# WONGAWILLI MODIFICATION 2

# Supplementary Groundwater Impact Assessment

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# 1. INTRODUCTION

Wongawilli Colliery (WWC) is an underground coal mine owned and operated by Wollongong Coal Limited (WCL) which is majority owned by Jindal Steel and Power Ltd (JSPL). WWC is located 15 km south-west of Wollongong within the Wollongong and Wingecarribee local government areas (LGAs) (Figure 1-1).

Mining activities at WWC have occurred since 1916, primarily producing metallurgical coal for steel production. Extracted coal is transported vial rail to Port Kembla for export to JSPL's production facilities. WWC lies within Mining Leases (ML) 1596, ML 1565 and CCL 766. ML 1596 incorporates surface facilities and underground mine areas, including Wongawilli 1 and Nebo longwall workings as well as historical bord and pillar workings within Elouera Colliery, Nebo Colliery, Avon Colliery and Avondale Colliery (refer Figure 1-1).

The most recent project approval (PA 09_0161) for WWC also includes the approved but not completed North West Mains Development (NWMD) under the Nebo Project. The Nebo Project was approved in November 2011, under Part 3A of the *Environment Planning and Assessment Act 1979* (EP&A Act) by the Planning Assessment Commission (now the Independent Planning Commission (IPC)). The original project approval (PA 09_0161) was subsequently modified in December 2015 (MOD1) to extend the project timeframe. Operations under PA 09_0161 commenced in 2016; however, the full project approval was not completed and the site has been in care and maintenance since May 2019.

In December 2020, WCL sought to modify the existing PA 09_0161, for extension of the previously approved NWM under a modification of consent (MOD2). As part of MOD2, henceforth referred to as the Project, WCL propose to undertake the NWM Development (NWMD) to:

- extend the life of the mine by five years to enable WCL to continue development of the approved NWMD;
- include additional driveage and underground mains heading of approximately 2.9 linear km to access the existing Wongawilli Ventilation Shaft 1;
- provide additional access to the NWMD to that currently approved via existing Portals W10 and W9;
- make minor alignment changes to the approved NWMD as ventilation infrastructure is no longer proposed at the western end of the approved NWMD alignment;
- relocate coal handling infrastructure including the crusher, sizer and screen from the Wongawilli lower pit top to the underground; and
- construct a new section of coal conveyor system, approximately 60 m in length, and coal storage bin at the Wongawilli upper pit top.
-

In 2019, WCL made a commitment to no longer undertake longwall mining within the Illawarra coal fields. Mining will involve first working mining methods using two continuous miners. First working mining methods leave the pillars intact and the overlying strata fully supported reducing the potential for surface ground movements and reduces potential environmental risks (SCT, 2020).

No longwall mining or secondary extraction is proposed as part of the Project.

A groundwater impact assessment was prepared for the Project by SLR (2020) on behalf of WCL and submitted as part of MOD2. As part of the approvals process, government agency submission comments and feedback were provided to the Department of Planning, Industry and Environment (DPIE) from DPIE Water and WaterNSW.

The government agency submission comments were discussed between DPIE, DPIE Water, WaterNSW, WCL, Umwelt Environmental and Social Consultants (Umwelt) and EMM Consulting Pty Ltd (EMM) on the 27th of May 2021. During the consultation, it was agreed a standalone supplementary groundwater impact assessment report would be prepared to support the MOD2 Submission Report to address the government agency comments in a consolidated format.

This supplementary groundwater impact assessment report prepared by Umwelt re-presents the conceptual groundwater model and site background information previously reported by SLR (2020), with additional reporting included to address DPIE Water and WaterNSW comments. The numerical groundwater model, developed by SLR (2020), was also used to extract additional information on the groundwater model setup and results in order to address DPIE Water comments.

Where additional data analysis and reporting was required, this was prepared by suitably qualified and experienced persons, including Principal Hydrogeologist Claire Stephenson and Principal Groundwater Modeller Dr Daan Herckenrath of Umwelt. The additional work and final supplementary groundwater impact assessment was also peer reviewed by Dr Doug Weatherill of EMM.

Further background on the approved and historical site activities is included in Section 1.1 and Section 1.2. The Project description is outlined in Section 1.3 and the regulatory framework outlined in Section1.4. Details on the approvals process and how and where comments from DPIE Water, WaterNSW and the peer reviewer have been addressed are provided in Section 1.5.

## 1.1 Approved Site Activities

WWC currently operates under PA 09_0161, initially granted on the 2nd of November 2011 with the most recent site activities approved in December 2015 (MOD1). The existing and approved site activities include historical underground workings and pit top facilities, which are shown in Figure 1-1 and Figure 1-2, and summarised below:

- Underground workings and shafts:
  - Five ventilation shafts including Nebo No1. to Nebo No.3 that have been rehabilitated, Nebo No.4 that is currently in use and Wongawilli No. 1 that has been decommissioned.
  - NWM that comprised four 5.5 m wide, 3.6 m high and 5 km long headings within the Bulli Seam and in one area to the Wongawilli Seam. By 2019 only a 500 m length of the NWM was completed prior to being put in care and maintenance in May 2019.
  - Nebo Colliery was opened in 1945 with extensive historical bord and pillar workings within the Wongawilli Seam, Nebo Longwall area approved under PA 09_0161 included six longwall panels (LWN1 to LWN6) targeting the Wongawilli Seam around existing Nebo Colliery workings (refer Figure 1-2). Mining commenced in June 2013 at LWN2 and was completed at LWN5 in January 2019.
  - Wongawilli Colliery undertook historical bord and pillar workings within the Wongawilli Seam between 1910 and 1993, and in the Bulli Seam in the south-west between 1966 and 1971. In 1982 the Blue 2 and Blue 4 pillar extraction panels were mined in the Wongawilli Seam, adjacent to the Avon Dam and 125 m to the north of the NWMD. The Colliery includes one ventilation shaft (Wongawilli No. 1).
  - Elouera Colliery undertook longwall mining targeting the Wongawilli Seam, conducted between 1994 and 2007. Longwalls 11, 12, 15, 16, 19 and 20 extracted remnant coal to the east and south of the historical Elouera workings (refer Figure 1-2).
- Pit top facilities:
  - Three portals, one for coal extraction, one for workers and materials and one for coal clearance;

- Coal conveyor and conveyor drive head buildings;
- Water tank;
- Water collection and treatment pond;
- Licence discharge point;
- Meteorological station;
- Administration office, bath houses and amenities;
- Sewage treatment plant and septic system;
- Maintenance workshop and mining equipment storage;
- Fire station and water tank;
- Electrical substations and switching rooms;
- Car parking space and inter roads;
- Railway line;
- Coal storage bins and coal stockpile area and load out facilities;
- Storm water settling basin;
- Mine water holding dam; and
- Electrical transformer compound.

## 1.2 Mine History

Wongawilli Colliery began coal production for the Lithgow Iron and Steel Plant in 1916. In 1928 Australian Iron and Steel (AIS) was formed to operate Wongawilli Colliery, which was then acquired by BHP in 1935 (WCL, 2020).

In 1993 the Elouera Colliery was formed from the merger of the Wongawilli Colliery and Nebo Colliery. The collieries operated separate adjoining reserves extracting coal from the Bulli and Wongawilli seams. The colliery was operated by BHP Billiton Illawarra Coal (BHPBIC) until 2005. Delta mined the area from 2005 to 2007. In December 2007 Gujarat NRE acquired the lease and renamed the site NRE Wongawilli Colliery (WCL, 2020).

Mining of the Wongawilli Seam (previously known as No. 3 seam) reserves in the area has been undertaken for more than 80 years. Prior to mining within the Wongawilli Seam, the Bulli Seam (previously known as No. 1 seam) was mined. The coal emplacement area ceased its operations in November 2005 and has been rehabilitated. Run of mine (ROM) coal is now transported unprocessed by rail to the Port Kembla Coal Terminal (WCL, 2020).

From 2014 to July 2016 WWC was put into care and maintenance due to low coal prices and the burial of the WC longwall. In July 2016 mining recommenced with the extraction of the LWN1 to LWN6 panels using conventional pillar extraction. Mining ceased in March 2019 due to strata control issues in the old outbye workings. In May 2019 WWC was put into care and maintenance (WCL, 2020).

The location of the historic collieries and mining areas are shown on Figure 1-2.

## 1.3 Project Description

Under the previous site approvals for the NWMD the timing for active operations was approved until the 31st of December 2020. This timeframe has lapsed and only a small section (500 m) of the NWM was completed in that time. The Project includes extension of the timeframe to enable completion of the previously approved NWM as follows:

- Extend the life of the mine by five years to enable WCL to continue development of the approved NWMD;
- NWMD:
  - Recommencement of first working mining method along the previously approved but not completed NWM alignment within the Wongawilli Seam (Approved NWM shown in Figure 1-2);
  - Extension of the previously approved NWM alignment, to the north-east in order to join with the existing Wongawilli No. 1 Shaft, as ventilation infrastructure is no longer proposed at the western end of the approved NWM alignment. Involves approximately 2.9 km of additional driveage and underground mains heading, as first working mining method, to access the existing Wongawilli Ventilation Shaft 1. To connect with Wongawilli Ventilation Shaft, 1 the alignment extends below part of Lake Avon (Proposed NWMD shown in Figure 1-2);
  - Provide additional access to the NWM to that currently approved, via existing Portals W10 and W9;
- Relocation of coal handling infrastructure, including the crusher, sizer and screen, from the current location at the Wongawilli lower pit top to a location underground; and
- Construction of a new section of coal conveyor system, approximately 60 m in length, and coal storage bin at the Wongawilli upper pit top. Coal conveyor system is proposed to transport material from the NWM B Portal to the existing Main North Underground Conveyor.

The Project layout and location of the new proposed alignment of the NWMD are shown in Figure 1-2.

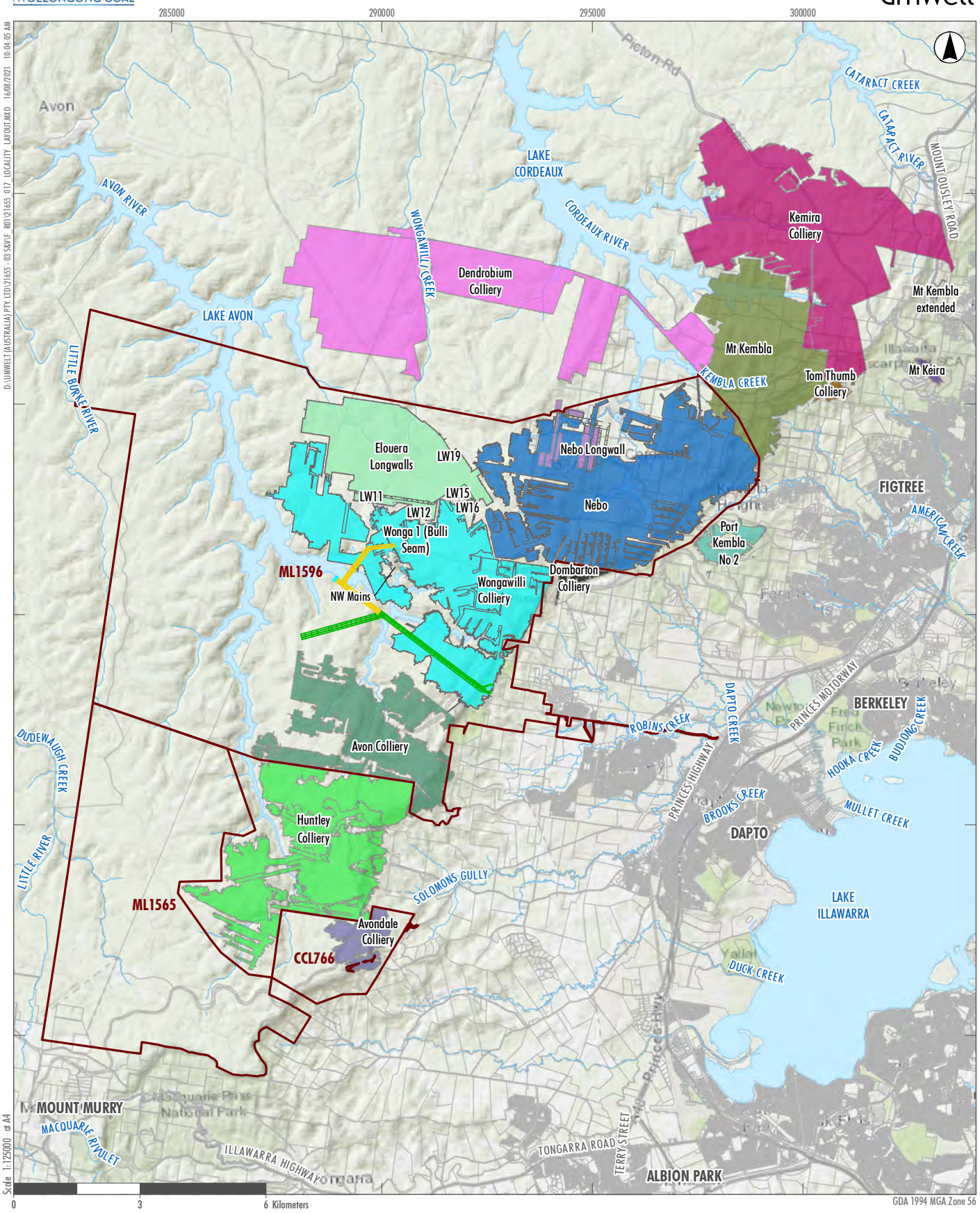
Initial works following approval of the Project, prior to commencement of mining operations, would include:

- Establishment of the surface mine services for the NWMD;
- Re-support existing (underground) workings to the design support criteria; and
- Installation of underground services.

It is likely that these initial works will take approximately three months to complete and enable progression to the initial underground mining activities. The first stage of mining will be completed in approximately 26 weeks and involve stone driveage with limited coal production during this time.

It is estimated that the second stage will be approximately 26 weeks duration.

Full operations are not expected to commence until two years after the Project approval is granted.



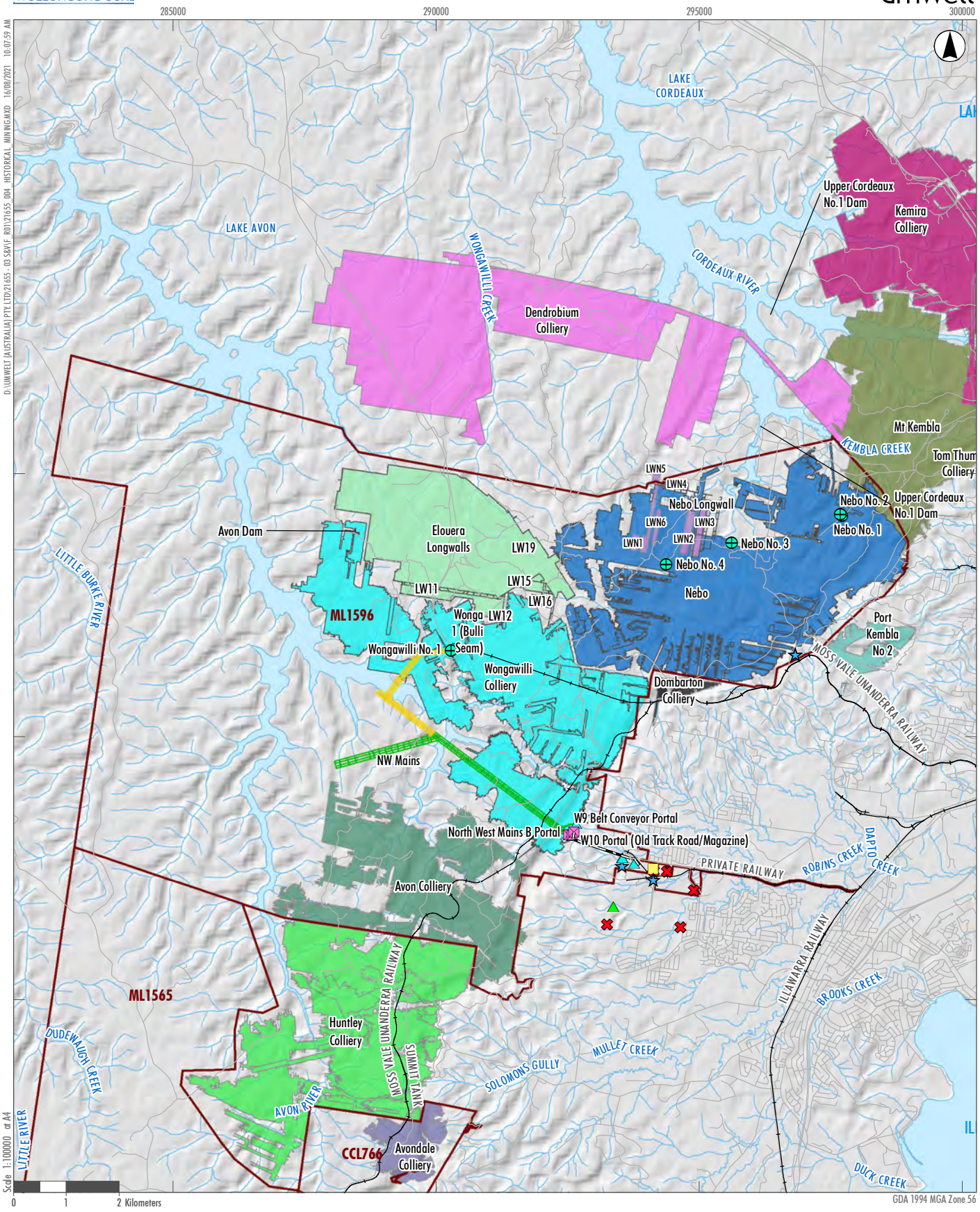

Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Avon Colliery
- Avondale Colliery
- Dendrobium Colliery
- Dombarton Colliery
- Elouera Longwalls
- Huntley Colliery
- Kemira Colliery
- Mt Keira
- Mt Kembla
- Mt Kembla extended
- Nebo
- Nebo Longwall
- Port Kembla No 2
- Tom Thumb Colliery
- Wongawilli Colliery
- Watercourses

FIGURE 1.1

Site Layout

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Avon Colliery
- Avondale Colliery
- Dendrobium Colliery
- Dombarton Colliery
- Elouera Longwalls
- Huntley Colliery
- Kemira Colliery
- Mt Kembla
- Nebo
- Nebo Longwall
- Port Kembla No 2
- Tom Thumb Colliery
- Wongawilli Colliery
- Roads
- Watercourse
- Railway
- Conveyor Belt
- Ventilation Shaft
- Portal
- Water Tank
- Ambient Air Monitoring
- Dust Deposition Site
- Licence Discharge Point
- Meteorological Station

FIGURE 1.2

Project Layout

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)

## 1.4 Regulatory Framework

This section provides background to the regulatory framework relevant to the Project, as previously reported by SLR (2020), along with additional information.

### 1.4.1 Water Management Act (NSW) 2000

The *Water Management Act 2000* (NSW) regulates the use and interference with groundwater in NSW.

Avon, Cordeaux and Nepean Reservoirs are water supply reservoirs formed by the damming of the upper Avon, Cordeaux and Nepean Rivers, and form part of the Upper Nepean Scheme (along with Cataract Reservoir). This forms part of the water supply for Sydney and the Illawarra. WaterNSW manages the water supply areas and infrastructure, with additional oversight by Dams Safety NSW.

Mine water at WWC will be managed and reused within the mine water management system with excess water discharged via one of the existing licenced discharge points.

WWC has a water take regulated under Water Access Licence (WAL) 36487. Water quality and discharges are regulated against Environmental Protection Licence (EPL) 1087.

### 1.4.2 WaterNSW Act 2014

The Project is partly located within the Upper Nepean catchment, which forms part of Sydney's drinking water catchment and designated as Metropolitan 'Special Areas' subject to the *WaterNSW Act 2014* as well as the Sydney Drinking Water Catchment State Environmental Planning Policy 2011.

The *WaterNSW Act 2014* specifies a set of mining principles for activities within Sydney's drinking water catchment including:

- Mining must not result in the integrity of the water supply infrastructure being compromised;
- Leakage from reservoirs resulting from mining activities must be avoided and regional depressurisation and diversion of surface water flows must be avoided and minimised by adopting a precautionary approach to mine design;
- All mining activities must have a neutral or beneficial effect on water quality; and
- Ecological integrity of the Special Areas must be maintained and protected.

### 1.4.3 Aquifer Interference Policy (NSW) 2012

The Water Group within DPIE manages water resources, including groundwater, through the use of Water Sharing Plans (WSPs). Groundwater at WWC is regulated by the Greater Metropolitan Region Groundwater Sources WSP. This WSP further divides the region into separate Groundwater Sources.

The WWC area is within Management Zone 1 (MZ1) of the Sydney Basin Nepean Sandstone Groundwater Source. This Groundwater Source is classified by DPIE as 'Highly Productive' under the Aquifer Interference Policy (AIP). The total assigned entitlement for all users within this Groundwater Source (for both Management Zones 1 and 2) is 24,576 megalitres per year (ML/yr), equivalent to 67 ML/d.

WCL has secured 1,500 units of shares from the Sydney Basin Nepean Groundwater Source under "Greater Metropolitan Region Groundwater Sources 2011" WSP with water WAL 36487. WWC is within the Nepean Sandstone MZ1 and mining in these areas is considered unlikely to increase the incidental take from other groundwater sources.

### 1.4.4 Mining Act 1992

Mining leases in NSW are granted under the provisions of the *Mining Act 1992*. The *Mining Act 1992* also refers to mining activities generally, places controls on methods of exploration and mining, the disposal of mining waste and rehabilitation and environmental management activities. Part 11 of this Act regulates the environmental protection and rehabilitation of lands disturbed by mining. The *Mining Act 1992* is administered by DPIE.

Under the *Mining Act 1992*, environmental protection and rehabilitation are regulated by conditions in all Mining leases including the Project. Mining leases also include requirements for the submission and approval from DPIE of a Mine Operation Plan (MOP) prior to the commencement of operations.

WWC operates under three mining leases CCL 766, ML 1565 and ML 1596. The MOP for WWC has previously been updated and approved. The MOP will be updated as required resulting from the Project.

### 1.4.5 Protection of the Environment Operations Act (NSW) 1997

The *Protection of the Environment Operations Act 1997* (POEO) is state based legislation administered by the NSW Environment Protection Agency (EPA). The object of the Act is to achieve the protection, restoration and enhancement of the quality of the NSW environment through the granting of licenses that place conditions of scheduled developments such as mines like WWC.

WCL holds EPL 1087 (modified on the 25th ofNovember 2020), which regulates the contribution of water (volume and quality) from the mine's discharge points..

### 1.4.6 Commonwealth Legislation

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is administered by the Department of Agriculture, Water and the Environment (DAWE), with advice from the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC). The IESC is a statutory body established under the EPBC Act that provides scientific advice to the Commonwealth Environment Minister.

It is understood that the Project is not likely to have significant impacts requiring referral to the Commonwealth under the EPBC Act.

## 1.5 Approval Process

This section presents a summary of regulator comments to the SLR (2020) groundwater impact assessment, as provided by DPIE Water (Section 1.5.1) WaterNSW (Section 1.5.2) and the Peer Reviewer (Section 1.5.3).

### 1.5.1 DPIE Water

DPIE Water provided comments on the SLR (2020) groundwater impact assessment on the 27th of April 2021. The comments from DPIE Water are summarised in Table 1-1 below, along with how and where the comments have been addressed in this report. The full response from DPIE Water is included in Appendix A.

Table 1-1 DPIE Groundwater Model Recommendations

| ID | DPIE Comment | Response | Section in This Report |
|---|---|---|---|
| 1 | The groundwater modelling report should be a standalone document, with minimal referral of the reader to external material. | Consolidated modelling report prepared | This report |
| 2 | The groundwater modelling report must include a clear description of the proposed Project, which is consistent with the description provided in other documents like the Main Report. | To include clear project description in report. | Section 1.3<br>Section 3.3.8 |
| 3 | The groundwater modelling report must demonstrate that the proposed Project is properly represented in the numerical model. If no longwall mining is proposed, longwalls must be removed from the conceptual and numerical model and the effects of longwall mining on the overlying hydrogeological system must not be represented. | Report updated to better clarify that the Project does not include longwall mining. | Section 1.3<br>Section 3.2 |
| 4 | Revise the Model and the Report addressing comments and recommendations in:<br>a. The EMM peer review.<br>b. WaterNSW submission to Environmental Impact Statement - Wongawilli Mine Modification 2 (MP 09_0161 MOD 2).<br>c. The Independent Expert Panel for Mining in the Catchment Report (IEMPC 2019) mentioned in Section 7.4 in the Report.<br>d. These comments by DPIE Water. | Incorporated into this report. | This report |
| 5 | Include self-assessment of modelling using checklists in the AGMG 2012. | Modelling reported on against AGMG 2012. | This report |
| 6 | There are omissions in the Report that must be addressed including errors and inconsistencies in text and between text, tables, and figures. Most of the figures must be reproduced to meet expected professional standards and be useful. The content and formatting of tables must also be checked. | Supplementary groundwater impact assessment report prepared to address errors and omissions in the original report. | This report |
| 7 | Please use consistent units. There are basic unit conversion errors that must be corrected, e.g. Table 3-7. | Consistent units applied throughout report, and conversion data checked and fixed. | This report<br>Section 2.7.1 |
| 8 | Explain what change in recharge and specific yield of less than 0% means (-300% and -500% as stated in Section 8, p 112). | Details on model setup presented in report. | Section 3.2 |
| 9 | Account for other mining operations in the area and clearly describe the approach adopted to assess cumulative impacts, including listing and characterisation of other considered operations. | Details on model setup including surrounding and historical mining presented in report. | Section 3.3.7 and<br>Section 3.6 |
| 10 | Provide maps of the predicted drawdown due to the Project alone and all developments in the area including the proposed Project for all model layers at key times, e.g. start of the Project, end of the Project, then selected dates that will help understand the long-term effects of the Project. | Predictions presented in report. | Section 4 |
| 11 | Clearly indicate other operations modelled at various stages. Particularly, describe how was the Dendrobium Mine included in the model while it occurs outside the model domain. | Details on model setup including surrounding and historical mining presented in report. | Section 3.3.7 |

| ID | DPIE Comment | Response | Section in This Report |
|---|---|---|---|
| 12 | Clarify the sources of all presented data. | From consultation, comment was related to hydraulic properties, source data information included in report. | Section 2.7.1 |
| 13 | Provide a clear geological map showing geological units and structure. | Geological details and map included in report | Section 2.4 |
| 14 | Clarify the extent of the used geological model/s. | Details on geological models included in geology section of report and model development details included in report. | Section 2.4<br><br>Section 3.2 |
| 15 | List the hydraulic parameter values and boundary conditions adopted from Golder 2010 SEEP/W modelling, including providing a map showing the alignment of the modelled cross-section/s. | Details on model setup including hydraulic properties assigned presented in report. | Section 2.7.1 |
| 16 | Provide a useful map of existing monitoring networks, including South 32 setups. | Included in report | Section 2.5 |
| 17 | Make appropriate recommendations to set up a useful monitoring network to support future modelling of the Project and expected future modifications. | Include monitoring recommendations. | Section 7 |
| 18 | Obtain relevant surface water data and incorporate in the model, e.g. rivers and lakes stage and bed elevations, bed conductance, baseflow, etc. | Details on model setup the river package and use of observation data presented in report. | Section 3.3.2 |
| 19 | Include lines representing the arithmetic and geometric mean of the K data in Figure 6-8. | Details on hydraulic properties included in report. | Section 2.7.1 |
| 20 | In all assessments of effects, present 'Project only' and 'cumulative' impacts. Cumulative impacts include all historical and approved developments in the area in addition to the proposed Project. | Include clarity on what each of the model scenarios are and what they represent. | Section 4 |
| 21 | Clarify the numerical model representation of surface water features, including the river zones shown in Figure 5-3. | Include map of the different river zones with a legend to explain the zonation and link to report. | Section 3.3.2 |
| 22 | Provide an assessment of potential groundwater level drawdown effects at individual nearby bores due to all developments in the area including the Project and due to the Project alone. The assessment must clarify assessment uncertainty. | Include details on registered landholder bores and also include a section to outline predicted impacts on registered bores (and if no impacts are predicted). | Section 2.10.1 and Section 4 |
| 23 | Include the Hawkesbury Sandstone in all impact, sensitivity, and uncertainty analysis as it represents an important water source in the area. | Include maps and results for the Hawkesbury Sandstone. | Section 5 |
| 24 | Provide an assessment of the water level variation in groundwater associated with GDEs in support to the views regarding drawdown effects on GDEs expressed in Section 7.4. | Include in impact assessment. | Section 4.4 |

| ID | DPIE Comment | Response | Section in This Report |
|---|---|---|---|
| 25 | Provide an assessment of potential impacts on individual neighbouring GDEs due to the Project alone and the Project and other developments in the area, including clarifying uncertainty in the analysis. | Include in impact assessment. | Section 4.4 |
| 26 | Clearly describe the northern GHB settings, including how the effects of the existing and future Dendrobium Mine operations have been accounted for. | Include detail on the model setup and assumptions. | Section 3.3.1 |
| 27 | Ensure that the model boundaries alignments, types, and descriptions are consistent in the text and figures. | Include detail on the model setup and assumptions. | Section 3.2 |
| 28 | Provide a clear description of the eastern model boundary. | Include detail on the model setup and assumptions. | Section 3.2 |
| 29 | Provide steady-state model calibration scatter plot (modelled vs observed heads). | Steady-state model calibration scatter plot presented. | Section 3.5.2.1 |
| 30 | Clearly describe the methodology for estimating initial rainfall recharge, including map presentation of the data. | Include details on recharge parameters. | Section 3.2 |
| 31 | Present maps showing rainfall recharge and evapotranspiration (ET) from the water table for steady-state conditions and an average from the transient simulation. | Include map of the different recharge zones with a legend to explain the zonation and link to report.<br>Include graph showing recharge input (timeseries). | Section 3.3.3 |
| 32 | Clarify the assigned confinement status for each model layer. | Confirm if layers are defined as confined or convertible in the model setup. | Section 3.2 |
| 33 | Obtain and calibrate the model against surface water and mine inflow data. | Include details on model setup and inputs (i.e. use of streamflow data to set up RIV package and mine inflows). | Section 3.3.2 |
| 34 | Clarify the source and rational behind the use of the Kh-depth equation to assign Kh values to the model cells, including the used factors and coefficients. | Include details on hydraulic data and depth dependence equation sources, and recommendations for future iterations. | Section 3.4.1 |
| 35 | Clarify whether the initial Kh values assigned using the adopted Kh-depth relationship have been altered during the model steady-state and transient calibrations. | Include details on model setup. | Section 2.7.1 and Section 3.4.1 |
| 36 | Undertake composite parametric sensitivity (parameter identifiability) analysis to determine influential parameters in the model. The results must be used to enhance the model calibration and guide the uncertainty analysis. | Include details of model setup, and recommendations for future iterations. | Section 3.5.4.3 |

| ID | DPIE Comment | Response | Section in This Report |
|---|---|---|---|
| 37 | Explain in simple analytical formula/s (or other means) how the rising water levels noticed in some piezometers is related to an increase in storage due to recharge of the historical workings. | Groundwater level trends reviewed and revised discussion on trends is included in report. | Section 2.6 |
| 38 | Identify possible reasons for the calibrated model not being able to replicate seasonality, long-term trends, and vertical relationships and discuss/implement potential solutions. | Include discussion on the model calibration performance and updated calibration, include mapped residuals and recommendations for future improvement. | Section 3.5 |
| 39 | Provide a revised assessment of expected mine inflows, including appropriate uncertainty analysis. | Included in report. | Section 4 |
| 40 | Undertake sensitivity analysis of heads and conductance values used in the model's GHB. | Include further information on the model setup and boundary head conditions. | Section 5 |
| 41 | Undertake sensitivity and uncertainty analyses of ET extension depth. | Include explanation of model setup, including ET, and describe the water balance components. | Section 3.3.5 and Section 5 |
| 42 | Undertake uncertainty analysis guided by the results of comprehensive sensitivity analysis including parameter identifiability assessment. | Include recommendations for future model improvements. | Section 3.5.4.3 |
| 43 | Examine the effects of concurrent changes in hydraulic properties in the uncertainty analysis (e.g. coinciding higher Sy and Kh). | Conducted additional sensitivity scenarios with combined parameters. | Section 5 |
| 44 | Arrange for the peer review to be re-done by an independent party, as required by the NSW Aquifer Interference Policy. | Peer reviewer independence declaration completed and included in peer review report. | Appendix C |

### 1.5.2 WaterNSW

WaterNSW provided comments on the SLR (2020) groundwater impact assessment on the 10th of March 2021. The comments from WaterNSW are summarised in Table 1-2 below, along with how and where the comments have been addressed in this report. The full response from WaterNSW is included in Appendix B.

Table 1-2 WaterNSW Recommendations

| ID | WaterNSW Comment | Response | Section in this Report |
|---|---|---|---|
| 1 | Potential impacts to Lake Avon. | Addressed in SCT (2021) | Section 2.7.3 |
| 2 | Potential inflows associated with mining through the Wongawilli Fault and dyke. | Addressed in SCT (2021) | **Section 2.7.3** |
| 3 | Potential increased stresses in the vicinity of geological structures associated with previous mining. | Addressed in SCT (2021) | **Section 2.7.3** |

| ID | WaterNSW Comment | Response | Section in this Report |
|---|---|---|---|
| 4 | Groundwater assessment:<br>a. WaterNSW notes that the groundwater model is heavily reliant on data from Dendrobium Mine (Areas 3A and 3B) with 635 monitoring locations compared to only 14 in Wongawilli Mine.<br>b. It is also noted that the model is a regional groundwater model, instead of a site-specific model. The lack of site-specific groundwater monitoring data means that the groundwater model predictions may not accurately represent the actual outcomes.<br>c. Further, the mass balance results for the predictive models (2020 and 2049) discussed in Section 7.1 do not match with results presented in Table 7-2. For example, rainfall recharge of 59.7 ML/day vs 179 ML/day. It is recommended that the mass balance estimates are updated to remove inconsistencies and provide more clarification on the presented results. | a) The model dependencies on site data as well as Dendrobium data and the Dendrobium impact model are outlined in the report.<br>b) The model is calibrated against all available site-specific monitoring data.<br>c) Model mass balance results reproduced and reported on. | a) Section 3.2.2, 3.4and 3.5.1<br>b) Section 3.5.1<br>c) Section 3.6 |
| 5 | Future infrastructure - the Burrawang to Avon tunnel (Illawarra Spur Pipeline). | Addressed in SCT (2021) | **Section 2.7.3** |

### 1.5.3 Peer Review

Peer review of the groundwater impact assessment and modelling completed by SLR (2020) was conducted by Dr Doug Weatherill of EMM. The peer review found that the work completed was generally considered fit for the purpose of the Project. However, some limitations with the reporting were identified. These included:

- Many of the figures were of a low image quality, lack scale or spatial references and/or legends and do not specify what is shown in the figure.
- The report does not present the data sources used to define the geometry of the layers.
- Drain boundary conditions were not explicitly stated in the report if they effectively dewater the coal seams during periods of active mining. This was confirmed separate to the report.
- Details on the Time-Variant-Materials package and adopted properties was not documented in the report.
- Further clarification on why bores were or were not included in the model calibration is required, including use of available data from Dendrobium and discussion on vibrating wire piezometer data.
- Confusion in reporting on steady state and calibration results that requires clarification.
- Calibration results do not compare to measured inflows, only previously modelled inflows.
- Further explanation on the approach taken with uncertainty analysis required.

Comments from the initial peer review were considered as part of this supplementary groundwater impact assessment report as reported in Section 3.

To ensure all comments were adequately addressed, the peer reviewer was engaged to progressively comment on the methodology undertaken and to conduct a peer review of the new report. Peer review findings of this supplementary groundwater impact assessment are presented in Appendix C.

# 2. BACKGROUND

This section presents background information on the existing environment and land use activities relevant to development of the conceptual groundwater model for the Project. The information presented is derived from the SLR (2020) report, along with additional information presented to address regulator comments (refer Section 1.5).

## 2.1 Climate

This section provides background to the climate for the Project area, as previously reported by SLR (2020). Climate data was obtained for the Project area from the Scientific Information for Land Owners (SILO) database of historical climate records for Australia (DES, 2020). It provides daily meteorological datasets for a range of climate variables in ready-to-use formats suitable for biophysical modelling, research and climate applications from 1889 to present. SILO is hosted by the Queensland Department of Environment and Science.

To describe the long-term local climate, data from the gridded SILO database was downloaded for the closest available location to the Project area (-34.45 degrees latitude and 150.75 degrees longitude) and for the time period between 1900 and 2020.

A summary of rainfall, evapotranspiration and evaporation data from SILO is presented in Table 2-1 and displayed in Figure 2-1. SILO climate trends are shown in Figure 2-2 and the location of the SILO data point is shown in Figure 2-3.

Table 2-1 Climate Summary (from SLR, 2020)

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Historical Average Rainfall (mm) | 143 | 172 | 160 | 132 | 120 | 138 | 96 | 85 | 74 | 101 | 113 | 121 | 1455 |
| Evapotranspiration (mm) | 134 | 110 | 93 | 55 | 28 | 19 | 22 | 38 | 66 | 96 | 117 | 135 | 915 |
| Pan Evaporation (mm) | 176 | 140 | 124 | 90 | 64 | 49 | 57 | 82 | 110 | 140 | 155 | 185 | 1374 |

SILO data is based on observational records provided by the Bureau of Meteorology (BoM), with data gaps addressed through data processing in order to provide a spatially and temporally complete climate dataset. Based on the SILO dataset, the region experienced 1455 millimetres (mm) of rainfall per year, on average. Historical rainfall averages indicate the majority of rainfall occurs in the first half of the year (summer and autumn). Figure 2-1 shows that average monthly rainfall exceeds the average monthly evapotranspiration during autumn, winter and the majority of the summer months, and exceeds the average monthly evaporation during autumn, winter and at the end of summer. This is the time when most steady recharge into groundwater would be expected to occur. However, the average conditions mask the fact that during the summer months recharge would also occur during large rain events.

Monthly records from the SILO dataset were used to calculate the Cumulative Rainfall Departure (CRD), presented in Figure 2-2. The CRD shows trends in recorded rainfall compared to the long-term average and provides a historical record of relatively wet and dry periods. A rising trend in slope in the CRD graph indicates periods of above average rainfall, whilst a declining slope indicates periods when rainfall is below average. A level slope indicates average rainfall conditions.

Figure 2-2 shows the CRD and total monthly rainfall for the SILO data node from January 1940 to June 2020. The CRD shows:

- Periods of above average rainfall in 1949-1953, 1965-1969, 1975-1979, and 1988-1992;
- Periods of average rainfall in 1954-1956, 1958-1960, 1969-1974, 1984-1987 and 2011-2016; and

- Periods of below average rainfall in 1940-1948, 1956-1957, 1961-1964, 1980-1983, 1993-2010 and 2017-2020.

Figure 2-1 SILO Average Monthly Rainfall, Evapotranspiration and Pan Evaporation (from SLR, 2020)

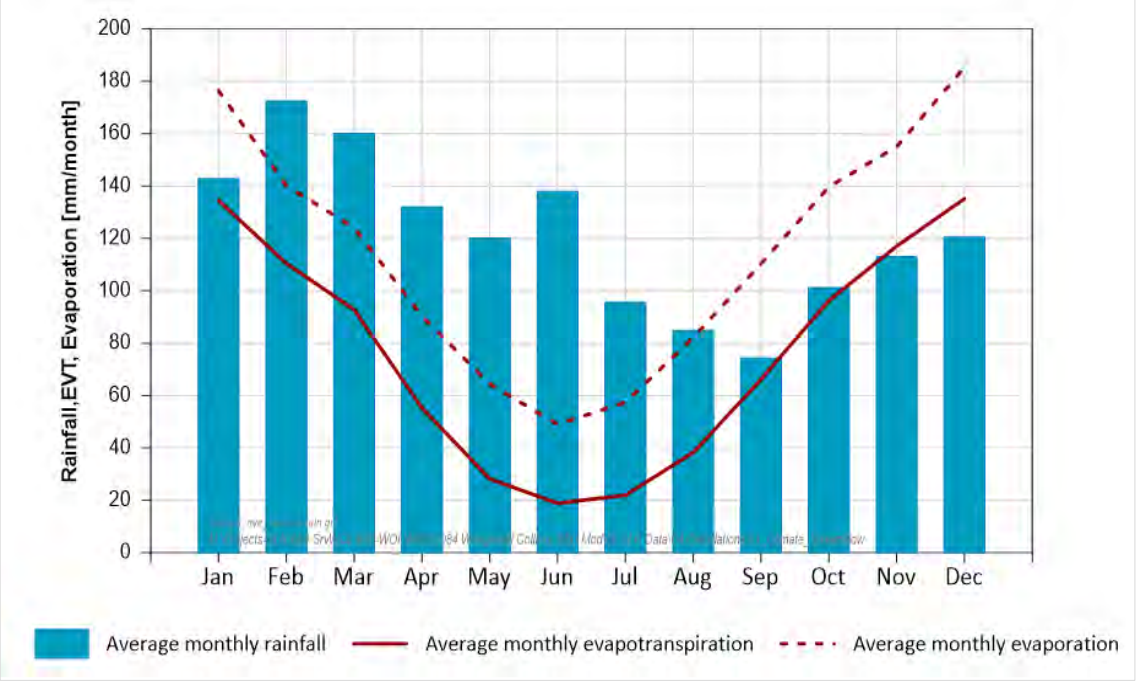
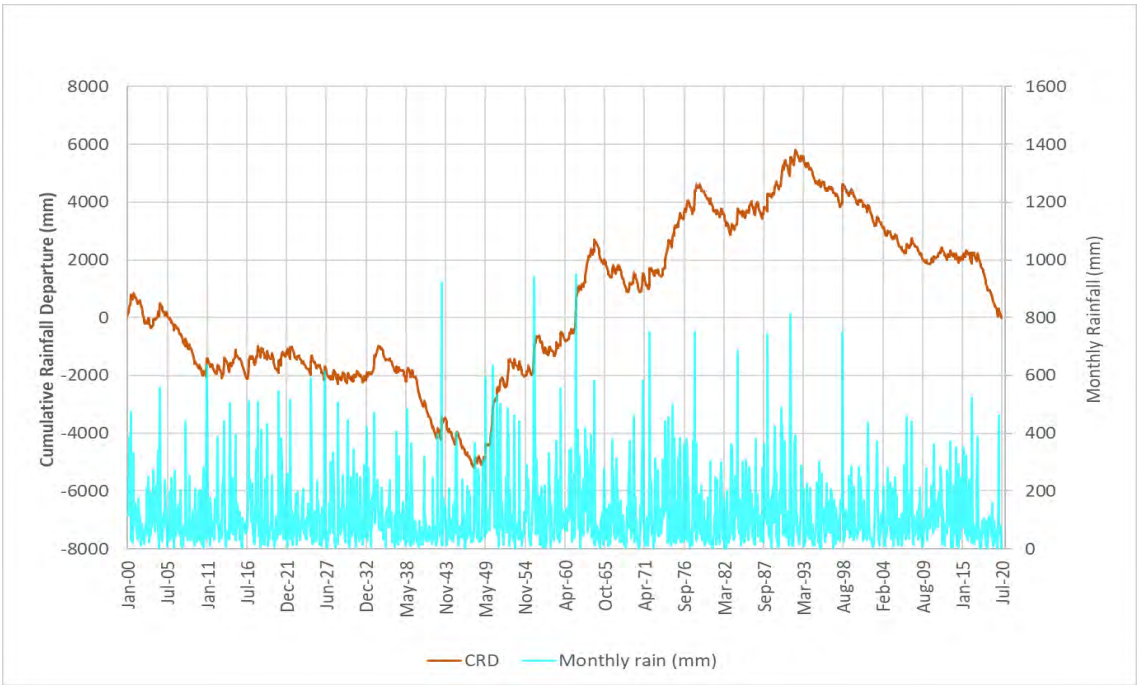



Figure 2-2 Rainfall and Cumulative Rainfall Departure (from SLR, 2020)



## 2.2 Topography and Drainage

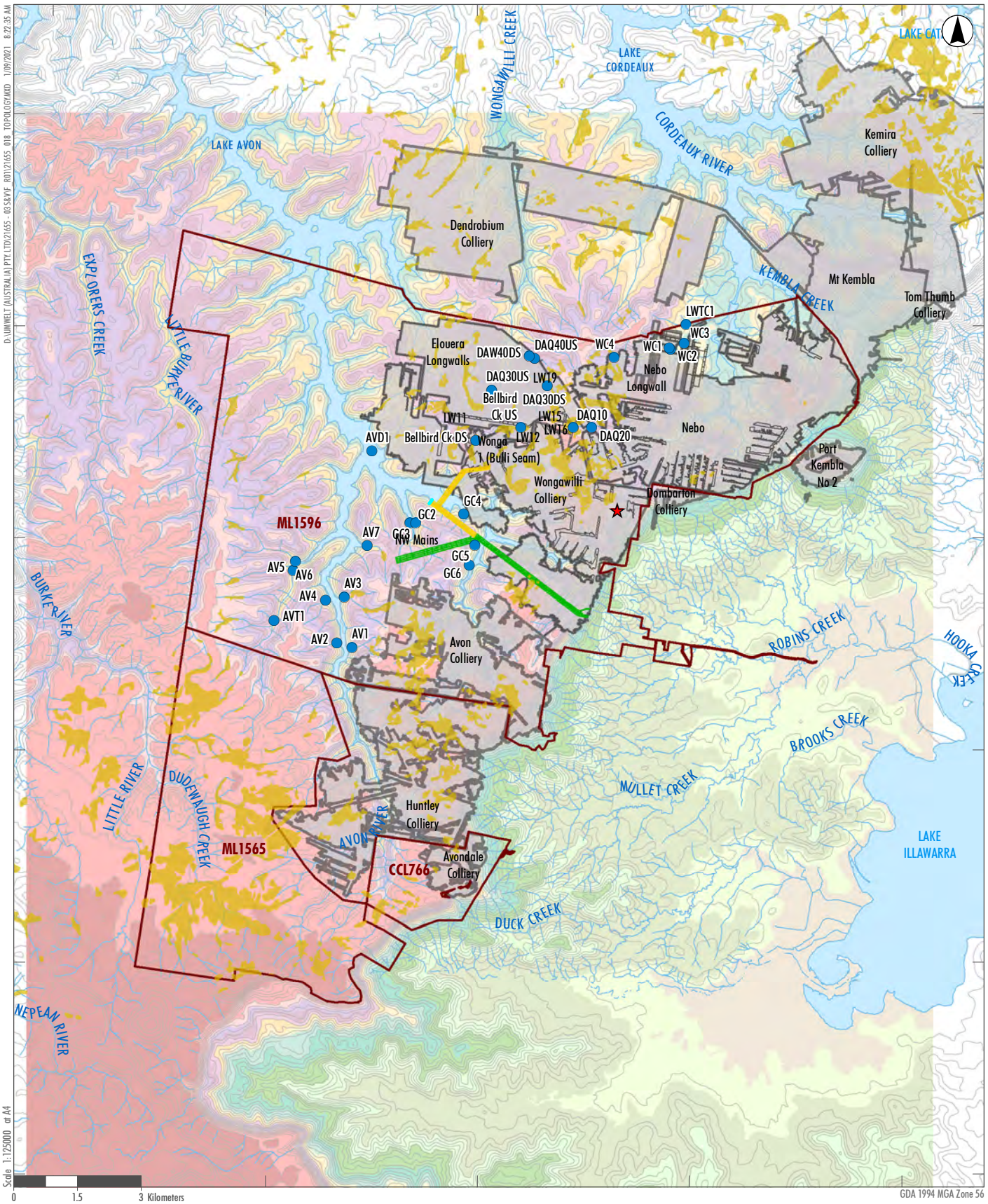
This section provides background to the topography and drainage of the Project, as previously reported by SLR (2020).

### 2.2.1 Topography

The Project is located on the Woronora Plateau, inland of the Illawarra Escarpment, approximately 15 km south-west of Wollongong, NSW. Locally, the Project is west of Lake Illawarra and includes Lake Avon (Figure 2-3). The rise of the escarpment from the coastal plain to Wongawilli is approximately 400 mAHD.

On the plateau, topography generally slopes to the north or north-west, toward the centre of the Sydney Basin. However, the plateau is incised with the large river valleys such as those associated with Wongawilli Creek and Cordeaux Reservoir between 50 m and 100 m deep.

Primarily, topography of the Wongawilli area consists of gentle undulating terrain with increasing prevalence of steep gorges and ridges north across the Project area. These valleys form part of the southern water catchment area for Sydney and Illawarra. A major reservoir, Avon, traverses the central / western area while the upper reaches of the Cordeaux Reservoir are in the north-eastern portion of the Project area. Water holds large tracts of land covered by native vegetation with a high biodiversity value. Access is mainly restricted to existing fire roads, except for dams and associated WaterNSW infrastructure such as the Moss Vale – Port Kembla railway line and power transmission lines. Minimal development has occurred in the area of Wongawilli, Huntley and Avondale (WCL, 2017).




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Swamp
- Watercourse
- 20m Contours
- Surface Water Monitoring Points
- SILO Data Point

Elevation (mAHD)

- <=10
- 10 - 25
- 25 - 100
- 100 - 175
- 175 - 250
- 250 - 300
- 300 - 350
- 350 - 375
- 375 - 400
- 400 - 425
- 425 - 450
- 450 - 475
- 475 - 500
- 500 - 600
- 600 - 700

FIGURE 2.3

Topography and Drainage

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)

### 2.2.2 Surface Water

This section is based on information presented by SLR (2020), as well as additional information on the site surface water monitoring program and water level trends.

The Wongawilli mining area is located within the Hawkesbury-Nepean catchment. Natural drainage is to the north-northwest, towards the Nepean River. Local surface runoff is captured by the headwater reservoirs (Nepean, Cordeaux, Avon, and Cataract) or rivers (Cordeaux and Avon) before eventually flowing into the Nepean River (Coffey, 2012). Figure 2-3 shows the watercourses around the Project, as well as the upstream catchment area and other selected sub-catchments.

A summary of attributes for the four major waterways within the Project area and surrounds is included below:

- Nepean River
  - Major perennial river of the Hawkesbury-Nepean catchment;
  - Prominent groundwater discharge system;
  - Flows north;
  - Receives runoff locally from the catchment; and
  - Discharge to the river is licensed.
- Avon River
  - Perennial river of the Hawkesbury-Nepean catchment;
  - Flows north;
  - Water impounded by Lake Avon; and
  - Flow diverted due to the Avon Dam.
- Cordeaux River
  - Perennial river of the Hawkesbury-Nepean catchment;
  - Flows north and north-west;
  - Joined by the Avon River; and
  - Discharges into the Nepean River.
- Wongawilli Creek
  - Joins Cordeaux River about 1.7 km west of Cordeaux Dam;
  - Predominately flows north; and
  - Flows east following the confluence with the Cordeaux River.

Additional information on these reservoirs is presented in Table 2-2. There are a number of smaller lower-order streams that flow within the Project area. The catchments of some of these lower-order streams (Wongawilli Creek and Donalds Castle Creek) have been undermined and the hydrographs exhibit some signs that they have been affected by mining (HydroSimulations, 2019).

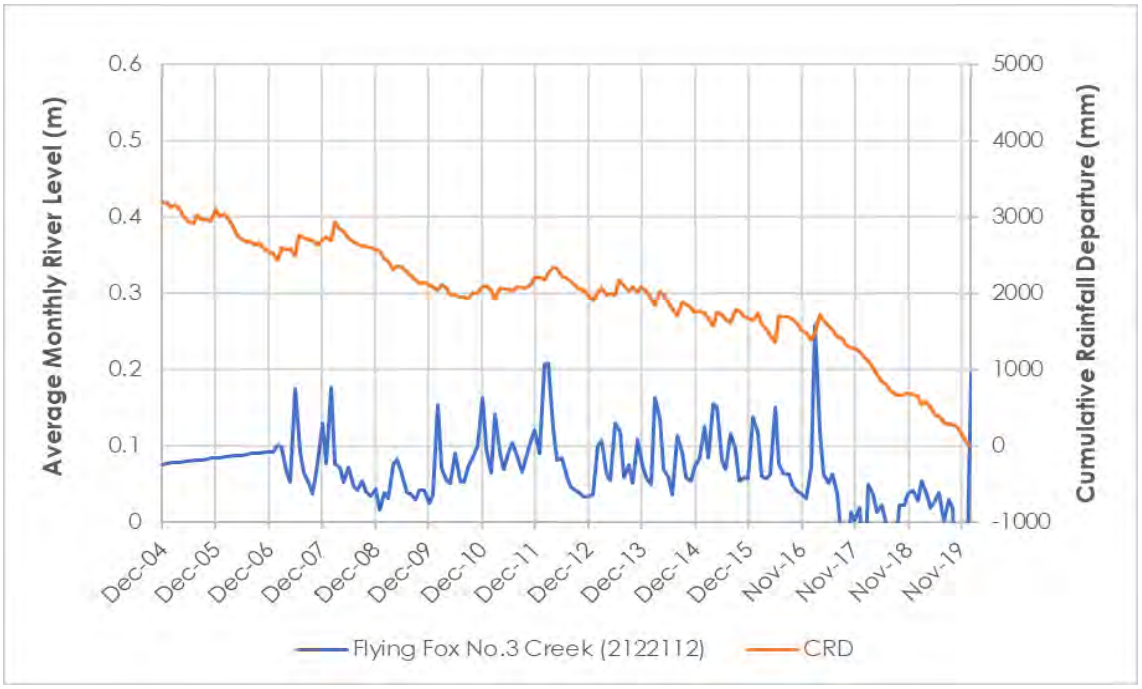
Table 2-2 Summary of Surface Water Features (from HEC, 2019)

| Surface Water Feature | Flow Response | Mean Annual Flow (ML/year) | Lake Floor (mAHD) | Lake Full Storage Level (FSL) | EC (µS/cm) | pH |
|---|---|---|---|---|---|---|
| Nepean River | Major Perennial | - | N/A | N/A | 52 - 338 | 7.23 (mean)* |
| Donalds Castle Creek | Perennial | 137 - 869 | N/A | N/A | 11 - 225 | 3.7 - 6.6 |
| Avon River | Perennial | - | - | - | 61 - 128 | 7.01 (mean)# |
| Wongawilli Creek | Perennial | - | N/A | N/A | 115 | 6.22 |
| Cordeaux River | Perennial | 33 - 468 | N/A | N/A | 70 - 307 | 5.1 - 7.4 |
| Avon Reservoir | Reservoir | 247 (LA4S1) | 253 | 320 | 47 - 158 | 5.1 - 7.6 |

* *BoM – Nepean River at Nepean Dam (accessed 29/07/20)*
\# *BoM – Avon River at Summit Tank (accessed 22/07/20)*

Surface water monitoring is conducted at government stream gauges across the region. This includes a gauge along Flying Fox No.3 Creek (station 212211), a tributary of Avon Reservoir that is approximately 1 km from the NWMD alignment. Surface water levels recorded in meters above the zero gauge level for station 212211 are presented in Figure 2-4, compared to rainfall trends (CRD). The graph shows changes in river levels in response to rainfall events. From 2017 to 2020 the creek levels declined with regular dry conditions recorded, which corresponds with very low rainfall conditions over this period.

Figure 2-4 Flying Fox No.3 Creek and CRD




Surface water monitoring is also conducted at site, with 28 surface water monitoring points across Bellbird Creek, Cordeaux River, Wongawilli Creek, Wattle Creek, Avon River and Gallahers Creek. Table 2-3 presents a summary of the surface water monitoring sites, and the locations are shown in Figure 2-3.

Table 2-3 Surface Water Monitoring

| Site ID | Easting | Northing | Watercourse | Mine Area |
|---|---|---|---|---|
| Bellbird Ck DS | 289962 | 6187290 | Bellbird Creek | Wongawilli |
| Bellbird Ck US | 291019 | 6187598 | Bellbird Creek | Wongawilli |
| DAQ10 | 292271 | 6187600 | Cordeaux River | Wongawilli |
| DAQ20 | 292696 | 6187597 | Cordeaux River | Wongawilli |
| DAQ30DS | 291652 | 6188582 | Wongawilli Creek | Wongawilli |
| DAQ30US | 290333 | 6188478 | Wongawilli Creek | Wongawilli |
| DAQ40US | 291355 | 6189221 | Wongawilli Creek | Wongawilli |
| DAW40DS | 291225 | 6189274 | Wongawilli Creek | Wongawilli |
| LWTC1 | 294920 | 6190020 | Little Wattle Tree Creek | Nebo |
| WC1 | 294560 | 6189435 | Wattle Creek | Nebo |
| WC2 | 294530 | 6189470 | Wattle Creek | Nebo |
| WC3 | 294875 | 6189570 | Wattle Creek | Nebo |
| WC4 | 293225 | 6189250 | Wattle Creek | Nebo |
| AV1 | 287047 | 6182414 | Avon River | Avon |
| AV2 | 286687 | 6182521 | Avon River | Avon |
| AV3 | 286862 | 6183598 | Avon River | Avon |
| AV4 | 286416 | 6183519 | Avon River | Avon |
| AV5 | 285660 | 6184215 | Avon River | Avon |
| AV6 | 285710 | 6184444 | Avon River | Avon |
| AV7 | 287400 | 6184811 | Avon River | Avon |
| AVD1 | 287507 | 6187048 | Avon River and Gallahers Creek confluence | Avon |
| AVT1 | 285207 | 6183050 | Avon River | Avon |
| GC1 | 28764 | 6185799 | Gallahers Creek | Avon |
| GC2 | 288409 | 6185353 | Gallahers Creek | Avon |
| GC3 | 288552 | 6185349 | Gallahers Creek | Avon |
| GC4 | 289677 | 6185550 | Gallahers Creek | Avon |
| GC5 | 289947 | 6184826 | Gallahers Creek | Avon |
| GC6 | 289802 | 6184352 | Gallahers Creek | Avon |

Surface water monitoring includes water quality analysis. A summary of average water quality monitored within the Project area's 28 surface water monitoring points is included in Appendix D.

Water quality is described in the Lake Avon and Gallahars Creek (Nebo) catchments below, as reported by SLR (2020).

Figure 2-5 shows the temporal distribution pattern of electrical conductivity (EC) and total dissolved solids (TDS) at two monitoring points (Creek bore AV1 and GC5) at Avon area with rainfall trends over the period 2011 to 2016. An assessment of EC and TDS in Figure 2-5 indicates that the Gallahars Creek has a high EC value due to higher TDS compared to the Avon River. The Avon River has a long-term EC average less than 100 µS/cm and the Gallahars Creek EC average exceeds 100 µS/cm. This surface water quality difference is attributed to the Lake Avon catchment having a high percentage of Hawkesbury Sandstone, which has a high quartz content and low salt content which in contrast to the dominant Bald Hill Claystone lithology of the Gallahars Creek catchment has a higher salt content.

Figure 2-6 and Figure 2-7 present the spatial distribution of average pH and EC near the Avon and Nebo (Gallahars Creek) area in the Project area. Mean values were estimated using available data over the period 2011 to 2016. Spatial distribution and variation of pH indicates water within the Avon area (average 5.5) has a lower pH than that of the Nebo area (average 6.5) (Figure 2-6).

HECON attribute low pH conditions in the Upper Nepean Catchment as natural due to the dissolution of silica and leaching of organic acids from peat and other organic matter. Under this scenario there may be more silica dissolution occurring and organic matter present in the Avon area compared to the Nebo area.

Figure 2-5 Avon Reservoir Salinity (Source: SLR 2020)

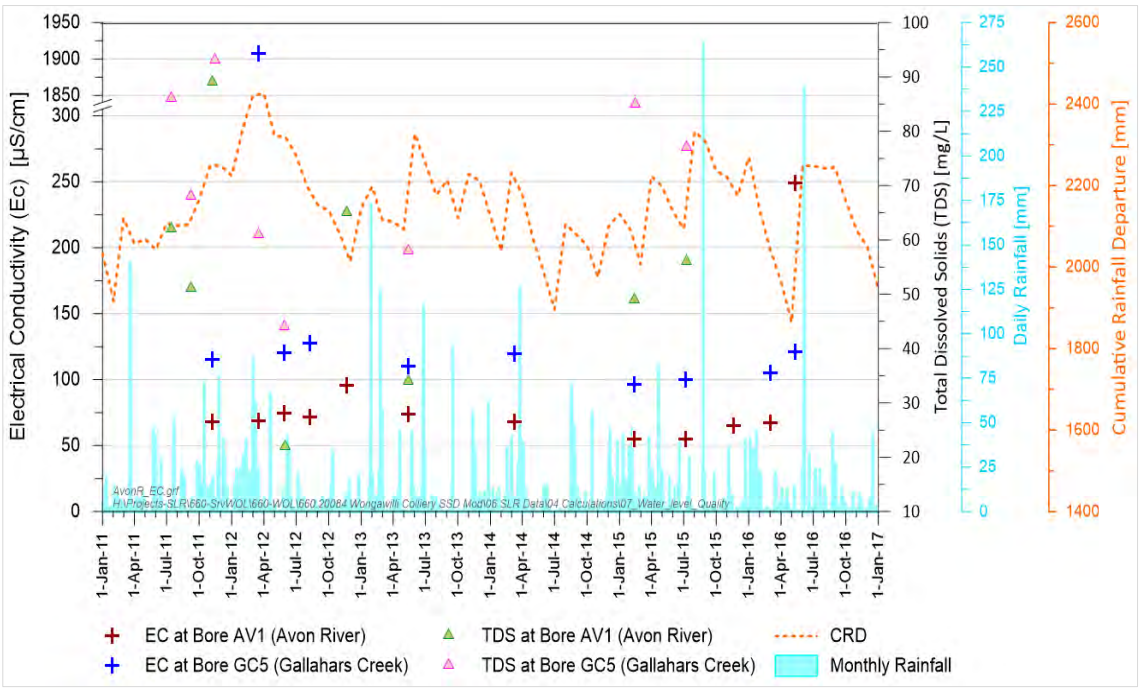


Figure 2-6 Spatial Distribution of Average pH (Source: SLR, 2020)

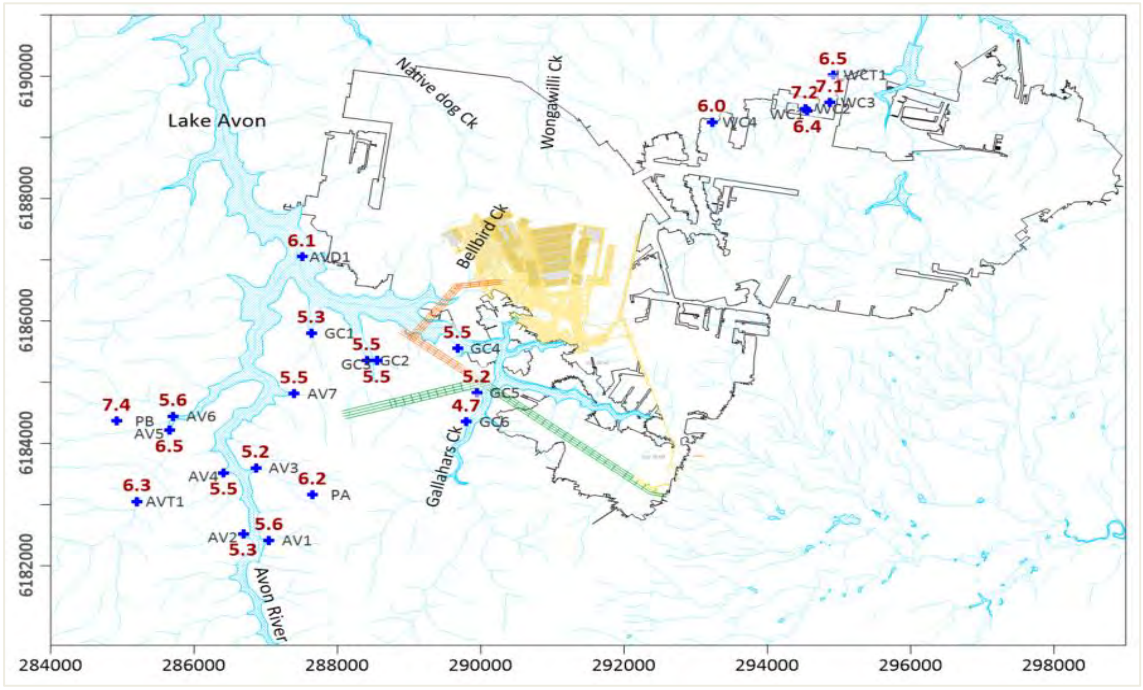
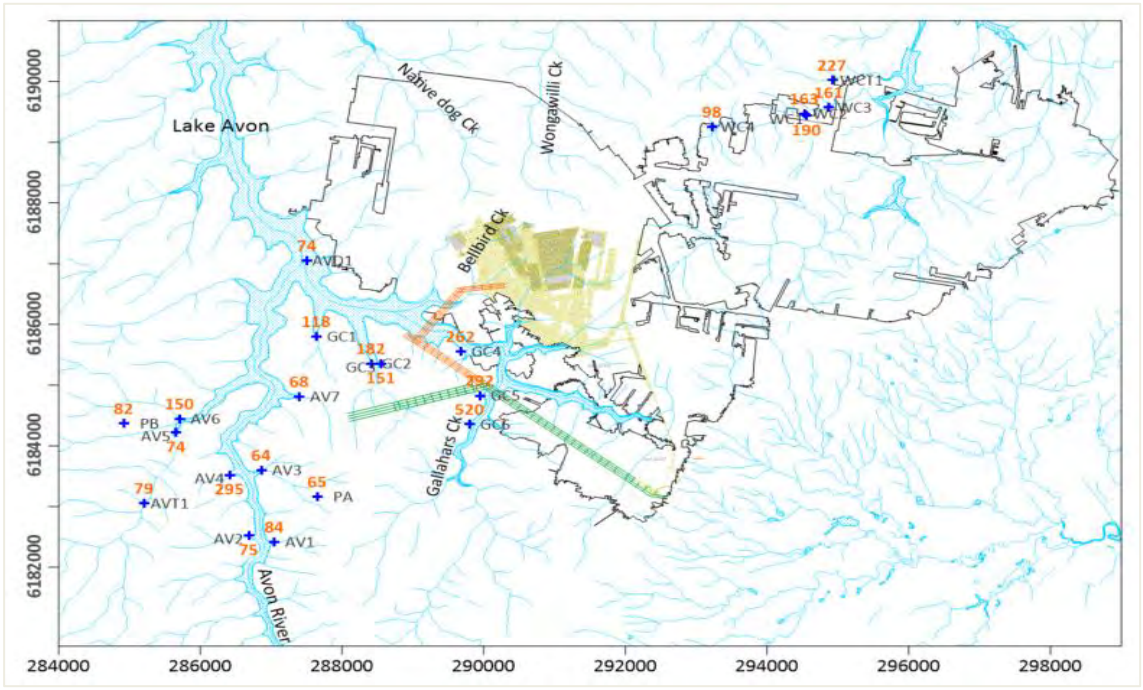



Figure 2-7 Spatial Distribution of Average EC in µS/cm (Source: SLR, 2020)



## 2.3 Surrounding Land Use

The Project is within ML 1596, which comprises the NWM, Wongawilli Colliery, Nebo Colliery and Elouera Colliery. Details on the historical mine workings within ML 1596, along with surrounding historical and existing mine operations are included in Table 2-4. The location of the mines immediately surrounding the Project are shown in Figure 1-1.

Table 2-4 Project Area and Surrounding Mines (adapted from SLR, 2020)

| ID | Mine | Operator | Seam | Timing | Distance from Project |
|---|---|---|---|---|---|
| ML 1596 | NWM (500 m section) | Wollongong Coal | Bulli Seam | 2016 – 2019 | Project Area |
| | Wongawilli Colliery | BHP/Wollongong Coal | Wongawilli Seam and Bulli Seam | 1916 – 1997 | Project Area |
| | Nebo Colliery | AIS/BHP | Wongawilli Seam | 1946 – 1993 | 6 km north |
| | | Wollongong Coal (LWN1 to LWN6) | Wongawilli Seam | 2013 - 2014<br>2016 - 2019 | 5.5 km north-east |
| | Elouera Colliery | BHP/Delta Mining Gujarat NRE (as part of NRE Wongawilli) | Wongawilli Seam<br>Wongawilli Seam | 1994 – 2007<br>2007 - 2014 | 3 km north-east |
| AUTH0067 | Avon Colliery | Austen & Butta (1971-1987), Avon Colliery Pty Ltd (1987-2000) | Wongawilli and Bulli Seams | 1971 – 2000 | 3.5 km south |
| CCL 700 | Huntley Colliery | Waugh Bros. (1946-1951), Joint Coal Board (1951-1955) Electricity Commission of NSW (1955-1989) | Tongarra, Wongawilli and Bulli Seams | 1946 – 1989 | 5.5 km south |
| - | Port Kembla No. 2 Colliery | Kembla Coal and Coke Co. Pty Ltd | Wongawilli and Bulli Seams | 1941 – 1964 | 6 km north-east |
| CCL766 | Avondale Colliery | Unknown | Bulli and Tongarra Seams | 1908 – 1983 | 7 km south |
| | Mt Kembla Colliery | Mount Kembla Collieries (1883-1946), AIS/BP (1946-1970) | Bulli Seam | 1882 – 1970 | 9.5 km south |
| | Dendrobium (Area 1, 2, 3A, 3B, 3C) | South32 | Wongawilli Seam | 2001 – 2043 | 10 km north |
| | Tom Thumb Colliery | Unknown | Bulli Seam | 1967 – 1971 | 12 km north-east |
| | Kemira Colliery | Mt Kembla | Bulli, Balgownie and Wongawilli Seams | 1848 – 1991 | 14 km north-east |
| - | Cordeaux Colliery (merged with Corrimal Colliery 1986) | BHP | Bulli Seam | 1976 – 2001 | 15 km east |
| | Corrimal Colliery | Southern Coal Company (1912-1964), AIS/BHP (1964-1985) | Bulli Seam | 1912 – 1985 | 17 km north-east |
| CCL745 | Russell Vale (Bellambi) | Wollongong Coal | Bulli, Balgownie and Wongawilli Seams | 1887 – present | 18 km north |
| CCL767 | Appin Colliery | South32/BHP | Bulli Seam | 1961 – present | 30 km north-west |

## 2.4 Geology

This section provides background to the site geology of the Project, as previously reported by SLR (2020).

### 2.4.1 Regional Geology

The Project is located within the (southern) Sydney Basin and is part of the Southern Coalfields. The stratigraphy of the Project area and surrounds is presented in Table 2-5 and shown in Figure 2-8. The area is primarily a Permo-Triassic sedimentary rock sequence and is underlain by undifferentiated consolidated sediments of Carboniferous and Devonian age.

Table 2-5 Stratigraphy (from SLR, 2020)

| Age | Group | Unit | | Description | Average Thickness (m) |
|---|---|---|---|---|---|
| Quaternary | Upland swamp (Qs) | | | Headwater-drainage deposits and valley infill deposits | - |
| | Alluvium (Valley Floor) | | | Alluvial and residual deposits comprising quartz and lithic fluvial sand, silt and clay | <2 |
| | Colluvium (Hillslopes) | | | Colluvial soil comprising ferruginous clays or sandy soils | <6.5 |
| Tertiary to Jurassic | Volcanic intrusions – sills and dykes | | | Cordeaux Crinanite (Hawkesbury Sandstone and Narrabeen Group) | <68 (sills) |
| | | | | Dendrobium Nephaline Syenite (Illawarra Coal Measures – WW) | 3 (dykes) |
| Triassic | Hawkesbury Sandstone (HBSS) | | | Consists of thickly bedded or massive quartzose sandstone with grey shale lenses up to several metres thick | 87.4 |
| | Narrabeen Group | BACS | Bald Hill Claystone | Newport Formation – Interbedded grey shales and sandstones | 5.9 |
| | | | | Garie Claystone – grey brown, massive, characteristically oolitic claystone | 3.8 |
| | | | | Bald Hill Claystone – brownish-red coloured 'chocolate shale', a lithological stable unit | 12.6 |
| | | BGSS | Bulgo Sandstone | Strong, thickly bedded, medium to coarse-grained lithic sandstone with occasional beds of conglomerate or shale | 65 |
| | | SPCS | Stanwell Park Claystone | Greenish-grey mudstones and sandstones | 6.6 |
| | | SBSS | Scarborough Sandstone | Thickly bedded sandstone with shale and sandy shale lenses up to several metres thick | 39.7 |
| | | WBCS | Wombarra Claystone | Greenish-grey mudstones and sandstones | 9.5 |
| | | CCSS | Coalcliff Sandstone | Basal shales and mudstones that are contiguous with the underlying Bulli Coal Seam | 8.3 |
| Permian | Illawarra Coal Measures | BUSM | Bulli Coal Seam | Interbedded shales, mudstones, lithic sandstone and coal | 200-300 |
| | | LDSS | Lawrence & Loddon Sandstones | | |
| | | WWSM | Wongawilli Coal Seam | | |
| | | KBSS | Kembla Sandstone | | |
| | | TGSM | Tongarra Coal Seam | | |

### 2.4.2 Local Geology

Within the Project area the geology includes upland swamps, Triassic Narrabeen Group and the Permian Illawarra Coal Measures, as well as volcanic intrusions. Further information about each of the sequences is included in Section 2.4.2.1 to Section 2.4.2.5, with details on structural geology included in Section 2.4.2.6. This section is presented based on reporting by SLR (2020) and discussion on the local geology was developed based on:

- Available site geological and geotechnical reports, including BHP (2005) and SCT (2010, 2012, 2017, 2020);
- Previous impact assessments including GeoTerra (2010, 2018), Golder (2010), Heritage Computing (2009) and HydroSimulations (2019);
- Publicly available regional geologically mapping including Bowman (1974) and Moffitt (1999); and
- WCL Geological Model that encompasses ML 1596, the Dendrobium geological model that covers CCL769 and the Sydney-Gunnedah Basins 3D Stratigraphic Model.

The geology within the Project area is presented in Figure 2-9. The WCL Geological Model surface structure for the Wongawilli Seam (base of seam and depth below surface) are presented in Figure 2-10. The conceptual groundwater model was developed based on the local geology, which is discussed later in Section 2.10.

#### 2.4.2.1 Upland Swamps

Small pockets of Quaternary-aged swamp deposits have been mapped across the Southern Coalfields, as shown on the Southern Coalfield Geology map (Qs) (Moffitt, 1999). Further local mapping, as presented by HydroSimulations (2019), identifies additional coastal upland swamps in the area, including one swamp area above the proposed alignment of the Project and one above the approved NWM (Figure 2-9).

The upland swamps can occur as 'headwater-drainage divide' swamp deposits along the riparian zone of major creeks within the headwater valleys. Valley infill swamps can also occur in the region, which are deposited within the steeply incised valleys of second or third order streams (Tomkins & Humphreys, 2006). The swamps generally comprise acidic soils and can vary from sandy loams likely derived from weathered sandstone (i.e. Hawkesbury Sandstone), with a shallow organic horizon to highly organic peats.

#### 2.4.2.2 Triassic Hawkesbury Sandstone

The Triassic Hawkesbury Sandstone predominantly occurs at outcrop (refer Figure 2-9) and comprises medium to coarse-grained quartz sandstone with minor shale and laminite lenses. The sandstone was deposited in a fluvial environment and consists of three main depositional environments, namely massive sandstone facies, cross-bedded or sheet facies and shale/siltstone interbedded facies. Interbedded shale lenses can provide local or extensive confining layers creating separate aquifers with different hydraulic properties and sometimes hydraulic heads. This lithological variation and the thickness of the unit mean that although this unit is considered a single stratigraphic entity, it essentially forms a vertical series of layered aquifers. Within the Project area the average and maximum thicknesses of the Hawkesbury Sandstone are 87.4 m and 154.7 m, respectively (WCL, 2017).

The Hawkesbury Sandstone displays bedding but also contains secondary structural features such as joints, fractures and faults. The sandstone weathers to a clayey sand residual skeletal soil profile typically one to two metres deep.

#### 2.4.2.3 Triassic Narrabeen Group

The Narrabeen Group underlies the Hawkesbury Sandstone and comprises interbedded quartz-lithic to quartzose sandstone, conglomerate, mudstone, siltstone and rare coal. Within the Project area the Clifton Subgroup is present, which includes the Bald Hill Claystone, Bulgo Sandstone, Stanwell Park Claystone, Scarborough Sandstone, Wombarra Claystone and Coal Cliff Sandstone. The Bald Hill Claystone and Bulgo Sandstone occur at outcrop where the topography is deeply incised by rivers and lakes Figure 2-9.

Section 2.11 presents a series of geological cross-sections through historic, current and proposed mining areas. The cross-sections illustrate the relative thickness of the Bulgo Sandstone in relation to the other units, as well as the layered nature of the geological sequence with alternating sandstones and claystones. The figures show that the Stanwell Park Claystone is extensive and sufficiently distinguishable from the underlying Scarborough Sandstone and overlying Bulgo Sandstone across the Project area.

#### 2.4.2.4 Illawarra Coal Measures

The Illawarra Coal Measures are the primary economic sequence of interest in the Sydney Basin, and consist of interbedded sandstone, shale and coal seams, with a thickness of approximately 200 m to 300 m. The two main coal seams mined in the Southern Coalfields are the uppermost Bulli Seam and the Wongawilli Seam (Holla & Barclay, 2000).

Within the Illawarra Coal Measures the Bulli Seam is the uppermost coal member. Within the Project area the Bulli Seam occurs at elevations of around 300 mAHD in the south-east, down to around 165 mAHD to the north. Due to the steeply incised nature of the topography, the depth to the Bulli Seam is variable, as shown in Figure 2-10.

The shallowest depth to the Bulli Seam for the proposed NWMD occurs in one location at 60 m below the base of the reservoir (SCT, 2020). The coal seams also occur at shallow depths within the historical workings at Wongawilli Colliery and Huntley Colliery, with main headings developed 55m and 65 m, respectively, below the Full Supply Level (FSL) of Avon Reservoir (SCT, 2021).

The Bulli Seam in the Project area is situated primarily in the western part of ML 1596. Due to the fault zone and the intrusion of crinanite replacing the Bulli Seam, the Bulli Seam workings were limited at the west. To the east the workings they were limited by decreasing Bulli Seam thickness. In the southern portion of the Project, the Bulli Seam consists primarily of thin coal bands and significant carbonaceous mudstone and claystone bands and is not considered economic. To the southwest the Bulli Seam is not recognisable in core. To the east within ML 1596, over much of the mined Wongawilli Seam, the Bulli Seam has a deteriorated coal section due to high inherent ash or its thickness is less than 1.5 m (WCL, 2017).

There are large areas of the Bulli Seam that have been intruded. Along the west to north-western margins of ML 1596 the Bulli Seam is extensively intruded by the Avon sill complex. In the Avondale area silling (Avondale sill complex) has also destroyed large areas of the Bulli Seam.

The Bulli Seam is underlain by the Wongawilli Seam. The vertical separation between the Bulli and Wongawilli Seams is approximately 22 m, on average, in the Project area. Even though consistent in thickness across the southern part of the Coalfield from 9 m to 11 m, the Wongawilli Seam has significant deterioration in quality to the north when compared to the southern part of the Coalfield where a basal section has been extensively mined in the past (WCL, 2017).

#### 2.4.2.5 Volcanics and Intrusions

There are several mapped intrusions within the Project area and surrounds, referred to as the Nebo Dome. Between Wongawilli (Nebo Colliery and Elouera Colliery) and Dendrobium is the Dendrobium Nephaline Syenite igneous intrusion that is up to 41 m in thickness within the Illawarra Coal Measures (BHP, 2005).

The intrusion includes a series of dykes and sills in the Tongarra, Wongawilli, Balgownie and Bulli Coal Seams. There are several northwest trending convergent dykes in the Nebo Colliery area. Dykes are generally doleritic, around 2 m thick and usually altered to white clay (BHP, 2005). Within the coal seam the coal is cindered (heat affected) around the dyke, generally to a thickness equal to the dyke (BHP, 2005).

The Cordeaux Crinanite is also mapped between Nebo and Dendrobium and described by Edwards (1953) as being comprised of thick (12 m to 50 m) olivine dolerite (crinanite) sills and thinner (2 m to 4 m) picrite sills at the base (SCT, 2010). The crinanite is intruded into the Narrabeen Group and Hawkesbury Sandstone. The Cordeaux Crinanite is exposed at surface in the Nebo area and was undermined in the Wongawilli Seam at Nebo Colliery (BHP, 2005).

Syenitic and doleritic sill intrusions vary in thickness up to 68 m. The doleritic Avondale sill complex is present within the Wongawilli Coal section and was intersected to the west and south of the Project area during exploration drilling (WCL, 2017).

The Project does not contain any crinanite found elsewhere in the Southern Coalfield stratigraphic sequence. The Bulli Seam thickness varies from 0.9 m to 1.93 m at the portal area at the first 3.3 km of the initial NW Main then thins to 1.7 m with the workings driveage turning to a WSW direction (Burea Veritas, 2010). The Project area is adjacent to the Blue Panel of the Wongawilli Colliery where a combination of geological structures, shallow depth, underground ponded water storages and pillar extraction, together with the proximity of the Avon reservoir, may have previously contributed to an inflow of water into the workings (GeoTerra, 2010).

#### 2.4.2.6 Structural Geology

There are regional geological structures, as mapped by Moffitt (1999) that run across the mining areas (Figure 2-9). A large syncline fold is present within the Project area, plunging to the north towards Dendrobium mine, with a dip of 1 in 25. Another significant fold runs to the south within 3.5 m of the Bulli Seam Driveage.

There are several domed structures in the Wongawilli area which are believed to be due to volcanic intrusions. Nebo Colliery mined around the southern flanks of the Nebo Dome, which is also associated with a large intrusion above the Wongawilli Seam, exposed to the surface, and known as the Cordeaux Crinanite. A steep dip of about 1 in 12 to 1 in 16 of the Wongawilli Seam is associated with varying flanks of the domes (WCL, 2017).

The main fault structure in the area is Wongawilli Fault, which is evident along the north-west to south-east alignment 600 to 1100 m to the north of the NWMD and is downthrown by up to 45 m to the north-east (Figure 2-9). There are existing Bulli and Wongawilli Seam workings on the eastern, downthrown side of the fault. The three heading mains that intersect the Wongawilli Ventilation Shaft 1 will need to cross this fault and mine through stone for approximately 340 m to intersect the shaft approximately 20 m above the Bulli Seam (SCT, 2020).

Another fault structure, Avon Fault, is 750 m south and parallel to the NWMD between the Wongawilli and Avon Collieries. The Avon Fault is aligned with Gallahers Creek and is approximately 5.5 km long. The fault does not affect the Project (SCT, 2020).

South of the Avon Fault into the previous Avon, Huntley and Avondale Collieries, faulting is not a frequent geological feature. Small scale faulting has been encountered in the workings of the Avondale and Huntley Collieries but not of a severity to impact significantly on mining. A prominent arcuate fault situated across the southern most part of the Project area is of low confidence and is estimated to have a throw of 10 m (WCL, 2017).




## Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Cinder
- Cordeaux Crinanite
- Cross Section Lines
- Watercourse

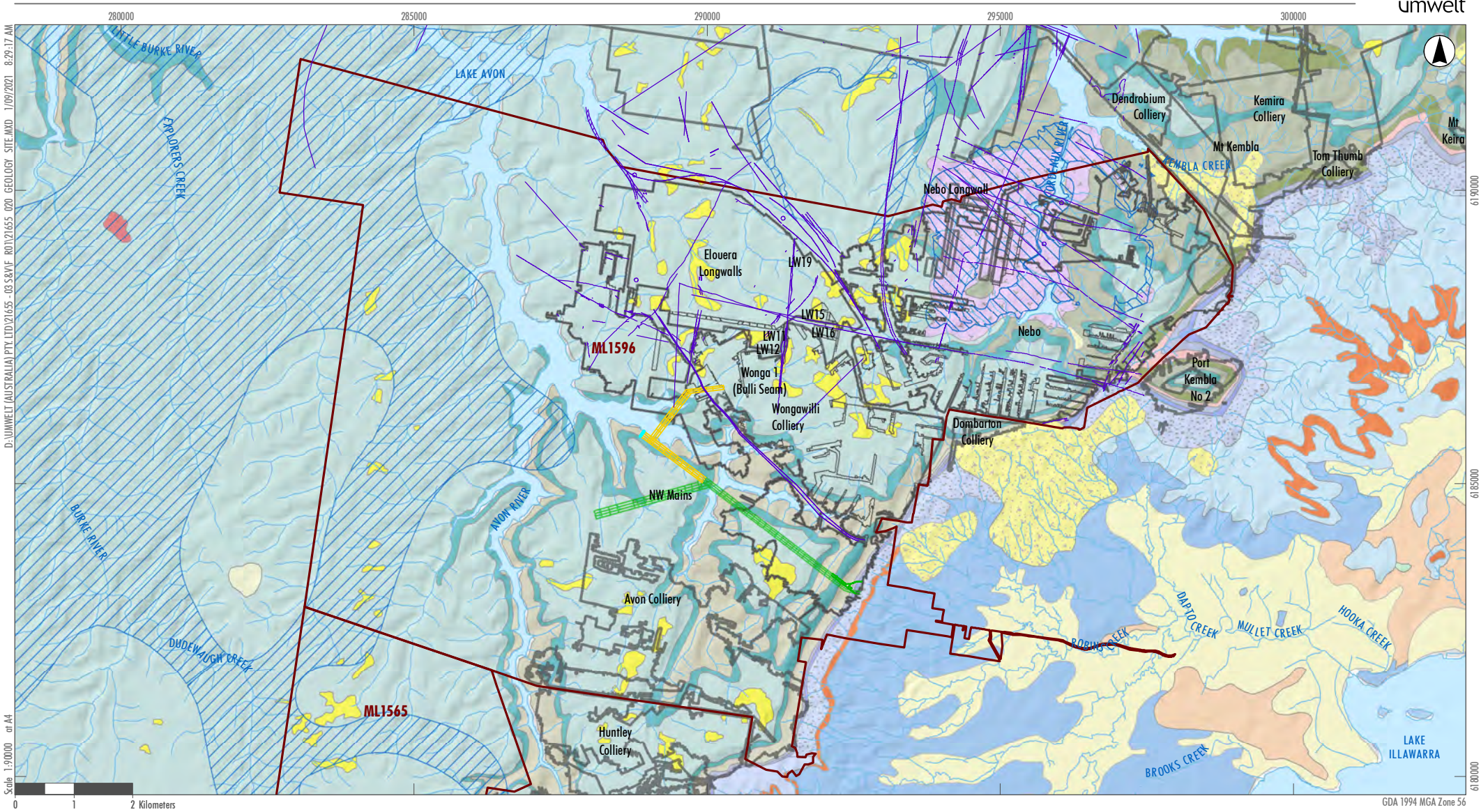
**Geology Type (1:100k Southern Coalfields Geology)**

- Qa – Quaternary alluvium
- Qs/Qal - alluvium
- Qs – Swamp sediments
- Qt – Talus
- T-Ct – Crinanite
- T-Rb – Alkali olivine basalt
- Jt – Microsyenite intrusion
- TRw – Wianamatta Group
- TRh – Hawkesbury Sandstone
- TRnz – Bald Hill Claystone
- TRnbu – Bulgo Sandstone
- TRnsp – Stanwell Park Claystone
- TRnc – Coal Cliff Sandstone
- TRnk – Kangaloon Sandstone
- Pi – Illawarra Coal Measures
- Pis – Sydney Group
- Pip – Unanderra Coal Member
- Pipm/Pipb – Sills
- Ps – Shoalhaven Group
- Psv – Broughton Formation
- Ktc – Trachyte
- P-TRns – Scarborough Sandstone
- Pnc – Trinkey Formation Claystone
- Pnw – Wombarra Claystone

FIGURE 2.8

Regional Surface Geology

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Cinder
- Cordeaux Crinanite
- Watercourse
- Faults

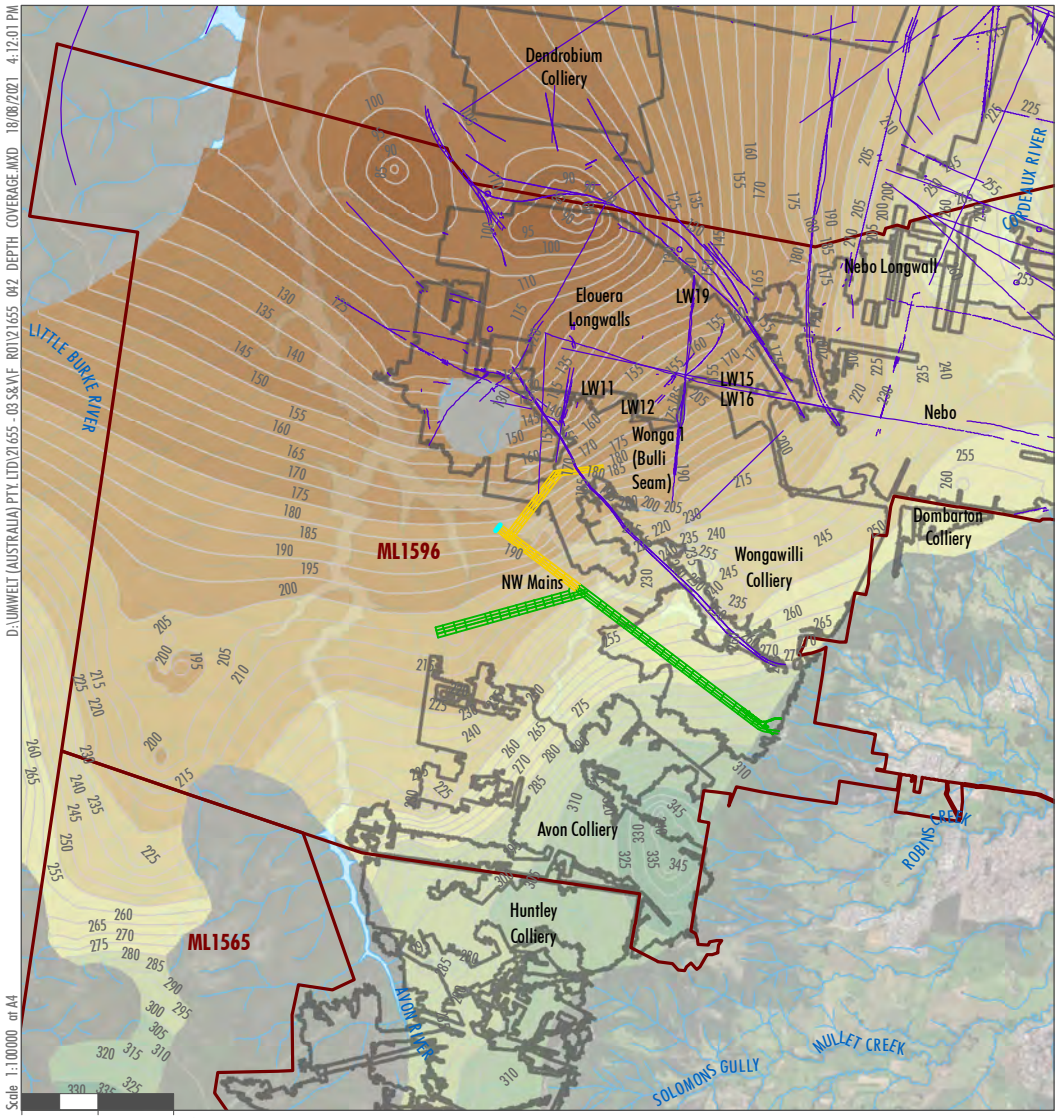
**Geology Type (1:100k Southern Coalfields Geology Map)**

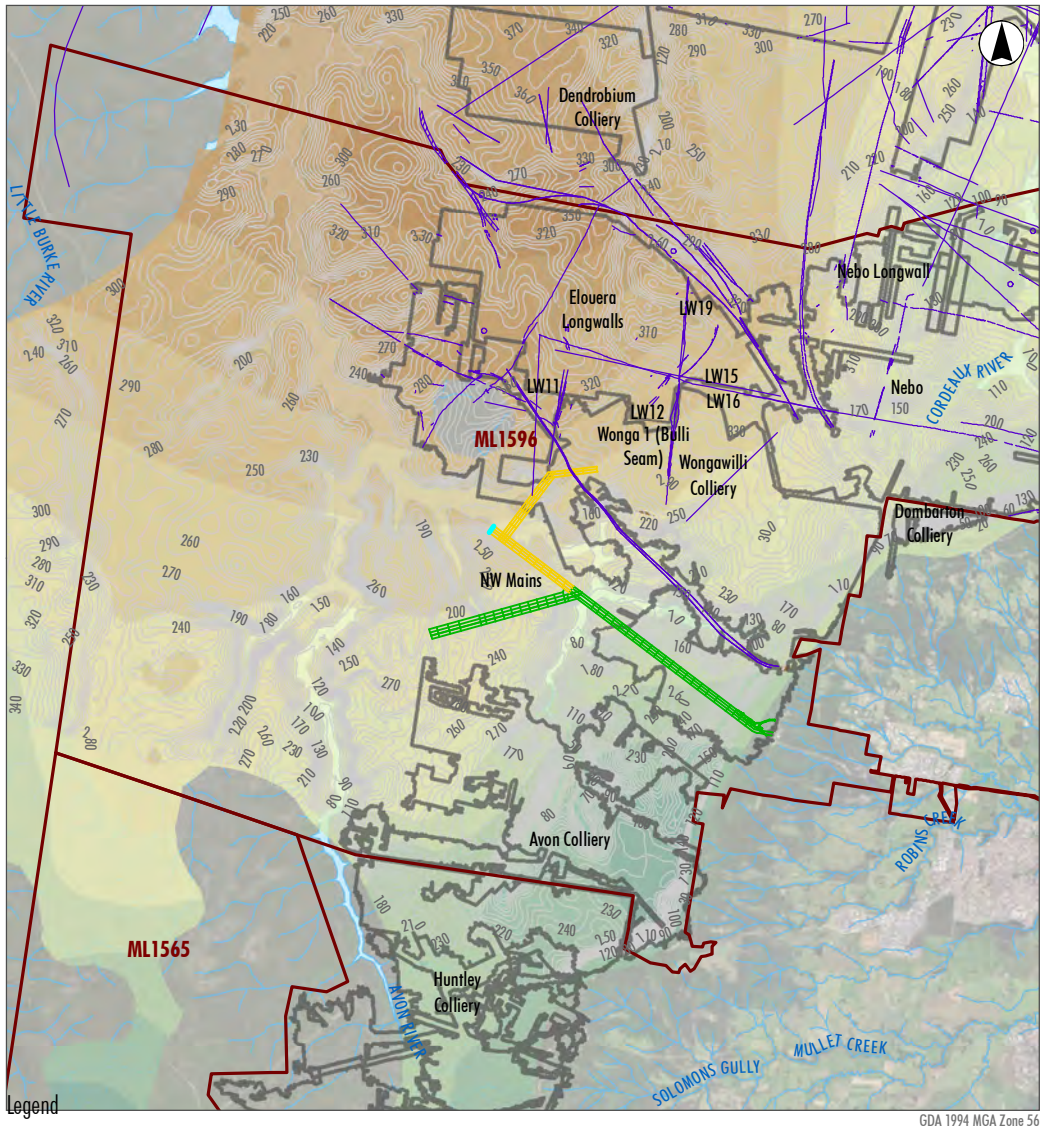
- Qa – Quaternary alluvium
- Qs – Swamp sediments
- Qt – Talus
- T-Ct – Crinanite
- Jt – Microsyenite intrusion
- TRh – Hawkesbury Sandstone
- TRnz – Bald Hill Claystone
- TRnbu – Bulgo Sandstone
- TRnsp – Stanwell Park Claystone
- TRnc – Coal Cliff Sandstone
- Pi – Illawarra Coal Measures
- Pis – Sydney Group
- Pip – Unanderra Coal Member
- Pipm/Pipb – Sills
- Ps – Shoalhaven Group
- Psv – Broughton Formation
- Ktc – Trachyte
- P-TRns – Scarborough Sandstone
- Pnc – Trinkey Formation Claystone
- Pnw – Wombarra Claystone
- Tn – Basalt Intrusion

FIGURE 2.9

Site Surface Geology

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




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Scale 1:100000 at A4

GDA 1994 MGA Zone 56

Legend

- Mine Lease Boundary
- Proposed NWMD (Project)
- Approved NWM
- Surrounding Mines
- Faults
- 5m Contours
- Watercourse

**Bulli Seam Structure (mAHD)**

- 75 - 100
- 100 - 125
- 125 - 150
- 150 - 175
- 175 - 200
- 200 - 225
- 225 - 250
- 250 - 275
- 275 - 300
- 300 - 325
- 325 - 350
- 350 - 375
- 375 - 400
- 400 - 425
- 425 - 450

Legend

- Faults
- Mine Lease Boundary
- Proposed NWMD (Project)
- Approved NWM
- Surrounding Mines
- 10m Contours

**Bulli Seam Depth (m)**

- 0 - 25
- 25 - 50
- 50 - 75
- 75 - 100
- 100 - 125
- 125 - 150
- 150 - 175
- 175 - 200
- 200 - 225
- 225 - 250
- 250 - 275
- 275 - 300
- 300 - 325
- 325 - 350
- 350 - 375
- 375 - 400
- 400 - 425
- 425 - 450
- Watercourse

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)

FIGURE 2.10

**Bulli Seam Structure and Depth**

## 2.5 Groundwater Monitoring

The groundwater monitoring network at WWC has been in place since 2009 and includes:

- Seven swamp deposit bores.
- Six Nebo open standpipes (Nebo1 to Nebo 4) within the Hawkesbury Sandstone, Crinanite, Bulli Seam and Wongawilli Seam, with nested bores at Nebo 1 and Nebo 2.
- 11 vibrating wire piezometers (VWP) (Nebo/NWW/NRE) with multiple sensors across various units.

The construction details of the VWPs, monitoring bores at Wongawilli, and the monitored geology are shown in Table 2-6 and locations shown in Figure 2-11. The groundwater monitoring program includes daily readings of pressure head at the VWP's, and manual measurement of water levels at the monitoring bores, as well as water quality sampling and analysis for electrical conductivity (EC), pH, major ions, minor ions and metals.

Table 2-6 Groundwater Monitoring Network (adapted from SLR, 2020)

| Bore | Easting (m)* | Northing (m)* | Ground Level (mAHD) | Total Depth (mbgl) | Screen/Sensor Depth (mbgl) | Sensor Level (mAHD)# | Unit Intersected | Date From - To |
|---|---|---|---|---|---|---|---|---|
| Nebo 1s | 295153 | 6188762 | 366.4 | 6.9 | 5.0 - 6.0 | 366.4 | Soil | 2010 - 2020 |
| Nebo 1d | 295152 | 6188761 | 366.5 | 98.6 | 85.6 - 97.6 | 366.5 | Siltstone | 2010 -2020 |
| Nebo 2s | 294662 | 6189246 | 347.7 | 9.9 | 5.5 - 6.5 | 347.7 | Crinanite | 2010 -2020 |
| Nebo 2d | 294662 | 6189237 | 348.5 | 32.2 | 19.0 - 31.0 | 348.5 | HBSS | 2010 -2020 |
| Nebo 3 | 295033 | 6189838 | 356.7 | 34.4 | 21.6 - 33.6 | 356.7 | HBSS | 2010 -2020 |
| Nebo 4 | 294661 | 6189893 | 374.1 | 110 | 107.5 - 109.5 | 374.1 | WWCO | Unknown |
| Nebo 6 | 295237 | 6189510 | 354.2 | 115 | 60 | 294.2 | Crinanite | 2009 - 2019 |
| | | | | | 80 | 274.2 | Crinanite | |
| | | | | | 100 | 254.2 | EKFM | |
| | | | | | 115 | 239.2 | WWCO | |
| Nebo 7 | 295477 | 6189585 | 336.4 | 90 | 30 | 306.4 | Crinanite | 2009 - 2019 |
| | | | | | 45 | 291.4 | Crinanite | |
| | | | | | 63 | 273.4 | LDSS | |
| | | | | | 90 | 246.4 | WWCO | |
| Nebo 8 | 294679 | 6189485 | 343.4 | 72 | 15 | 328.4 | Crinanite | 2009 - 2019 |
| | | | | | 35 | 308.4 | Crinanite | |
| | | | | | 52 | 291.4 | SPCS | |
| | | | | | 72 | 271.4 | CCSS | |
| Nebo 8A | 294549 | 6189499 | 359.6 | 45 | 25 | 334.6 | Crinanite | 2010 - 2019 |
| | | | | | 45 | 314.6 | Crinanite | |
| NWW PE1 | 291676 | 6187507 | 515.7 | 165 | 90 | 425.7 | HBSS | 2009 - 2019 |
| | | | | | 135 | 380.7 | HBSS | |
| | | | | | 150 | 365.7 | BHCS | |
| | | | | | 165 | 350.7 | BGSS | |
| NWW 11 | 288343 | 6184339 | 467.1 | 125 | 60 | 407.1 | HBSS | 2009 - 2018 |
| | | | | | 90 | 377.1 | HBSS | |
| | | | | | 104 | 363.1 | BHCS | |
| | | | | | 125 | 342.1 | BGSS | |
| NWW 16 | 283657 | 6183801 | 513.4 | 166 | 71 | 442.36 | HBSS | 2009 - 2015 |
| | | | | | 126 | 387.36 | HBSS | |
| | | | | | 146 | 367.36 | HBSS/NPFM | |
| | | | | | 166 | 347.36 | BHCS/BGSS | |
| NWW20B | 291099 | 6184158 | 488.3 | 135 | 33 | 455.3 | HBSS | 2009 - 2019 |
| | | | | | 60 | 428.3 | BHCS | |
| | | | | | 75 | 413.3 | BGSS | |
| | | | | | 135 | 353.3 | BGSS | |

| Bore | Easting (m)* | Northing (m)* | Ground Level (mAHD) | Total Depth (mbgl) | Screen/Sensor Depth (mbgl) | Sensor Level (mAHD)# | Unit Intersected | Date From - To |
|---|---|---|---|---|---|---|---|---|
| NWWSH1 | 288448 | 6184273 | 475.6 | 297 | 65 | 410.6 | HBSS | 2011 - 2019 |
| | | | | | 90 | 385.6 | HBSS | |
| | | | | | 110 | 365.6 | BHCS | |
| | | | | | 130 | 345.6 | BGSS | |
| | | | | | 215 | 260.6 | SBSS | |
| | | | | | 255 | 220.6 | CCSS | |
| | | | | | 267 | 208.6 | BUCO | |
| | | | | | 297 | 178.6 | WWCO | |
| NWGW01 | 289391 | 6184417 | 460.5 | 227 | 30 | 430.5 | HBSS | 2012 - 2016 |
| | | | | | 50 | 410.5 | HBSS | |
| | | | | | 70 | 390.5 | BHCS | |
| | | | | | 90 | 370.5 | BGSS | |
| | | | | | 150 | 310.5 | BGSS | |
| | | | | | 195 | 265.5 | SBSS | |
| | | | | | 227 | 233.0 | BUCO | |
| | | | | | 259 | 201.5 | WWCO | |
| NWGW02 | 285253 | 6184479 | 480.0 | 334 | 60 | 420.0 | HBSS | 2013 - 2019 |
| | | | | | 130 | 350.0 | HBSS | |
| | | | | | 160 | 320.0 | BHCS | |
| | | | | | 175 | 305.0 | BGSS | |
| | | | | | 250 | 230.0 | BGSS | |
| | | | | | 275 | 205.0 | SBSS | |
| | | | | | 301 | 178.8 | BUCO | |
| | | | | | 334 | 146.0 | WWCO | |
| P20 | 291144 | 6187583 | 486.2 | - | 2.93 | 483.3 | Swamp | 2010 – 2018# |
| P21a | 291860 | 6188293 | 462.1 | - | 3.37 | 458.7 | Swamp | 2010 – 2018# |
| P24 | 292076 | 6187585 | 501.9 | - | 2.86 | 499.0 | Swamp | 2010 – 2018# |
| P30 | 291867 | 6188897 | 479.6 | - | 3.07 | 476.5 | Swamp | 2010 – 2018# |
| P46 | 291875 | 6187988 | 489.3 | - | 3.40 | 485.9 | Swamp | 2010 – 2018# |
| PA | 287655 | 6183160 | 483.6 | - | - | - | Swamp | - |
| PB | 284921 | 6184365 | 483.6 | - | - | - | Swamp | - |

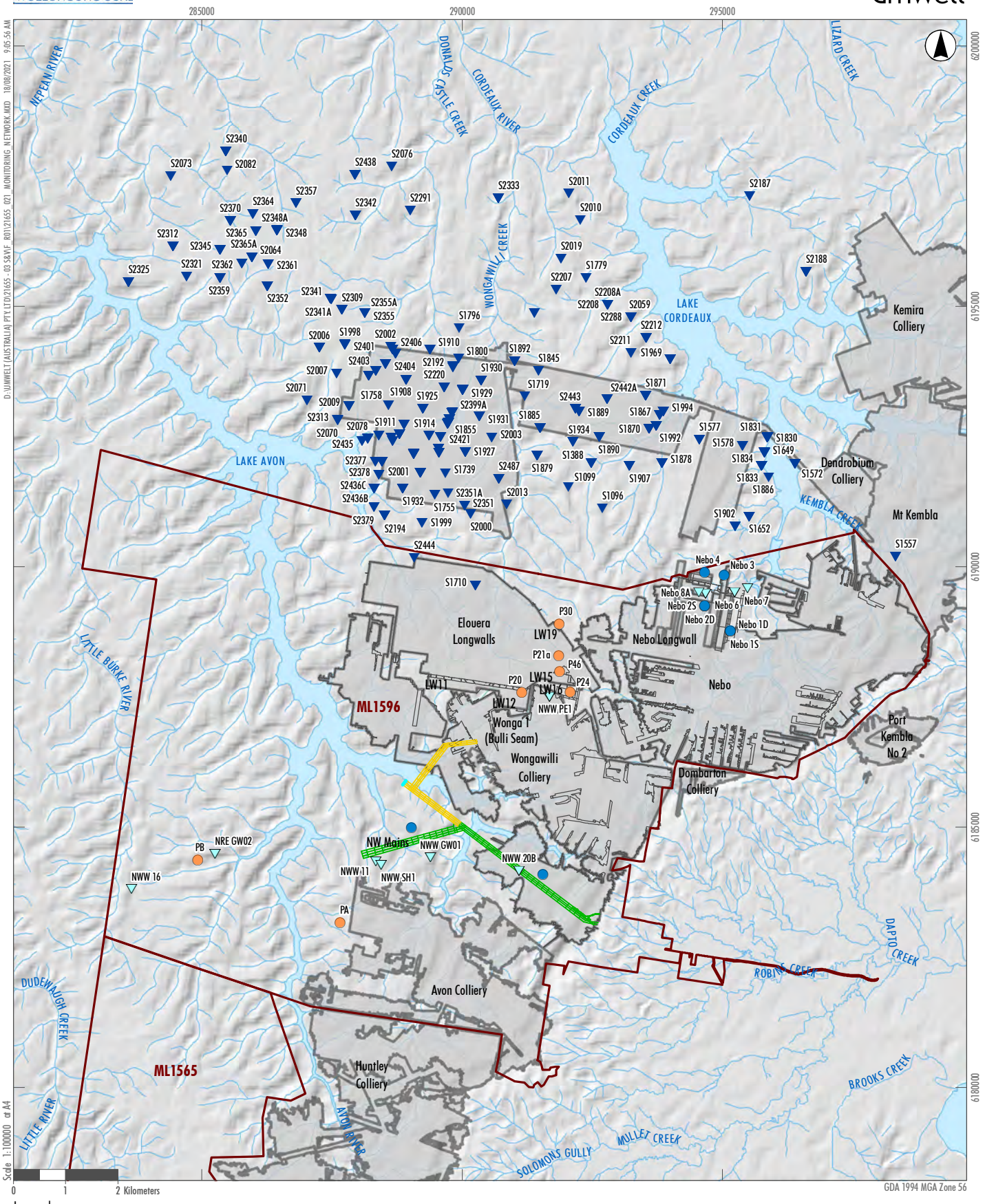
*Notes:*
**MGA94 Z56*
*# Data potentially erroneous, interpolated groundwater elevations from client data*
*LRSS – Lawrence Sandstone*
LDSS – Loddon Sandstone
KBSS – Kembla Sandstone
*WWCO – Wongawilli Coal*
*BACO – Balgownie Coal*
*BGSS – Bulgo Sandstone*
*BHCS – Bald Hill Claystone*
*BUCO – Bulli Coal*
*CCSS – Coalcliff Sandstone*
*EKFM – Eckersley Formation*
*HBSS – Hawkesbury Sandstone*

In addition, a data sharing agreement was put in place with South32, which enabled use of extensive site groundwater monitoring data from its network of VWPs in Areas 3A, 3B and 3C. Details on the Dendrobium monitoring network used as part of the groundwater assessment are provided in Appendix E.

The network with available data includes 155 VWPs with 832 sensors, including (but not limited to):

- 290 within the Hawkesbury Sandstone
- 141 within the Bulgo Sandstone
- 113 within the Scarborough Sandstone
- 29 in the Bald Hill Claystone
- 41 in the Stanwell Park Claystone
- 33 in the Bulli Coal Seam
- 59 in the Wongawilli Coal Seam

The location of the bores is shown in Figure 2-11. The timeseries water level data from the Dendrobium monitoring network were used in the development and calibration of the groundwater model. Hydrographs comparing the observed timeseries data to modelled levels are presented in Appendix F.




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Watercourse

Monitoring Bore Type

- MB
- Swamp
- VWP
- Dendrobium Monitoring Network

FIGURE 2.11

Groundwater Monitoring Network

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)

## 2.6 Hydrostratigraphic Units

The major hydrostratigraphic units within the Project area include the surficial alluvium (upland swamps), Triassic aged Hawkesbury Sandstone and Narrabeen Group, and the Permian aged Illawarra Coal Measures. Hydrogeological characteristics of each key unit are described below. This report is based on information presented by SLR (2020), with updates based on further review and analysis of available site data and trends.

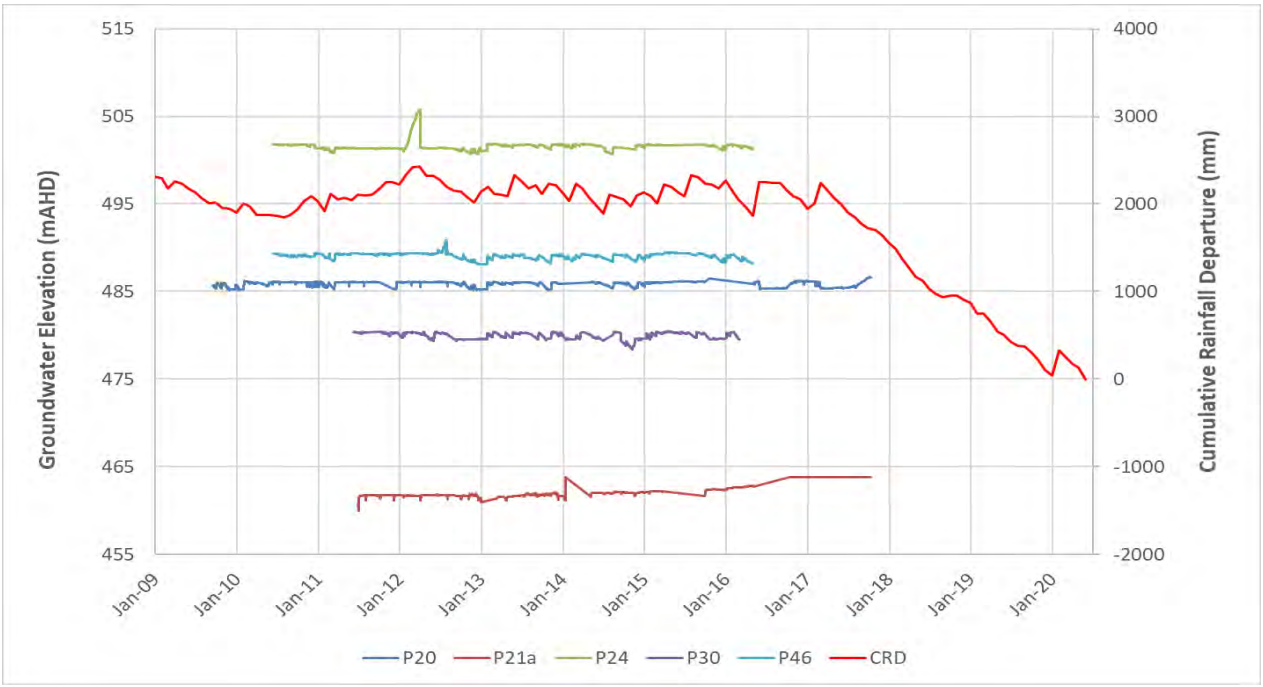
### 2.6.1 Upland Swamps

#### 2.6.1.1 Distribution and Flow

There is very little mapped alluvium within the Project area flanking rivers and creeks although small pockets of unconsolidated material (upland swamps) are mapped throughout the Project area (Figure 2-9). These features are generally oriented parallel to the direction of surface flow. Where present, geological mapping indicates minor outcrops of alluvium on valley floors and colluvium on hill slopes overlying the weathered Hawkesbury Sandstone.

There are no swamp monitoring bores in the Project area alignment, but there are five swamp monitoring points (P20, P21a, P24, P30 and P46) above the Wongawilli 1 workings around 1.2 km north-east. Water levels within the swamps were monitored between 2009 and 2018. Estimated groundwater elevations from the available data are presented in Figure 2-12. Monitoring was also conducted in 2019 but at the time of reporting no information was available to convert the pressure head data. The CRD data presented post 2017 indicates the continued influence of sustained low rainfall conditions.

Figure 2-12 Hydrographs – Upland Swamps (Source: SLR, 2020)



Groundwater levels are generally within 1 m of ground surface, an exception to this was P30 that recorded levels around 2 m below surface in November 2014. P20 and P46 also recorded a decline in levels at this time, which corresponds with below average rainfall. This shows the influence of climate trends on groundwater occurrence and levels within the upland swamps. Impacts have also been predicted in the region related to surface cracking and subsidence due to longwall mining in other mines. No longwall mining is proposed as part of the Project.

#### 2.6.1.2 Recharge and Discharge

Recharge to the upland swamps is dominated by direct rainfall and indirectly from runoff, with discharge to the underlying geological units and as river baseflow where there are positive hydraulic gradients towards the creeks or rivers.

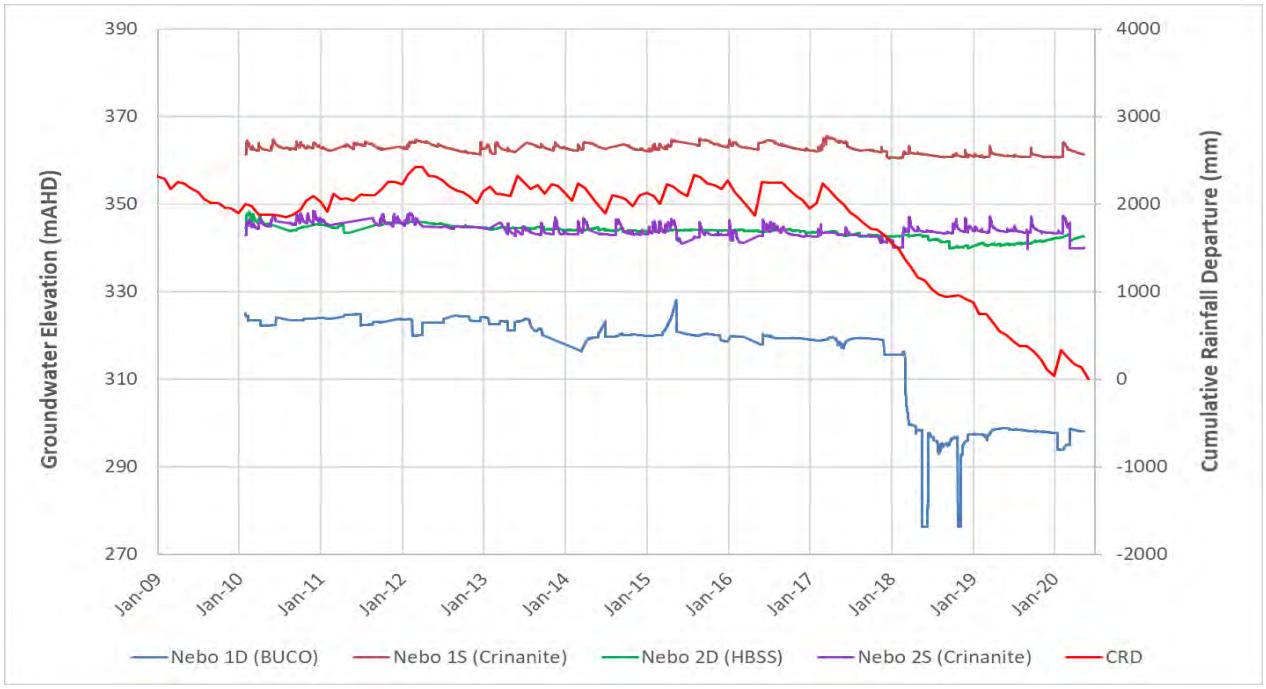
### 2.6.2 Cordeaux Crinanite

#### 2.6.2.1 Distribution and Flow

The Cordeaux Crinanite is not present within the Project area but is present to the north-east. The crinanite is considered a very low permeability aquitard up to 97.5 m thick that has intruded into and removed sections of the Bulli and Balgownie Seams (GeoTerra, 2010). Feeder dykes from the main intrusion are also present in the Wongawilli Seam. The dykes are primarily dry and are not considered to provide permeability pathways in the mining area (GeoTerra, 2010).

Groundwater monitoring of the crinanite and underlying strata is conducted in the area, at monitoring points Nebo 1S and Nebo 2S, which are paired bores screened in the Bulli Seam and Hawkesbury Sandstone, respectively. As shown in Figure 2-13, groundwater levels within the shallow crinanite show minimal change in response to below average rainfall experienced since 2017. Groundwater levels also remained stable despite depressurisation of the Bulli Seam at Nebo 1.

Figure 2-13 Hydrographs – Crinanite (Source: SLR, 2020)



#### 2.6.2.2 Recharge and Discharge

Since the crinanite has a very low hydraulic conductivity and is considered an aquitard, recharge and discharge are low. Limited recharge to the crinanite is via rainfall recharge and run-off where it outcrops and via leakage from overlying stratigraphic units. There is some minor leakage from the crinanite that discharges into the underlying hydrostratigraphic units.

### 2.6.3 Hawkesbury Sandstone

#### 2.6.3.1 Distribution and Flow

The Hawkesbury Sandstone occurs at surface within the Project area and is a productive aquifer. It consists of thickly bedded massive quartz sandstone with siltstone, claystone and grey shale lenses up to several metres thick (Moffitt, 1999; Bowman, 1974).

The Hawkesbury Sandstone is generally higher yielding than the underlying Narrabeen Group aquifers, including the Bulgo Sandstone, Scarborough Sandstone and the Coalcliff Sandstone. It is characterised as a dual porosity aquifer whereby groundwater is transmitted by both primary and secondary porosity. Groundwater flows through the interconnected void space between grains of the rock matrix and the secondary porosity features consisting of structural features such as joints, fractures, faults, shear zones and bedding planes. The Project area lies within the Hawkesbury Sandstone groundwater flow system that supports the 'Metropolitan and Woronora Special Areas' of Water NSW, including the Nepean, Avon, Cordeaux, Cataract and Woronora Dams (the Avon and Cordeaux Dams are shown on Figure 2-3.

Locally, the Hawkesbury Sandstone is present over the Project area except where it has been eroded away exposing the underlying Bald Hill Claystone and upper Bulgo Sandstone within the Gallahers Creek valley (GeoTerra, 2010). Groundwater flow is primarily horizontal along bedding planes, with minor vertical leakage along secondary structural features. Groundwater is controlled by the topography with flows towards major rivers that are deeply incised into the sandstone such as the Nepean River.

Within and surrounding the Project area groundwater levels within the Hawkesbury Sandstone are monitored at seven VWPs (NWW11, NWWSH1, NWGW01, NWW20B, NWWPE1, NWW16 and NW GW02). Groundwater trends for the monitoring points are presented in Figure 2-14 to Figure 2-19. Groundwater elevations in the Hawkesbury Sandstone range between 398 mAHD at NWW11 near Lake Avon, up to 470 mAHD at NWWPE1 to the north.

The hydrographs also show a downward vertical gradient within the Hawkesbury Sandstone, and the underlying Narrabeen Group. It is also noted that the fluctuations in initial sensor readings are likely due to construction and are not representative of groundwater conditions.

#### 2.6.3.2 Recharge and Discharge

The Hawkesbury Sandstone is regionally extensive across the Sydney Basin and is recharged by rainfall through the sandstone outcrop, as well as from water storage dams (i.e. Lake Avon).

Groundwater from the Hawkesbury Sandstone also discharges into incised rivers intersecting the Hawkesbury Sandstones such as the Cataract and Nepean Rivers. There are no registered water supply bores within 10 km of the Project area accessing groundwater from the Hawkesbury Sandstone. This is due to land use restrictions within the Metropolitan and Woronora Special Areas. Outside of the Metropolitan and Woronora Special Areas the Hawkesbury Sandstone is used for groundwater supply.

Figure 2-14 Hydrograph – NWW11 (Source: SLR, 2020)

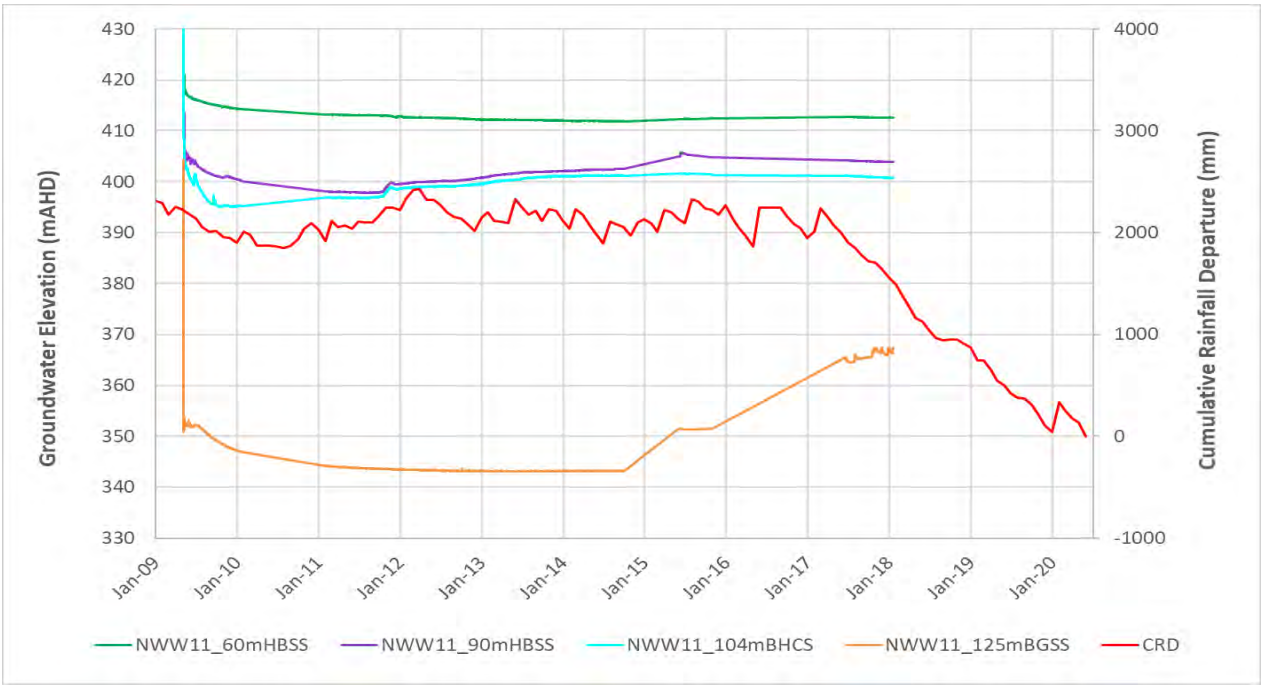



Figure 2-15 Hydrograph – NWWSH1 (Source: SLR, 2020)

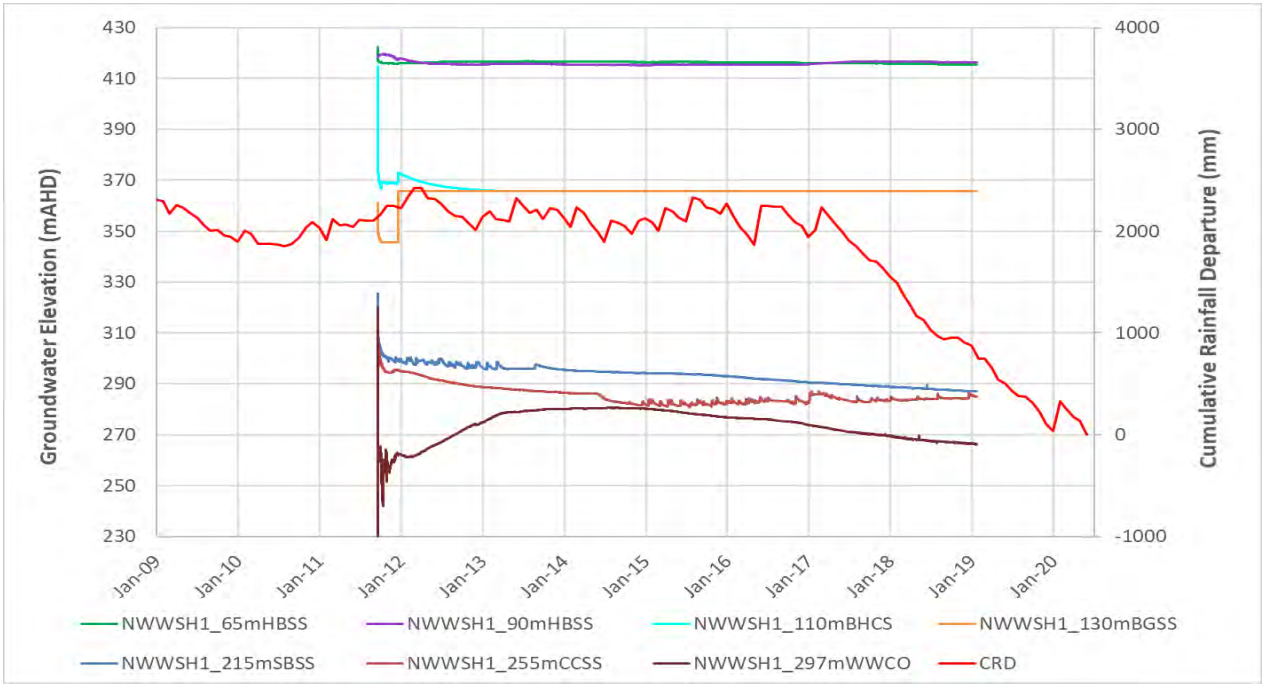


Figure 2-16 Hydrograph – NWGW01 (Source: SLR, 2020)

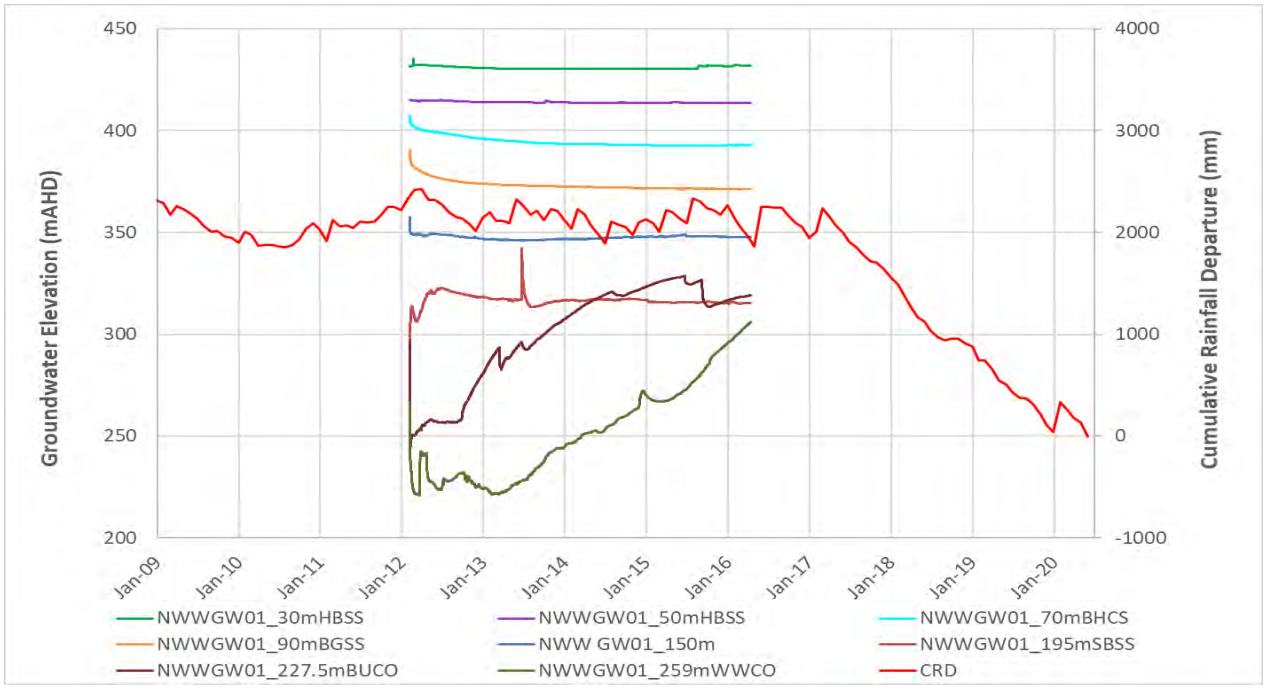



Figure 2-17 Hydrograph – NWGW02 (Source: SLR, 2020)

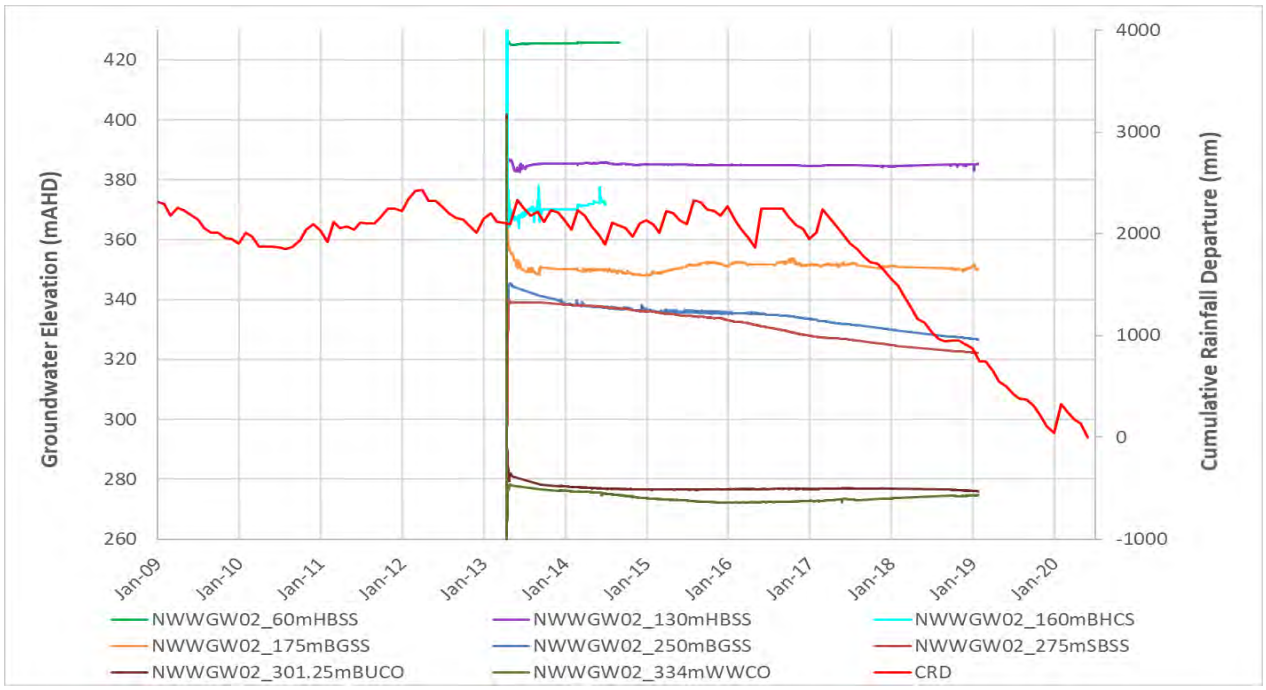


Figure 2-18 Hydrograph – NWW20B (Source: SLR, 2020)

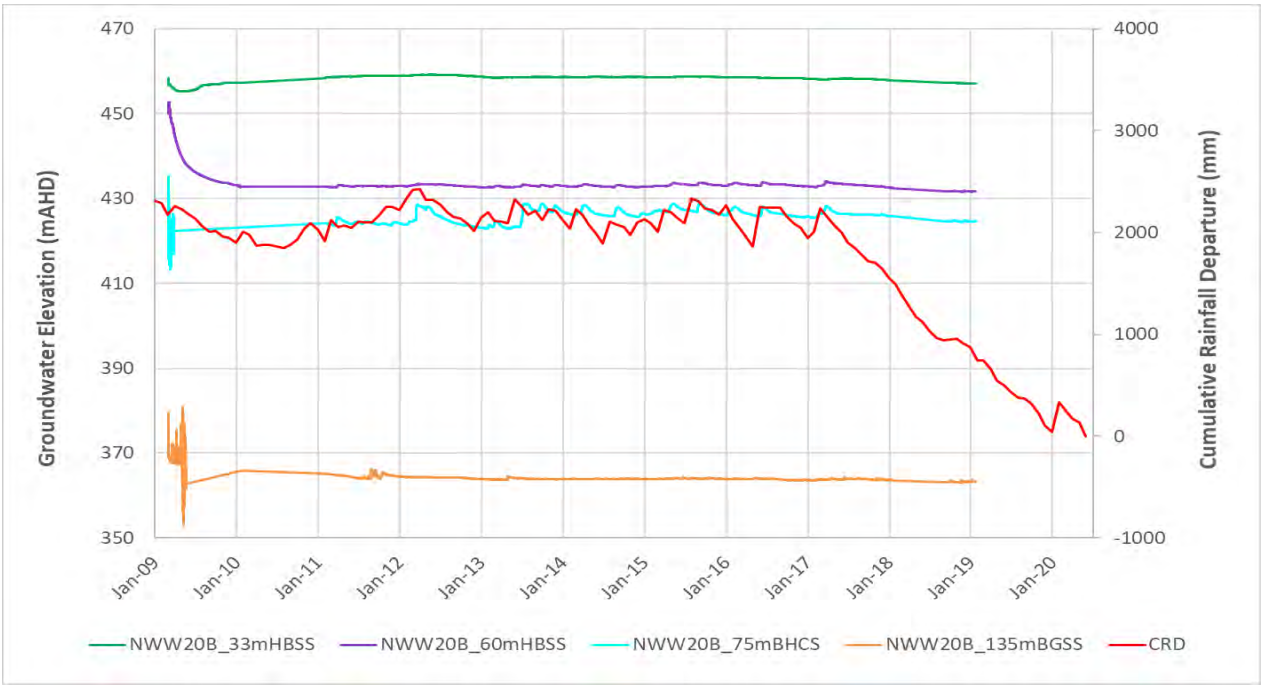
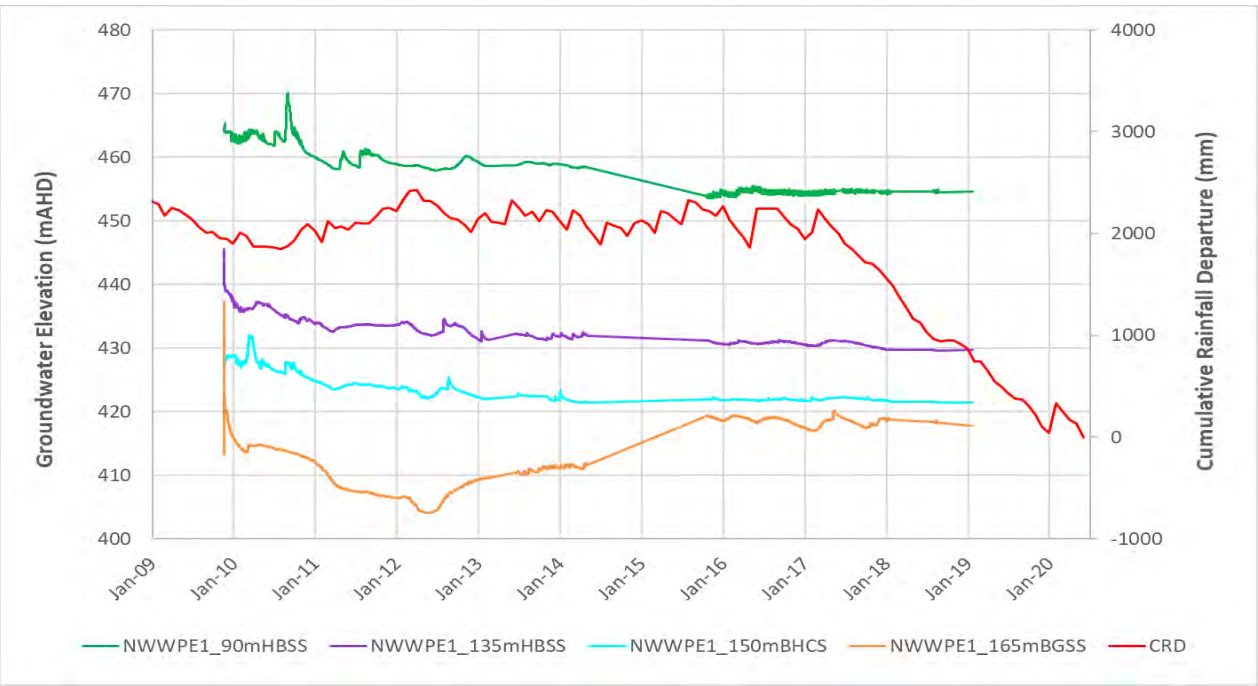



Figure 2-19 Hydrograph – NWWPE1 (Source: SLR, 2020)



### 2.6.4 Narrabeen Group

#### 2.6.4.1 Distribution and Flow

The Narrabeen Group is a sequence of interbedded sandstone, claystone, and siltstone of late Permian and early Triassic age that underlies the Hawkesbury Sandstone. The sequence is present across the Project area and thickens to the north-west. The Narrabeen Group comprises three formations of low permeability aquitards. These aquitards impede vertical flow within the unit and are described as:

- The Bald Hill Claystone at the top of the Bulgo Sandstone interrupts the vertical groundwater flow from the Hawkesbury Sandstone. The aquitard is present across the Project area and is around 25 m thick.
- The Stanwell Park Claystone limits the interaction of groundwater between the Bulgo Sandstone and the Scarborough Sandstone and is present across the Project area, ranging in thickness from 6 m to 20 m.
- The Wombarra Claystone forms the base of the Narrabeen Group and also impedes vertical flow to the Illawarra Coal Measures. It is present across the Project area and thickens south-easterly ranging from around 30 m to 40 m.

Sandstone can provide porous storage with limited fracture flow and have a low water transmission capacity whilst mudstone, siltstone and shale effectively impede vertical flow. The Narrabeen Group is typically low yielding with its highest yields obtained from coal seams with lower yields obtained from the other lithologies. Few groundwater supplies are extracted from the Southern Coalfields due to the generally low hydraulic conductivity of the units and poor groundwater quality. The hydraulic gradient within the Narrabeen Formation varies spatially due to the differences in hydraulic properties over varying depths. On a regional scale, groundwater flows horizontally from elevated areas in the south-east and western side of the Project area, with a hydraulic gradient towards the north. The seven VWPs (NWW11, NWWSH1, NW GW01, NWW20B, NWWPE1, NWW16 and NW GW02) around the Project area also have sensors within the Bald Hill Claystone, Bulgo Sandstone, Scarborough Sandstone and Coal Cliff Sandstone.

The hydrographs presented in Figure 2-14 to Figure 2-19 show a downward vertical gradient. The hydrographs also show that groundwater levels within the Bulgo Sandstone range between around 365 mAHD at NWWSH1 in the west, up to 430 mAHD at NWW20B to the east. Historically, groundwater levels would have been locally influenced by mining in the area, as indicated by VWP NWWPE1, which is located adjacent to Wongawilli Colliery workings (historical Wongawilli and Bulli Seam workings) and Elouera Colliery. Groundwater levels within the Bulgo Sandstone at NWWPE1 declined from installation in 2009 to June 2012, followed by a rise up to 418 mAHD in 2015. Since 2015 levels have fluctuated slightly but generally remained at around 418 mAHD ± 1 m. The groundwater level trends likely reflect localised recovery in groundwater conditions following cessation of longwall mining at Elouera (longwalls 11, 15, 16 and 19) in 2014.

VWP's NWWSH1 and NWW11 are located between Avon Colliery and Wongawilli Colliery, within 120 m of each other. The results for NWW11 show variability in levels since construction in 2009, with different trends compared to NWWSH1. It is considered the results for NWW11 are potentially erroneous; however, further review of the data and local geology is recommended. NWGW01 is located approximately 1 km east of the VWPs and has readings influenced by construction in the first year or two, but from 2014 shows similar results to NWWSH1. The results show groundwater levels within the Bulgo Sandstone at NWWSH1 and NWGW01 have remained relatively stable at around 365 mAHD and 371 mAHD, respectively.

#### 2.6.4.2 Recharge and Discharge

The Narrabeen Group occurs at surface in localised areas within the Project area, enabling recharge from Lake Avon and discharge to creeks where gradients enable this. Groundwater from the Narrabeen Group can also discharge naturally along the escarpment as springs, where it occurs at outcrops along the coast to the east. Localised depressurisation in response to historical longwall mining historically is also observed.

There are no registered water supply bores within 10 km of the Project area accessing groundwater from the Narrabeen Group. This is due to land use restrictions within the Metropolitan and Woronora Special Areas.

### 2.6.5 Illawarra Coal Measures

#### 2.6.5.1 Distribution and Flow

The Illawarra Coal Measures are the primary economic sequence of interest in the Sydney Basin, and consist of interbedded sandstones, shale and coal seams with a thickness of approximately 200 m to 300 m. The two main coal seams mined in the Project area are the uppermost Bulli Seam and the Wongawilli Seam.

On a regional scale, the groundwater in the Bulli Seam flows towards the north. Groundwater within the Permian coal measures is semi-confined where they occur at sub-crop, becoming confined with depth towards the north-west. Water quality within the Illawarra Coal measures is variable between coal measures and interburden typically ranging from brackish to saline. Groundwater levels within the coal measures are monitored within the Project area at NWWSH1, NWGW01 and NWGW02 (Figure 2-15 to Figure 2-17).

It is noted that trends in NWWSH1 (Figure 2-15) show a gradual decline in groundwater levels in the Bulli Seam and overlying Coal Cliff Sandstone from 2011 to 2015, followed by a slight rise in levels to around 275 mAHD in 2019. A similar trend is observed for the Wongawilli Seam and Bulli Seam at NWGW02 (Figure 2-17) with levels also recorded at around 275 mAHD in 2019.

In contrast, NWGW01 recorded a rise in levels for the Wongawilli Seam and Bulli Seam to pressure head elevations above the Bald Hill Claystone. No activities were conducted in this area over this time that explain this trend, and the high pressure head readings indicate the sensors are likely erroneous.

#### 2.6.5.2 Recharge and Discharge

Groundwater recharge is from downward seepage from the overlying Narrabeen Group, as well as from recharge where the coal measures occur at outcrop along the escarpment. Recharge and groundwater trends can also be influenced by water storage and movement associated with mine activities. Groundwater discharge occurs naturally as springs along the escarpment or where the coal measures are intersected by creeks. Discharge also occurs via inflows to active mine workings and dewatering, as well as natural seepage along the Illawarra Escarpment.

## 2.7 Hydraulic Properties

### 2.7.1 Hydraulic Conductivity (K)

This section incorporates information as presented by SLR (2020) as well as additional data and analysis to address regulator comments and provide further detail relevant to the conceptualisation and modelling.

Hydraulic conductivity is defined as horizontal hydraulic conductivity (Kh) and vertical hydraulic conductivity (Kv). Kh is typically measured from packer testing whereas values for Kv (where tested) are measured in the laboratory analysis of drill core (Hawkes, 2017). In contrast, hydraulic conductivity measured from test pumping is a combination of Kv and Kh and is referred to as the bulk hydraulic conductivity (K).

Testing of hydraulic properties of the various key geological units has been conducted within the Project area. This includes packer testing at the NWM within the Hawkesbury Sandstone (Piezometer WW11) and Bulgo Sandstone (piezometer WW20B) as well as packer testing in the Nebo area for various sequences (GeoTerra, 2010). The hydraulic conductivity values derived from this packer testing are presented in Table 2-7 from multiple boreholes in the NWM and Nebo areas.

In 2012 SCT undertook packer tests on site bores NWWSH1, NWWSH2 and NWGW01, located to the west of the Project. The hydraulic conductivity field data are summarised in

Table 2-8. The highest flow in NWWSH2 was recorded within the Hawkesbury Sandstone with a mean conductivity of $1.7x10^{-1}$ m/day. The lowest flows were within the Bald Hill Claystone recording conductivity of $8.6x10^{-7}$ m/day or less.

The highest flow in NWGW01 was recorded within the Hawksbury Sandstone/Newport Formation with a mean conductivity ranging from $1.8x10^{-2}$ to $1.4x10^{-1}$ m/day. The lowest flows were within the Bald Hill Claystone recording zero flow equating to a conductivity of $8.6x10^{-7}$ m/day or less.

The highest flow in NWWSH1 was recorded in the Hawkesbury Sandstone with a conductivity of $3.5x10^{-2}$ m/day. The lowest flow was recorded within the Bulga Sandstone, the Wombarra Claystone, the Lawrence Sandstone and the Mount Kembla Sandstone with conductivities of 8.6 x $10^{-7}$ m/day or less (SCT, 2012).

The hydraulic conductivity within the three bores generally decreased with depth indicating a reduction in conductivity with increased confining pressure. There is a marked increase in conductivity due to flow within fractures above 100 mbgl (SCT, 2012). However, SCT (2012) note several anomalies to this trend:

- The Bulli and Wongawilli Seams, which show relatively high conductivities ranging from $1x10^{-2}$ to $7x10^{-3}$ m/day. This conductivity was higher compared to surrounding test horizons.
- The Bald Hill Claystone generally shows low conductivity less than $8.6x10^{-7}$ m/day.
- Fracturing facilitated flows could be a cause for high conductivities in the rock units directly above the Bulli Seam in bore NWWSH1.

Table 2-7 Project Area Hydraulic Conductivity Summary (from GeoTerra, 2010)

| Formation | Area | Interval Tested (mbgl) | Median Kh (m/day) |
|---|---|---|---|
| Hawkesbury Sandstone | NWM | 25.15 – 31.35 | $6.7 \times 10^{-3}$ |
| Hawkesbury Sandstone | NWM | 31.15 – 37.35 | $1.5 \times 10^{-1}$ |
| Hawkesbury Sandstone | NWM | 37.15 – 43.35 | $1.3 \times 10^{-2}$ |
| Hawkesbury Sandstone | NWM | 43.15 – 49.35 | $3.9 \times 10^{-3}$ |
| Hawkesbury Sandstone | NWM | 49.15 – 55.35 | $1.0 \times 10^{-3}$ |
| Hawkesbury Sandstone | NWM | 55.15 – 61.35 | $7.3 \times 10^{-4}$ |
| Hawkesbury Sandstone | NWM | 61.15 – 67.35 | 0 x 10 |

| Formation | Area | Interval Tested (mbgl) | Median Kh (m/day) |
|---|---|---|---|
| Hawkesbury Sandstone | NWM | 67.15 – 73.35 | $1.0 \times 10^{-1}$ |
| Hawkesbury Sandstone | NWM | 73.15 – 79.35 | $7.3 \times 10^{-2}$ |
| Bald Hill Claystone – Bulgo Sandstone | NWM | 58.5 – 64.7 | $9.5 \times 10^{-4}$ |
| Bulgo Sandstone | NWM | 76.5 – 82.7 | $5.4 \times 10^{-4}$ |
| Bulgo Sandstone | NWM | 82.5 – 88.7 | $2.9 \times 10^{-4}$ |
| Bulgo Sandstone | NWM | 88.5 – 94.7 | $1.5 \times 10^{-4}$ |
| Bulgo Sandstone | NWM | 94.5 – 100.7 | $1.4 \times 10^{-4}$ |
| Bulgo Sandstone | NWM | 100.5 – 106.7 | $1.2 \times 10^{-4}$ |
| Bulgo Sandstone | NWM | 112.5 – 118.7 | $2.3 \times 10^{-4}$ |
| Bulgo Sandstone | NWM | 118.5 – 124.7 | $3.0 \times 10^{-4}$ |
| Bulgo Sandstone | NWM | 124.5 – 130.7 | $3.3 \times 10^{-4}$ |
| Crinanite (fine to medium grained) | Nebo | 0.0 – 72.1 | $2.12 \times 10^{-5}$ |
| Crinanite (medium to coarse grained) | Nebo | 45.1 – 78.1 | $3.95 \times 10^{-4}$ |
| Stanwell Park Claystone | Nebo | 51.4 – 63.3 | $7.43 \times 10^{-5}$ |
| Scarborough Sandstone | Nebo | 63.3 – 75.3 | $1.81 \times 10^{-5}$ |
| Loddon Sandstone | Nebo | 63.1 – 90.1 | $8.55 \times 10^{-3}$ |
| Balgownie Seam | Nebo | 90.1 – 96.1 | $3.02 \times 10^{-3}$ |
| Lawrence Sandstone | Nebo | 75.1 – 102.1 | $5.18 \times 10^{-5}$ |
| Un-named Member 3 | Nebo | 87.1 – 108.1 | $1.66 \times 10^{-2}$ |
| Wongawilli Seam / Kembla Sandstone | Nebo | 108.1 – 117.1 | $1.21 \times 10^{-3}$ |

Table 2-8 Project Area Hydraulic Conductivity Summary (adapted from SCT, 2012)

| Formation | Average (m/day) | Min (m/day) | Max (m/day) | Count |
|---|---|---|---|---|
| Hawkesbury Sandstone | $1.32 \times 10^{-2}$ | 0x10 | $1.73 \times 10^{-1}$ | 29 |
| Bald Hill Claystone | $6.28 \times 10^{-5}$ | 0x10 | $1.56 \times 10^{-4}$ | 3 |
| Bulgo Sandstone | $2.19 \times 10^{-4}$ | 0x10 | $1.12 \times 10^{-3}$ | 31 |
| Stanwell Park Claystone | $7.60 \times 10^{-4}$ | $7.60 \times 10^{-4}$ | $7.60 \times 10^{-4}$ | 1 |
| Scarborough Sandstone | 4.07x10-4 | 0x10 | $1.47 \times 10^{-3}$ | 7 |
| Wombarra Claystone | $5.86 \times 10^{-5}$ | 0x10 | $1.17 \times 10^{-4}$ | 2 |
| Coal Cliff Sandstone | $3.09 \times 10^{-3}$ | 0x10 | $1.84 \times 10^{-2}$ | 9 |
| Bulli Coal | 6.83x10-3 | $9.16 \times 10^{-4}$ | $1.12 \times 10^{-2}$ | 3 |
| Loddon Sandstone | $6.48 \times 10^{-4}$ | 0x10 | $3.49 \times 10^{-3}$ | 10 |
| Wongawilli Coal | $8.81 \times 10^{-3}$ | $2.41 \times 10^{-4}$ | $1.78 \times 10^{-2}$ | 6 |
| Balgownie Coal | $2.66 \times 10^{-2}$ | $2.66 \times 10^{-2}$ | $2.66 \times 10^{-2}$ | 1 |
| Kembla Sandstone | $3.36 \times 10^{-5}$ | 0x10 | $1.01 \times 10^{-4}$ | 3 |

Extensive packer testing has also been conducted at surrounding mines. Triassic and Permian strata within the Sydney Basin show significant lithological variation. Combined with the presence of weathering and secondary porosity, the hydraulic properties can show significant variability (HydroSimulations, 2019). Typically, the hydraulic conductivity within the Hawkesbury Sandstone is more variable and higher than the Bulgo Sandstone. Hydraulic conductivity also tends to reduce with depth, influenced by overburden pressures with fracture apertures decreasing with depth.

1. Horizontal hydraulic conductivity from the Project site data and available data for Dendrobium and Tahmoor (pre-mining) previously reported by HydroSimulations (2019) was collated. Summary statistics from the dataset is presented in Table 2-9 below.
2. The percentiles show similar data ranges for the Narrabeen Group sandstone units and the claystone units. Combined results for the Narrabeen Group sandstones and Narrabeen Group claystones are also provided, which provides a larger data population to inform the summary statistics.

Table 2-9 Hydraulic Conductivity Statistics – Combined Field Data (in m/day)

| Stratigraphy | Min | Max | 5th Percentile | 50th Percentile | 95th Percentile | Count |
|---|---|---|---|---|---|---|
| Hawkesbury Sandstone | $8.6x10^{-10}$ | $8.6x10^{-1}$ | $8.5x10^{-5}$ | $3.5x10^{-3}$ | $1.1x10^{-1}$ | 558 |
| Narrabeen Group – Sandstone (Bulgo, Scarborough and Coalcliff) | $8.6x10^{-7}$ | $3.2x10^{-1}$ | $5.5x10^{-6}$ | $2.6x10^{-4}$ | $1.1x10^{-2}$ | 540 |
| Bulgo Sandstone | $8.6x10^{-7}$ | $3.2x10^{-1}$ | $8.6x10^{-6}$ | $2.6x10^{-4}$ | $6.6x10^{-3}$ | 374 |
| Scarborough Sandstone | $8.6x10^{-7}$ | $2.5x10^{-1}$ | $8.6x10^{-7}$ | $2.6x10^{-4}$ | $7.1x10^{-2}$ | 112 |
| Coalcliff Sandstone | $8.6x10^{-7}$ | $1.3x10^{-1}$ | $8.6x10^{-7}$ | $2.6x10^{-4}$ | $1.4x10^{-2}$ | 54 |
| Narrabeen Group – Claystone (Bald Hill, Stanwell Park and Wombarra) | $8.6x10^{-7}$ | $3.2x10^{-1}$ | $7.1x10^{-6}$ | $1.6x10^{-4}$ | $9.8x10^{-3}$ | 234 |
| Bald Hill Claystone | $8.6x10^{-7}$ | $2.3x10^{-1}$ | $8.6x10^{-6}$ | $2.6x10^{-4}$ | $3.5x10^{-3}$ | 109 |
| Stanwell Park Claystone | $8.6x10^{-7}$ | $3.2x10^{-1}$ | $8.6x10^{-7}$ | $2.6x10^{-4}$ | $4.2x10^{-2}$ | 41 |
| Wombarra Claystone | $8.6x10^{-7}$ | $1.2x10^{-1}$ | $6.8x10^{-6}$ | $2.6x10^{-4}$ | $1.8x10^{-2}$ | 84 |
| Coal Seams (Bulli and Wongawilli Seams) | $8.6x10^{-6}$ | $4.1x10^{-1}$ | $1.5x10^{-5}$ | $3.5x10^{-4}$ | $1.7x10^{-2}$ | 108 |

The packer test data include depth intervals, which allow analysis of the relationship between hydraulic conductivity and depth for each unit. Figure 2-20 to Figure 2-23 illustrate the Kh range collected from samples at the Project area, Dendrobium and Tahmoor. The graphed data shows a general trend of declining Kh with depth. This is expected due to the greater prevalence of open joints, bedding planes and degree of weathering in the near surface. In the deeper subsurface joints and bedding planes are more likely closed due to the overburden pressure, as noted in AGC (1984) and subsequently outlined by various authors. Comparison of Kh within stratigraphic units compared to Kh relative to depth suggests that depth is the primary modifying factor or control on the magnitude of Kh, while lithology is a secondary modifying factor. This is because each stratigraphic unit is comprised of facies of differing coarse versus fine-grained sediment composition.

SLR (2020) present a depth dependence equation for the site, which was adapted from the equation used by HydroSimulations (2019). The equation is as follows:

$$Kh = Kh_0 * \exp(-1.7-0.022*d)$$

where:

Kh = Horizontal hydraulic conductivity [m/d]

$Kh_0$ = Hydraulic conductivity at zero depth (lithological factor) [m/d]

z = depth [m]

This equation has been calculated based on the maximum Kh value presented in Table 2-9, and is shown for each unit in Figure 2-20 to Figure 2-23. It should be noted the maximum values are indicative only as none of the readings were taken at surface.

Figure 2-20 Hydraulic Conductivity (Kh) versus depth (field data) – Hawkesbury Sandstone

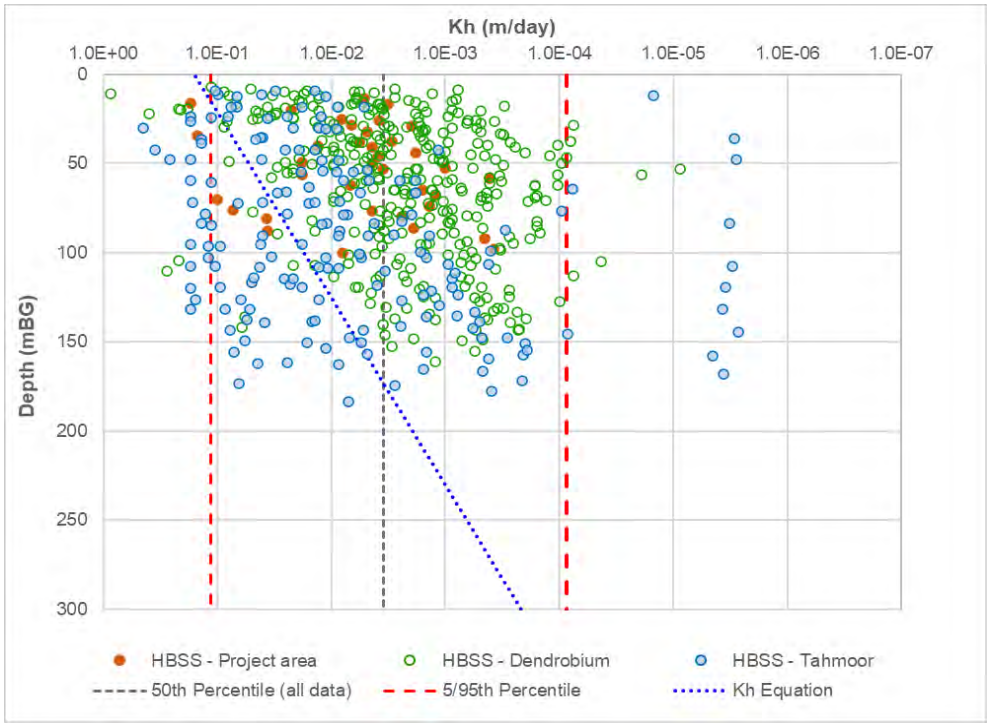



Figure 2-21 Hydraulic Conductivity (Kh) versus depth (field data) – Narrabeen Group Claystone

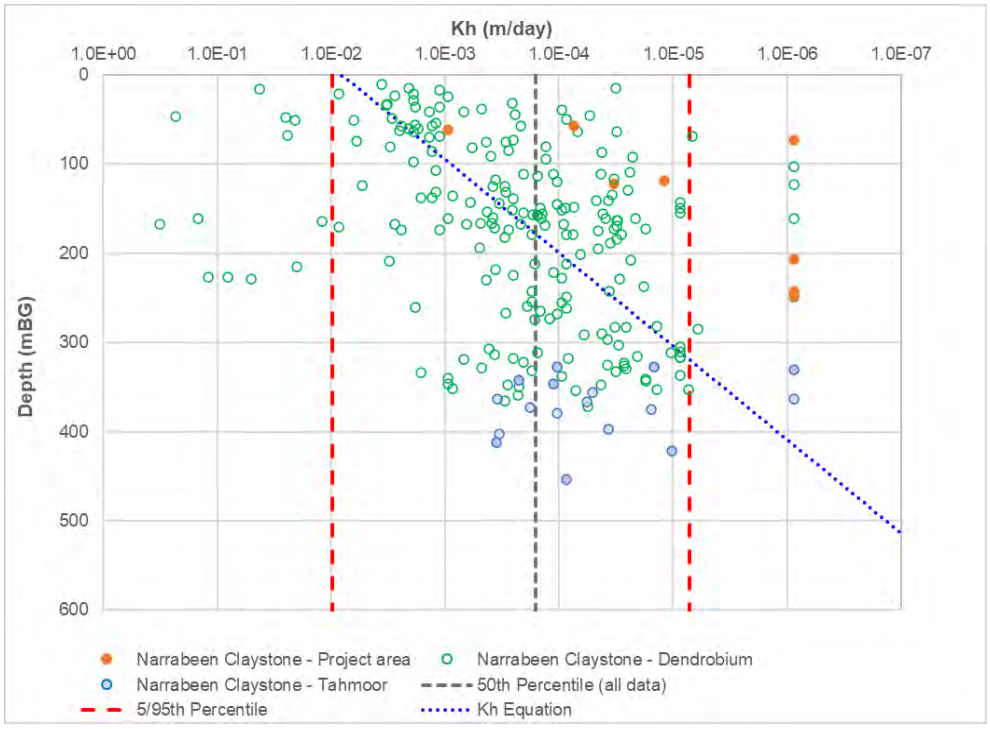


Figure 2-22 Hydraulic Conductivity (Kh) versus depth (field data) – Narrabeen Group Sandstone

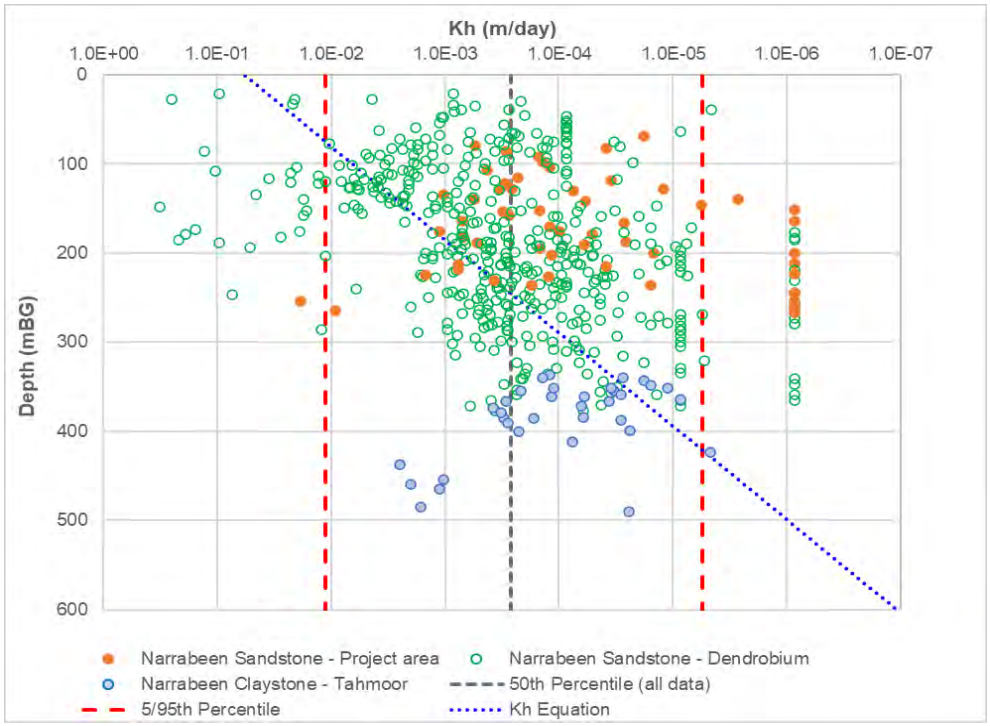
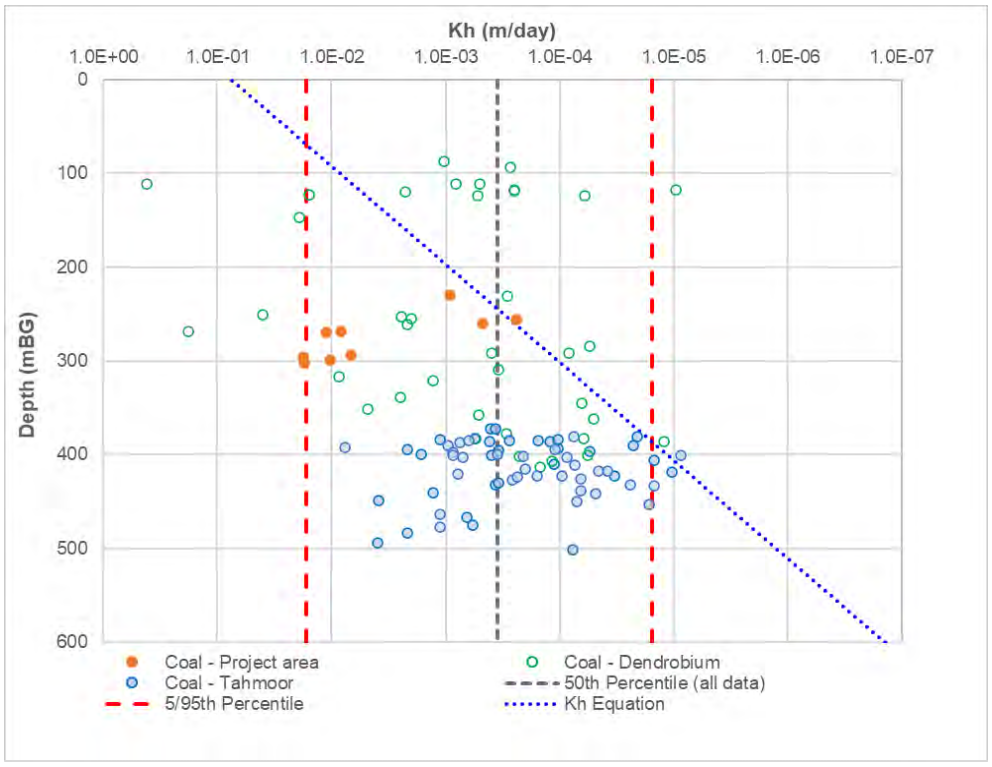



Figure 2-23 Hydraulic Conductivity (Kh) versus depth (field data) – Permian Coal Measures



### 2.7.2 Storage Properties (Sy and Ss)

This section is based on previous reporting by SLR (2020). There are no site specific data on storage properties. However, as reported in HydroSimulations (2019), testing of porosity (total) percentage has been completed at the neighbouring Dendrobium Mine. This included analysis of core from the upper stratigraphic units, such as the Hawkesbury Sandstone, Newport Formation, Bald Hill Claystone and Colo Vale Sandstone (essentially the equivalent of the Bulgo Sandstone). Estimates of total porosity have also been derived from data around Appin Mine as reported by Heritage Computing (2010). This includes average porosity and effective porosity for some geological units, where effective porosity is a reasonable approximation for specific yield. Table 2-10 provides total and effective porosity results from laboratory testing of core samples.

A review of the porosity data shows that this hydraulic parameter varies, and as for hydraulic conductivity, decreases approximately with depth. The values of total porosity range between 0.02% and 0.15%.

Direct test data is not generally available for confined storage, namely the specific storage (Ss). The specific storage of Hawkesbury Sandstone has been estimated to be approximately:

- $1x10^{-6}$ $m^{-1}$ in the shallower zones where fracture flow is the dominant flow process (Kelly *et al*., 2005); and
- $1.5x10^{-6}$ $m^{-1}$ , for intervals between ground surface and 300 m depth based on pumping tests in Hawkesbury Sandstone from Tammetta & Hawkes (2009).

Table 2-10 Summary of Porosity from Dendrobium and BSO Core Samples (from SLR, 2020)

| Geological Unit | Total Porosity (%) | | | | Effective Porosity (%) | |
|---|---|---|---|---|---|---|
| | Min | Mean | Max | Count | Mean | Count |
| Hawkesbury Sandstone | 3.8 | 15.4 (14.9) | 23.6 | 68 (4) | 11.2 | 2 |
| Newport Formation | 2 | 2.4 | 2.6 | 3 | - | - |
| Bald Hill Claystone | 4.1 | 6.1 | 9.9 | 6 | - | - |
| Colo Vale Sandstone | 3.7 | 9.4 | 18.1 | 10 | - | - |
| Upper Bulgo Sandstone | - | (8.2) | - | (5) | 3.3 | 5 |
| Lower Bulgo Sandstone | - | (5.6) | - | (4) | 0.7 | 4 |
| Stanwell Park Sandstone | - | (8.2) | - | (3) | 0.2 | 2 |
| Scarborough Sandstone | - | (8.5) | - | (4) | 1.5 | 2 |
| Wombara Sandstone | - | (3.7) | - | (1) | 0.2 | 1 |
| Coal Cliff Sandstone | - | (7) | - | (2) | - | - |

Notes: Total porosity data from HydroSimulations (2019)
Total porosity data in parentheses is from Bulli Seam Operations (BSO). All Effective Porosity measurements are from BSO.

Model calibration at other mines in the Southern Coalfields suggest that Ss is in the order of $1x10^{-7}$ to $3x10^{-5}$ $m^{-1}$ for the coal seams, and about $1x10^{-6}$ $m^{-1}$ for overburden or interburden. For the groundwater model developed for the Project, a range of generally decreasing Ss with depth is to be used, representing the concept that overburden pressure at depth steadily decreases the 'elastic storage' of the rock formation.

### 2.7.3 Mine Effects

Historical mining has occurred in the vicinity of the Project area. No longwall mining was historically undertaken along the alignment of the NWMD. Coal was extracted via the bord and pillar method and partial pillar extraction secondary workings has since occurred in some localised areas, which typically resulted in the partial collapse of the immediate roof structure strata over the mined void (IESC, 2014). Thus, the void space within the mined area increases, as does the hydraulic conductivity above the goaf due to induced or increased cracking.

As reported by GeoTerra (2010) and SCT (2021), historical workings within Wongawilli Colliery near the Wongawilli Fault and dyke structures recorded very low inflows during first workings. Geoterra (2010) do note that higher inflows occurred during secondary extraction in one area (Blue Panel 2 and 4) in 1982. Water tracer analysis was conducted at the time, and it was interpreted that inflows from secondary extraction at Blue Panel 2 related to groundwater inflows from the stratigraphy. However, inflows from secondary extraction at Blue Panel 4 were potentially due to subsidence following pillar extraction enabling a hydraulic connection to Avon Dam via structural features. GeoTerra (2010) emphasised that the event was related to the mine method used, and as the now approved NWM involves mains development (first workings) only, no interaction with structural features was expected. This corresponds with reporting by SCT (2021) that a heading was developed in the Bulli Seam 55 m below the Flying Fox No3 Creek arm of Avon Reservoir in 1997 through two dykes. During construction, and over a 22 year period until the mine was abandoned in 2019, no perceptible inflows were observed (SCT, 2021).

Sydney Water's Avon-Illawarra Tunnel constructed in the 1990's also crossed the Wongawilli Fault at depths around the Wongawilli Seam, approximately 115 m below base of Avon Reservoir (SCT, 2021). SCT (2021) noted that available records indicate no significant inflows were recorded during construction of the tunnel. Doyle (2007) also reviewed mining through geological structures in the Dendrobium area and found that fault structures are not hydraulically conductive (SCT, 2020). Also, as reported in Tonkin and Timms (2015), there has been no recorded "high level" mine inflows across the Southern Coalfields in the past 25 years. This suggests that with first workings, faults and dykes in the area typically act more as barriers than conduits to groundwater flow.

A subsidence assessment was conducted by MSEC (2010) for the approved operations. It was predicted that there would be no observable subsidence, strain or tilt, stream bed uplift or bed cracking in Gallahers Creek due to the approved Project workings (MSEC, 2010).

WCL also engaged SCT to undertake a subsidence and geotechnical assessment for the Project. The assessment indicated that there is no potential for the proposed main heading development roadways to cause surface ground movements of any consequence. Impacts to natural and built features are expected to be imperceptible. The following were taken into consideration during the SCT (2020) assessment:

- The proposed main headings will be formed within the Bulli Seam and will pass 25 to 30 m above areas of previous mining in the Wongawilli Seam including five areas of full or partial secondary extraction where the strata is likely to be significantly disturbed. The disturbance may include changes in grade around the goaf in the Wongawilli Seam, open fracturing of the Bulli Seam roof and floor, locally elevated vertical stresses in some areas and reduced vertical and horizontal stresses in others (SCT, 2020).
- The Bulli Seam pillars will be long-term stable. Rib deterioration is expected adjacent to full extraction in the Wongawilli Seam and where the overburden depth is greater than 250 m or pillar load is greater than 6 MPa.
- The main headings are located within the Sydney Water Supply Catchment (Metropolitan Special Area) of Avon Reservoir, below Gallahers Creek and Bellbird Creek, which are arms of the reservoir. The headings will be 60 m below the base of Avon Reservoir. A dyke is projected to pass near the base of Avon Reservoir; however, the dyke is not expected to be hydraulically conductive based on experience nearby along the same dyke.
- The first workings are not expected to cause significant changes to the hydraulic conductivity of the overburden strata. It has been recommended drilling ahead to confirm the absence of zones of elevated hydraulic conductivity (SCT, 2020).

Longwall mining occurs in the region, which can change the hydraulic properties of the insitu strata. After the panels of coal are extracted using longwall mining methods the overlying strata immediately above the extracted seam collapses into the void (forming the goaf). The strata above the goaf deform and fracture in response, and some level of subsidence and fracturing of overlying and adjacent strata occurs (Peng & Chiang, 1984; Whittaker & Reddish, 1989). Subsidence and goaf effects can cause surface cracking, resulting in enhanced vertical conductivity at the surface, which varies through natural deposition and infilling, as well as engineered remediation (i.e. surface grouting). Fracturing is most intense and vertically connected immediately above the collapsed longwall (goaf), and grades upwards through zones of less fractured strata (Booth, 2002).

Fracturing of the overburden can cause significant changes in aquifer characteristics such as hydraulic conductivity and storage, and potentially can provide pathways for vertical groundwater movement between shallow groundwater and surface water systems and underground mines (Advisian, 2016; McNally & Evans, 2007). Extensive data for surrounding mines (i.e. Dendrobium) indicate the goaf and fractured zone could result in an enhanced permeability of two to three orders of magnitude (HGEO, 2019).

The ratio of panel width (W) and depth of cover (D) is often used as a preliminary guide to the risk of connected fracturing extending from the goaf to the surface. The height of complete groundwater drainage and the height of fracturing above the workings can be calculated using the Tammetta (2012) and Ditton and Merrick (2014) methods respectively.

The impacts of subsidence and induced fracturing can be represented in groundwater models by increasing the hydraulic conductivity. Values for hydraulic conductivity applied in the previous Golder (2010) groundwater model for Nebo Panels 1 to 6, to represent the impacts of subsidence, are presented in Table 2-11. The ratio of vertical hydraulic conductivity (Kv) to horizontal hydraulic conductivity (Kh) is given by the anisotropy factor provided.

Table 2-11 Hydraulic Conductivity of Mining Impacted Stratigraphy (from Golder, 2010)

| Geological Unit | Hydraulic Conductivity (Kh) | | Anisotropy Factor* |
|---|---|---|---|
| | m/s | m/day | Max |
| Hawkesbury Sandstone | $3x10^{-8}$ | $3x10^{-3}$ | 0.1 |
| Bald Hill Claystone | $5x10^{-9}$ | $4x10^{-4}$ | 0.1 |
| Upper Cordeaux Crinanite | $3x10^{-8}$ | $3x10^{-3}$ | 1 |
| Lower Cordeaux Crinanite | $3x10^{-10}$ | $3x10^{-5}$ | 0.1 |
| Bulgo Sandstone | $6x10^{-8}$ | $5x10^{-3}$ | 0.05 |
| Bulgo Sandstone - delaminated | $3x10^{-7}$ | $3x10^{-2}$ | 0.05 |
| Stanwell Park Claystone | $3x10^{-10}$ | $3x10^{-5}$ | 0.05 |
| Fractured longwall | $3x10^{-9}$ | $3x10^{-4}$ | 0.1 |
| Fractured pillar extraction (bord & pillar) | $3x10^{-9}$ | $3x10^{-4}$ | 0.05 |
| Scarborough Sandstone | $2x10^{-8}$ | $2x10^{-3}$ | 0.05 |
| Fractured longwall | $2x10^{-6}$ | $2x10^{-1}$ | 0.05 |
| Fractured pillar extraction (bord & pillar) | $8x10^{-7}$ | $7x10^{-2}$ | 0.1 |
| Wombarra Shale | $1x10^{-9}$ | $9x10^{-5}$ | 0.01 |
| Fractured longwall | $1x10^{-7}$ | $9x10^{-3}$ | 0.1 |
| Fractured pillar extraction (bord & pillar) | $1x10^{-8}$ | $9x10^{-4}$ | 0.1 |
| Bulli Coal/Coalcliff Sandstone | $1x10^{-6}$ | $9x10^{-2}$ | 0.5 |
| Fractured longwall | $1x10^{-3}$ | 86.4 | 0.5 |
| Fractured pillar extraction (bord & pillar) | $1x10^{-4}$ | 8.6 | 0.5 |
| Eckersley Formation | $1x10^{-9}$ | $9x10^{-5}$ | 0.05 |
| Fractured | $1x10^{-7}$ | $9x10^{-3}$ | 0.1 |
| Wongawilli Seam | $5x10^{-7}$ | $4x10^{-2}$ | 0.1 |
| Mine workings / roadways | n/a (Void) | n/a (Void) | n/a (Void) |
| Kembla Sandstone | $1x10^{-9}$ | $9x10^{-5}$ | 0.1 |

*Note:* ** Ratio of vertical hydraulic conductivity ($K_v$) to horizontal* hydraulic *conductivity ($K_h$)*

## 2.8 Groundwater Quality

This section provides a summary of groundwater quality within the Project area, as previously reported by SLR (2020).

Groundwater quality data collected within the Project area from bores screened within the soil (Nebo 1s and 2s), crinanite (Nebo 2d and 3), Narrabeen Formation (Nebo 1d) and Bulli coal seam (Nebo 4) is presented in Appendix D. The groundwater quality data has been collected between 2010 and 2019. In summary, water within:

- Nepean River surface water is generally fresh (median EC 244 µS/cm) and generally has neutral pH (median pH 7.7).
- Groundwater within the soil is fresh (median EC 273 µS/cm) indicating the water is suitable for drinking water, irrigation and stock. pH conditions are relatively neutral (medium pH 6.5). The water is classified as sodium bi-carbonate type water.
- Groundwater within the crinanite is fresh to brackish (median EC 946 µS/cm, maximum EC 2,983 µS/cm) and generally has an alkaline pH (median pH of 9.7). The elevated pH is typical of these alkaline intrusive volcanics. Based on salinity the water is generally suitable for short term irrigation and stock water. The water is classified as calcium/sodium bi-carbonate type water.
- Groundwater within the Narrabeen Formation is generally fresh (median EC 724 µS/cm, maximum EC 1,404 µS/cm) indicating, based on salinity, the water is suitable for drinking water, irrigation and stock. pH conditions are generally alkaline (median pH 8.4). The water is classified as sodium bi-carbonate type water.
- Groundwater within the Bulli Seam is brackish (median TDS 2,375 mg/L) and, based on salinity, is suitable for irrigation and some stock (i.e. sheep and dairy cattle). The water is classified as sodium bi-carbonate type water.

Groundwater quality within the Permian coal measures is typically moderately saline to saline. With consideration of mine closure, as groundwater recovers, minerals that were oxidised under the drained conditions (i.e. sulphur) can undergo dissolution, in turn lowering the pH of the infilling waters (Wright et al., 2018). More acidic waters can lead to increased dissolution of precipitated metals such as zinc, iron and nickel (Wright et al., 2018; Price and Wright, 2016). The degree of acidity encountered during the saturation of the mine workings is dependent upon the acid forming potential of the mined material (Harries, 1997).

## 2.9 Groundwater Users

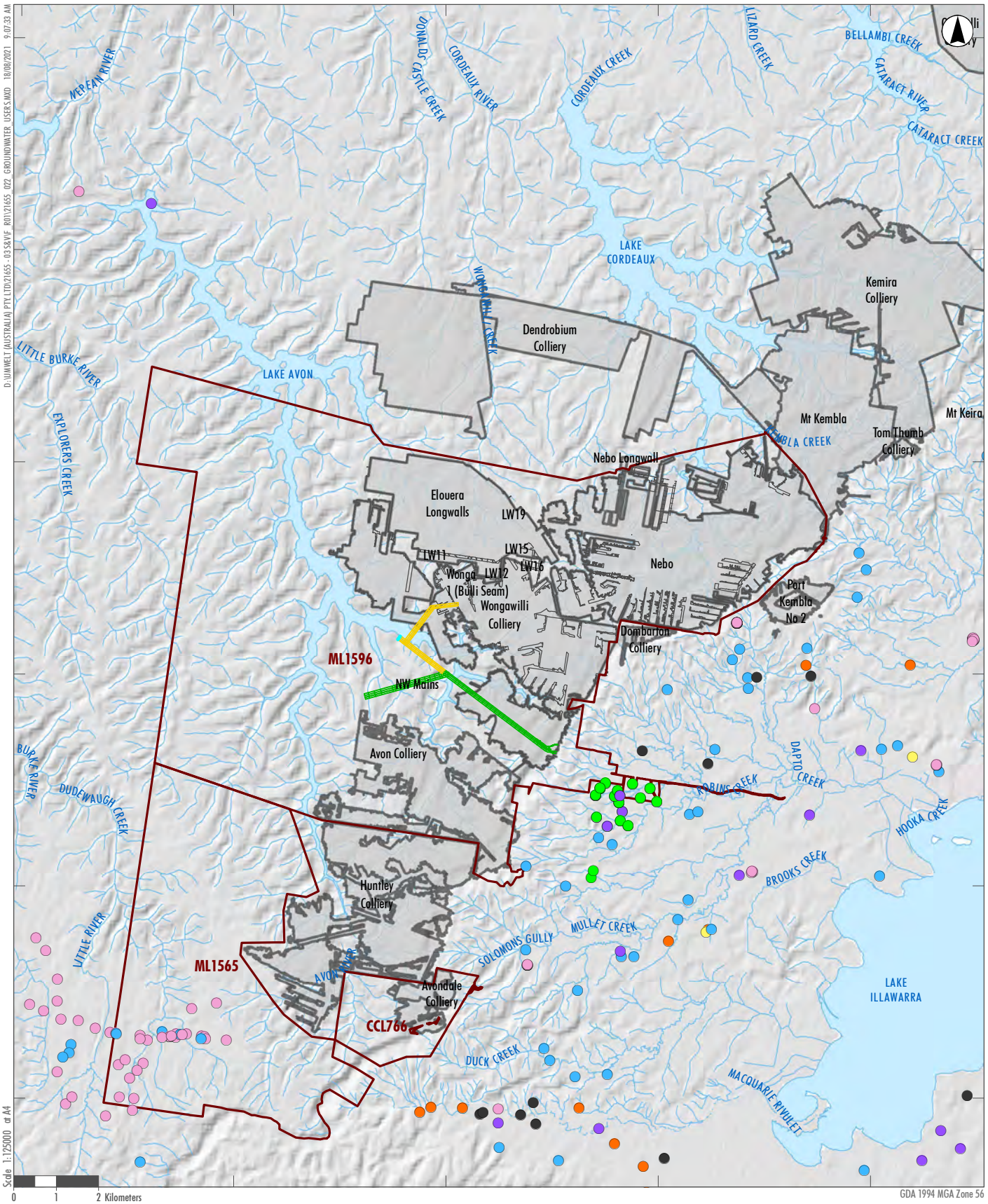
### 2.9.1 Groundwater Users – Anthropogenic

Due to discrepancies in previous reporting by SLR (2020), a new search of the Bureau of Meteorology's (BoM) National Groundwater Information System (NGIS) was carried out for registered bores surrounding the Project area. The NGIS database indicates there are no registered bores within 10 km of the Project area above the Illawarra Escarpment. This is due to land use restrictions within the Metropolitan and Woronora Special Areas.

There are 84 registered bores within 5 km of the Project area, all located below the Illawarra Escarpment. Table 2-12 presents a summary of the registered bore details and the bore locations are shown in Figure 2-24. As shown in the table, the majority of bores were installed for exploration and monitoring. Most bores target the shallow weathered Permian aged Shoalhaven Group, which underlies the Illawarra Coal Measures. As well as Quaternary alluvium that extends to the coast in the east.

Table 2-12 Registered Bore Details

| Feature Type | Number of Registered Bores | Average Bore Depth (m) |
|---|---|---|
| Exploration | 34 | 20 |
| Domestic supply | 9 | 58 |
| Industrial | 1 | 114 |
| Irrigation | 3 | 8 |
| Monitoring | 18 | 17 |
| Recreation | 1 | 54 |
| Stock | 3 | 40 |
| Unknown | 7 | 3 |
| Water Supply | 8 | 31 |




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Watercourse

NGIS Bores

- Exploration
- Water Supply
- Industrial
- Irrigation
- Monitoring
- Stock and Domestic
- Other

FIGURE 2.24

Groundwater Users Registered Bores

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)

### 2.9.2 Groundwater Dependent Ecosystems

This section provides a summary of Groundwater Dependent Ecosystems (GDEs) near the Project. The information presented is derived from the SLR (2020) report, along with additional information.

GDEs are communities of plants, animals and other organisms whose extent and life processes are dependent on groundwater. There are several ecosystems that are dependent on groundwater such as terrestrial vegetation, aquifer and cave ecosystems, and wetlands. Groundwater discharge to streams is also an important discharge mechanism. Shallow groundwater can support terrestrial vegetation, such as forests and woodlands, either permanently or seasonally. Faunae depend on this vegetation and therefore indirectly depend on groundwater. River flow is often maintained largely by groundwater, which provides baseflow long after rainfall runoff ceases. Groundwater below the riverbed is partially recharged by surface water and is an important habitat for invertebrates.

Searches of the following GDE databases were undertaken to identify potential GDE's within the Project area:

- Bureau of Meteorology (BoM) GDE Atlas;
- Greater Metropolitan Regional Groundwater Resources WSP; and
- Geoscience Australia (GA) Water Observations from Space.

Review of the Water Sharing Plan for the Greater Metropolitan Regional Groundwater Resources (NoW, 2013) indicated there are no high priority GDEs within the Project area.

Swamps have been mapped within the Project area and a review of the National Atlas of Groundwater Dependent Ecosystems (BoM, 2018) identified potential terrestrial GDEs, as shown on Figure 2-25.

- Moderate potential groundwater interaction – localised areas immediately north of the proposed workings and south of the Avon River. Coastal sandstone gully forest, coastal warm temperate rainforest, escarpment foothills wet forest; and
- Low potential groundwater interaction – areas north of the southern extent of the proposed workings including escarpment foothills wet forest, coastal warm temperate rain forest, coastal sandstone gully forest.

Water Observations from Space mapping was also reviewed (Figure 2-25), which shows a low occurrence of water at surface (percentage of observations) with water present at surface outside of the reservoirs, based on satellite imagery since 1987. WWC undertook an assessment of creeks within the approved mining area and developed an aquatic ecology monitoring program for the collection of baseline data (Biosis, 2014a/b). Natural springs/seepage also occur along the Illawarra Escarpment where gradients enable flow.

Further discussion on the swamps is included in Section 2.9.2.1.

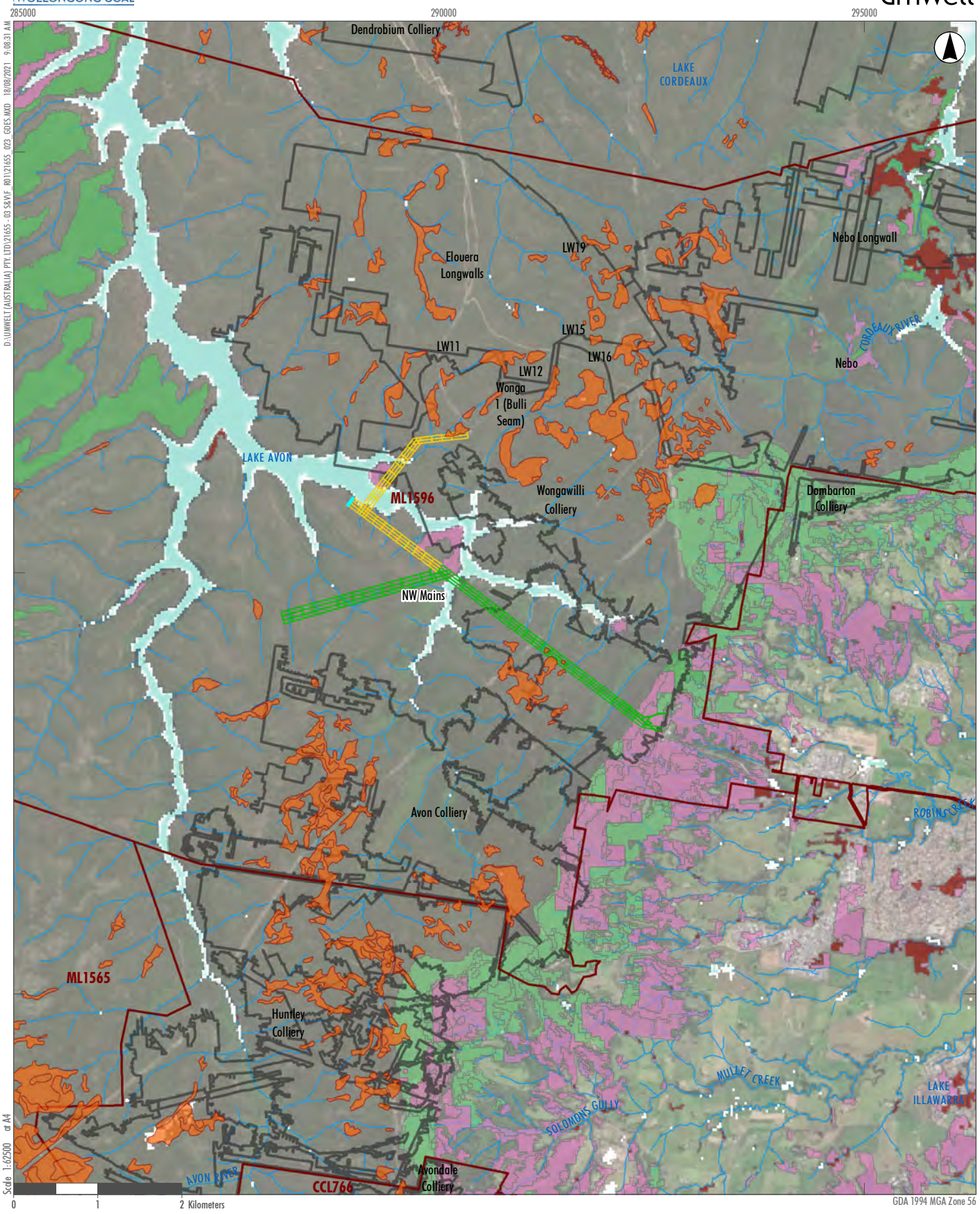
#### 2.9.2.1 Swamps

As discussed in Section 2.4.2.1, upland swamps have also been mapped within the area, consisting of headwater upland swamps and valley infill swamps, as well as creeks in the vicinity of mining.

With more recent mapping, one swamp area has been mapped above the proposed Project alignment and one above the alignment of the approved NWM (Figure 2-25). Coastal upland swamps are listed as an endangered ecological community under the EPBC Act, and the NSW Threatened Species Conservation Act, 1995. Swamp vegetation is highly variable, ranging from open graminoid (grassy) heaths and sedgelands to fernlands and scrub (TSSC, 2014).

The swamps are the main receptors within the Project area. These swamps are connected to groundwater within valley infill swamps and the sandstone aquifer. Shallow upland swamps in the Project area overly weathered Hawkesbury Sandstone. The swamps are recharged from rainfall and shallow flow, with trends influenced by climatic conditions and potentially by surface subsidence impacts from historical longwall mining. The swamps within the Project area are generally hydraulically separated from the lower Hawkesbury Sandstone regional water table.

Depressurisation due to first workings of the NWMD is not predicted to cause additional impacts to swamp water conditions (Umwelt, 2021).




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Watercourse
- Swamps

Potential Terrestrial GDEs

- High Potential GDE
- Moderate Potential GDE
- Low Potential GDE

Water Observations from Space (%)

100
80
50
20
1

FIGURE 2.25

Groundwater Dependent Ecosystems

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)

## 2.10 Conceptual Groundwater Model

This section summarises the conceptual groundwater model of the Project, as previously reported by SLR (2020). The main groundwater units within the Project area are:

- Upland swamps – saturated alluvial/colluvial sediments and organic matter. Recharged from rainfall as well as surface/subsurface water flow;
- The Cordeaux Crinanite is present in the Nebo area of the Project and has similar characteristics to dolerite intrusions. The crinanite has intruded into and removed sections of the Bulli and Balgownie Seams. Feeder dykes from the main intrusion are also present in the Wongawilli Seam. The dykes are primarily dry and are not considered to provide permeability pathways in the mining area. The crinanite is considered a very low permeability aquitard up to 97.5 m thick. The crinanite above the current and proposed workings is of low permeability, reducing leakage from overlying units into the workings where the crinanite is present;
- Hawkesbury Sandstone – main groundwater source and widely accessed for groundwater supply regionally and provides baseflow contributions where incised along major rivers (i.e. Cataract and Nepean Rivers). Groundwater flow is northward, and locally influenced where intersected by rivers and private abstraction bores. Current monitoring data indicates no depressurisation or drawdown within the Hawkesbury Sandstone in response to mining;
- Narrabeen Group – Sandstone interbedded with low permeability claystones that generally act as aquitards. Occurs at outcrop in localised areas along Lake Avon. Recharge to the Narrabeen Group is from water storage areas where intersected, rainfall recharge along the escarpment and downward seepage from overlying Hawkesbury Sandstone; and
- Illawarra Coal Measures – with groundwater occurrence largely associated with the more permeable coal seams, with confined groundwater conditions. Groundwater flow generally northward, and locally depressurised due to current and historical mining. Current monitoring shows depressurisation from historical operations, with recovery in levels in localised areas, potentially influenced by underground water storage.

Updated conceptual groundwater models for the Project area have been developed by Umwelt based on the geological sections presented by SLR (2020). The conceptual models are depicted schematically in Figure 2-26 to Figure 2-28. The figures show the main stratigraphic sequences, recharge and discharge processes and inferred groundwater conditions during and after mining.

The Project area intersects the Bulli Seam that dips north-westward. The shallowest depth to the Bulli Seam for the proposed NWMD is 60 m in one localised area below the base of the reservoir (SCT, 2020). The Project is likely to result in localised depressurisation within the Bulli Seam and Wongawilli Seam (where it declines) associated with direct interception with mine progression. Previous studies by Golder (2010) predicted up to 9.1 ML/year of groundwater inflows associated with the approved alignment of the NWM. The Project involves first workings along the approved NWM alignment and the proposed extension to connect to the existing vent shaft at Wongawilli 1. There is negligible subsidence predicted due to extraction associated with the Project, due to the design of the additional driveage. With no subsidence impacts predicted, changes in hydraulic properties of the strata overlying the Bulli Seam are unlikely. This includes no predicted changes associated with fault and dyke structures due to the mine approach being mains development (first workings).

Impacts to the groundwater system are shown conceptually on Figure 2-26 to Figure 2-28 and show the hydrogeological regime before, during and after mining. Pre-mining groundwater flows are north-westward down dip along the sandstone and coal beds. There is minimal vertical leakage between the hydrostratigraphic units with the Stanwell Park Claystone and Wombarra claystone that act as aquitards further restricting vertical groundwater movement. The inferred potentiometric surface for the Hawkesbury and Bulgo Sandstone is shown within the high in the

stratigraphic sequence above the Stanwell Park Claystone. In contrast, the inferred potentiometric surface within the Permian sediments is lower in the sequence above the Bulli Seam within the Bulgo Sandstone Scarborough Sandstone and Eckersley Formation.

During mining groundwater is pumped from the Bulli Seam to maintain dry working conditions. Consequently, the aquifers within the overlying hydrostratigraphic units of the Eckersley Formation, Wombarra Claystone and Scarborough Sandstone are depressurised lowering the potentiometric head within the Permian sequence to below the Bulli Seam. Locally groundwater flow directions are altered where there is greater vertical flow towards the Bulli Seam. Higher in the stratigraphic sequence there will be no impacts to the potentiometric surface of the Hawkesbury and Bulgo Sandstone. Regional groundwater flow will continue to the north-west.

Post mining groundwater will no longer be pumped from the mine workings, allowing the mine voids to become inundated and the recovery of potentiometric heads to pre-mining conditions, although this recovery may take many years. Goaf effects from historical mining will remain in the strata overlying the flooded voids and there may be some minor mixing of groundwater between the hydrostratigraphic units via the historical fracture zone. However, as the strata become inundated following the cessation of pumping local groundwater flow will return to pre-mining conditions. Regional groundwater flow will continue to the north-west. Potentiometric heads within the Hawkesbury and Bulgo Sandstone will remain unchanged.

Figure 2-26 Wongawilli Conceptual Groundwater Model – North South (A-**A') (adapted from SLR, 2020)**

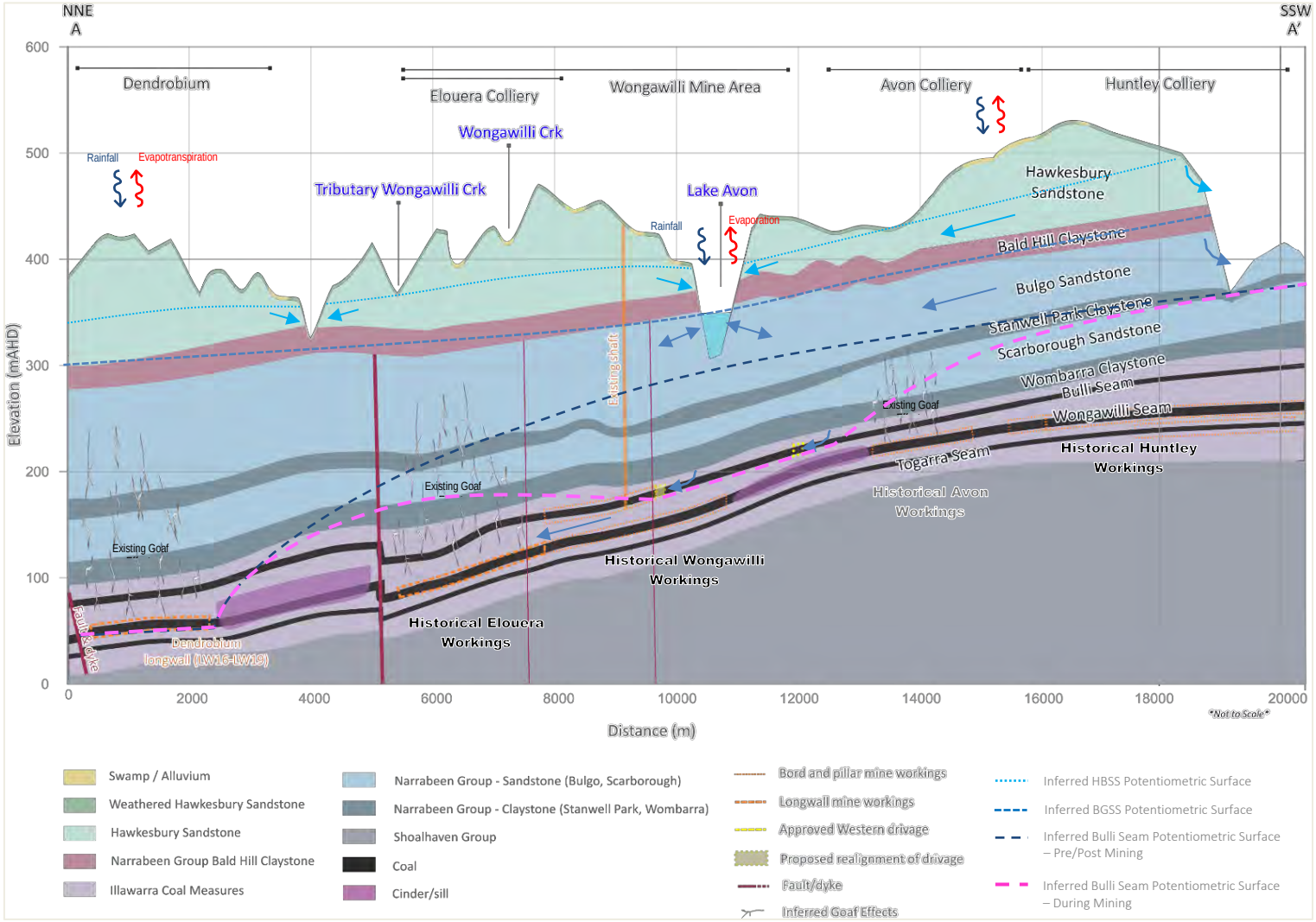


Figure 2-27 Wongawilli Conceptual Groundwater Model – West East (B-**B') (adapted from SLR, 2020)**

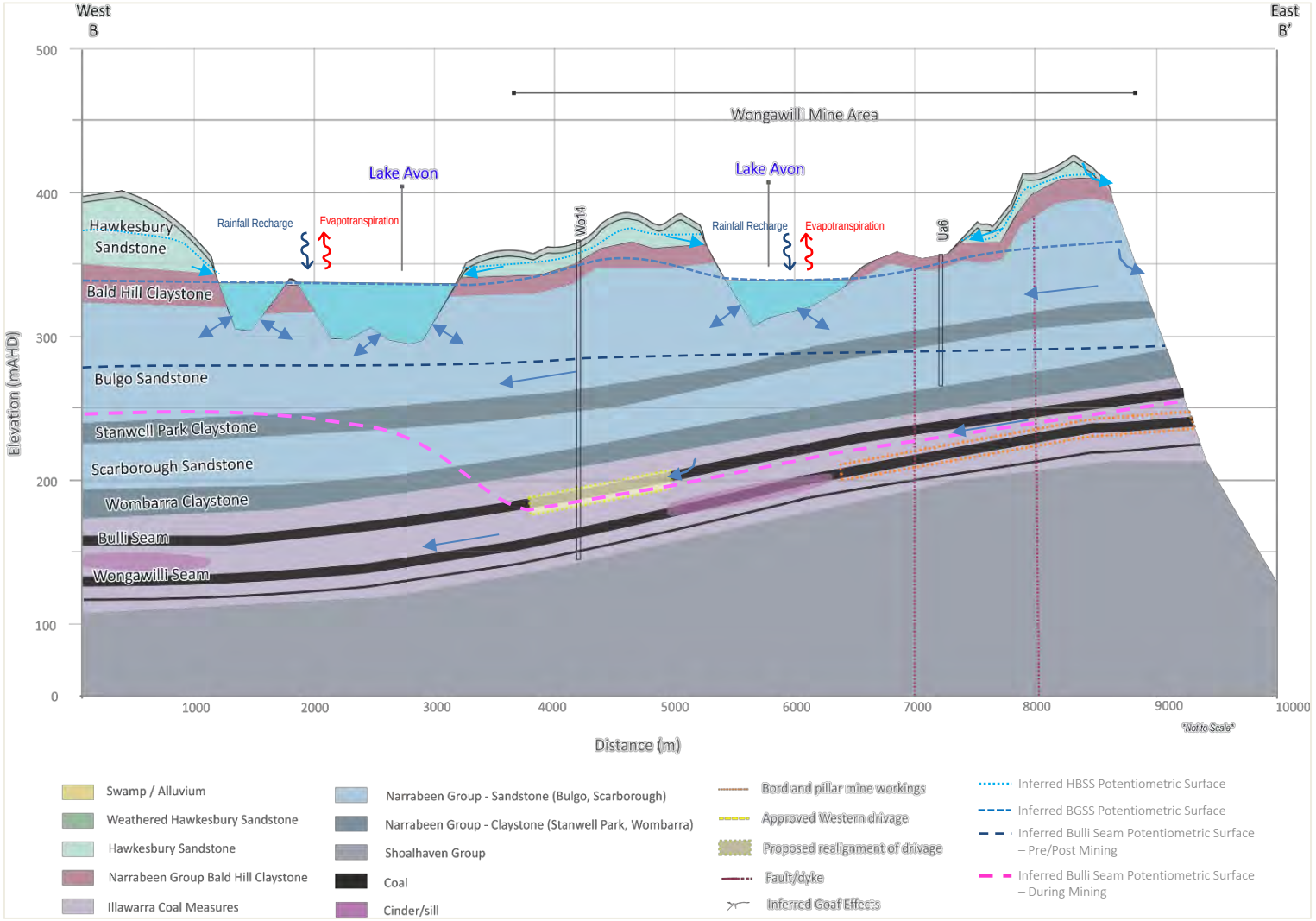
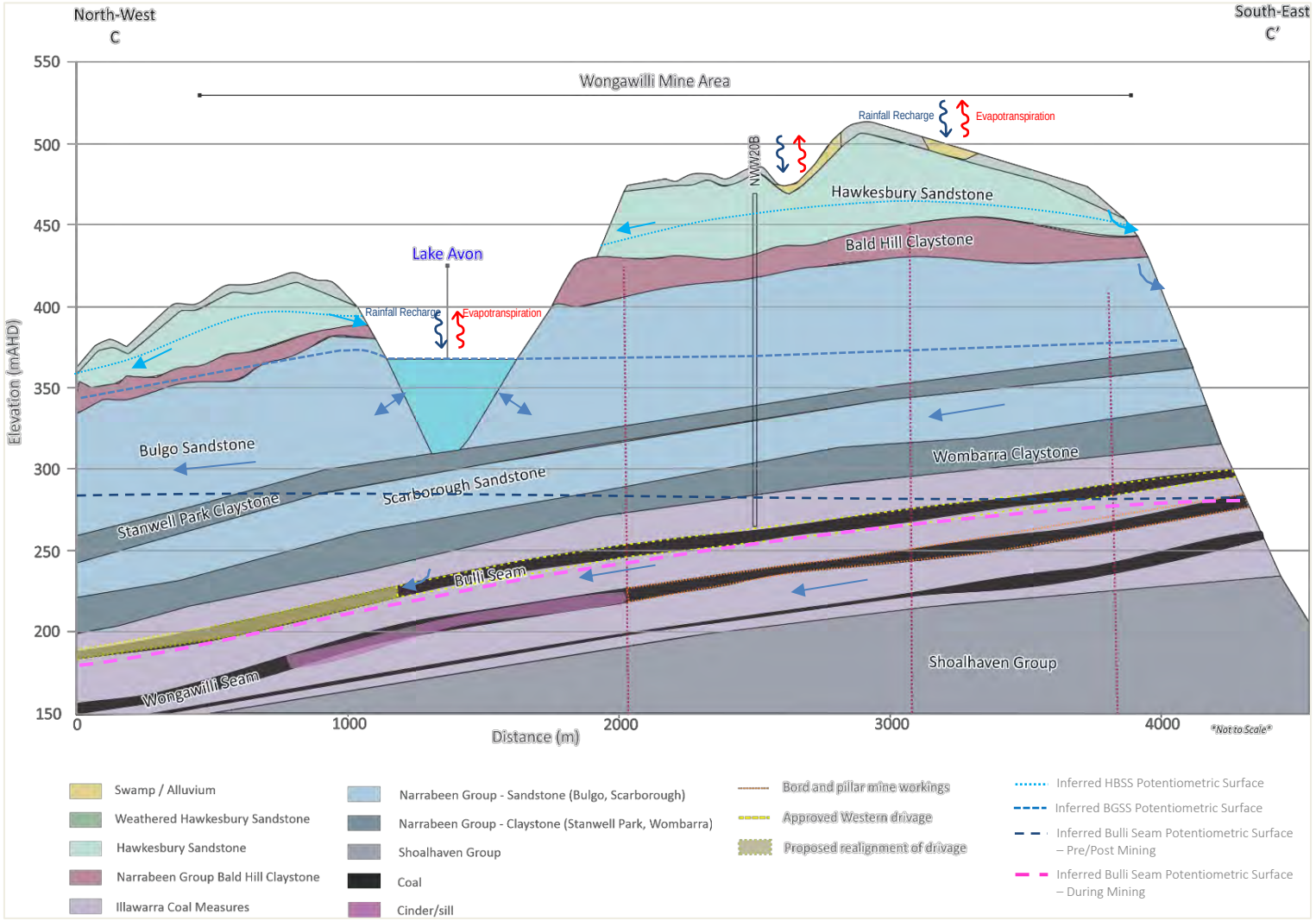


Figure 2-28 Wongawilli Conceptual Groundwater Model – West East (C-**C') (adapted from SLR**, 2020)



# 3. NUMERICAL GROUNDWATER MODEL

This section presents a summary of the objectives, design, calibration and predictive modelling for the numerical groundwater flow model developed by SLR (2020) for the groundwater impact assessment. The model files used for the assessment by SLR (2020) were reviewed by Umwelt, and additional information about the model has been reported to address comments from the regulator (refer Section 1.5). No changes to the construction of the model and predictive model runs developed by SLR (2020) have been undertaken. The only new modelling undertaken are additional sensitivity analysis runs that have been set up and run to address comments by DPIE Water (refer Section 1.5.1). Work was also conducted by Umwelt to process the model results and present in this report.

