DWLBC Technical Report

Morgan to Wellington numerical groundwater model 2010 for Salinity Register entry (Volume 1 - Report and Figures)

Government of South Australia

Department of Water, Land and Biodiversity Conservation

Report No. 2010/09

Morgan to Wellington numerical groundwater model 2010 for Salinity Register entry

Volume 1 — Report and figures

Wei Yan[1], Leanne Morgan[1], Joel Georgiou[2], Scott Evans[3] and Linda Vears[1]

[1] Department of Water, Land and Biodiversity Conservation
[2] Aquaterra
[3] Australian Water Environments

June 2010

Report DWLBC 2010/09

Government of South Australia
Department of Water, Land and Biodiversity Conservation

Science, Monitoring and Information Division
Department of Water, Land and Biodiversity Conservation
25 Grenfell Street, Adelaide
GPO Box 2834, Adelaide SA 5001
Telephone National (08) 8463 6946
International +61 8 8463 6946
Fax National (08) 8463 6999
International +61 8 8463 6999
Website www.dwlbc.sa.gov.au

Disclaimer

ISBN-978-1-921528-78-1

Preferred way to cite this publication

Yan W, Morgan L, Georgiou J, Evans S and Vears L, 2010, *Morgan to Wellington numerical groundwater model 2010 for Salinity Register entry,* DWLBC Report 2010/09, Government of South Australia, through Department of Water, Land and Biodiversity Conservation, Adelaide.

FOREWORD

South Australia's unique and precious natural resources are fundamental to the economic and social wellbeing of the state. It is critical that these resources are managed in a sustainable manner to safeguard them both for current users and for future generations.

The Department of Water, Land and Biodiversity Conservation (DWLBC) strives to ensure that our natural resources are managed so that they are available for all users, including the environment.

In order for us to best manage these natural resources, it is imperative that we have a sound knowledge of their condition and how they are likely to respond to management changes. DWLBC scientific and technical staff continue to improve this knowledge through undertaking investigations, technical reviews and resource modelling.

Scott Ashby
CHIEF EXECUTIVE
DEPARTMENT OF WATER, LAND AND BIODIVERSITY CONSERVATION

ACKNOWLEDGEMENTS

During the development of the Morgan to Wellington numerical groundwater model, contributions to the understanding of the hydrogeology were made by Scott Evans, Juliette Woods and Damian Newham from Australian Water Environments (Appendices in Volume 2 of this report).

Contributions were made to the irrigation and drainage section by Linda Vears and Christina Roberton (Department of Water, Land and Biodiversity Conservation, Policy Division). The original report can also be found within the Appendices (in Volume 2 of this report).

The modelling section was provided by Joel Georgiou and Virginia Riches from Aquaterra Consulting Pty Ltd.

Don Armstrong of Lisdon Associates undertook a review of the model and this report. As part of the review process numerous discussions were held regarding technical issues. Recommendations and suggestions made during this process were considered within the modelling work.

Peer review of the report and model was undertaken by Steve Barnett (Department of Water, Land and Biodiversity Conservation) and Hugh Middlemis (Aquaterra Consulting Pty Ltd).

CONTENTS

Appendices Appendices can be downloaded from web site below:
http://www.dwlbc.sa.gov.au/publications/rpts/index.html

LIST OF FIGURES

LIST OF TABLES

Appendices Appendices can be downloaded from:
http://www.dwlbc.sa.gov.au/publications/rpts/index.html

EXECUTIVE SUMMARY

To meet obligations under the Murray-Darling Basin Authority's (MDBA) Basin Salinity Management Strategy (BSMS), South Australia is developing a suite of accredited MODFLOW groundwater models to bring entries forward to the BSMS Salinity Registers. This work is undertaken by the Science, Monitoring and Information Division (SMI) of the Department of Water, Land and Biodiversity Conservation (DWLBC) under the broad direction of Policy Division DWLBC, in liaison with the MDBA. Through the groundwater modelling process, scenarios are established that assist in determining the origin and volume of salt entering the River Murray from groundwater sources.

The Morgan to Wellington area is located in the Lower Murray region of South Australia. Over recent years, the MDBA along with the South Australian Government have been focused on estimating past, present and future salt load impacts on the River Murray resulting from irrigation development and various drainage and infrastructure works.

DWLBC first developed a MODFLOW numerical groundwater flow model for the Morgan to Wellington area during the late 1990s. This model derived salt loads to the River Murray due to mallee clearance in the highland area east of the river (Barnett et al. 2001). Subsequent modelling work involved using updated recharge rates and included the area west of the river (Barnett & Yan 2006). The model was used to simulate a Natural System and Mallee Clearance scenario (Scenarios S–1 and S–2, see table ES-1 below).

In September 2008, DWLBC commissioned Australian Water Environments (AWE) to review and update the existing hydrogeological data and conceptual hydrogeological model for the area. This process involved collating and interpreting existing hydrogeological information, including the most recent drillhole, potentiometric head, groundwater salinity and aquifer test data. The outcome was a series of model layer surface structures, salinity zones and potentiometric head distributions for installation into the new updated numerical model.

In 2009, the model was updated based on the above latest information and the calibration was improved. All predictive scenarios as listed in ES-1 were run with the updated model to produce estimates of the groundwater fluxes (and resultant salt loads) entering the River Murray resulting from accountable irrigation and management actions and annual average river levels (Yan et al, 2009). The actual river level below Lock 1 in early 2009 (-0.7 m AHD) was used to run all scenarios (see table ES1).

According to information provided by the MDBA in early 2010, the salt load impact from river level should not be included in the model results for Salinity Register entry, which is an assessment of accountable irrigation and management actions under average climate conditions.

The fundamental objective of the 2010 modelling work has been to rerun scenarios for accreditation as Salinity Register entries by the MDBA.

In line with MDBA Salinity Register requirements, irrigation recharge and river level conditions that represent the average conditions (excluding recent drought impacts) have been applied within all prediction scenarios. In particular, the recent decline in River Murray water level below Lock 1 since 2000 has not been simulated in the 2010 model. An average value of 0.7 m AHD has been applied for all time, in line with requirements specified by the MDBA. For flux and salt load under declining annual average river level conditions please refer to the Morgan to Wellington numerical groundwater model 2009 (Yan et al., 2009).

Between Morgan and Wellington, the original pre-development base salt load entering the river was estimated by the model to be around 14 t/day. Current salt loads into the River Murray over the same reach at January 2009 (under average river level conditions of 0.7 m AHD) were predicted to be about 93 t/day. Much of this additional salt load has occurred in response to the development of dryland clearing and irrigation drainage.

The scenarios are summarised in Table ES–1 and predicted salt loads entering the River Murray are summarised in Tables ES–2 to ES–5 for the four sub-zones between Morgan and Wellington.

