Uley South groundwater model scenarios 2021

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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.

John Schutz
CHIEF EXECUTIVE
DEPARTMENT FOR ENVIRONMENT AND WATER

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Summary

This document summarises two model scenarios run with the Uley South groundwater model (DEW, 2020). The work follows scenarios run in 2020, with additional model updating. Scenarios assess the impact of future pumping and recharge on groundwater level and seawater intrusion in the Uley South Basin. Groundwater from the Uley South Basin is the main source of municipal water supply on the Eyre Peninsula, with current extraction of ~ 5 GL/y. Low rainfall and recharge conditions and declining groundwater levels have raised the risk profile for groundwater resources in Uley South in recent years, and SA Water has announced plans for a desalination plant to secure future water supply. This will reduce the reliance on groundwater resources in the basin, lowering the risk profile.

The scenarios use the Uley South groundwater model, developed by DEW (2020). The model was developed in MODFLOW and the position and movement of the seawater interface is simulated with the SWI2 package. The scenarios assume low rainfall/recharge conditions observed from 2015–20 persist into the future, with the five years of recharge rates repeated on a cycle from 2021 to 2040. Scenario 1 simulates a pumping rate of 5 GL/y from town water supply (TWS) wells, while scenario 2 simulates a pumping rate of 6.8 GL/y.

Results show that in scenario 1, ongoing groundwater level decline is observed, with groundwater levels declining to historic lows observed in the late 1990s in some, but not all locations. Accompanying the long-term decline in groundwater level is a long-term increase in the movement of the seawater interface inland, by a maximum of ~650 m by 2040. In scenario 2, groundwater levels decline close to and in some cases below the historic lows observed in the late 1990s. This results in further inland movement of the seawater interface, likewise by up 650 m, however the spatial extent of inland seawater intrusion is greater in scenario 2.

1 Introduction

1.1 Background

Groundwater is a critical source of water for the Eyre Peninsula, making up the majority of water sourced for municipal supply (EPNRMB, 2016). Groundwater from the Quaternary Limestone (QL) aquifer in the Uley South Basin provides most of this supply, with average annual extraction of approximately 5 GL (Figure 1.1). In 2018 SA Water contracted the Department for Environment and Water (DEW) to develop a groundwater flow model for the Uley South Basin. The model was used to assess the impact of various groundwater extraction and rainfall/recharge scenarios on groundwater levels in the basin. The model also simulated the position and movement of the seawater interface using the SWI2 package (Bakker et al. 2013).

The model was calibrated to groundwater level measurements from 1961 to 2017, and scenarios originally run from 2018 to 2040. Since modelling was completed, low rainfall and recharge conditions have persisted, and groundwater levels have continued to decline. A desalination plant is planned for the Eyre Peninsula, however groundwater resources in the Uley South Basin remain the main source of supply for the region until a plant is operational.

1.2 Objectives

The objective of this report is to document two additional model scenarios developed in January 2021, to assess the impact of pumping under continued low recharge conditions on groundwater level and seawater intrusion. Scenarios assess the impact of continued pumping at the current rate 5 GL/y and at an increased rate of 6.8 GL/y. In preparing these scenarios, the model was updated with new pumping data for the period 2018–20.

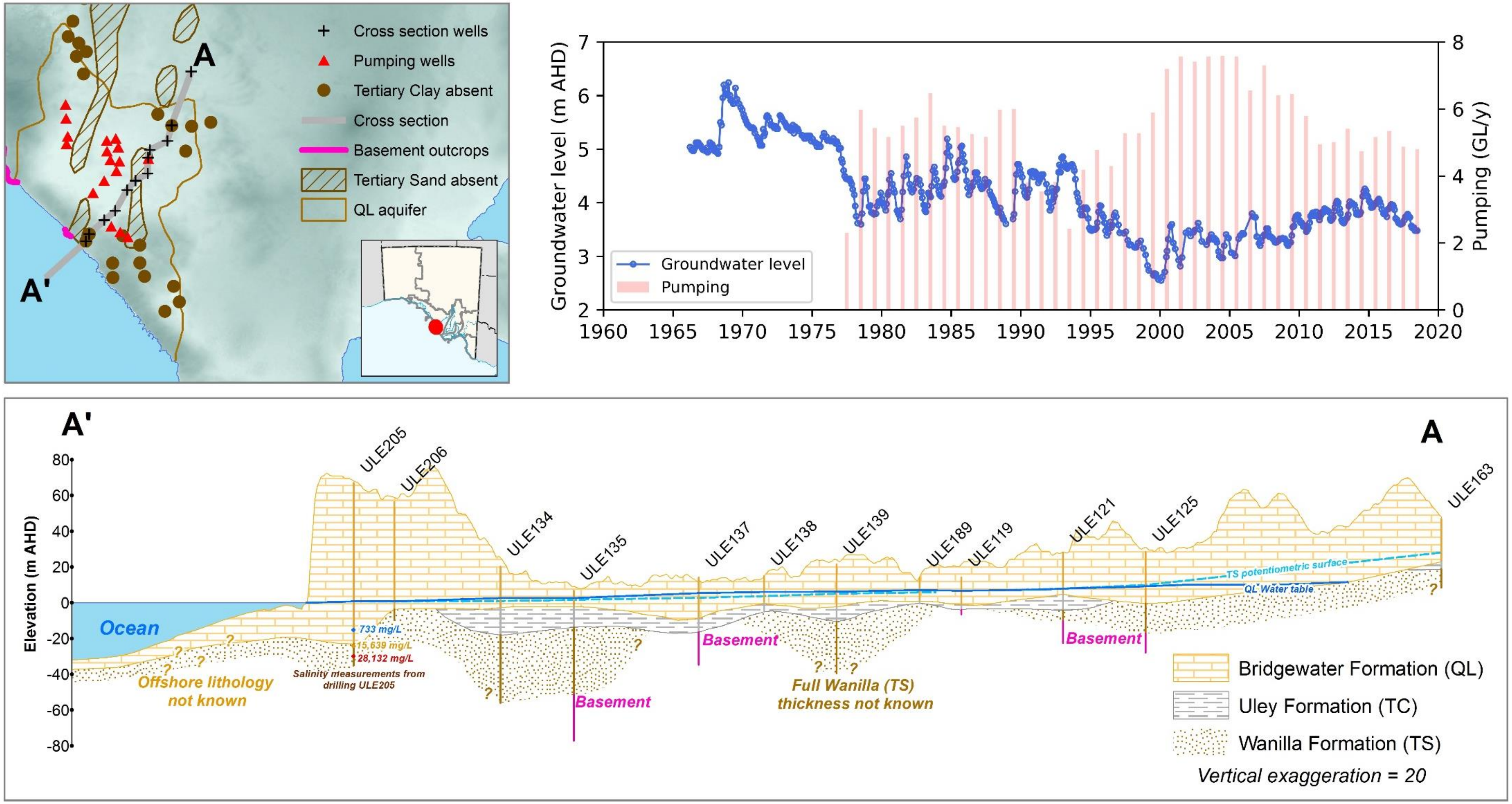


Figure 1.1. The Uley South Basin

2 Method

2.1 Model update

The Uley South groundwater model (DEW, 2020) was developed and calibrated to the best available information at the time. This included metered pumping data up to December 2017, with scenarios run from January 2018 onwards based on projected pumping rates (e.g. 3.5 GL/y, 5 GL/y, 6.8 GL/y). As part of this scenario exercise, metered pumping data from January 2018 to December 2020 was obtained from SA Water (Figure 2.1), and used to update the model to December 2020. No additional model calibration was performed.

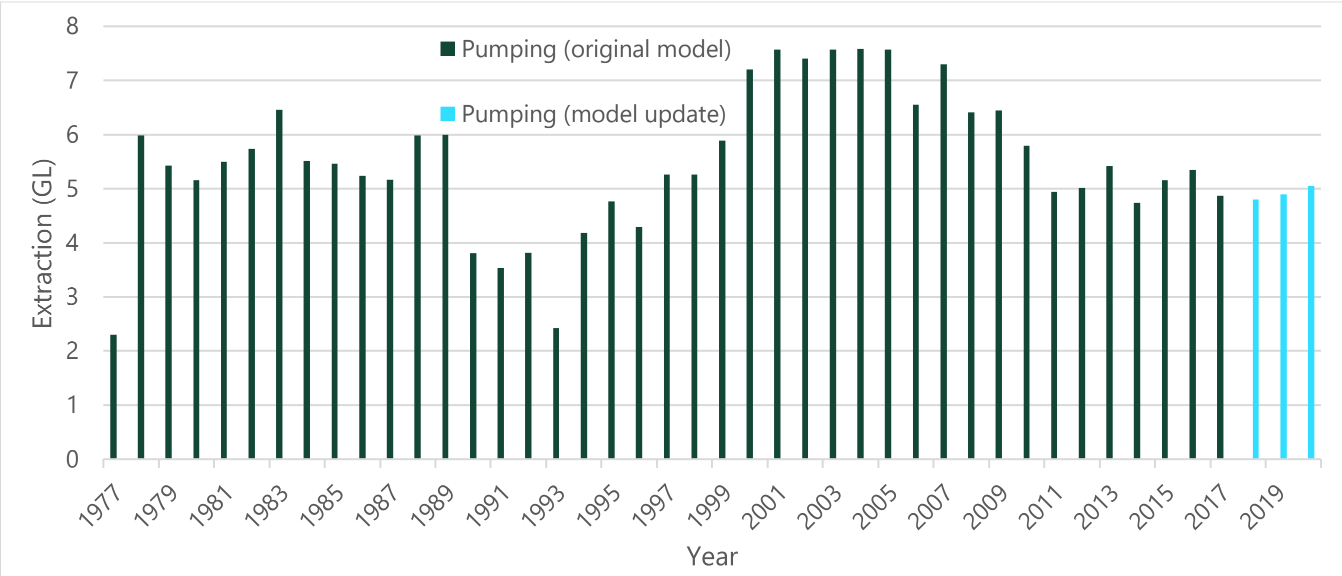


Figure 2.1. SA Water pumping data for Uley South Basin

2.2 Scenarios

Scenarios run from 2021 to 2040, with recharge from 2015 to 2020 repeated on a cycle, assuming low recharge conditions persist into the future. Scenario 1 simulates the impact of pumping 5 GL/y, continuing the current average rate of extraction. Scenario 2 simulates the impact of pumping 6.8 GL/y (Table 2.1). The spatial distribution of pumping rates between the 17 pumping wells in the basin is based on the distribution used in the original model (Figure 1.1). Likewise, the temporal distribution in the scenarios is the same as the original model, with monthly stress periods and generally higher pumping during summer months (DEW, 2020).