## 3.1 Model Objectives

Numerical groundwater modelling was undertaken to assess the impact of the Project on the groundwater regime. The objectives of the modelling were to:

- Quantify the groundwater inflows to the previously approved NWM and proposed NWMD, as a function of time;
- Predict the extent and area of influence of dewatering and the level and drawdown around the Project; and
- Identify areas of potential risk, where the mitigation of groundwater impacts may be required.

## 3.2 Model Design

To achieve the modelling objectives, the numerical groundwater requires an adequate conceptualisation of the groundwater regime and calibrating the model against observed data that influence the model's capability to make the intended predictions.

The conceptual model provides a representation of the current understanding about how the Project might impact the groundwater system as a basis for representing that system by a numerical groundwater model. Examples of conceptual model sections within the region are presented in this report in Figure 2-26 to Figure 2-28. The conceptual models represent how the groundwater regime operates based on available data and hydrogeological knowledge.

The numerical groundwater model was developed based on the conceptual groundwater model presented within Section 2.10 and is based on the SLR (2020) groundwater model. The SLR (2020) model was also developed based on the numerical groundwater model developed for Dendrobium Mine – Plan for the Future: Coal for Steelmaking Groundwater Assessment, prepared for Illawarra Coal South32 by HydroSimulations (2019). Through a data sharing agreement with South32, the calibrated MODFLOW-USG model developed by HydroSimulations (2019) was provided for use for the assessment. This enabled capture of all approved and potential cumulative groundwater impacts within the region.

To develop a tool tailored to the Project, a new model was developed by SLR (2020) with greater grid resolution at the Project area and reduced detail at Dendrobium. The model was also extended further south but shortened to the north to optimise the number of model cells and run times. The model layer surfaces developed by HydroSimulations (2019) were utilised within the Dendrobium area, but updated within ML1596 based on the site geological model. Mine progression and mine properties (i.e. drain conductance and goaf properties) for Dendrobium and surrounding mines were maintained from the HydroSimulations (2019) model. With the mine progression updated for the Project area, based on site specific data and the Project description. The layer zonation was also maintained from the HydroSimulations (2019) model, but with updates at site based on available data. Initial hydraulic properties were maintained from the

HydroSimulations (2019) model, including the depth dependence equation. However, the model was re-calibrated by SLR in order to improve predictions at site and account for the updates based on site specific data.

Further information on the design and setup of the numerical groundwater model developed for the Project is provided below.

### 3.2.1 Model Complexity and Software

The SLR (2020) model was developed using MODFLOW-USG, which is distributed by the United States Geological Survey (Panday, 2013). MODFLOW-USG is a new version of the popular MODFLOW groundwater flow simulator developed by the USGS (McDonald & Harbaugh, 1988). MODFLOW has long been considered an industry standard for groundwater impact modelling. MODFLOW-USG represents a major revision of MODFLOW and spin-off versions such as MODFLOW-SURFACT. MODFLOW-USG is based on a control volume finite difference (CVFD) formulation, rather than the traditional MODFLOW's rectilinear finite difference (FD) scheme. MODFLOW-USG uses unstructured grids ('USG' is an acronym for Un-Structured Grid), which supports a variety of structured and unstructured model grids, including those based on cell shapes such as prismatic triangles, rectangles, hexagons, and other cell shapes (Panday *et al.*, 2013).

The MODFLOW-USG code has the following advantages over the previous version of MODFLOW:

- The CVFD method allows a model cell to be connected to an arbitrary number of adjacent cells, which is not the case with a standard FD scheme.
- Allows more efficient model discretisation (mesh), enabling finer spatial resolution to be focused solely in areas of a model that require it (e.g. along mining trenches), which significantly reduces model cell count and runtimes.
- Model layers can be removed in parts of the model domain rather than be retained as "dummy" layers (e.g. for layer pinch-outs).
- Flexible model grids allow boundaries of model cells to follow important geographical or geological features, such as watercourses and faults.
- The orientations of interfaces between model cells may vary, which allows preferential flow directions to be modelled with better accuracy.
- Like MODFLOW-SURFACT, MODFLOW-USG can simulate variably saturated flow and handle desaturation and re-saturation of multiple hydrogeological layers without the "dry cell" problems of traditional MODFLOW, which is frequently encountered in variably saturated conditions during depressurisation and desaturation under mining conditions.

### 3.2.2 Model Extent and Mesh Design

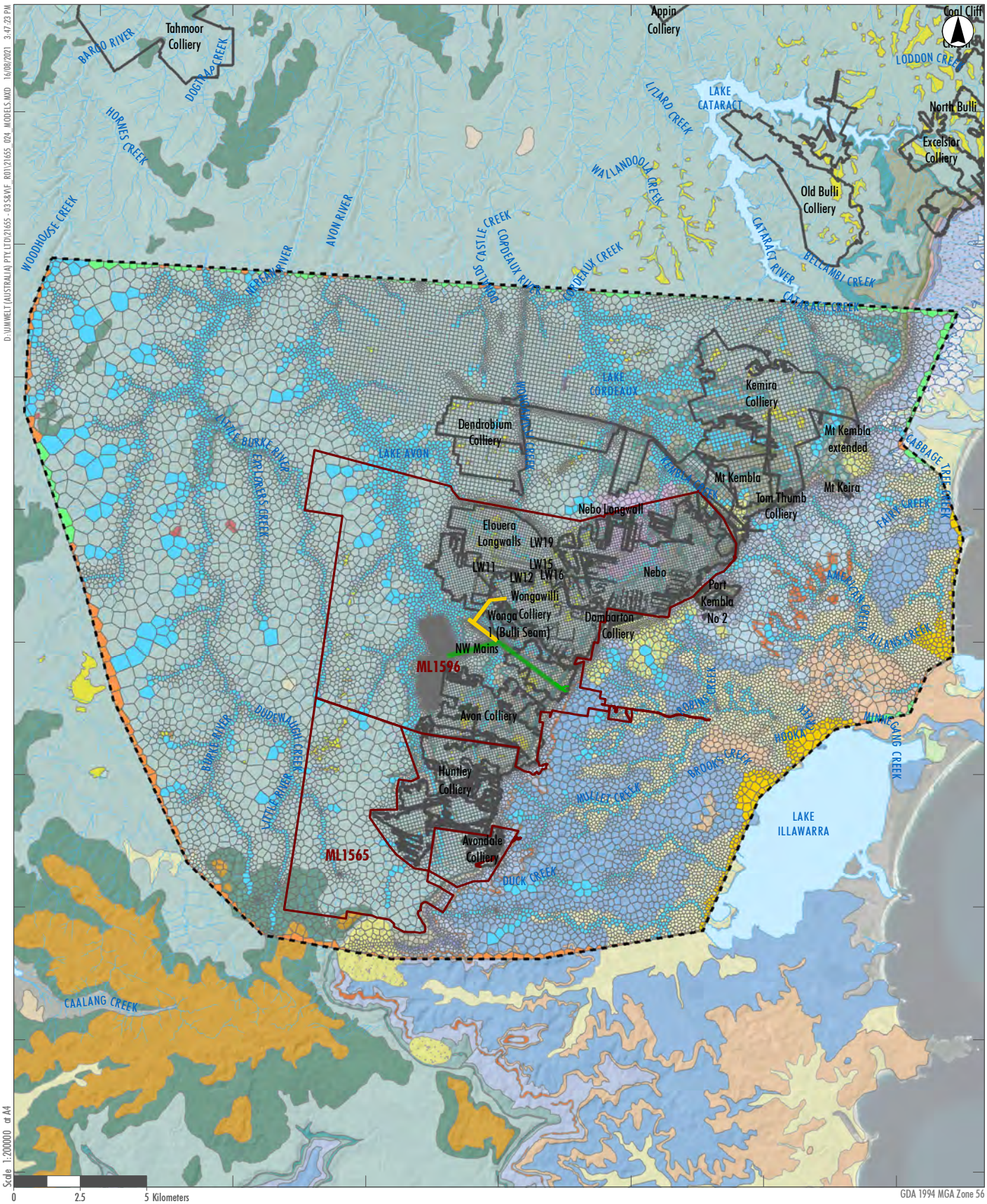
The SLR (2020) model domain is shown in Figure 3-1, which is centred around the Project with the model boundaries extending 26.4 km from north to south and 35.4 km from east to west. The model domain was selected based on the following considerations:

- The model domain to be large enough to prevent boundary influence on model mining drawdowns;
- North: the northern boundary of the model was set 13 km from the Project area and encompasses the full extent of the approved Dendrobium Mine to the north of the Project area, to account for cumulative impacts;
- South: the southern boundary of the model was set 12 km from the Project area and follows a catchment boundary and extends to an area where the escarpment runs in a west to east direction (outcrop of Narrabeen and Illawarra Coal Measures);

- West: the western boundary of the model was set 14 km from the Project area. The western boundary aligns along the regional syncline of the Triassic and Permian stratigraphy. Within the model domain the stratigraphy generally dips to the north-west, while west of the model domain the stratigraphy generally dips to the north-east. This is a structural feature, but does not form a groundwater divide; and
- East: the eastern boundary of the model was set 8 km from the Project area, encompassing the escarpment and lowland area out to Lake Illawarra in the south-east and up along the coastline in the north-east. It should be noted the lowland geology (below the escarpment) comprises two layers representing the surficial stratigraphy (i.e. alluvium and regolith) and the Permian aged Shoalhaven Group that underlies the Illawarra Coal Measures.

To allow stable numerical modelling of the large spatial area of the model domain, an unstructured grid with varying Voronoi cell sizes was created in the software AlgoMesh (HydroAlgorithmics, 2018). The model domain was vertically discretised into 18 layers and a total number of 555,074 model cells. Pinch-out areas exist in layers 2 to 18 to reflect the structural geology of hydrogeological units represented by the model. At these pinch-out locations one or more model layers are not present in the model and hydraulic connections bridge the layer(s) that pinch out. Grid refinement, as shown in Figure 3-1, was used in the following areas:

- Approved Wongawilli mining operations are represented using regular square cells of 25 m in size;
- Proposed Wongawilli mining operations are represented using regular square cells of 25 m in size;
- Historical and surrounding mines (i.e. Dendrobium) are represented using regular square cells of 100 m in size;
- Main rivers and creeks, represented by cell size constraints of less than 100 m throughout the model domain; and
- The escarpment is represented by a cell size of less than 100 m throughout the model domain.




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- Groundwater Model Cell
- Groundwater Model - CHD Node
- Groundwater Model - GHB Node
- Groundwater Model - River Node
- Groundwater Model - No Flow Node
- Watercourse

**Geology Type (1:100k Southern Coalfields Geology)**

- Qa – Quaternary alluvium
- Qs/Qal - alluvium
- Qs – Swamp sediments
- Qt – Talus
- T-Ct – Crinanite
- T-Rb – Alkali olivine basalt
- Jt – Microsyenite intrusion
- TRw – Wianamatta Group
- TRh – Hawkesbury Sandstone
- TRnz – Bald Hill Claystone
- TRnbu – Bulgo Sandstone
- TRnsp – Stanwell Park Claystone
- TRm – Mittagong Formation
- TRnc – Coal Cliff Sandstone
- TRnk – Kangaloon Sandstone
- Pi – Illawarra Coal Measures
- Pis – Sydney Group
- Pip – Unanderra Coal Member
- Pie
- Pipm/Pipb – Sills
- Ps – Shoalhaven Group
- Psv – Broughton Formation
- Jv
- Kal
- Kdt
- Ktc – Trachyte
- Mf
- P-TRns – Scarborough Sandstone
- Pnc – Trinkey Formation Claystone
- Pnw – Wombarra Claystone
- Tb

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)

FIGURE 3.1

Model Design

### 3.2.3 Model Layers and Zonation

Table 3-1 summarizes the SLR (2020) model layer setup, which is based on the conceptual hydrogeology described in Section 2, the Dendrobium model by HydroSimulations (2019) and site specific data.

A summary of the data sources used to develop the model layers is included below:

- Site geological model which includes the coal seam surfaces and base of key units (i.e. HBSS and Narrabeen Group units) was applied for all layers within ML1596;
- Available site bore logs was used to refine model layers and verify;
- Groundwater model built for Dendrobium (HydroSimulations, 2019);
- Sydney-Gunnedah Basins 3D Stratigraphic Model for layering outside of ML1596 and outside of the Dendrobium Mine area;
- State geological mapping, including 1:100k Southern Coalfields (Moffitt, 1999) and 1:50k Wollongong (Bowman, 1974) to inform geological unit extents and structure;
- CSIRO (2015) depth of regolith/unconsolidated, to inform the thickness of layer 1; and
- NGIS/PINEENA groundwater bore database was used to inform model layering, particularly in the lowland area (below the escarpment).

The top of layer 1 was developed based on LiDAR data for the Project area (ML 1596), Gallahers Creek and Avon River. Outside of these areas Digital Elevation Model (DEM) from Geoscience Australia (2011) was used to define the top of layer 1.

The stratigraphy of the coal measure layers was based on the site geological models for the Project area. Outside of the Wongawilli mine areas, the groundwater model built for Dendrobium by HydroSimulations (2019) and public domain data were also used to define the model layer elevations. Geospatial software Surfer and QGIS were used to develop, interpolate and visualise the model layers during development.

The basal elevation of the target coal seam from the site geological models was used, which captured displacement associated with localised minor faulting and folding. Coal seams have been simulated by combining the thicknesses of each constituent seam ply into a single coal seam layer.

Model layers vary in thickness from 100 m to a minimum thickness of 0.1 m. Layers pinch out where the model layer thickness falls below the minimum value of 0.1 m. All model layers are of a convertible type, which can simulate confined and unconfined groundwater flow depending on the groundwater level in a model cell (MODFLOW-USG layer type 4).

Model layer 1 extends across the whole model domain and was designed to capture the variability in unconsolidated units mapped across the model domains. The zones were developed based on the 1:100k Southern Coalfields mapping, site specific geology information and the mapped extent of swamps from HydroSimulations (2019). Within layer 1 the following zones are used (see Figure 3-2) to assign different values of hydraulic properties and recharge:

- Alluvium;
- Weathered Hawkesbury Sandstone;
- Shales of the Wianamatta Formation; and
- Swamp deposits.

The extent of the zones in Layer 1 are based on site bore and drill hole data, surficial geological mapping and public domain data (i.e. registered bores). The thickness of alluvium and regolith was derived from site specific data such as bore and drill logs as well as regolith depth mapping

by CSIRO (2015). Other layers are present to the limit of their subcrop extent except for Layer 18 (Shoalhaven Group) which does not subcrop within the model domain. The Shoalhaven Group and the older underlying stratigraphy is considered as the regional low-permeability basement.

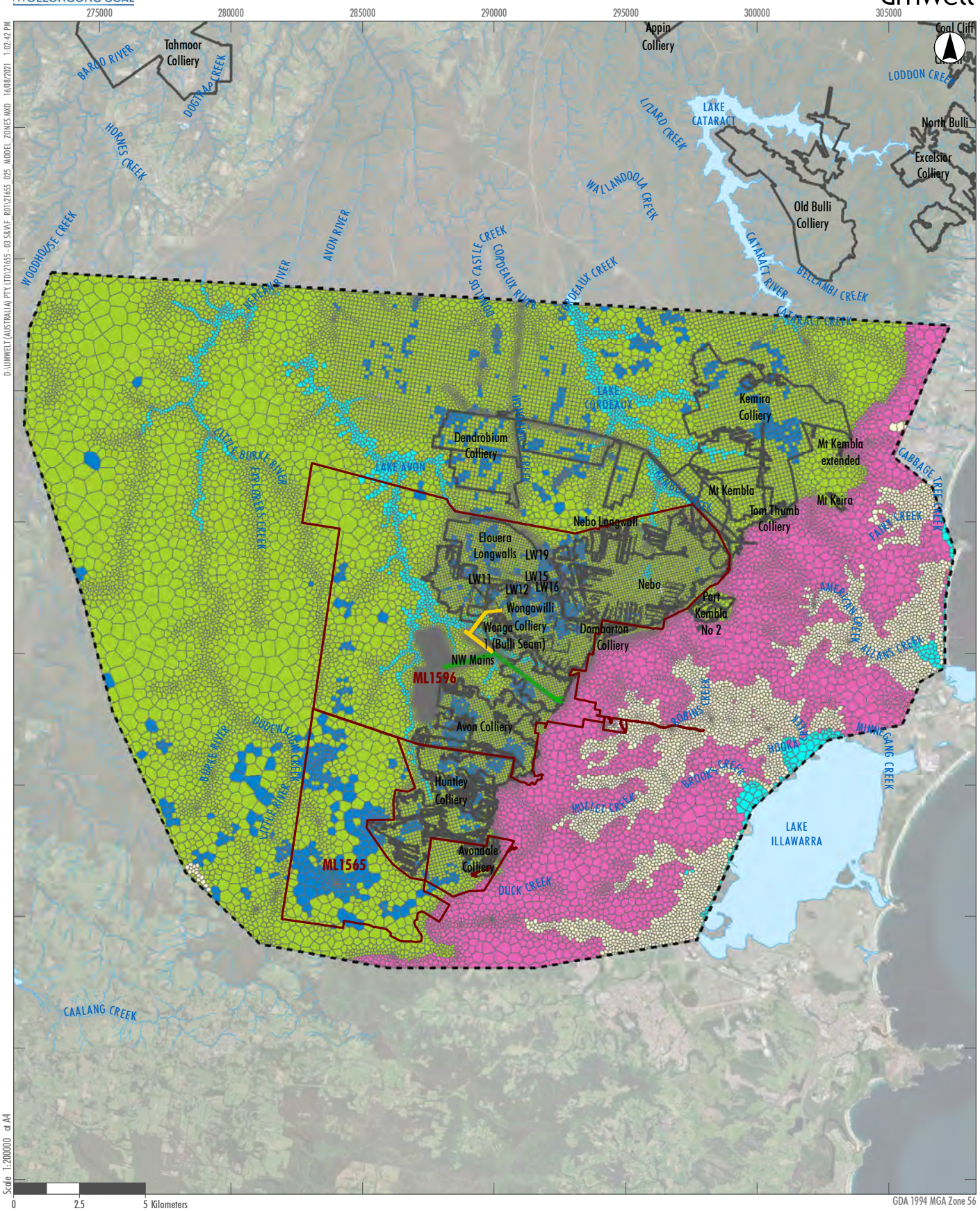
Zonation has also been applied within the deeper layers based on zonation within the Dendrobium model developed by HydroSimulations (2019) with updates based on site specific data. This includes:

- Cordeaux Crinanite between the Project area and Dendrobium mine (refer Figure 2-9);
- Areas of igneous intrusion and cinder within the Project area and around Dendrobium (refer Figure 2-9); and
- Fault zone at Dendrobium that was included in the Dendrobium model by HydroSimulations (2019).
- Zonation for Layer 12 (Bulli Seam) and Layer 14 (Wongawilli Seam) are shown in Figure 3-3 and Figure 3-4.

Table 3-1 Model Layer Assignment

| Model Layer | Stratigraphic unit/Lithology | Grouped units / Layer zonation | Typical Thickness |
|---|---|---|---|
| 1 | Alluvium/regolith/ waterbody/ Shoalhaven Group | Zones based on surface geological mapping, delineating rivers/lakes/ocean, swamp deposits, alluvium, regolith (weathered Hawkesbury Sandstone) and Shoalhaven Group shales (Figure 3-2) | Regolith 5 m, swamps 2 m, WMFM 10-30 m |
| 2 | Hawkesbury Sandstone (upper) | - | 25-40 m |
| 3 | Hawkesbury Sandstone (middle) | - | 40-50 m |
| 4 | Hawkesbury Sandstone (lower) | Hawkesbury Sandstone with localised areas representing the crinanite (intrusion) | 30-40 m |
| 5 | Bald Hill Claystone, including Garie [GRFM] & Newport Formations [NPFM] | Bald Hill Claystone with localised areas representing the crinanite (intrusion) | 20-30 m |
| 6 | Bulgo Sandstone (upper) | Bulgo Sandstone with localised areas representing the crinanite (intrusion) | 40-60 m |
| 7 | Bulgo Sandstone (lower) | Bulgo Sandstone with localised areas representing the crinanite (intrusion) | 40-60 m |
| 8 | Stanwell Park Claystone | Stanwell Park Claystone with localised areas representing the crinanite (intrusion) | 10-20 m |
| 9 | Scarborough Sandstone | Scarborough Sandstone with localised areas representing the crinanite (intrusion) | 30-40 m |
| 10 | Wombarra Claystone | Wombarra Claystone with localised areas representing the crinanite (intrusion) | 20-30 m |
| 11 | Coalcliff Sandstone | - | 15 m |
| 12 | Bulli Coal seam | Coal Seam with zones representing cindered coal, intrusions and a fault zone at Dendrobium | 2-4 m |
| 13 | Lawrence & Loddon Sandstones | Lawrence & Loddon Sandstone with zones representing cindered coal, intrusions and a fault zone at Dendrobium | 20-30 m |
| 14 | Wongawilli Coal seam | Coal Seam with zones representing cindered coal, intrusions and a fault zone at Dendrobium | 4-10 m (~4 m working section) |

| Model Layer | Stratigraphic unit/Lithology | Grouped units / Layer zonation | Typical Thickness |
|---|---|---|---|
| 15 | Kembla Sandstone [KBSS]/interburden | - | 15-25 m |
| 16 | Tongarra Seam | - | 2 – 4 m |
| 17 | Lower Permian Coal Measures | - | 20-30 m |
| 18 | Shoalhaven Group and older | - | 100 m |




## Legend

- Mine Lease Boundary
- Proposed NWMD (Project)
- Approved NWM
- Surrounding Mines
- Groundwater Model Boundary
- Watercourse

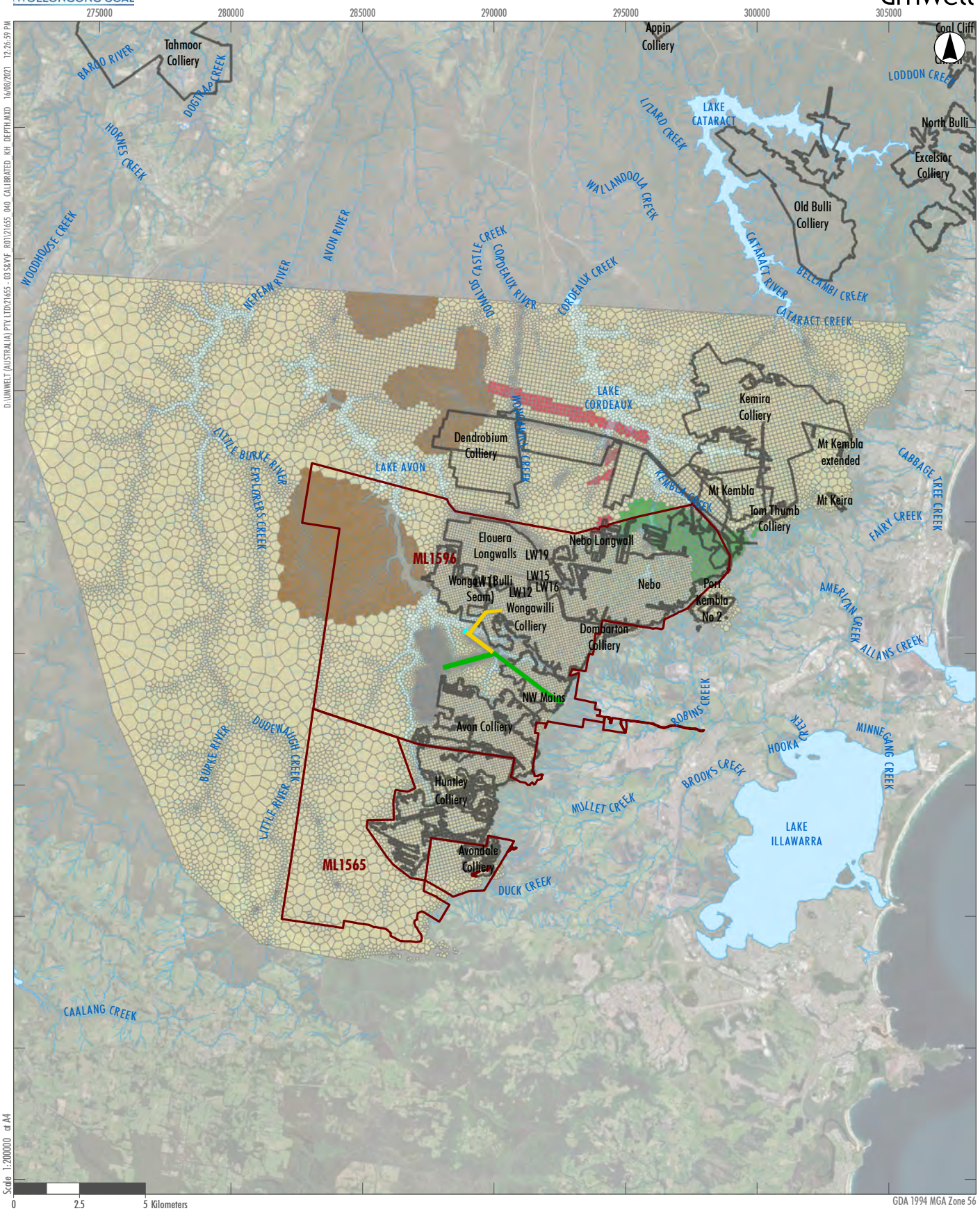
**Kx Zones**

- Regolith
- Swamps
- Shales
- Alluvium
- Rivers

FIGURE 3.2

# Hydraulic Conductivity Zones - Layer 1

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Watercourse

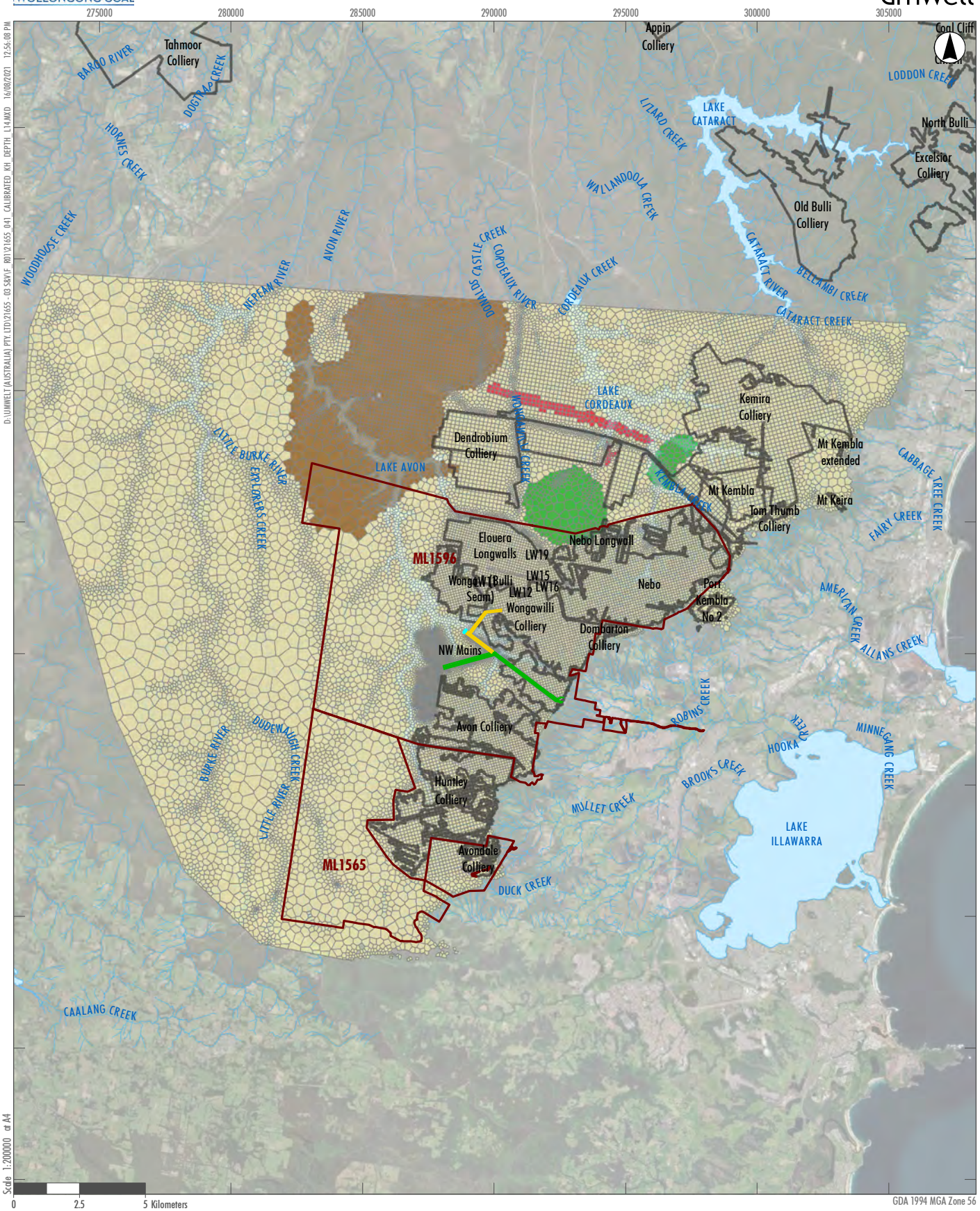
Hydraulic Property Zone

- Bulli Seam
- Cordeaux Crinanite
- Dendrobium Fault Zone
- Cinder/Intrusion

FIGURE 3.3

Hydraulic Conductivity Zones - Layer 12 (Bulli Seam)

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Watercourse

Hydraulic Property Zone

- Wongawilli Seam
- Cordeaux Crinanite
- Dendrobium Fault Zone
- Cinder/Intrusion

FIGURE 3.4

Hydraulic Conductivity Zones - Layer 14 (Wongawilli Seam)

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)

### 3.2.4 Faults

The SLR (2020) model layer elevations were based on the site geological model, which captured displacement associated with localised minor faulting and folding.

As discussed in Section 2.4.2.6 faults and dykes are mapped within the Project area, with the main structure being Wongawilli Fault but have not been known to cause inrush or enhanced hydraulic properties for mains development/first workings. A fault zone is captured in the model zonation at Dendrobium Mine, which involves longwall operations (refer Section 3.2.3). No discrete fault zones are included in the Project area as no impacts or influence due to faults and dykes are predicted based on the SCT (2020) subsidence assessment.

### 3.2.5 Model Timing

Both steady-state and transient models have been developed for model calibration, mine dewatering predictions and mine recovery predictions by SLR (2020). The following steady state and transient simulation periods are used in the model to represent the historical mining operations which are used for model calibration:

- Pre-mining Steady-state model representing average pre-1940 conditions, which excludes any mining stresses;
- Warm-up historical transient simulation period between 1940 and December 2003 using a single time interval (i.e. a single model stress-period) to represent old mine workings; and
- Historical transient simulation period between January 2004 and June 2020 using quarterly stress-periods.

The following transient simulation periods are used for predictive modelling to simulate dewatering and groundwater recovery as a result of mining activities of the Project:

- Predictive transient simulation used to predict impacts on the groundwater regime over the life of the Project using quarterly stress-periods between July 2020 and December 2049; and
- Recovery transient simulation used between January 2050 and December 2550 using varying stress-period lengths to simulate post-mining conditions for a period of 500 years after completion of the Project.

See also Table 3-2 for a more detailed overview of these different model simulation periods

Table 3-2 Summary of Model Simulation Periods

| Simulation Period | Date From-To | | Purpose | Notes | Stress-Periods |
|---|---|---|---|---|---|
| Pre-mining Steady-State | Pre-1940 | | Simulate the average groundwater regime pre-1940 | Single stress period, utilising long term historical averages for stresses such as recharge and river levels.<br>This period excludes any mining stresses. | 1 |
| Warm-up historical transient period | Jan-1940 | Dec-2003 | Simplified transient simulation to represent historic mining pre-2004 | Single stress-period of 63 years.<br>Mines operating prior to 2003 are active during the entire model period. | 2 |

| Simulation Period | Date From-To | | Purpose | Notes | Stress-Periods |
|---|---|---|---|---|---|
| Historical transient period | Jan-2004 | Jun-2020 | Transient simulation to model recent mining operations surrounding the Project and calibrate the model against observed temporal data | Quarterly stress periods, utilising quarterly averages for stresses such as recharge and river levels and to extract quarterly time-series of heads to compare with observed water levels | 3-68 |
| Predictive transient period | Jan-2020 | Dec-2049 | Transient simulations to model impacts during the life of the Project | Quarterly stress periods, utilising long term historical averages for stresses. The predictive model extends to 2050 to simulate the available surrounding proposed mine plans. | 69-186 |
| Recovery transient period | Jan-2050 | Dec-2550 | Transient simulations to model groundwater recovery after the end of the Project | Variable stress periods, utilising long term historical average annual data | 187-213 |

## 3.3 Boundary Conditions and Model Stresses

The model domain and boundaries shown in Figure 3-1 have been selected to incorporate any potential receptors impacted by the Project. This section provides detailed information on each of the model boundary conditions, system stresses and initial parameterisation.

### 3.3.1 Regional Groundwater Flow – Boundary Conditions

A combination of no flow, general head boundary (GHB) or constant head boundary (CHD) are specified as the boundary conditions of the SLR (2020) model perimeter, as shown in Figure 3-1.

- CHD - The ocean and Lake Illawarra at the eastern margin of the model have been specified as CHD boundaries set at 0 mAHD.
- GHB – Where rivers and creeks occur at the edge of the model boundary GHB cells have been applied.
- No flow – No flow cells have been applied in all other areas.

GHB boundaries are specified for the north and part of the western and eastern model boundaries to represent the regional flow into and out of the model area and have been assigned in Layers 1 to 18 using pre-mining head elevations (SLR, 2020). Where river cells are specified at the model boundary, GHB's in layer 1 are removed.

Groundwater will enter the model where the specified head for the GHB is higher than the modelled head in the adjacent cell and exit the model when the head level in the adjacent cell is higher than the GHB head.

GHB conductance is calculated using the modelled hydraulic conductivity of the layer in which the GHB sits, multiplied by the cell's vertical cross-sectional area along the model boundary, and divided by the distance to an external source of water. The latter is set to the cell length. As these properties vary by model cell, the GHB conductance is therefore different for each GHB model cell.

The southern and western extent of the model domain has been largely represented with no flow boundary condition, where no groundwater is assumed to enter or leave the model domain. A summary of the groundwater conditions where no flow boundary conditions have been applied is included below:

- The south-eastern edge of the model boundary comprises the lowland area (Shoalhaven Group) that is separate to the target lithology for the Project and predictions.
- Part of the southern edge is aligned along an area of the Illawarra Escarpment that trends in a west to east direction and forms a groundwater divide (outcrop of the Narrabeen Group and Illawarra Coal Measures).
- The Triassic and Permian stratigraphy extends out beyond the south-western and western boundary of the model. The Triassic and Permian stratigraphy occur within a regional basin structure, with the syncline trending along the western edge of the model boundary. Within the model domain the stratigraphy generally dips to the north-west, while west of the model domain the stratigraphy generally dips to the north-east. This is a structural feature, but does not form a groundwater divide.

The application of no flow on the south-western and western boundary potentially reduces the volume of water entering the model as it is up-gradient of the Project area. As a result the model predictions are likely more conservative with no flow conditions applied. Sensitivity analysis has been conducted with the no-flow boundary conditions in the south-western and western boundary set up as GHB. This has been undertaken to verify that the boundary conditions have not influenced the model predictions.

### 3.3.2 Watercourses and Lakes

Table 3-3 lists the major rivers, streams and lakes that are represented in the SLR (2020) model. The different surface water zones (18 zones in total) are shown in Figure 3-6, which were modelled using MODFLOW-USG's River (RIV) package. The RIV package assigns a head dependent boundary condition which can receive water from an aquifer (gaining stream) or pass water to an aquifer (losing stream) and requires specification of a river conductance, river bottom elevation and river stage height.

The river conductance is specified using the following equation:

$C = KA/B$ (Eq. 1)

where:

$K$ is vertical hydraulic conductivity of the riverbed [m/d]

$A$ is the riverbed area (river width x river length) [$m^2$]; and

$B$ is the riverbed thickness [m]

Table 3-3 lists the river widths and riverbed hydraulic conductivity for each river zone to calculate the river conductance. Calculation of the river conductance assumed a constant riverbed thickness of 1 m and a river length that is varied on a cell-by-cell basis, calculated from the length of the of the river line that falls within each cell area. This means river conductance values also vary on a cell-by-cell basis.

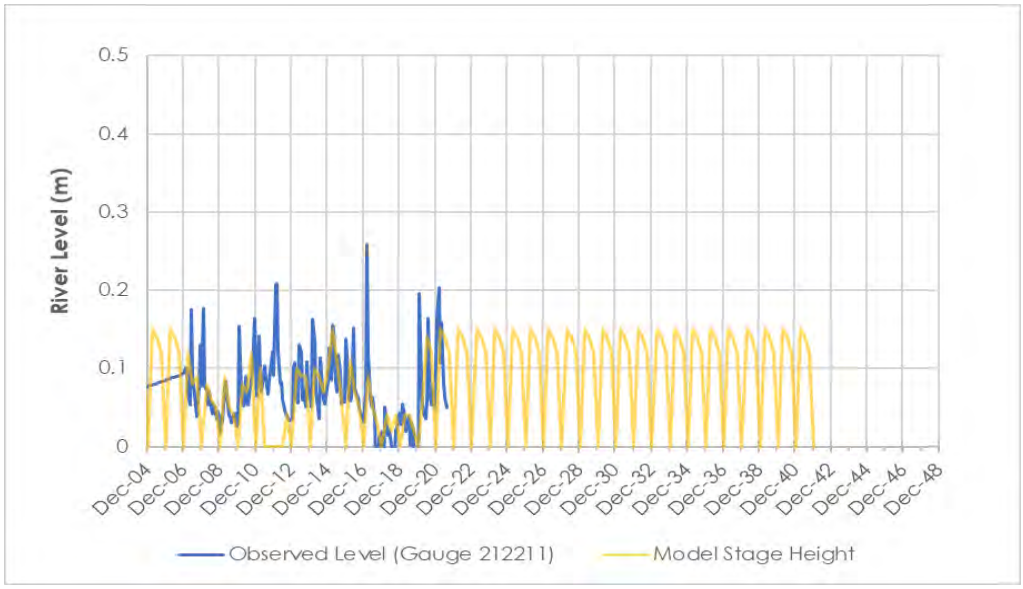
Table 3-3 River Package Parameters

| River Zone | River Stage Height [m] | Width [m] | Vertical Hydraulic Conductivity [m/d] |
|---|---|---|---|
| Avon Lake | 1-11.8 | 25 | 1.00E-03 |
| Cataract Lake | 1-12.61 | 25 | 1.00E-03 |
| Cordeaux Lake | 1-11.59 | 25 | 1.00E-03 |
| Nepean Lake | 1-16.62 | 25 | 1.00E-03 |
| Nepean River | 0-4.13 | 10 | 1.00E-02 |
| Burke River | 0-2.24 | 10 | 1.00E-02 |
| Avon River | 0.23-1.28 | 10 | 1.00E-02 |
| Wongawilli Creek | 0-0.45 | 10 | 1.00E-02 |
| Sandy Creek | 0.07-0.54 | 10 | 1.00E-02 |
| Goondarrin Creek | 0-0.45 | 10 | 1.00E-02 |
| Cordeaux River | 0-1.08 | 10 | 1.00E-02 |
| Cataract Creek | 0-0.5 | 10 | 1.00E-02 |
| Cataract Creek (East) | 0-0.49 | 10 | 1.00E-02 |
| Gallahers Creek | 0-0.87 | 10 | 1.00E-02 |
| Bellbird Creek | 0-0.19 | 10 | 1.00E-02 |
| Flying Fox | 0-0.24 | 10 | 1.00E-02 |
| Cordeaux Continued | 1.01-1.48 | 10 | 1.00E-02 |
| Other Tributaries | 0 | 10 | 1.00E-02 |
| Little Burke - Explorer | 0.52-2.24 | 10 | 1.00E-02 |

The assigned river stage heights were derived from river gauges installed at various locations across the model domain, including ten local river gauges along Gallahers Creek, Bellbird Creek and upper reaches of Avon River, and 16 public domain gauges for rivers including the Nepean, Burke, Avon, Cordeaux and Cataract Rivers as well as dam level gauges for the Nepean, Avon, Cordeaux and Cataract Dams.

Historical data averages were utilised to fill in data gaps where river gauge information was not available. Seasonal averages were calculated from 1990 to present (July 2020). Stage heights were set at 0 mAHD for all minor ephemeral streams and creeks. A summary of typical stage height by river zone are provided in Table 3-3 Within the transient model the stage heights for the main creeks were varied based on an average of the quarterly measured readings at the various gauges. Figure 3-5 presents the modelled stage height for a cell along Flying Fox No.3 Creek that is situated at government stream gauge 212211. The graph shows the variability in the river stage height in the model, which is based on the observed change in river levels.

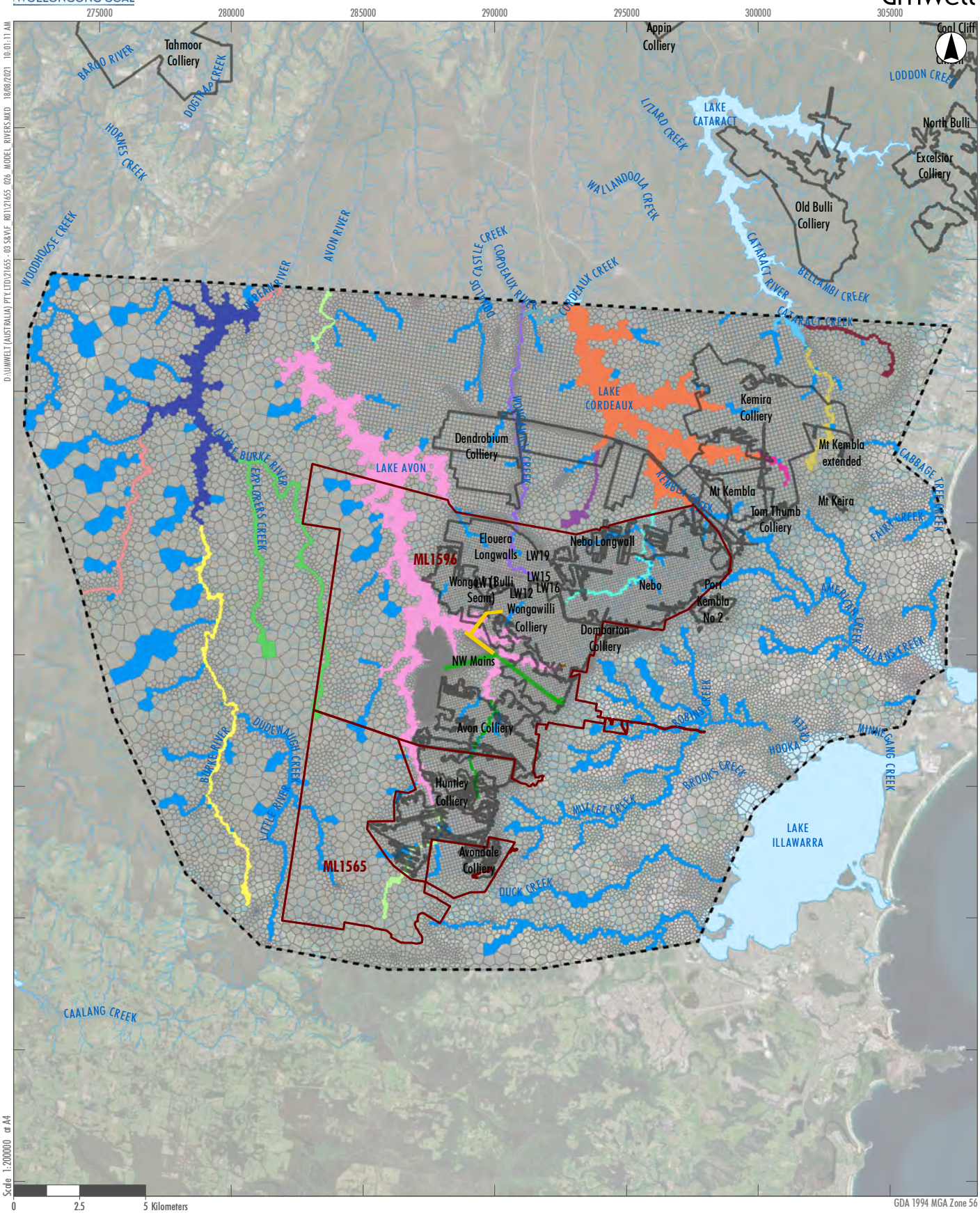
Figure 3-5 Flying Fox No.3 Creek – Modelled and Observed Levels




The steady state river stages were based upon the average of the gauge monitoring data. Where data was available, the river stages at gauge locations were averaged over that time period. If data was missing for a particular stress period, the long-term average for the months (e.g. averaged across all January, February and March dates) was calculated.

The predictive stress periods use the same method of averaging for long-term average as for the historic transient stress periods.

As specified in Section 3.3.1, Lake Illawara and the ocean are represented using constant head boundary (CHD package) with an elevation of 0 mAHD. Leakage to and from these surface water features are controlled by the hydraulic properties of the cells to which CHD boundary conditions are assigned.




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- Groundwater Model Cell
- Watercourse

**River Zone**

- Lake Avon
- Cataract River (Zone 1)
- Lake Cordeaux
- Lake Nepean and Nepean River
- Nepean River
- Burke River
- Avon River
- Wongawilli Creek
- Sandy Creek
- Goondarrin Creek
- Cordeaux River (Zone 1)
- Cataract River (Zone 2)
- Cataract Creek
- Gallahers Creek
- Bellbird Creek
- Flying Fox No 3 Creek
- Cordeaux River (Zone 2)
- Other
- Explorers Creek and Little Burke River

FIGURE 3.6

**Model River Zones**

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)

### 3.3.3 Rainfall Recharge

Rainfall recharge is simulated in the SLR (2020) model using the recharge package (RCH), which assigns a flux to the topmost model layer or uppermost active model cell at each model location.

Recharge has been imposed as a percentage of actual rainfall from the SILO Grid Point observations (for the transient calibration period) or long-term average rainfall (for steady-state calibration and prediction simulations) across different recharge zones. These are based on the zonation applied to layer 1, as described in Section 3.2.3 and shown in Figure 3-2. These zones are based on outcrop geology that define areas of varying hydraulic properties and capacity to transmit water to the deeper groundwater system.

No recharge is applied to cells that include a RIV or CHD boundary condition. The recharge rates are varied during the calibration process by estimating the rainfall recharge fraction for each of these recharge zones. Figure 3-7 shows the quarterly cumulative SILO rainfall together with the recharge rates applied during the transient model calibration period.

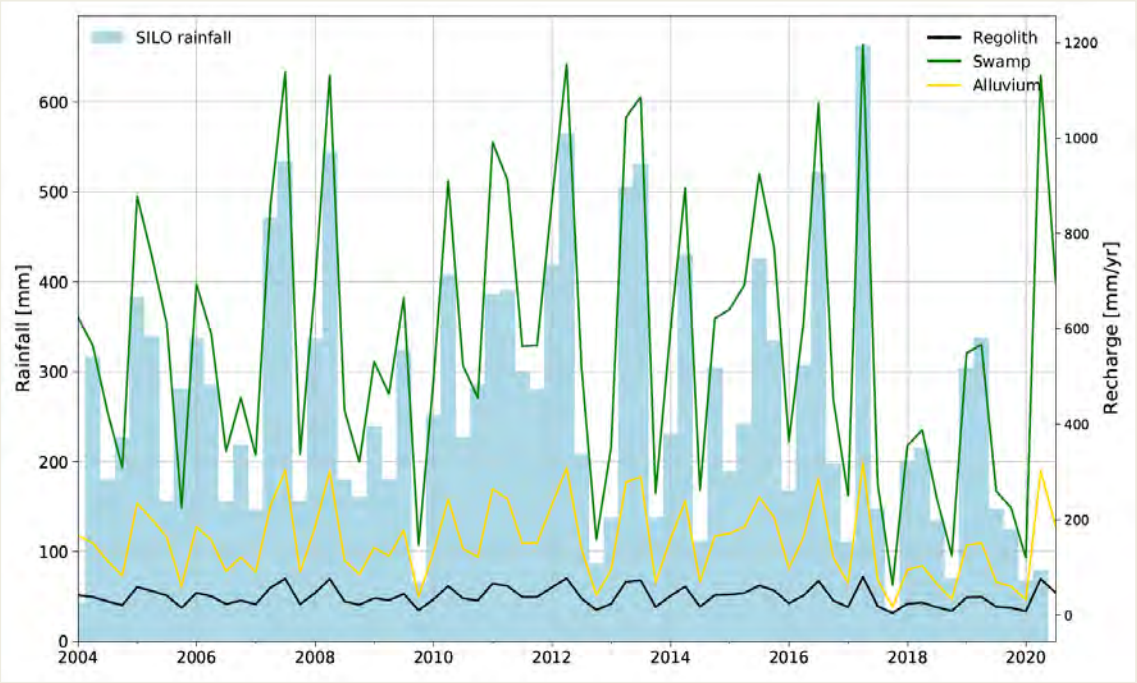
Model recharge zones and their corresponding annual recharge rates are summarised for the calibrated model in Table 3-4. The calibrated recharge rates also vary quarterly to match with observed rainfall. The values for regolith are similar to the Dendrobium model for the Hawkesbury Sandstone, as shown in Table 3-4.

Table 3-4 Calibrated Rainfall Recharge

| Unit | Calibrated Recharge (% Annual Rainfall) | Calibrated Average Recharge (mm/year) | Average Recharge (%) – Dendrobium Model (HydroSimulations, 2019) |
|---|---|---|---|
| Alluvium | 12.0 | 166.8 | - |
| Regolith and Escarpment | 3.0 | 41.7 | ~2.1 - 7.5% (25 – 90 mm/yr for HBSS) |
| Swamp | 45.0* | 625.5 | ~6.5 – 20.5 % (79 – 245 mm/yr) |

The calibrated recharge values are shown for each recharge zone in Figure 3-7, compared to observed rainfall. The graph shows how the calibration model captures seasonality with variability in rainfall recharge across the layer 1 zones. For the predictive model, to capture seasonality the average quarterly rainfall (mm) was used.

Figure 3-7 Observed Rainfall vs Modelled Recharge by Zone




### 3.3.4 Evapotranspiration

Evapotranspiration from shallow water tables is simulated in the SLR (2020) model using the evapotranspiration package (EVT). The EVT package implements a type of head-dependent flux boundary condition. Evapotranspiration can be applied to the topmost model layer or the uppermost active model layer. The EVT package only includes evapotranspiration from the saturated zone and requires the definition of a maximum evapotranspiration rate and extinction depth. The maximum evapotranspiration rate is for the water table at the top of the uppermost model layer and decreases linearly as the water table height drops below the surface until it equals zero at the extinction depth. The extinction depth is the depth below which evapotranspiration will not occur, defined, for example, by a plant rooting zone depth.

Evapotranspiration is represented in the upper most cells of the model domain using a uniform extinction depth of 3 m and a maximum rate of evapotranspiration of 600 mm/year based on the annual average BOM Areal Actual Evapotranspiration (BoM, 2016) value. EVT is applied to all cells in layer 1, where the maximum rate of evapotranspiration is applied at the top elevation of every model cell. This includes cells that represent lakes with the RIV and CHD package. This will result in large outfluxes from EVT at those locations.

### 3.3.5 Groundwater Use

Near the Project area, above the escarpment, there is no groundwater extraction from private bores (see Section 2.10.1). Therefore, abstraction from water supply bores has not been represented within the groundwater model.

#### 3.3.5.1 Historical/Surrounding Mining

The MODFLOW Drain (DRN) package is used to simulate mine dewatering as part of the Project and surrounding mining operations in the SLR (2020) model. The DRN-package is a type of head-dependent flux boundary that only allows groundwater flowing out of the model through the drain once heads in a drain model cell are exceeding a specified drain elevation. The magnitude of groundwater outflow through the drain depends on the specified drain conductance and by how much the head in the cell exceeds the drain elevation. Drain cells are therefore an effective way of representing removal of water seeping into a mine over time, where the actual removal of water being via pumping infrastructure, storage, and subsequent evaporation on site.

This section provides details of how non-Project related mine stresses are represented in the model, where the next section describes the model representation of mine operations as part of the Project.

Figure 3-8 shows a map with drain cell locations that represent mine operations surrounding the Project, which are colour coded based on their start date. No mine drains are used during the pre-1940 steady-state simulation.

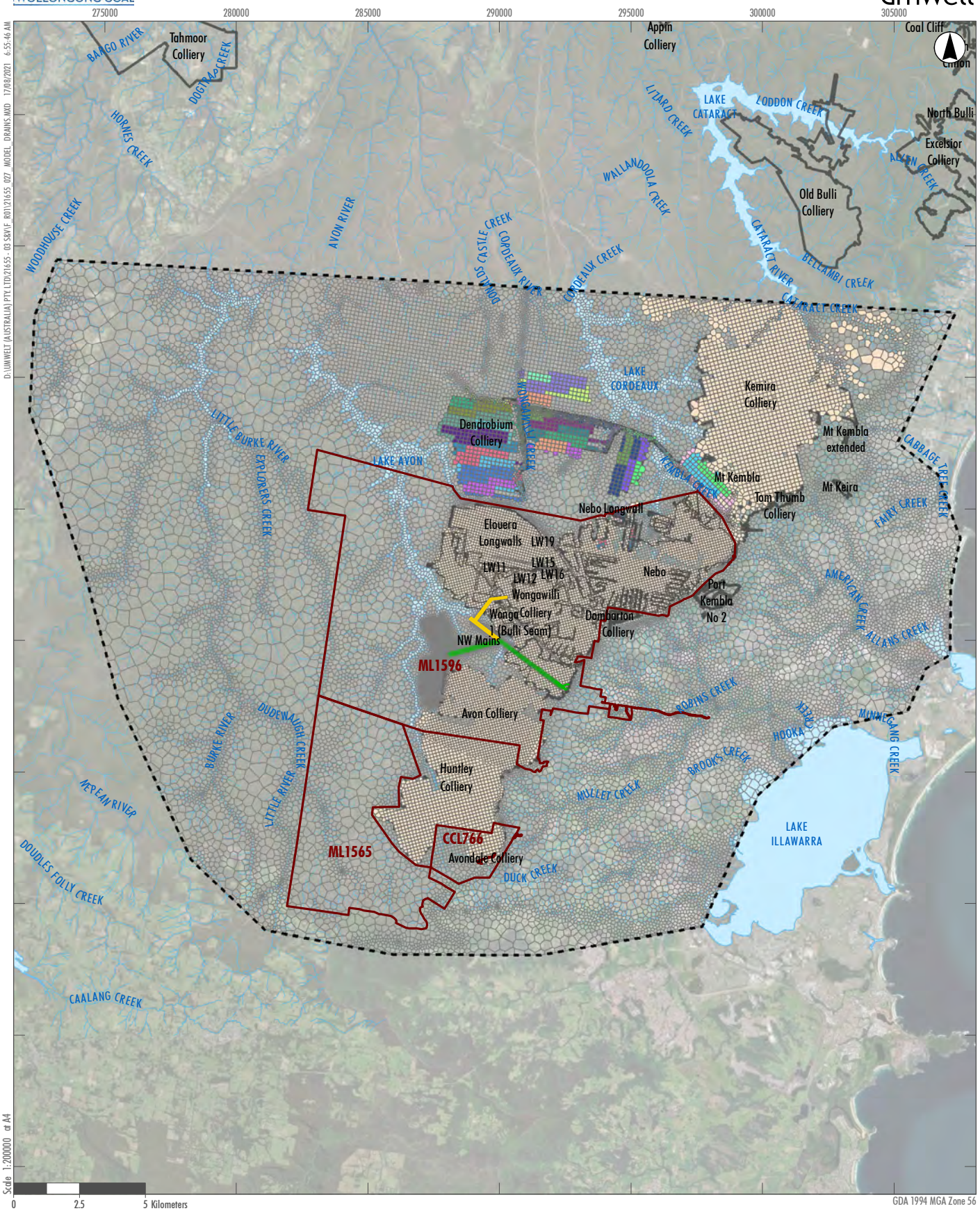
Most of the historical mine operations surrounding the Project are active in the model since 1940 (refer Figure 3-8) as part of a simplified representation of mining pre-2004 using a single model stress-period between Jan-1940 and Dec-2003. These areas include the following historical mine operations (see also Section 2.3):

- Avondale Colliery
- Avon Colliery
- Wongawilli Colliery
- Nebo LWN1-6
- Elouera Workings (LW11 to LW19)

Other surrounding mine operations that are represented in the model include the longwall extraction in the Dendrobium Mine to the north of the Project area, which has been active since 2001 and mining operations at Nebo that were active between 2013 to 2014 and 2016 to 2019. The timing of drain cells applied for the surrounding mines were interpolated from mine schedule information available from Environmental Impact Statement (EIS) documentation to extend the model timing to the end of the predictive model period of December 2049. The drain cells capture future mining within Dendrobium Area 3A until 2022, Area 3B until 2021 and in Area 3C until 2043.

Drain cells in the model are applied to the layers representing target coal seams for each of these active coal mines and the drain elevations for these cells have been set to the base of the model layer. For example, Dendrobium Mine workings are represented with drain cells in model layer 14 only (Wongawilli Seam) with their drain elevations set at the base of layer 14.

Drain cells that are activated between Jan-1940 and Dec-2003 are assigned a nominally high conductance value of 100 $m^2/d$. In the transient simulation period after Jan-2004, drain cells are activated in stress-periods that are commensurate with the start date of mining. When drains are activated their initial conductance are set to 1 $m^2/d$ and subsequently increased to 100 $m^2/d$ over the next three quarters. Drain cells are only assigned to model layers 12 (Bulli Seam) and 14 (Wongawilli Seam).




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- Groundwater Model Cell
- Watercourse

**Approved Mine Drain Year**

- 1940
- 2004
- 2005
- 2006
- 2007
- 2008
- 2009
- 2010
- 2011
- 2012
- 2013
- 2014
- 2015
- 2016
- 2017
- 2018
- 2019
- 2020
- 2021
- 2022
- 2023
- 2024
- 2025

FIGURE 3.8

Surrounding Mine Drain Cells

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)

To represent mining stresses in the model, hydraulic properties were varied with time using the Time-Variant Materials (TVM) package. The TVM package is activated in the transient calibration model, from 1940. At each TVM cell, the following properties are changed:

- Vertical hydraulic conductivity (Kv) and horizontal hydraulic conductivity (Kh); and
- Specific storage (Ss) and specific yield (Sy).

For bord and pillar (first workings) mining operations TVM cells are only used to change hydraulic properties within the model layers that represent the mined coal seam.

For historical and surrounding longwall operations, such as Dendrobium, the hydraulic properties were changed with time in model layers that contain the goaf and estimated connective cracking zone directly above each longwall panel. The maximum height of the connective cracking zone was derived using the Tammetta equation (Tammetta, 2014). The estimated cracking zone determines in which model layers the hydraulic properties were changed. The Tammetta equation estimates the height of complete groundwater drainage (H) above longwall panels depending on panel width, w, cut height, t, and depth of cover, d, according to the following equation:

$$H = 1438 \ln(4.315 \times 10^{-5} .u + 0.9818) + 26$$

where:

$$u = w.t^{1.4} d^{0.2}$$

A series of multipliers were applied to enhance the hydraulic conductivity and storage properties in these layers using the TVM-package. The multipliers follow the ramp function, where multipliers with highest values are applied to model layers closest to the mined seam and then gradually decay as model layers are located higher above the longwall panel (SLR, 2020). Details on the hydraulic properties in these layers are provided in HydroSimulations (2019). A logarithmic stepping function was used to change the hydraulic properties across stress periods.

### 3.3.6 Project Mining

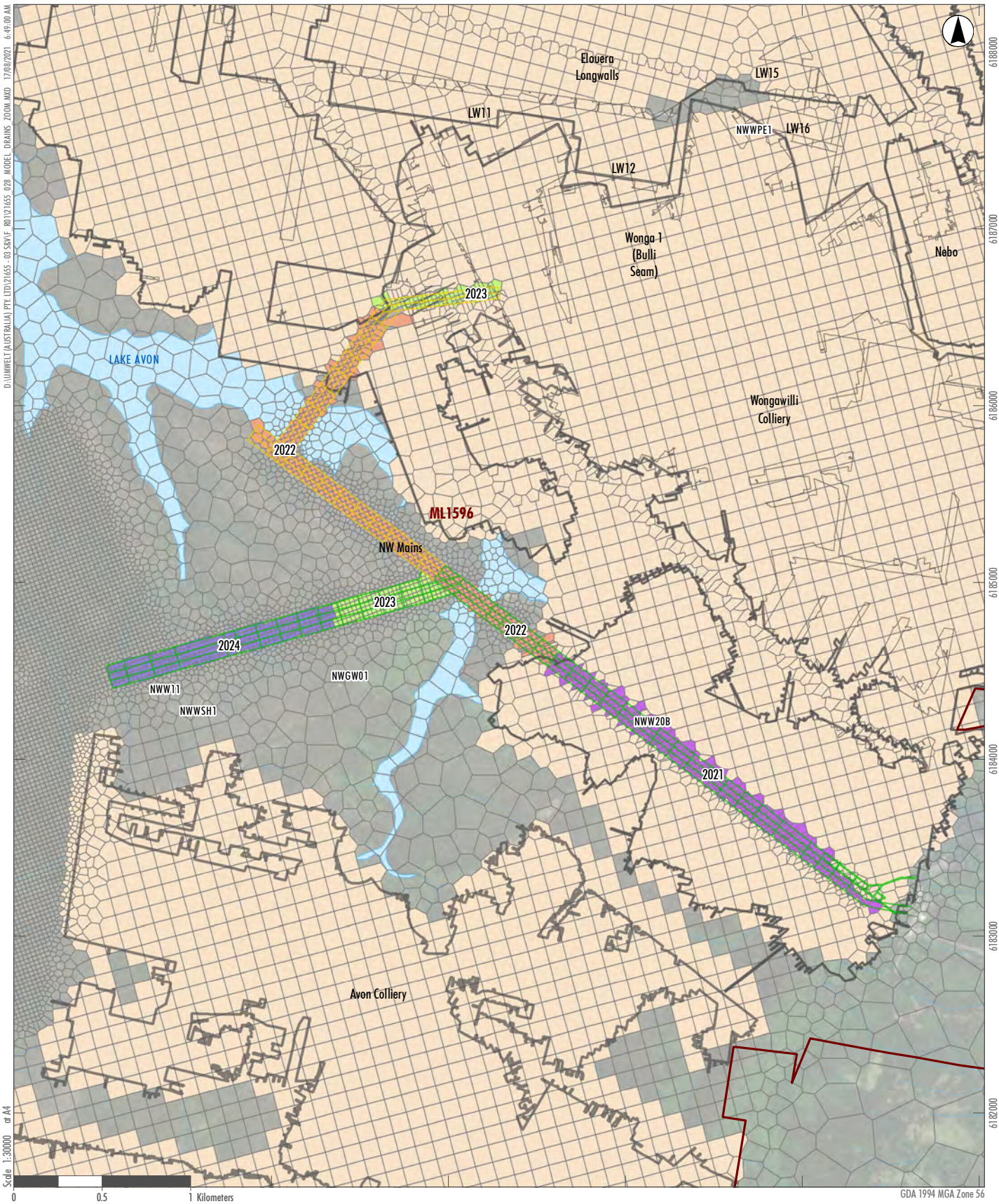
Proposed mining operations as part of the Project are implemented with the DRN and TVM packages in the SLR (2020) model, using the same methodology as described in Section 3.3.7.

Figure 3-9 shows a map with the mine drains representing the Project workings, which are activated between 2021 (Year 1) to 2024 (Year 4). It should be noted that the NWM alignment has been approved and the NWMD area is the only new area of proposed mining. However, as the previous approval project timeframe has lapsed, to be conservative the Project has been modelled as both the NWM and NWMD.

The Project mainly targets the Bulli Seam and therefore drain cells representing the Project are mainly assigned to layer 12. In the most western section of the Project (section L) the Wongawilli Seam is targeted, and drains have been assigned to layer 13 and layer 14.

The drain elevations were set to the base of the target coal seam, either layer 12 (Bulli Seam) or layer 14 (Wongawilli Seam). A nominally high drain conductance of 100 $m^2$/day was applied to all the drain cells and it was assumed that the driveages would remain dewatered for the duration of the underground mining, and therefore drains once activated, were active until the final year of mining (i.e. December 2025 / Year 5).

Since the Project comprises coal mine developments using the bord and pillar method, TVM cells are only applied to the model layers that represent the mined coal seam (mainly layer 12). Once the drains undertaking the dewatering are removed after the Project finishes, these drains were replaced by an equivalent porous medium with enhanced hydraulic properties using the TVM package that represent mine void properties, where Sy is set to 1, Ss set to 1.E-5 $m^{-1}$ and both vertical and horizontal hydraulic conductivity are assigned values of 100 m/day.




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Watercourse

Drain Year - Project Area

- 1940
- 2021 (Year 1)
- 2022 (Year 2)
- 2023 (Year 3)
- 2024 (Year 4)
- Groundwater Model Cell

FIGURE 3.9

Project Drain Cells

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)

## 3.4 Hydraulic Property Parameterisation

### 3.4.1 Hydraulic Conductivity

Uniform hydraulic conductivity values are assigned in the SLR (2020) model to five different hydrogeological units in Layer 1 (Figure 3-2), as these represent zones of varying hydraulic properties based on surface geology maps.

For other units in the model, horizontal hydraulic conductivity is conceptualized to be primarily controlled by lithology and depth, in accordance with available permeability measurements near the Project area. Layers 2-18 have been modelled using a hydraulic conductivity – depth relationship estimated from analysis of packer tests of all stratigraphic units (refer Section 2.7). The hydraulic conductivity of these layers is decreased with depth based on the depth dependence equation presented by SLR (2020) and discussed in Section 2.7. The Kh depth dependence relationship was capped in the model, with a minimum value of 8.6e-06 m/day and a maximum value of 1.0e-01 m/day applied to remain within field data ranges.

Consistent with the conceptualisation, the Kh at surface ($Kh_0$) was varied based on the different geological units. For example, the coal seams are more permeable than the surrounding siltstones and sandstones even though they occur at similar depths. As no data are available for the units at surface, initial values for $Kh_0$ and Kv were derived from the Dendrobium EIS model (HydroSimulations, 2019), which were subsequently changed during model calibration (refer Section 3.5.1). These properties in the Dendrobium EIS model are conditioned by the field data from Dendrobium, BSO and Tahmoor, and subsequently adjusted during calibration against available monitoring data.

Similar to HydroSimulations (2019), vertical hydraulic conductivity (Kv) was not varied with depth, as it is assumed that Kv is governed more by the dominant lithology than depth.

Table 3-5 is derived from the SLR (2020) report and summarises the minimum, maximum and average horizontal (Kh) and vertical (Kv) hydraulic conductivity values for each unit within the model domain for the calibrated model. Figure 3-10 compares the minimum and maximum model values to the minimum and maximum of the field data (refer Section 2.7). As shown in Figure 3-10 the modelled parameters are within the bounds of the field data.

Figure 3-10 Kh Comparison of Field to Model Data

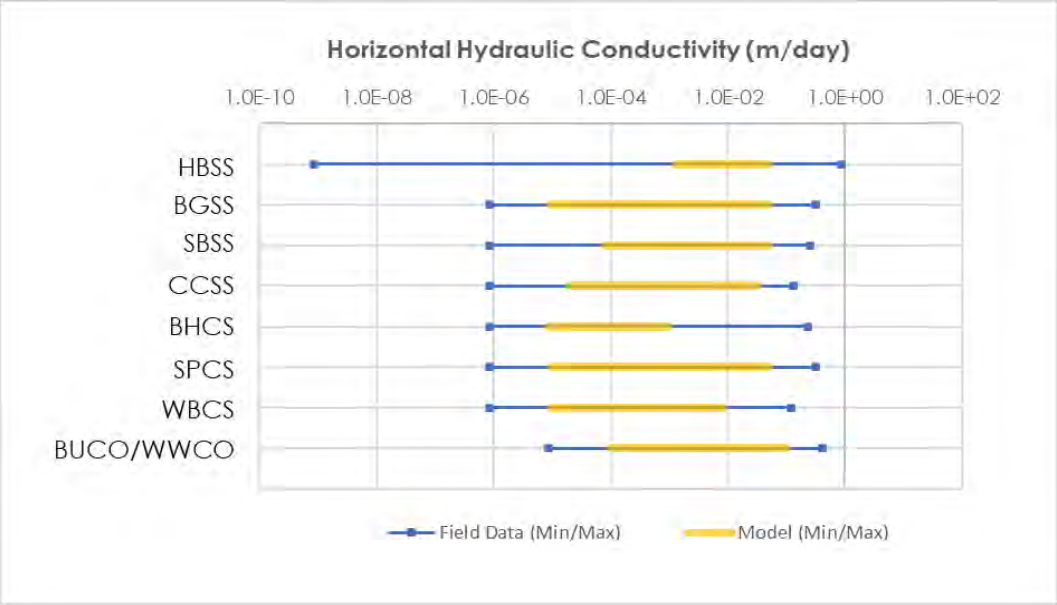
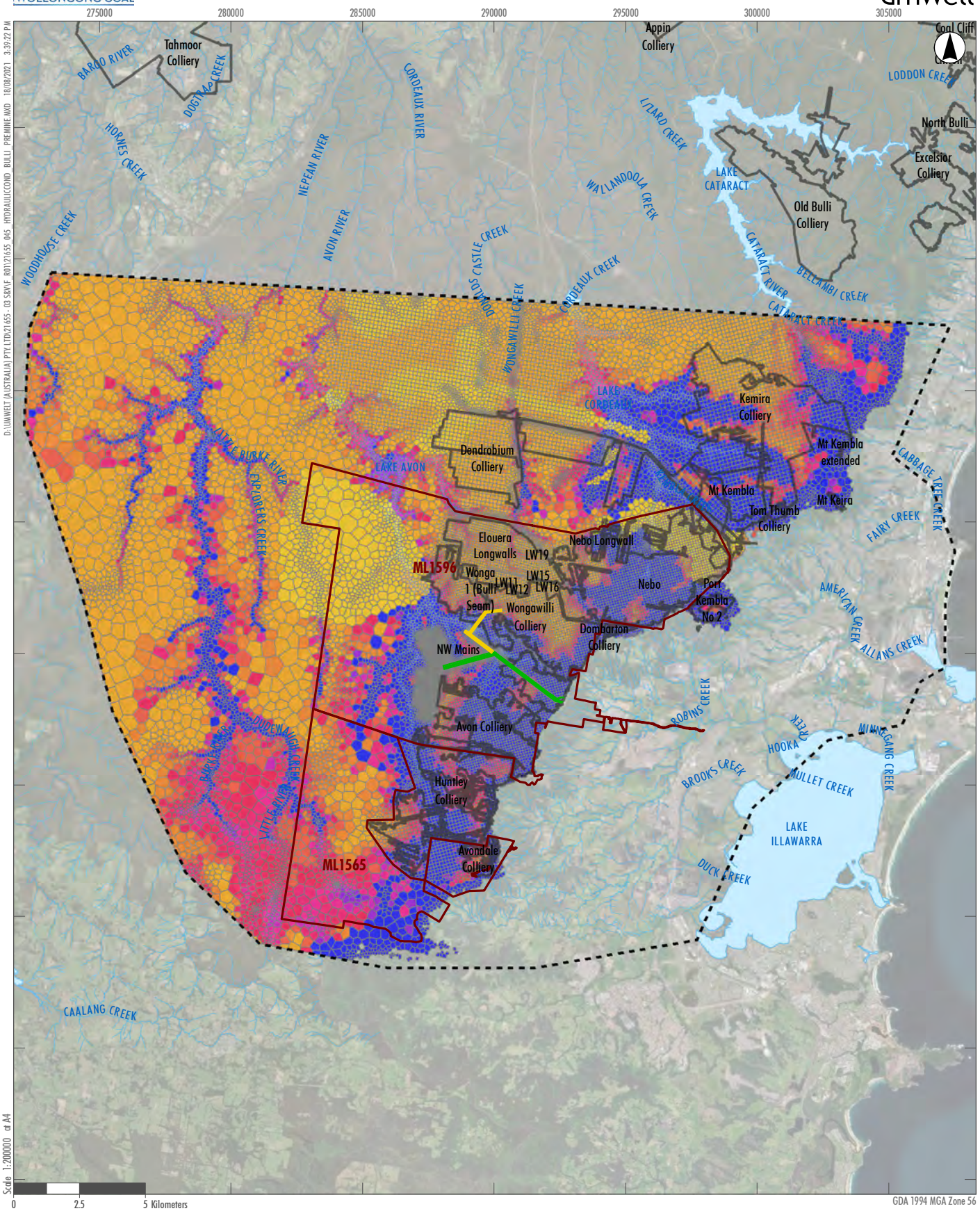


Table 3-5 Calibrated Hydraulic Conductivity Values (SLR, 2020)

| Stratigraphic Unit | Kx (m/d) | | | Kz (m/d) | | |
|---|---|---|---|---|---|---|
| | Min | Mean | Max | Min | Mean | Max |
| L01 - Alluvium | 5.80E+00 | 5.80E+00 | 5.80E+00 | 5.90E-02 | 5.90E-02 | 5.90E-02 |
| L01 – Escarpment | 4.20E-01 | 4.20E-01 | 4.20E-01 | 7.50E-06 | 7.50E-06 | 7.50E-06 |
| L01 – Lake and Ocean and Swamps | 2.20E-01 | 5.84E+00 | 1.50E+01 | 7.40E-04 | 3.38E-03 | 5.00E-03 |
| L01 – Regolith | 1.50E-01 | 1.50E-01 | 1.50E-01 | 3.20E-02 | 3.20E-02 | 3.20E-02 |
| L02 - Hawkesbury Sst (upper) | 1.70E-02 | 4.25E-02 | 5.00E-02 | 1.90E-05 | 1.90E-05 | 1.90E-05 |
| L03 - Hawkesbury Sst (mid) | 2.40E-02 | 4.99E-02 | 5.00E-02 | 2.20E-04 | 2.20E-04 | 2.20E-04 |
| L04 - Hawkesbury Sst (lower) | 1.30E-03 | 2.23E-02 | 5.00E-02 | 1.50E-04 | 1.50E-04 | 1.50E-04 |
| L05- Bald Hill Claystone | 8.60E-06 | 3.12E-04 | 9.70E-04 | 3.10E-06 | 3.10E-06 | 3.10E-06 |
| L05- Crinanite (weathered) | 8.10E-03 | 3.63E-02 | 5.00E-02 | 3.20E-04 | 3.20E-04 | 3.20E-04 |
| L06 - Bulgo Sst (upper) | 4.10E-05 | 1.11E-02 | 5.00E-02 | 1.00E-05 | 1.03E-05 | 3.10E-05 |
| L06 – Crinanite | 2.00E-05 | 2.00E-05 | 2.00E-05 | 1.00E-05 | 1.00E-05 | 1.00E-05 |
| L07 - Bulgo Sst (lower) | 9.50E-06 | 1.41E-03 | 2.90E-02 | 1.20E-06 | 6.46E-06 | 1.50E-05 |
| L07 – Crinanite | 3.10E-05 | 3.78E-03 | 2.80E-02 | 7.90E-06 | 5.47E-05 | 1.00E-04 |
| L08 – Stanwell Park Claystone | 1.00E-05 | 1.02E-02 | 5.00E-02 | 1.00E-07 | 7.33E-06 | 1.60E-04 |
| L08 – Crinanite | 1.00E-04 | 7.66E-03 | 1.70E-02 | 5.20E-05 | 2.43E-04 | 2.50E-04 |
| L09 – Scarborough Sst | 8.10E-05 | 2.61E-02 | 5.00E-02 | 4.00E-06 | 9.01E-06 | 1.00E-05 |
| L09 – Crinanite | 2.80E-04 | 2.35E-02 | 5.00E-02 | 1.40E-04 | 2.50E-04 | 2.50E-04 |
| L10 – Wombarra Claystone | 1.00E-05 | 3.47E-04 | 8.10E-03 | 5.00E-06 | 1.68E-05 | 2.00E-05 |
| L10 – Crinanite | 8.60E-06 | 6.18E-04 | 3.40E-03 | 4.30E-06 | 2.00E-05 | 2.10E-05 |
| L11 – Coalcliff Sandstone | 2.00E-05 | 9.84E-04 | 3.20E-02 | 1.00E-05 | 1.44E-05 | 1.70E-05 |
| L11 – Crinanite | 1.00E-05 | 1.04E-03 | 8.00E-03 | 5.00E-06 | 1.38E-05 | 1.40E-05 |
| L12- Bulli Coal Seam | 2.00E-04 | 2.95E-02 | 5.00E-02 | 8.60E-06 | 8.36E-05 | 2.50E-04 |
| L12- Crinanite | 3.00E-05 | 2.70E-03 | 1.90E-02 | 6.80E-06 | 6.80E-06 | 6.80E-06 |
| L13- Lawrence and Loddon Sandstones | 4.00E-05 | 7.84E-04 | 2.80E-02 | 3.20E-06 | 3.20E-06 | 3.20E-06 |
| L13- Nepheline syenite | 1.60E-05 | 3.72E-04 | 3.30E-03 | 2.20E-06 | 2.57E-06 | 4.10E-06 |
| L14- Wongawilli Coal Seam | 1.00E-04 | 2.52E-02 | 1.00E-01 | 1.00E-07 | 8.79E-06 | 1.20E-05 |
| L14- Nepheline syenite | 2.00E-04 | 3.27E-04 | 1.00E-03 | 1.00E-05 | 9.41E-06 | 1.00E-05 |
| L15- Kembla Sandstone | 4.00E-05 | 1.73E-03 | 5.00E-02 | 1.30E-06 | 3.27E-06 | 1.70E-04 |
| L16- Tongarra Coal Seam | 2.90E-03 | 1.52E-02 | 1.00E-01 | 4.10E-05 | 4.10E-05 | 4.10E-05 |
| L17- Lower Permian Coal | 2.00E-04 | 3.64E-04 | 1.20E-02 | 8.60E-06 | 1.10E-05 | 1.00E-04 |
| L18- Shoalhaven Group | 1.00E-03 | 1.12E-02 | 5.00E-02 | 1.80E-07 | 1.80E-07 | 1.80E-07 |

Figure 3-11 and Figure 3-12 present the spatial distribution of calibrated pre-mining hydraulic conductivity values applied to layers 12 and 14, respectively. The values for the Bulli Seam (layer 12) range between $3.0x10^{-5}$ m/day and $5.0x10^{-2}$ m/day, and the values for the Wongawilli Seam (layer 14) range between $1.6x10^{-5}$ m/day and $1.0x10^{-1}$ m/day.

As discussed in Section 3.4.1, the layers also include zonation based on the mapped extent of cinders, the Cordeaux Crinanite and a fault zone near Dendrobium. Consistent with the approach undertaken in HydroSimulations (2019), separate Kh0 values were applied to the different zones, resulting in different properties to the insitu coal seam.




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- Watercourse

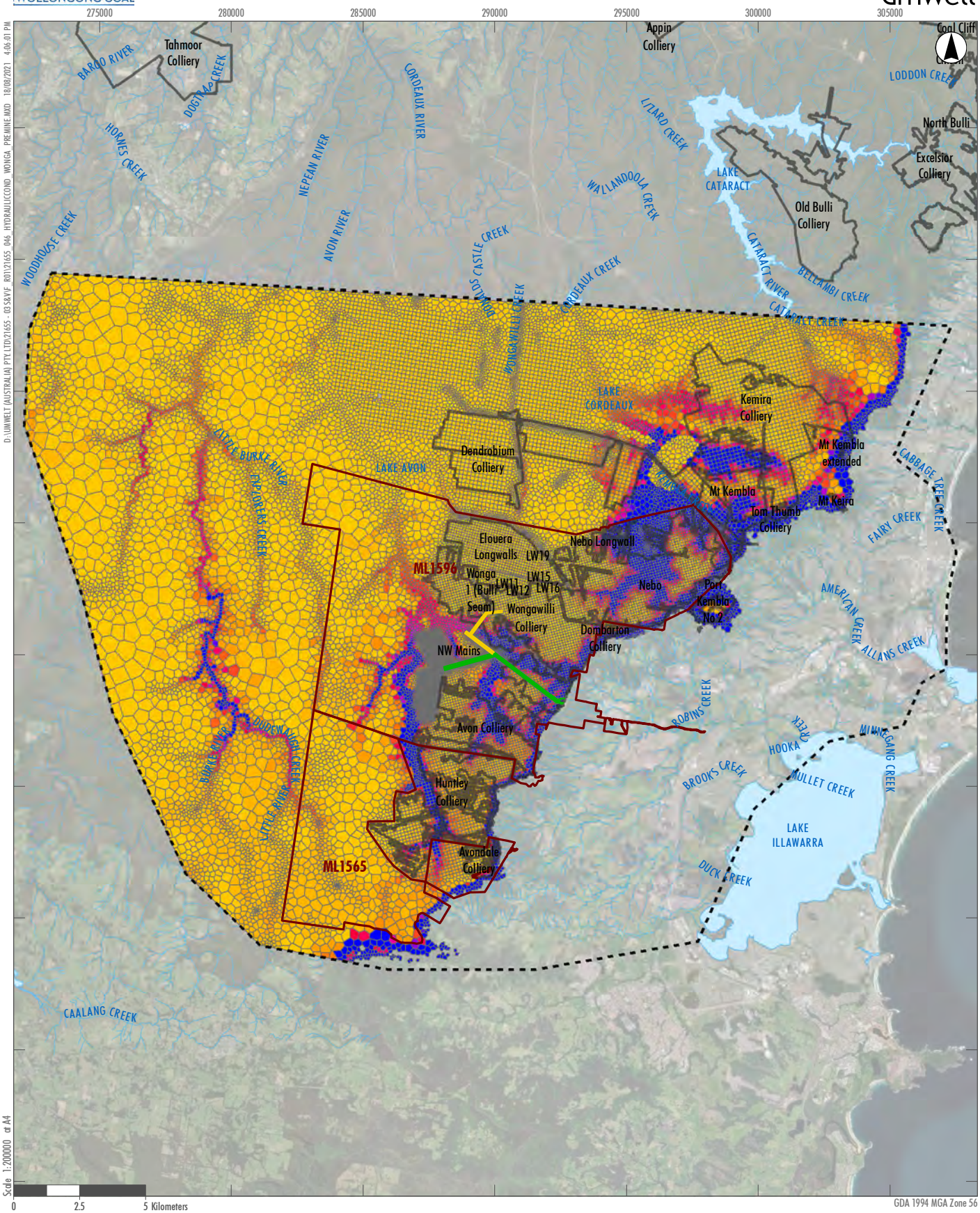
Hydraulic Conductivity (Kh)

- 0.0000 - 0.0050
- 0.0051 - 0.0100
- 0.0101 - 0.0150
- 0.0151 - 0.0200
- 0.0201 - 0.0250
- 0.0251 - 0.0300
- 0.0301 - 0.0350
- 0.0351 - 0.0400
- 0.0401 - 0.0450
- 0.0451 - 0.0500

FIGURE 3.11

Hydraulic Conductivity (Pre-mining) Layer 12 Bulli Seam

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




## Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- Watercourse

**Hydraulic Conductivity (Kh)**

- 0.000016 - 0.005000
- 0.005 - 0.01
- 0.01 - 0.015
- 0.015 - 0.02
- 0.02 - 0.025
- 0.025 - 0.03
- 0.03 - 0.035
- 0.035 - 0.04
- 0.04 - 0.045
- 0.045 - 0.05
- 0.05 - 0.055
- 0.055 - 0.06
- 0.06 - 0.065
- 0.065 - 0.07
- 0.07 - 0.075
- 0.075 - 0.08
- 0.08 - 0.085
- 0.085 - 0.09
- 0.09 - 0.095
- 0.095 - 0.100

FIGURE 3.12

# Hydraulic Conductivity (Pre-mining) Layer 14 Wongawilli Seam

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)

### 3.4.2 Storage Properties

Initial values for Sy and Ss in the SLR (2020) model were also based on the Dendrobium Model (HydroSimulations, 2019). Maximum specific storage limits have been set at 1.3 x$10^{-5}$, which is in accordance with its maximum theoretical limit defined by Rau *et al.* (2018). It should be noted that no depth relationship was applied to any of the units in Layer 1.

Table 3-6 shows the specific storage (Ss) and specific yield (Sy) for each hydrostratigraphic unit within the model domain as reported by SLR (2020).

Table 3-6 Calibrated Storage Parameters (SLR, 2020)

| Stratigraphic Unit | Specific Storage (Ss) [$m^{-1}$] | Specific Yield (Sy) [-] |
|---|---|---|
| L01 - Alluvium | 1.00E-05 | 1.00E-01 |
| L01 – Escarpment | 1.00E-05 | 1.00E-01 |
| L01 – Lake and Ocean and Swamps | 1.00E-05 | 2.24E-01 |
| L01 – Regolith | 1.00E-05 | 1.00E-01 |
| L02 - Hawkesbury Sst (upper) | 1.30E-05 | 5.00E-02 |
| L03 - Hawkesbury Sst (mid) | 1.00E-06 | 2.50E-02 |
| L04 - Hawkesbury Sst (lower) | 1.00E-06 | 1.20E-02 |
| L05- Bald Hill Claystone | 1.00E-06 | 6.00E-03 |
| L05- Crinanite (weathered) | 1.00E-05 | 1.00E-02 |
| L06 - Bulgo Sst (upper) | 1.00E-05 | 8.75E-03 |
| L06 – Crinanite | 9.00E-07 | 8.00E-03 |
| L07 - Bulgo Sst (lower) | 1.00E-05 | 8.09E-03 |
| L07 – Crinanite | 9.00E-07 | 8.47E-03 |
| L08 – Stanwell Park Claystone | 1.00E-05 | 6.39E-03 |
| L08 – Crinanite | 7.00E-07 | 5.00E-03 |
| L09 – Scarborough Sst | 6.00E-06 | 1.00E-02 |
| L09 – Crinanite | 9.00E-07 | 1.00E-02 |
| L10 – Wombarra Claystone | 5.00E-07 | 3.50E-03 |
| L10 – Crinanite | 9.00E-07 | 1.00E-02 |
| L11 – Coalcliff Sandstone | 1.00E-05 | 6.52E-03 |
| L11 – Crinanite | 5.00E-07 | 4.00E-03 |
| L12 - Bulli Coal Seam | 5.00E-07 | 1.04E-02 |
| L12 – Crinanite | 9.00E-07 | 1.00E-02 |
| L13 - Lawrence and Loddon Sandstones | 5.00E-07 | 1.00E-02 |
| L13 - Nepheline syenite | 5.00E-07 | 1.00E-02 |
| L14 - Wongawilli Coal Seam | 5.00E-07 | 1.02E-02 |
| L14 - Nepheline syenite | 4.00E-06 | 2.00E-02 |
| L15 - Kembla Sandstone | 5.00E-07 | 2.00E-02 |
| L16 - Tongarra Coal Seam | 5.00E-07 | 4.00E-03 |
| L17 - Lower Permian Coal | 5.00E-07 | 2.92E-02 |
| L18 - Shoalhaven Group | 5.00E-07 | 5.00E-03 |

## 3.5 Model Calibration

### 3.5.1 Calibration Strategy

The SLR (2020) model was developed based on the calibrated model developed for Dendrobium by HydroSimulations (2019). Initial hydraulic properties were maintained from the HydroSimulations (2019) model, including the depth dependence equation. However, the model was re-calibrated by SLR (2020) in order to condition the model to additional site specific data.

Calibration was conducted using a pre-mining steady-state simulation, followed by a transient simulation for the period Jan-1940 to June-2020 (see also Section 3.2.5 describing the stress-period setup). Calibration was undertaken using the parameter estimation software PEST (Doherty, 2010), which automates the process of matching modelled and observed data by adjusting model input parameters.

#### 3.5.1.1 Calibration Targets

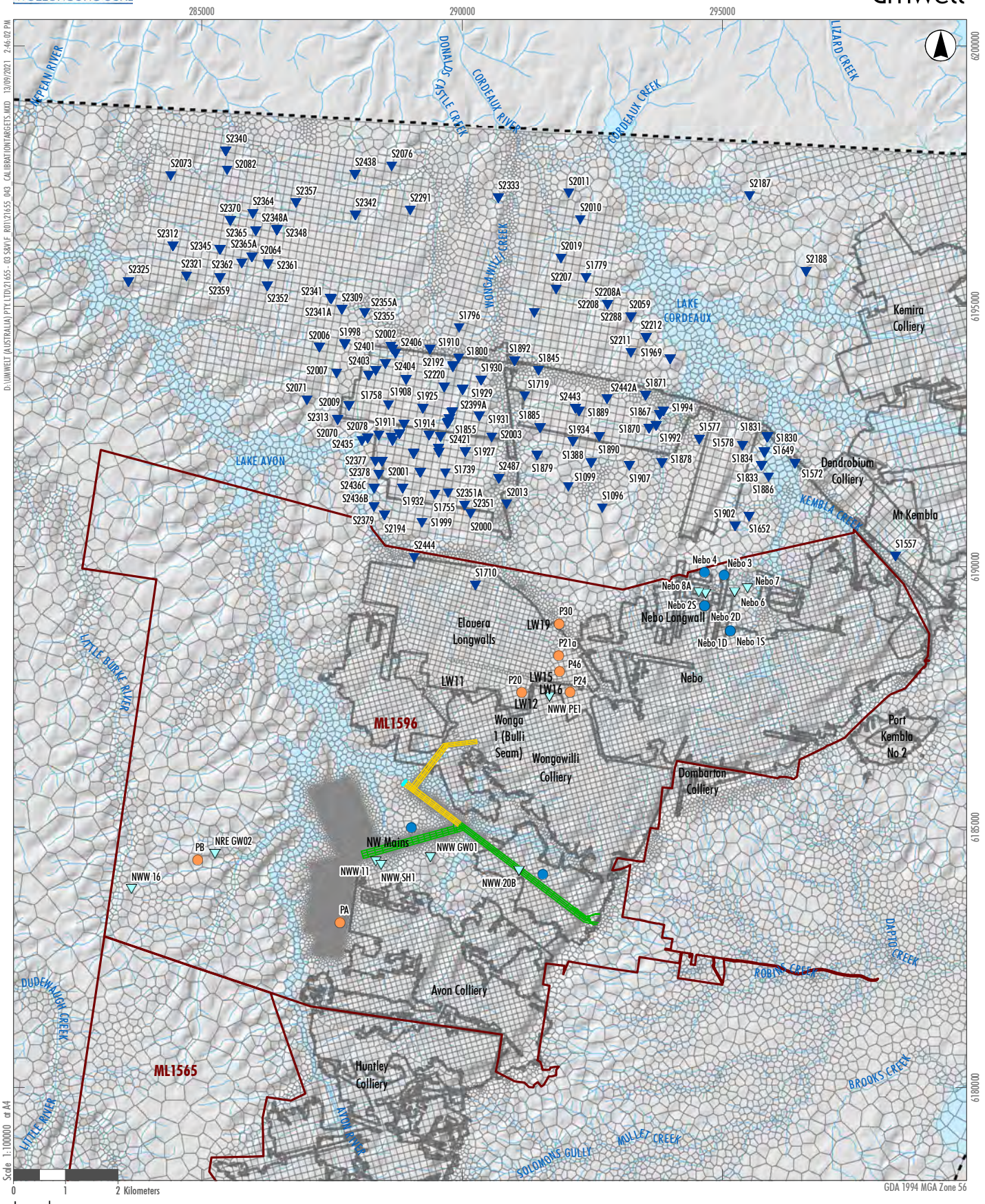
A total of 4,655 measurements across 59 site monitoring points were used for transient and steady-state model calibration, As described in Section 2.5, these monitoring locations include five open standpipes (OSP) and 54 VWPs, which record groundwater levels between March 2009 and May 2020. The locations of site monitoring points used in the steady-state and transient calibration are presented in Figure 3-13 and Table 3-7.

The earliest water level measurement (observation data) for each site monitoring bore was used to calibrate the steady state model, which measurement dates range from 2009 to 2013. Observations used for transient model calibration are averaged per month to reduce the frequency of the monitoring data and thus the temporal weight to the calibration statistics.

As shown in Figure 3-13, a large monitoring dataset was also available for the Dendrobium Mine (Areas 3A and 3B), which was applied to the model. The model was not directly calibrated against this dataset, but the model is conditioned to this information as the model architecture and initial parameterisation of the model for the Project are based on the groundwater impact model for Dendrobium (HydroSimulations, 2019), which has been calibrated to this monitoring data. To verify the model's performance the transient calibration results have been assessed for Dendrobium targets.

Table 3-7 Number of Monitoring Points by Stratigraphic Unit

| Stratigraphic unit | Number of monitoring locations |
|---|---|
| Crinanite | 10 |
| Hawkesbury Sandstone | 15 |
| BaldHill Claystone | 6 |
| Newport Formation | 1 |
| Bulgo Sandstone | 9 |
| Stanwell Park Claystone | 1 |
| Scarborough Sandstone | 3 |
| Coalcliff Sandstone | 2 |
| Bulli Coal | 4 |
| Loddon Sandstone | 1 |
| Eckersley Formation | 1 |
| Wongawilli Coal | 6 |
| Total | 59 |




## Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- Groundwater Model Cell
- Watercourse

**Monitoring Bore Type**

- MB
- Swamp
- VWP
- Dendrobium Monitoring Network

FIGURE 3.13

## Calibration and Validation Targets

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)

- Rainfall recharge fractions for the three recharge zones, defined in Section 3.3.3, and depth-dependent hydraulic conductivity values;
- Constant values for vertical hydraulic conductivity (Kv) and horizontal conductivity (Kh) for four zones in Layer 1;
- Depth-dependent horizontal conductivity values in layers 2-18, by adjusting the value for Kh0 in Eq. 2 (Section 2.7);
- Vertical hydraulic conductivity for layers 2-18; and
- Specific yield (Sy) and specific storage (Ss) for all layers.

Initial values of hydraulic conductivity and storage properties are based on the calibrated groundwater model for Dendrobium (HydroSimulations, 2019). Hydraulic conductivity values are then allowed to change during calibration by half an order of magnitude and their bounds were set in consideration of available site data for each of the geological units. The range in storage properties was set based on bounds reported by Rau *et al*. (2018).

### 3.5.2 Calibration Results – Steady State

Steady state calibration results were not reported by SLR (2020). The SLR (2020) model was used to extract the steady state calibration results, as reported below.

#### 3.5.2.1 Statistics

Calibration is achieved by matching observed groundwater levels over time, developing an equalised water balance, and adjusting parameters within realistic bounds. A common industry standard to evaluate the calibration performance of a groundwater model is calculating the error between the modelled and observed groundwater levels using the root mean square (RMS) error, which is defined as:

$$\text{RMS} = \left[1/n\sum(h_m - h_o)_i^{\,2}\right]^{0.5} \quad \text{(Eq. 3)}$$

where:

$n$ = number of measurements

$h_o$ = observed groundwater level

$h_m$ = modelled groundwater level

RMS is assumed to be a good measure of error when errors are normally distributed. The acceptable value for the calibration criterion depends on the magnitude of the change in heads over the model domain. If the ratio of the RMS error to the total head range in the system is small, the errors are only a small part of the overall model response. This is assessed using the Scaled RMS, which divides the RMS by the observed head range.

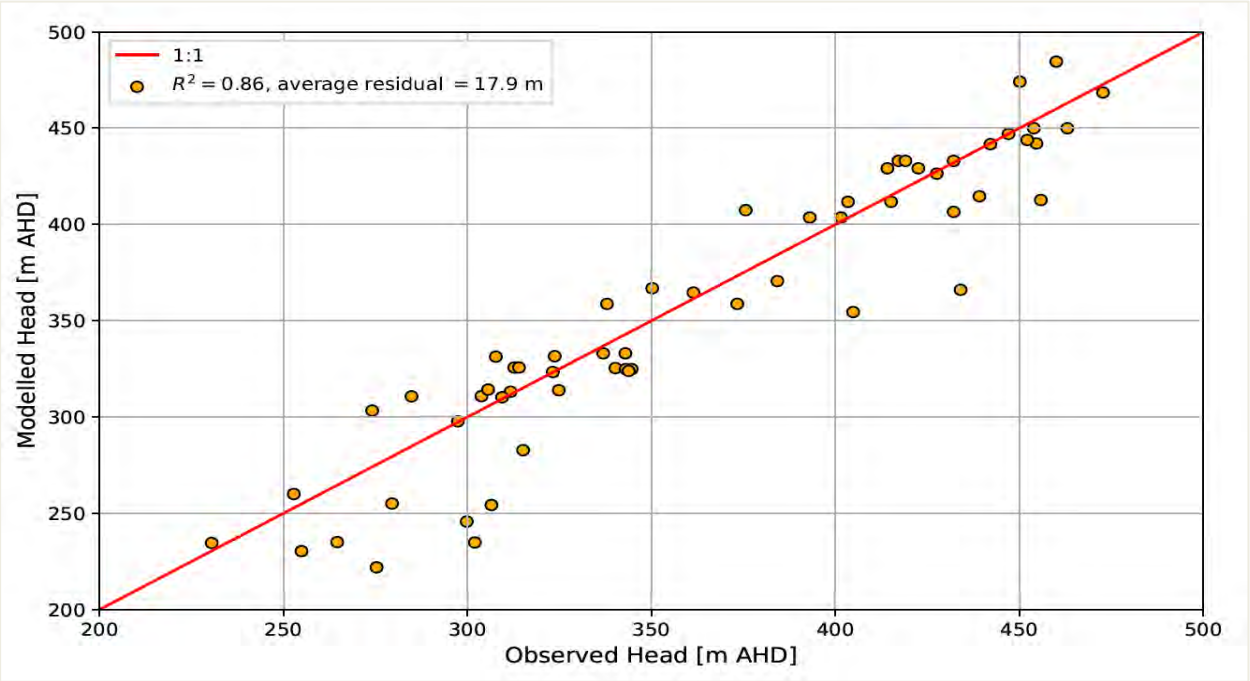
Table 3-8 provides the summary of calibration statistics that quantify the level of fit of the site monitoring data by the model. The RMS calculated for the calibrated model is 24.4 m for the site monitoring data. The site monitoring data have an observed head range of 242.2 m, which yields a Scaled RMS of 10.1%. This indicates a reasonable fit to the site monitoring data, as the Australian guideline indicator of 10% Scaled RMS is considered an acceptable overall performance (Murray Darling Basin Committee [MDBC], 2001; Barnett *et al*., 2012).

Table 3-8 Calibration Statistics – Steady-State

| Statistic | Site Monitoring Data |
|---|---|
| Residual Mean [m] | -6.5 |
| Abs. Residual Mean [m] | 17.9 |
| RMS Error [m] | 24.4 |
| Scaled RMS Error [%] | 10.1 |

Figure 3-14 presents the observed and simulated steady-state groundwater levels graphically as a scattergram for the site monitoring data. Overall, the simulations show a reasonable fit. For nine monitoring points, residuals (i.e., difference between modelled and observed groundwater level) exceed 30 m.

Figure 3-14 Scattergram of Observed and Simulated Groundwater Levels – Steady State




### 3.5.2.2 Steady-State Calibration Mass Balance

The water balance for the calibrated steady-state simulation is presented in Table 3-9. The mass balance error (the difference between calculated model inflows and outflows) at the completion of the steady state simulation was 0.0%, which shows that the model is stable and achieved an accurate numerical solution.

The steady-state water balance shows a total inflow and outflow of 185.1 ML/day. The major inflow component is recharge to the groundwater system of 173.8 ML/day, with other inflows being river inflows and regional groundwater inflow from areas outside the model domain. The major groundwater outflow component is 164.0 ML/day via evapotranspiration in areas where the water table is within 3 m of the ground surface, with approximately 18.2 ML/day being discharged via surficial drainage. Contributions to the high evapotranspiration outflow include EVT in cells that represent lakes in which RIV and CHD boundary conditions are applied. Other minor losses include regional groundwater outflow to areas outside the model domain.

Table 3-9 Steady-State Model Mass Balance

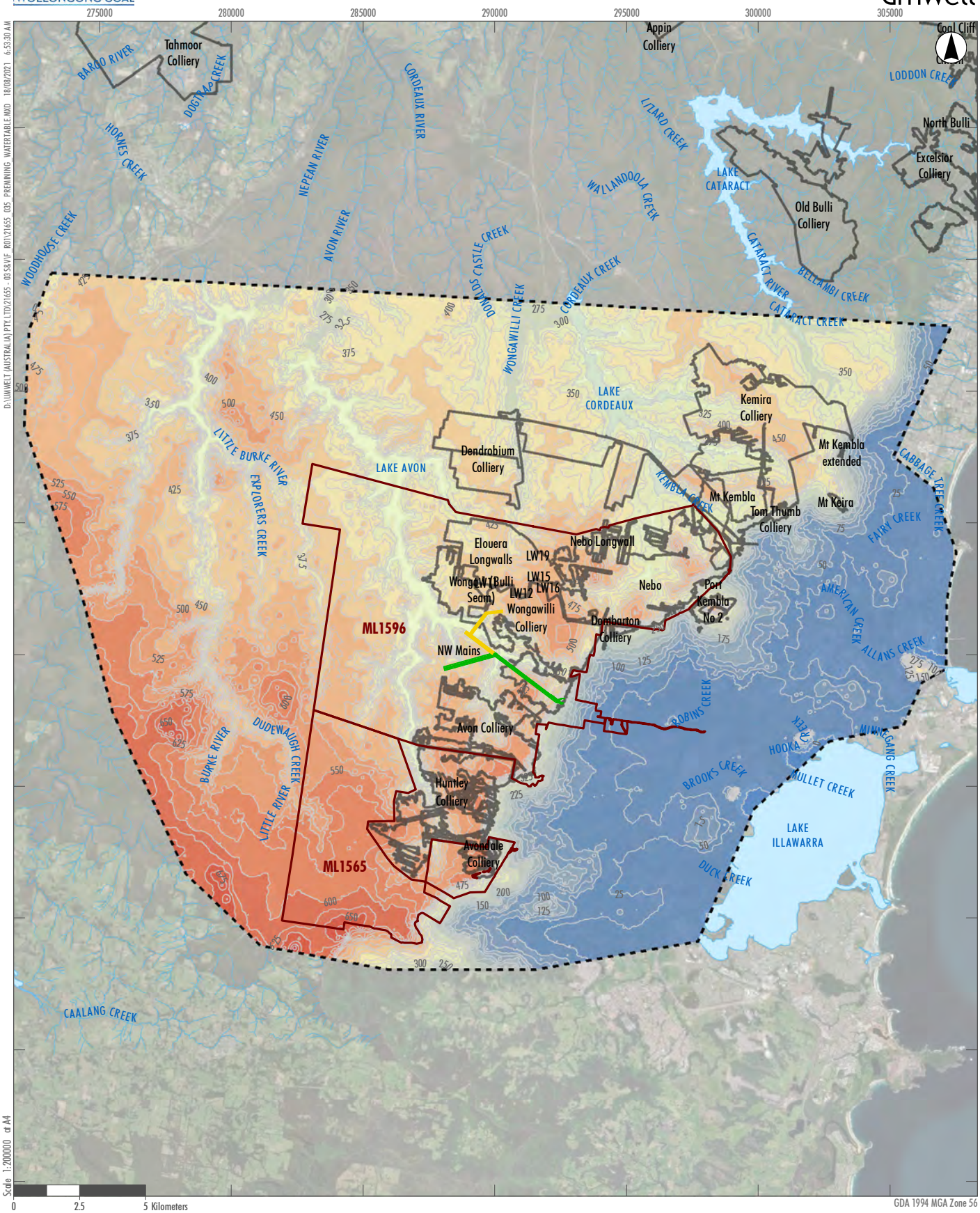
| Component | Inflow (ML/day) | Outflow (ML/day) |
|---|---|---|
| Recharge (RCH) | 173.8 | 0.0 |
| ET (from GW) (EVT) | 0.0 | 164.0 |
| Rivers (RIV) | 11.1 | 18.2 |
| Regional GW Flow (GHB) | 0.2 | 0.4 |
| Lakes and Ocean (CHD) | 0.0 | 2.5 |
| Mines (DRN) | 0.0 | 0.0 |
| Total | 185.1 | 185.1 |
| Mass Balance Error [%] | 0.0% | |

#### 3.5.2.3 Predicted Pre-Mining Groundwater Conditions

Figure 3-15 presents the simulated pre-mining water table based on the calibrated steady-state model. Modelled pre-mining groundwater levels at the end of the steady state calibration are presented in Figure 3-16 to Figure 3-19 for the alluvium/weathered zone, Hawkesbury Sandstone, Bulgo Sandstone and Bulli and Wongawilli Coal Seams, respectively.

These results show that:

- The water table (the elevation of the saturated zone) in the upland area northwest of the escarpment ranges between 650 mAHD in the southwest to 320 mAHD near major rivers. Pre-mining groundwater flow directions are oriented towards major rivers and lakes and towards the north.
- On the downside of the escarpment water table elevations range between 50 mAHD to 0 mAHD, with groundwater flow directions oriented towards the coast.
- Groundwater levels in the Hawkesbury Sandstone range from 580 mAHD in the southwest to 235 mAHD in the northeast. Groundwater flow directions are directed toward major rivers and the north.
- Groundwater levels in the Bulgo Sandstone range from 630 mAHD in the southwest to 290 mAHD in the northeast. Pre-mining groundwater flow directions are directed towards the north and northeast.
- Groundwater levels in the Bulli Seam Sandstone range from 485 mAHD in the south to 180 mAHD in the northeast. In the southern part of the model domain, pre-mining groundwater flow directions are directed towards the north, where groundwater flow directions gradually rotate towards the northeast and east in the northern part of the model domain.
- In the Project area, pre-mining heads in the Bulli Seam range between 360 mAHD and 316 mAHD, with groundwater flow directions towards the northeast and east.
- Predicted pre-mining heads in the Wongawilli Seam show similar groundwater levels and flow directions as the Bulli Seam.




## Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- 25m Contours
- Watercourse

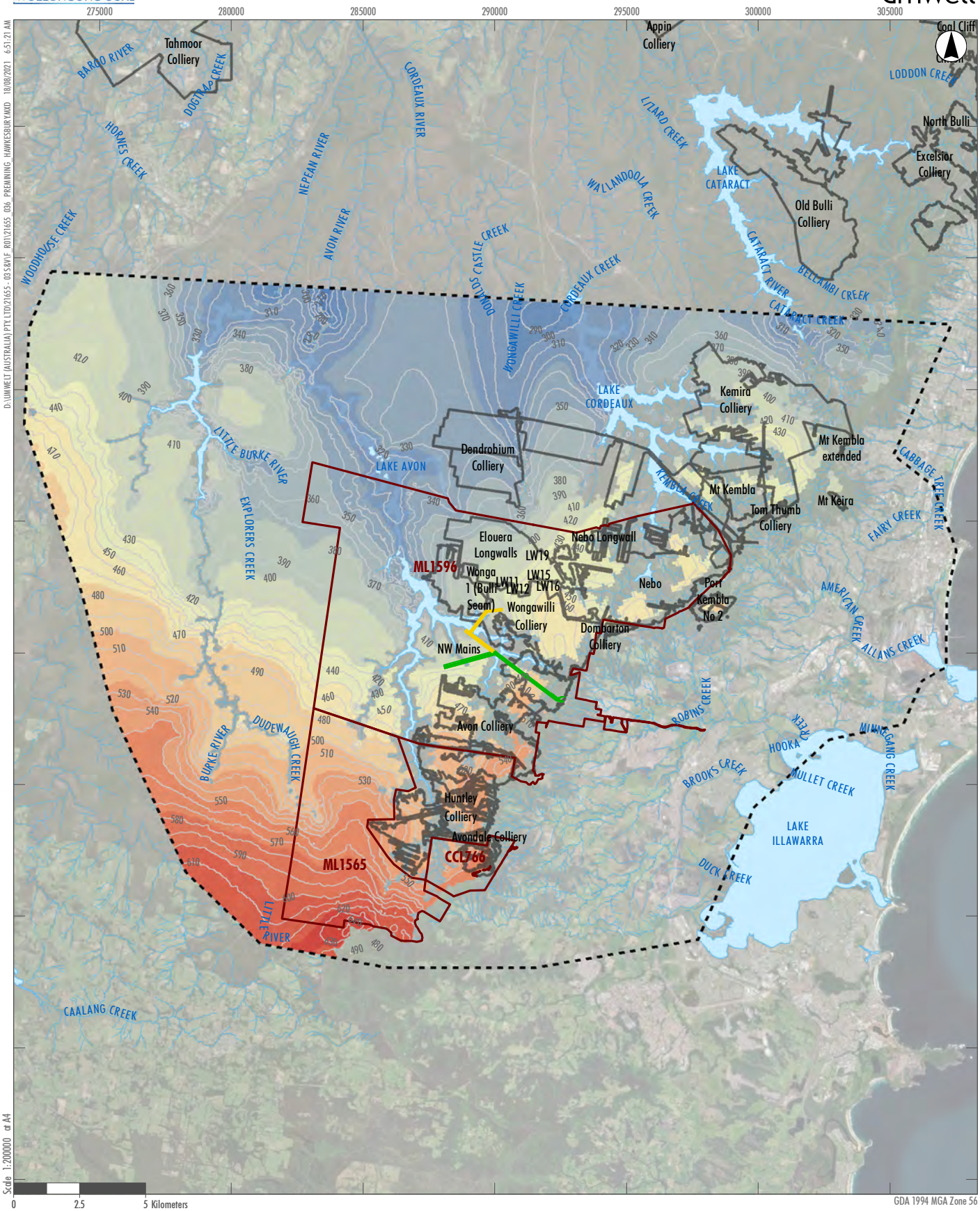
**Modelled Groundwater Level (mAHD)**

- -0.1 - 0
- 0 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- 451 - 500
- 501 - 550
- 551 - 600
- 601 - 650
- 651 - 700
- 701 - 750

FIGURE 3.15

# Calibrated Steady-State Heads (pre-mining) Water Table

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- 10m Contours
- Watercourse

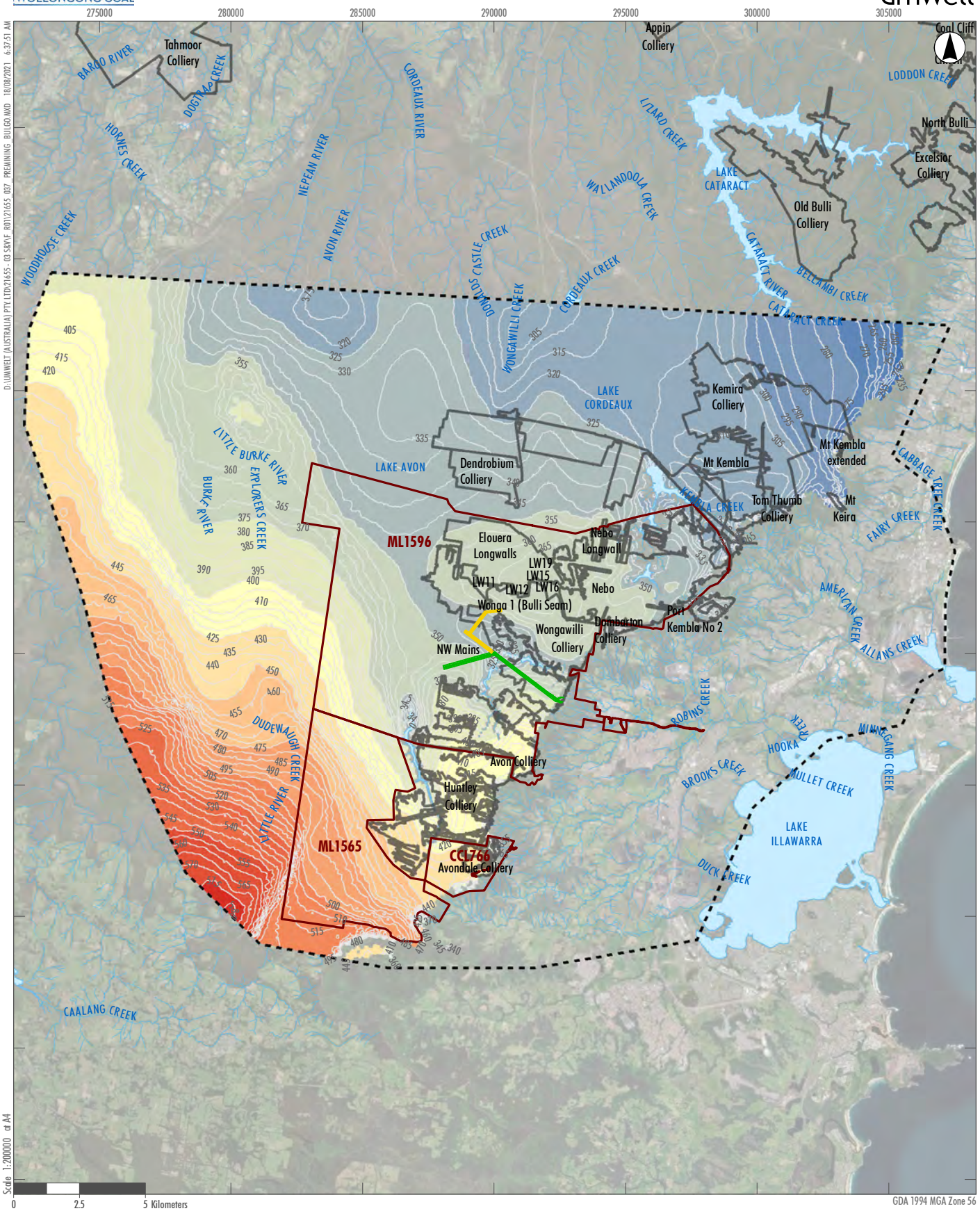
Modelled Groundwater Level (mAHD)

- 250 - 275
- 275 - 300
- 300 - 325
- 325 - 350
- 350 - 375
- 375 - 400
- 400 - 425
- 425 - 450
- 450 - 475
- 475 - 500
- 500 - 525
- 525 - 550
- 550 - 575
- 575 - 600
- 600 - 625
- 625 - 650

FIGURE 3.16

Calibrated Heads
(pre-mining)
Hawkesbury Sandstone (Layer 4)

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- 5m Contours
- Watercourse

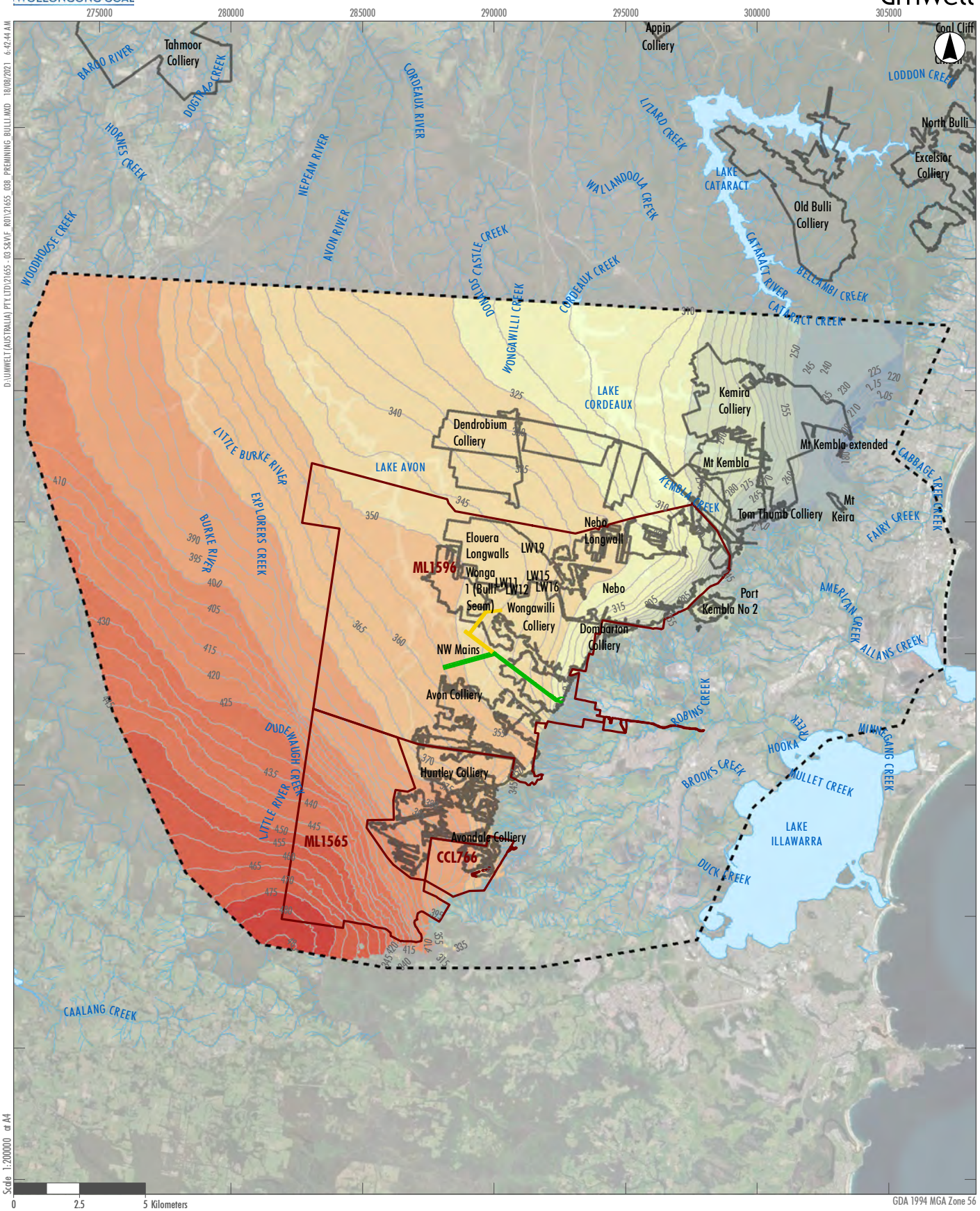
Modelled Groundwater Level (mAHD)

- 225- 250
- 250 - 275
- 275 - 300
- 300 - 325
- 325 - 350
- 350- 375
- 375 - 400
- 400 - 425
- 425 - 450
- 450 - 475
- 475 - 500
- 500 - 525
- 525 - 550
- 550 - 575
- 575 - 600

FIGURE 3.17

Calibrated Heads
(pre-mining)
Bulgo Sandstone (Layer 7)

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- 5m Contours
- Watercourse

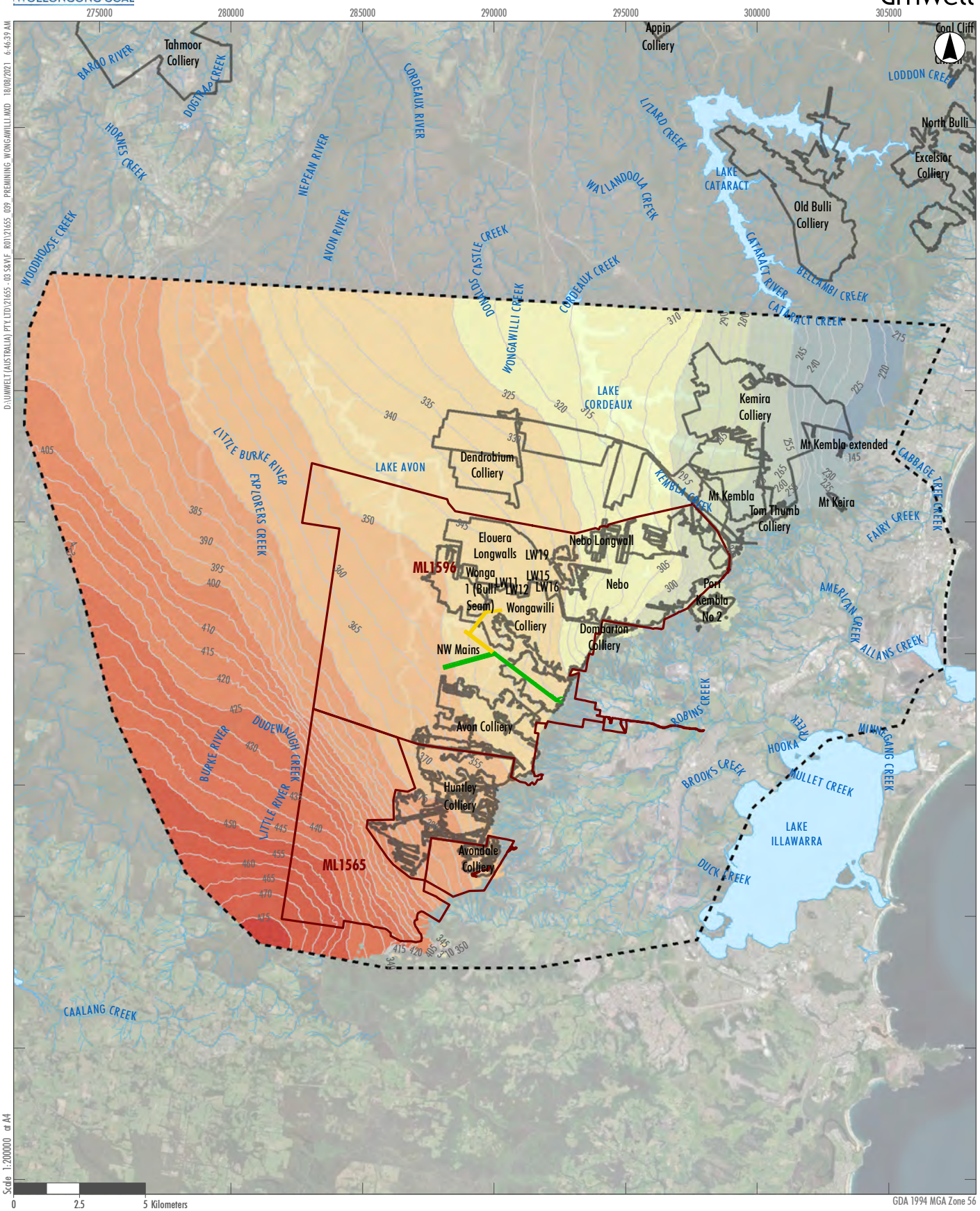
Modelled Groundwater Level (mAHD)

- 125 - 150
- 150 - 175
- 175 - 200
- 200 - 225
- 225 - 250
- 250 - 275
- 275 - 300
- 300 - 325
- 325 - 350
- 350 - 375
- 375 - 400
- 400 - 425
- 425 - 450
- 450 - 475
- 475 - 500

FIGURE 3.18

Calibrated Heads (pre-mining) Bulli Seam (Layer 12)

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- 5m Contours
- Watercourse

Modelled Groundwater Level (mAHD)

- 125 - 150
- 150 - 175
- 175 - 200
- 200 - 225
- 225 - 250
- 250 - 275
- 275 - 300
- 300 - 325
- 325 - 350
- 350 - 375
- 375 - 400
- 400 - 425
- 425 - 450
- 450 - 475
- 475 - 500

FIGURE 3.19

Calibrated Heads (pre-mining) Wongawilli Seam (Layer 14)

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)

### 3.5.3 Calibration Results - Transient

The transient calibration results are based on reporting by SLR (2020), with additional information provided by Umwelt on the calibration performance and findings, as well as verification against Dendrobium measured water levels (observation data).

#### 3.5.3.1 Statistics

Table 3-8 provides the summary of transient calibration statistics for both the site monitoring and Dendrobium data. The RMS calculated for the calibrated model is 21.2 m for the site monitoring data. The site monitoring data have a observed head range of 250.8 m, which yields a Scaled RMS of 8.44%. This indicates a reasonable fit to the site monitoring data, based on the Australian guideline indicator of 10% Scaled RMS being considered an acceptable overall performance (Murray Darling Basin Committee [MDBC], 2001; Barnett *et al*., 2012)). History matching between modelled and observed water level trends is also presented in Section 3.5.3.3.

The RMS for the Dendrobium data is 47.9 m. The observed head range of the Dendrobium data is 433.4 m, which yields a Scaled RMS of 11.1%. These indicators show that the fit to the Dendrobium data is not as good as the level of fit to the site monitoring data.

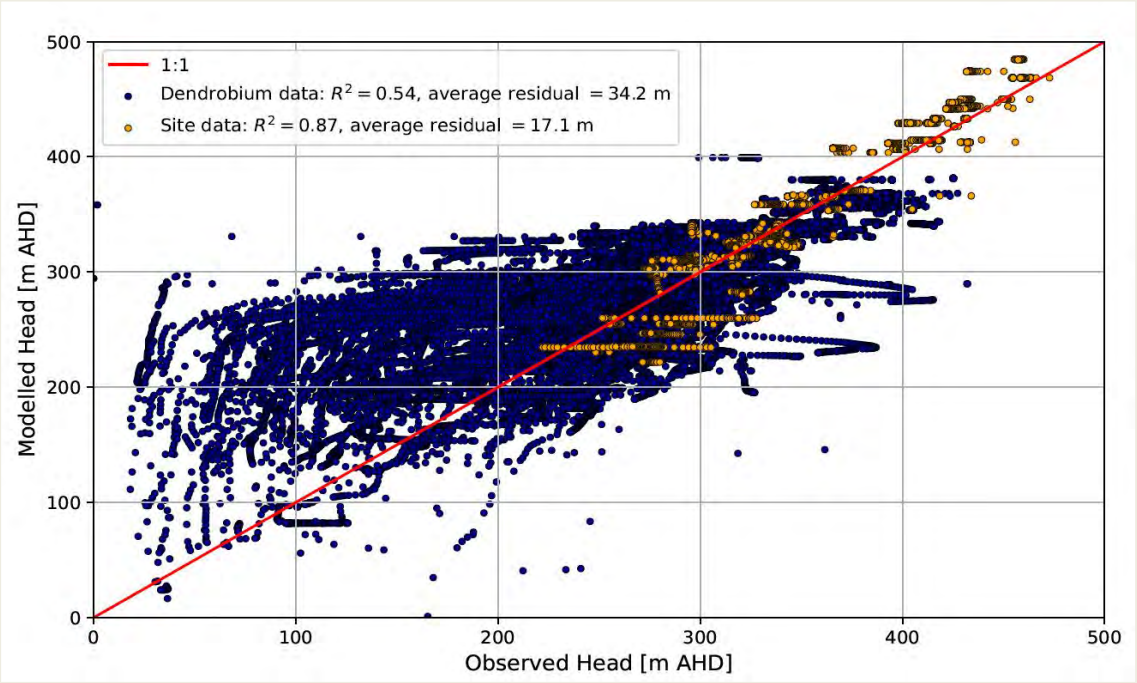
Table 3-10 Calibration Statistics - Transient

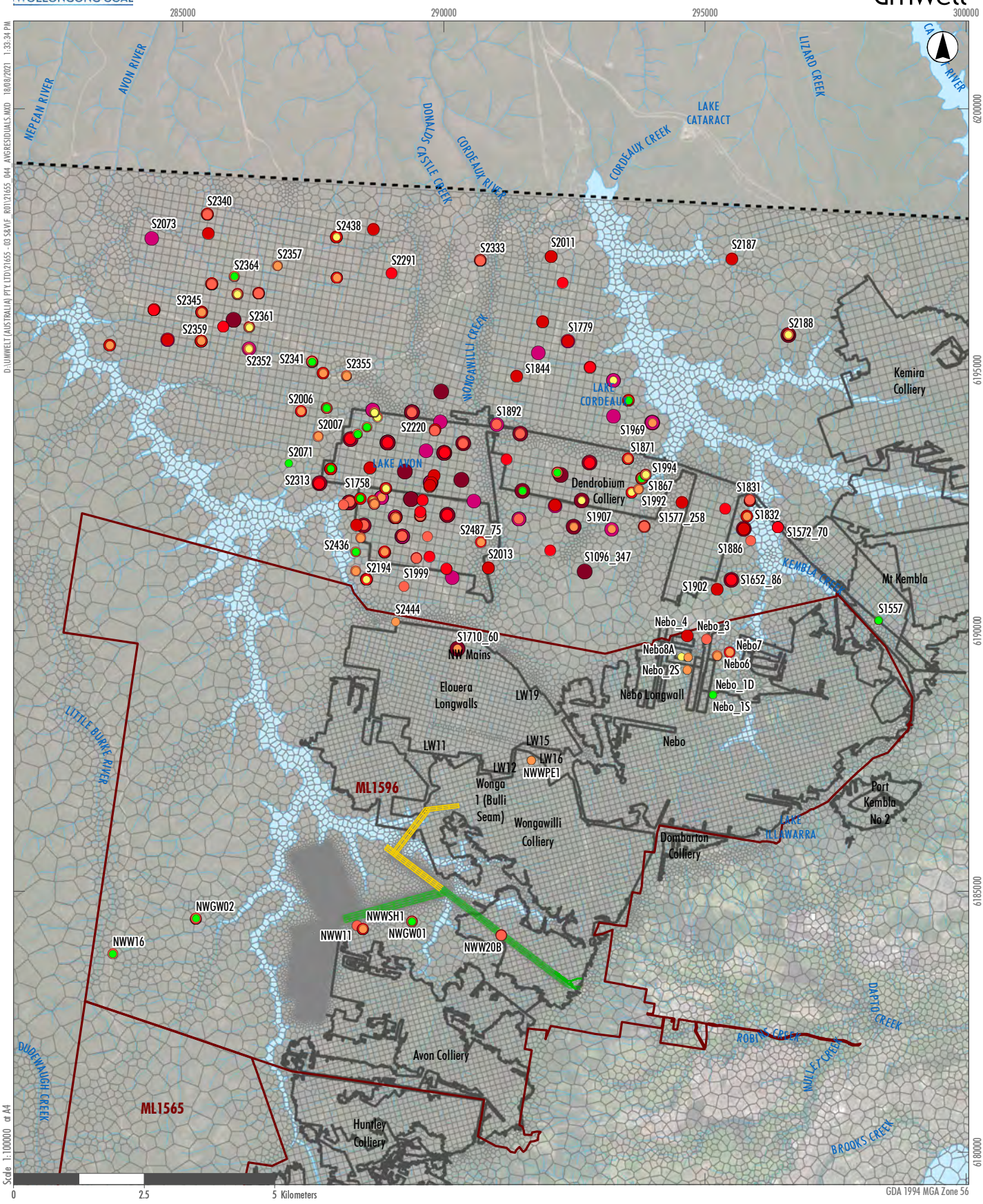
| Statistic | Site Monitoring Data | Dendrobium Data |
|---|---|---|
| Residual Mean [m] | 0.64 | 10.90 |
| Abs. Residual Mean [m] | 17.1 | 34.2 |
| RMS Error [m] | 21.2 | 47.9 |
| Scaled RMS Error [%] | 8.44 | 11.1 |

Figure 3-20 presents the observed and simulated groundwater levels graphically as a scattergram for both the site monitoring data and monitoring data at Dendrobium. Overall, the simulations show a reasonable fit to the site monitoring data, without a large bias. This is supported by the RMS statistics shown earlier. The scattergram for the Dendrobium data shows larger differences between modelled and observed groundwater levels, where observed heads below 200 mAHD are overestimated by the calibrated model.

Figure 3-21 spatially presents the average absolute residuals for each of the calibration targets for the Project area and the Dendrobium observation points. The figure shows greater model fit within the Project area, with the available site data generally showing a lower average residual compared to the Dendrobium sites. The Dendrobium sites also show more spatial variability in average residual compared to the site data locations. Further review and discussion on history matching and modelled versus observed groundwater level trends is included in Section 3.5.3.2.

Figure 3-20 Scattergram of Observed and Simulated Groundwater Levels - Transient






Legend

- Mine Lease Boundary
- Proposed NWMD (Project)
- Approved NWM
- Surrounding Mines
- Groundwater Model Boundary
- Groundwater Model Cell
- Watercourse

Residual Values

- 0.1 - 5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 50
- 50 - 70
- 70 - 100
- 100 - 359.1

FIGURE 3.21

Average Residuals - Transient Calibration

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)

### 3.5.3.2 Modelled vs. Observed Hydrographs

Appendix F presents a comparison of time-series of modelled and observed groundwater levels for all the site monitoring bores and Dendrobium monitoring points. A selection of results is also presented below for discussion.

The hydrographs for the Project area show a reasonable fit between modelled and observed trends. This is demonstrated in results for Nebo1D shown in Figure 3-22, with the modelled levels replicating the vertical gradient and the observed decline in groundwater levels in response to mining at Nebo from 2016.

Figure 3-22 Modelled vs Observed Hydrograph – Nebo1D/S

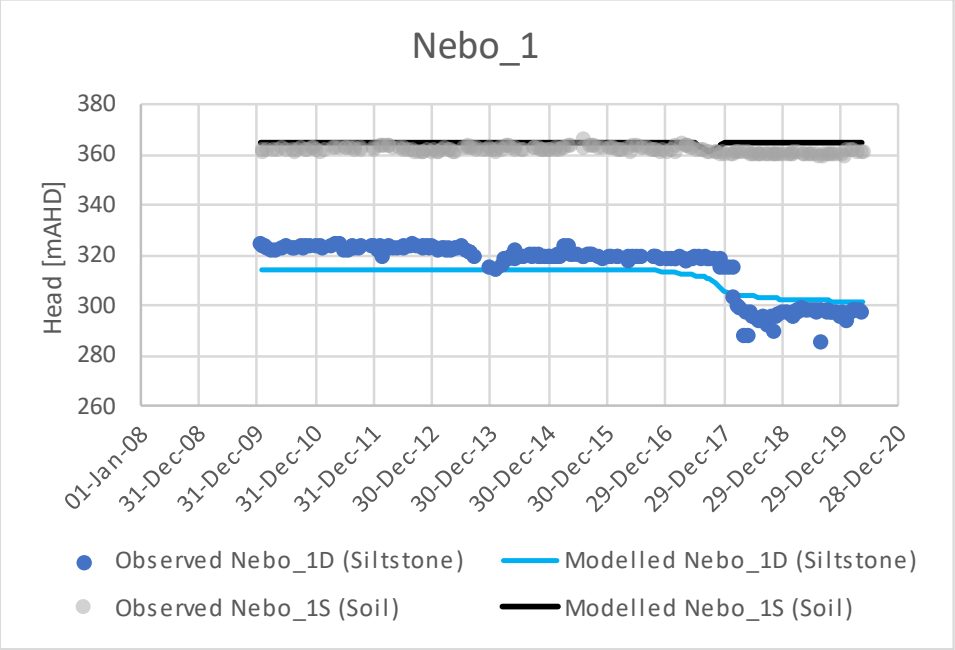
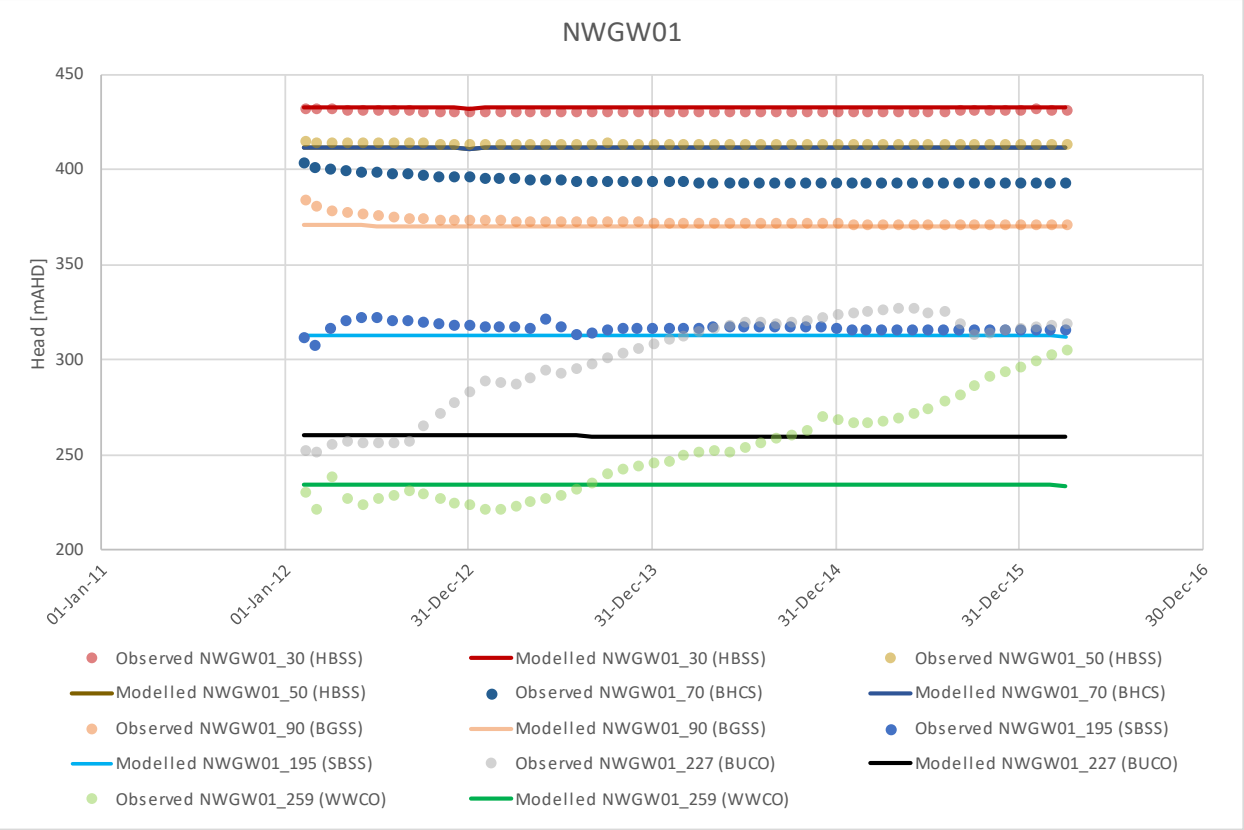



Figure 3-23 presents the modelled and observed trends for VWP NNGW01. As discussed in Section 2.6.4, the initial observed levels measured for NNGW01 are influenced by VWP installation but equilibrate by 2014. An exception to this were the two lowermost sensors (195 and 259) that were assessed as erroneous.

Umwelt consider that the modelled levels show good fit to observed data from 2014 and replicate the observed downward vertical head gradient.

Figure 3-23 Modelled vs Observed Hydrograph – NWGW01




The results for NWWPE1 also replicate the downward vertical gradient that is shown in the observation data. However, the model does over-predict groundwater levels in the Hawkesbury Sandstone and does not capture the observed depressurisation in the Bulgo Sandstone with mining at Elouera (refer Section 2.6.4). Depressurisation from mining is not captured due to the simplification of the historical mine progression in the calibration model. Elouera longwall mining was active until 2014; however, the drain cells for Elouera are also active in the transient warmup model (1940 to 2004).

Irrespective of this, Umwelt consider the model largely replicates current conditions within the Bulgo Sandstone with further improvement in the historical mine progression to be made in future updates to the model.

Figure 3-24 Modelled vs Observed Hydrograph – NWWPE1

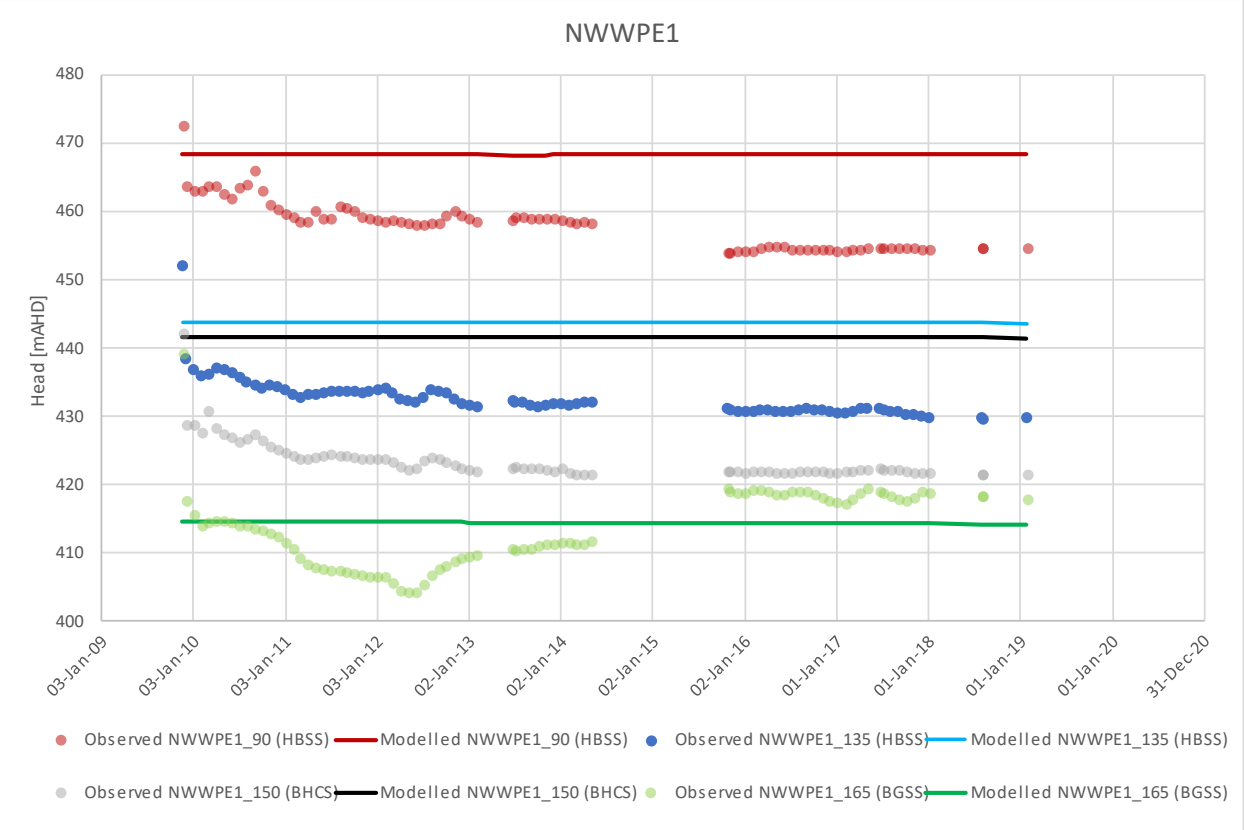



Figure 3-25 to Figure 3-27 present hydrographs for monitoring points S2013, S1994 and S1867, which are located near active mining at Dendrobium. The graphs show that the model replicates observed depressurisation within the Bulli Seam with mine progression. The model also replicates the vertical gradient at Dendrobium and trends within the overlying stratigraphy. The results indicate the model is adequate to predict responses to mining and capture cumulative groundwater impacts for the Project.

Figure 3-25 Modelled vs Observed Hydrograph – S2013

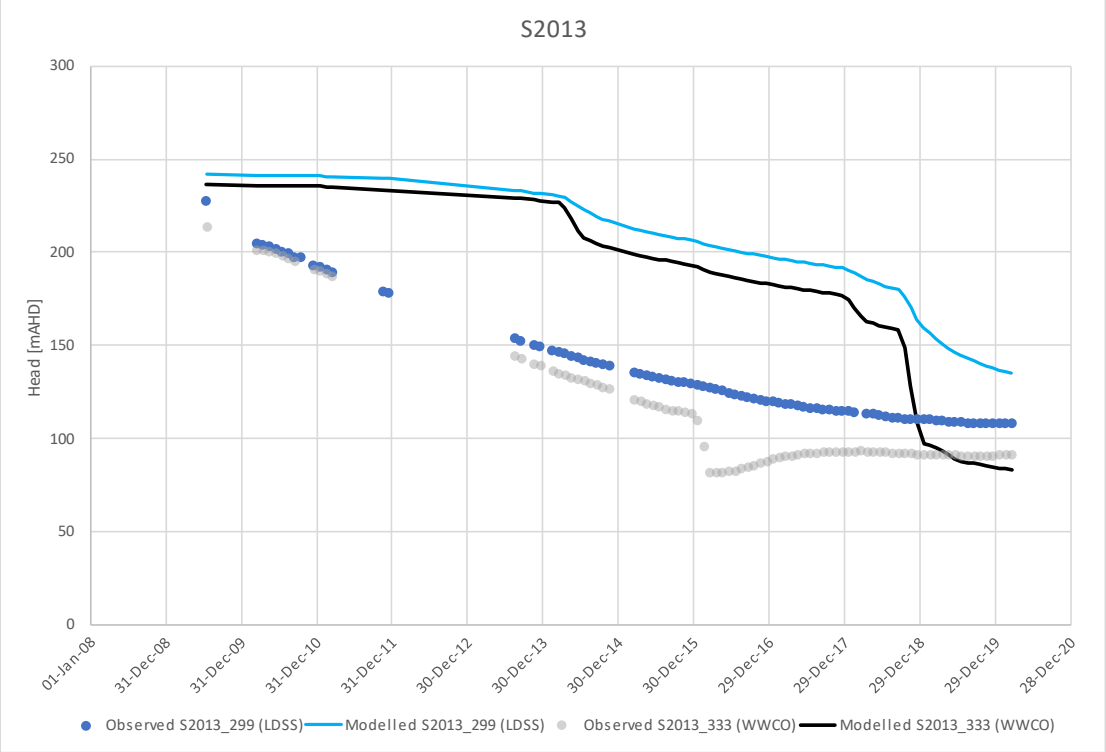



Figure 3-26 Modelled vs Observed Hydrograph – S1994

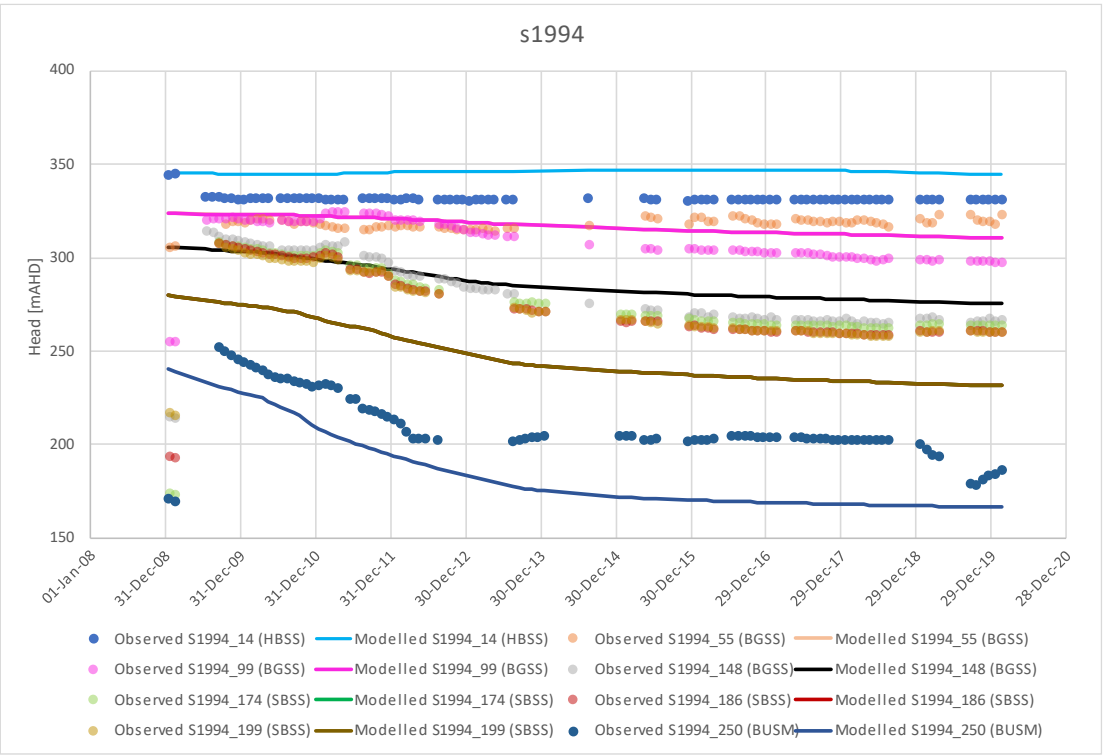
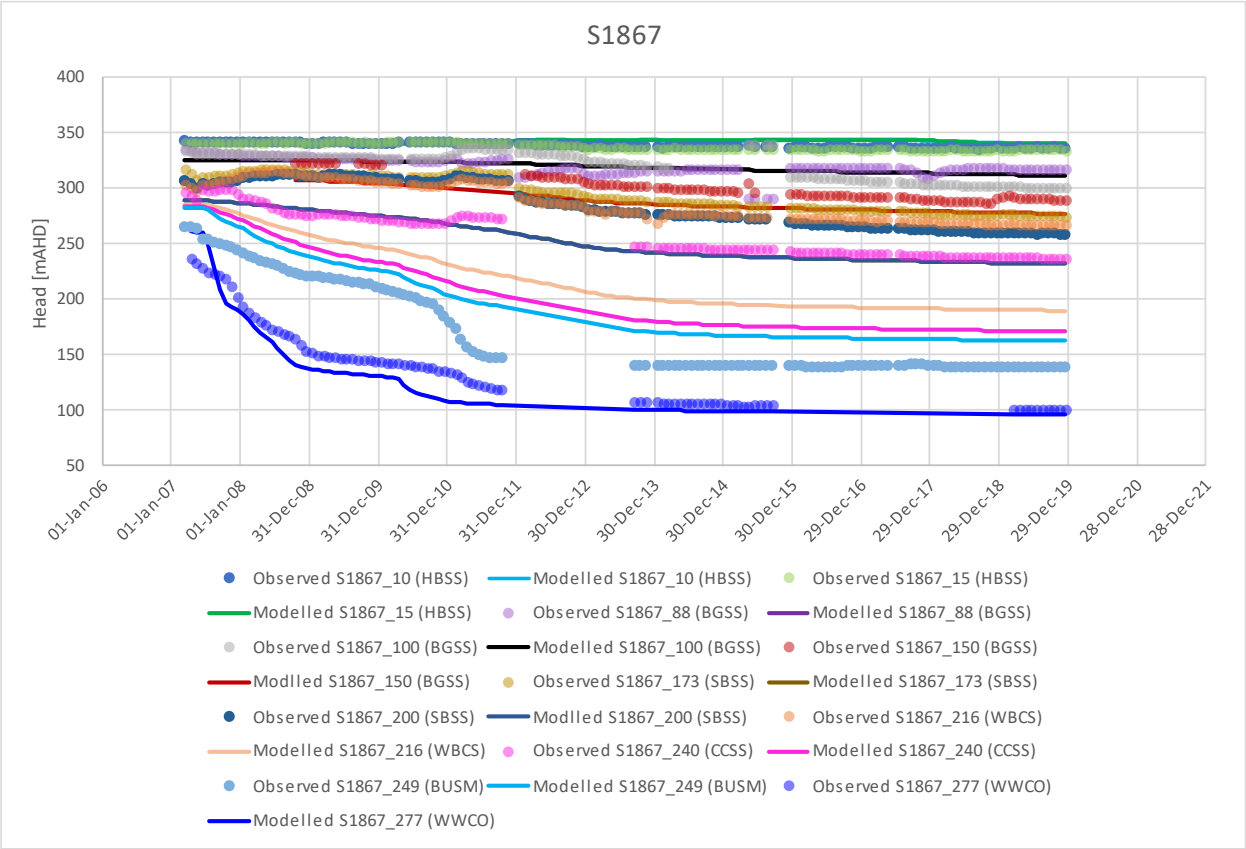


Figure 3-27 Modelled vs Observed Hydrograph – S1867



### 3.5.3.3 Transient Calibration Mass Balance

As reported by SLR (2020), the average water balance for the transient simulation between Jan-2004 and June-2020 is presented in Table 3-11. The water budget indicates that recharge to the groundwater system within the model averages 160.6 ML/day, with approximately 19.7 ML/day being discharged via surface drainage. This recharge is lower compared to the steady-state model, as transient recharge rates for period 2004 – 2020 are on average lower than the recharge rates applied in the steady-state simulation. The model simulates 153.7 ML/day lost to evapotranspiration in areas where the water table is within 3 m of the land surface. This is less than 164 ML/d modelled during the pre-mining steady-state simulation, which corresponds with the reduction in recharge in the transient model run.

Table 3-11 Transient Model Mass Balance – Average (2004 – 2020)

| Component | Average Inflow (ML/day) | Average Outflow (ML/day) |
|---|---|---|
| Recharge (RCH) | 160.6 | 0.00 |
| Evapotranspiration (from GW) (EVT) | 0.0 | 153.7 |
| Rivers (RIV) | 13.8 | 19.7 |
| Regional GW Flow (GHB) | 0.9 | 0.4 |
| Constant Head (CHD) | 0.0 | 2.3 |
| Mines (DRN) | 0.0 | 1.8 |
| Storage | 31.7 | 29.2 |
| Total | 207.0 | 207.0 |
| Mass Balance Error (%) | 0.0 | |

### 3.5.3.4 Historical Mine Inflows

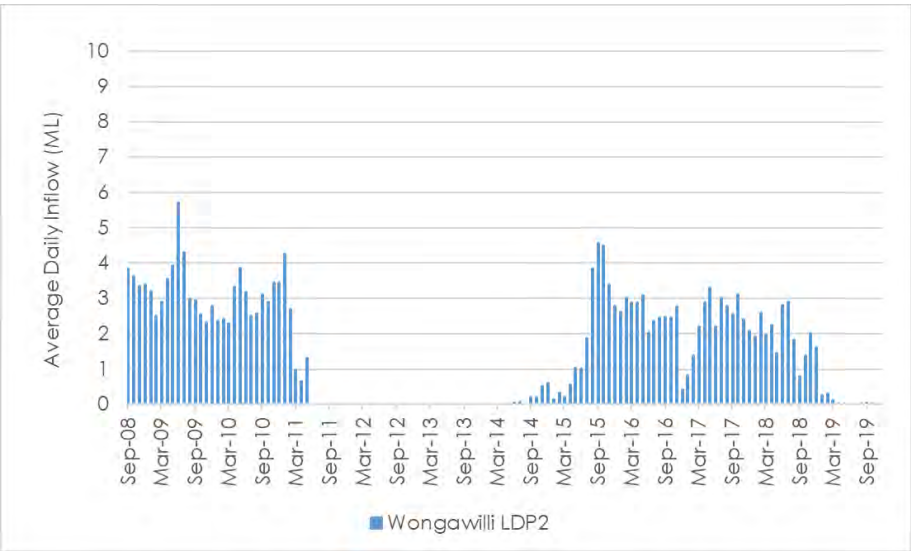
The transient model simulates that surrounding mines capture an average of 1.8 ML/day of groundwater during the period 2003 to 2020., predicted inflows to mine areas were compared against measured inflows (where available) in Table 3-12, which shows the inflows against the observed inflows at Wongawilli historical bord and pillar and Elouera longwalls. As shown in Table 3-12, the average groundwater mine inflows generally align with mining inflow measurements. Note that the simulated mine inflows in Table 3-12 exceed the average total mine outflow of 1.8 ML/day in Table 3-11 as mines are not active during the entire period to which this average outflow pertains.

Table 3-12 Transient Calibration – Mine Inflows

| Mine | Type | Year | Measured Inflow (ML/day) | Simulated Inflow (ML/day) | Source |
|---|---|---|---|---|---|
| Elouera | Longwall | | Max 10 ML/day | Max 3.4 - average 1.3 ML/day | GeoTerra, 2010 |
| Wongawilli | Bord and pillar | | Max 3.4 ML/day – background 1.7 ML/day | Max 14.5 – average 2.65 ML/day | GeoTerra, 2010 |
| Cordeaux | Bord and pillar | 1992-2002 | Average 1.2 ML/day | Average 2.7 ML/day | HydroSimulations, 2019 |
| Dendrobium | Longwall | | Average 4.7 ML/day | Average 2.5 ML/day | HydroSimulations, 2019 |

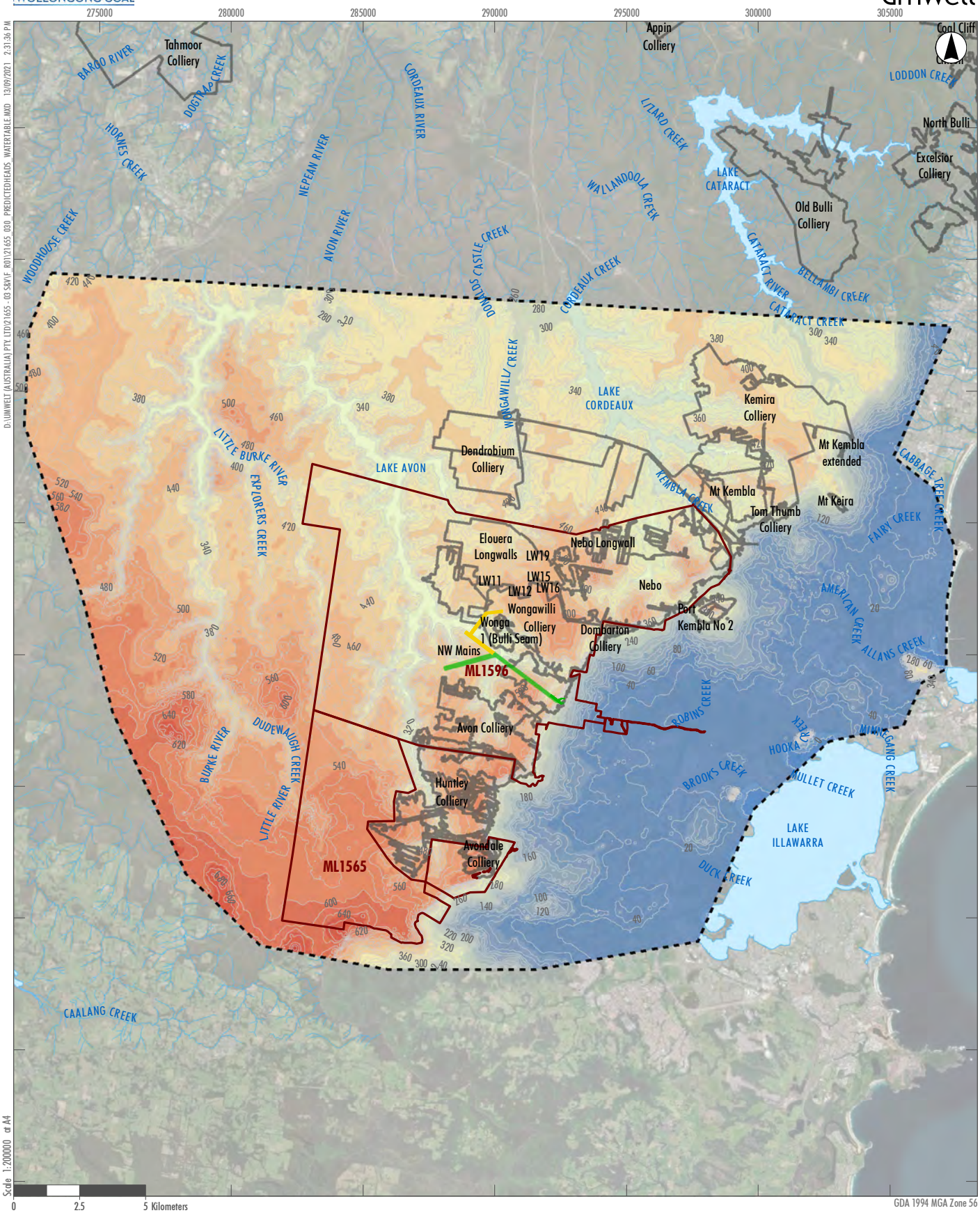
Monitoring of average daily pump volumes from Wongawilli is conducted by WCL at LDP2. The recorded average daily volumes are presented in Figure 3-28, compared to modelled average daily inflows to the Wongawilli workings over this period.

Figure 3-28 Wongawilli LDP2 Observed Discharge Volumes vs Modelled Inflows




### 3.5.3.5 Heads (June 2020)

Figure 3-29 presents the simulated water table at the end of the transient simulation period (June 2020). Modelled groundwater levels for this period are presented in Figure 3-30 to Figure 3-32 for the alluvium/weathered zone, Hawkesbury Sandstone, Bulgo Sandstone and Bulli and Wongawilli Coal Seams, respectively. Mining in Dendrobium underground and Elouera have caused depressurised zones within the centre of the model in the Bulli and Wongawilli Coal Seams. In addition, the depressurisation has extended to the shallower layers (e.g. Bulgo Sandstone) above the longwall panels indicating that the changes in hydraulic properties within the fracture zone have increased the vertical connection between the layers. Bord and pillar mining in Avon, Wongawilli, Kamira and Cordeaux has also caused depressurisation in Wongawilli coal seam along the escarpment and north of model boundary.




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- 20m Contours
- Watercourse

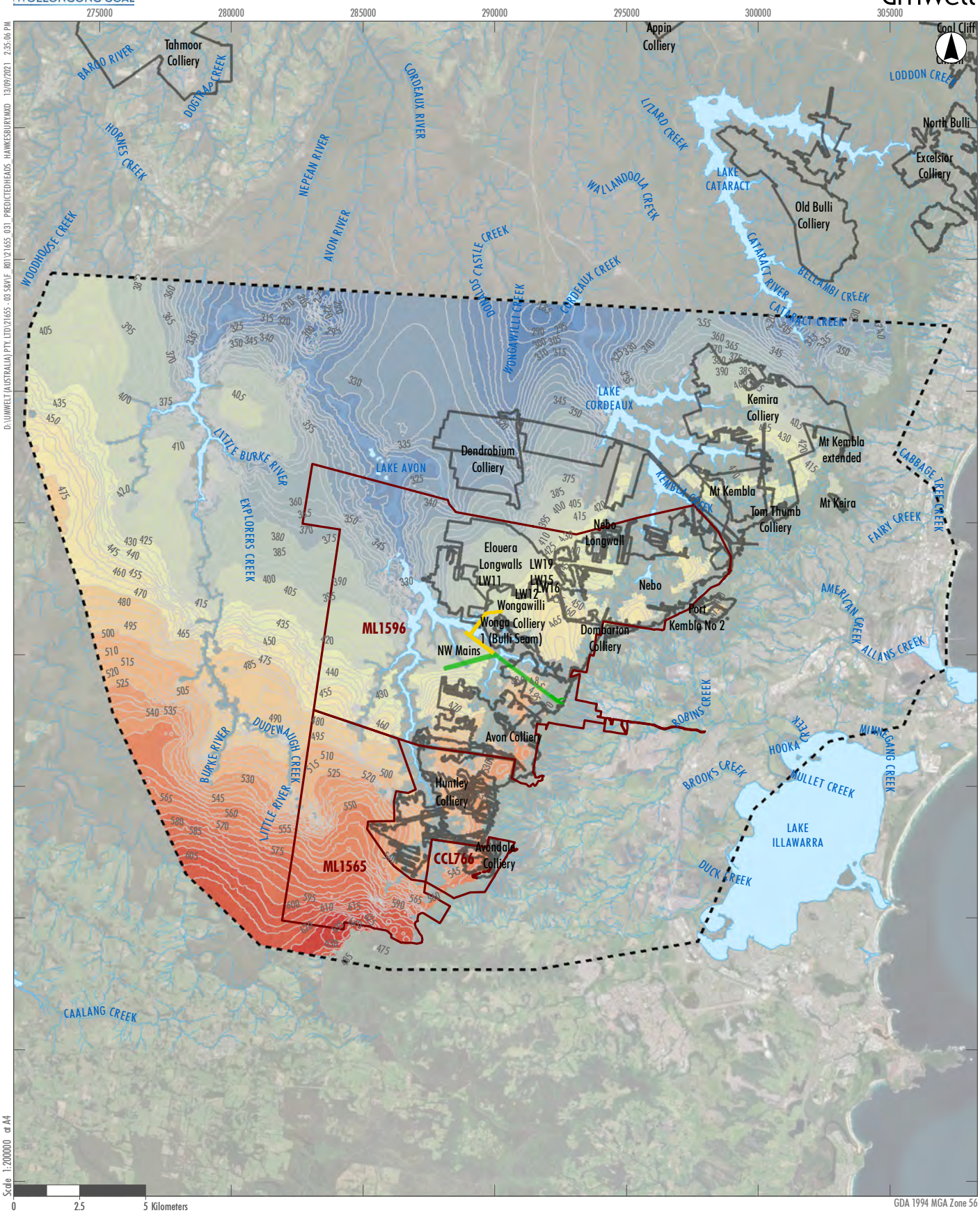
Modelled Groundwater Level (mAHD)

- -0.04 - 0
- 0 - 50
- 50 - 100
- 100 - 150
- 150 - 200
- 200 - 250
- 250 - 300
- 300 - 350
- 350 - 400
- 400 - 450
- 450 - 500
- 500 - 550
- 550 - 600
- 600 - 650
- 650 - 700
- 700 - 750

FIGURE 3.29

Modelled Heads (June 2020) Water Table

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- 5m Contours
- Watercourse

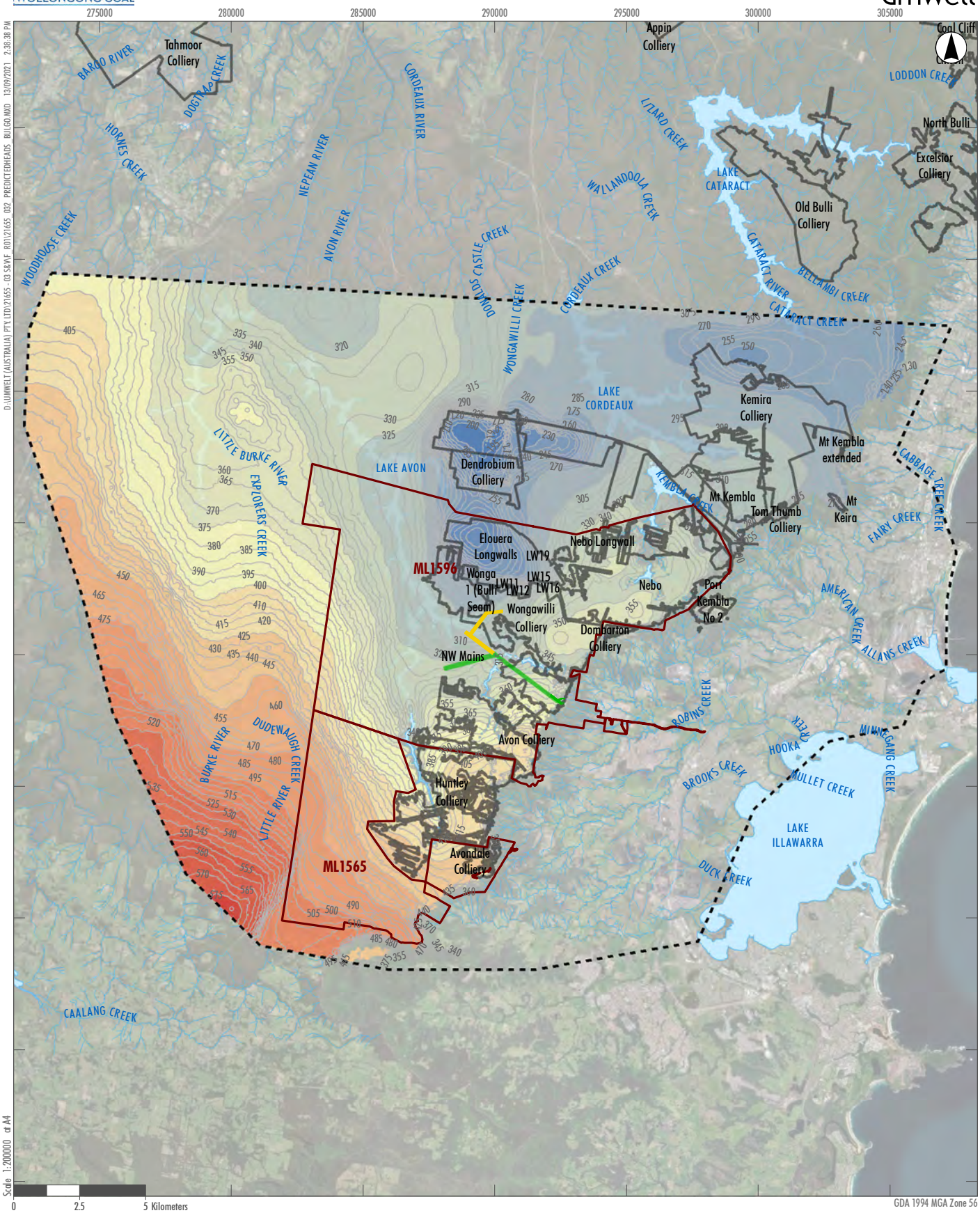
Modelled Groundwater Level (mAHD)

- 255 - 275
- 275 - 300
- 300 - 325
- 325 - 350
- 350 - 375
- 375 - 400
- 400 - 425
- 425 - 450
- 450 - 475
- 475 - 500
- 500 - 525
- 525 - 550
- 550 - 575
- 575 - 600
- 600 - 625
- 625 - 650

FIGURE 3.30

Modelled Heads (June 2020) Hawkesbury Sandstone (Layer 4)

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




## Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- 5m Contours
- Watercourse

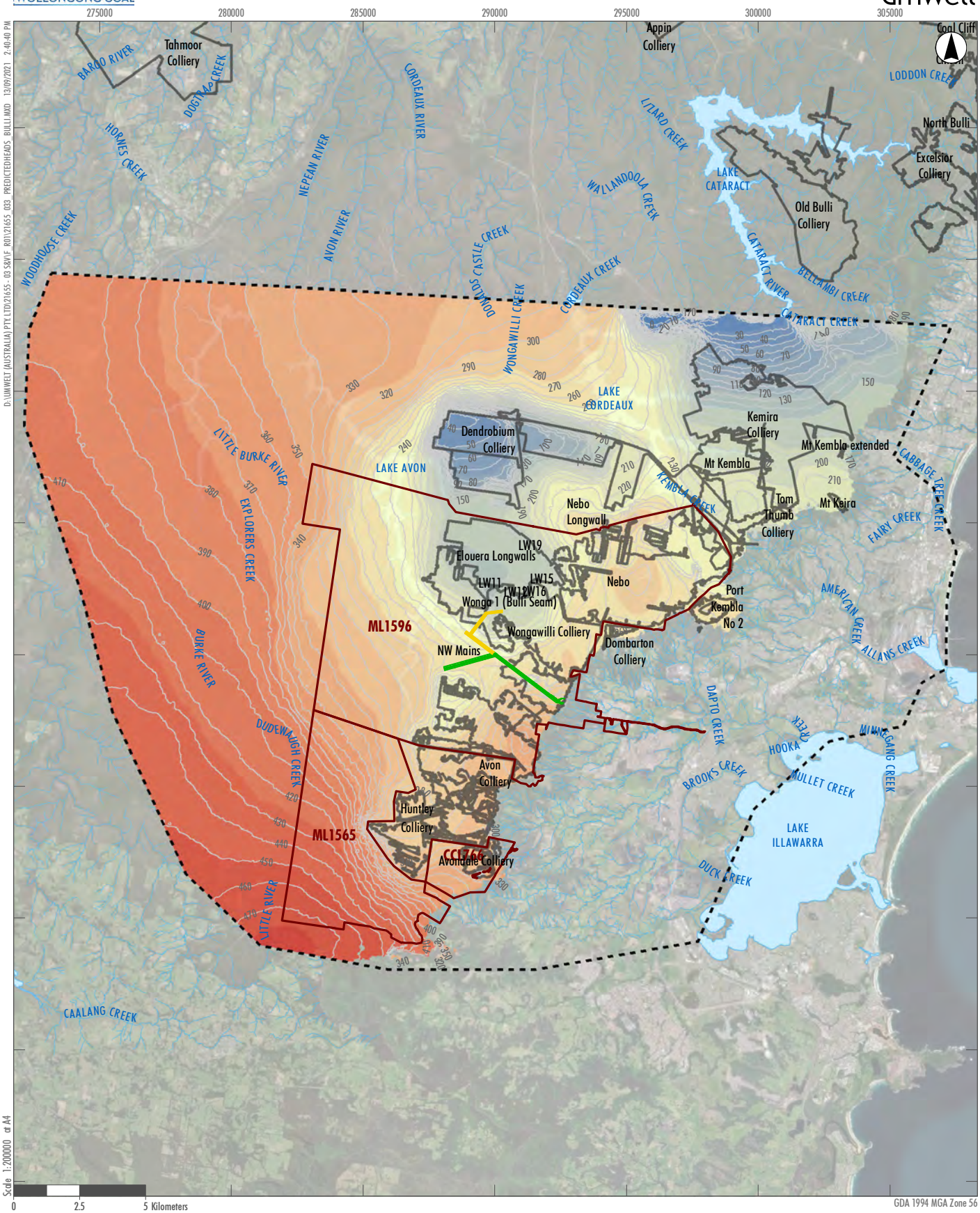
**Modelled Groundwater Level (mAHD)**

- 175 - 200
- 200 - 225
- 225 - 250
- 250 - 275
- 275 - 300
- 300 - 325
- 325 - 350
- 350 - 375
- 375 - 400
- 400 - 425
- 425 - 450
- 400 - 475
- 475 - 500
- 500 - 525
- 525 - 550
- 550 - 575
- 575 - 600

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)

FIGURE 3.31

# Modelled Heads (June 2020) Bulgo Sandstone (Layer 7)




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- 10m Contours
- Watercourse

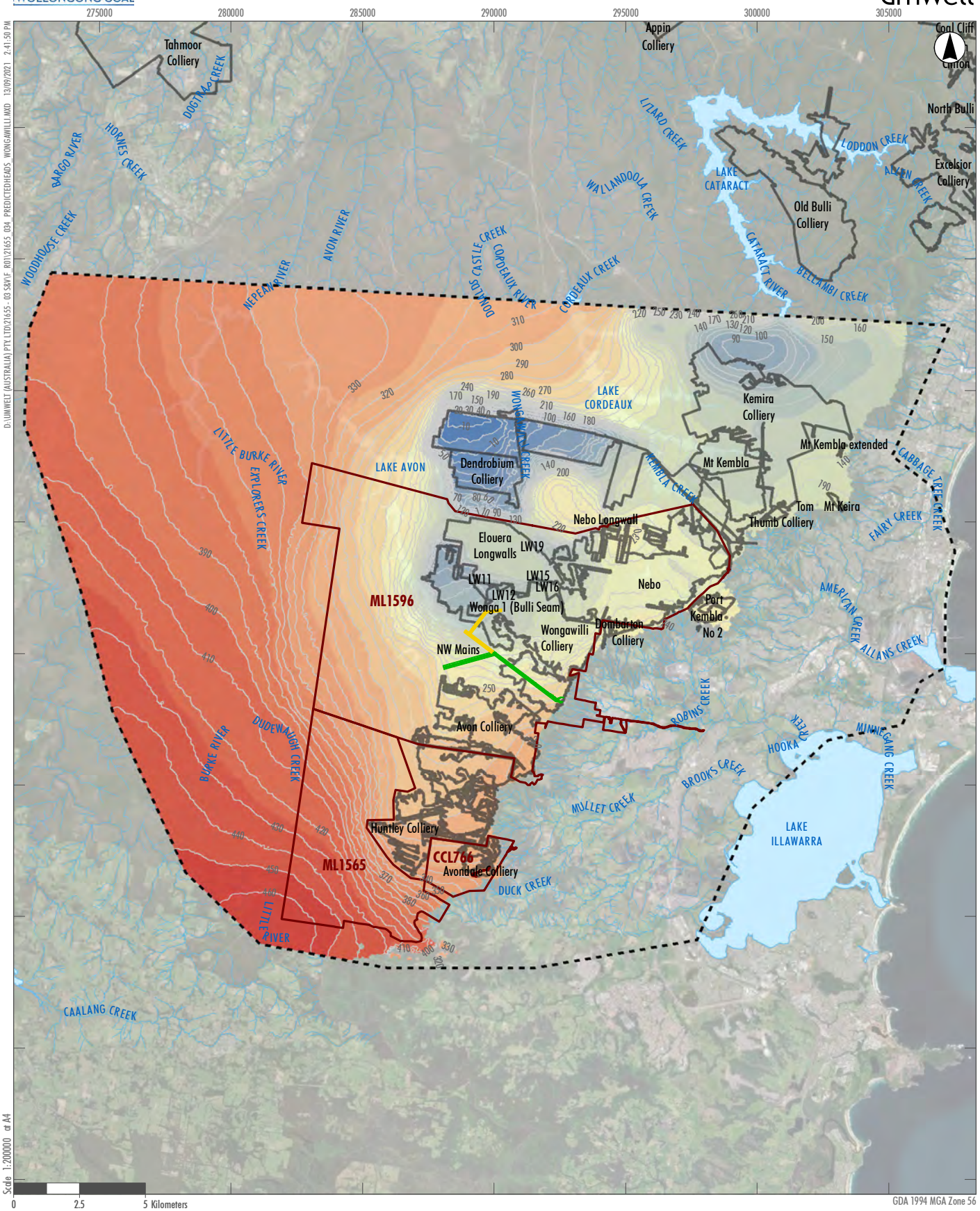
Modelled Groundwater Level (mAHD)

- -6 - 0
- 0 - 25
- 25 - 50
- 50 - 75
- 75 - 100
- 100- 125
- 125 - 150
- 150 - 175
- 175 - 200
- 200 - 225
- 225 - 250
- 250 - 275
- 275 - 300
- 300 - 325
- 325 - 350
- 350 - 375
- 375 - 400
- 400 - 425
- 425 - 450
- 450 - 475
- 475 - 500

FIGURE 3.32

Modelled Heads (June 2020) Bulli Seam (Layer 12)

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- 10m Contours
- Watercourse

Modelled Groundwater Level (mAHD)

- -25 - 0
- 0 - 25
- 25 - 50
- 50 - 75
- 75 - 100
- 100 - 125
- 125 - 150
- 150 - 175
- 175 - 200
- 200 - 225
- 225 - 250
- 250 - 275
- 275 - 300
- 300 - 325
- 325 - 350
- 350 - 375
- 375 - 400
- 400 - 425
- 425 - 450
- 450 - 475

FIGURE 3.33

Modelled Heads (September 2021) Wongawilli Seam (Layer 14)

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)

### 3.5.3 Model Performance

#### 3.5.4.1 Model Confidence Level Classification

Groundwater modelling has been conducted in accordance with the Australian Groundwater Modelling Guidelines (Barnett *et al*., 2012), the MDBC Groundwater Flow Modelling Guideline (MDBC, 2001) and the IESC Explanatory Note for Uncertainty Analysis (IESC, 2018). These are mostly generic guides and do not include specific guidelines on special applications, such as underground coal mine modelling.

The 2012 guide assigns a "model confidence level" (Class 1, Class 2 or Class 3 in order of increasing confidence) depending on:

- Available data (and the accuracy of those data) for the conceptualisation, design, and construction;
- Calibration procedures that are undertaken during model development;
- Consistency between the calibration and predictive analysis; and
- Level of stresses applied in predictive models.

Table 3-13 summarises the classification criteria and shows a scoring system allowing model classification. The criteria which are satisfied for this model have been bolded and the total number of criteria which are met for each classification is shown. As summarised in Table 3-13, the groundwater model developed for this Groundwater Assessment has satisfied 12 criteria for Class two and hence can be classified as primarily Class 2 (effectively "medium confidence") with some items meeting the Class 3 criteria, which is considered an appropriate level for this Project context.

Under the earlier MDBC (2001) modelling guidelines (Middlemis *et al*., 2001), the model is best categorised as an Impact Assessment Model of medium complexity. That earlier guide describes this model type as follows:

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

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

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

#### 3.5.4.2 Peer Review

As outlined in Section 1.5.3 a peer review of the groundwater impact assessment and modelling completed by SLR (2020) was conducted by Dr Doug Weatherill of EMM. The peer review found that the work completed was generally considered fit for the purpose of the Project. However, some limitations with the reporting were identified.

Umwelt have undertaken further work as presented in this report to address the peer review comments, along with government agency comments with a subsequent peer review conducted by Dr Weatherill in accordance with Australian Groundwater Modelling Guidelines (Barnett *et al*. 2012). The final peer review findings are included in Appendix C.

#### 3.5.4.3 Model Performance and Limitations

The model is considered fit for purpose for the Project. However, future improvements in the model setup, calibration and runs are recommended as new data becomes available and for any future approvals. These include:

- Refine the boundary conditions to remove no-flow cells where they might influence model predictions in future;
- Refine the EVT, RIV and CHD cells to minimise potential interactions between packages that may influence the water balance.
- Utilise observed mine inflow data for future model calibration.
- Undertake composite parametric sensitivity (parameter identifiability) analysis to determine influential parameters in the model. The results must be used to enhance the model calibration and guide the uncertainty analysis.
- Undertake uncertainty analysis guided by the results of comprehensive sensitivity analysis including parameter identifiability assessment
- No discrete fault zones are included in the Project area as no impacts or influence due to faults and dykes are predicted based on the SCT (2020) subsidence assessment. However, for future iterations of the model, further testing of the influence of fault zones should be considered, in line with subsidence assessment findings.
- Revise representation of historical mining within the transient calibration model, as discrepancies have been observed between the commencement of actual mining and the activation of mine drains in the model by SLR (2020). It is also recommended that the single 40-year long stress-period between 1940 and 2004 is split into multiple stress-periods to represent the timing of active mining prior to 2004 more accurately.

Table 3-13 Groundwater Model Classification Table

| Class | Data | | Classification | | Prediction | | Indicators | | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Not much | | Not Possible | | Timeframe>>calibration | | Timeframe>10x | | 1 |
| | Sparse | | Large error statistics | | Long stress periods | | Stresses>5x | | |
| | No metered usage | | Inadequate data spread | | Transient prediction but steady state calibration | | Mass balance>1% (or single 5%) | | |
| | Remote climate data | | Targets incompatible with model purpose | | Bad verification | | Properties<>Field | | |
| | | | | | | | Bad discretisation | | |
| | | | | | | | No review | | |
| 2 | Some data | 1 | Partial performance | 1 | Timeframe>calibration | 1 | Timeframe=3-10 | 1 | 13 |
| | Poor coverage | 1 | Long-term trends wrong | | Long stress periods | | Stresses=2-5x | 1 | |
| | Some usage info | | Short time record | | New stresses not in calibration | 1 | Mass balance<0.5% | 1 | |
| | Baseflow estimates | | Weak seasonal replication | 1 | Poor verification | 1 | Properties<>Field measurements | 1 | |
| | | | No use of targets compatible with model purpose | | | | Some key coarse discretisation | 1 | |
| | | | | | | | Reviewed by hydrogeologist | 1 | |
| 3 | Lots of data | | Good performance stats | | Timeframe ~ calibration | | Timeframe<3x | | 8 |
| | Good aquifer geometry | 1 | Long-term trends replicated | | Similar stress periods | | Stresses<2x | | |
| | Good usage info | | Seasonal fluctuations OK | | Similar stresses to those in calibration | | Mass balance<0.5% | 1 | |
| | Local climate info | 1 | Present day data targets | 1 | Steady state prediction consistent with steady state calibration | | Properties~ Field measurements | 1 | |
| | K measurements | 1 | Head and flux targets | | Good verification | | Some key coarse discretisation | | |
| | Hi –res DEM | 1 | | | | | Reviewed by modeller | 1 | |

Note: Bold indicates when a condition has been met

## 3.6 Predictive Modelling Approach

Potential impacts of the Project were assessed by making comparisons between baseline predictive runs and stressed predictive runs (with the Project simulated as outlined later in this report section). This allows the simulated impact of the Project on the hydrogeological environment to be isolated from other modelled processes that cause changes in groundwater levels (such as recharge and river leakage).

Three predictive model scenarios were run:

1. No Mining: A baseline scenario without any mining stresses (i.e. a 'no mining' or 'null' run as per Barnett *et al*., 2012);
2. Approved: A baseline scenario with approved and foreseeable mining within the model domain at Dendrobium, but no active mining within ML1596 during the predictive run; and
3. Approved plus Project: A predictive scenario with approved and foreseeable mining plus proposed mining stresses associated with the Project (NWM and NWMD).

The two baseline scenarios enable the assessment of cumulative and incremental impacts due to the project. Cumulative impacts are based on the difference in model simulation results between the "No Mining"-scenario and the scenario "Approved plus Project". Incremental impacts are based on the difference in model simulation results between the "Approved"-scenario and the scenario "Approved plus Project".

All models used the same steady-state calibration period, which ensures that initial heads for all predictive and baseline runs are the same. The calibrated transient historical period is the same for all scenarios, except for the "No Mining" scenario in which all historic mining stresses are removed. The predictive transient model runs ran from 01/Jul/2020 to 31/Dec/2550, where mining ends at 31/Dec/2049 in the "Approved" and "Approved plus Project" scenario.

As described in Section 3.3.7 and Section 3.3.8, the model represented proposed and other mining using the drain (DRN) package and time-variant material (TVM) package. During the predictive run, drain cells were used to simulate the dewatering effect of the proposed mine and other mines in the area. A nominally high drain conductance of 100 $m^2$/day was applied to the drain cells and the elevation of the base of the modelled layer was used as the drain level. For the Project, during the predicted mine year, the drain cells were set to the base of the target coal seam, either layer 12 (Bulli Seam) or layer 14 (Wongawilli Seam). It was assumed that the driveages would remain dewatered for the duration of the underground mining, and therefore drains once activated, were active until the final year of mining. At the completion of mining, the drains undertaking the dewatering are removed and void parameters are assigned to these model cells with the TVM package. Details on the timing of mining in the predictive model scenarios are presented in Table 3-2.

## 3.7 Predictive Model Mass Balance

Table 3-14 and Table 3-15 show the average rates of water transfer into and out of the model over the period of the predictive model (July 2020 to December 2049) for the "Approved" scenario and "Approved plus Project" scenario, respectively.

In both scenarios, rainfall recharge to the groundwater system is 179.29 ML/day and 0.96 ML/day entering the model through the regional groundwater flow (GHB). Evapotranspiration for the predictive model is 160.85 ML/day where the groundwater is within 3 m of the ground surface across the model domain. 18.38 ML/day of water exits the model through baseflow and through the minor drainages. The mass balance discrepancy for both predictive models was less than 0.01% indicating that the model achieved an accurate numerical solution.

A comparison between water budgets in Table 3-14 and Table 3-15 indicates no change in recharge, surface water discharge and evapotranspiration between the "Approved" and the "Approved plus Project" scenarios.

The model predicts that, with the Project, an additional 0.08 ML/day on average would be captured by the Project.

Table 3-14 Average Predictive Model Mass Balance – Approved **(July 2020 to December 2049)**

| | Inflow (ML/day) | Outflow (ML/day) |
|---|---|---|
| Recharge | 179.29 | 0.00 |
| ET (From GW (EVT) | 0.00 | 160.85 |
| Rivers (RIV) | 11.94 | 18.38 |
| Regional GW Flow (GHB) | 0.91 | 0.41 |
| Constant Head (CHD) | 0.00 | 2.54 |
| Mines (DRN) | 0.00 | 3.28 |
| Storage | 14.01 | 20.70 |
| Total | 206.16 | 206.16 |
| % Error | 0.00 | 0.00 |

Table 3-15 Average Predictive Model Mass Balance – Approved Plus Project **(July 2020 to December 2049)**

| | Inflow (ML/day) | Outflow (ML/day) |
|---|---|---|
| Recharge | 179.29 | 0.00 |
| ET (From GW (EVT) | 0.00 | 160.85 |
| Rivers (RIV) | 11.94 | 18.38 |
| Regional GW Flow (GHB) | 0.91 | 0.41 |
| Constant Head (CHD) | 0.00 | 2.54 |
| Mines (DRN) | 0.00 | 3.36 |
| Storage | 14.08 | 20.70 |
| Total | 206.23 | 206.23 |
| % Error | 0.00 | 0.00 |

## 3.8 Recovery Modelling

As reported by SLR (2020), post mining impacts were investigated with a recovery model time period, commencing from the end of the predictive model and run for 500 years. The transient simulation was created for the purpose of predicting postmining inflows, with all predictive model drain cells removed. The recovery model was a continuation of the predictive mining periods, where groundwater levels recover and eventually equilibrate. At the end of mining, the properties of the mined cells are maintained from the TVM package to simulate representative goaf properties. These properties, specifically high storage parameters (specific yield of 0.1, storage coefficient of 5.0 x $10^{-5}$ $m^{-1}$ based on the compressibility of water), are applied to simulate increased water storage within the mined cells. Similarly, in surrounding mines where longwall mining was simulated, the cracking parameters were maintained.

Umwelt reviewed the model packages developed by SLR (2020) and identified slight differences between the Approved and Approved Plus Project scenarios in the TVM setup and properties in some localised areas. The differences appear to be around Eloeura and Dendrobium, and are unrelated to the Project design. These differences are very slight but can cause incremental differences in simulation results between the approved and Project model scenarios for the long-term post closure period. This would result in over-prediction of potential impacts due to the Project.

# 4. GROUNDWATER IMPACT ASSESSMENT

This section describes the numerical model predictions and potential impacts from the Project, including the:

- Drawdown in groundwater levels in the Triassic sediments and Permian coal measures as a result of the Project and cumulative impacts (Section 4.1);
- Groundwater take (Section 4.2);
- Drawdown for groundwater users – anthropogenic and environmental (Section 4.3 and Section 4.4);
- Post closure equilibrium conditions (Section 4.5);
- Water licensing requirements (Section 4.6); and
- Potential for impacts on groundwater quality (Section 4.7).

## 4.1 Drawdown and Depressurisation

The main development as part of the Project will result in localised depressurisation of the coal seam and immediately overlying stratigraphy. With the confined conditions in the Narrabeen Group and Permian coal measures, the groundwater potentiometric surface is higher than the elevation at which the unit occurs (refer Section 2.10). With the progression of mining, the pressure head is reduced (depressurisation) with dewatering of mine inflows and removal of moisture captured in coal material. However, depressurisation, or depression of the potentiometric surface, does not necessarily result in desaturation of the coal seam.

The predicted change in groundwater potentiometric surface due to the Project during active operations to the end of mining in model year 5 (to end of 2025) is presented in Section 4.1.1. The predicted change in groundwater potentiometric surface due to the Project plus surrounding mining (i.e. Dendrobium) is presented in Section 4.1.3.

### 4.1.1 Project Drawdown and Depressurisation – End of Mining

This section presents the predicted depressurisation in the coal seams and immediately overlying units, during Project operations. This is the incremental additional impact due to the Project to the end of mining in model year 5 (to end of 2025), which conservatively includes the already approved NWM and the NWMD.

Figure 4-1 to Figure 4-4 show the predicted depressurisation within Bulgo Sandstone (Layer 7), Scarborough Sandstone (Layer 9), Bulli Seam (Layer 12) and Wongawilli Seam (Layer 14) at the end of mining (end of 2025).

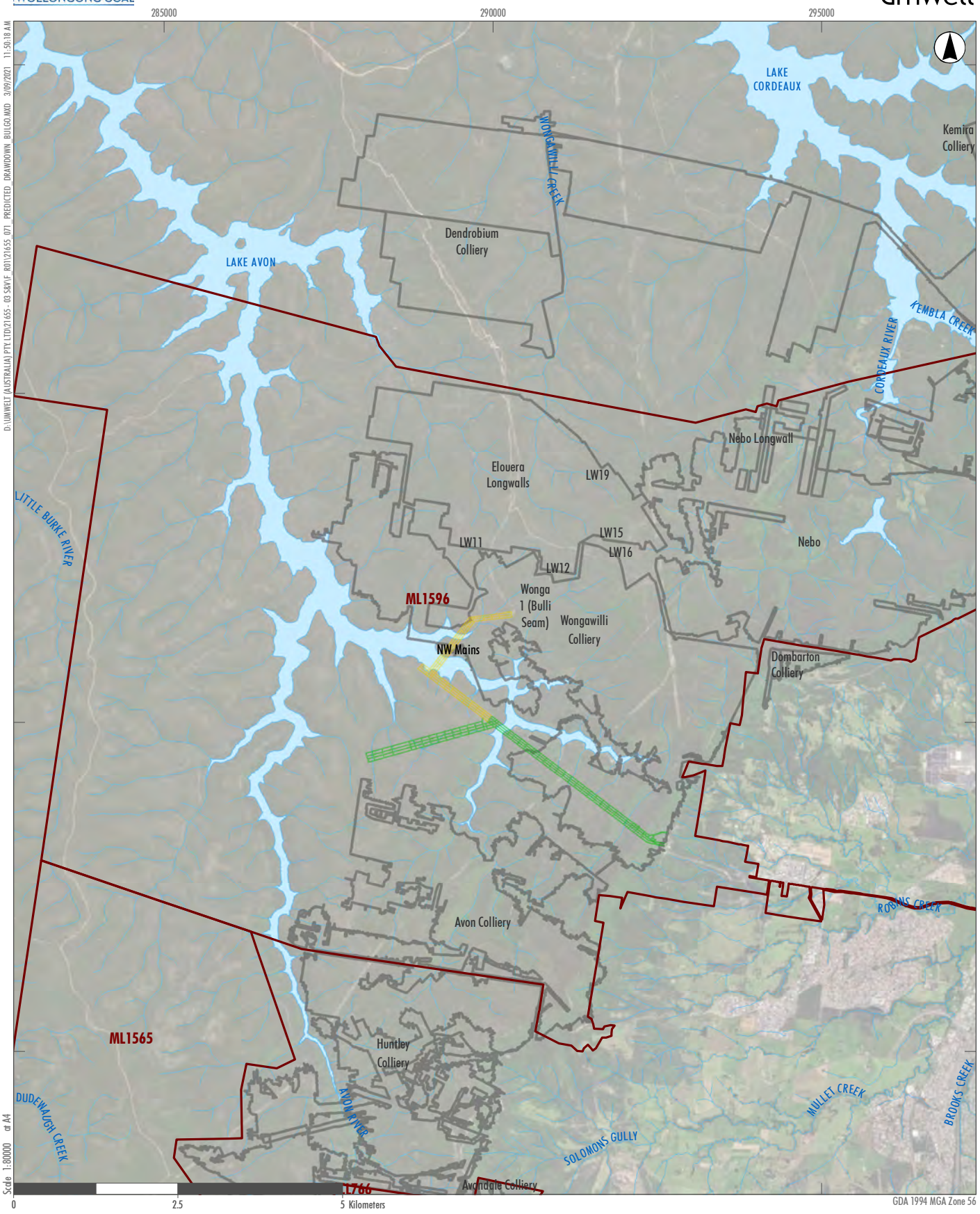
No depressurisation or drawdown greater than 1 m was predicted at the end of mining within the Hawkesbury Sandstone (Layer 4) or Bulgo Sandstone (Layer 7).

Key results are summarised as follows:

- no depressurisation greater than 1 m predicted in the Hawkesbury Sandstone (Layer 4) at the end of mining, as previously reported by SLR (2020).
- Figure 4-1 shows there is no depressurisation greater than 1 m predicted in the Bulgo Sandstone (Layer 7) at the end of mining , as previously reported by SLR (2020).
- Figure 4-2 shows depressurisation localised above the proposed mains development within the Scarborough Sandstone (Layer 9). The maximum predicted extent of 1 m depressurisation due to the Project extends around 1 km to the north, 1 km to the south and 2.5 km to the west of the mains. This predicted depressurisation in the Scarborough Sandstone relates to depressurisation of the mined coal seam. This depressurisation to the

overlying stratigraphy is also potentially facilitated by existing vertical connectivity between the coal seam and Lower Narrabeen Group units from historical mining in the area. The Project is not predicted to result in any changes to hydraulic connectivity above the workings.

- Figure 4-3 shows localised depressurisation within the Bulli Seam (Layer 12) around the proposed mains development, as previously reported by SLR (2020). The drawdown in the Bulli Seam at the end of mining is localised around the workings, extending up to 3 km west of the Project. There is limited predicted drawdown in the east along the alignment of the approved NWM, this is due to modelled groundwater levels being below the model layer at the commencement of mining, as is presented in the conceptualisation (Section 2.10)
- Figure 4-4 shows localised depressurisation within the Wongawilli Seam (Layer 14) around the proposed mains development, as previously reported by SLR (2020). The maximum predicted extent of 1 m depressurisation due to the Project extends up to 2 km west of the Project. The drawdown is localised at the western end of the approved NWM alignment, where the Bulli Seam mains decline down to the Wongawilli Seam.




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Watercourse

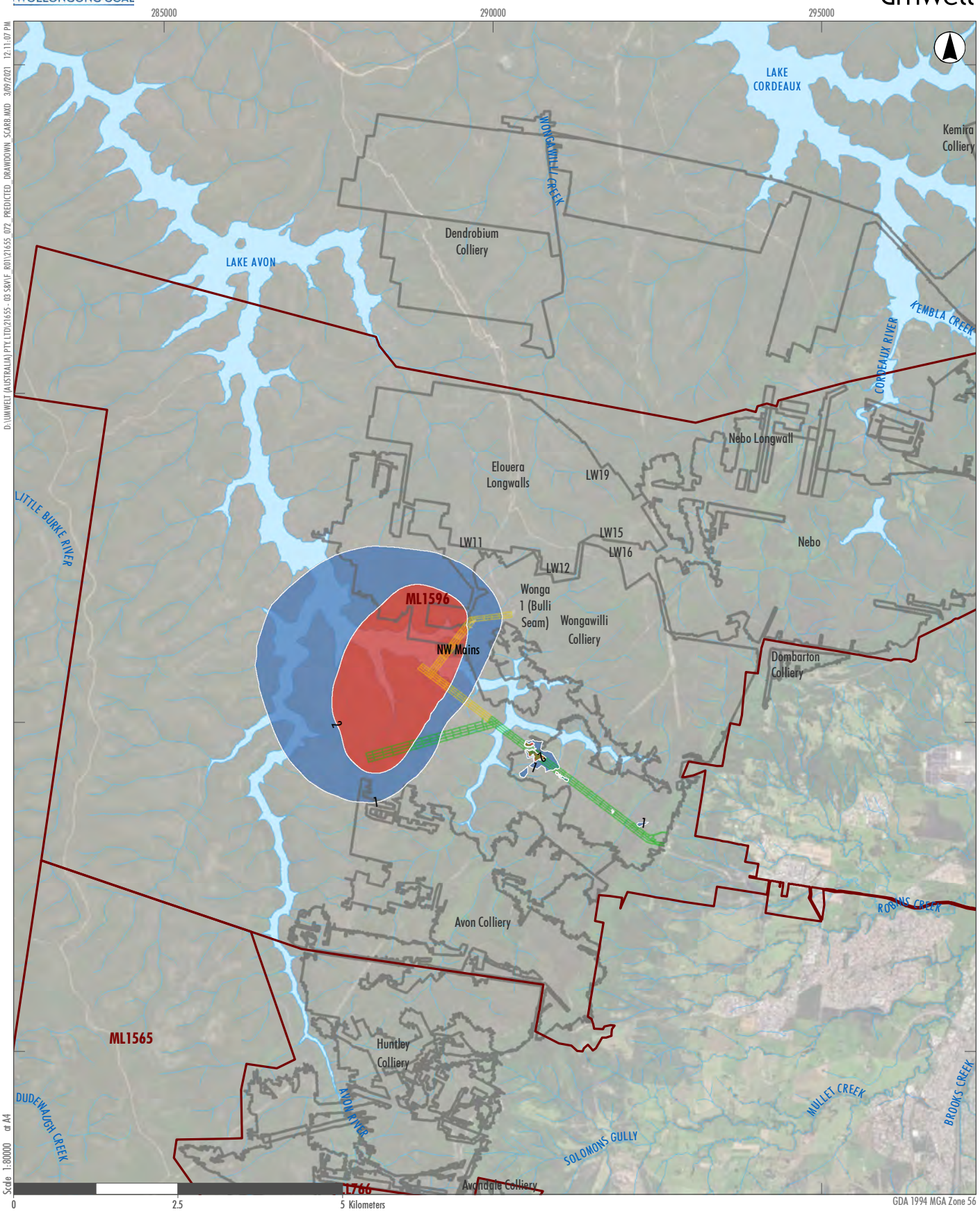
Predicted Drawdown (m)

- No Predicted Drawdown

FIGURE 4.1

Predicted Drawdown Due to Project - End of Mining - Bulgo Sandstone (Layer 7)

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Watercourse
- Contours

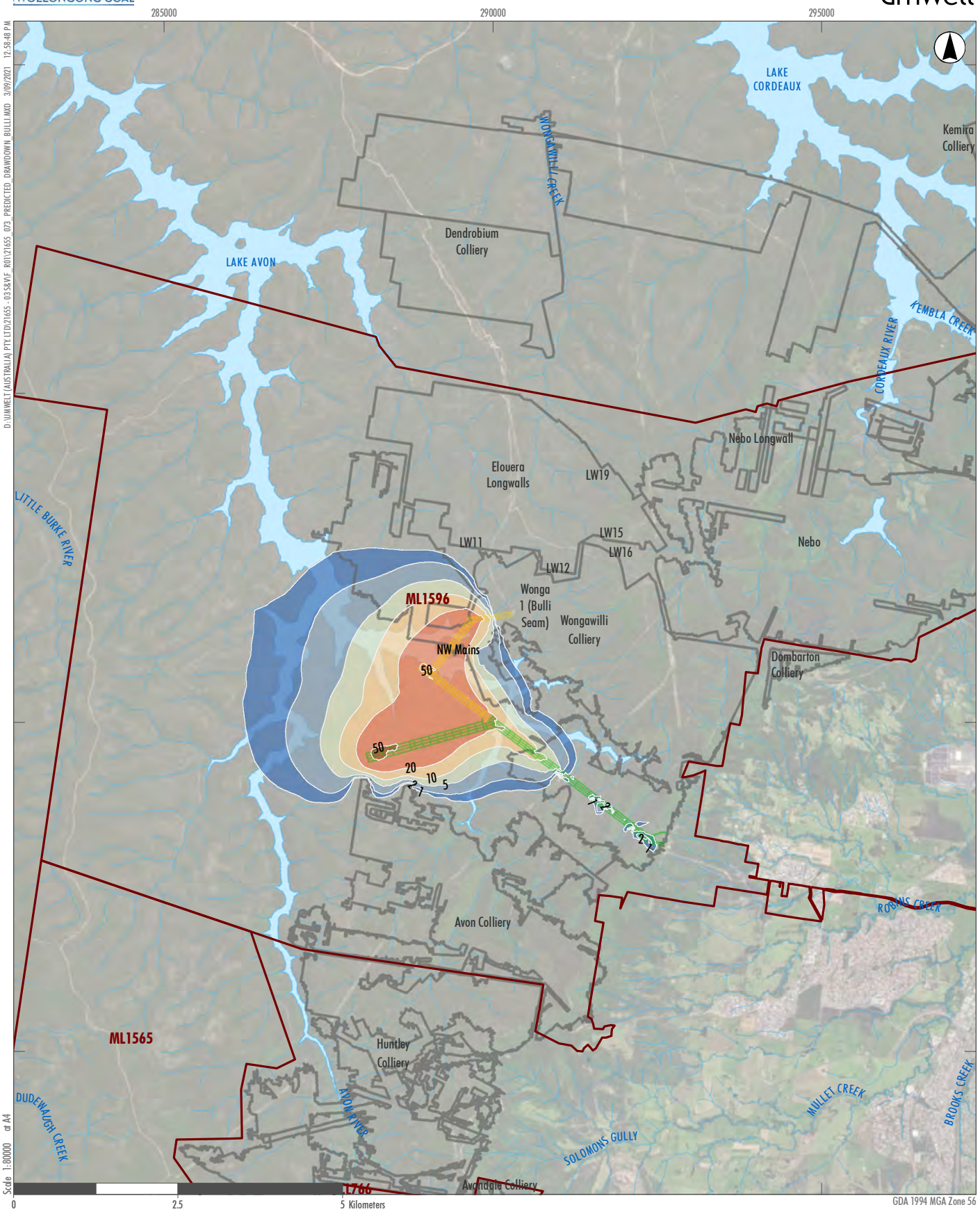
Predicted Drawdown (m)

- 1 - 2
- 2 - 5

FIGURE 4.2

Predicted Drawdown Due to Project - End of Mining - Scarborough Sandstone (Layer 9)

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Watercourse
- Contours

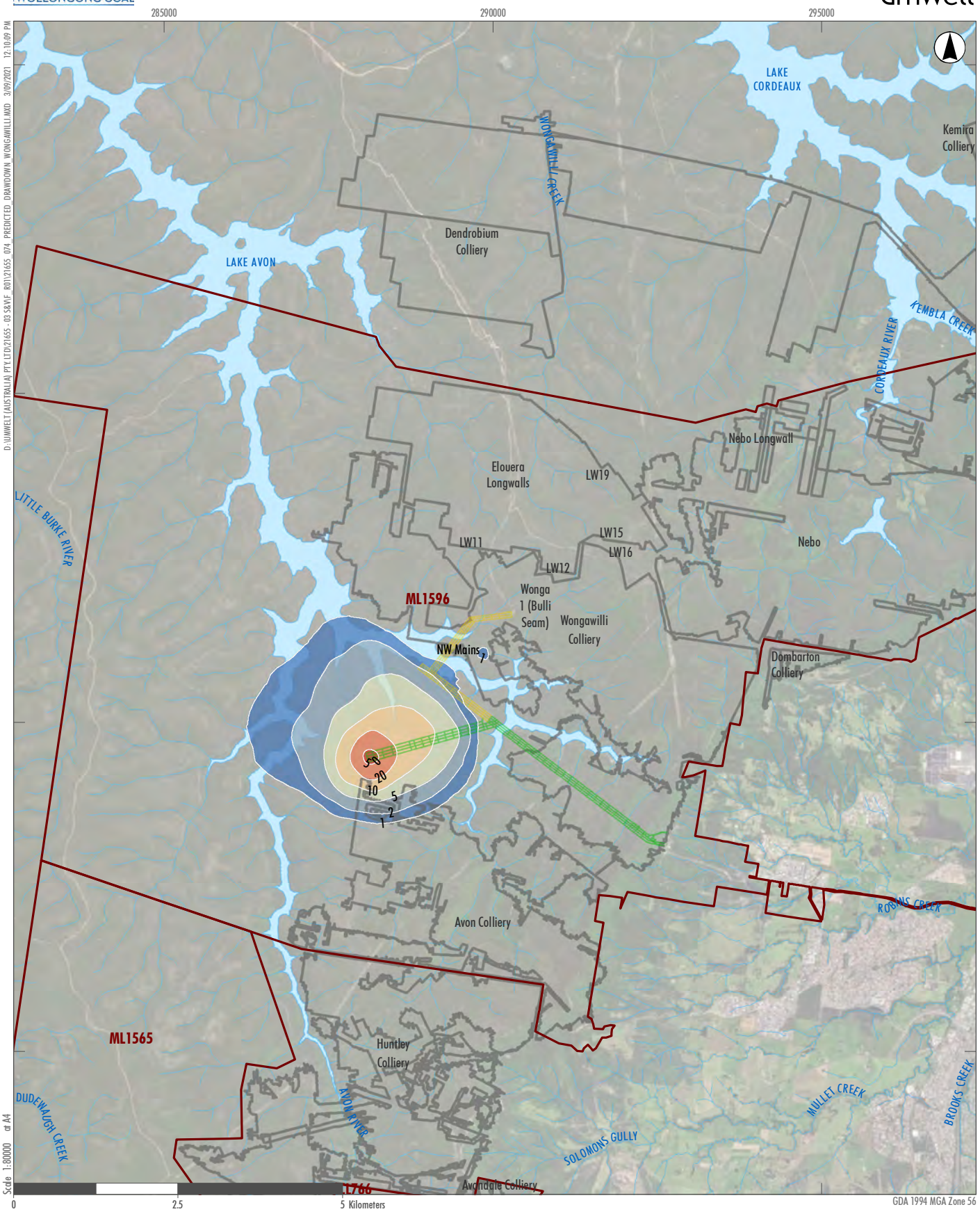
Predicted Drawdown (m)

- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 - 100

FIGURE 4.3

Predicted Drawdown Due to Project - End of Mining - Bullii Seam (Layer 12)

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Watercourse
- Contours

Predicted Drawdown (m)

- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 - 100

FIGURE 4.4

Predicted Drawdown Due to Project - End of Mining - Wongawilli Seam (Layer 14)

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)

### 4.1.2 Project Drawdown and Depressurisation - Maximum

Due to the short Project timeframe (5 years), in some areas, the maximum depressurisation occurs following active mining. This section presents the maximum predicted depressurisation due to the Project, from model year 1 (2021) to model year 29 (end of 2049).