Table ES–1 Summary of modelling scenarios

Scenario	Name	Model run	Irrigation development area	IIP[1]	RH[2]	SIS[3]
S–1	Natural system	Steady State	None	–	–	–
S–2	Mallee clearance	1920–2109	None (but includes mallee clearance area)	–	–	–
S–3A	Pre-1988, no IIP, no RH	1988–2109	Pre-1988	No	No	–
S–3B	Pre-1988, with IIP, no RH	1988–2109	Pre-1988	Yes	No	–
S–3C	Pre-1988, with IIP and with RH	1988–2109	Pre-1988	Yes	Yes	–
S–4	Current irrigation	1920–2109	Pre-1988 + Post-1988	Yes	Yes	No
S–5	Current plus future irrigation	2009–2109	Pre-1988 + Post-1988 + Future development	Yes	Yes	No

Note: [1] Improved Irrigation Practices (see *Glossary* for definitions) [2] Rehabilitation [3] Salt Interception Scheme

Table ES–2 Summary of predicted salt load (t/day) entering the River Murray (Morgan to Lock 1 sub-zone)

Morgan to Lock 1 Area	Year				
	1988	2000	2009	2050	2109
S–1	2.8	2.8	2.8	2.8	2.8
S–2	2.9	3.3	3.6	10.6	20.5
S–3A	2.8	2.8	13.9	18.1	18.8
S–3B	2.8	2.8	9.9	10.7	10.9
S–3C	2.8	2.8	9.9	10.7	10.9
S–4	2.8	2.8	9.9	17.8	19.3
S–5	2.8	2.8	9.9	17.8	19.3

Table ES–3 Summary of predicted salt load (t/day) entering the River Murray (Lock 1 to Mannum sub-zone)

Lock 1 to Mannum Area	Year				
	1988	2000	2009	2050	2109
S–1	8.4	8.4	8.4	8.4	8.4
S–2	9.8	10.1	10.3	11.2	13.7
S–3A	14.1	14.9	22.6	25.4	26.1
S–3B	14.1	14.3	17.4	16.5	16.5
S–3C	14.1	14.3	17.4	16.5	16.5
S–4	14.1	14.3	17.4	30.0	37.0
S–5	14.1	14.3	17.4	30.0	36.9

Table ES–4 Summary of predicted salt load (t/day) entering the River Murray (Mannum to Murray Bridge sub-zone)

Mannum to Murray Bridge Area	Year				
	1988	2000	2009	2050	2109
S–1	0.2	0.2	0.2	0.2	0.2
S–2	20.4	21.1	21.3	23.4	27.5
S–3A	43.0	44.8	49.0	50.8	51.3
S–3B	43.0	42.9	42.7	41.9	41.9
S–3C	43.0	40.3	34.1	30.3	30.2
S–4	43.0	40.3	34.1	39.3	41.2
S–5	43.0	40.3	34.1	39.3	41.3

Table ES–5 Summary of predicted salt load (t/day) entering the River Murray (Murray Bridge to Wellington sub-zone)

Murray Bridge to Wellington Area	Year				
	1988	2000	2009	2050	2109
S–1	2.7	2.7	2.7	2.7	2.7
S–2	25.1	26.9	28.1	35.9	47.1
S–3A	33.1	33.3	43.6	46.8	47.7
S–3B	33.1	30.5	32.0	30.8	30.8
S–3C	33.1	30.5	32.0	30.8	30.8
S–4	33.1	30.5	32.0	43.4	45.8
S–5	33.1	30.5	32.0	43.4	46.2

1. INTRODUCTION

1.1 POLICY BACKGROUND

Salinity is a significant issue for South Australia because of its location on the lower reach of the River Murray; the natural geological structure of the Murray-Darling Basin (MDB) in which the River Murray acts as a drain for salt out of the landscape; the influence of human development in mobilising salt to the River; and the ultimate implications of salinity in terms of water quality for all uses, including metropolitan Adelaide. Salinity impacts largely occur in South Australia through reduced water quality and degradation of the floodplain.

1.1.1 FEDERAL INITIATIVES

Schedule B of the Murray-Darling Basin Agreement 2008 (the Agreement) provides the legislative framework to manage and reduce the impacts of salinity in the MDB, and the Basin Salinity Management Strategy 2001–2015 (BSMS) provides the strategic policy framework.

Achievement of the BSMS objectives is measured through a set of Salinity Registers, the degree of achievement of end-of-valley targets and the Basin Salinity Target at Morgan in South Australia. The Basin Salinity Target is:

> *'to maintain the average daily salinity at Morgan at a simulated level of less than 800 EC for at least 95% of the time, during the benchmark period'*[1].

Progress towards meeting the agreed end-of-valley targets and the land management objectives is assessed through annual reports from the contracting governments and MDBA. The Independent Audit Group for Salinity (IAG-Salinity) provides an independent annual audit of the reports, the Register entries and the performance of the contracting governments and the MDBA.

The key principle in the BSMS is 'capping' increases in salinity of the MDB and managing this via a system of salinity credits and debits, recorded and reported on the Salinity Registers (where a credit corresponds to an action that decreases salinity and a debit relates to an action that increases salinity). The Salinity Registers track all actions that are assessed to have a significant effect on salinity, being a change in average daily salinity at Morgan which will be at least ±0.1 EC within 100 years. A significant effect can result from a change in the magnitude or timing of either or both of salt loads and water flows. To separate the salinity impact of offsetting new accountable actions and the impact of past actions, the Salinity Registers comprise two components—Register A and Register B. Entries of salinity credits and salinity debits in the Salinity Registers are recorded in dollars to reflect the cost effects of salinity. As with any form of accounting, currency conversions can be performed for different applications.

[1] The benchmark period is used to standardise for climate variability. It is an observed climatic sequence over a defined period that has been chosen to be hydrologically representative. The benchmark period is used consistently in the BSMS as a basis for simulating catchment responses (such as groundwater movements and river behaviour) at specified scenario dates (for example 2015, 2050 and 2100). The benchmark period is currently 1 May 1975 to 30 April 2000. It is intended to review the benchmark period climatic sequence in conjunction with the periodic reviews of the operation of Schedule B (formerly C) (in 2007 and every 7 years thereafter). The review may include extending the sequence to a longer period such as 30 years.

Hydrologic modelling uses salt loads and flows to compute water quality outcomes along the river, which are then converted to an economic impact through the application of a cost function. To date, the participating Australian and state governments have managed their involvement in the BSMS through two major approaches. One is joint investment in salt interception schemes and associated infrastructure; and the other is investment in target setting and monitoring systems at the end-of-valleys in concert with plans and actions to improve land management practices across the basin.

1.1.2 STATE INITIATIVES

As well as the BSMS, and in recognition of the significance of salinity as a River Murray water quality issue, South Australia has a number of state initiatives that link to achieving the BSMS objectives:

- Salinity Zoning Policy: New irrigation developments along the River Murray are limited to areas of low salinity impact in accordance with the Water Allocation Plan (WAP) for the River Murray Prescribed Water Course. The administrative aspects of the policy are currently being refined to accommodate the separation of water rights. Any major changes to the policy will be incorporated in the amendment of the WAP.
- Salinity Target in South Australia's Strategic Plan: Target 3.11 of South Australia's Strategic Plan is:

  'South Australia maintains a positive balance on the Murray-Darling Basin Commission salinity register'.
- Strategies to achieve this include construction and maintenance of infrastructure to reduce salt loads to the river, working in partnership with communities to reduce the salinity impacts of irrigation, developing and implementing salinity management policies and ensuring that South Australia's salinity accountability is transparent and accurate.
- South Australia's River Murray Salinity Strategy (SARMSS): As well as the BSMS Basin Salinity Target, the SARMSS also establishes the Basin Salinity Target as a state objective. In addition, under SARMSS South Australia undertakes monitoring at a number of sites and this may give an ongoing indicator of likely performance against the Basin Salinity Target.

The overall result of progress to date under the BSMS and other strategies is that productive agricultural areas have been able to expand (the recent drought notwithstanding) while achieving significant reductions in river salinity, both in terms of modelled salinity outcomes over the long term as recorded on the BSMS Salinity Registers and in terms of in river salinity, at least above Lock 1. Indeed, the Salinity Register currently assesses South Australia as having a strong positive balance. This assessment indicates that South Australia is currently removing more salt than it is putting into the River Murray.

However, there remain a number of key salinity management issues that need to be addressed to ensure that both South Australia's interests, and the interests of other states and the MDBA, are protected in terms of overall River Murray system health. Issues include the need to address the potential salt impacts from future flooding and development of a set of salinity targets for the section of river below Morgan, from which Adelaide draws much of its water supply. These issues are being considered in the development of the forthcoming Basin Plan.

