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Groundwater Response to Planning Assessment Report

BYLONG COAL PROJECT
Response to PAC Review Report

Hansen Bailey
ENVIRONMENTAL CONSULTANTS

Australasian Groundwater and
Environmental Consultants Pty Ltd

Report on

Bylong Coal Project

Response to Planning Assessment Commission

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Australasian Groundwater and Environmental Consultants Pty Ltd

AGE Head Office
Level 2 / 15 Mallon Street,
Bowen Hills, QLD 4006, Australia
T. +61 7 3257 2055
F. +61 7 3257 2088
brisbane@ageconsultants.com.au

AGE Newcastle Office
4 Hudson Street
Hamilton, NSW 2303, Australia
T. +61 2 4962 2091
F. +61 2 4962 2096
newcastle@ageconsultants.com.au

AGE Townsville Office
Level 3 / 201 Sturt Street
Townsville, QLD 4810, Australia
T. +61 429 492 716
F. +61 7 3257 2088
townsville@ageconsultants.com.au

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Report on

Bylong Coal Project
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1 Purpose of summary report

The purpose of this report is to summarise the results of the groundwater investigations conducted for the Project for non-specialists in groundwater. It aims to provide a plain English summary of the groundwater investigations conducted at Bylong and the approach to modelling and managing the predicted impacts on aquifers and private landholders.

KEPCO Bylong Australia Pty Ltd (KEPCO) is planning to develop an integrated open cut and underground coal mine in the Bylong Valley (the Project), which is located in the Mid-Western Region of New South Wales (NSW). The Project has been subject to two levels of groundwater assessment, according to the NSW Regulatory Regime. The first was an initial groundwater assessment addressing the requirements of the NSW Gateway Certificate Assessment process (Gateway). The second stage was a groundwater impact assessment prepared for the Environmental Impact Statement (EIS). Major milestones for the EIS process relating to groundwater include:

- July 2015 EIS submitted to the NSW Government and placed on public exhibition between 23 September 2015 and 6 November 2015;
- March 2016 Response to submissions (RTS) document submitted;
- May 2016 Additional submissions from NSW Government agencies received;
- August 2016 Supplementary Response to Submissions (Supplementary RTS) document submitted; and
- March 2017 Department of Planning and Environment (DP&E) Assessment Report released.

In January 2017, the then Minister for Planning requested the Planning Assessment Commission (PAC) to conduct a review of the Project and to prepare a review report. The PAC subsequently conducted a review of the Project which comprised a site visit and public hearings held on 10 and 11 May 2017, respectively. The PAC has reviewed the EIS and supplementary reports during the course of preparing its review report for the Project. The PAC Review Report notes the complexity of the groundwater study, the multiple versions of the numerical model and the uncertainty around predictions. In this regard, the PAC Review Report has suggested that "*a summary that outlines the course of particular issues, as they received increasingly detailed attention, would be beneficial*".

Hansen Bailey Environmental Consultants Pty Ltd (Hansen Bailey) engaged Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) to respond to the PAC Review Report on behalf of its client WorleyParsons Services Pty Ltd (WorleyParsons). The purpose of this report is to clarify and summarise the results of the groundwater investigations conducted for the Project for non-specialists in groundwater. This summary report provides the following information:

- Section 2 provides a simplified summary of numerical groundwater flow models and the modelling undertaken for the Project;
- Section 3 summaries the results of additional groundwater monitoring and investigation undertaken by KEPCO and how this relates to the groundwater modelling; and

- Section 4 discusses measures to monitor, manage and mitigate impacts on groundwater systems and users.

2 Groundwater modelling

2.1 How computer models are used to model flow of groundwater

Water moving through rocks and sediment underground cannot be seen - this often means the processes that control the flow of underground water are often considered mysterious. Whilst the processes remain mysterious for those who have not undertaken research on the subject, the disciplines of science and engineering have been unravelling this mystery for literally centuries. A law describing the flow of groundwater was developed by Henry Darcy in 1856 and remains in common use today. Through this culminated effort over time, the flow of groundwater can now be represented with complex mathematical equations, and the complex effects of major projects understood by using powerful modern software and computers.

Groundwater models represent processes occurring in groundwater systems. Historically, there have been a range of different types of models designed to represent groundwater systems. These have ranged from physical models (basically boxes of sand and clay) and electrical models (using resistors), to simple analytical models and complex computer based numerical models. Numerical models are now routinely employed to assist in decision making for the management of groundwater resources. They are based on the governing groundwater flow equation[1].

Improvements in computational power over recent decades have allowed numerical groundwater models to represent groundwater flow across larger regional areas in three dimensions (3D). The models are designed to solve the groundwater flow equation at thousands or even millions of spatial locations to represent the movement of groundwater on a regional scale. For example, a computer can calculate the level of the water table every 50 m on a grid pattern across many hundreds of square kilometres.

The most successful computer program is MODFLOW, which was developed by the United States Geological Survey in the early 1980's. MODFLOW has since become a widely used program for 3D simulations of the groundwater flow in Australia and overseas, as it has been demonstrated to effectively represent the impacts of human or natural processes on groundwater systems. MODFLOW has been used to assess the impact of the Bylong Project on the regional groundwater system.

In Australia the process used to construct a model is described by guidelines released by the National Water Commission (Barnett et al, 2012). The first stage of the modelling process requires development of a conceptual model that describes processes affecting the groundwater system. This typically requires field data. The aim of collecting field data[2] is to develop an understanding of how a groundwater system operates and then represent the key processes in a simplified manner within a numerical model. Once the conceptual model is complete the subject area is to be divided into an appropriate number of units[3] and then the characteristics and conditions are assigned at each unit.

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[1] The groundwater flow equation is the mathematical relationship which is used to describe the flow of groundwater through an aquifer.

[2] At Bylong, the field data has included installing 111 groundwater monitoring points, and monitoring over a six year period commencing in 2011.

[3] Units are typically aquifers, aquitards or aquicludes - an aquifer is an underground layer of water-bearing permeable rock, rock fractures or unconsolidated materials (gravel, sand, or silt) from which groundwater can

Computer code such as MODFLOW is then used to calculate changes in groundwater levels by solving the groundwater flow equation[1]. The ability of the model to reproduce water level changes that have been measured in bores or base flows measured in streams is typically improved through a calibration process. Once the calibration process has refined the ability to accurately represent natural variations in groundwater flow, the model can then be used to predict changes to groundwater systems based on various management activities. Finally, the results of the modelling are described in a report that aims to make the results of the modelling clear to both specialists and non-specialists in the discipline.

2.2 Summary of groundwater modelling for the Bylong Project

Groundwater modelling has been used to assess the impact of the Bylong Project on the regional groundwater systems. The work on the model is described in a series of documents including the Gateway Application, EIS, RTS and supplementary RTS. As more data has become available, the model has gradually been refined from an initially simple representation of the aquifer system to one with an appropriate degree of complexity and now describes uncertainty and the range of possible outcomes for the decision making process.

2.2.1 History of modelling

Data collection including drilling bores, testing permeability and monitoring groundwater levels commenced at the Project site in late-2011. The field data was used to develop a conceptual understanding of how the groundwater systems operated and forms the basis of the numerical model. The first numerical model was commissioned in 2012 and was completed in late 2013. This model provided preliminary predictions of Project impacts and formed part of a submission seeking a Gateway Certificate for the Project to the Mining and Petroleum Gateway Panel (Gateway Panel) (AGE 2013). Following receipt of the Gateway Certificate, a new version of the numerical model was developed for the Bylong Coal Project EIS (AGE 2015) throughout 2014 and 2015.

The purpose of the revised modelling within the EIS was to address the Secretary's Environmental Assessment Requirements (SEARs) and the recommendations from the Gateway Panel. The numerical groundwater model was updated to respond to the various submissions received on the EIS in early 2016 as described by AGE (2016a). In August 2016, the numerical model was refined to incorporate the results of a pump testing program conducted within the alluvial aquifer and to respond to subsidiary comments on the EIS and RTS. This report was included as supporting information within the Supplementary RTS (AGE 2016b).

Finally this document, which responds to the PAC report includes the results of a further validation of the numerical model using recent water level data. Figure 2-1 shows graphically a timeline of how the numerical modelling has progressed over the approvals period.

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be extracted using a water well. An aquitard is a bed of low permeability along an aquifer, whilst an aquiclude is a solid, virtually impermeable area underlying or overlying an aquifer.

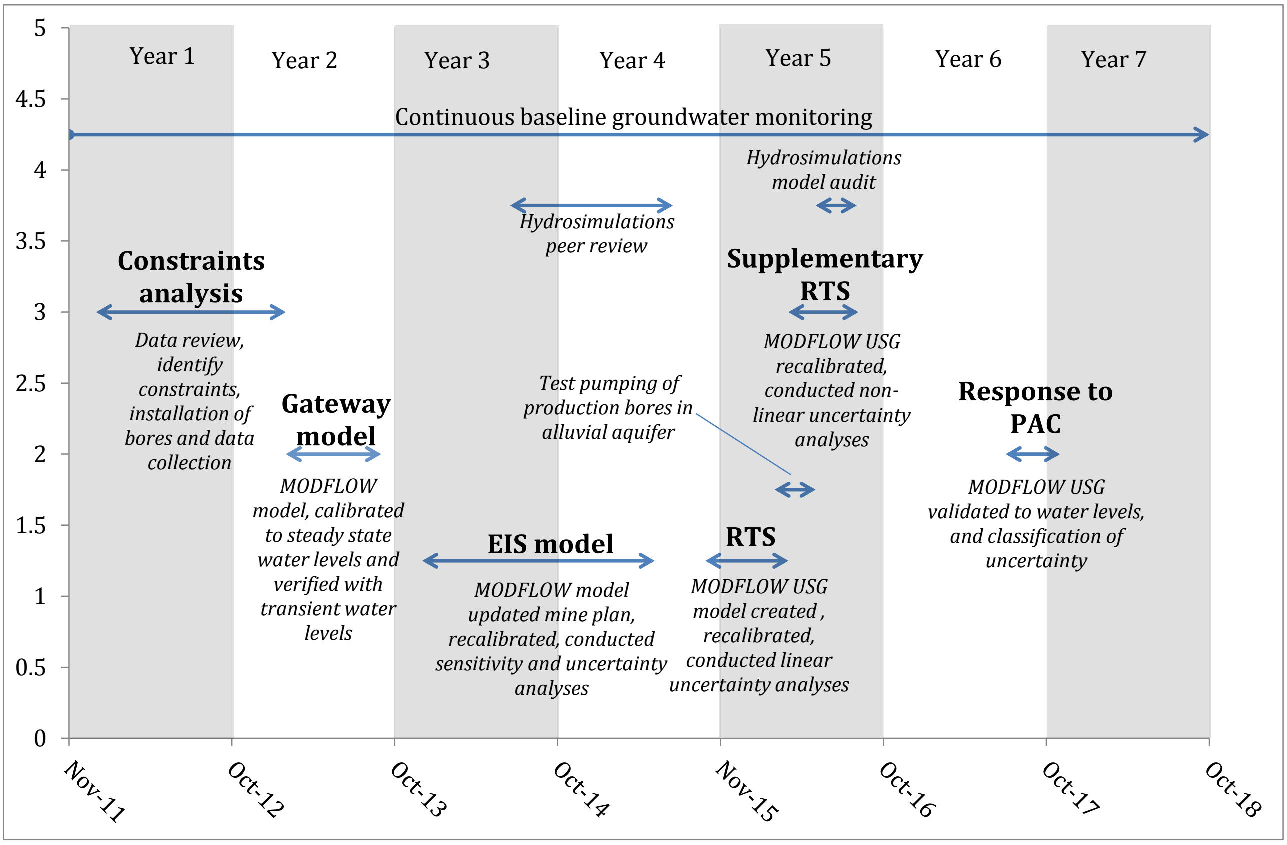

Figure 2-1 Timeline showing evolution of numerical model

When considering the numerical modelling for the Project, the PAC (2017) noted that *"…the many documents, peer reviews and counter responses may have been difficult for non-specialist observers to follow. For transparency, a summary that outlines the course of particular issues, as they received increasingly detailed attention, would be beneficial"*

The following describes how the modelling evolved to address a range of issues identified during the approvals process. Some of the key issues that were gradually addressed through the numerical modelling over time were:

- the permeability and sustainable yield of the alluvial aquifer;
- connectivity of the coal seams with the alluvial aquifer;
- the approach to representing the unsaturated zone; and
- validation of the model codes being used.

The permeability and sustainable yield of the alluvial aquifer system was a focus for stakeholders from the commencement of the Project. The initial field investigation programs conducted for the Gateway and EIS utilised water level tests within monitoring bores installed within the alluvial aquifer to characterise the permeability of the alluvial sediments. The results of this testing then guided the permeability range adopted for the alluvial aquifer within the numerical model.

A submission from the Department of Primary Industries – Water (DPI-Water) requested larger diameter pumping bores be installed to provide more confidence in the permeability and yields from bores within the alluvial groundwater system. In early 2016, KEPCO subsequently installed test bores at four sites and conducted extended yield testing. The results of the pumping tests (described in AGE 2016b – Section 5.1.1) indicated the permeability and available yield was higher than indicated through the monitoring bore testing. Given the results of the testing was not available for use within the RTS, the information was utilised to revise the groundwater model within the Supplementary RTS as described by AGE (2016b).

Between mid 2012 and mid 2016, a four year period of low rainfall resulted in the groundwater levels within the alluvium at the Project site declining by some 2 m. When the numerical model was recalibrated as part of the RTS work (AGE 2016a) to represent this dry period using the lower range permeability for the alluvium (I.e. prior to the pumping tests becoming available), the results indicated the borefield yield would be heavily influenced by climatic conditions. However, after the pumping tests were conducted and the modelling was updated within the Supplementary RTS (AGE 2016b) the modelling confirmed the alluvial system would be a more reliable source of make up water during extended dry periods.

During the RTS, the DPI-Water raised concerns about how the groundwater model represented the connection between the coal seams and the alluvial aquifer. AGE (2016a) agreed that the sub-crop of the coal seams where they are buried under the Quaternary alluvium may provide a pathway for alluvial groundwater to enter the open cut mine workings. Within the early versions of the model developed for the Gateway and the EIS model the alluvium and coal seams were not directly connected, but separated by two layers of interburden within the model. When the numerical model was updated to MODFLOW USG by AGE (2016a) the ability to connect the alluvial and coal layers directly through the sub-crop was available in the computer code. The MODFLOW USG version of the model therefore represented a direct connection of the coal with the alluvium, where this has been identified in the Project site.

The most appropriate model code, and also settings within the model code to represent recharge through the unsaturated zone also resulted in some evolution of the modelling. The history of the modelling described by AGE (2016b) describes the early use of the vadose zone approach in the Gateway and EIS, and the change in the methodology to the pseudo soil approach in the RTS and supplementary RTS.

The peer review commissioned by the DP&E and conducted by Kalf and Associates also requested a significant investigation to compare the results between MODFLOW SURFACT[4] used in the Gateway/EIS and the MODFLOW USG utilised for the RTS and supplementary RTS. Hydrosimulations (2015) conducted the review and concluded after comparing multiple versions of the model it had *"not been possible to state that either of the two software packages (SURFACT and USG) is more suitable than the other, or that vadose (using Richards equation) versus pseudo soils (or upstream weighting) simulations are more suitable than the other. In different situations and with different conceptual models, the various combinations appear to perform more stably, and produce more 'realistic' or more conservative results than the other.*

Kalf and Associates (2016) in their response to the model audit on behalf of the DP&E stated *"with regard to the choice of modelling code, KA agrees with HS that both USG and MS codes can be applied for model application but that there will be differences depending on how they are applied and what method is used to represent unsaturated conditions"*. Finally Kalf and Associates (2016) concurred with the conclusion of the audit that *"modelling assessments need to consider and acknowledge this source of uncertainty, additional to the other inherent sources of uncertainty associated with estimation or simulation of subsurface conditions and groundwater behaviour. The choice of model code, given the lack of a definitive finding on suitability here, therefore remains with the modeller and the other perceived benefits of the software (e.g. cost, familiarity, boundary condition types, functionality)."*

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[4] MODFLOW SUFACT was the primary groundwater modelling code used to assess the impacts of major projects in Australia from the mid 2000s. Since the release of MODFLOW USG in mid 2013 and the gradual development of associated software tools it has become popular for assessing major projects due to the ability of the unstructured grid to better represent complex environmental, geological and mining features.

For the approvals process, the modelling results as presented in the Supplementary RTS (AGE 2016b) are based on the most recently calibrated version of the model and should be considered as the best indicator of the impacts resulting from the Project. This was supported by Kalf and Associates (2016) who concluded *"overall the updated model changes and analysis has provided greater confidence in the predicted outcomes supported by the uncertainty analysis. AGE model prediction of higher recharge to the alluvium should improve the capacity for bore make-up water during dry periods of reduced surface water flow."*

As described above, the numerical modelling for the Project has been gradually refined over five years in response to new data and peer review experts. This refinement in the numerical modelling over time does not indicate that the modelling is inadequate, but simply indicates a commitment to gradually improve the model over time and address requests from various parties by modelling further scenarios. This is the great advantage of numerical models that many potential outcomes can be tested and their acceptability considered by decision makers before Projects' commence. Numerical groundwater models used for mining operations inherently require continuous updates and revisions as new information and data is continually collected through monitoring networks and needs to be considered. The on-going nature of the model development is a good example of best practice as defined by Middlemis (2004), which is *"the fundamental guiding principle for best practice modelling is that model development is an on-going process of refinement from an initially simple representation of the aquifer system to one with an appropriate degree of complexity. Thus, the model realisation at any stage is neither the best nor the last, but simply the latest representation of our developing understanding of the aquifer system."*

2.2.2 Climatic conditions and alluvial aquifer recharge

The PAC (2017) note in their review they *"….find it difficult to accept the applicant's and the Department's assertions that there is a low probability of dry periods over the life of the mine, which would lead to impacts that only need to be identified and managed post approval. The Commission's view is that the available evidence of existing variability in the alluvial aquifers, as well as potential effects of climatic variability, suggest that there continues to be significant uncertainty about potential consequences. This necessitates that the risk of impacts requires very careful consideration before a decision is made about the project."*

In response to the above, it is important to note that drought cycles were represented in the groundwater modelling. The most recent update to the groundwater model described by AGE (2016b) as part of the supplementary RTS (AGE 2016b – Section 6.4.2) outlines how climatic cycles were used to inform the modelling predictions. Groundwater recharge for the predictive model was calculated using rainfall records from 2000 to 2013 that encompassed the 'Millennium drought' that occurred between 1995 and 2007. Figure 2-2 shows the Southern Oscillation Index and the El Niño[5] and La Niña climate cycles that occurred over the 2000 to 2013 period and illustrates the periods of below average and above average rainfall utilised in the numerical model to represent variability in groundwater recharge due to drought. Drought is therefore built into the predictions from the numerical model. In addition, the uncertainty analysis described by AGE (2016b) allowed the recharge during the droughts to reduce by up to 14 times lower than within the basecase, in effect increasing the severity of drought conditions. The modelling showed that yields from the borefield decreased below the required 'make up' water volume in 10% of the cases (AGE 2016b Section 6.4.8), and this small deficit could be addressed by installing additional bores to augment the borefield.

[5] http://www.bom.gov.au/climate/updates/articles/a008-el-nino-and-australia.shtml

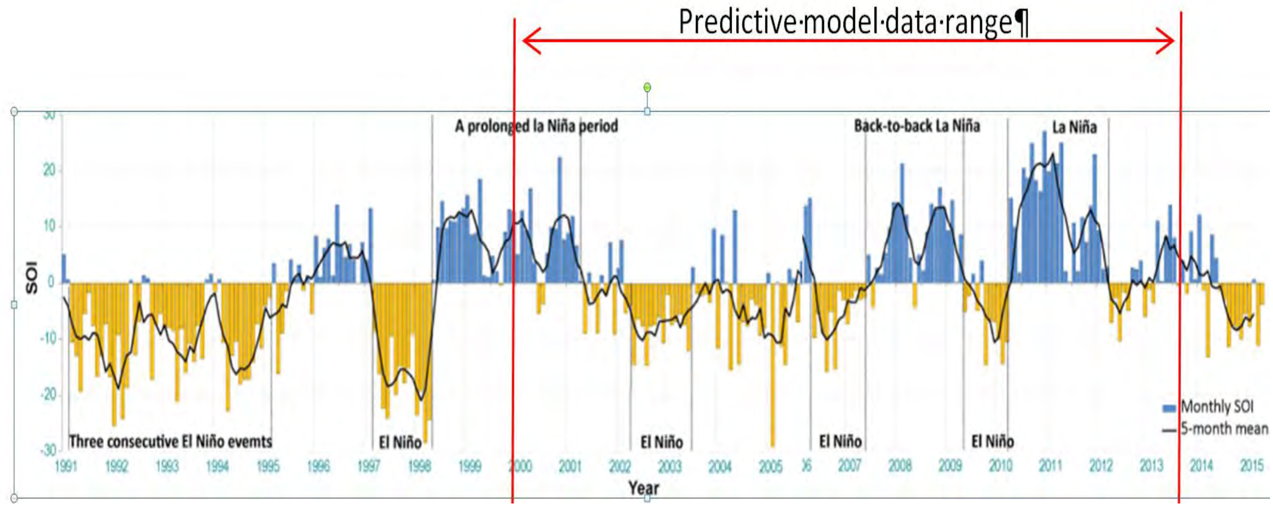

Figure 2-2 Southern Oscillation Index between 1991 and mid-2015[6]

2.3 Model uncertainty

2.3.1 Uncertainty and likelihood

In reality, the impacts predicted by numerical models have some level of uncertainty that cannot be feasibly eliminated. It is therefore important to assess the range of potential outcomes using modelling and determine if these are manageable. The range of impacts identified for the Bylong Project through the uncertainty analysis has been addressed with management measures documented within a draft Water Management Plan that includes measures such as water licensing, water monitoring and has also included the provisions for compensatory water supply agreements for landholders to account for unforeseen impacts.

Aquifers are somewhat similar to dams, in that they require rainfall to be replenished. Again similar to dams, aquifers have a finite storage volume, and are influenced by climate conditions and the rate of withdrawal. Groundwater models that represent aquifers therefore require estimates of aquifer replenishment rates (recharge) and aquifer properties (permeability and storage rates) to represent the groundwater flow through these underground systems. Permeability is simply the ease with which water can move through pore spaces or fractures underground, whereas storage is the volume of water stored in each cubic meter of rock or sediment.

For dams, the rainfall runoff into the dam, and the storage volume are commonly well known. An aquifer can be thought of as a dam filled with porous material. In contrast to a dam, the flow of water into an aquifer (recharge), along with the properties of the porous material that make up the aquifer are not typically uniform and vary over short distances in most groundwater systems.

In the groundwater flow equation the aquifer recharge and properties are also correlated, meaning that adjusting each of the values in a model can result in the same response being predicted in the aquifer. At its most simple level, this problem is demonstrated by the equations 1 x 4 and 2 x 2, both equalling 4, despite the equations having different variables. This is the referred to as non-uniqueness and demonstrates how input values in the groundwater model can be varied to give the same groundwater level result. Because of this, the predictions from groundwater models have a level of uncertainty, which needs to be understood and tested if models are to be useful in the decision making process for major projects.

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[6] http://www.bom.gov.au/climate/about/australian-climate-influences.shtml?bookmark=enso

The inherent uncertainty in model parameters introduces uncertainty in the model predictions. This has been addressed by the Project via conducting an 'uncertainty analysis'. The uncertainty analysis was essentially a three part process. Firstly the valid range for the non-unique parameters of recharge and aquifer properties was determined by referring to the testing data collected at the site and from experience at other sites with similar groundwater regimes. Then 2000 model realisations were created each having differing values of the non-unique parameters. The models that could not achieve adequate calibration were rejected leaving the output from the 140 successful models which were analysed to provide a statistical distribution of the important predictions. For the Project, the important predictions are the volume of groundwater removed by the proposed mining and how this affects the water table within the neighbouring alluvial aquifers.

The above process was undertaken for the RTS (AGE 2016a) and again for the supplementary RTS (AGE 2016b), with the results provided as percentiles. The percentiles indicate the value below which a given percentage of uncertainty modelling results fall. In the supplementary RTS, the 99th and 1st percentiles were presented to show the range of uncertainty in drawdown and mine inflow. The 99th percentile indicates that 99 % of model results from the uncertainty analysis reported inflow and drawdown less than the indicated value. For the Project, these results represent the predictions from the 2nd highest and lowest results. The results 99th percentile for inflow and drawdown is not drawn from one single model, but the pool of results created by all the 140 models. Therefore the result for the 99th percentile for mine inflow each year can be from different models. This approach ensures the worst case scenario created by the variability in model parameters is identified in the statistics. Whilst these percentiles intuitively suggest the potential for these predictions to actually occur is low, the likelihood of these extremes occurring is still subjective and depends on the perception of risk.

This issue has been encountered in other fields. Mastrandrea et al (2010) prepared a guidance note for developers of climate models to assist in the explanation of numerical modelling uncertainty. The purpose was to guide authors of climatic models in a consistent treatment of uncertainties and how to communicate the degree of certainty in the model findings.

This process is useful for all models with uncertain results and has been adapted for use within this report to further explain the results of groundwater modelling undertaken for the Project. Figure 2-3 shows the scale and language recommended by Mastrandrea et al (2010) to describe the likelihood of an event predicted by a model from occurring.

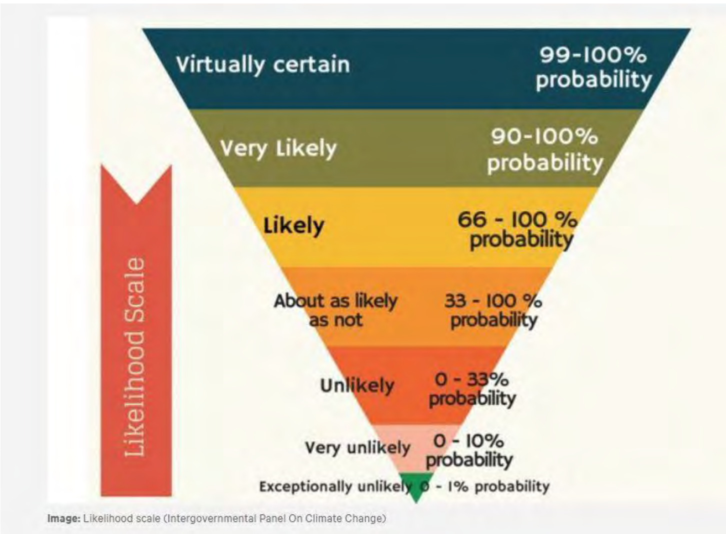


Figure 2-3 Likelihood scale

The likelihood scale provides a probability of an event occurring based on model results. ‘Likely’ means there is greater than 66 per cent chance of a result, while ‘unlikely’ means less than 33 per cent chance, ‘very unlikely’ means less than 10 per cent, ‘exceptionally unlikely’ means less than 1 per cent likelihood of a result or outcome.

The likelihood scale was applied to the distribution of the results from the uncertainty analysis conducted within the Supplementary RTS for the Project. This was done by determining the number of model results from the 140 runs that fell between the bands in the likelihood scale. For example a 0% to 1 % probability was the results from the single most extreme model, i.e. only one model out of 140 provided results within this range.

Figure 2-4 below shows the volume of groundwater predicted to flow into the mining areas from the 140 models classified according to the likelihood scale. It should be noted, the scale developed by Mastrandrea et al (2010) has some overlapping boundaries (referred to as ‘fuzzy boundaries’). To allow classification of the model results for the Project, the boundaries were made ‘hard’ as shown in the graph below.

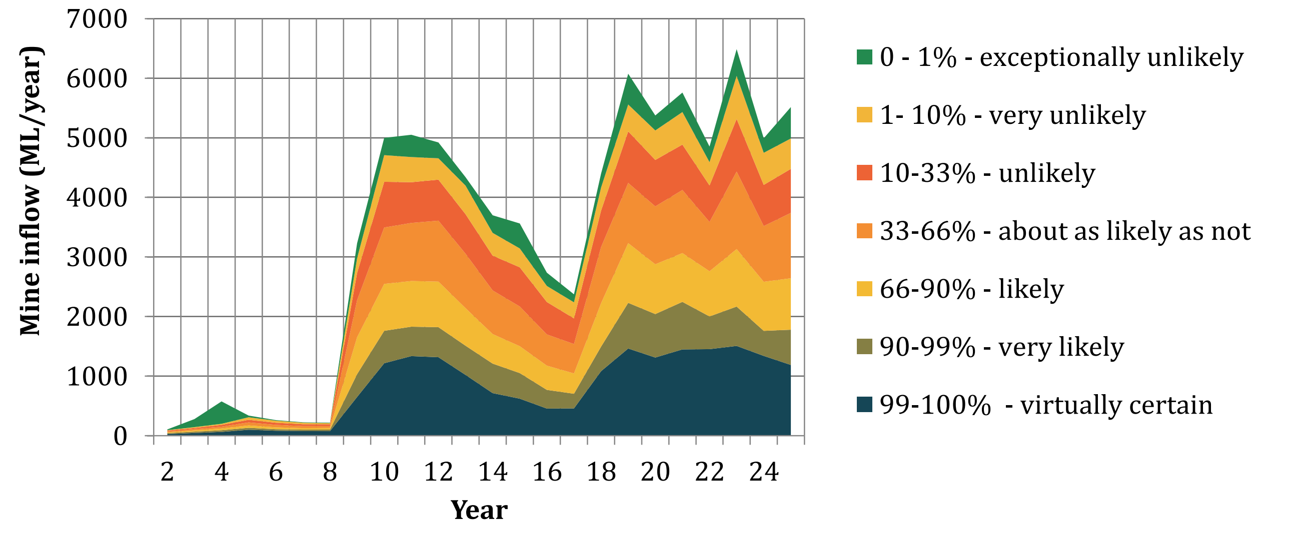


Figure 2-4 Likelihood of inflow to mining areas

The likelihood scale can be used to put the results of the uncertainty analysis in context. For example, using the scale, it can be stated according to the uncertainty modelling results, it is ‘virtually certain’ the underground mine will extract over 1,000 ML/year during periods of the mine life. It is also unlikely that the volume of groundwater entering the mine will exceed 5,100 ML/year, and exceptionally unlikely the peak will exceed 6,500 ML/yr. It is important to note the ranges are based on a composite of statistics from the 140 calibrated model runs, and therefore does not represent any single model run, but rather the likelihood of inflow occurring within the defined ranges.

