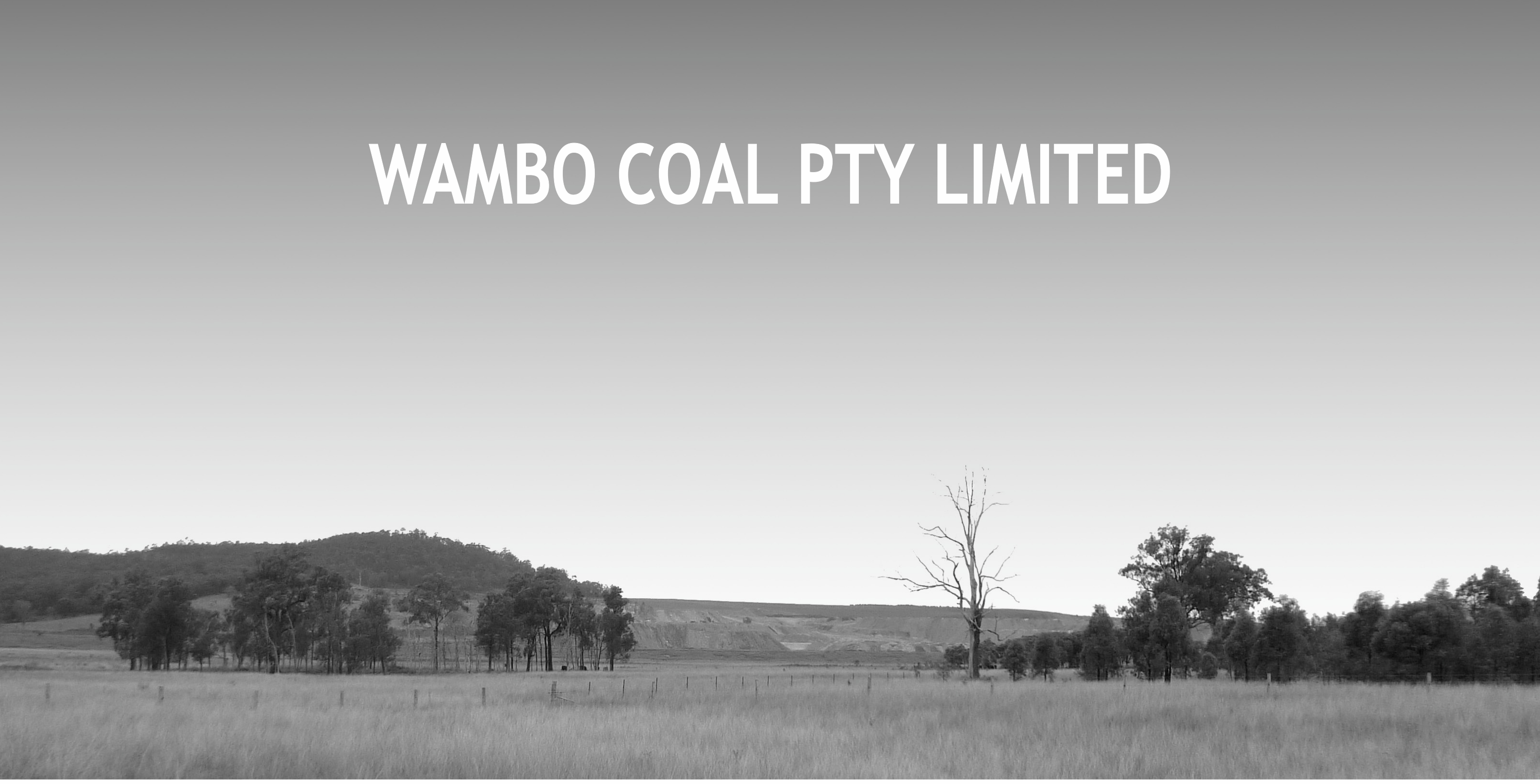


WAMBO COAL PTY LIMITED

SOUTH BATES EXTENSION UNDERGROUND MINE

EXTRACTION PLAN
LONGWALLS 21 TO 24

REPORT 2

GROUNDWATER ASSESSMENT REVIEW

SBE LW21-24 GROUNDWATER TECHNICAL REVIEW

Underground Mine Longwalls 21 - 24
Groundwater Assessment In Support of the Extraction Plan

Prepared for:

Wambo Coal Pty Ltd
Jerry's Plains Road
Warkworth, NSW 2330

SLR Ref: 665.10008-R02
Version No: -v3.0
February 2020

PREPARED BY

SLR Consulting Australia Pty Ltd
ABN 29 001 584 612
Level 1, The Central Building, UoW Innovation Campus
North Wollongong NSW 2500 Australia

T: +61 404 939 922
E: wollongong@slrconsulting.com   www.slrconsulting.com

BASIS OF REPORT

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

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
665.10008-R02-v3.0	28 February 2020	Tingting Liu	Claire Stephenson	Claire Stephenson
665.10008-R02-v2.0	13 February 2020	Tingting Liu, Claire Stephenson	Angus McFarlane	Angus McFarlane
665.10008-R02-v1.0	11 February 2020	Tingting Liu, Claire Stephenson	Angus McFarlane	Angus McFarlane

CONTENTS

DOCUMENT REFERENCES

CONTENTS

TABLES

FIGURES

APPENDICES

1 Introduction

Wambo Coal Mine (Wambo) is an open cut and underground coal mine located approximately 15 kilometres (km) west of Singleton, near the town of Warkworth, New South Wales. Wambo is owned and operated by Wambo Coal Pty Ltd (WCPL), a subsidiary of Peabody Energy Australia Pty Ltd. Wambo operates under Development Consent (DA 305-7-2003), which was last revised in August 2019 with the United Wambo Joint Venture Project Modification (Modification 16).

The active underground mining domain at WCPL is the South Bates Extension (SBE) Underground Mine. The SBE Underground Mine (Modification 17) was assessed and approved by the Department of Planning and Environment (now Department of Planning, Industry and Environment) in December 2017.

In accordance with the development consent conditions, an Extraction Plan (EP) is required to be prepared prior to commencement of secondary extraction. The EP outlines the proposed management, mitigation, monitoring and reporting of potential subsidence impacts and environmental consequences from the secondary extraction of approved longwalls at SBE. Mining is currently being undertaken in Longwalls 17 to 20 under an approved Extraction Plan. WCPL is in the process of preparing an Extraction Plan for the next series of longwalls at SBE (i.e. Longwalls 21-24).

A groundwater impact assessment was conducted by HydroSimulations (2017) for the approved SBE, which comprises longwall mining of panels 17 to 25 in the Whybrow Seam of the Wittingham Coal Measures. HydroSimulations (2018) completed a technical review of the predicted groundwater impacts for longwall panels 17 to 20 for the previous EP.

SLR Consulting Pty Ltd (SLR) have been engaged by WCPL to complete a technical review of the predicted groundwater impacts for longwall panels 21 to 24 based on the latest longwall layout. This area is referred to as the study area throughout this report. This report presents the latest groundwater modelling methodology and results, as well as discussion on the impact predictions for longwall panels 21 to 24 compared to predictions for the approved operation by HydroSimulations (2017).

1.1 Background

Condition B7, Schedule 2 of the Development Consent requires the Extraction Plan to "…provide updated predictions of the potential subsidence effects, subsidence impacts and environmental consequences of the proposed mining covered by the Extraction Plan, incorporating any relevant information obtained since this consent…."

Since Modification 17 was approved (December 2017) the following additional studies and information has been obtained (with relevance to longwalls panels 21 to 24):

- Alluvial investigation program along North Wambo Creek (NWC) as reported by AGE (2019), which included test drilling and construction of monitoring bores to delineate the extent and depth of alluvium overlying weathered coal measures (sandstone);
- Groundwater and surface water observation data collected across the site since the SBE groundwater assessment;
- Ecological assessment along NWC to assess tree species and potential reliance on groundwater;
- Surface water study, including installation of additional surface water gauges along NWC and the North Wambo Creek Diversion (NWCD);

- Subsidence assessment in support of the Longwalls 21-24 Extraction Plan conducted by MSEC (2020);
- Groundwater study by HydroSimulations (2018) to assist in the groundwater dependent ecosystems (GDE) study along NWC. The work included updates to the HydroSimulations (2017) numerical groundwater model of:
  - Conversion of the HydroSimulations (2017) MODFLOW-SURFACT model code to MODFLOW-USG code, but maintain the existing model grid and layering;
  - Updated model layer 1 thickness based on findings from the drill investigation by AGE (2019a and b);
  - Update to hydraulic properties for Permian overburden; and
  - Verification of model performance, which showed improved fit between modelled and observed groundwater levels with a statistical measure (scaled root mean square – SRMS) of 5.0 % compared to 7.0 % reported by HydroSimulations (2017).
- Groundwater study by SLR (2020) to provide further assistance in the GDE study along NWC. The work included further updates to the existing numerical groundwater model (HydroSimulations 2018), which included:
  - Update to the model grid using Groundwater Vistas 7 quadtree refinement along NWC;
  - Update to the model timing to include monthly stress periods from 2003 to 2029 and quarterly stress periods from 2029 to 2040;
  - Update Recharge package to match updated model timing and utilise observed rainfall data (Bulga station 061191) to replicate historical trends to 2019 and include average month or quarterly rainfall for the predictive model;
  - Update River package for river cells along NWC and NWCD to include variable stage heights based on interpolated trends from observed streamflow data and rainfall trends; and
  - Verification of model performance, the model calibration period has been extended in time from 31 December 2017 to 31 December 2019 which showed improved fit between modelled and observed groundwater levels with a statistical measure (scaled root mean square – SRMS) of 4.8%.

1.2 Scope of Work

The scope of works to conduct the groundwater component of the Longwalls 21 to 24 EP included:

- Review of data relevant to the study, including climate, subsidence, surface water and groundwater data;
- Updates to the existing Wambo numerical groundwater model, including:
  - Development of a new model run with longwall panels 21 to 24 excluded; and
  - Running of the models and processing the results to assess the incremental impacts associated with extraction from longwall panels 21 to 24.
- Reporting on work completed and results, including discussion on groundwater impacts compared to what was previously reported for the approved operations by HydroSimulations (2017).

2 Site Setting

This section provides a brief summary of the site setting around longwall panels 21 to 24 relevant to this study. For full details on the regional context refer to HydroSimulations (2017).

2.1 Climate

The nearest Commonwealth Bureau of Meteorology (BoM) climate station is at Bulga (South Wambo) (station 061191) (32.61°S, 150.98°E at 80 m elevation), located approximately 3 km to the south of the site. The SILO (Scientific Information for Land Owners) database of Australian climate data was used for the period commencing January 1959 to December 2019 to generate long-term rainfall trends. The long-term monthly mean generated for the BOM Baralaba Post Office location by SILO Data Drill are presented in **Table 1**, with an average annual rainfall of 658.6 millimetres (mm) per year.

Average historical monthly rainfall is presented in **Table 1**, along with monthly rainfall for 2017, 2018 and 2019. The table shows that since the initial groundwater assessment by HydroSimulations (2017) the area has generally experienced below average annual and monthly rainfall. Exceptions to this were in March 2017 and 2019, and October 2017 and 2018 when the area experienced above average rainfall.

Table 1 Average Monthly Rainfall (mm) – SILO Data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Historical Average (1959 – 2019)	87.2	83.2	68.0	45.6	39.7	43.8	30.3	34.2	38.5	54.3	62.0	71.7	658.6
2017	54.2	11.3	171.3	35.4	22.2	29.8	1.4	13.6	9.7	97.9	23.1	51.4	521.3
2018	6.8	76.0	59.2	11.5	6.7	32.9	2.1	19.9	28.9	96.7	49.5	45.2	435.4
2019	59.6	21.0	145.6	3.4	11.8	6.4	13.4	21.8	21.4	4.4	30.8	0.2	339.8

Residual mass curve (RMC) (or cumulative rainfall departure from the mean [CRD]) plot using rainfall data from Bulga (South Wambo) since 2003 is shown in **Figure 2**. This curve is generated by aggregating the residuals between recorded monthly rainfall and long-term average rainfall for each month. The procedure is essentially a low-pass filter operation that suppresses the natural spikes in rainfall and enhances the long-term trends. The RMC displays trends in rainfall, with positive slope (rising limbs) indicating periods of rainfall greater than the mean, and negative slope (falling limbs) indicating below-mean conditions. Given the usually slow response of groundwater levels to rainfall inputs, the RMC can be expected to correlate well with groundwater hydrographs over the long term.

Figure 2 shows that the wetter periods on record occurred during mid-2007, January 2009, early 2012, December 2012 to January 2013, December 2015 to January 2016, March 2017 and March 2019. Below average rainfall conditions were observed from late 2005 to mid-2007 and from April 2017 towards the end of 2019.

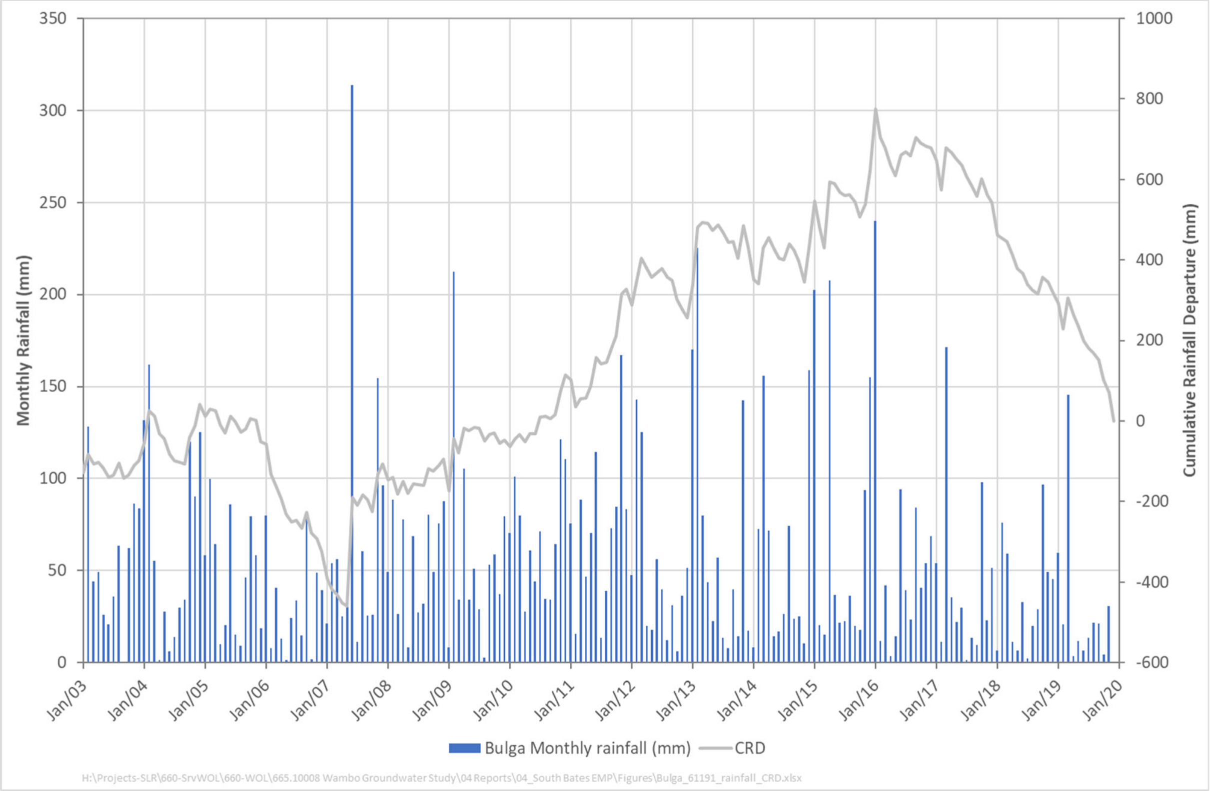
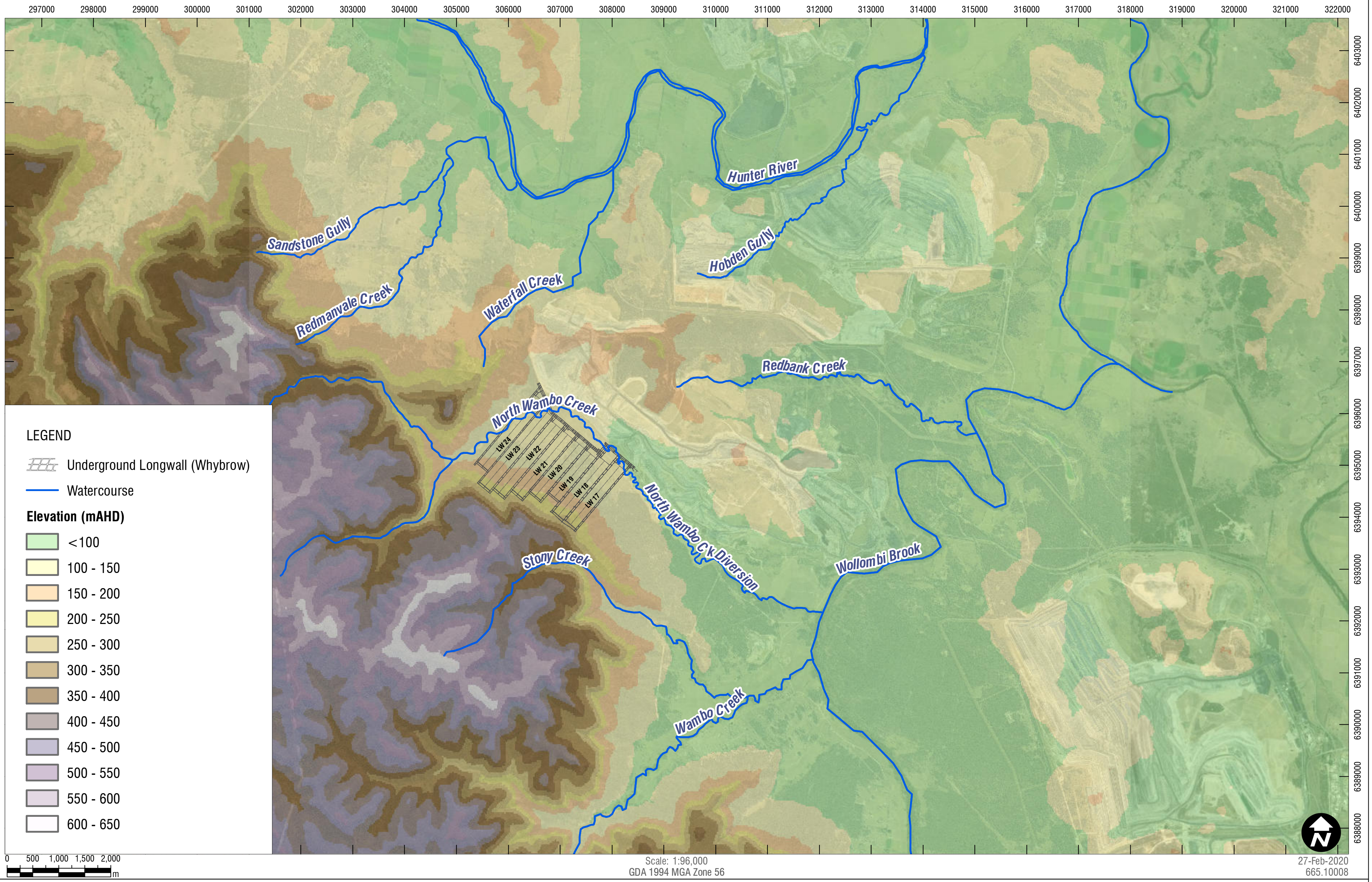


Figure 1 **Cumulative Rainfall Deficit**

2.2 Drainage

Wambo is located in the Upper Hunter Valley region where landforms are characterised by gently sloping floodplains associated with the Hunter River and the undulating foothills, ridges and escarpments of the Mount Royal Range and Great Dividing Range. The majority of lands within WCPL mining tenements drain via Wambo, Stony, North Wambo and Redbank Creeks to Wollombi Brook, while Waterfall Creek drains directly to the Hunter River (**Figure 2**). These watercourses are generally characterised by ephemeral and semi-perennial flow regimes (Gilbert and Associates, 2003).

Monitoring of surface water levels and flow is undertaken along Wollombi Brook at government station Wollombi Brook @ Bulga (210028) (32.65oS, 151.02oE at 65.693 m elevation), as shown in **Figure 3**. Stream levels along Wollombi Brook are 1.0 m on average above river bed. No flow has been recorded along Wollombi Brook since January 2018, with the zero gauge level at 0.57 m above river bed. Monitoring along NWC and the NWCD has been conducted at site stream gauges FM1 and FM4 since 2015 and 2012, respectively. Data shows NWC is ephemeral in nature, with flows recorded less than 30% of the time, following peak rainfall periods.



H:\Projects-SLR\610-SrvSYD\660-WOL\665.10008 Wambo Groundwater\GIS\66510008 F03 Topography and Drainage.mxd

Sheet Size : A4

SLR
www.slrconsulting.com

Topography and Drainage

FIGURE 2

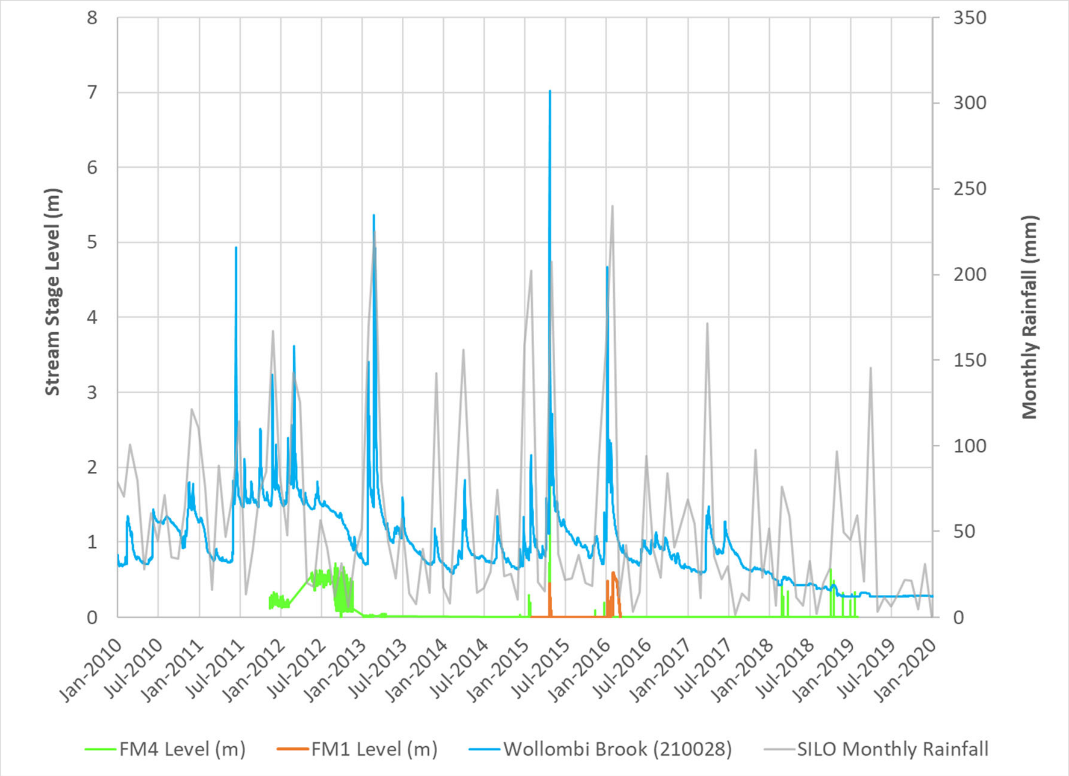


Figure 3 Streamflow vs CRD

2.2.1 Groundwater Users

Review of the National Groundwater Information System (NGIS) database (Groundwater Explorer) indicates there are no registered private water supply bores within 2 km of the study area.

2.3 Geology

Wambo is situated within the Hunter Coalfield subdivision of the Sydney Basin, which forms the southern part of the Sydney-Gunnedah-Bowen Basin. The stratigraphy in the Wambo area comprises the Triassic Narrabeen Group, Permian coal measures and more recent (Quaternary) alluvial deposits associated with major drainage pathways. Discussion on each of the main geological units relevant to the site is included below.

2.3.1 Alluvium

The alluvium within the Hunter Valley region and more locally is associated with fluvial depositional sequences. The alluvium along the main drainage channels (i.e. Hunter River and Wollombi Brook) comprises up to 10 m to 20 m of unconsolidated materials including gravels, sands, silts and clays depending upon location (Mackie, 2009). Alluvium has also been mapped along creeks and minor drainage lines including Wambo Creek and NWC. Several investigations were conducted into the extent, properties and depth of alluvium near SBE, as reported by HydroSimulations (2017).

The alluvium along Wambo Creek was found to be around 4 m to 7 m deep and comprises clayey to sandy, brown silt with areas of localised fine to medium grained sand (HLA-Envirosciences, 1999). There are also indications that the alluvial aquifer of Wambo Creek is discontinuous, probably due to bedrock highs (HLA Envirosciences, 1999).

Consistent with this, geological information from recent drilling and installation of monitoring bores shows the alluvium along the upper reaches of NWC is around 4 m to 10 m deep. The alluvium generally comprises sands, silts and gravels, overlying weathered sandstones (regolith). **Figure 4** shows the extent of alluvium was revised based on the site drill data, and discussed further in HydroSimulations (2018). The current extent of alluvium along NWC is limited by the footprint of Montrose Pit.

2.3.2 Triassic Narrabeen Group

The Triassic Narrabeen Group forms the prominent escarpment on elevated areas to the south-west of Wambo and unconformably overlies the Permian coal measures. The Narrabeen Group is present in the south-western part of the Wambo mining lease area.

2.3.3 Permian Coal Measures

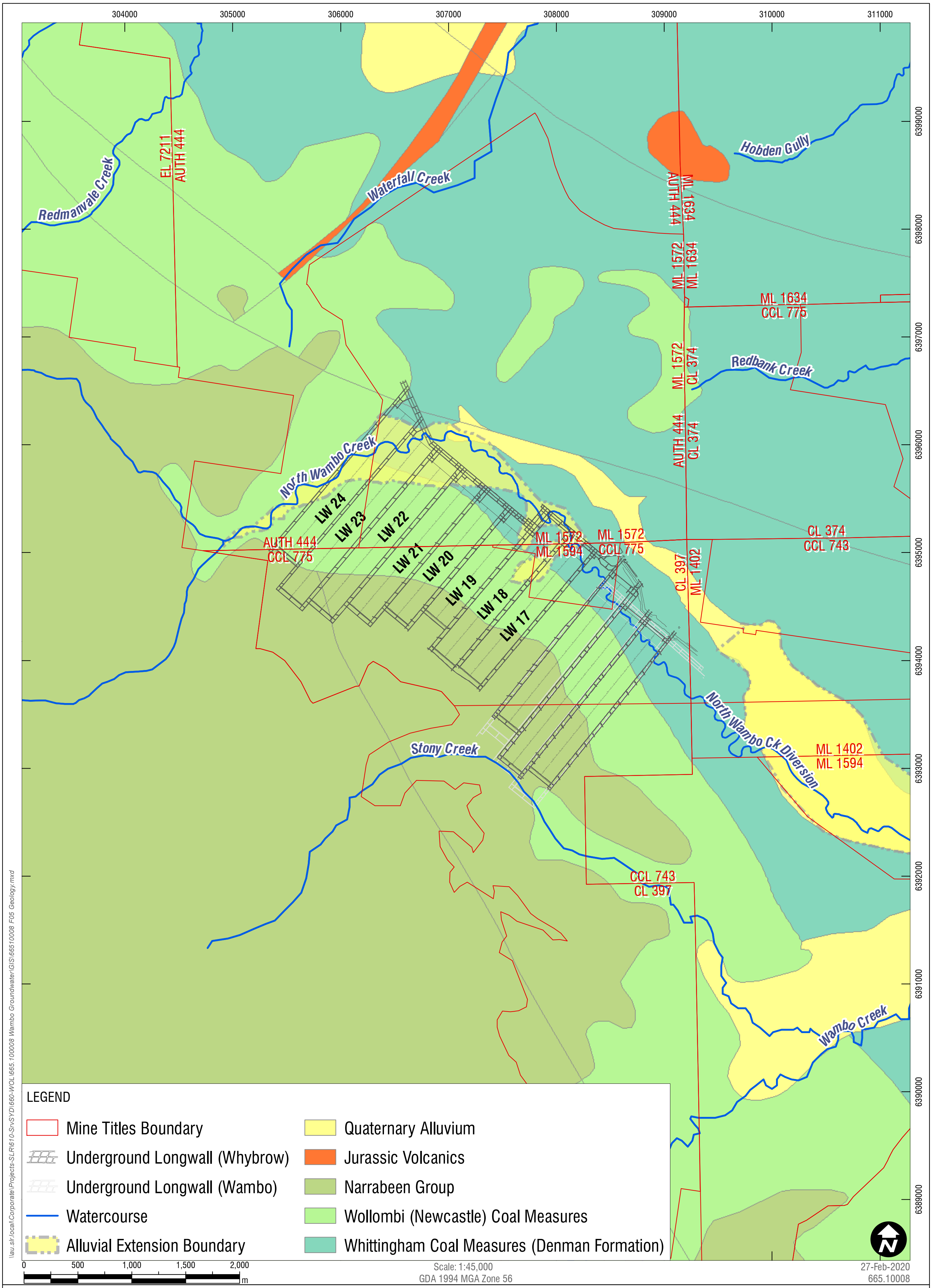
The coal measures are Permian age sediments which contain numerous coal seams and associated splits. These are separated by interburden comprising interbedded sandstones and laminated mudstones and siltstones. The Permian strata containing the Newcastle and the Wittingham Coal Measures dip gently to the south-west and subcrop in the Wambo area. The Newcastle Coal Measures subcrop to the south of NWC and the Wittingham Coal Measures subcrop in the north-east of the Wambo mining lease area along a northwest–southeast strike.

At SBE, mining targets the Whybrow Seam of the Wittingham Coal Measures, the seam is 2.4 m to 3.6 m thick within the study area and is present between 60 m to 290 m below surface. The seam is overlain by interbedded sequences of siltstone, sandstone and conglomerates. From surface, these overburden sequences are weathered to approximately 20 m below surface (regolith), based on CSIRO (2015) regolith depth mapping and drill hole data.

2.3.4 Structural Geology

The Permian coal measures generally dip at approximately three degrees to the south-west with structure complicated by some local variations in seam dip and direction. Notwithstanding, seams generally have consistent thicknesses and interburden intervals. The main fault structure in the area is the Redmanvale Fault located over 100 m from the longwall panels.

There is a series of north-northeast to south-southwest trending faults within and adjacent to the South Bates Underground (SBU) area with throws between 0.5 m and 1 m (MSEC, 2015). Some larger faults have been identified to the north-west and to the south-east of the SBU with throws ranging between 3 metres and 12 metres (MSEC, 2015). SLR have been advised that geological structures were recently identified in the vicinity of SBE during the development of first workings. This includes a normal fault with approximately 8 m displacement near the commencing end of Longwall 19. These structures have resulted in minor changes to the mine plan (i.e. shortening of the commencing ends of Longwalls 19 and 20, and shortening of the finishing ends of Longwalls 18 to 22).



Sheet Size : A4

SLR
www.slrconsulting.com

Geology

FIGURE 4

2.4 Mining

2.4.1 Mine Areas

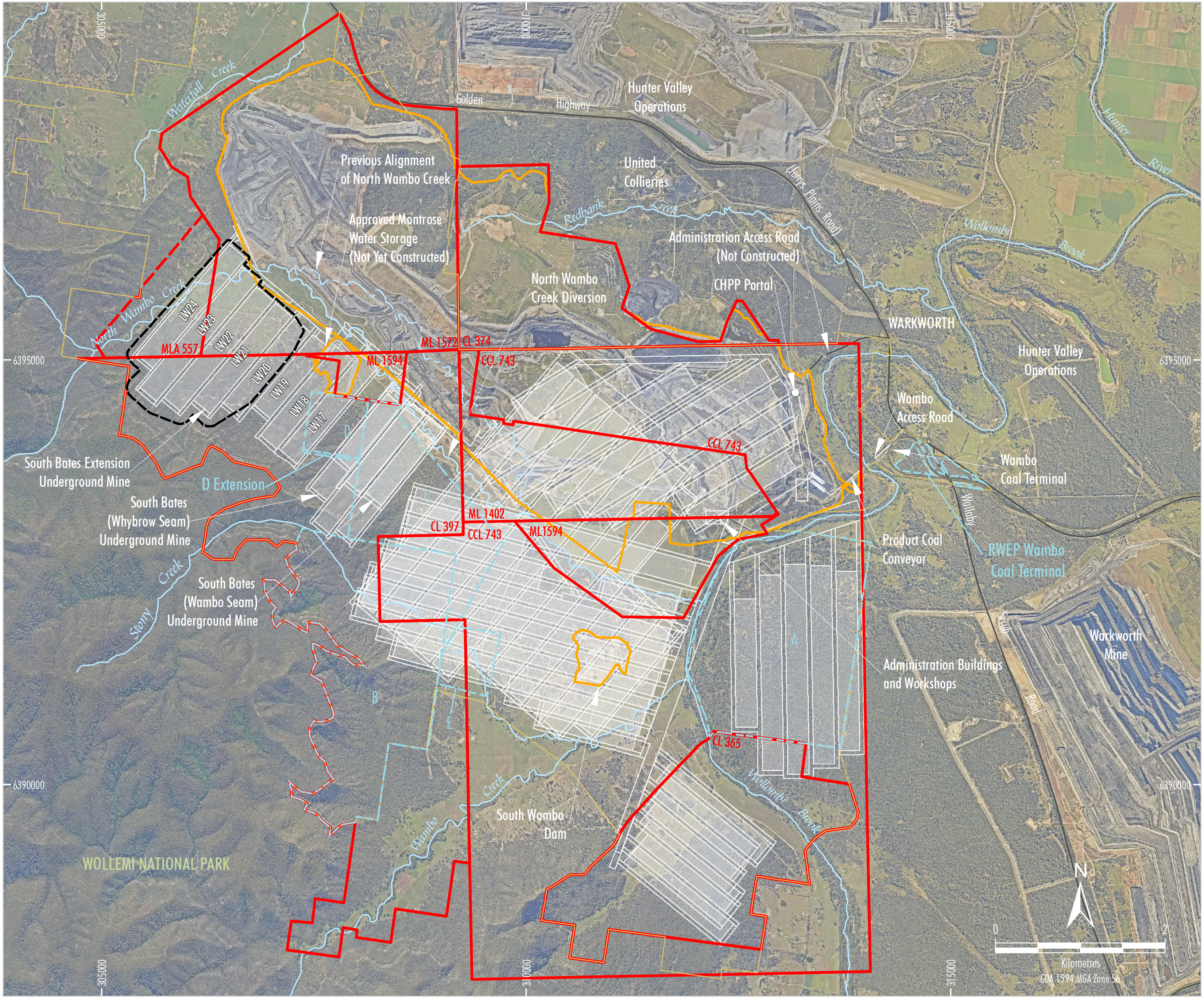
Substantial coal mining activity has occurred historically and is continuing currently in the vicinity of Wambo, by a number of companies, with development across several coal seams. Coal is extracted by means of both underground and open cut mining methods. Coal mines neighbouring Wambo include United Colliery to the north and east of Wambo, Mt Thorley Warkworth to the south-east, and a number of open cut and underground mines to the north and east within the Hunter Valley Operations.

A summary of mining operations across Wambo is included in **Table 2**, and shown on **Figure 4**. Open cut and underground mining at Wambo commenced in 1969. Longwall mining operations are active at Arrowfield Underground, Woodlands Hill Underground and SBE, with mining to commence in Bowfield Underground from 2021. Mining at Montrose open cut is planned to cease in 2020, with transfer over to the United Wambo open cut, a 50:50 joint venture between United Collieries and Wambo Coal.

Table 2 Mine Summary

Area	Type	Seam(s) Mined	Timing
No. 1 Underground	Underground	Wambo and Whybrow seams	1969 – 1977
Homestead Underground	Underground	Whybrow seam	1979 – 1999
Wollemi Underground	Underground	Whybrow seam	1997 – 2002
Ridge Underground	Underground	Whybrow seam	1976 – 1983
North Wambo Underground	Underground	Wambo seam	2007 – 2016
Arrowfield Underground	Underground	Arrowfield seam	TBC
Bowfield Underground	Underground	Bowfield seam	TBC
Woodlands Hill Underground	Underground	Woodlands Hill seam	TBC
South Bates Underground (SBU)	Underground	Whybrow seam (LW11 – LW13) Wambo seam (LW14 – L16)	2016 – 2017 2017 – 2019
South Bates Extension (SBE)	**Underground**	**Whybrow seam (LW17 – LW25)**	**2017 – 2024**
Bates Pit/ Bates South Pit	Open Cut	Whybrow to Whynot seams	1986 – 2016
Homestead Pit	Open Cut	Whybrow to Whynot seams	1969 – 2016
Wombat Pit	Open Cut	Whybrow to Whynot seams	1969 – 2009
Hunter Pit	Open Cut	Whybrow to Whynot seams	1969 – 2011
Wambo Boxcut	Open Cut	Woodlands Hill seam	2016 – 2017
Montrose Pit	**Open Cut**	**Whybrow to Whynot seams**	**2013 – 2020**
United Wambo Open Cut	**Open Cut**	**Wambo to Vaux seams**	**2020 – 2039**

Note: *TBC - to be confirmed, commencement of Arrowfield, Bowfield and Woodlands Hill underground operations has not yet occurred, but is currently approved, anticipated to commence after completion of SBE.*



Source: WCPL (2020); NSW Spatial Services (2019)
Orthophoto: WCPL (May 2019)

Peabody

WAMBO COAL MINE

Plan of Mining at Wambo and Surrounds

Figure 5

WAM-09-15_SBX EP_LW21-24_211A

2.4.2 Subsidence

Above longwalls 21 to 24 in the Whybrow Seam, the depth of cover is 60 m to 290 m. Potential subsidence impacts to the creeks and watercourses directly above and adjacent to longwalls 21 to 24 have been assessed by MSEC (2020). A length of 1.2 km of NWC is located directly above longwalls 23 and 24, with ground elevations ranging between 109 mAHD and 117 mAHD. The maximum predicted total vertical subsidence for NWC is 1,950 mm (MSEC 2020).

