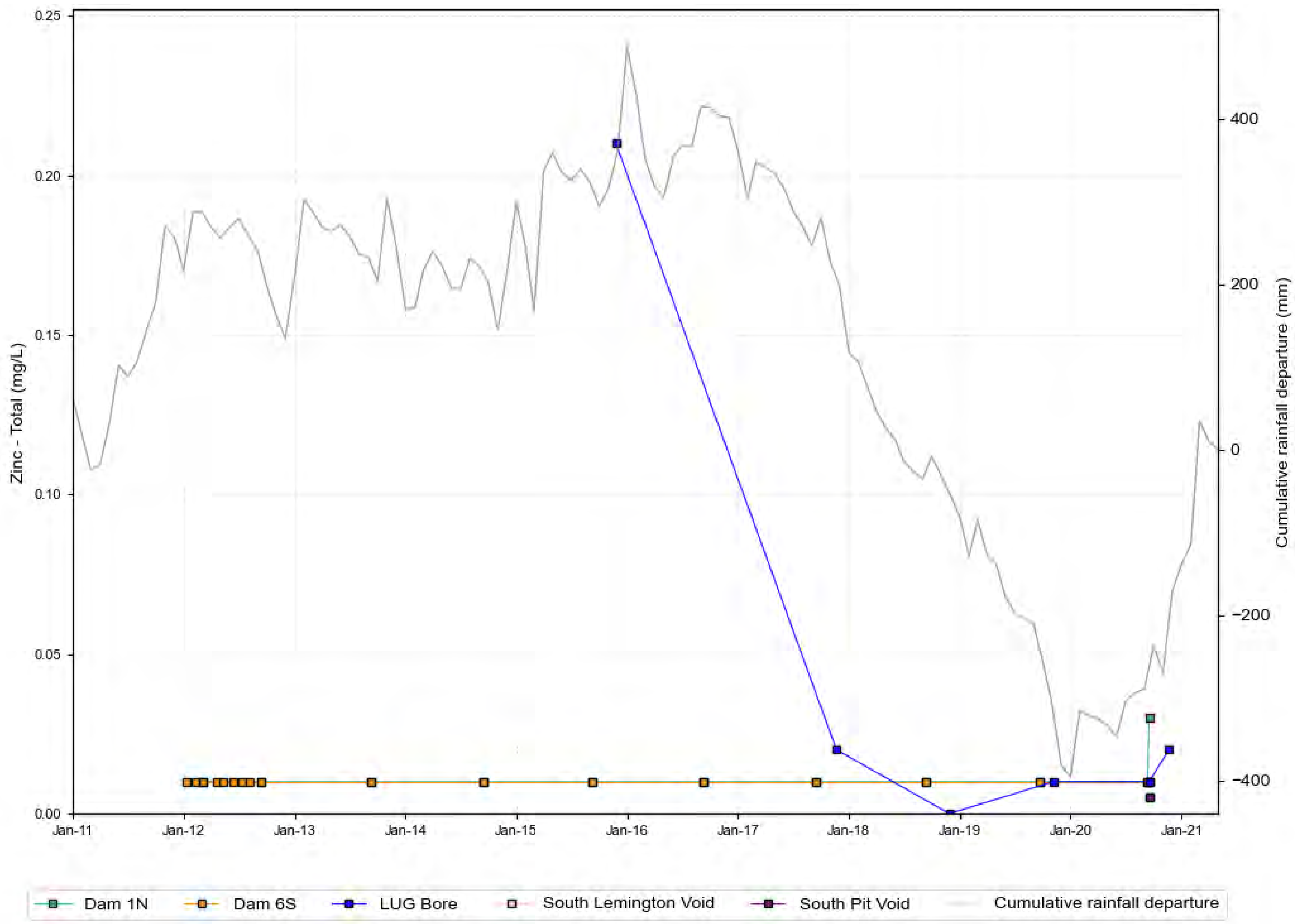

Figure B 13 MTW main surface water stores and LUG Bore, zinc time series data