When considering the likelihood scale described above, it is important to note that there are some assumptions within the numerical model that do not change during the uncertainty analysis, and therefore cannot be reflected within the likelihood scale. The most significant of these assumptions is the perfect connectivity assumed within the numerical model between the aquifer layers and does not restrict groundwater flow through the coal and interburden. The perfect connectivity represented within the numerical model will not occur in reality due to the natural variability in the density of fractures within these layers of bedrock. Where fracture networks are not perfectly interconnected, the bulk permeability of the bedrock is reduced. This process that reduces the bulk hydraulic conductivity is not represented within the numerical model and therefore also not within the likelihood scale.

Of the 140 models created for the uncertainty analysis, it is the versions with the higher values of storage and hydraulic conductivity that when combined create higher groundwater inflows to the mining areas. If the variability in fracture networks were represented in the model, it is expected the likelihood of the higher inflows to the mining area would be reduced. The combination of all model layers having uniformly high storage and hydraulic conductivity at the same time, as perfect interconnectivity within the layers becomes even less probable. Therefore, it is important to see the likelihood scale as a conservative guide, and influenced by the assumptions within the numerical model which are not always a perfect representation of the spatial complexity within geology.

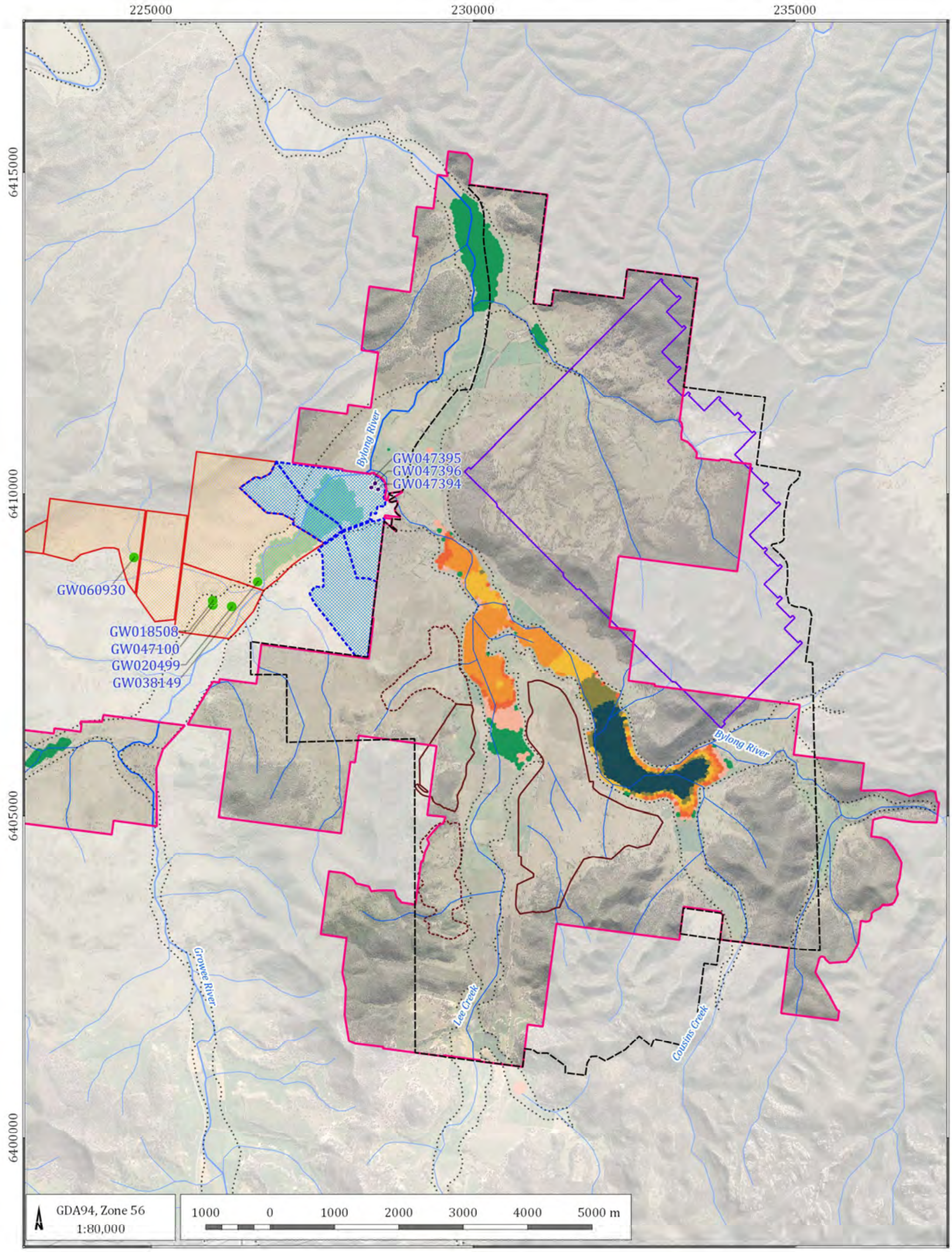
The likelihood scale was also used to classify the water table drawdown within the alluvial aquifers predicted by the 140 calibrated models. Figure 2-5 shows the likelihood of the maximum drawdown within the alluvium exceeding the 2 m limit nominated in the NSW Aquifer Interference Policy. As noted earlier the drawdown shown is a composite of statistics from the 140 calibrated model runs shown spatially over the Project area, and therefore does not represent any single model run, but rather the likelihood of drawdown exceeding 2 m at any time throughout the Project life.

When applying the likelihood scale to drawdown, it can be said it is virtually certain that the maximum drawdown will exceed 2 m within the Bylong River alluvium east of the open cut mine, due to the cumulative effects of the borefield and mining. As distance increases from the mining area and the borefield, the likelihood of drawdown exceeding 2 m at any time reduces. It is worth noting, a single model run from the 140 runs predicted a drawdown exceeding 2 m on the Eagle Hill and Cherrydale properties. This prediction was not presented in the Supplementary RTS reports, because it occurred between the 0 and 1st percentile. Figure 2-5 shows that the isolated area of drawdown on the Eagle Hill and Cherrydale properties is not directly connected to other areas of drawdown around the mining areas. This is because the coal seams sub-crop under the alluvium in this area, and the single model run that resulted in this outcome had a combination of properties that heightened the connectivity between the mining areas and these landholders. The model required highly permeable coal and alluvium to achieve this result; a combination that is exceptionally unlikely based on the available field measurements. When the variability in connectivity of the fracture networks[7] is considered, this further reduces the probability of this outcome occurring. Whilst the model predicted the drawdown on the Eagle Hill and Cherrydale properties, it did not occur in areas where private water bores are registered on the DPI-Water database.

This is where the likelihood scale becomes useful, as it indicates this is an exceptionally unlikely outcome that does not technically require 'Make Good Agreements' under the AIP. However in this case, to alleviate concerns from landholders, KEPCO is entering into Compensatory Water Supply Agreements (or as previously committed Make Good Agreements) with property owners surrounding the mine to safeguard their water supplies (refer Section 4.5).

The uncertainty analysis provides a range of outcomes. This can be problematic when absolute values are required to license the water take associated with mining. For decision making purposes, the base case model from the supplementary RTS (AGE 2016b) is considered the most appropriate to base licensing upon as it is based on the most recent calibration and represents the mean results from the uncertainty analysis. The likelihood of this scenario generally falls within the 'as likely as not' range.

[7] , varying interconnectivity through fracture networks is not represented within the numerical model



LEGEND

Open Cut Mining Area
Overburden Emplacement Area
Underground Extraction Area
Quaternary alluvium
Cherrydale
Eagle Hill property
Project Boundary
KEPCO owned land
Major drainage
Minor drainage
Registered bores
Private bores on Eagle Hill property

Likelihood Scale (%)

0 - 1 (Exceptionally unlikely)
1 - 10 (Very unlikely)
10 - 33 (Unlikely)
33 - 66 (About as likely as not)
66 - 90 (Likely)
90 - 99 (Very Likely)
99 - 100 (Virtually Certain)

Bylong Coal Project (G1606Q)

Likelihood of 2 m drawdown with alluvial aquifers

DATE
21/11/2017

FIGURE No:
2.5

AGE

G:/Projects/G1606.Bylong Coal Project/3_GIS/Workspaces_QGIS/Probability_map_20171013/04-03_G1606_Likelihood of 2 m drawdown with alluvial aquifers.qgs

2.3.2 Model confidence

As noted previously, numerical models represent complex natural systems in a highly simplified manner and it is not possible to have 100% confidence in their predictions. Their purpose is to assist decision making by identifying the range of potential outcomes from a major project, and allow the potential to manage these outcomes to be determined.

Confidence in the available information is an important factor for the decision making process. Mastrandrea et al (2010) also provided an approach to evaluating and categorising the confidence in the model predictions. The process requires evidence for the prediction, and agreement between different sources of predictions. A matrix is used to determine the confidence level as shown in Figure 2-6 below.

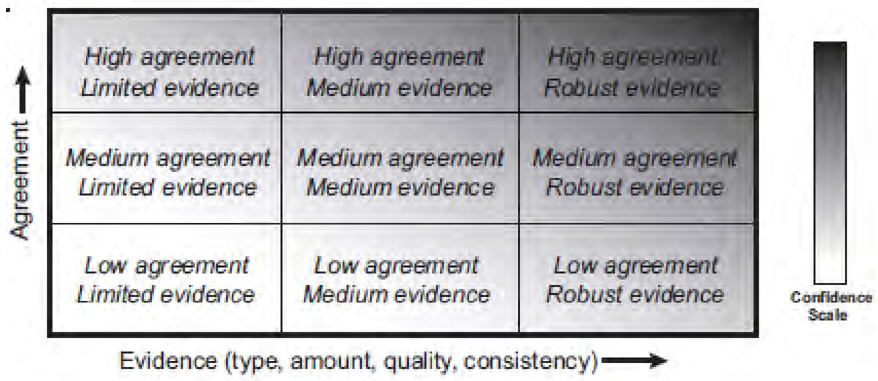


Figure 2-6 Confidence scale - from Mastrandrea et al (2010)

To determine where the predictions for the Project fall on the confidence scale, we need to make subjective judgements about the available evidence (type, amount, quality, and consistency) and agreement between the available information (limited, medium, high). Because the Project is a greenfield site, and there is no historical mining that can be used as a guide to impacts on groundwater, there is limited, or at best medium evidence on the likely impacts. There is some agreement between various stages of modelling undertaken for the Project (EIS, RTS, and the Supplementary RTS), that is considered a medium level of agreement. When these judgments are applied to the matrix above, it indicates the confidence in the predictions is at around the medium level. Whilst the decision making process may wish for a higher level of confidence, a medium level of confidence is a common and inevitable outcome for greenfield mining developments. This is because the evidence to validate the predicted impacts on groundwater simply is not available at the time when the modelling is being undertaken for the approvals process and can only realistically be obtained throughout the mining operations.

Major projects commonly deal with this by conducting uncertainty analysis to determine if the range of possible impacts is possible. This leads to the proponent potentially entering into 'Make Good Agreements' to compensate for any loss of water should it occur. The Make Good Agreement is the approach documented within the NSW Aquifer Interference Policy that requires make good provisions apply where there is predicted to be more than a 2 m decline in the water table cumulatively at any water supply work in alluvial water sources for the basecase predictions.

As noted above, KEPCO is in the process of negotiating Compensatory Water Supply Agreements with neighbouring landholders, the intention of which is to provide further certainty for neighbouring landholders that should unforeseen impacts occur (refer Section 4.5).

2.3.3 Model predictions versus reality – observations at other mines

Whilst there is no information on the magnitude of potential mining impacts in the Project area, modelling from other active mines in the Upper Hunter Valley catchment area is available. It shows that numerical models conducted when these sites were greenfield proposals predicted groundwater inflow within a range that was later validated by monitoring undertaken during mining operations. The models therefore achieved their intended purpose of identifying the likely impacts of a development on the surrounding groundwater regime and determining measures to monitor manage and mitigate the actual impacts on the ground.

To further understand the ability of models to predict impacts on groundwater systems at greenfield sites, information available for other mines in the Upper Hunter valley catchment area was reviewed. The Wilpinjong and Moolarben mines provide useful case studies, as numerical models were constructed for both whilst they were greenfield proposals several years ago. There are now operational measurements for these mines that the operators are comparing back to determine the level of agreement with the original model, as required by conditions of consent. This process allows the mines to improve the numerical models over time and adaptively manage any unforeseen impacts beyond those addressed within the original approval.

Wilpinjong coal mine

A groundwater model was developed for the Wilpinjong EIS in 2005 (AGE, 2005). The mine plan for the greenfield site included six open cut pits, to be mined from 2006 to 2026. A five layer numerical model of the hydrogeological units from the surficial Quaternary alluvium down to the Marangaroo Sandstone, which underlies the coal seams, was developed and provided estimates of drawdown and mine inflows.

An EIS document for the Wilpinjong Expansion Project in 2015 provides a plan of the actual areas mined and estimates of the actual groundwater inflow. It indicates that the areas mined and the timing of the mining varied slightly to that anticipated during the EIS in 2005. Despite this, the report contains some useful information on groundwater inflows. It notes the pit inflows collected from 2006 to 2011 at Wilpinjong could not be corrected for runoff or other processes. Therefore these inflows represent a maximum possible amount of groundwater inflow that actually occurred. From late 2012, the inflows were able to be corrected to remove other sources of water. The measured estimates of groundwater inflow for each water year are compared with the model predictions from 2005 in Figure 2-7.

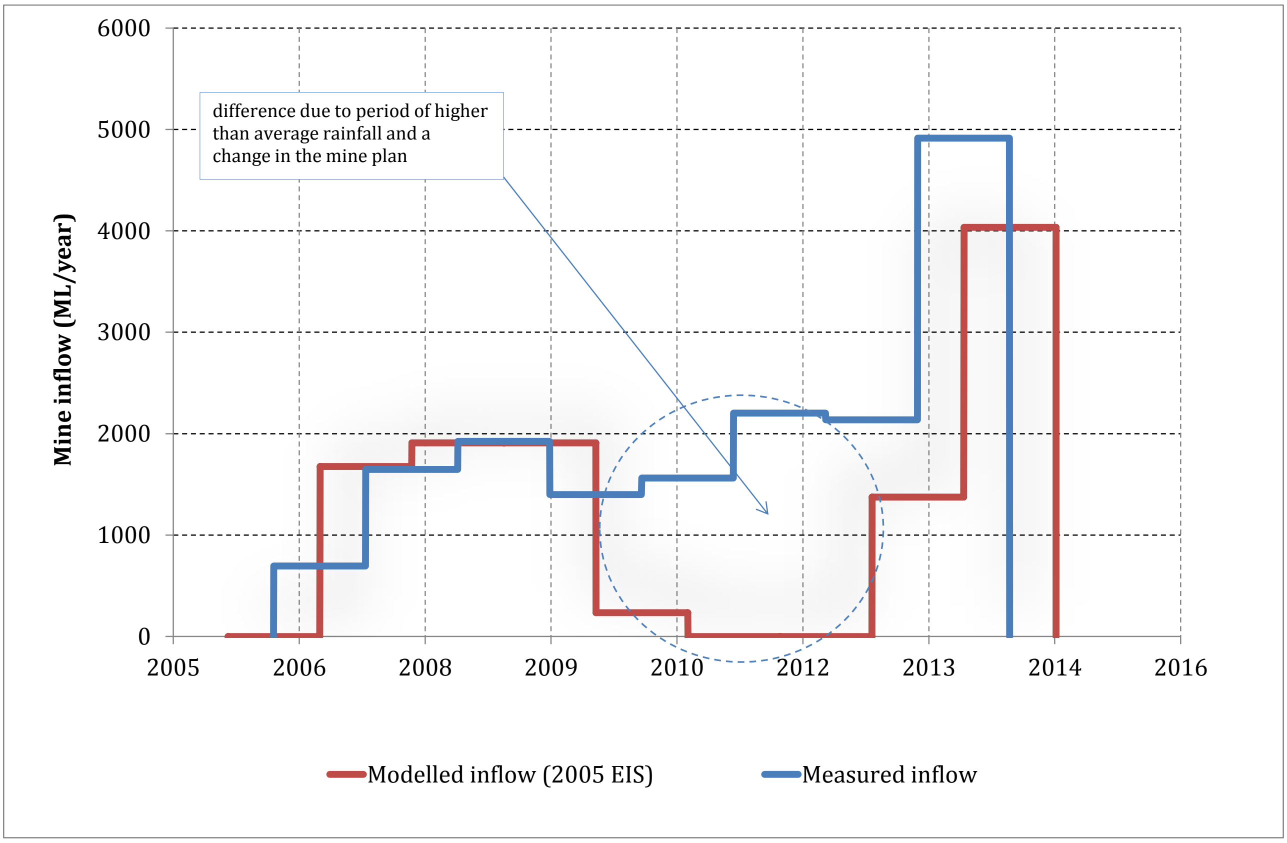


Figure 2-7 Wilpinjong predicted and actual estimated inflows

Whilst the predicted and inferred actual inflows are not exactly the same, they are similar in magnitude for the initial and most recent period of mining. There is an obvious miss match in totals from 2010 to 2013 which coincides with a period of higher than average rainfall and a change in the mine plan from that envisioned in 2005. Subjectively, the agreement between the model predictions and the measurements is considered at least a medium level.

Moolarben mine

A groundwater model was developed for the Moolarben Coal Project at a similar time in 2006 (PJ Dundon, 2006) for the greenfield mining proposal. The Stage 1 mine plan included three open cut pits and an underground longwall mine. The underground was proposed adjacent to the already existing Ulan mining complex. A five layer numerical model of the hydrogeological units from the surficial alluvial deposits to the Shoalhaven Group that underlies the coal seams was developed.

Construction commenced at Moolarben Mine in 2009 with the mine becoming operational in mid 2010. A second EIS and associated groundwater assessment was submitted in 2011 for Stage 2 of the mining project (RPS Aquaterra, 2011). Stage 2 proposed the inclusion of a fourth open cut pit and two new undergrounds beyond that previously approved for Stage 1. The estimated actual groundwater inflows to the open cut pits are available in the annual reports produced since 2011 to compare with the model predictions. The predicted and measured open cut inflows are shown on Figure 2-8.

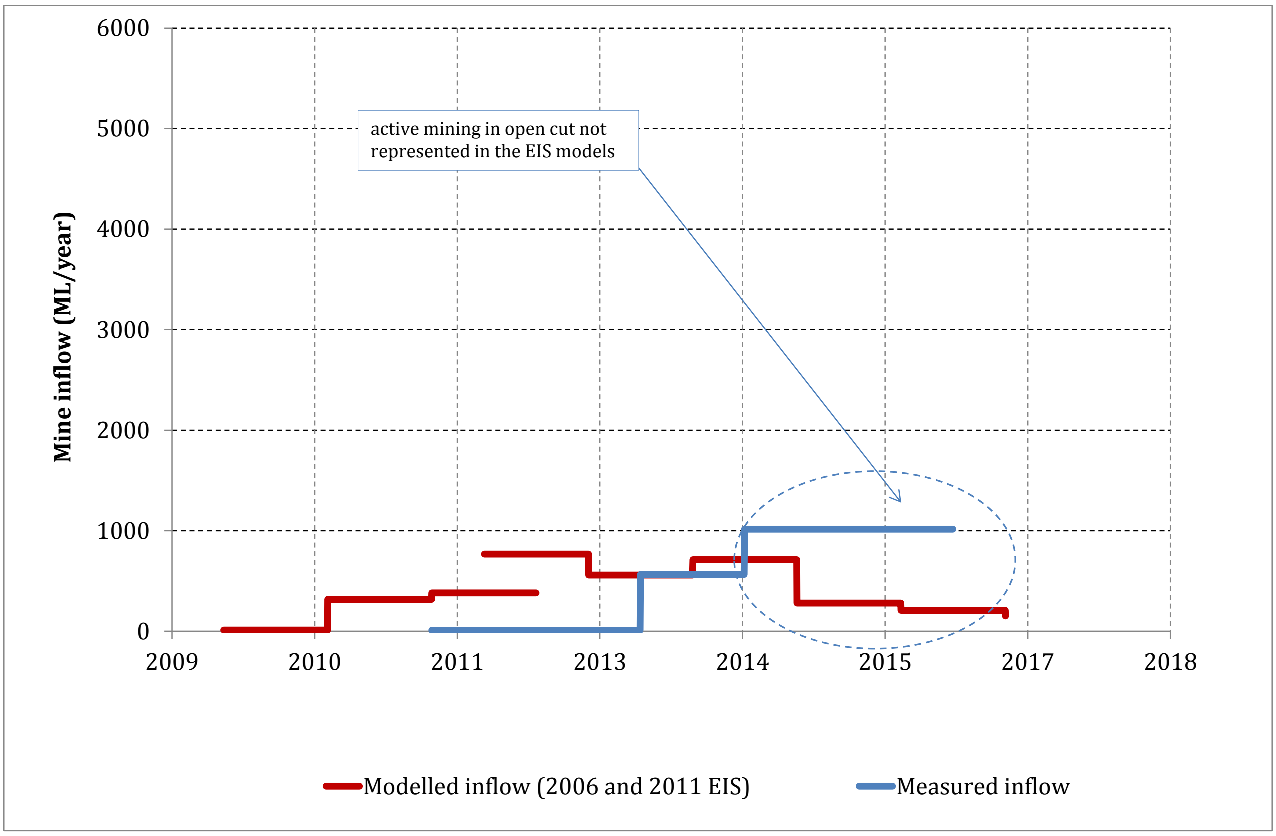


Figure 2-8 Moolarben Open cut pits predicted and actual estimated inflows

The obvious difference between Wilpinjong and Moolarben is the scale of the inflows, which are significantly lower at Moolarben and therefore more difficult to measure. No measurable groundwater inflows were noted in the annual reports for 2011-12 or 2012-13.

Similar to Wilpinjong, mining at Moolarben has also progressed on a different timescale and with a different mine plan to that originally planned in 2006. Despite these differences, the reported groundwater inflows from the 2015 and 2016 annual reviews are marginally higher than those predicted by the 2006 and 2011 modelling. The 2016 annual review indicates that open cut mining was still active from pits OC1 and OC2, whereas mining had ceased in these pits in the EIS models. Visually, the agreement between the model predictions and the measurements may appear low, however when the relatively low volumes of groundwater are considered, and compared to other mines such as Wilpinjong which has higher inflows, the agreement could be considered a medium level, at a minimum.

Ulan Coal Mine

Coal mining at Ulan dates back to the 1920's[8]. The early mines utilised underground bord and pillar mining methods to remove the coal. Mining from Ulan No. 1 colliery and then Ulan No. 2 mine continued on and off until 1969 when the power station closed and demand dropped significantly. An exploration program in the mid 1970's identified additional resources and an open cut and augmented underground (Ulan No. 3) was approved in 1982. The open cut operated from 1982 to 2008 when the reserves were exhausted. Highwall mining was also completed within the open cut in the mid-1990s. A further extension to the open cut was approved in 2010.

Underground mining restarted at Ulan in 1986 and continues to present day. The Ulan No. 3 underground utilises longwall mining techniques and is expected to continue until at least 2031.

The long history of mining at Ulan pre-dates the available computational power to complete numerical groundwater modelling. Although reports are available on the more recent approvals and modifications, no publically available documents were found for the open cut and underground expansion approved in 1982. Any subsequent reports and numerical models will have been influenced and calibrated to data collected for these existing mines and will not represent greenfield sites. It has therefore not been possible to compare predicted and actual inflows for the open cut developments at Ulan.

2.3.4 Summary

As noted previously, the confidence in the predictions for the Project is around a medium level, but cannot be considered high because it is a greenfield site, and therefore the model predictions cannot be validated by measurements of inflow to the mining areas and the resulting drawdown to the alluvial aquifers monitored until mining commences. However, it is important to note the purpose of numerical modelling is not to accurately forecast actual impacts, but to determine the range of impacts likely and to assess whether these impacts will be manageable and acceptable. It is therefore important to have confidence in the likely range of impacts rather than the actual impacts.

A review of other similar mines in the Upper Hunter Valley catchment area that were once greenfields does provide some further confidence that numerical models of greenfield areas in the Upper Hunter Valley have the capability to predict groundwater inflow within an acceptable range. The models have achieved therefore their intended purpose of identifying the likely impacts of a development on the surrounding groundwater regime and determining measures to monitor, manage and mitigate the actual impacts on the ground.

As noted, whilst the results from other mines in the Upper Hunter provides confidence in the ability of numerical models to predict impacts, when considering this historical work, it is also important to note that since the last mines were developed in the Upper Hunter Valley in the mid-2000s, the ability to conduct uncertainty analysis has significantly improved due to increased computer power and improved software. The uncertainty analysis for the Project is informed by a more significant network of monitoring bores, and a longer baseline record of data for calibration of the model than compared with the Wilpinjong and Moolarben models. There has also been ongoing measurement of hydraulic conductivity in the alluvium (pumping tests) and coal measures (packer tests) to inform the numerical modelling for the Project, as well as a process of continual refinement from an initially simple representation of the aquifer system at the Gateway stage to one with an appropriate degree of complexity and an assessment of uncertainty during the EIS and RTS stages. The uncertainty analysis provides the ability for proponents and decision makers to implement the relevant requirements for the establishment of various management, monitoring and mitigation measures within the Development Consent approval for the development. The proposed management, monitoring and mitigation measures for the Project have been outlined within a draft Water Management Plan which will be provided for review.

[8] http://www.ulancoal.com.au/en/about-us/Pages/history.aspx

3 Additional data collection

KEPCO engaged Douglas Partners Pty Ltd in 2011 to supervise and document the installation of the baseline monitoring network and the characterisation of the hydrogeological regime. Douglas Partners commenced monitoring of groundwater levels at the Project site in mid 2011 and has continued monitoring generally on a monthly or quarterly basis to the present time. At the time of writing, around six years of baseline monitoring data is available.

Water quality monitoring began in 2012 and the monitoring network has steadily grown to incorporate an extensive number of groundwater monitoring sites which have been installed during various exploration drilling campaigns. The groundwater monitoring network at Bylong currently consists of 97 open standpipe monitoring bores and 14 vibrating wire piezometers. Groundwater level measurement is automated in the majority of the monitoring bores with water level data loggers installed within 70 of the monitoring bores and pore pressures recorded by data loggers in all 14 vibrating wire piezometers. Ten of the vibrating wires piezometers are downloaded automatically via telemetry, while the remaining four are manually downloaded on a monthly basis. KEPCO has also undertaken a series of exploration campaigns to collect geological information and has utilised these programs for the ongoing collection of information on hydrogeology. The additional water level measurements collected since the numerical model was last calibrated in mid 2016 can be used to validate the water levels predicted by the numerical model as described below.

3.1 Water level validation

Model validation is a process that determines if the calibrated model can adequately represent processes within the groundwater system. The validation of a model involves the checking of its outputs over time against an independent set of data collected from the field. As noted previously, the predicted mine inflows and water table drawdown associated with mining activities within the model cannot be validated at this point because mining is not currently approved and this data is therefore not available. However the model does provide a prediction of water levels within the aquifers that can be validated against water levels measured in the monitoring bores installed by KEPCO.

As noted above, the Bylong groundwater model was last calibrated in mid-2016. KEPCO have continued monitoring groundwater levels and rainfall since this time. An extra year of data is now available, which can be used to validate the model and its responses to rainfall.

Around 750 mm of rain fell in the period from June 2016 to July 2017. Rainfall was above average from mid-2016 to the beginning of December 2016, and then fell mostly below average to mid-2017. The largest rainfall events were between September and November 2016, and again at the end of March 2017. These events have resulted in the soil profile reaching field capacity and significant recharge of the groundwater system occurring. In most bores, the groundwater levels increased around 2 m between June and December 2016. In many bores, the peak water levels during this period were the highest recorded since KEPCO's monitoring program began in mid-2011. Groundwater levels began steadily declining again from early to mid-2017, in line with the below average rainfall experienced during this time. An example of this water level cycle during 2016/2017 and the longer term cycle over the baseline monitoring period is shown for two monitoring bores installed within the alluvium in Figure 3-1 below. The graph shows the groundwater levels on the primary y axis and the cumulative rainfall departure on the secondary y axis. The cumulative rainfall departure has a rising trend if rainfall exceeds long term averages and a falling trend when it is below the average. The graph shows the correlation between rainfall and groundwater levels with rising groundwater levels responding to periods of above average rainfall, and falling groundwater levels when rainfall is continually below averages. This data therefore provides a good dataset for validation, because a significant change in rainfall conditions occurred during the 2016/2017 validation period.

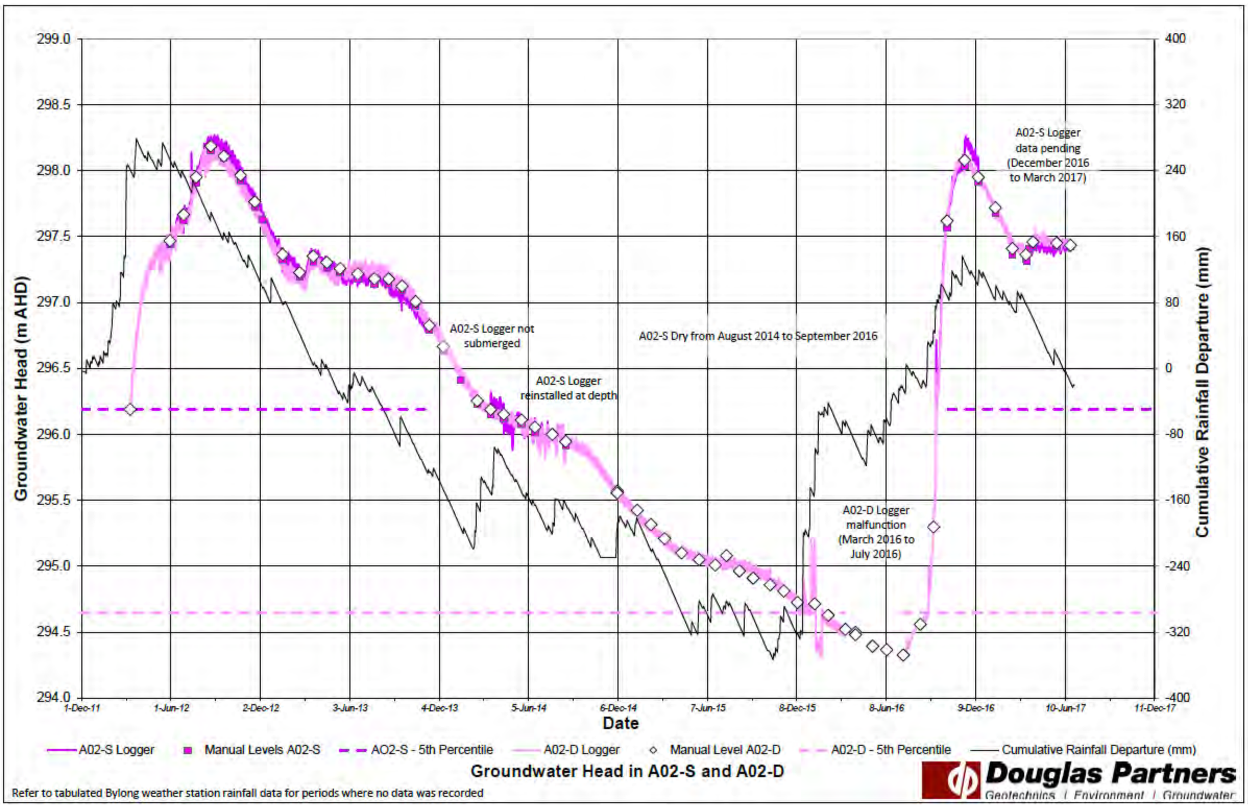


Figure 3-1 Groundwater level A02S and A02D (source Douglas Partners 2017)

When rain falls onto dry soils, it usually does not infiltrate straight through to the water table. The rain will dampen the soil, evaporate, or flow overland. After prolonged rainfall, however, the soil will eventually become saturated (field capacity), and the excess water will either runoff or infiltrate down into the water table. The volume of rainwater that reaches the water table was estimated from rainfall records using a field capacity calculation and fed into the Bylong model. The model then predicted how much the groundwater levels would increase in response to the estimated recharge. These increases were then compared to the actual groundwater level increases as routinely monitored from the bores themselves following rainfall.