NWC joins with the NWCD over 300 m north-east of the study area. At this distance, the creek diversion is predicted to experience less than 20 mm vertical subsidence due to mining at Longwalls 21 to 24 (MSEC 2020).

Ponding areas have been predicted to develop along NWC to depths of up to 1.3 m and lengths of 300 m. Surface cracking with longwall extraction has also been predicted in line with observed surface cracking at longwall 11 to 13 and longwall 17. This is largely localised at the north-eastern ends of the panels, where the depth of covers is shallowest (MSEC 2020). In these areas surface cracks were observed to typically be 25 mm to 50 mm wide, and up to 400 mm wide in localised areas (MSEC 2020). Compression and dilation is also expected to impact the upper 10 m to 20 m of bedrock (regolith), which has the potential to impact on groundwater conditions within the regolith.

MSEC (2020) conclude that direct hydraulic connection between the surface and Longwalls 21 to 24 is not expected, as this has not been previously observed at the Wambo Coal Mine under similar conditions. However, remediation (i.e. infilling) will likely be required in localised area as a result of subsidence and surface cracking due to longwall extraction. It is expected that there would be no long-term adverse impacts on these streams after the completion of the necessary surface remediation.

2.5 Hydrogeology

This section presents a summary of the site groundwater monitoring network and discussion on groundwater level and quality trends in the study area.

2.5.1 Groundwater Network

Groundwater monitoring at Wambo is undertaken in accordance with the Groundwater Monitoring Program (GWMP) (WCPL, 2015). The objectives of the GWMP are to establish baseline groundwater quality and water level data and to implement a programme of data collection that can be utilised to assess potential impacts of mining activities on the groundwater resources of the area. Consistent with the GWMP, groundwater quality sampling has been undertaken by WCPL in accordance with AS/NZS 5667.11:1998 – Guidance on Sampling of Ground Waters. Samples are measured in the field for acidity (pH), electrical conductivity (EC) and temperature (T).

The Wambo groundwater monitoring network comprises bores established in the alluvium associated with the principal drainage pathways, as well as regolith and interburden sequences. Multi-level vibrating wire piezometers (VWPs) have also been installed across the site, intersecting the shallow stratigraphy and Permian coal measures. Between 2017 and 2019 a drill program was conducted with test holes to delineate the extent of alluvium, as well as installation of groundwater monitoring bores, as documented in SLR (2017) and AGE (2019a,b). In total, 13 bores were installed, 11 in the alluvium to depths of up to 10 m, and two within the weathered sandstone (regolith) to depth of up to 13.2 m shown on **Figure 7**. Installation of timeseries dataloggers within the existing monitoring bores has also been proposed for selected alluvial and regolith bores to capture seasonal trends.

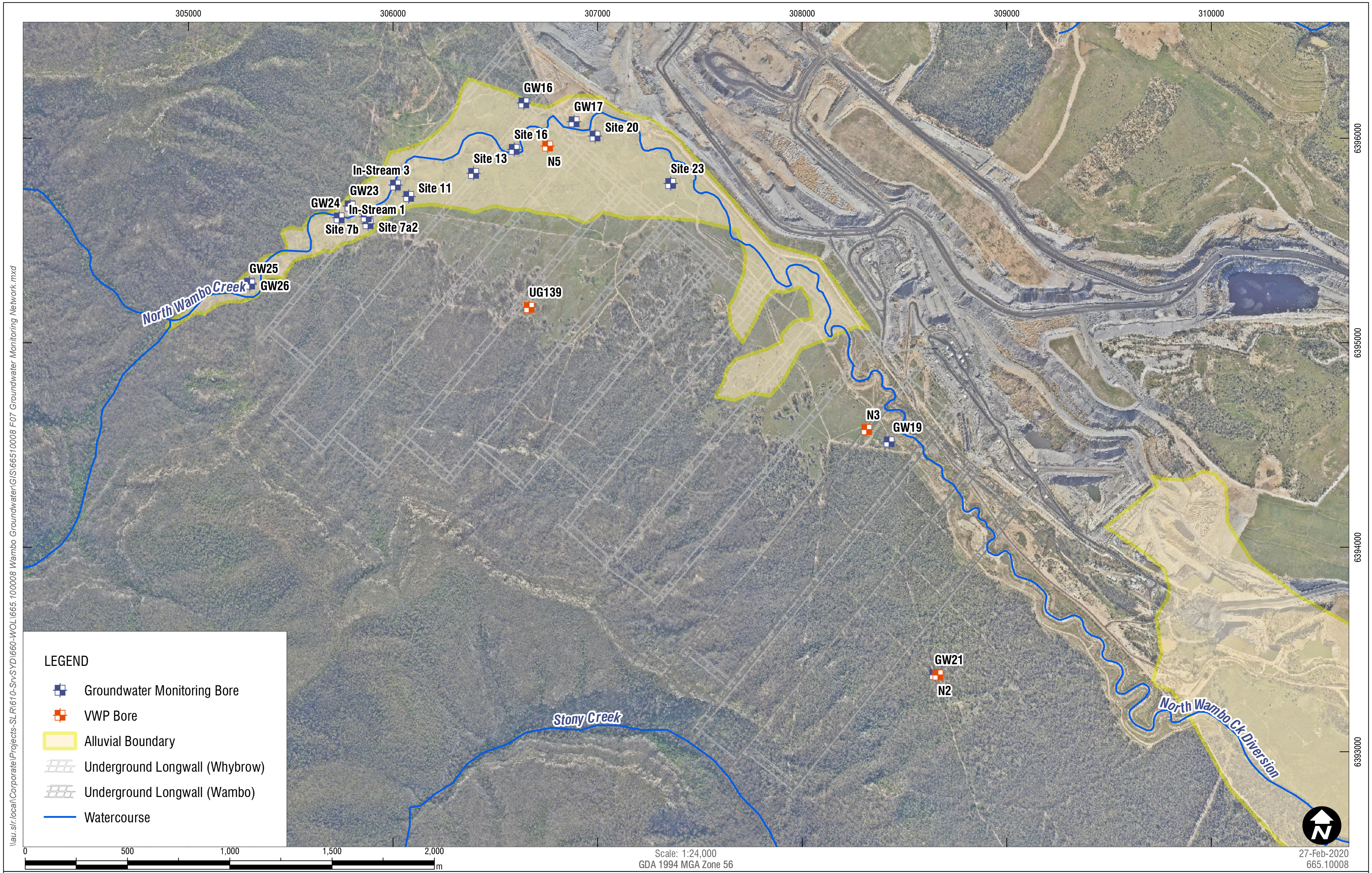
As identified in the MSEC (2020) subsidence study, surface cracking and subsidence is predicted over Longwalls 21 to 24. This has the potential to impact on the condition of the site monitoring network. Review of the condition of the monitoring network will be undertaken during each sampling event, and bores remediated/replaced as required, to maintain a long-term monitoring network.

Table 3 Summary of Monitoring Network near South Bates Extension

ID	Type	Easting	Northing	Ground Level (mAHD)	Screen (mbgl)	Target Lithology	Data Range
GW16	MB	306639	6396174	110.6	6.15 - 12.15	Clayey sand and weathered sandstone	2010 – present
GW17	MB	306885	6396081	109.5	11-14	Weathered sandstone	2010 – present
GW19	MB	308424	6394517	102.4	4.5 - 10.5	Alluvium and sandstone	2010 – present
GW21	MB	308647	6393378	121.8	24 - 36	Permian overburden	2010 – present
GW23	MB	305789	6395670	118.8	5.2-8.2	Alluvium	2017 – present
GW24	MB	305791	6395668	118.8	11.7-13.2	Weathered sandstone	2017 – present
GW25	MB	305297	6395291	129.6	2.6-5.6	Alluvium	2017 – present
GW26	MB	305299	6395288	129.4	11.7-13.2	Weathered sandstone	2017 – present
In-Stream 1	MB	305736	6395612	117.4	1.1 - 2.6	Alluvium	2019 – present
In-Stream 3	MB	306011	6395772	115.0	2.85 - 5.85	Alluvium	2019 – present
Site 11	MB	306076	6395716	118.6	5.5 - 8.5	Alluvium	2018 – present
Site 13	MB	306394	6395829	115.1	4.0 - 7.0	Alluvium	2019 – present
Site 16	MB	306592	6395946	110.0	4.0 - 7.0	Alluvium	2019 – present
Site 20	MB	306988	6396012	107.3	6.0 - 9.0	Alluvium	2019 – present
Site 23	MB	307357	6395779	104.2	2.5-4	Alluvium	2019 – present
Site 7a2	MB	305877	6395582	122.1	7.0-10.0	Alluvium	2019 – present
Site 7b	MB	305869	6395616	121.8	4.14 - 7.14	Alluvium	2019 – present
N2	VWP	308663	6393376	122.5	40	Permian overburden	2015 – 2016
					70	Permian overburden	2015 – present
					100	Permian overburden	2015 – present
					140	Whybrow Seam	2015 – present
					173	Inberburden	2015 - present
					204	Wambo Seam	2015 - present
N3	VWP	308314	6394575	105.0	30	Permian overburden	2015 - 2016
					55	Permian overburden	2015 – 2018
					75	Permian overburden	2015 – 2016
					109	Whybrow Seam	2015 – 2016

ID	Type	Easting	Northing	Ground Level (mAHD)	Screen (mbgl)	Target Lithology	Data Range
					142	Interburden	2015 – 2016
					190	Wambo Seam	2015 - 2016
N5	VWP	306755	6395963	110.8	30	Permian overburden	2015 - present
					73	Whybrow Seam	2015 – present
					89.5	Interburden	2015 – present
					133	Wambo Seam	2015 - present
UG139	VWP	306665	6395173	128.9	263	Unnamed D	2011 – present
					281	Unnamed E	2011 – present
					319	Interburden Glen Munro - Unnamed E	2011 – present
					329	Glen Munro	2011 – present
					375	Interburden Arrowfield - Glen Munro	2011 – present
					382	Arrowfield	2011 – present
					402	Interburden Warkworth - Bowfield	2011 – 2013

Note: *Coordinates in GDA94 Zone 56* *mAHD – metres Australian Height Datum*
Mbgl – metres below ground level



Scale: 1:24,000
GDA 1994 MGA Zone 56

27-Feb-2020
665.10008

\au.slr.local\Corporate\Projects-SLR\610-SrvSYD\660-WOL\665.10008 Wambo Groundwater\GIS\66510008 F07 Groundwater Monitoring Network.mxd

Sheet Size : A4

SLR
www.slrconsulting.com

Groundwater Monitoring Network

FIGURE 6

2.5.2 Groundwater Trends

Groundwater level trends for bores intersecting alluvium and regolith within the study area are presented in **Figure 7** compared to CRD. Alluvial bores GW23 and GW25 indicate the alluvium along NWC is unsaturated. The alluvial bores are paired with deeper bores within the regolith (GW24 and GW26) that record groundwater levels 5 m to 10 m below surface. Bores GW16 and GW17 intersect regolith further down-slope towards Montrose Pit and record groundwater levels 4 m to 12 m below surface. Both GW16 and GW17 show strong correlation with CRD until mid-2012. From 2012 there is a general decline in groundwater levels despite periods of average to above average rainfall, correlating with encroachment of open cut mining in Montrose Pit.

Figure 8 presents groundwater levels and electrical conductivity (EC) trends for the regolith bores. Bores GW16, GW24 and GW26 record similar EC of around 1,000 µS/cm to 2,000 µS/cm indicating fresh water quality. The three bores also show a general trend of rising EC with a decline in groundwater levels. In contrast bore GW17 records brackish water quality with an EC of around 5,000 µS/cm to 6,000 µS/cm. Review of bore logs as reported by PB (2009) shows that GW16 intersects alluvium and weathered sandstone, while GW17 is screened only within the weathered sandstone and siltstone.

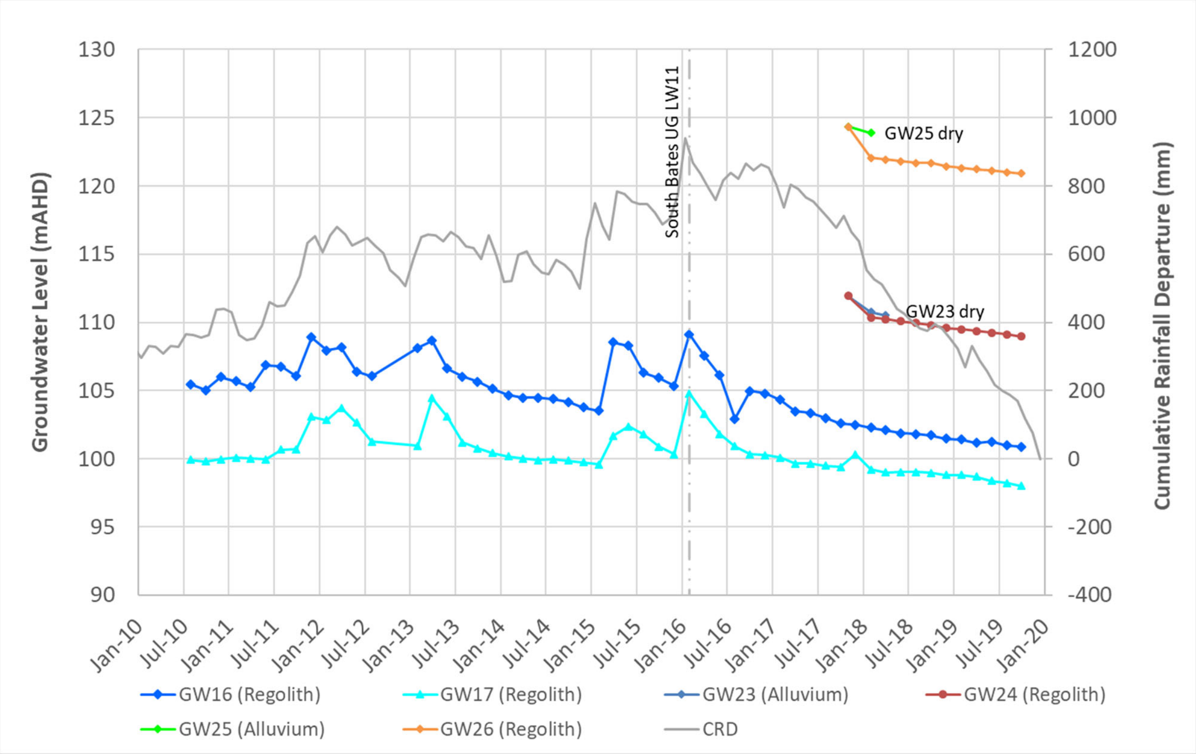


Figure 7 Hydrograph – North Wambo Creek Alluvium and Regolith vs CRD

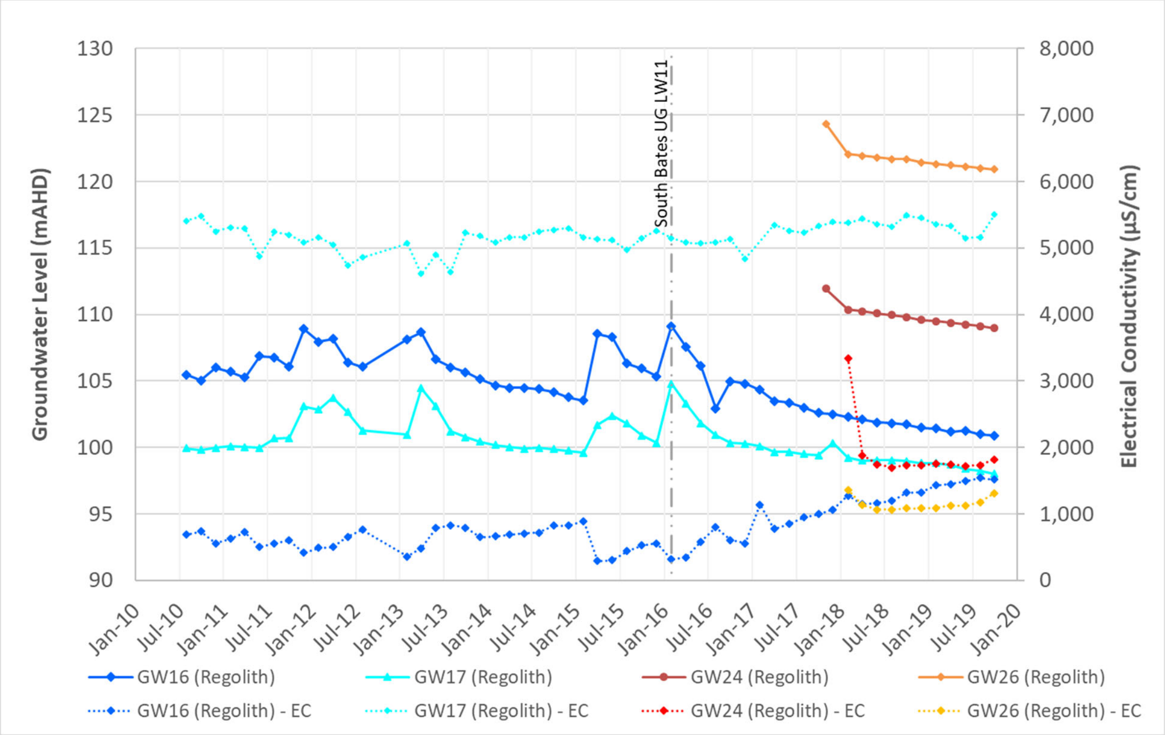


Figure 8 Regolith Groundwater Level vs EC

Figure 9 shows groundwater levels at GW21 in the Permian coal measures versus CRD and progression of mining at SBU. Bore GW21 recorded groundwater levels around 36 m below surface at around 85 mAHD, near the base of the bore. The bore has been recorded dry since 2016 but was potentially dry prior. Bore GW19 also intersects the Permian overburden to 10.5 m depth, but has been recorded as dry since 2003. This indicates the Permian coal measures are largely depressurised in response to historical mining in the area, with groundwater levels over 36 m below surface.

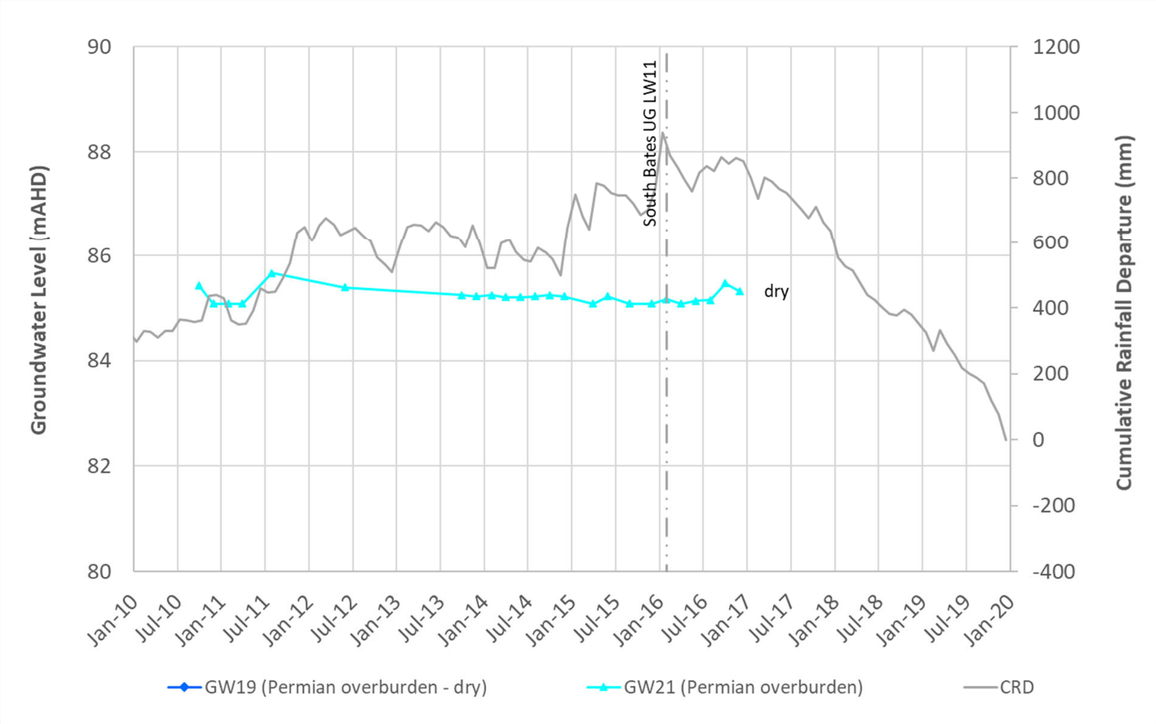


Figure 9 **Hydrograph – Permian Overburden vs CRD**

Potentiometric levels within the Permian coal measures at various depths are presented for VWPs N2, N3, N5 and UG139 in **Figure 10** to **Figure 13**. At N2 and N3, the Wambo Seam heads are similar (-10 to -20 mAHD) with substantial pressure heads (60 to 70 m). The Whybrow Seam heads also are similar at both locations (near 0 mAHD), again with substantial pressure heads (15 to 35 m). The sensor in the interburden between the two seams records a higher head at each location than observed in the Whybrow Seam (about 15 mAHD), whereas at N5 the head is very similar to that in the Whybrow Seam. This suggests mining-induced lateral depressurisation in the two seams, with less effect in the interburden.

At N3, the four lowest piezometers were destroyed on 25 May 2016 as SBU longwall 11 approached. The fifth sensor ceased to work from October 2018 with progression of longwall 16.

VWP N5 records groundwater elevations at around 88 mAHD and is located near regolith bore GW17, which records groundwater levels at around 98 mAHD. This indicates a downward gradient from the weathered regolith to the underlying fresh Permian overburden. N5 and UG139 record a gradual decline in groundwater elevations within the deeper sensors, in response to mining. VWP N5 shallow sensor (30 m depth) recorded relatively stable groundwater elevations until March 2019, after which time a slight 0.3 m decline in groundwater elevations was recorded. Sensors within the Whybrow Seam and interburden recorded a sharp change in groundwater elevations in March 2019.

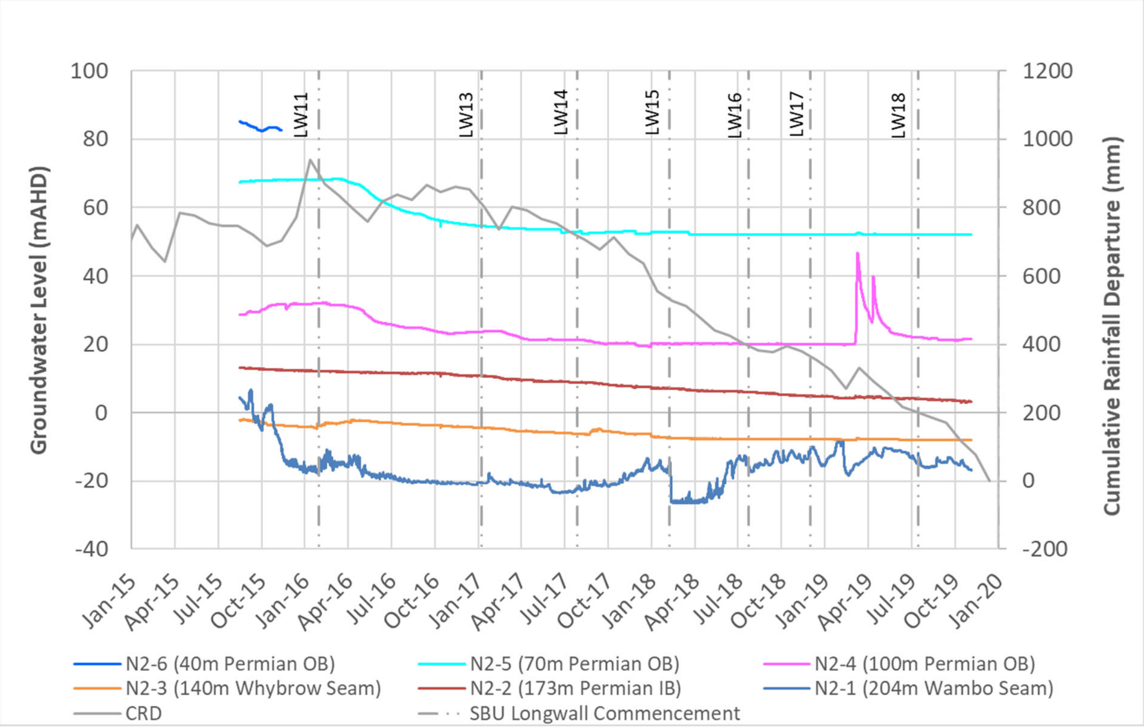


Figure 10 Hydrograph – VWP Bore N2

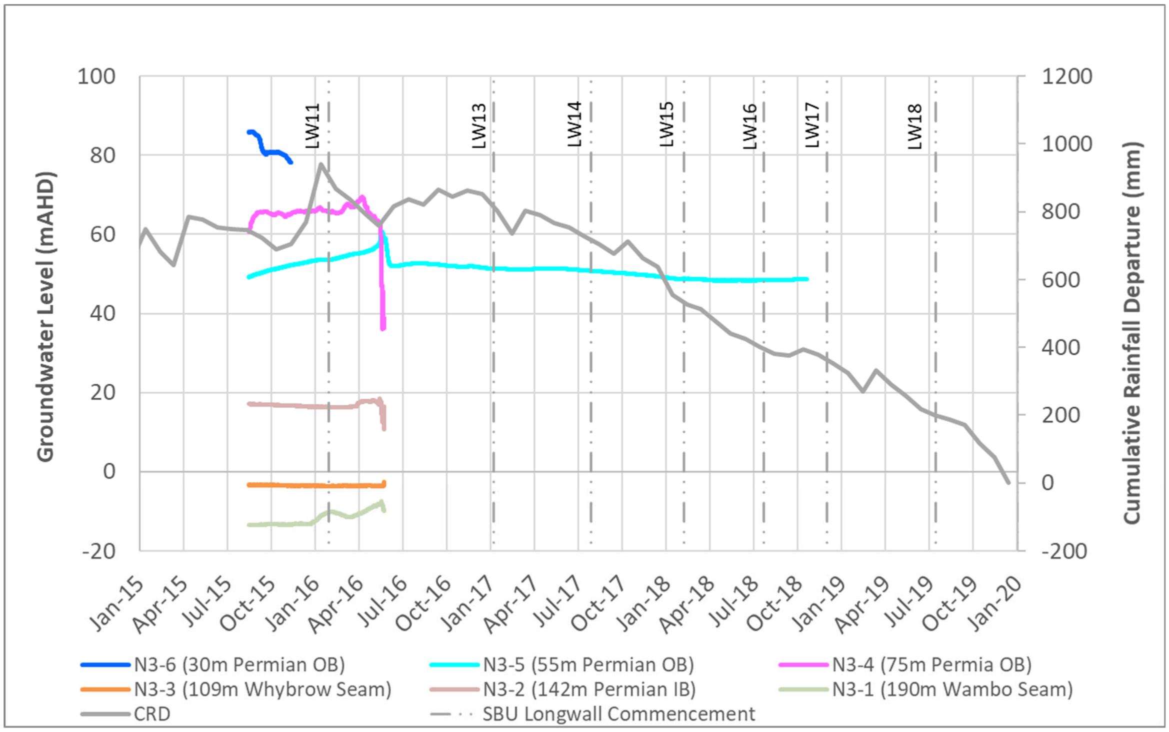


Figure 11 Hydrograph – VWP Bore N3

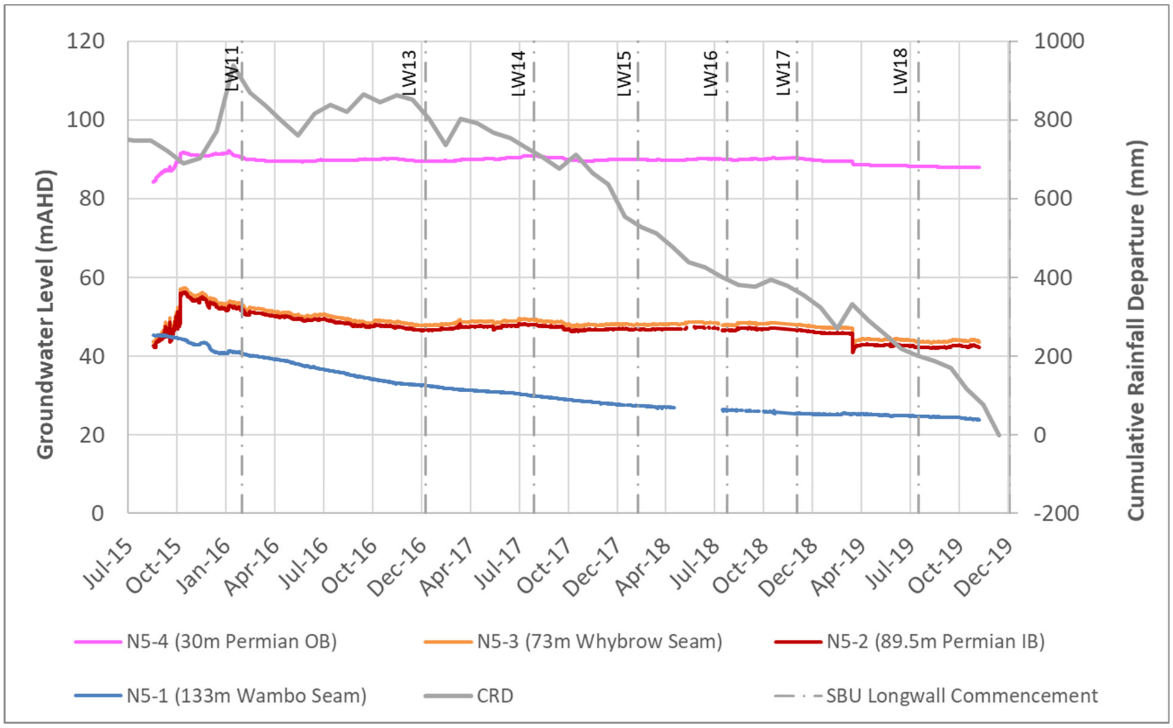


Figure 12 Hydrograph – VWP Bore N5

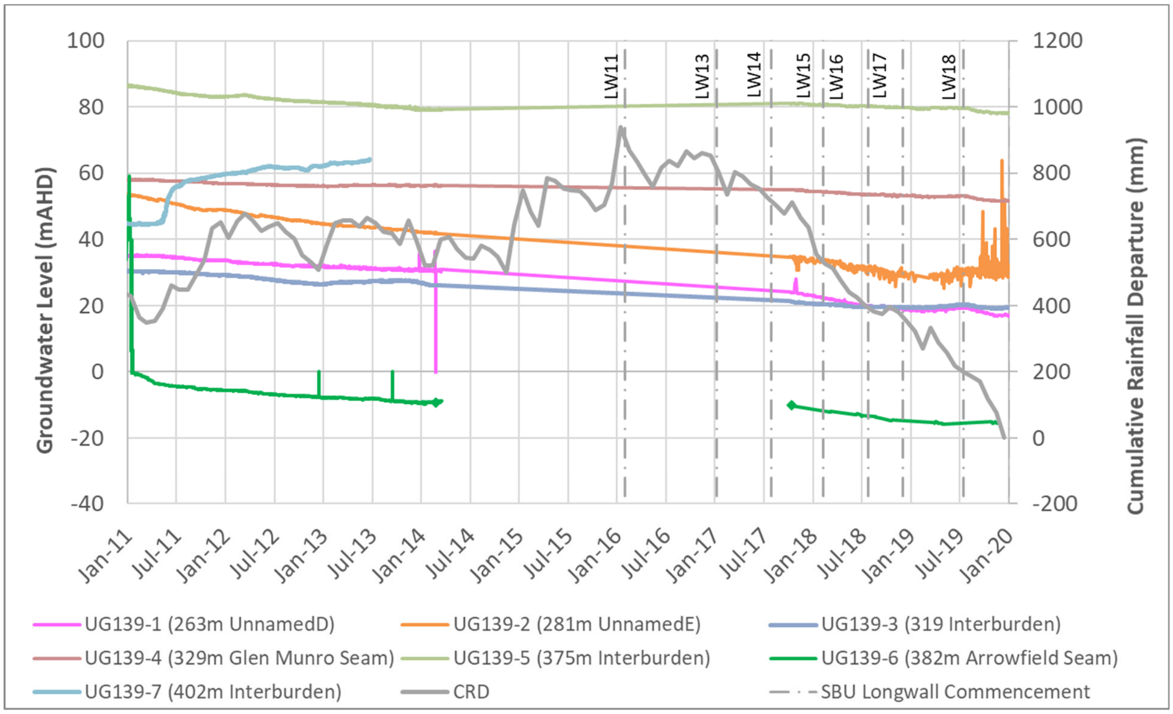


Figure 13 Hydrograph – VWP Bore UG139

3 Groundwater Modelling

3.1 Groundwater Model Setup

The study utilised the HydroSimulations (2018) numerical groundwater model, which was based on the groundwater model developed for the SBE groundwater assessment (HydroSimulations 2017). The updates in the HydroSimulations (2018) model included refined alluvial thickness (layer 1) based on field data along NWC and manual recalibration using recent observation data. Full details on the model updates and results are included in HydroSimulations (2018).

The HydroSimulations (2018) groundwater model utilises MODFLOW-USG code and was developed in Groundwater Vistas Version 7 (GWVistas 7). As part of this study the model grid was updated with greater discretisation along NWC and NWCD (**Figure 14)**, using the quadtree refinement function in GWVistas 7.

The model is roughly 19 km (EW) by 16 km (NS) at its widest extents and with the grid refinement has 2,253,746 total active cells. The model domain is discretised into 18 layers representing key geological units within the alluvium, Narrabeen Group and Wittingham Coal Measures. The model captures pre-mining conditions, including the natural alignment of NWC and alluvium, and the transient model replicates mine progression and the NWCD.

3.1.1 Model Timing

The stress period timing in the model was updated to include more temporal detail to better capture seasonal trends in recharge to alluvium along NWC. To achieve this, the historical and predictive stages of the model were updated to:

- Transient historical period from 1 January 2003 to December 2019 with monthly stress periods;
- Transient predictive period from January 2020 to December 2029 with monthly stress periods; and
- Transient predictive period from December 2029 to December 2040, with quarterly stress periods.

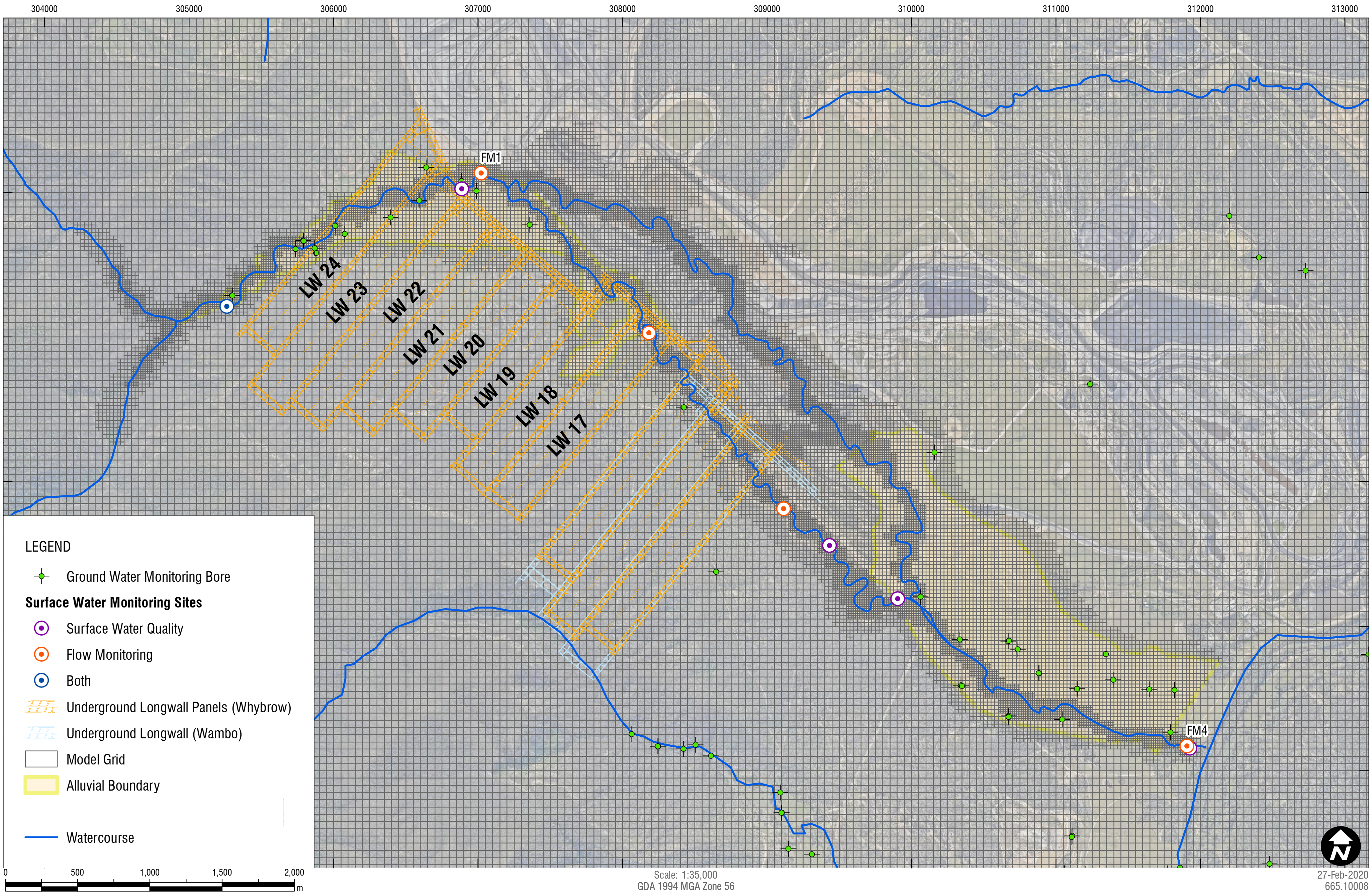
3.1.2 Model Scenarios

In order to calculate the impacts associated with mining at longwall panels 21 to 24 the following scenarios were run:

- NULL Run – No mining in region;
- Approved Run – All approved mining, excluding mining of SBU longwall 25; and
- NULL Extension Run – All approved mining excluding mining of SBU longwalls 21 to 25.