1.2 MODELLING BACKGROUND

Numerical groundwater flow models enable the creation of a computer based mathematical representation of the conceptual understanding of an aquifer system. The model is a useful tool for validating the understanding and for predicting the response of the aquifer system to imposed stresses.

The objectives of groundwater modelling carried out by the Department of Water, Land and Biodiversity Conservation (DWLBC) were to develop an *impact assessment model of moderate complexity* (in the terminology of the Murray Darling Basin Authority [MDBC 2001]) capable of simulating the regional aquifer system.

The objectives of this modelling were to:

- develop a (processing) time efficient model that could be used to further revise salt loads from accountable actions, resulting from existing and future irrigation development
- obtain accreditation of the model by the MDBA
- calculate modelled salt loads acceptable as Salinity Register entries
- develop a model that can be used to assist with broad scale planning of groundwater management strategies in the future.

The model region covered in this report consists of a section of the River Murray between Morgan and Wellington in South Australia (Fig. 1). DWLBC first developed a MODFLOW numerical groundwater flow model for the Morgan to Wellington area during the late 1990's. This model considered salt load to the River Murray from the highland east of the river due to mallee clearance (Barnett et al. 2001). Subsequent modelling work involved using updated recharge rates and included the area west of the river (Barnett & Yan 2006). Due to limited data, model design was based on Murray Basin hydrogeological map sheets (Barnett 1991) and available drillhole data at the time. The latest version of the numerical model as documented in this report includes the most up-to-date conceptualisation, drillhole information and groundwater level data.

1.3 CURRENT MODELLING EXERCISE

DWLBC commissioned Aquaterra Consulting Pty Ltd (Aquaterra) to refine and update the existing DWLBC Morgan to Wellington model incorporating data from a recent hydrogeological review completed by AWE (2008). The review outcomes were a collation of up-to-date information and data sets that could easily be implemented into the numerical model. The methodology adopted for the review included five interpretive parts, as described below:

- structure contours for the top of the Murray Group Limestone aquifer, Ettrick Formation aquitard and Renmark Group aquifer; and bottom elevation data for the Renmark Group aquifer
- potentiometric head contours for 2008 (Murray Group and Renmark Group aquifers)
- latest groundwater salinities (Murray Group and Renmark Group aquifers)
- aquifer test data for all aquifers and aquitards
- conceptual hydrogeological model.

INTRODUCTION

The aim of this project is to provide a predictive management tool for determining salt loads entering the River Murray between Morgan in the north and Wellington in the south. The refined model provides quantitative estimates of salt loads entering the River Murray under a range of past and future land and water use conditions (previously, model scenarios only considered pre-development and mallee clearing conditions).

Accreditation of the groundwater model by the MDBA is required for Salinity Register entries. This report summarises the model updates and extensively documents the model inputs and outputs in a format that will assist in the MDBA's review and accreditation process. The report has two volumes:

- Volume 1—Report and figures, which contains the report and key figures depicting the project area, model structure, parameters and model results.
- Volume 2—Appendices, which contain detailed model inputs (recharge zones and rates); outputs of groundwater flux and salt loads for the various scenarios modelled; reports detailing the updated hydrogeological information; and review of the irrigation activity in the area.

2. HYDROGEOLOGY OF THE MODEL AREA

2.1 LOCATION

The Morgan to Wellington area is located on the western side of the Murray Basin, to the east of the Mount Lofty Ranges. The model covers an area from Morgan in the north, to Wellington in the south (Fig. 1). Water bodies and irrigation areas are clearly distinguishable on aerial photography (Figs. 2a and 2b) which also includes transient electromagnetics (TEM) results discussed later in this report (Berens et al. 2004).

The model area is bounded by the Mount Lofty Ranges to the west, and extends ~40 km to the east of the River Murray. The topography in the model area is relatively steep along the foothills and river valley regions, and flat in most highland regions east of the River Murray (Fig. 3). The River Murray is the major surface water system in the model area. Lock 1 is located next to Blanchetown with average pool level ~3.2 m AHD upstream and ~0.7 m AHD downstream. The River Murray valley is filled with a complex network of anabranches, lagoons, floodplain and floodplain irrigations (AWE 2008).

2.2 CLIMATE

The climate in the Lower Murray region is typically characterised by hot dry summers and cool, wetter winters. The meteorology station at Murray Bridge has experienced a mean rainfall of ~350 mm per annum since 1966. The mean minimum and maximum temperature range from 5.5°C in July to 29°C in February. No evaporation records were available for the Lower Murray region on the Bureau of Meteorology website (AWE 2008).

2.3 REGIONAL HYDROGEOLOGY

The Murray Basin is a closed groundwater basin containing Cainozoic unconsolidated sediments and sedimentary rock up to 600 m in thickness, and contains a number of regional aquifer systems (Evans & Kellet 1989).

Within the study area, there are three major aquifer systems of significance (Fig. 4). In the highland areas, the watertable aquifer occurs in the Murray Group Limestone. This aquifer forms a regionally extensive unconfined to semi-confined aquifer into which the channel of the ancestral River Murray is incised. The Ettrick Formation aquitard separates the Murray Group aquifer from the underlying Renmark Group aquifer.

The semi-confined Monoman Formation sand aquifer and clays of the Coonambidgal Formation have been deposited within the ancestral channel, and it is within this sequence that the modern channel of the River Murray is incised. The Murray Group aquifer and the Monoman Formation aquifer are considered to be in direct hydraulic connection. Within the floodplains, the watertable can occur within the overlying superficial sediments of the Coonambidgal Formation (AWE 2008).

Within the model area, the groundwater flow direction in all aquifers of interest is generally towards the River Murray. The river and its anabranches behave as a sink for regional groundwater in the study area.

Saline groundwater can enter the river through any of three mechanisms:

1. Lateral flow from the Murray Group Limestone aquifer (in most cases via the Monoman Formation within the Murray Trench).
2. Slow upward leakage through the Ettrick Formation aquitard from the underlying regional confined Renmark Group aquifer.
3. Seepage of perched groundwater from cliff faces (in areas where the river is immediately adjacent to the cliff).

Groundwater discharge occurs either directly to the River Murray (or one of its backwaters or anabranches) through the Murray Group Limestone or Monoman Formation aquifer, or through evapotranspiration. Typical rates of evapotranspiration from the floodplain are 250 mm/year (Holland et al. 2001), however recent investigations by Aquaterra suggest this may be higher (refer to section 3.8). With reference to upward leakage from the Renmark Group, upward gradients are interpreted to exist across the project area providing a potential for the upward movement of groundwater. However, the rate of upward leakage is expected to be low because of the presence of the thick Ettrick Formation confining layer (AWE 2008).

As anecdotal evidence indicates that only minor seepage occurs from cliff faces in the model area, it is assumed that lateral flow from the Murray Group Limestone aquifer is the main mechanism for saline groundwater discharge to the River Murray/floodplain. It should also be noted that within the study area, there is no evidence at this stage that the River Murray is in direct contact with the Renmark Group. The above two points lead to the conclusion that the Murray Group and Monoman Formation aquifers contribute the majority of the salt load to the River Murray, and thus are the targets for salt accession investigation (AWE 2008).

Schematic diagrams of the Morgan to Wellington conceptual hydrogeological model are presented in Figures 5a, b and c, which highlight the regional groundwater flow directions and leakage between the various hydrogeological units.

Figure 5a represents a typical hydrogeological cross section of the Lock 1 area which shows:

- the Murray Group Limestone is in direct contact with the River Murray/floodplain
- the regional groundwater flow is towards the river/floodplain
- there is potential for upward leakage from the deeper Renmark Group.

Figure 5b represents the hydrogeological condition upstream of Mannum where there is no irrigation on the floodplain.