The water levels predicted by the model and measured in the monitoring bores for the validation period of mid 2016 to mid 2017 are included within Appendix A for comparison. Results show that within the alluvial aquifer, the model can make valid predictions of both groundwater level and its response to rainfall recharge.

In deeper layers of coal and rock, which have more restricted groundwater flows and recharge, the model's ability to predict groundwater levels / pressures within these layers and their response to rainfall diminishes. This occurs because the recharge rates and the hydraulic conductivity can usually be characterised more readily for shallow alluvial systems, compared with the deeper and somewhat constrained bedrocks aquifers that have inherently more variability in their properties and recharge rates. Despite this, the model shows valid predictions of groundwater level changes within the alluvium in response to rainfall, which is the key aquifer of concern for the Project, and has been able to be utilised to increase the confidence in the model predictions.

3.2 Hydraulic conductivity

Since acquiring the exploration leases, KEPCO have undertaken a series of drilling programs to define the extent and quality of the coal resources and determine appropriate mine plans. As noted above, KEPCO have integrated the collection of hydrogeological data into each of these campaigns, including the in-situ measurement of rock permeability using packers. Packers are instruments inserted into boreholes that can seal off geological layers of interest with inflatable rubber balloons and allow water to be injected into the zone of interest to measure the rock permeability. At Bylong, this technique has been used to measure the permeability of the coal seams and the non-coal rock units. The data has then formed the basis of the conceptual model and the numerical model developed to assess the impact of the Project on the regional groundwater system.

In 2017, as part of an exploration campaign KEPCO conducted packer testing on a further three boreholes (BY0514, BY0516, BY0527) to continue to build up the available dataset on permeability of these layers at certain depths. The graphs in Figure 3-2 to Figure 3-5 below show the historical packer testing as well as the new data collected during 2017 and how this compares with the permeability ranges adopted within the numerical model in the uncertainty analysis. The blue zone within each graph shows the typical range within which the parameters in the model were varied during the uncertainty analysis. The data collected during 2017 falls within the ranges previously adopted in the numerical modelling, and serves as an indirect validation of the ranges adopted. The figures do show some test results that fall outside the modelled range. These represent more permeable parts of the rock units, however on a regional scale groundwater flow is controlled by the combination of both the lower and higher permeability zones and the ranges adopted for the numerical modelling reflect this process.

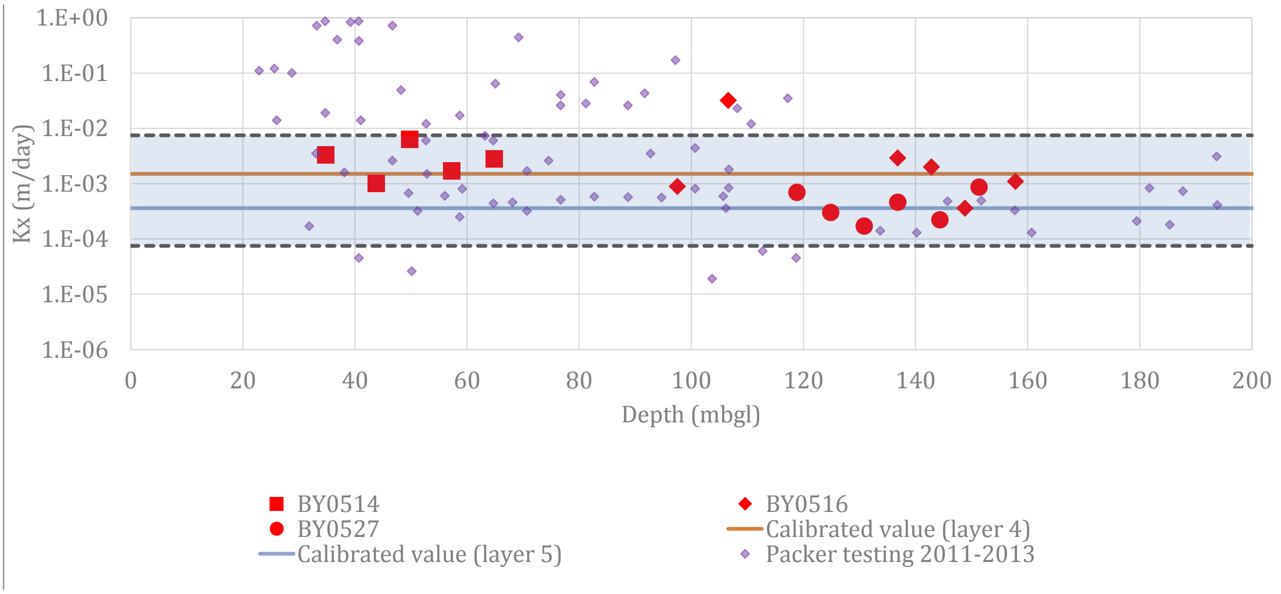


Figure 3-2 Ulan seam overburden – packer testing versus model ranges

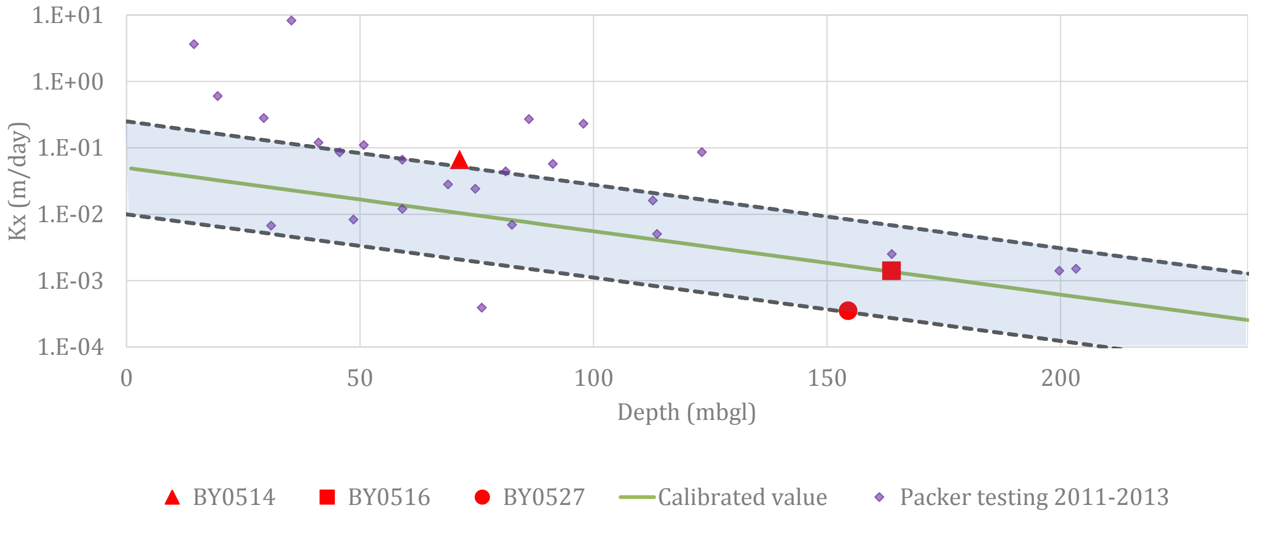


Figure 3-3 Ulan coal seam – packer testing versus model ranges

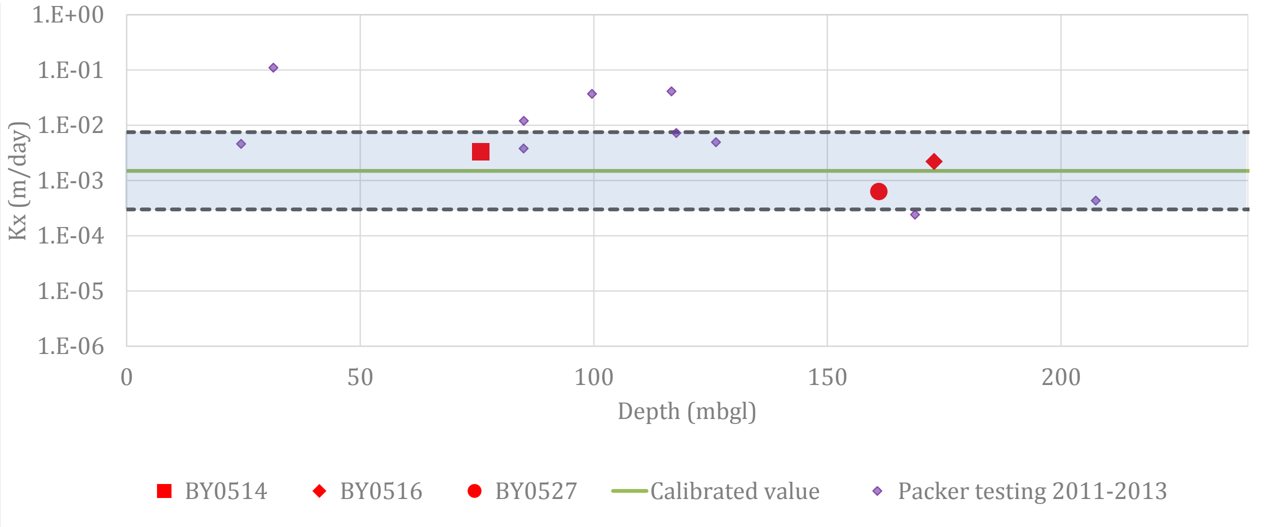


Figure 3-4 Ulan / Coggan seam interburden – packer testing versus model ranges

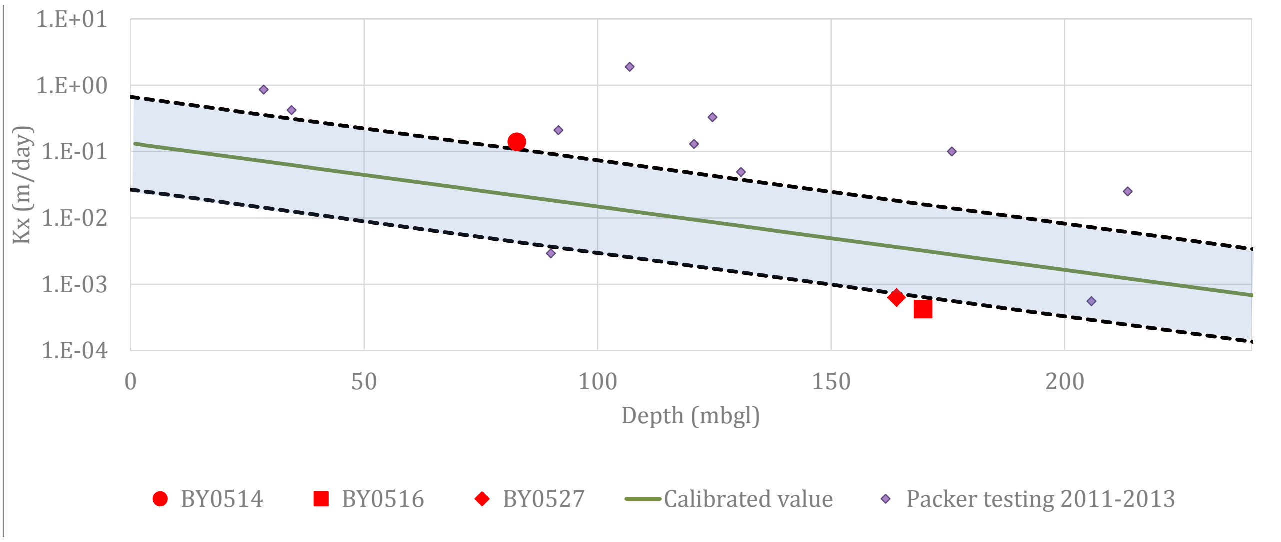


Figure 3-5 Coggan seam – packer testing versus model ranges

3.3 Water use

KEPCO operate agricultural properties that are currently utilising groundwater from the alluvial aquifer in volumes similar to potential ‘make up’ water requirements without any detectable impacts on the groundwater systems. This usage indicates the productivity of the alluvial groundwater system.

KEPCO own a number of agricultural properties within and immediately adjacent the Project Boundary which are currently utilised to run an integrated agricultural business focused on beef production and some lucerne cropping. Figure 3-6 shows the names of agricultural properties within and adjacent to the Project Boundary. Groundwater is utilised to irrigate pasture and lucerne and also for stock watering. KEPCO is proposing a program of installing flow meters on the existing bores and wells that were present on the properties at the time of purchase to ensure that water use from these bores is accurately recorded. In the interim, the KEPCO agricultural company keep records when pumps are operating, which is used to estimate groundwater usage annually. Table 3.1 below summarises the estimated volumes pumped from bores or wells on each property for stock and irrigation respectfully. The table shows the dominant water use is for irrigation of pasture and fodder crops, with only around 1 ML/yr required to water stock.

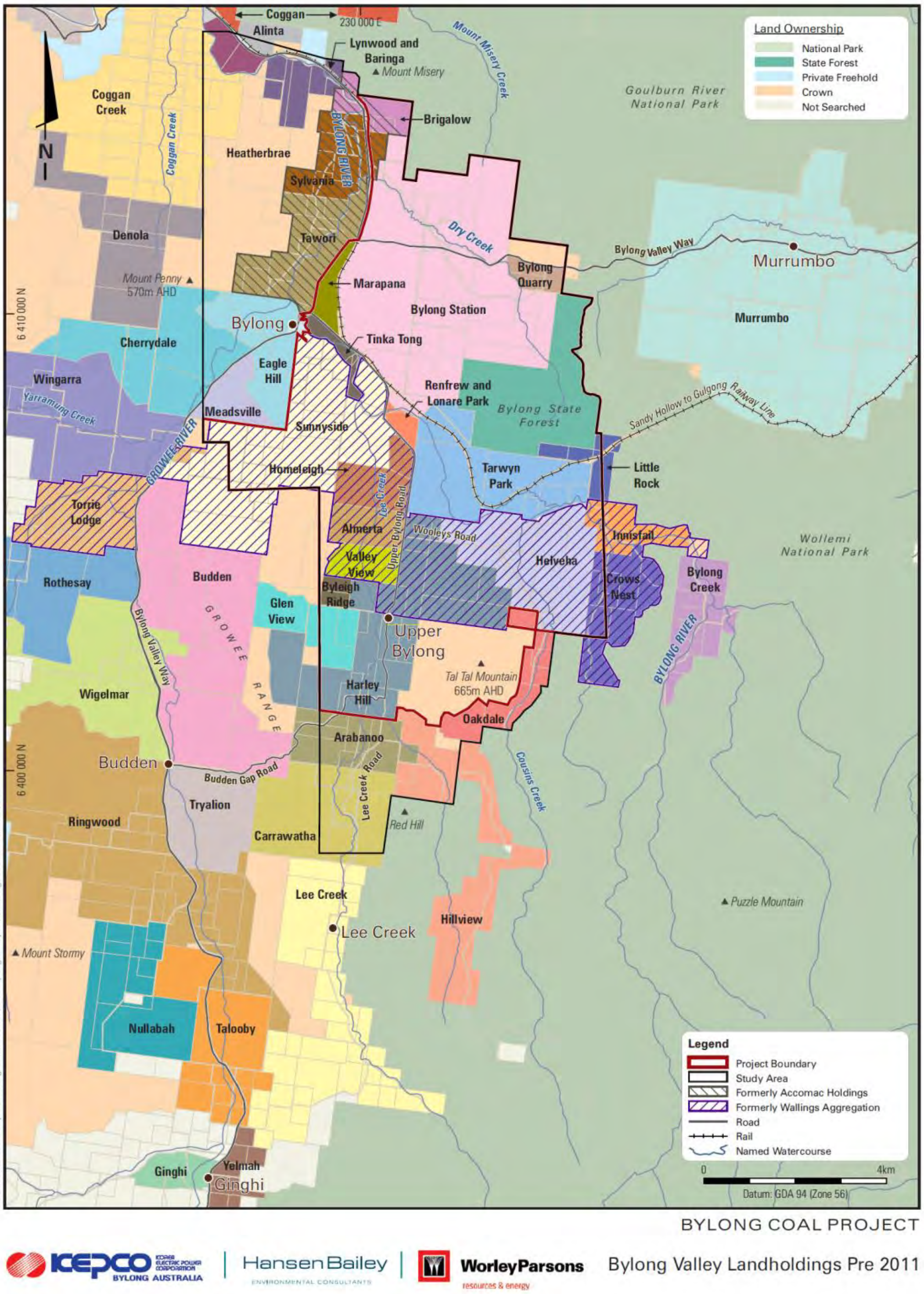


Figure 3-6 Property Names within the vicinity of the Project, including KEPCO agricultural company properties (source Hansen Bailey)

Table 3.1 Annual groundwater use by KEPCO agricultural company

Property	Estimated annual water use (ML)	
	Irrigation	Stock
Bylong Station	591	
Sylvania / Brigalow	355	
Taworri	460	
Sunnyside	-	0.24
Renfrew Park	-	0.036
Homeleigh	-	0.024
Almerta	-	0.024
Valley View	-	0.024
Harley Hill	-	0.048
Helvetia	-	0.192
Oakdale	-	0.036
Innisvale	-	0.036
Tarwyn Park	-	0.192
Hillview	-	0.0216
Arabanoo	-	0.0864
Lee Creek	-	0.18
Yarran View	-	0.072
Tranquil Valley	-	-
Iron Tank		
Totals	**1,406**	**1.212**

Table 3.1 shows most of the groundwater is extracted from Bylong Station, Sylvania / Brigalow and Taworri properties which are located in the Bylong River valley, north of the township of Bylong. KEPCO monitor groundwater levels within the alluvial groundwater systems in this area in a series of monitoring bores (A01, AGE02, A09 and A13). The groundwater level measurements in the alluvial monitoring bores are shown in Figure 3-7 to Figure 3-10. As noted previously The graphs for each bore show the groundwater levels and the cumulative rainfall departure on the indicating the relationship between rainfall and groundwater levels, with rising groundwater levels occurring during periods of above average rainfall, and falling groundwater levels when rainfall is continually below averages. There is no obvious impact on groundwater levels within the neighbouring alluvial aquifer from the KEPCO abstraction for irrigation in bores A01, AGE02 and A09. A13 shows fluctuations in groundwater level of about 0.2 m to 0.5 m that appear related to agricultural pumping. Whilst there is an influence of pumping evident in the water levels, this bore also has recorded water level cycles that are influenced by the climatic conditions and there is no declining trend evident from the agricultural abstraction. The conclusion is that the abstraction from the alluvial aquifer for agricultural use is sustainable and is not detrimentally impacting upon groundwater levels.

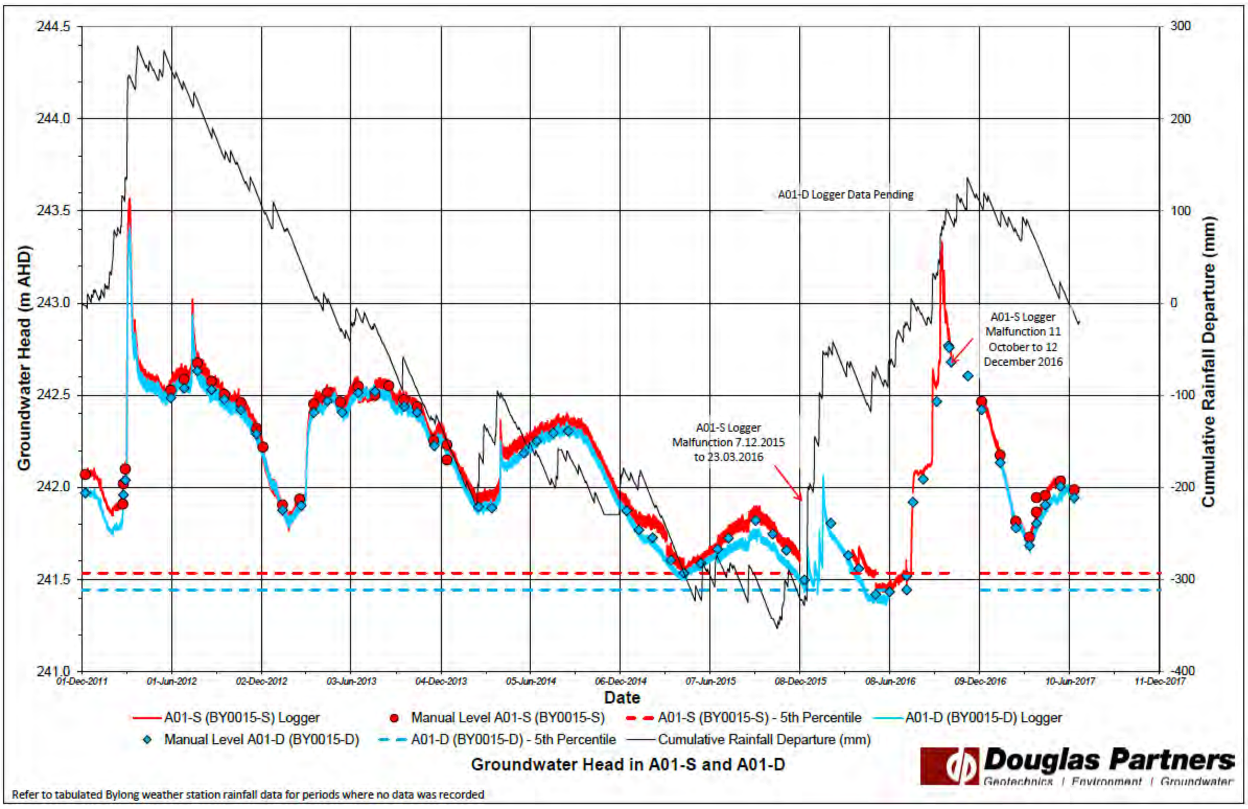


Figure 3-7 Groundwater level in A01S and A01D

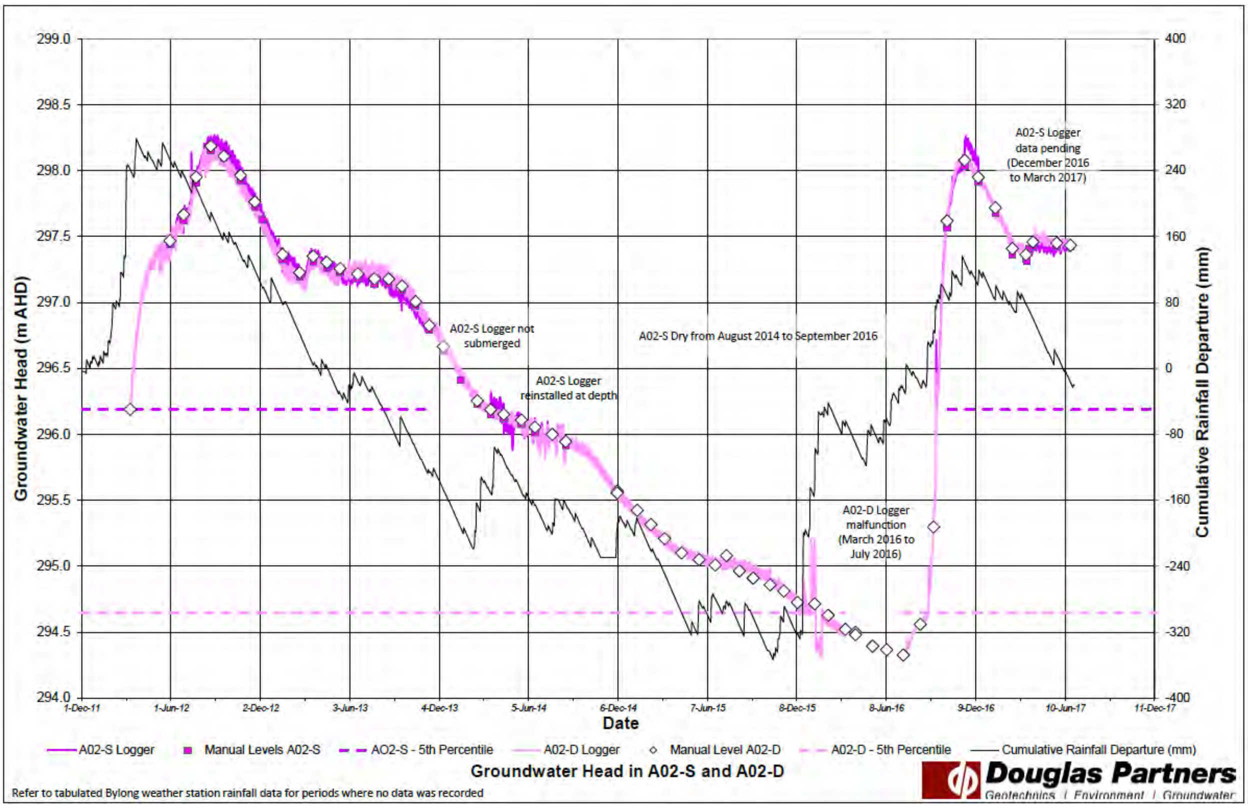


Figure 3-8 Groundwater level in AGE02S and AGE02D

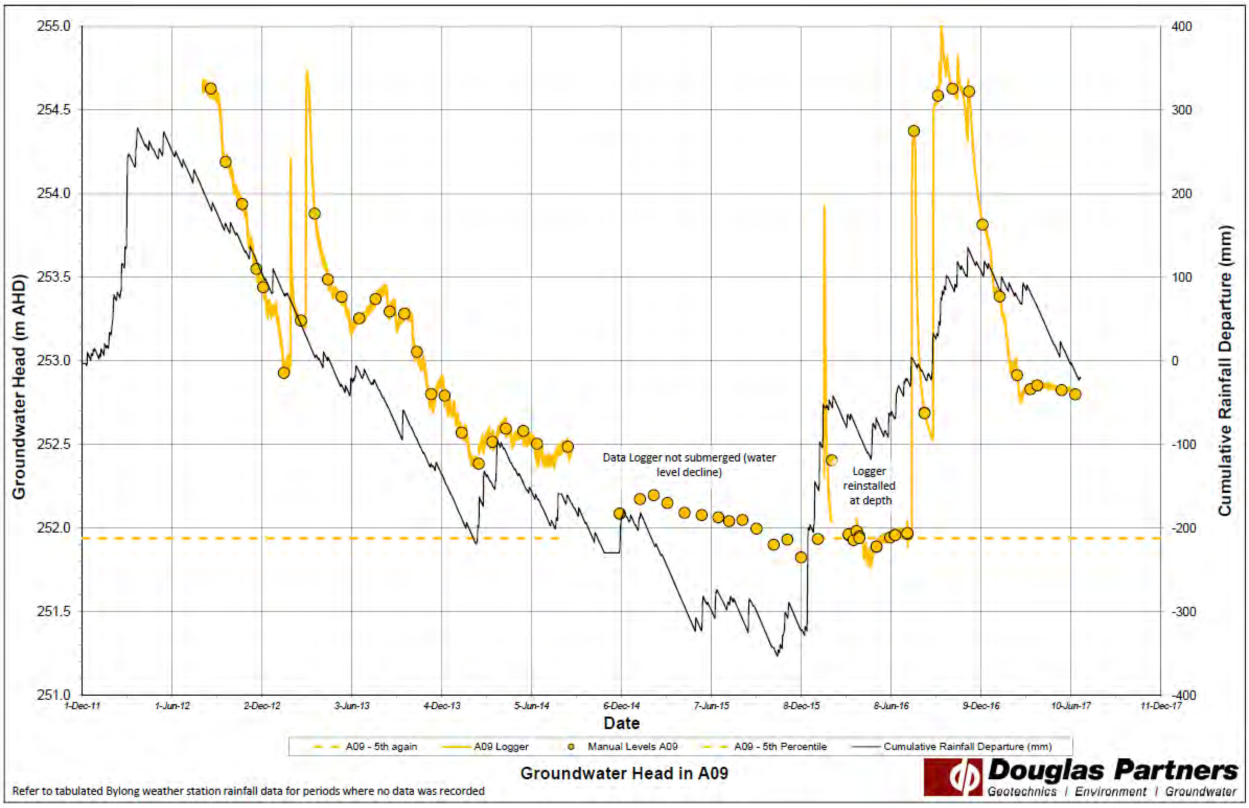


Figure 3-9 Groundwater level in A09

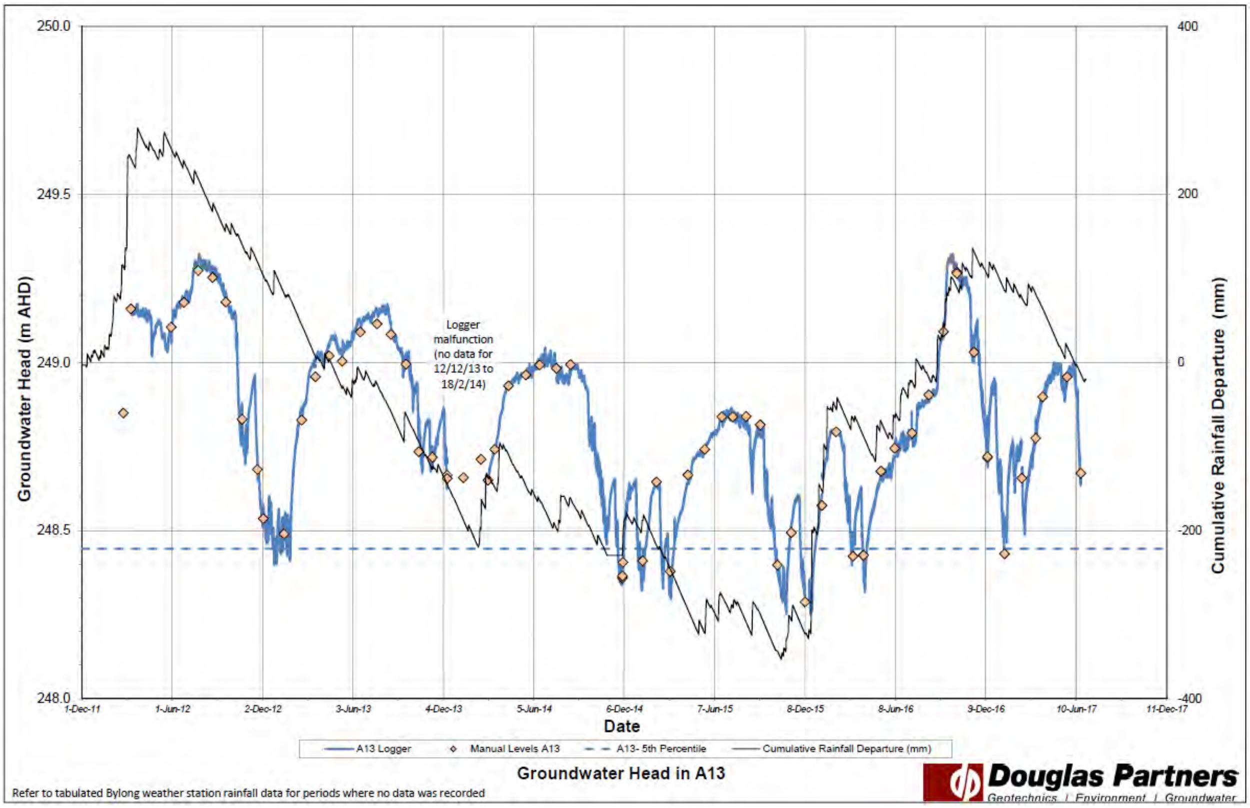


Figure 3-10 Groundwater level in A13

Table 3.2 below summarises the Water Access Licences held by KEPCO for the Bylong River Water Source. It indicates KEPCO now hold 3,045 units of groundwater within the alluvial groundwater systems within and immediately adjacent the Project Boundary. The current agricultural business uses less than half of the current entitlement, and indicates the additional capacity available to abstract makeup water for the mining project, if required.

