APPENDIX F4

Updates to Stuart Shelf regional groundwater flow model

Schlumberger
WATER SERVICES

OLYMPIC DAM EIS PROJECT

UPDATES TO STUART SHELF REGIONAL GROUNDWATER FLOW MODEL

6-072/R4

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Final Report

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ATTACHMENTS

1 INTRODUCTION

1.1 Background

A three dimensional numerical groundwater flow model was constructed by BHP Billiton Olympic Dam Corporation Pty Ltd (BHP Billiton) to support the expansion of the Olympic Dam (OD) mine Draft EIS submission in relation to groundwater impact assessment. As part of the EIS review process, a number of queries were raised about the model construction and model results. Schlumberger Water Services (SWS) were commissioned by BHP Billiton to update the numerical model based on hydrogeological data collected since it was constructed. Refinement and further work was also required in order to address submissions from the public and regulatory agencies in response to the Draft EIS. The model has been re-calibrated, and therefore the predictive and sensitivity scenarios described in Appendix K6 of the Draft EIS have been re-run.

This report describes the adjustments made, the calibration of the model and the results of the prediction and sensitivity analyses.

1.2 Objectives of the updated model

The model update is required so that the groundwater model is physically representative of the latest conceptualisation of the Stuart Shelf groundwater system and incorporates data collected since the Draft EIS submission. The model update process requires:

- Changes to the model construction – layering, grid and flow boundaries
- Re-calibration of the model
- Re-running the prediction and sensitivity analyses
- Re-running particle tracking analyses
- Documenting the redevelopment in a standalone report to support the Supplementary EIS submission.

In order to address specific comments from public and regulatory agencies additional description and sensitivity runs were also undertaken.

The objectives of the modelling remain the same as those of the Draft EIS model.

This report documents the updates and the results of simulations using the updated model.

1.3 Report structure

The report is divided into the following sections:

- Section 2 – The Stuart Shelf Numerical Model. This section introduces the fundamentals of the Draft EIS numerical model and identifies the inputs that have remained unchanged during the update and those that have been modified.
- Section 3 – Model Updates. This section summarises the additional data sources and the changes that have been made to the model.
- Section 4 – Calibration. This section describes the calibration dataset, parameters and results.
- Section 5 – Predictive Model. This section describes the predictive model and provides a detailed analysis of the results.
- Section 6 –.Sensitivity Analyses. This section provides a summary of the sensitivity runs and the results. Particle tracking results are also discussed.

2 THE DRAFT EIS STUART SHELF NUMERICAL MODEL

2.1 Introduction

The objectives, conceptualisation and construction of the Draft EIS Stuart Shelf groundwater model are summarised in this section, and described in full in Appendix K6 of the Draft EIS. Where the model update has required changes being made to the original this is noted, but described further in Section 3.

The numerical model was constructed in order to assess the potential changes to the Stuart Shelf groundwater system in response to the expansion of the OD mine. The predictive requirements therefore ranged from local scale, such as the influence of seepage from proposed tailings storage facilities on groundwater at the mine site, to regional scale, such as groundwater head changes at the boundaries of the Stuart Shelf.

The Stuart Shelf groundwater system covers an area exceeding 25,000 square kilometres, over the majority of which little is known of the hydraulic properties, the inflows and outflows to / from the basin or the response of the system to the abstraction of water. The Draft EIS model was therefore calibrated against the available data in areas where it existed and populated with realistic parameter values and inputs in the areas where no calibration was possible. This provided an exploratory model which was used to test the sensitivity of the predictions to variations in the most uncertain parameters.

It is also known that the groundwater flow within the main aquifers (the Andamooka Limestone and Corraberra Sandstone) is dominated by fracture flow and karstic features which result in significant heterogeneity. Whilst this mechanism of flow would be most accurately simulated with a fracture flow model, very little is known about the regional distribution and properties of major structures and a fracture flow model was considered inappropriate. Instead the model assumes “porous media” flow which at the regional scale should provide an adequate representation of the flow system (for example pseudo radial drawdown is observed in response to current OD operations) but at the local scale may show significant discrepancy with the natural system.

2.2 Objectives

A model was required that could provide support to the expansion of the OD mine Draft EIS submission in relation to groundwater impact assessment. This required the construction of a regional scale groundwater flow model capable of the following:

- Simulating regional inflows to the model and outflows at discharge locations.
- Simulating historical, current and future groundwater affecting activities at OD and the expansion of OD.

- Assisting in the evaluation of potential head change at a potential third party or environmental receptor.
- Supporting a licence application to extract saline groundwater from the Andamooka Limestone (ZAL) and Corraberra Sandstone (ZWC).
- Complementing the estimates of potential pit inflow and dewatering requirements.
- Assessing the fate of seepage from the Tailings Storage Facilities (TSF) and Rock Storage Facilities (RSF).
- Identifying uncertainties and gaps in hydrogeological knowledge.
- Providing a management tool to evaluate broader water supply and water management options for OD and the expansion of OD.

Potential receptors were defined during the Draft EIS process following an environmental risk assessment. They include both environmental and 3rd party locations (Table 2.1 and Figure 2.1).

Table 2.1 Potential environmental and 3rd party receptors

Potential receptor	Type	Comments
Yarra Wurta Spring	Environmental	Groundwater dependent
Discharge to the north of the Stuart Shelf	Environmental	Groundwater dependent
Comet Well	3rd party bore	Private bore
New Parakylia Bore	3rd party bore	Private bore
Southern Cross	3rd party bore	Private bore
Old Homestead	3rd party bore	Private bore
Alex's Bore 2	3rd party bore	Private bore
No. 1 Well	3rd party bore	Private bore
Knoll Well 2	3rd party bore	Private bore
19 Mile Bore	3rd party bore	Private bore
Loch Well	3rd party bore	Private bore

Borehole RT9, located in the northern portion of the model, was used to assess the predicted drawdown in that area and thus assess the potential impacts on discharge to the north of the Stuart Shelf.

The model was required to replicate observed groundwater observations from the pre-mine period and the period from commencement of mining at OD until the present day. Due to the exploratory nature of the modelling and the acknowledgement of the importance of the sensitivity analysis, no statistical calibration targets were set prior to modelling.

2.3 Conceptual groundwater model

2.3.1 Introduction

The hydrogeological conceptualisation is described in full in Appendix K1 of the Draft EIS and Douglas and Howe (2007). Further investigations and data gathering have been undertaken since the submission of the Draft EIS and these, along with an updated conceptual model are described in SKM (2010), see Appendix F1 and F2 of the Supplementary EIS. No major variations to the original conceptualisation were required in light of this additional information. Those aspects that have a direct impact on the modelling are described below.

2.3.2 Geological setting

The OD mine is located in the Stuart Shelf geological province. The geology comprises Neoproterozoic to Cambrian age sedimentary units. From youngest to oldest, those with significant thickness are:

- Quaternary alluvial and Tertiary Aeolian sediments. Clayey sands, sand plains and dune fields, playa and drainage lakes. This unit presents a thickness between 0 and 20 m.
- Andamooka Limestone (ZAL). Indurated limestones, variably dolomitic and shaley, extending to the north of OD. Well jointed karstic features. This unit presents a thickness up to 200 m.
- Yarloo Shale. Laminated shale, discontinuous and absent beneath and south of OD. This unit presents a thickness between 0 and 50 m.
- Arcoona Quartzite (ZWA). Quartzite with shale interbeds in upper part. Thickness between 150 and 200 m.
- Corraberra Sandstone (ZWC). Silty sandstone and micaceous siltstone with shaley interbeds. Extends to the south of OD and maintains a thickness of about 30 m.
- Tregolana Shale (ZWT). Laminated shale and siltstone with a thickness between 150 and 300 m.

The sedimentary sequence is underlain by Proterozoic crystalline and sedimentary basement rocks of the Gawler Craton.

The Stuart Shelf sediments are bounded by and in some cases overlain by the following sedimentary basins:

- The Permian Arckaringa Basin to the west.
- The Mesozoic Eromanga Basin to the north and northeast. This is the largest of the three basins that comprise the Great Artesian Basin (GAB).
- The Torrens Basin to the east.
- The Adelaide Geosyncline to the north and northeast.

Lake Windabout, Island Lagoon, Lake Hart and Lake Younghusband (extensive salt lakes, similar to, but smaller than Lake Torrens), are considered to be areas of regional groundwater discharge to the south of the Stuart Shelf and thus represent a groundwater divide in this area.

The sedimentary rock sequences of the Stuart Shelf and Adelaide Geosyncline are separated by the Torrens Fault and Torrens Hinge Zone (THZ).

2.3.3 Stuart Shelf hydrogeology

The shallow sedimentary rocks of the Stuart Shelf (specifically the ZAL and ZWC) are also its most important aquifers. The ZAL is the regional water table aquifer and comprises dolomitic limestone with highly developed karst features in some areas. The ZWC is a fractured rock aquifer to the south of OD which, in the presence of major structures, can yield significant volumes.

Groundwater is generally encountered about 50 m below ground level in the area of OD. In areas of low topographic relief (e.g. Lake Torrens and towards the artesian Eromanga (GAB) aquifers to the north and northwest) the water level shallows to less than 10 m below ground level. Groundwater gradients are relatively flat north of OD and in the ZAL are generally between 40 and 50 mAHD. The groundwater elevation increases to the south and west to levels greater than 90 mAHD towards the basin margins. A detailed description of the regional groundwater elevation dataset is presented in Section 4.

These observations provide evidence of groundwater inflow to the Stuart Shelf region from the west (Arckaringa Basin) and south. Discharge is predominantly via the northern portion of Lake Torrens and to a lesser extent to the northern margins of the basin. The relatively flat hydraulic gradients in the ZAL suggest a high aquifer transmissivity which is supported by high airlift yields in this region. The higher groundwater gradients presented by the ZWC suggest a lower transmissivity in this unit compared to the ZAL. Other evidence suggests that flow is controlled by fractures within the ZWC and that the unit presents a high degree of heterogeneity.

Recent hydraulic testing, groundwater elevation (the presence of a groundwater divide), hydrochemical data and the presence of geological and structural controls suggest that the Eromanga (GAB) Basin is hydraulically separate from the Stuart Shelf groundwater system (SKM, 2010). Therefore the ecologically important GAB springs are not supported by Stuart Shelf groundwater.

Connection between the ZAL and ZWC is controlled primarily by the vertical permeability of the ZWA. To the north the connection is also controlled by the presence of the Yarloo Shale in this area as well as the ZWA.

Rainfall recharge is likely to be very low in comparison to total rainfall. Values of up to 0.1 mm/yr have been adopted in previous studies (Kellett et al, 1999 and Waterhouse, 2002).

Lake Torrens is the largest most important groundwater sink of the Stuart Shelf. Over time, the discharge of groundwater into the north of the lake and its subsequent evaporation has produced a brine water body in the ZAL that extends beneath the lake and towards the west. Total dissolved solids (TDS) measured in groundwater within this brine is typically in excess of 200,000 mg/L. The saline water that flows above it typically has a TDS of around 50,000 mg/L. This presents a density contrast between the two waters and results in limited flow from one to the other.

2.4 Model construction

The model was constructed using the finite element code FEFLOW (WASY 2007). The model area incorporates the outcrop and subcrop extent of the ZAL, ZWA and ZWC and covers an area roughly 150 km by 200 km (Figure 2.1).

The model is bounded by the following features:

- Lake Torrens to the east.
- Lakes Windabout, Hart and Younghusband and Island Lagoon to the south.
- The catchment divide to the west.
- A groundwater elevation contour of roughly 60 m to the northwest in the area of inflow from the Arckaringa Basin.
- The southern margin of the GAB to the north and northeast (this necessitated extension of the model in this area to include the THZ and Adelaide Geosyncline).

The original model mesh has been modified slightly and is described in more detail in Section 3.

Eight model layers are used to simulate the Stuart Shelf hydrostratigraphy (Table 2.2). The ZAL is represented with 3 model layers to enable the simulation of both the saline and brine water bodies present in this unit. The base of Layer 8 has been set to -1000 mAHD to allow a simulation of both the ZWT and basement material at depth, which, for the purposes of this study were considered to share similar hydraulic parameters.

The 3D interpretation of hydrostratigraphy was undertaken selecting unit tops and bottoms from the following data sources:

- BHP Billiton resource drilling (within the SML).
- BHP Billiton sterilisation drilling (within the SML).
- BHP Billiton mineral exploration holes (outside of SML).
- The PIRSA website, SARIG (mostly outside of SML).

This data was used to define the top and base of each of the model layers. The ground surface (top of model Layer 1) was defined from the state 90 m Digital Elevation Model (DEM). The resultant layer thicknesses as used in the model are presented in Figures 2.2 to 2.6. These show that:

- The thickness and extent of the Quaternary alluvial and Tertiary Aeolian sediments is controlled by a limited number of observations. Where control does not exist these sediments are postulated to fill the space between the topographic surface and whichever of the ZAL, ZWA, Yarloo Shale or ZWT is present directly beneath.
- The thickness of the ZAL is defined by numerous observations both local to OD and regional in distribution. Its thickness is modelled to increase from the south and southwest where it is between 0 and 30 m thick, to the northeast where it reaches over 150 m in thickness.
- The thickness of the ZWA is also defined by a good regional and OD local distribution of observations. The thickness ranges from 0 to 10 m in the south to over 250 m in the north.
- The strata in the northern area of the model, including the THZ and Adelaide Geosyncline are poorly controlled, with very few observations to confirm their distribution in the model.

- The available data is limited for the Yarloo Shale, but where no data is available it is postulated to fill in the gap between the ZWA above and the ZWC below. The modelled extent is constrained to the centre of the Stuart Shelf where it ranges in thickness between 10 and 100 m.

- The thickness of the ZWC is controlled both regionally and locally to OD. The modelled thickness is limited to a maximum of about 100 m in the OD area but is between 2 and 40 m away from the mine.

Table 2.2 Hydrostratigraphy and model layers

Model Layer	Hydrostratigraphy
1	Quaternary alluvial and Tertiary Aeolian sediments
2	ZAL (1)
3	ZAL (2)
4	ZAL (3)
5	Yarloo Shale
6	ZWA
7	ZWC
8	ZWT / Basement

Where a stratigraphy is known to pinch out to zero thickness the associated model layer is reduced to a thickness of 1 m and the hydraulic properties are copied from the slice below. This is illustrated well in the southern portion of Layers 2, 3, 4 and 5 (the ZAL and Yarloo Shale) where the layer thickness reduces to 1 m and the hydraulic properties are taken from the ZWA below (Figures 2.3 and 2.4).

To fulfil the objectives, three model variants were constructed:

- A steady state model for simulation of the "equilibrium" condition prior to mining at OD and to provide the initial conditions for the time variant historical model.

- A time variant historical model for simulation of the effects of past mining related activities on the groundwater system and to provide the initial conditions for the time variant predictive model.

- A time variant predictive model for simulation of the effects of future mining related activities on the groundwater system (e.g. the open pit and wellfield options).

The start and end times of the time variant models have been varied from those used in the Draft EIS and are described in Section 3.

The predictive model allows for the simulation of groundwater flow for the 40 years of active mining (life of mine (LoM)) followed by 500 years of recovery "post closure".

2.5 Boundary conditions

Boundary conditions were used in the model to simulate natural inflow and discharge features as well as historical and future mining-related activities affecting the groundwater system. The location of the historical activities is presented in Figure 2.7 and the future activities in Figure 2.8. The mechanisms and their representation in the model are summarised below:

- Rainfall recharge. An inflow of water was applied to the top of the model to represent rainfall recharge. The inflow was variable over the model extent and is split into 5 zones (Figure 2.9). The delineation of the zones and recharge rates assigned to them are based on the findings of Kellett et al (1999):

  - ZAL outcrop (porous and transmissive aquifer) – 0.075 mm/yr (0.05% of rainfall)

  - Arcoona Plateaux (low permeability with high runoff) – 0.045 mm/yr (0.03% of rainfall)

  - Adelaide Geosyncline and THZ outcrop (very low permeability) – 0.006 mm/yr (0.004% of rainfall)

  - Northern Flinders Ranges (low permeability and steep topography) – 0.004 mm/yr (0.0025% of rainfall)

  - Southern salt lakes – no recharge.

- Inflow from the Arckaringa Basin into the ZAL of the Stuart Shelf. In the Draft EIS model this was represented with constant head boundary conditions located in Layer 2 (top of the ZAL) which provided an inflow of 3057 m^3/d to the model. This has been modified and is described in detail in Section 3.

- Discharge via evaporative loss at the margins of the Stuart Shelf groundwater system (Lake Torrens, the southern lakes and the northern boundary with the GAB). This mechanism was represented using drain conditions placed in model Layer 1. Drains allow water to leave the model if the groundwater elevation is greater than the reference elevation (set to equal ground surface in this model). They do not allow water to flow into the model.

- Interaction with the GAB aquifers. Four constant heads with a reference elevation of 22 mAHD were placed in Layer 1 in the vicinity of the northern model boundary. These were used to allow water to flow into the model domain from the GAB if the groundwater elevation dropped significantly. The elevation of 22 mAHD was based on the groundwater elevation at the southern most extent of the GAB margin. This boundary condition has been modified in the updated model as described in Section 3.

- Historical and estimated future abstraction from the ZWC and ZAL. This was represented using abstraction wells and includes:

  - Historical abstraction from the ZAL via the LP2 bore (Figure 2.10)

  - Historical abstraction from the ZWC via the Saline Wellfield (Figure 2.11)

  - Historical flow from ZWC to mine raise bores (RBs). The representation has been revised and is described in detail in Section 3.

  - Construction period abstraction from wellfields in the ZWC at Roxby Downs, Hiltaba / Airport, MMIA / Process Plant and TPW4 and TPW5 (Figure 3.11 and Table 2.3)
  - Future abstraction from the ZAL via the Motherwell Wellfield (Table 2.3)
  - Future trial depressurisation and active dewatering of the pit. The trial depressurisation component has been modified and is now included in the time variant historical model as described in Section 3
- Historical and future seepage from the TSFs and RSF and mine evaporation ponds (MWEP). This was represented with injection wells placed under the footprint of each of these facilities. The injection rates have been modified since the Draft EIS and are described in detail in Section 3.
- Inflow to the open pit. This was represented using drain conditions placed at the base of Layers 4 (the ZAL), 6 (ZWA), 7 (ZWC) and 8 (ZWT / basement). The locations were determined by where the pit intersects each of these layers. With the exception of Layer 8, the drains were assigned reference elevations equal to the elevation of the cell on which they are located. Drains in Layer 8 were assigned a reference elevation equal to the base of the pit or bench.

Areas of the model boundary that were not deemed to be receiving inflow from the Arckaringa Basin or providing discharge via evaporation were treated as no flow boundaries. The representation of rainfall recharge, inflow from the Arckaringa Basin and evaporative discharge features remained consistent throughout the steady state, time variant historical and time variant predictive models.

Table 2.3 Additional abstractions simulated in the predictive model

Wellfield	Aquifer	Abstraction rate (m^3/d)	Start	End
Roxby	ZWC	700	1/10/2008	1/01/2018
Hiltaba	ZWC	900	1/07/2010	1/10/2017
MMIA	ZWC	643	1/07/2010	1/10/2017
Motherwell 1	ZAL	2500	1/01/2011	1/10/2017
Motherwell 2 and 3	ZAL	5000	1/04/2011	1/10/2017
Motherwell 4	ZAL	2500	1/07/2011	1/10/2017
Motherwell 5 and 6	ZAL	5000	1/10/2011	1/10/2017
Motherwell 7 and 8	ZAL	5000	1/01/2012	1/10/2017
Motherwell 9	ZAL	2500	1/04/2012	1/10/2017
Motherwell 10	ZAL	2500	1/07/2012	1/10/2017
Motherwell 11	ZAL	2500	1/10/2012	1/10/2017

2.6 Calibration methodology

A “trial and error” method was used to calibrate the Draft EIS model. Hydraulic conductivity, specific yield and specific storage were varied within realistic ranges (supported by data) to improve the fit between observed and simulated groundwater elevations. The steady state and time variant historical models were calibrated in parallel, as changes to hydraulic conductivity in one would affect the calibration in the other.

One hundred and one observations were considered representative of the steady state condition and used in the calibration of the Draft EIS model. Of these 46 were in the ZAL, 38 in the ZWA and 17 in the ZWC.

A subset of time variant groundwater elevation dataset was used (6 in the ZAL and 9 in the ZWC). Both of these datasets have been expanded for the model update and are described in detail in Section 4.

Complexity was not introduced where data was sparse or there was no evidence to suggest that it was present. Only in the ZAL was any significant heterogeneity developed to aid calibration.

2.7 Predictive model

The time variant predictive model was split into 9 separate models to provide the mechanism whereby the development of the open pit and other engineering milestones could be simulated in distinct steps. The principle remains the same in the updated model however the timing and groundwater stresses have been modified in some cases (see Section 3 for full details).

A single "basecase" predictive model was constructed (broken into 9 smaller models). These used the same hydraulic parameters defined in the calibrated steady state and time variant historical models.

The prediction results were discussed in terms of:

- Inflow to the pit from the ZWC and ZAL.
- Groundwater drawdown in the vicinity of the Motherwell wellfield.
- Groundwater mounding in the vicinity of the TSFs and RSF.
- Groundwater drawdown at potential environmental and third party receptors.

2.8 Sensitivity analyses

The basecase predictive model was used to investigate the sensitivity of predictions to variations in model parameters and boundary conditions. The focus of these analyses was on regional scale post closure predictions, rather than local scale short term predictions. For this reason the 9 separate models which together make up the basecase predictive model were amalgamated into a single model. To achieve this, the 40 year pit shell was activated at the start of the sensitivity models and the dewatering and construction phase abstractions were removed. A comparison of predictions using this methodology and those using the predictive basecase showed no discernable difference at the end of simulation (500 years post closure). Therefore this significantly more rapid methodology was used for the sensitivity runs.

Where applicable the sensitivity analysis has been completely re-run with the updated model and is described in detail in Section 6.

2.9 Particle tracking

Particle tracking (both steady state and time variant) was undertaken to investigate the potential fate of water entering the system via seepage from the TSFs and RSF. The exercise was undertaken with the predictive basecase and the increased RSF seepage sensitivity. The particle tracking analysis has been re-run and expanded with the updated model and is described in Section 6.

3 MODEL UPDATE

3.1 Introduction

In the two years since the submission of the Draft EIS a number of additional hydrogeological investigations have been undertaken in the Stuart Shelf and neighbouring areas. These investigations have provided information that was used to refine and confirm physical aspects of the Stuart Shelf groundwater model and to supplement the calibration dataset. This has necessitated minor variations to model configuration and inputs.

The studies, their integration into the model and any other changes required, are described below.

3.2 Finite-element mesh

The FEFLOW finite-element mesh has been modified to allow for a number of improvements and is displayed in Figure 3.1. These were:

- Adjusting the regional model mesh to produce a more uniform mesh and a maximum element size of 5,000 m.
- Increased refinement in the area of the mine. The minimum element size is 40 m.

The refinement of the mesh in the area of the mine provides the opportunity to simulate each of the 31 raise bores and the 4 saline wellfield wells with individual boundary conditions (Figure 2.7). Each of the raise bores are assigned individual abstraction rates (Figures 3.2 and 3.3). The raise bores were simplified in the Draft EIS model into 7 boundary conditions which had the effect of limiting the fine scale predictive capability of the model.

3.3 Lake Torrens brine

The hydrochemical data used to develop the conceptual model outlined in Appendix K1 of the Draft EIS describes a significant salinity gradient within the ZAL in the northern and north-western area of Lake Torrens. This understanding has been confirmed and refined by SKM (2010), see Appendix F1 of the Supplementary EIS. Saline water, characteristic of the Stuart Shelf aquifers, occurs in the upper parts of the ZAL and flows towards the east where it discharges. Brine, produced by evaporation of the flow of saline water into Lake Torrens, occurs in the lower part of the ZAL and flows away from the lake to the west. Due to the significantly different densities of the two water bodies, limited mixing occurs and thus each body is able to maintain opposite flow directions.

In order to incorporate this feature into the single density groundwater flow model constructed for the Draft EIS the ZAL was split into 3 separate layers of identical thickness. The hydraulic conductivity was reduced in the regions of these layers where the brine occurs. Its extent was greatest therefore in the lowest layer of the ZAL and smallest in the upper layer. This methodology replicates the reduced transmissivity available to the saline water body towards the northern area of Lake Torrens.

For the purposes of the Supplementary EIS (SEIS) additional hydrogeological and hydrochemical data has been collected and the entire dataset considered in more detail. The results are described by SKM (2010), see Appendix F1 of the SEIS. These additional data have confirmed the conceptualisation described above and provided additional data on which to base the representation in the numerical model.

Groundwater salinity measurements at 17 boreholes (Figure 3.4) were used to refine the position and depth of the interface between the saline and brine water bodies for the purposes of modelling. Where data was not available, the brine was interpreted to be limited vertically to a depth of about -50 mRL (SKM, 2010). The intersection of the interface elevation and the elevations of the tops of the three ZAL layers was used to assign the low hydraulic conductivity zones in the appropriate areas.

The resultant representation of the brine in the numerical model can be seen in plan view in Figure 3.5 and in cross section in Figure 3.6.

3.4 Hydrostratigraphy and groundwater elevations

A number of investigation boreholes (SKM, 2010) have been drilled since the Draft EIS was submitted. These bores are located to the north and northwest of OD and have provided stratigraphic information and groundwater heads in areas which are significant in terms of model predictions, but were previously lacking in observations.

The head data has been added to the groundwater model calibration dataset. The groundwater heads in these areas are not expected to have changed significantly since operations at OD commenced and are therefore considered representative of the steady state condition.

The stratigraphic information (mostly related to the position of the ZAL) has been compared to the existing modelled layer surfaces and in the majority of cases the difference is less than 20 m and for this reason the model surfaces have not been modified from their original configuration.

3.5 Hydraulic parameters

In the conceptualisation developed to support the construction of the Draft EIS numerical model, the rocks of the THZ and Adelaide Geosyncline were identified as presenting a very low hydraulic conductivity and therefore acting as a barrier to groundwater flow. This aspect of the conceptual understanding has been investigated since the submission by the undertaking of several falling head “slug tests” in monitoring bores in the northern Stuart Shelf area. The slug test results have been supported by the results of numerous airlift tests undertaken during drilling. The tests and results are described in full in SKM (2010), and are summarised below.

Four tests of the THZ and Adelaide Geosyncline tests returned hydraulic conductivity values of between $1x10^{-2}$ and $1x10^{-4}$ m/d ($1x10^{-7}$ and $1x10^{-9}$ m/s) with a mean of $2x10^{-3}$ m/d ($2x10^{-8}$ m/s).

A single hole completed within the ZWA was tested and returned an estimated hydraulic conductivity of 3.5×10^{-3} m/d (4×10^{-8} m/s), which is very similar to the value used in the original model.

Analysis of test results from several holes completed in the Bulldog Shale and Cadna-owie Formations returned hydraulic conductivity estimates between 4×10^{-2} m/d (5×10^{-7} m/s) and 33 m/d (4×10^{-4} m/s). These formations are thought to be discontinuous remnants of the non-artesian Eromanga Basin sediments that lie on top of the THZ and Adelaide Geosyncline.

The results substantiate the earlier conceptualisation of the system within the northeast of the model domain and provide a range within which to calibrate the model in this area.

3.6 Trial depressurisation

A long term and high volume pumping test of the ZWC was commenced in September 2008. The test was carried out to increase confidence in the site hydrogeological understanding, particularly in the behaviour of the ZWC under significant groundwater stress, and the response of the lower conductivity units above (ZWA) and below (ZWT). These units had been identified as requiring significant depressurisation prior to the development of the open pit.

This “trial depressurisation” involved the drilling of, and abstraction from, 7 test production wells in the vicinity of the proposed open pit (Figures 3.7 and 3.8). All of the wells were located within the current SML boundaries and targeted the ZWC. Between March 2008 and September 2008 the combined abstraction from the OD saline wellfield was about 500 m^3/d (6 L/s), but following commencement of the trial depressurisation abstraction it increased to between 1000 and 3500 m^3/d (12 and 40 L/s). The time variant abstraction from each of the bores is displayed in Figures 3.9 and 3.10.

For the entire period detailed monitoring was carried out at the pumping wells, monitoring bores and vibrating wire piezometers (VWPs). The positions of these are included in Figures 3.7 and 3.8.

Monitoring at the pumping wells was carried out daily. Pressures and piezometric heads at the VWPs and monitoring bores were collected with data loggers which recorded at 6 hourly intervals and downloaded weekly.

The abstraction and the monitoring have provided an additional dataset with which to calibrate the numerical model against.

3.7 Miscellaneous groundwater stresses

A number of groundwater stresses have been added to the time variant historical model. These are:

- Estimated seepage from the “new” MWEP. This is simulated with well boundary conditions placed in Layer 1 of the model (Figure 3.11).
- Abstraction from the evaporation pond 5 (EP5) construction water supply wells (TPW4 and 5). These wells were used to supply water during the construction of EP5 which commenced in 2007 (Figure 3.11). As they abstract from the ZWC they have been placed in model Layer 7.

3.8 Seepage estimates

The estimates of seepage from the tailings storage facilities (TSFs) have been refined since the submission of the Draft EIS. BHP Billiton supplied an updated annual seepage schedule for the existing (TSF1 - 4) and proposed tailings cells (TSF5 - 13) and this was used directly for the model calibration and predictions. The schedule included two variants (as supplied by BHP Billiton, 2010), based on 53% and 48% tailings solids. The 53% schedule has a higher solids content and therefore lower hydraulic loading in the tailings cells than the 48% schedule. The seepage estimates using the 53% schedule are therefore lower than the 48% schedule. At the request of BHP Billiton, the 53% seepage case was used as the basecase seepage rate in the model. This was coupled with a 0.1 mm/year post-closure seepage rate. The 53% seepage rate was regarded by BHP Billiton as a more accurate reflection of the likely performance of the engineered TSF cover and the 0.1 mm/year post-closure seepage rate was considered to be more consistent with natural background recharge rates.

As part of a sensitivity analysis, the alternative 48% solids seepage schedule was used with a 1% post-closure seepage/recharge rate (1.5 mm/yr). This sensitivity is considered to be conservative, and is consistent with the assumption of no engineered TSF cover. Also, the 1% post closure seepage rate is consistent with the modelled RSF post-closure recharge rate.

The seepage was applied uniformly beneath the footprint of the TSFs and RSF. Time variant seepage rates (which span both the historical and predictive time variant models) defined by the 53% and 48% cases are presented in Figure 3.12.

3.9 Inflow from the Arckaringa Basin

The calibrated Prominent Hill groundwater flow model (Aquaterra 2007) provided an estimate of inflow (2,142 m^3/d) into the western boundary of the Draft EIS model. This model has since been updated (Aquaterra 2009) and the steady state inflow has been reduced to 740 m^3/d. Flows were also reported for the time variant historical and prediction models, for the case where groundwater is abstracted by the Prominent Hill mine. These show that the inflow is predicted to decrease to about 87% (644 m^3/d) of the steady state by 2019 (life of the Prominent Hill mine) and then increase again to about 90% (665 m^3/d) of the steady state by 2119.

The representation of inflow in the Draft EIS model was provided using constant heads with a reference elevation of 60 mAHD. The calibrated inflow using this methodology was 3057 m^3/d. Whilst this estimate is quite different to the updated Prominent Hill estimate, there is no evidence to suggest one is closer to reality than the other. There is also no clear understanding of how this inflow will react to drawdown in the Stuart Shelf and whether the calculated inflow represents a maximum flow or whether inflow can increase as drawdown propagates from OD and the expansion of the OD mine.

Given the above the Arckaringa Basin inflow boundary condition in the Stuart Shelf model has been changed to a constant flux boundary providing a combined inflow of 740 m^3/d (Figure 3.13). This should ensure that:

- The lowest estimate (e.g. worst case) is used in the Stuart Shelf model.
- Inflow from the Arckaringa Basin will not increase in response to an increased groundwater gradient towards OD and the open pit (again a worst case and conservative scenario).
- The Prominent Hill and Stuart Shelf groundwater models are aligned.

- The flux can be reduced with time to represent the predicted effects of the Prominent Hill mine on inflow.

- The inflow will not vary when hydraulic parameters are changed during the calibration phase.

3.10 Model discharge

The Draft EIS model included a number of constant head boundary conditions close to the northern boundary with the GAB. These would allow water to flow into the model if the groundwater elevation dropped below the reference elevation, however, as there is not thought to be a connection with the GAB aquifers this situation would not be representative. These have been replaced with drain boundary conditions with reference elevations set to equal ground surface (Figure 3.13). These only allow water to flow out of the model.

3.11 Time period

The time variant historical model commences on the 1st January 1983 and has been extended to run until the 2nd March 2009. This was undertaken in order to incorporate a greater period of monitoring data and the abstraction associated with the trial depressurisation. The time variant predictive model was adjusted to commence from this date and runs until the 1st January 2550.

As with the Draft EIS, the predictive model is made up from a number of sub-models that allow for the progressive expansion of the open pit to be simulated (Table 3.1), but the sensitivity analyses were undertaken with a single model in which the LoM pit was active from the start of the model.

Table 3.1 Sub-models used in the predictive simulation

Predictive sub-model	Start	Stop	Duration (days)
1	2009	2010	305
2	2010	2013	1096
3	2013	2015	730
4	2015	2016	366
5	2016	2020	1,461
6	2020	2027	2,557
7	2027	2038	4,018
8	2038	2050	4,383
9	2050	2550	185,000

3.12 Initial parameter values

The calibrated values from the Draft EIS model were used as the starting point for the calibration of the adjusted model.

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4 CALIBRATION

4.1 Introduction

The calibration dataset of observed groundwater head has been expanded for the purposes of this model update. The model simulation time has been extended to incorporate a greater time series of data and this has included the addition of very detailed monitoring data associated with the trial depressurisation study as well as the latest observations from the long term monitoring bores.

The Draft EIS model was calibrated by varying hydraulic parameters by a process of "trial and error" in order to improve the match between observed and simulated groundwater elevations at a series of (assumed) steady state and time variant monitoring locations. Heterogeneity was introduced into the model where this was backed up by evidence, otherwise uniform parameters were used within model layers.

This additional data does not provide any reason to alter the calibration methodology from that used in the Draft EIS modelling. This is because:

- The steady state groundwater observations are assumed to relate to an equilibrium condition which is very unlikely to exist.
- The time variant groundwater observations are limited to within the OD SML or very close to it. This provides no opportunity to calibrate the model to a time variant stress in the majority of the model domain. The area of the SML represents about 1% of the total model domain area.
- Many of the major groundwater fluxes in the system are poorly understood and cannot be measured easily (e.g. flow to the raise bores, evaporative losses at Lake Torrens, rainfall recharge etc.).

The Stuart Shelf groundwater model is an exploratory model which should be used to investigate the ranges of groundwater responses that can be expected during, and for a limited time after, expansion of the OD mine. To overly complicate the model in order to achieve a statistically correct or visually pleasing calibration to this dataset would be misguided and would only serve to incorrectly heighten the expectations of the predictive capability of the model.

Furthermore, the parameter distributions and values (especially in the ZAL) were explored exhaustively in the Draft EIS. For this reason, the re-calibration philosophy was that in general terms these would not be altered significantly.

4.2 Steady state observations

The steady state dataset was expanded to comprise groundwater head observations at 125 separate locations (Figure 4.1 and Table 4.1). The data spans the period from 2006 until 2010. Although these are all recent observations, due to their distance from OD most are assumed to be representative of the pre-mine condition in the Stuart Shelf. Some monitoring bores however are situated in the vicinity of the OD mine and these observations may have been affected by mining operations.

Of the 125 observations 11 are in the area of the THZ / Adelaide Geosyncline, 58 in the ZAL, 1 in the Yarloo Shale, 38 in the ZWA and 17 in the ZWC.

The data is regionally extensive. The distribution by hydrostratigraphic layer is described below:

- THZ and Adelaide Geosyncline: The data are situated in the region of the central and southern THZ. These groundwater measurements show significant variation, returning values between 17 mAHD and 87 mAHD).
- ZAL: Data are spread throughout the extent of the ZAL, although data density is much lower to the southwest of OD. The observed groundwater elevations are between 27 mAHD and 72 mAHD. The highest observed elevations occur towards the southern margin of the ZAL. The measurements are broadly consistent, however to the north of OD and in the vicinity of Lake Torrens differences of over 10 m are observed at boreholes within a few hundred metres of each other.
- ZWA: Data density is high in central and southern areas. There is no data outside of these zones. The groundwater elevation observations vary from between 29 mAHD and 119 mAHD. The highest values are generally found to the south although considerable variation is observed over short distances.
- ZWC: The data are confined to a very small area within the south western portion of the SML and just to the south of the SML. The regional extent of ZWC data is poor. The observed groundwater elevations are between 44 mAHD and 54 mAHD. Variation of 5 metres or more is observed at boreholes only a few hundred metres apart.

Table 4.1 Steady state groundwater head observations in the Stuart Shelf

Lithology	Minimum (mAHD)	Maximum (mAHD)	Variance (m)
THZ / Adelaide Geosyncline	29.8	86.7	56.9
ZAL	16.9	71.8	54.9
ZWA	29.0	119.4	90.4
Yarloo Shale	33.2	33.2	N/A
ZWC	39.6	53.7	14.1

4.3 Time variant historical observations

4.3.1 Introduction

One hundred and eighty long term time variant historical observation locations are available within the Stuart Shelf numerical model domain, 45 in the ZAL, 60 in the ZWC and 75 in the ZWC associated with the trial depressurisation (Figures 4.2 and 4.3).

The ZAL monitoring bores are situated beneath and around mine facilities that are likely to produce seepage into the groundwater system; the TSFs and the MWEPs. The ZWC monitoring bores are situated around the underground mine and the OD mine project area.

4.3.2 ZAL monitoring

Figure 4.4 presents a selection of hydrographs from bores screened in the ZAL that are considered representative of the range of observed groundwater responses. The full data set is presented in Attachment A. The following summarises the dataset as a whole:

- Time variant groundwater observations are available from 1994 to 2009.
- The range of measured values is between about 40 and 70 mAHD.
- Most of the bores are clustered around the TSFs, but a set of perimeter bores (LR series) provide sub-regional observations (LR08 for example is about 10 km north of OD).
- The TSF bores show significant variation in groundwater elevation and time variant response over short distances. Observed groundwater elevation in 1999 ranges between 48 mAHD and 70 mAHD in these locations. Five response types are observed:
    1) A gradual increase in groundwater head of about 1 m in total. These are found both within and around the TSFs.
    2) A more significant increase in groundwater head of between 1 and 10 m. This is observed in two areas; in the vicinity of TSF4 and to the east of TSF1.
    3) Relatively flat observed groundwater head through time. This is observed mostly through the centre of the TSF complex, between TSF4 and TSFs 1, 2 and 3.
    4) A reduction in groundwater head through time of between 5 and 10 m (these are in the vicinity of the LP02 abstraction bore)
    5) A quite complex response which begins in 1994 with an abrupt reduction in head (roughly 5 m), followed by almost 5 years of gradual increase (back to 1994 levels) and then 2 or 3 years of rapid reduction (roughly 10 m) followed by several years of relatively stable observations. Boreholes that record this response are typically located beneath and to the east of TSF 1, 2 and 3.
- The perimeter bores show a much more subdued response than the TSF bores. They are:
    - LR08 (about 10 km north of TSF3) returned an initial groundwater elevation of 42.9 mAHD in 1996. A gradual decrease in head has been observed since then of about 0.5 m in 13 years.

- LR01 (about 4 km north of TSF3) provides an initial groundwater elevation of 47.4 mAHD in 1994 which is followed by 14 years of gradual decline in elevation totalling about 0.6 m.
- LR02 (about 10 km northeast of the TSF complex) provided a groundwater elevation of about 45.4 mAHD in 1994 which was followed by periods of both reduction and increase in elevation (of about 0.2 m) resulting in a final observation (2008) about 20 cm higher than the initial.
- LR04 (about 13 km east of the TSF complex) which returned an initial groundwater elevation of about 44 mAHD in 1997 followed by about 6 years of declining levels and another 6 years of relatively stable levels. The final observed groundwater elevation at this location was 40 mAHD in 2008.
- LR03 (about 11 km southeast of the TSF complex) provides an initial groundwater head of about 66 mAHD in 1994. Observed elevations increase from 1997 by about 8 m in 2002, from which point they decline again to reach about 69 mAHD in 2008. The observed increase in heads is likely due to a leak in the town water supply storage dam that occurred at roughly the same time.
- LR09 (about 8 km southwest of TSF4) provides an initial groundwater elevation (1996) of about 47.9 mAHD. Over the following 12 years the elevation increases by 30 cm to about 48.2 mAHD.

The ZAL perimeter bores show subtle but important variations in groundwater response to the OD mine. To the north groundwater elevations are shown to be falling slightly over time (less than 50 cm from 1997 to 2008). To the east levels are falling by a greater amount (4 m) in the same time but to the southwest levels are increasing slightly (less than 50 cm).

The TSF local bores show significant variation, although the responses fall into one of five type groups (described above). The type observations are intermingled and characteristic of a system of significant heterogeneity. To what extent this heterogeneity comes from the hydrostratigraphy or the very local variation in seepage from the TSFs is unclear, but it is likely to be affected by both.

4.3.3 ZWC monitoring

Figure 4.5 presents a selection of hydrographs from bores screened in the ZWC that are considered representative of the range of observed groundwater responses. The full data set is presented in Attachment B. The following summarises the dataset:

- Time variant groundwater observations are available from 1985 and 2009.
- The range of measured values is between about 60 and -90 mAHD.
- Most of these bores are clustered around the OD mine and the expansion project area, however, as with the ZAL, a set of perimeter bores (QR series) provide a sub-regional observation set (QR02 for example is about 7 km north of OD).
- All bores local to OD show significant drawdown in response to the numerous groundwater stresses in the ZWC. Away from OD the response magnitude reduces. In general observed groundwater elevations reduce

from the commencement of monitoring (in the mid 1980's) until 2000 when they level off and in some cases start to recover. In the centre of the OD underground workings the observed groundwater elevation falls to as low as -90 mAHD. The greatest drawdown is recorded to the north of the workings, the smallest to the south. Observed responses that diverge from this description are rare.

- The perimeter bores record drawdown of between 1 and 2 m between 1994 and 2008.
- Four bores are located in the vicinity of the TSFs (QT01, 02 and 03 and RD308). The observed drawdown at QT02, QT03 and RD308 is between 5 and 25 m. At QT01 (on the north western edge of TSF4) no drawdown is observed.

Figure 4.6 presents representative hydrographs corresponding to the trial depressurisation. The full dataset is presented in Attachment C. The data can be summarised as follows:

- The monitoring bores are located in the vicinity of the trial depressurisation bores and towards the margins of the SML. A number of bores are also located to the south of the SML.
- The observations span the period from 2008 to 2009.
- The observations show that drawdown in response to the trial was observed to be between 20 and 40 m in the area immediately around the abstraction bores. About 5 km to the east the drawdown was between 1 and 10 m. Directly to the east drawdown of 5 m was observed at the boundary of the SML, but at other locations along the boundary no drawdown was observed.

4.4 Calibration relevance

All of the time variant calibration data are from monitoring bores in the Extended SML or within a few hundred metres of it. There are no long term pumping tests and associated monitoring in areas away from the OD mine and there is therefore no available data with which to assess the time variant response in the regional aquifers.

A stated previously, the time variant data is located in an area that occupies less than 1% of the Stuart Shelf groundwater model. When considering the significance of the calibration it should be noted therefore that 99% of the model cannot be calibrated to a time variant groundwater response.

It follows therefore that the regional predictions provided by the single predictive model constructed using the calibrated parameters should be interpreted with caution.

The sensitivity analyses are key to this study and are used as a tool to assess the potential range of regional predictions based on changes to the most important and uncertain model input parameters.

4.5 Hydraulic testing data

A significant amount of hydraulic testing data is available which provides ranges of parameter values to constrain the groundwater model inputs. The data is mapped in Figures 4.7 to 4.12 and summarised in Table 4.2. Details of all tests can be found in Attachment D.

The following comments can be made about the dataset:

- There are no hydraulic parameter measurements for the Yarloo Shale.
- There are no storage parameter measurements for the THZ and Adelaide Geosyncline rocks.
- Measured hydraulic conductivity of the ZWA is significantly higher than the other lithologies.

Table 4.2 Range of measured hydraulic data, Stuart Shelf

Lithology	Hydraulic conductivity (m/d)		Specific storage (m^{-1})	
	Minimum	Maximum	Minimum	Maximum
THZ and Adelaide Geosyncline	$1x10^{-4}$	$6x10^{-3}$	No data	
Bulldog and Yarra Wurta Shale	$4x10^{-2}$	$1x10^{0}$	No data	
ZAL	$1x10^{-1}$	$7x10^{+2}$	$1x10^{-6}$	$2x10^{-3}$
Yarloo Shale	No data		No data	
ZWA	$5x10^{-4}$	$2x10^{-1}$	No data	
ZWC	$6x10^{-4}$	$3x10^{+1}$	$1x10^{-6}$	$6x10^{-4}$
ZWT	$2x10^{-4}$	$2x10^{-2}$	No data	

4.6 Methodology

Variation of hydraulic conductivity values in the steady state model control the absolute groundwater elevations and regional gradients. The regional boundary conditions described in Sections 2 and 3 were fixed during this process. The steady state calibration (in terms of matching the observed and simulated groundwater elevations) was considered to have the lowest priority in the overall calibration (especially in the area of OD) as it provides no information on how the system will react in a time variant manner to groundwater stresses.

The time variant calibration was given highest priority. However, within this, calibration to the observations local to the mine were given a lower priority than calibration to the observations around the perimeter of the mine. These perimeter observations are made up of the QR series (ZWC) and LR series (ZAL) holes mentioned above and provide the only opportunity to calibrate the sub-regional response of the groundwater system to the activities at OD. For this reason these observations were considered to have the greatest weighting in the calibration of the Stuart Shelf model. The time variant calibration involved variation of both hydraulic conductivity and storage parameters (specific yield and specific storage). Changes to hydraulic conductivity in the time variant model required the same changes to be made to the steady state model. In this way a compromise must be reached, as a change that may benefit the time variant calibration may have the opposite effect on the steady state. The calibration priorities discussed above were used to control this in a logical manner.

The Stuart Shelf groundwater model is an exploratory model required to investigate the ranges of groundwater responses that can be expected during and, for a limited time, after the OD expansion project. To overly complicate the model to achieve a statistically correct or visually pleasing calibration would be misguided and would only serve to incorrectly heighten the expectation of the predictive capability of the model. Therefore no additional hydraulic parameter complexity was introduced in addition to that already present in the Draft EIS model.

4.7 Adopted model parameters

Hydraulic parameters used in the calibrated model are presented in Figures 4.13 to 4.26 and summarised in Table 4.3.

Table 4.3 Summary of adopted hydraulic parameters following calibration

Lithology / feature	Kh (m/s)	Kv (m/s)	Ss (m-1)	Sy (%)
Alluvial sediments	$2x10^{-5}$ - $1x10^{-10}$	$2x10^{-6}$ - $1x10^{-10}$	$1x10^{-6}$	7.5
THZ / Adelaide Geosyncline	$1x10^{-10}$	$1x10^{-10}$	$5x10^{-4}$ - $1x10^{-6}$	1.0 – 7.5
ZAL	$2.5x10^{-4}$ - $1x10^{-5}$	$2.5x10^{-5}$ - $1x10^{-6}$	$1x10^{-4}$ - $5x10^{-4}$	7.5
Brine	$1.5x10^{-5}$	$1.5x10^{-6}$	$5x10^{-4}$	7.5
Yarloo Shale	$1x10^{-7}$ - $1x10^{-8}$	$1x10^{-8}$ - $8x10^{-10}$	$5x10^{-6}$	1.0
ZWA	$1x10^{-8}$	$1x10^{-9}$ - $1x10^{-10}$	$5x10^{-6}$	1.0
ZWC	$2x10^{-6}$	$2x10^{-7}$	$5x10^{-5}$	1.0
ZWT / basement	$1x10^{-10}$	$1x10^{-10}$	$1x10^{-6}$	1.0

* THZ / Adelaide Geosyncline Kh and Kv values have not been altered from those used in the Draft EIS, however the sensitivity analyses explore the significance of using higher values on model predictions.

Only minor modifications have been made from the calibrated parameters used in the Draft EIS model. These were:

1) Brine horizontal and vertical hydraulic conductivity increased by a factor of 2. This was done to maintain the correct steady state groundwater elevations with the increased extent of the brine in this model compared to the Draft EIS model.

2) Vertical hydraulic conductivity increased by a factor of 8 in a section of the Yarloo Shale and by 10 in a section of the ZWA in the vicinity of the OD mine (to increase connection between the ZAL and ZWC, so that observed sub-regional drawdown in ZAL could be better simulated).

3) Specific storage of the ZAL was decreased away from OD mine area from $1.7x10^{-3}$ to $5.0x10^{-4}$. This was done so that the regional storage in the ZAL was more in line with the regional (limited) testing data.

4) Specific storage was simplified in the Yarloo Shale to a single value of $5.0x10^{-6}$.

4.8 Calibration results (hydrographs)

4.8.1 Introduction

Results of the calibration in terms of the predicted groundwater elevations compared to the observed are presented in the Figures 4.27 to 4.38. The entire dataset is presented in Appendices A, B and C. Discussion of the calibration of selected hydrographs is provided below.

4.8.2 Observed and simulated steady state groundwater elevations

As discussed in Section 4.2, the steady state observation dataset comprises 125 separate locations with observations spanning between 2006 and 2010. Whilst these are recent observations, they are assumed to be representative of the pre-mine in the Stuart Shelf, however, it is acknowledged that those observations in the vicinity of the OD mine may have been affected by mining operations.

The observed and simulated groundwater heads are presented in Figures 4.27 to 4.31. These figures represent observations and simulated groundwater elevations and contours for the ZAL, ZWC, THZ, Yarloo and ZWA respectively. The spatial distribution of these errors within the model domain is summarised as:

- ZAL: The residuals are highest to the south and southwest and in an area to the northeast of OD. In these areas residuals of over 10 m are observed (Figure 4.27). Modelled groundwater elevation is generally lower than measured to the south and southwest and higher than observed to the north and northeast. In the central areas of the model the residuals are generally less than 5 m and modelled elevations are higher than measured.

- ZWC: The ZWC observations are clustered around the centre of the model in the vicinity of OD (Figure 4.28). Residuals are generally low (less than 2 m) but increase slightly to the east (maximum 5.7 m). It could be argued, given the proximity of these observations to OD, that they may not truly represent pre-mine conditions.

- THZ: The residuals are high throughout the THZ as the observed values show significant variability (minimum 17 mAHD, maximum 87 mAHD) over a small area (Figure 4.29). The high variability in the observed values however results in a low calculated Scaled Root Mean Square (SRMS).

- ZWA: The most significant residuals (maximum 40 m) are found within the ZWA (Figure 4.29). As with the ZAL, towards the centre of the model the residuals tend to be lower, and towards the south they tend to be higher.

4.8.3 Observed and simulated time variant groundwater elevations in the ZAL

As the ZAL observations show such a range of time variant responses to groundwater related activities at OD and the groundwater model does incorporate any local variations in hydraulic parameters or TSF seepage, not all observations are reproduced accurately. However in general the observed and simulated groundwater elevations compare well, especially those listed as “type” responses 1, 3, 4 and 5 and described in Section 4.3.2. These are the observations that either indicate a limited increase (roughly 1 m) in groundwater elevation with time, steady elevations with time, or any reduction with time (Figure 4.32).

Observations where the groundwater elevation increases by 1 to 10 m are not reproduced well (“type” 2). This observation type is found in two locations; one to the east of TSF1 and the other in the centre and west of TSF4. The first location appears to be responding to seepage from the now decommissioned mine water evaporation pond (MWEP). The actual rate of seepage from the MWEP is not well constrained and has therefore been excluded from the model. For this reason these observations should not be used to assess the predictive capability of the model. The second set show that seepage beneath TSF4 is either greater than assumed in the model or the hydraulic parameters are such that uniform seepage has the effect of causing greater increase in groundwater heads here than beneath the eastern portion of TSF4 and TSF 1, 2 and 3. Varying the model to include either of these possibilities was not considered worthwhile given the calibration methodology, however, both were investigated in the sensitivity analysis (Section 6).

The sub-regional response in the ZAL is reproduced well at bores LR01, LR02, LR03 and LR09 (Figure 4.33). These bores record both decreases and increases in groundwater elevation with time associated with TSF leakage, abstraction from the ZAL (LP02) and leakage from the ZAL to the ZWC below. The observed drawdown at LR08 to the north is not reproduced with the calibrated model and the drawdown at LR04 to the east is reproduced only minimally. The vertical conductivity of the ZWA in the model provides the primary control of the drawdown at these locations but increasing it above what is used in the calibrated model worsens the observed and simulated match at most other bores (in the ZAL and ZWC) significantly. This situation is considered in the sensitivity analysis (Section 6).

Observed and simulated groundwater contours for the ZAL in July 2008 are presented in Figure 4.34. This shows a reasonable correlation of the observed and simulated contours with the major difference to the east of TSF1, as discussed above this area appears to be responding to seepage from a non-TSF source, this seepage is not understood and is not simulated within the model.

4.8.4 Observed and simulated time variant groundwater elevations in the ZWC

The model reproduces observed time variant groundwater elevations in the ZWC with a high degree of accuracy (Figure 4.35). This is true in the area of the OD workings, in the vicinity of the TSF complex and at the peripheral bores. Only in the area around RD136, RD170 and RD172 is there any significant discrepancy between observed and simulated responses. Drawdown is underestimated by the model in this area by tens of metres. Whether this is due to heterogeneity within the ZWC or even ZWA or ZWT above and below it, or due to uncertainties in the flows assigned to the raise bores and saline wellfield is unclear, and changes to the model to improve the calibration in this small area are would not be the intent of the model.

The subdued drawdown responses observed in the vicinity of the TSF at QT02, QT03 and RD308 are simulated accurately by the model. The observed groundwater head at QT01 (which shows no variation over time) is not reproduced by the model as it simulates drawdown of the order observed and simulated at the other three holes.

The model reproduces the observed time variant groundwater response recorded at the peripheral ZWC monitoring bores very well (Figure 4.36). Furthermore, as the vertical conductivity value assigned to the ZWA is an important factor controlling this, the sub-regional calibration suggests that overall the parameters assigned to the ZAL, ZWA and ZWC, in the area of OD at least, are representative of the system.

Observed and simulated groundwater contours for the ZWC in July 2008 are presented in Figure 4.37. The contours show a reasonable correlation between observed and simulated. On a sub-regional scale the observed and simulated contours demonstrate an oval (sub-radial) shape which is caused by the northwest southeast trend of the underground workings. The greatest error occurs to the east and southeast where there is an offset of up to 20 m. Locally, the difference between the observed and simulated ZWC contours is exaggerated by the distribution of the observed data and the magnitude of drawdown to the existing underground mine. In general, the correlation for the ZWC is considered very good.

4.8.5 Observed and simulated groundwater elevations in the ZWC (trial depressurisation)

Short term drawdown in response to the trial depressurisation was reproduced well with the model at almost all locations in the area local to OD (Figure 4.38). The only exception to this was in the area of RD3516 where the modelled drawdown was less than observed. This is the same area that was seen to underestimate drawdown in the long term ZWC monitoring locations (described above).

4.9 Calibration results (statistics)

Statistical analysis of the steady state and time variant calibration has been undertaken using methods summarised by MDBC (2000) and is consistent with the methodology applied in the Draft EIS which considers the Root Mean Square (RMS) and SRMS. These were derived using the formulas below (where h and H are the simulated and observed groundwater elevations respectively).

$$RMS = \sqrt{\frac{1}{n}\sum\left[Wi(hi - Hi)\right]}^{\;2}$$

$$SRMS = \frac{100.RMS}{\Delta H}$$

The RMS and SRMS for the calibrated steady state model are presented in Table 4.4.

Table 4.4 Steady state model calibration statistics

Observation set	Number of Observations	Variation in observed data (m)	Mean residual (m)	RMS (m)	SRMS (%)
All observations	125	102.5	8.2	12.5	12.2
THZ only	8	56.9	5.1	6.6	9.5
ZAL only	62	54.8	5.2	7.7	17.0
ZWA only	38	90.4	16.4	20.1	22.2
ZWC only	17	14.1	3.8	2.8	19.5

These statistics show that the calibration of the steady state model produces an SRMS of 12.2% which is considered acceptable. The calculated SRMS is around 20% for the ZAL, ZWA and ZWC but this is not considered significant given the case that the steady state calibration was given the lowest priority and that for the ZAL and ZWC especially these values represent the fact that the variation in observed values is low. The variation in observed groundwater elevation in the ZWC is 14 m, which means that in this case even a fairly small average residual will result in a high SRMS (the mean residual in the ZWC is 2.8 m, which results in an SRMS of 19.5%).

The RMS and SRMS for the calibrated time variant model are presented in Table 4.5.

Table 4.5 Time variant model calibration statistics – absolute values

Observation set	Number of Observations	Variation in observed data (m)	Mean residual (m)	RMS (m)	SRMS (%)
All long term	6615	169	3.7	10.1	6.0
ZAL long term	3888	39.3	6.3	7.9	20.2
ZWC long term	2727	147.6	8.8	12.5	8.5

This shows that the SRMS calculated against the combined long term groundwater head observations in the ZWC and ZAL is just above the preferred value of 5% and is considered acceptable. The greatest error is contributed by the ZAL dataset. This reflects the observed situation to the extent that both the response and absolute groundwater heads in the ZAL show significant variability within short distances. Several factors may contribute to this observed variation however, it is likely that this high SRMS is controlled primarily by two factors:

- Karstic and fracture dominated flow in the ZAL.
- Non uniform leakage (spatially and time variantly) from the TSFs and MWEP.

The RMS and SRMS adjusted to consider drawdown (or mounding) for the calibrated time variant model are presented in Table 4.6. In this analysis only the change in values over the calibration period is considered as opposed to comparison of absolute values over the period (Table 4.3). This provides a better statistical indication of the quality of the calibration against the trends in the observed behaviour (or in other words the response of the groundwater system to stress).

Table 4.6 Time variant model calibration statistics – magnitude of changes

Observation set	Variation in observed data (m)	Mean residual (m)	RMS (m)	SRMS (%)
All long term	131.8	3.6	7.1	5.4
ZAL long term	26.5	1.8	2.9	11.1
ZWC long term	131.8	6.3	10.5	7.9

This shows that the time variant model calibration (identified as the priority previously) returns a SRMS of 5.4% when the entire long term dataset is considered. This is very close to the MDBC (2000) “preferred” value of 5% and is considered acceptable. The analysis also shows that a significant proportion of the SRMS in the ZAL comes from errors in the absolute groundwater head rather than the groundwater response. When the groundwater response is used to calculate SRMS, the resultant value is 11.1%, rather than 20.2% as calculated from the absolute values.

4.10 Mass balance

The steady state mass balance is illustrated in Figure 4.39. This shows that:

- Recharge provides the largest inflow (3,243 m^3/d).
- The greatest discharge of water from the model (over 75% of total inflow) occurs at the northern portion of Lake Torrens.
- Discharge from the central portion of Lake Torrens is much less (516 m^3/d).
- Discharge from the model along the northern boundary is small (45 m^3/d).

The discrepancy between the calibrated steady state model inflow and outflows is less than 0.001%.

The main inflows and outflows to the model simulated in 2550 are as follows:

- Recharge and inflow from the Arckaringa Basin remains unchanged from the steady state rates at 3,243 m^3/d and 740 m^3/d respectively.
- Inflow from TSF and RSF seepage is 290 m^3/d.
- Discharge of water from the northern portion of Lake Torrens is about 2040 m^3/d (compared to 3100 m^3/d at steady state).
- Discharge from the model along the northern boundary is small (45 m^3/d).
- Inflow to the LoM pit is 5700 m^3/d.

The mass balance at 2550 shows that at this time the model has not reached an equilibrium in terms of flows to the pit and inflows to the model.

5 PREDICTIVE MODELLING

5.1 Introduction

A single predictive model is used to provide an assessment of how the Stuart Shelf groundwater system will respond to the expansion of the OD mine. This response is considered at both local scale (pit inflow, dewatering rates, mounding beneath the TSF and RSFs) and regionally (at potential receptors, the boundary with the GAB and Lake Torrens).

The predictive model uses the calibrated hydraulic parameters discussed in Section 4.7.

There is currently no opportunity to calibrate the regional hydraulic parameters to a stress in the groundwater system. The specific storage value for example can be varied without limits in about 95% of the model domain and produce no effect on the results of the calibration. In addition, the regional coverage of hydraulic testing is limited and the testing that has been conducted has returned a significant range of values for both hydraulic conductivity and storage.

It is therefore the case that the set of parameter values used in this model (and therefore the predictions) should not be considered as being more realistic than the parameter values (and predictions) used in the sensitivity runs. The regional parameter values used in the calibrated model that have been adopted sit comfortably within the ranges of what might be expected in the Stuart Shelf. However, these are the most uncertain of the model inputs and they also have the greatest effect on the regional responses discussed below.

The predictive model runs from March 2009 to January 2550. All physical aspects (mesh, layering, hydraulic parameters) of the model are the same as the calibrated steady state and time variant historical models described in Sections 2 and 3.

In order to assess the response in both the short term and long term, results have been extracted from the model at the following time intervals; 2017 (end construction period), 2050 (end of mining), 2150 (100 years post closure) and 2550 (500 years post closure) where relevant.

As results were provided at 500 year post closure in the Draft EIS this has been reproduced here. However, given the data available for construction and calibration of the model this time step is considered at the very limits of reasonable predictive capability of the model. This is based on the significant uncertainties that are associated with the regional configuration of the model (parameters, recharge etc), the length of time variant data available for calibration (24 years in the ZWC, 15 years in the ZAL), the size of the model and the uncertainty in the predictive inputs (pit size, abstraction requirements).

5.2 Results

5.2.1 Regional predictions

2017 (end construction period)

The predicted changes in groundwater elevation (Figure 5.1) show that by 2017 seepage from the TSF, flow to the open pit and abstraction from the Motherwell wellfield have all resulted in changes to the groundwater elevation in the ZAL. These effects can be summarised as:

- Mounding beneath the TSFs of between 6 and 8 m in response to seepage.
- Predicted drawdown around the open pit, which extends a few kilometres to the south, east and north. This area includes the RSF, and seepage from these facilities is not enough to offset the flow to the pit, therefore no mounding is predicted.
- Drawdown in the vicinity of the Motherwell wellfield of between 2 and 4 m. Abstraction from Motherwell terminates from 2017 onwards.
- At the end of 2017 the predicted effects of the expansion of the OD operations are confined to the area of the Extended SML and the Motherwell wellfield.

The model predicts drawdown in the ZWC in 2017 of just over 100 m in the area of the open pit (Figure 5.5). A number of “centres” of drawdown are also present just to the south and southeast of open pit. These are:

- A maximum of 60 m drawdown associated with the MMIA abstraction.
- A maximum of 20 m drawdown associated with the Roxby Downs abstraction.
- A maximum of 105 m drawdown associated with the Hiltaba abstraction.

Predicted drawdown at this time is confined to these areas.

2050 (end of mining)

The predicted changes in groundwater elevation (Figure 5.2) show that by 2050 mounding in the ZAL in response to continued seepage from the TSF has reduced to between 2 and 4 m. Mounding beneath the RSF is still not predicted and drawdown in this area and over most of the SML has increased to between 10 and 20 m. Regionally, the 1 m drawdown contour has extended to about 5 km north and about 20 km south of the Extended SML. The drawdown predicted in response to abstraction from the Motherwell wellfield has recovered to less than 1 m (33 years after abstraction ceased).

By 2050 the predicted response to dewatering and pit inflow in the ZWC is more radial around the SML than in 2017 but maximum drawdown has remained at just over 100 m in the centre (Figure 5.6). The 1 m drawdown contour now extends to the south almost as far as Coorlay Lagoon.

2150 (100 years post closure)

The model predicts that by 2150 there is no mounding of groundwater beneath either the RSF or the TSFs. Instead a cone of drawdown extends throughout the Extended SML of between 10 and 30 m (Figure 5.3). The 1 m drawdown contour has now migrated to the north and is in the vicinity of the northern portion of Lake Torrens. Drawdown to the south of the SML has also increased and is now between 6 and 4 m at the most southerly extent of the ZAL.

Predicted drawdown in the ZWC in the vicinity of the open pit has increased laterally and is now between 10 and 110 m within the Extended SML (Figure 5.7). Predicted drawdown has migrated further to the south and extends up to 50 km from the open pit.

2550 (500 years post closure)

Simulated drawdown in the ZAL exceeds 30 m in the area of the open pit, is between 2 and 4 m in the regional extent of the ZAL and is about 1 m at the Yarra Wurta Spring (Figure 5.4). Drawdown now extends into the THZ and northern portion of the model but this is limited to a 5 km portion at the boundary with the ZAL extent.

Predicted drawdown in the ZWC is now between about 15 m and 110 m within the Extended SML and the 1 m drawdown contour has migrated out to the position of Alex's Bore 2 and No. 1 Well (Figure 5.8).

5.2.2 Potential receptors

Time variant hydrographs of predicted groundwater elevation at the potential environmental and third party receptors are presented in Figure 5.9. These show that:

- Predicted drawdown at all potential receptors is less than 1 m until about 130 years post closure.
- 500 years post closure there is no discernable drawdown at RT9 in the THZ.
- 500 years post closure the maximum predicted drawdown at potential 3rd party receptors is less than 3 m.
- Drawdown at Yarra Wurta Spring is not predicted to increase above 1 m within 500 years post closure.

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6 SENSITIVITY ANALYSIS

6.1 Introduction

The sensitivity analysis is intended to explore the control that various hydraulic parameters and boundary condition settings have on model predictions.

The calibrated model settings are used as the template and selected inputs are varied independently and the model run to evaluate the effects on results. Changes to hydraulic conductivity require that the steady state and time variant historical models are re-run also, with the results ultimately providing the initial conditions for the predictive sensitivity run. Changes to storage parameters require that only the time variant historical model is re-run. Changes to boundary conditions and hydraulic conductivity can require both, one or none of the steady state and time variant models variants to be run.

A single predictive model has been constructed to facilitate the sensitivity analysis. In this model the 40 year (LoM) pit is used from the start of the model and associated dewatering is not simulated. This method was shown in the Draft EIS to produce comparable results (especially long term) to the far more complex methodology employed in the standard predictive model (requiring 9 sub-models).

The parameter values that are likely to have the greatest control on the regional scale model predictions are the specific storage of the ZAL and ZWC, the horizontal hydraulic conductivity of the ZAL and ZWC and the vertical hydraulic conductivity of the ZWA. The sensitivity of predictions at both the local and regional scale to variations in boundary conditions has also been assessed. The sensitivities are summarised in Table 6.1. Where possible the sensitivities explored in the Draft EIS have been replicated here, however in some cases (such as varying the constant heads at the boundary with the Arckaringa Basin) this was not possible. Additional sensitivities have also been investigated.

As was the case in the Draft EIS, these are considered below by varying the parameters in the predictive model and considering the results (including particle tracking) at 500 year post closure.

Table 6.1 Sensitivity analyses

Run	Description	Details	Model suite
I	Predictive model	Described in Section 5	SS, TV, PR
II	Low ZAL specific storage	$1x10^{-4}$ m^{-1} (excluding mine area)	TV, PR
III	High ZAL specific storage	$2.5x10^{-3}$ m^{-1} (excluding mine area)	TV, PR
IV	High ZWA Kv	$1x10^{-8}$ m/s	SS, TV, PR
V	High ZWC Kh and Kv	Multiply by 2.5	SS, TV, PR
VI	Reduced future recharge	-40%	PR
VII	Increased future Recharge	+40%	PR
VIII	THZ and Adelaide Geosyncline high K	Kh and Kv $1x10^{-7}$ m/s	SS, TV, PR
IX	THZ / Adelaide Geosyncline high K band	Kh $1x10^{-6}$ m/s	SS, TV, PR
X	Declining inflow from Arckaringa Basin	Reduced by 50% over time	PR
XI	Higher TSF seepage	48% BHP Billiton model	TV, PR
XII	Higher RSF seepage	5% (7.5 mm/yr)	PR
XIII	No Motherwell abstraction	Motherwell wellfield removed	PR
XIV	Revised TSF configuration	TSF location modified	PR

6.2 Results

6.2.1 Introduction

In the following discussion the results of the sensitivity analyses are compared against the basecase predictive model so that the sensitivity of predictions to each parameter or boundary condition can be quantified. It is also of note that runs which require changes to the hydraulic conductivity will result in the model varying significantly from the calibrated state described in Section 4. Whilst these runs are useful for understanding the sensitivity of model predictions they actually represent a parameter combination which is very unlikely to be representative of the natural case. The results of these analyses are therefore subject to additional uncertainties in addition to those outlined in the sections above.

6.2.2 Run II: Low ZAL specific storage (Figures 6.1 and 6.2)

In this sensitivity, the specific storage in the ZAL was reduced from $5x10^{-4}$ m^{-1} to $1x10^{-4}$ m^{-1}. This sensitivity was carried out to explore predictions using a specific storage at the lower end of the range of measured hydraulic data. This has the effect of increasing the predicted regional drawdown in both the ZWC and ZAL. 500 years post closure predicted drawdown is between 4 and 6 m greater over most of the ZAL extent, and about 2 m greater at the northern tip of Lake Torrens. Predicted drawdown in the northern extent of the model is greater but it is restricted to a limited band just north of the ZAL boundary. The magnitude of the effect is roughly the same in the ZWC, but it is restricted to the northern part of the permeable ZWC extent.

6.2.3 Run III: High ZAL specific storage (Figures 6.3 and 6.4)

In this sensitivity the specific storage in the ZAL was increased from $5x10^{-4}$ m^{-1} to $2.5x10^{-3}$ m^{-1}. This sensitivity was carried out to explore predictions using a specific storage at the upper end of the range of measured hydraulic data. This has the effect of decreasing the predicted regional drawdown in the ZAL by about 2 m. Predicted drawdown in the ZAL is restricted to a sub-regional area around the Extended SML and in the rest of the ZAL and northern extent of the model the predicted drawdown is less than 1 m. Predicted drawdown in the ZWC is also reduced in both magnitude and extent.

6.2.4 Run IV: High ZWA Kv (Figures 6.5 and 6.6)

In this sensitivity the vertical hydraulic conductivity of the ZWA is increased by two orders of magnitude from 1×10^{-10} m/s (8.6×10^{-6} m/d) to 1×10^{-8} m/s (8.6×10^{-4} m/d). In doing so, the hydraulic connection between the ZWC and ZAL is increased significantly and represents a scenario whereby leakage is much greater than has been calibrated regionally. Predicted drawdown 500 years post closure is greater in both the ZWC and ZAL. The difference is more pronounced in the ZAL where predicted drawdown in the vicinity of the open pit increases by over 30 m. Regionally within the ZAL the predicted drawdown is between 2 and 4 m greater.

6.2.5 Run V: High ZWC Kh and Kv (Figures 6.7 and 6.8)

This sensitivity was carried out to explore predictions using a hydraulic conductivity greater than what was calibrated. In this scenario the horizontal and vertical hydraulic conductivity of the ZWC were increased from 2×10^{-6} m/s (0.2 m/d) to 5×10^{-6} m/s (0.4 m/d) and from 2×10^{-7} m/s (0.02 m/d) to 5×10^{-7} m/s (0.04 m/d) respectively. The most significant effect is seen in the ZWC, where predicted drawdown 500 years post closure is about 30 m greater in the area of the expansion of the OD mine, and is at least 1 m greater over the majority of the northern and central extent of the ZWC. In the ZAL the predicted drawdown is up to 20 m greater in the area of the expansion of the OD mine and about 2 m greater in the regional ZAL. At the northern extent of Lake Torrens predicted drawdown is between 1 and 2 m.

6.2.6 Run VI: Reduced future recharge (Figures 6.9 and 6.10)

In this scenario rainfall recharge to the model was reduced by 40% from the start of the predictive model (2009). This sensitivity was undertaken so as to consider the potential and uncertain effects of climate change on the model predictions. This has the most obvious effect in the ZWC, where 500 year post closure predicted drawdown has increased by between 1 and 4 m over most of the extent of this unit. In the ZAL predicted drawdown has increased by less than 1 m over the majority of its extent.

6.2.7 Run VII: Increased future recharge (Figures 6.11 and 6.12)

As per Run VI, this sensitivity was also undertaken so as to consider the potential and uncertain effects of climate change on the model predictions. In this scenario rainfall recharge to the model was increased by 40% from the start of the predictive model (2009). The results are almost identical to the run above, although in this case the sensitivity results in lower drawdown being simulated in both the ZWC and ZAL.

6.2.8 Run VIII: THZ and Adelaide Geosyncline high K (Figures 6.13 and 6.14)

This sensitivity was carried out to consider the predictive changes using the upper range of measured hydraulic conductivity values that have been reported for the THZ and Adelaide Geosyncline (SKM, 2010). By increasing the hydraulic conductivity of the THZ and Adelaide Geosyncline in the numerical model, this represents a worst case scenario in terms of hydraulic connection between the Stuart Shelf and the Eromanga Basin (GAB). In this sensitivity the hydraulic conductivity (horizontal and vertical) was increased by three orders of magnitude, from 1×10^{-10} m/s (8.6×10^{-6} m/d) to 1×10^{-7} m/s (8.6×10^{-3} m/d). Five hundred years post closure this has almost no effect in the THZ and Adelaide Geosyncline or anywhere else in the model domain.

6.2.9 Run IX: THZ / Adelaide Geosyncline high K band (Figures 6.15 and 6.16)

This sensitivity scenario was undertaken to allow for the unlikely situation whereby an enhanced hydraulic connection exists in the THZ and Adelaide Geosyncline. By assuming a higher permeability channel between the Stuart Shelf and Eromanga Basin, this represents a worst case scenario in terms of hydraulic connection and long term drawdown. In this sensitivity the horizontal hydraulic conductivity was increased by four orders of magnitude, from $1x10^{-10}$ m/s ($8.6x10^{-6}$ m/d) to $1x10^{-6}$ m/s ($8.6x10^{-2}$ m/d), in model Layers 1 and 2, in the vicinity of boreholes PT63, RT41 and PT62, in the THZ and Adelaide Geosyncline. These holes intersect discontinuous remnants of Eromanga Basin sediments, which present a higher hydraulic conductivity than the THZ rocks that underlie them.

There are no discernable differences in predicted drawdown from this scenario compared to the lower hydraulic conductivity case.

6.2.10 Run X: Declining inflow from Arckaringa Basin (Figures 6.17 and 6.18)

In this sensitivity the inflow to the model from the western boundary (conceptually from the Arckaringa Basin) was reduced over time. The decline through time was based on the Prominent Hill model results (Aquaterra 2009), but was much more dramatic with a maximum reduction of 50%.

At 500 years post closure an increase in predicted drawdown of less than 1 m is predicted in the full extent of both the ZWC and ZAL. An increase of between 1 and 2 m is predicted within a kilometre of the Arckaringa boundary condition.

6.2.11 Run XI: Higher TSF seepage (Figures 6.19 and 6.20)

In this scenario the higher TSF seepage estimate as defined by the 48% tailings solids schedule was used instead of the 53% tailings solids schedule (Figure 3.12). The 48% tailings solids schedule was provided by BHP Billiton and is considered to be a conservative case for TSF seepage rate during mine operations. This 48% tailings solids schedule was coupled with a post closure seepage rate of 1% of rainfall (1.5 mm/yr). This post closure seepage is consistent with the RSF post closure recharge rate and is appropriate for a TSF with no engineered cover. The higher seepage rate from the TSF has been modelled as a sensitivity to assess the potential for solute (particle tracking) to flow away from the open pit post closure.

At 500 years post closure an increase in groundwater head beneath the TSF in excess of the basecase model of between 1 and 2 m is predicted in the ZAL. Differences between predictions from this variant and the 53% tailings solids schedule are less than 1 m in all other parts of the model.

6.2.12 Run XII: Higher RSF seepage (Figures 6.21 and 6.22)

In this scenario a seepage rate equivalent to 5% of rainfall is applied to the RSF. This seepage rate is five times the "basecase" and was modelled by SRK (2010) to be the upper range of net percolation into the RSF. A higher seepage rate from the RSF has been modelled as a sensitivity to assess the potential for solute (particle tracking) to flow away from the open pit.

At 500 years post closure an increase in groundwater heads beneath the RSF in excess of the basecase model of up to 6 m is predicted in the ZAL. Drawdown is reduced by at least 1 m is over the majority of the Extended SML and to the south in the ZAL. A reduction in predicted drawdown is observed in the ZWC of up to 2 m in response to the increased seepage from the RSF above.

6.2.13 Run XIII: No Motherwell abstraction (Figures 6.23 and 6.24)

In this scenario no abstraction is generated from the Motherwell wellfield. This sensitivity was carried out to assess to predicted post closure change should the Motherwell wellfield not be operated during the construction period. The predicted regional drawdown at 2550 is very similar to that from the basecase model (with Motherwell abstraction).

6.2.14 Run XIV: Revised TSF configuration

This sensitivity scenario considers whether a minor revision to the location of the tailings cells proposed for the expansion constitutes a material change to the environmental assessment presented in the Draft EIS. The water balance and seepage rates are identical to Run I, however the physical location of the TSF cells has changed slightly, and is based on the recently approved TSF5 east and west positions.

The predicted regional drawdown at 2550 is very similar to that predicted by the basecase model with about 1 m drawdown predicted at Yarra Wurta.

6.3 Potential receptors

Predicted changes in groundwater elevation (for all sensitivity runs) at the potential receptors identified in Section 2 are provided in Figures 6.25 to 6.27. Two hydrographs are presented for each potential receptor; the first showing the results from sensitivities involving changes to model hydraulic parameters and the second showing changes to model boundary conditions.

The results show that:

- In all but one of the sensitivity runs, predicted drawdown at the Yarra Wurta Spring is between less than 1 m to about 2 m at 500 years post closure. Only the low specific storage sensitivity produces a predicted drawdown (about 3 m) in excess of this. The low specific storage sensitivity predicted groundwater heads show early time response to abstraction from the Motherwell wellfield, followed by tens of years of relatively stable conditions (possibly the influence of TSF and RSF seepage on the development of the drawdown pressure migration from the expansion of the OD mine, then steady decline until 2550 (response to inflow to the open pit). This detail is not observed in the predictions of any other sensitivity.