3.1.3 System Stresses

This section presents a summary of the main model inputs to replicate system stresses that were varied as part of this study, including streamflow, recharge and mining.



Scale: 1:35,000
GDA 1994 MGA Zone 56

27-Feb-2020
665.10008

\\au.slr.local\Corporate\Projects-SLR\610-SrvSYD\660-WOL\665.100008 Wambo Groundwater\GIS\66510008 F02 Model Grid v2.mxd

Sheet Size : A4

SLR
www.slrconsulting.com

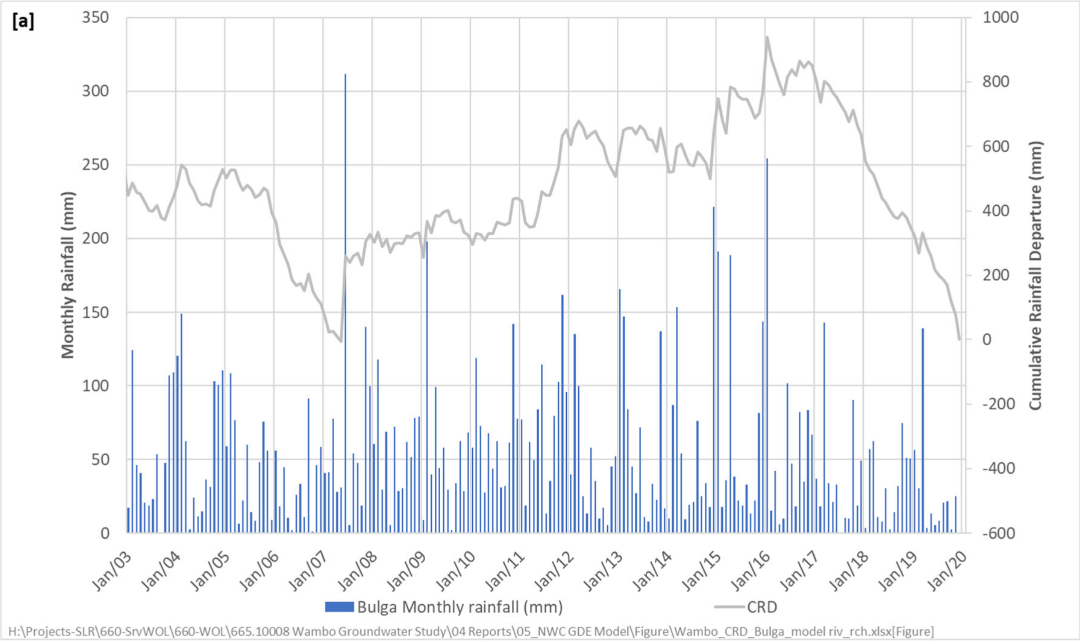
Model Grid

FIGURE 14

3.1.3.1 Streamflow

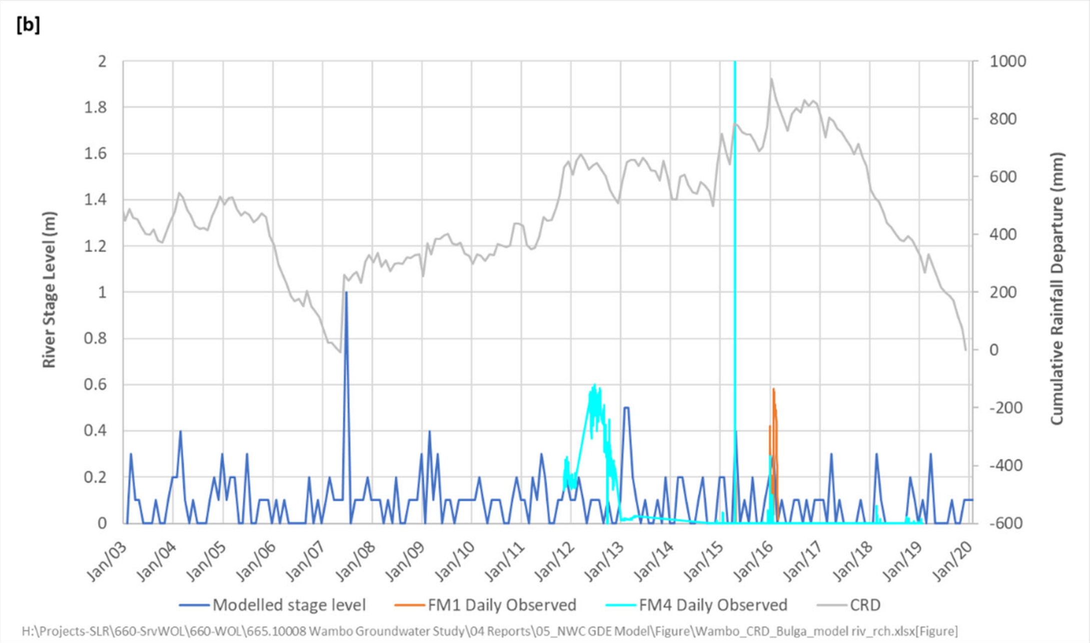
Groundwater interaction with surface drainage was simulated using the river package (RIV). The RIV package assumed a river bed elevation at the top of layer 1, which was defined based on site LiDAR data. Stream monitoring conducted along NWC was used to interpolate stage levels, and a simple relationship applied to interpolate stage levels historically based on observed rainfall (**Figure 15**). A positive river stage was applied in the model whenever a single daily rainfall event within a month recorded a total greater than 20 mm. Stage heights were scaled based on the magnitude of this daily rainfall event based on observed responses at flow monitoring stations. The modelled stage levels along NWC are presented in **Figure 16**, compared to observed daily levels at stream monitoring points FM1 and FM4. It is noted that with ongoing streamflow monitoring to be conducted along NWC and NWCD, this assumption in the model could be further refined in future.

Observations of stream levels along NWC and NWCD show that the creek is generally dry, with water present following peak rainfall periods (i.e. water present on specific days rather than constant for a full month). The groundwater model was set up with monthly stress periods, therefore to account for the higher water availability in the creek the RIV conductance term was set at 2 m/day for NWCD and NWC.



H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\04 Reports\05_NWC GDE Model\Figure\Wambo_CRD_Bulga_model riv_rch.xlsx[Figure]

Figure 15 Monthly Rainfall and CRD



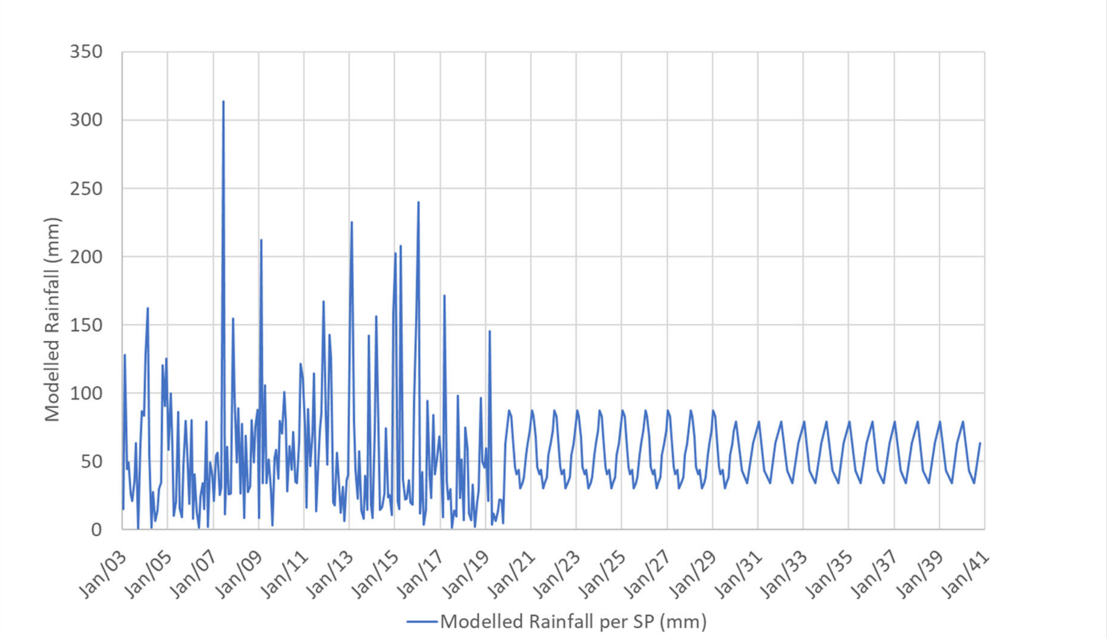
H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\04 Reports\05_NWC GDE Model\Figure\Wambo_CRD_Bulga_model riv_rch.xlsx[Figure]

Figure 16 Modelled NWC Stage Levels vs CRD

3.1.3.2 Recharge and Evapotranspiration

Diffuse rainfall recharge is simulated using the recharge package (RCH). Recharge was distributed in laterally distinct zones within the model domain. The zones are based on outcropping geology and were updated with the change in alluvial extent and depth by HydroSimulations (2018). A portion of annual rainfall was assigned to each zone and varied to match historical observed monthly rainfall.

Observed rainfall data from the Bureau of Meteorology (BoM) rainfall gauge at Bulga (Station 61143) was used to establish the modelled recharge (refer **Figure 15**). For the predictive model average monthly rainfall was applied from 2019 to 2029 and based on average quarterly rainfall for the quarterly stress periods from 2029. The modelled recharge for alluvium is presented in **Figure 17**. The percentages of rainfall used for rainfall recharge on alluvium is 1.2%.



H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\04 Reports\05_NWC GDE Model\Figure\Wambo_CRD_Bulga_model riv_rch.xlsx

Figure 17 Modelled Rainfall Recharge to Alluvium

Evapotranspiration from shallow water tables is simulated using the evapotranspiration package (ET). Evapotranspiration is represented in the top most cells of the model domain down to an extinction depth of 1 m to 8 m, dependent on ground vegetation as explained in HydroSimulations (2018). A uniform ET rate of 1 mm/day was applied to the model.

3.1.3.3 Mining

The MODFLOW Drain (DRN) package is used to simulate mine dewatering in the model for the Project and the surrounding mines. Drain boundary conditions allow a one-way flow of water out of the model. When the computed head drops below the stage of the drain, the drain cells become inactive (Rumbaugh, 2011). This is an effective way of theoretically representing removal of water seeping into a mine over time, with the actual removal of water being via pumping and evaporation.

Drain cells for open cut mining are applied in all layers from surface to the base of the lowest mined seam. For longwall extraction drain cells are only applied to the layer representing the mined coal seam. The hydraulic properties were varied with time using the Time-Variant Materials (TVM) package of MODFLOW-USG. For the underground mines, the hydraulic properties where changed with time in the goaf and overlying fractured zone directly above each longwall panel. The DRN and TVM packages were updated for the study to align with the updated model timing. The calibrated hydraulic and storage parameters were applied to the model consistent with HydroSimulations (2018).

3.2 Model Performance

Model performance was reviewed to ensure the updates to the model for the study did not impact on the ability of the model to replicate historical groundwater level trends. **Figure 18** presents the observed and simulated groundwater levels graphically as a scattergram. The industry standard method to evaluate the performance of the model is to examine the error between the modelled and observed (measured) water levels in terms of the root mean square (RMS). A root mean square (RMS) expressed as:

$$RMS = \left[1/n \sum (h_o - h_m)_i^2\right]^{0.5}$$

where: n = number of measurements

ho = observed water level

hm = simulated water level

RMS is considered to be the best measure of error, if errors are normally distributed. The RMS error calculated for the calibrated model is 11.8 m. If the ratio of the RMS error to the total head change in the system is small, the errors are only a small part of the overall model response. The total measured head change across the model domain is 245 m; therefore, the ratio of RMS to the total head loss (SRMS) is 4.8 % with no weighting applied to the values. This indicates adequate calibration for a local scale model (Barnett *et al*., 2012), with the best performance in matching groundwater level trends at bores within the study area, as presented in calibration hydrographs in **Appendix A**. The average residuals for points around the study area are also presented in **Figure 19**. The residuals were calculated as observed minus modelled, therefore a positive value indicates observed levels are higher than modelled and vice versa.

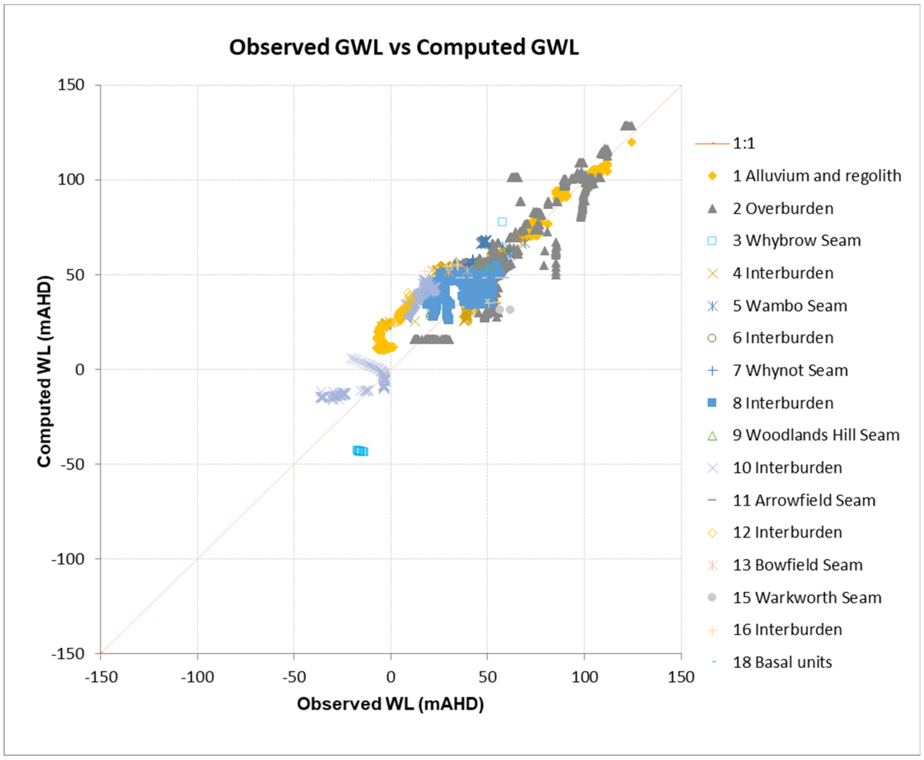
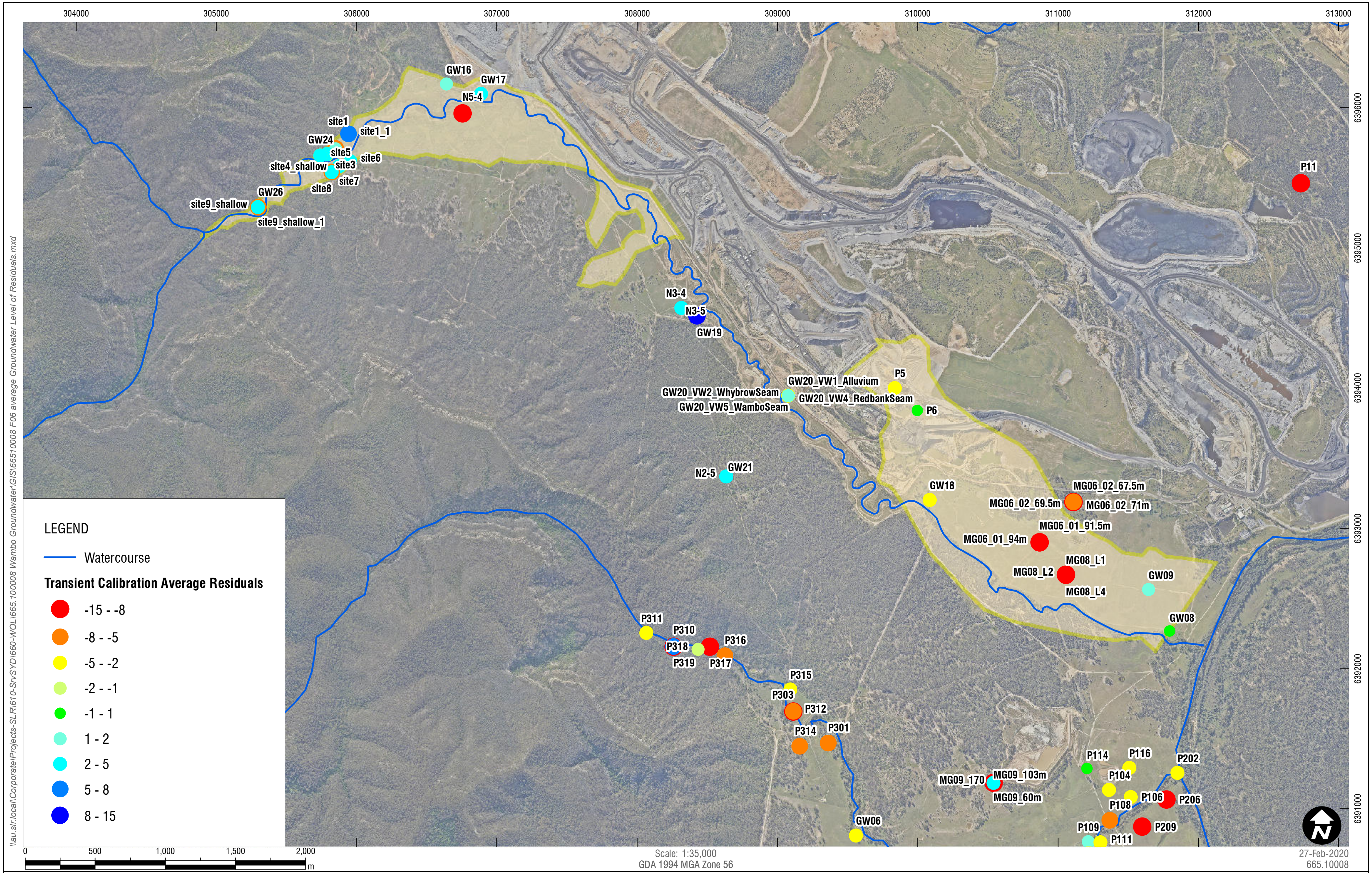


Figure 18 Modelled vs Observed Groundwater Levels



Sheet Size : A4

SLR
www.slrconsulting.com

Average Groundwater Level of Residuals

FIGURE 19

3.3 Groundwater Modelling Results

3.3.1 Mine Inflows

Predicted groundwater inflows from the Permian coal measures to active mining in SBU is presented in **Figure 20**. The graph shows that extraction of Longwalls 21 to 24 will result in up to 0.19 ML/day (69 ML/year) of groundwater inflows, lower than the predicted inflows for 2017 with mining of the Wambo Seam in longwall panels 13 and 14. These predictions are within the range of inflows predicted by HydroSimulations (2017).

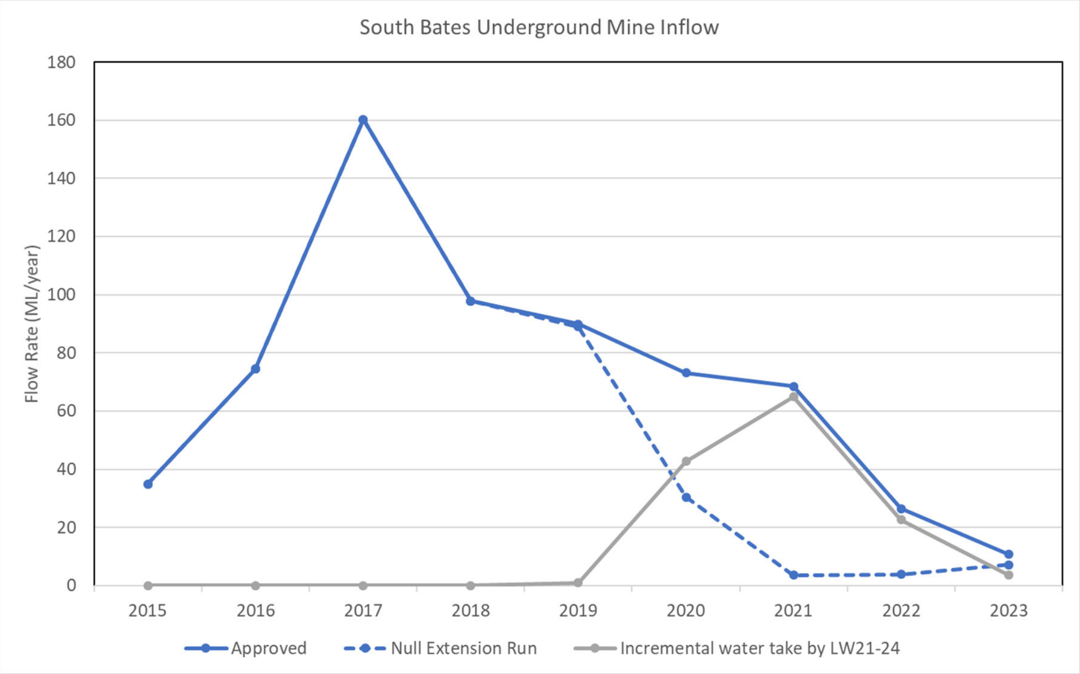


Figure 20 Predicted Mine Inflow for South Bates Underground

3.3.2 Groundwater Drawdown

This section presents the predicted groundwater level drawdown for all operations based on comparison between the NULL run and Approved run. The results are based on the period of active mining at SBU and SBE (Longwalls 11 to 24) from 2016 to 2023 (SP157 to SP252). The incremental additional drawdown due to mining at Longwalls 21 to 24 has also been calculated by comparing NULL Extension Run minus the approved run. The predicted maximum drawdowns are cumulative as they include the effects of concurrent surrounding underground and open cut mining.

Figure 21 shows the predicted cumulative maximum drawdown in layer 1 (alluvium and regolith) following completion of mining. Negligible incremental drawdown is predicted in layer 1 (alluvium and regolith) for the entire duration of the SBE (**Figure 22**). The negligible drawdown is largely a function of the current modelled unsaturated conditions in layer 1. The cumulative drawdown also shows historical drawdown within the open cut area where the alluvium along the original alignment of NWC was mined through.

Figure 23 shows the predicted cumulative maximum drawdown in the Whybrow Seam (Layer 3) following completion of mining. A similar drawdown extent is predicted for the overburden material in Layer 2. **Figure 24** shows the difference in maximum drawdown between the Approved Run and the Null Extension Run from SP157 to SP252. In the Whybrow Seam, mining is expected to generate cumulative maximum drawdowns of up to 200 m over the SBE Longwalls 17 to 24, and also over the SBU Longwalls 11 to 13. Comparison of the predicted difference between the maximum drawdown for the Approved and Null Extension Runs (**Figure 24**) shows that the drawdown in the Whybrow Seam over the SBE Longwalls 21 to 24 is attributable to the Extension.

For longwalls 21 to 24, the 2 m drawdown extent in the Whybrow Seam is predicted to remain within 500 m from the extent of the mined panel. As outlined in **Section 2.2.1**, there are no private water supply bores within 2km of the study area, therefore there are no expected impacts on landholder bores.

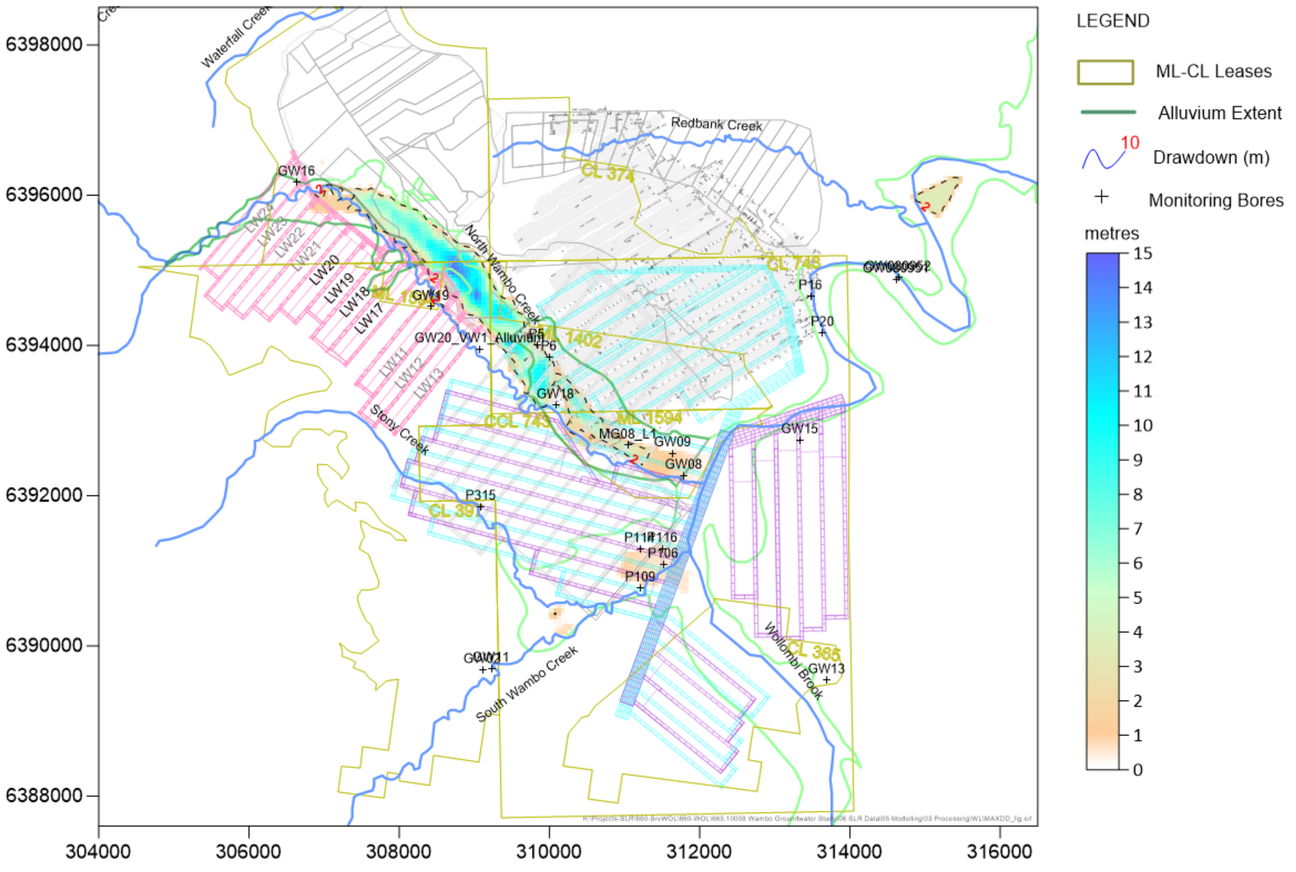


Figure 21 Cumulative Maximum Drawdown (m) in Alluvium/Regolith during Longwalls 17 to 24 Mining

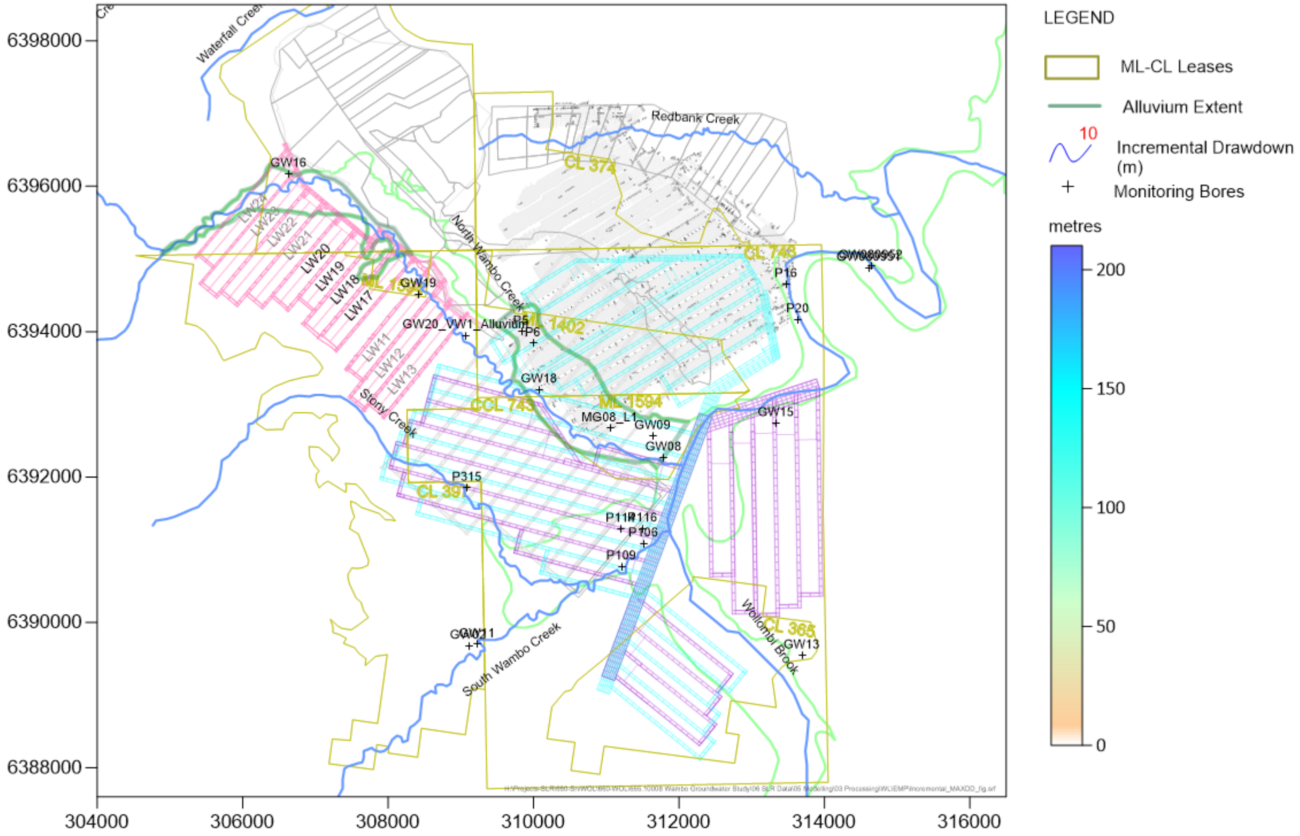


Figure 22 Incremental Maximum Drawdown (m) in Alluvium/Regolith due to Longwalls 21 to 24 Mining

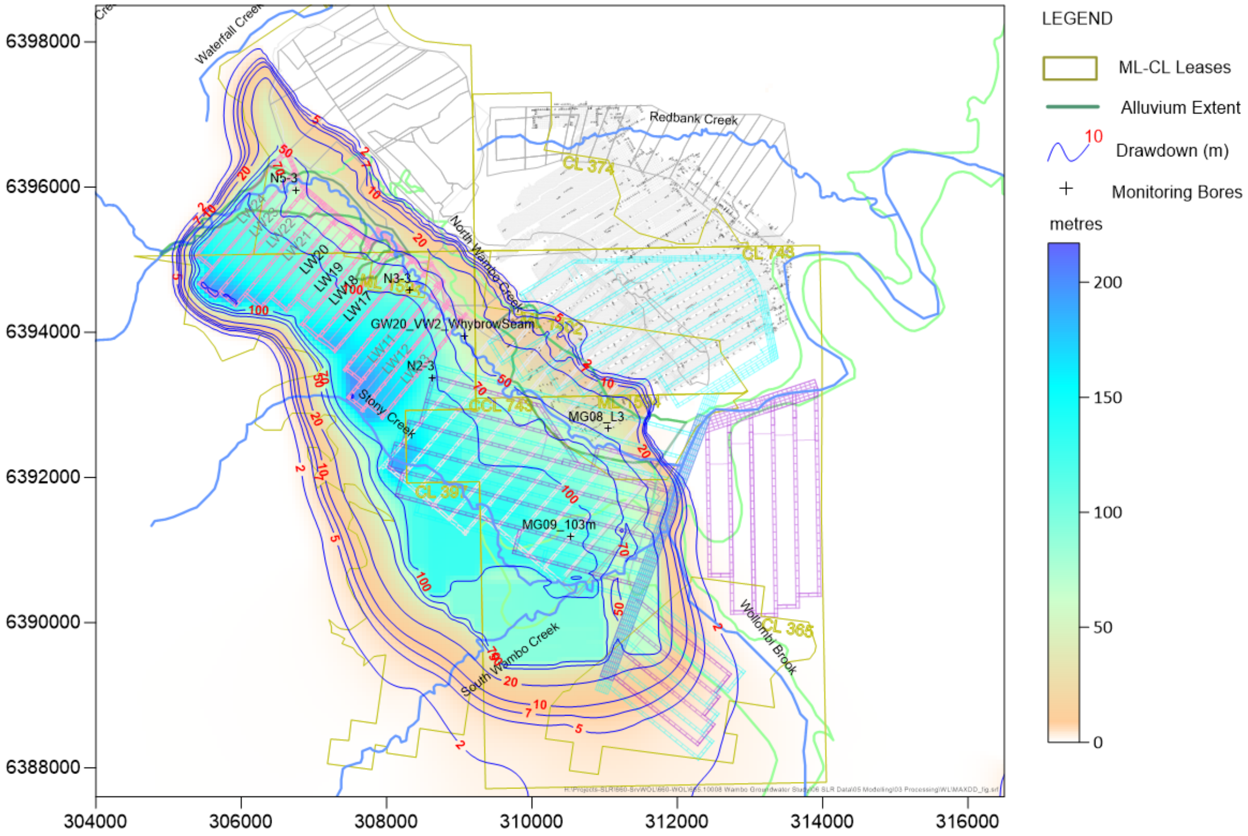


Figure 23 Cumulative Maximum Drawdown (m) in Whybrow Seam during Longwalls 17 to 24 Mining

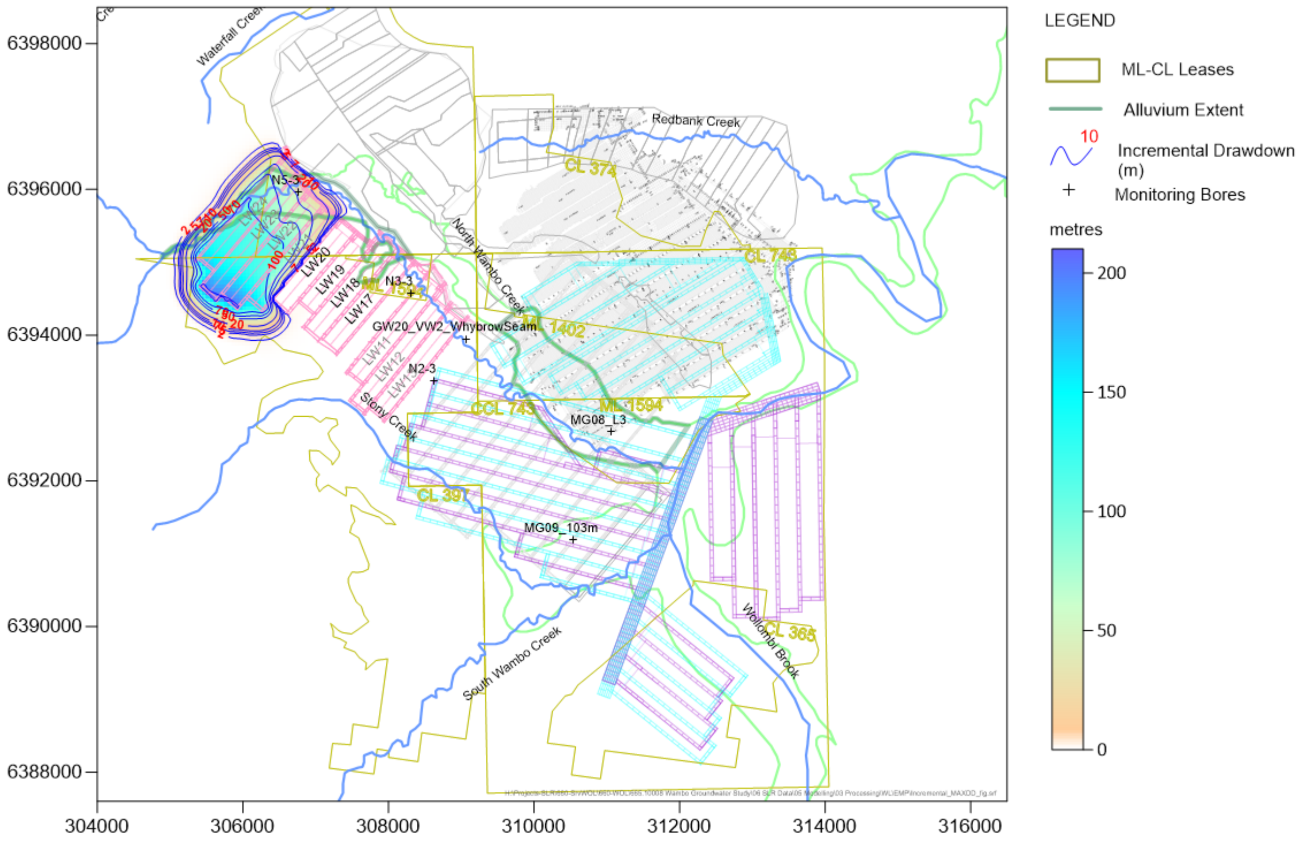


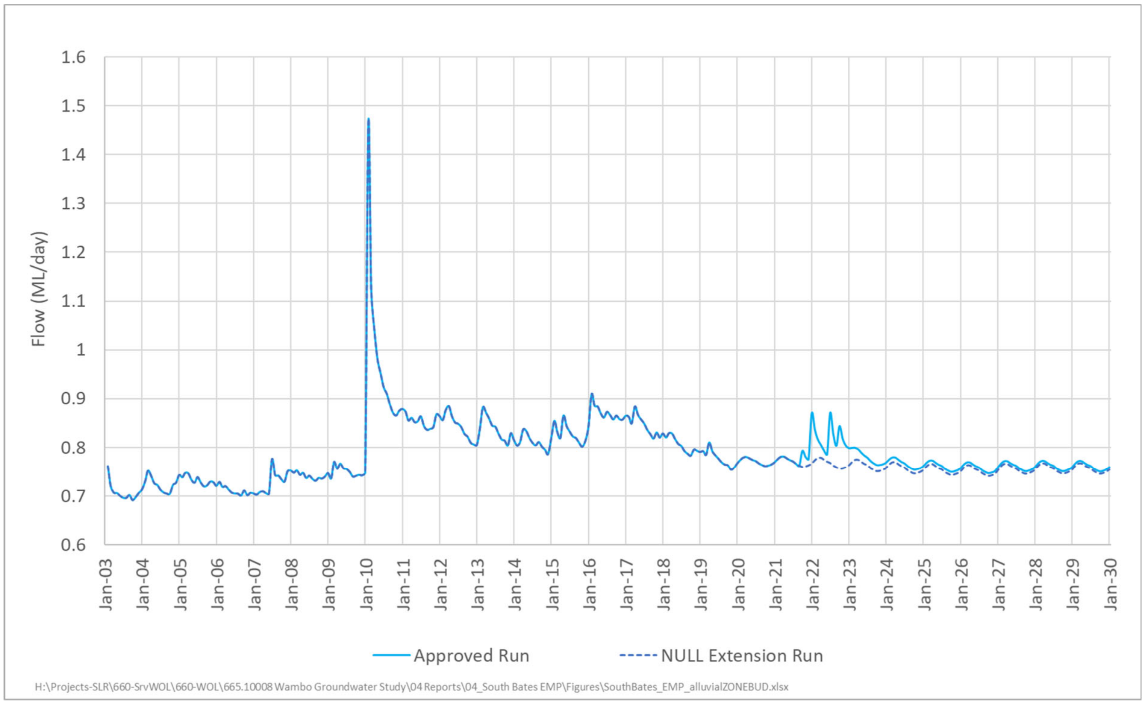
Figure 24 Incremental Maximum Drawdown (m) in Whybrow Seam due to Longwalls 21 to 24 Mining

3.3.3 Groundwater Take - Alluvium and Regolith

As outlined in **Section 2.3.1** the alluvium is localised along NWC and generally 4 m to 10 m thick. Weathered sandstone (regolith) is present across the study area at surface, and underlying alluvium. As discussed in **Section 2.5.2**, alluvial bores across the site show unsaturated alluvial conditions, but saturated conditions within the regolith with water levels around 4 m to 12 m below surface. Groundwater within the regolith exhibits fresh to brackish water quality, with increasing salinity with depth of strata (within Permian coal measures).