Table 3.2 Bylong River Water Source - Water Access Licences held by KEPCO

Water Access Licence	Units	Property
17731 (20AL206647)	486	Bylong Park - Taworri
17711 (20AL206637)	248	Sylvania Park
17716 (20AL206649)	240	Brigalow
17709 (20AL206625)	494	Bylong Station
17729 (20AL206629)	486	Bylong Station
17732 (20AL206665)	5	Renfrew Park
17712 (20AL206645)	240	Lonair Park
17713 (20AL206655)	336	Wallings Aggregation
17714 (20AL206663)	104	Tinka Tong
17720 (20AL206633)	155	Lee Creek
17726	251	Lee Creek
Total	**3,045**	

4 Management of impacts

The numerical modelling has provided guidance on the potential range of impacts that could occur due to the Project. In response to this information, a range of measures to manage impacts have been developed which are detailed in a draft Water Management Plan. In order to manage ongoing landholder concerns around the uncertainty of groundwater modelling and the implications that the impacts of the Project may have on landholders licenced water entitlements, KEPCO has proposed to negotiate Compensatory Water Supply Agreements with the neighbouring landholders in the unforeseen event that the Project does affect licenced water supplies.

4.1 Water management plan

KEPCO has prepared a draft Water Management Plan (WMP) to provide further information around the proposed management of water resources associated with the Project. The draft WMP provides information on the proposed groundwater monitoring, management and mitigation measures that will be implemented throughout the life of the Project. The Groundwater Management Plan within the draft WMP outlines the continuing monitoring during the life of the Project, and additional monitoring sites that will be installed to improve the ability to detect impacts early. The monitoring program is designed to supply information that will be analysed every quarter and if predetermined limits are exceeded trigger an investigation. Trigger Action Response Plans (TARPs) have been developed which utilise trigger thresholds to provide an early warning of potential impacts, and higher level triggers to mitigate, manage and remediate any impacts.

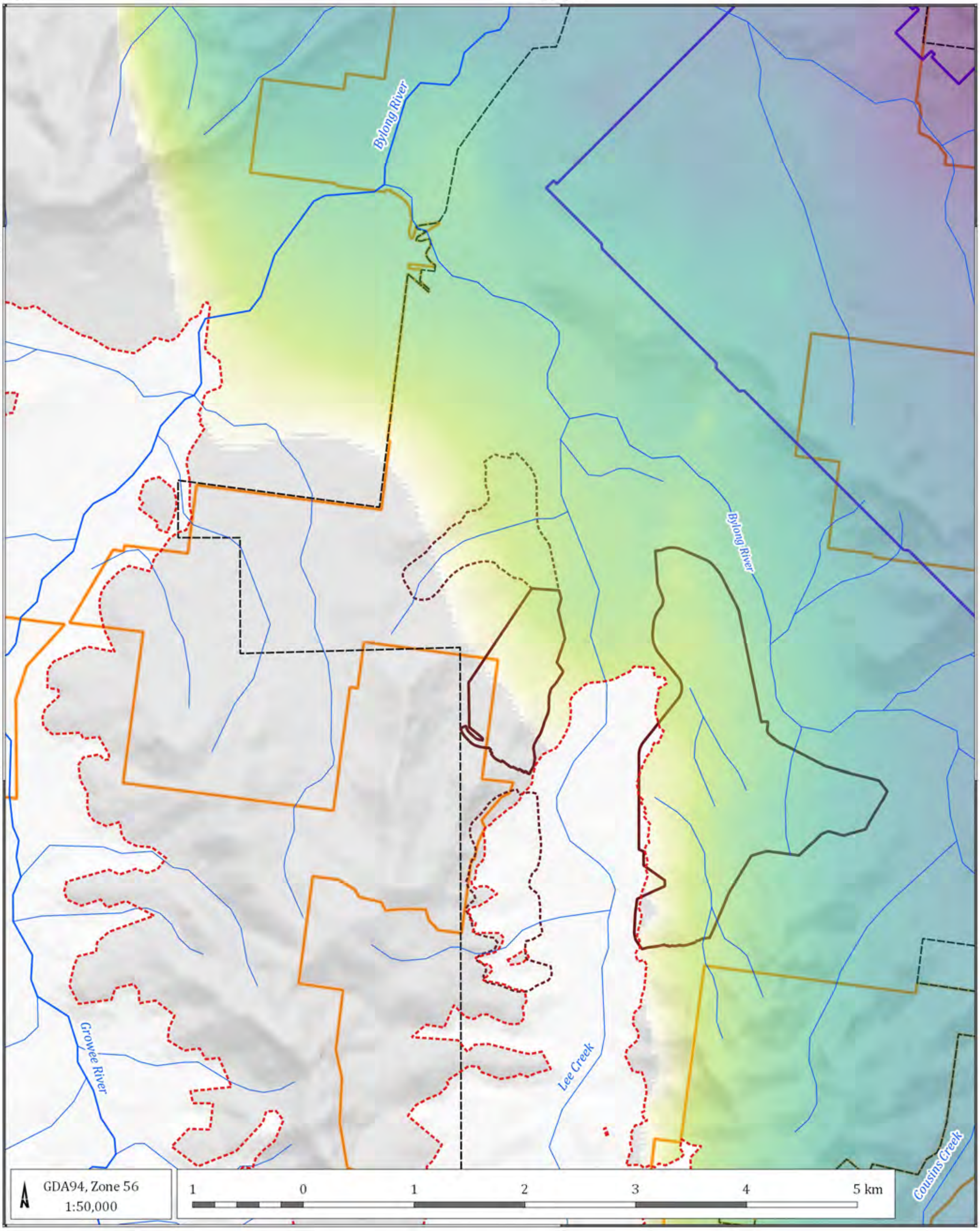
4.2 Management of impacts on private water bores

As noted previously the Project's mining operations will not directly excavate any alluvial sediments which form the aquifer from which the landholders on private properties extract their water. Therefore, the impact of the Project's mining operations on private bores can only occur indirectly through the coal measures. For an impact to occur as a result of mining operations, the coal seams need to be connected via alluvial aquifers to areas where private bores are located. Figure 4-1 below shows the area where the Coggan coal seam occurs below the water table and is therefore saturated (blue-green coloured area), as well as where the seam is above the water table and unsaturated (grey area). The figure demonstrates that the potential for impacts to occur at private properties occurring along the Growee River to the west of the Project is very low for two reasons; firstly the coal seam rises above the water table and is therefore unsaturated to the west of the Project, and secondly, the seam is cut and removed by erosion along the alignment of Lee Creek. These factors combine to hydraulically disconnect the coal seams from the private properties to the west along the Growee River.

Despite the extremely low risk of impact to landholders in the Growee River catchment to the west, as noted previously, KEPCO has developed a draft Compensatory Water Supply Agreement which is to be discussed and negotiated with neighbouring landholders to address the residual concerns. Alluvial water take during mining

As noted previously, the Project will directly abstract groundwater from the Permian coal measures that are intercepted due to mining, and also from a borefield within the Quaternary alluvium, if make up water is required for mining operations. In addition to this, mining will also indirectly influence the flow of groundwater from the bedrock into the alluvial aquifers. Whilst the Project will not directly excavate any alluvial sediments, the indirect impact will occur when the groundwater pressure within the Permian bedrock reduces, which reduces the flow of water from the bedrock into the overlying alluvial aquifers. The changes in the groundwater flow were extracted from the numerical model to show where these changes in flow occurred and were most significant.

Figure 4-2 below shows the maximum change in flow through from the bedrock into the alluvial aquifer during the Project life. The figures show the change in the flow of groundwater to the alluvium is most significant around the edges of the alluvium as this is where the higher pressure from the underlying bedrock occurs and drives water into the alluvium.



LEGEND

- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Project Boundary
- Kepco owned land
- Coggan Seam presence
- Major drainage
- Minor drainage

Coggan Seam depth below water level

- 0.5
- 20
- 40
- 60
- 80
- 100
- 120

Bylong Coal Project (G1606Q)

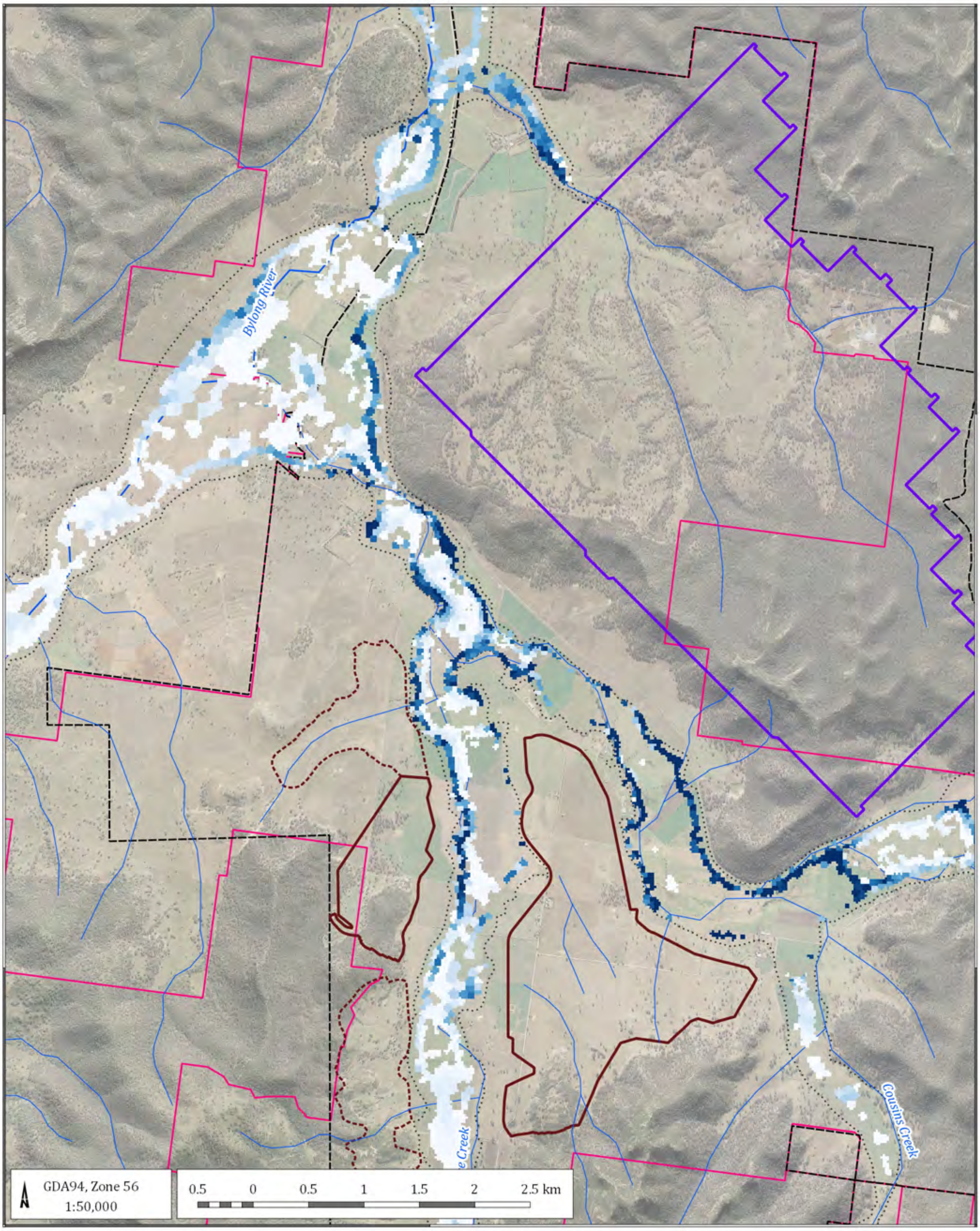
Occurrence and groundwater saturation within Coggan coal seam

AGE

DATE 13/12/2017

FIGURE No: **4-1**

G:/Projects/G1606.Bylong Coal Project/3_GIS/Workspaces_QGIS/G1606Q/04-01_G1606_Occurance and saturation within Coggan Coal Seam.qgs



LEGEND

- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Project Boundary
- Kepco owned land
- Quaternary alluvium
- Coggan Seam subcrop
- Thickness contour (m)
- Major drainage
- Minor drainage

Maximum flux change (m3/year)

- 1
- 10
- 25
- 50
- 150

Bylong Coal Project (G1606Q)

Peak change in groundwater flux through base of alluvial sediments

AGE

DATE 13/12/2017

FIGURE No: **4-2**

G:/Projects/G1606.Bylong Coal Project/3_GIS/Workspaces_QGIS/G1606Q/04-02_G1606_Peak change in groundwater flux through base of alluvial sediments.qgs

The very small changes in the flow of groundwater from the bedrock to the alluvial aquifers indicated by the Supplementary RTS modelling above cannot be directly measured in the field. This impact can only be inferred from any changes in groundwater levels measured in monitoring bores, and then estimated using numerical modelling. The change in groundwater flow to the alluvium will be accounted for with water licences each year. A methodology for this is included within the Draft Water Management Plan.

AGE (2016b) provided estimates of the volume of water predicted to be indirectly removed from the alluvium due to a reduction in the water pressure in the Permian bedrock (refer Figure 6-20 and Table 6-9 in AGE 2016b). The results showed that whilst the open cut is operating, the borefield will reduce water levels within the alluvium, which results in an increase in Permian groundwater entering the alluvium due to the pressure differential between the units. An analysis of the water budgets from the model indicates the reduced flux to the alluvium is predominantly due to the presence of the open cut mine, both during the active mining period and the rehabilitation period when it is refilling. As the underground operation is more distant from the alluvium, the influence on the alluvial aquifer is a lesser portion of the overall impact. Again, the analysis shows the indirect take of water from the alluvial systems can be readily accounted for with the water licences held by KEPCO for the Bylong River Water Source.

4.3 Permian groundwater use

KEPCO has previously applied for a water licence for 2,093 units under the *Water Act 1912* for the Project to extract groundwater from the Permian strata. DPI Water has advised this licence application is valid and will be transferred as a licence under the *North Coast Fractured and Porous Rock Groundwater Sources Water Sharing Plan 2016* (North Coast WSP) which commenced on 1 July 2016. During the Supplementary RTS phase, further modelling indicated the potential for an increased peak water take of 4,099 ML/year to occur from the Permian strata. KEPCO has acquired 411 units of water access licences from the Sydney Basin – North Coast Water Source (North Coast water source) under the North Coast WSP as a result of land acquisitions which have occurred. The additional water licences to account for the water taken from the North Coast WSP will be obtained by KEPCO from the open market. At the time of writing, there were 182 Water Access Licences within the Sydney Basin – North Coast Water Source with a total share component of 96,047units (including potable and domestic water). Given the amount of licences within this water source and the volume of units required for the Project (i.e. 1,596 units), it is expected the additional entitlement will be obtainable prior to underground mining to account for predicted water takes.

4.4 Management of groundwater entering mining areas

When managing any excess mine water make within the underground, it is important to understand the quality of the water. Figure 4-3 shows the range in electrical conductivity measurements for samples collected from monitoring bores installed within the Coggan coal seam, the alluvial aquifer and surface water samples. The electrical conductivity measurements indicate the water samples range from fresh to slightly brackish. Of note is the similarity in the salinity range of samples collected from the alluvial aquifer and the Coggan coal seam. Whilst there may be some variability of salinity across the longwall mining area, this data suggests that salinity may not be a major impediment to management of any excess water sourced from the Coggan coal seam, and that any excess water not required for mine operations could potentially be used beneficially in a similar manner to the alluvial groundwater.

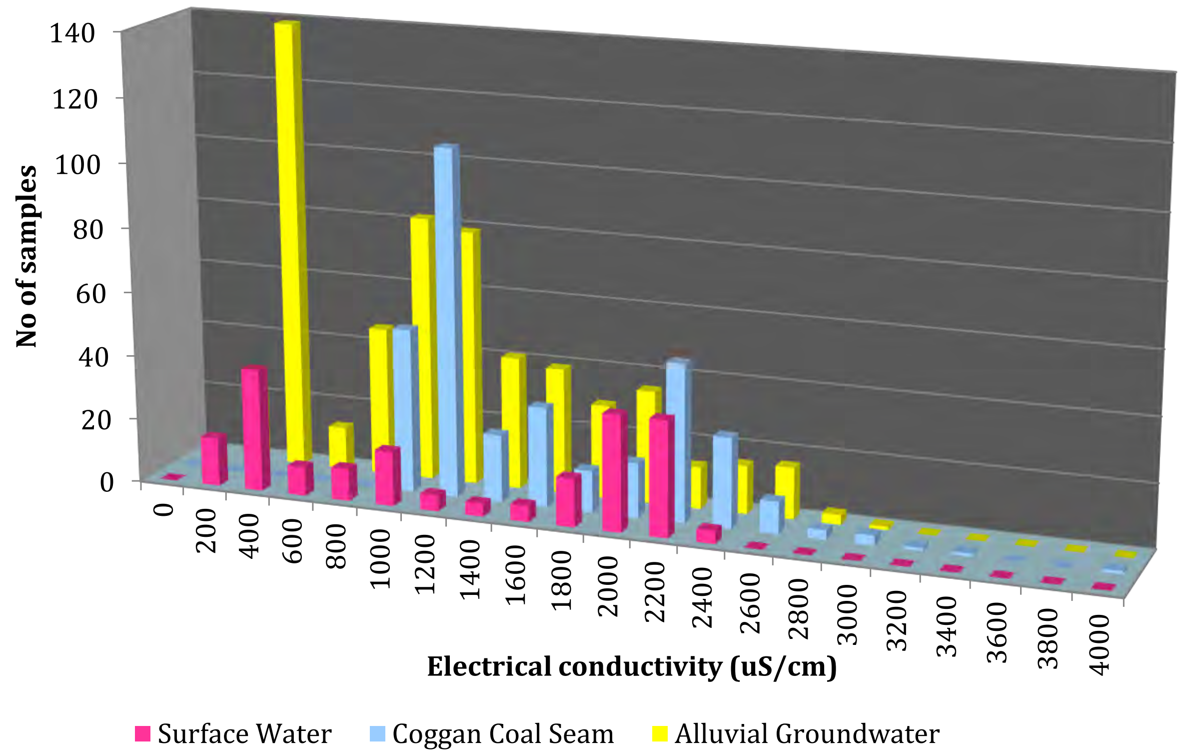


Figure 4-3 **Histogram of electrical conductivity in groundwater and surface water samples**

4.5 Unforeseen impacts

It is acknowledged that there is the possibility that unforeseen impacts occur. A monitoring program detailed within the draft Water Management Plan will be utilised in conjunction with TARPs and Compensatory Water Supply Agreements to ensure that any unforeseen adverse impacts from the Project are detected early, then appropriately mitigated or managed by KEPCO.

As outlined previously in Section2.3, because the Project is a greenfield development, the predictions from numerical modelling cannot be validated at this point because mining has not commenced. To address this limitation, a significant effort to characterise the groundwater regime using field investigations occurred including bores installations, pumping tests in the alluvium and packer tests in the coal measures. This field data guided the calibration of the model and influenced the impact predictions. The remaining uncertainty in the model predictions was then assessed to indicate the upper and lower bound of likely impacts, and to determine appropriate management and mitigation measures to be developed. This is the same processes that has been followed for other greenfield mining projects in the upper Hunter Valley and Gunnedah Basin in NSW in recent years. This is the same process that will have to be undertaken for any other future greenfield mines undertaken in NSW. A draft Water Management Plan has been developed that outlines the proposed management and mitigation measures.

Submissions and consultation with neighbouring landholders who are outside the area predicted to be impacted (including in the most exceptional uncertainty modelling scenarios), indicate some have remaining concerns about the potential for their water supplies to be affected, despite the modelling indicating this will not occur. Many of these landholders are located in areas where the coal seams proposed to be mined within the Project Boundary do not occur or are above the water table – therefore, a direct connection between the mine and the landholders does not exist in many cases.

Despite the low risk of impact and to address the residual concerns from neighbouring landholders, KEPCO has developed a draft Compensatory Water Supply Agreement which is to be discussed and negotiated with neighbouring landholders. The intention for these agreements is to provide further up front certainty for neighbouring landholders that should unforeseen impacts to their licenced water resources be experienced as a direct result of the Project that KEPCO will be responsible for managing, mitigating, and compensating these impacts to their agricultural operations. This responsibility is outlined within the draft Compensatory Water Supply Agreement and will be legally binding, which will provide the landholder with certainty over the process prior to any unforeseen impacts being experienced. It should be noted that similar provisions are already afforded in Schedule 4, Condition 27 of the Recommended Development Consent conditions. However the draft Compensatory Water Supply Agreement are proposed to be provided upfront to provide certainty and clarity over how any unforeseen impacts would be managed and mitigated by KEPCO.

KEPCO has also prepared a draft Water Management Plan that includes a monitoring program for the alluvial groundwater levels within the vicinity of the Project, as well as more broadly within the Bylong and Growee River valleys to identify the impacts of the Project's operations on the alluvium. The existence of the extensive buffer within the alluvium surrounding the Project's activities means it will act as an early warning system, providing time to detect and react should monitoring indicate impacts are propagating further than predicted by the numerical model. The monitoring program detailed within the draft Water Management Plan will provide information for interrogation against the TARPs. The TARPs include trigger thresholds, which if exceeded, provide an early warning of potential impacts, and higher level triggers to mitigate, manage and remediate any impacts. The draft Compensatory Water Supply Agreements ensure the Project will comply with the Aquifer Interference Policy and that any unforeseen adverse impacts to neighbouring landholders' water supplies as a direct result of the Project are appropriately managed and addressed by KEPCO. In the worst case scenario, the agreements are designed to allow landholders properties to be acquired by KEPCO, if monitoring indicates water supply bores have been impacted by more than the 2 m threshold stipulated within the Aquifer Interference Policy.

5 Summary and conclusions

Extensive information has been gathered on the hydrogeological regime within the Bylong River catchment over the past five years which has been utilised to develop a comprehensive conceptual understanding of the groundwater systems. This information has then been utilised to construct and calibrate a regional numerical model. The numerical model has been refined and updated at the various stages of the approvals process as new information has become available. The Supplementary RTS provides the latest calibrated model which includes improved understanding of the alluvial aquifer gained through an alluvial pump testing program in early 2016. The most recent validation of the numerical model utilises the latest monitoring information and confirmed that it represents the alluvial groundwater responses to rainfall recharge, which is the main source of replenishment for the alluvial system adjacent to the Project.

Uncertainties within the groundwater modelling have been comprehensively assessed within the modelling and provided an indication of the bounds of groundwater impacts that could occur. This process has confirmed that there will be no adverse impacts on neighbouring private landholder's bores within the alluvium.

The NSW Aquifer Interference Policy requires proponents *"demonstrate that they have the ability to obtain the necessary licences in order to account for the take of water from any relevant water source requires."* KEPCO holds an extensive amount of water access licences for the Bylong River Water Source, significantly more than is required to account for predicted water takes. KEPCO currently also holds valid applications for and entitlements for predicted water takes from the Sydney Basin North Coast water source up to Year 19 of the Project and there is a sufficient depth in the market for KEPCO to secure additional licence allocations in the future.

A draft Water Management Plan has been prepared early on to provide further detail on the proposed monitoring, management and mitigation measures to be implemented to manage impacts from the Project. The management plan is supported by an extensive monitoring network that comprises 111 monitoring sites and over five years of data collection that has comprehensively characterised baseline conditions. A draft Compensatory Water Supply Agreement has also been prepared and is proposed to be negotiated up front with landholders whom continue to be concerned in relation to the potential impacts on their licenced water allocations.

In conclusion, the assessment indicates the Project's impacts on groundwater can be managed throughout the life of mining operations in accordance with relevant NSW legislation, and the draft Water Management Plan and Compensatory Water Supply Agreements and will allow the Project to coexist within the surrounding agricultural environment.

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Appendix A Validation hydrographs

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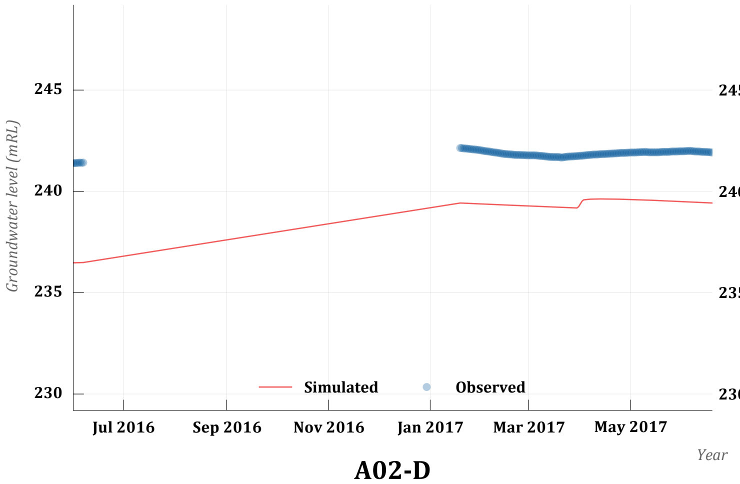

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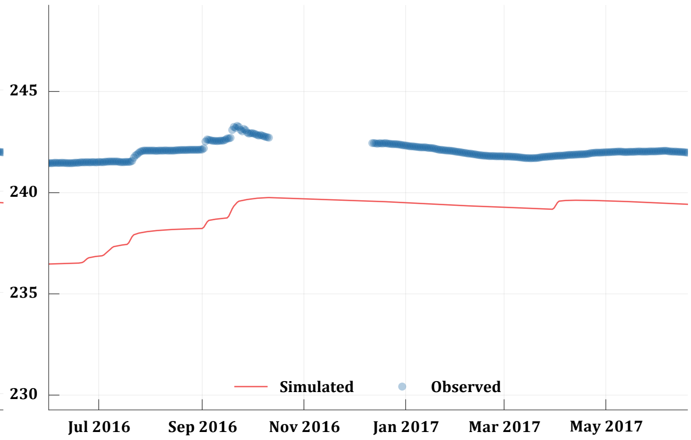

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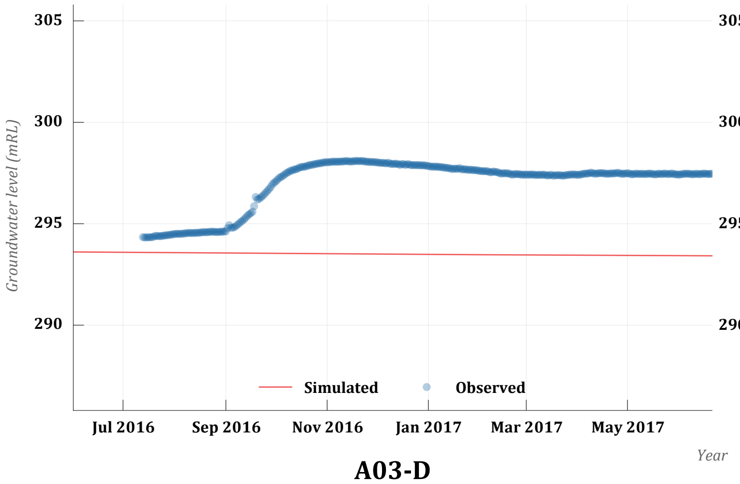

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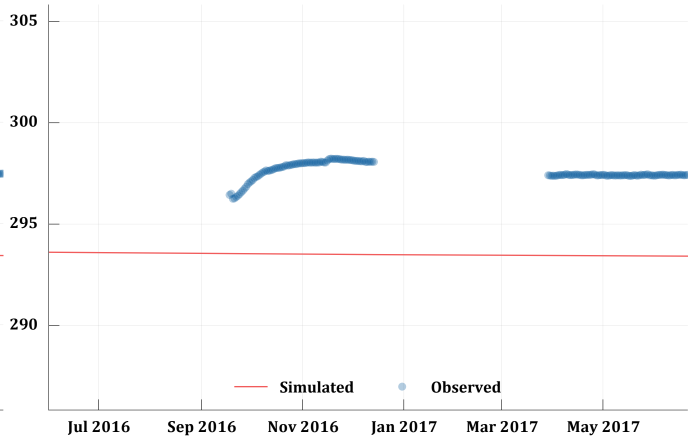

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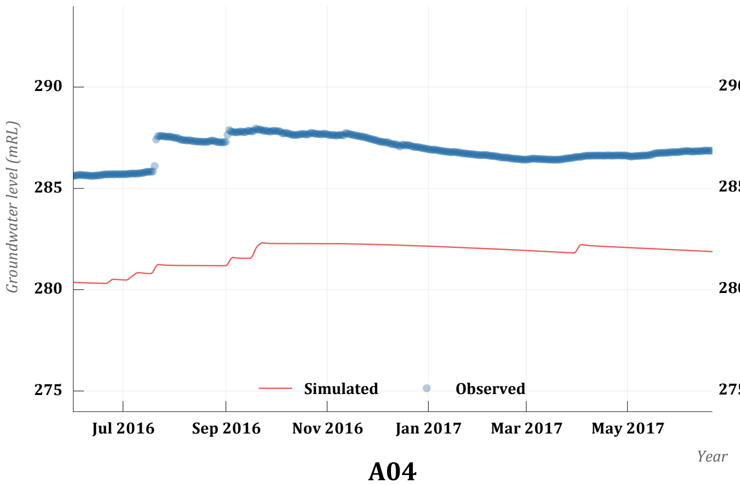

