Bramfield groundwater model

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Foreword

The Department for Environment and Water (DEW) is responsible for the management of the State's natural resources, ranging from policy leadership to on-ground delivery in consultation with government, industry and communities.

High-quality science and effective monitoring provides the foundation for the successful management of our environment and natural resources. This is achieved through undertaking appropriate research, investigations, assessments, monitoring and evaluation.

DEW's strong partnerships with educational and research institutions, industries, government agencies, Landscape Boards and the community ensures that there is continual capacity building across the sector, and that the best skills and expertise are used to inform decision making.

Ben Bruce
CHIEF EXECUTIVE
DEPARTMENT FOR ENVIRONMENT AND WATER

Acknowledgements

The model described here was completed as part of the National Water Grid Fund (NWGF) project *'Ensuring water security, economic prosperity and nature positive outcomes for Elliston, Eyre Peninsula.'*

Development of the model benefitted significantly from datasets collected through the study, as well as discussions with all members of the project team across the Department for Environment and Water (DEW), Flinders University, CSIRO and the Eyre Peninsula Landscape Board. Hugh Middlemis is thanked for reviewing the model report.

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**In-kind contributions are contributions of goods and services and do not contribute to the total project cost.*

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Summary

A groundwater flow model has been developed for the Bramfield lens in the Musgrave Prescribed Wells Area, Eyre Peninsula, South Australia, as part of the National Water Grid Fund project 'Ensuring water security, economic prosperity and nature positive outcomes for Elliston'. The model simulates changes to groundwater levels from 1965 to 2024 which is the extent of available groundwater level data. The model produces a good fit to measured data, matching interannual fluctuations related to rainfall-recharge and long-term declines related to declining rainfall. The model also simulates the position and movement of the seawater interface in the coastal zone using the SWI2 package which simulates a sharp interface with no dispersive mixing. The model compares well with the limited information (geophysics and drilling) that is available on the position of the seawater interface, much of which was collected during the model build. The modelling study has also highlighted several areas where further data could be collected to help improve the hydrogeological understanding, conceptualisation and model confidence.

The model has been used to run three scenarios simulating variations in pumping and climate through to 2050. In all three scenarios groundwater levels continue to decline into the future, largely due to projected ongoing declines in rainfall-recharge. Some ongoing decline may be attributed to potential increases in groundwater extraction. However, groundwater extraction at current and potential full allocation rates is a relatively small component of the water balance, so it has limited impact at the scale of the Bramfield freshwater lens.

All scenarios show the seawater interface continues to move inland as groundwater levels decline with intrusion varying from 200 to 600 m in different parts of the study area by 2050. Based on model results, the sharp interface (the 50:50 isohaline between freshwater and seawater) is unlikely to reach town water supply wells by 2050. However, it is not known to what degree dispersive mixing associated with the interface may impact town water supply wells. Given the current rising trend in salinity in town water supply wells, increases in salinity are likely to continue into the future. Ongoing monitoring of groundwater quality at the new observation well (5830-357) and town water supply wells is recommended to assess future salinity trends.

1 Introduction

This report documents the development of a groundwater flow model for the Bramfield groundwater lens within the Musgrave Prescribed Wells Area in South Australia. It forms part of the Australian Government's National Water Grid Fund (NWGF) funded project 'Ensuring water security, economic prosperity and nature positive outcomes for Elliston' (the Elliston project). The project aims to investigate the long-term viability of the Bramfield freshwater lens, in light of a drying climate, to help inform decision making regarding future water supply. The project includes several tasks aimed at increasing the knowledge and conceptual understanding of the groundwater resource, particularly in relation to groundwater recharge and coastal groundwater processes. Some of these project tasks such as the collection of geophysical data have fed directly into the model conceptualisation. Other aspects of the study necessarily will rely on longer time series data which may not be incorporated into the model for this current report. These data can be incorporated when the model is required to be updated.

Alongside the NWGF project, the Eyre Peninsula Landscape Board (EPLB, 2024) announced the review of the Eyre Peninsula Water Allocation Plan (EP WAP) scheduled to be completed by mid-2026. Given the timeliness of the Elliston project, it was decided that the modelling should be accelerated in the NWGF project to be completed by mid-2025 to inform the WAP review.

The model area covers ~644 km^2 centred around the Bramfield lens where the Quaternary Limestone (QL) aquifer is saturated and of good (<1000 mg/L) quality. The model domain includes the towns of Elliston and Bramfield (Figure 1.1). The objectives of this report are to:

- consolidate the conceptual understanding of the Bramfield lens, including data collected through the NWGF project;
- detail the construction and calibration of the groundwater model for the Bramfield lens;
- document model scenarios and their results regarding future trends to inform the EP WAP review; and
- document model limitations and uncertainties to help inform future studies.

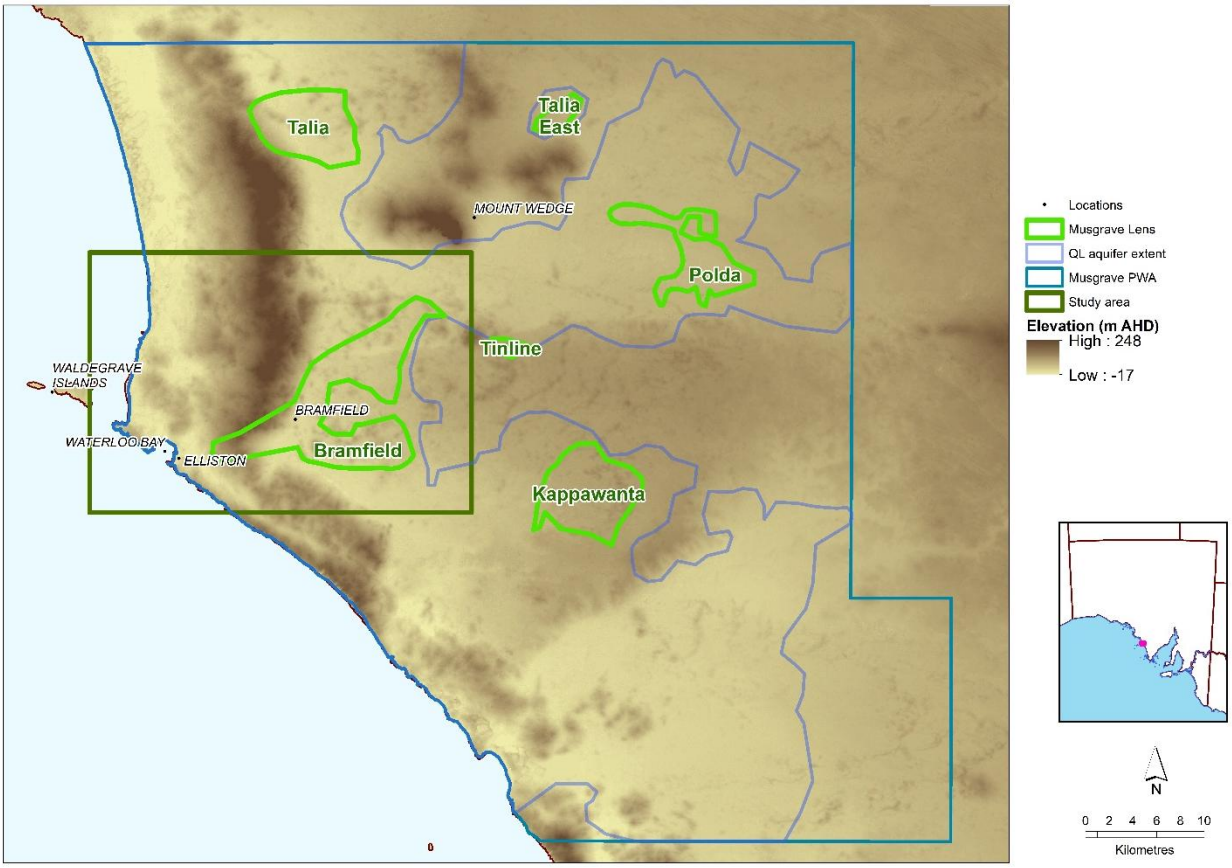


Figure 1.1. Location of the study area

2 Conceptual model

2.1 Location and topography

The study area encompasses the Bramfield fresh groundwater lens within the Musgrave Prescribed Wells Area (PWA) (EPNRMB, 2016) on the Eyre Peninsula, South Australia (Figure 1.1). The Musgrave PWA consists of several groundwater lenses where the Quaternary Limestone (QL) aquifer is saturated and of good (<1000 mg/L) quality. Groundwater is used for town water supply for Elliston and Bramfield, stock and domestic use and irrigation. The area is bounded by the Southern Ocean to the west and south with ground elevation increasing inland. The coastal margin varies from steep coastal cliffs to the south to sandy beaches to the north and in Waterloo Bay. Topographic highs include a ridge of up to 170 metres elevation between Elliston and Bramfield and Mount Wedge north-west of the area of interest.

2.2 Climate

The climate is characterised as Mediterranean with hot dry summers and cool, wet winters with rainfall generally exceeding evapotranspiration from April-May to August-September (Figure 2.1). Average annual rainfall is 427 mm with cumulative deviation in rainfall (rainfall trend in Figure 2.2) showing generally declining long-term trend in annual rainfall since the 1990s with short, intervening wet periods.

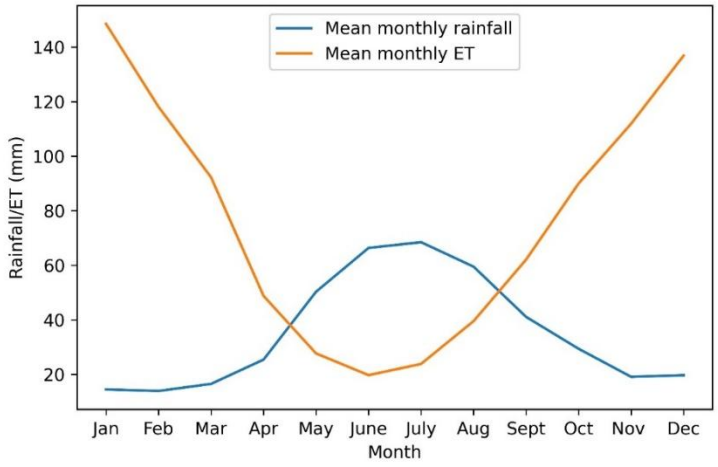


Figure 2.1. Average monthly rainfall and evapotranspiration at Elliston (station 18069) over the period 1965–2024

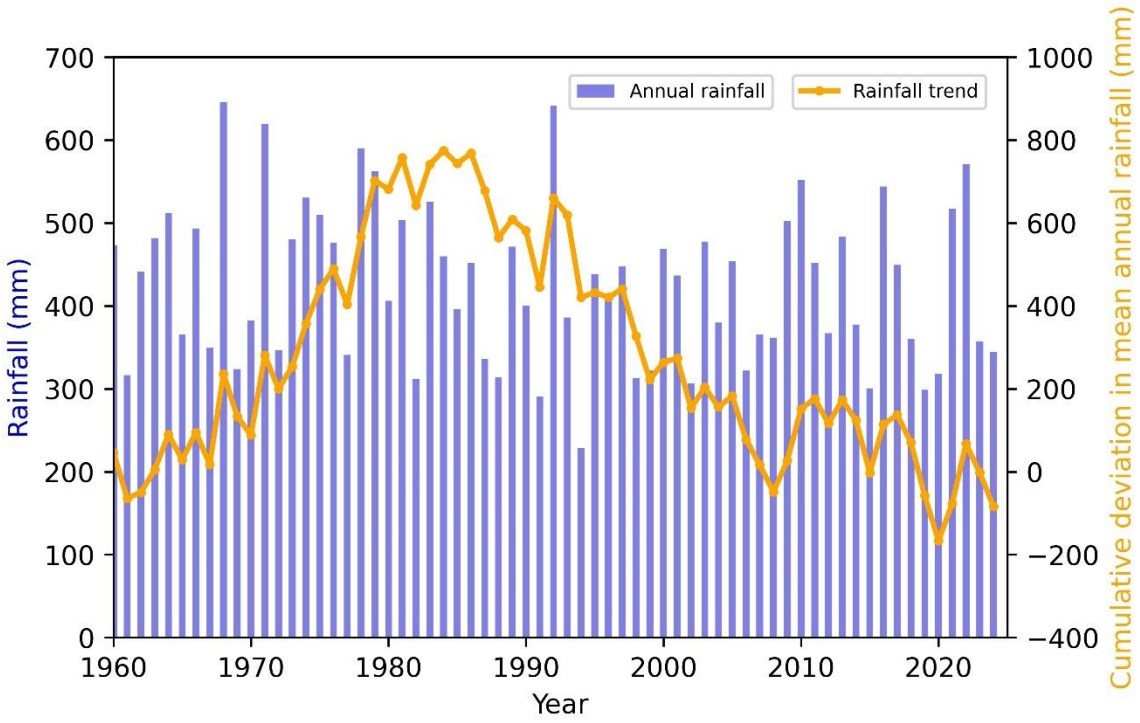


Figure 2.2. Annual rainfall and trend in Elliston (station 18069)

2.3 Soil, vegetation and land use

Soil types in the study area generally consist of shallow soils overlying calcrete with the soil types described by Hall, Maschmedt and Billing (2009) shown in Figure 2.3. Exceptions include the carbonate sands associated with coastal dune systems and 'saline soils' which generally correspond with vegetation over playa sediments. This correlation may reflect the amount of mapping of karst features that has taken place but, interestingly, the areas of shallow sandy loam on calcrete have the greatest abundance of known karst features (sinkholes and caves). Much of the area is cleared of native vegetation with the land used for cropping or livestock grazing (predominantly sheep). A large area of mallee heath and shrublands occupies the south-east of the study area (Figure 2.4) with other smaller areas of mallee and shrublands scattered throughout the study area.

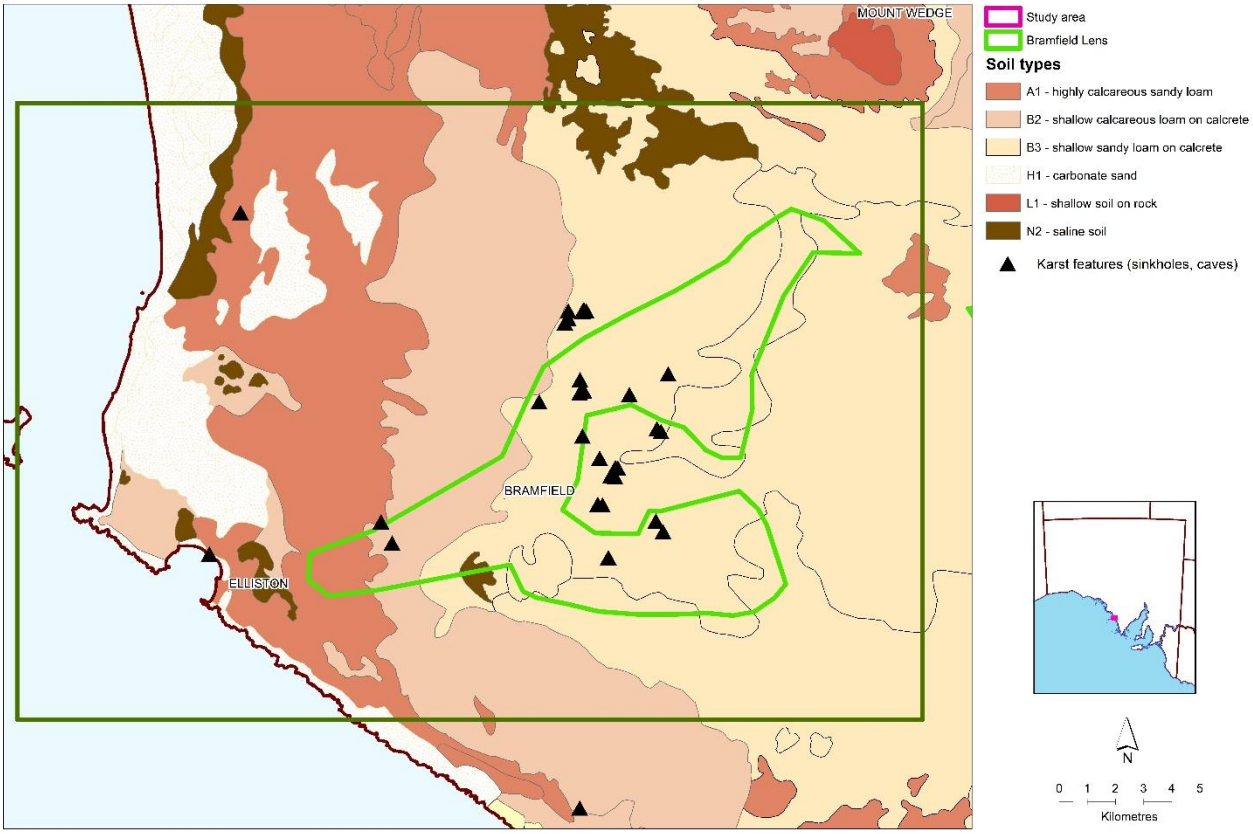


Figure 2.3. Soil types in the study area

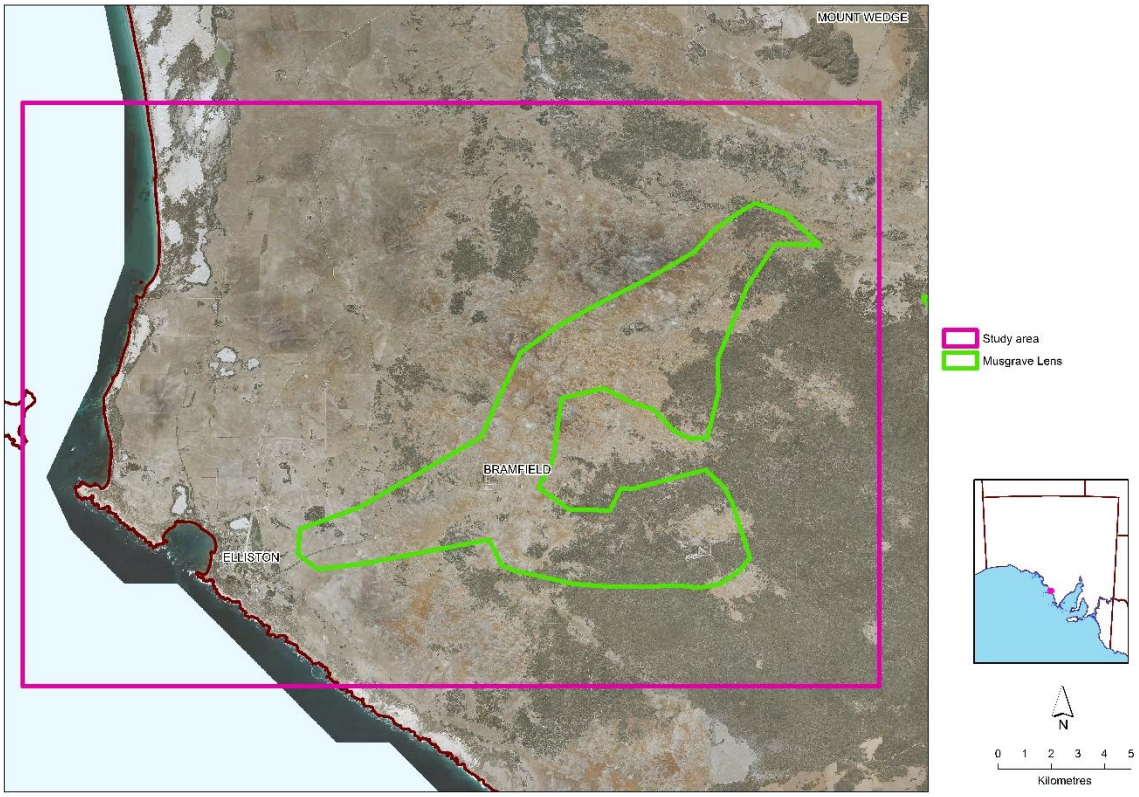


Figure 2.4. Aerial imagery showing vegetation cover in the study area

2.4 Geology

Surface geology is dominated by the Bridgewater Formation, a Quaternary aeolian calcarenite that hosts the unconfined aquifer, sometimes referred to as the Quaternary Limestone Aquifer (Flint, 1992). Extensive dissolution features are present in surface calcretes of the Bridgewater Formation across the study area. Holocene sands of the Semaphore Member are present in coastal sand dunes, while Holocene and Pleistocene playa sediments underly surface water features and some areas of vegetation. On the southern margin of the Bramfield lens, one small area of playa sediment appears to host terrestrial vegetation, suggesting that a surface water system was once present. This feature is adjacent to small surface outcrops of the Sleaford Complex, an Archaean well-banded quartz, feldspar and biotite gneiss. Basement also outcrops offshore with the northern margin of the Waldegrave Islands hosting the Proterozoic Calca Granite, part of the Hiltaba Suite.

The Bridgewater Formation is typically underlain by an unnamed Tertiary Clay described as sticky to stiff with coarse sand and gravel (Love et al., 1994) which varies in thickness from 1 to 5 metres. Given the small thickness, it does not appear on all drillhole logs which results in uncertainty regarding its persistence across the Bramfield lens. Nevertheless, it is conceptualised as a thin aquitard layer which confines the underlying Tertiary Poelpena Formation and separates it from the overlying Bridgewater Formation (Evans 2002). The Poelpena Formation, also referred to as the Tertiary Sand Aquifer, consists of unconsolidated fine quartz sands.

Period	Epoch	Formation	Description	Hydrogeology	Model layer
Quaternary	Holocene	Semaphore Sand Member (Qhcks)	Coastal dunes	Unconfined aquifer (Quaternary Limestone or QL)	1
	Pleistocene	Bridgewater Formation (Qpb)	Calcarenite		
Tertiary	Eocene	Undifferentiated, unnamed clay	Sticky to stiff clay with coarse sand and gravel	Aquitard	2
		Poelpena Formation (Tep)	Quartz sand, silt and clay	Confined Aquifer (Tertiary Sand or TS)	3
Jurassic		Polda Formation	Sands, silts and clay, generally carbonaceous with lignite beds	Confined aquifer, very low permeability and high salinity	N/A
Neo-Proterozoic		Pre-Cambrian basement	Schists, gneisses and quartzites with granite intrusions of the Sleaford Complex, Blue Range Beds and Hiltaba Suite	Confined aquifer	N/A

Table 2.1. Study area geology in relation to groundwater model setup

Analysis of existing geophysical and geological data by Lanigan (2025) developed a new conceptualisation of the extent and distribution of the Tertiary Clay and Tertiary Sand layers (model layers 2 and 3 in Table 2.1) in the study area with the layers unlikely to be present west of the boundaries shown in Figure 2.5.

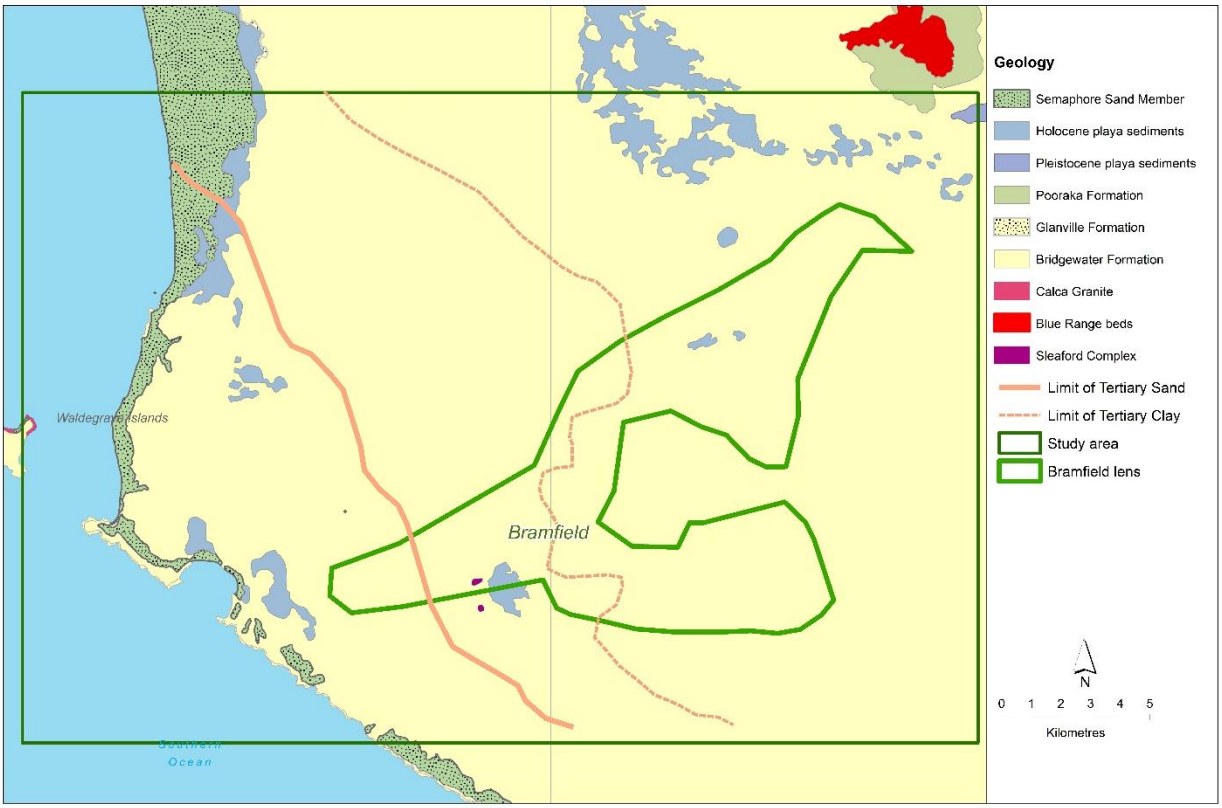


Figure 2.5. Surface geology of the study area

2.5 Hydrogeology

2.6 Groundwater flow and trends

The groundwater resources of the Musgrave PWA are characterised as occurring in the lenses outlined in Figure 1.1. These are locations where the QL aquifer is saturated and has salinity generally <1000 mg/L. Evans (2002) notes there is likely to be some connection or thin saturation of the QL aquifer between these lenses. However, longer term data on groundwater level are generally limited to areas within the lenses. Given the scope of this study, the following discussion focuses on groundwater level trend in and around the Bramfield lens.

In the Bramfield lens, groundwater levels for the QL and TS aquifers are available from the mid-1960s onwards. In the QL aquifer, groundwater levels have varied significantly over time, showing large rises in the early 1970s in response to higher rainfall (Figure 2.2) and consequent recharge. Hydrograph analysis for the contemporary period (2011-2023) also show rainfall to be the key influence on trends (Hyland and Fawns, 2024). Some locations show continued periodic rises associated with rainfall recharge during short term wet periods, while the trend since the early 1970s is one of overall decline (Figure 2.6). There are no bores with long-term records closer to the coast which impacts on the ability to plot potentiometric surfaces over time (Figure 2.7). Nevertheless, potentiometric surfaces generally show groundwater flow through the lens is from east to west towards the coast. Wells closer to the coast that do have observations from 2014 onwards show relatively static trends since that time due to the buffering effect of the seawater.

There is less groundwater level information available for the TS aquifer (Figure 2.8). Levels in the TS aquifer also show long term decline, but with periodic rises which correspond to recharge events in the QL, which may demonstrate vertical recharge is occurring to the TS. Dowie and Love (1996) also report improvements

in TS salinity during aquifer tests which, they suggested, were due to leakage from the QL aquifer. The authors suggest leakage may occur through preferential flow paths rather than through the clay.

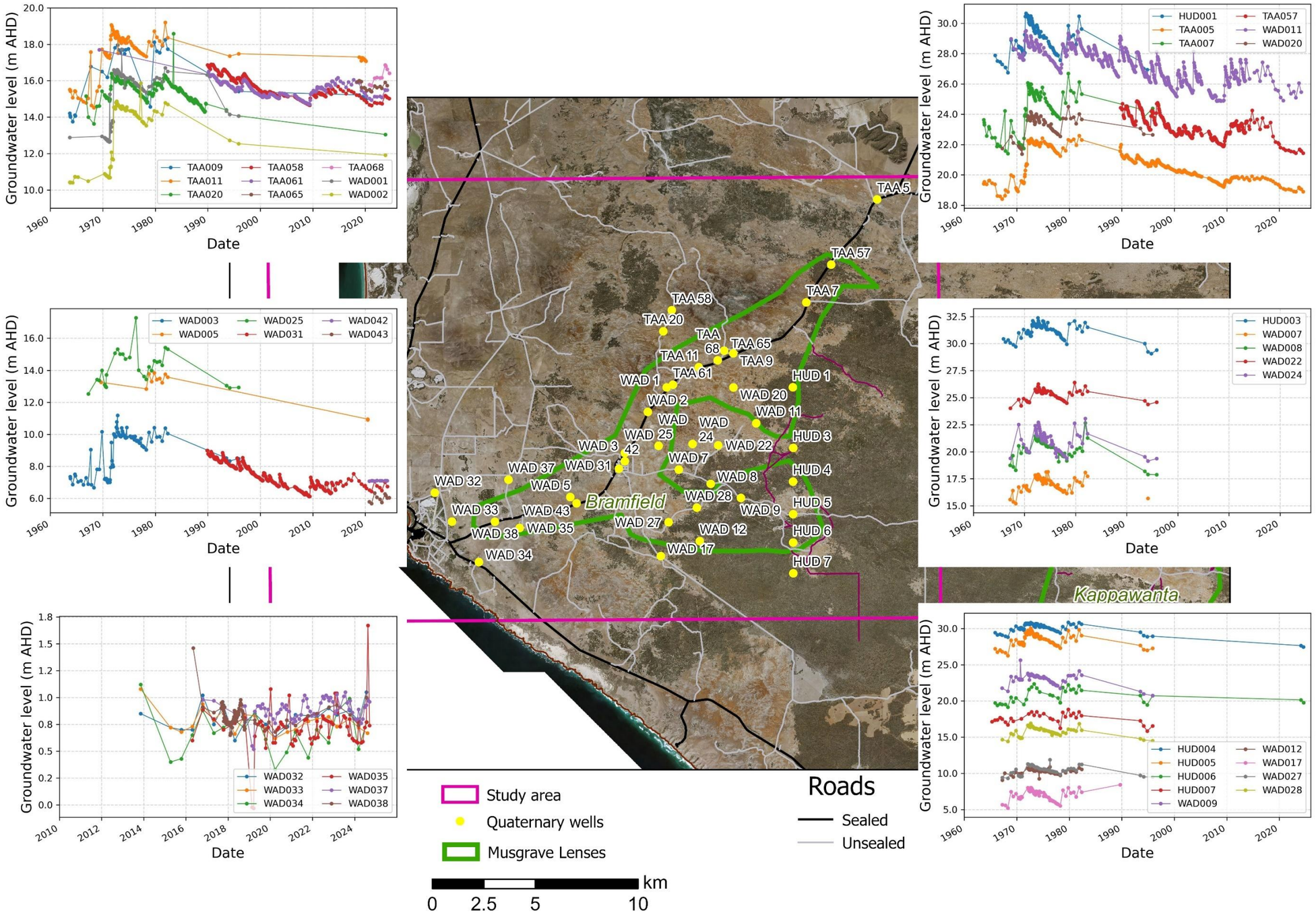


Figure 2.6. Groundwater levels in the Quaternary Limestone aquifer

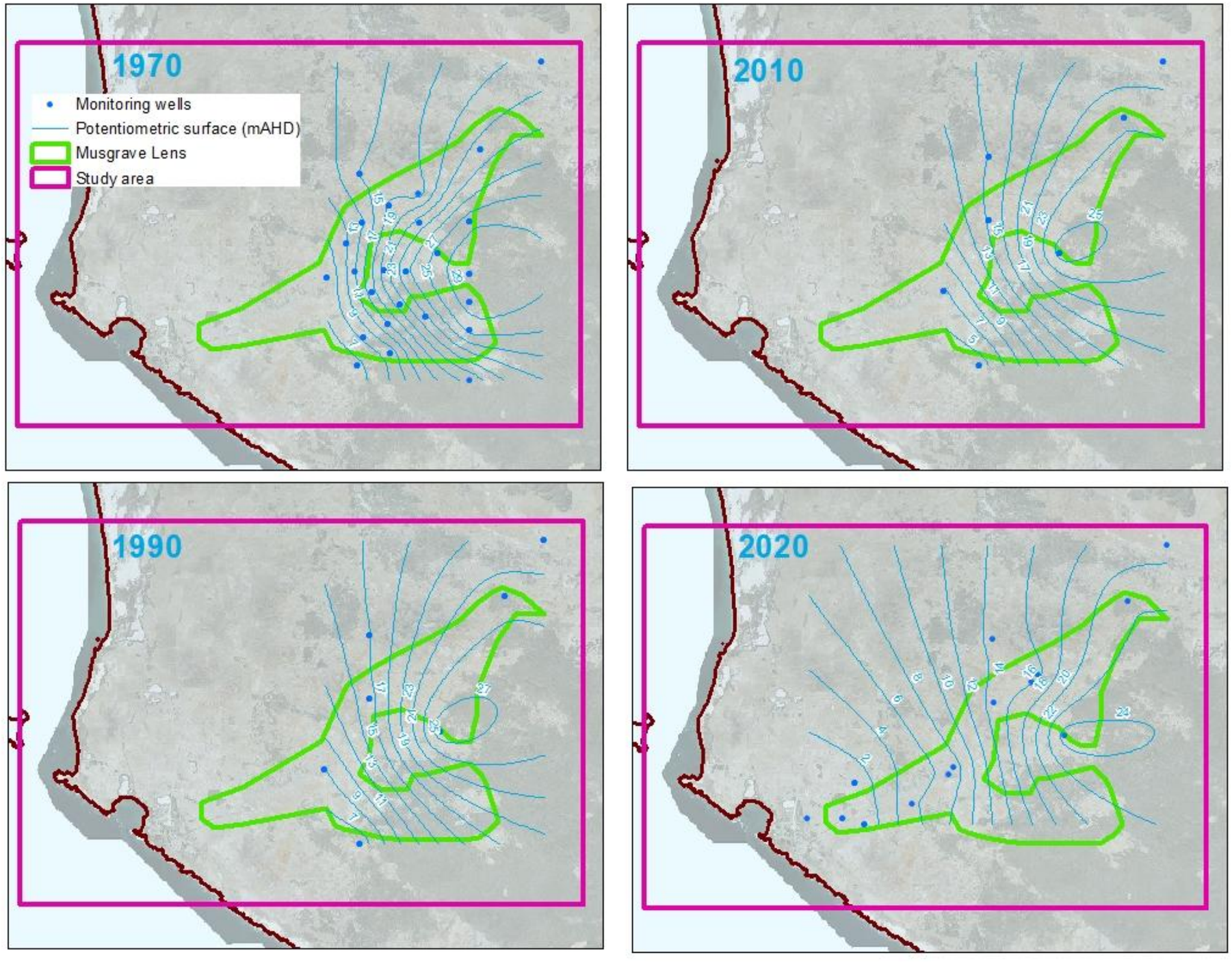


Figure 2.7. Potentiometric surfaces in the QL aquifer for 1970, 1990, 2010 and 2020

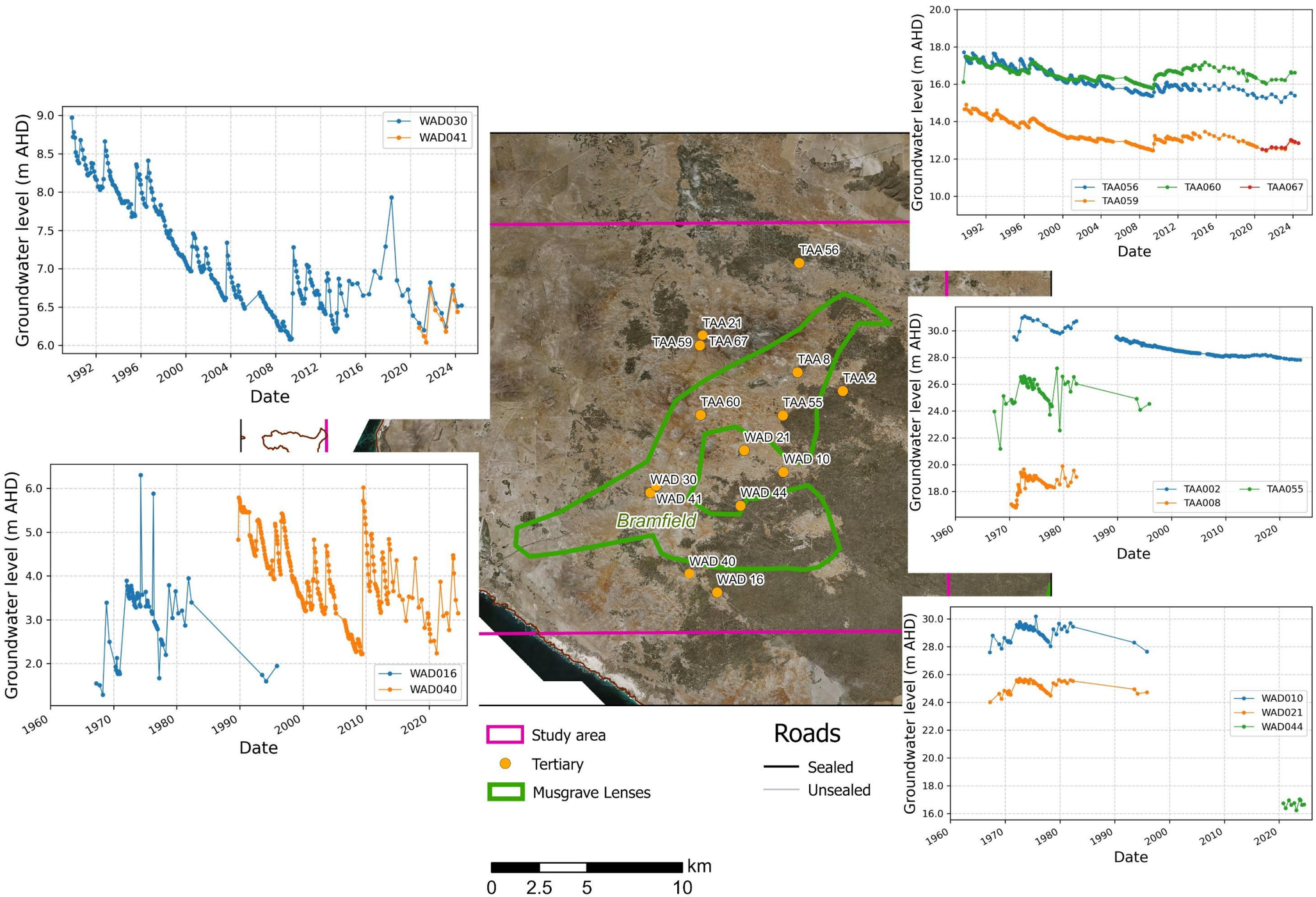


Figure 2.8. Groundwater levels in the Tertiary Sand aquifer

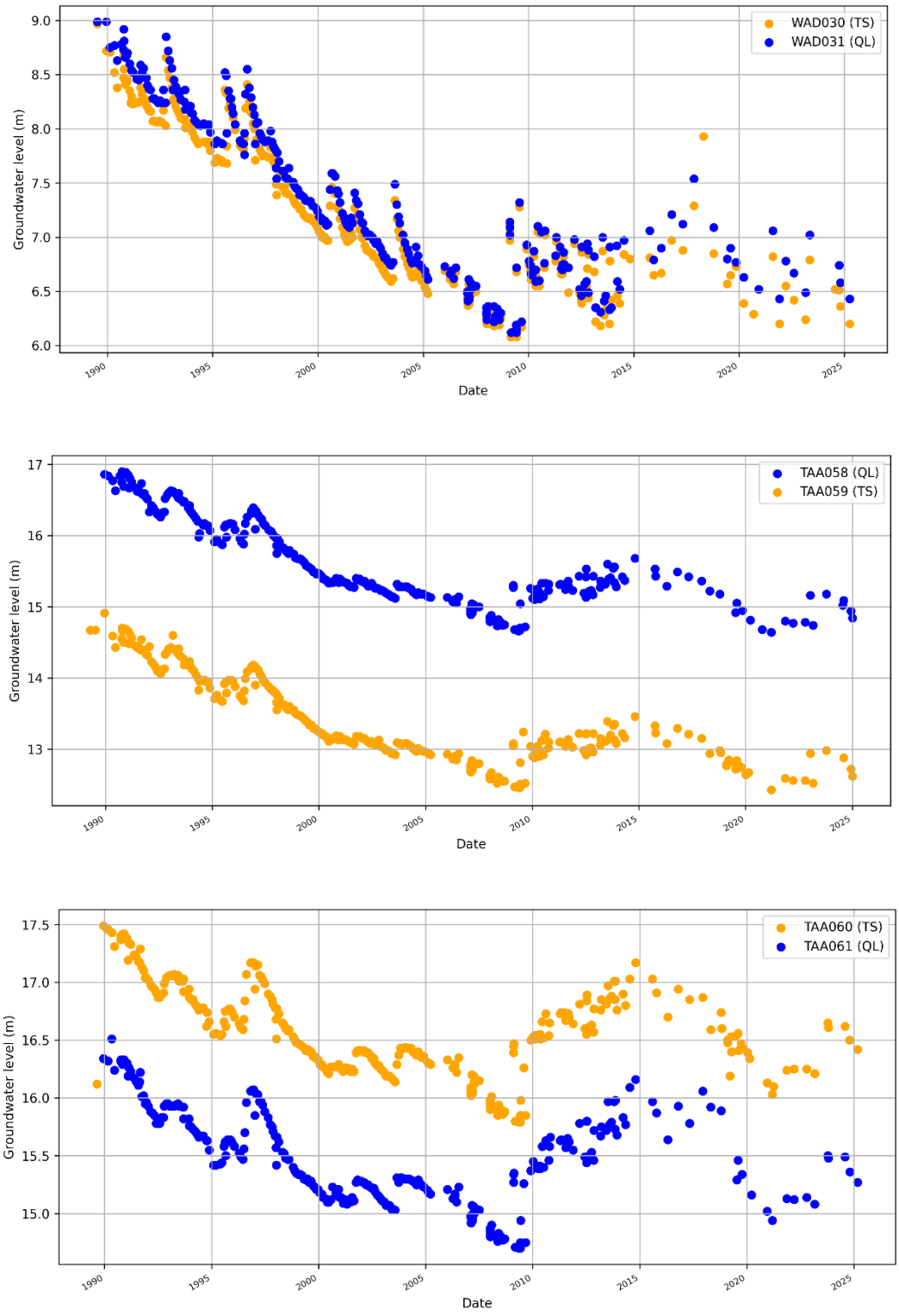


Figure 2.9. Groundwater levels in the QL and TS aquifers at co-located sites

Groundwater levels in the two aquifers at co-located sites show different patterns spatially (Figure 2.9). For example, the aquifers show little to no head difference at WAD030 and WAD031 (centre-west part of the lens), QL levels above TS levels at TAA058/TAA059 (outside the lens, to the north) and TS levels above QL at TAA060/TAA061 (northern arm of the lens, between WAD030/31 and TAA058/059) (Figures 2.6 and 2.8).

2.7 Aquifer properties

There is scant aquifer property data within the Bramfield lens alone, hence the discussion here draws on information from surrounding lenses in the Musgrave PWA where the same aquifers are present. Smith (1984) reports transmissivity for the QL ranging from 800 to 3500 m^2/d. Love et al., (1994) relate these transmissivities to hydraulic conductivity of 160 to 700 m/d based on an aquifer thickness of 5m. Assuming greater aquifer thickness, such as that observed near the town water supply wells and closer to the coast, a lower bound on conductivity in the QL may be more realistic. Love et al., (1994) cite Painter (1972) in reporting the unconfined QL specific yield ranging from 3×10^{-5} to 6×10^{-2}. The low values likely relate to the Theis non-equilibrium and the Jacob modified non-equilibrium methods used to interpret the pumping test data (Painter 1972) which treat the aquifer as confined. Therefore, the specific yield values are not considered reliable.

Gogoll and Howles (2019) reported on a pumping test at a new supply well which showed very little drawdown during testing. As a result, the authors reported transmissivity values ranging from 10,000 to 70,000 m^2/d, noting that the values are likely to be unreliable given the minimal amount of drawdown observed.

For the TS aquifer, Dowie and Love (1996) reported transmissivities ranging from 1 to 300 m^2/d and confined storage coefficients ranging from 1.7×10^{-4} to 1.1×10^{-2}. The authors also collected core samples of the Tertiary Clay layer separating the QL and TS aquifers and measured its vertical permeability as ranging from 4.4×10^{-6} to 1.1×10^{-4} m/d. However, the authors also calculated leakage rates from aquifer test data in the TS to be 2.3×10^{-2} m/d with the suggestion that leakage occurs through preferential flow paths.

2.8 Recharge

Love et al., (1994) describe the groundwater systems of the Musgrave PWA, including the Bramfield lens, as recharge controlled. That is, the aquifer is mainly recharged by rainfall infiltration and groundwater levels rise significantly during periods of higher rainfall. Analysis of chloroflurocarbons (CFC) in groundwater in Bramfield showed much of the water to have been recharged within 38 years of sampling (Cook, Love and Dowie, 1996). That is to say, the Bramfield lens is highly reliant upon contemporary rainfall-recharge. Recharge rates across the Musgrave PWA estimated from CFC analysis were generally in the range 20 to 50 mm/y with some rates of up to 150 mm/y. The higher recharge rates are hypothesised to correspond to preferential recharge via dissolution features. Hydrochemical results are further discussed in Love et al., (1996), notably lower recharge estimates at sites covered by native Eucalyptus vegetation ranging from 0.1 to 12 mm/y.

Recharge rates were also estimated by Love et al., (1994) at a number of wells in Bramfield using the chloride mass balance method and reported as 15-78 mm/y (average 31 mm/y). Recharge was further estimated via the water table fluctuation method, using specific yields between 0.1 to 0.3, and reported as 130-151 mm/y in two wells in Bramfield; however, lower reliability was assigned to the fluctuation estimates of recharge. The authors also suggested that recharge is only likely to occur if monthly rainfall exceeds 60 mm. Additional analysis being conducted as part of a separate National Water Grid Fund project run by the Department for Environment and Water (the 'Rainfall, runoff and recharge – what has climate change done to this critical relationship?' project) has found a correlation between the number of months of the year in which rainfall exceeds evapotranspiration and the annual groundwater level rise.