Table 2.1. Model scenarios

Scenario	Pumping	Recharge
1	5 GL/y	Recharge based on 2015-20
2	6.8 GL/y	Recharge based on 2015-20

Scenario results are shown as modelled groundwater levels for a series of observation wells and the modelled position of the seawater interface in a coastal observation well. One of the wells for which modelled trends are shown is ULE190. ULE190 is located adjacent to inland productions well TWS3-20 (town water supply (TWS) well

TWS3 was replaced with well TWS20 in 2014). This is a well which showed increased salinity in the late 1990s when groundwater levels were at a minimum (Figure 2.2). This increase in salinity was attributed to increased flow from the underlying TS aquifer, based on modelling results (DEW, 2020). Three other TWS bores have shown salinity increases as groundwater levels have declined (Figure 2.2).

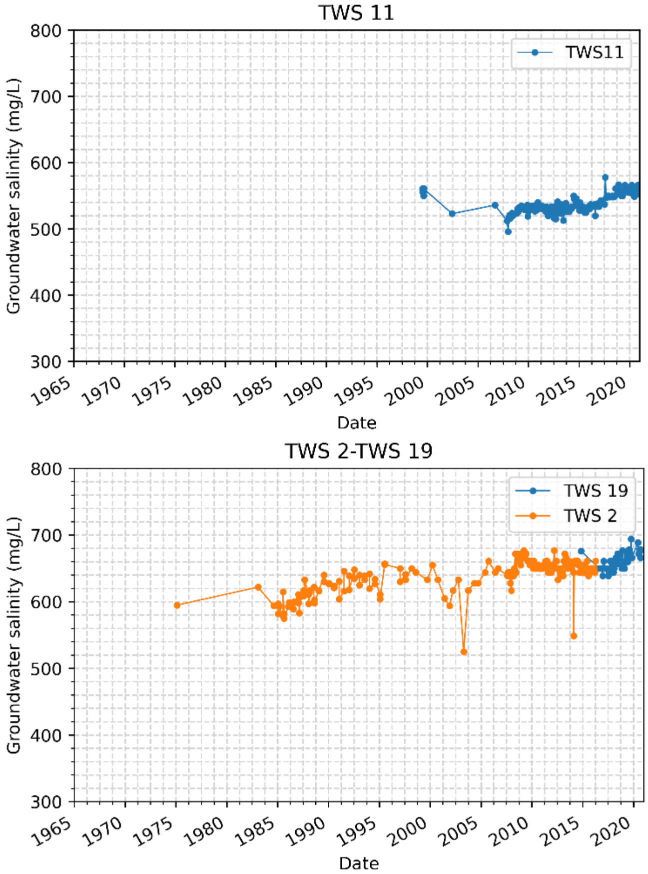


Figure 2.2. Groundwater salinity trends in production wells

3 Results

3.1 Model update

The updated pumping data used in the model from January 2018 to December 2020 resulted in a generally good fit (Figure 3.1). In some areas the fit is better than others, generally consistent with the original model results from 1961-2017. No attempt to re-calibrate or improve the fit was made, and the results here can be considered a post-audit. Further refinement to the model can be made in future if required.

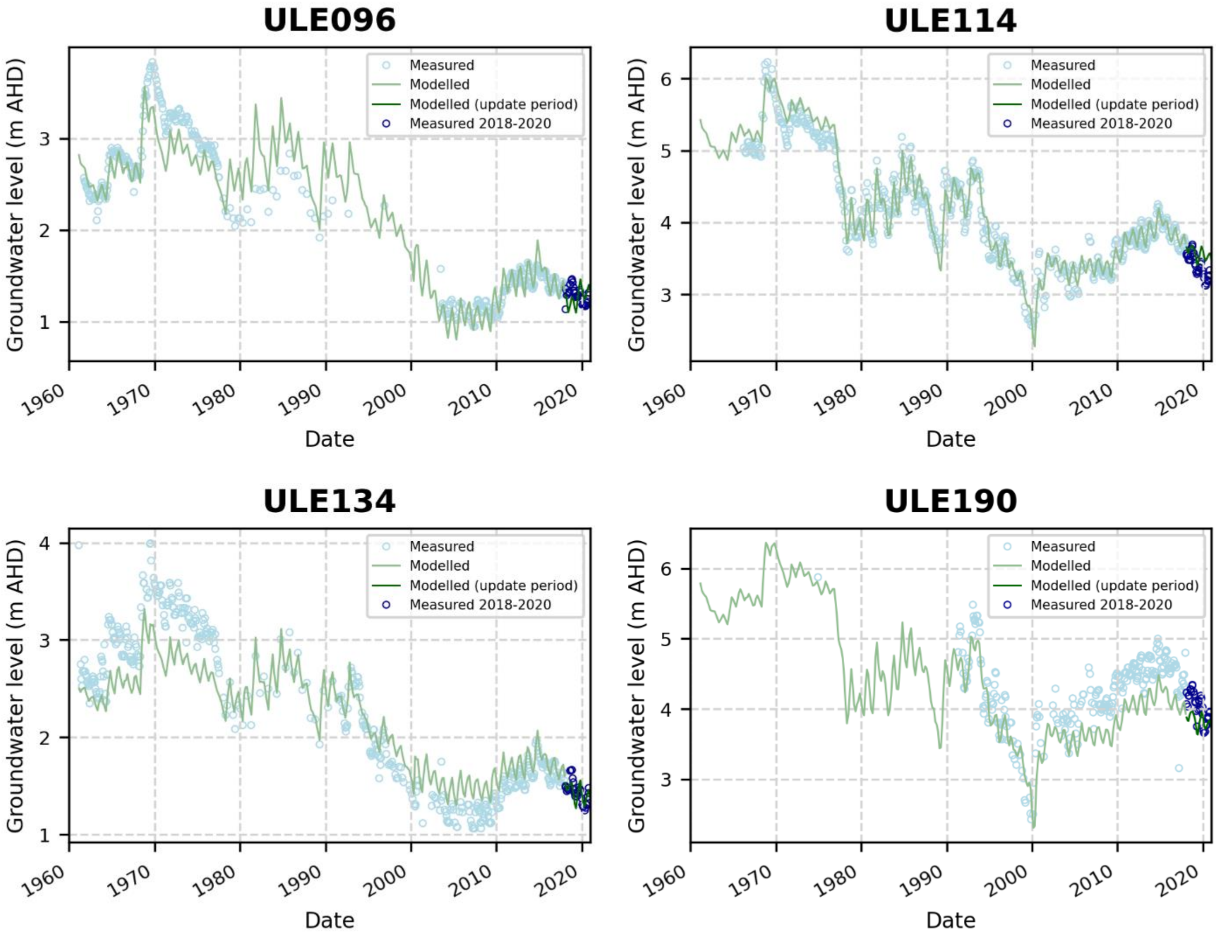


Figure 3.1. Examples of model fit for the period of update (2018–20)

3.2 Scenarios - groundwater level

Modelled groundwater level results are presented for selected observation wells ULE096 (north-western pumping wells), ULE114 (south of main 8 supply wells), ULE134 (adjacent to southern pumping wells) and ULE190 (Figure 3.1). ULE190 is located adjacent to town water supply (TWS) well 3 (replaced by TWS well 20), see Appendix A for a map of observation well and pumping well locations. TWS3 showed an increase in salinity in the late 1990s as groundwater extraction increased and groundwater level decreased. This increase in salinity was attributed to increased flow from the underlying TS aquifer (DEW, 2020). Results from additional observations wells can be found in Appendix B and C.

Scenario 1 shows that groundwater levels generally decline towards 2040. Levels remain well above the historic lows they declined to in the late 1990s in ULE114 and ULE190, while declining close to historic lows elsewhere (Figure 3.2). In scenario 2 groundwater levels decline as a result of the increased extraction rate (Figure 3.2). In some cases levels decline below historic minimums (ULE096 and ULE134) while elsewhere the decline to historic minimums (ULE114, ULE190). Based on past observations of groundwater level and salinity at ULE190 and TWS3, these declines may result in increased salinity resulting from inflow from the underlying TS aquifer.