- Predicted drawdown at RT9 (towards the northern boundary with the GAB) is significantly lower than 1 m in all sensitivity runs.

- Predicted drawdown at Comet well (which is in the same location as Old Homestead, Southern Cross and New Parakylia bores) and 19 Mile Bore varies between less than 1 m to about 9 m. As these observation points are within the ZAL, the results show greatest sensitivity to the specific storage value assigned to that unit.

- Alex's Bore 2 and Loch Well are the only locations where predictions show a significant sensitivity to model recharge. The greatest sensitivity is however to ZAL specific storage, which at Alex's Bore 2 the high sensitivity value results in less than 1 m drawdown in 2550 and at the low value results in about 6 m in 2550.

6.4 Particle tracking

Time variant particle tracking undertaken on the predictive run (Figure 6.28) shows that the rate of fluid flow is such that in 500 years particles move a maximum of between 800 to 1,000 m.

Steady state particle tracking shows that seepage emanating from beneath, and in the vicinity of, the TSFs and RSF is captured by the pit in the predictive run and all sensitivity analyses, including the 5% (7.5 mm/yr) RSF seepage scenario (Figures 6.29 to 6.31).

These results show that none of the parameter combinations and increased seepage scenarios considered in this study provide a mechanism whereby seepage from the TSFs or RSF can migrate away from the SML and the open pit.

6.5 Conclusions

The sensitivity analyses have been undertaken to assess the significance of model parameter variations on the predictions from the basecase (Run I). The range of hydraulic parameters (hydraulic conductivity and specific storage) used in the analysis has generally been based upon measured values. However, a number of the sensitivities relied upon non measurable or assumed fluxes, such as future recharge or inflow from the Arckaringa Basin.

All sensitivities have been designed to demonstrate a worst case scenario or a variation to the conceptual model which provides a 'what if' scenario. The results of the sensitivity analyses show that when the upper bound values of hydraulic conductivity are used for the THZ and Adelaide Geosyncline units, the predictions in these areas and in the model domain in general remain relatively unchanged. The model predictions are more sensitive to regional variations in horizontal hydraulic conductivity of the ZWC and vertical hydraulic conductivity of the ZWA. In both cases additional drawdown is predicted over the regional extent of the ZAL. However, predicted drawdown to the north of the ZAL (including in the THZ and Adelaide Geosyncline) is relatively unchanged in these sensitivities.

The model is most sensitive to regional variations in specific storage of the ZAL. Lowering the specific storage of this unit has the effect of increasing the predicted regional drawdown in both the ZWC and ZAL. In this scenario the model predicts a post closure drawdown between 4 and 6 m greater over most of the ZAL extent, and about 2 m greater at the northern tip of Lake Torrens. Predicted drawdown in the northern extent of the model is greater but it is restricted to a limited band just north of the ZAL boundary. Increasing the specific storage of the ZAL has the opposite effect and predicted drawdown is reduced.

Steady state particle tracking shows that seepage emanating from beneath, and in the vicinity of, the TSF and RSF is captured by the pit in the predictive run and all sensitivity analyses.

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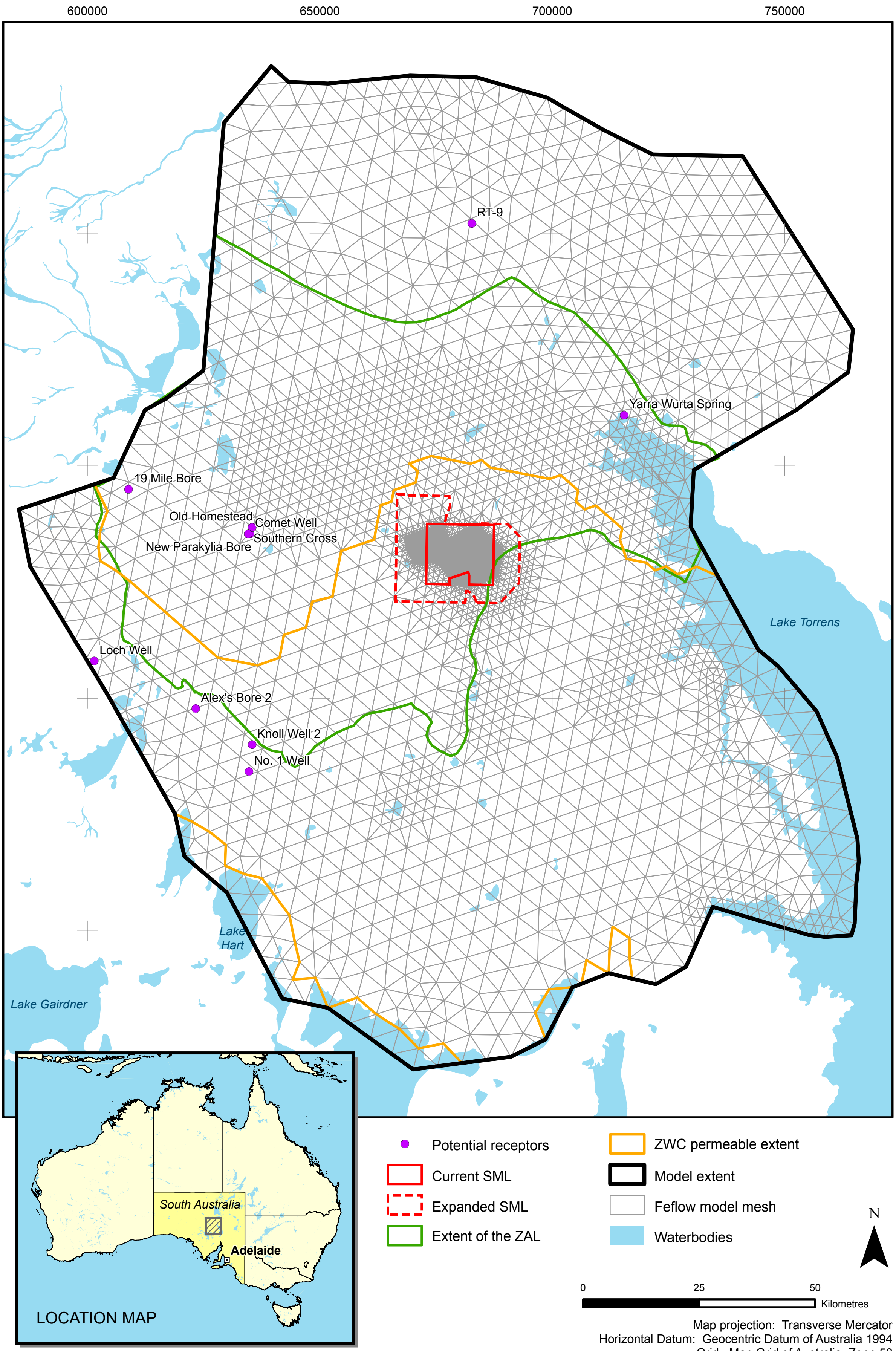
Figure 2.1 Regional context and potential receptors



Map projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 53

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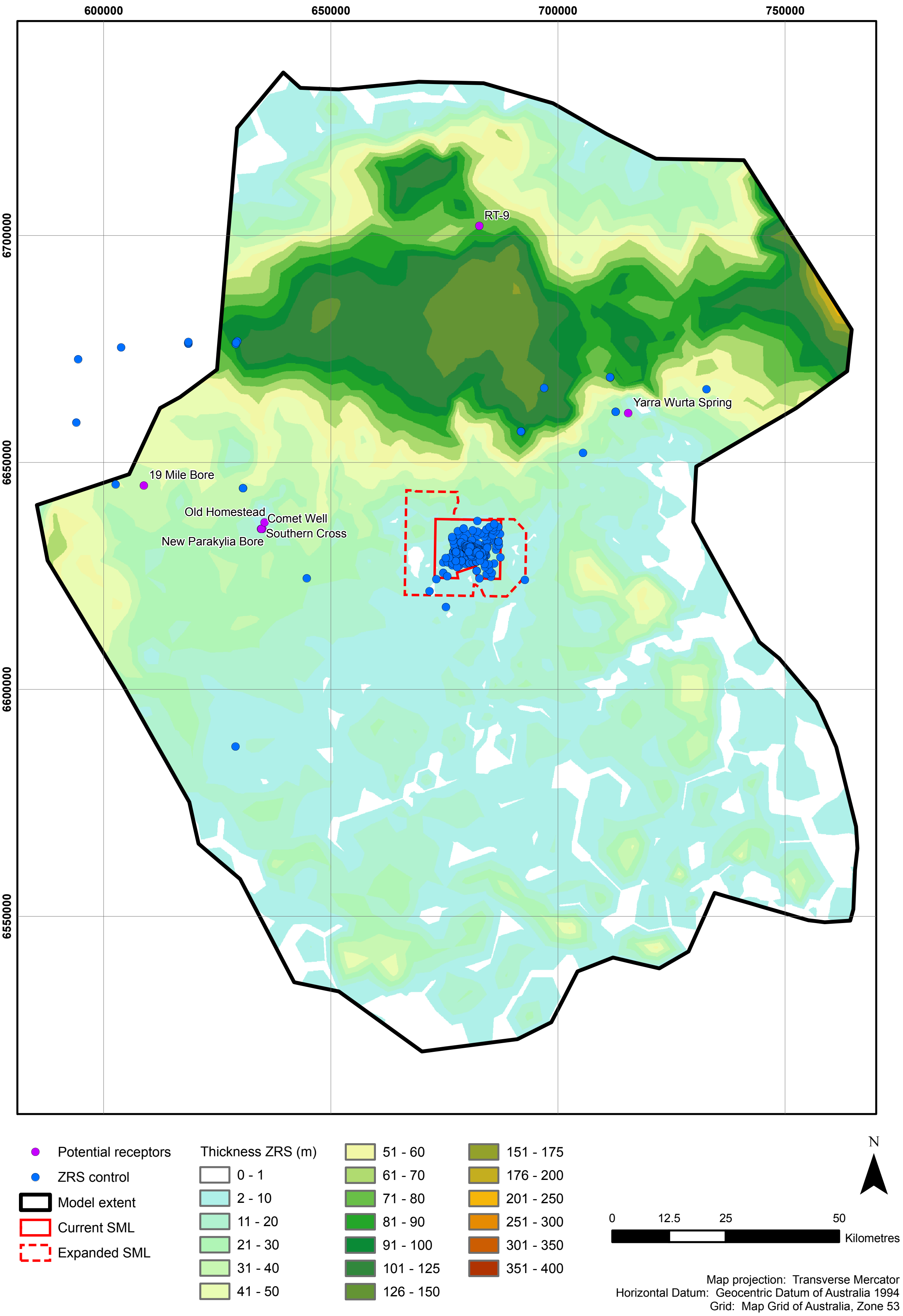
Figure 2.2 Thickness of Quaternary alluvial and Tertiary aeolian sediments (model Layer 1)



Map projection: Transverse Mercator
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Grid: Map Grid of Australia, Zone 53

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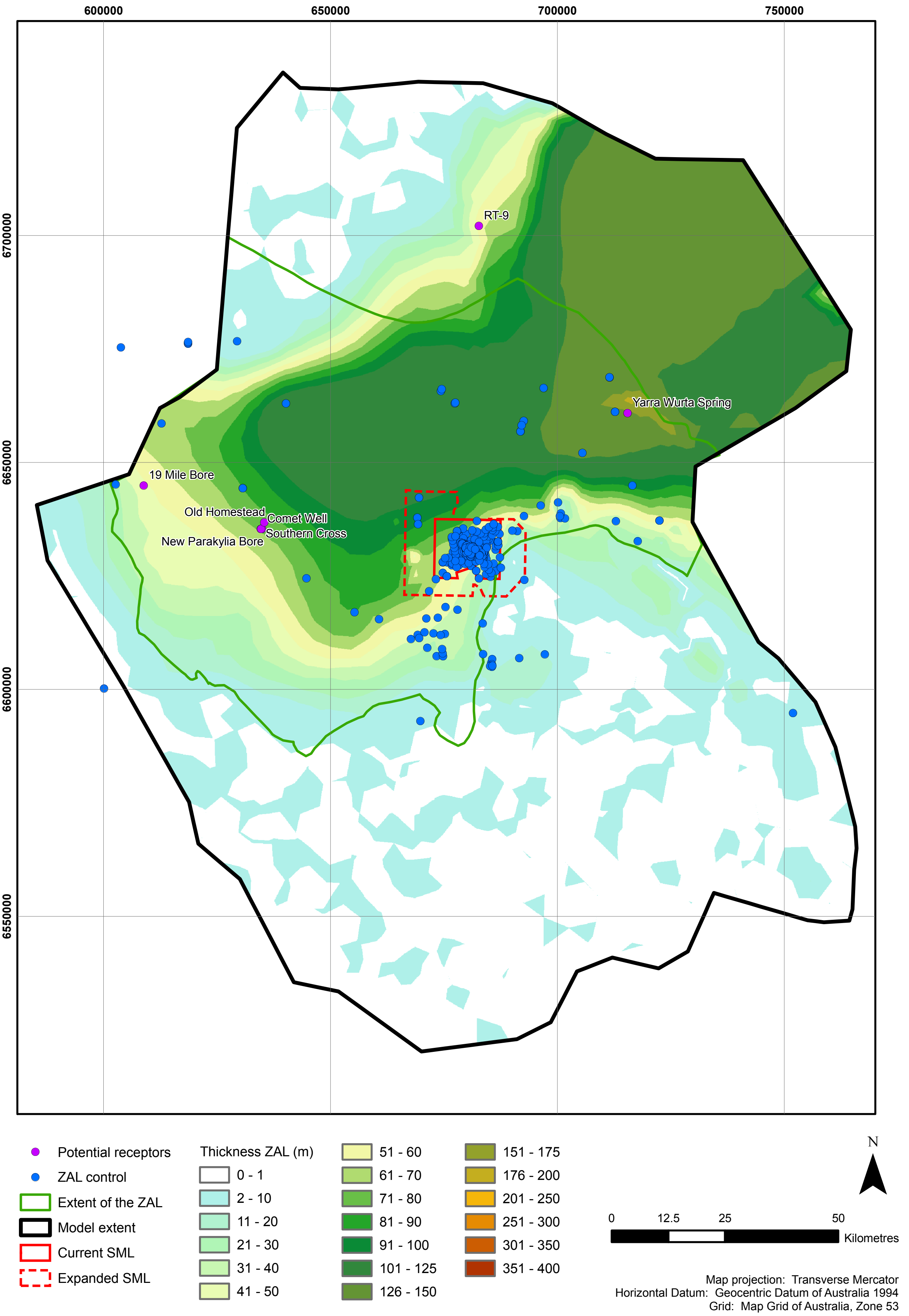
Figure 2.3 Thickness of Andamooka Limestone (model Layers 2 to 4)



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Grid: Map Grid of Australia, Zone 53

Figure 2.4 Thickness of Yarloo Shale (model Layer 5)

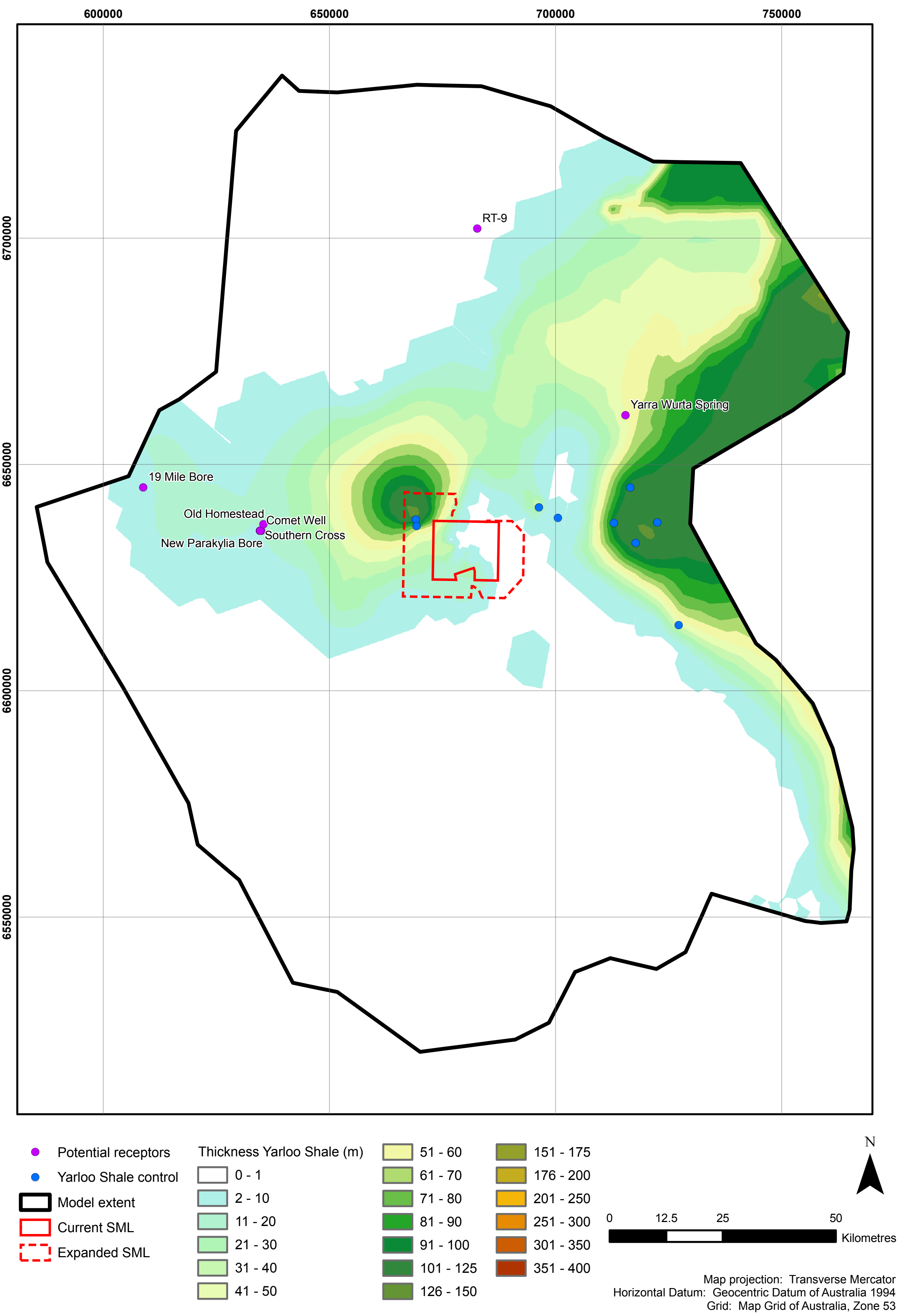

Figure 2.5 Thickness of Arcoona Quartzite (model Layer 6)

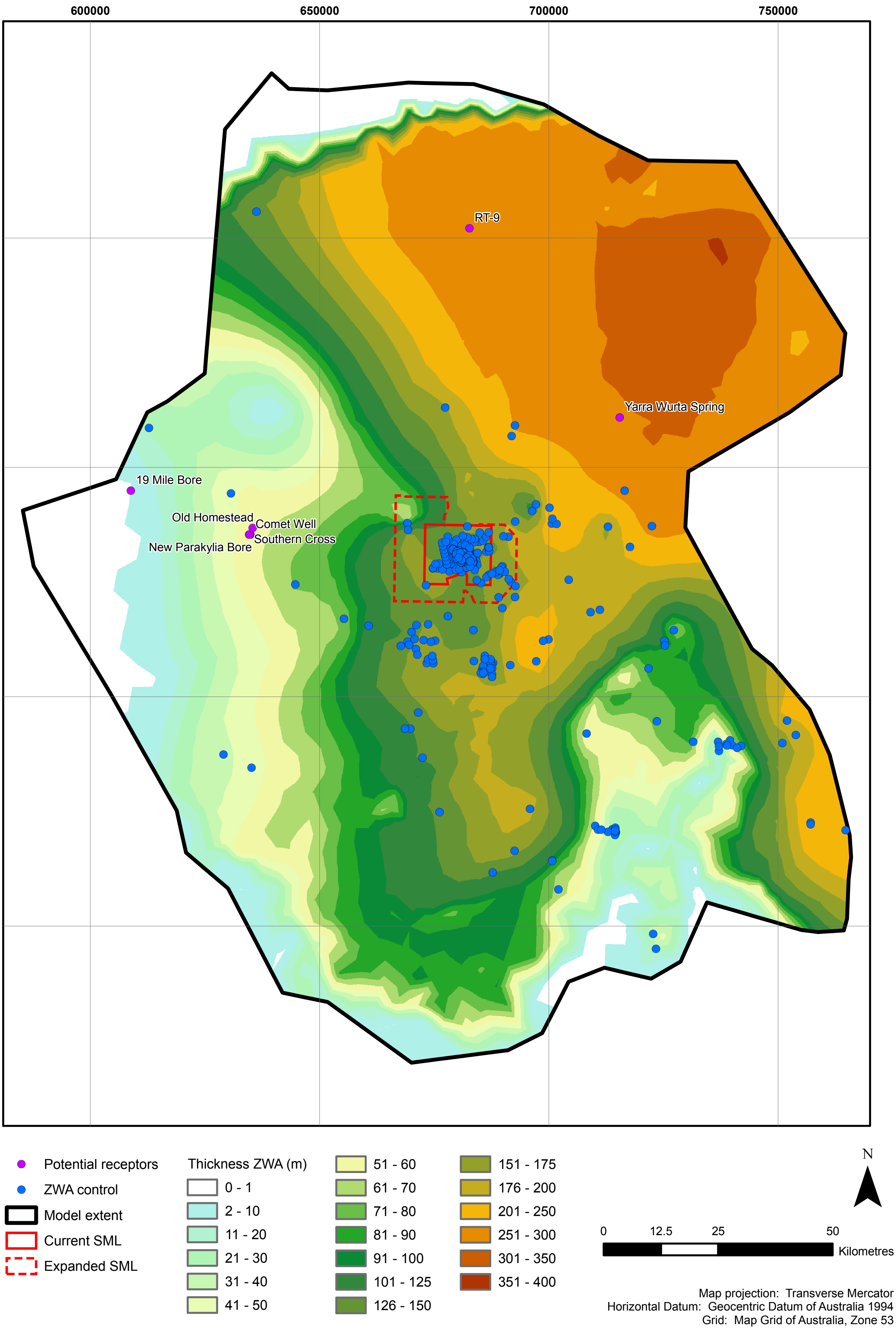

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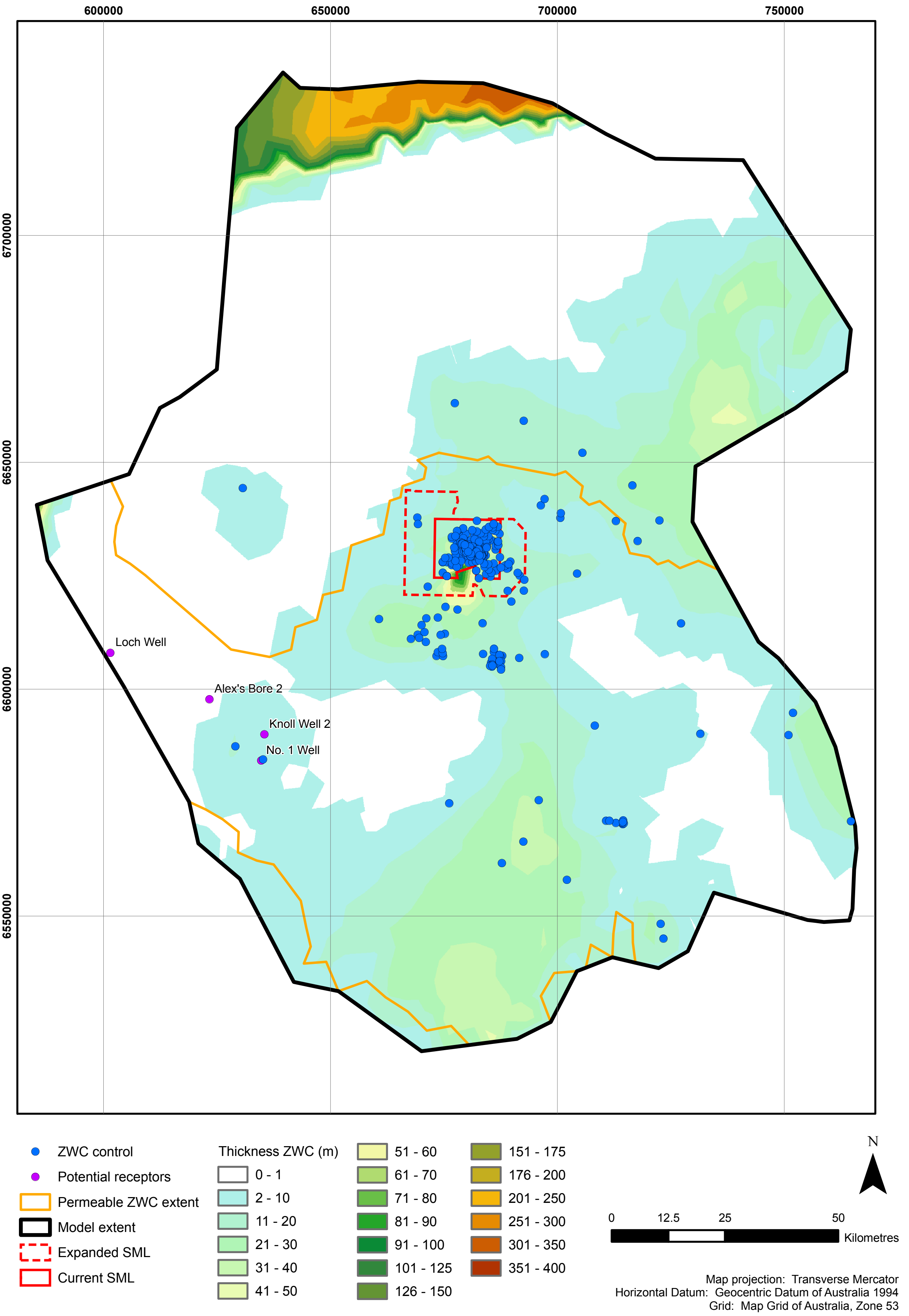
Figure 2.6 Thickness of Corraberra Sandstone (model Layer 7)



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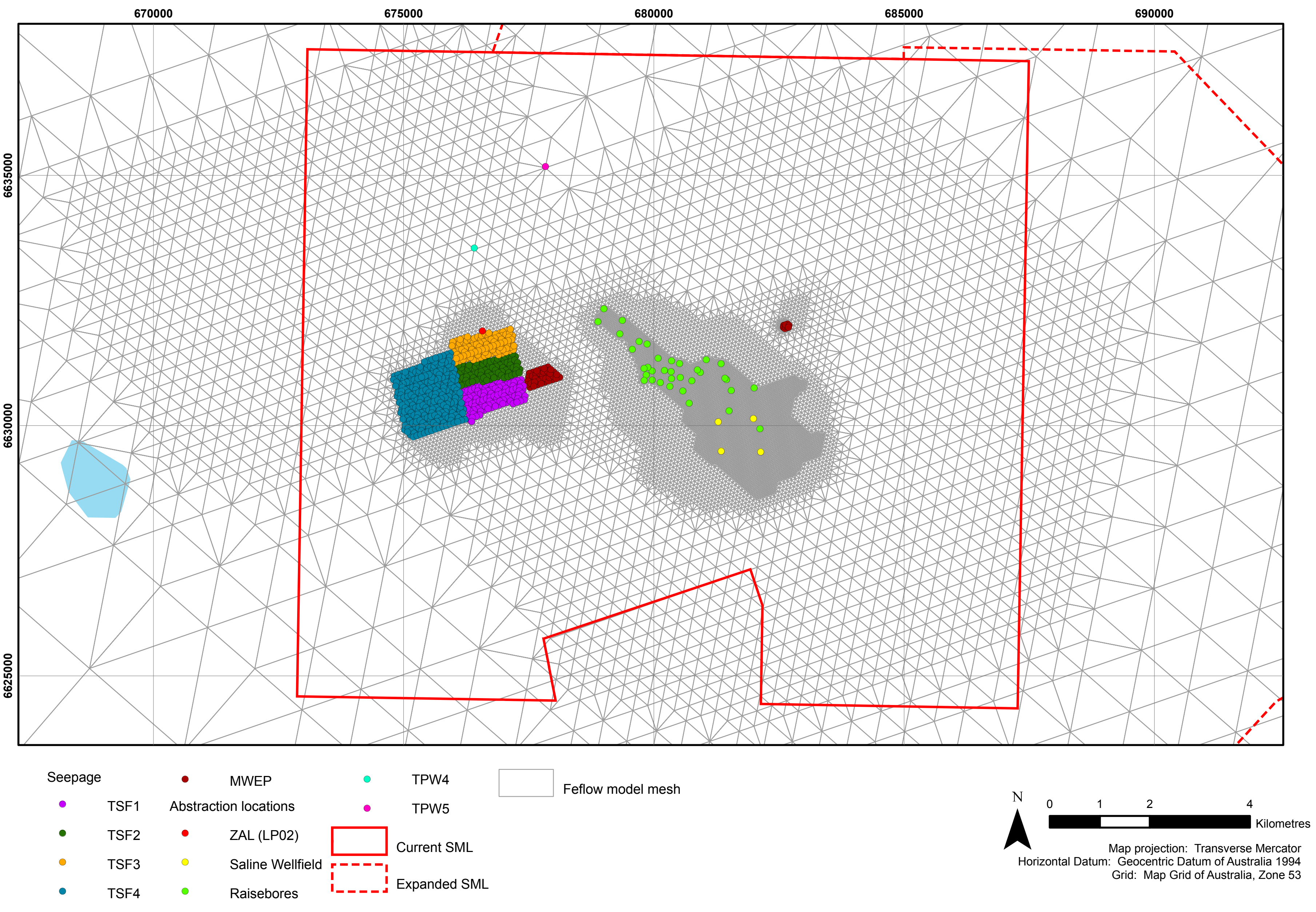

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Figure 2.7 Boundary conditions in historical time variant model

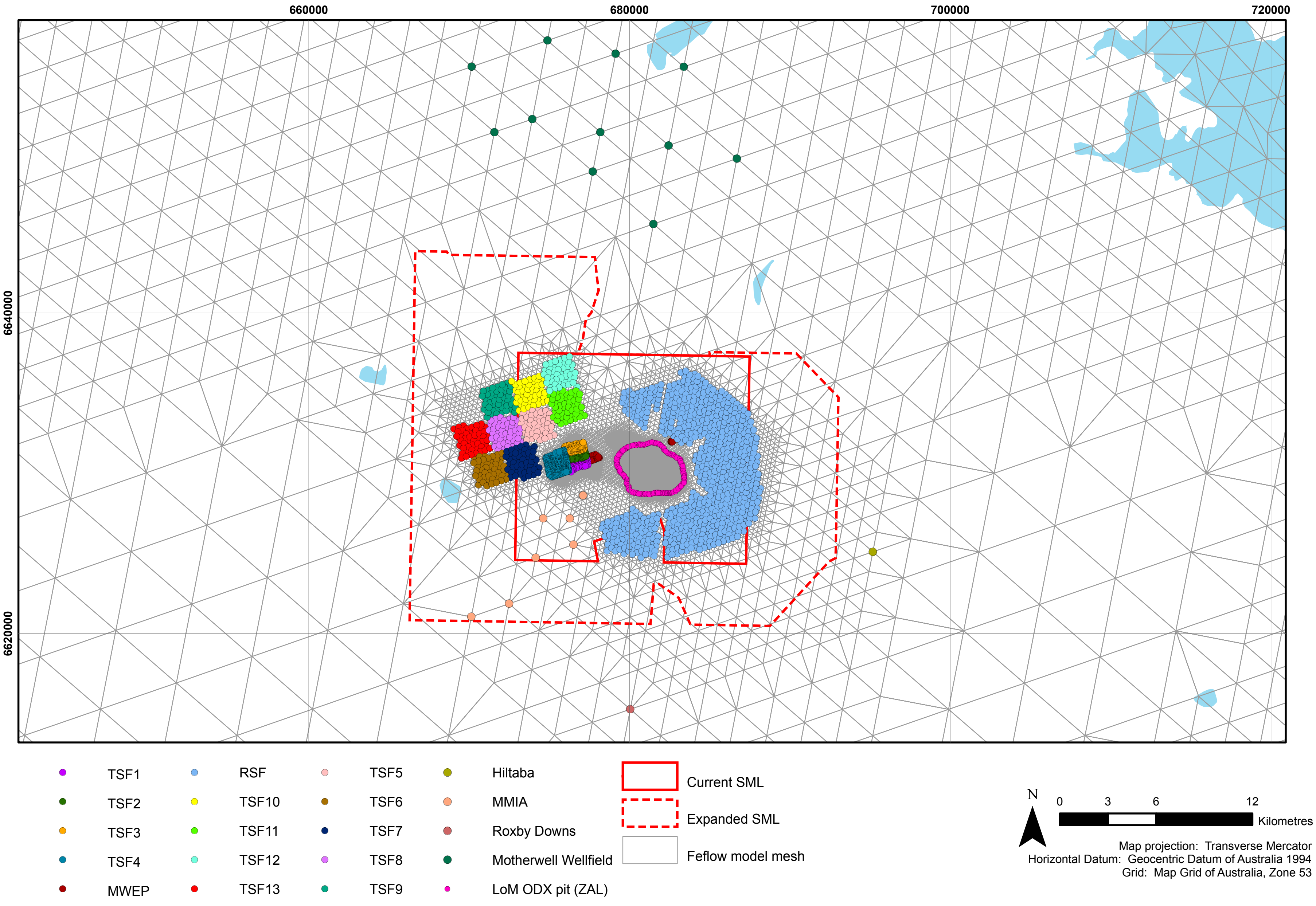

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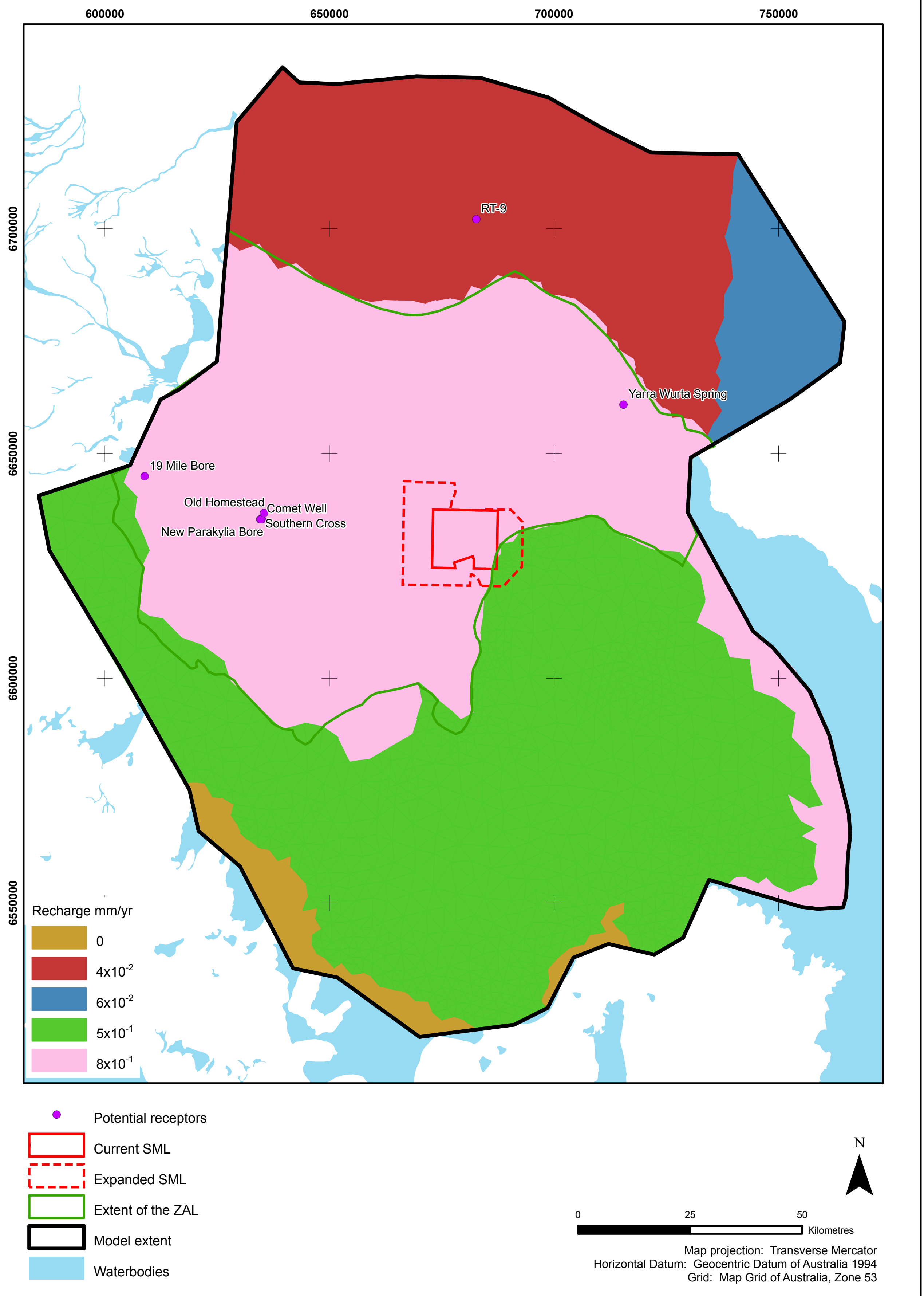
Figure 2.8 Boundary conditions in predictive time variant model

Figure 2.9 Rainfall recharge applied to the model



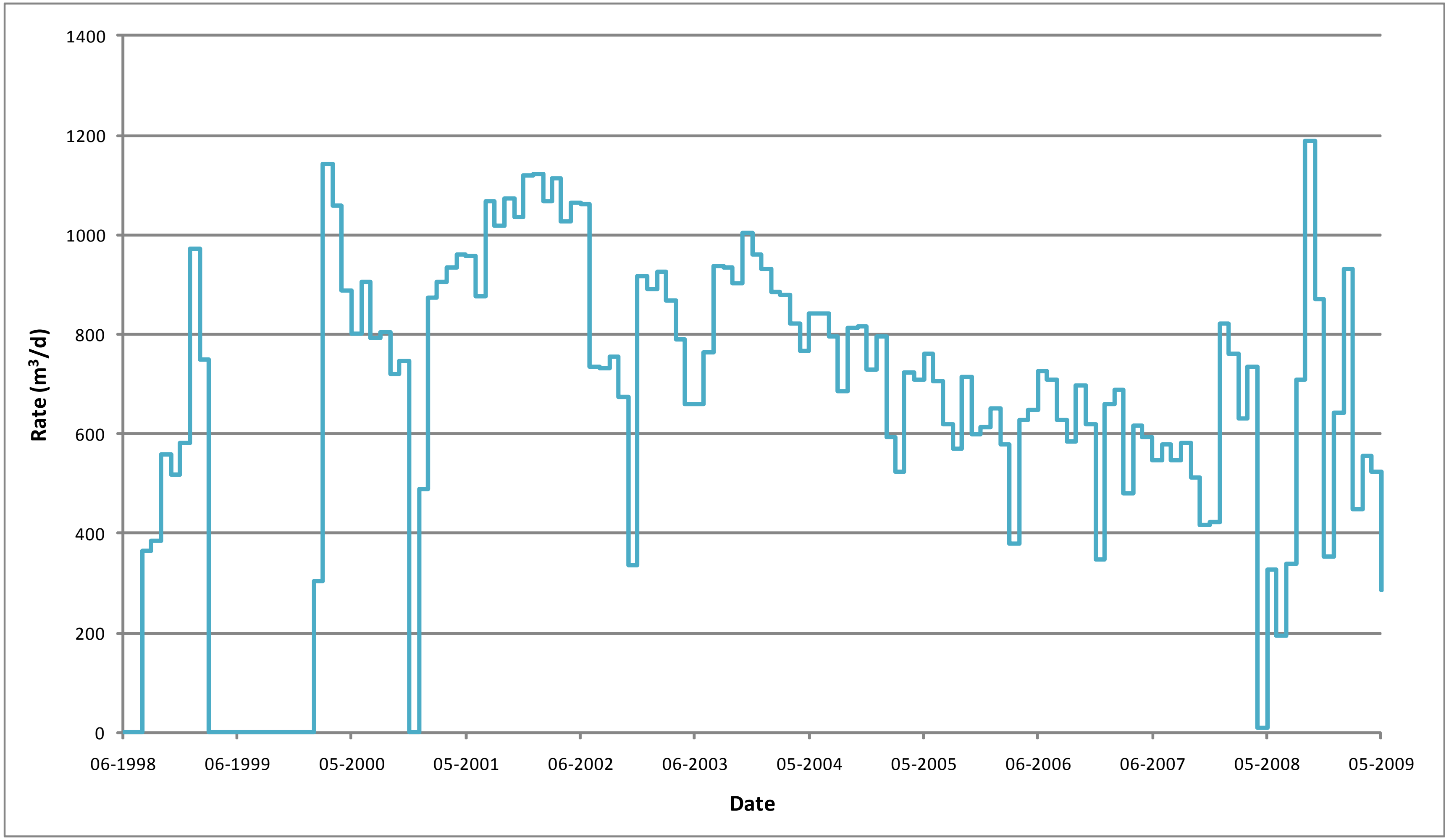


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Figure 2.10 Simulated abstraction from LP02 (ZAL)

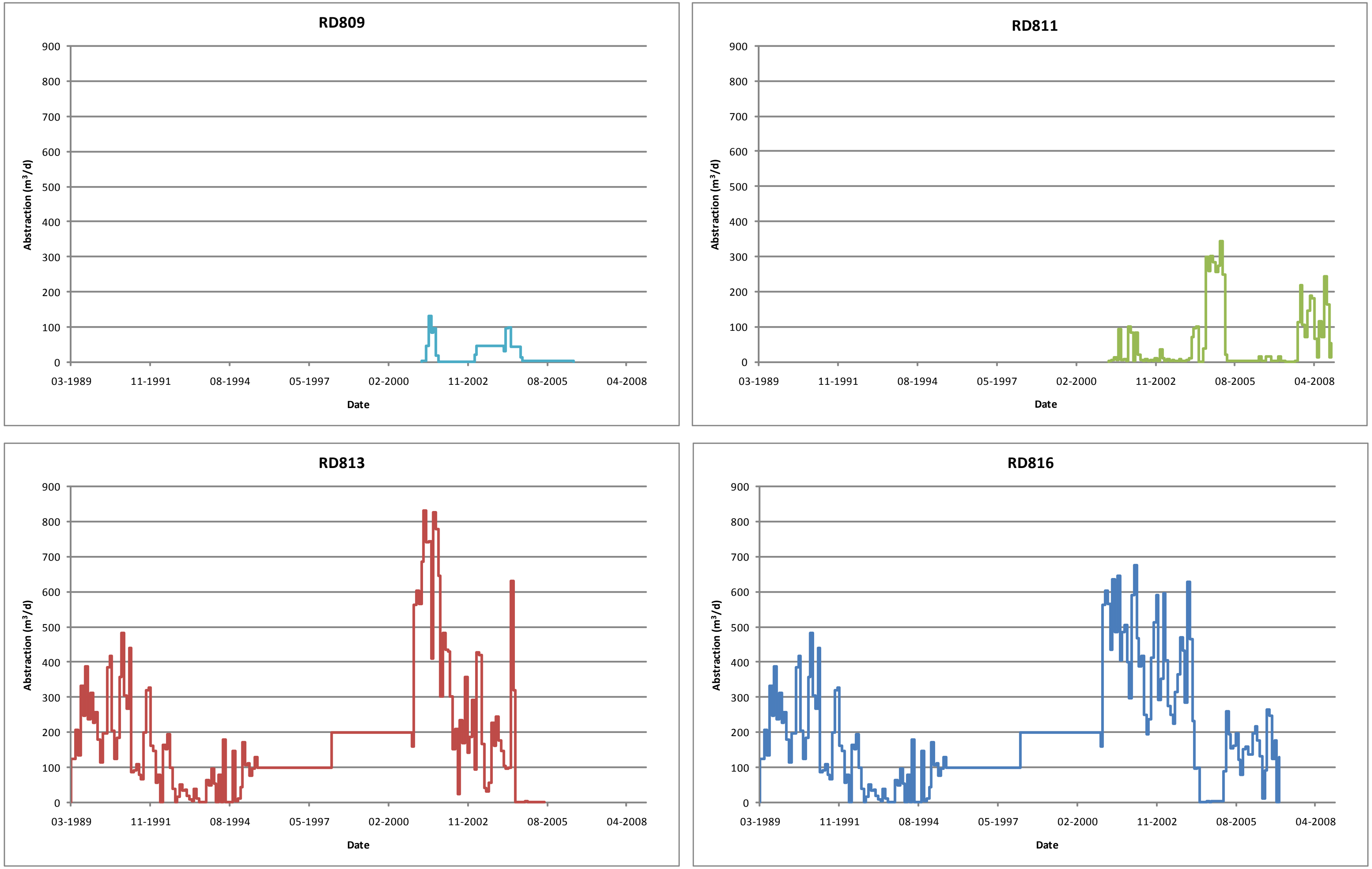

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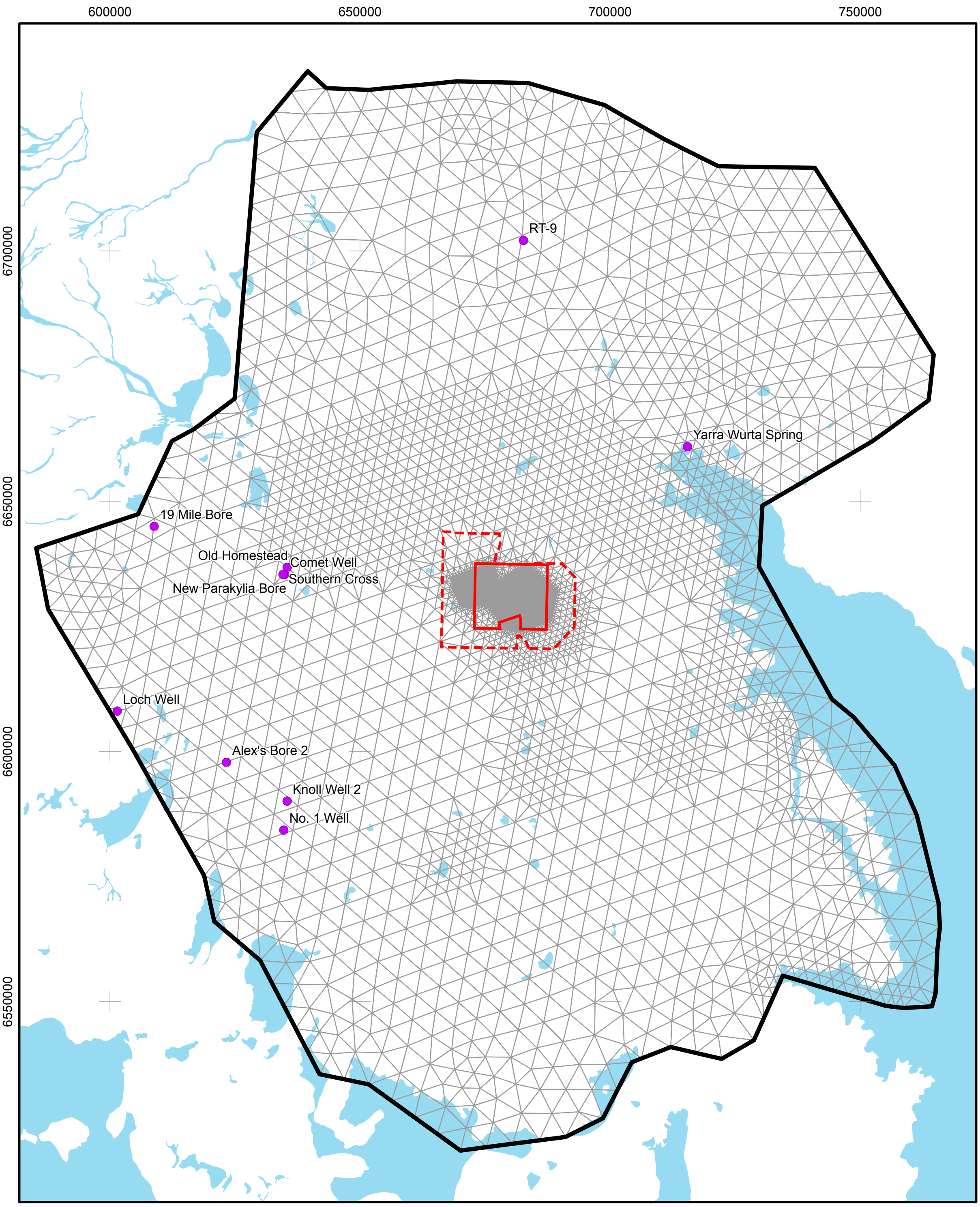
Figure 2.11 Simulated abstraction from the Saline Wellfield (ZWC)

Figure 3.1 FEFLOW finite element mesh



Potential receptors
Current SML
Expanded SML
Model extent
Feflow model mesh
Waterbodies

N

0 25 50 Kilometres

Map projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 53

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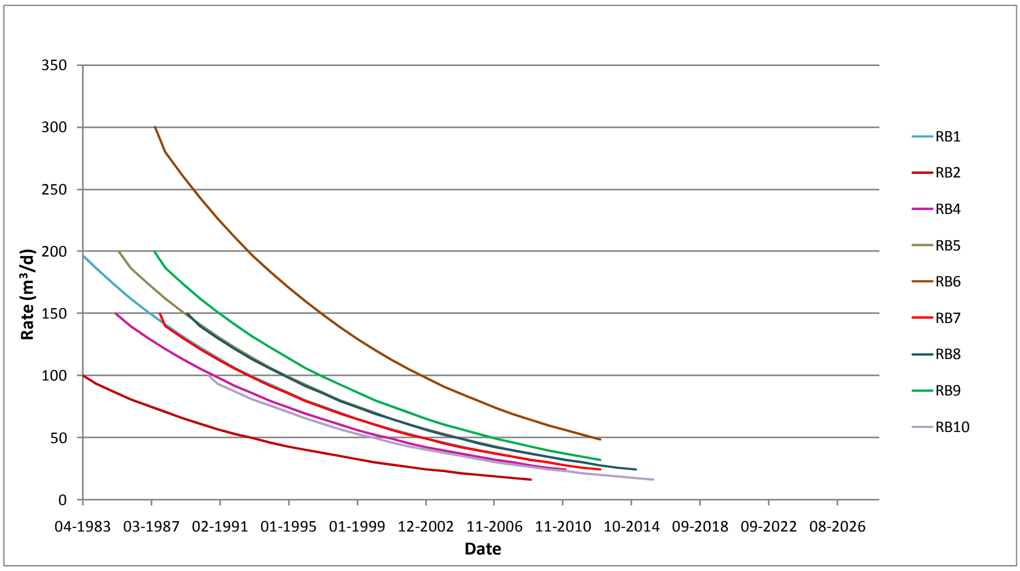
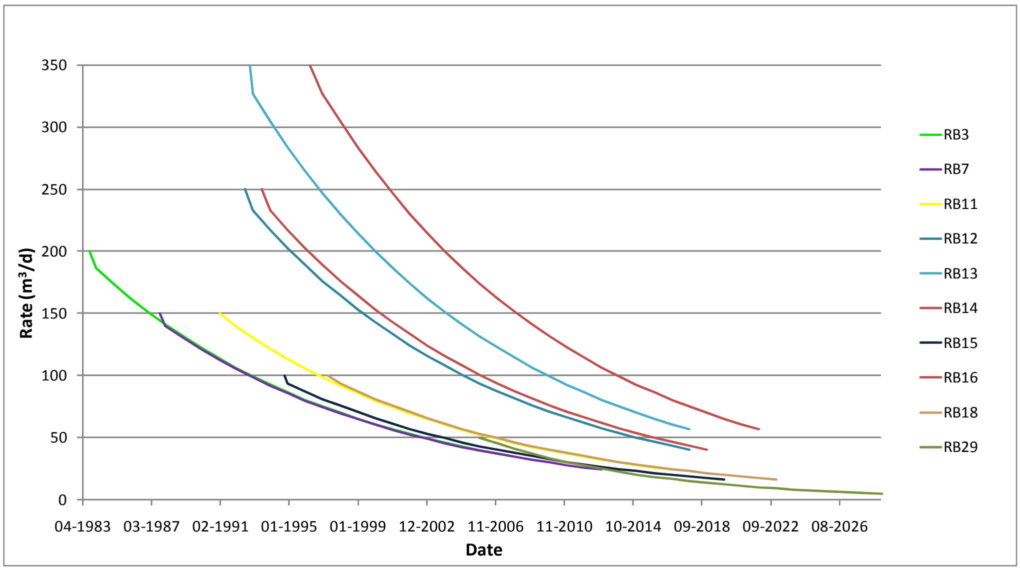
Figure 3.2 Simulated raise bore abstraction (1)





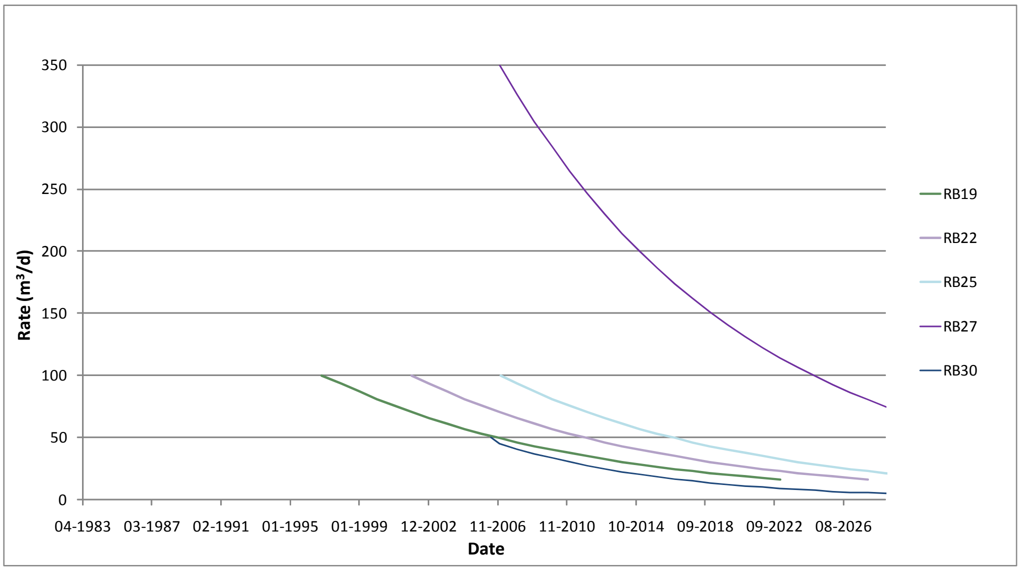


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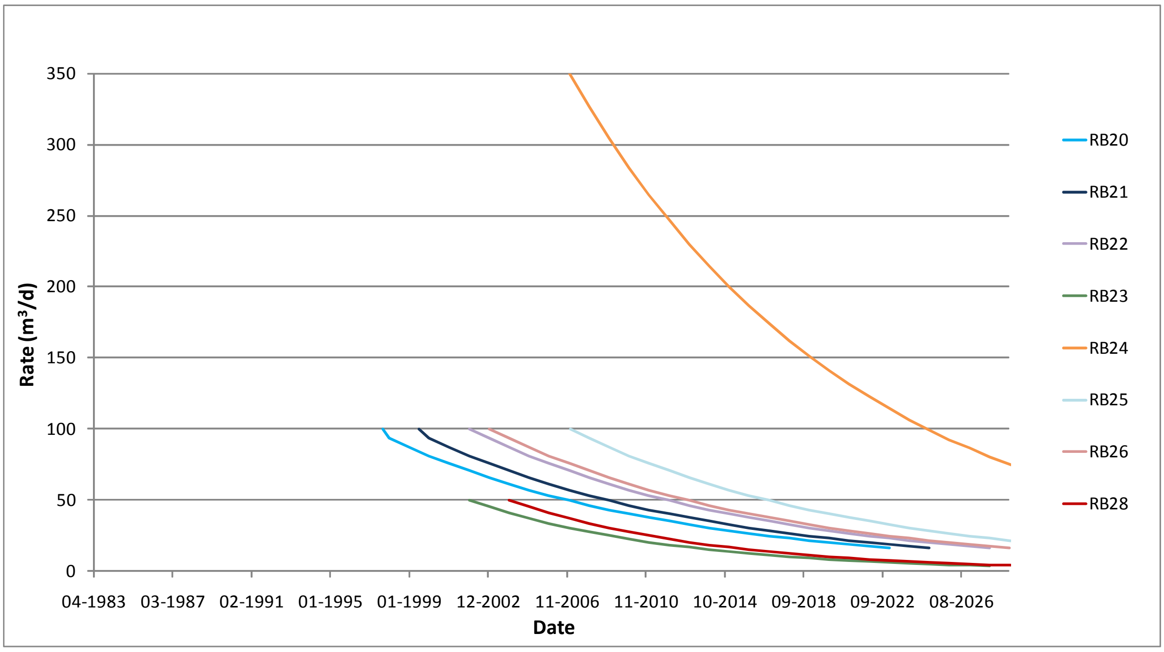
Figure 3.3 Simulated raise bore abstraction (2)



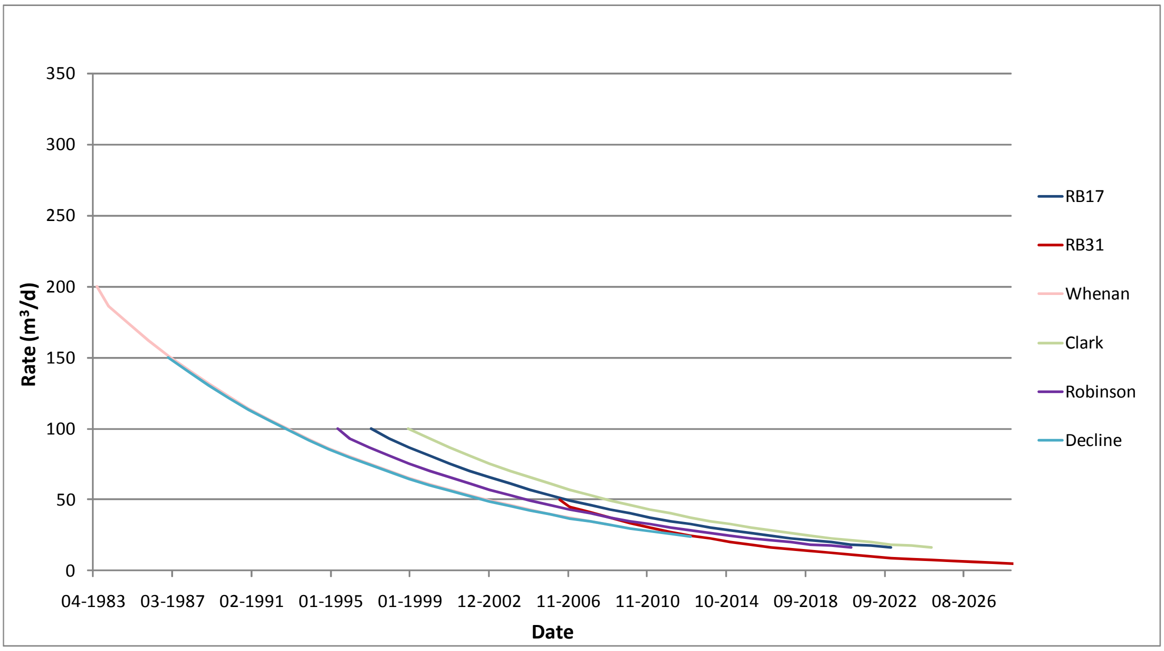
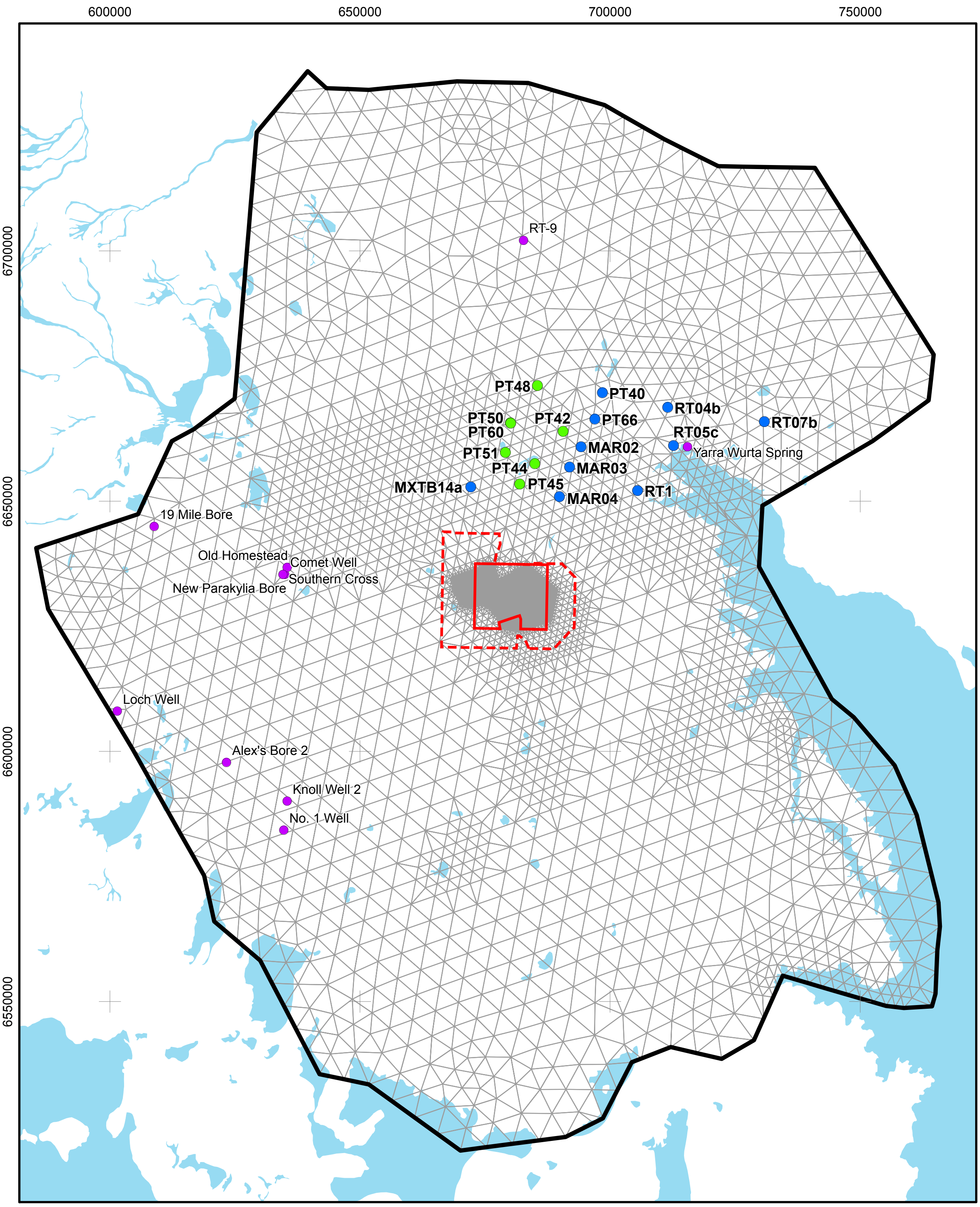


Figure 3.4 Boreholes providing additional data



Potential receptors

Brine

Inferred

Measured

Current SML

Expanded SML

Model extent

Feflow model mesh

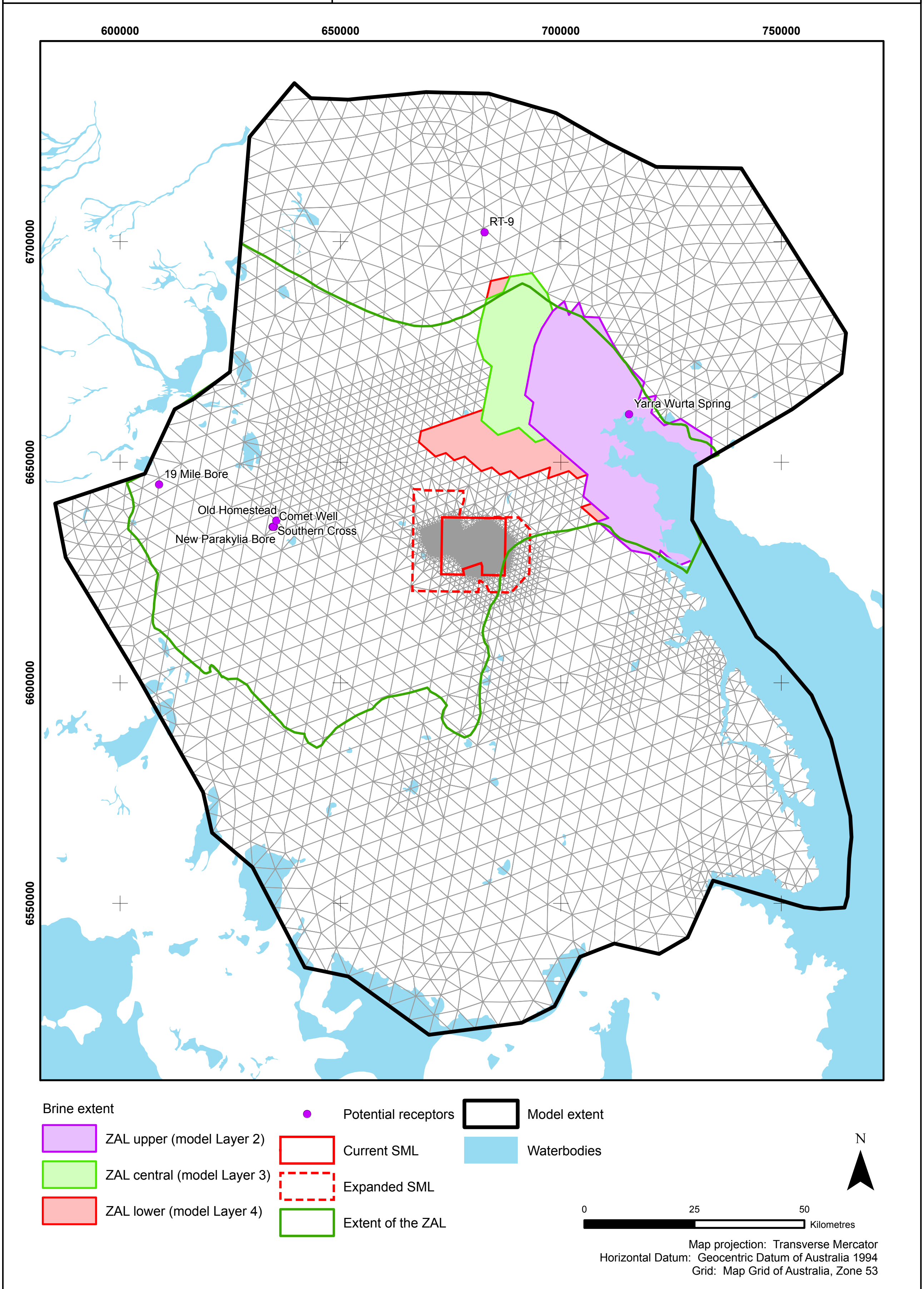
Waterbodies

N

0 25 50 Kilometres

Map projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 53

Figure 3.5 Model representation of the brine water body in the ZAL (plan view)



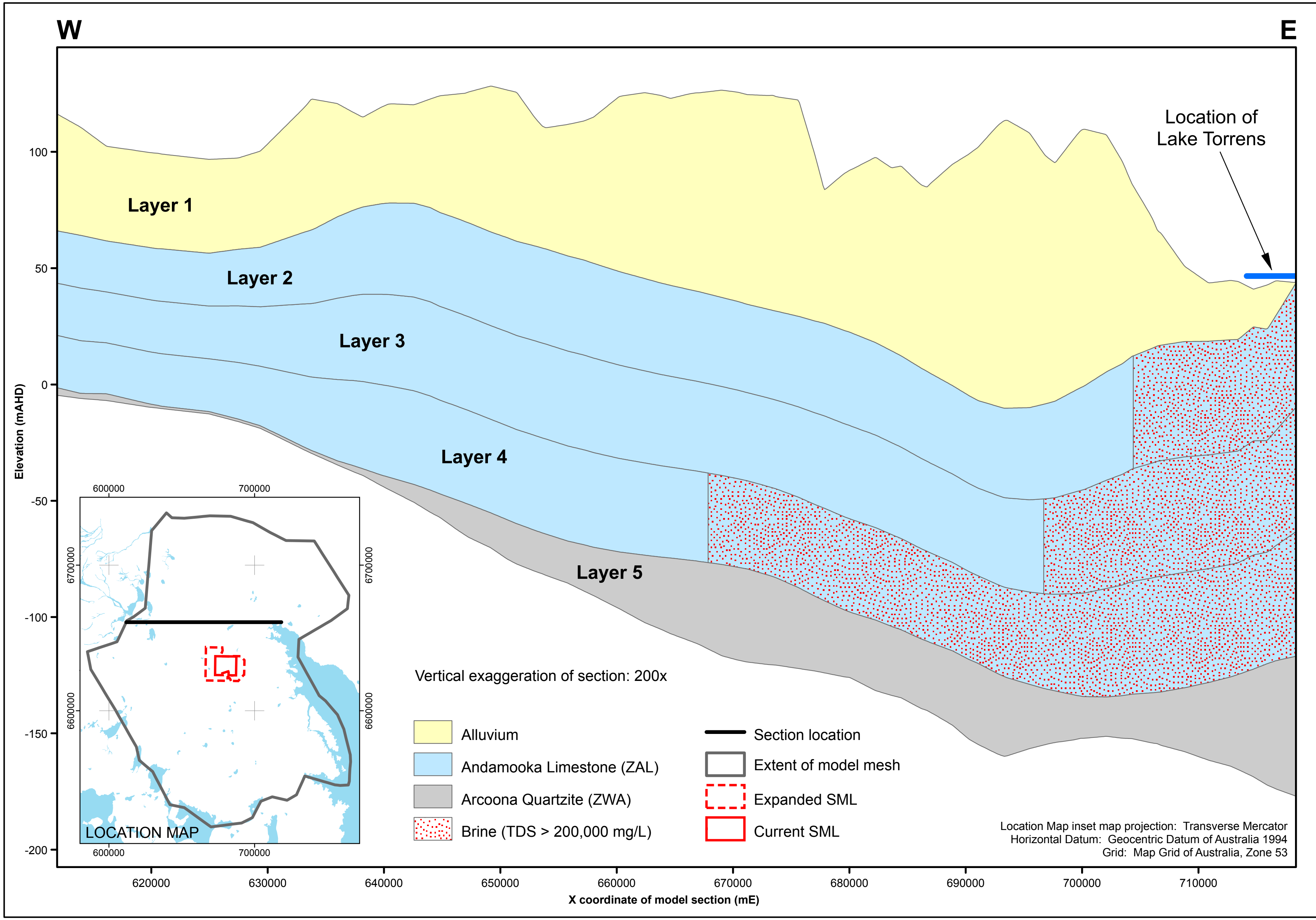


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Figure 3.6 Model representation of the brine water body in the ZAL (section view)

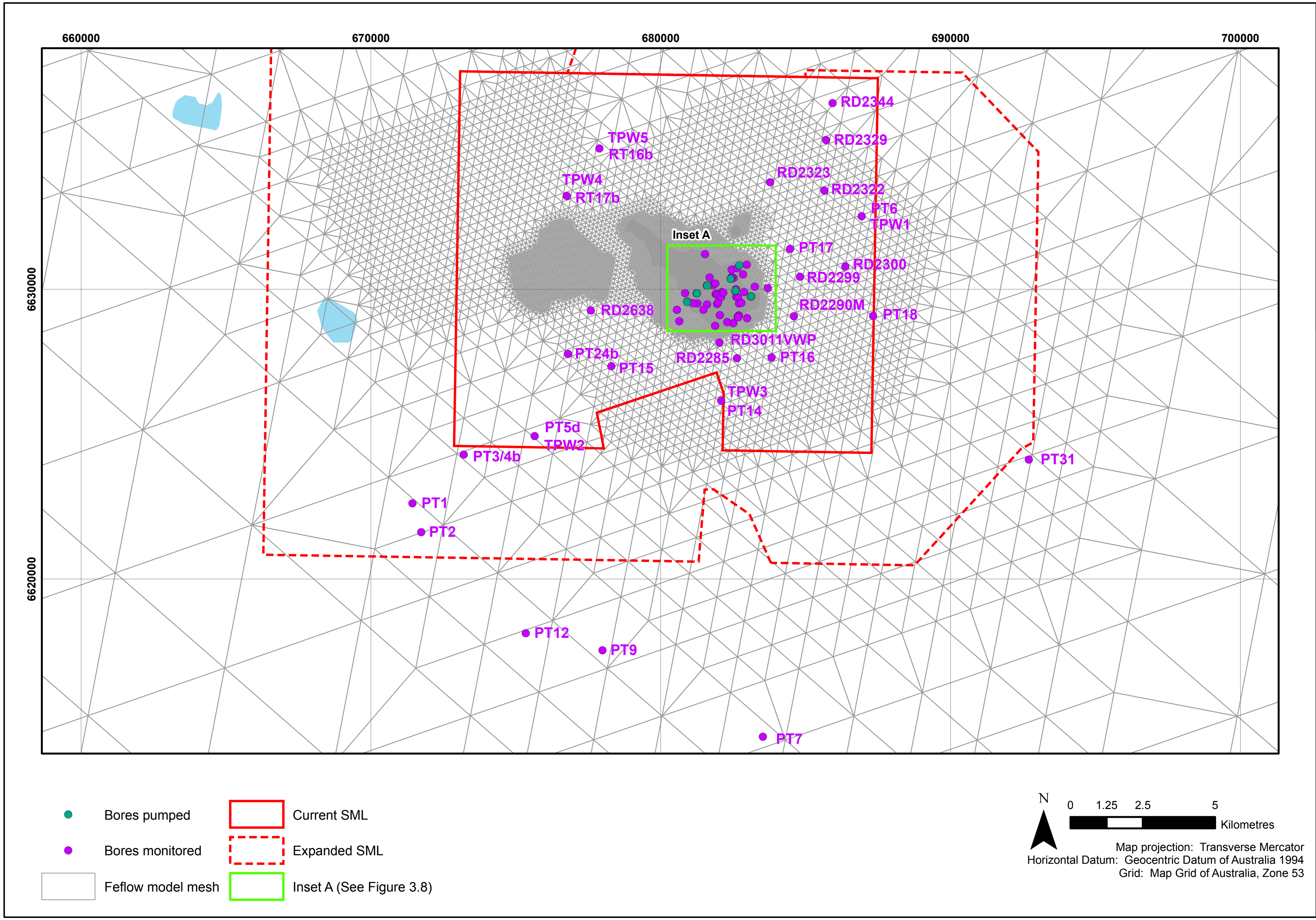

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Figure 3.7 Boreholes associated with the trial depressurisation

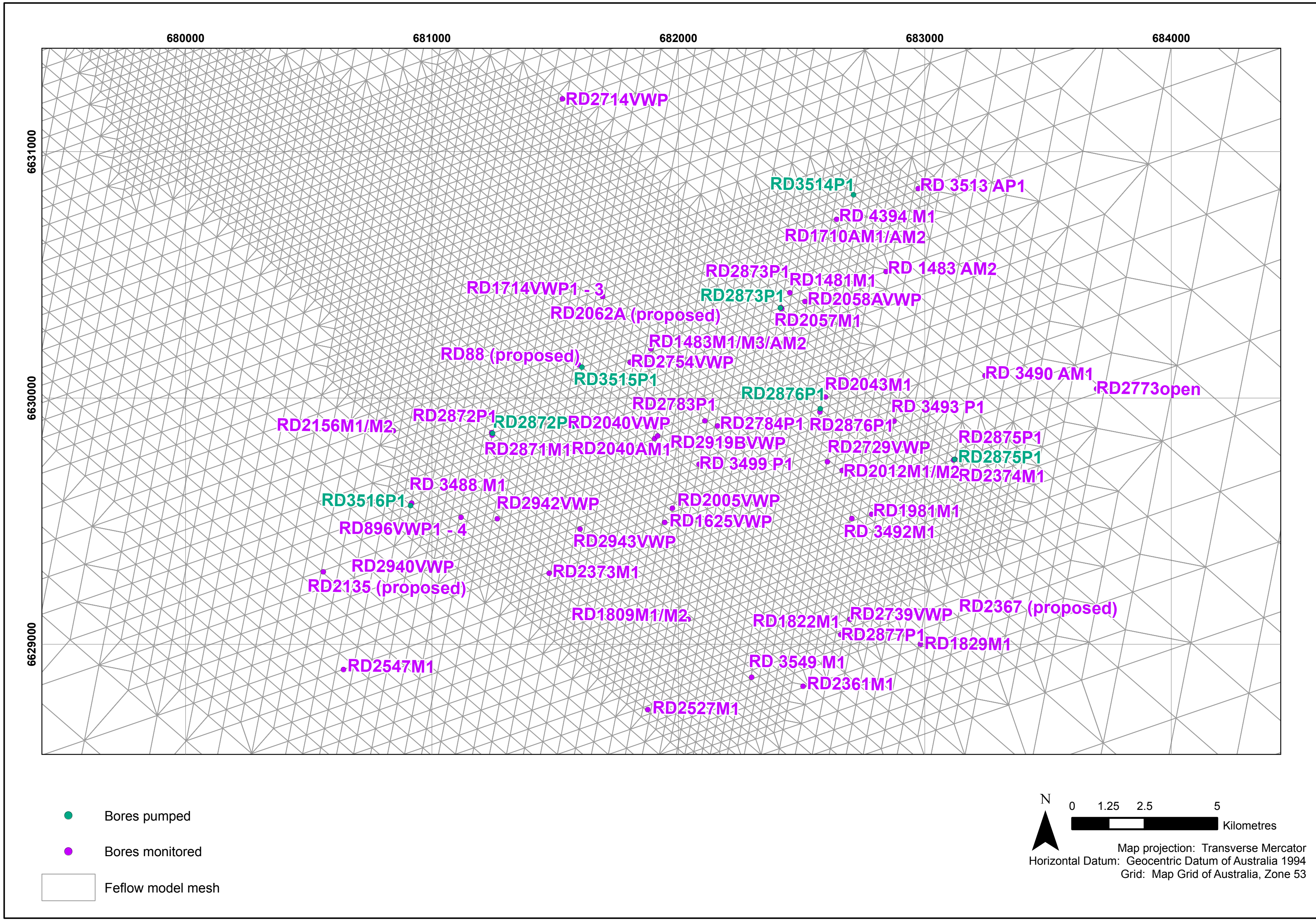

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Figure 3.8 Boreholes associated with the trial depressurisation (Inset A)