The predicted vertical flow from the alluvial/regolith (layer 1) for the Approved and NULL Extension Run are shown in **Figure 17**. The maximum total interception of shallow groundwater for the approved operations is predicted at 0.87 ML/day, derived from the regolith. The graph shows that mining of Longwalls 21 to 24 will induce up to 0.10 ML/day of additional interception of groundwater compared to current mining SBE.

There is no predicted additional take from highly productive alluvium associated with the Wollombi Brook and Hunter River as a result of extraction of longwalls 21 to 24.



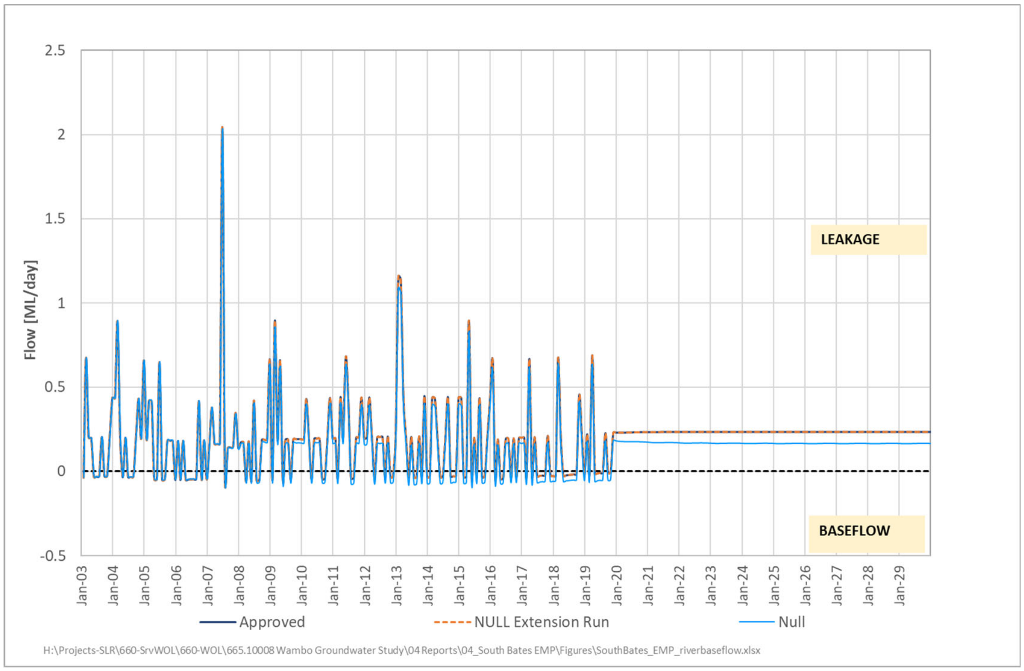
H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\04 Reports\04_South Bates EMP\Figures\SouthBates_EMP_alluvialZONEBUD.xlsx

Figure 25 Predicted Groundwater Take – Layer 1

3.3.4 Baseflow Loss

NWC is ephemeral, with flows influenced by rainfall trends. The creek is characterised as dominantly having losing conditions, with limited baseflow contributions. This has been replicated in the groundwater model, with the flow change for the RIV package along NWC and the NWCD near the study area presented in **Figure 26** for the three model scenarios.

The difference between the Approved and Null run shows the overall indirect take from the surface water system for the approved operations. **Figure 26** shows a maximum predicted additional seepage from the creek to the underlying strata of up to 0.1 ML/day for approved operations. This is consistent with predictions for the SBE (HydroSimulations 2017). There is negligible difference predicted between the Approved and Null Extension Run (i.e. negligible contribution due to Longwalls 21 to 24).



H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\04 Reports\04_South Bates EMP\Figures\SouthBates_EMP_riverbaseflow.xlsx

Figure 26 Predicted NWC River Flow Change

4 Environmental Risk Review

An Environmental Risk Assessment (ERA), was undertaken in February 2020. The scope of the risk assessment included:

- establishing the context including review of supporting information and objectives;
- identifying potential issues by review of the project description and similar issues from previous Wambo risk assessments;
- analysis of identified risks and nomination of key environmental issues; and
- ranking of the key issues and associated risks, including consideration of mitigation measures.

The ERA identifies environmental issues and ranks these issues in consideration of control measures. As part of the ERA, a risk review team identified the key environmental issues associated with the project, including those related to (Risk Mentor, 2020):

- impacts on NWC flow regime associated with subsidence resulting from the underground mine;
- impacts on shallow groundwater sources (i.e. regolith and alluvium) with subsidence resulting from the underground mine;
- impacts on groundwater users in the study area with groundwater loss, including private landholders and vegetation;
- impacts of subsidence on the existing NWCD;
- incremental increases in subsidence induced ponding effects on areas of agricultural land;
- potential subsidence impacts on the groundwater monitoring network;
- potential subsidence impacts on cliffs and steep slopes; and
- potential subsidence impacts on items of Aboriginal heritage.

The review team risk ranked the key environmental issues and concluded that with the application of the identified controls, the subsidence related impacts over Longwalls 21 to 24 could be managed at a tolerable level of risk (Risk Mentor, 2020). Ongoing actions were identified with regards to surface remediation requirements in potentially impacted areas of NWC to manage the flow regime, as well as ongoing management of the groundwater monitoring network to maintain a long-term monitoring program.

5 Conclusions

The key findings of this groundwater assessment review are:

1. The alluvium adjacent to the SBE footprint has been disconnected from the regional alluvial system due to the removal of alluvium downstream of the longwalls by the approved open cut mining operations (and associated construction of the NWCD).
2. The alluvium adjacent to the SBE footprint has been affected by open cut mining activities, with several metres of drawdown in the alluvium and regolith observed to date.
3. There is expected to be negligible impact on the highly productive alluvium associated with the Wollombi Brook and Hunter River as a result of extraction of Longwalls 21 to 24.
4. Extraction of Longwalls 21 to 24 would not result in reduced beneficial uses of the alluvium (from a water quality perspective).
5. There are no bores above the SBE footprint that are used for irrigation, domestic or stock use. There are no private registered bores that would be likely to be affected by 2 m drawdown or more if Longwalls 21 to 24 were to occur in isolation.
6. Site monitoring bores have the potential to be impacted during mining, therefore review of the condition of the monitoring network will be undertaken during each sampling event, and bores remediated/replaced as required, to maintain a long-term monitoring network.
7. Drawdowns up to 200 m, due to extraction of Longwalls 21 to 24, are expected in the Whybrow Seam in accordance with the depth of cover.
8. Extraction of Longwalls 21 to 24 would not have a significant impact on water levels in the Permian coal measures from a regional perspective due to the regional zone of depressurisation within the Permian coal measures created by historical and ongoing open cut and underground mining.
9. Extraction of Longwalls 21 to 24 would not lower the beneficial use category of the groundwater within the Permian aquifers, as there would be no migration of groundwater away from the underground mining areas in the Permian aquifers either during mining or following completion of mining activities.
10. There is an expectation of enhanced leakage from the NWC if the creek happens to flow during the period of extraction of Longwalls 21 to 24 underneath the diversion.
11. Negligible loss of baseflow to the natural NWC is expected due to extraction of Longwalls 21 to 24, however, surface remediation is required to maintain the long-term flow regime along NWC (MSEC 2020).

The groundwater data analysis, based on currently available records, has shown that there are no observed material impacts from longwall mining beyond what was foreseen for the cumulative impacts described in the South Bates Extension Modification – Groundwater Assessment (HydroSimulations, 2017).

6 References

AGE, 2019a. *Wambo Coal Mine – Alluvial drilling and monitoring bore installation report – Phase 1*, Prepared for Peabody Energy, January 2018.

AGE, 2019b. *Wambo Coal Mine – Alluvial Drilling and Monitoring Bore Installation Report – Phase 2*, Prepared for Peabody Energy, July 2018.

HydroSimulations, 2017. *South Bates Extension Modification Groundwater Assessment*. HydroSimulations Report HC2016/51, prepared for Wambo Coal, February 2017.

HydroSimulations, 2018. *Advice on additional alluvial investigation sites at North Wambo Creek.* HydroSimulations Report HS2018/54, October 2018.

MSEC, 2020. *South Bates Extension Subsidence Assessment*, prepared for Wambo Coal, Report No. MSEC1080.

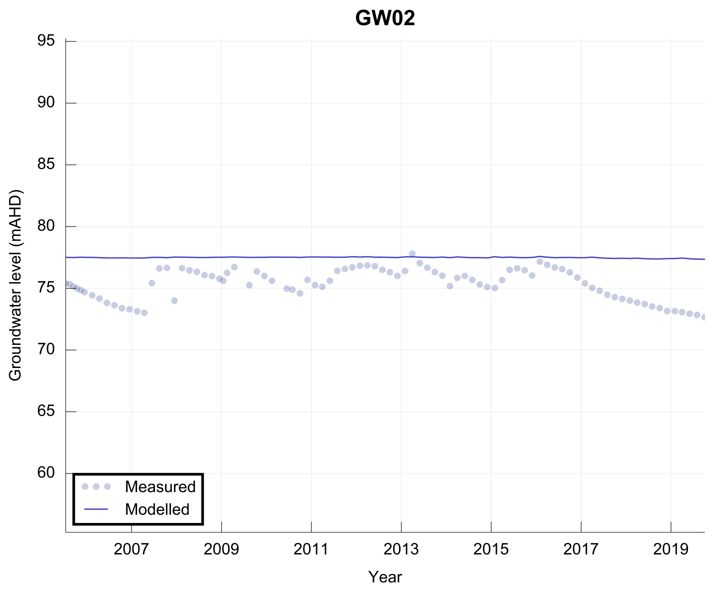
Parsons Brinckerhoff, 2009. *Piezometer Installation for Groundwater Monitoring, Wambo Coal Mining*, December 2009.

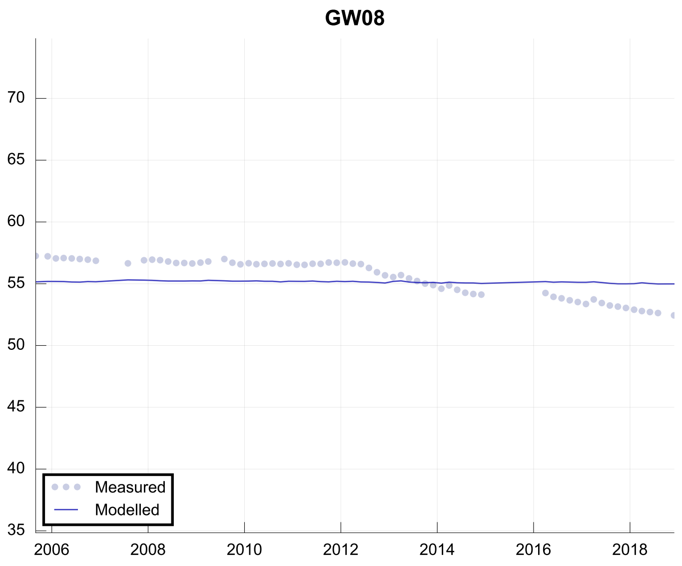
Risk Mentor, 2020. *Wambo U/G South Bates Extension – Longwalls 21-24 – Extraction Risk Assessment Report*, February 2020.

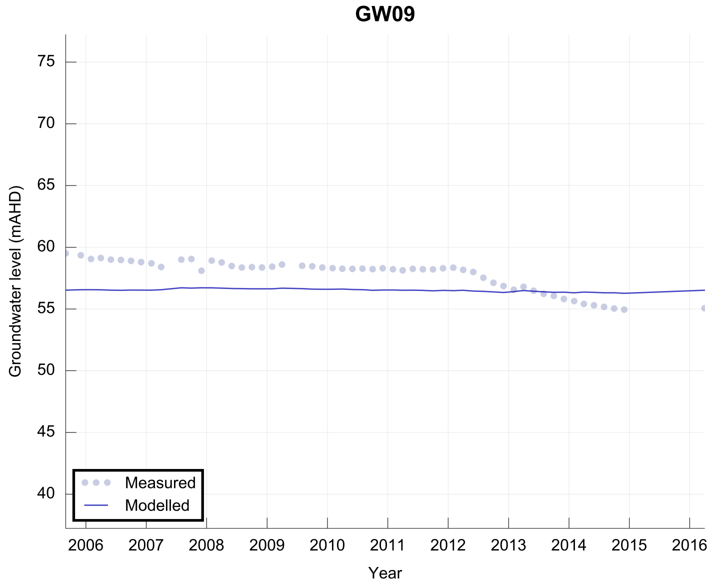
SLR, 2017. *Wambo Drilling Program – Upper North Wambo Creek, Prepared for Peabody Energy*, December 2017.

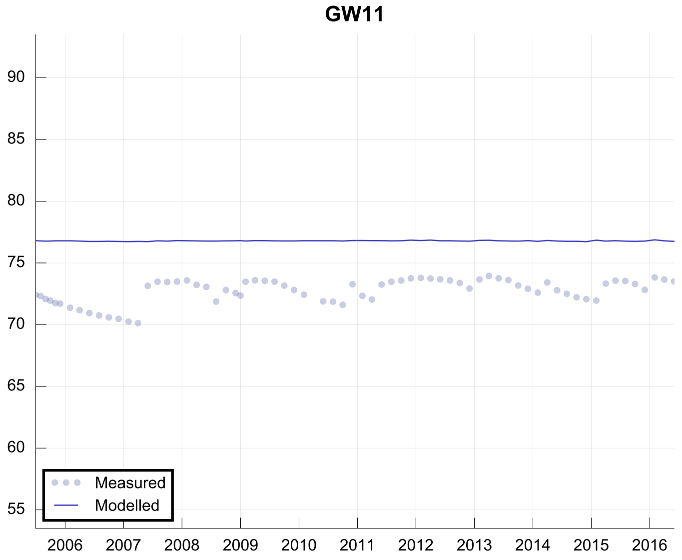
APPENDIX A

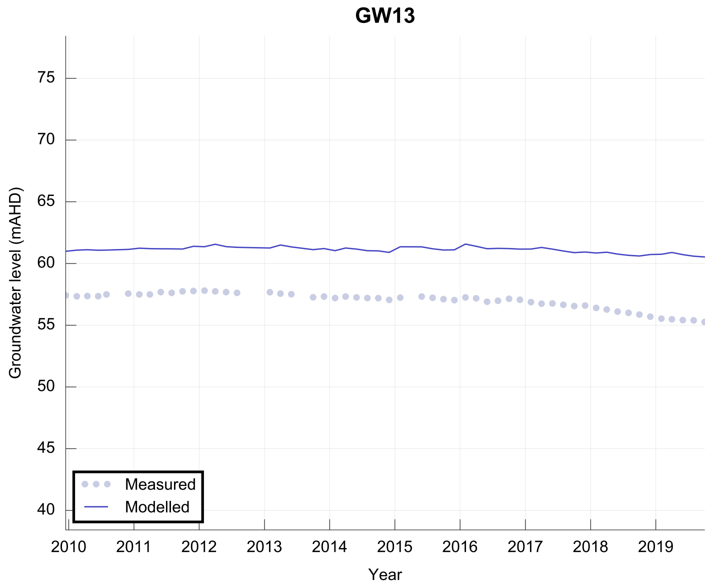
Calibration Hydrographs

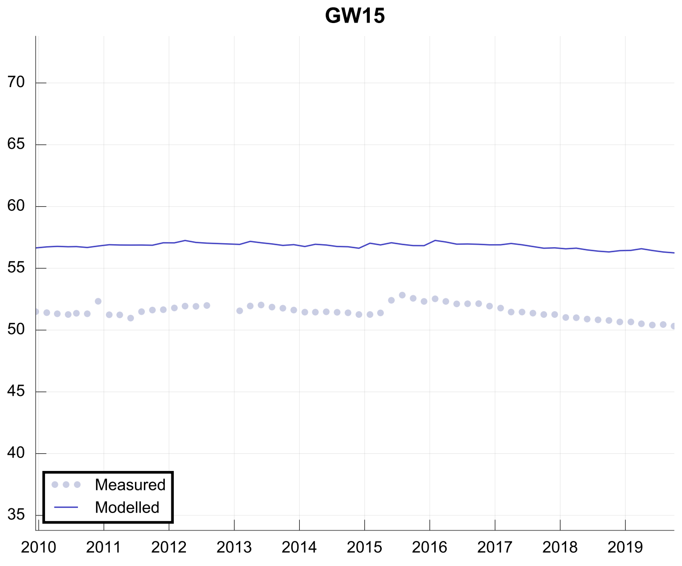

GW02
Groundwater level (mAHD)
95
90
85
80
75
70
65
60
2007
2009
2011
2013
2015
2017
2019
Year
Measured
Modelled

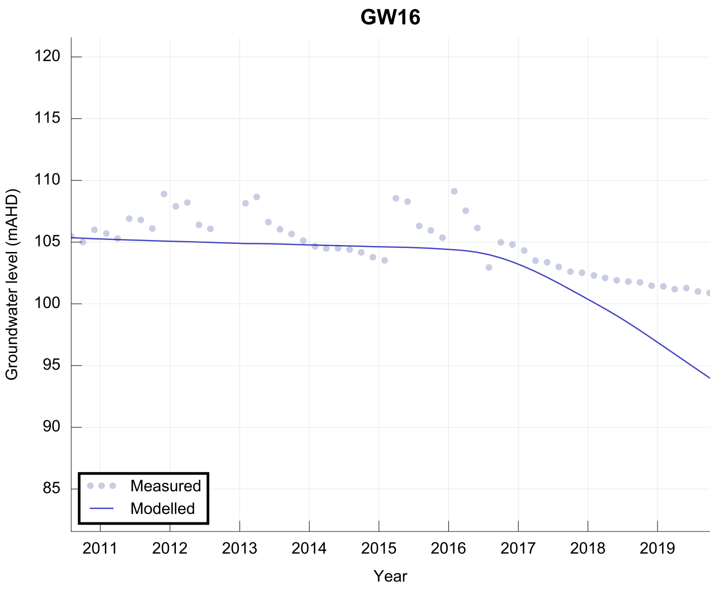

GW08
70
65
60
55
50
45
40
35
2006
2008
2010
2012
2014
2016
2018
Measured
Modelled

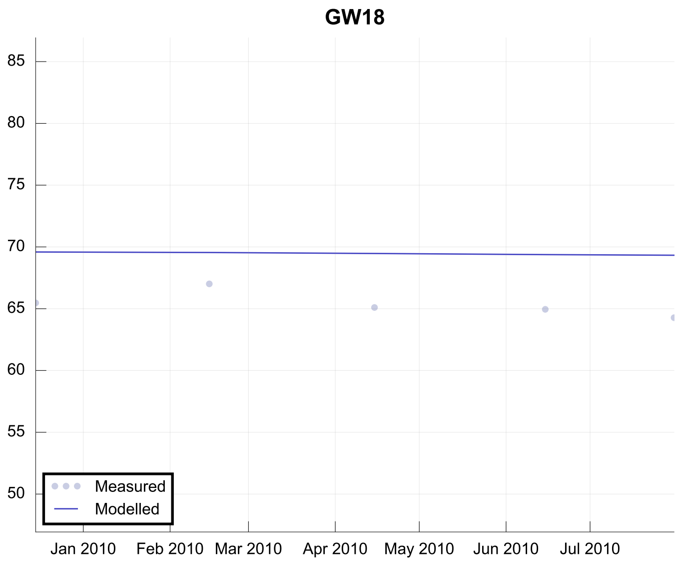

GW09
Groundwater level (mAHD)
75
70
65
60
55
50
45
40
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Year
Measured
Modelled

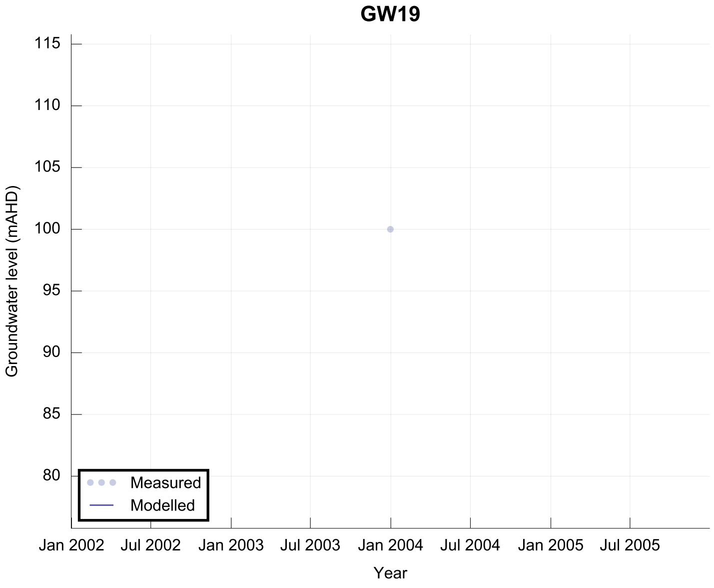

GW11
90
85
80
75
70
65
60
55
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Measured
Modelled

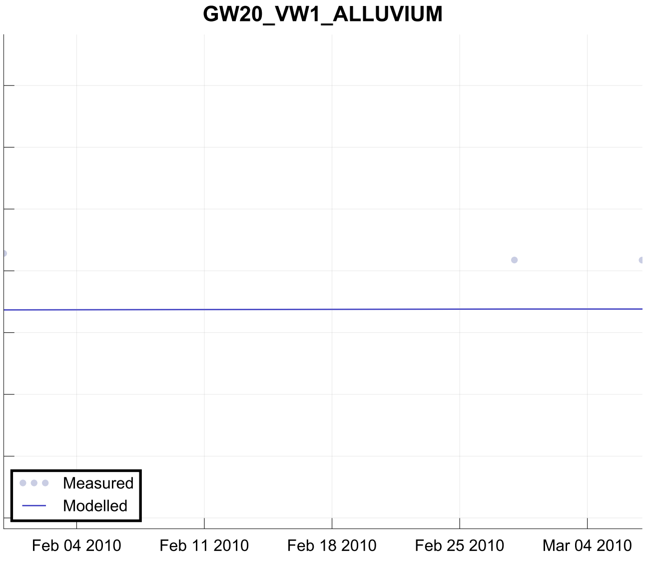

GW13
Groundwater level (mAHD)
75
70
65
60
55
50
45
40
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Year
Measured
Modelled

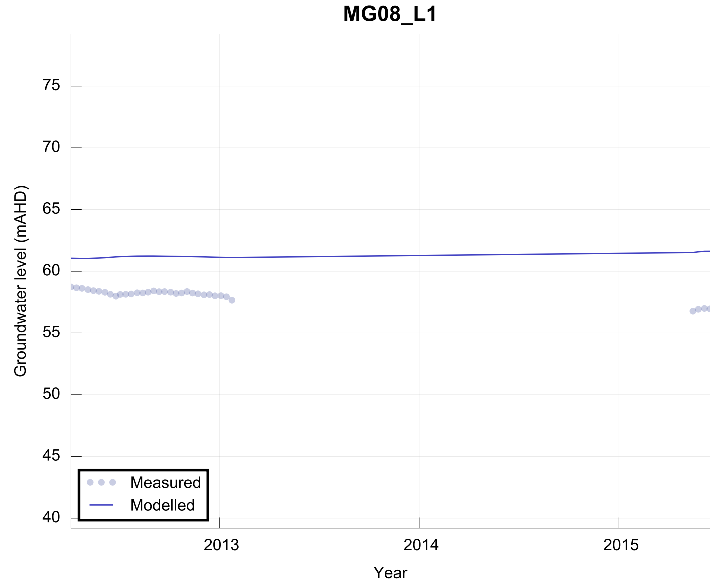

GW15
70
65
60
55
50
45
40
35
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Measured
Modelled

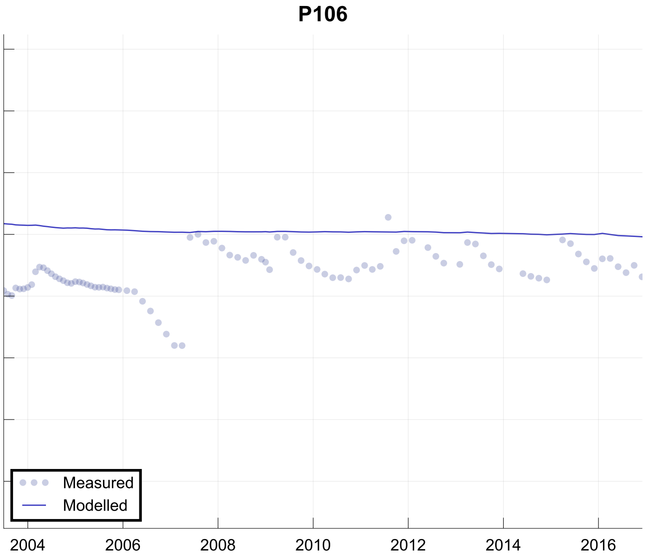

GW16
Groundwater level (mAHD)
120
115
110
105
100
95
90
85
2011
2012
2013
2014
2015
2016
2017
2018
2019
Year
Measured
Modelled

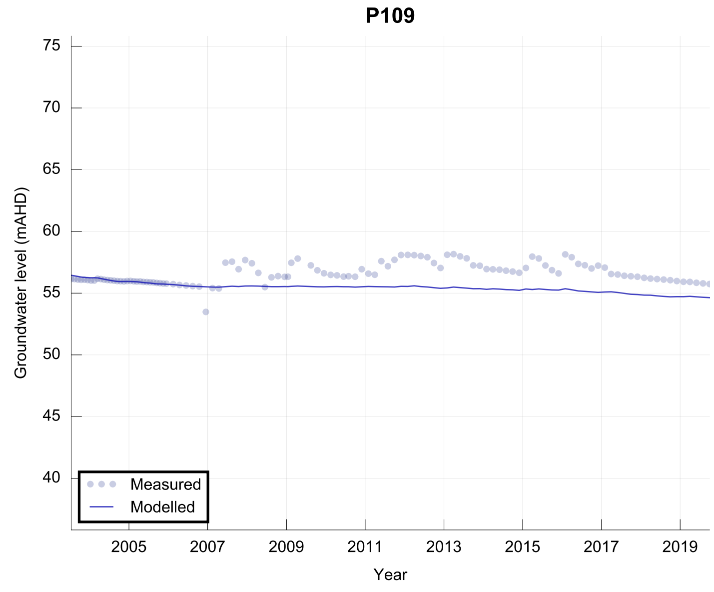

GW18
85
80
75
70
65
60
55
50
Jan 2010
Feb 2010
Mar 2010
Apr 2010
May 2010
Jun 2010
Jul 2010
Measured
Modelled