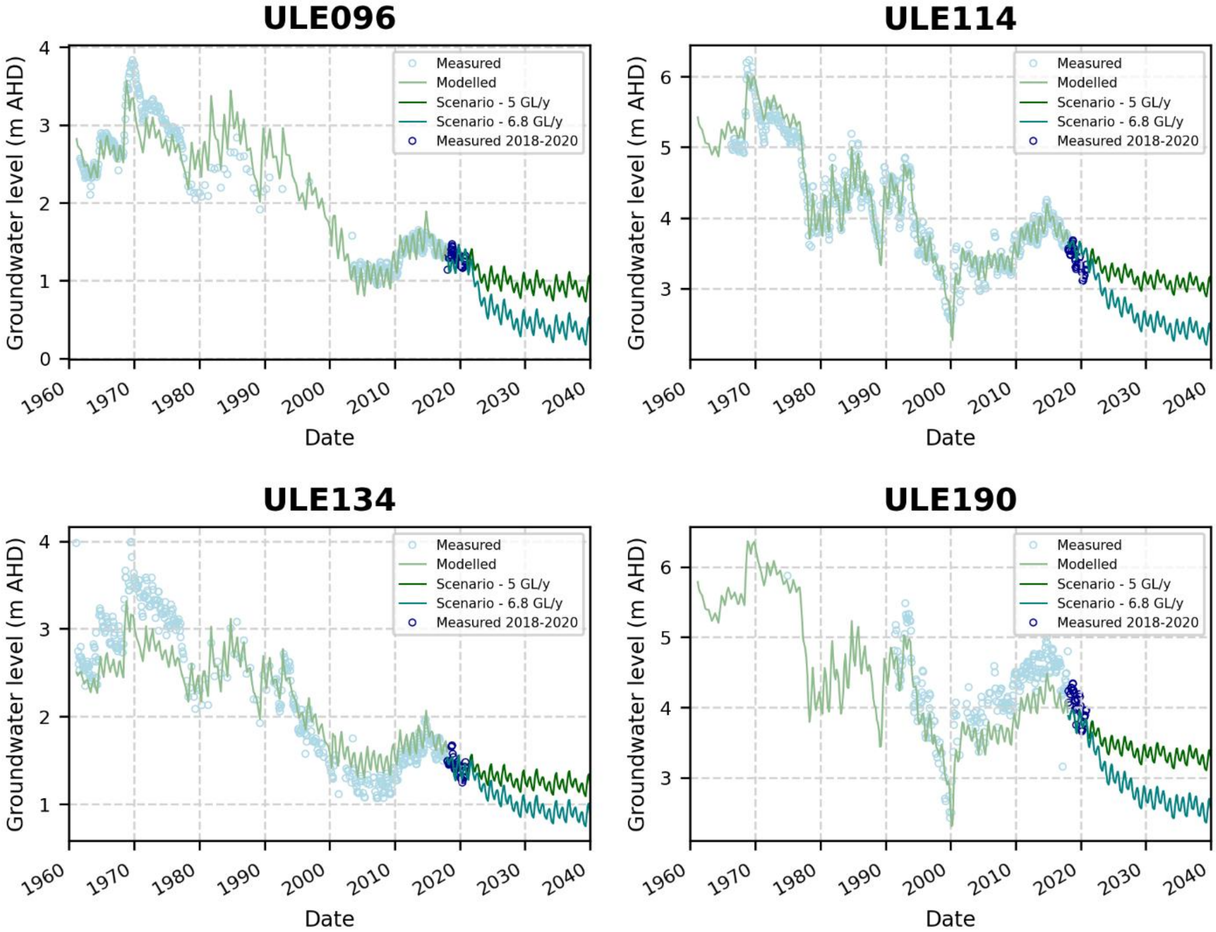


Figure 3.2. Examples of modelled groundwater levels for scenario 1 and 2

3.3 Scenarios - seawater interface

Position and movement of the seawater interface was modelled using SWI2 (Bakker et al. 2013). Results show that in scenario 1, where pumping remains at 5 GL/y from 2021 to 2040, the interface shows an increase in elevation of 2.8 m in SLE069 (Figure 3.3). This movement can be related to the declining trend in groundwater level in scenario 1 (Figure 3.2). In scenario 2 where pumping increases to 6.8 GL/y, the elevation of the interface in SLE069 increases by 3.9 m, associated with declining groundwater levels (Figure 3.3).

Figure 3.4 shows the position of the seawater interface toe – the location at which the interface intersects the base of the QL aquifer. This can be thought of as the furthest point inland that the interface extends. Results are shown for the recalibrated version of the model. In scenario 1 the interface toe is seen to migrate up to 650 m further inland. In scenario 2 the interface toe moves similarly up to 650 m further inland, however the spatial extent of inland movement is greater.

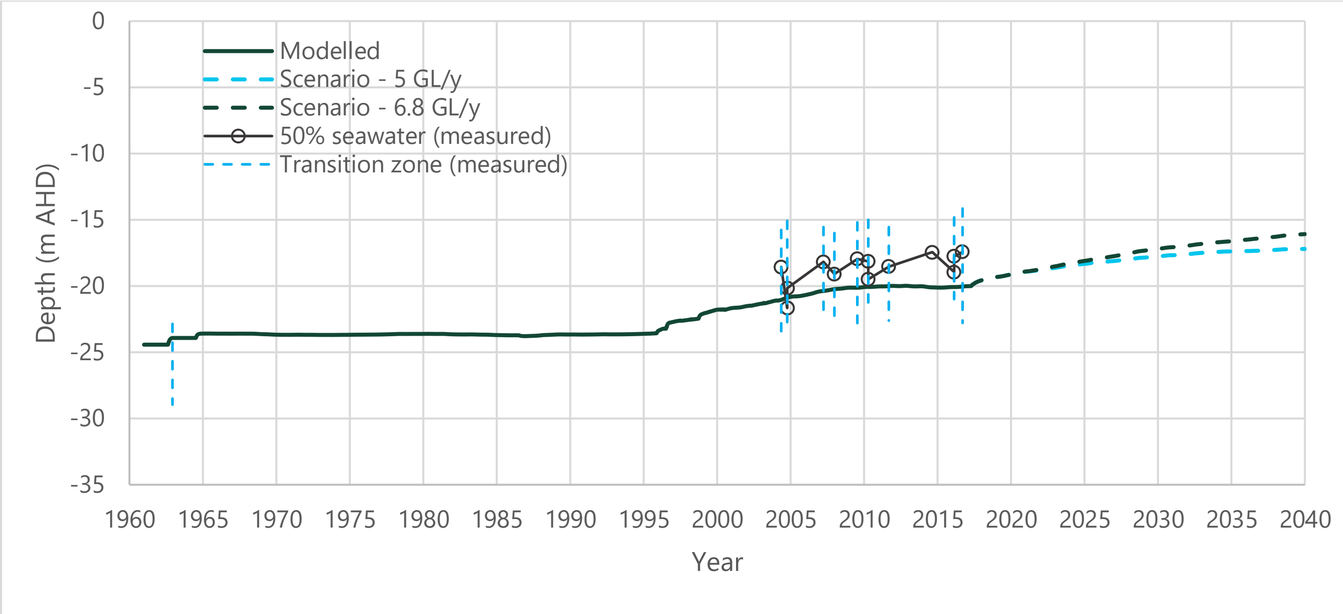


Figure 3.3. Modelled seawater interface at SLE069 in scenarios 1 and 2

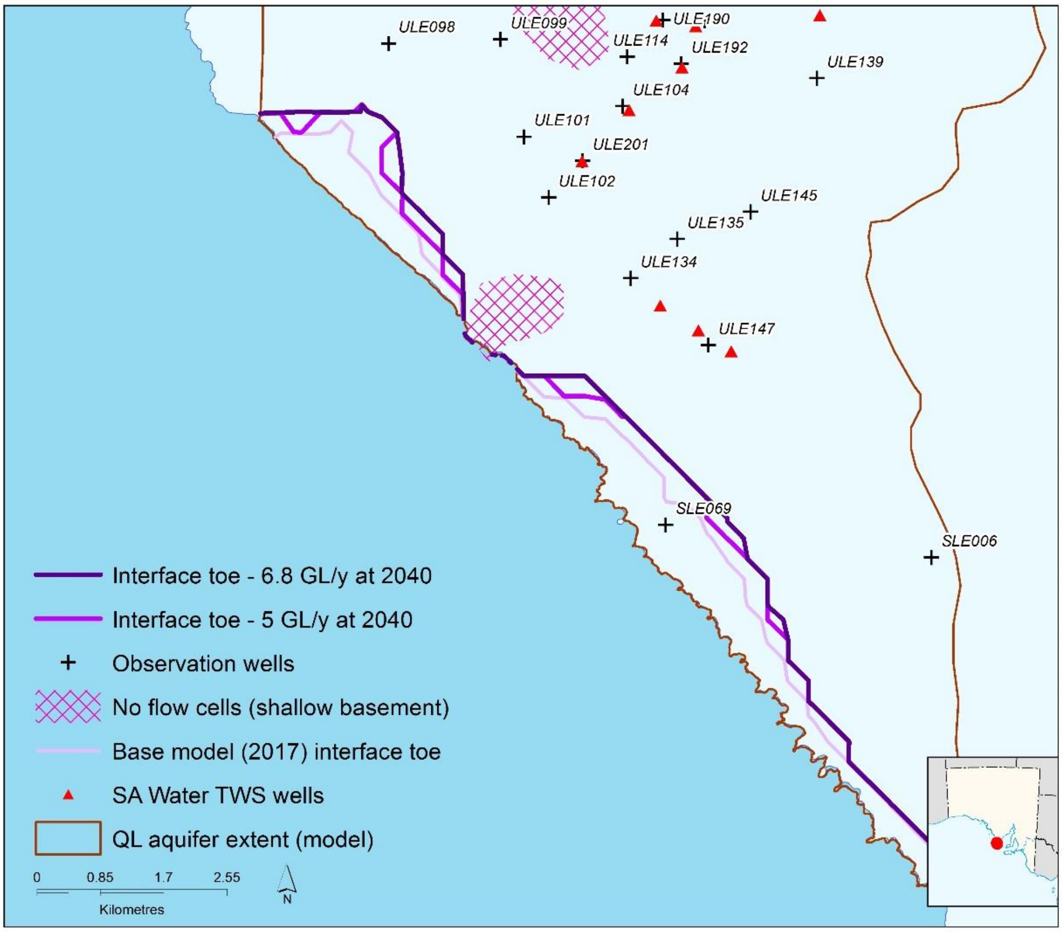


Figure 3.4. Position of the seawater interface toe (recalibrated model)

4 Conclusions and recommendations

4.1 Conclusions

The Uley South groundwater model (DEW 2020) has been updated to include pumping data from 2018–20. Two scenarios were run with the model to test the impact of future pumping and recharge on groundwater level and seawater intrusion. Scenario 1 simulated the impact of continued pumping at 5 GL/y from 2021 to 2040, with low rainfall/recharge conditions from 2015–20 repeated on a cycle. The modelled seawater interface increased in elevation by 2.8 m in monitoring well SEL069, and moved up to 650 m further inland in the eastern half of the basin. Movement of the interface inland corresponds with a long-term decline in groundwater level.