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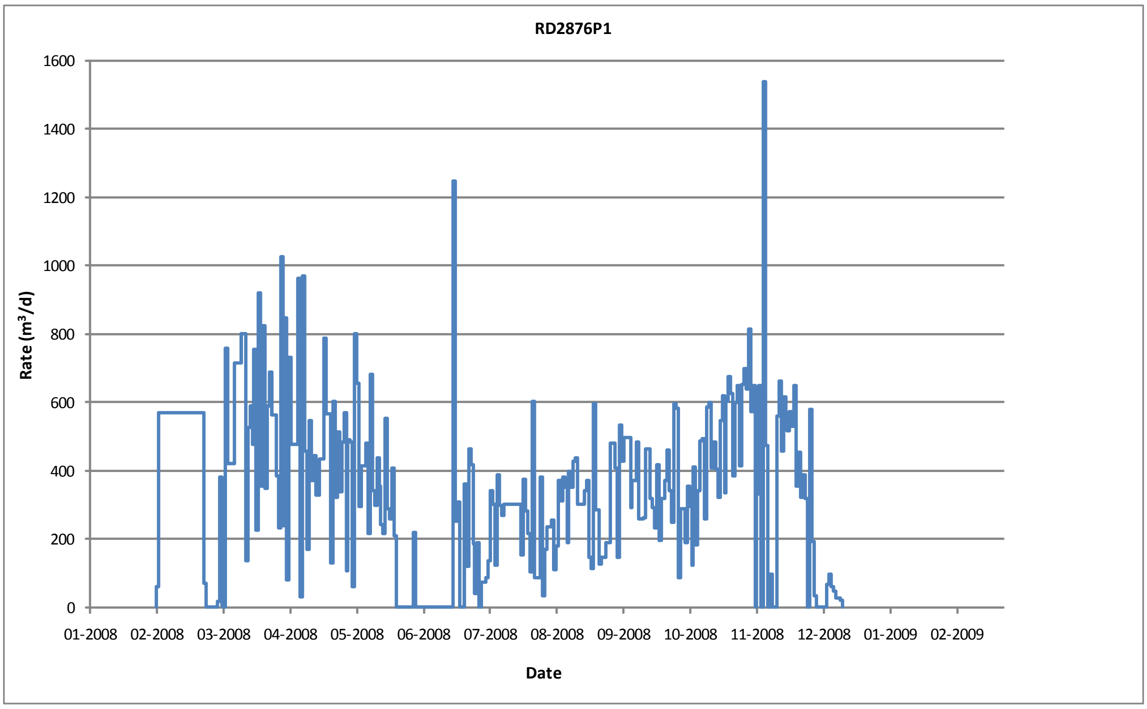
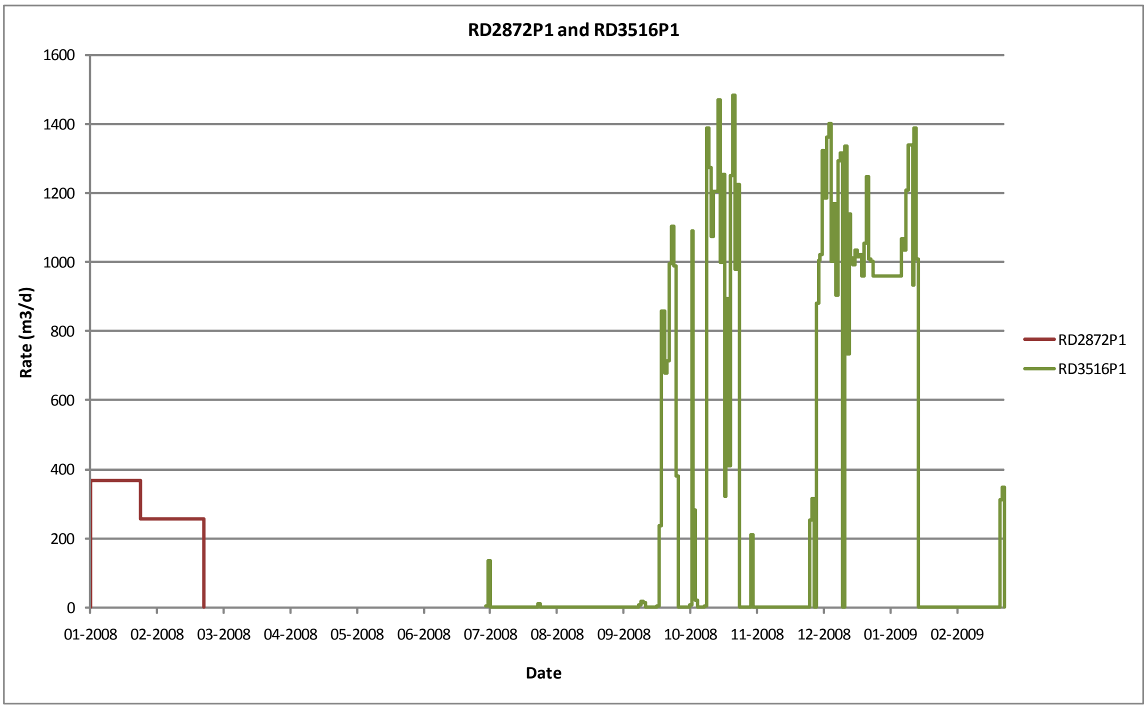
Figure 3.9 Abstraction from the trial depressurisation bores RD2876P1, RD2872P1 and RD3516P1





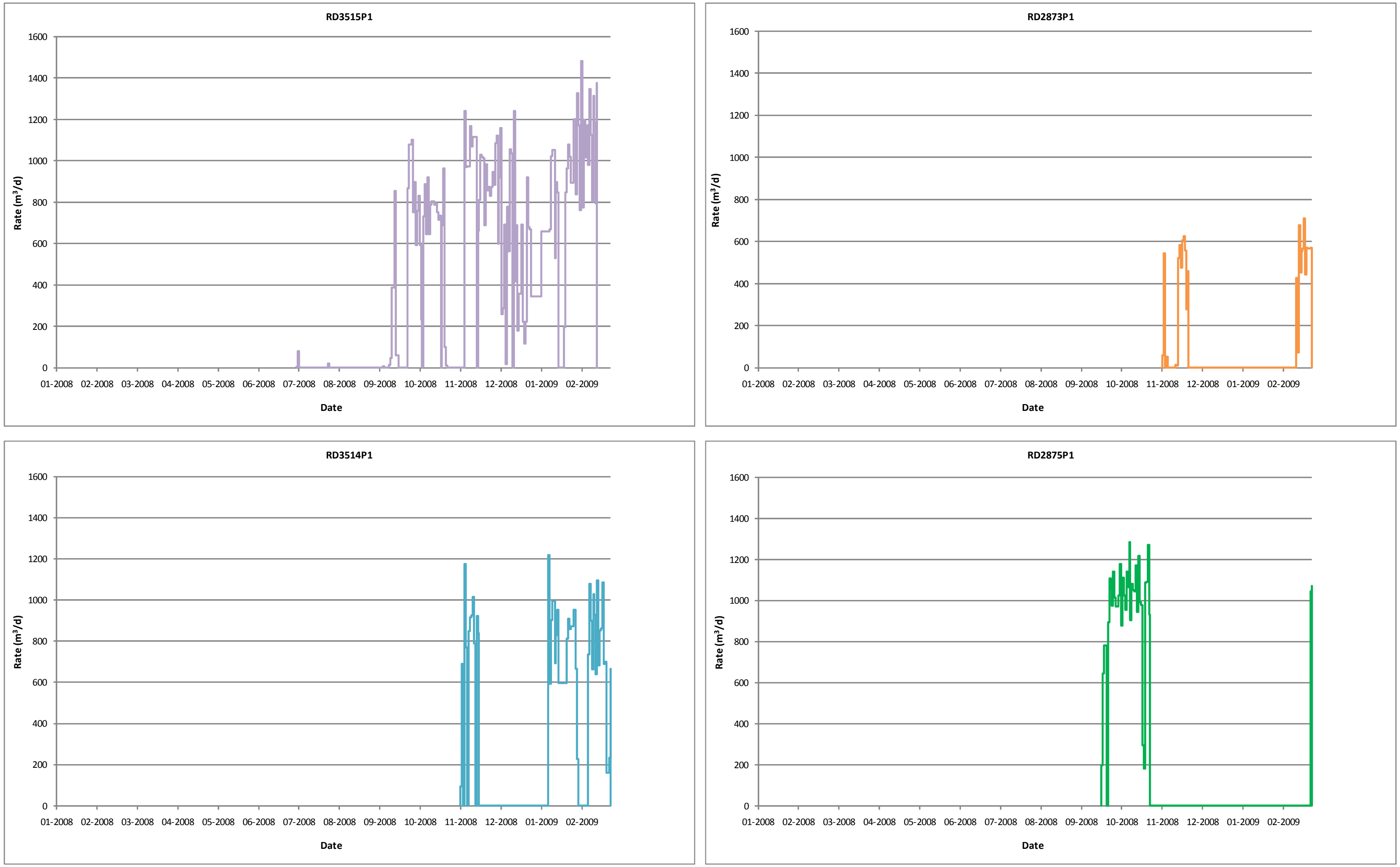


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Figure 3.10 Abstraction from the trial depressurisation bores RD3515P1, RD3514P1, RD2873P1 and RD2875P1

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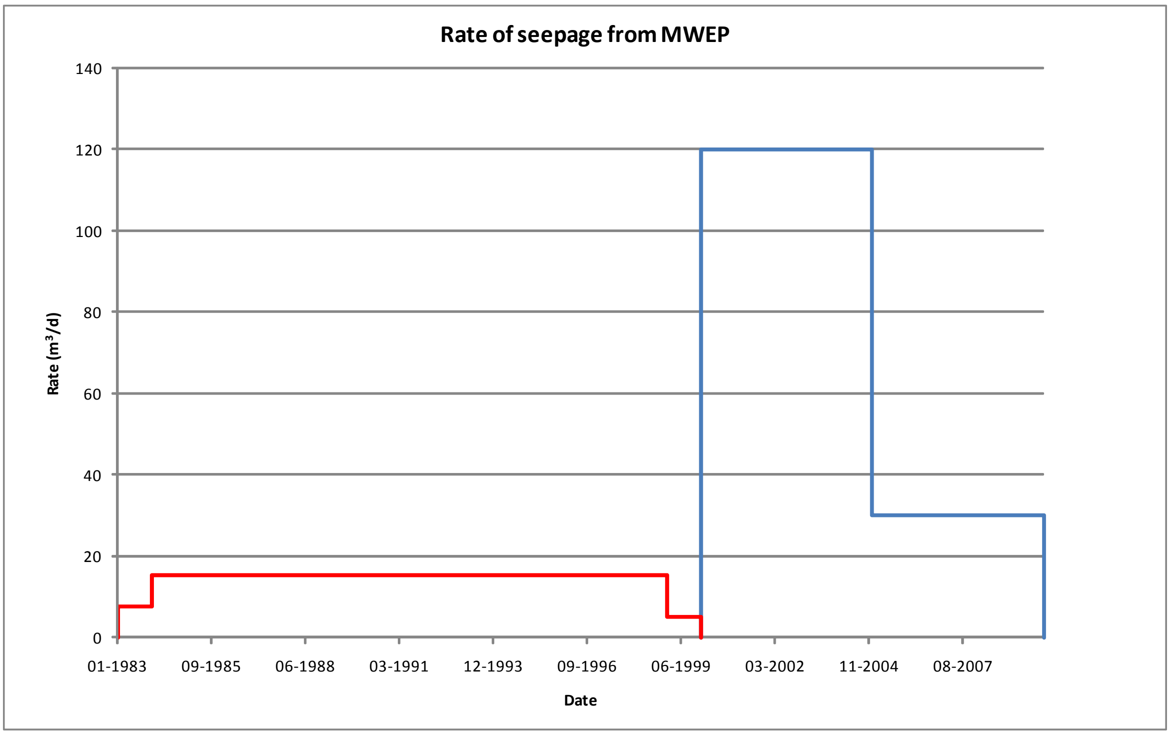
Figure 3.11 Additional groundwater stresses applied to redeveloped time variant historical model



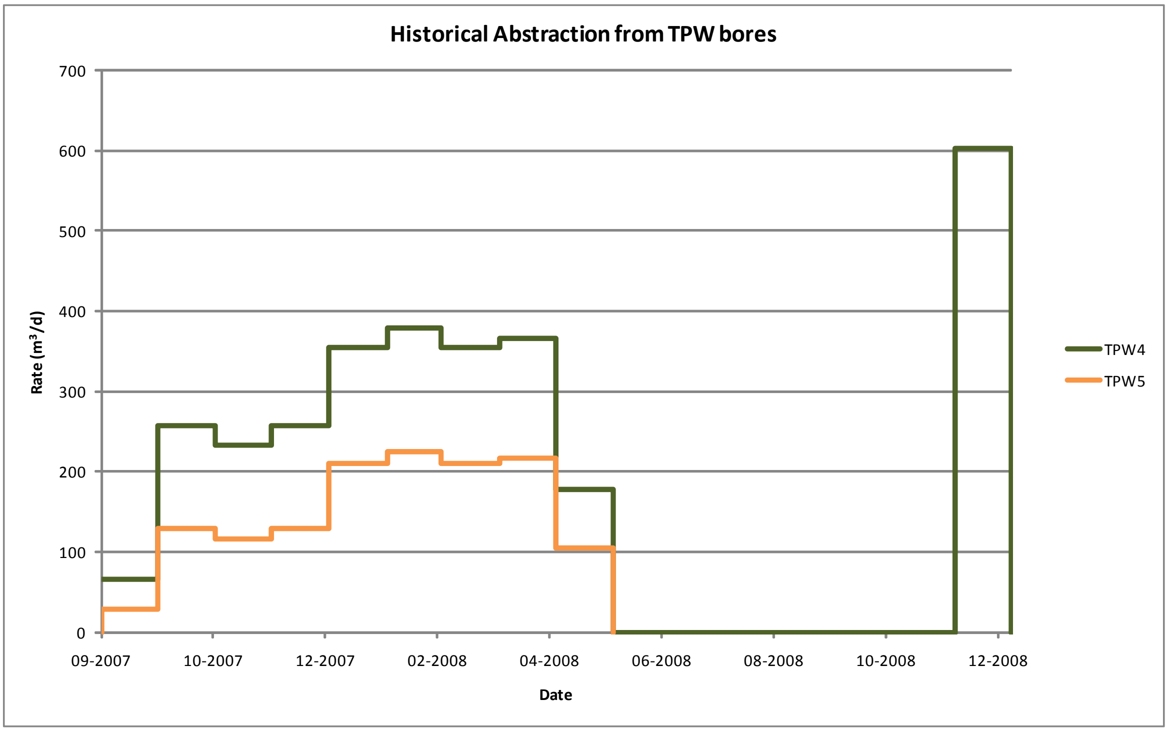


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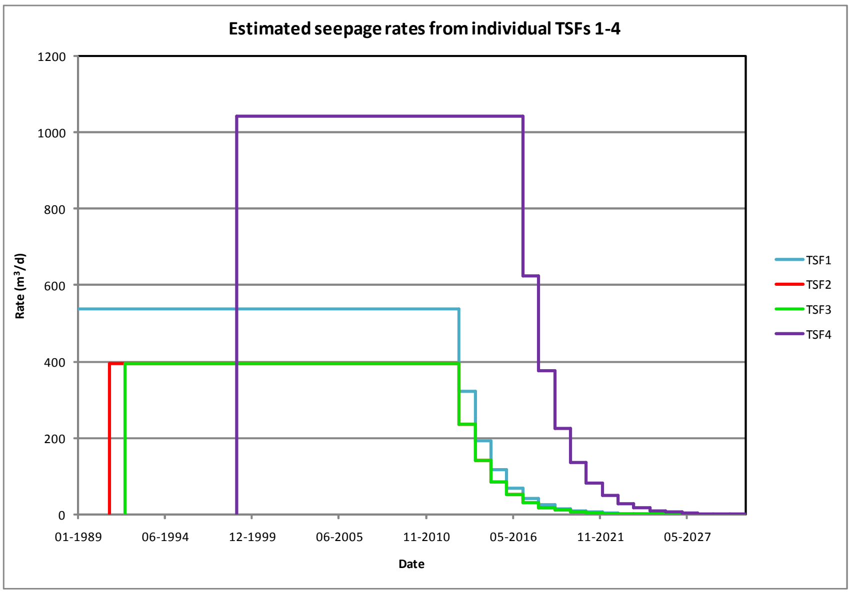
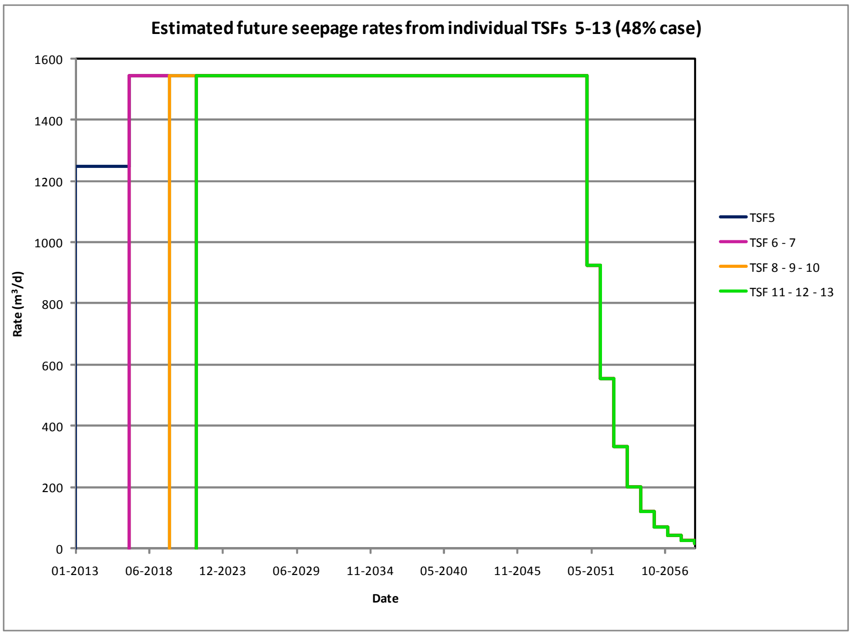
Figure 3.12 TSF seepage estimates used in the modelling





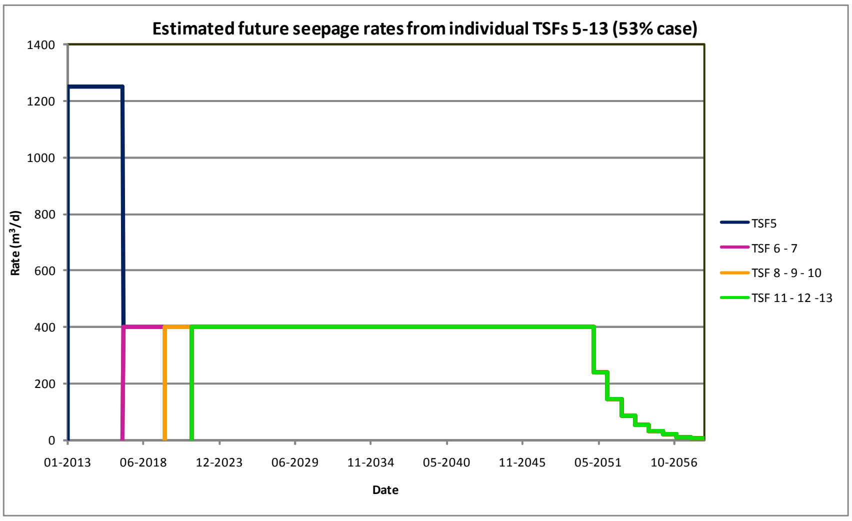


Figure 3.13 Regional boundary conditions

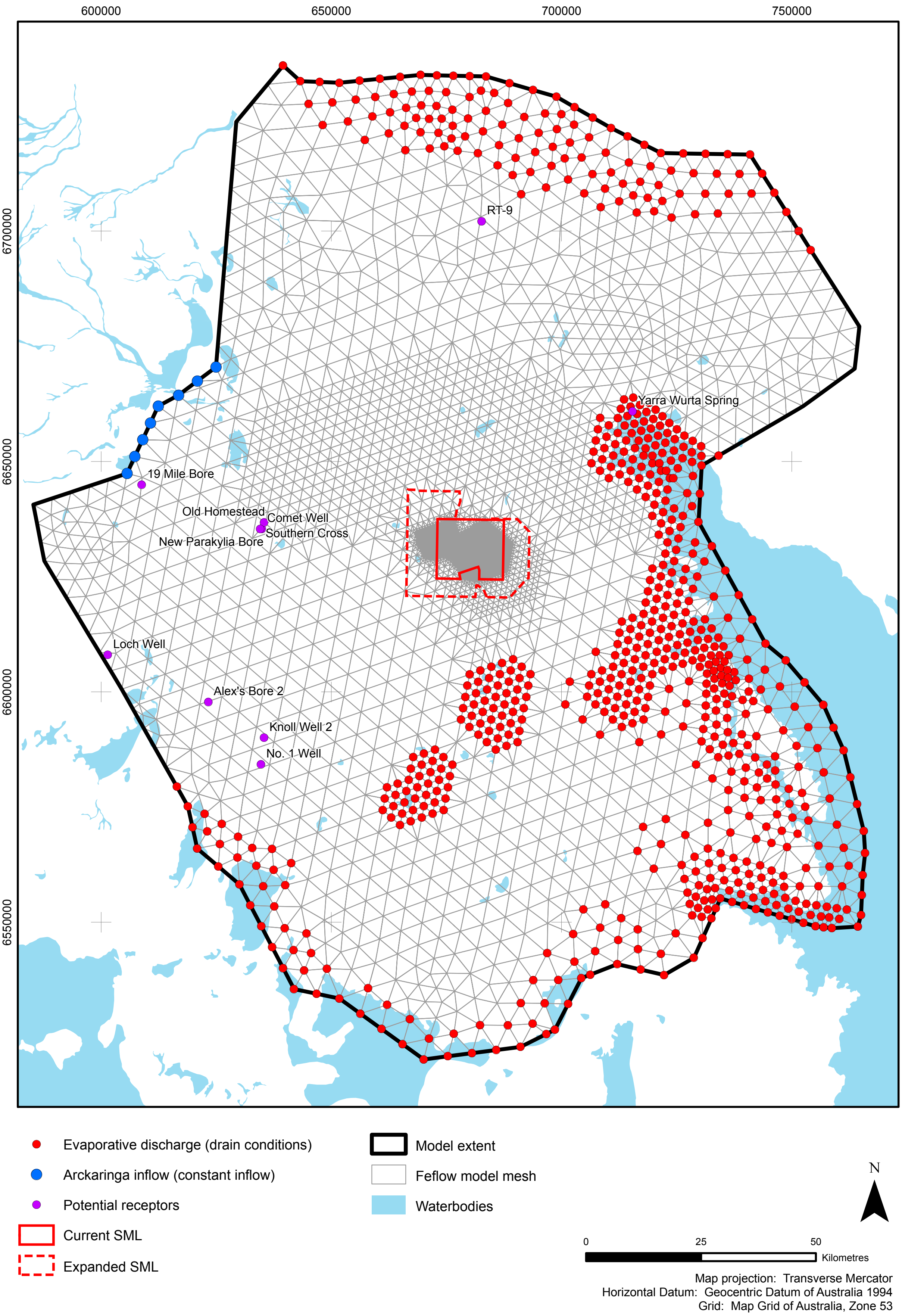


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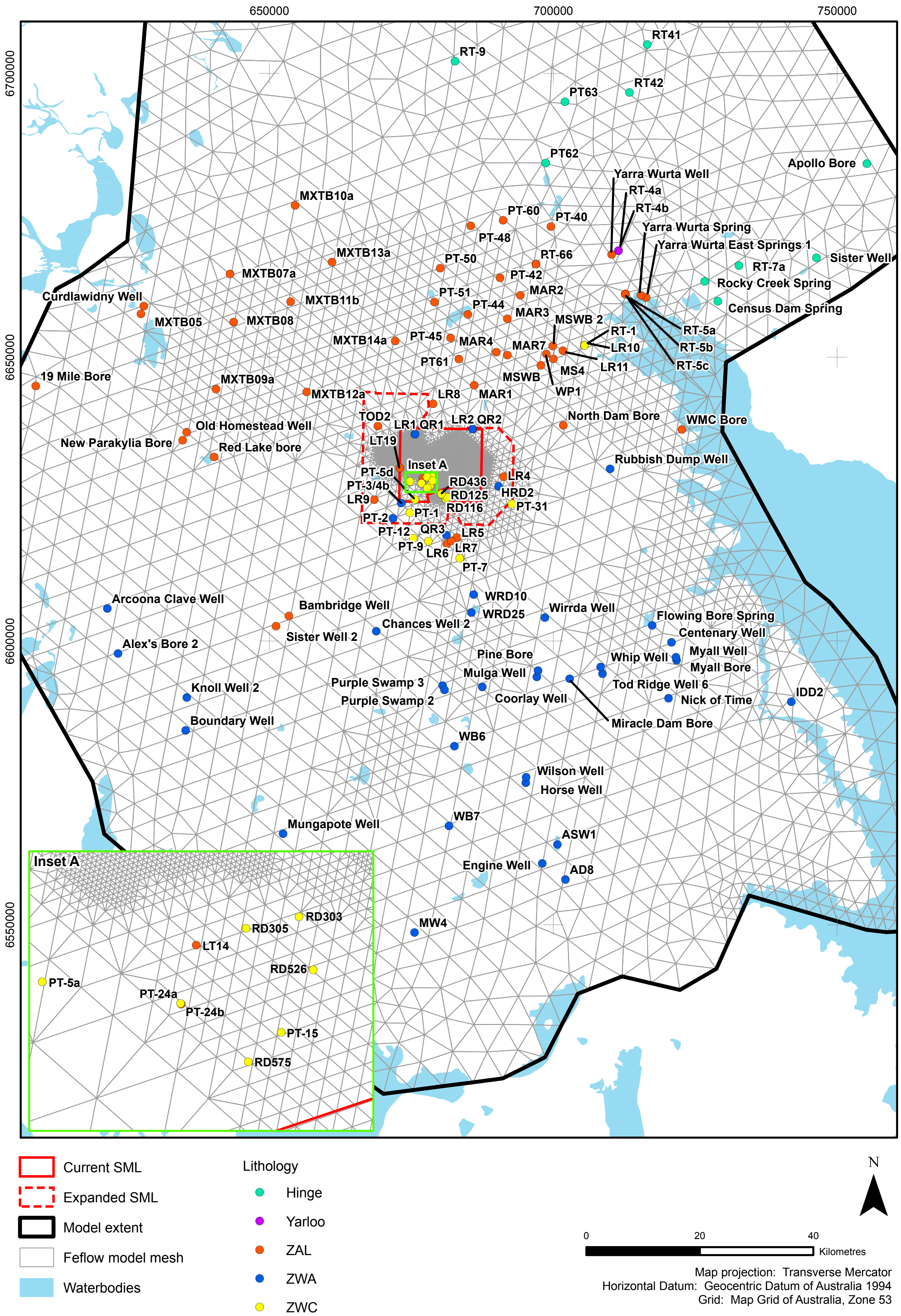
Figure 4.1 Steady state monitoring locations



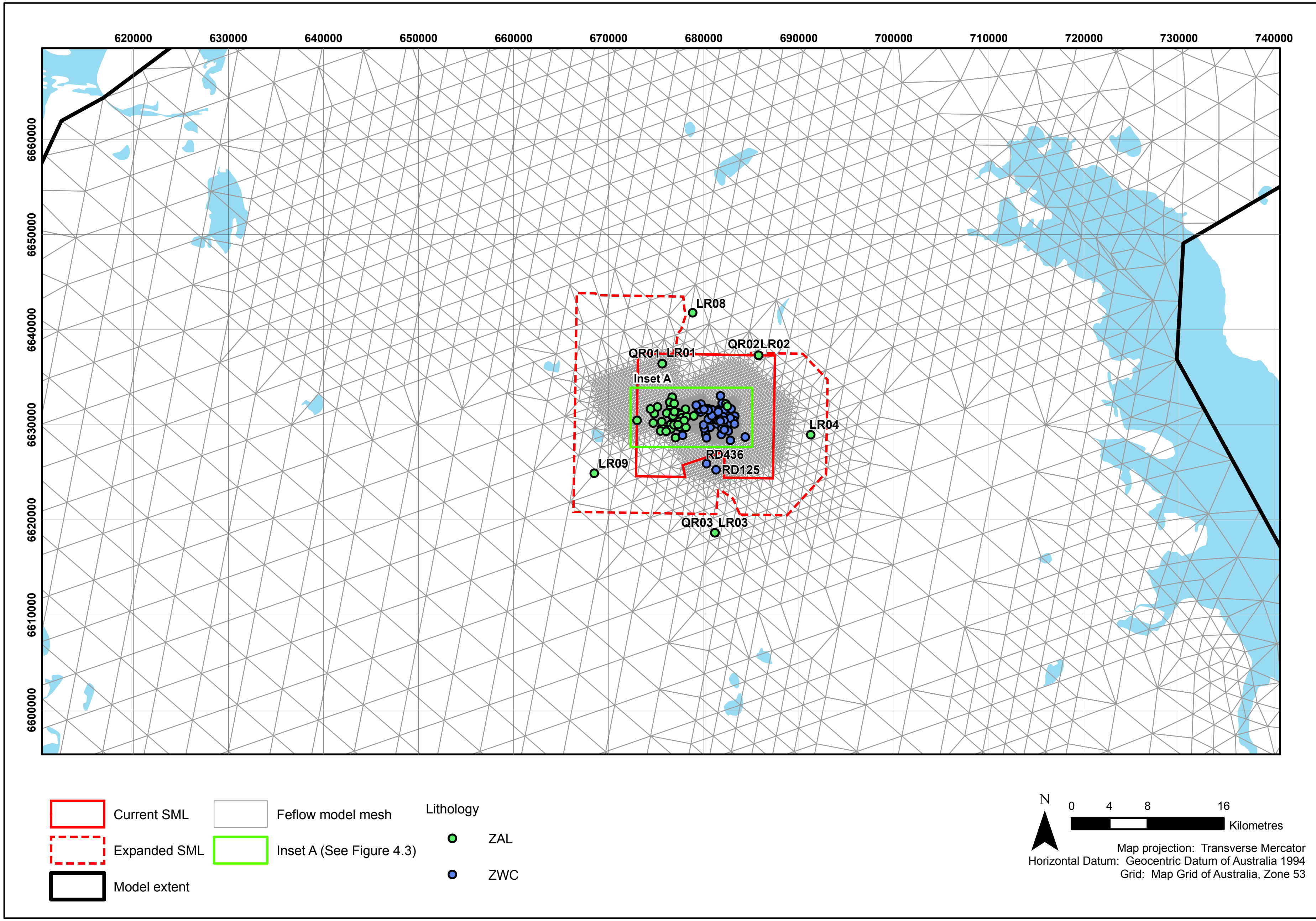


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Figure 4.2 Time variant monitoring locations

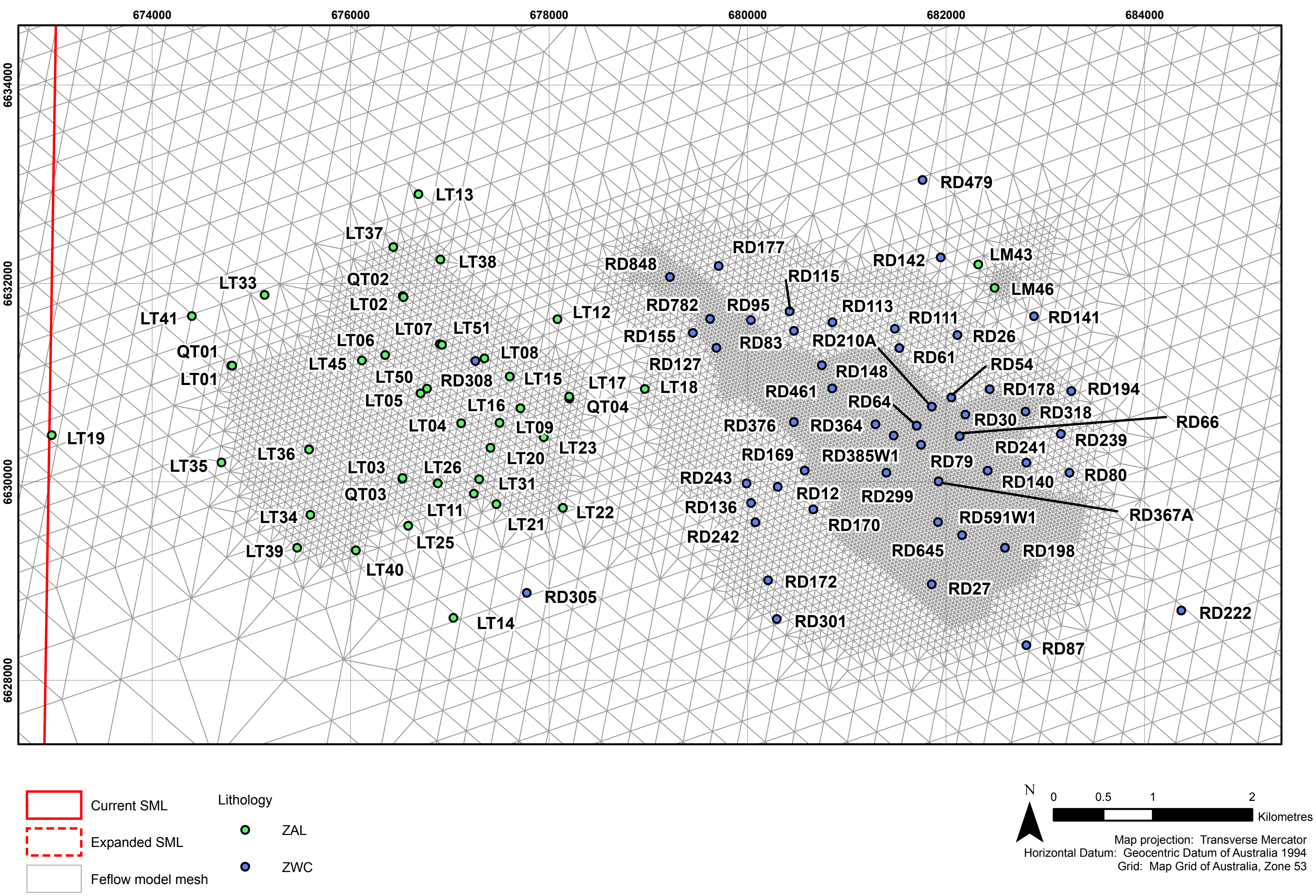

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Figure 4.3 Time variant monitoring locations (Inset A)

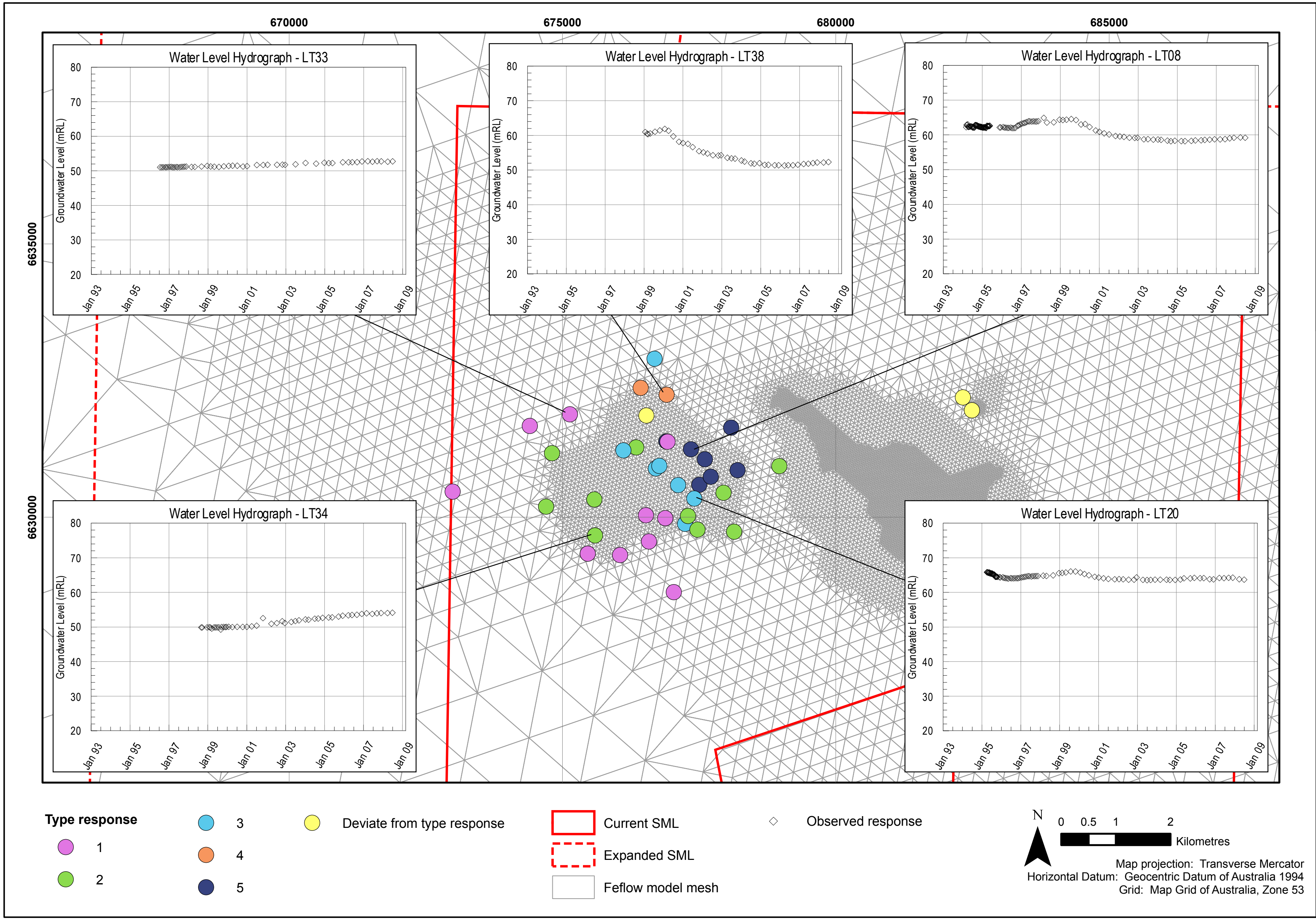

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Figure 4.4 Representative ZAL groundwater hydrographs

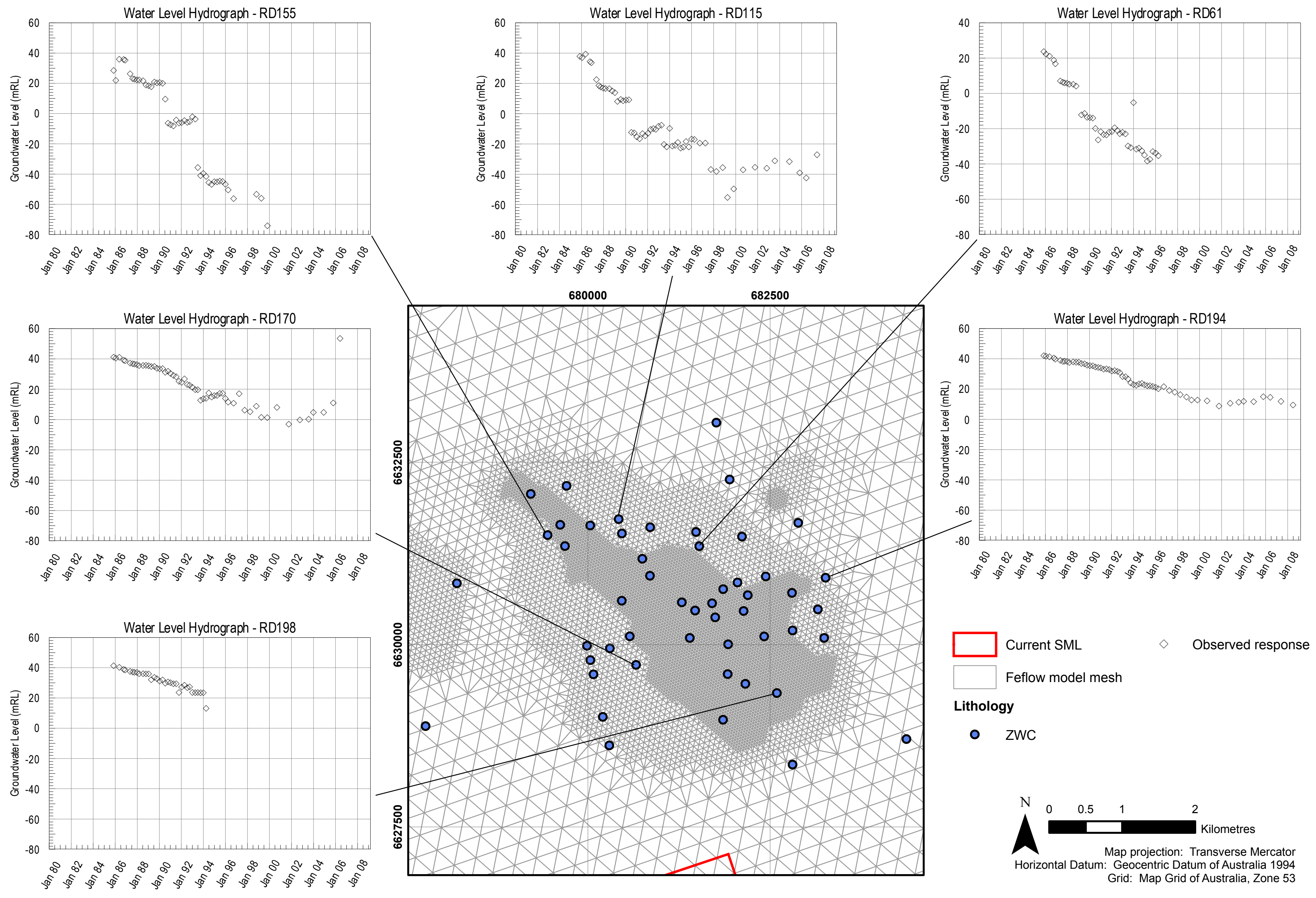

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Figure 4.5 Representative ZWC groundwater hydrographs

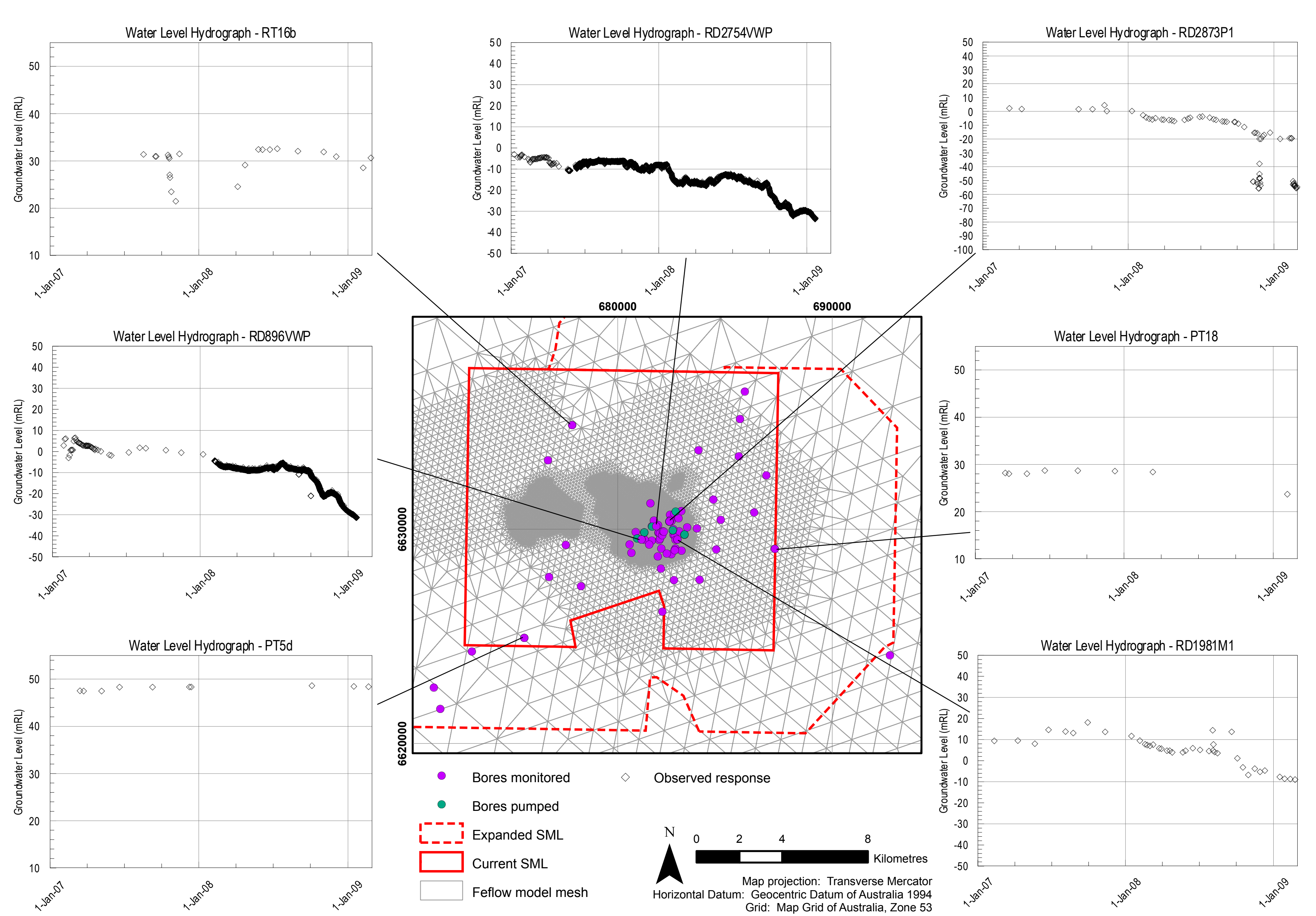

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Figure 4.6 Representative trial depressurisation (ZWC) groundwater hydrographs

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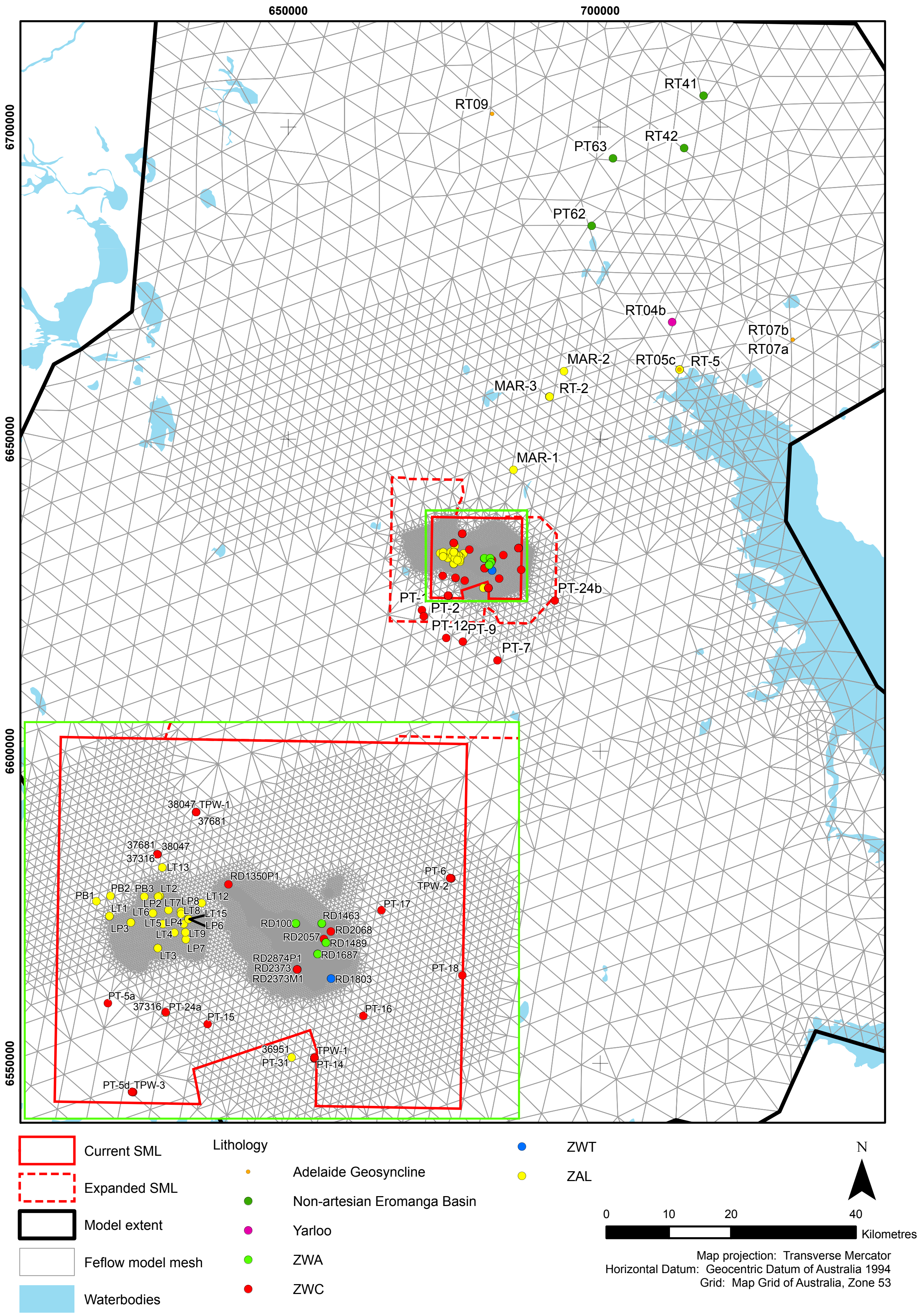
Figure 4.7 Location of measured hydraulic conductivity



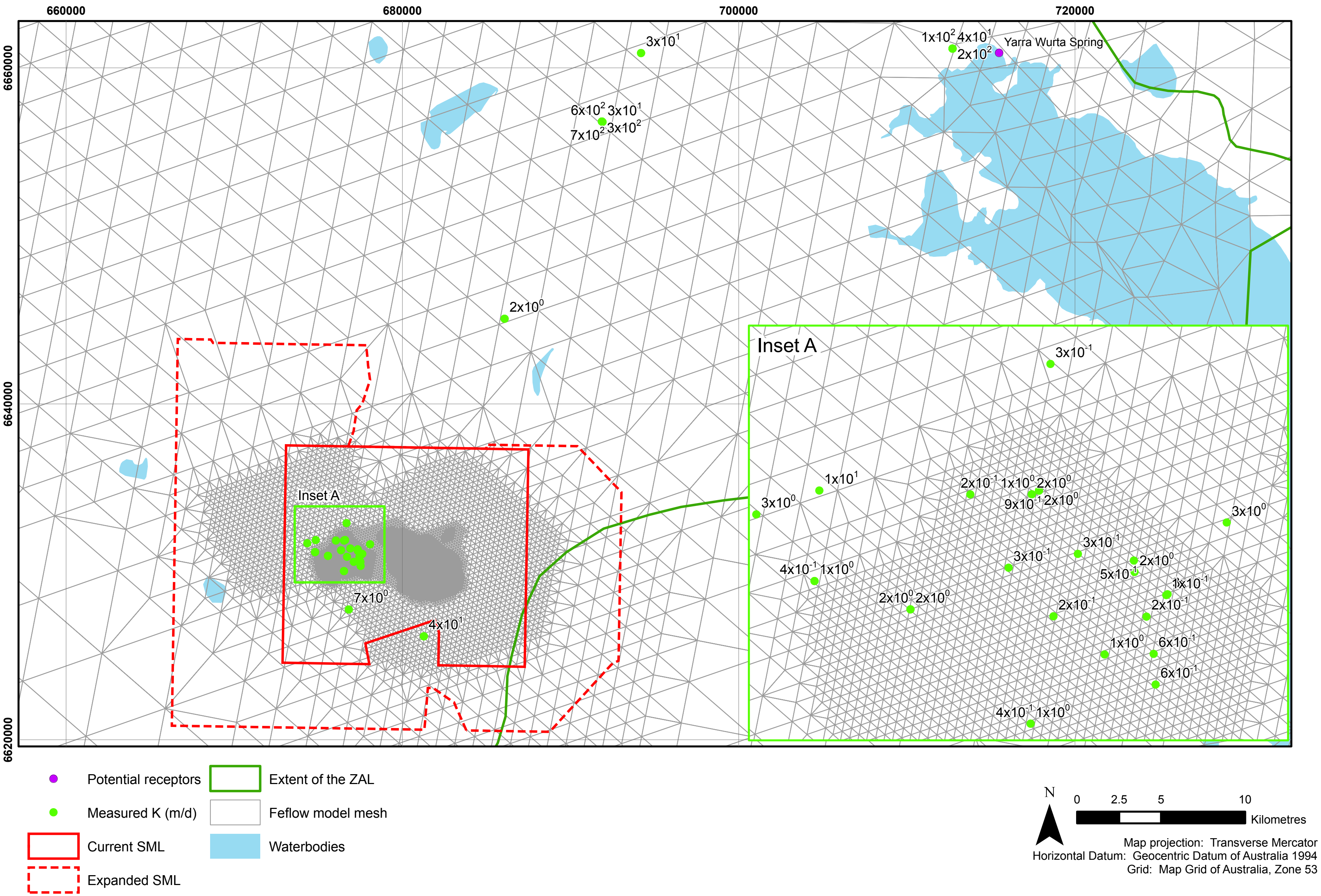


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Figure 4.8 Measured hydraulic conductivity (ZAL)

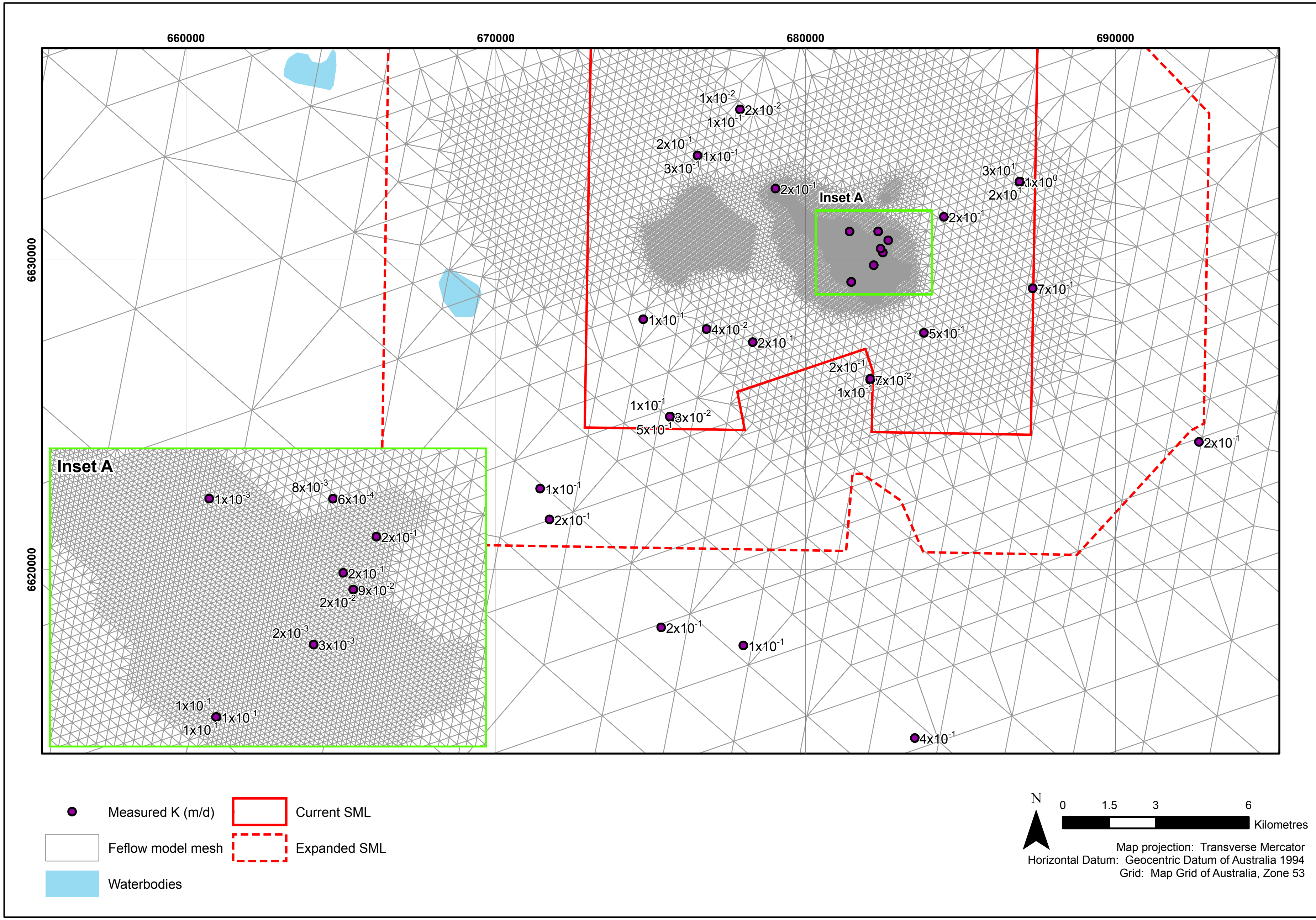

Figure 4.9 Measured hydraulic conductivity (ZWC)

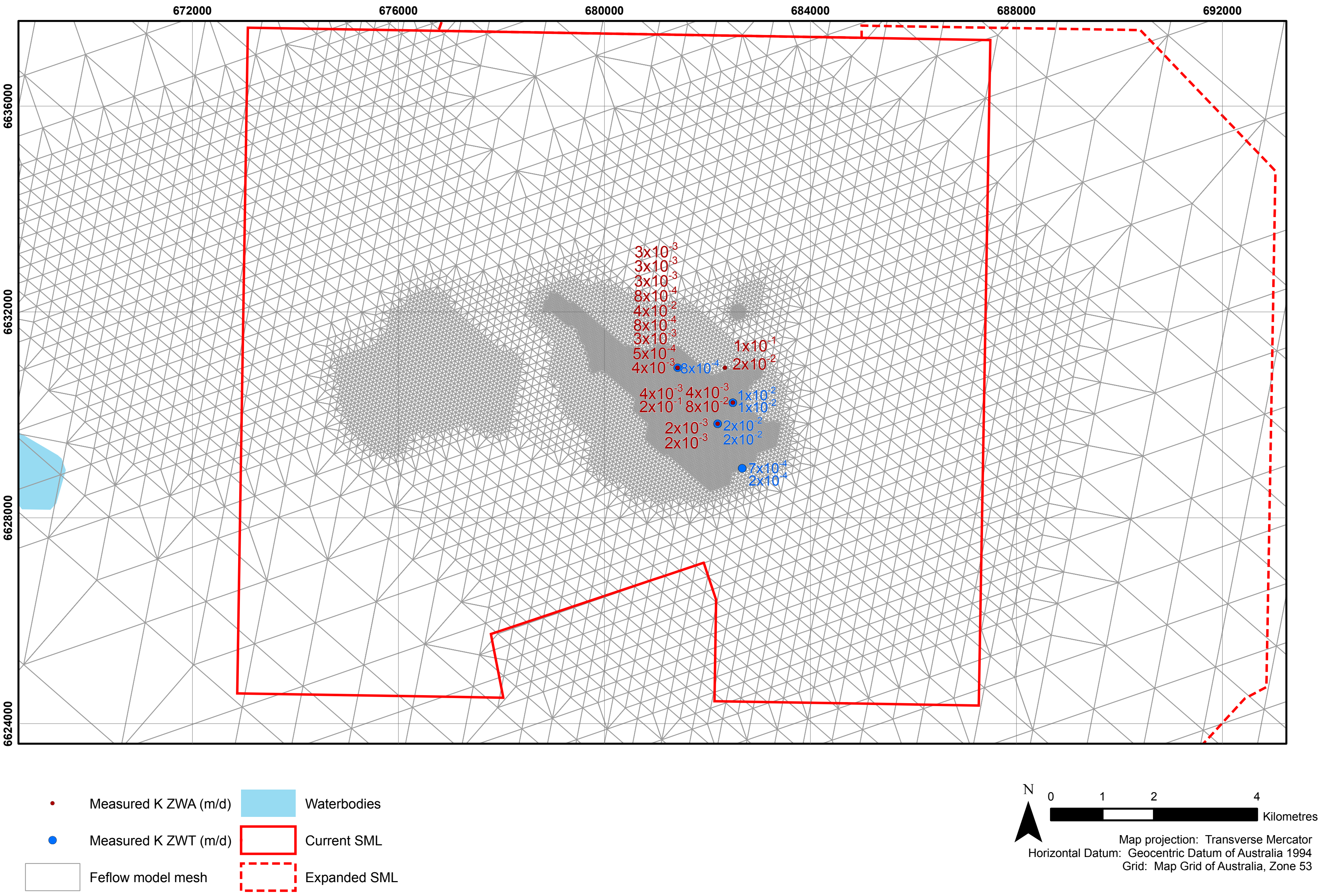

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Figure 4.10 Measured hydraulic conductivity (ZWA and ZWT)

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Figure 4.11 Location of measured specific storage

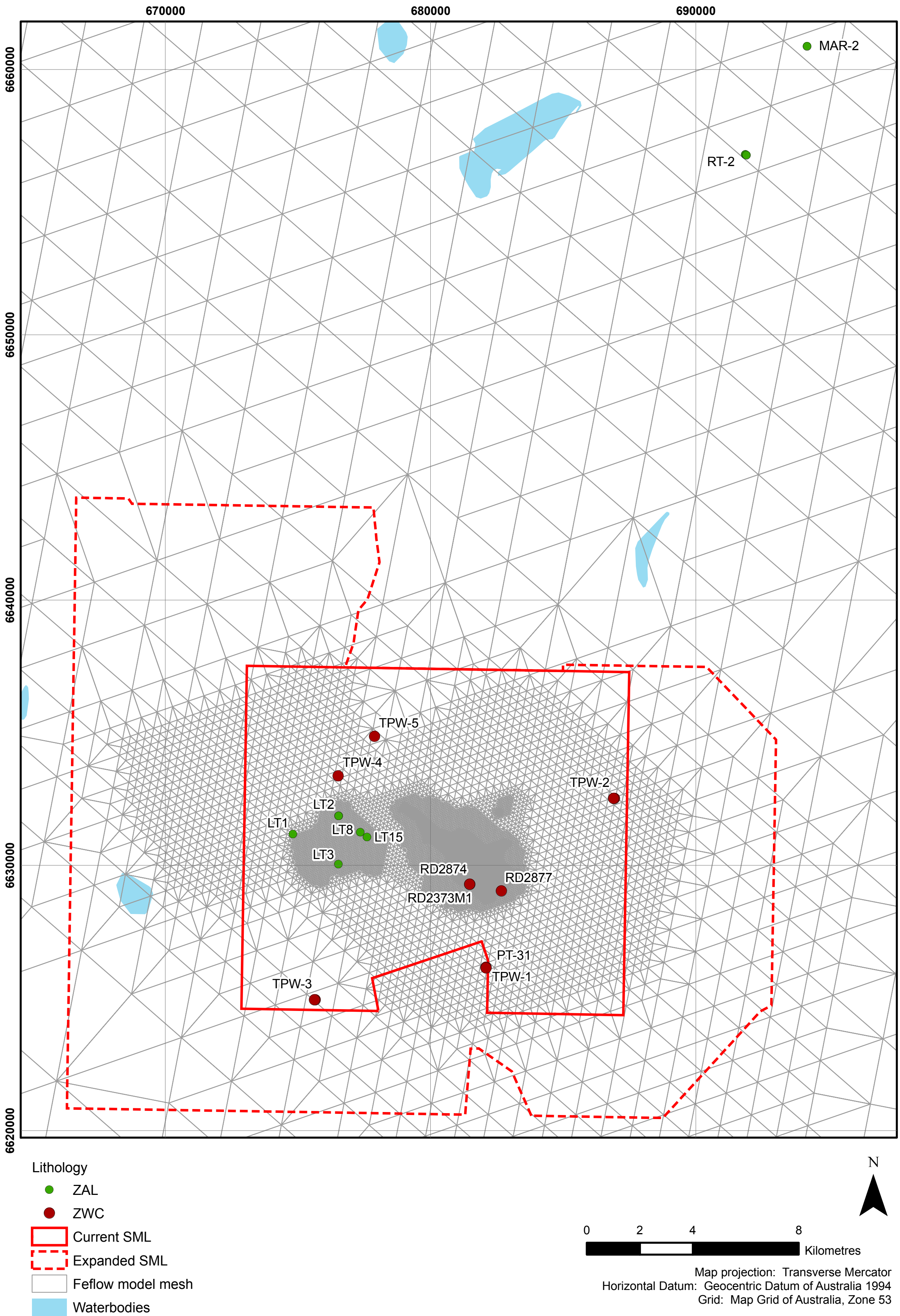
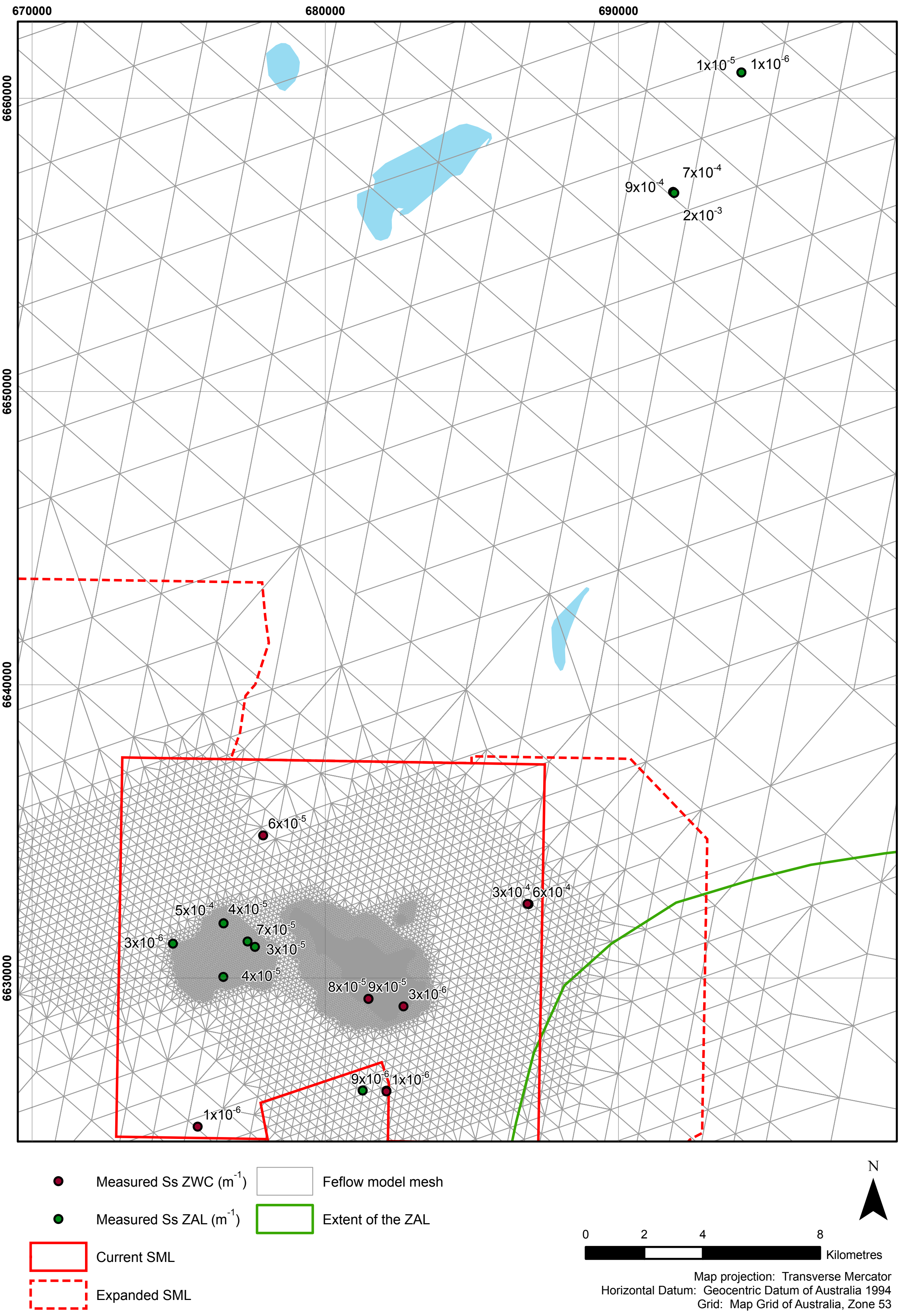


Figure 4.12 Measured specific storage (ZAL and ZWC)



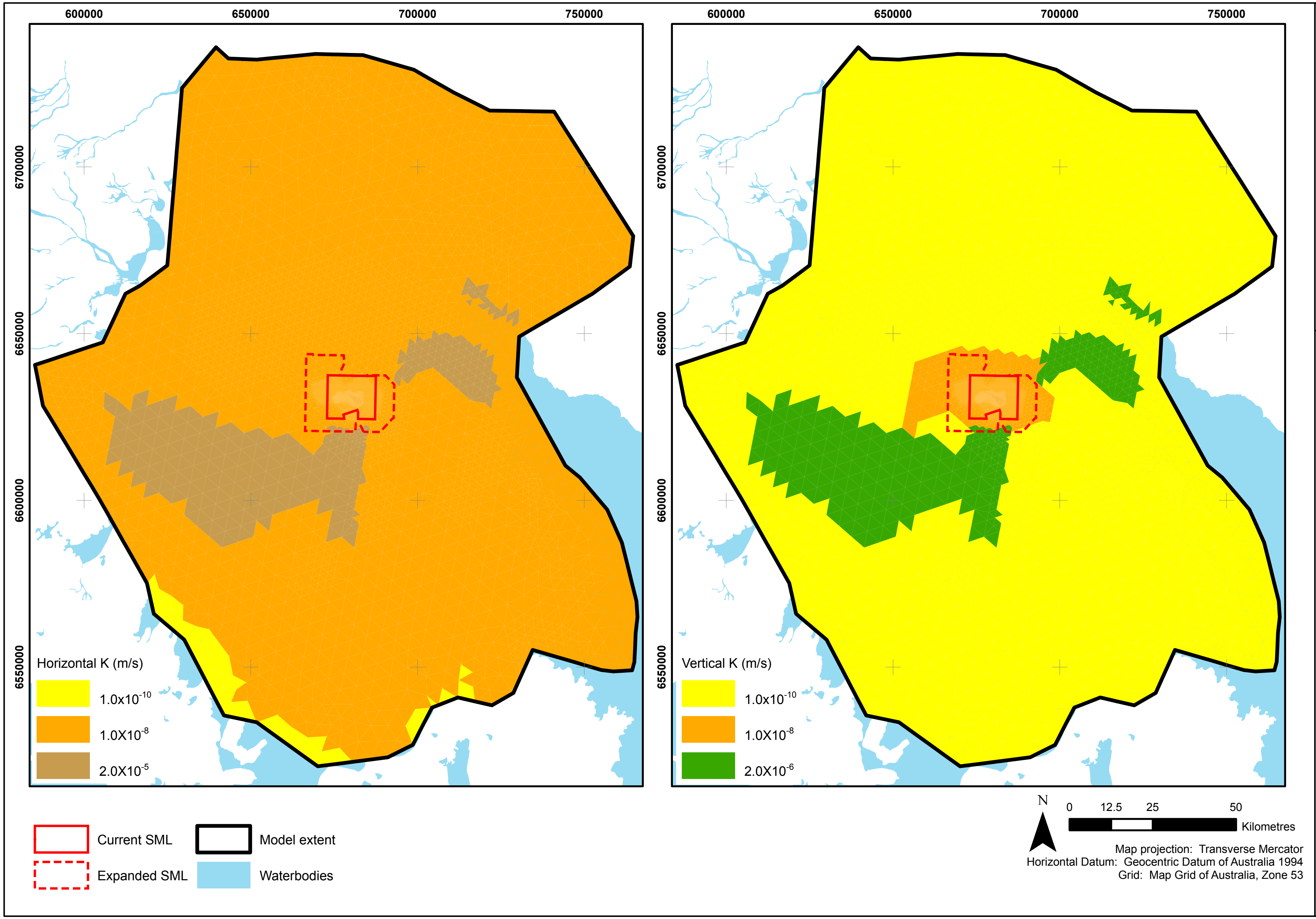


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Figure 4.13 Calibrated hydraulic conductivity values used for the Quaternary alluvial and Tertiary aeolian sediments (model Layer 1)

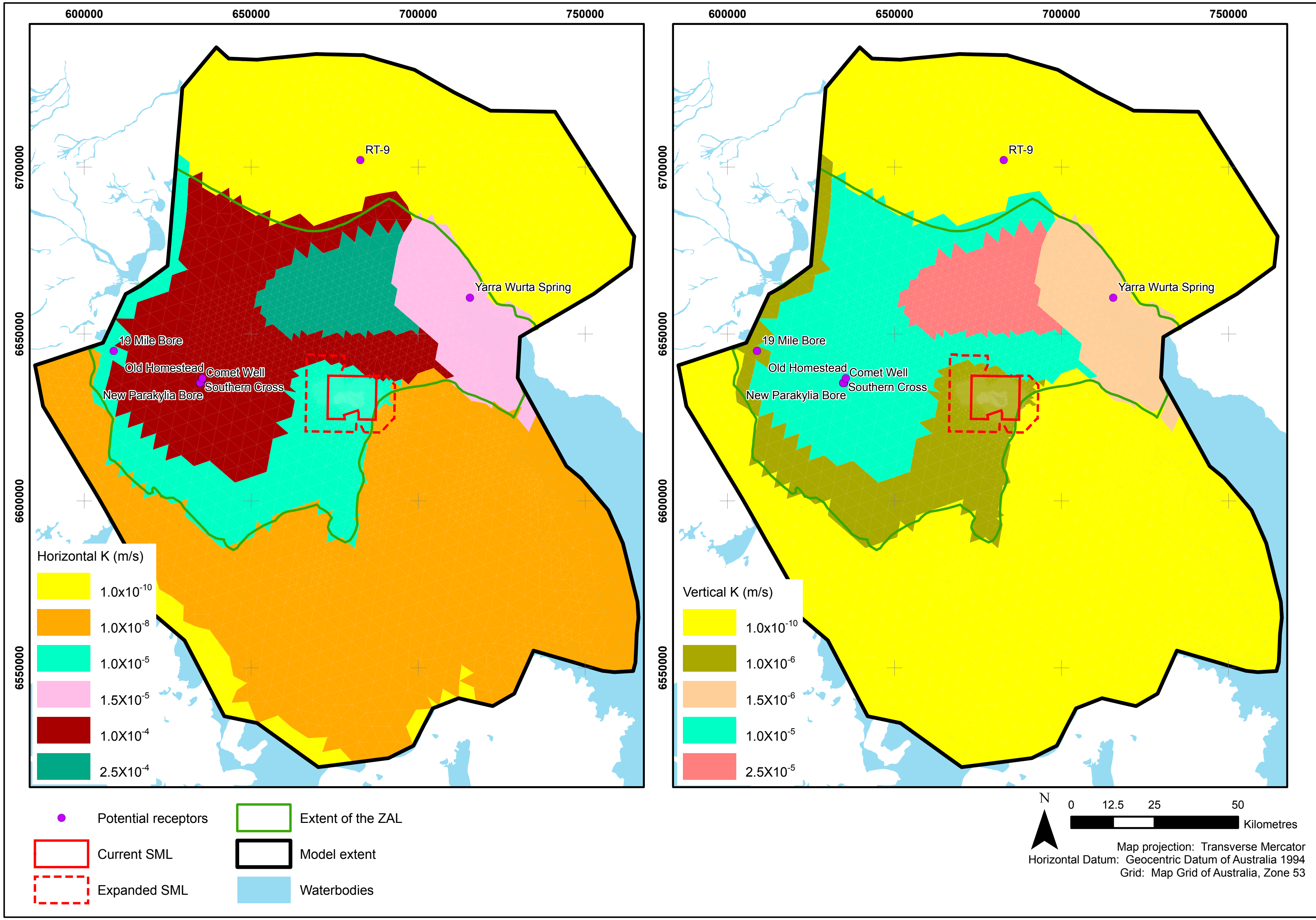

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Figure 4.14 Calibrated hydraulic conductivity values used for the upper ZAL (model Layer 2)