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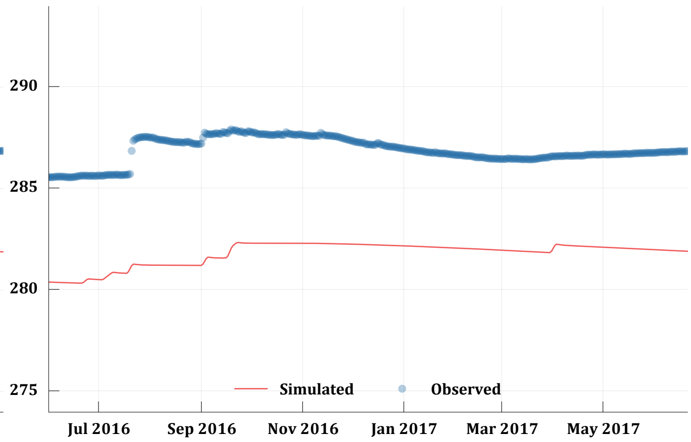

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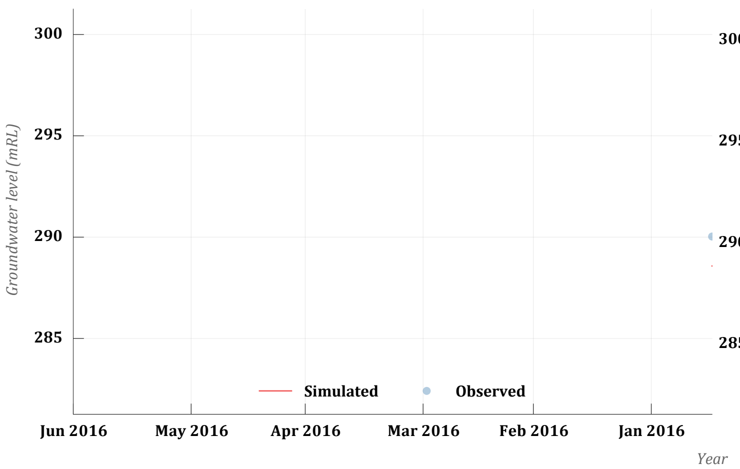

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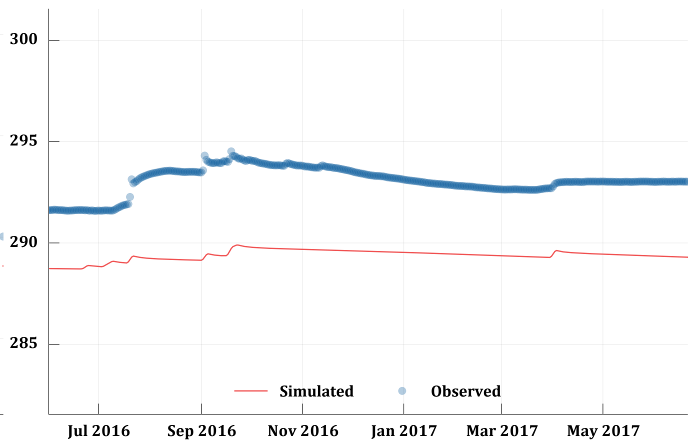

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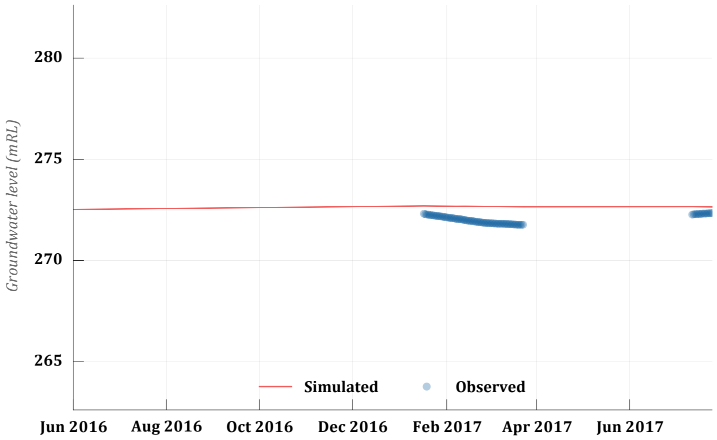

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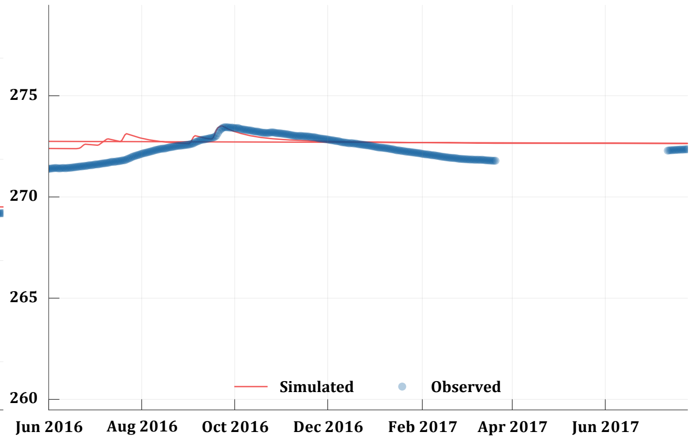

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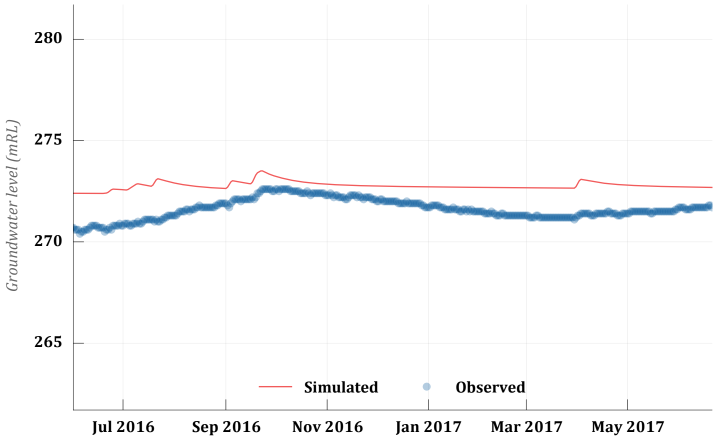

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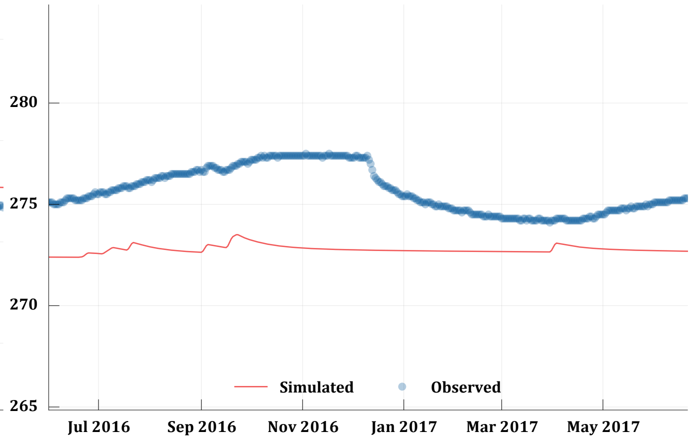

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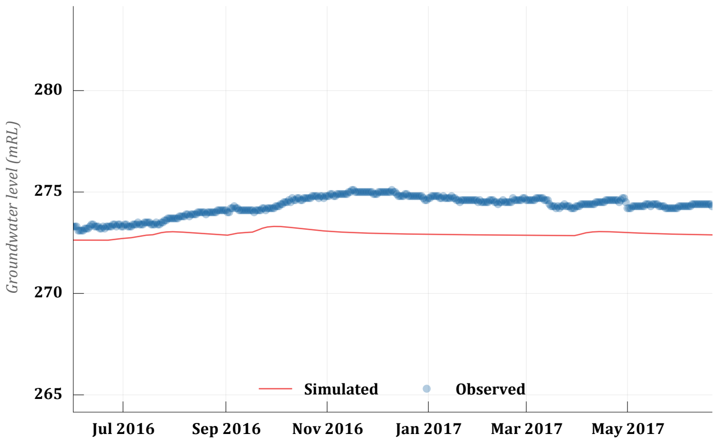

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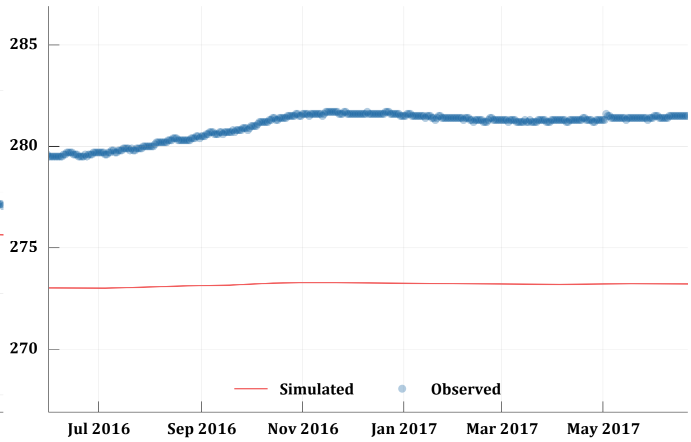

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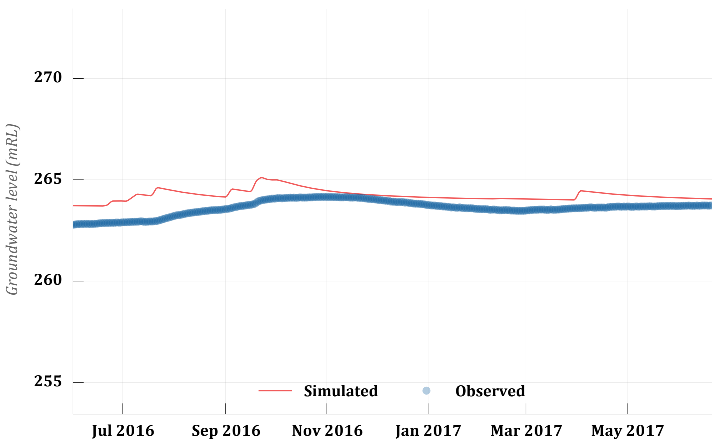

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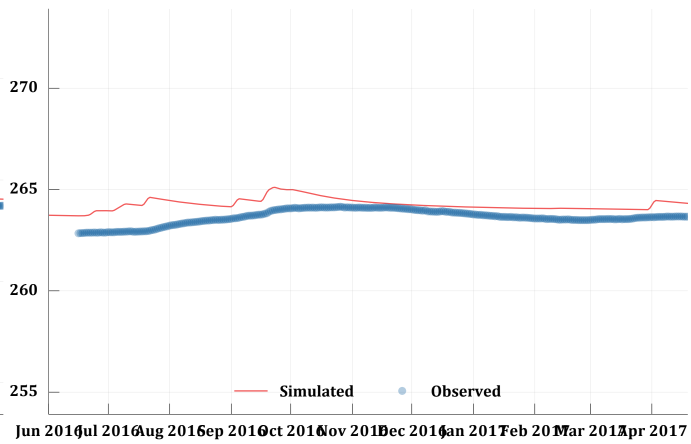

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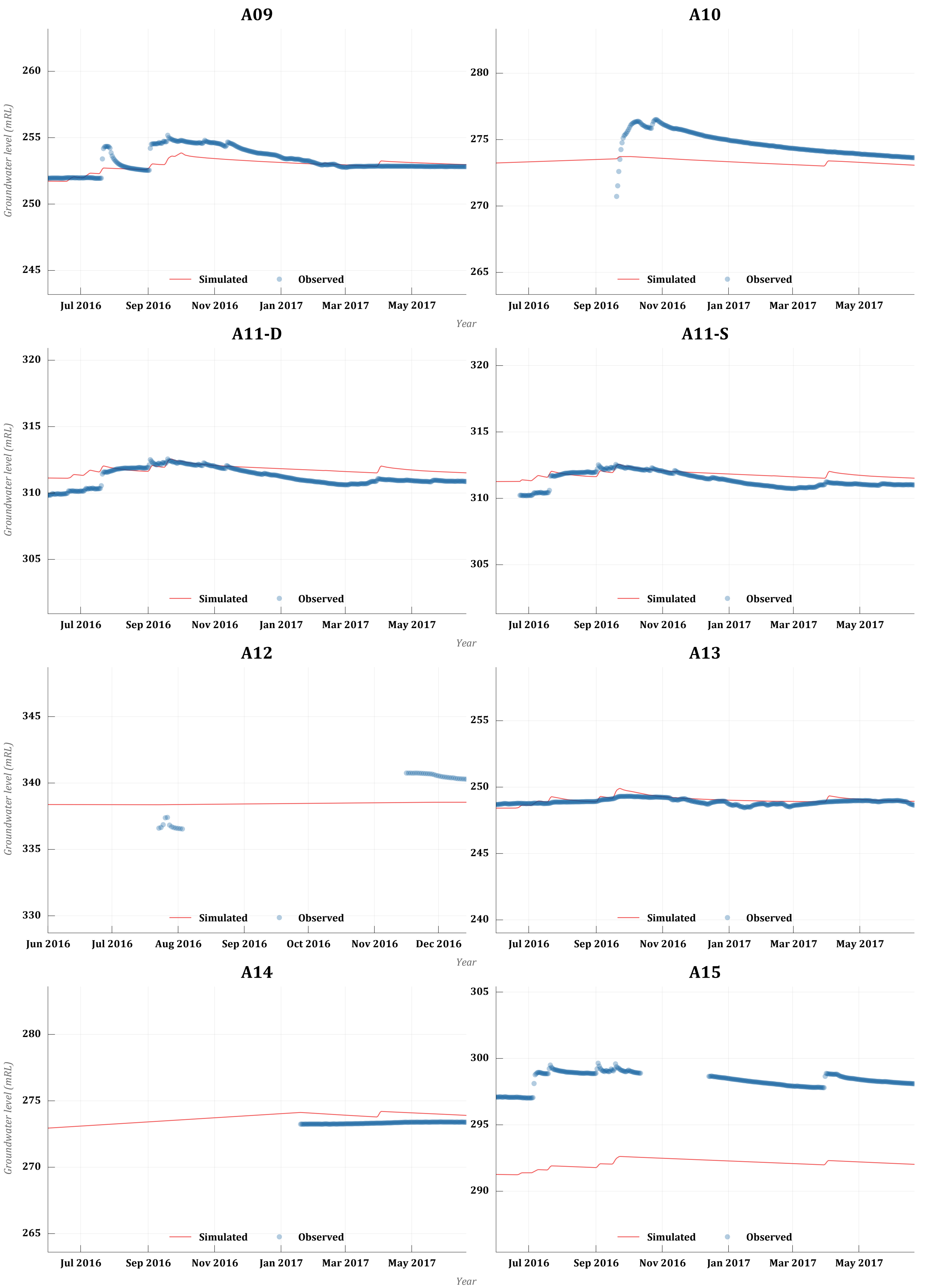
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Observed
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Sep 2016
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Mar 2017
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Year
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275
270
265
Simulated
Observed
Jul 2016
Sep 2016
Nov 2016
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Mar 2017
May 2017
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315
310
305
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Observed
Jul 2016
Sep 2016
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Jan 2017
Mar 2017
May 2017
Year
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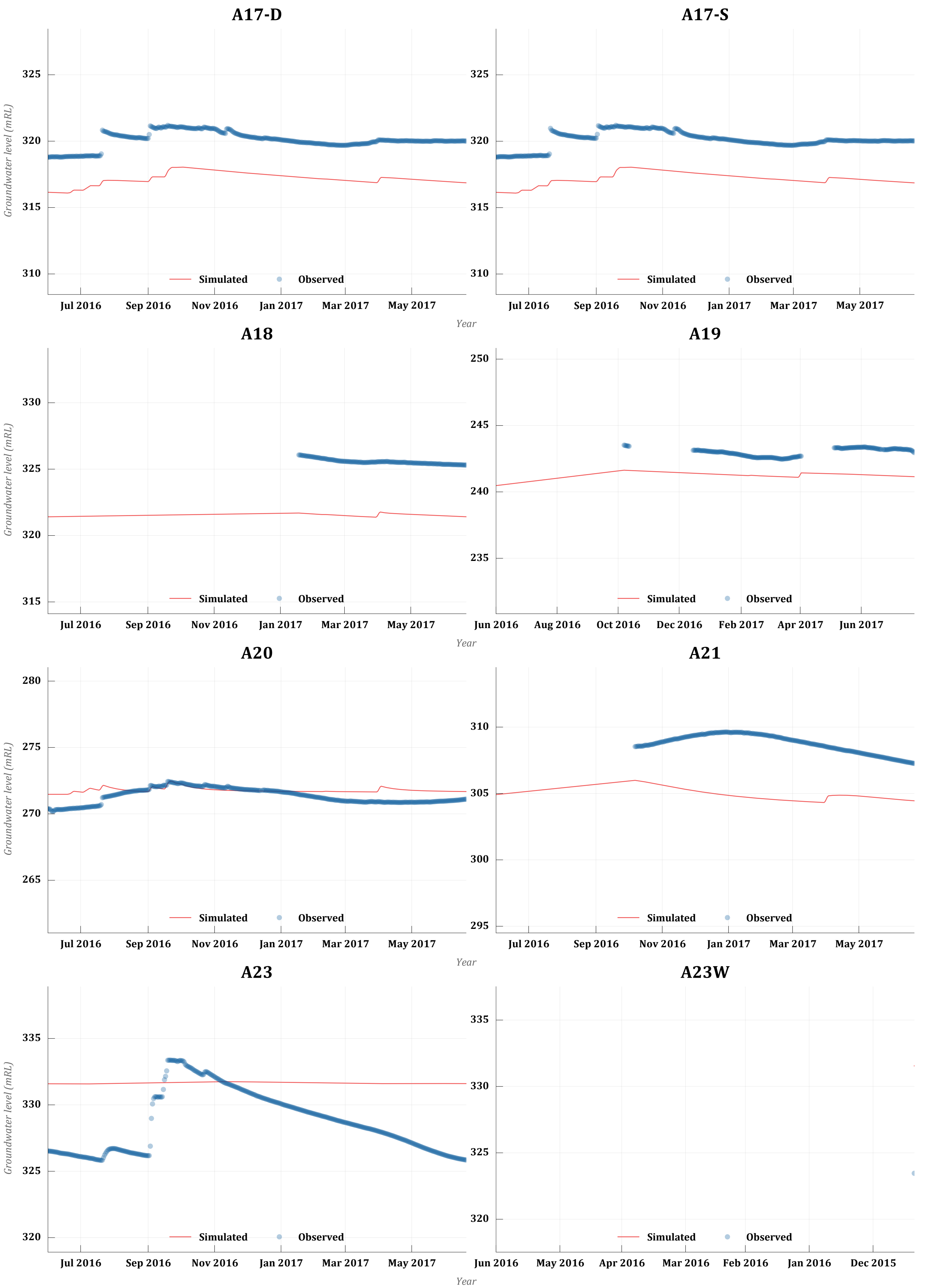
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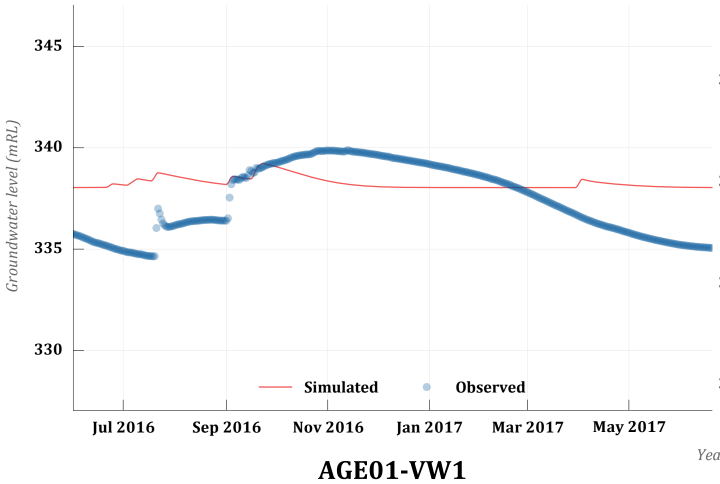

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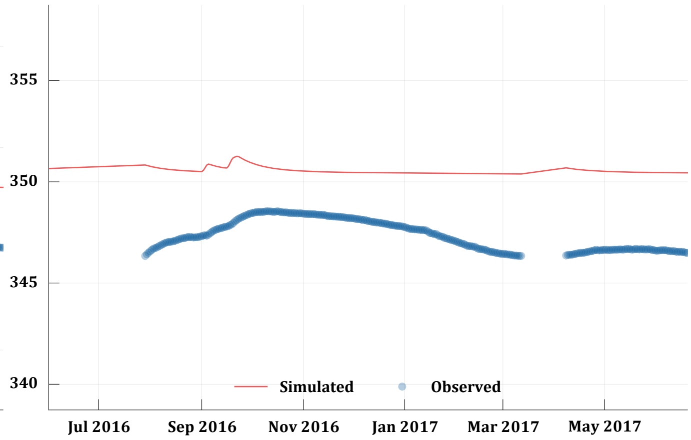

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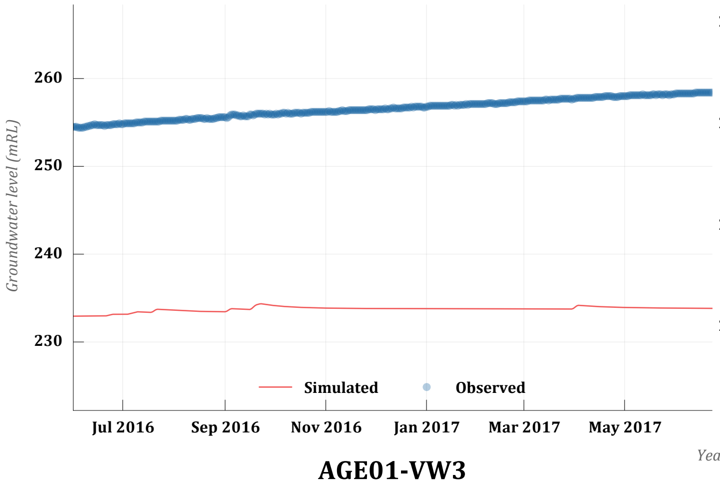

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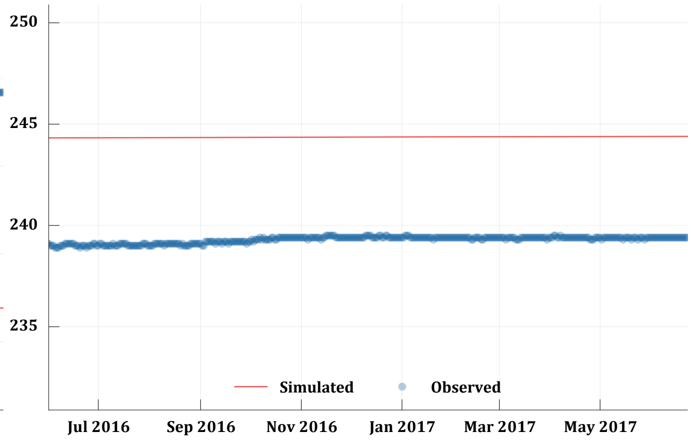

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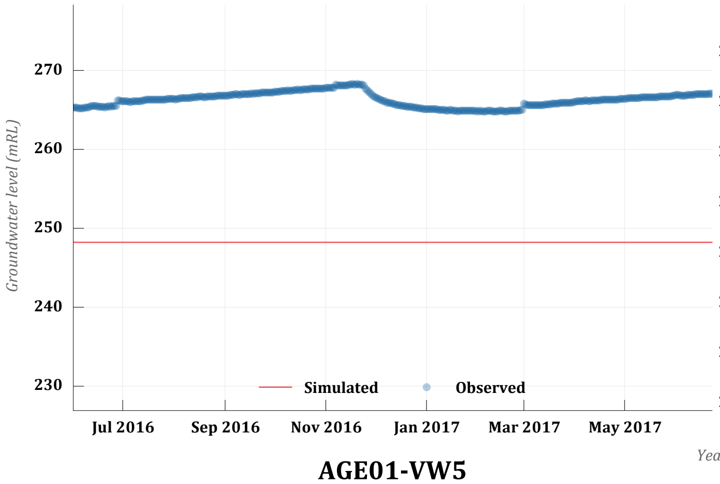

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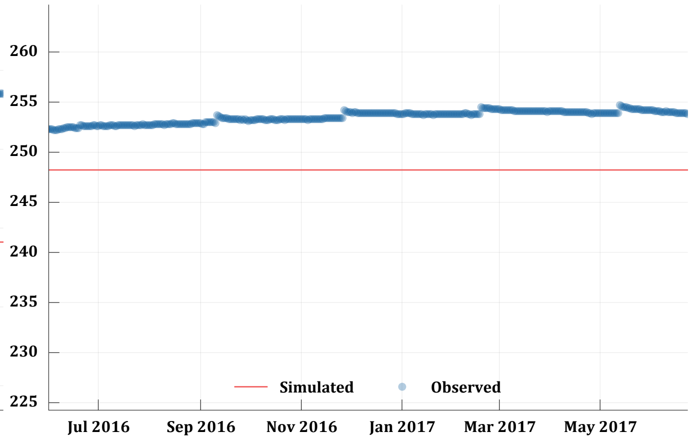

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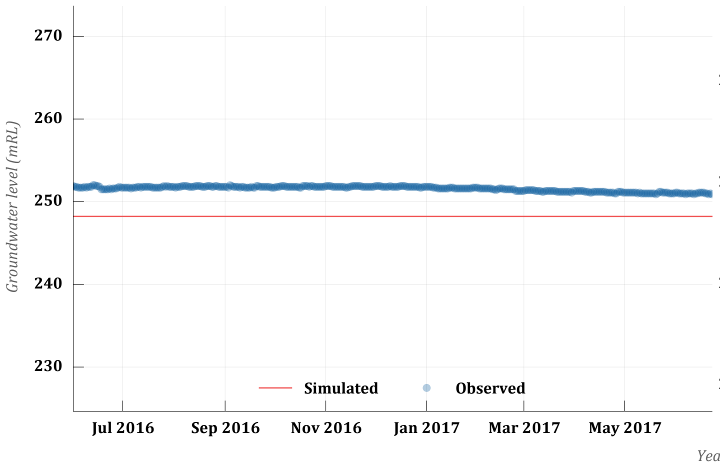

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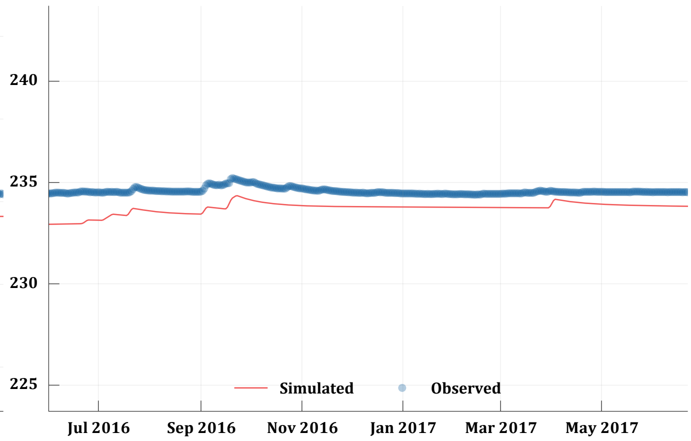

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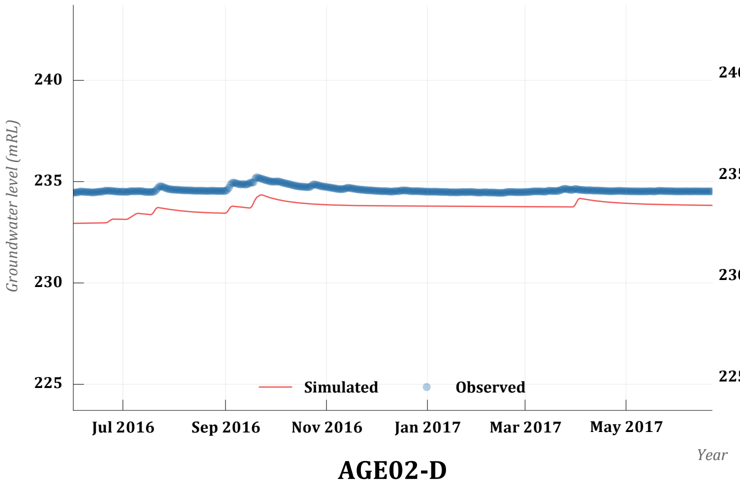

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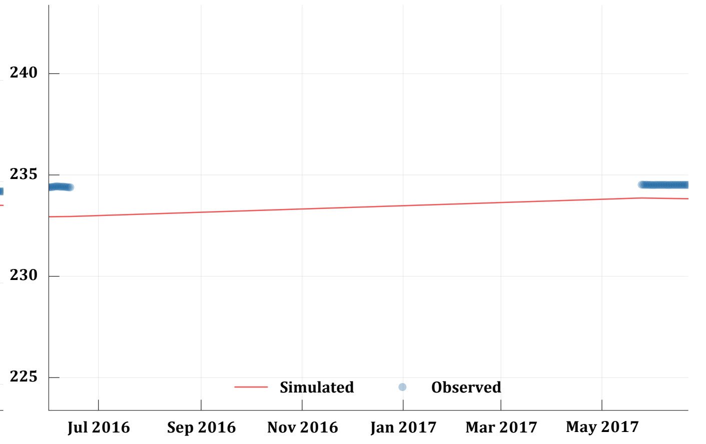

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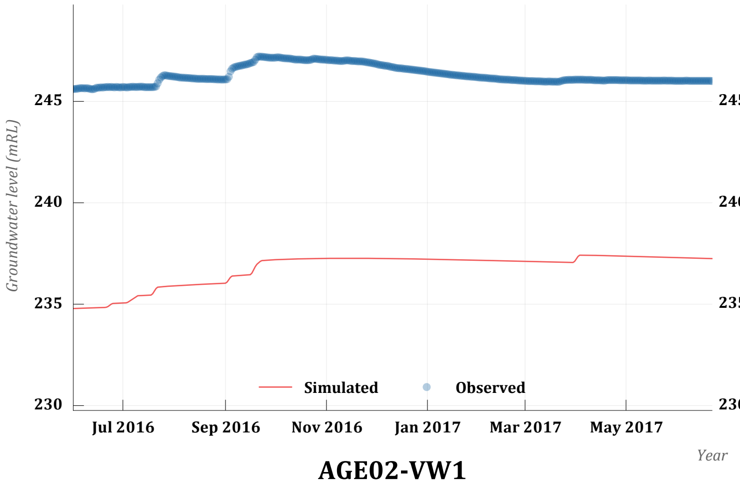