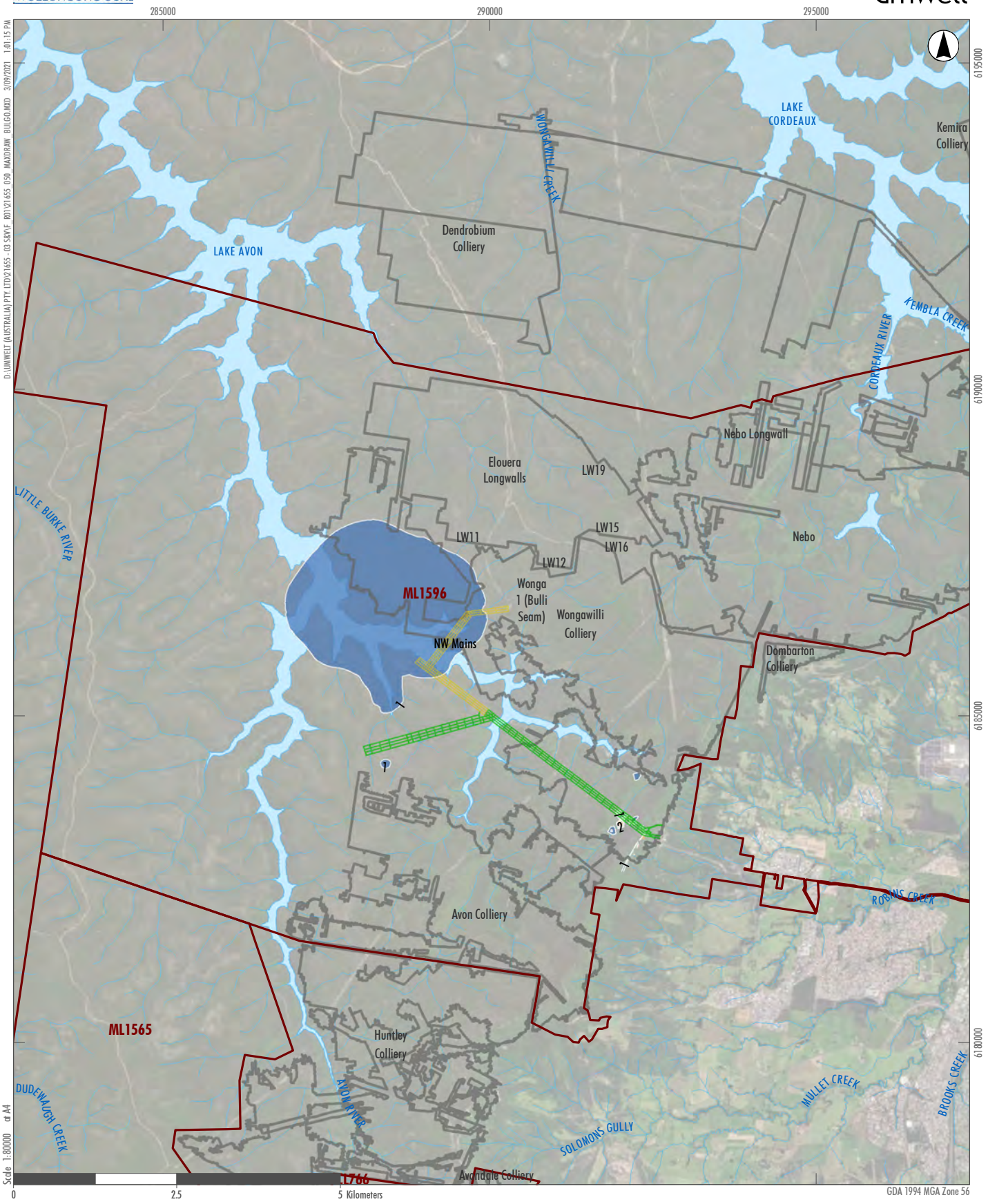
It should be noted that the predictive model replicates average rainfall recharge and includes no-flow boundary conditions to the south-west. This produces conservative predictions due to low recovery to the groundwater system, resulting in potentially increased drawdown extents (i.e. worst case predictions).

Figure 4-5 to Figure 4-8 show the maximum predicted depressurisation within Bulgo Sandstone (Layer 7), Scarborough Sandstone (Layer 9), Bulli Seam (Layer 12) and Wongawilli Seam (Layer 14). The results show the incremental additional impact due to the Project, which conservatively includes the already approved NWM and the NWMD. The results present the maximum predicted change in water levels on a cell-by-cell basis at any point in time from model year 1 to 29 (to the end of 2049).

No maximum depressurisation or drawdown greater than 1 m was predicted within the overlying upper Bulgo Sandstone (Layer 6) or Hawkesbury Sandstone (Layer 4) over this post mining period.

Key results are summarised as follows:

- Figure 4-5 shows depressurisation above the proposed mains development within the lower Bulgo Sandstone (Layer 7). The maximum predicted extent of 1 m depressurisation due to the Project extends up to 1 km to the north and 2.5 km west of the mains. The depressurisation appears to occur in an area north-west of the Project area, above historical Wongawilli workings. Negligible change in groundwater levels (<1 m) was predicted for the upper Bulgo Sandstone (Layer 6).
- Figure 4-6 shows depressurisation localised above the proposed mains development within the Scarborough Sandstone (Layer 9). The maximum predicted extent of 1 m depressurisation due to the Project extends up to 2 km to the north, 2 km south and 5.3 km to the west of the mains. This predicted depressurisation in the Scarborough Sandstone is potentially facilitated by existing vertical connectivity between the coal seam and lower Narrabeen Group units from historical mining. The Project is not predicted to result in any changes to hydraulic connectivity above the workings.
- Figure 4-7 shows localised depressurisation within the Bulli Seam (Layer 12) around the proposed mains development. As previously reported by SLR (2020), drawdown in the Bulli Seam at the end of mining is localised around the workings, extending up to 2 km west of the Project. The extent of depressurisation increases following active mining. The maximum predicted extent of 1 m depressurisation due to the Project extends up to 3 km to the north, 2 km to the south and 4.5 km to the west of the mains. The extent of depressurisation is within ML1596 and does not extend to Dendrobium (to the north).
- Figure 4-8 shows localised depressurisation within the Wongawilli Seam (Layer 14) around the proposed mains development, as previously reported by SLR (2020). The maximum predicted extent of 1 m depressurisation due to the Project extends up to 4 km to the north, 2 km to the south and 4.5 km to the west of the mains. The extent of depressurisation is within ML1596 and does not extend to Dendrobium.




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Watercourse
- Contours

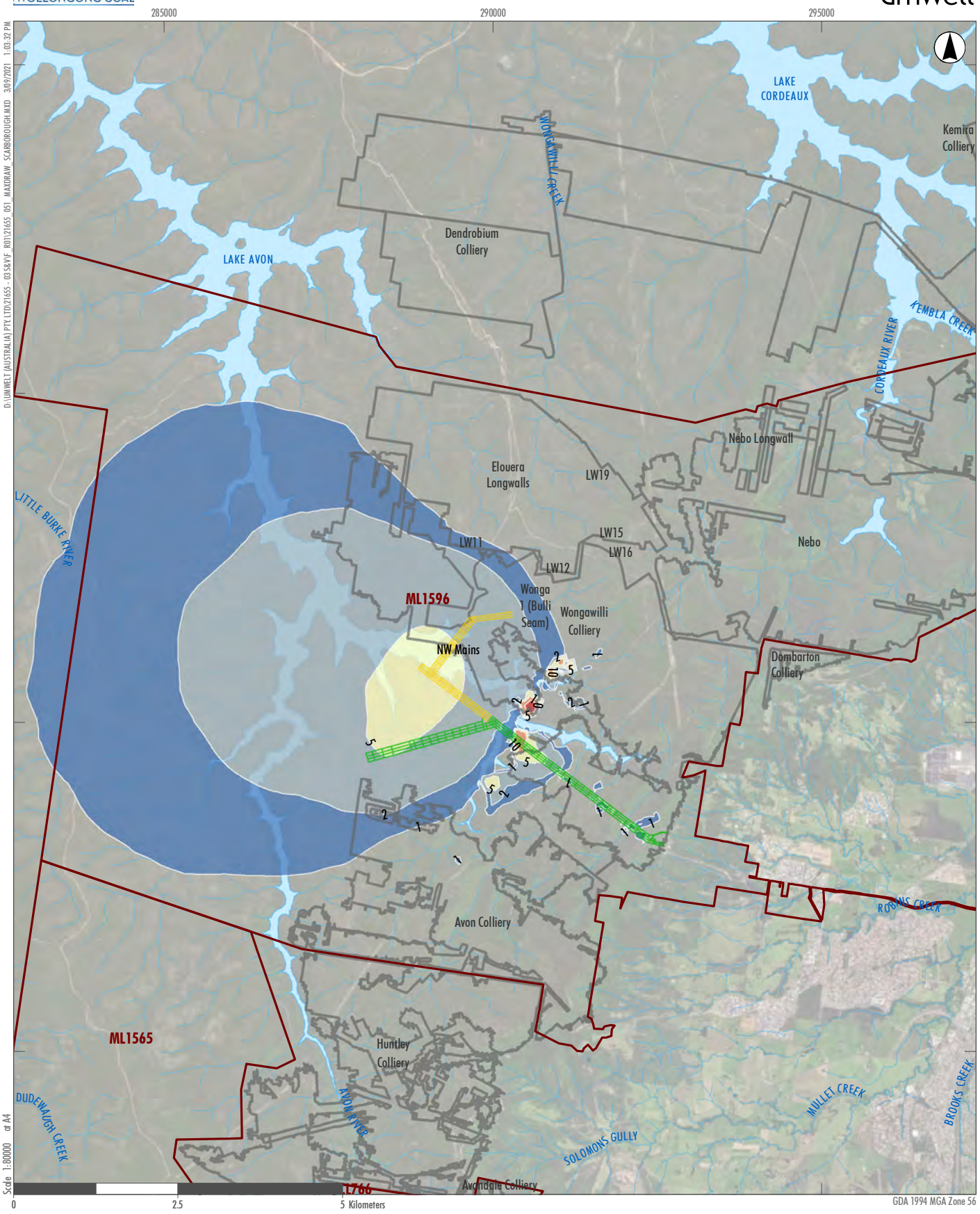
Predicted Drawdown (m)

- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20

FIGURE 4.5

Maximum Predicted Drawdown Due to Project - Bulgo Sandstone (Layer 7)

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Watercourse
- Contours

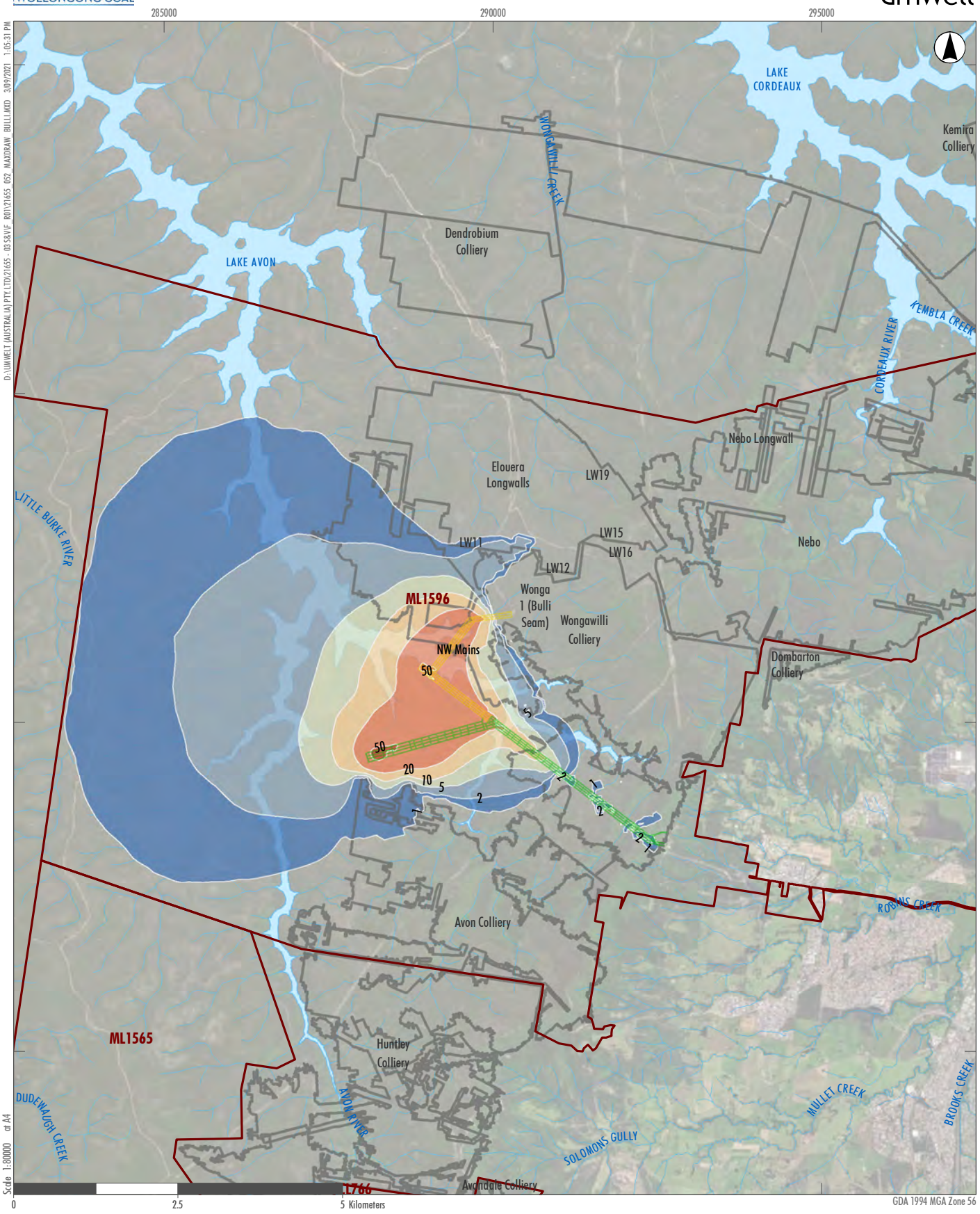
Predicted Drawdown (m)

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

FIGURE 4.6

Maximum Predicted Drawdown Due to Project - Scarborough Sandstone (Layer 9)

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Watercourse
- Contours

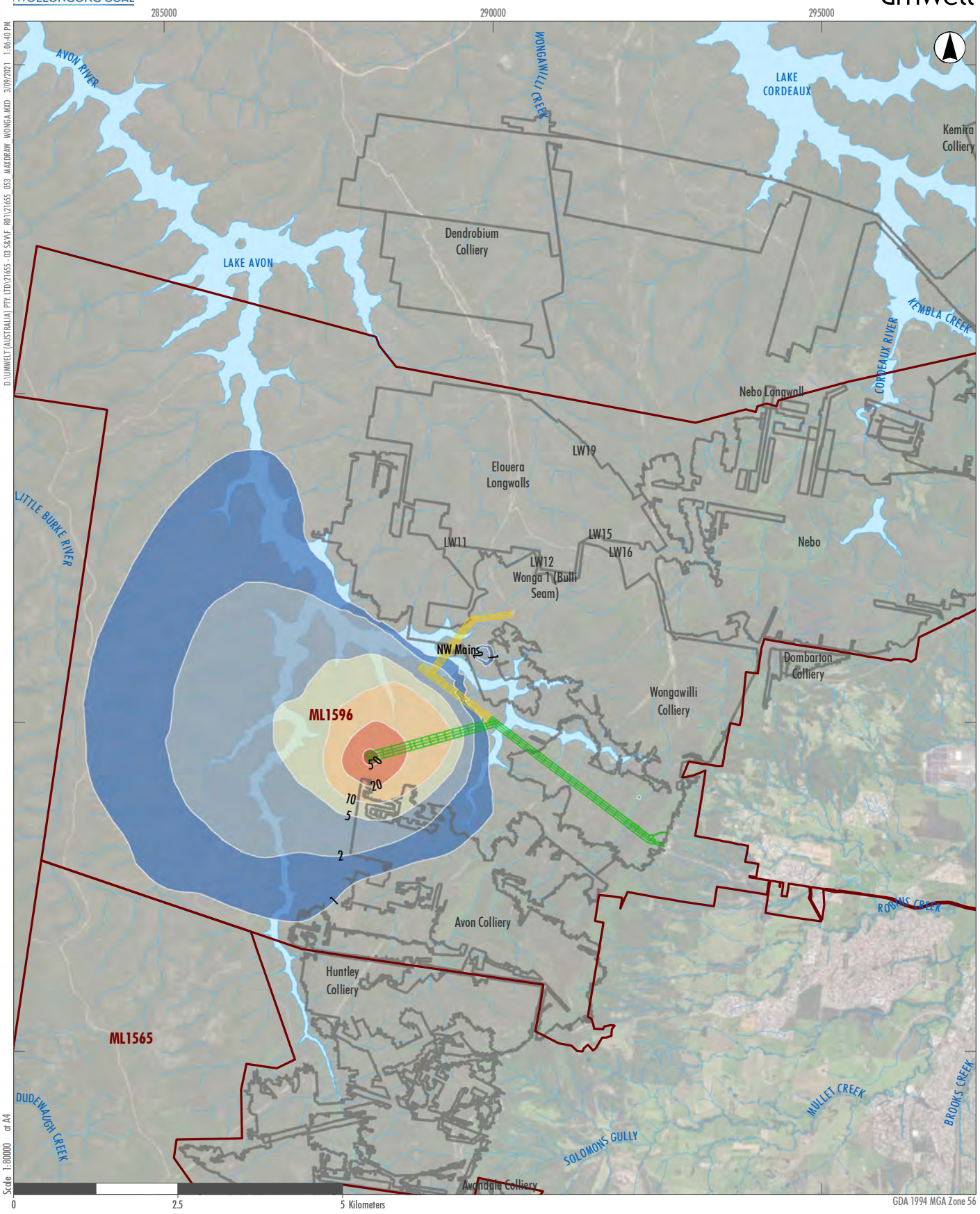
Predicted Drawdown (m)

- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 - 100

FIGURE 4.7

Maximum Predicted Drawdown Due to Project - Bulli Seam (Layer 12)

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Watercourse
- Contours

Predicted Drawdown (m)

- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 - 100

FIGURE 4.8

Maximum Predicted Drawdown Due to Project - Wongawilli Seam (Layer 14)

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)

### 4.1.3 Cumulative Drawdown and Depressurisation - Maximum

This section presents the maximum predicted cumulative drawdown of the water table and depressurisation by model layer/unit, from model year 1 (2021) to model year 29 (end of 2049).

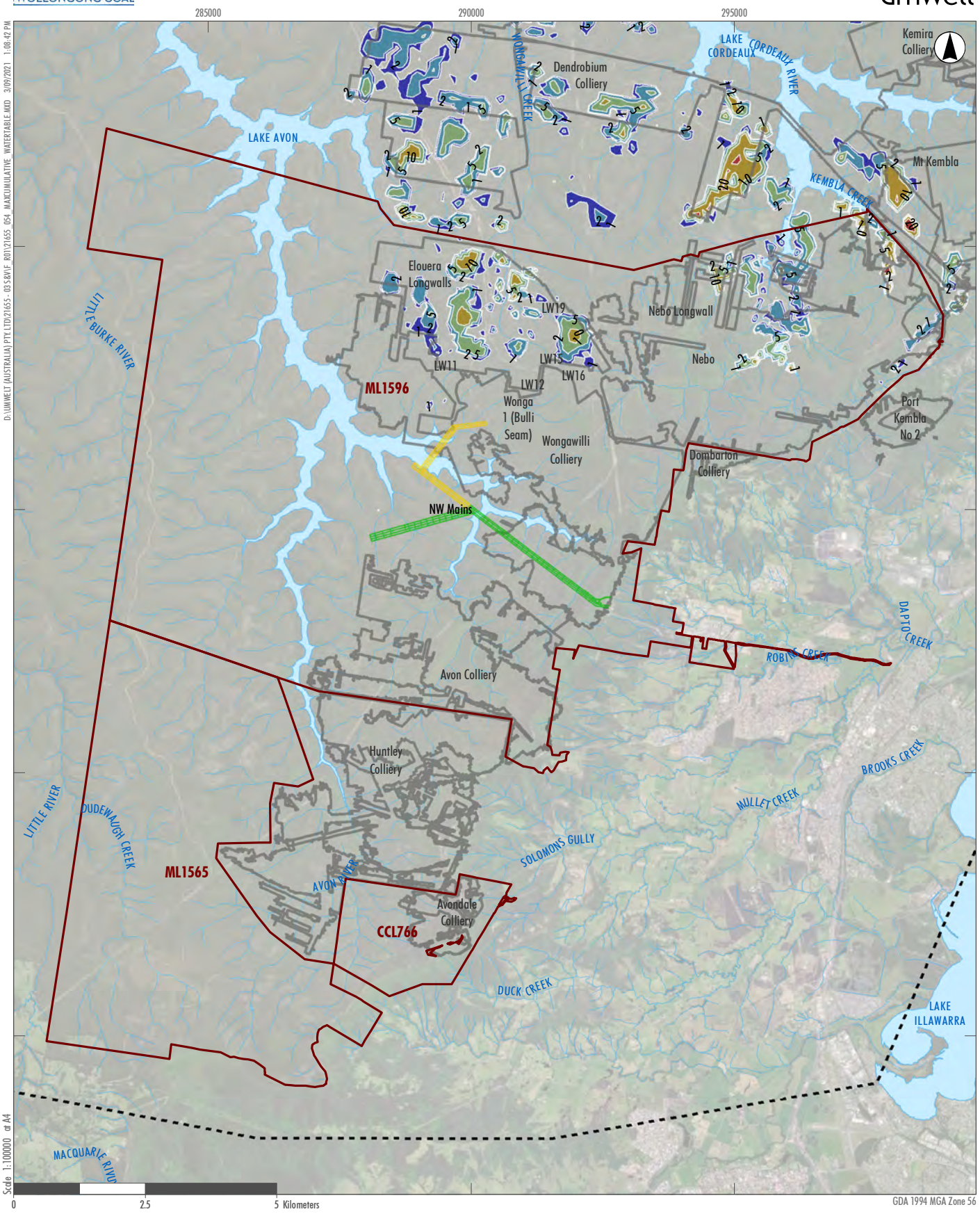
The cumulative drawdown represents the combined change in groundwater potentiometric surface due to the Project, historical mining in the region and active approved mining at Dendrobium. The cumulative drawdown was calculated by comparing groundwater levels from the 'No Mining' model, to results for the Project model run.

Due to the long history of mining in the region, comparison to the 'No Mining' run also captures historical drawdown impacts. This can be seen with depressurisation localised along the historical workings, including Elouera longwall workings, Kemira and Avondale. As presented in Appendix F, the 'No Mining' run predicted groundwater levels that are higher than observed groundwater levels. These results are therefore considered indicative of long-term historical changes, not just future cumulative impacts.

Figure 4-9 to Figure 4-14 show the maximum predicted cumulative drawdown for the water table (regardless of layer), as well as predicted depressurisation within individual model layers. This includes depressurisation within the Hawkesbury Sandstone (Layer 4), Bulgo Sandstone (Layer 7), Scarborough Sandstone (Layer 9), Bulli Seam (Layer 12) and Wongawilli Seam (Layer 14).

Key results are summarised as follows:

- Figure 4-9 shows predicted drawdown of the water table due to cumulative mine operations. Cumulative water table drawdown is predicted in localised areas above the historical Elouera longwall workings, Nebo and Dendrobium. No water table drawdown is predicted above the Project.
- Figure 4-10 shows no depressurisation in the Hawkesbury Sandstone (Layer 4) is predicted above the Project, with predicted depressurisation within localised areas around the historical Elouera longwall workings and Dendrobium (to the north).
- Figure 4-11 shows depressurisation within the lower Bulgo Sandstone (Layer 7) due to historical and future mining across the region. Cumulative impacts of more than 100 m extend into ML1596 from the Elouera workings and Dendrobium located in the north.
- Figure 4-12 shows extensive depressurisation within the Scarborough Sandstone (Layer 9) around the historical workings across the region. Cumulative impacts of more than 100 m extend into ML1596 from the Elouera workings and Dendrobium located in the north.
- Figure 4-13 and Figure 4-14 show extensive depressurisation within the Bulli Seam (Layer 12) and Wongawilli Seam (Layer 14) across all historical workings, including the historical workings at Avondale and Kemira. Cumulative impacts of more than 200 m extend into ML1596.




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- Watercourse
- Contours

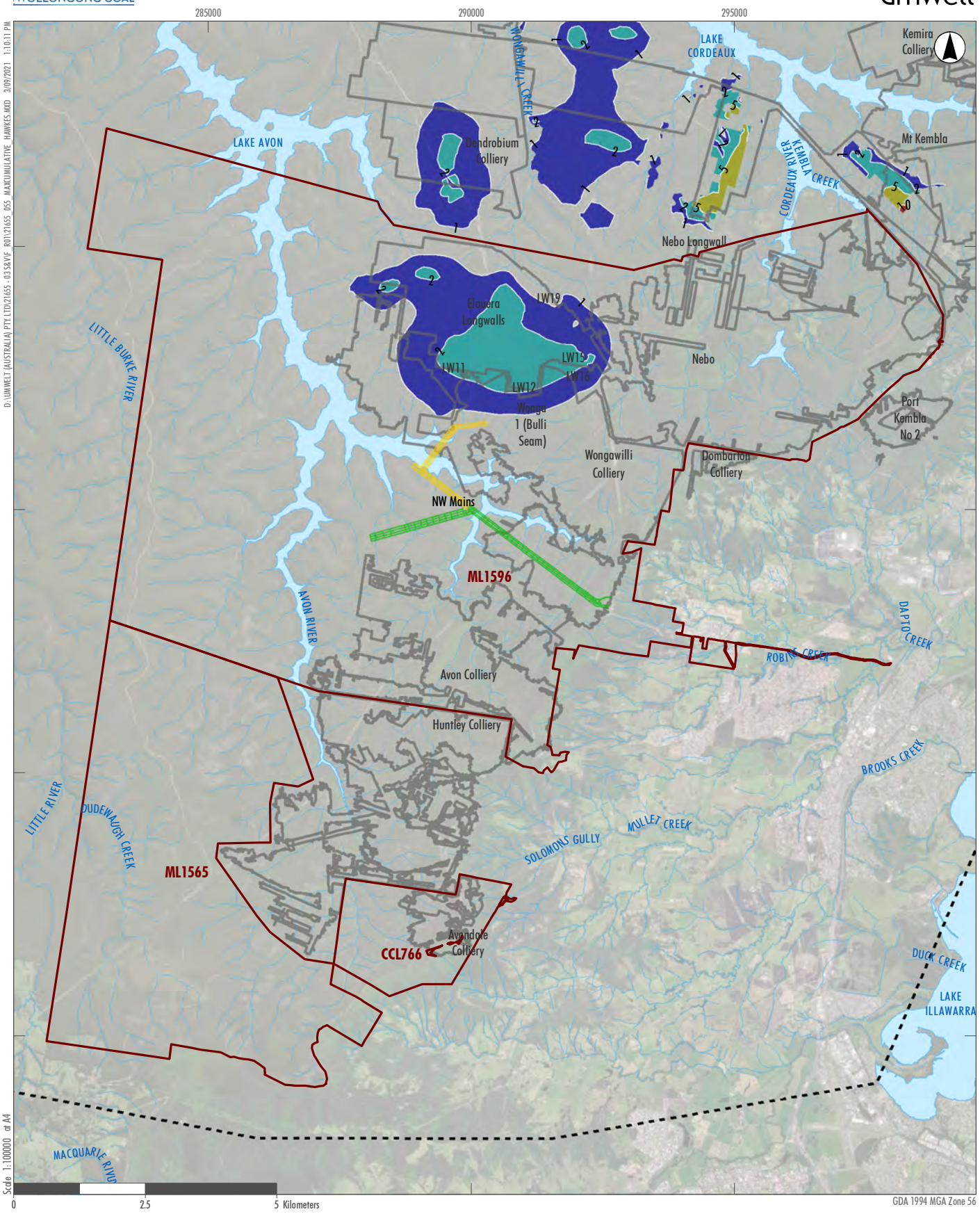
Predicted Drawdown (m)

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

FIGURE 4.9

## Maximum Predicted Cumulative Drawdown - Water Table

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- Watercourse
- Contours

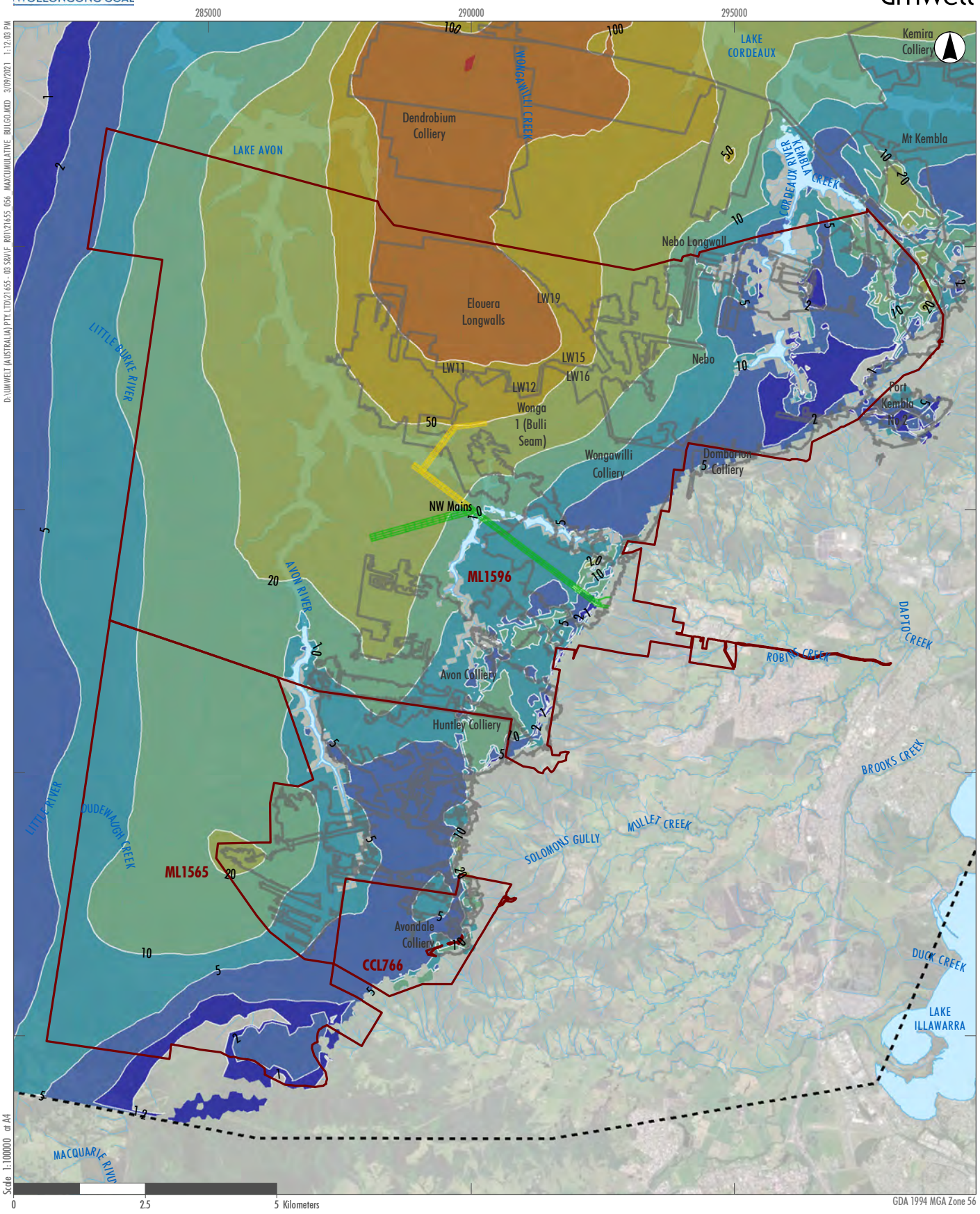
Predicted Drawdown (m)

- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20

FIGURE 4.10

Maximum Predicted Cumulative Drawdown - Hawkesbury Sandstone (Layer 4)

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- Watercourse
- Contours

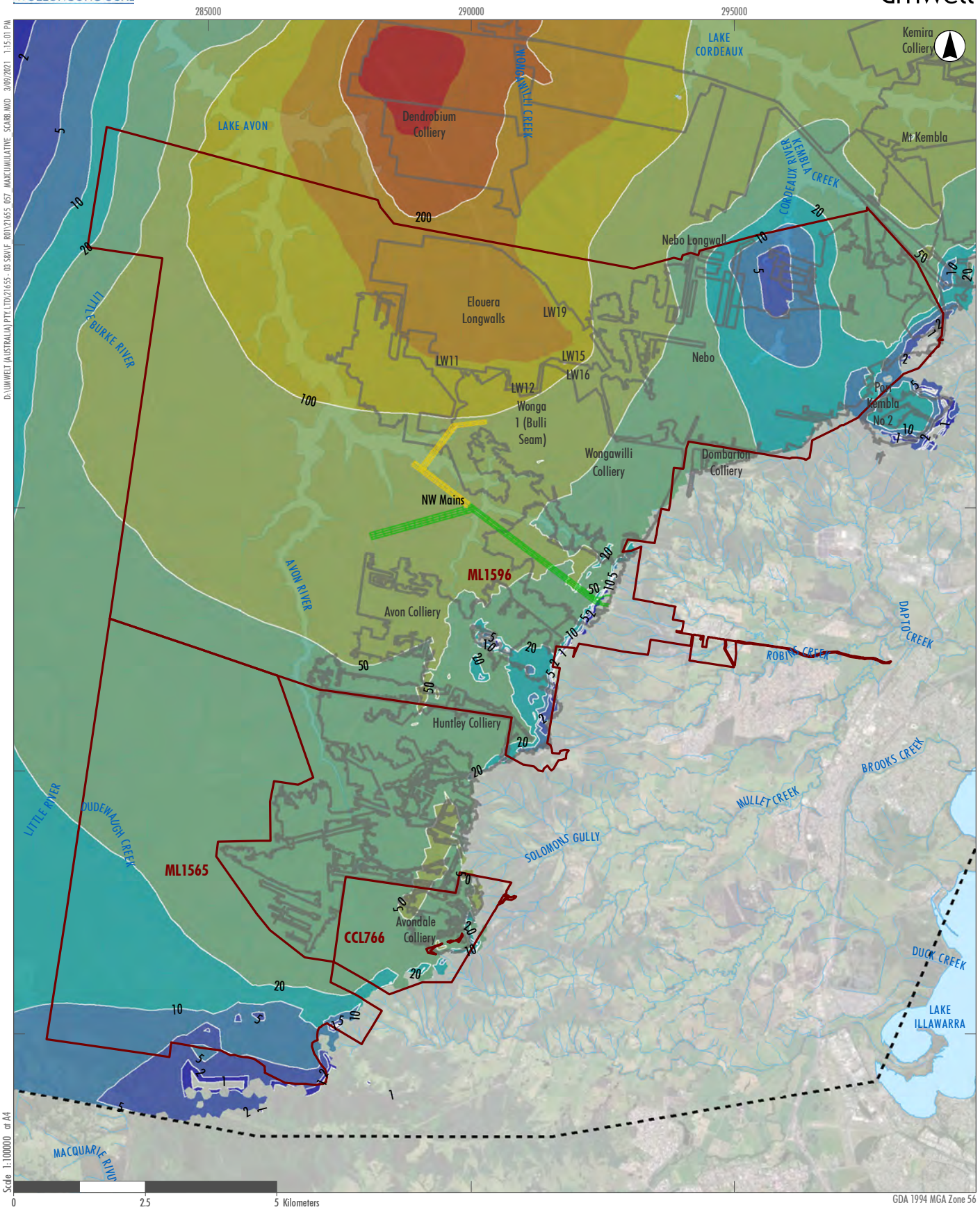
Predicted Drawdown (m)

- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 - 100
- 100 - 150
- 150 - 200

FIGURE 4.11

Maximum Predicted Cumulative Drawdown - Bulgo Sandstone (Layer 7)

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




## Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- Watercourse
- Contours

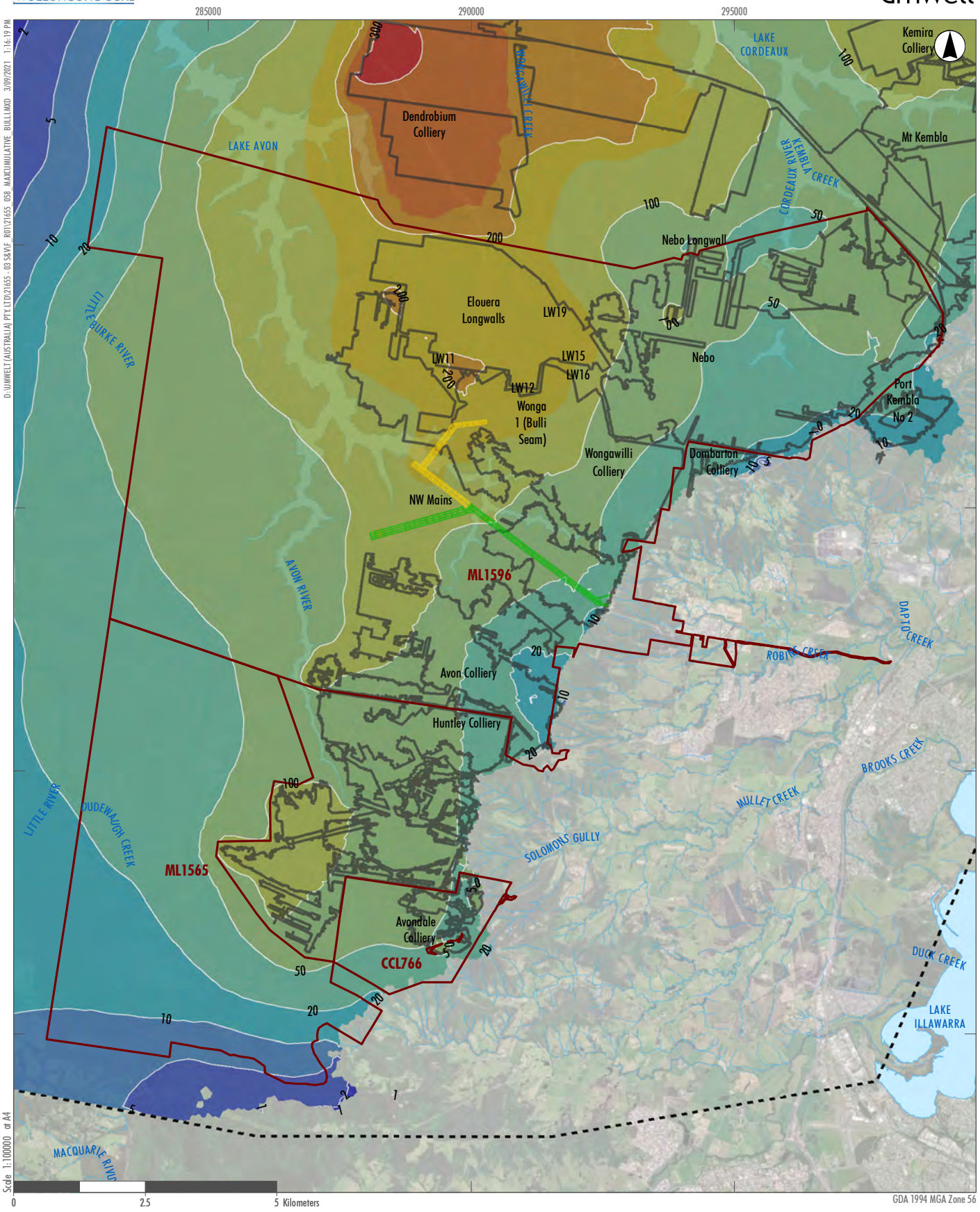
**Predicted Drawdown (m)**

- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 - 100
- 100 - 150
- 150 - 200
- 200 - 250
- 250 - 300

FIGURE 4.12

## Maximum Predicted Cumulative Drawdown - Scarborough Sandstone (Layer 9)

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- Watercourse
- Contours

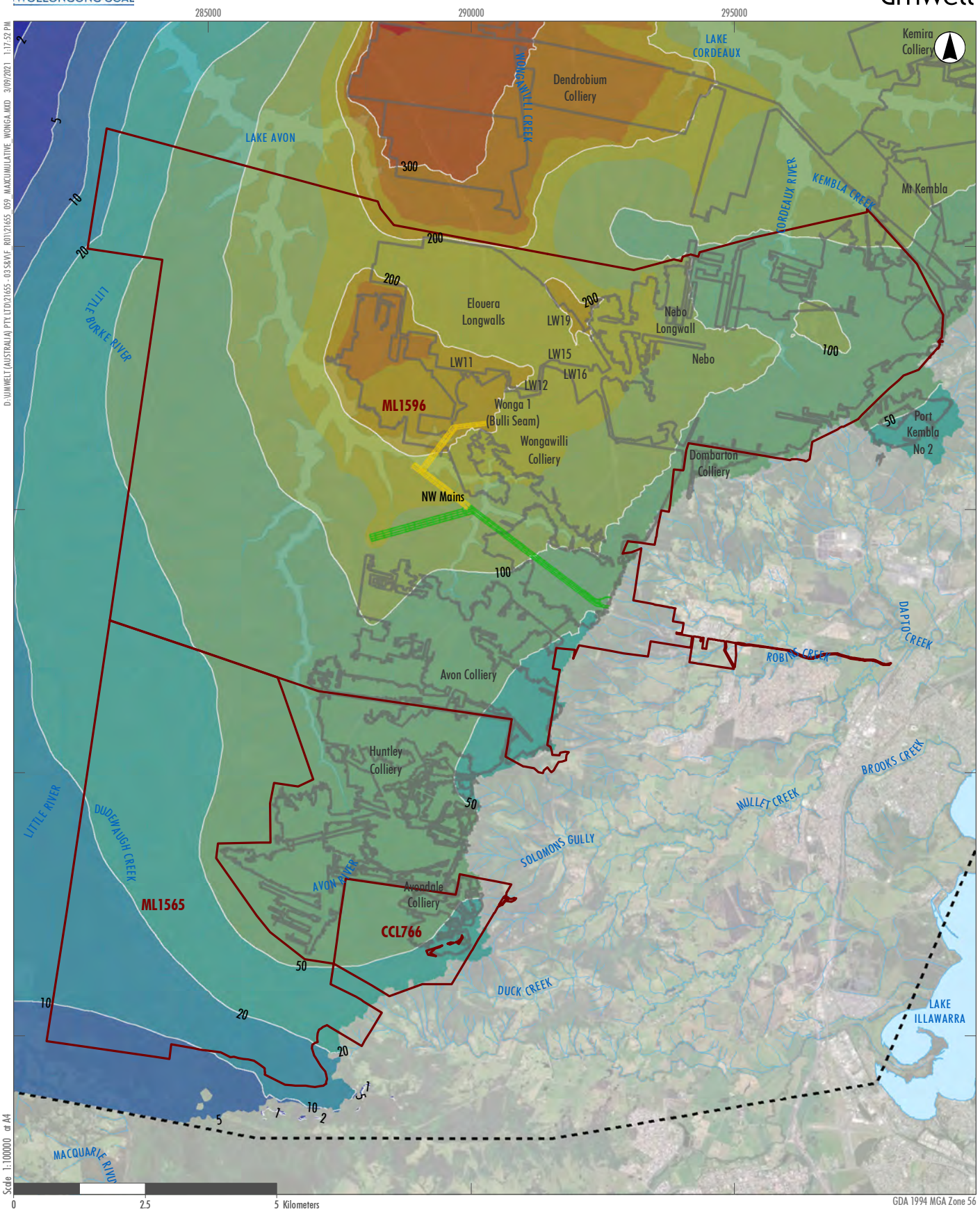
Predicted Drawdown (m)

- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 - 100
- 100 - 150
- 150 - 200
- 200 - 250
- 250 - 300
- 300 - 350

FIGURE 4.13

## Maximum Predicted Cumulative Drawdown - Bulli Seam (Layer 12)

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- Watercourse
- Contours

Predicted Drawdown (m)

- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 - 100
- 100 - 150
- 150 - 200
- 200 - 250
- 250 - 300
- 300 - 350
- 350 - 400

FIGURE 4.14

Maximum Predicted Cumulative Drawdown - Wongawilli Seam (Layer 14)

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)

## 4.2 Predicted Incidental Take

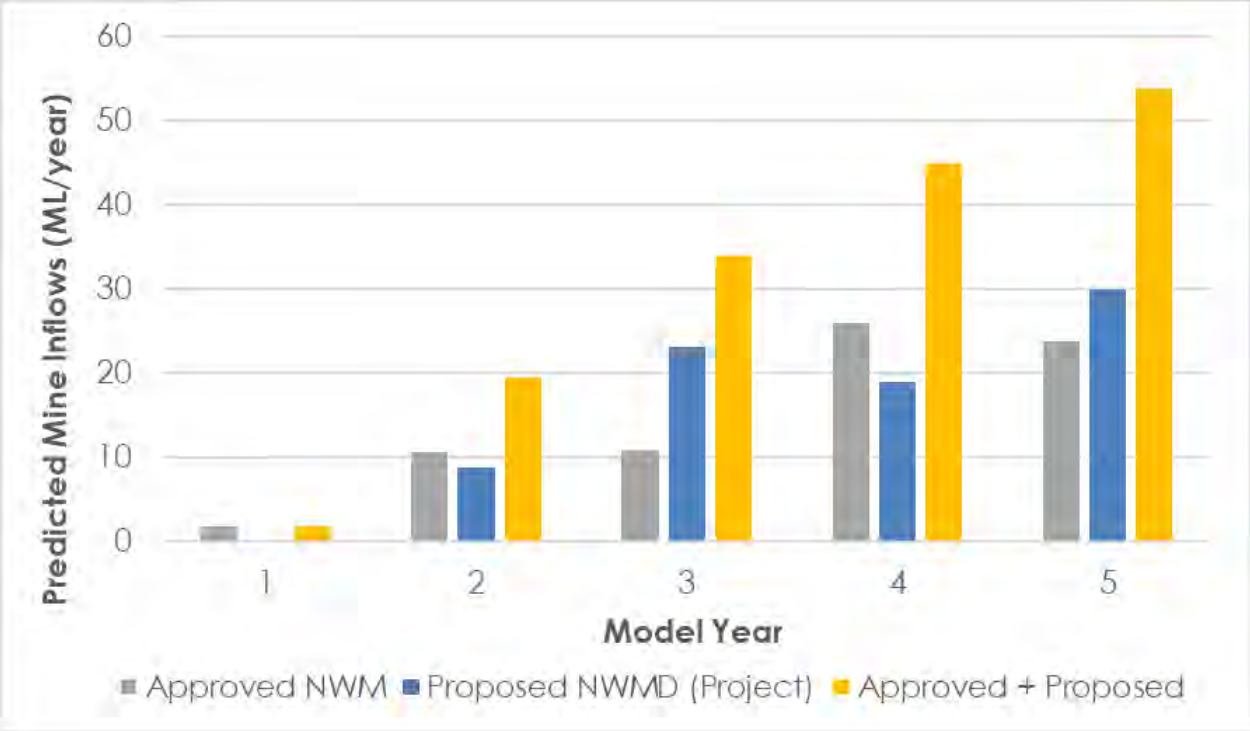
### 4.2.1 Mine Inflows

#### 4.2.1.1 During Operations

Figure 4-15 presents the predicted average annual groundwater inflows to the Project by model year. The graph shows the predicted inflows for the previously approved NWM alignment, the additional NWMD area, and the total predicted inflows for the Project. Figure 4-15 shows the predicted total mine inflows for the Project peak in Year 5, with predicted inflows up to 54 ML/year.

The annual predicted direct take of groundwater from the Permian coal measures is presented in Table 4-1. The predicted inflows to the active workings as part of the Project range between 2 ML/year and 54 ML/year. The predicted inflows to the previously approved alignment of the NWM are 0.06 ML/day on average, peaking at 0.13 ML/day in stress period 86 (final quarter of model year 4) when the mains extend into the Wongawilli Seam. These predictions are slightly higher than the previous predictions by GeoTerra (2010) of 0.025 ML/day (9.1 ML/year) for the approved NWM.

Figure 4-15 Predicted Mine Inflows - Project




It should be noted that the predicted inflows for the Project were extracted as the flux volume from the SLR (2020) model drain package. The rate per stress period (in ML/day) was multiplied by the stress period length (91.3125 days) and summed for the model year. The outputs approximately match previous reporting by SLR (2020) but there are slight differences noted. The slight differences in values may relate to differences in the approach to calculating the total. However, it is noted that the predicted total inflows in Year 5 are higher. This is due to a higher flux reported in stress period 90 (final quarter in model year 5) of 0.25 ML/day, which coincides with when all drain cells for the Project are active (refer Figure 3-9).

Groundwater conditions within the historical workings within ML1596 are gradually recovering since mining ceased in 2019. With this recovery, there is a net flux of groundwater into the mine workings. A budget zone was set up to quantify the inflows to the mine workings within ML1596 to represent the current take for all approved historical operations within ML1596. Ideally a separate

model scenario would be developed to estimate the potential inflows of all approved historical operations within ML1596, and should be undertaken for future model updates. However, using the model provided, to give a conservative indication of the potential inflows to the historical workings for all approved historical operations within ML1596, the net flux to the coal seam layers in ML1596 was used.

The results are presented in Table 4-1 for the Project scenario, which encompasses the Project interception plus flow into historical workings. The maximum inflows to approved existing workings and Project is estimated at 186.0 ML/year in model year 4.

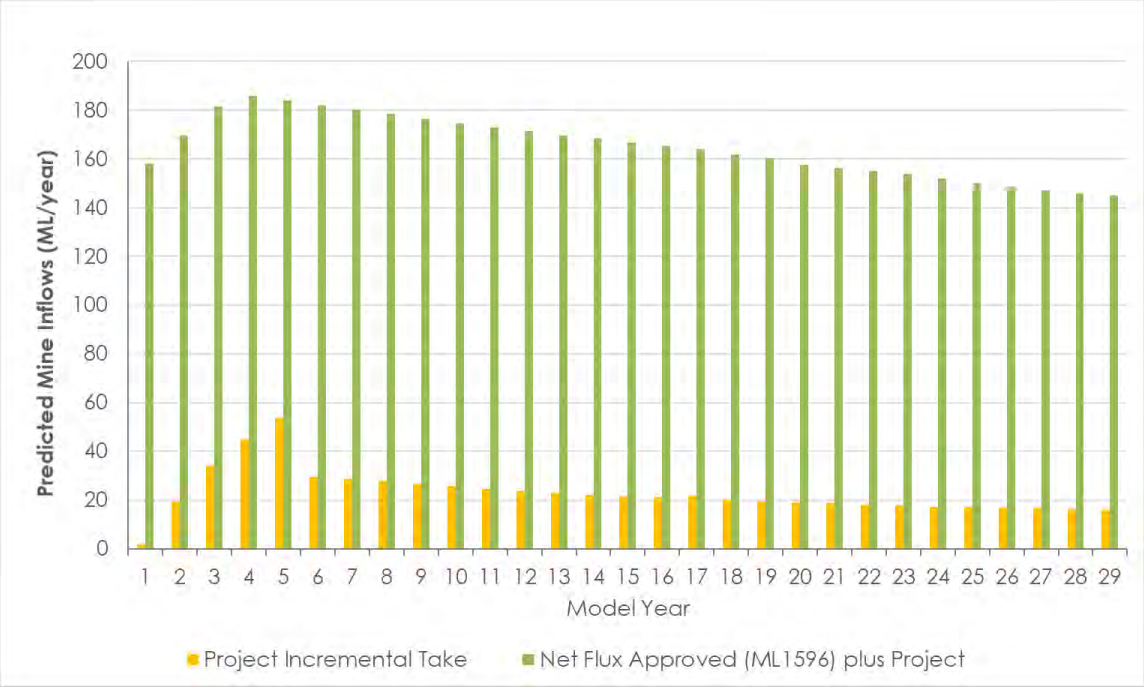
Table 4-1 Predicted Direct Interception of Groundwater – Average Annual

| Model Year | Approved NWM (ML/year) | Proposed NWMD (ML/year) | Project Total (ML/year) | Approved ML1596 Workings Plus Project (ML/year) |
|---|---|---|---|---|
| 1 | 1.9 | 0.0 | 1.9 | 158.1 |
| 2 | 10.7 | 8.9 | 19.5 | 169.6 |
| 3 | 10.8 | 23.2 | 34.0 | 181.8 |
| 4 | 26.0 | 19.0 | 45.0 | 186.0 |
| 5 | 23.8 | 30.1 | 53.9 | 184.0 |

#### 4.2.1.2 Post Mining

Depressurisation due to the Project continues to occur following active mining. The predicted mine inflows to the existing workings within ML1596 and the Project were based on the net flux in ML1596 coal seam layers for the Project model scenario. The results are presented in Figure 4-16 by model year. Figure 4-16 also shows the incremental take associated with the Project, which was calculated by comparing the net flux for the approved and Project model scenarios. The results show that inflows to the approved workings and Project peak during active mining (model year 4) and gradually decline over time with ongoing recovery.

Figure 4-16 Predicted Incidental Inflows to Mine Workings



### 4.2.2 Predicted Incidental (Indirect) Take

The model was used to determine the potential for the Project to interfere with the overlying Triassic groundwater systems and provide estimates of indirect 'water take' in accordance with the AIP. As previously discussed in Section 2.6 and illustrated in Section 2.10, there is a downward vertical gradient from the Triassic strata to the underlying Permian coal measures. This gradient has been enhanced in some areas in ML1596 due to historical mining (i.e. second workings and longwall mining).

Mining, as part of the Project, will not directly intercept the Triassic strata; however, an indirect impact or 'water take' occurs as the Permian strata become depressurised and the volume of natural downward seepage is increased. Under the AIP this flow pathway is considered 'water take', which needs to be accounted for with water licences.

Budget zones were set up to represent the Triassic sediments in ML1596, which included the Hawkesbury Sandstone (Layer 2 to 4) and Narrabeen Group (Layer 5 to 11). This section presents the predicted flux change (indirect take) for the Triassic sediments during operations (model year 1-5) and post mining (to model year 29).

#### 4.2.1.3 During Operations

The predicted indirect take from the Triassic strata over the Project life (to Year 5) is presented in Table 4-2. The results showed a maximum indirect take from the Triassic strata of 23.7 ML/year. In order to provide an indicative estimate of indirect take from all approved historical workings within ML1596, the net flux change for the Project model scenario was extracted. This was based on the net flux into the budget zones representing the Triassic strata (Layer 2 to 11) for the Project model scenario. Ideally for quantifying inflows to existing historical workings in ML1596 a separate model scenario would be developed to explicitly extract inflows to all the historic approved mine workings in ML1596, and should be undertaken for future model updates. However, this approach is considered overly conservative and provides an indication of the maximum potential licensable volumes for the Project and historical approved operations within ML1596.

The combined indirect take for the Project and approved operations was estimated at 141.7 ML/year in model year 3.

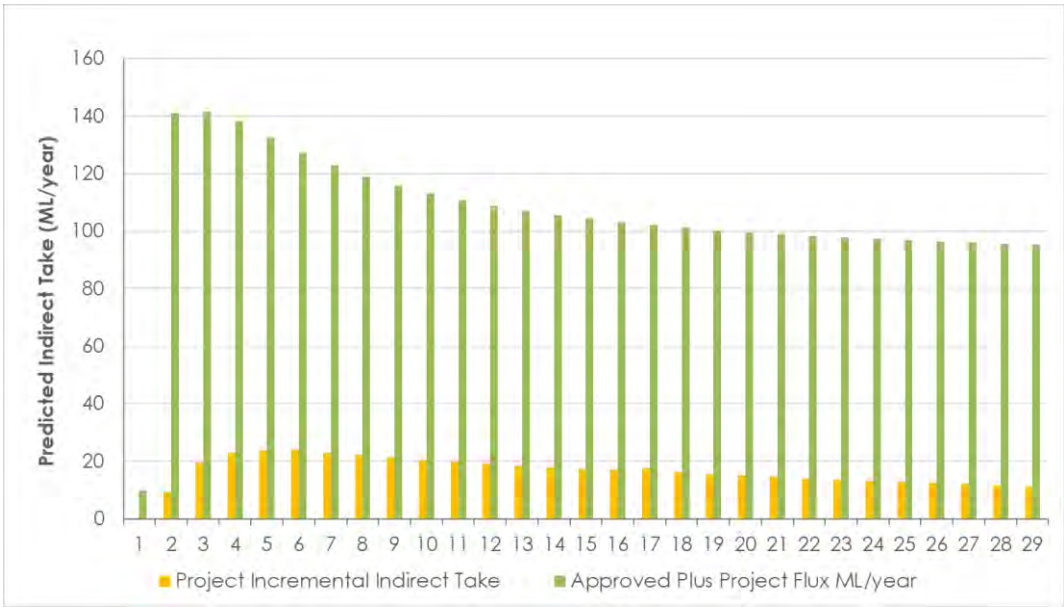
Table 4-2 Predicted Indirect Interception of Groundwater

| Model Year | Project Total (ML/year) | Approved Plus Project Net Flux (ML/year) |
|---|---|---|
| 1 | 0.2 | 9.9 |
| 2 | 9.3 | 141.2 |
| 3 | 19.6 | 141.7 |
| 4 | 23.0 | 138.1 |
| 5 | 23.7 | 132.5 |

#### 4.2.1.4 Post Mining

Figure 4-17 presents the predicted net flux change for the Triassic strata for the Project and approved operations in ML1596. The results show that peak indirect take for the Project occurs in model year 6 with an estimate of 24.1 ML/year. However, peak net flux change for the approved workings and Project occurs during active mining (model year 3) at 141.7 ML/year, and gradually declines over time with ongoing recovery. As outlined in Section 4.2.1.3, while not the preferred approach for estimating inflows to approved workings and should be addressed in future model updates, this is included to provide a conservative estimate of potential maximum licensable volumes for the approved operations within ML1596 and Project.

Figure 4-17 Predicted Indirect Take – Post Mining




### 4.2.3 Predicted Stream Flow/Lake Effects

The model river package flux changes for the approved and Project model scenarios were compared to estimate the indirect take from surface water features.

#### 4.2.3.1 During Operations

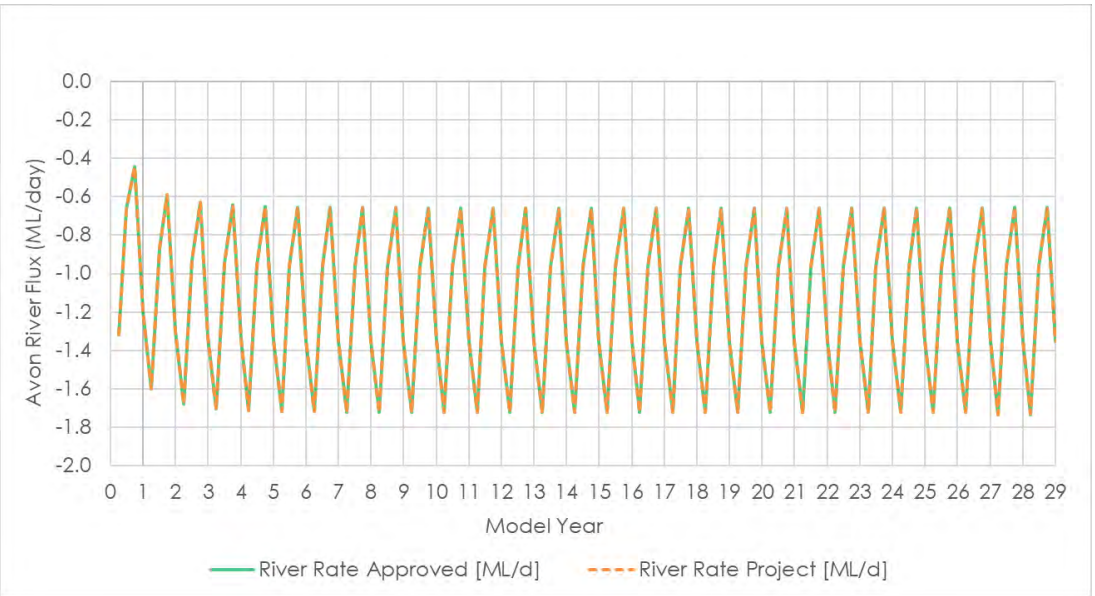
The results showed negligible (<0.05ML/year) change in net river flux between the Project and Approved model scenarios during mining. This corresponds with the predicted change in groundwater heads in Section 4.1 that showed no drawdown of the water table, Hawkesbury Sandstone and negligible change in the Bulgo Sandstone.

#### 4.2.3.2 Post Mining

The results showed negligible (<0.5ML/year) change in net river flux between the Project and Approved model scenarios post mining within ML1596. A small flux difference of 0.42 ML/year between the approved and Project scenarios is noted for model year 29 (stress periods 183 to 186) within ML1596.

The river flux results for the Avon River were separated out from the approved and Project model scenarios and are presented in Figure 4-18 from model year 1 to 29. The graph shows that both model scenarios predict a negative river flux, of between 0.6 ML/day and 1.73 ML/day. The negative flux value indicates a net gaining system, with water flowing from the underlying stratigraphy (i.e. Bulgo Sandstone) to the river. The flux changes align between the two model scenarios. The flux difference in model year 29 (stress periods 183 to 186) is estimated at 0.39 ML/year within the Avon River area of the river package. This difference is too small to observe in Figure 4-18.

Figure 4-18 Avon River - Net River Flux




## 4.3 Predicted Impact on Private Bores

As discussed in Section 2.9.1, there are no registered landholder bores within 10 km of the Project area above the Illawarra Escarpment. This is due to the area being designated Metropolitan and Woronora Special Areas.

As discussed in Section 4.1.1, the extent of depressurisation at the end of mining and maximum extent post mining to model year 29 (2049) is predicted to remain within 6 km of the proposed NWM/NMWD and largely within ML1596. The extent of drawdown due to the Project is not predicted to extend to any registered private water supply bores.

## 4.4 Predicted Impact on Groundwater Dependent Ecosystems

As discussed in Section 2.9.2, there are no GDEs with a high potential groundwater interaction. There are GDEs with a moderate potential groundwater interaction have been identified in localised areas immediately north of the proposed workings and south of the Avon River. Also, GDEs with a low potential groundwater interaction have been identified in areas north of the southern extent of the proposed workings. Upland swamps have also been mapped within the area, with one swamp area mapped above the proposed Project alignment and one above the alignment of the approved NWM.

The swamps are recharged from rainfall and shallow flow represented in model layer 1. The swamps are conceptualised as being hydraulically separated from the lower Hawkesbury Sandstone regional groundwater table, represented in model layers 2 to 4.

Predicted groundwater levels at the upland swamp site above the alignment of the approved NWM, and at a mapped moderate potential GDE near Gallahers Creek, are presented in Figure 4-19 and Figure 4-20, respectively. Figure 4-19 shows that the modelled groundwater elevations in the Hawkesbury Sandstone (model layer 2) are around 7 m below the water table levels. Comparison between the approved and Project model results show no difference in levels near the swamp.

Similar conditions are shown for the potential GDE mapped near Gallaher Creek, as shown in Figure 4-20. Figure 4-20 shows 45 m decline in groundwater levels in the Bulli Seam (Layer 12) from

2022, which only recovers slightly to the end of 2049. A slight (1 m) decline is predicted for the overlying Bulgo Sandstone (Layer 7). However, no change to groundwater levels between the approved and Project model runs is observed for the shallow layers from 1 to 6. These results correspond with no predicted change in the shallow water table of greater than 1 m due to the Project, as discussed in Section 4.1.1. The predicted depth to the water table prior to commencement and at the end of mining are also shown in Figure 4-21.

Figure 4-19 Predicted Groundwater Levels – Swamp Site

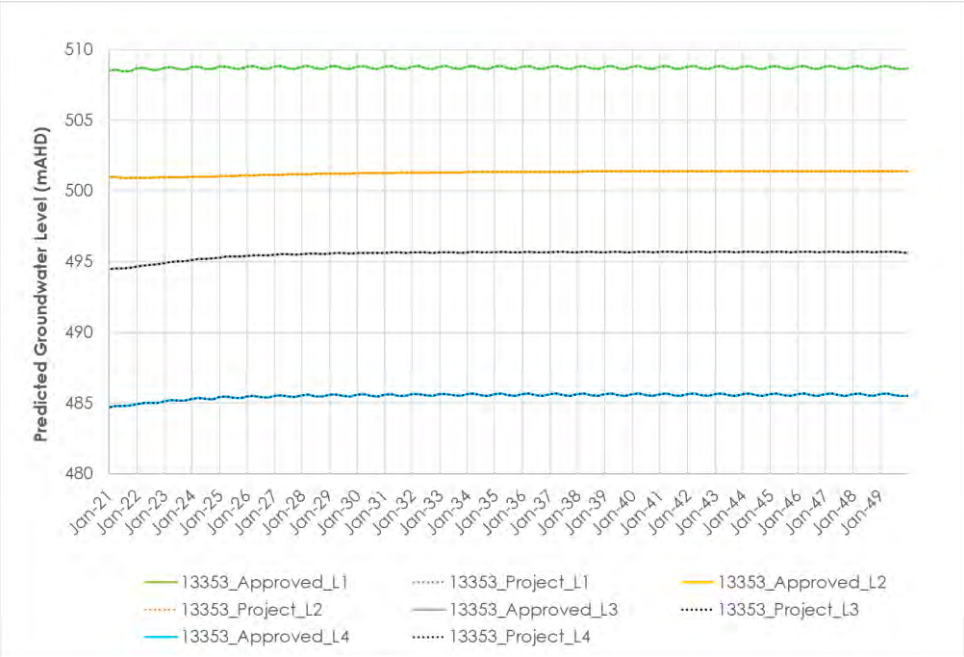



Figure 4-20 Predicted Groundwater Levels – Gallahers Creek

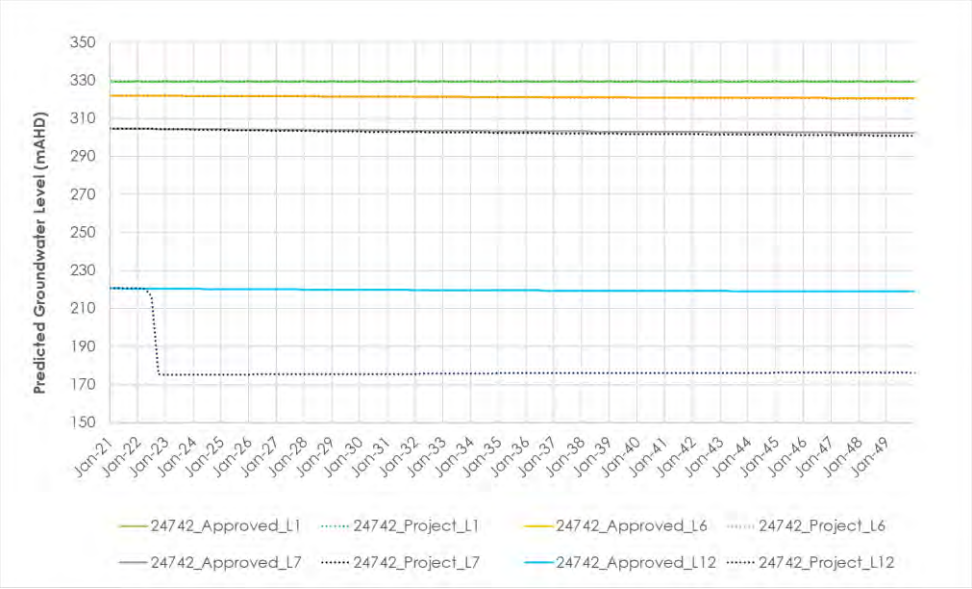
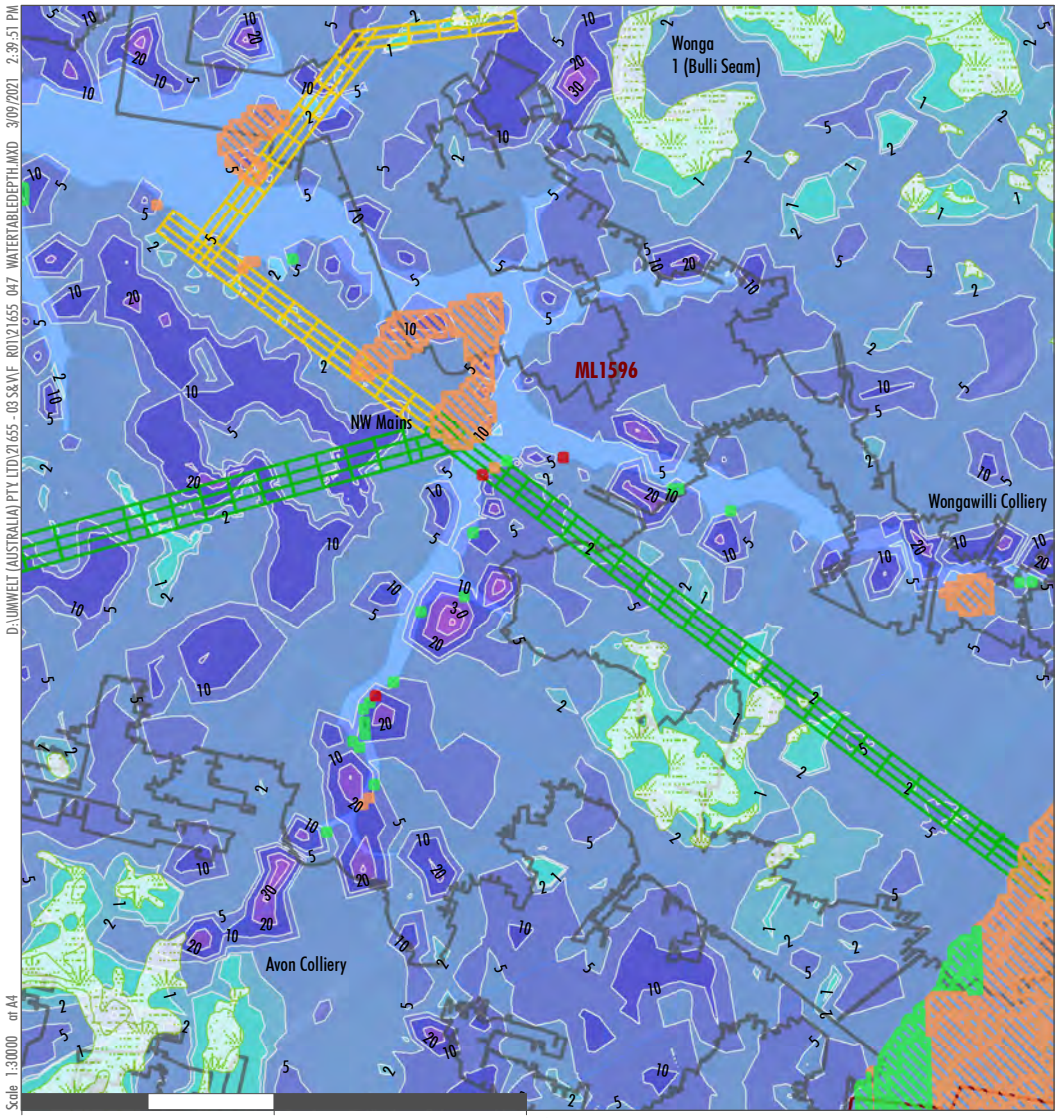
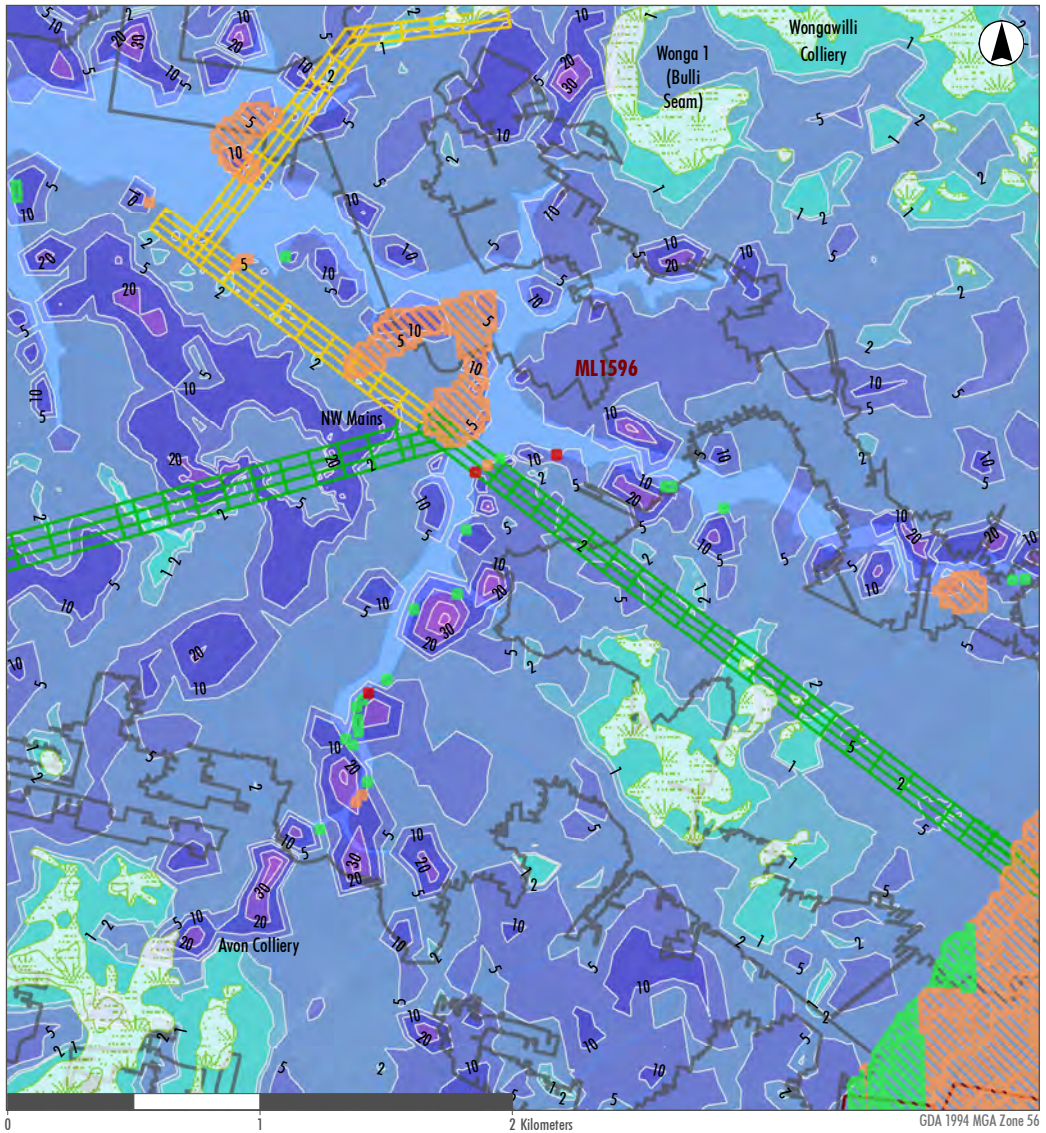



Figure 4-21 Predicted Depth to Water Table – End of Calibration (2020) and End of Mining




Legend

- Mine Lease Boundary
- Proposed NWMD (Project)
- Approved NWM
- Surrounding Mines
- Swamps
- Watercourse
- Contours

**Potential Terrestrial GDEs**

- High Potential GDE
- Moderate Potential GDE
- Low Potential GDE

**Depth to Water (m) 2020**

- < 1
- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- > 50

Legend

- Mine Lease Boundary
- Proposed NWMD (Project)
- Approved NWM
- Surrounding Mines
- Swamps
- Watercourse
- Contours

**Potential Terrestrial GDEs**

- High Potential GDE
- Moderate Potential GDE
- Low Potential GDE

**Depth to Water (m) End of Mining**

- < 1
- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- > 50

FIGURE 4.21

## Predicted Depth to Water Table - End of Calibration (2020) and End of Mining

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)

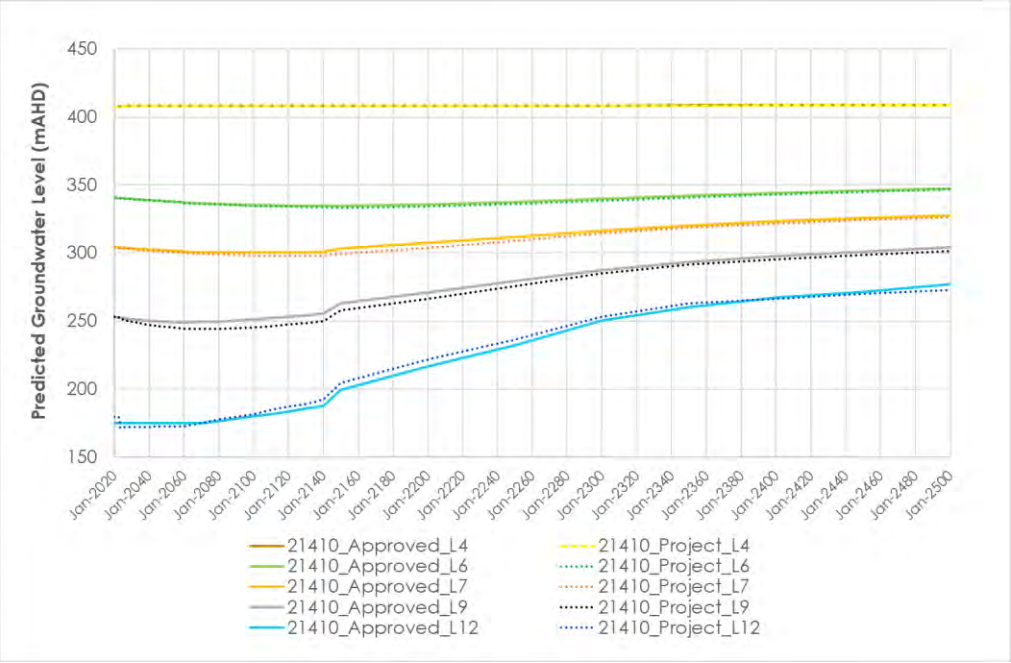
## 4.5 Post Mining Recovery

The predictive model included the Project operations modelled quarterly for five years, followed by quarterly post-mining recovery to 2049, and long-term recovery to 2545. The timing of groundwater level recovery within the proposed workings for the approved and Project model scenarios is presented in Figure 4-22. The levels were output for all layers in the model near Wongawilli No.1 Shaft (node 21410), which is along the alignment of the Proposed NWMD.

The graph shows no change in groundwater levels in the Hawkesbury Sandstone (Layer 4) for the approved and Project scenarios. Depressurisation due to approved operations and the Project are visible in the lower layers representing the Bulgo Sandstone (Layer 7), Scarborough Sandstone (Layer 9) and Bulli Seam (Layer 12).

Figure 4-22 shows slow recovery of water levels, particularly in the coal seam layer. This slow recovery likely reflects the long history of mining in the region, as well as the model assumptions, including average rainfall and no flow boundary conditions to the south-west (upgradient). Slight differences in groundwater levels are also observed in the long-term recovery period between the approved and Project scenarios. Review of the model packages identified slight differences in the TVM setup that may be introducing incremental differences in results between the two model scenarios unrelated to Project impacts.

Figure 4-22 Post Closure Recovery Levels – within Project




At the end of recovery (end of 2549) the predicted net flux representing direct (from coal) and indirect (Triassic strata) groundwater take was extracted. The net flux was extracted for layers within ML1596, and is reported in Table 4-3. The predicted take due to the Project at the end of recovery is 12.22 ML/year. These results are slightly higher than the volume previously reported by SLR (2020) for the end of recovery, or 10.15 ML/year. This difference may relate to how the budget zones were defined and processed (i.e. unrelated to Project impacts).

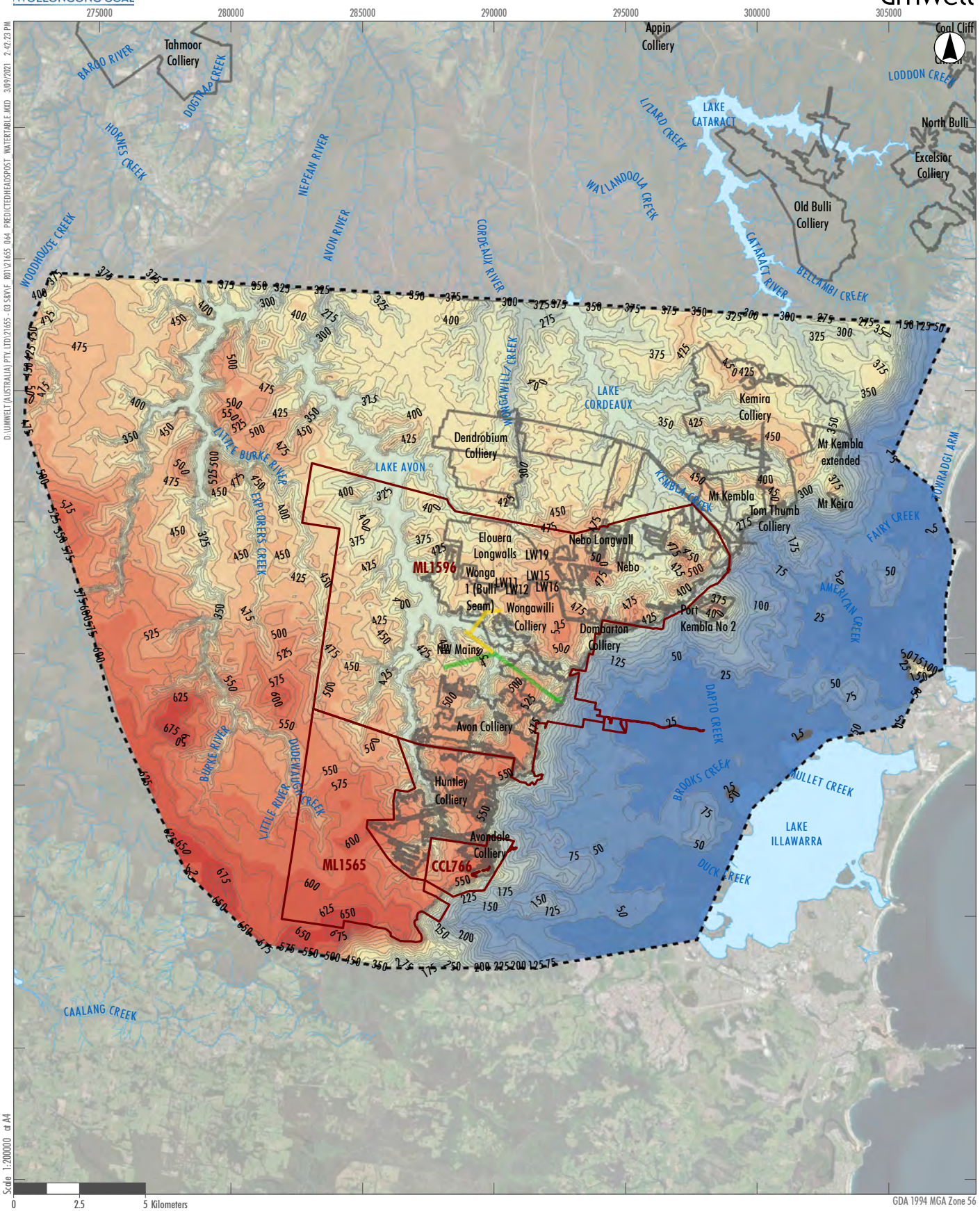
It is also noted that SLR (2020) reported a higher net flux around 2400 of up to 18.08 ML/year. This flux difference appears to correspond with differences in the setup of the approved and Project scenarios around Elouera and Dendrobium. Further refinement and improvement in the recovery model is recommended for future iterations of the model.

The net river boundary condition flux at the end of the recovery run was also calculated at 1.47 ML/year. However, as discussed in Section 3.8, discrepancies with the approved and Project recovery model were identified that may contribute to minor differences in flow budgets between the two scenarios (i.e. not Project related impacts).

Table 4-3 End of Recovery Predicted Take (Direct and Indirect)

| | Project Incremental Take (ML/year) |
|---|---|
| Hawkesbury Sandstone | 0.06 |
| Narrabeen Group | 2.44 |
| Coal Seams | 9.72 |
| Total | 12.22 |

Groundwater levels at the end of the recovery model (2545) for the water table, Hawkesbury Sandstone (Layer 4), Bulgo Sandstone (Layer 7), Bulli Seam (Layer 12) and Wongawilli Seam (Layer 14) are presented in Figure 4-23 to Figure 4-27. The figures show the flow gradient towards the north to north-east are re-established in recovery. Figure 4-26 and Figure 4-27 show a depression in groundwater elevations around the historical workings for the Bulli Seam and Wongawilli Seam, respectively. This indicates slow predicted recovery to the historical workings post closure, which may be influenced by how the mine workings are represented in the model and the post-mining hydraulic properties in these regions.




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- Watercourse
- Contours

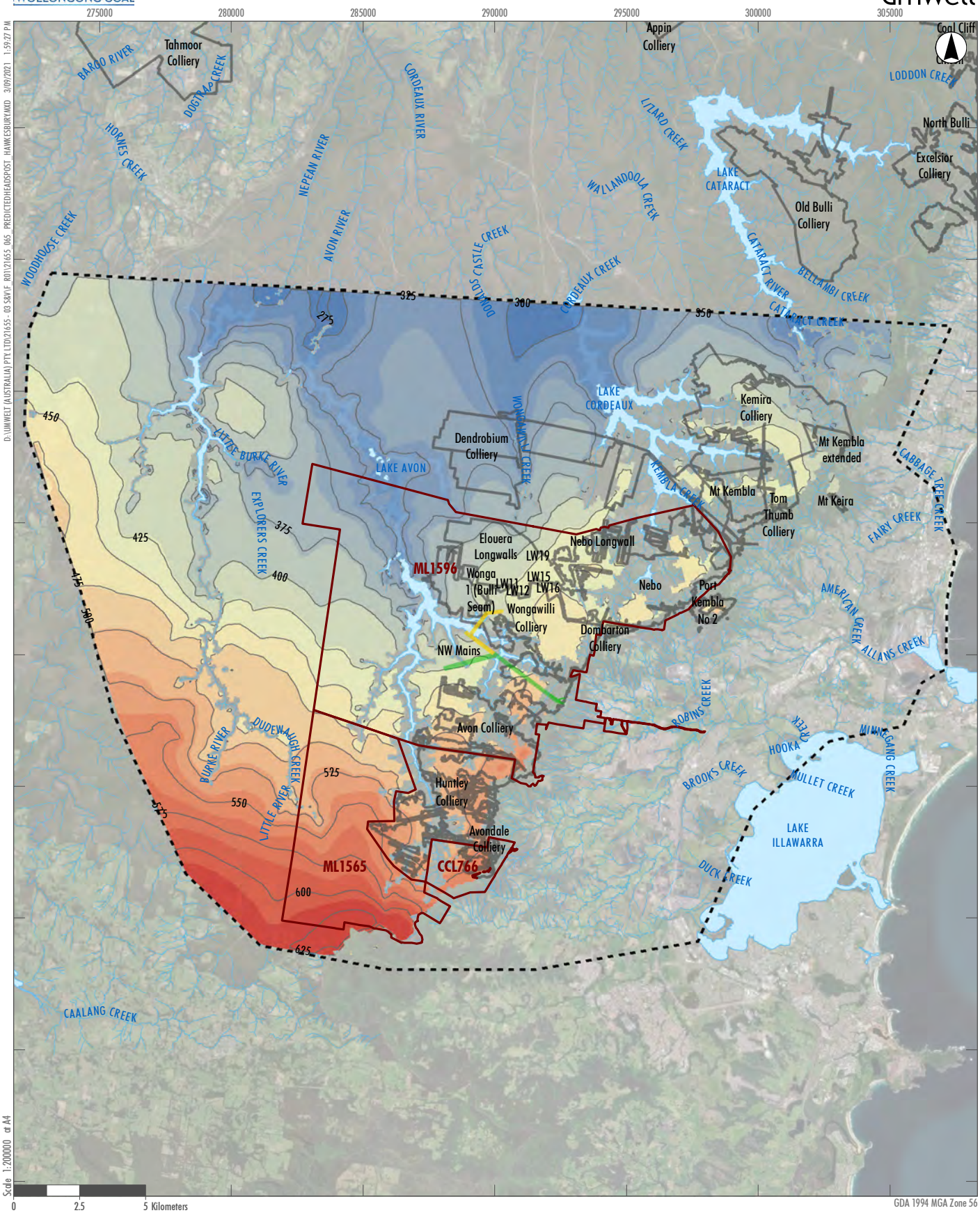
Modelled Groundwater Level (mAHD)

- -0.02 - 23
- 23 - 60
- 60 - 112
- 112 - 170
- 170 - 234
- 234 - 289
- 289 - 335
- 335 - 375
- 375 - 413
- 413 - 451
- 451 - 485
- 485 - 520
- 520 - 558
- 558 - 592
- 592 - 633
- 633 - 737

FIGURE 4.23

Predicted Heads Post-Closure (December 2549) Water Table

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- Watercourse
- 25m Contours

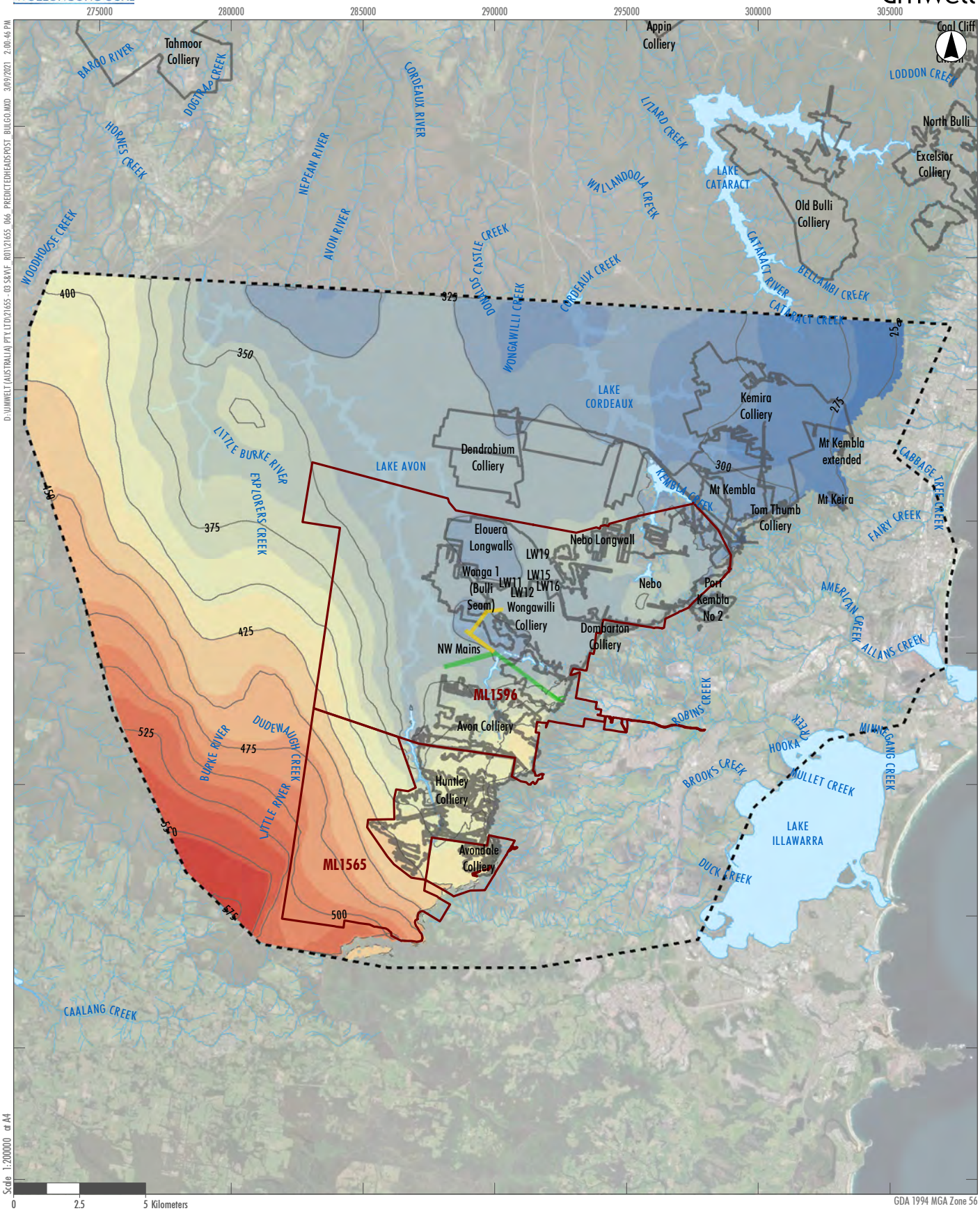
Modelled Groundwater Level (mAHD)

- 256 - 300
- 300 - 319
- 319 - 335
- 335 - 355
- 355 - 377
- 377 - 400
- 400 - 423
- 423 - 449
- 449 - 475
- 475 - 498
- 498 - 520
- 520 - 541
- 541 - 563
- 563 - 586
- 586 - 609
- 609 - 647

FIGURE 4.24

Predicted Heads Post-Closure (December 2549) Hawkesbury Sandstone (Layer 4)

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




## Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- Watercourse
- 25m Contours

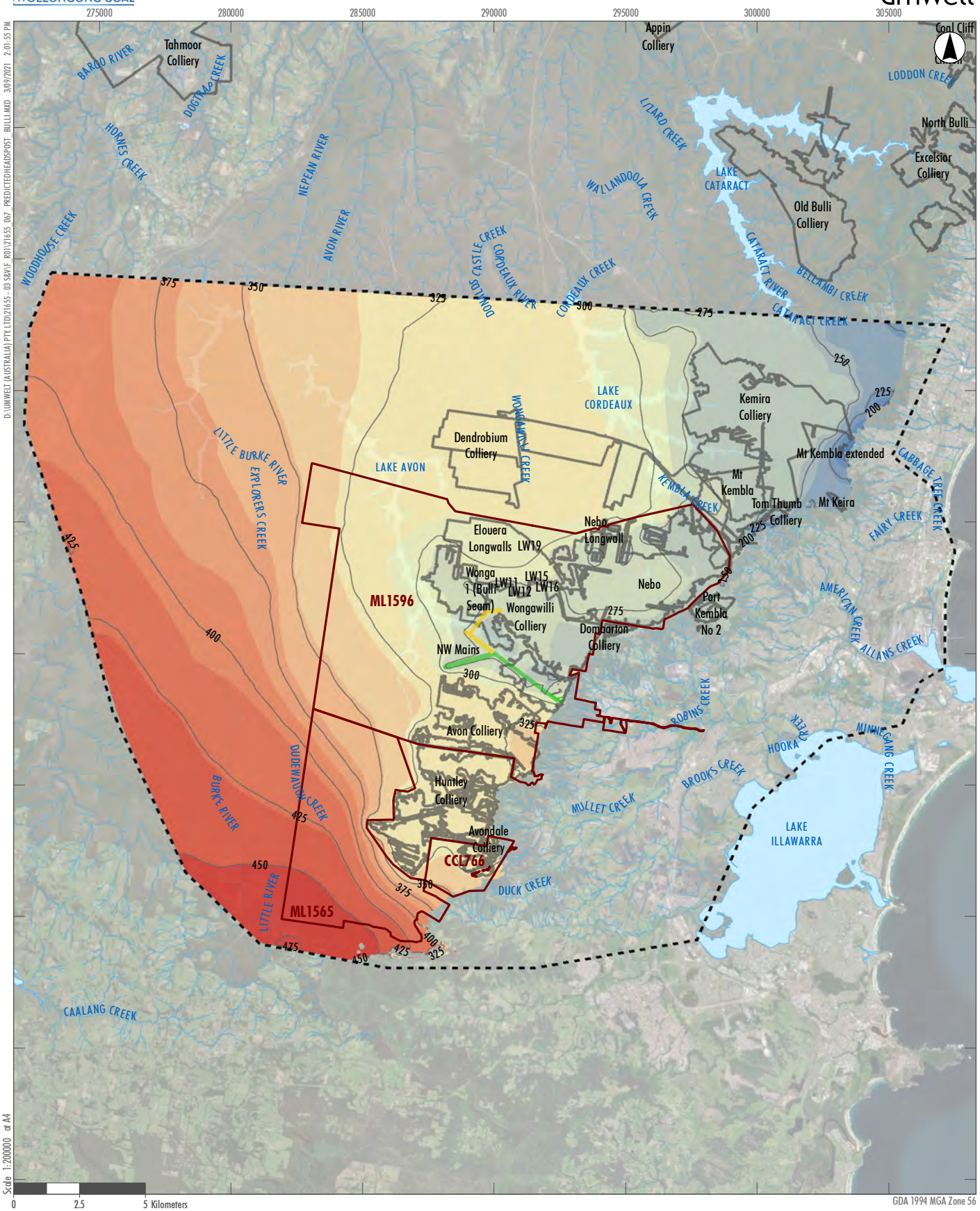
**Modelled Groundwater Level (mAHD)**

- 232 - 272
- 272 - 294
- 294 - 311
- 311 - 325
- 325 - 341
- 341 - 362
- 362 - 384
- 384 - 404
- 404 - 425
- 425 - 446
- 446 - 468
- 468 - 490
- 490 - 511
- 511 - 531
- 531 - 553
- 553 - 580

FIGURE 4.25

**Predicted Heads Post-Closure (December 2549) Bulgo Sandstone (Layer 7)**

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




## Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- Watercourse
- 25m Contours

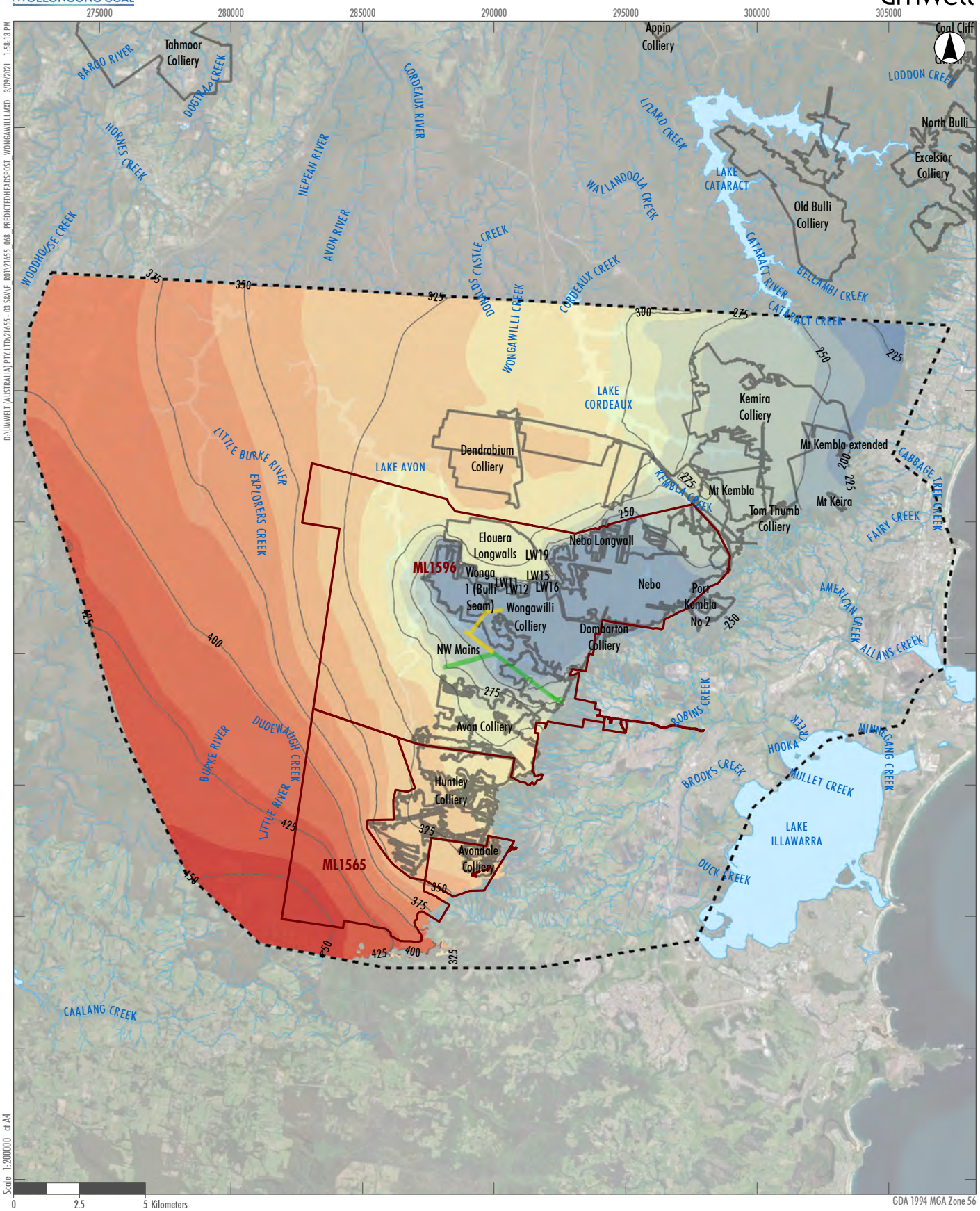
**Modelled Groundwater Level (mAHD)**

- 128 - 196
- 196 - 214
- 214 - 228
- 228 - 241
- 241 - 256
- 256 - 270
- 270 - 289
- 289 - 311
- 311 - 328
- 328 - 347
- 347 - 368
- 368 - 387
- 387 - 406
- 406 - 426
- 426 - 450
- 450 - 475

FIGURE 4.26

**Predicted Heads Post-Closure (December 2549) Bulli Seam (Layer 12)**

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




## Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Groundwater Model Boundary
- Watercourse
- 25m Contours

**Modelled Groundwater Level (mAHD)**

- 128 - 172
- 172 - 206
- 206 - 226
- 226 - 238
- 238 - 253
- 253 - 270
- 270 - 289
- 289 - 306
- 306 - 319
- 319 - 336
- 336 - 359
- 359 - 380
- 380 - 401
- 401 - 420
- 420 - 441
- 441 - 466

FIGURE 4.27

**Predicted Heads Post-Closure (December 2549) Wongawilli Seam (Layer 14)**

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)

## 4.6 Water Licensing

The AIP requires all water taken by aquifer interference activities to be accounted for within the extraction limits set by the relevant water sharing plan.

As discussed in Section 1.4, the water sharing plan relevant to the Project is:

- Water Sharing Plan for the Sydney Basin Nepean Sandstone Groundwater Source - Management Zone 1 (MZ1).

The volume of groundwater intercepted and required to be accounted for via shares for the project includes water actively extracted during mining operations (water take) and groundwater predicted to flow into the underground following completion of mining.

The predicted annual groundwater volumes required to be licensed over the life of the Project and post mining are summarised in Table 4-1. During mining, the predicted total annual direct interception of groundwater (mine water inflow) due to the Project is 54 ML/year in model year 5. Up to 186 ML/year of inflows is predicted for the Project plus historical workings in ML1596.

Indirect take can also occur from the overlying Triassic strata, due to depressurisation of the coal seams from historical operations within ML1596 and due to the Project. No specific model scenario was set up for the approved operations, therefore the indirect take was conservatively estimated based on the net flux change within ML1596. The model predicted a maximum net flux change for the Triassic strata of 141.7 ML/year for the approved operations and Project in model year 3, with the Project contributing up to 24.1 ML/year of indirect take in model year 6 (1st year post-mining).

Table 4-4 Predicted Maximum Direct and Indirect Take for Licensing

| Model Year | Direct Take Project (ML/year) | Indirect Take Project (ML/year) | Direct Take - Project Plus Approved (ML/year) | Indirect Take - Project Plus Approved (ML/year) | Total Licensable Volume (ML/year) |
|---|---|---|---|---|---|
| 1 | 1.9 | 0.2 | 158.1 | 9.9 | 168.0 |
| 2 | 19.5 | 9.3 | 169.6 | 141.2 | 310.8 |
| 3 | 34.0 | 19.6 | 181.8 | 141.7 | 323.5 |
| 4 | 45.0 | 23.0 | 186.0 | 138.1 | 324.1 |
| 5 | 53.9 | 23.7 | 184.0 | 132.5 | 316.5 |

As shown in Table 4-1, the maximum annual take of groundwater from the hardrock aquifer under the Sydney Basin Nepean Groundwater Source is estimated at 324.1 ML/year. This includes both direct and indirect interception of groundwater for the Project plus approved historical workings.

WCL has secured 1,500 units (equivalent to 1,500 ML) of shares of groundwater in Management Zone 1 of the Sydney Basin Nepean Groundwater Source under "Greater Metropolitan Region Groundwater Sources 2011" WSP with water WAL 36487.

WCL has a sufficient WAL entitlement to provide for the predicted maximum water take of 324.1 ML/year.

As reported in Section 4.2.3, the model predicted negligible (<0.05 ML/year) change in the net river flux between the Project and approved model scenarios during operations. This corresponds with the predicted change in groundwater heads in Section 4.1 that showed no drawdown in the water table, Hawkesbury Sandstone and negligible change in the Bulgo Sandstone.

Post mining the flux difference increases slightly, with a maximum flux difference of 0.42 ML/year between the approved and Project scenarios in model year 29 (stress periods 183 to 186). This flux difference increases in the recovery model, with a net flux difference of 1.47 ML/year at the end of recovery (2545). However, as discussed in Section 3.8, discrepancies with the approved and

Project recovery model were identified that may contribute to minor differences in flow budgets between the two scenarios. Further improvements in the recovery model are recommended for future model iterations to better refine the post-processing of closure predictions.

## 4.7 Potential Impacts on Groundwater Quality

Mine water inflows to the Project will be controlled by the groundwater salinity within the intercepted Permian coal measures. The Project is mains development, first workings only, and no changes in hydraulic connectivity to overlying strata is predicted. Therefore, it is predicted that groundwater quality within the Project area will remain in line with baseline data with no change in the beneficial use of water within the Permian coal measures during or following the Project.

As outlined in Section 2.8, groundwater quality data collected from bores within the Project area between 2010 and 2019 shows that:

- Groundwater within the Narrabeen Formation is generally fresh (median EC 724 µS/cm, maximum EC 1,404 µS/cm) with pH conditions that are generally alkaline (median pH 8.4).
- Groundwater within the Bulli Seam is brackish (median TDS 2,375 mg/L).
- Groundwater within the crinanite is fresh to brackish (median EC 946 µS/cm, maximum EC 2,983 µS/cm) and generally has an alkaline pH (median pH of 9.7).
- Groundwater within the soil is fresh (median EC 273 µS/cm) with pH relatively neutral pH (medium pH 6.5).

# 5. SENSITIVITY ANALYSIS

Due to the low risk of the Project as indicated by the basecase model predictions, an uncertainty analysis was undertaken using a deterministic sensitivity analysis. This approach is testing the sensitivity of predicted impacts to changes in key parameters and is one of three methods of undertaking uncertainty analysis outlined in the IESC guidelines for uncertainty analysis (Middlemis and Peeters, 2018).

The following parameter sets were run and reported by SLR (2020) and subsequently re-run by Umwelt. As discussed in Section 4.2.1, the post processing methodology to extract the predicted inflows appears to differ slightly between SLR (2020) and Umwelt. Therefore, the results have been re-processed by Umwelt for consistency with the results presented for the additional model scenarios. It should also be noted that the applied hydraulic property changes to the depth dependence function did not separate out the different zones within the deeper layers (i.e. crinanite, which has resulted in some changes to the sensitivity analysis results compared to those reported by SLR (2020). The re-run scenarios included:

- + 1 OM (order of magnitude) change in hydraulic conductivity in alluvium;
- - 1 OM change in hydraulic conductivity in alluvium;
- + 1 OM change in hydraulic conductivity in coal (with no zonation in layer);
- - 1 OM change in hydraulic conductivity in coal (with no zonation in layer);
- + 1 OM change in hydraulic/vertical conductivity in Bulgo Sandstone (with no zonation in layer;
- - 1 OM change in hydraulic/vertical conductivity in Bulgo Sandstone (with no zonation in layer;
- + factor 3 change in recharge;
- - factor 3 change in recharge;
- + factor 5 change in specific yield in coal (with no zonation in layer;
- - factor 5 change in specific yield in coal (with no zonation in layer; and
- + 1OM Global RIV conductance.

Following feedback from DPIE, additional sensitivity runs with composite parameter changes were also tested by Umwelt, as follows:

- No flow cells replaced with GHB in the southern and western extent of the model domain;
- Increase hydraulic conductivity (Kv and Kh) and specific yield (Sy) in the Hawkesbury Sandstone;
- Increase hydraulic conductivity (Kv and Kh) and specific yield (Sy) in the Bulli Seam, Wongawilli Seam and Tongarra Seam;
- Increase hydraulic conductivity (Kv and Kh) and specific yield (Sy) in Bulgo Sandstone;
- Increase hydraulic conductivity (Kv and Kh) and specific yield (Sy) in Bald Hill Claystone and Stanwell Park Claystone; and
- Increase hydraulic conductivity (Kv and Kh) and specific yield (Sy) in Hawkesbury Sandstone, coal seams, BGSS, BHCS and SPCS.

For the change in boundary conditions from no-flow to GHB, the heads were applied based on the pre-mining steady-state groundwater levels. A uniform conductance was applied at 100 $m^2/d$.

For the additional sensitivity runs, a constant hydraulic conductivity (Kh) was applied based on the 95th percentile of field data. Comparison between the field data ranges, basecase model ranges and additional sensitivity analysis Kh values is presented in Figure 5-1.

Also, as shown in Figure 5-1, Kv was adjusted proportionate to the changes in Kh based on simplified anisotropic relationship informed by available permeability data (refer Section 2.7) and previous calibrated model parameters, as follows:

- Sandstone units Kh:Kv of 10:1
- Claystone units Kh:Kv of 100:1
- Coal units Kh:Kv of 10:1

Finally, specific yield values for the additional sensitivity runs were based on maximum values of measured effective porosity and an available NMR log for bore S2324. A summary of all adopted properties for the additional sensitivity runs are provided in Table 5-1.

Figure 5-1 Comparison of Field Kh to Model Data and Sensitivity for Kh and Kv

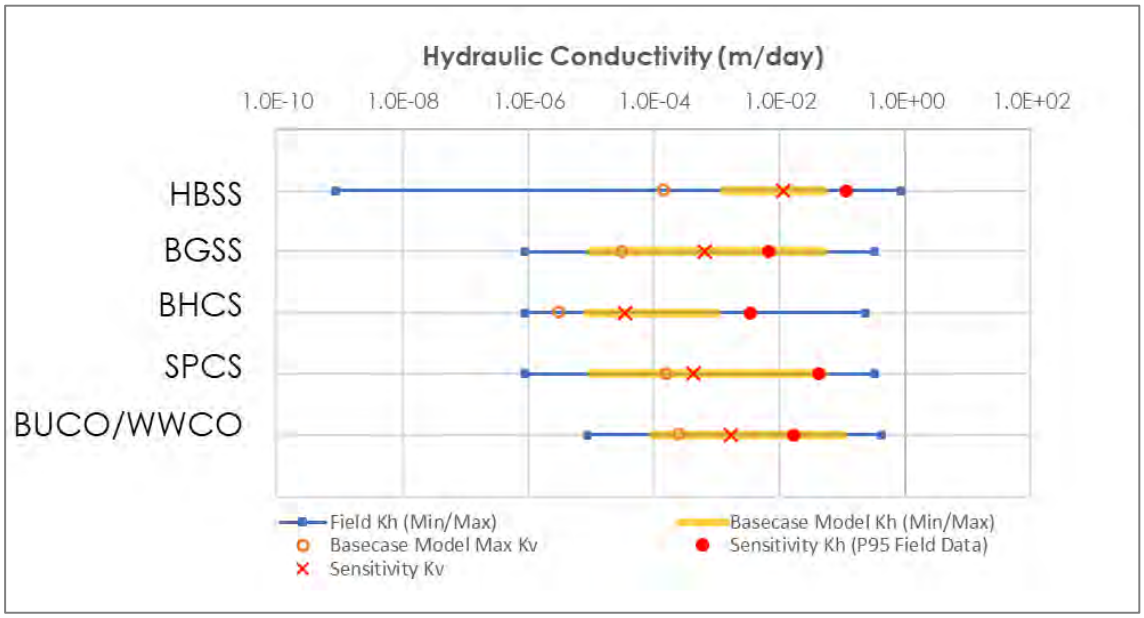



Table 5-1 Hydraulic properties used for the additional sensitivity runs

| Stratigraphy | Kh [m/d] | Kv [m/d] | Kh/Kv ratio | Sy [-] |
|---|---|---|---|---|
| *Hawkesbury Sandstone* | 1.10E-01 | 1.10E-02 | 10 | 0.15 |
| *Bulgo Sandstone* | 6.60E-03 | 6.60E-04 | 10 | 0.10 |
| *Bald Hill Claystone* | 3.50E-03 | 3.50E-05 | 100 | 0.03 |
| *Stanwell Park Claystone* | 4.20E-02 | 4.20E-04 | 100 | 0.03 |
| *Bulli/Wongawilli/Tongarra Seam* | 1.70E-02 | 1.70E-03 | 10 | 0.10 |

## 5.1 Calibration Sensitivity and Predicted Inflows

The sensitivity of model calibration to changes in parameters is summarised in Table 5-2. SLR (2020) noted that varying the parameters had little influence on the RMS and SRMS for the site monitoring data, with only less than 10% change indicating that the calibration performance is relatively insensitive to the input parameters. This indicates that the calibration may not be able to constrain the parameter values well.

As previously reported by SLR (2020), decreasing the Bulgo Sandstone hydraulic conductivity had the greatest influence on the calibration statistics, while decreasing the hydraulic conductivity of the coal seams resulted in an improved calibration result. This indicates the model parameter sensitivity to calibration and thus how field measurements are valuable to constrain the parameter within a realistic range in the model.

The parameters from the sensitivity runs conducted by SLR (2020) that had the highest relative change in SRMS percentage were the recharge, hydraulic conductivity in the Bulgo Sandstone and coal layers, even though the magnitude of change was considered low. SLR (2020) noted that the specific yield of the coal, alluvium horizontal hydraulic conductivity and river conductance appeared to have low calibration sensitivity.

The influence of specific yield in conjunction with changes in hydraulic conductivity was further tested with the additional sensitivity scenarios run by Umwelt, also included in Table 5-2. As noted in Table 5-2 the model scenario with increased Kv, Kh and Sy for the Hawkesbury Sandstone did not converge. The remaining additional scenarios converged and showed that there was no change in SRMS compared to the base case for the sensitivity scenario with revised GHB boundaries. Increased Kv, Kh and Sy in the coal seams produced an improved model fit to observations compared with the base case, marked by a 3.7% decrease in SRMS. Increased Kv, Kh and Sy in the Bulgo Sandstone and the Claystone produced a reduction in calibration fit compared to the base case, with a change of 7.1% and 12.1%, respectively. The last additional sensitivity run in which Kh, Kv and Sy in the coal seams are increased together with those in other formations yielded the worst SRMS, which increased by 48.2% compared to the base case.

Table 5-2 Calibration Sensitivity and Calibration Statistics for Site Monitoring data

| Sensitivity Scenario | SRMS (%) | SRMS change (%) |
|---|---|---|
| Base case | 8.4 | 0.0 |
| + 1 OM change in hydraulic conductivity in alluvium | 8.4 | 0.0 |
| - 1 OM change in hydraulic conductivity in alluvium | 8.4 | 0.0 |
| + 1 OM change in hydraulic conductivity in coal | 10.1 | 19.1 |
| - 1 OM change in hydraulic conductivity in coal | 7.9 | -5.9 |
| + 1 OM change in hydraulic/vertical conductivity in Bulgo Sandstone | 8.3 | -1.6 |
| - 1 OM change in hydraulic/vertical conductivity in Bulgo Sandstone | 10.3 | 21.9 |
| +factor 3 change in recharge | 24.4 | 189.2 |
| - factor 3 change in recharge | 8.6 | 2.2 |
| + factor 5 change in specific yield in coal | 8.4 | -0.1 |
| - factor 5 change in specific yield in coal | 8.4 | 0.0 |
| + 1oM Global RIV conductance | 8.4 | -0.3 |
| GHB | 8.4% | 0.0 |
| HBSS increased Kv, Kh and Sy | Model did not converge | Model did not converge |
| Coal seam increased Kv, Kh and Sy | 8.1% | -3.7% |
| BGSS increased Kv, Kh and Sy | 9.0% | 7.1% |
| Claystone increased Kv, Kh and Sy | 9.5% | 12.1% |
| Hawkesbury Sandstone, coal seams, BGSS, BHCS and SPCS increased Kv, Kh and Sy | 12.5% | 48.2% |

## 5.2 Sensitivity of Groundwater Take

The influence of changes to model parameters on the predicted average annual mine inflows to the Project during operations is presented in Table 5-3. The results have been re-processed for the SLR (2020) sensitivity runs due to differences in results previously discussed in Section 4.2.1.

The results show no change in modelled inflows for changes in hydraulic conductivity within the alluvium. Changes in Kv and Kh within the coal seam produced an increase in mine inflow by 52.3% for the +1 OM change and a decrease of 35.5% for the -1 OM change in hydraulic conductivity. The change in specific yield in the coal seam produced a 46.3% increase in mine inflows for the + 500% change in Sy and a 9.6% decrease in mine inflows when Sy is reduced by a factor 5. The +1 and -1 OM change in Kh and Kv in the Bulgo Sandstone changed mine inflows by 13.3% and -12.9%, respectively. Reducing recharge by a factor 3 did not significantly change the average mine inflows, where an increase of recharge by a factor 3 resulted in a 3% increase in mine inflows. The +1 OM change in Global RIV conductance did not substantially change average annual mine inflows to the Project.

The additional sensitivity scenario with increased Kv, Kh and Sy for the Hawkesbury Sandstone did not converge. The models for the remaining additional scenarios showed that there was no change in the inflow compared to the base case for the sensitivity scenario with revised GHB boundaries. Increased Kv, Kh and Sy for the coal seams yielded a 79% increase in average annual mine inflows to the Project. The additional sensitivity scenario where the Kv, Kh and Sy of Bulgo Sandstone are increased, mine inflows increased by 30.9%, while increasing the hydraulic properties of Claystone produced a relatively small increase of 11.1% in inflows. The last additional sensitivity run in which Kh, Kv and Sy in the coal seams are increased together with those in other formations yielded the largest inflows, which increased by 122.4% compared to the base case.

Table 5-3 Calibration Sensitivity and Predicted Direct Inflows due to Project During Operations

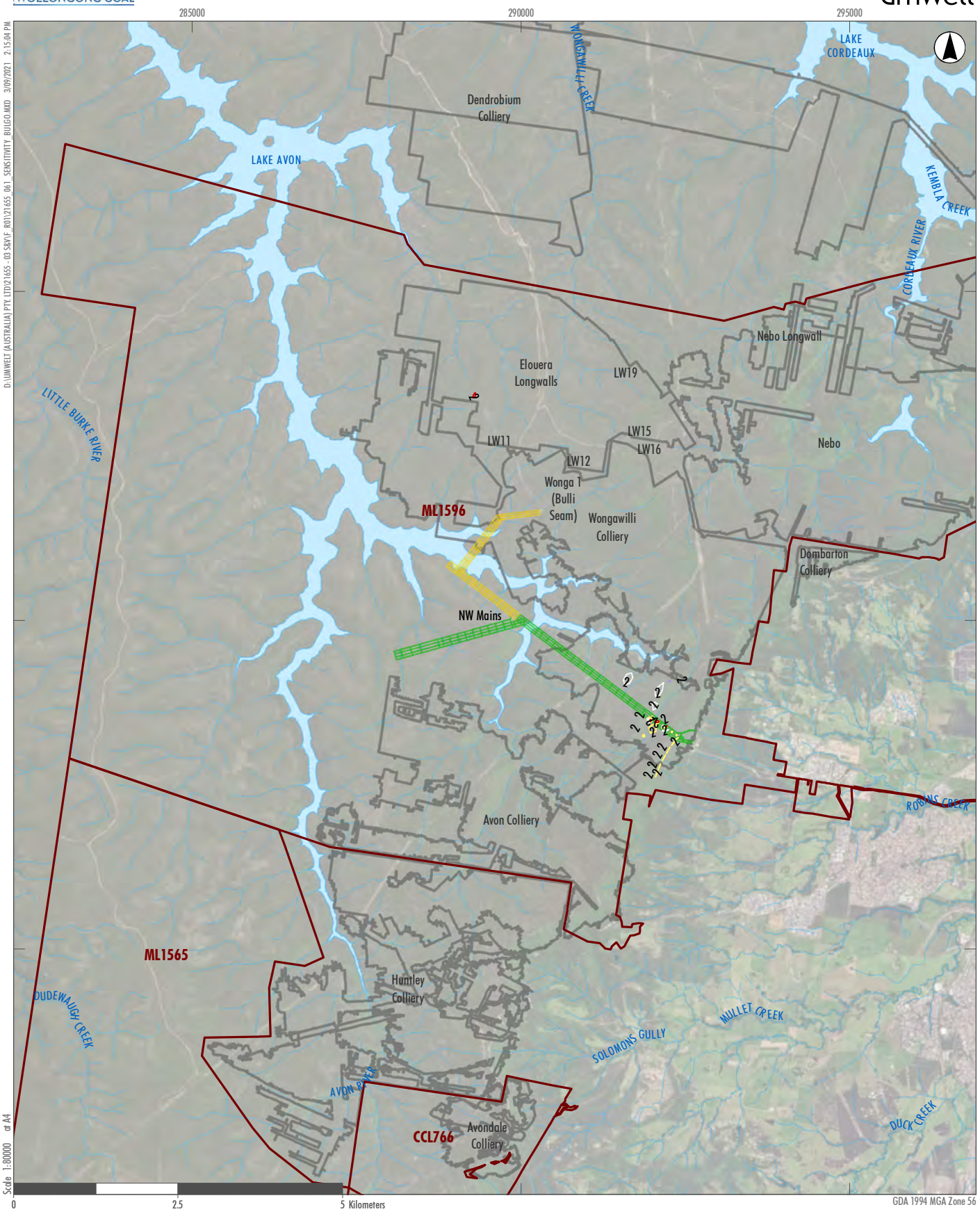
| Sensitivity Scenario | Average Project Inflows (ML/yr) | Inflow Change (%) |
|---|---|---|
| Base case | 30.9 | |
| + 1 OM Kh and Kv - alluvium | 30.9 | 0.0 |
| - 1 OM change in hydraulic conductivity in alluvium | 30.9 | 0.0 |
| + 1 OM change in hydraulic conductivity in coal | 47.0 | 52.3 |
| - 1 OM change in hydraulic conductivity in coal | 19.9 | -35.5 |
| + 1 OM change in hydraulic/vertical conductivity in BGSS | 35.0 | 13.3 |
| - 1 OM change in hydraulic/vertical conductivity in BGSS | 26.9 | -12.9 |
| + 300 % change in recharge | 31.8 | 3.0 |
| - 300 % change in recharge | 30.8 | -0.4 |
| + 500 % change in specific yield in coal | 45.2 | 46.3 |
| - 500 % change in specific yield in coal | 27.9 | -9.6 |
| + 1OM Global RIV conductance | 30.9 | -0.1 |
| GHB | 30.9 | 0.0 |
| HBSS increased Kv, Kh and Sy | - | - |
| Coal seam increased Kv, Kh and Sy | 55.3 | 79.0 |
| BGSS increased Kv, Kh and Sy | 40.4 | 30.9 |
| Claystone increased Kv, Kh and Sy | 34.3 | 11.1 |
| HBSS, coal seams, BGSS, BHCS and SPCS increased Kv, Kh and Sy | 68.7 | 122.4 |

## 5.3 Sensitivity of Groundwater Depressurisation Extent

Changes in model parameters influence the model prediction of groundwater depressurisation. Figure 5-2 to Figure 5-5 show the 2 m predicted depressurisation for the SLR sensitivity runs and the additional Umwelt sensitivity scenarios, with results shown for layer 7 (Bulgo Sandstone) and layer 12 (Bulli Seam).

The results show:

- Figure 5-2 shows minor localised changes in predicted drawdown in the Bulgo Sandstone (layer 7) with an increase in the hydraulic conductivity for the coal seams and alluvium.
- Figure 5-3 shows a decrease in the extent of drawdown for the Bulli Seam with a reduction in hydraulic conductivity, and an increase in drawdown extent with an increase in hydraulic conductivity and recharge. Changes to river conductance and specific yield resulted in negligible change to the basecase results.
- Figure 5-4 is similar to Figure 5-2, with minor localised changes in predicted drawdown in the Bulgo Sandstone (layer 7) with the composite change in hydraulic conductivity and specific yield for the coal, and the change in GHB. The change in properties for the claystone units had the greatest influence on the extent of drawdown, with 2 m extent of drawdown predicted above the proposed workings. This highlights the importance of the claystone units in mitigating impacts from depressurisation. No changes to the hydraulic connectivity of the overlying strata is predicted for the Project, which involves mains development (first workings) only.Figure 5-4 No drawdown was predicted in the Bulgo Sandstone with an increase in hydraulic properties for the Bulgo Sandstone, likely reflecting buffering of impacts from increased recharge to the unit.
- Figure 5-5 shows a slight decline in the extent of drawdown for the Bulli Seam with an increase in hydraulic conductivity and specific yield for the coal seams and all units. The extent of drawdown in the Bulli Seam increased in a localised area around Avon Colliery with the increase in properties for the claystone. This is due to historical workings in this area and existing goaf effects. The increase in properties for the Bulgo Sandstone also resulted in a slight increase in the extent of drawdown for the Bulli Seam.



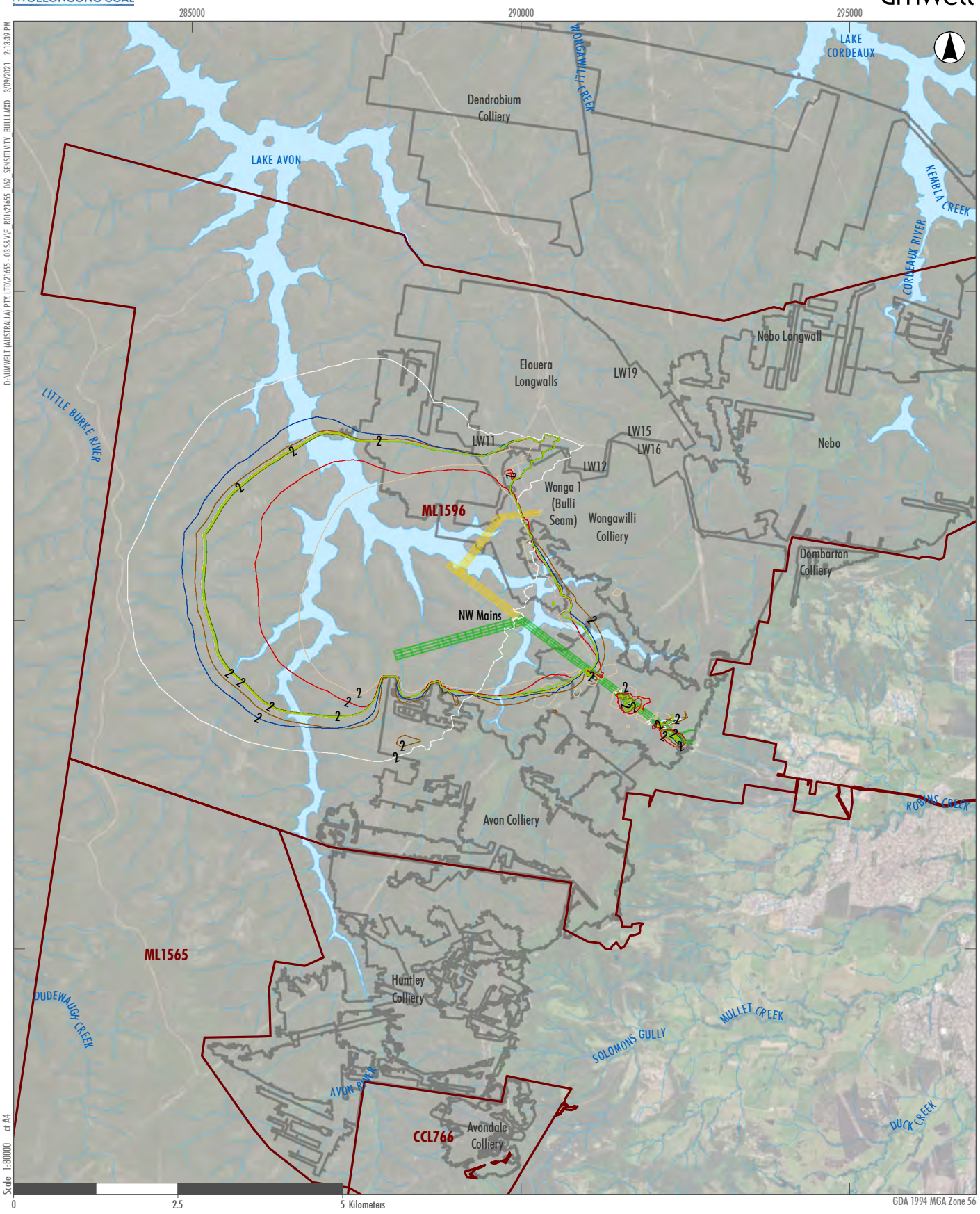

Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Watercourse
- Base
- K Coal Up
- K Coal Down
- K Alluvium Up
- K Alluvium Down

FIGURE 5.2

Sensitivity of 2m Maximum Extent of Drawdown - Bulgo Sandstone (Layer 7) - SLR Scenarios

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)



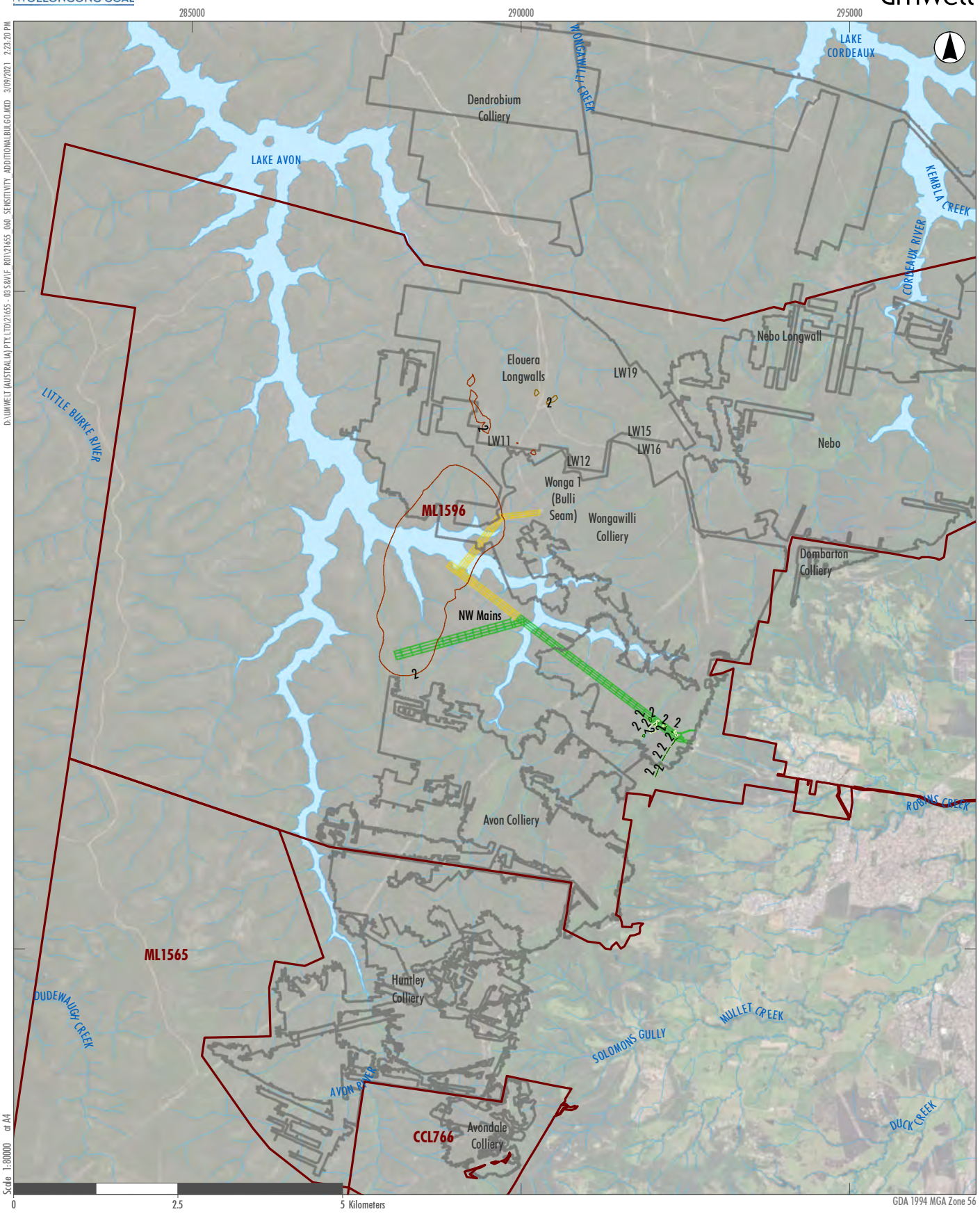

Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Watercourse
- Sy Coal Up
- Sy Coal Down
- River Cond. Up
- Recharge Up
- Recharge Down
- K Coal Up
- K Coal Down
- K Bulgo Up
- K Bulgo Down
- Base
- K Alluvium Up
- K Alluvium Down

FIGURE 5.3

Sensitivity of 2m Maximum Extent of Drawdown - Bulli Seam (Layer 12)

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)



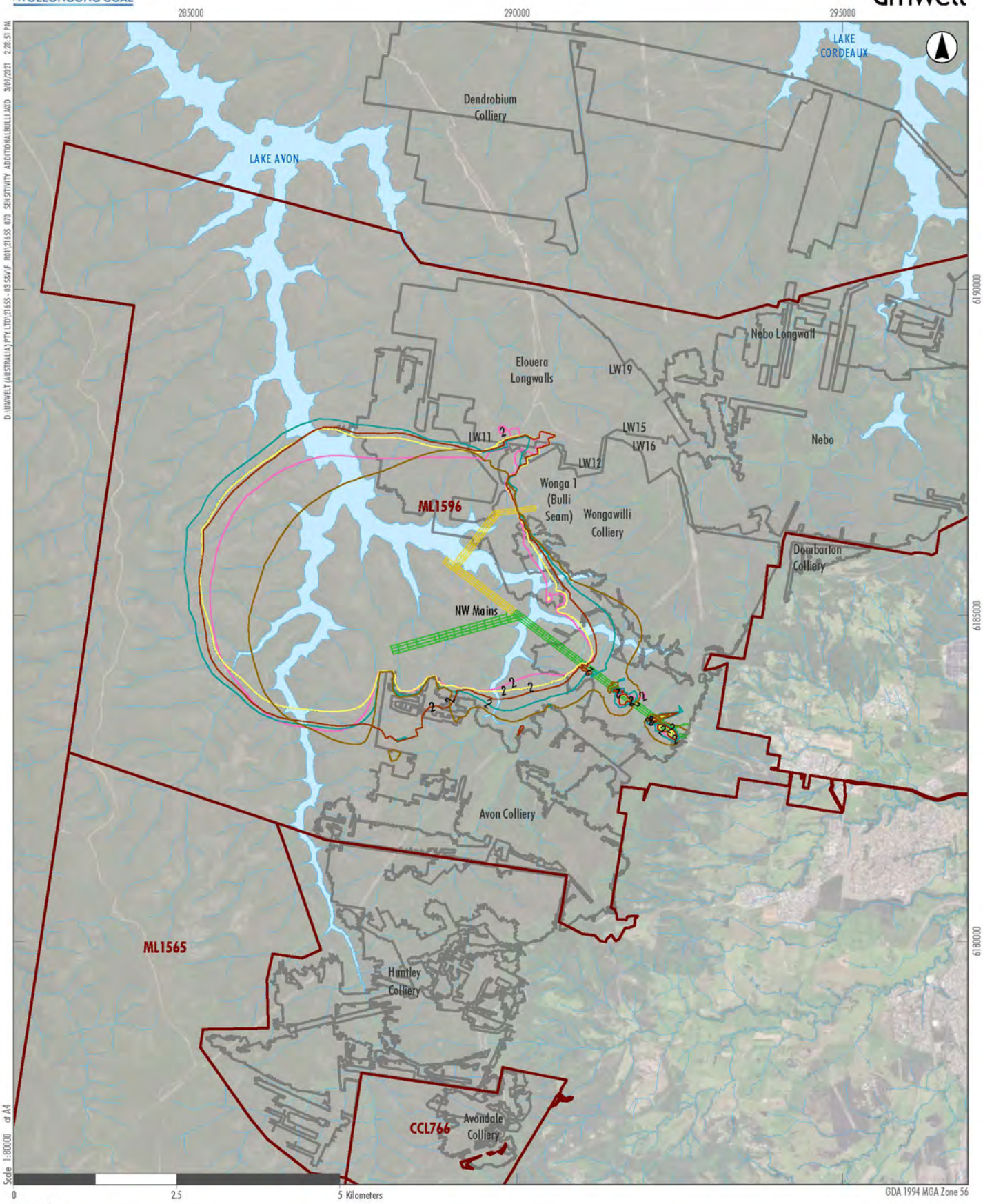

Legend

- Mine Lease Boundary
- Wongawilli Approved Workings
- Proposed NWMD (Project)
- Surrounding Mines
- Watercourse
- Base
- K Sy All Up
- K Sy BHC SPC Up
- K Sy Coal Up
- Revised GHB

FIGURE 5.4

Sensitivity of 2m Maximum Extent of Drawdown - Bulgo Sandstone (Layer 7): Additional Scenarios

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Watercourse
- K Sy All Up
- K Sy BHC SPC Up
- Base
- K Sy Bulgo Up
- K Sy Coal Up
- Revised GHB

FIGURE 5.5
Sensitivity of 2m Maximum Extent of Drawdown - Bulli Seam (Layer 12): Additional Scenarios

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)

# 6. IMPACT CONDITIONS

## 6.1 Aquifer Interference Policy

The following section outlines the groundwater impact predictions for the incremental change due to the proposed modification compared to the requirements under the NSW Aquifer Interference Policy (AIP) (NOW, 2012).

Groundwater at WWC is regulated by the Greater Metropolitan Region Groundwater Sources WSP. This WSP further divides the region into separate Groundwater Sources. The Project is within Management Zone 1 (MZ1) of the Sydney Basin Nepean Sandstone Groundwater Source. This Groundwater Source is classified by DPIE as 'Highly Productive' under the AIP.

The total assigned entitlement for all users within this Groundwater Source (for both Management Zones 1 and 2) is 24,576 ML/year. WCL has secured 1,500 units (equivalent to 1,500 ML/year of shares from the Sydney Basin Nepean Groundwater Source under "Greater Metropolitan Region Groundwater Sources 2011" WSP with WAL 36487. WWC is within the Nepean Sandstone MZ1 and mining in these areas is considered unlikely to increase the incidental take from other groundwater sources.

### 6.1.1 Water Take

Responses to requirements stipulated under Section 2 of the NSW AIP (NOW, 2012) and the AIP Assessment Framework are included in Table 6-1 based on the groundwater impact assessment.

As outlined in Table 6-1, the predicted impacts are less than the Level 1 minimal impact considerations; therefore, these impacts will be considered as acceptable under the AIP framework.

Table 6-1 AIP Impact Considerations

| No. | AIP Requirement | Response |
|---|---|---|
| 1 | Described the water source (s) the activity will take water from? | Based on the AIP, the groundwater system impacted by the Project is the porous and/or fractured consolidated sedimentary rock of the Triassic Narrabeen Group and Permian coal measures. |
| 2 | Predict the total amount of water that will be taken from each connected groundwater or surface water source on an annual basis as a result of the activity? | Refer Section 4.6 for licensing |
| 3 | Predicted the total amount of water that will be taken from each connected groundwater or surface water source after the closure of the activity? | Refer Section 4.6 for licensing |
| 4 | Made these predictions in accordance with Section 3.2.3 of the AIP? (Page 27) | Based on 3D numerical groundwater modelling |
| 5 | Described how and in what proportions this take will be assigned to the affected aquifers and connected surface water sources? | Refer Section 4.6 for licensing |
| 6 | Described how any licence exemptions might apply? | Not applicable |
| 7 | Described the characteristics of the water requirements? | Urban potable water supply and utilise mine inflows for processing on site. Refer to Surface Water Impact Assessment |

| No. | AIP Requirement | Response |
|---|---|---|
| 8 | Determined if there are sufficient water entitlements and water allocations that are able to be obtained for the activity? | Refer Appendix H of the EIS (Site Water Management Section within Surface Water Impact Assessment) |
| 9 | Considered the rules of the relevant water sharing plan and if it can meet these rules? | Refer Appendix H of the EIS (Site Water Management Section within Surface Water Impact Assessment) |
| 10 | Determined how it will obtain the required water? | Refer Appendix H of the EIS (Site Water Management Section within Surface Water Impact Assessment) |
| 11 | Considered the effect that activation of existing entitlement may have on future available water determinations? | Refer Appendix H of the EIS (Site Water Management Section within Surface Water Impact Assessment) |
| 12 | Considered actions required both during and post-closure to minimise the risk of inflows to a mine void as a result of flooding? | Refer to Surface Water Assessment for further information. |
| 13 | Developed a strategy to account for any water taken beyond the life of the operation of the Project? | Refer Section 4.6, modelling predicts negligible (<2 ML/year) of net take due to the Project at the end of the recovery model.<br>Future updates to the model will be undertaken to refine model predictions over time. Relevant entitlements under the Project water access licences would be retired at the completion of the Project to account for groundwater take during the recovery of the groundwater system post mining. |
| Will uncertainty in the predicted inflows have a significant impact on the environment or other authorised water users? Items 14-16 must be addressed if so. | | |
| 14 | Considered any potential for causing or enhancing hydraulic connections, and quantified the risk? | Negligible subsidence impacts and no predicted changes in enhanced hydraulic connections due to proposed mine method as first workings.<br>Geotechnical assessment conducted by SCT and included in Appendix K of the EIS. |
| 15 | Quantified any other uncertainties in the groundwater or surface water impact modelling conducted for the activity? | Sensitivity analysis has been completed to identify parameters that demonstrate most substantial changes in the predictions. |
| 16 | Considered strategies for monitoring actual and reassessing any predicted take of water throughout the life of the Project, and how these requirements will be accounted for? | Ongoing monitoring and verification of modelling recommended. |
| SECTION 3.2.3 OF AIP<br>For State Significant Development or mining or coal seam gas production, is the estimate based on a complex modelling platform that is: | | |
| - | Calibrated against suitable baseline data, and in the case of a reliable water source, over at least two years? | Steady state and transient calibration conducted with 11 years of data, as reported in Section 3.5 |
| - | Consistent with the Australian Modelling Guidelines? | Conducted in accordance with guidelines as outlined in Section 3.5.3 and external peer review conducted as documented in Appendix C |

| No. | AIP Requirement | Response |
|---|---|---|
| - | Independently reviewed, robust and reliable, and deemed fit-for-purpose | Peer review conducted by Dr Doug Weatherill, as outlined in Appendix C |
| 1 | Establishment of baseline groundwater conditions? | Baseline conditions established based on historical data for the site and Dendrobium, collected since 2009. Baseline conditions presented in Section 2.6 and model's performance at history matching presented in Section 1103.5.3.2 |
| 2 | A strategy for complying with any water access rules? | Discussion of the relevant water sharing plan rules is provided in Section 5.2.3 of the EIS |
| 3 | Potential water level, quality or pressure drawdown impacts on nearby basic landholder rights water users? | No registered water supply bores above the Illawarra Escarpment within 10 km of the Project area.<br>No impacts predicted for registered water supply bores. |
| 4 | Potential water level, quality or pressure drawdown impacts on nearby licensed water users in connected groundwater and surface water sources? | No impacts predicted for registered water supply bores. |
| 5 | Potential water level, quality or pressure drawdown impacts on groundwater dependent ecosystems? | No drawdown predicted within the water table and Hawkesbury Sandstone which occurs at surface and underlies identified swamps. |
| 6 | Potential for increased saline or contaminated water inflows to aquifers and highly connected river systems? | As outlined in Section 4.7, no impacts to groundwater quality due to the Project are predicted. |
| 7 | Potential to cause or enhance hydraulic connection between aquifers? | Negligible subsidence impacts and no predicted changes in enhanced hydraulic connections above the mine workings due to proposed mine method as first workings.<br>Geotechnical assessment conducted by SCT and included in Appendix K of the EIS. |
| 8 | Potential for riverbank instability, or high wall instability or failure to occur? | Negligible subsidence impacts and no predicted changes in enhanced hydraulic connections above the mine workings due to proposed mine method as first workings.<br>Geotechnical assessment conducted by SCT and included in Appendix K of the EIS. |

### 6.1.2 Minimal Impact Considerations

This section provides discussion of potential impacts of the Project in terms of the AIP minimal impact considerations for the Sydney Basin Porous Rock groundwater source (Highly Productive Porous Rock Aquifer). The water source is assessed against the AIP minimal impact considerations in Table 6-2.

Table 6-2 Summary of AIP Assessment Criteria – Highly Productive Porous Rock Aquifer

| Aquifer: Sydney Basin Porous Rock<br>Sydney Basin – Nepean and Sydney Basin – South Groundwater Sources<br>(Greater Metropolitan Groundwater Sources 2011) | |
|---|---|
| Category: Highly Productive Groundwater Source | |
| **Level 1 Minimal Impact Considerations** | **Assessment** |
| Water Table:<br>1. Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any:<br>(a) high priority groundwater dependent ecosystem; or<br>(b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan; or A maximum of a 2 m decline cumulatively at any water supply work.<br>2. If more than 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any:<br>(a) high priority groundwater dependent ecosystem; or<br>(b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan then appropriate studies will need to demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or "culturally" significant site.<br>If more than 2 m decline cumulatively at any water supply work then make good provisions should apply. | There are no High Priority Groundwater Dependent Ecosystems (GDE) listed in the Water Sharing Plan for the Greater Metropolitan Groundwater Sources 2011 within 10 km of the Project<br><br>There are no High Priority culturally significant sites listed in the Water Sharing Plan for the Greater Metropolitan Groundwater Sources 2011 in the Project area.<br><br>The groundwater assessment predicts that there is a very low risk of drawdown in excess of the water supply work drawdown criterion due to mining activities at the Project.<br><br>There are no other relevant water supply works.<br>Project complies with Level 1 minimal impact considerations. |
| Water Pressure:<br>1. A cumulative pressure head decline of not more than 2 m decline, at any water supply work.<br>2. If the predicted pressure head decline is greater than requirement 1. above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply. | The groundwater assessment for the Project predicts that no water supply works would be affected by drawdown from the Project.<br>Project complies with Level 1 minimal impact considerations. |
| Water Quality:<br>1. Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity.<br>2. If condition 1 is not met then appropriate studies will need to demonstrate to the Minister's satisfaction that the change in groundwater quality will not prevent the long- | The Project is proposed as mains development with first workings mine method only.<br>Subsidence due to the Project is predicted to be negligible due to the mine method selected.<br>Project complies with Level 1 minimal impact considerations. |

| Aquifer: Sydney Basin Porous Rock<br>Sydney Basin – Nepean and Sydney Basin – South Groundwater Sources<br>(Greater Metropolitan Groundwater Sources 2011) | |
|---|---|
| Category: Highly Productive Groundwater Source | |
| Level 1 Minimal Impact Considerations | Assessment |
| term viability of the dependent ecosystem, significant site or affected water supply works. | |

## 6.2 EPBC Act Significant Impact on Water Resources Guidelines

Under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) 'Water Trigger', water resources are included as a matter of national environmental significance in relation to coal seam gas and large coal mining developments.

The previously approved NWM was not deemed a 'controlled action', with no impacts to MNES listed under the EPBC Act. Based on the groundwater impact assessment for the Project, it is considered there are no predicted significant impacts on MNES in relation to water. This is further discussed in Section 6.2.1 to Section 6.2.3 below against the significant impact considerations.

### 6.2.1 Potential Impacts on Hydrological Characteristics

The Significant Impact Guidelines for Water Resources provide guidance on potential impacts of an action on hydrological characteristics, as outlined in Table 6-3.

Table 6-3 Significant Impacts to Hydrological Characteristics

| Guideline Consideration | Response |
|---|---|
| A significant impact on the hydrological characteristics of a water resource may occur where there are, as a result of the action: | |
| a) Changes in the water quantity, including the timing of variations in water quantity. | Modelling indicates no drawdown in the Hawkesbury Sandstone |
| b) Changes in the integrity of hydrological or hydrogeological connections, including substantial structural damage (e.g. large scale subsidence). | Negligible subsidence impacts and no predicted changes in enhanced hydraulic connections above the mine workings, due to proposed mine method as first workings.<br>Geotechnical assessment conducted by SCT and included in Appendix K of the EIS. |
| c) Changes in the area or extent of a water resource where these changes are of sufficient scale or intensity as to significantly reduce the current or future utility of the water resource for third party users, including environmental and other public benefit outcomes. | No registered water supply bores above the Illawarra Escarpment within 10 km of the Project area.<br>No impacts predicted for registered water supply bores.<br>No drawdown predicted within the Hawkesbury Sandstone, which occurs at surface and underlies identified swamps. |

### 6.2.2 Potential Impacts on Water Quality

The Significant Impact Guidelines for Water Resources provide guidance on potential impacts of an action on water quality, as outlined in Table 6-4.

Table 6-4 Significant Impacts to Water Quality

| Guideline Consideration | Response |
|---|---|
| A significant impact on a water resource may occur where, as a result of the action: | |
| a) there is a risk that the ability to achieve relevant local or regional water quality objectives would be materially compromised, and as a result the action: | No predicted change in groundwater table levels, and change in water quality or introduction of contaminant sources planned as part of the Project. |
| i. Creates risks to human or animal health or to the condition of the natural environment as a result of the change in water quality | No predicted change in groundwater table levels, and change in water quality or introduction of contaminant sources planned as part of the Project. |
| ii. Substantially reduces the amount of water available for human consumptive uses or for other uses, including environmental uses, which are dependent on water of the appropriate quality | No predicted change in groundwater table levels, and change in water quality or introduction of contaminant sources planned as part of the Project. |
| iii. Causes persistent organic chemicals, heavy metals, salt or other potentially harmful substances to accumulate in the environment | No change in water quality or introduction of contaminant sources planned as part of the Project. |
| iv. Seriously affects the habitat or lifecycle of a native species dependent on a water resource, or | No predicted change in groundwater table levels, and change in water quality or introduction of contaminant sources planned as part of the Project. |
| v. Causes the establishment of an invasive species (or the spread of an existing invasive species) that is harmful | No ground disturbance proposed above the escarpment. Monitoring programs to include consideration of weed and seed management. |
| vi. to the ecosystem function of the water resource, or | No predicted change in groundwater table levels or river levels. No predicted change in water quality or introduction of contaminant sources planned as part of the Project. |
| b) There is a significant worsening of local water quality (where current local water quality is superior to local or regional water quality objectives), or | No predicted change in groundwater table levels, and change in water quality or introduction of contaminant sources planned as part of the Project. |
| c) High quality water is released into an ecosystem which is adapted to a lower quality of water. | No surface water releases assessed under this groundwater impact assessment. |

### 6.2.3 Cumulative Impacts

The Significant Impact Guidelines for Water Resources require the action to be:

> *Considered with other developments, whether past, present or reasonably foreseeable developments.*

Cumulative groundwater depressurisation contours showing the magnitude and water table pattern caused by coincident mining at Dendrobium and the Project are presented in Section 4.1.3. The cumulative impacts of the Project and Dendrobium include:

- Drawdown is predicted in the water table due to cumulative mine operations. Within 1 km of the Project there are four locations with a cumulative impact of more than 1 m. More extensive areas with drawdown of more than 1 m are present in the northern mine workings within ML1596. Water table drawdown around Dendrobium does not extend into ML1596 and does not interact with the Project area.
- Depressurisation is predicted within the Hawkesbury Sandstone around the Project and around Dendrobium. Cumulative impacts of up to 1 m extend 1 km south from the Elouera workings. Dendrobium drawdown of more than 1 m in the Hawkesbury Sandstone does not extend into ML1596 and does not interact with the Project.
- Extensive depressurisation within the Bulgo Sandstone and Scarborough Sandstone around the Project, Elouera workings and around Dendrobium is predicted. Cumulative impacts of more than 100 m extend into ML1596 from the Elouera workings and Dendrobium located in the north.
- Extensive depressurisation within the Bulli Seam and Wongawilli Seam around the Project, Elouera workings and around Dendrobium is predicted. Cumulative impacts of more than 200 m extend into ML1596 from the Elouera workings and Dendrobium located in the north.

# 7 PROPOSED GROUNDWATER MONITORING PROGRAM

Groundwater monitoring will be conducted in accordance with a Groundwater Monitoring Plan (GWMP) that will be prepared in consultation with DPIE Water/NRAR and WaterNSW. The GWMP will include full details on how and when groundwater will be monitored across the Project area and surrounds.

## 7.2 Groundwater Monitoring Program

Table 7-1 summarises the proposed monitoring network and program, and Figure 7-1 shows the bore locations. Seven new monitoring sites are proposed to be installed; two screened within the Hawkesbury Sandstone, two screened within the Bulgo Sandstone, two swamp piezometers and one VWP targeting the Wongawilli Fault in the north of the Project area.

The purpose of the proposed monitoring bores is to identify any impacts to the swamps and overlying sandstone due to the Project. Monitoring bores NWW 21 and NWW 24 will monitor the Hawkesbury and Bulgo Sandstone, respectively, in the southern area of the Project. The final location of these bores will be confirmed once access is identified.

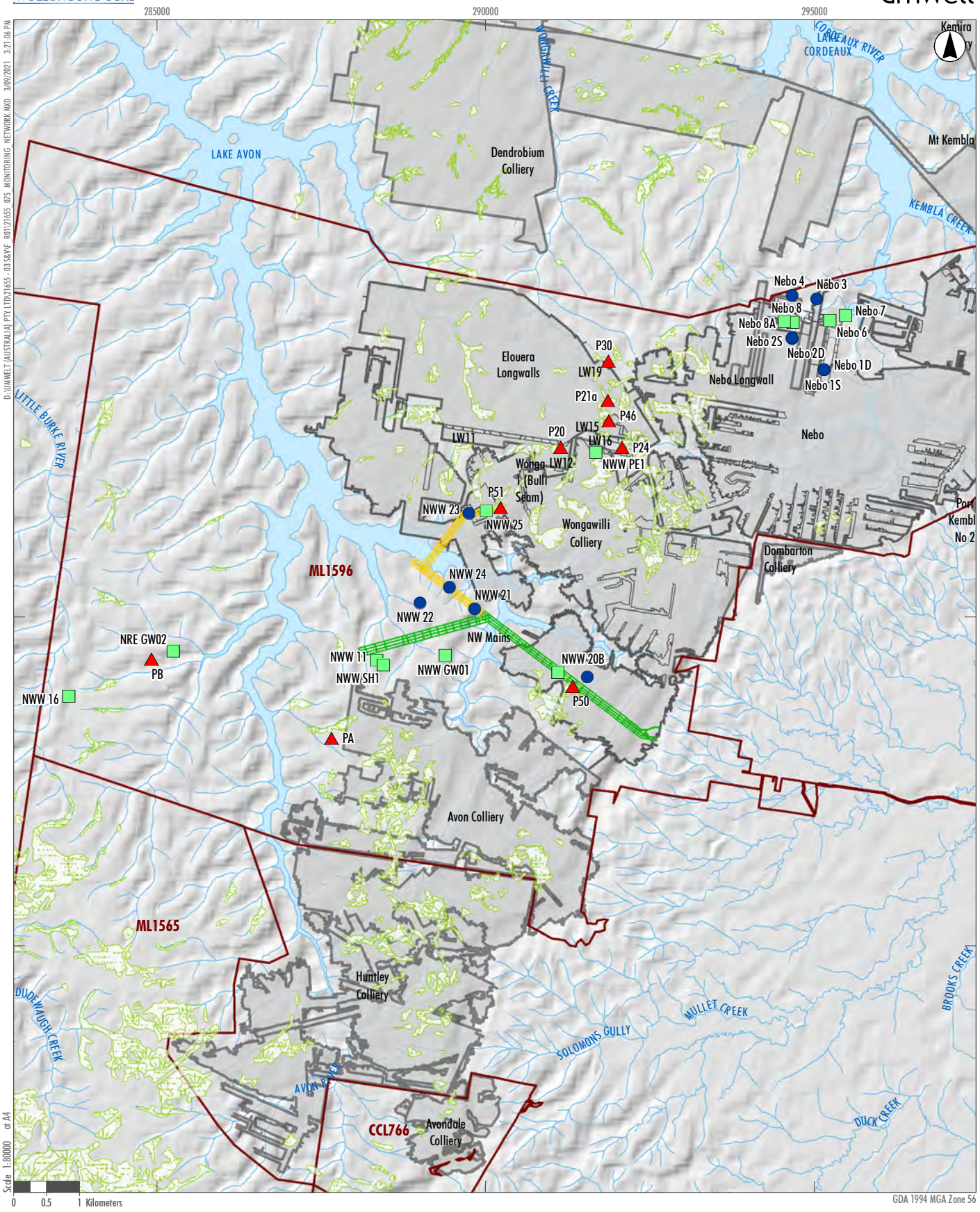
Monitoring bore NWW 23 will monitor any impacts on the Hawkesbury Sandstone due to the Project in the northern area of the Project. Monitoring bore NWW 22 is located south of the Project and will act as a background monitoring bore for comparison to the Hawkesbury Sandstone monitoring bores located directly above the Project. The VWP, NWW 25, will monitor any changes within the vicinity of the Wongawilli Fault. Swamp monitoring piezometers, P50 and P51 will monitor if there are any changes within the two swamps located within the Project area.

Table 7-1 Proposed Groundwater Monitoring Program

| Bore | Status/ Type | Easting (m)* | Northing (m)* | Ground Level (mAHD) | Screen/ Sensor Depth (mbgl) | Unit Intersected | SWL | Field WQ | Full WQ |
|---|---|---|---|---|---|---|---|---|---|
| NWW 21 | PR/MB | 289836 | 6185128 | TBC | TBC | HBSS | D/Q | Q | A |
| NWW 22 | PR/MB | 289002 | 6185215 | TBC | TBC | BGSS | D/Q | Q | A |
| NWW 23 | PR/MB | 289748 | 6186582 | TBC | TBC | HBSS | D/Q | Q | A |
| NWW 24 | PR/MB | 289451 | 6185448 | TBC | TBC | BGSS | D/Q | Q | A |
| NWW 25 | PR/VWP | 290010 | 6186615 | TBC | TBC | Wongawilli Fault | D/Q | - | - |
| P50 | PR/MB | 291325 | 6183946 | TBC | TBC | Swamp | D/Q | Q | A |
| P51 | PR/MB | 290224 | 6186666 | TBC | TBC | Swamp | D/Q | Q | A |
| P20 | EX/MB | 291144 | 6187583 | 486.2 | 2.93 | Swamp | D/Q | Q | A |
| P21a | EX/MB | 291860 | 6188293 | 462.1 | 3.37 | Swamp | D/Q | Q | A |
| P24 | EX/MB | 292076 | 6187585 | 501.9 | 2.86 | Swamp | D/Q | Q | A |
| P30 | EX/MB | 291867 | 6188897 | 479.6 | 3.07 | Swamp | D/Q | Q | A |
| P46 | EX/MB | 291875 | 6187988 | 489.3 | 3.40 | Swamp | D/Q | Q | A |
| PA | EX/MB | 287655 | 6183160 | 483.6 | - | Swamp | D/Q | Q | A |
| PB | EX/MB | 284921 | 6184365 | - | - | Swamp | D/Q | Q | A |
| Nebo 1s | EX/MB | 295153 | 6188762 | 366.4 | 5.0 - 6.0 | Soil | D/Q | Q | A |
| Nebo 1d | EX/MB | 295152 | 6188761 | 366.5 | 85.6 - 97.6 | Siltstone | D/Q | Q | A |
| Nebo 2s | EX/MB | 294662 | 6189246 | 347.7 | 5.5 - 6.5 | Crinanite | D/Q | Q | A |
| Nebo 2d | EX/MB | 294662 | 6189237 | 348.5 | 19.0 - 31.0 | HBSS | D/Q | Q | A |
| Nebo 3 | EX/MB | 295033 | 6189838 | 356.7 | 21.6 - 33.6 | HBSS | D/Q | Q | A |
| Nebo 4 | EX/MB | 294661 | 6189893 | 374.1 | 107.5 - 109.5 | WWCO | D/Q | Q | A |

| Bore | Status/ Type | Easting (m)* | Northing (m)* | Ground Level (mAHD) | Screen/ Sensor Depth (mbgl) | Unit Intersected | SWL | Field WQ | Full WQ |
|---|---|---|---|---|---|---|---|---|---|
| Nebo 6 | EX/VWP | 295237 | 6189510 | 354.2 | 60 | Crinanite | D/Q | - | - |
| | | | | | 80 | Crinanite | | | |
| | | | | | 100 | EKFM | | | |
| | | | | | 115 | WWCO | | | |
| Nebo 7 | EX/VWP | 295477 | 6189585 | 336.4 | 30 | Crinanite | D/Q | - | - |
| | | | | | 45 | Crinanite | | | |
| | | | | | 63 | LDSS | | | |
| | | | | | 90 | WWCO | | | |
| Nebo 8 | EX/VWP | 294679 | 6189485 | 343.4 | 15 | Crinanite | D/Q | - | - |
| | | | | | 35 | Crinanite | | | |
| | | | | | 52 | SPCS | | | |
| | | | | | 72 | CCSS | | | |
| Nebo 8A | EX/VWP | 294549 | 6189499 | 359.6 | 25 | Crinanite | D/Q | - | - |
| | | | | | 45 | Crinanite | | | |
| NWW PE1 | EX/VWP | 291676 | 6187507 | 515.7 | 90 | HBSS | D/Q | - | - |
| | | | | | 135 | HBSS | | | |
| | | | | | 150 | BHCS | | | |
| | | | | | 165 | BGSS | | | |
| NWW 11 | EX/VWP | 288343 | 6184339 | 467.1 | 60 | HBSS | D/Q | - | - |
| | | | | | 90 | HBSS | | | |
| | | | | | 104 | BHCS | | | |
| | | | | | 125 | BGSS | | | |
| NWW 16 | EX/VWP | 283657 | 6183801 | 513.4 | 71 | HBSS | D/Q | - | - |
| | | | | | 126 | HBSS | | | |
| | | | | | 146 | HBSS/NPFM | | | |
| | | | | | 166 | BHCS/BGSS | | | |
| NWW20B | EX/VWP | 291099 | 6184158 | 488.3 | 33 | HBSS | D/Q | - | - |
| | | | | | 60 | BHCS | | | |
| | | | | | 75 | BGSS | | | |
| | | | | | 135 | BGSS | | | |

*Notes:*
**MGA94 Z56*
*LRSS – Lawrence Sandstone*
*WWCO – Wongawilli Coal*
*BHCS – Bald Hill Claystone*
*EKFM – Eckersley Formation*
*Q – Quarterly frequency*
LDSS – Loddon Sandstone
*BACO – Balgownie Coal*
*BUCO – Bulli Coal*
*HBSS – Hawkesbury Sandstone*
*A – Annual frequency*
KBSS – Kembla Sandstone
*BGSS – Bulgo Sandstone*
*CCSS – Coalcliff Sandstone*
*D/Q – Daily level logger/VWP logger downloaded quarterly*




Legend

- Mine Lease Boundary
- Approved NWM
- Proposed NWMD (Project)
- Surrounding Mines
- Swamps
- Watercourse

Bore Type

- Monitoring Bore
- Swamp Piezometer
- VWP

FIGURE 7.1

Proposed Monitoring Network

Image Source: Wollongong Coal (2021) Data source: Wollongong Coal (2021)

## 7.3 Groundwater Monitoring and Reporting

Groundwater monitoring and reporting will be undertaken in accordance with the GWMP.

Groundwater level monitoring will be conducted to capture natural groundwater level fluctuations (such as responses to rainfall) and detect any potential groundwater level impacts due to depressurisation resulting from the Project. Ongoing monitoring of groundwater levels will also be used to assess the extent and rate of depressurisation against model predictions.

The monitoring program will include:

- Manual groundwater level monitoring to be conducted for all monitoring bores;
- Dataloggers installed within selected bores to gather temporal changes in water levels;
- Data downloaded from the existing VWPs, pressure readings recorded and converted to groundwater elevations; and
- QA/QC field data and stored within a central database.

Groundwater quality sampling will be conducted to detect any changes in groundwater quality during and post mining. Baseline data have been collected from the existing bores, as presented in Appendix D.

Sampling will include collection of field analytes of pH and EC on a quarterly basis, as well as annual sampling for laboratory analysis of a full suite of analytes to determine any changes in beneficial groundwater use (i.e. livestock drinking water).

The full suite will include:

- Physio-chemical indicators – pH, electrical conductivity, total dissolved solids;
- Major ions – Na, K, Ca, Mg, Cl, SO4, F;
- Total P;
- Organics - NO3 and Total N;
- Total alkalinity as CaCO3, HCO3, CO3; and
- Dissolved metals Ag, Al, As, B, Ba, Cd, Co, Cu, Fe, Hg, Li, Mn, Mo, Ni, P, Pb, Sb, Se, Zn.

Yearly reporting of the water level results from the monitoring network will be included in the Annual Review. The Annual Review will also identify if any additional monitoring sites are required, or if optimisation of the existing monitoring sites should be undertaken.

Within the GWMP, proposed triggers for water level and water quality for the site compliance monitoring network will be documented. This will include establishment of triggers for EC and pH. The observed groundwater levels will also be reviewed against the model predictions on an annual basis. The trends will be reviewed by a suitably qualified and experienced hydrogeologist to determine potential adverse changes. The review will consider the impact of mining, and other factors that could result in declining water levels including climatic conditions and surrounding mining.

## 7.4 Swamp Monitoring

Swamp monitoring and reporting will be undertaken in accordance with the GWMP. Swamp monitoring will be conducted to capture natural water level fluctuations (such as responses to rainfall) and detect any potential water level impacts resulting from the Project.

Monitoring of the soil moisture and water level within swamp deposits will be conducted with a paired soil moisture probe and water level piezometer. The soil moisture probe will be installed to determine the moisture content of the swamp with probes at a 1 m depth with five sensors at 10,

30, 50, 70 and 90 cm below surface. It is recommended that the paired piezometers at the proposed monitoring sites be installed as close to the centre of the swamp, . Table 7-1 includes indicative locations, to be confirmed based on land accessibility and agreement with the regulatory authority.

## 7.5 Geological, Hydraulic and Geotechnical Investigations

The groundwater assessment utilises geological information to understand and characterize the groundwater regime. Over the life of the Project, additional geological data will be collected, including details on lithology, groundwater intersection and intersection of structures (i.e. faults and dykes). This information will be used to routinely update the site geological model. This information will be stored and made available as required for future groundwater investigations and/or updates to the model.

Packer testing will be conducted on the four proposed monitoring bores and VWP. This will provide further hydraulic properties of the overlying sandstone and the Wongawilli fault and can be used to inform future groundwater investigations and model updates.

## 7.6 Mine Inflows and Groundwater Balance

Monitoring of mine inflow volumes into the Project area within ML1596 area will be undertaken on a monthly basis. Field water quality analysis will also be undertaken on a monthly basis, with full water quality analysis undertaken annually.

The objective of the monitoring is to provide an early indication of any groundwater mixing between the Triassic and Permian strata that might indicate a change in vertical connectivity. The monitoring program will include:

- Volumetric measurement of water pumped from the mining areas using flow meters or equivalent devices;
- Monitoring the quality of water pumped from the mining areas;
- Correlation of rainfall records (and catchments); and
- Monitoring of coal moisture content.

The mine water balance will be reported annually.

## 7.7 Model Updates

Every three years the validity of the model predictions will be assessed by comparing observed groundwater levels and mine inflows. If the comparison between observed and modelled data indicate significant deviation, an update to the groundwater model may be required.

Updates will include consideration of the limitations and recommended improvements as discussed in Section 3.5.4.3.

# 8 MANAGEMENT AND MITIGATION MEASURES

Management of groundwater beneath and adjacent to the Project will involve the establishment of a robust surface water and groundwater level and quality monitoring program, for relevant groundwater and surface water sources. Operational reporting will occur at frequencies suited to the mine development and be part of the annual reporting to key stakeholders.

Should monitoring indicate the changes in groundwater levels and quality are more extensive or significant than predicted, mitigation measures will be considered.

This may include mine sealing. The installation of seals to isolate areas can be conducted as specific mining areas are completed, with the seals containing monitoring, drainage and sampling facilities to allow water accumulation behind the seals to be monitored, sampled and managed while current areas are mined.

The final sealing of the mine requires seals to be installed to manage seepage. Trigger mechanisms that will initiate the decision to abandon other remedial techniques and commence the installation of seals either to isolate areas or to seal the mine will be defined as part of the mine closure plan.

Other mitigation measures that are currently in place include:

- Grouting and cut off measures;
- Sourcing of water from other sources to support site activities;
- Maintain current water licence allocations that are sufficient to cover predicted groundwater take;
- Treatment of mine water for reuse within the water management system.

No impacts to landholder bores are predicted. If potential impacts are identified in future and mitigation measures are not feasible, 'make good' measures with affected land owners would be carried out that may include:

- Ensuring the bore owner has access to a similar quantity and quality of water for the water bore's authorised purpose by:
  - Bore enhancement by deepening the bore or improving its pumping capacity;
  - Constructing a new water bore; or
  - Providing a supply of an equivalent amount of water of a suitable quality by piping it from an alternative source.
- Carry out a plan to monitor the water bore by undertaking periodic bore assessments.

# 9 CONCLUSIONS

The Project involves the NWMD, which extends the mine life by five years to complete the previously approved mains development (NWM), extension of the length of the approved alignment to access the existing Wongawilli Ventilation Shaft 1 and minor surface activities. All mining is proposed to be conducted as first workings only as WCL made a commitment in 2019 to no longer undertake longwall mining within the Illawarra coal fields.

A groundwater impact assessment was prepared for the Project by SLR (2020) and submitted as part of the Modification of Consent (MOD2). Due to the nature of the comments and feedback on the groundwater assessment report by DPIE Water and WaterNSW, a separate supplementary groundwater impact assessment has been prepared (this report).

This report re-presents the conceptual groundwater model and site background information previously reported by SLR (2020), with additional reporting undertaken by Umwelt included to address regulator comments. No changes to the SLR (2020) numerical groundwater model were undertaken; however, further work was done to extract additional information on the model development and predictions. Additional sensitivity scenarios were run to address comments from DPIE Water. This supplementary groundwater assessment has been guided by the requirements of the regulator, peer review comments and the NSW Aquifer Interference Policy.

Model parameters are based on the Dendrobium model but have been refined in the Project area based on site specific data and calibration to site water levels. Steady-state and transient calibration of the numerical groundwater flow model were conducted in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al., 2012).

Calibration was conducted using groundwater levels and validated against observed mine inflows. A variety of approaches to analysing the data were applied, including vertical groundwater head differences and temporal groundwater head differences. Model calibration to the available groundwater level/pressure data, including verification against observations for Dendrobium, was generally good.

The numerical groundwater flow model can be described as a Class 2 model as outlined by the Australian Groundwater Modelling Guidelines.

The key conclusions from the groundwater assessment are summarised as follows:

- The modelled groundwater responses over the historical period of monitoring generally match the time series of observed groundwater levels and groundwater level trends.
- The model scaled RMS is 8.44 % for the site monitoring data, indicating a reasonable statistical match to head targets, and calibration hydrographs indicate the model is able to history match observed trends in response to stressors (mining).
- No depressurisation is predicted in the water table and Hawkesbury Sandstone due to the Project. This is due to the Project being mains development (first workings) only with no predicted changes to hydraulic connectivity above the workings.
- Minor localised depressurisation is predicted above the proposed mains development within the lower layer of the Bulgo Sandstone (Layer 7).
- Localised depressurisation above the proposed mains development within the Scarborough Sandstone (Layer 9). This depressurisation is facilitated by existing vertical connectivity between the coal seam and lower Narrabeen Group units from historical mining. The Project is not predicted to result in any changes to hydraulic connectivity above the workings.

- Localised depressurisation within the Bulli Seam (Layer 12) and Wongawilli Seam (Layer 14) around the proposed mains development. The extent of depressurisation is within ML1596 and does not extend to Dendrobium.
- No groundwater drawdown in the alluvium/weathered zone or Hawkesbury Sandstone, therefore losses or diversions of surface water are not predicted and are therefore unlikely;
- No high priority GDEs are mapped within the Project area and there is no drawdown within the water table due to the Project, therefore no impacts are predicted on GDEs;
- No predicted changes in groundwater conditions in the Bulgo Sandstone and Hawkesbury Sandstone at or near surface, therefore negligible impact on baseflow to rivers and creeks due to the Project has been predicted. Minor flux changes were observed post closure, which appear to correspond to differences in the model setup for the "Approved and Project model scenarios (i.e. unrelated to the Project). Future improvements to the recovery model design are recommended for future expansion plans;
- No private land holder bores within 10 kms of the Project and no drawdown due to the project beyond 6 km from the proposed workings, therefore no impact predicted on private bores;
- Predicted direct and indirect take of groundwater under the Water Sharing Plan for the Sydney Basin Nepean Sandstone Groundwater Source - Management Zone 1 (MZ1) of up to 324.1 ML/year, of which the Project contributes up to 53.9 ML/year of direct take during operations and 24.1 ML/year of indirect take in model year 6. It should be noted that the maximum predicted take for the Project plus approved historical workings in ML1596 was based on the net flux change in ML1596. This is a highly conservative estimate, and it is recommended that with future updates, a scenario be run to quantify the approved mine take; and
- Groundwater quality within the Project area will remain in line with baseline data with no change in the beneficial use of water within the Permian coal measures during or following the Project.

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# 11 CONTROL AND REVISION HISTORY

| PROPERTY | VALUE |
|---|---|
| Approved by | WCL |
| Document Owner | WCL |
| Effective Date | 22/9/2021 |

Revisions

| VERSION | DATE REVIEWED | REVIEW TEAM (CONSULTATION) | NATURE OF THE AMENDMENT |
|---|---|---|---|
| 1 | 26/8/21 | Umwelt | First draft for review |
| 2 | 3/9/21 | Peer Reviewer – Doug Weatherill | Peer Review Input to Model Setup and Calibration, updates by Umwelt |
| 3 | 16/9/21 | Peer Reviewer – Doug Weatherill<br>WCL | Peer Review Input to Impact Assessment, updates by Umwelt |
| 4 | 22/9/21 | Final | Final |

# Appendix A – DPIE Comments

OUT21/1380

Jack Turner
Planning and Assessment Group
NSW Department of Planning, Industry and Environment

Jack.Turner@planning.nsw.gov.au

Dear Mr Turner

**Wongawilli Coal Mine Mod 2 - North West Mains Development (MP09_0161)**
**Modification Report**

I refer to your email of 4 February 2021 to the Department of Planning, Industry and Environment (DPIE) Water and the Natural Resources Access Regulator (NRAR) about the above matter.

Although the surface and groundwater impacts of the modification are predicted as low risk, the significant shortcomings of the numerical modelling and reporting, some of them fundamental, means that we are not confident in the reliability of the impact predictions. This concern is exacerbated by the sensitive environment hosting the proposal, noting that the working is planned to go directly underneath Avon Dam and nearby to other mining projects where cumulative impacts are a consideration.

Please refer to Attachments A and B for associated recommendations and detailed advice.

Any further referrals to DPIE Water and NRAR can be sent by email to: landuse.enquiries@dpie.nsw.gov.au.

Yours sincerely



Mitchell Isaacs
Chief Knowledge Officer,
**Department of Planning, Industry and Environment: Water**
27 April 2021

# Attachment A

# Detailed advice to DPIE Planning & Assessment regarding the Wongawilli Coal Mine Mod 2 North West Mains Development (MP-09_0161)

## 1.0 Entitlement, works approval and water take

### 1.1 Explanation

***Licencing***

The proposal concludes that during excavation of the drivage, groundwater will be drawdown to the base of the Bulli and Wongawilli Seams but will have negligible groundwater drawdown in the upper units i.e. alluvium/weathered zone or Hawkesbury Sandstone. The report advises there will be negligible impact to registered bores or to baseflow in rivers and creeks due to the project.

The mine inflow is predicted to peak at 36.8 ML/year in 2024. This represents the combined inflows for the already approved mining and the additional inflows due to the modification. Wollongong Coal's water take is regulated under WAL 36487 with a share entitlement of 1500 units/ML in the Sydney Basin Nepean Groundwater Source, Management Zone 1. This adequately addresses the project's groundwater entitlement requirements

However, should surface water baseflow in rivers and creeks be reduced as a result of Mod 2, this water take would need to be licenced under the *Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Source 2011*.

As a controlled allocation from the Sydney Basin Nepean Groundwater Source, Management Zone 1 is unlikely, any additional groundwater entitlement if needed should be acquired through water trading.

Please note that the summary Water Sharing Plan rules (https://www.industry.nsw.gov.au/__data/assets/pdf_file/0008/149885/Greater-Metro-Region-Groundwater-Rules.pdf) for the groundwater source advises that it would be very unlikely water would be made available from Management Zone 1 through a controlled allocation.

***Works Approval***

WAL36487 held by the project is linked to water supply work approval 10WA118768. This water supply work approval is located within the Sydney Basin South Groundwater Source.

The proponent should contact NRAR to modify this approval or link a new approval to ensure there is a linked water supply work (miscellaneous work) located in the same water source as the WAL which holds entitlement, i.e. Sydney Basin Nepean Groundwater Source, Management Zone 1.

Note – the WAL awarded to Wongawilli originally under a controlled allocation was located in the incorrect water source- Sydney Basin South Groundwater Source. This was modified to the correct Groundwater source.

***Surface water take – Lake Avon Reservoir***

The approved and proposed North West Mains Development (NWMD) partially underlies Gallahers Creek which forms the western arm of Lake Avon Reservoir. The modification report includes the following statement with regard to surface water impacts:

*"The 2010 EA identified that, although there will be some lateral depressurisation of the overburden above Gallahers Creek, the depressurization will not be notably transferred through the claystone to Lake Avon. As such, there will be no observable, adverse effect on the water storage capacity or water quality of Lake Avon (GeoTerra 2010). Additionally, there will be no*

*loss of flow from surface water systems upstream of Lake Avon Reservoir and no adverse effect on the ephemeral shallow soil groundwater system (GeoTerra 2010b).*

*Given that the existing surface water management system will be maintained for Mod 2, with minimal changes to Wongawilli pit top surface infrastructure, no impacts to the surface water systems or the surface water management system is expected to occur as a result of the proposed modification."*

NRAR is concerned that the project may indirectly impact on the secure water supply currently held with Lake Avon Reservoir. Observable effects may not be predicted but this does not rule out the potential risks associated with mining under the water storage area. This issue is discussed further below in Section 2.

The proposal still may potentially cause lateral depressurisation that could lead to water take from the surface water source. This water take would need to be licenced.

The report also includes this statement in relation to subsidence:

*"There is no potential for the proposed NWMD roadways to cause any significant surface ground movement. Any surface subsidence is expected to be so small as to be imperceptible. Any potential impacts to natural and built features are expected to be imperceptible."*

The project indicates there is expected to be no perceived impacts to natural and built features. The report has not clearly ruled out the potential for impacts in relation to surface cracking along bedrock within creek areas on the surface. Impacts to the surface may still occur, although imperceptible, potentially causing a reduction in baseflow.

### 1.2 Recommendation – Post Determination

NRAR has reviewed the modification report and has the following recommendations:

- The project holds Water Access Licence (WAL) 36487 with a share entitlement of 1500 units/ML in the Sydney Basin Nepean Groundwater Source, Management Zone 1. The project is to ensure all water take falls under the existing entitlement as further entitlements in this water source will only be available by trading within the water source as controlled allocation in this zone is unlikely.
- The project has not indicated it holds any entitlement in the surface water source above the proposed location of Mod 2. If as a result of Mod 2, surface water baseflow in rivers and creeks were to reduce, this would be considered water take and must be licenced under the *Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Source 2011*.
- The proposal is located in close proximity to the Lake Avon Reservoir, part of the Sydney Drinking Water supply. Any surface cracking that leads to water take must be licenced and any reduction in the reservoir capacity may directly impact on WaterNSW's licensable take.
- Any licensable water take requiring a meter must install a meter that is compliant with the NSW non-urban water metering Policy - https://www.industry.nsw.gov.au/__data/assets/pdf_file/0017/312335/nsw-non-urban-water-metering-policy.pdf
- The proponent should contact NRAR to modify water supply work 10WA118768 or link a new work to ensure there is a linked water supply work (miscellaneous work) located in the same water source as the WAL which holds entitlement, i.e. Sydney Basin Nepean Groundwater Source, Management Zone 1.

## 2.0 Groundwater impact assessment and modelling

### 2.1 Explanation

The proponent has not undertaken a full assessment against the NSW Aquifer Interference Policy (AIP, 2012) using the standard assessment framework. However, the AIP minimal impact

considerations have been adequately applied in evaluating the acceptability of the modelled drawdown impacts.

Drawdown predictions are provided for the mined coal seams (Illawarra Coal Measures) and the Bulgo Sandstone, which is the main aquifer of the Narrabeen Group that lies directly above the Illawarra Coal Measures. In summary, the model predicts:

- >0.5 m drawdown in the Bulgo Sandstone and water table during active mining
- No third-party bores impacted by >2 m minimal impact consideration
- 50 m drawdown in the mined coal seams.

Drawdown predictions for the Hawkesbury Sandstone are not provided. The Hawkesbury Sandstone is the main groundwater source and is widely accessed for groundwater supply regionally. It also provides baseflow contributions where incised along major rivers. Although it is reasonable to assume that drawdowns would be negligible due to the negligible drawdown in the Bulgo Sandstone, this omission is a significant concern.

The proponent concludes that Groundwater Dependent Ecosystem (GDE) impacts are unlikely due to the minimal change in water table levels predicted.

There are several instances of contradiction and uncertainty in the description of the project and the modifications proposed. The most concerning relates to the stated intention by the proponent not to mine using longwall methods (Sections 1.1, 3.2.4 and 4.7.2 of the Mod 2 report) that is contradicted by several statements describing the project and modelling. For example, in the description of mining system stresses (Section 5.4.3) and the report conclusion (Section 10) that states "*The proposed mining activities (NW Mains Modification) are to extend approved mining of six long wall panels in the Nebo Area (Nebo Longwalls 1 to 6) for another 5 years, until 31st of December 2025*".

The predicted groundwater impacts of the modification are generally considered to be plausible and hence likely to represent low impact risks. However, as reported below, the significant shortcomings of the numerical modelling and reporting, some of them fundamental, give DPIE Water significantly diminished confidence in the reliability of the impact predictions. This concern is exacerbated by the sensitive environment hosting the proposal, noting that the mining is planned to go directly underneath Avon Dam and nearby to other mining projects where cumulative impacts are a consideration.

The results of the groundwater model must be reliable with robust uncertainty analysis. They must include an assessment of potential depressurising under the Avon Dam. These predictions must be used in geotechnical modelling and assessment of material stability and potential for cracking under this important water asset.

Even if impact risks are low for this proposal, the proponent states that they intend to use the model for future potential developments. This reinforces the requirement for the model improvements as outline below to occur, to avoid errors and omissions moving forward into future assessments.

Accepting the numerical modelling without an insistence on improvement creates an unacceptable precedent for other project developments.

***Model Review***

Below is a summary of a review of the modelling report which is provided in detail in Attachment B.

- The details of the proposed Project are unclear. The information provided in different documents and within each of them is contradicting and confusing.
- There are omissions in the groundwater modelling documentation.
- The stated modelling objectives were not met. The modelling work and reporting were not undertaken according to best practice guidelines. The model is not adequately calibrated

against an adequate number of targets that are of different types (heads and fluxes) and do not provide reasonable spatial coverage and representation across the model domain.

- There are discrepancies in the conceptualisation of mining that must be resolved. It is unclear that longwall mining is planned. If not, the longwalls represented in the model and their effects on the hydraulic properties of the overlying strata are not applicable and must be removed from the conceptual and numerical models and the report. Otherwise, the area's hydrogeology is well conceptualised.
- The report does not show that the modelling has made adequate use of available data, including data from South 32 (Dendrobium), which is accessible to the Project through formal data sharing agreement between the two mining operations
- The identified groundwater level rise is not reasonably explained.
- The report does not specify potentially affected parties, e.g. bores, and the assessment of effects is lacking, especially in terms of effects on the Hawkesbury Sandstone.
- There are inconsistencies between the text and figures with regards to the model boundaries. These must be resolved. Some boundary types seem to be wrong. The model representation of longwalls and foreseen associated changes in hydraulic properties in the overlying strata may be unnecessary.
- The model is not well calibrated against head and flux targets that are adequately distributed throughout the model domain. The report does not present model calculated and observed heads for all available points. The model mainly achieves model confidence level class 1, with very few attributes from classes 2 and 3.
- The impact assessment is incomplete. The Proponent is required to revise the model predictions in terms of potential impacts and licencing requirements following amending the model according to the recommendations made here.
- The adopted uncertainty analysis approach is basic, but acceptable considering the low–medium level of risk of the proposed Project. However, the analysis requires refinement. The results of the uncertainty analysis must be reported for all strata and potentially affected features and environs.
- The Groundwater Impact Assessment conclusions need to be revised and revalidated after improvements are made as identified by this review. This must include an assessment of drawdown impacts on the alluvium/weathered zone and the Hawkesbury Sandstone.
- The main modification report was prepared by EMM. The groundwater modelling and reporting was undertaken by SLR Consulting Australia Pty Ltd and the peer review by EMM. The NSW Aquifer Interference Policy (AIP, 2012) requires an *independent* review. Given that EMM is the main author of the modification report, the review is not considered independent.
- The included peer review report highlights important matters that the Proponent must address for the model to be considered fit for the purposes of assessing the Project's impacts and licencing requirements. Notwithstanding, DPIE Water does not agree with the conclusion that '*the modelling is fit for purpose for scenario modelling to inform groundwater impact assessment and water licensing.*'
- DPIE Water accepts and endorses the WaterNSW submission regarding the need to revise and update the mass water balance estimates to remove inconsistencies and clarify the model results.

Section 1.2 in the Groundwater Impact Assessment notes that the developed model is intended to be used for potential future mine modifications and groundwater impact assessments. This gives additional weight to the model. Deficiencies in the model could easily transpire to future model versions and form unfavourable precedents.

### 2.2 Recommendation - Prior to determination:

DPIE Water recommends the following:

1. Address the contradictory and uncertain descriptions of the project and modification, in particular regarding the use of longwall mining methods.
2. Address all the requirements for improved modelling and reporting, these are listed in Attachment B.
3. With the improved modelling, provide updated predictions of drawdown effects at different receptors (bores, wetlands and adding the Hawkesbury Sandstone to the reporting), and inflow volumes of the approved and proposed mine workings.

**End Attachment A**

## Attachment B: Recommended groundwater model improvements

1. The groundwater modelling report should be a standalone document, with minimal referral of the reader to external material.
2. The groundwater modelling report must include a clear description of the proposed Project, which is consistent with the description provided in other documents like the Main Report.
3. The groundwater modelling report must demonstrate that the proposed Project is properly represented in the numerical model. If no longwall mining is proposed, longwalls must be removed from the conceptual and numerical model and the effects of longwall mining on the overlying hydrogeological system must not be represented.
4. Revise the Model and the Report addressing comments and recommendations in:
    a. The EMM peer review.
    b. WaterNSW submission to Environmental Impact Statement - Wongawilli Mine Modification 2 (MP 09_0161 MOD 2).
    c. The Independent Expert Panel for Mining in the Catchment Report (IEMPC 2019) mentioned in Section 7.4 in the Report.
    d. These comments by DPIE Water.
5. Include self-assessment of modelling using checklists in the AGMG 2012.
6. There are omissions in the Report that must be addressed including errors and inconsistencies in text and between text, tables, and figures. Most of the figures must be reproduced to meet expected professional standards and be useful. The content and formatting of tables must also be checked.
7. Please use consistent units. There are basic unit conversion errors that must be corrected, e.g. Table 3-7.
8. Explain what change in recharge and specific yield of less than 0% means (-300% and -500% as stated in Section 8, p 112).
9. Account for other mining operations in the area and clearly describe the approach adopted to assess cumulative impacts, including listing and characterisation of other considered operations.
10. Provide maps of the predicted drawdown due to the Project alone and all developments in the area including the proposed Project for all model layers at key times, e.g. start of the Project, end of the Project, then selected dates that will help understand the long-term effects of the Project.
11. Clearly indicate other operations modelled at various stages. Particularly, describe how was the Dendrobium Mine included in the model while it occurs outside the model domain.
12. Clarify the sources of all presented data.
13. Provide a clear geological map showing geological units and structure.
14. Clarify the extent of the used geological model/s.
15. List the hydraulic parameter values and boundary conditions adopted from Golder 2010 SEEP/W modelling, including providing a map showing the alignment of the modelled cross-section/s.
16. Provide a useful map of existing monitoring networks, including South 32 setups.
17. Make appropriate recommendations to set up a useful monitoring network to support future modelling of the Project and expected future modifications.
18. Obtain relevant surface water data and incorporate in the model, e.g. rivers and lakes stage and bed elevations, bed conductance, baseflow, etc.
19. Include lines representing the arithmetic and geometric mean of the K data in Figure 6-8.
20. In all assessments of effects, present ‘Project only’ and ‘cumulative’ impacts. Cumulative impacts include all historical and approved developments in the area in addition to the proposed Project.
21. Clarify the numerical model representation of surface water features, including the river zones shown in Figure 5-3.
22. Provide an assessment of potential groundwater level drawdown effects at individual nearby bores due to all developments in the area including the Project and due to the Project alone. The assessment must clarify assessment uncertainty.
23. Include the Hawkesbury Sandstone in all impact, sensitivity, and uncertainty analysis as it represents an important water source in the area.
24. Provide an assessment of the water level variation in groundwater associated with GDEs in support to the views regarding drawdown effects on GDEs expressed in Section 7.4.

25. Provide an assessment of potential impacts on individual neighbouring GDEs due to the Project alone and the Project and other developments in the area, including clarifying uncertainty in the analysis.
26. Clearly describe the northern GHB settings, including how the effects of the existing and future Dendrobium Mine operations have been accounted for.
27. Ensure that the model boundaries alignments, types, and descriptions are consistent in the text and figures.
28. Provide a clear description of the eastern model boundary.
29. Provide steady-state model calibration scatter plot (modelled vs observed heads).
30. Clearly describe the methodology for estimating initial rainfall recharge, including map presentation of the data.
31. Present maps showing rainfall recharge and evapotranspiration (ET) from the water table for steady-state conditions and an average from the transient simulation.
32. Clarify the assigned confinement status for each model layer.
33. Obtain and calibrate the model against surface water and mine inflow data.
34. Clarify the source and rational behind the use of the Kh-depth equation to assign Kh values to the model cells, including the used factors and coefficients.
35. Clarify whether the initial Kh values assigned using the adopted Kh-depth relationship have been altered during the model stead-state and transient calibrations.
36. Undertake composite parametric sensitivity (parameter identifiability) analysis to determine influential parameters in the model. The results must be used to enhance the model calibration and guide the uncertainty analysis.
37. Explain in simple analytical formula/s (or other means) how the rising water levels noticed in some piezometers is related to an increase in storage due to recharge of the historical workings.
38. Identify possible reasons for the calibrated model not being able to replicate seasonality, long-term trends, and vertical relationships and discuss/implement potential solutions.
39. Provide a revised assessment of expected mine inflows, including appropriate uncertainty analysis.
40. Undertake sensitivity analysis of heads and conductance values used in the model's GHB.
41. Undertake sensitivity and uncertainty analyses of ET extension depth.
42. Undertake uncertainty analysis guided by the results of comprehensive sensitivity analysis including parameter identifiability assessment.
43. Examine the effects of concurrent changes in hydraulic properties in the uncertainty analysis (e.g. coinciding higher Sy and Kh).
44. Arrange for the peer review to be re-done by an independent party, as required by the NSW Aquifer Interference Policy.

**End Attachment B**

# Appendix B – WaterNSW Comments

10 March 2021

WaterNSW Ref. D2021/21308

Jack Turner
Resource Assessments
Department of Planning, Industry and Environment
Locked Bag 5022
PARRAMATTA NSW 2124

Dear Mr Turner,

**WaterNSW submission to Environmental Impact Statement - Wongawilli Mine Modification 2 (MP 09_0161 MOD 2)**

WaterNSW appreciates the opportunity to comment on the Wongawilli Mine Modification 2 application, including the granting of an extension to provide comments by 10 March 2021.

The proposed modification is partly located within the Metropolitan Special Area of Sydney's drinking water catchment. Under the *WaterNSW Act 2014*, WaterNSW has statutory responsibilities to protect and enhance water quantity and quality in the catchment, and to maintain the ecological integrity of the Special Area.

In order to meet its statutory responsibilities, WaterNSW has adopted a set of Mining Principles for mining proposals in Sydney's drinking water catchment, which are summarised below:

1) **Water supply infrastructure** – mining must not result in the integrity of water supply infrastructure being compromised.
2) **Water quantity** – leakage from reservoirs as a result of mining activities must be avoided, and regional depressurisation and diversion of surface water flows must be avoided and minimised by adopting a precautionary approach to mine design.
3) **Water quality** – all mining activities must have a neutral or beneficial effect on water quality.
4) **Ecological integrity** – of the Special Areas must be maintained and protected.

Our comments on this proposal relate primarily to the proposed extension of the North West Mains Drive within the Metropolitan Special Area. In summary, WaterNSW has the following concerns:

1. **Potential impacts to Lake Avon**:
   WaterNSW notes that it is unlikely the modification would result in any noticeable subsidence, strain or tilt, stream bed uplift or bed cracking in Gallaghers Creek. The subsidence assessment undertaken by SCT concluded that cracking from the void would not extend into the Bulgo sandstone or the higher Hawkesbury sandstone.

   However, within the project area, WaterNSW notes that that base of Lake Avon is located below the Bulgo Sandstone in the Stanwell Park Claystone. WaterNSW seeks clarification as to how close cracking from the void will be to the base of Lake Avon.

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2. **Subsidence uncertainties**

The proposed modification would extend the main drive through the Wongawilli fault and a known dyke. No subsidence predictions have been undertaken because the impact due to first workings is considered insignificant. Nevertheless, WaterNSW considers that the following matters should be further addressed:

- The potential for increased stresses above the previously extracted Wongawilli Seam.
- The impact of mining through the Wongawilli fault.
- Interactions with the dyke, noting that a steady inflow of water was observed during previous mining, consistent with an increase in hydraulic conductivity. It is acknowledged that this occurred during secondary extraction, rather than during first workings. However, given that this dyke will be intersected by the proposed modification below the surface of Avon Reservoir, it requires detailed assessment.

While no significant subsidence or inflows are expected, WaterNSW recommends a precautionary approach, including:

- a subsidence monitoring program for measuring stresses and pillar performance, and
- drilling ahead to confirm the absence of zones of elevated hydraulic conductivity and to manage any inflows from the reservoir into the first workings.

3. **Groundwater assessment**:

WaterNSW notes that the groundwater model is heavily reliant on data from Dendrobium Mine (Areas 3A and 3B) with 635 monitoring locations compared to only 14 in Wongawilli Mine. It is also noted that the model is a regional groundwater model, instead of a site-specific model. The lack of site-specific groundwater monitoring data means that the groundwater model predictions may not accurately represent the actual outcomes.

Further, the mass balance results for the predictive models (2020 and 2049) discussed in Section 7.1 do not match with results presented in Table 7-2. For example, rainfall recharge of 59.7 ML/day vs 179 ML/day. It is recommended that the mass balance estimates are updated to remove inconsistencies and provide more clarification on the presented results.

4. **Future infrastructure**:

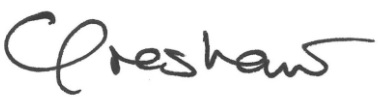
The proposal has not considered potential for impacts on a future water infrastructure project, the Burrawang to Avon tunnel (Illawarra Spur Pipeline).

**Conclusion**

WaterNSW does not object to the proposed modification, however we request that our concerns above are addressed. WaterNSW also requests to continue to be listed as a key agency for consultation on this and other projects by Wollongong Coal in the future.

If you have any further questions, please contact Miles Ellis via email at environmental.assessments@waternsw.com.au.

Yours sincerely



**CLAY PRESHAW**
**Manager Catchment Protection**

# Appendix C – Peer Review Report

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17 September 2021

Richard Sheehan
Group Environmental & Approvals Manager
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**Re: Wongawilli Colliery North West Mains Modification groundwater modelling independent review**

# 1 Summary

This letter presents the findings of a peer review of numerical groundwater flow modelling of the Wongawilli Colliery North West Mains modification (MOD2). The model was initially developed by SLR Consulting Australia Pty Ltd (SLR) for Wollongong Coal Limited (WCL) to support the MOD2 proposal. The SLR modelling and assessment was documented in a report, dated 12 November 2020. Peer review, by Dr Doug Weatherill of EMM Consulting Pty Ltd (EMM), was summarised in a report dated 13 November 2020. Following comments and advice from NSW Department of Planning Industry and Environment (DPIE) and Water NSW on the SLR modelling and report, it was agreed that an updated, standalone supplementary report would be prepared. This work has been undertaken by Umwelt Environmental and Social Consultants (Umwelt) and is the focus of this review.

This review focusses on the numerical groundwater modelling carried out in support of the groundwater impact assessment. It does not focus on the field testing, data collection and analysis used in support of the groundwater model.

The review was carried out by Dr Doug Weatherill of EMM Consulting Pty Ltd in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al. 2012).

Discussions were held between Umwelt and the peer reviewer throughout the update process, during which comparison was made between modelled outputs over the history-matching period with data from Dendrobium Mine, additional scenarios (requested by DPIE) were developed to increase the rigour of the uncertainty analysis, and an updated report was written.

Draft documentation was provided by Umwelt for review as follows:

- 18 August 2021: Introduction, Background and Numerical Groundwater Model chapters (up to the start of predictive modelling); and
- 3 September 2021: complete draft report.

The final supplementary groundwater impact assessment (Umwelt 2021) was delivered on 16 September 2021 and forms the basis for this peer review.

The Australian Groundwater Modelling Guidelines (Barnett et al. 2012) suggests a compliance checklist to summarise key review findings. This is presented in Table 1.1.

It is my view that, despite some limitations in the local site data and model calibration, which are expected to be addressed with an expanded monitoring network, extended monitoring period and future model updates, the modelling is fit for purpose for scenario modelling to inform groundwater impact assessment and water licensing.

## Table 1.1 Groundwater Model Compliance Checklist: 10-point essential summary

| Question | Y/N | Comments re Wongawilli groundwater model |
|---|---|---|
| 1. Are the model objectives and model confidence level classification clearly stated? | Yes | Yes. The report indicates the model is best described by a Class 2 confidence level with a number of attributes of a Class 3 model. The peer reviewer's own assessment is provided in Table 2.1, which suggests the model aligns best with a Class 2 confidence classification. |
| 2. Are the objectives satisfied? | Yes | The groundwater assessment lists a number of tasks. Specific to the numerical modelling they are:<br>1) Quantify the groundwater inflows to the previously approved NWM and proposed NWMD, as a function of time;<br>2) Predict the extent and area of influence of dewatering and the level and drawdown around the Project; and<br>3) Identify areas of potential risk, where the mitigation of groundwater impacts may be required. |
| 3. Is the conceptual model consistent with objectives and confidence level? | Yes | Conceptual model is sound, based on data and local mining experience, modelling objectives and for impact assessment and licensing purposes. |
| 4. Is the conceptual model based on all available data, presented clearly and reviewed by an appropriate reviewer? | Yes | The conceptual model refers to groundwater investigations from previous mining and modelling in the area and uses two previous numerical models (GeoTerra 2010 and HydroSimulations 2019) as its basis. The conceptualisation considers ranges of hydraulic property values from field testing as well as previous modelling. Current, during and post-project conceptualisations are presented. |
| 5. Does the model design conform to best practice? | Yes | Industry-leading software (MODFLOW-USG in combination with a flexible Voronoi polygon mesh) is applied. Model domain is sufficiently large to encompass predicted project impacts but does display impacts of other projects at boundaries. Alternative boundary conditions have been tested to identify the consequence of this aspect. Layers, mesh and boundary conditions generally consistent with best practice. |
| 6. Is the model calibration satisfactory? | Yes | Calibration performance is acceptable. SRMS errors of 10.1% (steady state) and 8.44% (transient) are okay, but strongly skewed by a 250 m range in hydraulic head across monitoring locations. Although calibrated in transient mode, the model does not display a good match to seasonality. Only one location, Nebo 1D (Bulli Coal seam) displays a clear response to mining. The model simulates drawdown at this location, but less than measured, and matches the zero impact at the overlying watertable measured at Nebo 1S.<br>The update since the previous modelling (SLR 2020) now makes use of data from Dendrobium, as recommended by this reviewer. These data are employed as what is effectively a regional history-matching verification dataset, as these data were not employed as targets during the history-matching process. The model has a SRMS error of 11.1% when compared to Dendrobium data. Whilst higher than would be generally targeted, this is unsurprising given the complex groundwater affecting activities occurring in that area, and the fact that the model was not tailored to match measurements in that area specifically. |
| 7. Are the calibrated parameter values and estimated fluxes plausible? | Yes | Calibrated parameter values are generally consistent with ranges of hydraulic conductivity and effective porosity from testing and previous modelling. Values are presented as min, mean and max with reference to tested values. Indicating model values lie within measured ranges. Spatial distributions are presented for pre-mining hydraulic conductivity in the Bulli and Wongawilli coal seams. Recharge rates, assigned as a percentage of rainfall, are plausible. The high recharge assigned in swamp areas (45% of rainfall) may be reflective of seepage from ponded water rather than episodic rainfall. Modelled historical mine inflows are compared to average measured inflows, with some modelled values above and some below measured average fluxes. |
| 8. Do the model predictions conform to best practice? | Yes | Mining and post-mining periods are simulated with appropriate boundary conditions to represent mining such that predictions of drawdown impacts and mine inflows can be made. |

## Table 1.1 Groundwater Model Compliance Checklist: 10-point essential summary

| Question | Y/N | Comments re Wongawilli groundwater model |
|---|---|---|
| 9. Is the uncertainty associated with the simulations/predictions reported? | Yes | A series of deterministic predictions with selected alternative hydraulic properties was run. The updated modelling now incorporates realisations in which modelled values of multiple parameters are varied simultaneously, in response to a request for this by DPIE. Overall, the approach can be described as providing predictive sensitivity and aligns best with type 1 uncertainty analysis as outlined in the IESC explanatory note on uncertainty analysis (Middlemis & Peeters 2018). |
| 10. Is the model fit for purpose? | Yes | It is my opinion that the model is fit for the purpose of predicting drawdown impacts and mine inflows for licensing purposes. |

# 2 Model confidence level classification

The Australian Groundwater Modelling Guidelines (Barnett et al. 2012) provides a classification system that takes into account data used to inform the model conceptualisation, model design, calibration and predictive scenarios. Most models will have attributes that align with more than one class and, generally, the overall confidence level class is determined by the clustering of attributes.