Scenario 2 simulated the impact of pumping 6.8 GL/y from 2021 to 2040, with low rainfall/recharge conditions from 2015–20 repeated on a cycle. The modelled seawater interface increased in elevation by ~3.9 m in monitoring well SEL069, and moved inland by up to 650 m in the eastern half of the basin, with a greater spatial extent of ingress compared to scenario 1. This inland movement of the interface corresponds with a decline in groundwater level from increased pumping. Groundwater levels are also observed to decline to and in some cases below the historic lows observed in the late 1990s. This may result in more inflow from the TS aquifer with implications for salinity in TWS wells, separate from any issues related to seawater intrusion.

Thus continued low recharge conditions in Uley South may result in further inland movement of the seawater interface, even if groundwater pumping remains at the current rate. Increased pumping will result in groundwater level declines in some cases below historic lows observed in the late 1990s. Based on the modelling, this will result in increased seawater intrusion risk. It may also have implications for salinity in TWS wells further inland. For example groundwater levels may decline to levels previously observed in the late 1990s as observed in in ULE190, with potential salinity implcaitions for inland production wells due to inflow from the underlying TS aquifer. Based on these findings, care should be taken in changing pumping rates in the basin into the future, and any changes in pumping should be accompanied by appropriate monitoring.

4.2 Assumptions and limitations

The Uley South groundwater model report (DEW, 2020) discusses the assumptions and limitations associated with the model in great detail. It should be reiterated here that the seawater interface is simulated using the SWI2 package in MODFLOW (Bakker et al. 2013). This package simulates a 'sharp interface', approximating the 50% seawater-freshwater isohaline, and does not simulate movement of seawater in the aquifer by diffusion or dispersion. Therefore the results showing movement and position of the interface do not represent full dispersive mixing of seawater intruding in the aquifer, and thus results may be an underestimate of the extent of seawater intrusion for the model and scenarios considered here.

4.3 Recommendations

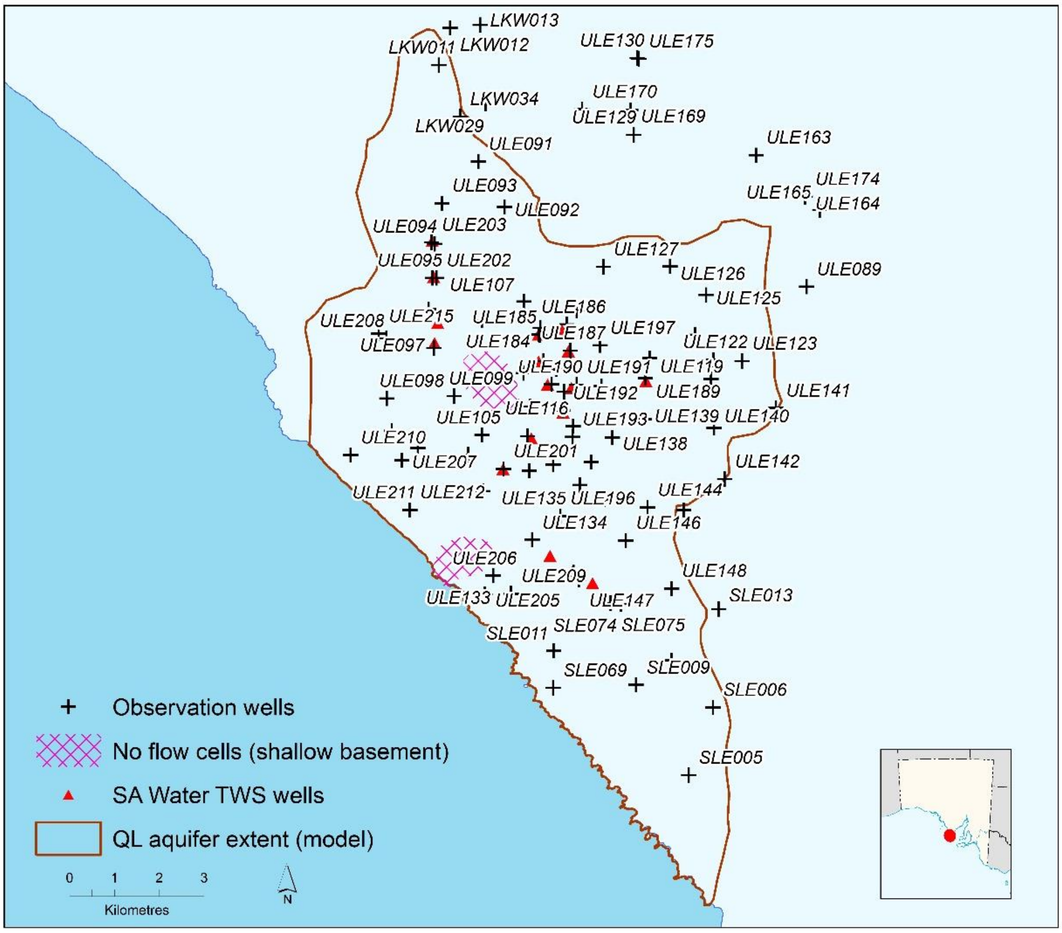
Several recommendations for additional monitoring and modelling related to the Uley South groundwater model work were made in DEW (2020). Some of these recommendations, such as consideration of different future recharge and a sudden increase in pumping rates, are carried out in this current piece of work. Additional recommendations in DEW (2020) are considered still valid and for convenience are included in Appendix D. Recommendations that relate directly to the work in this report are:

- These scenarios are based on the assumption that current low rainfall/recharge conditions persist into the future. They do not assess the potential impact of climate change projections on rainfall into the future. Previous work (DEW 2020) has considered climate change impacts on groundwater recharge in the Uley South Basin, and further such work could be conducted in future.

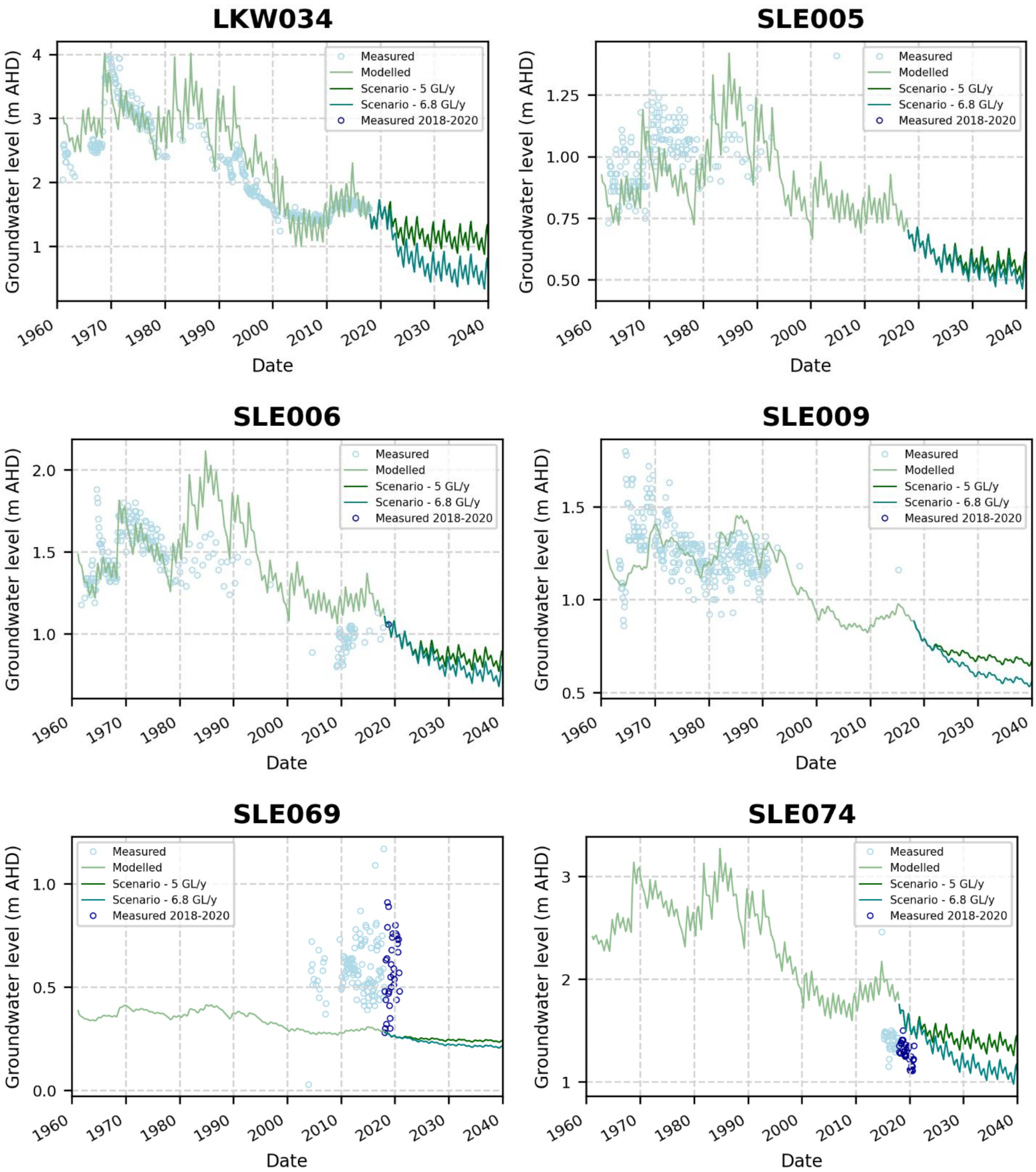
- The scenarios simulate potential impacts for the given recharge assumptions up to 2040. Further movement of the seawater interface past 2040 may be expected if low rainfall and recharge conditions persist. Consideration should be given to simulating impacts further into the future if continued extraction from Uley South Basin past 2040 is considered likely.