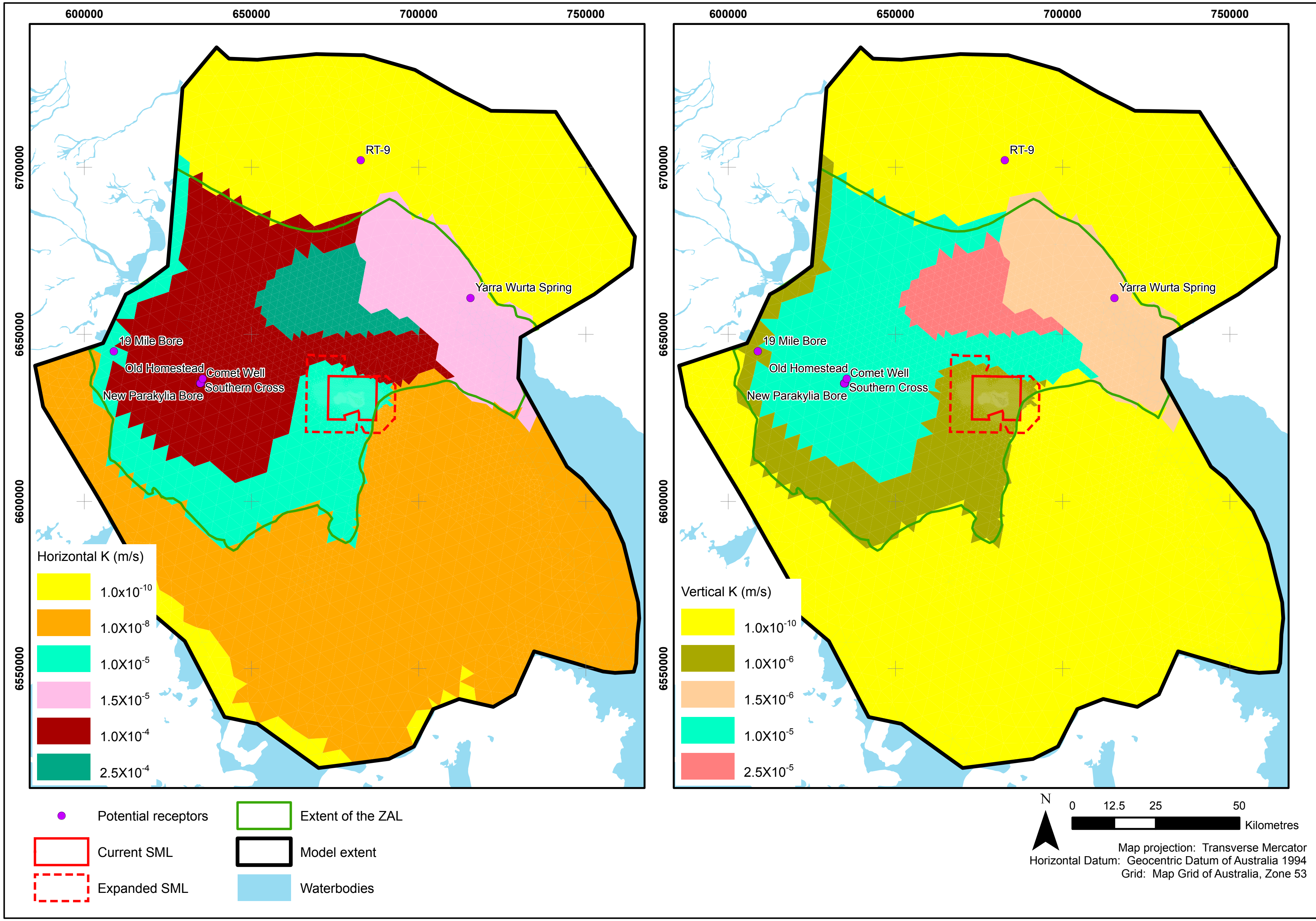

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Figure 4.15 Calibrated hydraulic conductivity values used for the central ZAL (model Layer 3)

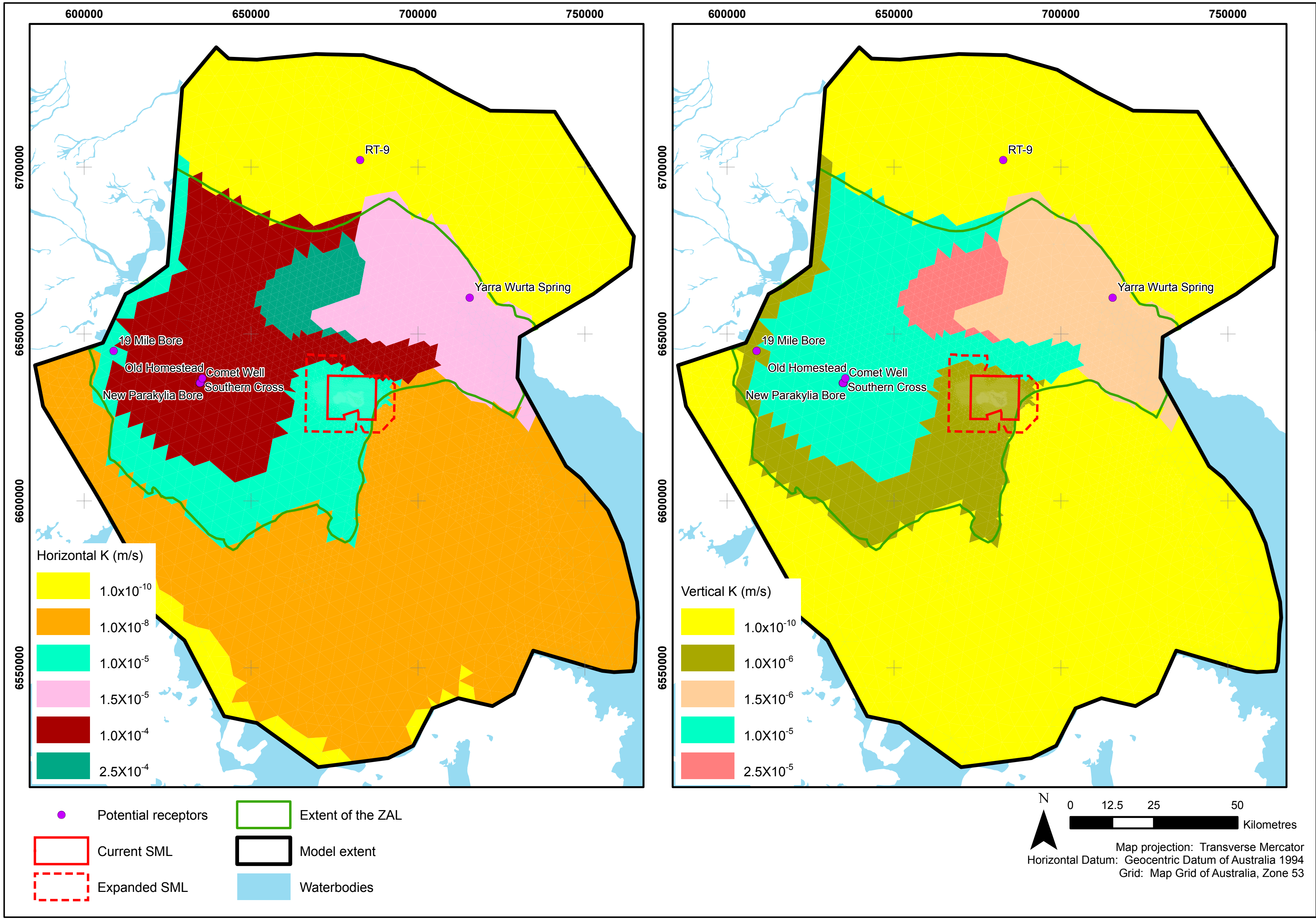

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Figure 4.16 Calibrated hydraulic conductivity values used for the lower ZAL (model Layer 4)

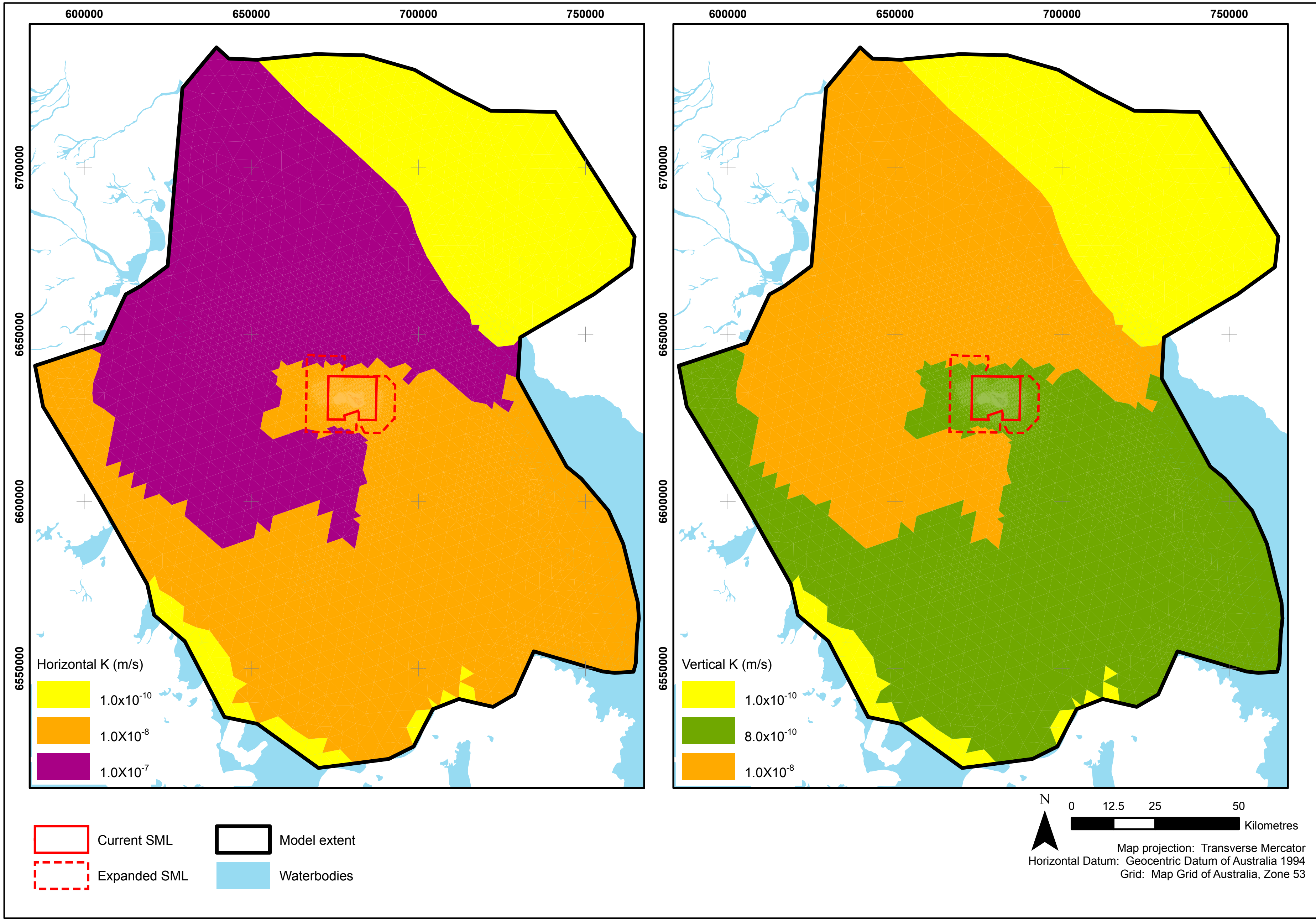

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Figure 4.17 Calibrated hydraulic conductivity values used for the Yarloo Shale (model Layer 5)

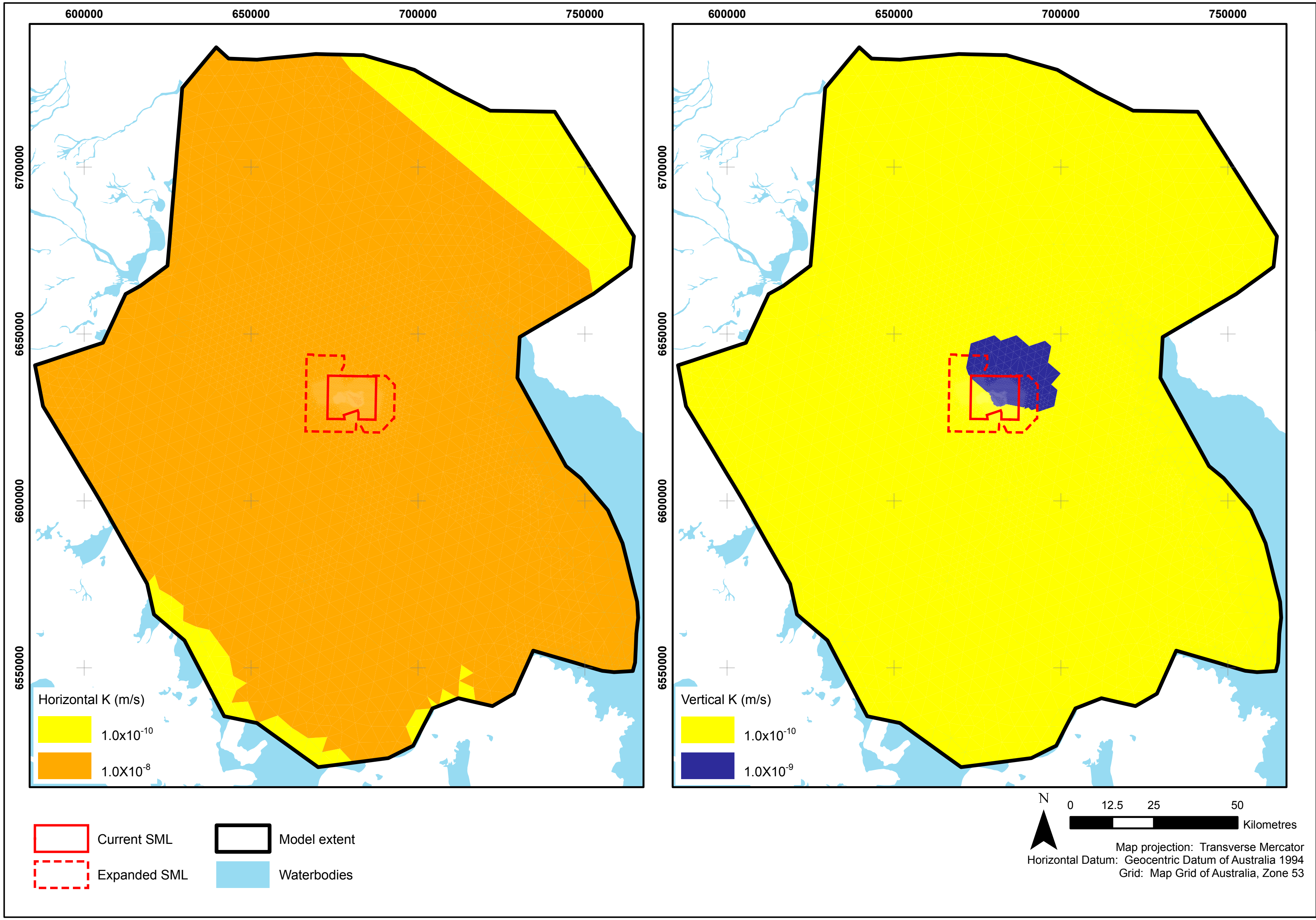

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Figure 4.18 Calibrated hydraulic conductivity values used for the ZWA (model Layer 6)

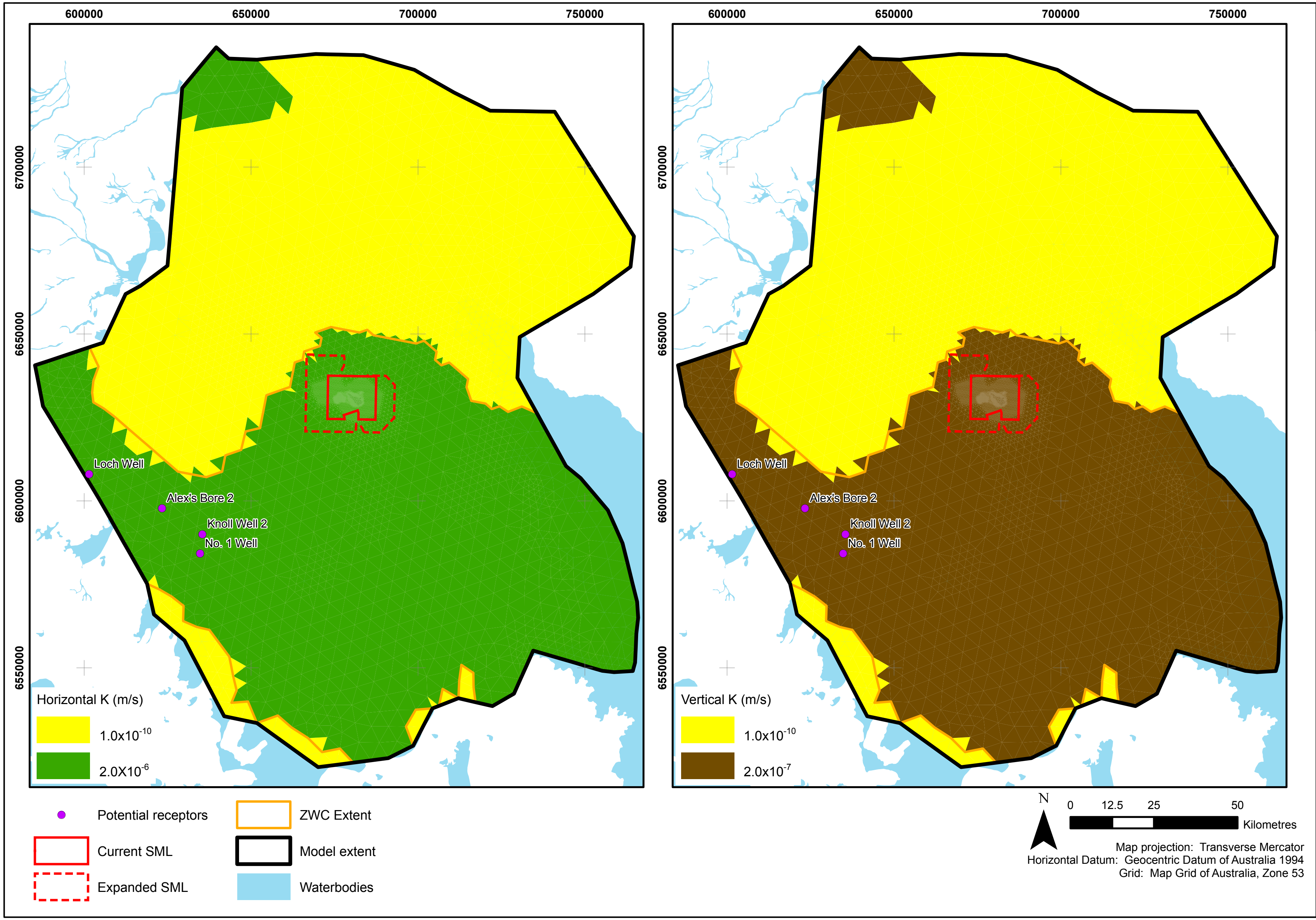

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Figure 4.19 Calibrated hydraulic conductivity values used for the ZWC (model Layer 7)

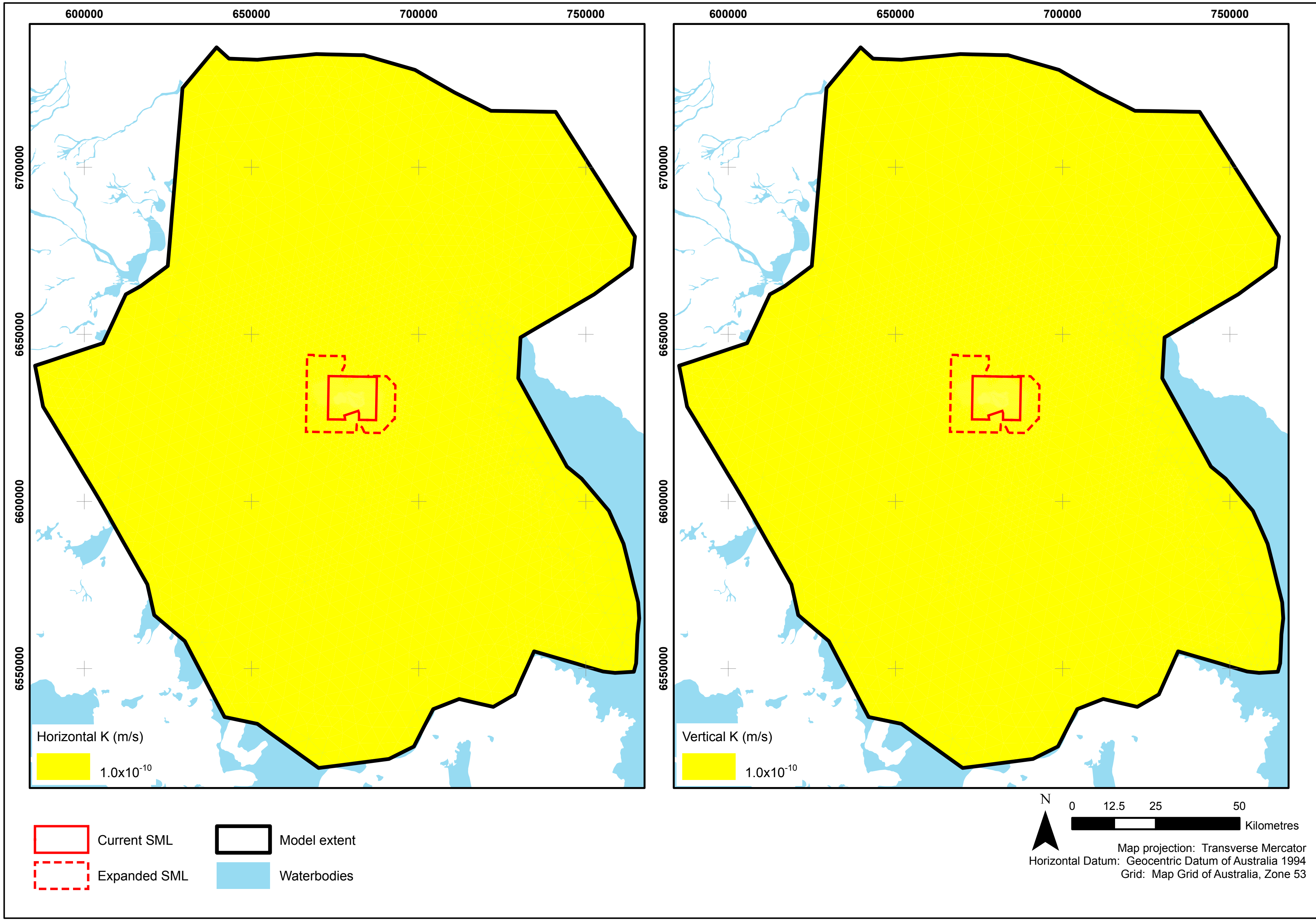

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Figure 4.20 Calibrated hydraulic conductivity values used for the ZWT (model Layer 8)

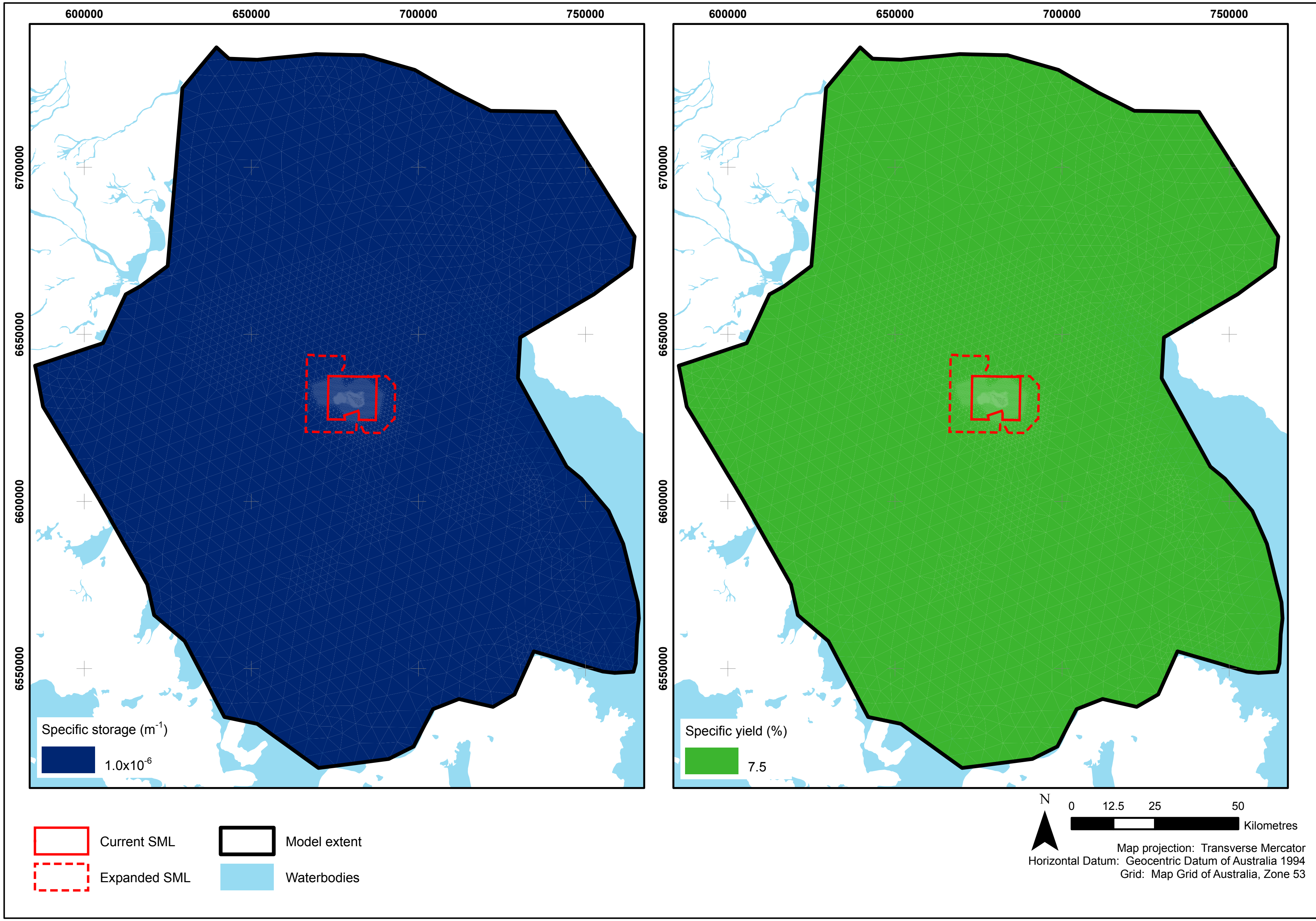

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Figure 4.21 Calibrated storage values used for the Quaternary alluvial and Tertiary aeolian sediments (model Layer 1)

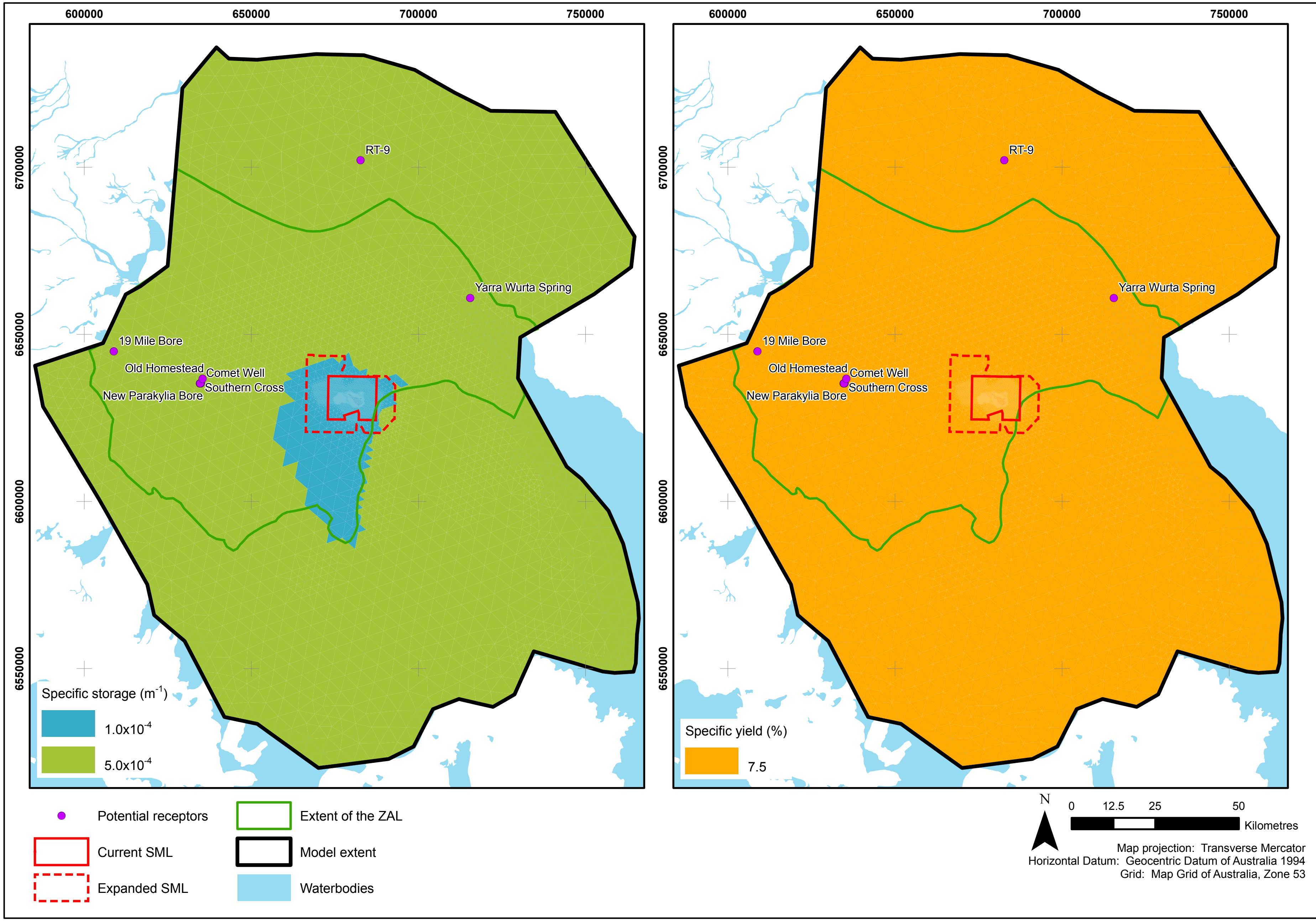

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Figure 4.22 Calibrated storage values used for the ZAL (model Layers 2, 3 and 4)

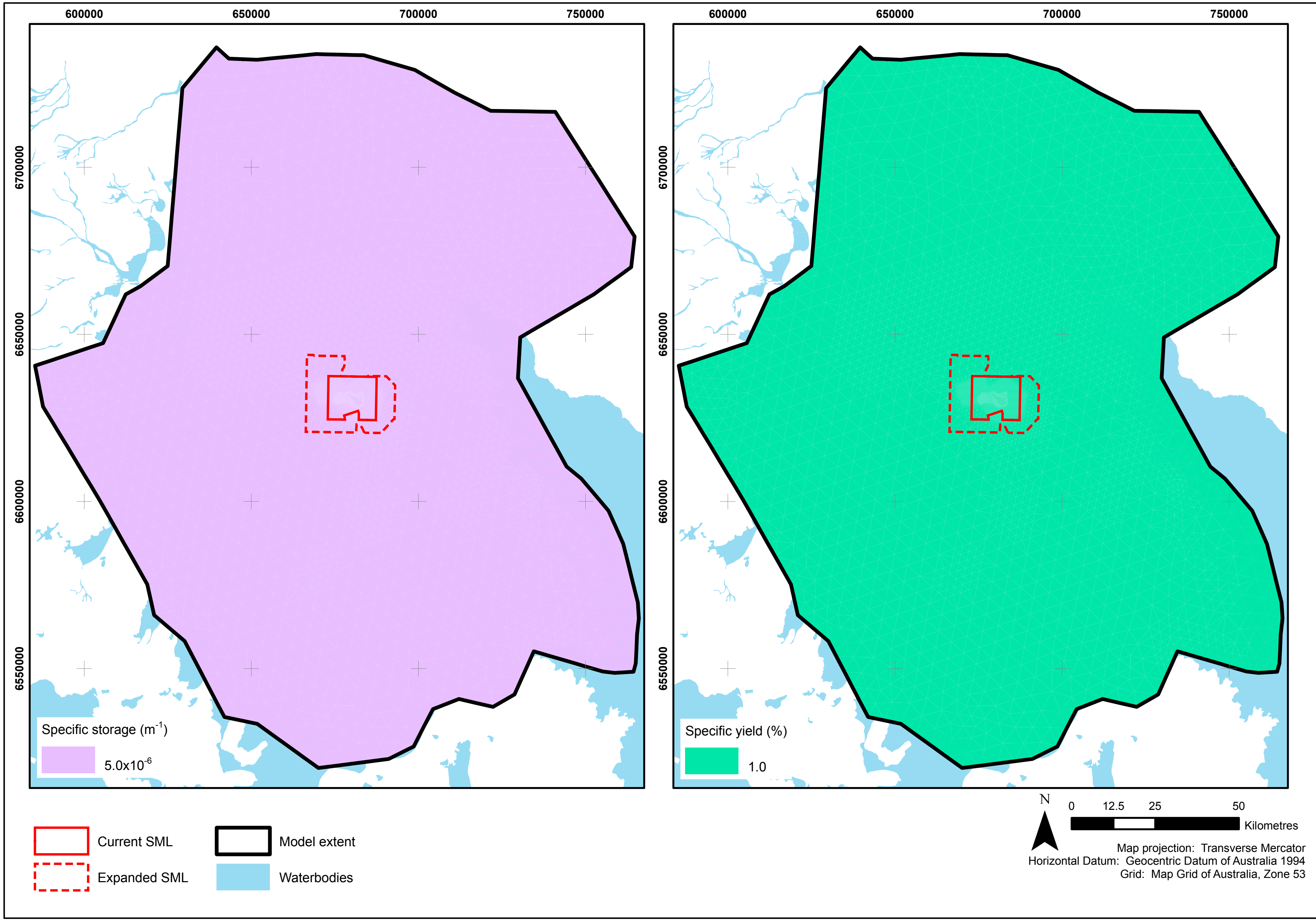

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Figure 4.23 Calibrated storage values used for the Yarloo Shale (model Layer 5)

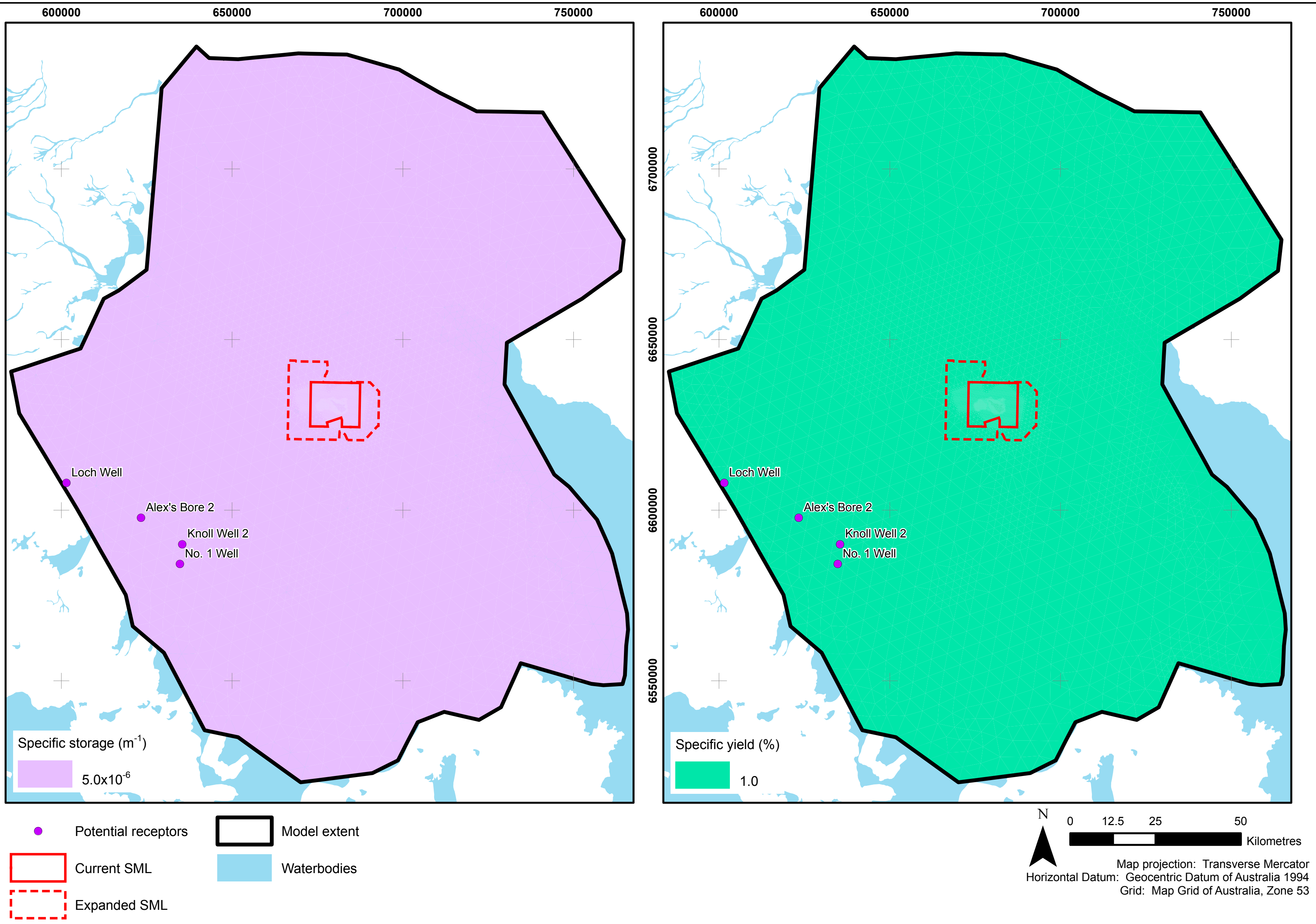

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Figure 4.24 Calibrated storage values used for the ZWA (model Layer 6)

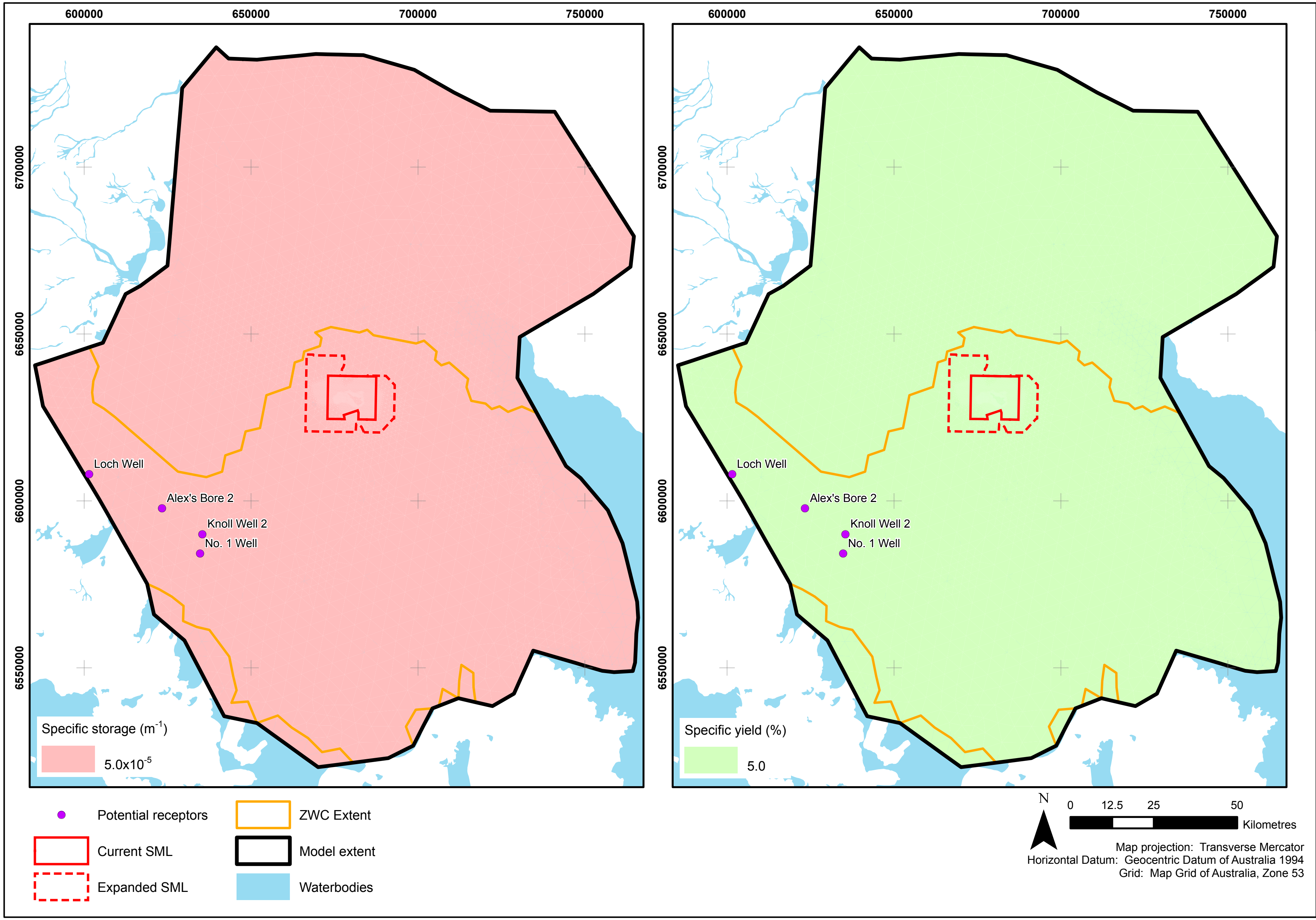

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Figure 4.25 Calibrated storage values used for the ZWC (model Layer 7)

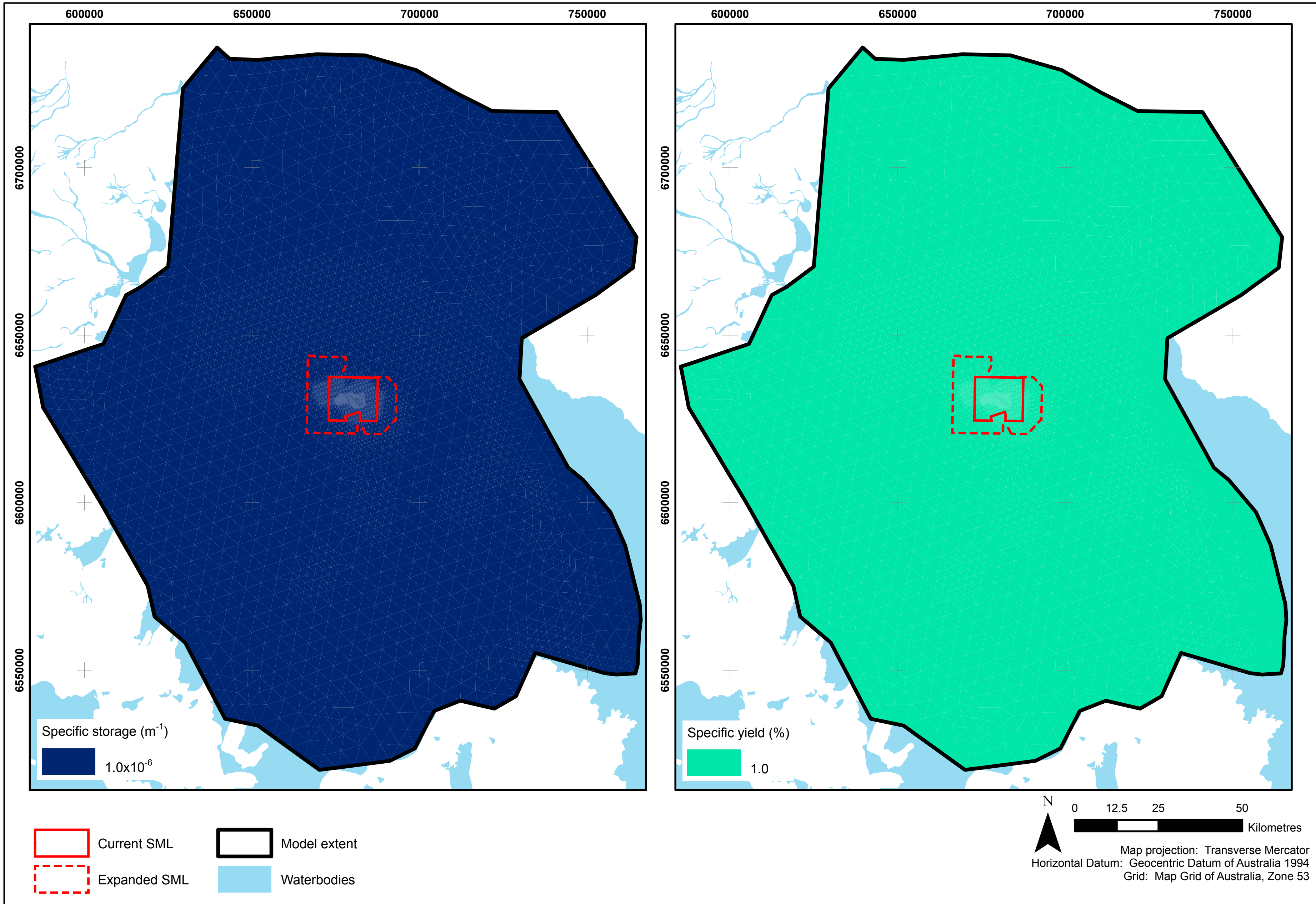

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Figure 4.26 Calibrated storage values used for the ZWT (model Layer 8)

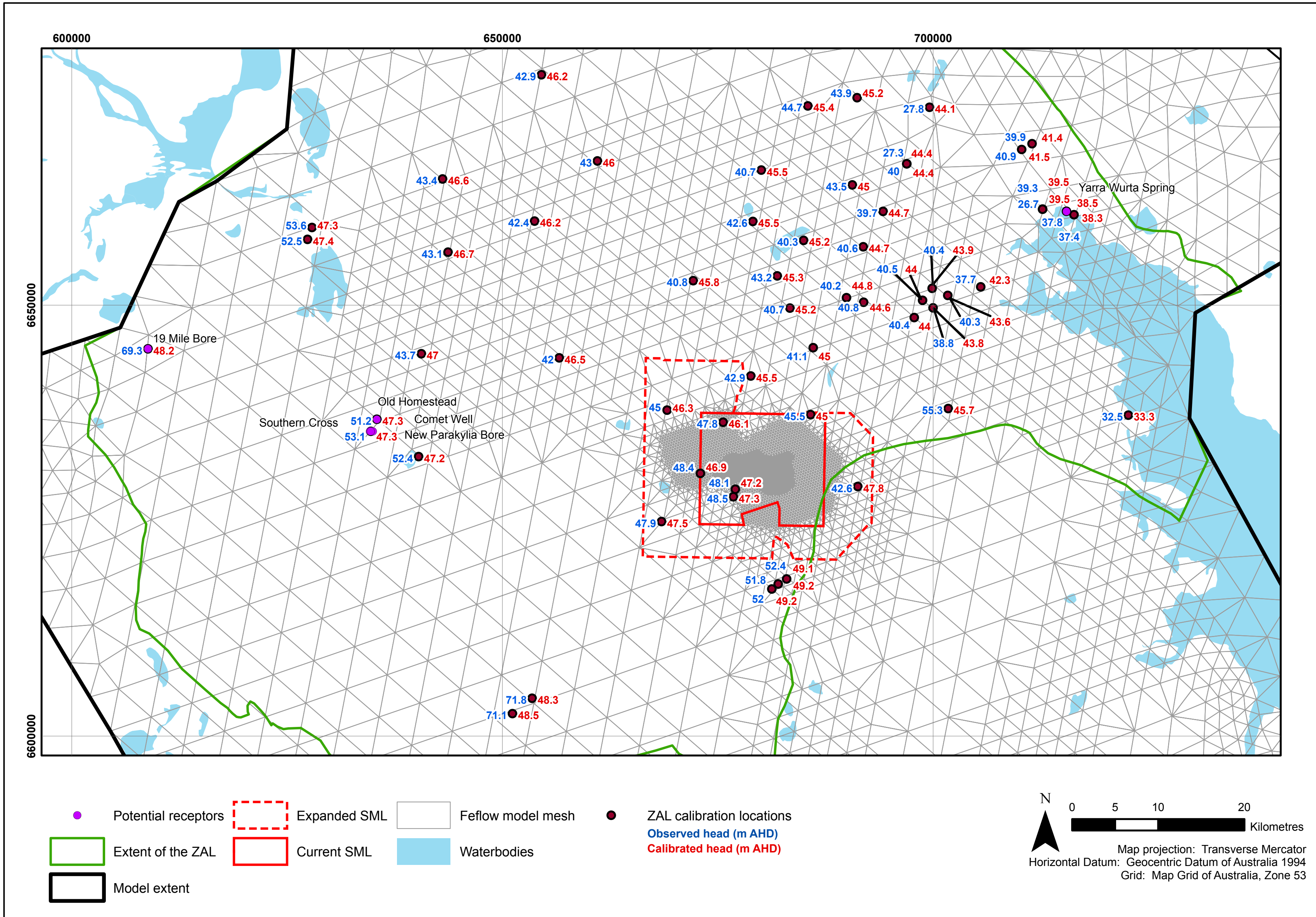

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Figure 4.27 Steady state observed and simulated groundwater elevations (ZAL)

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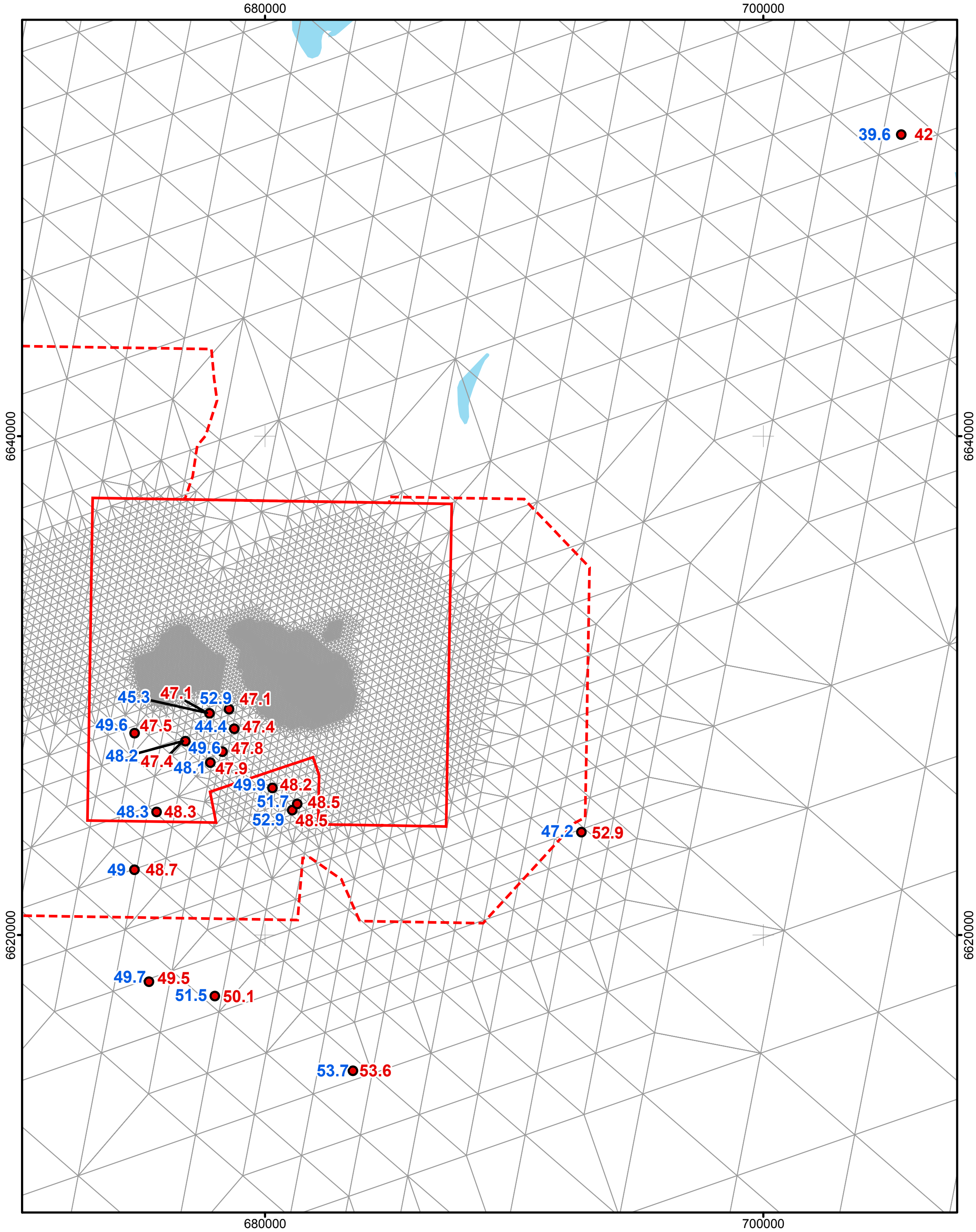
Figure 4.28 Steady state observed and simulated groundwater elevations (ZWC)



Current SML
Expanded SML
Feflow model mesh
Waterbodies

ZWC calibration locations
Observed head (m AHD)
Calibrated head (m AHD)

N

0 5 10
Kilometres

Map projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 53

Figure 4.29 Steady state observed and simulated groundwater elevations (THZ / Yarloo Shale and ZWA)

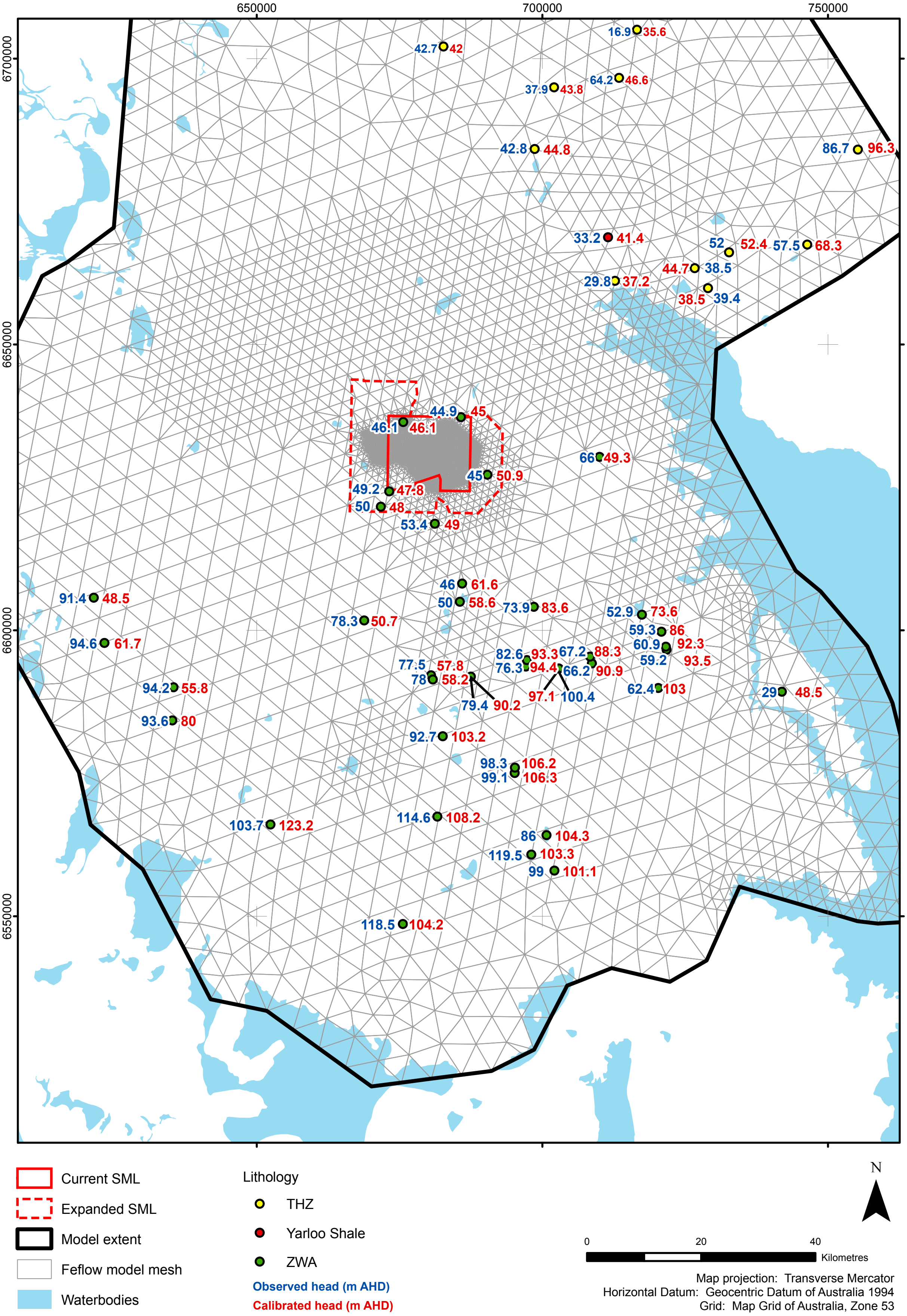


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Figure 4.30 Steady state simulated groundwater contours (ZAL)

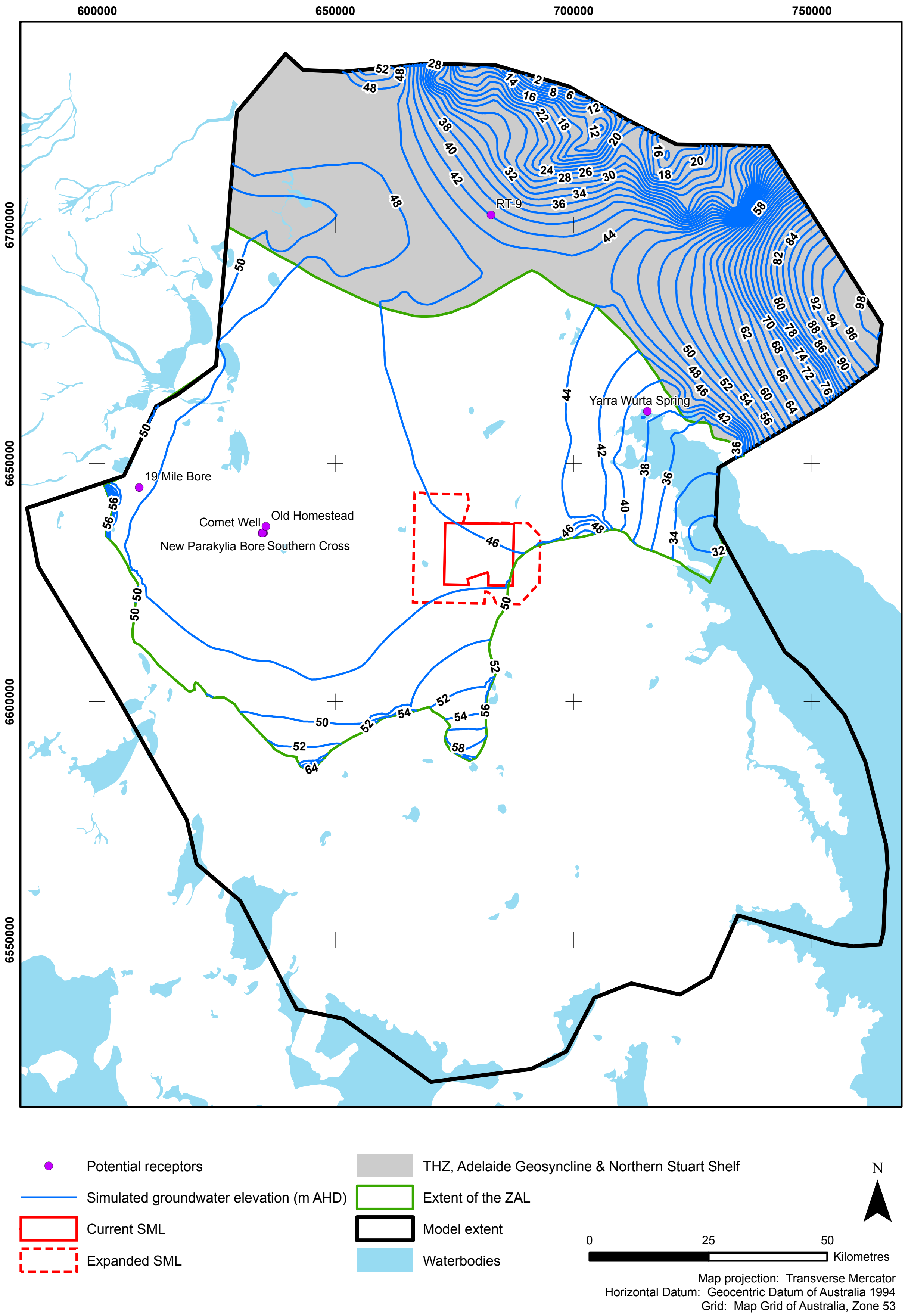

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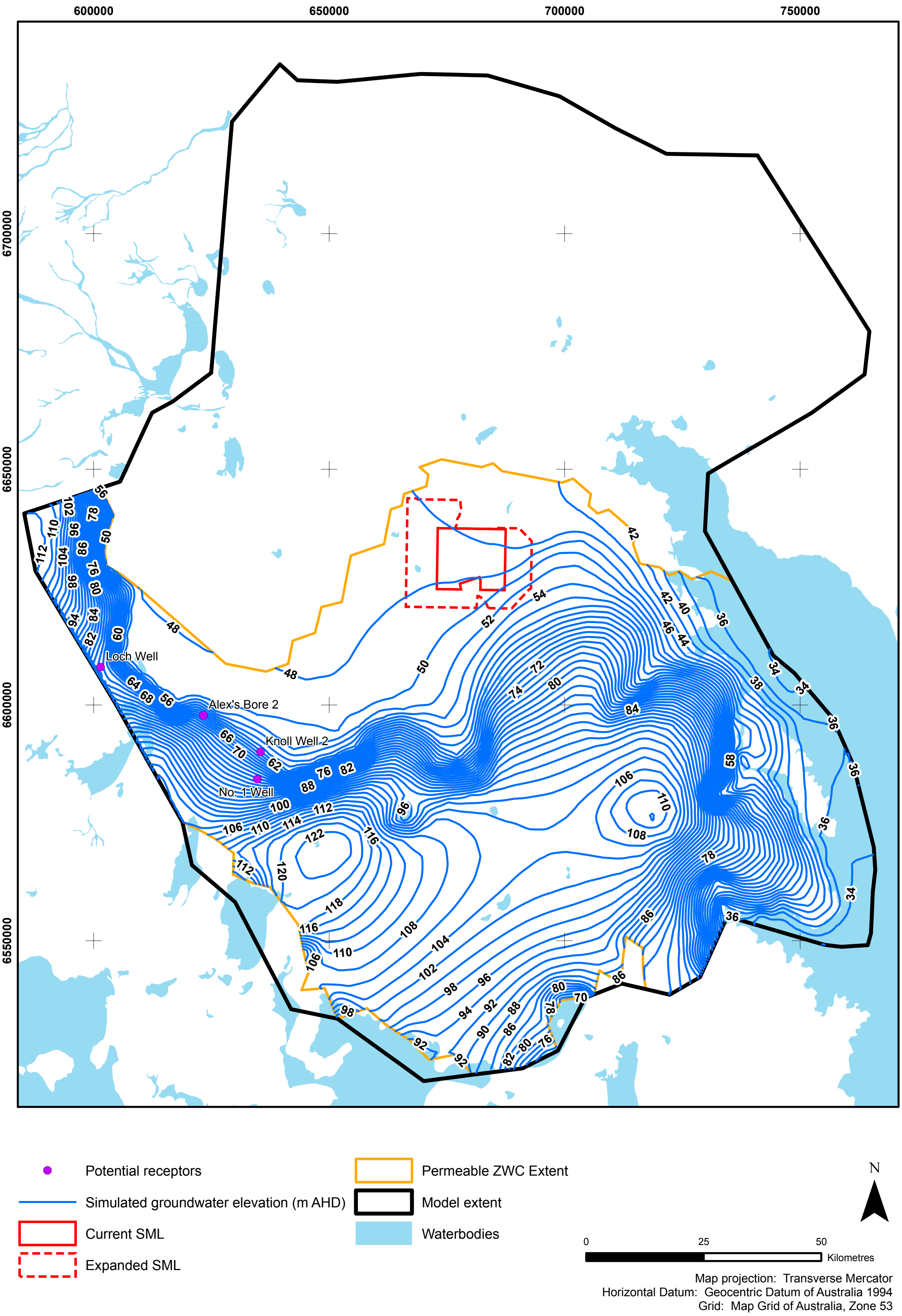
Figure 4.31 Steady state simulated groundwater contours (ZWC)



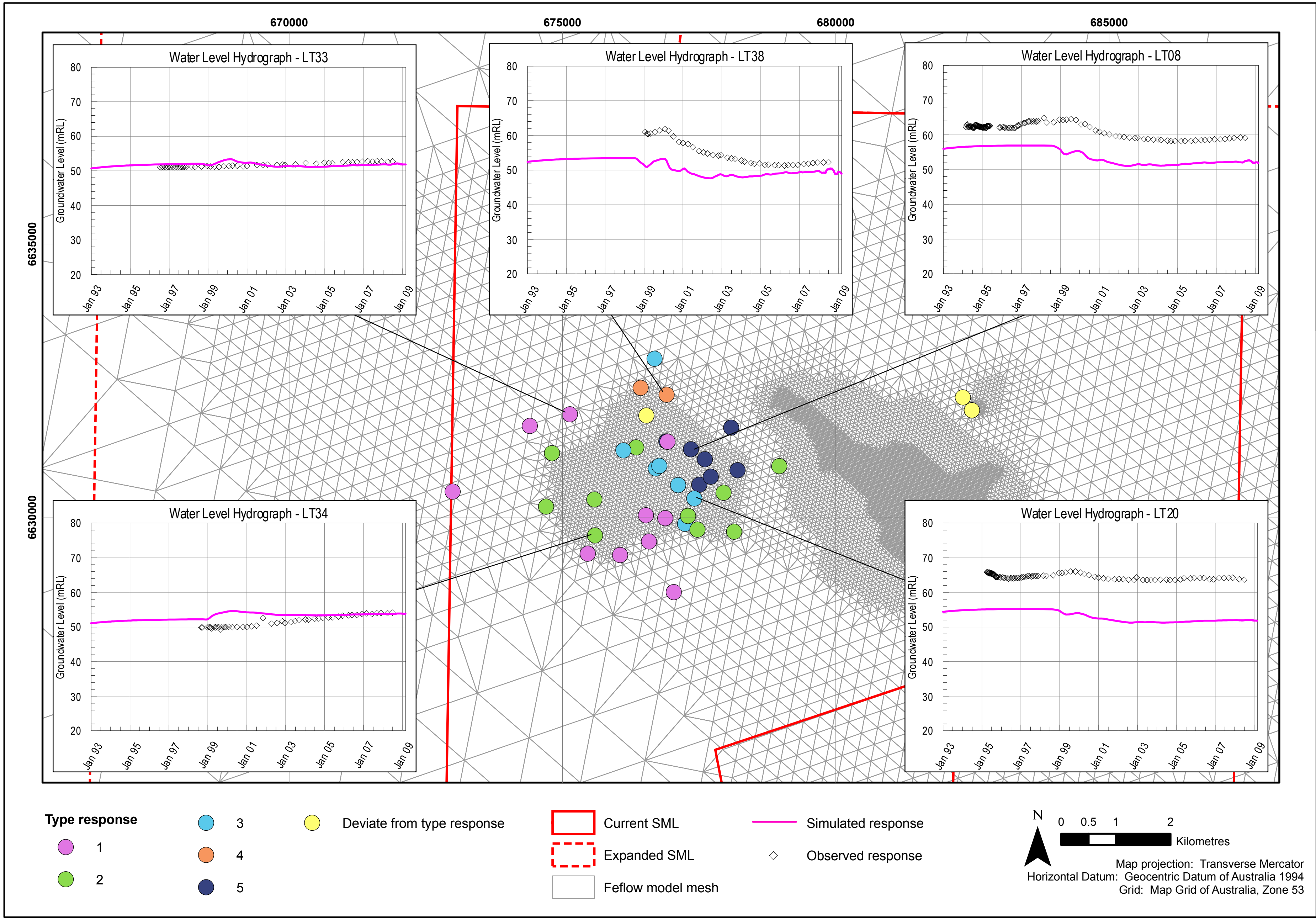


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Figure 4.32 Time variant observed and simulated responses at representative ZAL locations

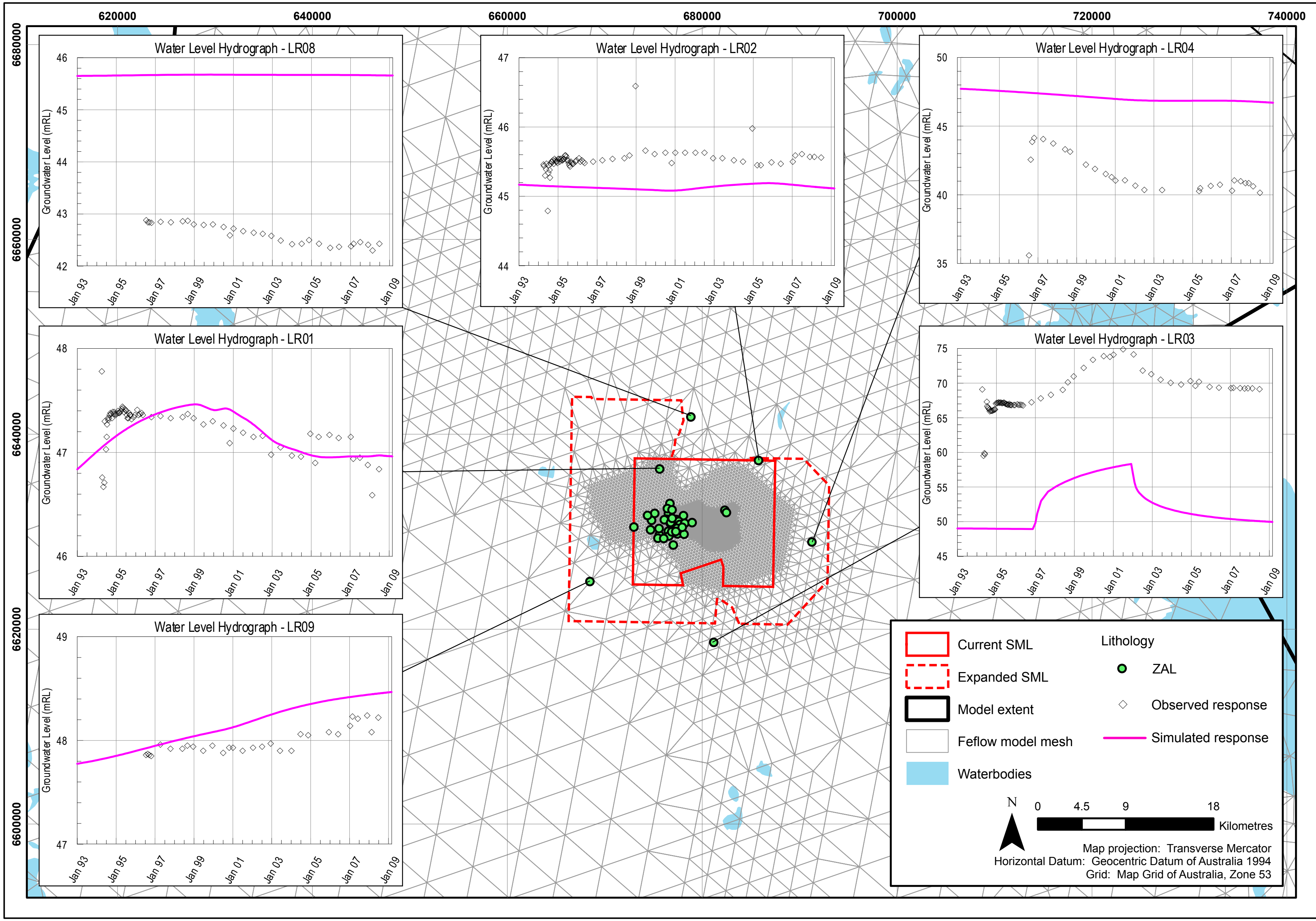

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Figure 4.33 Time variant observed and simulated responses at representative "sub-regional" ZAL locations

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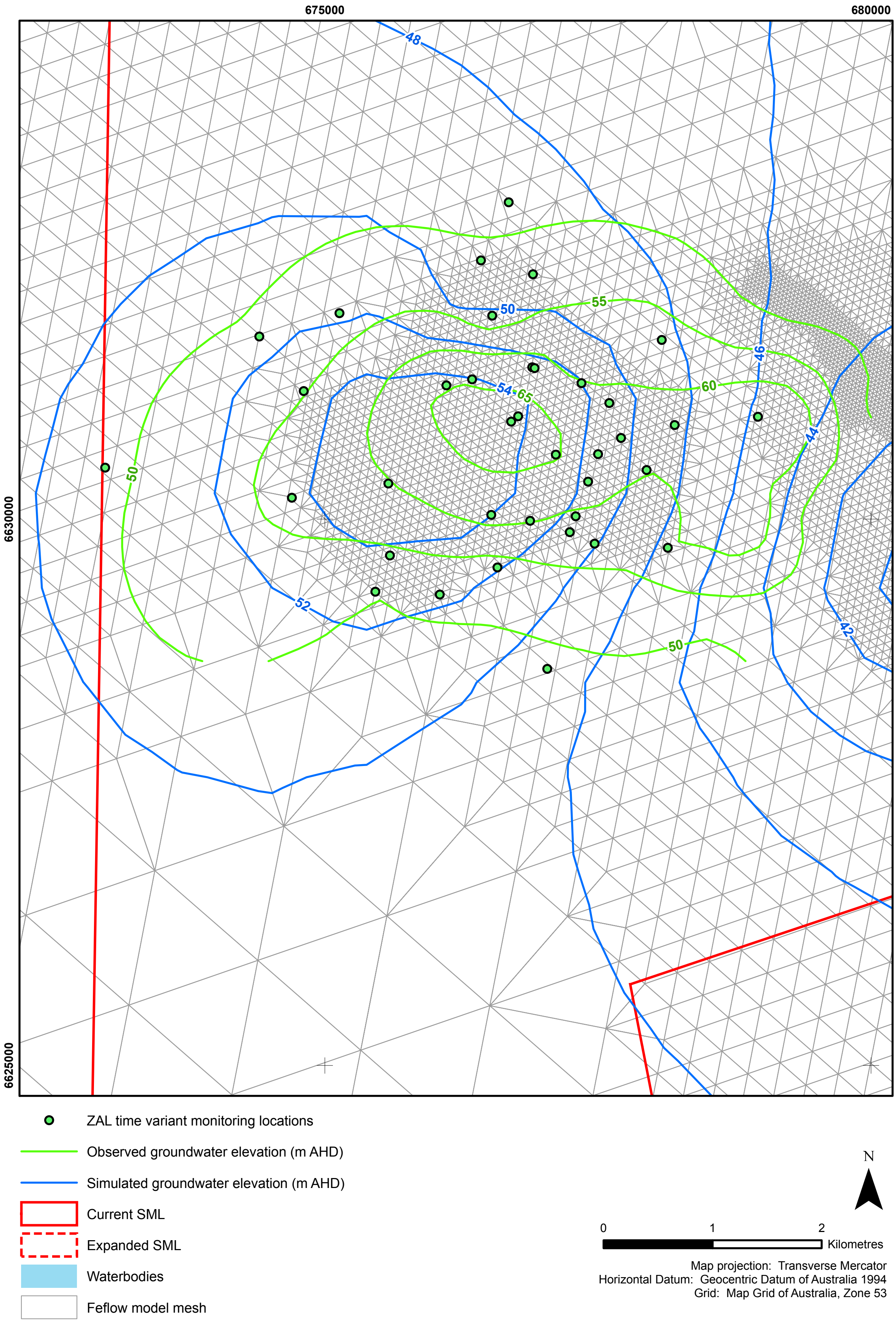
Figure 4.34 Observed and simulated groundwater elevations in the ZAL (2008)



Map projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 53

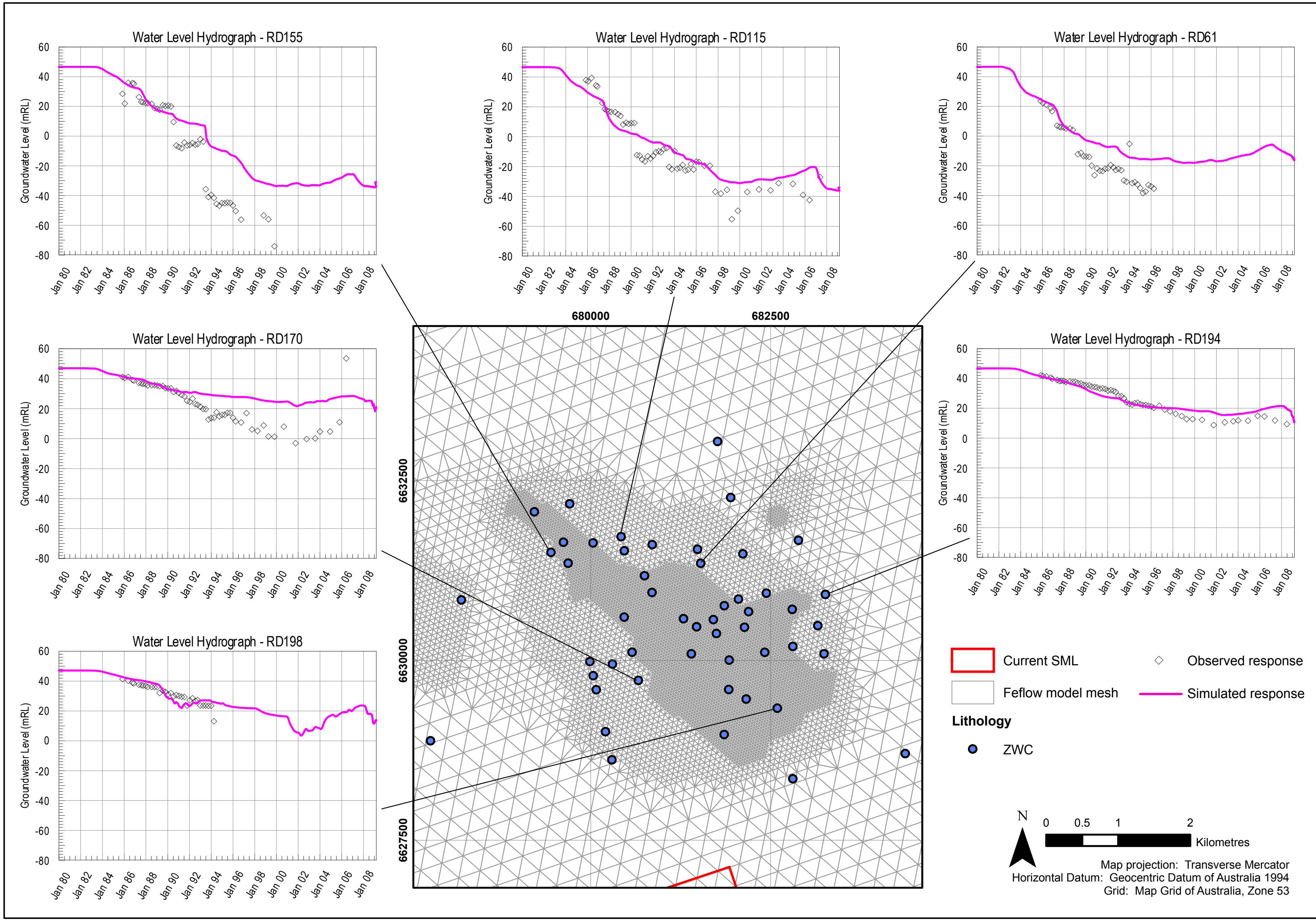


Figure 4.35 Time variant observed and simulated responses at representative ZWC locations