The peer reviewer's assessment of the model using a modified version of the classification table is presented in Table 2.1. This assessment indicates that the model best aligns with a Class 2 description, with some attributes of a Class 3 model. This classification indicates that the modelling conducted for Wongawilli Colliery North West Mains Modification is suitable for impact assessment scenario modelling.

## Table 2.1 Model Confidence Class characteristics

| Class | Data | Calibration | Prediction | Quantitative Indicators |
|---|---|---|---|---|
| 1 | Not much / Sparse coverage | Not possible | Timeframe >> Calibration | Predictive Timeframe >10x Calib'n |
| | No metered usage | Large error statistic | Large stresses/periods | Predictive Stresses >5x Calib'n |
| | Low resolution topo DEM | Inadequate data spread | Poor/no verification | Mass balance > 1% (or one-off <5%) |
| | Poor aquifer geometry | Targets incompatible with model purpose | Transient prediction but steady-state calibration | Properties <> field values |
| | Basic/Initial conceptualisation | | | Poor performance stats / no review |
| 2 | Some data / OK coverage | Weak seasonal match | Predictive Timeframe > Calib'n | Predictive Timeframe = 3-10x Calib'n |
| | Some usage data | Some long-term trends wrong | Different stresses &/or periods | Predictive Stresses = 2-5x Calib'n |
| | Some baseflow estimates and some K & S measurements | Partial performance (eg some stats / part record / model-measure offsets) | No verification but key simulations constrained by data | Mass balance < 1% (all periods) |
| | Some high res. topo DEM and adequate aquifer geometry | Head & Flux targets constrain calibration | Calib. & prediction consistent (transient or steady-state) | Some properties maybe <> field values. |
| | Sound conceptualisation, reviewed & stress-tested | Non-uniqueness, sensitivity and qualitative uncertainty addressed | Magnitude & type of stresses outside range of calib'n stresses | Some poor performance or coarse discretisation in key areas/times |
| 3 | Plenty data, good coverage | Good performance statistics | Timeframe ~ Calibration | Predictive Timeframe <3x Calib'n |
| | Good metered volumes (all users) | Most long-term trends matched | Similar stresses &/or periods | Predictive Stresses <2x Calib'n |
| | Local climate data & baseflows | Most seasonal matches OK | Good verification or all simulations constrained by data | Mass balance < 0.5% (all periods) |
| | Kh, Kv & Sy measurements from range of tests | Calibration to present day head and flux targets | - Steady state prediction only when calibration in steady state | Properties ~ field measurements |
| | High res. topo DEM all areas & good aquifer geometry | Non-uniqueness minimised &/or parameter identifiability &/or minimum variance or RCS assessed | Suitable computational methods applied & parameters are consistent with conceptualisation | No poor performance or coarse discretisation in key areas (grid/time) |
| | Mature conceptualisation | Sensitivity &/or Qualitative Uncertainty | Quantitative uncertainty analysis | Review by experienced Hydro/Modeller |

(after Table 2-1 of Australian Groundwater Modelling guidelines (Barnett et al. 2012)

**Legend**

| | | | |
|---|---|---|---|
| Criterion met at higher Class | Criterion partially met at the relevant Class | Criterion met at the relevant Class | Criterion not met |

# 3 Discussion

The supplementary groundwater assessment report (Umwelt 2021) covers the broad aspects expected in a modelling report, including project background and modelling objectives, conceptualisation, model design, history matching/calibration and associated sensitivity analysis, predictive modelling and uncertainty analysis. This updated assessment, in the reviewer's opinion, provides substantially better documentation of the numerical groundwater modelling and a more thorough handling of impact assessment and water licencing, with reference to the relevant regulatory assessment criteria than the previously reviewed assessment report.

Conceptualisation of the groundwater system covers the geological setting, hydraulic properties of the hydrostratigraphic units, climate, surface water, historical mining activities, measured groundwater responses and aspects of water quality. The modelling then focusses on hydraulics only.

The model is built using the MODFLOW-USG numerical groundwater modelling code in combination with a flexible Voronoi polygon mesh. The option to pinch out/deactivate model cells where units are absent is employed for more numerically efficient solution than older MODFLOW codes, whilst enabling greater spatial resolution in areas of interest (25 m node spacing at proposed mining areas and 100 m or less at major rivers/creeks, the escarpment and historical mines). The model is discretised vertically into 18 model layers that enable representation of the variability in hydraulic properties, hydraulic head and groundwater flow in the different units. The report does not present the data sources used to define the geometry of the layers but indicates that geological models were used for the coal seams in the project area and the Dendrobium model (HydroSimulations 2019) was used outside of that.

Boundary conditions around the model edge are assigned using the Constant Head (CH) package (ocean and Lake Illawarra), General Head Boundary (GHB) package (inland boundaries) or are no flow boundaries. In response to review by DPIE, the supplementary report includes modelling of alternative boundary conditions to identify the consequence of boundary condition choice. Surface water features are represented with the River (RIV) package and stage is allowed to vary over time based on gauge data. Conductance is calculated in a meaningful way, using properties of the individual features represented. Recharge from rainfall and evapotranspiration are represented using the Recharge (RCH) and Evapotranspiration (EVT) packages and the values adopted are reasonable. Inflow to mine voids is simulated with the Drain (DRN) package. The reviewer has confirmed that the implemented boundary conditions do effectively dewater the coal seams during periods of active mining, thereby implementing the localised hydraulic stresses that will be induced by excavation activities. Hydraulic properties are changed over time to represent mining, goaf and fracture zones using the Time-Variant Materials (TVM) package.

Transient hydraulic head monitoring data from five open standpipes and 54 vibrating wire piezometers (VWPs) were used to compile a calibration target dataset. The selected monitoring locations are focussed around the project area and do not provide good coverage of the whole model domain. An independent check by the reviewer of the available data on the BoM Australian Groundwater Explorer online database (BoM 2020) confirmed that, although there are many bores registered, they do not have recorded hydraulic head data in their records. A data sharing agreement meant that WCL has access to groundwater monitoring data for the Dendrobium mine. The supplementary report has made use of these data to quantify model performance against this additional dataset, in what is effectively a verification of the model on a broader spatial scale than the site data alone allow.

There appears to be significant "noise" in the measured data for the monitoring sites used as calibration targets. Some of this may be due to VWP stabilisation following installation, recovery from previous mining or underground water storage activity.

The model was calibrated to transient hydraulic head data using an automated approach. The model generally predicts stable head values at the target sites, not producing a great match to apparent seasonality. However, the model does simulate drawdown at the one monitoring location, Nebo 1D, that does show an

apparent measured response to mining. The overlying watertable monitoring site, Nebo 1S, displays no evidence of impact from mining and this is replicated by the model. The key finding is that underground mining has not impacted shallow groundwater monitoring sites and the model is able to simulate this.

Despite the limitations of the calibration dataset (local sites only, only one site with mining impact and "noise" in measured data), the hydraulic parameters employed in the model were initially based on those from the Dendrobium model (HydroSimulations 2019) which has been calibrated to a more substantial dataset displaying impacts of underground mining. Whilst the parameter values were allowed to vary in the calibration process, they should only have done so to improve the fit to the selected calibration dataset and hydraulic conductivity was not allowed to diverge from the Dendrobium model values more than half an order of magnitude.

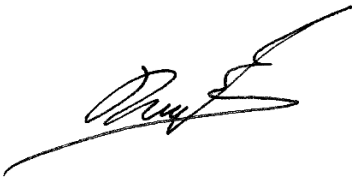
Predictive scenarios are conducted for a null case, approved mining and approved mining plus the project. These scenarios enable identification of groundwater impacts both cumulatively (ie total impact) and incrementally (ie additional impact due to the project). This is consistent with best practice and reduces uncertainty in the results.

Uncertainty analysis is conducted in a simple manner, with somewhat arbitrary variations in selected hydraulic properties that are not based on outcomes of the calibration sensitivity analysis. The supplementary report has added further model runs to expand the uncertainty analysis to explore simultaneous variation of modelled values of multiple parameters. The adopted approach best aligns with type 1 uncertainty analysis as outlined in the IESC explanatory note on uncertainty analysis (Middlemis & Peeters 2018). This approach is appropriate in this case given the low risk to third party groundwater users and groundwater dependent ecosystems sensitive to watertable drawdown. This is largely due to the presence of three aquitards overlying the coal seams proposed to be mined. These are the Bald Hill Claystone, Stanwell Park Claystone and Wombarra Claystone.

# 4 Conclusion

It is my professional opinion that, despite some limitations in the local site data and model calibration, the modelling is fit for purpose for scenario modelling to inform groundwater impact assessment and water licensing.

Yours sincerely



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# 5 References

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Umwelt 2021, Wongawilli Modification 2 supplementary groundwater assessment, prepared for Wollongong Coal Limited, 16 September 2021.

# Appendix D – Water Quality Summary

| Analyte | Value | Wongawilli River | Avon River | Nebo River | Crinanite | Narrabeen Group | Bulli Seam |
|---|---|---|---|---|---|---|---|
| pH (field) | Max | - | 13.2 | 7.36 | 12.1 | 10.2 | - |
| | Mean | - | 5.7 | 6.65 | 8.2 | 8.3 | - |
| | Median | - | 5.5 | 6.55 | 8.2 | 8.4 | - |
| | Min | - | 3.9 | 6.04 | 4.4 | 7.1 | - |
| | Count | - | 177 | 14 | 207 | 51 | - |
| EC (field) µS/cm | Max | - | 2224.0 | 227 | 2983 | 1404 | - |
| | Mean | - | 154.9 | 167.8 | 632 | 736 | - |
| | Median | - | 73.7 | 163 | 618 | 724 | - |
| | Min | - | 41.0 | 98 | - | - | - |
| | Count | - | 177 | 5 | 207 | 51 | - |
| Resistivity (Ω/cm) | Max | 24.0 | 16.0 | - | 250000 | 1976 | - |
| | Mean | 10.7 | 11.3 | - | 4692 | 1594 | - |
| | Median | 9.5 | 11.0 | - | 3362 | 1617 | - |
| | Min | 6.0 | 7.0 | - | 379 | 827 | - |
| | Count | 225 | 127 | - | 205 | 50 | - |
| TDS (mg/L) | Max | 13.0 | 4.0 | - | 1938 | 912 | 6560 |
| | Mean | 1.3 | 1.1 | - | 408 | 478 | 2526 |
| | Median | 1.0 | 1.0 | - | 398 | 470 | 2375 |
| | Min | 0.8 | 1.0 | - | 137 | 0 | 460 |
| | Count | 224 | 127 | - | 206 | 51 | 24 |
| Sodium (Total) mg/L | Max | 22.0 | 3.0 | - | 148 | 150 | 282 |
| | Mean | 1.5 | 1.0 | - | 51 | 126 | 231 |
| | Median | 1.0 | 1.0 | - | 38 | 130 | 236 |
| | Min | 0.1 | 1.0 | - | 6 | 29 | 130 |
| | Count | 224 | 126 | - | 185 | 46 | 24 |
| Calcium (Total) mg/L | Max | 4.0 | 3.0 | - | 770 | 15 | 780 |
| | Mean | 1.3 | 1.4 | - | 52 | 10 | 623 |
| | Median | 1.0 | 1.0 | - | 11 | 10 | 682 |
| | Min | 1.0 | 0.0 | - | <1 | 2 | 30 |
| | Count | 225 | 127 | - | 185 | 46 | 24 |
| Potassium (Total) mg/L | Max | - | - | 23.0 | 105 | 33 | 300 |
| | Mean | - | - | 13.7 | 9 | 14 | 167 |
| | Median | - | - | 13.7 | 3 | 14 | 155 |
| | Min | - | - | 10.9 | <1 | 1 | 7 |
| | Count | - | - | 101 | 185 | 46 | 24 |
| Magnesium (Total) mg/L | Max | - | - | 6.0 | 50 | 9 | 15 |
| | Mean | - | - | 3.4 | 8 | 7 | 2 |
| | Median | - | - | 3.7 | 4 | 7 | 1 |
| | Min | - | - | 1.0 | <1 | 4 | <1 |
| | Count | - | - | 101 | 184 | 46 | 24 |
| Chloride (Total) mg/L | Max | - | - | 1.0 | 89 | 82 | 110 |
| | Mean | - | - | 1.0 | 24 | 45 | 46 |
| | Median | - | - | 1.0 | 21 | 44 | 46 |
| | Min | - | - | 1.0 | 4 | 32 | 24 |
| | Count | - | - | 101 | 185 | 46 | 24 |
| Fluoride (Total) mg/L | Max | - | - | 8.0 | 1.3 | 2 | 0.2 |
| | Mean | - | - | 4.4 | 0.4 | 0.4 | 0.1 |
| | Median | - | - | 4.8 | 0.3 | 0.4 | 0.1 |
| | Min | - | - | 2.0 | <0.1 | <0.1 | 0.1 |
| | Count | - | - | 101 | 185 | 46 | 24 |
| Manganese (Total) mg/L | Max | 50.0 | 34.0 | 45.0 | 2.240 | 0.24 | 0.51 |
| | Mean | 21.0 | 20.8 | 25.4 | 0.307 | 0.05 | 0.069 |
| | Median | 18.5 | 20.0 | 24.7 | 0.082 | 0.04 | 0.011 |
| | Min | 9.0 | 9.0 | 21.0 | <0.001 | 0.01 | 0.003 |
| | Count | 225 | 126 | 101 | 185 | 46 | 24 |
| | Max | 1.0 | 0.3 | 0.2 | 177 | 17.9 | 22 |

| Analyte | Value | Wongawilli River | Avon River | Nebo River | Crinanite | Narrabeen Group | Bulli Seam |
|---|---|---|---|---|---|---|---|
| Iron (Total) mg/L | Mean | 0.1 | 0.1 | 0.1 | 8.57 | 2.42 | 3.1 |
| | Median | 0.1 | 0.1 | 0.1 | 1.54 | 0.81 | 0.84 |
| | Min | 0.010 | 0.100 | 0.1 | <0.05 | 0.20 | 0.13 |
| | Count | 224 | 126 | 137 | 185 | 46 | 24 |
| Copper (Filtered) mg/L | Max | 0.2 | 0.2 | - | 0.048 | 0.015 | 0.103 |
| | Mean | 0.025 | 0.029 | - | 0.009 | 0.003 | 0.057 |
| | Median | 0.017 | 0.020 | - | 0.004 | 0.002 | 0.058 |
| | Min | 0.001 | 0.001 | - | <0.001 | <0.001 | 0.008 |
| | Count | 224 | 127 | - | 185 | 46 | 24 |
| Lead (Filtered mg/L | Max | 0.2 | 0.2 | 1.1 | 0.050 | 0.084 | 0.16 |
| | Mean | 0.030 | 0.036 | 0.034 | 0.003 | 0.006 | 0.02 |
| | Median | 0.018 | 0.023 | 0.023 | 0.001 | 0.001 | 0.012 |
| | Min | 0.001 | 0.007 | 0.006 | <0.001 | <0.001 | 0.006 |
| | Count | 225 | 115 | 202 | 185 | 46 | 24 |
| Zinc (Filtered mg/L | Max | 115.0 | 1.8 | 2.8 | 0.250 | 0.47 | 1.2 |
| | Mean | 3.8 | 0.1 | 0.2 | 0.029 | 0.039 | 0.115 |
| | Median | 0.5 | 0.1 | 0.2 | 0.015 | 0.011 | 0.066 |
| | Min | 0.010 | 0.050 | 0.1 | <0.001 | <0.005 | 0.042 |
| | Count | 225 | 127 | 202 | 185 | 46 | 24 |
| Nickel (Filtered mg/L | Max | 4.6 | 5.3 | - | 0.190 | 0.011 | 0.17 |
| | Mean | 0.4 | 0.4 | - | 0.008 | 0.005 | 0.01 |
| | Median | 0.1 | 0.1 | - | 0.006 | 0.004 | 0.002 |
| | Min | 0.010 | 0.050 | - | <0.001 | 0.001 | 0.002 |
| | Count | 224 | 115 | - | 185 | 46 | 24 |
| Aluminium (Filtered mg/L) | Max | 1.3 | 0.2 | 0.1 | 1.610 | 0.31 | 0.55 |
| | Mean | 0.1 | 0.0 | 0.0 | 0.20 | 0.06 | 0.40 |
| | Median | 0.001 | 0.001 | 0.001 | 0.07 | 0.04 | 0.42 |
| | Min | 0.001 | 0.001 | 0.001 | 0.01 | 0.01 | 0.04 |
| | Count | 220 | 113 | 106 | 161 | 40 | 24 |
| Arsenic (Filtered mg/L | Max | 0.3 | 0.0 | 0.0 | 0.096 | 0.01 | 0.01 |
| | Mean | 0.010 | 0.002 | 0.001 | 0.003 | 0.002 | 0.002 |
| | Median | 0.001 | 0.001 | 0.001 | 0.001 | 0.002 | 0.001 |
| | Min | 0.001 | 0.001 | 0.001 | <0.001 | <0.001 | <0.001 |
| | Count | 222 | 113 | 106 | 185 | 46 | 24 |
| Lithium (Total) | Max | 2.5 | 2.2 | 0.1 | 0.120 | 0.096 | 0.902 |
| | Mean | 0.2 | 0.1 | 0.0 | 0.006 | 0.045 | 0.466 |
| | Median | 0.010 | 0.007 | 0.006 | 0.003 | 0.036 | 0.451 |
| | Min | 0.001 | 0.005 | 0.005 | <0.001 | 0.002 | 0.007 |
| | Count | 223 | 113 | 106 | 185 | 46 | 24 |
| Barium (Total) | Max | 0.7 | 0.7 | 0.0 | 0.266 | 0.264 | 2.12 |
| | Mean | 0.018 | 0.021 | 0.001 | 0.043 | 0.203 | 1.30 |
| | Median | 0.001 | 0.001 | 0.001 | 0.021 | 0.213 | 1.31 |
| | Min | 0.001 | 0.001 | 0.001 | 0.003 | 0.05 | 0.02 |
| | Count | 222 | 113 | 106 | 185 | 46 | 24 |
| Strontium (Total) | Max | 4.7 | 0.7 | 0.2 | 10.000 | 0.501 | 8.00 |
| | Mean | 0.3 | 0.1 | 0.0 | 0.898 | 0.373 | 4.67 |
| | Median | 0.2 | 0.1 | 0.0 | 0.056 | 0.390 | 4.72 |
| | Min | 0.010 | 0.010 | 0.024 | 0.001 | 0.034 | 0.07 |
| | Count | 201 | 100 | 101 | 184 | 46 | 24 |
| Total Nitrogen as N | Max | 0.030 | 0.001 | 0.001 | 79.7 | 47 | 17.0 |
| | Mean | 0.002 | 0.001 | 0.001 | 2.6 | 2.74 | 11.8 |
| | Median | 0.001 | 0.001 | 0.001 | 1.3 | 1.50 | 12.1 |
| | Min | 0.001 | 0.001 | 0.001 | 0.1 | 0.40 | 4.1 |
| | Count | 223 | 113 | 185 | 182 | 46 | 24 |
| Total Phosphorus as P | Max | 0.048 | 0.006 | 0.004 | 13.7 | 1.86 | 0.41 |
| | Mean | 0.002 | 0.001 | 0.001 | 0.60 | 0.12 | 0.11 |
| | Median | 0.001 | 0.001 | 0.001 | 0.13 | 0.07 | 0.07 |

| Analyte | Value | Wongawilli River | Avon River | Nebo River | Crinanite | Narrabeen Group | Bulli Seam |
|---|---|---|---|---|---|---|---|
| | Min | 0.001 | 0.001 | 0.001 | <0.01 | 0.01 | <0.01 |
| | Count | 223 | 113 | 185 | 170 | 46 | 24 |
| Sulfate as SO4 Turbidimetric | Max | 0.3 | 0.026 | 0.041 | 860 | 430 | 14 |
| | Mean | 0.005 | 0.008 | 0.017 | 69 | 66 | 4 |
| | Median | 0.002 | 0.007 | 0.018 | 11 | 68 | 3 |
| | Min | 0.001 | 0.001 | 0.008 | <1 | 4 | <1 |
| | Count | 223 | 113 | 185 | 163 | 46 | 24 |
| Dissolved Organic Carbon | Max | 0.039 | 0.018 | 0.071 | 210 | 155 | 18 |
| | Mean | 0.004 | 0.006 | 0.036 | 18 | 5 | 12 |
| | Median | 0.003 | 0.005 | 0.033 | 4 | 1 | 13 |
| | Min | 0.001 | 0.001 | 0.010 | 1 | 1 | 3 |
| | Count | 223 | 110 | 106 | 181 | 44 | 23 |

# Appendix E – Dendrobium Bore Network Details

| Site ID | Easting (GDA94Z56) | Northing | Sensor Depth (mbgl) | Formation |
|---|---|---|---|---|
| S1096 | 292700 | 6191121 | 347 | WongawilliCoalSeam |
| S1099 | 292041 | 6191531 | 358 | WongawilliCoalSeam |
| S1388 | 292129 | 6192393 | 363 | WongawilliCoalSeam |
| S1557 | 298326 | 6190192 | 19 | StanwellParkClaystone |
| | | | 55 | ScarboroughSst |
| | | | 70 | ScarboroughSst |
| S1572 | 296398 | 6191978 | 20 | StanwellParkClaystone |
| | | | 28 | StanwellParkClaystone |
| | | | 30 | ScarboroughSst |
| | | | 39 | ScarboroughSst |
| | | | 42 | ScarboroughSst |
| | | | 50 | WombarraClaystone |
| | | | 59 | WombarraClaystone |
| | | | 70 | WombarraClaystone |
| | | | 25 | BaldHillClaystone |
| S1577 | 294558 | 6192447 | 130 | BulgoSst |
| | | | 170 | ScarboroughSst |
| | | | 258 | KemblaSst |
| | | | 25 | BulgoSst |
| S1578 | 295387 | 6192332 | 122 | StanwellParkClaystone |
| | | | 152 | ScarboroughSst |
| | | | 234 | WongawilliCoalSeam |
| | | | 12 | StanwellParkClaystone |
| | | | 27 | ScarboroughSst |
| | | | 33 | ScarboroughSst |
| | | | 42 | ScarboroughSst |
| | | | 62 | WombarraClaystone |
| | | | 87 | BulliCoalSeam |
| S1649 | 295806 | 6192201 | 115 | WongawilliCoalSeam |
| S1652 | 295511 | 6190966 | 10 | StanwellParkClaystone |
| | | | 20 | StanwellParkClaystone |
| | | | 45 | ScarboroughSst |
| | | | 60 | WombarraClaystone |
| | | | 86 | CoalcliffSandstone |
| | | | 117 | WongawilliCoalSeam |
| S1710 | 290258 | 6189646 | 10 | HawkesburySst |
| | | | 60 | HawkesburySst |
| | | | 120 | BaldHillClaystone |
| | | | 145 | BulgoSst |
| S1719 | 291202 | 6193277 | 371 | WongawilliCoalSeam |
| S1739 | 289684 | 6191799 | 392 | WongawilliCoalSeam |
| S1755 | 289475 | 6191380 | 362 | BulliCoalSeam |
| | | | 389 | WongawilliCoalSeam |
| S1758 | 288587 | 6193107 | 376 | LawrenceLoddonSst |
| | | | 406 | WongawilliCoalSeam |
| S1779 | 292381 | 6195551 | 318 | LawrenceLoddonSst |
| | | | 343 | WongawilliCoalSeam |
| S1796 | 289947 | 6194587 | 421 | KemblaSst |
| S1800 | 289933 | 6193997 | 373 | LawrenceLoddonSst |
| | | | 403 | KemblaSst |
| | | | 15 | StanwellParkClaystone |
| | | | 30 | ScarboroughSst |
| | | | 40 | ScarboroughSst |
| | | | 63 | WombarraClaystone |
| | | | 81 | CoalcliffSandstone |
| | | | 94 | BulliCoalSeam |
| S1830 | 295865 | 6192481 | 106 | LawrenceLoddonSst |
| | | | 124 | KemblaSst |

| Site ID | Easting (GDA94Z56) | Northing | Sensor Depth (mbgl) | Formation |
|---|---|---|---|---|
| | | | 18 | ScarboroughSst |
| | | | 33 | ScarboroughSst |
| | | | 47 | ScarboroughSst |
| | | | 65 | WombarraClaystone |
| | | | 86 | CoalcliffSandstone |
| | | | 97 | LawrenceLoddonSst |
| S1831 | 295867 | 6192499 | 106 | LawrenceLoddonSst |
| | | | 124 | KemblaSst |
| | | | 14 | StanwellParkClaystone |
| | | | 29 | ScarboroughSst |
| | | | 42 | ScarboroughSst |
| | | | 55 | WombarraClaystone |
| | | | 80 | CoalcliffSandstone |
| | | | 86 | BulliCoalSeam |
| | | | 95 | LawrenceLoddonSst |
| S1832 | 295807 | 6192192 | 113 | WongawilliCoalSeam |
| | | | 15 | StanwellParkClaystone |
| | | | 22 | ScarboroughSst |
| | | | 37 | ScarboroughSst |
| | | | 53 | WombarraClaystone |
| | | | 75 | CoalcliffSandstone |
| | | | 83 | BulliCoalSeam |
| | | | 91 | LawrenceLoddonSst |
| S1833 | 295749 | 6191939 | 107 | LawrenceLoddonSst |
| | | | 13 | StanwellParkClaystone |
| | | | 32 | ScarboroughSst |
| | | | 42 | WombarraClaystone |
| | | | 52 | WombarraClaystone |
| | | | 75 | CoalcliffSandstone |
| | | | 84 | BulliCoalSeam |
| | | | 92 | LawrenceLoddonSst |
| S1834 | 295747 | 6191940 | 111 | WongawilliCoalSeam |
| | | | 329 | BulliCoalSeam |
| | | | 356 | WongawilliCoalSeam |
| S1845 | 291464 | 6193770 | 334 | LawrenceLoddonSst |
| | | | 363 | WongawilliCoalSeam |
| S1855 | 289747 | 6192833 | 325 | LawrenceLoddonSst |
| | | | 356 | WongawilliCoalSeam |
| S1867 | 293793 | 6192913 | 10 | HawkesburySst |
| | | | 15 | HawkesburySst |
| | | | 88 | BulgoSst |
| | | | 100 | BulgoSst |
| | | | 150 | BulgoSst |
| | | | 173 | ScarboroughSst |
| | | | 200 | ScarboroughSst |
| | | | 216 | WombarraClaystone |
| | | | 240 | CoalcliffSandstone |
| | | | 249 | BulliCoalSeam |
| | | | 277 | WongawilliCoalSeam |
| S1870 | 293593 | 6192648 | 10 | HawkesburySst |
| | | | 15 | HawkesburySst |
| | | | 23 | HawkesburySst |
| | | | 55 | BulgoSst |
| | | | 125 | BulgoSst |
| | | | 149 | BulgoSst |
| | | | 177 | ScarboroughSst |
| | | | 204 | ScarboroughSst |
| | | | 221 | WombarraClaystone |
| | | | 244 | CoalcliffSandstone |
| | | | 252 | BulliCoalSeam |

| Site ID | Easting (GDA94Z56) | Northing | Sensor Depth (mbgl) | Formation |
|---|---|---|---|---|
| | | | 284 | WongawilliCoalSeam |
| S1871 | 293525 | 6193287 | 10 | HawkesburySst |
| | | | 31 | HawkesburySst |
| | | | 40 | HawkesburySst |
| | | | 88 | BulgoSst |
| | | | 134 | BulgoSst |
| | | | 184 | BulgoSst |
| | | | 210 | ScarboroughSst |
| | | | 235 | ScarboroughSst |
| | | | 253 | WombarraClaystone |
| | | | 275 | CoalcliffSandstone |
| | | | 285 | BulliCoalSeam |
| | | | 312 | WongawilliCoalSeam |
| S1878 | 293842 | 6191994 | 10 | BulgoSst |
| | | | 25 | BulgoSst |
| | | | 71 | BulgoSst |
| | | | 118 | BulgoSst |
| | | | 145 | StanwellParkClaystone |
| | | | 157 | ScarboroughSst |
| | | | 169 | ScarboroughSst |
| | | | 188 | WombarraClaystone |
| | | | 212 | CoalcliffSandstone |
| | | | 223 | LawrenceLoddonSst |
| | | | 252 | WongawilliCoalSeam |
| S1879 | 291440 | 6192133 | 10 | HawkesburySst |
| | | | 29 | HawkesburySst |
| | | | 48 | HawkesburySst |
| | | | 97 | BulgoSst |
| | | | 153 | BulgoSst |
| | | | 210 | ScarboroughSst |
| | | | 227 | ScarboroughSst |
| | | | 236 | ScarboroughSst |
| | | | 245 | ScarboroughSst |
| | | | 263 | WombarraClaystone |
| | | | 292 | LawrenceLoddonSst |
| | | | 319 | WongawilliCoalSeam |
| S1885 | 291504 | 6192668 | 11 | HawkesburySst |
| | | | 51 | HawkesburySst |
| | | | 93 | HawkesburySst |
| | | | 147 | BulgoSst |
| | | | 203 | BulgoSst |
| | | | 260 | StanwellParkClaystone |
| | | | 280 | ScarboroughSst |
| | | | 288 | ScarboroughSst |
| | | | 296 | ScarboroughSst |
| | | | 314 | WombarraClaystone |
| | | | 340 | BulliCoalSeam |
| | | | 369 | WongawilliCoalSeam |
| S1886 | 295884 | 6191720 | 38 | ScarboroughSst |
| | | | 8 | HawkesburySst |
| | | | 48 | HawkesburySst |
| | | | 92 | BulgoSst |
| | | | 211 | StanwellParkClaystone |
| | | | 221 | ScarboroughSst |
| | | | 235 | ScarboroughSst |
| | | | 282 | BulliCoalSeam |
| | | | 310 | LawrenceLoddonSst |
| S1889 | 292245 | 6192980 | 10 | HawkesburySst |
| | | | 123 | HawkesburySst |
| | | | 158 | BulgoSst |

| Site ID | Easting (GDA94Z56) | Northing | Sensor Depth (mbgl) | Formation |
|---|---|---|---|---|
| | | | 269 | StanwellParkClaystone |
| | | | 289 | ScarboroughSst |
| | | | 305 | ScarboroughSst |
| | | | 347 | BulliCoalSeam |
| | | | 376 | WongawilliCoalSeam |
| | | | 73 | HawkesburySst |
| S1890 | 292637 | 6192491 | 119 | BulgoSst |
| | | | 213 | BulgoSst |
| | | | 245 | ScarboroughSst |
| | | | 263 | ScarboroughSst |
| | | | 281 | WombarraClaystone |
| | | | 311 | BulliCoalSeam |
| | | | 340 | WongawilliCoalSeam |
| | | | 8 | HawkesburySst |
| | | | 49 | HawkesburySst |
| S1892 | 291014 | 6193952 | 113 | BulgoSst |
| | | | 191 | BulgoSst |
| | | | 231 | ScarboroughSst |
| | | | 257 | ScarboroughSst |
| | | | 308 | LawrenceLoddonSst |
| | | | 336 | KemblaSst |
| S1902 | 295241 | 6190780 | 15 | BulgoSst |
| | | | 35 | StanwellParkClaystone |
| | | | 55 | ScarboroughSst |
| | | | 75 | WombarraClaystone |
| S1907 | 293212 | 6191943 | 11 | HawkesburySst |
| | | | 21 | HawkesburySst |
| | | | 65 | BulgoSst |
| | | | 169 | StanwellParkClaystone |
| | | | 204 | ScarboroughSst |
| | | | 209 | ScarboroughSst |
| | | | 256 | BulliCoalSeam |
| | | | 290 | WongawilliCoalSeam |
| S1908 | 288926 | 6193601 | 10 | HawkesburySst |
| | | | 154 | HawkesburySst |
| | | | 201 | BulgoSst |
| | | | 276 | BulgoSst |
| | | | 304 | StanwellParkClaystone |
| | | | 337 | ScarboroughSst |
| | | | 379 | CoalcliffSandstone |
| | | | 412 | WongawilliCoalSeam |
| | | | 96 | HawkesburySst |
| S1910 | 289387 | 6194176 | 125 | HawkesburySst |
| | | | 169 | BulgoSst |
| | | | 247 | BulgoSst |
| | | | 273 | StanwellParkClaystone |
| | | | 313 | ScarboroughSst |
| | | | 362 | LawrenceLoddonSst |
| | | | 391 | WongawilliCoalSeam |
| | | | 68 | HawkesburySst |
| S1911 | 288803 | 6192549 | 135 | HawkesburySst |
| | | | 187 | BulgoSst |
| | | | 229 | BulgoSst |
| | | | 277 | StanwellParkClaystone |
| | | | 301 | ScarboroughSst |
| | | | 318 | ScarboroughSst |
| | | | 331 | WombarraClaystone |
| | | | 349 | CoalcliffSandstone |
| | | | 359 | CoalcliffSandstone |
| | | | 387 | LawrenceLoddonSst |

| Site ID | Easting (GDA94Z56) | Northing | Sensor Depth (mbgl) | Formation |
|---|---|---|---|---|
| S1914 | 289370 | 6192512 | 147 | HawkesburySst |
| | | | 187 | BulgoSst |
| | | | 300 | ScarboroughSst |
| | | | 330 | ScarboroughSst |
| | | | 371 | BulliCoalSeam |
| | | | 400 | WongawilliCoalSeam |
| S1925 | 289252 | 6193041 | 10 | HawkesburySst |
| | | | 144 | HawkesburySst |
| | | | 202 | BulgoSst |
| | | | 295 | BulgoSst |
| | | | 320 | ScarboroughSst |
| | | | 342 | ScarboroughSst |
| | | | 383 | LawrenceLoddonSst |
| | | | 413 | WongawilliCoalSeam |
| S1926 | 289660 | 6193445 | 10 | HawkesburySst |
| | | | 139 | HawkesburySst |
| | | | 192 | BulgoSst |
| | | | 289 | StanwellParkClaystone |
| | | | 313 | ScarboroughSst |
| | | | 337 | ScarboroughSst |
| | | | 378 | LawrenceLoddonSst |
| | | | 408 | WongawilliCoalSeam |
| | | | 94 | HawkesburySst |
| S1927 | 290066 | 6192211 | 133 | HawkesburySst |
| | | | 176 | BulgoSst |
| | | | 254 | BulgoSst |
| | | | 270 | StanwellParkClaystone |
| | | | 316 | ScarboroughSst |
| | | | 360 | LawrenceLoddonSst |
| | | | 388 | WongawilliCoalSeam |
| | | | 76 | BaldHillClaystone |
| | | | 85 | HawkesburySst |
| S1929 | 290011 | 6193398 | 114 | BulgoSst |
| | | | 207 | StanwellParkClaystone |
| | | | 236 | ScarboroughSst |
| | | | 260 | ScarboroughSst |
| | | | 302 | LawrenceLoddonSst |
| | | | 333 | WongawilliCoalSeam |
| | | | 45 | HawkesburySst |
| | | | 87 | HawkesburySst |
| | | | 93 | HawkesburySst |
| S1930 | 290367 | 6193583 | 123 | BulgoSst |
| | | | 168 | BulgoSst |
| | | | 219 | StanwellParkClaystone |
| | | | 248 | ScarboroughSst |
| | | | 260 | ScarboroughSst |
| | | | 273 | ScarboroughSst |
| | | | 294 | WombarraClaystone |
| | | | 317 | LawrenceLoddonSst |
| | | | 346 | WongawilliCoalSeam |
| S1931 | 290336 | 6192890 | 120 | HawkesburySst |
| | | | 136 | BaldHillClaystone |
| | | | 151 | BulgoSst |
| | | | 157 | BulgoSst |
| | | | 245 | StanwellParkClaystone |
| | | | 279 | ScarboroughSst |
| | | | 301 | ScarboroughSst |
| | | | 345 | LawrenceLoddonSst |
| | | | 373 | WongawilliCoalSeam |
| | | | 48 | HawkesburySst |

| Site ID | Easting (GDA94Z56) | Northing | Sensor Depth (mbgl) | Formation |
|---|---|---|---|---|
| | | | 92 | HawkesburySst |
| | | | 96 | HawkesburySst |
| S1932 | 288863 | 6191505 | 148 | BulgoSst |
| | | | 194 | BulgoSst |
| | | | 234 | BulgoSst |
| | | | 264 | ScarboroughSst |
| | | | 272 | ScarboroughSst |
| | | | 281 | ScarboroughSst |
| | | | 318 | CoalcliffSandstone |
| | | | 346 | LawrenceLoddonSst |
| S1934 | 292128 | 6192398 | 38 | HawkesburySst |
| | | | 55 | HawkesburySst |
| | | | 65 | HawkesburySst |
| | | | 85 | HawkesburySst |
| S1969 | 293998 | 6193986 | 10 | HawkesburySst |
| | | | 24 | HawkesburySst |
| | | | 44 | HawkesburySst |
| | | | 83 | BulgoSst |
| | | | 128 | BulgoSst |
| | | | 179 | BulgoSst |
| | | | 200 | ScarboroughSst |
| | | | 217 | ScarboroughSst |
| | | | 235 | ScarboroughSst |
| | | | 285 | LawrenceLoddonSst |
| | | | 313 | WongawilliCoalSeam |
| | | | 8 | BaldHillClaystone |
| | | | 48 | BulgoSst |
| | | | 92 | BulgoSst |
| S1992 | 293732 | 6192707 | 142 | BulgoSst |
| | | | 172 | ScarboroughSst |
| | | | 182 | ScarboroughSst |
| | | | 192 | ScarboroughSst |
| | | | 241 | BulliCoalSeam |
| S1994 | 293865 | 6192982 | 14 | HawkesburySst |
| | | | 55 | BulgoSst |
| | | | 99 | BulgoSst |
| | | | 148 | BulgoSst |
| | | | 174 | ScarboroughSst |
| | | | 186 | ScarboroughSst |
| | | | 199 | ScarboroughSst |
| | | | 250 | BulliCoalSeam |
| S1995 | 288212 | 6193662 | 384 | LawrenceLoddonSst |
| | | | 411 | WongawilliCoalSeam |
| S1998 | 287751 | 6194273 | 381 | BulliCoalSeam |
| | | | 407 | WongawilliCoalSeam |
| S1999 | 289233 | 6190844 | 313 | CoalcliffSandstone |
| | | | 342 | WongawilliCoalSeam |
| S2000 | 290161 | 6191011 | 357 | BulliCoalSeam |
| | | | 385 | WongawilliCoalSeam |
| S2001 | 288463 | 6192020 | 10 | HawkesburySst |
| | | | 65 | HawkesburySst |
| | | | 125 | HawkesburySst |
| | | | 183 | BulgoSst |
| | | | 231 | BulgoSst |
| | | | 285 | StanwellParkClaystone |
| | | | 300 | ScarboroughSst |
| | | | 315 | ScarboroughSst |
| | | | 353 | BulliCoalSeam |
| | | | 382 | WongawilliCoalSeam |
| S2002 | 288633 | 6194222 | 386 | LawrenceLoddonSst |

| Site ID | Easting (GDA94Z56) | Northing | Sensor Depth (mbgl) | Formation |
|---|---|---|---|---|
| | | | 417 | WongawilliCoalSeam |
| S2003 | 290571 | 6192478 | 341 | LawrenceLoddonSst |
| | | | 368 | WongawilliCoalSeam |
| | | | 42 | HawkesburySst |
| | | | 72 | HawkesburySst |
| S2006 | 287263 | 6194204 | 140 | HawkesburySst |
| | | | 192 | BulgoSst |
| | | | 244 | BulgoSst |
| | | | 302 | ScarboroughSst |
| | | | 320 | ScarboroughSst |
| | | | 329 | ScarboroughSst |
| | | | 370 | CoalcliffSandstone |
| | | | 396 | LawrenceLoddonSst |
| S2007 | 287591 | 6193719 | 360 | CoalcliffSandstone |
| | | | 386 | LawrenceLoddonSst |
| | | | 68 | HawkesburySst |
| S2009 | 287828 | 6193092 | 100 | HawkesburySst |
| | | | 132 | HawkesburySst |
| | | | 185 | BulgoSst |
| | | | 220 | BulgoSst |
| | | | 261 | BulgoSst |
| | | | 295 | ScarboroughSst |
| | | | 309 | ScarboroughSst |
| | | | 366 | LawrenceLoddonSst |
| | | | 394 | WongawilliCoalSeam |
| S2010 | 292273 | 6196658 | 371 | WongawilliCoalSeam |
| S2011 | 292055 | 6197166 | 360 | LawrenceLoddonSst |
| | | | 385 | WongawilliCoalSeam |
| S2013 | 290858 | 6191198 | 299 | LawrenceLoddonSst |
| | | | 333 | WongawilliCoalSeam |
| S2019 | 291898 | 6195914 | 325 | BulliCoalSeam |
| | | | 351 | WongawilliCoalSeam |
| | | | 33 | HawkesburySst |
| | | | 61 | HawkesburySst |
| | | | 79 | BaldHillClaystone |
| S2059 | 293246 | 6194795 | 113 | BulgoSst |
| | | | 151 | BulgoSst |
| | | | 195 | BulgoSst |
| | | | 221 | StanwellParkClaystone |
| | | | 242 | ScarboroughSst |
| | | | 263 | ScarboroughSst |
| | | | 311 | LawrenceLoddonSst |
| | | | 340 | WongawilliCoalSeam |
| | | | 15 | HawkesburySst |
| S2064 | 285967 | 6195946 | 149 | BaldHillClaystone |
| | | | 190 | BulgoSst |
| | | | 235 | BulgoSst |
| | | | 285 | ScarboroughSst |
| | | | 305 | ScarboroughSst |
| | | | 330 | BulliCoalSeam |
| | | | 373 | LawrenceLoddonSst |
| | | | 401 | KemblaSst |
| S2070 | 287619 | 6192813 | 361 | BulliCoalSeam |
| | | | 388 | WongawilliCoalSeam |
| S2071 | 287027 | 6193201 | 365 | CoalcliffSandstone |
| | | | 392 | LawrenceLoddonSst |
| S2073 | 284405 | 6197510 | 359 | BulliCoalSeam |
| | | | 385 | LawrenceLoddonSst |
| S2076 | 288651 | 6197693 | 401 | BulliCoalSeam |
| | | | 428 | WongawilliCoalSeam |

| Site ID | Easting (GDA94Z56) | Northing | Sensor Depth (mbgl) | Formation |
|---|---|---|---|---|
| S2078 | 288190 | 6192452 | 293 | BulliCoalSeam |
| | | | 323 | WongawilliCoalSeam |
| S2082 | 285488 | 6197607 | 377 | CoalcliffSandstone |
| S2187 | 295522 | 6197121 | 302 | LawrenceLoddonSst |
| | | | 331 | WongawilliCoalSeam |
| | | | 45 | HawkesburySst |
| | | | 93 | BulgoSst |
| S2188 | 296605 | 6195670 | 145 | BulgoSst |
| | | | 197 | BulgoSst |
| | | | 235 | ScarboroughSst |
| | | | 245 | ScarboroughSst |
| | | | 256 | ScarboroughSst |
| | | | 304 | LawrenceLoddonSst |
| | | | 335 | WongawilliCoalSeam |
| | | | 385 | LowerPermian |
| | | | 50 | HawkesburySst |
| | | | 95 | HawkesburySst |
| S2192 | 289827 | 6193849 | 140 | BaldHillClaystone |
| | | | 175 | BulgoSst |
| | | | 260 | BulgoSst |
| | | | 278 | BulgoSst |
| S2194 | 288515 | 6190979 | 10 | HawkesburySst |
| | | | 30 | HawkesburySst |
| | | | 55 | HawkesburySst |
| | | | 111 | BulgoSst |
| | | | 150 | BulgoSst |
| | | | 195 | BulgoSst |
| | | | 210 | StanwellParkClaystone |
| | | | 239 | ScarboroughSst |
| | | | 274 | CoalcliffSandstone |
| | | | 302 | WongawilliCoalSeam |
| | | | 339 | TongarraCoalSeam |
| S2207 | 291808 | 6195324 | 372 | LawrenceLoddonSst |
| | | | 397 | KemblaSst |
| | | | 77 | BulgoSst |
| S2208 | 292801 | 6195037 | 143 | BulgoSst |
| | | | 219 | ScarboroughSst |
| | | | 229 | ScarboroughSst |
| | | | 307 | WongawilliCoalSeam |
| S2208A | 292801 | 6195037 | 23 | HawkesburySst |
| | | | 32 | HawkesburySst |
| S2211 | 293247 | 6194106 | 317 | LawrenceLoddonSst |
| | | | 350 | KemblaSst |
| | | | 64 | BaldHillClaystone |
| | | | 92 | BulgoSst |
| S2212 | 293535 | 6194403 | 154 | BulgoSst |
| | | | 215 | ScarboroughSst |
| | | | 239 | ScarboroughSst |
| | | | 250 | WombarraClaystone |
| | | | 260 | WombarraClaystone |
| | | | 289 | BulliCoalSeam |
| | | | 320 | WongawilliCoalSeam |
| | | | 370 | TongarraCoalSeam |
| | | | 50 | HawkesburySst |
| | | | 95 | HawkesburySst |
| S2220 | 289827 | 6193831 | 140 | BaldHillClaystone |
| S2288 | 292801 | 6195037 | 280 | BulliCoalSeam |
| S2291 | 289004 | 6196840 | 394 | CoalcliffSandstone |
| | | | 419 | LawrenceLoddonSst |
| S2306 | 288643 | 6192484 | 10 | HawkesburySst |

| Site ID | Easting (GDA94Z56) | Northing | Sensor Depth (mbgl) | Formation |
|---|---|---|---|---|
| | | | 30 | HawkesburySst |
| | | | 50 | HawkesburySst |
| | | | 70 | HawkesburySst |
| S2307 | 288666 | 6192425 | 10 | HawkesburySst |
| | | | 22 | HawkesburySst |
| | | | 35 | HawkesburySst |
| | | | 50 | HawkesburySst |
| | | | 65 | HawkesburySst |
| S2309 | 287690 | 6194933 | 112 | HawkesburySst |
| | | | 159 | HawkesburySst |
| | | | 198 | BulgoSst |
| | | | 256 | StanwellParkClaystone |
| | | | 315 | ScarboroughSst |
| | | | 350 | WombarraClaystone |
| | | | 360 | WombarraClaystone |
| | | | 387 | BulliCoalSeam |
| | | | 413 | WongawilliCoalSeam |
| | | | 55 | HawkesburySst |
| S2312 | 284450 | 6196151 | 100 | HawkesburySst |
| | | | 146 | HawkesburySst |
| | | | 192 | BulgoSst |
| | | | 232 | BulgoSst |
| | | | 271 | StanwellParkClaystone |
| | | | 302 | ScarboroughSst |
| | | | 318 | ScarboroughSst |
| | | | 372 | LawrenceLoddonSst |
| | | | 395 | WongawilliCoalSeam |
| | | | 49 | HawkesburySst |
| S2313 | 287609 | 6192816 | 131 | HawkesburySst |
| | | | 182 | BulgoSst |
| | | | 29 | HawkesburySst |
| | | | 75 | HawkesburySst |
| S2314 | 288194 | 6192470 | 128 | BulgoSst |
| S2314A | 288194 | 6192470 | 28 | HawkesburySst |
| S2321 | 284710 | 6195576 | 368 | LawrenceLoddonSst |
| | | | 392 | KemblaSst |
| | | | 50 | HawkesburySst |
| | | | 97 | HawkesburySst |
| S2325 | 283596 | 6195467 | 145 | BaldHillClaystone |
| | | | 182 | BulgoSst |
| | | | 243 | BulgoSst |
| | | | 303 | ScarboroughSst |
| | | | 321 | WombarraClaystone |
| | | | 332 | WombarraClaystone |
| | | | 49 | HawkesburySst |
| | | | 68 | HawkesburySst |
| | | | 86 | HawkesburySst |
| S2333 | 290697 | 6197087 | 130 | BulgoSst |
| | | | 191 | BulgoSst |
| | | | 251 | StanwellParkClaystone |
| | | | 266 | ScarboroughSst |
| | | | 288 | ScarboroughSst |
| | | | 339 | BulliCoalSeam |
| | | | 364 | LawrenceLoddonSst |
| S2335 | 289725 | 6192749 | 15 | HawkesburySst |
| | | | 25 | HawkesburySst |
| | | | 30 | HawkesburySst |
| | | | 40 | HawkesburySst |
| | | | 50 | HawkesburySst |
| S2335A | 289727 | 6192755 | 10 | BaldHillClaystone |

| Site ID | Easting (GDA94Z56) | Northing | Sensor Depth (mbgl) | Formation |
|---|---|---|---|---|
| | | | 26 | HawkesburySst |
| | | | 41 | HawkesburySst |
| | | | 51 | HawkesburySst |
| | | | 81 | HawkesburySst |
| | | | 91 | HawkesburySst |
| S2336 | 289722 | 6192758 | 32 | HawkesburySst |
| S2337 | 290021 | 6193412 | 25 | HawkesburySst |
| | | | 36 | HawkesburySst |
| | | | 47 | HawkesburySst |
| S2338 | 290012 | 6193407 | 25 | HawkesburySst |
| | | | 42 | HawkesburySst |
| | | | 50 | HawkesburySst |
| | | | 56 | HawkesburySst |
| S2340 | 285468 | 6197979 | 102 | HawkesburySst |
| | | | 148 | HawkesburySst |
| | | | 195 | BulgoSst |
| | | | 232 | BulgoSst |
| | | | 270 | BulgoSst |
| | | | 307 | StanwellParkClaystone |
| | | | 344 | ScarboroughSst |
| | | | 383 | BulliCoalSeam |
| | | | 50 | HawkesburySst |
| | | | 97 | HawkesburySst |
| S2341 | 287474 | 6195150 | 145 | HawkesburySst |
| | | | 185 | BaldHillClaystone |
| | | | 221 | BulgoSst |
| | | | 257 | StanwellParkClaystone |
| | | | 293 | ScarboroughSst |
| | | | 329 | ScarboroughSst |
| | | | 372 | CoalcliffSandstone |
| | | | 401 | LawrenceLoddonSst |
| S2341A | 287489 | 6195138 | 10 | HawkesburySst |
| | | | 26 | HawkesburySst |
| | | | 42 | HawkesburySst |
| | | | 59 | HawkesburySst |
| | | | 55 | HawkesburySst |
| S2342 | 287953 | 6196756 | 105 | HawkesburySst |
| | | | 145 | HawkesburySst |
| | | | 190 | BulgoSst |
| | | | 225 | BulgoSst |
| | | | 260 | StanwellParkClaystone |
| | | | 296 | StanwellParkClaystone |
| | | | 335 | ScarboroughSst |
| | | | 384 | CoalcliffSandstone |
| | | | 412 | LawrenceLoddonSst |
| | | | 55 | HawkesburySst |
| | | | 99 | HawkesburySst |
| S2345 | 285357 | 6196095 | 144 | HawkesburySst |
| | | | 185 | BulgoSst |
| | | | 221 | BulgoSst |
| | | | 257 | BulgoSst |
| | | | 293 | ScarboroughSst |
| | | | 329 | WombarraClaystone |
| | | | 371 | LawrenceLoddonSst |
| S2345A | 285360 | 6196097 | 10 | HawkesburySst |
| | | | 25 | HawkesburySst |
| | | | 40 | HawkesburySst |
| | | | 55 | HawkesburySst |
| S2348 | 286451 | 6196462 | 105 | HawkesburySst |
| | | | 145 | HawkesburySst |

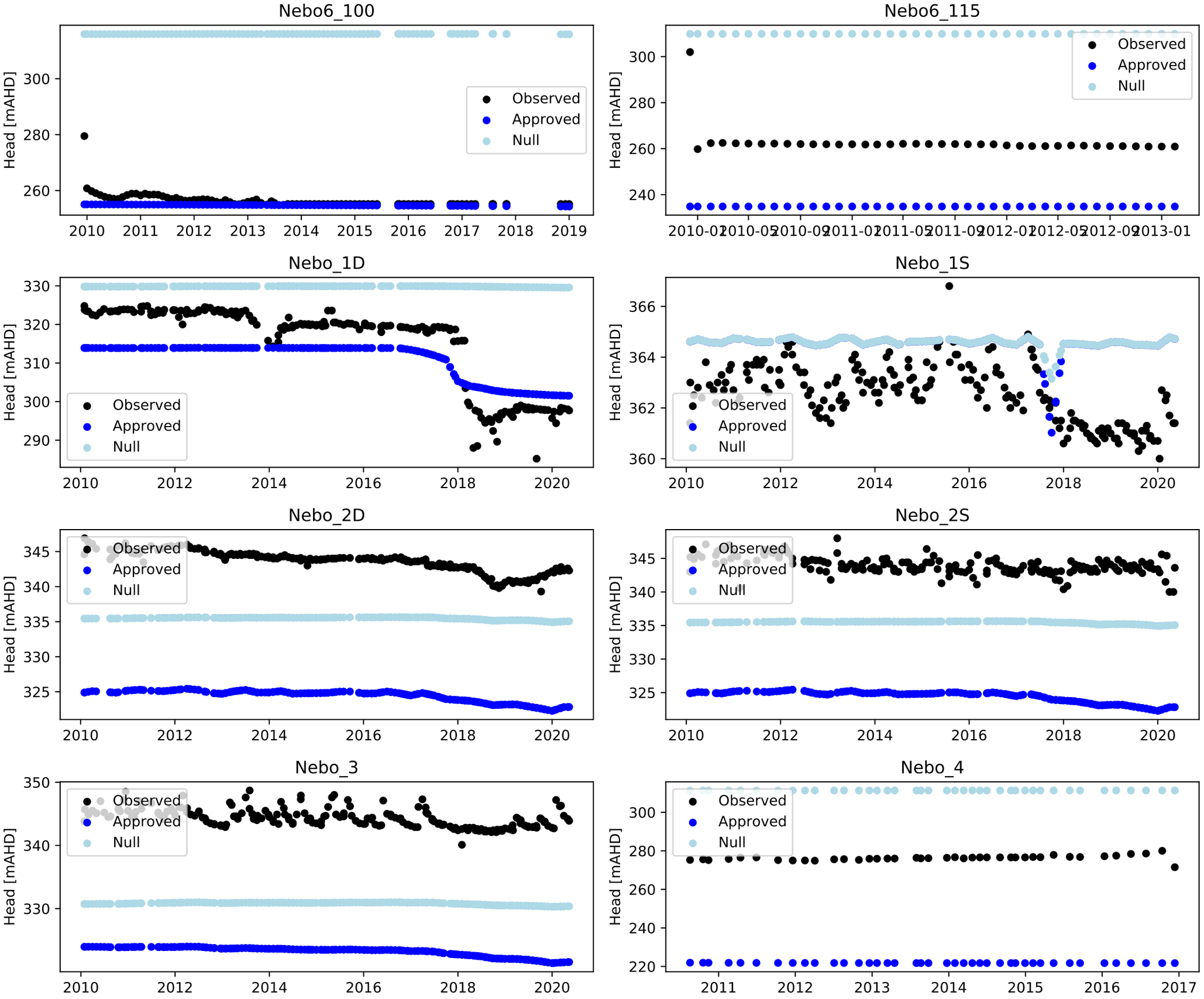
| Site ID | Easting (GDA94Z56) | Northing | Sensor Depth (mbgl) | Formation |
|---|---|---|---|---|
| | | | 192 | BulgoSst |
| | | | 227 | BulgoSst |
| | | | 262 | StanwellParkClaystone |
| | | | 297 | ScarboroughSst |
| | | | 333 | WombarraClaystone |
| | | | 376 | BulliCoalSeam |
| | | | 403 | LawrenceLoddonSst |
| S2348A | 286451 | 6196465 | 10 | HawkesburySst |
| | | | 25 | HawkesburySst |
| | | | 40 | HawkesburySst |
| S2351 | 290050 | 6191178 | 14 | HawkesburySst |
| S2351A | 290054 | 6191175 | 29 | HawkesburySst |
| | | | 55 | HawkesburySst |
| | | | 91 | HawkesburySst |
| S2352 | 286265 | 6195393 | 127 | HawkesburySst |
| | | | 202 | BulgoSst |
| | | | 235 | BulgoSst |
| | | | 265 | StanwellParkClaystone |
| | | | 298 | ScarboroughSst |
| | | | 337 | WombarraClaystone |
| | | | 378 | LawrenceLoddonSst |
| | | | 410 | KemblaSst |
| S2354 | 289731 | 6191414 | 42 | HawkesburySst |
| S2355 | 288136 | 6194878 | 10 | HawkesburySst |
| | | | 25 | HawkesburySst |
| | | | 43 | HawkesburySst |
| | | | 60 | HawkesburySst |
| S2355A | 288135 | 6194879 | 10 | HawkesburySst |
| S2357 | 286815 | 6196984 | 10 | HawkesburySst |
| | | | 27 | HawkesburySst |
| | | | 42 | HawkesburySst |
| | | | 56 | HawkesburySst |
| | | | 55 | HawkesburySst |
| | | | 93 | HawkesburySst |
| S2359 | 285355 | 6195548 | 131 | HawkesburySst |
| | | | 186 | BulgoSst |
| | | | 247 | StanwellParkClaystone |
| | | | 308 | WombarraClaystone |
| | | | 318 | WombarraClaystone |
| | | | 343 | CoalcliffSandstone |
| | | | 363 | LawrenceLoddonSst |
| | | | 387 | WongawilliCoalSeam |
| S2361 | 286278 | 6195811 | 10 | HawkesburySst |
| | | | 27 | HawkesburySst |
| | | | 42 | HawkesburySst |
| | | | 60 | HawkesburySst |
| S2362 | 285773 | 6195823 | 10 | HawkesburySst |
| | | | 41 | HawkesburySst |
| | | | 58 | HawkesburySst |
| S2364 | 285983 | 6196782 | 10 | HawkesburySst |
| | | | 27 | HawkesburySst |
| | | | 42 | HawkesburySst |
| | | | 60 | HawkesburySst |
| S2365 | 286042 | 6196449 | 10 | HawkesburySst |
| | | | 25 | HawkesburySst |
| | | | 41 | HawkesburySst |
| | | | 64 | HawkesburySst |
| S2365A | 286042 | 6196443 | 10 | HawkesburySst |
| | | | 47 | HawkesburySst |
| | | | 70 | HawkesburySst |

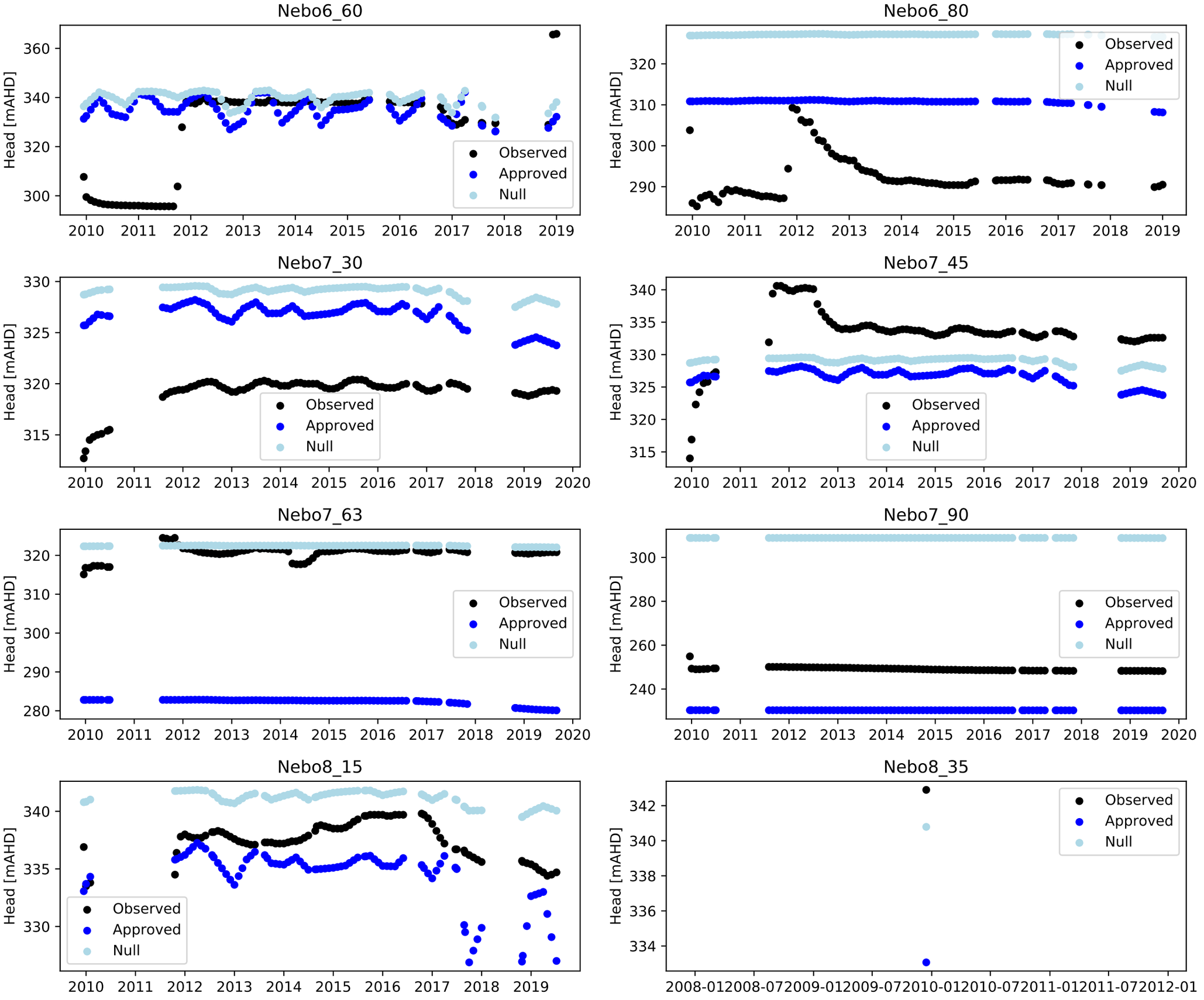
| Site ID | Easting (GDA94Z56) | Northing | Sensor Depth (mbgl) | Formation |
|---|---|---|---|---|
| S2370 | 285555 | 6196643 | 112 | HawkesburySst |
| | | | 162 | BulgoSst |
| | | | 203 | BulgoSst |
| | | | 257 | StanwellParkClaystone |
| | | | 282 | ScarboroughSst |
| | | | 298 | ScarboroughSst |
| | | | 339 | WombarraClaystone |
| | | | 362 | LawrenceLoddonSst |
| | | | 29 | HawkesburySst |
| S2376 | 288400 | 6192527 | 107 | BaldHillClaystone |
| | | | 169 | BulgoSst |
| | | | 27 | HawkesburySst |
| S2377 | 288333 | 6192020 | 112 | HawkesburySst |
| | | | 187 | BulgoSst |
| | | | 30 | HawkesburySst |
| | | | 90 | HawkesburySst |
| S2378 | 288407 | 6191771 | 164 | BulgoSst |
| | | | 30 | HawkesburySst |
| | | | 50 | HawkesburySst |
| S2379 | 288313 | 6191141 | 108 | BulgoSst |
| | | | 30 | HawkesburySst |
| | | | 69 | HawkesburySst |
| S2398 | 289073 | 6192164 | 108 | HawkesburySst |
| | | | 147 | HawkesburySst |
| | | | 171 | BaldHillClaystone |
| | | | 190 | BulgoSst |
| | | | 233 | BulgoSst |
| S2398A | 289073 | 6192157 | 10 | HawkesburySst |
| S2398B | 289071 | 6192173 | 10 | BulgoSst |
| | | | 14 | HawkesburySst |
| | | | 17 | HawkesburySst |
| | | | 19 | BaldHillClaystone |
| | | | 23 | BulgoSst |
| | | | 30 | HawkesburySst |
| | | | 69 | HawkesburySst |
| | | | 11 | HawkesburySst |
| | | | 30 | HawkesburySst |
| | | | 48 | HawkesburySst |
| | | | 65 | HawkesburySst |
| | | | 88 | HawkesburySst |
| S2399 | 289811 | 6192965 | 107 | BaldHillClaystone |
| | | | 132 | BulgoSst |
| | | | 172 | BulgoSst |
| S2399A | 289816 | 6192968 | 11 | HawkesburySst |
| | | | 30 | HawkesburySst |
| | | | 15 | HawkesburySst |
| | | | 26 | HawkesburySst |
| | | | 45 | HawkesburySst |
| | | | 67 | HawkesburySst |
| | | | 90 | HawkesburySst |
| S2401 | 287752 | 6194265 | 116 | HawkesburySst |
| S2402 | 288208 | 6193667 | 15 | HawkesburySst |
| | | | 23 | HawkesburySst |
| | | | 40 | HawkesburySst |
| | | | 55 | HawkesburySst |
| | | | 80 | HawkesburySst |
| | | | 91 | HawkesburySst |
| S2403 | 288345 | 6193761 | 15 | HawkesburySst |
| | | | 23 | HawkesburySst |
| | | | 39 | HawkesburySst |

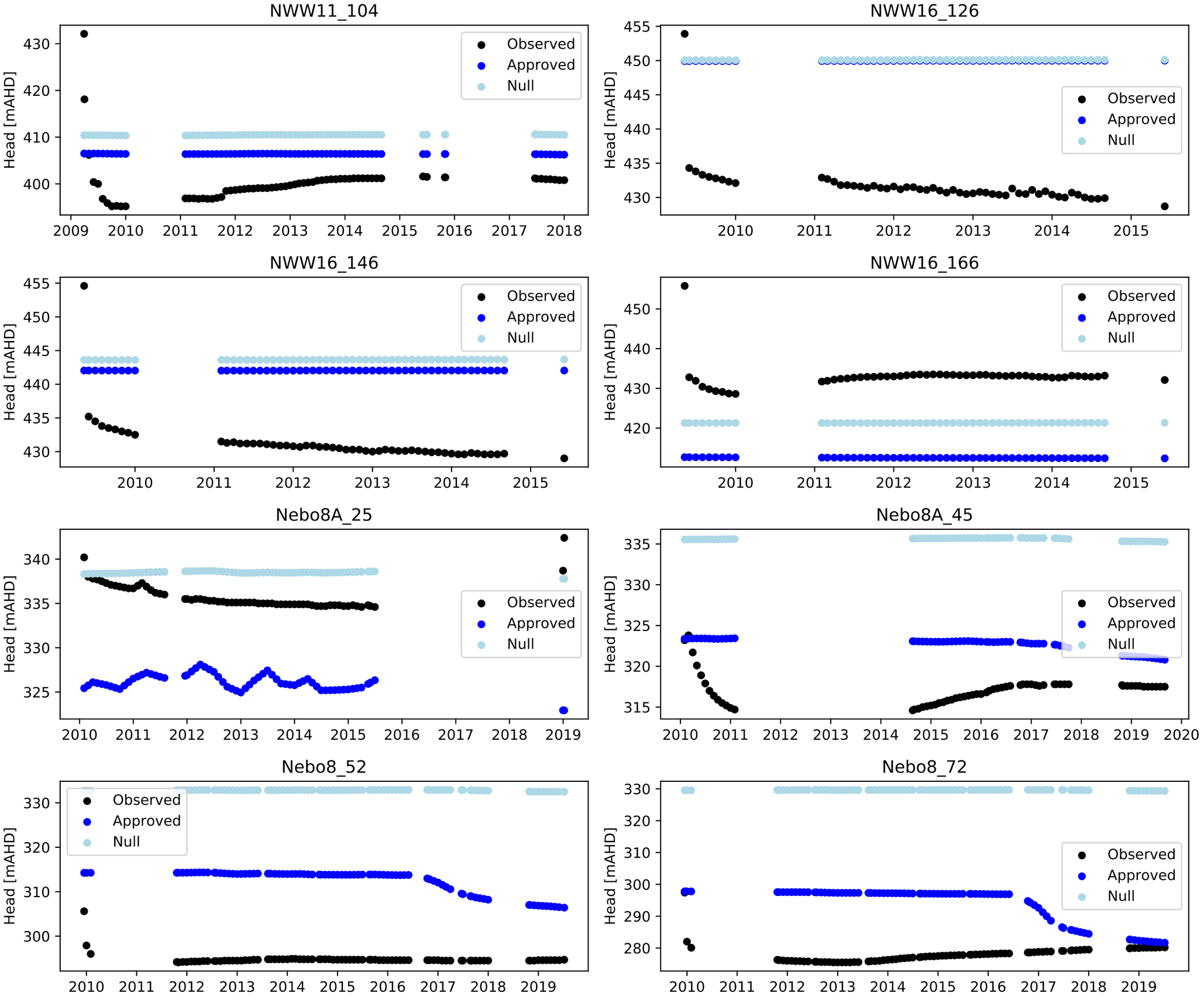
| Site ID | Easting (GDA94Z56) | Northing | Sensor Depth (mbgl) | Formation |
|---|---|---|---|---|
| | | | 48 | HawkesburySst |
| | | | 55 | HawkesburySst |
| | | | 59 | HawkesburySst |
| S2404 | 288529 | 6193897 | 10 | HawkesburySst |
| | | | 20 | HawkesburySst |
| | | | 30 | HawkesburySst |
| | | | 40 | HawkesburySst |
| | | | 50 | HawkesburySst |
| | | | 58 | HawkesburySst |
| S2405 | 288730 | 6194088 | 10 | HawkesburySst |
| | | | 24 | HawkesburySst |
| | | | 34 | HawkesburySst |
| | | | 48 | HawkesburySst |
| | | | 58 | HawkesburySst |
| | | | 64 | HawkesburySst |
| S2406 | 288669 | 6194176 | 10 | HawkesburySst |
| | | | 25 | HawkesburySst |
| | | | 32 | HawkesburySst |
| | | | 48 | HawkesburySst |
| | | | 58 | HawkesburySst |
| | | | 79 | HawkesburySst |
| S2408 | 289552 | 6192193 | 11 | HawkesburySst |
| | | | 15 | HawkesburySst |
| | | | 26 | HawkesburySst |
| | | | 45 | HawkesburySst |
| | | | 67 | HawkesburySst |
| | | | 90 | HawkesburySst |
| | | | 113 | HawkesburySst |
| | | | 15 | HawkesburySst |
| | | | 26 | HawkesburySst |
| | | | 45 | HawkesburySst |
| | | | 67 | HawkesburySst |
| | | | 90 | HawkesburySst |
| S2409 | 289546 | 6192270 | 118 | HawkesburySst |
| | | | 11 | HawkesburySst |
| | | | 30 | HawkesburySst |
| | | | 50 | HawkesburySst |
| | | | 69 | HawkesburySst |
| | | | 89 | HawkesburySst |
| S2411 | 289761 | 6192838 | 109 | BaldHillClaystone |
| | | | 137 | BulgoSst |
| | | | 177 | BulgoSst |
| S2411A | 289762 | 6192839 | 11 | HawkesburySst |
| S2412 | 289201 | 6191807 | 10 | HawkesburySst |
| | | | 30 | HawkesburySst |
| | | | 69 | HawkesburySst |
| | | | 107 | HawkesburySst |
| | | | 146 | HawkesburySst |
| | | | 173 | BaldHillClaystone |
| | | | 192 | BulgoSst |
| | | | 232 | BulgoSst |
| S2412B | 289201 | 6191807 | 10 | BulgoSst |
| | | | 14 | HawkesburySst |
| | | | 17 | BaldHillClaystone |
| | | | 19 | BulgoSst |
| | | | 23 | BulgoSst |
| | | | 38 | HawkesburySst |
| | | | 69 | HawkesburySst |
| | | | 30 | HawkesburySst |
| | | | 51 | HawkesburySst |

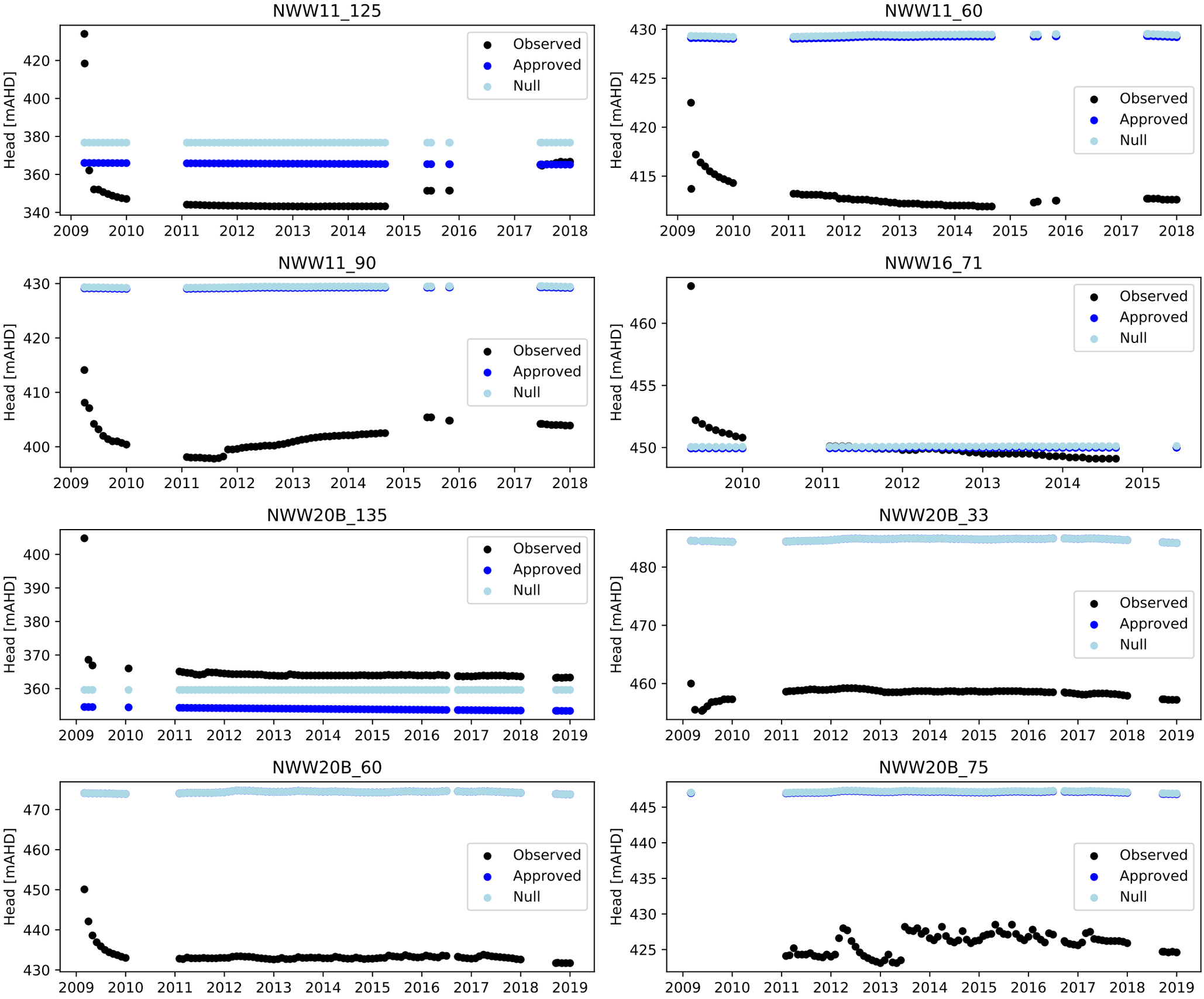
| Site ID | Easting (GDA94Z56) | Northing | Sensor Depth (mbgl) | Formation |
|---|---|---|---|---|
| | | | 72 | HawkesburySst |
| | | | 93 | HawkesburySst |
| S2420 | 289738 | 6192780 | 121 | BaldHillClaystone |
| | | | 140 | BulgoSst |
| | | | 180 | BulgoSst |
| S2421 | 289590 | 6192492 | 11 | HawkesburySst |
| | | | 30 | HawkesburySst |
| | | | 58 | HawkesburySst |
| | | | 86 | HawkesburySst |
| | | | 114 | BaldHillClaystone |
| | | | 134 | BaldHillClaystone |
| | | | 157 | BulgoSst |
| | | | 197 | BulgoSst |
| | | | 25 | HawkesburySst |
| | | | 60 | HawkesburySst |
| S2435 | 288081 | 6192412 | 100 | BulgoSst |
| S2436 | 288314 | 6191500 | 25 | HawkesburySst |
| | | | 65 | BaldHillClaystone |
| | | | 93 | BulgoSst |
| S2436B | 288314 | 6191500 | 35 | BaldHillClaystone |
| S2436C | 288320 | 6191501 | 45 | BaldHillClaystone |
| | | | 98 | HawkesburySst |
| S2438 | 287945 | 6197535 | 136 | HawkesburySst |
| | | | 194 | BulgoSst |
| | | | 233 | BulgoSst |
| | | | 265 | StanwellParkClaystone |
| | | | 315 | ScarboroughSst |
| | | | 350 | WombarraClaystone |
| | | | 400 | LawrenceLoddonSst |
| S2442A | 292788 | 6193213 | 11 | BaldHillClaystone |
| | | | 12 | BulgoSst |
| | | | 15 | BulgoSst |
| | | | 20 | BulgoSst |
| | | | 49 | HawkesburySst |
| | | | 80 | HawkesburySst |
| | | | 14 | HawkesburySst |
| | | | 65 | HawkesburySst |
| S2443 | 292176 | 6193027 | 113 | HawkesburySst |
| | | | 138 | BaldHillClaystone |
| | | | 155 | BulgoSst |
| | | | 225 | BulgoSst |
| S2444 | 289078 | 6190168 | 44 | HawkesburySst |
| | | | 38 | HawkesburySst |
| | | | 70 | HawkesburySst |
| S2486 | 288890 | 6192725 | 113 | HawkesburySst |
| | | | 150 | HawkesburySst |
| | | | 198 | BulgoSst |
| | | | 252 | BulgoSst |
| | | | 285 | StanwellParkClaystone |
| | | | 30 | HawkesburySst |
| | | | 75 | HawkesburySst |
| S2487 | 290707 | 6191689 | 120 | BaldHillClaystone |
| | | | 150 | BulgoSst |
| | | | 165 | BulgoSst |

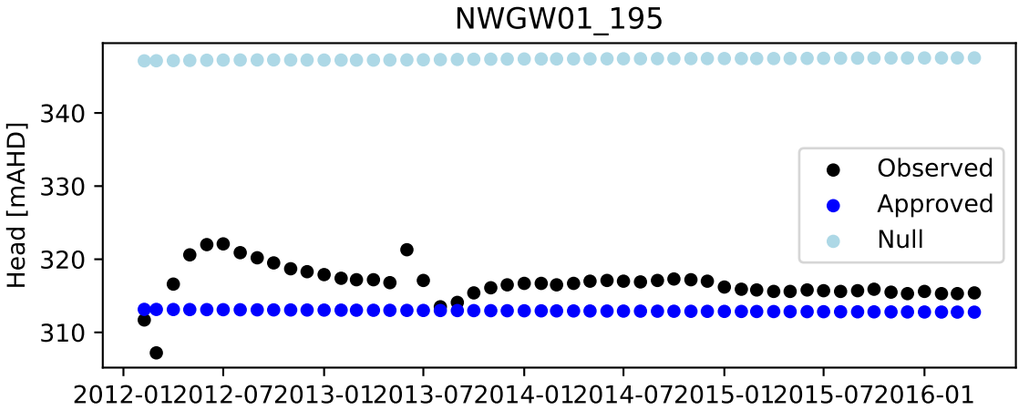
# Appendix F – Calibration Hydrographs

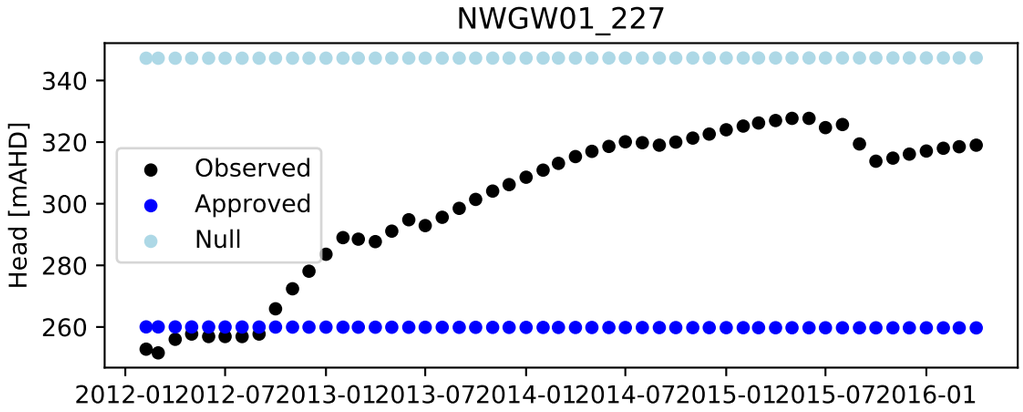

Nebo6_100
Head [mAHD]
Observed
Approved
Null
Nebo6_115
Nebo_1D
Nebo_1S
Nebo_2D
Nebo_2S
Nebo_3
Nebo_4

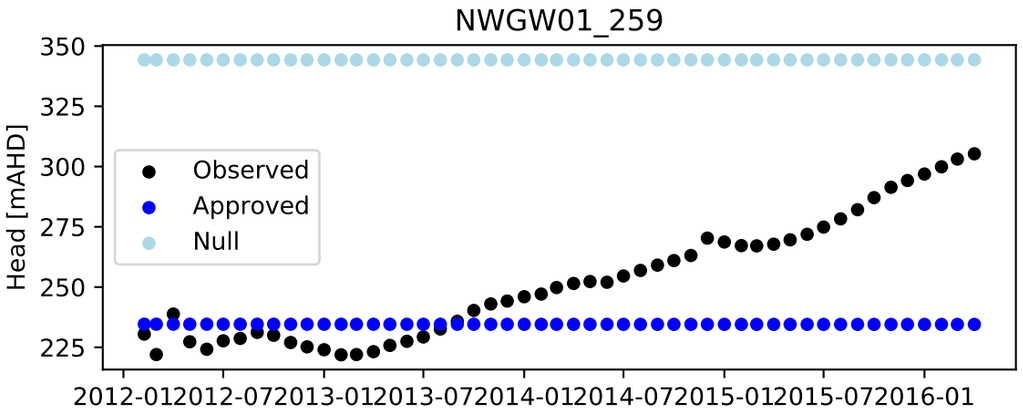

Nebo6_60
Nebo6_80
Nebo7_30
Nebo7_45
Nebo7_63
Nebo7_90
Nebo8_15
Nebo8_35
Head [mAHD]
Observed
Approved
Null
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2008-012008-072009-012009-072010-012010-072011-012011-072012-01

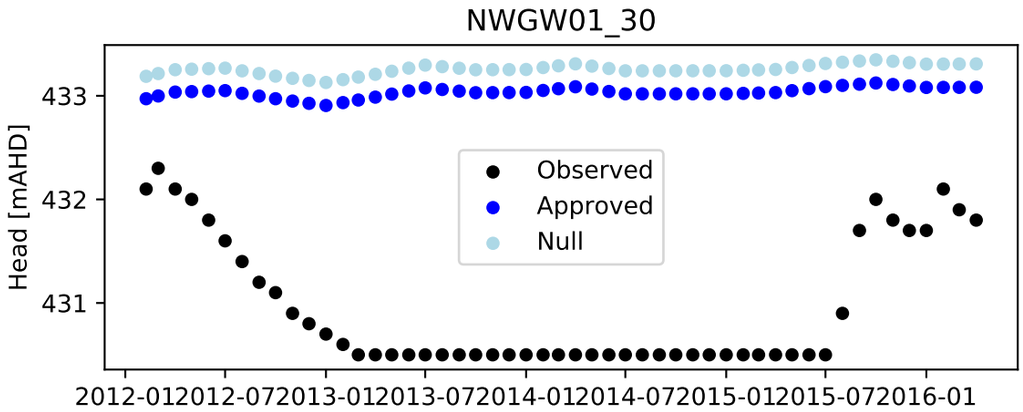

NWW11_104
Head [mAHD]
Observed
Approved
Null
NWW16_126
NWW16_146
NWW16_166
Nebo8A_25
Nebo8A_45
Nebo8_52
Nebo8_72

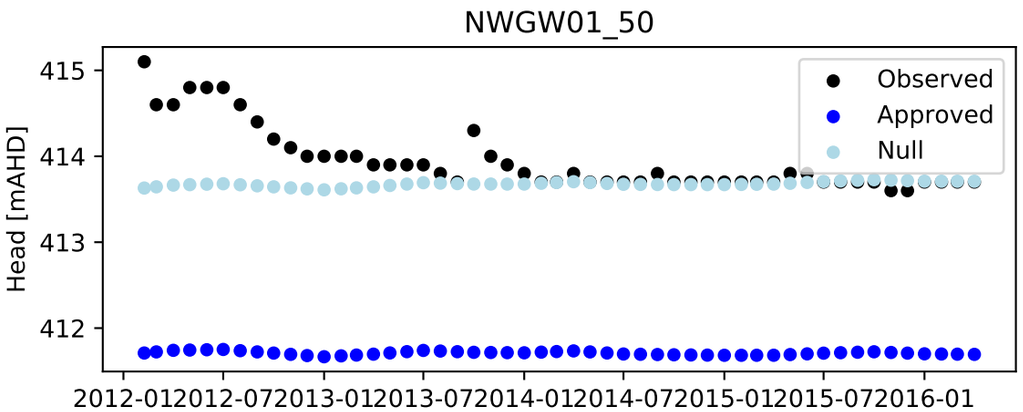

NWW11_125
NWW11_60
NWW11_90
NWW16_71
NWW20B_135
NWW20B_33
NWW20B_60
NWW20B_75
Head [mAHD]
Observed
Approved
Null

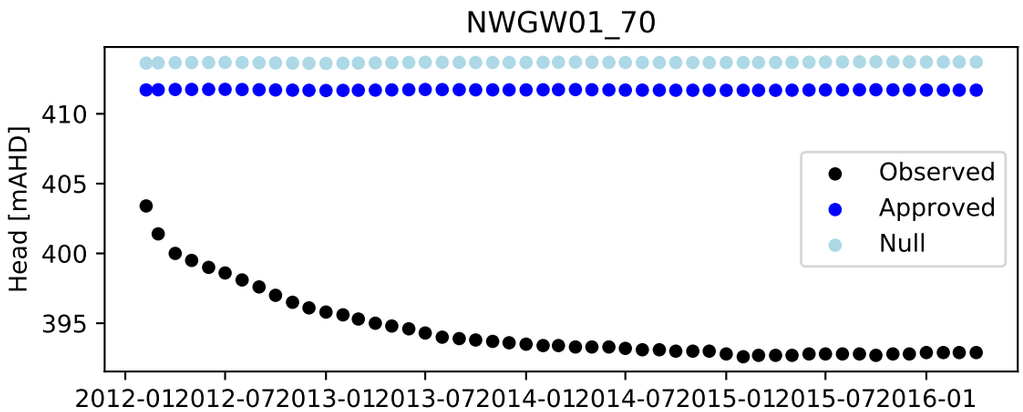

NWGW01_195
Head [mAHD]
340
330
320
310
Observed
Approved
Null
2012-012012-072013-012013-072014-012014-072015-012015-072016-01

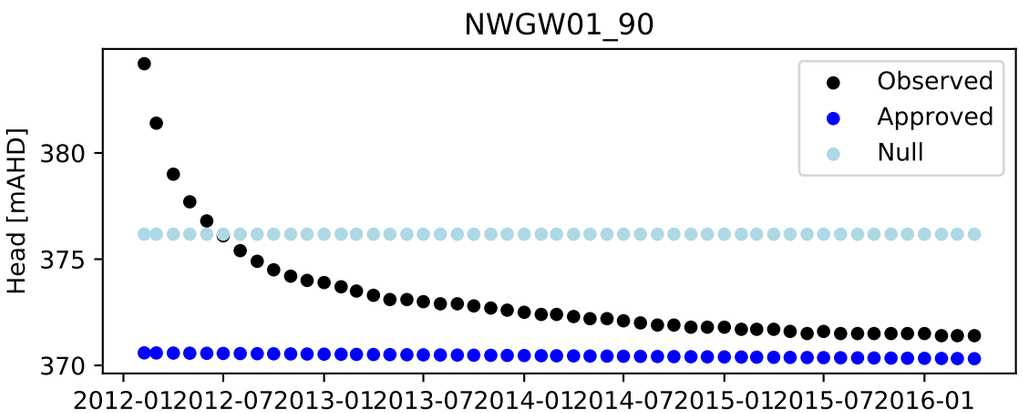

NWGW01_227
Head [mAHD]
340
320
300
280
260
Observed
Approved
Null
2012-012012-072013-012013-072014-012014-072015-012015-072016-01

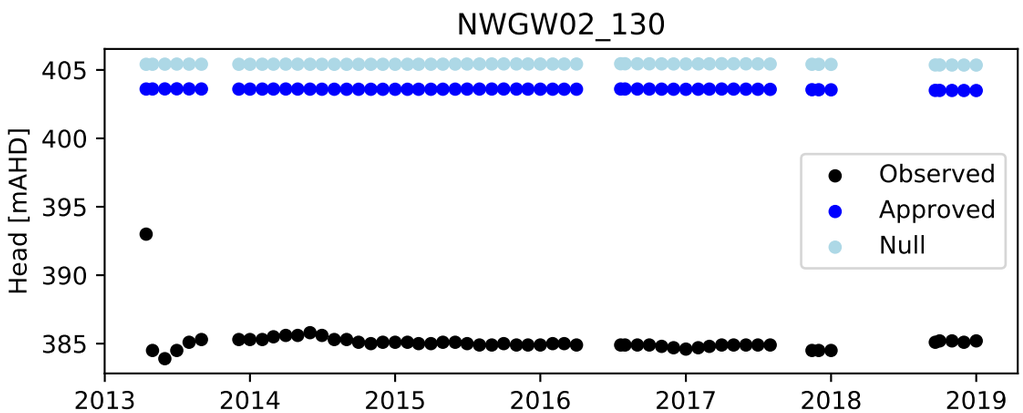

NWGW01_259
Head [mAHD]
350
325
300
275
250
225
Observed
Approved
Null
2012-012012-072013-012013-072014-012014-072015-012015-072016-01

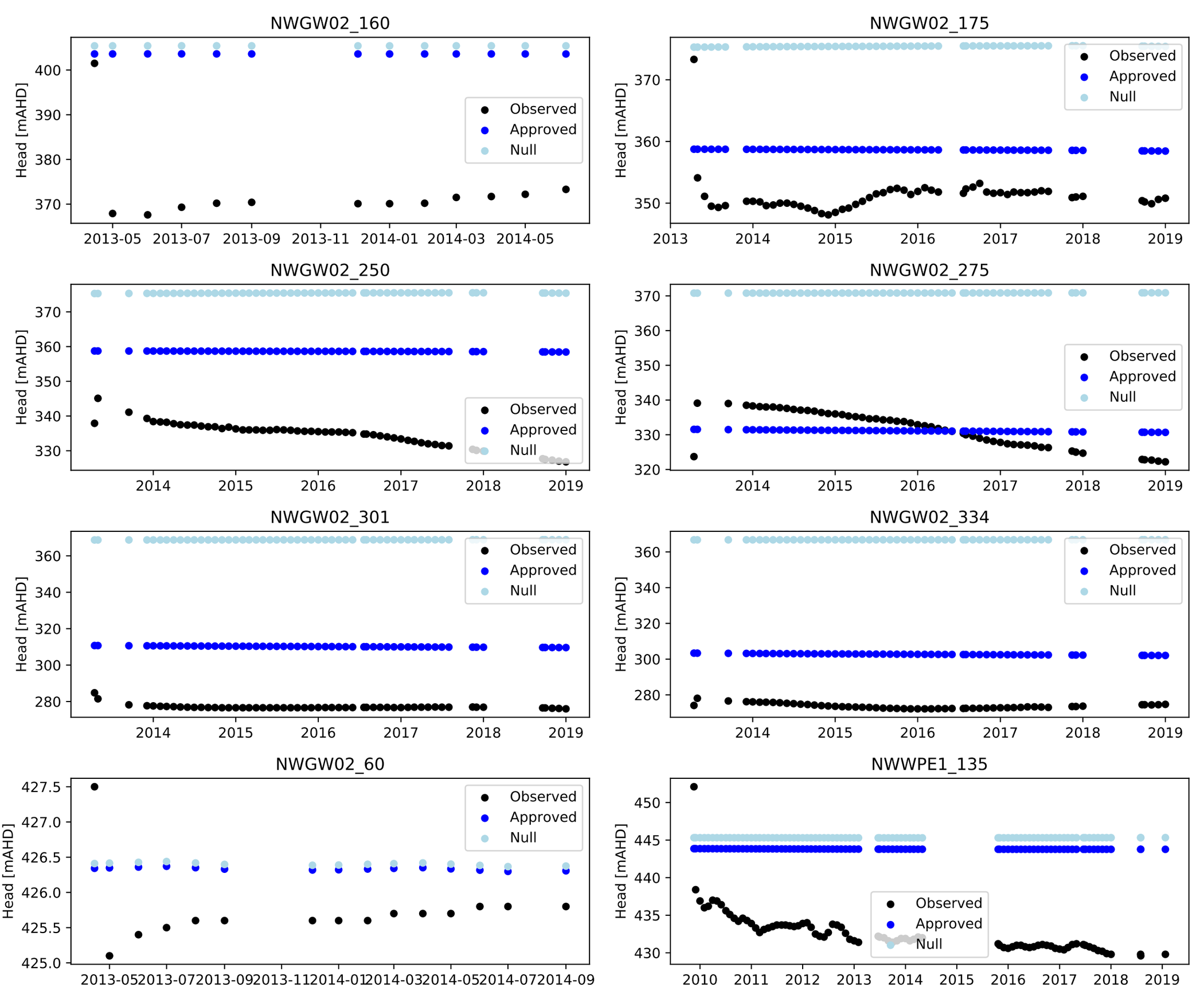

NWGW01_30
Head [mAHD]
433
432
431
Observed
Approved
Null
2012-012012-072013-012013-072014-012014-072015-012015-072016-01

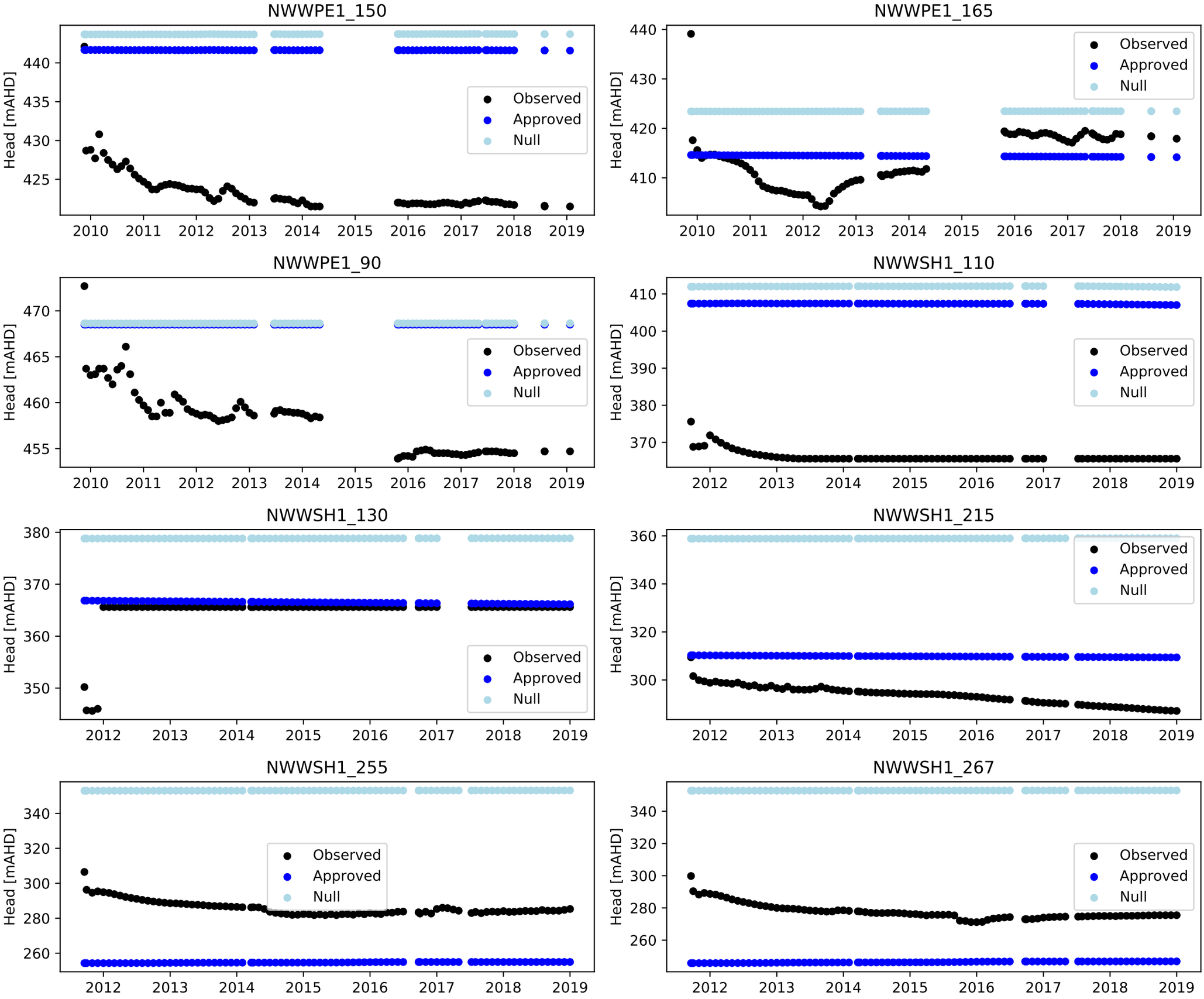

NWGW01_50
Head [mAHD]
415
414
413
412
Observed
Approved
Null
2012-012012-072013-012013-072014-012014-072015-012015-072016-01

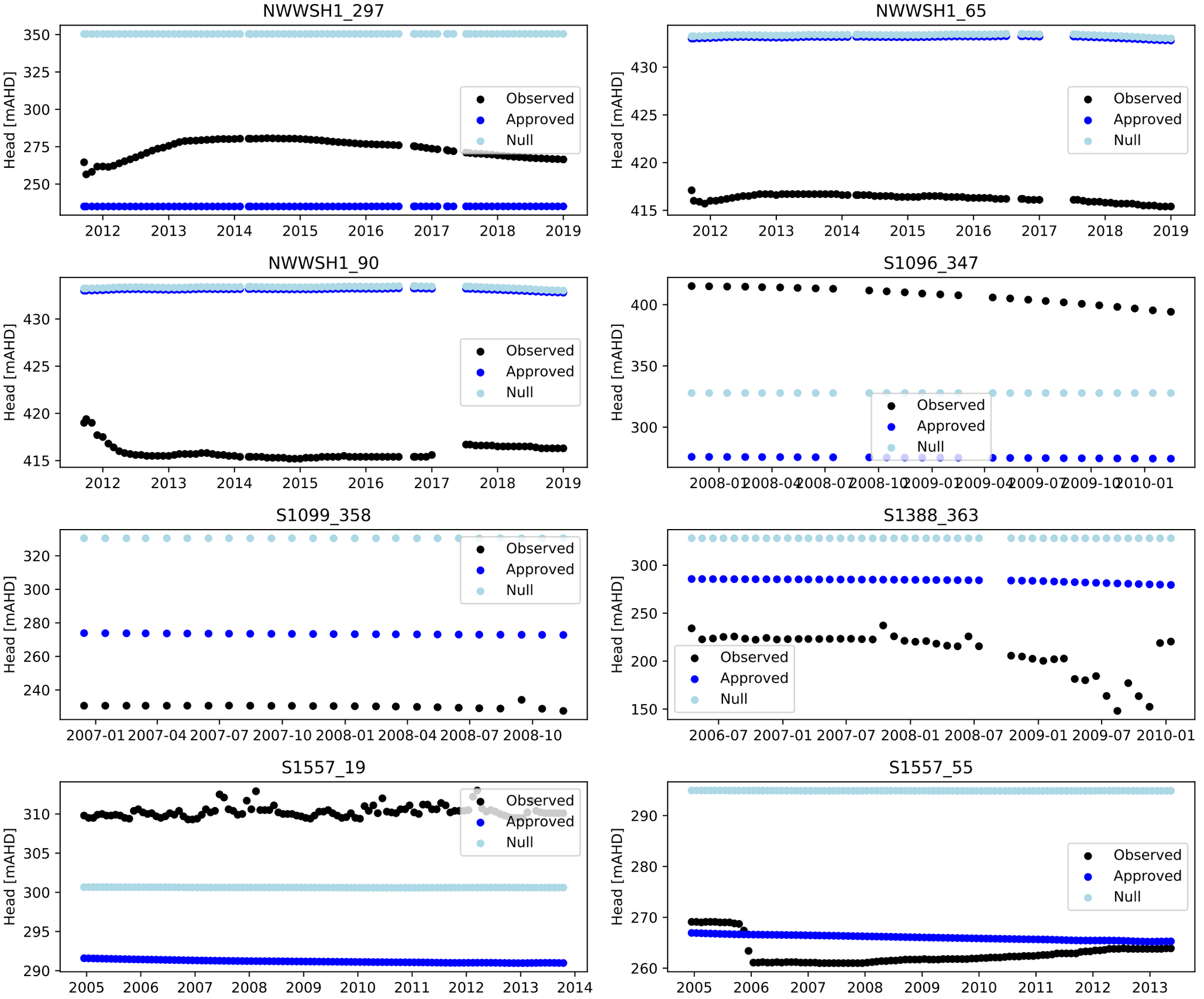

NWGW01_70
Head [mAHD]
410
405
400
395
Observed
Approved
Null
2012-012012-072013-012013-072014-012014-072015-012015-072016-01

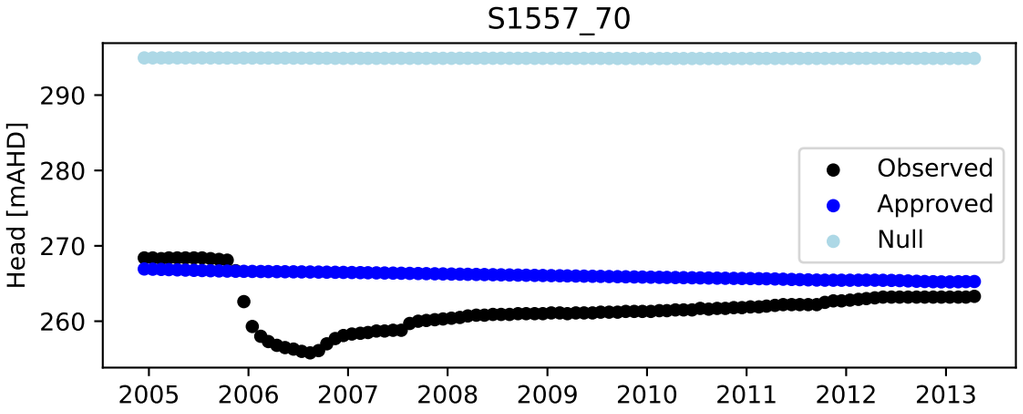

NWGW01_90
Head [mAHD]
380
375
370
Observed
Approved
Null
2012-012012-072013-012013-072014-012014-072015-012015-072016-01

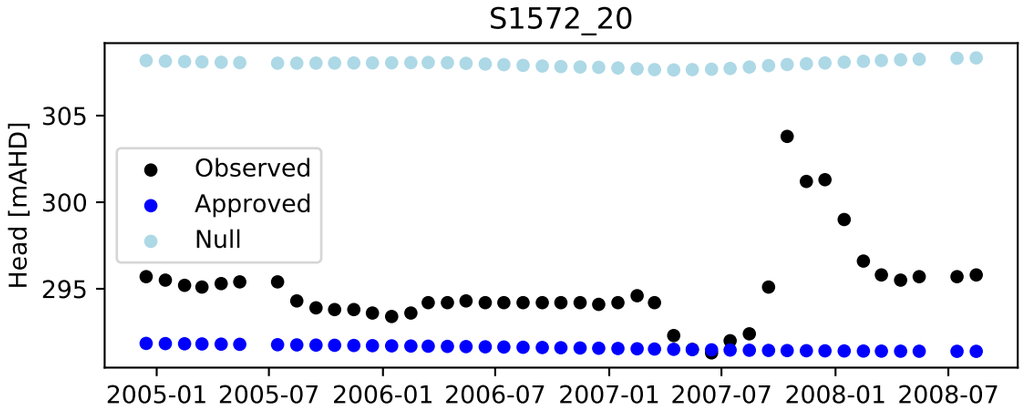

NWGW02_130
Head [mAHD]
405
400
395
390
385
Observed
Approved
Null
2013
2014
2015
2016
2017
2018
2019

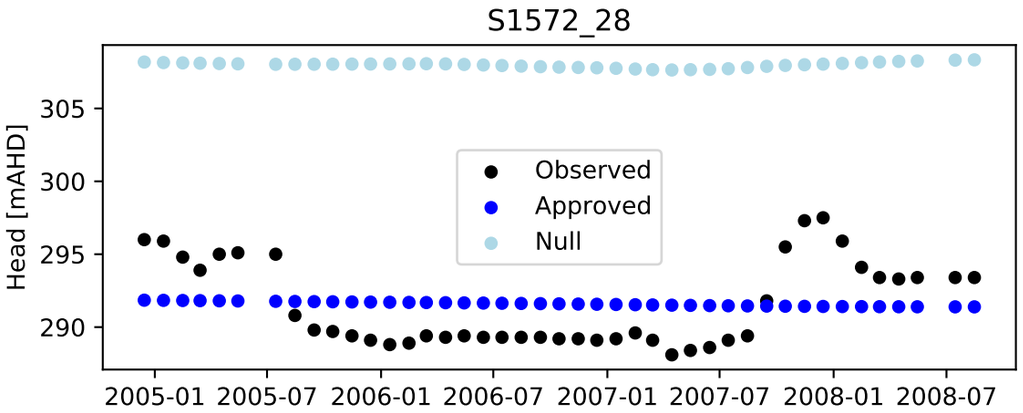

NWGW02_160
Head [mAHD]
Observed
Approved
Null
NWGW02_175
NWGW02_250
NWGW02_275
NWGW02_301
NWGW02_334
NWGW02_60
NWWPE1_135

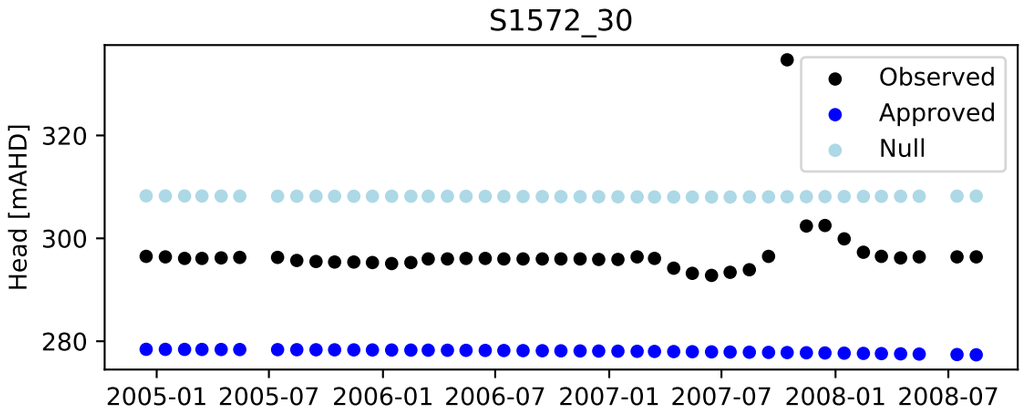

NWWPE1_150
NWWPE1_165
NWWPE1_90
NWWSH1_110
NWWSH1_130
NWWSH1_215
NWWSH1_255
NWWSH1_267
Head [mAHD]
Observed
Approved
Null

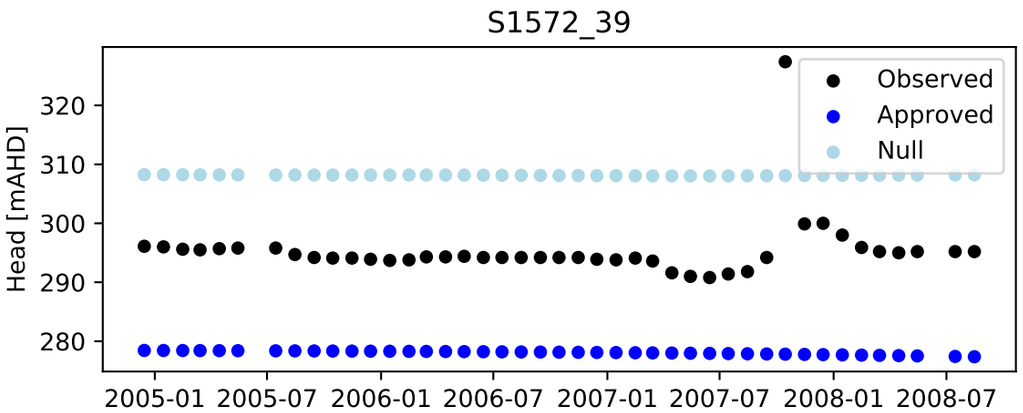

NWWSH1_297
Head [mAHD]
Observed
Approved
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NWWSH1_65
NWWSH1_90
S1096_347
S1099_358
S1388_363
S1557_19
S1557_55

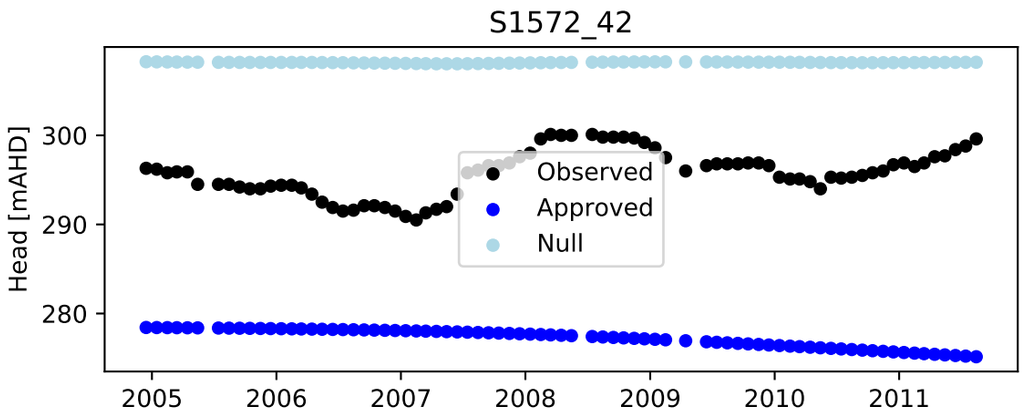

S1557_70
Head [mAHD]
290
280
270
260
2005
2006
2007
2008
2009
2010
2011
2012
2013
Observed
Approved
Null

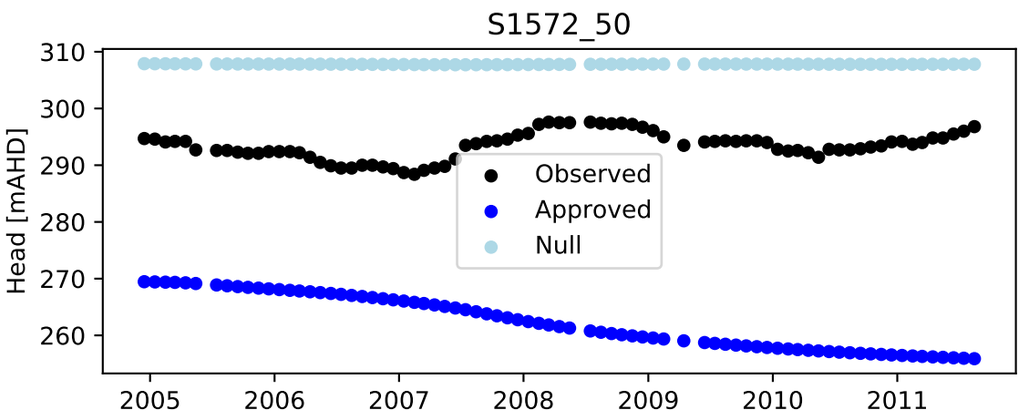

S1572_20
Head [mAHD]
305
300
295
2005-01
2005-07
2006-01
2006-07
2007-01
2007-07
2008-01
2008-07
Observed
Approved
Null

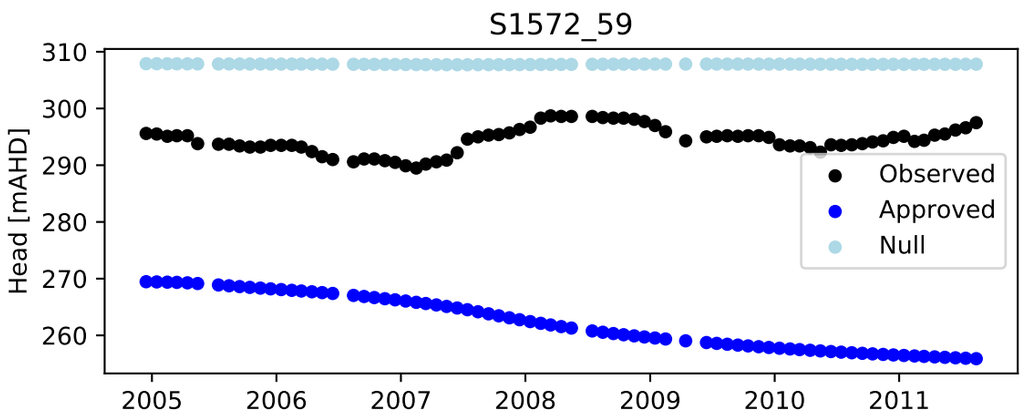

S1572_28
Head [mAHD]
305
300
295
290
2005-01
2005-07
2006-01
2006-07
2007-01
2007-07
2008-01
2008-07
Observed
Approved
Null

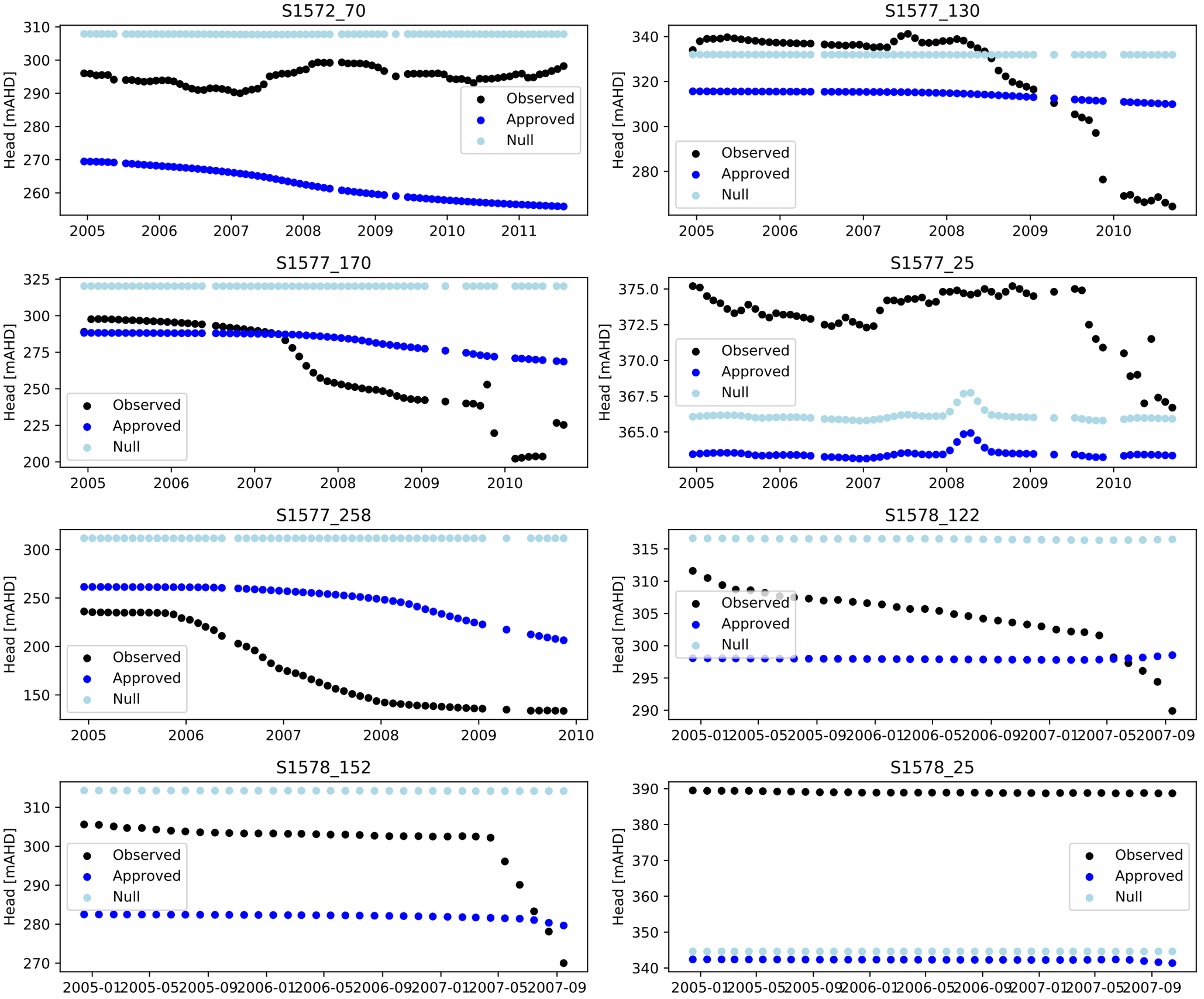

S1572_30
Head [mAHD]
320
300
280
2005-01
2005-07
2006-01
2006-07
2007-01
2007-07
2008-01
2008-07
Observed
Approved
Null

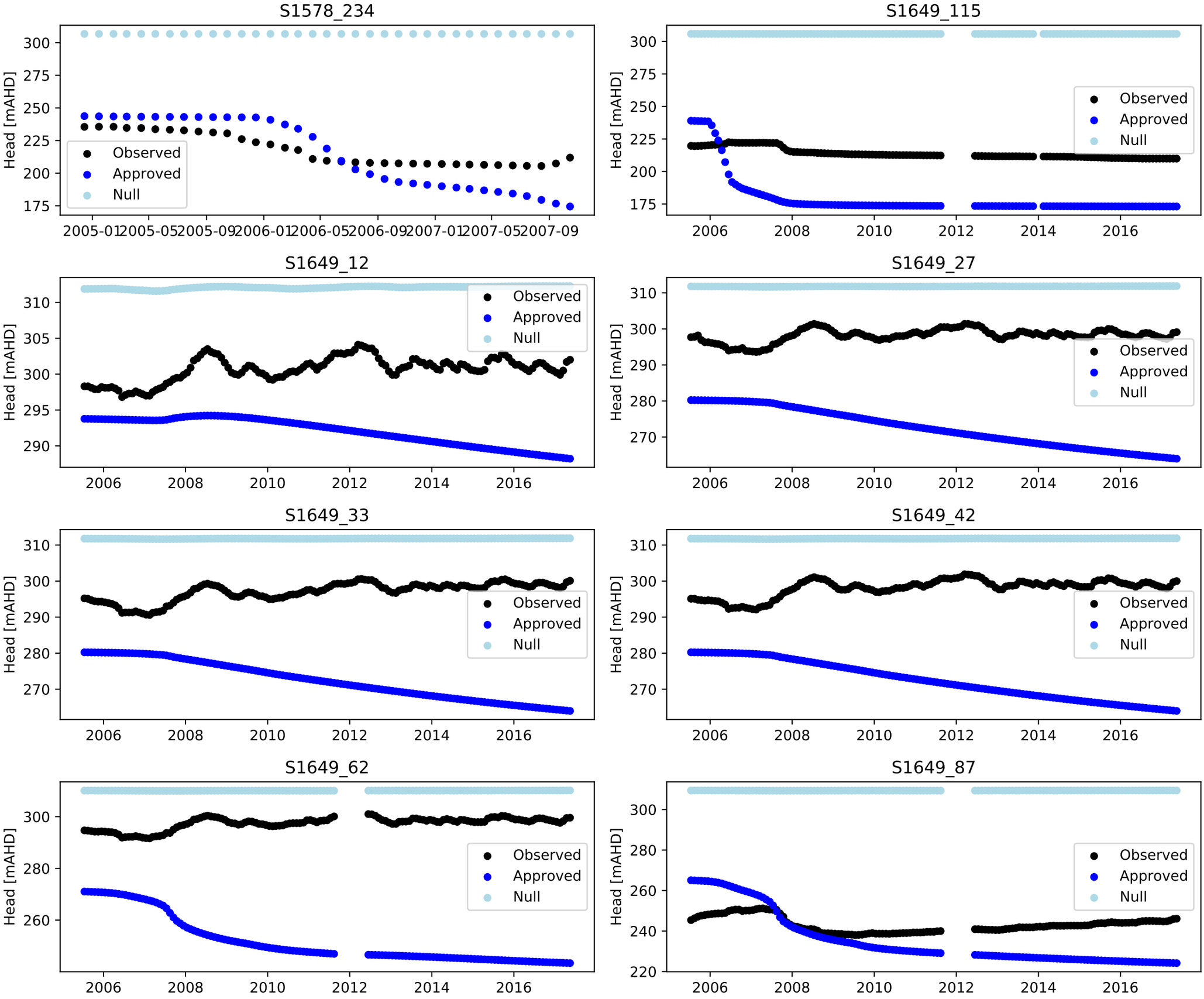

S1572_39
Head [mAHD]
320
310
300
290
280
2005-01
2005-07
2006-01
2006-07
2007-01
2007-07
2008-01
2008-07
Observed
Approved
Null

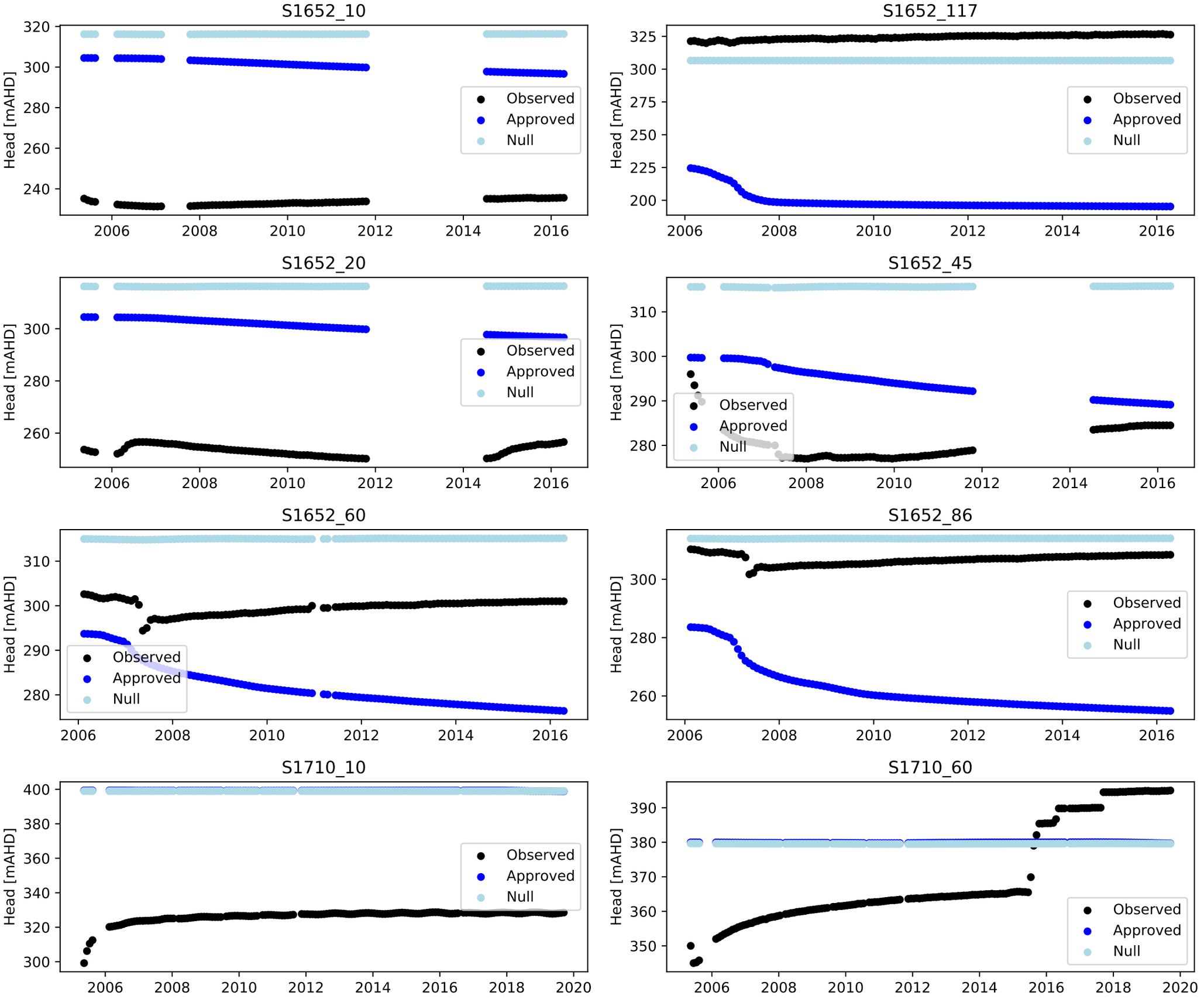

S1572_42
Head [mAHD]
300
290
280
2005
2006
2007
2008
2009
2010
2011
Observed
Approved
Null

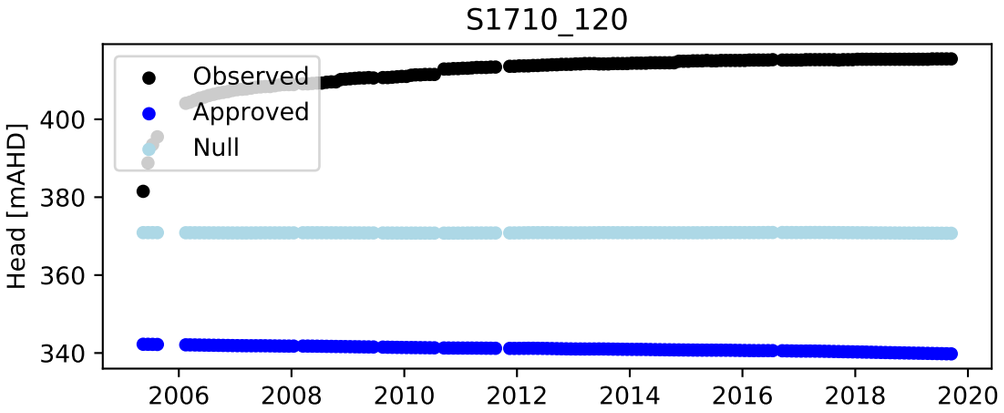

S1572_50
Head [mAHD]
310
300
290
280
270
260
2005
2006
2007
2008
2009
2010
2011
Observed
Approved
Null

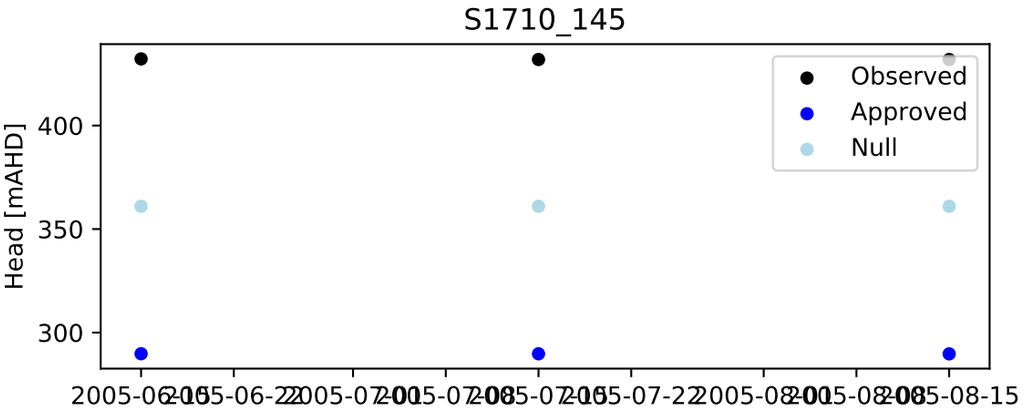

S1572_59
Head [mAHD]
310
300
290
280
270
260
2005
2006
2007
2008
2009
2010
2011
Observed
Approved
Null

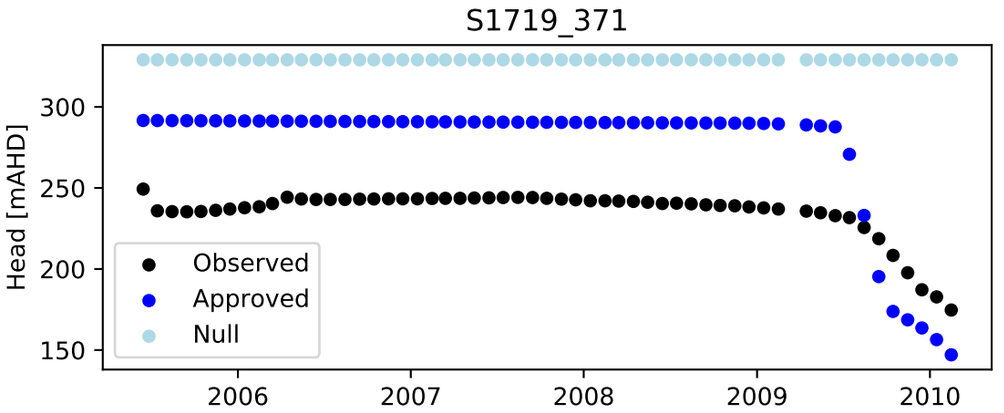

S1572_70
Head [mAHD]
Observed
Approved
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S1577_130
S1577_170
S1577_25
S1577_258
S1578_122
S1578_152
S1578_25

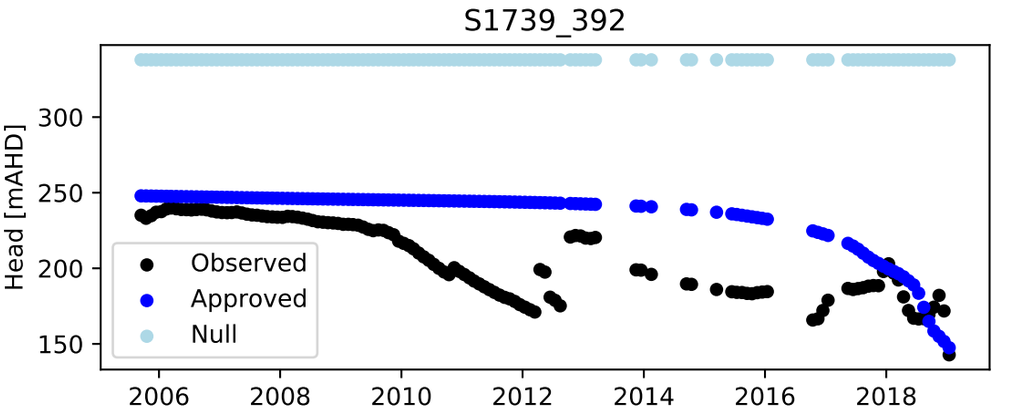

S1578_234
S1649_115
S1649_12
S1649_27
S1649_33
S1649_42
S1649_62
S1649_87
Head [mAHD]
Observed
Approved
Null
2005-01
2005-05
2005-09
2006-01
2006-05
2006-09
2007-01
2007-05
2007-09
2006
2008
2010
2012
2014
2016

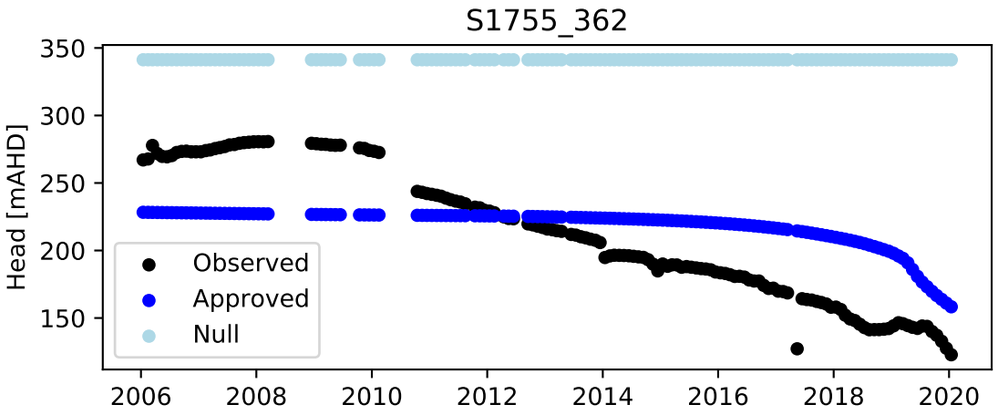

S1652_10
S1652_117
S1652_20
S1652_45
S1652_60
S1652_86
S1710_10
S1710_60
Head [mAHD]
Observed
Approved
Null

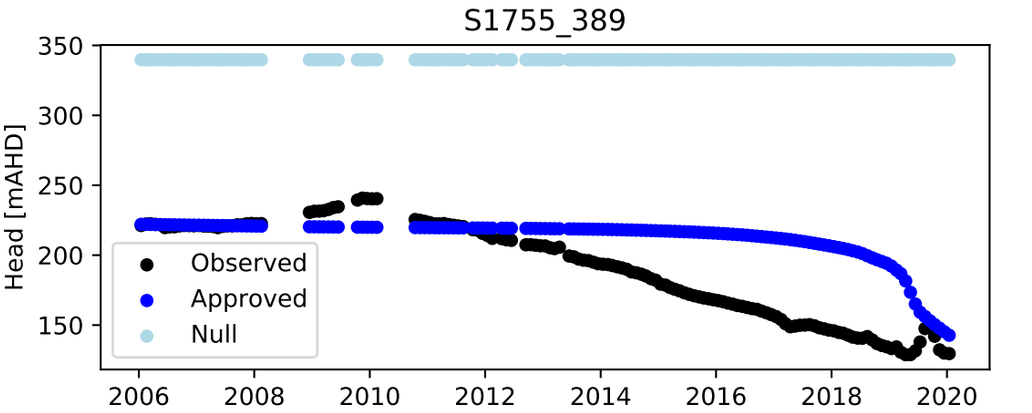

S1710_120
Observed
Approved
Null
Head [mAHD]
400
380
360
340
2006
2008
2010
2012
2014
2016
2018
2020

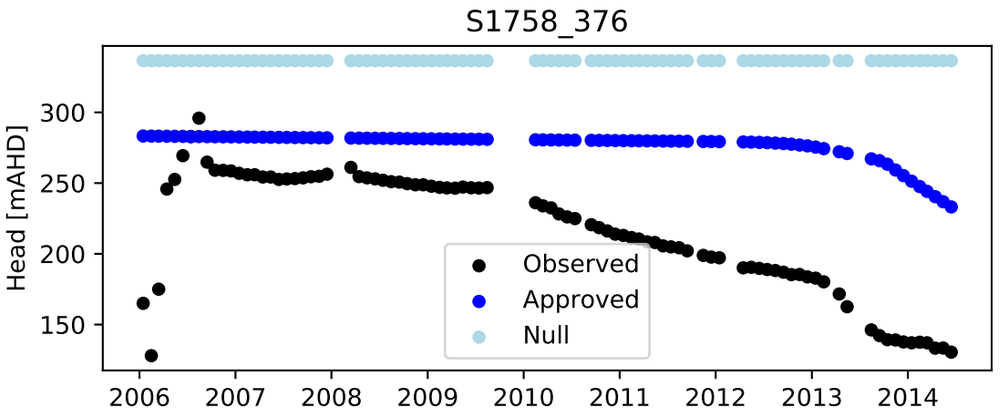

S1710_145
Observed
Approved
Null
Head [mAHD]
400
350
300
2005-06-15
2005-06-22
2005-07-01
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2005-08-08
2005-08-15

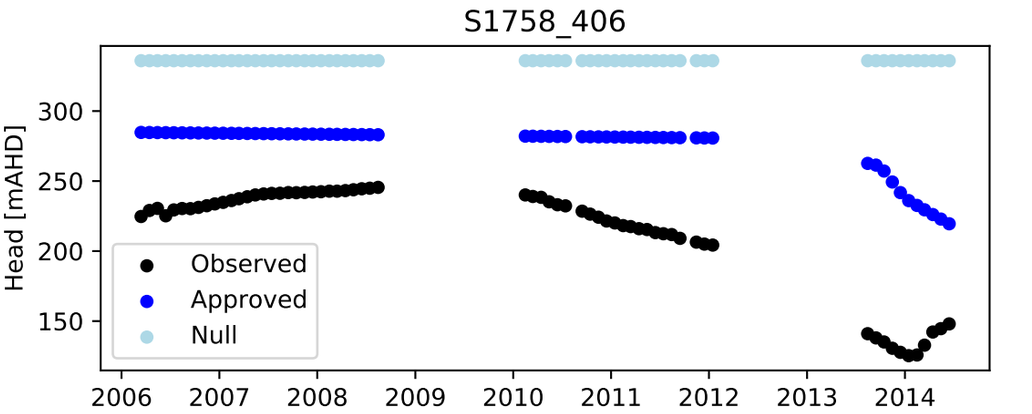

S1719_371
Observed
Approved
Null
Head [mAHD]
300
250
200
150
2006
2007
2008
2009
2010

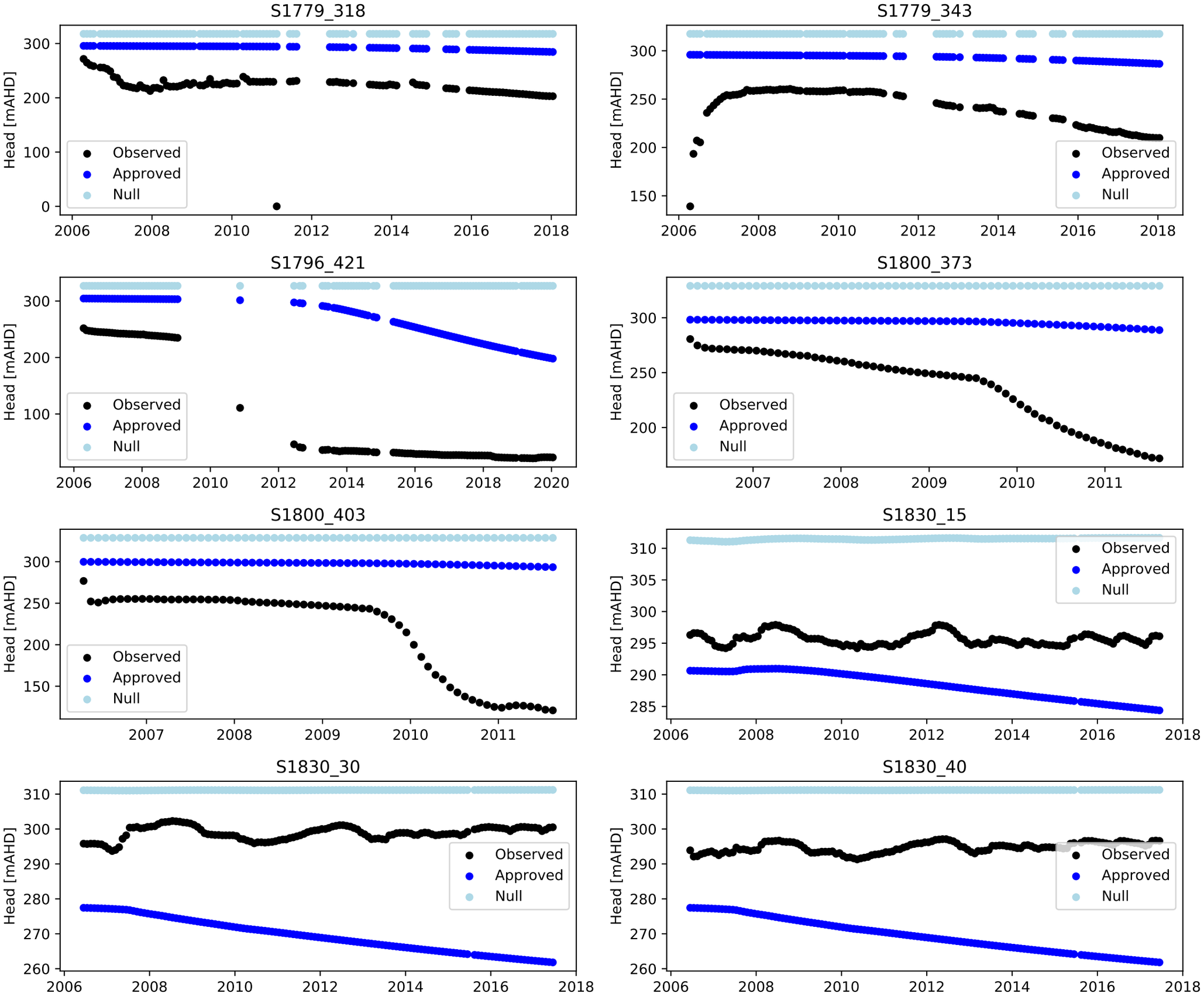

S1739_392
Observed
Approved
Null
Head [mAHD]
300
250
200
150
2006
2008
2010
2012
2014
2016
2018

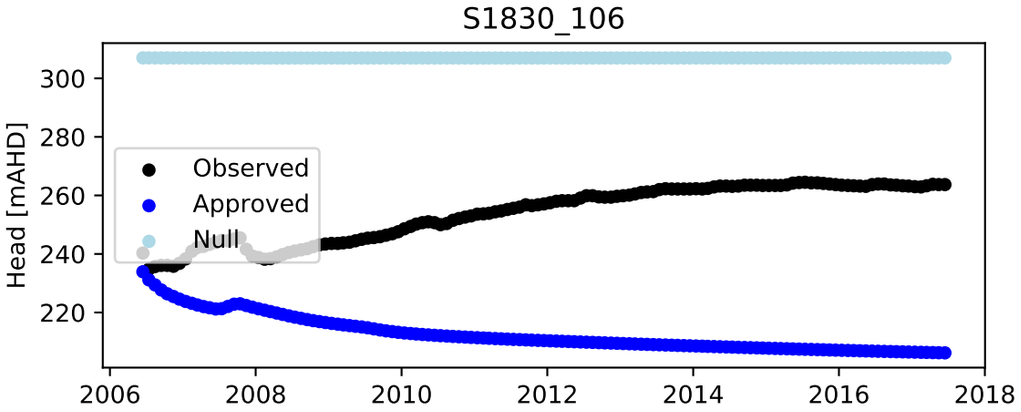

S1755_362
Observed
Approved
Null
Head [mAHD]
350
300
250
200
150
2006
2008
2010
2012
2014
2016
2018
2020

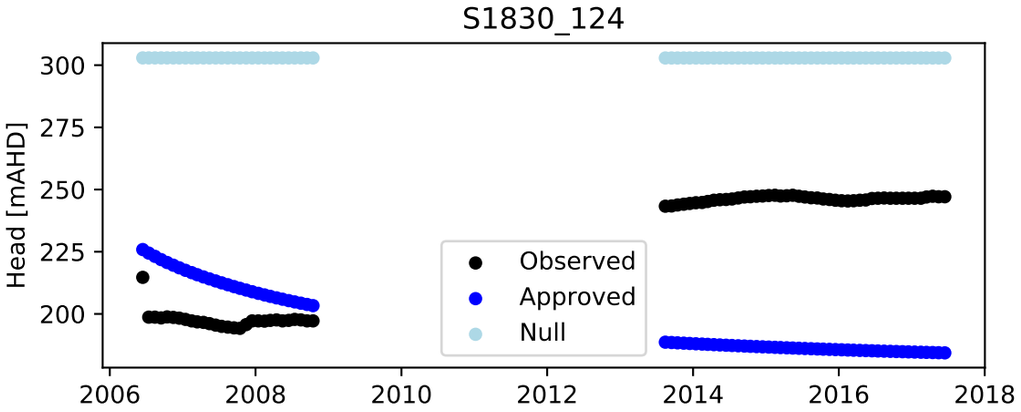

S1755_389
Observed
Approved
Null
Head [mAHD]
350
300
250
200
150
2006
2008
2010
2012
2014
2016
2018
2020

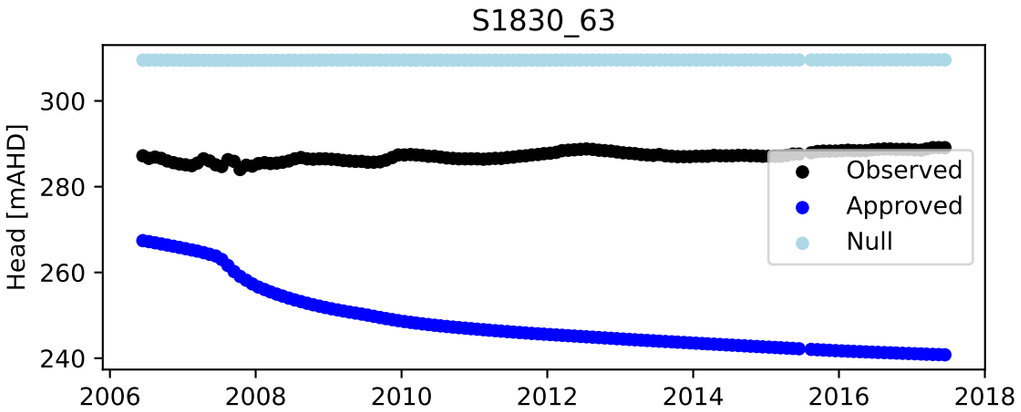

S1758_376
Observed
Approved
Null
Head [mAHD]
300
250
200
150
2006
2007
2008
2009
2010
2011
2012
2013
2014

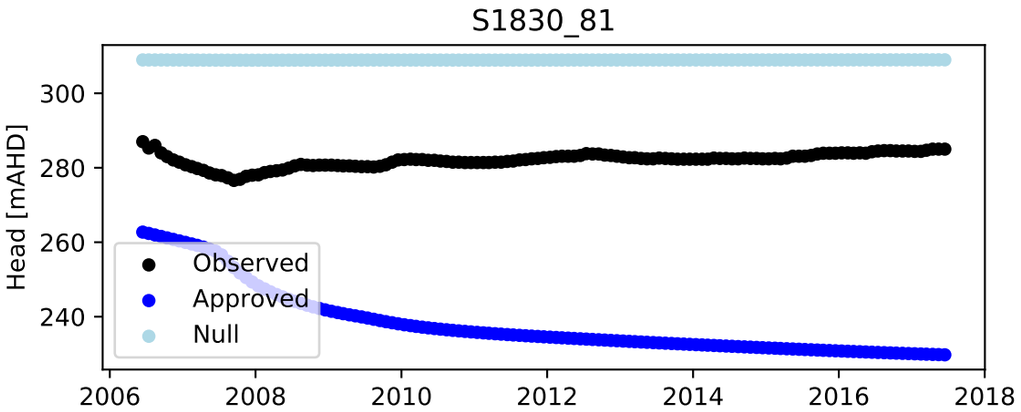

S1758_406
Observed
Approved
Null
Head [mAHD]
300
250
200
150
2006
2007
2008
2009
2010
2011
2012
2013
2014

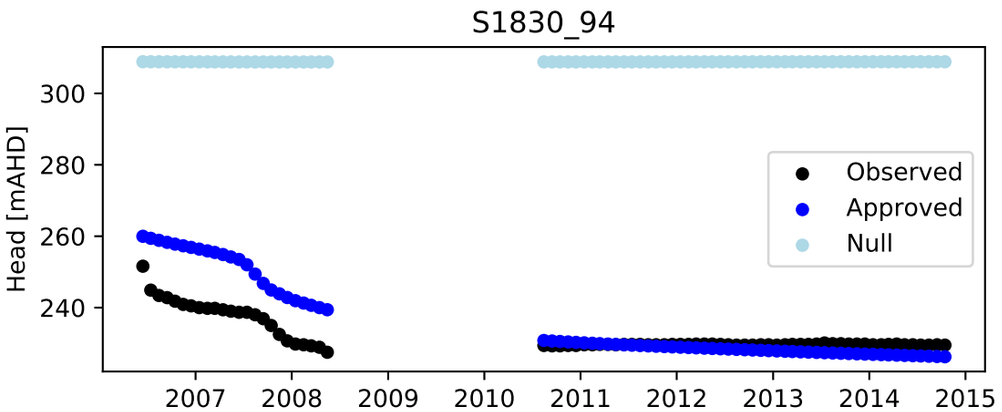

S1779_318
S1779_343
S1796_421
S1800_373
S1800_403
S1830_15
S1830_30
S1830_40
Head [mAHD]
Observed
Approved
Null

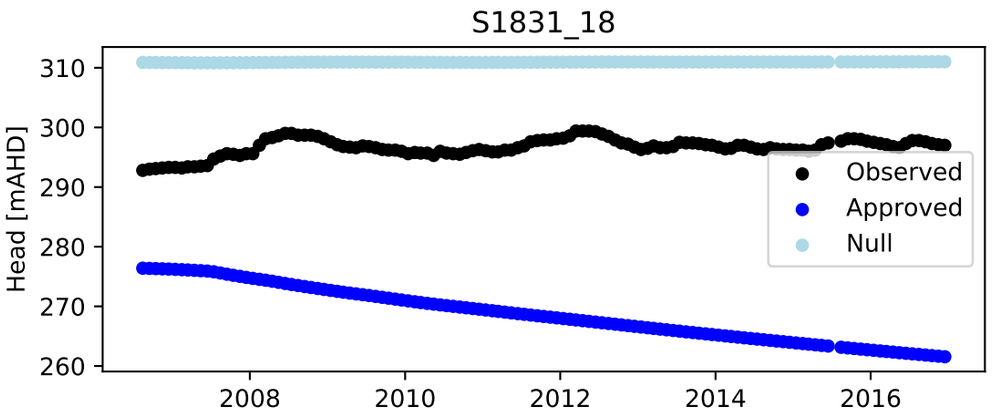

S1830_106
Head [mAHD]
Observed
Approved
Null

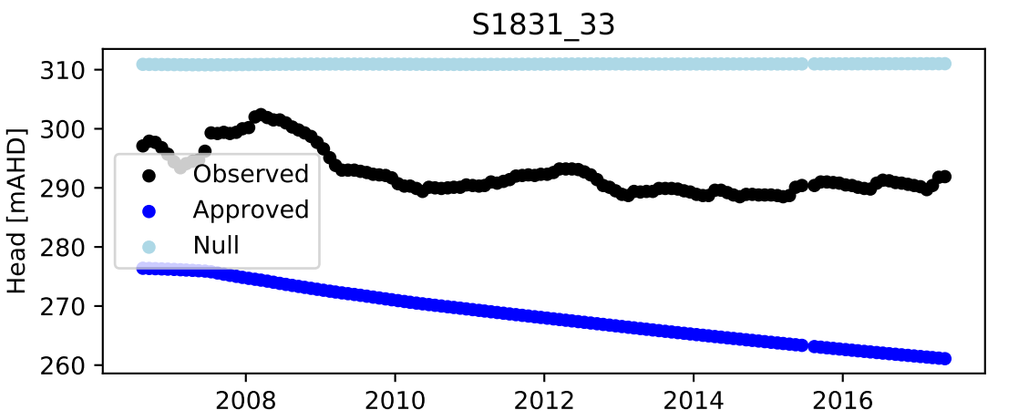

S1830_124
Head [mAHD]
Observed
Approved
Null

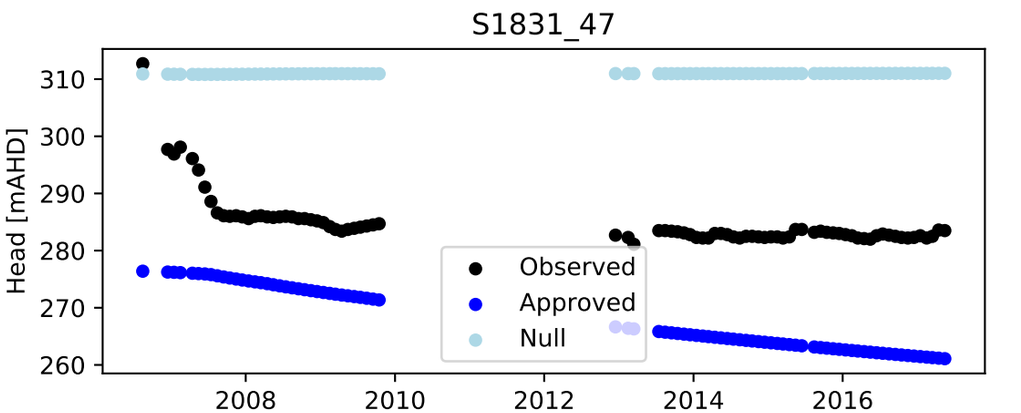

S1830_63
Head [mAHD]
Observed
Approved
Null

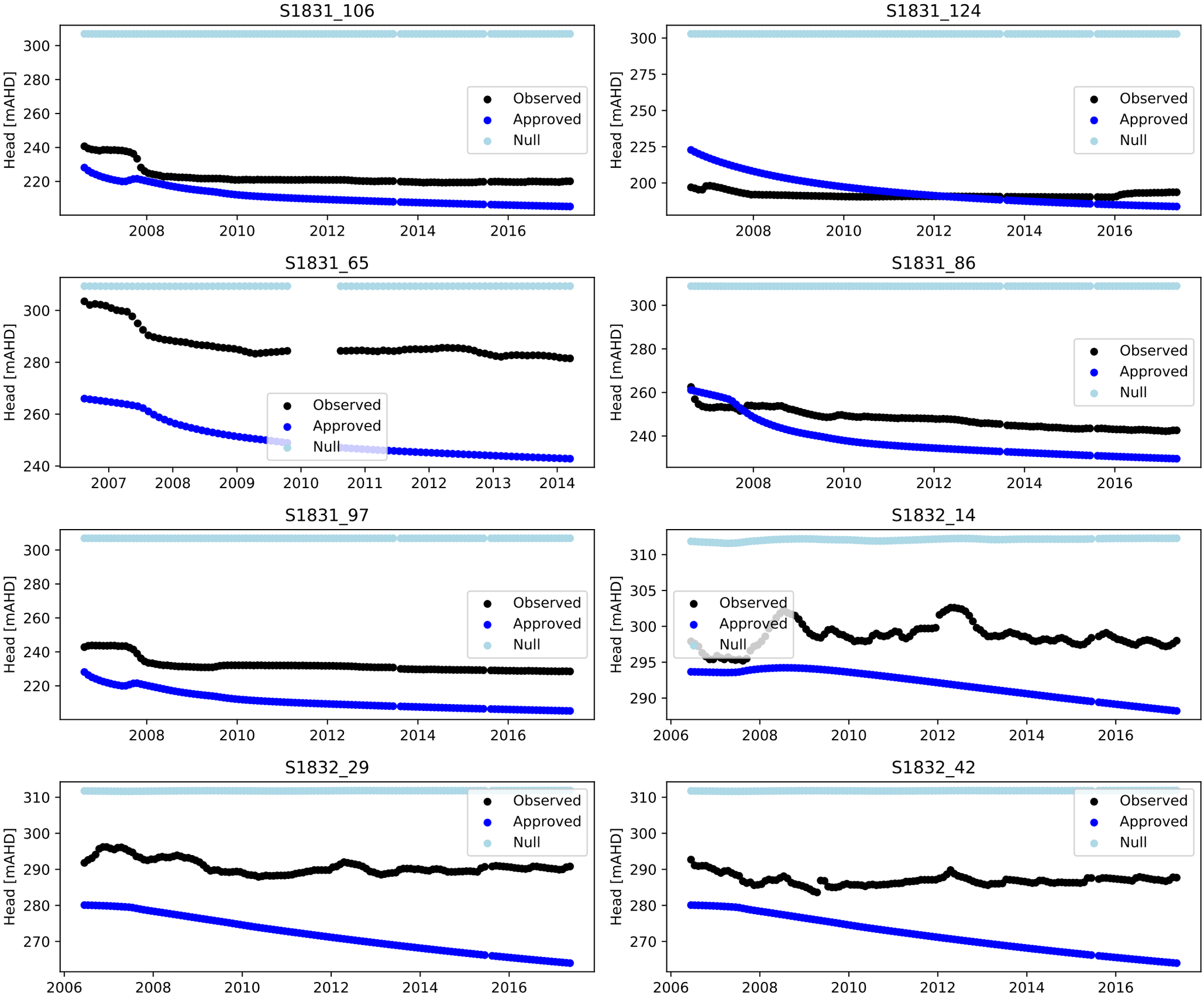

S1830_81
Head [mAHD]
Observed
Approved
Null

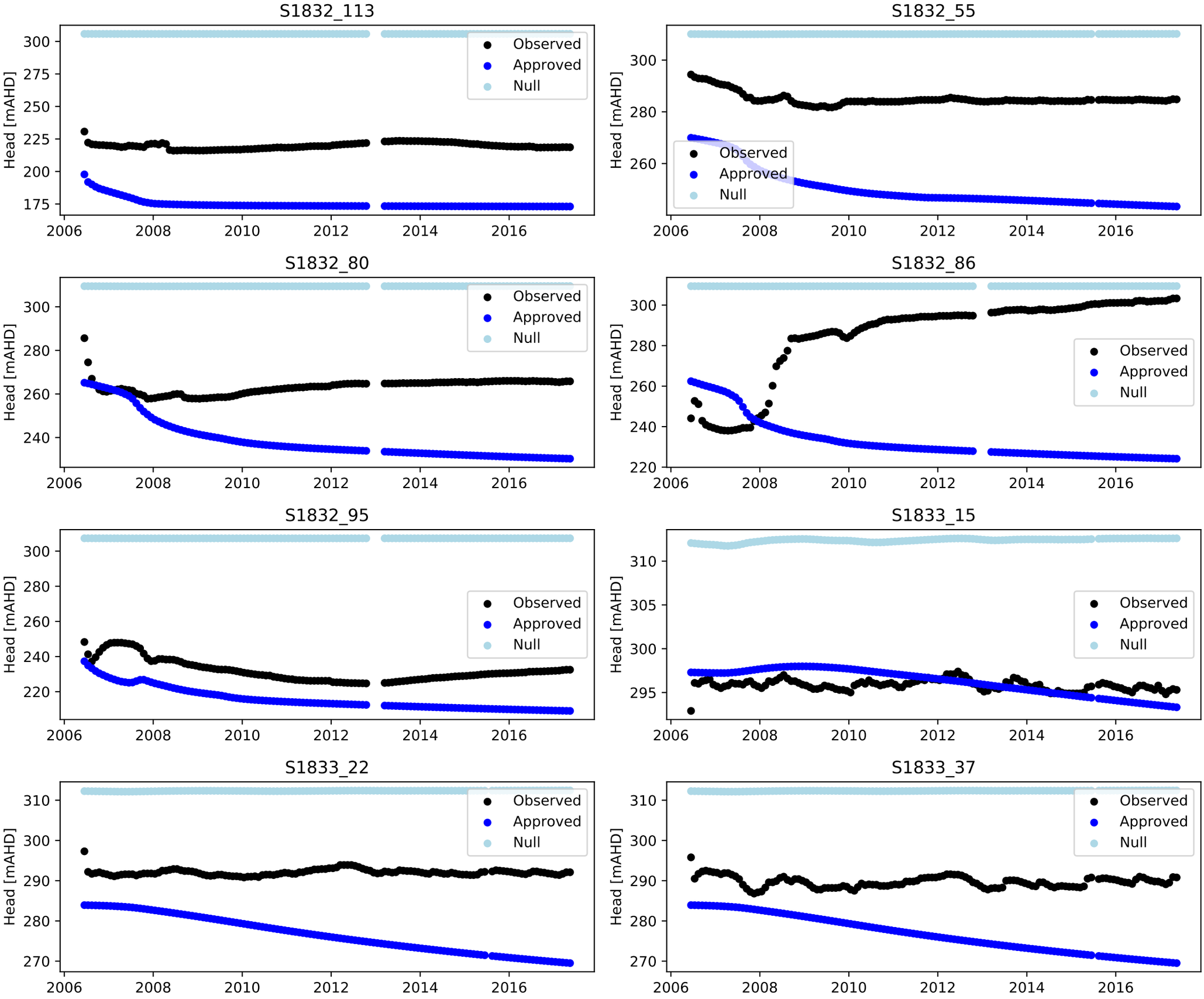

S1830_94
Head [mAHD]
Observed
Approved
Null

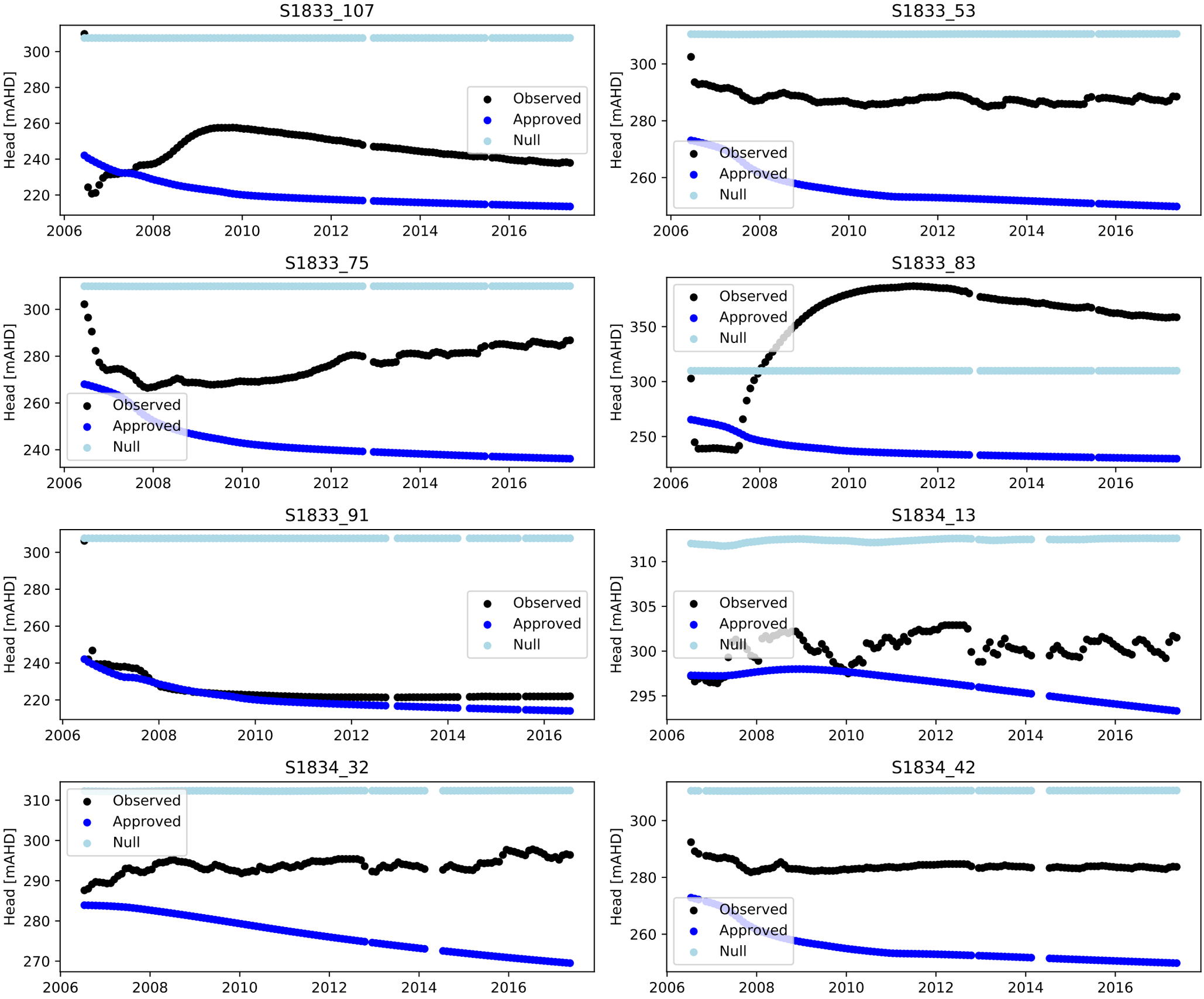

S1831_18
Head [mAHD]
Observed
Approved
Null

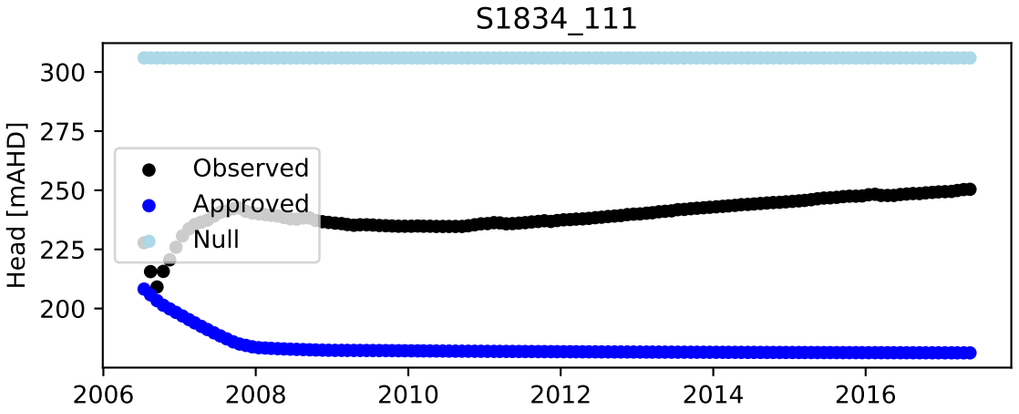

S1831_33
Head [mAHD]
Observed
Approved
Null

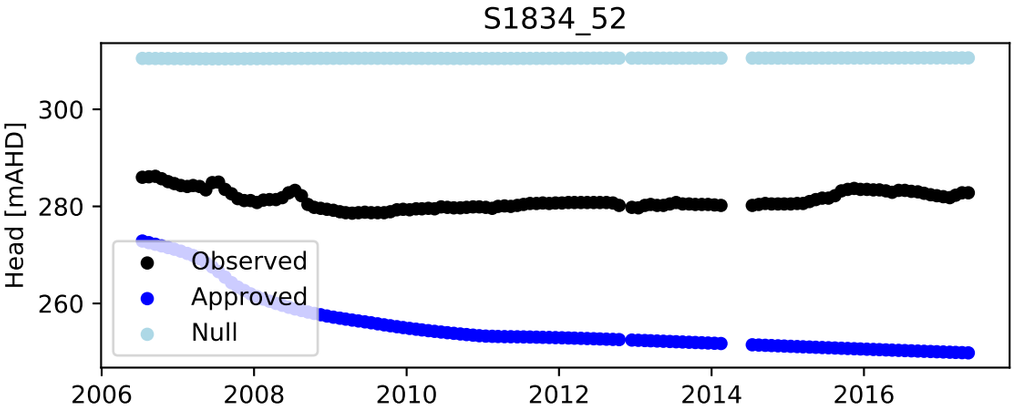

S1831_47
Head [mAHD]
Observed
Approved
Null

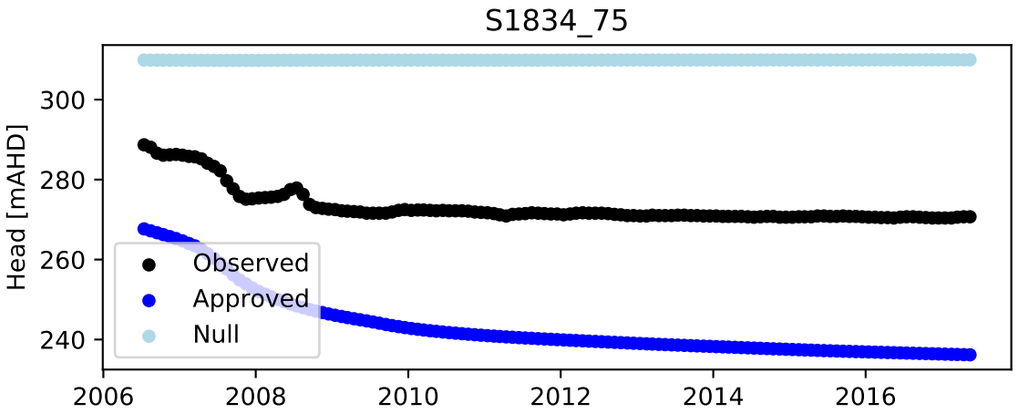

S1831_106
S1831_124
S1831_65
S1831_86
S1831_97
S1832_14
S1832_29
S1832_42
Head [mAHD]
Observed
Approved
Null

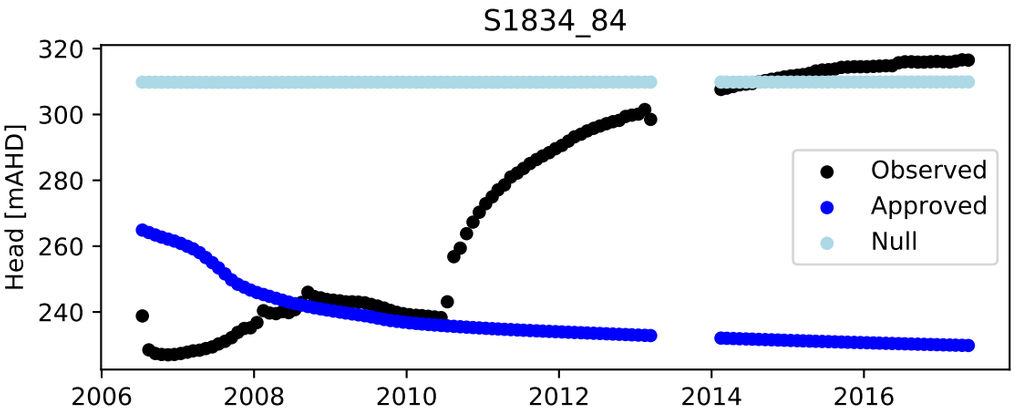

S1832_113
S1832_55
S1832_80
S1832_86
S1832_95
S1833_15
S1833_22
S1833_37
Observed
Approved
Null
Head [mAHD]
2006
2008
2010
2012
2014
2016

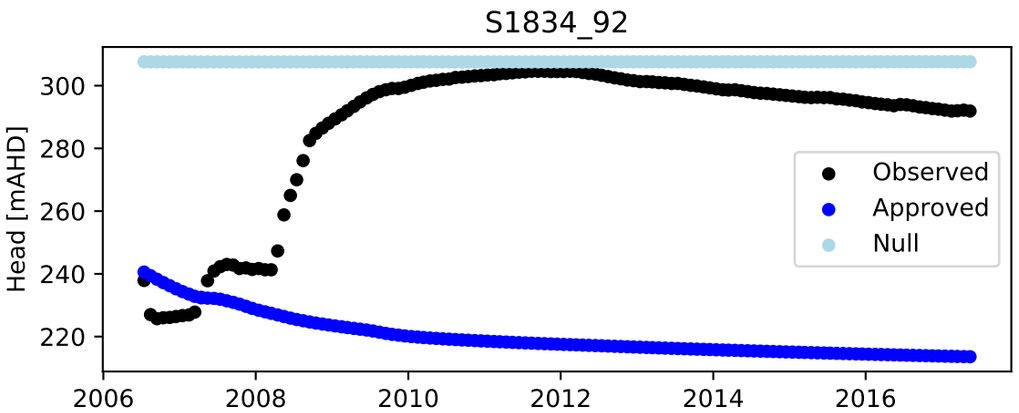

S1833_107
S1833_53
S1833_75
S1833_83
S1833_91
S1834_13
S1834_32
S1834_42
Head [mAHD]
Observed
Approved
Null
2006
2008
2010
2012
2014
2016

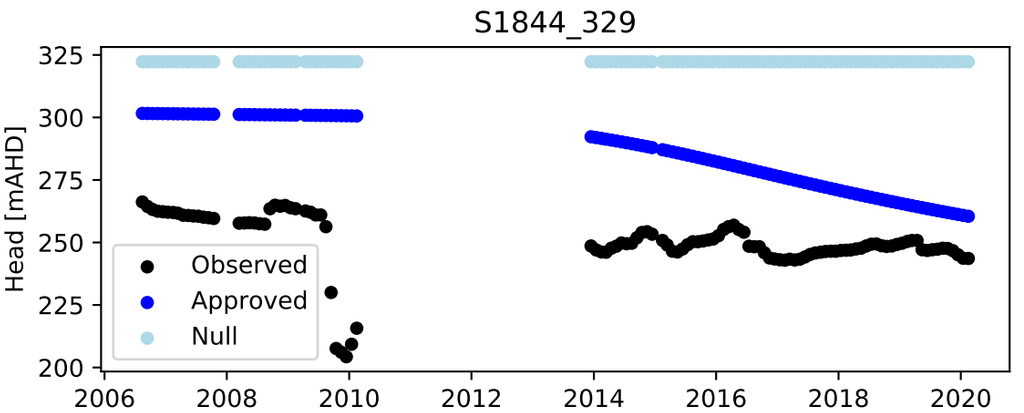

S1834_111
Head [mAHD]
Observed
Approved
Null

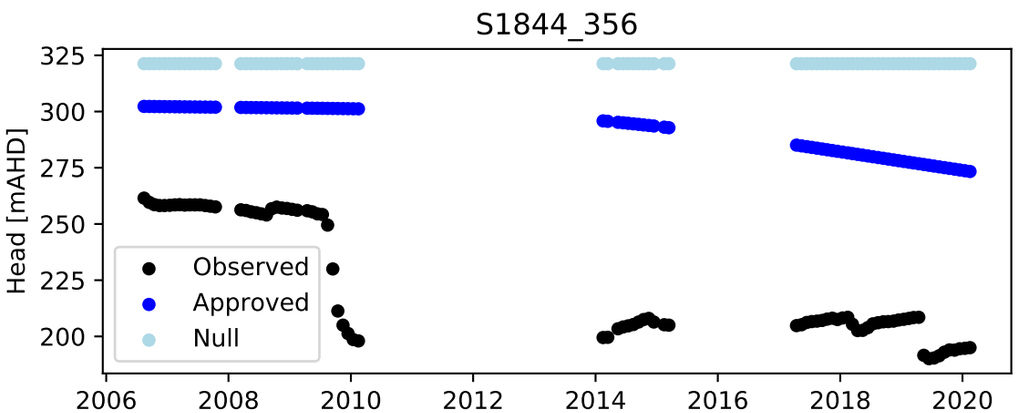

S1834_52
Head [mAHD]
Observed
Approved
Null

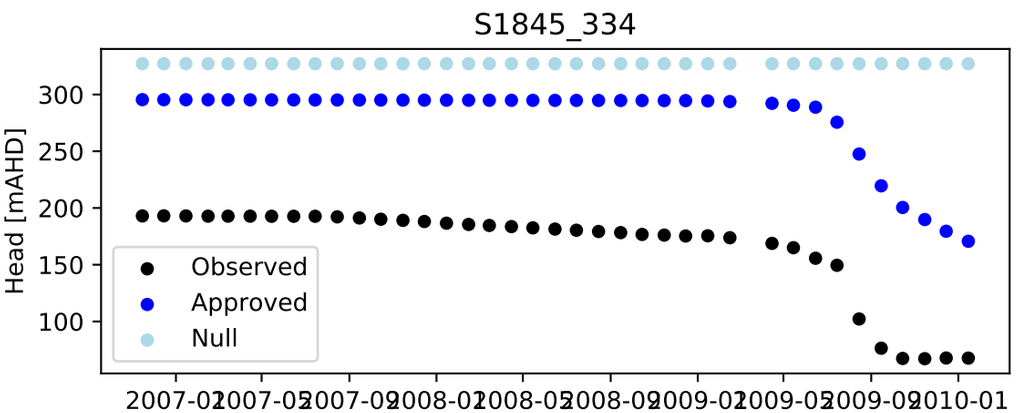

S1834_75
Head [mAHD]
Observed
Approved
Null

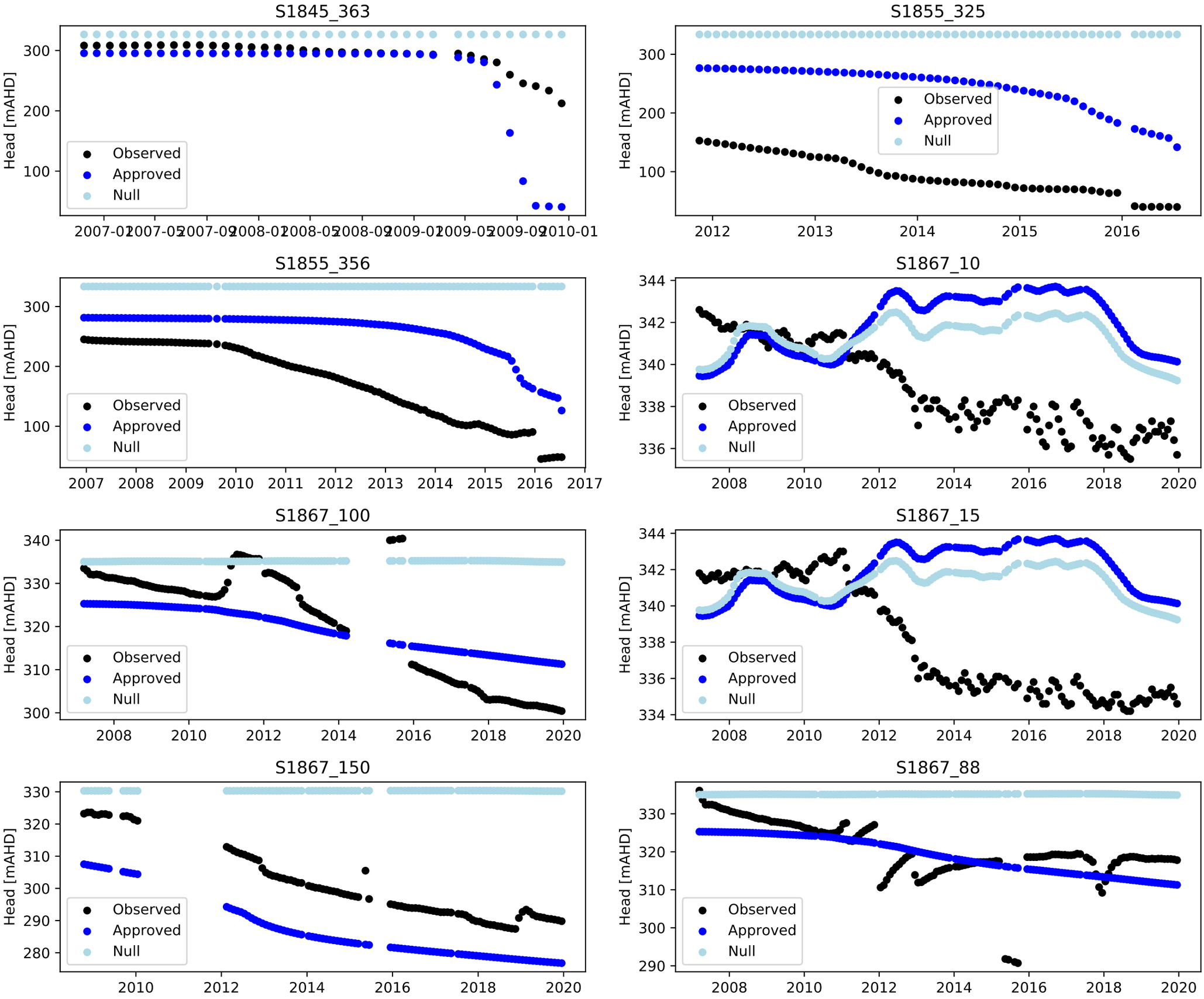

S1834_84
Head [mAHD]
Observed
Approved
Null

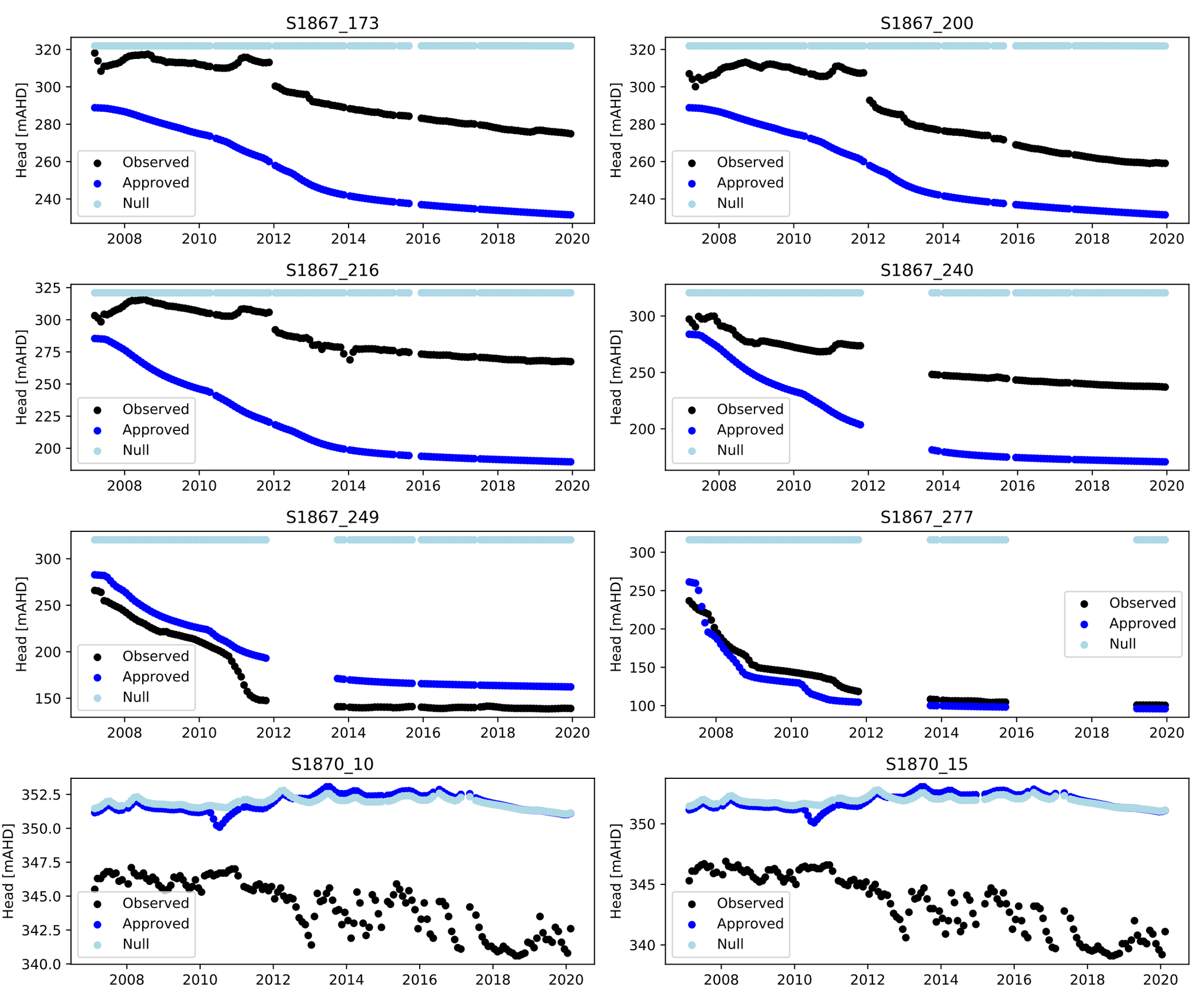

S1834_92
Head [mAHD]
Observed
Approved
Null

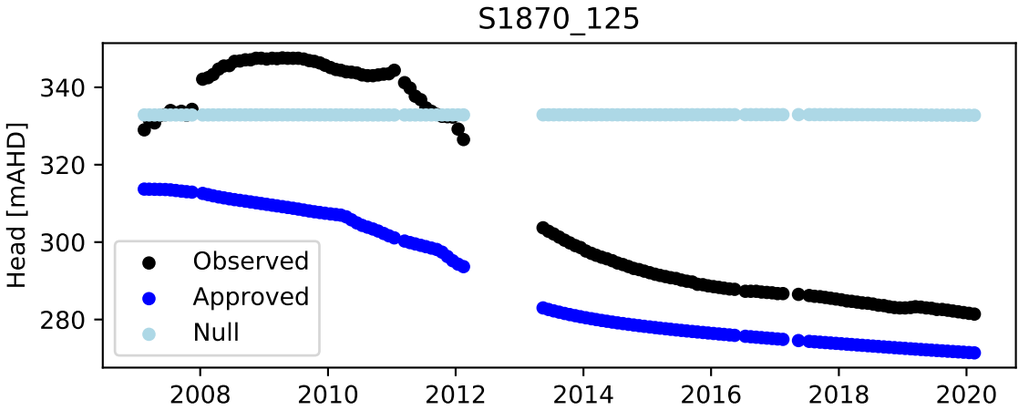

S1844_329
Head [mAHD]
Observed
Approved
Null

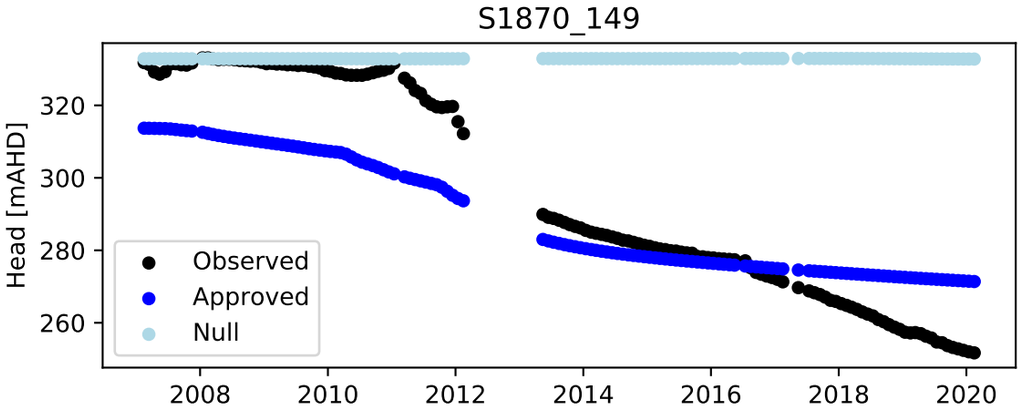

S1844_356
Head [mAHD]
Observed
Approved
Null

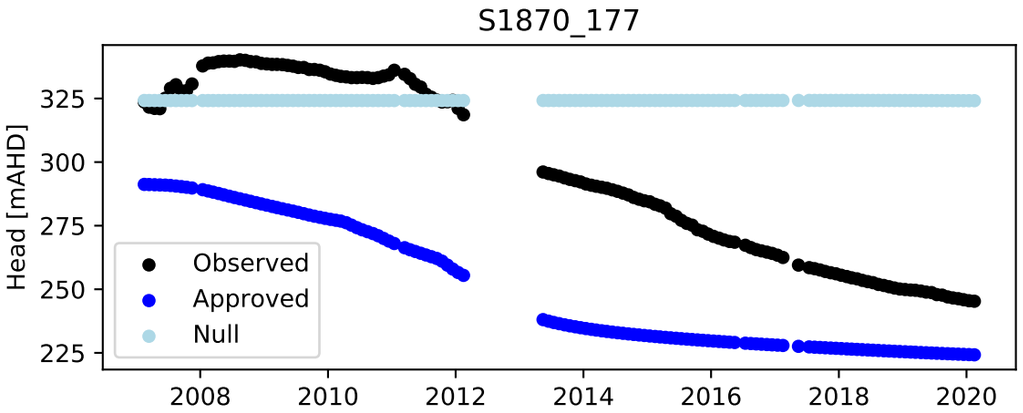

S1845_334
Head [mAHD]
Observed
Approved
Null

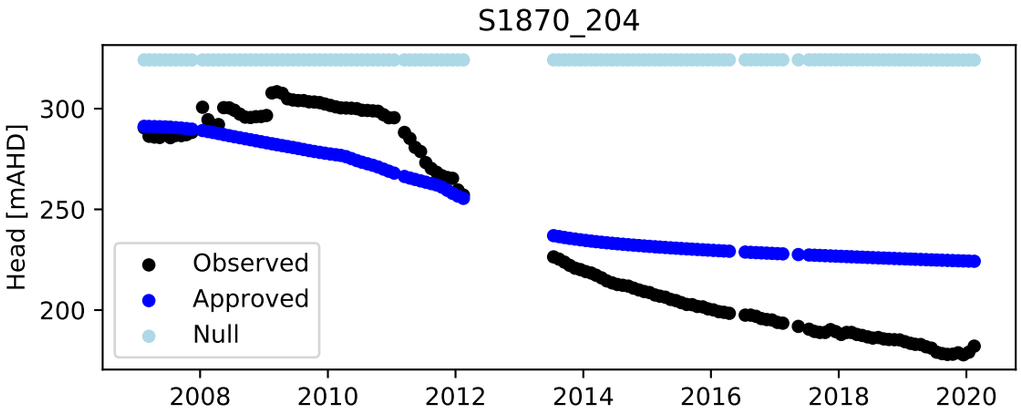

S1845_363
S1855_325
S1855_356
S1867_10
S1867_100
S1867_15
S1867_150
S1867_88
Head [mAHD]
Observed
Approved
Null

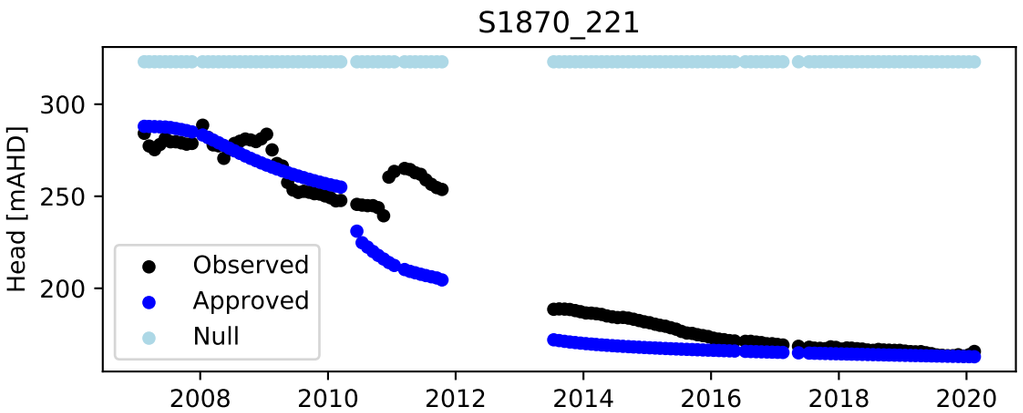

S1867_173
S1867_200
S1867_216
S1867_240
S1867_249
S1867_277
S1870_10
S1870_15
Head [mAHD]
Observed
Approved
Null
2008
2010
2012
2014
2016
2018
2020

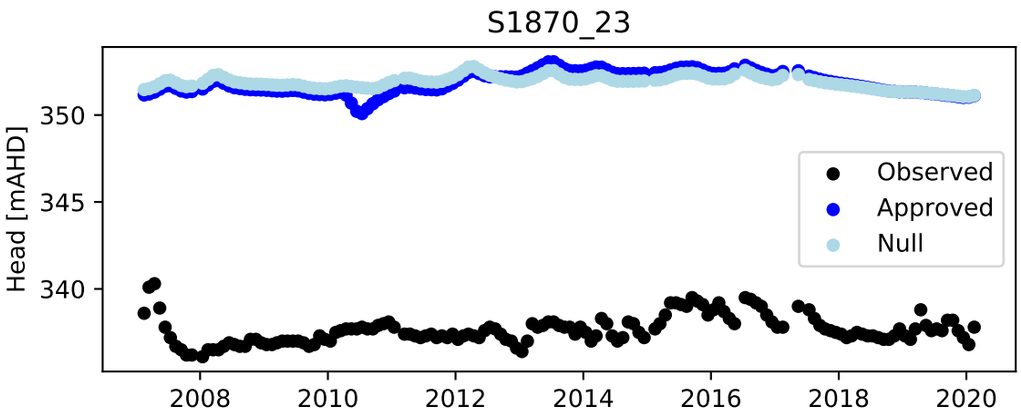

S1870_125
Head [mAHD]
Observed
Approved
Null

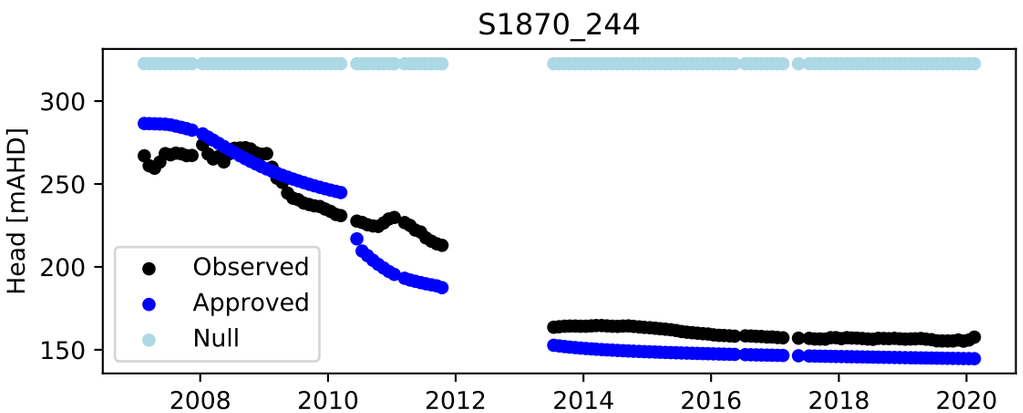

S1870_149
Head [mAHD]
Observed
Approved
Null

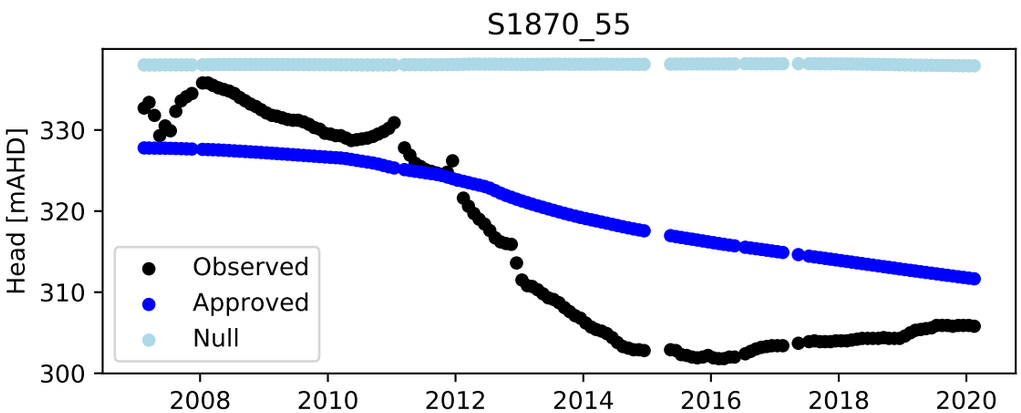

S1870_177
Head [mAHD]
Observed
Approved
Null

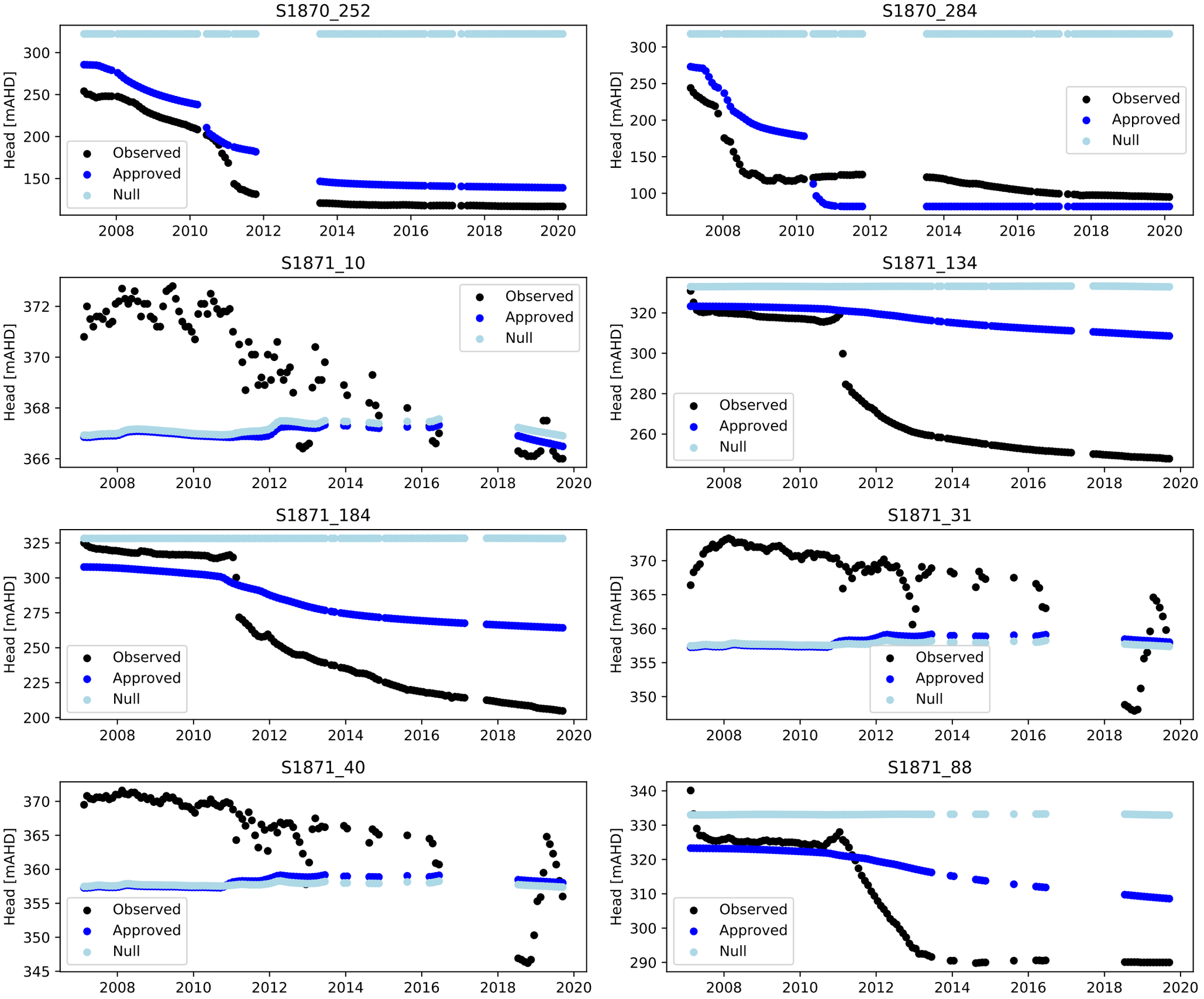

S1870_204
Head [mAHD]
Observed
Approved
Null

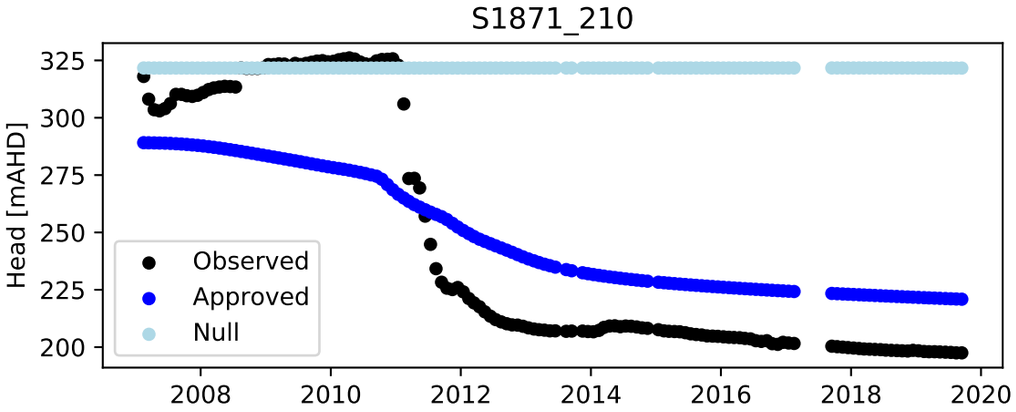

S1870_221
Head [mAHD]
Observed
Approved
Null

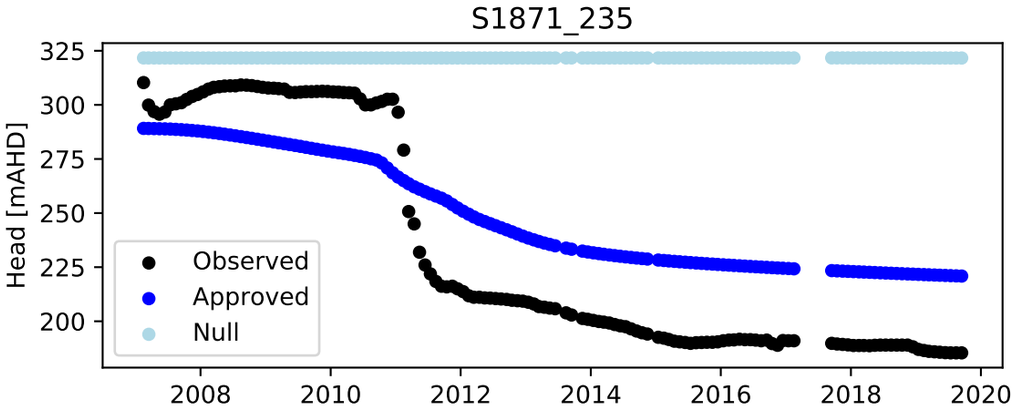

S1870_23
Head [mAHD]
Observed
Approved
Null

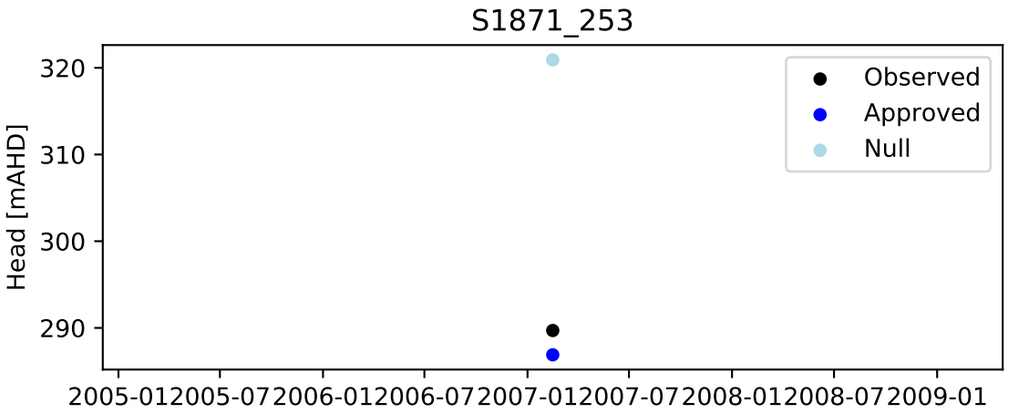

S1870_244
Head [mAHD]
Observed
Approved
Null

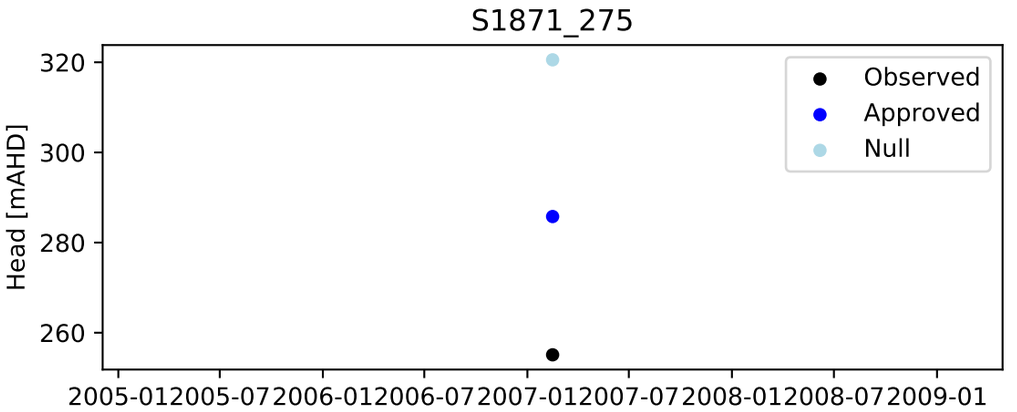

S1870_55
Head [mAHD]
Observed
Approved
Null

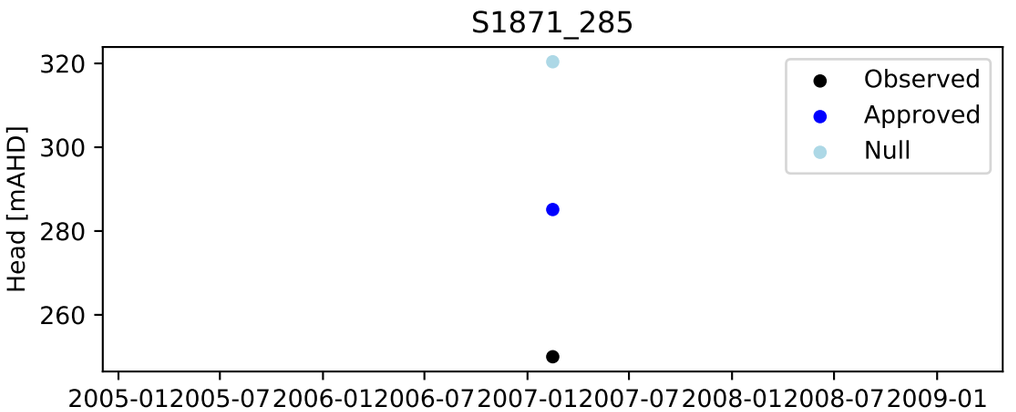

S1870_252
S1870_284
S1871_10
S1871_134
S1871_184
S1871_31
S1871_40
S1871_88
Head [mAHD]
Observed
Approved
Null
2008
2010
2012
2014
2016
2018
2020