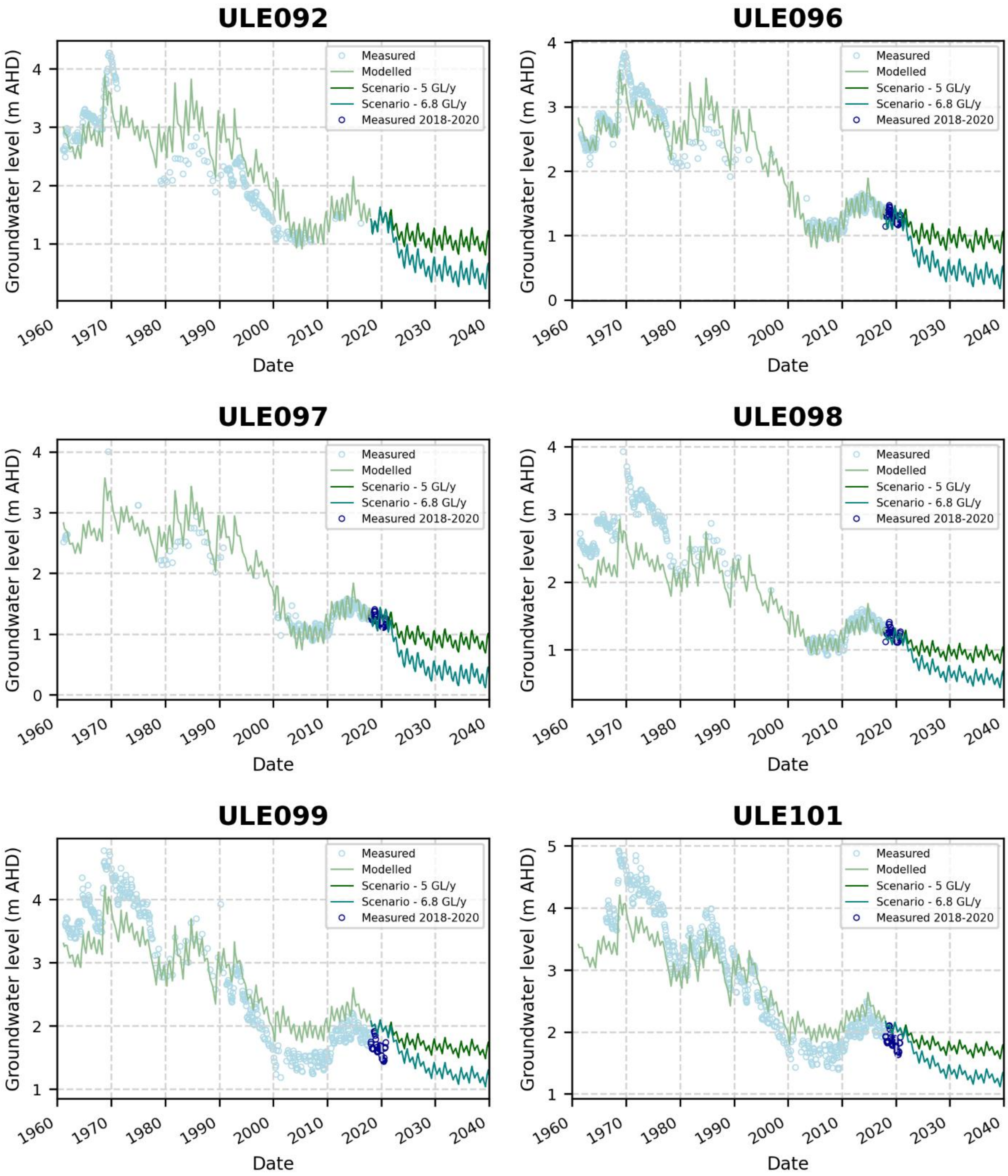
5 Appendices

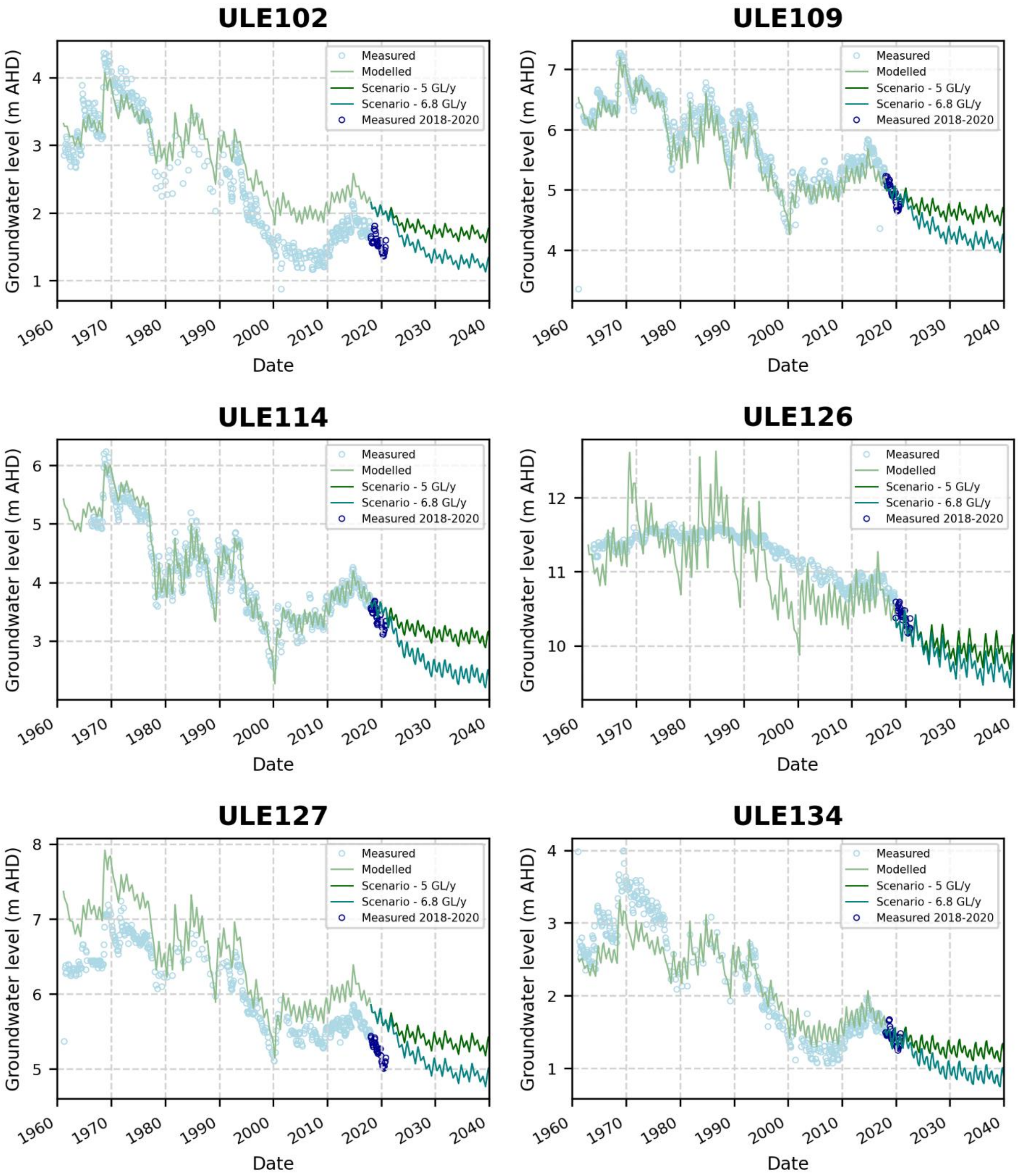
A. Observation well locations

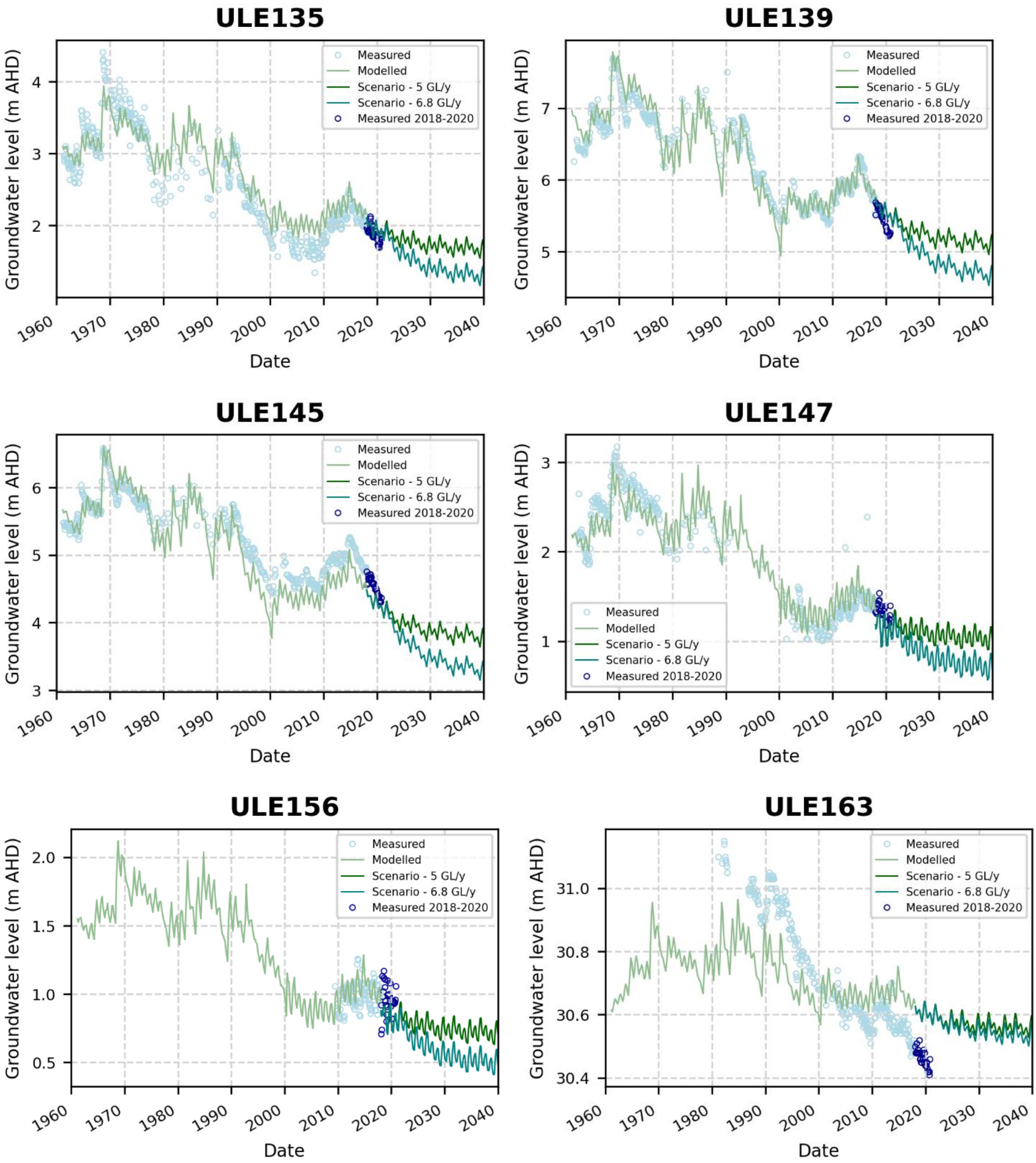


B. Scenario groundwater level results

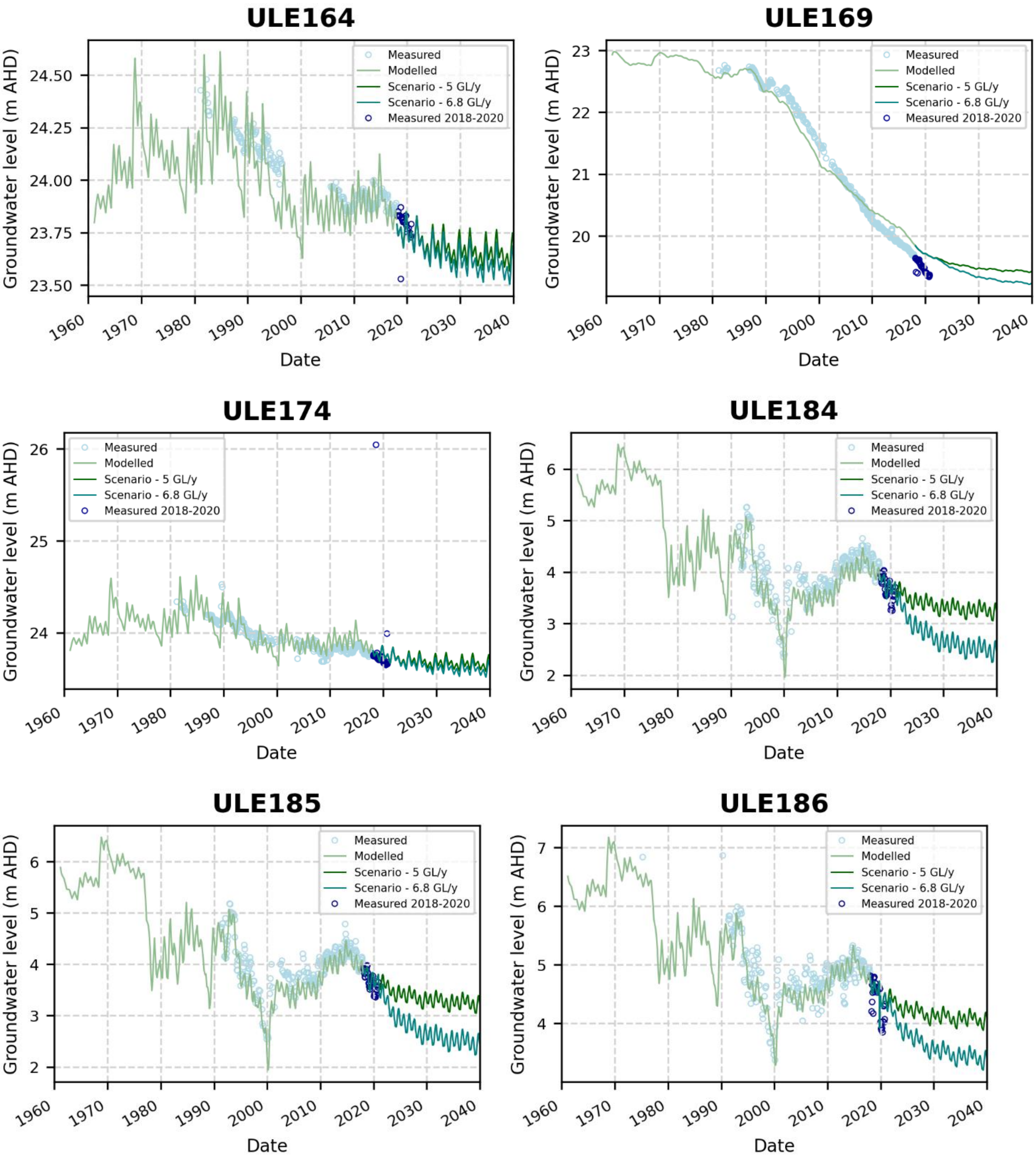