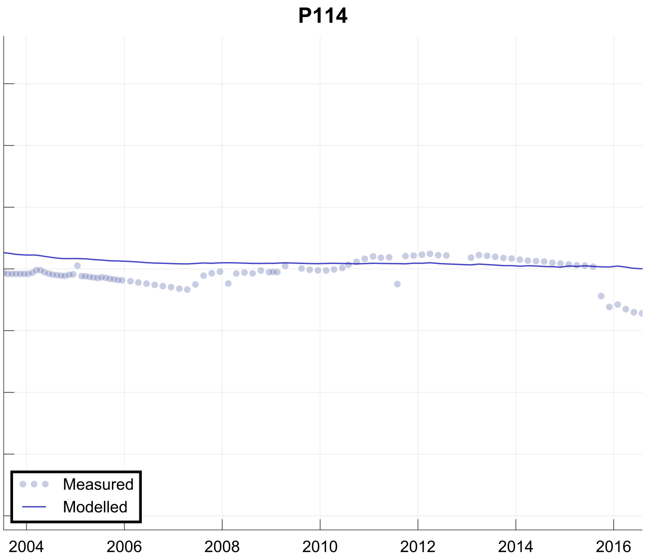

GW19

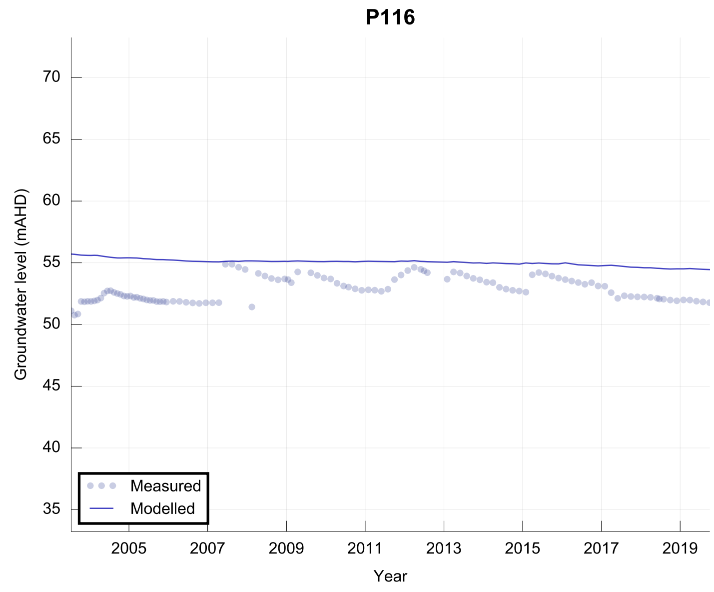

GW20_VW1_ALLUVIUM

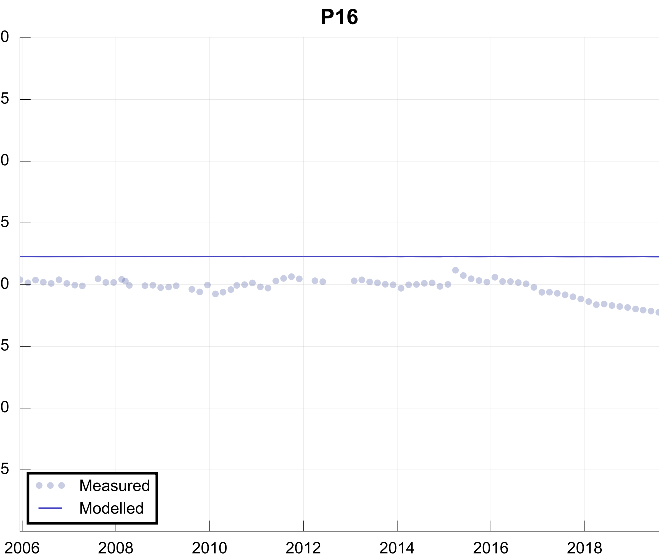

MG08_L1

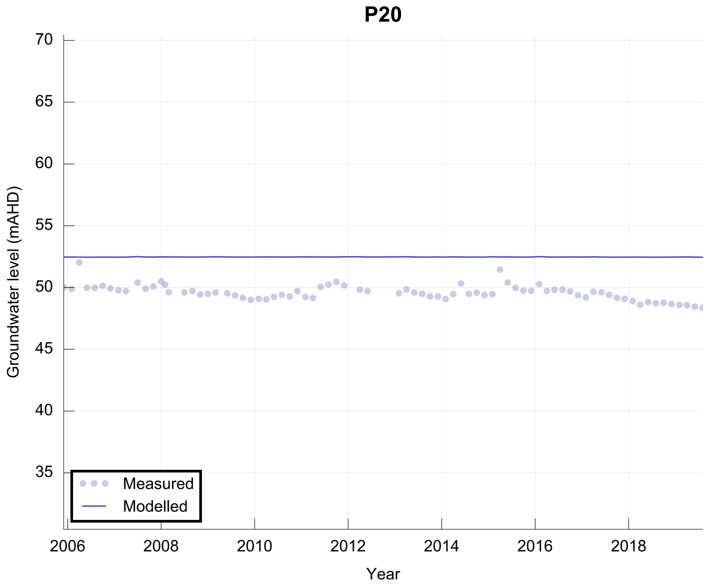

P106

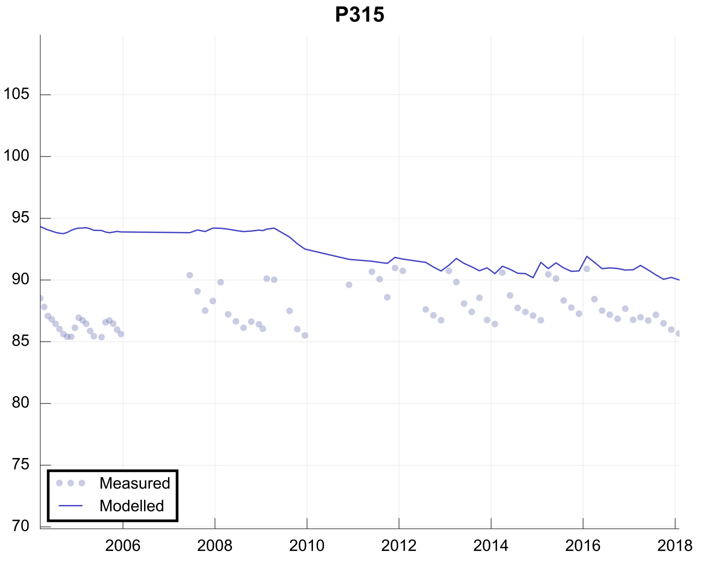

P109

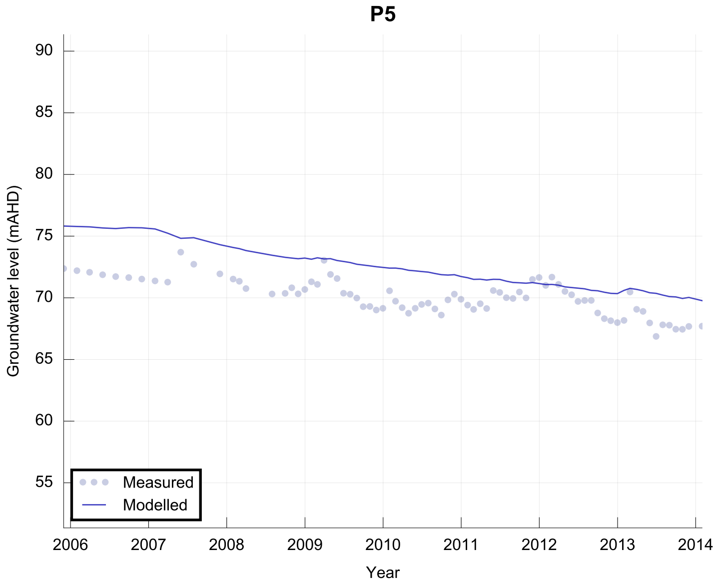

P114

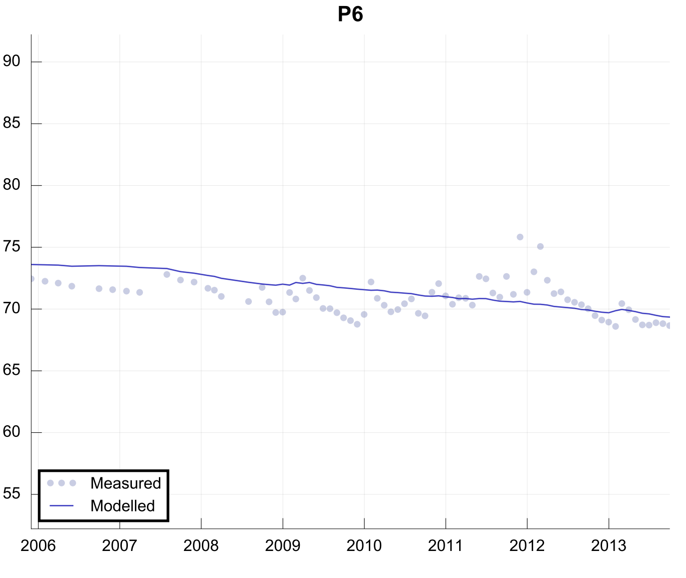

P116

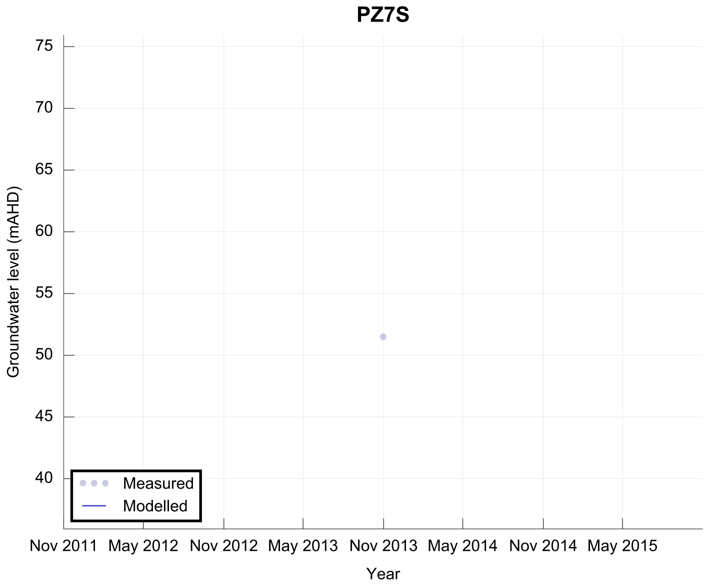

P16

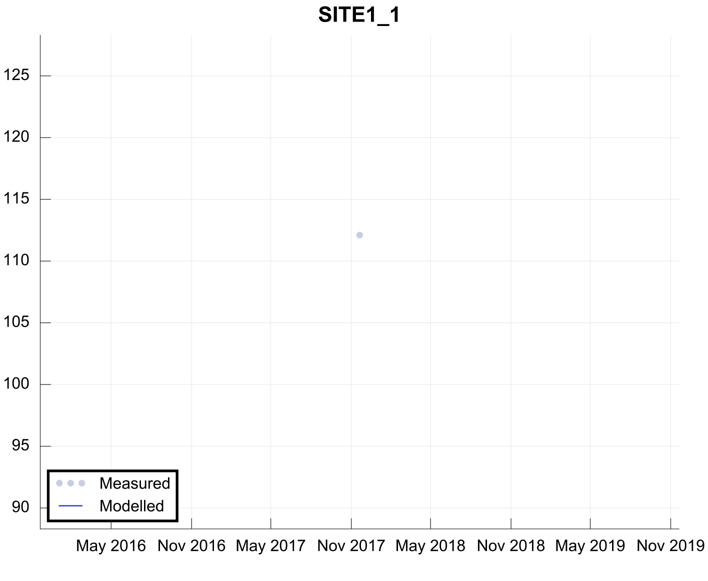

P20

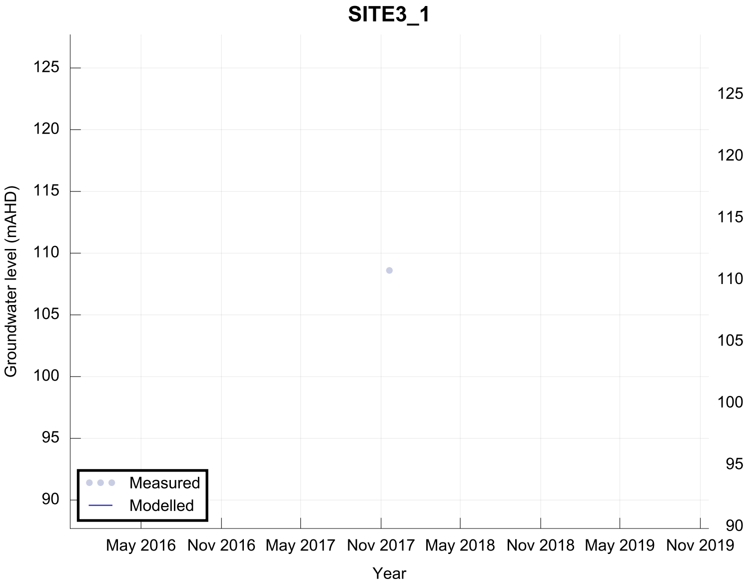

P315

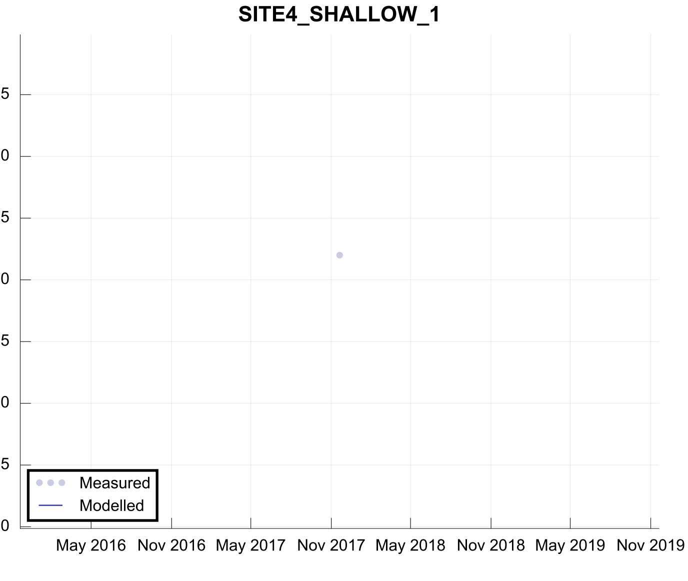

P5

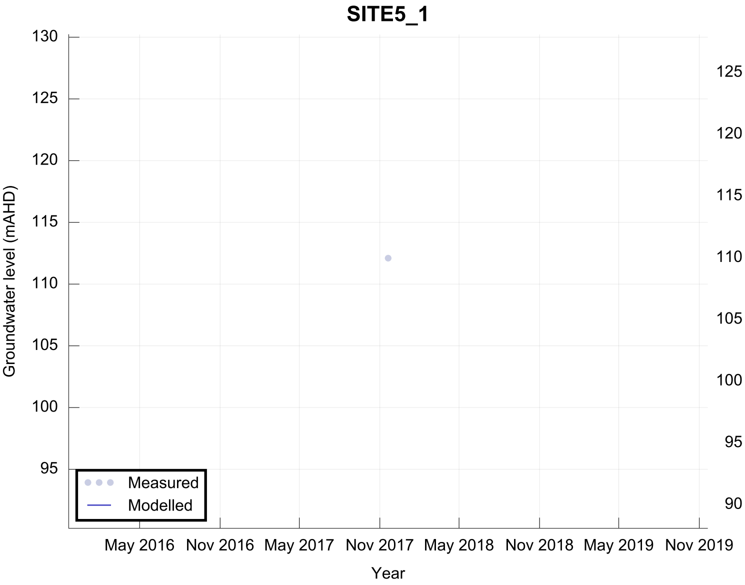

P6

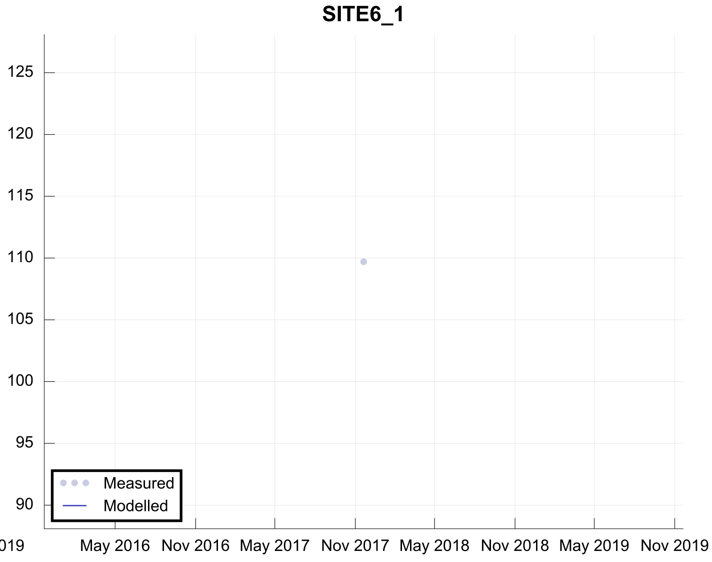

PZ7S

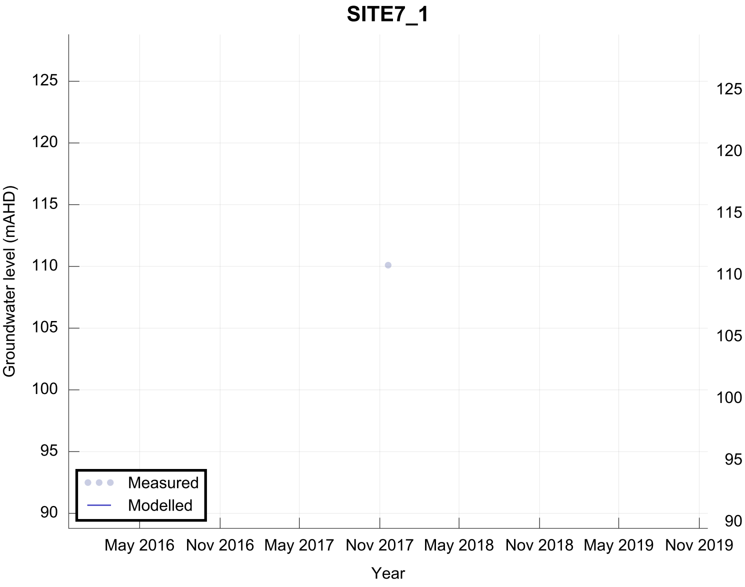

SITE1_1

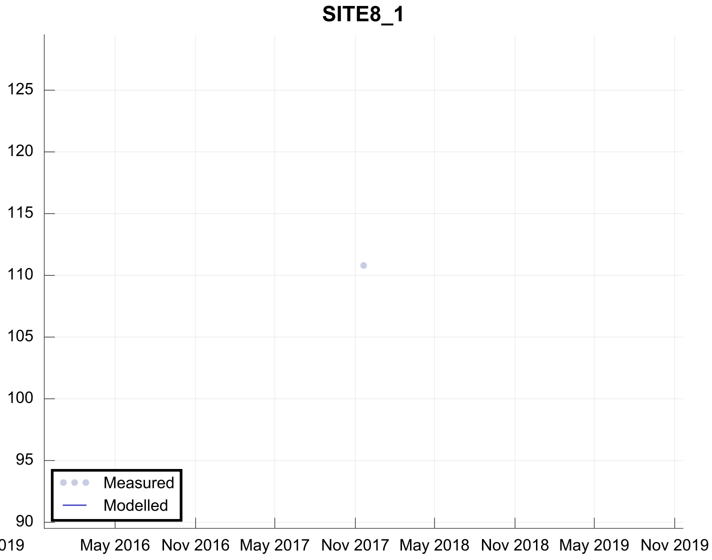

SITE3_1

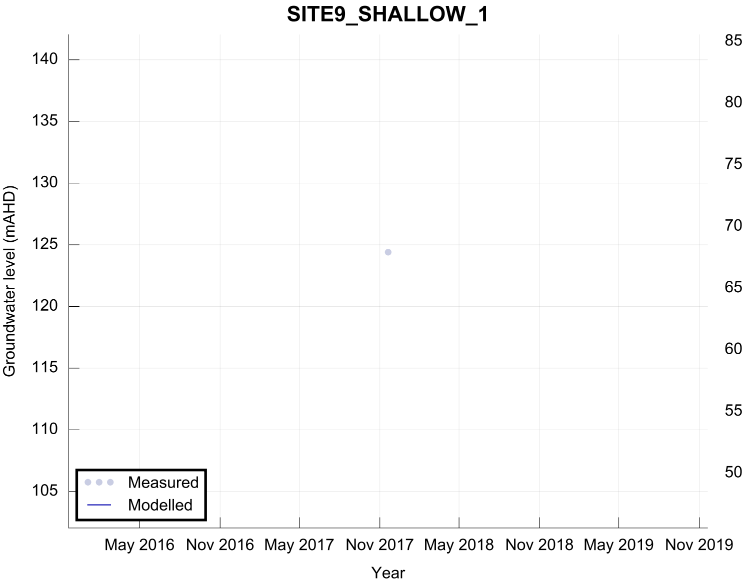

SITE4_SHALLOW_1


SITE5_1

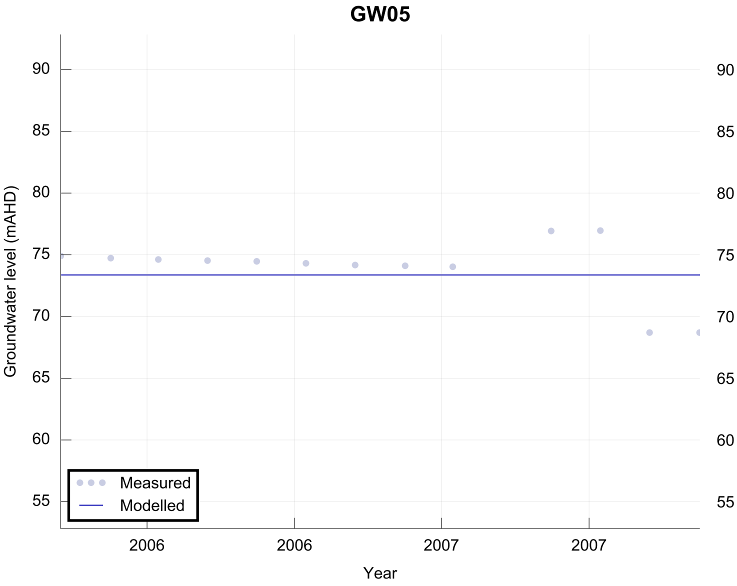

SITE6_1


SITE7_1

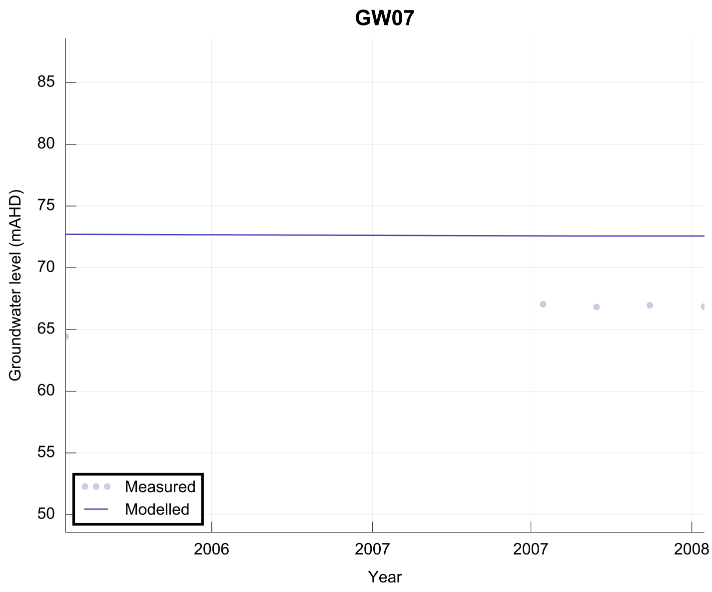

SITE8_1

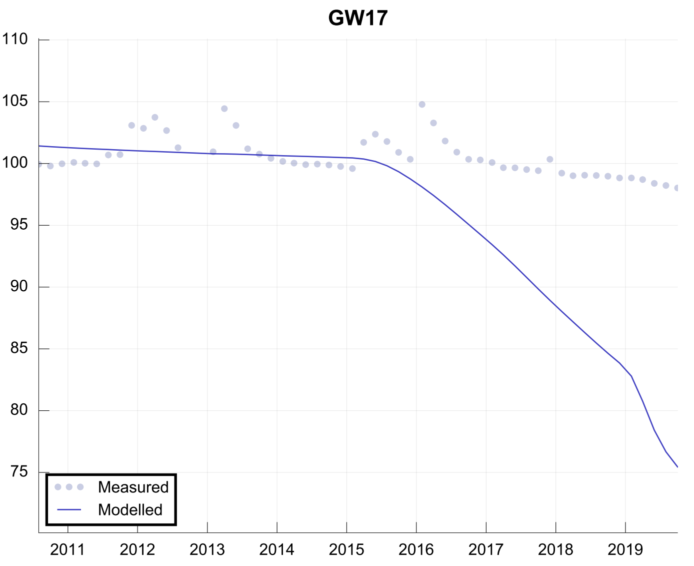

SITE9_SHALLOW_1

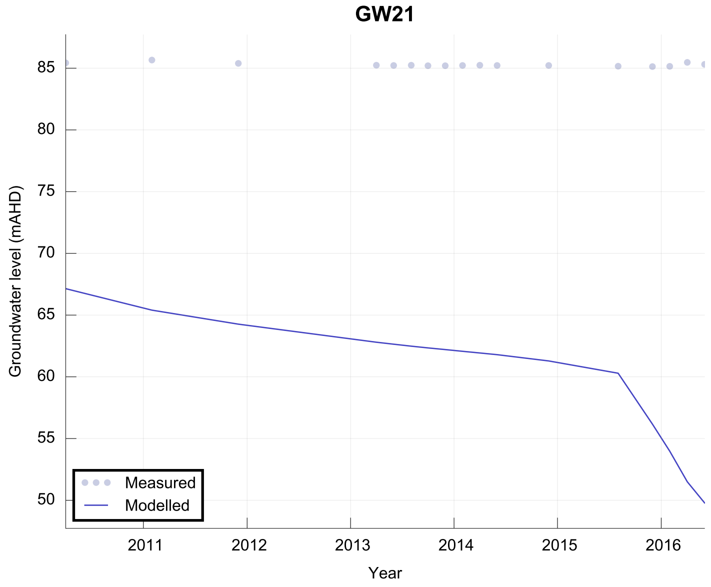

GW04

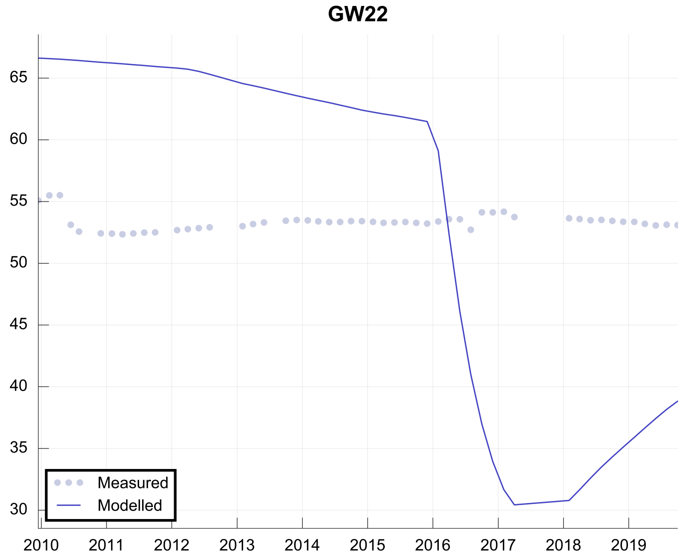

GW05

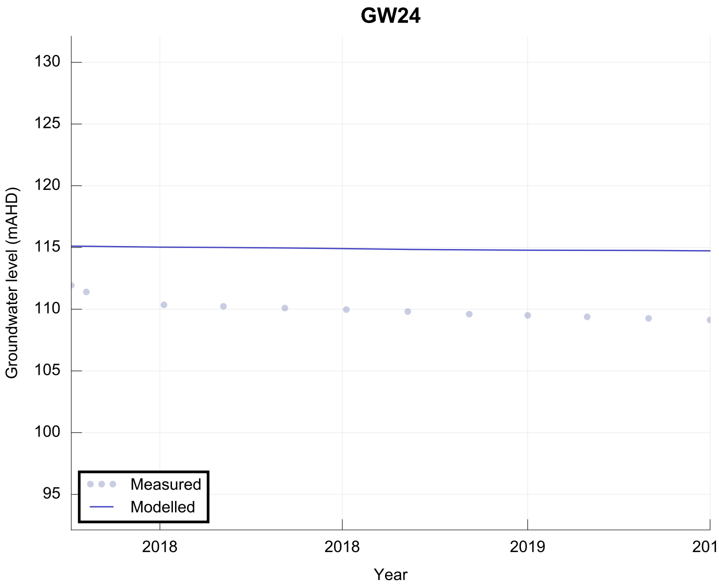

GW06

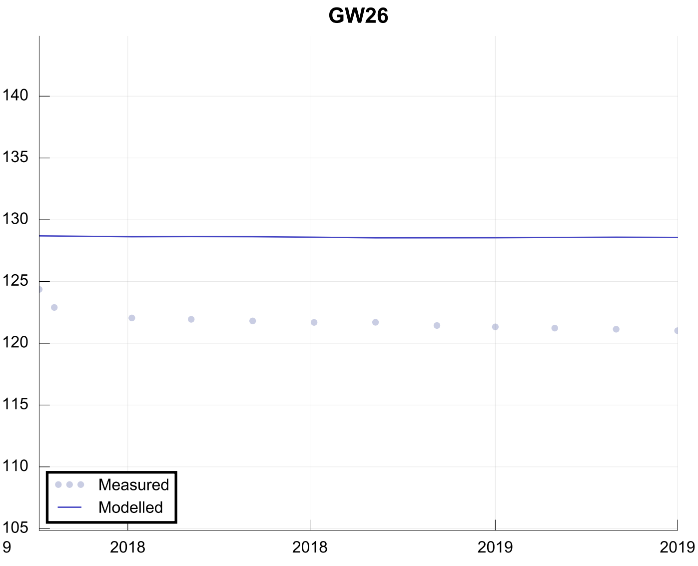

GW07
Groundwater level (mAHD)
85
80
75
70
65
60
55
50
2006
2007
2007
2008
Year
Measured
Modelled

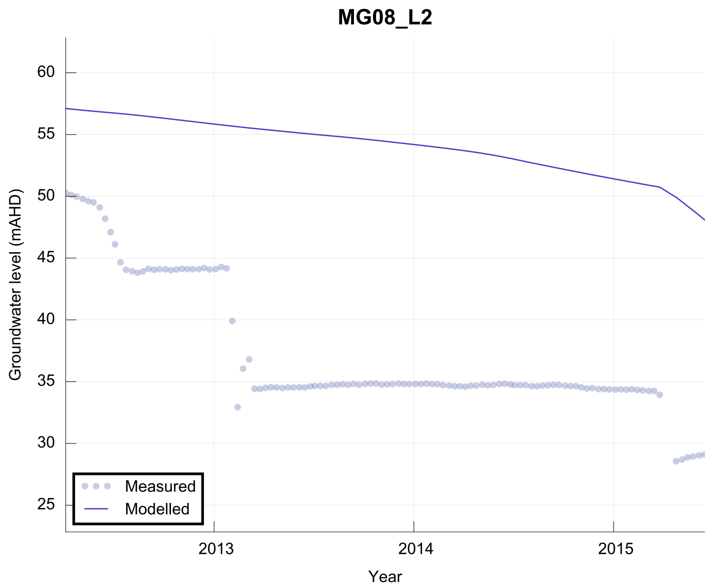

GW17
110
105
100
95
90
85
80
75
2011
2012
2013
2014
2015
2016
2017
2018
2019
Measured
Modelled

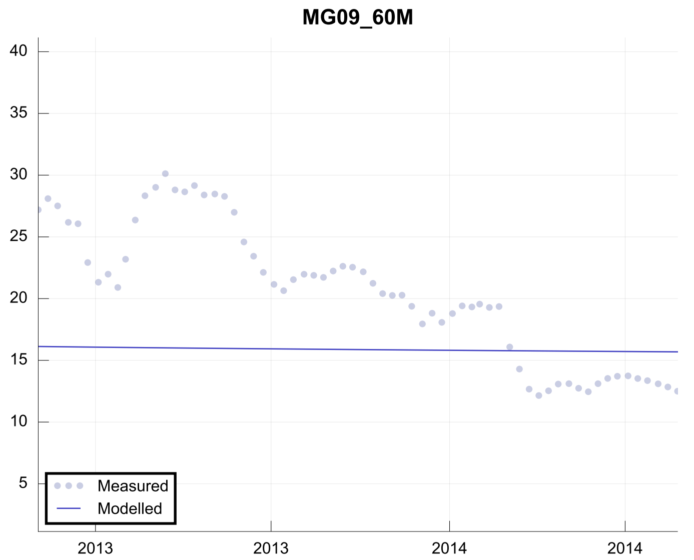

GW21
Groundwater level (mAHD)
85
80
75
70
65
60
55
50
2011
2012
2013
2014
2015
2016
Year
Measured
Modelled

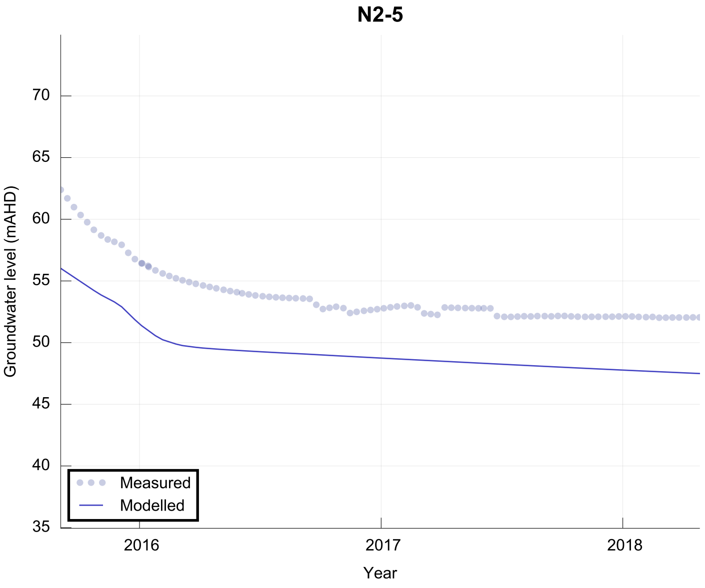

GW22
65
60
55
50
45
40
35
30
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Measured
Modelled

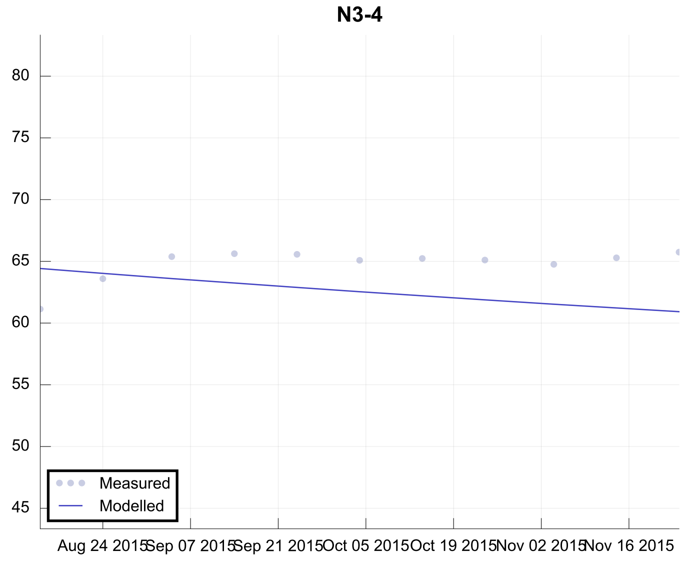

GW24
Groundwater level (mAHD)
130
125
120
115
110
105
100
95
2018
2018
2019
2019
Year
Measured
Modelled

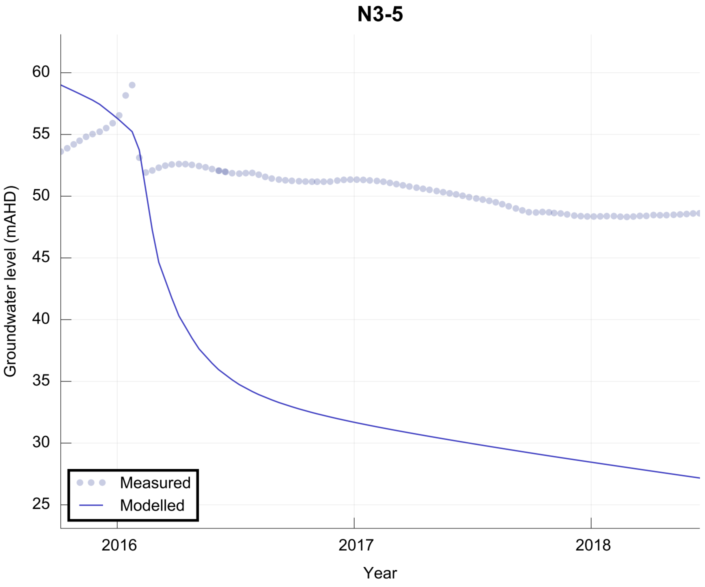

GW26
140
135
130
125
120
115
110
105
2018
2018
2019
2019
Measured
Modelled

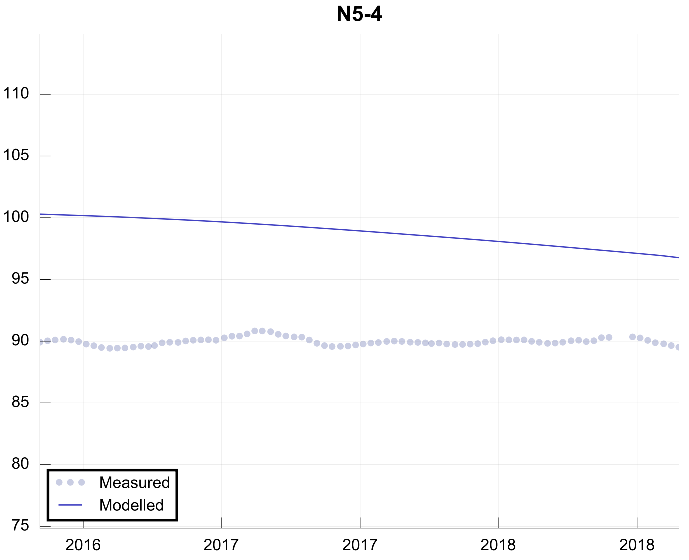

MG08_L2
Groundwater level (mAHD)
60
55
50
45
40
35
30
25
2013
2014
2015
Year
Measured
Modelled

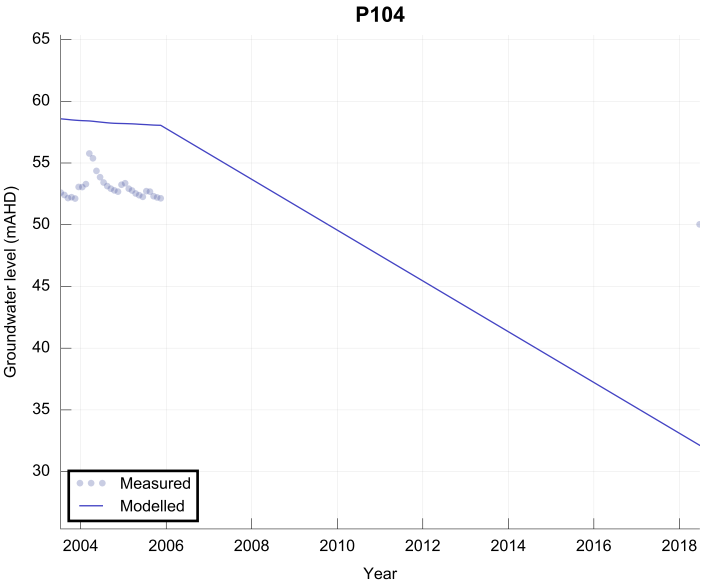

MG09_60M
40
35
30
25
20
15
10
5
2013
2013
2014
2014
Measured
Modelled

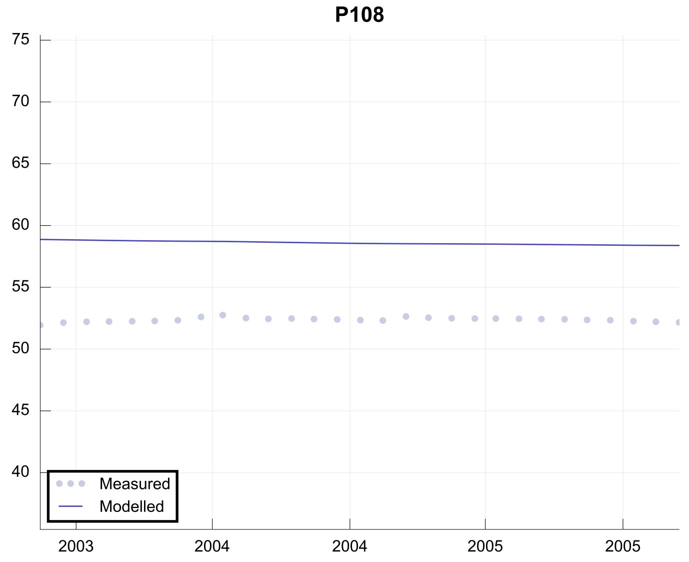

N2-5
Groundwater level (mAHD)
70
65
60
55
50
45
40
35
2016
2017
2018
Year
Measured
Modelled

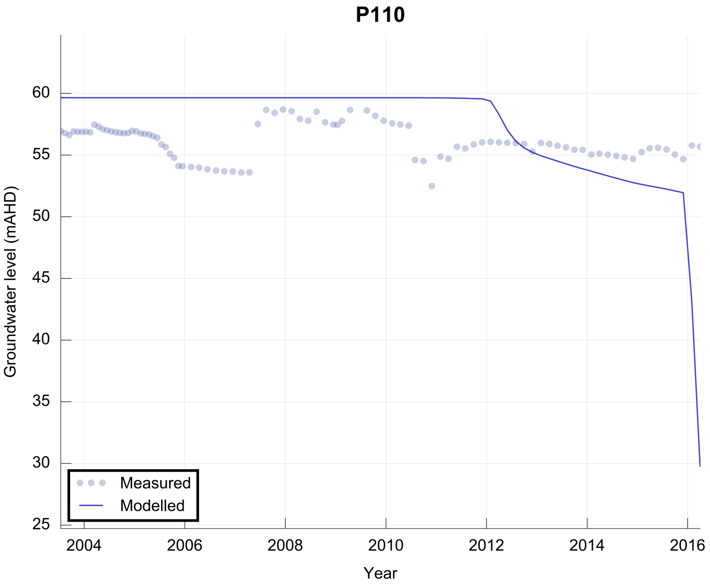

N3-4
80
75
70
65
60
55
50
45
Aug 24 2015
Sep 07 2015
Sep 21 2015
Oct 05 2015
Oct 19 2015
Nov 02 2015
Nov 16 2015
Measured
Modelled

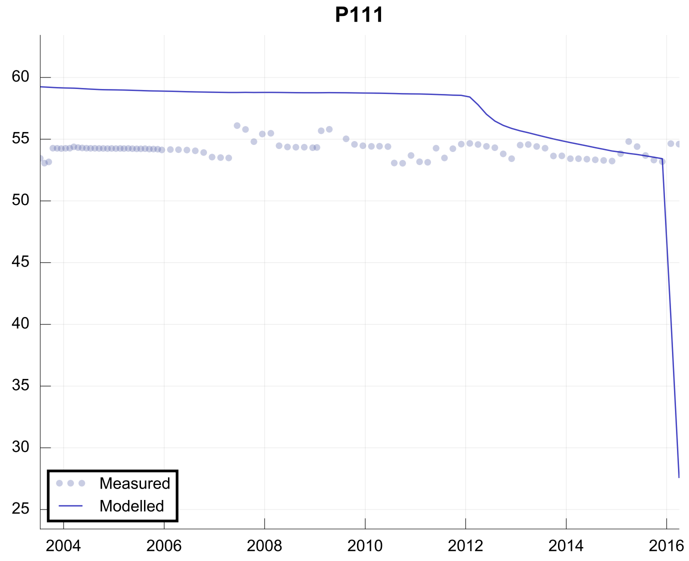

N3-5
Groundwater level (mAHD)
60
55
50
45
40
35
30
25
2016
2017
2018
Year
Measured
Modelled