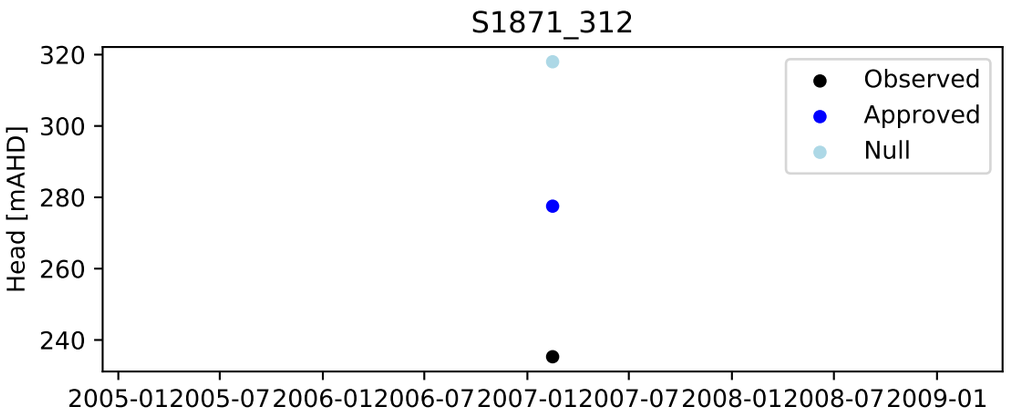

S1871_210
Head [mAHD]
325
300
275
250
225
200
Observed
Approved
Null
2008
2010
2012
2014
2016
2018
2020

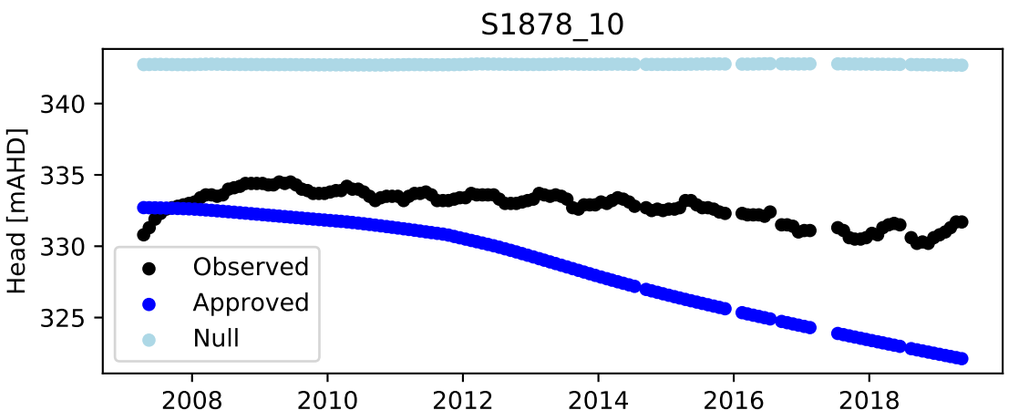

S1871_235
Head [mAHD]
325
300
275
250
225
200
Observed
Approved
Null
2008
2010
2012
2014
2016
2018
2020

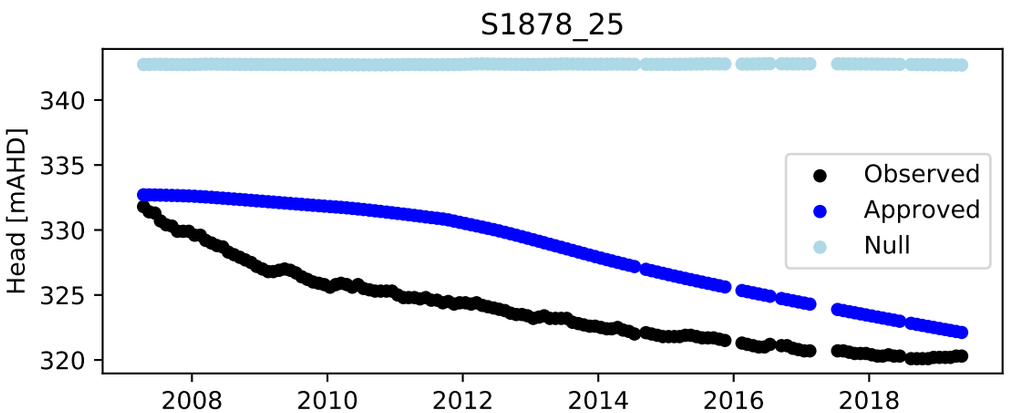

S1871_253
Head [mAHD]
320
310
300
290
Observed
Approved
Null
2005-01
2005-07
2006-01
2006-07
2007-01
2007-07
2008-01
2008-07
2009-01

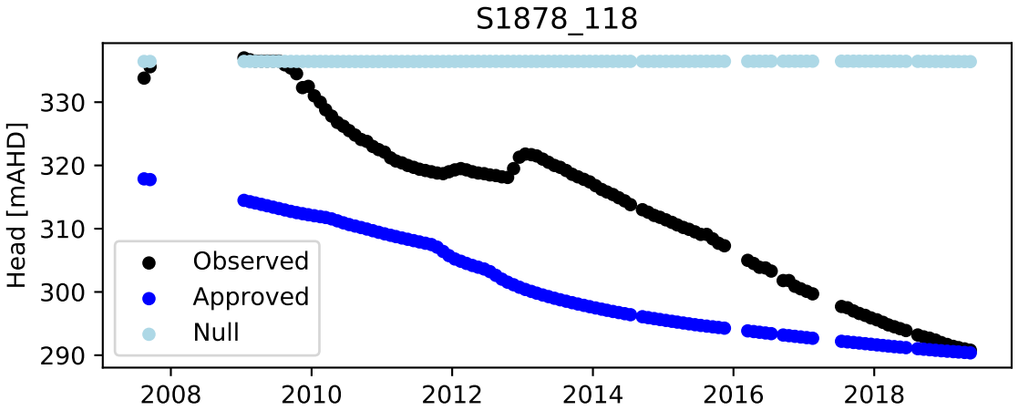

S1871_275
Head [mAHD]
320
300
280
260
Observed
Approved
Null
2005-01
2005-07
2006-01
2006-07
2007-01
2007-07
2008-01
2008-07
2009-01

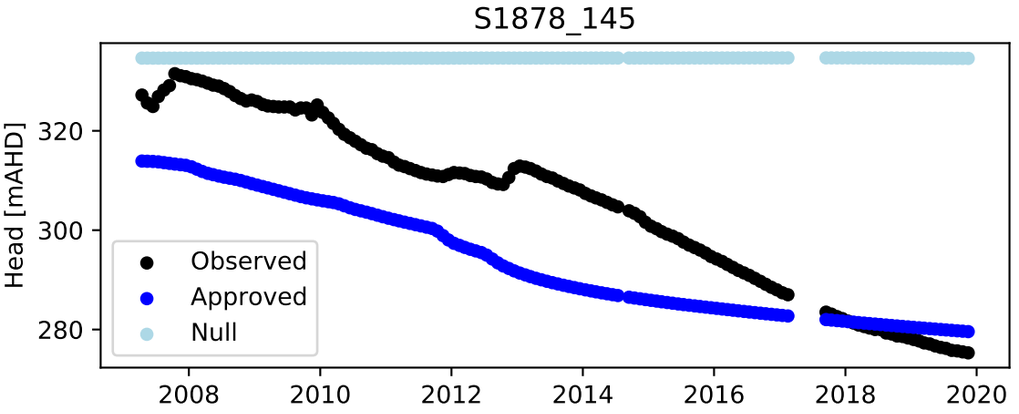

S1871_285
Head [mAHD]
320
300
280
260
Observed
Approved
Null
2005-01
2005-07
2006-01
2006-07
2007-01
2007-07
2008-01
2008-07
2009-01

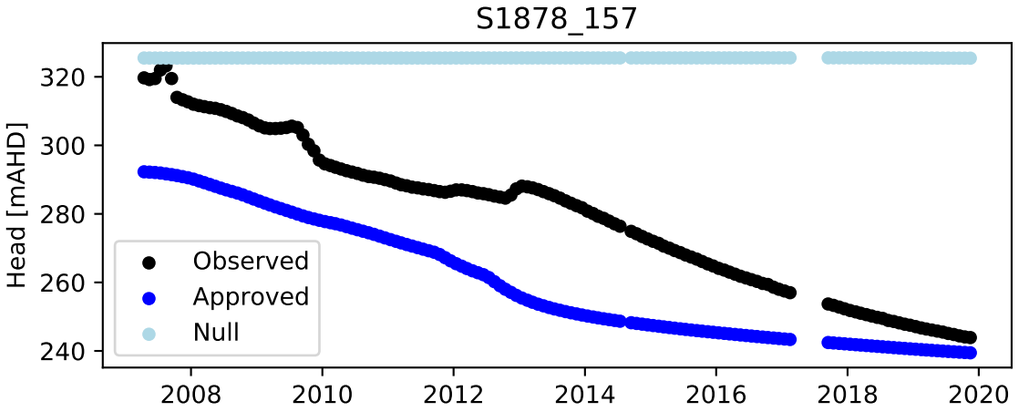

S1871_312
Head [mAHD]
320
300
280
260
240
Observed
Approved
Null
2005-01
2005-07
2006-01
2006-07
2007-01
2007-07
2008-01
2008-07
2009-01

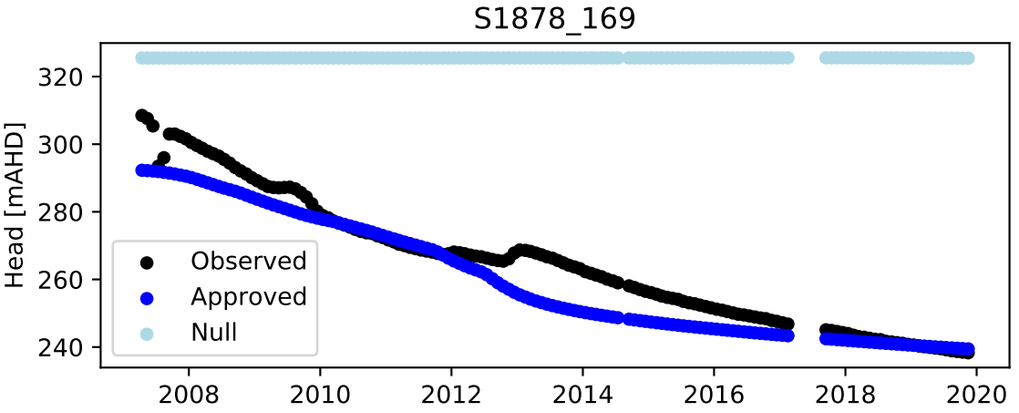

S1878_10
Head [mAHD]
340
335
330
325
Observed
Approved
Null
2008
2010
2012
2014
2016
2018

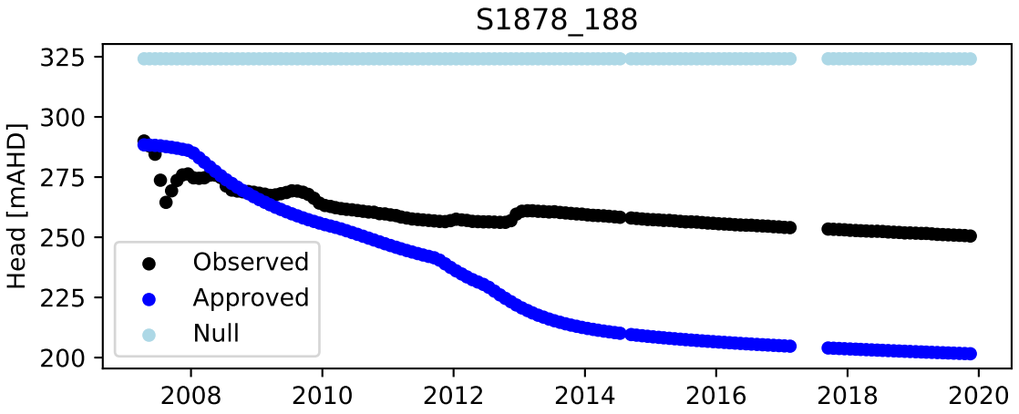

S1878_25
Head [mAHD]
340
335
330
325
320
Observed
Approved
Null
2008
2010
2012
2014
2016
2018

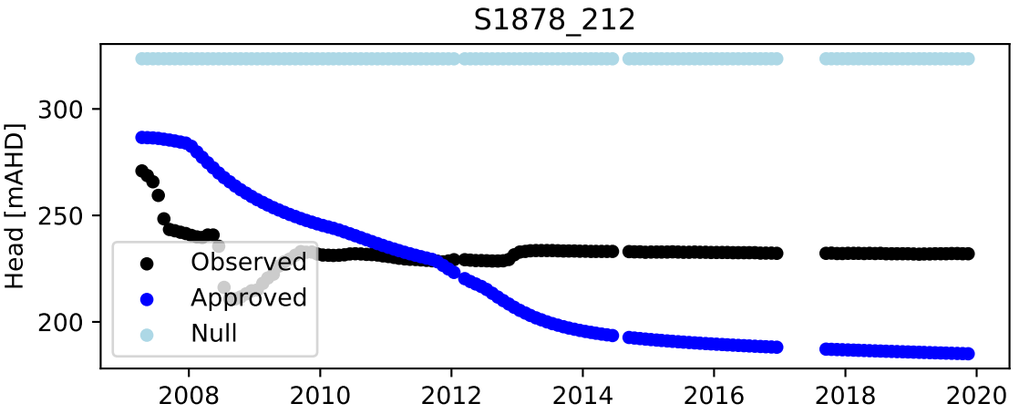

S1878_118
Head [mAHD]
330
320
310
300
290
2008
2010
2012
2014
2016
2018
Observed
Approved
Null

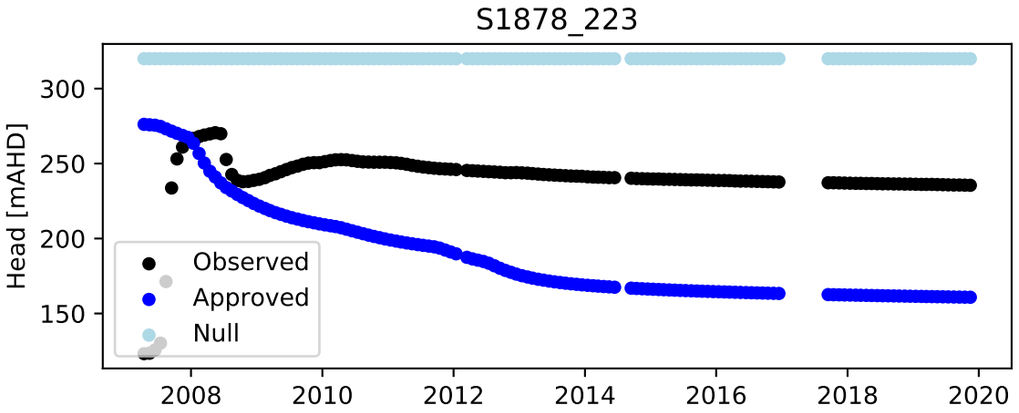

S1878_145
Head [mAHD]
320
300
280
2008
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

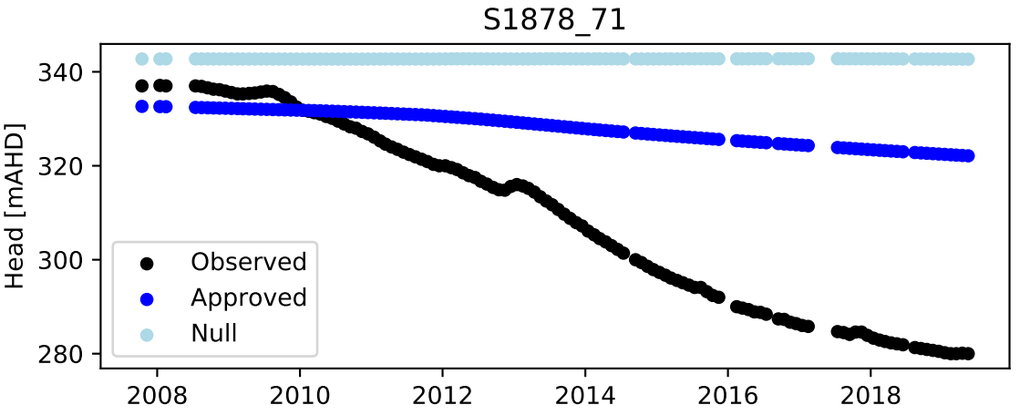

S1878_157
Head [mAHD]
320
300
280
260
240
2008
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

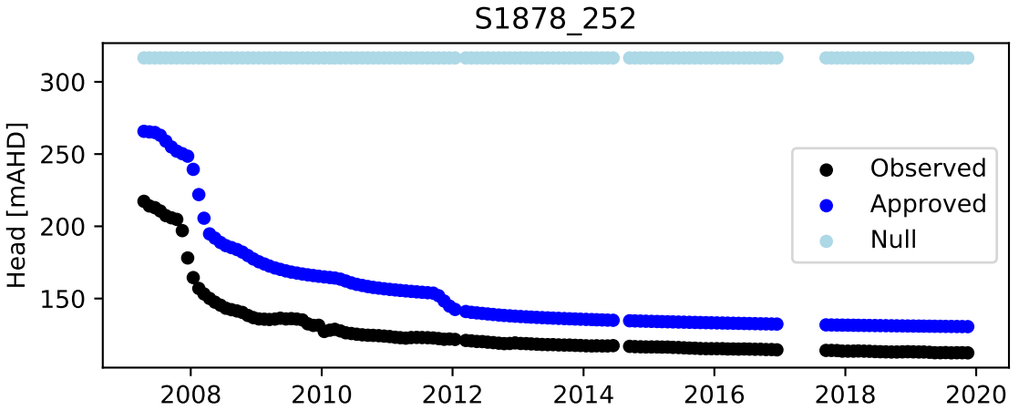

S1878_169
Head [mAHD]
320
300
280
260
240
2008
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

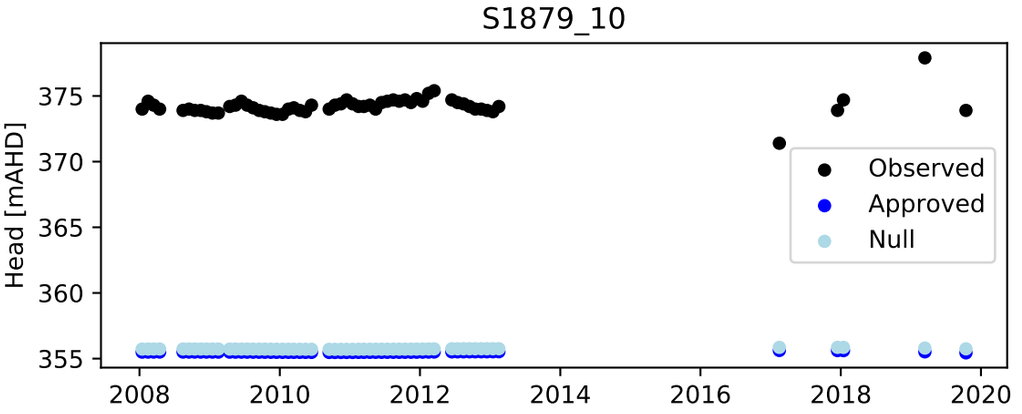

S1878_188
Head [mAHD]
325
300
275
250
225
200
2008
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

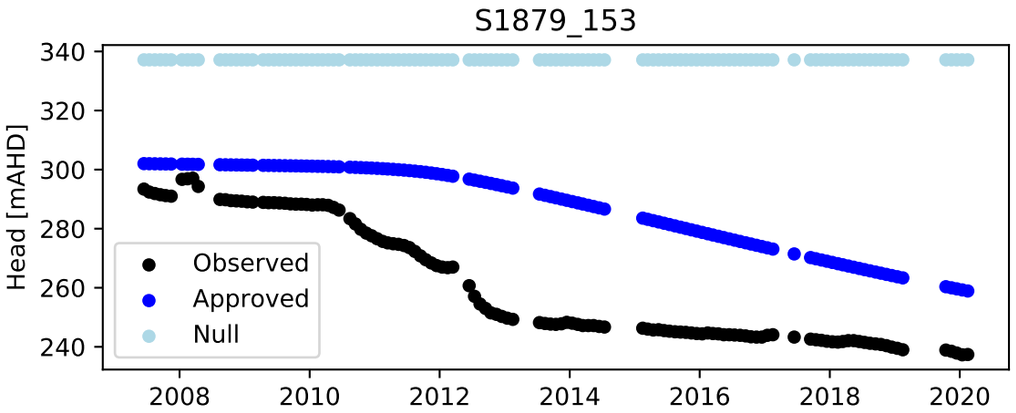

S1878_212
Head [mAHD]
300
250
200
2008
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

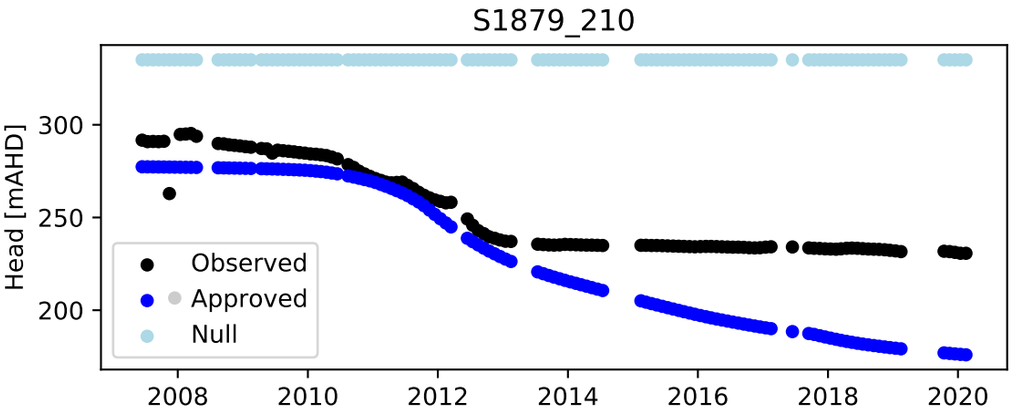

S1878_223
Head [mAHD]
300
250
200
150
2008
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

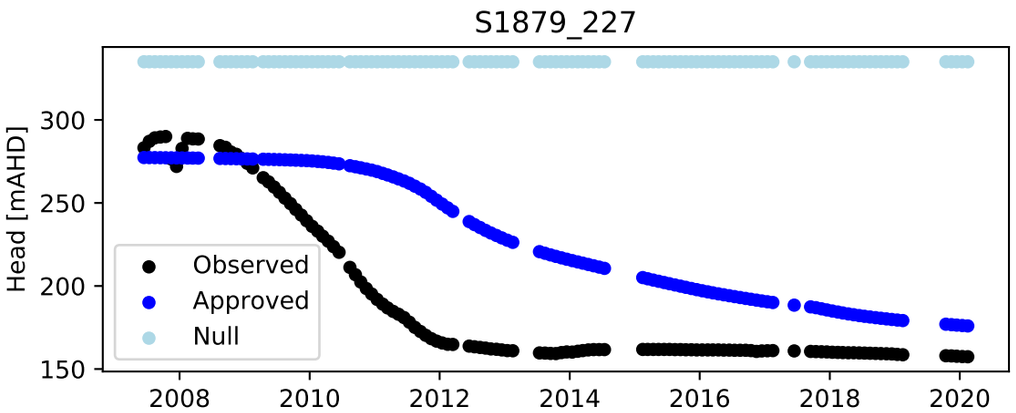

S1878_71
Head [mAHD]
340
320
300
280
2008
2010
2012
2014
2016
2018
Observed
Approved
Null

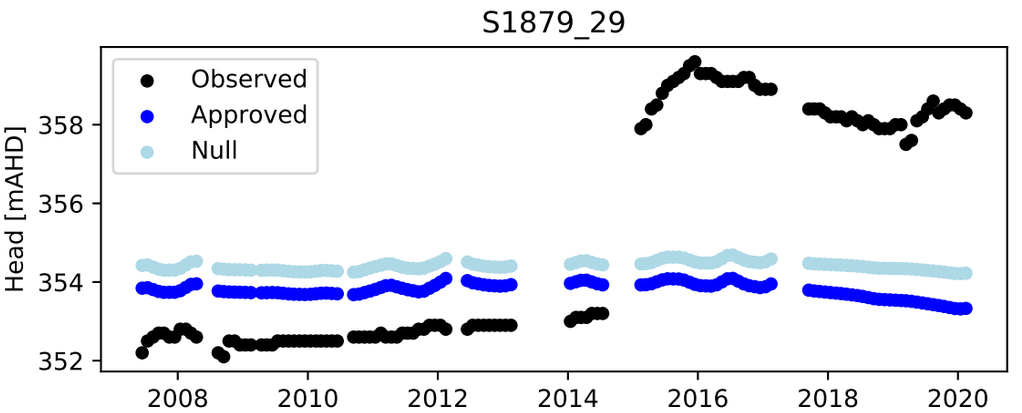

S1878_252
Head [mAHD]
300
250
200
150
2008
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

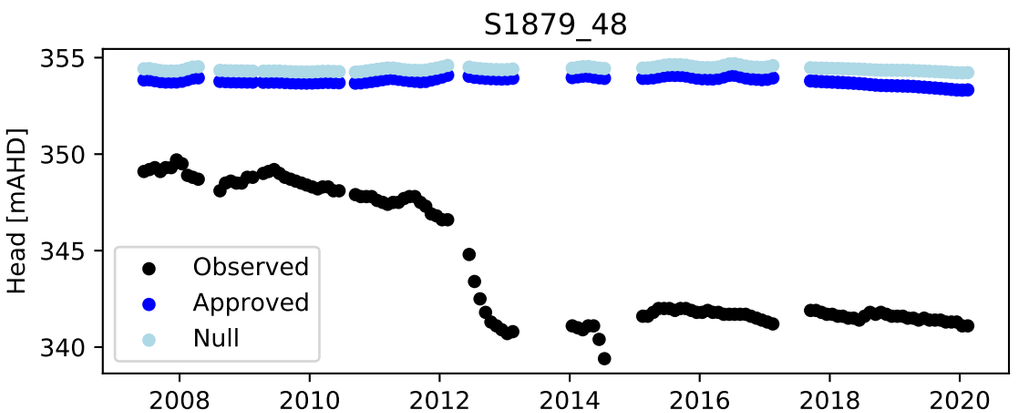

S1879_10
Head [mAHD]
375
370
365
360
355
2008
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

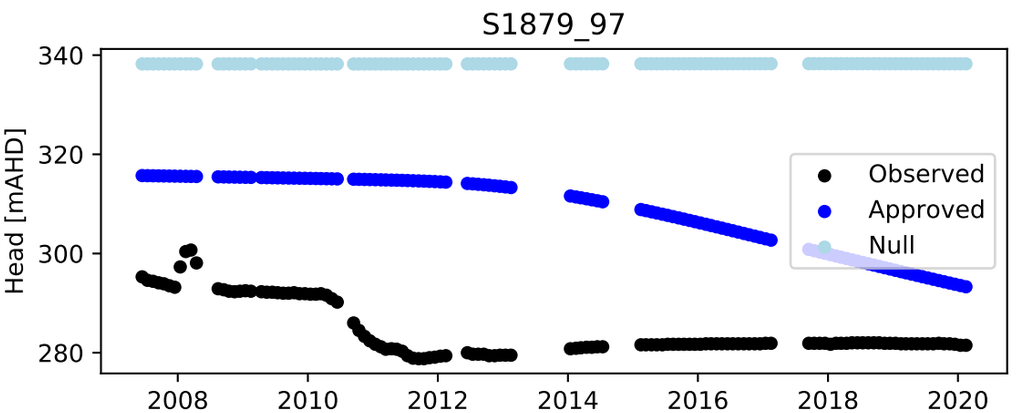

S1879_153
Head [mAHD]
340
320
300
280
260
240
2008
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

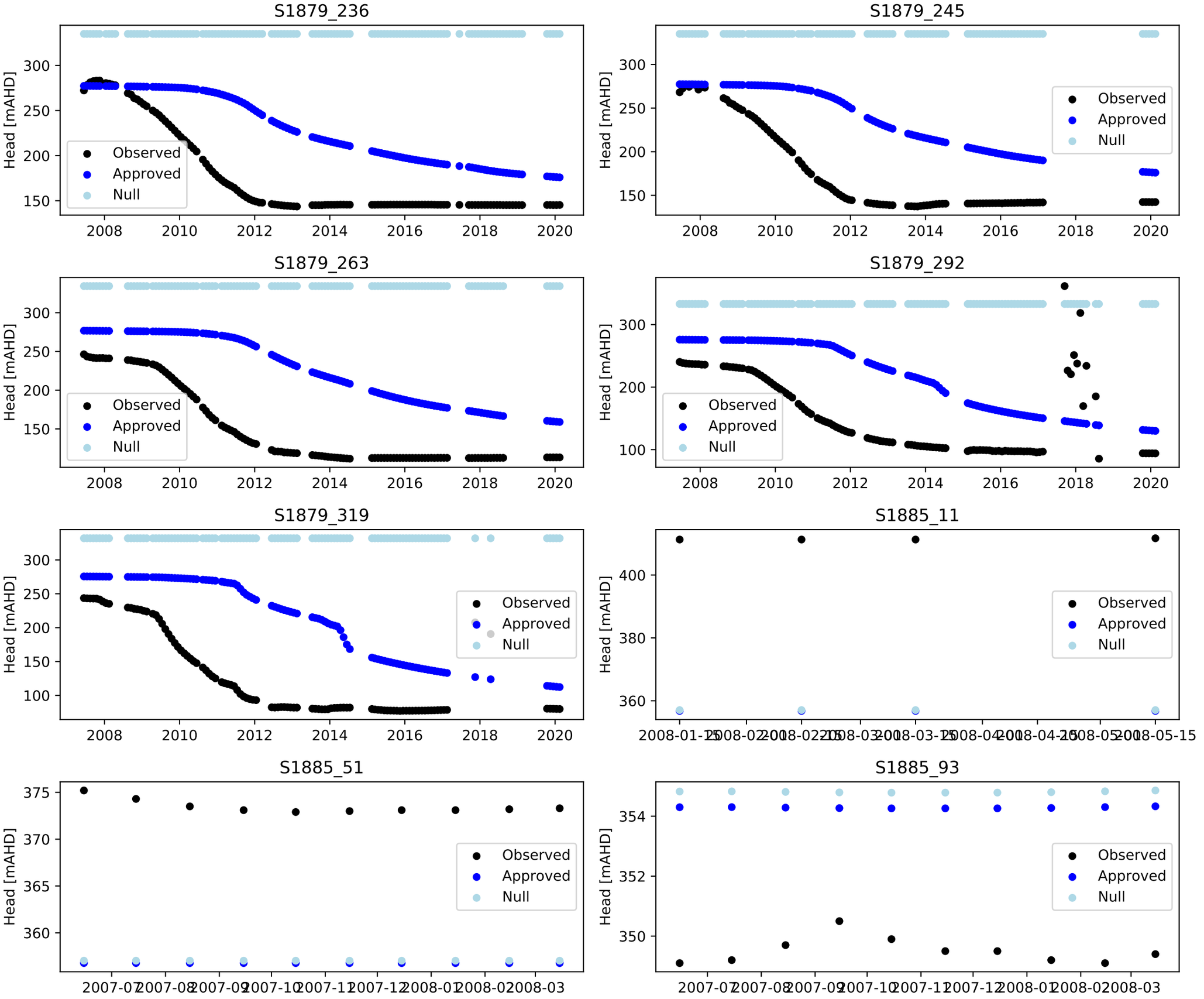

S1879_210
Head [mAHD]
300
250
200
2008
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

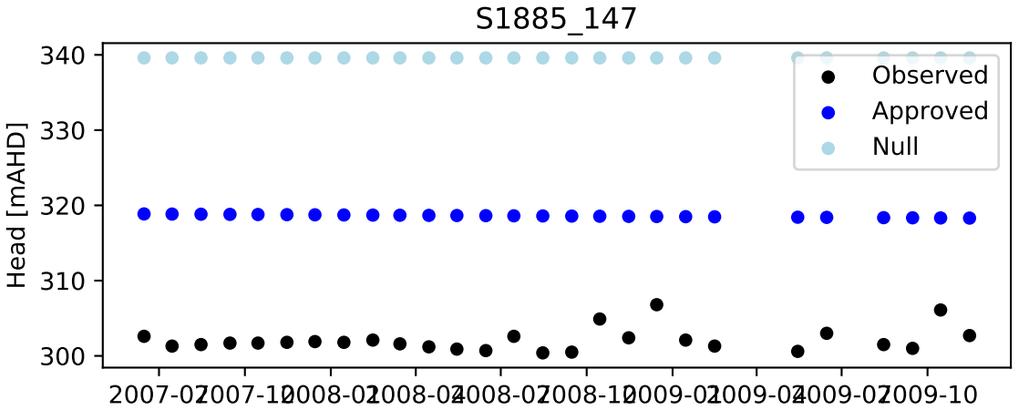

S1879_227
Head [mAHD]
300
250
200
150
2008
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

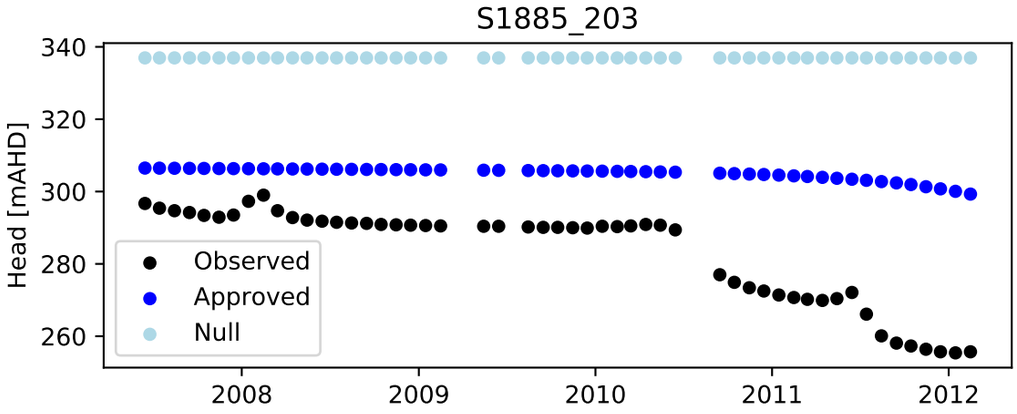

S1879_29
Head [mAHD]
358
356
354
352
2008
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

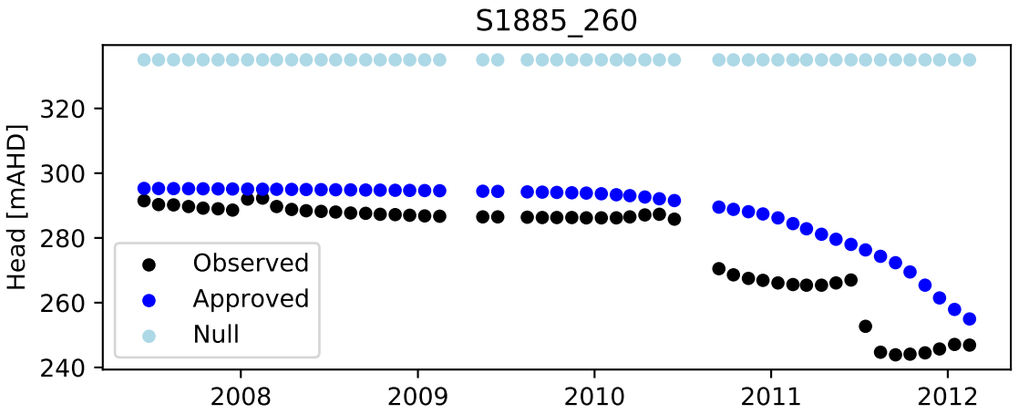

S1879_48
Head [mAHD]
355
350
345
340
2008
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

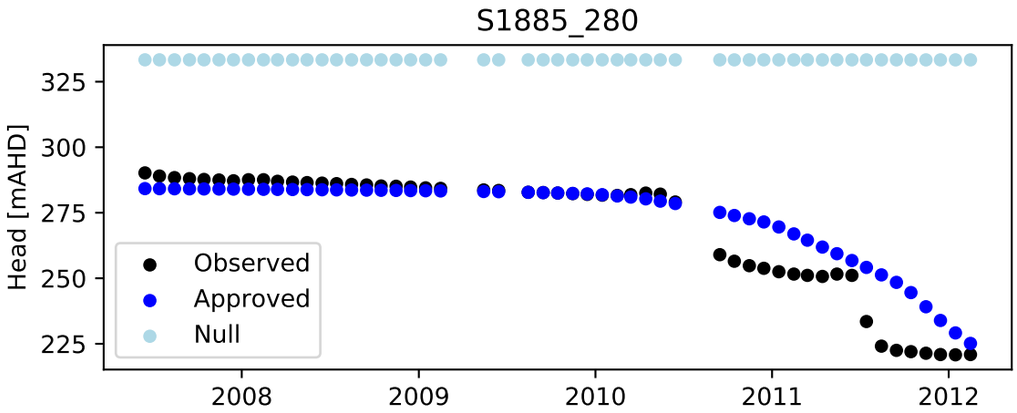

S1879_97
Head [mAHD]
340
320
300
280
2008
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

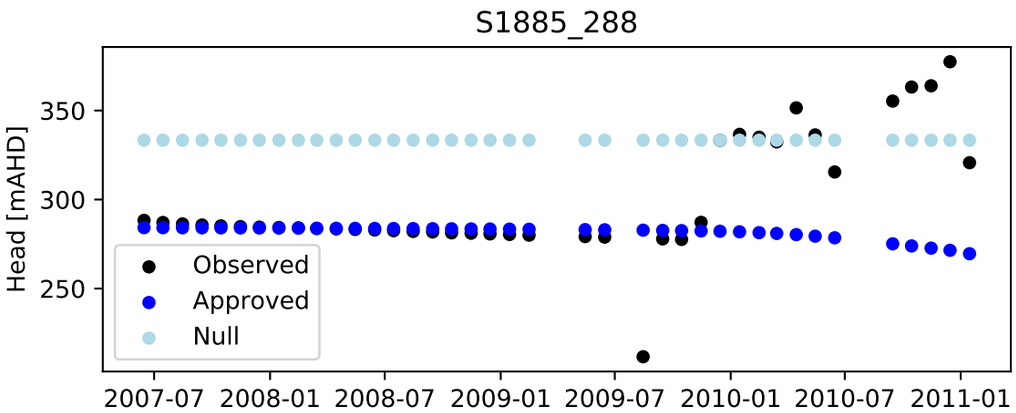

S1879_236
S1879_245
S1879_263
S1879_292
S1879_319
S1885_11
S1885_51
S1885_93
Head [mAHD]
Observed
Approved
Null

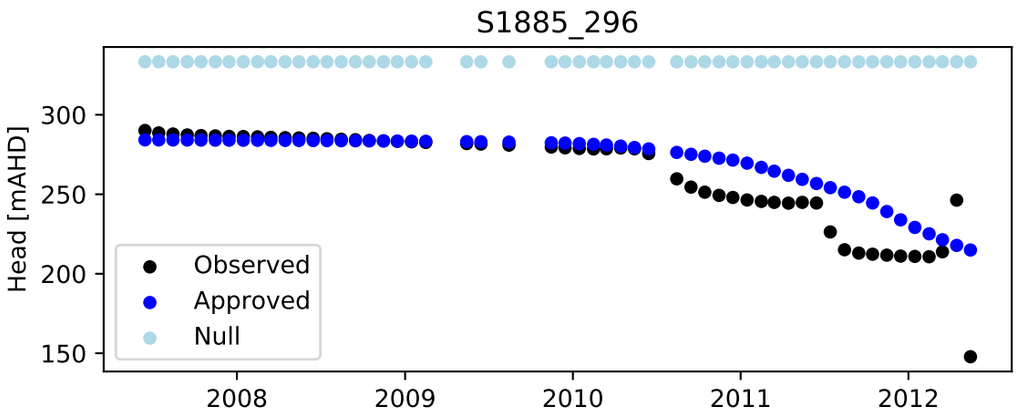

S1885_147
Head [mAHD]
Observed
Approved
Null

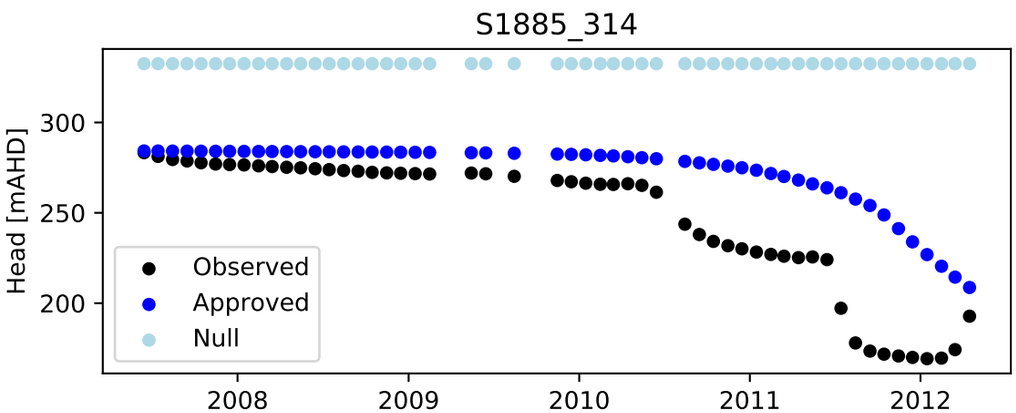

S1885_203
Head [mAHD]
Observed
Approved
Null

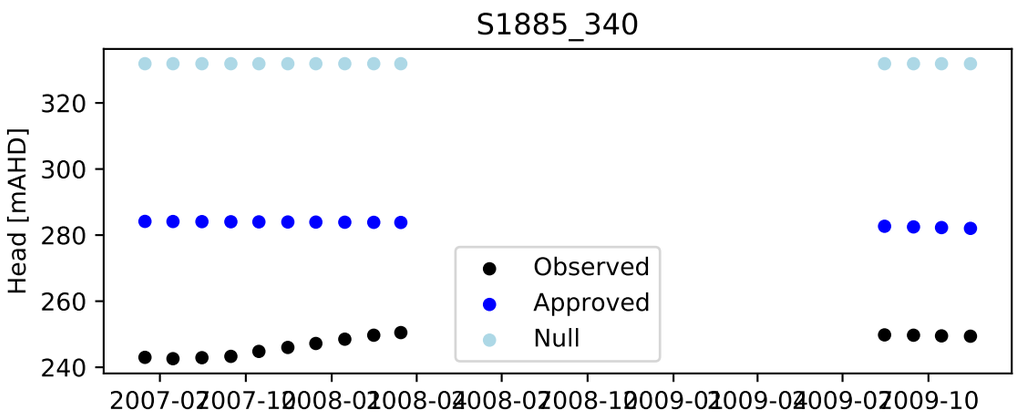

S1885_260
Head [mAHD]
Observed
Approved
Null

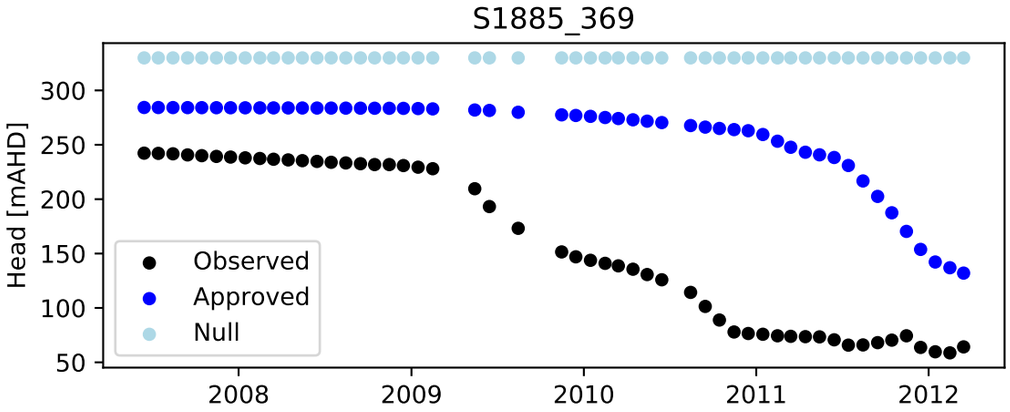

S1885_280
Head [mAHD]
Observed
Approved
Null

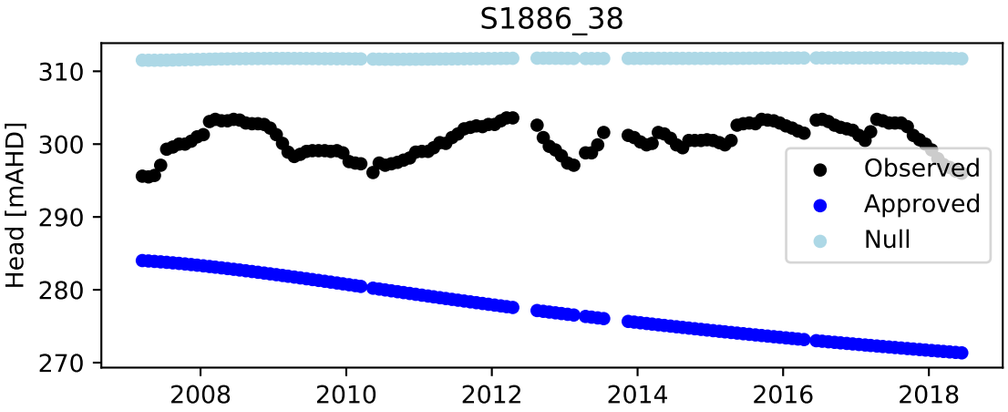

S1885_288
Head [mAHD]
Observed
Approved
Null

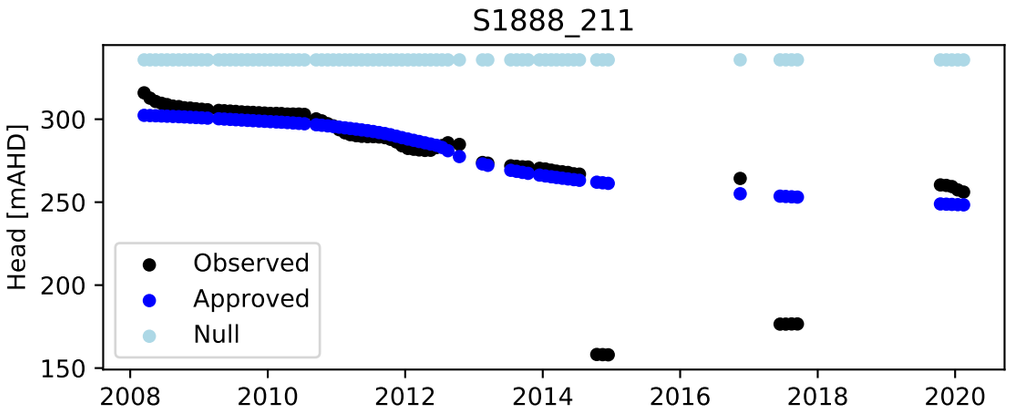

S1885_296
Head [mAHD]
Observed
Approved
Null

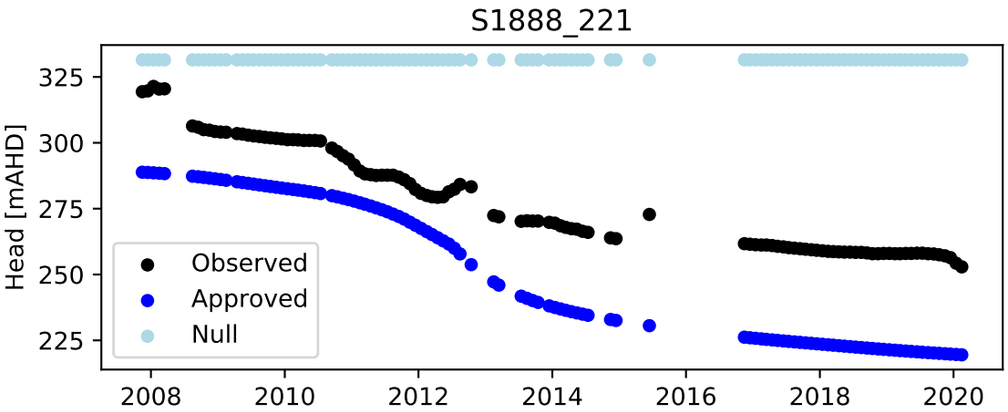

S1885_314
Head [mAHD]
Observed
Approved
Null

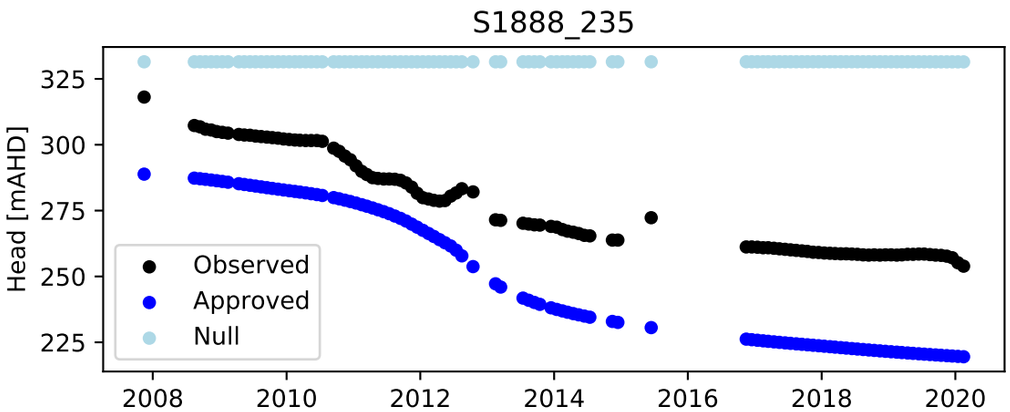

S1885_340
Head [mAHD]
Observed
Approved
Null

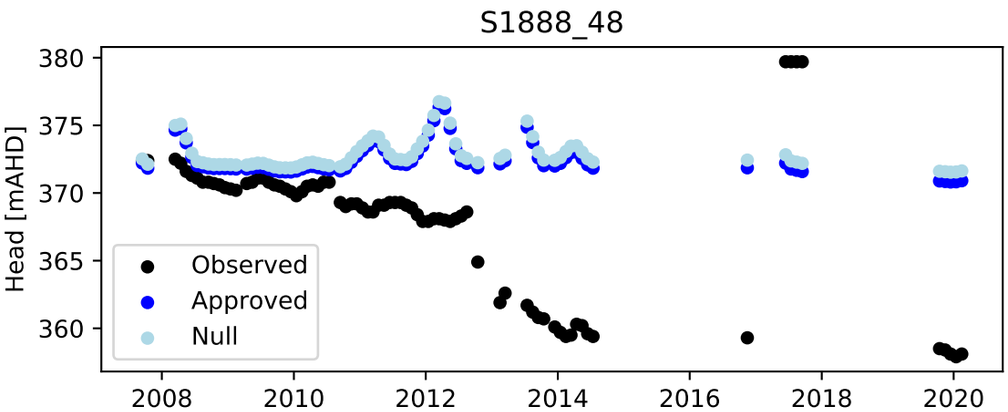

S1885_369
Head [mAHD]
Observed
Approved
Null

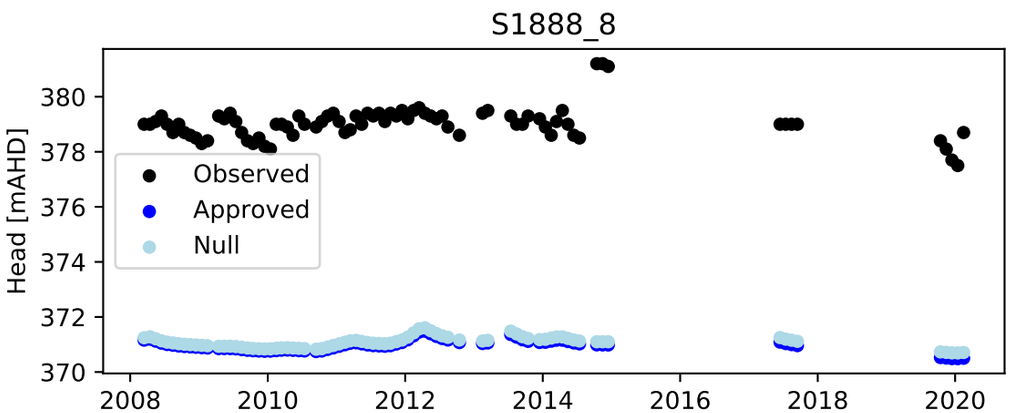

S1886_38
Head [mAHD]
Observed
Approved
Null

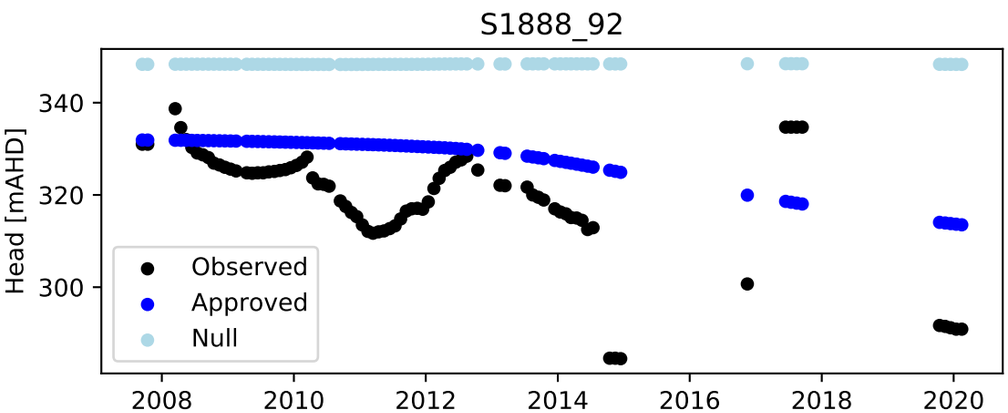

S1888_211
Head [mAHD]
Observed
Approved
Null

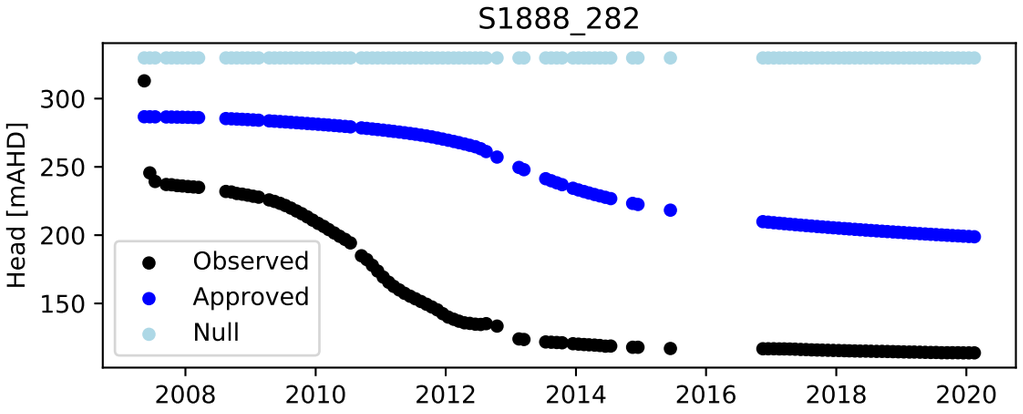

S1888_221
Head [mAHD]
Observed
Approved
Null

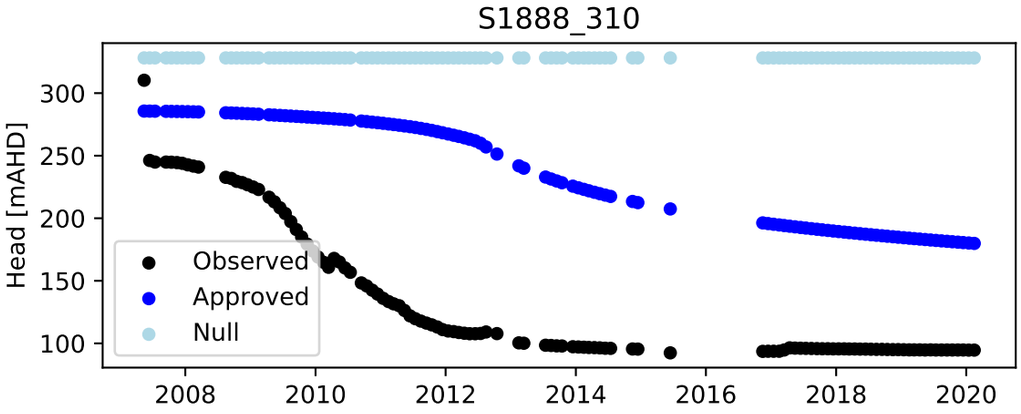

S1888_235
Head [mAHD]
Observed
Approved
Null

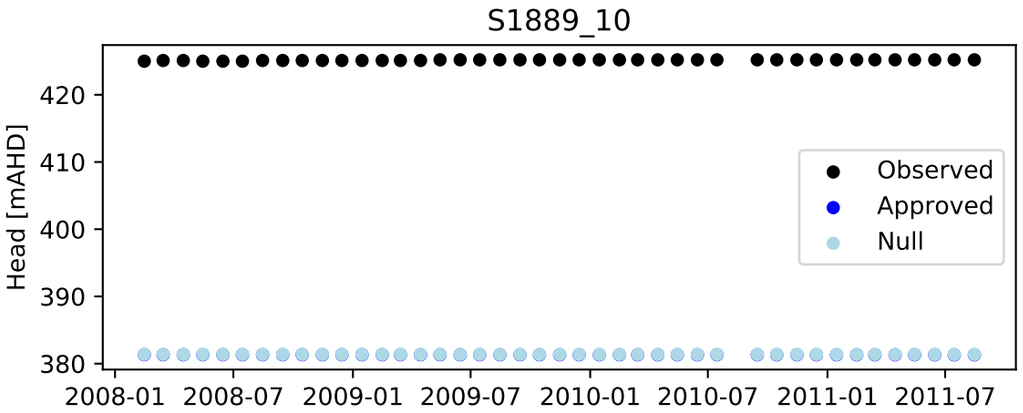

S1888_48
Head [mAHD]
Observed
Approved
Null

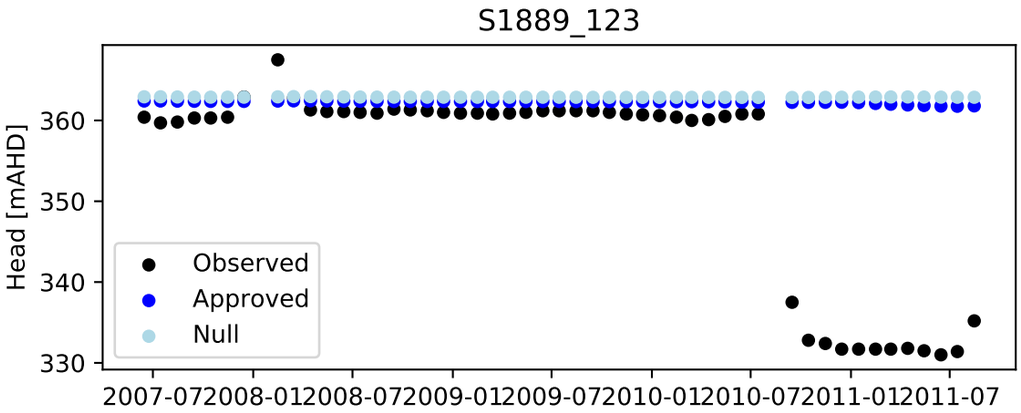

S1888_8
Head [mAHD]
Observed
Approved
Null

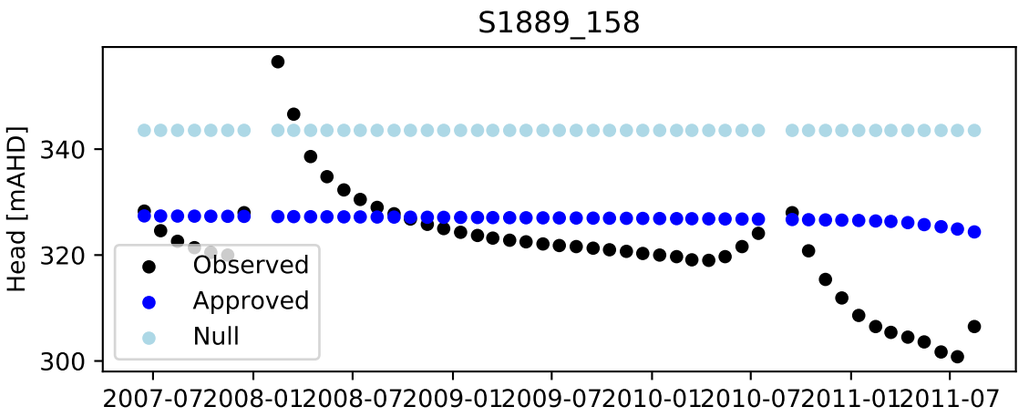

S1888_92
Head [mAHD]
Observed
Approved
Null

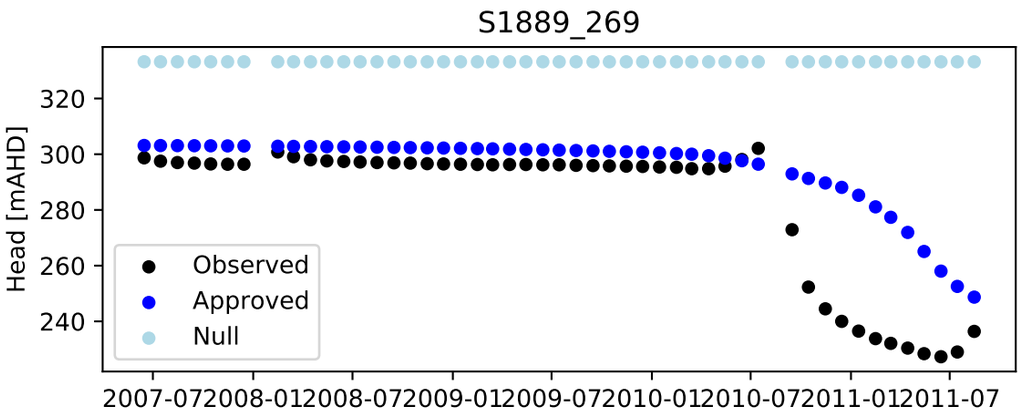

S1888_282
Head [mAHD]
300
250
200
150
Observed
Approved
Null
2008
2010
2012
2014
2016
2018
2020

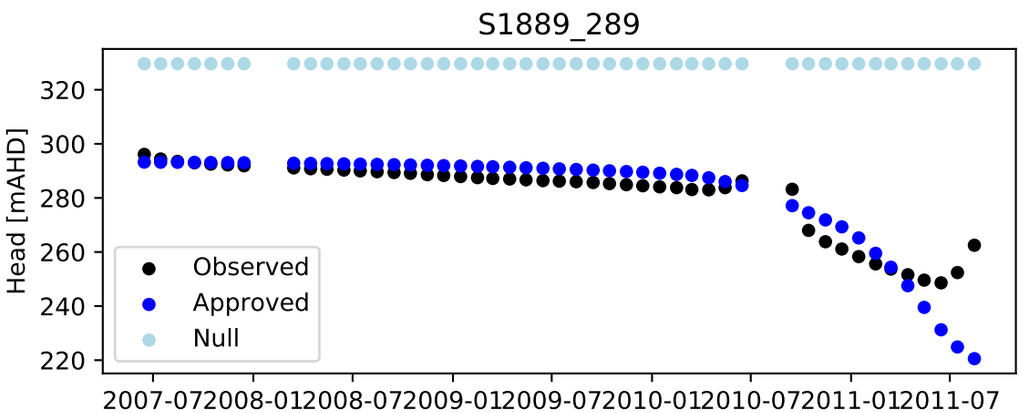

S1888_310
Head [mAHD]
300
250
200
150
100
Observed
Approved
Null
2008
2010
2012
2014
2016
2018
2020

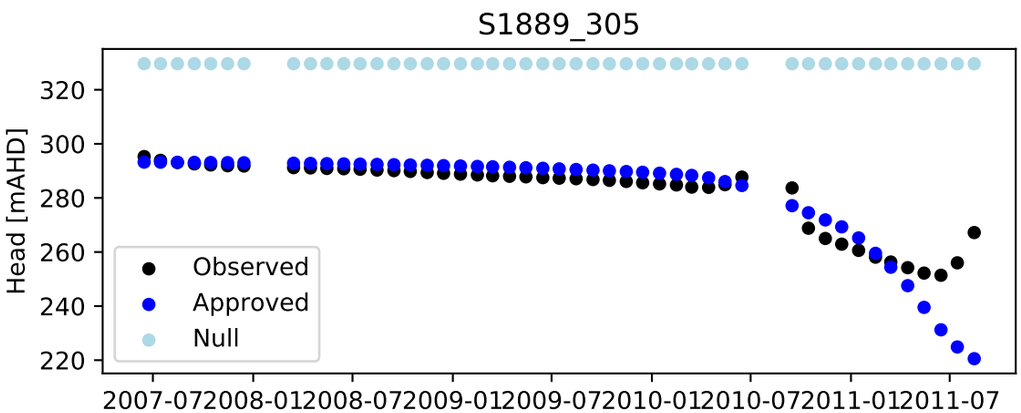

S1889_10
Head [mAHD]
420
410
400
390
380
Observed
Approved
Null
2008-01
2008-07
2009-01
2009-07
2010-01
2010-07
2011-01
2011-07

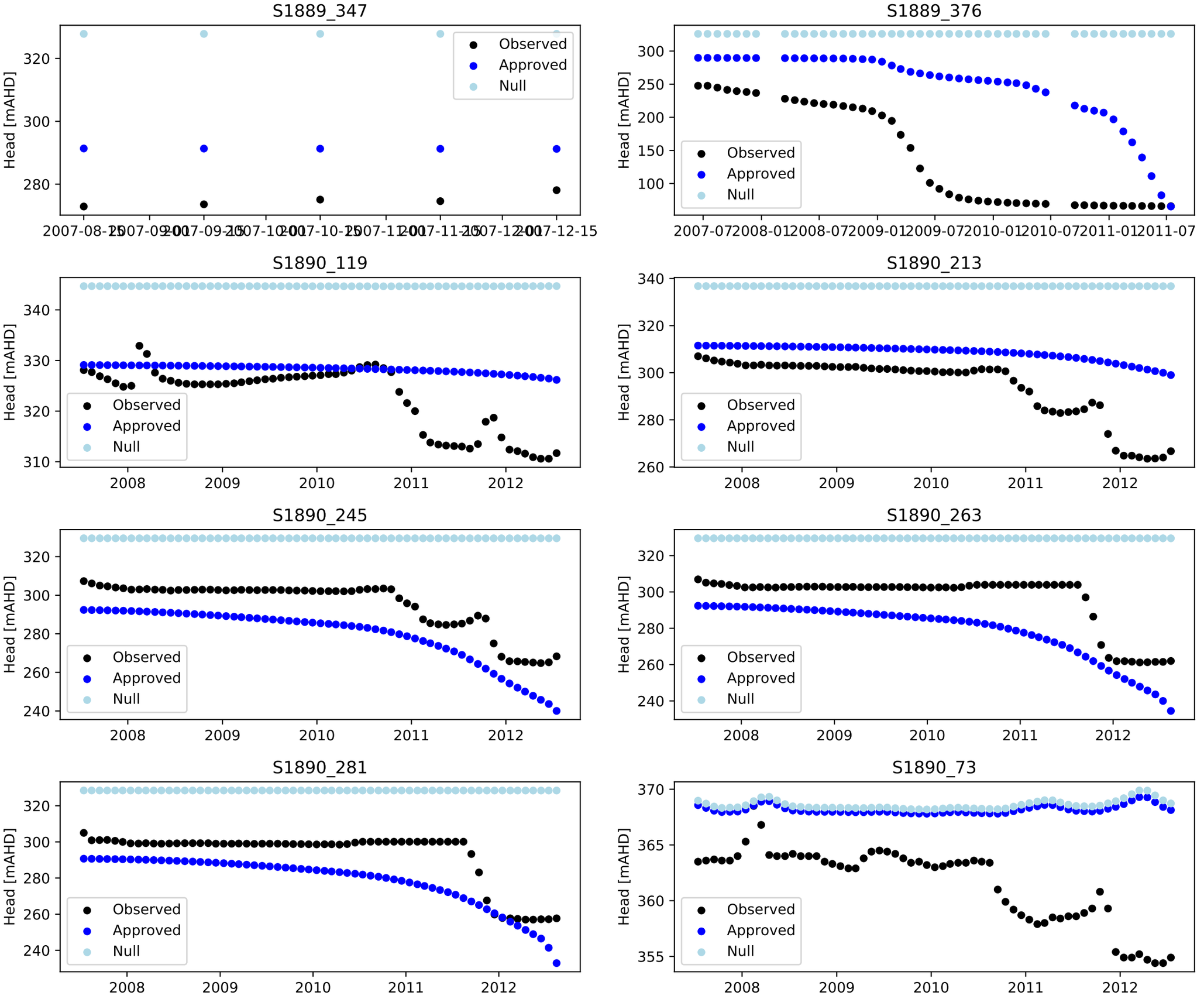

S1889_123
Head [mAHD]
360
350
340
330
Observed
Approved
Null
2007-07
2008-01
2008-07
2009-01
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2010-01
2010-07
2011-01
2011-07

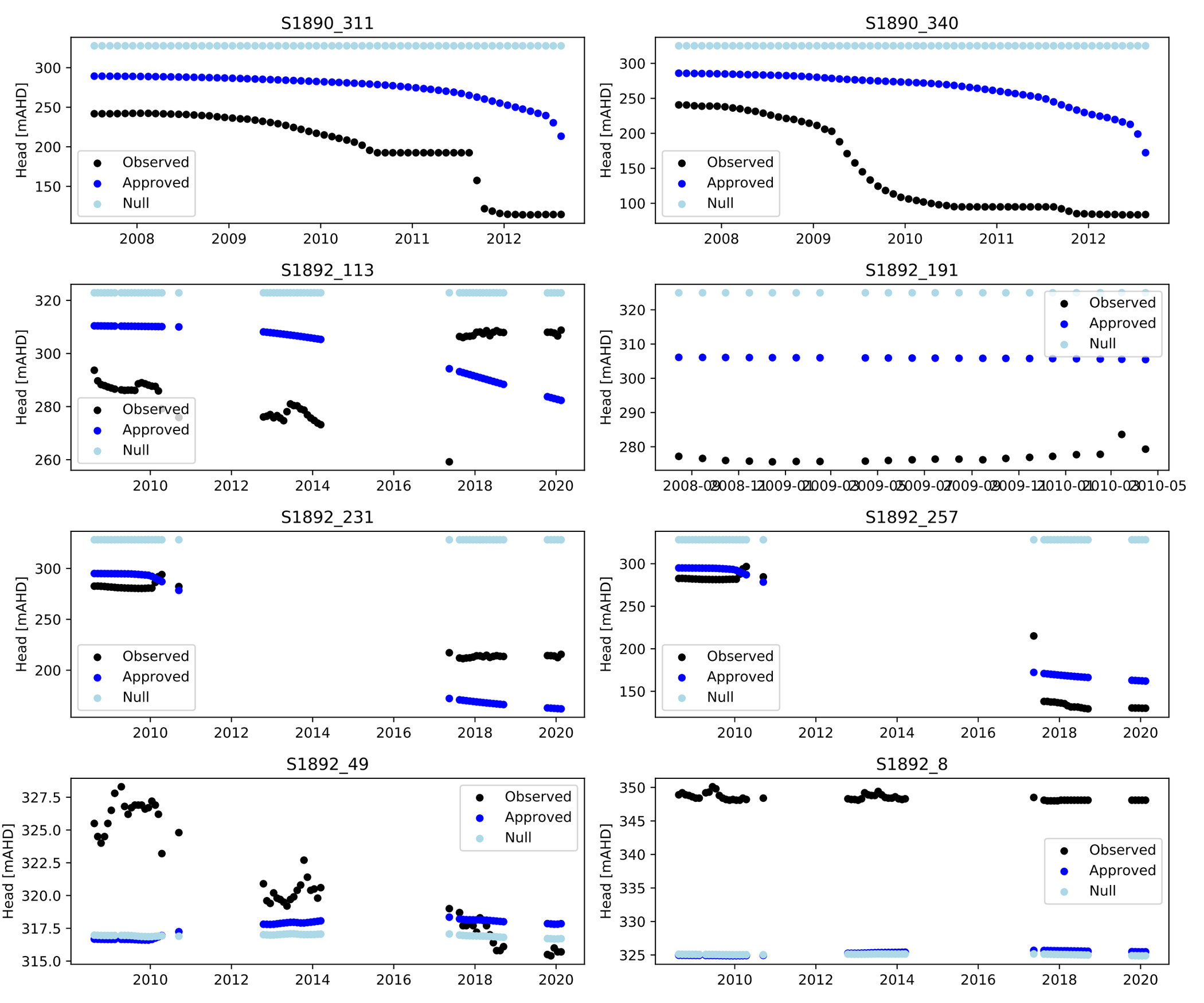

S1889_158
Head [mAHD]
340
320
300
Observed
Approved
Null
2007-07
2008-01
2008-07
2009-01
2009-07
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2010-07
2011-01
2011-07

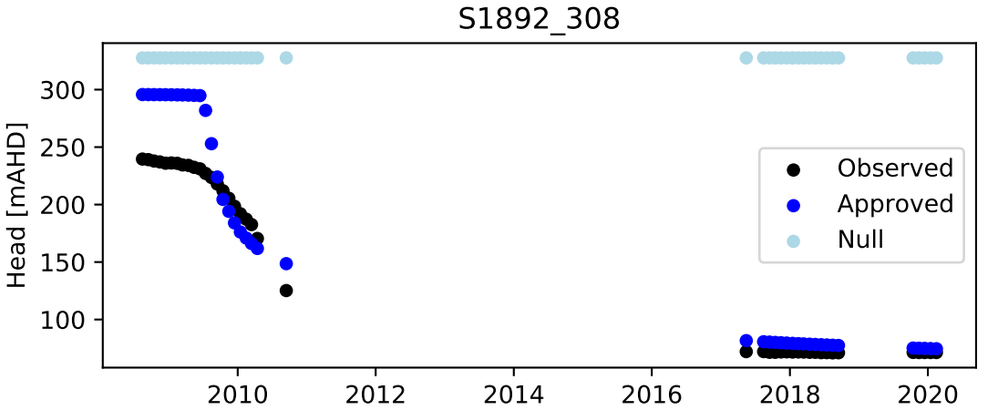

S1889_269
Head [mAHD]
320
300
280
260
240
Observed
Approved
Null
2007-07
2008-01
2008-07
2009-01
2009-07
2010-01
2010-07
2011-01
2011-07

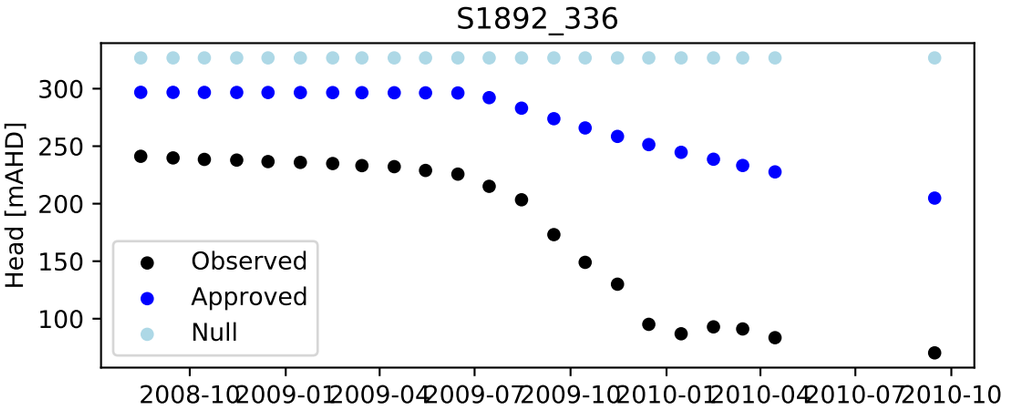

S1889_289
Head [mAHD]
320
300
280
260
240
220
Observed
Approved
Null
2007-07
2008-01
2008-07
2009-01
2009-07
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2010-07
2011-01
2011-07

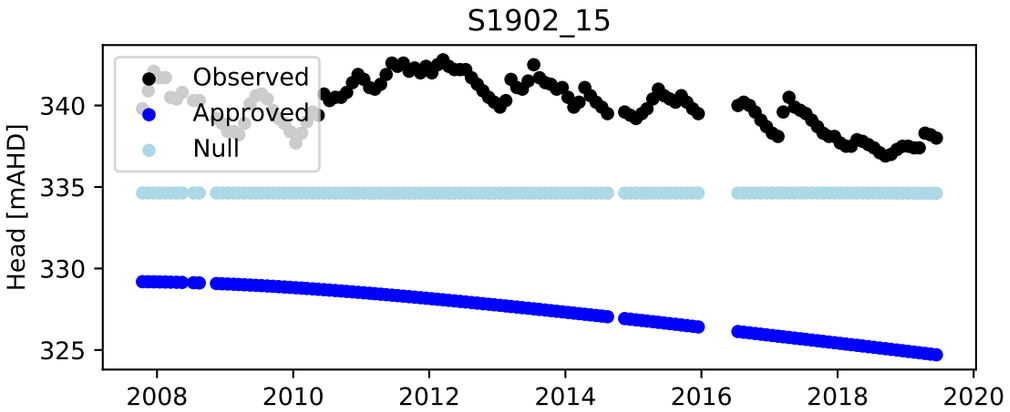

S1889_305
Head [mAHD]
320
300
280
260
240
220
Observed
Approved
Null
2007-07
2008-01
2008-07
2009-01
2009-07
2010-01
2010-07
2011-01
2011-07

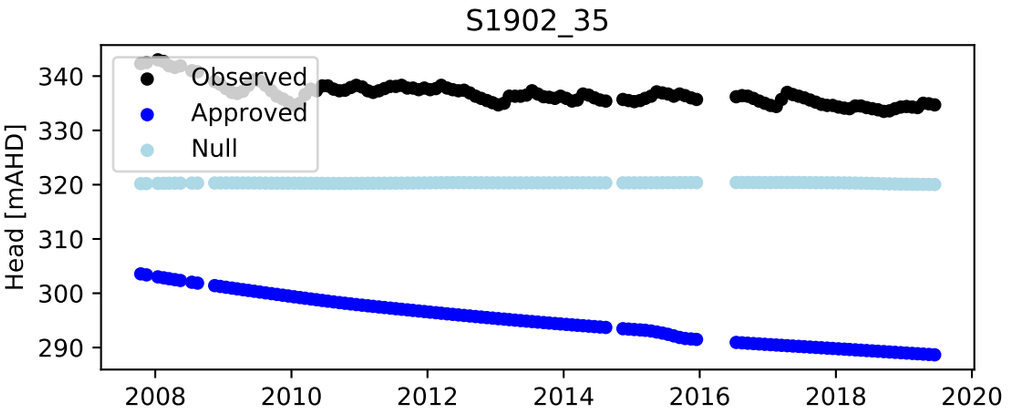

S1889_347
Head [mAHD]
Observed
Approved
Null
S1889_376
Head [mAHD]
Observed
Approved
Null
S1890_119
Head [mAHD]
Observed
Approved
Null
S1890_213
Head [mAHD]
Observed
Approved
Null
S1890_245
Head [mAHD]
Observed
Approved
Null
S1890_263
Head [mAHD]
Observed
Approved
Null
S1890_281
Head [mAHD]
Observed
Approved
Null
S1890_73
Head [mAHD]
Observed
Approved
Null

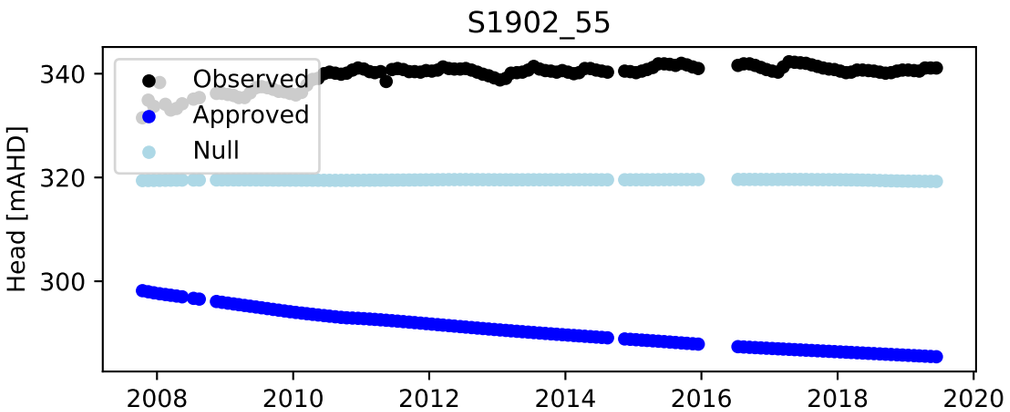

S1890_311
S1890_340
S1892_113
S1892_191
S1892_231
S1892_257
S1892_49
S1892_8
Head [mAHD]
Observed
Approved
Null

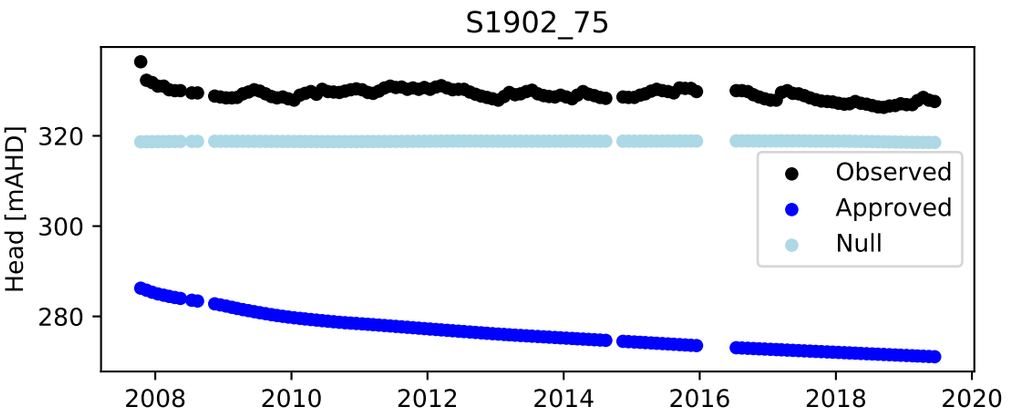

S1892_308
Head [mAHD]
300
250
200
150
100
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

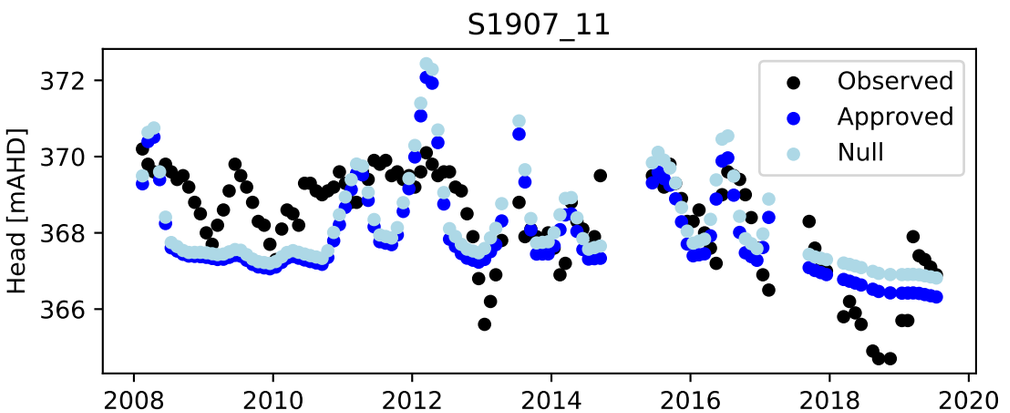

S1892_336
Head [mAHD]
300
250
200
150
100
2008-10
2009-01
2009-04
2009-07
2009-10
2010-01
2010-04
2010-07
2010-10
Observed
Approved
Null

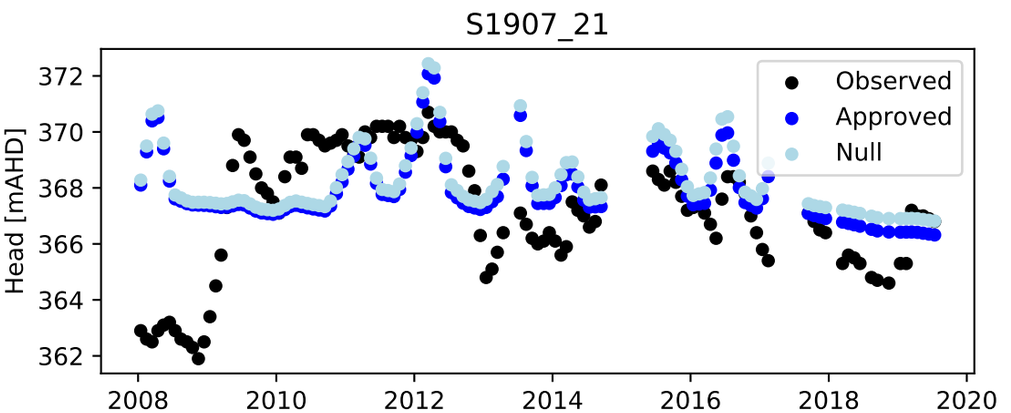

S1902_15
Head [mAHD]
340
335
330
325
2008
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

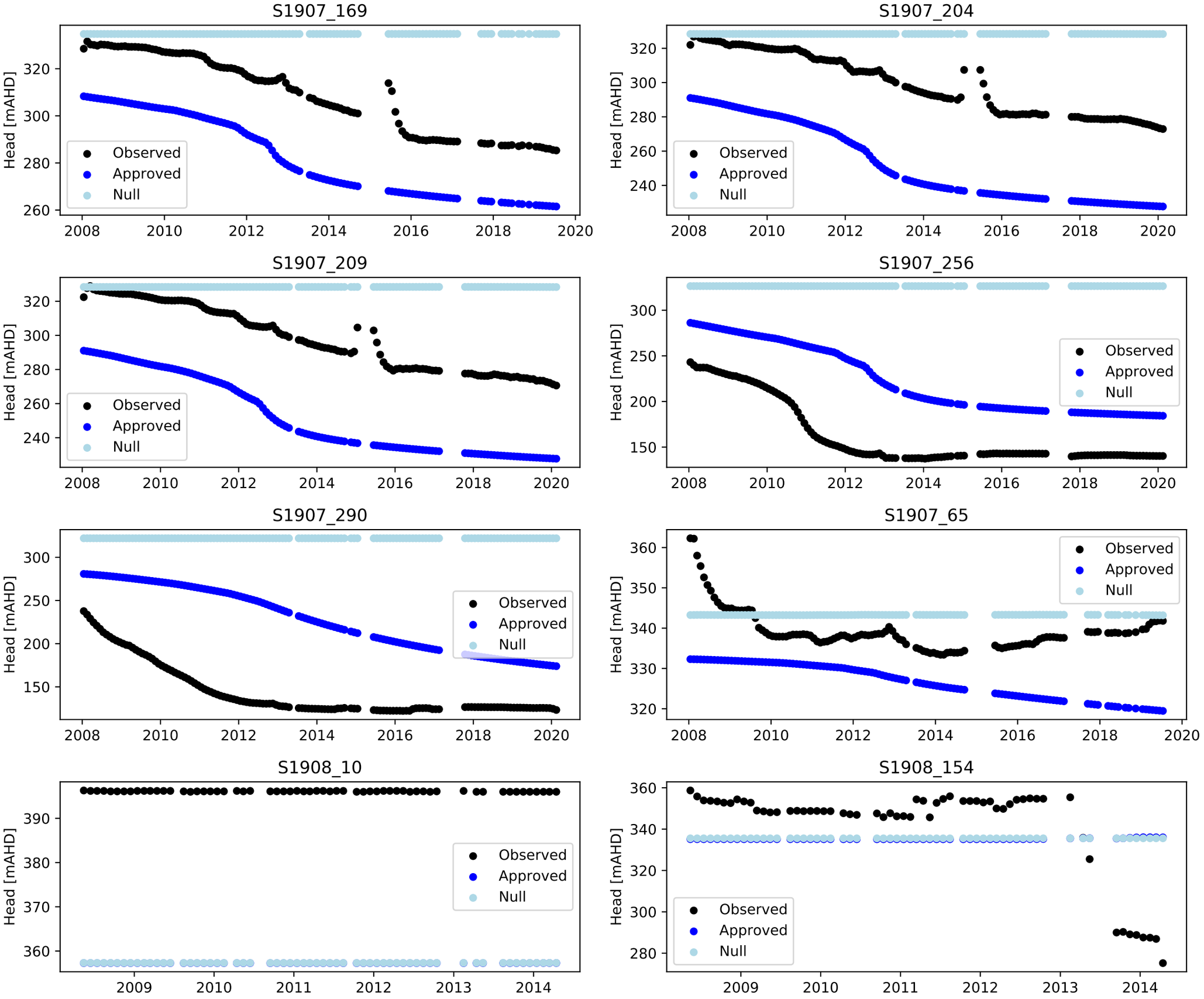

S1902_35
Head [mAHD]
340
330
320
310
300
290
2008
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

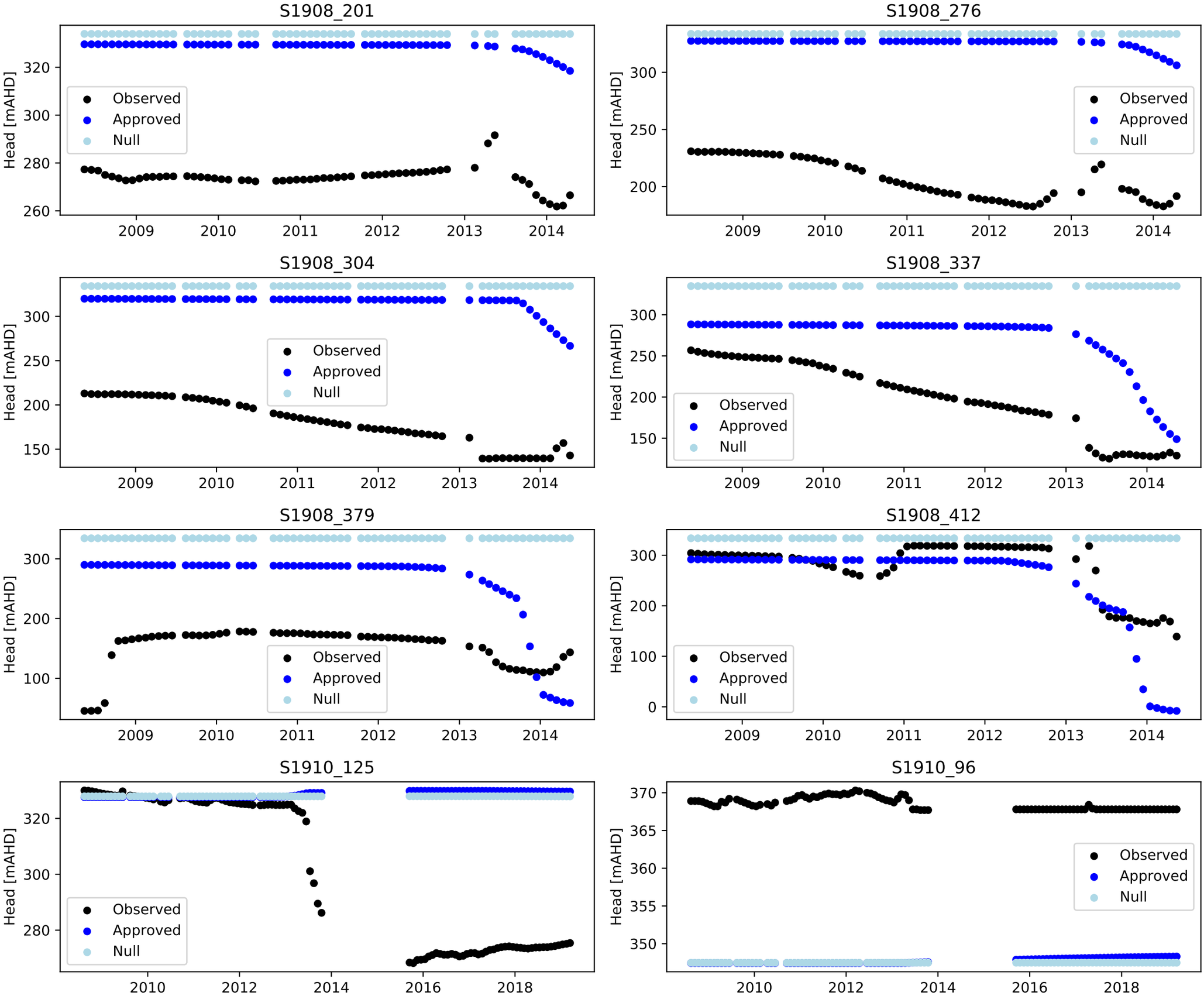

S1902_55
Head [mAHD]
340
320
300
2008
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

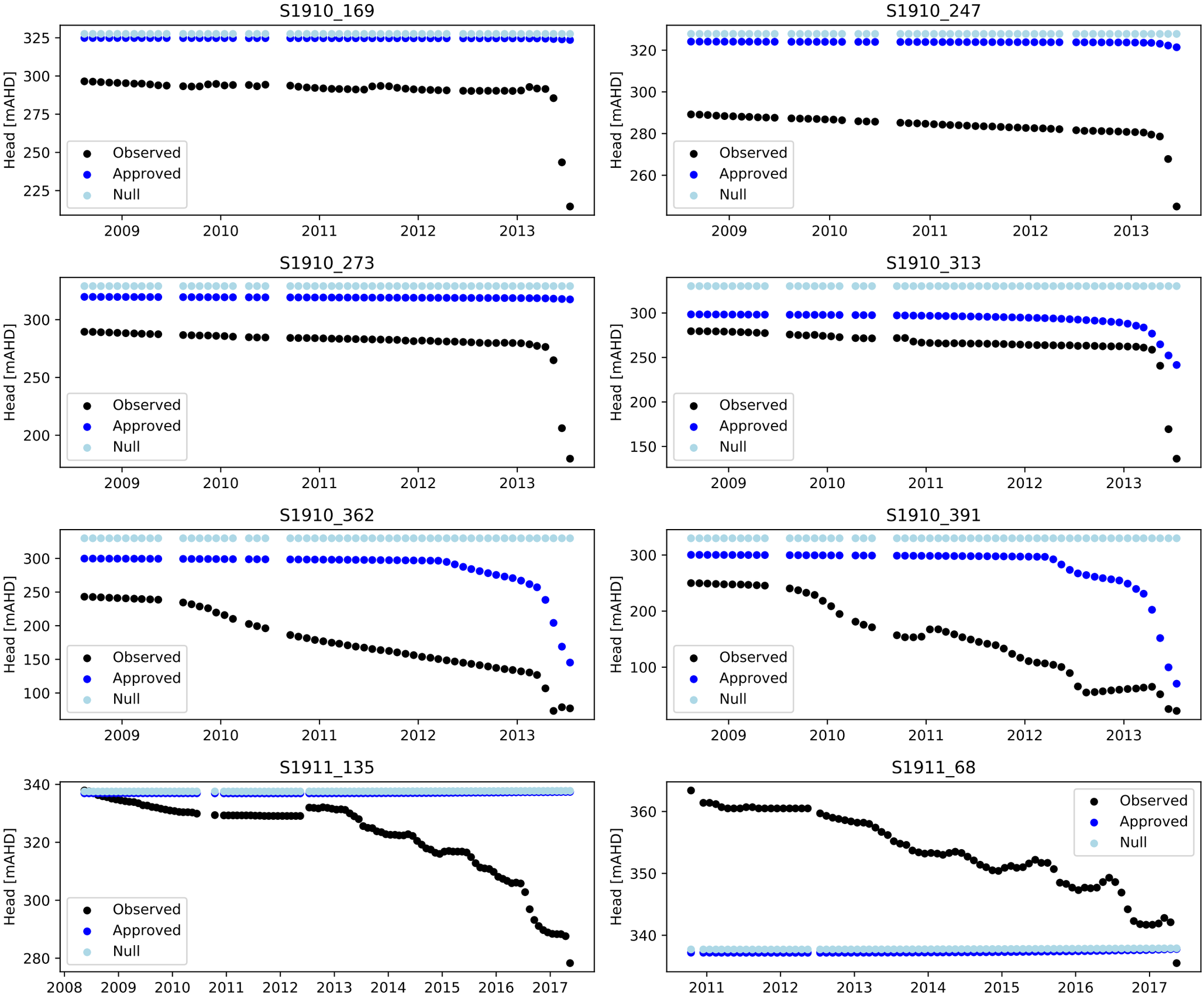

S1902_75
Head [mAHD]
320
300
280
2008
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

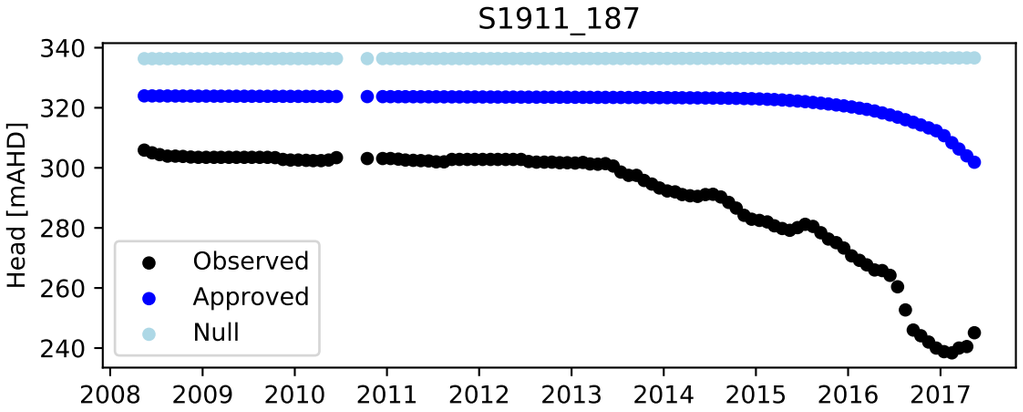

S1907_11
Head [mAHD]
372
370
368
366
2008
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

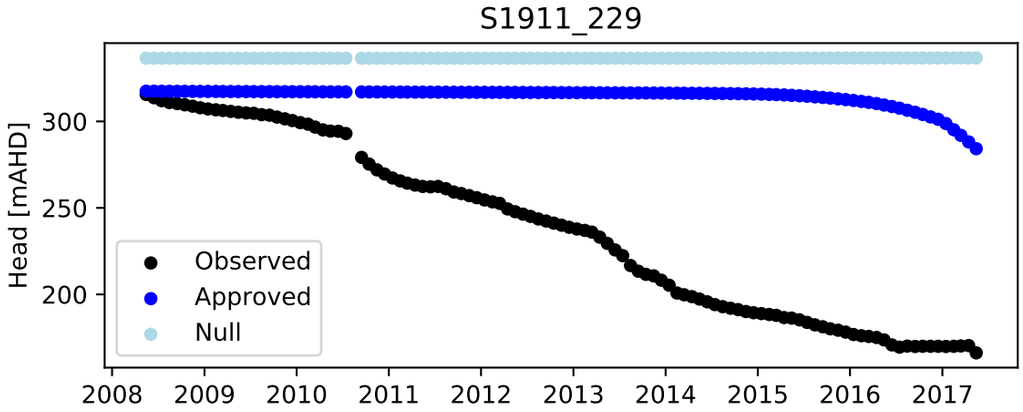

S1907_21
Head [mAHD]
372
370
368
366
364
362
2008
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

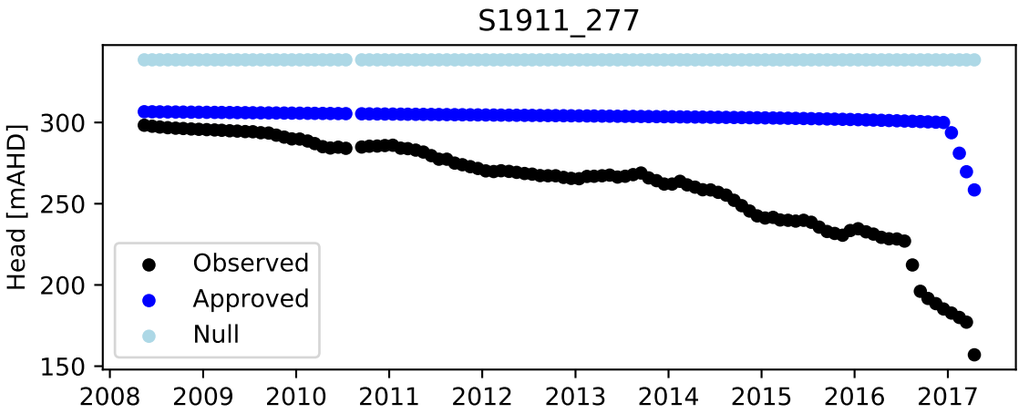

S1907_169
S1907_204
S1907_209
S1907_256
S1907_290
S1907_65
S1908_10
S1908_154
Head [mAHD]
Observed
Approved
Null

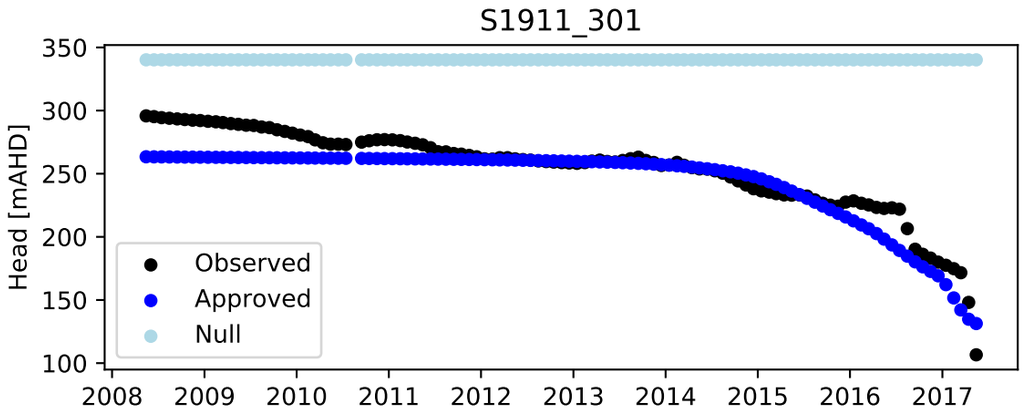

S1908_201
S1908_276
S1908_304
S1908_337
S1908_379
S1908_412
S1910_125
S1910_96
Head [mAHD]
Observed
Approved
Null

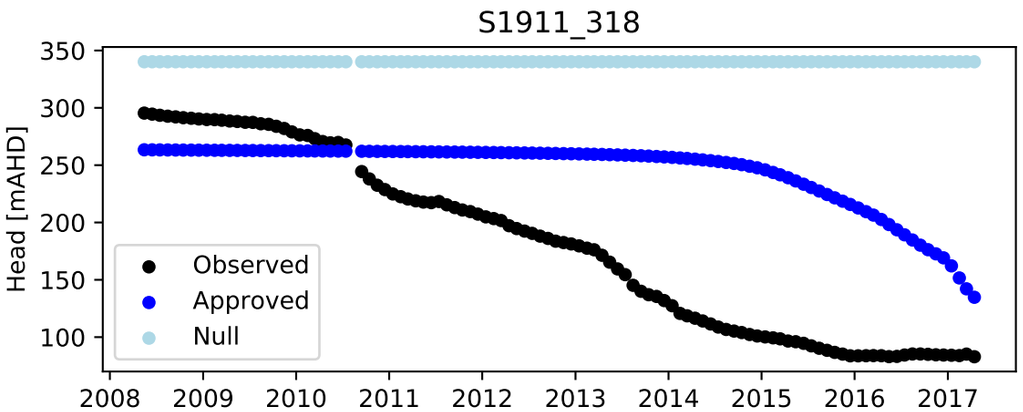

S1910_169
S1910_247
S1910_273
S1910_313
S1910_362
S1910_391
S1911_135
S1911_68
Head [mAHD]
Observed
Approved
Null
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017

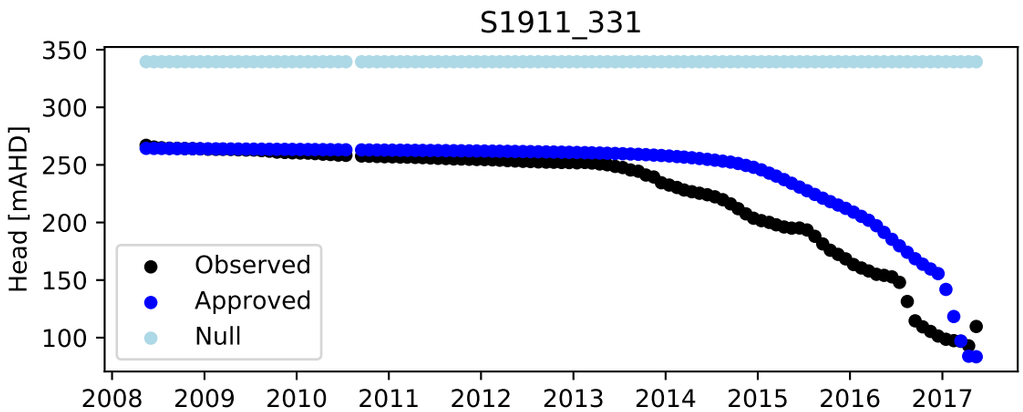

S1911_187
Head [mAHD]
Observed
Approved
Null

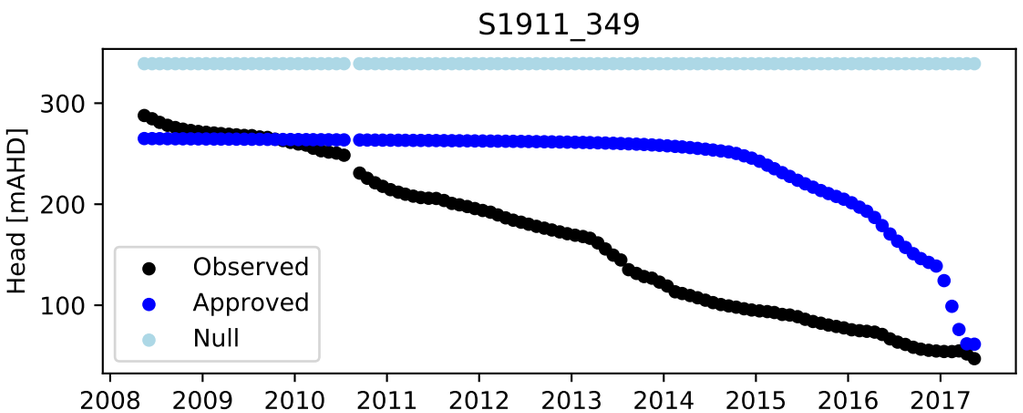

S1911_229
Head [mAHD]
Observed
Approved
Null

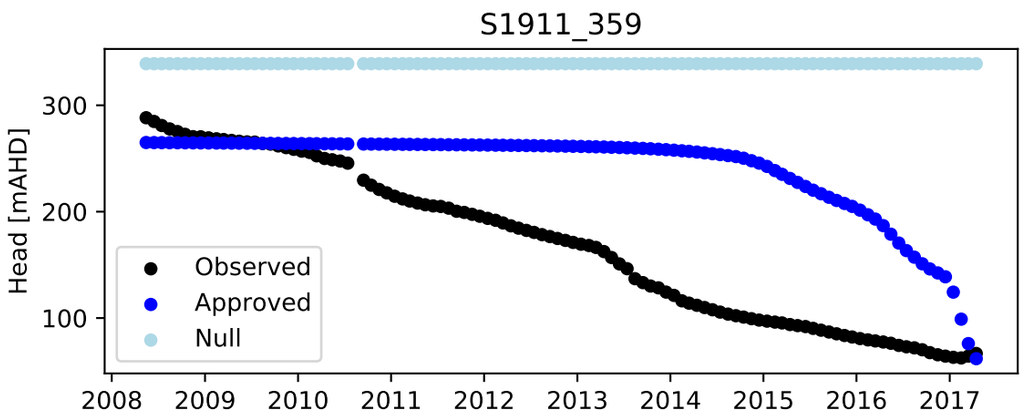

S1911_277
Head [mAHD]
Observed
Approved
Null

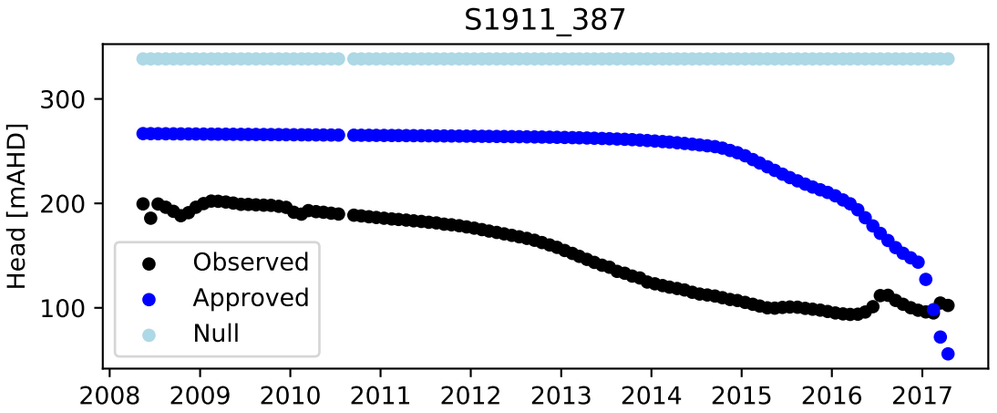

S1911_301
Head [mAHD]
Observed
Approved
Null

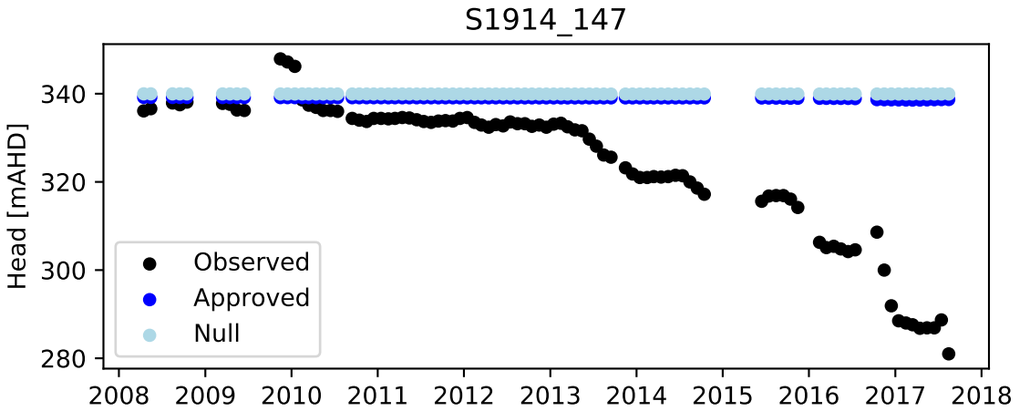

S1911_318
Head [mAHD]
Observed
Approved
Null

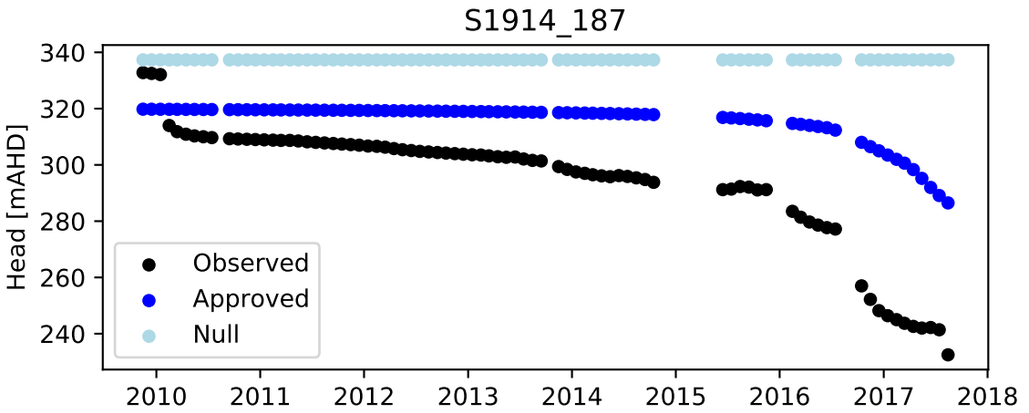

S1911_331
Head [mAHD]
Observed
Approved
Null

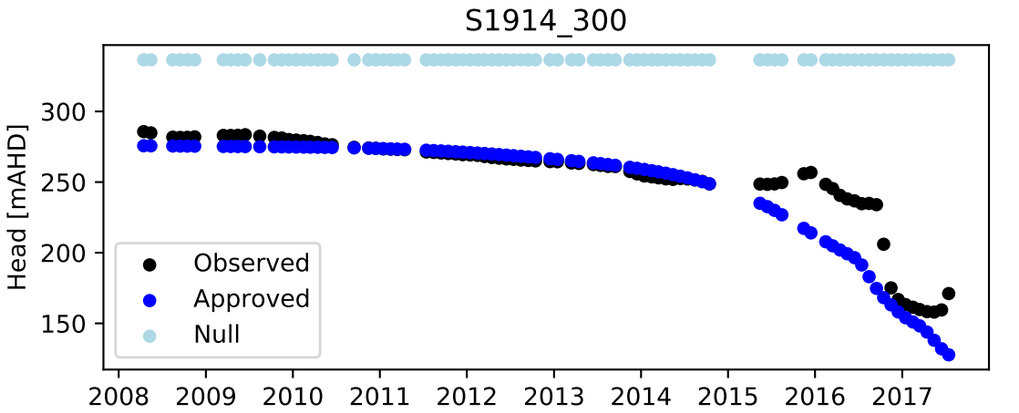

S1911_349
Head [mAHD]
Observed
Approved
Null

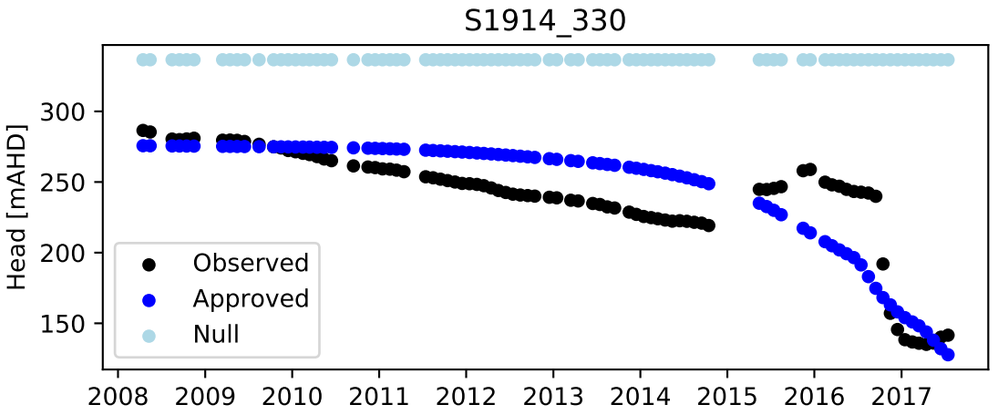

S1911_359
Head [mAHD]
Observed
Approved
Null

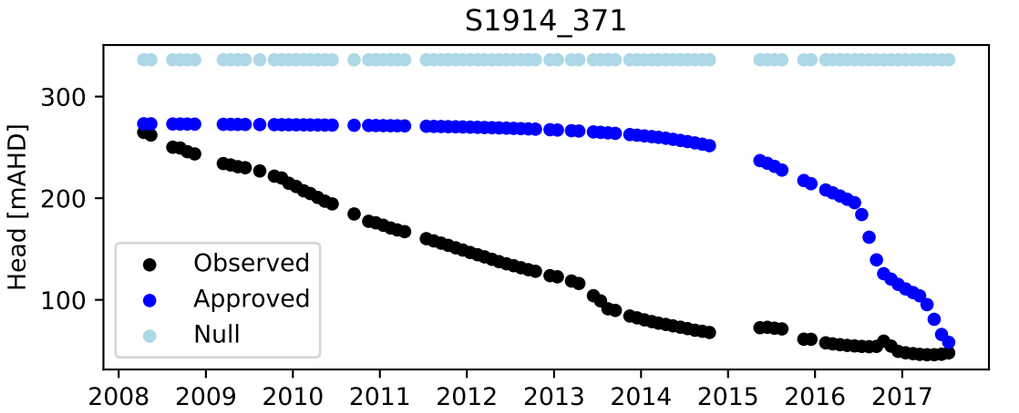

S1911_387
Head [mAHD]
Observed
Approved
Null

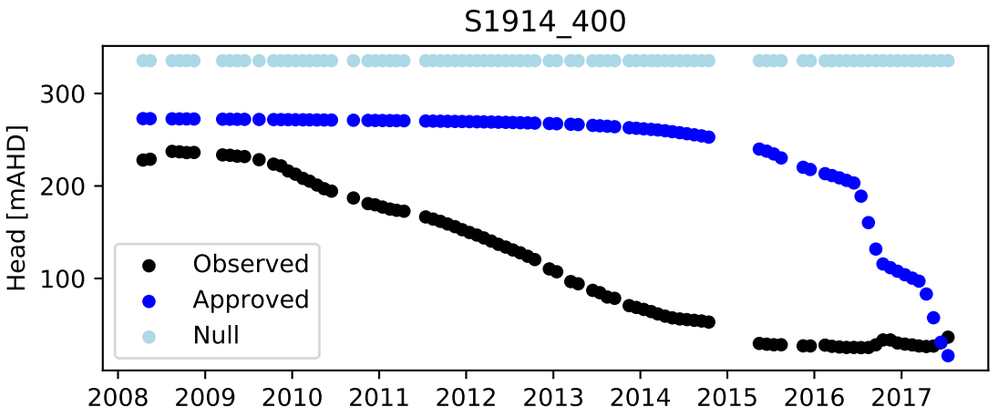

S1914_147
Head [mAHD]
Observed
Approved
Null

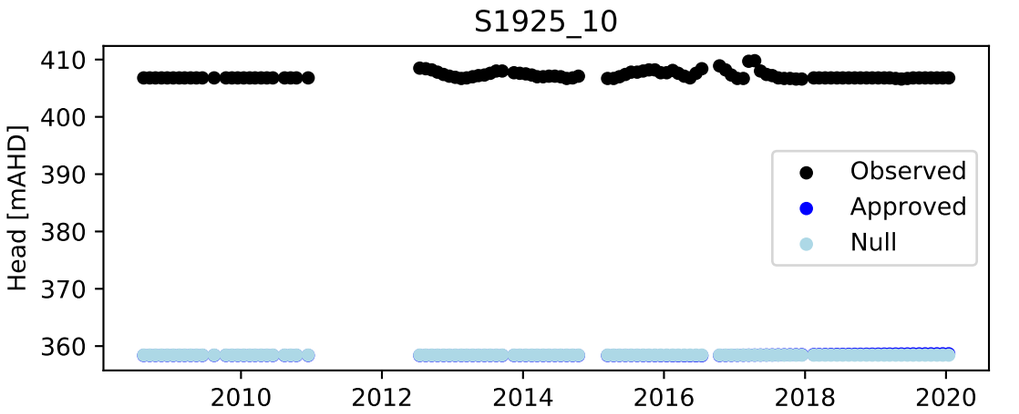

S1914_187
Head [mAHD]
Observed
Approved
Null

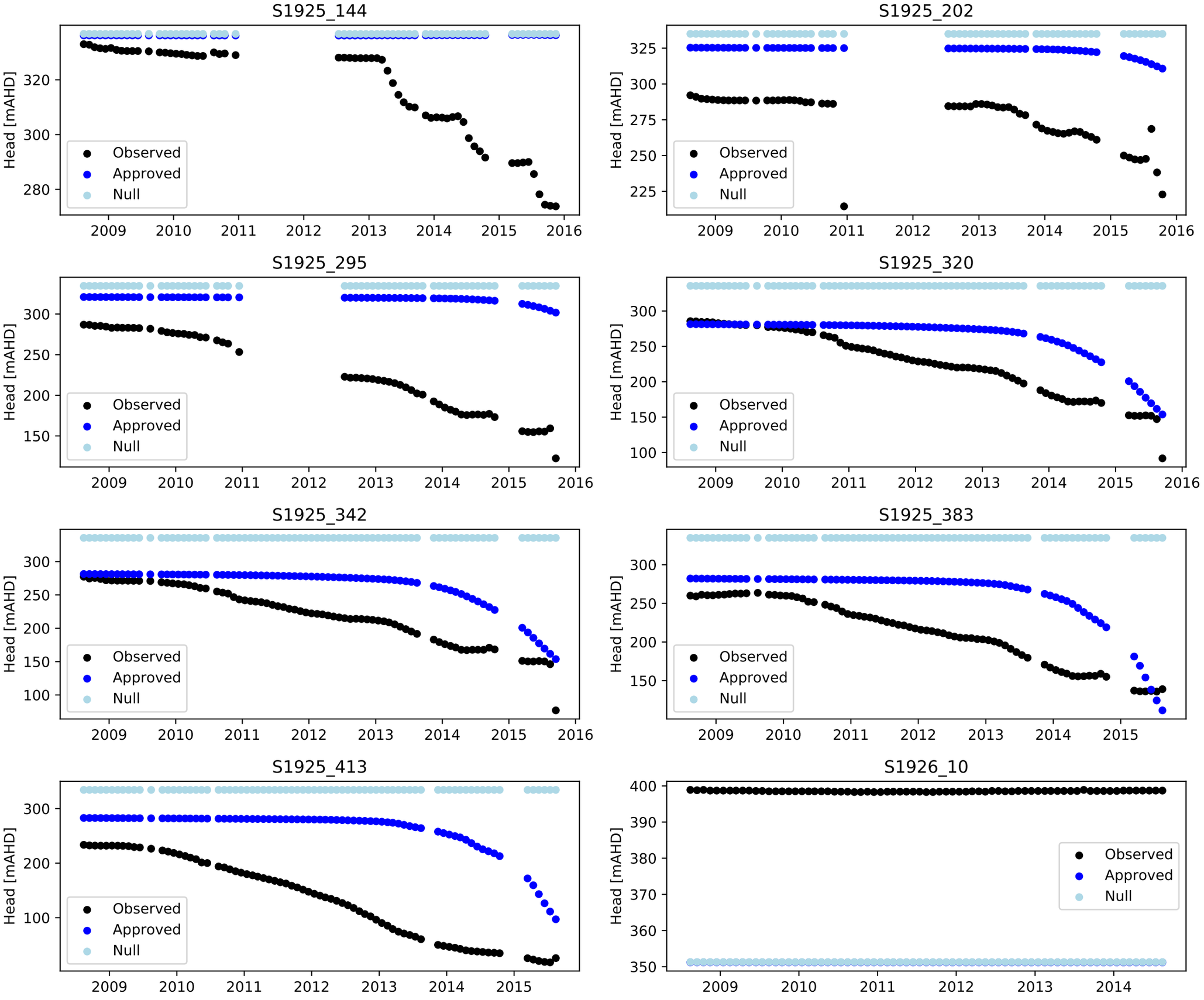

S1914_300
Head [mAHD]
Observed
Approved
Null

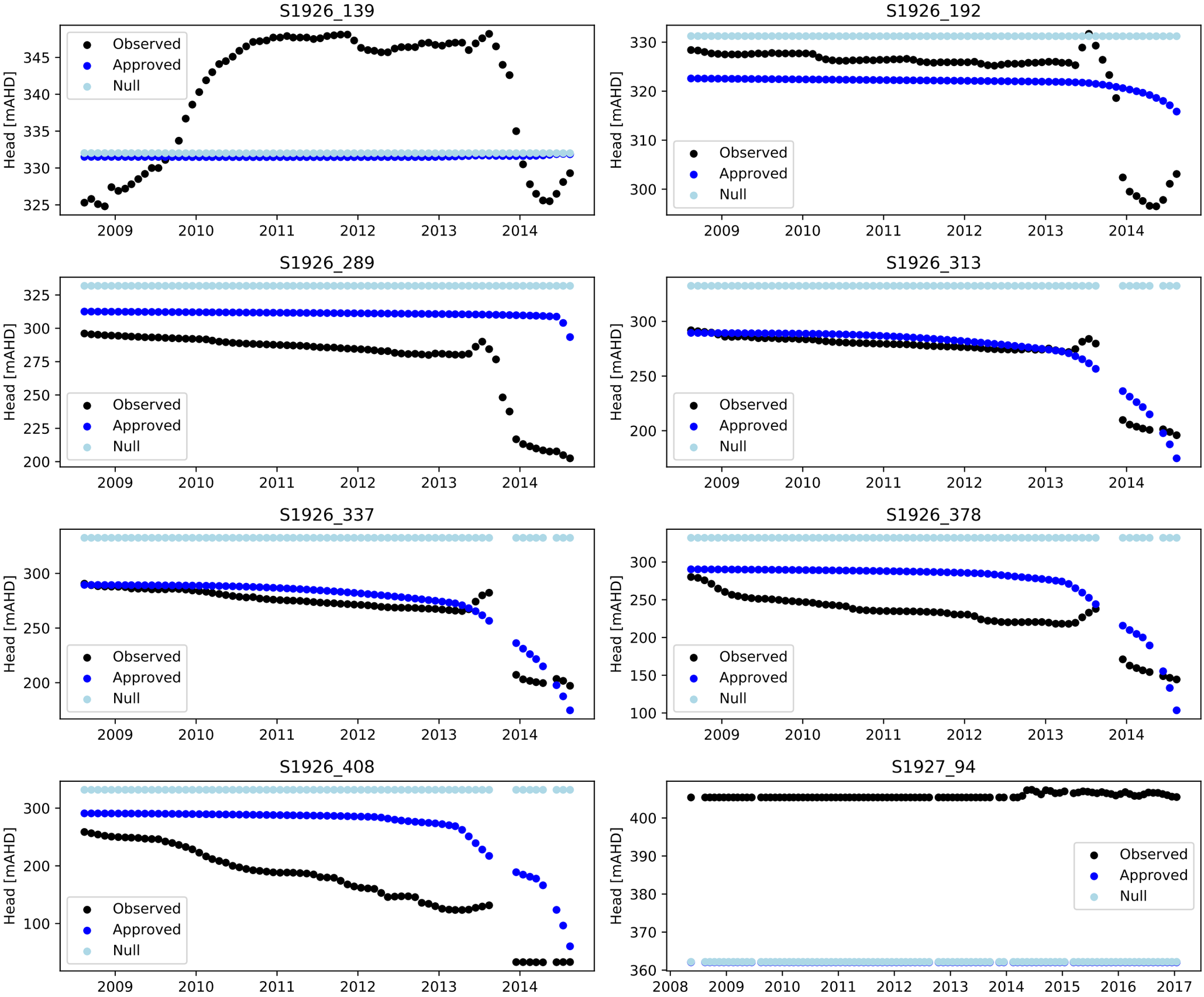

S1914_330
Head [mAHD]
Observed
Approved
Null

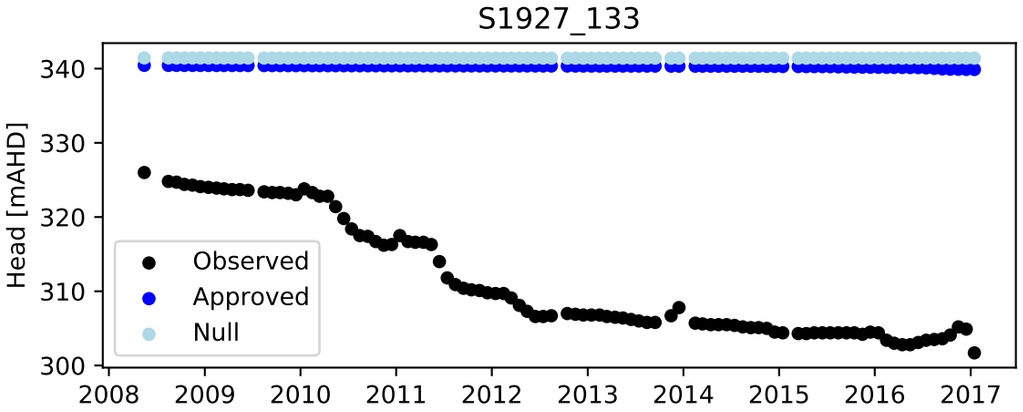

S1914_371
Head [mAHD]
Observed
Approved
Null

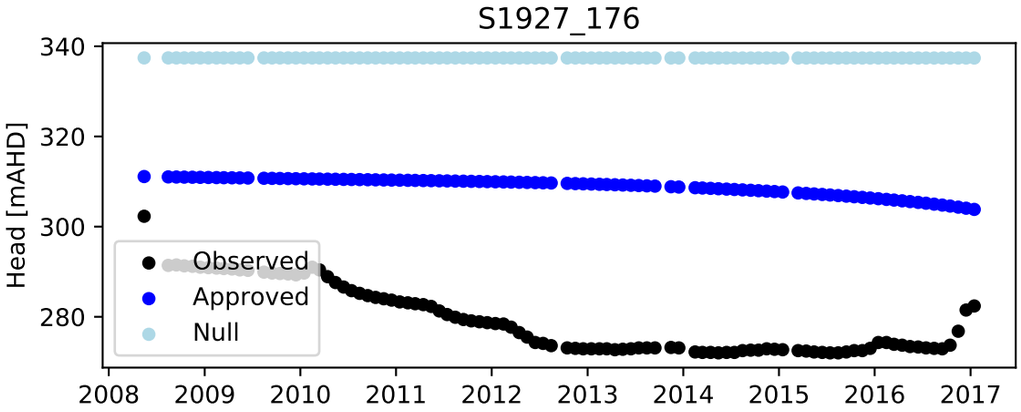

S1914_400
Head [mAHD]
Observed
Approved
Null

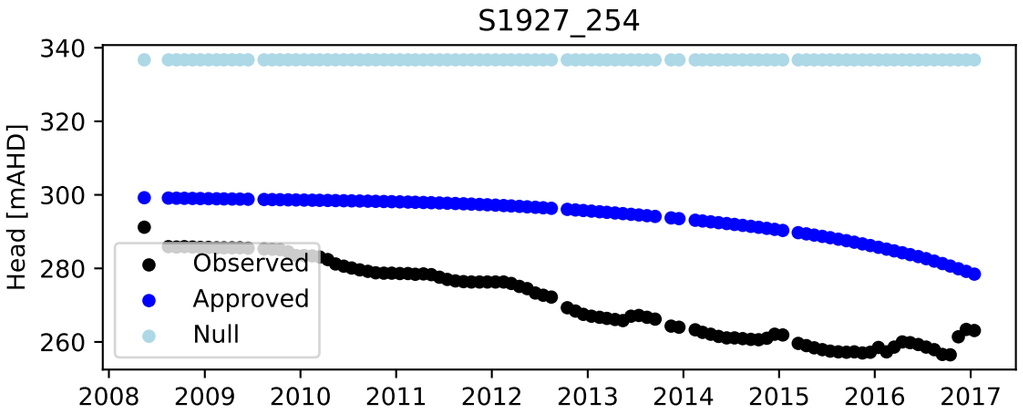

S1925_10
Head [mAHD]
Observed
Approved
Null

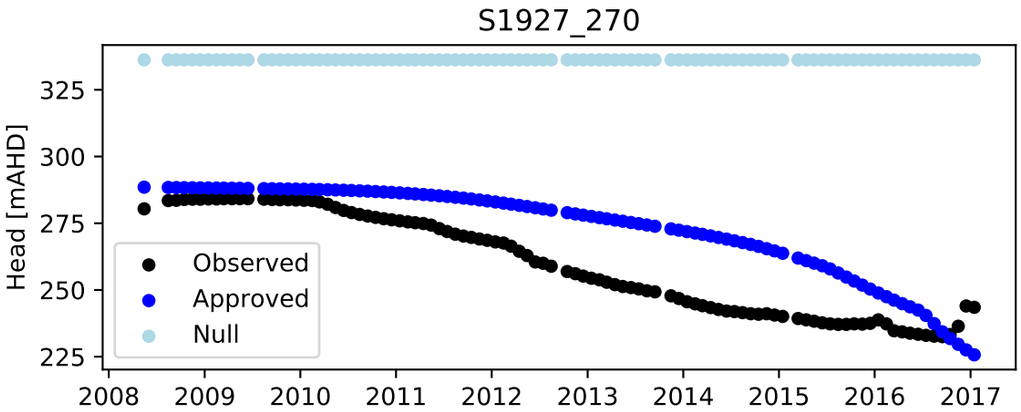

S1925_144
S1925_202
S1925_295
S1925_320
S1925_342
S1925_383
S1925_413
S1926_10
Head [mAHD]
Observed
Approved
Null

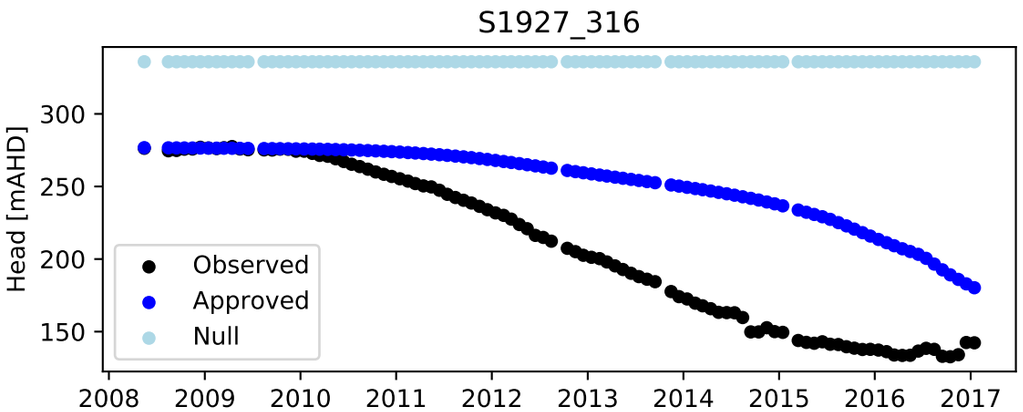

S1926_139
S1926_192
S1926_289
S1926_313
S1926_337
S1926_378
S1926_408
S1927_94
Observed
Approved
Null
Head [mAHD]

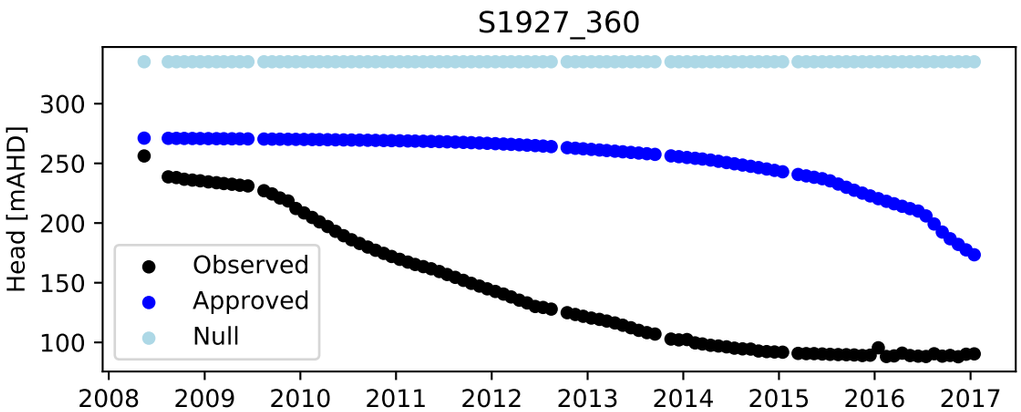

S1927_133
Head [mAHD]
Observed
Approved
Null

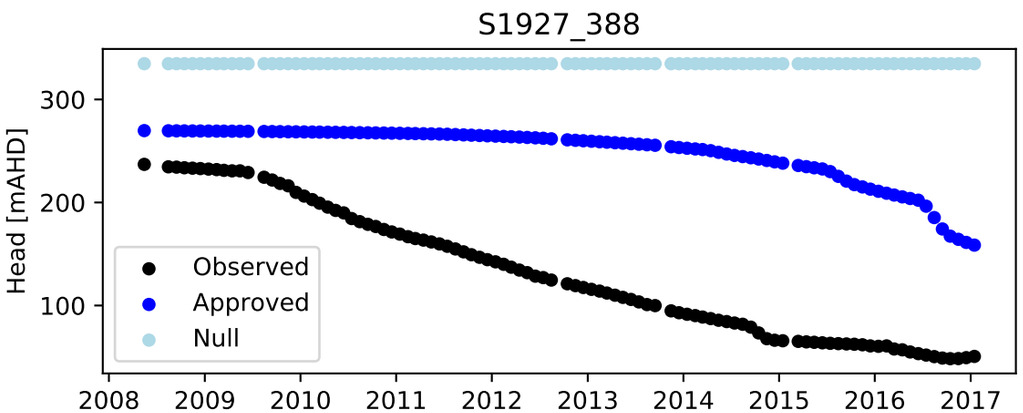

S1927_176
Head [mAHD]
Observed
Approved
Null

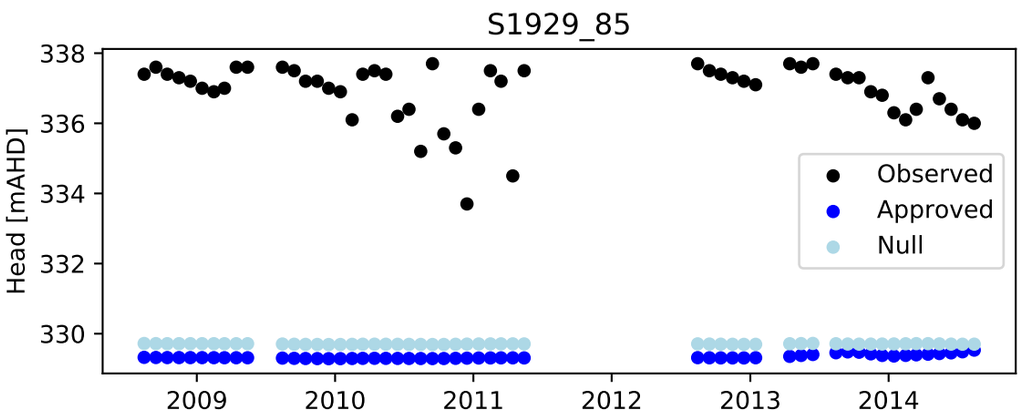

S1927_254
Head [mAHD]
Observed
Approved
Null

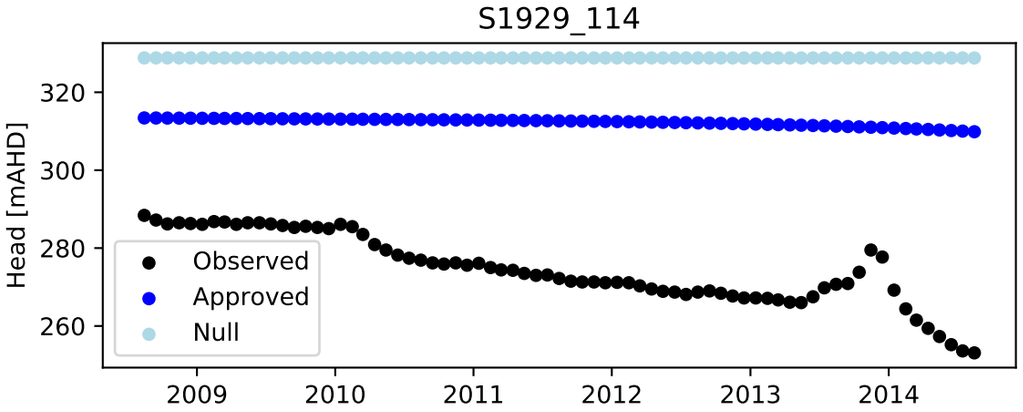

S1927_270
Head [mAHD]
Observed
Approved
Null

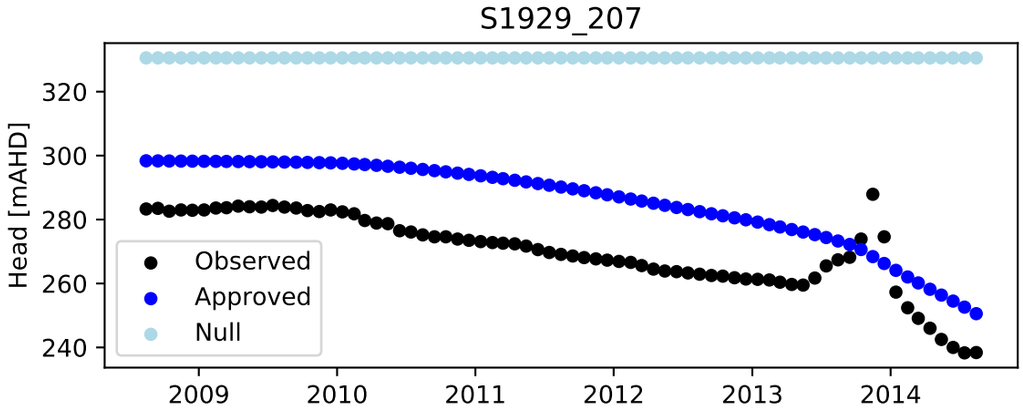

S1927_316
Head [mAHD]
Observed
Approved
Null

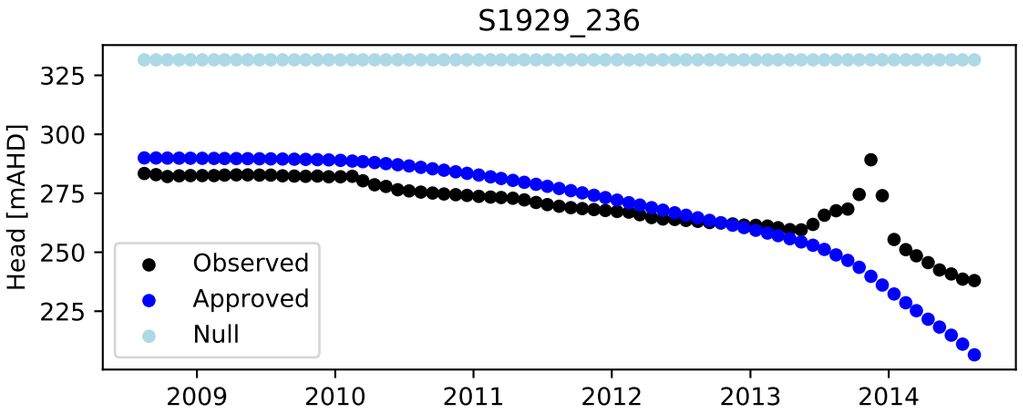

S1927_360
Head [mAHD]
Observed
Approved
Null

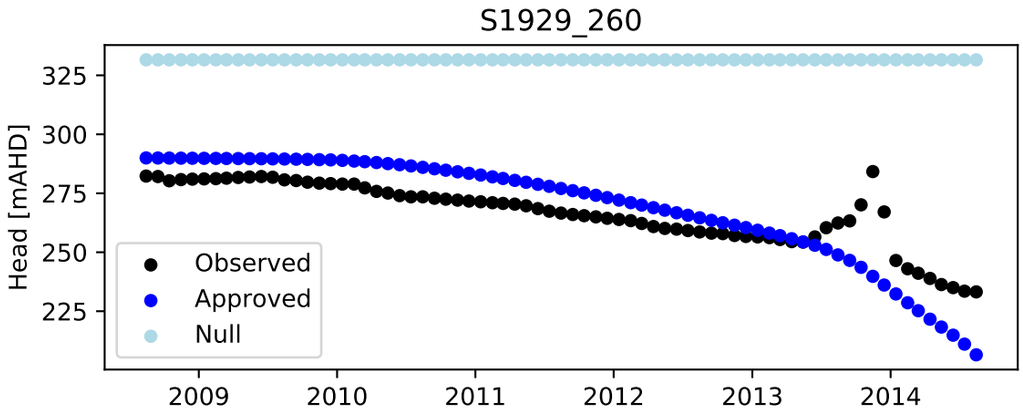

S1927_388
Head [mAHD]
Observed
Approved
Null

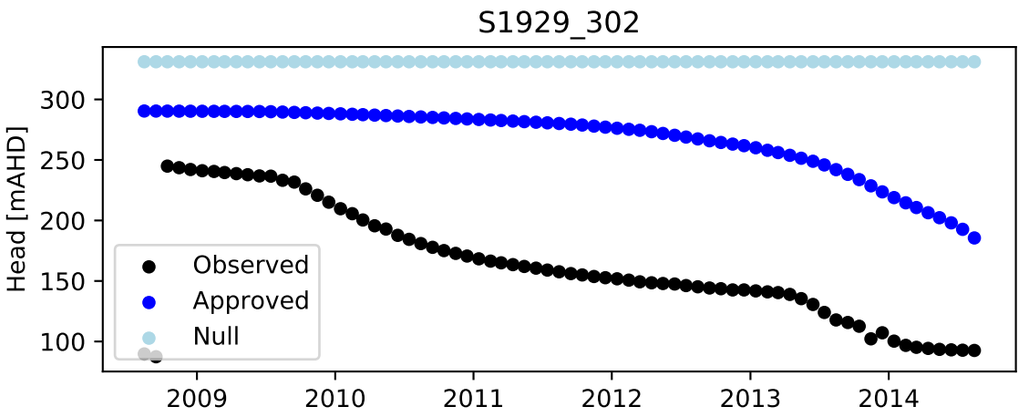

S1929_85
Head [mAHD]
Observed
Approved
Null

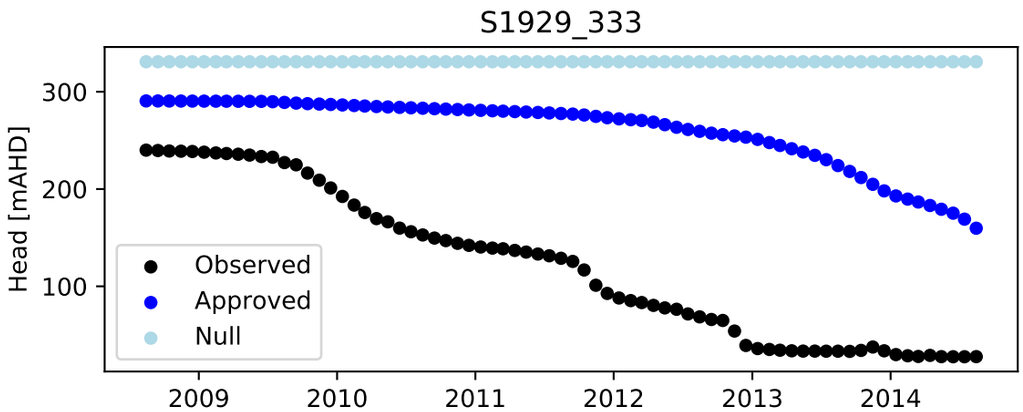

S1929_114
Head [mAHD]
320
300
280
260
Observed
Approved
Null
2009
2010
2011
2012
2013
2014

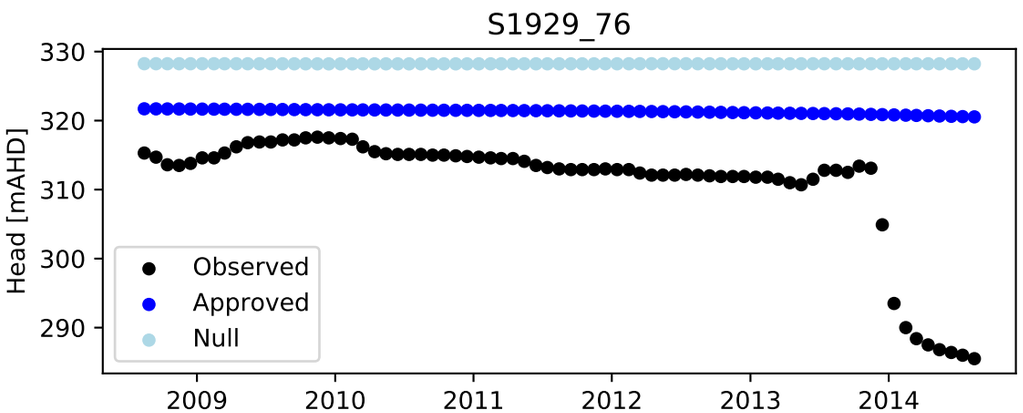

S1929_207
Head [mAHD]
320
300
280
260
240
Observed
Approved
Null
2009
2010
2011
2012
2013
2014

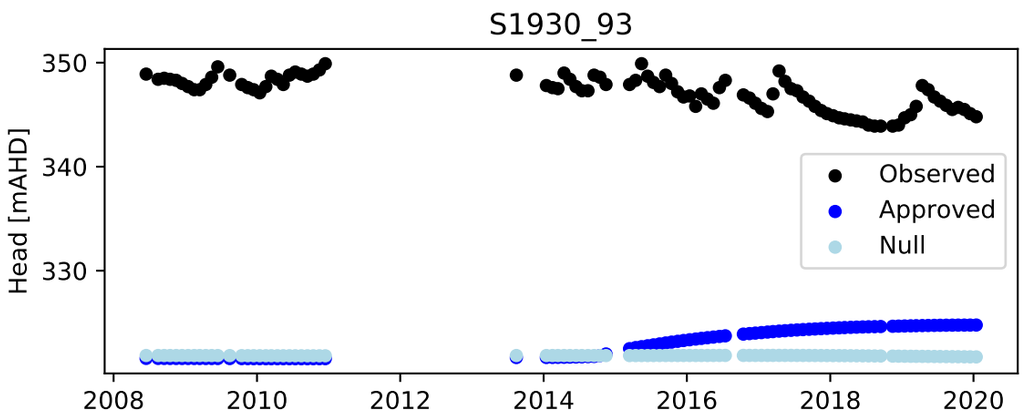

S1929_236
Head [mAHD]
325
300
275
250
225
Observed
Approved
Null
2009
2010
2011
2012
2013
2014

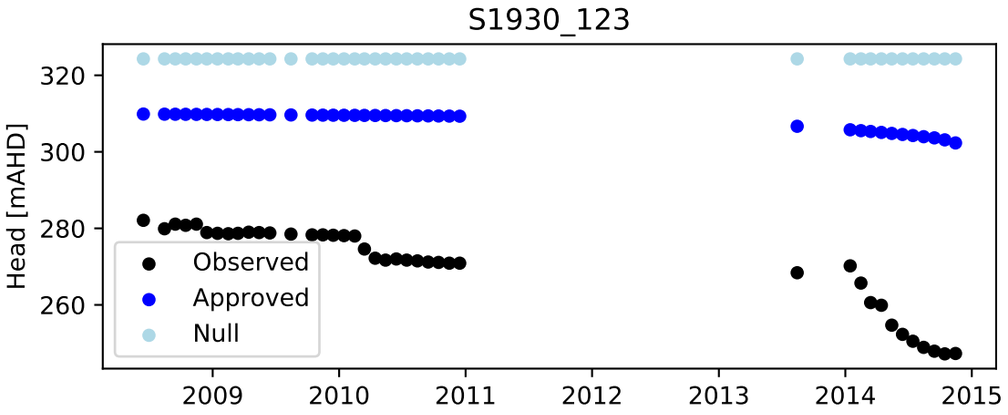

S1929_260
Head [mAHD]
325
300
275
250
225
Observed
Approved
Null
2009
2010
2011
2012
2013
2014

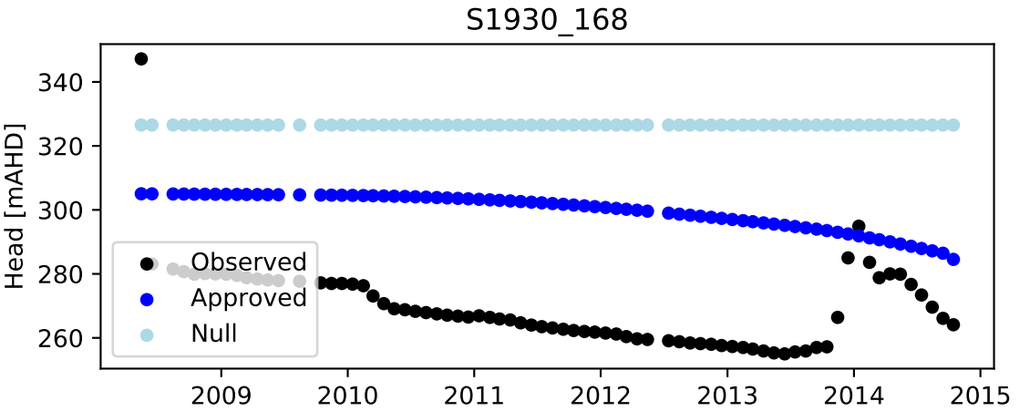

S1929_302
Head [mAHD]
300
250
200
150
100
Observed
Approved
Null
2009
2010
2011
2012
2013
2014

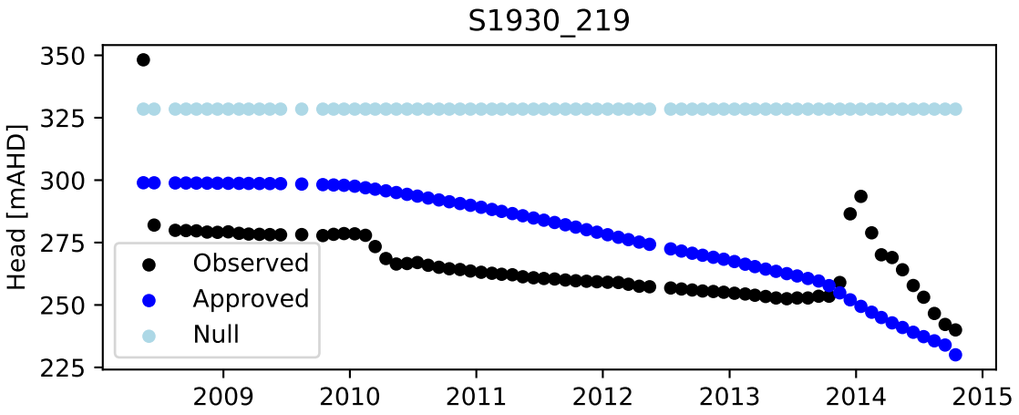

S1929_333
Head [mAHD]
300
200
100
Observed
Approved
Null
2009
2010
2011
2012
2013
2014

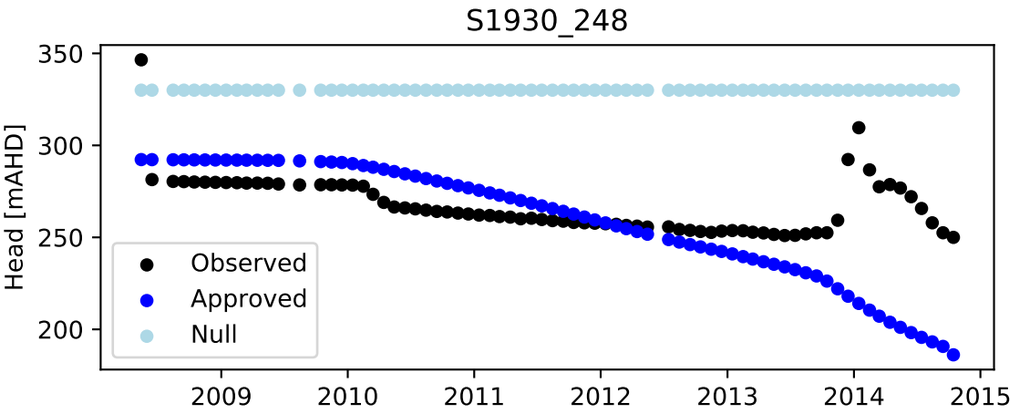

S1929_76
Head [mAHD]
330
320
310
300
290
Observed
Approved
Null
2009
2010
2011
2012
2013
2014

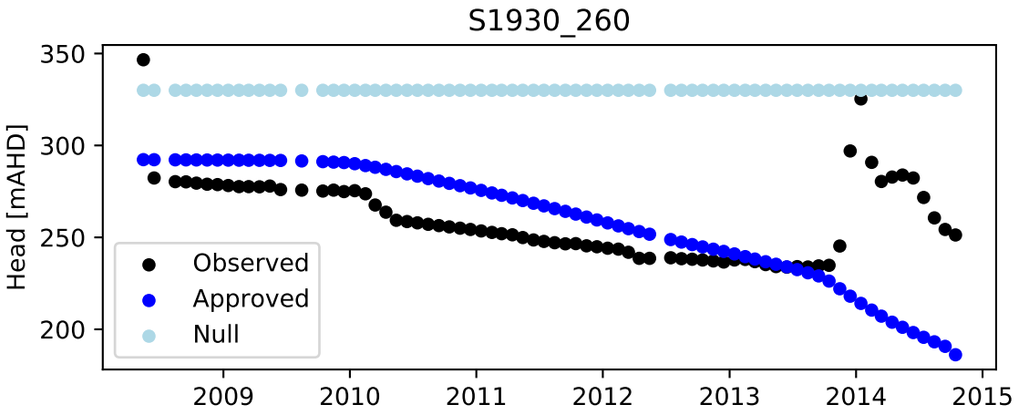

S1930_93
Head [mAHD]
350
340
330
Observed
Approved
Null
2008
2010
2012
2014
2016
2018
2020

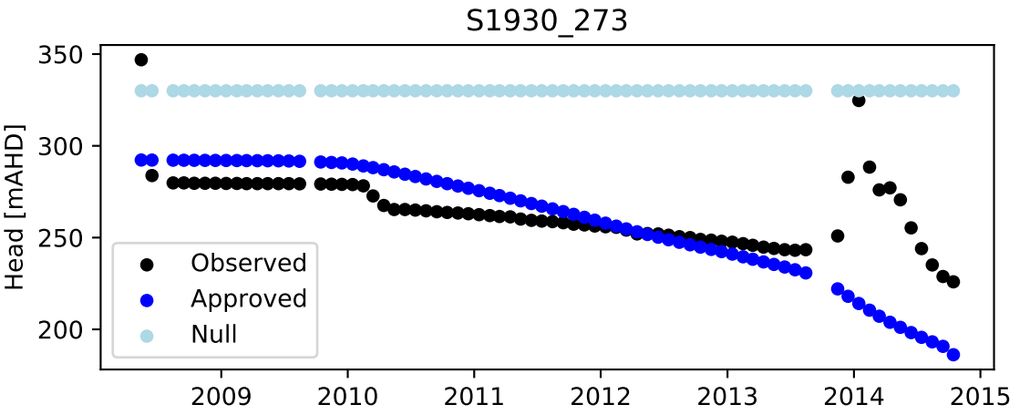

S1930_123
Head [mAHD]
320
300
280
260
Observed
Approved
Null
2009
2010
2011
2012
2013
2014
2015

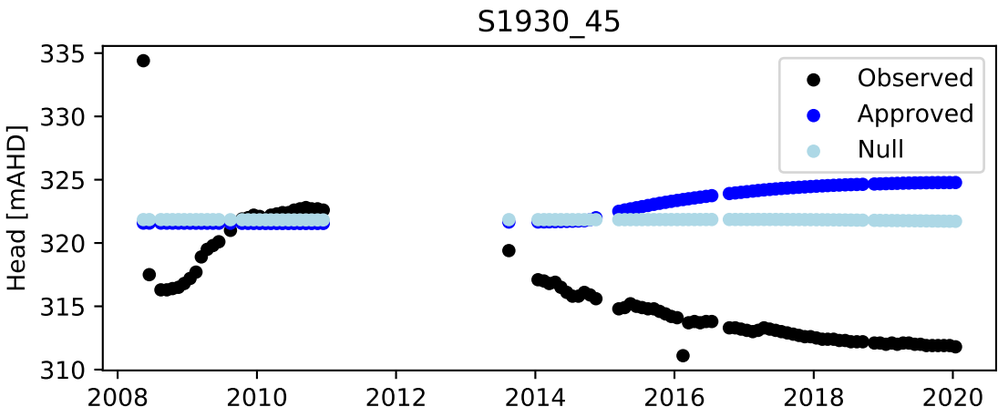

S1930_168
Head [mAHD]
340
320
300
280
260
Observed
Approved
Null
2009
2010
2011
2012
2013
2014
2015

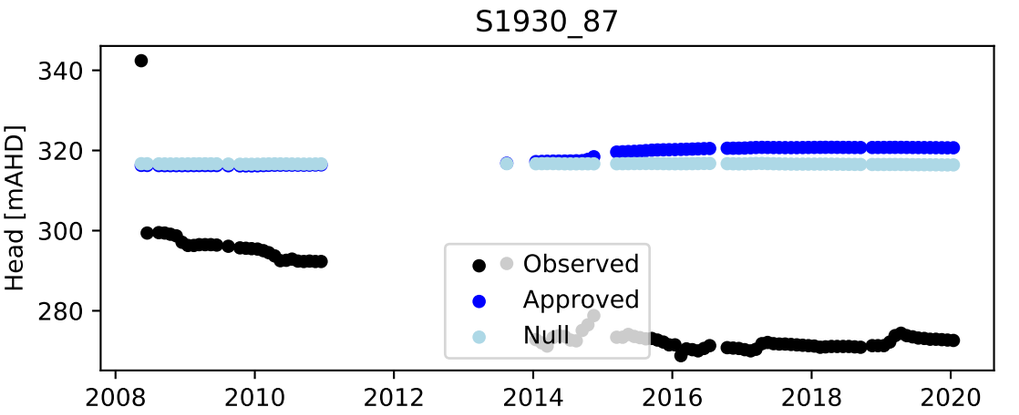

S1930_219
Head [mAHD]
350
325
300
275
250
225
Observed
Approved
Null
2009
2010
2011
2012
2013
2014
2015

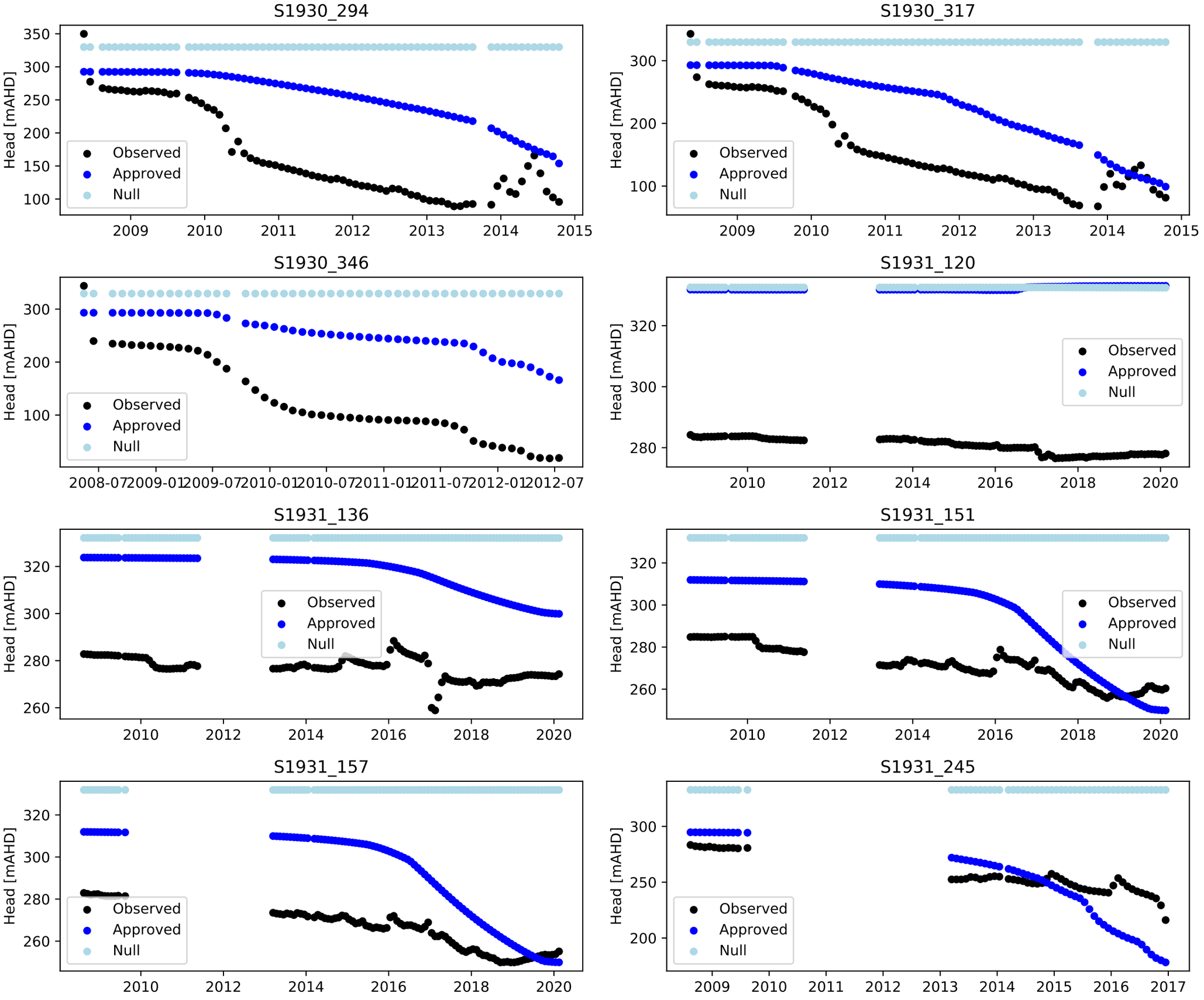

S1930_248
Head [mAHD]
350
300
250
200
Observed
Approved
Null
2009
2010
2011
2012
2013
2014
2015

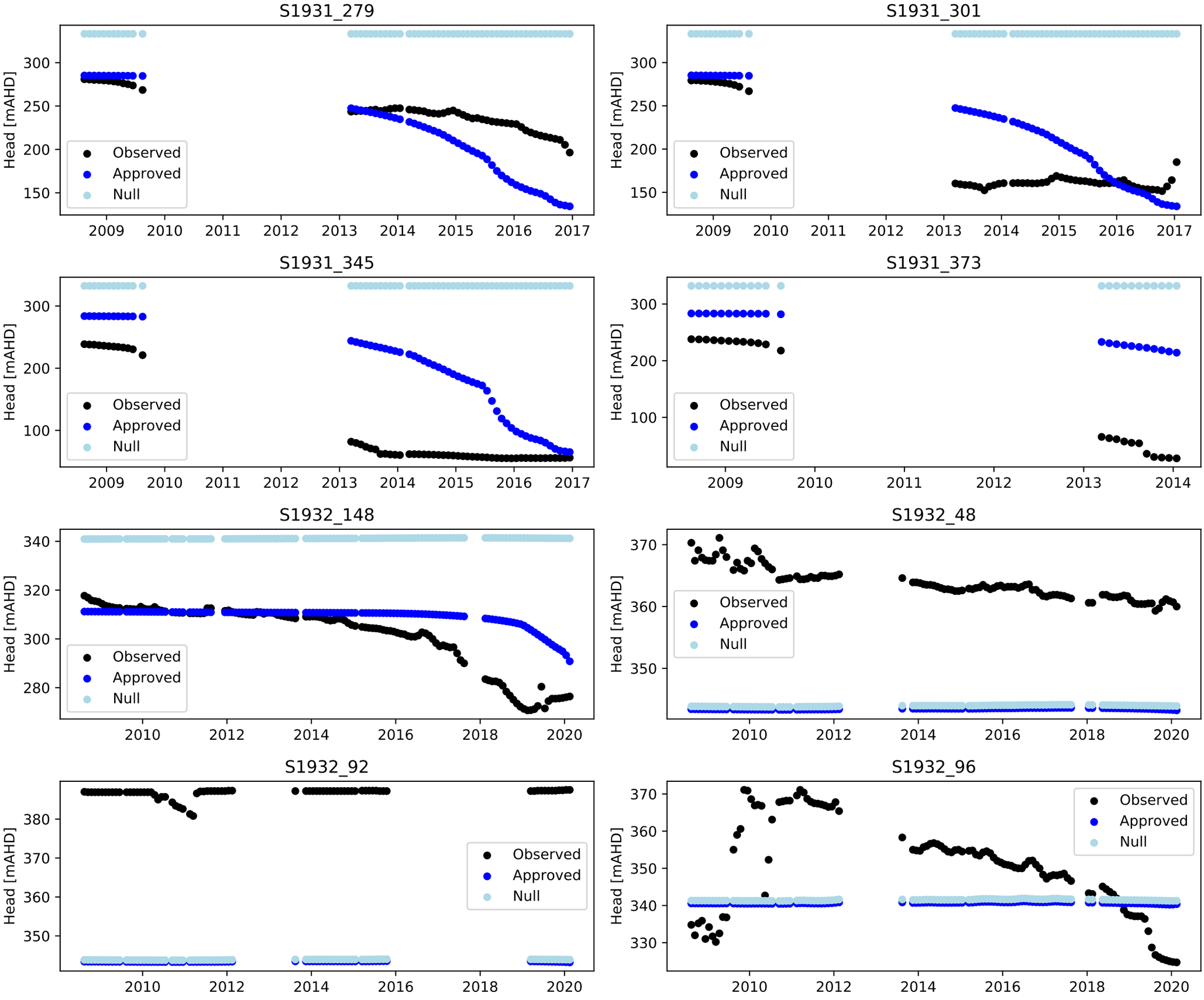

S1930_260
Head [mAHD]
350
300
250
200
Observed
Approved
Null
2009
2010
2011
2012
2013
2014
2015

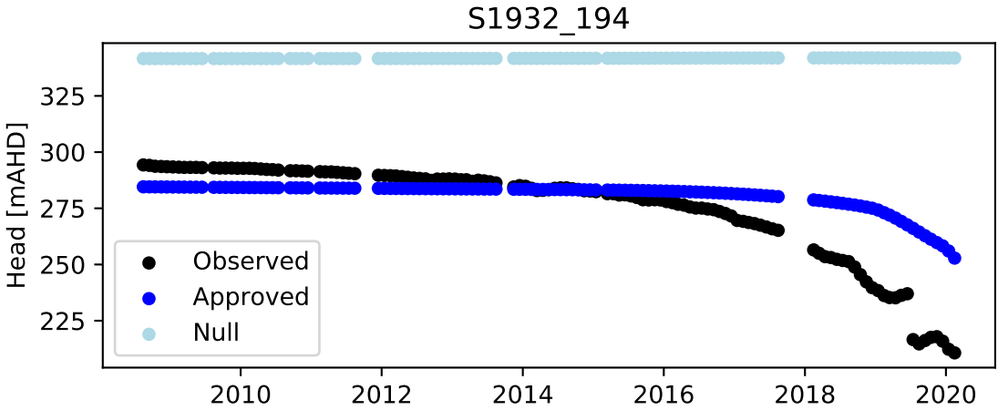

S1930_273
Head [mAHD]
350
300
250
200
Observed
Approved
Null
2009
2010
2011
2012
2013
2014
2015

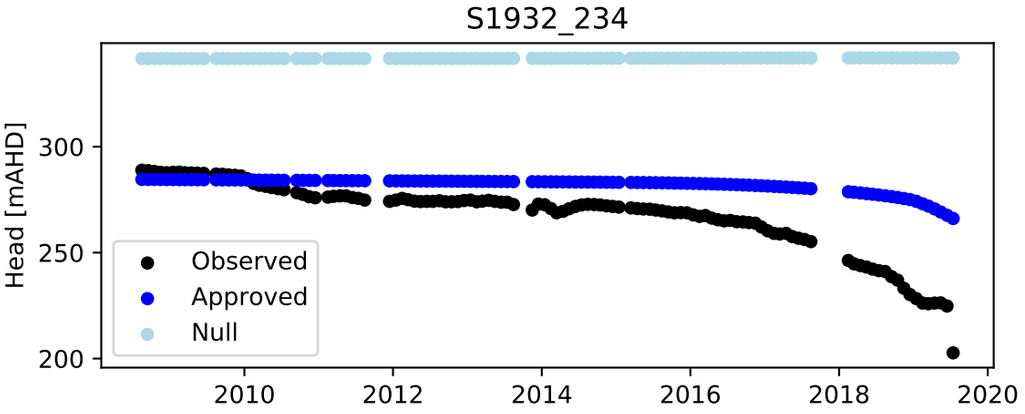

S1930_45
Head [mAHD]
335
330
325
320
315
310
Observed
Approved
Null
2008
2010
2012
2014
2016
2018
2020

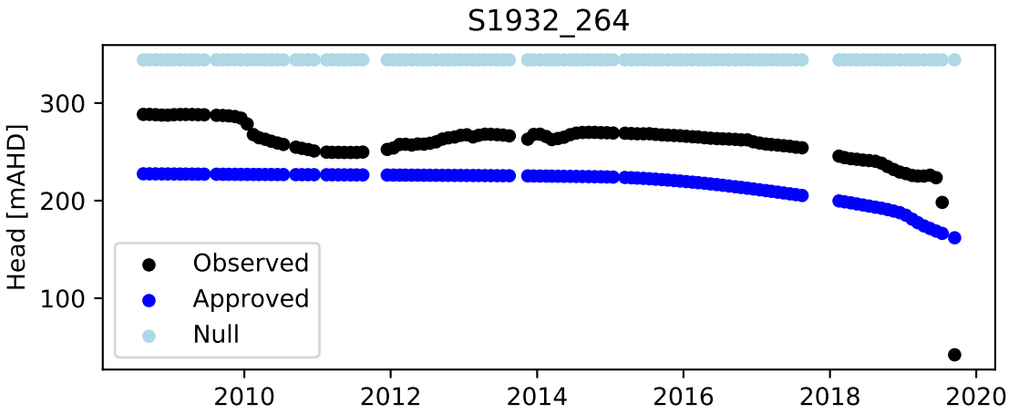

S1930_87
Head [mAHD]
340
320
300
280
Observed
Approved
Null
2008
2010
2012
2014
2016
2018
2020

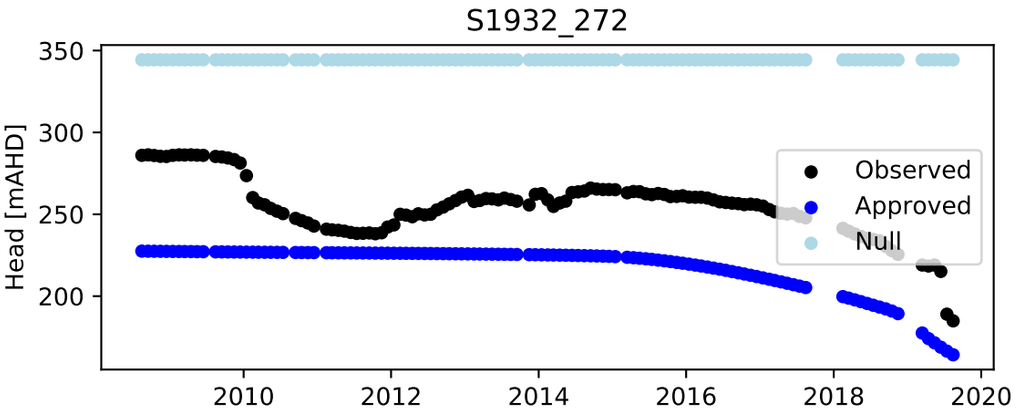

S1930_294
S1930_317
S1930_346
S1931_120
S1931_136
S1931_151
S1931_157
S1931_245
Head [mAHD]
Observed
Approved
Null

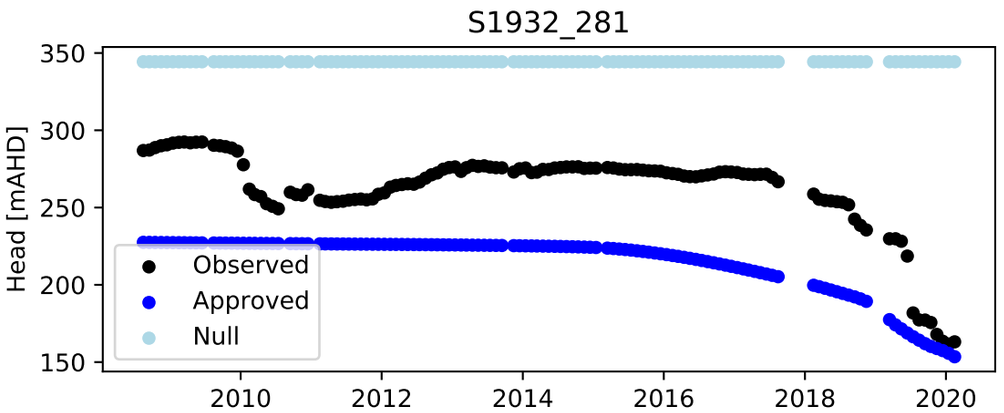

S1931_279
S1931_301
S1931_345
S1931_373
S1932_148
S1932_48
S1932_92
S1932_96
Head [mAHD]
Observed
Approved
Null

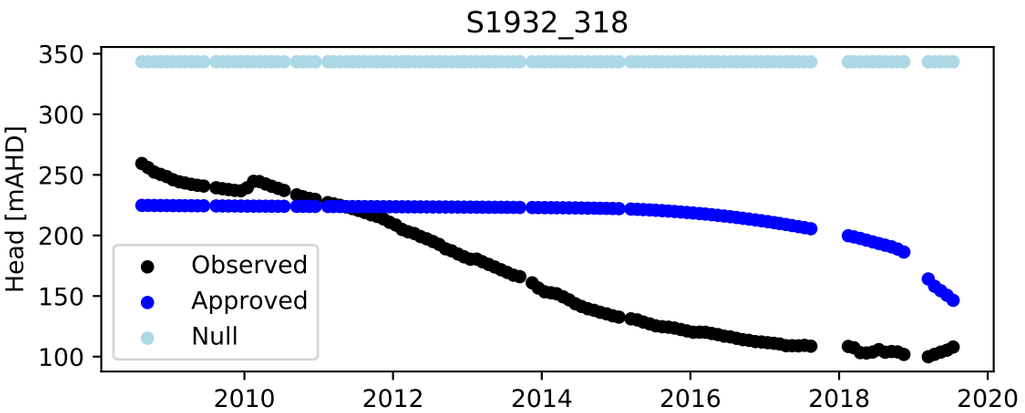

S1932_194
Head [mAHD]
325
300
275
250
225
Observed
Approved
Null
2010
2012
2014
2016
2018
2020

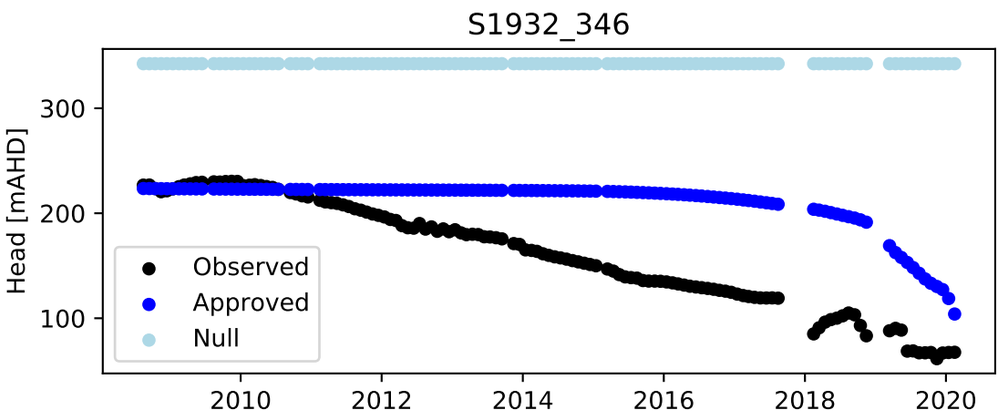

S1932_234
Head [mAHD]
300
250
200
Observed
Approved
Null
2010
2012
2014
2016
2018
2020

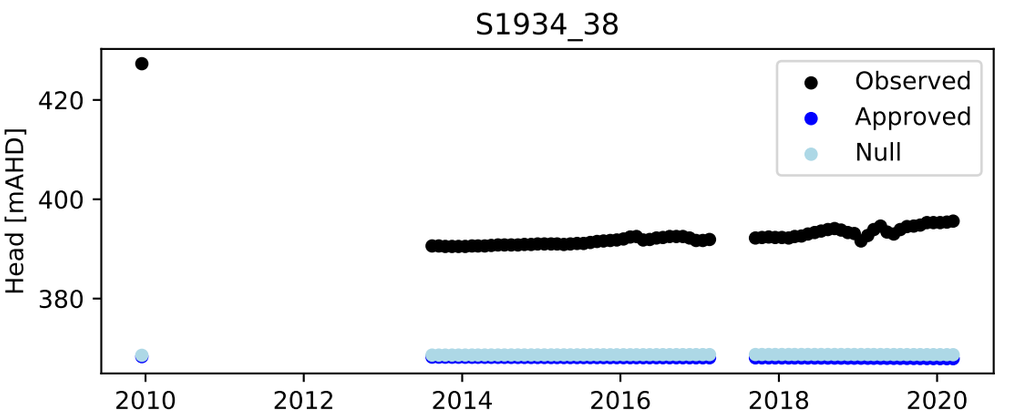

S1932_264
Head [mAHD]
300
200
100
Observed
Approved
Null
2010
2012
2014
2016
2018
2020

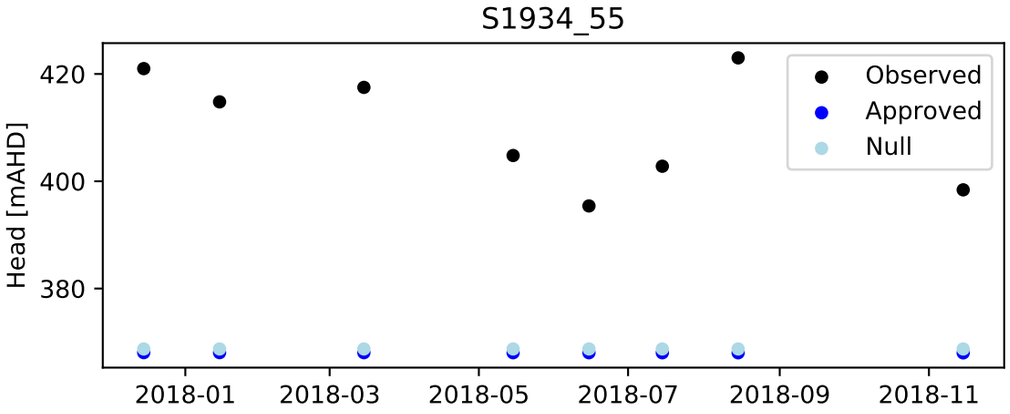

S1932_272
Head [mAHD]
350
300
250
200
Observed
Approved
Null
2010
2012
2014
2016
2018
2020

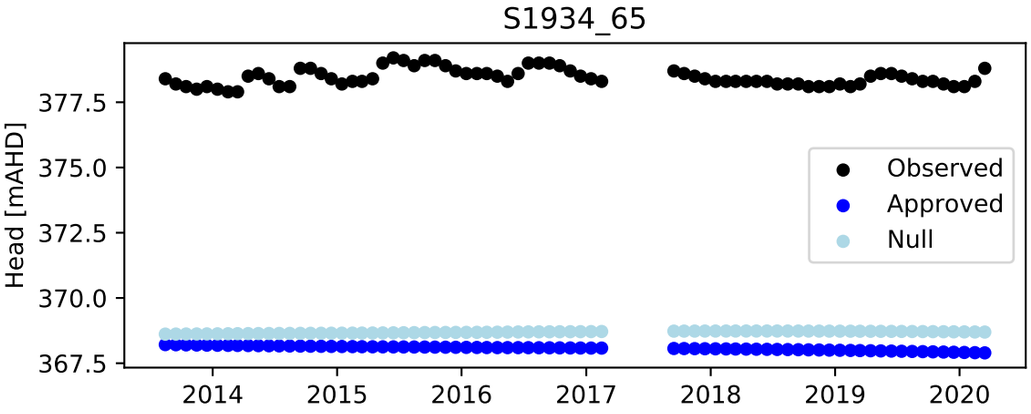

S1932_281
Head [mAHD]
350
300
250
200
150
Observed
Approved
Null
2010
2012
2014
2016
2018
2020

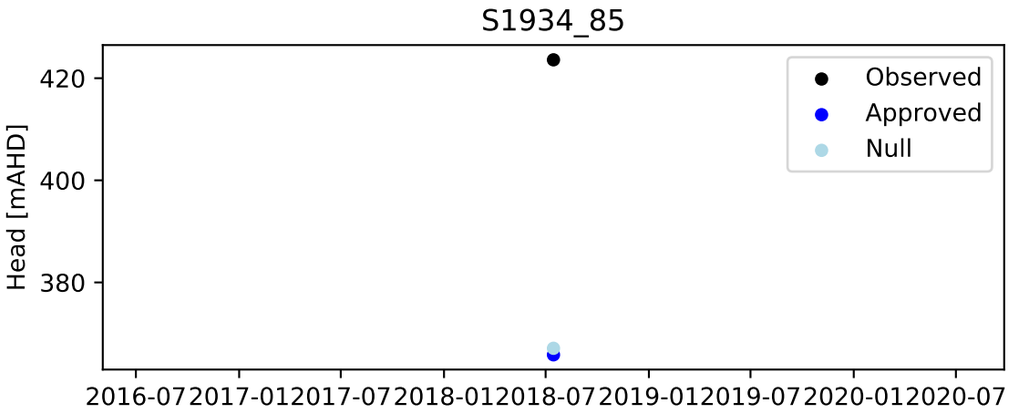

S1932_318
Head [mAHD]
350
300
250
200
150
100
Observed
Approved
Null
2010
2012
2014
2016
2018
2020

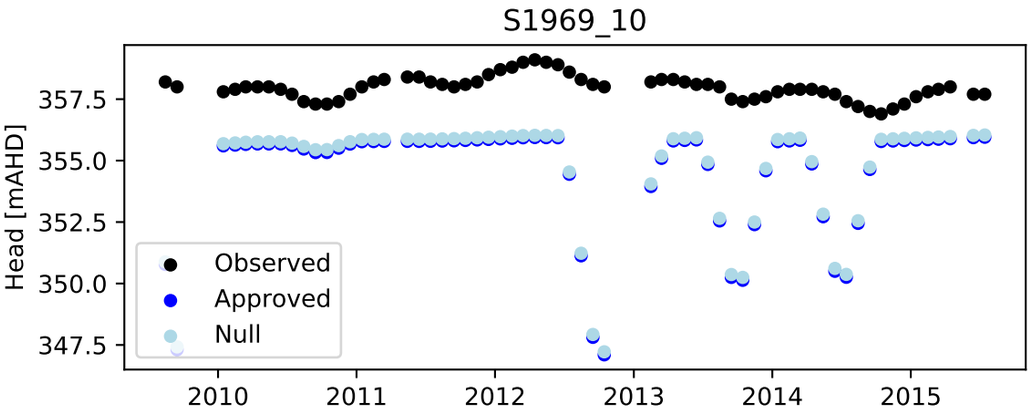

S1932_346
Head [mAHD]
300
200
100
Observed
Approved
Null
2010
2012
2014
2016
2018
2020

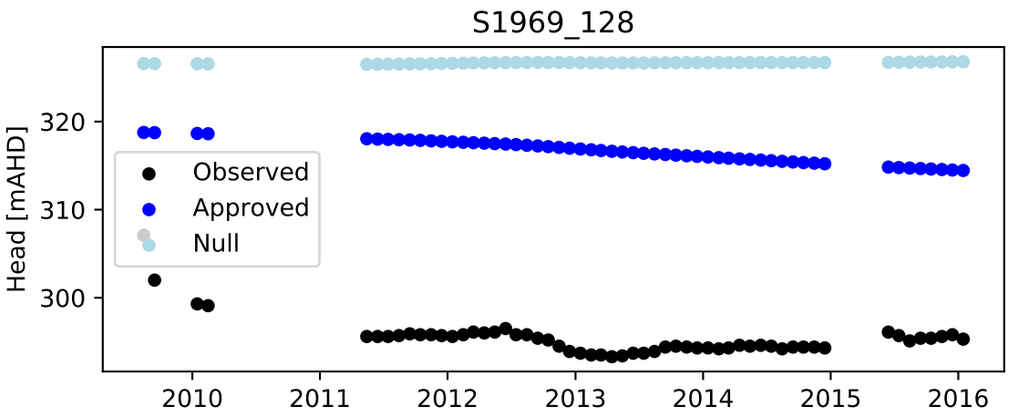

S1934_38
Head [mAHD]
420
400
380
Observed
Approved
Null
2010
2012
2014
2016
2018
2020

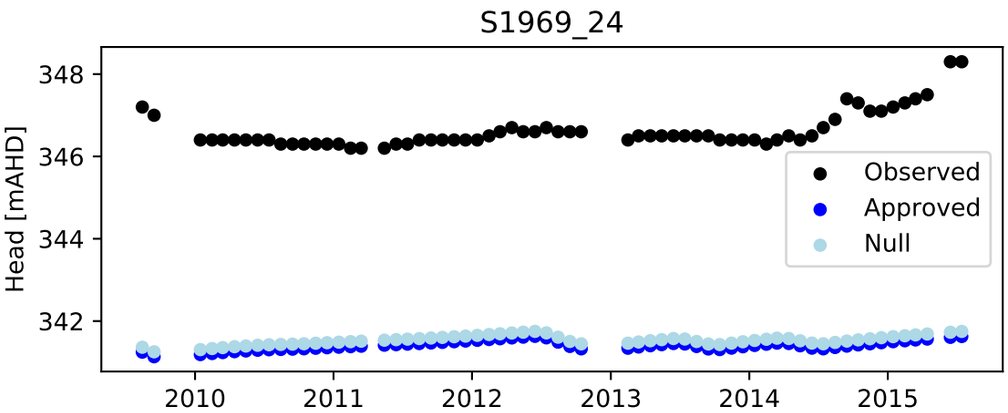

S1934_55
Head [mAHD]
420
400
380
2018-01
2018-03
2018-05
2018-07
2018-09
2018-11
Observed
Approved
Null

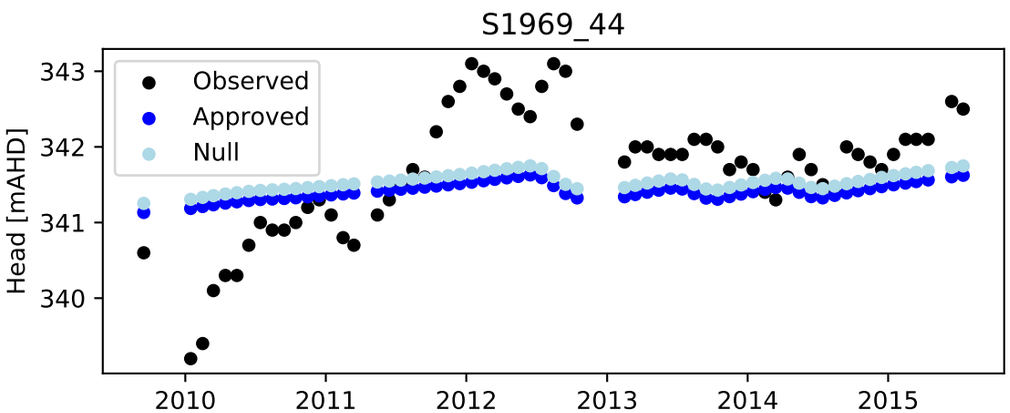

S1934_65
Head [mAHD]
377.5
375.0
372.5
370.0
367.5
2014
2015
2016
2017
2018
2019
2020
Observed
Approved
Null

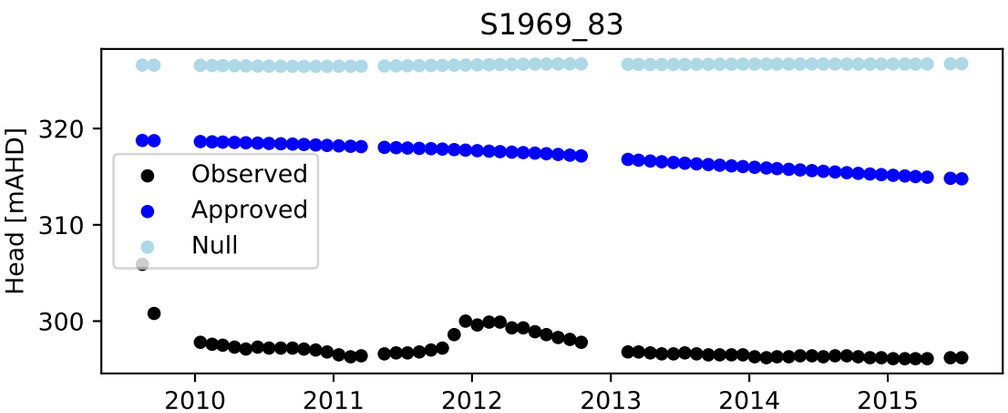

S1934_85
Head [mAHD]
420
400
380
2016-07
2017-01
2017-07
2018-01
2018-07
2019-01
2019-07
2020-01
2020-07
Observed
Approved
Null

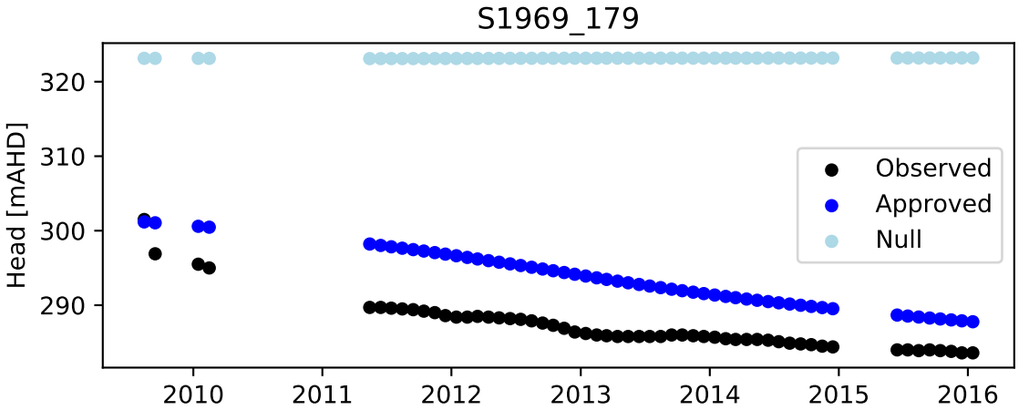

S1969_10
Head [mAHD]
357.5
355.0
352.5
350.0
347.5
2010
2011
2012
2013
2014
2015
Observed
Approved
Null

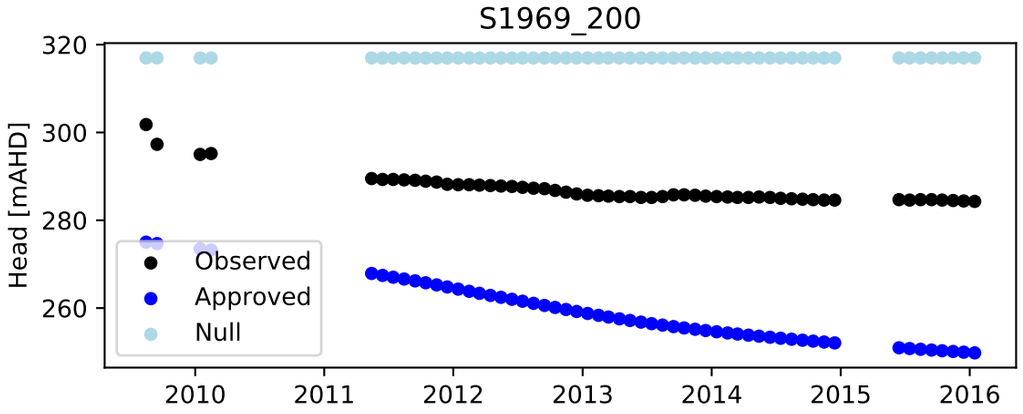

S1969_128
Head [mAHD]
320
310
300
2010
2011
2012
2013
2014
2015
2016
Observed
Approved
Null

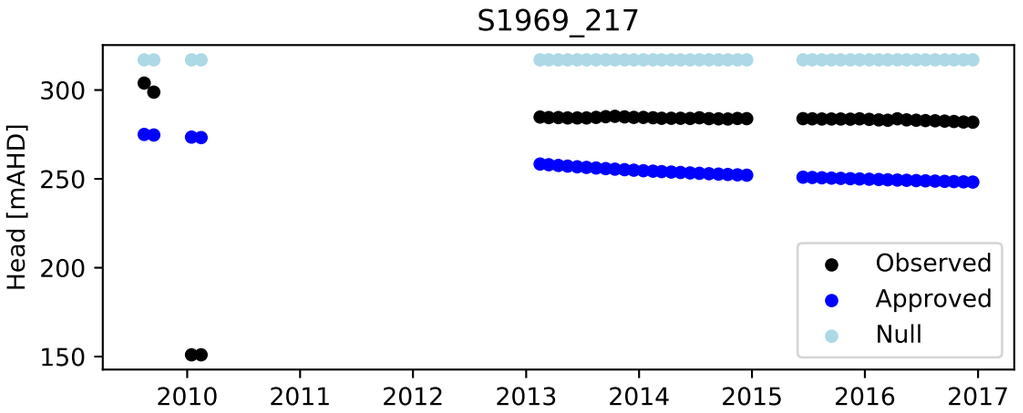

S1969_24
Head [mAHD]
348
346
344
342
2010
2011
2012
2013
2014
2015
Observed
Approved
Null

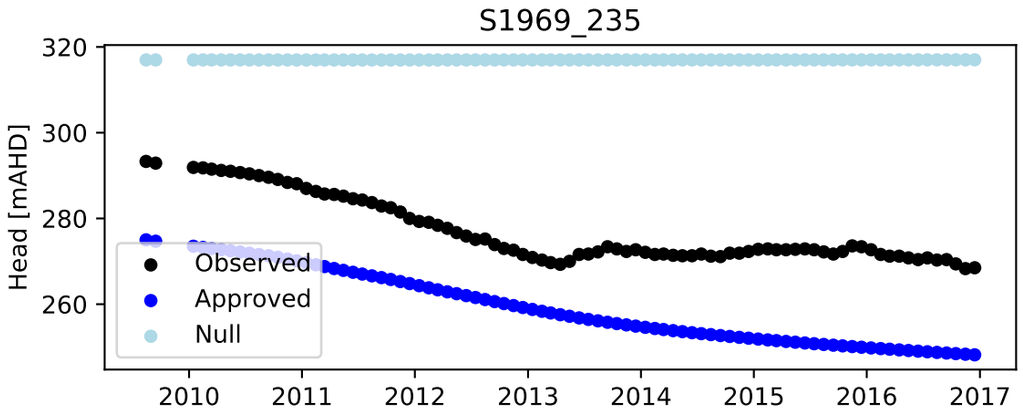

S1969_44
Head [mAHD]
343
342
341
340
2010
2011
2012
2013
2014
2015
Observed
Approved
Null

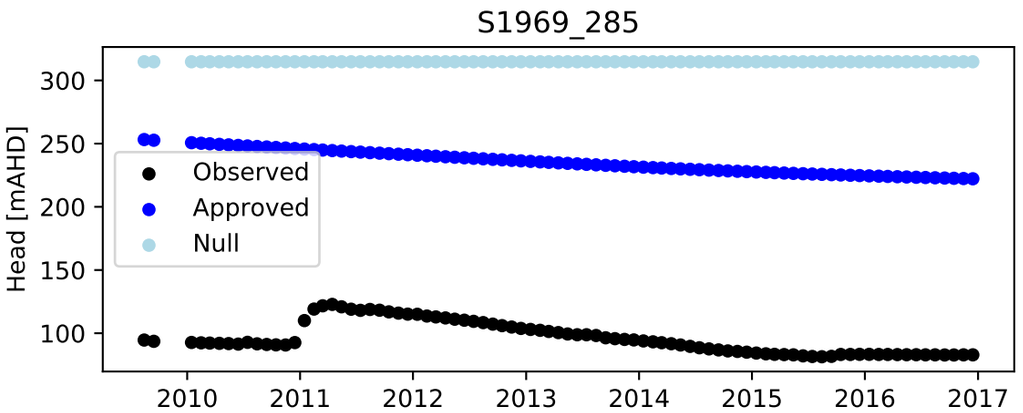

S1969_83
Head [mAHD]
320
310
300
2010
2011
2012
2013
2014
2015
Observed
Approved
Null

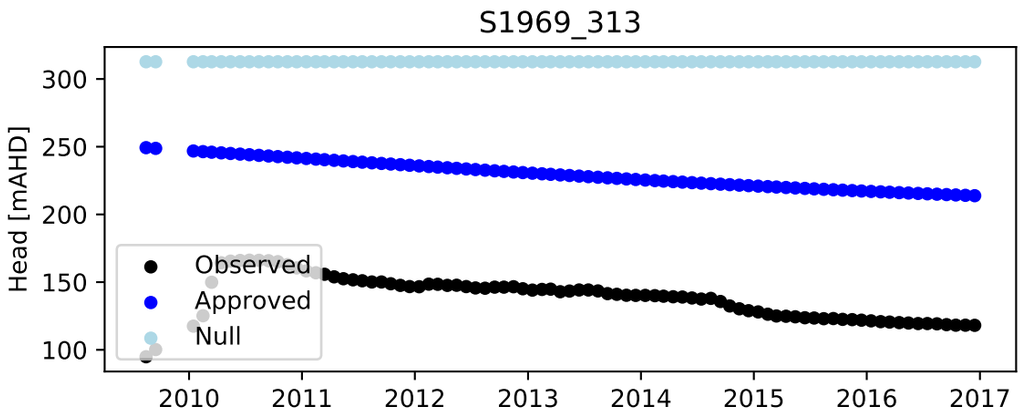

S1969_179
Head [mAHD]
320
310
300
290
2010
2011
2012
2013
2014
2015
2016
Observed
Approved
Null

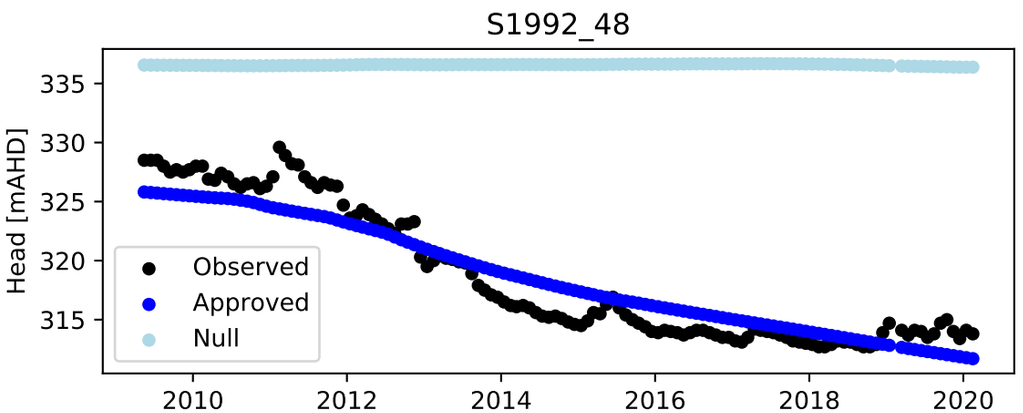

S1969_200
Head [mAHD]
320
300
280
260
2010
2011
2012
2013
2014
2015
2016
Observed
Approved
Null

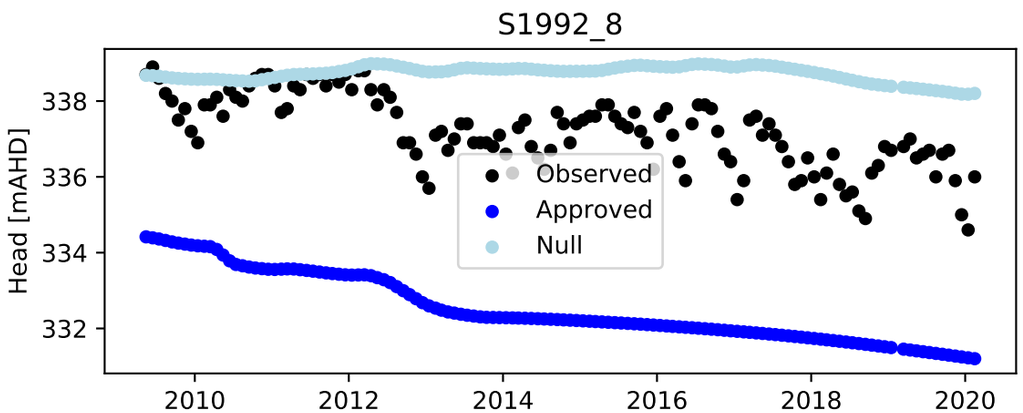

S1969_217
Head [mAHD]
300
250
200
150
2010
2011
2012
2013
2014
2015
2016
2017
Observed
Approved
Null

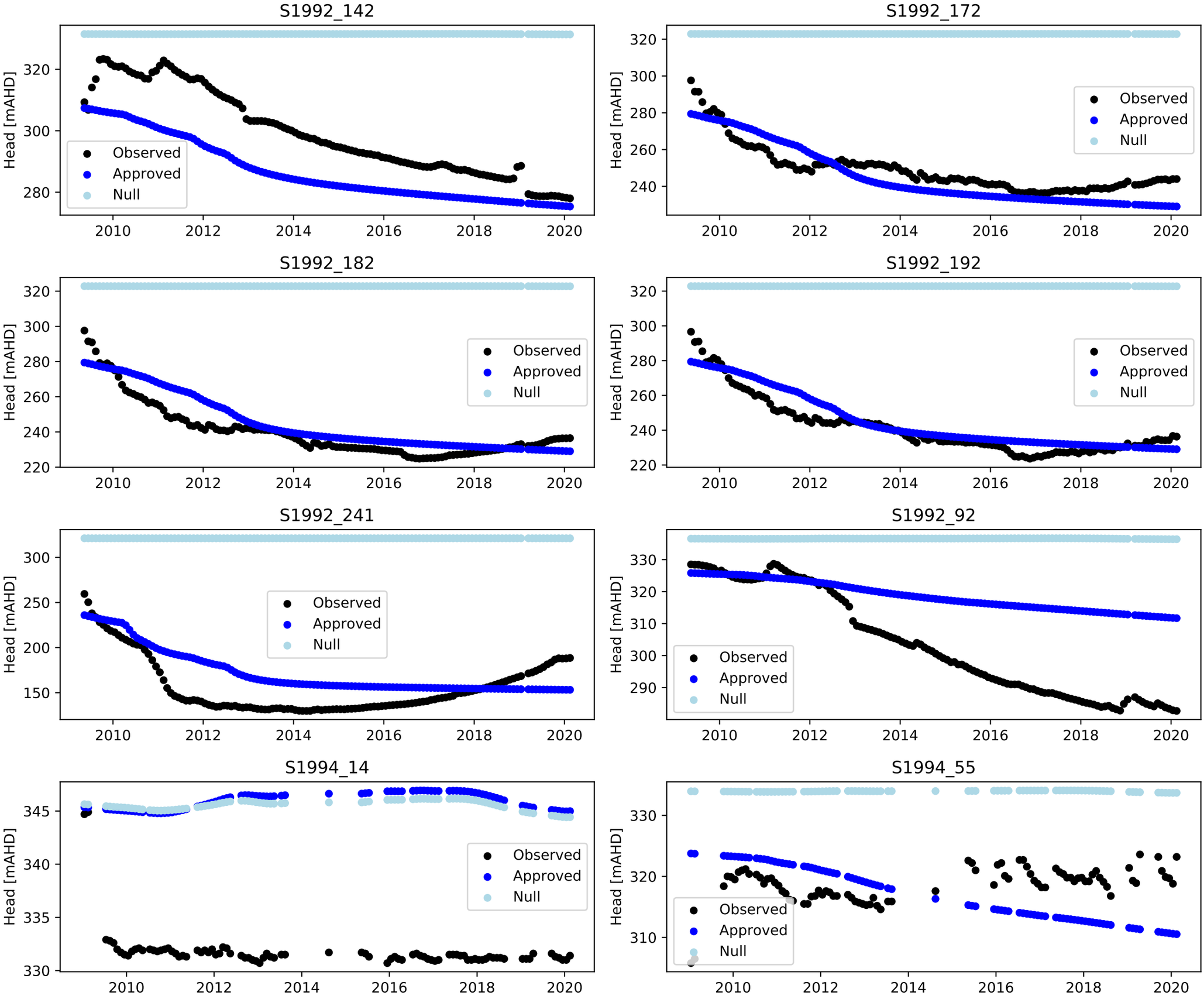

S1969_235
Head [mAHD]
320
300
280
260
2010
2011
2012
2013
2014
2015
2016
2017
Observed
Approved
Null