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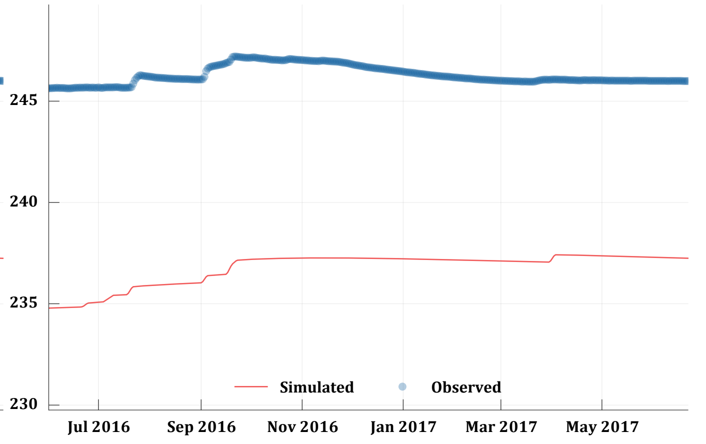

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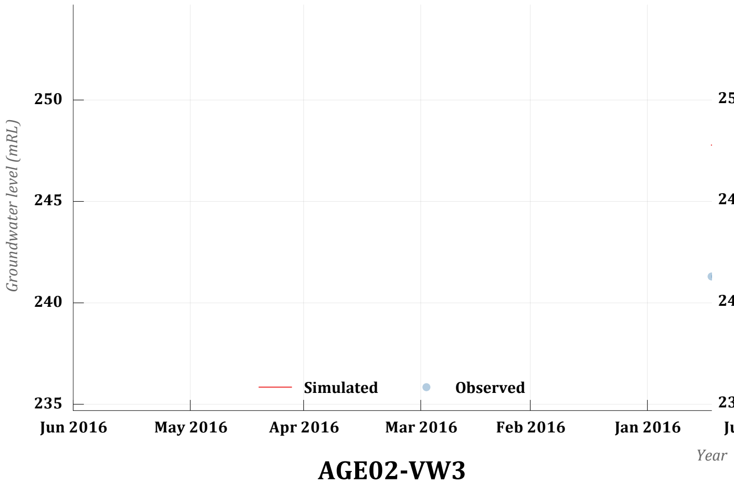

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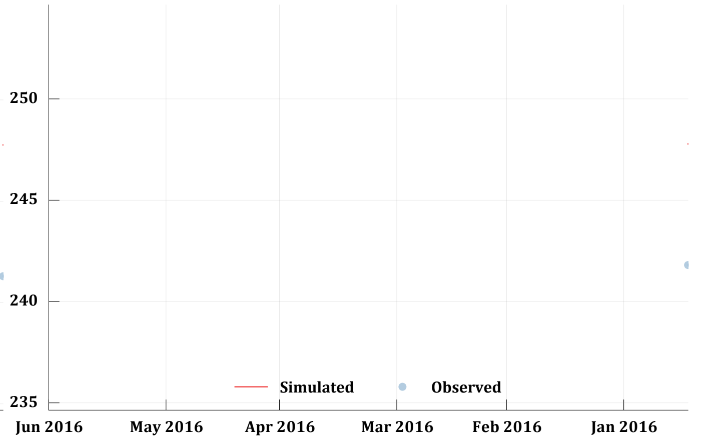

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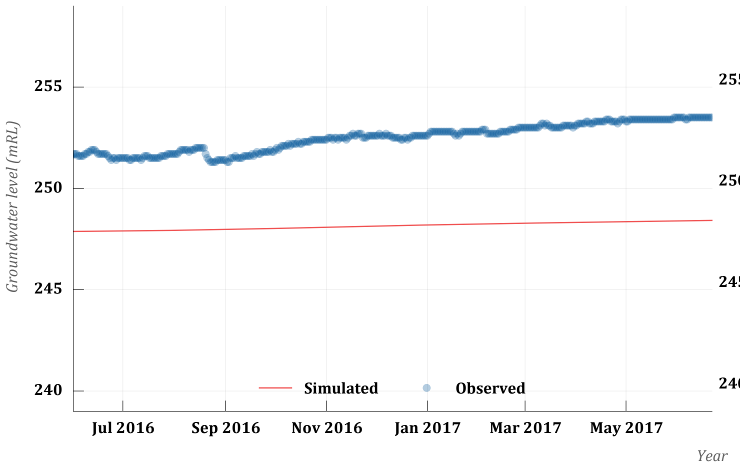

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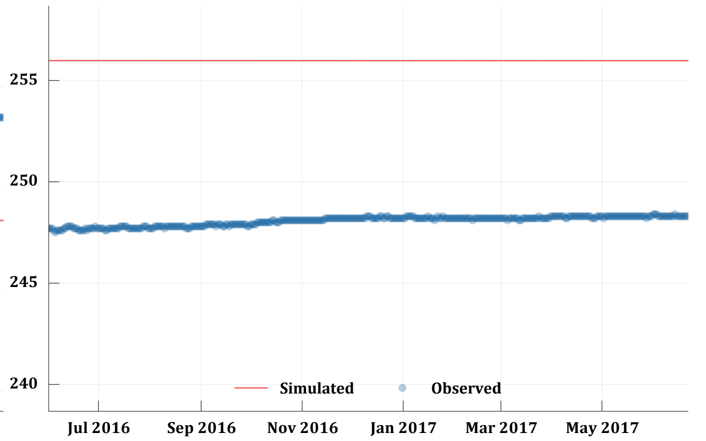

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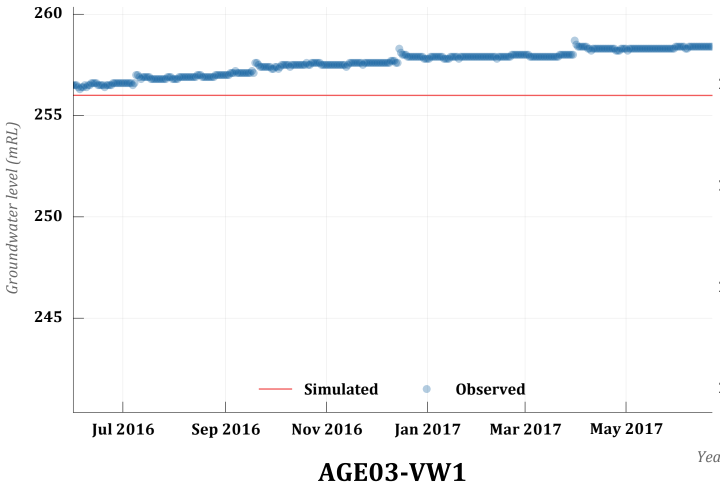

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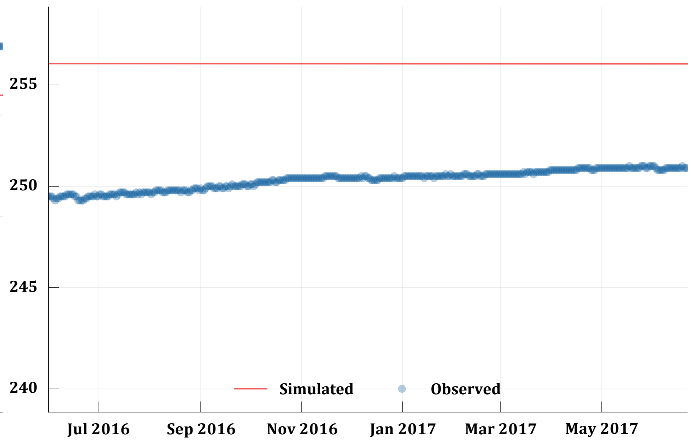

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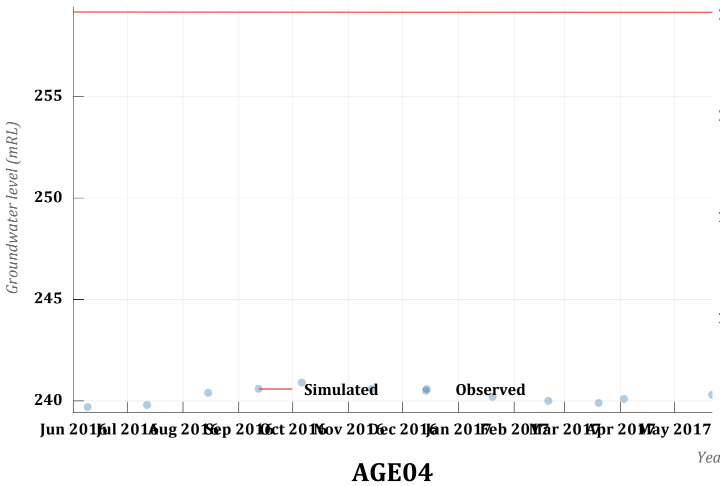

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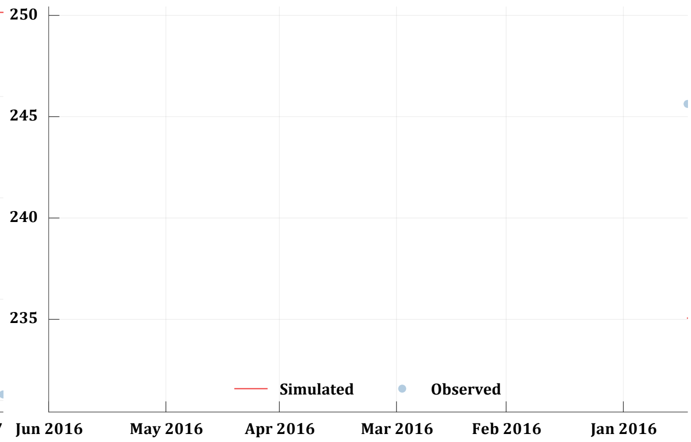

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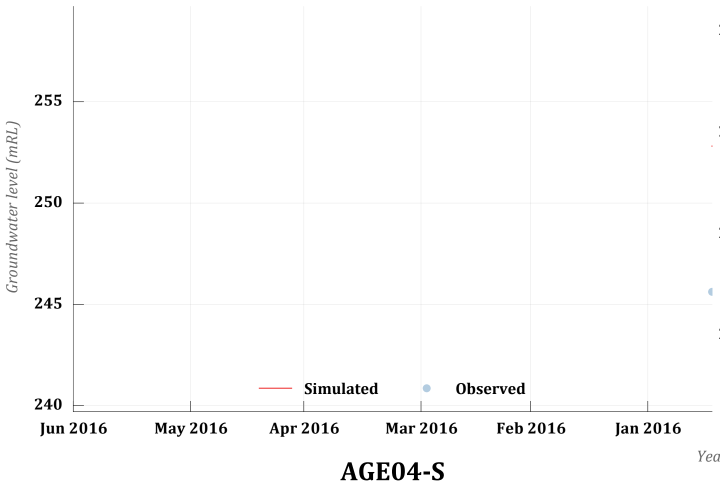

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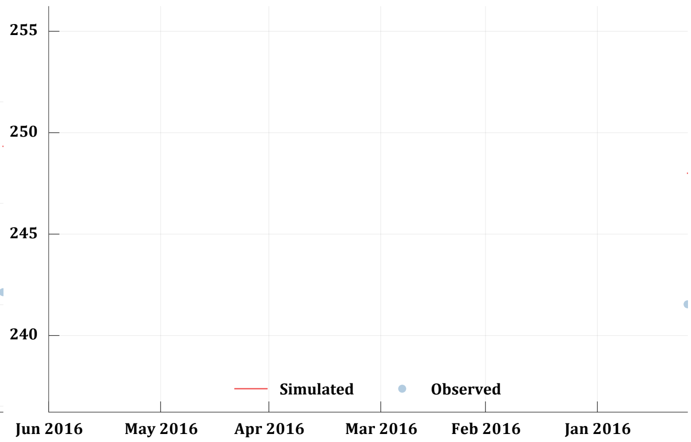
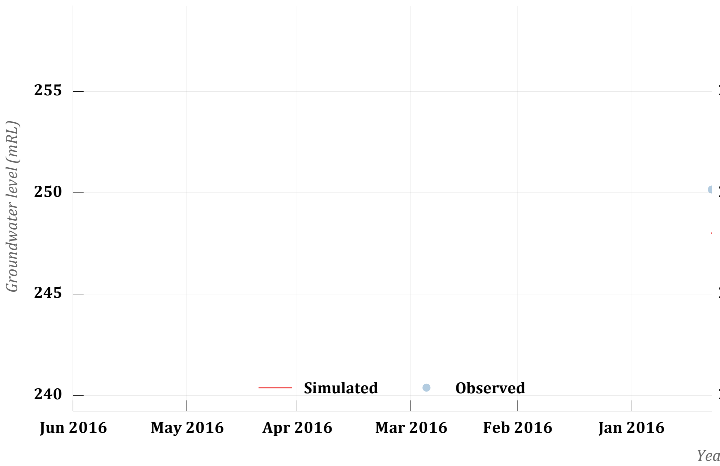
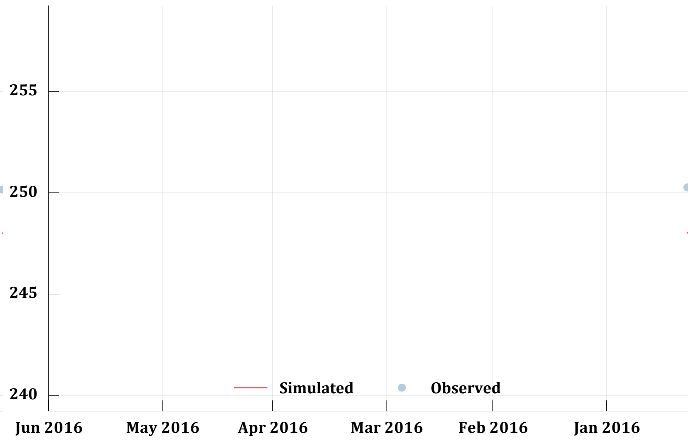