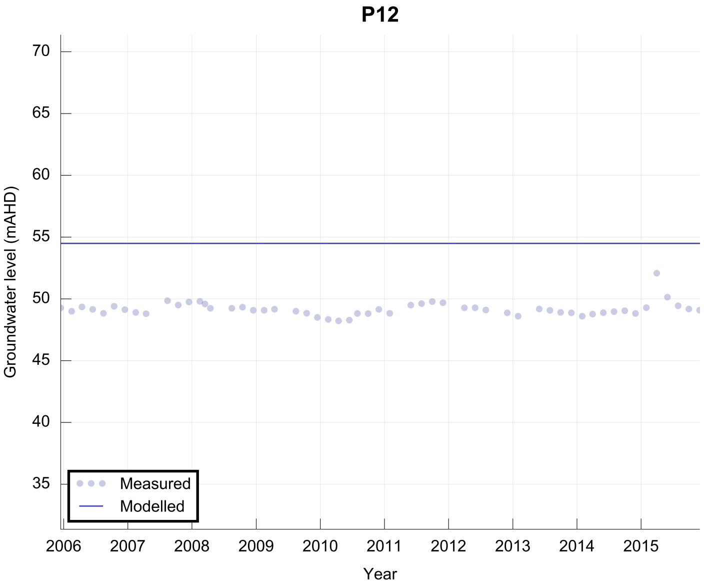

N5-4
110
105
100
95
90
85
80
75
2016
2017
2017
2018
2018
Measured
Modelled

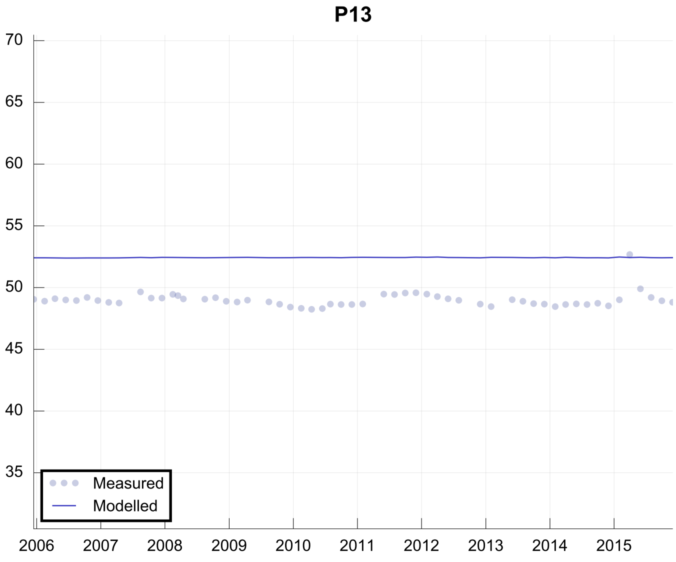

P104
Groundwater level (mAHD)
65
60
55
50
45
40
35
30
2004
2006
2008
2010
2012
2014
2016
2018
Year
Measured
Modelled

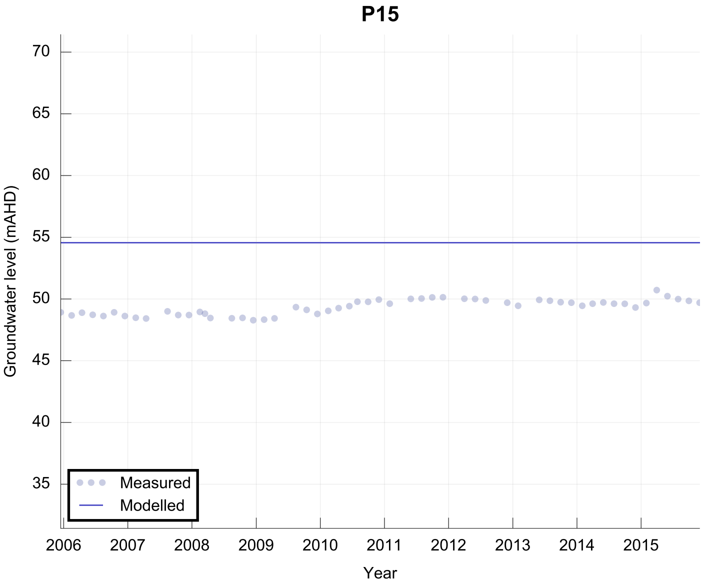

P108
75
70
65
60
55
50
45
40
2003
2004
2004
2005
2005
Measured
Modelled

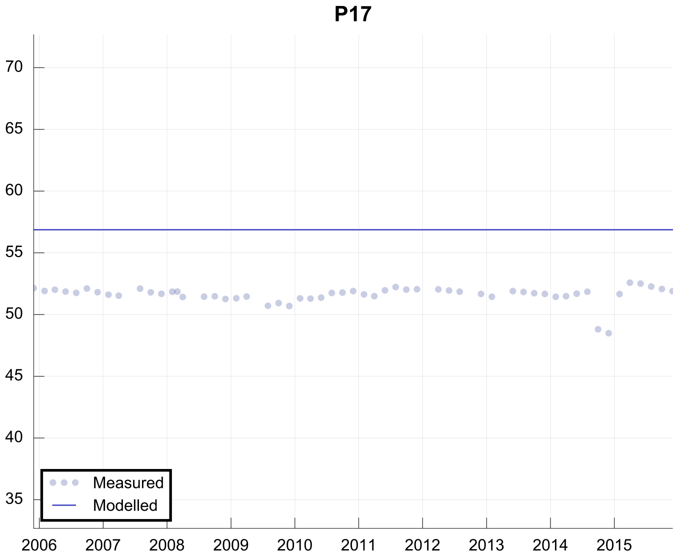

P110
Groundwater level (mAHD)
60
55
50
45
40
35
30
25
2004
2006
2008
2010
2012
2014
2016
Year
Measured
Modelled

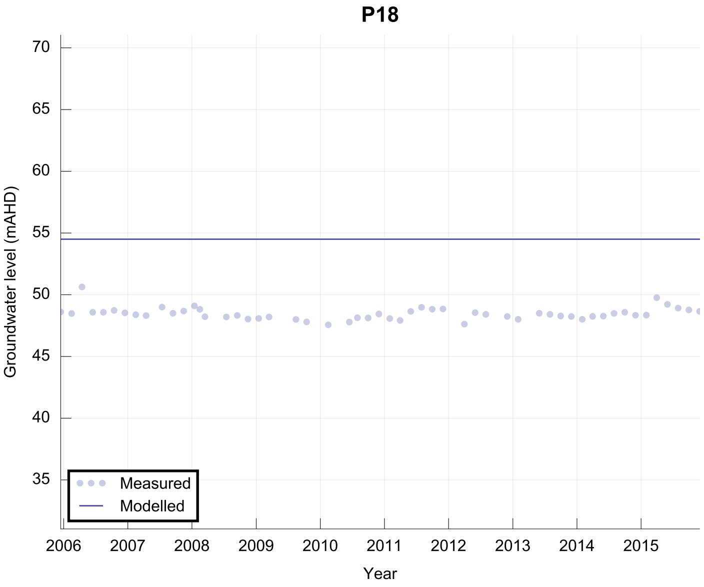

P111
60
55
50
45
40
35
30
25
2004
2006
2008
2010
2012
2014
2016
Measured
Modelled

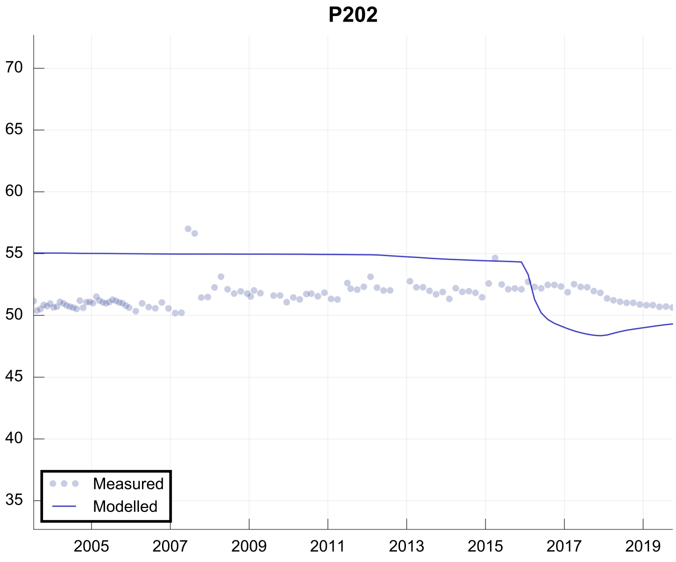

P12
Groundwater level (mAHD)
70
65
60
55
50
45
40
35
Measured
Modelled
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Year

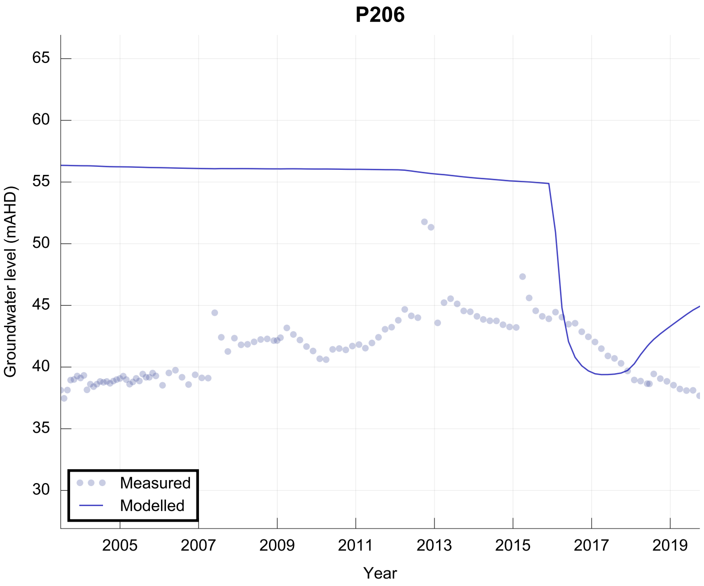

P13
70
65
60
55
50
45
40
35
Measured
Modelled
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015

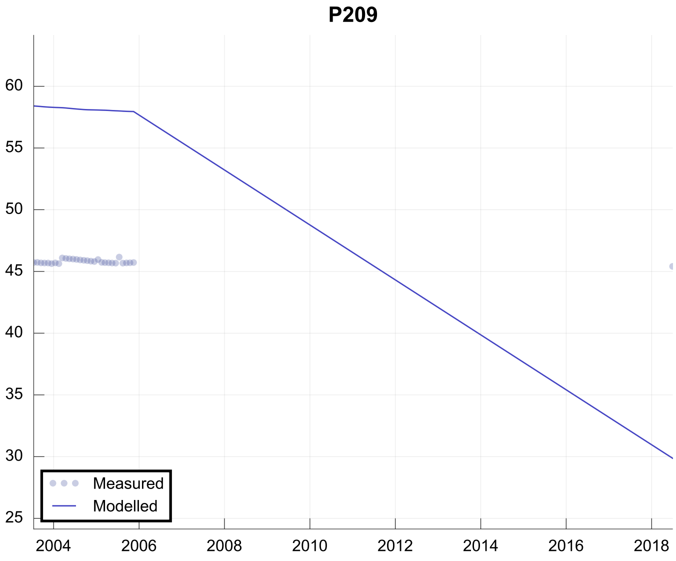

P15
Groundwater level (mAHD)
70
65
60
55
50
45
40
35
Measured
Modelled
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Year

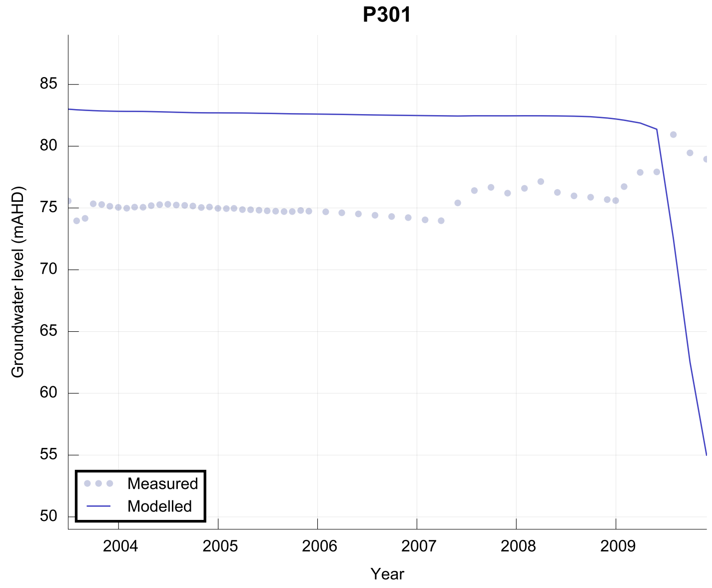

P17
70
65
60
55
50
45
40
35
Measured
Modelled
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015

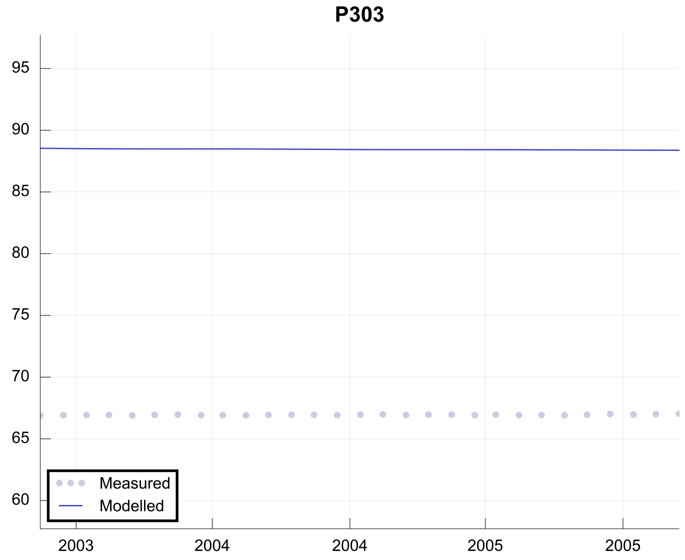

P18
Groundwater level (mAHD)
70
65
60
55
50
45
40
35
Measured
Modelled
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Year

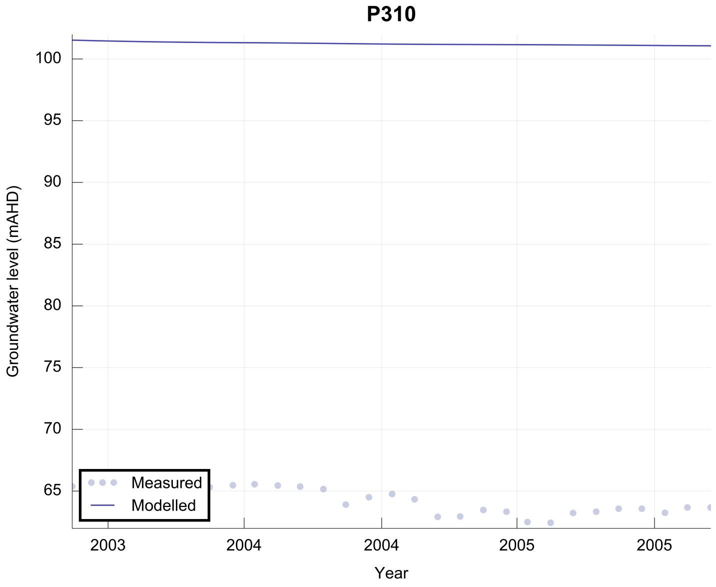

P202
70
65
60
55
50
45
40
35
Measured
Modelled
2005
2007
2009
2011
2013
2015
2017
2019

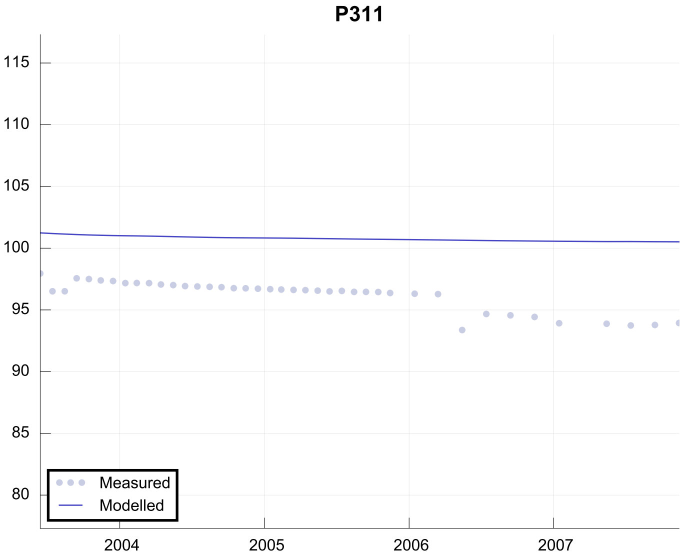

P206
Groundwater level (mAHD)
65
60
55
50
45
40
35
30
Measured
Modelled
2005
2007
2009
2011
2013
2015
2017
2019
Year

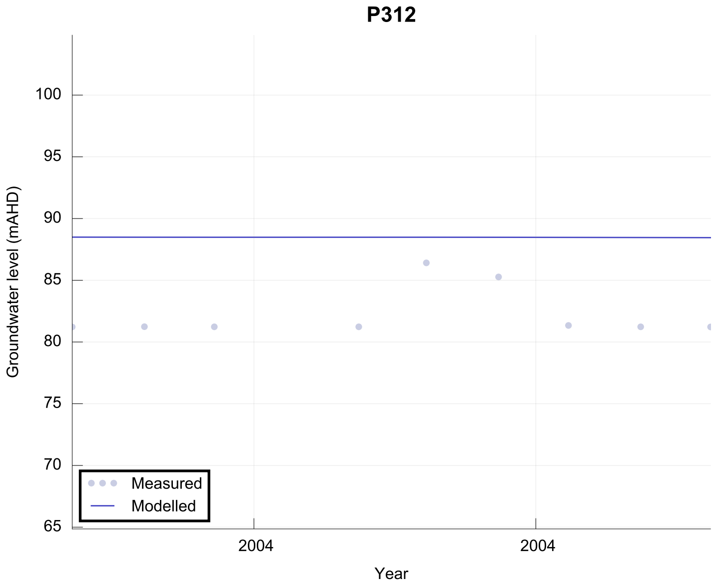

P209
60
55
50
45
40
35
30
25
Measured
Modelled
2004
2006
2008
2010
2012
2014
2016
2018

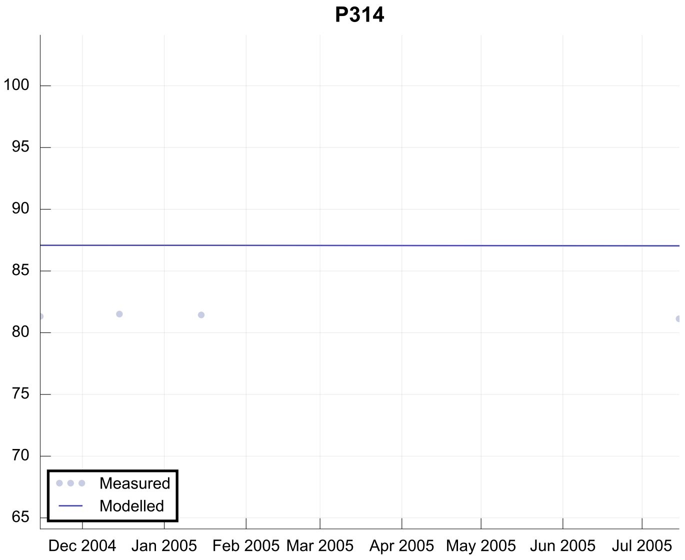

P301
Groundwater level (mAHD)
85
80
75
70
65
60
55
50
2004
2005
2006
2007
2008
2009
Year
Measured
Modelled

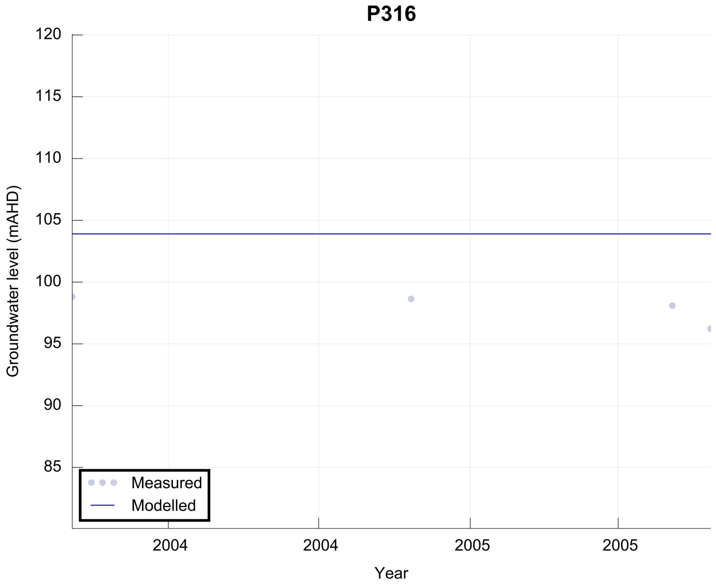

P303
95
90
85
80
75
70
65
60
2003
2004
2004
2005
2005
Measured
Modelled

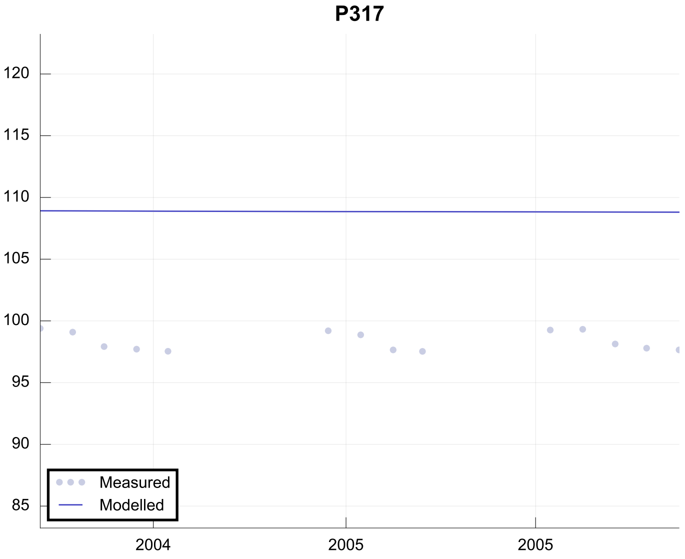

P310
Groundwater level (mAHD)
100
95
90
85
80
75
70
65
2003
2004
2004
2005
2005
Year
Measured
Modelled

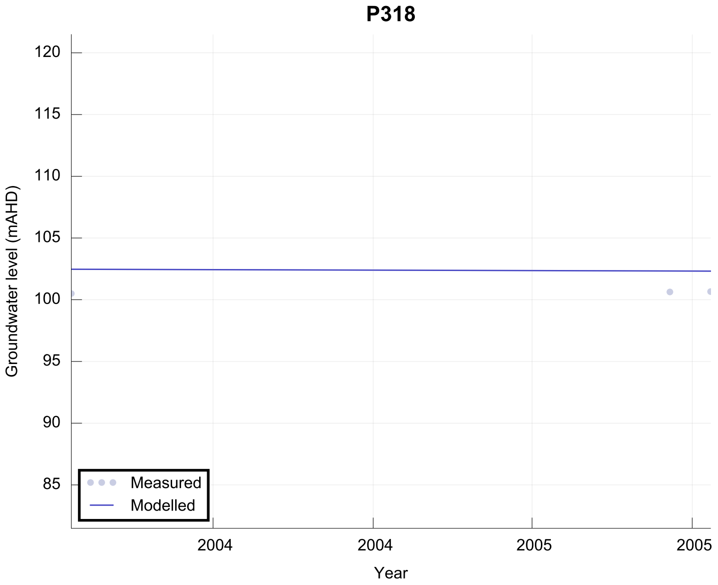

P311
115
110
105
100
95
90
85
80
2004
2005
2006
2007
Measured
Modelled

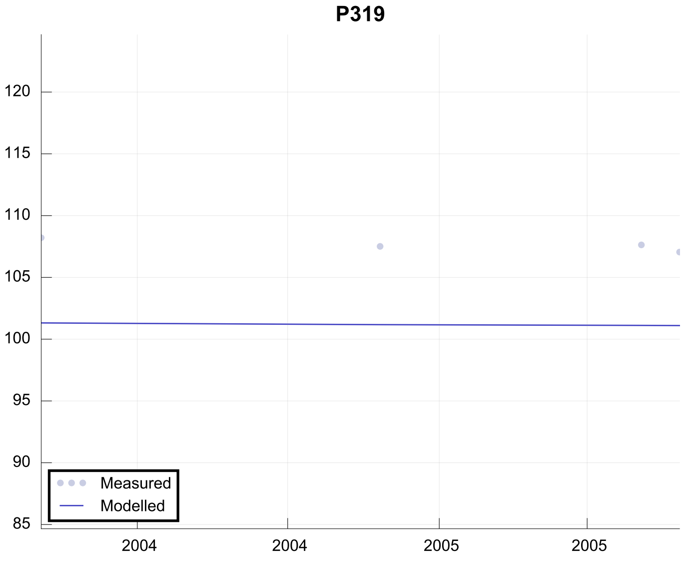

P312
Groundwater level (mAHD)
100
95
90
85
80
75
70
65
2004
2004
Year
Measured
Modelled

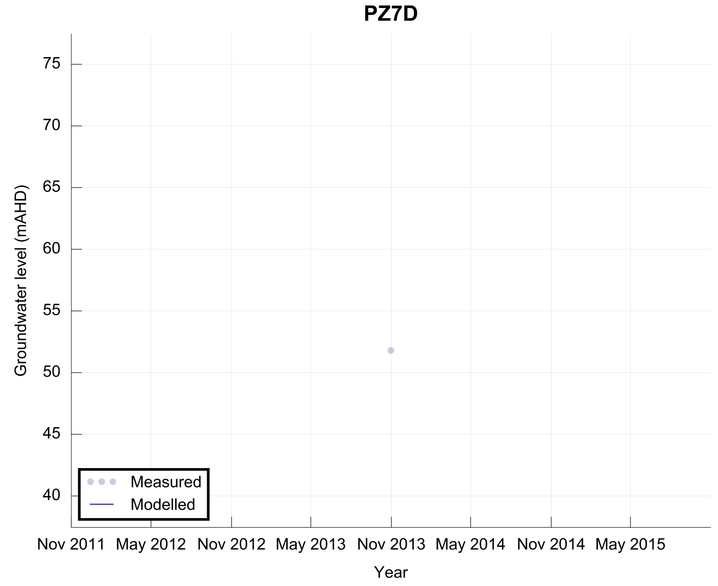

P314
100
95
90
85
80
75
70
65
Dec 2004
Jan 2005
Feb 2005
Mar 2005
Apr 2005
May 2005
Jun 2005
Jul 2005
Measured
Modelled

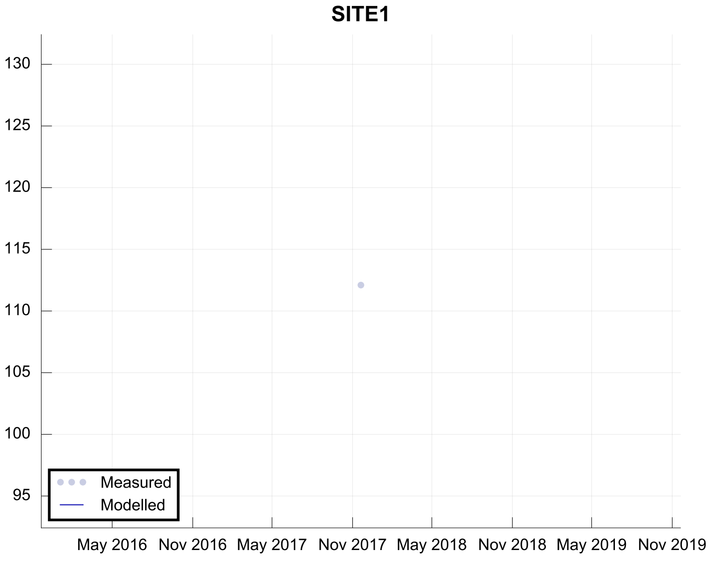

P316
Groundwater level (mAHD)
120
115
110
105
100
95
90
85
2004
2004
2005
2005
Year
Measured
Modelled