2.9 Groundwater extraction

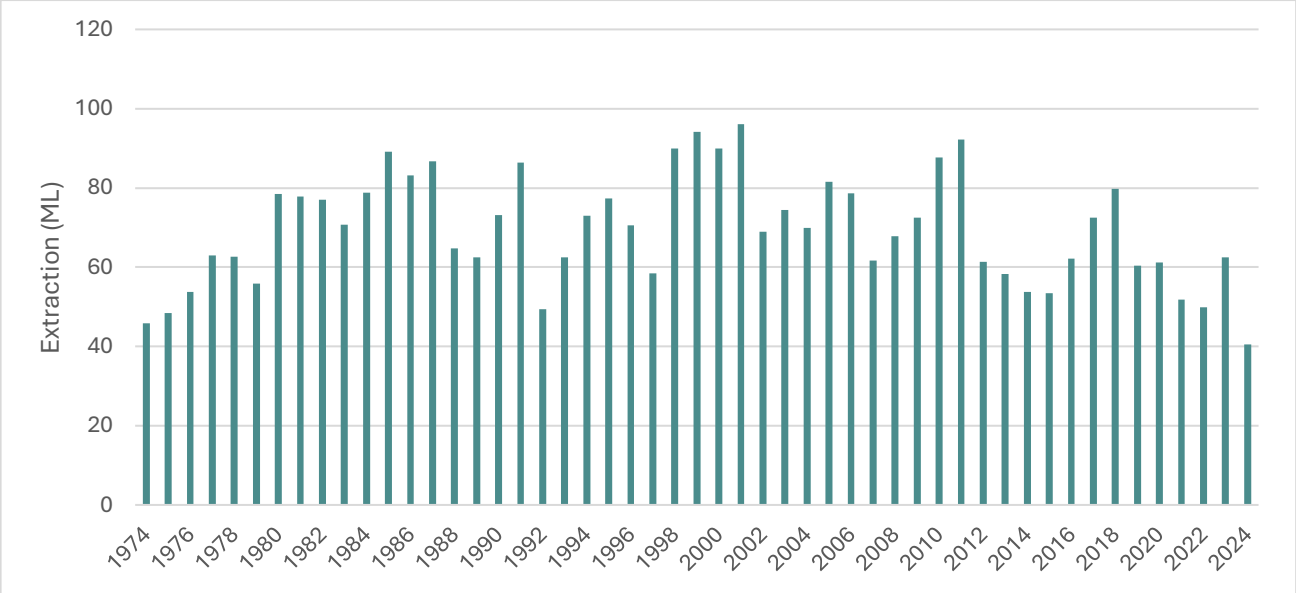


Figure 2.10. Town water supply extraction volumes (data provided by SA Water)

Long-term records of groundwater extraction in the study area are generally limited to town water supply pumping, which commenced in 1974 and has varied from 40 to 96 ML/y (Figure 2.12). Extraction peaked in the late 1990s before generally decreasing; however, extraction still varies year to year. There is a small amount of irrigation extraction in Bramfield with metered extraction volumes from 2005 ranging from 4 to 18 ML/y, averaging around 12 ML/y. This irrigation is assumed to have commenced around the mid-to-late 1990s.

Stock and domestic extraction is the other main groundwater use in the study area. However, there is no metered data on stock and domestic use. Estimates of stock water use are based on assumptions outlined in the EP WAP (EPNRMB 2016) and Stewart (2013) which relate the number of stock on a land parcel to a volume of water. Adopting this approach, and overlaying the relevant land parcels (and associated stock numbers) on the study area yields a volume of 77 ML/y. There is no information available on how stocking rates have changed over time. Domestic water use is likewise estimated based on assumptions in the EP WAP, i.e., use from each well is 280 kL/y. Based on the number of domestic wells in the study area, this equates to 20 ML/y. The location of all extraction wells is shown in Figure 2.13.

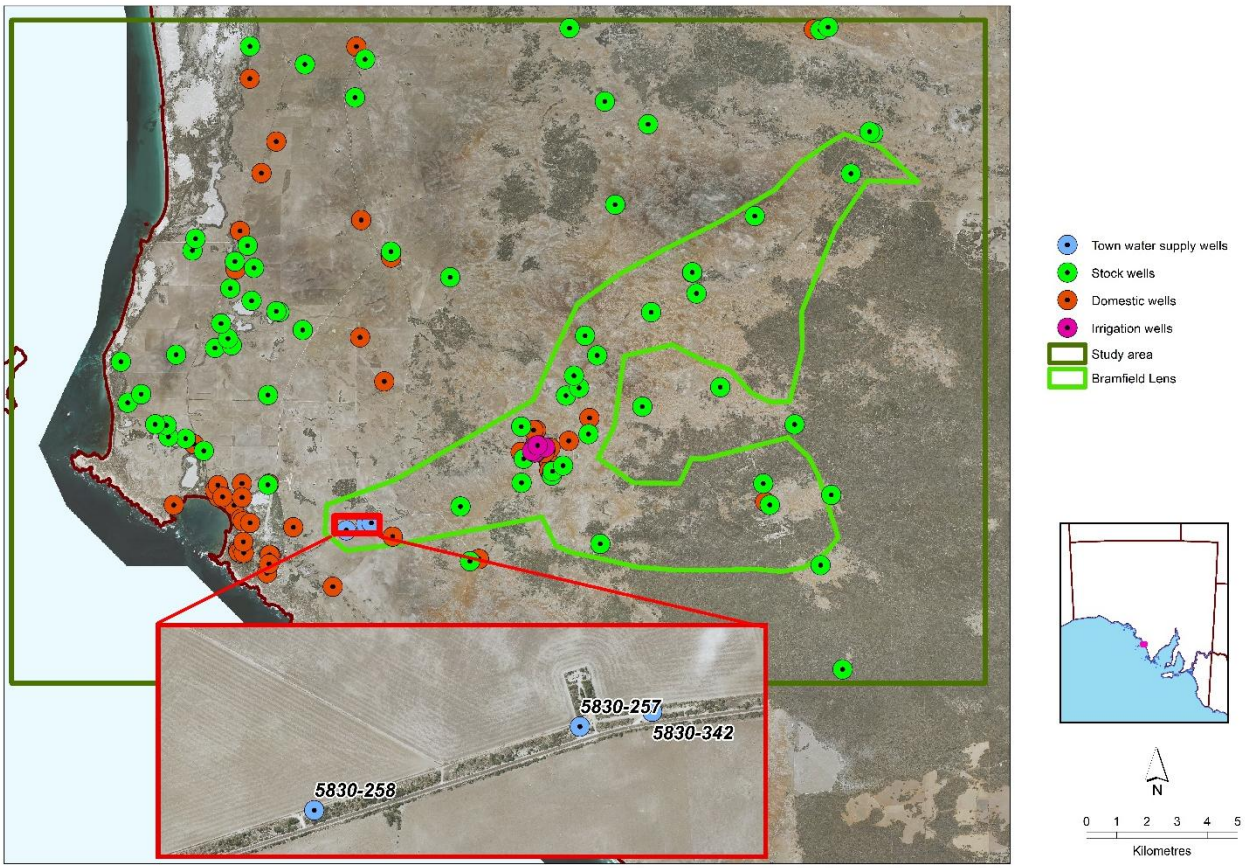


Figure 2.11. Location of extraction wells in the study area

2.10 Groundwater quality

Groundwater salinity data are scarce in terms of time series from which trends may be determined. The best available data record is from the town water supply wells from 1999 onwards. All town water supply wells show a trend of increasing salinity (Figure 2.12) with the highest salinity (1865 µS/cm) in the western-most well 5830-258 (well locations in Figure 2.11), less than 4 km from the coast.

A Piper plot of available water quality data shows the QL and TS groundwaters vary within similar ranges (Figure 2.13) which supports the general conceptualisation that recharge to the TS is derived from downward leakage from the QL. The town water supply well with the higher salinity (5830-258) shows a stronger Na-Cl signature which indicates the trend is driven by incursion of water with a seawater signature. Analysis of available stable isotope data from QL and TS wells in Bramfield and surrounding lenses also shows the water types are very similar, plotting near or on top of the Adelaide meteoric water line (Figure 2.14). This also suggests recharge is likely to be rapid (little evapotranspiration prior to infiltration), supporting the overall conceptualisation that recharge to the QL only occurs following large rainfall events and that recharge to the TS occurs via downward leakage via preferential features.

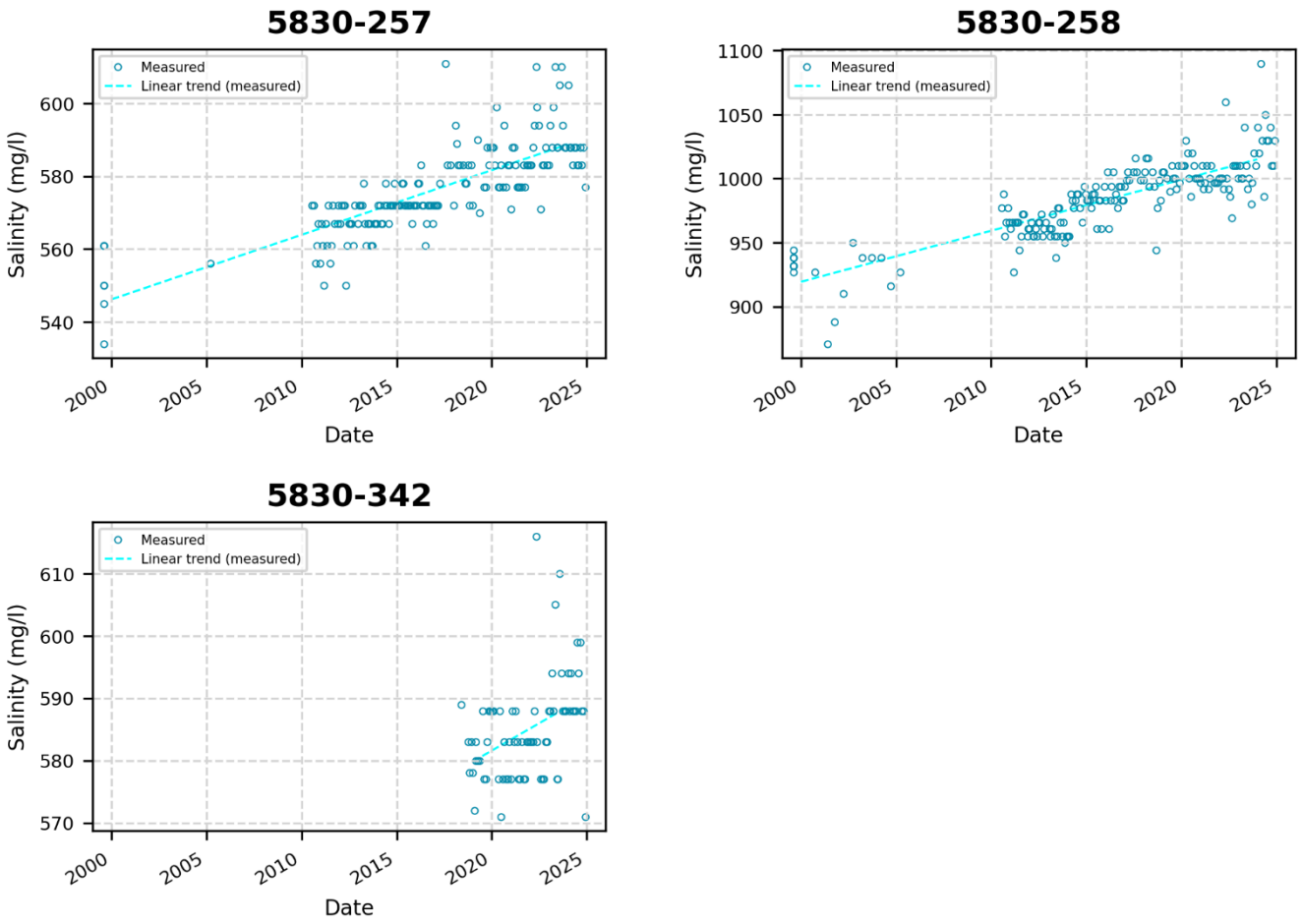


Figure 2.12. Measured salinity and trends at town water supply wells

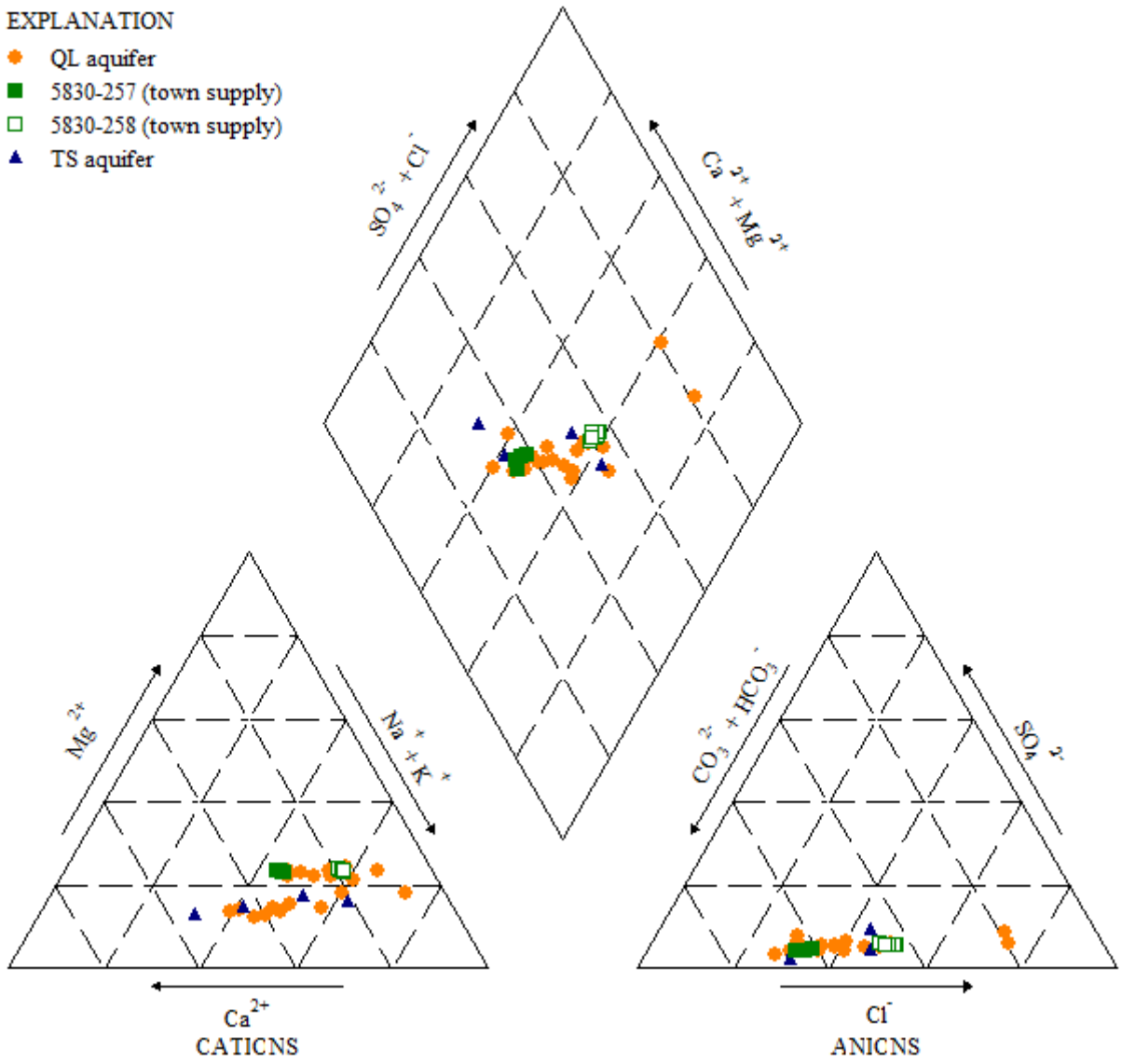


Figure 2.13. Piper plot of groundwater chemistry in the Bramfield lens

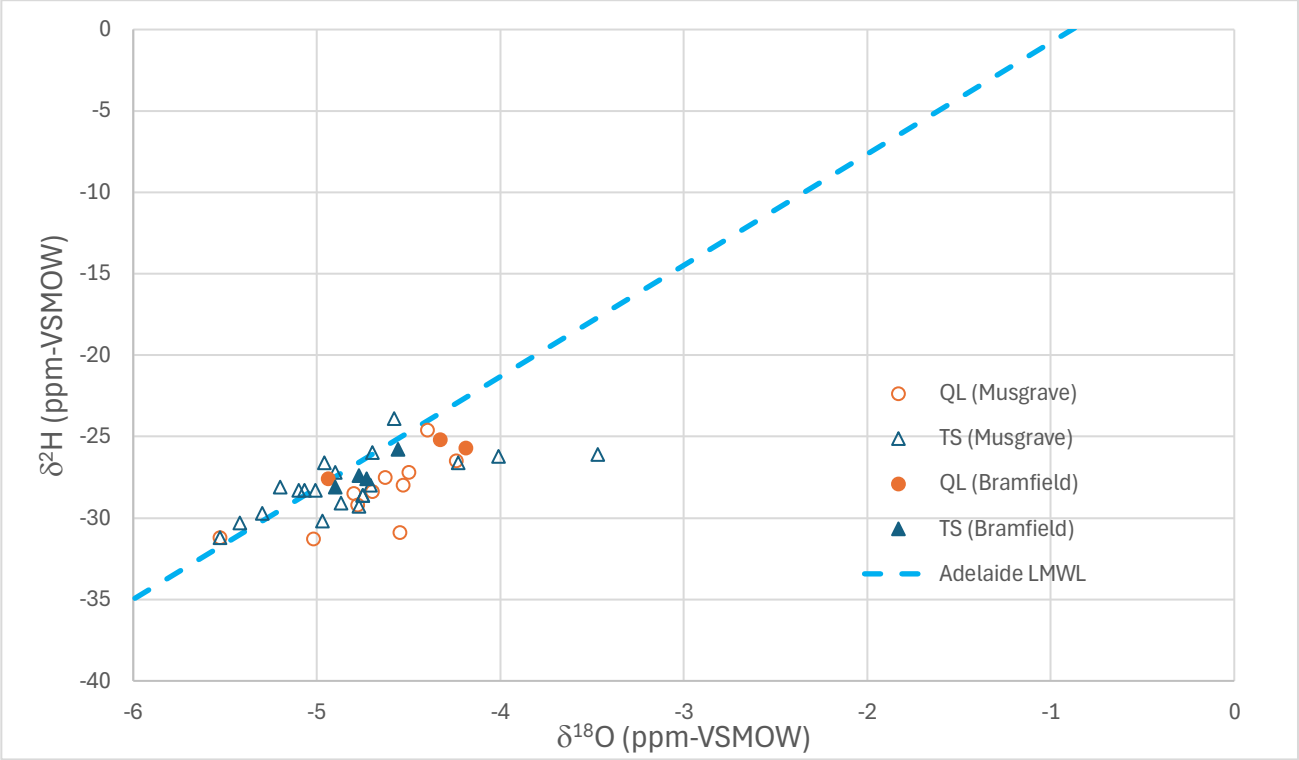


Figure 2.14. Stable isotope content of Bramfield lens groundwater and groundwater from surrounding basins

2.11 Groundwater-dependent ecosystems

The main wetlands of interest in this study are those in and around Elliston – down-gradient of the Bramfield groundwater lens (see inset in Figure 2.15). The wetlands in Elliston (extending south-east from Waterloo Bay) have been previously classified as 'seasonal saline marsh' (Ecological Associates 2021) and are thought to receive water primarily from rainfall, plus the surface or subsurface expression of groundwater (Ecological Associates 2021). This includes Lake Hamp (which experiences higher salinity than the bores in proximity (WAD032 which is less than 50 m from Lake Hamp)), and the wetlands to the east of Lake Hamp around the Elliston Cemetery and Elliston Golf Course, and also to the west along the Flinders Highway (Figure 2.15). These wetlands are highly saline and likely influenced by the shallow water table in the area – providing a shallow source of groundwater which may contribute to seasonal waterlogging and flooding (Ecological Associates 2021). White et al., (2014) measured groundwater level in a shallow piezometer adjacent to Lake Hamp and observed groundwater levels rising above ground level between June and October in four out of six years between 2007 and 2013.

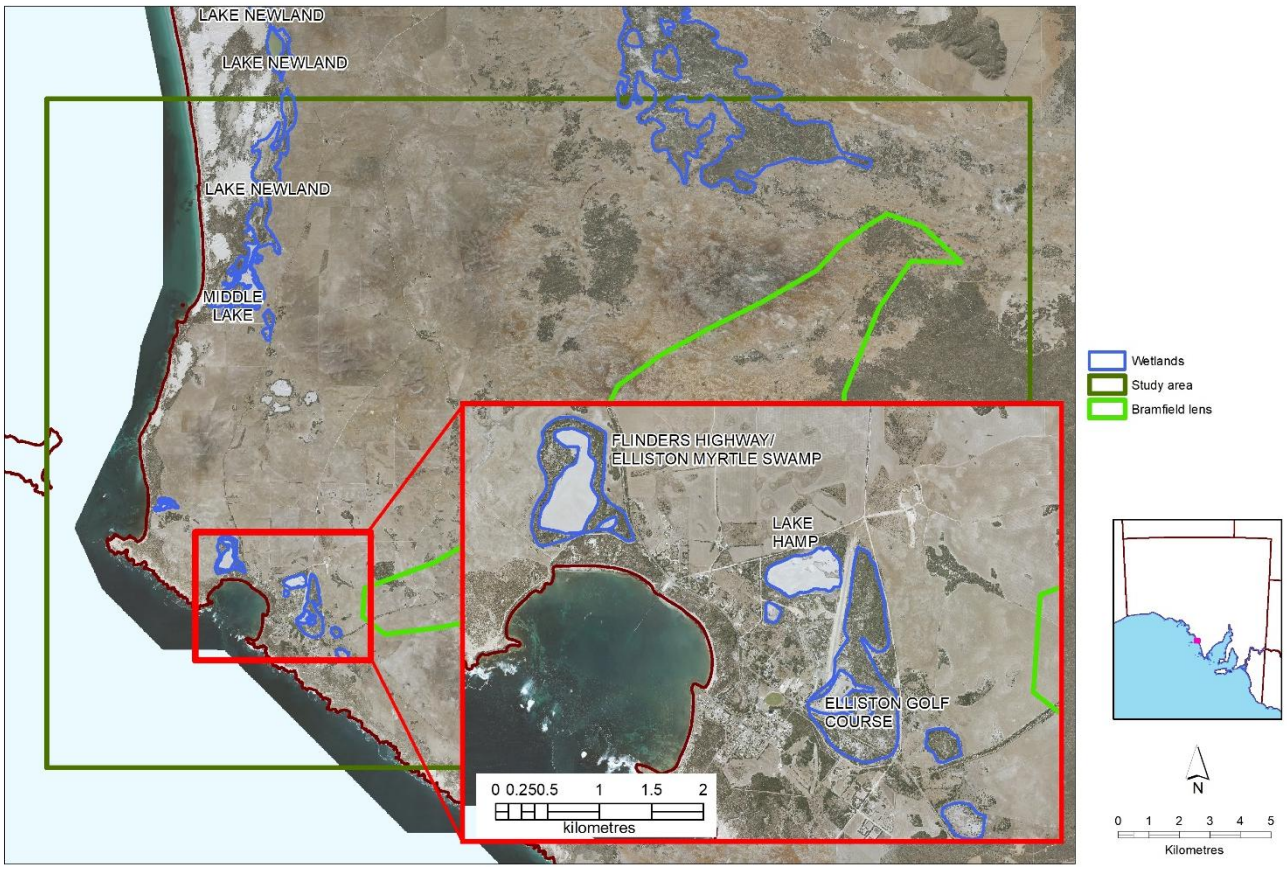


Figure 2.15. Location of wetlands in the study area

To investigate the dynamics of these wetlands further, an analysis of Digital Earth Australia Water Observations (Geoscience Australia 2024) was performed based on data available. Observations showed the expression of water in these wetlands seemed to be relatively seasonal with surface area coverage increasing in the wetter months (Figure 2.16). However, during dry seasons, observations still saw an expression of water – possibly indicating a persistent source of water such as groundwater.

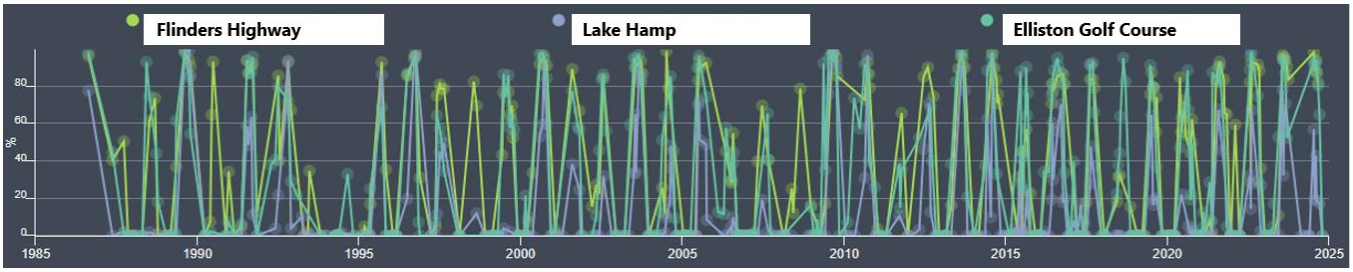


Figure 2.16. DEA Water Observations of percent of time water is present at key wetlands in the study area

River red gums (*Eucalyptus camaldulensis*) around the Eyre Peninsula are known to be associated with (or an indicator of) groundwater-dependent ecosystems (GDEs) – reliant on groundwater in the subsurface for part, or all, of the year and affected by reduced groundwater levels. A 2023 study conducted by Banks and Shanafield on river red gums demonstrated patterns of evapotranspiration (and partitioning) – discerned through diurnal signals in water level and chemistry data, as well as xylem water samples from Bramfield GDEs. This study not only demonstrated potential water table fluctuations via the process of evapotranspiration but also used additional geophysical methods to study subsurface conductivity (as an indication of water salinity). Although the results for increased salinity were more prominent in groundwater

near Coffin Bay (approximately 110 kilometres south of Elliston) than Bramfield, the study confirms that evapotranspiration can indeed impact salinity of the groundwater (Banks and Shanafield 2023).

The results of the Banks and Shanafield (2023) study share similarities with an earlier study completed by Swaffer (2014) which indicated considerable evapotranspiration in later summer, as well as confirmed groundwater dependence. It is likely that the river red gums contribute to a decline in the water table over summer as they access the water table and increase evapotranspiration with the warmer seasons (Swaffer 2014; Banks and Shanafield 2023). However, there is no information on rates of vegetation water use to include in the groundwater model.

2.12 Preliminary research findings of relevance to the conceptual model

The NWGF project 'Ensuring water security, economic prosperity and nature positive outcomes for Elliston' is underway at the time of writing and scheduled to continue after completion and reporting on this model. Therefore, not all that project's outcomes can be summarised and referenced. However, several components of the project were completed to a satisfactory level during the development of this model and have consequently influenced the development of the conceptual and numerical models. Rather than thread these aspects through the report, a brief summary of relevant information is provided here.

An initial survey of existing geophysical logs was carried out, leading to an updated interpretation of the geology of the region, cited earlier (Lanigan, 2025). Additional geophysical data has also been collected in the coastal area surrounding Elliston. Banks (2025) described the collection of several near-surface geophysical data sets in October and November 2024 including Loupe time-domain electromagnetic (TEM) data, short offset TEM (sTEM) data, subsurface nuclear magnetic resonance (sNMR), as well as surveys of subsurface salinity in the near-coastal zone and radon-222 data in the Waterloo Bay area.

The Loupe and sTEM data has revealed insights into coastal groundwater salinity which has been interpreted to show the extent of seawater intrusion in the coastal aquifer. Further results will be discussed in relation to model results, but Figure 2.17 gives an example of one of the sTEM transects described in Banks (2025). These data suggest the presence of a high-conductivity plume in the nearshore zone, extending ~3.5km inland which is approaching the location of the eastern-most town water supply well. Higher conductivity anomalies further inland (8.5 to 10 km in Figure 2.17) may relate Sleaford Complex outcrops observed in this vicinity in Figure 2.5. Based on this and other results, Banks (2025) produced Figure 2.18 which shows the interpreted zone of seawater in the aquifer in the near shore zone around Elliston. Further geophysical surveys to better define the seawater intrusion interface will be conducted in early 2026.

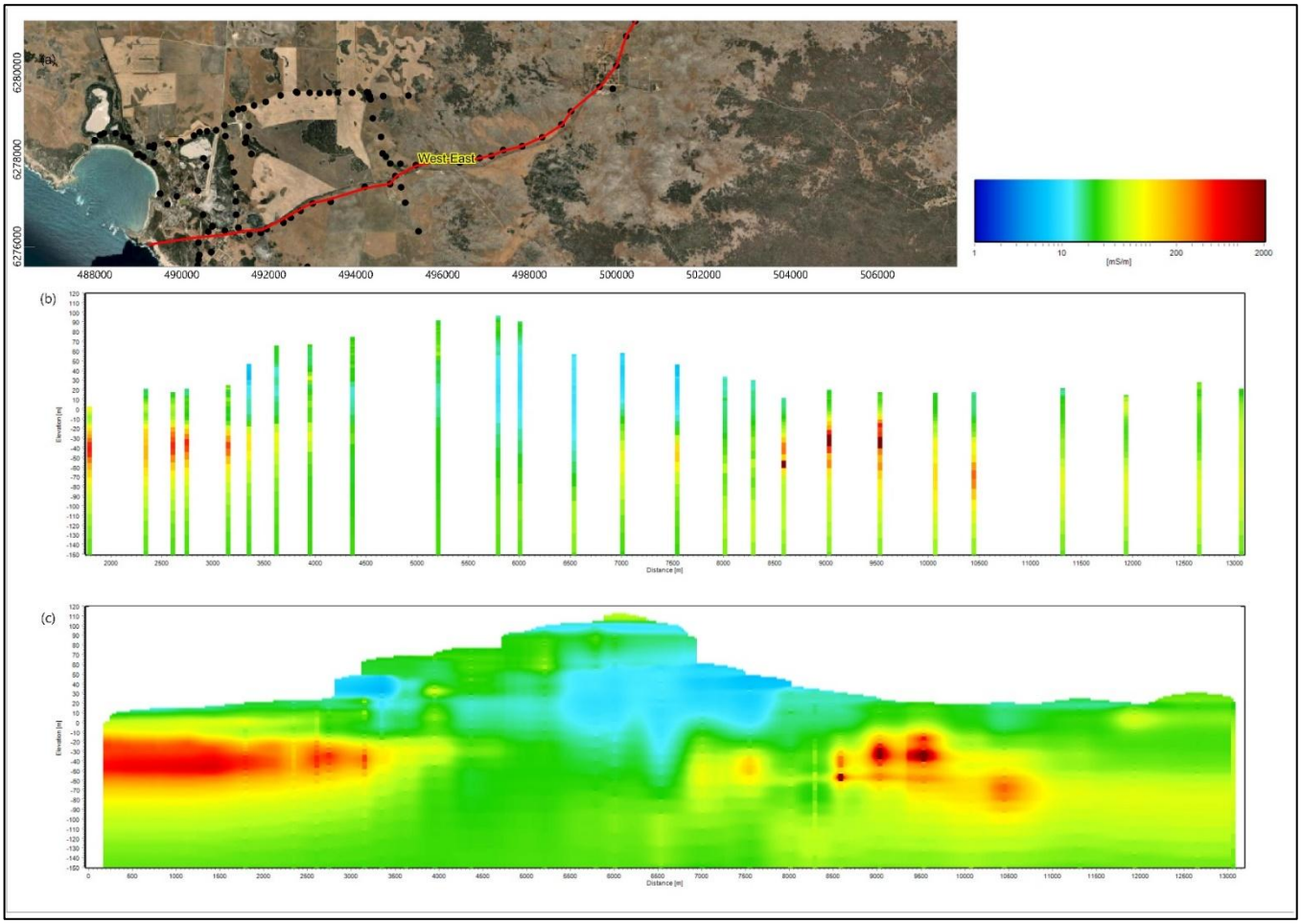


Figure 2.17. Example results of an sTEM data transect described in Banks (2025)

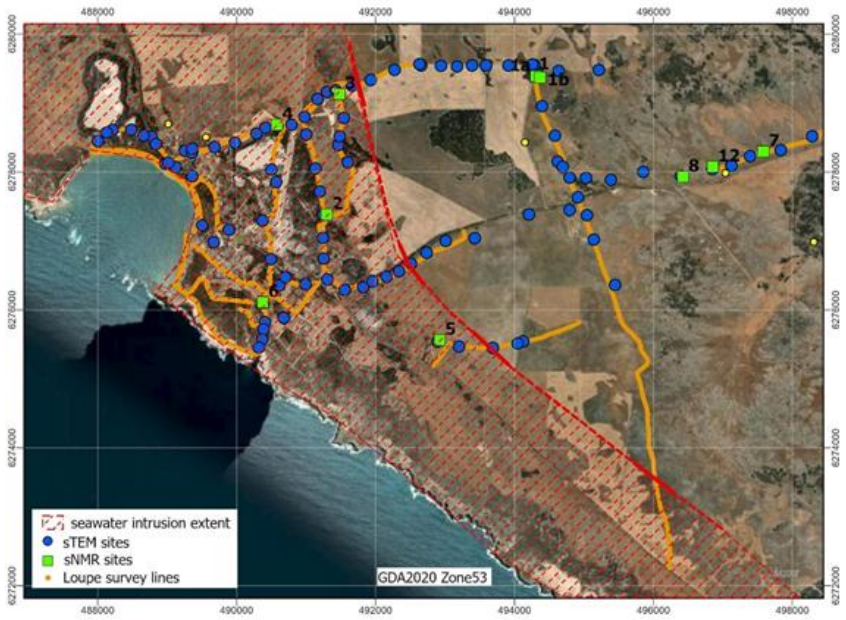


Figure 2.18. Interpreted extent of seawater intrusion as described in Banks (2025)

2.13 Conceptual model summary

The study area for this modelling investigation encompasses the Bramfield lens within the Musgrave PWA (Figure 2.1). The lens area is approximately coincident with areas of the unconfined Quaternary Limestone aquifer that are saturated and of salinity <1000 mg/L. The Quaternary Limestone is underlain by the Tertiary Sand aquifer with the two units often separated by the Tertiary Clay layer. Conceptually the TS aquifer is a confined aquifer but drill log and pumping test data suggests it to be only partially confined. Groundwater flows from east to west, discharging towards the coast and, likely, into coastal lakes. The QL spans the entirety of the study area; however, the aquifer is likely to be dry in eastern parts. The Tertiary Clay is discontinuous west of Bramfield, while the TS aquifer is thin west of Bramfield and discontinuous west of the town water supply wells.

The Bramfield lens is likely connected to and fed by other saturated lenses in the Musgrave PWA; as well as rainfall recharge within the lens area. Recharge to the QL is reliant upon annual rainfall and is estimated at generally around 30 mm/y but with a high degree of spatial and temporal variability. Higher recharge (>100 mm/y) may occur preferentially through karst features, while lower recharge (<12 mm/y) is expected in areas covered by native vegetation. Long term declines in groundwater levels follow the trend of declining rainfall (Figure 2.2). A range of data indicates that recharge to the TS aquifer is likely to occur via downwards leakage from the QL aquifer through preferential pathways.

There are several groundwater discharge processes. Groundwater is extracted for town water supply with a long-term average extraction of 70 ML/y. A similar volume of water is likely to be extracted annually for stock and domestic use; however, stock and domestic use figures are only estimates as it is not officially metered. Approximately 12 ML/y is extracted for irrigated agriculture, predominantly in the Bramfield town area. Groundwater is also likely to discharge into coastal wetlands, as well as to the coast. The seawater interface is present in the aquifer up to 3.5 km inland based on recent geophysics (Banks 2025).

For illustrative purposes, the Bramfield lens can be conceptualised in much the same as was presented by Evans (2002), with the exception of the regional extent of the TS aquifer, which is likely to be absent west of the town water supply wells where the QL is underlain by basement (Figure 2.19)

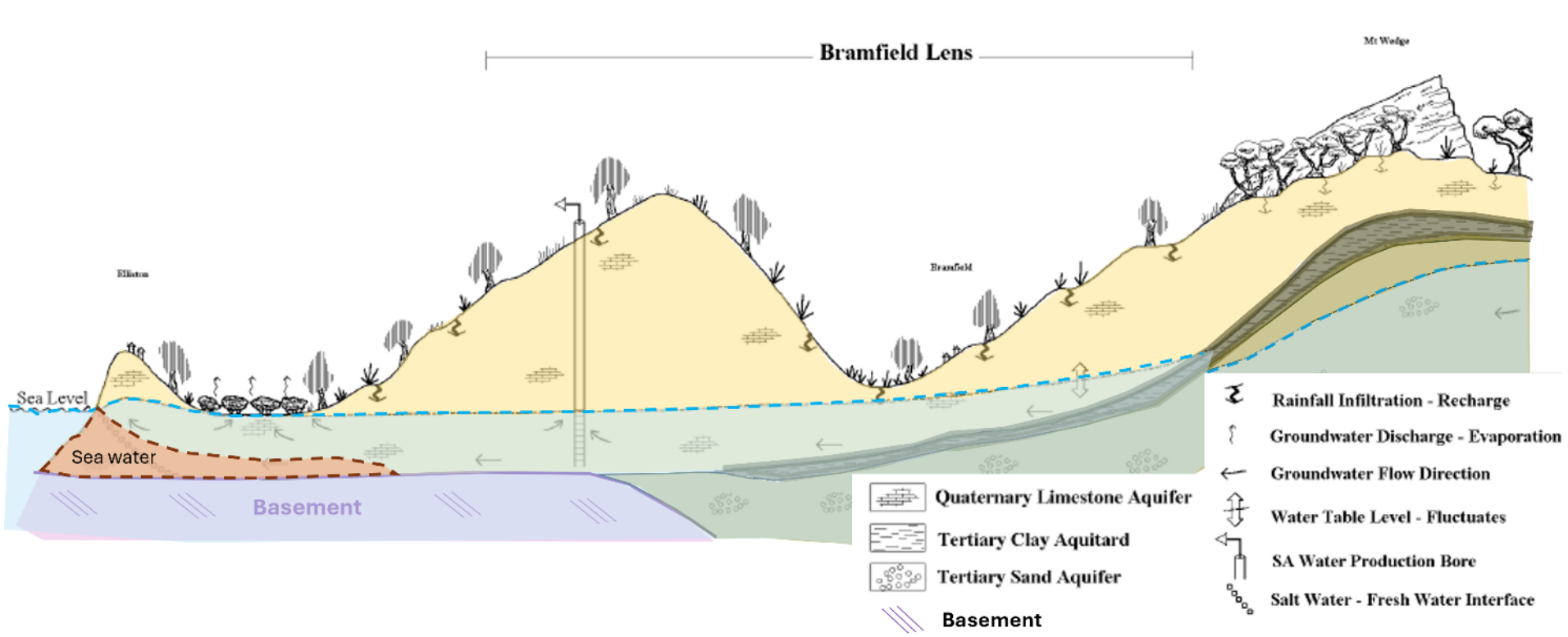


Figure 2.19. Bramfield conceptual model, modified from the conceptual model of Evans (2002) – not to scale

2.14 Conceptual model uncertainty

Despite a generally good understanding of the overall conceptual model and how groundwater levels have changed since the mid-1960s in the Elliston area, several areas of uncertainty in the conceptual model remain, predominantly due to a lack of data. Though this lack of data may not be addressed through the model development here, it is noted here so that it may be investigated further in future. These uncertainties include the:

- volume of stock and domestic water use as this is unmetered and therefore volumes of extraction presented here are estimates;
- aquifer thickness, particularly near the coast as the data regarding the thickness of the QL aquifer is limited to drillhole locations across the basin and is scarce near the coast. This means that any model results related to the extent of drying the QL aquifer must be considered with this conceptual uncertainty in mind;
- groundwater use by native vegetation as although groundwater-dependent vegetation has been identified as being likely to be present in the study area, rates of vegetation groundwater use are not known, and hence are not included in the modelling; and
- groundwater discharge to wetlands, as while there are studies which relate groundwater levels near wetlands with the likelihood of groundwater dependence, rates of groundwater discharge to wetlands are not known.

3 Model construction

3.1 Model purpose and design summary

The intended use of the Elliston model is to understand the drivers of groundwater level change in the past, in particular the roles of rainfall-recharge and extraction, as well as understanding the water balance including the volume of groundwater discharge to the coast and the position and movement of the seawater interface. This is achieved through calibrating the model to past groundwater level observations. The model is then used to simulate how the system may respond to future climate and pumping. In terms of system response, the key metrics of interest are:

- changes in groundwater level (e.g., are parts of the freshwater lens at risk of running dry?); and
- changes in the location of the seawater interface (e.g., could changes in climate or extraction increase the risk of seawater intrusion?).

Thus, the model encompasses the Bramfield lens within the Musgrave PWA. Given that groundwater level responds rapidly to rainfall-recharge, the model is set up with monthly stress periods. This is justified given there are some historic groundwater level data recorded at monthly intervals and monthly pumping volumes for town water supply are available since pumping commenced in 1974. The model used for the transient history match calibration runs from May 1965 to December 2024 which equates to 716 monthly stress periods.

The model is built using MODFLOW-2005 to accommodate use of the Seawater Intrusion package SWI2 (Bakker et al., 2013). The SWI2 package simulates a sharp seawater interface representing a specific isohaline, typically the 50:50 split between freshwater and seawater. As such, it does not simulate the effects of diffusion or dispersion associated with the mixing between freshwater and seawater. This assumption makes it more computationally efficient than packages such as SEAWAT (Langevin et al., 2008) and more advantageous in regional scale modelling. It has previously been applied in a modelling study of the Uley South Basin in Eyre Peninsula (DEW 2020). Use of the SWI2 package also necessitates a large number of times steps per stress period with 50 time steps adopted here.

The model is run using the MODFLOW-NWT solver and with cell rewetting using the up-stream weighting (UPW) method. UPW was initiated during the model calibration as issues were found with observation wells which have been periodically dry, such as WAD011 (Figure 2.6). Activating UPW allowed for drying and re-wetting to occur and no differences were observed between modelled groundwater levels with and without UPW in locations where re-wetting was not occurring.

The model is divided into three layers to represent the Quaternary Limestone (QL) aquifer and the underlying Tertiary Clay aquitard and Tertiary Sand (TS) aquifer (Table 3.1). A uniform grid of 100m x 100m cells was applied (Figure 3.1). The extent of layers 2 and 3 is set at the limit of the Tertiary Sand based on the work of Lanigan (2025) (Figure 2.5). Using this approach the model has a total of 157,741 active cells.

Period	Formation	Description	Hydrogeology	Model layer
Quaternary	Bridgewater Formation (Qpb)	Calcarenite/coastal dunes	Unconfined aquifer (Quaternary Limestone or QL)	1
Tertiary	Undifferentiated, unnamed clay	Sticky to stiff clay with coarse sand and gravel	Aquitard	2
	Poelpena Formation (Tep)	Quartz sand, silt and clay	Confined Aquifer (Tertiary Sand or TS)	3

Table 3.1. Elliston model layers

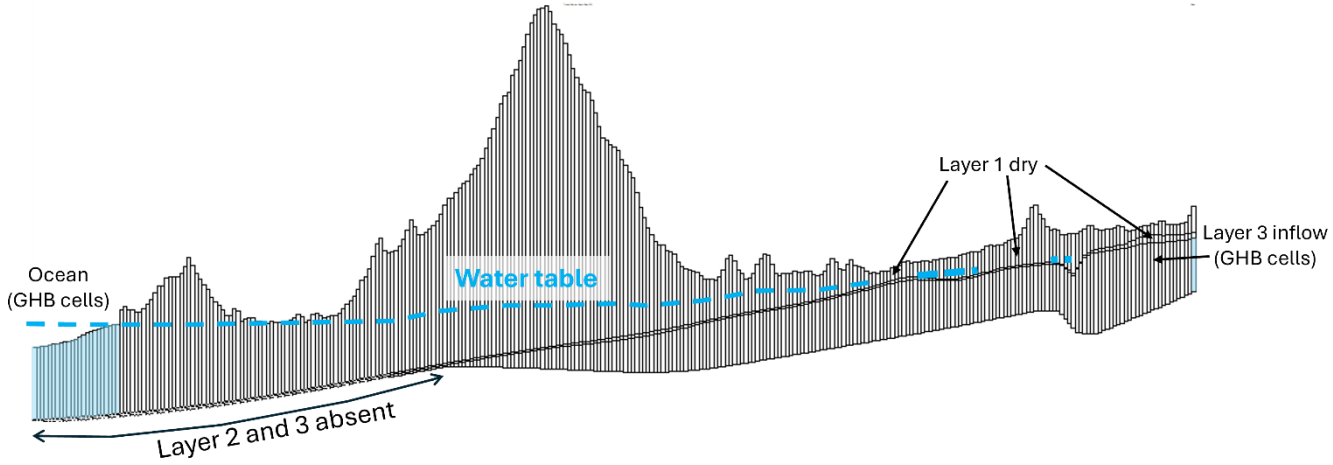


Figure 3.1. Elliston model setup in cross section (with reference to the conceptual model in Figure 2.18)

3.2 Layer elevations

The surface elevation is based on a 2019 digital surface model (DSM) of the region with a resolution of 10m. The DSM was generated during the process of orthorectifying aerial imagery collected in 2019 (Aerometrex, 2019). As such, it is an elevation data set with no accuracy specification, compared to other regional scale datasets such as the Shuttle Radar Topographic Mission (SRTM) digital elevation model (DEM), used for other groundwater models in the Eyre Peninsula (DEW 2020). However, a comparison between elevations given by the DSM and the SRTM datasets and measured ground elevations at observation wells showed the DSM to correlate better with ground survey elevations, particularly in lower lying elevations (Figure 3.2). Given that the water table may be shallower in lower elevation areas, accurate surface elevation is important for constraining model processes such as evapotranspiration. For this reason, the DSM data set was used for ground surface elevations in the model. Offshore surface elevations were based on bathymetry data from Geoscience Australia Australian Bathymetry and Topography Grid (Whiteway, 2009). Layer elevations for the remaining layers are based on contouring elevation data from drillhole information as well as incorporating analysis of geophysical data described by Lanigan (2025). Layer elevations for the model layers are shown in Figure 3.3.