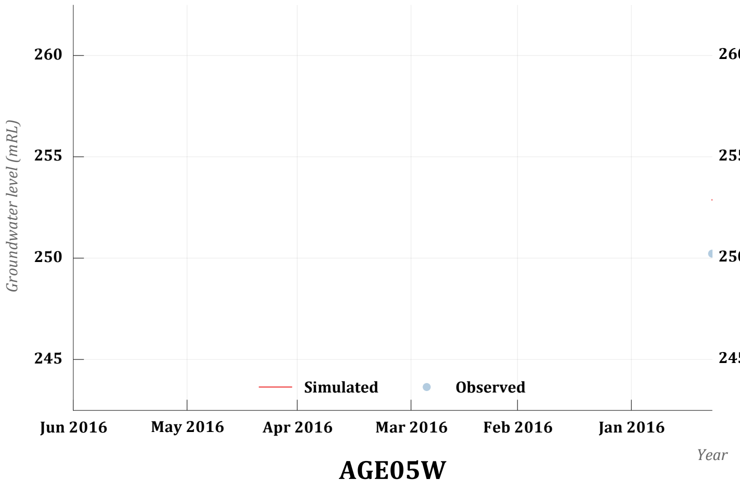
AGE04-S



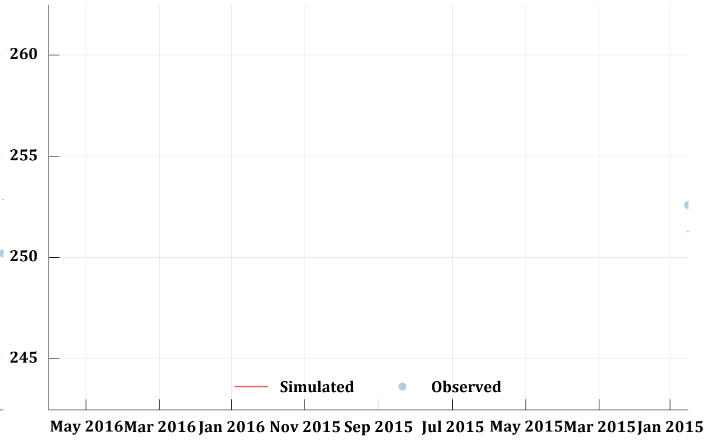
AGE04W



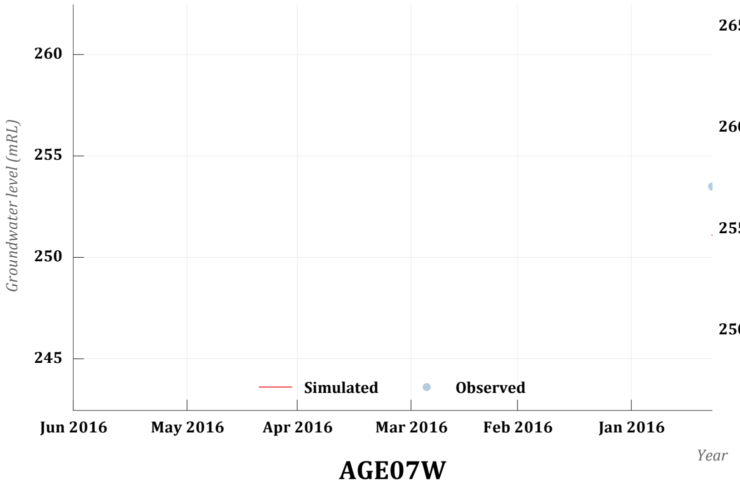
AGE05



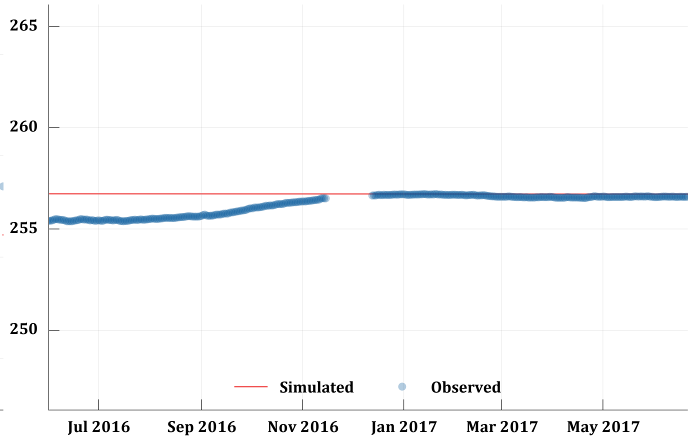
AGE05A



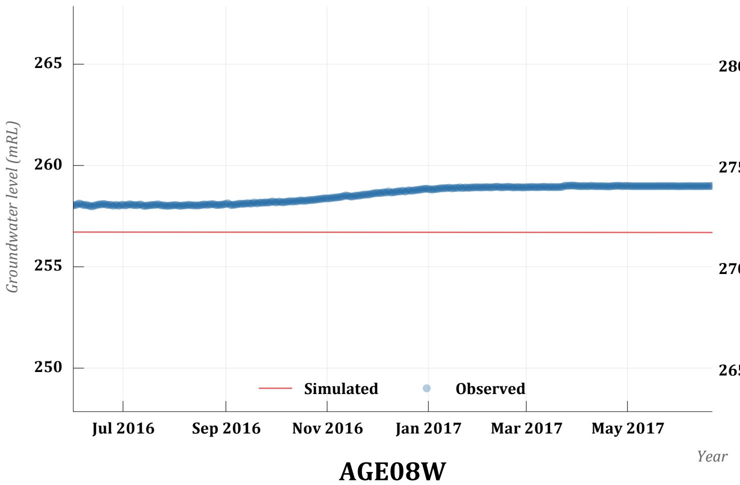
AGE05W



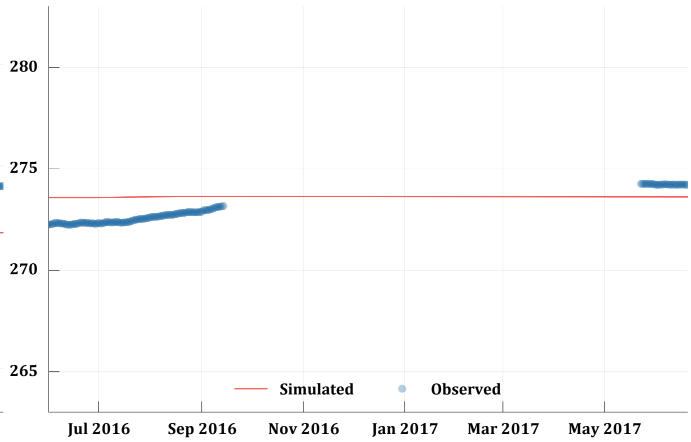
AGE07



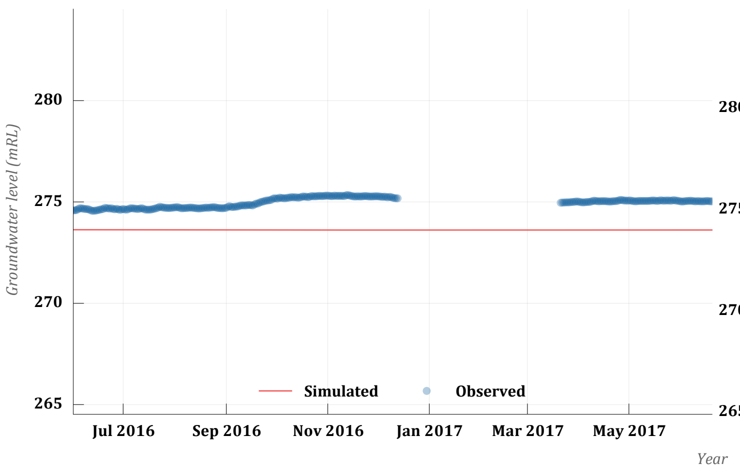
AGE07W



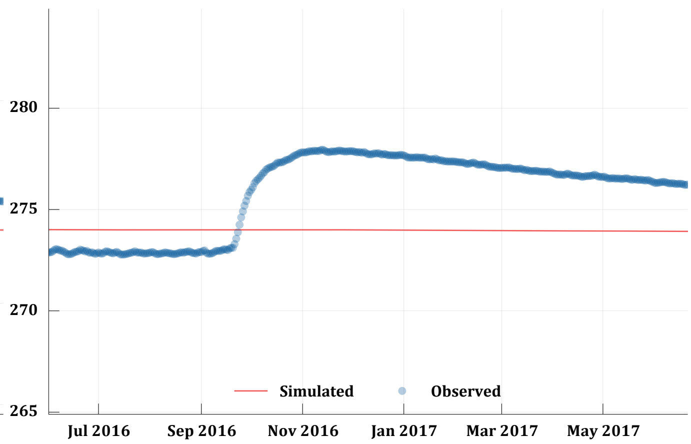
AGE08



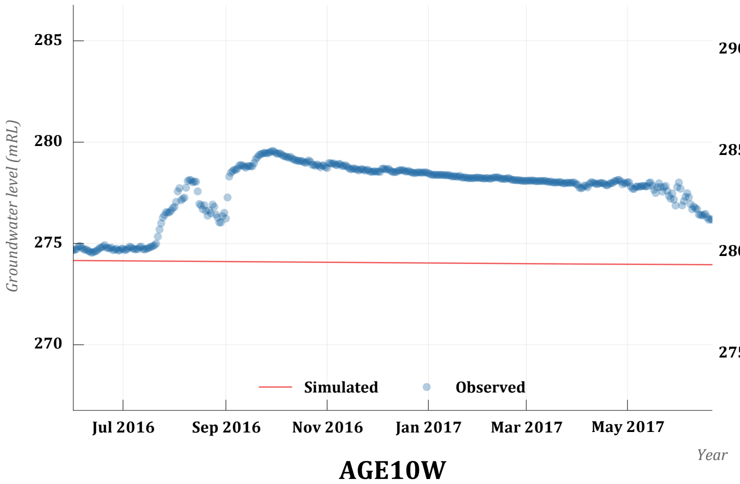
AGE08W



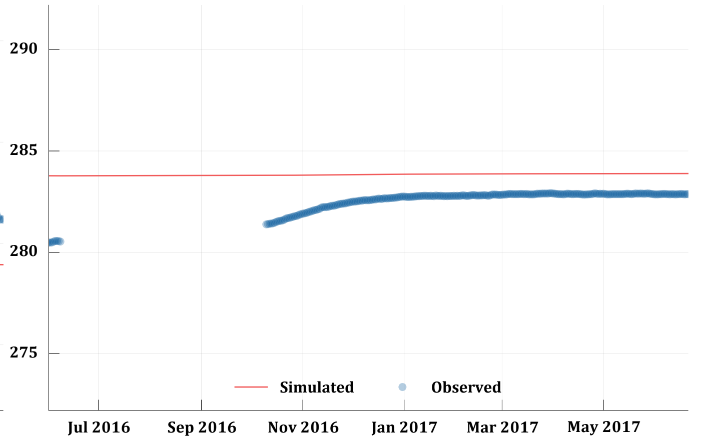
AGE09



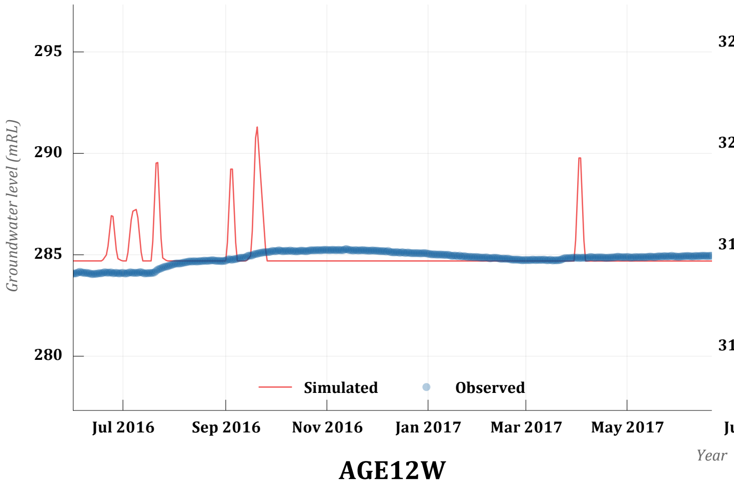
AGE09W



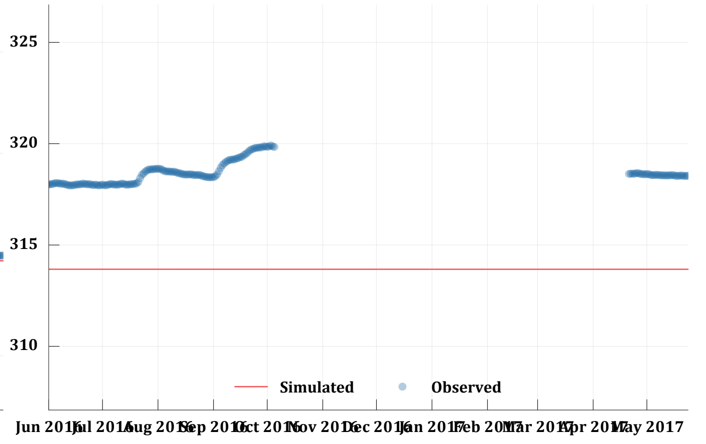
AGE10



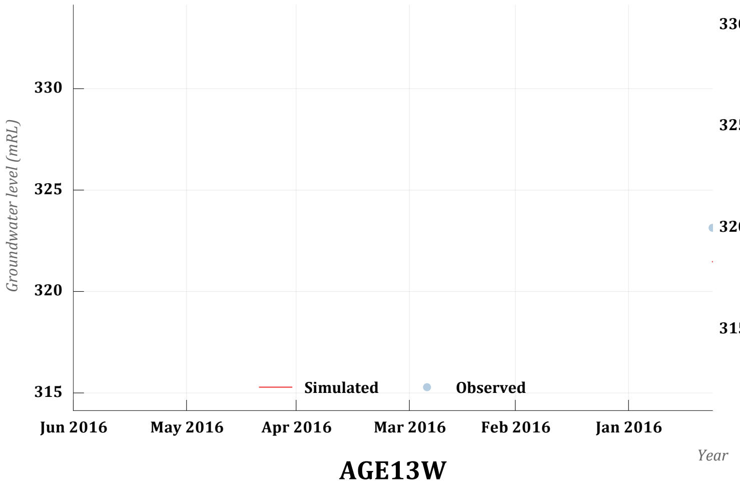
AGE10W



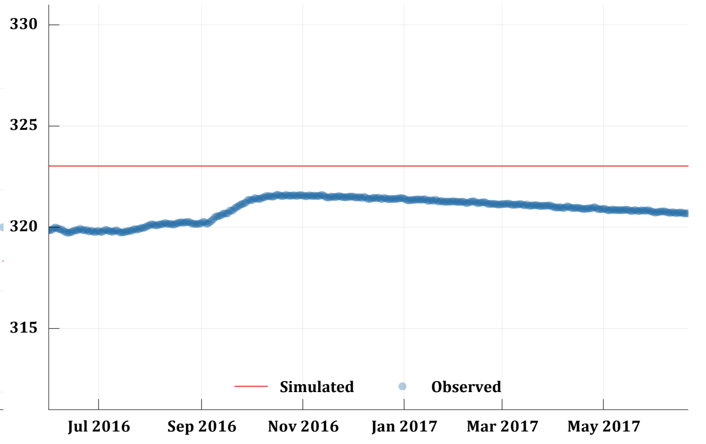
AGE11W



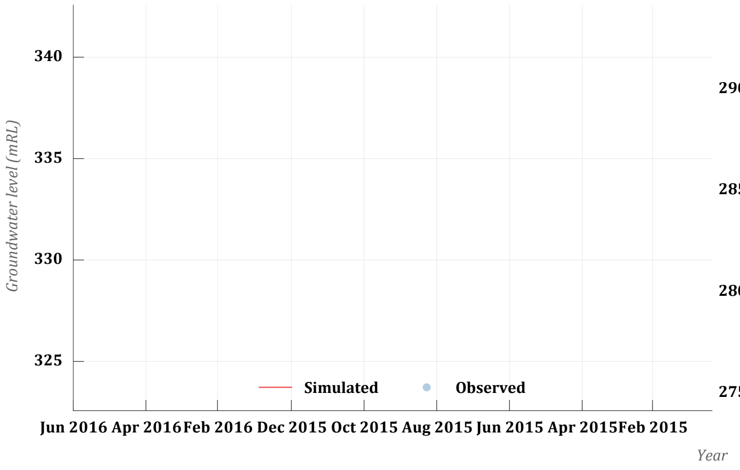
AGE12W



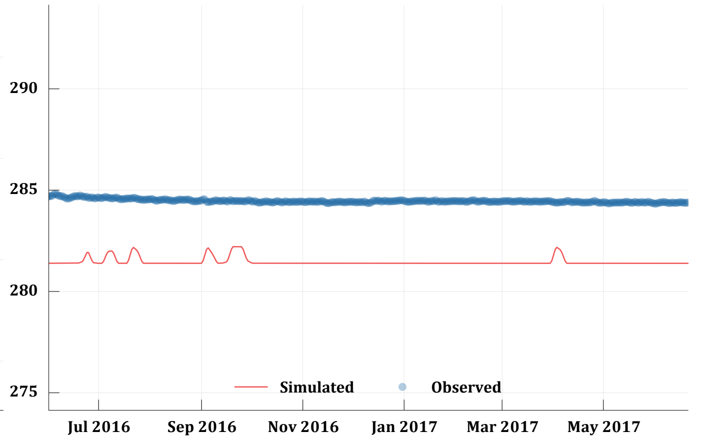
AGE13



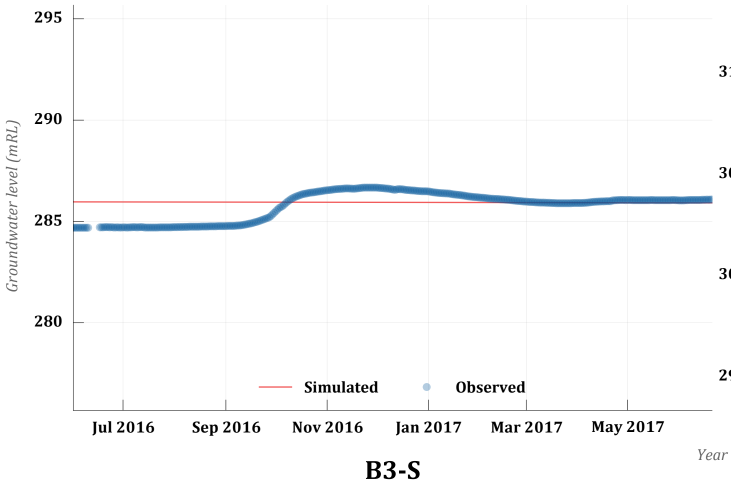
AGE13W



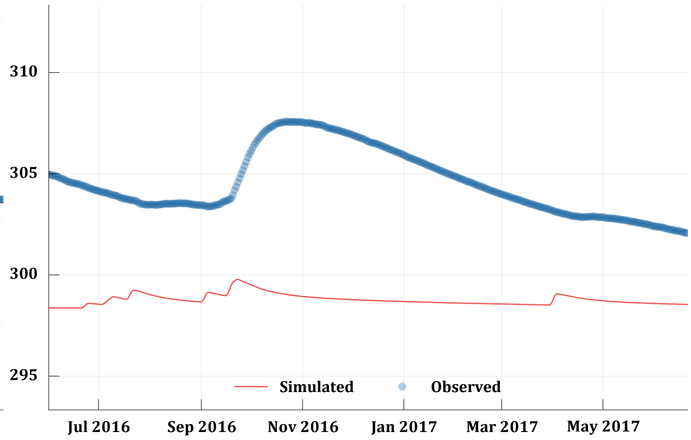
AGE14



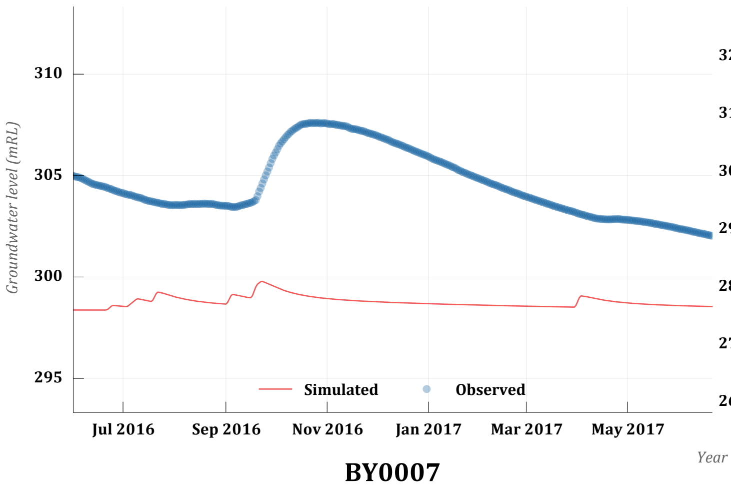
AGE15



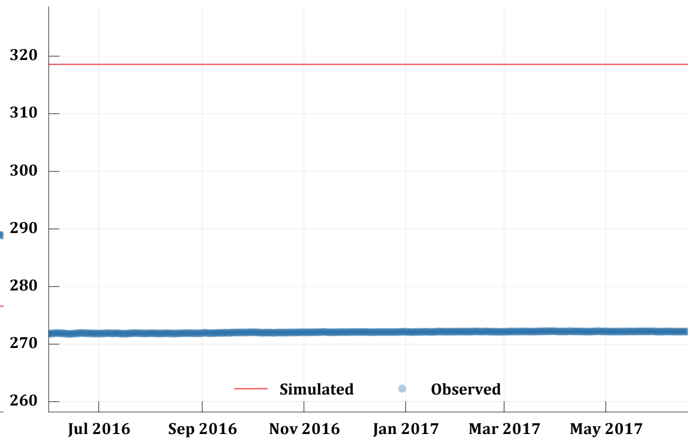
B3-D



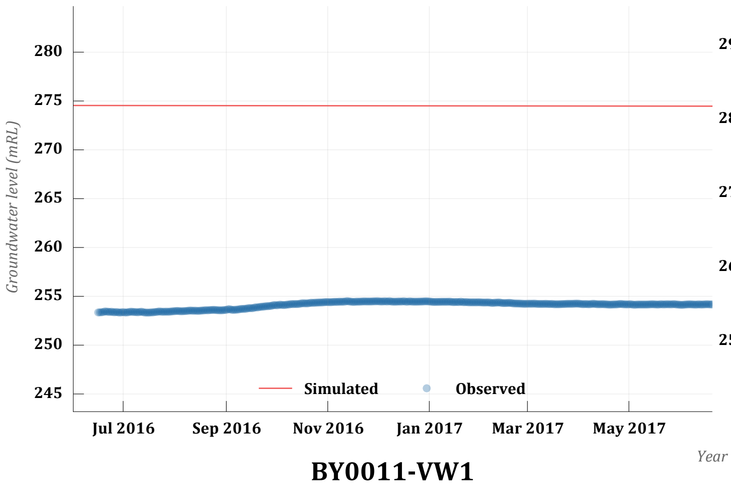
B3-S



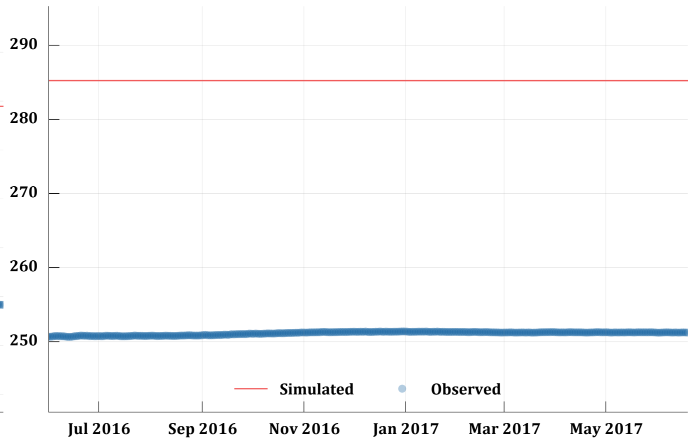
BY0001



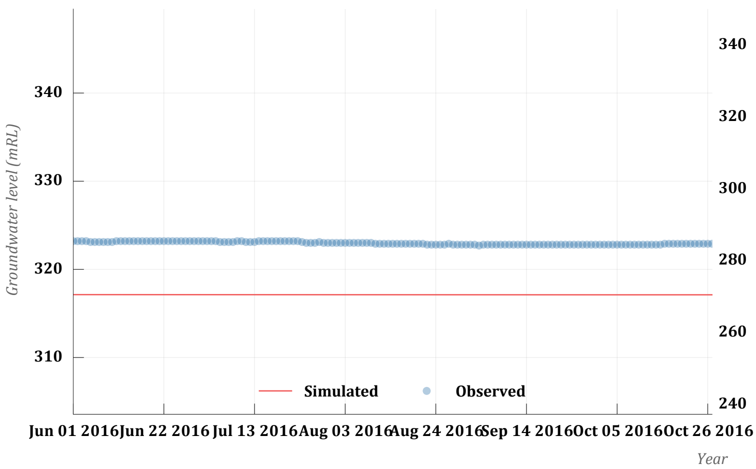
BY0007



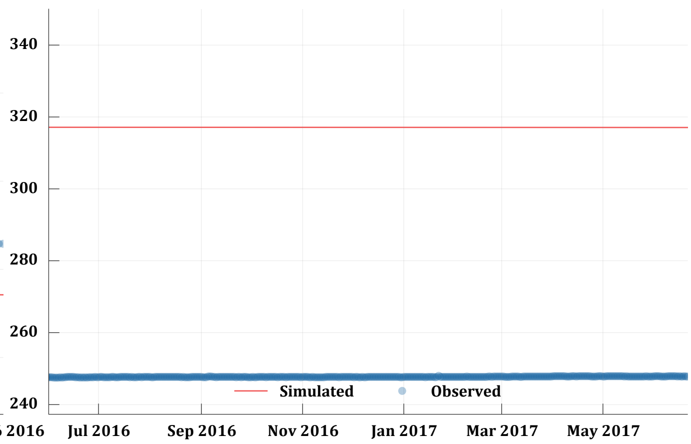
BY0010

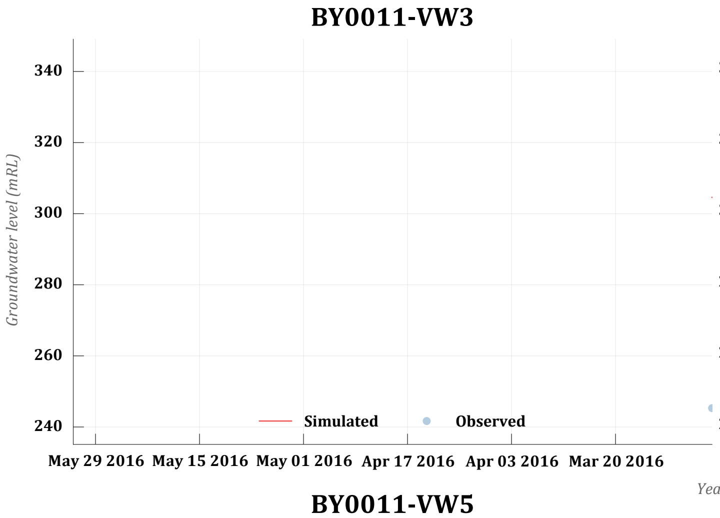


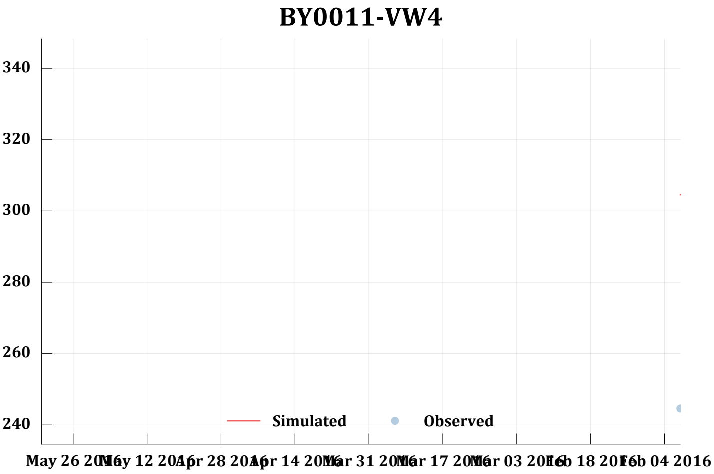
BY0011-VW1

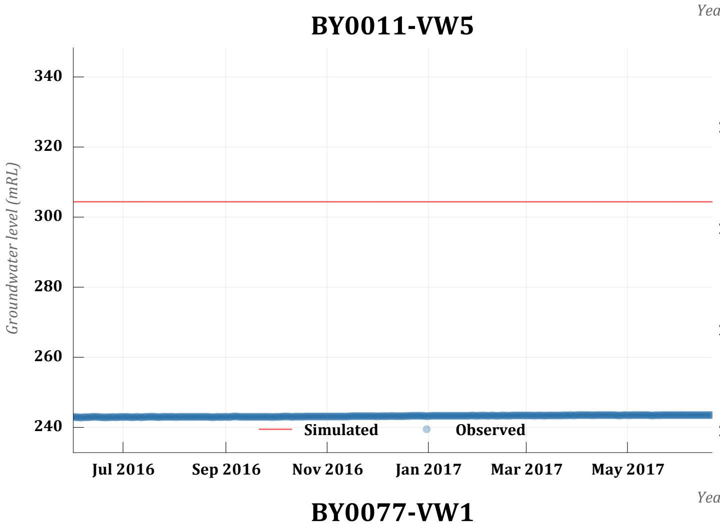


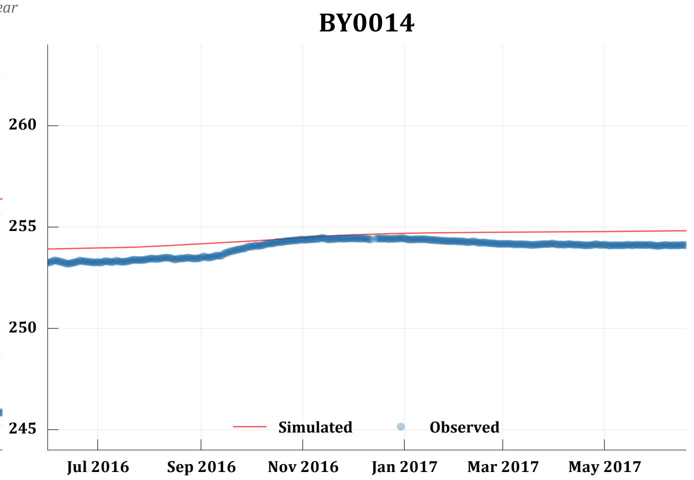
BY0011-VW2

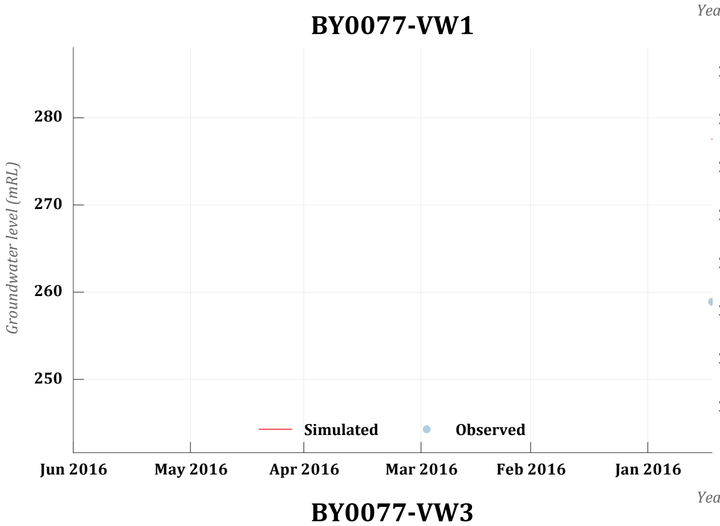


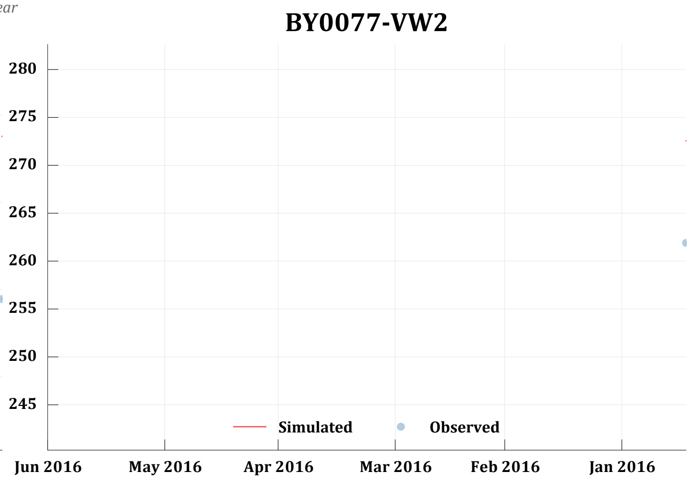

BY0011-VW3
Groundwater level (mRL)
340
320
300
280
260
240
Simulated
Observed
May 29 2016
May 15 2016
May 01 2016
Apr 17 2016
Apr 03 2016
Mar 20 2016
Year

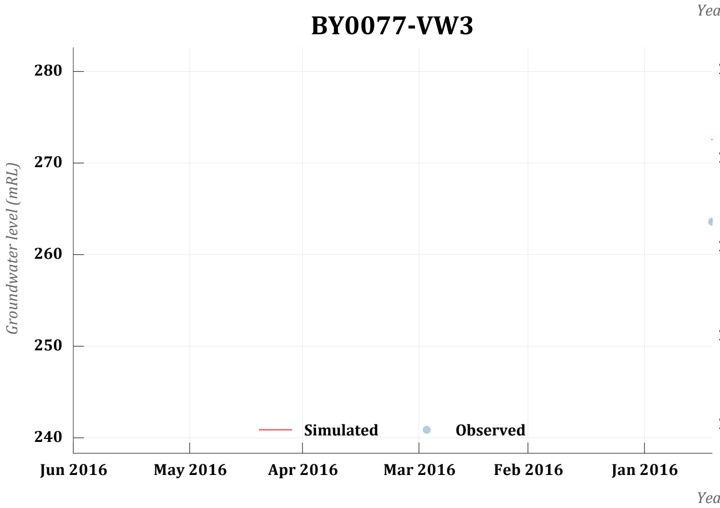

BY0011-VW4
340
320
300
280
260
240
Simulated
Observed
Feb 04 2016

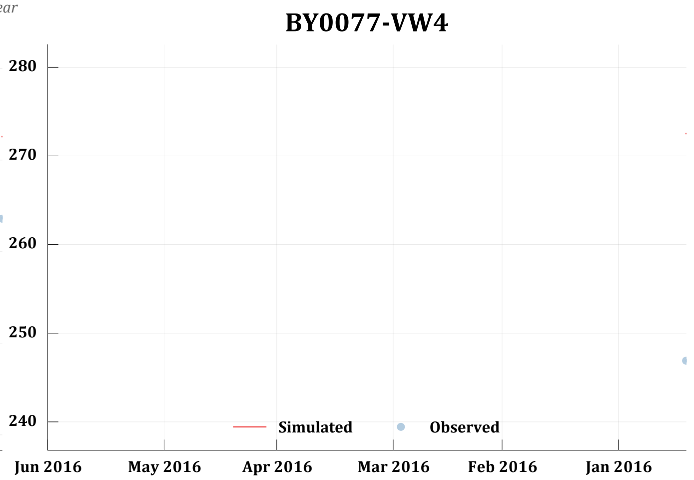

BY0011-VW5
Groundwater level (mRL)
340
320
300
280
260
240
Simulated
Observed
Jul 2016
Sep 2016
Nov 2016
Jan 2017
Mar 2017
May 2017
Year


BY0014
260
255
250
245
Simulated
Observed
Jul 2016
Sep 2016
Nov 2016
Jan 2017
Mar 2017
May 2017

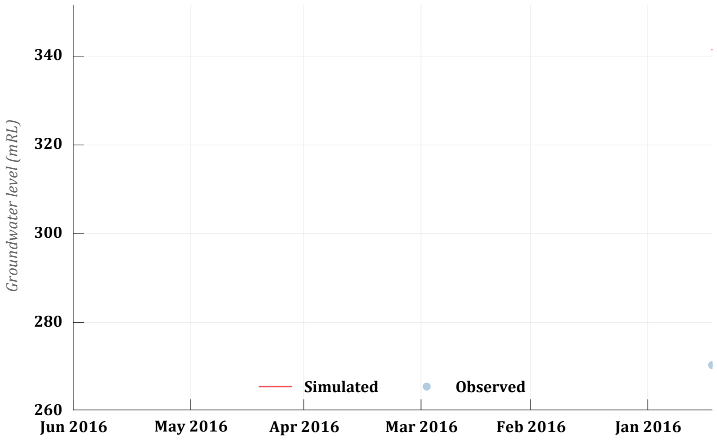

BY0077-VW1
Groundwater level (mRL)
280
270
260
250
Simulated
Observed
Jun 2016
May 2016
Apr 2016
Mar 2016
Feb 2016
Jan 2016
Year


BY0077-VW2
280
275
270
265
260
255
250
245
Simulated
Observed
Jun 2016
May 2016
Apr 2016
Mar 2016
Feb 2016
Jan 2016

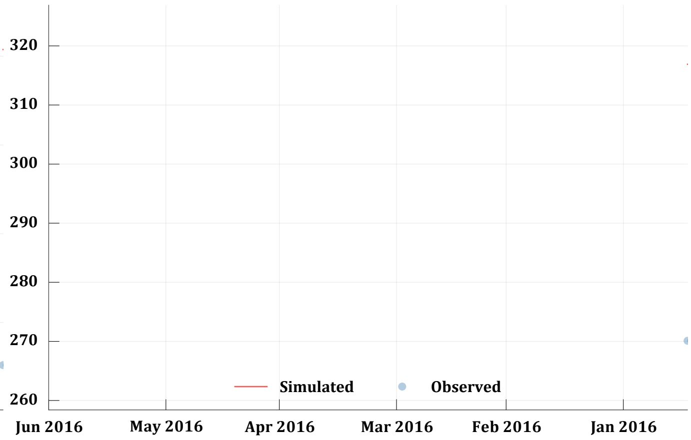

BY0077-VW3
Groundwater level (mRL)
280
270
260
250
240
Simulated
Observed
Jun 2016
May 2016
Apr 2016
Mar 2016
Feb 2016
Jan 2016
Year


BY0077-VW4
280
270
260
250
240
Simulated
Observed
Jun 2016
May 2016
Apr 2016
Mar 2016
Feb 2016
Jan 2016