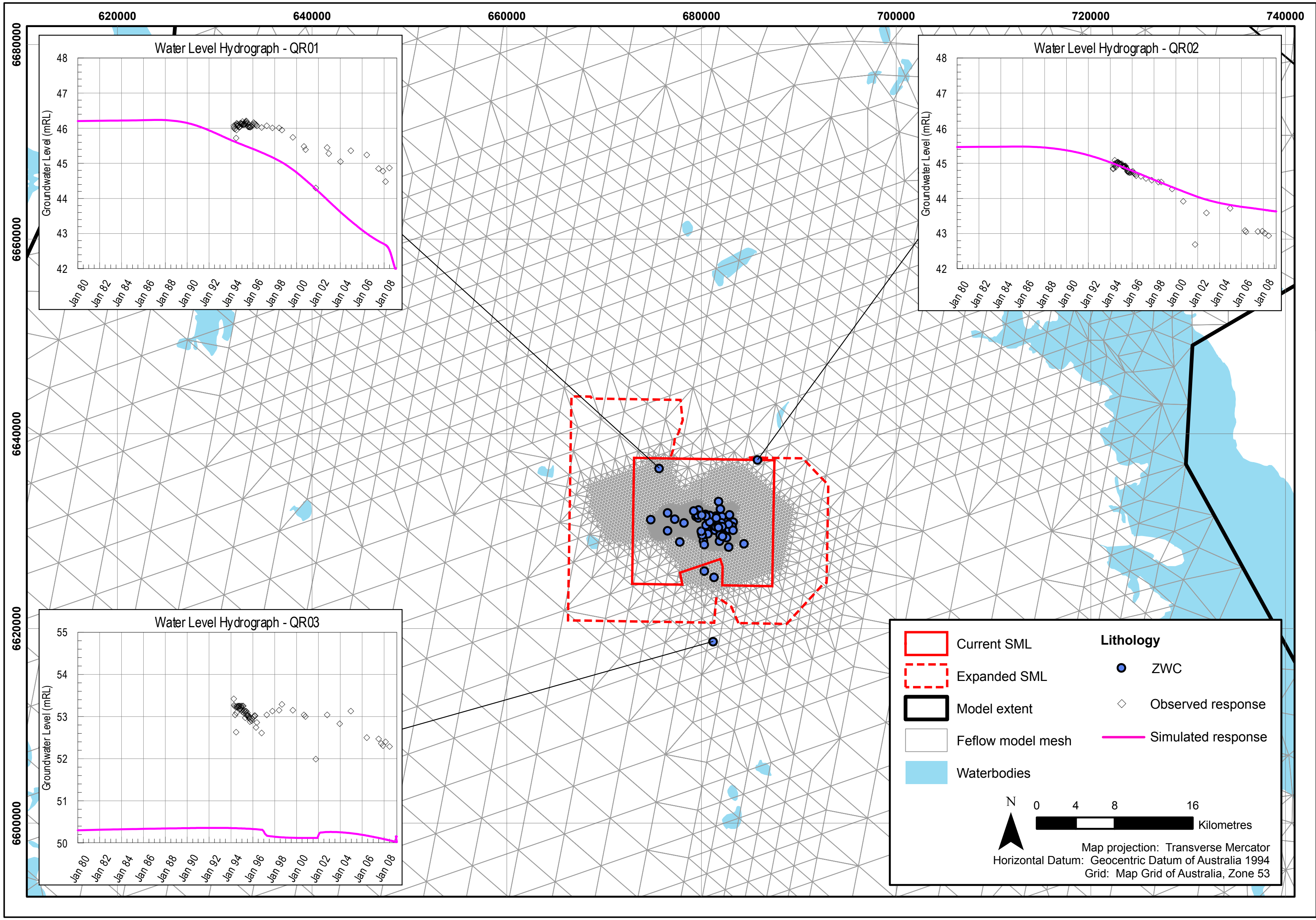


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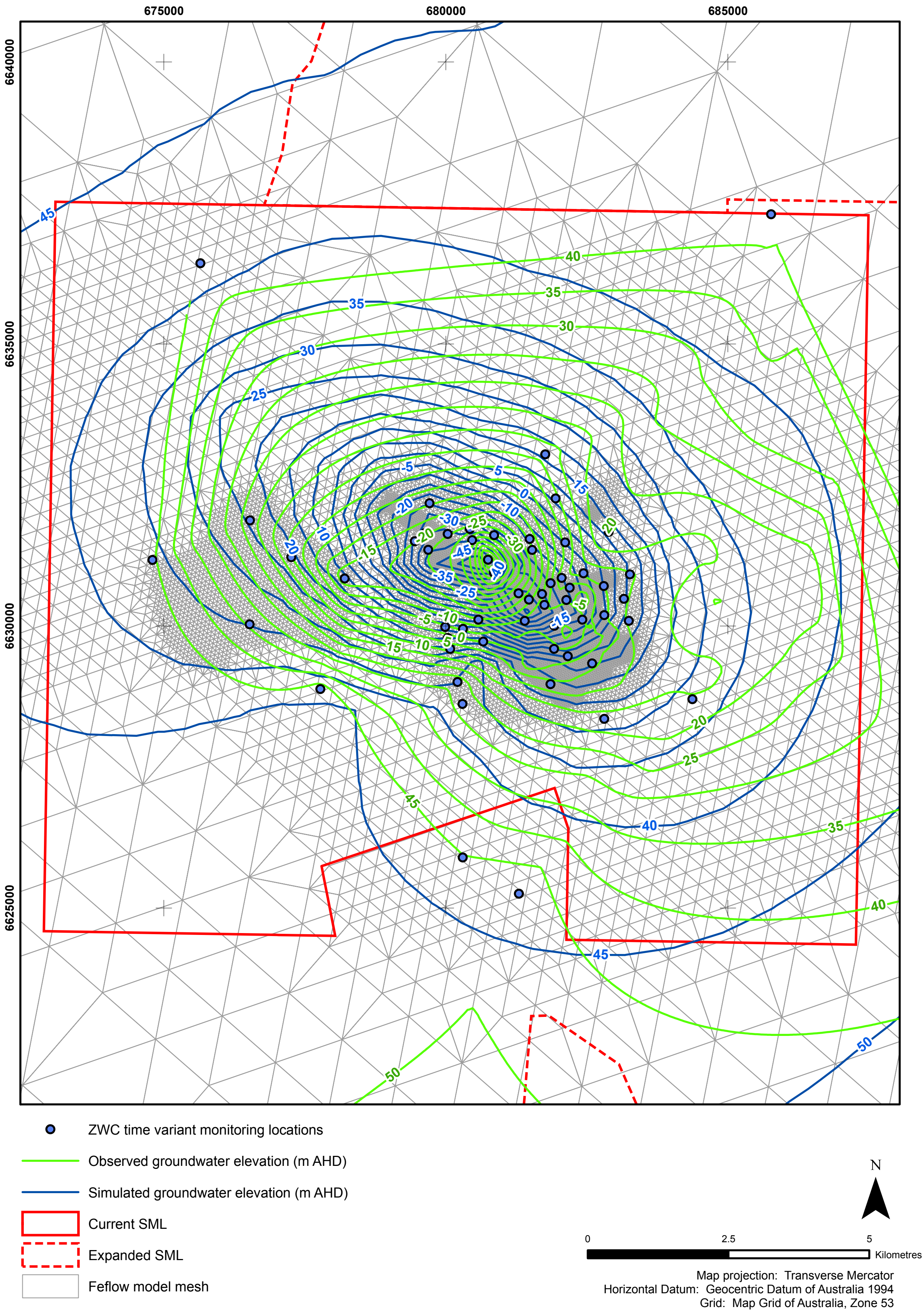
Figure 4.36 Time variant observed and simulated responses at representative "sub-regional" ZWC locations

Figure 4.37 Observed and simulated groundwater elevations in the ZWC (2008)



Map projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 53

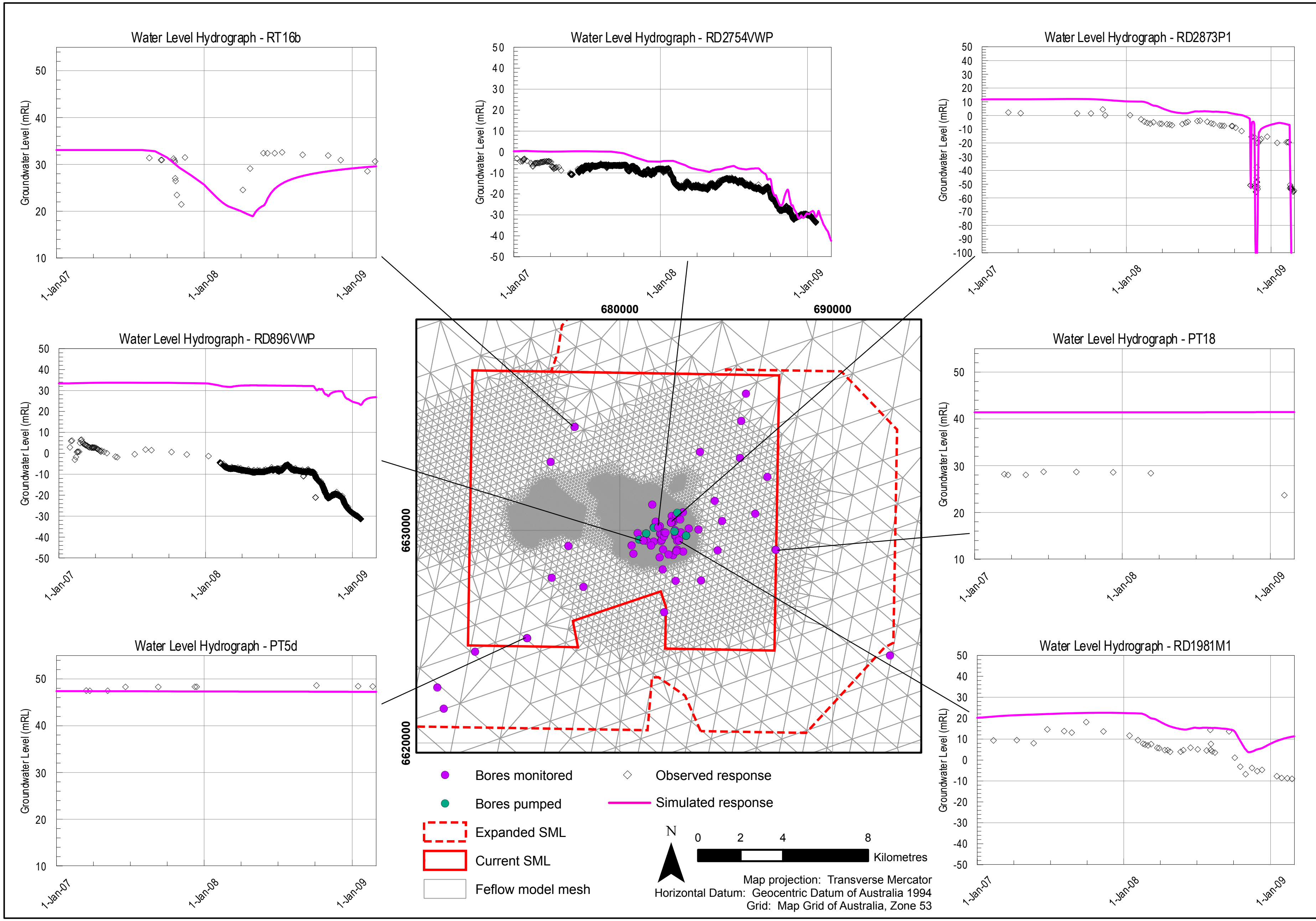


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Figure 4.38 Time variant observed and simulated responses at representative trial depressurisation (ZWC) locations

Figure 4.39 Calibrated steady state model mass balance

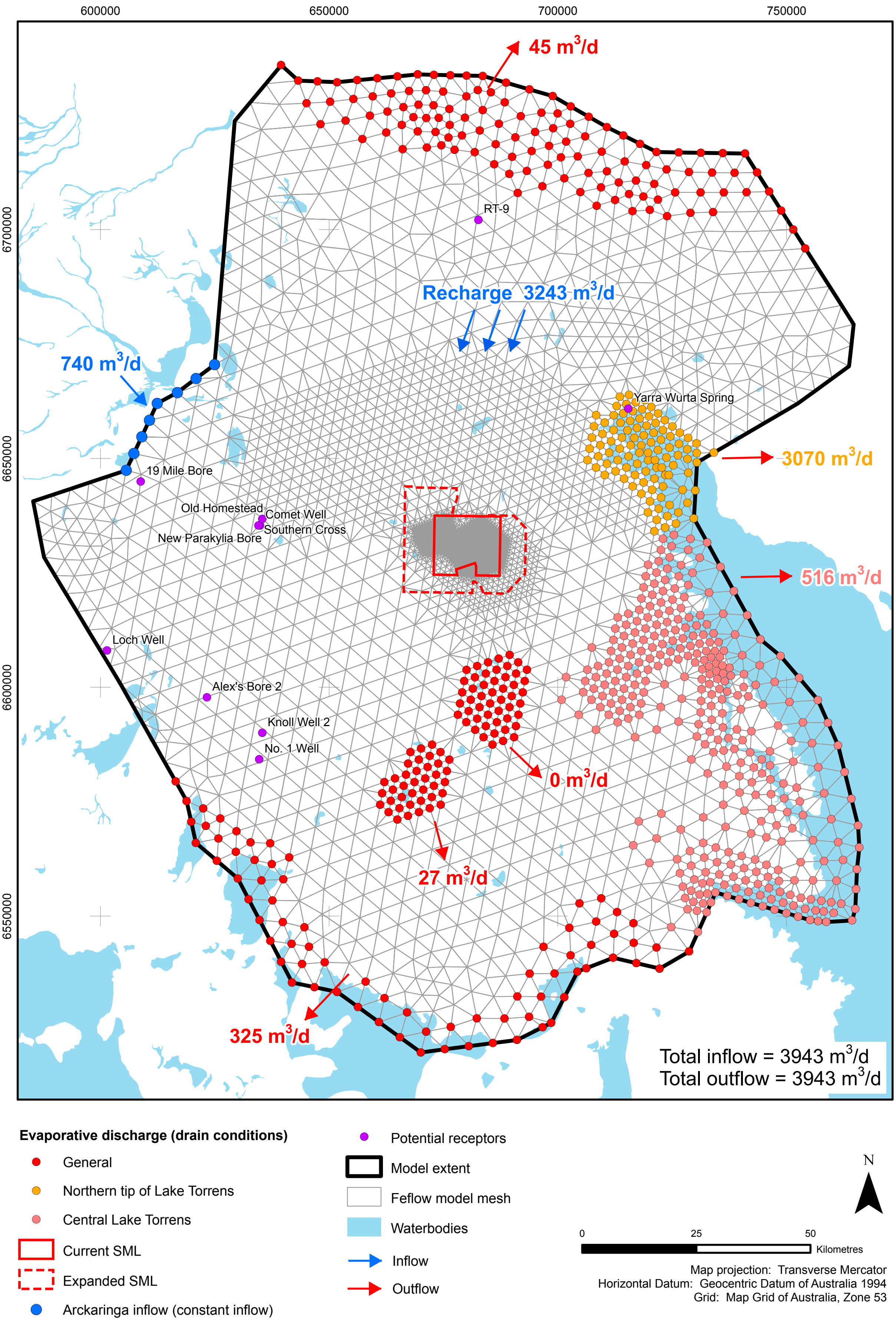

Figure 5.1 Predicted change in ZAL groundwater elevation (2017)

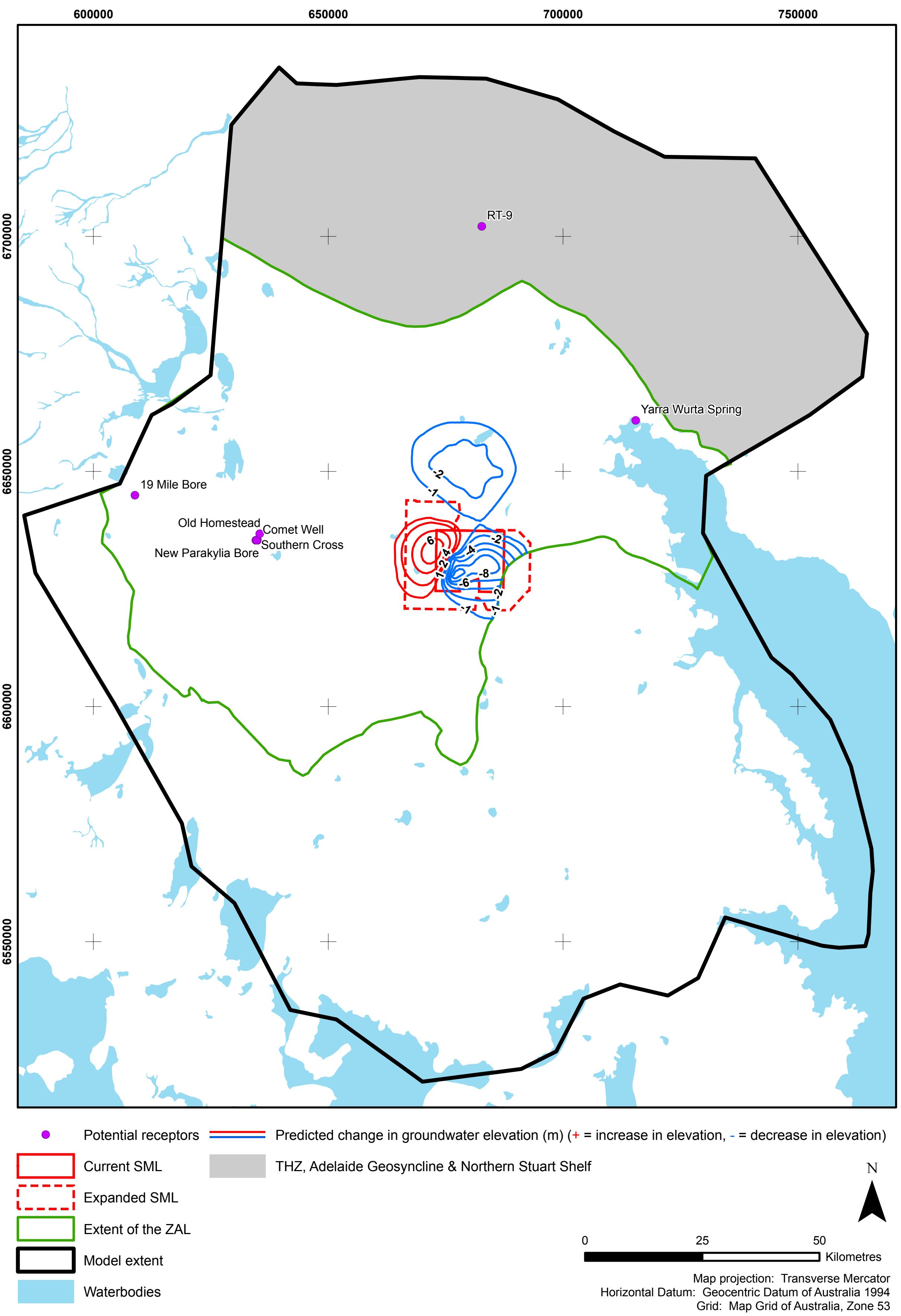

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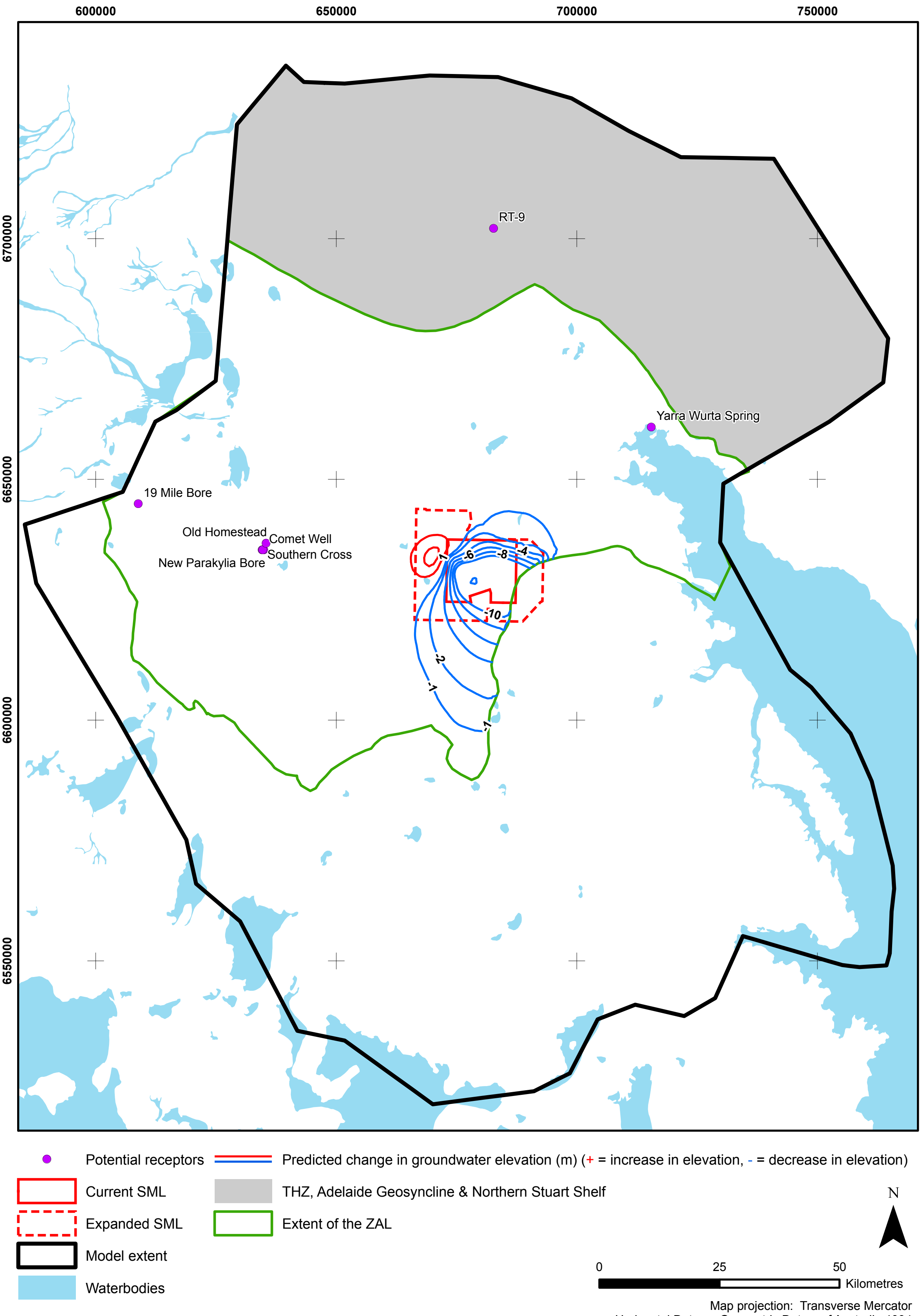
Figure 5.2 Predicted change in ZAL groundwater elevation (2050)



Map projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 53

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Figure 5.3 Predicted change in ZAL groundwater elevation (2150)

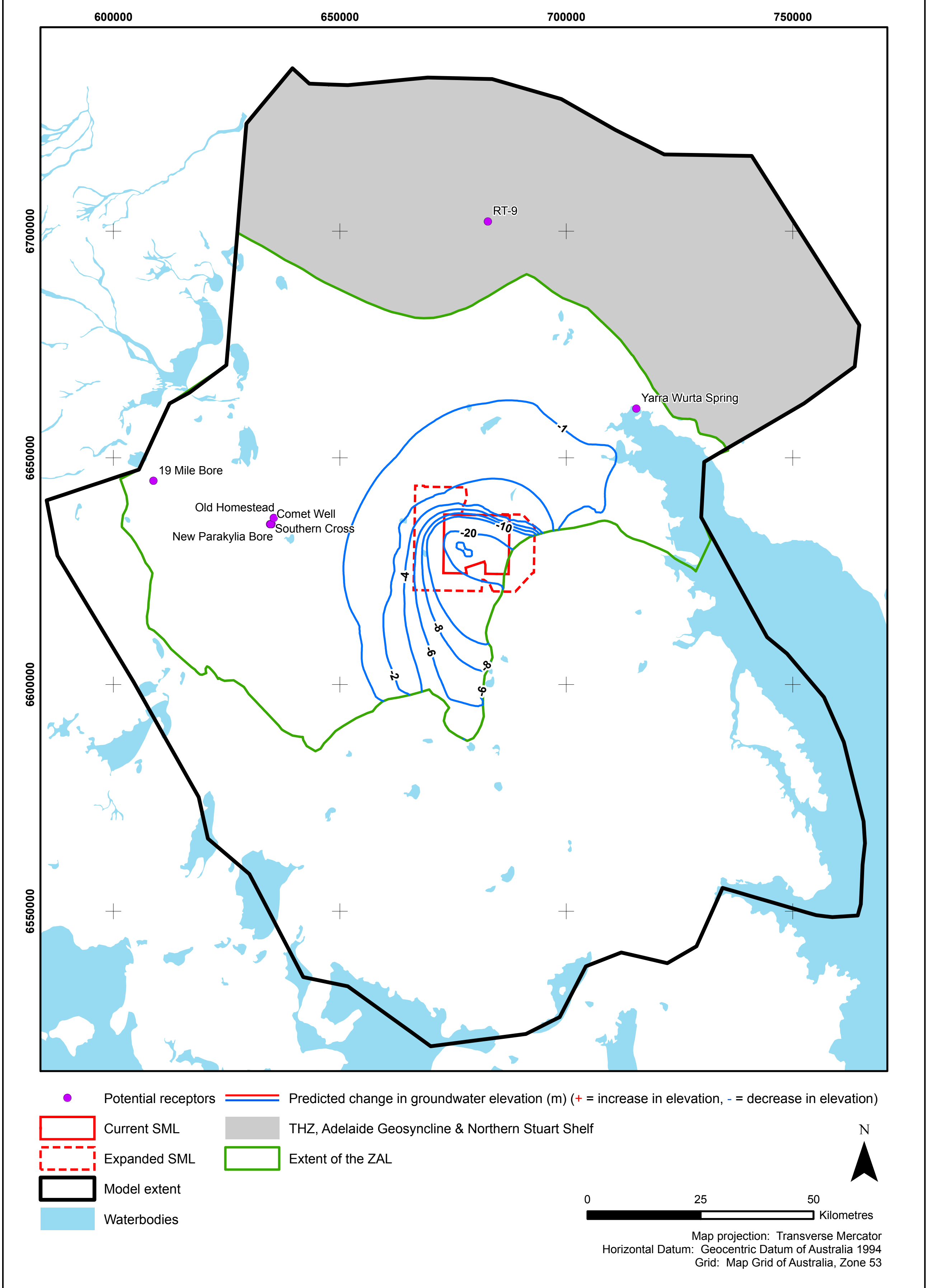

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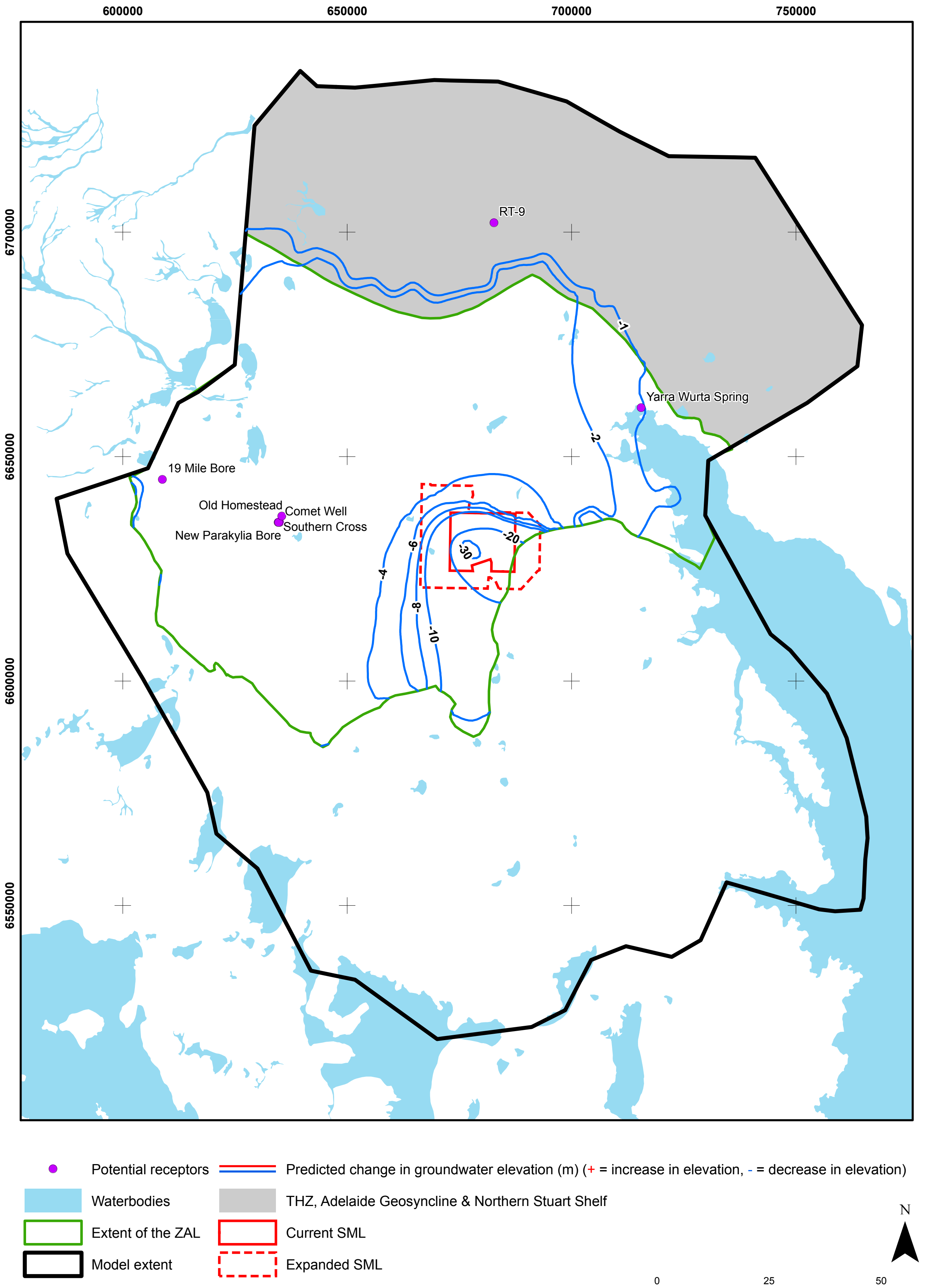
Figure 5.4 Predicted change in ZAL groundwater elevation (2550)



Map projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 53

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Figure 5.5 Predicted change in ZWC groundwater elevation (2017)

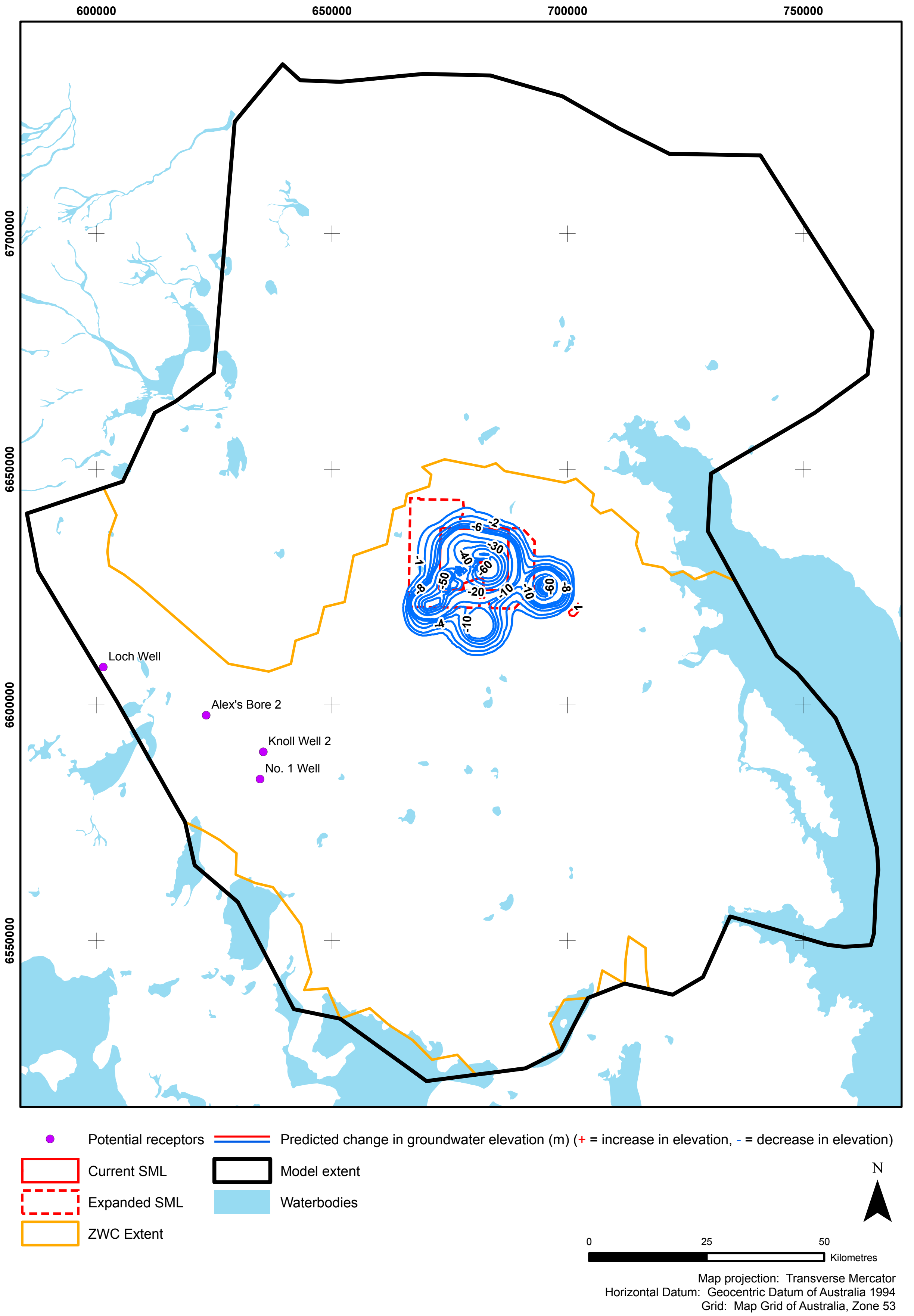

Figure 5.6 Predicted change in ZWC groundwater elevation (2050)

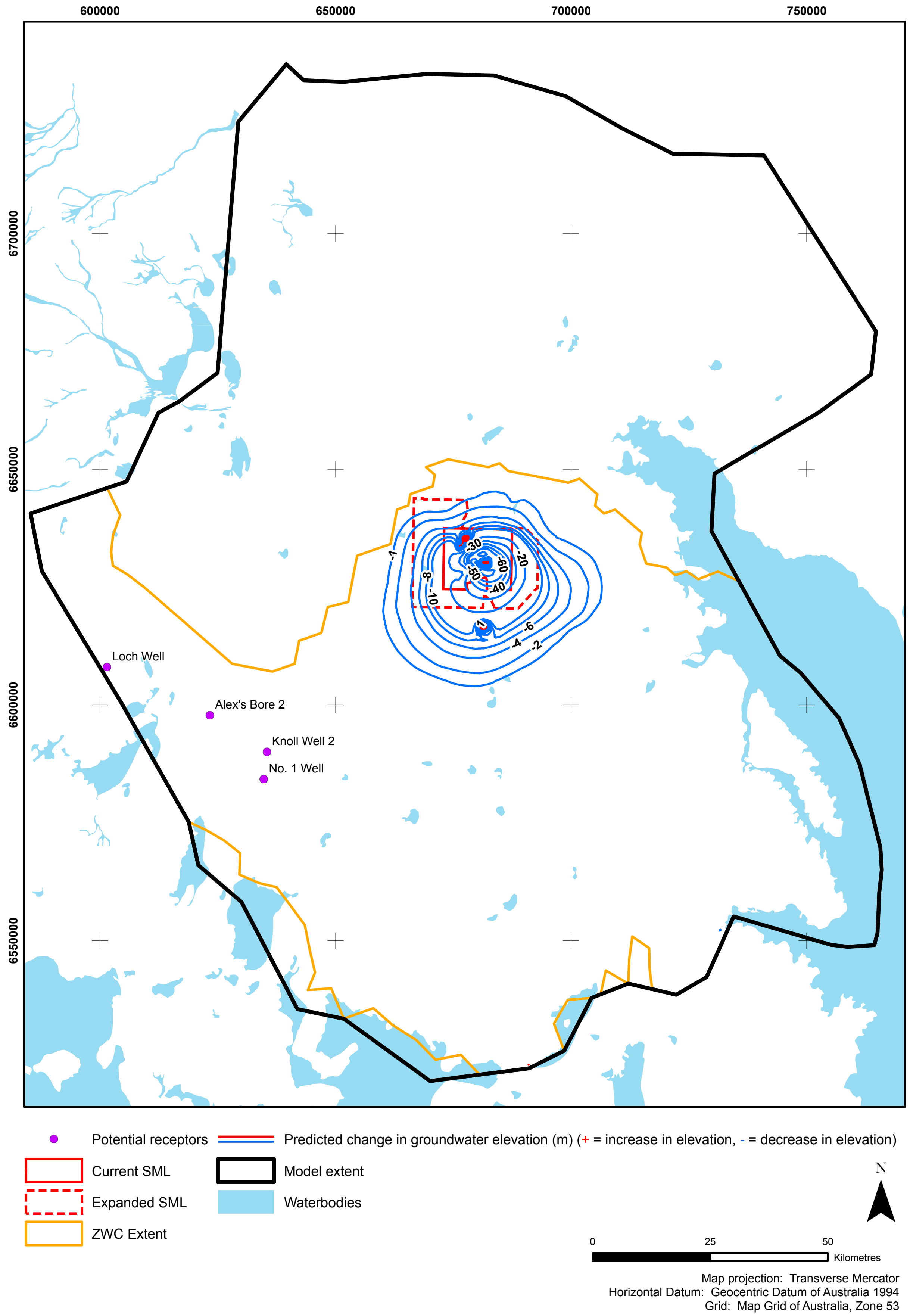

Figure 5.7 Predicted change in ZWC groundwater elevation (2150)

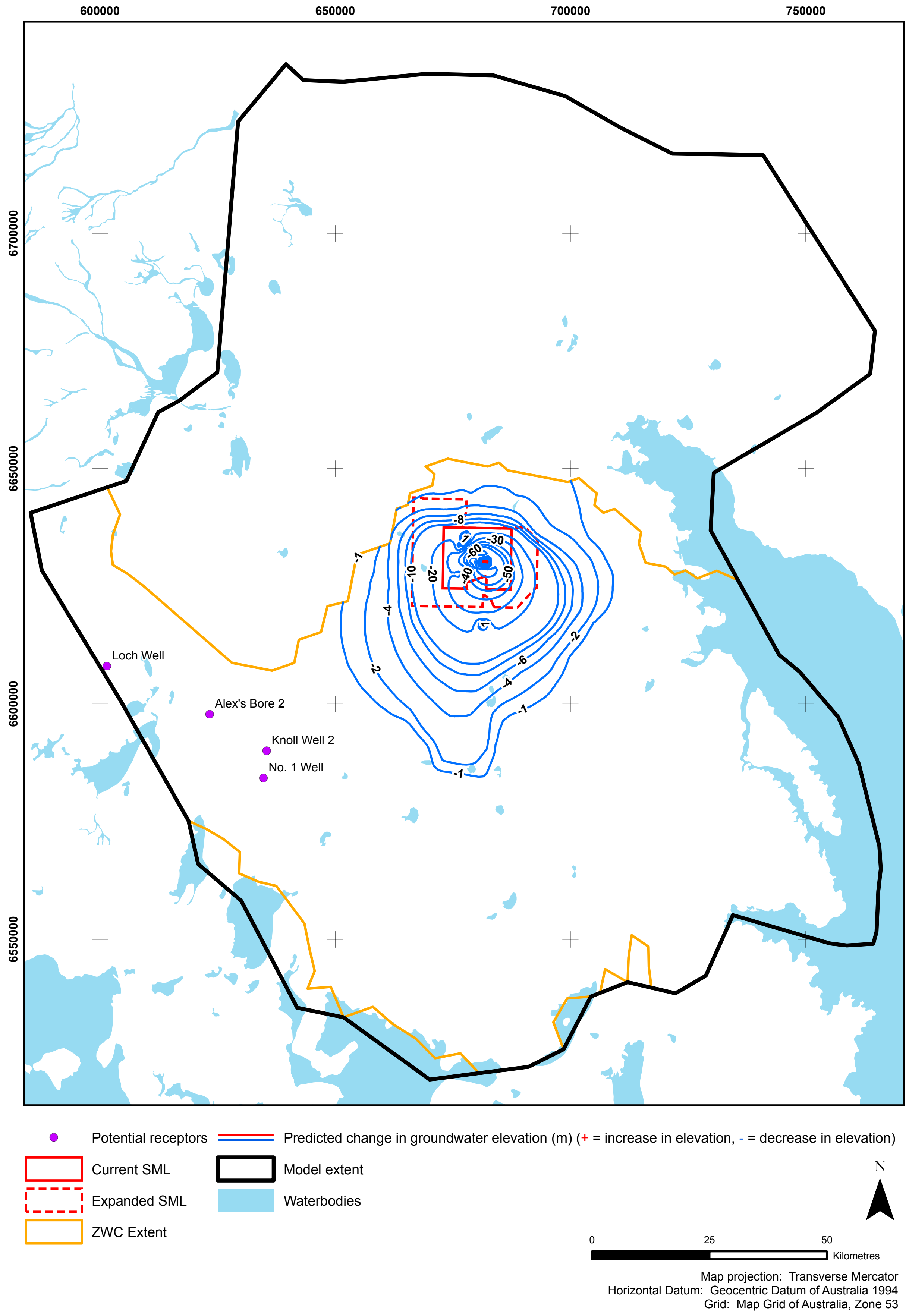

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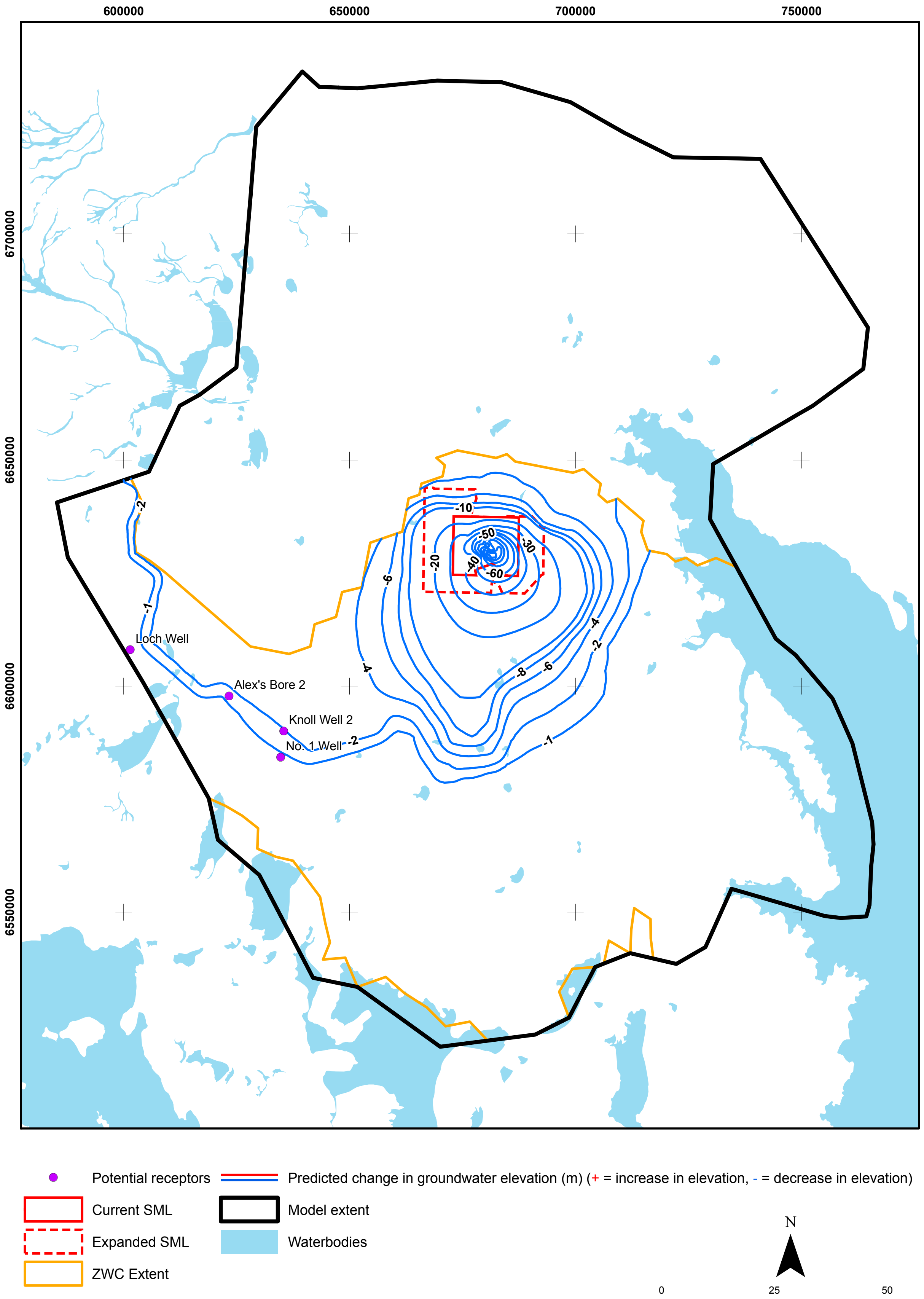
Figure 5.8 Predicted change in ZWC groundwater elevation (2550)



Map projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 53

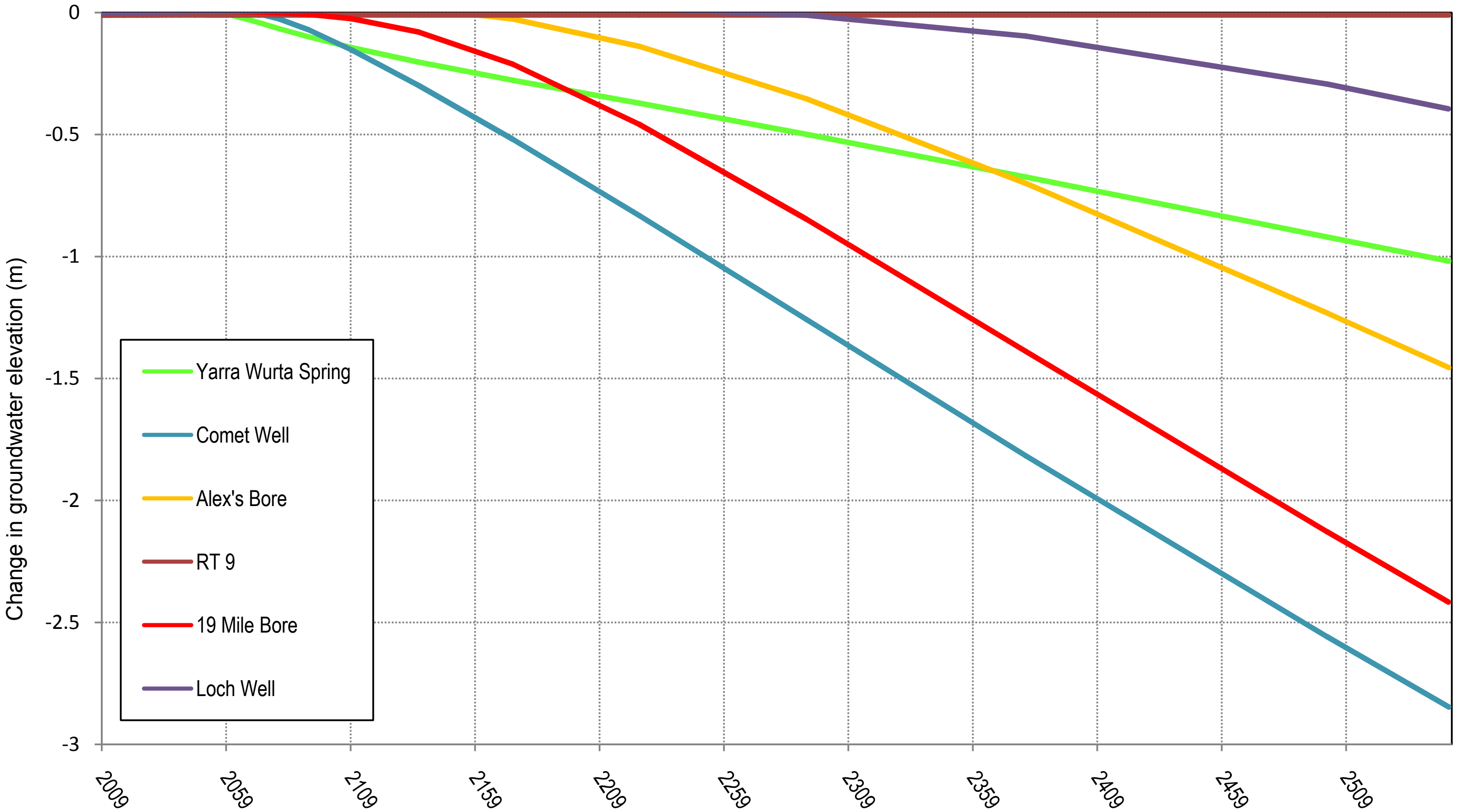


Figure 5.9 Predicted drawdown at potential receptors

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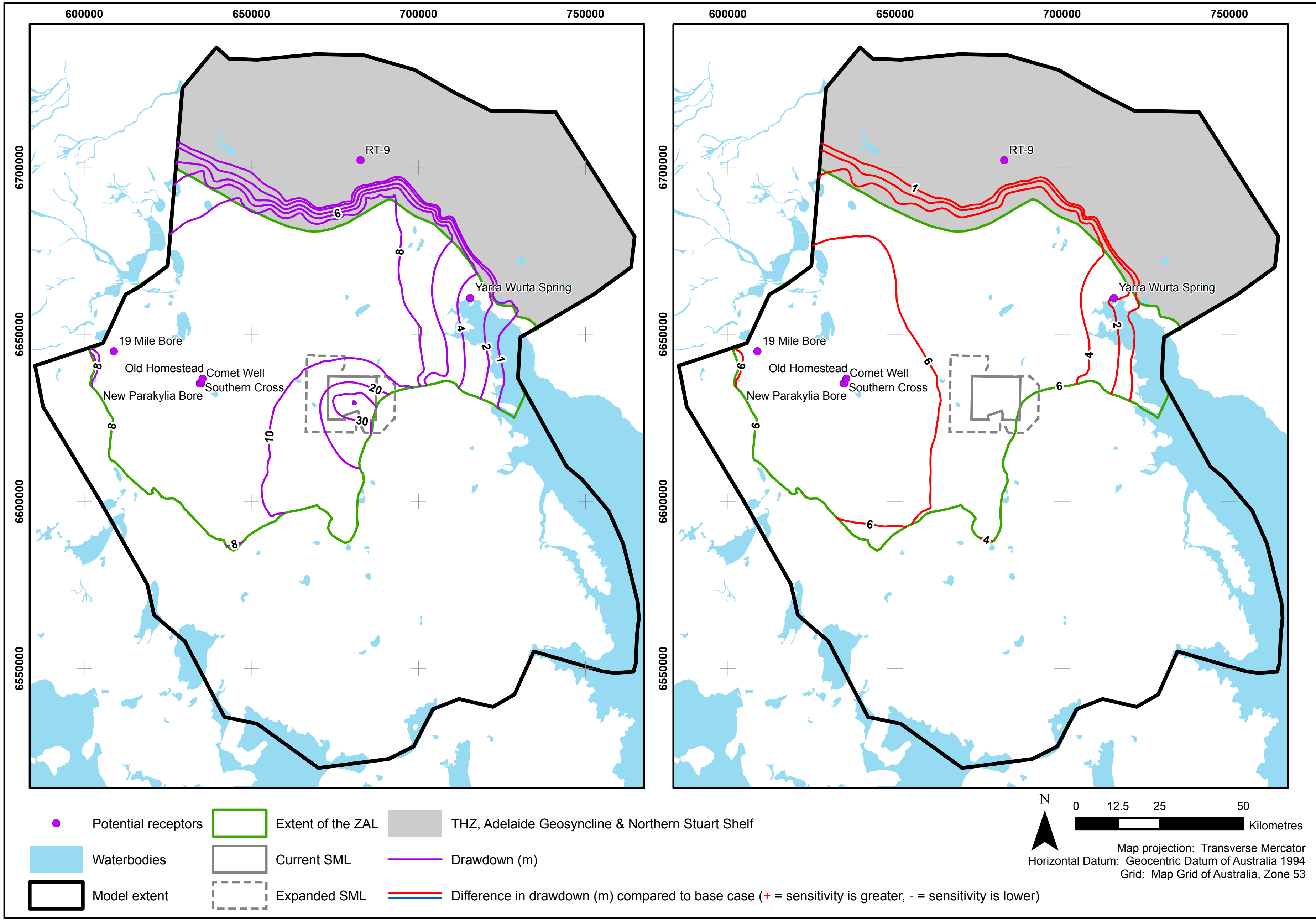
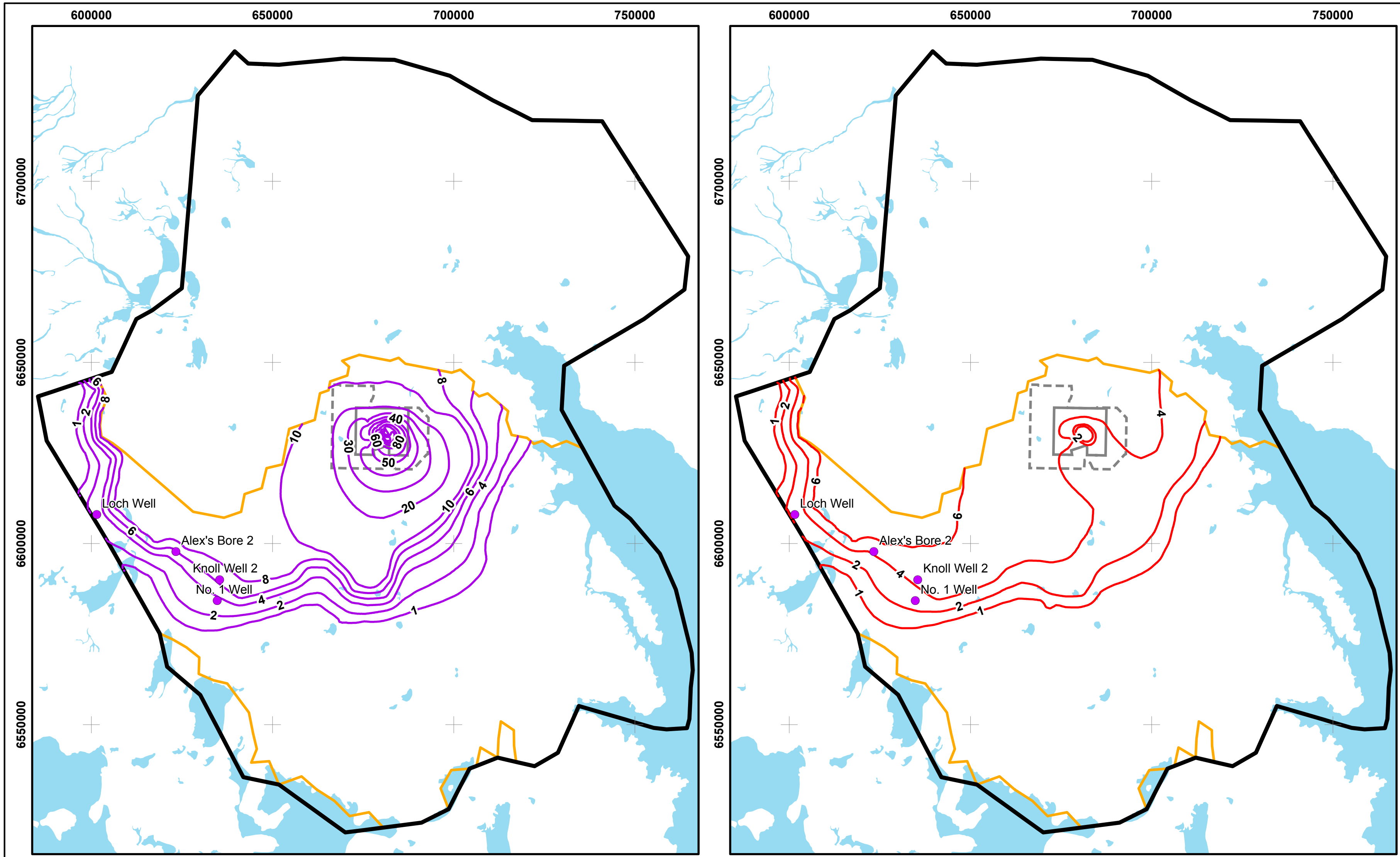


Figure 6.1 Predictions of ZAL drawdown (2550) in "Low ZAL specific storage" sensitivity (run II)



Potential receptors | Model extent | Current SML | Drawdown (m)

Waterbodies | ZWC Extent | Expanded SML | Difference in drawdown (m) compared to base case (+ = sensitivity is greater, - = sensitivity is lower)

N

0 12.5 25 50 Kilometres

Map projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 53

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Figure 6.2 Predictions of ZWC drawdown (2550) in "Low ZAL specific storage" sensitivity (run II)

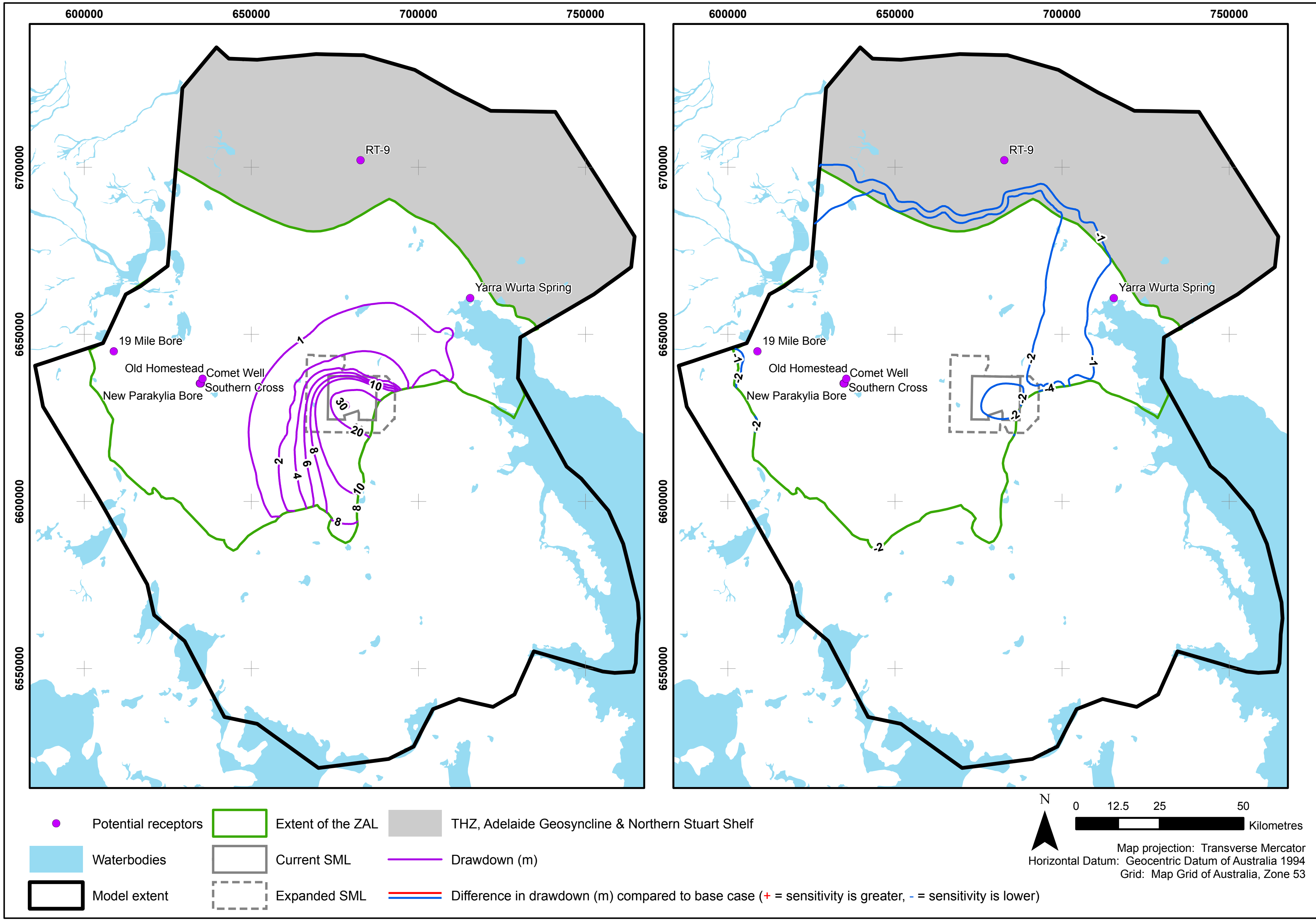

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Figure 6.3 Predictions of ZAL drawdown (2550) in "High ZAL specific storage" sensitivity (run III)

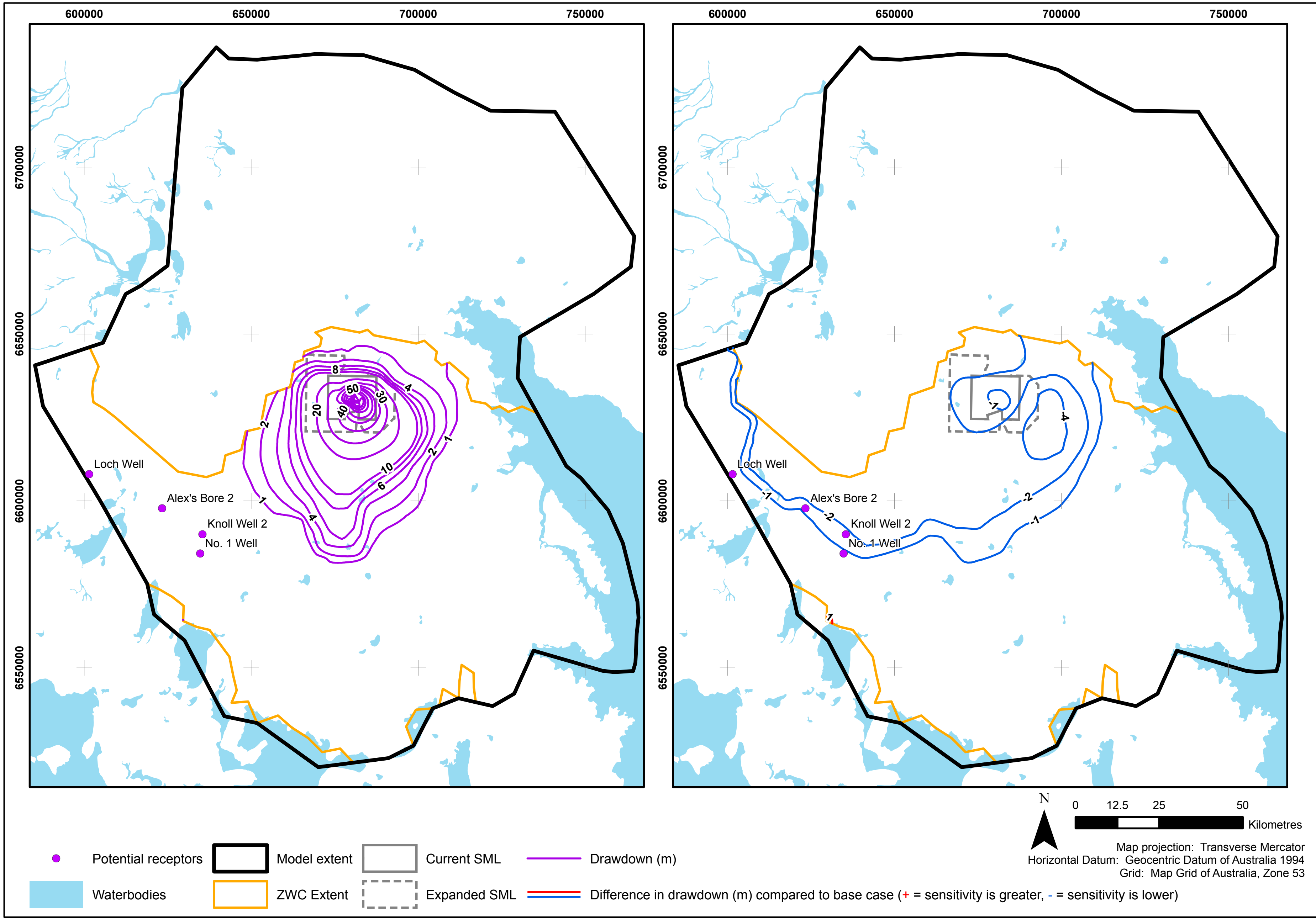

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Figure 6.4 Predictions of ZWC drawdown (2550) in "High ZAL specific storage" sensitivity (run III)

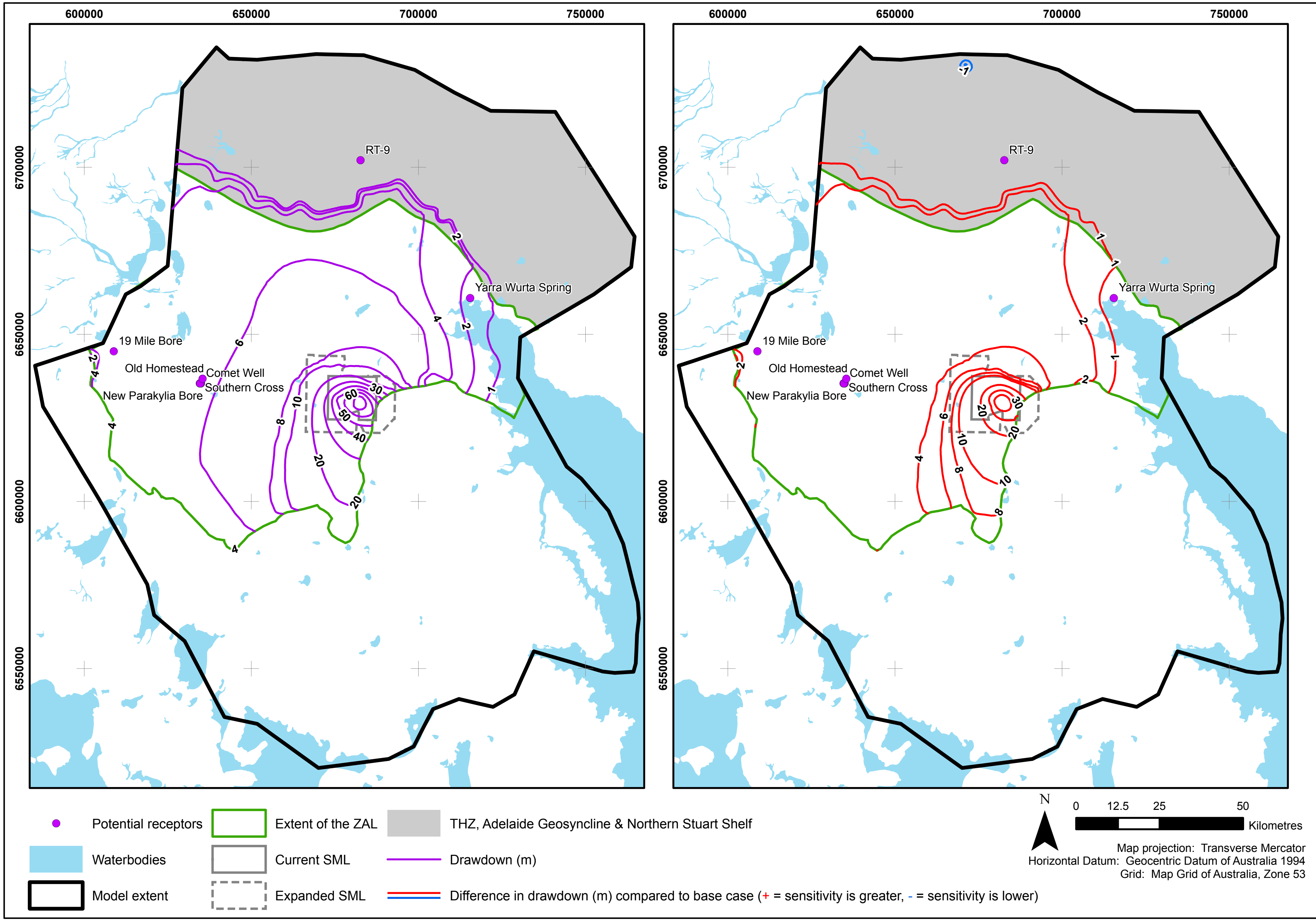

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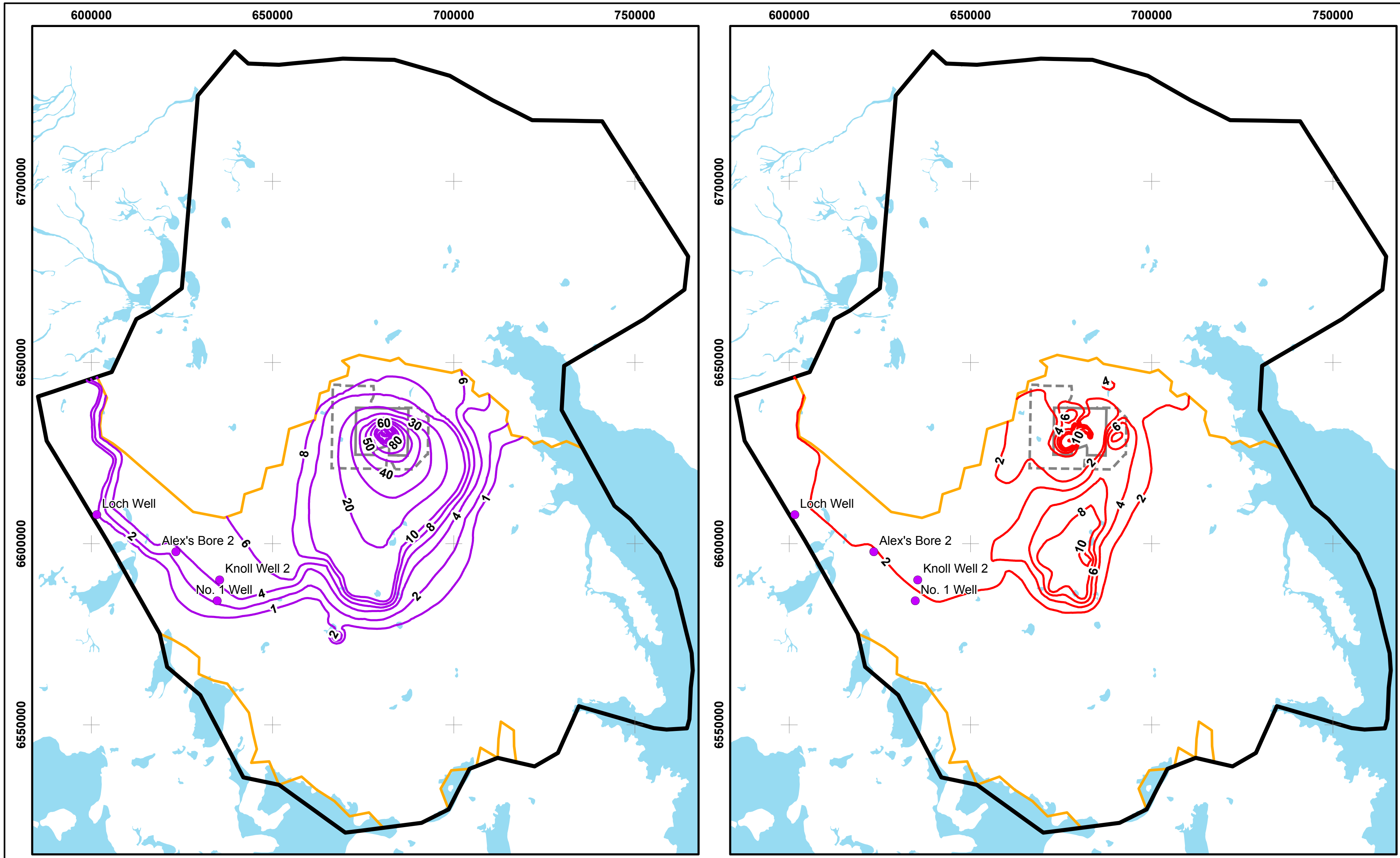
Figure 6.5 Predictions of ZAL drawdown (2550) in "High ZWA Kv" sensitivity (run IV)



Potential receptors
Waterbodies
Model extent
ZWC Extent
Current SML
Expanded SML
Drawdown (m)
Difference in drawdown (m) compared to base case (+ = sensitivity is greater, - = sensitivity is lower)

Map projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 53

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Figure 6.6 Predictions of ZWC drawdown (2550) in "High ZWA Kv" sensitivity (run IV)

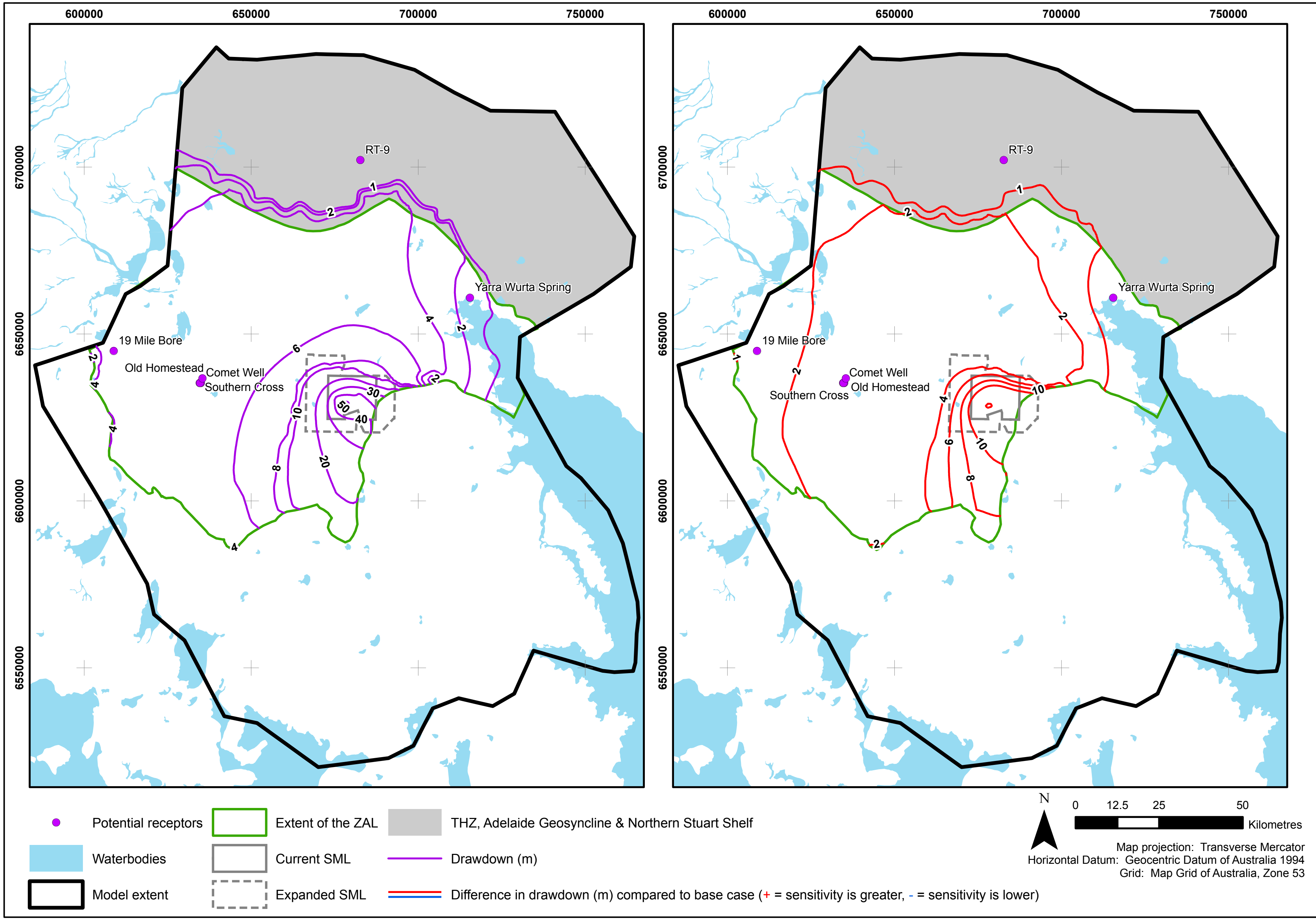

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Figure 6.7 Predictions of ZAL drawdown (2550) in "High ZWC Kh and Kv" sensitivity (run V)