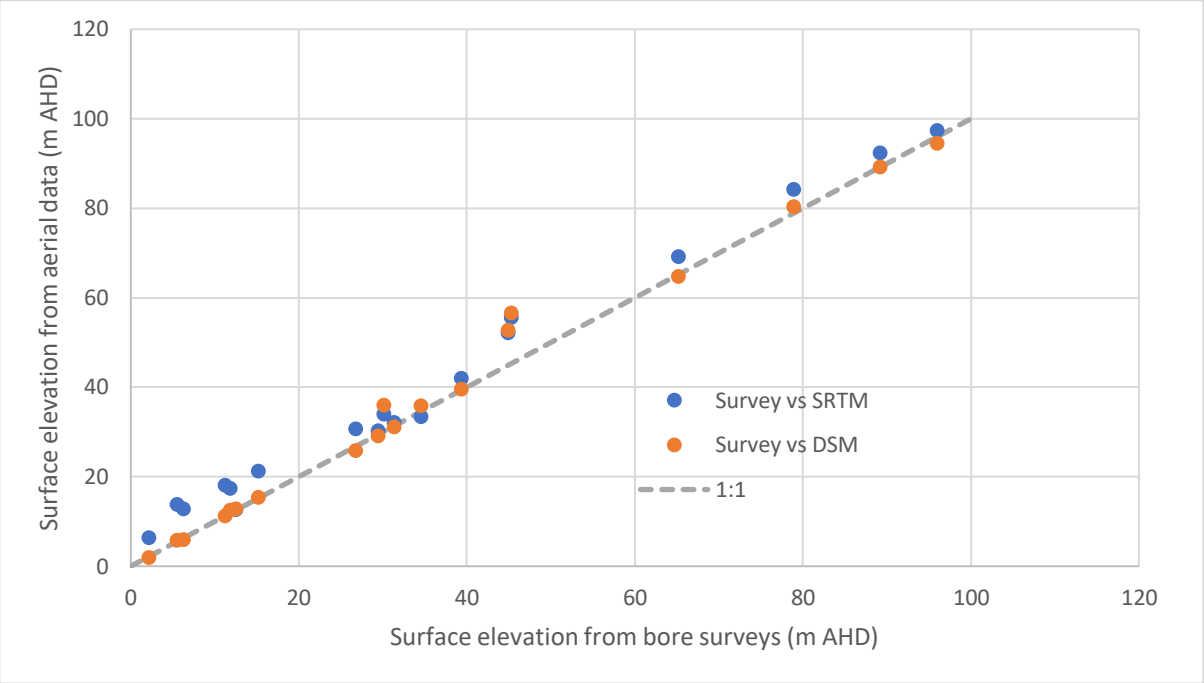


Figure 3.2. Comparison between different elevation model elevations and surveyed ground elevations

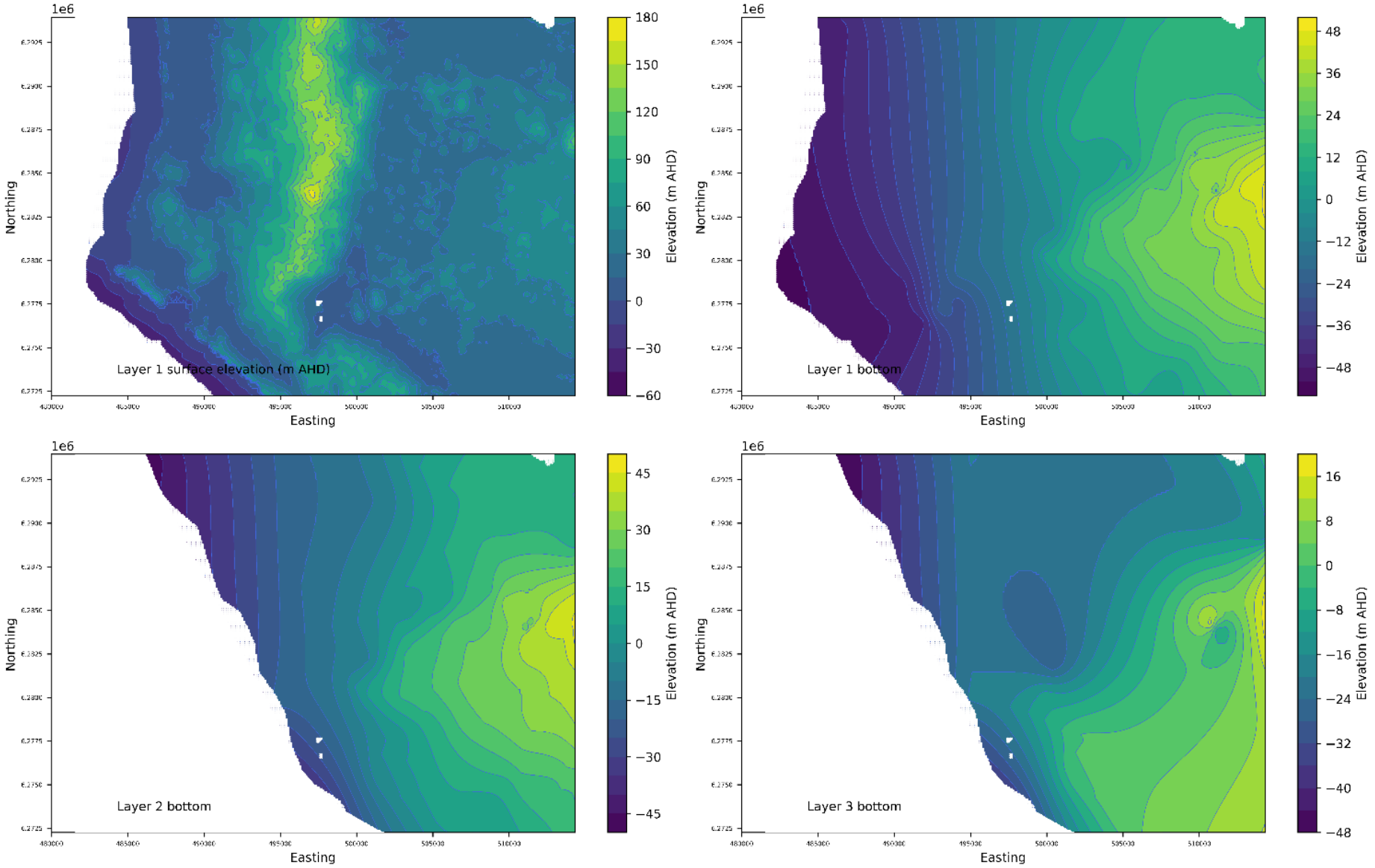


Figure 3.3. Model layer elevations

3.3 Head boundaries

The coastal outflow/inflow boundary zone is set as a general head boundary in Layer 1 consistent with requirements of the SWI2 package (Bakker et al., 2013), wherein head values in coastal cells are set as equivalent freshwater heads at the ocean bottom following:

$$\Delta h = \Delta\rho \frac{C_i}{C_{max}}(h_i - z_i)$$

where Δh is the head boundary value, $\Delta\rho$ is the fractional difference in density between seawater and freshwater (0.025), C_i and C_{max} are the concentrations at the cell and the max seawater concentration respectively, h_i is the boundary head at the cell (assumed to be 0 m AHD) and z_i is the surface elevation at the cell. Values resulting from this approach are shown in Figure 3.4.

A general head boundary for inflow to Layer 1 is assigned in the top right portion of the domain, approximating the extent of saturated QL aquifer (Figure 1.1) with head values based on the potentiometric surface (Figure 3.4).

A general head boundary is used to simulate inflow to Layer 3 with heads based on groundwater level observations. The head boundary is steady state in the northern portion of the boundary, and transient further south, with the transient head values used in the model based on groundwater level observations in the TS (Figure 3.5). There is no outflow boundary as such for layers 2 and 3 because the Tertiary Clay and Tertiary Sand units pinch out eastwards of the coast, as shown in Figures 3.1, 3.3 and 3.4 (i.e., discharge occurs via upwards flow into layer 1). Layer 2 has no inflow boundary as the Tertiary Clay would effectively limit lateral inflow.

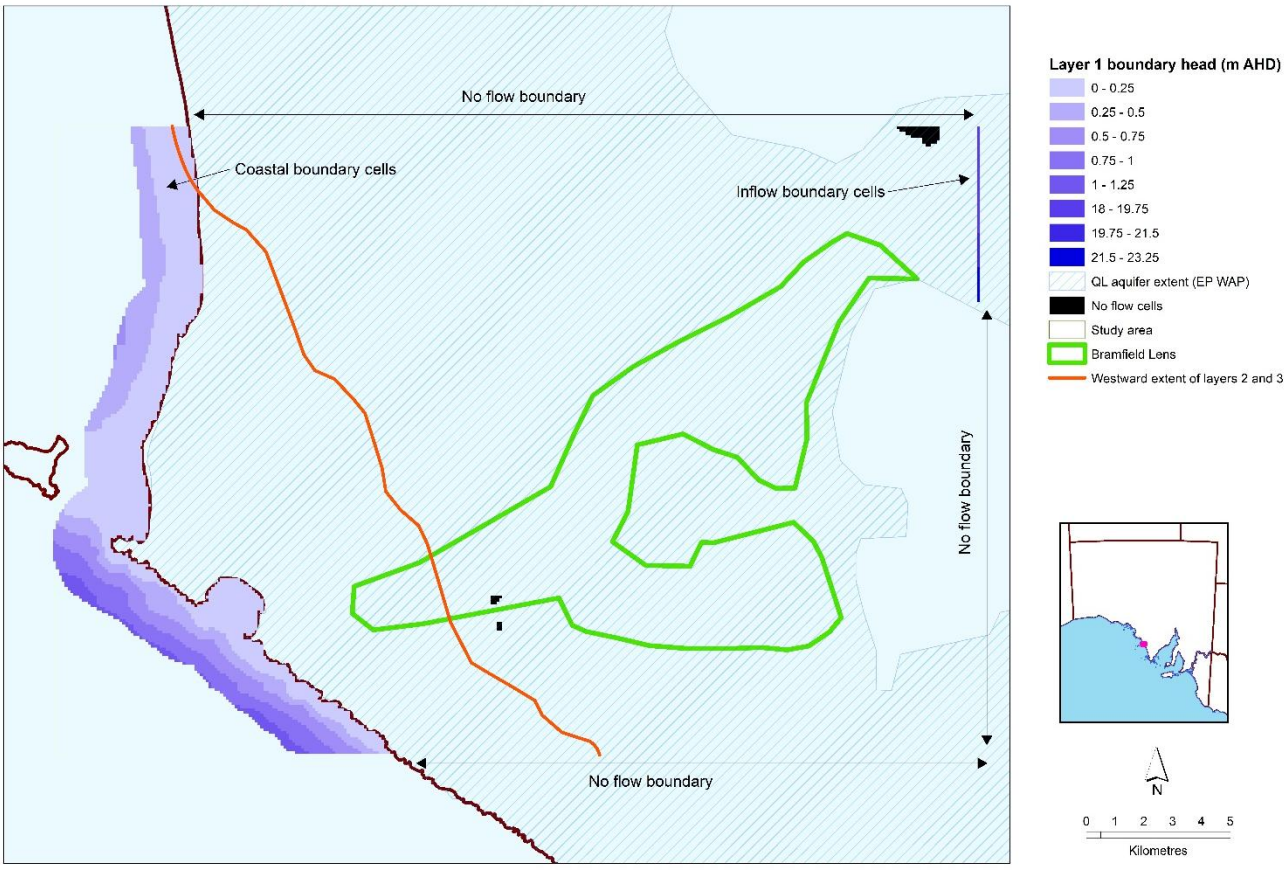


Figure 3.4. Layer 1 general head boundary values

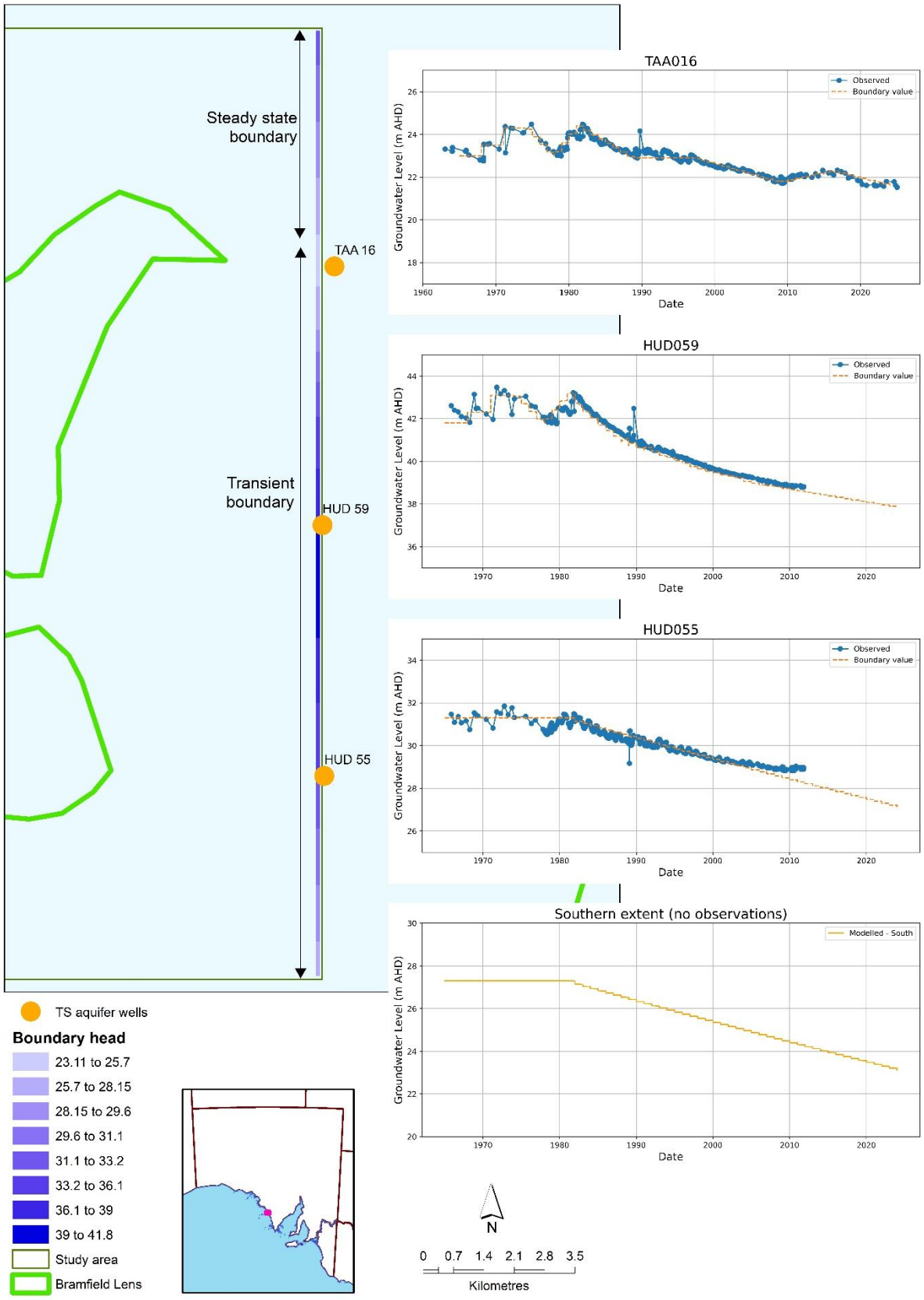


Figure 3.5. Layer 3 general head boundary values

3.4 Recharge and evapotranspiration

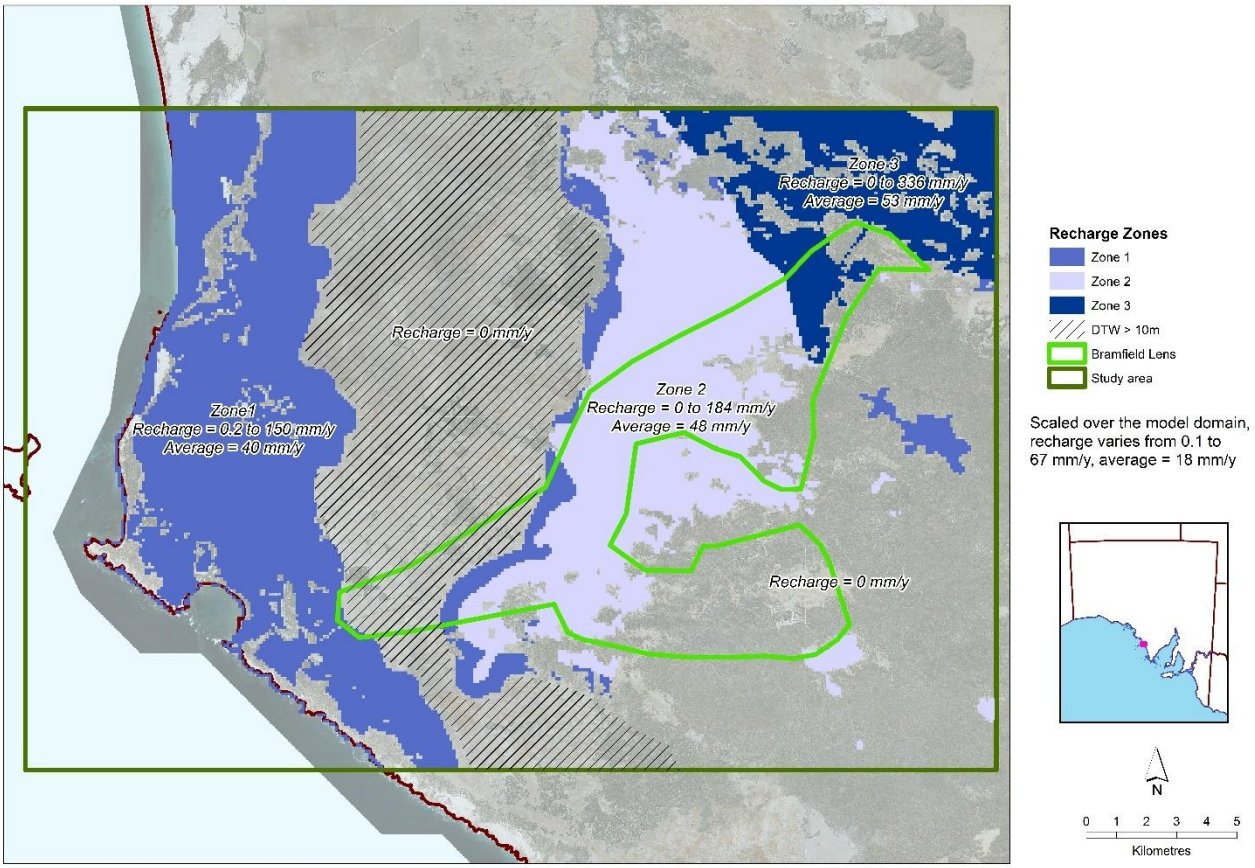


Figure 3.6. Recharge zones in the groundwater model

Recharge was developed iteratively through model calibration. Recharge zones were delineated based on soil and vegetation types (Figure 2.3, Figure 2.4) as well as the depth to groundwater (Figure 3.6). Zones of zero recharge were assigned to areas of native vegetation and the central region where the depth to groundwater increases from 10m up to 90m below ground level (Figure 3.6). While there may be a small amount of recharge under native vegetation (Love et al., 1996) and where the water table is deep, there is limited evidence to support significant recharge. The assignation of 0 mm/y is a simplification but it is supported by the data available and overall model performance in these zones. Rates for the other zones were initially based on trends in groundwater level fluctuation and their relationship with rainfall. This was applied with reference to the ranges reported by Love et al., (1994) of 15 to 78 mm/y, noting some higher estimates of 150 mm/y and an average of 31 mm/y. Rates were then varied through calibration until a good fit was found, while taking into account the ranges previously reported. Recharge rates are applied to May-October each year, approximating the period of the year in which rainfall typically has the potential to exceed evapotranspiration (Figure 2.1) and groundwater level rises are observed. The resulting recharge values for zones (ranges and averages) are shown in Figure 3.6. Scaled over the entire model domain area, these translate to a range from 0 to 67 mm/y with an average of 24 mm/y for the 1965–1994 period (for comparison with Love et al., 1994) and a long-term average (1965–2024) of 18 mm/y. Over the last ten years (2015–2024) the average is 7.8 mm/y, ranging from 0 to 32 mm/y. Recharge is applied to the top layer of the model only. That is, in areas of the model where layer 1 goes dry, recharge does not continue to occur to layers 2 to 3.

The transient pattern in recharge was also informed by findings in a parallel National Water Grid Fund project being run by DEW. The 'Rainfall, Runoff and Recharge – what has climate change done to this critical relationship?' project has found preliminary relationships for monthly differences between rainfall and evapotranspiration (rainfall minus ET, referred to herein as 'climate flux') and annual fluctuations in groundwater level in several unconfined aquifers across South Australia. Figure 3.7 shows the spatially averaged recharge rates in the model alongside the positive climate flux, which is a measure of the period of time each year in which monthly rainfall exceeds monthly ET, with the area approximated using the trapezoidal rule (essentially a method of integration). While the two do not correlate perfectly (Figure 3.8), the time series of positive climate flux was beneficial in calibrating the time series of recharge.

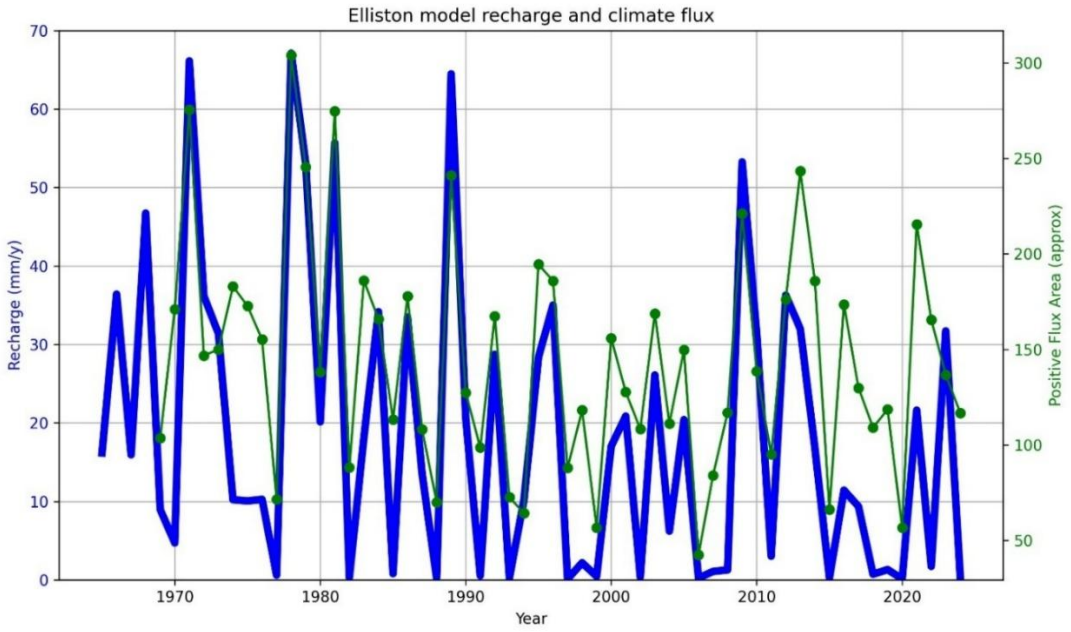


Figure 3.7. Time series of spatially averaged recharge rates in the model and annual positive climate flux

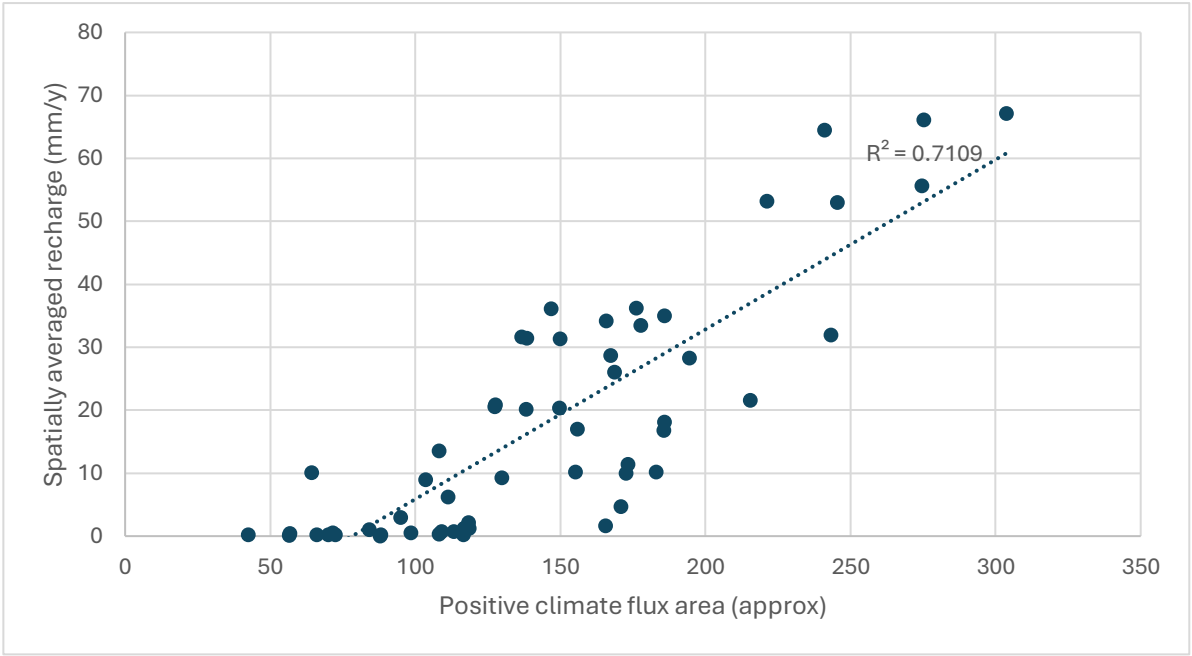


Figure 3.8. Correlation between spatially averaged recharge rates in the model and annual positive climate flux

Love et al., (1996) also report minimal recharge under native vegetation. Consequently, areas of dense native vegetation, as well as areas where the depth to groundwater is > 10m, are assigned no recharge. A similar approach has previously been used for the Uley South Basin in the Eyre Peninsula (DEW 2020).

The maximum recharge rate of 336 mm/y in zone 3 occurs in 1971, when rainfall was 619 mm in Elliston and 661 mm in Mt Wedge (which is closer to recharge zone 3). This equates to a very high recharge rate of about 50% of rainfall; however, it seems justified by data from wells in this zone (e.g., TAA005, TAA007) that show very high rises in water level of 2.7 to 4.3 m between 1971-1972 (Figure 2.6). One unknown factor that could have influenced recharge in this area at this time was native vegetation clearance. Vegetation clearance occurred at rates of 23,000 to 38,000 hectares per year from the mid- to late-1960s to mid-1980s in the Eyre Peninsula; however, data on the spatial distribution of clearing events are not available for this period (Australian Greenhouse Office, 2000). Clearance of native vegetation may have resulted in a period of enhanced recharge during the high rainfall years prior to the 1980s, leading to the large rises in groundwater level.

Evapotranspiration is applied during the November-April stress periods, when recharge is not active. Maximum rates of depth-dependent evapotranspiration were set at 2 mm/d with an extinction depth of 2 m and were tested through model calibration. These rates were found to provide suitable evapotranspiration fluxes which vary from November to April as the groundwater level declines. It should be noted that there may be areas where native vegetation is accessing groundwater and rates of evapotranspiration and extinction depth may be greater than that specified here. Spatial variation in the rate and extinction depth is not explicitly implemented in the model due to lack of detailed information. However, the implementation of zero recharge in these areas goes some way to representing the effect of groundwater use by native vegetation.

Extraction rates are based on metered data for town water supply. Extraction rates for stock and domestic wells are based on estimates as outlined in section 2.5.4. Irrigation extraction rates are based on metered data from 2005 with extraction from 1997-2005 estimated based on the metered extraction data. The resulting time series of extraction rates from wells (well locations in Figure 2.11) is shown in Figure 3.9. Town water supply is the only data set with monthly metered data and is continuous throughout the year, generally higher in summer. Stock and domestic water use is also assumed to occur year-round with higher rates in summer. Irrigation extraction is assumed to occur primarily over summer months.

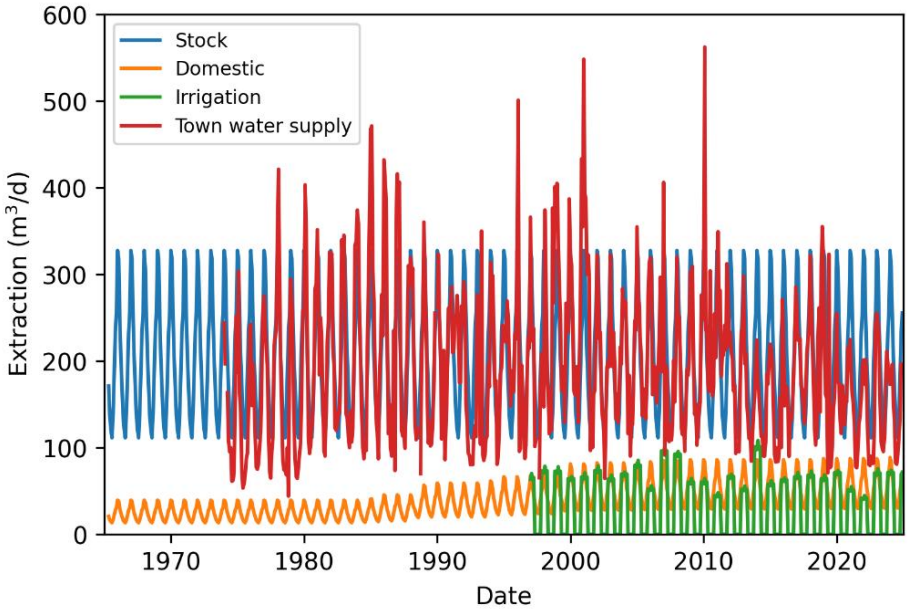


Figure 3.9. Extraction volumes within the model domain

3.5 Aquifer properties

Aquifer properties are based on reported values, noting that aquifer property data are scarce, with final model values determined through calibration. A pilot point approach to aquifer property calibration was adopted through the use of PEST (Doherty, 2010) with some manual adjustment of parameter values following automated calibration. The range of resulting values is presented in Table 3.2 and displayed in Figure 3.10 to Figure 3.12.

Layer (Aquifer)	Parameter	Geometric mean	Range	Units
1 (QL)	Horizontal hydraulic conductivity	42	0.1 to 1000	m/d
2 (Clay)	Horizontal hydraulic conductivity	0.73	$2.7x10^{-3}$ to $7.5x10^{1}$	m/d
3 (TS)	Horizontal hydraulic conductivity	1.05	0.01 to 75	m/d
1 (QL)	Vertical hydraulic conductivity	2.86	0.01 to 10	m/d
2 (Clay)	Vertical hydraulic conductivity	0.02	$1.4x10^{-5}$ to $1.9x10^{0}$	m/d
3 (TS)	Vertical hydraulic conductivity	0.11	$9x10^{-4}$ to 10^{1}	m/d
1 (QL)	Specific yield	0.07	0.01 to 0.3	-
2 (Clay)	Specific storage	$1x10^{-5}$	N/A	m^{-1}
3 (TS)	Specific storage	$6x10^{-6}$	$1.4x10^{-6}$ to $1.31x10^{-5}$	m^{-1}

Table 3.2. Model aquifer properties

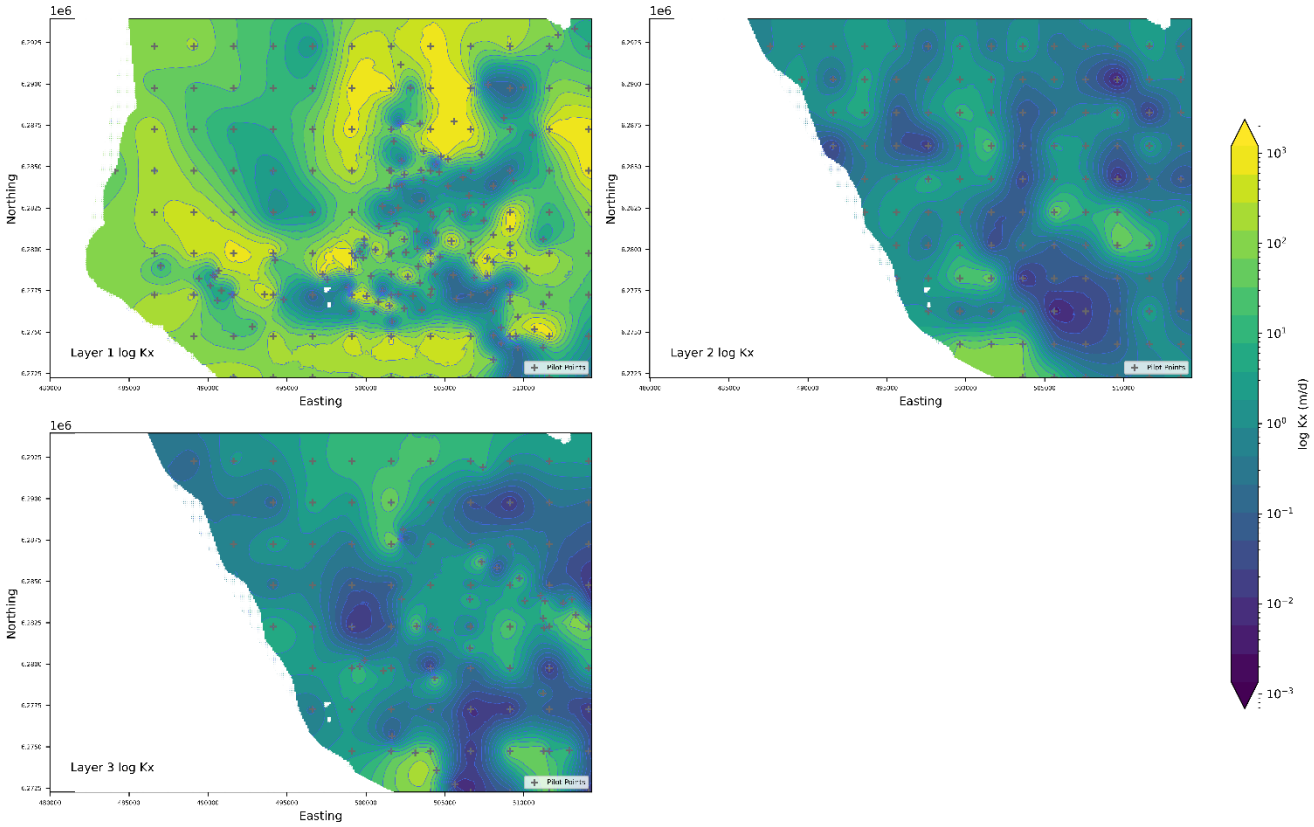


Figure 3.10. Horizontal hydraulic conductivity values in the model after calibration

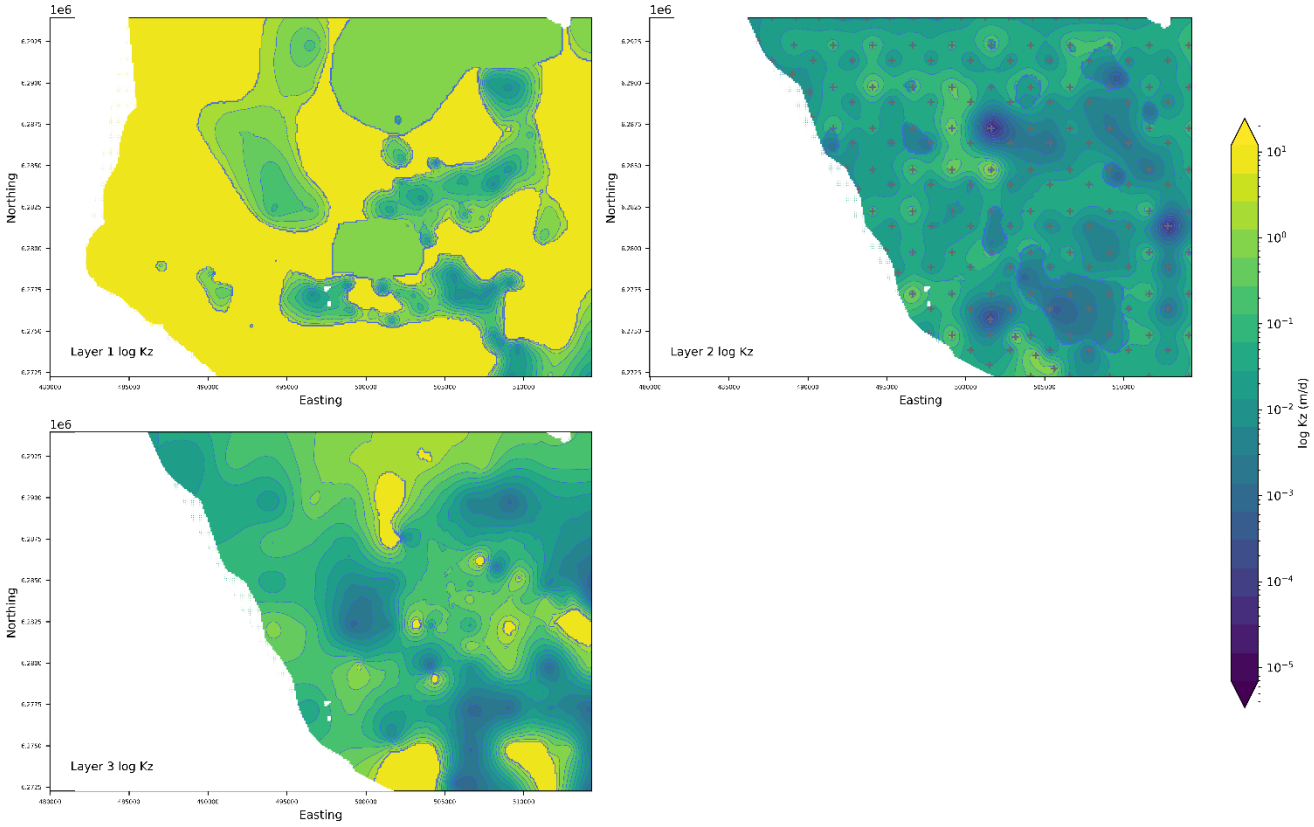


Figure 3.11. Vertical hydraulic conductivity values in the model after calibration

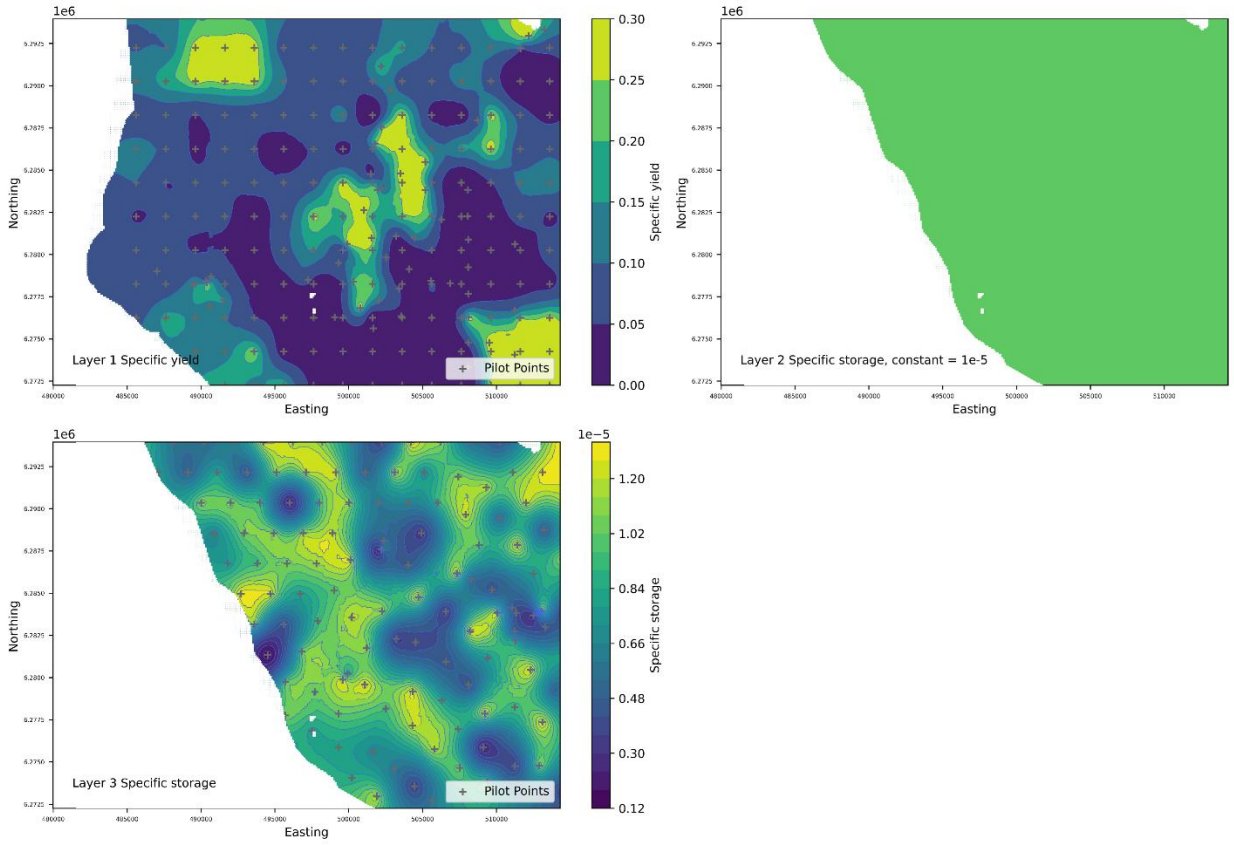


Figure 3.12. Aquifer storage parameters in the model after calibration

4 Model calibration

4.1 Calibration approach and results

A steady state model was initially constructed. However, there was difficulty in selecting appropriate steady state groundwater levels given the large fluctuations in early observations (Figure 2.6). Therefore, a 'pre-development' transient model was constructed to run from 1965 to 1973, prior to the commencement of town water supply pumping, and this model was used to test conceptualisations regarding recharge zones and rates, aquifer layering and boundary conditions and to develop an approximate calibration. Initial heads were based on the potentiometric surface in the first instance. However, for the steady state time period this needed to be supplemented with estimated groundwater levels (e.g., 0 m AHD at the coast) due to lack of data in the late 1960s and early 1970s (Figure 2.7). Once an approximate fit between measured and modelled groundwater levels had been obtained by varying recharge rates and aquifer parameters, the model run time was extended to December 2024 and calibration to all available groundwater level data was performed. Calibration of this longer transient model was performed iteratively with manual calibration focusing on recharge rates followed by automated calibration of aquifer parameters using PEST++, then further manual adjustments and repeated as required. Aquifer parameters resulting from this process are displayed in the preceding chapter. The resulting fit between measured and modelled groundwater levels is shown in Figure 4.1. The fit demonstrates a root mean squared (RMS) error of 0.72m (scaled root mean squared (SRMS) error is 1.6%).

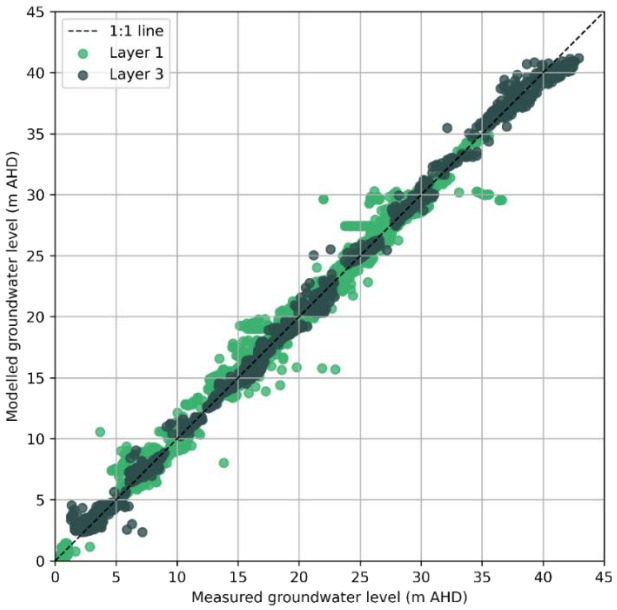


Figure 4.1. Results of transient calibration, RMS = 0.72m, SRMS = 1.6%

4.2 Groundwater levels

The fit to groundwater levels in the QL is generally good in terms of level and trend over time (Figure 4.2). Much of this is achieved through the temporal variability in recharge. The fit between measured and modelled potentiometric surfaces is reasonable, although potentially impacted by a lack of data spatially (Figure 4.3).