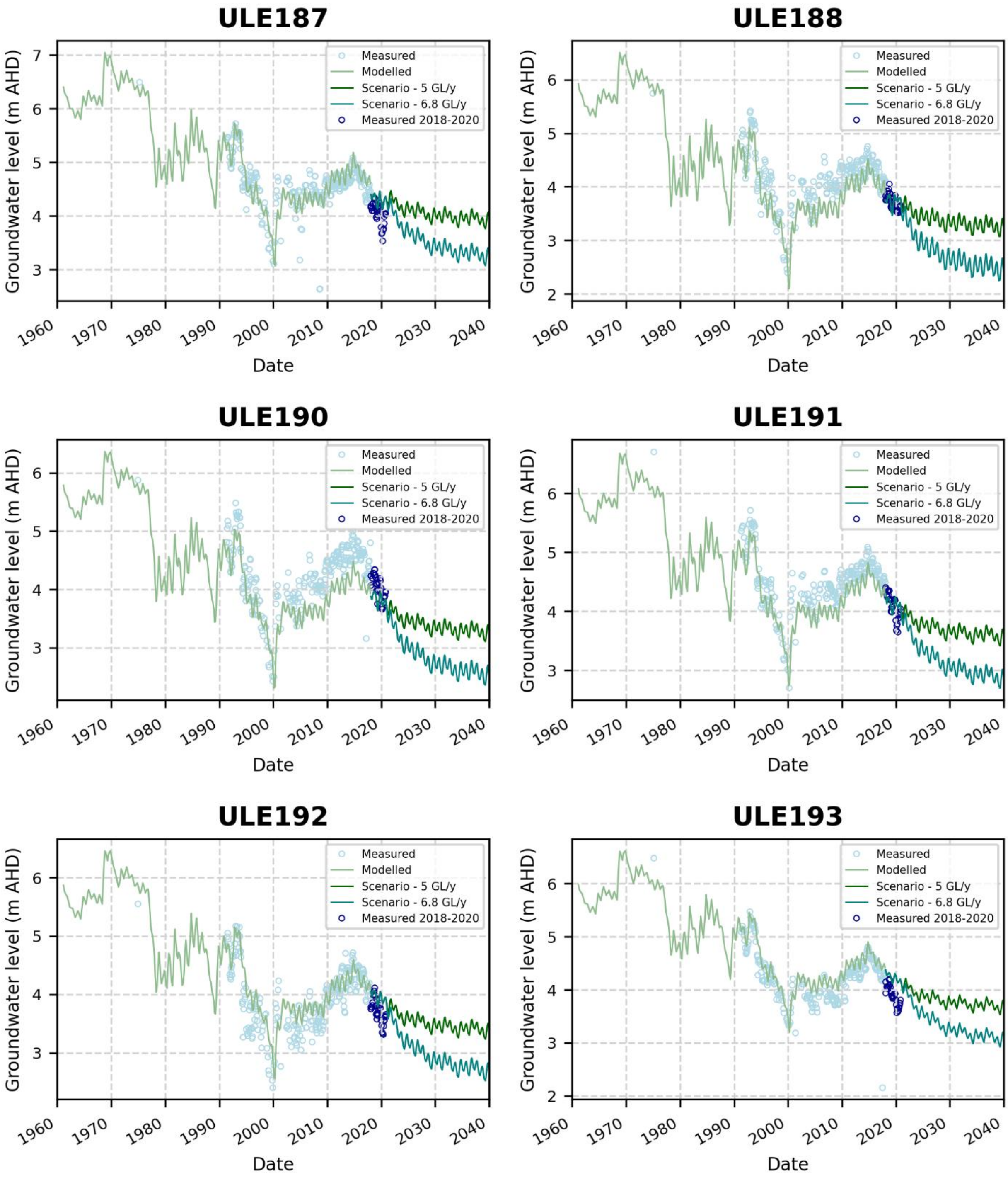

ULE092
ULE096
ULE097
ULE098
ULE099
ULE101
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario - 5 GL/y
Scenario - 6.8 GL/y
Measured 2018-2020
1960
1970
1980
1990
2000
2010
2020
2030
2040