Figure 5c represents the hydrogeological conditions in the Lower Murray area, and shows that there is irrigation on the floodplain as well as drainage channels that can potentially intercept groundwater fluxes before they reach the floodplain. Historically, water levels in the drainage schemes have been set to ~1–1.5 m below river levels which create hydraulic gradients that can move groundwater away from the river. Due to the presence of the drainage schemes, evapotranspiration on the floodplain may also be diminished. The fundamental difference from Figure 5c is that the river is located within the Coonambidgal Formation, however in the Morgan to Mannum reach (Fig. 5b) the river penetrates through to the Monoman Formation.

2.4 HYDROGEOLOGY OF MODEL AREA

Within the study area, sediment thicknesses can vary significantly and in some cases pinch out completely on basement outcrops. Superficial Quaternary sediments exist within the study area, however they are generally limited to several metres thickness, and for purposes of model construction, have not been considered as part of the project scope (AWE 2008).

2.4.1 WOORINEN FORMATION

The Woorinen Formation provides a thin capping of Quaternary sediments across the highlands of the project area. This layer is not significant enough to be defined separately and is incorporated into the uppermost layer of the numerical model.

2.4.2 COONAMBIDGAL FORMATION

The Coonambidgal Formation layer occurs ubiquitously across the floodplain and comprises clay and silts deposited during periods of episodic flooding. The unit varies in thickness. This layer is not significant enough to be defined separately and is incorporated into the uppermost layer of the numerical model (AWE 2008).

2.4.3 MONOMAN FORMATION

The Monoman Formation underlies the Coonambidgal Formation and typically comprises a mixture of channel and sheet sand deposits with intervening sequences of silty clay. This is likely to result in highly variable transmissivities throughout the floodplain similar to that encountered in previous investigation in Riverland areas.

There are not sufficient data to reliably construct groundwater elevation contours for the Monoman Formation aquifer for the entire length of the floodplain within the project area. However, there are observations regarding groundwater flow in the floodplain aquifers between Mannum to Wellington, which are likely to be relevant to the project area.

Due to its semi-unconfined nature and hydraulic connection, the potentiometric surface for the Monoman Formation has been merged with the Murray Group Limestone aquifer, which will be used as a semi qualitative calibration measure during the model calibration process (AWE 2008).

2.4.4 MURRAY GROUP LIMESTONE

The Murray Group Limestone has been partially eroded (and fully eroded in a minor portion) across the floodplain but is present throughout the highland areas, and is often exposed in cliff faces within the project area.

For the purposes of the model, the depth from surface topography to the base of the Murray Group Limestone (top of Ettrick Formation aquitard), has been considered to be the thickness of the Murray Group Limestone. Within the model area, the top of the Murray Group Limestone sits at an elevation of more than 60 m AHD in the north-east portion of the project area, and 5 m AHD in the south-west portion of the project area. Similarly, these sediments thin along a north-east/south-west axis. The thickness ranges from greater than 120 m in the north-east part of the project area to 50 m in the south-west portion of the project area.

A potentiometric contour map for March 2008 has been produced by AWE for the Murray Group Limestone aquifer and is presented in Figure 6a. The groundwater flow direction is predominantly toward the River Murray from both east and west. Contours on the floodplain may not be accurate due to lack of reliable data and numerous boundary conditions, which exist due to the extensive system of permanent anabranches and backwaters being present (AWE 2008).

2.4.5 ETTRICK FORMATION

The Ettrick Formation, which is considered an aquitard, generally appears as a green/grey layer of glauconitic and fossiliferous marl, calcareous clay and mudstone, with silts and fine quartz sand indicative of a low energy marine environment (Drexel 1995). It is recognised as a discrete stratigraphic unit, forming the major confining bed throughout the region separating the Murray Group Limestone from the Renmark Group aquifer. This confining bed primarily dips toward to the east. The top of the Ettrick Formation sediments reach an elevation of ~60 m AHD along the margin of Mount Lofty Ranges, but dips to an elevation of ~–90 m AHD to the east. A maximum thickness of ~80 m is attained in this sequence of sediments, thinning to the north and west of the project area to less than 20 m, and is absent in a small section north of Mannum.

2.4.6 RENMARK GROUP

The Renmark Group is the oldest (mid-Palaeocene to mid-Oligocene; ~50–30 Ma) and deepest sedimentary sequence in the study area, and directly overlies the pre-Cainozoic basement. The sediments consist of fluvial clays, silts, sands and minor gravels with carbonaceous deposits. The Renmark Group aquifer is confined, with the potential for upward leakage to occur into the overlying Murray Group aquifer (Rural Solutions 2004).

Structure contours for the top of the Renmark Group show that the sediments are generally dipping along an approximate west–east axis. In the north-west part of the study area, the elevation of the top of the Remark Group is ~40 m AHD, dipping down to an elevation of ~–100 m AHD. Renmark Group sediment thickness increases from approximately 40 m in the west, to 80 m in the south-east and more than 100 m in the north-east.

As previously mentioned, the Renmark Group aquifer is not in direct contact with the river and is therefore unlikely to contribute a significant salt load to the River Murray in comparison with the Murray Group Limestone aquifer. This formation is considered as the base layer in the model to simulate upward leakage to the Murray Group aquifer (AWE 2008).

Generally, basement elevation structure contours reflect a similar pattern to the top of Renmark Group sediments, dipping from west to east, with the lowest elevations reported in the north-east of the model area.

The March 2008 contours of potentiometric groundwater elevation for the Renmark Group aquifer are presented in Figure 6b. Regional groundwater flow (based on the 31 wells used to generate the contour plan) occurs from the east to west, and east to south-west (AWE 2008).

2.5 AQUIFER TEST RESULTS AND YIELDS

Currently, there are no recent aquifer tests analysed for wells completed in the region, however hydraulic conductivity in the Lower Mannum Formation has been reported from 1 to

4 m/day in the Woolpunda – Cadell Reach Salt Interception Scheme (Rural Solutions 2004), and from 5 to 15 m/day in the Renmark Group between Lake Victoria and Morgan (Rammers, Hill & Yan 2005).

Yields at the time of well production reported ranges from 0.1 L/s to more than 20 L/s in the Murray Group Limestone aquifer and from 0.1 L/s to 8.0 L/s in the Renmark Group aquifer. Historical Hydrogeological Map Sheet (Barnett 1991) data reports higher yields in both aquifers are generally east of the river channel, with scattered patches of high yield in the western highlands and south of Mannum (AWE 2008).

2.6 GROUNDWATER SALINITY

A salinity review of all Murray Group Limestone and Renmark Group wells was completed by AWE in 2008. This included 41 new Murray Group Limestone wells and one Remark Group well, which were drilled since January 2004. Historic data from microfiche was revisited and all wells were classified on the quality of data available.

There is a wide range in salinity from ~1,000 to greater than 50 000 mg/L TDS in the Murray Group Limestone aquifer. The highest salinity value (greater than 50 000 mg/L TDS) occurs north-west of Blanchetown. Groundwater salinity in the model area generally tends to be slightly elevated from 1,500 to 10 000 mg/L TDS in the Murray Group Limestone aquifer (Fig. 7a).

The groundwater salinity values in the Renmark Group aquifer range from ~1,300 to greater than 20 000 mg/L TDS, with higher salinity groundwater reported in the northern region of the model. A band of higher salinity groundwater (>14 000 mg/L TDS) extends from the north-east corner westerly and finishes north-west of Blanchetown (Fig. 7b).

Figures 8 to 11 show the derived model flow budget zones and the groundwater salinities (S Barnett [DWLBC] 2009, pers. comm.) that were applied in the calculation of the salt load for the Morgan to Wellington area.