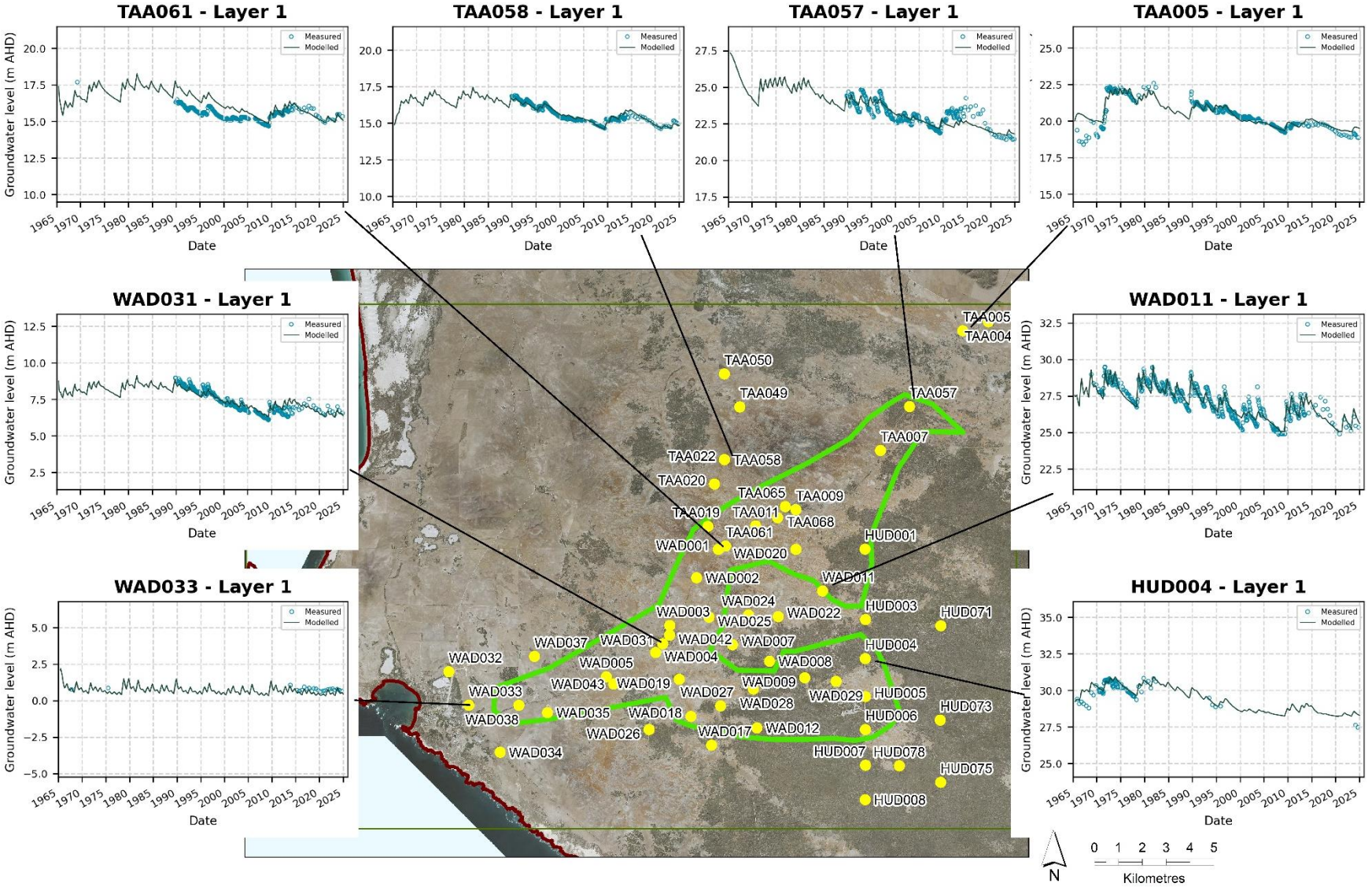


Figure 4.2. Time series of groundwater levels in the QL aquifer

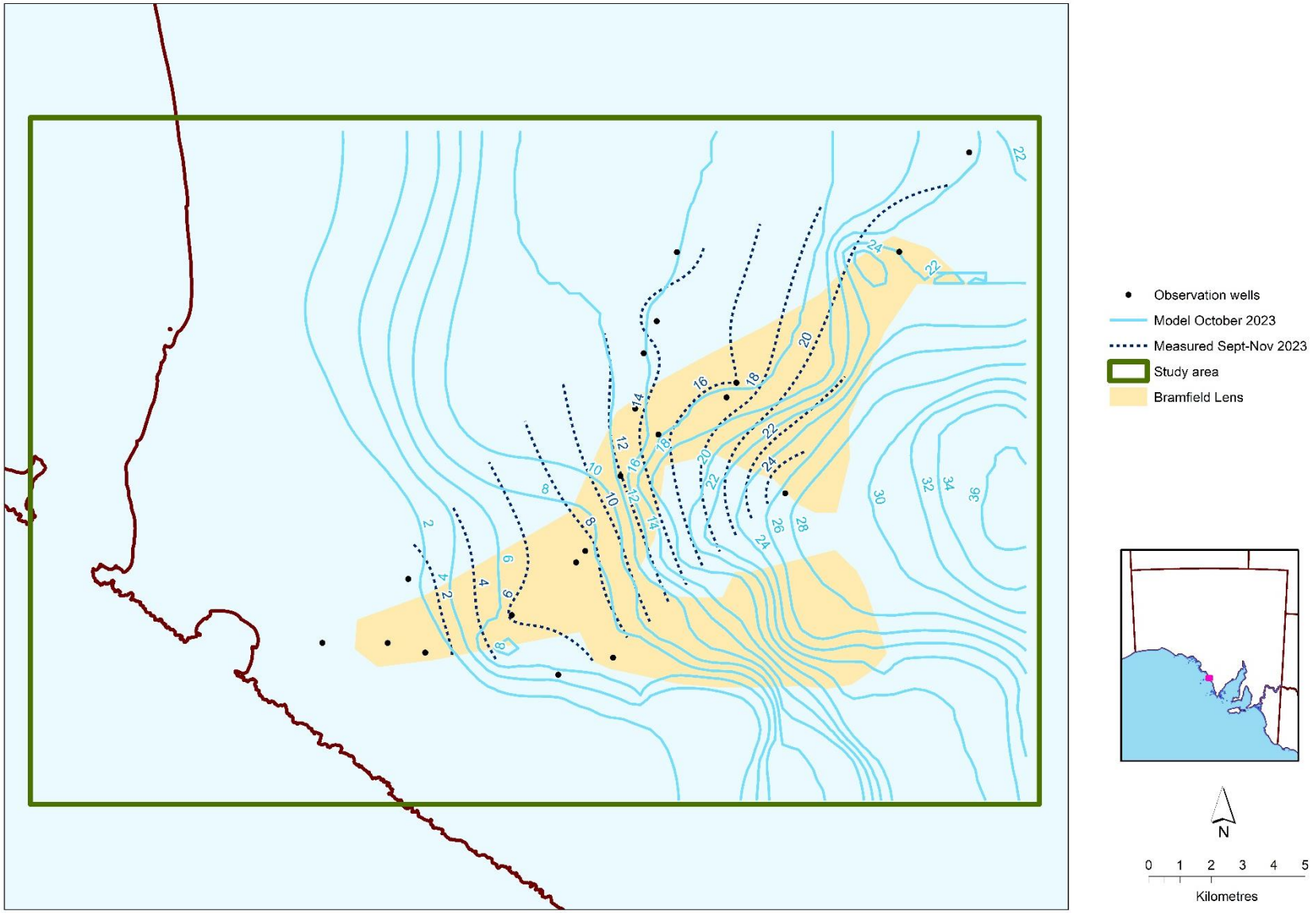


Figure 4.3. Measured and modelled potentiometric surfaces for spring 2023 in the QL aquifer

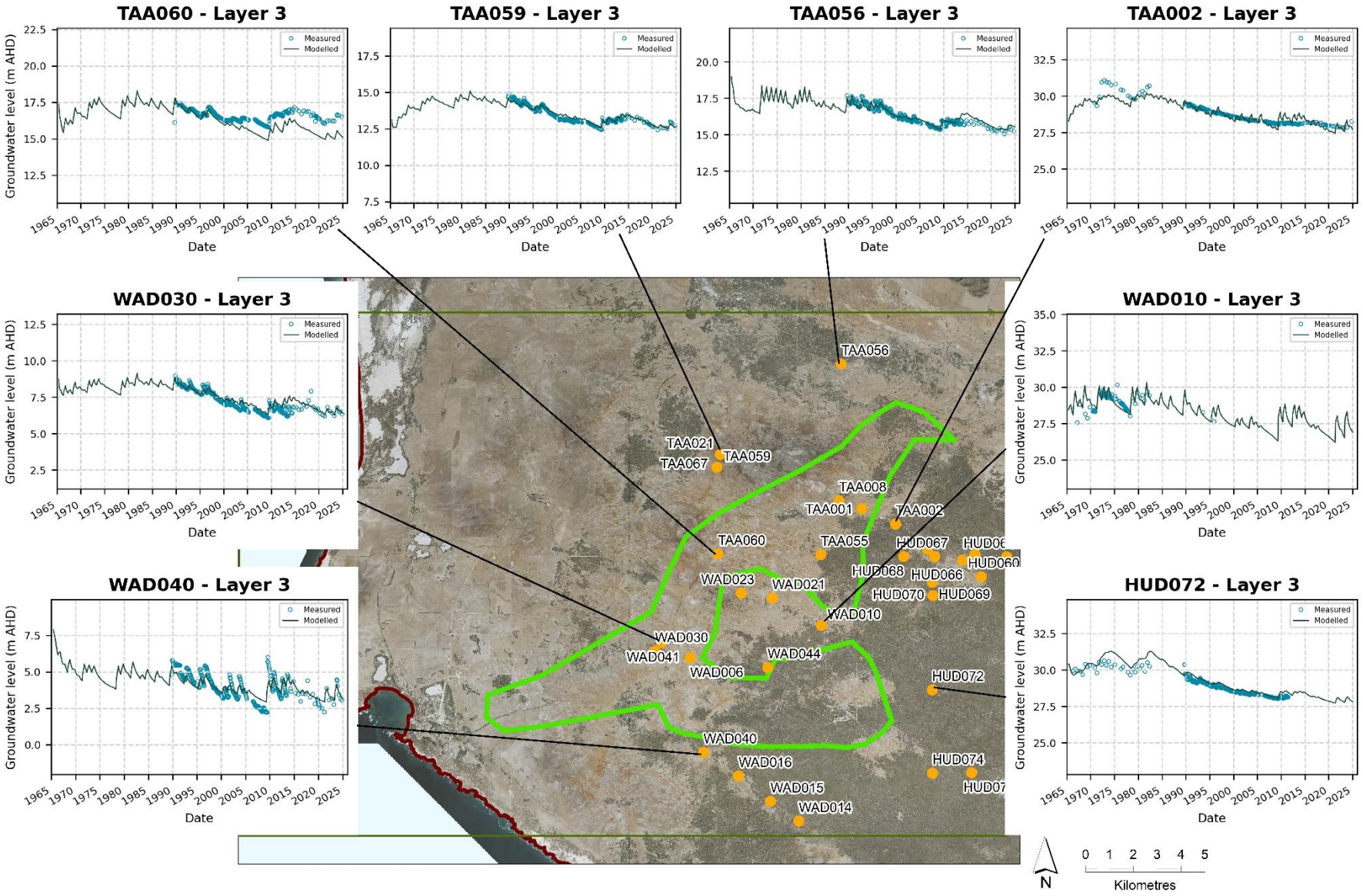


Figure 4.4. Time series of groundwater levels in the TS aquifer

The fit is also good in the TS aquifer (Figure 4.4) with some of the fluctuations thought to be associated with downwards leakage from the QL aquifer being well matched. This provides reasonable confidence that the approach to simulating the confining clay layer (layer 2) with vertical hydraulic conductivity generally around 10^{-2} m/d (the value derived from pump test analysis by Dowie and Love 1996) is adequate. Measured and modelled hydrographs at all observation wells are supplied in Appendix A.

4.3 Water balance

The water balance for the model shows that boundary fluxes through the GHB cells are the largest volumetric fluxes in and out of the model. Rates of recharge exceed rates of boundary inflow in some high rainfall years, but otherwise boundary flows are largest. While pumping is plotted on Figure 4.5, it is not visible at the scale presented, demonstrating that it represents a small component of the water balance at the overall model scale.

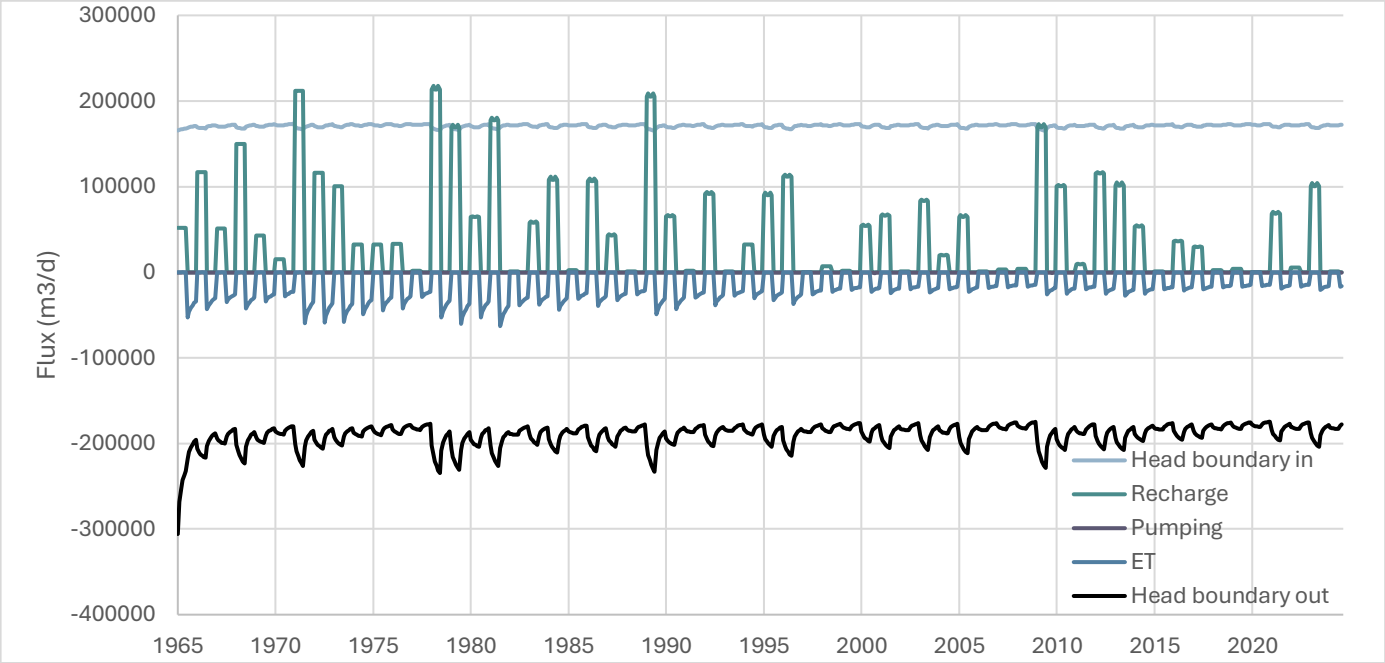


Figure 4.5. Water balance for the Elliston flow model

4.4 Seawater intrusion

The model predictions of the position of the (50/50 isohaline sharp) seawater interface at December 1973 (prior to commencement of town water supply extraction) and in December 2024 (end of the model history-match period) are shown in Figure 4.6. The model predicts that the interface has moved inland during the 50-year period which is consistent with observed groundwater level decline over time. The modelled position of the interface in December 2024 is also approximately aligned with the geophysical survey results of Banks (2025) (Figure 4.6, Figure 4.8). The geophysical interpretation is based on sTEM profiles collected at the locations shown in Figure 4.8. The modelled position of the interface is consistent with data collected from a new monitoring well, 5830-357 (WAD049) drilled in May 2025, where the conductivity log showed the transition to saline water occuring at approx -30m AHD and the modelled interface is at -33m AHD (Figure 4.7). Further geophysical surveys to better define the seawater intrusion interface will be conducted in early 2026.

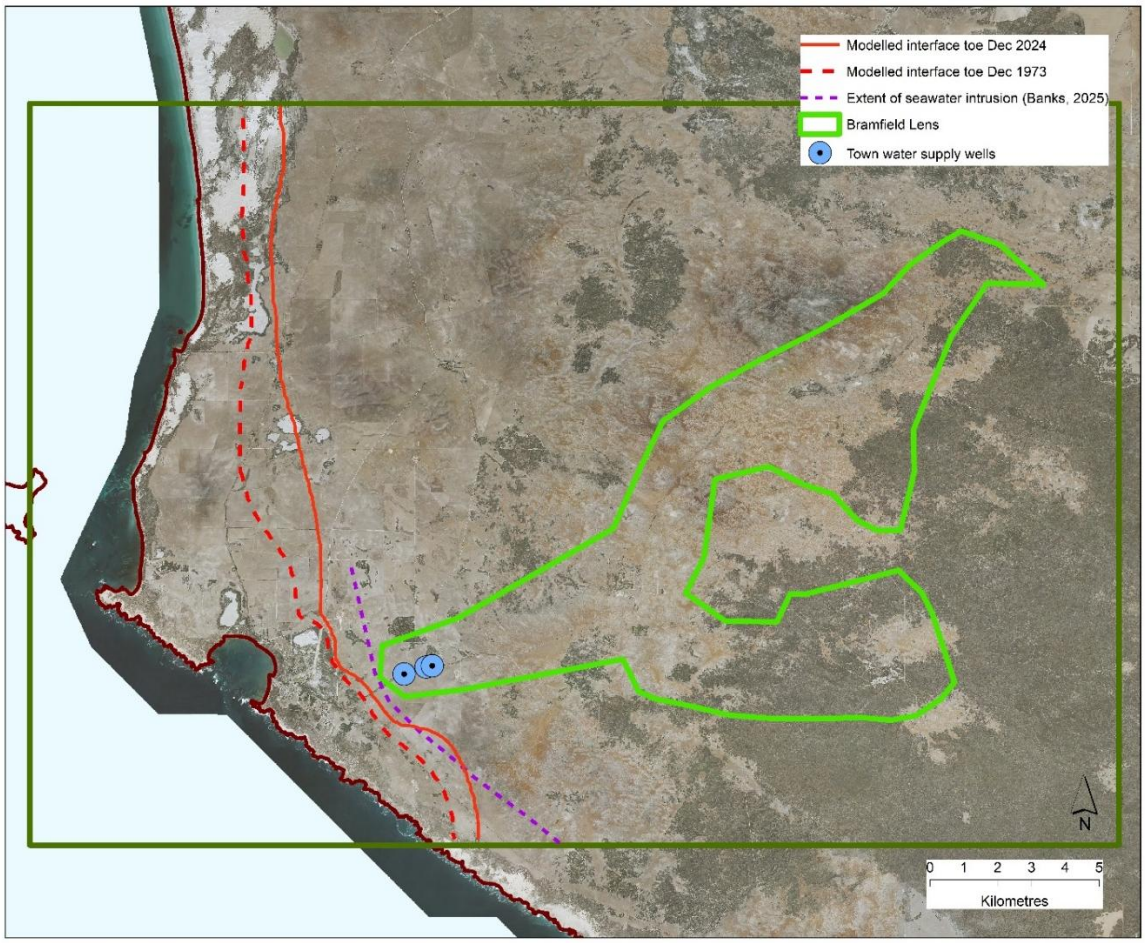


Figure 4.6. Positions of the seawater interface toe from geophysics and groundwater modelling

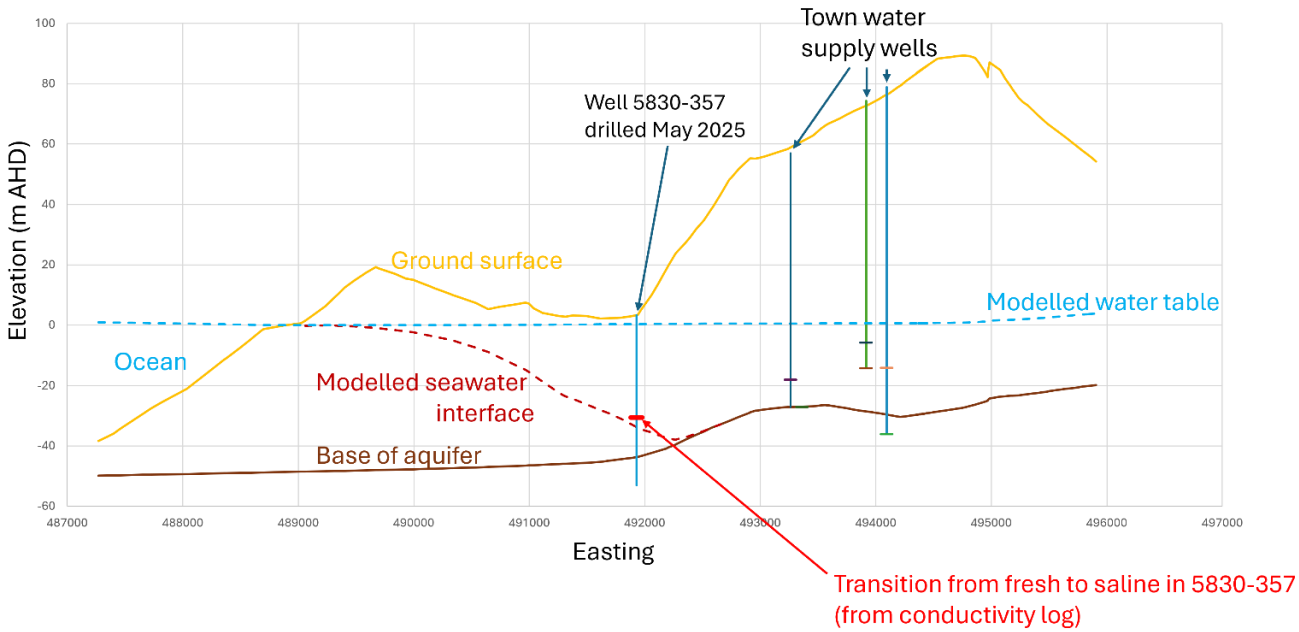


Figure 4.7. Cross section of modelled seawater interface at December 2024 with information collected from new well

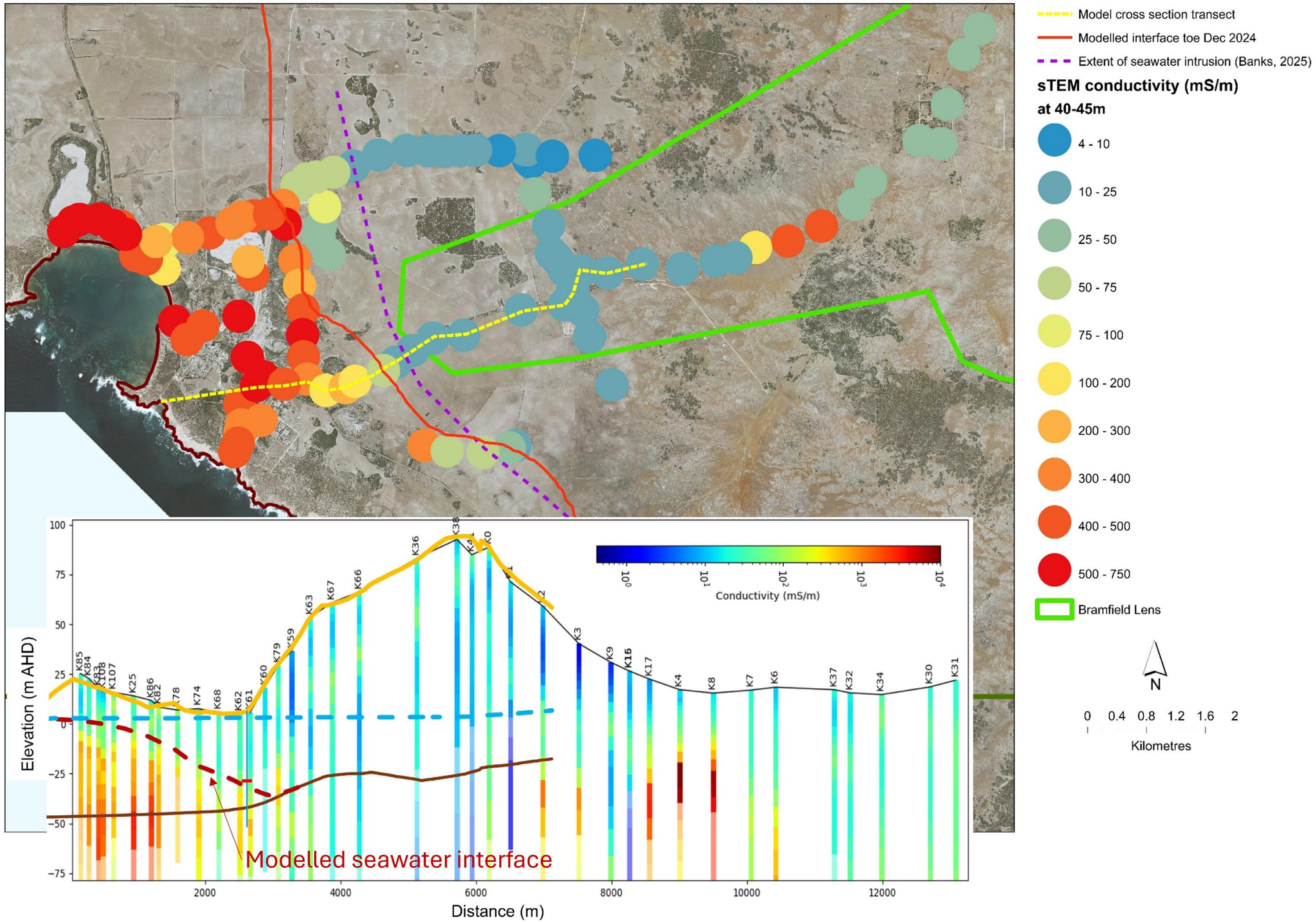


Figure 4.8. Modelled position of the seawater interface and STEM derived conductivity values at 40-45m depth below ground

4.5 Groundwater-dependent ecosystems

There is limited information on groundwater levels in and around wetlands and lakes in the study area. The groundwater level data that are available were collected around Lake Hamp; however, a survey elevation for the data was not available (White et al., 2014). In an attempt to make use of these data, the measured groundwater level data have been expressed as an elevation here using ground elevation from the digital surface model described in Section 3.2. It should be stressed that these measured groundwater level elevations were not used in the calibration process and may be inaccurate. They merely serve as an attempt to assess model performance around potential GDEs. Figure 4.9 shows the modelled groundwater levels which demonstrate a good fit to the interpreted observation data. Consequently, the model may be suitable for assessing groundwater behaviour in and around wetlands in the region; however, high confidence cannot be placed on this conclusion due to current lack of survey data (i.e., this could be improved with reliable survey data).

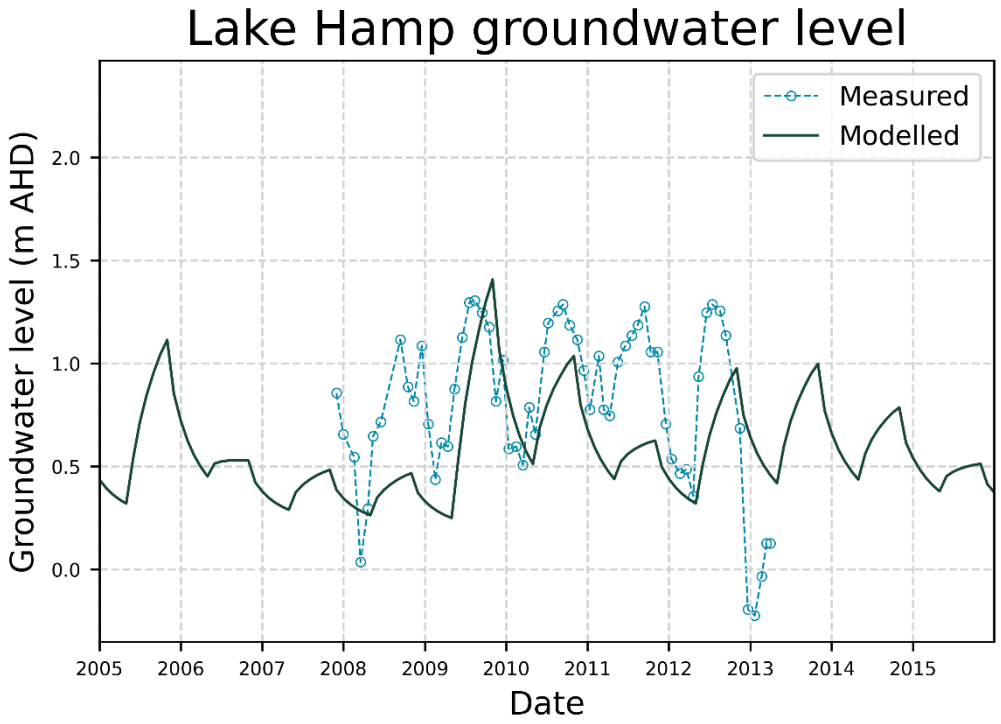


Figure 4.9. Measured and modelled groundwater levels at Lake Hamp (based on DEM not surveyed levels)

4.6 Extent of Quaternary Limestone aquifer saturation

With the model solver implementing upstream-weighting (UPW), the wetting and drying of the QL is simulated. Consequently, the extent of the area in which the QL aquifer is dry fluctuates in size across the simulation. By December 2024, a significant portion of the eastern domain is dry (Figure 4.10). Part of this extent matches the saturated extent of the QL aquifer as shown in the EP WAP (EPNRMB 2016). However, the model shows additional areas as dry, including parts of the Bramfield lens. The transient nature of wetting and drying can be seen in the measured and modelled levels at WAD011 (Figure 4.11), which is located near the edge of the Bramfield lens. The modelled extent of dry cells is sensitive to the modelled elevation of the base of the QL aquifer, which is based on locations where data are available. Therefore, the modelled extent of dry cells must be considered in that context, and a result which is underlain by some

conceptual and data uncertainty. Nevertheless, the model provides good results and agreement with measured data where available.

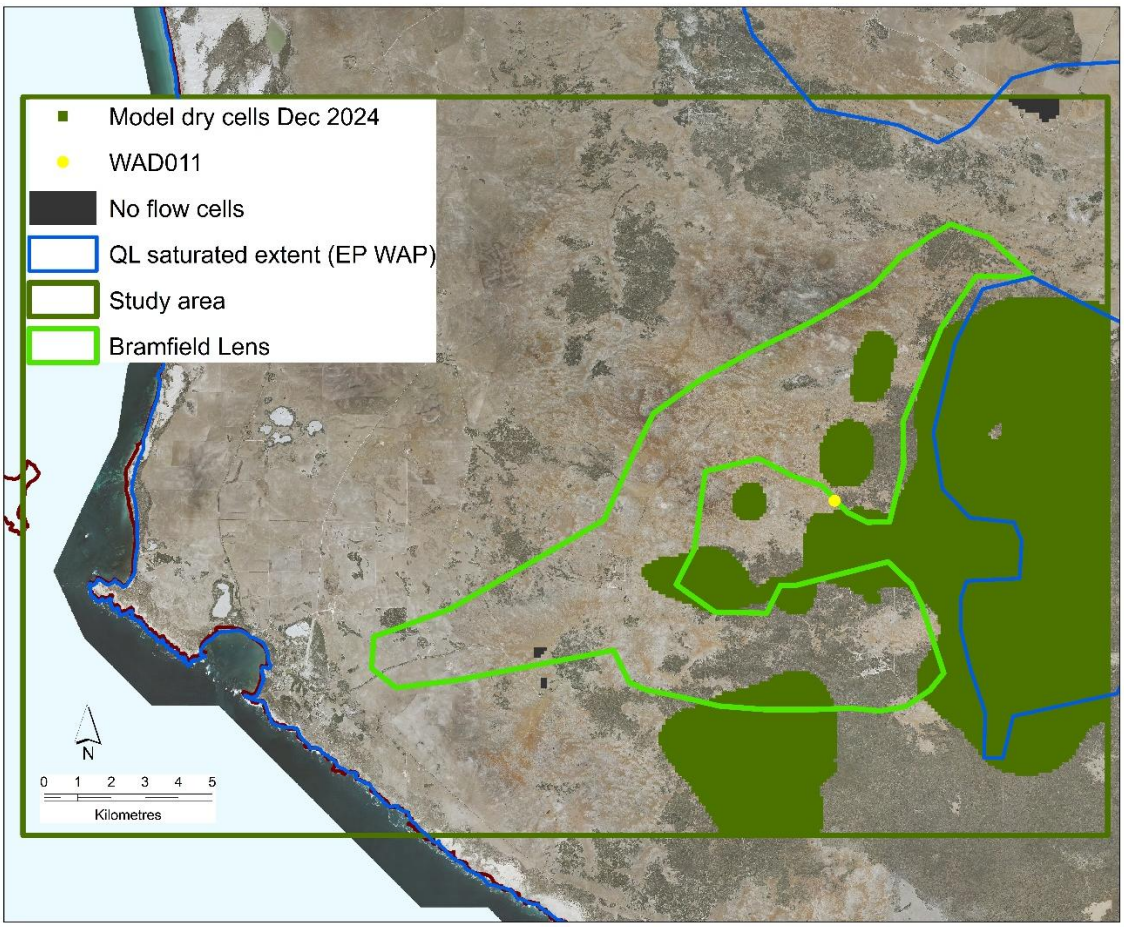


Figure 4.10. Modelled dry cells at December 2024

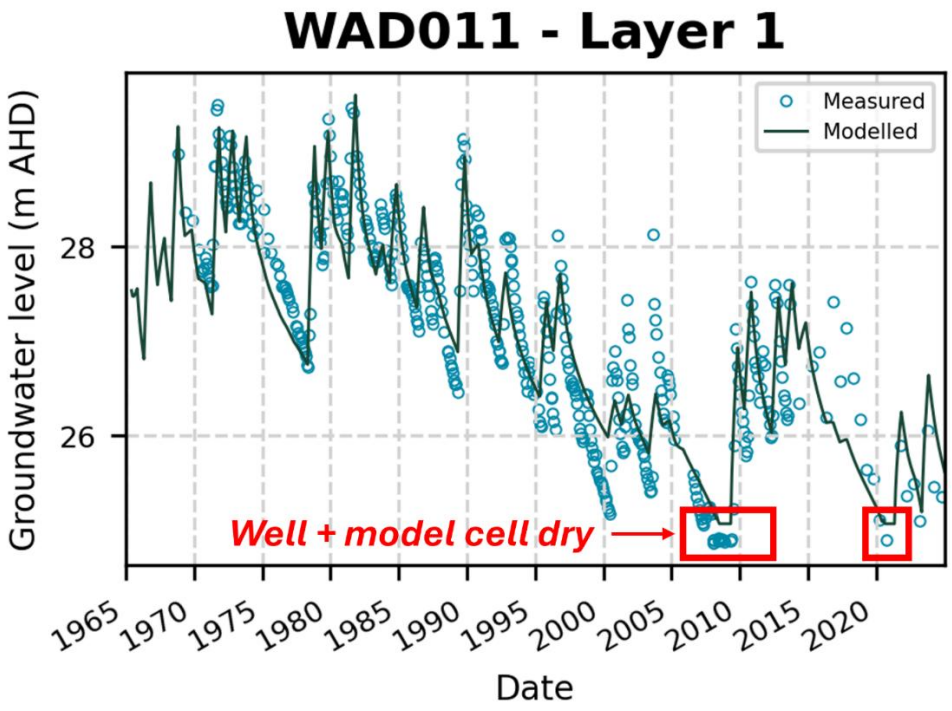


Figure 4.11. Measured and modelled water levels at WAD011

The extent of drying in the QL aquifer does not impact town water supply or irrigation extraction wells in their current locations at the present time, but it may impact stock and domestic wells. For example, based on the number of stock and domestic wells present in the model domain (131), their location and their depth, model results indicate that 45% of these wells are likely to have gone dry by December 2024 with 11% showing less than 1m of saturation in the well column.

5 Model uncertainty, sensitivity and limitations

5.1 Uncertainty

Model development here was undertaken as part of the NWGF project but a compressed time schedule was adopted such that model results could inform the review of the EP WAP. Consequently, an emphasis was placed on developing the transient model to a suitable level of calibration before commencing scenario runs immediately. It was therefore decided that while a parameter uncertainty analysis is recommended, it was not warranted in the scope of the current project. Furthermore, as will be discussed below, areas of conceptual model uncertainty which are difficult to assess without additional data may contribute just as much to overall model uncertainty as parameter uncertainty.

5.2 Sensitivity

Model sensitivity was assessed in two different ways. Firstly, parameter sensitivity, as estimated by the PEST optimisation, was assessed. Figure 5.1 shows the relative parameter sensitivity for all pilot point parameter types. The relative sensitivity is based on normalising the parameter sensitivity values reported by PEST. The most sensitive parameters are horizontal hydraulic conductivity (Kx) in layers 1 and 3 in the model. Therefore, any potential future parameter uncertainty work may be best placed by focusing on horizontal conductivity parameters.

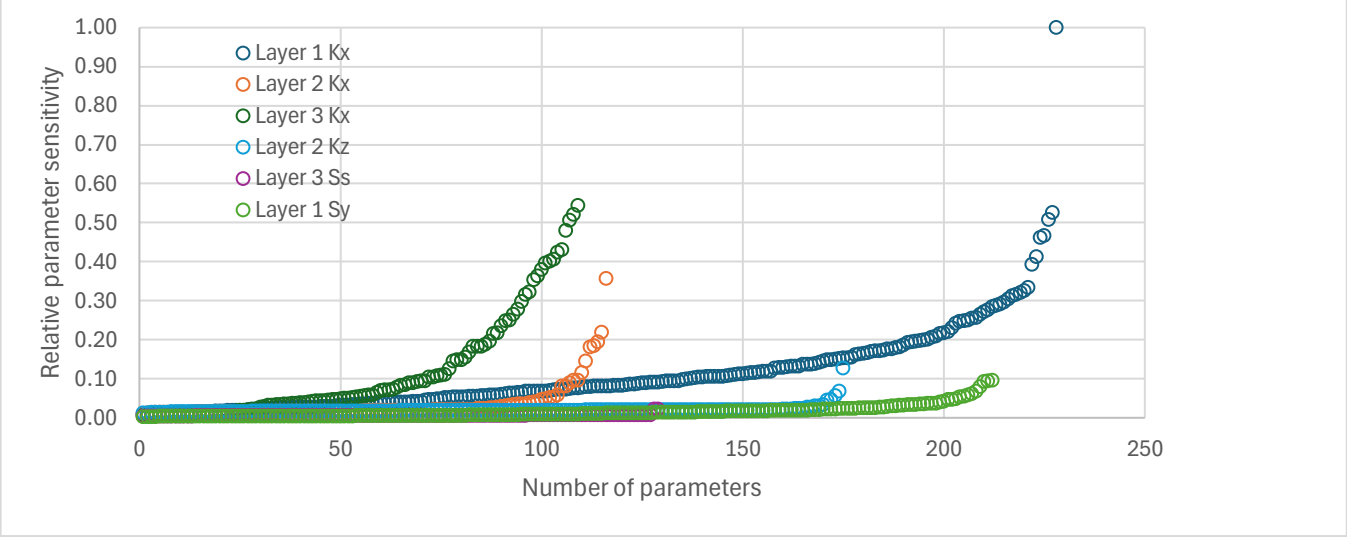


Figure 5.1. Relative parameter sensitivity based on model optimisation

A brief attempt was made to test conceptual model sensitivity in relation to the bottom elevation of the QL aquifer (layer 1). Drilling conducted in May 2025 revealed new information regarding the depth of the basement in the coastal region. This information was fed into the model and the base of layer 1 re-contoured. This was initially done by contouring based on existing data and the new well only, leading to layer 1 base elevations on the left of Figure 5.2. However, given the orientation of the coastline, it was postulated that the basement depth could be continuous in a south-west direction parallel to the coastline. Therefore,

additional elevation points were added and the layer elevation was re-contoured (image on the right in Figure 5.2). The model had undergone calibration by this point and a suitable fit to measured data had been obtained. The recontouring did result in a slightly different model fit with RMS increasing from 0.71m to 0.74m, demonstrating that alternate conceptualisations of QL thickness may result in slightly different model results. However, the alternate model still produced the overall trend in groundwater level decline and, importantly, it did not show significantly different modelled position of the seawater interface.

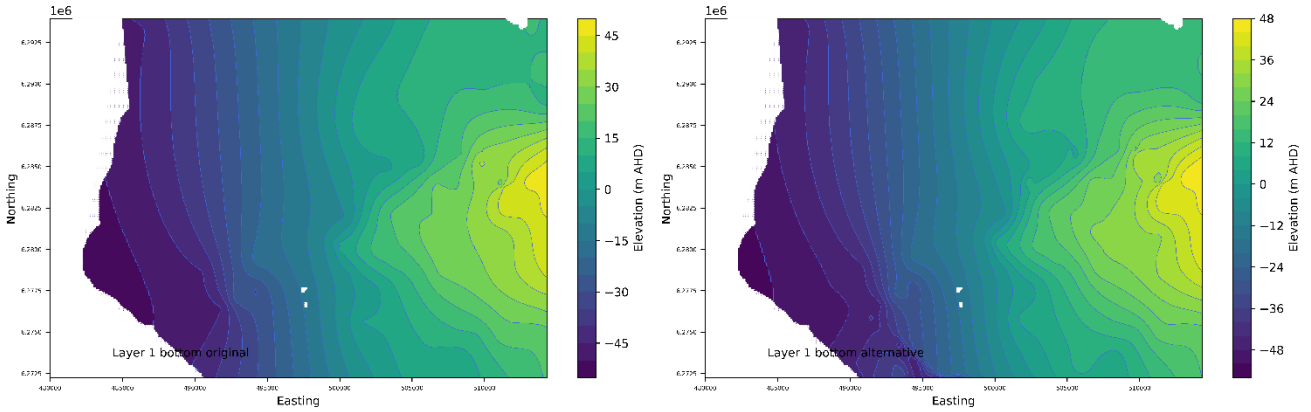


Figure 5.2. Alternate layering for layer 1 bottom

5.3 Limitations

The model is informed by available information which is considered to be good, achieving a very good fit to measured data and is consistent with the overall conceptual understanding of the groundwater flow system. However, there are limitations in available data which should be kept in mind when interpreting model results. These are not modelling limitations as such, rather they are data limitations of what can be drawn from the information available. These limitations relate to:

- the modelled extent of dry cells in layer 1 – this result is sensitive to the bottom of layer 1 (QL aquifer), which is informed by available information at drillholes. In much of the eastern portion of the domain, the QL aquifer is thin (Figure 3.1), and small variations in the bottom elevation of this model layer may produce different results regarding the extent of dry cells (unsaturated aquifer) in layer 1;
- the Modelled groundwater level near GDEs – an attempt has been made to compare modelled groundwater levels with available information near Lake Hamp has been made but it must be emphasised that the measured groundwater levels there are not surveyed;
- stock and domestic water use – the modelling has included estimated stock and domestic extraction volumes, which form a significant portion of total extraction, although these estimates may be quite significantly in error; and
- the modelled seawater level – the model considers the sea level to be static with no long-term trend and no seasonal fluctuation. In reality, sea level fluctuates tidally and seasonally, which is likely to have an impact on coastal groundwater levels and movement of the interface. The model does not consider this.

6 Model scenarios

6.1 Scenario background

Three scenarios are presented in this report to provide input to the review of the EP WAP. All model scenarios are run from January 2025 to December 2050, and all assume steady stock and domestic extractions. Scenario 1 considers the use of full allocation for town water supply and irrigation based on allocations in the 2016 EP WAP (EP NRMB 2016), shown in Table 6.1. This is assessed with recharge continuing based on 'current conditions' (recharge from the past 10 years repeated cyclically). Scenario 2 considers reduced allocation with rates of town water supply and irrigation set at 35% of full allocation. These rates of use more closely resemble current rates of use. This scenario is also run with the current climate assumptions.

Scenario	Pumping	Recharge
1	Full allocation Town water supply = 200 ML/y Irrigation = 46 ML/y Stock use = 77 ML/y Domestic use = 20 ML/y	Recharge based on last 10 years (2015 to 2024)
2	Reduced allocation Town water supply = 70 ML/y Irrigation = 16 ML/y Stock use = 77 ML/y Domestic use = 20 ML/y	Recharge based on last 10 years (2015 to 2024)
3	Reduced allocation Town water supply = 70 ML/y Irrigation = 16 ML/y Stock use = 77 ML/y Domestic use = 20 ML/y	Recharge based on projected declines in rainfall from SSP3-7.0

Table 6.1. Model scenarios

Scenario 3 mimics scenario 2 in terms of pumping but with recharge reduced based on potential climate change impacts on rainfall and recharge. Climate change impacts on rainfall were determined by assessing projected rainfall data for Elliston with results from New South Wales and Australian Regional Climate Modelling (NARCliM) dataset NARCliM 2.0 (State Government of New South Wales, 2024). DEW (2022) recommend that when using a single emission scenario for climate change analysis for assessments to 2050, a climate in line with Representative Concentration Pathway (RCP) 8.5 is used, commonly referred to as a high greenhouse gas (or high emissions) concentration pathway. This recommendation is followed with NARCliM 2.0 data, noting that NARCliM 2.0 uses updated information from the IPCC (2021), where the high emission scenario is referred to as Shared Socio-economic Pathway (SSP) 3-7.0. Based on a 30-year average around 2050 (compared to a 30–year average around 2000), the NARCliM 2.0 data projects an average 14% decline in rainfall based on ten model results (five global climate models (GCMs) each with two downscaling methods applied). The projected rainfall changes from all ten models range from a 3% increase to a 32% decrease over the same time frame. Given this large range, an averaged approach is taken in applying these results to the groundwater model with a 14% decline in rainfall assumed to take place from the start of the scenario (2025) to 2050.

The project change in rainfall is translated to a projected change in recharge using findings from Green et al., (2012). The authors developed unsaturated zone models for representative landscapes in the Eyre Peninsula and calibrated drainage fluxes (a model proxy for recharge) to observations of annual water table fluctuation

(a measured proxy for recharge). The authors then simulated future impacts of changes in rainfall and evapotranspiration on the modelled drainage fluxes and expressed results in terms of the percentage change in rainfall vs percentage change in recharge (Figure 6.1). Using this approach, the 14% decline in rainfall results in a 45% decline in recharge by 2050. The decline is implemented incrementally on an annual basis across the modelled recharge for the last 10 years and is repeated cyclically in the scenario implementation.

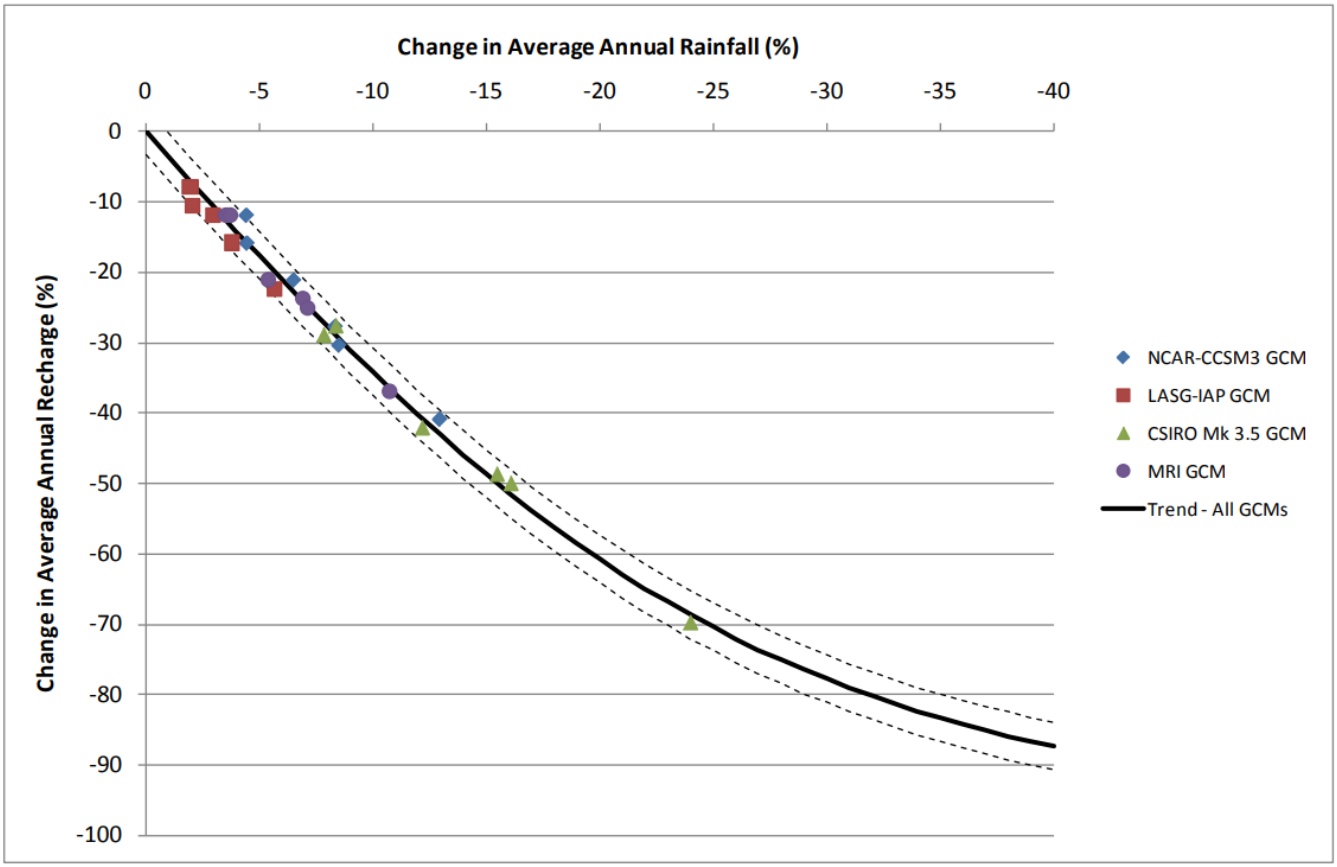


Figure 6.1. Changes in modelled recharge for changes in rainfall in the Musgrave PWA, taken from Green et al., (2012)

6.2 Scenario results

All scenarios show groundwater levels continuing to decline throughout the basin. Scenario 1 and scenario 2 only have minor differences in modelled groundwater level in locations where town water supply and irrigation pumping are occurring. For example, near the irrigation in Bramfield, WAD031 shows a greater seasonal drawdown in summer with irrigation extraction simulated to occur seasonally in scenario 1 (Figure 6.2). The increase in extraction from town water supply in scenario 1 is greater volumetrically than that from irrigation. However, town water supply extraction occurs throughout the year and hence the impact is more spread-out, and occurring in a location where the aquifer is deeper and has a higher transmissivity (consistent with observations from pump tests on water supply wells reported by Gogoll and Howles, 2018); therefore the modelled impact is smaller (Figure 6.2). In both locations, scenario 3 shows that the impacts of reduced rainfall recharge on groundwater levels with pumping continuing at approximately current levels, leads to groundwater levels at the same minimums simulated by scenario 1 by 2050. In scenario 3, by 2050, groundwater levels show declines of 0.2 to 4.4 m since December 2024.