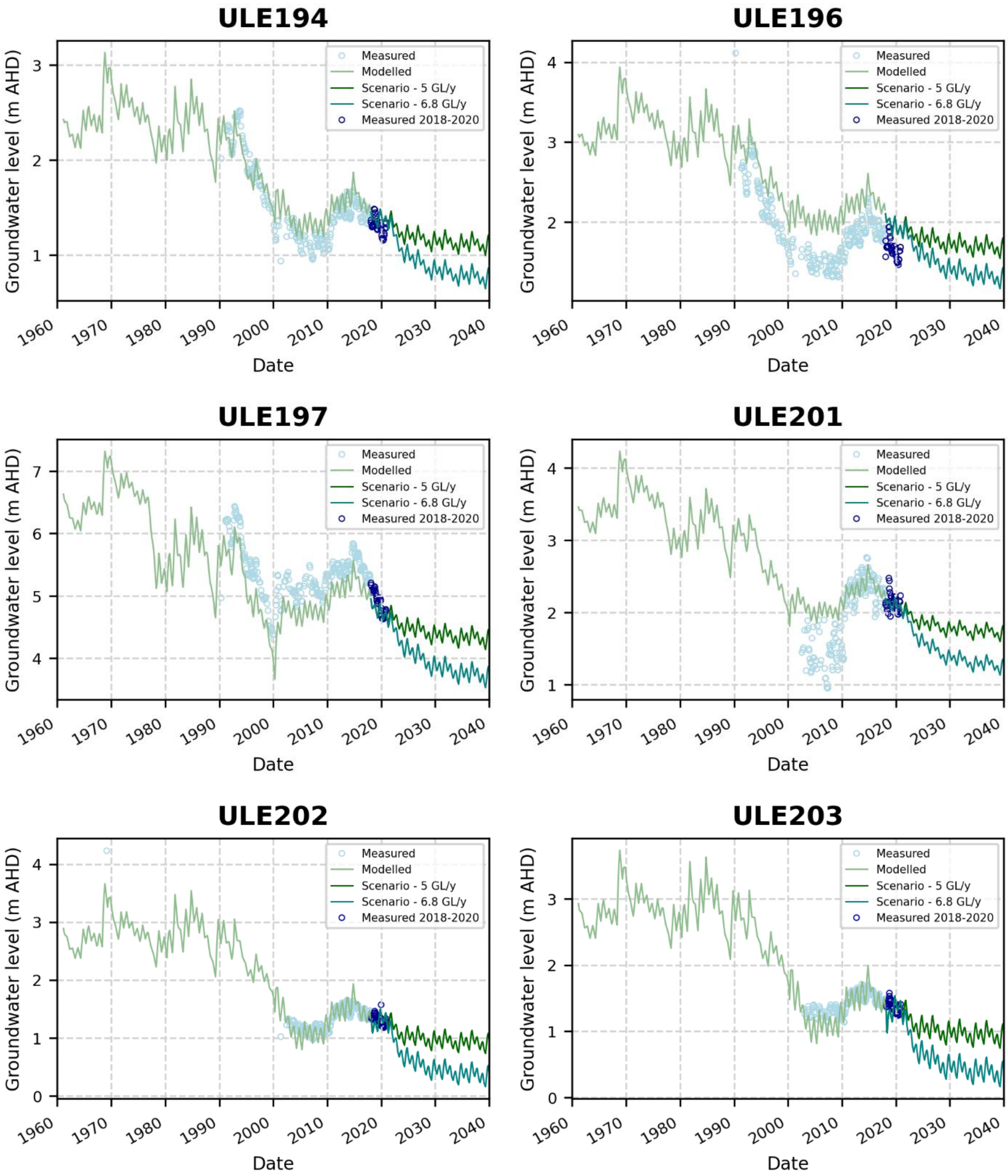

ULE102
ULE109
ULE114
ULE126
ULE127
ULE134
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario - 5 GL/y
Scenario - 6.8 GL/y
Measured 2018-2020
1960
1970
1980
1990
2000
2010
2020
2030
2040

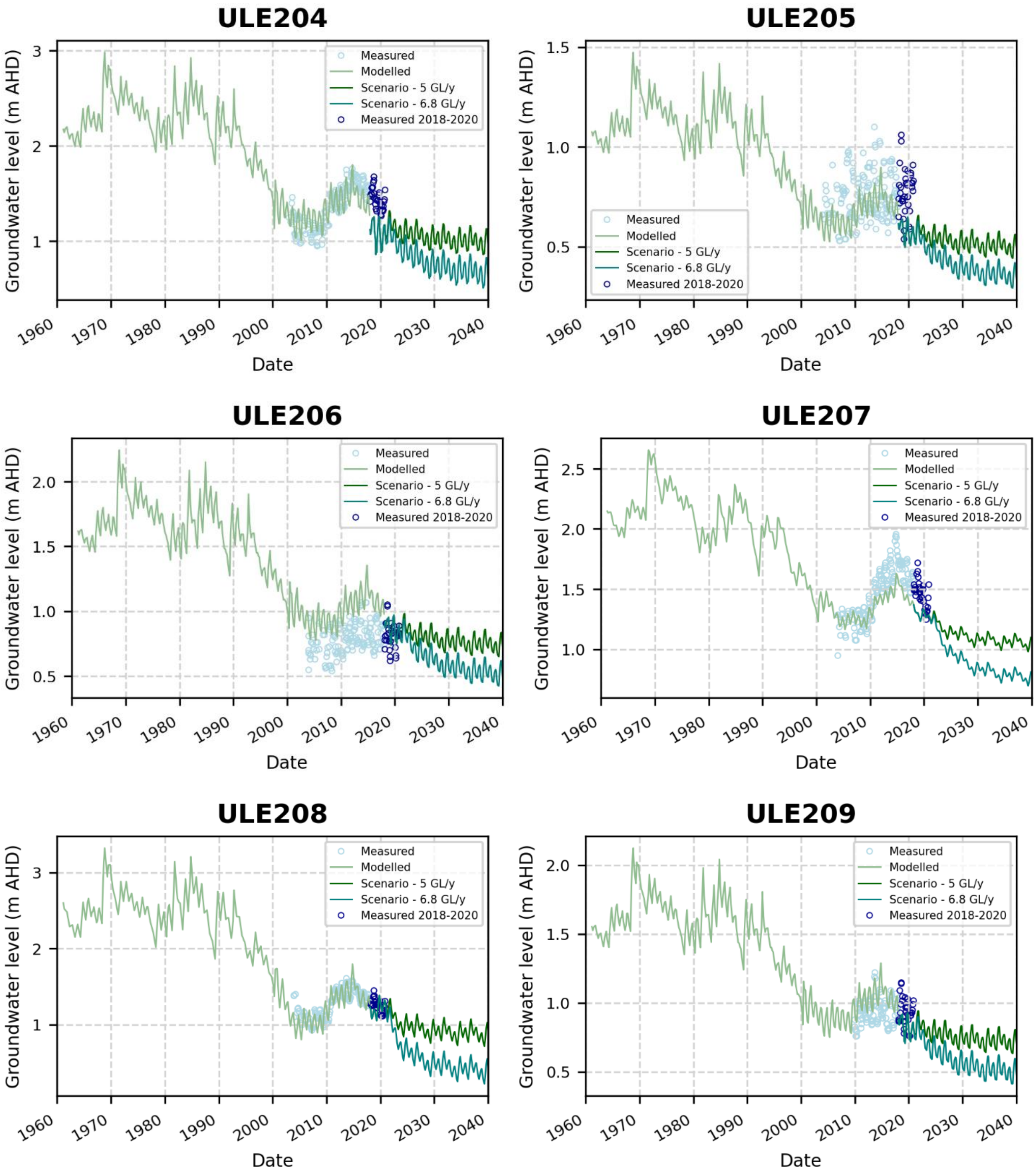


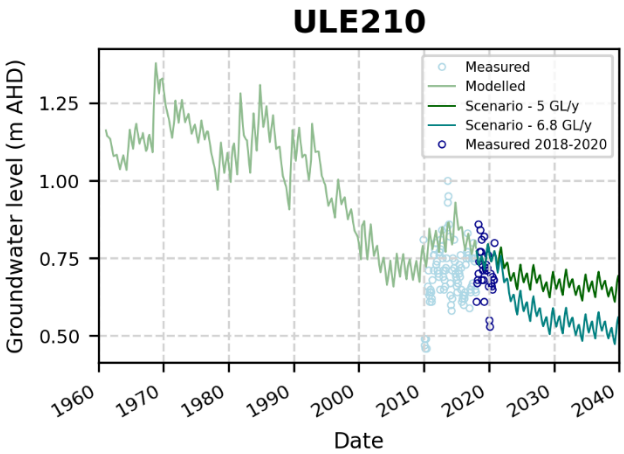
ULE135
ULE139
ULE145
ULE147
ULE156
ULE163
Measured
Modelled
Scenario - 5 GL/y
Scenario - 6.8 GL/y
Measured 2018-2020
Groundwater level (m AHD)
Date
1960
1970
1980
1990
2000
2010
2020
2030
2040