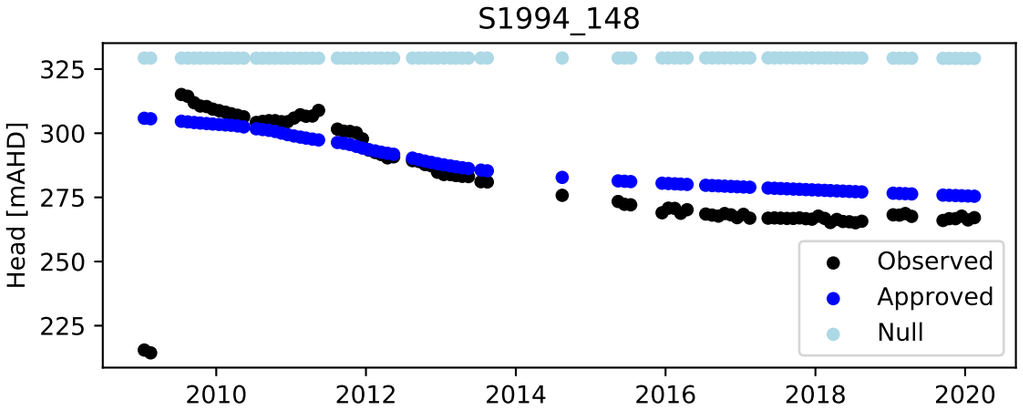

S1969_285
Head [mAHD]
300
250
200
150
100
2010
2011
2012
2013
2014
2015
2016
2017
Observed
Approved
Null

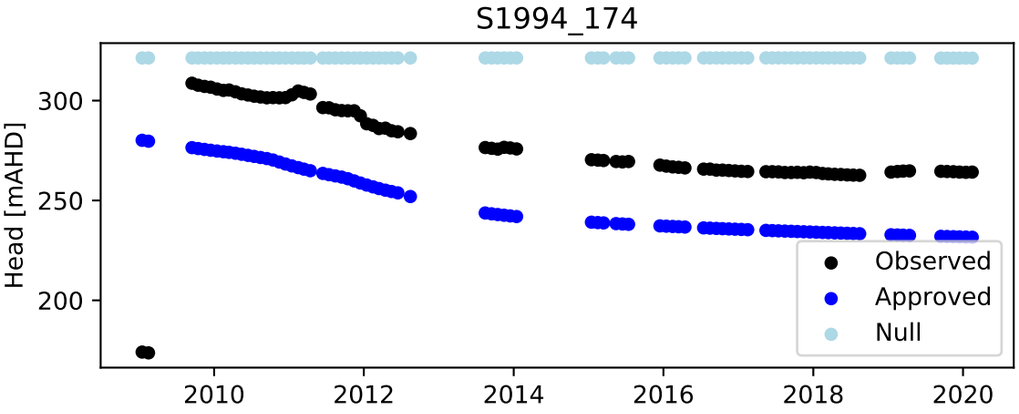

S1969_313
Head [mAHD]
300
250
200
150
100
2010
2011
2012
2013
2014
2015
2016
2017
Observed
Approved
Null

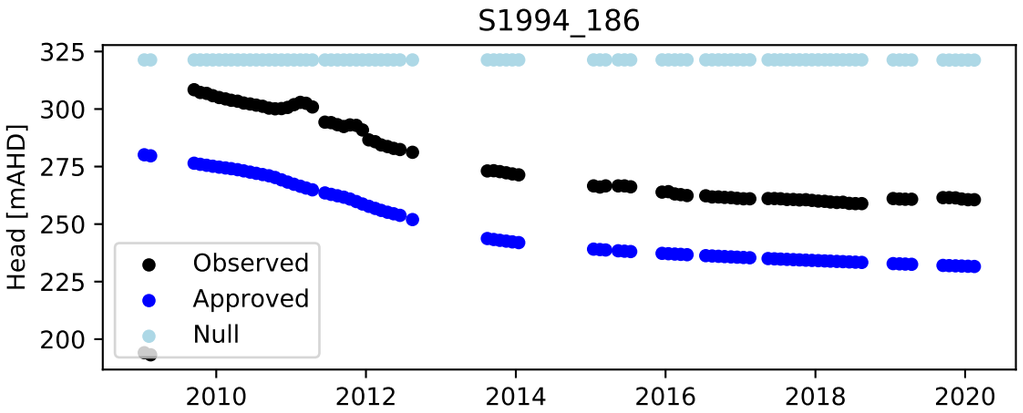

S1992_48
Head [mAHD]
335
330
325
320
315
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

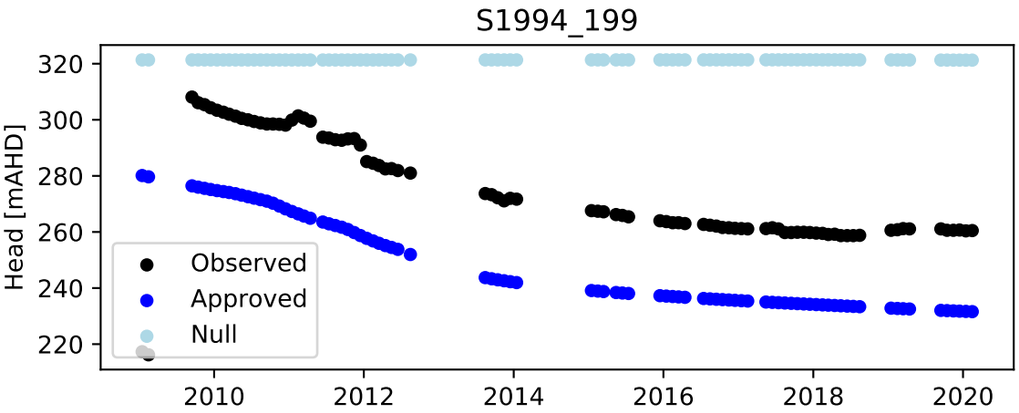

S1992_8
Head [mAHD]
338
336
334
332
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

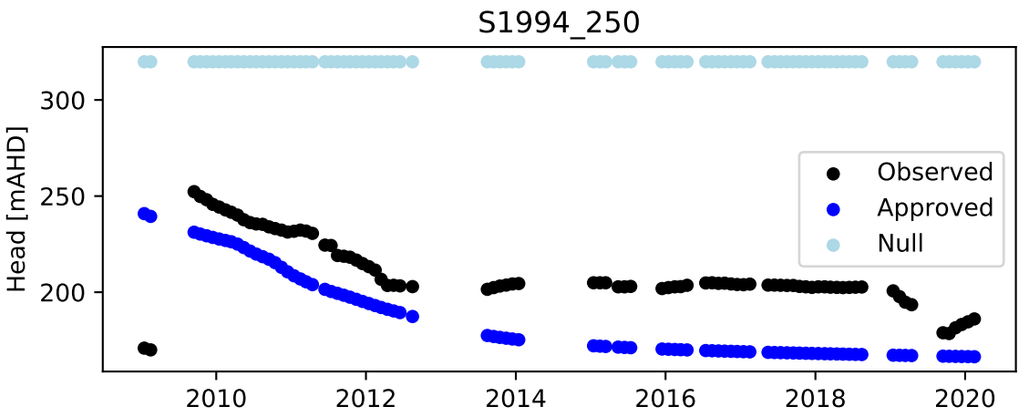

S1992_142
S1992_172
S1992_182
S1992_192
S1992_241
S1992_92
S1994_14
S1994_55
Head [mAHD]
Observed
Approved
Null
2010
2012
2014
2016
2018
2020

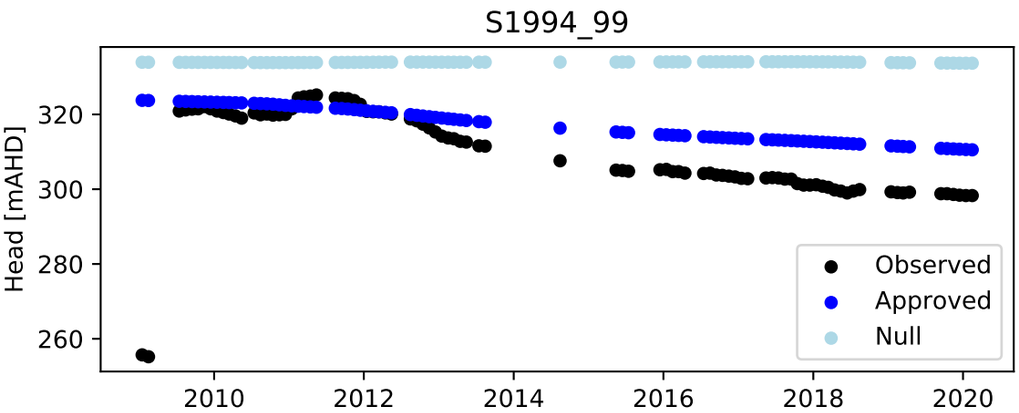

S1994_148
Head [mAHD]
325
300
275
250
225
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

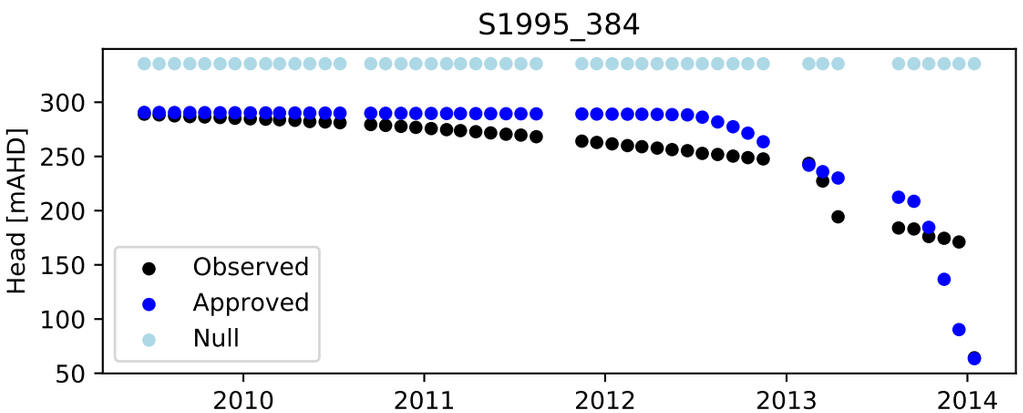

S1994_174
Head [mAHD]
300
250
200
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

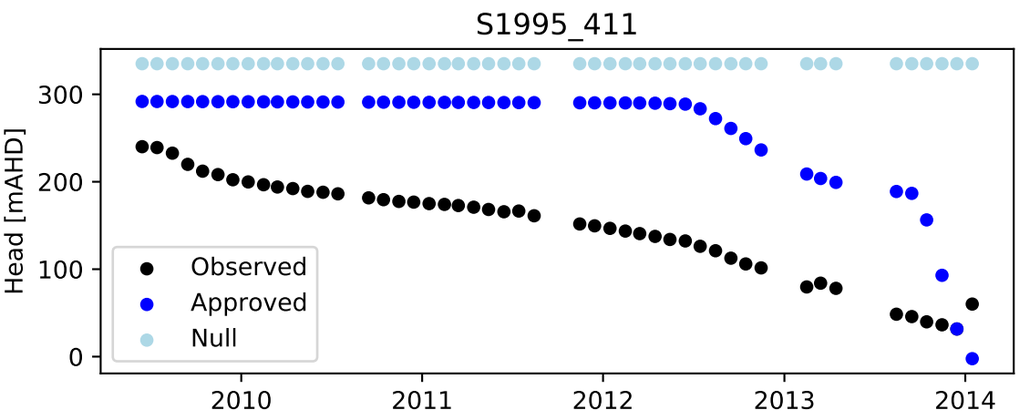

S1994_186
Head [mAHD]
325
300
275
250
225
200
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

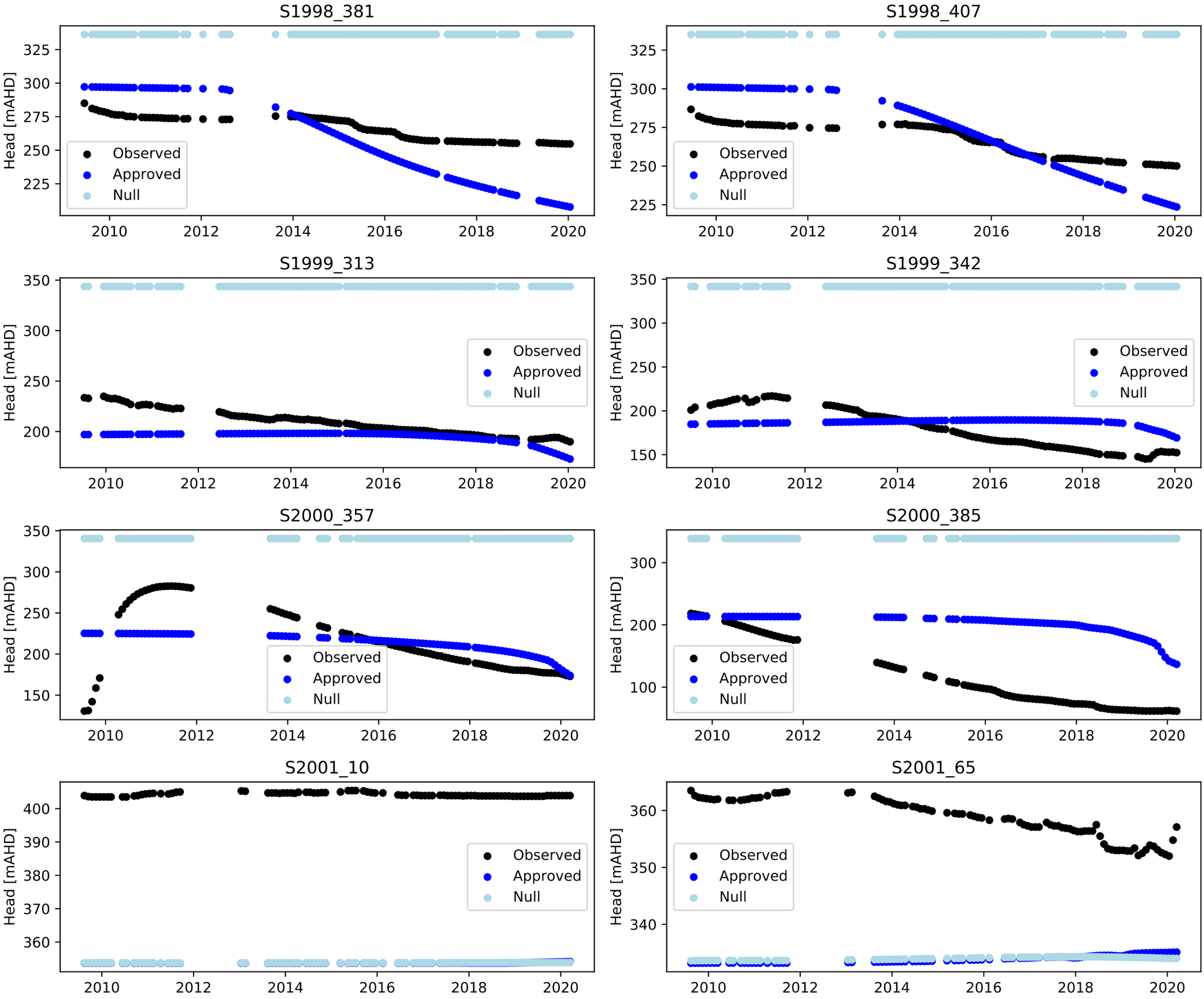

S1994_199
Head [mAHD]
320
300
280
260
240
220
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

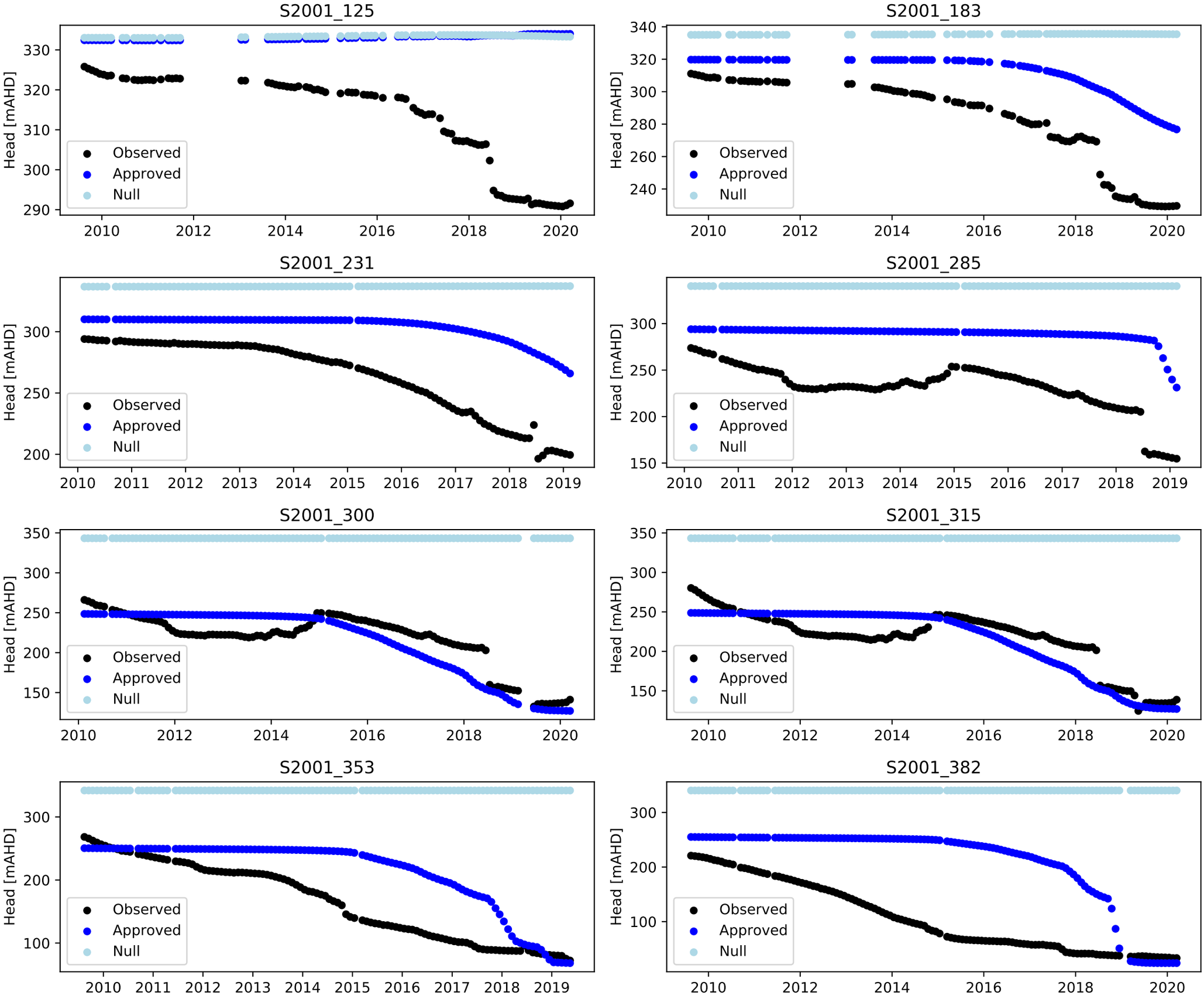

S1994_250
Head [mAHD]
300
250
200
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

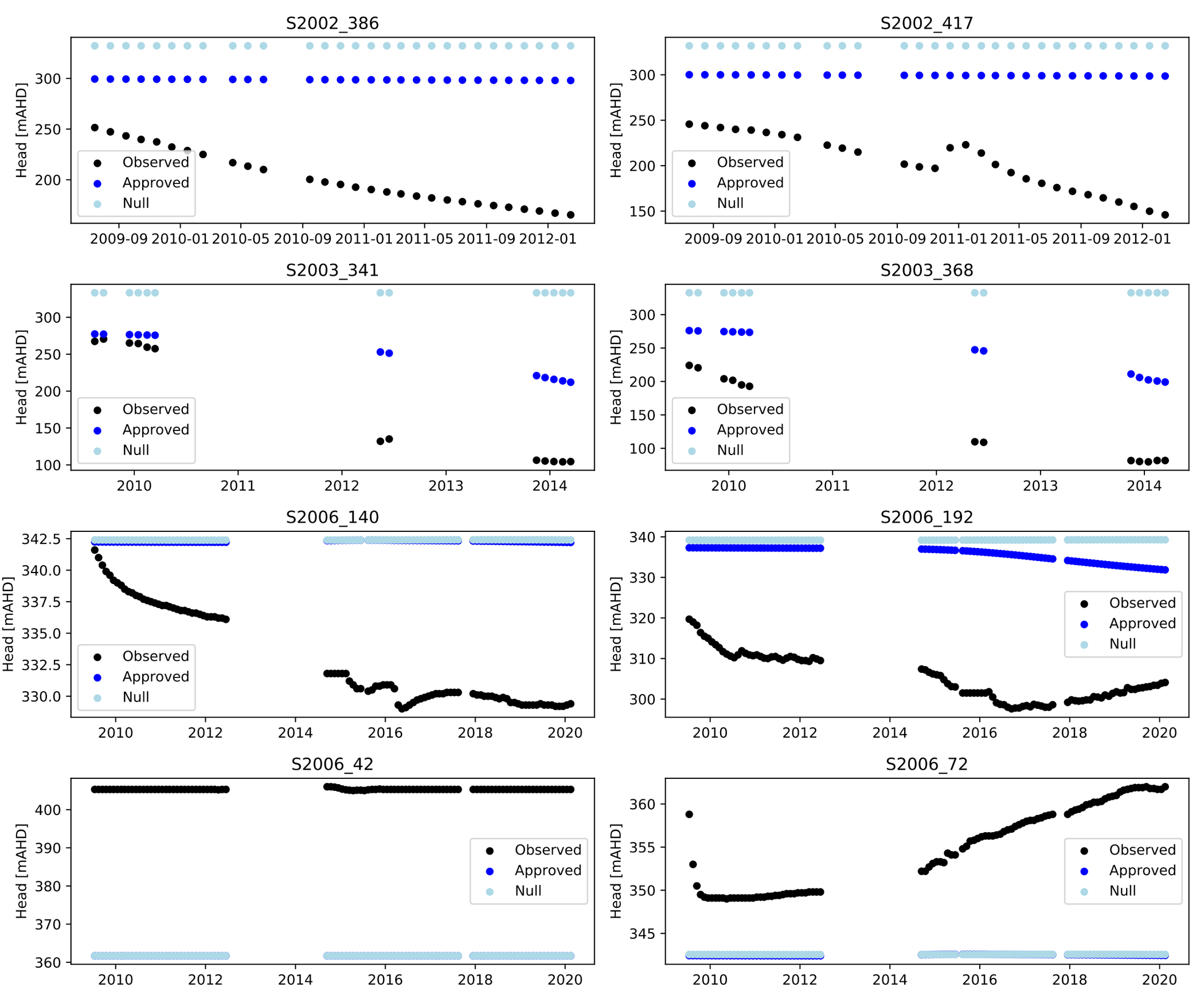

S1994_99
Head [mAHD]
320
300
280
260
2010
2012
2014
2016
2018
2020
Observed
Approved
Null

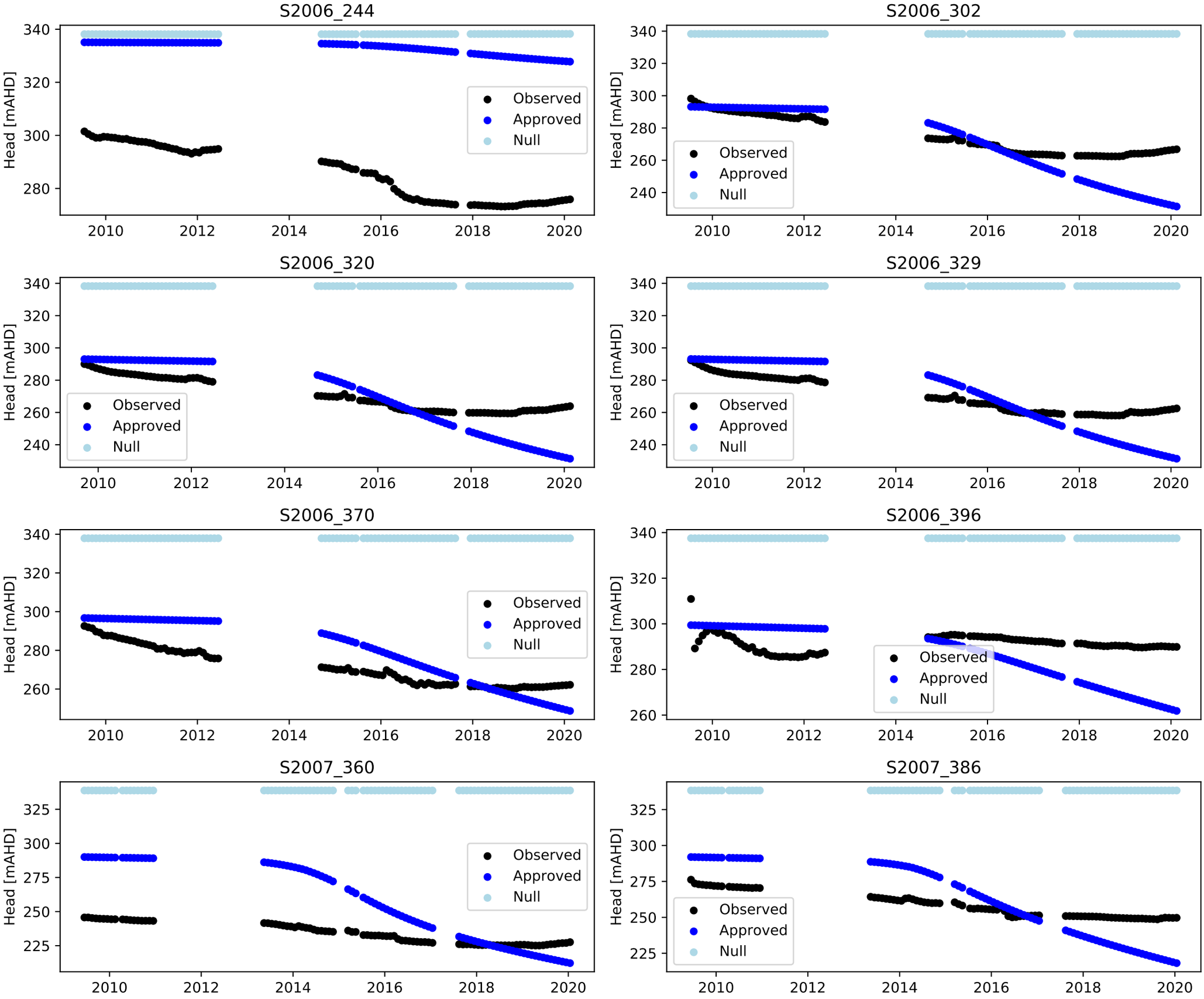

S1995_384
Head [mAHD]
300
250
200
150
100
50
2010
2011
2012
2013
2014
Observed
Approved
Null

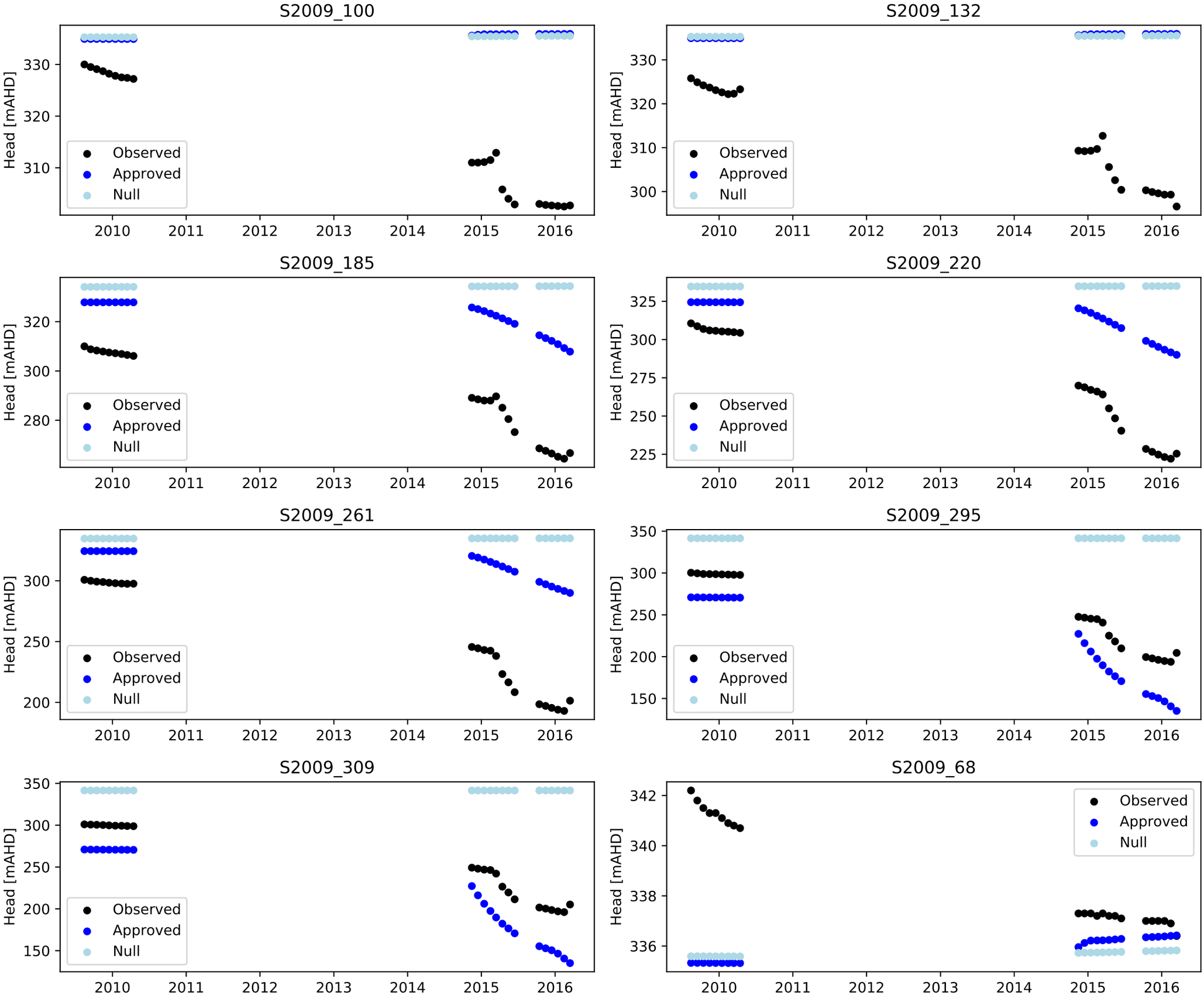

S1995_411
Head [mAHD]
300
200
100
0
2010
2011
2012
2013
2014
Observed
Approved
Null

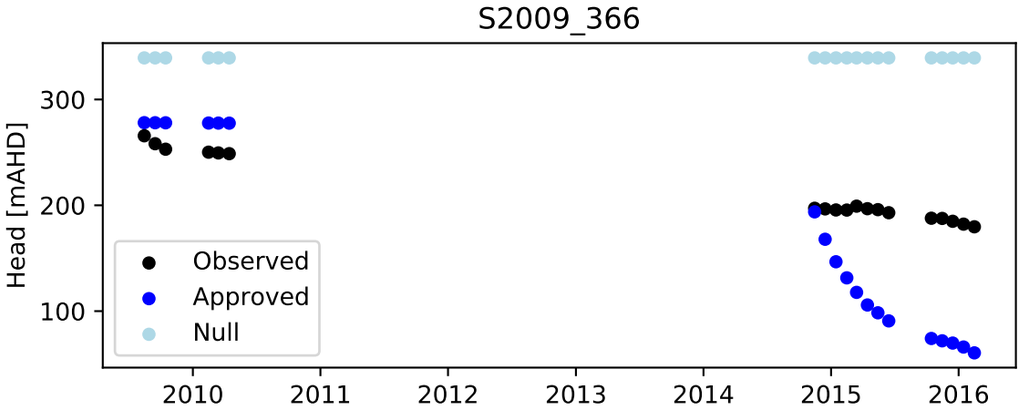

S1998_381
S1998_407
S1999_313
S1999_342
S2000_357
S2000_385
S2001_10
S2001_65
Head [mAHD]
Observed
Approved
Null
2010
2012
2014
2016
2018
2020

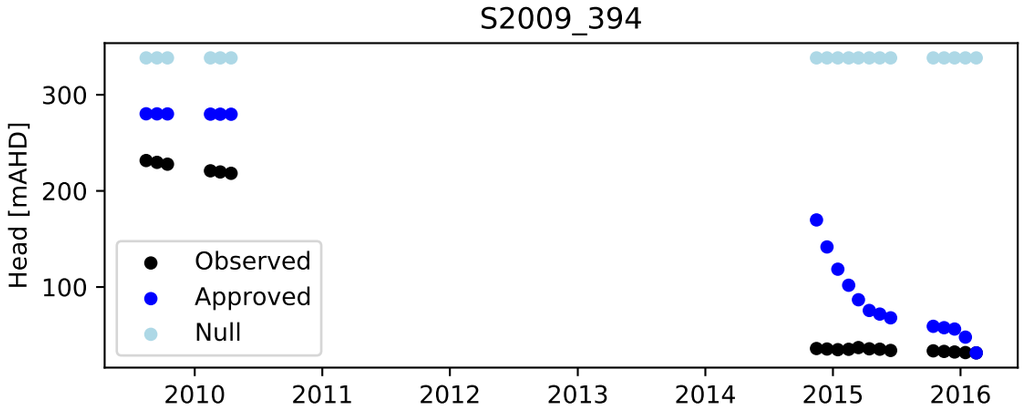

S2001_125
S2001_183
S2001_231
S2001_285
S2001_300
S2001_315
S2001_353
S2001_382
Head [mAHD]
Observed
Approved
Null

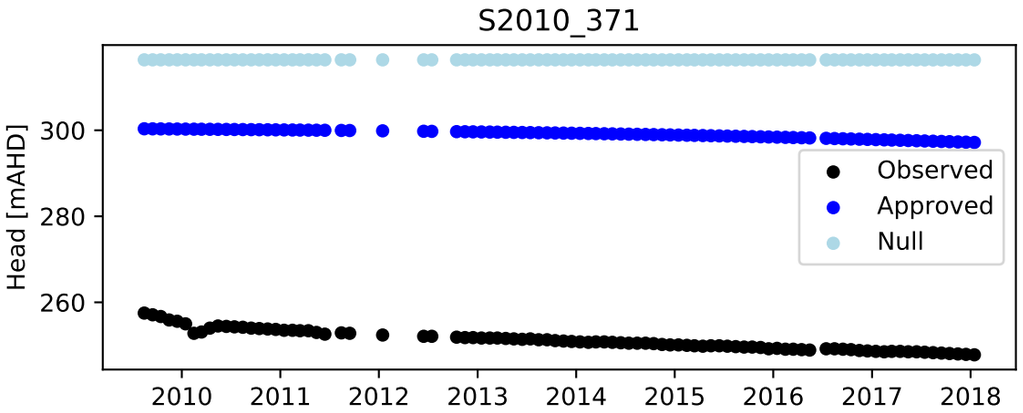

S2002_386
Head [mAHD]
300
250
200
Observed
Approved
Null
2009-09 2010-01 2010-05 2010-09 2011-01 2011-05 2011-09 2012-01
S2002_417
Head [mAHD]
300
250
200
150
Observed
Approved
Null
2009-09 2010-01 2010-05 2010-09 2011-01 2011-05 2011-09 2012-01
S2003_341
Head [mAHD]
300
250
200
150
100
Observed
Approved
Null
2010 2011 2012 2013 2014
S2003_368
Head [mAHD]
300
250
200
150
100
Observed
Approved
Null
2010 2011 2012 2013 2014
S2006_140
Head [mAHD]
342.5
340.0
337.5
335.0
332.5
330.0
Observed
Approved
Null
2010 2012 2014 2016 2018 2020
S2006_192
Head [mAHD]
340
330
320
310
300
Observed
Approved
Null
2010 2012 2014 2016 2018 2020
S2006_42
Head [mAHD]
400
390
380
370
360
Observed
Approved
Null
2010 2012 2014 2016 2018 2020
S2006_72
Head [mAHD]
360
355
350
345
Observed
Approved
Null
2010 2012 2014 2016 2018 2020

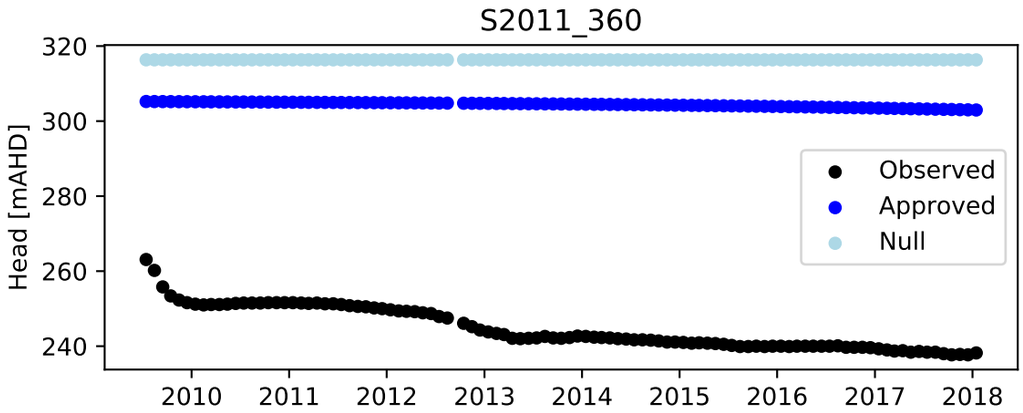

S2006_244
S2006_302
S2006_320
S2006_329
S2006_370
S2006_396
S2007_360
S2007_386
Head [mAHD]
Observed
Approved
Null
2010
2012
2014
2016
2018
2020

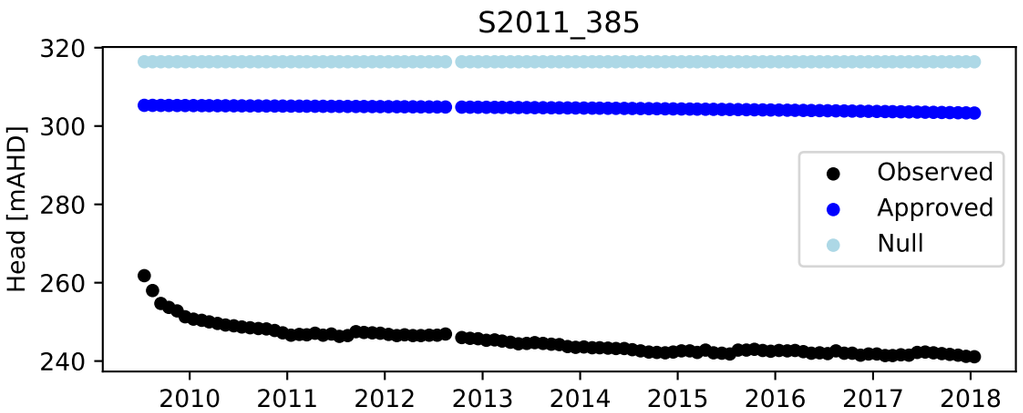

S2009_100
S2009_132
S2009_185
S2009_220
S2009_261
S2009_295
S2009_309
S2009_68
Head [mAHD]
Observed
Approved
Null
2010
2011
2012
2013
2014
2015
2016

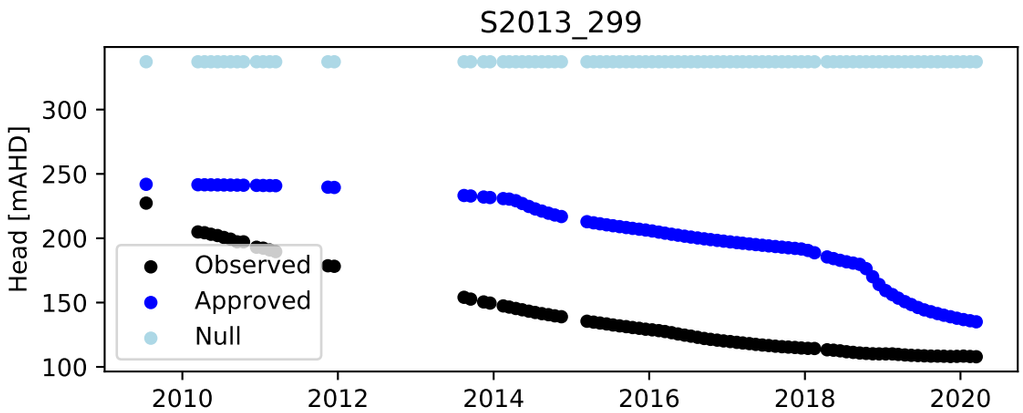

S2009_366
Head [mAHD]
Observed
Approved
Null

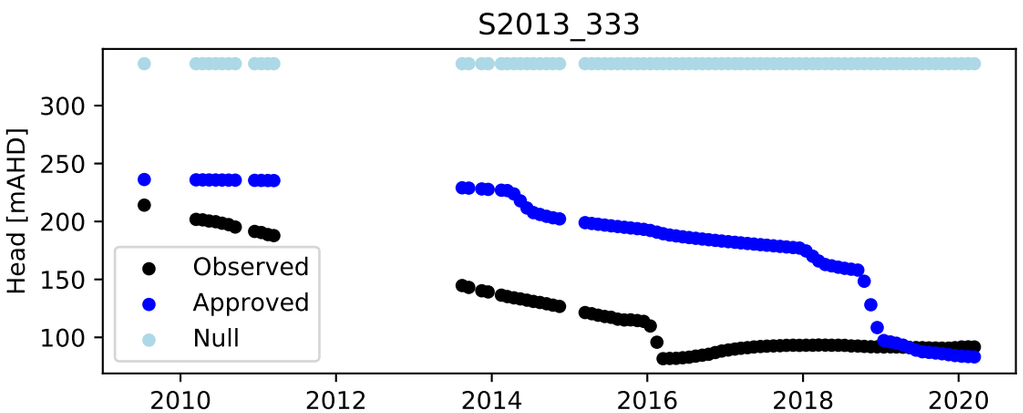

S2009_394
Head [mAHD]
Observed
Approved
Null

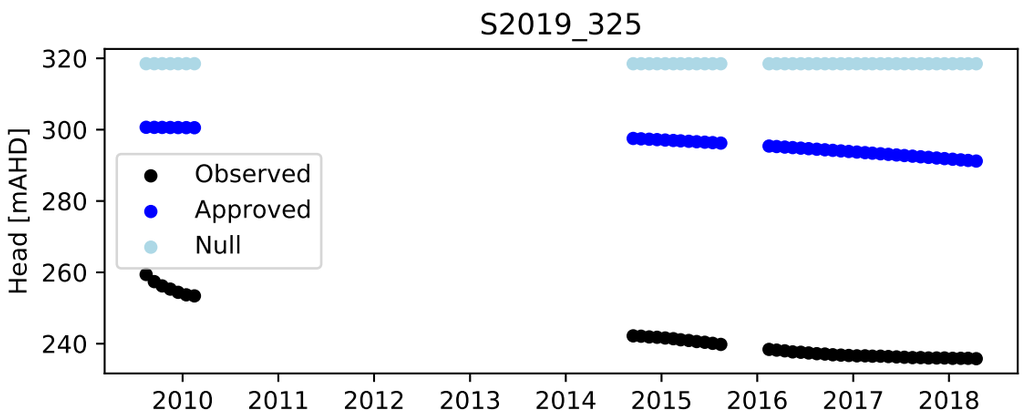

S2010_371
Head [mAHD]
Observed
Approved
Null

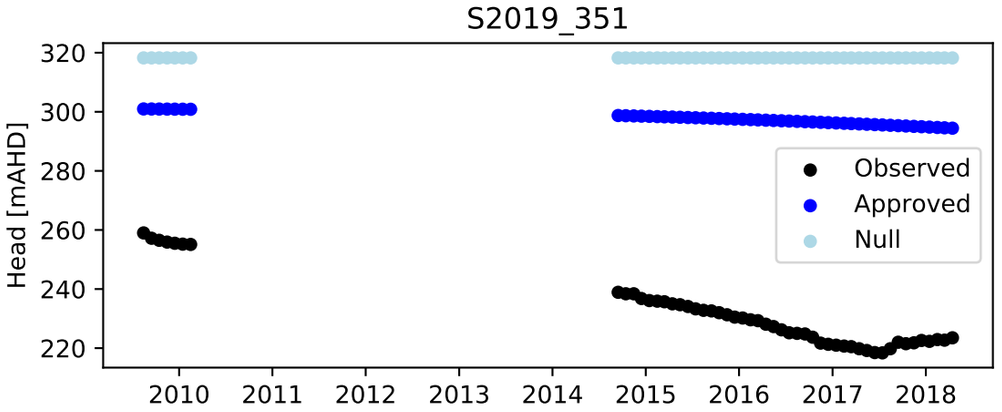

S2011_360
Head [mAHD]
Observed
Approved
Null

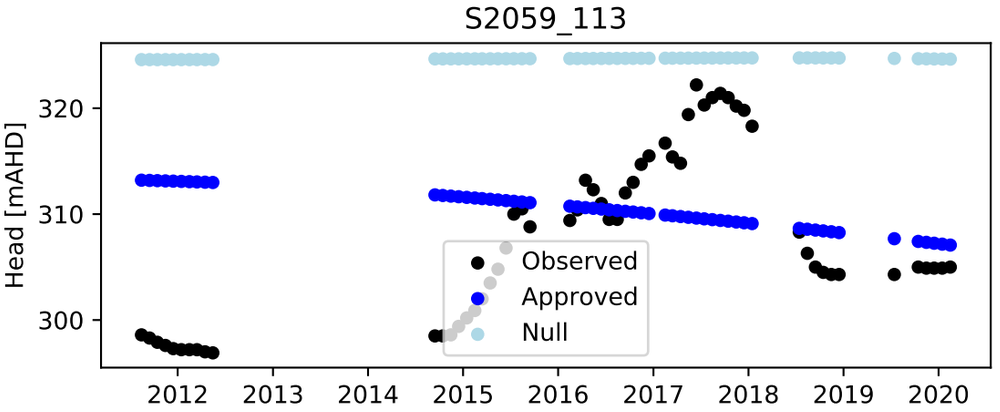

S2011_385
Head [mAHD]
Observed
Approved
Null

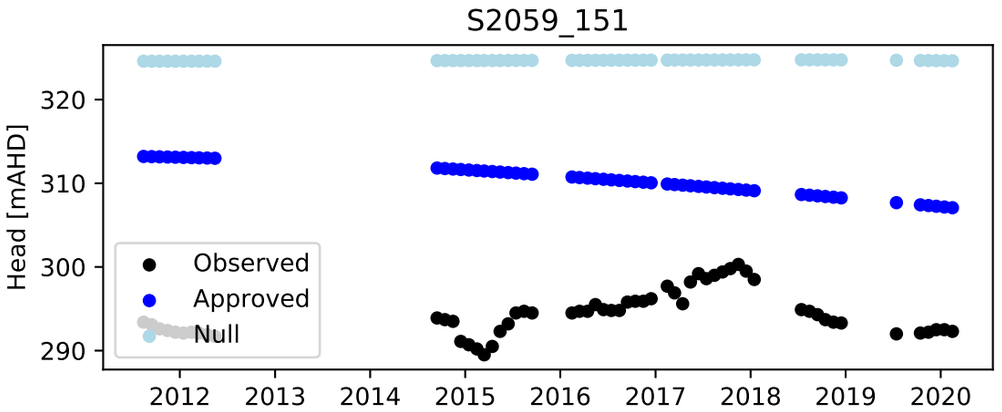

S2013_299
Head [mAHD]
Observed
Approved
Null

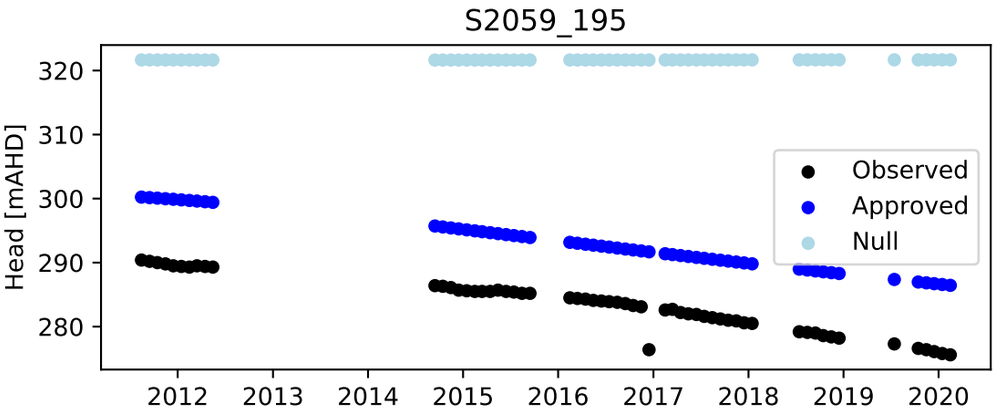

S2013_333
Head [mAHD]
Observed
Approved
Null

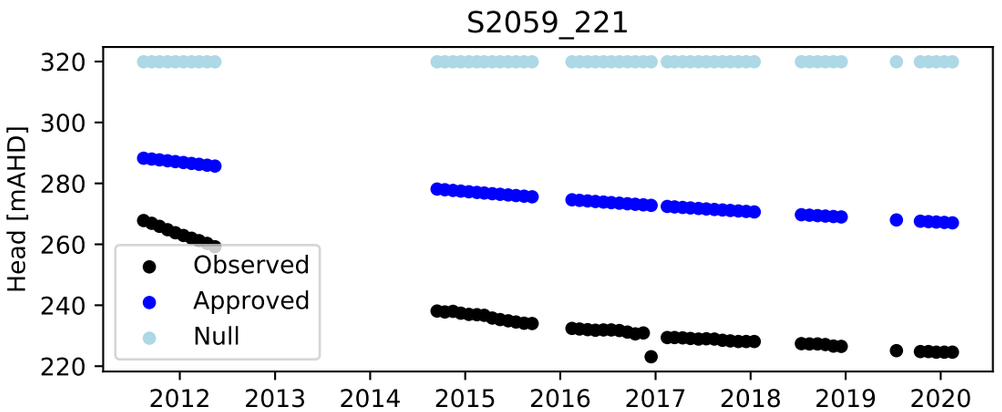

S2019_325
Head [mAHD]
Observed
Approved
Null

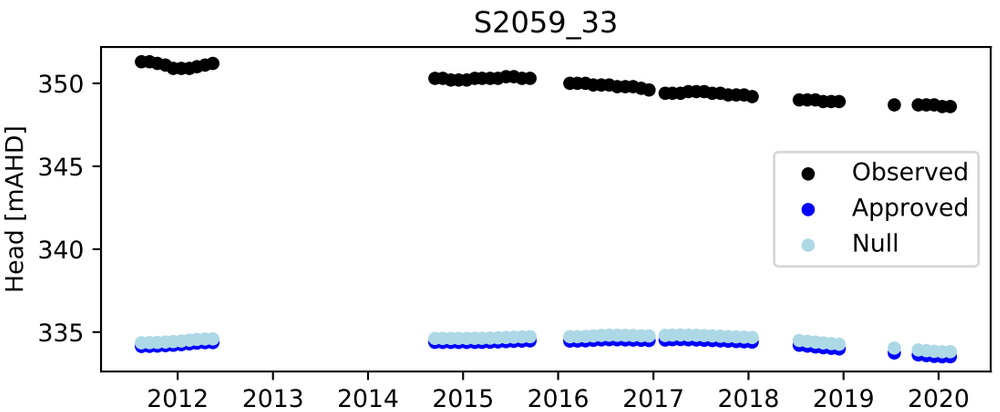

S2019_351
Head [mAHD]
320
300
280
260
240
220
2010
2011
2012
2013
2014
2015
2016
2017
2018
Observed
Approved
Null

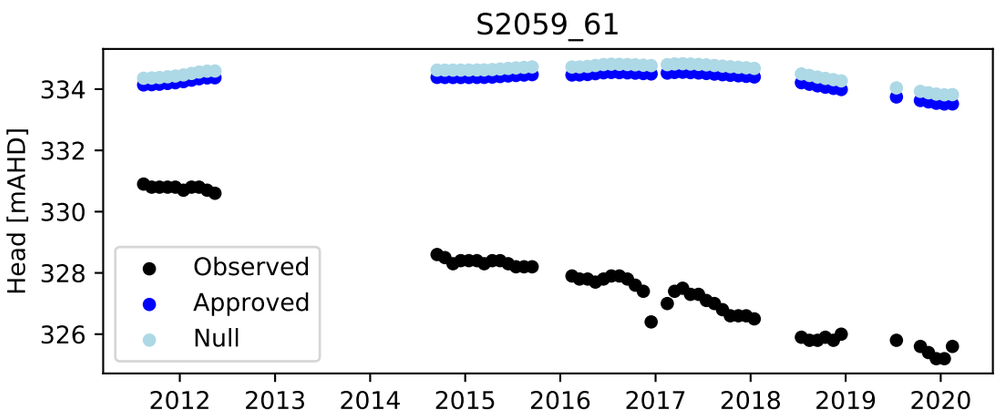

S2059_113
Head [mAHD]
320
310
300
2012
2013
2014
2015
2016
2017
2018
2019
2020
Observed
Approved
Null

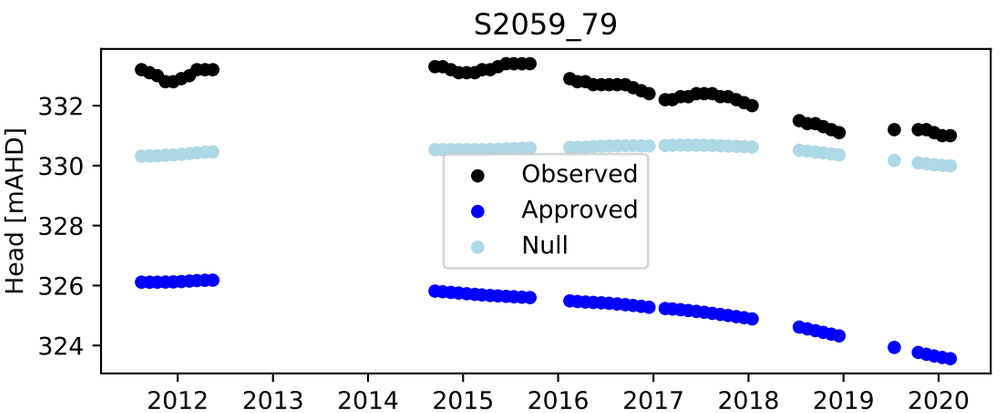

S2059_151
Head [mAHD]
320
310
300
290
2012
2013
2014
2015
2016
2017
2018
2019
2020
Observed
Approved
Null

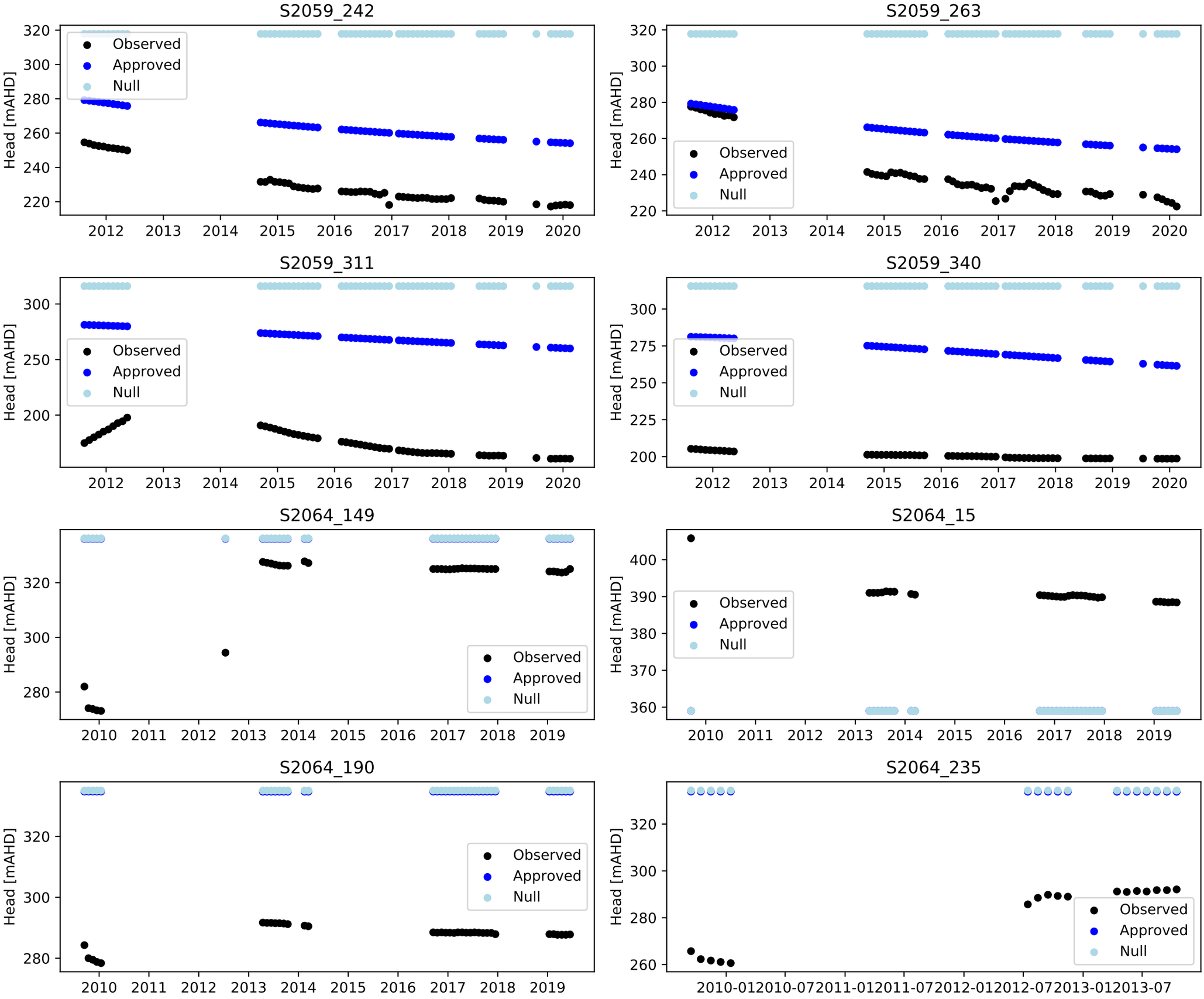

S2059_195
Head [mAHD]
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310
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290
280
2012
2013
2014
2015
2016
2017
2018
2019
2020
Observed
Approved
Null

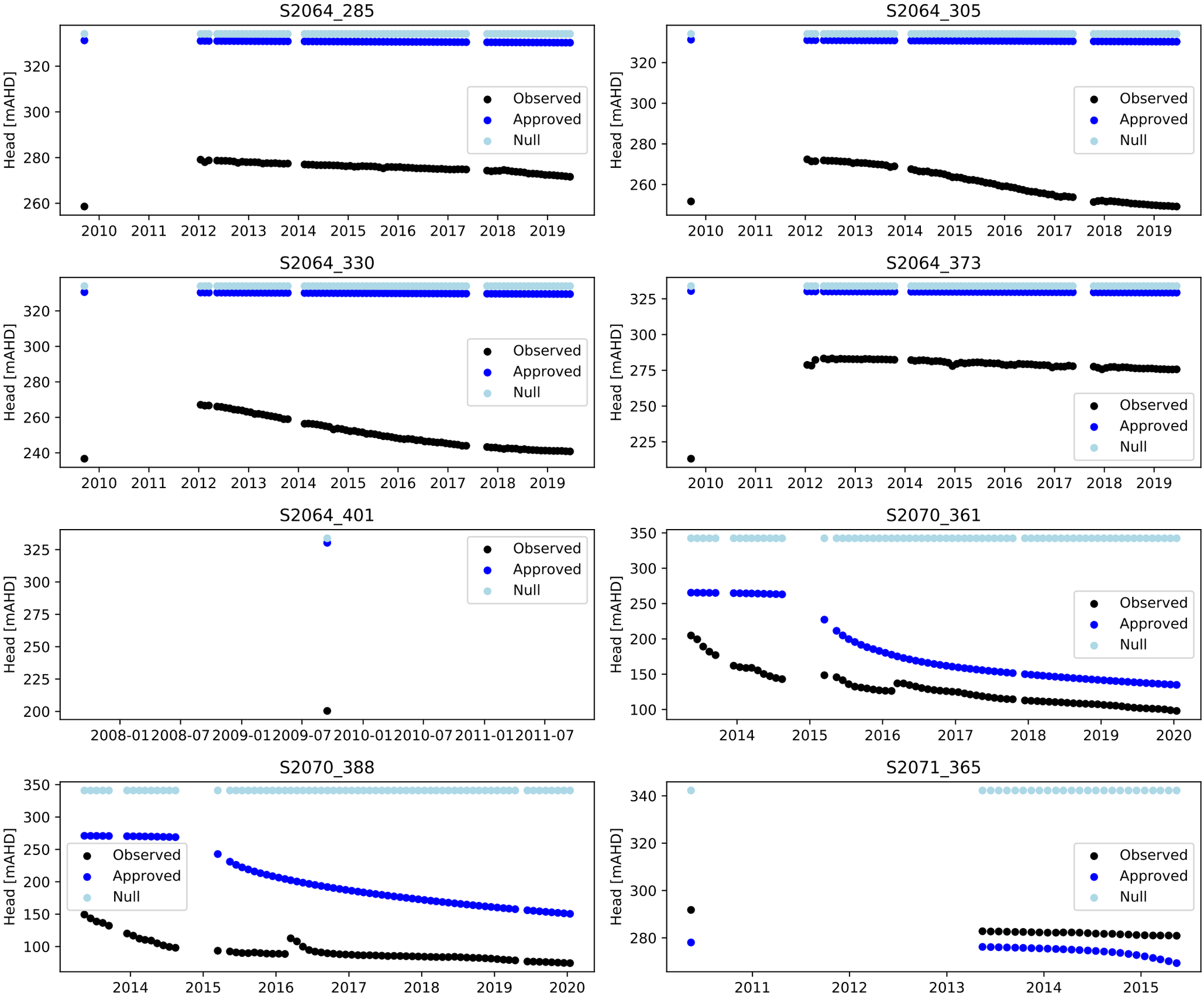

S2059_221
Head [mAHD]
320
300
280
260
240
220
2012
2013
2014
2015
2016
2017
2018
2019
2020
Observed
Approved
Null

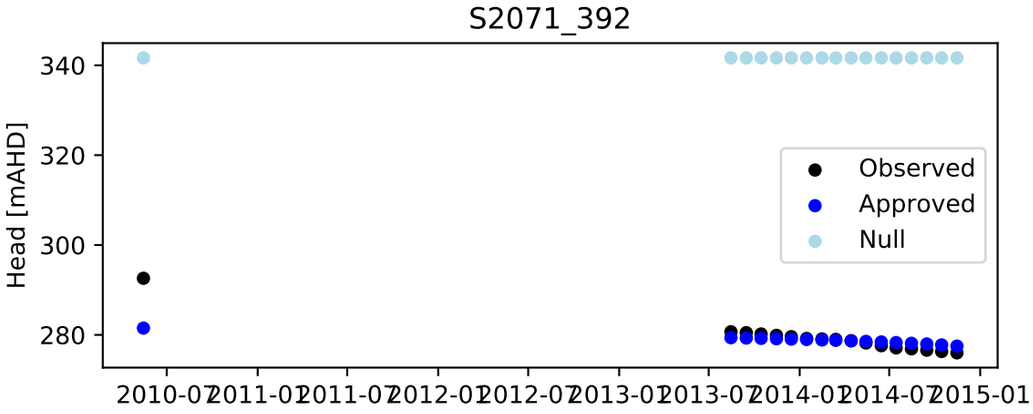

S2059_33
Head [mAHD]
350
345
340
335
2012
2013
2014
2015
2016
2017
2018
2019
2020
Observed
Approved
Null

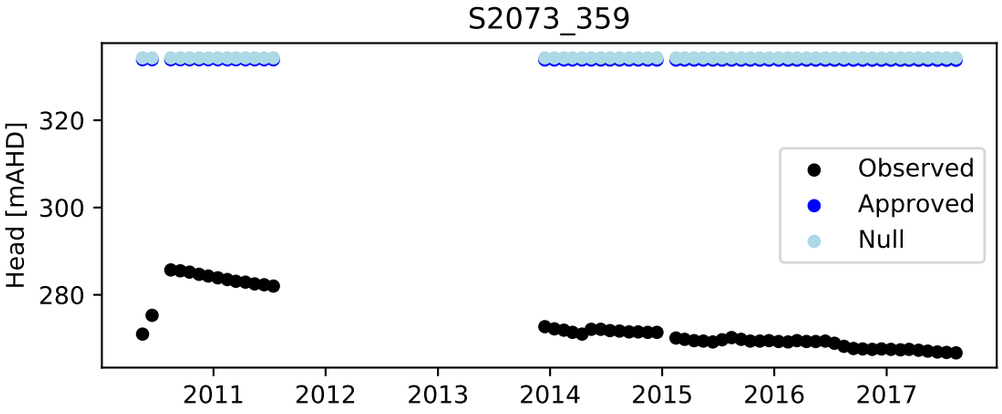

S2059_61
Head [mAHD]
334
332
330
328
326
2012
2013
2014
2015
2016
2017
2018
2019
2020
Observed
Approved
Null

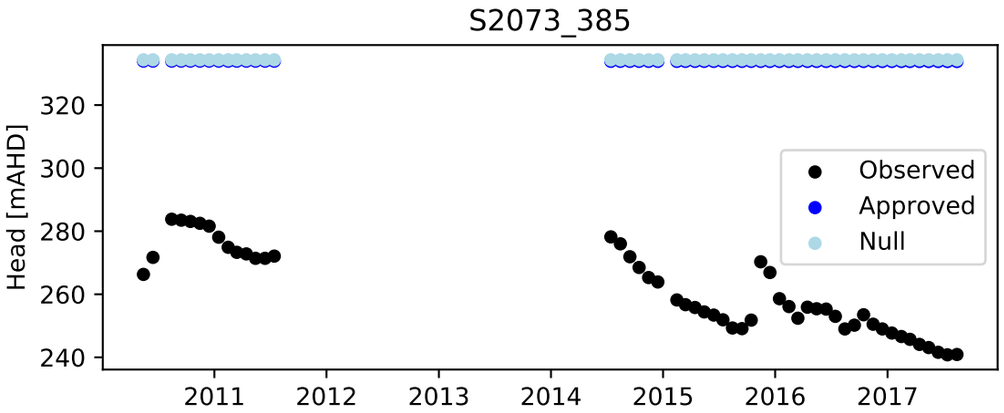

S2059_79
Head [mAHD]
332
330
328
326
324
2012
2013
2014
2015
2016
2017
2018
2019
2020
Observed
Approved
Null

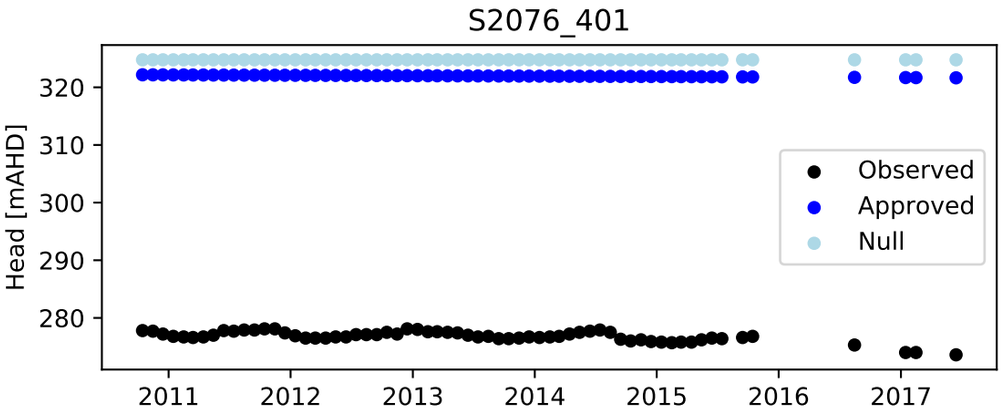

S2059_242
S2059_263
S2059_311
S2059_340
S2064_149
S2064_15
S2064_190
S2064_235
Head [mAHD]
Observed
Approved
Null
2012
2013
2014
2015
2016
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2018
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2020
2010
2011
2012-01
2010-07
2011-01
2011-07
2012-01
2012-07
2013-01
2013-07

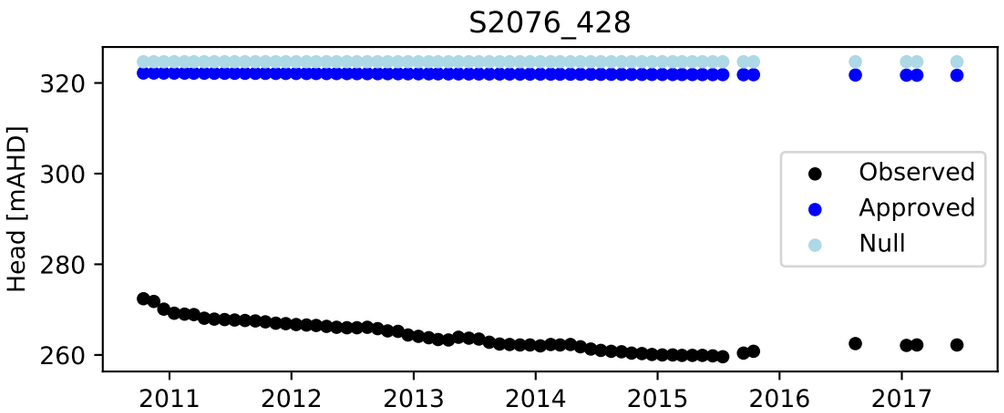

S2064_285
S2064_305
S2064_330
S2064_373
S2064_401
S2070_361
S2070_388
S2071_365
Head [mAHD]
Observed
Approved
Null

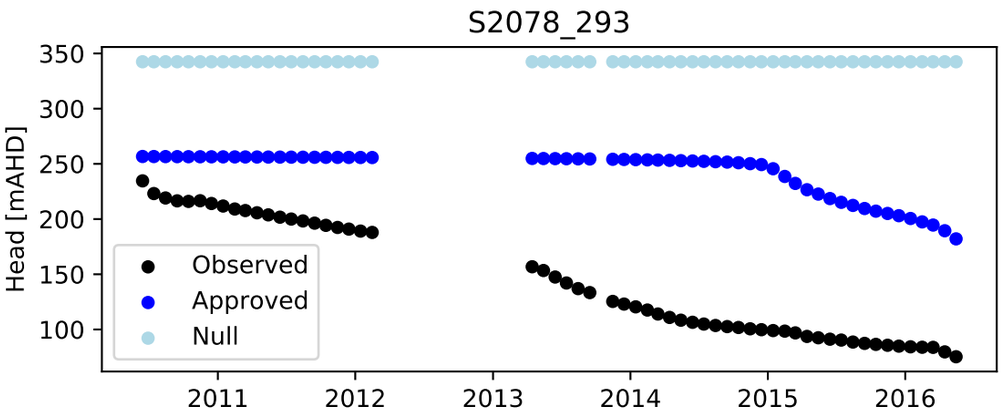

S2071_392
Head [mAHD]
340
320
300
280
2010-07
2011-01
2011-07
2012-01
2012-07
2013-01
2013-07
2014-01
2014-07
2015-01
Observed
Approved
Null

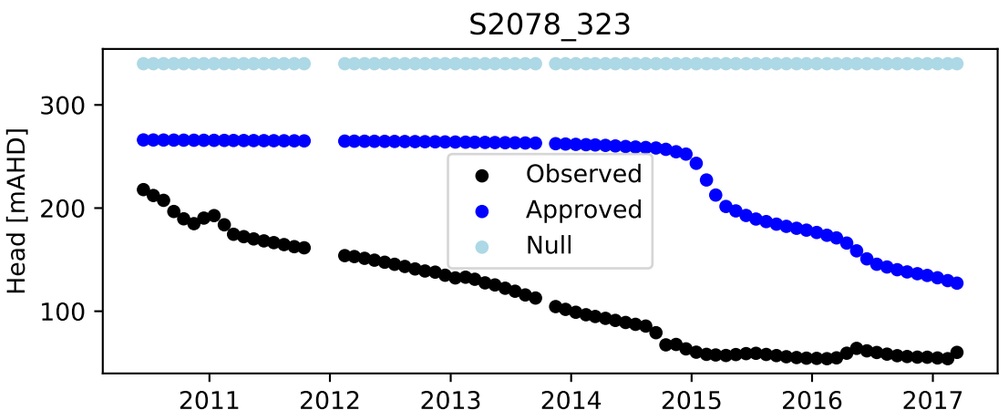

S2073_359
Head [mAHD]
320
300
280
2011
2012
2013
2014
2015
2016
2017
Observed
Approved
Null

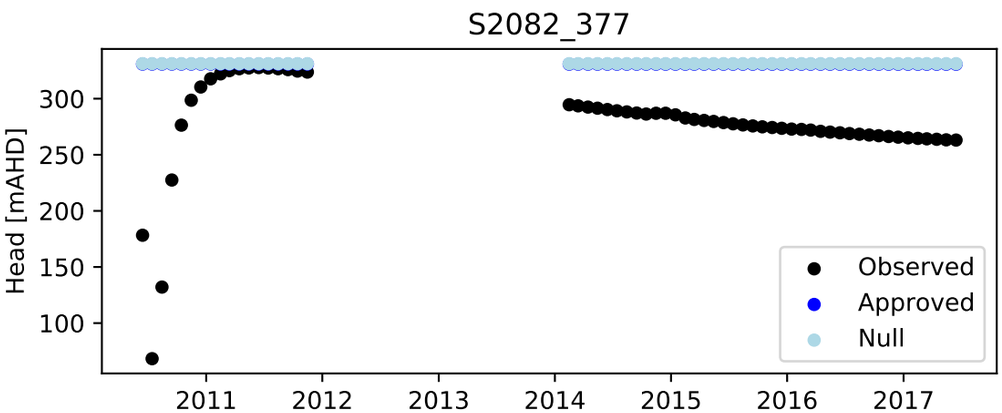

S2073_385
Head [mAHD]
320
300
280
260
240
2011
2012
2013
2014
2015
2016
2017
Observed
Approved
Null

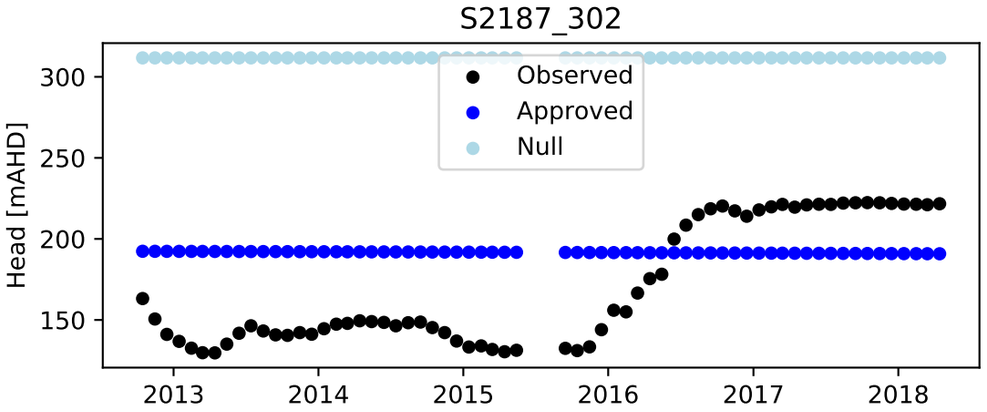

S2076_401
Head [mAHD]
320
310
300
290
280
2011
2012
2013
2014
2015
2016
2017
Observed
Approved
Null

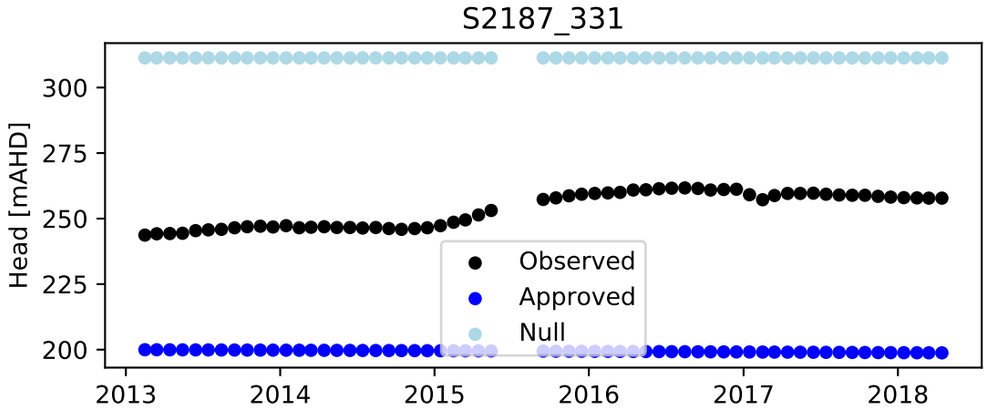

S2076_428
Head [mAHD]
320
300
280
260
2011
2012
2013
2014
2015
2016
2017
Observed
Approved
Null

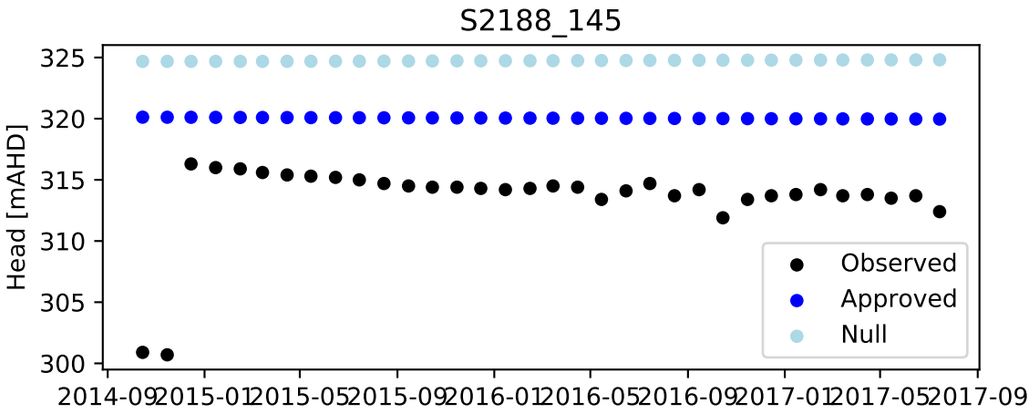

S2078_293
Head [mAHD]
350
300
250
200
150
100
2011
2012
2013
2014
2015
2016
Observed
Approved
Null

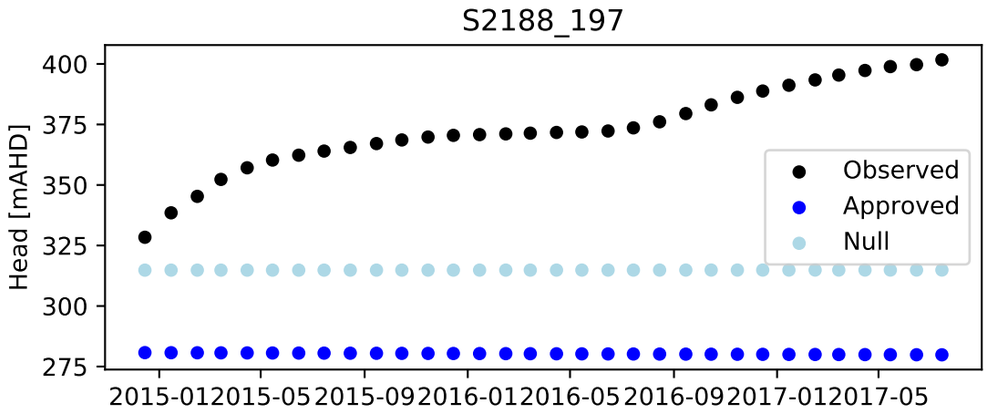

S2078_323
Head [mAHD]
300
200
100
2011
2012
2013
2014
2015
2016
2017
Observed
Approved
Null

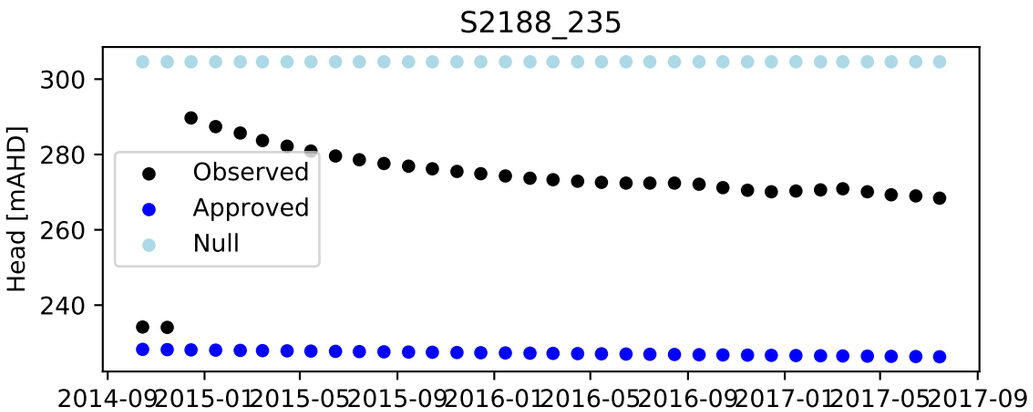

S2082_377
Head [mAHD]
300
250
200
150
100
2011
2012
2013
2014
2015
2016
2017
Observed
Approved
Null

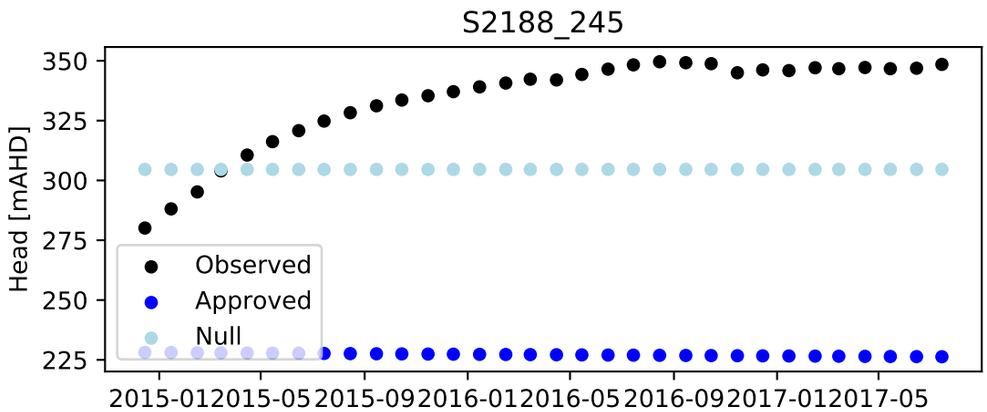

S2187_302
Head [mAHD]
Observed
Approved
Null
2013
2014
2015
2016
2017
2018

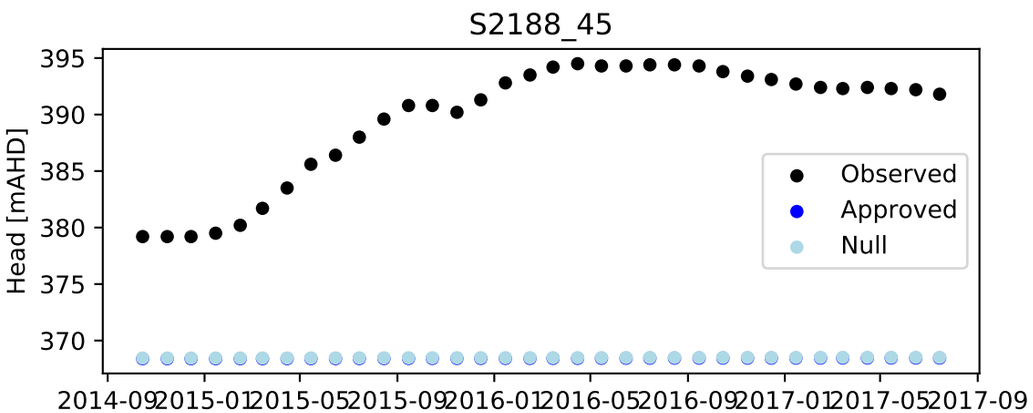

S2187_331
Head [mAHD]
Observed
Approved
Null
2013
2014
2015
2016
2017
2018

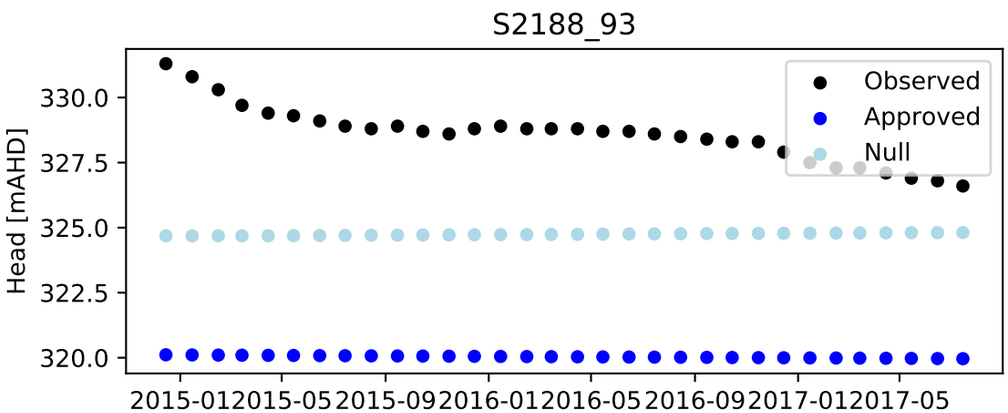

S2188_145
Head [mAHD]
Observed
Approved
Null

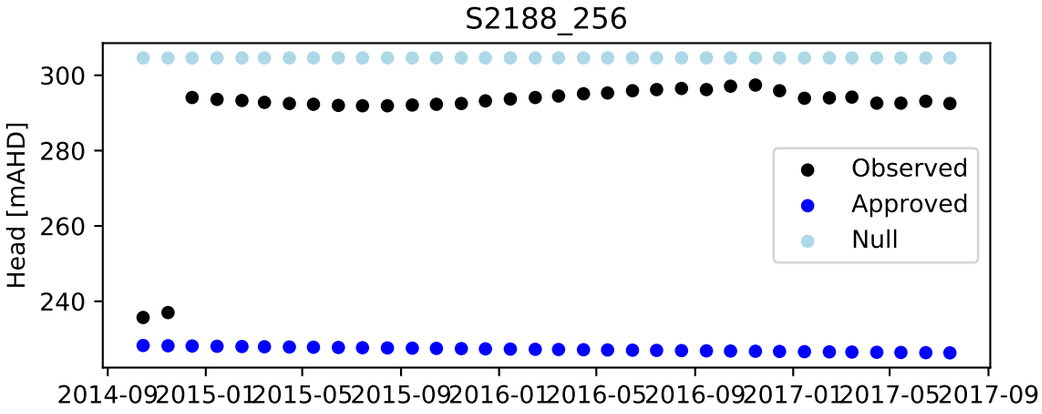

S2188_197
Head [mAHD]
Observed
Approved
Null

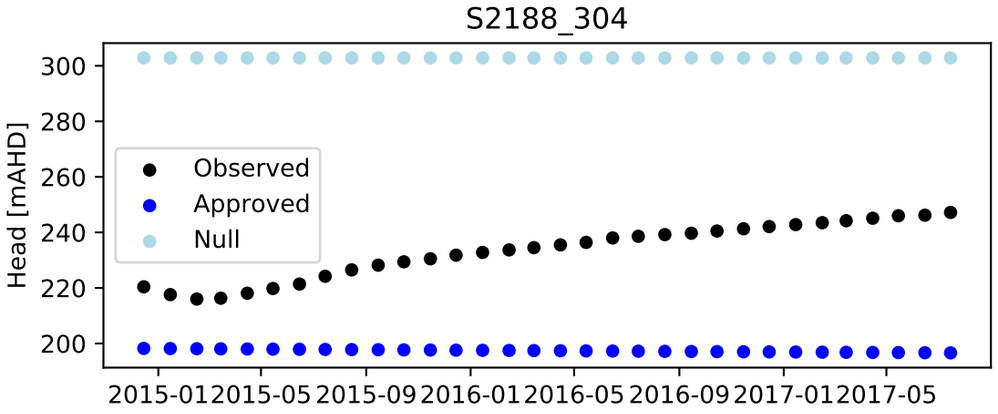

S2188_235
Head [mAHD]
Observed
Approved
Null

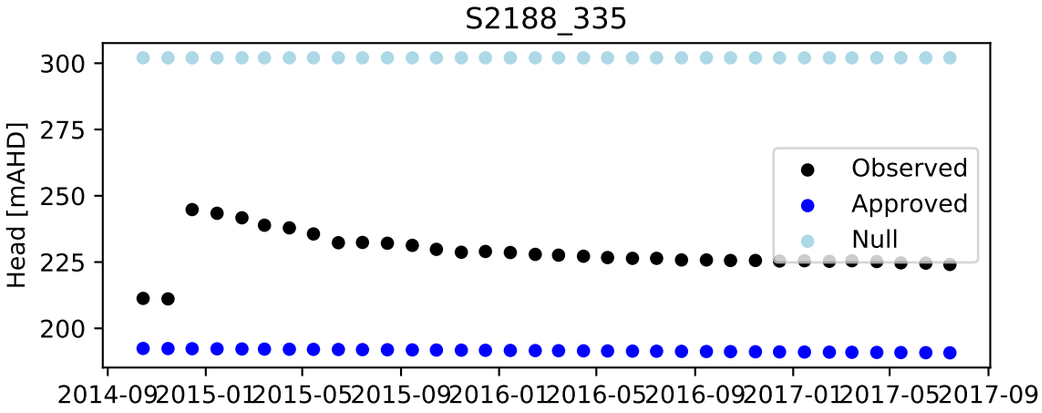

S2188_245
Head [mAHD]
Observed
Approved
Null

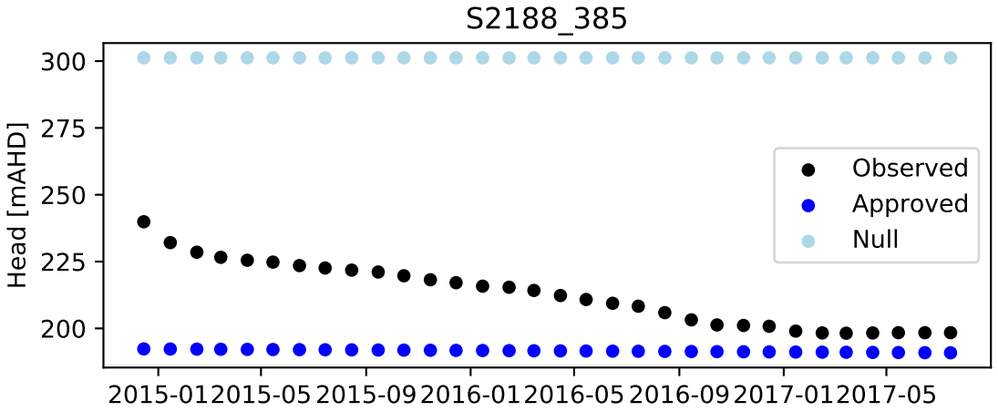

S2188_45
Head [mAHD]
Observed
Approved
Null

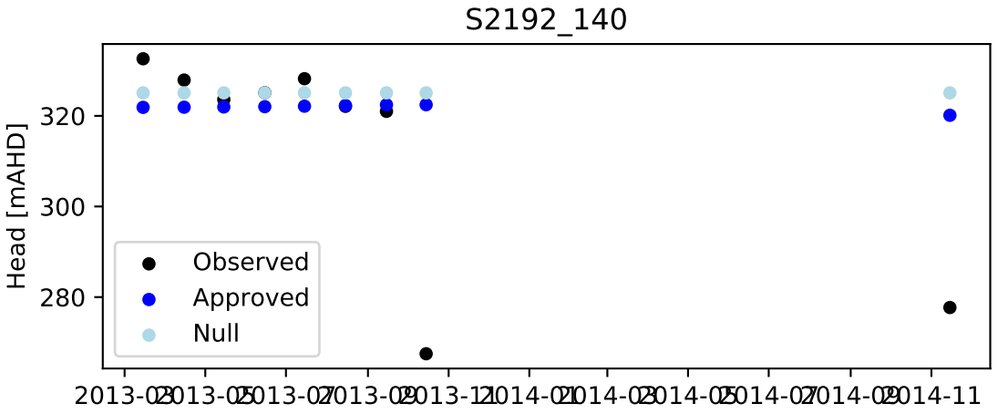

S2188_93
Head [mAHD]
Observed
Approved
Null

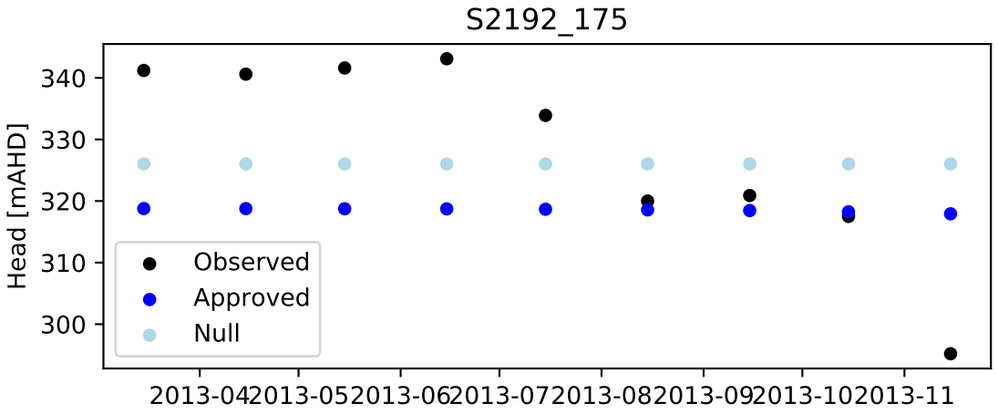

S2188_256
Head [mAHD]
Observed
Approved
Null

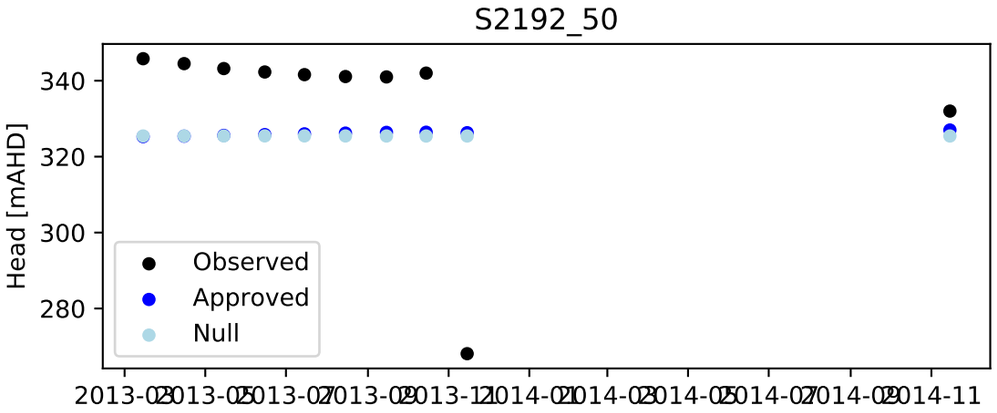

S2188_304
Head [mAHD]
Observed
Approved
Null

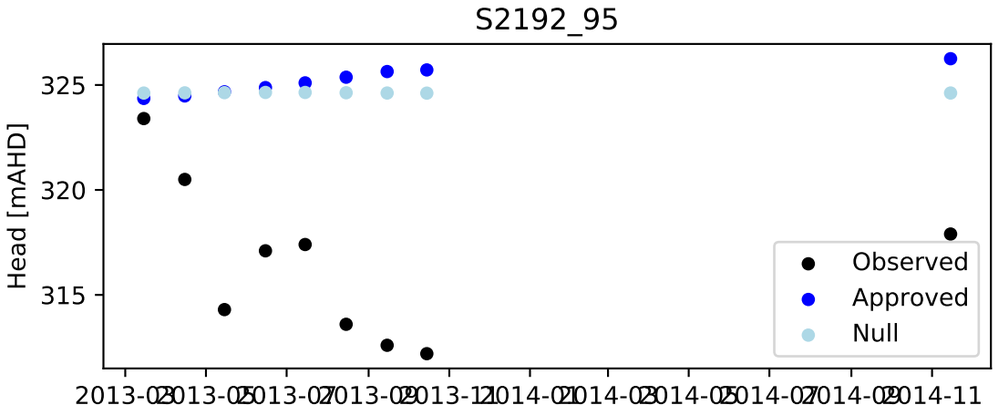

S2188_335
Head [mAHD]
Observed
Approved
Null

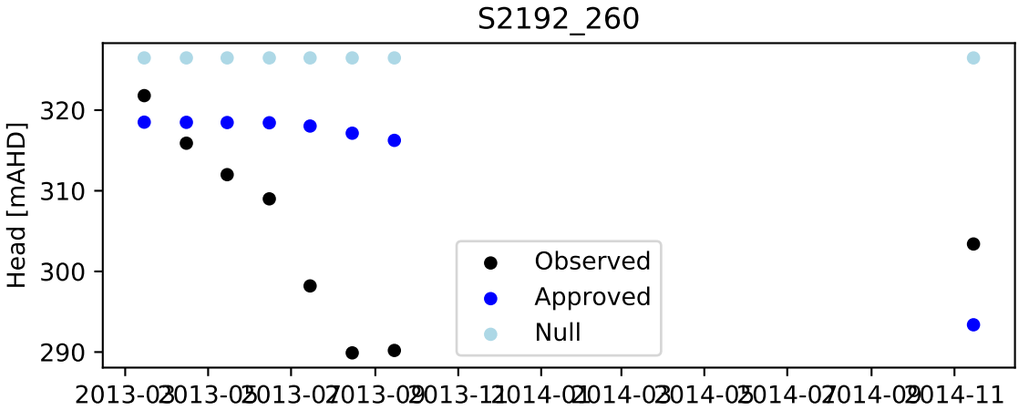

S2188_385
Head [mAHD]
Observed
Approved
Null

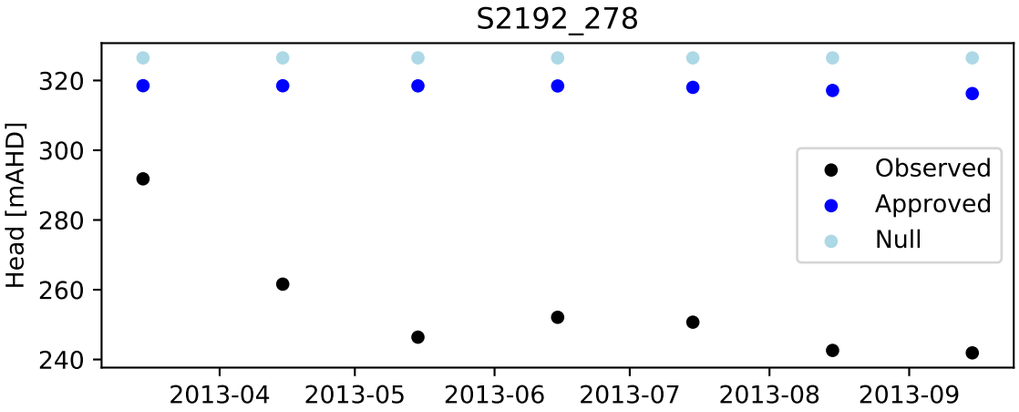

S2192_140
Head [mAHD]
Observed
Approved
Null

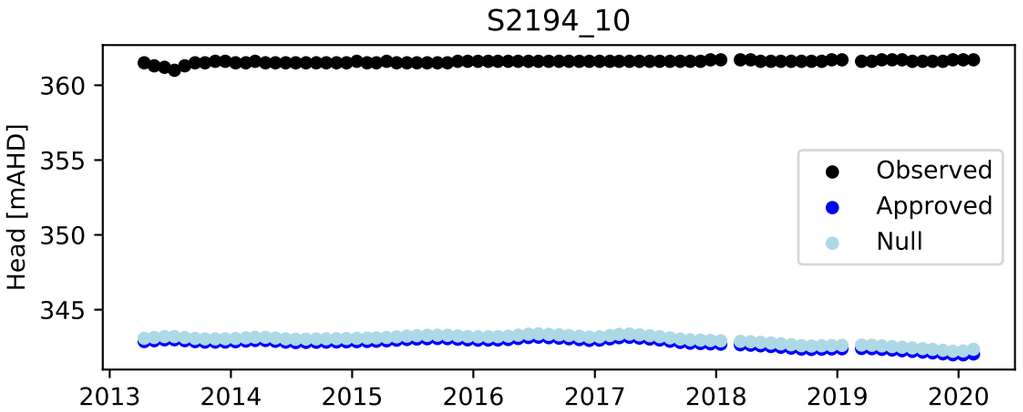

S2192_175
Head [mAHD]
Observed
Approved
Null

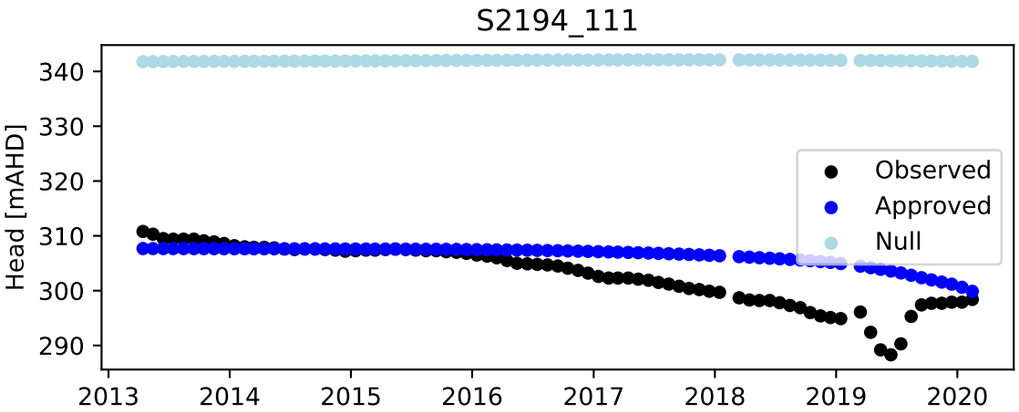

S2192_50
Head [mAHD]
Observed
Approved
Null

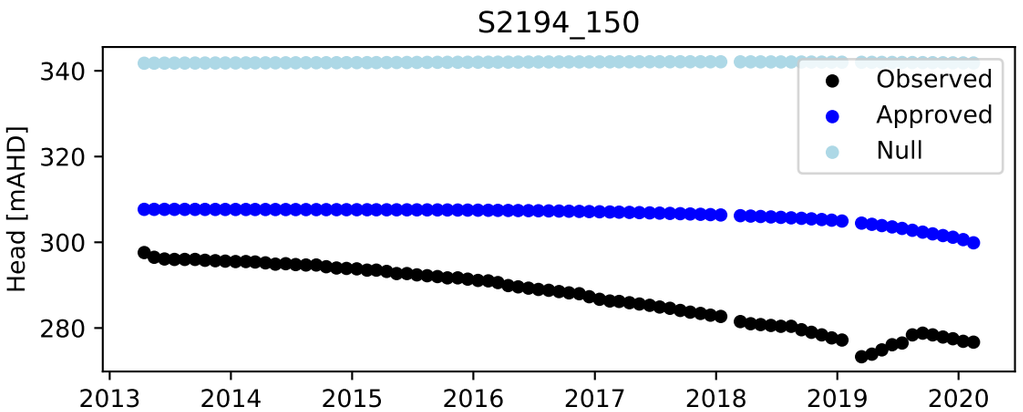

S2192_95
Head [mAHD]
Observed
Approved
Null

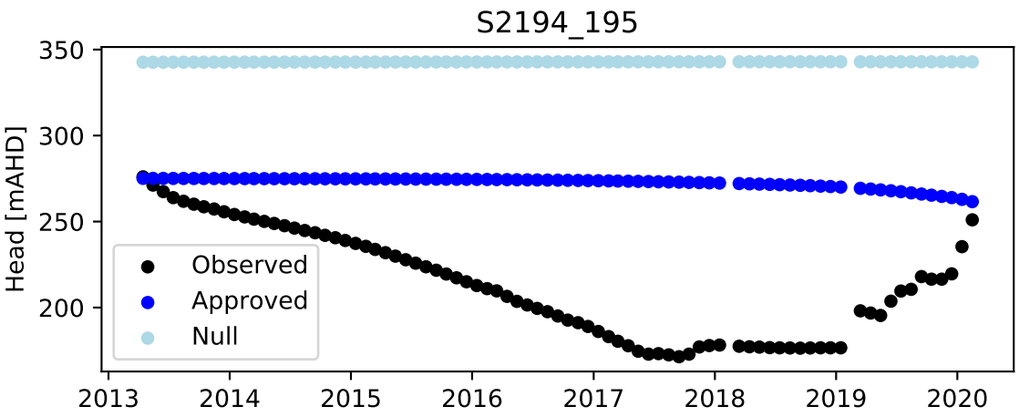

S2192_260
Head [mAHD]
320
310
300
290
Observed
Approved
Null
2013-03
2013-05
2013-07
2013-09
2013-11
2014-01
2014-03
2014-05
2014-07
2014-09
2014-11

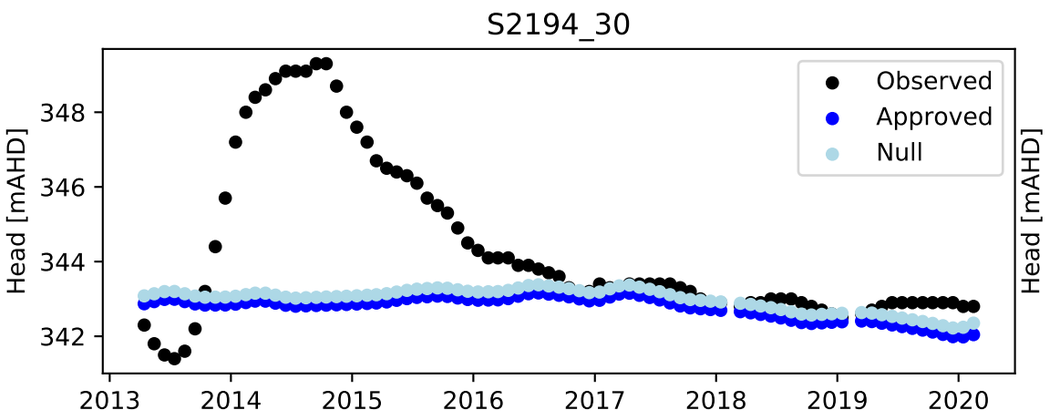

S2192_278
Head [mAHD]
320
300
280
260
240
Observed
Approved
Null
2013-04
2013-05
2013-06
2013-07
2013-08
2013-09

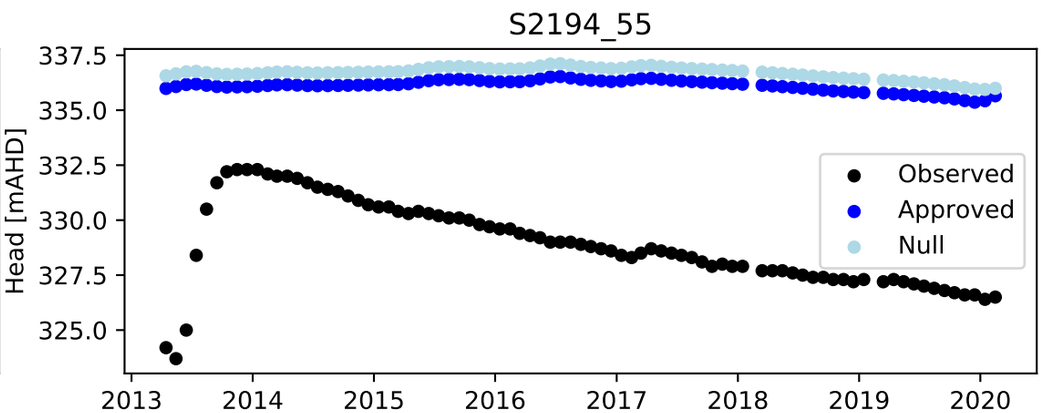

S2194_10
Head [mAHD]
360
355
350
345
Observed
Approved
Null
2013
2014
2015
2016
2017
2018
2019
2020

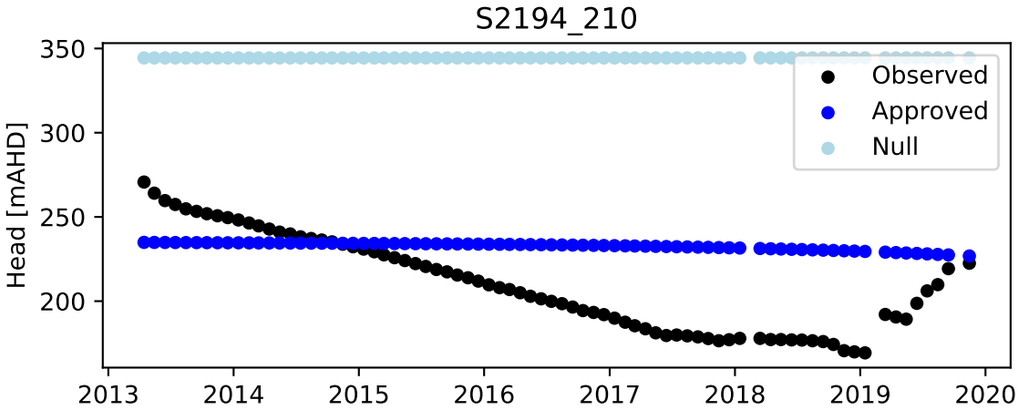

S2194_111
Head [mAHD]
340
330
320
310
300
290
Observed
Approved
Null
2013
2014
2015
2016
2017
2018
2019
2020

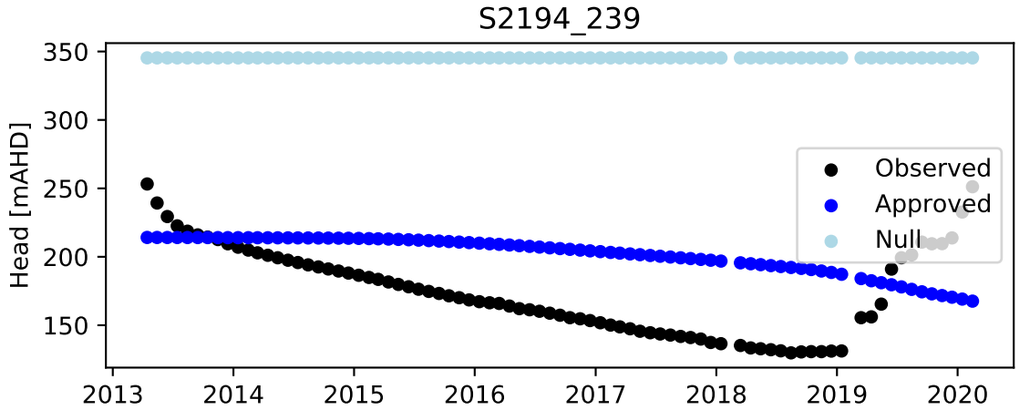

S2194_150
Head [mAHD]
340
320
300
280
Observed
Approved
Null
2013
2014
2015
2016
2017
2018
2019
2020

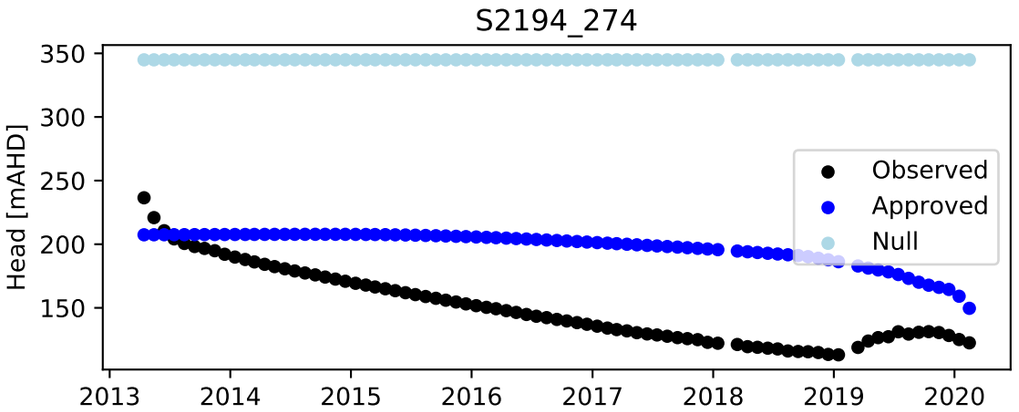

S2194_195
Head [mAHD]
350
300
250
200
Observed
Approved
Null
2013
2014
2015
2016
2017
2018
2019
2020

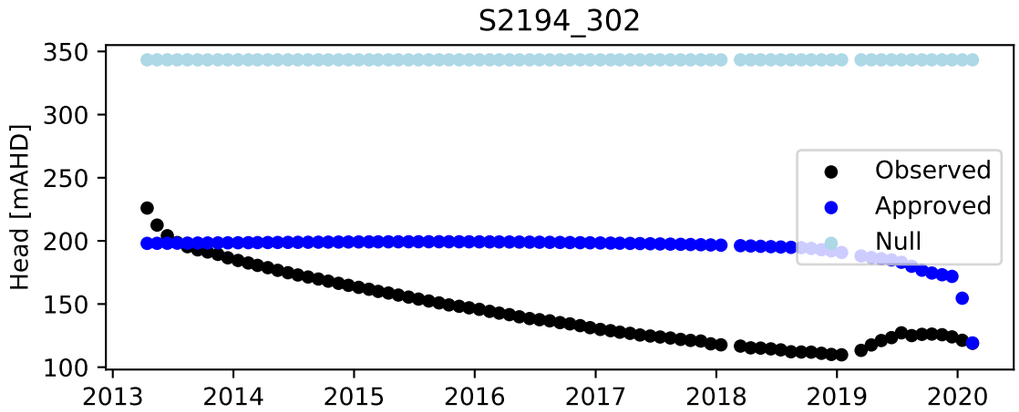

S2194_30
Head [mAHD]
348
346
344
342
Observed
Approved
Null
2013
2014
2015
2016
2017
2018
2019
2020

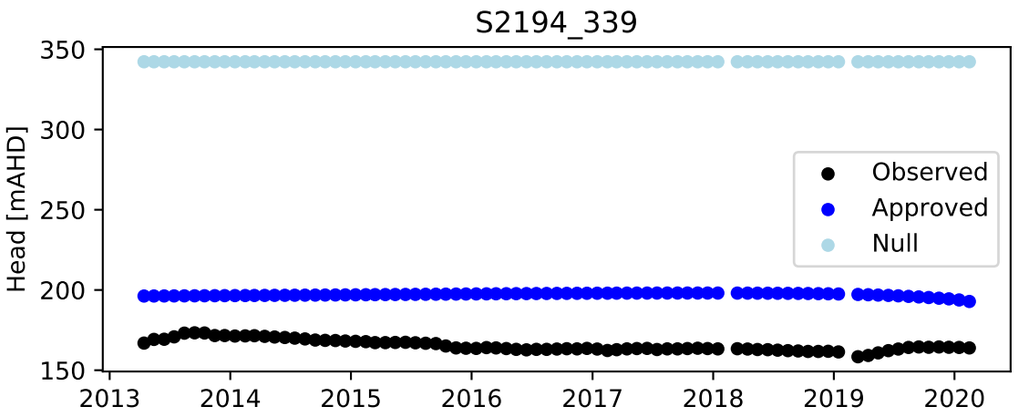

S2194_55
Head [mAHD]
337.5
335.0
332.5
330.0
327.5
325.0
Observed
Approved
Null
2013
2014
2015
2016
2017
2018
2019
2020

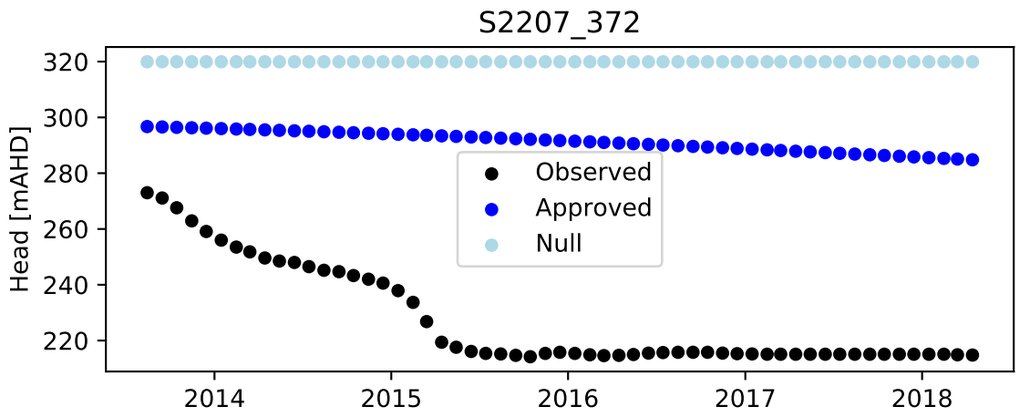

S2194_210
Head [mAHD]
Observed
Approved
Null

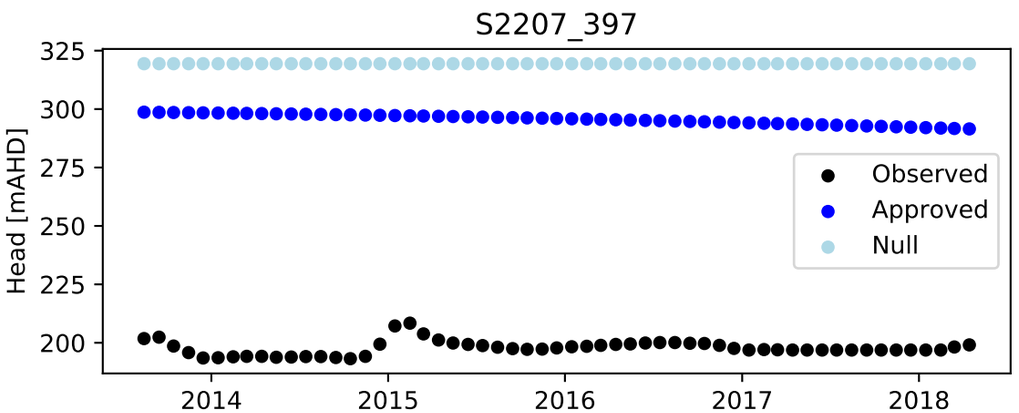

S2194_239
Head [mAHD]
Observed
Approved
Null

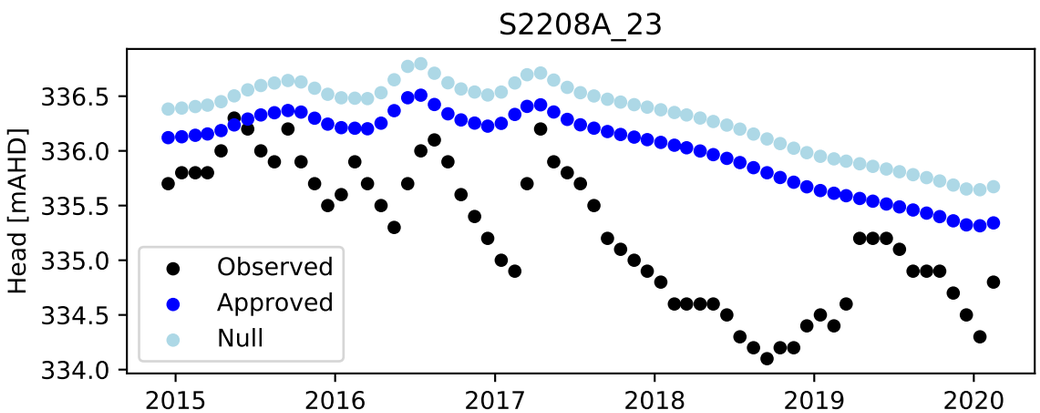

S2194_274
Head [mAHD]
Observed
Approved
Null

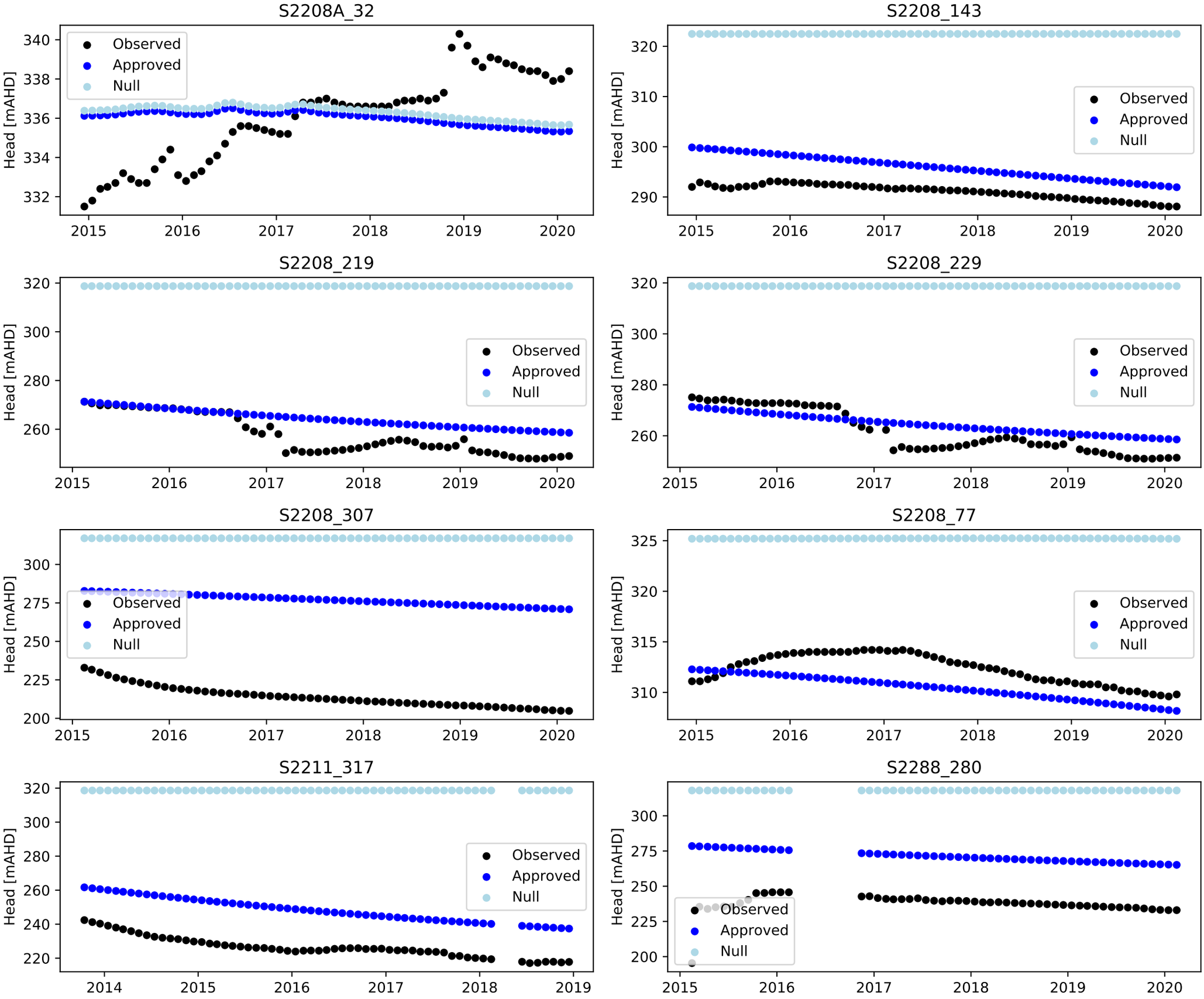

S2194_302
Head [mAHD]
Observed
Approved
Null

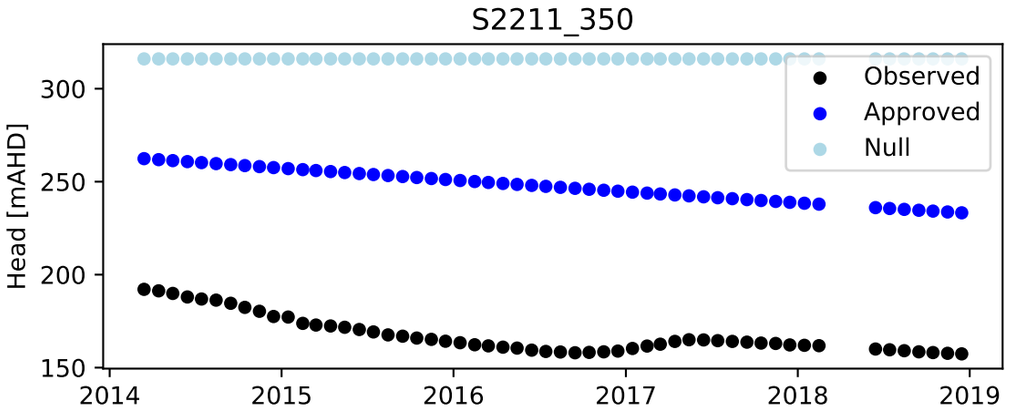

S2194_339
Head [mAHD]
Observed
Approved
Null

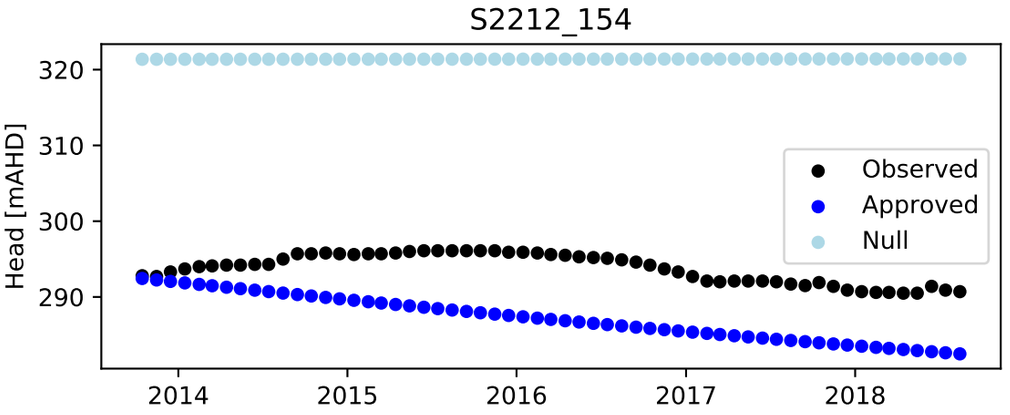

S2207_372
Head [mAHD]
Observed
Approved
Null

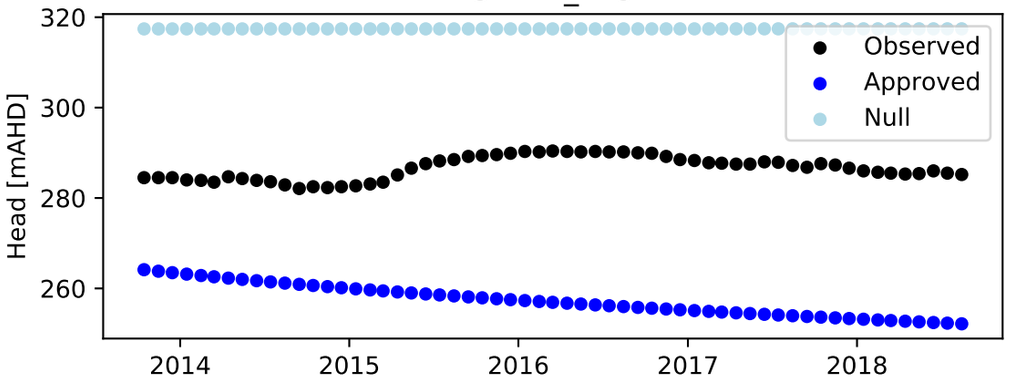

S2207_397
Head [mAHD]
Observed
Approved
Null

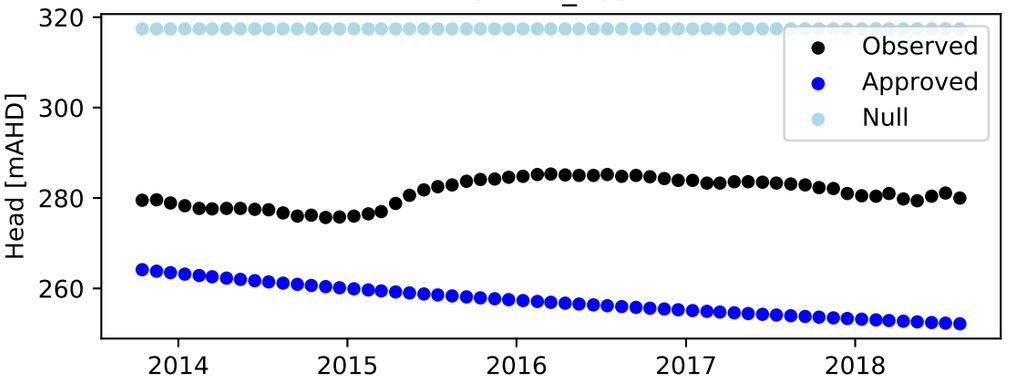

S2208A_23
Head [mAHD]
Observed
Approved
Null

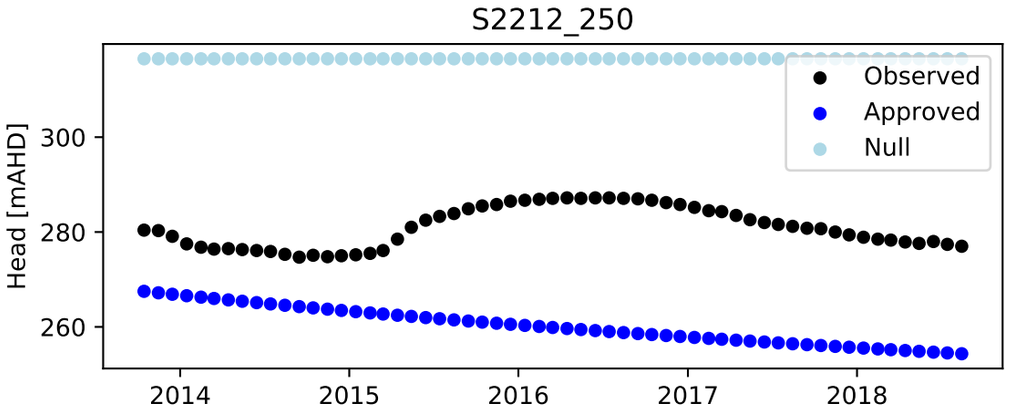

S2208A_32
S2208_143
S2208_219
S2208_229
S2208_307
S2208_77
S2211_317
S2288_280
Observed
Approved
Null
Head [mAHD]

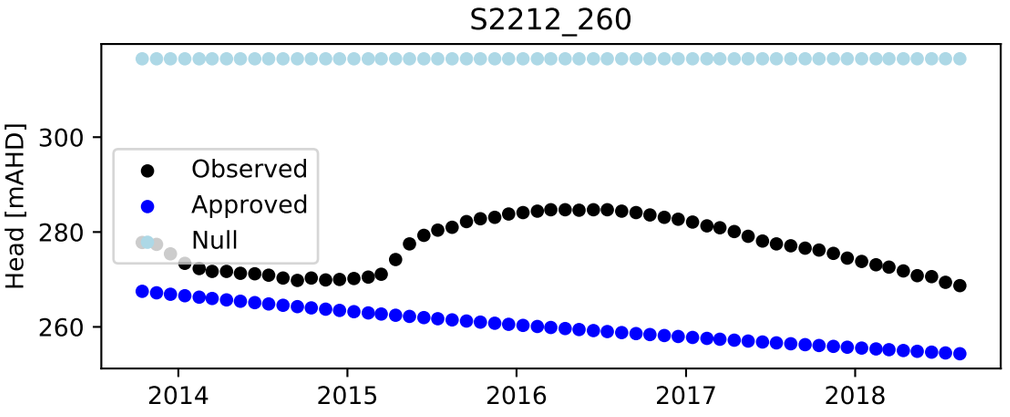

S2211_350
Head [mAHD]
Observed
Approved
Null

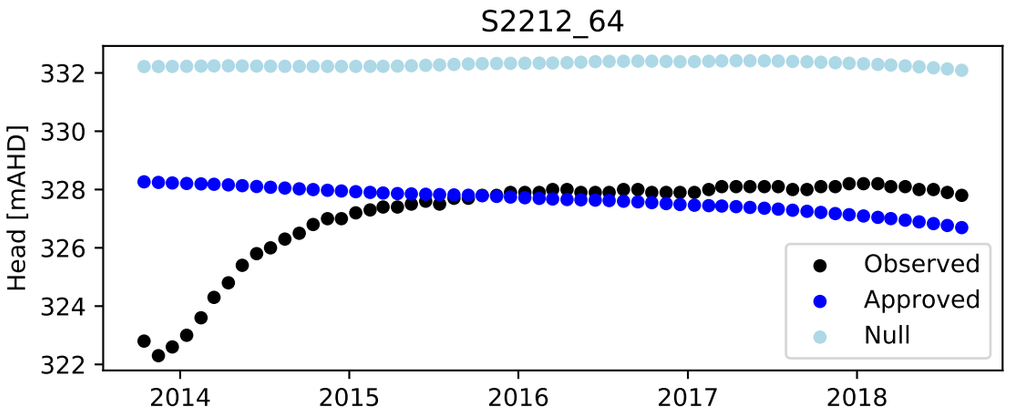

S2212_154
Head [mAHD]
Observed
Approved
Null

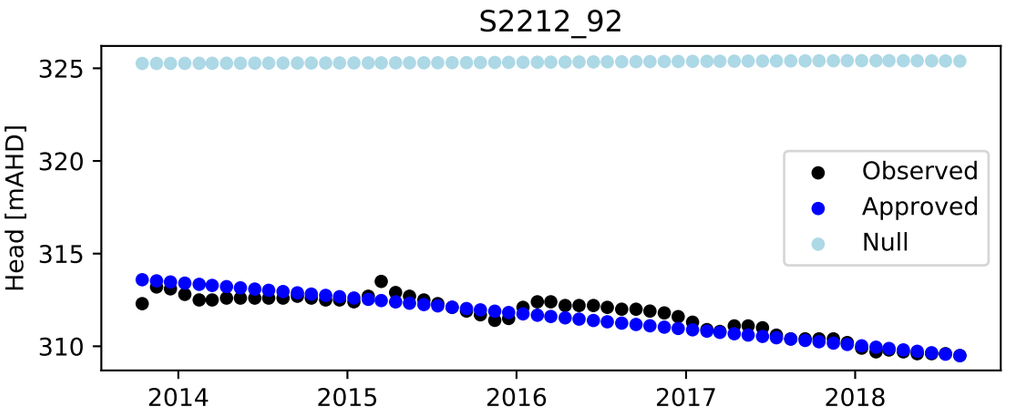

S2212_215
Head [mAHD]
Observed
Approved
Null

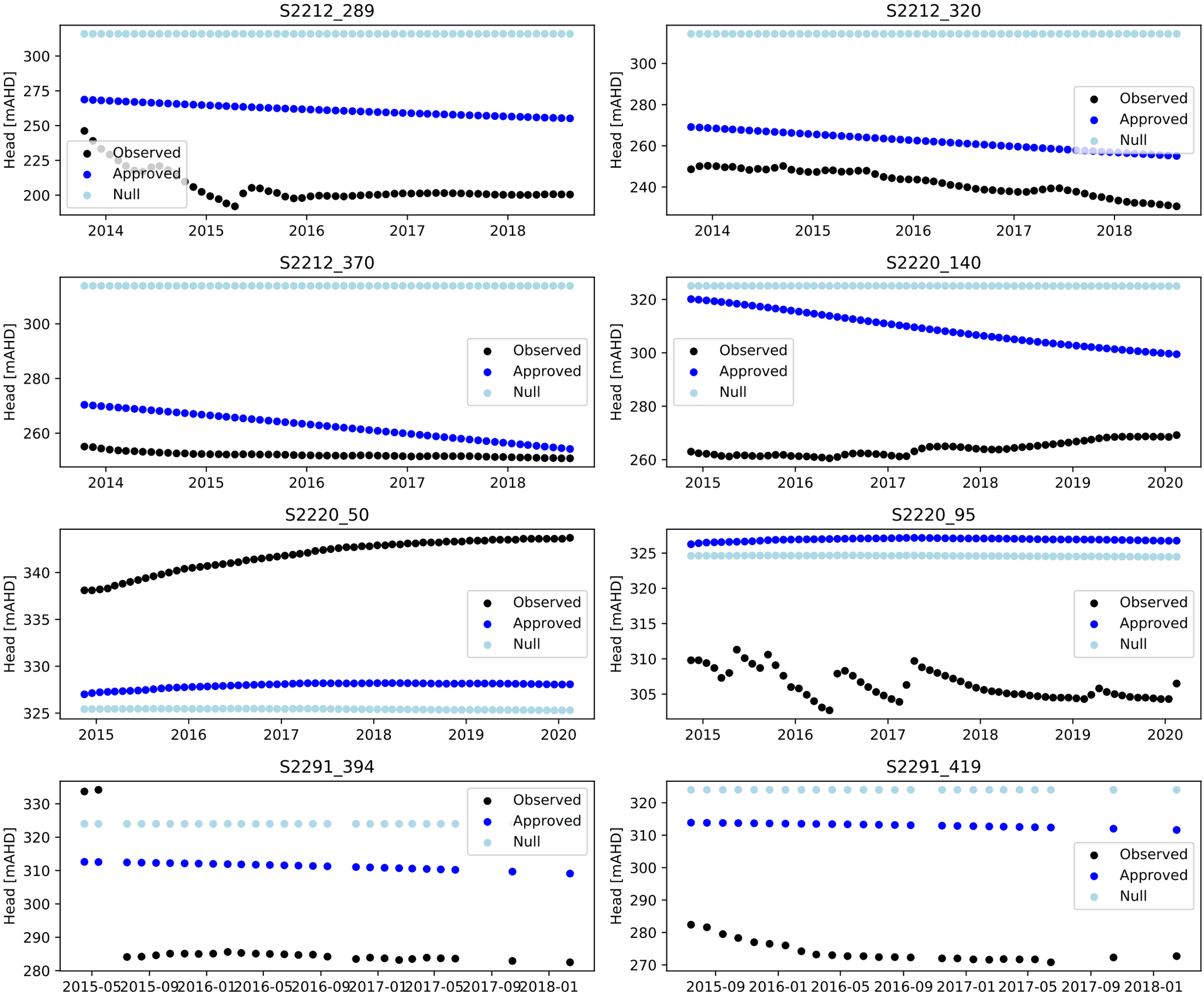

S2212_239
Head [mAHD]
Observed
Approved
Null

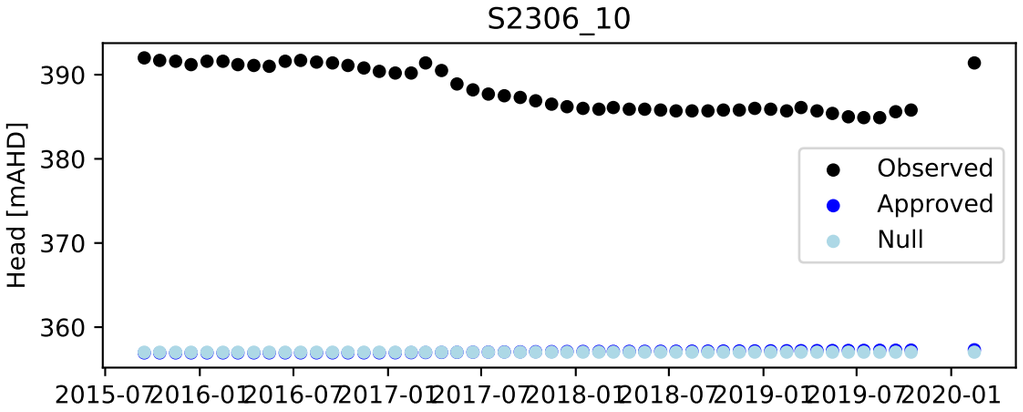

S2212_250
Head [mAHD]
Observed
Approved
Null

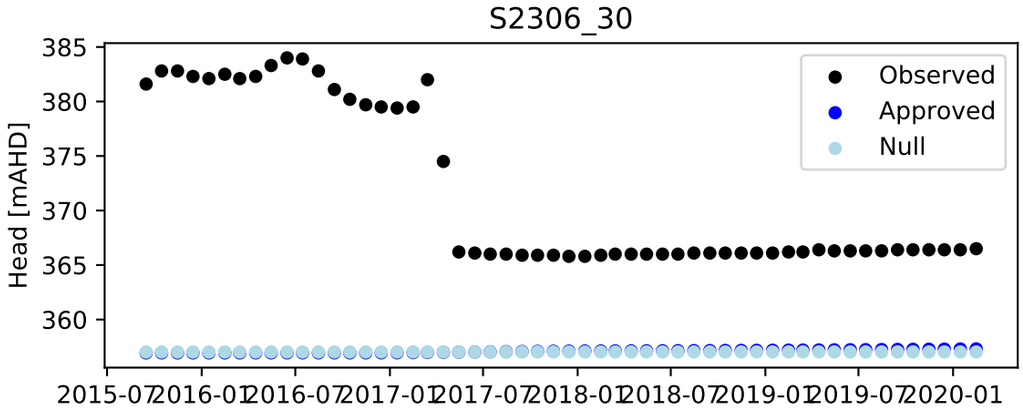

S2212_260
Head [mAHD]
Observed
Approved
Null

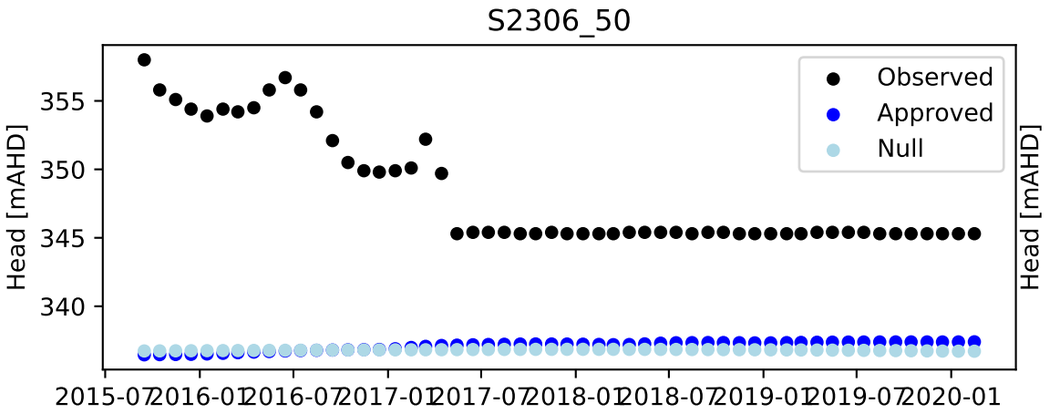

S2212_64
Head [mAHD]
Observed
Approved
Null

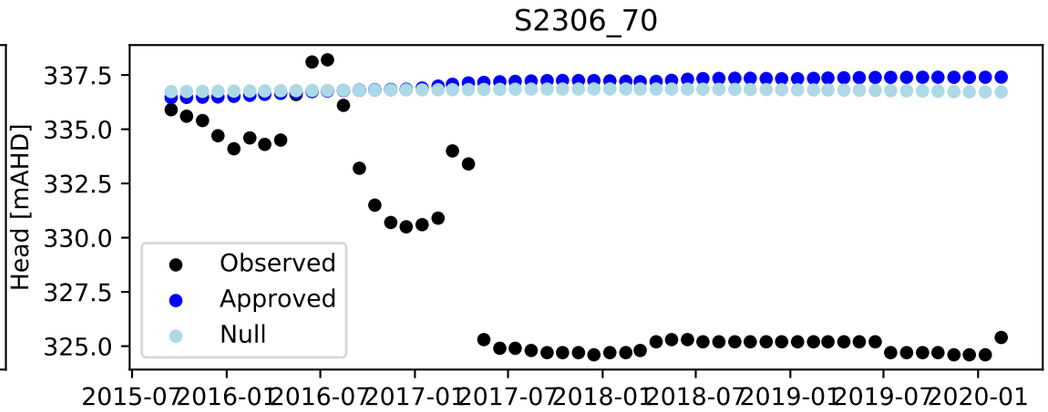

S2212_92
Head [mAHD]
Observed
Approved
Null

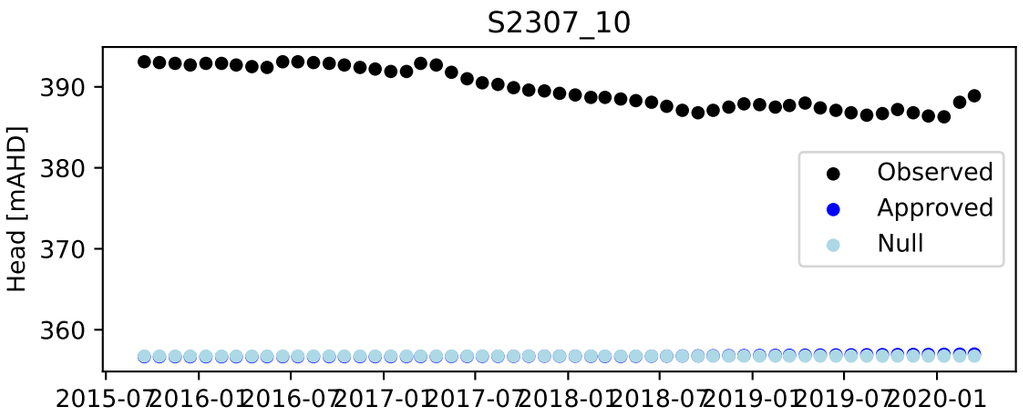

S2212_289
S2212_320
S2212_370
S2220_140
S2220_50
S2220_95
S2291_394
S2291_419
Head [mAHD]
Observed
Approved
Null

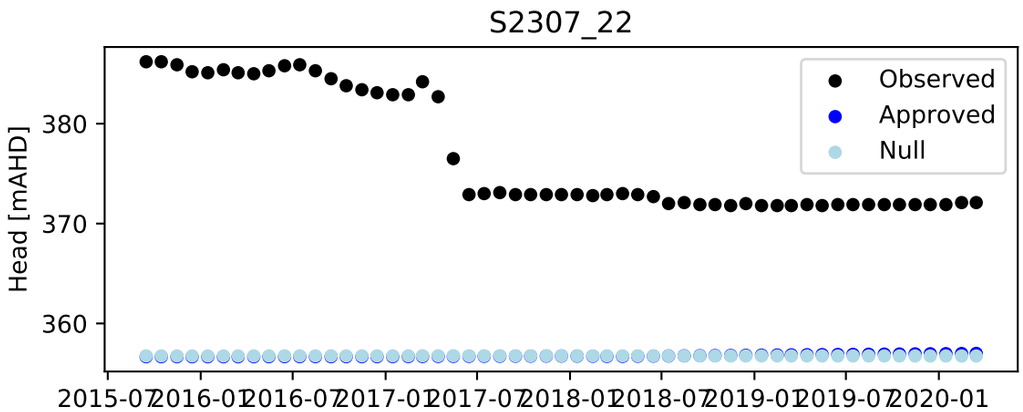

S2306_10
Head [mAHD]
390
380
370
360
Observed
Approved
Null
2015-07
2016-01
2016-07
2017-01
2017-07
2018-01
2018-07
2019-01
2019-07
2020-01

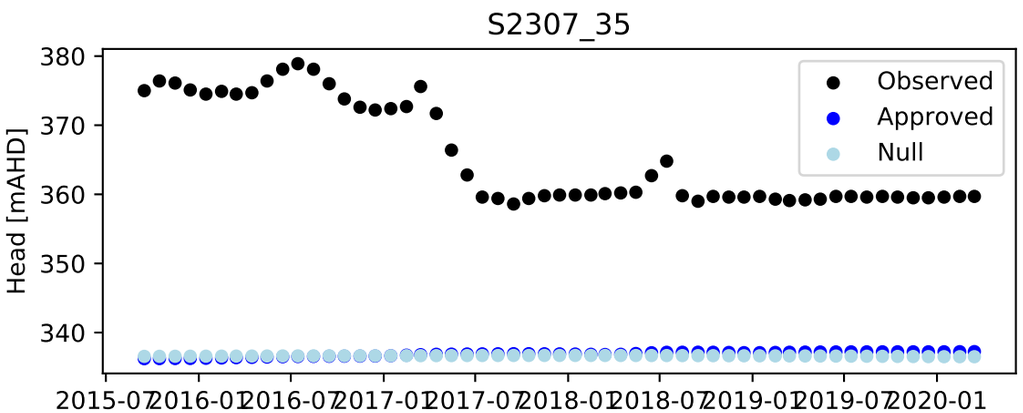

S2306_30
Head [mAHD]
385
380
375
370
365
360
Observed
Approved
Null
2015-07
2016-01
2016-07
2017-01
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2018-01
2018-07
2019-01
2019-07
2020-01

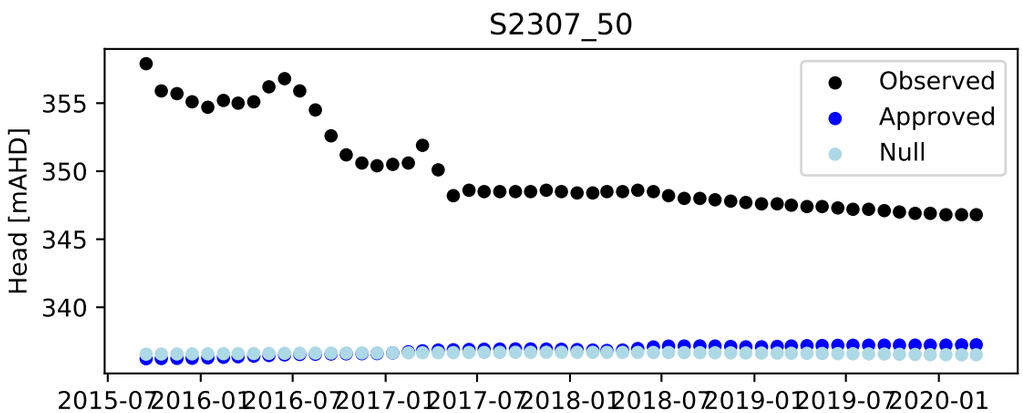

S2306_50
Head [mAHD]
355
350
345
340
Observed
Approved
Null
2015-07
2016-01
2016-07
2017-01
2017-07
2018-01
2018-07
2019-01
2019-07
2020-01

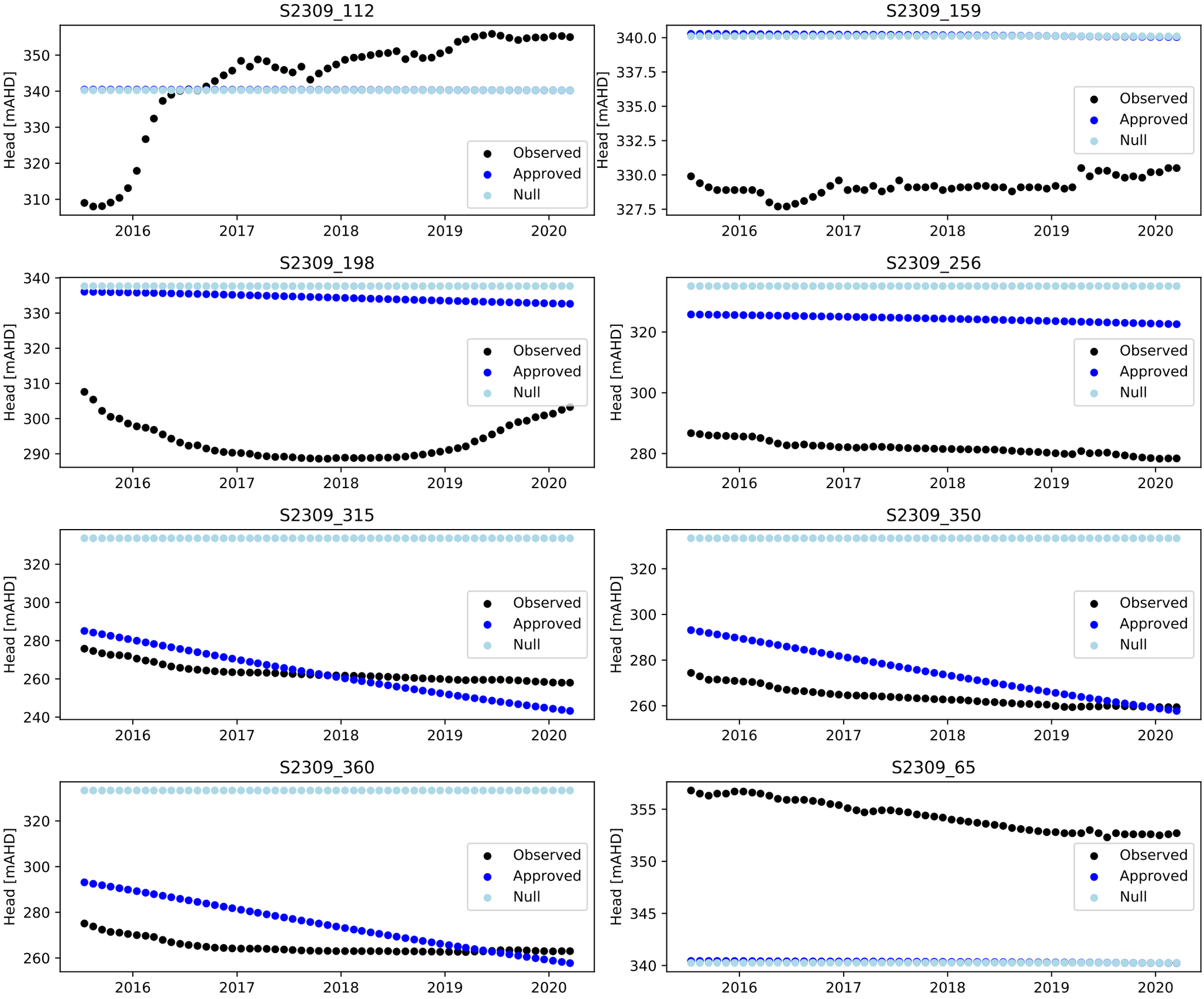

S2306_70
Head [mAHD]
337.5
335.0
332.5
330.0
327.5
325.0
Observed
Approved
Null
2015-07
2016-01
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2017-01
2017-07
2018-01
2018-07
2019-01
2019-07
2020-01

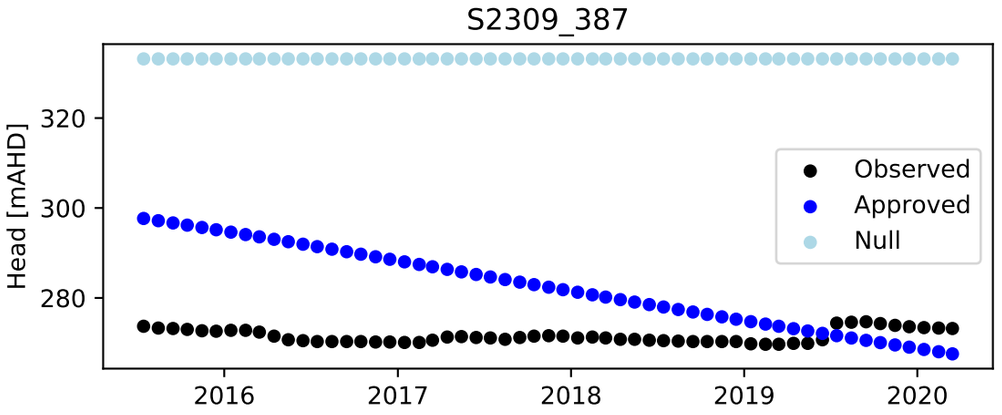

S2307_10
Head [mAHD]
390
380
370
360
Observed
Approved
Null
2015-07
2016-01
2016-07
2017-01
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2018-07
2019-01
2019-07
2020-01

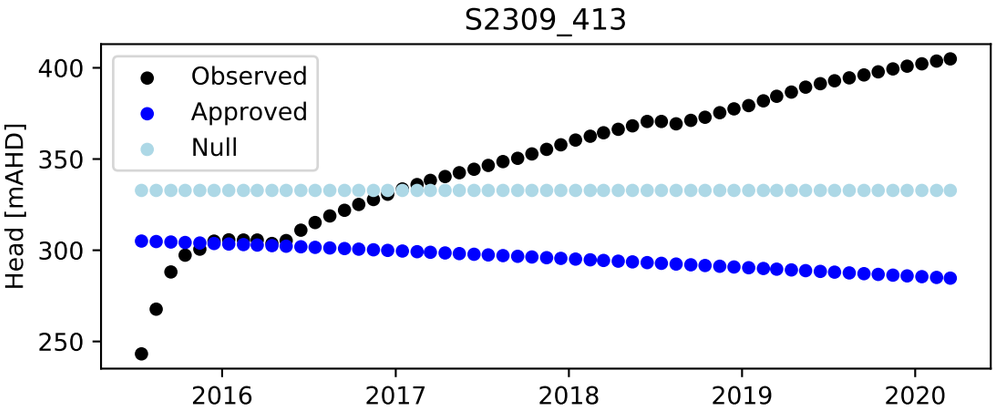

S2307_22
Head [mAHD]
380
370
360
Observed
Approved
Null
2015-07
2016-01
2016-07
2017-01
2017-07
2018-01
2018-07
2019-01
2019-07
2020-01

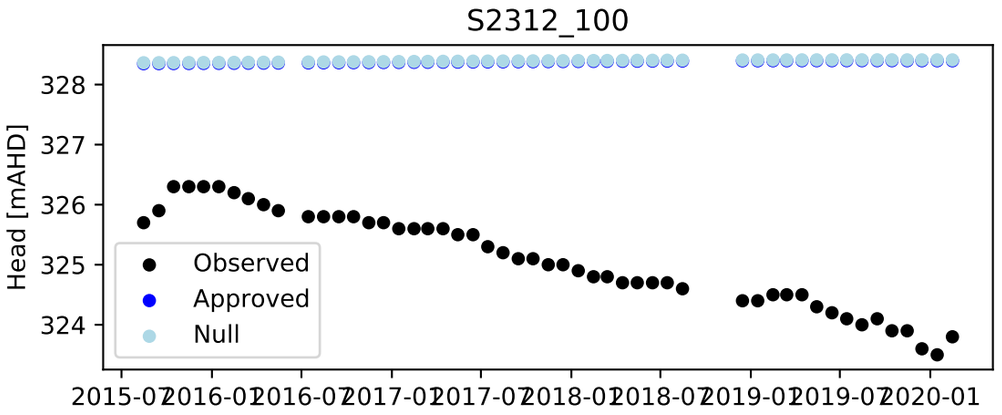

S2307_35
Head [mAHD]
380
370
360
350
340
Observed
Approved
Null
2015-07
2016-01
2016-07
2017-01
2017-07
2018-01
2018-07
2019-01
2019-07
2020-01

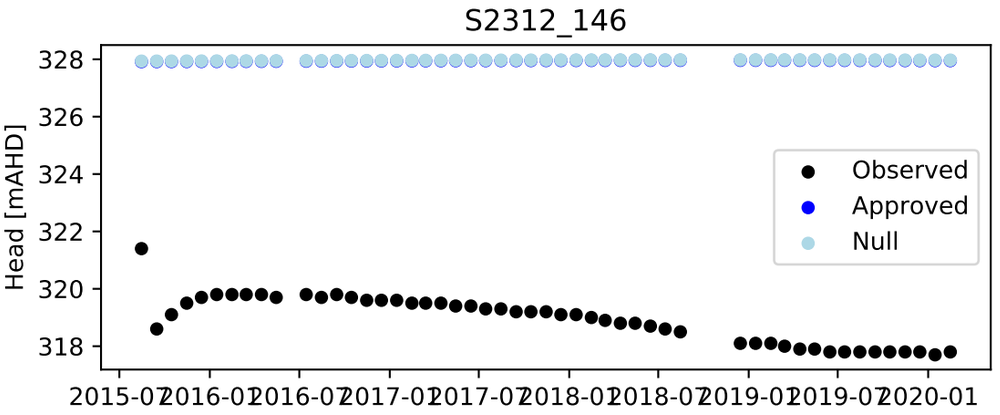

S2307_50
Head [mAHD]
355
350
345
340
Observed
Approved
Null
2015-07
2016-01
2016-07
2017-01
2017-07
2018-01
2018-07
2019-01
2019-07
2020-01

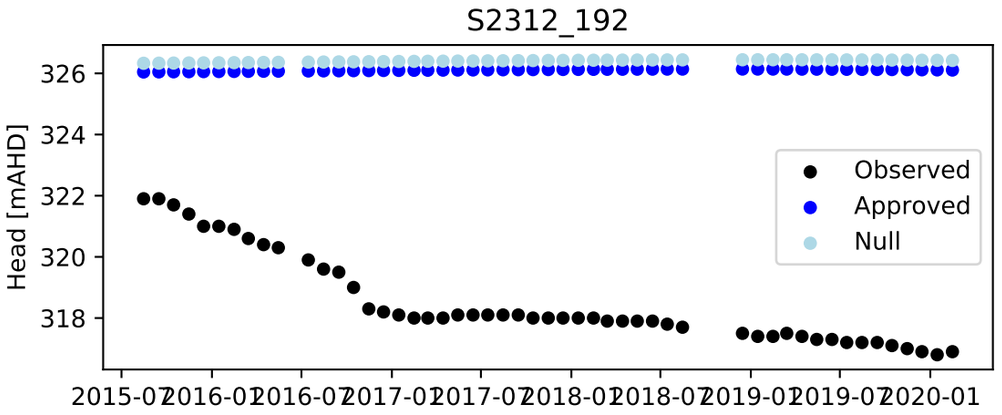

S2309_112
S2309_159
S2309_198
S2309_256
S2309_315
S2309_350
S2309_360
S2309_65
Head [mAHD]
Observed
Approved
Null
2016
2017
2018
2019
2020

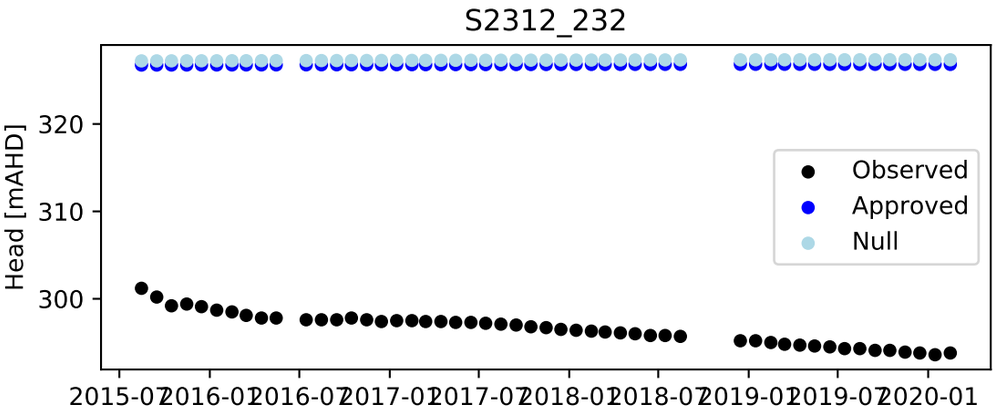

S2309_387
Head [mAHD]
320
300
280
2016
2017
2018
2019
2020
Observed
Approved
Null

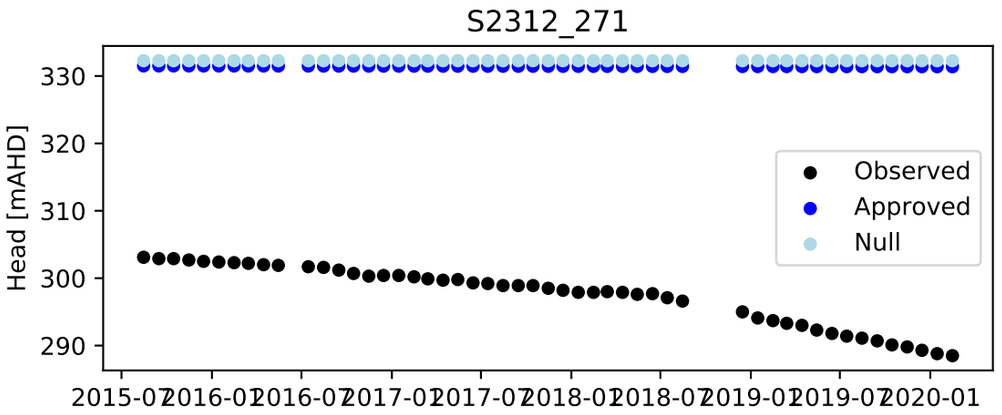

S2309_413
Head [mAHD]
400
350
300
250
2016
2017
2018
2019
2020
Observed
Approved
Null

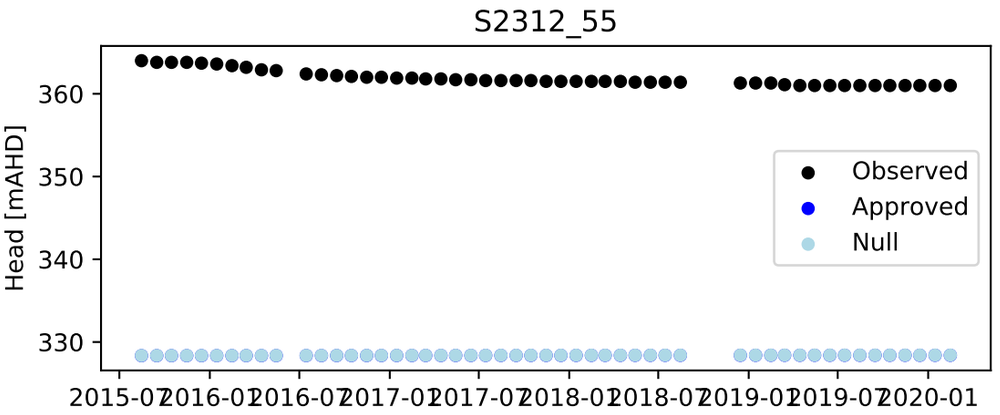

S2312_100
Head [mAHD]
328
327
326
325
324
2015-07
2016-01
2016-07
2017-01
2017-07
2018-01
2018-07
2019-01
2019-07
2020-01
Observed
Approved
Null

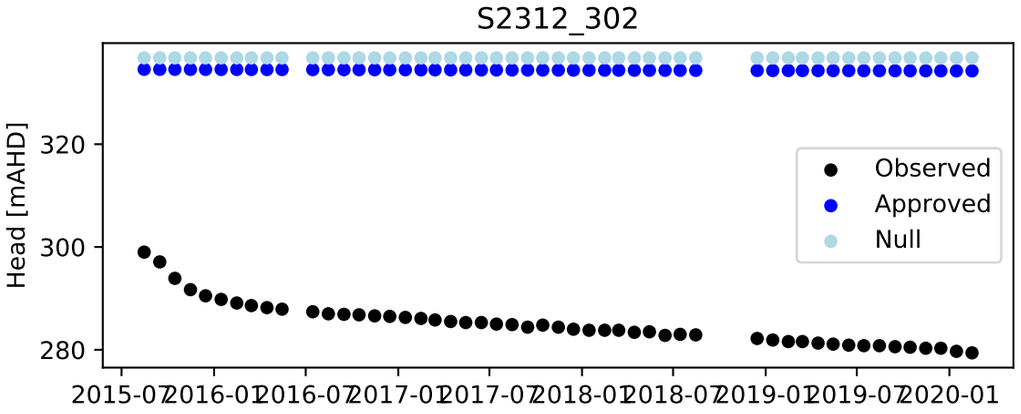

S2312_146
Head [mAHD]
328
326
324
322
320
318
2015-07
2016-01
2016-07
2017-01
2017-07
2018-01
2018-07
2019-01
2019-07
2020-01
Observed
Approved
Null

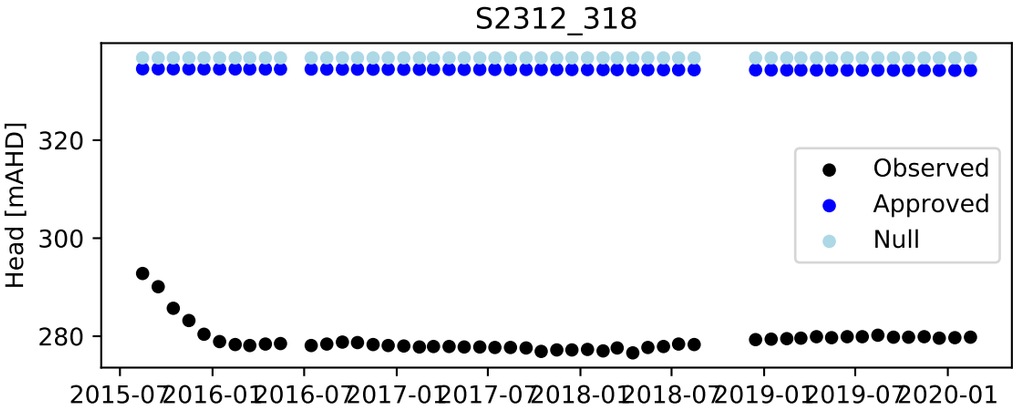

S2312_192
Head [mAHD]
326
324
322
320
318
2015-07
2016-01
2016-07
2017-01
2017-07
2018-01
2018-07
2019-01
2019-07
2020-01
Observed
Approved
Null

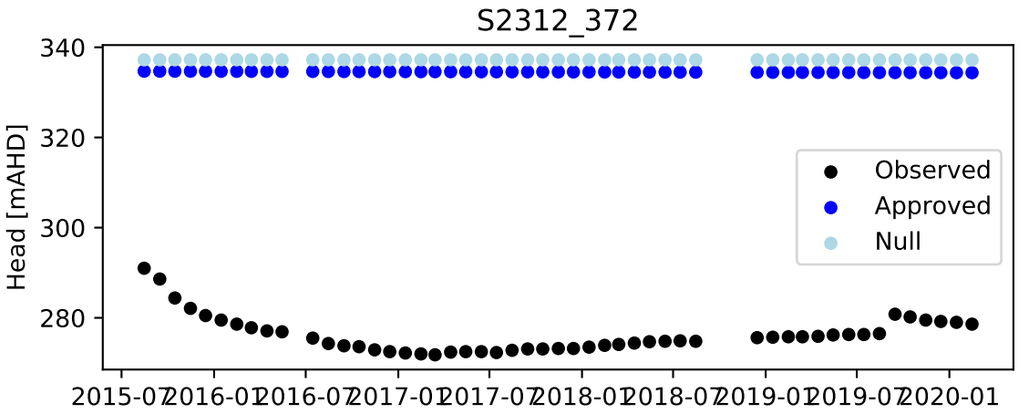

S2312_232
Head [mAHD]
320
310
300
2015-07
2016-01
2016-07
2017-01
2017-07
2018-01
2018-07
2019-01
2019-07
2020-01
Observed
Approved
Null

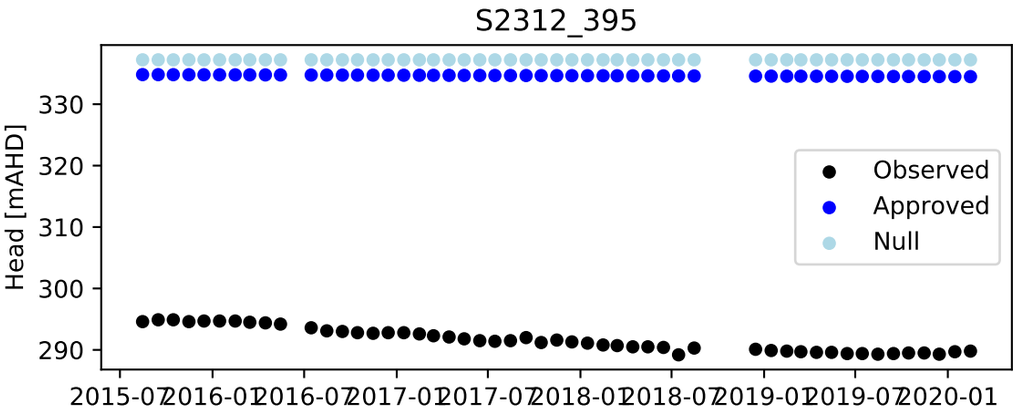

S2312_271
Head [mAHD]
330
320
310
300
290
2015-07
2016-01
2016-07
2017-01
2017-07
2018-01
2018-07
2019-01
2019-07
2020-01
Observed
Approved
Null

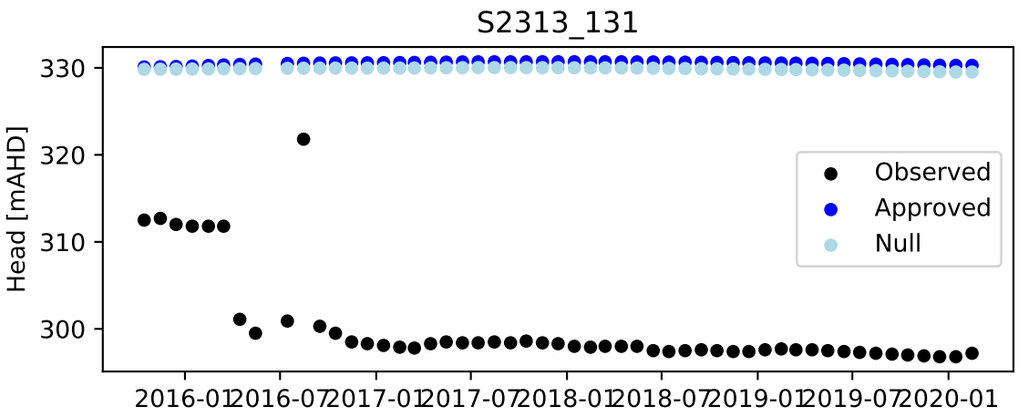

S2312_55
Head [mAHD]
360
350
340
330
2015-07
2016-01
2016-07
2017-01
2017-07
2018-01
2018-07
2019-01
2019-07
2020-01
Observed
Approved
Null

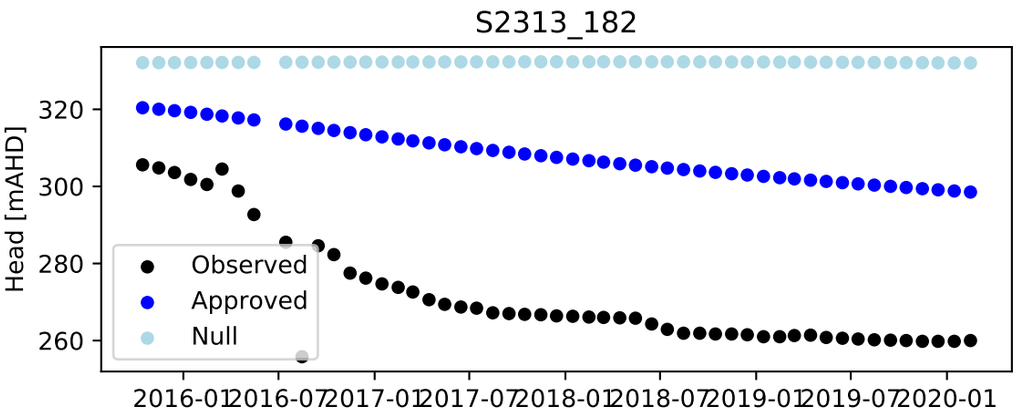

S2312_302
Head [mAHD]
320
300
280
2015-07
2016-01
2016-07
2017-01
2017-07
2018-01
2018-07
2019-01
2019-07
2020-01
Observed
Approved
Null

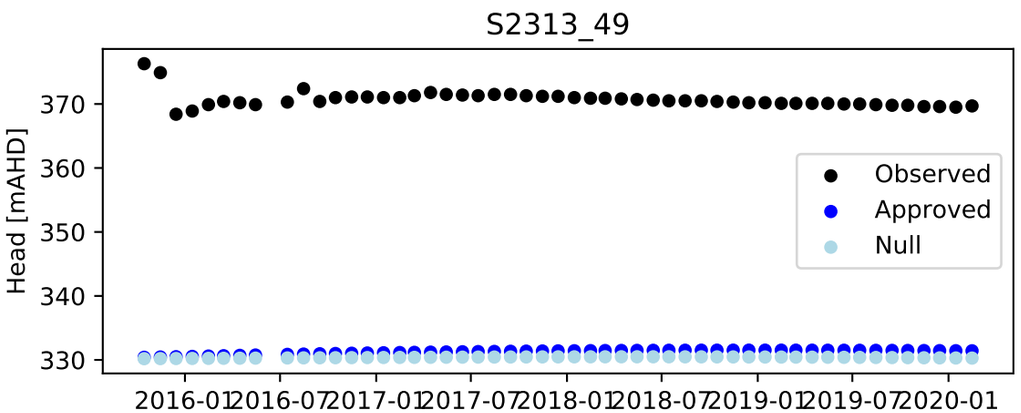

S2312_318
Head [mAHD]
320
300
280
2015-07
2016-01
2016-07
2017-01
2017-07
2018-01
2018-07
2019-01
2019-07
2020-01
Observed
Approved
Null

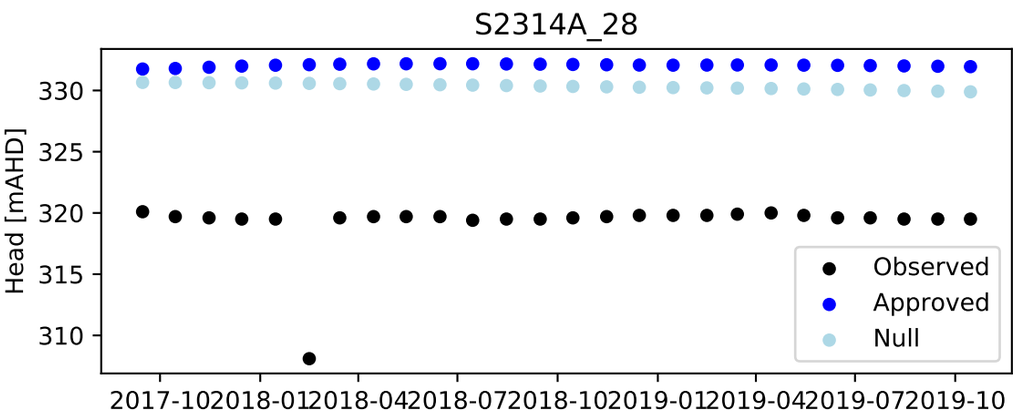

S2312_372
Head [mAHD]
340
320
300
280
2015-07
2016-01
2016-07
2017-01
2017-07
2018-01
2018-07
2019-01
2019-07
2020-01
Observed
Approved
Null

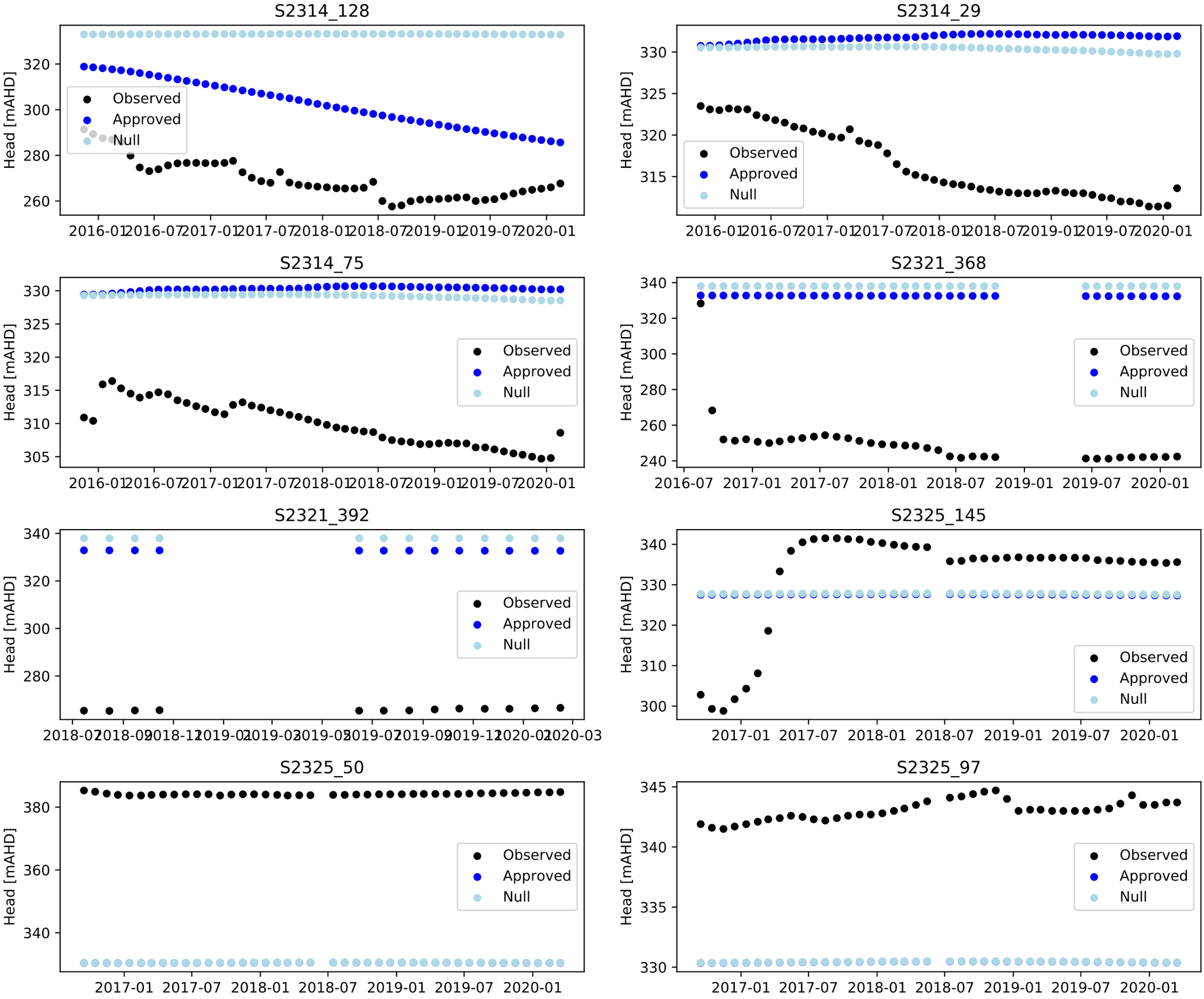

S2312_395
Head [mAHD]
330
320
310
300
290
2015-07
2016-01
2016-07
2017-01
2017-07
2018-01
2018-07
2019-01
2019-07
2020-01
Observed
Approved
Null

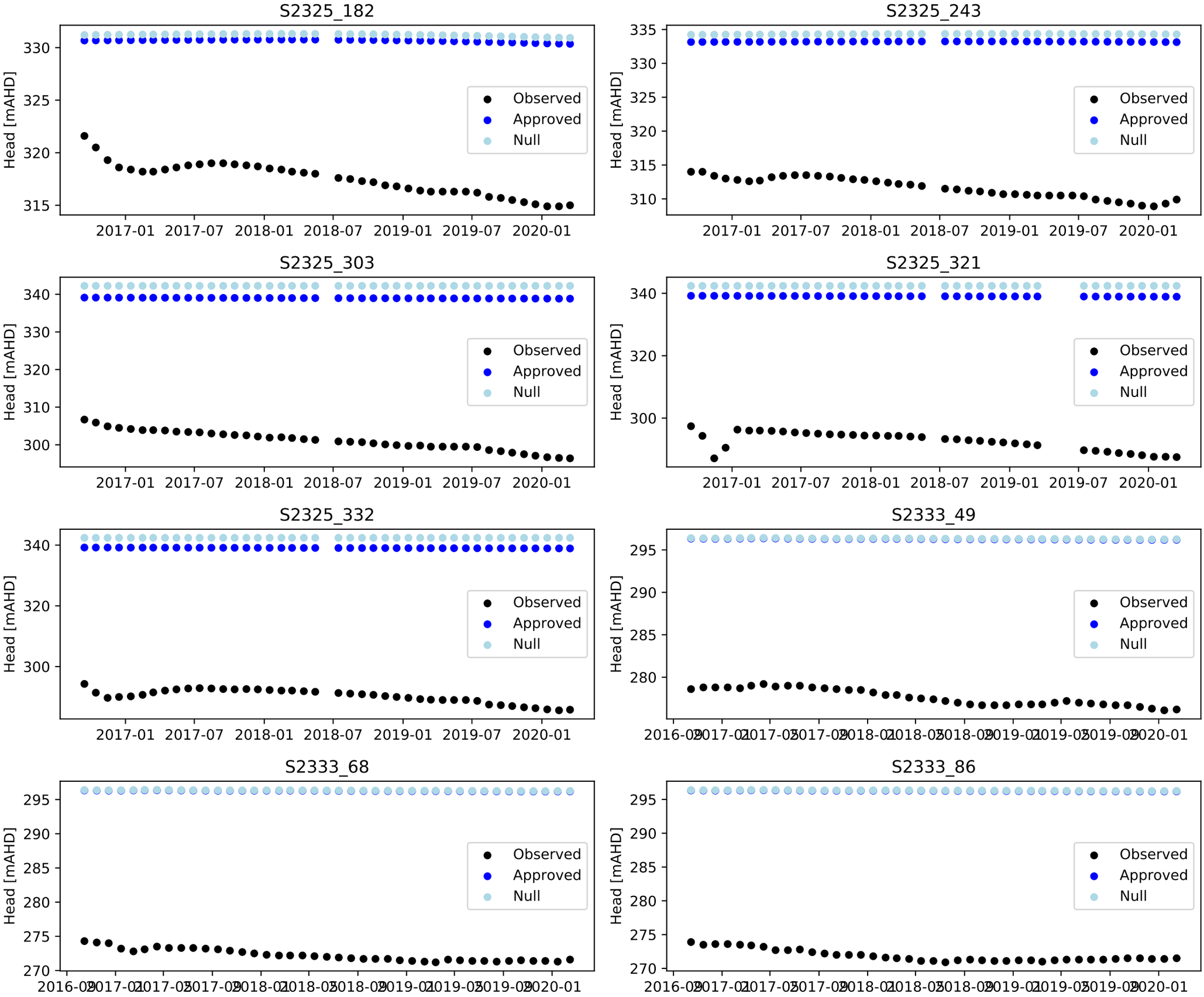

S2313_131
Head [mAHD]
330
320
310
300
2016-01
2016-07
2017-01
2017-07
2018-01
2018-07
2019-01
2019-07
2020-01
Observed
Approved
Null

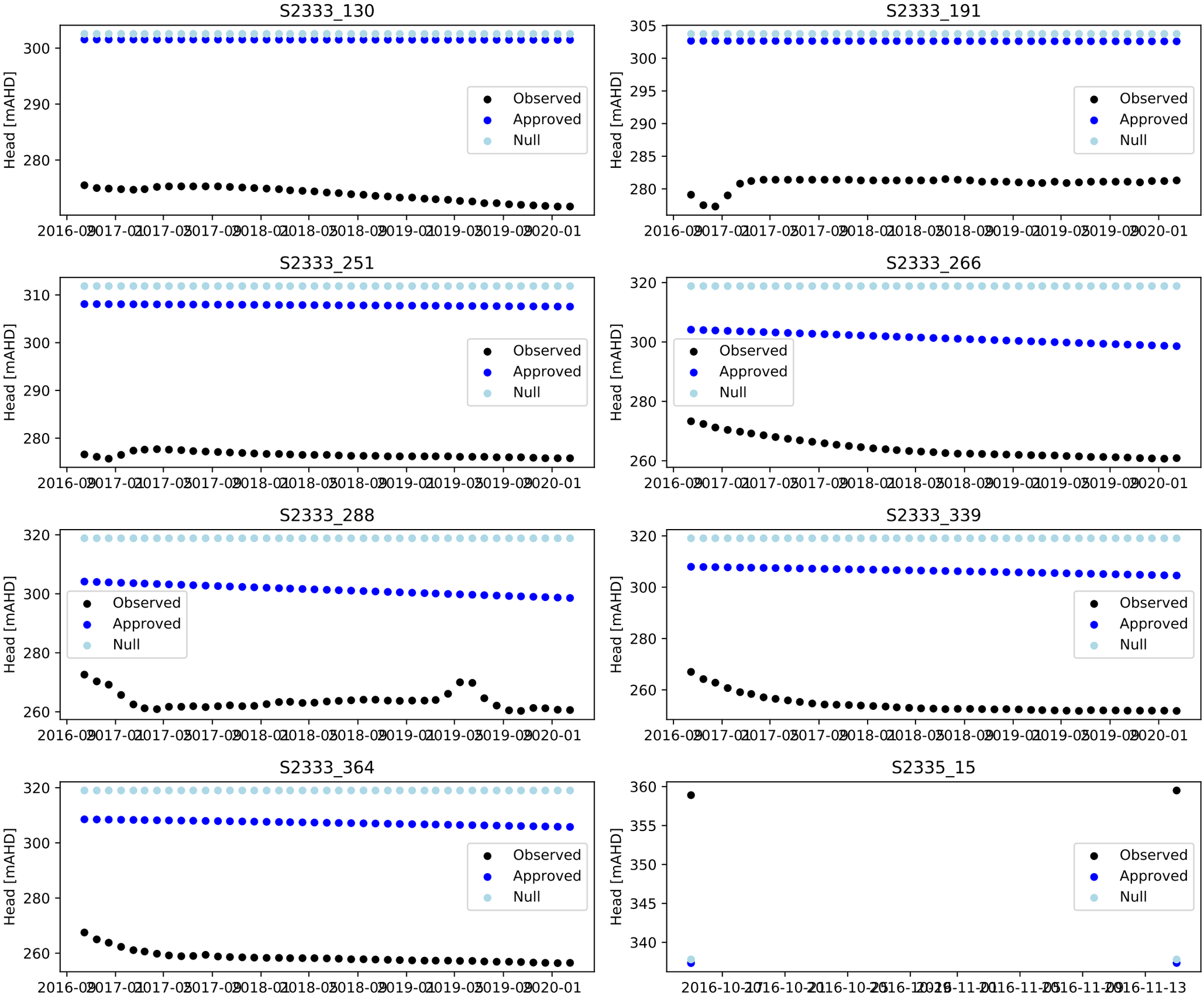

S2313_182
Head [mAHD]
320
300
280
260
2016-01
2016-07
2017-01
2017-07
2018-01
2018-07
2019-01
2019-07
2020-01
Observed
Approved
Null

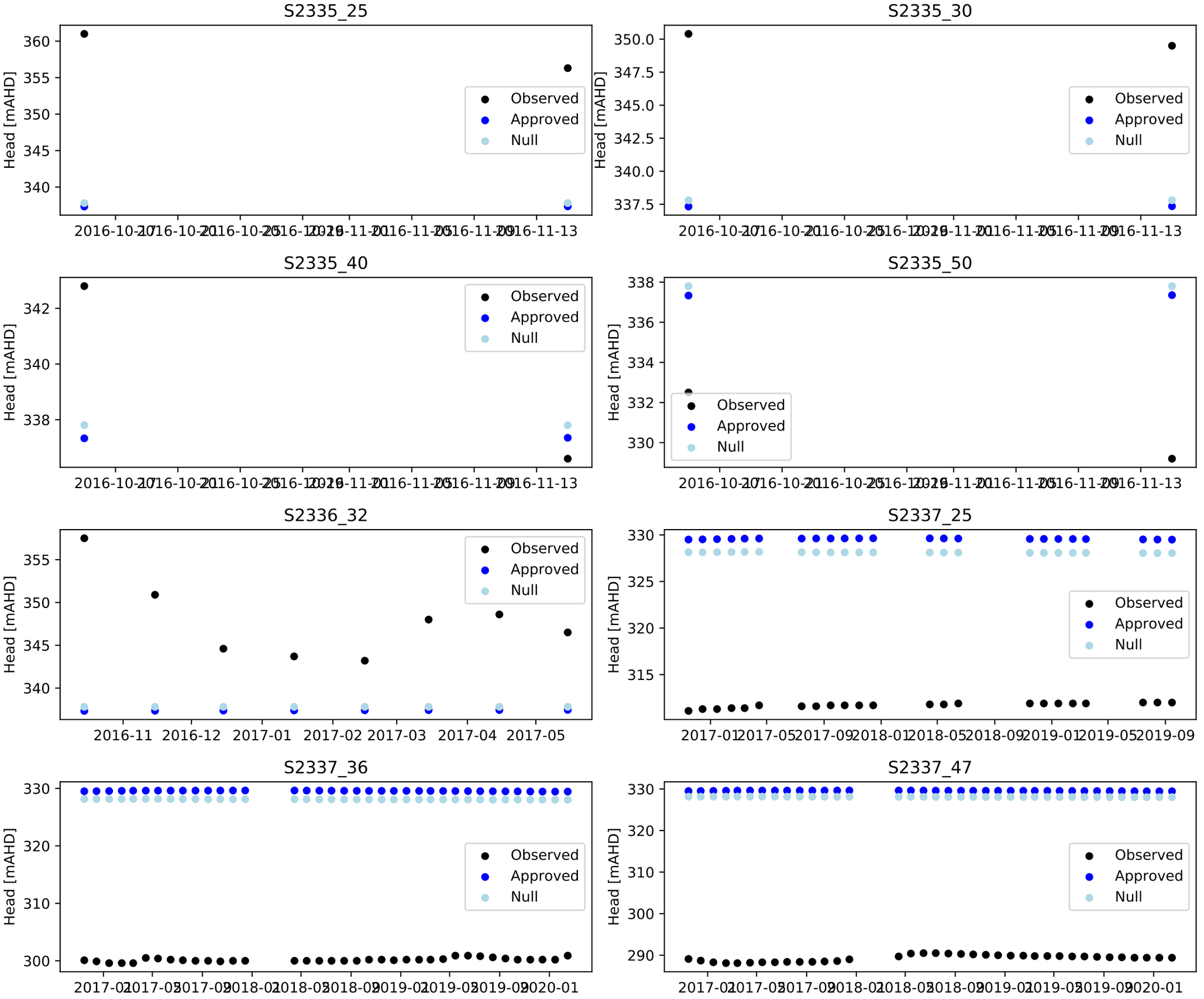

S2313_49
Head [mAHD]
370
360
350
340
330
2016-01
2016-07
2017-01
2017-07
2018-01
2018-07
2019-01
2019-07
2020-01
Observed
Approved
Null

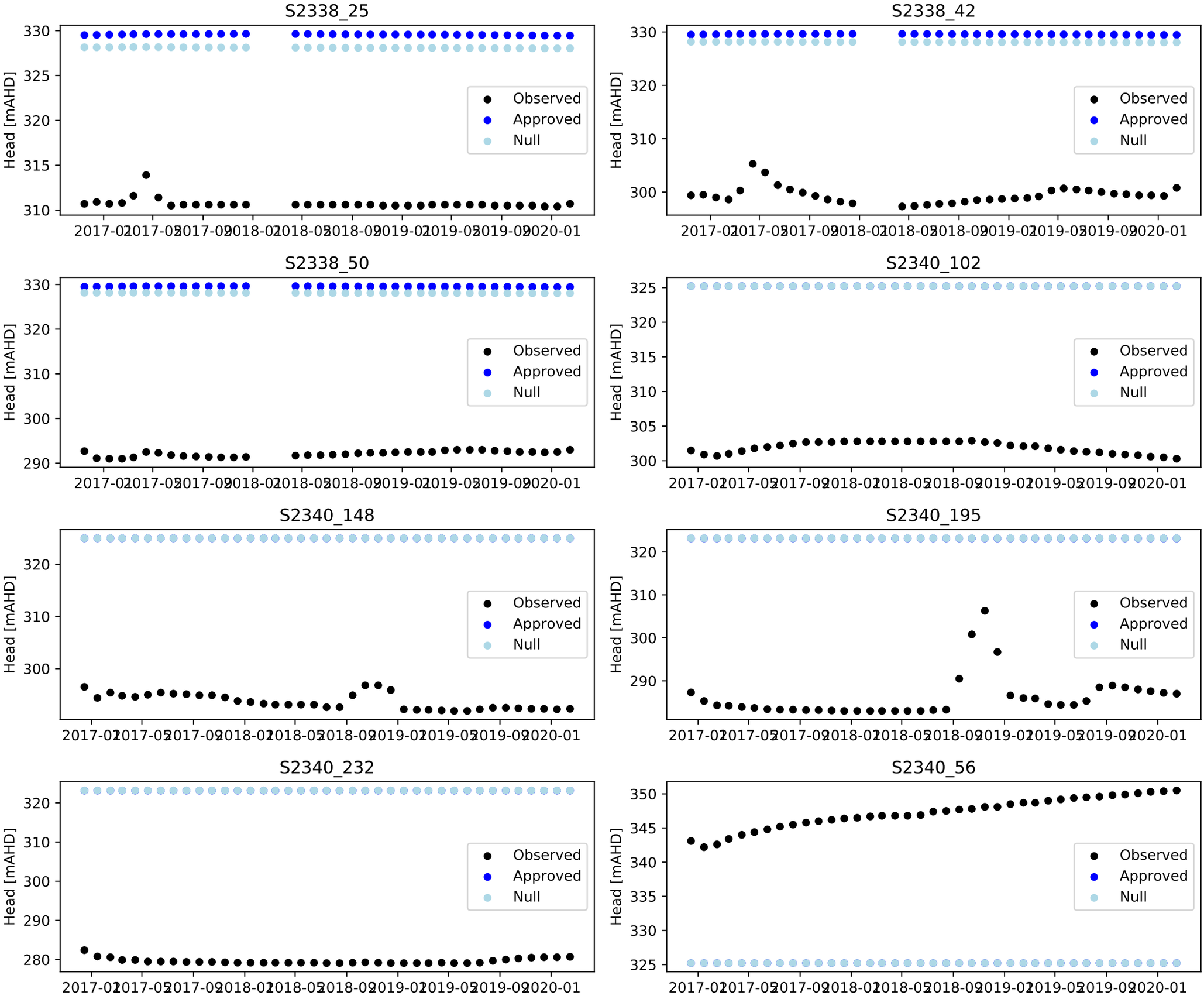

S2314A_28
Head [mAHD]
330
325
320
315
310
2017-10
2018-01
2018-04
2018-07
2018-10
2019-01
2019-04
2019-07
2019-10
Observed
Approved
Null

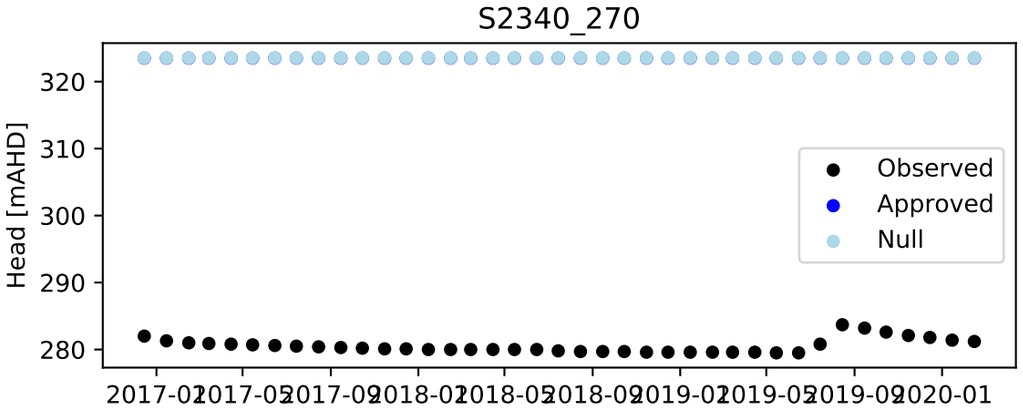

S2314_128
Head [mAHD]
Observed
Approved
Null
S2314_29
S2314_75
S2321_368
S2321_392
S2325_145
S2325_50
S2325_97

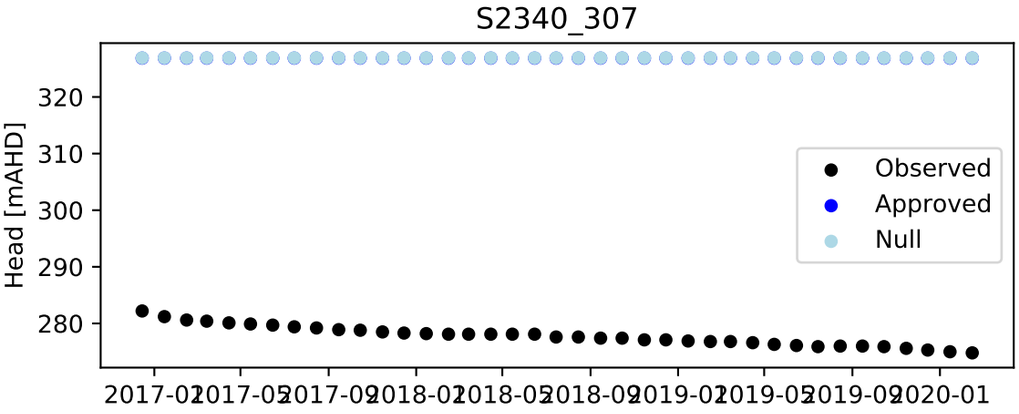

S2325_182
S2325_243
S2325_303
S2325_321
S2325_332
S2333_49
S2333_68
S2333_86
Head [mAHD]
Observed
Approved
Null
2017-01
2017-07
2018-01
2018-07
2019-01
2019-07
2020-01

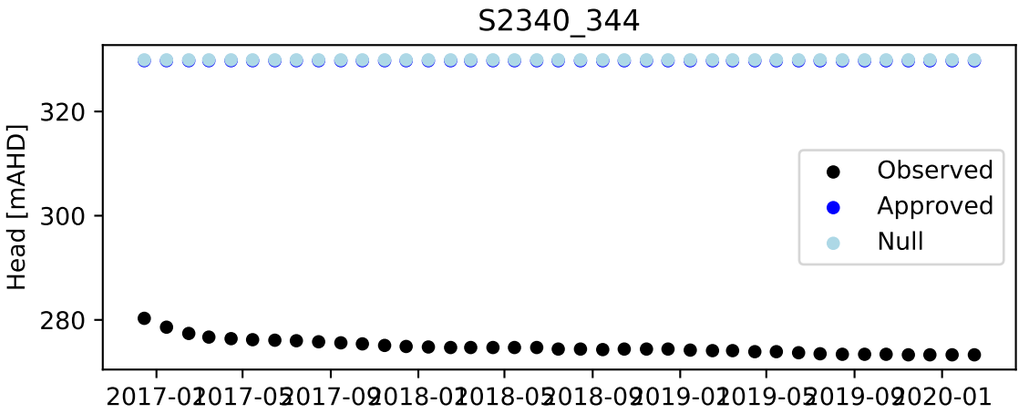

S2333_130
S2333_191
S2333_251
S2333_266
S2333_288
S2333_339
S2333_364
S2335_15
Head [mAHD]
Observed
Approved
Null

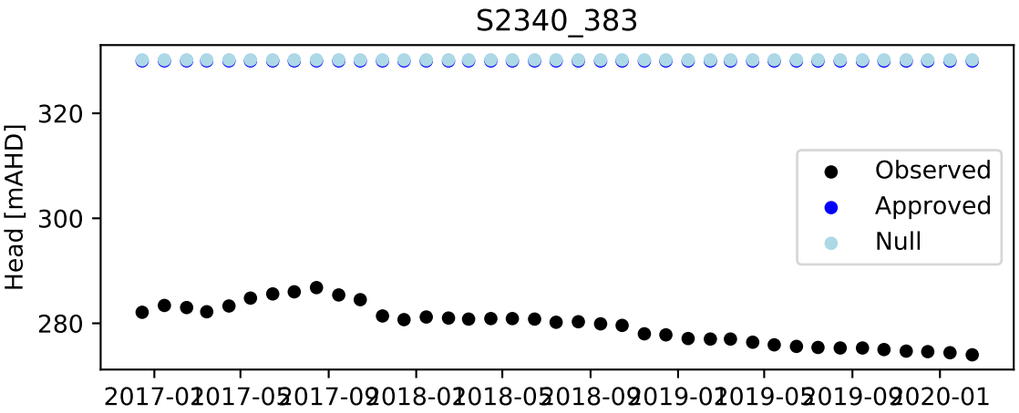

S2335_25
S2335_30
S2335_40
S2335_50
S2336_32
S2337_25
S2337_36
S2337_47
Head [mAHD]
Observed
Approved
Null

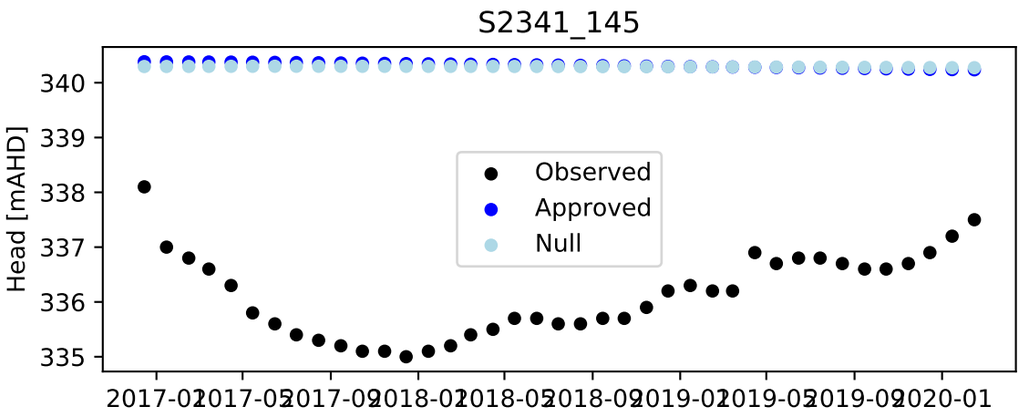

S2338_25
S2338_42
S2338_50
S2340_102
S2340_148
S2340_195
S2340_232
S2340_56
Head [mAHD]
Observed
Approved
Null
2017-01
2017-05
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01