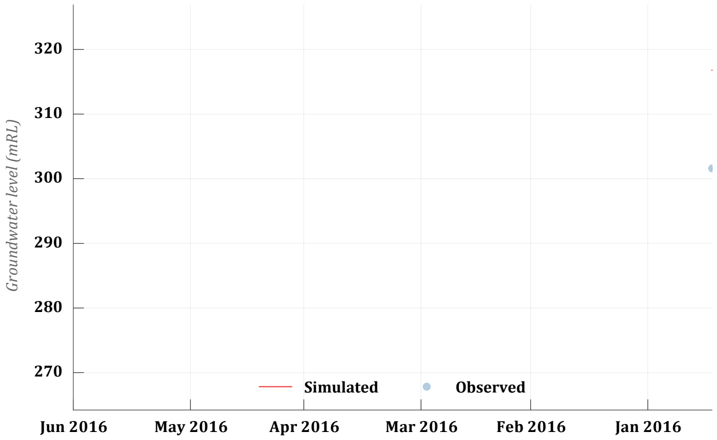
BY0080-VW1



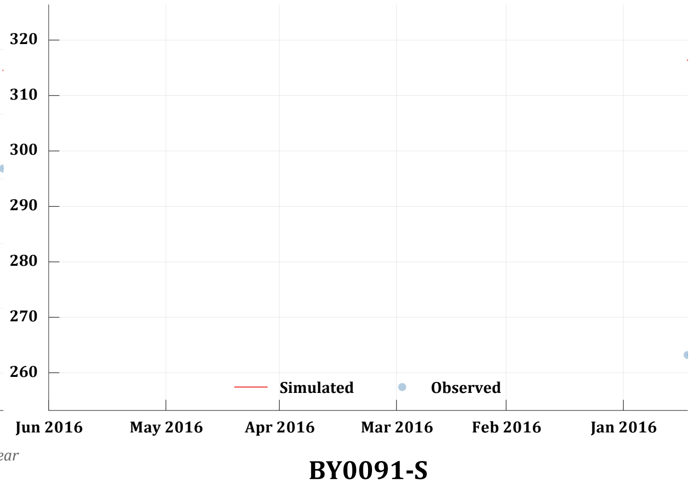
BY0080-VW2



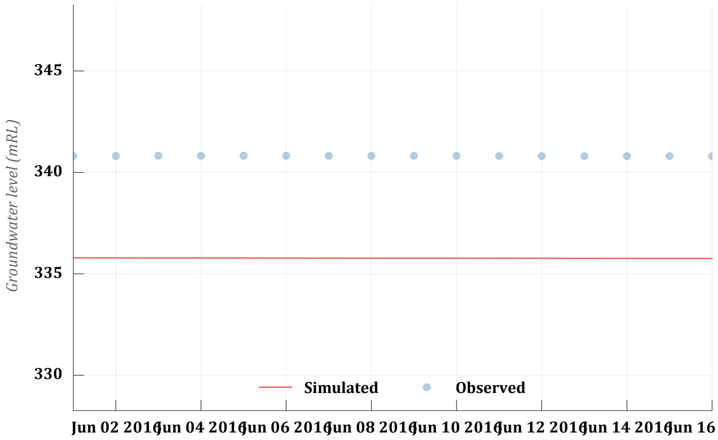
BY0080-VW3



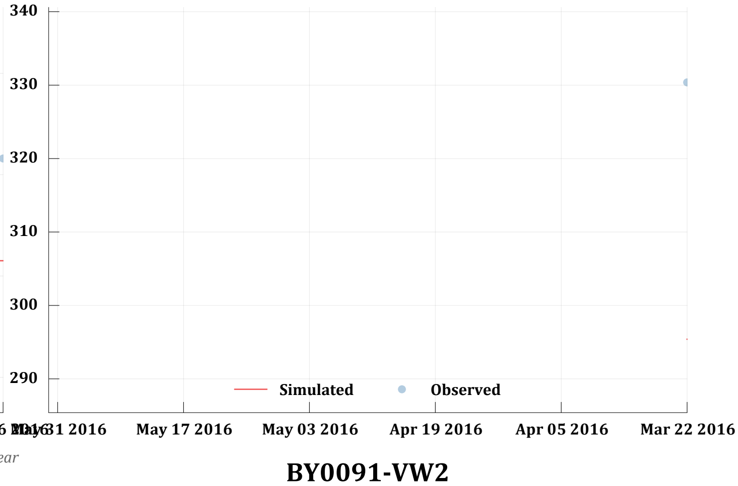
BY0080-VW4



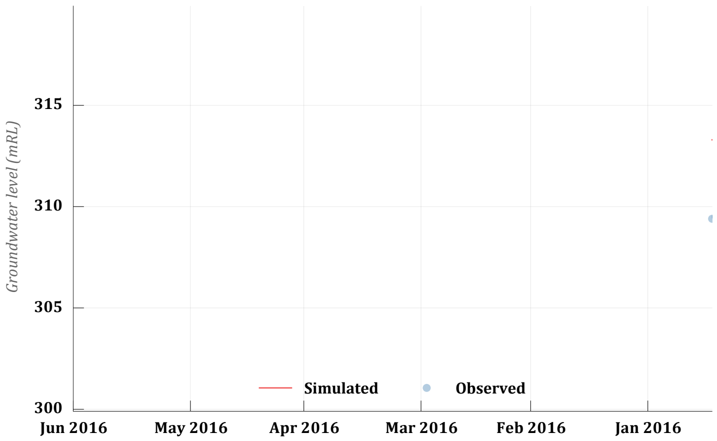
BY0091-B



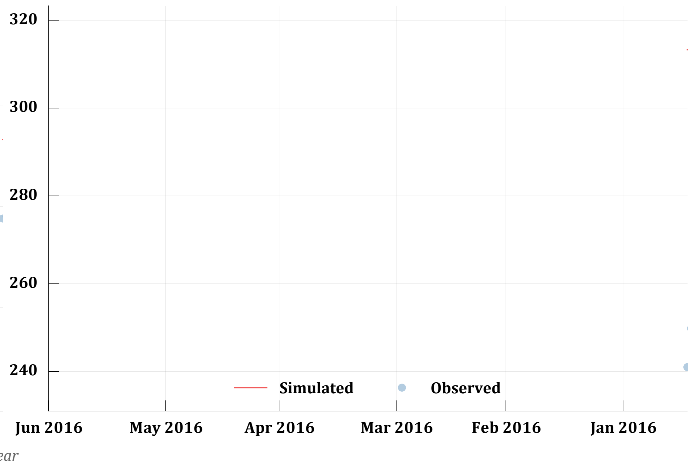
BY0091-S



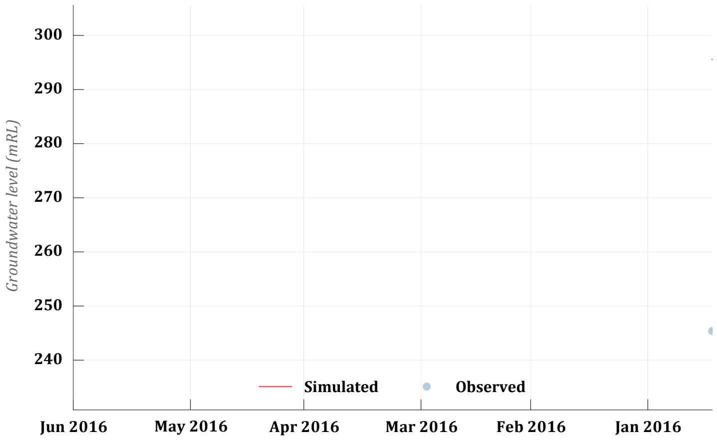
BY0091-VW1



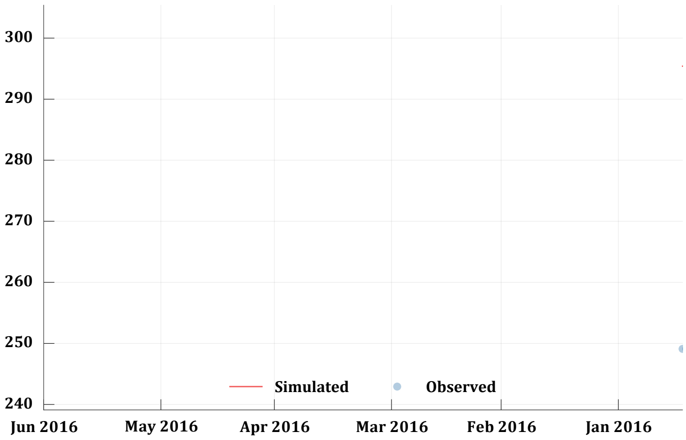
BY0091-VW2



BY0091-VW3

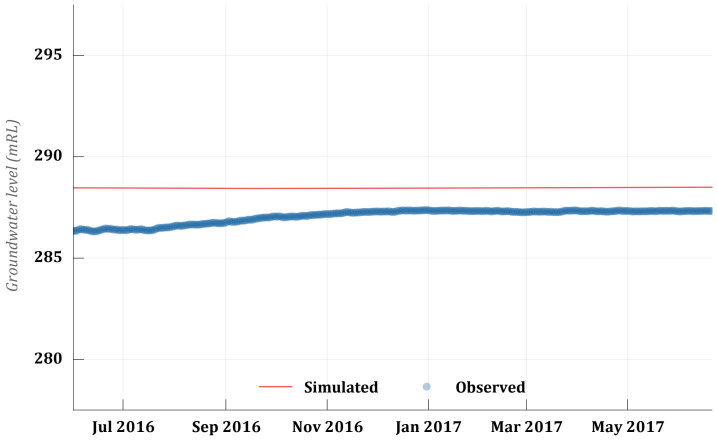


BY0091-VW4

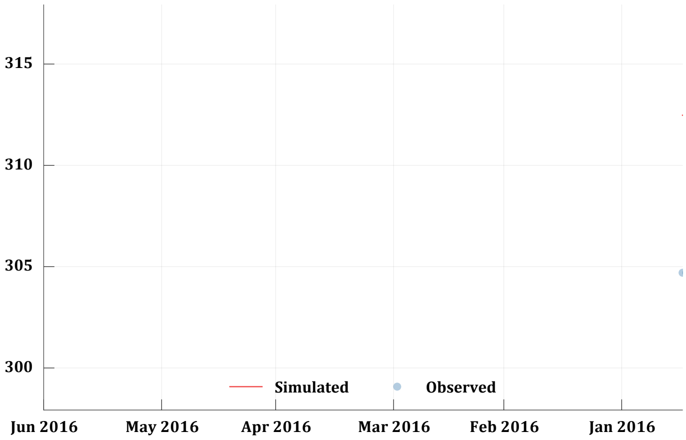


Year

BY0204

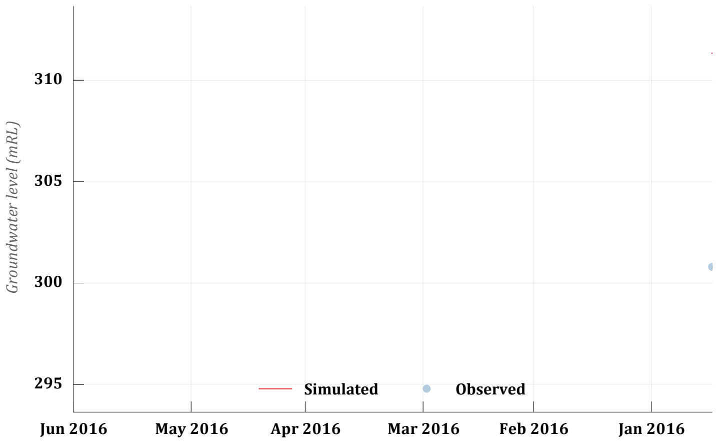


BY0208-VW1

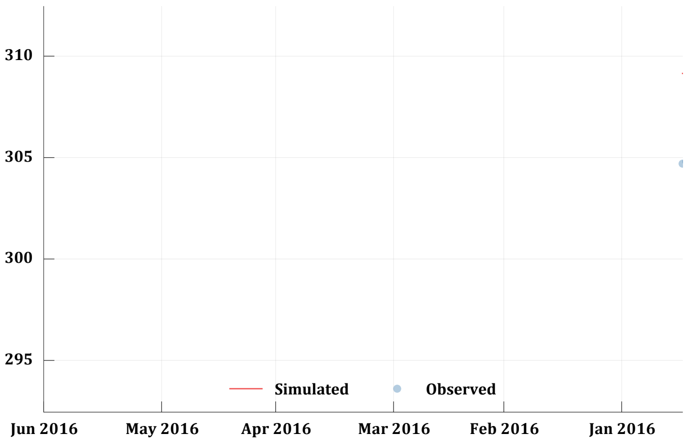


Year

BY0208-VW2

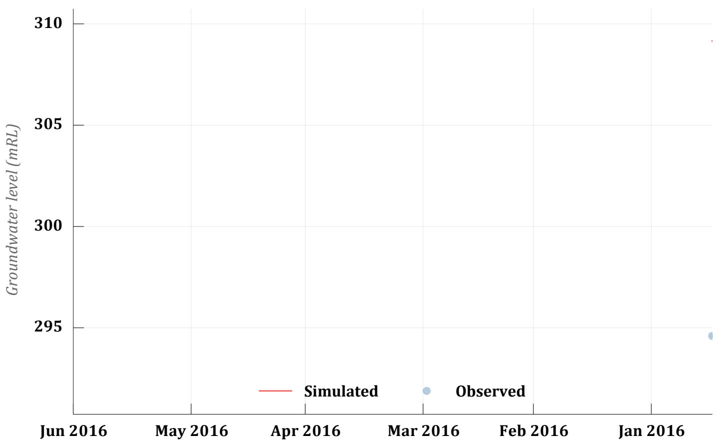


BY0208-VW3

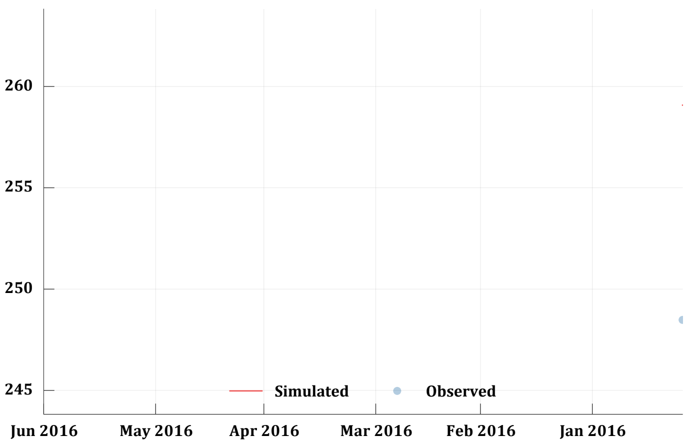


Year

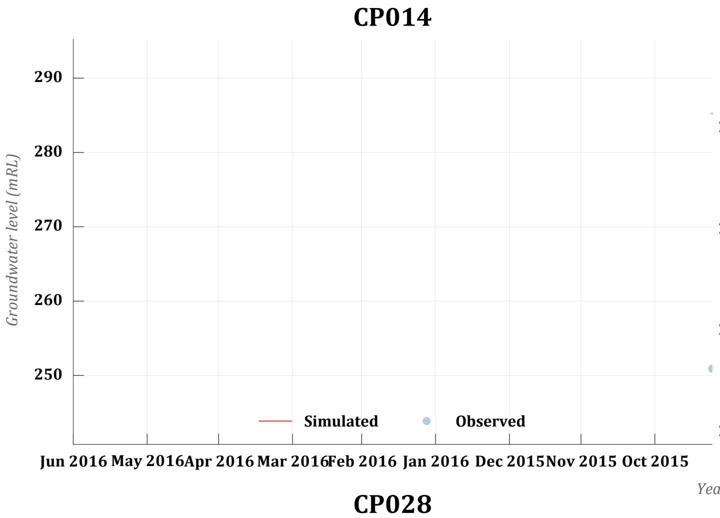
BY0208-VW4

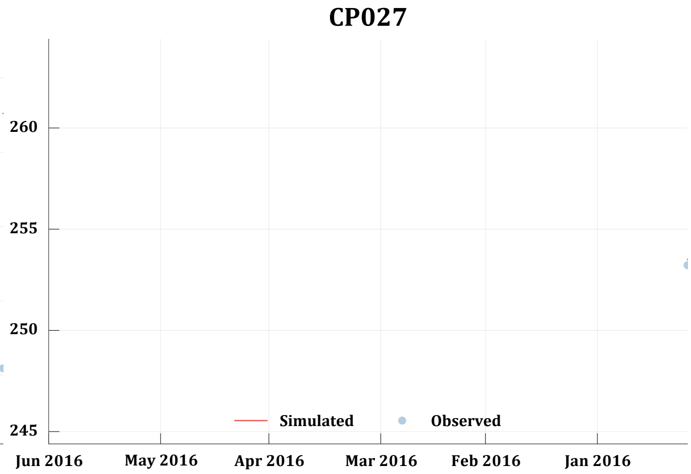


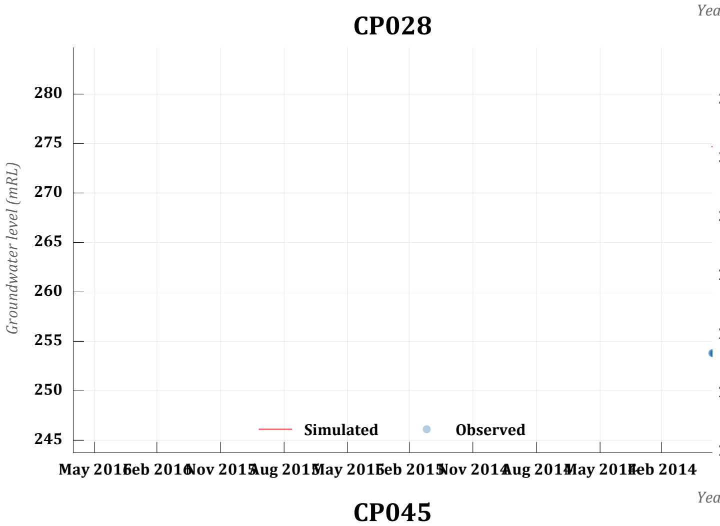
CP009

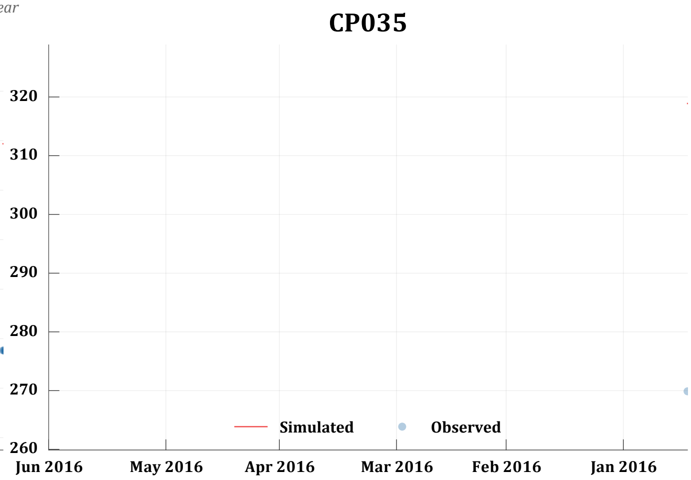


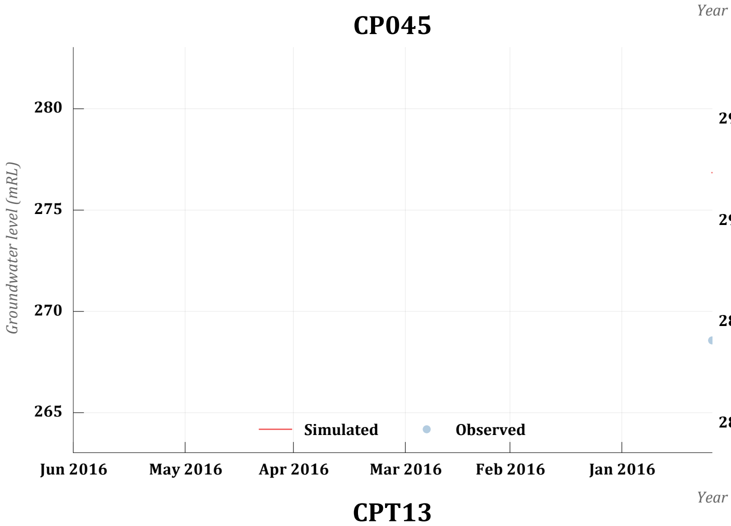
Year

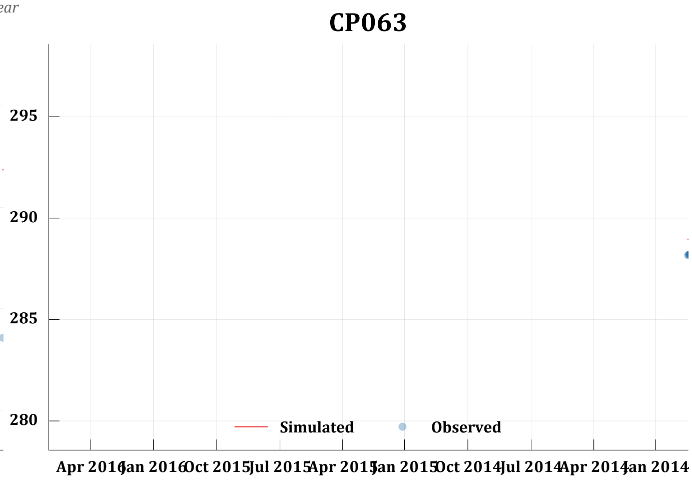

CP014
Groundwater level (mRL)
Simulated
Observed

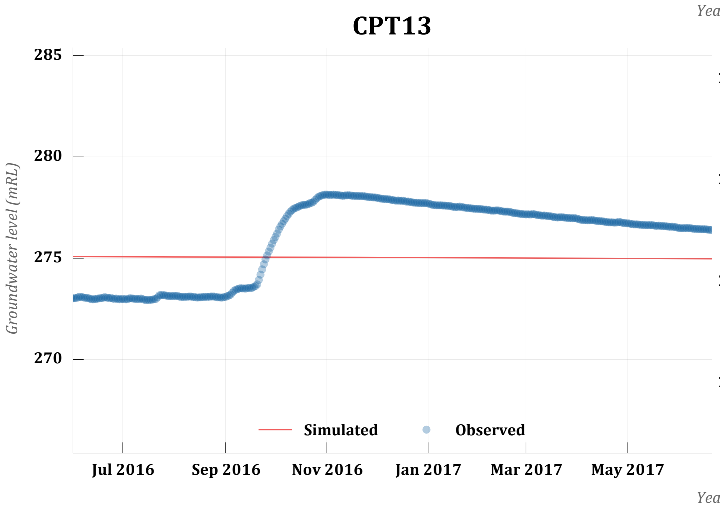

CP027
Simulated
Observed

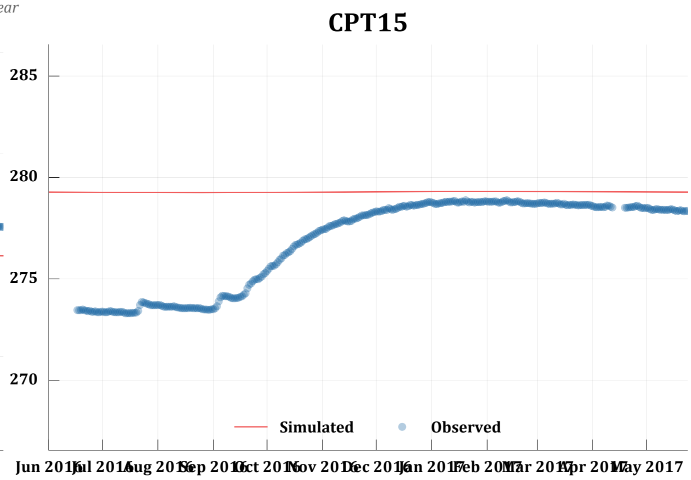

CP028
Groundwater level (mRL)
Simulated
Observed


CP035
Simulated
Observed

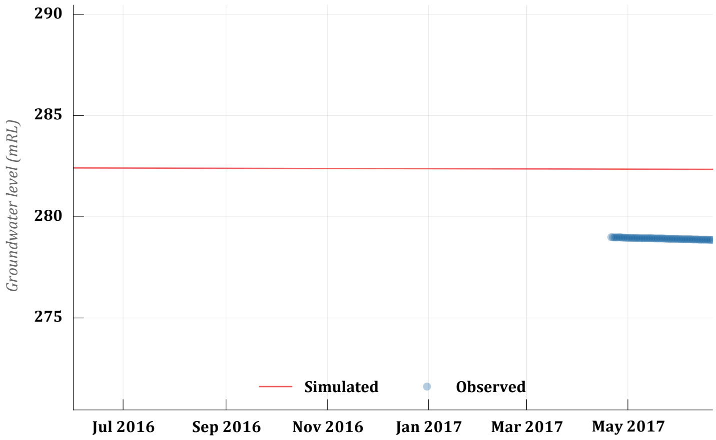

CP045
Groundwater level (mRL)
Simulated
Observed


CP063
Simulated
Observed

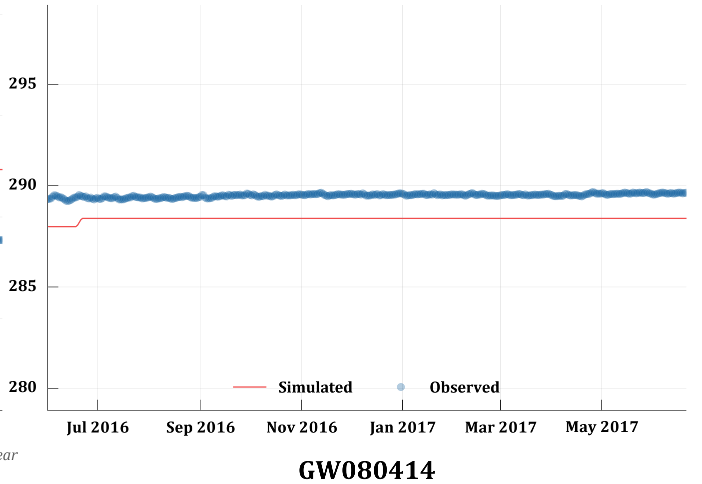

CPT13
Groundwater level (mRL)
Simulated
Observed
Year


CPT15
Simulated
Observed

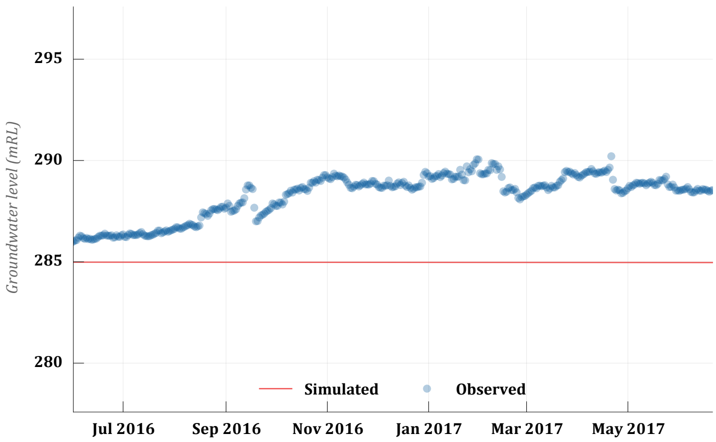
CPT18-VW1



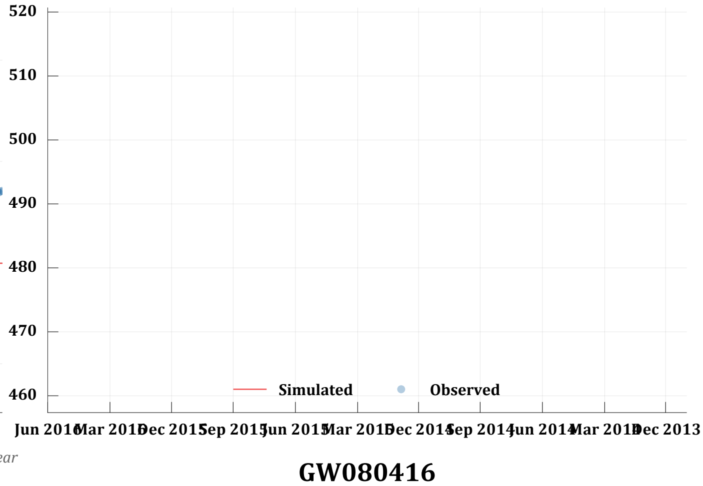
CPT36



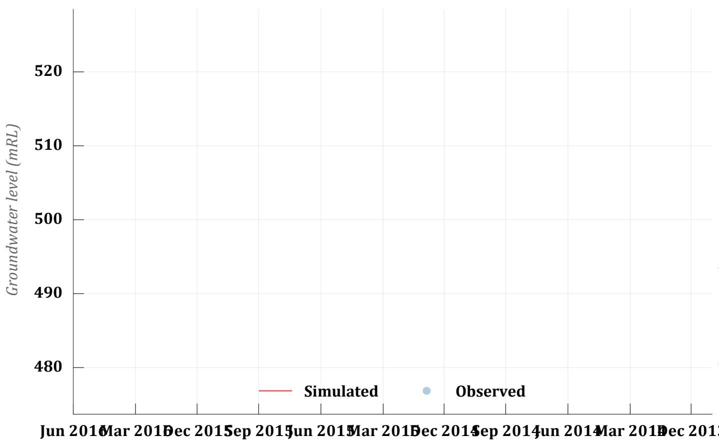
CPT39W



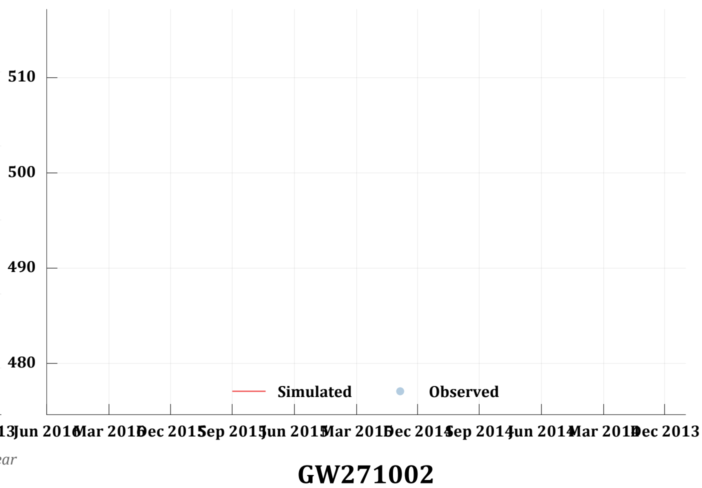
GW080414



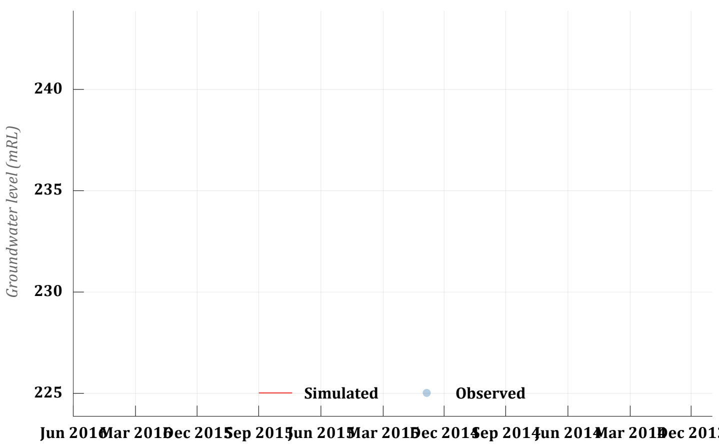
GW080415



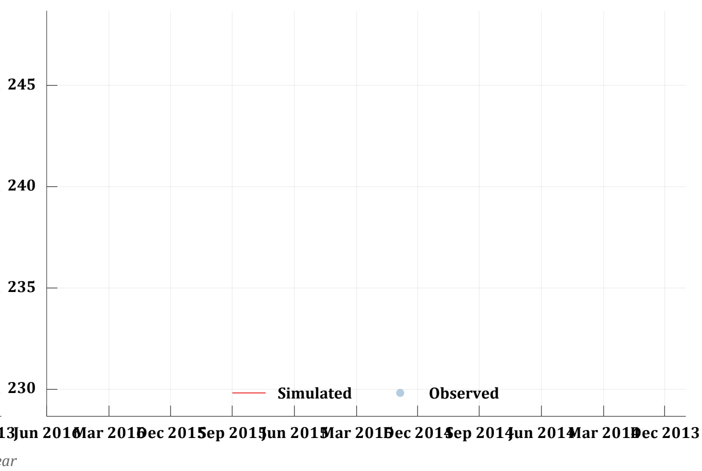
GW080416



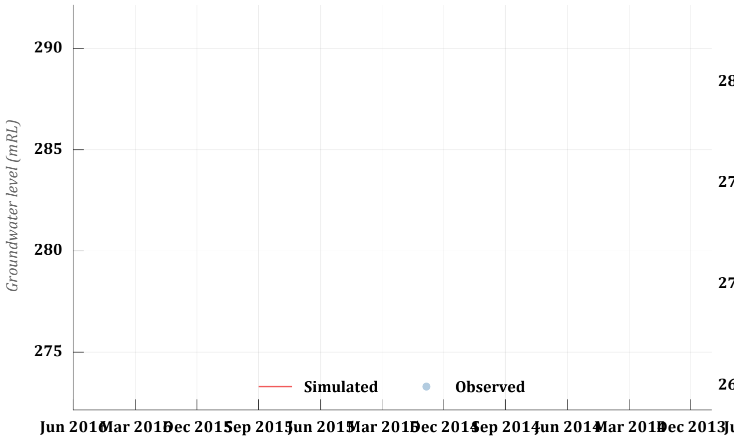
GW080941



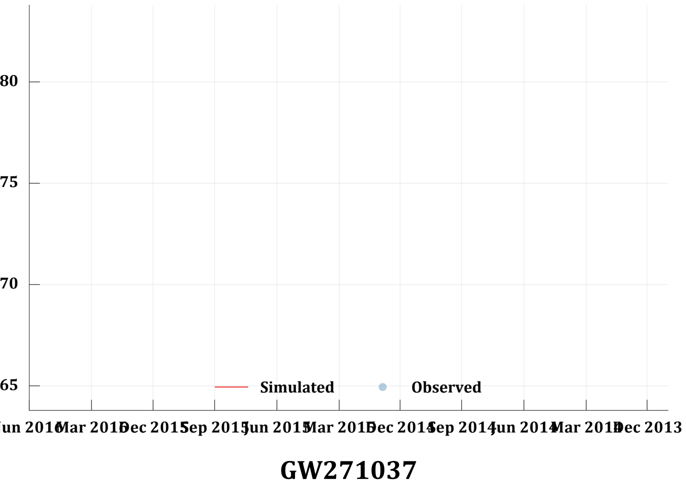
GW271002



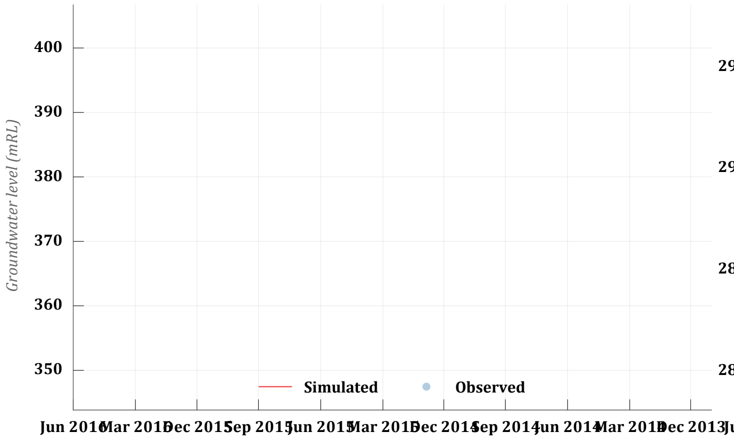
GW271003



GW271004



GW271006



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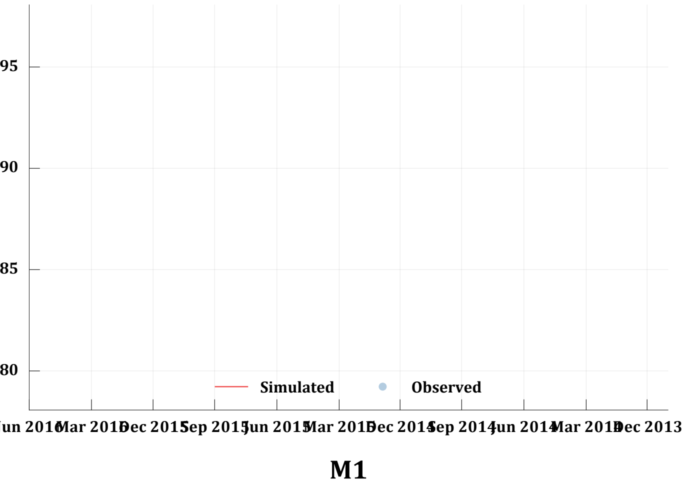

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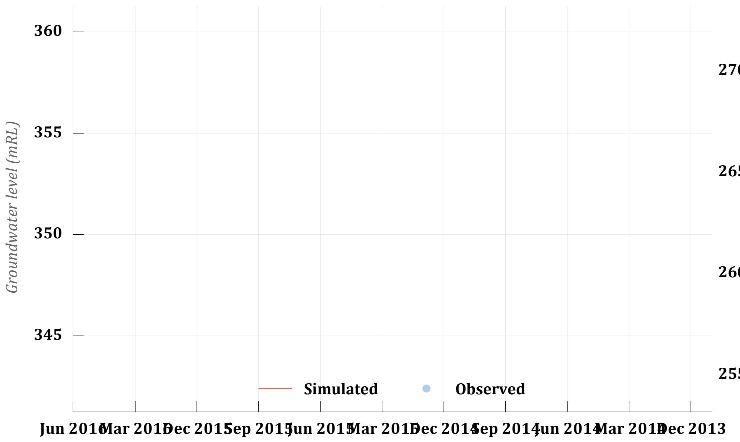
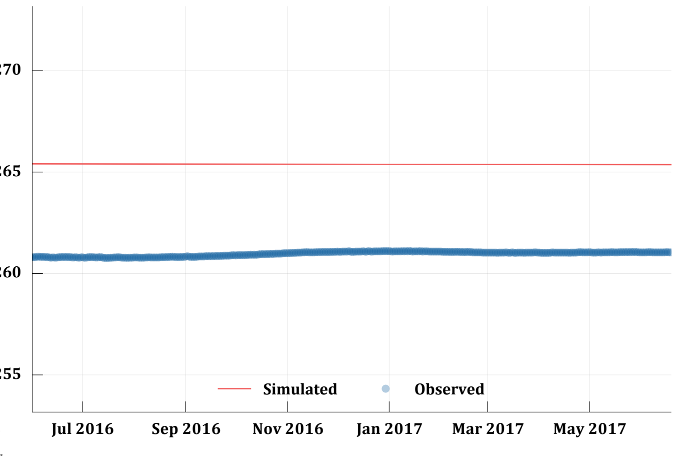


M1



M2