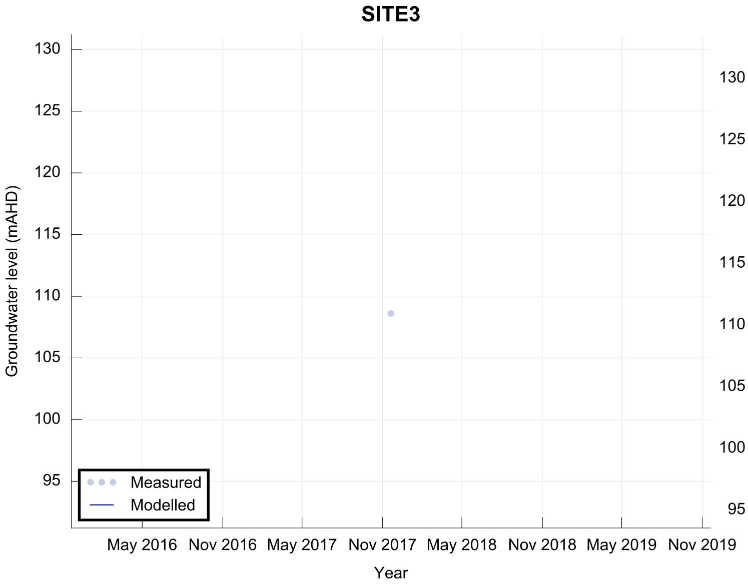

P317
120
115
110
105
100
95
90
85
2004
2005
2005
Measured
Modelled

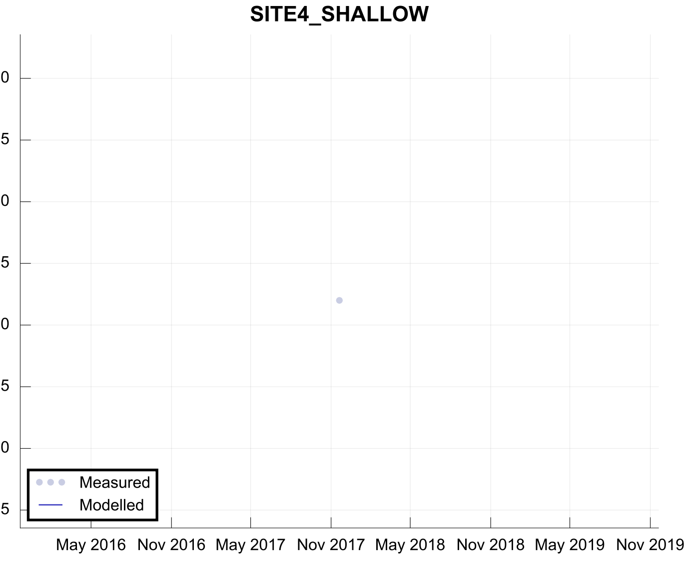

P318

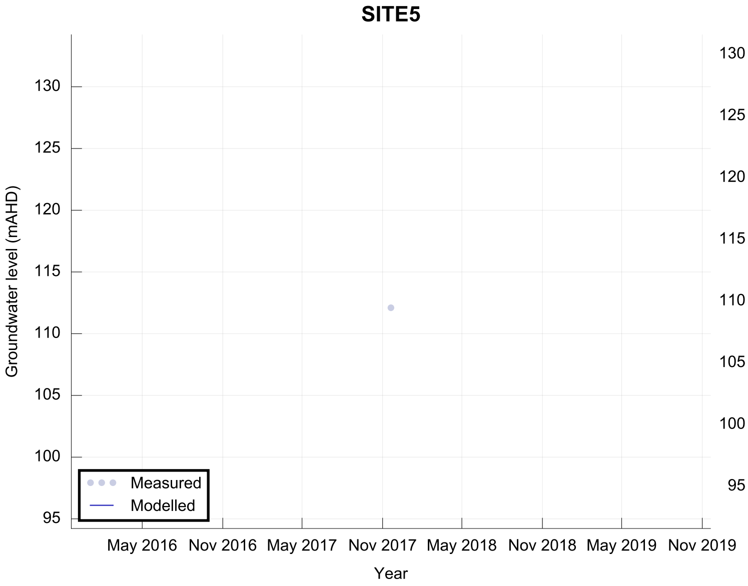

P319

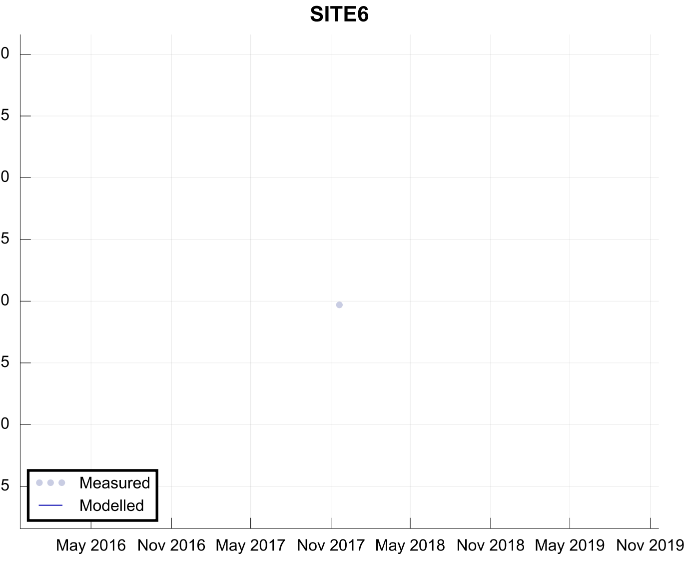

PZ7D


SITE1

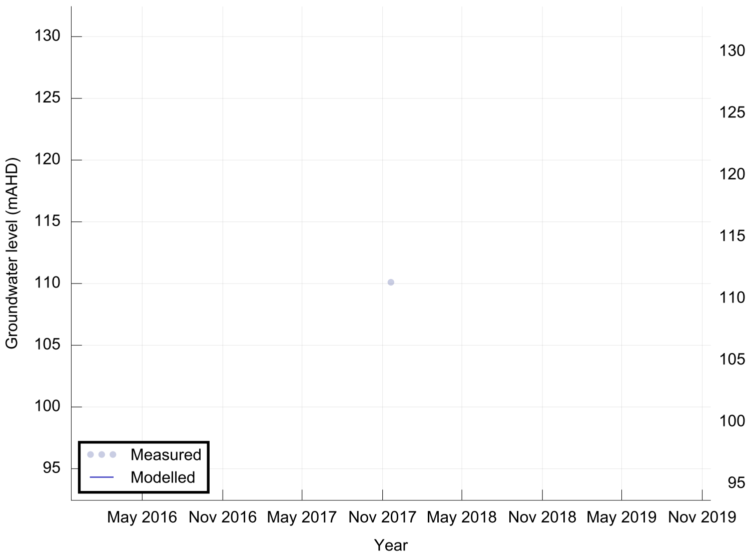

SITE3


SITE4_SHALLOW

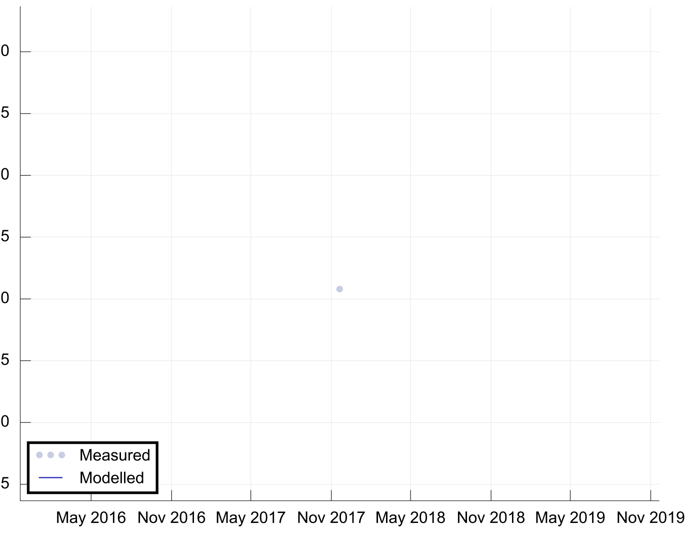

SITE5


SITE6

SITE7

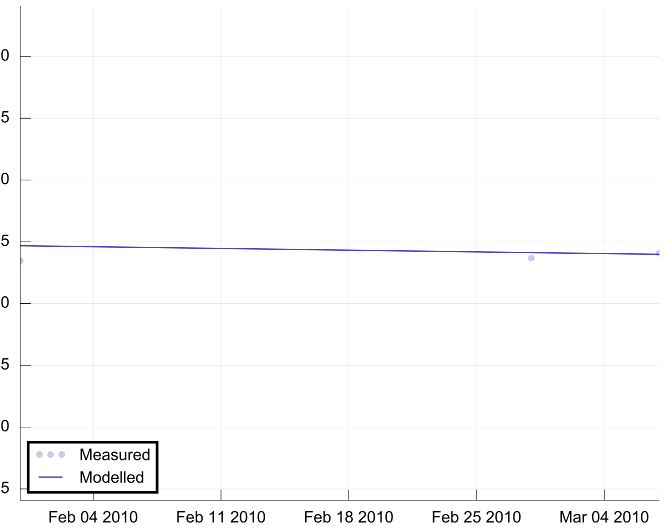


SITE8

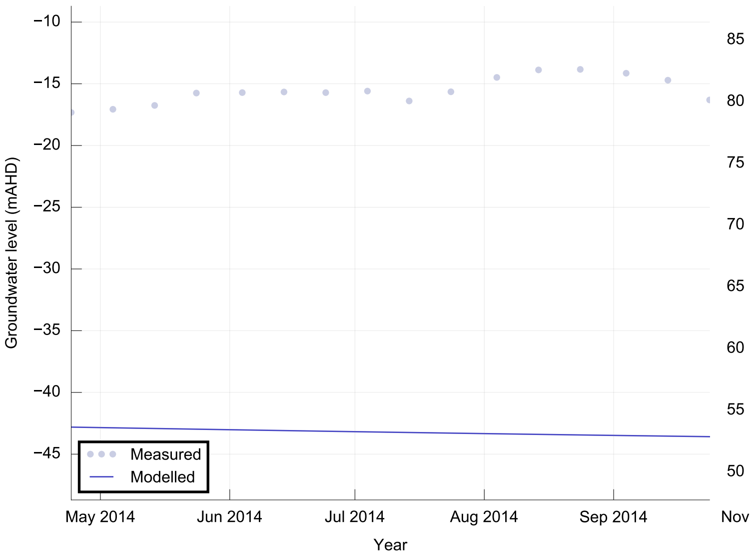


SITE9_SHALLOW

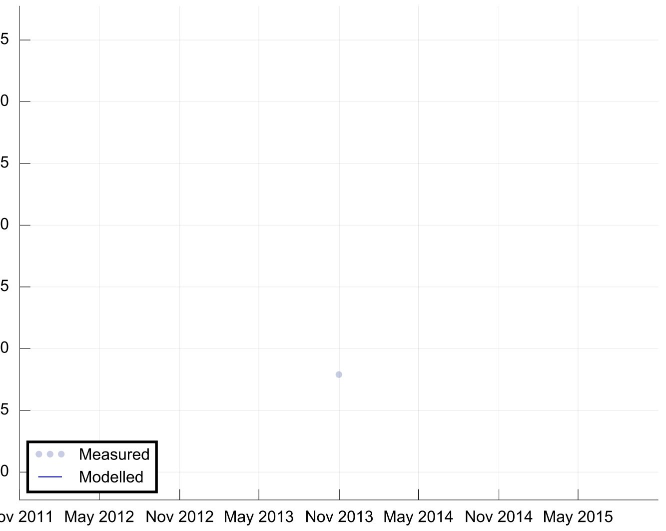
GW20_VW2_WHYBROWSEAM



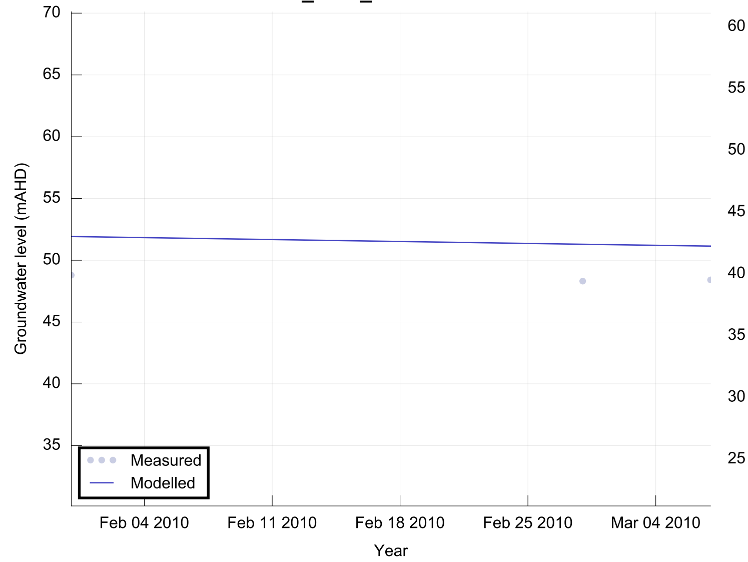
MG09_103M



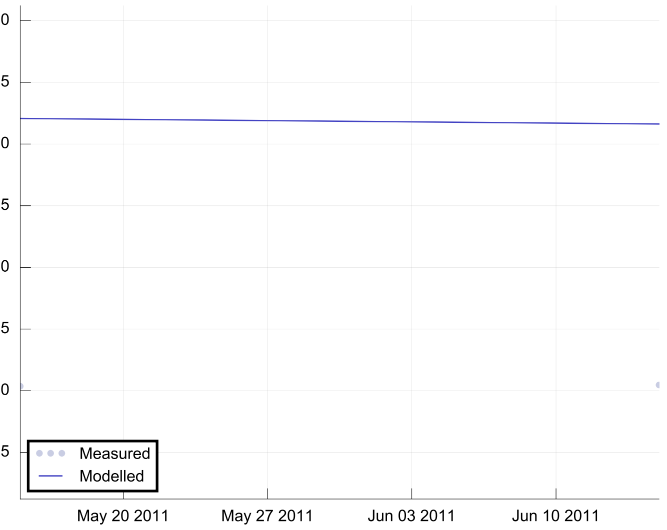
WD625P

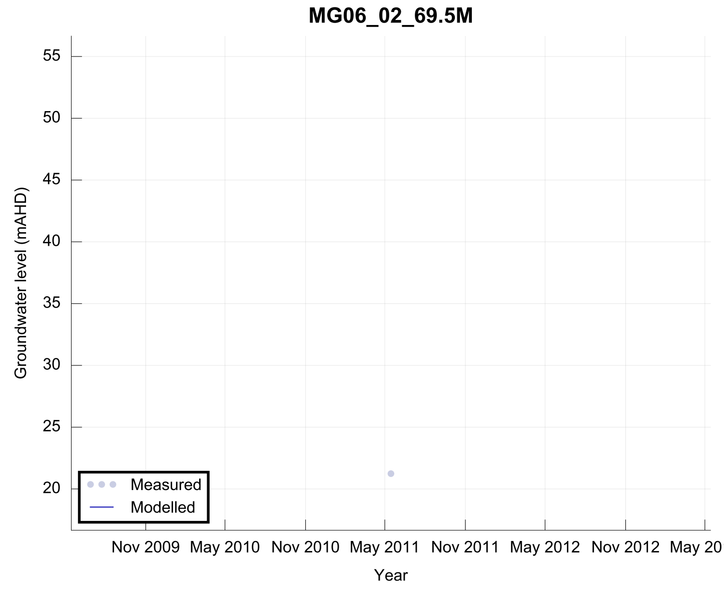


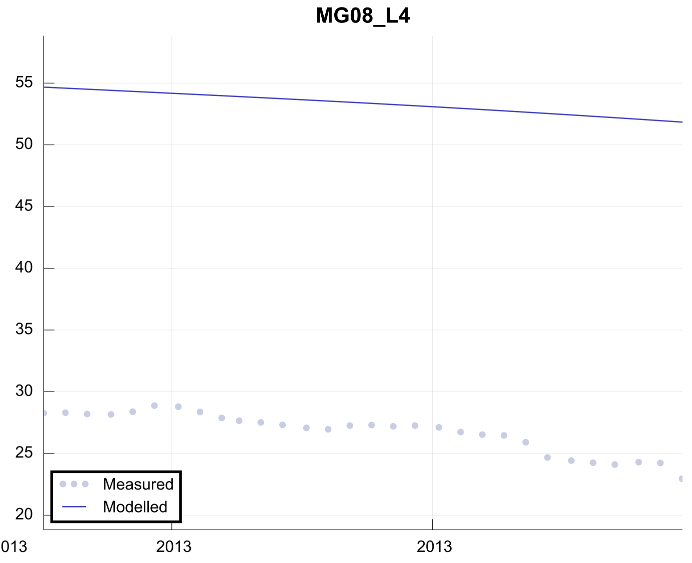
GW20_VW4_REDBANKSEAM

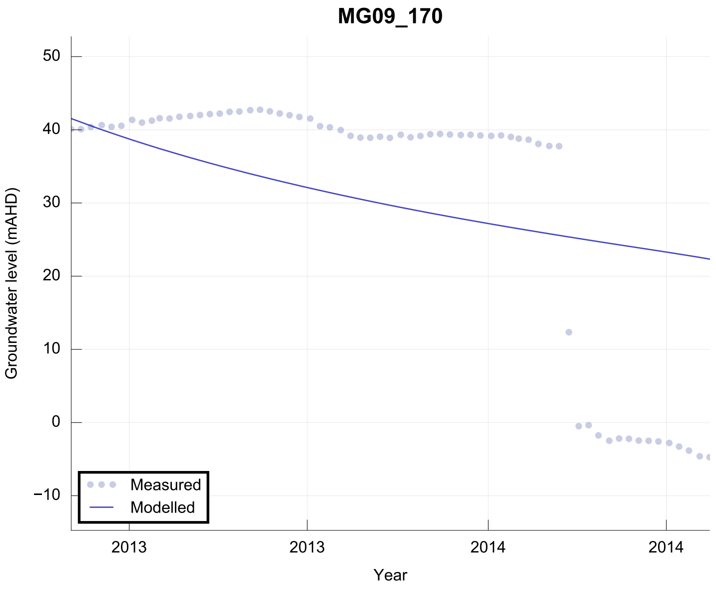


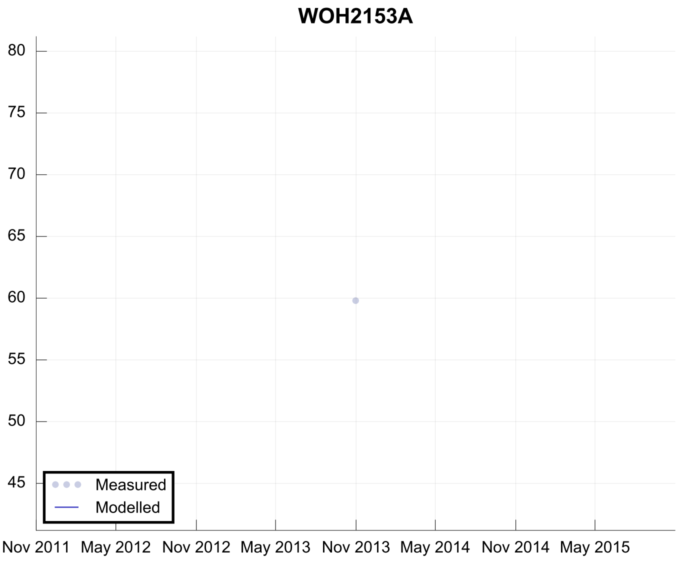
MG06_02_67.5M

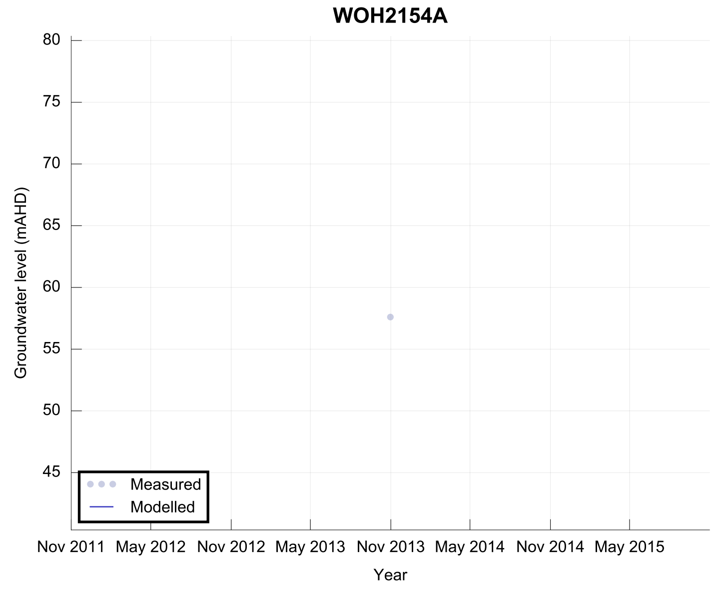


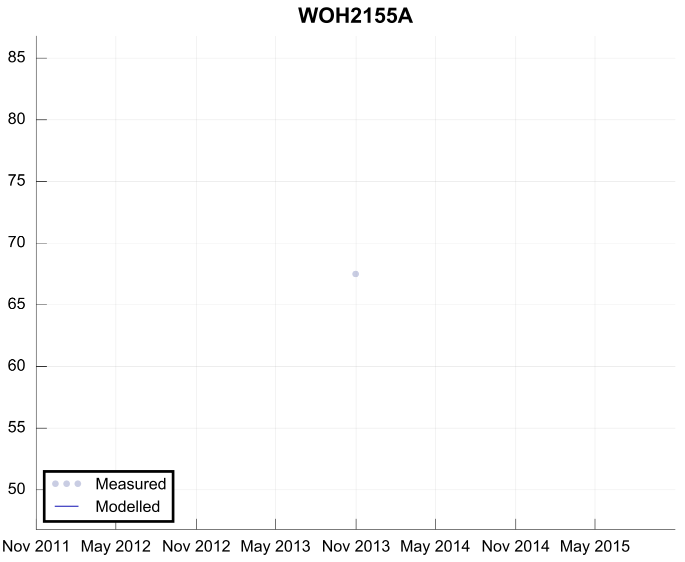

MG06_02_69.5M
Groundwater level (mAHD)
55
50
45
40
35
30
25
20
Measured
Modelled
Nov 2009
May 2010
Nov 2010
May 2011
Nov 2011
May 2012
Nov 2012
May 2013
Year

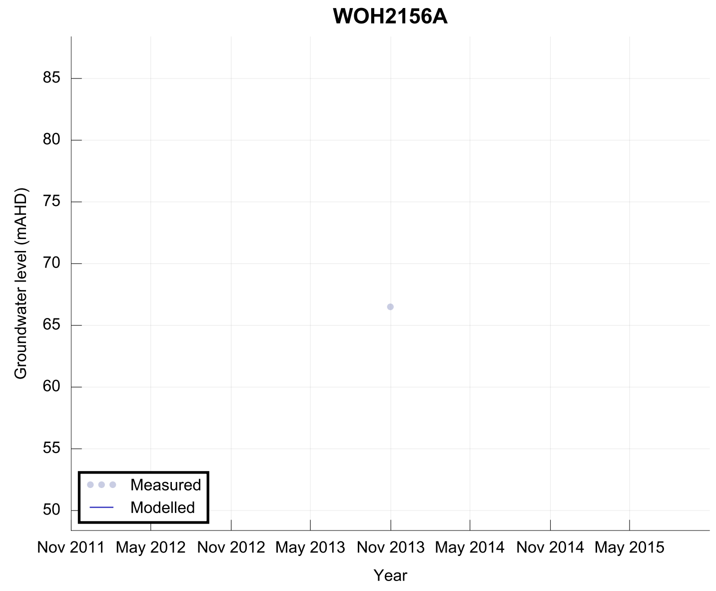

MG08_L4
55
50
45
40
35
30
25
20
Measured
Modelled
2013
2013

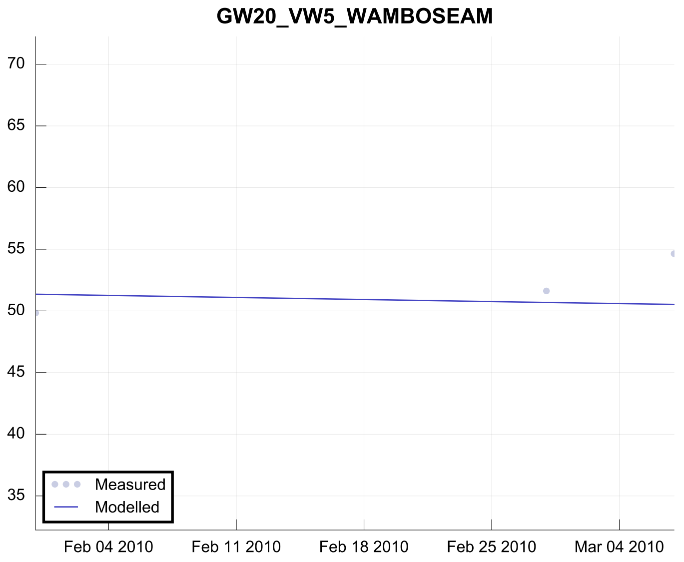

MG09_170
Groundwater level (mAHD)
50
40
30
20
10
0
−10
Measured
Modelled
2013
2013
2014
2014
Year


WOH2153A
80
75
70
65
60
55
50
45
Measured
Modelled
Nov 2011
May 2012
Nov 2012
May 2013
Nov 2013
May 2014
Nov 2014
May 2015

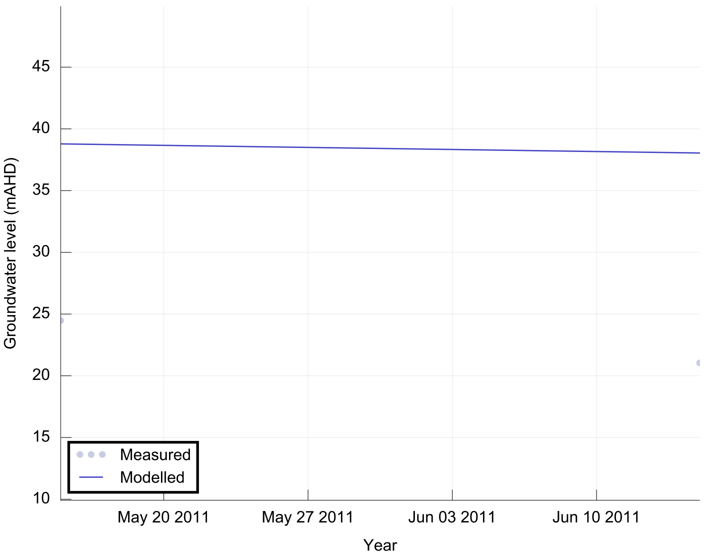

WOH2154A
Groundwater level (mAHD)
80
75
70
65
60
55
50
45
Measured
Modelled
Nov 2011
May 2012
Nov 2012
May 2013
Nov 2013
May 2014
Nov 2014
May 2015
Year


WOH2155A
85
80
75
70
65
60
55
50
Measured
Modelled
Nov 2011
May 2012
Nov 2012
May 2013
Nov 2013
May 2014
Nov 2014
May 2015

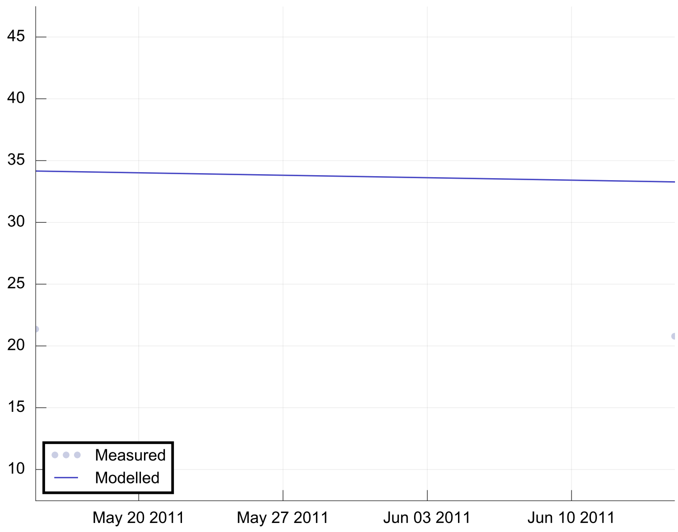

WOH2156A
Groundwater level (mAHD)
85
80
75
70
65
60
55
50
Measured
Modelled
Nov 2011
May 2012
Nov 2012
May 2013
Nov 2013
May 2014
Nov 2014
May 2015
Year


GW20_VW5_WAMBOSEAM
70
65
60
55
50
45
40
35
Measured
Modelled
Feb 04 2010
Feb 11 2010
Feb 18 2010
Feb 25 2010
Mar 04 2010