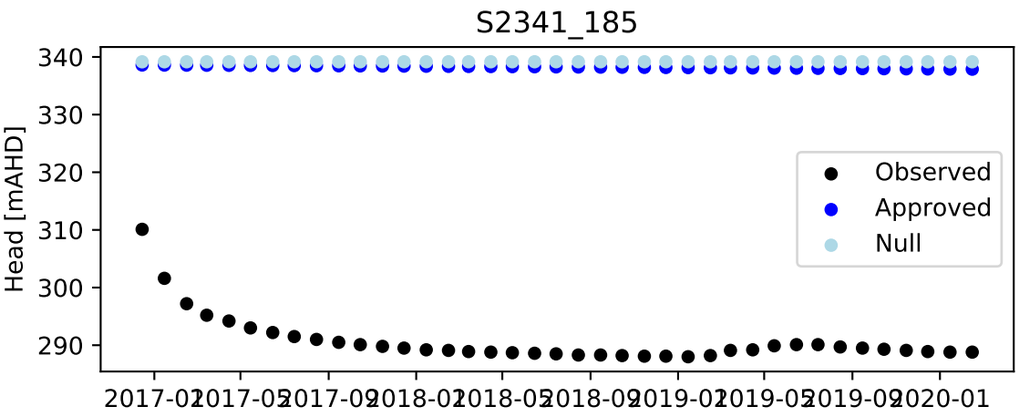

S2340_270
Head [mAHD]
320
310
300
290
280
Observed
Approved
Null
2017-01
2017-05
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01

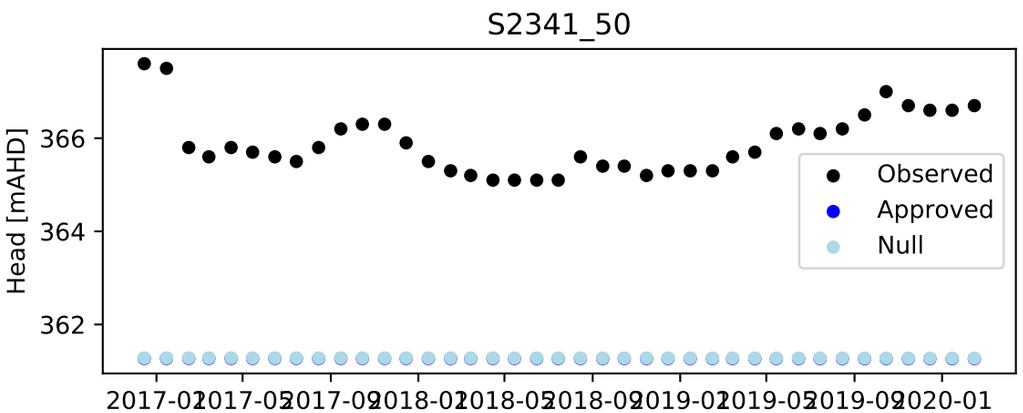

S2340_307
Head [mAHD]
320
310
300
290
280
Observed
Approved
Null
2017-01
2017-05
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01

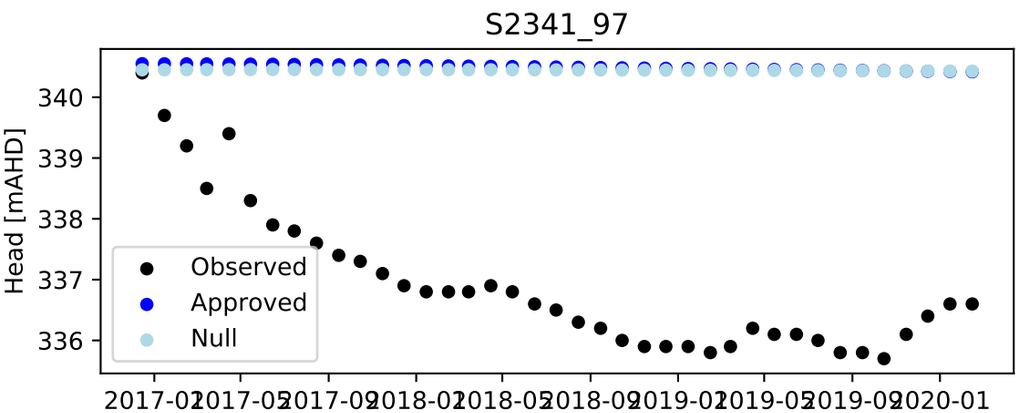

S2340_344
Head [mAHD]
320
300
280
Observed
Approved
Null
2017-01
2017-05
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01

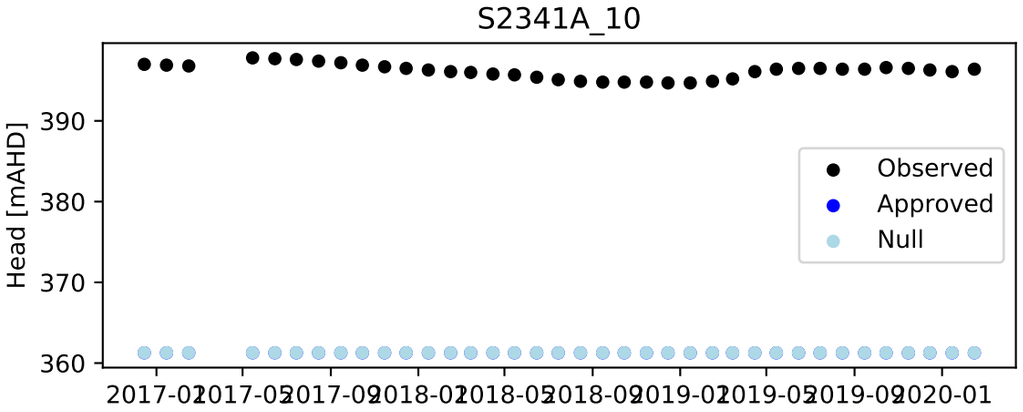

S2340_383
Head [mAHD]
320
300
280
Observed
Approved
Null
2017-01
2017-05
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01

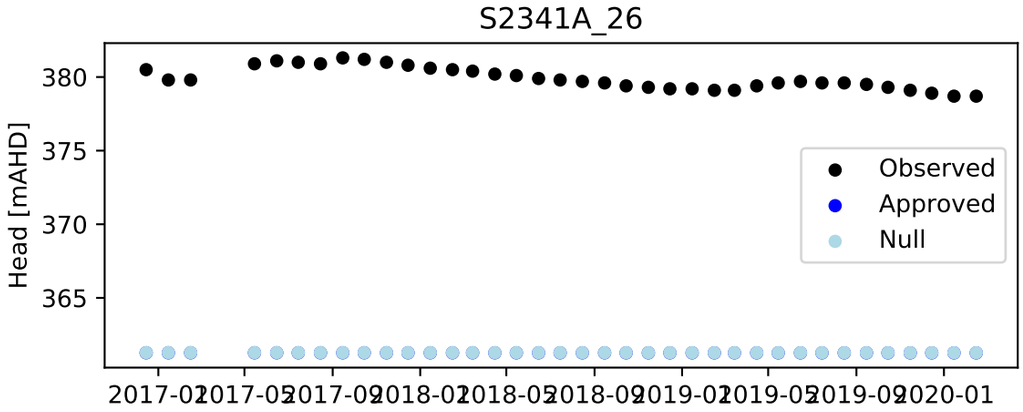

S2341_145
Head [mAHD]
340
339
338
337
336
335
Observed
Approved
Null
2017-01
2017-05
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01

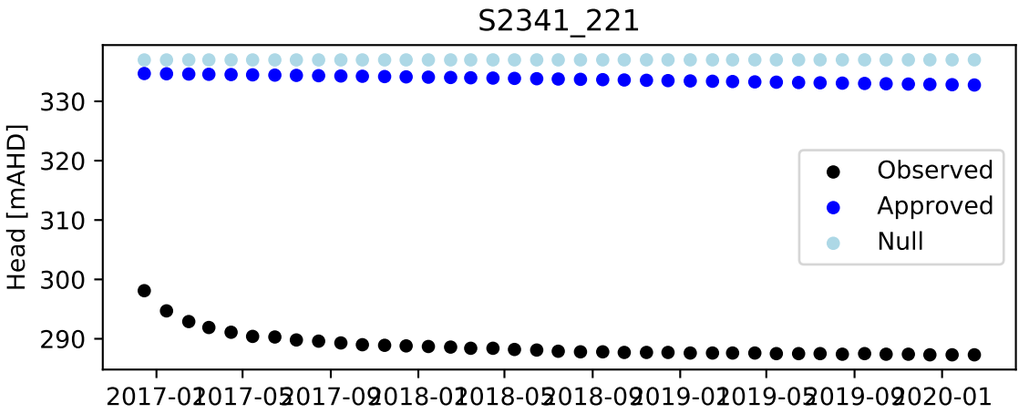

S2341_185
Head [mAHD]
340
330
320
310
300
290
Observed
Approved
Null
2017-01
2017-05
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01

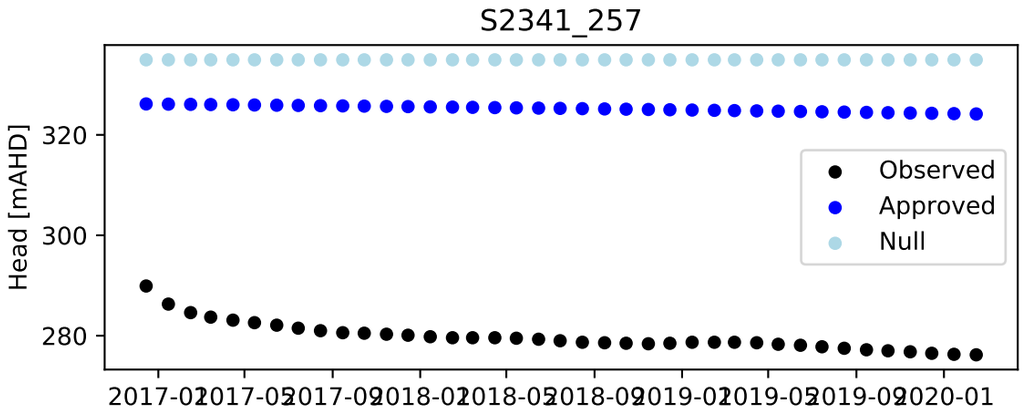

S2341_50
Head [mAHD]
366
364
362
Observed
Approved
Null
2017-01
2017-05
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01

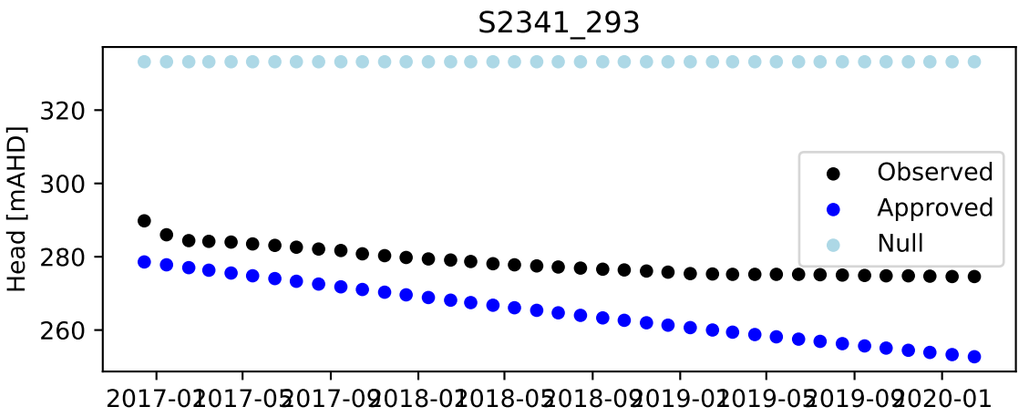

S2341_97
Head [mAHD]
340
339
338
337
336
Observed
Approved
Null
2017-01
2017-05
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01

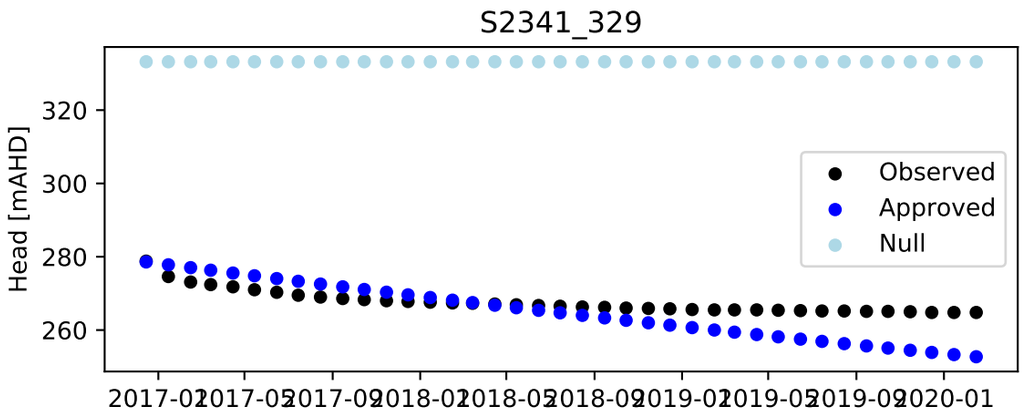

S2341A_10
Head [mAHD]
Observed
Approved
Null

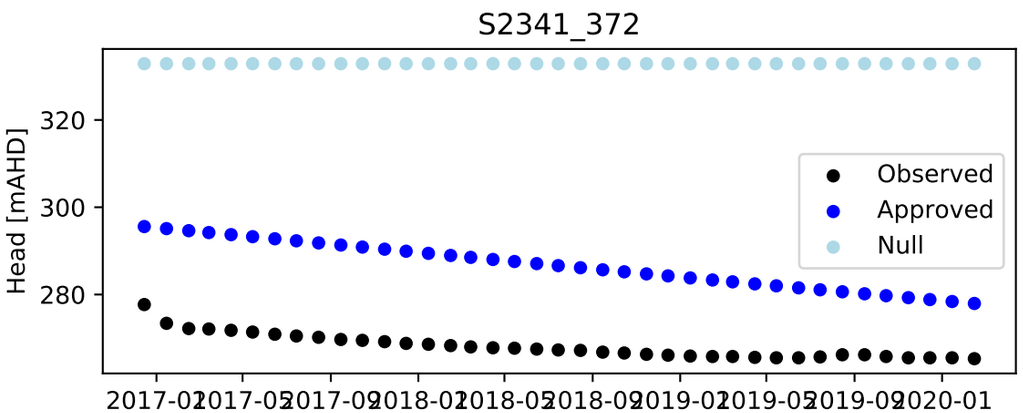

S2341A_26
Head [mAHD]
Observed
Approved
Null

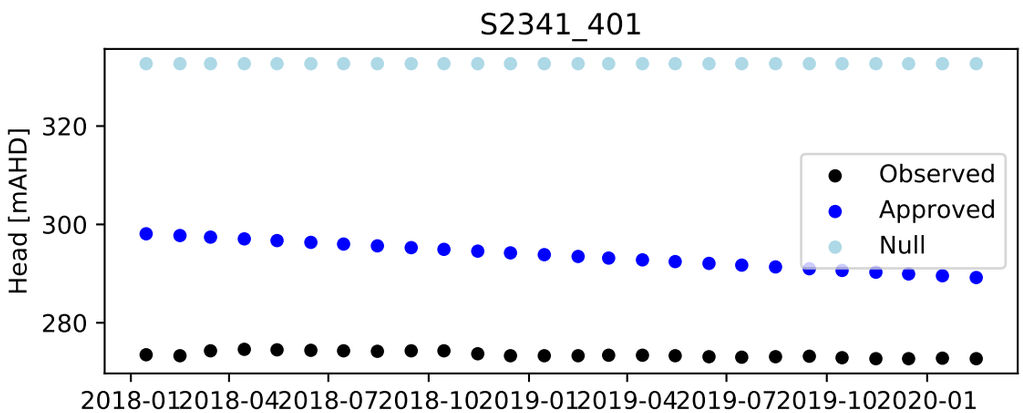

S2341_221
Head [mAHD]
Observed
Approved
Null

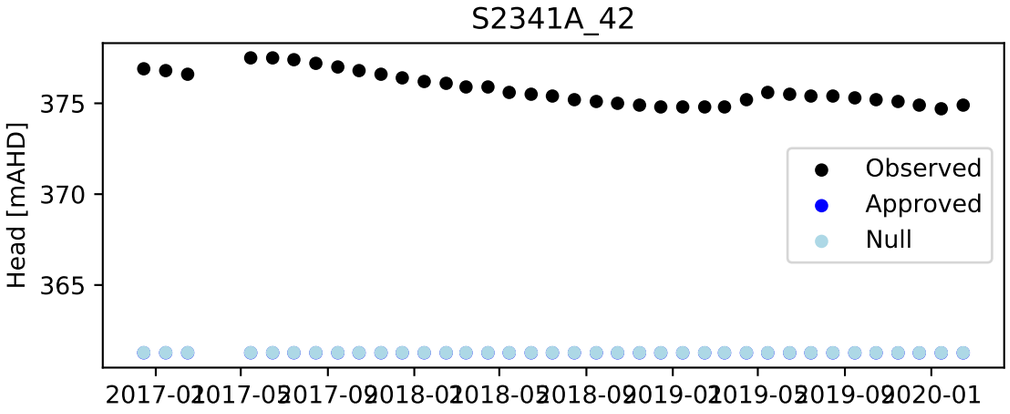

S2341_257
Head [mAHD]
Observed
Approved
Null

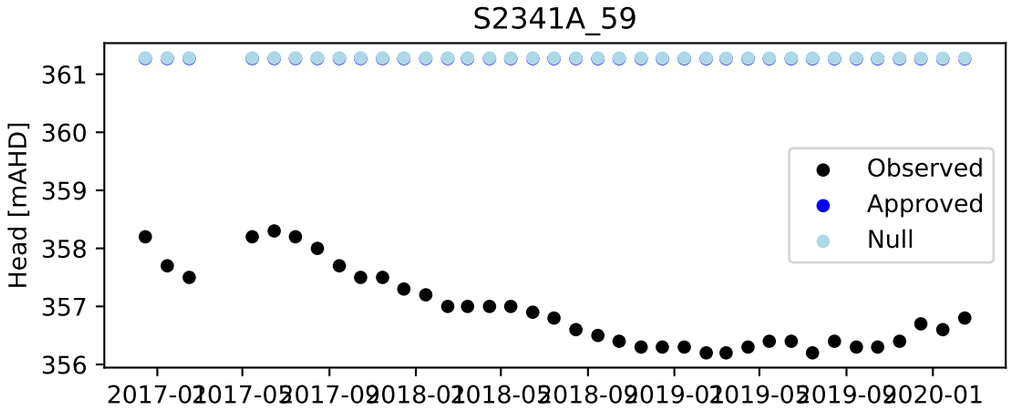

S2341_293
Head [mAHD]
Observed
Approved
Null

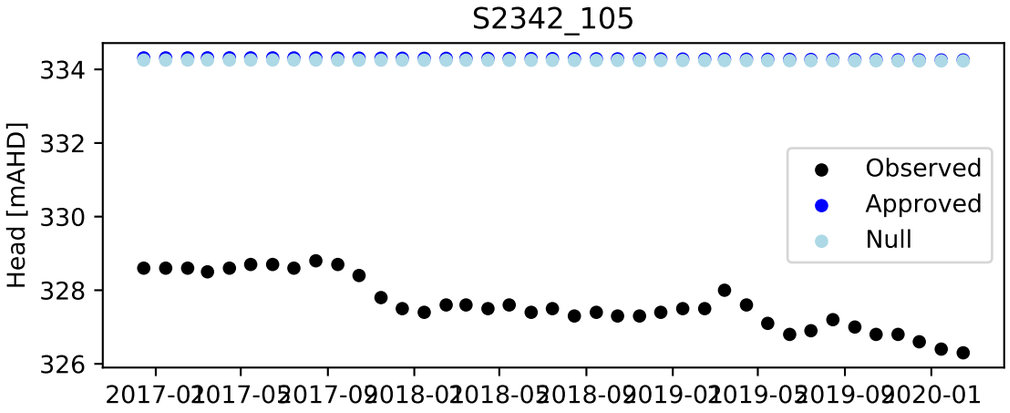

S2341_329
Head [mAHD]
Observed
Approved
Null

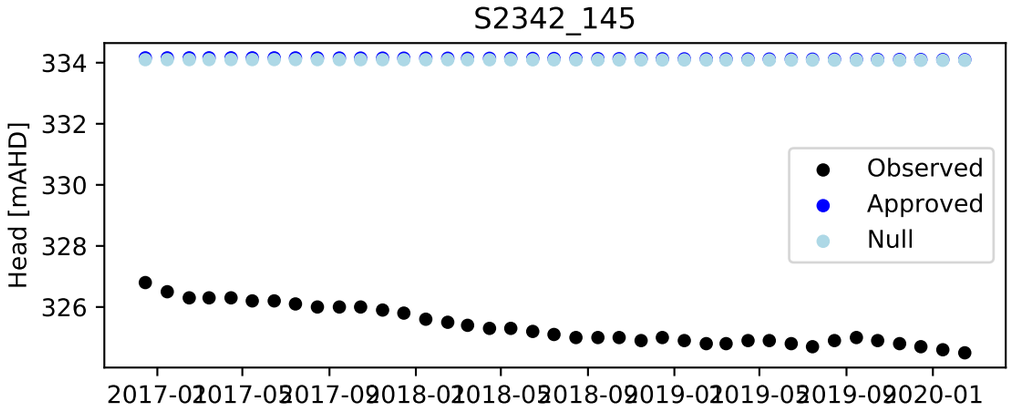

S2341_372
Head [mAHD]
Observed
Approved
Null

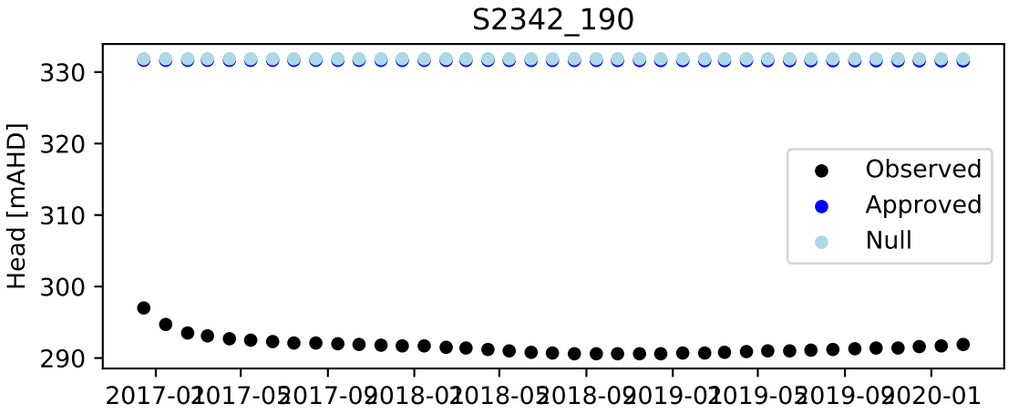

S2341_401
Head [mAHD]
Observed
Approved
Null

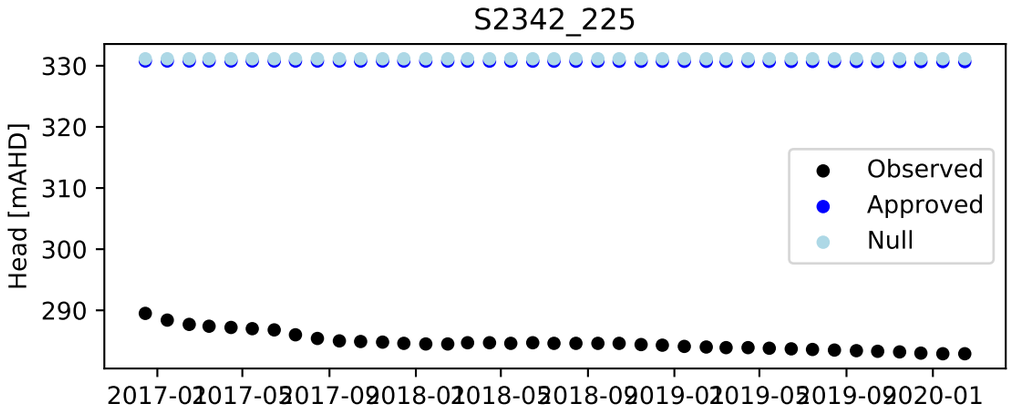

S2341A_42
Head [mAHD]
375
370
365
Observed
Approved
Null
2017-01
2017-05
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01

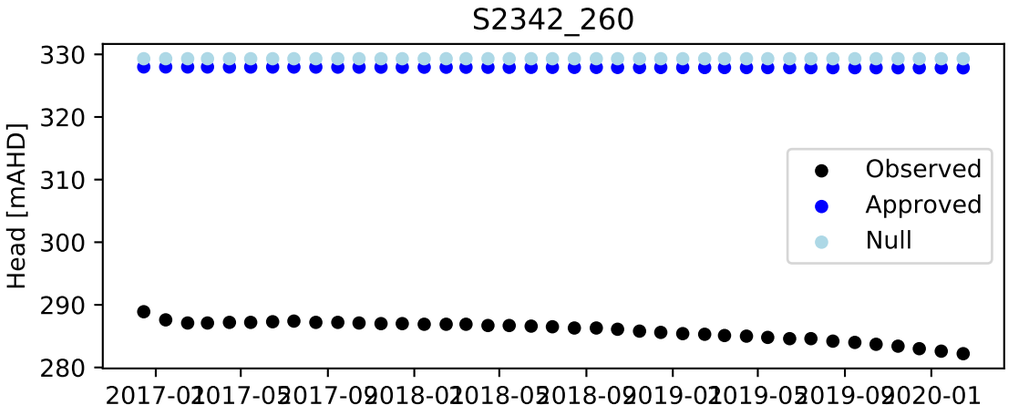

S2341A_59
Head [mAHD]
361
360
359
358
357
356
Observed
Approved
Null
2017-01
2017-05
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01

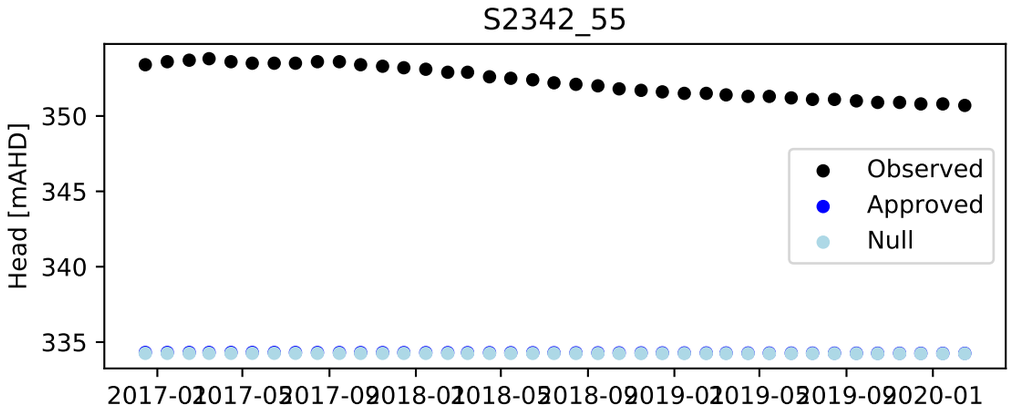

S2342_105
Head [mAHD]
334
332
330
328
326
Observed
Approved
Null
2017-01
2017-05
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01

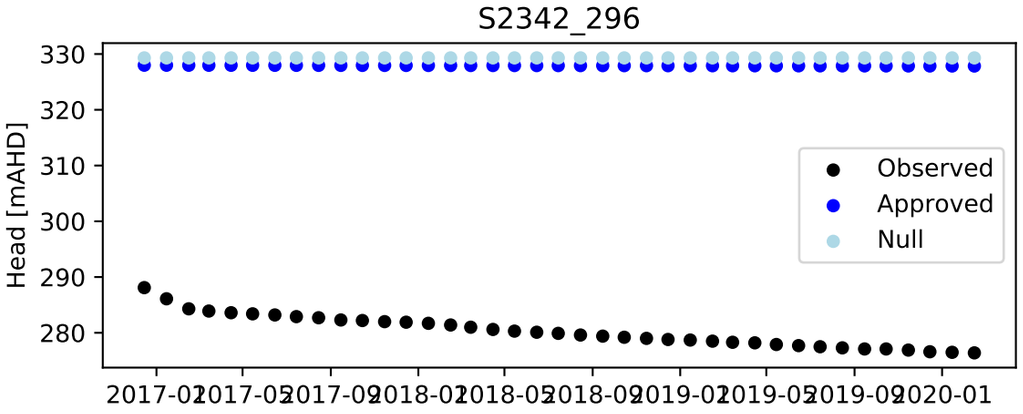

S2342_145
Head [mAHD]
334
332
330
328
326
Observed
Approved
Null
2017-01
2017-05
2017-09
2018-01
2018-05
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2019-01
2019-05
2019-09
2020-01

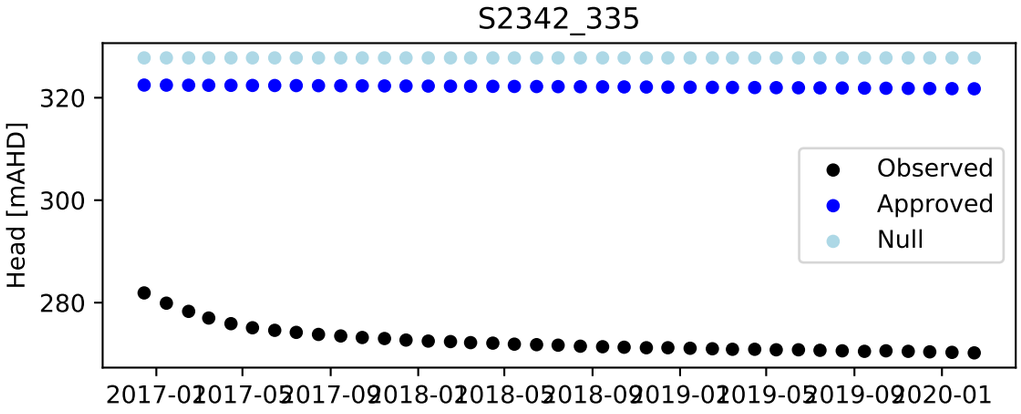

S2342_190
Head [mAHD]
330
320
310
300
290
Observed
Approved
Null
2017-01
2017-05
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01

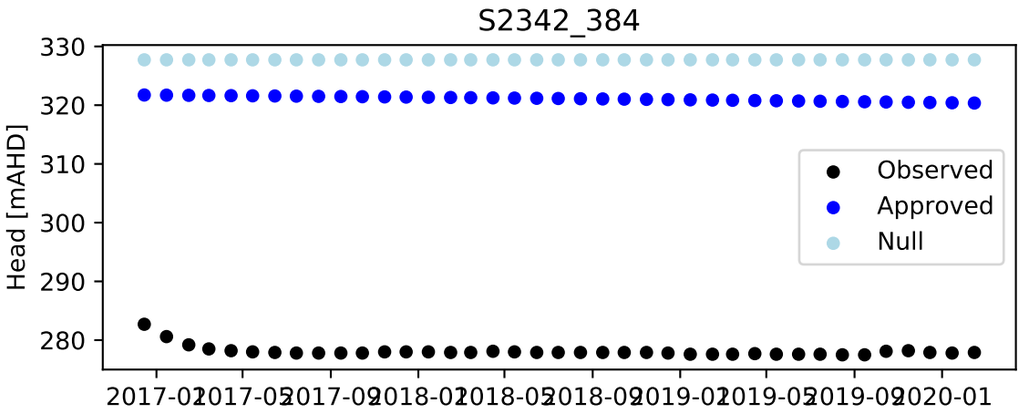

S2342_225
Head [mAHD]
330
320
310
300
290
Observed
Approved
Null
2017-01
2017-05
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01

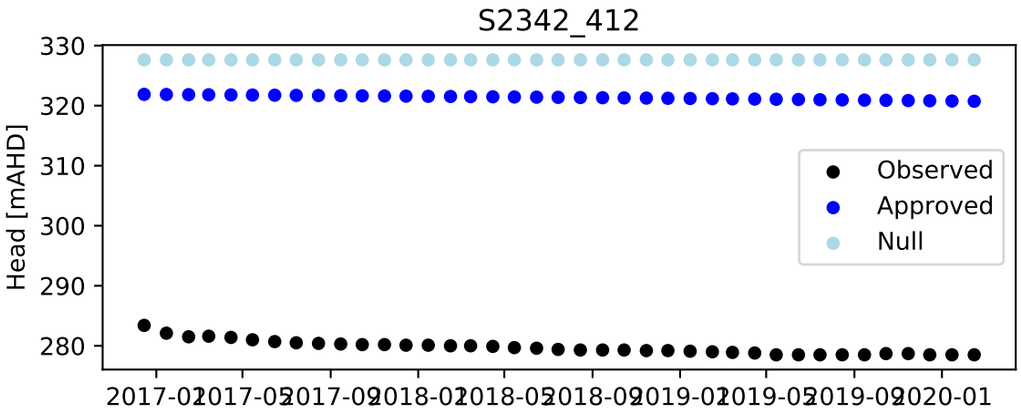

S2342_260
Head [mAHD]
330
320
310
300
290
280
Observed
Approved
Null
2017-01
2017-05
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01

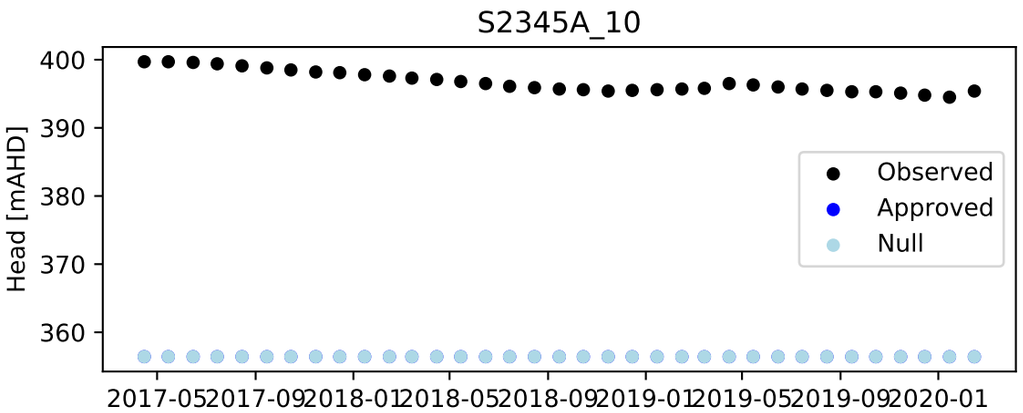

S2342_55
Head [mAHD]
350
345
340
335
Observed
Approved
Null
2017-01
2017-05
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01

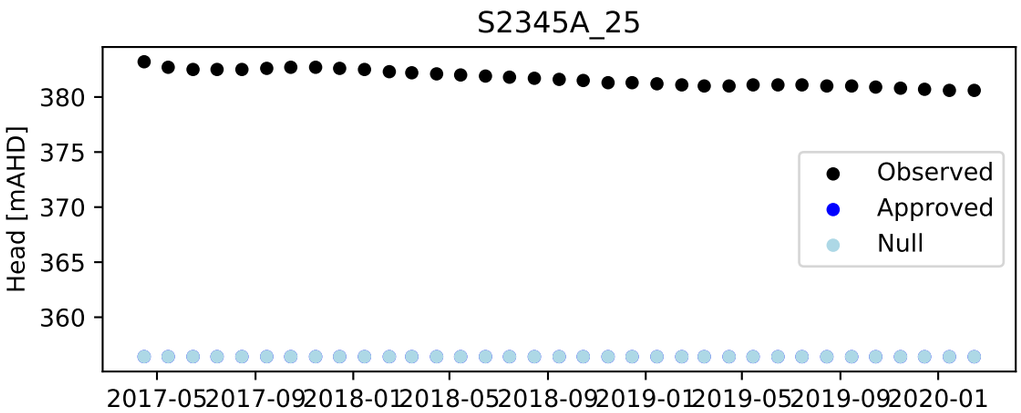

S2342_296
Head [mAHD]
Observed
Approved
Null

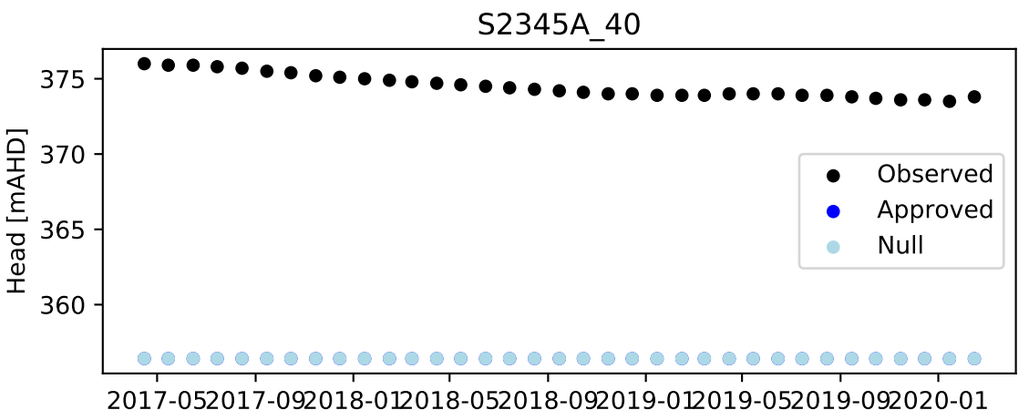

S2342_335
Head [mAHD]
Observed
Approved
Null

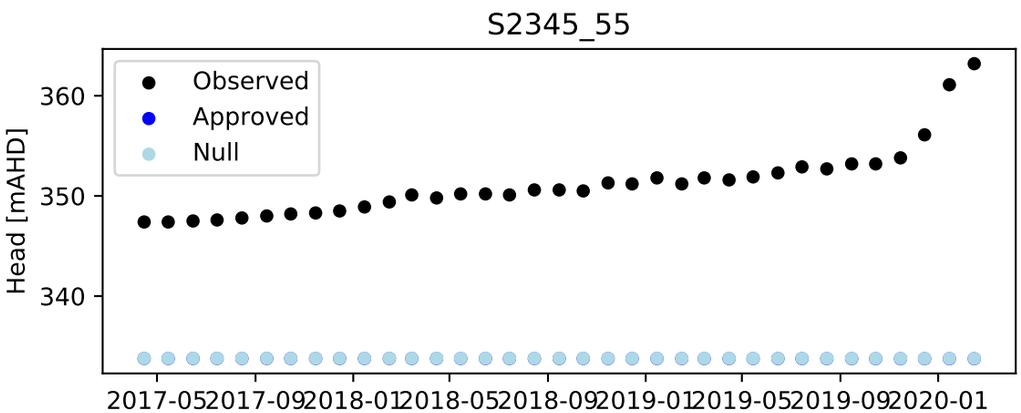

S2342_384
Head [mAHD]
Observed
Approved
Null

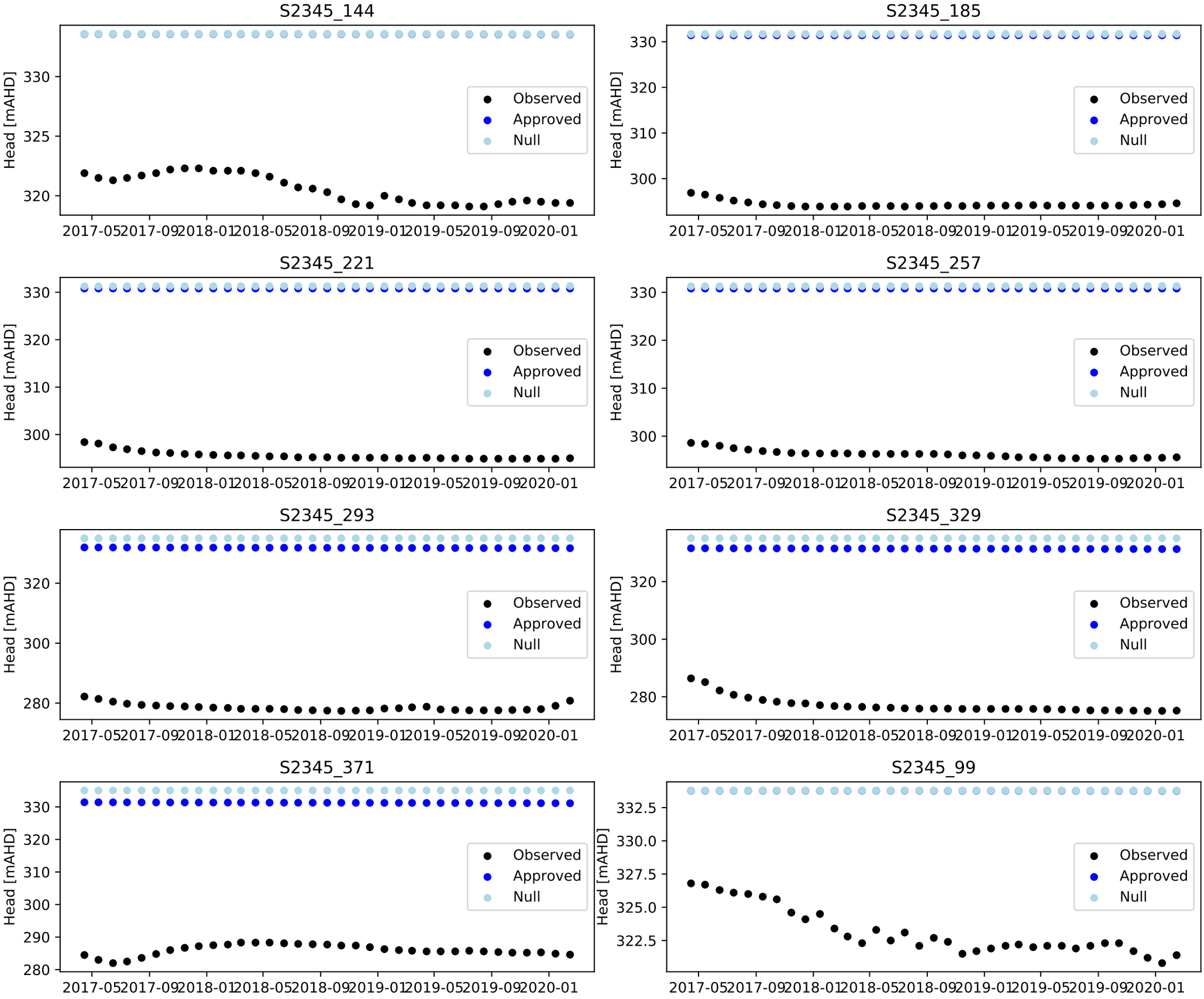

S2342_412
Head [mAHD]
Observed
Approved
Null

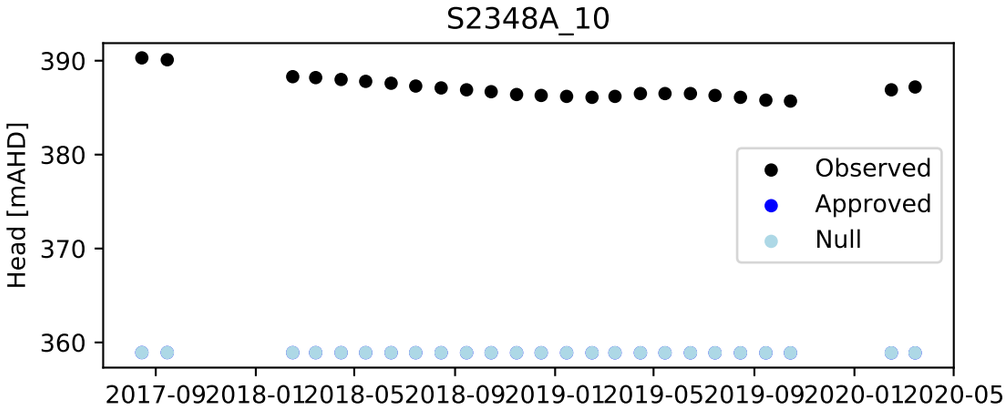

S2345A_10
Head [mAHD]
Observed
Approved
Null

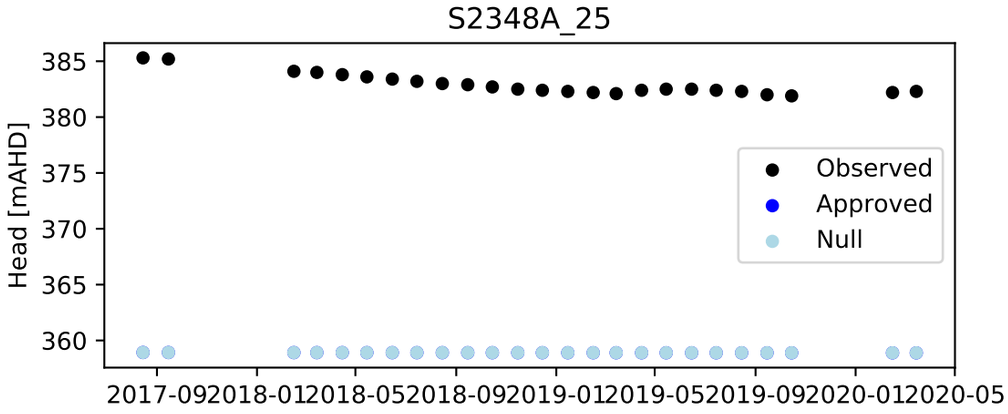

S2345A_25
Head [mAHD]
Observed
Approved
Null

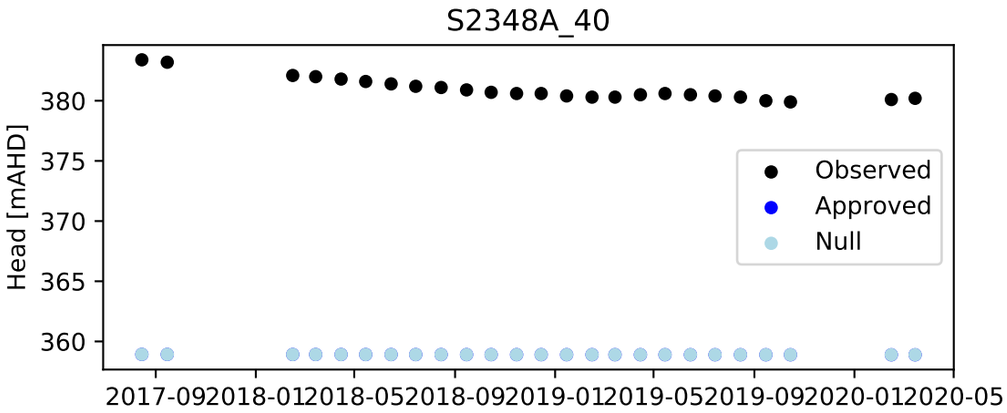

S2345A_40
Head [mAHD]
Observed
Approved
Null

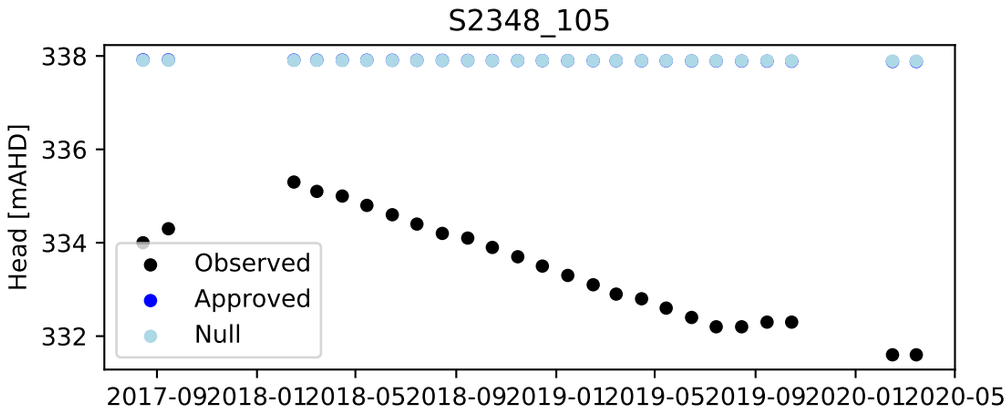

S2345_55
Head [mAHD]
Observed
Approved
Null

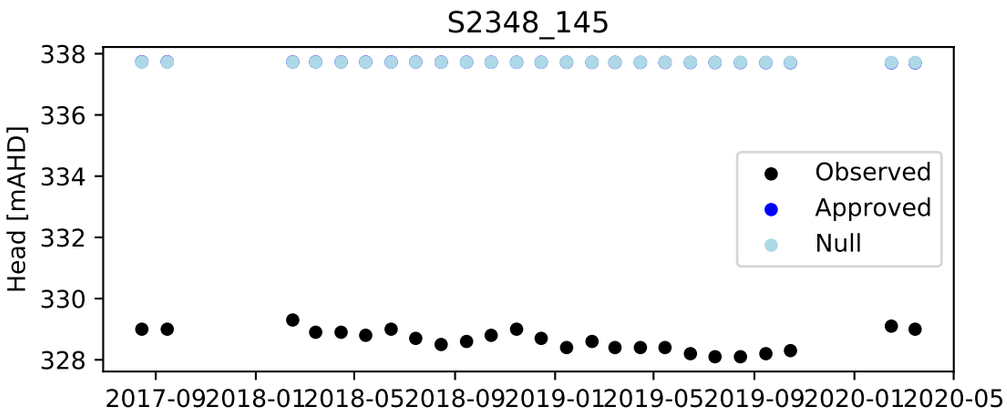

S2345_144
S2345_185
S2345_221
S2345_257
S2345_293
S2345_329
S2345_371
S2345_99
Head [mAHD]
Observed
Approved
Null
2017-05
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01

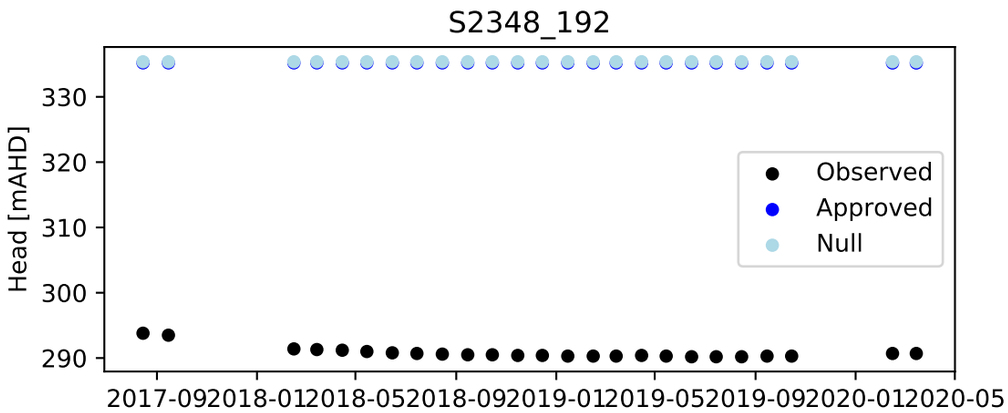

S2348A_10
Head [mAHD]
390
380
370
360
Observed
Approved
Null
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01
2020-05

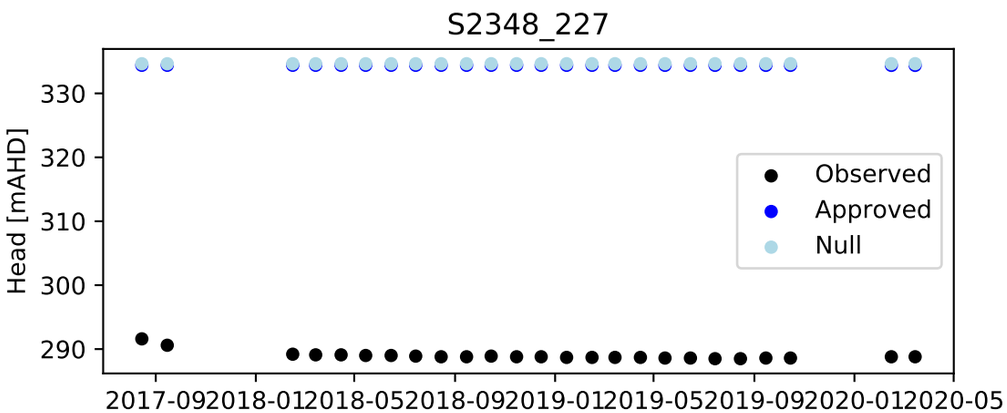

S2348A_25
Head [mAHD]
385
380
375
370
365
360
Observed
Approved
Null
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01
2020-05

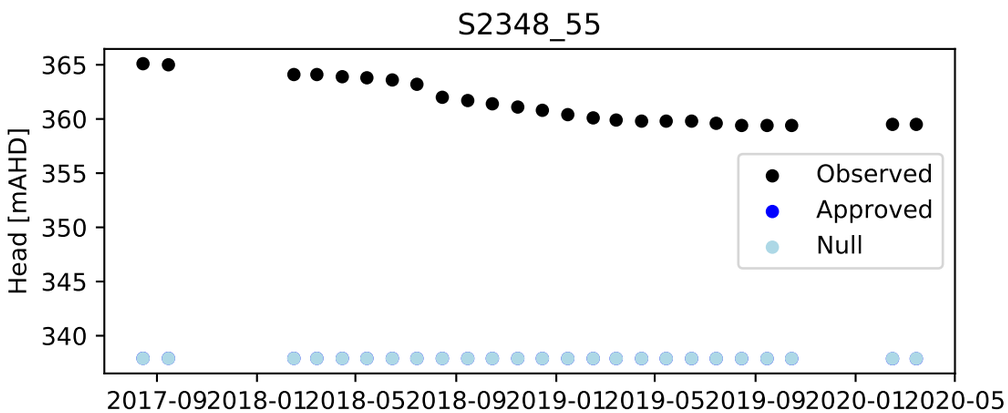

S2348A_40
Head [mAHD]
380
375
370
365
360
Observed
Approved
Null
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01
2020-05

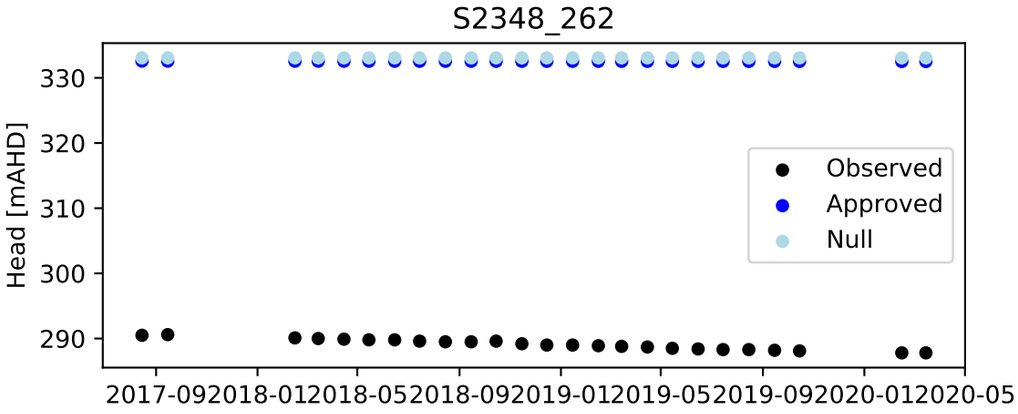

S2348_105
Head [mAHD]
338
336
334
332
Observed
Approved
Null
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01
2020-05

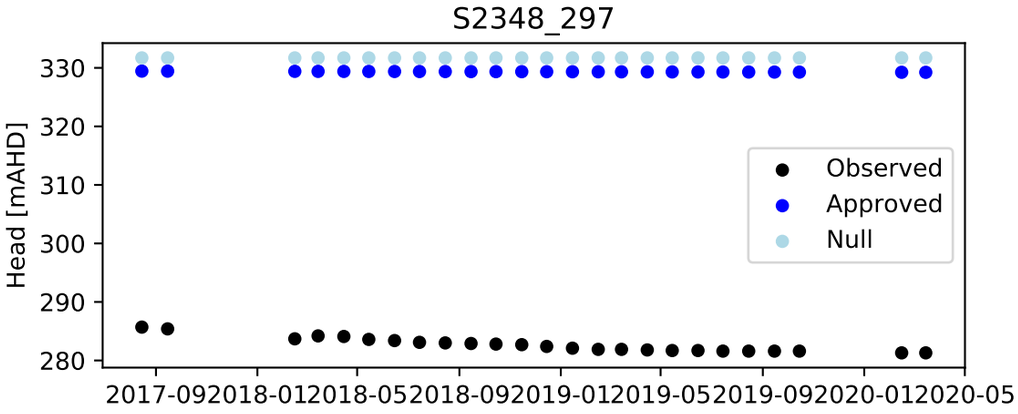

S2348_145
Head [mAHD]
338
336
334
332
330
328
Observed
Approved
Null
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01
2020-05

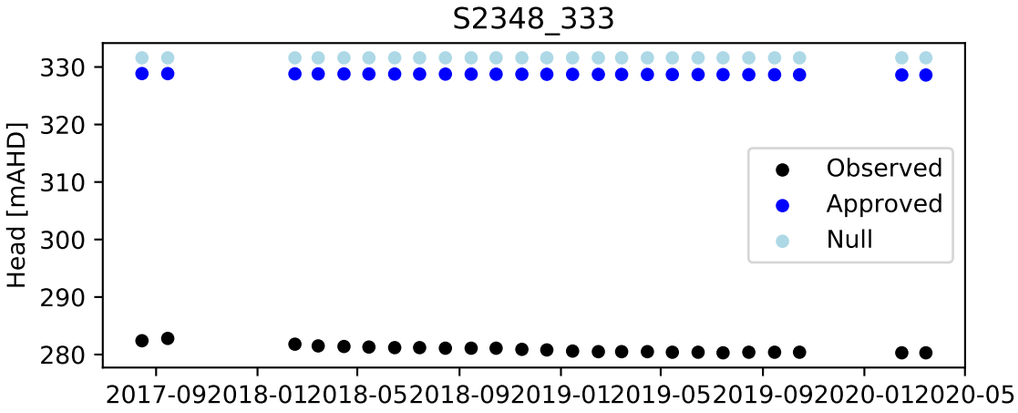

S2348_192
Head [mAHD]
330
320
310
300
290
Observed
Approved
Null
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01
2020-05

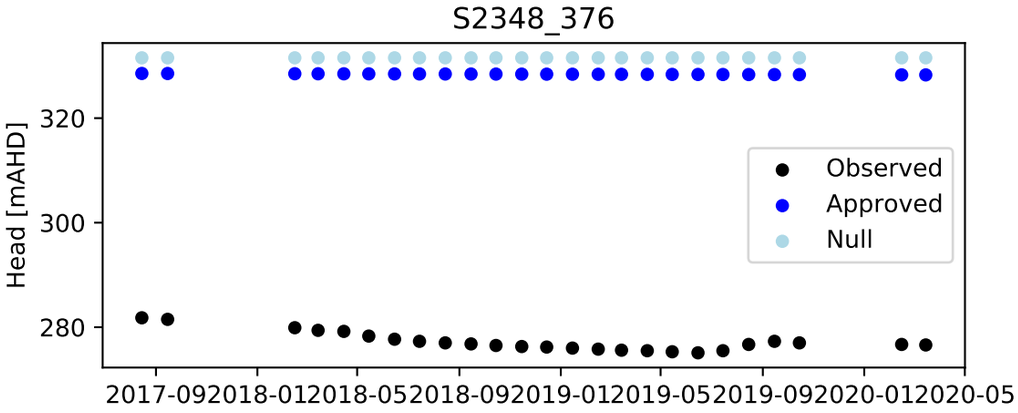

S2348_227
Head [mAHD]
330
320
310
300
290
Observed
Approved
Null
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01
2020-05

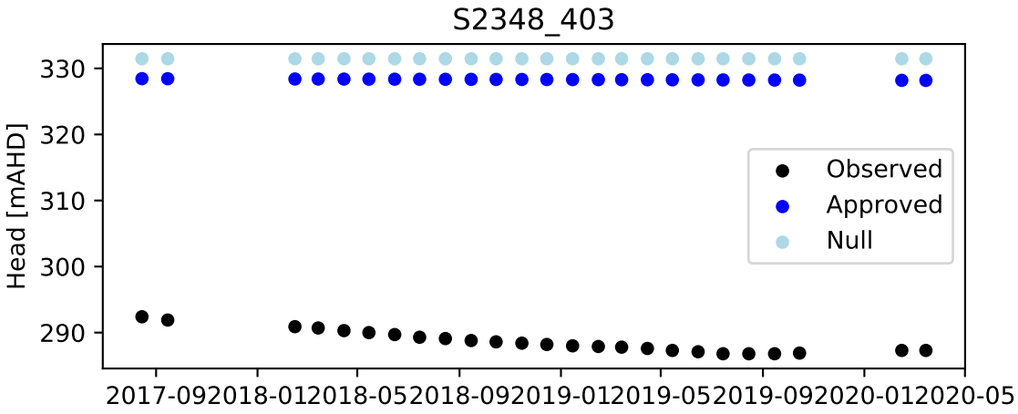

S2348_55
Head [mAHD]
365
360
355
350
345
340
Observed
Approved
Null
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01
2020-05

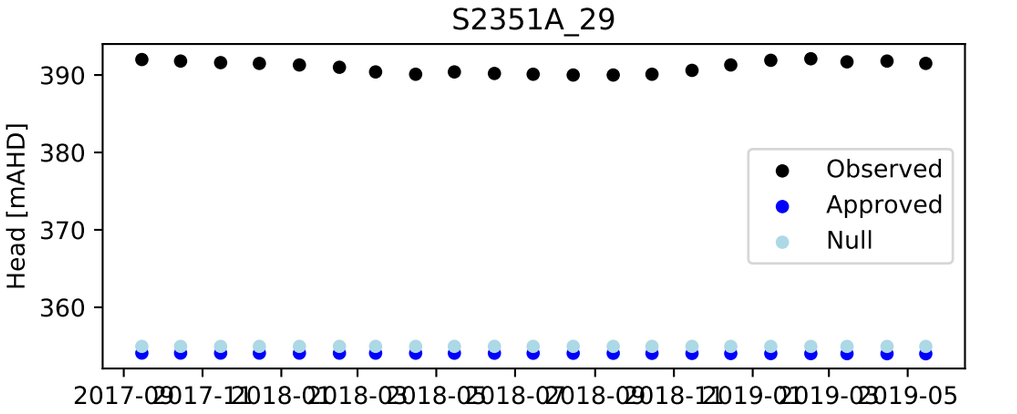

S2348_262
Head [mAHD]
330
320
310
300
290
Observed
Approved
Null
2017-09
2018-01
2018-05
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2019-01
2019-05
2019-09
2020-01
2020-05

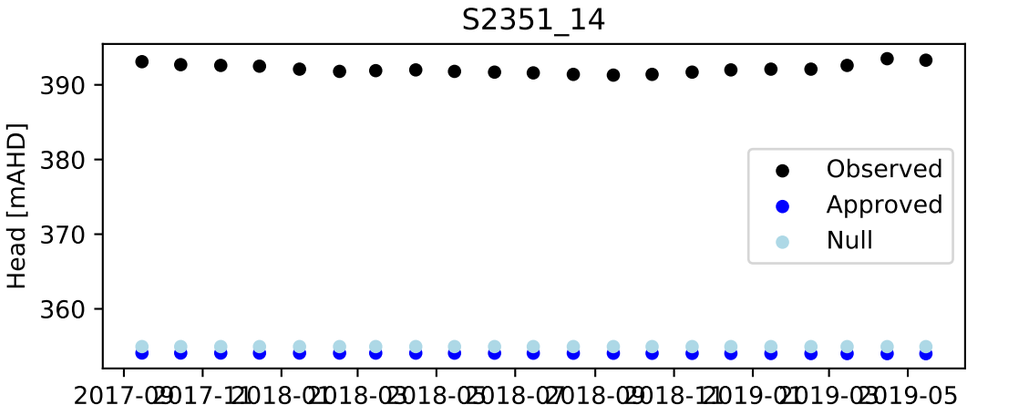

S2348_297
Head [mAHD]
330
320
310
300
290
280
Observed
Approved
Null
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01
2020-05

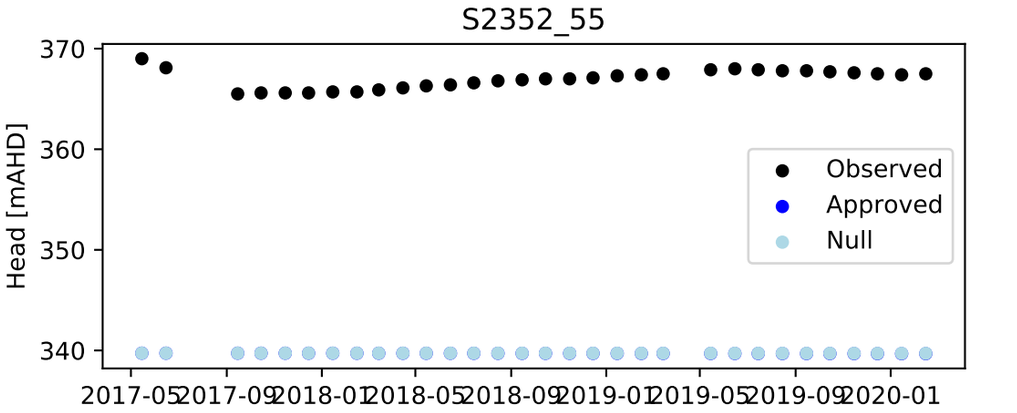

S2348_333
Head [mAHD]
330
320
310
300
290
280
Observed
Approved
Null
2017-09
2018-01
2018-05
2018-09
2019-01
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2019-09
2020-01
2020-05

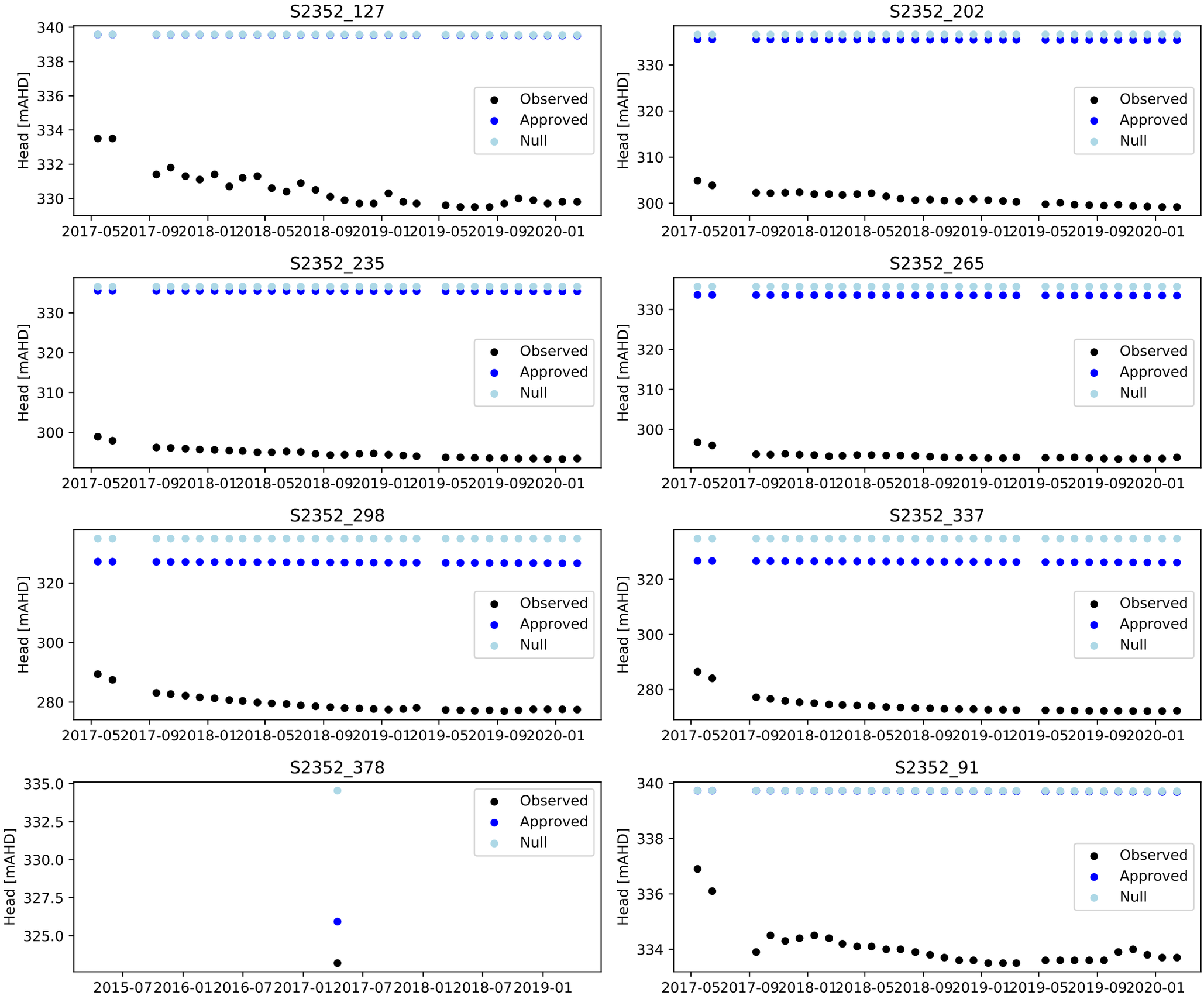

S2348_376
Head [mAHD]
320
300
280
Observed
Approved
Null
2017-09
2018-01
2018-05
2018-09
2019-01
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2019-09
2020-01
2020-05

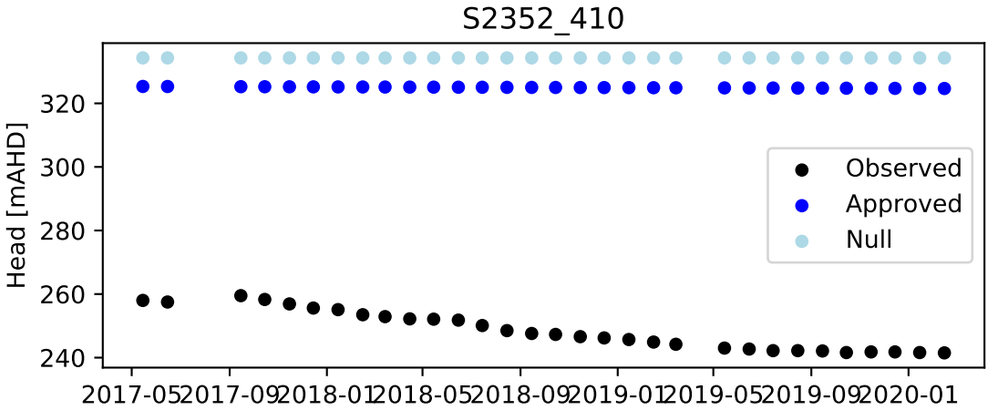

S2348_403
Head [mAHD]
330
320
310
300
290
Observed
Approved
Null
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01
2020-05

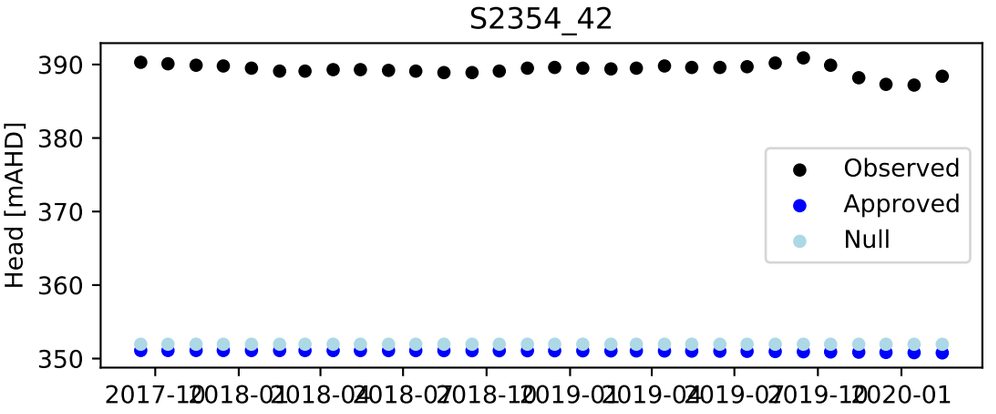

S2351A_29
Head [mAHD]
390
380
370
360
Observed
Approved
Null
2017-09
2017-11
2018-01
2018-03
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2018-09
2018-11
2019-01
2019-03
2019-05

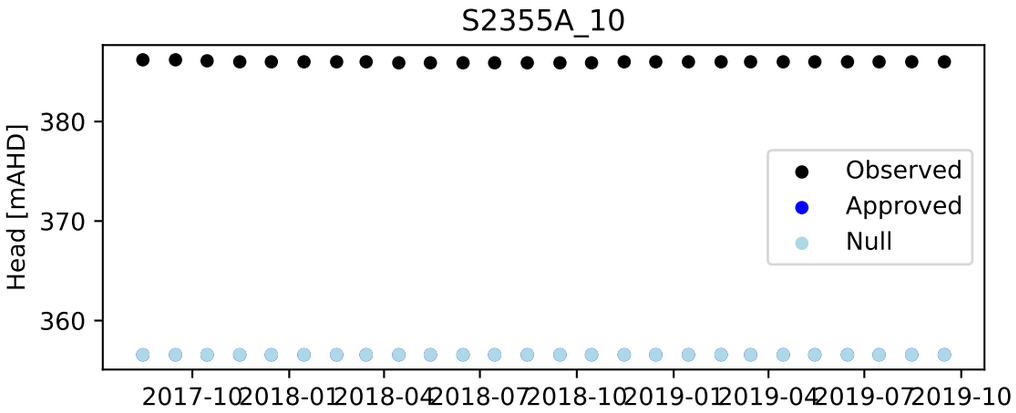

S2351_14
Head [mAHD]
390
380
370
360
Observed
Approved
Null
2017-09
2017-11
2018-01
2018-03
2018-05
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2018-09
2018-11
2019-01
2019-03
2019-05

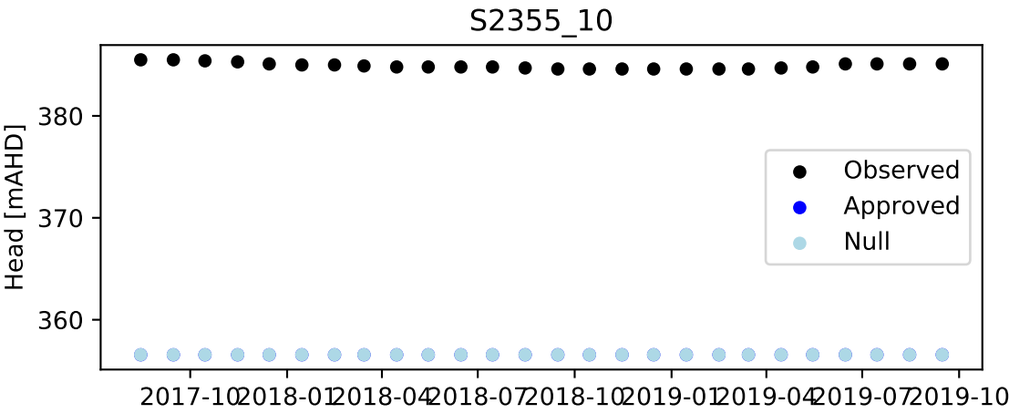

S2352_55
Head [mAHD]
370
360
350
340
Observed
Approved
Null
2017-05
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01

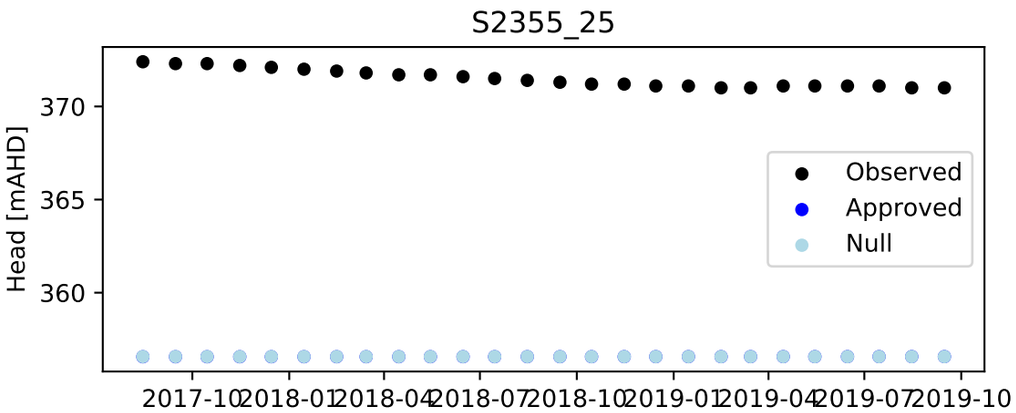

S2352_127
Head [mAHD]
340
338
336
334
332
330
2017-05
2017-09
2018-01
2018-05
2018-09
2019-01
2019-05
2019-09
2020-01
Observed
Approved
Null
S2352_202
Head [mAHD]
330
320
310
300
S2352_235
Head [mAHD]
330
320
310
300
S2352_265
Head [mAHD]
330
320
310
300
S2352_298
Head [mAHD]
320
300
280
S2352_337
Head [mAHD]
320
300
280
S2352_378
Head [mAHD]
335.0
332.5
330.0
327.5
325.0
2015-07
2016-01
2016-07
2017-01
2017-07
2018-01
2018-07
2019-01
S2352_91
Head [mAHD]
340
338
336
334

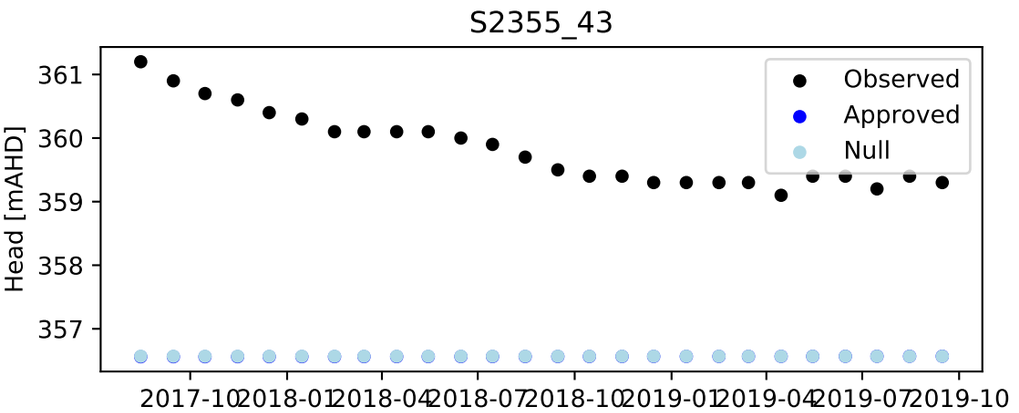

S2352_410
Head [mAHD]
Observed
Approved
Null

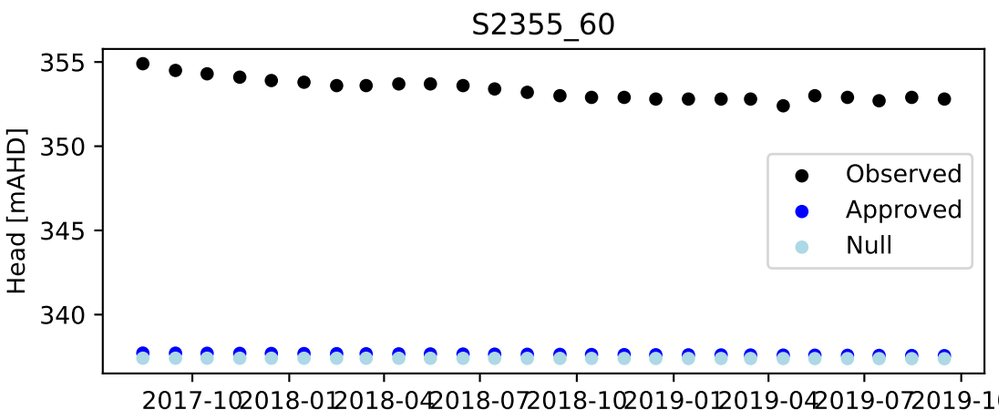

S2354_42
Head [mAHD]
Observed
Approved
Null

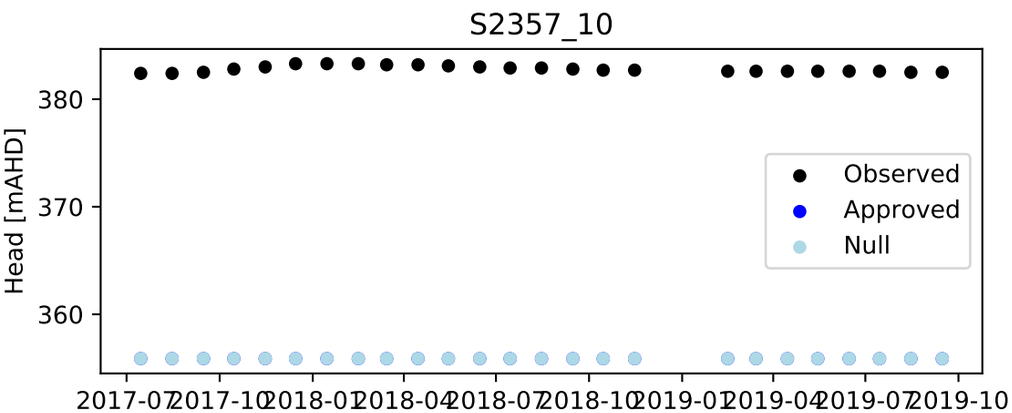

S2355A_10
Head [mAHD]
Observed
Approved
Null

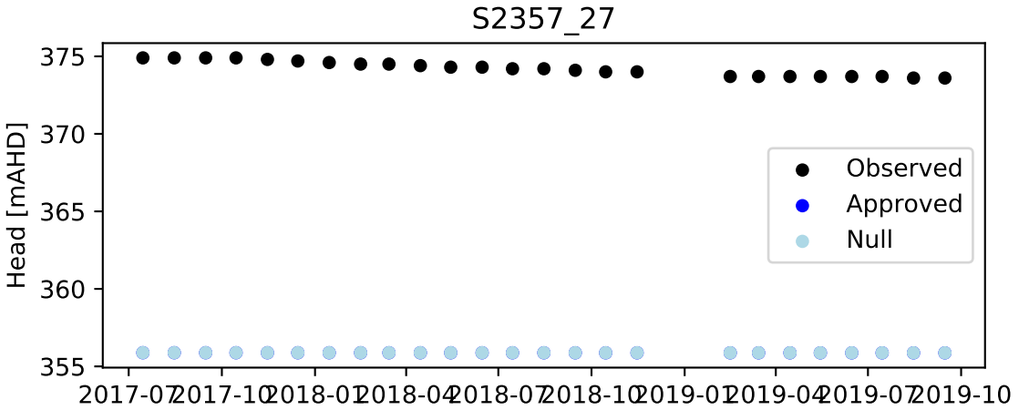

S2355_10
Head [mAHD]
Observed
Approved
Null

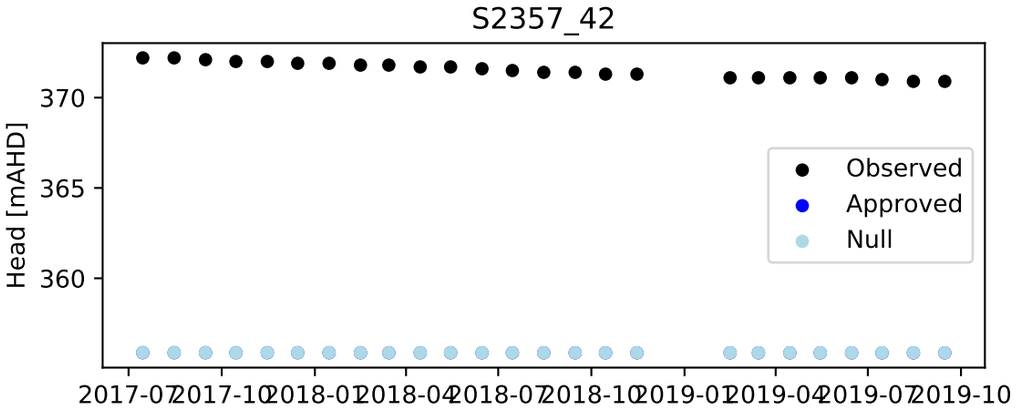

S2355_25
Head [mAHD]
Observed
Approved
Null

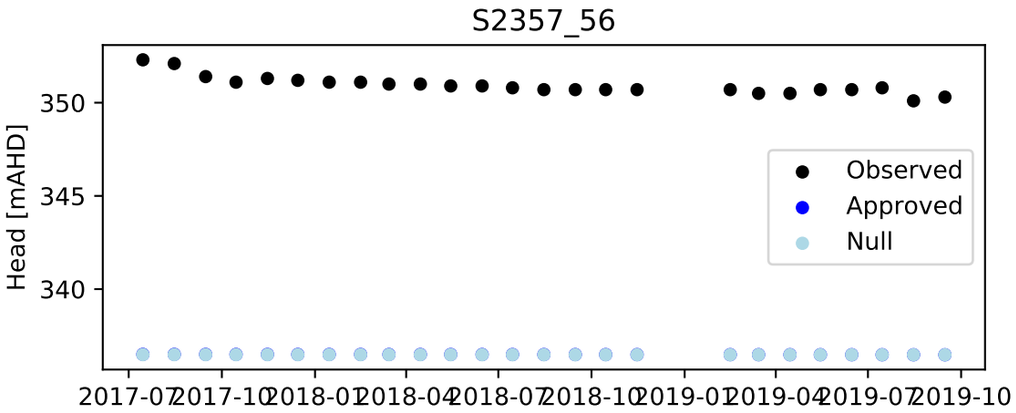

S2355_43
Head [mAHD]
Observed
Approved
Null

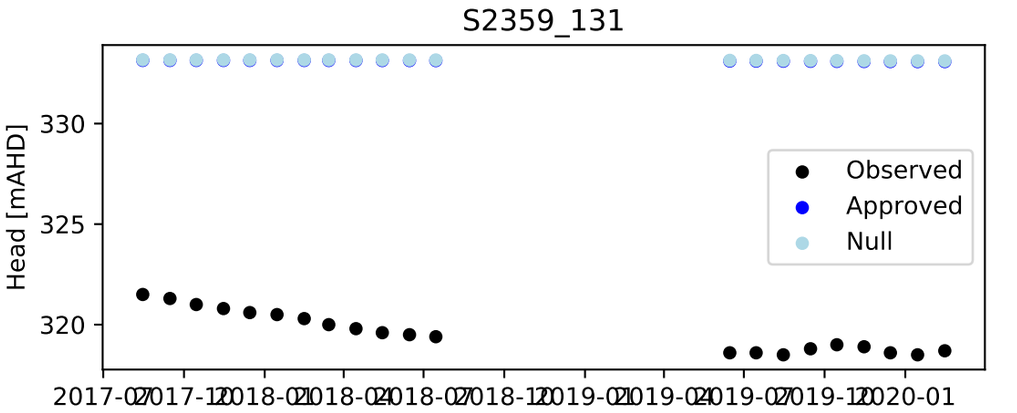

S2355_60
Head [mAHD]
Observed
Approved
Null

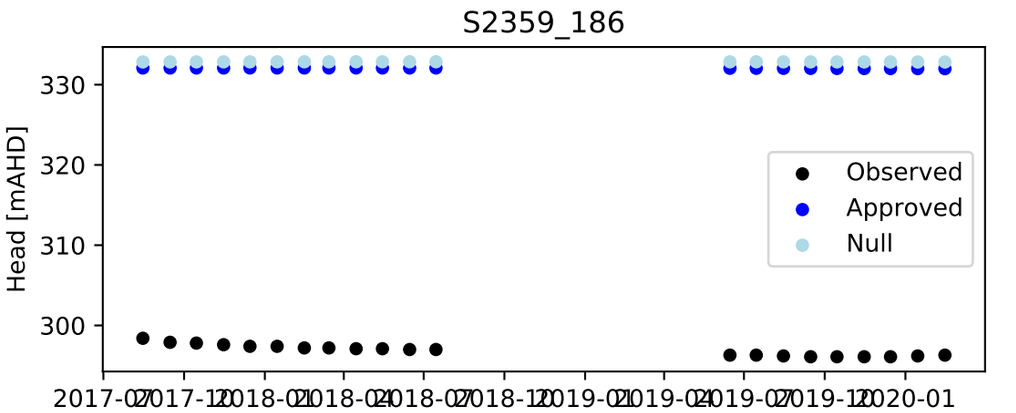

S2357_10
Head [mAHD]
Observed
Approved
Null

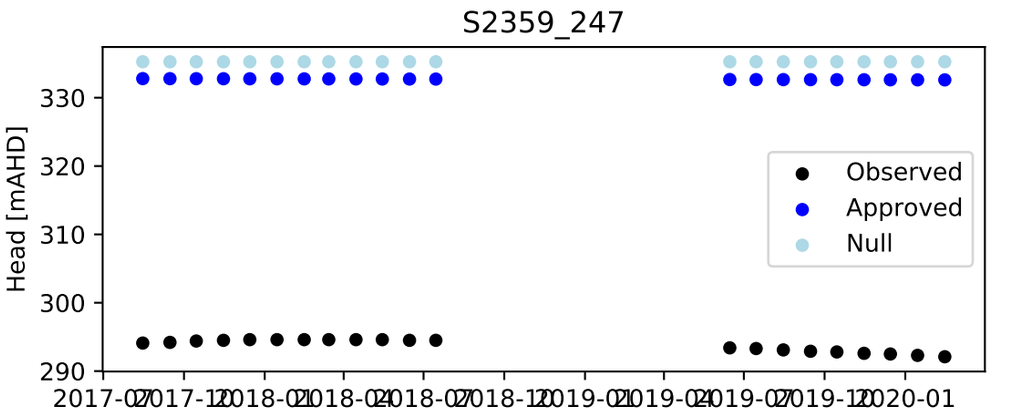

S2357_27
Head [mAHD]
Observed
Approved
Null

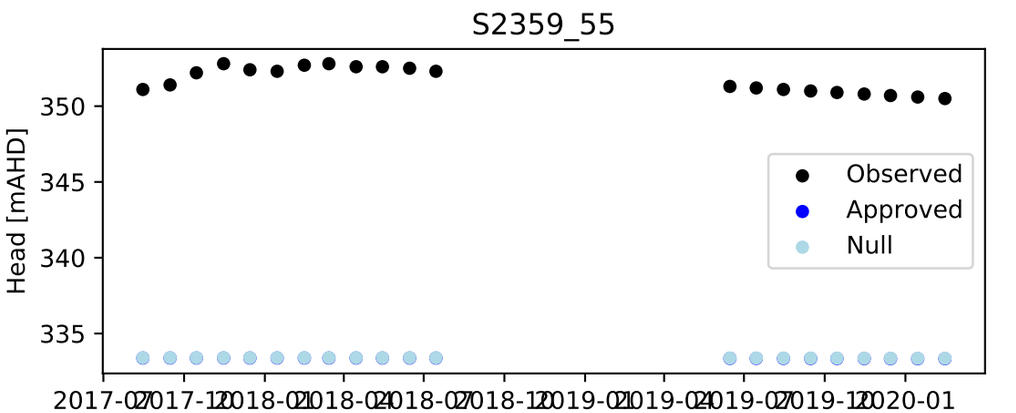

S2357_42
Head [mAHD]
Observed
Approved
Null

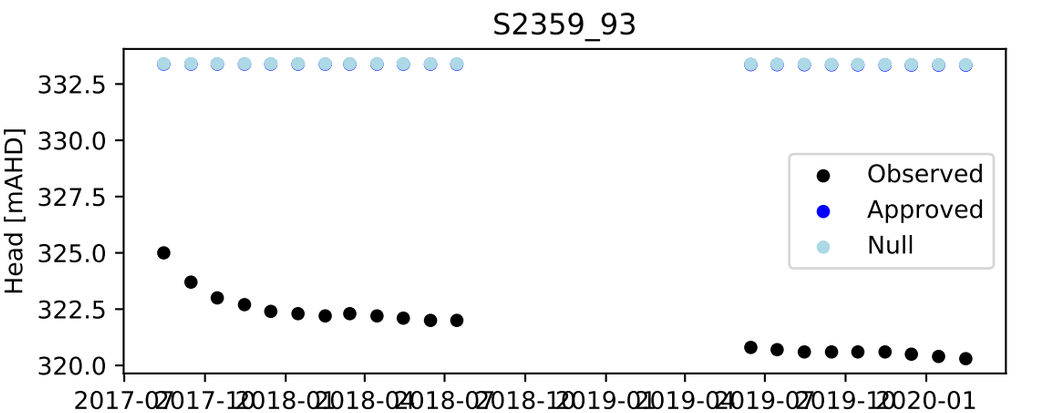

S2357_56
Head [mAHD]
Observed
Approved
Null

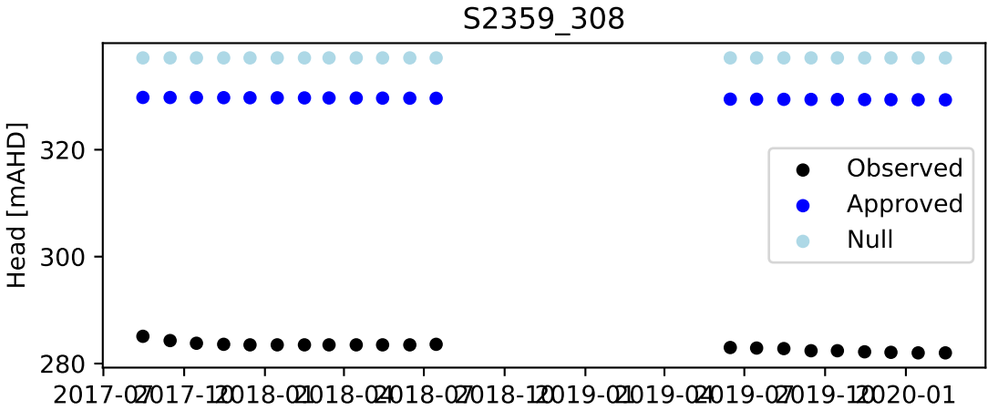

S2359_131
Head [mAHD]
Observed
Approved
Null

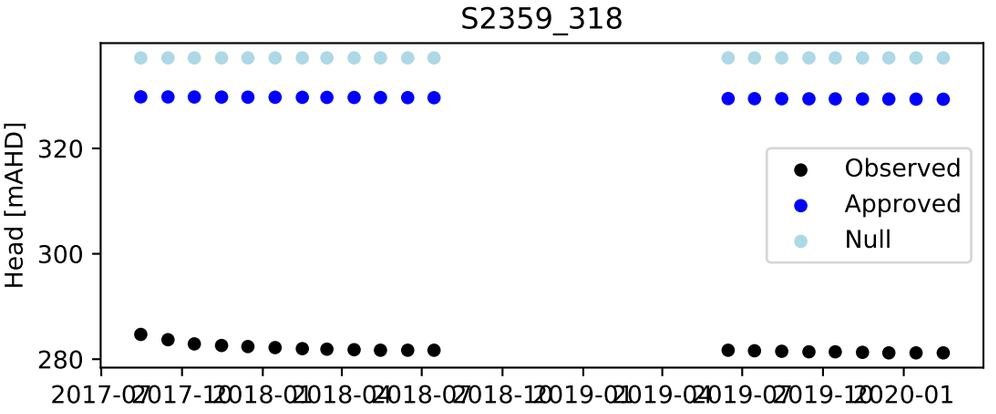

S2359_186
Head [mAHD]
Observed
Approved
Null

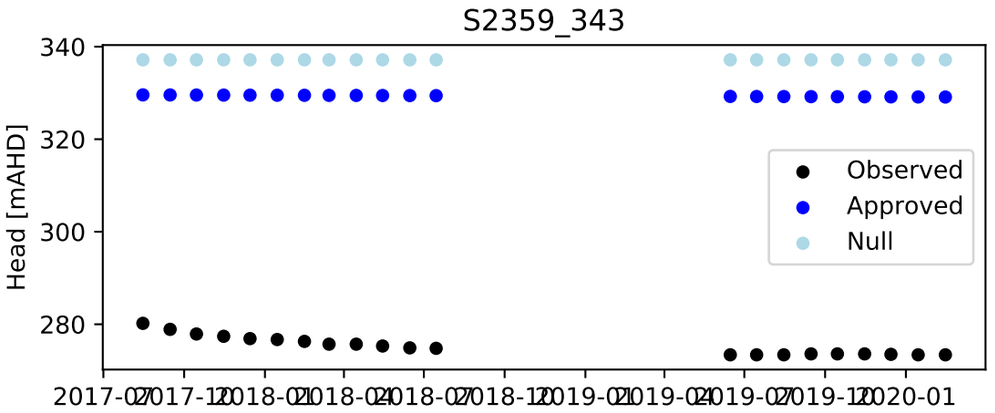

S2359_247
Head [mAHD]
Observed
Approved
Null

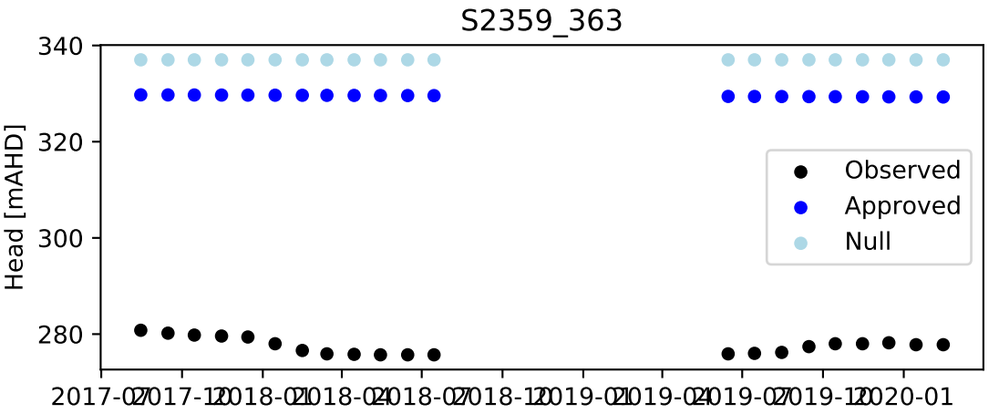

S2359_55
Head [mAHD]
Observed
Approved
Null

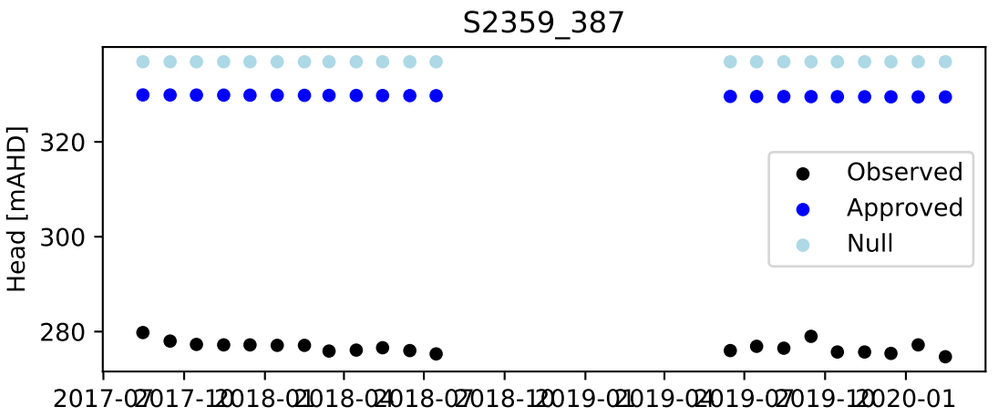

S2359_93
Head [mAHD]
Observed
Approved
Null

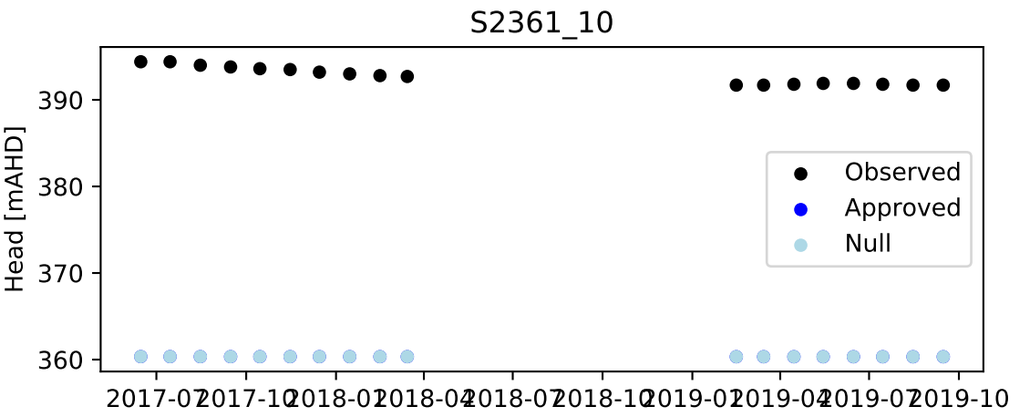

S2359_308
Head [mAHD]
320
300
280
Observed
Approved
Null
2017-07
2017-10
2018-01
2018-04
2018-07
2018-10
2019-01
2019-04
2019-07
2019-10
2020-01

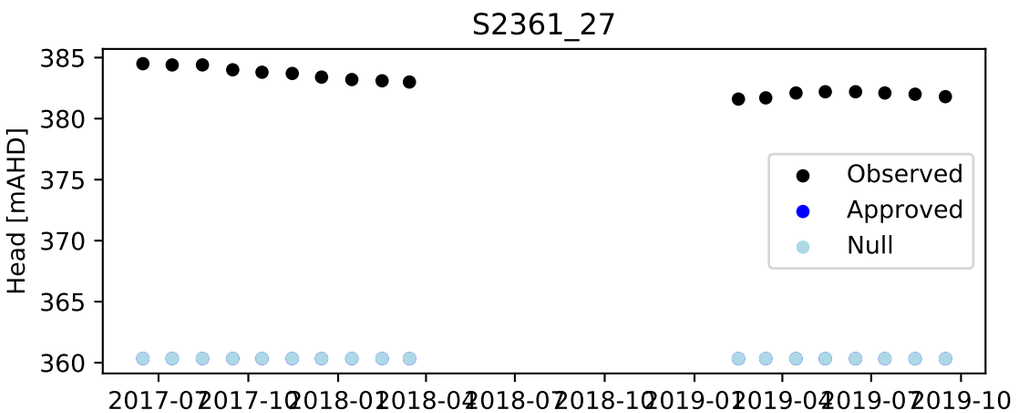

S2359_318
Head [mAHD]
320
300
280
Observed
Approved
Null
2017-07
2017-10
2018-01
2018-04
2018-07
2018-10
2019-01
2019-04
2019-07
2019-10
2020-01

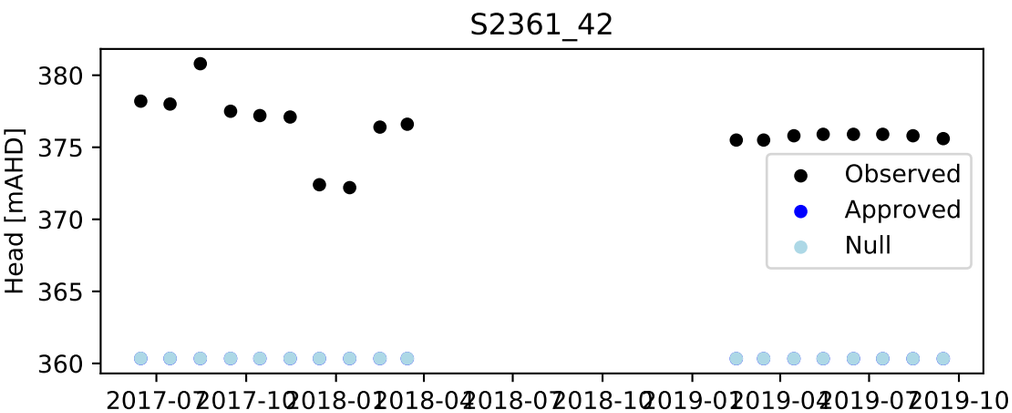

S2359_343
Head [mAHD]
340
320
300
280
Observed
Approved
Null
2017-07
2017-10
2018-01
2018-04
2018-07
2018-10
2019-01
2019-04
2019-07
2019-10
2020-01

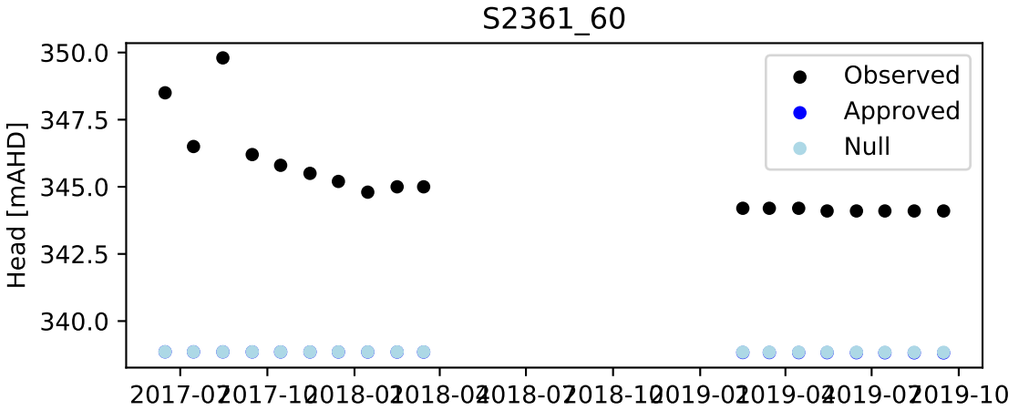

S2359_363
Head [mAHD]
340
320
300
280
Observed
Approved
Null
2017-07
2017-10
2018-01
2018-04
2018-07
2018-10
2019-01
2019-04
2019-07
2019-10
2020-01

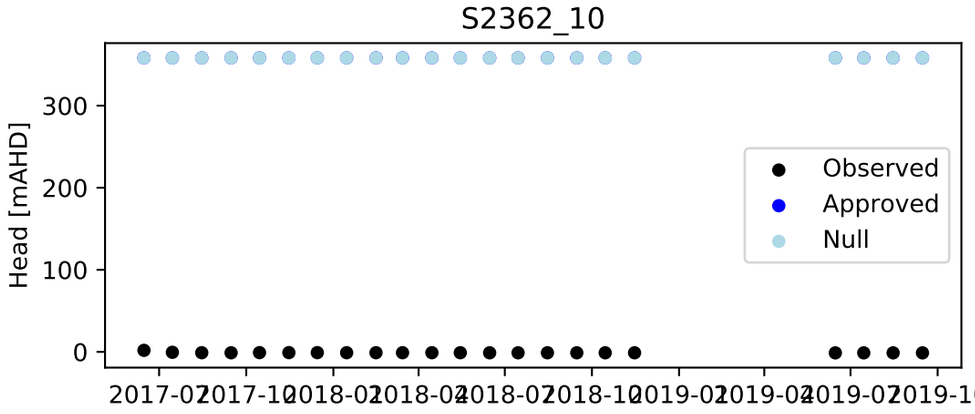

S2359_387
Head [mAHD]
320
300
280
Observed
Approved
Null
2017-07
2017-10
2018-01
2018-04
2018-07
2018-10
2019-01
2019-04
2019-07
2019-10
2020-01

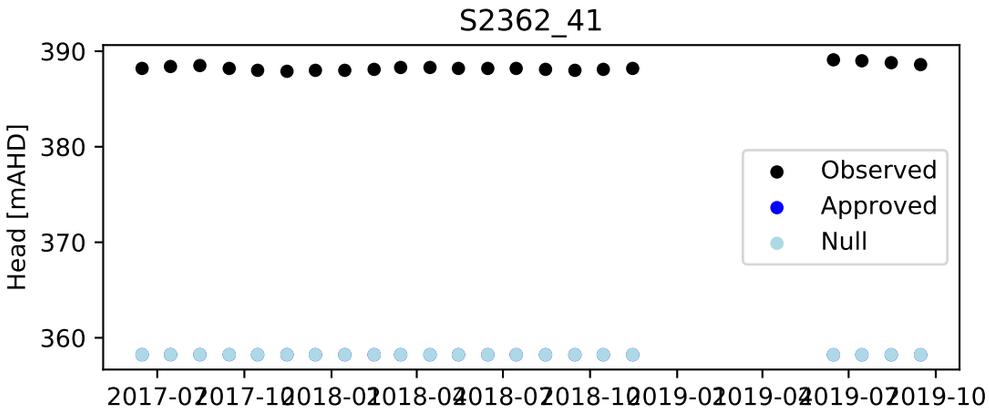

S2361_10
Head [mAHD]
390
380
370
360
Observed
Approved
Null
2017-07
2017-10
2018-01
2018-04
2018-07
2018-10
2019-01
2019-04
2019-07
2019-10

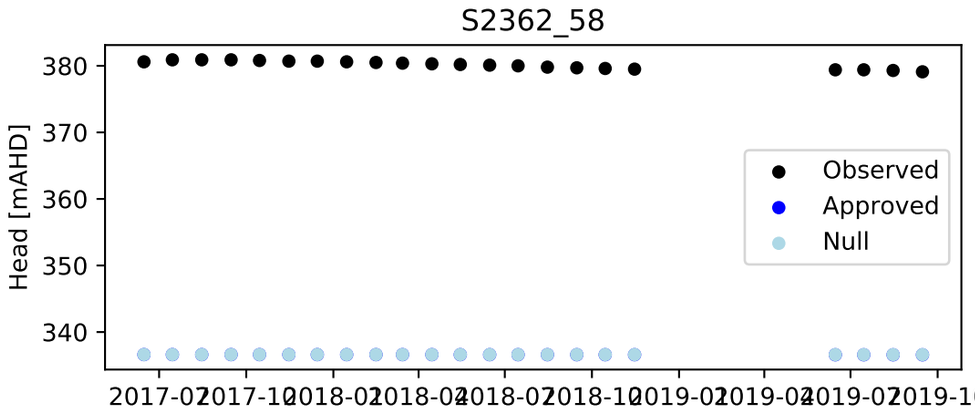

S2361_27
Head [mAHD]
385
380
375
370
365
360
Observed
Approved
Null
2017-07
2017-10
2018-01
2018-04
2018-07
2018-10
2019-01
2019-04
2019-07
2019-10

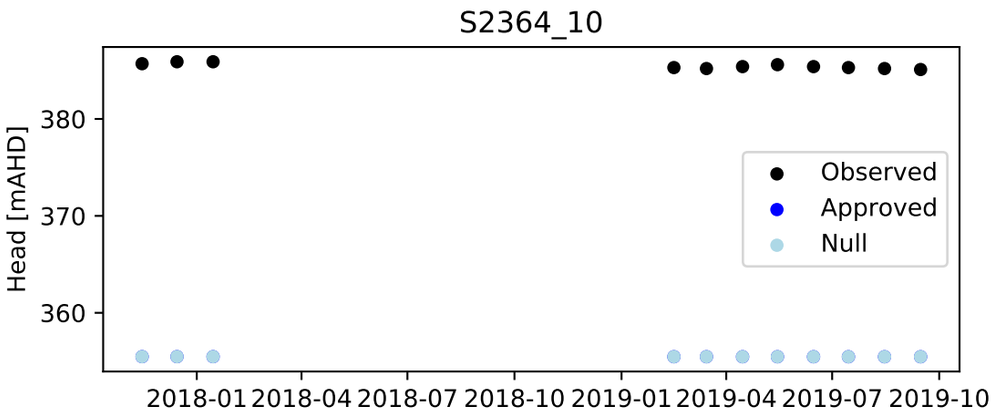

S2361_42
Head [mAHD]
380
375
370
365
360
Observed
Approved
Null
2017-07
2017-10
2018-01
2018-04
2018-07
2018-10
2019-01
2019-04
2019-07
2019-10

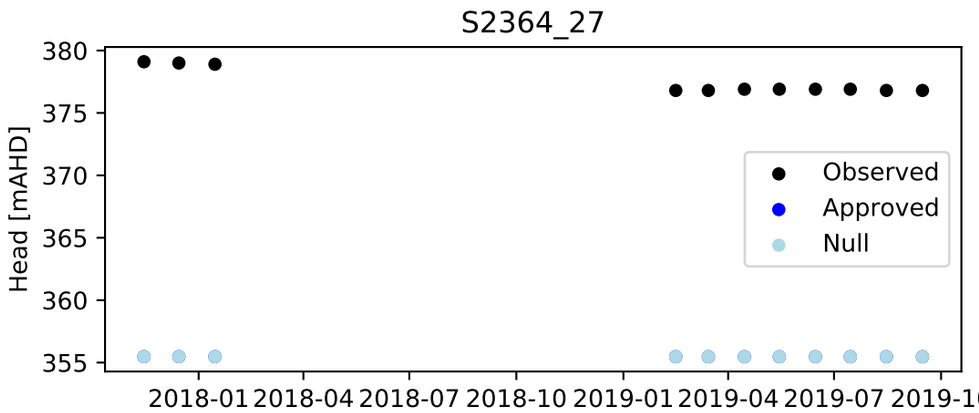

S2361_60
Head [mAHD]
Observed
Approved
Null

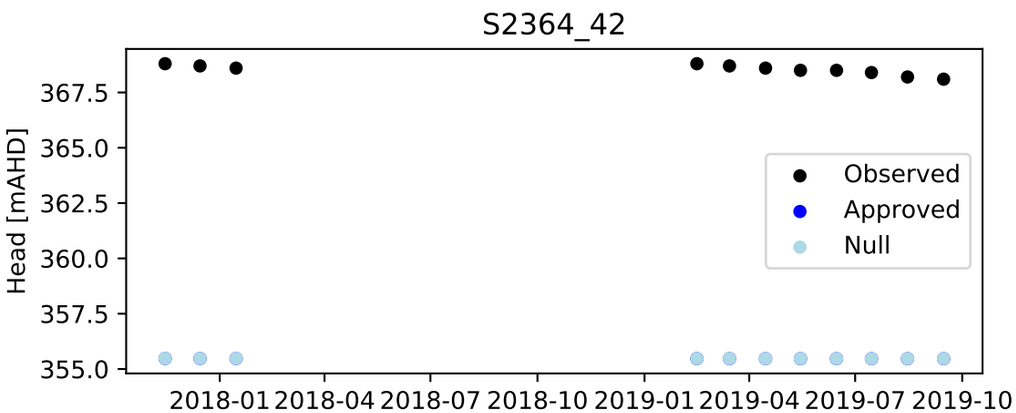

S2362_10
Head [mAHD]
Observed
Approved
Null

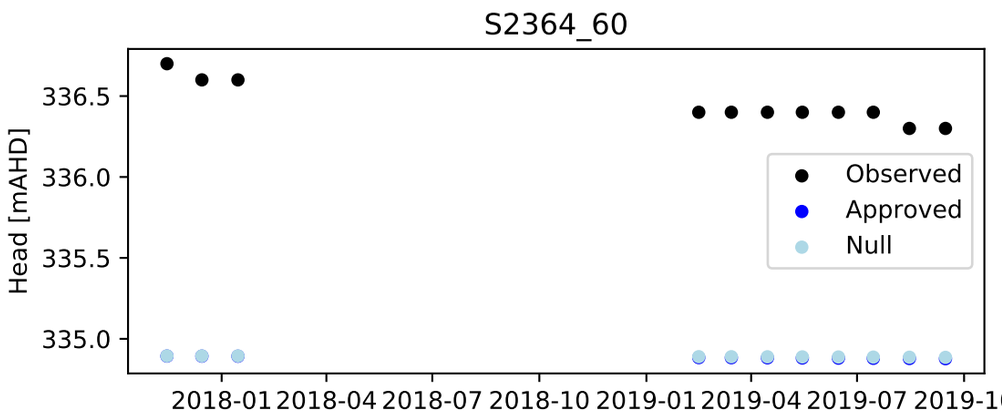

S2362_41
Head [mAHD]
Observed
Approved
Null

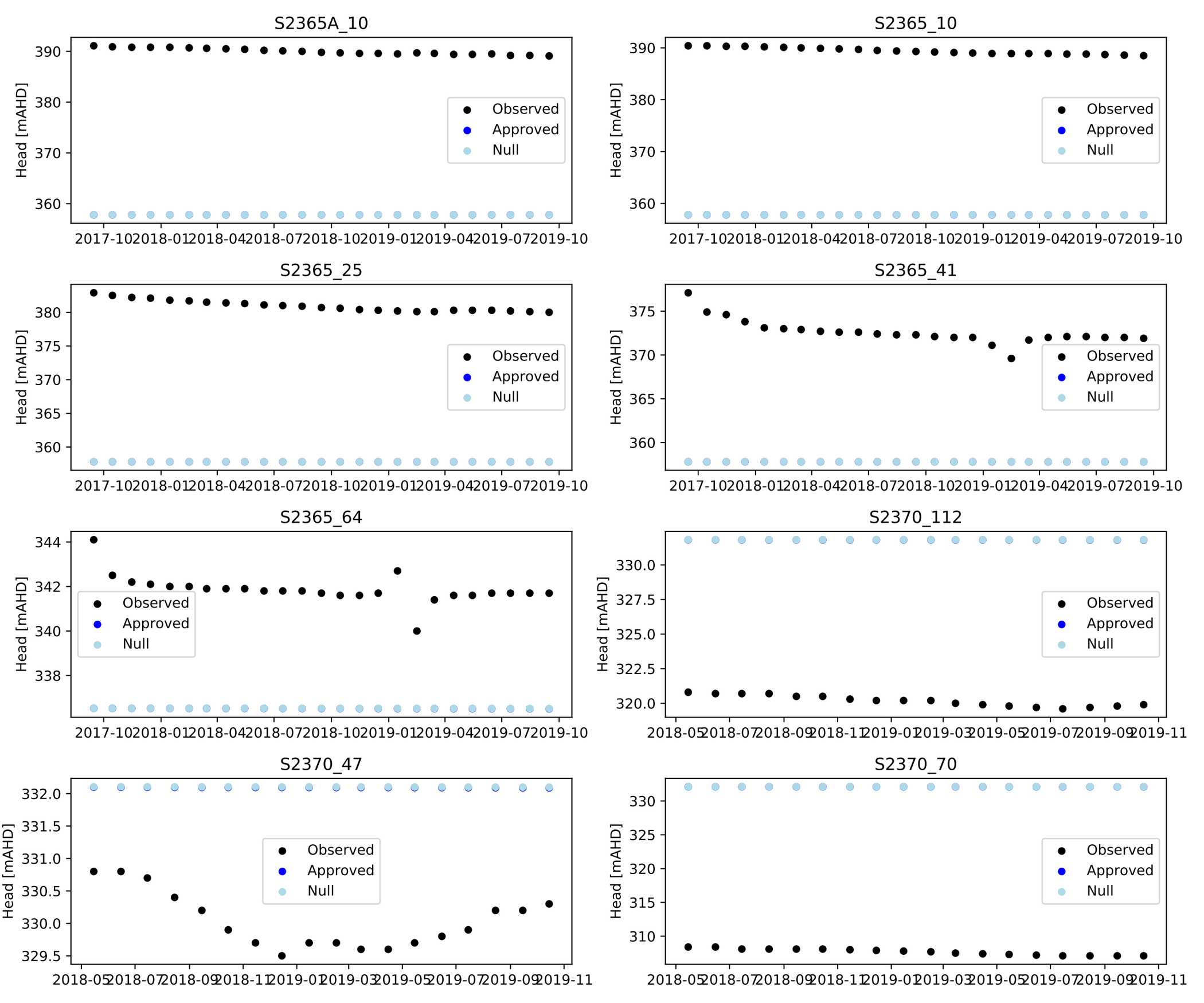

S2362_58
Head [mAHD]
Observed
Approved
Null

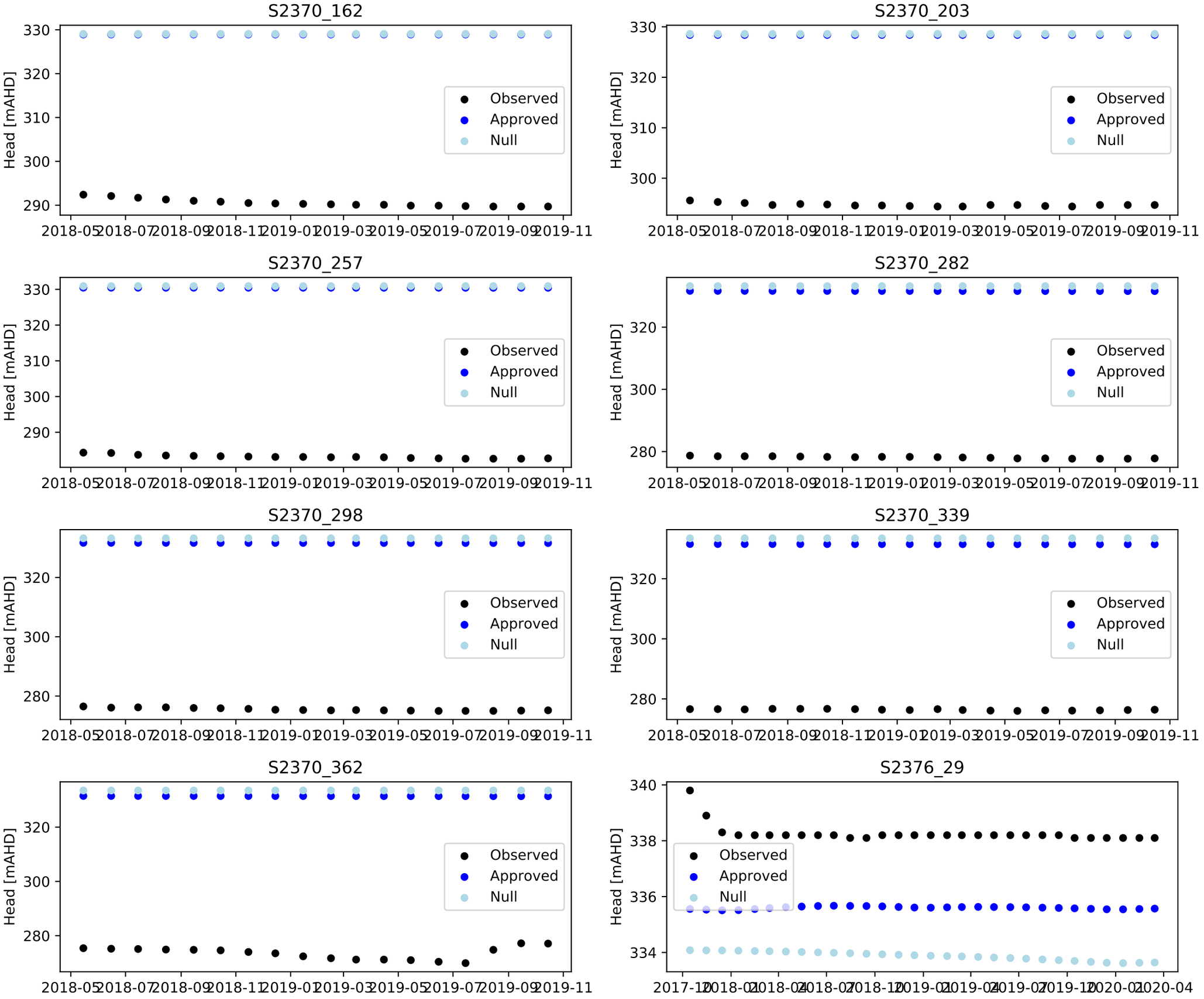

S2364_10
Head [mAHD]
Observed
Approved
Null

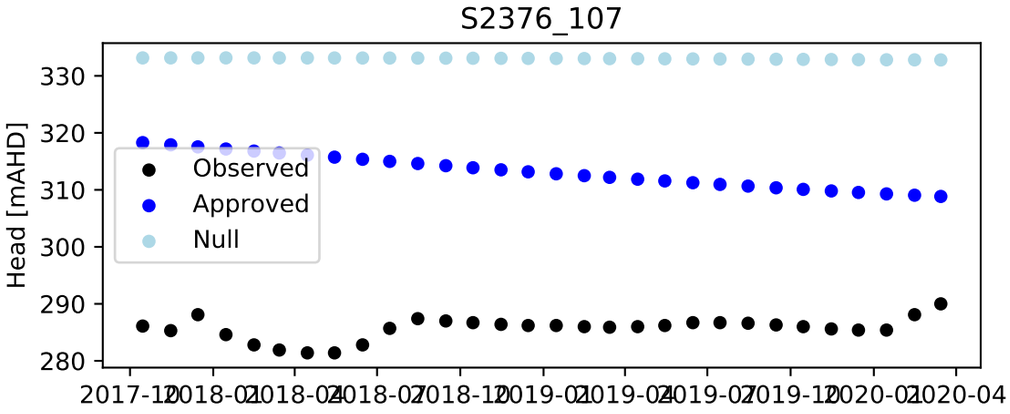

S2364_27
Head [mAHD]
Observed
Approved
Null

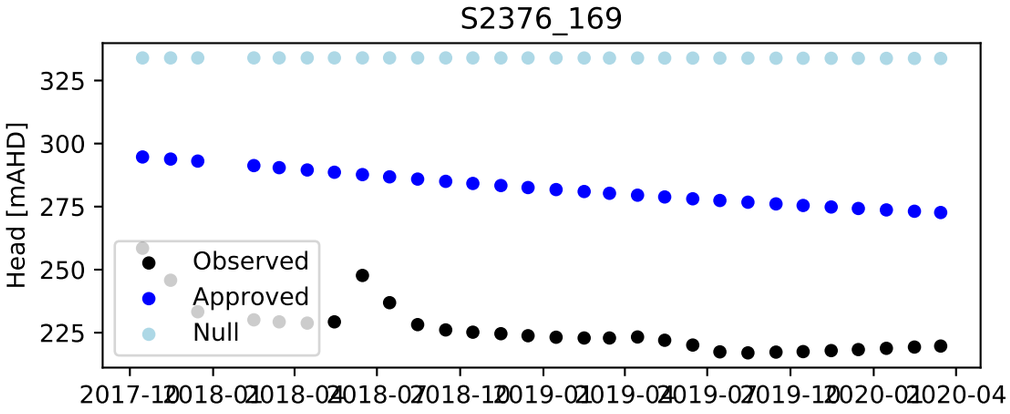

S2364_42
Head [mAHD]
Observed
Approved
Null

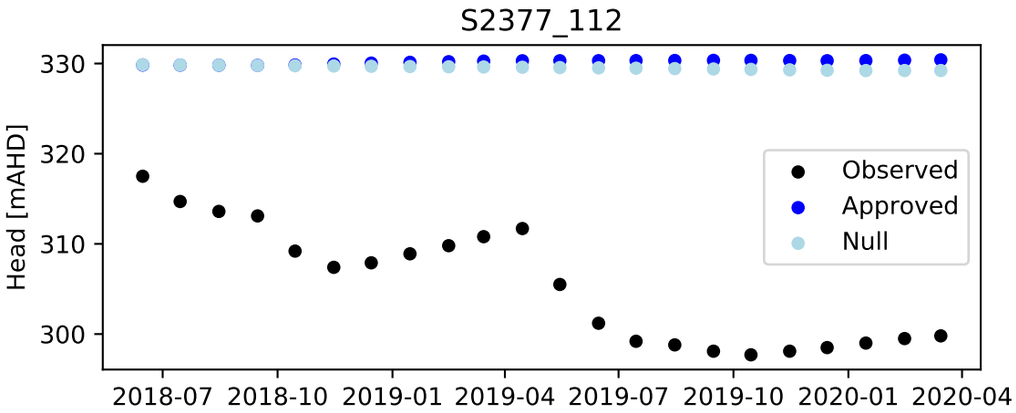

S2364_60
Head [mAHD]
Observed
Approved
Null

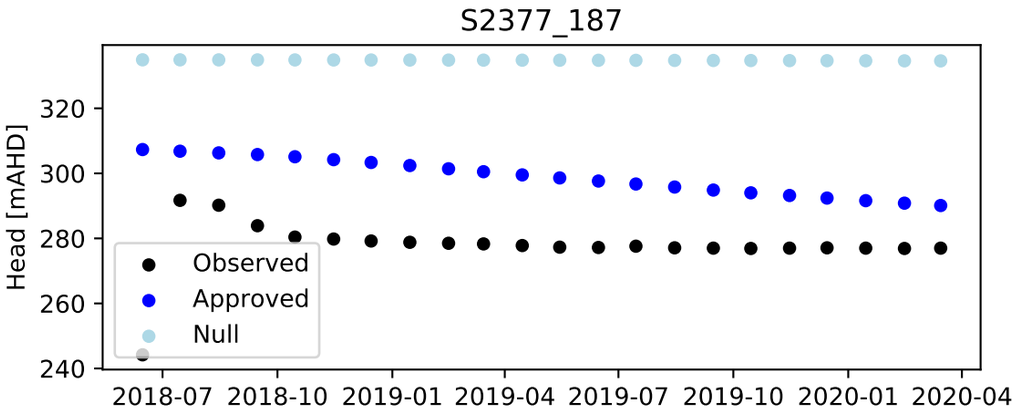

S2365A_10
S2365_10
S2365_25
S2365_41
S2365_64
S2370_112
S2370_47
S2370_70
Head [mAHD]
Observed
Approved
Null

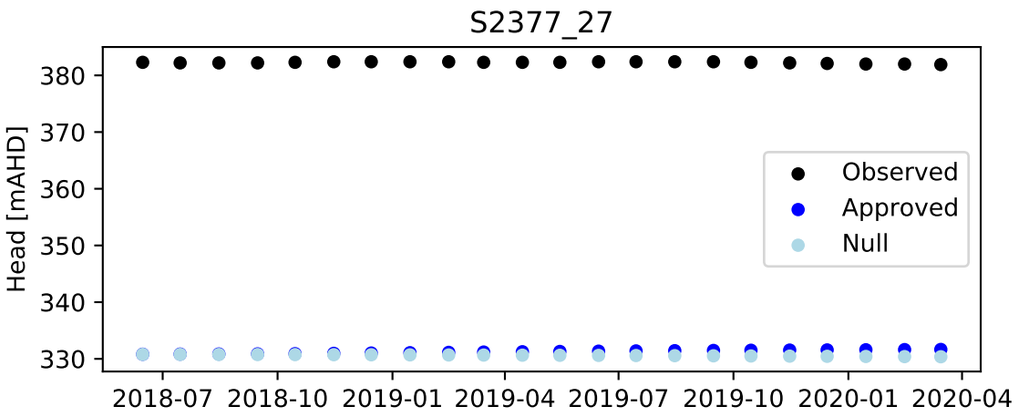

S2370_162
S2370_203
S2370_257
S2370_282
S2370_298
S2370_339
S2370_362
S2376_29
Head [mAHD]
Observed
Approved
Null

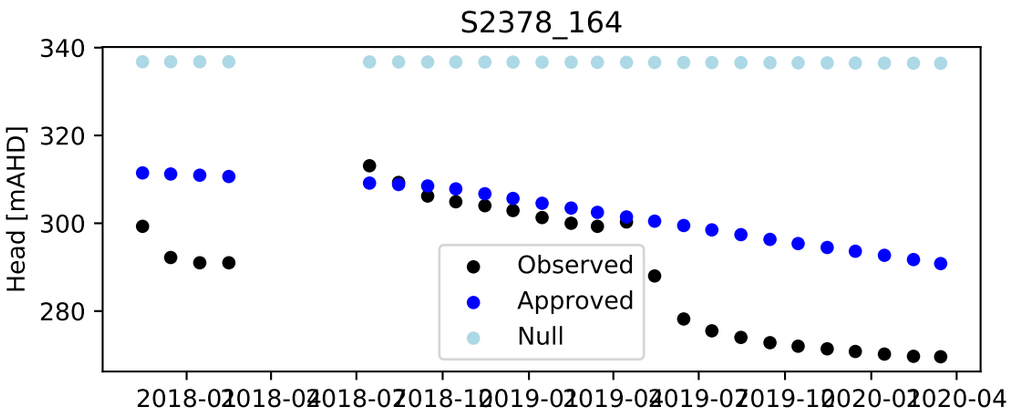

S2376_107
Head [mAHD]
Observed
Approved
Null

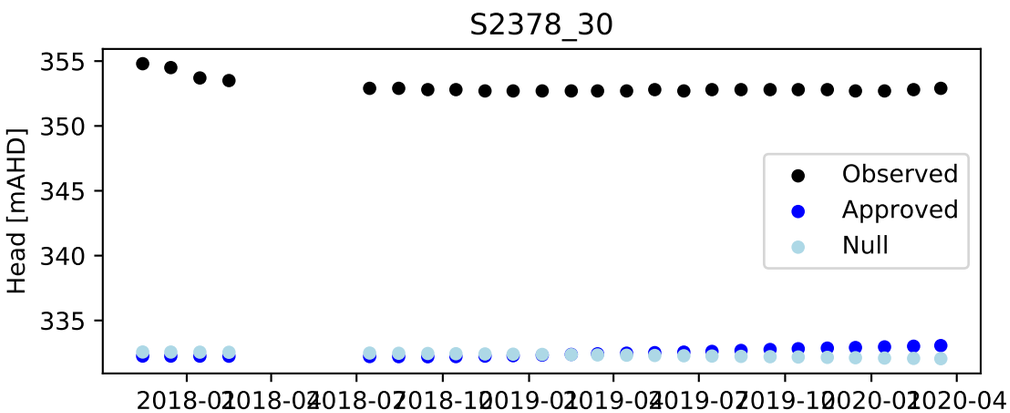

S2376_169
Head [mAHD]
Observed
Approved
Null

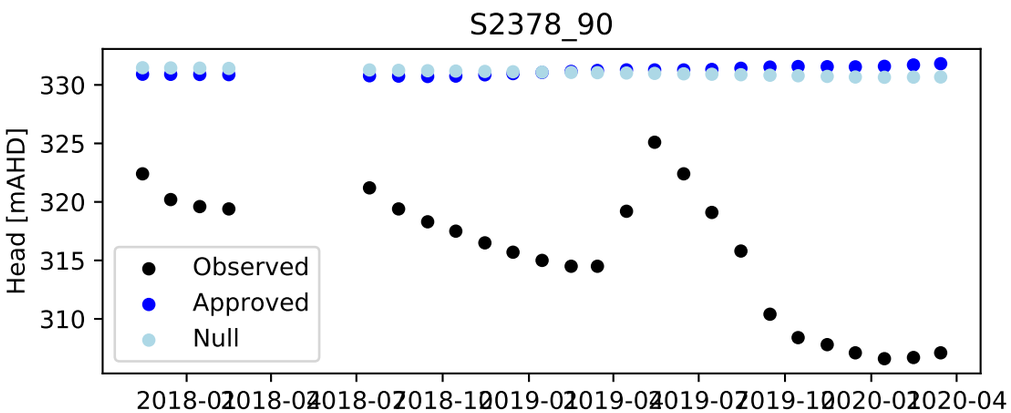

S2377_112
Head [mAHD]
Observed
Approved
Null

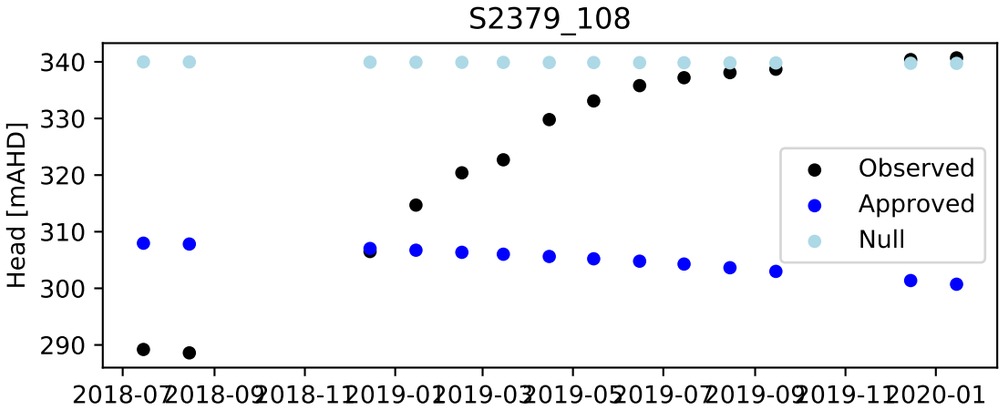

S2377_187
Head [mAHD]
Observed
Approved
Null

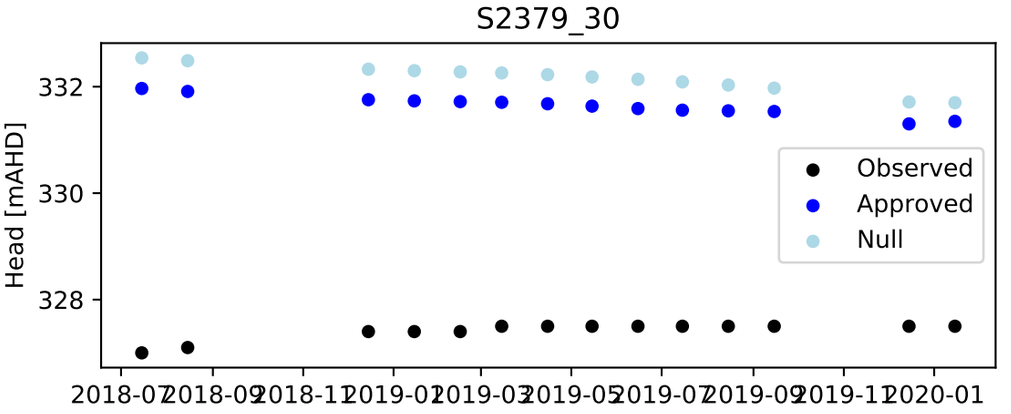

S2377_27
Head [mAHD]
Observed
Approved
Null

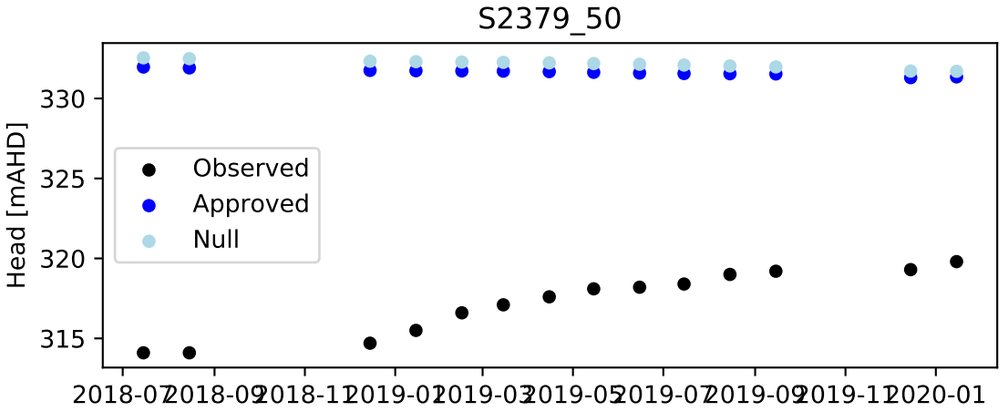

S2378_164
Head [mAHD]
Observed
Approved
Null

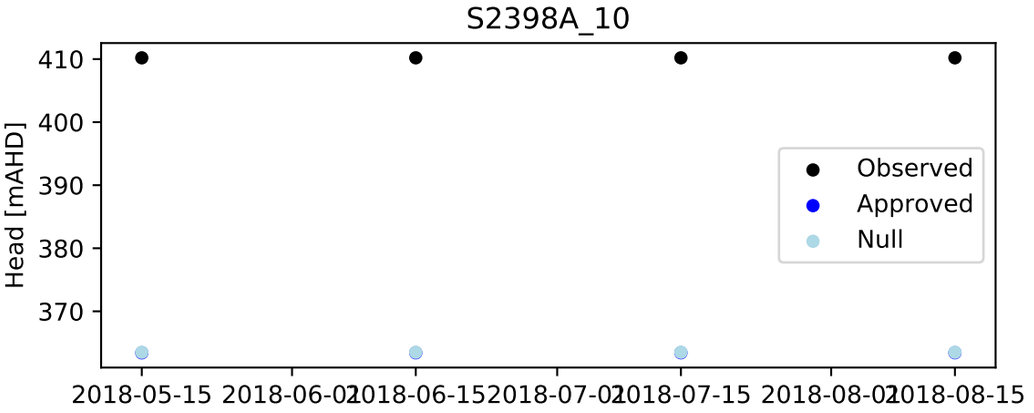

S2378_30
Head [mAHD]
Observed
Approved
Null

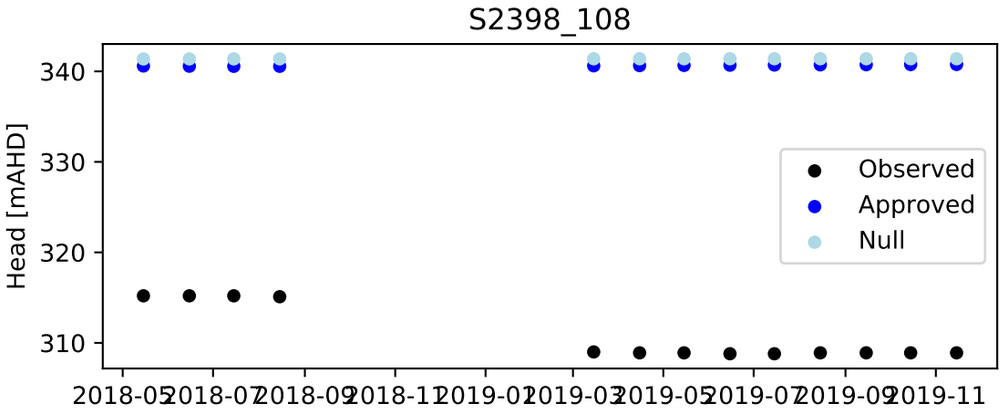

S2378_90
Head [mAHD]
Observed
Approved
Null

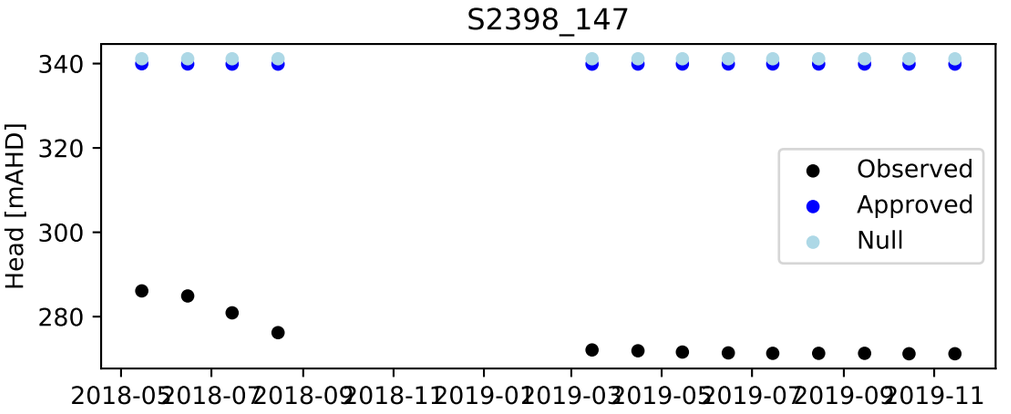

S2379_108
Head [mAHD]
Observed
Approved
Null

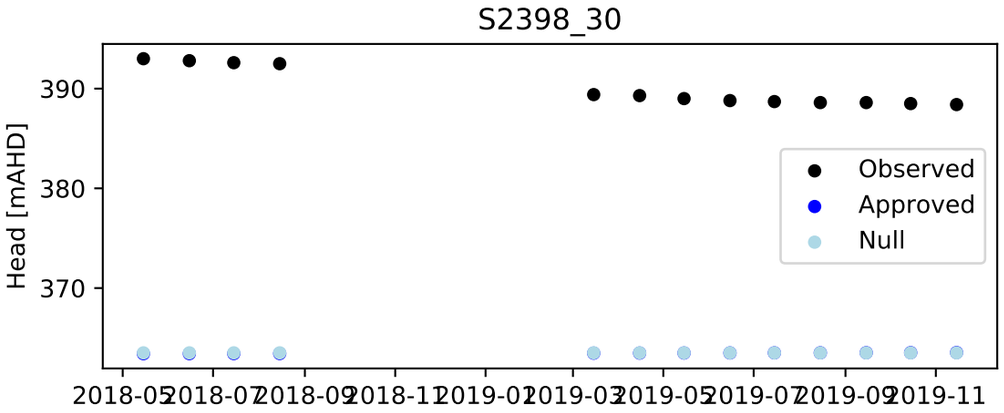

S2379_30
Head [mAHD]
Observed
Approved
Null

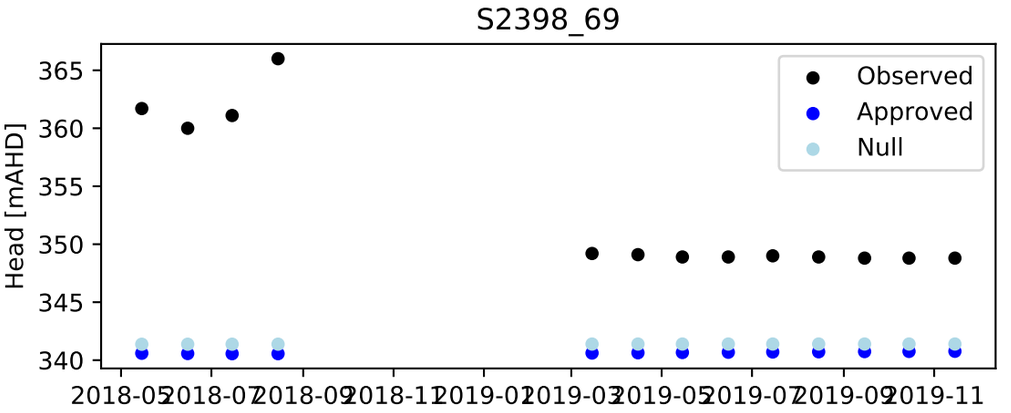

S2379_50
Head [mAHD]
Observed
Approved
Null

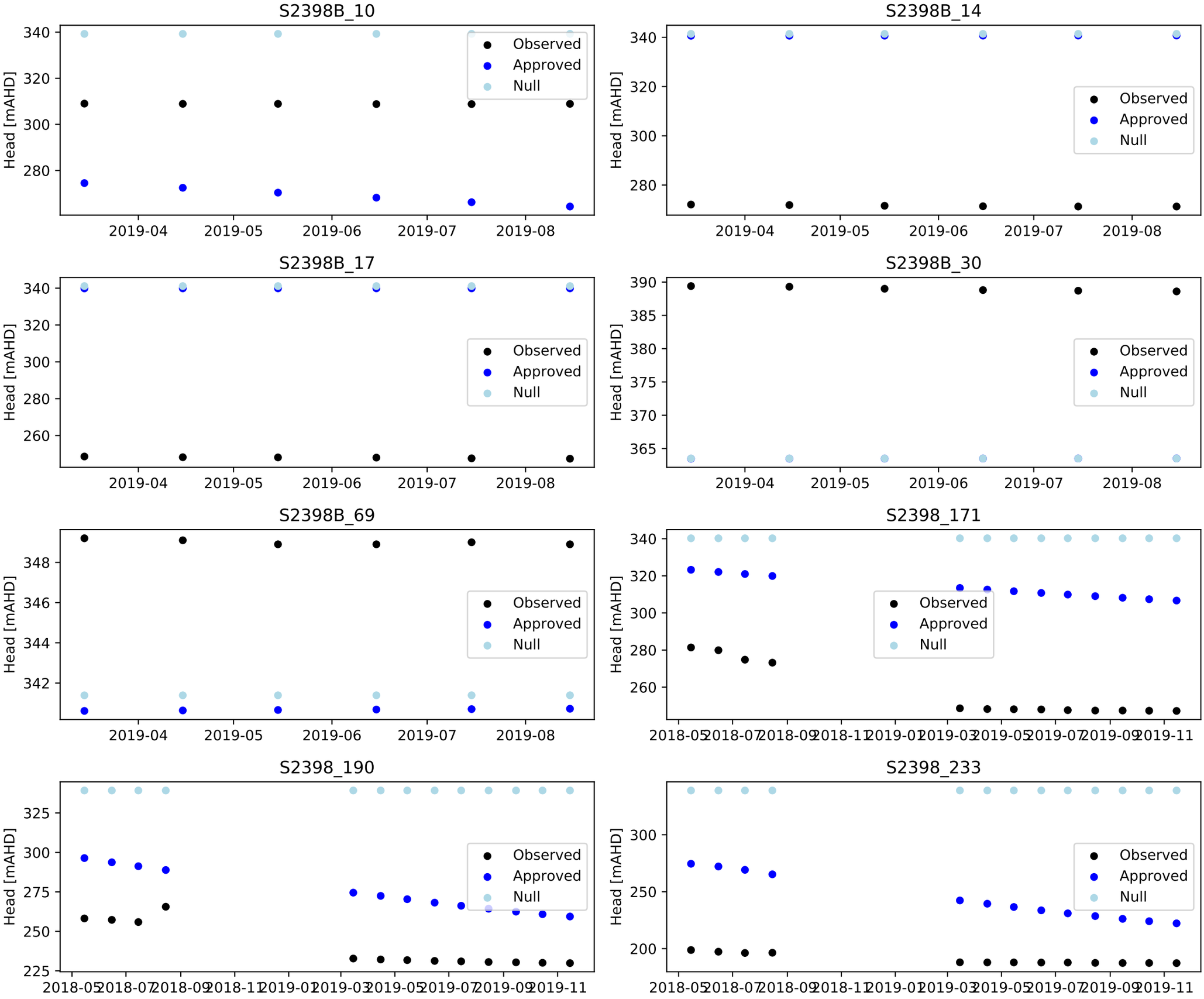

S2398A_10
Head [mAHD]
Observed
Approved
Null

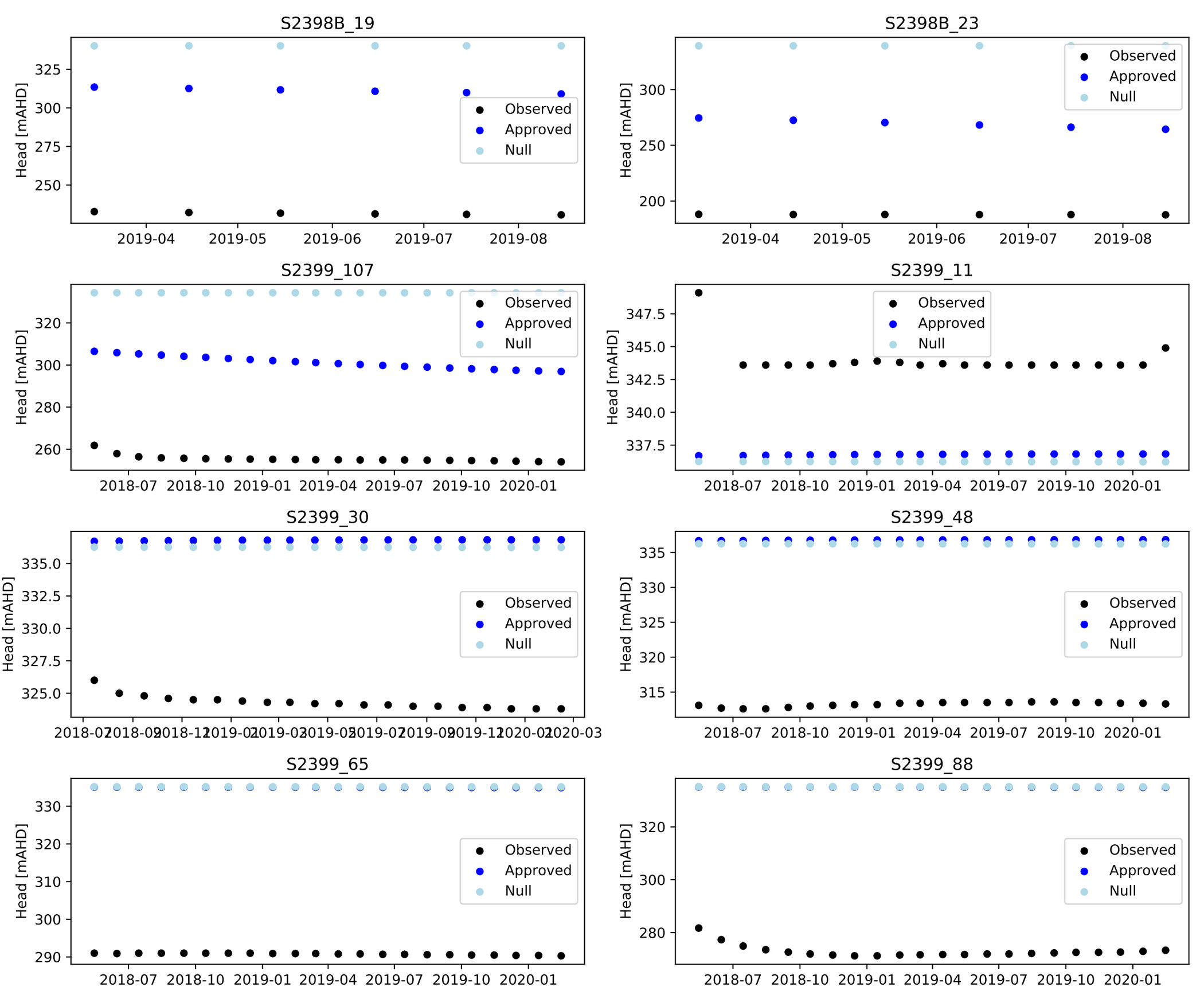

S2398_108
Head [mAHD]
Observed
Approved
Null

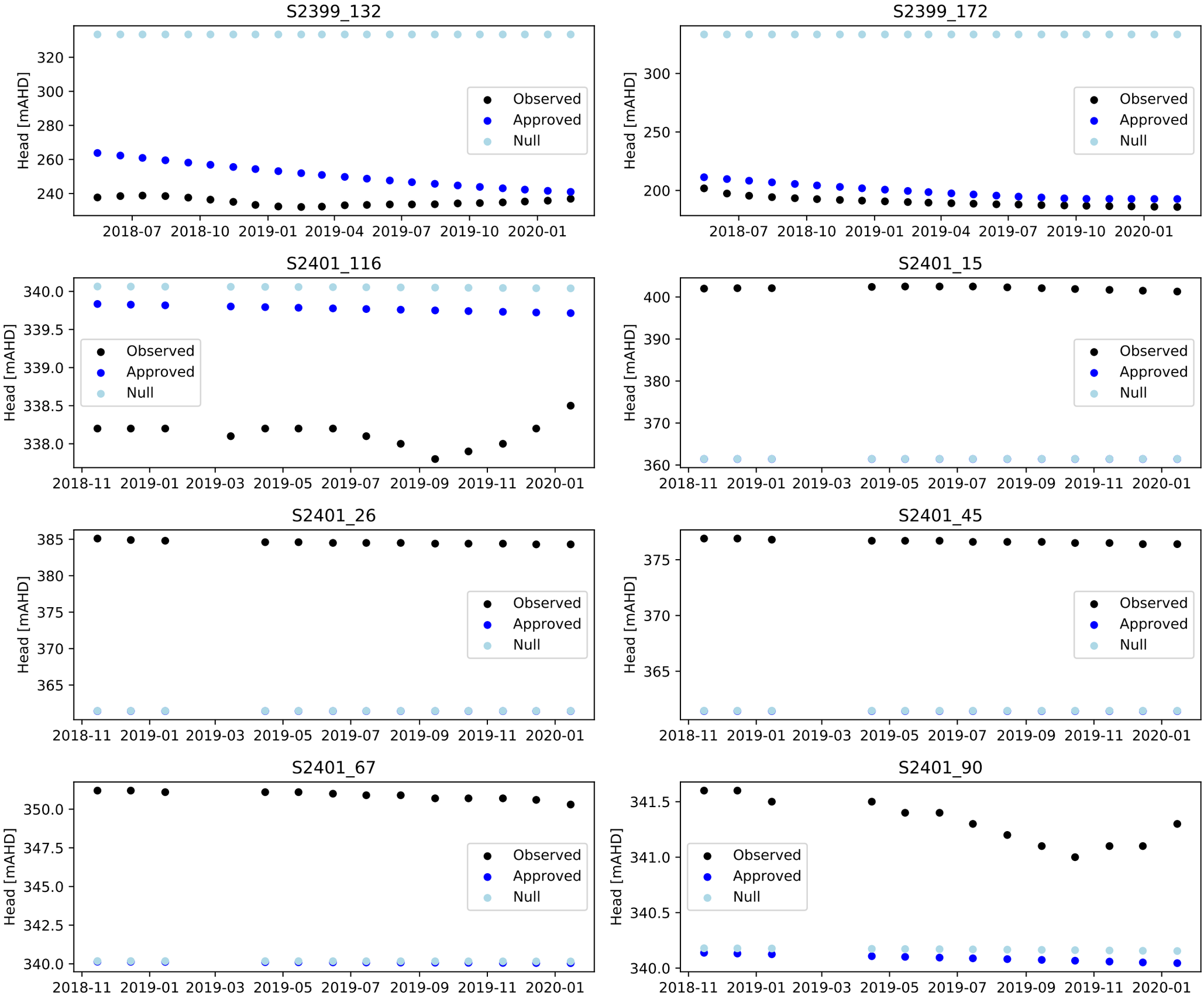

S2398_147
Head [mAHD]
Observed
Approved
Null

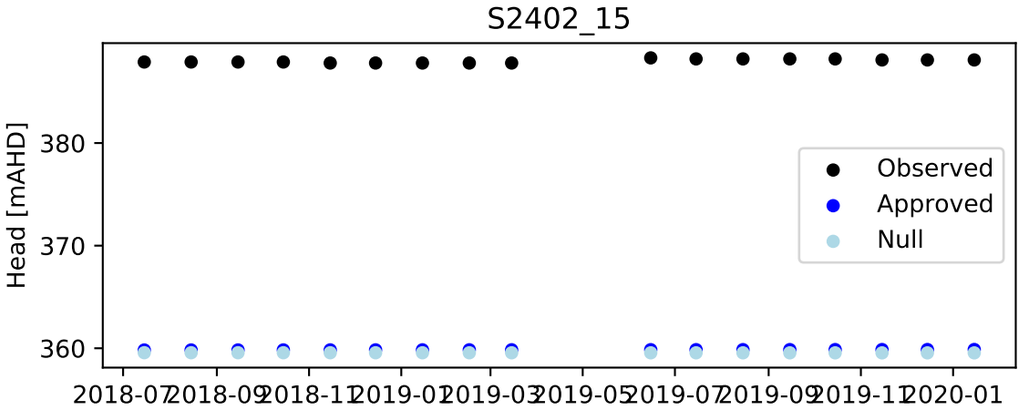

S2398_30
Head [mAHD]
Observed
Approved
Null

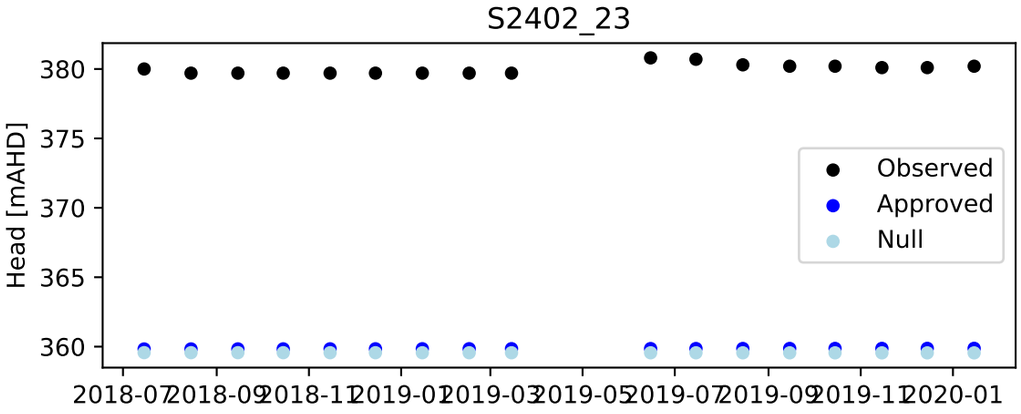

S2398_69
Head [mAHD]
Observed
Approved
Null

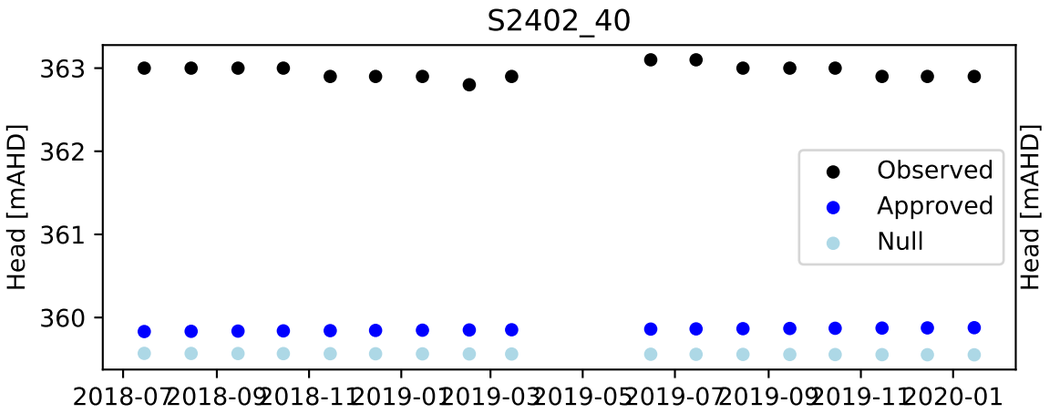

S2398B_10
S2398B_14
S2398B_17
S2398B_30
S2398B_69
S2398_171
S2398_190
S2398_233
Observed
Approved
Null
Head [mAHD]

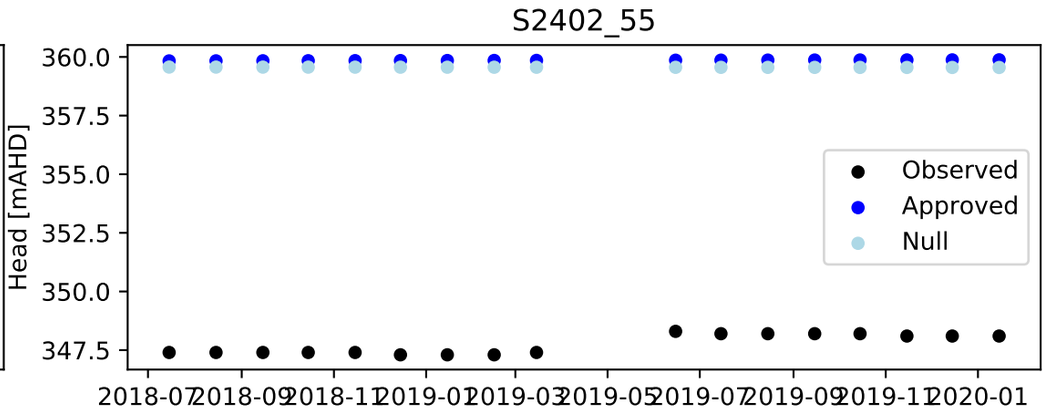

S2398B_19
Head [mAHD]
325
300
275
250
2019-04
2019-05
2019-06
2019-07
2019-08
Observed
Approved
Null
S2398B_23
Head [mAHD]
300
250
200
2019-04
2019-05
2019-06
2019-07
2019-08
Observed
Approved
Null
S2399_107
Head [mAHD]
320
300
280
260
2018-07
2018-10
2019-01
2019-04
2019-07
2019-10
2020-01
Observed
Approved
Null
S2399_11
Head [mAHD]
347.5
345.0
342.5
340.0
337.5
2018-07
2018-10
2019-01
2019-04
2019-07
2019-10
2020-01
Observed
Approved
Null
S2399_30
Head [mAHD]
335.0
332.5
330.0
327.5
325.0
2018-07
2018-09
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01
2020-03
Observed
Approved
Null
S2399_48
Head [mAHD]
335
330
325
320
315
2018-07
2018-10
2019-01
2019-04
2019-07
2019-10
2020-01
Observed
Approved
Null
S2399_65
Head [mAHD]
330
320
310
300
290
2018-07
2018-10
2019-01
2019-04
2019-07
2019-10
2020-01
Observed
Approved
Null
S2399_88
Head [mAHD]
320
300
280
2018-07
2018-10
2019-01
2019-04
2019-07
2019-10
2020-01
Observed
Approved
Null

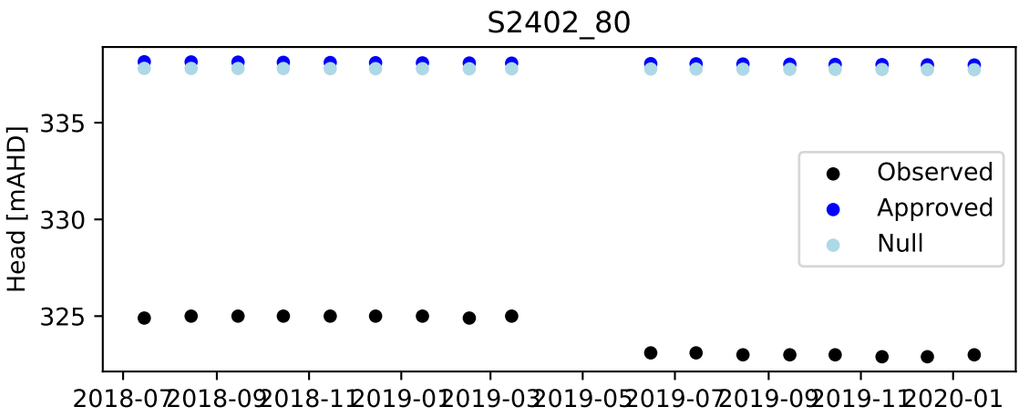

S2399_132
Head [mAHD]
320
300
280
260
240
2018-07
2018-10
2019-01
2019-04
2019-07
2019-10
2020-01
Observed
Approved
Null
S2399_172
Head [mAHD]
300
250
200
2018-07
2018-10
2019-01
2019-04
2019-07
2019-10
2020-01
Observed
Approved
Null
S2401_116
Head [mAHD]
340.0
339.5
339.0
338.5
338.0
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01
Observed
Approved
Null
S2401_15
Head [mAHD]
400
390
380
370
360
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01
Observed
Approved
Null
S2401_26
Head [mAHD]
385
380
375
370
365
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01
Observed
Approved
Null
S2401_45
Head [mAHD]
375
370
365
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01
Observed
Approved
Null
S2401_67
Head [mAHD]
350.0
347.5
345.0
342.5
340.0
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01
Observed
Approved
Null
S2401_90
Head [mAHD]
341.5
341.0
340.5
340.0
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01
Observed
Approved
Null

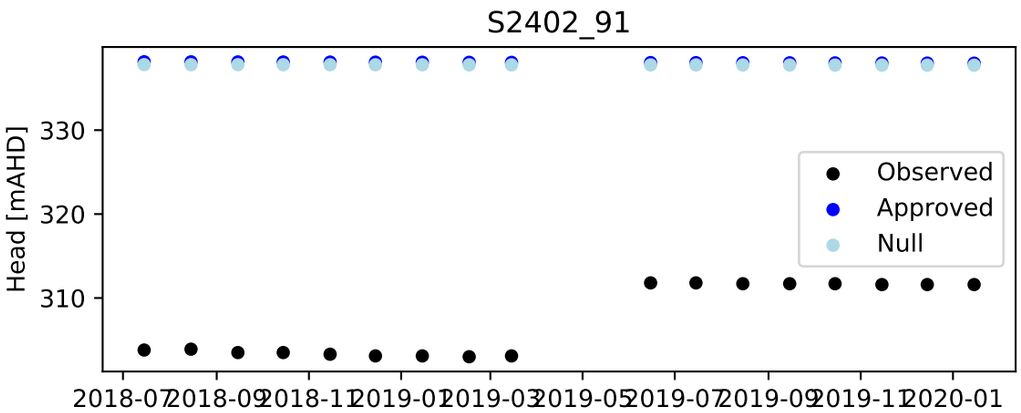

S2402_15
Head [mAHD]
380
370
360
Observed
Approved
Null
2018-07
2018-09
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01

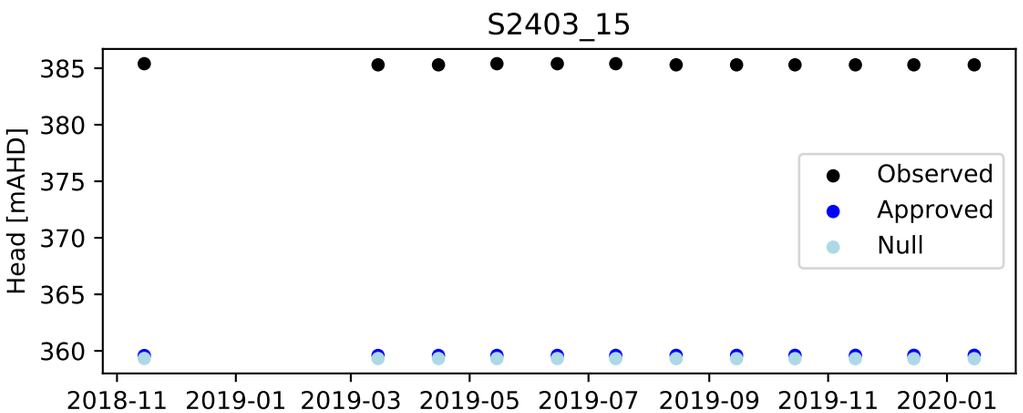

S2402_23
Head [mAHD]
380
375
370
365
360
Observed
Approved
Null
2018-07
2018-09
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01

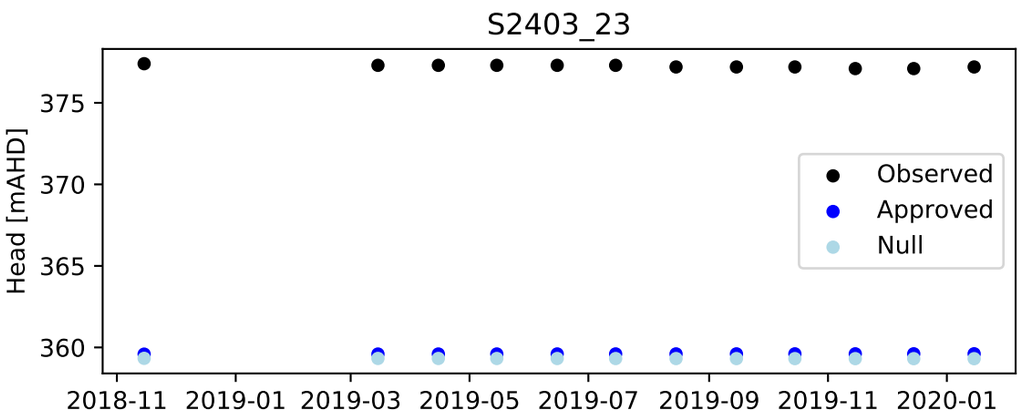

S2402_40
Head [mAHD]
363
362
361
360
Observed
Approved
Null
2018-07
2018-09
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01

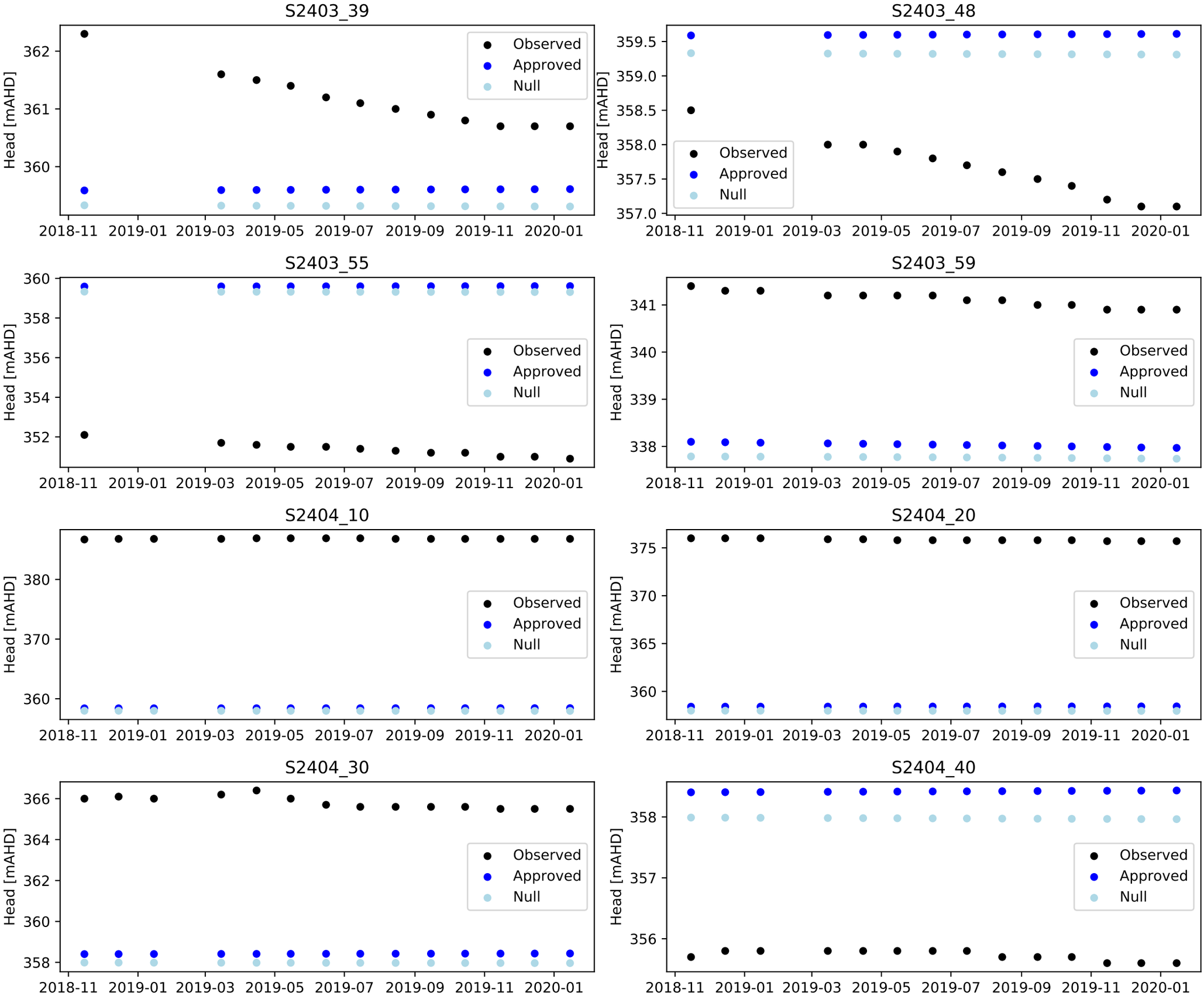

S2402_55
Head [mAHD]
360.0
357.5
355.0
352.5
350.0
347.5
Observed
Approved
Null
2018-07
2018-09
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01

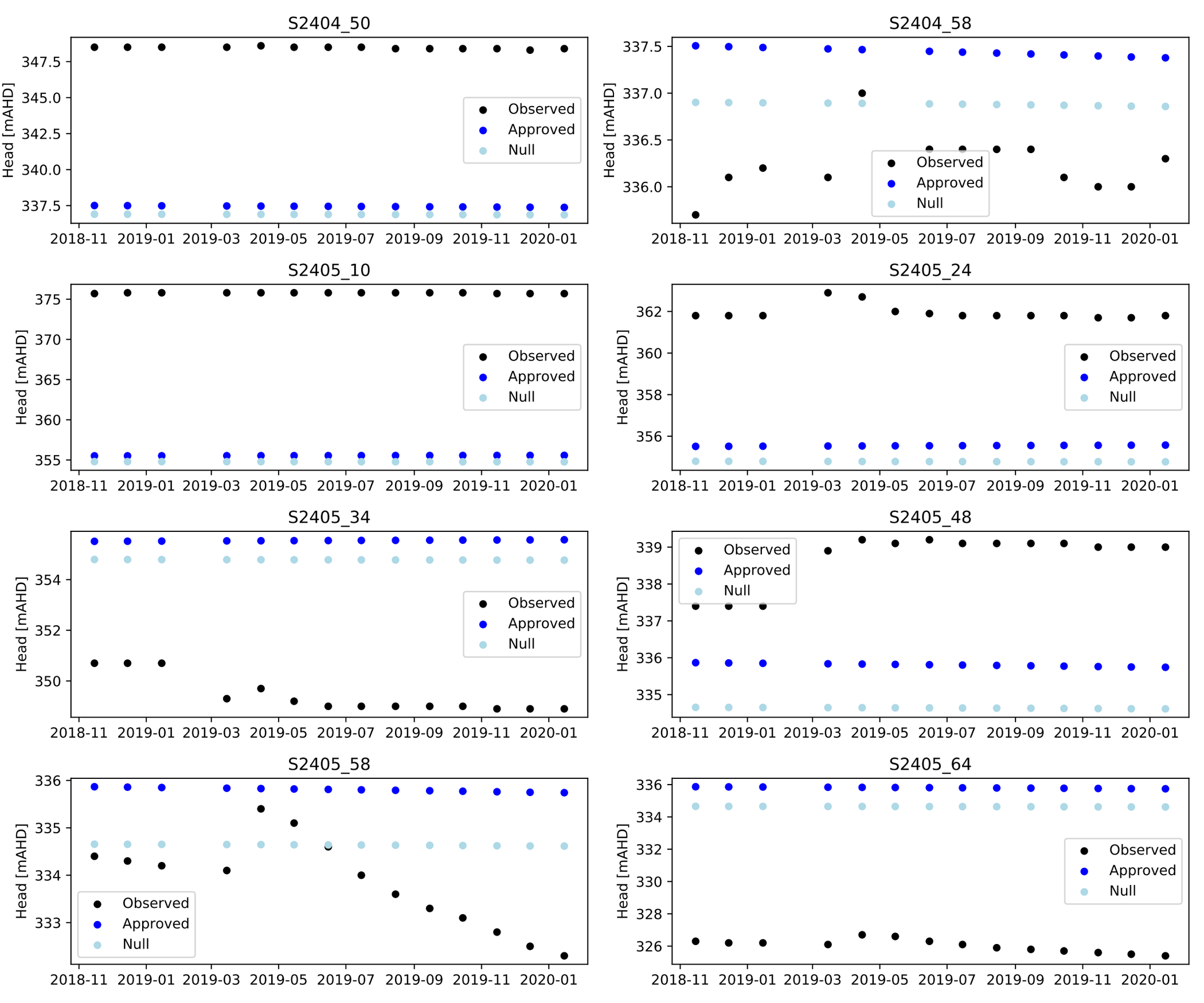

S2402_80
Head [mAHD]
335
330
325
Observed
Approved
Null
2018-07
2018-09
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01

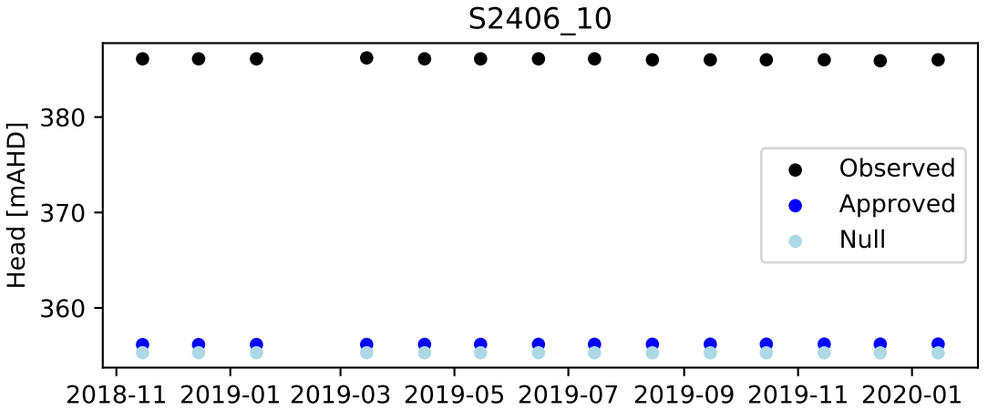

S2402_91
Head [mAHD]
330
320
310
Observed
Approved
Null
2018-07
2018-09
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01

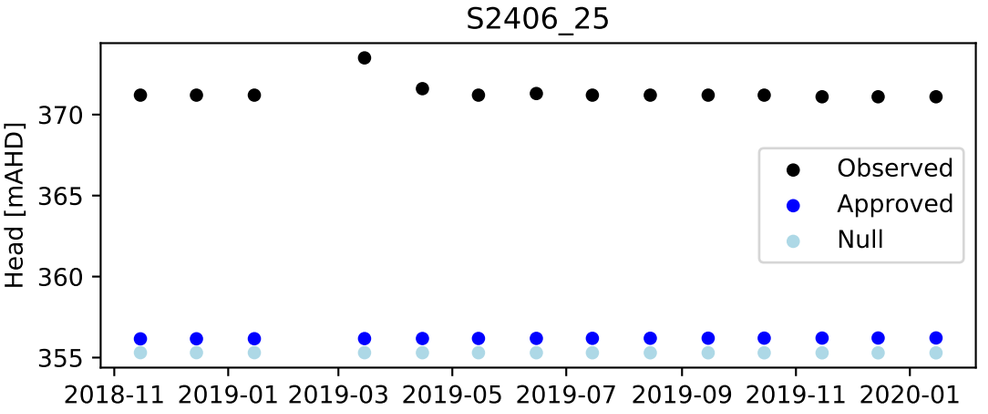

S2403_15
Head [mAHD]
385
380
375
370
365
360
Observed
Approved
Null
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01

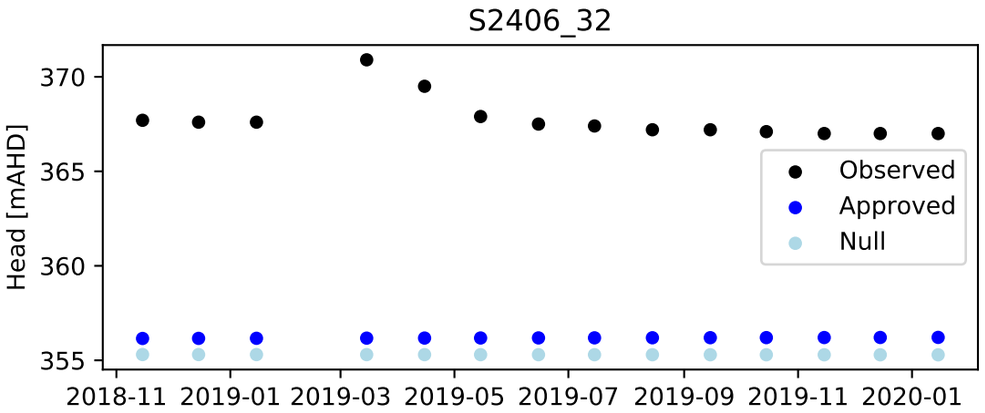

S2403_23
Head [mAHD]
375
370
365
360
Observed
Approved
Null
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01

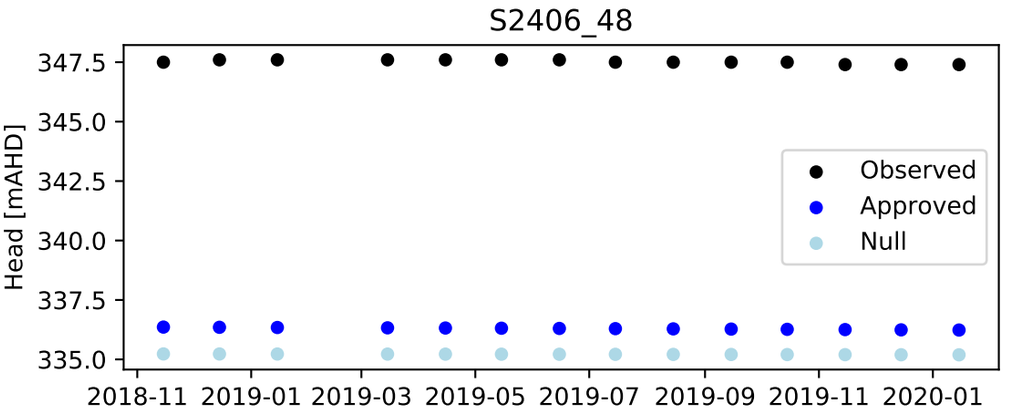

S2403_39
S2403_48
S2403_55
S2403_59
S2404_10
S2404_20
S2404_30
S2404_40
Head [mAHD]
Observed
Approved
Null
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01

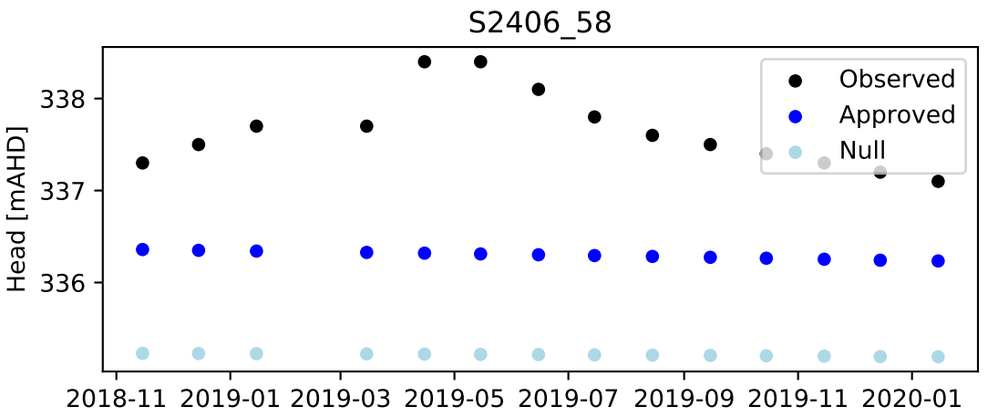

S2404_50
S2404_58
S2405_10
S2405_24
S2405_34
S2405_48
S2405_58
S2405_64
Head [mAHD]
Observed
Approved
Null
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01

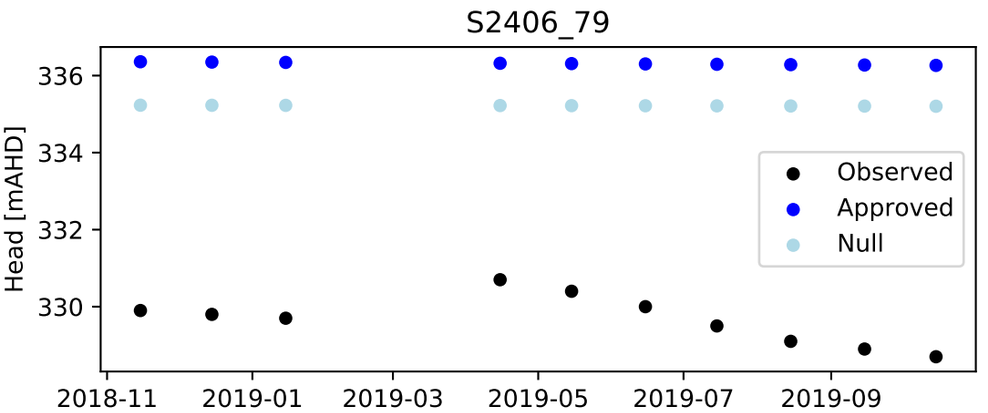

S2406_10
Head [mAHD]
380
370
360
Observed
Approved
Null
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01

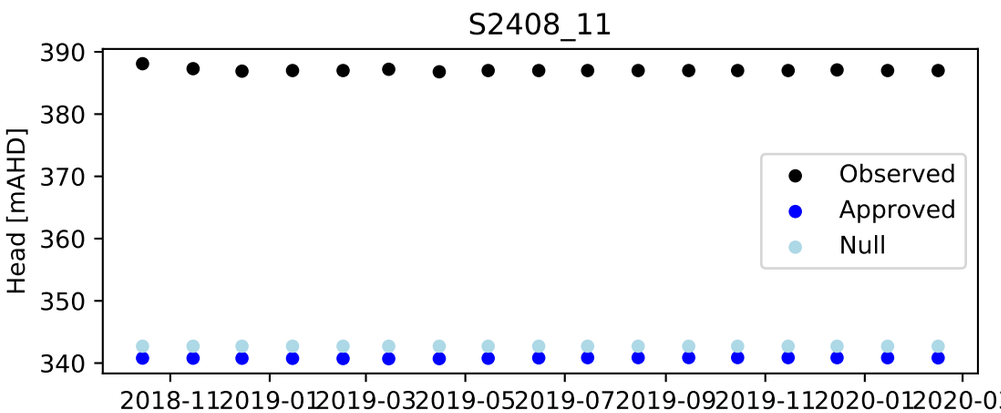

S2406_25
Head [mAHD]
370
365
360
355
Observed
Approved
Null
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01

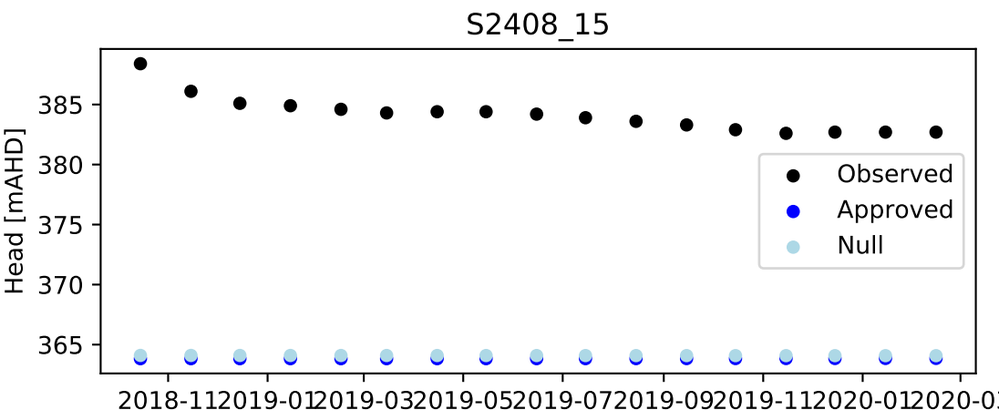

S2406_32
Head [mAHD]
370
365
360
355
Observed
Approved
Null
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01

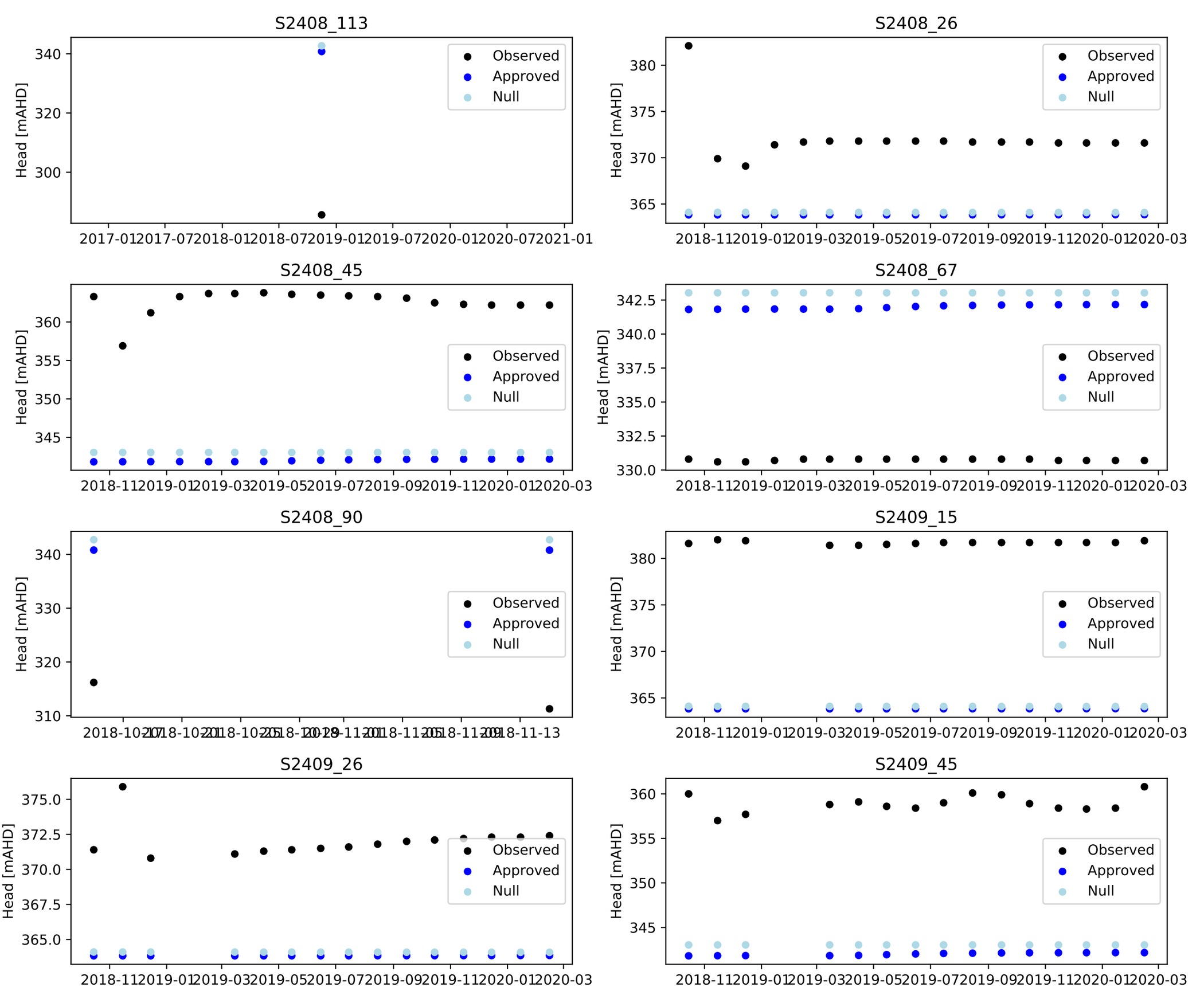

S2406_48
Head [mAHD]
347.5
345.0
342.5
340.0
337.5
335.0
Observed
Approved
Null
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01

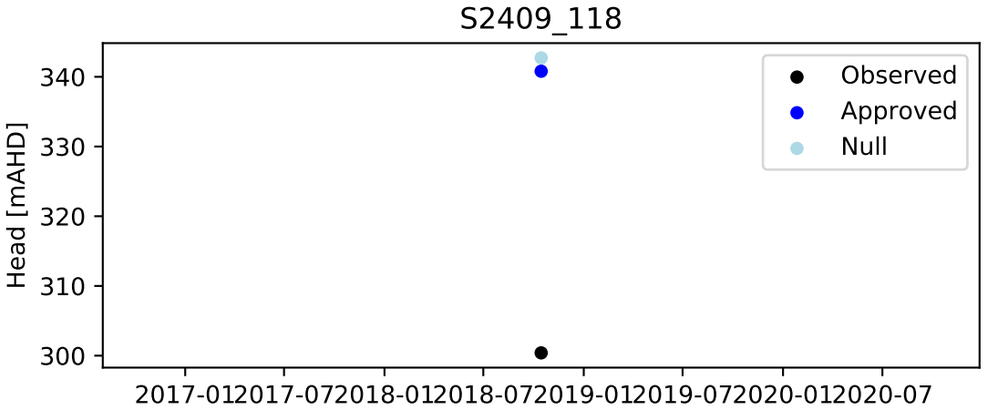

S2406_58
Head [mAHD]
338
337
336
Observed
Approved
Null
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01

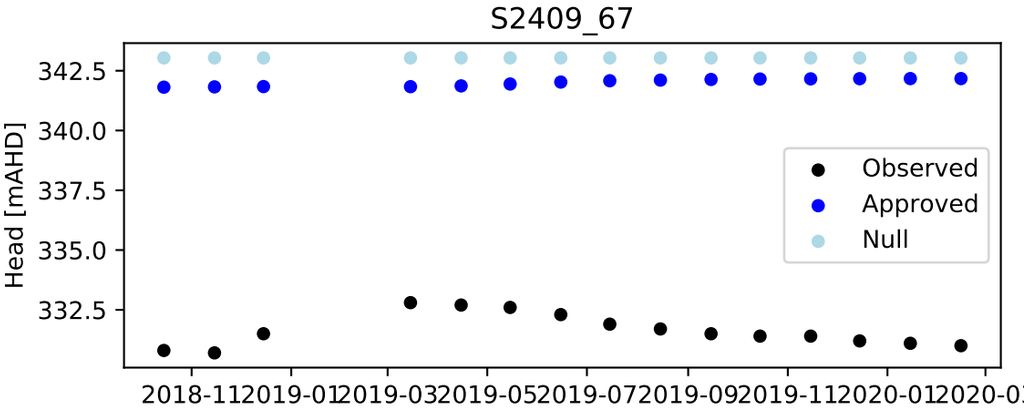

S2406_79
Head [mAHD]
336
334
332
330
Observed
Approved
Null
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09

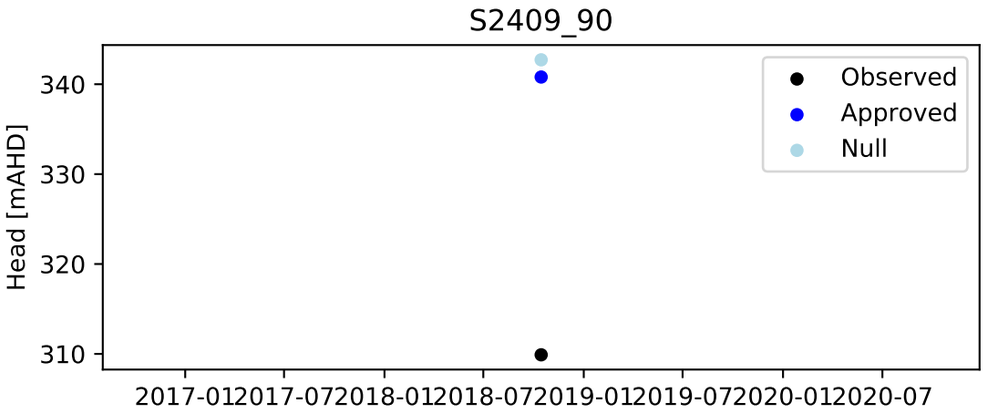

S2408_11
Head [mAHD]
390
380
370
360
350
340
Observed
Approved
Null
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01
2020-03

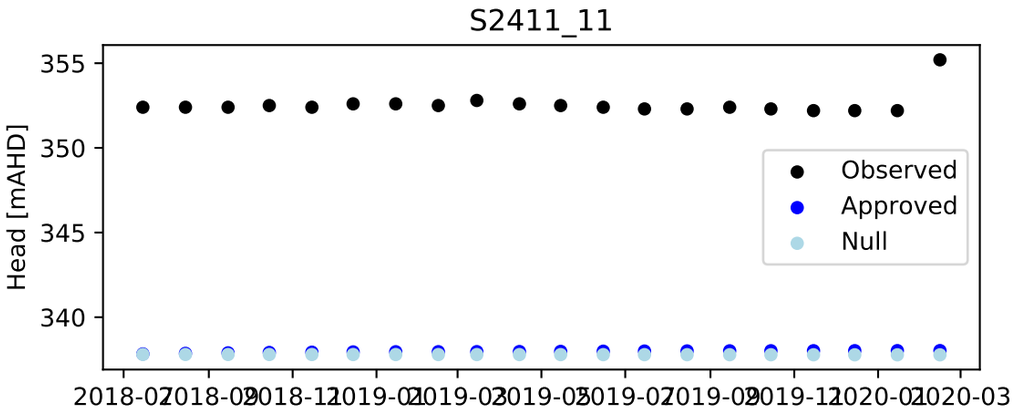

S2408_15
Head [mAHD]
385
380
375
370
365
Observed
Approved
Null
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01
2020-03

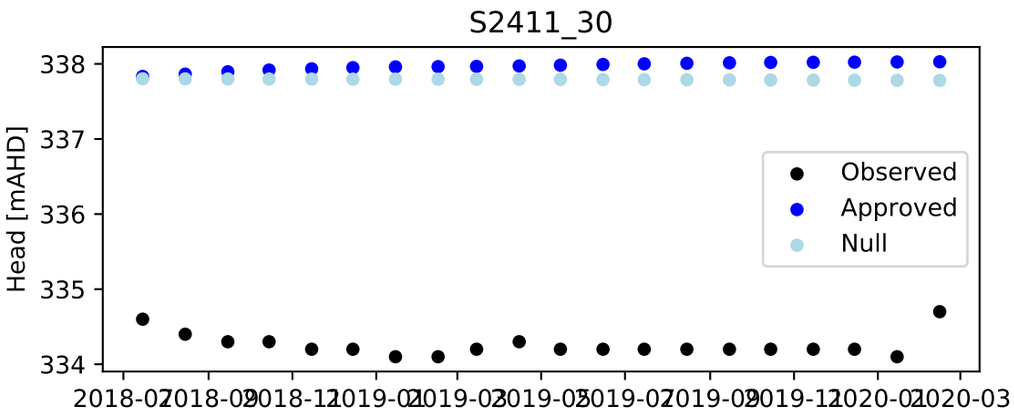

S2408_113
S2408_26
S2408_45
S2408_67
S2408_90
S2409_15
S2409_26
S2409_45
Head [mAHD]
Observed
Approved
Null