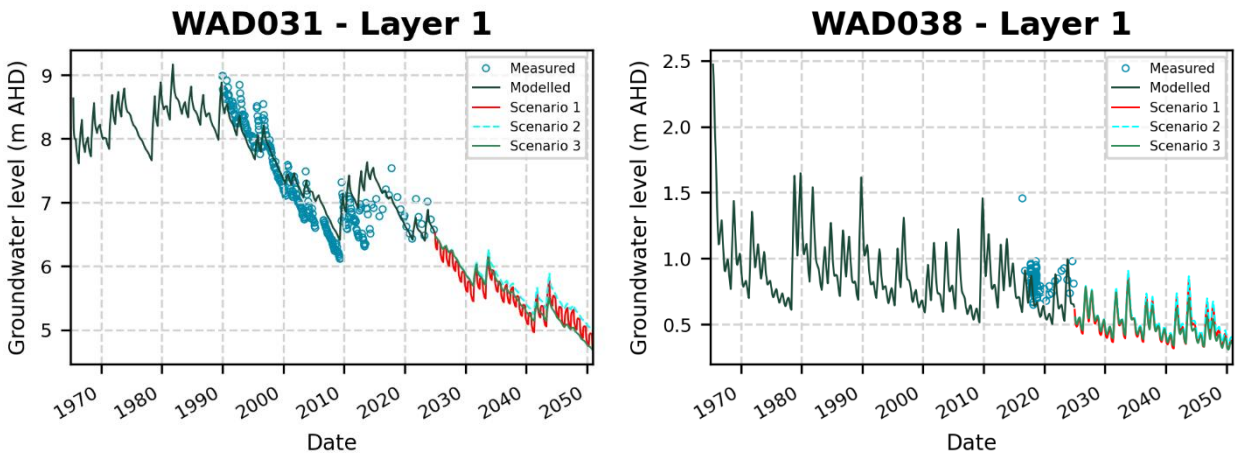


Figure 6.2. Modelled groundwater levels at WAD031 (near irrigation) and WAD038 (near town supply wells)

In other parts of the model domain, away from irrigation or town water supply pumping (and there is no difference between modelled water levels in scenario 1 and 2), groundwater levels generally decline the greatest in scenario 3, where recharge reduces due to climate change. Further scenario hydrographs are presented in Appendix B.

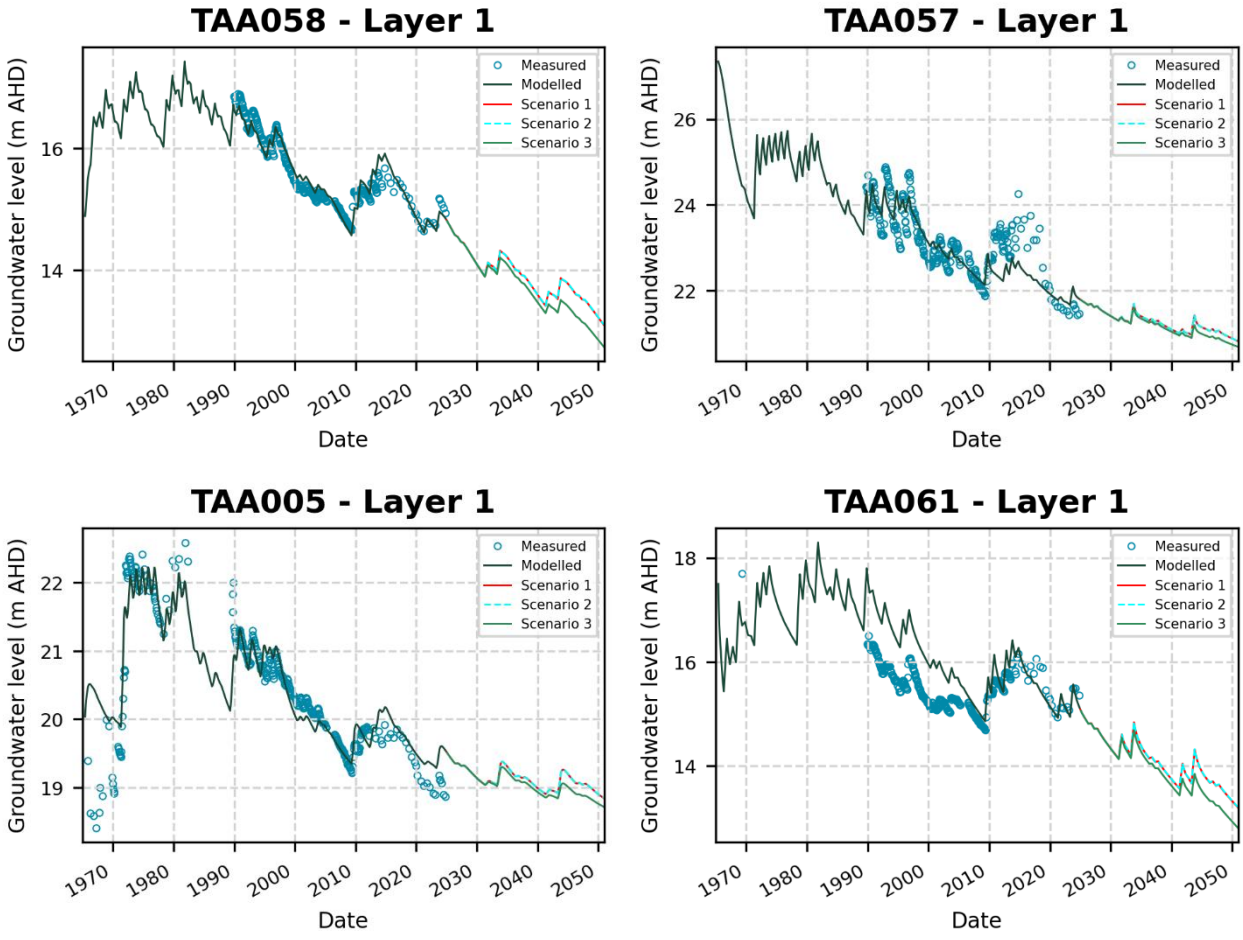


Figure 6.3. Modelled groundwater levels at locations remote from irrigation and supply pumping

All model scenarios also show an increase in the area of modelled dry cells in the thinner eastern parts of the QL aquifer (Figure 6.4). The drying does not impact town water supply or irrigation locations by 2050 but it may impact stock and domestic wells. Analysis of how this may impact stock and domestic wells, based on their depths and locations, shows that by 2050, and additional 7% of stock and domestic wells are likely to have gone dry under scenario 1 and 2, and 8% additionally dry under scenario 3.

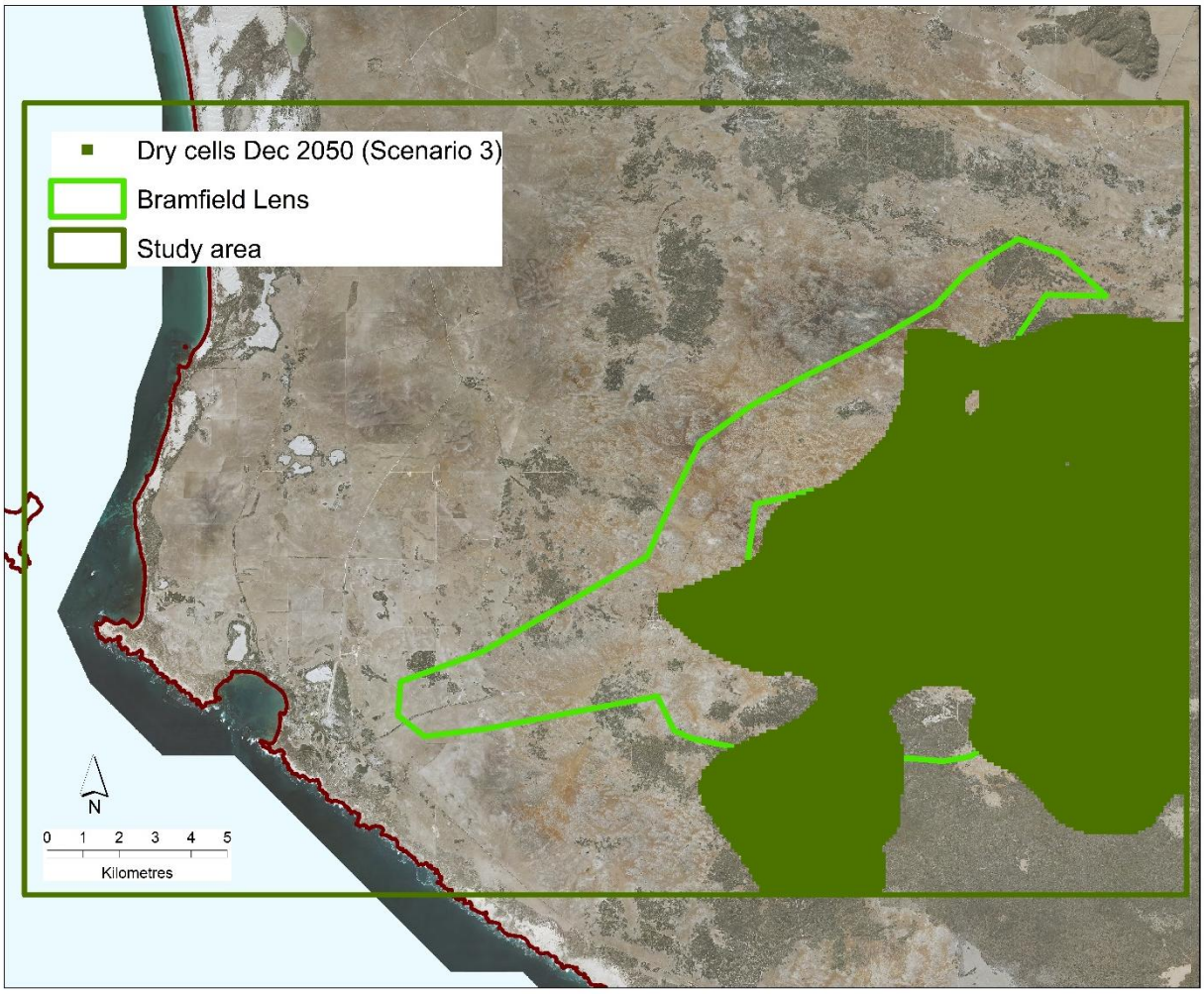


Figure 6.4. Modelled extent of dry cells at 2050 in scenario 3

In all three scenarios the seawater interface is predicted to move further inland (Figure 6.5). The greatest intrusion is predicted to occur for scenario 3 where groundwater levels decline the greatest amount due to declining rainfall recharge. However, the modelled position of the interface toe in December 2050 is very similar for all scenarios (Figure 6.5). In general, the seawater interface is predicted to move a maximum of 600m further inland with the greatest incursion in the area north of Elliston. Along the transect shown in Figure 4.8, the seawater interface is predicted to move 200m further inland.

Based on the model results, the 50:50 isohaline (the sharp interface simulated by the SWI2 package) should not reach town water supply wells by 2050. However, it is not known how far or how wide any potential dispersive mixing around the interface may be, nor what role karst conduits could play in preferential pathways. Even with the geophysical data collected in this study (Figure 4.8), it is unclear exactly how far inland higher salinity water from seawater intrusion may occur. The new geophysical surveys in early 2026 are designed to help address this. However, based on the trend in town water supply wells, further increases in salinity are likely to occur regardless of the position of the seawater interface (Figure 6.6).

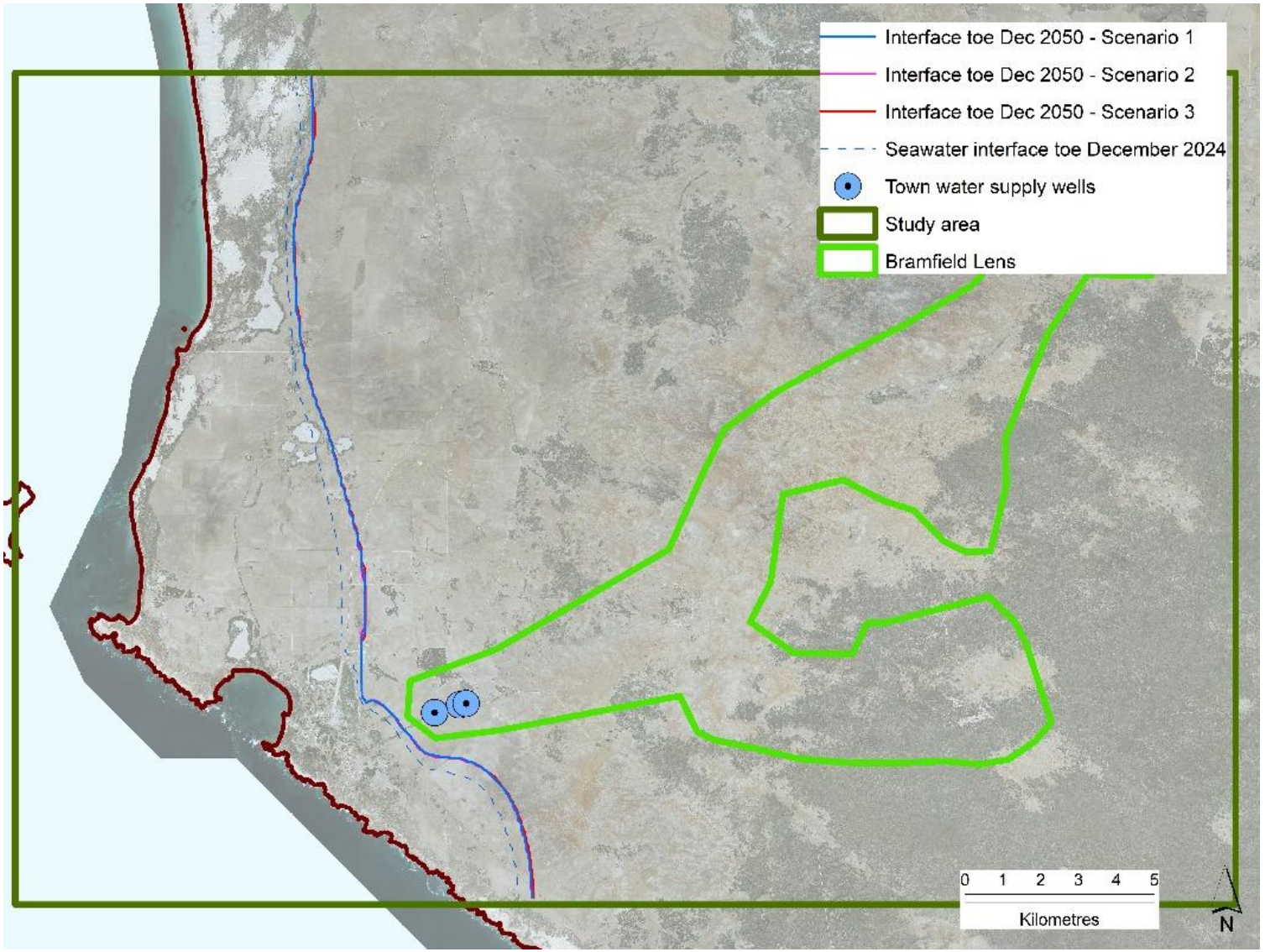


Figure 6.5. Modelled position of the seawater interface toe in all scenarios at December 2050

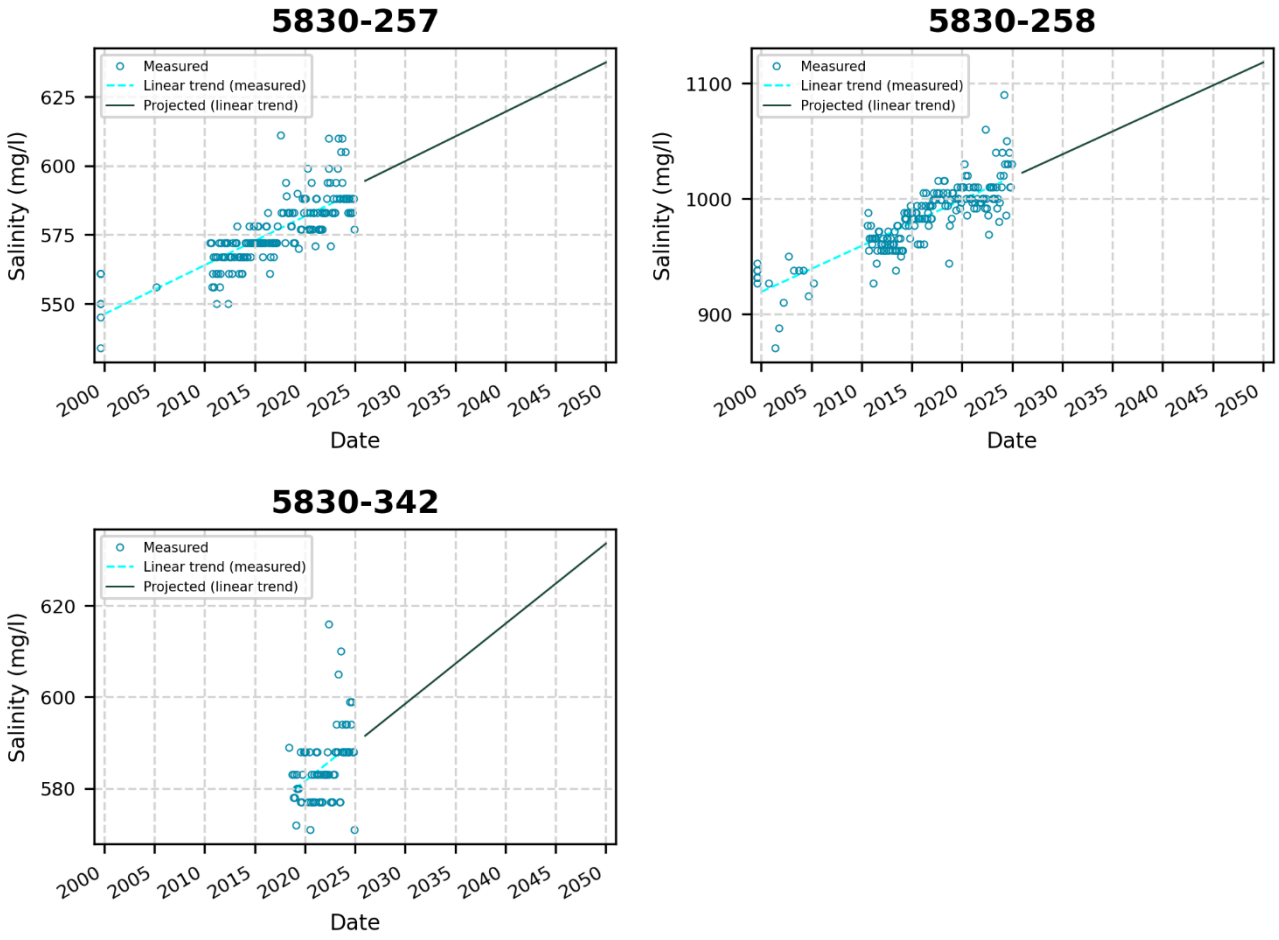


Figure 6.6. Projected town water supply salinity based on the linear trend observed to date

7 Conclusions and recommendations

7.1 Conclusion

A groundwater flow model has been developed for the Bramfield lens and surrounding areas in the Musgrave Prescribed Wells Area. The model performs well in simulating groundwater level changes over time and demonstrates how responsive the aquifer is to changes in rainfall recharge. Groundwater extraction plays some role in influencing groundwater levels locally, but given the overall low extraction volumes, the change in rainfall–recharge over time is the main factor influencing groundwater level change.

The model simulates the position and movement of the seawater interface using the SWI2 package. There is limited information to compare model results with but what information is available (much of it being geophysical survey data collected during the model build period) is well matched by the model.

Three scenarios have been run to simulate the impact of potential increases in pumping and decreases in rainfall-recharge in the future. Increases in pumping to full allocation are only likely to impact areas adjacent to pumping wells. Based on the scenario results, it is likely that groundwater level decline will continue into the future, which will result in further landward movement of the seawater interface (e.g., a maximum of 600m further inland with the greatest incursion in the area north of Elliston). Based on model results, the 50:50 isohaline is unlikely to reach town water supply wells by 2050. However, it is not known to what degree dispersive mixing associated with the interface may impact town water supply wells. Given the current rising trend in salinity in town water supply wells, increases in salinity are likely to continue into the future.

7.2 Recommendations

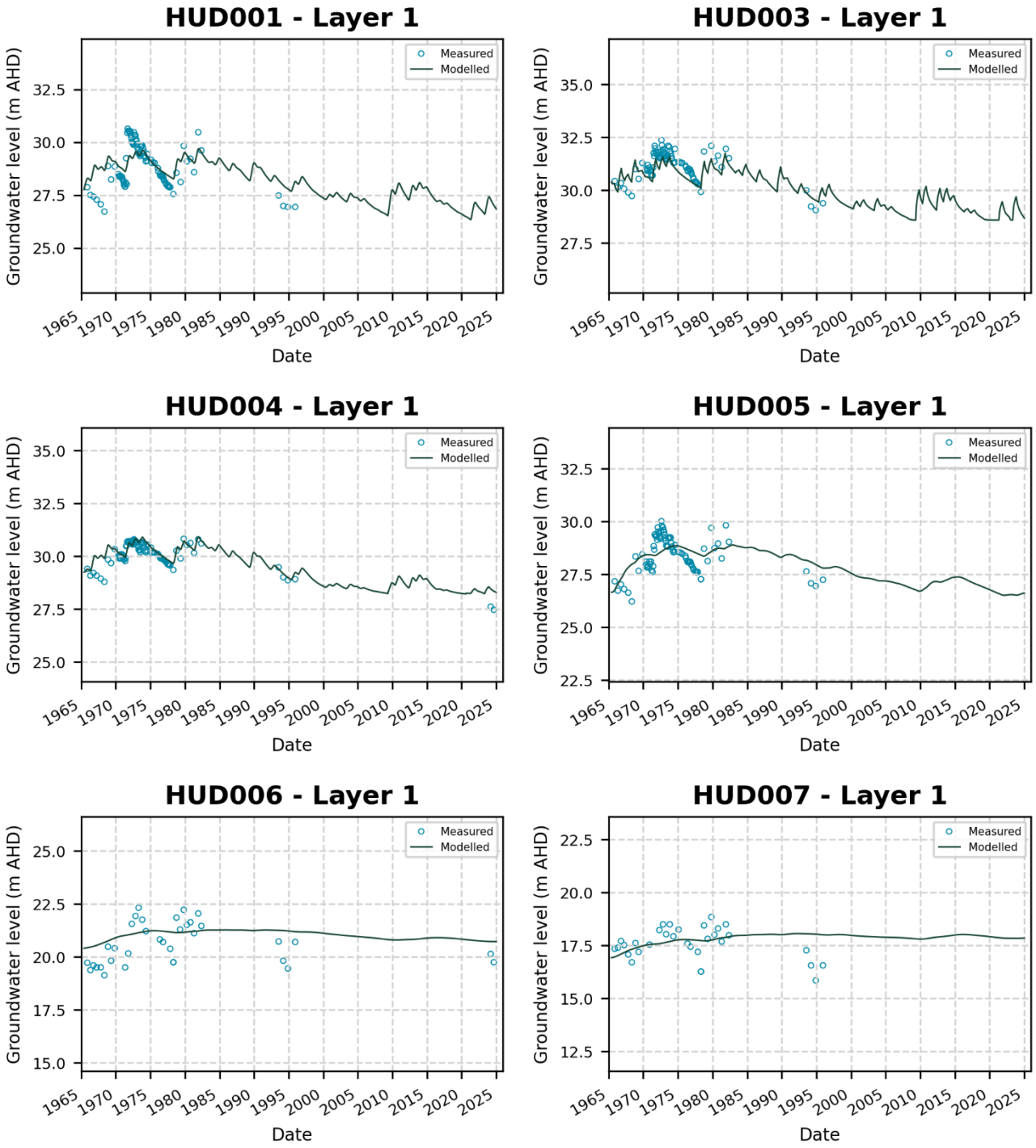
Overall, the model developed here is considered fit-for-purpose to inform water security in the Bramfield lens in the short- to medium-term (e.g., development, implementation and subsequent review of the new EP WAP). However, several areas of conceptual uncertainty have been outlined in the report. The following recommendations are made to help improve the conceptual and numerical model in the future.

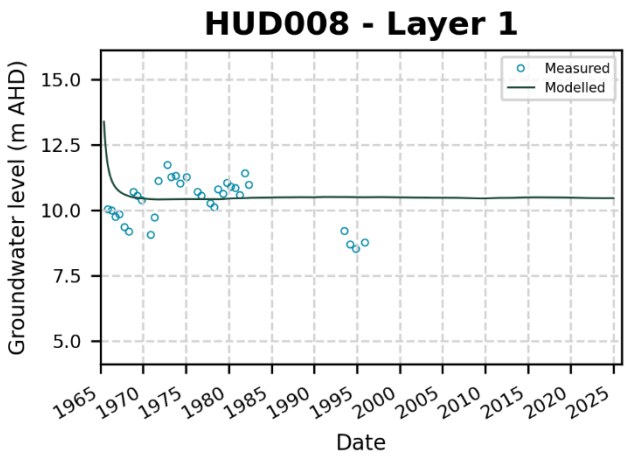
- Re-assess model conceptualisation, results and scenario assumptions once the overall NWGF project is complete.
- Monitor salinity at the new well (5830-357) to assess changes in movement of the seawater interface. Ideally, additional new monitoring wells could be installed on the transect between 5830-357 and town water supply wells to monitor for any salinity changes associated with seawater intrusion.
- Consider performing a parameter uncertainty analysis focusing on horizontal hydraulic conductivity to see what impact it may have on the seawater interface.
- Test the sensitivity of model results to variations in sea level by modelling a transient sea level boundary that fluctuates seasonally.
- Collect ground level survey data and further groundwater level data in and around wetlands to further investigate their relationship to groundwater.

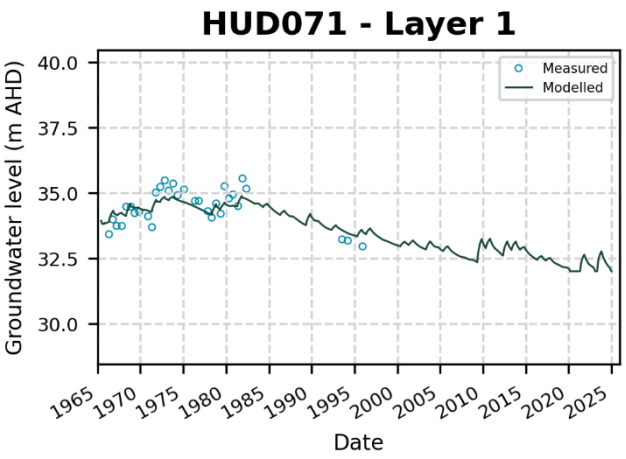
- Collect further information on stock and domestic well use, either through metering or at the very least updating estimates of the number of stock associated with relevant land parcels and how this may have changed over time.
- Further consideration of the potential impact of seasonal sea level variations on the modelled position of the interface, which may rely on longer term tidal data being collected near Elliston. The impact of potential future sea level rise on the seawater interface could also be considered.

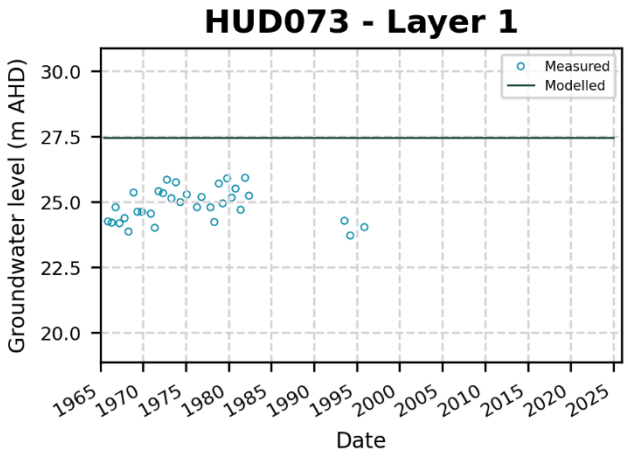
8 Appendices

A. Measured and modelled groundwater levels




HUD008 - Layer 1
Groundwater level (m AHD)
Measured
Modelled
Date


HUD071 - Layer 1
Groundwater level (m AHD)
Measured
Modelled
Date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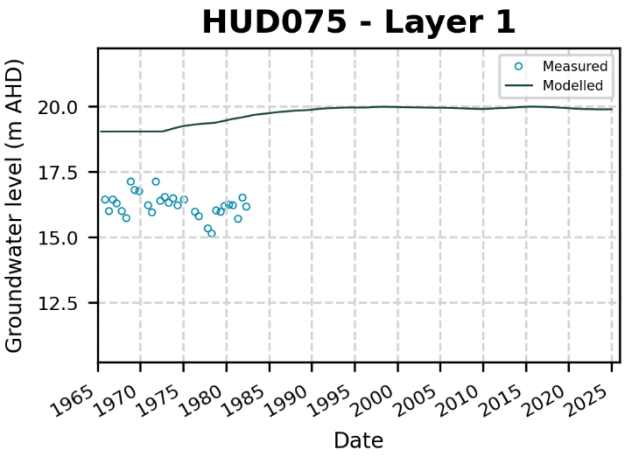
Measured
Modelled
Date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Measured
Modelled
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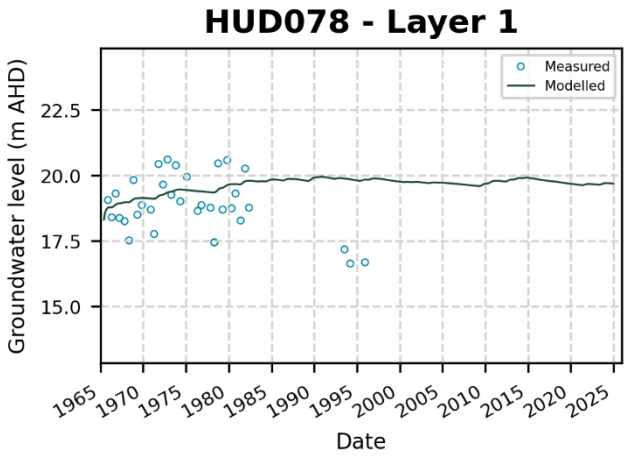
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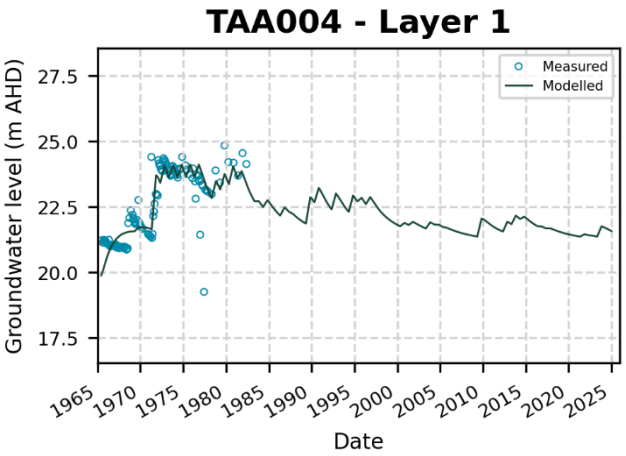
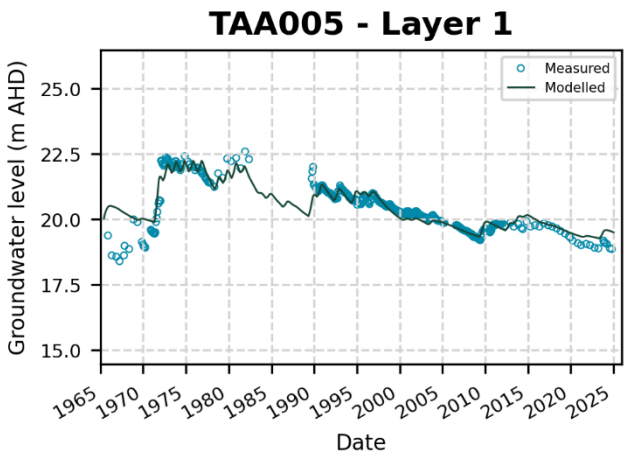
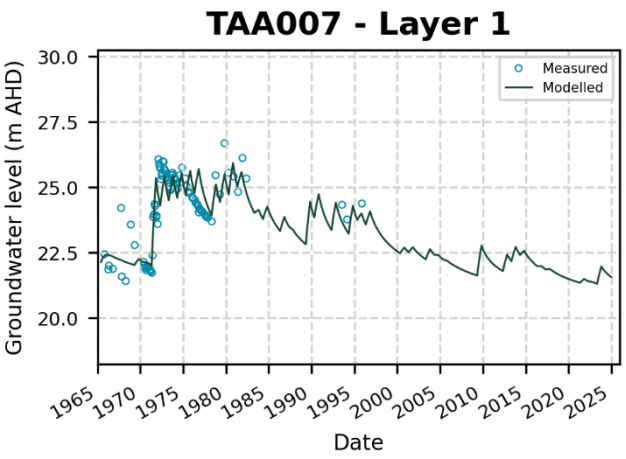
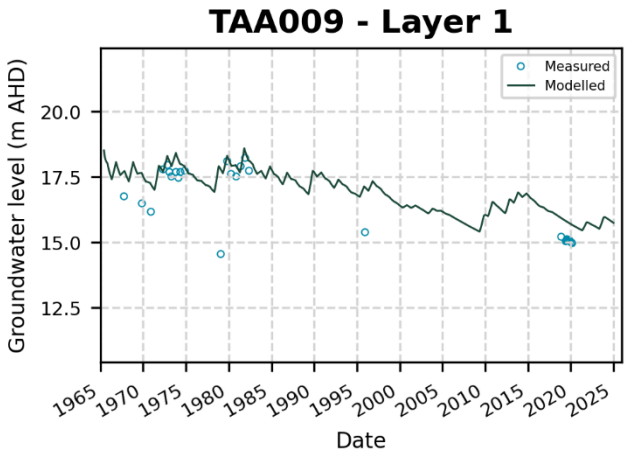
Groundwater level (m AHD)
Measured
Modelled
Date


TAA004 - Layer 1
Groundwater level (m AHD)
Measured
Modelled
Date


TAA005 - Layer 1
Groundwater level (m AHD)
Measured
Modelled
Date


TAA007 - Layer 1
Groundwater level (m AHD)
Measured
Modelled
Date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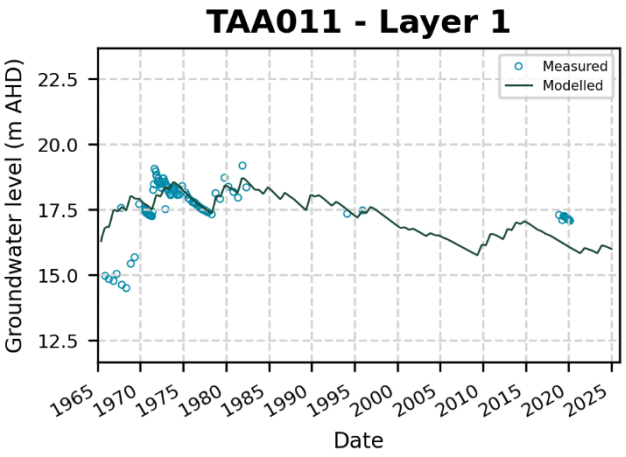
Measured
Modelled
Date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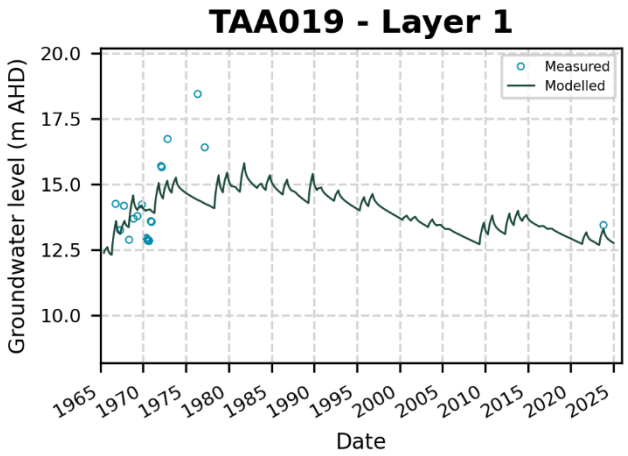
Groundwater level (m AHD)
Measured
Modelled
Date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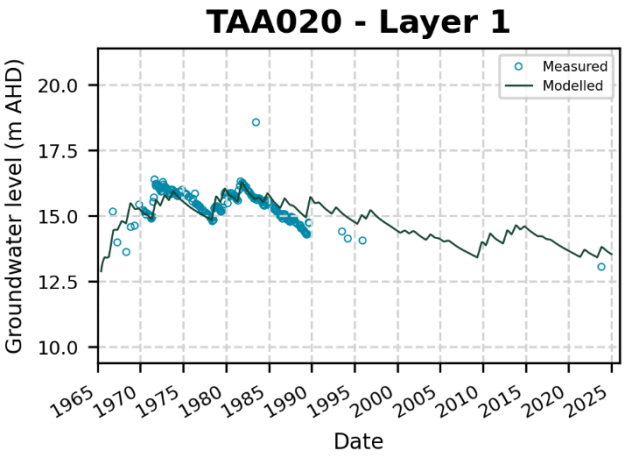
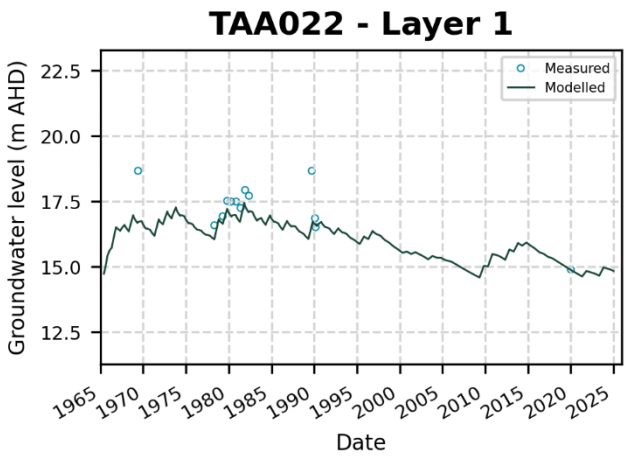
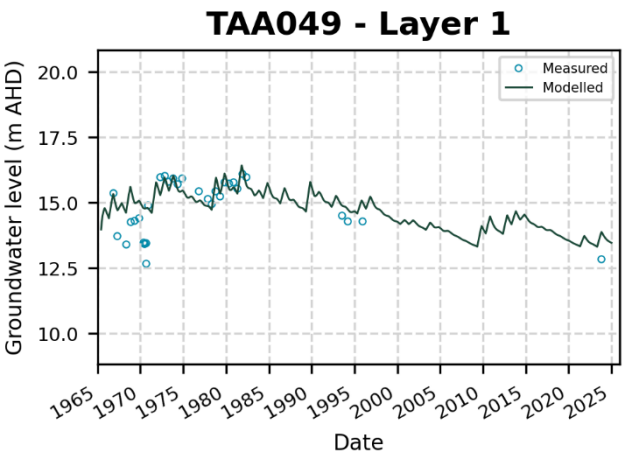
Groundwater level (m AHD)
Measured
Modelled
Date


TAA020 - Layer 1
Groundwater level (m AHD)
Measured
Modelled
Date


TAA022 - Layer 1
Groundwater level (m AHD)
Measured
Modelled
Date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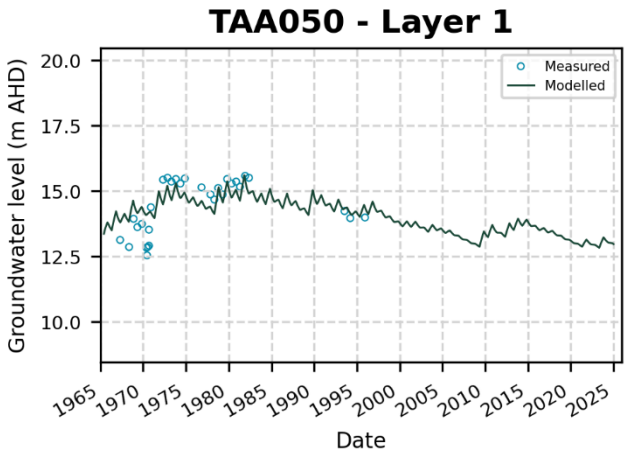
Groundwater level (m AHD)
Measured
Modelled
Date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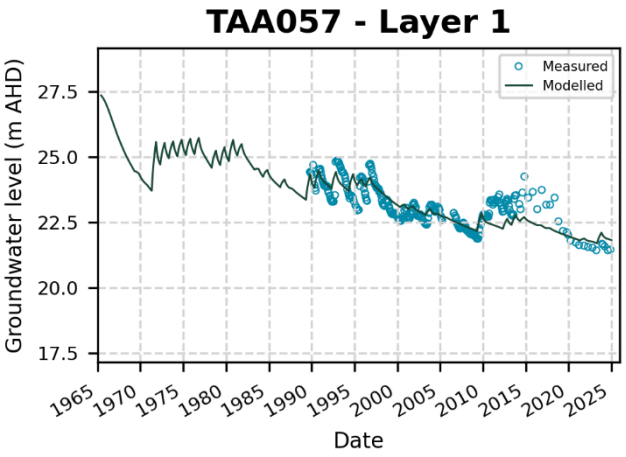
Measured
Modelled
Date


TAA057 - Layer 1
Groundwater level (m AHD)
Measured
Modelled
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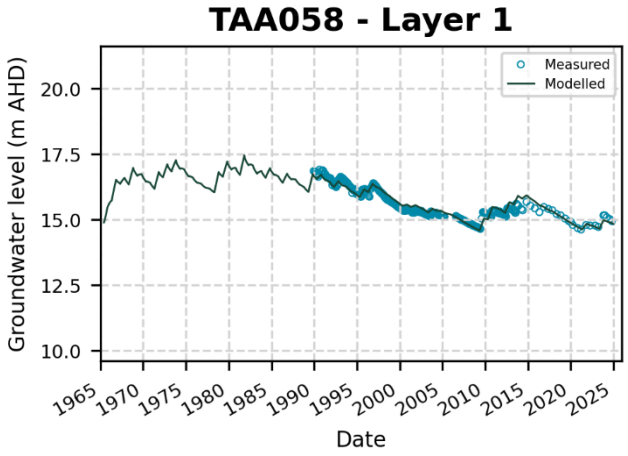
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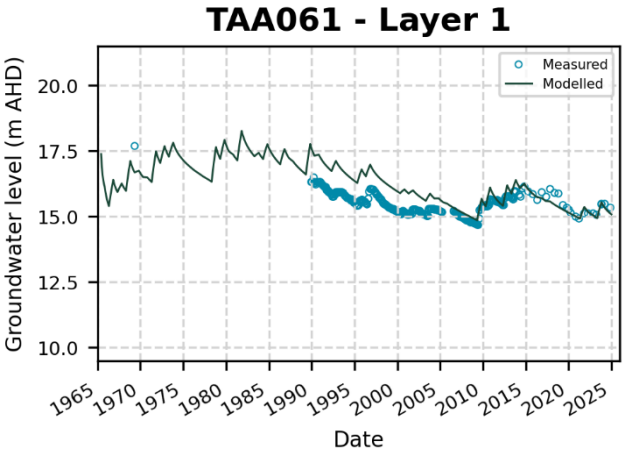
Measured
Modelled
Date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Measured
Modelled
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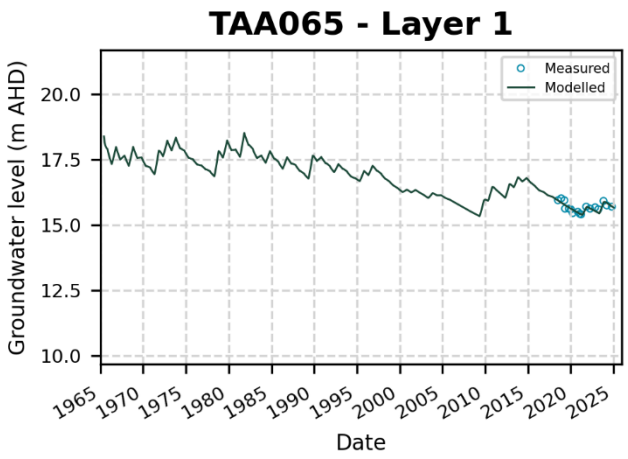
TAA065 - Layer 1
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Modelled
Groundwater level (m AHD)
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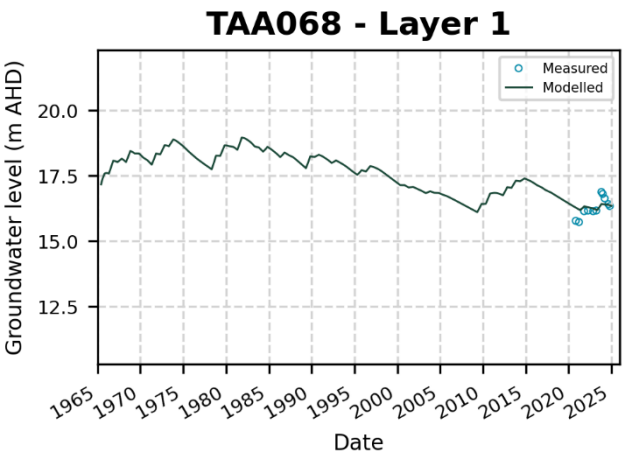
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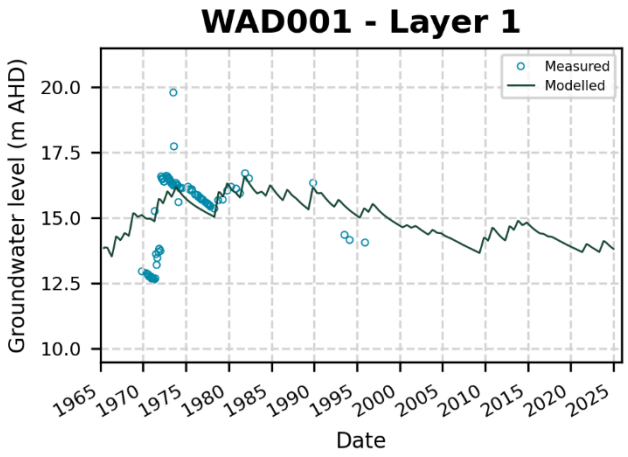
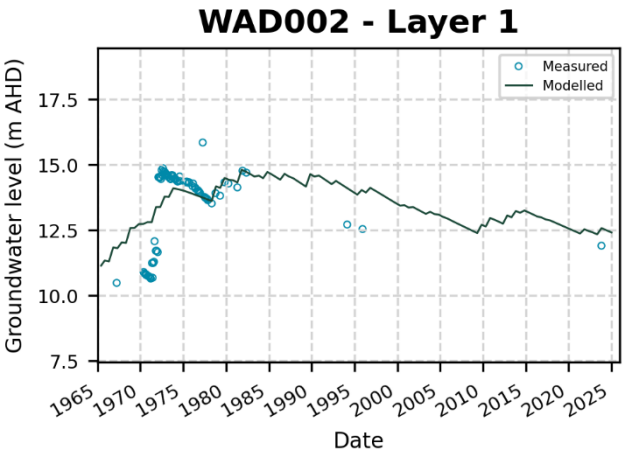