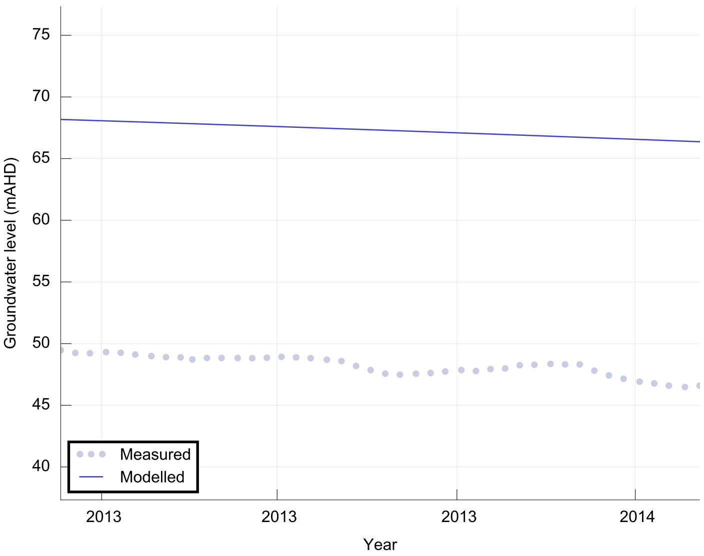
MG06_01_91.5M



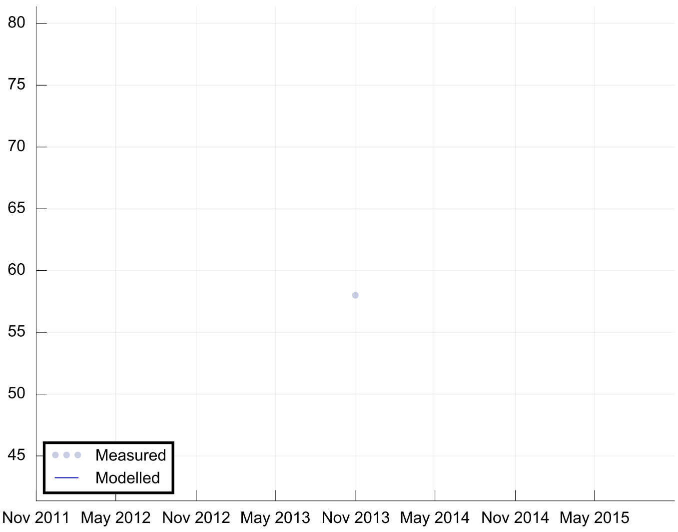
MG06_02_71M



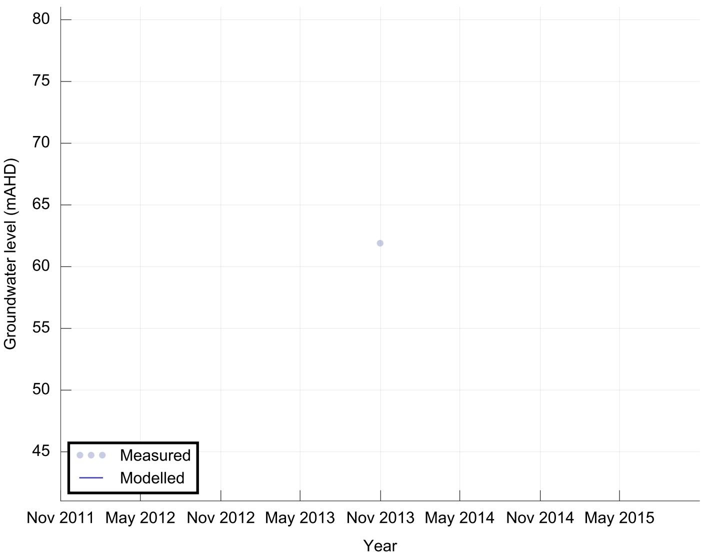
MG09_192M



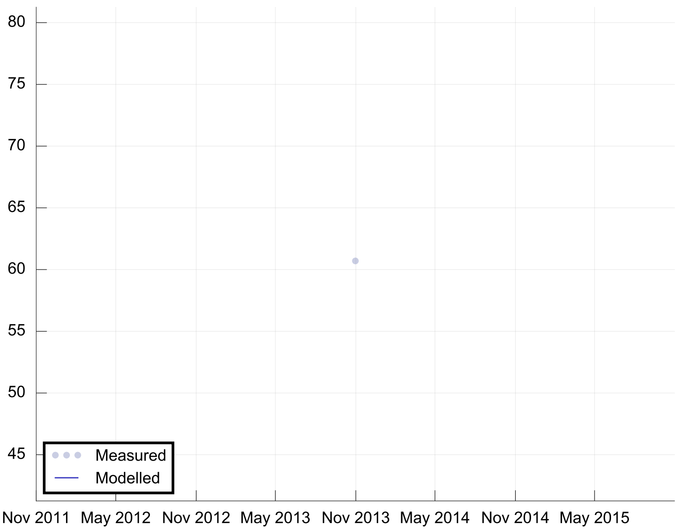
WD622_P1



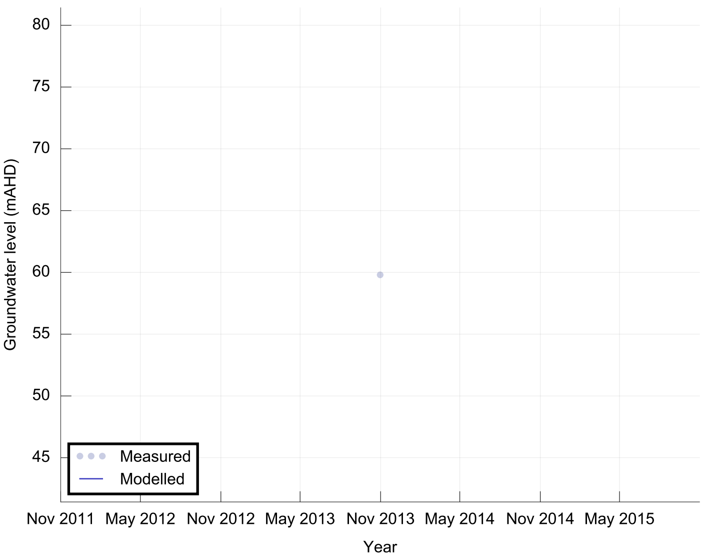
WOH2153B



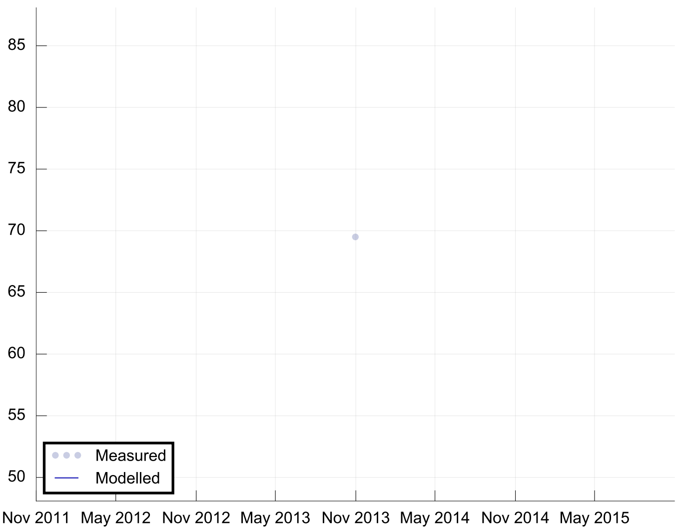
WOH2154B

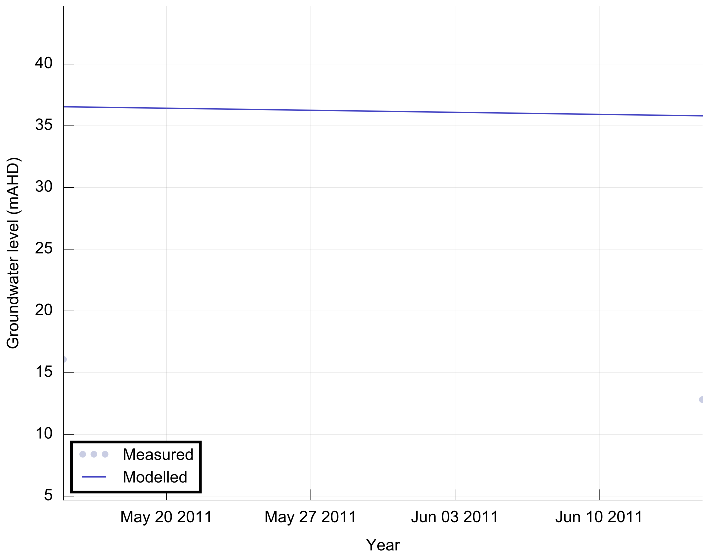


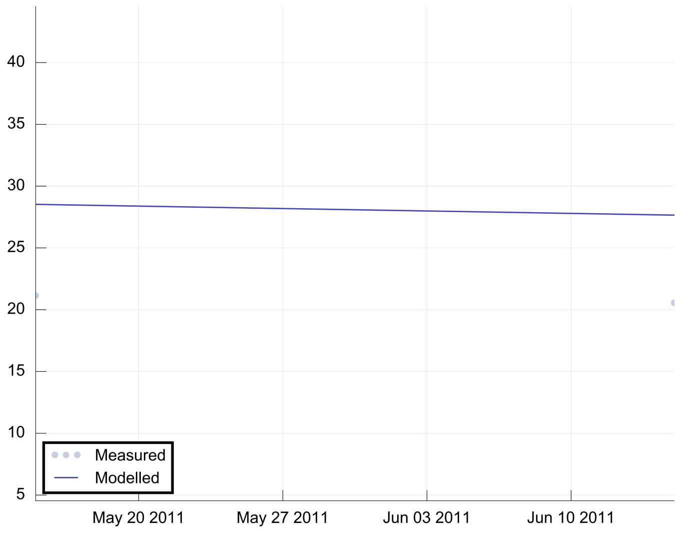
WOH2155B

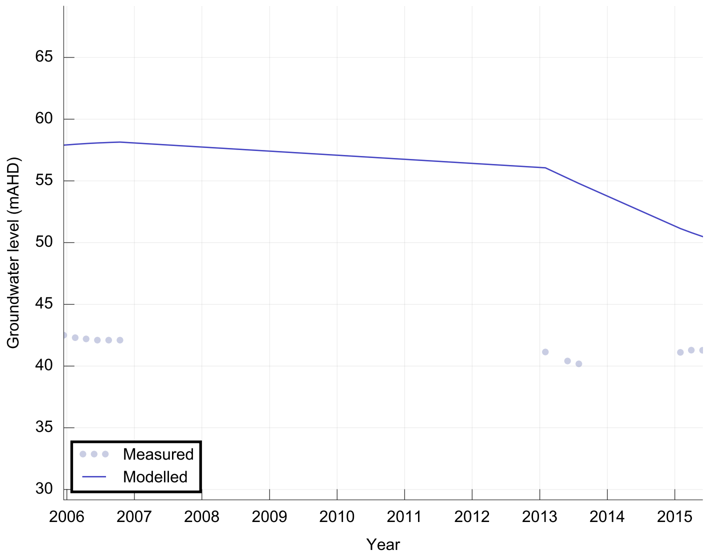


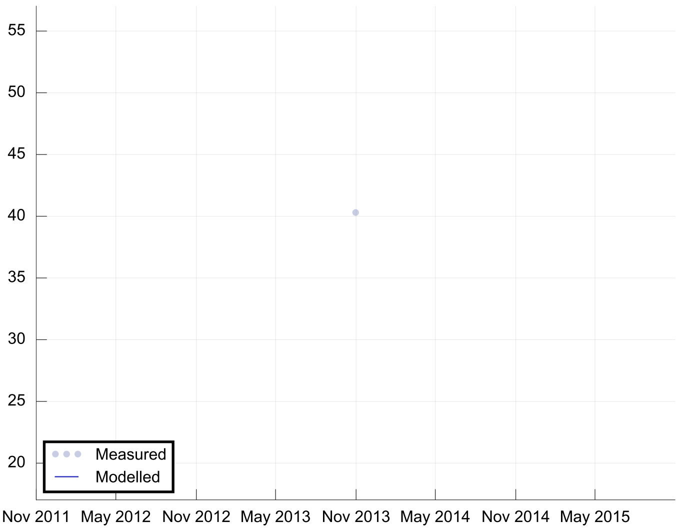
WOH2156B

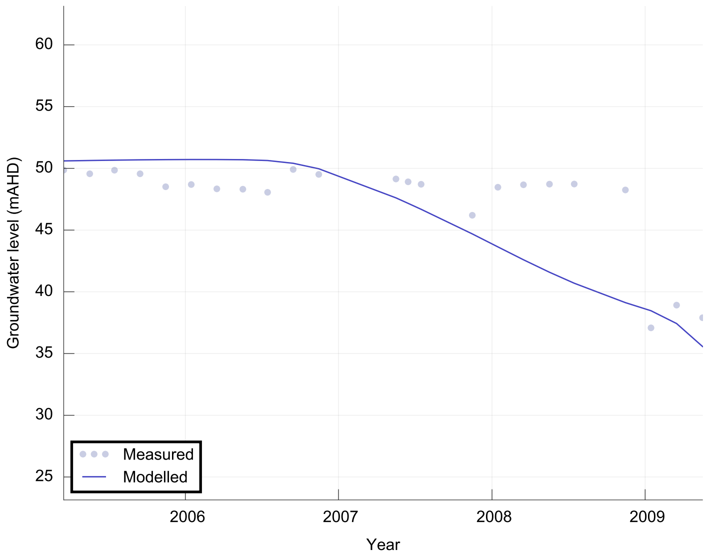


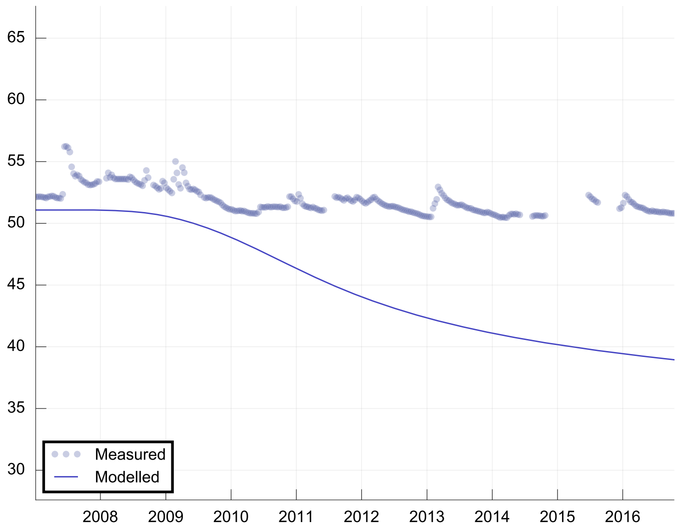

MG06_01_94M

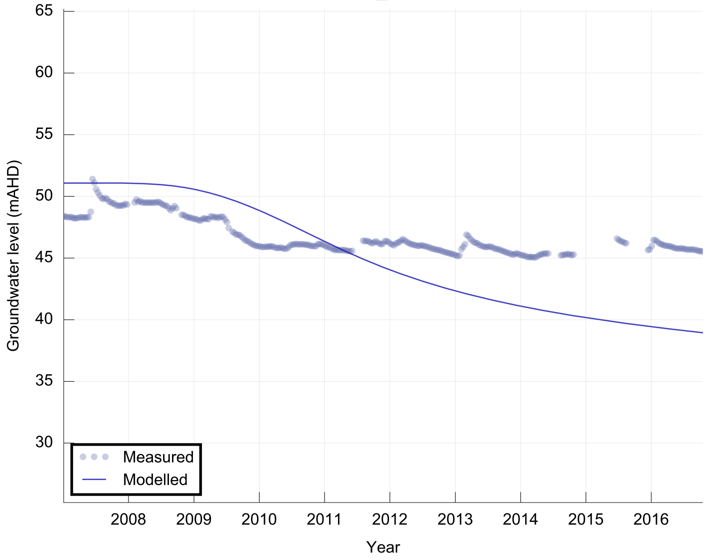

MG06_02_74M

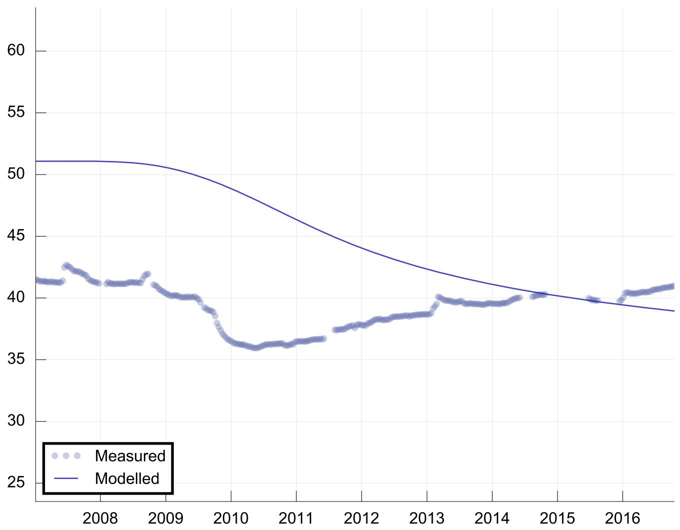

P11

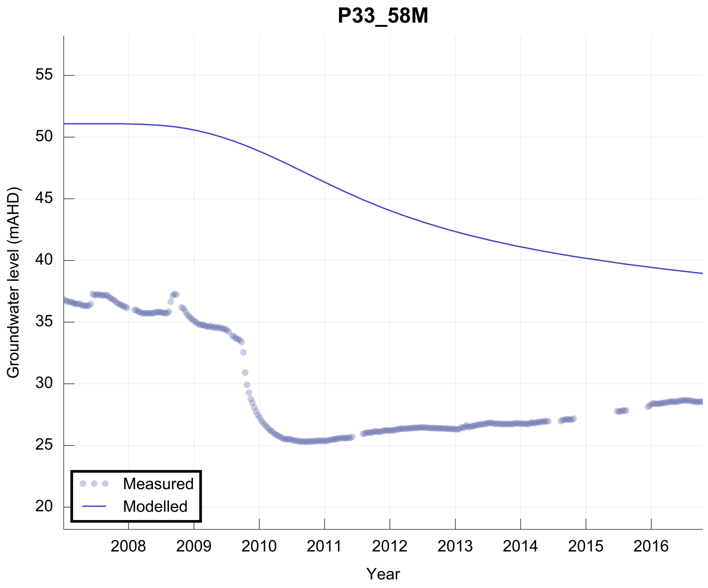

OH1123_2

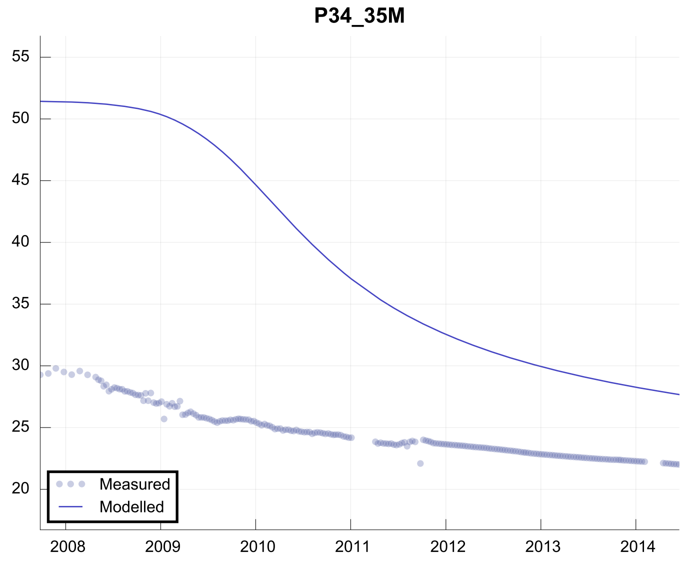

P3

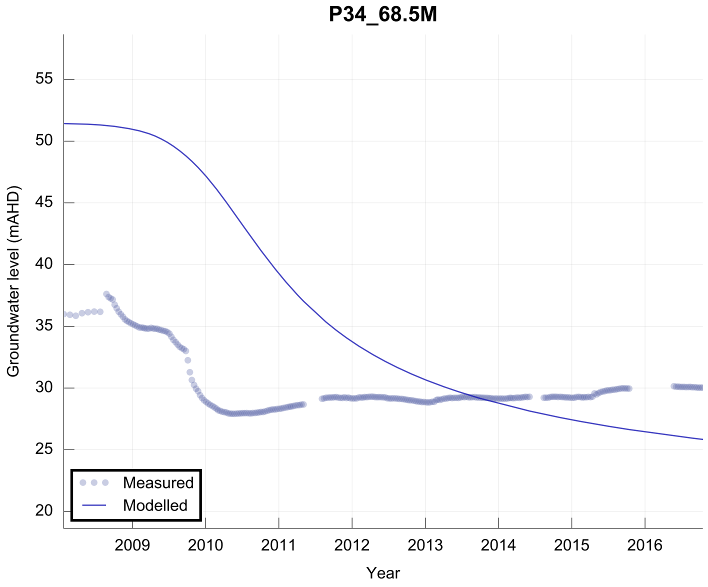

P33_13M

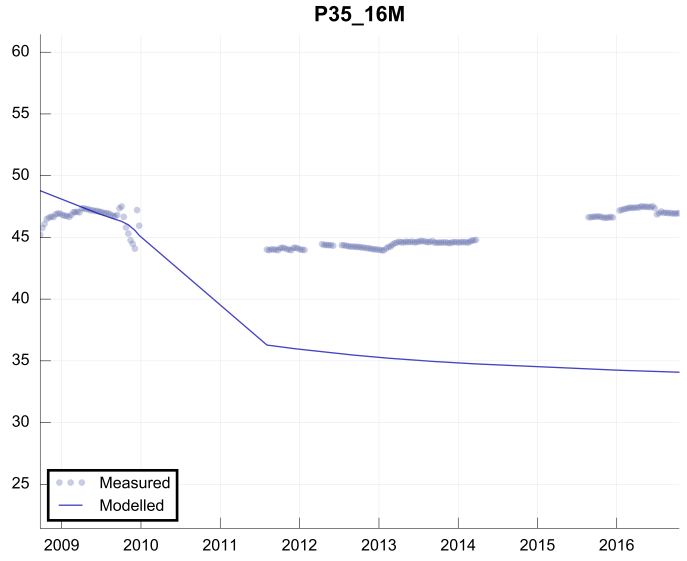

P33_19M

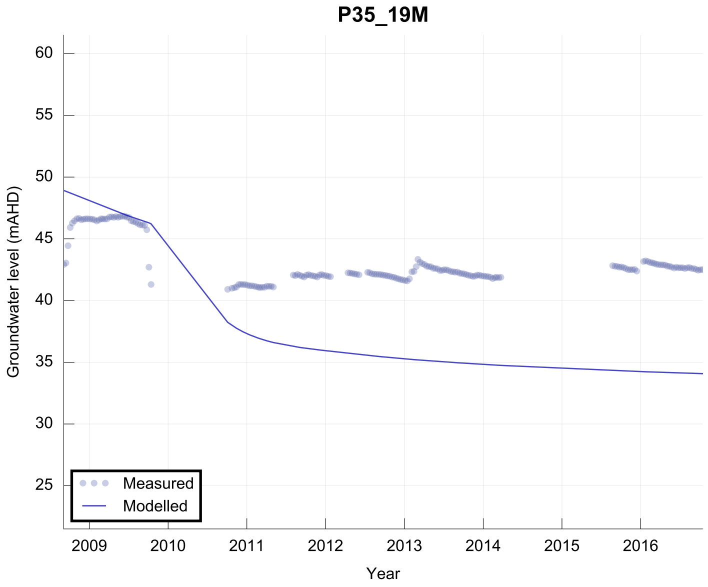

P33_46.5M

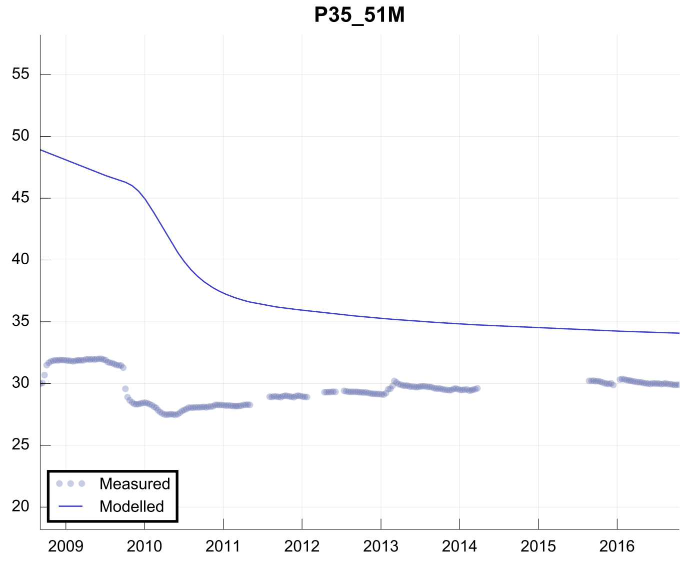

P33_58M

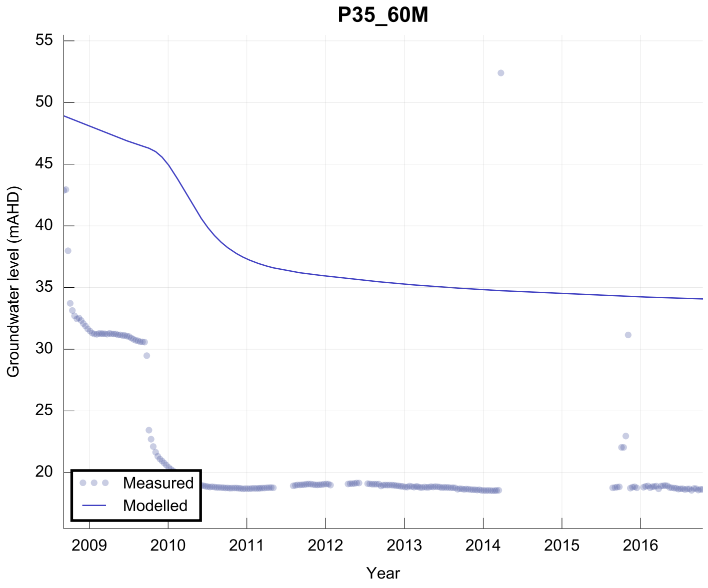

P34_35M

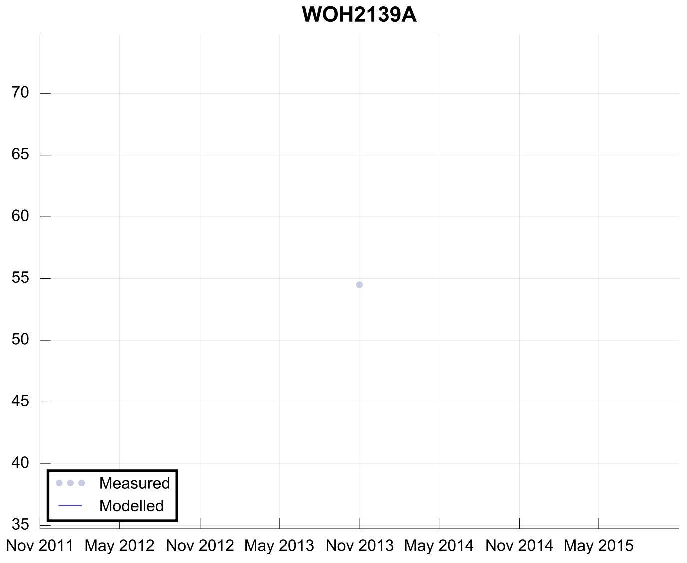

P34_68.5M


P35_16M

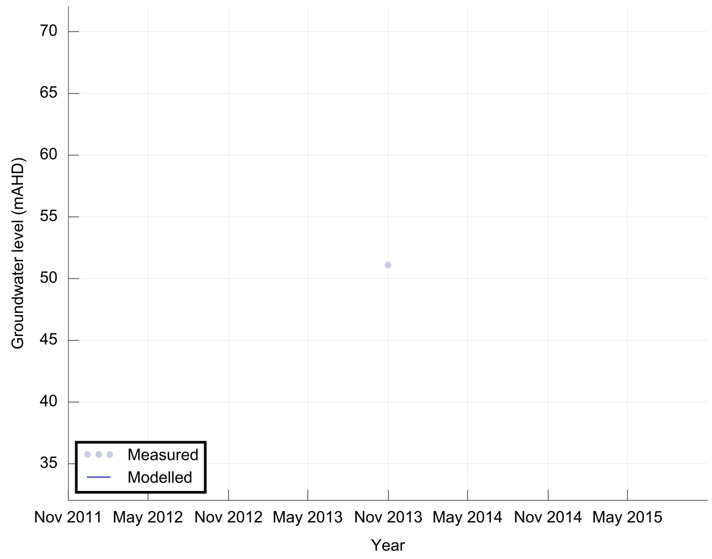

P35_19M


P35_51M

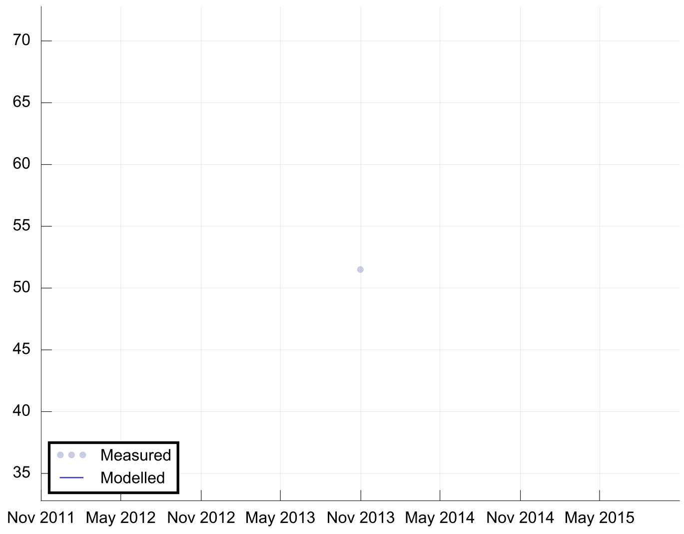

P35_60M


WOH2139A

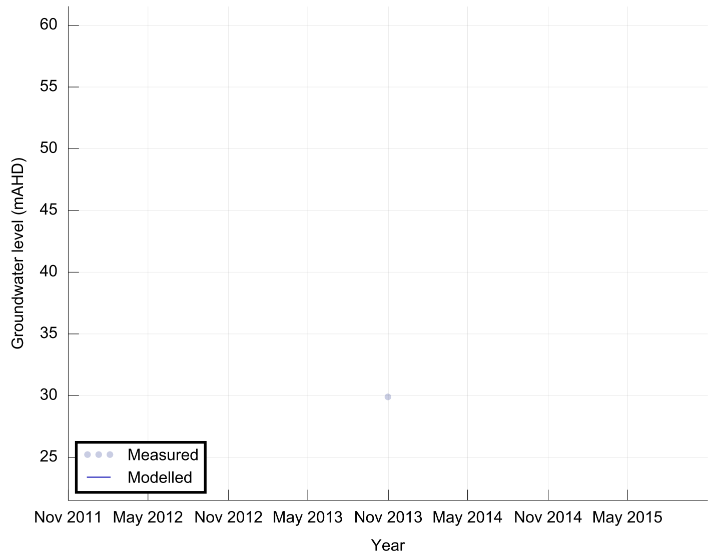
WOH2141B



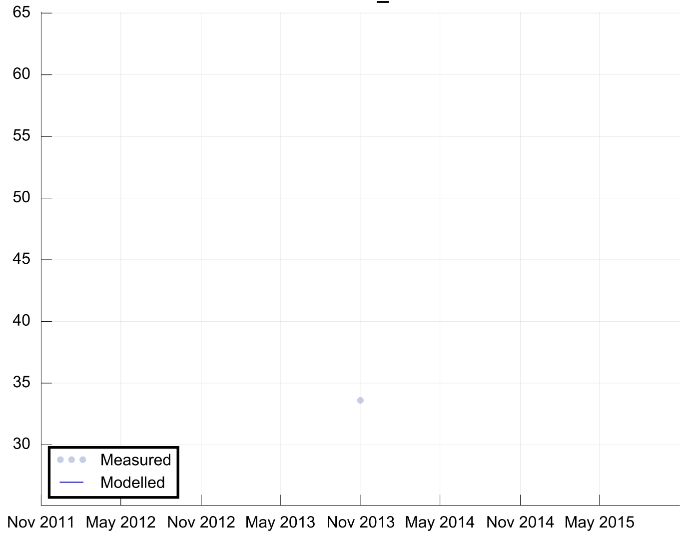
OH1123_1



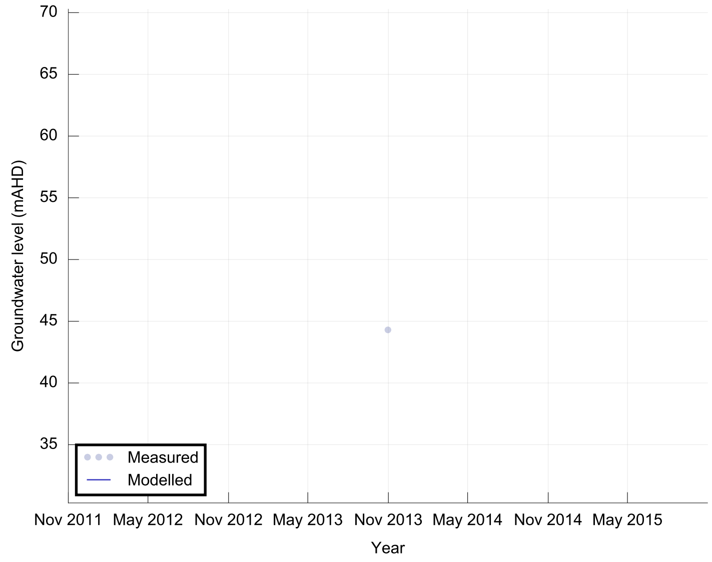
WD462_P3



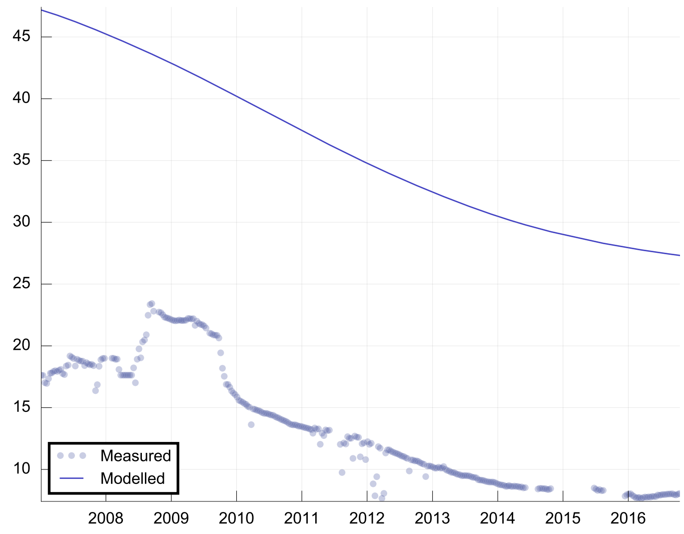
WD622_P2



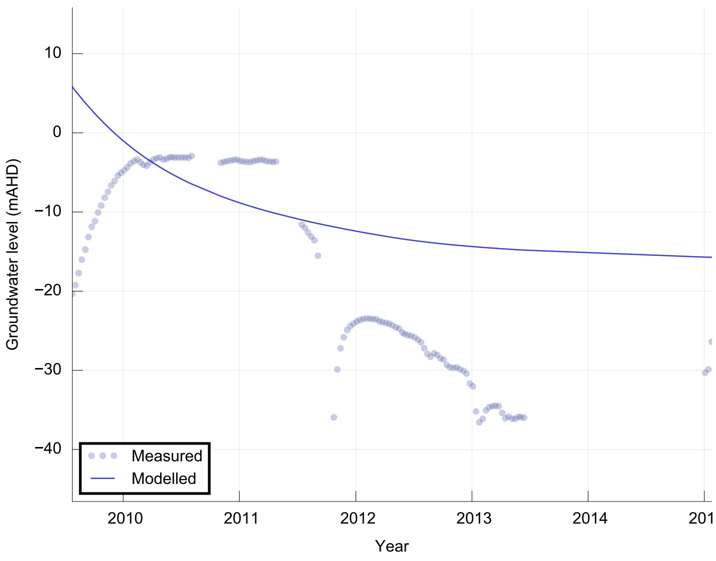
WD625_P1



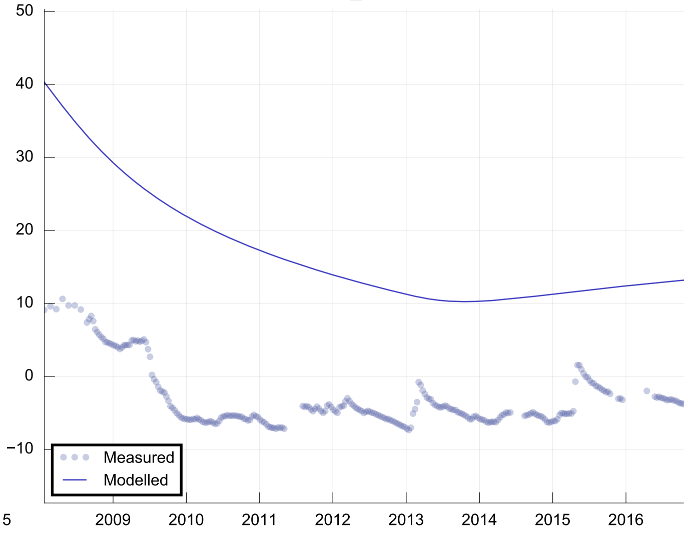
P33_113M

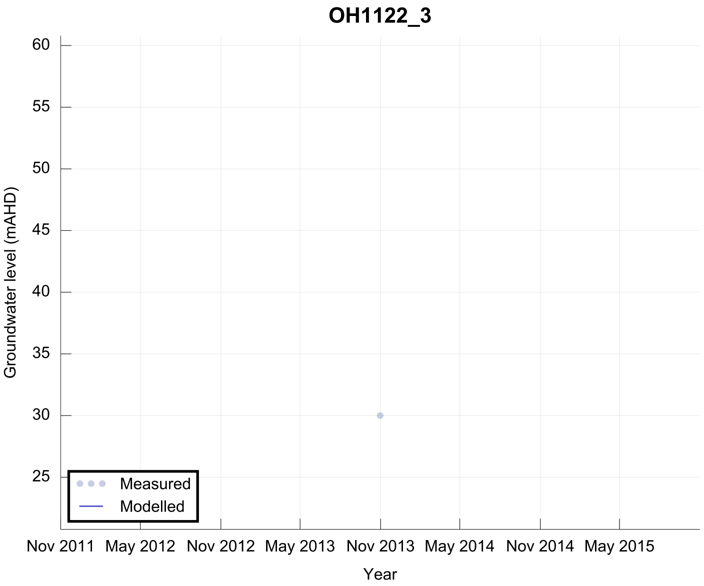


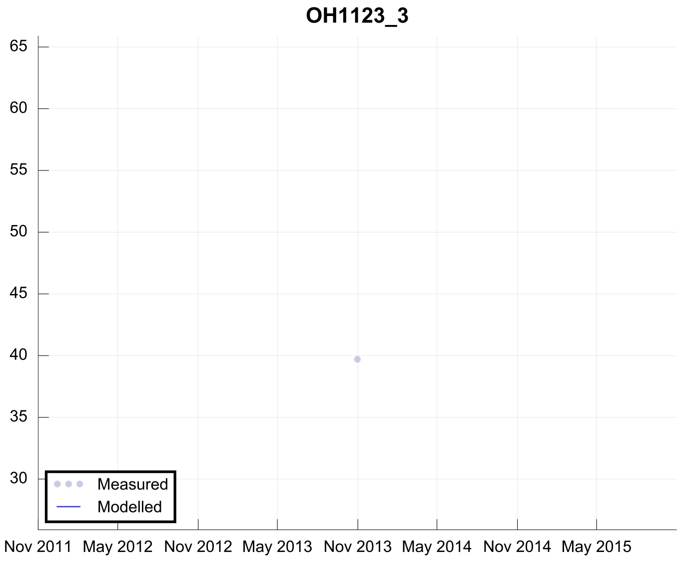
P35_112M

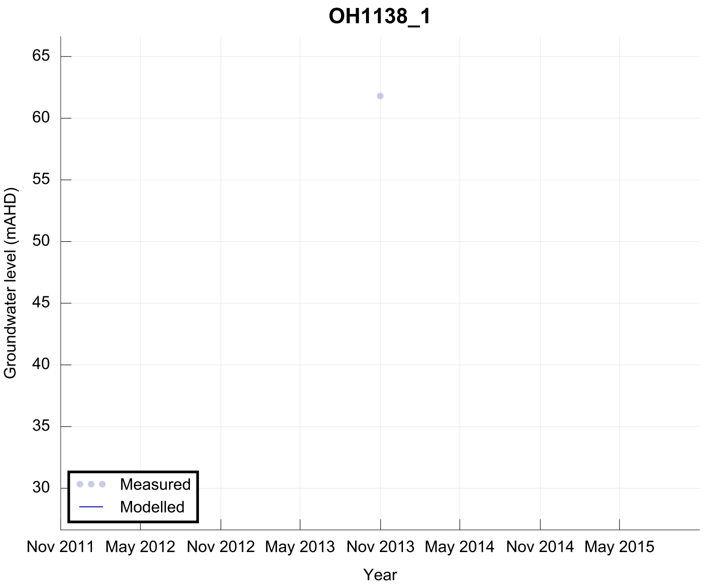


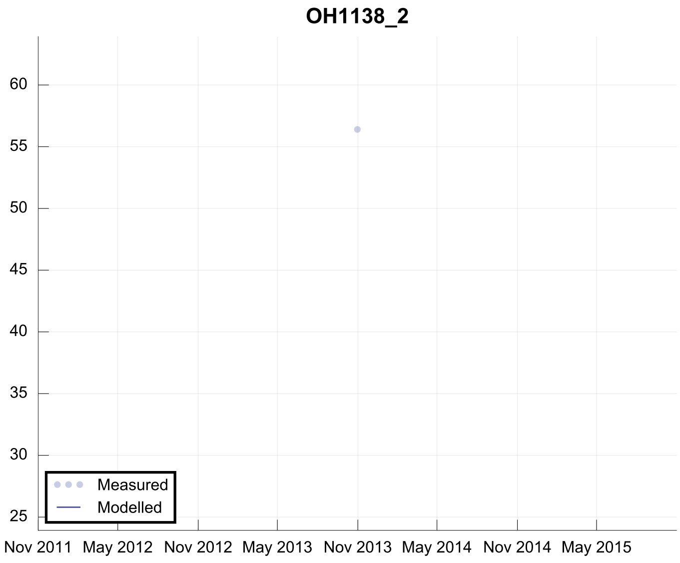
P34_144M

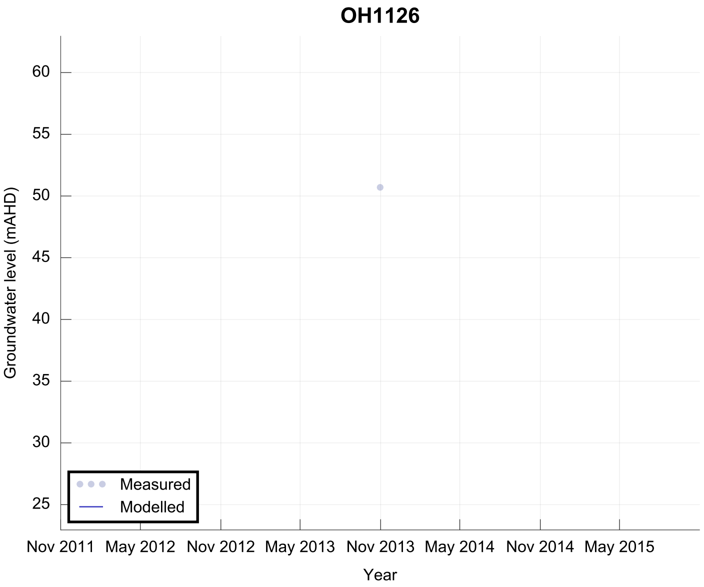


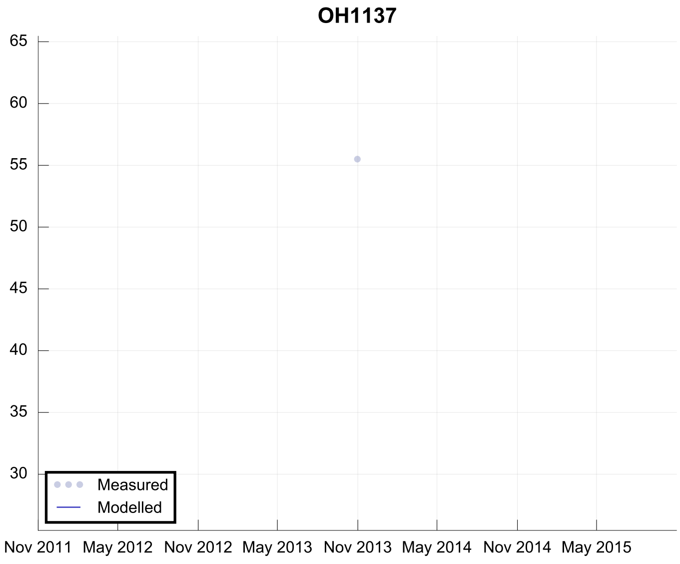

OH1122_3
Groundwater level (mAHD)
60
55
50
45
40
35
30
25
Measured
Modelled
Nov 2011
May 2012
Nov 2012
May 2013
Nov 2013
May 2014
Nov 2014
May 2015
Year

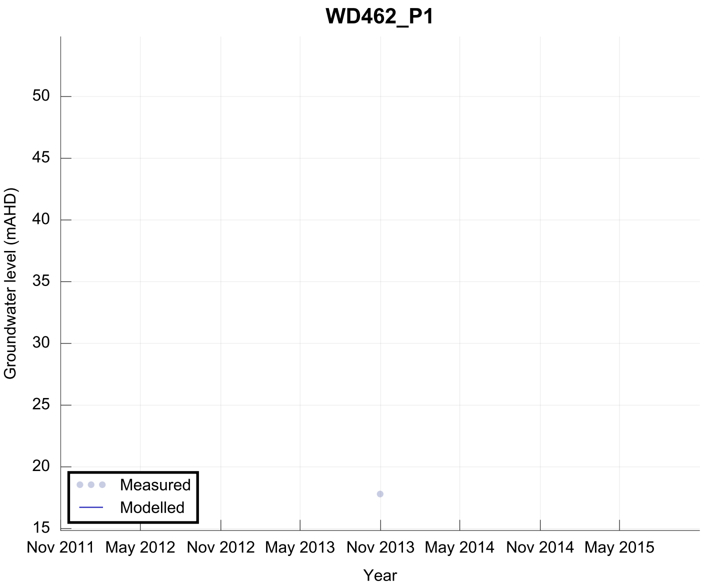

OH1123_3
65
60
55
50
45
40
35
30
Measured
Modelled
Nov 2011
May 2012
Nov 2012
May 2013
Nov 2013
May 2014
Nov 2014
May 2015

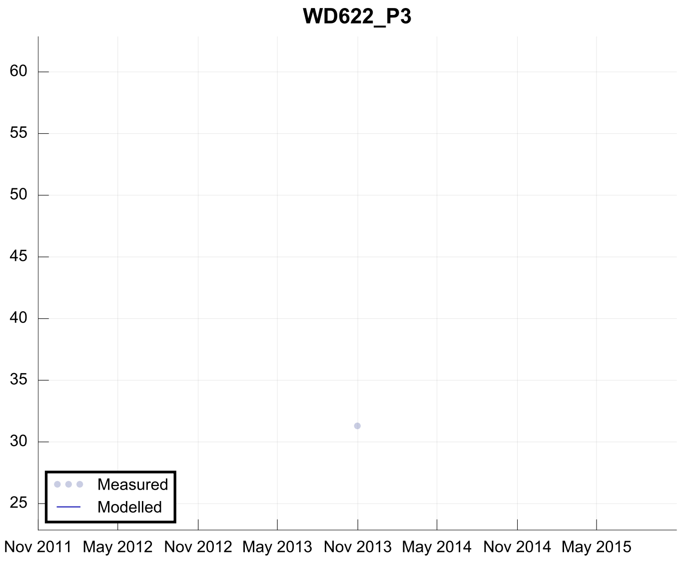

OH1138_1
Groundwater level (mAHD)
65
60
55
50
45
40
35
30
Measured
Modelled
Nov 2011
May 2012
Nov 2012
May 2013
Nov 2013
May 2014
Nov 2014
May 2015
Year

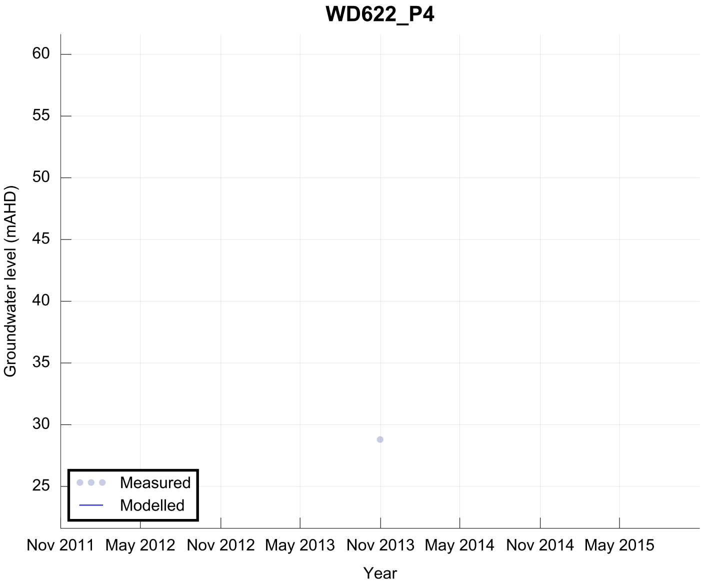

OH1138_2
60
55
50
45
40
35
30
25
Measured
Modelled
Nov 2011
May 2012
Nov 2012
May 2013
Nov 2013
May 2014
Nov 2014
May 2015

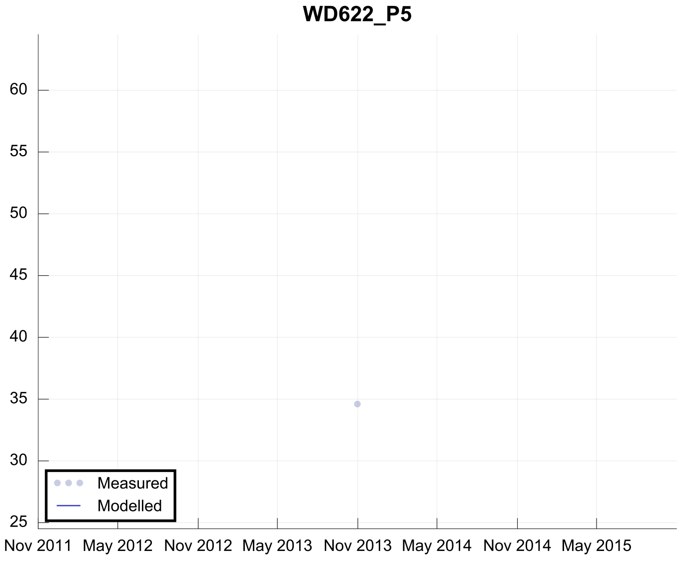

OH1126
Groundwater level (mAHD)
60
55
50
45
40
35
30
25
Measured
Modelled
Nov 2011
May 2012
Nov 2012
May 2013
Nov 2013
May 2014
Nov 2014
May 2015
Year

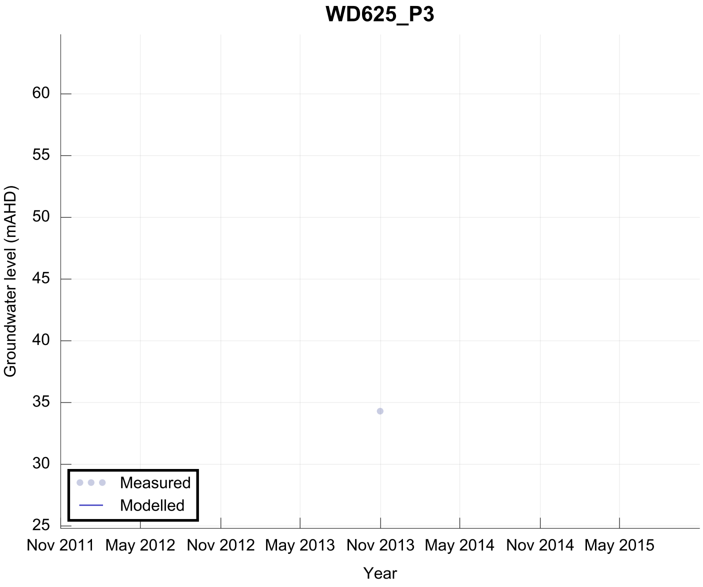

OH1137
65
60
55
50
45
40
35
30
Measured
Modelled
Nov 2011
May 2012
Nov 2012
May 2013
Nov 2013
May 2014
Nov 2014
May 2015


WD462_P1
Groundwater level (mAHD)
50
45
40
35
30
25
20
15
Measured
Modelled
Nov 2011
May 2012
Nov 2012
May 2013
Nov 2013
May 2014
Nov 2014
May 2015
Year


WD622_P3
60
55
50
45
40
35
30
25
Measured
Modelled
Nov 2011
May 2012
Nov 2012
May 2013
Nov 2013
May 2014
Nov 2014
May 2015


WD622_P4


WD622_P5


WD625_P3


GW080963

ASIA PACIFIC OFFICES

BRISBANE
Level 2, 15 Astor Terrace
Spring Hill QLD 4000
Australia
T: +61 7 3858 4800
F: +61 7 3858 4801

CANBERRA
GPO 410
Canberra ACT 2600
Australia
T: +61 2 6287 0800
F: +61 2 9427 8200

DARWIN
Unit 5, 21 Parap Road
Parap NT 0820
Australia
T: +61 8 8998 0100
F: +61 8 9370 0101

GOLD COAST
Level 2, 194 Varsity Parade
Varsity Lakes QLD 4227
Australia
M: +61 438 763 516

MACKAY
21 River Street
Mackay QLD 4740
Australia
T: +61 7 3181 3300

MELBOURNE
Suite 2, 2 Domville Avenue
Hawthorn VIC 3122
Australia
T: +61 3 9249 9400
F: +61 3 9249 9499

NEWCASTLE
10 Kings Road
New Lambton NSW 2305
Australia
T: +61 2 4037 3200
F: +61 2 4037 3201

PERTH
Ground Floor, 503 Murray Street
Perth WA 6000
Australia
T: +61 8 9422 5900
F: +61 8 9422 5901

SYDNEY
2 Lincoln Street
Lane Cove NSW 2066
Australia
T: +61 2 9427 8100
F: +61 2 9427 8200

TOWNSVILLE
Level 1, 514 Sturt Street
Townsville QLD 4810
Australia
T: +61 7 4722 8000
F: +61 7 4722 8001

TOWNSVILLE SOUTH
12 Cannan Street
Townsville South QLD 4810
Australia
T: +61 7 4772 6500

WOLLONGONG
Level 1, The Central Building
UoW Innovation Campus
North Wollongong NSW 2500
Australia
T: +61 404 939 922

AUCKLAND
68 Beach Road
Auckland 1010
New Zealand
T: +64 27 441 7849

NELSON
6/A Cambridge Street
Richmond, Nelson 7020
New Zealand
T: +64 274 898 628

www.slrconsulting.com