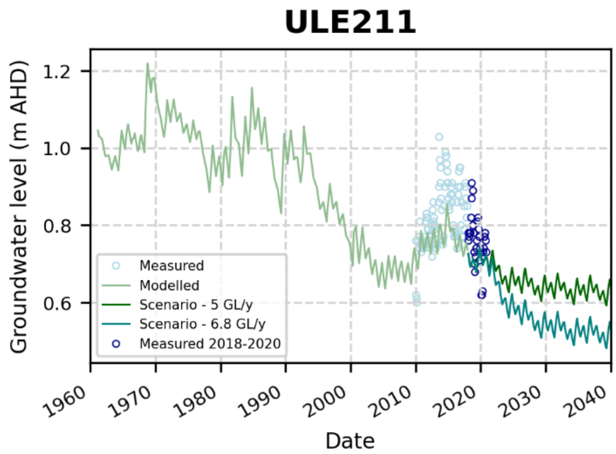

ULE164
ULE169
ULE174
ULE184
ULE185
ULE186
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario - 5 GL/y
Scenario - 6.8 GL/y
Measured 2018-2020
1960 1970 1980 1990 2000 2010 2020 2030 2040


ULE187
ULE188
ULE190
ULE191
ULE192
ULE193
Groundwater level (m AHD)
Date
1960
1970
1980
1990
2000
2010
2020
2030
2040
Measured
Modelled
Scenario - 5 GL/y
Scenario - 6.8 GL/y
Measured 2018-2020


ULE194
ULE196
ULE197
ULE201
ULE202
ULE203
Measured
Modelled
Scenario - 5 GL/y
Scenario - 6.8 GL/y
Measured 2018-2020
Groundwater level (m AHD)
Date
1960
1970
1980
1990
2000
2010
2020
2030
2040


ULE204
ULE205
ULE206
ULE207
ULE208
ULE209
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario - 5 GL/y
Scenario - 6.8 GL/y
Measured 2018-2020
1960
1970
1980
1990
2000
2010
2020
2030
2040


ULE210
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario - 5 GL/y
Scenario - 6.8 GL/y
Measured 2018-2020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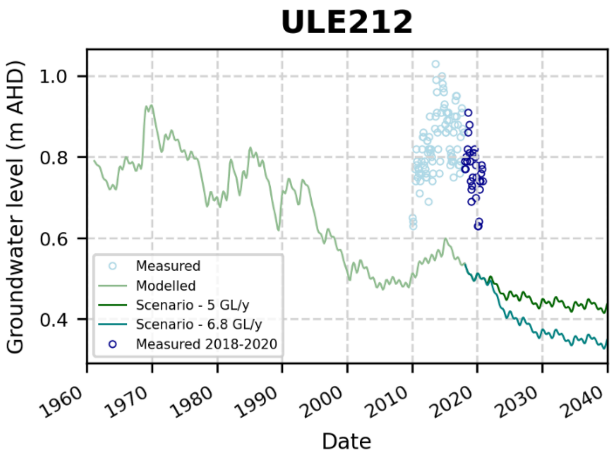
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario - 5 GL/y
Scenario - 6.8 GL/y
Measured 2018-2020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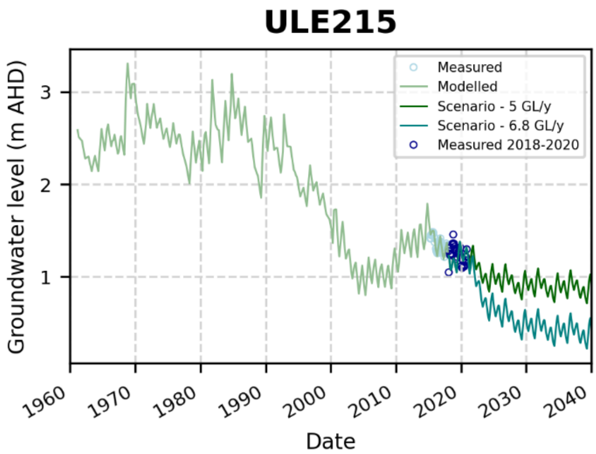
Date
Measured
Modelled
Scenario - 5 GL/y
Scenario - 6.8 GL/y
Measured 2018-2020


ULE215
Groundwater level (m AHD)
Date
Measured
Modelled
Scenario - 5 GL/y
Scenario - 6.8 GL/y
Measured 2018-2020

C. Existing model recommendations

The following list of recommendations are based on those given in DEW (2020), with minor revisions based on data and information that has become available since the recommendations were originally made, and the work carried out in this report.

Recommendations for data collection and conceptualisation:

1. Replacement of long-screened coastal wells (e.g. SLE069 and ULE205) with short-screened wells constructed with PVC: Salinity profiles with depth in long-screened wells may give an inaccurate measure of the seawater interface elevation (Shalev et al., 2009), and another method such as geophysical logging on PVC wells with short screens (Kamps et al., 2016), or installation and sampling of nested wells with short screens may be more appropriate. Following the review by Inverarity (2019), ambient flow profiling of these wells long-screened coastal wells is recommended to determine whether active inflow zones can be identified.
2. Re-interpretation of AEM data (Fitzpatrick et al., 2009): This may offer more insight into the position of the freshwater-seawater interface, which could be used to better constrain the SWI2 simulations. Supplementary data collection may be required close to the coast, where AEM data is missing (based around the location of the wind farm). This could also improve constraints on basement elevation, to give a better understanding of the TS thickness across the basin (particularly in coastal areas).
3. Elevation surveys where required: Accurate elevation surveys on all wells should be carried out, as discrepancies in water table elevation like those at sites ULE130 andULE175 (see Section 5.3) may be due to inaccurate survey elevation data.

Recommendations for modelling:

1. Assessing the impact of scenario uncertainty on model predictions: Further work is recommended to consider the impact of other rainfall scenarios on groundwater resources e.g. successive years of below average rainfall.
2. Improved understanding of the connection between the TS and QL aquifer: Current understanding and assumptions regarding TS flow into QL are conceptual, based on comparisons in ion chemistry in both aquifers, and changes in salinity that have been observed in the TWS wells over time. A better understanding of the connection between the two formations is needed. The development of a solute transport model (e.g. based on this flow model) may be one such way to test the conceptual model for interaction between the TS and QL aquifers.
3. Further work on climate change scenarios: Climate change scenarios modelled only consider changes in mean annual rainfall. However, Charles and Fu (2015a) show the seasonality of rainfall is likely to change in the Eyre Peninsula, with larger declines in spring rainfall compared with other seasons. Further work will be required to determine the impact of changing seasonal rainfall on recharge and groundwater processes in the Uley South Basin.
4. Assessing the impact of parameter uncertainty on SWI2 simulations: This has not been assessed, due to large file sizes and processing time required for SWI2 simulations. However, further work could be done with preferred model version 1c to derive parameter sets which represent the 5th, 50th and 95th percentiles of the modelled distributions (e.g. modelled distributions in Figure 7.10) and run SWI2 simulations on this subset of models.
5. Further work on parameter uncertainty: The approach taken to assessing parameter uncertainty in DEW (2020) was limited in scope compared with a full null space Monte Carlo analysis, in that models were not recalibrated due to time constraints (model non-linearity resulted in a large number of models with an objective function (phi) significantly higher than the calibrated model). Further work could be done to

recalibrate all realisations, and possibly use a technique such as polynomial chaos expansion (which provides progressive estimates of the reduction in confidence limits) to assess the number of realisations that should be used for scenario analysis (Miller et al., 2018).

6. Further work on modelling TS to QL interlayer flow in the northern part of the basin: Conversion to MODFLOW-USG would help appropriately handle flow between layers, as MODFLOW-USG allows layers to 'pinch-out' and horizontal flow to occur between layers.

7. Further work on seawater intrusion modelling: Conversion of the MODFLOW/SWI2 model to a SEAWAT model or MODFLOW-USG, to better understand impact of dispersive mixing on coastal groundwater salinity. However, improved measurement and monitoring of the seawater interface may be required before modelling seawater-freshwater mixing in a more detailed way.

8. Assessing the potential impact of sea level rise on seawater intrusion: The scenarios do not include the potential impact of sea level rise, which should be assessed as it may impact the simulated extent of intrusion (i.e. current scenario results may underestimate seawater intrusion).

9. Sensitivity analysis of SWI2 results: Particular attention should be paid to the sensitivity of seawater intrusion scenarios to coastal hydraulic conductivity. Despite variation in recharge and pumping, the simulated position of the interface will also depend upon the hydraulic conductivity of cells close to the coast, for which there is limited data. Improved conceptualisation of hydraulic conductivity in the coastal region will improve confidence in simulations of the interface position. Geophysical techniques such as NMR may provide improved understanding of the spatial variability of aquifer properties in the coastal zone.

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