WAD001 - Layer 1
Measured
Modelled
Groundwater level (m AHD)
Date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Measured
Modelled
Groundwater level (m AHD)
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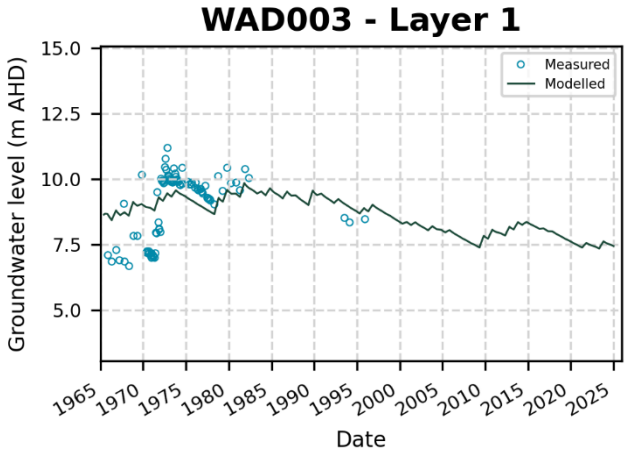
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Groundwater level (m AHD)
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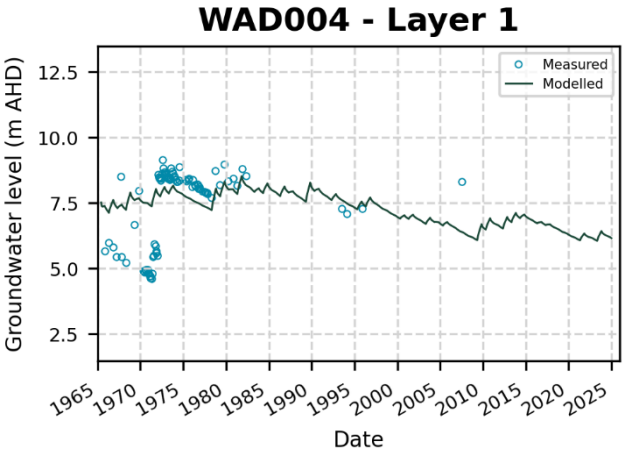
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Modelled
Groundwater level (m AHD)
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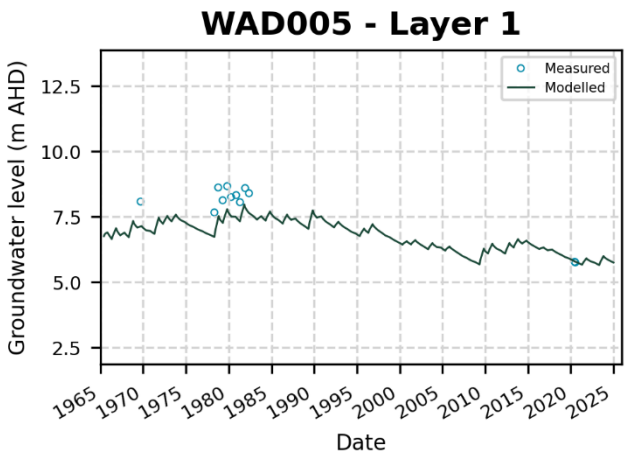
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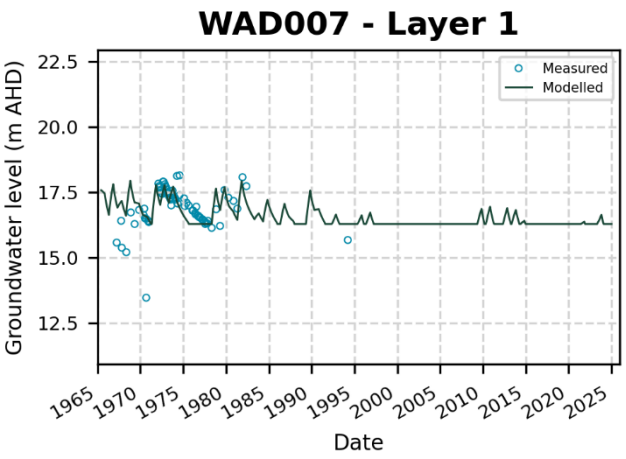
Measured
Modelled
Date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Groundwater level (m AHD)
Measured
Modelled
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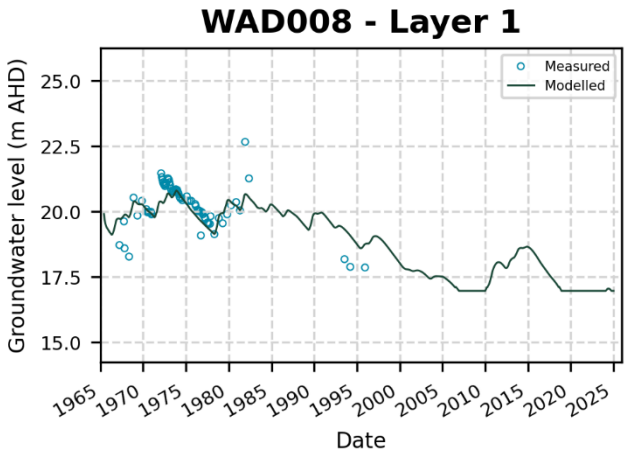
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Groundwater level (m AHD)
Measured
Modelled
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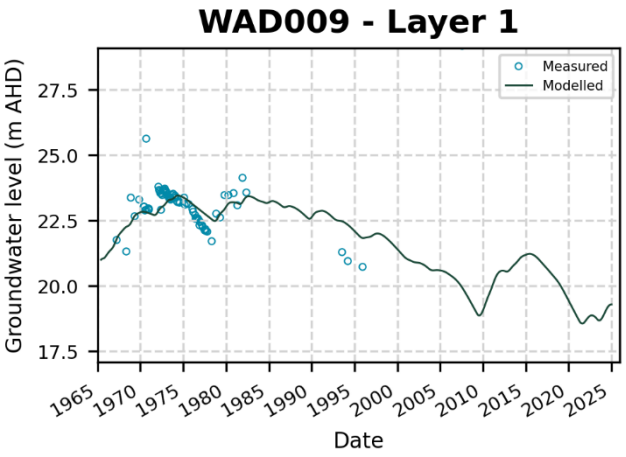
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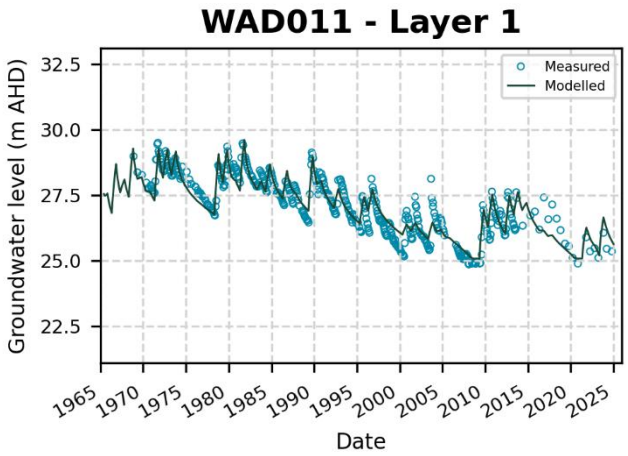
Groundwater level (m AHD)
Measured
Modelled
Date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Groundwater level (m AHD)
Measured
Modelled
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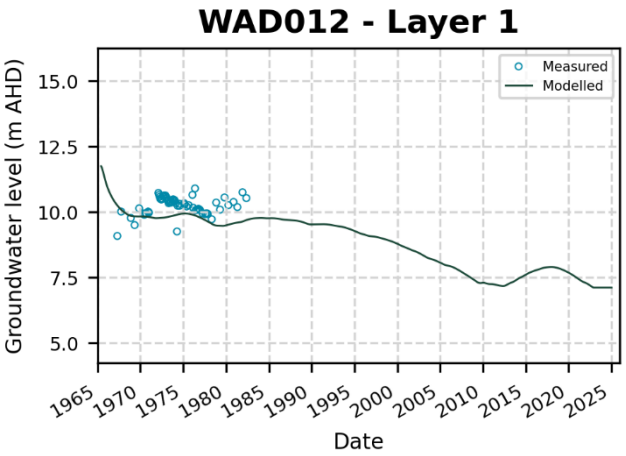
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Modelled
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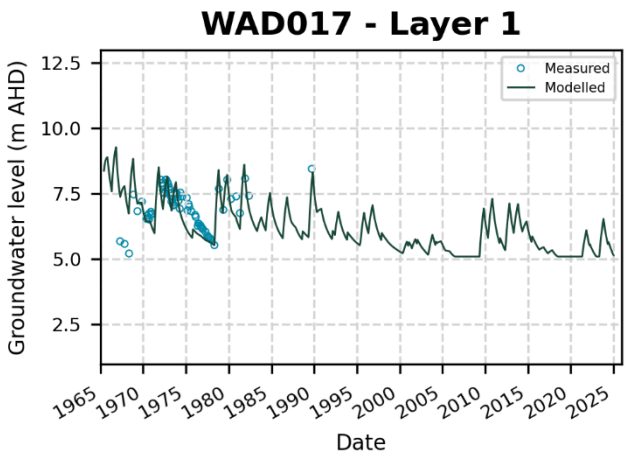
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Groundwater level (m AHD)
Measured
Modelled
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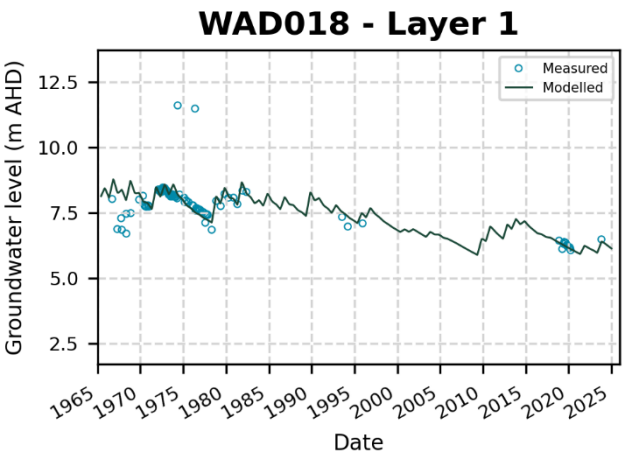
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Modelled
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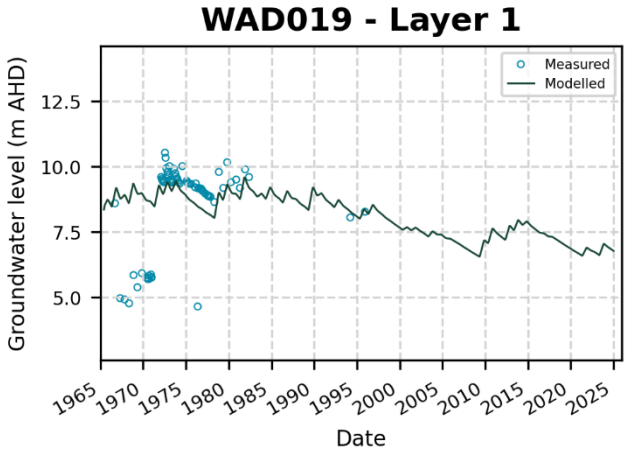
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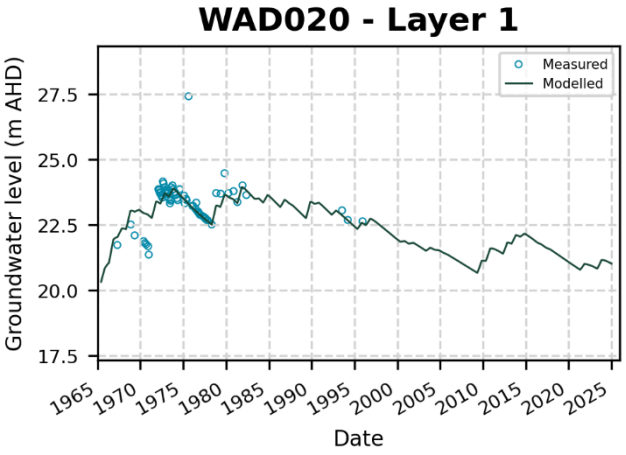
Groundwater level (m AHD)
Measured
Modelled
Date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Measured
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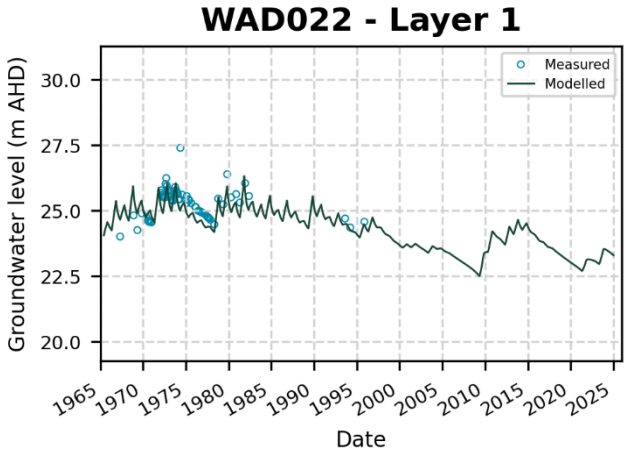
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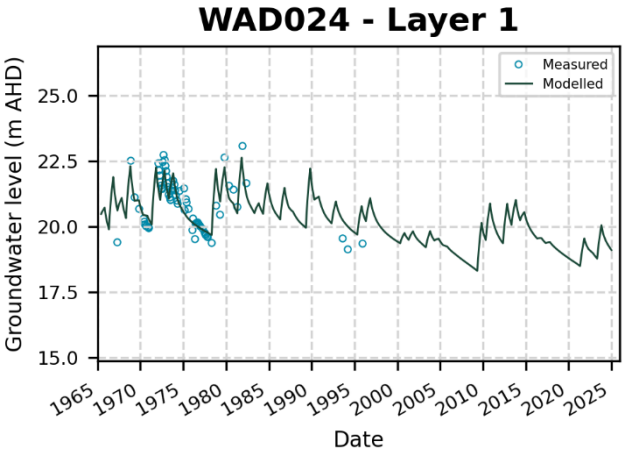
Groundwater level (m AHD)
Measured
Modelled
Date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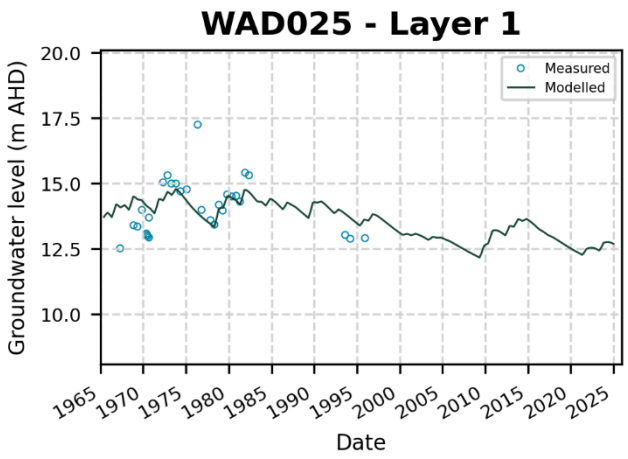
Groundwater level (m AHD)
Measured
Modelled
Date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Groundwater level (m AHD)
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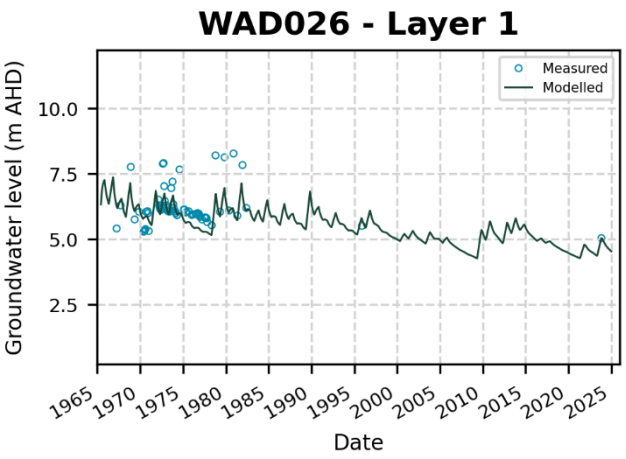
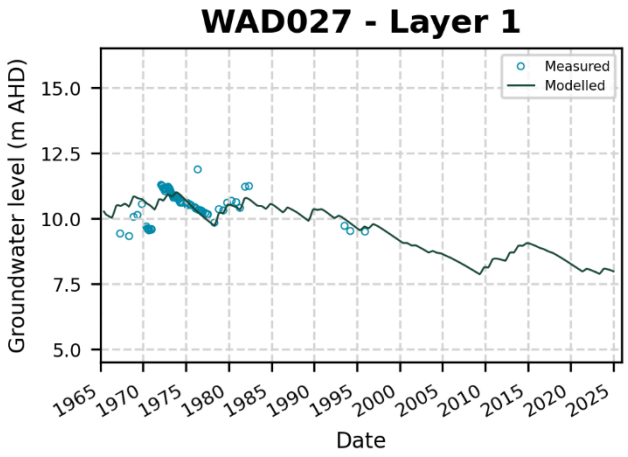
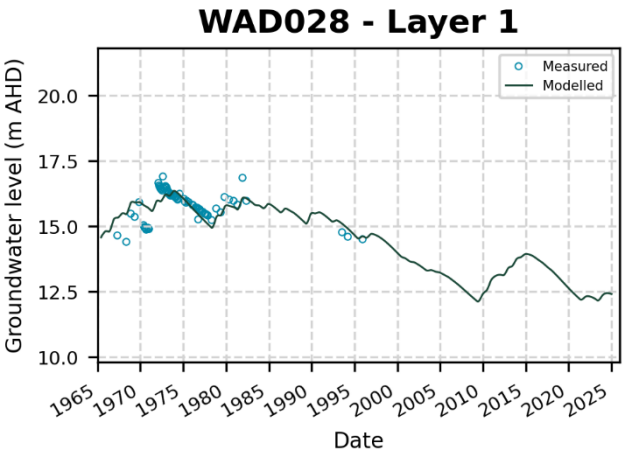
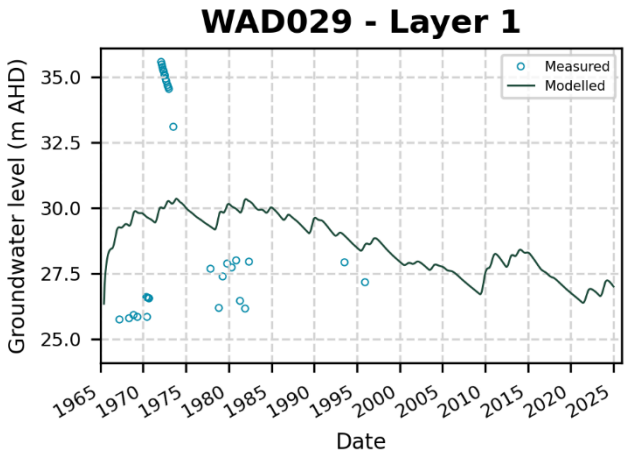
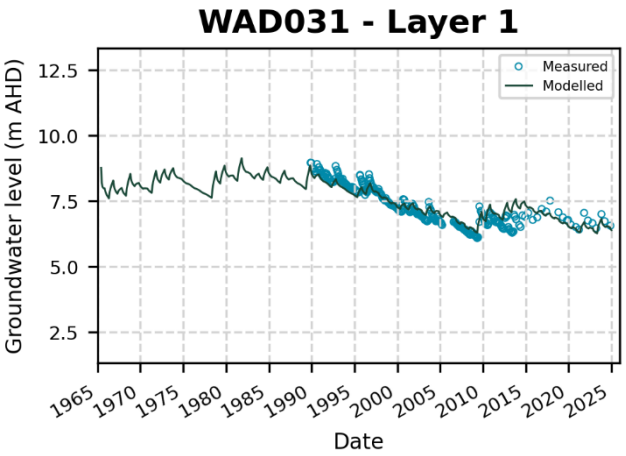
Modelled
Date


WAD026 - Layer 1
Groundwater level (m AHD)
Measured
Modelled
Date


WAD027 - Layer 1
Groundwater level (m AHD)
Measured
Modelled
Date


WAD028 - Layer 1
Groundwater level (m AHD)
Measured
Modelled
Date


WAD029 - Layer 1
Groundwater level (m AHD)
Measured
Modelled
Date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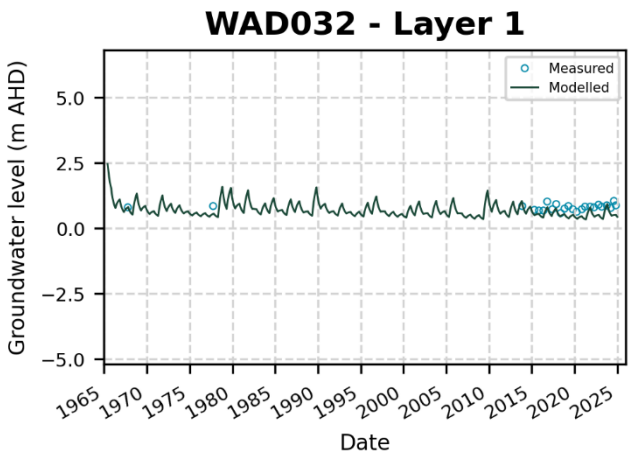
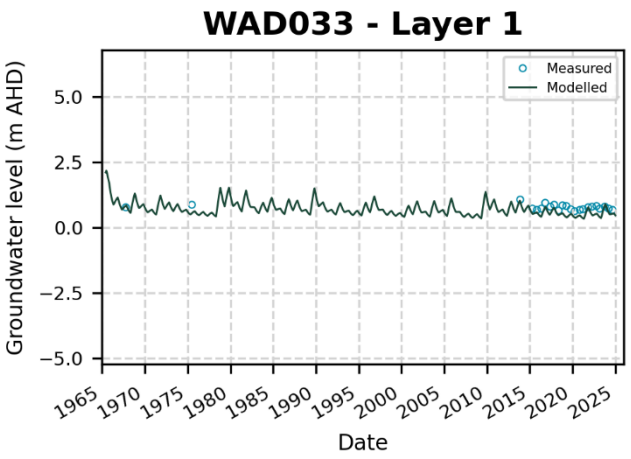
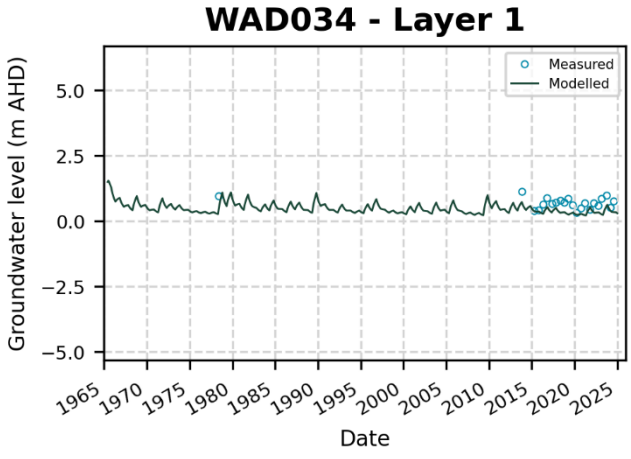
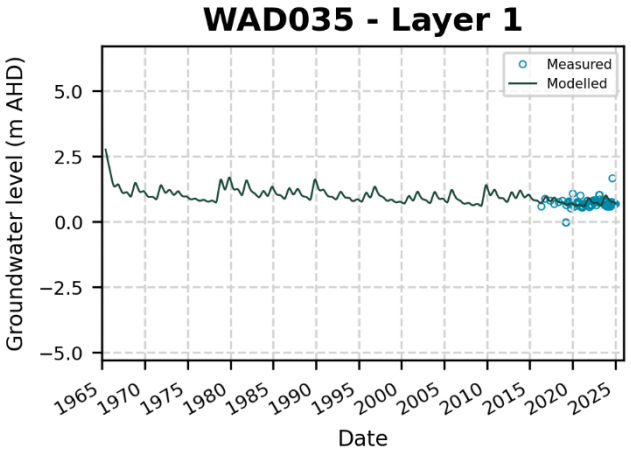
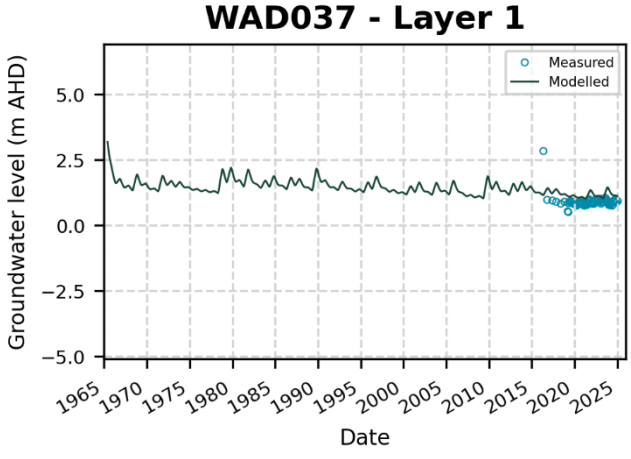
Groundwater level (m AHD)
Measured
Modelled
Date

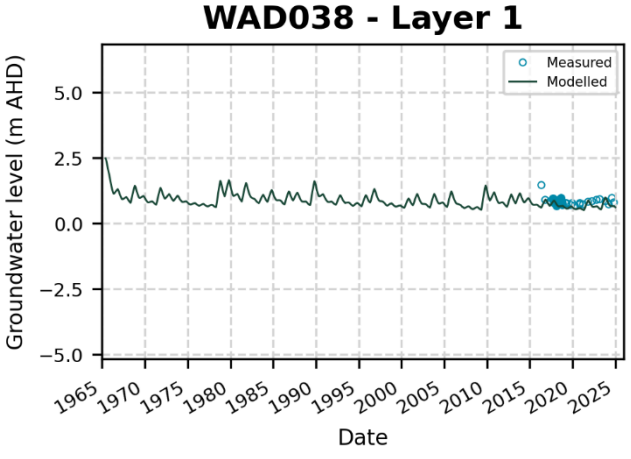

WAD032 - Layer 1
Measured
Modelled
Groundwater level (m AHD)
5.0
2.5
0.0
−2.5
−5.0
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Date

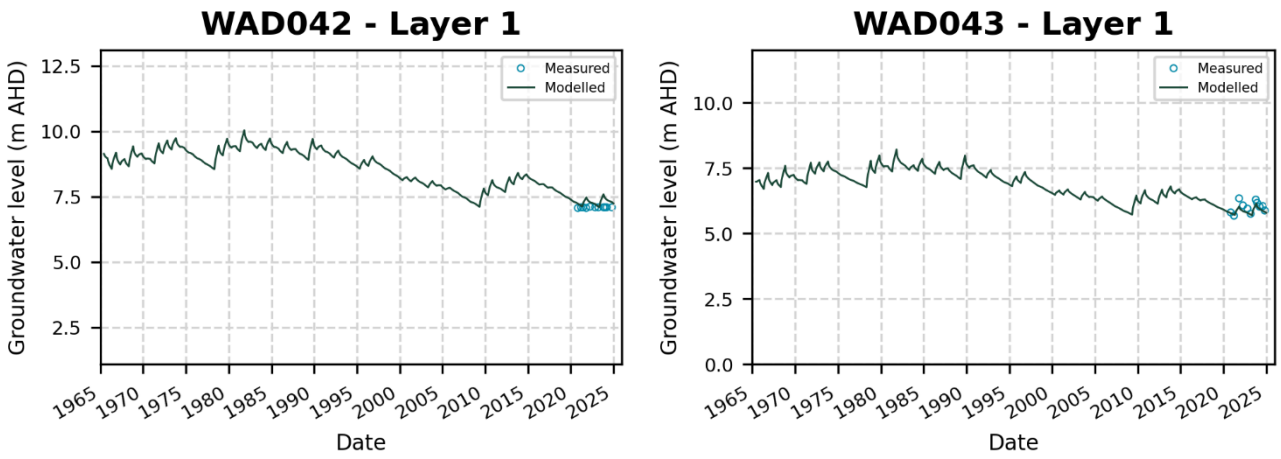

WAD033 - Layer 1
Measured
Modelled
Groundwater level (m AHD)
5.0
2.5
0.0
−2.5
−5.0
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Date


WAD034 - Layer 1
Measured
Modelled
Groundwater level (m AHD)
5.0
2.5
0.0
−2.5
−5.0
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Date

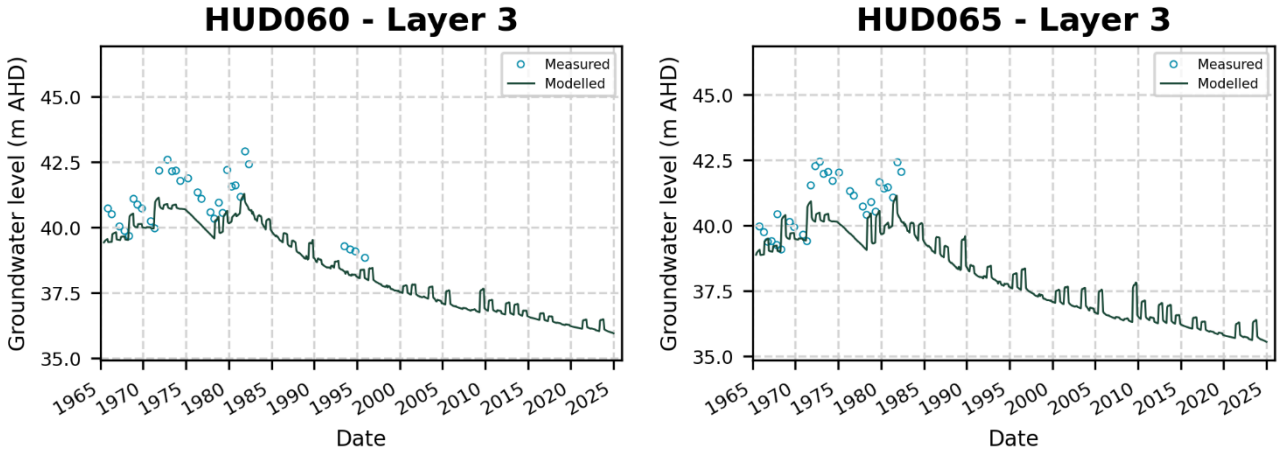

WAD035 - Layer 1
Measured
Modelled
Groundwater level (m AHD)
5.0
2.5
0.0
−2.5
−5.0
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Date


WAD037 - Layer 1
Measured
Modelled
Groundwater level (m AHD)
5.0
2.5
0.0
−2.5
−5.0
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Date

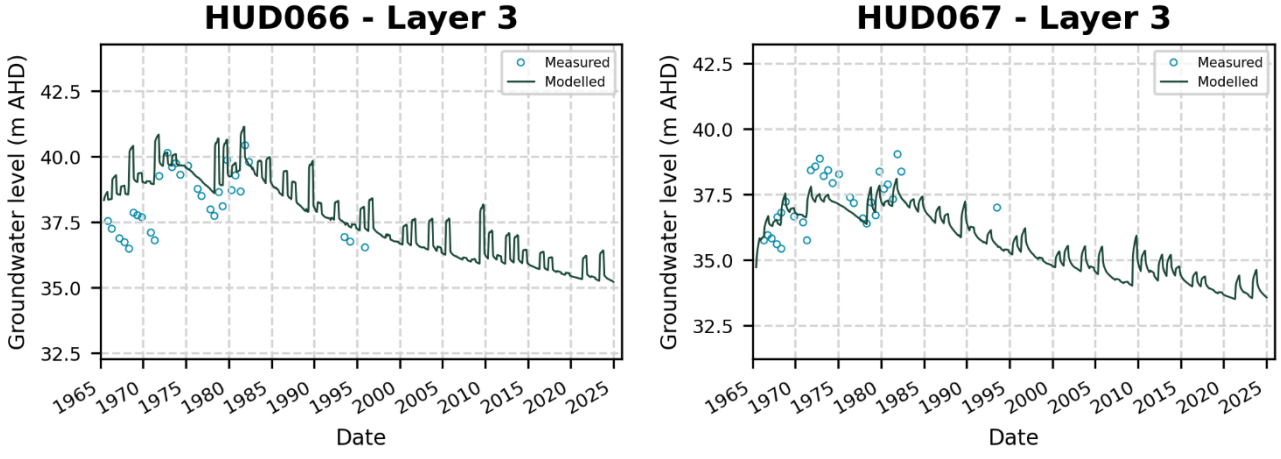

WAD038 - Layer 1
Measured
Modelled
Groundwater level (m AHD)
5.0
2.5
0.0
−2.5
−5.0
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Date


WAD042 - Layer 1
Groundwater level (m AHD)
Measured
Modelled
Date

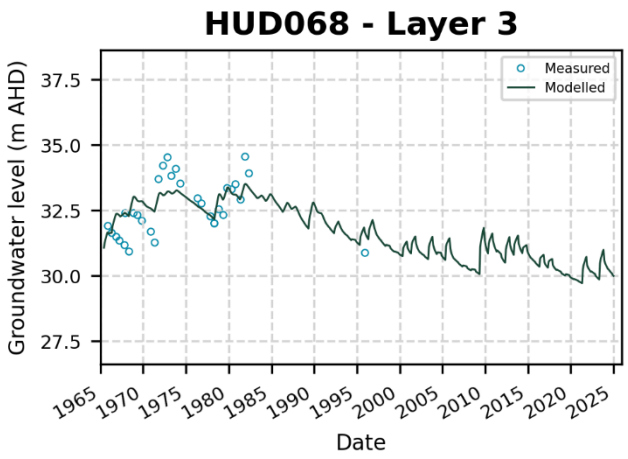
WAD043 - Layer 1
Groundwater level (m AHD)
Measured
Modelled
Date

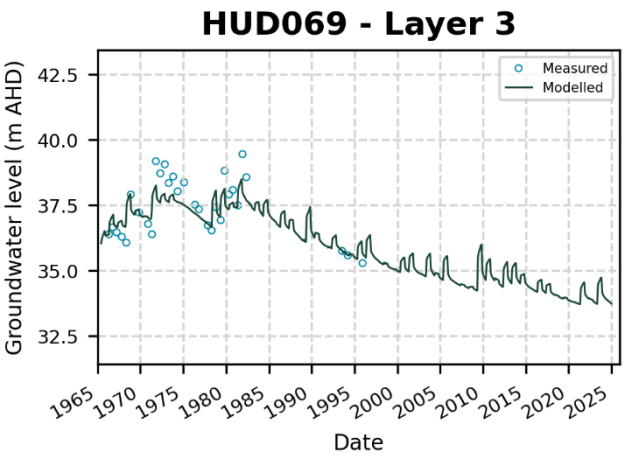

HUD060 - Layer 3
Groundwater level (m AHD)
Measured
Modelled
Date

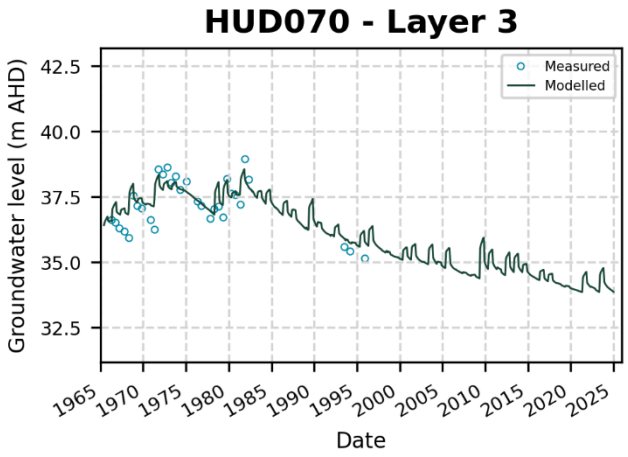
HUD065 - Layer 3
Groundwater level (m AHD)
Measured
Modelled
Date

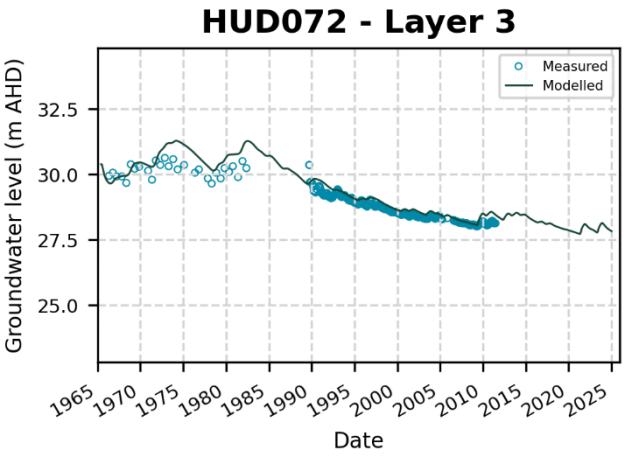

HUD066 - Layer 3
Groundwater level (m AHD)
Measured
Modelled
Date

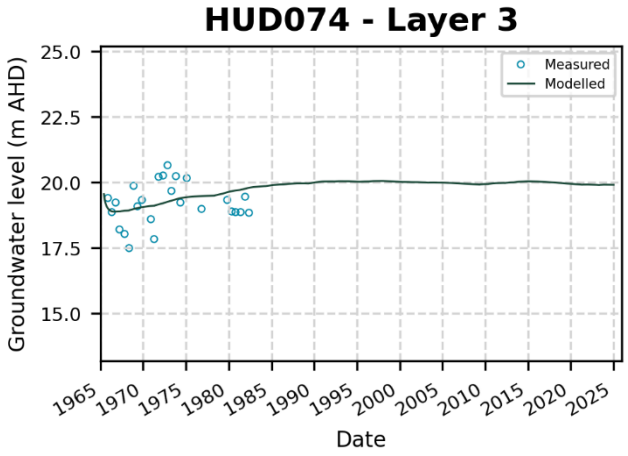
HUD067 - Layer 3
Groundwater level (m AHD)
Measured
Modelled
Date

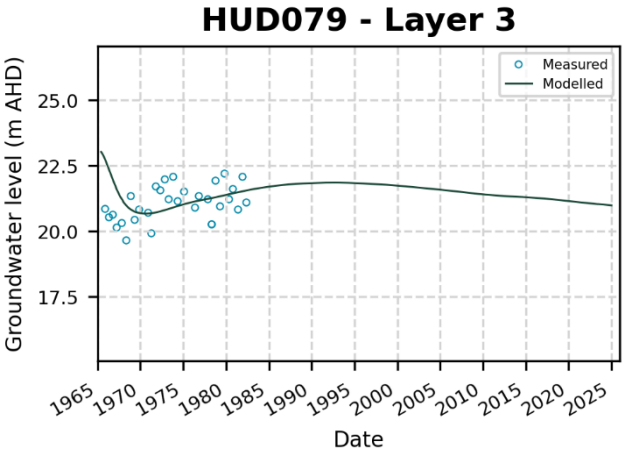

HUD068 - Layer 3
Groundwater level (m AHD)
Measured
Modelled
Date

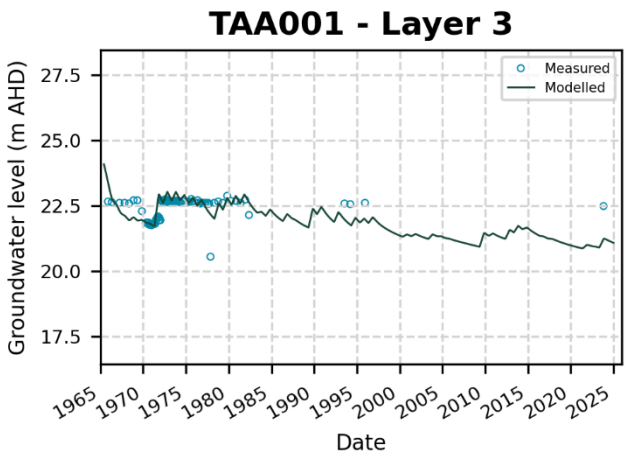

HUD069 - Layer 3
Groundwater level (m AHD)
Measured
Modelled
Date

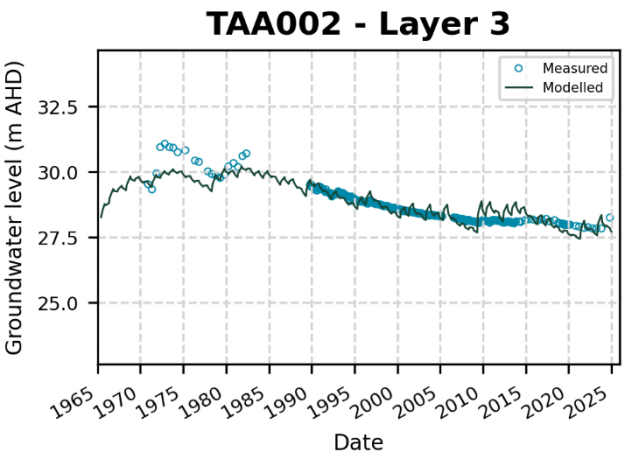

HUD070 - Layer 3
Groundwater level (m AHD)
Measured
Modelled
Date

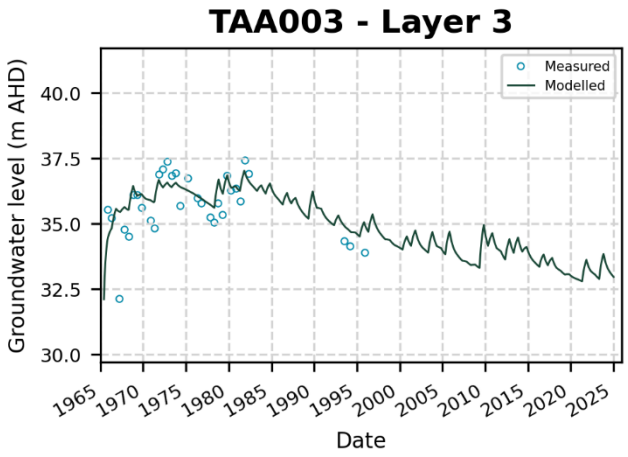

HUD072 - Layer 3
Groundwater level (m AHD)
Measured
Modelled
Date

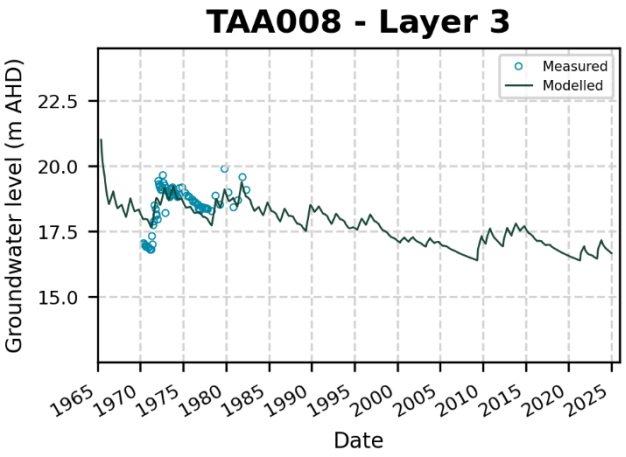

HUD074 - Layer 3
Groundwater level (m AHD)
Measured
Modelled
Date

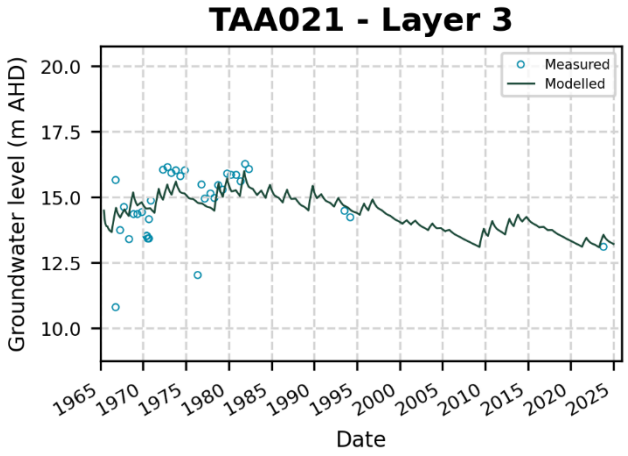

HUD079 - Layer 3
Groundwater level (m AHD)
Measured
Modelled
Date

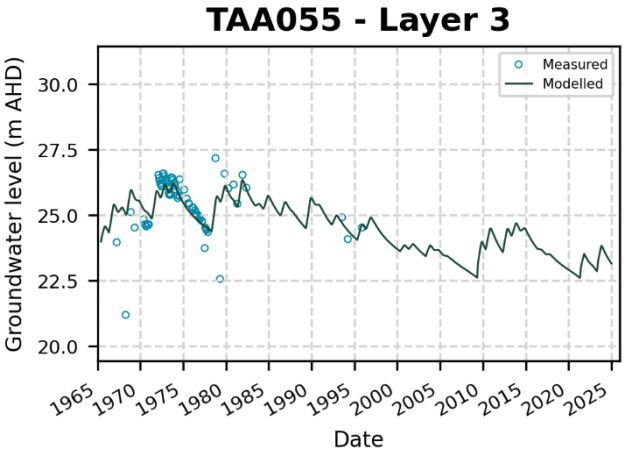

TAA001 - Layer 3
Measured
Modelled
Groundwater level (m AHD)
27.5
25.0
22.5
20.0
17.5
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Date

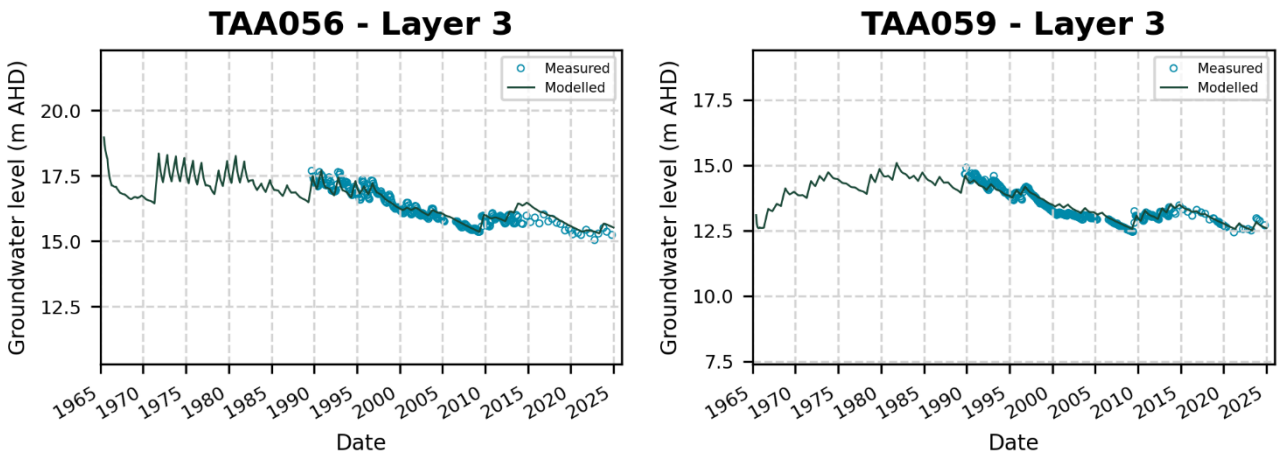

TAA002 - Layer 3
Measured
Modelled
Groundwater level (m AHD)
32.5
30.0
27.5
25.0
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Date