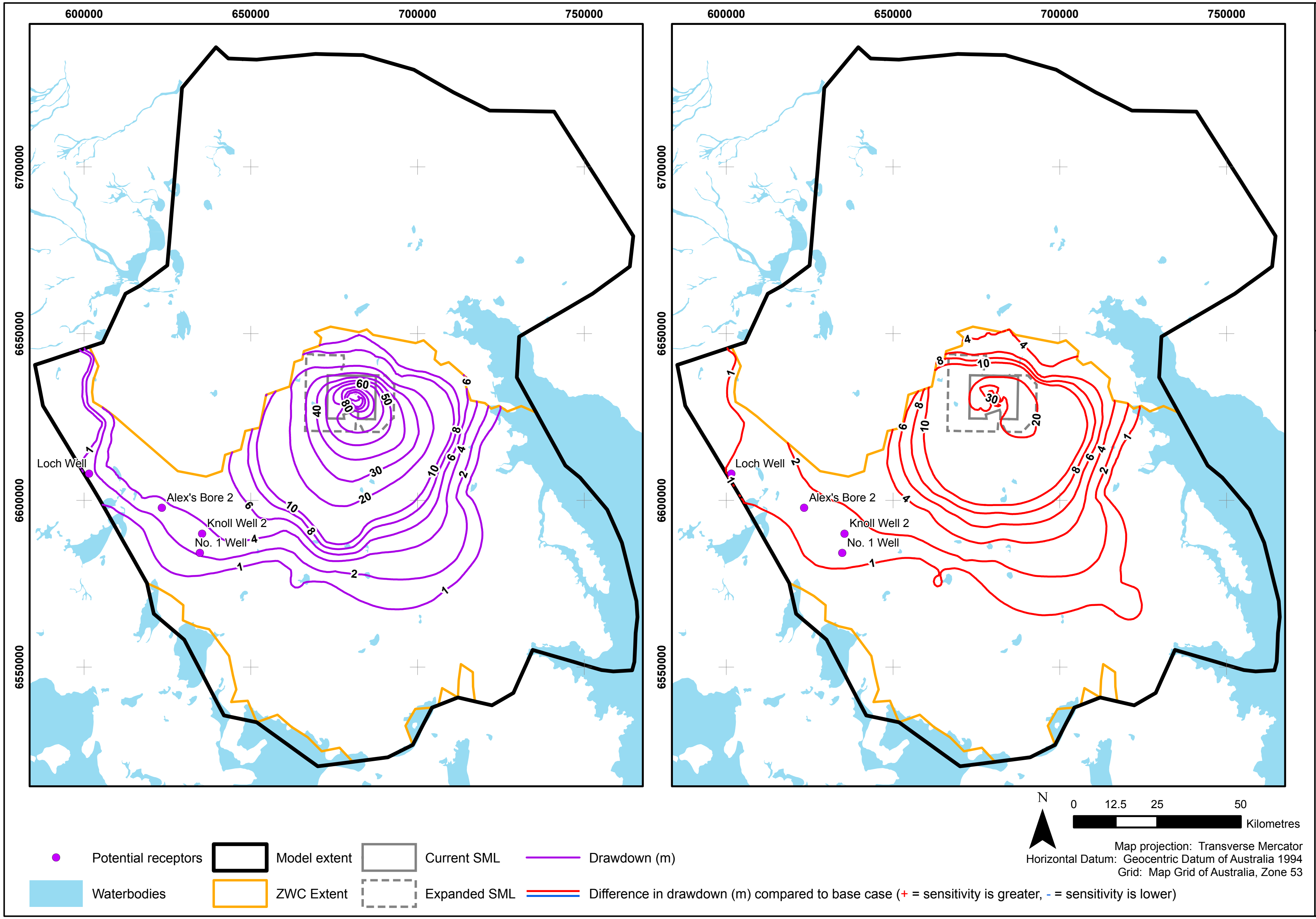

Figure 6.8 Predictions of ZWC drawdown (2550) in "High ZWC Kh and Kv" sensitivity (run V)

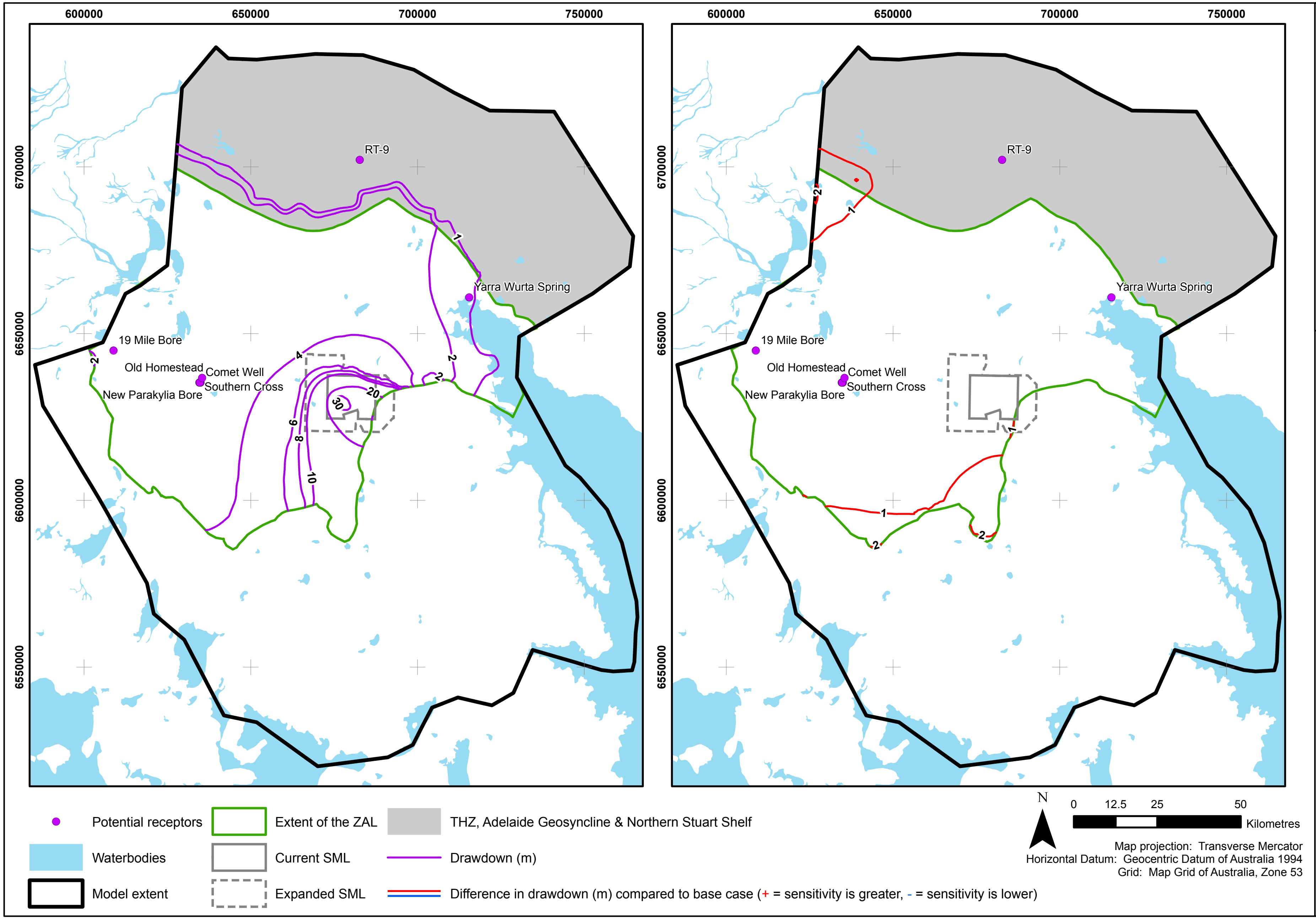

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Figure 6.9 Predictions of ZAL drawdown (2550) in "Reduced future recharge" sensitivity (run VI)

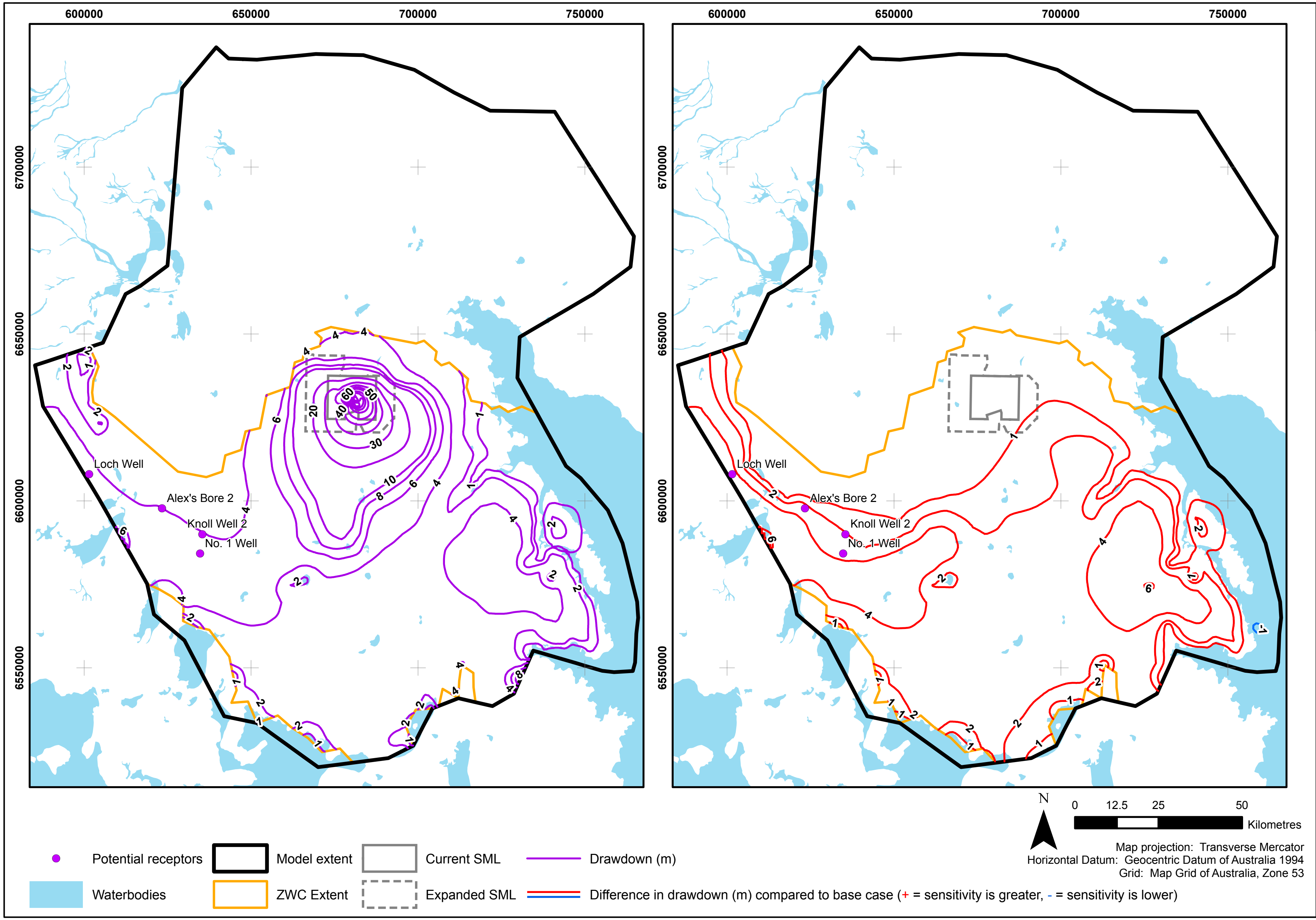

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Figure 6.10 Predictions of ZWC drawdown (2550) in "Reduced future recharge" sensitivity (run VI)

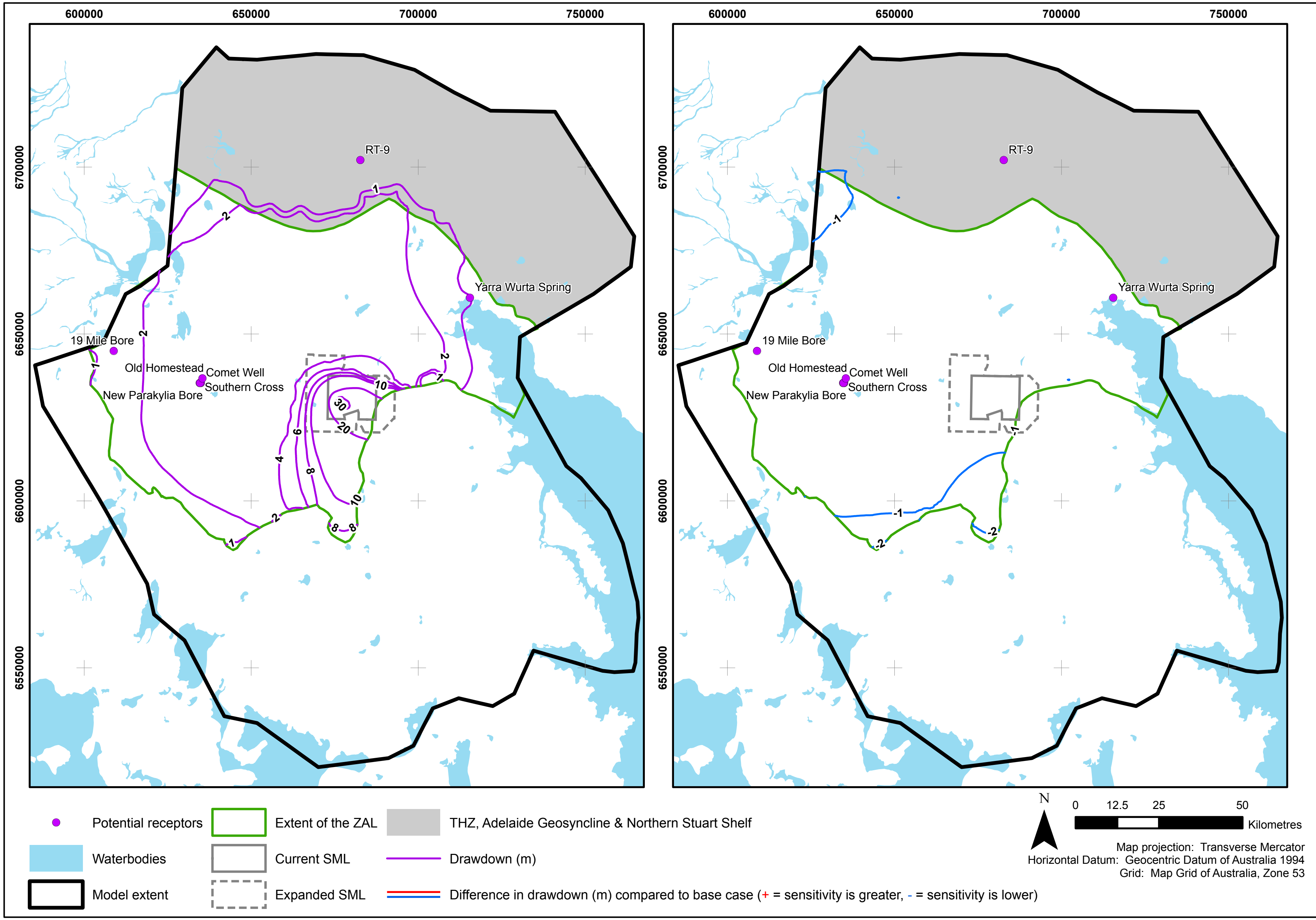

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Figure 6.11 Predictions of ZAL drawdown (2550) in "Increased future recharge" sensitivity (run VII)

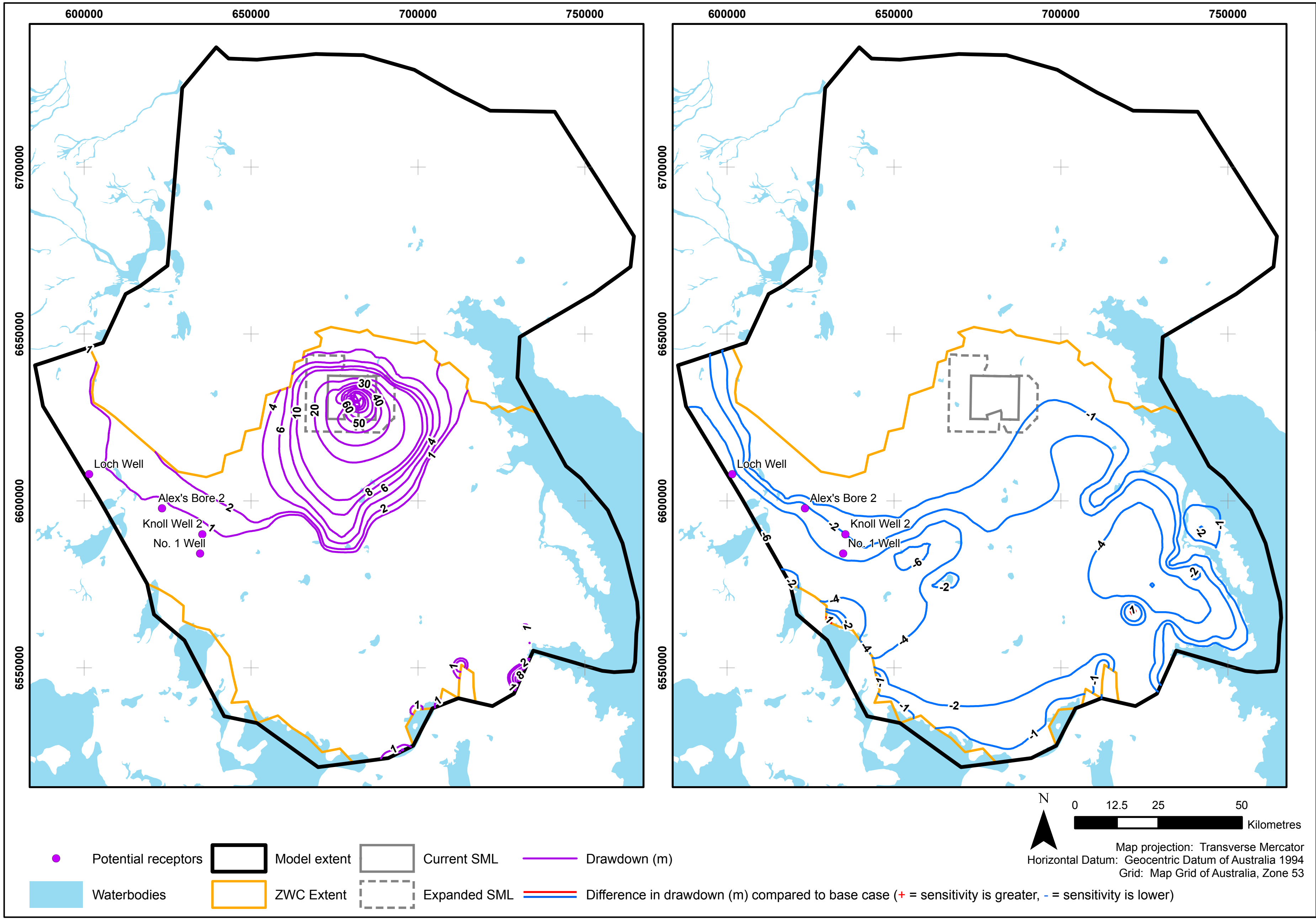

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Figure 6.12 Predictions of ZWC drawdown (2550) in "Increased future recharge" sensitivity (run VII)

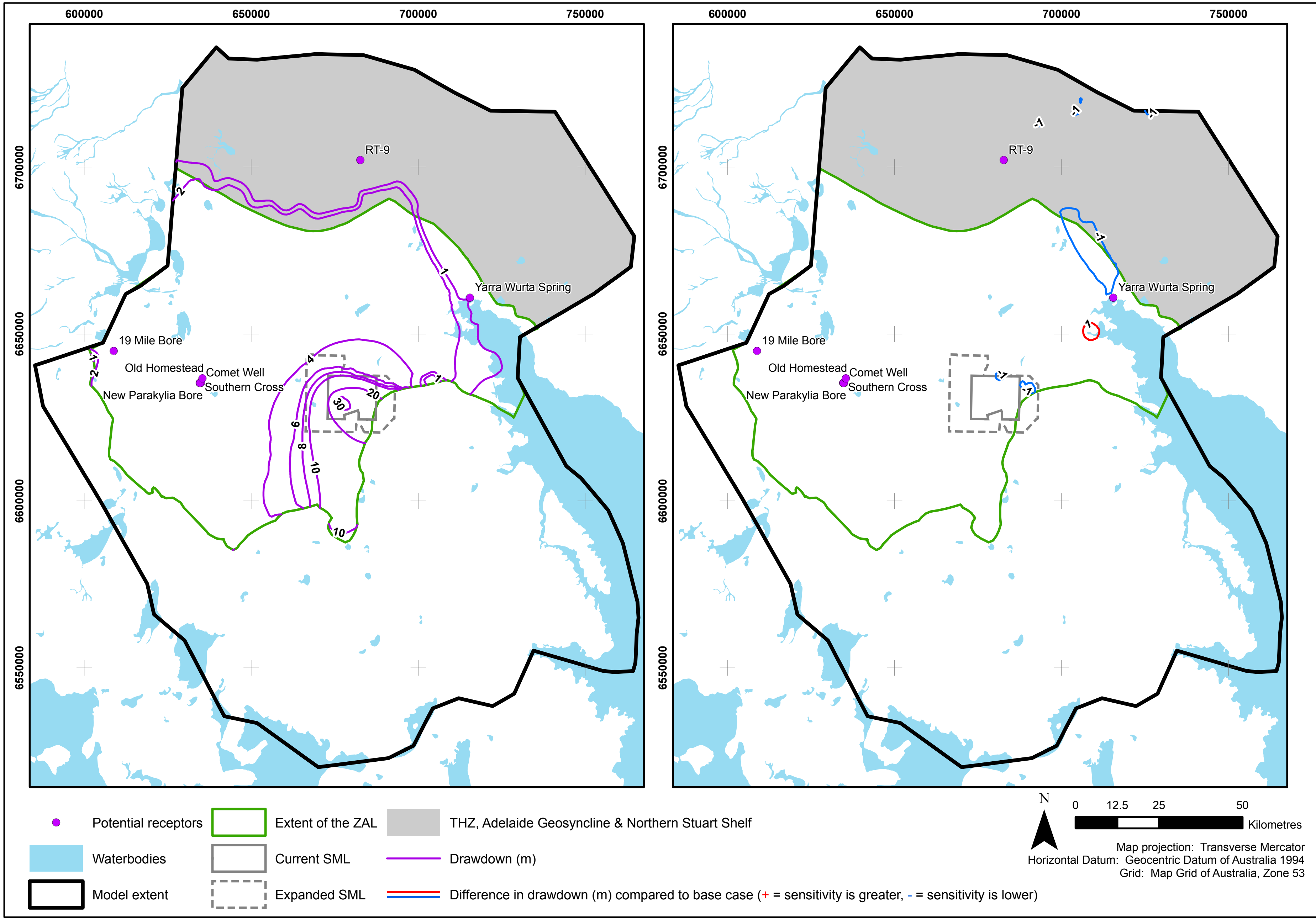

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Figure 6.13 Predictions of ZAL drawdown (2550) in "THZ and Adelaide Geosyncline high K" sensitivity (run VIII)

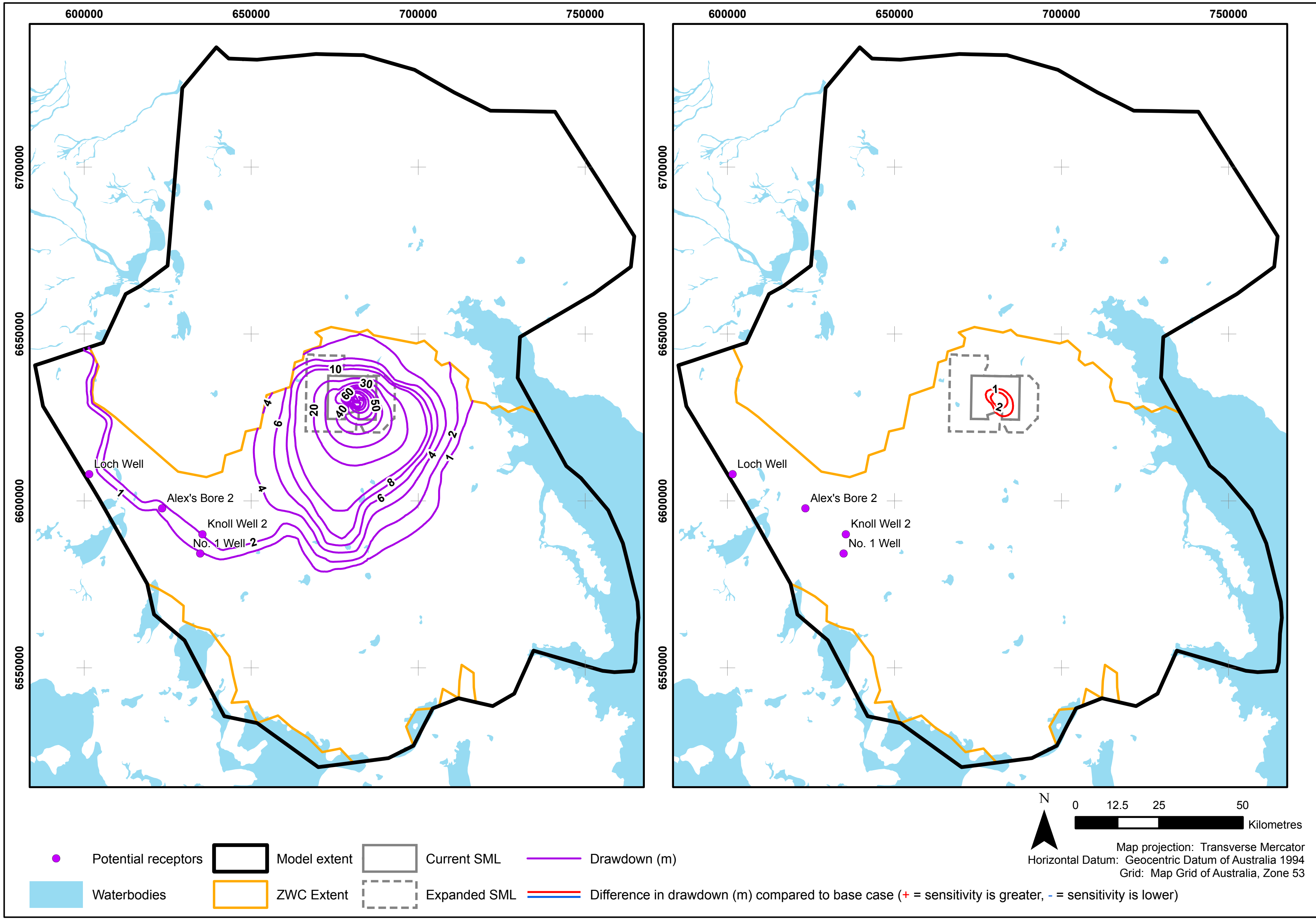

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Figure 6.14 Predictions of ZWC drawdown (2550) in "THZ and Adelaide Geosyncline high K" sensitivity (run VIII)

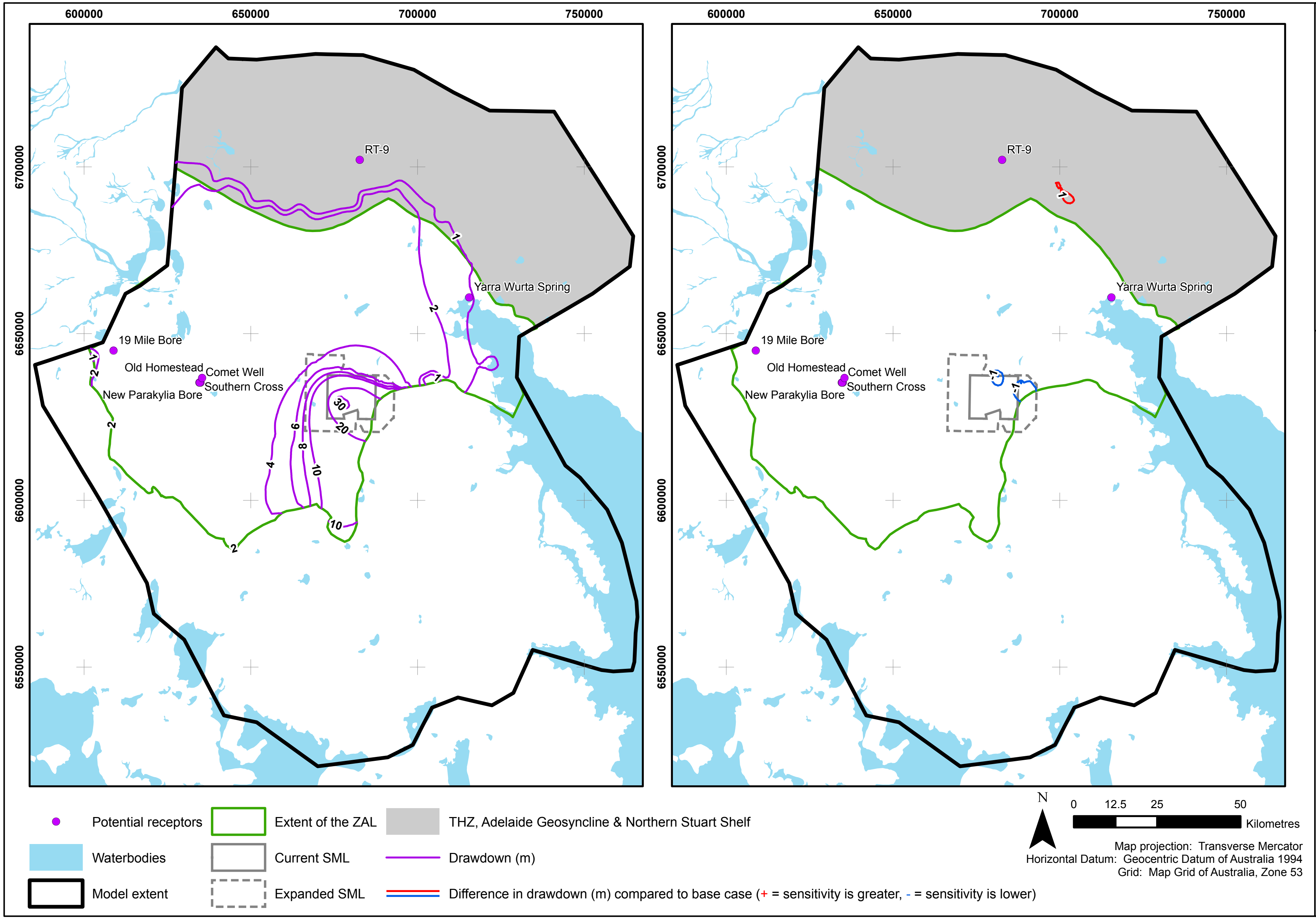

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Figure 6.15 Predictions of ZAL drawdown (2550) in "THZ / Adelaide Geosyncline high K band" sensitivity (run IX)

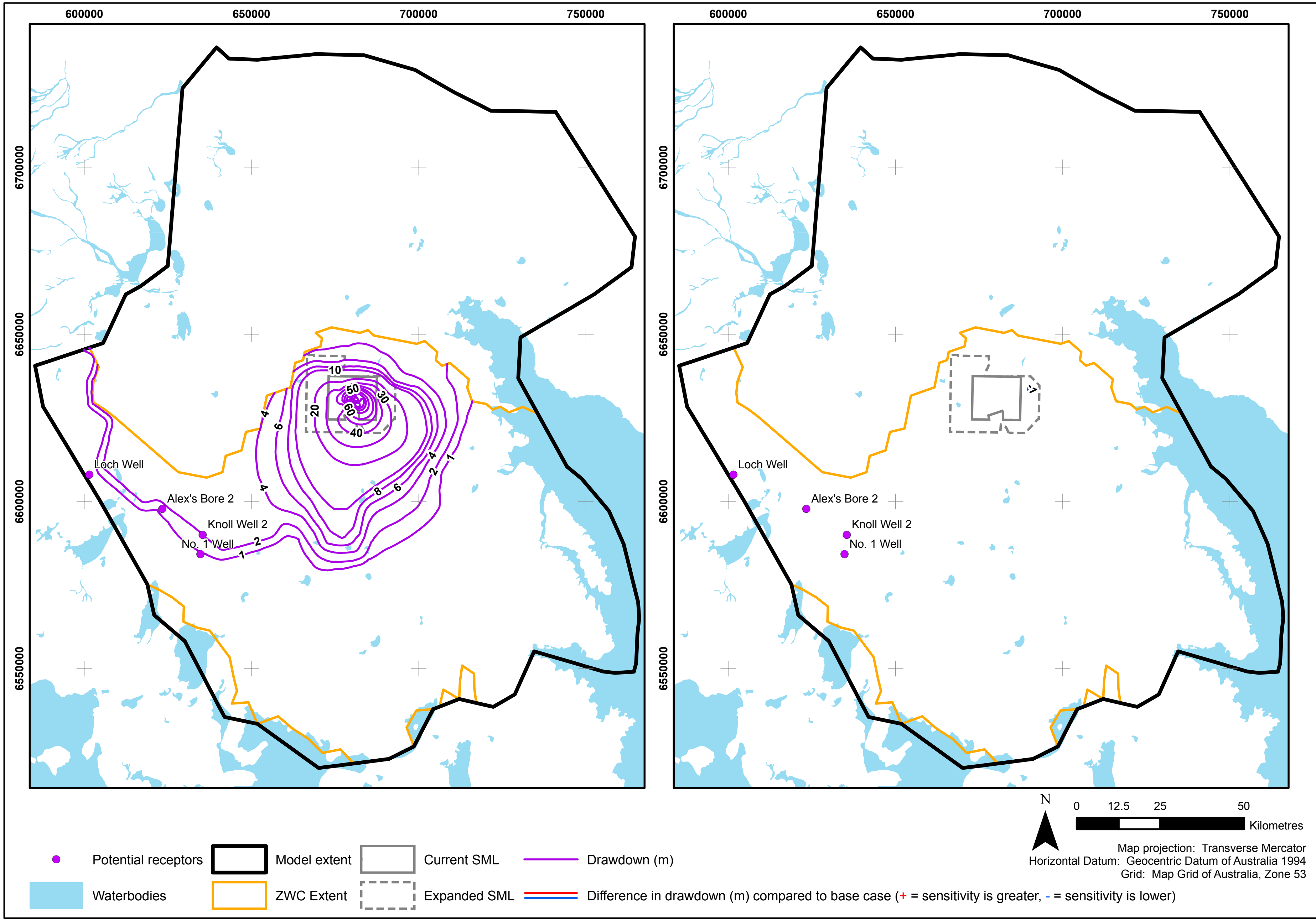

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Figure 6.16 Predictions of ZWC drawdown (2550) in "THZ / Adelaide Geosyncline high K band" sensitivity (run IX)

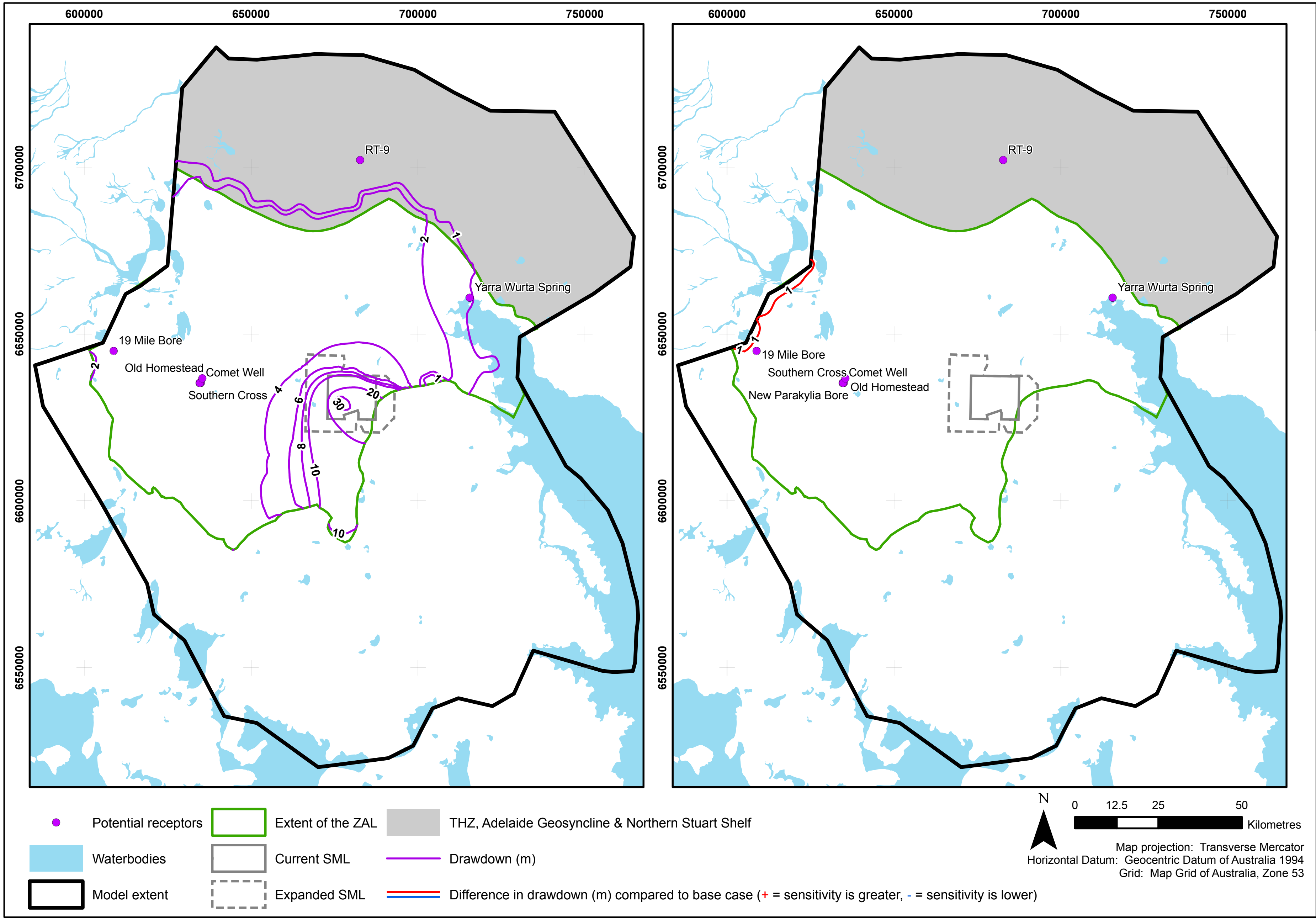

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Figure 6.17 Predictions of ZAL drawdown (2550) in "Declining inflow from Arckaringa Basin" sensitivity (run X)

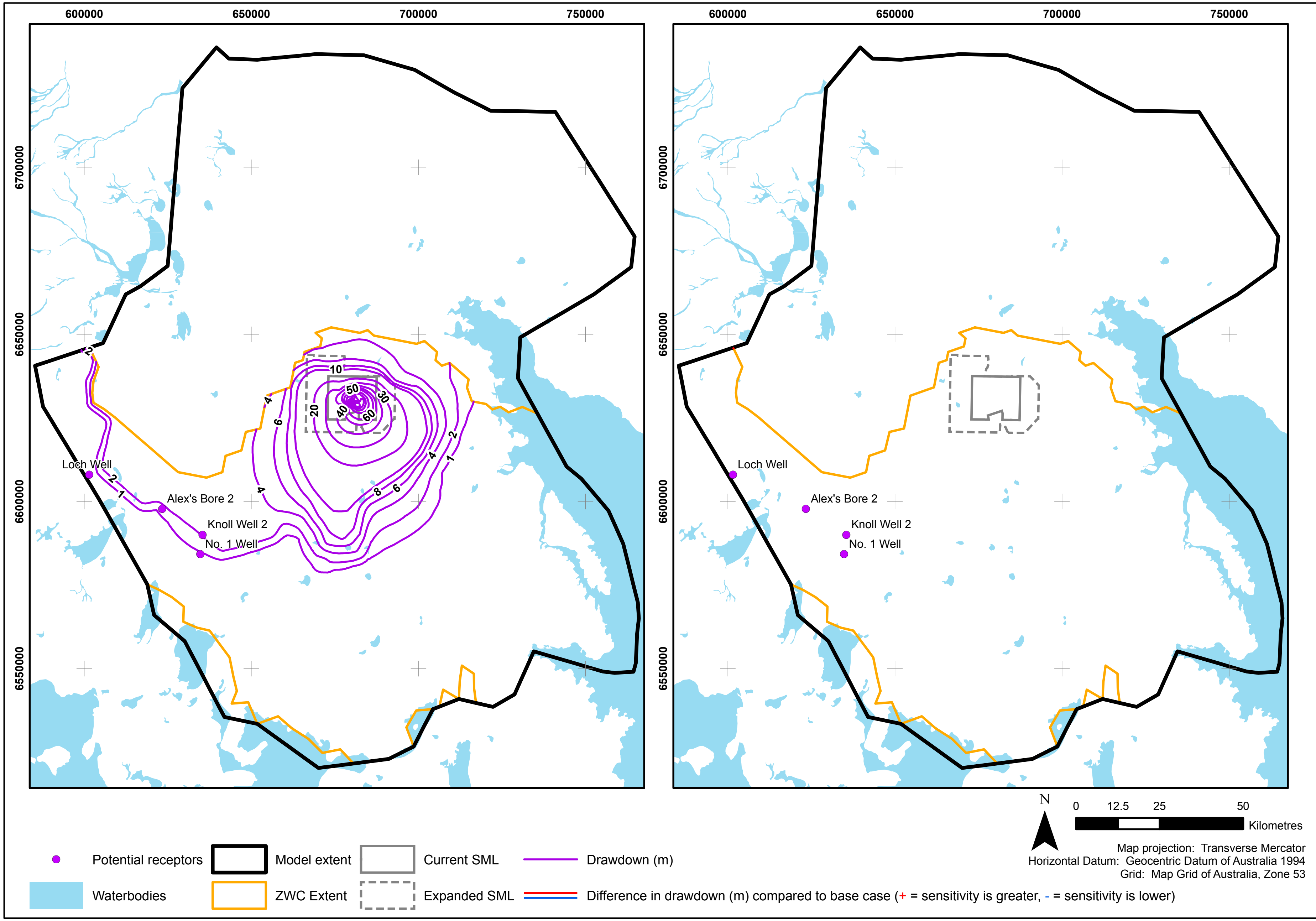

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Figure 6.18 Predictions of ZWC drawdown (2550) in "Declining inflow from Arckaringa Basin" sensitivity (run X)

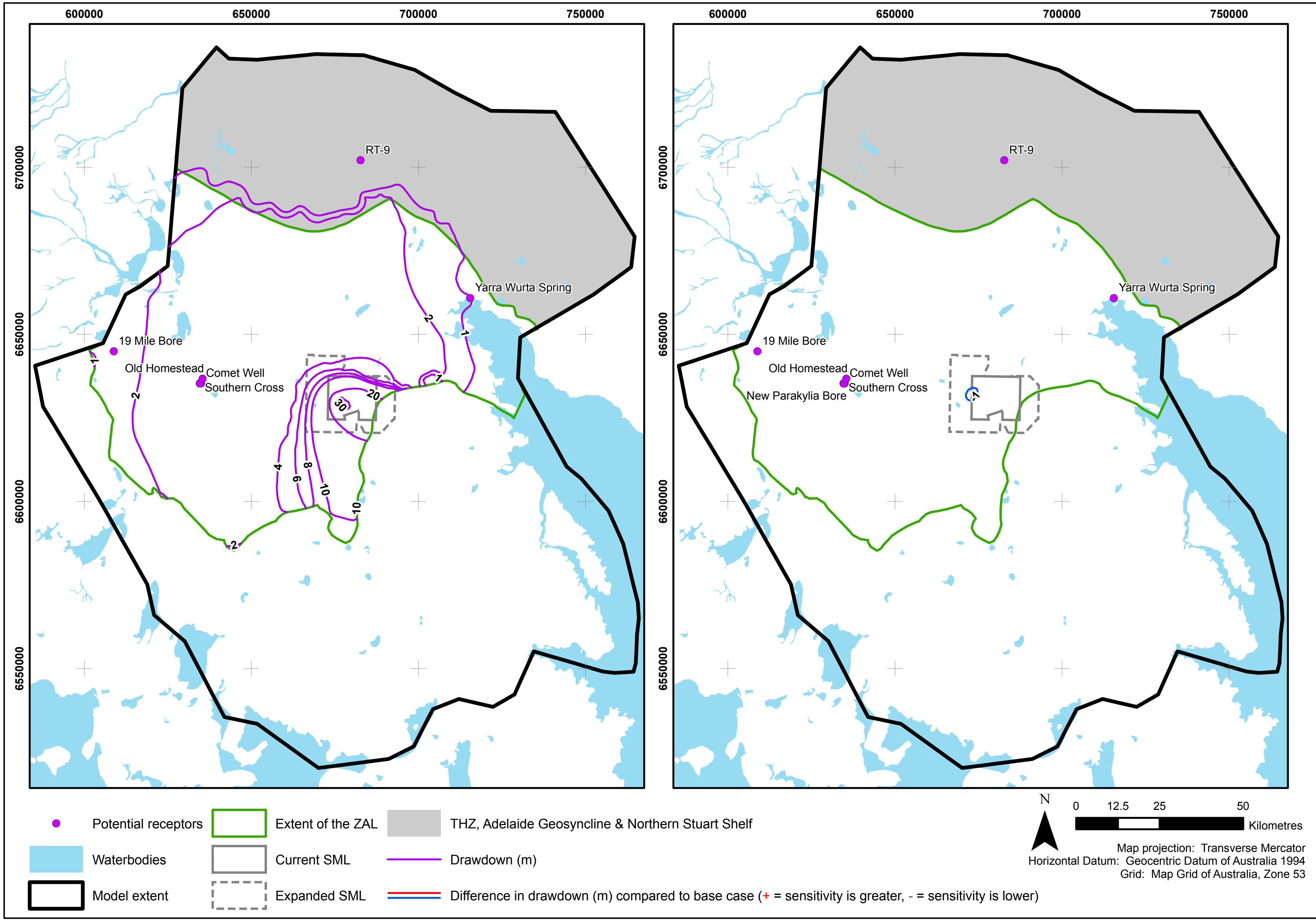

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Figure 6.19 Predictions of ZAL drawdown (2550) in "Higher TSF seepage" sensitivity (run XI)

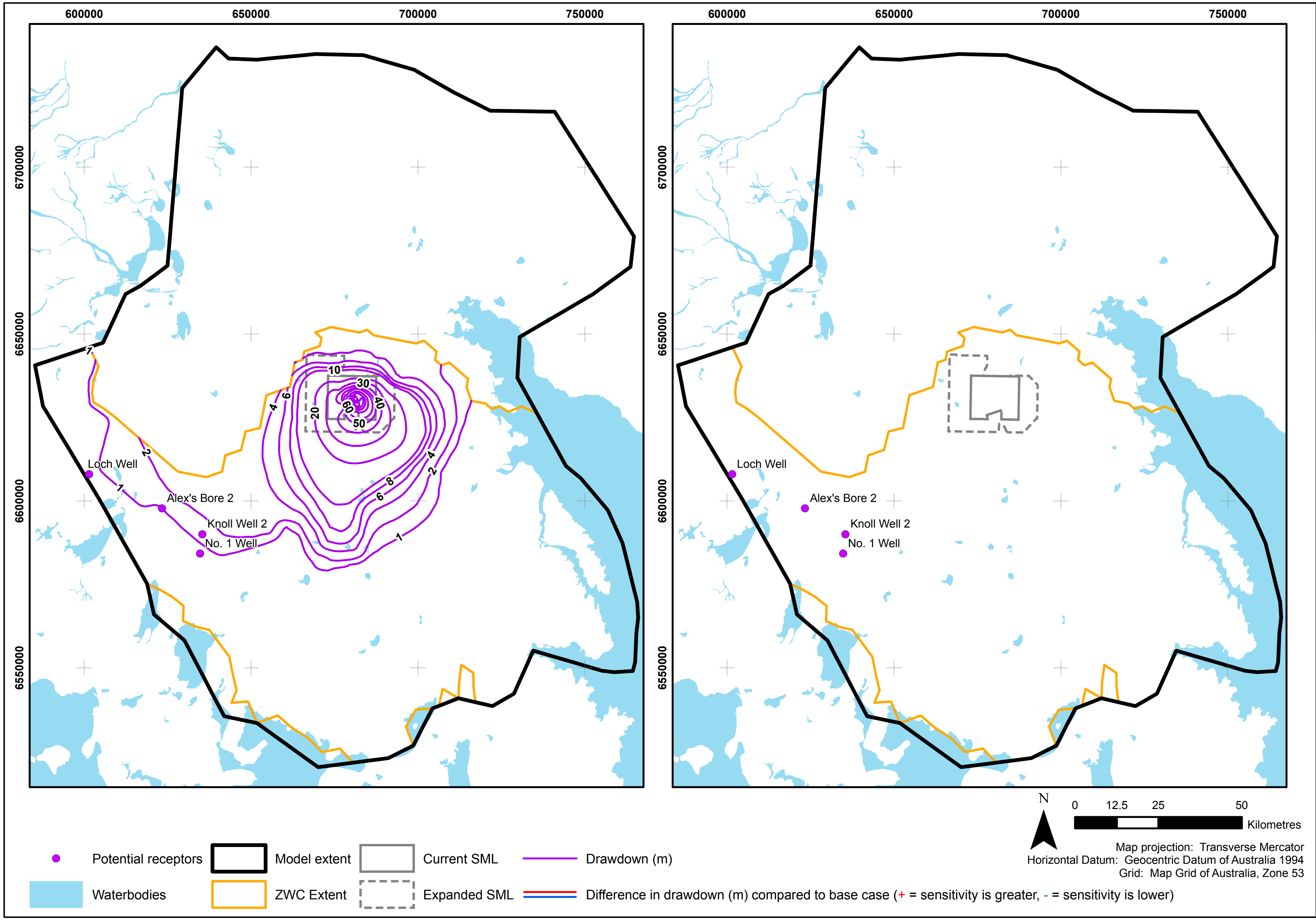

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Figure 6.20 Predictions of ZWC drawdown (2550) in "Higher TSF seepage" sensitivity (run XI)

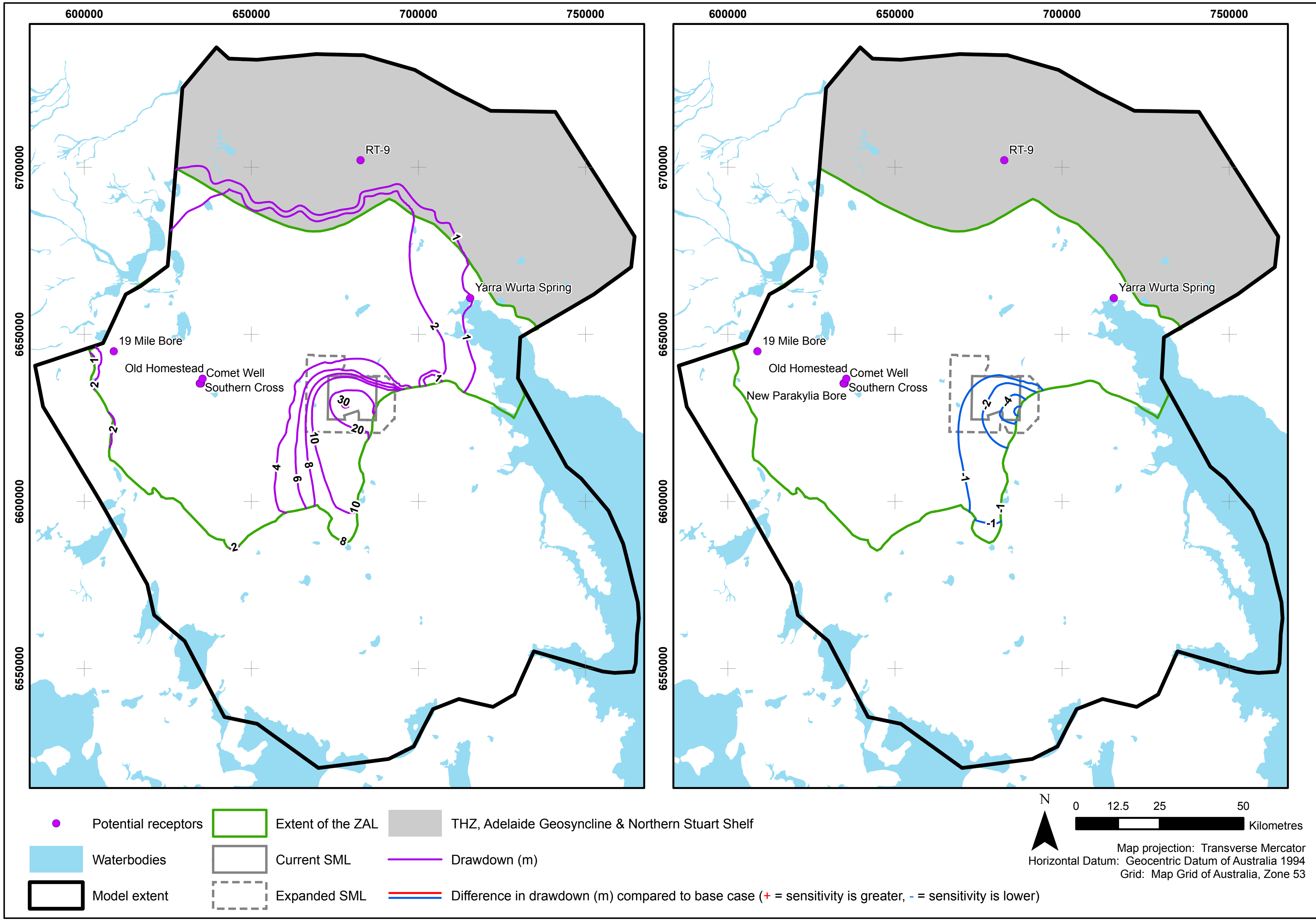

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Figure 6.21 Predictions of ZAL drawdown (2550) in "Higher RSF seepage" sensitivity (run XII)

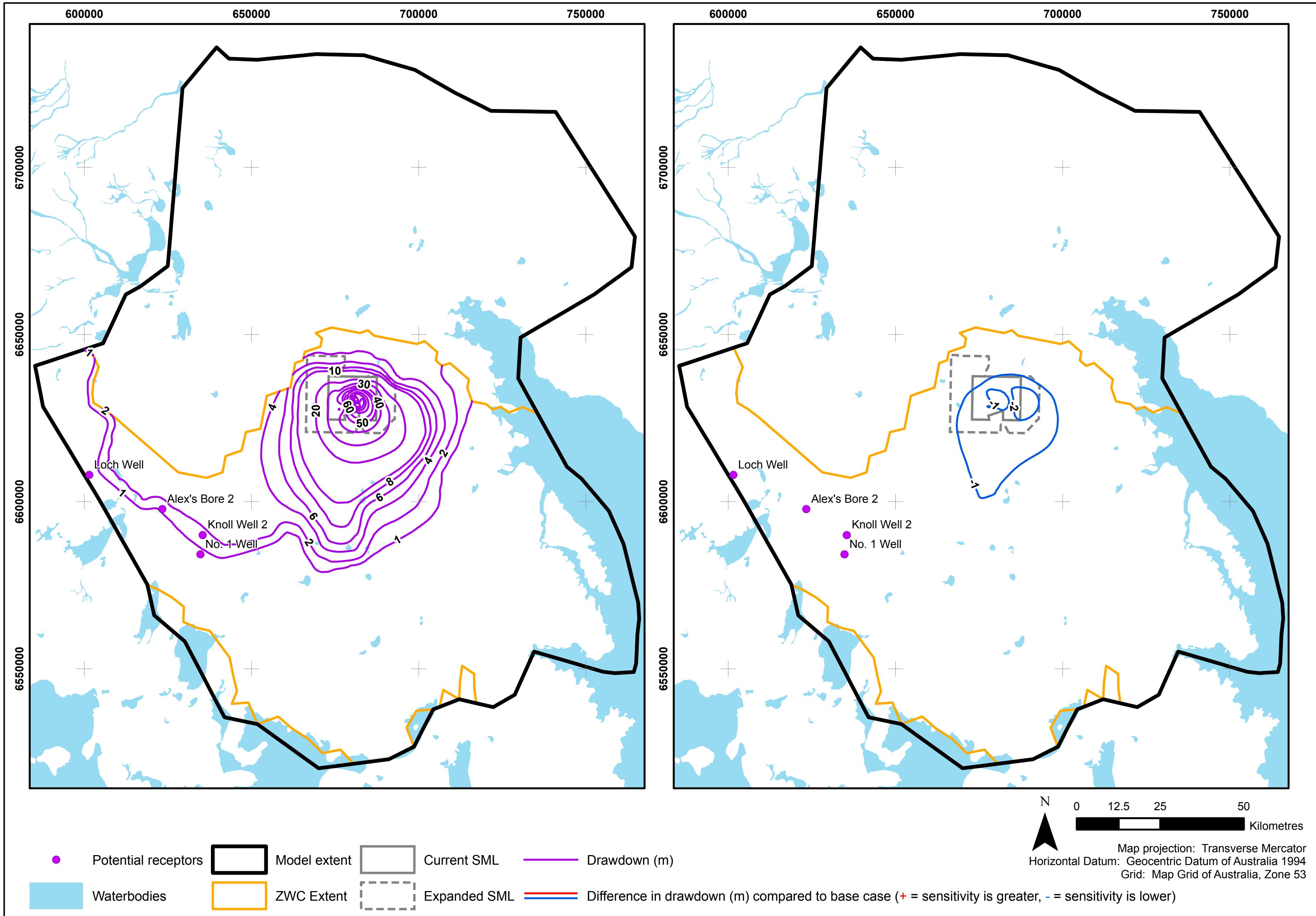

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Figure 6.22 Predictions of ZWC drawdown (2550) in "Higher RSF seepage" sensitivity (run XII)

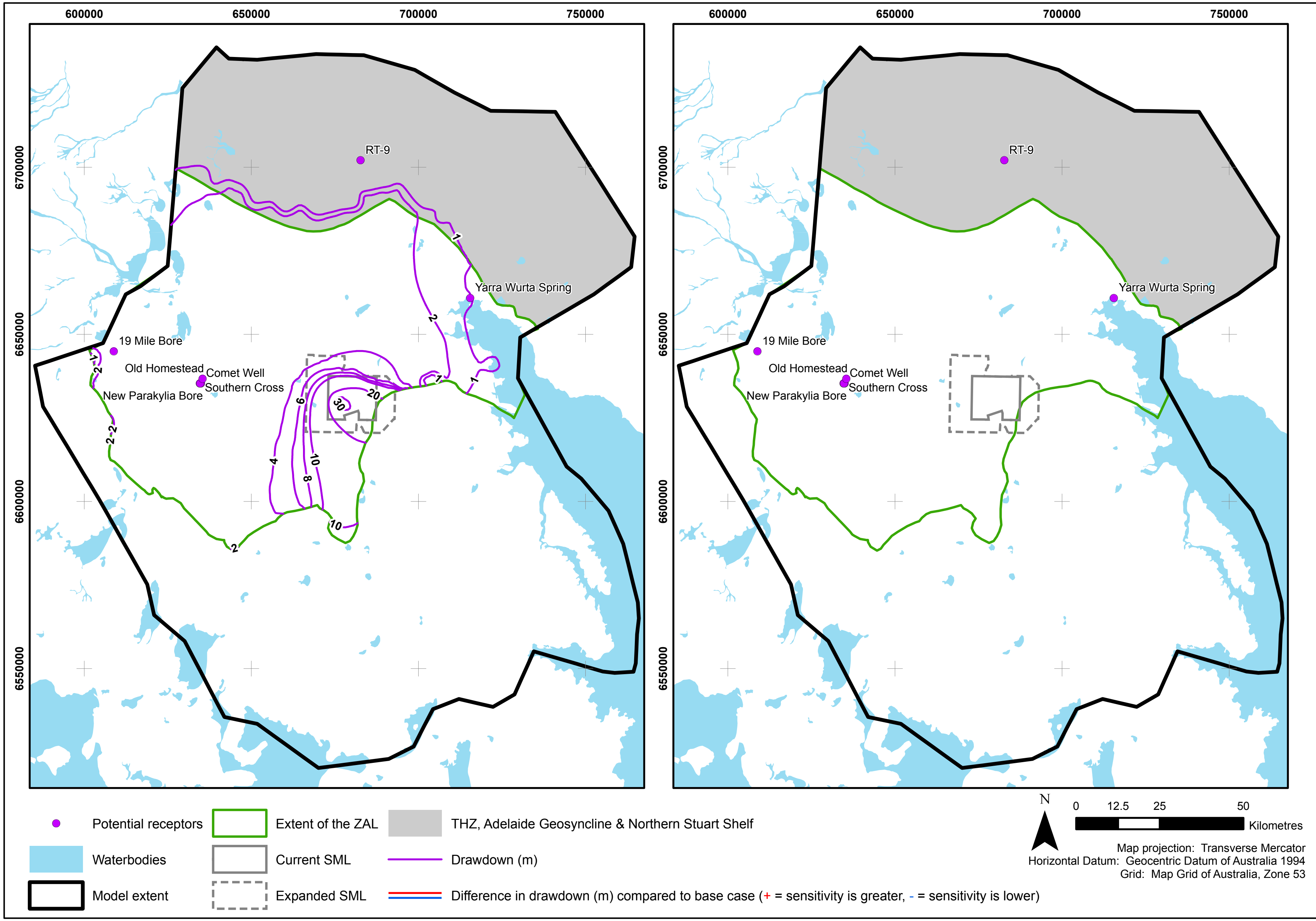

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Figure 6.23 Predictions of ZAL drawdown (2550) in "No Motherwell abstraction" sensitivity (run XIII)

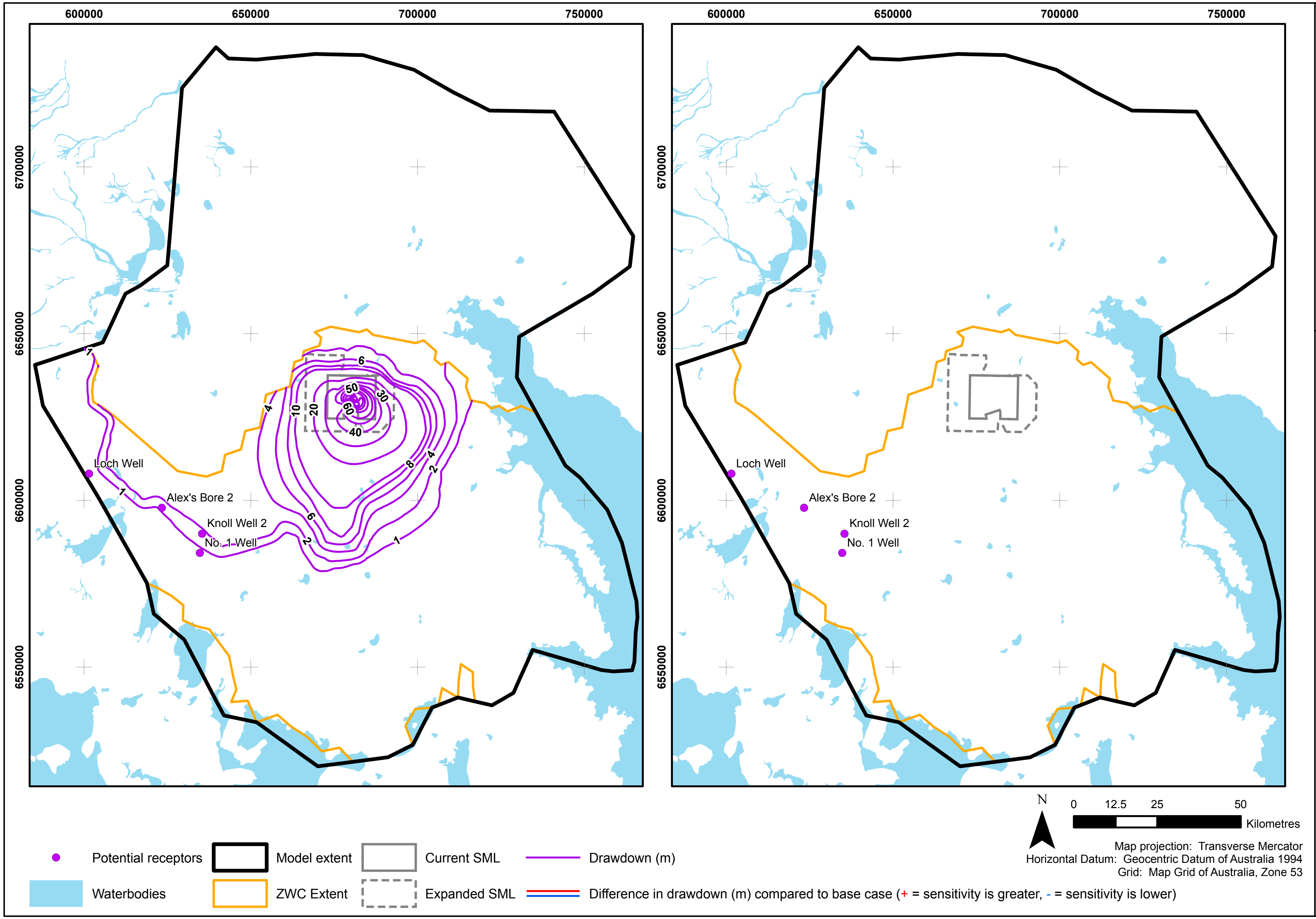

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Figure 6.24 Predictions of ZWC drawdown (2550) in "No Motherwell abstraction" sensitivity (run XIII)

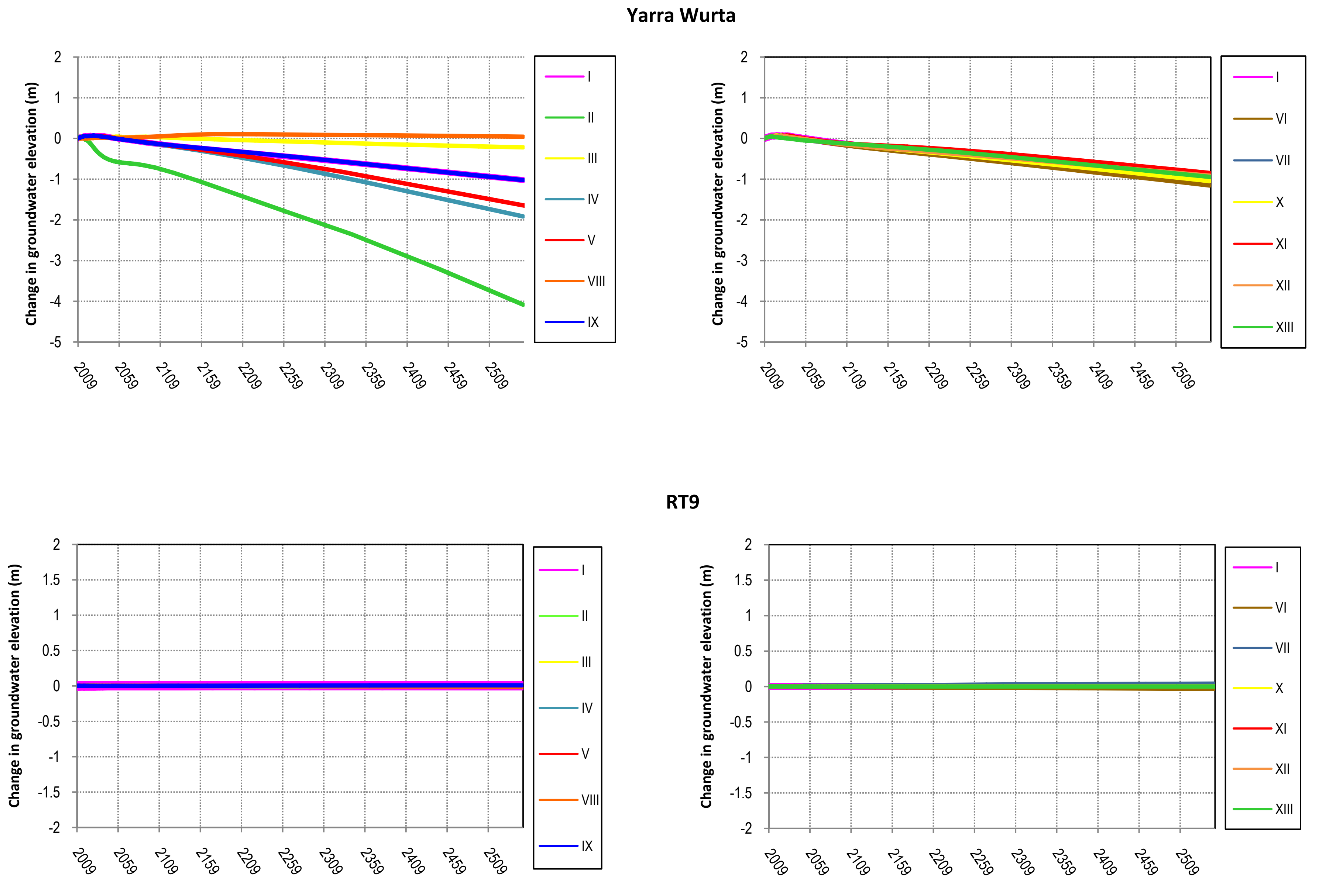
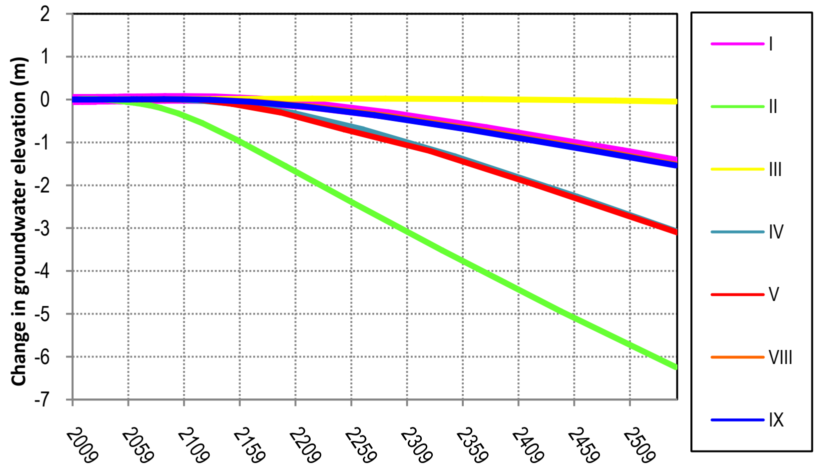
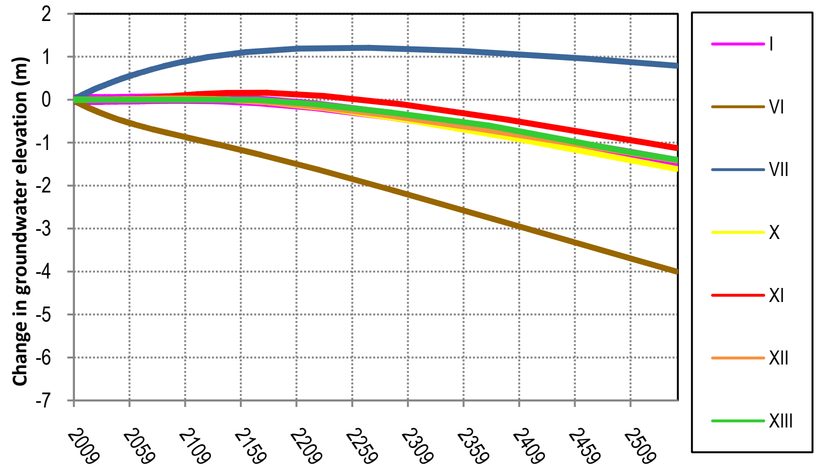


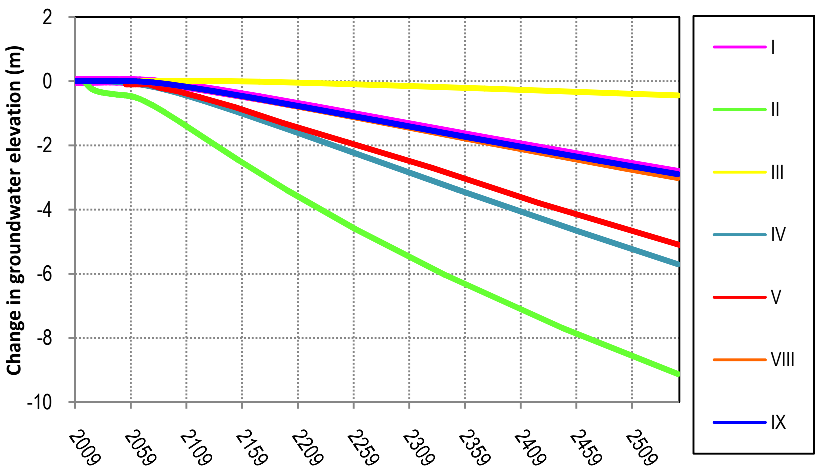
Figure 6.25 Potential receptor hydrographs (Yarra Wurta and RT9)

Alex's Bore 2





Comet Well



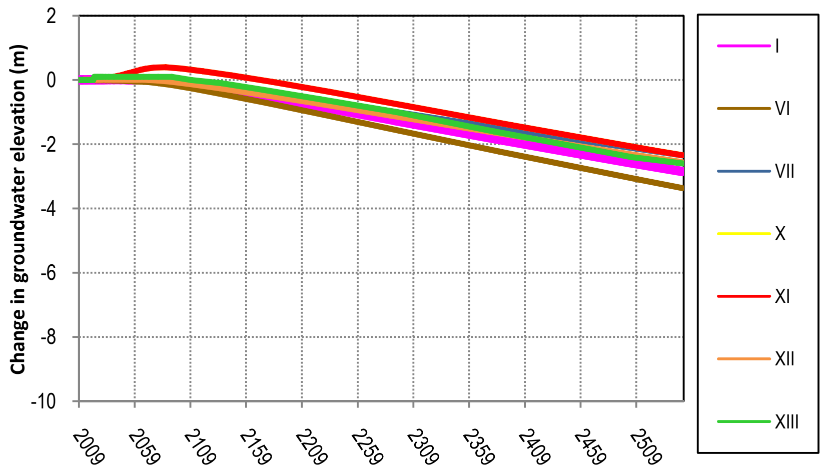


Figure 6.26 Potential receptor hydrographs (Alex's Bore 2 and Comet Well)

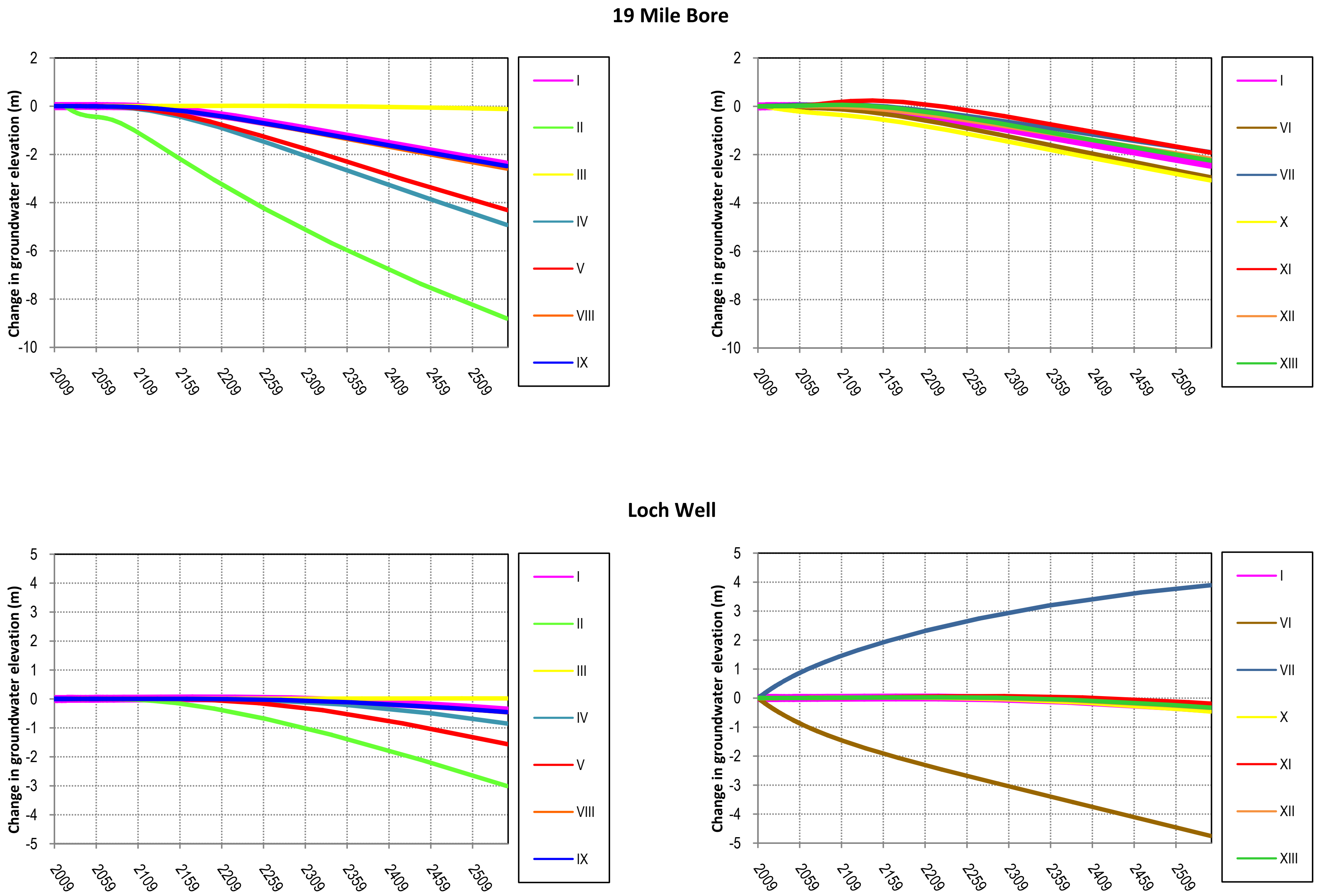


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Figure 6.27 Potential receptor hydrographs (19 Mile Bore and Loch Well)