2.7 REGIONAL HYDROLOGY

Within the model domain, the River Murray is the major surface water system between Morgan to Wellington, and the floodplain is covered with a complex network of anabranches, lagoons, floodplain and floodplain irrigations. It acts as a discharge point for both sides of the river and the river pool level plays a critical component in terms of how much groundwater will be discharged into the river. The average pool level upstream of Lock 1 is ~3.2 m AHD and downstream is ~0.7 m AHD. However the current river pool level below Lock 1 has dropped below sea level due to continuing nationwide drought conditions (AWE 2008).

3. MODEL CONSTRUCTION

3.1 MODFLOW AND VISUAL MODFLOW

MODFLOW is a three-dimensional finite difference mathematical code that was developed by the US Geological Survey (McDonald & Harbaugh 1988), and continues to be updated. Visual MODFLOW Version 4.1.0.145 was developed by Waterloo Hydrogeologic Inc. in recent years and is a pre-processor for quick generation of data files for MODFLOW.

Visual MODFLOW was used as a tool for generating MODFLOW model grids, boundary conditions, observation well data and zones for aquifer hydraulic parameters. The software was also used for establishing settings to run the model, and to obtain quick and convenient output results. The PCG2 solver was used for all steady state and transient modelling runs.

3.2 MODEL DOMAIN AND GRID

The model domain simulates an area 80 km (east–west) by 145 km (north–south). The bounding AMG coordinates of the model domain are (south-west) E340000 N6090000 and (north-east) E420000 N6235000 (GDA 1994) (Fig. 1).

The selection of a large model domain that incorporates the smaller study area is consistent with good modelling practice. The model domain boundaries are set at a sufficient distance from the study area such that they do not influence the behaviour of the aquifer system in the study area.

The rectangular model grid was divided into 496 columns and 992 rows with a regular model cell size of ~150 x 150 m over the entire domain, resulting in a total of 492 032 finite difference cells over the 3 model layers.

3.3 MODEL LAYERS

3.3.1 LAYER STRUCTURE

The model layers and structure contours have been updated in the latest model, consistent with the updated data from the hydrogeological review (AWE 2008). However, to avoid potential problems with numerical instability where aquifer layers become too thin, a minimum layer thickness of 5 m has been adopted. Figure 12 shows two modelled east–west orientated cross sections through model rows 835 and 414.

The regional aquifer system in the Morgan to Wellington area was conceptualised as a three layer model, including two aquifer layers and one aquitard layer (Table 1).

Table 1 Model layer aquifers and aquitards

Layer No	Hydrogeological unit	Aquifer/aquitard	MODFLOW layer
1	Murray Group Limestone	Aquifer	Type-1
2	Ettrick Formation	Aquitard	Type-3
3	Renmark Group	Aquifer	Type-0

MODFLOW layer options are given in Table 2.

Table 2 MODFLOW layer types

Layer type	Aquifer type	Aquifer hydraulic parameters
Type-0	Confined	Transmissivity and storage coefficient (specific storage, SS) are constant
Type-1	Unconfined	Transmissivity varies and is calculated from saturated thickness and hydraulic conductivity. The storage coefficient (specific yield—SY) is constant. Type-1 is only valid for the uppermost layer of a model
Type-2	Confined/ Unconfined	Transmissivity is constant—the storage coefficient may alternate between values applicable to the confined (SS) or unconfined (SY) states
Type-3	Confined/ unconfined	Transmissivity varies and is calculated from the saturated thickness and hydraulic conductivity. The storage coefficient may alternate between values applicable to the confined (SS) or unconfined (SY) state

The ground surface elevation (Fig. 3) is represented by shuttle radar ground surface elevations as adopted by AWE (2008). The elevation of the floodplain is ~0–10 m AHD and the elevation of the highland is over 100m AHD to the west, and as low as 10 m AHD to the south within the project area. As explained earlier, the topography of the model also represents the top of the model Layer 1.

3.3.2 LAYER 1: MURRAY GROUP LIMESTONE

Layer 1 represents the Murray Group Limestone unconfined aquifer:

- The topography is assumed to be the top of the Murray Group Limestone and is derived from shuttle radar ground surface elevations adopted from AWE (2008).
- Base elevations were determined from geological logs supplied by DWLBC and the Drillhole Enquiry System (DES), using a total of 37 wells within the model domain. In addition, contours of base elevations were constructed by AWE taking into account information from the Murray Basin hydrogeological 1:250 000 map sheets (Barnett 1991). The elevation of the base of Layer 1 (top of Layer 2) occurs approximately between –90 and 80 m AHD within the model domain (Fig. 13, after AWE).

3.3.3 LAYER 2: ETTRICK FORMATION AQUITARD

Layer 2 represents the Ettrick Formation aquitard:

- Detailed Ettrick Formation contours are based on hydrogeological map sheet data (Barnett 1991).
- The Ettrick Formation (Layer 2) has a thickness ranging from ~80 to 20 m. The base elevation of Layer 2 (top of Layer 3) occurs between ~40 m AHD in the north-west of the model domain, to ~–100 m AHD to the east (Fig. 14, after AWE).
- The top of the Ettrick Formation is reported near ground surface at Mannum with the 0 m AHD passing beneath the river (AWE 2008).

3.3.4 LAYER 3: RENMARK GROUP AQUIFER

Layer 3 represents the regionally distributed confined Renmark Group aquifer. Little information is known about the Renmark Group in this area, but it is thought to be an aquifer of medium permeability. The base elevation of Layer 3 (Fig. 15) was interpreted by AWE

from geological logs and interpretations from hydrogeological map sheet data (Barnett 1991). Contours were then hand drawn by AWE which took into account all the above mentioned data sets. The Renmark Group thickness ranges from ~40 m in the west to 80 m in the south-east and more than 100 m in the north-east.

3.4 MODEL HYDRAULIC PARAMETERS

There are no aquifer test data in the region, with the only data available on aquifer parameters the estimated yield recorded during well construction and development. This is a model limitation as identified by AWE. In order to constrain the model calibration, a physically realistic range of aquifer and aquitard hydraulic parameters were derived from previous reports, and referenced to current aquifer tests.

Spatial variability in aquifer hydraulic properties was modified in specific areas during both steady state and transient calibration to achieve the final values required for accurate calibration. The final aquifer and aquitard hydraulic parameters are given in Table 3, with their spatial distribution within each layer given in Figures 16 to 18.

Table 3 Calibrated aquifer and aquitard hydraulic parameters in the project area

Aquifer/aquitard	Layer	Hydraulic conductivity		Storage	
		Kh (m/d)	**Kv** (m/d)	**Sy** (–)	**Ss** (/m)
Murray Group aquifer	1	0.5–15	0.01–1.5	0.15	n/a
Ettrick Formation	2	10^{-9}–10^{-4}	10^{-9}–10^{-4}	n/a	10^{-5}
Renmark Group aquifer	3	1	0.1	n/a	10^{-5}

3.4.1 AQUIFER HYDRAULIC PARAMETERS

Horizontal and vertical hydraulic conductivities ranging from 0.5–15 m/day and a specific yield of 0.15 for the Murray Group aquifer in model layer 1 resulted in the best fit to the observed (historic) potentiometric head data. The range of modelled horizontal hydraulic conductivity values are within the range of plausible estimates based on literature from other studies and areas (refer to section 2.5).

Values of horizontal hydraulic conductivity of 1 m/day, vertical hydraulic conductivity of 0.1 m/day and a confined storage coefficient of 10^{-5} m^{-1} for the Renmark Group aquifer were adopted. The Renmark Group layer in the model was included to supply potential flow upwards into the Murray Group Limestone aquifer. Modelling the Renmark Group accurately is beyond the scope for this project since the current accepted conceptual model indicates that nearly all of the salt flux comes from the Murray Group Limestone aquifer in this region. Further field investigations are also required to collect more data on the Renmark Group including hydraulic properties and water levels.