TAA003 - Layer 3
Measured
Modelled
Groundwater level (m AHD)
40.0
37.5
35.0
32.5
30.0
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Date

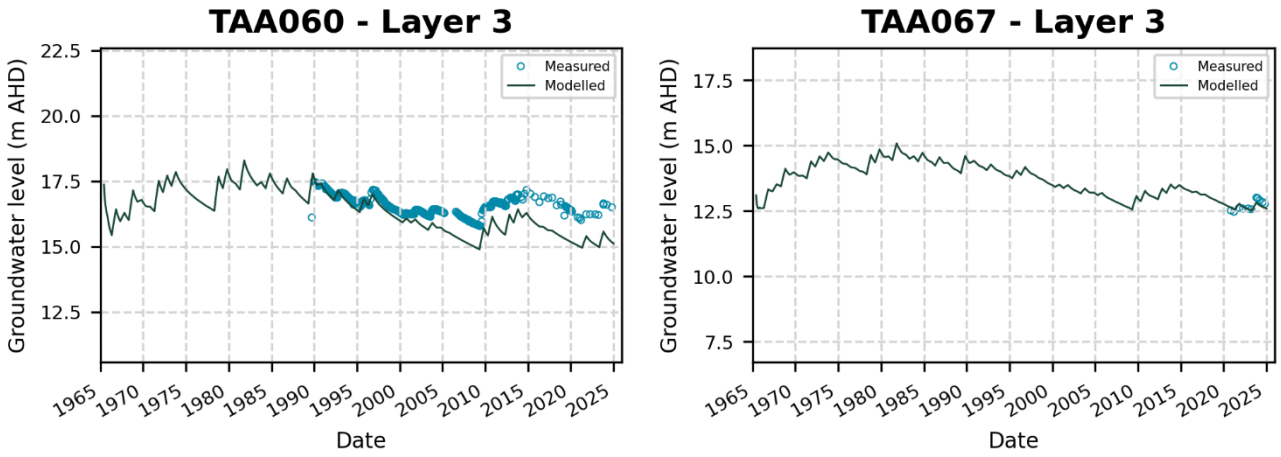

TAA008 - Layer 3
Measured
Modelled
Groundwater level (m AHD)
22.5
20.0
17.5
15.0
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Date


TAA021 - Layer 3
Measured
Modelled
Groundwater level (m AHD)
20.0
17.5
15.0
12.5
10.0
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Date

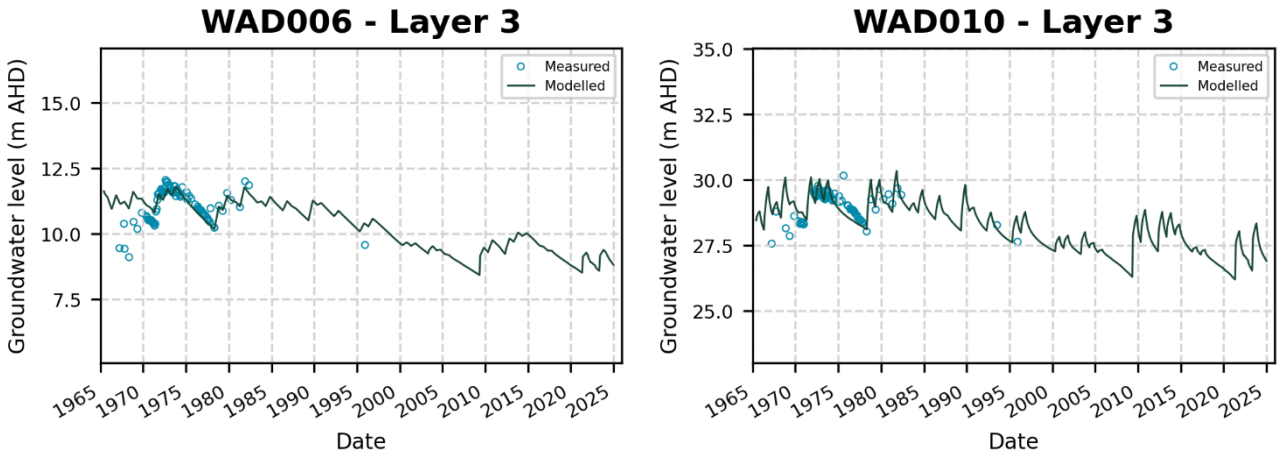

TAA055 - Layer 3
Measured
Modelled
Groundwater level (m AHD)
30.0
27.5
25.0
22.5
20.0
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Date


TAA056 - Layer 3
Groundwater level (m AHD)
Measured
Modelled
Date

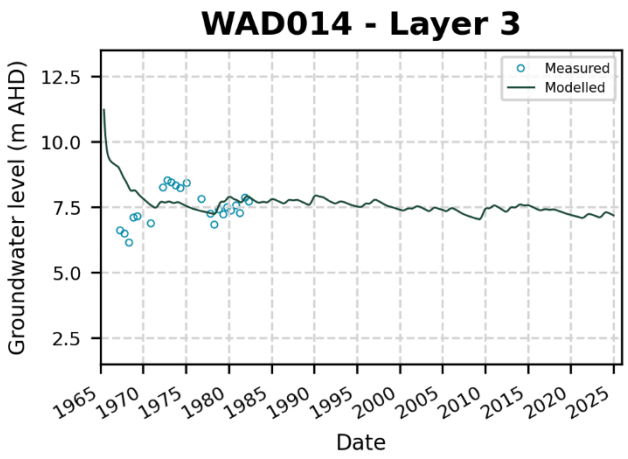
TAA059 - Layer 3
Groundwater level (m AHD)
Measured
Modelled
Date

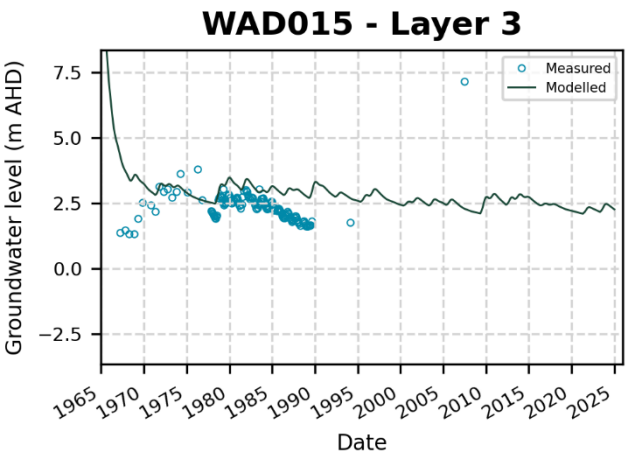

TAA060 - Layer 3
Groundwater level (m AHD)
Measured
Modelled
Date

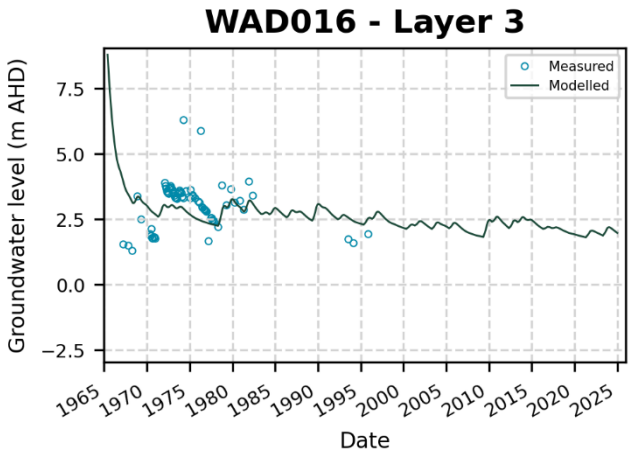
TAA067 - Layer 3
Groundwater level (m AHD)
Measured
Modelled
Date

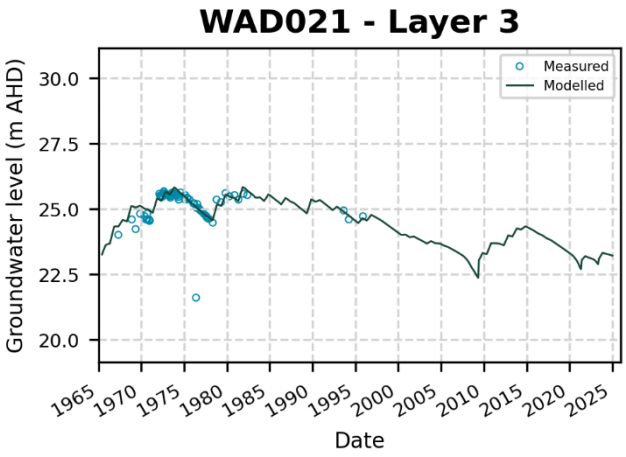

WAD006 - Layer 3
Groundwater level (m AHD)
Measured
Modelled
Date

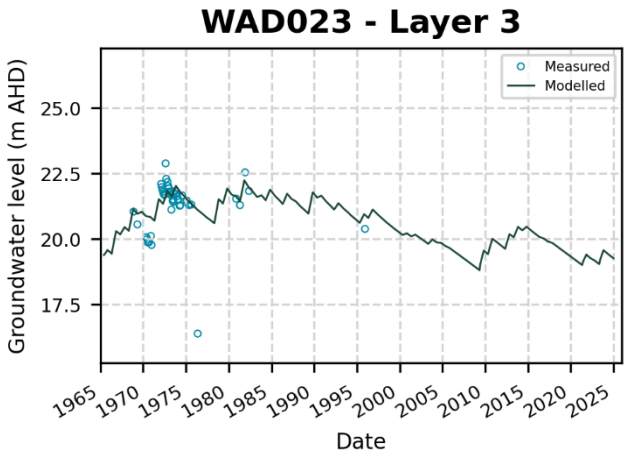
WAD010 - Layer 3
Groundwater level (m AHD)
Measured
Modelled
Date

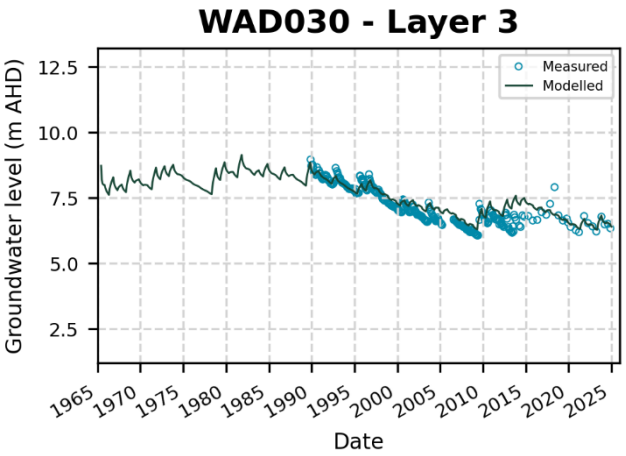

WAD014 - Layer 3
Measured
Modelled
Groundwater level (m AHD)
Date

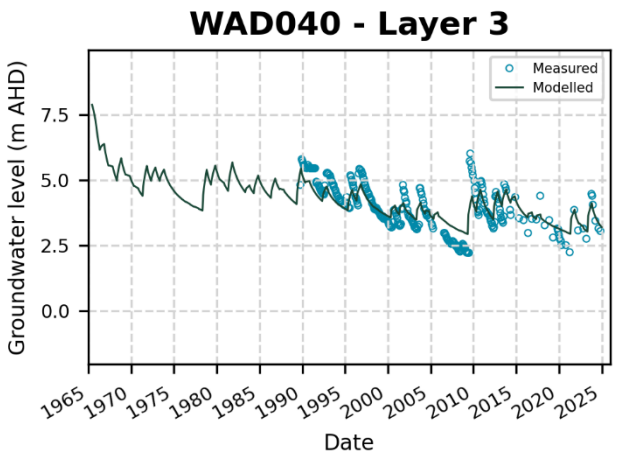

WAD015 - Layer 3
Measured
Modelled
Groundwater level (m AHD)
Date

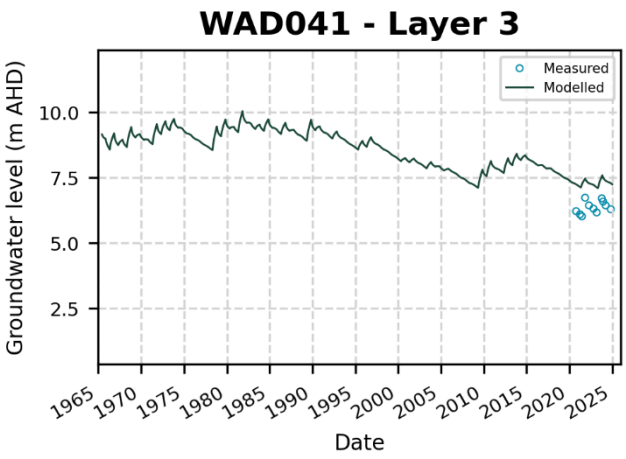

WAD016 - Layer 3
Measured
Modelled
Groundwater level (m AHD)
Date

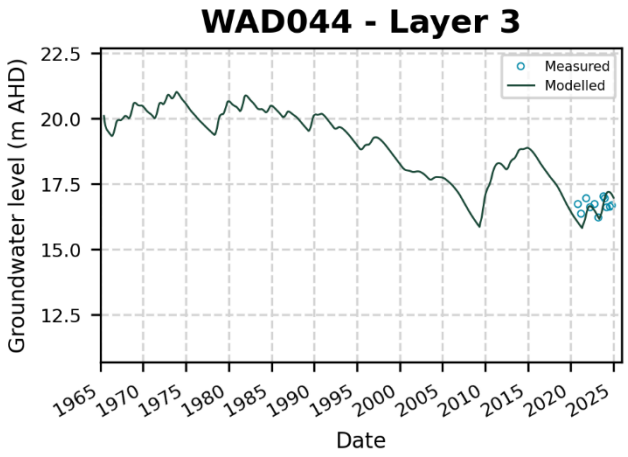

WAD021 - Layer 3
Measured
Modelled
Groundwater level (m AHD)
Date


WAD023 - Layer 3
Measured
Modelled
Groundwater level (m AHD)
Date

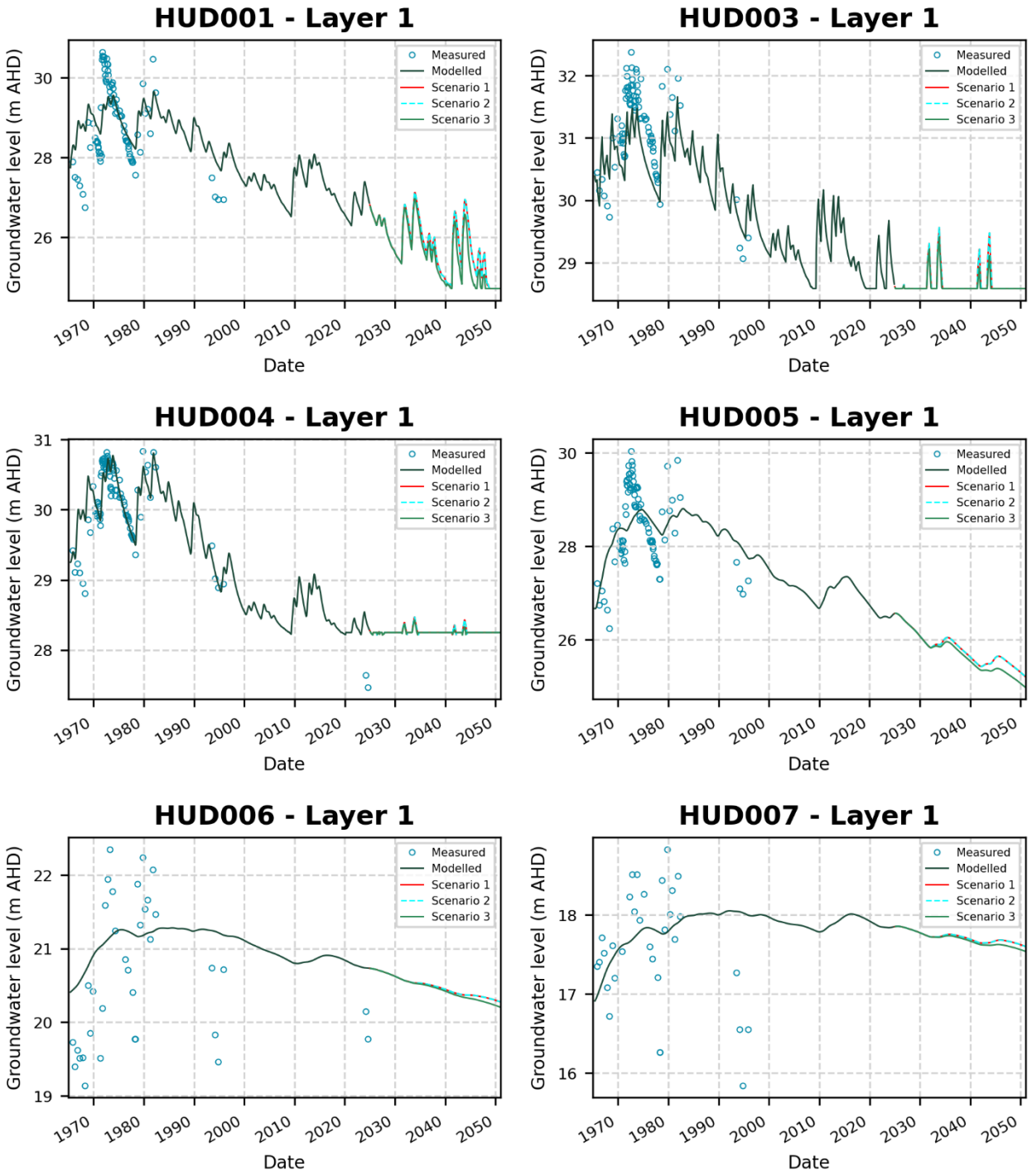

WAD030 - Layer 3
Measured
Modelled
Groundwater level (m AHD)
Date

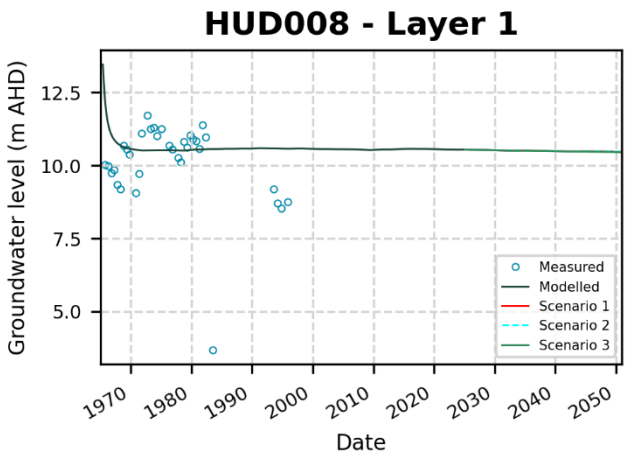

WAD040 - Layer 3
Measured
Modelled
Groundwater level (m AHD)
7.5
5.0
2.5
0.0
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Date

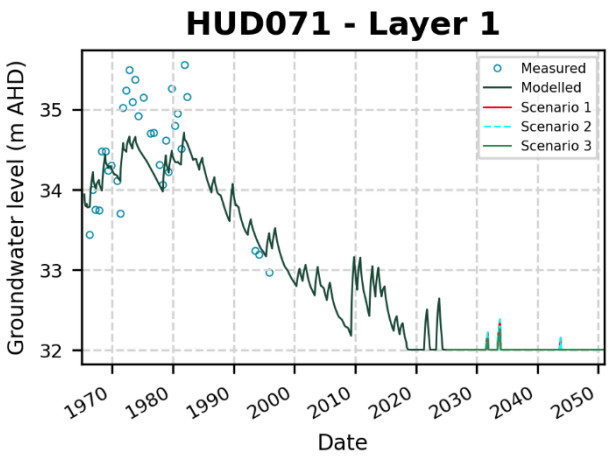

WAD041 - Layer 3
Measured
Modelled
Groundwater level (m AHD)
10.0
7.5
5.0
2.5
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Date

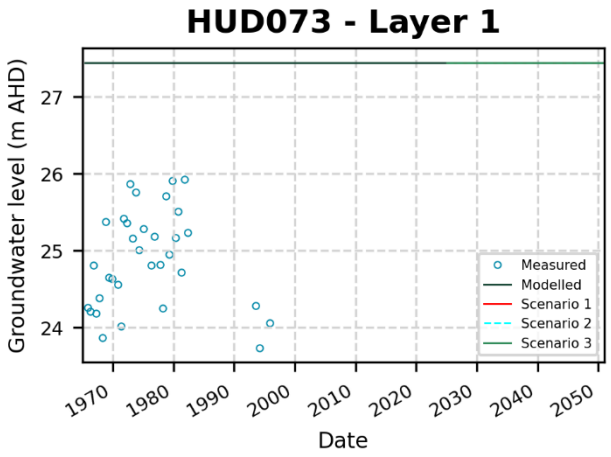

WAD044 - Layer 3
Measured
Modelled
Groundwater level (m AHD)
22.5
20.0
17.5
15.0
12.5
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
Date

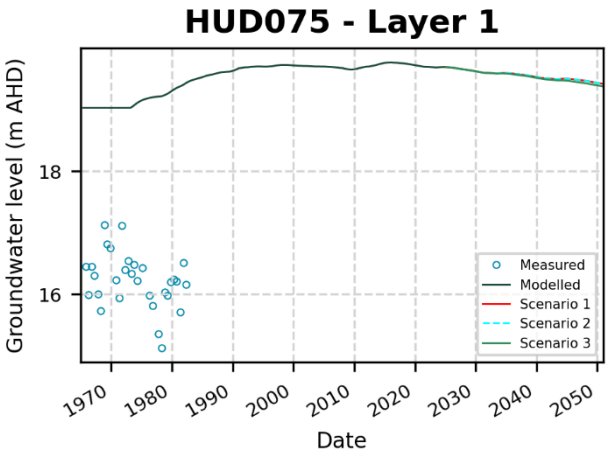
B. Model scenario hydrographs

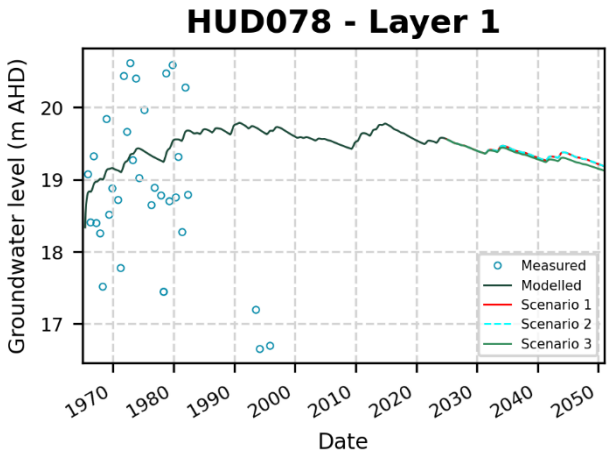


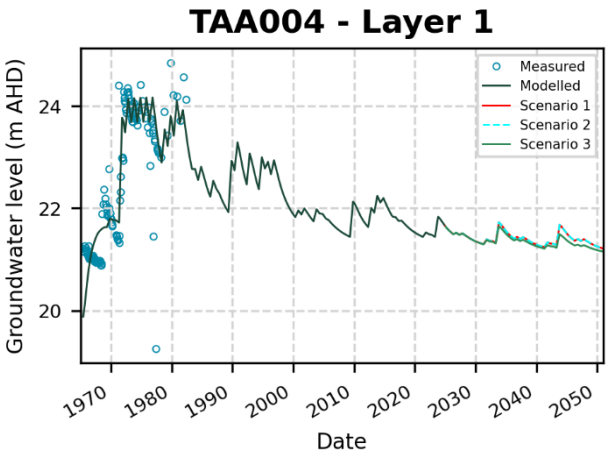

HUD008 - Layer 1
Groundwater level (m AHD)
12.5
10.0
7.5
5.0
1970
1980
1990
2000
2010
2020
2030
2040
2050
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

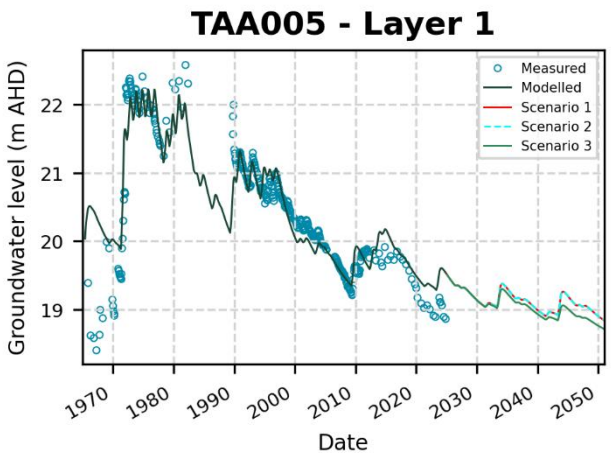

HUD071 - Layer 1
Groundwater level (m AHD)
35
34
33
32
1970
1980
1990
2000
2010
2020
2030
2040
2050
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

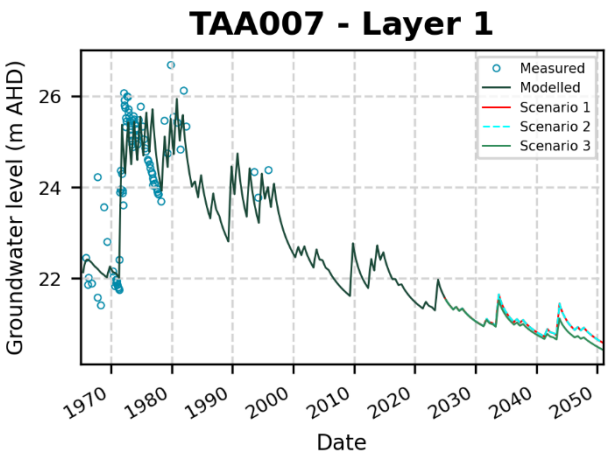

HUD073 - Layer 1
Groundwater level (m AHD)
27
26
25
24
1970
1980
1990
2000
2010
2020
2030
2040
2050
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

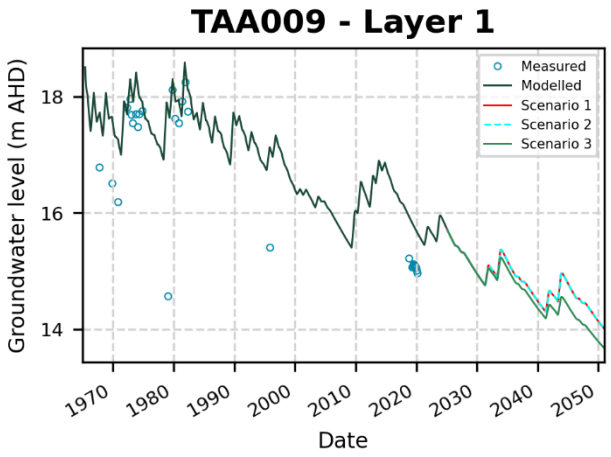

HUD075 - Layer 1
Groundwater level (m AHD)
18
16
1970
1980
1990
2000
2010
2020
2030
2040
2050
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

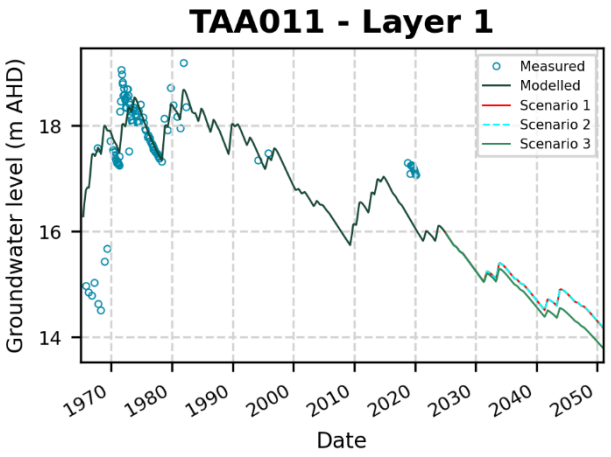

HUD078 - Layer 1
Groundwater level (m AHD)
20
19
18
17
1970
1980
1990
2000
2010
2020
2030
2040
2050
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

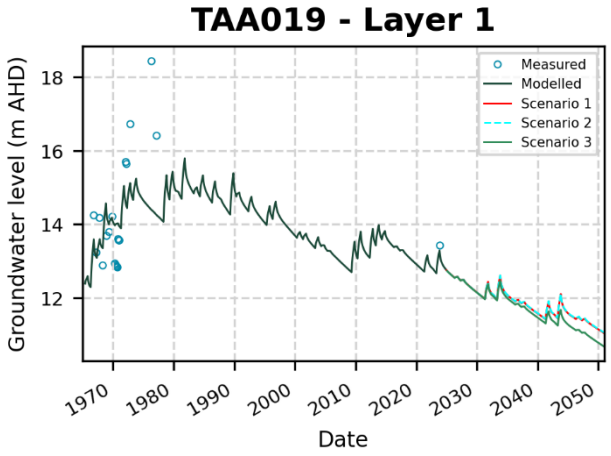

TAA004 - Layer 1
Groundwater level (m AHD)
24
22
20
1970
1980
1990
2000
2010
2020
2030
2040
2050
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