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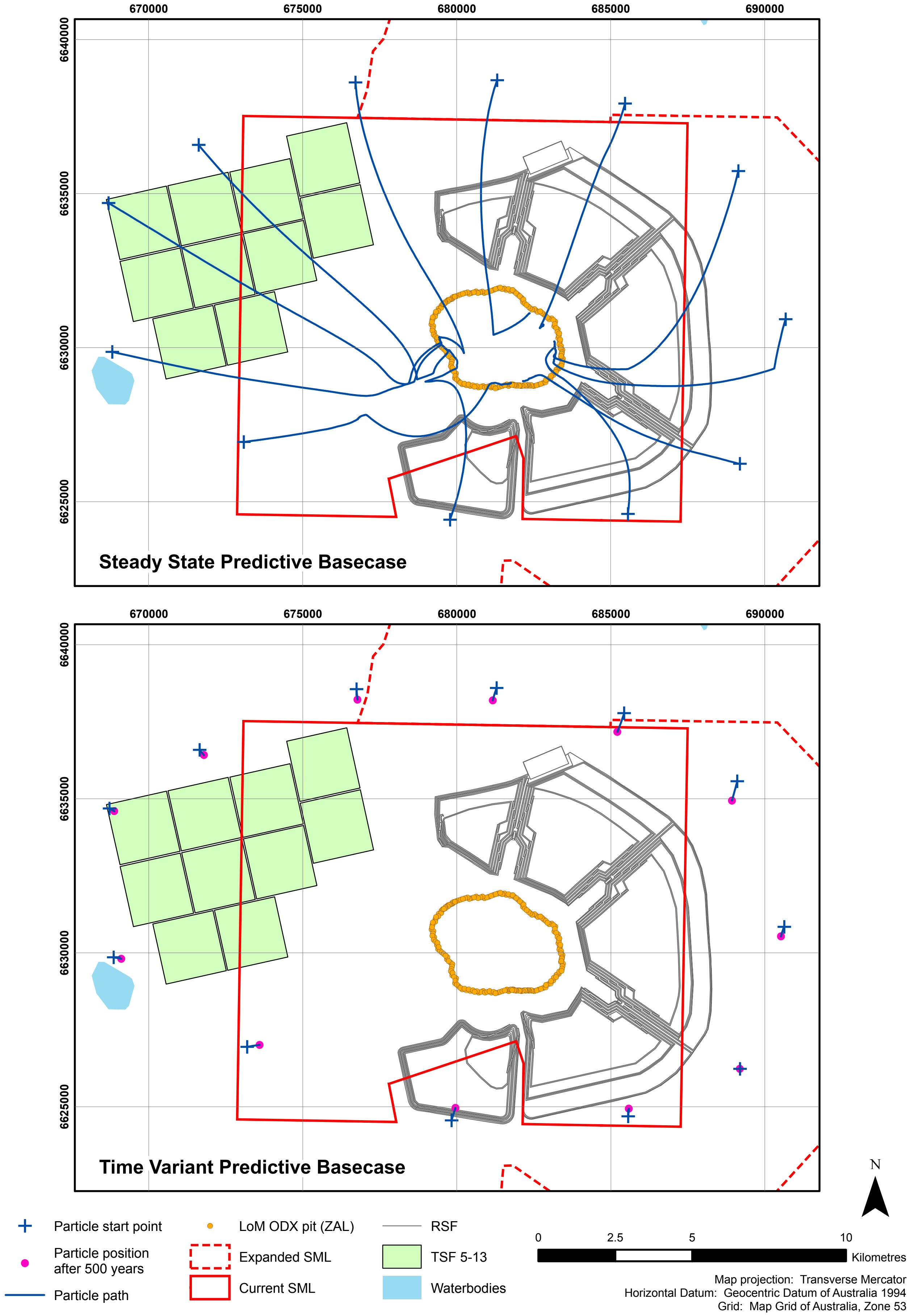
Figure 6.28 Steady state and time variant particle tracking for the predictive basecase



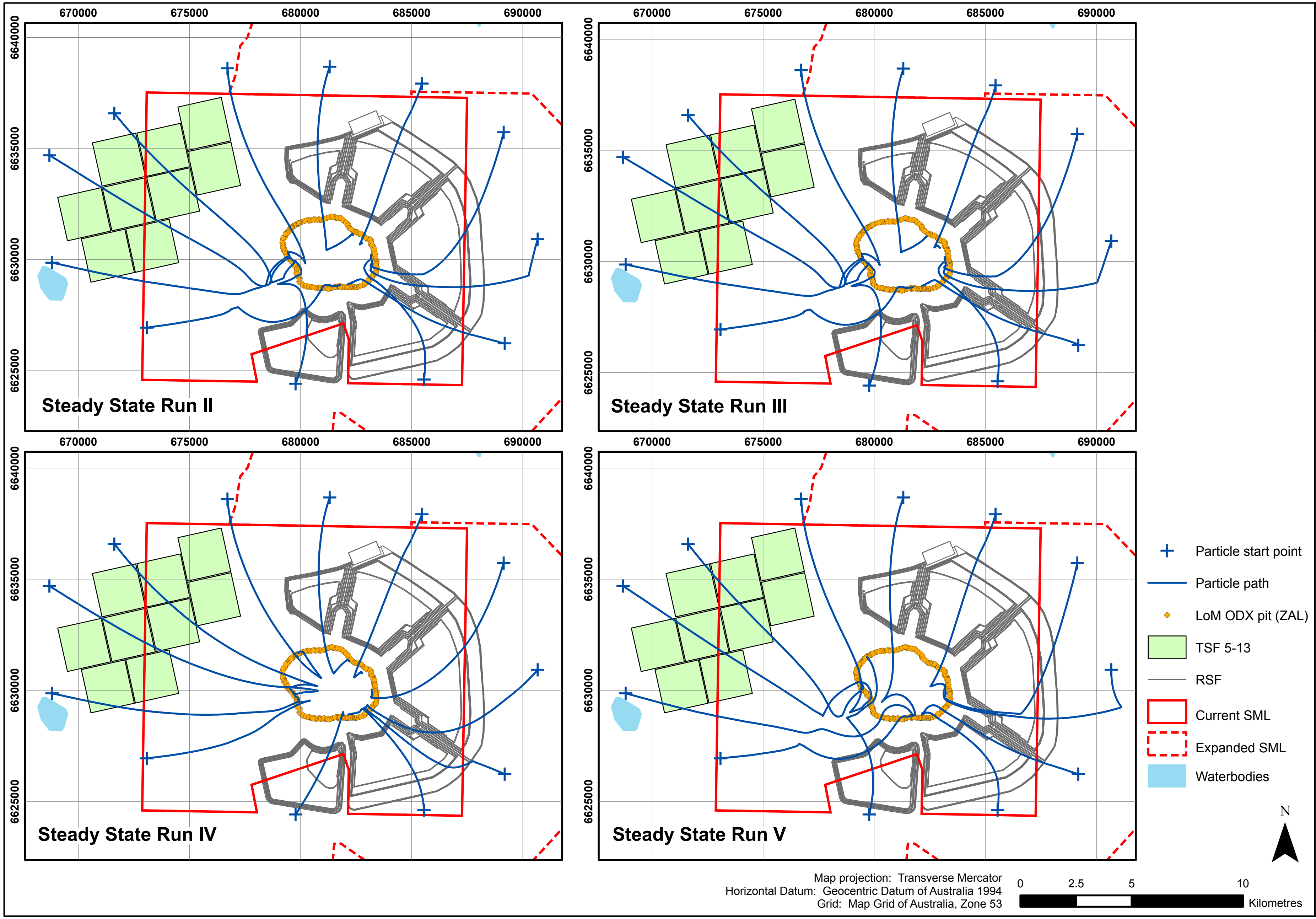


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Figure 6.29 Steady state particle tracking for sensitivity runs II, III, IV and V

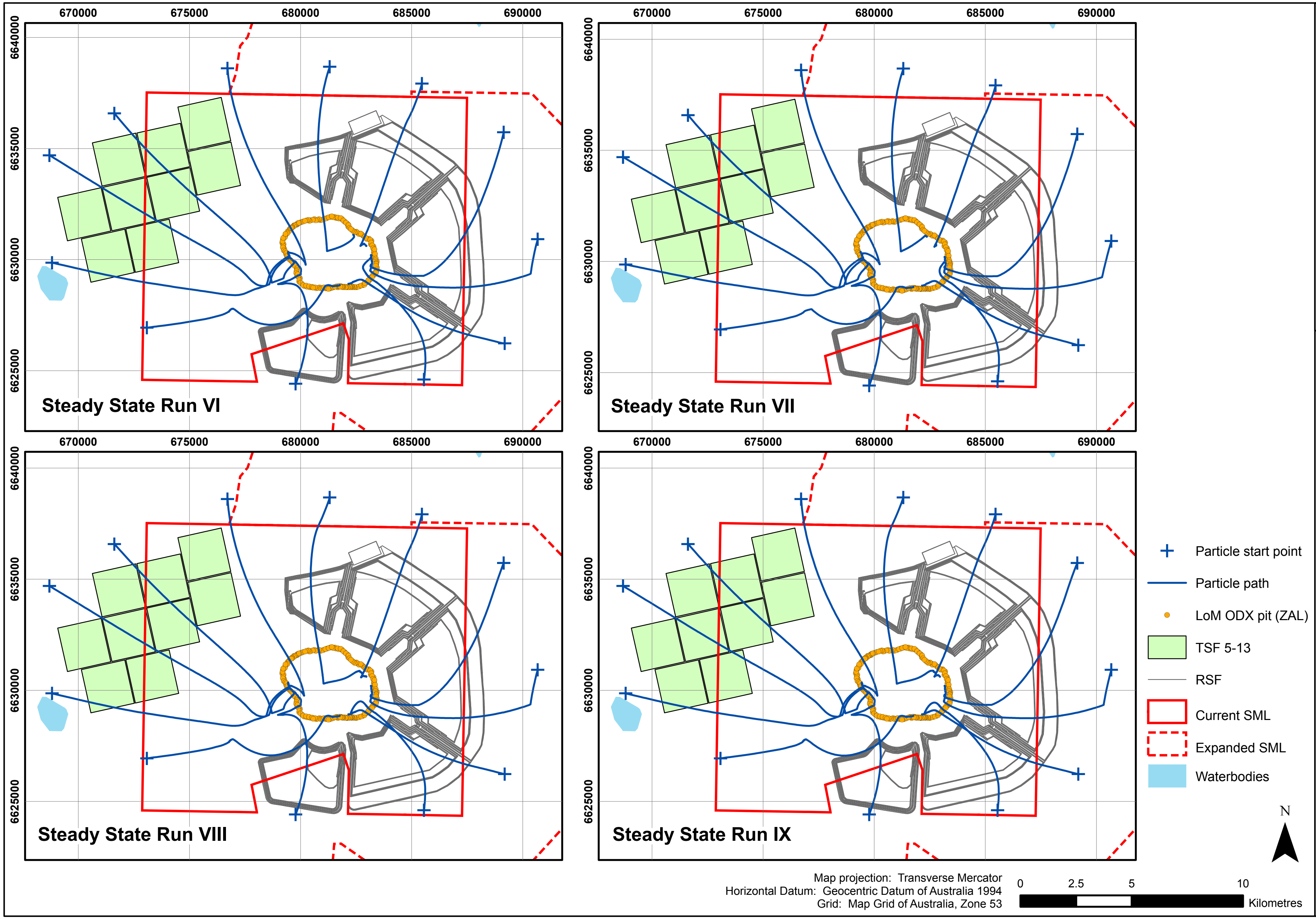

Figure 6.30 Steady state particle tracking for sensitivity runs VI, VII, VIII and IX

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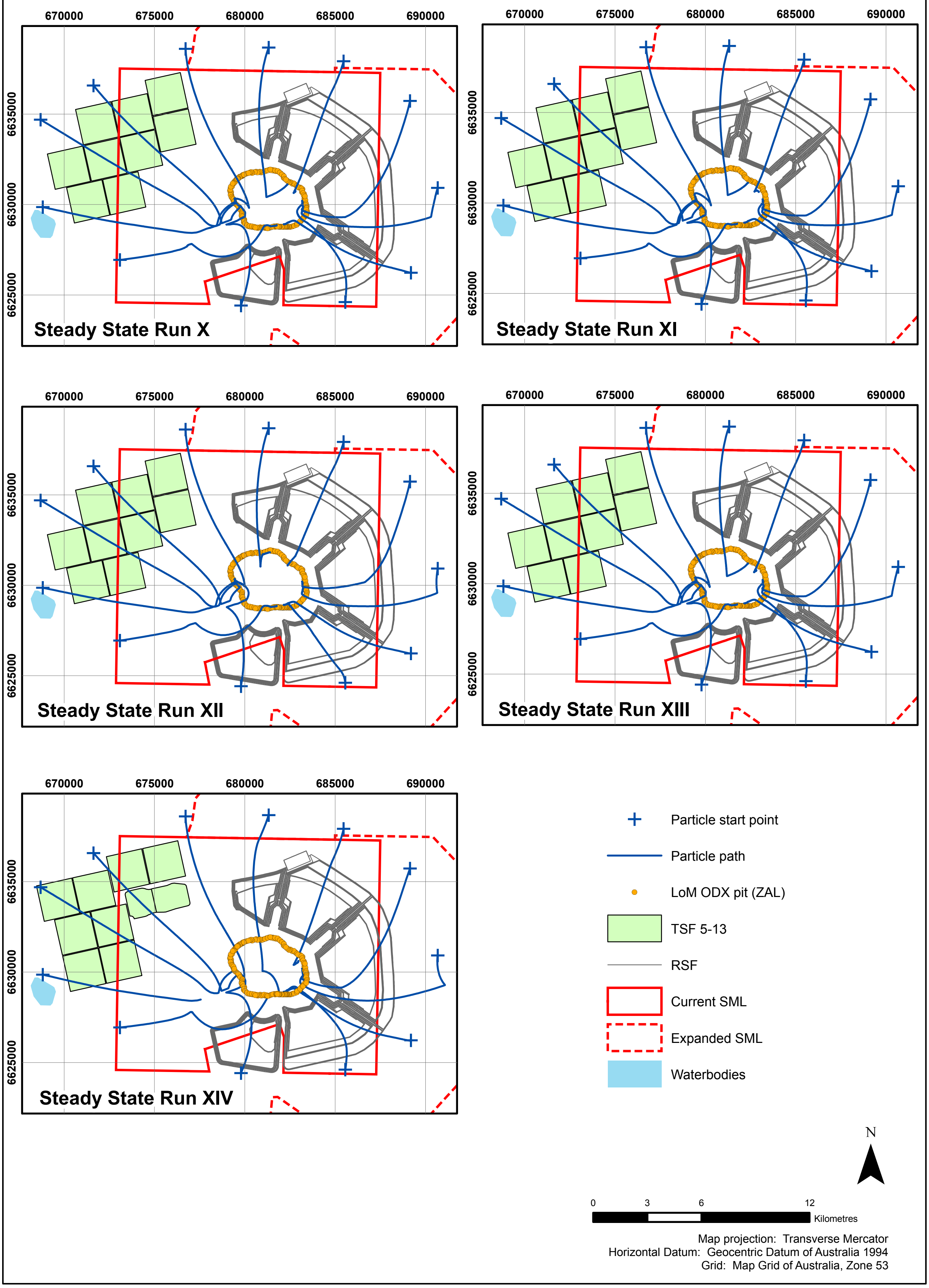
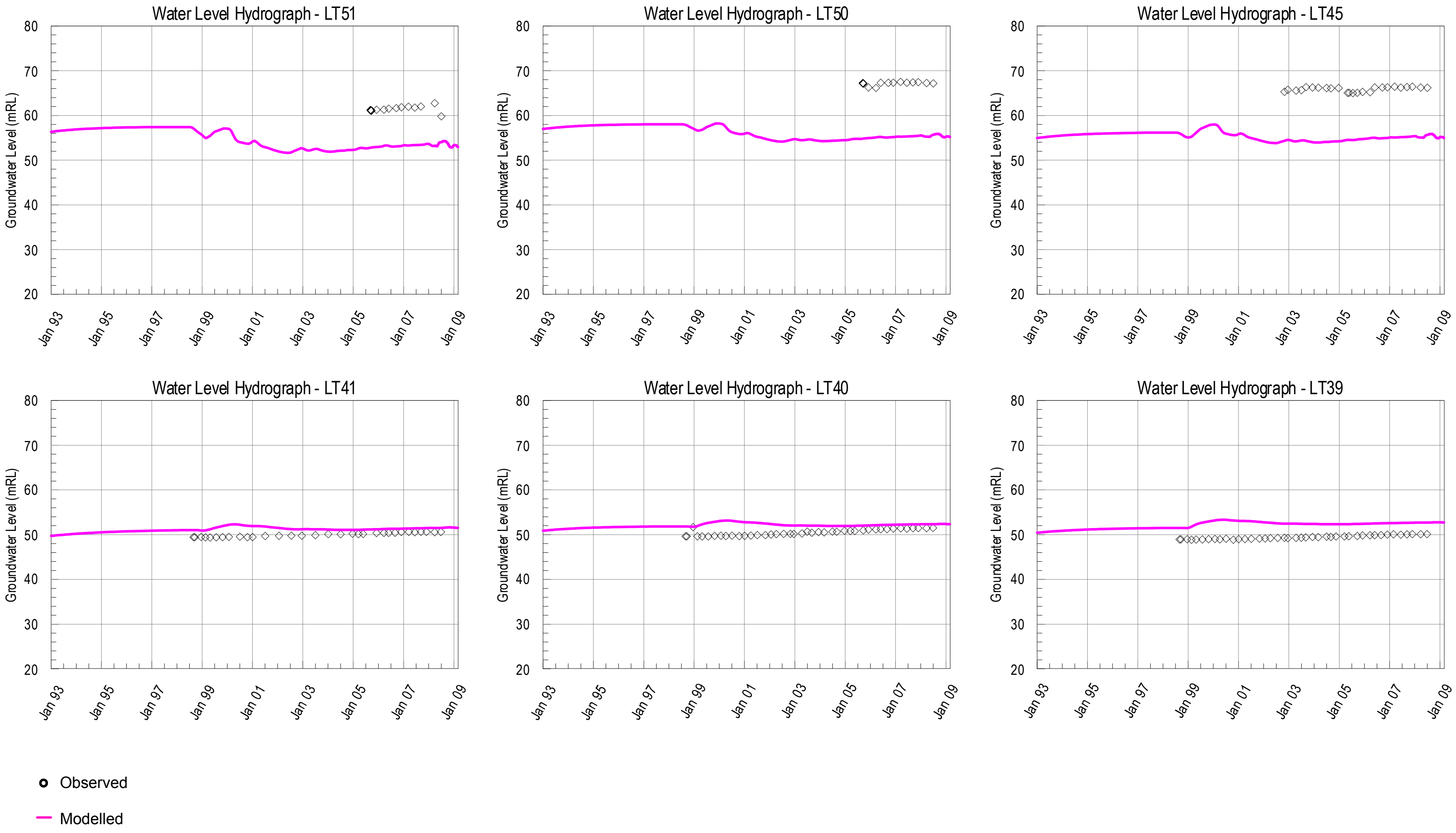
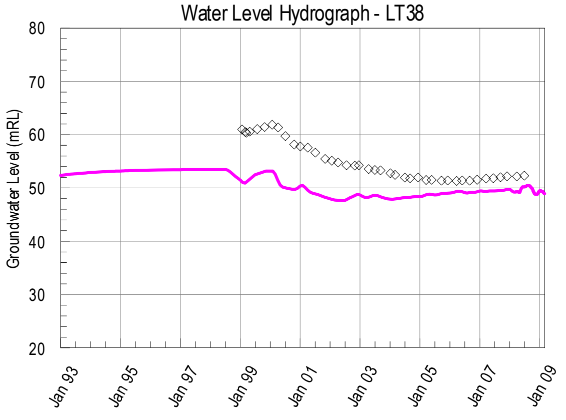
Figure 6.31 Steady state particle tracking for sensitivity runs X, XI, XII, XIII and XIV

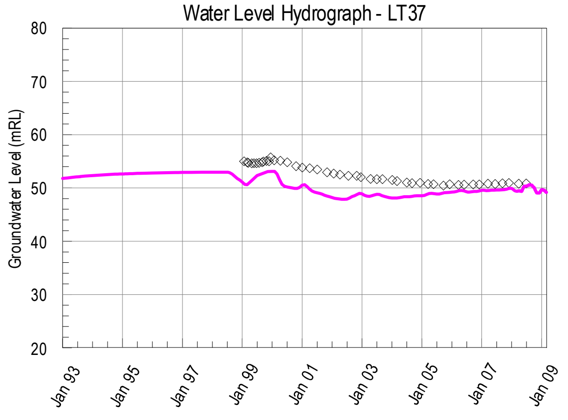


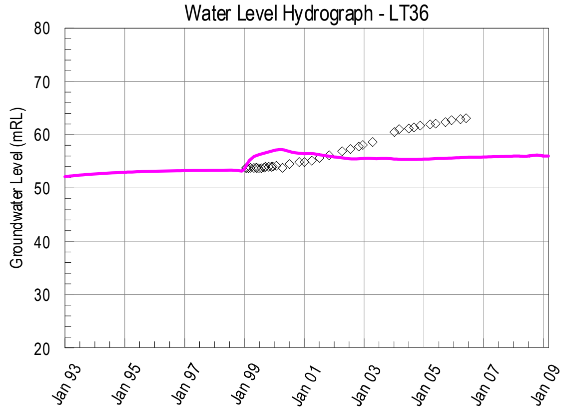
Attachment A
ZAL observed and simulated hydrographs

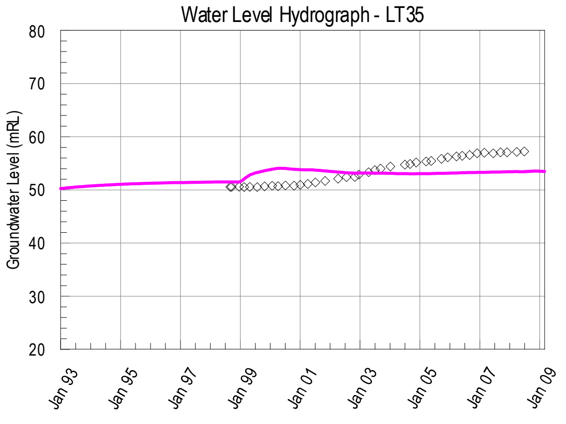


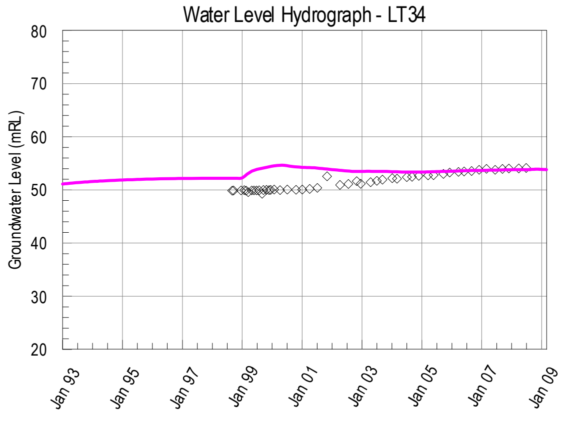
Attachment A1 Historical - 2010 recalibrations - ZAL

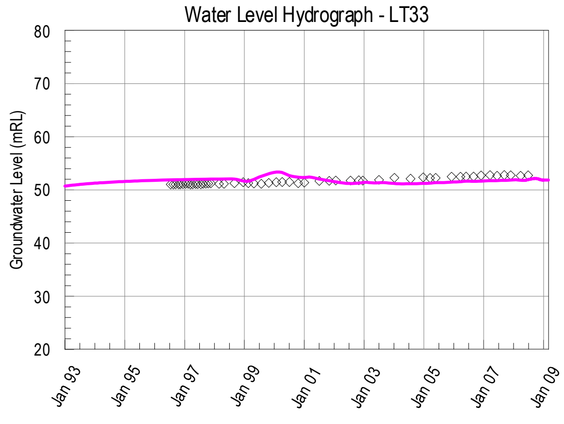












Observed

Modelled

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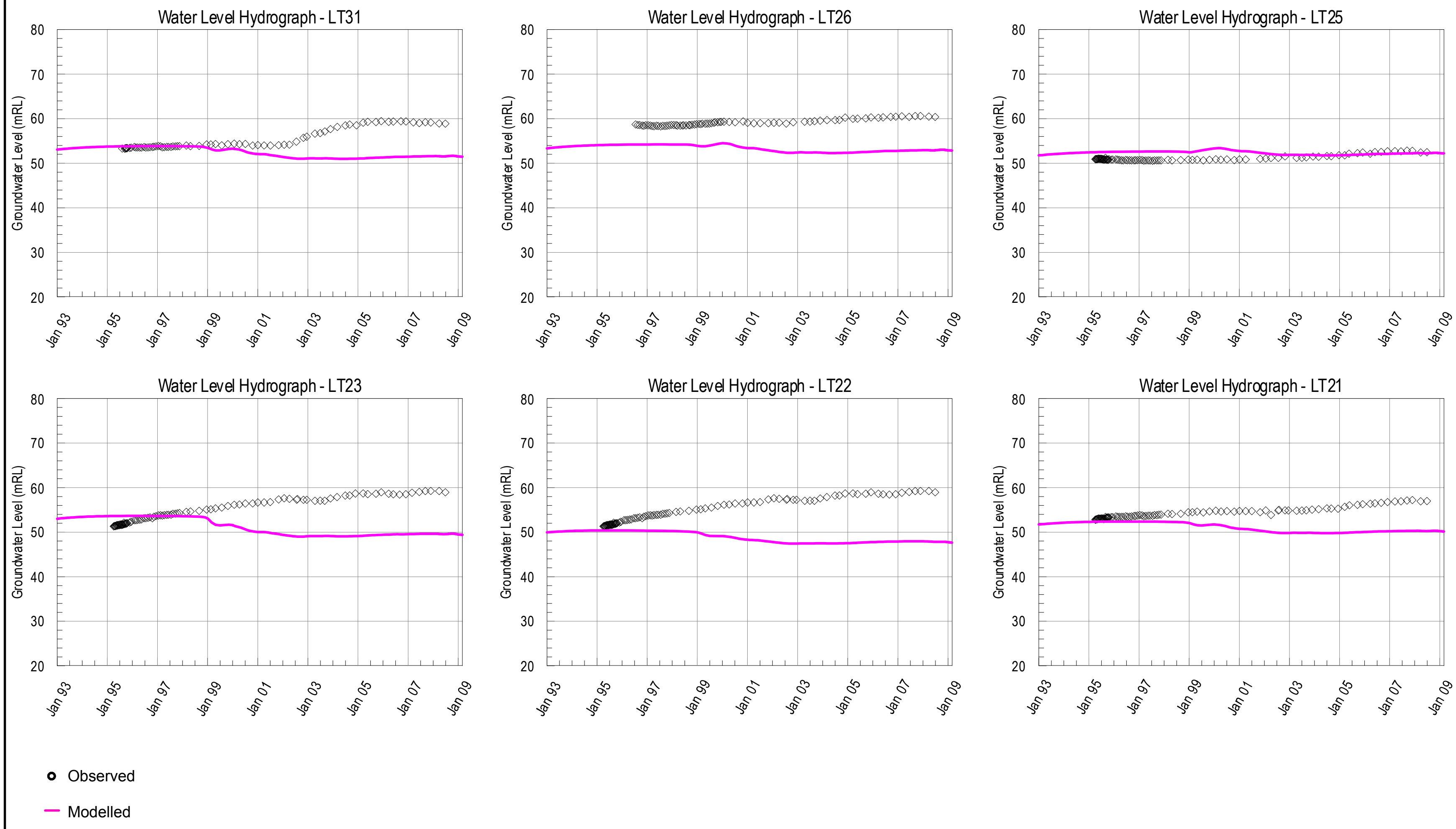
Attachment A2 Historical - 2010 recalibrations - ZAL



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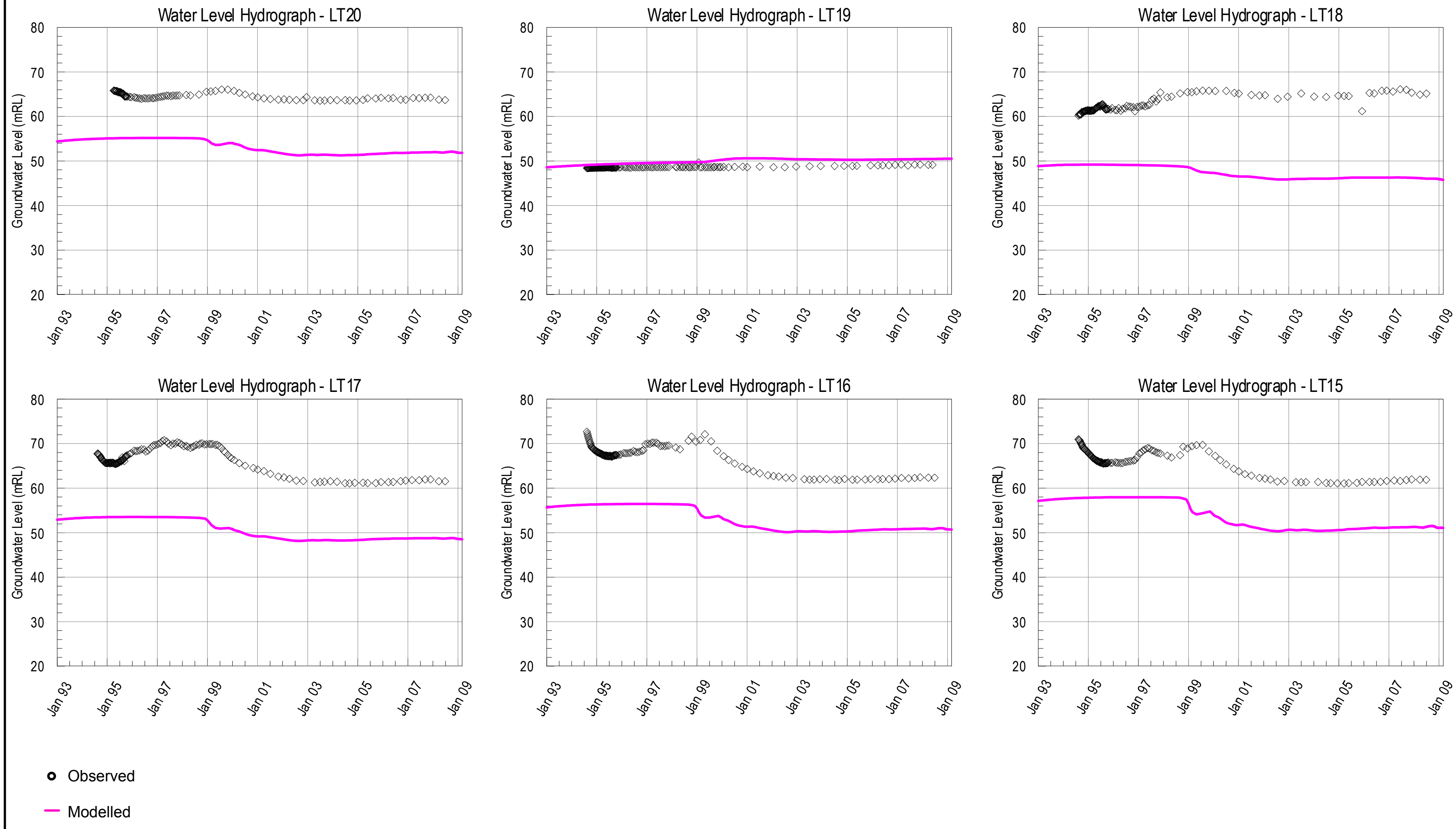
Attachment A3 Historical - 2010 recalibrations - ZAL



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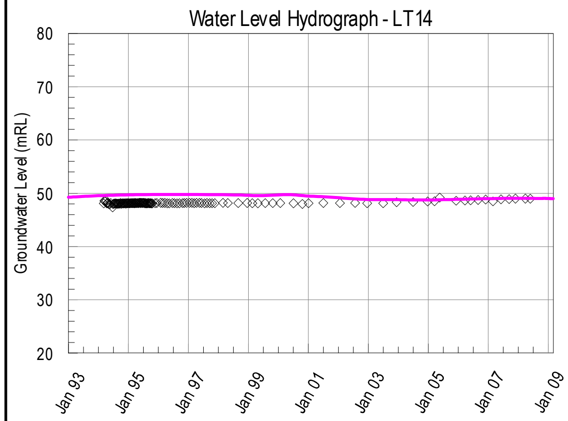
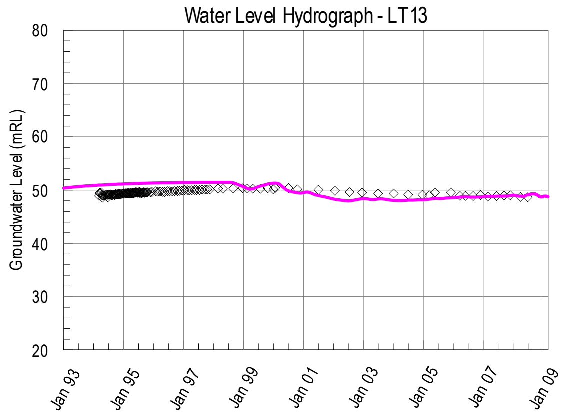
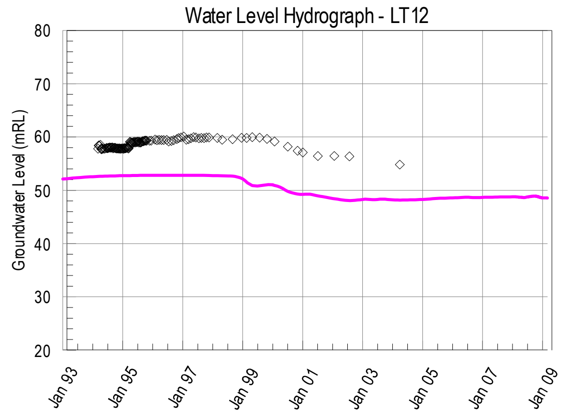
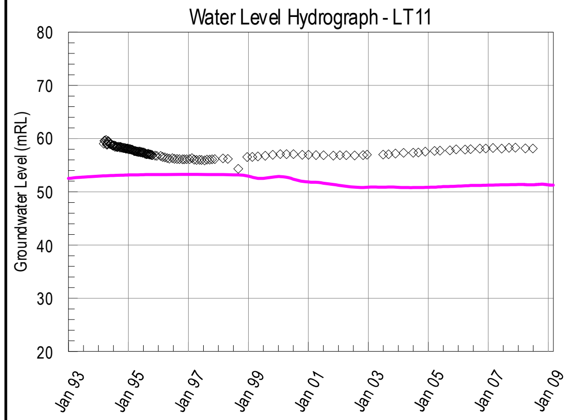
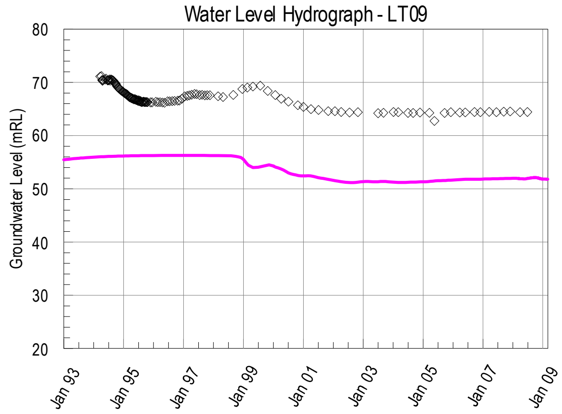
Attachment A4 Historical - 2010 recalibrations - ZAL

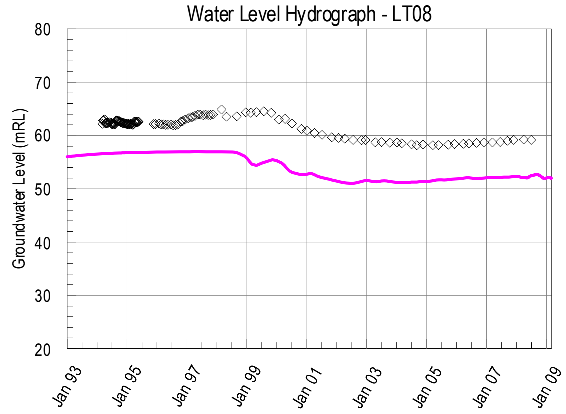












Observed

Modelled

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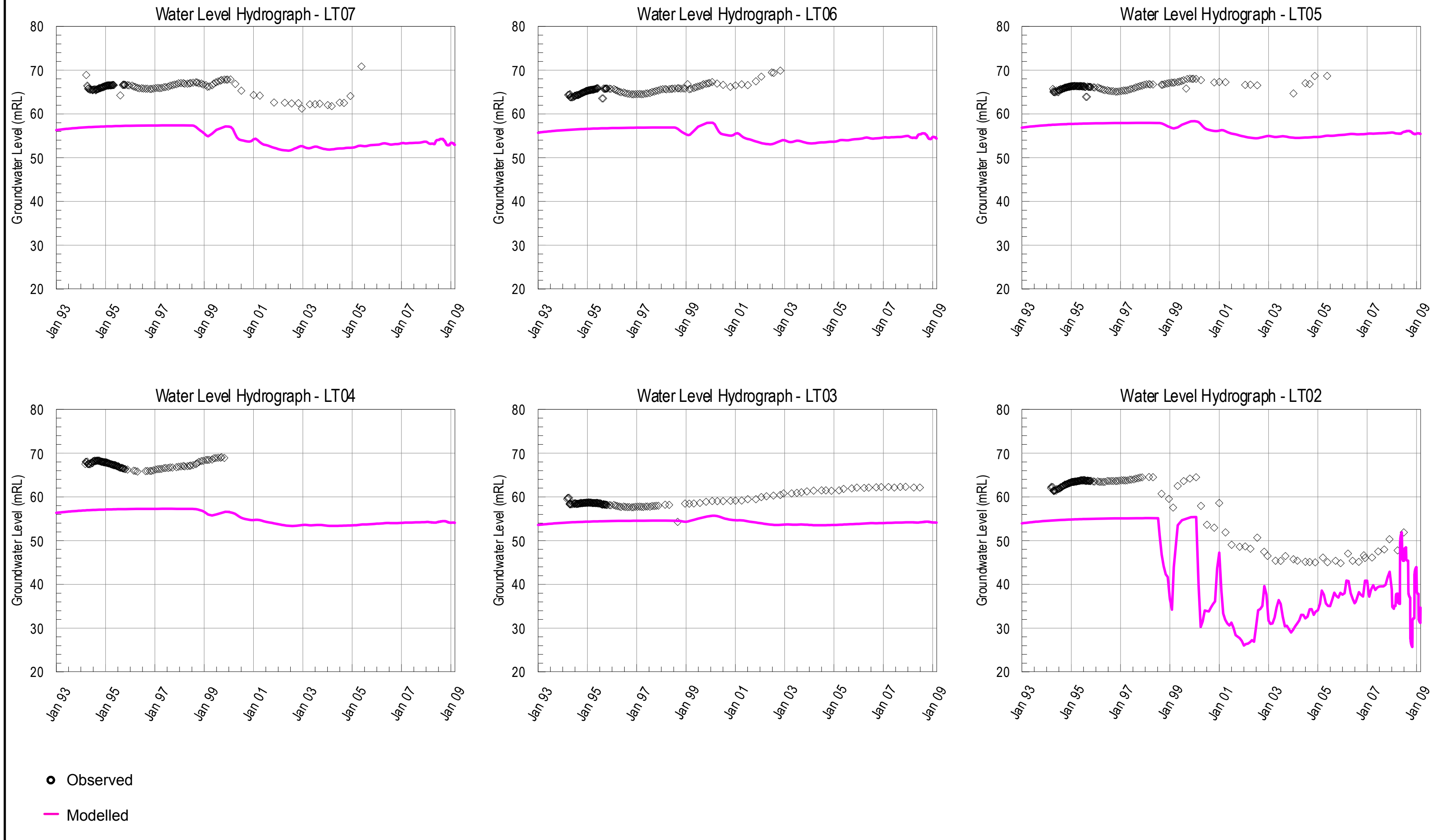
WATER SERVICES

Attachment A5 Historical - 2010 recalibrations - ZAL



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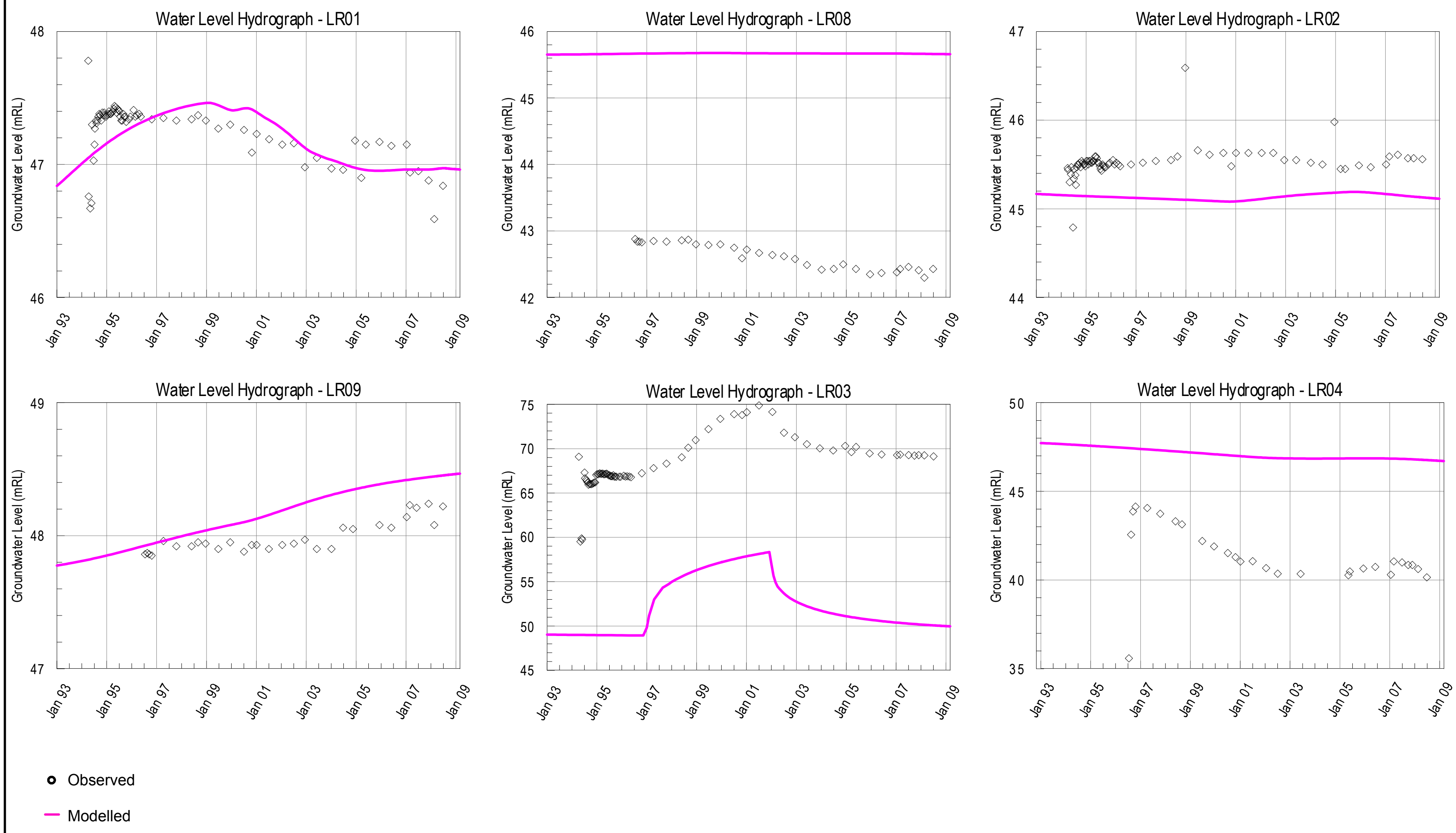
Attachment A6 Historical - 2010 recalibrations - ZAL



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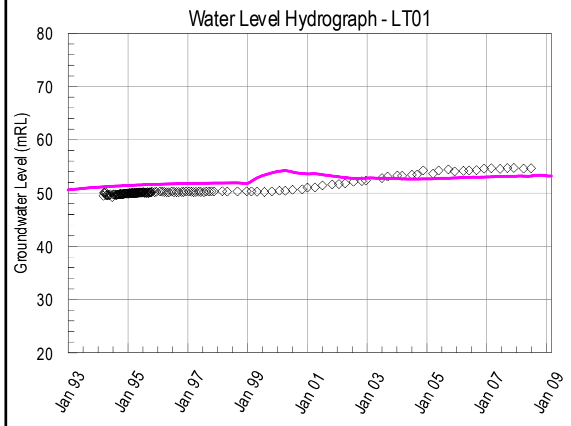
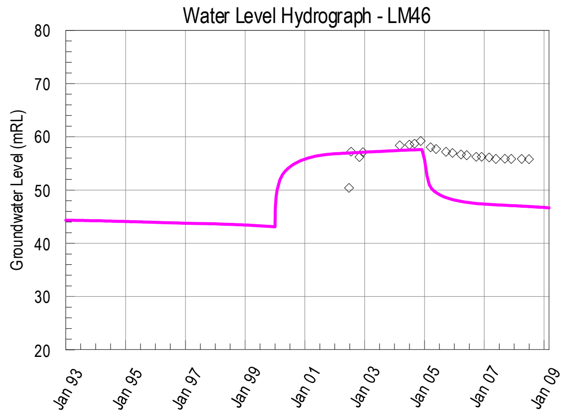
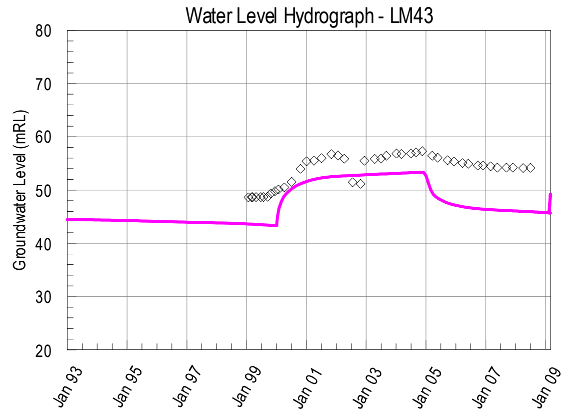
WATER SERVICES

Attachment A7 Historical - 2010 recalibrations - ZAL







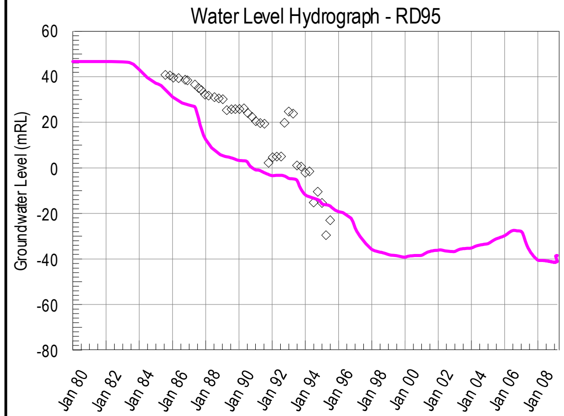
Observed

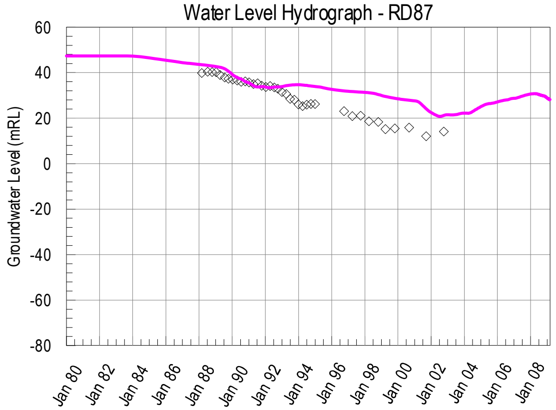
Modelled

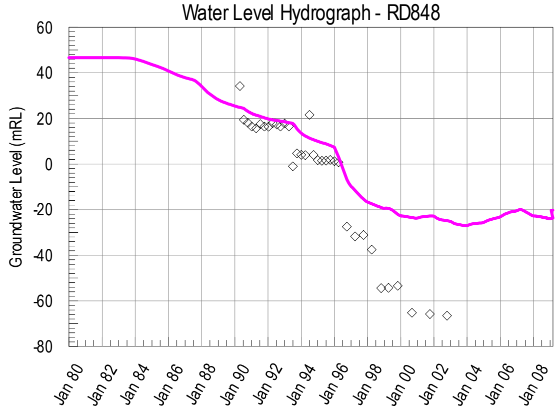
Schlumberger WATER SERVICES

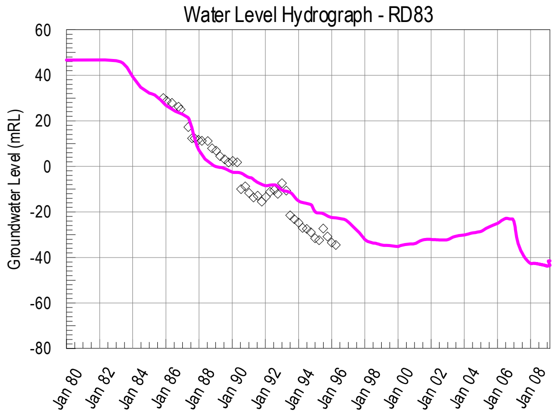
Attachment A8 Historical - 2010 recalibrations - ZAL

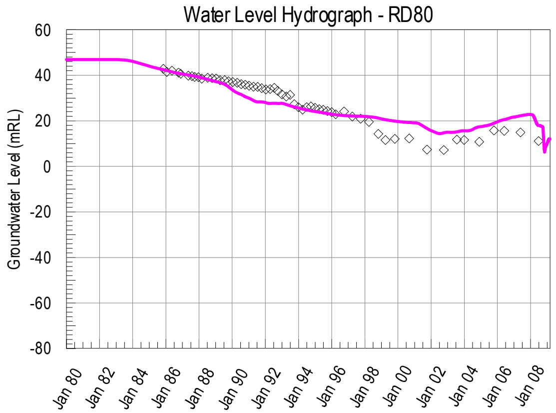
Attachment B
ZWC observed and simulated hydrographs

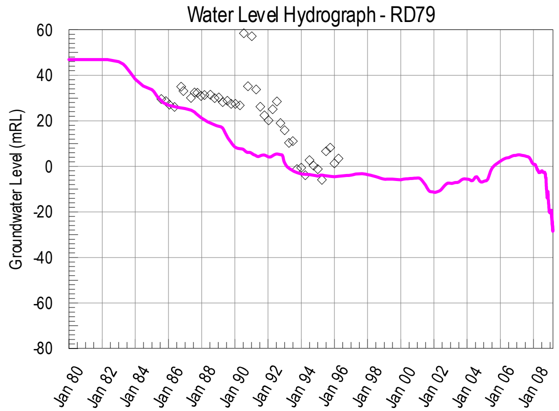










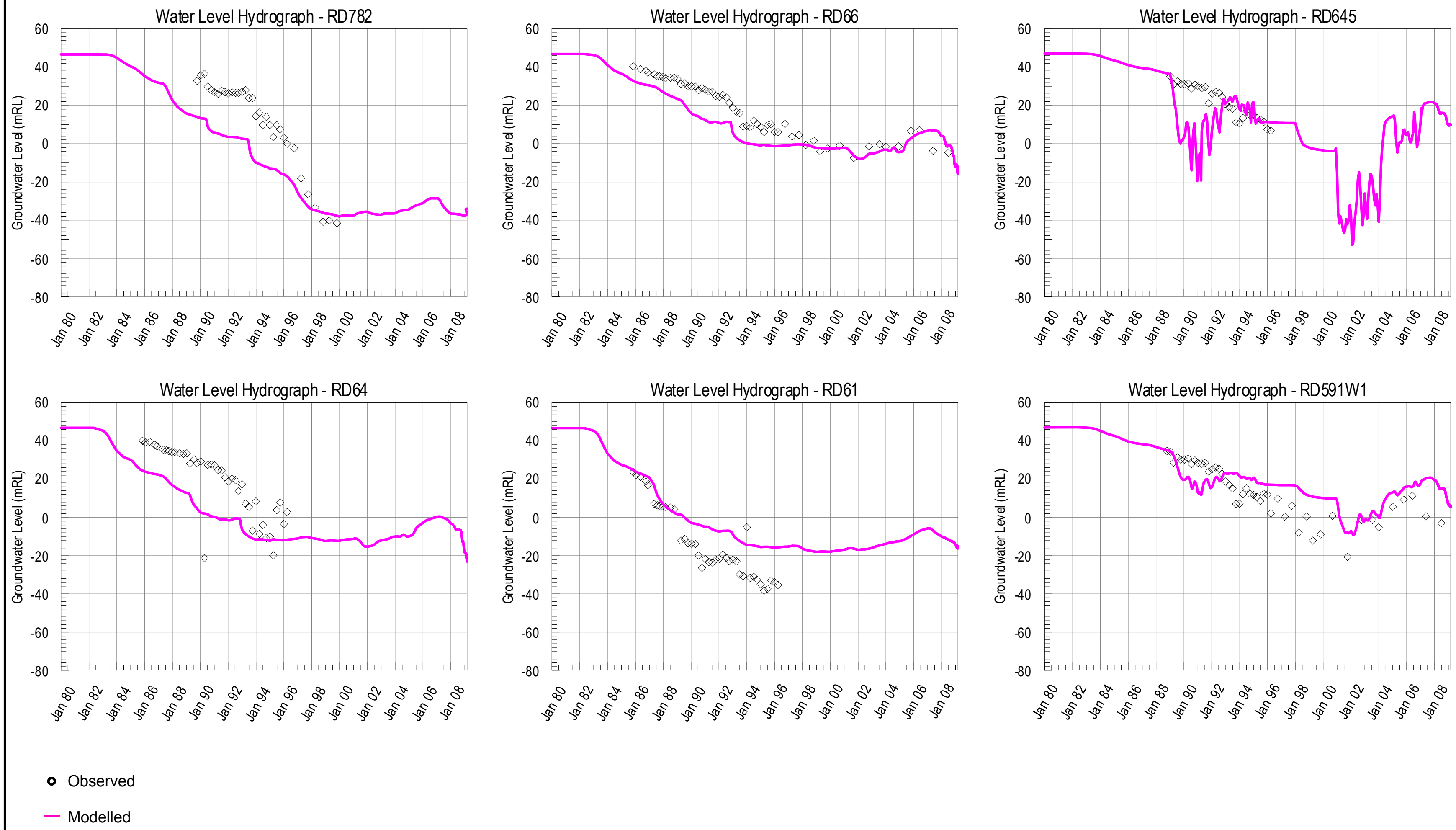


Observed

Modelled

Schlumberger
WATER SERVICES

Attachment B1 Historical - 2010 recalibrations - ZWC



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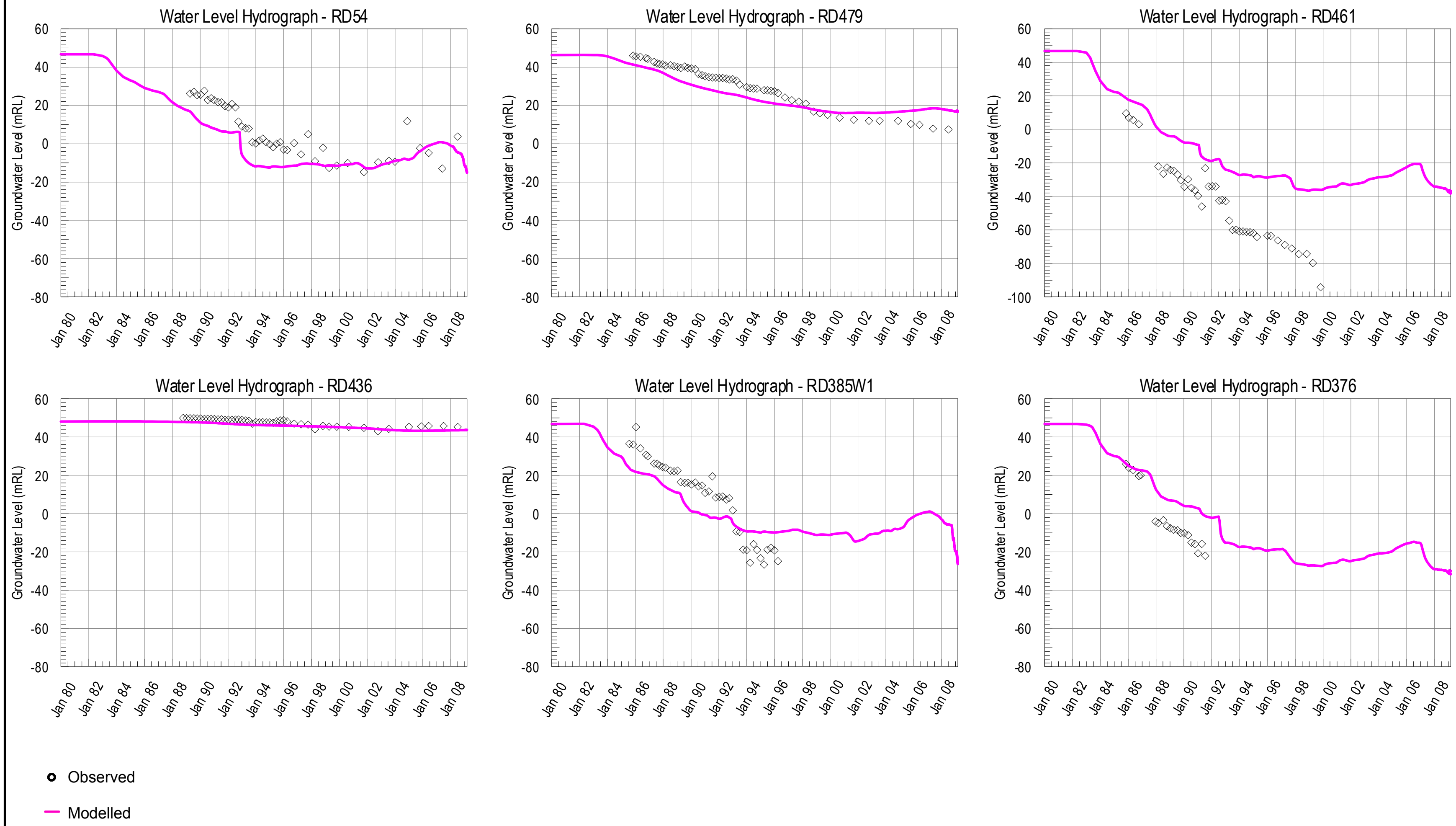
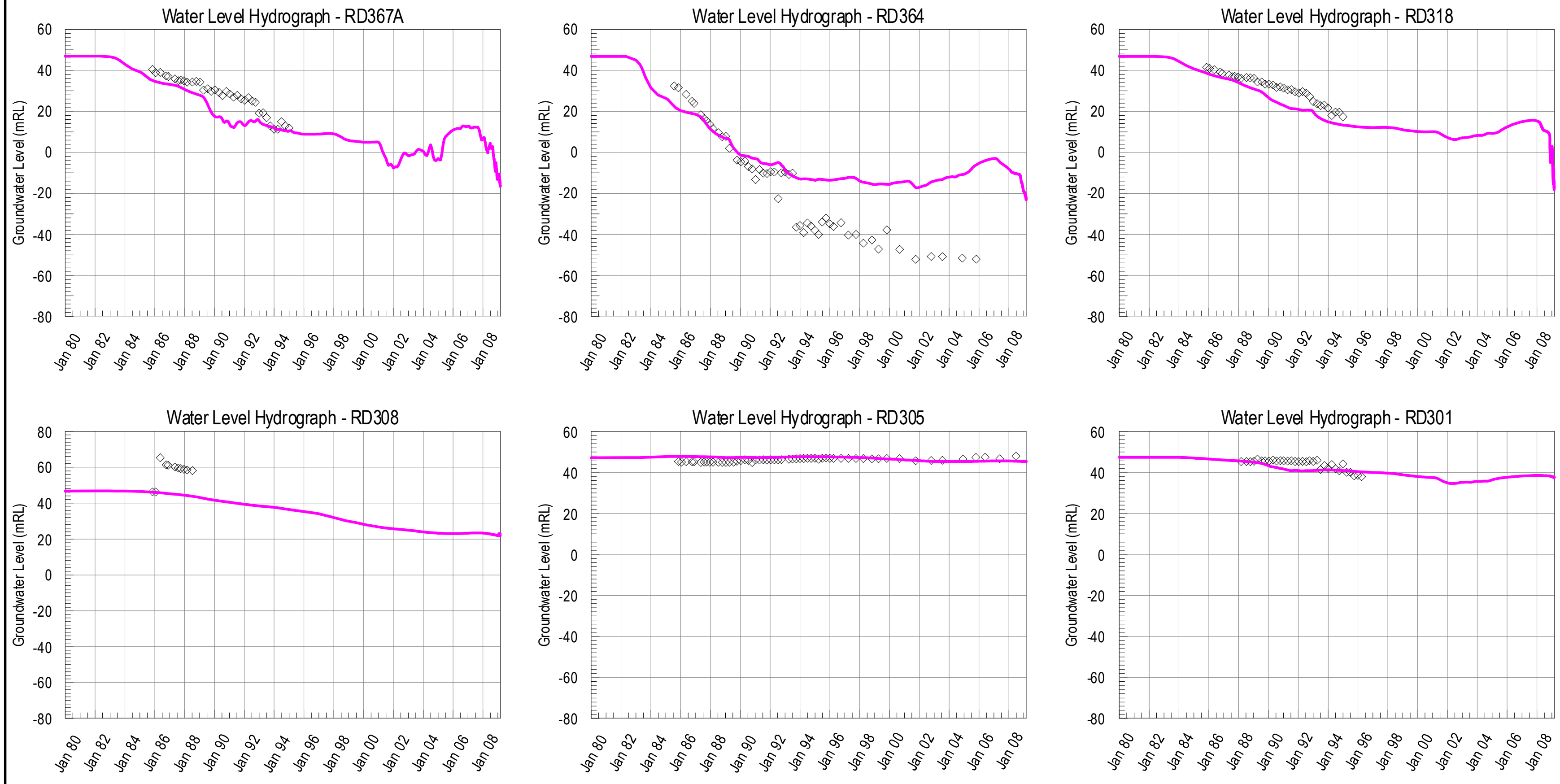
Attachment B2 Historical - 2010 recalibrations - ZWC

Schlumberger WATER SERVICES

Attachment B3 Historical - 2010 recalibrations - ZWC



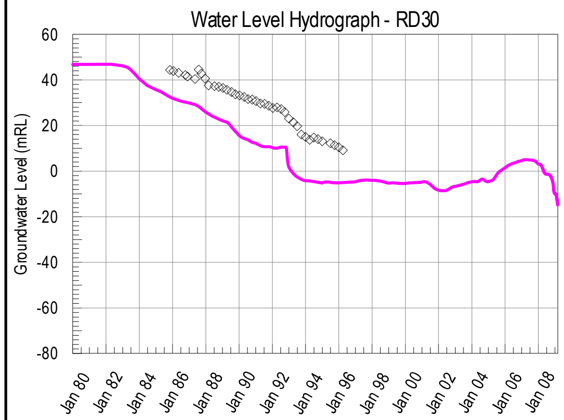


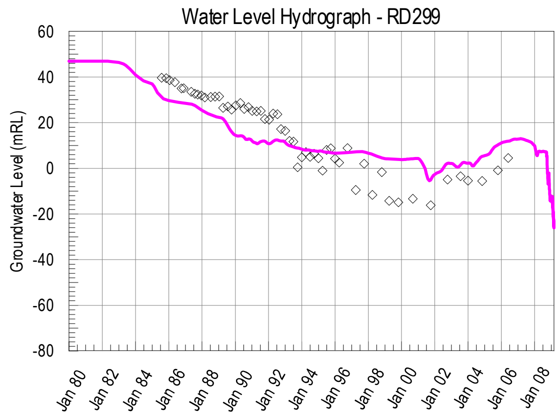
Observed

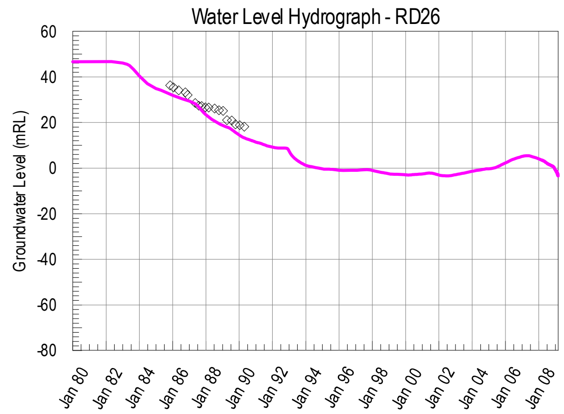
Modelled

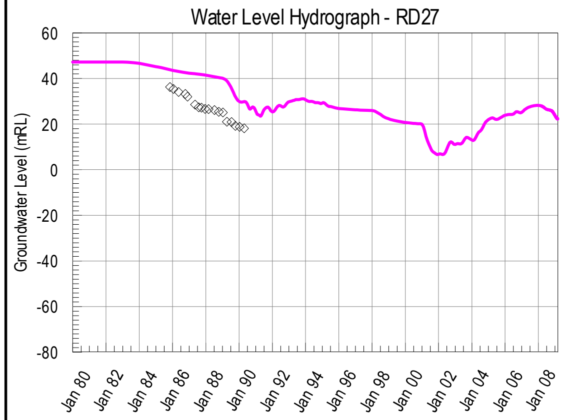
Schlumberger WATER SERVICES

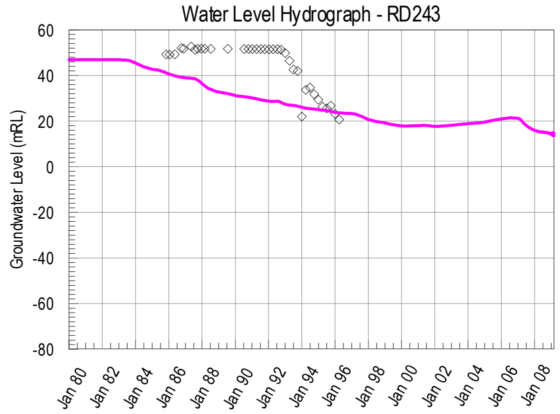
Attachment B4 Historical - 2010 recalibrations - ZWC

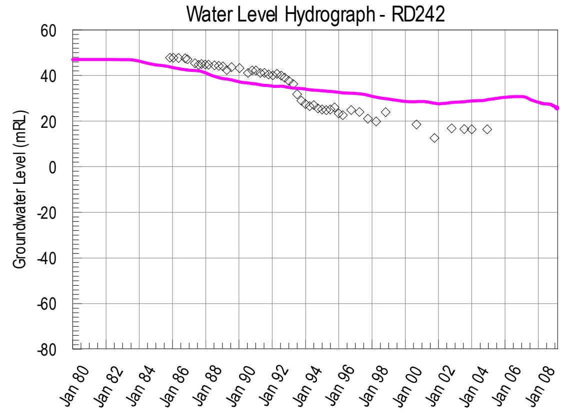










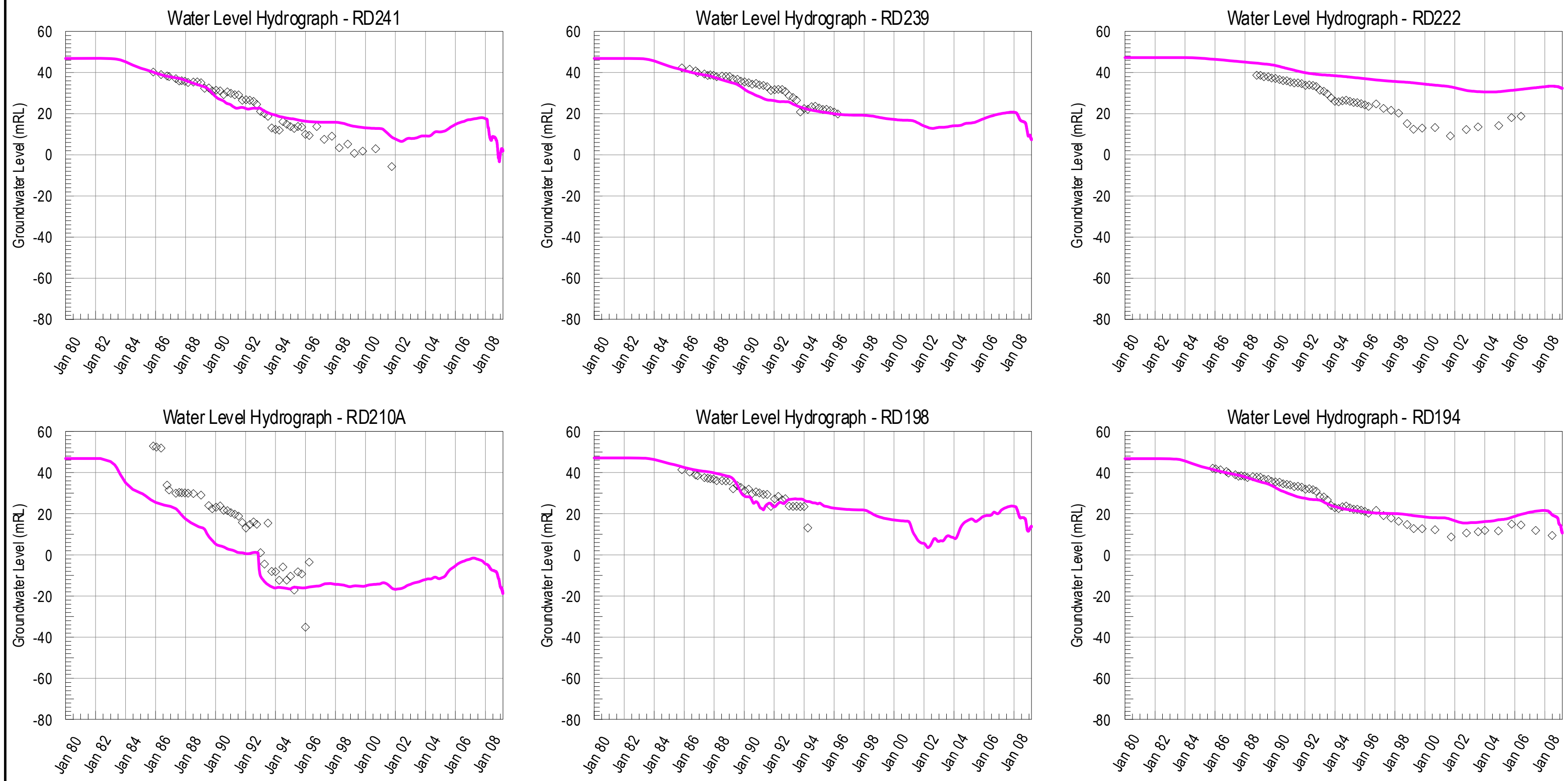


Observed

Modelled

Schlumberger
WATER SERVICES

Attachment B5 Historical - 2010 recalibrations - ZWC



Observed

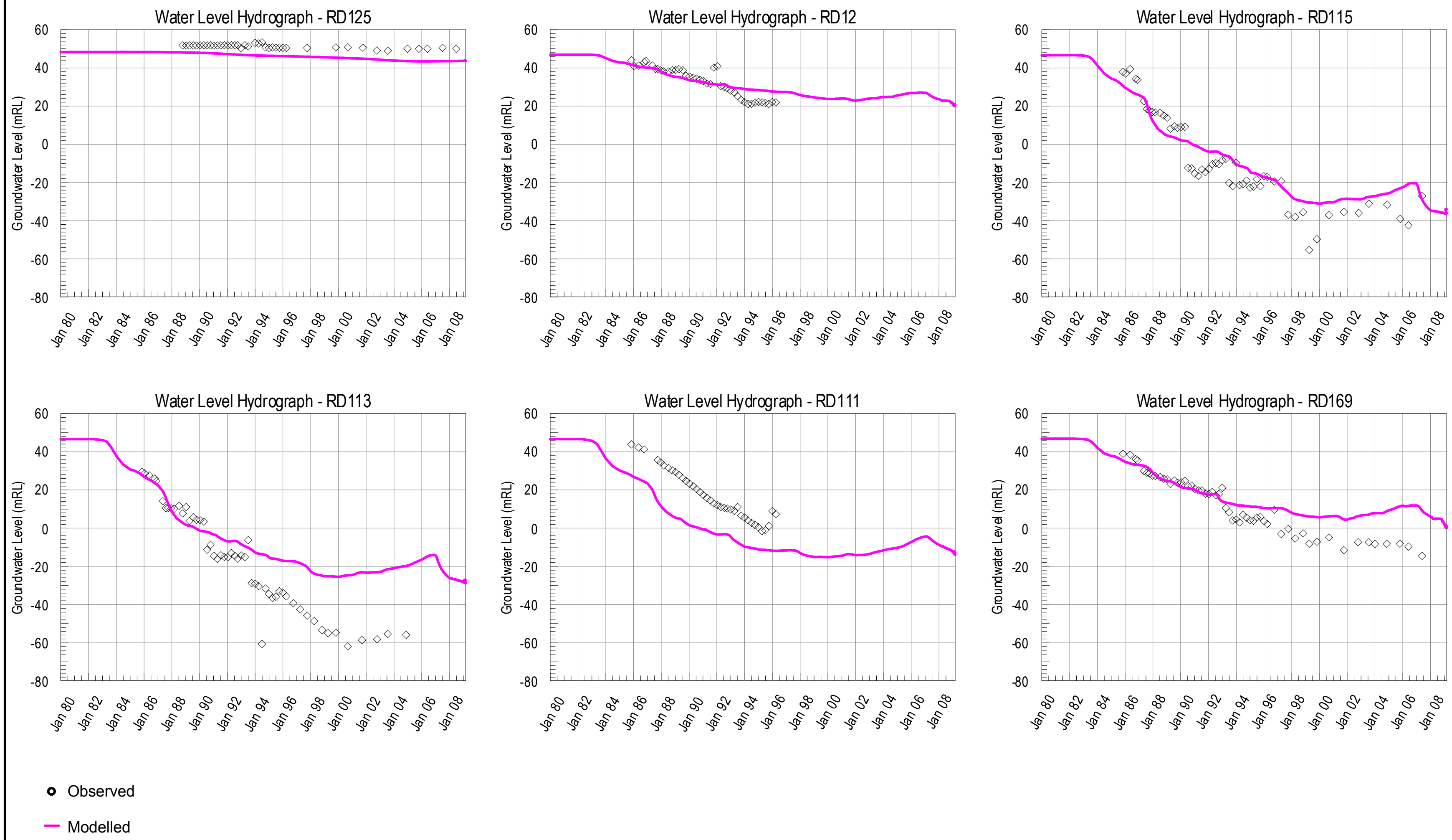
Modelled

Schlumberger
WATER SERVICES

Attachment B6 Historical - 2010 recalibrations - ZWC

Schlumberger WATER SERVICES

Attachment B7 Historical - 2010 recalibrations - ZWC



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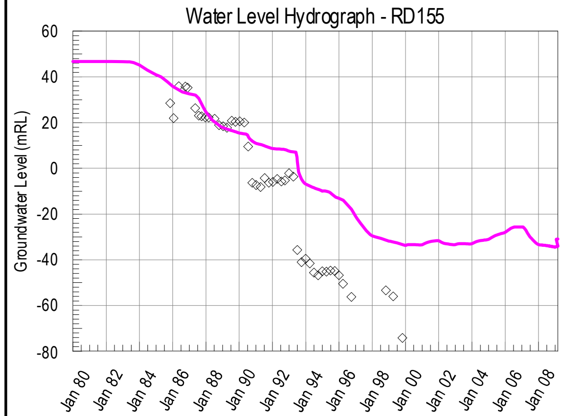
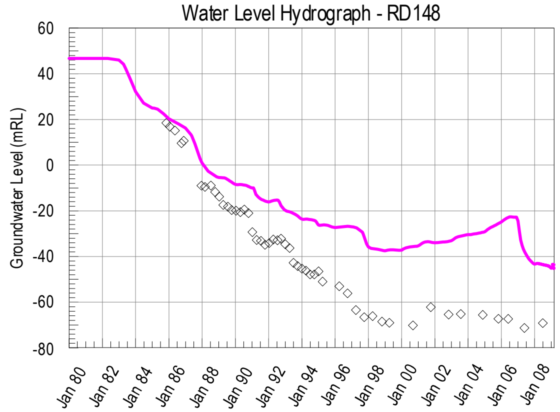
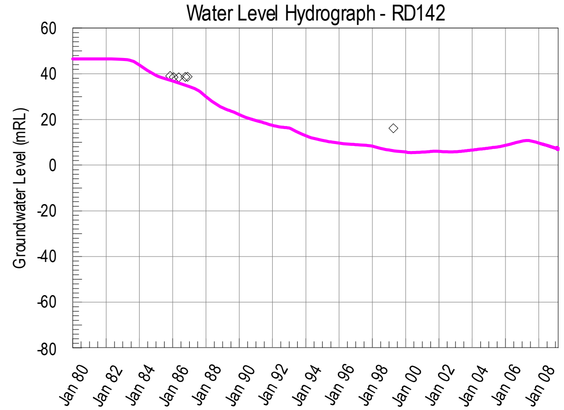
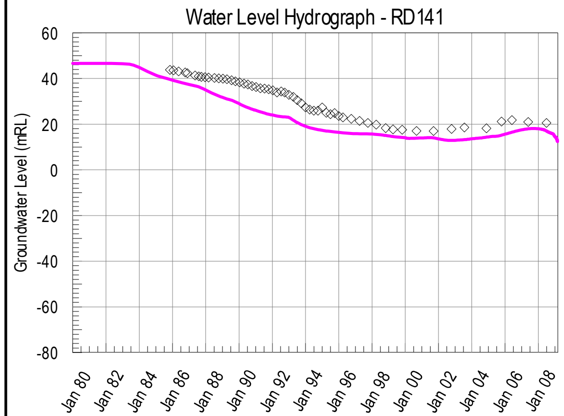
WATER SERVICES