3.4.2 AQUITARD HYDRAULIC PARAMETERS

Aquitard hydraulic parameters were applied to the Ettrick Formation to control the leakage between the Murray Group Limestone and the deeper Renmark Group aquifer. No aquifer parameter data exists for the Ettrick Formation, but it is believed to be a regional confining unit with very low hydraulic parameter values. Horizontal and vertical hydraulic conductivities ranging from 10^{-9} – 10^{-4} m/day, and a confined specific storage of 10^{-5} m^{-1} for the Ettrick Formation have been adopted.

3.5 MODEL BOUNDARIES

The three-layer model has a moderately complex structure, and different boundary conditions were applied to simulate the aquifer system, the River Murray, and their hydraulic communication.

3.5.1 LAYER 1: MURRAY GROUP LIMESTONE AQUIFER

The regional groundwater flow is generally from the eastern model edge, which is driven by the natural pressure mound supported by upward leakage from the deeper Renmark Group. Groundwater flow is also from the west originating from the Mount Lofty Ranges. Groundwater flows from the Murray Group Limestone and through the Monoman Formation towards the River Murray where it is discharged. The following boundary conditions were applied (Fig. 19):

- No-flow boundaries where groundwater flow is parallel to the model edge (south-eastern and north-western section of model domain).
- No-flow boundaries are also implemented in the north-eastern side of the model domain, as there is no need to model the irrigation mounds at Waikerie and Qualco as the effect of these irrigation areas on salt loads are modelled within the Lock 3 to Morgan Model.
- General head (head dependent flow) boundaries simulate groundwater flow on the model edges where flow occurs into and out of the model.
- Constant head boundary cells simulate the River Murray. Upstream of Lock 1, the river level was maintained at 3.2 m AHD. There are two conditions applied for river level downstream of Lock 1:
    - During calibration actual annual average river levels of 0.7m AHD prior to 2000 were applied. Post 2000, river levels downstream of Lock 1 have been steadily declining due to the recent drought conditions. Final river levels at the end of the calibration period (1 January 2009) are set at –0.7 m AHD which was the most recent measured data at the time of the modelling project.
    - For model scenario runs, river levels downstream of Lock 1 were held at 0.7 m AHD for all time, in line with Salinity Register entry requirements for average river level conditions.
- Drainage cells in the floodplain between Mannum and Wellington represent all drainage schemes on the reclaimed swamps and simulations of evapotranspiration on the floodplain. The levee banks and drains were built to maintain swamp watertable levels at 1–1.5 metres below the river level. This range of difference has been observed in the monitoring bores on the irrigation floodplain. Drainage cells in the floodplain areas have been applied at 1.5 metres below the river level at all times.

3.5.2 LAYER 2: ETTRICK FORMATION

Very small volumes of water move laterally into and out of this layer due to its very low permeability. No-flow boundaries were used at the model edges, while some constant head boundaries representing the River Murray were used in the upstream section of Mannum where it is assumed the river is in direct hydraulic connection with this unit (Fig. 21).

3.5.3 LAYER 3: RENMARK GROUP

Regional groundwater flows from the western to south-western side of the model edge to the east. The following boundary conditions were applied to layer 3 (Fig. 22):

- No-flow boundaries were used at the model edges.
- Fixed head cells have been set along the potentiometric contours in the model domain to represent the regional flow regime of the Renmark Group. The Renmark Group's presence in this model is only to act as a potential source of upwards leakage for the Murray Group Limestone aquifer, hence the application of fixed head cells as a simplifying conceptualisation assumption (as suggested by DWLBC) rather than a feature that represents a dynamic groundwater flow process.

3.6 MODEL RECHARGE

The Morgan to Wellington area has a semiarid climate with hot, dry summers and some rainfall during winter months. The average rainfall is ~350 mm/year at Murray Bridge (since 1966) with a pan evaporation of ~1900 mm/year (Bureau of Meteorology 2008).

Prior to clearance of the native vegetation, vertical recharge to the watertable aquifer resulting from rainfall infiltration is believed to have been as low as 0.07–0.1 mm/year (Allison et al. 1990). A recharge rate of 0.07 mm/year was applied in the steady state model, and also to the non-cleared and non-irrigated areas in the transient model.

3.6.1 RECHARGE DUE TO MALLEE CLEARANCE

The widespread clearance of native vegetation in the dryland region of the project area has resulted in an increased rate of rainfall drainage past the root zone to the watertable. The total area of mallee clearance and SIMRAT derived drainage rates are shown in Figure 23 and the rates are shown in *Appendix A*. Between Morgan and Lock 1, the majority of highland area is uncleared. There is also very little clearance between Blanchetown and Swan Reach. However, there are large areas in the highland and swamp areas between Mannum and Wellington that have undergone extensive clearing and modification with little of the original vegetation remaining.

A total of 40 recharge zones are applied to the areas of mallee clearance within the model domain, with rates ranging between 0.07 and 11 mm/year over a period of 189 years (1920–2109). This data has been supplied by Department of Environment and Heritage and is based on studies by DWLBC and Commonwealth Scientific and Industrial Research Organisation (CSIRO) during development of the SIMPACT/SIMRAT models. Time lags and recharge rates to the watertable aquifer were estimated using information on soil type, depth to groundwater and thickness of Blanchetown Clay. The combined timelag and recharge rates for mallee clearance are displayed in *Appendix A*.

3.6.2 REGIONAL ASSUMPTIONS ON IRRIGATION RECHARGE

Recharge due to irrigation is complex to define because there is considerable uncertainty relating to commencement time of irrigation flux to the surface and the time for the flux to reach the watertable. It is accepted that the values reported by Aquaterra, DWLBC and Department for Environment and Heritage (DEH) involve the application of professional judgement in their derivation.

These recharge zones, rates and lag times have been further modified during the latest calibration process to better match the modelled water levels to the observed potentiometric heads. The recharge zones and recharge rates due to irrigation in the Morgan to Wellington area are based on the following assumptions and information supplied by Vears and Roberton (2008):

- The irrigation recharge analysis began with consideration of geographic information system (GIS) information provided by DWLBC and AWE in the form of shape files of areas irrigated at specific milestones (1880, 1900, 1920, 1929, 1960, 1970, 1995, 1997, 1999, 2001, 2003 and 2006). Figure 24 of this report and Figures 3 to 5 of the Vears and Roberton (2008) report (*Appendix D*) give a broad indication of the pattern of irrigation commencement years and where specified recharge rates have been applied to the model due to irrigation.
- Recharge rates for irrigation districts have been estimated by Vears and Roberton (2008) (*Appendix D*) based on estimated river diversion volumes, irrigation areas and estimated irrigation efficiencies. However, the level of accuracy of the data was not sufficient for this modelling exercise, and it was decided that the deep drainage rates should be used as a guide only. Alternatively, CSIRO's 'rule of thumb' rates with time have been incorporated as the basis of the recharge model and adjusted during the calibration process to achieve a satisfactory match to both measured water levels and salt loads. *Appendix D* contains the original CSIRO rates and the final adopted rates.
- The timing of the specified recharge flux to the watertable is dependent on the applicable lag time between irrigation application to the land, and the root zone drainage to the watertable. Vears and Roberton (2008) provided initial estimates of time lags under irrigation areas from the SIMRAT model (Figs. 10 to 15 of *Appendix D*). SIMRAT predicts that initial lag time under irrigation areas can range between 0–60 years.
- To calculate initial lag time SIMRAT uses an algorithm developed by Cook, Leaney and Miles (2004) to describe the behaviour over time as irrigation, at time of commencement, creates a 'wetting' scenario where the dry unsaturated profile is 'wetted up' by the increased root zone drainage (MDBC 2005).
- Following recharge onset and the development of an irrigation mound it is subsequently assumed that late lag time becomes short. That is, root zone drainage (recharge) reaches the groundwater table in a short time period once the wetting front has passed and an irrigation mound has developed.
- This short late lag time approach has been applied in previous modelling work in the Riverland area (Yan, Howles & Hill 2005, Yan et al. 2007, Yan & Stadter 2008) and has been confirmed within recent work carried out by Aquaterra (2009) in the Sunraysia irrigation area.
- The final adopted recharge with time under irrigation areas is found in *Appendix A*.