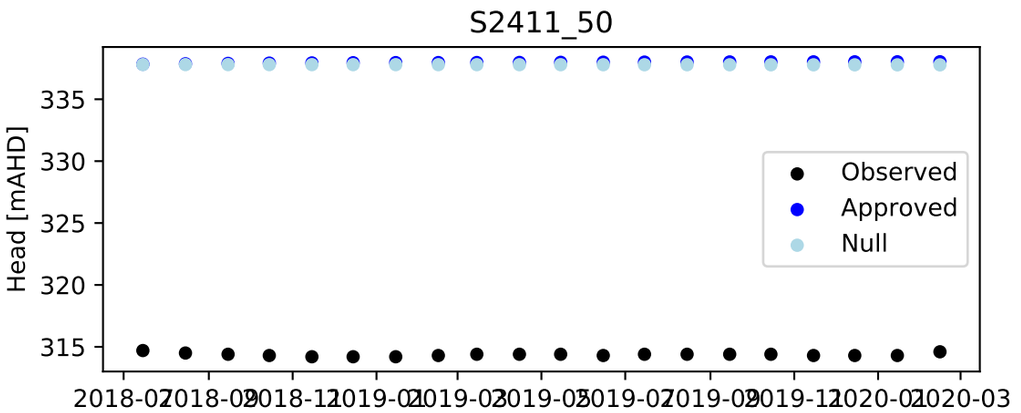

S2409_118
Head [mAHD]
Observed
Approved
Null

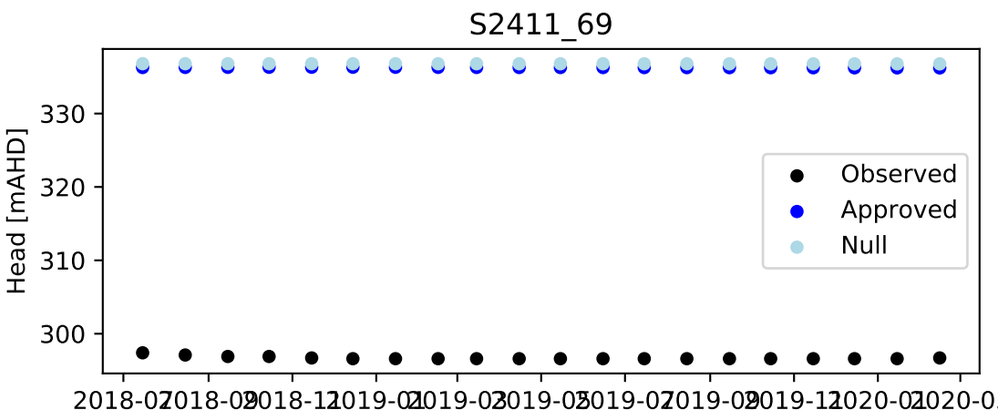

S2409_67
Head [mAHD]
Observed
Approved
Null

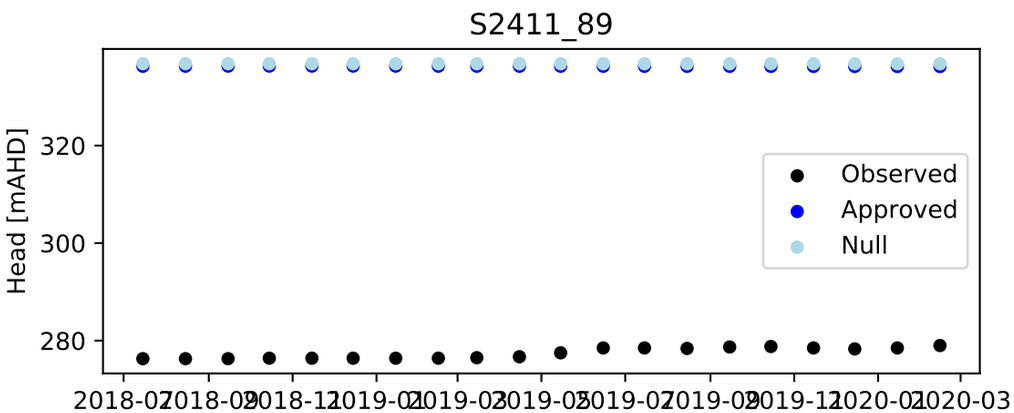

S2409_90
Head [mAHD]
Observed
Approved
Null

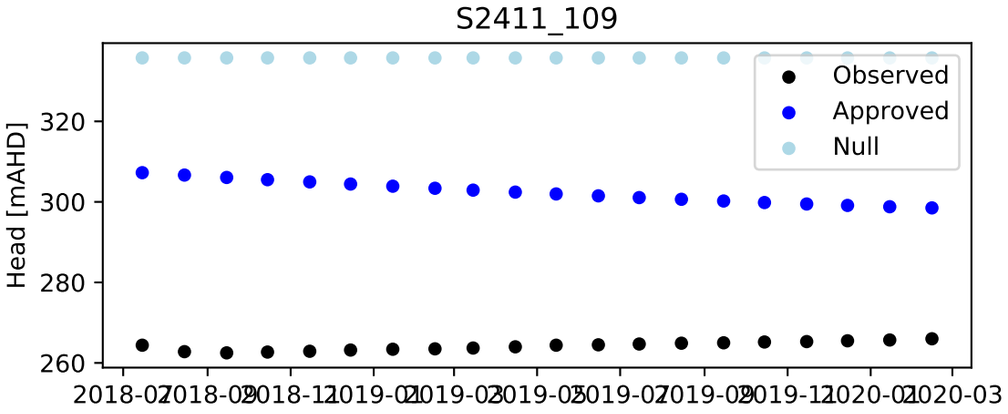

S2411_11
Head [mAHD]
Observed
Approved
Null

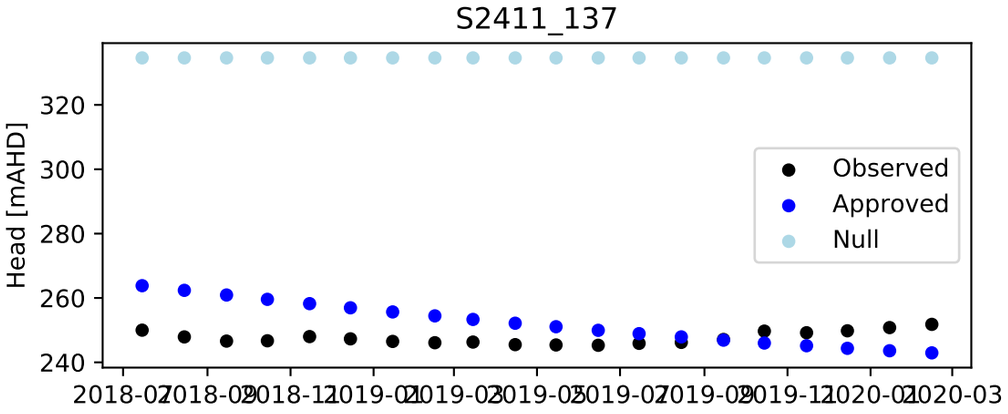

S2411_30
Head [mAHD]
Observed
Approved
Null

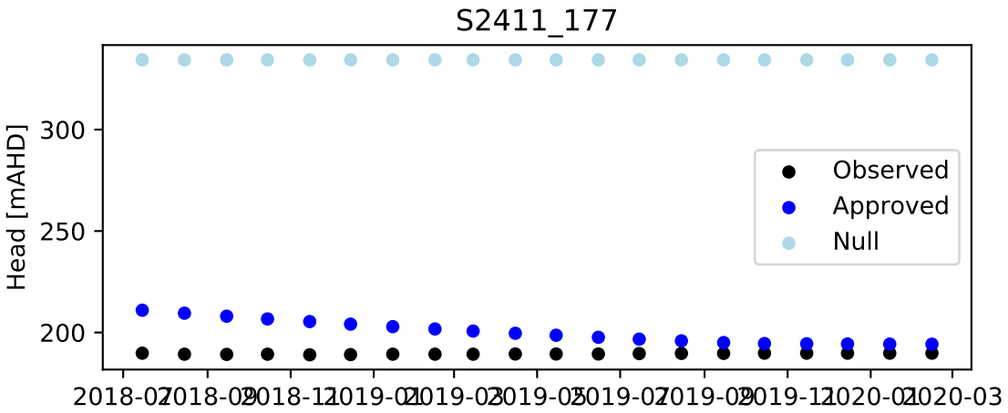

S2411_50
Head [mAHD]
Observed
Approved
Null

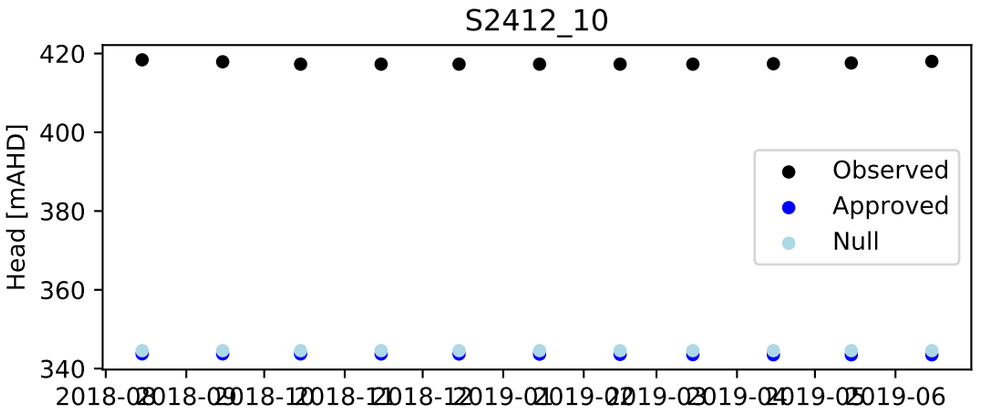

S2411_69
Head [mAHD]
Observed
Approved
Null

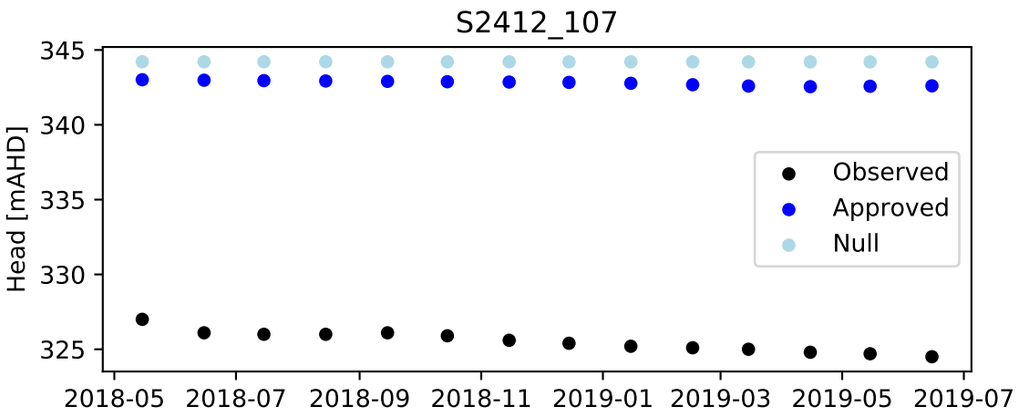

S2411_89
Head [mAHD]
Observed
Approved
Null

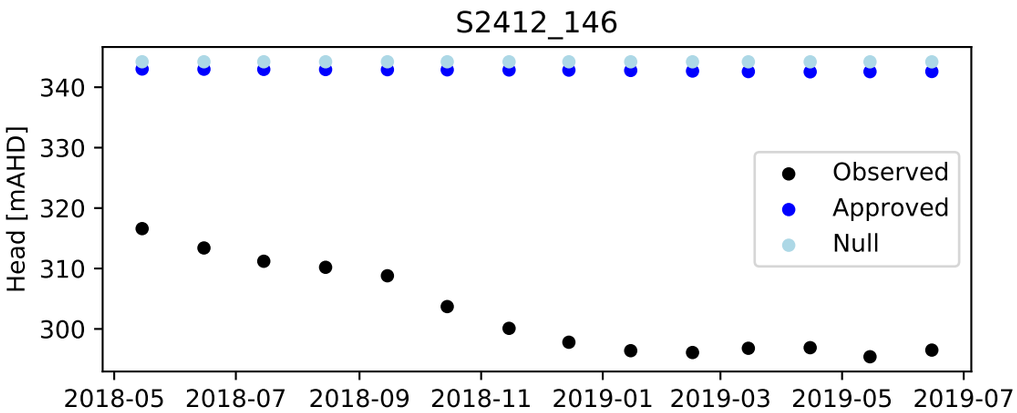

S2411_109
Head [mAHD]
Observed
Approved
Null

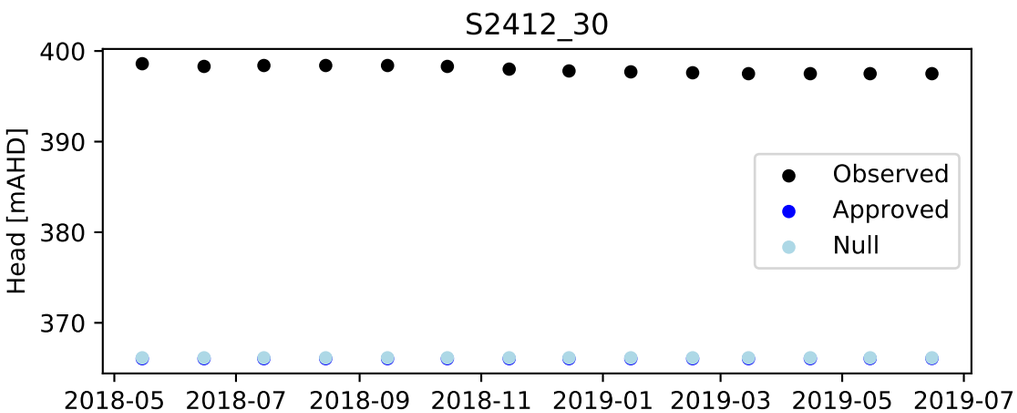

S2411_137
Head [mAHD]
Observed
Approved
Null

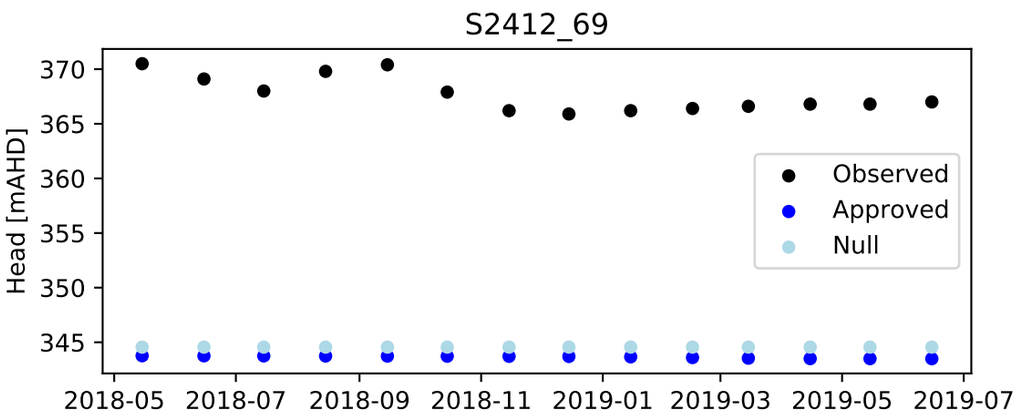

S2411_177
Head [mAHD]
Observed
Approved
Null

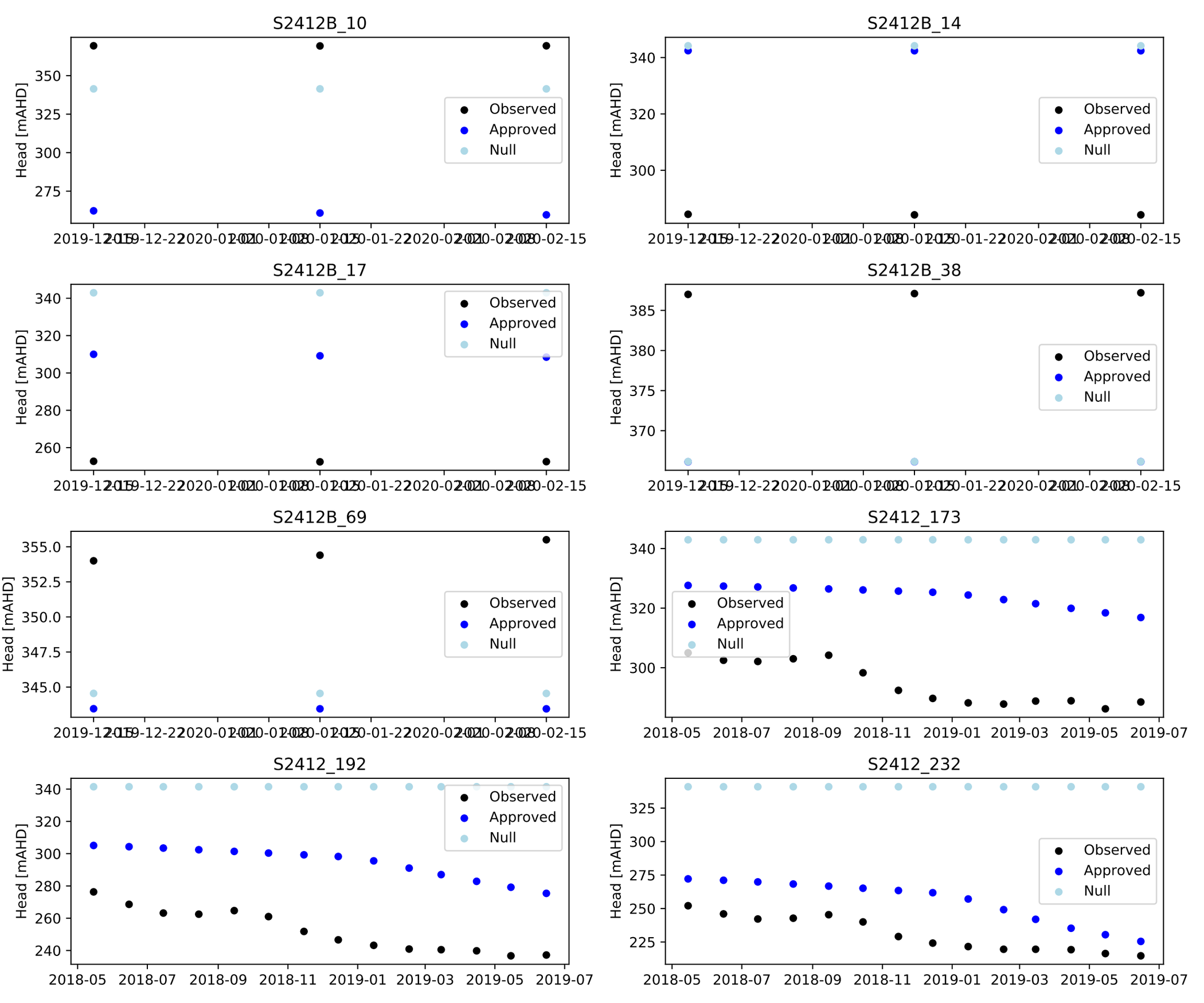

S2412_10
Head [mAHD]
Observed
Approved
Null

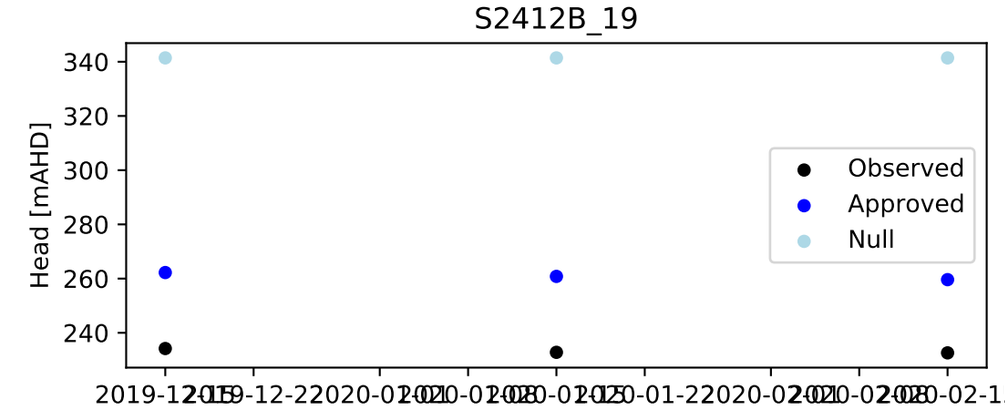

S2412_107
Head [mAHD]
Observed
Approved
Null

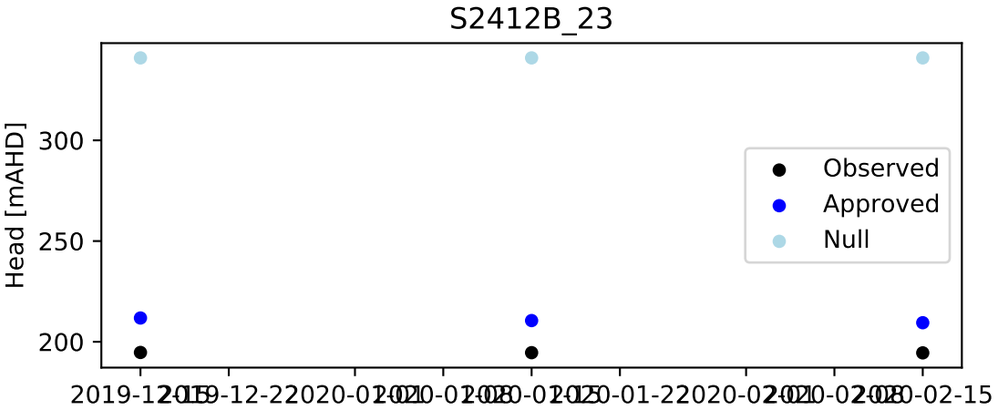

S2412_146
Head [mAHD]
Observed
Approved
Null

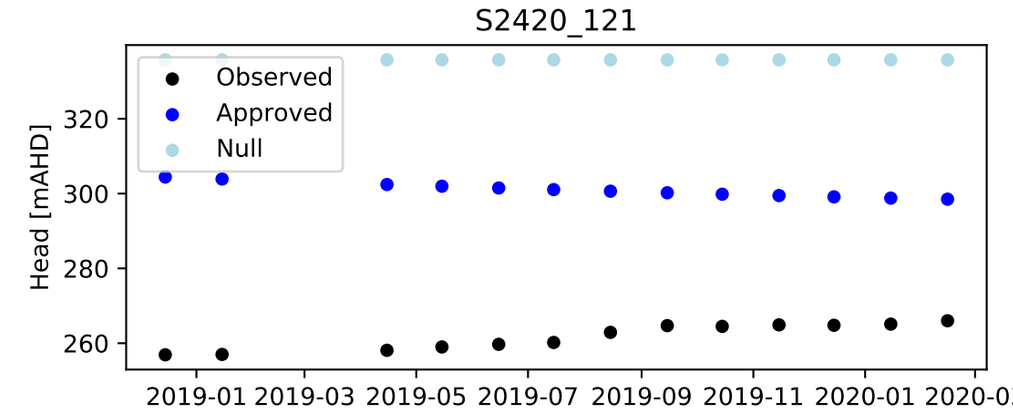

S2412_30
Head [mAHD]
Observed
Approved
Null

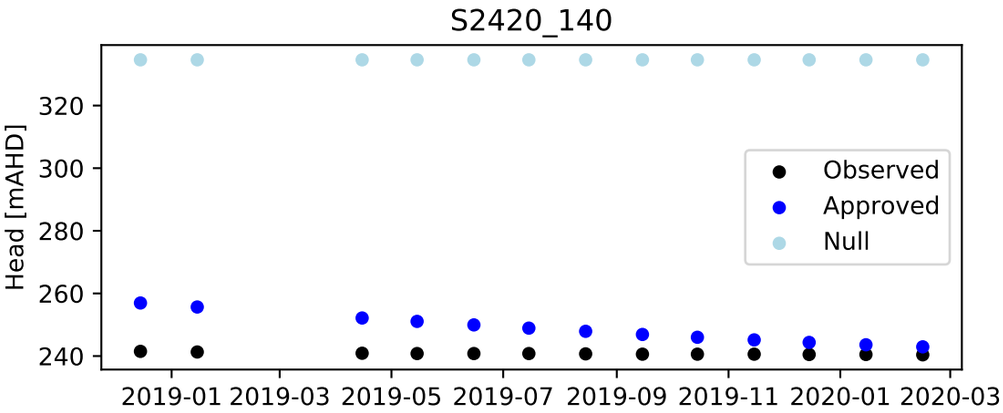

S2412_69
Head [mAHD]
Observed
Approved
Null

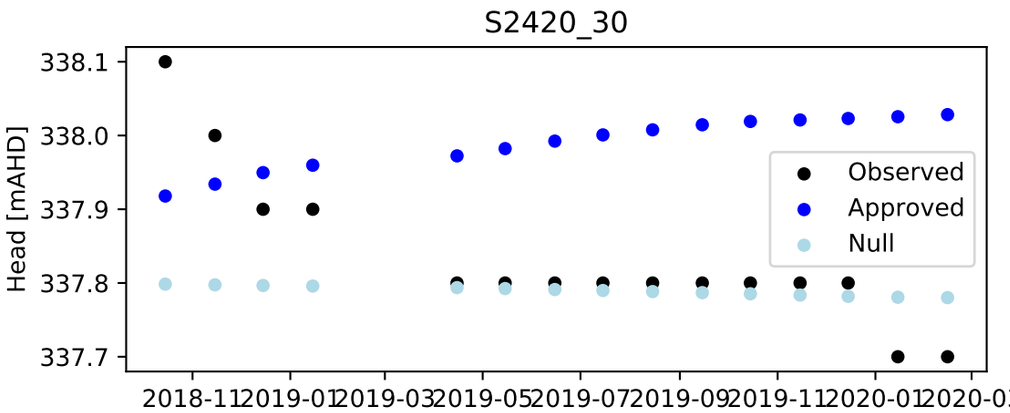

S2412B_10
Head [mAHD]
Observed
Approved
Null
S2412B_14
Head [mAHD]
Observed
Approved
Null
S2412B_17
Head [mAHD]
Observed
Approved
Null
S2412B_38
Head [mAHD]
Observed
Approved
Null
S2412B_69
Head [mAHD]
Observed
Approved
Null
S2412_173
Head [mAHD]
Observed
Approved
Null
S2412_192
Head [mAHD]
Observed
Approved
Null
S2412_232
Head [mAHD]
Observed
Approved
Null

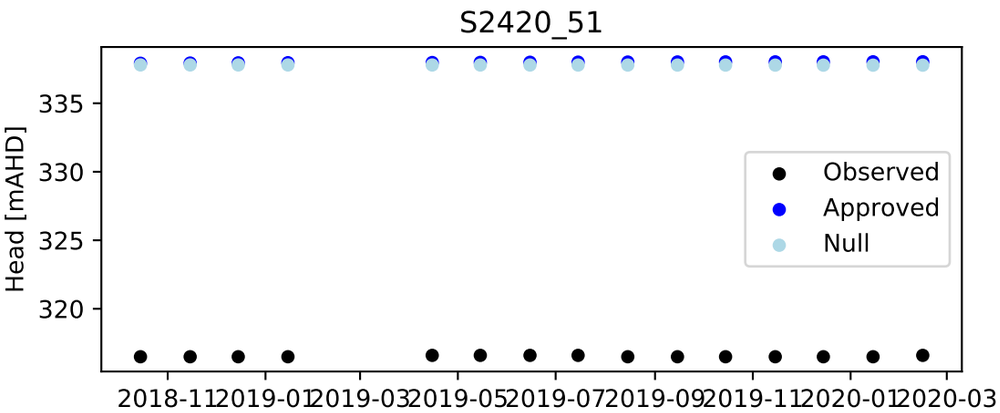

S2412B_19
Head [mAHD]
Observed
Approved
Null

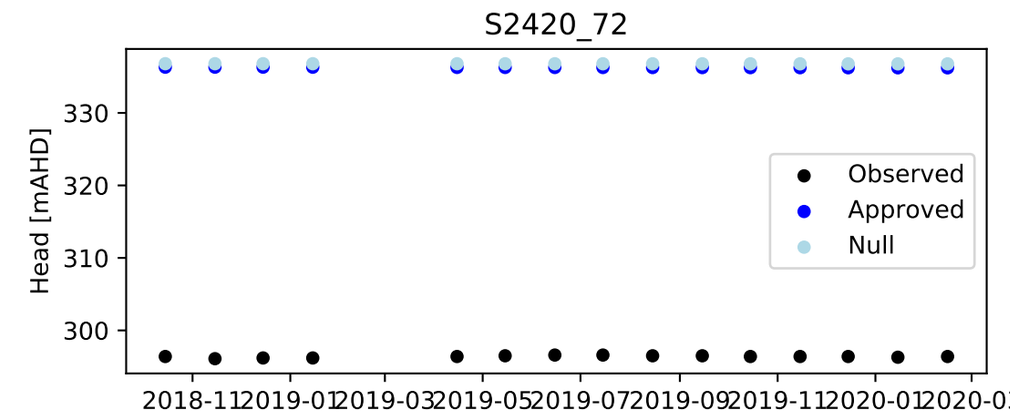

S2412B_23
Head [mAHD]
Observed
Approved
Null

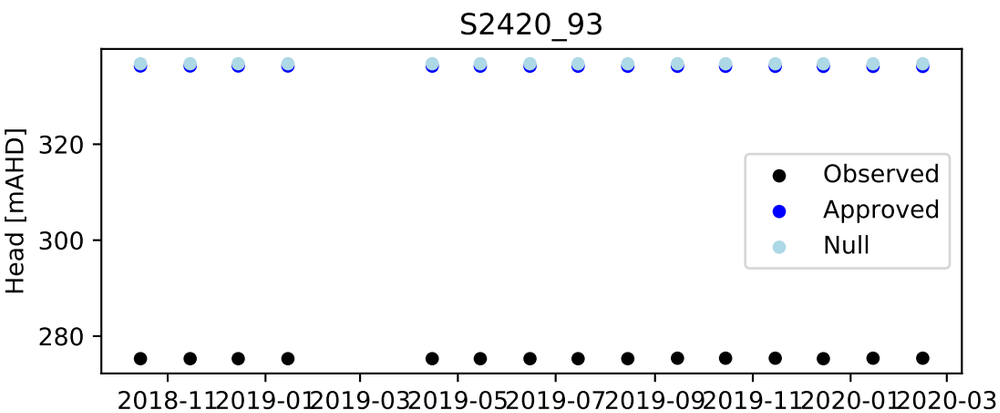

S2420_121
Head [mAHD]
Observed
Approved
Null

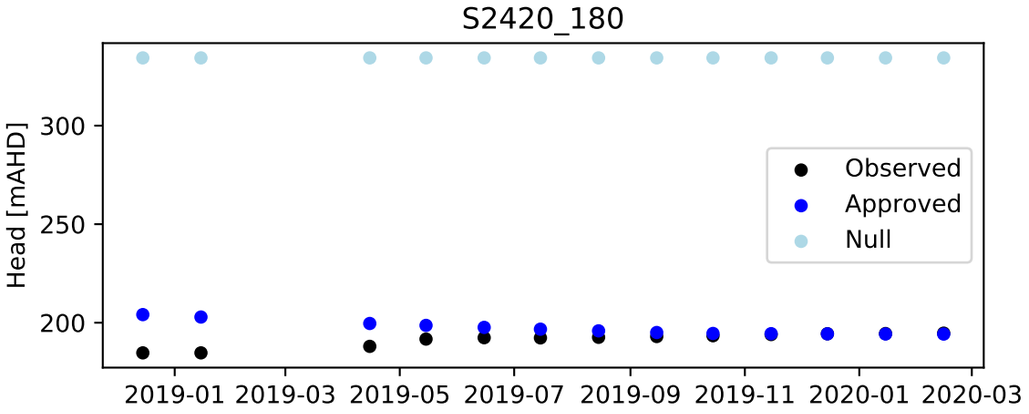

S2420_140
Head [mAHD]
Observed
Approved
Null

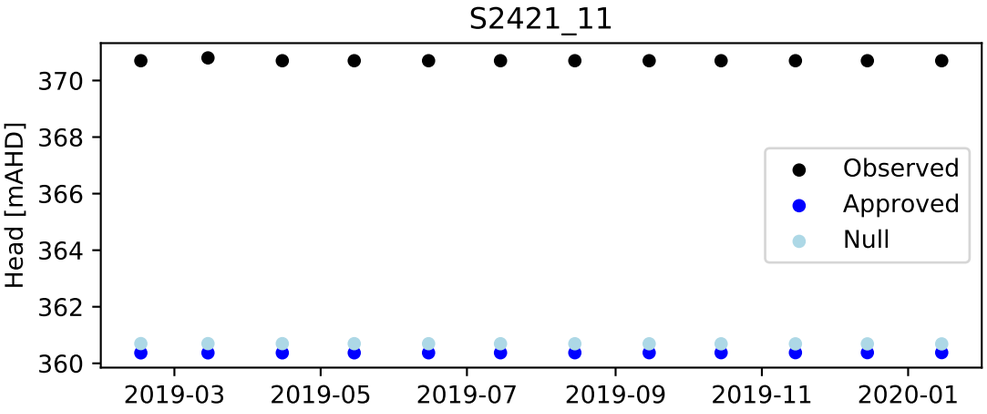

S2420_30
Head [mAHD]
Observed
Approved
Null

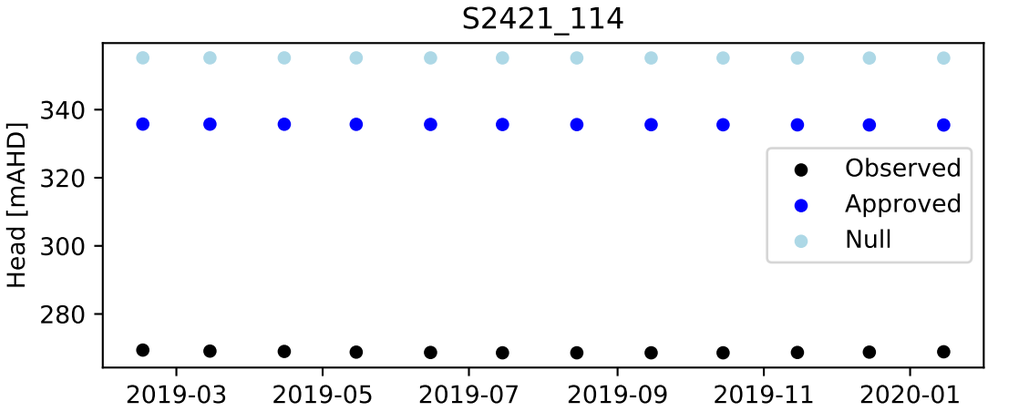

S2420_51
Head [mAHD]
Observed
Approved
Null

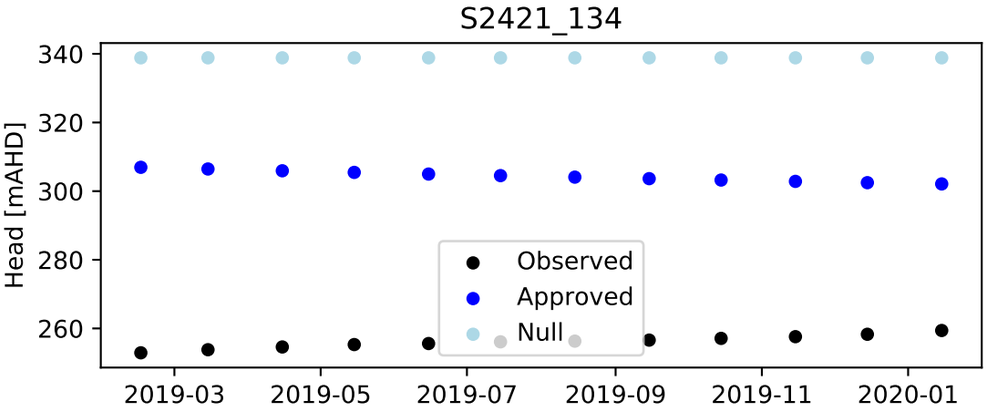

S2420_72
Head [mAHD]
Observed
Approved
Null

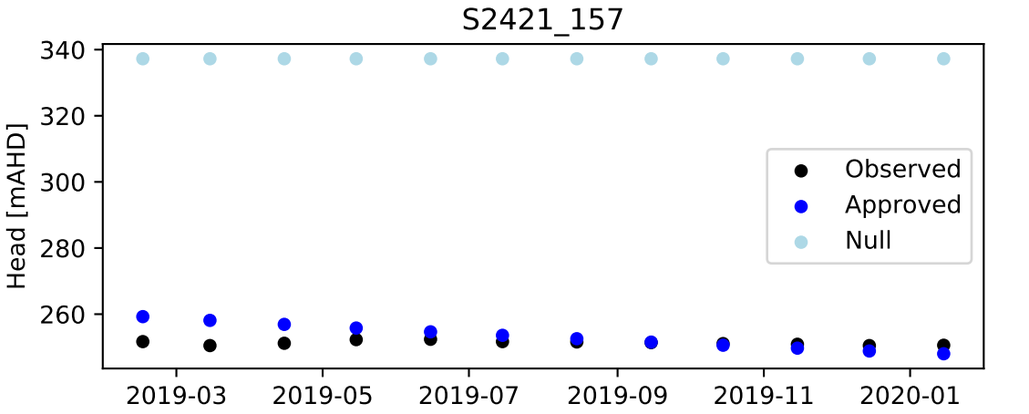

S2420_93
Head [mAHD]
Observed
Approved
Null

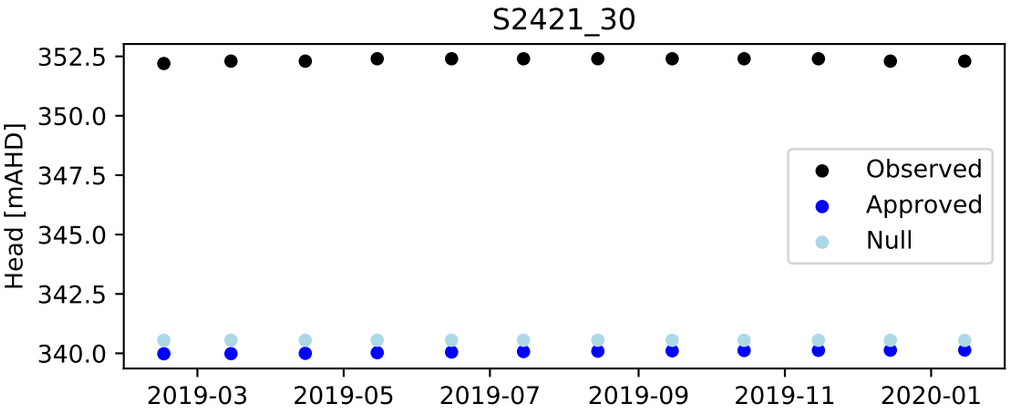

S2420_180
Head [mAHD]
300
250
200
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01
2020-03
Observed
Approved
Null

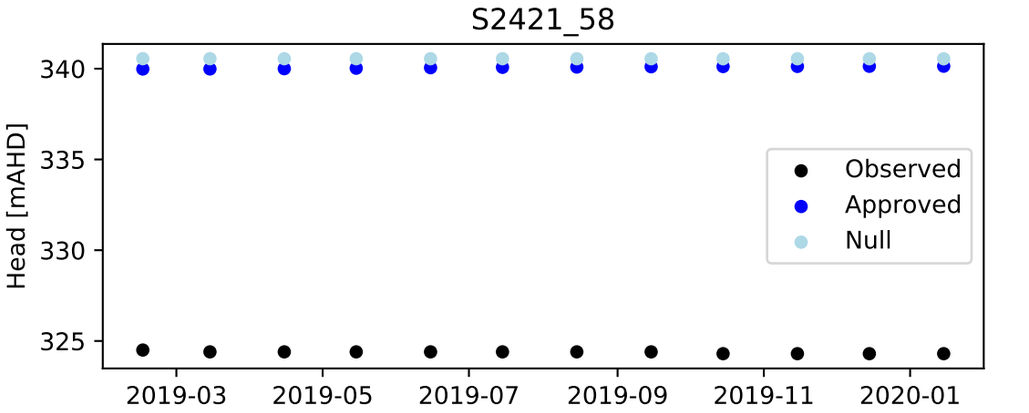

S2421_11
Head [mAHD]
370
368
366
364
362
360
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01
Observed
Approved
Null

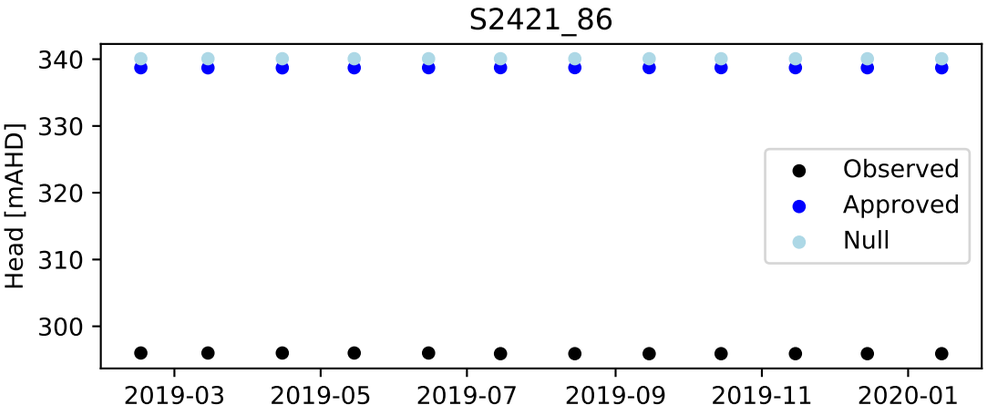

S2421_114
Head [mAHD]
340
320
300
280
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01
Observed
Approved
Null

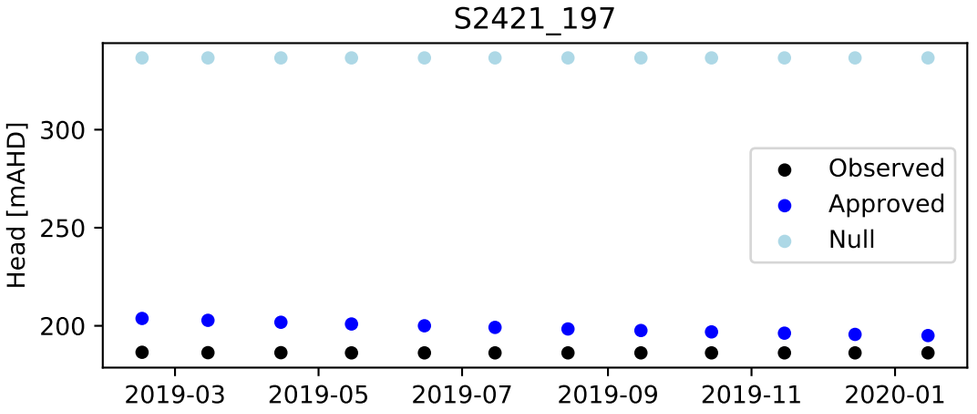

S2421_134
Head [mAHD]
340
320
300
280
260
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01
Observed
Approved
Null

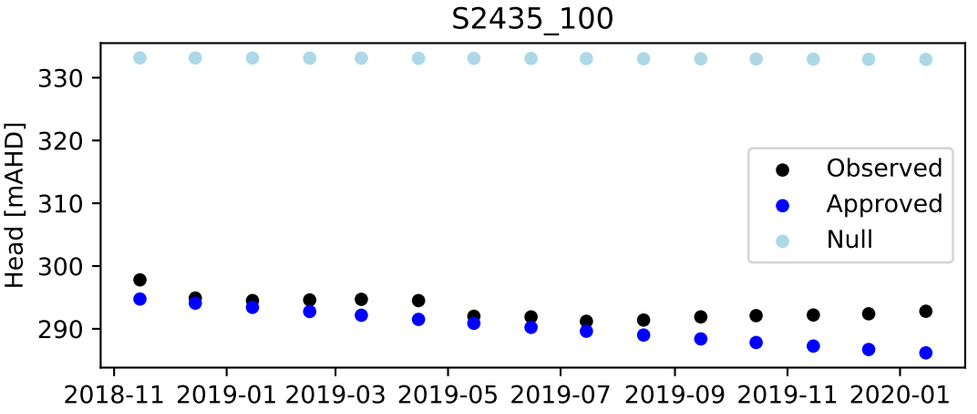

S2421_157
Head [mAHD]
340
320
300
280
260
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01
Observed
Approved
Null

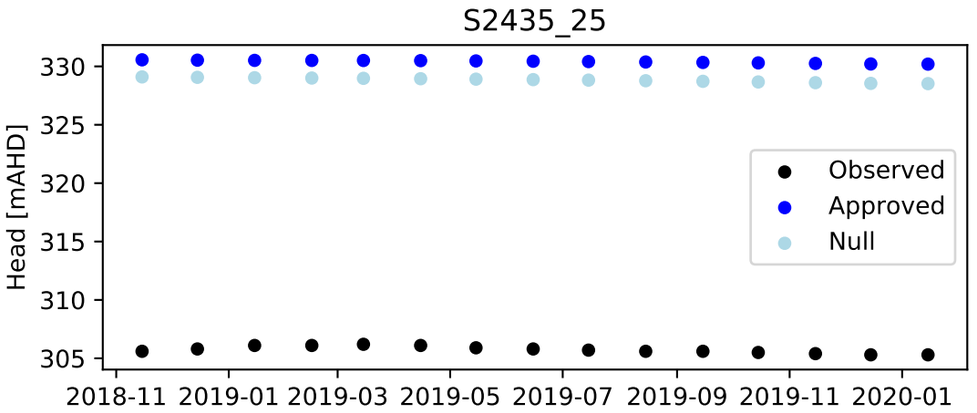

S2421_30
Head [mAHD]
352.5
350.0
347.5
345.0
342.5
340.0
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01
Observed
Approved
Null

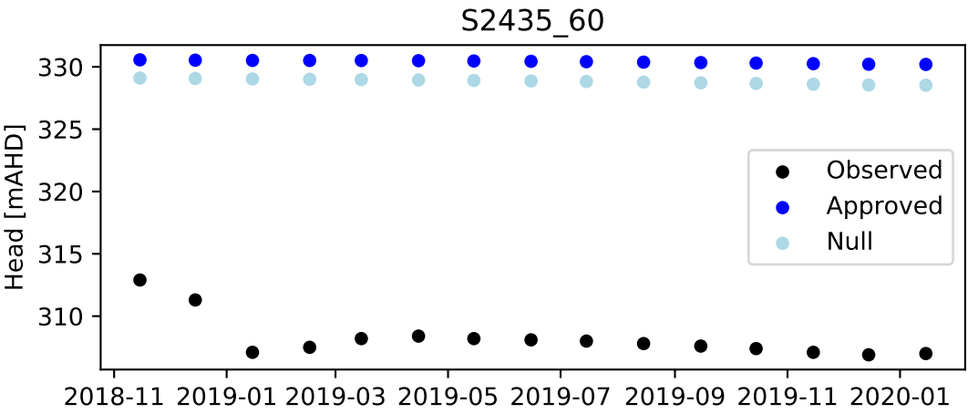

S2421_58
Head [mAHD]
340
335
330
325
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01
Observed
Approved
Null

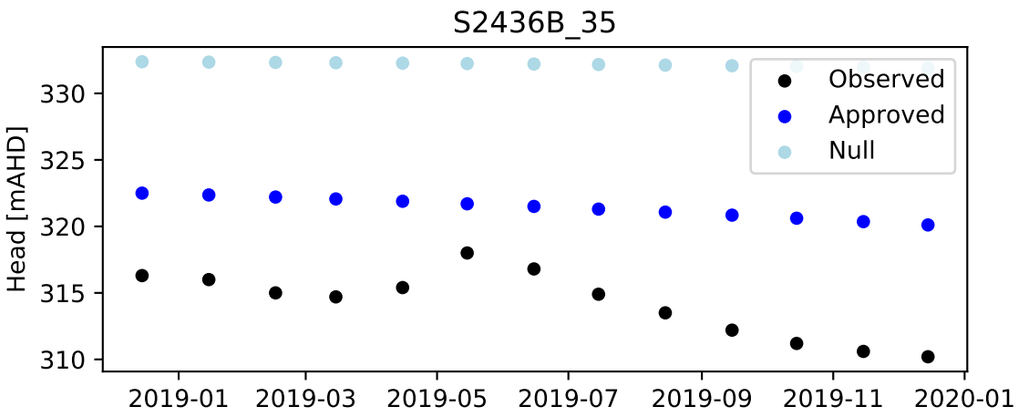

S2421_86
Head [mAHD]
340
330
320
310
300
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01
Observed
Approved
Null

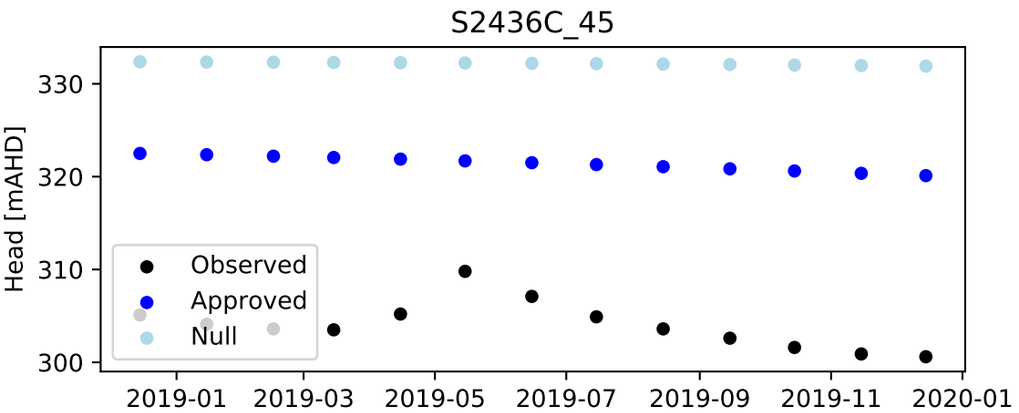

S2421_197
Head [mAHD]
300
250
200
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01
Observed
Approved
Null

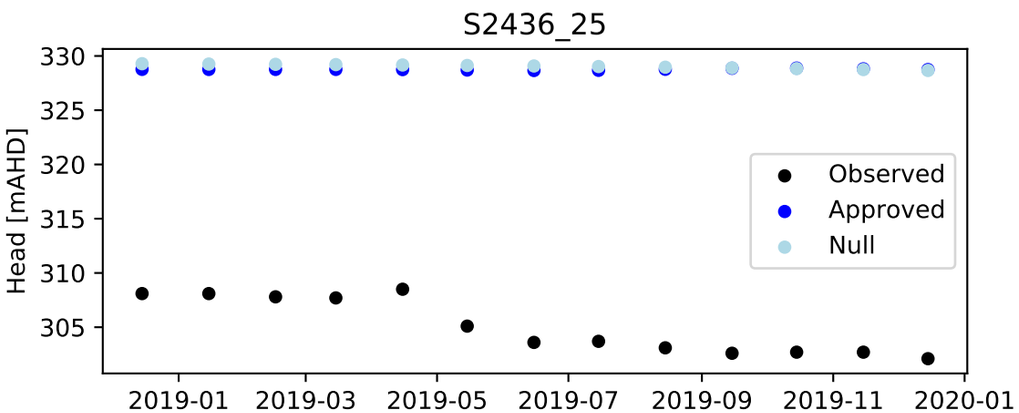

S2435_100
Head [mAHD]
330
320
310
300
290
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01
Observed
Approved
Null

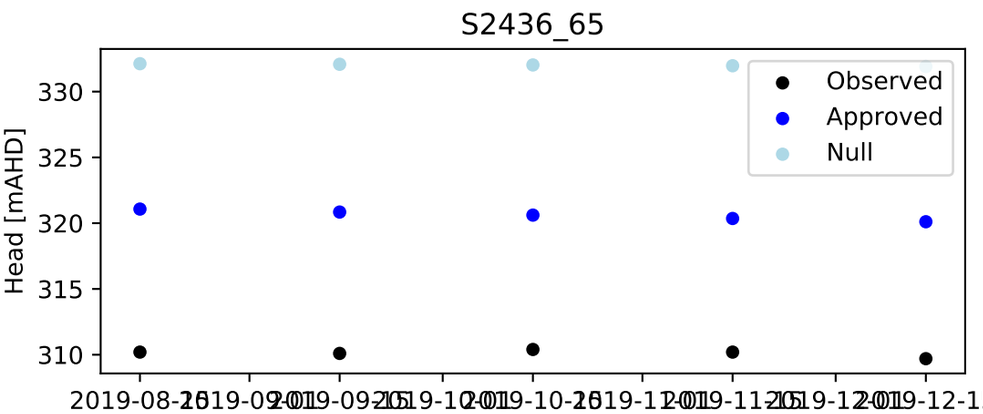

S2435_25
Head [mAHD]
330
325
320
315
310
305
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01
Observed
Approved
Null

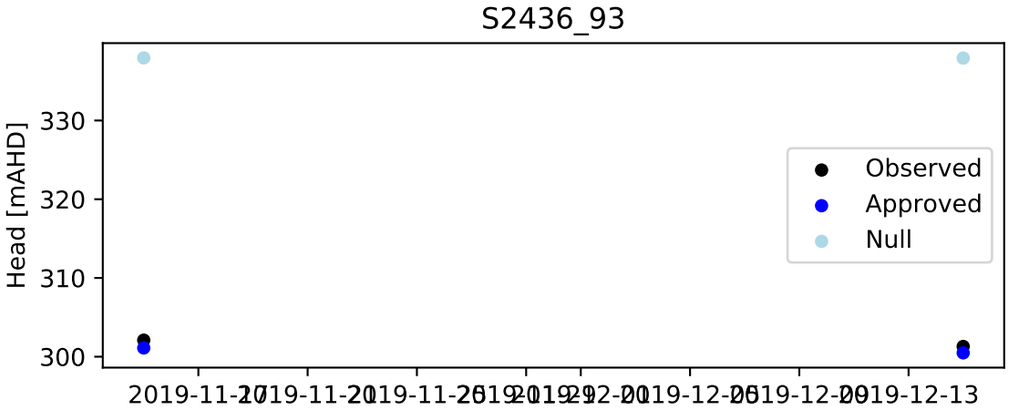

S2435_60
Head [mAHD]
330
325
320
315
310
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01
Observed
Approved
Null

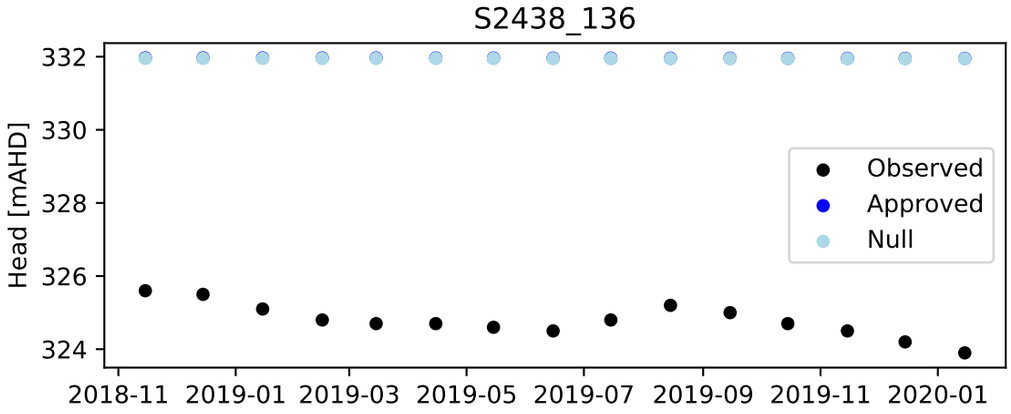

S2436B_35
Head [mAHD]
330
325
320
315
310
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01
Observed
Approved
Null

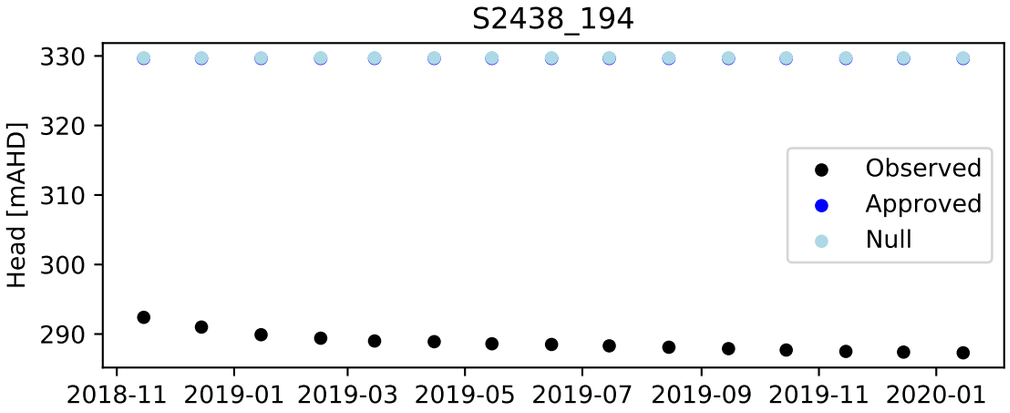

S2436C_45
Head [mAHD]
330
320
310
300
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01
Observed
Approved
Null

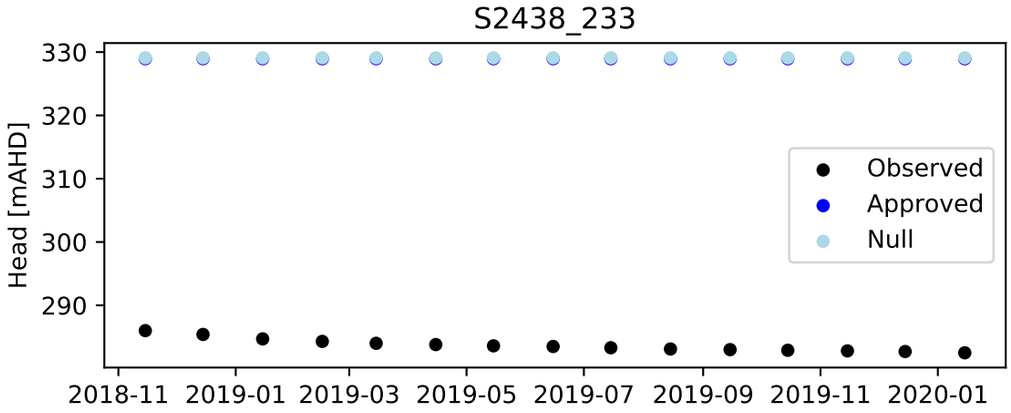

S2436_25
Head [mAHD]
330
325
320
315
310
305
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01
Observed
Approved
Null

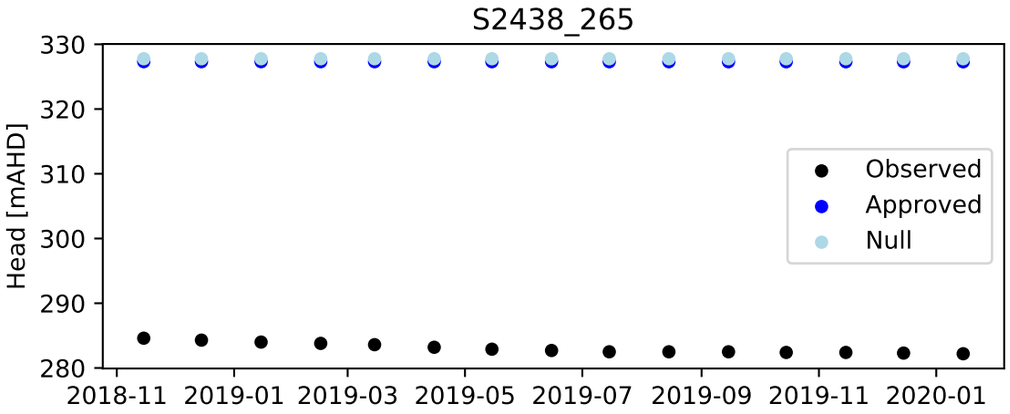

S2436_65
Head [mAHD]
330
325
320
315
310
2019-08-15
2019-09-15
2019-10-15
2019-11-15
2019-12-15
Observed
Approved
Null

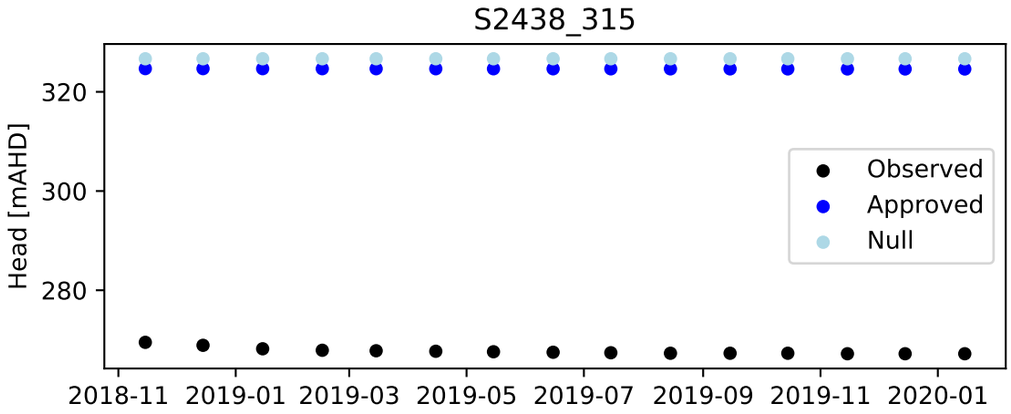

S2436_93
Head [mAHD]
330
320
310
300
Observed
Approved
Null
2019-11-27
2019-11-29
2019-12-01
2019-12-03
2019-12-05
2019-12-07
2019-12-09
2019-12-11
2019-12-13

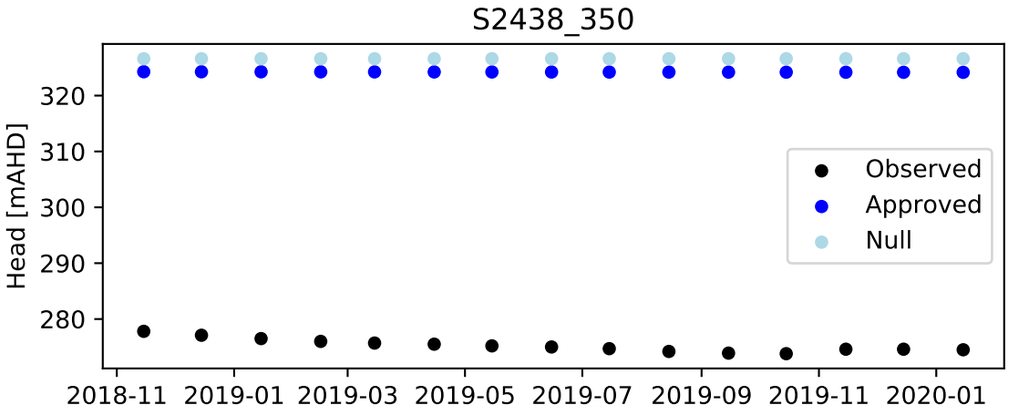

S2438_136
Head [mAHD]
332
330
328
326
324
Observed
Approved
Null
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01

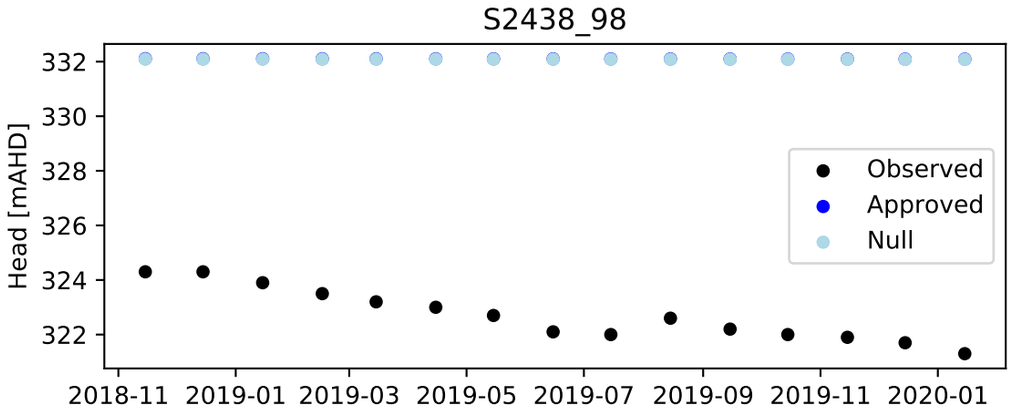

S2438_194
Head [mAHD]
330
320
310
300
290
Observed
Approved
Null
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01

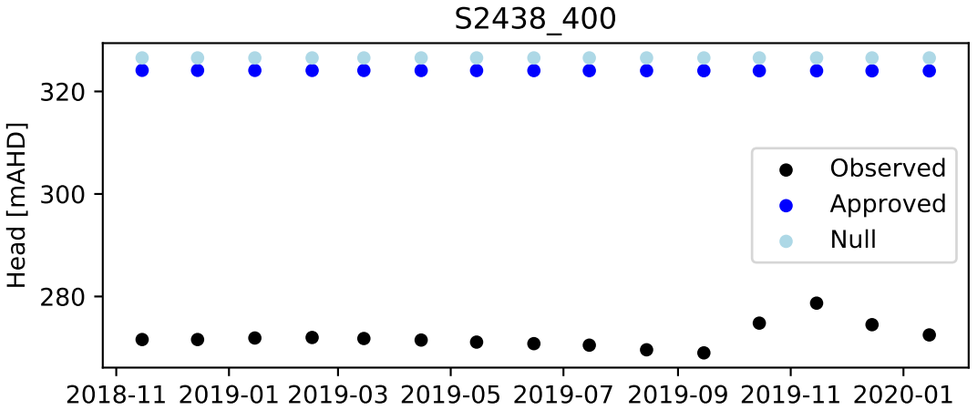

S2438_233
Head [mAHD]
330
320
310
300
290
Observed
Approved
Null
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01

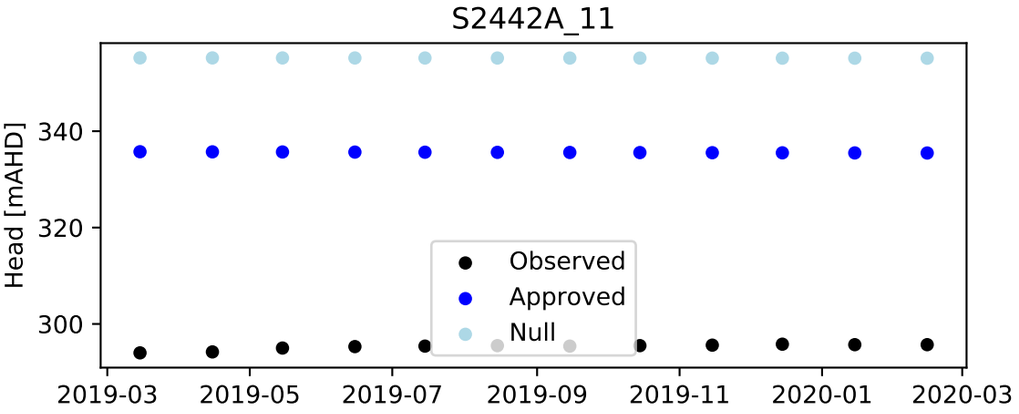

S2438_265
Head [mAHD]
330
320
310
300
290
280
Observed
Approved
Null
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01

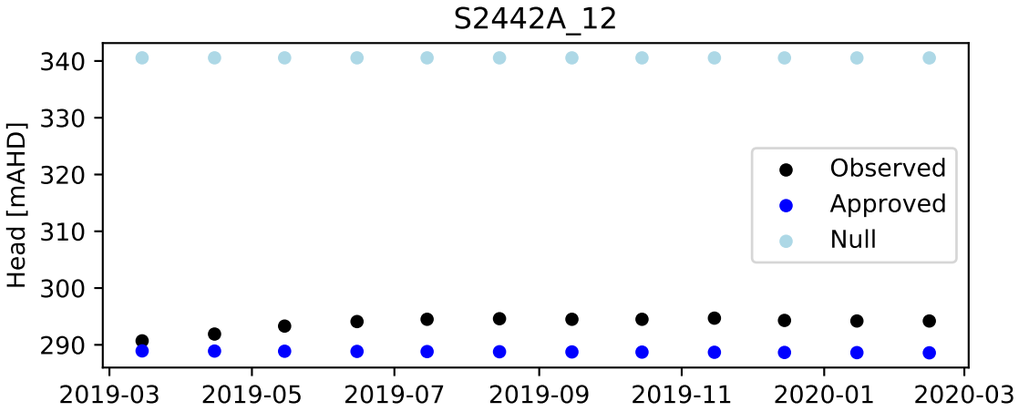

S2438_315
Head [mAHD]
320
300
280
Observed
Approved
Null
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01

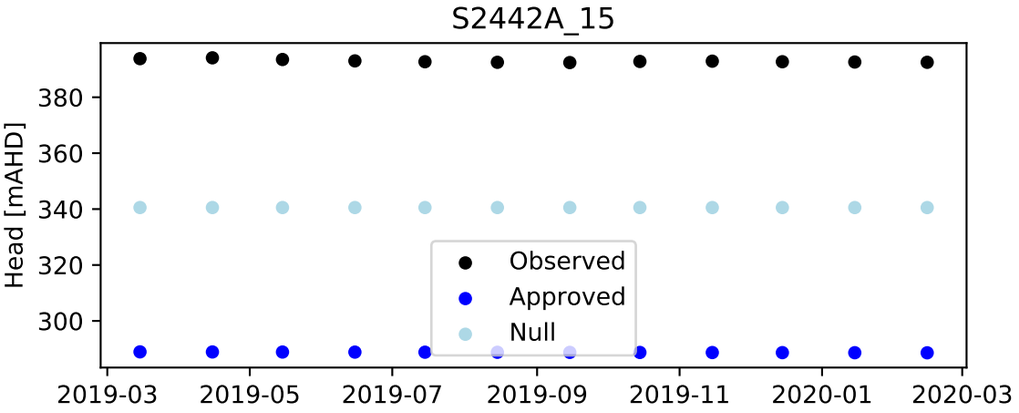

S2438_350
Head [mAHD]
320
310
300
290
280
Observed
Approved
Null
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01

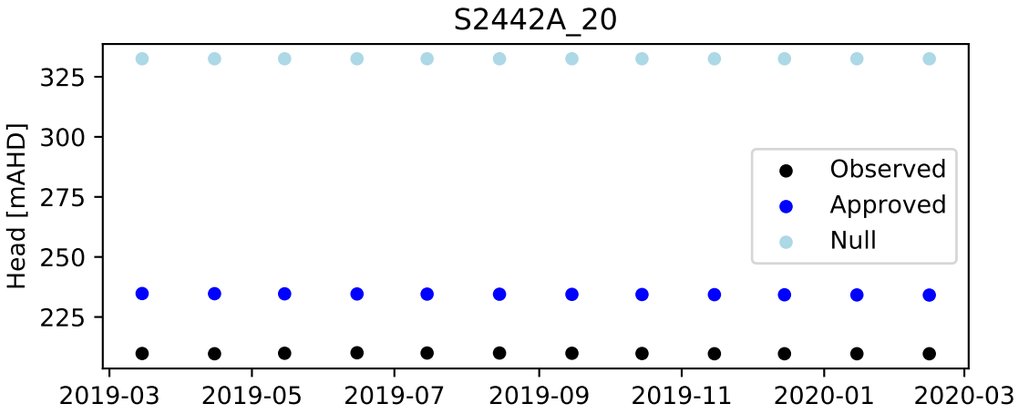

S2438_98
Head [mAHD]
332
330
328
326
324
322
Observed
Approved
Null
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
2020-01

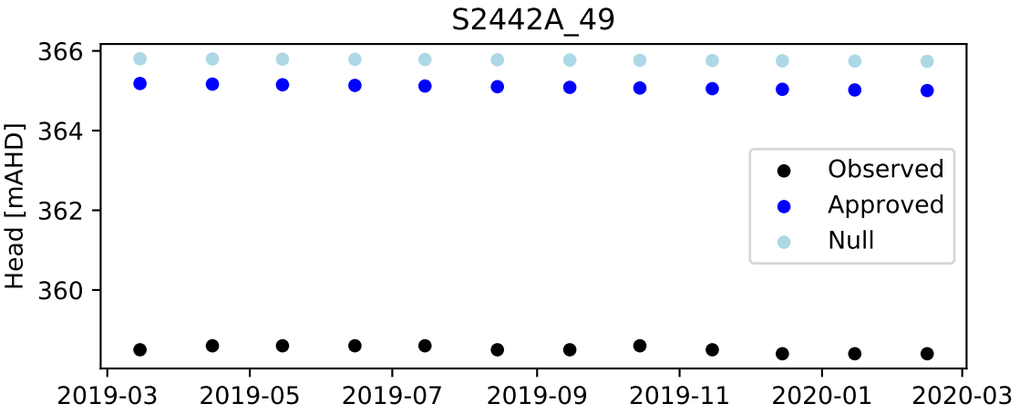

S2438_400
Head [mAHD]
320
300
280
2018-11 2019-01 2019-03 2019-05 2019-07 2019-09 2019-11 2020-01
Observed
Approved
Null

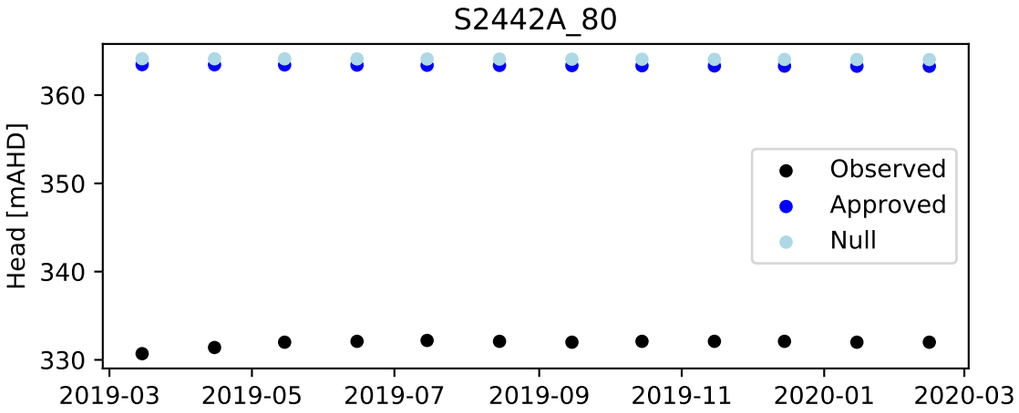

S2442A_11
Head [mAHD]
340
320
300
2019-03 2019-05 2019-07 2019-09 2019-11 2020-01 2020-03
Observed
Approved
Null

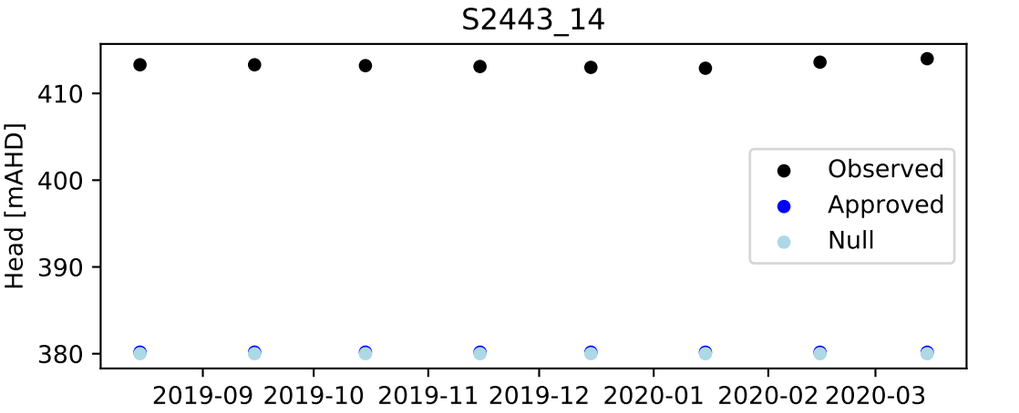

S2442A_12
Head [mAHD]
340
330
320
310
300
290
2019-03 2019-05 2019-07 2019-09 2019-11 2020-01 2020-03
Observed
Approved
Null

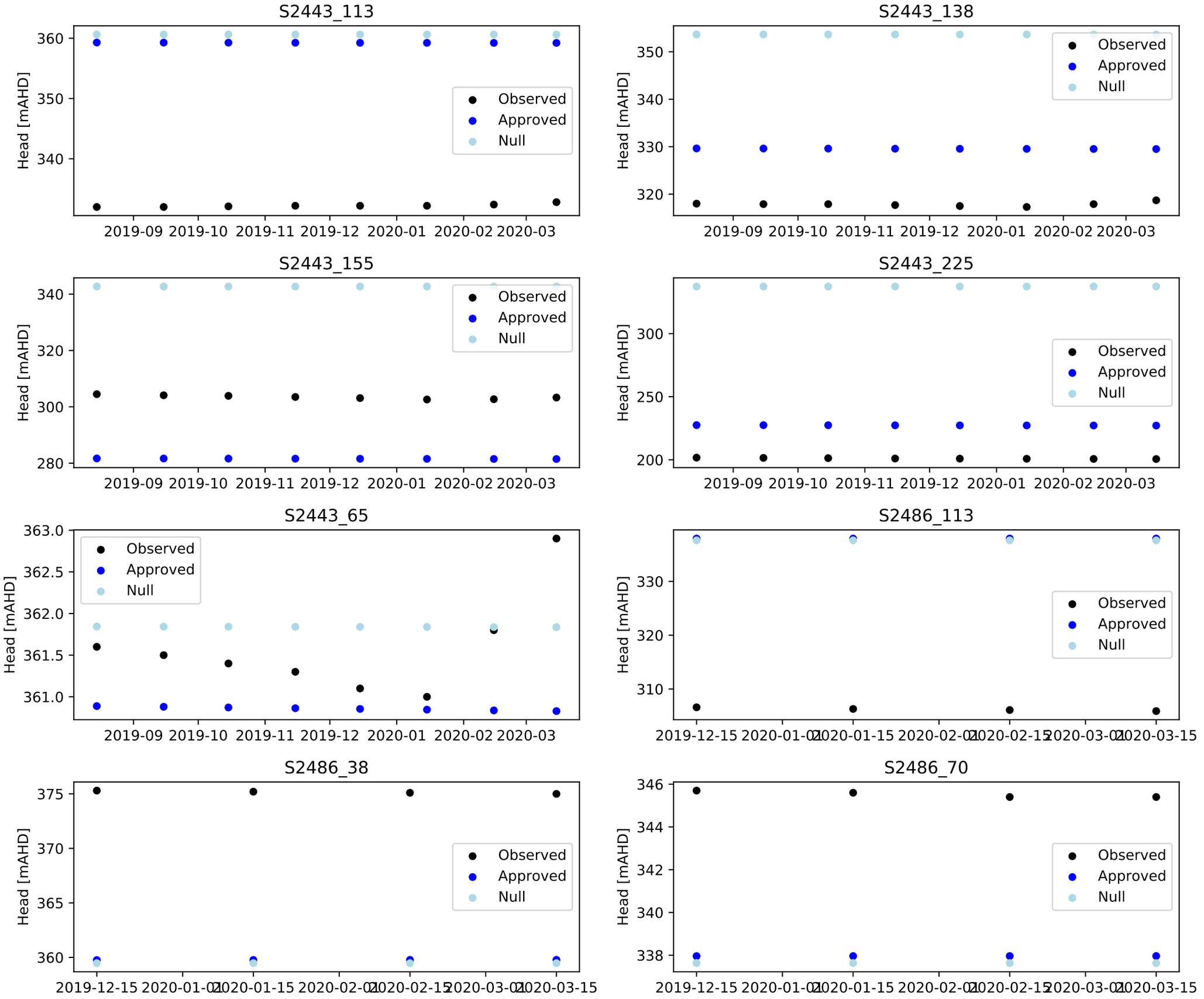

S2442A_15
Head [mAHD]
380
360
340
320
300
2019-03 2019-05 2019-07 2019-09 2019-11 2020-01 2020-03
Observed
Approved
Null

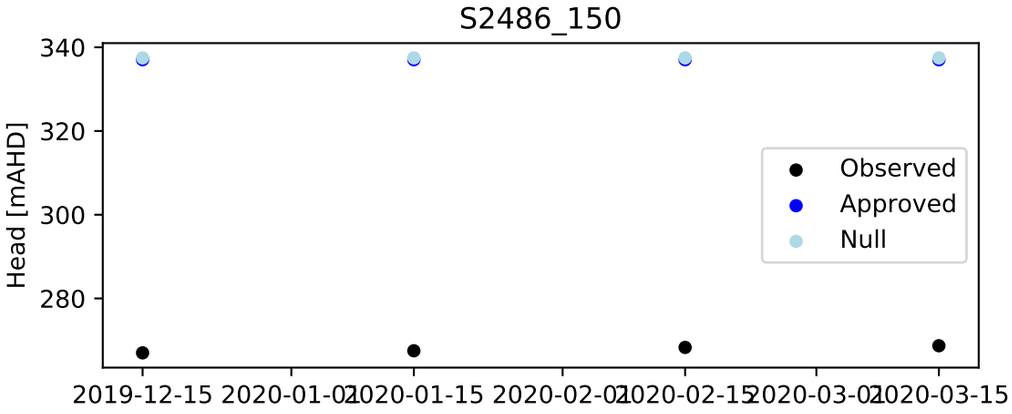

S2442A_20
Head [mAHD]
325
300
275
250
225
2019-03 2019-05 2019-07 2019-09 2019-11 2020-01 2020-03
Observed
Approved
Null

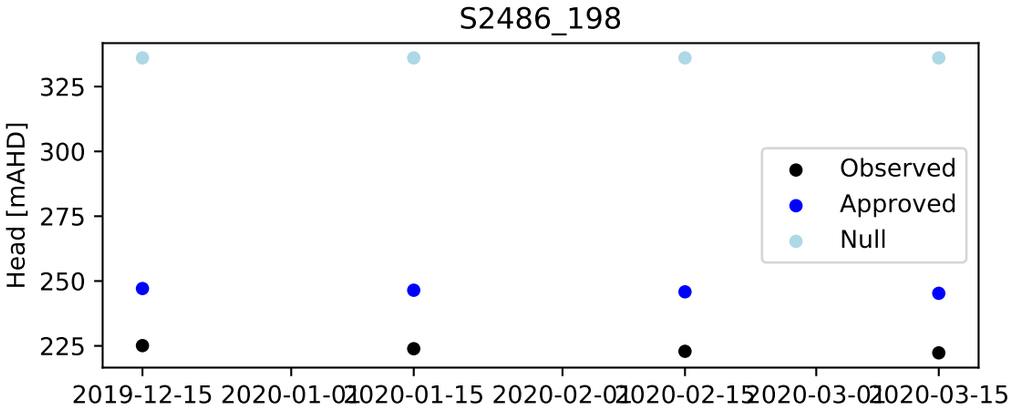

S2442A_49
Head [mAHD]
366
364
362
360
2019-03 2019-05 2019-07 2019-09 2019-11 2020-01 2020-03
Observed
Approved
Null

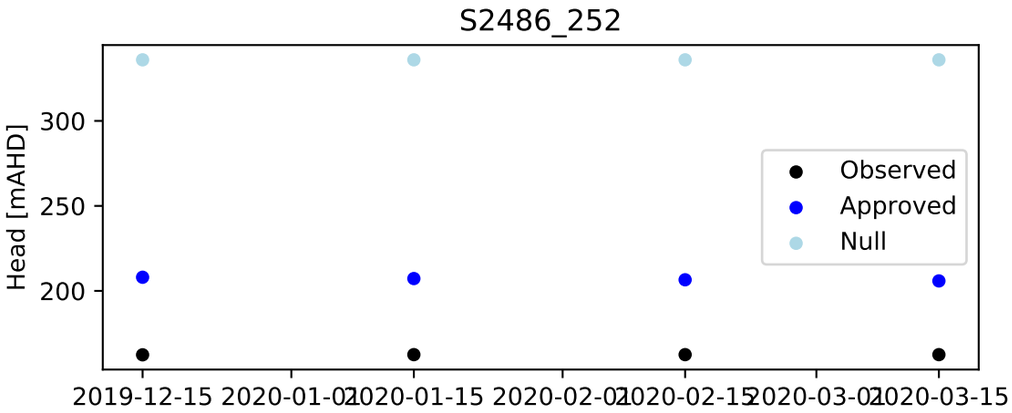

S2442A_80
Head [mAHD]
360
350
340
330
2019-03 2019-05 2019-07 2019-09 2019-11 2020-01 2020-03
Observed
Approved
Null

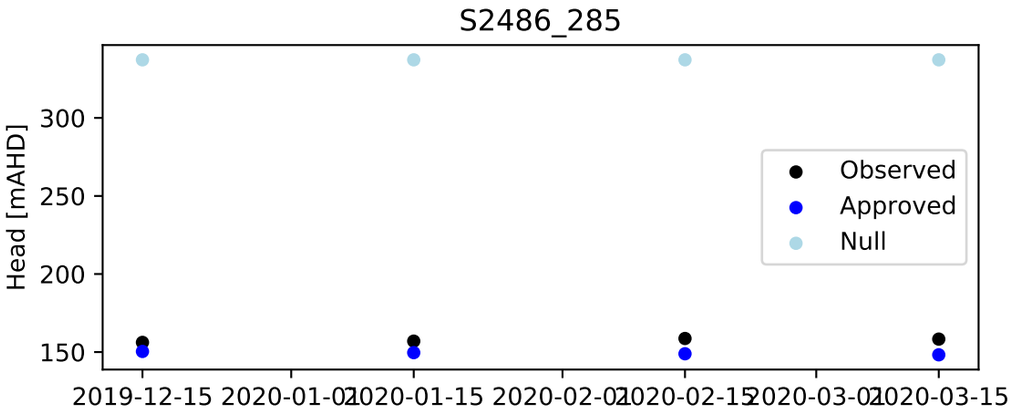

S2443_14
Head [mAHD]
410
400
390
380
2019-09 2019-10 2019-11 2019-12 2020-01 2020-02 2020-03
Observed
Approved
Null

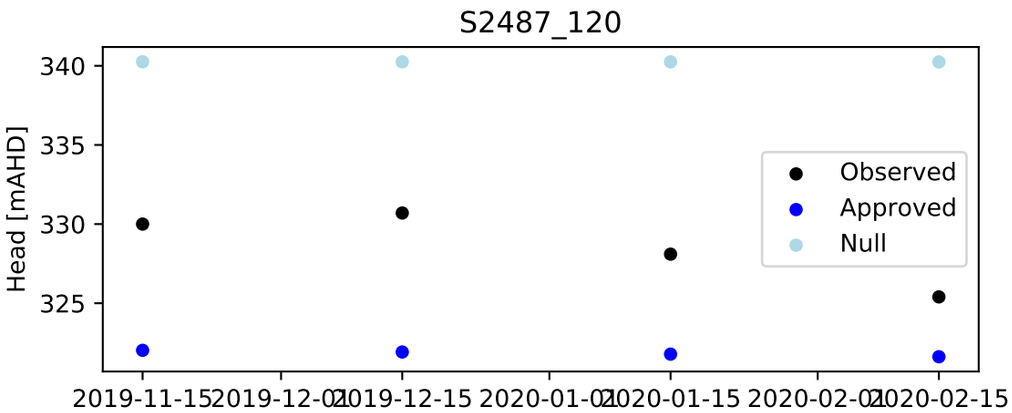

S2443_113
Head [mAHD]
Observed
Approved
Null
S2443_138
S2443_155
S2443_225
S2443_65
S2486_113
S2486_38
S2486_70
2019-09
2019-10
2019-11
2019-12
2020-01
2020-02
2020-03
2019-12-15
2020-01-01
2020-01-15
2020-02-01
2020-02-15
2020-03-01
2020-03-15

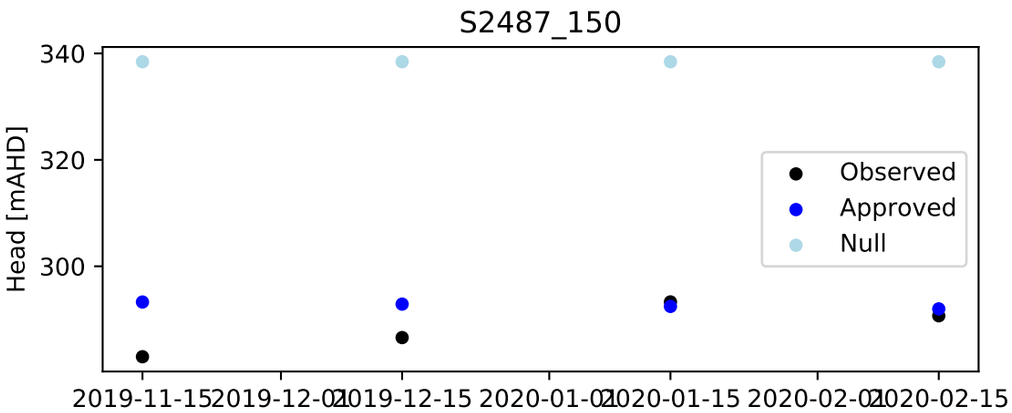

S2486_150
Head [mAHD]
340
320
300
280
Observed
Approved
Null
2019-12-15
2020-01-01
2020-01-15
2020-02-01
2020-02-15
2020-03-01
2020-03-15

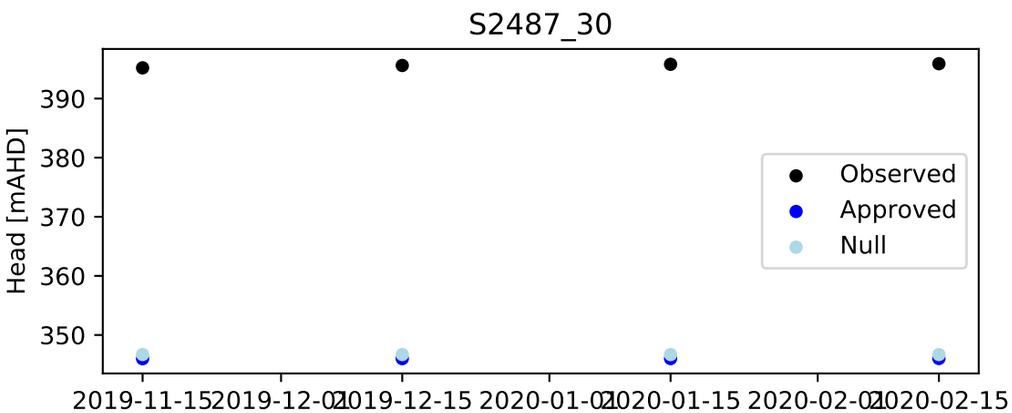

S2486_198
Head [mAHD]
325
300
275
250
225
Observed
Approved
Null
2019-12-15
2020-01-01
2020-01-15
2020-02-01
2020-02-15
2020-03-01
2020-03-15

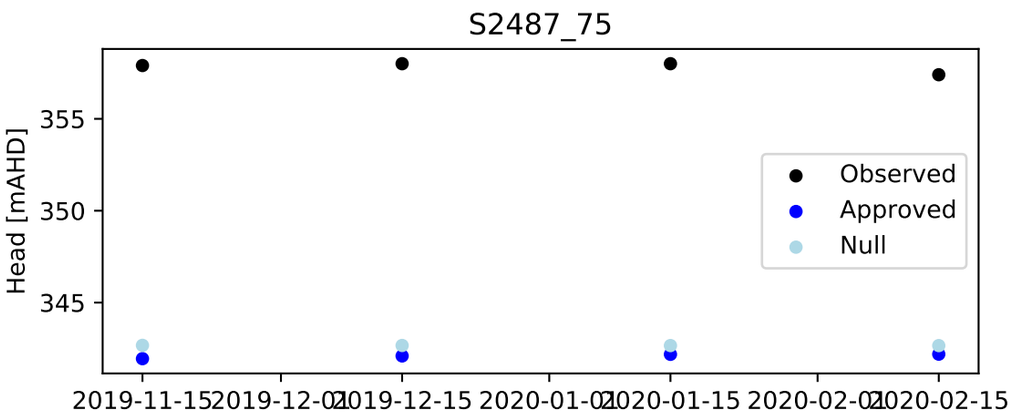

S2486_252
Head [mAHD]
300
250
200
Observed
Approved
Null
2019-12-15
2020-01-01
2020-01-15
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2020-02-15
2020-03-01
2020-03-15

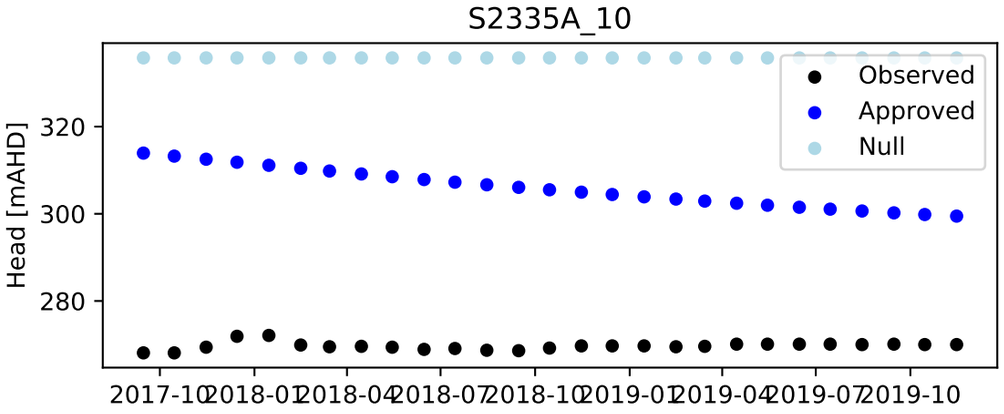

S2486_285
Head [mAHD]
300
250
200
150
Observed
Approved
Null
2019-12-15
2020-01-01
2020-01-15
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2020-02-15
2020-03-01
2020-03-15

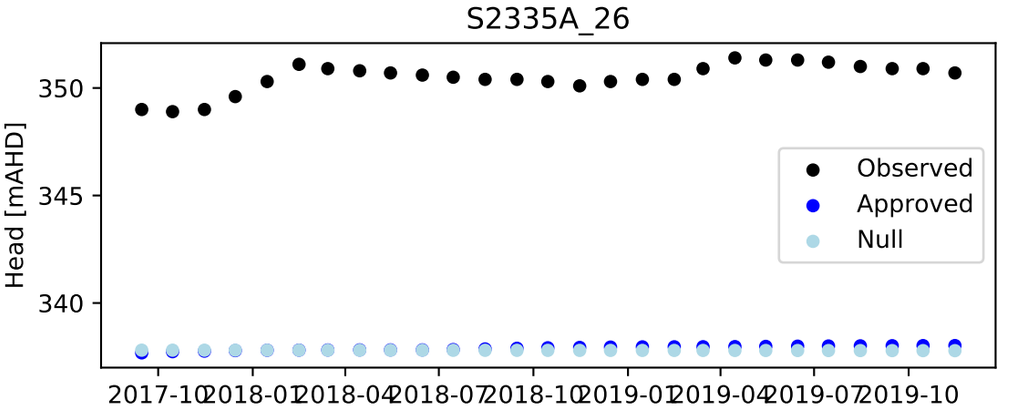

S2487_120
Head [mAHD]
340
335
330
325
Observed
Approved
Null
2019-11-15
2019-12-01
2019-12-15
2020-01-01
2020-01-15
2020-02-01
2020-02-15

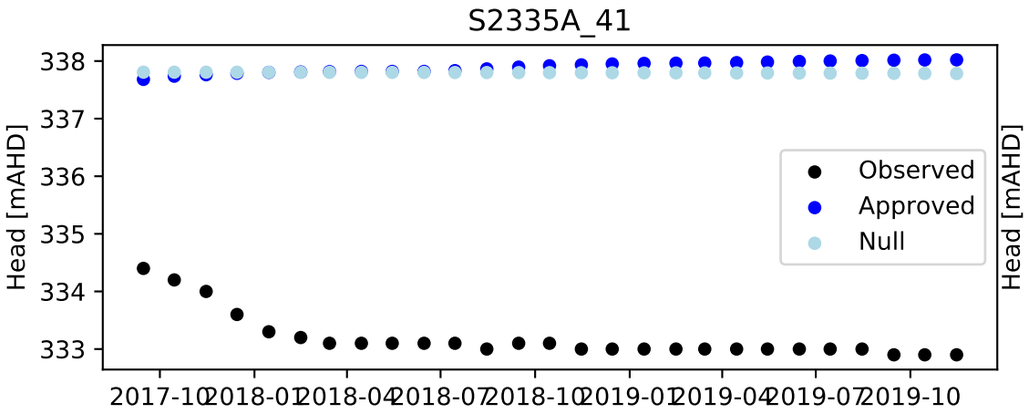

S2487_150
Head [mAHD]
340
320
300
Observed
Approved
Null
2019-11-15
2019-12-01
2019-12-15
2020-01-01
2020-01-15
2020-02-01
2020-02-15

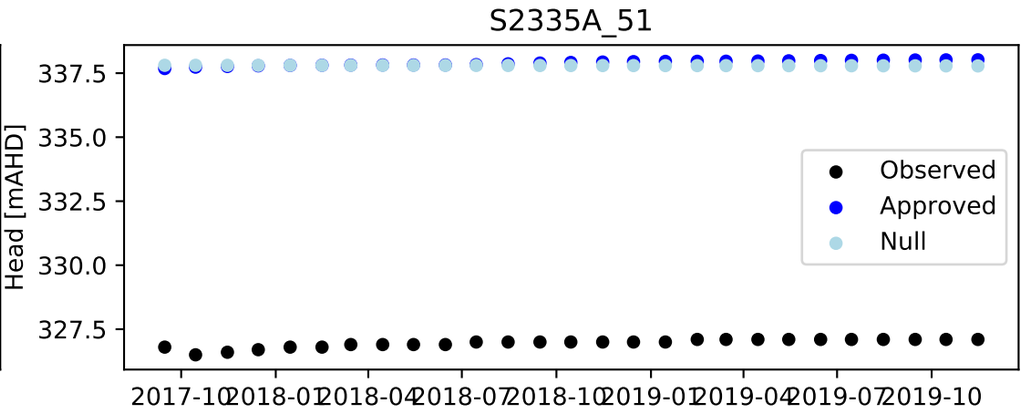

S2487_30
Head [mAHD]
390
380
370
360
350
Observed
Approved
Null
2019-11-15
2019-12-01
2019-12-15
2020-01-01
2020-01-15
2020-02-01
2020-02-15

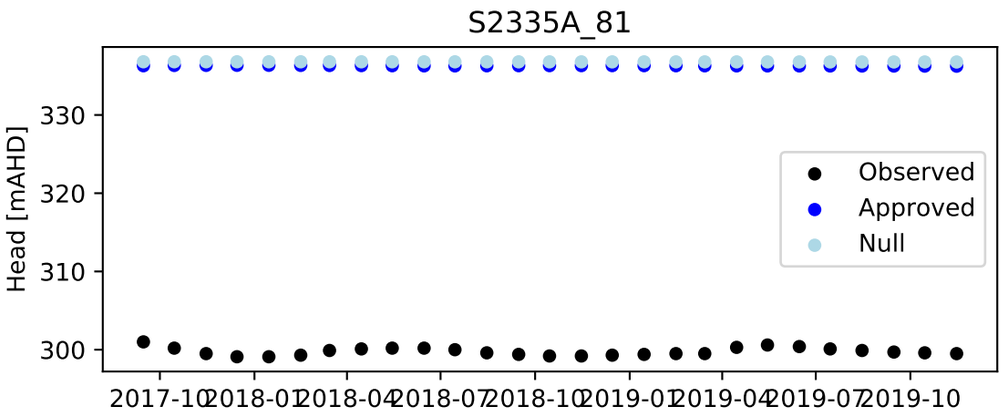

S2487_75
Head [mAHD]
355
350
345
Observed
Approved
Null
2019-11-15
2019-12-01
2019-12-15
2020-01-01
2020-01-15
2020-02-01
2020-02-15

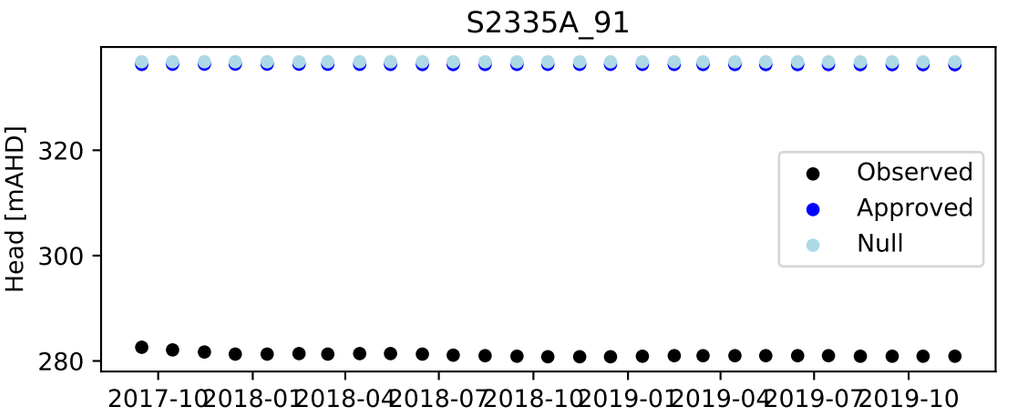

S2335A_10
Head [mAHD]
320
300
280
Observed
Approved
Null
2017-10
2018-01
2018-04
2018-07
2018-10
2019-01
2019-04
2019-07
2019-10

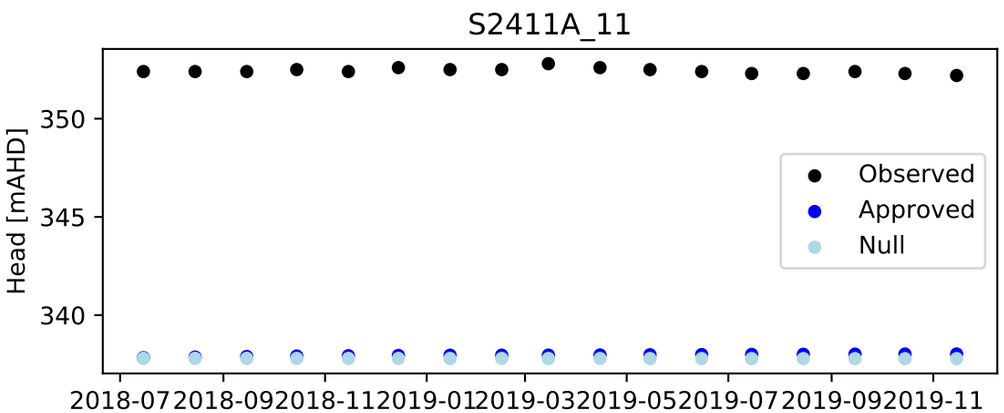

S2335A_26
Head [mAHD]
350
345
340
Observed
Approved
Null
2017-10
2018-01
2018-04
2018-07
2018-10
2019-01
2019-04
2019-07
2019-10

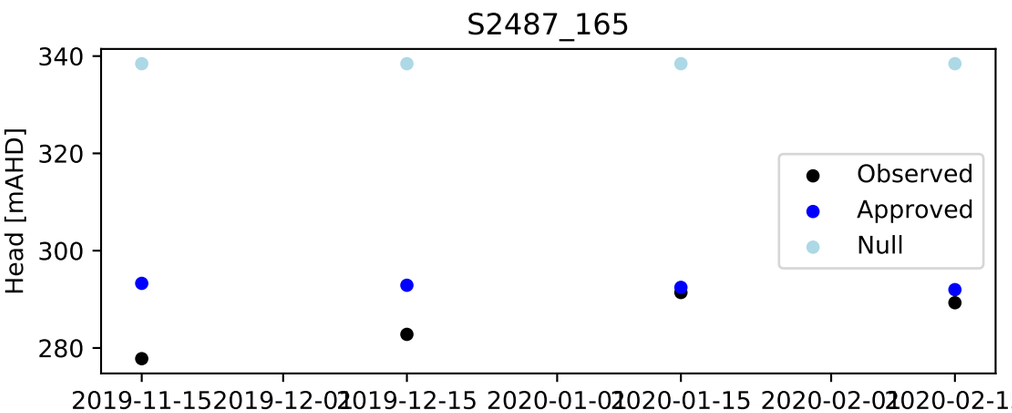

S2335A_41
Head [mAHD]
338
337
336
335
334
333
Observed
Approved
Null
2017-10
2018-01
2018-04
2018-07
2018-10
2019-01
2019-04
2019-07
2019-10

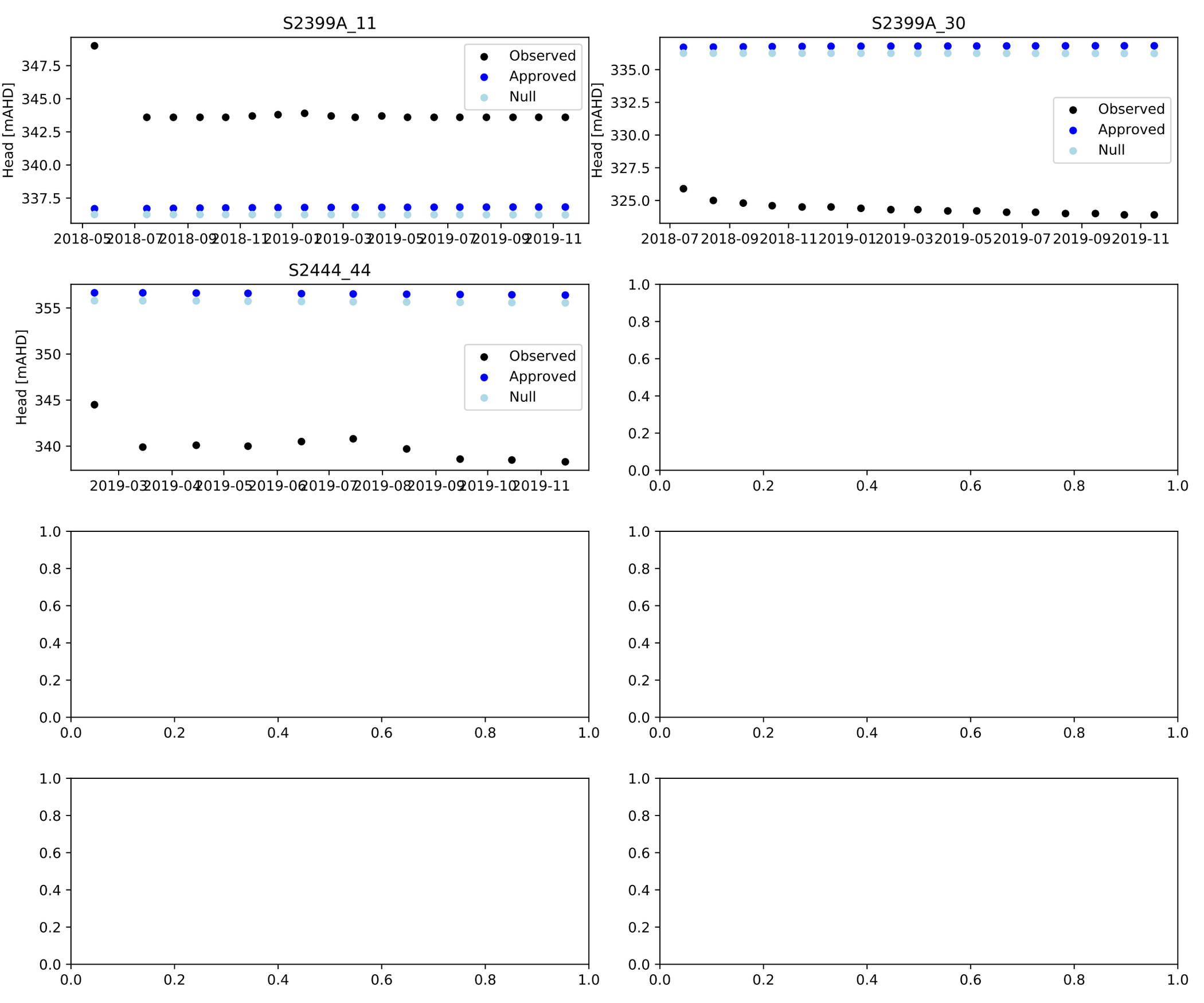

S2335A_51
Head [mAHD]
337.5
335.0
332.5
330.0
327.5
Observed
Approved
Null
2017-10
2018-01
2018-04
2018-07
2018-10
2019-01
2019-04
2019-07
2019-10


S2335A_81
Head [mAHD]
330
320
310
300
Observed
Approved
Null
2017-10
2018-01
2018-04
2018-07
2018-10
2019-01
2019-04
2019-07
2019-10


S2335A_91
Head [mAHD]
320
300
280
Observed
Approved
Null
2017-10
2018-01
2018-04
2018-07
2018-10
2019-01
2019-04
2019-07
2019-10


S2411A_11
Head [mAHD]
350
345
340
Observed
Approved
Null
2018-07
2018-09
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11


S2487_165
Head [mAHD]
340
320
300
280
Observed
Approved
Null
2019-11-15
2019-12-01
2019-12-15
2020-01-01
2020-01-15
2020-02-01
2020-02-15


S2399A_11
Head [mAHD]
347.5
345.0
342.5
340.0
337.5
Observed
Approved
Null
2018-05
2018-07
2018-09
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
S2399A_30
Head [mAHD]
335.0
332.5
330.0
327.5
325.0
Observed
Approved
Null
2018-07
2018-09
2018-11
2019-01
2019-03
2019-05
2019-07
2019-09
2019-11
S2444_44
Head [mAHD]
355
350
345
340
Observed
Approved
Null
2019-03
2019-04
2019-05
2019-06
2019-07
2019-08
2019-09
2019-10
2019-11
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0

# Appendix G – Calibration Residuals

| Site ID | Easting | Northing | Layer | Formation | Absolute Average Residual | Average Residual |
|---|---|---|---|---|---|---|
| NWGW01_195 | 289391 | 6184417 | 8 | StanwellParkClaystone | 4.0 | 3.8 |
| NWGW01_227 | 289391 | 6184417 | 12 | BulliCoalSeam | 42.4 | 41.1 |
| NWGW01_259 | 289391 | 6184417 | 14 | WongawilliCoalSeam | 23.4 | 17.8 |
| NWGW01_30 | 289391 | 6184417 | 4 | HawkesburySst | 2.1 | -2.1 |
| NWGW01_50 | 289391 | 6184417 | 4 | HawkesburySst | 2.2 | 2.2 |
| NWGW01_70 | 289391 | 6184417 | 5 | BaldHillClaystone | 17.1 | -17.1 |
| NWGW01_90 | 289391 | 6184417 | 6 | BulgoSst | 2.8 | 2.8 |
| NWGW02_130 | 285253 | 6184479 | 4 | HawkesburySst | 18.4 | -18.4 |
| NWGW02_160 | 285253 | 6184479 | 5 | BaldHillClaystone | 30.8 | -30.8 |
| NWGW02_175 | 285253 | 6184479 | 7 | BulgoSst | 7.9 | -7.4 |
| NWGW02_250 | 285253 | 6184479 | 7 | BulgoSst | 23.9 | -23.9 |
| NWGW02_275 | 285253 | 6184479 | 8 | StanwellParkClaystone | 4.5 | 0.6 |
| NWGW02_301 | 285253 | 6184479 | 12 | BulliCoalSeam | 33.2 | -33.2 |
| NWGW02_334 | 285253 | 6184479 | 14 | WongawilliCoalSeam | 29.0 | -29.0 |
| NWGW02_60 | 285253 | 6184479 | 4 | HawkesburySst | 0.8 | -0.6 |
| NWW11_104 | 288343 | 6184339 | 5 | BaldHillClaystone | 7.2 | -6.1 |
| NWW11_125 | 288343 | 6184339 | 6 | BulgoSst | 19.4 | -15.6 |
| NWW11_60 | 288343 | 6184339 | 4 | HawkesburySst | 16.2 | -16.2 |
| NWW11_90 | 288343 | 6184339 | 4 | HawkesburySst | 27.4 | -27.4 |
| NWW16_126 | 283657 | 6183801 | 4 | HawkesburySst | 18.4 | -18.3 |
| NWW16_146 | 283657 | 6183801 | 5 | BaldHillClaystone | 11.2 | -10.7 |
| NWW16_166 | 283657 | 6183801 | 7 | BulgoSst | 20.5 | 20.5 |
| NWW16_71 | 283657 | 6183801 | 4 | HawkesburySst | 0.8 | 0.2 |
| NWW20B_135 | 291099 | 6184158 | 7 | BulgoSst | 10.7 | 10.7 |
| NWW20B_33 | 291099 | 6184158 | 3 | HawkesburySst | 26.4 | -26.4 |
| NWW20B_60 | 291099 | 6184158 | 4 | HawkesburySst | 40.9 | -40.9 |
| NWW20B_75 | 291099 | 6184158 | 5 | BaldHillClaystone | 21.0 | -21.0 |
| NWWPE1_135 | 291676 | 6187507 | 4 | HawkesburySst | 11.3 | -11.1 |
| NWWPE1_150 | 291676 | 6187507 | 5 | BaldHillClaystone | 18.1 | -18.1 |
| NWWPE1_165 | 291676 | 6187507 | 6 | BulgoSst | 4.7 | -0.8 |
| NWWPE1_90 | 291676 | 6187507 | 4 | HawkesburySst | 10.5 | -10.4 |
| NWWSH1_110 | 288448 | 6184273 | 5 | BaldHillClaystone | 41.1 | -41.1 |
| NWWSH1_130 | 288448 | 6184273 | 6 | BulgoSst | 1.8 | -1.8 |
| NWWSH1_215 | 288448 | 6184273 | 8 | StanwellParkClaystone | 16.1 | -16.1 |
| NWWSH1_255 | 288448 | 6184273 | 11 | CoalcliffSandstone | 31.3 | 31.3 |
| NWWSH1_267 | 288448 | 6184273 | 12 | BulliCoalSeam | 31.3 | 31.3 |
| NWWSH1_297 | 288448 | 6184273 | 14 | WongawilliCoalSeam | 38.6 | 38.6 |
| NWWSH1_65 | 288448 | 6184273 | 4 | HawkesburySst | 16.8 | -16.8 |
| NWWSH1_90 | 288448 | 6184273 | 4 | HawkesburySst | 17.2 | -17.2 |
| Nebo6_100 | 295237 | 6189510 | 13 | LawrenceLoddonSst | 1.6 | 1.6 |
| Nebo6_115 | 295237 | 6189510 | 13 | LawrenceLoddonSst | 27.8 | 27.8 |
| Nebo6_60 | 295237 | 6189510 | 10 | WombarraClaystone | 13.5 | -7.7 |
| Nebo6_80 | 295237 | 6189510 | 14 | WongawilliCoalSeam | 18.4 | -18.4 |
| Nebo7_30 | 295477 | 6189585 | 10 | WombarraClaystone | 7.4 | -7.4 |
| Nebo7_45 | 295477 | 6189585 | 10 | WombarraClaystone | 7.3 | 6.7 |
| Nebo7_63 | 295477 | 6189585 | 13 | LawrenceLoddonSst | 38.4 | 38.4 |
| Nebo7_90 | 295477 | 6189585 | 14 | WongawilliCoalSeam | 18.8 | 18.8 |
| Nebo8A_25 | 294549 | 6189499 | 9 | ScarboroughSst | 9.7 | 9.7 |
| Nebo8A_45 | 294549 | 6189499 | 9 | ScarboroughSst | 5.6 | -5.5 |
| Nebo8_15 | 294679 | 6189485 | 9 | ScarboroughSst | 3.2 | 3.2 |
| Nebo8_35 | 294679 | 6189485 | 9 | ScarboroughSst | 9.8 | 9.8 |
| Nebo8_52 | 294679 | 6189485 | 8 | StanwellParkClaystone | 17.7 | -17.7 |
| Nebo8_72 | 294679 | 6189485 | 11 | CoalcliffSandstone | 16.0 | -16.0 |
| Nebo_1D | 295152 | 6188761 | 10 | WombarraClaystone | 7.3 | 4.1 |
| Nebo_1S | 295153 | 6188762 | 1 | AlluvRegolith | 2.0 | -2.0 |
| Nebo_2D | 294662 | 6189237 | 9 | ScarboroughSst | 19.2 | 19.2 |
| Nebo_2S | 294662 | 6189246 | 8 | StanwellParkClaystone | 19.5 | 19.5 |
| Nebo_3 | 295033 | 6189838 | 9 | ScarboroughSst | 21.2 | 21.2 |
| Nebo_4 | 294661 | 6189893 | 14 | WongawilliCoalSeam | 54.5 | 54.5 |
| S1096_347 | 292699.6 | 6191121 | 14 | WongawilliCoalSeam | 132.3 | 132.3 |
| S1099_358 | 292040.9 | 6191531 | 14 | WongawilliCoalSeam | 43.1 | -43.1 |

| Site ID | Easting | Northing | Layer | Formation | Absolute Average Residual | Average Residual |
|---|---|---|---|---|---|---|
| S1388_363 | 292128.9 | 6192393 | 14 | WongawilliCoalSeam | 73.6 | -73.6 |
| S1557_19 | 298325.8 | 6190192 | 8 | StanwellParkClaystone | 19.1 | 19.1 |
| S1557_55 | 298325.8 | 6190192 | 9 | ScarboroughSst | 3.6 | -3.1 |
| S1557_70 | 298325.8 | 6190192 | 9 | ScarboroughSst | 4.6 | -4.3 |
| S1572_20 | 296398.1 | 6191978 | 8 | StanwellParkClaystone | 3.4 | 3.4 |
| S1572_28 | 296398.1 | 6191978 | 8 | StanwellParkClaystone | 2.7 | -0.1 |
| S1572_30 | 296398.1 | 6191978 | 9 | ScarboroughSst | 19.0 | 19.0 |
| S1572_39 | 296398.1 | 6191978 | 9 | ScarboroughSst | 17.3 | 17.3 |
| S1572_42 | 296398.1 | 6191978 | 9 | ScarboroughSst | 18.5 | 18.5 |
| S1572_50 | 296398.1 | 6191978 | 10 | WombarraClaystone | 31.1 | 31.1 |
| S1572_59 | 296398.1 | 6191978 | 10 | WombarraClaystone | 32.2 | 32.2 |
| S1572_70 | 296398.1 | 6191978 | 10 | WombarraClaystone | 32.6 | 32.6 |
| S1577_130 | 294558 | 6192447 | 7 | BulgoSst | 22.2 | 8.9 |
| S1577_170 | 294558 | 6192447 | 9 | ScarboroughSst | 22.5 | -17.2 |
| S1577_25 | 294558 | 6192447 | 5 | BaldHillClaystone | 9.7 | 9.7 |
| S1577_258 | 294558 | 6192447 | 15 | KemblaSst | 69.5 | -69.5 |
| S1578_122 | 295387 | 6192332 | 8 | StanwellParkClaystone | 7.3 | 6.4 |
| S1578_152 | 295387 | 6192332 | 9 | ScarboroughSst | 19.2 | 18.5 |
| S1578_234 | 295387 | 6192332 | 14 | WongawilliCoalSeam | 15.0 | 2.4 |
| S1578_25 | 295387 | 6192332 | 6 | BulgoSst | 46.7 | 46.7 |
| S1649_115 | 295805.7 | 6192201 | 14 | WongawilliCoalSeam | 36.3 | 34.2 |
| S1649_12 | 295805.7 | 6192201 | 8 | StanwellParkClaystone | 8.7 | 8.7 |
| S1649_27 | 295805.7 | 6192201 | 9 | ScarboroughSst | 25.7 | 25.7 |
| S1649_33 | 295805.7 | 6192201 | 9 | ScarboroughSst | 24.7 | 24.7 |
| S1649_42 | 295805.7 | 6192201 | 9 | ScarboroughSst | 25.7 | 25.7 |
| S1649_62 | 295805.7 | 6192201 | 10 | WombarraClaystone | 45.5 | 45.5 |
| S1649_87 | 295805.7 | 6192201 | 12 | BulliCoalSeam | 11.8 | 7.4 |
| S1652_10 | 295510.6 | 6190966 | 8 | StanwellParkClaystone | 67.7 | -67.7 |
| S1652_117 | 295510.6 | 6190966 | 14 | WongawilliCoalSeam | 125.2 | 125.2 |
| S1652_20 | 295510.6 | 6190966 | 8 | StanwellParkClaystone | 47.7 | -47.7 |
| S1652_45 | 295510.6 | 6190966 | 9 | ScarboroughSst | 14.0 | -14.0 |
| S1652_60 | 295510.6 | 6190966 | 10 | WombarraClaystone | 18.0 | 18.0 |
| S1652_86 | 295510.6 | 6190966 | 11 | CoalcliffSandstone | 44.8 | 44.8 |
| S1710_10 | 290258 | 6189646 | 2 | HawkesburySst | 72.8 | -72.8 |
| S1710_120 | 290258 | 6189646 | 5 | BaldHillClaystone | 71.1 | 71.1 |
| S1710_145 | 290258 | 6189646 | 6 | BulgoSst | 142.2 | 142.2 |
| S1710_60 | 290258 | 6189646 | 3 | HawkesburySst | 16.6 | -9.6 |
| S1719_371 | 291202 | 6193277 | 14 | WongawilliCoalSeam | 46.4 | -40.6 |
| S1739_392 | 289683.6 | 6191799 | 14 | WongawilliCoalSeam | 28.8 | -27.7 |
| S1755_362 | 289475.4 | 6191380 | 12 | BulliCoalSeam | 36.2 | -7.9 |
| S1755_389 | 289475.4 | 6191380 | 14 | WongawilliCoalSeam | 26.6 | -23.4 |
| S1758_376 | 288586.6 | 6193107 | 13 | LawrenceLoddonSst | 61.0 | -60.7 |
| S1758_406 | 288586.6 | 6193107 | 14 | WongawilliCoalSeam | 61.3 | -61.3 |
| S1779_318 | 292381.4 | 6195551 | 13 | LawrenceLoddonSst | 70.7 | -68.7 |
| S1779_343 | 292381.4 | 6195551 | 14 | WongawilliCoalSeam | 52.9 | -52.9 |
| S1796_421 | 289946.6 | 6194587 | 15 | KemblaSst | 168.8 | -168.8 |
| S1800_373 | 289933.4 | 6193997 | 13 | LawrenceLoddonSst | 58.2 | -58.2 |
| S1800_403 | 289933.4 | 6193997 | 15 | KemblaSst | 81.8 | -81.8 |
| S1830_106 | 295865.2 | 6192481 | 13 | LawrenceLoddonSst | 41.4 | 41.4 |
| S1830_124 | 295865.2 | 6192481 | 15 | KemblaSst | 42.8 | 31.3 |
| S1830_15 | 295865.2 | 6192481 | 8 | StanwellParkClaystone | 7.3 | 7.3 |
| S1830_30 | 295865.2 | 6192481 | 9 | ScarboroughSst | 29.5 | 29.5 |
| S1830_40 | 295865.2 | 6192481 | 9 | ScarboroughSst | 25.3 | 25.3 |
| S1830_63 | 295865.2 | 6192481 | 10 | WombarraClaystone | 38.8 | 38.8 |
| S1830_81 | 295865.2 | 6192481 | 11 | CoalcliffSandstone | 43.9 | 43.9 |
| S1830_94 | 295865.2 | 6192481 | 12 | BulliCoalSeam | 5.4 | -3.4 |
| S1831_106 | 295866.7 | 6192499 | 13 | LawrenceLoddonSst | 11.4 | 11.4 |
| S1831_124 | 295866.7 | 6192499 | 15 | KemblaSst | 7.3 | -3.1 |
| S1831_18 | 295866.7 | 6192499 | 9 | ScarboroughSst | 28.0 | 28.0 |
| S1831_33 | 295866.7 | 6192499 | 9 | ScarboroughSst | 24.0 | 24.0 |
| S1831_47 | 295866.7 | 6192499 | 9 | ScarboroughSst | 16.9 | 16.9 |

| Site ID | Easting | Northing | Layer | Formation | Absolute Average Residual | Average Residual |
|---|---|---|---|---|---|---|
| S1831_65 | 295866.7 | 6192499 | 10 | WombarraClaystone | 36.5 | 36.5 |
| S1831_86 | 295866.7 | 6192499 | 11 | CoalcliffSandstone | 10.8 | 9.9 |
| S1831_97 | 295866.7 | 6192499 | 13 | LawrenceLoddonSst | 20.8 | 20.8 |
| S1832_113 | 295807.3 | 6192192 | 14 | WongawilliCoalSeam | 44.7 | 44.7 |
| S1832_14 | 295807.3 | 6192192 | 8 | StanwellParkClaystone | 6.8 | 6.8 |
| S1832_29 | 295807.3 | 6192192 | 9 | ScarboroughSst | 19.0 | 19.0 |
| S1832_42 | 295807.3 | 6192192 | 9 | ScarboroughSst | 15.2 | 15.2 |
| S1832_55 | 295807.3 | 6192192 | 10 | WombarraClaystone | 34.9 | 34.9 |
| S1832_80 | 295807.3 | 6192192 | 11 | CoalcliffSandstone | 24.5 | 24.4 |
| S1832_86 | 295807.3 | 6192192 | 12 | BulliCoalSeam | 56.0 | 51.9 |
| S1832_95 | 295807.3 | 6192192 | 13 | LawrenceLoddonSst | 16.1 | 16.1 |
| S1833_107 | 295749.2 | 6191939 | 13 | LawrenceLoddonSst | 26.4 | 25.2 |
| S1833_15 | 295749.2 | 6191939 | 8 | StanwellParkClaystone | 1.2 | -0.4 |
| S1833_22 | 295749.2 | 6191939 | 9 | ScarboroughSst | 15.4 | 15.4 |
| S1833_37 | 295749.2 | 6191939 | 9 | ScarboroughSst | 13.1 | 13.1 |
| S1833_53 | 295749.2 | 6191939 | 10 | WombarraClaystone | 32.3 | 32.3 |
| S1833_75 | 295749.2 | 6191939 | 11 | CoalcliffSandstone | 33.0 | 33.0 |
| S1833_83 | 295749.2 | 6191939 | 12 | BulliCoalSeam | 119.0 | 114.9 |
| S1833_91 | 295749.2 | 6191939 | 13 | LawrenceLoddonSst | 4.5 | 4.4 |
| S1834_111 | 295747.1 | 6191940 | 14 | WongawilliCoalSeam | 56.2 | 56.2 |
| S1834_13 | 295747.1 | 6191940 | 8 | StanwellParkClaystone | 4.2 | 4.1 |
| S1834_32 | 295747.1 | 6191940 | 9 | ScarboroughSst | 17.1 | 17.1 |
| S1834_42 | 295747.1 | 6191940 | 10 | WombarraClaystone | 28.6 | 28.6 |
| S1834_52 | 295747.1 | 6191940 | 10 | WombarraClaystone | 25.8 | 25.8 |
| S1834_75 | 295747.1 | 6191940 | 11 | CoalcliffSandstone | 29.9 | 29.9 |
| S1834_84 | 295747.1 | 6191940 | 12 | BulliCoalSeam | 45.9 | 37.4 |
| S1834_92 | 295747.1 | 6191940 | 13 | LawrenceLoddonSst | 68.0 | 66.8 |
| S1844_329 | 291391.1 | 6194869 | 12 | BulliCoalSeam | 34.6 | -34.6 |
| S1844_356 | 291391.1 | 6194869 | 14 | WongawilliCoalSeam | 67.8 | -67.8 |
| S1845_334 | 291464 | 6193770 | 13 | LawrenceLoddonSst | 113.7 | -113.7 |
| S1845_363 | 291464 | 6193770 | 14 | WongawilliCoalSeam | 29.9 | 29.9 |
| S1855_325 | 289746.5 | 6192833 | 13 | LawrenceLoddonSst | 149.0 | -149.0 |
| S1855_356 | 289746.5 | 6192833 | 14 | WongawilliCoalSeam | 84.7 | -84.7 |
| S1867_10 | 293792.6 | 6192913 | 4 | HawkesburySst | 3.6 | -2.9 |
| S1867_100 | 293792.6 | 6192913 | 6 | BulgoSst | 7.6 | 1.5 |
| S1867_15 | 293792.6 | 6192913 | 4 | HawkesburySst | 4.8 | -3.8 |
| S1867_150 | 293792.6 | 6192913 | 7 | BulgoSst | 14.5 | 14.5 |
| S1867_173 | 293792.6 | 6192913 | 9 | ScarboroughSst | 41.8 | 41.8 |
| S1867_200 | 293792.6 | 6192913 | 9 | ScarboroughSst | 31.6 | 31.6 |
| S1867_216 | 293792.6 | 6192913 | 10 | WombarraClaystone | 69.3 | 69.3 |
| S1867_240 | 293792.6 | 6192913 | 11 | CoalcliffSandstone | 54.4 | 54.4 |
| S1867_249 | 293792.6 | 6192913 | 12 | BulliCoalSeam | 23.6 | -23.6 |
| S1867_277 | 293792.6 | 6192913 | 14 | WongawilliCoalSeam | 13.3 | 10.7 |
| S1867_88 | 293792.6 | 6192913 | 6 | BulgoSst | 4.6 | 1.3 |
| S1870_10 | 293593.2 | 6192648 | 4 | HawkesburySst | 7.6 | -7.6 |
| S1870_125 | 293593.2 | 6192648 | 7 | BulgoSst | 22.1 | 22.1 |
| S1870_149 | 293593.2 | 6192648 | 7 | BulgoSst | 13.6 | 7.3 |
| S1870_15 | 293593.2 | 6192648 | 4 | HawkesburySst | 8.4 | -8.4 |
| S1870_177 | 293593.2 | 6192648 | 9 | ScarboroughSst | 45.8 | 45.8 |
| S1870_204 | 293593.2 | 6192648 | 9 | ScarboroughSst | 24.3 | -11.4 |
| S1870_221 | 293593.2 | 6192648 | 10 | WombarraClaystone | 11.4 | 8.7 |
| S1870_23 | 293593.2 | 6192648 | 4 | HawkesburySst | 14.2 | -14.2 |
| S1870_244 | 293593.2 | 6192648 | 11 | CoalcliffSandstone | 13.7 | 7.7 |
| S1870_252 | 293593.2 | 6192648 | 12 | BulliCoalSeam | 25.5 | -25.5 |
| S1870_284 | 293593.2 | 6192648 | 14 | WongawilliCoalSeam | 34.1 | 1.5 |
| S1870_55 | 293593.2 | 6192648 | 6 | BulgoSst | 7.8 | -4.6 |
| S1871_10 | 293525 | 6193287 | 3 | HawkesburySst | 3.0 | 2.8 |
| S1871_134 | 293525 | 6193287 | 6 | BulgoSst | 39.0 | -38.9 |
| S1871_184 | 293525 | 6193287 | 7 | BulgoSst | 34.4 | -25.4 |
| S1871_210 | 293525 | 6193287 | 9 | ScarboroughSst | 28.0 | -2.5 |
| S1871_235 | 293525 | 6193287 | 9 | ScarboroughSst | 29.8 | -14.5 |

| Site ID | Easting | Northing | Layer | Formation | Absolute Average Residual | Average Residual |
|---|---|---|---|---|---|---|
| S1871_253 | 293525 | 6193287 | 10 | WombarraClaystone | 2.8 | 2.8 |
| S1871_275 | 293525 | 6193287 | 11 | CoalcliffSandstone | 30.7 | -30.7 |
| S1871_285 | 293525 | 6193287 | 12 | BulliCoalSeam | 35.1 | -35.1 |
| S1871_31 | 293525 | 6193287 | 4 | HawkesburySst | 10.7 | 9.5 |
| S1871_312 | 293525 | 6193287 | 14 | WongawilliCoalSeam | 42.2 | -42.2 |
| S1871_40 | 293525 | 6193287 | 4 | HawkesburySst | 9.3 | 7.9 |
| S1871_88 | 293525 | 6193287 | 6 | BulgoSst | 10.7 | -7.5 |
| S1878_10 | 293842.3 | 6191994 | 6 | BulgoSst | 4.3 | 4.3 |
| S1878_118 | 293842.3 | 6191994 | 7 | BulgoSst | 13.6 | 13.6 |
| S1878_145 | 293842.3 | 6191994 | 8 | StanwellParkClaystone | 12.5 | 11.7 |
| S1878_157 | 293842.3 | 6191994 | 9 | ScarboroughSst | 19.9 | 19.9 |
| S1878_169 | 293842.3 | 6191994 | 9 | ScarboroughSst | 5.6 | 5.3 |
| S1878_188 | 293842.3 | 6191994 | 10 | WombarraClaystone | 31.2 | 29.4 |
| S1878_212 | 293842.3 | 6191994 | 11 | CoalcliffSandstone | 31.7 | 14.1 |
| S1878_223 | 293842.3 | 6191994 | 13 | LawrenceLoddonSst | 60.9 | 50.0 |
| S1878_25 | 293842.3 | 6191994 | 6 | BulgoSst | 4.6 | -4.6 |
| S1878_252 | 293842.3 | 6191994 | 14 | WongawilliCoalSeam | 26.8 | -26.8 |
| S1878_71 | 293842.3 | 6191994 | 6 | BulgoSst | 20.1 | -18.9 |
| S1879_10 | 291440.3 | 6192133 | 3 | HawkesburySst | 18.7 | 18.7 |
| S1879_153 | 291440.3 | 6192133 | 7 | BulgoSst | 26.3 | -26.3 |
| S1879_210 | 291440.3 | 6192133 | 9 | ScarboroughSst | 24.6 | 23.3 |
| S1879_227 | 291440.3 | 6192133 | 9 | ScarboroughSst | 40.0 | -38.2 |
| S1879_236 | 291440.3 | 6192133 | 9 | ScarboroughSst | 53.8 | -53.2 |
| S1879_245 | 291440.3 | 6192133 | 9 | ScarboroughSst | 60.9 | -60.9 |
| S1879_263 | 291440.3 | 6192133 | 10 | WombarraClaystone | 77.5 | -77.5 |
| S1879_29 | 291440.3 | 6192133 | 4 | HawkesburySst | 2.8 | 1.5 |
| S1879_292 | 291440.3 | 6192133 | 13 | LawrenceLoddonSst | 80.1 | -63.5 |
| S1879_319 | 291440.3 | 6192133 | 14 | WongawilliCoalSeam | 91.4 | -88.6 |
| S1879_48 | 291440.3 | 6192133 | 4 | HawkesburySst | 9.4 | -9.4 |
| S1879_97 | 291440.3 | 6192133 | 6 | BulgoSst | 23.9 | -23.9 |
| S1885_11 | 291504.4 | 6192668 | 3 | HawkesburySst | 54.6 | 54.6 |
| S1885_147 | 291504.4 | 6192668 | 6 | BulgoSst | 16.5 | -16.5 |
| S1885_203 | 291504.4 | 6192668 | 7 | BulgoSst | 22.0 | -22.0 |
| S1885_260 | 291504.4 | 6192668 | 8 | StanwellParkClaystone | 10.8 | -10.8 |
| S1885_280 | 291504.4 | 6192668 | 9 | ScarboroughSst | 6.7 | -4.1 |
| S1885_288 | 291504.4 | 6192668 | 9 | ScarboroughSst | 23.6 | 18.0 |
| S1885_296 | 291504.4 | 6192668 | 9 | ScarboroughSst | 11.1 | -8.5 |
| S1885_314 | 291504.4 | 6192668 | 10 | WombarraClaystone | 26.4 | -26.4 |
| S1885_340 | 291504.4 | 6192668 | 12 | BulliCoalSeam | 36.6 | -36.6 |
| S1885_369 | 291504.4 | 6192668 | 14 | WongawilliCoalSeam | 100.8 | -100.8 |
| S1885_51 | 291504.4 | 6192668 | 3 | HawkesburySst | 16.7 | 16.7 |
| S1885_93 | 291504.4 | 6192668 | 4 | HawkesburySst | 4.8 | -4.8 |
| S1886_38 | 295883.8 | 6191720 | 9 | ScarboroughSst | 23.2 | 23.2 |
| S1888_211 | 292486.5 | 6191987 | 8 | StanwellParkClaystone | 12.2 | -4.9 |
| S1888_221 | 292486.5 | 6191987 | 9 | ScarboroughSst | 26.9 | 26.9 |
| S1888_235 | 292486.5 | 6191987 | 9 | ScarboroughSst | 26.7 | 26.7 |
| S1888_282 | 292486.5 | 6191987 | 12 | BulliCoalSeam | 90.6 | -90.1 |
| S1888_310 | 292486.5 | 6191987 | 13 | LawrenceLoddonSst | 103.7 | -103.3 |
| S1888_48 | 292486.5 | 6191987 | 4 | HawkesburySst | 5.5 | -4.7 |
| S1888_8 | 292486.5 | 6191987 | 3 | HawkesburySst | 8.1 | 8.1 |
| S1888_92 | 292486.5 | 6191987 | 6 | BulgoSst | 11.2 | -9.4 |
| S1889_10 | 292244.8 | 6192980 | 2 | HawkesburySst | 43.8 | 43.8 |
| S1889_123 | 292244.8 | 6192980 | 4 | HawkesburySst | 8.4 | -8.2 |
| S1889_158 | 292244.8 | 6192980 | 6 | BulgoSst | 8.5 | -5.2 |
| S1889_269 | 292244.8 | 6192980 | 8 | StanwellParkClaystone | 12.8 | -12.6 |
| S1889_289 | 292244.8 | 6192980 | 9 | ScarboroughSst | 5.4 | -0.6 |
| S1889_305 | 292244.8 | 6192980 | 9 | ScarboroughSst | 5.1 | 0.5 |
| S1889_347 | 292244.8 | 6192980 | 12 | BulliCoalSeam | 16.4 | -16.4 |
| S1889_376 | 292244.8 | 6192980 | 14 | WongawilliCoalSeam | 106.5 | -106.5 |
| S1890_119 | 292637.3 | 6192491 | 6 | BulgoSst | 5.9 | -5.7 |
| S1890_213 | 292637.3 | 6192491 | 7 | BulgoSst | 14.6 | -14.6 |

| Site ID | Easting | Northing | Layer | Formation | Absolute Average Residual | Average Residual |
|---|---|---|---|---|---|---|
| S1890_245 | 292637.3 | 6192491 | 9 | ScarboroughSst | 15.5 | 15.5 |
| S1890_263 | 292637.3 | 6192491 | 9 | ScarboroughSst | 17.7 | 17.7 |
| S1890_281 | 292637.3 | 6192491 | 10 | WombarraClaystone | 14.1 | 14.1 |
| S1890_311 | 292637.3 | 6192491 | 12 | BulliCoalSeam | 74.5 | -74.5 |
| S1890_340 | 292637.3 | 6192491 | 14 | WongawilliCoalSeam | 118.0 | -118.0 |
| S1890_73 | 292637.3 | 6192491 | 4 | HawkesburySst | 6.7 | -6.7 |
| S1892_113 | 291014.1 | 6193952 | 6 | BulgoSst | 24.1 | -12.0 |
| S1892_191 | 291014.1 | 6193952 | 7 | BulgoSst | 28.9 | -28.9 |
| S1892_231 | 291014.1 | 6193952 | 9 | ScarboroughSst | 28.2 | 16.7 |
| S1892_257 | 291014.1 | 6193952 | 9 | ScarboroughSst | 22.3 | -19.2 |
| S1892_308 | 291014.1 | 6193952 | 13 | LawrenceLoddonSst | 23.6 | -19.3 |
| S1892_336 | 291014.1 | 6193952 | 15 | KemblaSst | 93.7 | -93.7 |
| S1892_49 | 291014.1 | 6193952 | 4 | HawkesburySst | 4.5 | 3.7 |
| S1892_8 | 291014.1 | 6193952 | 3 | HawkesburySst | 23.2 | 23.2 |
| S1902_15 | 295241.3 | 6190780 | 7 | BulgoSst | 12.7 | 12.7 |
| S1902_35 | 295241.3 | 6190780 | 8 | StanwellParkClaystone | 41.7 | 41.7 |
| S1902_55 | 295241.3 | 6190780 | 9 | ScarboroughSst | 49.1 | 49.1 |
| S1902_75 | 295241.3 | 6190780 | 10 | WombarraClaystone | 52.9 | 52.9 |
| S1907_11 | 293212.2 | 6191943 | 4 | HawkesburySst | 1.1 | 0.4 |
| S1907_169 | 293212.2 | 6191943 | 8 | StanwellParkClaystone | 26.4 | 26.4 |
| S1907_204 | 293212.2 | 6191943 | 9 | ScarboroughSst | 46.1 | 46.1 |
| S1907_209 | 293212.2 | 6191943 | 9 | ScarboroughSst | 45.4 | 45.4 |
| S1907_21 | 293212.2 | 6191943 | 4 | HawkesburySst | 1.8 | -0.7 |
| S1907_256 | 293212.2 | 6191943 | 12 | BulliCoalSeam | 60.9 | -60.9 |
| S1907_290 | 293212.2 | 6191943 | 14 | WongawilliCoalSeam | 85.0 | -85.0 |
| S1907_65 | 293212.2 | 6191943 | 6 | BulgoSst | 12.3 | 12.3 |
| S1908_10 | 288925.9 | 6193601 | 2 | HawkesburySst | 38.8 | 38.8 |
| S1908_154 | 288925.9 | 6193601 | 4 | HawkesburySst | 20.1 | 6.7 |
| S1908_201 | 288925.9 | 6193601 | 6 | BulgoSst | 54.7 | -54.7 |
| S1908_276 | 288925.9 | 6193601 | 7 | BulgoSst | 119.2 | -119.2 |
| S1908_304 | 288925.9 | 6193601 | 8 | StanwellParkClaystone | 134.9 | -134.9 |
| S1908_337 | 288925.9 | 6193601 | 9 | ScarboroughSst | 71.2 | -71.2 |
| S1908_379 | 288925.9 | 6193601 | 11 | CoalcliffSandstone | 118.1 | -108.6 |
| S1908_412 | 288925.9 | 6193601 | 14 | WongawilliCoalSeam | 35.7 | 28.2 |
| S1910_125 | 289387.4 | 6194176 | 4 | HawkesburySst | 26.9 | -26.5 |
| S1910_169 | 289387.4 | 6194176 | 6 | BulgoSst | 34.4 | -34.4 |
| S1910_247 | 289387.4 | 6194176 | 7 | BulgoSst | 40.3 | -40.3 |
| S1910_273 | 289387.4 | 6194176 | 8 | StanwellParkClaystone | 39.0 | -39.0 |
| S1910_313 | 289387.4 | 6194176 | 9 | ScarboroughSst | 28.4 | -28.4 |
| S1910_362 | 289387.4 | 6194176 | 13 | LawrenceLoddonSst | 108.4 | -108.4 |
| S1910_391 | 289387.4 | 6194176 | 14 | WongawilliCoalSeam | 128.1 | -128.1 |
| S1910_96 | 289387.4 | 6194176 | 2 | HawkesburySst | 20.8 | 20.8 |
| S1911_135 | 288802.8 | 6192549 | 4 | HawkesburySst | 15.1 | -15.0 |
| S1911_187 | 288802.8 | 6192549 | 6 | BulgoSst | 31.8 | -31.8 |
| S1911_229 | 288802.8 | 6192549 | 7 | BulgoSst | 77.7 | -77.7 |
| S1911_277 | 288802.8 | 6192549 | 8 | StanwellParkClaystone | 41.3 | -41.3 |
| S1911_301 | 288802.8 | 6192549 | 9 | ScarboroughSst | 11.6 | 9.8 |
| S1911_318 | 288802.8 | 6192549 | 9 | ScarboroughSst | 76.5 | -65.6 |
| S1911_331 | 288802.8 | 6192549 | 10 | WombarraClaystone | 17.8 | -17.1 |
| S1911_349 | 288802.8 | 6192549 | 11 | CoalcliffSandstone | 76.1 | -73.3 |
| S1911_359 | 288802.8 | 6192549 | 11 | CoalcliffSandstone | 74.7 | -72.3 |
| S1911_387 | 288802.8 | 6192549 | 13 | LawrenceLoddonSst | 93.9 | -92.4 |
| S1911_68 | 288802.8 | 6192549 | 3 | HawkesburySst | 16.2 | 16.2 |
| S1914_147 | 289370 | 6192512 | 4 | HawkesburySst | 15.3 | -14.8 |
| S1914_187 | 289370 | 6192512 | 6 | BulgoSst | 22.1 | -21.2 |
| S1914_300 | 289370 | 6192512 | 9 | ScarboroughSst | 10.3 | 8.6 |
| S1914_330 | 289370 | 6192512 | 9 | ScarboroughSst | 21.2 | -6.3 |
| S1914_371 | 289370 | 6192512 | 12 | BulliCoalSeam | 109.8 | -109.8 |
| S1914_400 | 289370 | 6192512 | 14 | WongawilliCoalSeam | 120.7 | -120.2 |
| S1925_10 | 289251.6 | 6193041 | 2 | HawkesburySst | 48.7 | 48.7 |
| S1925_144 | 289251.6 | 6193041 | 4 | HawkesburySst | 20.3 | -20.3 |

| Site ID | Easting | Northing | Layer | Formation | Absolute Average Residual | Average Residual |
|---|---|---|---|---|---|---|
| S1925_202 | 289251.6 | 6193041 | 6 | BulgoSst | 47.5 | -47.5 |
| S1925_295 | 289251.6 | 6193041 | 7 | BulgoSst | 91.7 | -91.7 |
| S1925_320 | 289251.6 | 6193041 | 9 | ScarboroughSst | 37.5 | -36.9 |
| S1925_342 | 289251.6 | 6193041 | 9 | ScarboroughSst | 43.8 | -43.8 |
| S1925_383 | 289251.6 | 6193041 | 13 | LawrenceLoddonSst | 51.3 | -50.3 |
| S1925_413 | 289251.6 | 6193041 | 14 | WongawilliCoalSeam | 125.9 | -125.9 |
| S1926_10 | 289660.4 | 6193445 | 2 | HawkesburySst | 47.3 | 47.3 |
| S1926_139 | 289660.4 | 6193445 | 4 | HawkesburySst | 11.0 | 8.6 |
| S1926_192 | 289660.4 | 6193445 | 6 | BulgoSst | 6.3 | 1.4 |
| S1926_289 | 289660.4 | 6193445 | 8 | StanwellParkClaystone | 34.3 | -34.3 |
| S1926_313 | 289660.4 | 6193445 | 9 | ScarboroughSst | 6.9 | -3.6 |
| S1926_337 | 289660.4 | 6193445 | 9 | ScarboroughSst | 9.1 | -6.3 |
| S1926_378 | 289660.4 | 6193445 | 13 | LawrenceLoddonSst | 44.5 | -42.9 |
| S1926_408 | 289660.4 | 6193445 | 14 | WongawilliCoalSeam | 95.3 | -95.3 |
| S1927_133 | 290066 | 6192211 | 4 | HawkesburySst | 29.0 | -29.0 |
| S1927_176 | 290066 | 6192211 | 6 | BulgoSst | 29.7 | -29.7 |
| S1927_254 | 290066 | 6192211 | 7 | BulgoSst | 22.6 | -22.6 |
| S1927_270 | 290066 | 6192211 | 8 | StanwellParkClaystone | 14.5 | -13.7 |
| S1927_316 | 290066 | 6192211 | 9 | ScarboroughSst | 44.5 | -44.4 |
| S1927_360 | 290066 | 6192211 | 13 | LawrenceLoddonSst | 110.1 | -110.1 |
| S1927_388 | 290066 | 6192211 | 14 | WongawilliCoalSeam | 117.4 | -117.4 |
| S1927_94 | 290066 | 6192211 | 2 | HawkesburySst | 43.7 | 43.7 |
| S1929_114 | 290010.6 | 6193398 | 6 | BulgoSst | 37.8 | -37.8 |
| S1929_207 | 290010.6 | 6193398 | 8 | StanwellParkClaystone | 16.5 | -15.6 |
| S1929_236 | 290010.6 | 6193398 | 9 | ScarboroughSst | 10.3 | 0.7 |
| S1929_260 | 290010.6 | 6193398 | 9 | ScarboroughSst | 10.8 | -2.8 |
| S1929_302 | 290010.6 | 6193398 | 13 | LawrenceLoddonSst | 104.5 | -104.5 |
| S1929_333 | 290010.6 | 6193398 | 14 | WongawilliCoalSeam | 138.7 | -138.7 |
| S1929_76 | 290010.6 | 6193398 | 5 | BaldHillClaystone | 10.2 | -10.2 |
| S1929_85 | 290010.6 | 6193398 | 3 | HawkesburySst | 7.6 | 7.6 |
| S1930_123 | 290367.3 | 6193583 | 6 | BulgoSst | 37.7 | -37.7 |
| S1930_168 | 290367.3 | 6193583 | 7 | BulgoSst | 31.2 | -30.0 |
| S1930_219 | 290367.3 | 6193583 | 8 | StanwellParkClaystone | 19.9 | -11.7 |
| S1930_248 | 290367.3 | 6193583 | 9 | ScarboroughSst | 21.8 | 8.8 |
| S1930_260 | 290367.3 | 6193583 | 9 | ScarboroughSst | 24.3 | 1.6 |
| S1930_273 | 290367.3 | 6193583 | 9 | ScarboroughSst | 18.6 | 5.0 |
| S1930_294 | 290367.3 | 6193583 | 10 | WombarraClaystone | 90.1 | -88.5 |
| S1930_317 | 290367.3 | 6193583 | 13 | LawrenceLoddonSst | 71.4 | -69.2 |
| S1930_346 | 290367.3 | 6193583 | 14 | WongawilliCoalSeam | 126.9 | -124.8 |
| S1930_45 | 290367.3 | 6193583 | 3 | HawkesburySst | 7.8 | -7.3 |
| S1930_87 | 290367.3 | 6193583 | 4 | HawkesburySst | 39.6 | -39.1 |
| S1930_93 | 290367.3 | 6193583 | 3 | HawkesburySst | 24.1 | 24.1 |
| S1931_120 | 290335.6 | 6192890 | 4 | HawkesburySst | 51.6 | -51.6 |
| S1931_136 | 290335.6 | 6192890 | 5 | BaldHillClaystone | 40.1 | -40.1 |
| S1931_151 | 290335.6 | 6192890 | 6 | BulgoSst | 24.1 | -22.7 |
| S1931_157 | 290335.6 | 6192890 | 6 | BulgoSst | 25.1 | -24.7 |
| S1931_245 | 290335.6 | 6192890 | 8 | StanwellParkClaystone | 20.1 | 7.1 |
| S1931_279 | 290335.6 | 6192890 | 9 | ScarboroughSst | 30.9 | 27.5 |
| S1931_301 | 290335.6 | 6192890 | 9 | ScarboroughSst | 36.1 | -29.9 |
| S1931_345 | 290335.6 | 6192890 | 13 | LawrenceLoddonSst | 93.8 | -93.8 |
| S1931_373 | 290335.6 | 6192890 | 14 | WongawilliCoalSeam | 111.1 | -111.1 |
| S1932_148 | 288863.3 | 6191505 | 6 | BulgoSst | 8.5 | -7.6 |
| S1932_194 | 288863.3 | 6191505 | 7 | BulgoSst | 11.7 | -5.7 |
| S1932_234 | 288863.3 | 6191505 | 7 | BulgoSst | 15.1 | -14.2 |
| S1932_264 | 288863.3 | 6191505 | 9 | ScarboroughSst | 44.2 | 42.2 |
| S1932_272 | 288863.3 | 6191505 | 9 | ScarboroughSst | 36.6 | 36.6 |
| S1932_281 | 288863.3 | 6191505 | 9 | ScarboroughSst | 47.0 | 47.0 |
| S1932_318 | 288863.3 | 6191505 | 11 | CoalcliffSandstone | 55.0 | -47.0 |
| S1932_346 | 288863.3 | 6191505 | 13 | LawrenceLoddonSst | 51.1 | -49.7 |
| S1932_48 | 288863.3 | 6191505 | 3 | HawkesburySst | 20.3 | 20.3 |
| S1932_92 | 288863.3 | 6191505 | 3 | HawkesburySst | 43.3 | 43.3 |

| Site ID | Easting | Northing | Layer | Formation | Absolute Average Residual | Average Residual |
|---|---|---|---|---|---|---|
| S1932_96 | 288863.3 | 6191505 | 4 | HawkesburySst | 13.6 | 9.6 |
| S1934_38 | 292128 | 6192398 | 3 | HawkesburySst | 24.7 | 24.7 |
| S1934_55 | 292128 | 6192398 | 3 | HawkesburySst | 41.7 | 41.7 |
| S1934_65 | 292128 | 6192398 | 3 | HawkesburySst | 10.4 | 10.4 |
| S1934_85 | 292128 | 6192398 | 4 | HawkesburySst | 57.8 | 57.8 |
| S1969_10 | 293998.1 | 6193986 | 3 | HawkesburySst | 3.4 | 3.4 |
| S1969_128 | 293998.1 | 6193986 | 6 | BulgoSst | 21.2 | -21.2 |
| S1969_179 | 293998.1 | 6193986 | 7 | BulgoSst | 6.3 | -6.3 |
| S1969_200 | 293998.1 | 6193986 | 9 | ScarboroughSst | 28.2 | 28.2 |
| S1969_217 | 293998.1 | 6193986 | 9 | ScarboroughSst | 35.1 | 24.5 |
| S1969_235 | 293998.1 | 6193986 | 9 | ScarboroughSst | 17.9 | 17.9 |
| S1969_24 | 293998.1 | 6193986 | 4 | HawkesburySst | 5.2 | 5.2 |
| S1969_285 | 293998.1 | 6193986 | 13 | LawrenceLoddonSst | 139.0 | -139.0 |
| S1969_313 | 293998.1 | 6193986 | 14 | WongawilliCoalSeam | 90.6 | -90.6 |
| S1969_44 | 293998.1 | 6193986 | 4 | HawkesburySst | 0.7 | 0.3 |
| S1969_83 | 293998.1 | 6193986 | 6 | BulgoSst | 19.7 | -19.7 |
| S1992_142 | 293732.1 | 6192707 | 7 | BulgoSst | 12.6 | 12.6 |
| S1992_172 | 293732.1 | 6192707 | 9 | ScarboroughSst | 7.9 | 4.1 |
| S1992_182 | 293732.1 | 6192707 | 9 | ScarboroughSst | 6.7 | -4.8 |
| S1992_192 | 293732.1 | 6192707 | 9 | ScarboroughSst | 5.4 | -3.4 |
| S1992_241 | 293732.1 | 6192707 | 12 | BulliCoalSeam | 23.0 | -15.9 |
| S1992_48 | 293732.1 | 6192707 | 6 | BulgoSst | 1.7 | 0.1 |
| S1992_8 | 293732.1 | 6192707 | 5 | BaldHillClaystone | 4.7 | 4.7 |
| S1992_92 | 293732.1 | 6192707 | 6 | BulgoSst | 15.6 | -14.9 |
| S1994_14 | 293865.2 | 6192982 | 4 | HawkesburySst | 14.2 | -14.2 |
| S1994_148 | 293865.2 | 6192982 | 7 | BulgoSst | 9.3 | -5.7 |
| S1994_174 | 293865.2 | 6192982 | 9 | ScarboroughSst | 33.1 | 28.2 |
| S1994_186 | 293865.2 | 6192982 | 9 | ScarboroughSst | 30.0 | 26.0 |
| S1994_199 | 293865.2 | 6192982 | 9 | ScarboroughSst | 28.9 | 26.0 |
| S1994_250 | 293865.2 | 6192982 | 12 | BulliCoalSeam | 26.9 | 23.7 |
| S1994_55 | 293865.2 | 6192982 | 6 | BulgoSst | 5.8 | 1.5 |
| S1994_99 | 293865.2 | 6192982 | 6 | BulgoSst | 8.2 | -7.7 |
| S1995_384 | 288212.4 | 6193662 | 13 | LawrenceLoddonSst | 17.7 | -12.7 |
| S1995_411 | 288212.4 | 6193662 | 14 | WongawilliCoalSeam | 112.6 | -110.0 |
| S1998_381 | 287750.6 | 6194273 | 12 | BulliCoalSeam | 22.3 | 9.5 |
| S1998_407 | 287750.6 | 6194273 | 14 | WongawilliCoalSeam | 13.1 | -4.2 |
| S1999_313 | 289232.8 | 6190844 | 11 | CoalcliffSandstone | 13.6 | 13.6 |
| S1999_342 | 289232.8 | 6190844 | 14 | WongawilliCoalSeam | 21.5 | -7.5 |
| S2000_357 | 290161.4 | 6191011 | 12 | BulliCoalSeam | 25.0 | 2.3 |
| S2000_385 | 290161.4 | 6191011 | 14 | WongawilliCoalSeam | 86.8 | -86.5 |
| S2001_10 | 288462.6 | 6192020 | 2 | HawkesburySst | 50.5 | 50.5 |
| S2001_125 | 288462.6 | 6192020 | 4 | HawkesburySst | 21.1 | -21.1 |
| S2001_183 | 288462.6 | 6192020 | 6 | BulgoSst | 30.6 | -30.6 |
| S2001_231 | 288462.6 | 6192020 | 7 | BulgoSst | 40.6 | -40.6 |
| S2001_285 | 288462.6 | 6192020 | 8 | StanwellParkClaystone | 57.5 | -57.5 |
| S2001_300 | 288462.6 | 6192020 | 9 | ScarboroughSst | 18.3 | 3.2 |
| S2001_315 | 288462.6 | 6192020 | 9 | ScarboroughSst | 18.4 | 1.9 |
| S2001_353 | 288462.6 | 6192020 | 12 | BulliCoalSeam | 49.5 | -47.4 |
| S2001_382 | 288462.6 | 6192020 | 14 | WongawilliCoalSeam | 106.2 | -104.0 |
| S2001_65 | 288462.6 | 6192020 | 3 | HawkesburySst | 24.6 | 24.6 |
| S2002_386 | 288633.4 | 6194222 | 13 | LawrenceLoddonSst | 98.1 | -98.1 |
| S2002_417 | 288633.4 | 6194222 | 14 | WongawilliCoalSeam | 96.8 | -96.8 |
| S2003_341 | 290571.1 | 6192478 | 13 | LawrenceLoddonSst | 66.8 | -66.8 |
| S2003_368 | 290571.1 | 6192478 | 14 | WongawilliCoalSeam | 99.9 | -99.9 |
| S2006_140 | 287263.2 | 6194204 | 4 | HawkesburySst | 9.4 | -9.4 |
| S2006_192 | 287263.2 | 6194204 | 6 | BulgoSst | 30.5 | -30.5 |
| S2006_244 | 287263.2 | 6194204 | 7 | BulgoSst | 47.7 | -47.7 |
| S2006_302 | 287263.2 | 6194204 | 9 | ScarboroughSst | 9.8 | 5.8 |
| S2006_320 | 287263.2 | 6194204 | 9 | ScarboroughSst | 11.2 | 1.9 |
| S2006_329 | 287263.2 | 6194204 | 9 | ScarboroughSst | 11.1 | 0.9 |
| S2006_370 | 287263.2 | 6194204 | 11 | CoalcliffSandstone | 10.3 | -7.3 |

| Site ID | Easting | Northing | Layer | Formation | Absolute Average Residual | Average Residual |
|---|---|---|---|---|---|---|
| S2006_396 | 287263.2 | 6194204 | 13 | LawrenceLoddonSst | 12.3 | 5.9 |
| S2006_42 | 287263.2 | 6194204 | 2 | HawkesburySst | 43.6 | 43.6 |
| S2006_72 | 287263.2 | 6194204 | 3 | HawkesburySst | 12.5 | 12.5 |
| S2007_360 | 287590.8 | 6193719 | 11 | CoalcliffSandstone | 25.1 | -21.6 |
| S2007_386 | 287590.8 | 6193719 | 13 | LawrenceLoddonSst | 17.3 | -3.1 |
| S2009_100 | 287828.2 | 6193092 | 4 | HawkesburySst | 20.6 | -20.6 |
| S2009_132 | 287828.2 | 6193092 | 4 | HawkesburySst | 23.9 | -23.9 |
| S2009_185 | 287828.2 | 6193092 | 6 | BulgoSst | 32.5 | -32.5 |
| S2009_220 | 287828.2 | 6193092 | 7 | BulgoSst | 44.1 | -44.1 |
| S2009_261 | 287828.2 | 6193092 | 7 | BulgoSst | 64.0 | -64.0 |
| S2009_295 | 287828.2 | 6193092 | 9 | ScarboroughSst | 37.8 | 37.8 |
| S2009_309 | 287828.2 | 6193092 | 9 | ScarboroughSst | 39.3 | 39.3 |
| S2009_366 | 287828.2 | 6193092 | 13 | LawrenceLoddonSst | 65.2 | 50.3 |
| S2009_394 | 287828.2 | 6193092 | 14 | WongawilliCoalSeam | 51.2 | -51.2 |
| S2009_68 | 287828.2 | 6193092 | 3 | HawkesburySst | 2.8 | 2.8 |
| S2010_371 | 292273.2 | 6196658 | 14 | WongawilliCoalSeam | 47.9 | -47.9 |
| S2011_360 | 292055.1 | 6197166 | 13 | LawrenceLoddonSst | 59.6 | -59.6 |
| S2011_385 | 292055.1 | 6197166 | 14 | WongawilliCoalSeam | 59.4 | -59.4 |
| S2013_299 | 290857.7 | 6191198 | 13 | LawrenceLoddonSst | 64.1 | -64.1 |
| S2013_333 | 290857.7 | 6191198 | 14 | WongawilliCoalSeam | 63.0 | -61.7 |
| S2019_325 | 291897.6 | 6195914 | 12 | BulliCoalSeam | 54.6 | -54.6 |
| S2019_351 | 291897.6 | 6195914 | 14 | WongawilliCoalSeam | 66.0 | -66.0 |
| S2059_113 | 293245.7 | 6194795 | 6 | BulgoSst | 7.5 | -2.8 |
| S2059_151 | 293245.7 | 6194795 | 6 | BulgoSst | 16.0 | -16.0 |
| S2059_195 | 293245.7 | 6194795 | 7 | BulgoSst | 9.5 | -9.5 |
| S2059_221 | 293245.7 | 6194795 | 8 | StanwellParkClaystone | 38.9 | -38.9 |
| S2059_242 | 293245.7 | 6194795 | 9 | ScarboroughSst | 34.1 | -34.1 |
| S2059_263 | 293245.7 | 6194795 | 9 | ScarboroughSst | 22.7 | -22.7 |
| S2059_311 | 293245.7 | 6194795 | 13 | LawrenceLoddonSst | 95.4 | -95.4 |
| S2059_33 | 293245.7 | 6194795 | 4 | HawkesburySst | 15.6 | 15.6 |
| S2059_340 | 293245.7 | 6194795 | 14 | WongawilliCoalSeam | 70.5 | -70.5 |
| S2059_61 | 293245.7 | 6194795 | 4 | HawkesburySst | 6.5 | -6.5 |
| S2059_79 | 293245.7 | 6194795 | 5 | BaldHillClaystone | 7.2 | 7.2 |
| S2064_149 | 285966.7 | 6195946 | 5 | BaldHillClaystone | 18.3 | -18.3 |
| S2064_15 | 285966.7 | 6195946 | 2 | HawkesburySst | 31.6 | 31.6 |
| S2064_190 | 285966.7 | 6195946 | 6 | BulgoSst | 46.8 | -46.8 |
| S2064_235 | 285966.7 | 6195946 | 7 | BulgoSst | 51.8 | -51.8 |
| S2064_285 | 285966.7 | 6195946 | 9 | ScarboroughSst | 55.2 | -55.2 |
| S2064_305 | 285966.7 | 6195946 | 9 | ScarboroughSst | 70.2 | -70.2 |
| S2064_330 | 285966.7 | 6195946 | 12 | BulliCoalSeam | 78.9 | -78.9 |
| S2064_373 | 285966.7 | 6195946 | 13 | LawrenceLoddonSst | 51.0 | -51.0 |
| S2064_401 | 285966.7 | 6195946 | 15 | KemblaSst | 129.9 | -129.9 |
| S2070_361 | 287619.3 | 6192813 | 12 | BulliCoalSeam | 52.2 | -52.2 |
| S2070_388 | 287619.3 | 6192813 | 14 | WongawilliCoalSeam | 106.6 | -106.6 |
| S2071_365 | 287027.2 | 6193201 | 11 | CoalcliffSandstone | 8.0 | 8.0 |
| S2071_392 | 287027.2 | 6193201 | 13 | LawrenceLoddonSst | 1.4 | 0.5 |
| S2073_359 | 284404.7 | 6197510 | 12 | BulliCoalSeam | 61.2 | -61.2 |
| S2073_385 | 284404.7 | 6197510 | 13 | LawrenceLoddonSst | 73.1 | -73.1 |
| S2076_401 | 288650.8 | 6197693 | 12 | BulliCoalSeam | 45.2 | -45.2 |
| S2076_428 | 288650.8 | 6197693 | 14 | WongawilliCoalSeam | 57.9 | -57.9 |
| S2078_293 | 288190 | 6192452 | 12 | BulliCoalSeam | 100.0 | -100.0 |
| S2078_323 | 288190 | 6192452 | 14 | WongawilliCoalSeam | 120.8 | -120.8 |
| S2082_377 | 285488.4 | 6197607 | 11 | CoalcliffSandstone | 52.6 | -52.6 |
| S2187_302 | 295521.6 | 6197121 | 13 | LawrenceLoddonSst | 40.7 | -20.8 |
| S2187_331 | 295521.6 | 6197121 | 14 | WongawilliCoalSeam | 54.1 | 54.1 |
| S2188_145 | 296605.1 | 6195670 | 6 | BulgoSst | 6.5 | -6.5 |
| S2188_197 | 296605.1 | 6195670 | 7 | BulgoSst | 93.0 | 93.0 |
| S2188_235 | 296605.1 | 6195670 | 9 | ScarboroughSst | 45.5 | 45.5 |
| S2188_245 | 296605.1 | 6195670 | 9 | ScarboroughSst | 106.5 | 106.5 |
| S2188_256 | 296605.1 | 6195670 | 9 | ScarboroughSst | 63.3 | 63.3 |
| S2188_304 | 296605.1 | 6195670 | 13 | LawrenceLoddonSst | 36.0 | 36.0 |

| Site ID | Easting | Northing | Layer | Formation | Absolute Average Residual | Average Residual |
|---|---|---|---|---|---|---|
| S2188_335 | 296605.1 | 6195670 | 14 | WongawilliCoalSeam | 37.1 | 37.1 |
| S2188_385 | 296605.1 | 6195670 | 17 | LowerPermian | 21.2 | 21.2 |
| S2188_45 | 296605.1 | 6195670 | 4 | HawkesburySst | 21.2 | 21.2 |
| S2188_93 | 296605.1 | 6195670 | 6 | BulgoSst | 8.5 | 8.5 |
| S2192_140 | 289826.7 | 6193849 | 5 | BaldHillClaystone | 14.1 | -7.9 |
| S2192_175 | 289826.7 | 6193849 | 6 | BulgoSst | 14.9 | 9.7 |
| S2192_260 | 289826.7 | 6193849 | 7 | BulgoSst | 13.1 | -9.8 |
| S2192_278 | 289826.7 | 6193849 | 7 | BulgoSst | 62.6 | -62.6 |
| S2192_50 | 289826.7 | 6193849 | 3 | HawkesburySst | 19.8 | 8.1 |
| S2192_95 | 289826.7 | 6193849 | 4 | HawkesburySst | 8.6 | -8.6 |
| S2194_10 | 288514.9 | 6190979 | 3 | HawkesburySst | 18.8 | 18.8 |
| S2194_111 | 288514.9 | 6190979 | 6 | BulgoSst | 3.8 | -3.4 |
| S2194_150 | 288514.9 | 6190979 | 6 | BulgoSst | 19.0 | -19.0 |
| S2194_195 | 288514.9 | 6190979 | 7 | BulgoSst | 59.4 | -59.4 |
| S2194_210 | 288514.9 | 6190979 | 8 | StanwellParkClaystone | 29.7 | -22.8 |
| S2194_239 | 288514.9 | 6190979 | 9 | ScarboroughSst | 38.3 | -27.1 |
| S2194_274 | 288514.9 | 6190979 | 11 | CoalcliffSandstone | 48.8 | -47.6 |
| S2194_30 | 288514.9 | 6190979 | 3 | HawkesburySst | 1.8 | 1.6 |
| S2194_302 | 288514.9 | 6190979 | 14 | WongawilliCoalSeam | 50.6 | -49.4 |
| S2194_339 | 288514.9 | 6190979 | 16 | TongarraCoalSeam | 31.7 | -31.7 |
| S2194_55 | 288514.9 | 6190979 | 4 | HawkesburySst | 7.2 | -7.2 |
| S2207_372 | 291807.6 | 6195324 | 13 | LawrenceLoddonSst | 63.8 | -63.8 |
| S2207_397 | 291807.6 | 6195324 | 15 | KemblaSst | 97.8 | -97.8 |
| S2208A_23 | 292801.1 | 6195037 | 4 | HawkesburySst | 0.8 | -0.8 |
| S2208A_32 | 292801.1 | 6195037 | 4 | HawkesburySst | 2.1 | 0.0 |
| S2208_143 | 292801.1 | 6195037 | 7 | BulgoSst | 4.9 | -4.9 |
| S2208_219 | 292801.1 | 6195037 | 9 | ScarboroughSst | 6.6 | -6.6 |
| S2208_229 | 292801.1 | 6195037 | 9 | ScarboroughSst | 5.3 | -2.7 |
| S2208_307 | 292801.1 | 6195037 | 14 | WongawilliCoalSeam | 62.9 | -62.9 |
| S2208_77 | 292801.1 | 6195037 | 6 | BulgoSst | 2.0 | 1.9 |
| S2211_317 | 293247 | 6194106 | 13 | LawrenceLoddonSst | 22.0 | -22.0 |
| S2211_350 | 293247 | 6194106 | 15 | KemblaSst | 80.6 | -80.6 |
| S2212_154 | 293534.8 | 6194403 | 7 | BulgoSst | 6.6 | 6.6 |
| S2212_215 | 293534.8 | 6194403 | 9 | ScarboroughSst | 29.3 | 29.3 |
| S2212_239 | 293534.8 | 6194403 | 9 | ScarboroughSst | 23.9 | 23.9 |
| S2212_250 | 293534.8 | 6194403 | 10 | WombarraClaystone | 20.8 | 20.8 |
| S2212_260 | 293534.8 | 6194403 | 10 | WombarraClaystone | 16.7 | 16.7 |
| S2212_289 | 293534.8 | 6194403 | 12 | BulliCoalSeam | 55.8 | -55.8 |
| S2212_320 | 293534.8 | 6194403 | 14 | WongawilliCoalSeam | 20.0 | -20.0 |
| S2212_370 | 293534.8 | 6194403 | 16 | TongarraCoalSeam | 10.4 | -10.4 |
| S2212_64 | 293534.8 | 6194403 | 5 | BaldHillClaystone | 1.2 | -0.5 |
| S2212_92 | 293534.8 | 6194403 | 6 | BulgoSst | 0.4 | 0.1 |
| S2220_140 | 289827.2 | 6193831 | 5 | BaldHillClaystone | 45.1 | -45.1 |
| S2220_50 | 289827.2 | 6193831 | 3 | HawkesburySst | 13.9 | 13.9 |
| S2220_95 | 289827.2 | 6193831 | 4 | HawkesburySst | 20.6 | -20.6 |
| S2288_280 | 292801.1 | 6195037 | 12 | BulliCoalSeam | 33.6 | -33.6 |
| S2291_394 | 289003.8 | 6196840 | 11 | CoalcliffSandstone | 26.6 | -23.4 |
| S2291_419 | 289003.8 | 6196840 | 13 | LawrenceLoddonSst | 39.0 | -39.0 |
| S2306_10 | 288643.3 | 6192484 | 2 | HawkesburySst | 31.2 | 31.2 |
| S2306_30 | 288643.3 | 6192484 | 2 | HawkesburySst | 14.7 | 14.7 |
| S2306_50 | 288643.3 | 6192484 | 3 | HawkesburySst | 11.2 | 11.2 |
| S2306_70 | 288643.3 | 6192484 | 3 | HawkesburySst | 8.8 | -8.7 |
| S2307_10 | 288665.9 | 6192425 | 2 | HawkesburySst | 33.1 | 33.1 |
| S2307_22 | 288665.9 | 6192425 | 2 | HawkesburySst | 20.1 | 20.1 |
| S2307_35 | 288665.9 | 6192425 | 3 | HawkesburySst | 28.7 | 28.7 |
| S2307_50 | 288665.9 | 6192425 | 3 | HawkesburySst | 13.1 | 13.1 |
| S2309_112 | 287689.9 | 6194933 | 3 | HawkesburySst | 11.4 | 3.2 |
| S2309_159 | 287689.9 | 6194933 | 4 | HawkesburySst | 11.0 | -11.0 |
| S2309_198 | 287689.9 | 6194933 | 6 | BulgoSst | 40.8 | -40.8 |
| S2309_256 | 287689.9 | 6194933 | 8 | StanwellParkClaystone | 42.5 | -42.5 |
| S2309_315 | 287689.9 | 6194933 | 9 | ScarboroughSst | 7.5 | 0.5 |

| Site ID | Easting | Northing | Layer | Formation | Absolute Average Residual | Average Residual |
|---|---|---|---|---|---|---|
| S2309_350 | 287689.9 | 6194933 | 10 | WombarraClaystone | 11.1 | -11.0 |
| S2309_360 | 287689.9 | 6194933 | 10 | WombarraClaystone | 11.0 | -10.0 |
| S2309_387 | 287689.9 | 6194933 | 12 | BulliCoalSeam | 12.4 | -11.0 |
| S2309_413 | 287689.9 | 6194933 | 14 | WongawilliCoalSeam | 59.0 | 54.6 |
| S2309_65 | 287689.9 | 6194933 | 3 | HawkesburySst | 14.0 | 14.0 |
| S2312_100 | 284450.1 | 6196151 | 3 | HawkesburySst | 3.3 | -3.3 |
| S2312_146 | 284450.1 | 6196151 | 4 | HawkesburySst | 9.0 | -9.0 |
| S2312_192 | 284450.1 | 6196151 | 6 | BulgoSst | 7.6 | -7.6 |
| S2312_232 | 284450.1 | 6196151 | 7 | BulgoSst | 30.2 | -30.2 |
| S2312_271 | 284450.1 | 6196151 | 8 | StanwellParkClaystone | 33.9 | -33.9 |
| S2312_302 | 284450.1 | 6196151 | 9 | ScarboroughSst | 49.3 | -49.3 |
| S2312_318 | 284450.1 | 6196151 | 9 | ScarboroughSst | 55.1 | -55.1 |
| S2312_372 | 284450.1 | 6196151 | 13 | LawrenceLoddonSst | 58.3 | -58.3 |
| S2312_395 | 284450.1 | 6196151 | 14 | WongawilliCoalSeam | 43.0 | -43.0 |
| S2312_55 | 284450.1 | 6196151 | 3 | HawkesburySst | 33.5 | 33.5 |
| S2313_131 | 287609 | 6192816 | 4 | HawkesburySst | 30.4 | -30.4 |
| S2313_182 | 287609 | 6192816 | 6 | BulgoSst | 36.7 | -36.7 |
| S2313_49 | 287609 | 6192816 | 3 | HawkesburySst | 39.5 | 39.5 |
| S2314A_28 | 288193.5 | 6192470 | 3 | HawkesburySst | 12.8 | -12.8 |
| S2314_128 | 288193.5 | 6192470 | 6 | BulgoSst | 32.9 | -32.9 |
| S2314_29 | 288193.5 | 6192470 | 3 | HawkesburySst | 15.3 | -15.3 |
| S2314_75 | 288193.5 | 6192470 | 4 | HawkesburySst | 20.3 | -20.3 |
| S2321_368 | 284710 | 6195576 | 13 | LawrenceLoddonSst | 82.6 | -82.6 |
| S2321_392 | 284710 | 6195576 | 15 | KemblaSst | 66.9 | -66.9 |
| S2325_145 | 283596.2 | 6195467 | 5 | BaldHillClaystone | 12.2 | 4.6 |
| S2325_182 | 283596.2 | 6195467 | 6 | BulgoSst | 13.2 | -13.2 |
| S2325_243 | 283596.2 | 6195467 | 7 | BulgoSst | 21.6 | -21.6 |
| S2325_303 | 283596.2 | 6195467 | 9 | ScarboroughSst | 37.8 | -37.8 |
| S2325_321 | 283596.2 | 6195467 | 10 | WombarraClaystone | 46.4 | -46.4 |
| S2325_332 | 283596.2 | 6195467 | 10 | WombarraClaystone | 48.8 | -48.8 |
| S2325_50 | 283596.2 | 6195467 | 3 | HawkesburySst | 53.7 | 53.7 |
| S2325_97 | 283596.2 | 6195467 | 3 | HawkesburySst | 12.6 | 12.6 |
| S2333_130 | 290697.1 | 6197087 | 6 | BulgoSst | 27.6 | -27.6 |
| S2333_191 | 290697.1 | 6197087 | 7 | BulgoSst | 21.7 | -21.7 |
| S2333_251 | 290697.1 | 6197087 | 8 | StanwellParkClaystone | 31.3 | -31.3 |
| S2333_266 | 290697.1 | 6197087 | 9 | ScarboroughSst | 37.0 | -37.0 |
| S2333_288 | 290697.1 | 6197087 | 9 | ScarboroughSst | 37.7 | -37.7 |
| S2333_339 | 290697.1 | 6197087 | 12 | BulliCoalSeam | 52.0 | -52.0 |
| S2333_364 | 290697.1 | 6197087 | 13 | LawrenceLoddonSst | 48.6 | -48.6 |
| S2333_49 | 290697.1 | 6197087 | 4 | HawkesburySst | 18.6 | -18.6 |
| S2333_68 | 290697.1 | 6197087 | 4 | HawkesburySst | 24.0 | -24.0 |
| S2333_86 | 290697.1 | 6197087 | 4 | HawkesburySst | 24.4 | -24.4 |
| S2335A_10 | 289727 | 6192755 | 5 | BaldHillClaystone | 36.3 | -36.3 |
| S2335A_26 | 289727 | 6192755 | 3 | HawkesburySst | 12.6 | 12.6 |
| S2335A_41 | 289727 | 6192755 | 3 | HawkesburySst | 4.7 | -4.7 |
| S2335A_51 | 289727 | 6192755 | 3 | HawkesburySst | 10.9 | -10.9 |
| S2335A_81 | 289727 | 6192755 | 4 | HawkesburySst | 36.5 | -36.5 |
| S2335A_91 | 289727 | 6192755 | 4 | HawkesburySst | 55.1 | -55.1 |
| S2335_15 | 289725.4 | 6192749 | 3 | HawkesburySst | 21.9 | 21.9 |
| S2335_25 | 289725.4 | 6192749 | 3 | HawkesburySst | 21.3 | 21.3 |
| S2335_30 | 289725.4 | 6192749 | 3 | HawkesburySst | 12.6 | 12.6 |
| S2335_40 | 289725.4 | 6192749 | 3 | HawkesburySst | 3.1 | 2.4 |
| S2335_50 | 289725.4 | 6192749 | 3 | HawkesburySst | 6.5 | -6.5 |
| S2336_32 | 289721.9 | 6192758 | 3 | HawkesburySst | 10.5 | 10.5 |
| S2337_25 | 290021 | 6193412 | 4 | HawkesburySst | 17.9 | -17.9 |
| S2337_36 | 290021 | 6193412 | 4 | HawkesburySst | 29.4 | -29.4 |
| S2337_47 | 290021 | 6193412 | 4 | HawkesburySst | 40.2 | -40.2 |
| S2338_25 | 290012.2 | 6193407 | 4 | HawkesburySst | 18.8 | -18.8 |
| S2338_42 | 290012.2 | 6193407 | 4 | HawkesburySst | 30.1 | -30.1 |
| S2338_50 | 290012.2 | 6193407 | 4 | HawkesburySst | 37.4 | -37.4 |
| S2340_102 | 285468.1 | 6197979 | 3 | HawkesburySst | 23.3 | -23.3 |

| Site ID | Easting | Northing | Layer | Formation | Absolute Average Residual | Average Residual |
|---|---|---|---|---|---|---|
| S2340_148 | 285468.1 | 6197979 | 4 | HawkesburySst | 31.3 | -31.3 |
| S2340_195 | 285468.1 | 6197979 | 6 | BulgoSst | 36.9 | -36.9 |
| S2340_232 | 285468.1 | 6197979 | 6 | BulgoSst | 43.5 | -43.5 |
| S2340_270 | 285468.1 | 6197979 | 7 | BulgoSst | 43.0 | -43.0 |
| S2340_307 | 285468.1 | 6197979 | 8 | StanwellParkClaystone | 49.1 | -49.1 |
| S2340_344 | 285468.1 | 6197979 | 9 | ScarboroughSst | 54.9 | -54.9 |
| S2340_383 | 285468.1 | 6197979 | 12 | BulliCoalSeam | 50.3 | -50.3 |
| S2340_56 | 285468.1 | 6197979 | 3 | HawkesburySst | 22.0 | 22.0 |
| S2341A_10 | 287489 | 6195138 | 2 | HawkesburySst | 34.9 | 34.9 |
| S2341A_26 | 287489 | 6195138 | 2 | HawkesburySst | 18.6 | 18.6 |
| S2341A_42 | 287489 | 6195138 | 2 | HawkesburySst | 14.5 | 14.5 |
| S2341A_59 | 287489 | 6195138 | 2 | HawkesburySst | 4.3 | -4.3 |
| S2341_145 | 287473.5 | 6195150 | 4 | HawkesburySst | 4.2 | -4.2 |
| S2341_185 | 287473.5 | 6195150 | 5 | BaldHillClaystone | 47.6 | -47.6 |
| S2341_221 | 287473.5 | 6195150 | 7 | BulgoSst | 44.9 | -44.9 |
| S2341_257 | 287473.5 | 6195150 | 8 | StanwellParkClaystone | 45.4 | -45.4 |
| S2341_293 | 287473.5 | 6195150 | 9 | ScarboroughSst | 13.5 | 13.5 |
| S2341_329 | 287473.5 | 6195150 | 9 | ScarboroughSst | 4.7 | 2.5 |
| S2341_372 | 287473.5 | 6195150 | 11 | CoalcliffSandstone | 18.6 | -18.6 |
| S2341_401 | 287473.5 | 6195150 | 13 | LawrenceLoddonSst | 20.1 | -20.1 |
| S2341_50 | 287473.5 | 6195150 | 2 | HawkesburySst | 4.6 | 4.6 |
| S2341_97 | 287473.5 | 6195150 | 3 | HawkesburySst | 3.6 | -3.6 |
| S2342_105 | 287953.2 | 6196756 | 3 | HawkesburySst | 6.7 | -6.7 |
| S2342_145 | 287953.2 | 6196756 | 4 | HawkesburySst | 8.8 | -8.8 |
| S2342_190 | 287953.2 | 6196756 | 6 | BulgoSst | 39.9 | -39.9 |
| S2342_225 | 287953.2 | 6196756 | 7 | BulgoSst | 45.9 | -45.9 |
| S2342_260 | 287953.2 | 6196756 | 8 | StanwellParkClaystone | 42.0 | -42.0 |
| S2342_296 | 287953.2 | 6196756 | 8 | StanwellParkClaystone | 47.6 | -47.6 |
| S2342_335 | 287953.2 | 6196756 | 9 | ScarboroughSst | 49.5 | -49.5 |
| S2342_384 | 287953.2 | 6196756 | 11 | CoalcliffSandstone | 43.0 | -43.0 |
| S2342_412 | 287953.2 | 6196756 | 13 | LawrenceLoddonSst | 41.6 | -41.6 |
| S2342_55 | 287953.2 | 6196756 | 3 | HawkesburySst | 18.0 | 18.0 |
| S2345A_10 | 285359.8 | 6196097 | 2 | HawkesburySst | 40.3 | 40.3 |
| S2345A_25 | 285359.8 | 6196097 | 2 | HawkesburySst | 25.3 | 25.3 |
| S2345A_40 | 285359.8 | 6196097 | 2 | HawkesburySst | 18.1 | 18.1 |
| S2345_144 | 285356.8 | 6196095 | 4 | HawkesburySst | 13.0 | -13.0 |
| S2345_185 | 285356.8 | 6196095 | 6 | BulgoSst | 37.1 | -37.1 |
| S2345_221 | 285356.8 | 6196095 | 7 | BulgoSst | 35.2 | -35.2 |
| S2345_257 | 285356.8 | 6196095 | 7 | BulgoSst | 34.6 | -34.6 |
| S2345_293 | 285356.8 | 6196095 | 9 | ScarboroughSst | 53.3 | -53.3 |
| S2345_329 | 285356.8 | 6196095 | 10 | WombarraClaystone | 54.4 | -54.4 |
| S2345_371 | 285356.8 | 6196095 | 13 | LawrenceLoddonSst | 45.2 | -45.2 |
| S2345_55 | 285356.8 | 6196095 | 3 | HawkesburySst | 17.4 | 17.4 |
| S2345_99 | 285356.8 | 6196095 | 3 | HawkesburySst | 10.6 | -10.6 |
| S2348A_10 | 286450.9 | 6196465 | 2 | HawkesburySst | 28.2 | 28.2 |
| S2348A_25 | 286450.9 | 6196465 | 2 | HawkesburySst | 24.0 | 24.0 |
| S2348A_40 | 286450.9 | 6196465 | 2 | HawkesburySst | 22.1 | 22.1 |
| S2348_105 | 286450.5 | 6196462 | 3 | HawkesburySst | 4.5 | -4.5 |
| S2348_145 | 286450.5 | 6196462 | 4 | HawkesburySst | 9.1 | -9.1 |
| S2348_192 | 286450.5 | 6196462 | 6 | BulgoSst | 44.4 | -44.4 |
| S2348_227 | 286450.5 | 6196462 | 7 | BulgoSst | 45.4 | -45.4 |
| S2348_262 | 286450.5 | 6196462 | 8 | StanwellParkClaystone | 43.4 | -43.4 |
| S2348_297 | 286450.5 | 6196462 | 9 | ScarboroughSst | 46.7 | -46.7 |
| S2348_333 | 286450.5 | 6196462 | 10 | WombarraClaystone | 47.8 | -47.8 |
| S2348_376 | 286450.5 | 6196462 | 12 | BulliCoalSeam | 51.2 | -51.2 |
| S2348_403 | 286450.5 | 6196462 | 13 | LawrenceLoddonSst | 39.7 | -39.7 |
| S2348_55 | 286450.5 | 6196462 | 3 | HawkesburySst | 23.6 | 23.6 |
| S2351A_29 | 290054.3 | 6191175 | 3 | HawkesburySst | 37.0 | 37.0 |
| S2351_14 | 290049.6 | 6191178 | 3 | HawkesburySst | 38.1 | 38.1 |
| S2352_127 | 286264.6 | 6195393 | 4 | HawkesburySst | 9.0 | -9.0 |
| S2352_202 | 286264.6 | 6195393 | 7 | BulgoSst | 34.5 | -34.5 |

| Site ID | Easting | Northing | Layer | Formation | Absolute Average Residual | Average Residual |
|---|---|---|---|---|---|---|
| S2352_235 | 286264.6 | 6195393 | 7 | BulgoSst | 40.7 | -40.7 |
| S2352_265 | 286264.6 | 6195393 | 8 | StanwellParkClaystone | 40.1 | -40.1 |
| S2352_298 | 286264.6 | 6195393 | 9 | ScarboroughSst | 47.4 | -47.4 |
| S2352_337 | 286264.6 | 6195393 | 10 | WombarraClaystone | 52.1 | -52.1 |
| S2352_378 | 286264.6 | 6195393 | 13 | LawrenceLoddonSst | 2.7 | -2.7 |
| S2352_410 | 286264.6 | 6195393 | 15 | KemblaSst | 76.4 | -76.4 |
| S2352_55 | 286264.6 | 6195393 | 3 | HawkesburySst | 27.3 | 27.3 |
| S2352_91 | 286264.6 | 6195393 | 3 | HawkesburySst | 5.7 | -5.7 |
| S2354_42 | 289730.9 | 6191414 | 3 | HawkesburySst | 38.3 | 38.3 |
| S2355A_10 | 288135.3 | 6194879 | 2 | HawkesburySst | 29.4 | 29.4 |
| S2355_10 | 288136.2 | 6194878 | 2 | HawkesburySst | 28.3 | 28.3 |
| S2355_25 | 288136.2 | 6194878 | 2 | HawkesburySst | 14.9 | 14.9 |
| S2355_43 | 288136.2 | 6194878 | 2 | HawkesburySst | 3.3 | 3.3 |
| S2355_60 | 288136.2 | 6194878 | 3 | HawkesburySst | 15.7 | 15.7 |
| S2357_10 | 286815 | 6196984 | 2 | HawkesburySst | 26.9 | 26.9 |
| S2357_27 | 286815 | 6196984 | 2 | HawkesburySst | 18.3 | 18.3 |
| S2357_42 | 286815 | 6196984 | 2 | HawkesburySst | 15.6 | 15.6 |
| S2357_56 | 286815 | 6196984 | 3 | HawkesburySst | 14.4 | 14.4 |
| S2359_131 | 285354.6 | 6195548 | 4 | HawkesburySst | 13.5 | -13.5 |
| S2359_186 | 285354.6 | 6195548 | 6 | BulgoSst | 35.2 | -35.2 |
| S2359_247 | 285354.6 | 6195548 | 8 | StanwellParkClaystone | 39.0 | -39.0 |
| S2359_308 | 285354.6 | 6195548 | 10 | WombarraClaystone | 46.4 | -46.4 |
| S2359_318 | 285354.6 | 6195548 | 10 | WombarraClaystone | 47.6 | -47.6 |
| S2359_343 | 285354.6 | 6195548 | 11 | CoalcliffSandstone | 54.0 | -54.0 |
| S2359_363 | 285354.6 | 6195548 | 13 | LawrenceLoddonSst | 52.0 | -52.0 |
| S2359_387 | 285354.6 | 6195548 | 14 | WongawilliCoalSeam | 53.0 | -53.0 |
| S2359_55 | 285354.6 | 6195548 | 3 | HawkesburySst | 18.3 | 18.3 |
| S2359_93 | 285354.6 | 6195548 | 3 | HawkesburySst | 11.6 | -11.6 |
| S2361_10 | 286277.9 | 6195811 | 2 | HawkesburySst | 32.4 | 32.4 |
| S2361_27 | 286277.9 | 6195811 | 2 | HawkesburySst | 22.6 | 22.6 |
| S2361_42 | 286277.9 | 6195811 | 2 | HawkesburySst | 15.9 | 15.9 |
| S2361_60 | 286277.9 | 6195811 | 3 | HawkesburySst | 6.5 | 6.5 |
| S2362_10 | 285772.9 | 6195823 | 2 | HawkesburySst | 359.1 | -359.1 |
| S2362_41 | 285772.9 | 6195823 | 2 | HawkesburySst | 30.1 | 30.1 |
| S2362_58 | 285772.9 | 6195823 | 3 | HawkesburySst | 43.6 | 43.6 |
| S2364_10 | 285982.8 | 6196782 | 2 | HawkesburySst | 30.0 | 30.0 |
| S2364_27 | 285982.8 | 6196782 | 2 | HawkesburySst | 22.0 | 22.0 |
| S2364_42 | 285982.8 | 6196782 | 2 | HawkesburySst | 13.1 | 13.1 |
| S2364_60 | 285982.8 | 6196782 | 3 | HawkesburySst | 1.6 | 1.6 |
| S2365A_10 | 286041.9 | 6196443 | 2 | HawkesburySst | 32.2 | 32.2 |
| S2365_10 | 286042.3 | 6196449 | 2 | HawkesburySst | 31.6 | 31.6 |
| S2365_25 | 286042.3 | 6196449 | 2 | HawkesburySst | 23.2 | 23.2 |
| S2365_41 | 286042.3 | 6196449 | 2 | HawkesburySst | 14.8 | 14.8 |
| S2365_64 | 286042.3 | 6196449 | 3 | HawkesburySst | 5.4 | 5.4 |
| S2370_112 | 285554.8 | 6196643 | 4 | HawkesburySst | 11.6 | -11.6 |
| S2370_162 | 285554.8 | 6196643 | 6 | BulgoSst | 38.4 | -38.4 |
| S2370_203 | 285554.8 | 6196643 | 7 | BulgoSst | 33.7 | -33.7 |
| S2370_257 | 285554.8 | 6196643 | 8 | StanwellParkClaystone | 47.3 | -47.3 |
| S2370_282 | 285554.8 | 6196643 | 9 | ScarboroughSst | 53.5 | -53.5 |
| S2370_298 | 285554.8 | 6196643 | 9 | ScarboroughSst | 56.1 | -56.1 |
| S2370_339 | 285554.8 | 6196643 | 10 | WombarraClaystone | 55.1 | -55.1 |
| S2370_362 | 285554.8 | 6196643 | 13 | LawrenceLoddonSst | 57.9 | -57.9 |
| S2370_47 | 285554.8 | 6196643 | 3 | HawkesburySst | 2.1 | -2.1 |
| S2370_70 | 285554.8 | 6196643 | 3 | HawkesburySst | 24.4 | -24.4 |
| S2376_107 | 288400.4 | 6192527 | 5 | BaldHillClaystone | 27.5 | -27.5 |
| S2376_169 | 288400.4 | 6192527 | 6 | BulgoSst | 56.1 | -56.1 |
| S2376_29 | 288400.4 | 6192527 | 3 | HawkesburySst | 2.7 | 2.7 |
| S2377_112 | 288333.4 | 6192020 | 4 | HawkesburySst | 24.7 | -24.7 |
| S2377_187 | 288333.4 | 6192020 | 6 | BulgoSst | 21.3 | -21.3 |
| S2377_27 | 288333.4 | 6192020 | 3 | HawkesburySst | 51.0 | 51.0 |
| S2378_164 | 288407.4 | 6191771 | 6 | BulgoSst | 13.4 | -13.1 |

| Site ID | Easting | Northing | Layer | Formation | Absolute Average Residual | Average Residual |
|---|---|---|---|---|---|---|
| S2378_30 | 288407.4 | 6191771 | 3 | HawkesburySst | 20.5 | 20.5 |
| S2378_90 | 288407.4 | 6191771 | 4 | HawkesburySst | 15.6 | -15.6 |
| S2379_108 | 288312.9 | 6191141 | 6 | BulgoSst | 24.5 | 19.0 |
| S2379_30 | 288312.9 | 6191141 | 4 | HawkesburySst | 4.2 | -4.2 |
| S2379_50 | 288312.9 | 6191141 | 4 | HawkesburySst | 14.4 | -14.4 |
| S2398A_10 | 289072.9 | 6192157 | 2 | HawkesburySst | 46.8 | 46.8 |
| S2398B_10 | 289070.9 | 6192173 | 6 | BulgoSst | 39.5 | 39.5 |
| S2398B_14 | 289070.9 | 6192173 | 3 | HawkesburySst | 69.1 | -69.1 |
| S2398B_17 | 289070.9 | 6192173 | 4 | HawkesburySst | 91.9 | -91.9 |
| S2398B_19 | 289070.9 | 6192173 | 5 | BaldHillClaystone | 79.6 | -79.6 |
| S2398B_23 | 289070.9 | 6192173 | 6 | BulgoSst | 81.5 | -81.5 |
| S2398B_30 | 289070.9 | 6192173 | 2 | HawkesburySst | 25.5 | 25.5 |
| S2398B_69 | 289070.9 | 6192173 | 3 | HawkesburySst | 8.3 | 8.3 |
| S2398_108 | 289073.2 | 6192164 | 3 | HawkesburySst | 29.8 | -29.8 |
| S2398_147 | 289073.2 | 6192164 | 4 | HawkesburySst | 65.2 | -65.2 |
| S2398_171 | 289073.2 | 6192164 | 5 | BaldHillClaystone | 56.7 | -56.7 |
| S2398_190 | 289073.2 | 6192164 | 6 | BulgoSst | 34.8 | -34.8 |
| S2398_233 | 289073.2 | 6192164 | 7 | BulgoSst | 52.9 | -52.9 |
| S2398_30 | 289073.2 | 6192164 | 2 | HawkesburySst | 26.5 | 26.5 |
| S2398_69 | 289073.2 | 6192164 | 3 | HawkesburySst | 12.4 | 12.4 |
| S2399A_11 | 289815.6 | 6192968 | 3 | HawkesburySst | 7.2 | 7.2 |
| S2399A_30 | 289815.6 | 6192968 | 3 | HawkesburySst | 12.4 | -12.4 |
| S2399_107 | 289810.5 | 6192965 | 5 | BaldHillClaystone | 45.7 | -45.7 |
| S2399_11 | 289810.5 | 6192965 | 3 | HawkesburySst | 7.2 | 7.2 |
| S2399_132 | 289810.5 | 6192965 | 6 | BulgoSst | 16.0 | -16.0 |
| S2399_172 | 289810.5 | 6192965 | 7 | BulgoSst | 8.9 | -8.9 |
| S2399_30 | 289810.5 | 6192965 | 3 | HawkesburySst | 12.5 | -12.5 |
| S2399_48 | 289810.5 | 6192965 | 3 | HawkesburySst | 23.5 | -23.5 |
| S2399_65 | 289810.5 | 6192965 | 4 | HawkesburySst | 44.3 | -44.3 |
| S2399_88 | 289810.5 | 6192965 | 4 | HawkesburySst | 62.1 | -62.1 |
| S2401_116 | 287752.2 | 6194265 | 4 | HawkesburySst | 1.6 | -1.6 |
| S2401_15 | 287752.2 | 6194265 | 2 | HawkesburySst | 40.6 | 40.6 |
| S2401_26 | 287752.2 | 6194265 | 2 | HawkesburySst | 23.1 | 23.1 |
| S2401_45 | 287752.2 | 6194265 | 2 | HawkesburySst | 15.2 | 15.2 |
| S2401_67 | 287752.2 | 6194265 | 3 | HawkesburySst | 10.8 | 10.8 |
| S2401_90 | 287752.2 | 6194265 | 3 | HawkesburySst | 1.2 | 1.2 |
| S2402_15 | 288207.8 | 6193667 | 2 | HawkesburySst | 28.1 | 28.1 |
| S2402_23 | 288207.8 | 6193667 | 2 | HawkesburySst | 20.2 | 20.2 |
| S2402_40 | 288207.8 | 6193667 | 2 | HawkesburySst | 3.1 | 3.1 |
| S2402_55 | 288207.8 | 6193667 | 2 | HawkesburySst | 12.1 | -12.1 |
| S2402_80 | 288207.8 | 6193667 | 3 | HawkesburySst | 14.0 | -14.0 |
| S2402_91 | 288207.8 | 6193667 | 3 | HawkesburySst | 30.8 | -30.8 |
| S2403_15 | 288345.1 | 6193761 | 2 | HawkesburySst | 25.7 | 25.7 |
| S2403_23 | 288345.1 | 6193761 | 2 | HawkesburySst | 17.6 | 17.6 |
| S2403_39 | 288345.1 | 6193761 | 2 | HawkesburySst | 1.6 | 1.6 |
| S2403_48 | 288345.1 | 6193761 | 2 | HawkesburySst | 2.0 | -2.0 |
| S2403_55 | 288345.1 | 6193761 | 2 | HawkesburySst | 8.2 | -8.2 |
| S2403_59 | 288345.1 | 6193761 | 3 | HawkesburySst | 3.1 | 3.1 |
| S2404_10 | 288528.6 | 6193897 | 2 | HawkesburySst | 28.4 | 28.4 |
| S2404_20 | 288528.6 | 6193897 | 2 | HawkesburySst | 17.4 | 17.4 |
| S2404_30 | 288528.6 | 6193897 | 2 | HawkesburySst | 7.4 | 7.4 |
| S2404_40 | 288528.6 | 6193897 | 2 | HawkesburySst | 2.7 | -2.7 |
| S2404_50 | 288528.6 | 6193897 | 3 | HawkesburySst | 11.0 | 11.0 |
| S2404_58 | 288528.6 | 6193897 | 3 | HawkesburySst | 1.2 | -1.2 |
| S2405_10 | 288729.5 | 6194088 | 2 | HawkesburySst | 20.2 | 20.2 |
| S2405_24 | 288729.5 | 6194088 | 2 | HawkesburySst | 6.4 | 6.4 |
| S2405_34 | 288729.5 | 6194088 | 2 | HawkesburySst | 6.1 | -6.1 |
| S2405_48 | 288729.5 | 6194088 | 3 | HawkesburySst | 2.9 | 2.9 |
| S2405_58 | 288729.5 | 6194088 | 3 | HawkesburySst | 2.0 | -2.0 |
| S2405_64 | 288729.5 | 6194088 | 3 | HawkesburySst | 9.8 | -9.8 |
| S2406_10 | 288669.1 | 6194176 | 2 | HawkesburySst | 29.9 | 29.9 |

| Site ID | Easting | Northing | Layer | Formation | Absolute Average Residual | Average Residual |
|---|---|---|---|---|---|---|
| S2406_25 | 288669.1 | 6194176 | 2 | HawkesburySst | 15.2 | 15.2 |
| S2406_32 | 288669.1 | 6194176 | 2 | HawkesburySst | 11.6 | 11.6 |
| S2406_48 | 288669.1 | 6194176 | 3 | HawkesburySst | 11.2 | 11.2 |
| S2406_58 | 288669.1 | 6194176 | 3 | HawkesburySst | 1.3 | 1.3 |
| S2406_79 | 288669.1 | 6194176 | 3 | HawkesburySst | 6.6 | -6.6 |
| S2408_11 | 289552.1 | 6192193 | 4 | HawkesburySst | 46.3 | 46.3 |
| S2408_113 | 289552.1 | 6192193 | 4 | HawkesburySst | 55.2 | -55.2 |
| S2408_15 | 289552.1 | 6192193 | 2 | HawkesburySst | 20.3 | 20.3 |
| S2408_26 | 289552.1 | 6192193 | 2 | HawkesburySst | 8.2 | 8.2 |
| S2408_45 | 289552.1 | 6192193 | 3 | HawkesburySst | 20.6 | 20.6 |
| S2408_67 | 289552.1 | 6192193 | 3 | HawkesburySst | 11.3 | -11.3 |
| S2408_90 | 289552.1 | 6192193 | 4 | HawkesburySst | 27.0 | -27.0 |
| S2409_118 | 289546.1 | 6192270 | 4 | HawkesburySst | 40.4 | -40.4 |
| S2409_15 | 289546.1 | 6192270 | 2 | HawkesburySst | 17.8 | 17.8 |
| S2409_26 | 289546.1 | 6192270 | 2 | HawkesburySst | 8.2 | 8.2 |
| S2409_45 | 289546.1 | 6192270 | 3 | HawkesburySst | 16.9 | 16.9 |
| S2409_67 | 289546.1 | 6192270 | 3 | HawkesburySst | 10.4 | -10.4 |
| S2409_90 | 289546.1 | 6192270 | 4 | HawkesburySst | 30.9 | -30.9 |
| S2411A_11 | 289761.6 | 6192839 | 3 | HawkesburySst | 14.5 | 14.5 |
| S2411_109 | 289761.1 | 6192838 | 5 | BaldHillClaystone | 38.2 | -38.2 |
| S2411_11 | 289761.1 | 6192838 | 3 | HawkesburySst | 14.6 | 14.6 |
| S2411_137 | 289761.1 | 6192838 | 6 | BulgoSst | 7.6 | -4.6 |
| S2411_177 | 289761.1 | 6192838 | 7 | BulgoSst | 10.8 | -10.8 |
| S2411_30 | 289761.1 | 6192838 | 3 | HawkesburySst | 3.7 | -3.7 |
| S2411_50 | 289761.1 | 6192838 | 3 | HawkesburySst | 23.6 | -23.6 |
| S2411_69 | 289761.1 | 6192838 | 4 | HawkesburySst | 39.6 | -39.6 |
| S2411_89 | 289761.1 | 6192838 | 4 | HawkesburySst | 58.8 | -58.8 |
| S2412B_10 | 289201.1 | 6191807 | 6 | BulgoSst | 108.5 | 108.5 |
| S2412B_14 | 289201.1 | 6191807 | 4 | HawkesburySst | 58.2 | -58.2 |
| S2412B_17 | 289201.1 | 6191807 | 5 | BaldHillClaystone | 56.7 | -56.7 |
| S2412B_19 | 289201.1 | 6191807 | 6 | BulgoSst | 27.7 | -27.7 |
| S2412B_23 | 289201.1 | 6191807 | 7 | BulgoSst | 16.0 | -16.0 |
| S2412B_38 | 289201.1 | 6191807 | 2 | HawkesburySst | 21.0 | 21.0 |
| S2412B_69 | 289201.1 | 6191807 | 3 | HawkesburySst | 11.2 | 11.2 |
| S2412_10 | 289201.1 | 6191807 | 3 | HawkesburySst | 73.9 | 73.9 |
| S2412_107 | 289201.1 | 6191807 | 4 | HawkesburySst | 17.3 | -17.3 |
| S2412_146 | 289201.1 | 6191807 | 4 | HawkesburySst | 39.9 | -39.9 |
| S2412_173 | 289201.1 | 6191807 | 5 | BaldHillClaystone | 29.4 | -29.4 |
| S2412_192 | 289201.1 | 6191807 | 6 | BulgoSst | 42.3 | -42.3 |
| S2412_232 | 289201.1 | 6191807 | 7 | BulgoSst | 24.7 | -24.7 |
| S2412_30 | 289201.1 | 6191807 | 2 | HawkesburySst | 31.9 | 31.9 |
| S2412_69 | 289201.1 | 6191807 | 3 | HawkesburySst | 24.0 | 24.0 |
| S2420_121 | 289738.4 | 6192780 | 5 | BaldHillClaystone | 39.1 | -39.1 |
| S2420_140 | 289738.4 | 6192780 | 6 | BulgoSst | 7.8 | -7.8 |
| S2420_180 | 289738.4 | 6192780 | 7 | BulgoSst | 5.6 | -5.5 |
| S2420_30 | 289738.4 | 6192780 | 3 | HawkesburySst | 0.2 | -0.2 |
| S2420_51 | 289738.4 | 6192780 | 3 | HawkesburySst | 21.5 | -21.5 |
| S2420_72 | 289738.4 | 6192780 | 4 | HawkesburySst | 39.9 | -39.9 |
| S2420_93 | 289738.4 | 6192780 | 4 | HawkesburySst | 60.9 | -60.9 |
| S2421_11 | 289590.4 | 6192492 | 2 | HawkesburySst | 10.3 | 10.3 |
| S2421_114 | 292788.5 | 6193213 | 5 | BaldHillClaystone | 66.8 | -66.8 |
| S2421_134 | 289590.4 | 6192492 | 5 | BaldHillClaystone | 48.3 | -48.3 |
| S2421_157 | 289590.4 | 6192492 | 6 | BulgoSst | 3.0 | -2.0 |
| S2421_197 | 289590.4 | 6192492 | 7 | BulgoSst | 12.8 | -12.8 |
| S2421_30 | 289590.4 | 6192492 | 3 | HawkesburySst | 12.3 | 12.3 |
| S2421_58 | 289590.4 | 6192492 | 3 | HawkesburySst | 15.7 | -15.7 |
| S2421_86 | 289590.4 | 6192492 | 4 | HawkesburySst | 42.8 | -42.8 |
| S2435_100 | 288080.8 | 6192412 | 6 | BulgoSst | 2.9 | 2.9 |
| S2435_25 | 288080.8 | 6192412 | 4 | HawkesburySst | 24.7 | -24.7 |
| S2435_60 | 288080.8 | 6192412 | 4 | HawkesburySst | 22.2 | -22.2 |
| S2436B_35 | 288313.8 | 6191500 | 5 | BaldHillClaystone | 7.2 | -7.2 |

| Site ID | Easting | Northing | Layer | Formation | Absolute Average Residual | Average Residual |
|---|---|---|---|---|---|---|
| S2436C_45 | 288319.6 | 6191501 | 5 | BaldHillClaystone | 17.4 | -17.4 |
| S2436_25 | 288313.8 | 6191500 | 4 | HawkesburySst | 23.7 | -23.7 |
| S2436_65 | 288313.8 | 6191500 | 5 | BaldHillClaystone | 10.5 | -10.5 |
| S2436_93 | 288313.8 | 6191500 | 6 | BulgoSst | 0.9 | 0.9 |
| S2438_136 | 287944.9 | 6197535 | 4 | HawkesburySst | 7.2 | -7.2 |
| S2438_194 | 287944.9 | 6197535 | 6 | BulgoSst | 40.9 | -40.9 |
| S2438_233 | 287944.9 | 6197535 | 7 | BulgoSst | 45.2 | -45.2 |
| S2438_265 | 287944.9 | 6197535 | 8 | StanwellParkClaystone | 44.2 | -44.2 |
| S2438_315 | 287944.9 | 6197535 | 9 | ScarboroughSst | 56.9 | -56.9 |
| S2438_350 | 287944.9 | 6197535 | 10 | WombarraClaystone | 48.9 | -48.9 |
| S2438_400 | 287944.9 | 6197535 | 13 | LawrenceLoddonSst | 51.9 | -51.9 |
| S2438_98 | 287944.9 | 6197535 | 3 | HawkesburySst | 9.4 | -9.4 |
| S2442A_11 | 292788.5 | 6193213 | 5 | BaldHillClaystone | 40.3 | -40.3 |
| S2442A_12 | 292788.5 | 6193213 | 6 | BulgoSst | 5.0 | 5.0 |
| S2442A_15 | 292788.5 | 6193213 | 6 | BulgoSst | 104.2 | 104.2 |
| S2442A_20 | 292788.5 | 6193213 | 7 | BulgoSst | 24.6 | -24.6 |
| S2442A_49 | 292788.5 | 6193213 | 3 | HawkesburySst | 6.6 | -6.6 |
| S2442A_80 | 292788.5 | 6193213 | 4 | HawkesburySst | 31.5 | -31.5 |
| S2443_113 | 292176 | 6193027 | 4 | HawkesburySst | 27.0 | -27.0 |
| S2443_138 | 292176 | 6193027 | 5 | BaldHillClaystone | 11.7 | -11.7 |
| S2443_14 | 292176 | 6193027 | 2 | HawkesburySst | 33.1 | 33.1 |
| S2443_155 | 292176 | 6193027 | 6 | BulgoSst | 21.9 | 21.9 |
| S2443_225 | 292176 | 6193027 | 7 | BulgoSst | 26.3 | -26.3 |
| S2443_65 | 292176 | 6193027 | 3 | HawkesburySst | 0.7 | 0.7 |
| S2444_44 | 289077.9 | 6190168 | 4 | HawkesburySst | 16.4 | -16.4 |
| S2486_113 | 288890 | 6192725 | 3 | HawkesburySst | 31.7 | -31.7 |
| S2486_150 | 288890 | 6192725 | 4 | HawkesburySst | 69.2 | -69.2 |
| S2486_198 | 288890 | 6192725 | 6 | BulgoSst | 22.6 | -22.6 |
| S2486_252 | 288890 | 6192725 | 7 | BulgoSst | 44.4 | -44.4 |
| S2486_285 | 288890 | 6192725 | 8 | StanwellParkClaystone | 8.2 | 8.2 |
| S2486_38 | 288890 | 6192725 | 2 | HawkesburySst | 15.4 | 15.4 |
| S2486_70 | 288890 | 6192725 | 3 | HawkesburySst | 7.6 | 7.6 |
| S2487_120 | 290707 | 6191689 | 5 | BaldHillClaystone | 6.7 | 6.7 |
| S2487_150 | 290707 | 6191689 | 6 | BulgoSst | 4.7 | -4.3 |
| S2487_165 | 290707 | 6191689 | 6 | BulgoSst | 7.3 | -7.3 |
| S2487_30 | 290707 | 6191689 | 3 | HawkesburySst | 49.6 | 49.6 |
| S2487_75 | 290707 | 6191689 | 4 | HawkesburySst | 15.7 | 15.7 |