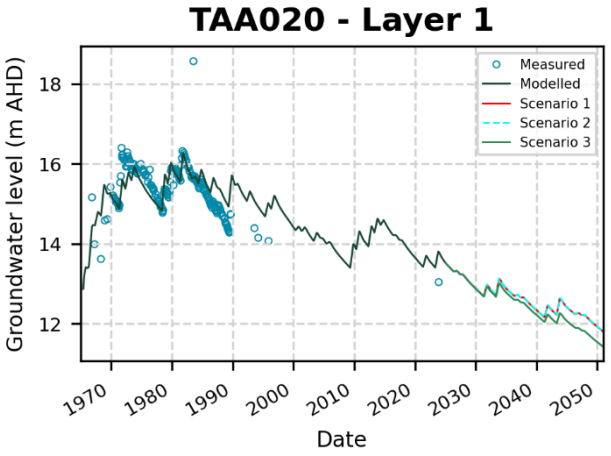

TAA005 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

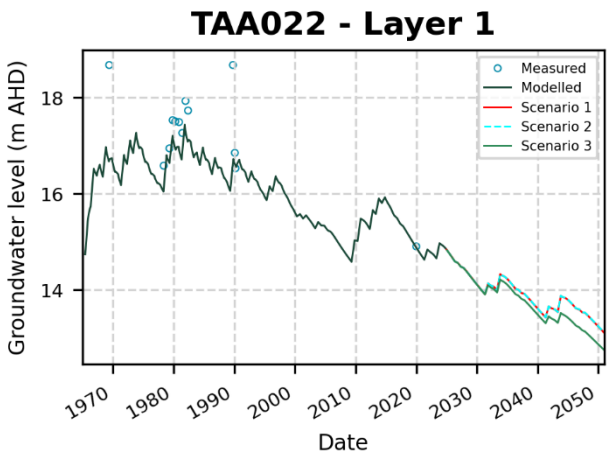

TAA007 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

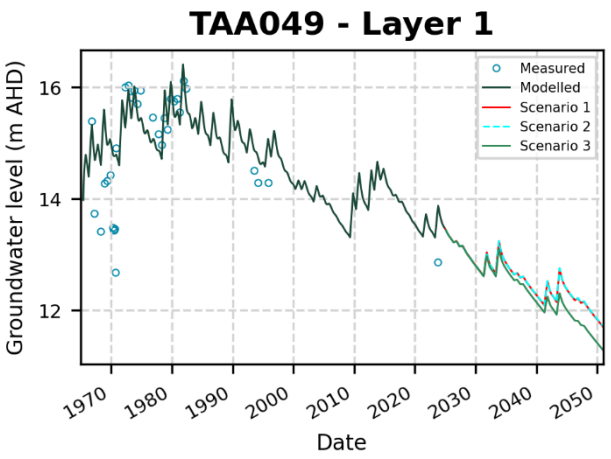

TAA009 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

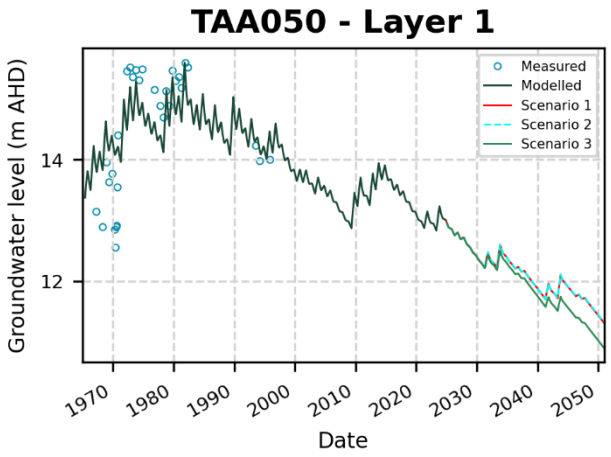

TAA011 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

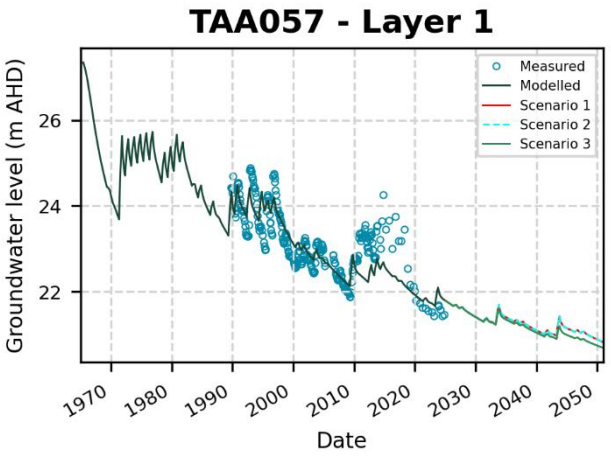

TAA019 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

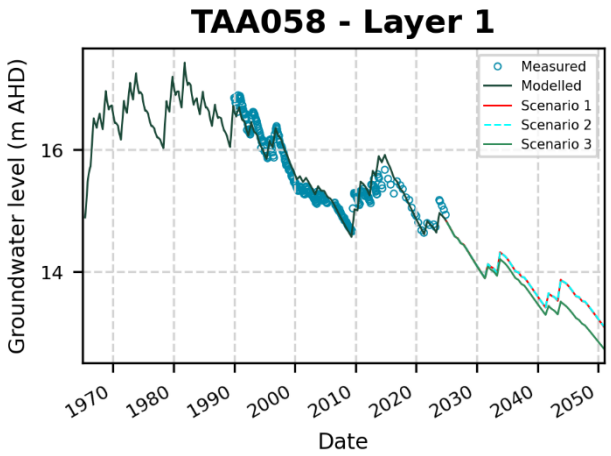

TAA020 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

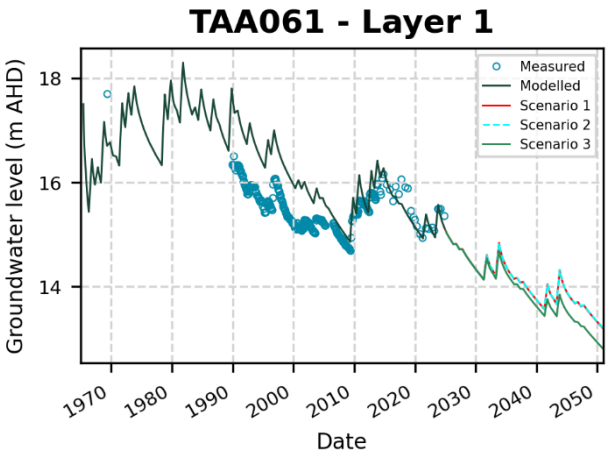

TAA022 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

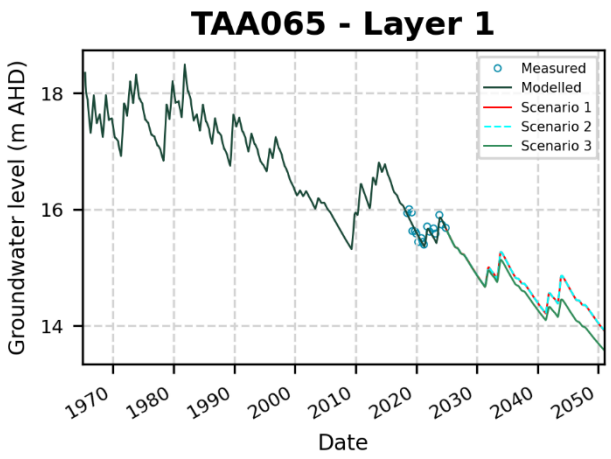

TAA049 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

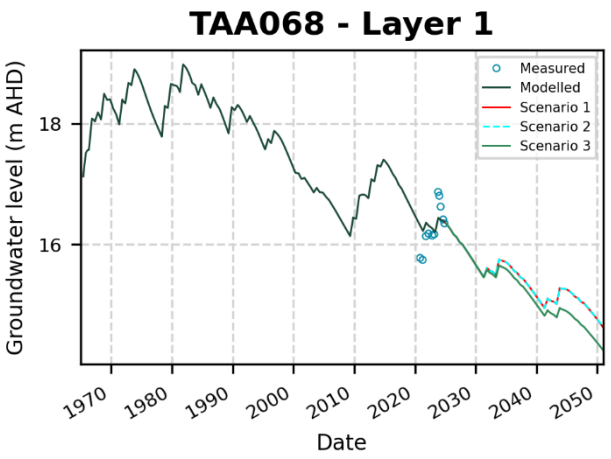

TAA050 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

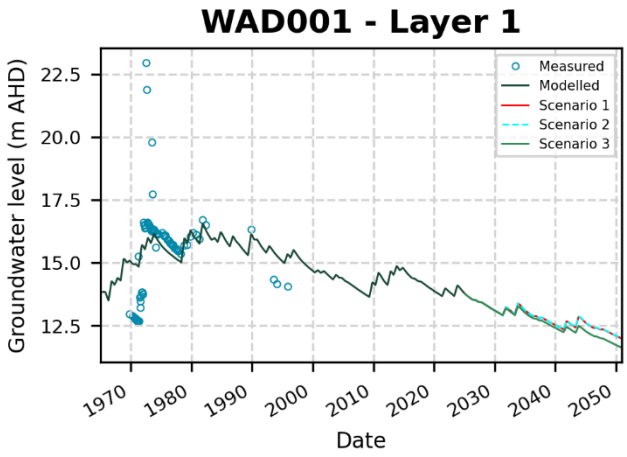

TAA057 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

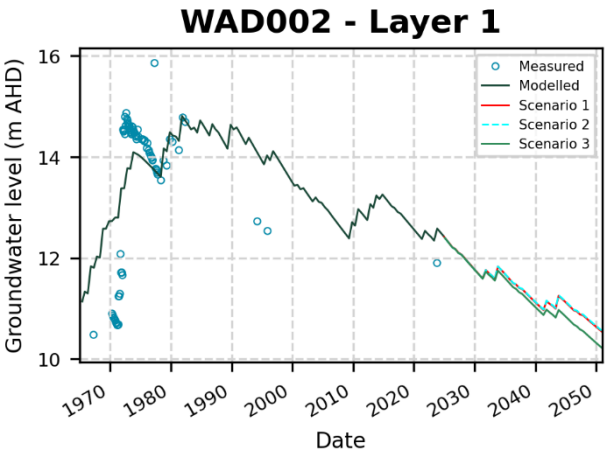

TAA058 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

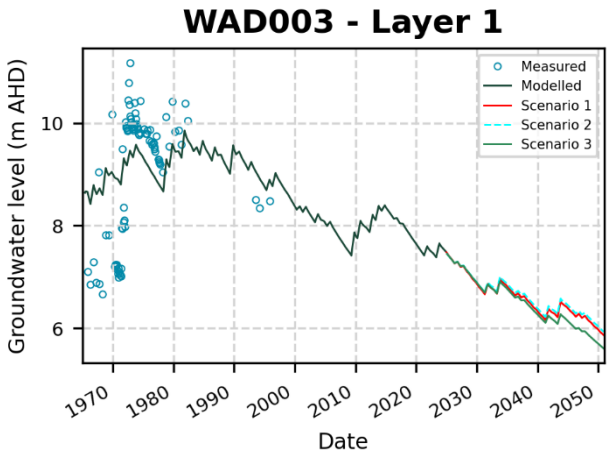

TAA061 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

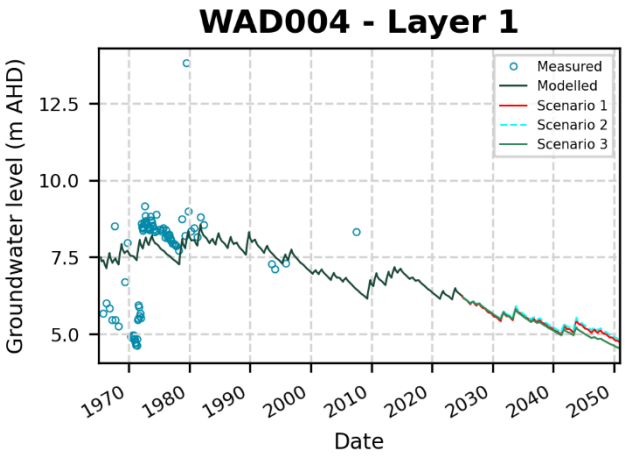

TAA065 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

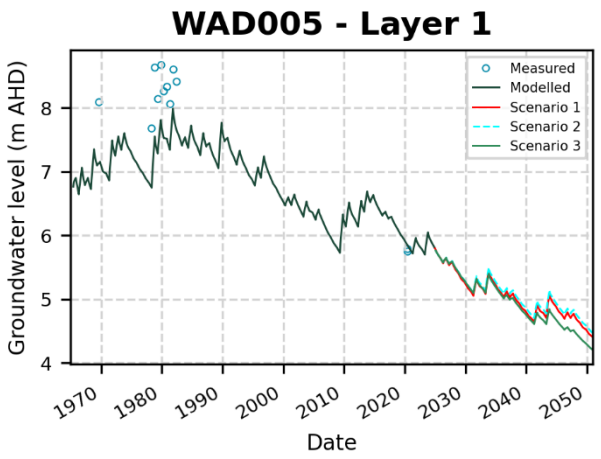

TAA068 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

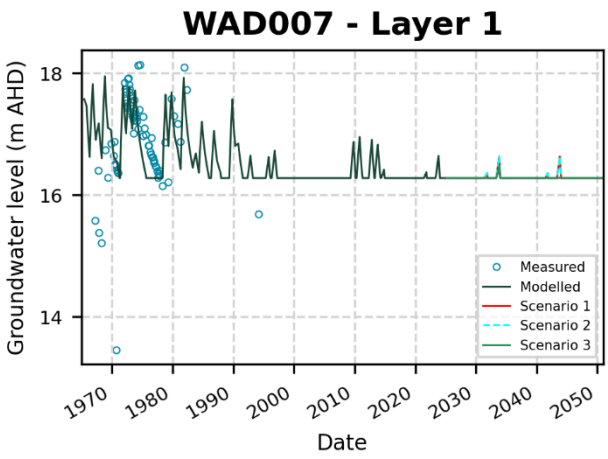

WAD001 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

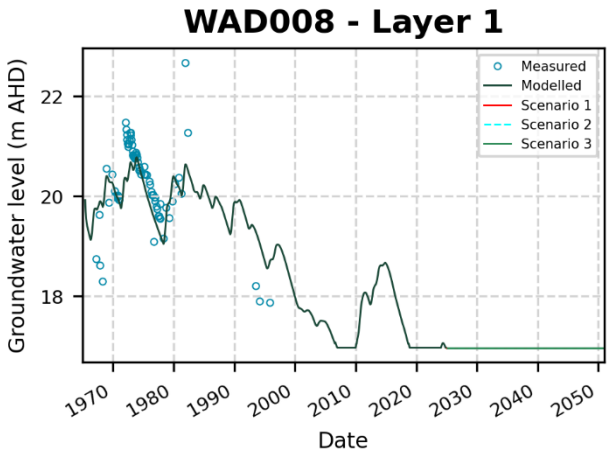

WAD002 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

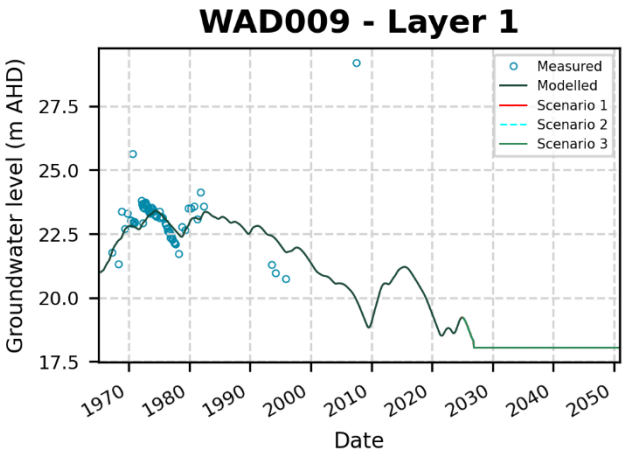

WAD003 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

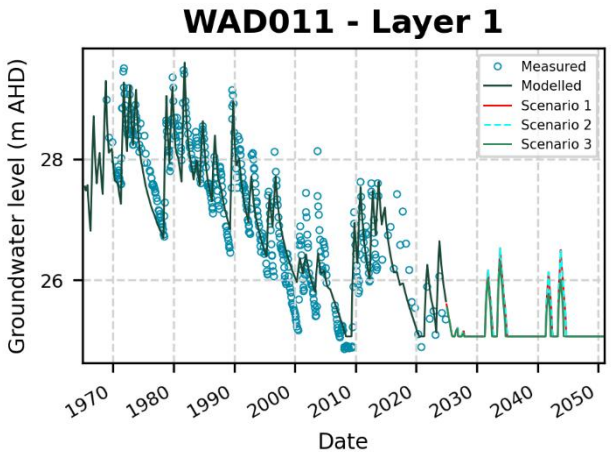

WAD004 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

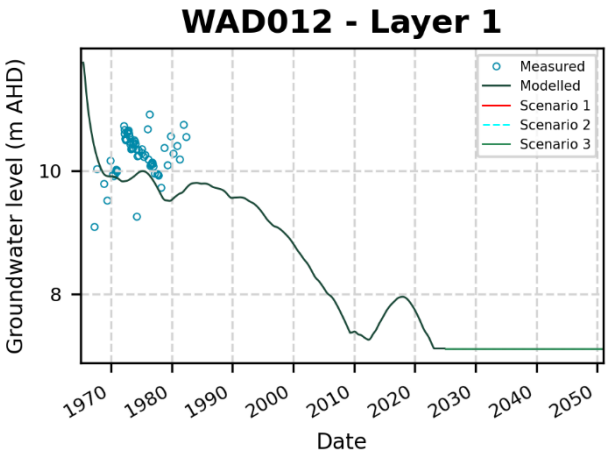

WAD005 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

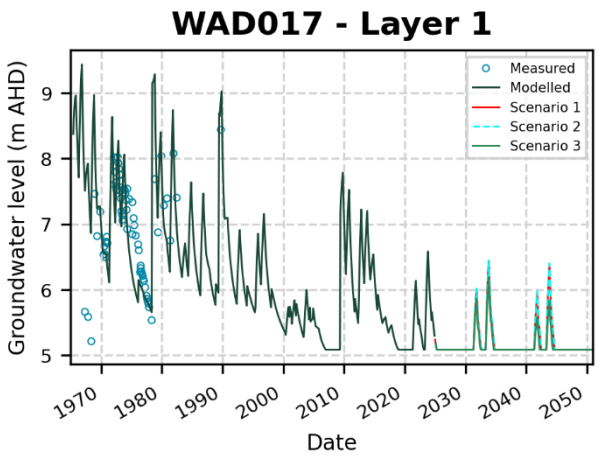

WAD007 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

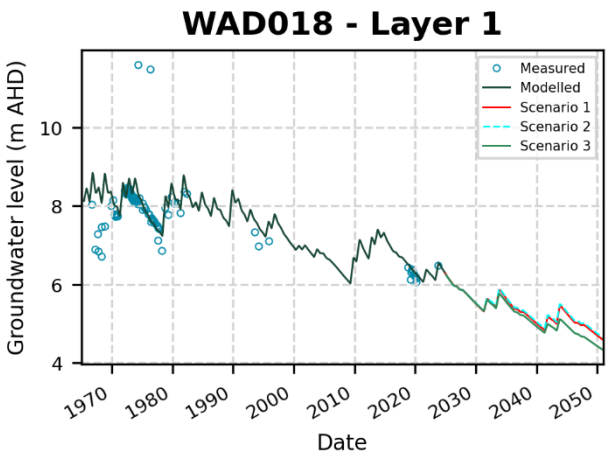

WAD008 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

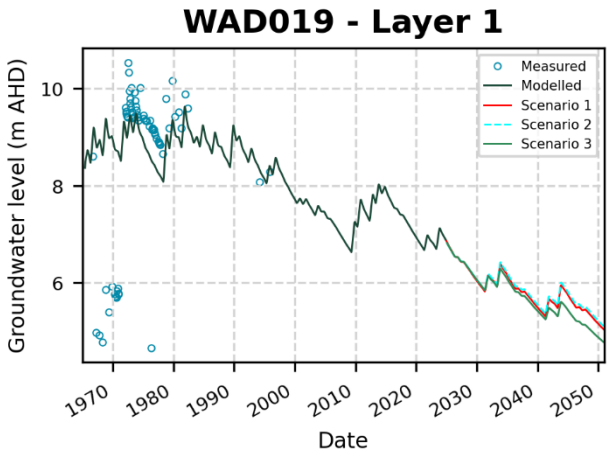

WAD009 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

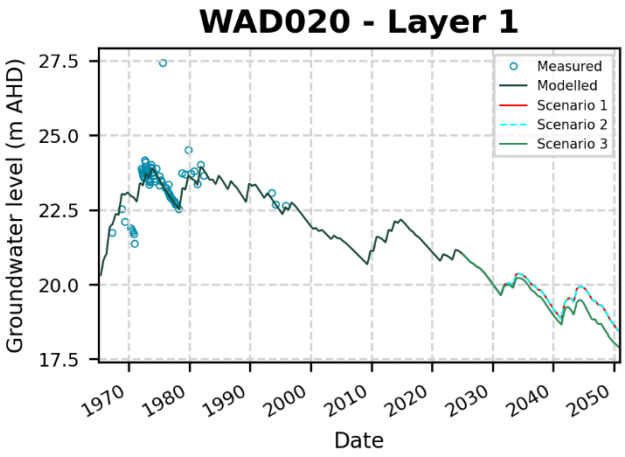

WAD011 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

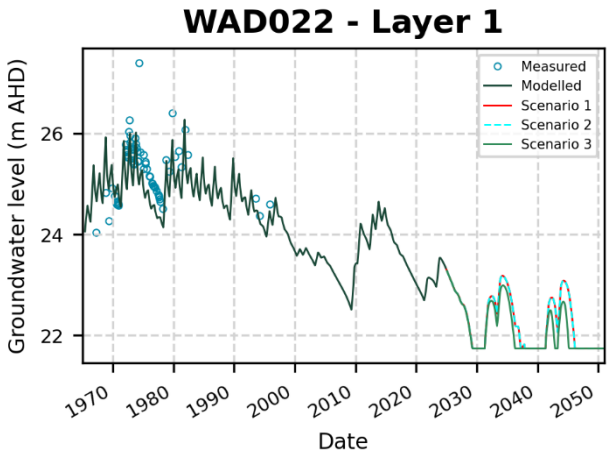

WAD012 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

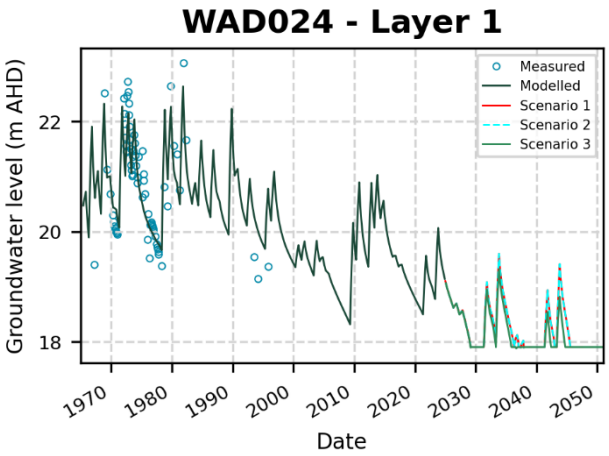

WAD017 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

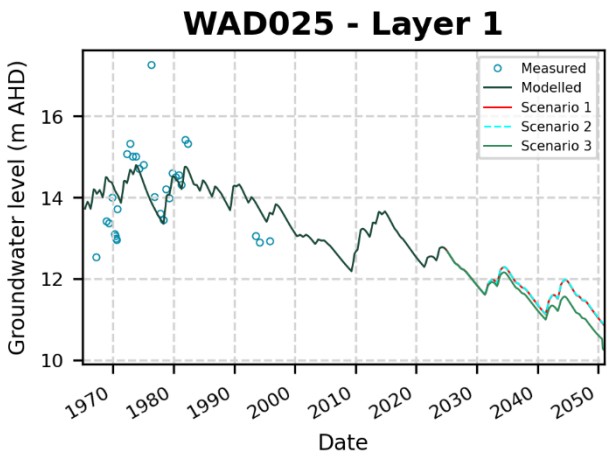

WAD018 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

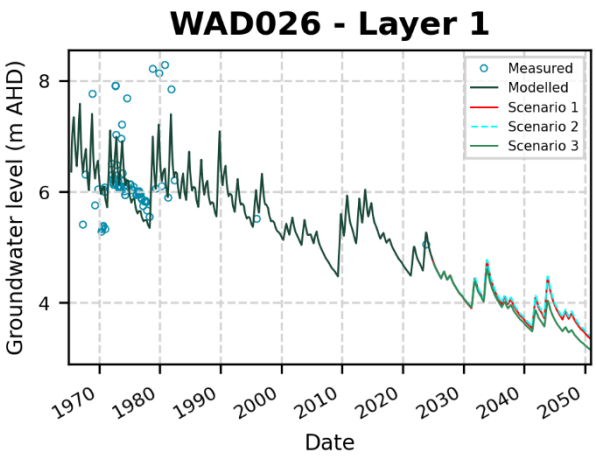

WAD019 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

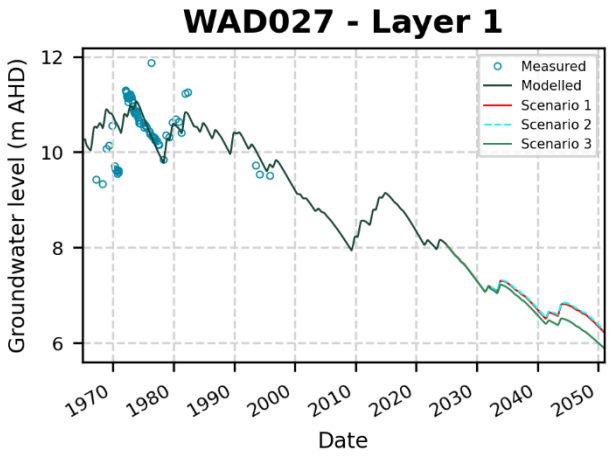

WAD020 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

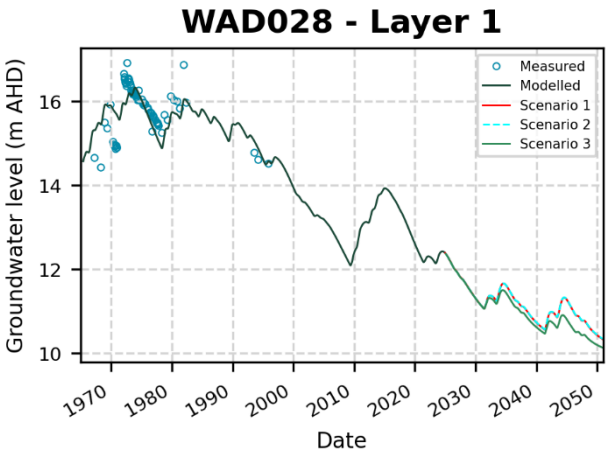

WAD022 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

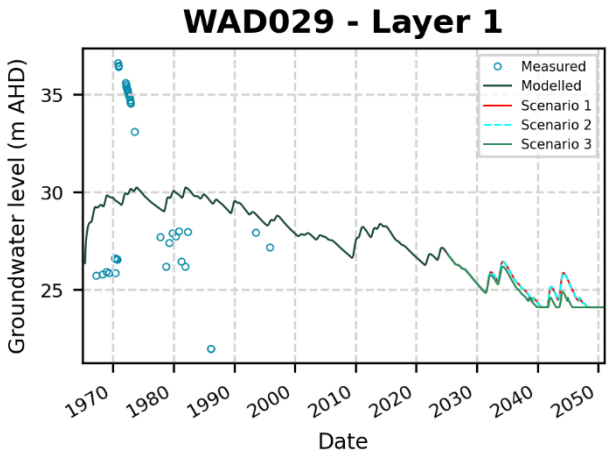

WAD024 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

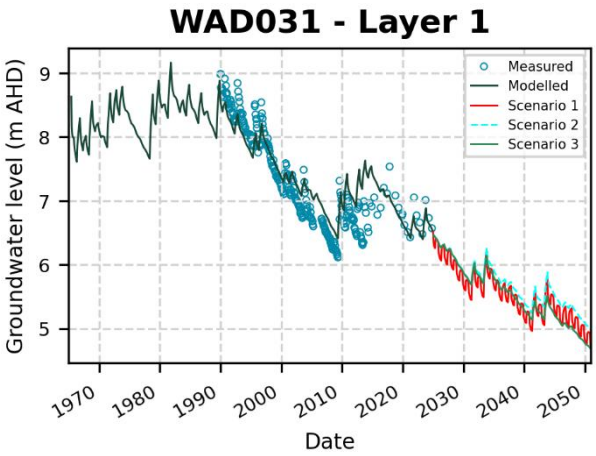

WAD025 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

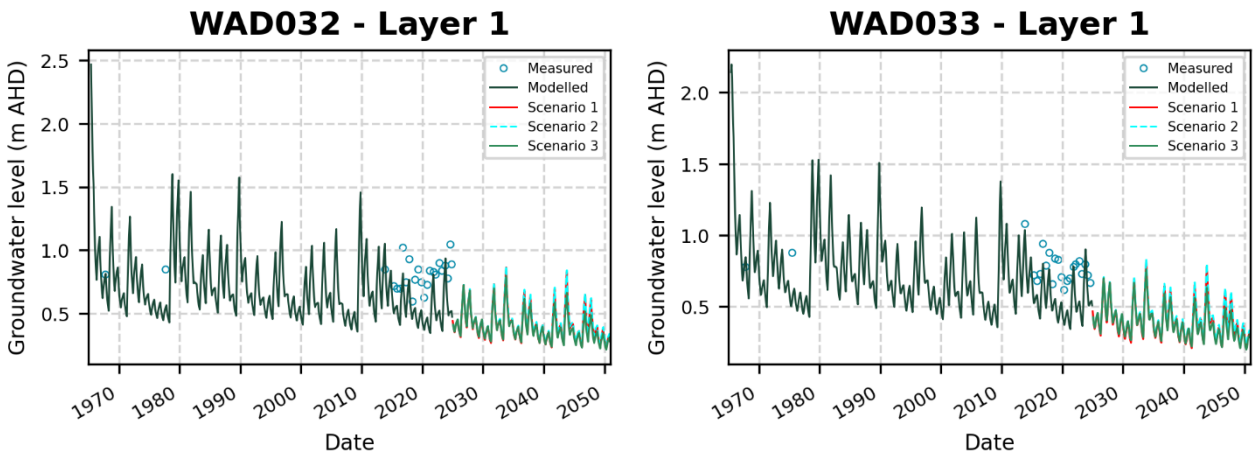

WAD026 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3


WAD027 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

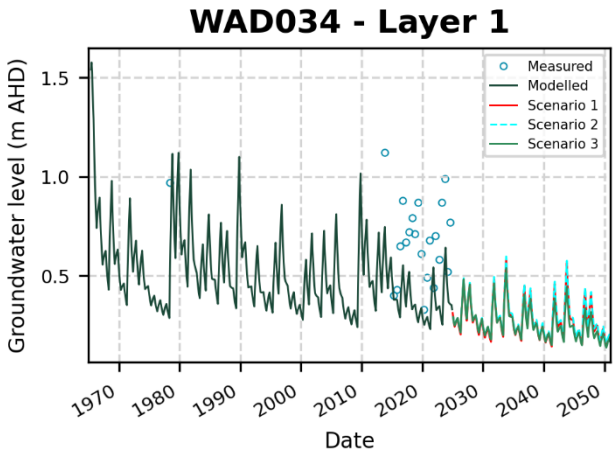

WAD028 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

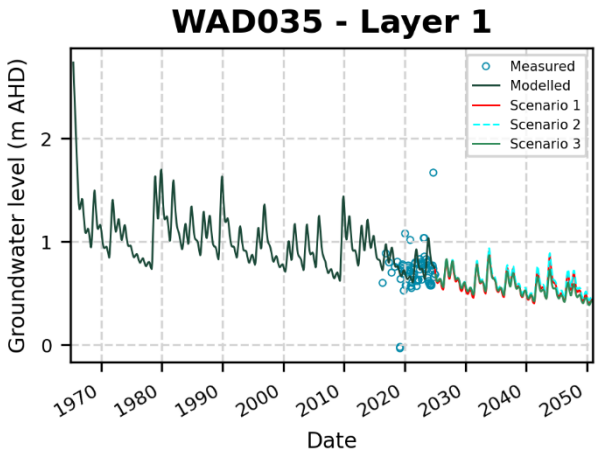

WAD029 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

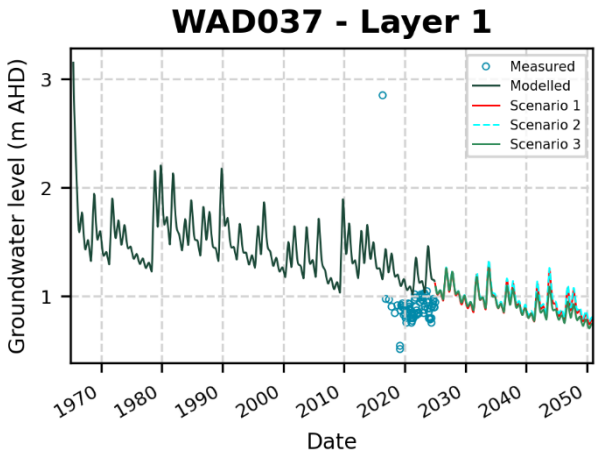

WAD031 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

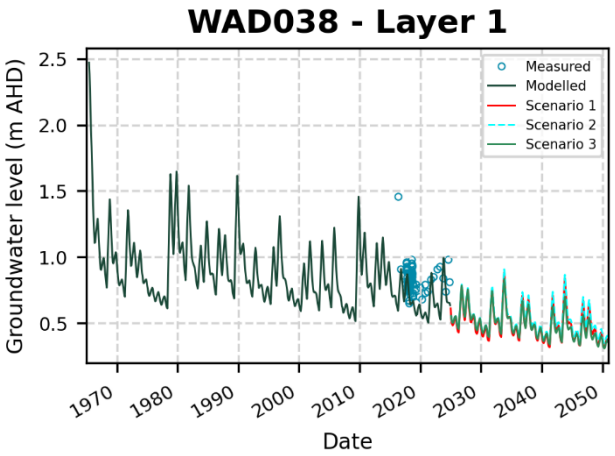

WAD032 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

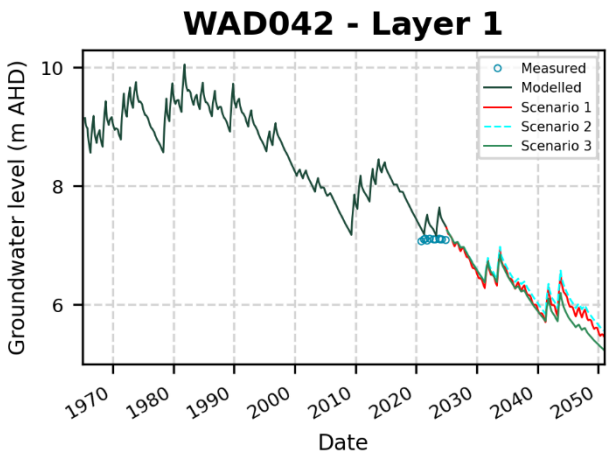
WAD033 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

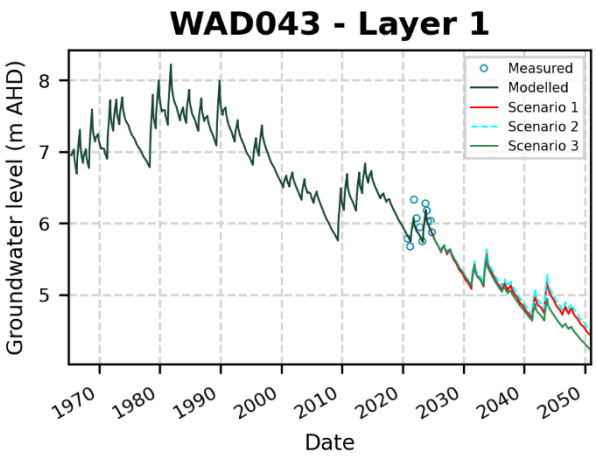

WAD034 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

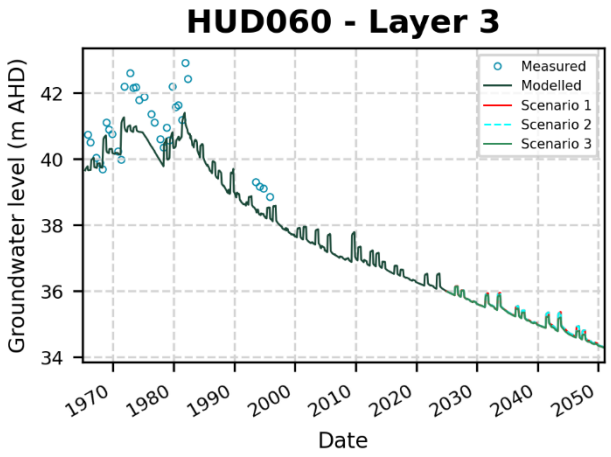

WAD035 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

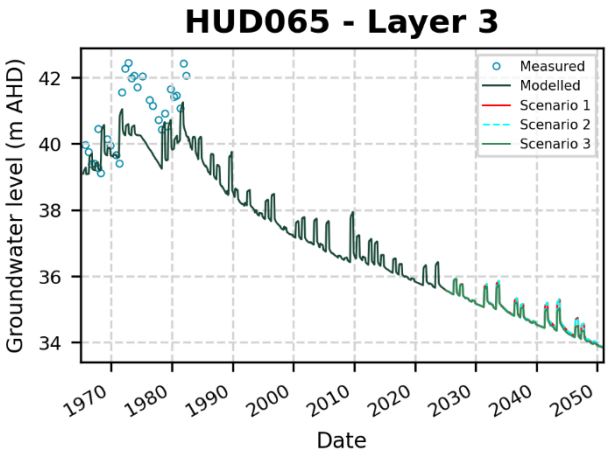

WAD037 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

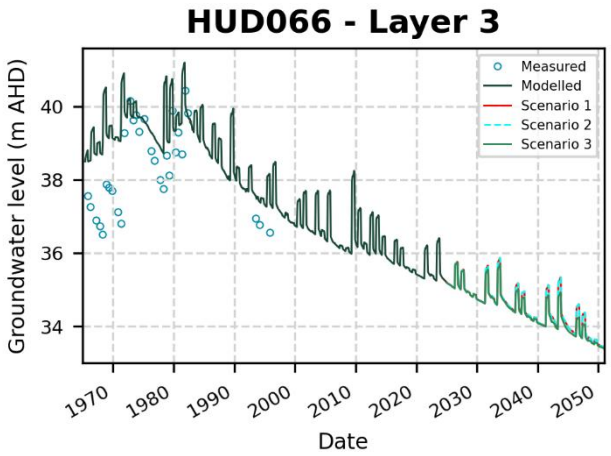

WAD038 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3

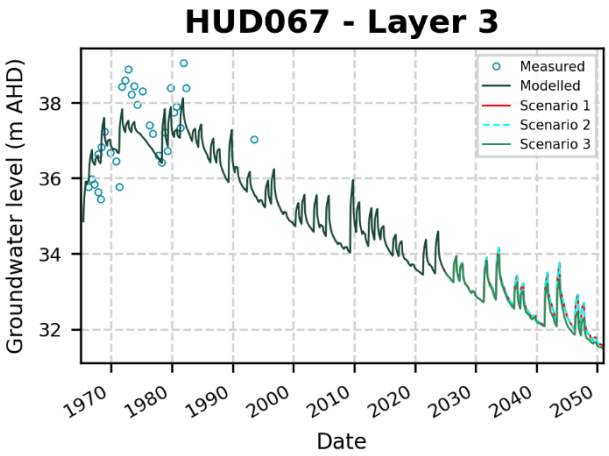

WAD042 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3


WAD043 - Layer 1
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3


HUD060 - Layer 3
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3


HUD065 - Layer 3
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3


HUD066 - Layer 3
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario 1
Scenario 2
Scenario 3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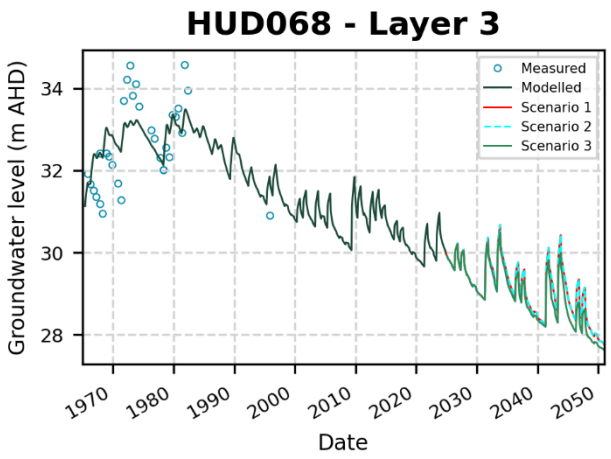
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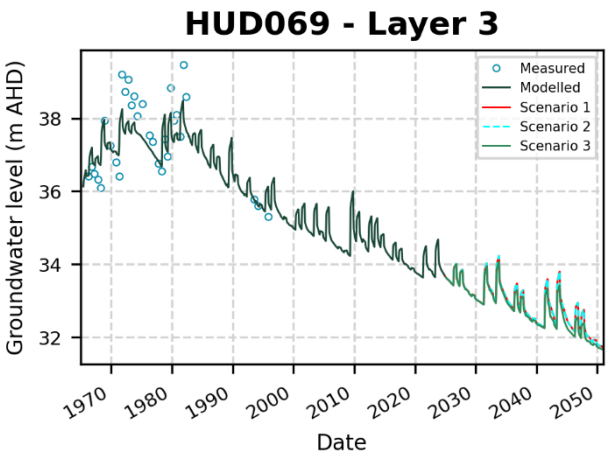
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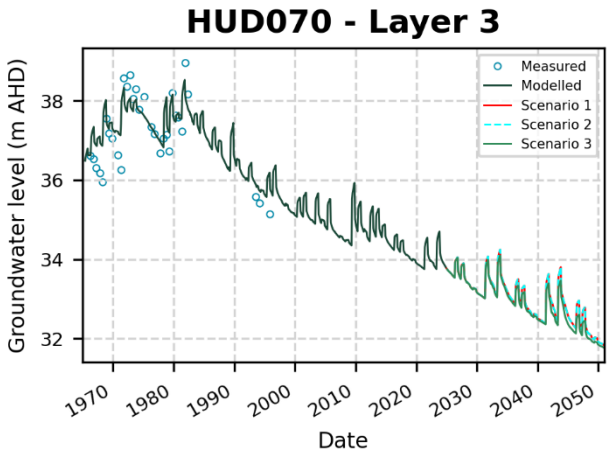
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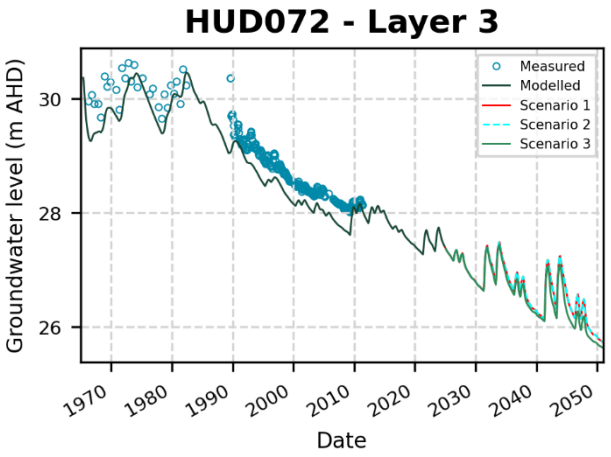
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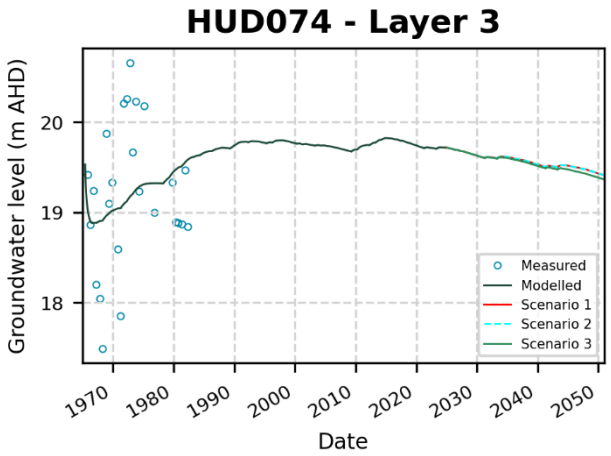
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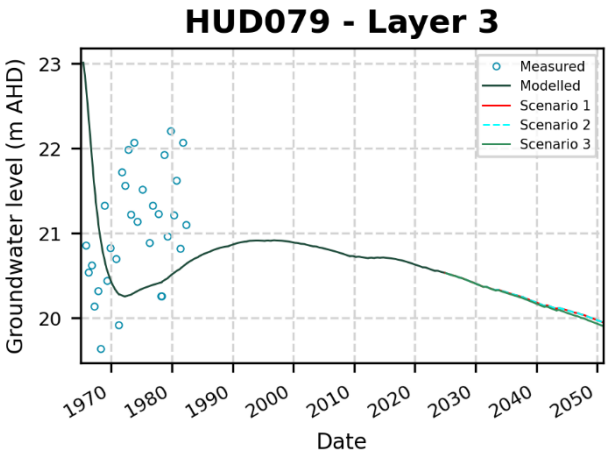
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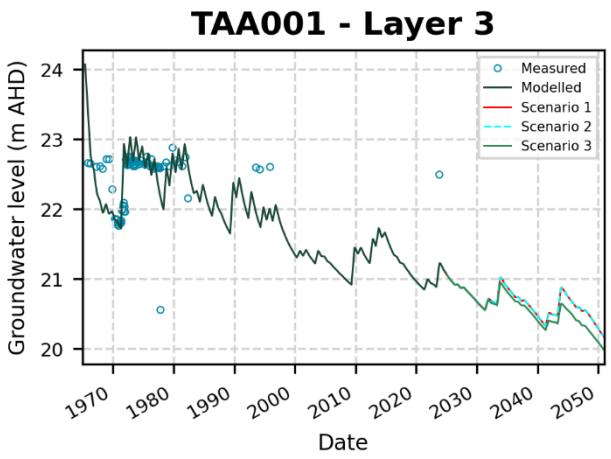
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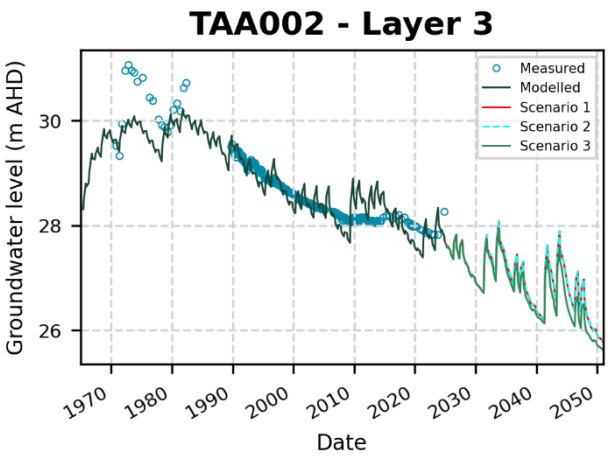
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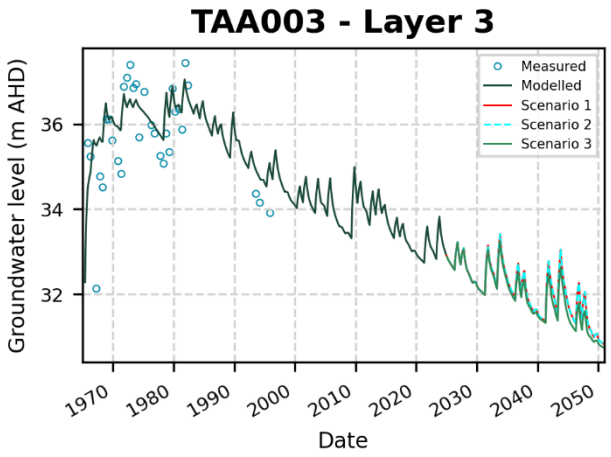
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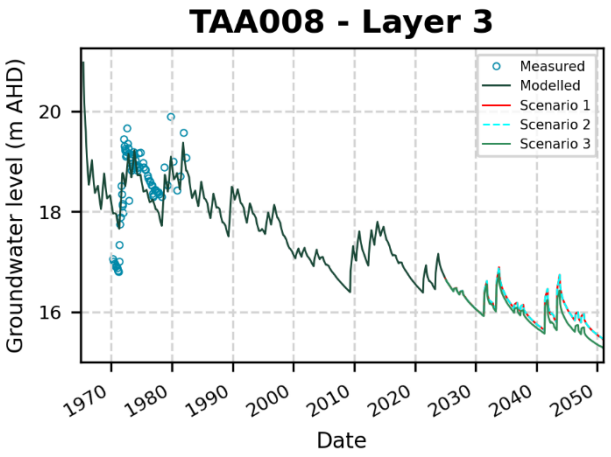
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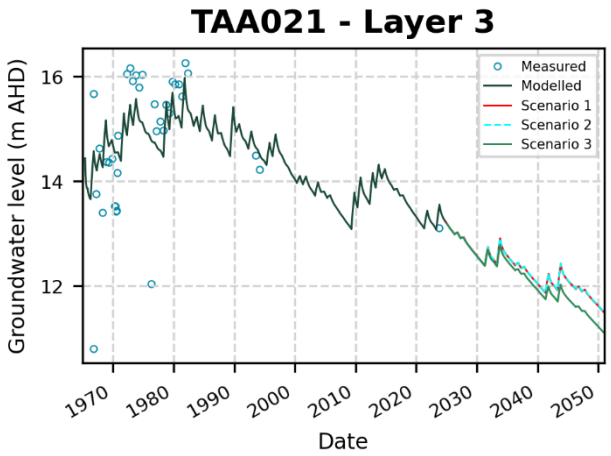
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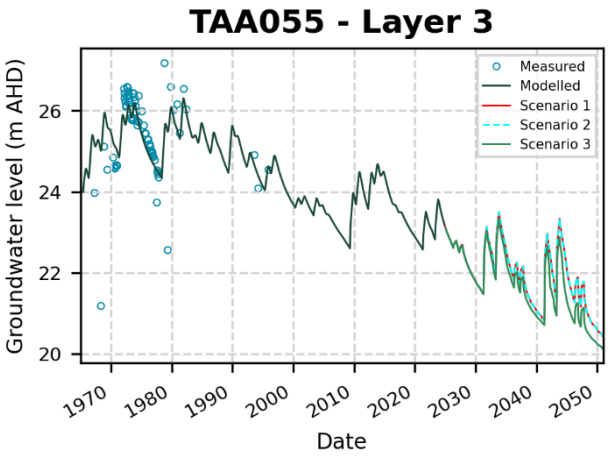
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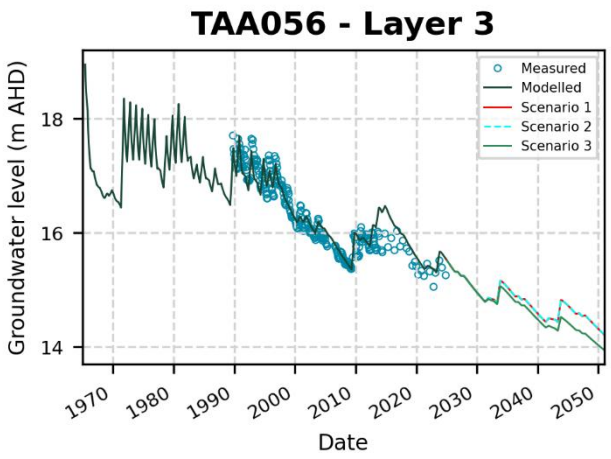
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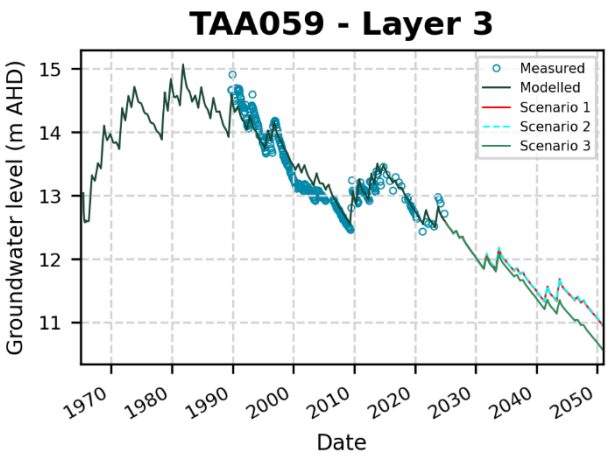
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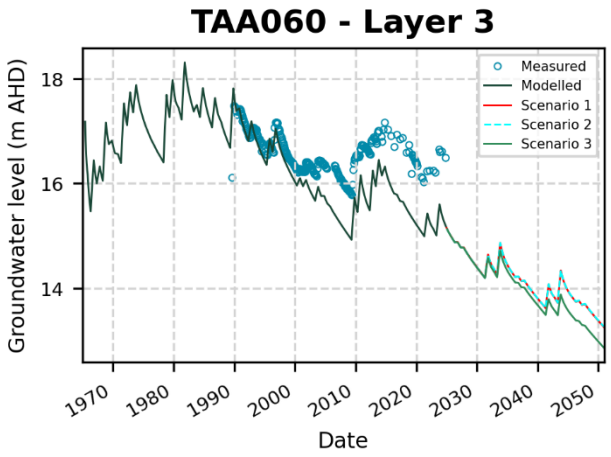
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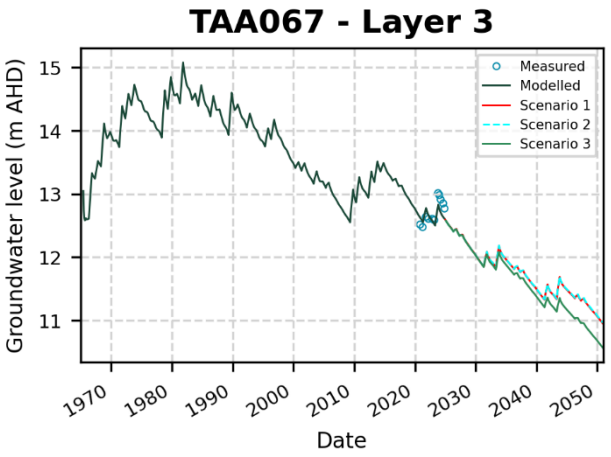
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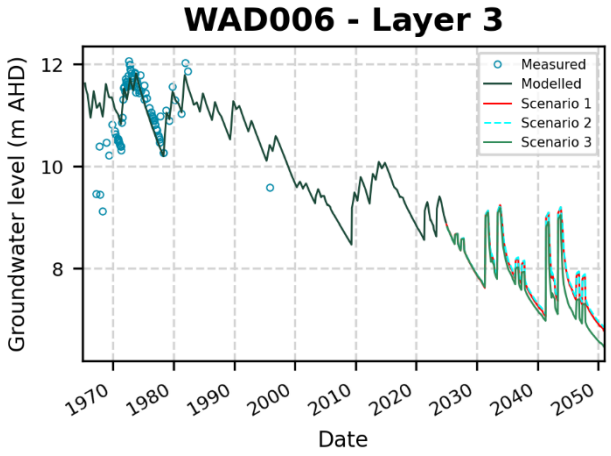
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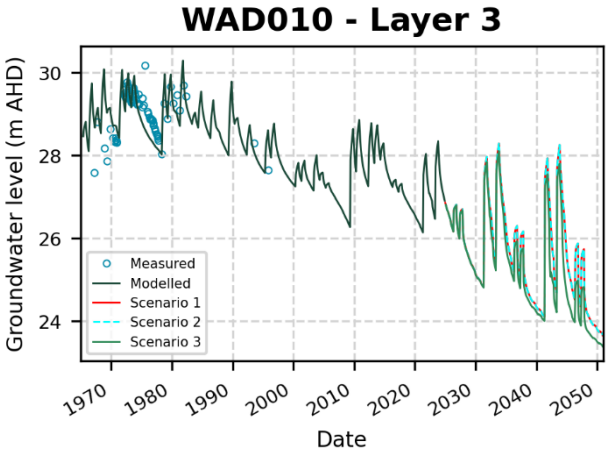
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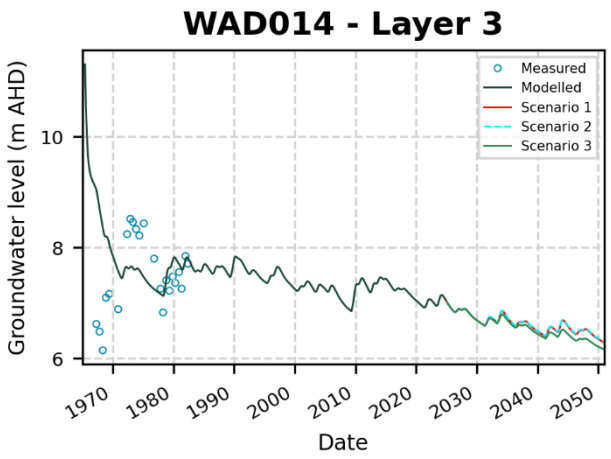
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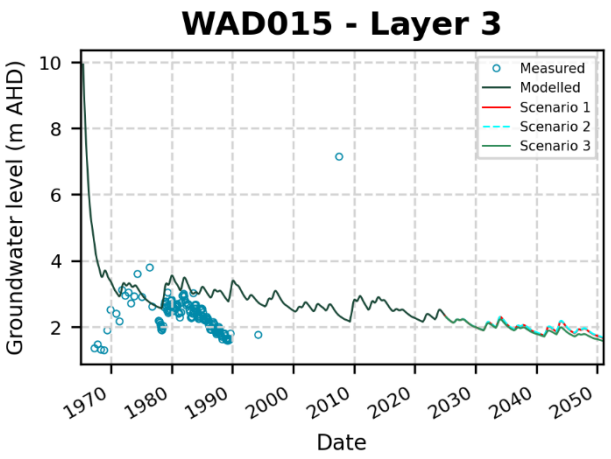
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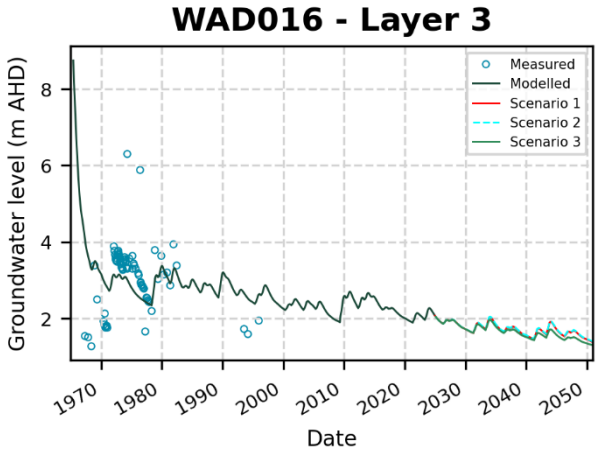
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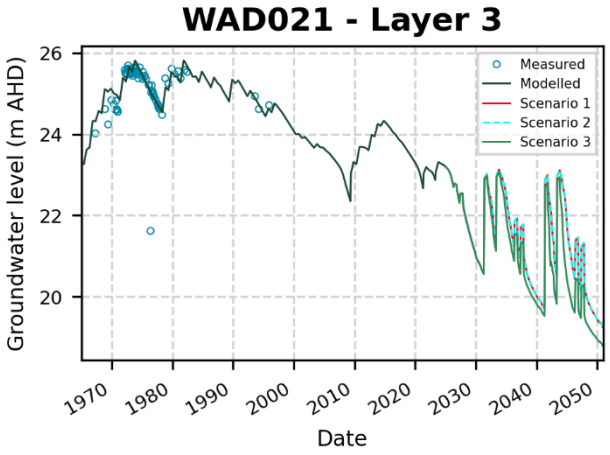
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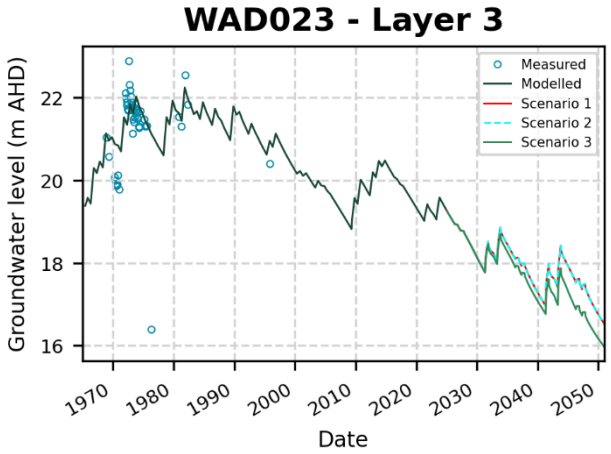
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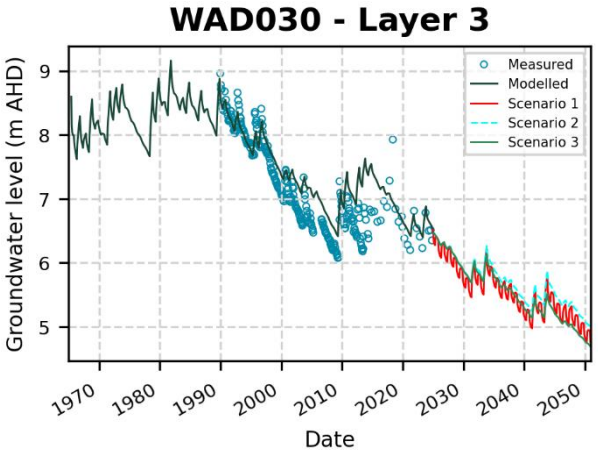
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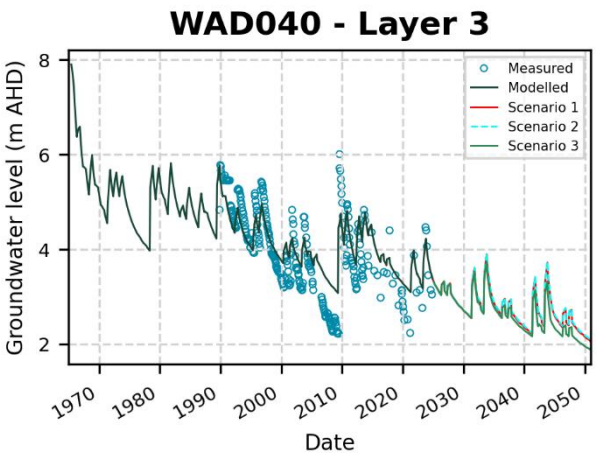
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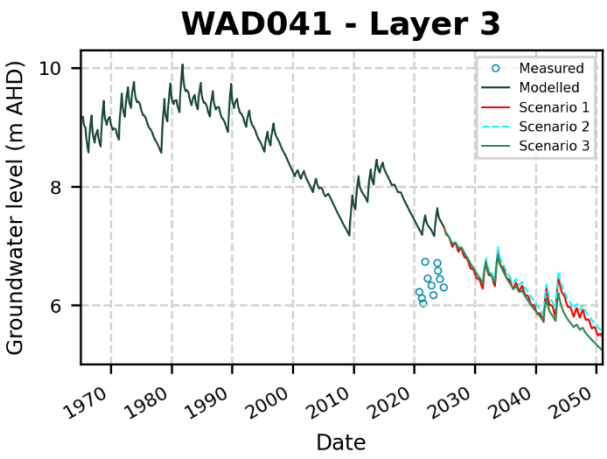
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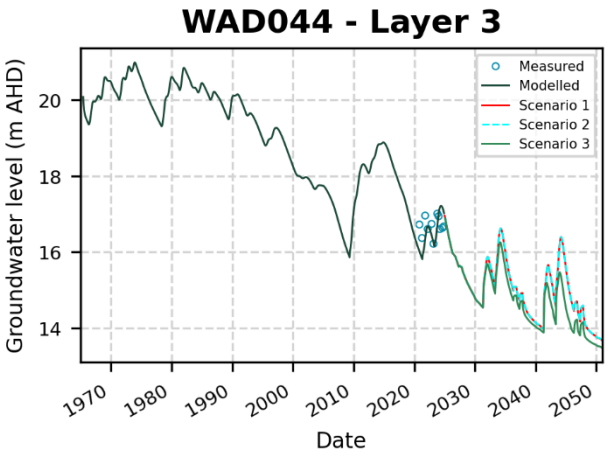
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