3.6.3 IRRIGATION HISTORY

3.6.3.1 Morgan to Lock 1

Irrigation commenced in this area around the 1970s (P Cole [DWLBC] 2008, pers. comm.) and was located in the highland area. Most of the irrigated vines at this time were drip irrigated, and a number of developments failed soon after planting due to the development of

perched watertables and the underlying presence of Blanchetown Clay. Many areas of plantings were removed and replanted. Water was applied daily to vines at a rate of 2–3 ML/ha, or approximately 1000 L per vine per season during the mid 1970s (D Davidson [Davidson Viticulture] 2008, pers. comm.). Since the 1980s, centre pivots have been used to irrigate horticultural produce within this area.

The total area of irrigation in 2007 was 2,321 ha, with areas of expansion occurring in 2000, 2003 and 2005. The development of irrigated areas over time in the Morgan to Lock 1 sub-zone is shown in Figure 3 in *Appendix D*.

3.6.3.2 Lock 1 to Mannum

Irrigation in this area is mostly located on the highland areas and commenced in the 1960s, when the Greenways and Swan Reach irrigation areas commenced (Mid Murray LAP Committee 2000). Figures from the South Australian Murray-Darling Basin Natural Resources (SA MDB NRM) Board currently estimate that there are approximately 5564 ha of irrigated horticulture in this zone, including vegetables, vines, citrus and stone fruit. Some irrigated pasture for grazing exists on the floodplain.

The development of irrigated areas over time in the Lock 1 to Mannum sub-zone is shown in Figure 4 in *Appendix D*. The major irrigation systems used in this area are under canopy and drip system for citrus; and drip system, overhead sprinkler and under canopy for vines (Vears & Roberton 2008).

3.6.3.3 Mannum to Wellington

Irrigation development occurred from 1881 to 1929 following the reclamation of a number of swamps for pasture, with most areas reclaimed by 1945. Little further development has occurred since this time. On the highland areas, approximately 325 ha were developed at Mypolonga between 1914 and 1944, with a further 414 ha developed up until 2001 (Jolly, Overton & Smitt 2003).

In 2005, there were 27 reclaimed swamp irrigation areas totalling 5200 ha of pasture irrigated for dairy and cattle, and 1700 ha of irrigated highland (including 780 ha of horticulture, mainly citrus and stone fruit) (Environment Protection Authority 2005). Not included in this total are an increasing number of glasshouses producing horticultural crops on the highland. The number of individual irrigators on the reclaimed swamps has reduced in the last few years, as irrigators leave the industry as a result of reduced water allocations due to the current drought.

Recent figures for 2007 from the SA MDB NRM Board suggest there are approximately 9700 ha (reclaimed swamp and highland) irrigated within this sub-zone (including Environmental Land Management Allocation—ELMA—only irrigation).

As the Lower Murray reclaimed irrigation areas were unmetered prior to rehabilitation (RH), there is not an accurate historical record of water use before meters were installed. What little information is available has been documented in *Appendix D*.

The development of irrigated areas over time in the Mannum to Murray Bridge sub-zone and Murray to Wellington sub-zone are shown in *Appendix D*, Figure 5.

3.6.4 RECHARGE APPLIED FOR PREDICTIVE MODELLING

Based on the calibrated model, five future scenarios were developed to predict salt loads to the River Murray as a result of various accountable irrigation actions. Figures 25a to 25d show the modelled recharge zones between Morgan to Wellington. Further details of the recharge zones and rates in the scenarios are included later in this report (section 5, Model Scenarios and Predictions).

The following groundwater recharge assumptions were made to predict salt loads to the River Murray under the five irrigation scenarios:

- **Scenario–3A**, Pre-1988 irrigation without improved irrigation practices (IIP) or RH:
  a. Used only recharge zones that represent irrigation that commenced prior to 1 January 1988.
  b. Recharge rates for prediction (after 1988) correspond with the calibrated 1988 irrigation rates from the calibration model. Two cases can apply:
     - Case 1. In recharge zones where an irrigation mound is present at 1988 in the calibration model the calibrated recharge rates at 1988 are applied for that zone from 1988 to all future times.
     - Case 2. In recharge zones where an irrigation mound is not present at 1988 (due to lag time) in the calibration model the maximum calibrated recharge rates for that zone is applied from 1988 to all future times.
- **Scenario–3B**, Pre-1988 irrigation with IIP but without RH:
  a. Used only recharge zones that represent irrigation that commenced prior to 1 January 1988.
  b. Recharge rates for prediction (after 1988) reduce gradually to 2009 irrigation rates of 100mm/year based on CSIRO findings (see section 3.6.2) and consistent with the calibrated model for areas outside of the RH area. For areas that experienced RH (i.e. highland area at Mypolonga which was completed in 1998), recharge rates were held constant at the 1998 calibration rates. Refer to section 3.7 below for more information on RH.
- **Scenario–3C**, Pre-1988 irrigation with IIP and with RH (i.e. historical development):
  a. Used only recharge zones that represent irrigation that commenced prior to 1 January 1988.
  b. Recharge rates for prediction (after 1988) reduce gradually to 2009 irrigation rates of 100mm/year based on CSIRO findings (see section 3.6.2) for all regions, assuming an improvement in irrigation efficiency and RH, i.e. same as the calibration (history match).
- **Scenario–4**, Current Irrigation:
  a. Used all recharge zones that represent irrigation that commenced prior to 1 January 2009.
  b. All recharge decreases to 100 mm/year by 2007 due to IIP during the 1990s and early 2000s.
- **Scenario–5**, Future Development Irrigation:
  a. Same recharge condition as Scenario–4 (current irrigation) but with the addition of predicted future irrigation zones.
  b. Future development irrigation areas were adopted from licences that have been approved for prior commitment by the state (Figure 26). Irrigation in these areas

were assumed to commence in 2015 and 40 year initial lag time was applied based on SIMRAT estimates.

c. A recharge rate of 100 mm/year was assumed for future irrigation areas that exist on the highland area located between the upstream area of Murray Bridge to Wellington.

3.7 DRAINAGE NETWORK AND REHABILITATION

Salt drains along the edge of the irrigated floodplain areas (Fig. 5c) collect irrigation drainage water and regional groundwater discharge from the highland, which is diverted into the River Murray. A combination of the implementation of metering and tail drains, as well as reduced irrigation allocations due to the drought, has lead to little if any water being pumped from the drains to the River Murray since 2007.

Very little maintenance was undertaken on the drainage systems over the years, and much of the infrastructure was in poor condition. The original irrigation and drainage systems were designed to follow the natural characteristics of the land and not necessarily for efficient use. The levee banks, built to reclaim the floodplain, contain the river which is maintained at an average level of ~0.7 m AHD by the barrages near Goolwa. Due to recent drought conditions this level has dropped below sea level. The watertable beneath the reclaimed swamps is controlled by the drainage system at 1–1.5 m below the river level. Water for irrigation is gravity-fed from the river through infrastructure, including sluices and syphons (Vears & Roberton 2008). The location of drainage channels from Mannum to Wellington are shown in Figures 7 and 8 in *Appendix D*.

The rehabilitation and restructure of the government highland irrigation areas in South Australia commenced in 1992, and was carried out for seven years to 1999. It involved improved on-farm management practices; replacing irrigation channels and gates with pressurised pipes and metered outlets; and the transfer of control of the areas from state government to self-management. Key irrigation districts that were rehabilitated included Cobdogla, Moorook, Cadell and Mypolonga. Rehabilitation of the highland area of Mypolonga was completed in 1997–98, with 10 ha retired through the land suitability assessment process. The location of rehabilitated infrastructure at Mypolonga is shown in Figure 9 of *Appendix D*.