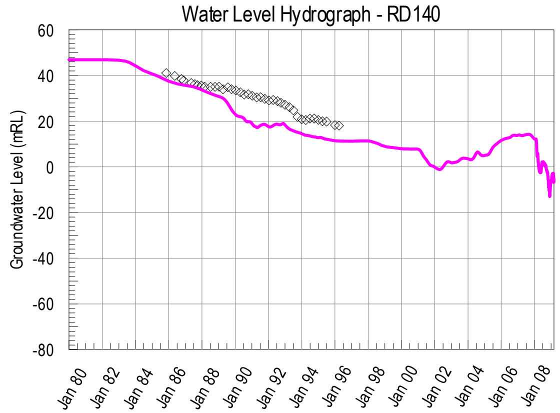
Attachment B8 Historical - 2010 recalibrations - ZWC

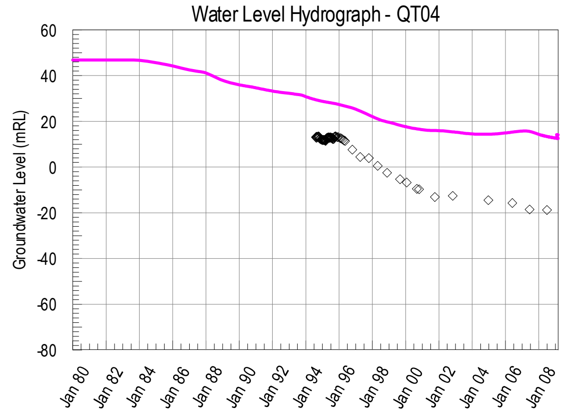












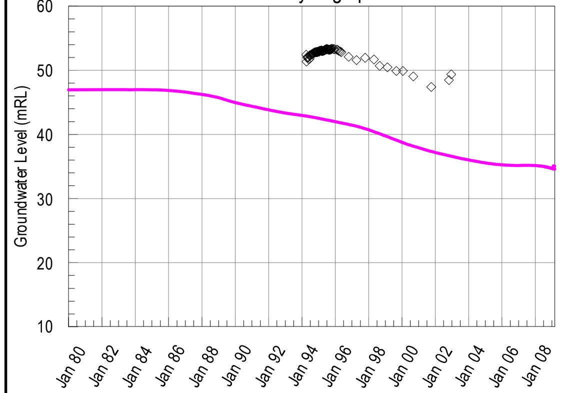
Observed

Modelled

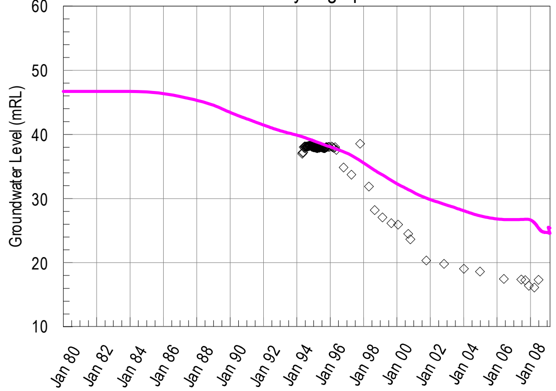
Schlumberger WATER SERVICES

Attachment B9 Historical - 2010 recalibrations - ZWC

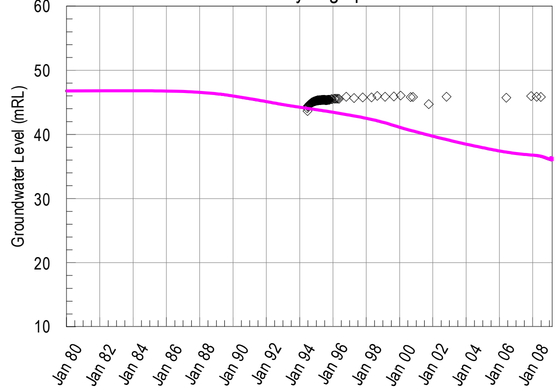
Water Level Hydrograph - QT03



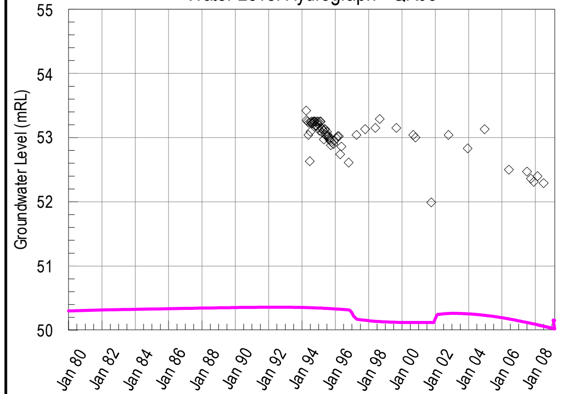
Water Level Hydrograph - QT02



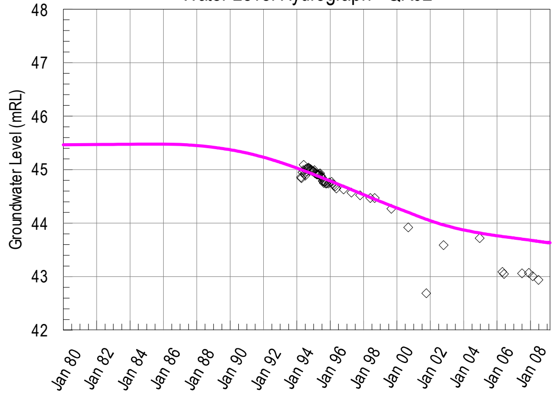
Water Level Hydrograph - QT01



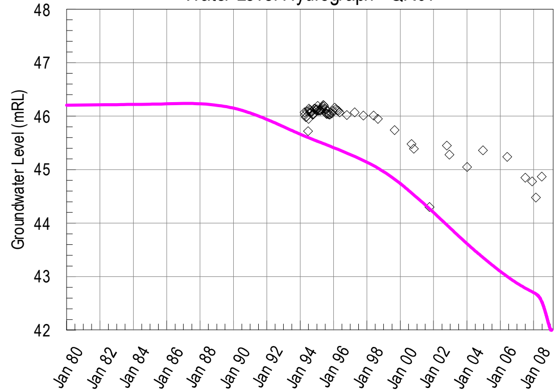
Water Level Hydrograph - QR03



Water Level Hydrograph - QR02



Water Level Hydrograph - QR01



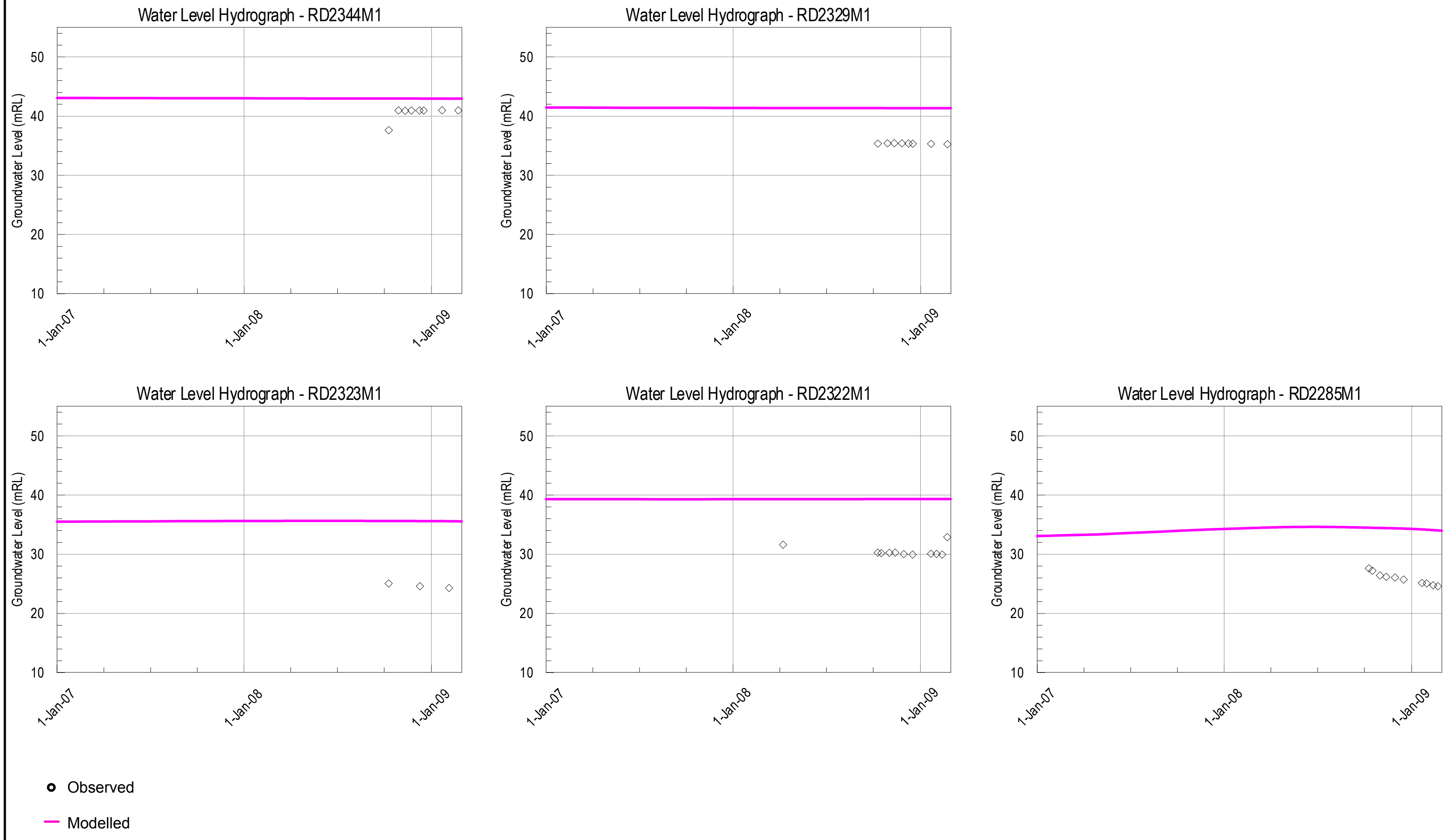
Observed

Modelled

Schlumberger WATER SERVICES

Attachment B10 Historical - 2010 recalibrations - ZWC

Attachment C
ZWC trial depressurisation
observed and simulated hydrographs



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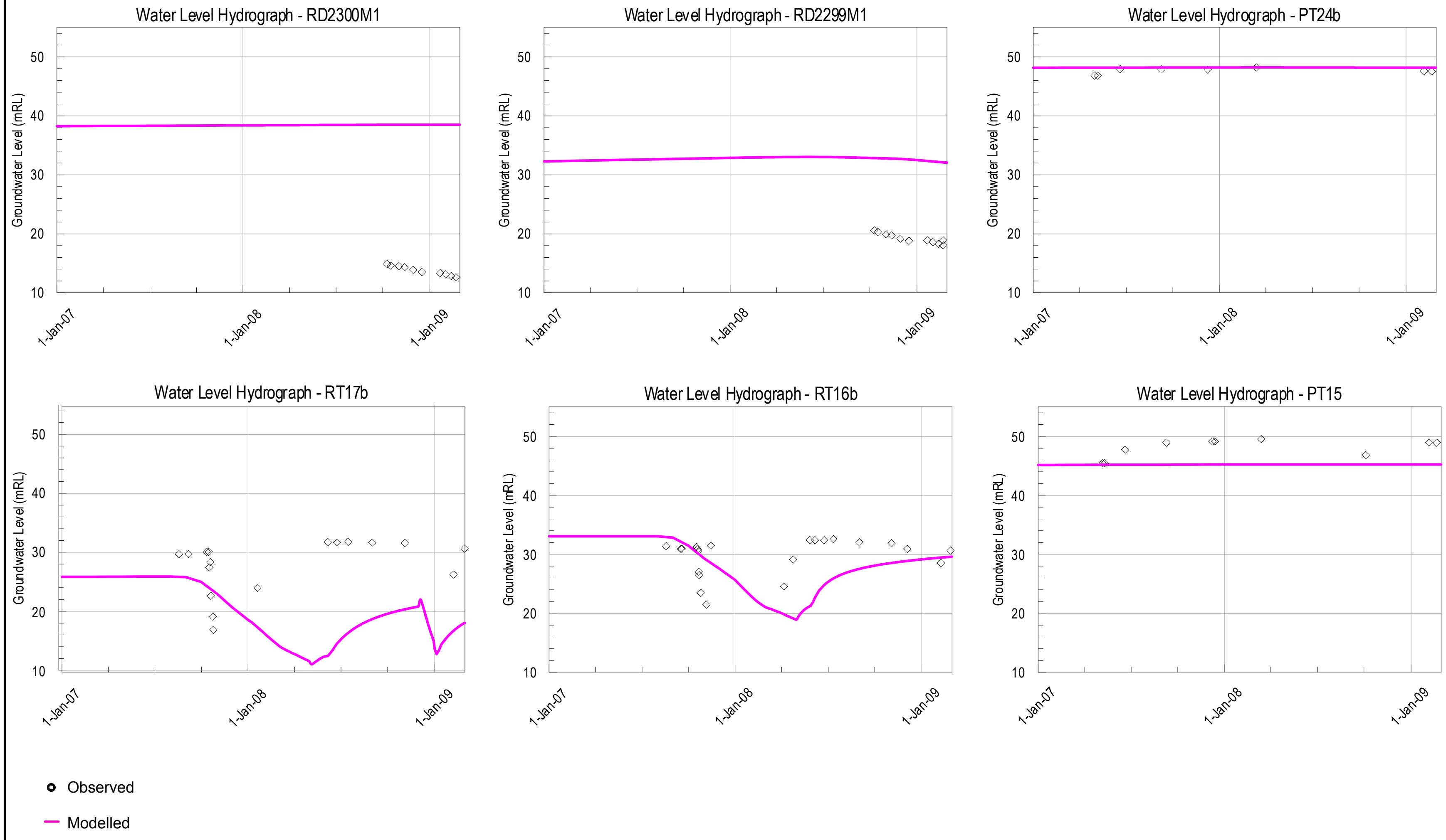
WATER SERVICES

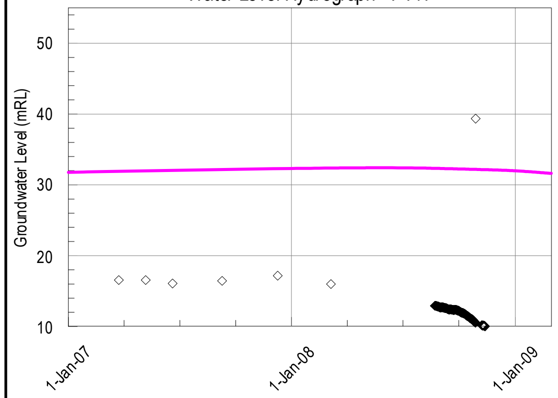
Attachment C1 Trial depressurisation hydrographs



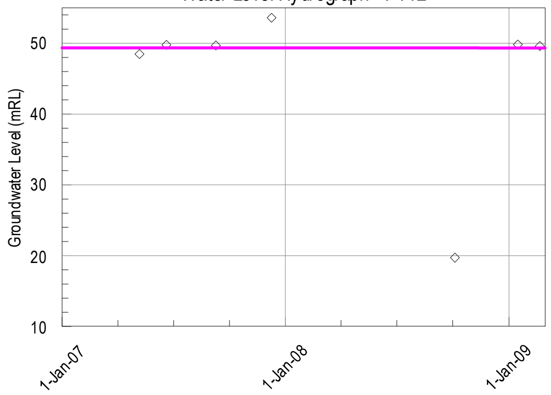
Schlumberger WATER SERVICES

Attachment C2 Trial depressurisation hydrographs

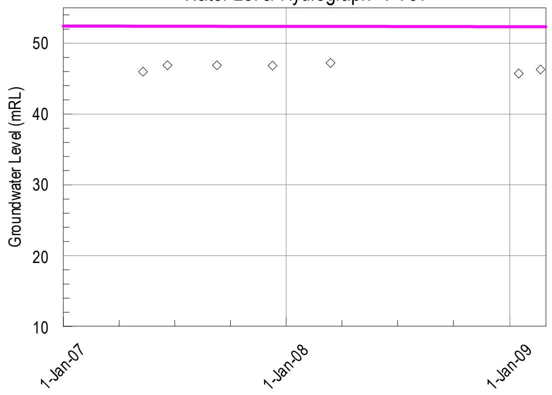
Water Level Hydrograph - PT17



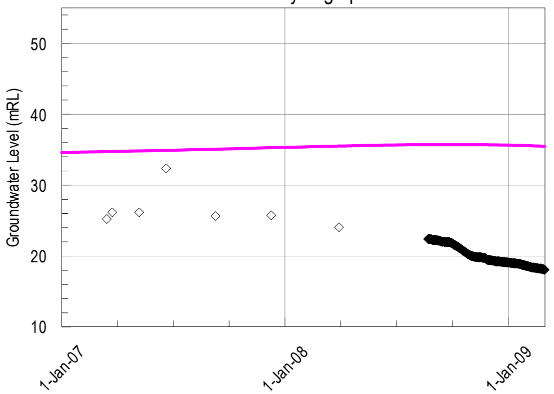
Water Level Hydrograph - PT12



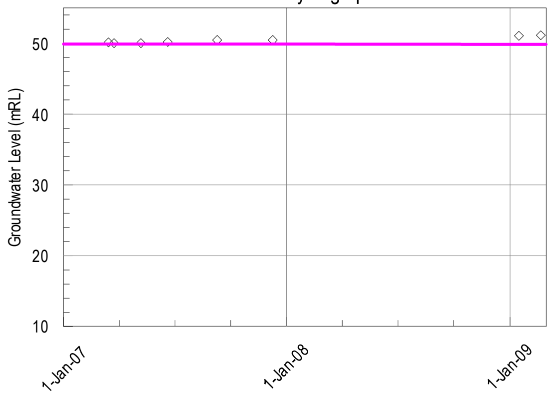
Water Level Hydrograph - PT31



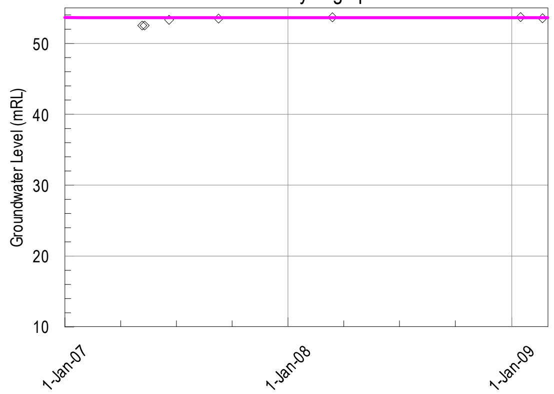
Water Level Hydrograph - PT16



Water Level Hydrograph - PT9



Water Level Hydrograph - PT7

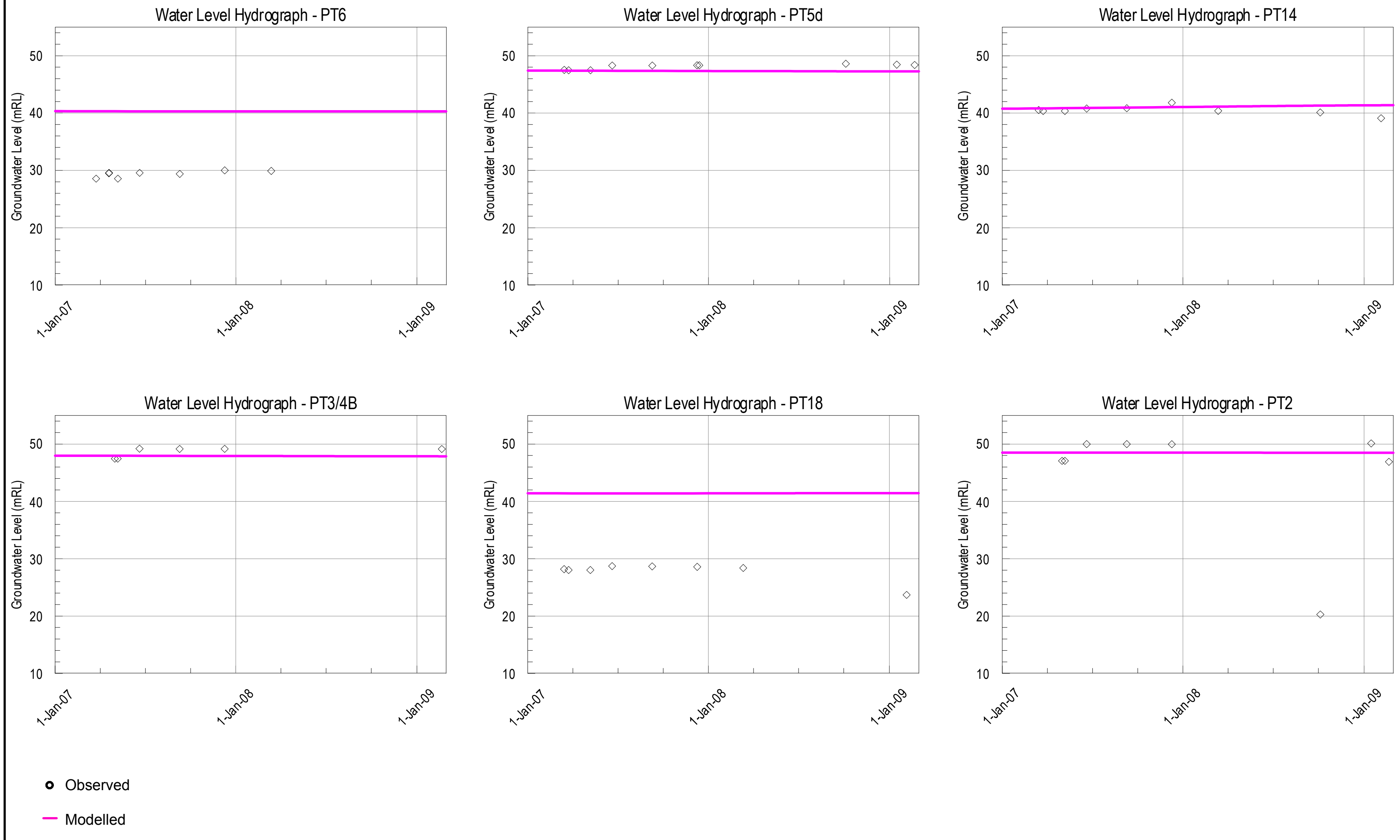


Observed

Modelled

Schlumberger
WATER SERVICES

Attachment C3 Trial depressurisation hydrographs



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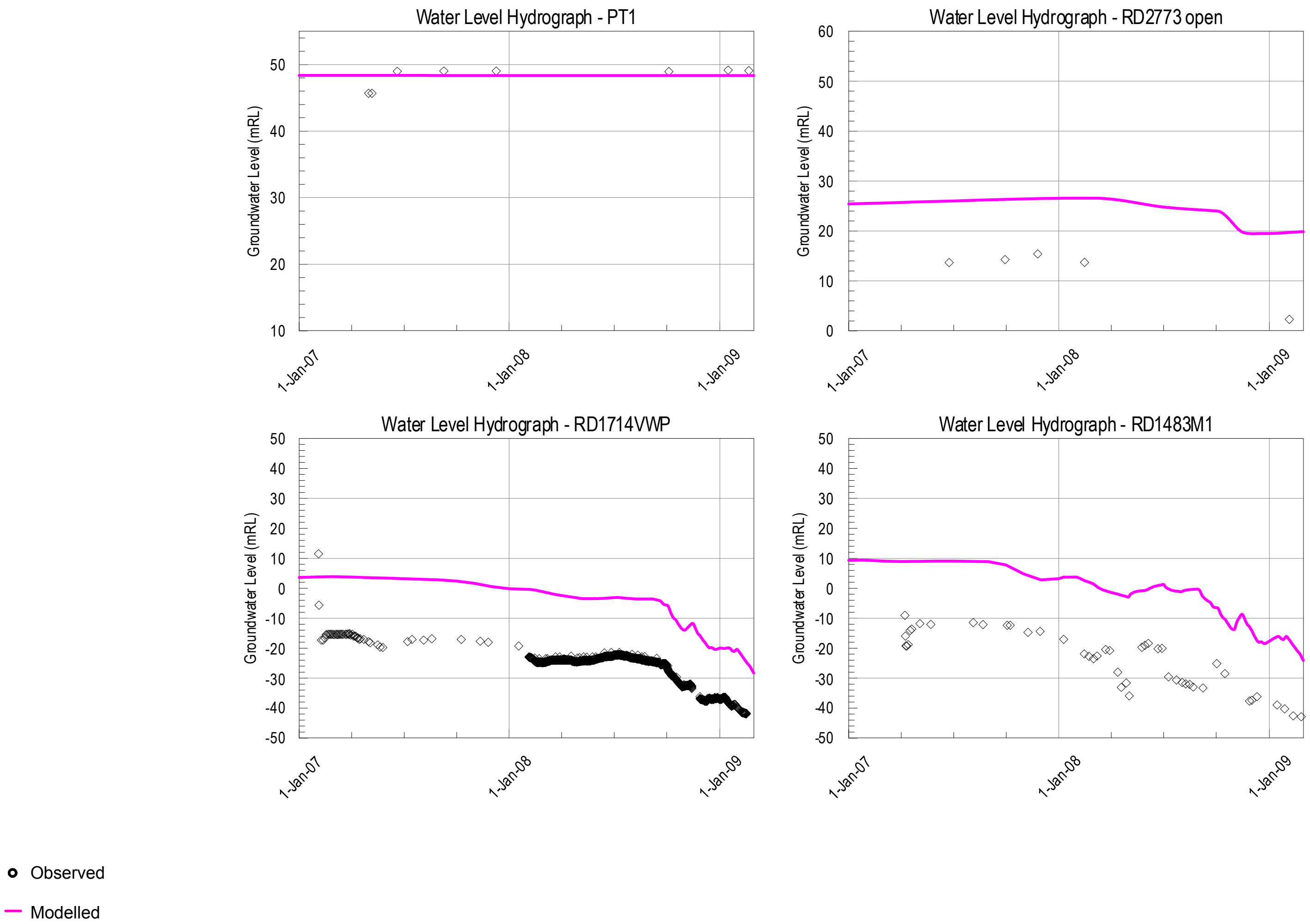
Attachment C4 Trial depressurisation hydrographs



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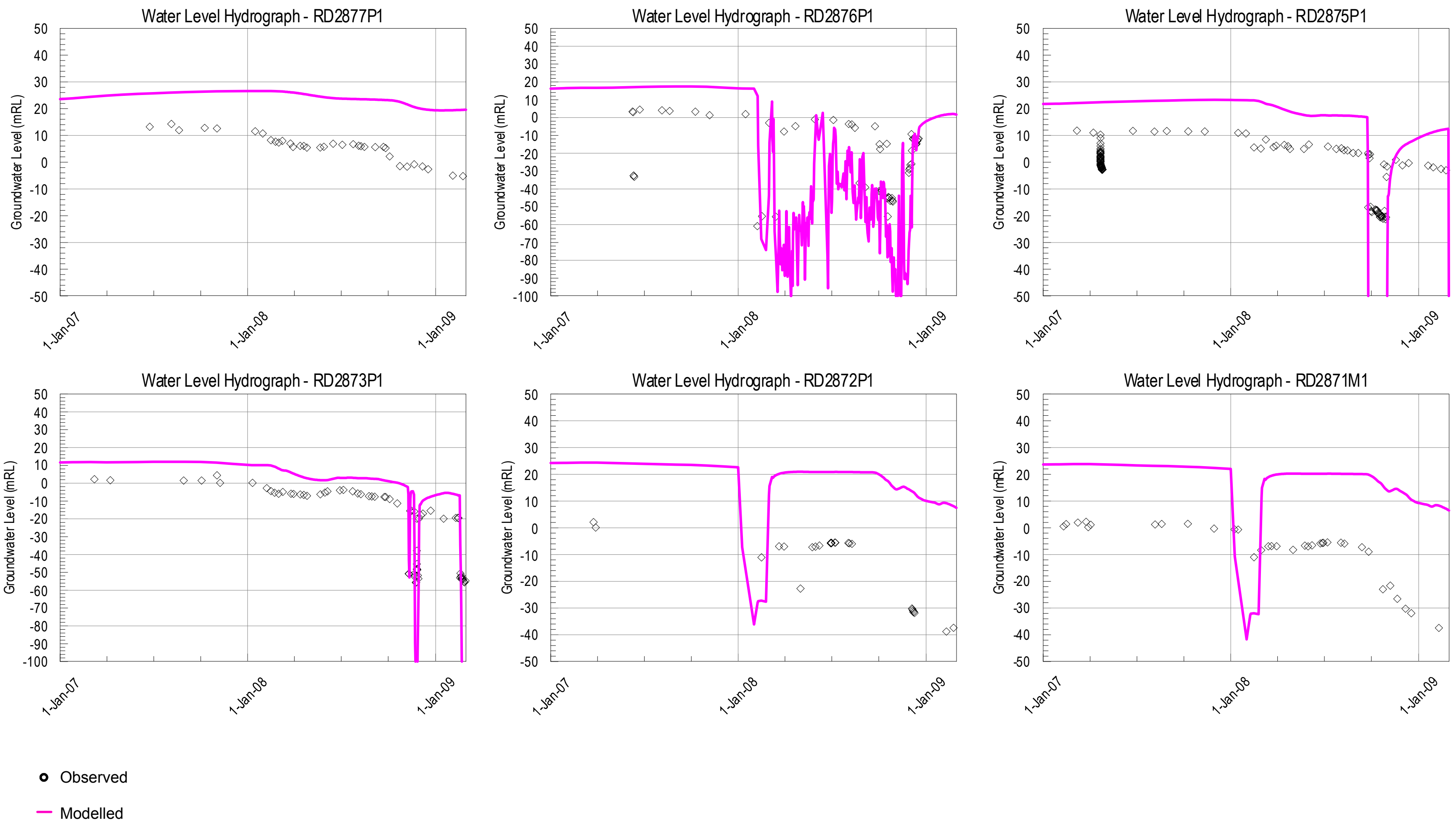
WATER SERVICES

Attachment C5 Trial depressurisation hydrographs



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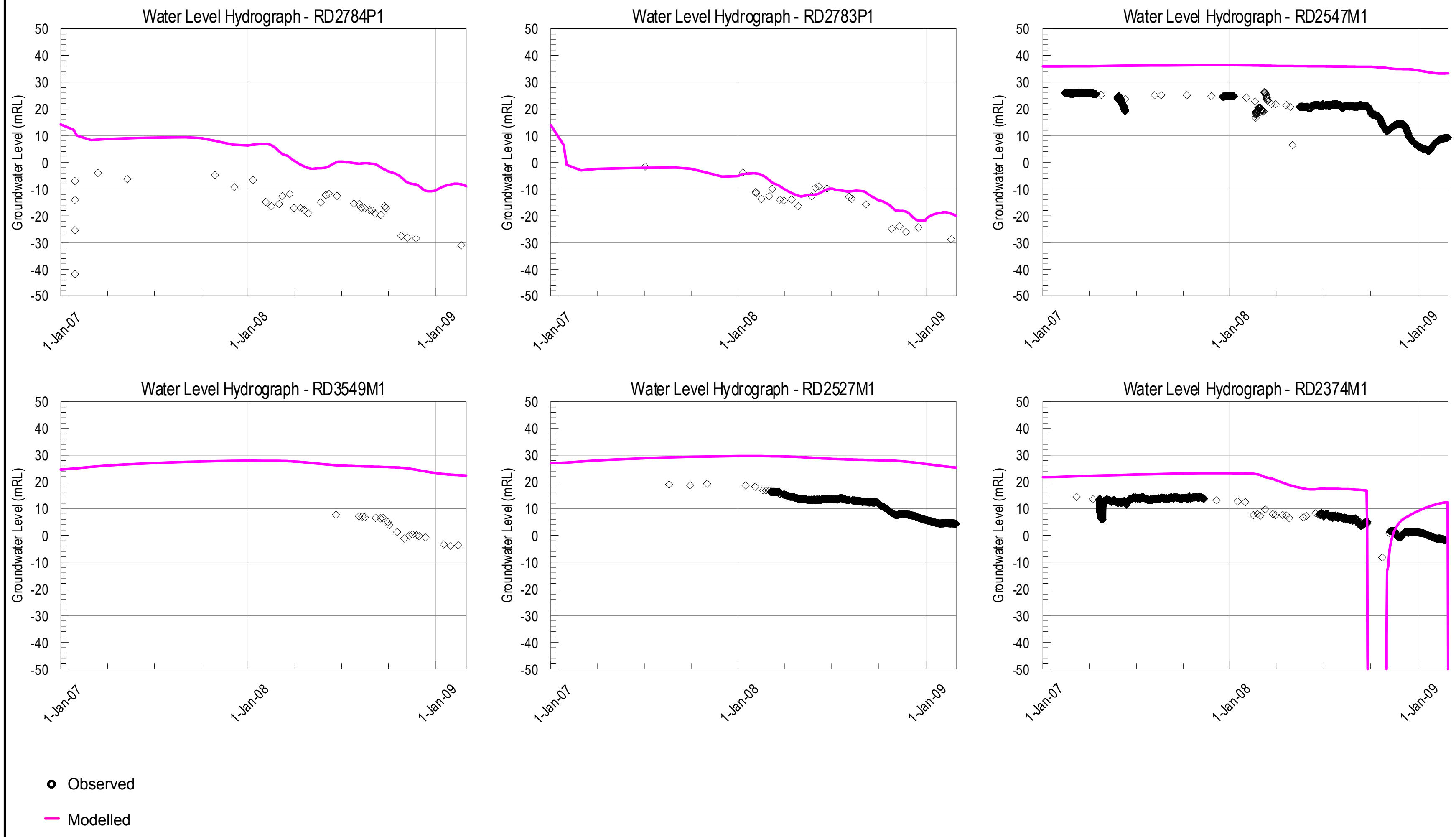
Attachment C6 Trial depressurisation hydrographs



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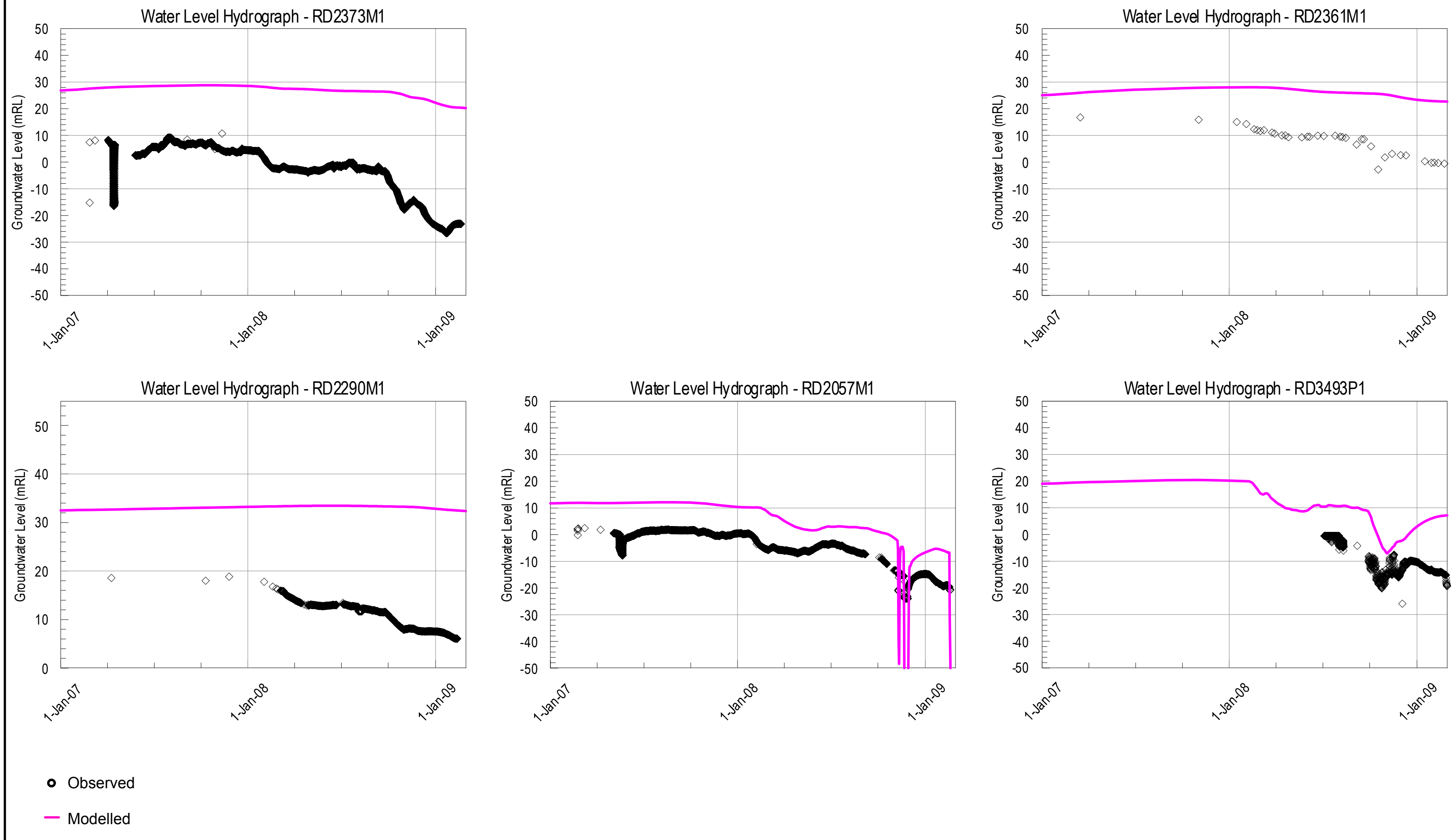
WATER SERVICES

Attachment C7 Trial depressurisation hydrographs



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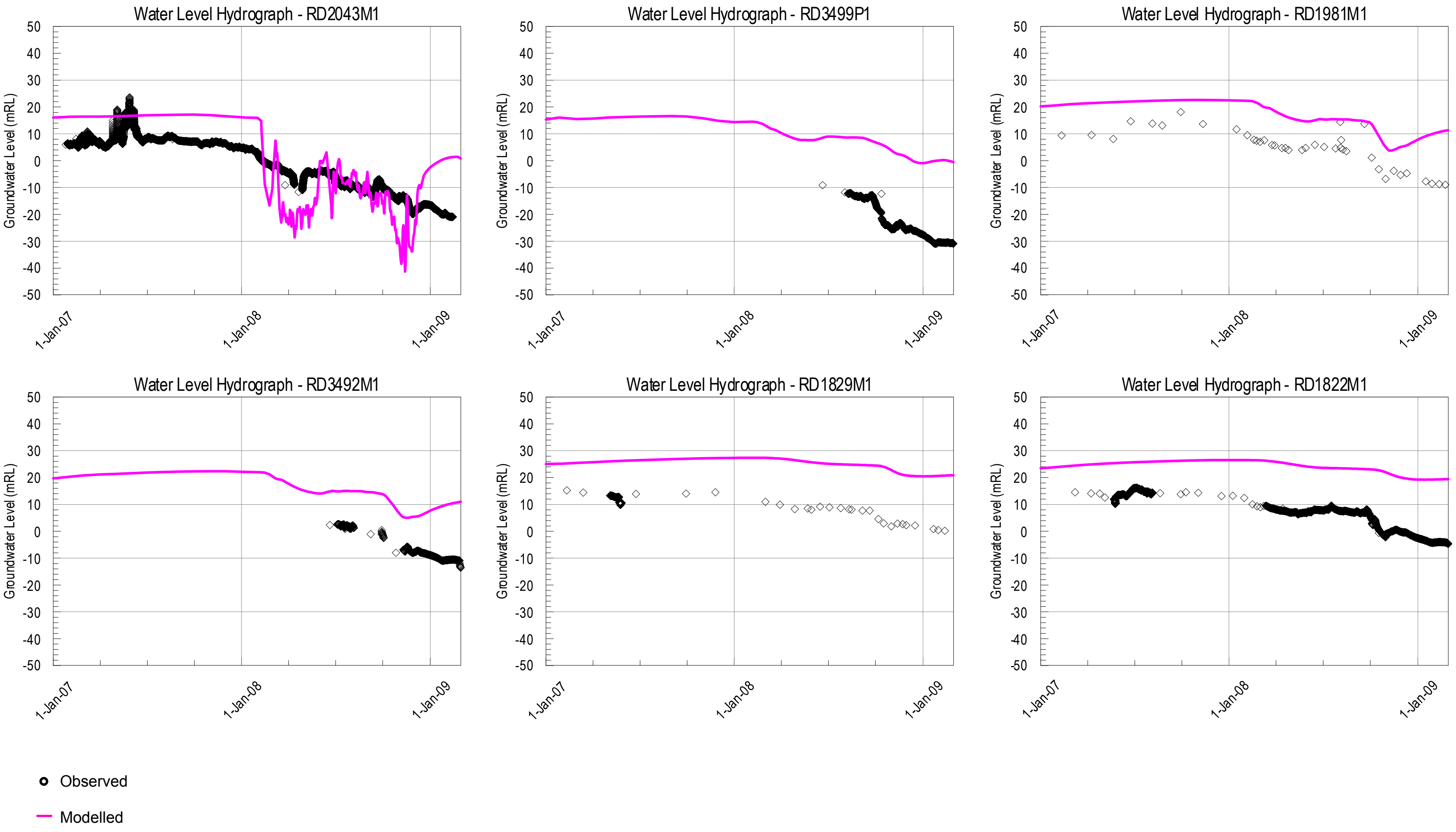
Attachment C8 Trial depressurisation hydrographs



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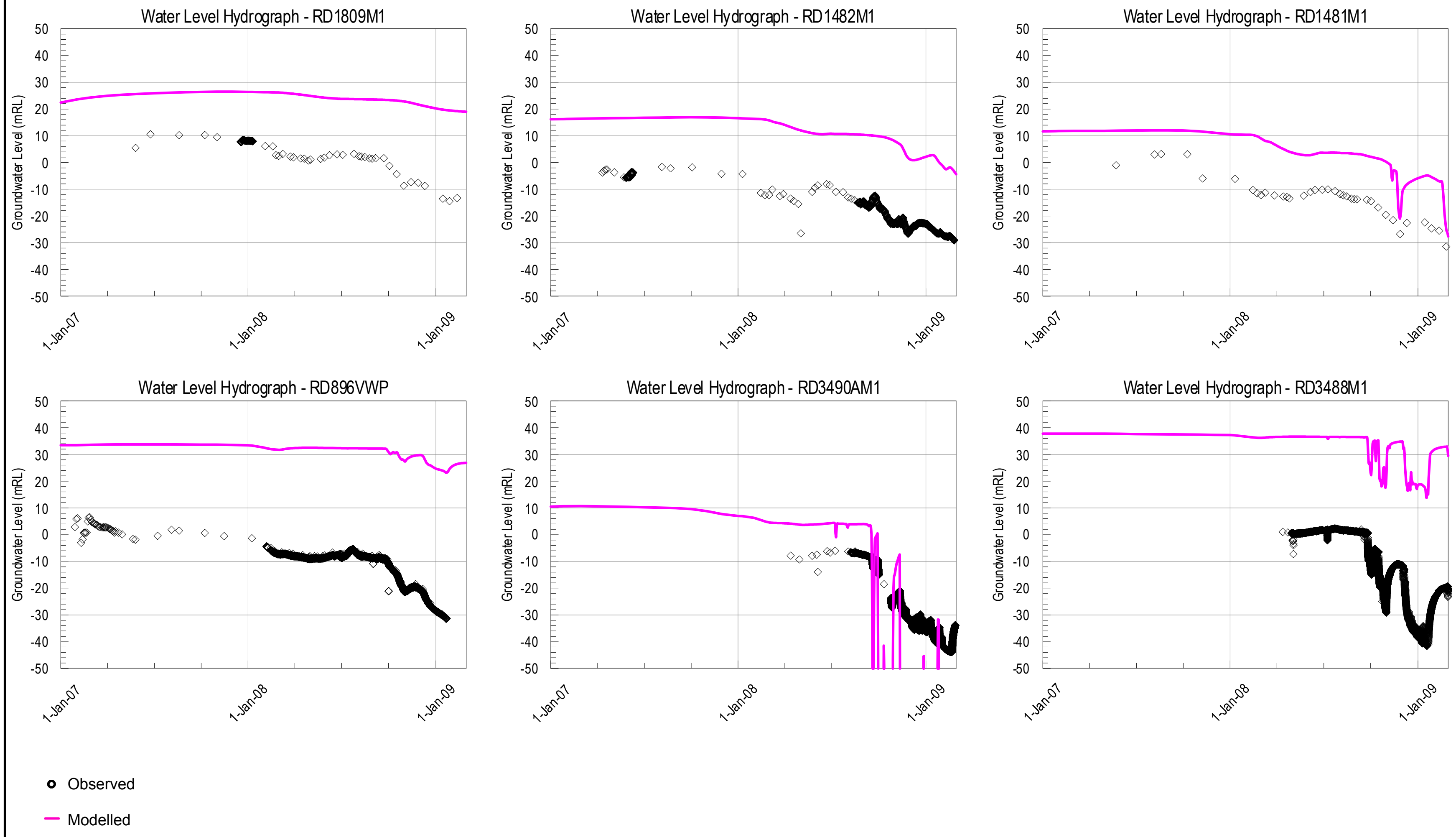
Attachment C9 Trial depressurisation hydrographs



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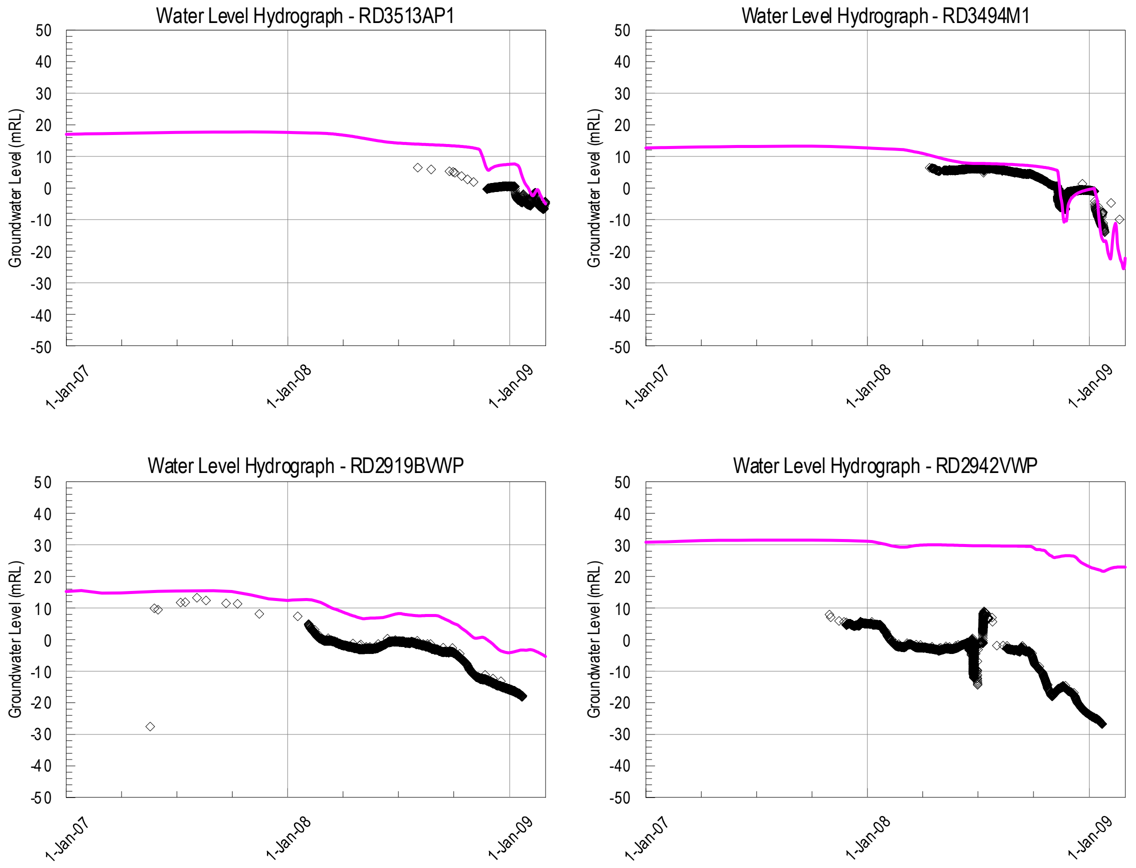
Attachment C10 Trial depressurisation hydrographs



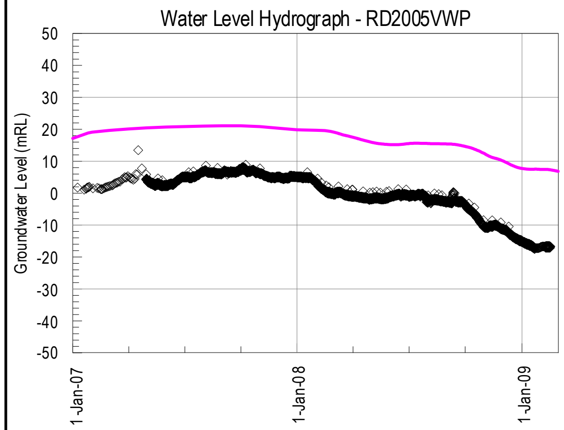
Observed

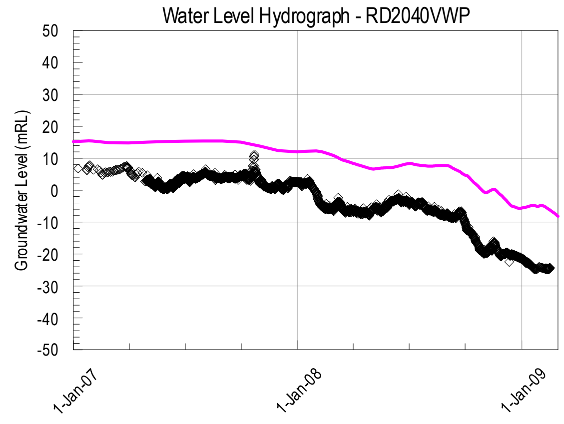
Modelled

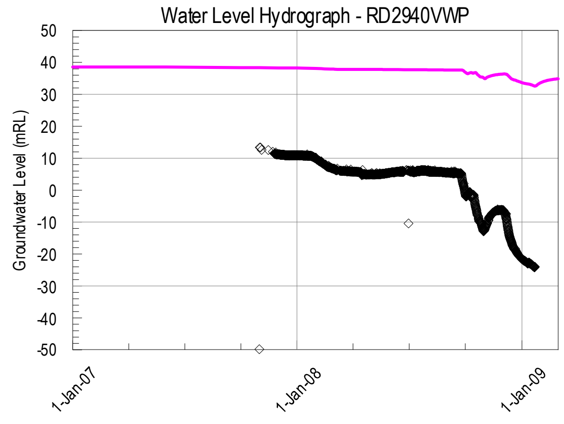
Schlumberger

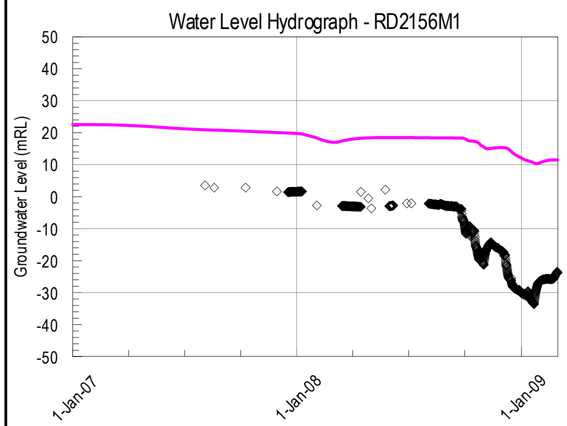
WATER SERVICES

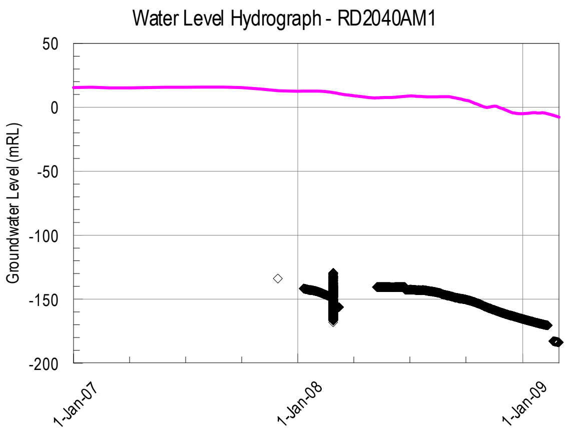
Attachment C11 Trial depressurisation hydrographs

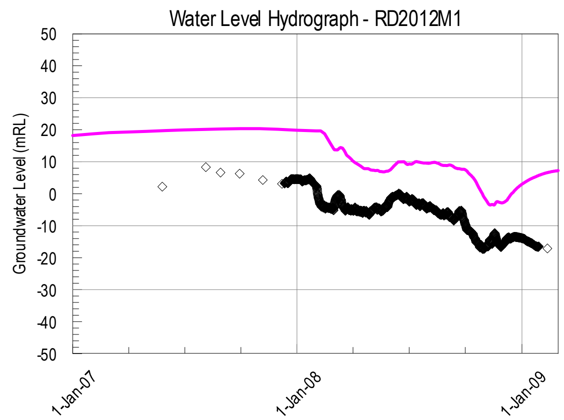










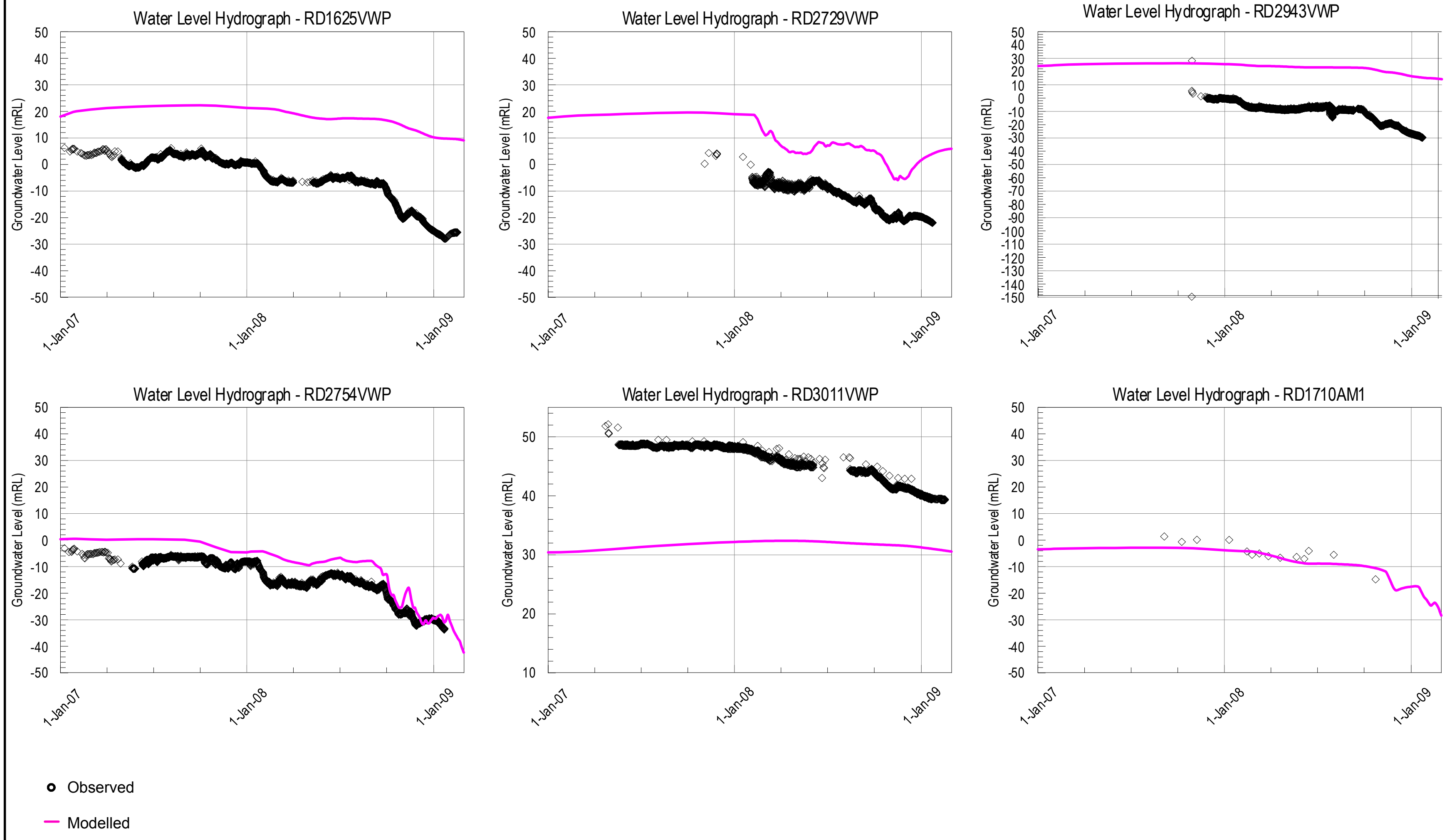


Observed

Modelled

Schlumberger WATER SERVICES

Attachment C12 Trial depressurisation hydrographs



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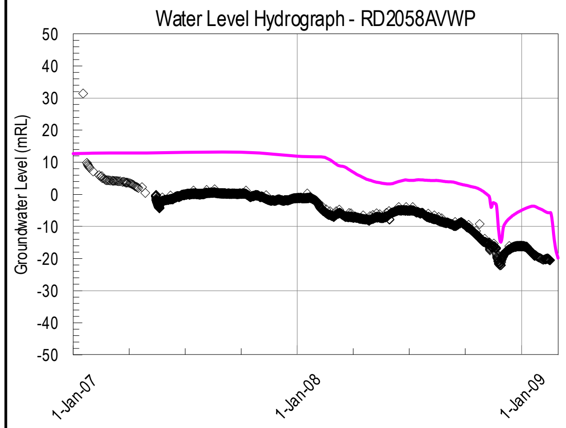
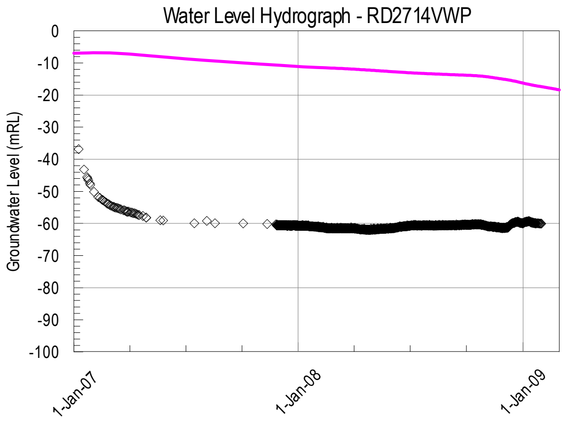
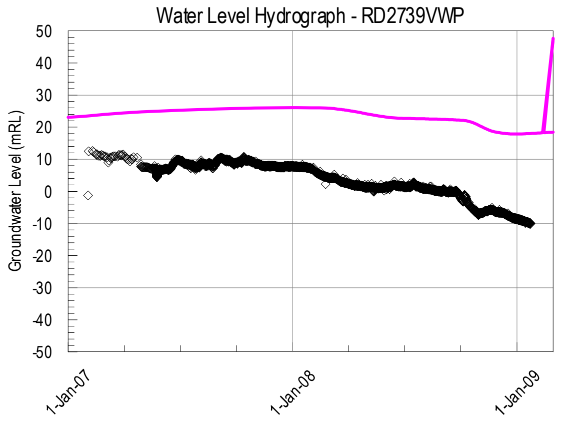
Attachment C13 Trial depressurisation hydrographs







Observed

Modelled

Schlumberger
WATER SERVICES

Attachment C14 Trial depressurisation hydrographs

Attachment D
Hydraulic testing in the Stuart Shelf

Attachment D.1. Measured hydraulic conductivity values

Well ID	Aquifer Unit	Test Type (analysis)	K (m/d)	Easting (GDA)	Northing (GDA)	Source
TPW-4	*Tent Hill*	*Constant Rate Recovery*	*3.3E-01*	*676513*	*6633370*	*Evap Pond Drilling Completion Report (REM)*
TPW-5	*Tent Hill*	*Constant Rate Pump Test*	*1.4E-01*	*677884*	*6634860*	*Evap Pond Drilling Completion Report (REM)*
TPW-4	*Tent Hill*	*Constant Rate Recovery*	*2.4E-01*	*676513*	*6633370*	*Evap Pond Drilling Completion Report (REM)*
TPW-5	*Tent Hill*	*Constant Rate Pump Test*	*1.1E-02*	*677884*	*6634860*	*Evap Pond Drilling Completion Report (REM)*
TPW-4	*Tent Hill*	*Constant Rate Recovery*	*1.4E-01*	*676513*	*6633370*	*Evap Pond Drilling Completion Report (REM)*
TPW-5	*Tent Hill*	*Constant Rate Pump Test (pumped well)*	*1.7E-02*	*677884*	*6634860*	*Evap Pond Drilling Completion Report (REM)*
PT-6	*Tent Hill*	*Constant Rate Pump Test (monitoring well)*	*1.0E+00*	*686901*	*6632525*	*PFS Saline Water Supply (REM)*
TPW-2	*Tent Hill*	*Constant Rate Pump Test (pumped well)*	*2.0E+01*	*686936*	*6632520*	*PFS Saline Water Supply (REM)*
PT-5d	*Tent Hill*	*Constant Rate Pump Test (monitoring well)*	*3.0E-02*	*675620*	*6624935*	*PFS Saline Water Supply (REM)*
TPW-3	*Tent Hill*	*Constant Rate Pump Test (pumped well)*	*1.0E-01*	*675651*	*6624933*	*PFS Saline Water Supply (REM)*
PT-14	*Tent Hill*	*Constant Rate Pump Test (monitoring well)*	*7.0E-02*	*682087*	*6626131*	*PFS Saline Water Supply (REM)*
TPW-1	*Tent Hill*	*Constant Rate Recovery Test (pumped well)*	*2.0E-01*	*682089*	*6626155*	*PFS Saline Water Supply (REM)*
PT-6	*Tent Hill*	*Constant Rate Recovery Test (monitoring well)*	*3.4E+01*	*686901*	*6632525*	*PFS Saline Water Supply (REM)*
TPW-2	*Tent Hill*	*Constant Rate Recovery Test (pumped well)*	*2.5E+01*	*686936*	*6632520*	*PFS Saline Water Supply (REM)*
PT-5d	*Tent Hill*	*Constant Rate Recovery Test (monitoring well)*	*4.0E-02*	*675620*	*6624935*	*PFS Saline Water Supply (REM)*
TPW-3	*Tent Hill*	*Constant Rate Recovery Test (pumped well)*	*1.0E-01*	*675651*	*6624933*	*PFS Saline Water Supply (REM)*
PT-14	*Tent Hill*	*Constant Rate Recovery Test (monitoring well)*	*2.0E-01*	*682087*	*6626131*	*PFS Saline Water Supply (REM)*
TPW-1	*Tent Hill*	*Constant Rate Pump Test (Clark)*	*2.1E+01*	*682089*	*6626155*	*PFS Saline Water Supply (REM)*
TPW-2	*Tent Hill*	*Constant Rate Pump Test (Clark)*	*2.3E+01*	*686901*	*6632525*	*PFS Saline Water Supply (REM)*
TPW-3	*Tent Hill*	*Constant Rate Pump Test (Clark)*	*7.7E-03*	*675620*	*6624935*	*PFS Saline Water Supply (REM)*
PT-31	*Tent Hill*	*Slug Test (Hvorslev)*	*9.9E-02*	*682087*	*6626131*	*PFS Saline Water Supply (REM)*
PT-24b	*Tent Hill*	*Slug Test (Hvorslev)*	*2.0E-01*	*692701*	*6624120*	*PFS Saline Water Supply (REM)*
PT-24a	*Tent Hill*	*Slug Test (Hvorslev)*	*4.0E-02*	*676805*	*6627765*	*PFS Saline Water Supply (REM)*
PT-18	*Tent Hill*	*Slug Test (Hvorslev)*	*7.0E-01*	*687332*	*6629082*	*PFS Saline Water Supply (REM)*
PT-17	*Tent Hill*	*Slug Test (Hvorslev)*	*2.0E-01*	*684464*	*6631390*	*PFS Saline Water Supply (REM)*
PT-16	*Tent Hill*	*Slug Test (Hvorslev)*	*5.0E-01*	*683823*	*6627644*	*PFS Saline Water Supply (REM)*
PT-15	*Tent Hill*	*Slug Test (Hvorslev)*	*2.0E-01*	*678297*	*6627345*	*PFS Saline Water Supply (REM)*
PT-14	*Tent Hill*	*Slug Test (Hvorslev)*	*9.0E-01*	*682089*	*6626155*	*PFS Saline Water Supply (REM)*
PT-12	*Tent Hill*	*Slug Test (Hvorslev)*	*2.0E-01*	*675342*	*6618130*	*PFS Saline Water Supply (REM)*
PT-9	*Tent Hill*	*Slug Test (Hvorslev)*	*1.0E-01*	*677991*	*6617546*	*PFS Saline Water Supply (REM)*
PT-7	*Tent Hill*	*Slug Test (Hvorslev)*	*4.0E-01*	*683526*	*6614555*	*PFS Saline Water Supply (REM)*
PT-6	*Tent Hill*	*Slug Test (Hvorslev)*	*1.2E+00*	*686936*	*6632520*	*PFS Saline Water Supply (REM)*
PT-5d	*Tent Hill*	*Slug Test (Hvorslev)*	*5.0E-01*	*675651*	*6624933*	*PFS Saline Water Supply (REM)*
PT-5a	*Tent Hill*	*Slug Test (Hvorslev)*	*1.2E-01*	*674761*	*6628083*	*PFS Saline Water Supply (REM)*
PT-2	*Tent Hill*	*Slug Test (Hvorslev)*	*2.0E-01*	*671735*	*6621617*	*PFS Saline Water Supply (REM)*
PT-1	*Tent Hill*	*Slug Test (Hvorslev)*	*1.0E-01*	*671433*	*6622612*	*PFS Saline Water Supply (REM)*
RD100	*ZWC*	*Unknown*	*1.3E-03*	*681422*	*6630916*	*AGC (1982)*
RD1350P1	*ZWC*	*Theis analysis*	*2.0E-01*	*679028*	*6632302*	*BHPB (2001)*
RD1463	*ZWC*	*Unknown*	*8.3E-03*	*682344*	*6630915*	*GRM (June 2005)*
RD1463	*ZWC*	*Unknown*	*5.5E-04*	*682344*	*6630915*	*GRM (June 2005)*

RD1489	ZWC	Unknown	2.4E-02	682495	6630238	GRM (June 2005)
RD1489	ZWC	Unknown	9.2E-02	682495	6630238	GRM (June 2005)
RD1687	ZWC	Unknown	2.4E-03	682200	6629829	GRM (June 2005)
RD1687	ZWC	Unknown	3.1E-03	682200	6629829	GRM (June 2005)
RD2057	ZWC	Estimated based on precollar falling head test and assumed aquifer thickness of 20 m.	2.0E-01	682420	6630363	WMC (2007)
RD2068	ZWC	Estimated based on precollar falling head test and assumed aquifer thickness of 20 m.	2.0E-01	682667	6630632	WMC (2007)
RD2373	ZWC	Estimated based on precollar falling head test and assumed aquifer thickness of 20 m.	1.0E-01	681476	6629289	WMC (2007)
RD2373M1	ZWC	Theis analysis. Pumping at RD2874P1.	1.0E-01	681477	6629289	WMC (2007)
RD2373M1	ZWC	Hantush-Jacob analysis. Pumping at RD2874P1.	1.0E-01	681477	6629289	WMC (2007)
RD2874P1	ZWC	Hantush-Jacob analysis. Pumping at RD2874P1.	1.0E-01	681474	6629289	WMC (2007)
RD2874P1	ZWC	Theis analysis.	1.0E-01	681474	6629289	WMC (2007)
RT-2	ZAL	Constant Rate Pump Test (mid time)	6.8E+02	691869	6656802	Regional EIS Drilling Completion Report (REM)
RT-2	ZAL	Constant Rate Pump Test (late time)	2.6E+02	691869	6656802	Regional EIS Drilling Completion Report (REM)
RT-5	ZAL	Constant Rate Pump Test (mid time)	1.8E+02	712726	6661145	Regional EIS Drilling Completion Report (REM)
RT-2	ZAL	Recovery Test	5.6E+02	691869	6656802	Regional EIS Drilling Completion Report (REM)
RT-5	ZAL	Recovery Test	1.3E+02	712726	6661145	Regional EIS Drilling Completion Report (REM)
RT-5	ZAL	Recovery Test	4.1E+01	712726	6661145	Regional EIS Drilling Completion Report (REM)
MAR-1	ZAL	Pump Test (Jacob Straight Line)	1.9E+00	686082	6645061	Motherwell Selection phase Study(REM)
MAR-2	ZAL	Pump Test (Theis Recovery)	3.0E+01	694200	6660880	Motherwell Selection phase Study(REM)
MAR-3	ZAL	Pump Test (Clark Model)	2.5E+01	691905	6656771	Motherwell Selection phase Study(REM)
MAR-4	ZAL	Airlift Pump Test	3.7E+01	681280	6626162	Motherwell Selection phase Study(REM)
PT-24a	ZAL	Constant Rate Pump Test	6.9E+00	676816	6627754	PFS Saline Water Supply (REM)
LP2	ZAL	Unknown	9.0E-01	676593	6631891	WMC (2007) - reconciled from 1998 test
LP2	ZAL	Unknown	1.8E+00	676593	6631891	WMC (2007) - reconciled from 1995 test
LP3	ZAL	Unknown	1.5E+00	675573	6630947	WMC (2007) - reconciled from 1998 test
LP3	ZAL	Unknown	1.5E+00	675573	6630947	WMC (2007) - reconciled from 1995 test
LP4	ZAL	Unknown	2.0E-01	677448	6630891	WMC (2007) - reconciled from 1998 test
LP6	ZAL	Unknown	3.0E-01	677615	6631069	WMC (2007) - reconciled from 1998 test
LP7	ZAL	Unknown	6.0E-01	677521	6630351	WMC (2007) - reconciled from 1998 test
LP8	ZAL	Unknown	5.0E-01	677347	6631336	WMC (2007) - reconciled from 1998 test
PB1	ZAL	Unknown	2.6E+00	674348	6631701	WMC (2007) - reconciled from 1998 test
PB2	ZAL	Unknown	1.2E+00	674848	6631891	WMC (2007) - reconciled from 1998 test
PB3	ZAL	Unknown	2.0E-01	676048	6631862	WMC (2007) - reconciled from 1998 test
LT8	ZAL	Unknown	1.7E+00	677352	6631245	WMC (2007) - reconciled from 1998 test
LT3	ZAL	Unknown	4.0E-01	676528	6630038	WMC (2007) - reconciled from 1995 test
LT3	ZAL	Unknown	1.4E+00	676528	6630038	WMC (2007) - reconciled from 1995 test
LT1	ZAL	Unknown	4.0E-01	674810	6631172	WMC (2007) - reconciled from 1995 test
LT1	ZAL	Unknown	1.2E+00	674810	6631172	WMC (2007) - reconciled from 1995 test
LT6	ZAL	Unknown	3.0E-01	676352	6631279	WMC (2007) - reconciled from 1995 test
LT7	ZAL	Unknown	3.0E-01	676902	6631389	WMC (2007) - reconciled from 1995 test
LT5	ZAL	Unknown	2.0E-01	676709	6630893	WMC (2007) - reconciled from 1995 test
LT9	ZAL	Unknown	6.0E-01	677505	6630595	WMC (2007) - reconciled from 1995 test
LT4	ZAL	Unknown	1.1E+00	677115	6630589	WMC (2007) - reconciled from 1995 test
LT2	ZAL	Unknown	1.0E+00	676536	6631862	WMC (2007) - reconciled from 1995 test
LT2	ZAL	Unknown	1.9E+00	676536	6631862	WMC (2007) - reconciled from 1998 test

RD100	ZWT	Unknown	7.9E-04	681422	6630916	AGC (1982)
RD1489	ZWT	Unknown	1.1E-02	682495	6630238	GRM (June 2005)
RD1489	ZWT	Unknown	1.0E-02	682495	6630238	GRM (June 2005)
RD1687	ZWT	Unknown	1.6E-02	682200	6629829	GRM (June 2005)
RD1687	ZWT	Unknown	1.9E-02	682200	6629829	GRM (June 2005)
RD1803	ZWT	Unknown	6.8E-04	682677	6628960	GRM (June 2005)
RD1803	ZWT	Unknown	1.7E-04	682677	6628960	GRM (June 2005)
RT02B	ZWA	Slug Test (Bouwer & Rice / Hvorslev)	3.5E-03	712703	6661139	SKM 2010
RD100	ZWA	Unknown	2.6E-03	681422	6630916	AGC (1982)
RD100	ZWA	Unknown	3.6E-03	681422	6630916	AGC (1982)
RD100	ZWA	Unknown	4.3E-02	681422	6630916	AGC (1982)
RD100	ZWA	Unknown	8.2E-04	681422	6630916	AGC (1982)
RD100	ZWA	Unknown	3.0E-03	681422	6630916	AGC (1982)
RD100	ZWA	Unknown	4.5E-04	681422	6630916	AGC (1982)
RD100	ZWA	Unknown	7.7E-04	681422	6630916	AGC (1982)
RD100	ZWA	Unknown	2.8E-03	681422	6630916	AGC (1982)
RD100	ZWA	Unknown	2.9E-03	681422	6630916	AGC (1982)
RD1463	ZWA	Unknown	1.3E-01	682344	6630915	GRM (June 2005)
RD1463	ZWA	Unknown	2.4E-02	682344	6630915	GRM (June 2005)
RD1489	ZWA	Unknown	1.9E-01	682495	6630238	GRM (June 2005)
RD1489	ZWA	Unknown	8.0E-02	682495	6630238	GRM (June 2005)
RD1489	ZWA	Unknown	3.8E-03	682495	6630238	GRM (June 2005)
RD1489	ZWA	Unknown	3.9E-03	682495	6630238	GRM (June 2005)
RD1687	ZWA	Unknown	1.7E-03	682200	6629829	GRM (June 2005)
RD1687	ZWA	Unknown	1.9E-03	682200	6629829	GRM (June 2005)
RT05c	THZ	Slug Test (Bouwer & Rice / Hvorslev)	2.2E-03	712703	6661139	SKM 2010
RT09	THZ	Slug Test (Bouwer & Rice / Hvorslev)	1.0E-04	682697	6702115	SKM 2010
RT07a	THZ	Slug Test (Bouwer & Rice / Hvorslev)	5.5E-03	730858	6665913	SKM 2010
RT07b	THZ	Slug Test (Bouwer & Rice / Hvorslev)	1.0E-03	730858	6665913	SKM 2010
PT63	Bulldog	Slug Test (Bouwer & Rice / Hvorslev)	4.0E-02	702051	6694967	SKM 2010
RT41	Bulldog	Slug Test (Bouwer & Rice / Hvorslev)	1.1E+00	716569	6705046	SKM 2010
PT62	Cadna-o	Slug Test (Bouwer & Rice / Hvorslev)	2.8E+01	713439	6696621	SKM 2010

Attachment D.2. Measured specific storage values

Well ID	Aquifer Unit	Test Type (analysis)	Ss (m^{-1})	Easting (GDA)	Northing (GDA)	Source
RT-2	*ZAL*	*Constant Rate Pump Test (mid time)*	*2.4E-03*	*691869*	*6656802*	*Regional EIS Drilling Completion Report (REM)*
RT-2	*ZAL*	*Constant Rate Pump Test (late time)*	*9.4E-04*	*691869*	*6656802*	*Regional EIS Drilling Completion Report (REM)*
RT-2	*ZAL*	*Recovery Test*	*6.7E-04*	*691869*	*6656802*	*Regional EIS Drilling Completion Report (REM)*
MAR-1	*ZAL*	*Pump Test (Jacob Straight Line)*	*1.4E-06*	*686082*	*6645061*	*Motherwell Selection phase Study (REM)*
MAR-2	*ZAL*	*Pump Test (Theis Recovery)*	*1.4E-05*	*694200*	*6660880*	*Motherwell Selection phase Study (REM)*
LT15	*ZAL*	*Abstraction at LP6*	*3.4E-05*	*677605*	*6631062*	*Woodward-Clyde (1998).*
LT8	*ZAL*	*Abstraction at LP8*	*6.8E-05*	*677352*	*6631245*	*Woodward-Clyde (1998).*
LT3	*ZAL*	*Unknown*	*4.0E-05*	*676528*	*6630038*	*Woodward-Clyde (1995).*
LT1	*ZAL*	*Unknown*	*2.5E-06*	*674810*	*6631172*	*Woodward-Clyde (1995).*
LT2	*ZAL*	*Abstraction at LP2*	*5.2E-04*	*676536*	*6631862*	*Woodward-Clyde (1998).*
LT2	*ZAL*	*Abstraction at LP2*	*3.6E-05*	*676536*	*6631862*	*Woodward-Clyde (1995).*
TPW-1	*Tent Hill*	*Constant Rate Pump Test (pumped well)*	*5.8E-05*	*677884*	*6634860*	*Evap Pond Drilling Completion Report (REM)*
TPW-2	*Tent Hill*	*Constant Rate Pump Test (pumped well)*	*3.3E-04*	*686936*	*6632520*	*PFS Saline Water Supply (REM)*
TPW-3	*Tent Hill*	*Constant Rate Pump Test (pumped well)*	*1.0E-06*	*675651*	*6624933*	*PFS Saline Water Supply (REM)*
TPW-1	*Tent Hill*	*Constant Rate Recovery Test (pumped well)*	*8.7E-06*	*682089*	*6626155*	*PFS Saline Water Supply (REM)*
TPW-2	*Tent Hill*	*Constant Rate Pump Test (Clark)*	*6.1E-04*	*686901*	*6632525*	*PFS Saline Water Supply (REM)*
PT-31	*Tent Hill*	*Slug Test (Hvorslev)*	*1.4E-06*	*682087*	*6626131*	*PFS Saline Water Supply (REM)*
RD2373M1	*ZWC*	*Hantush-Jacob analysis. Pumping at RD2874P1.*	*8.0E-05*	*681476*	*6629289*	*WMC (2007)*
RD2874	*ZWC*	*Hantush-Jacob*	*9.0E-05*	*681474*	*6629289*	*WMC (2007)*
RD2877	*ZWC*	*Theis*	*3.0E-06*	*682670*	*6629033*	*WMC (2007)*