In the early 2000s, the South Australian government approved further RH strategies for the Lower Murray reclaimed irrigation areas which included improving irrigation efficiencies, mandatory installation of water meters, digging drains to intercept surface irrigation runoff (toe drains) and installing re-use pumps and systems. This program is expected to have a lifespan of 25 years (*Appendix D*).

3.8 EVAPOTRANSPIRATION

Evapotranspiration (ET) is the removal of water from soils as water vapour via direct evaporation and/or via plant transpiration, and is affected by climate, availability of water and vegetation type (Bureau of Meteorology 2001). The effect of evapotranspiration is typically assumed to reduce with depth from a maximum rate at the ground surface, to zero at the maximum depth (referred to as the ‘extinction depth’), which is assumed to be ~3 m below ground surface and could be up to ~5 m below ground surface (Aquaterra 2009).

Studies by CSIRO at Chowilla indicate that transpiration by river red gums is limited by salinity and soil properties, typically to around 1–2 mm/day (365–730 mm/year) (Thorburn, Hatton & Walker 1993). Transpiration by black box is typically ten times lower at less than 0.1–0.3 mm/day (37–110 mm/year) (Thorburn, Hatton & Walker 1993). In these studies, both species were identified as removing water from a depth of between 0.1 and 3.3 m (Aquaterra 2009).

At locations where the watertable is shallow (typically less than 3 m), ET has a direct influence on the watertable. Within the study area, areas of shallow watertable exist within some areas of the floodplain. As demonstrated during previous work on the EM1 model (Aquaterra 2007), ET is critical to the proper simulation of floodplain processes, and has a significant effect on ambient groundwater fluxes to the River Murray through interception.

Based on the *Climatic Atlas of Australia* (Bureau of Meteorology 2001), which uses Morton's (1983) complementary relationship, the average actual ET in the Morgan to Wellington area is ~300–400 mm/year. This is the actual ET that would take place in an area where there is limited water supply, i.e. limited by rainfall, which includes most of the 'highland' areas away from the floodplain. In areas where there is a shallow watertable (i.e. most floodplain areas), and hence an effectively unlimited water supply, ET may be much greater and could be as high as the average potential ET of 1100 mm/year (Bureau of Meteorology 2001).

Based on the recommendations of the project steering committee during the EM2.2 project, a maximum ET rate of 1100 mm/year has been applied to the surface with an extinction depth of 2 m. By applying ET using this method, the actual ET rate would be 550 mm/year for groundwater at 1 m below the surface, and only 276 mm/year for groundwater at 1.5 m below the surface (Aquaterra 2009). As a point of interest, ET may be greatly reduced in the areas downstream of Mannum due to the dense drainage networks that exist there.

3.9 GROUNDWATER ALLOCATION AND USE

Because of high groundwater salinities, there is no allocation of groundwater or known groundwater consumptive use in the Morgan to Wellington area.

3.10 MODEL STRESS PERIODS

The transient model was used to simulate the historical period (1920–2009) using stress period lengths ranging between 8 and 20 years during the early periods of the model (pre-1988), and stress periods of 1 year duration during later periods of the model (1988–2109).

4. MODEL CALIBRATION

Steady state models are used to model equilibrium hydrologic conditions and/or conditions when changes in storage are insignificant. Transient models are used to model time dependent stresses and/or where water is released from, or taken into, storage.

Calibration (history matching) of the model with existing data must be conducted in order to have confidence in predictive modelling. Calibration is necessary to demonstrate that the model can replicate the behaviour of the aquifer system for at least the historical set of conditions. A sensitivity analysis has also been undertaken to determine the relative importance of model parameters (i.e. the system drivers) in achieving calibration.

4.1 STEADY STATE MODEL CALIBRATION

Steady state calibration is undertaken to develop a broad-scale hydraulic conductivity distribution by matching modelled to observed potentiometric heads. A steady state calibration was performed by adjusting hydraulic conductivities (within reasonable limits) and model boundary conditions. Dynamic stresses and storage effects are excluded from the steady state calibration.

Due to the absence of pre-irrigation development potentiometric head data, the steady state model was calibrated using a potentiometric surface developed by AWE that represents current irrigation development and post river regulation conditions. The steady state model was run repeatedly until a representative pre-European modelled water level distribution was achieved. Since no pre-European potentiometric surface exists, the modelled surface can only be compared to the March 2008 surface (Fig. 27), which is thought to have changed very little from pre-European conditions apart from the small irrigation mound that exists at Mypolonga.

4.2 TRANSIENT MODEL CALIBRATION

Transient calibration is undertaken on an iterative basis by adjusting hydraulic parameters, recharge rates and boundary conditions until a satisfactory match with observed data is obtained. The potentiometric surface output from the steady state model was used as the starting point for transient model runs up to 2009. Each time a change to the boundary conditions and aquifer hydraulic parameters was made in the transient model, the steady state model was altered and re-run, with the output being used as the starting point for further transient model calibration. Model calibration was achieved by the following actions, in accordance with the *Groundwater flow modelling guideline* (MDBC 2001):

- Qualitative comparison between modelled and observed potentiometric heads (contours and hydrographs).
- Quantitative assessments of the (scaled RMS) iteration residual error (less 5%).
- Quantitative confirmation that the water balance criteria is < 1% for all times.
- Confirmation (as a water balance cross check) using:
  a. total ‘Run of River’ salt load into the River Murray
  b. comparison of recharge volumes
  c. comparison between model results and in-river NanoTEM.

In the project area, salt loads entering the River Murray occur mainly from lateral groundwater flux through the Murray Group Limestone and Monoman Sands aquifers as a result of natural gradients and irrigation-induced watertable mounding. Therefore matching observed trends in the Murray Group aquifer was considered most important during calibration. The head level in the Renmark Group aquifer was not considered in the calibration exercise, as this aquifer only exists in the model domain to supply potential upward leakage through the Ettrick Formation.

4.2.1 POTENTIOMETRIC HEAD COMPARISON

Initial qualitative calibration of the transient model was undertaken by trying to closely match the 2008 regional potentiometric head contours. The modelled and observed potentiometric heads from 2008 contours of the Murray Group and Monoman Formation were compared to determine the accuracy of the calibration (Fig. 27). It can be seen that the modelled distribution closely represents the shape and form of the observed distribution, including the groundwater mound in the Mypolonga area. Observation wells that are located in the Waikerie and Stockyard Plain area have only been used to determine an appropriate steady state head. The mound that exists in the north-eastern section of the model is due to the hydraulic processes of the Qualco and Waikerie irrigation districts and Stockyard Plain Disposal Basin, which have not been modelled and is out of scope for this project.

Quantitative calibration focused on hydrographs for the Murray Group aquifer (layer 1), with locations of observation wells used in the calibration shown in Figure 28. All wells that existed within the model domain were chosen, with the aim being to either match regional water levels and hydraulic gradients or irrigation watertable mounds at Mypolonga. In total, 28 wells were chosen to calibrate the steady state model and 18 wells were used to calibrate the historical model. The wells chosen contained reliable long-term historical observation data and represented a good distribution of calibration points over the model domain.

Comparison between modelled and observed (historical) potentiometric heads indicates a close match in most bores (Figs. 29 to 32) in terms of actual levels and trends.

4.2.2 ASSESSMENT OF ITERATION RESIDUAL ERROR

The iteration residual error between modelled and observed potentiometric heads of the Murray Group and Monoman Formation aquifers was calculated using the available irrigation footprints, an indicative root zone drainage rate which is based on CSIRO's methodology and the water level data for downstream of Lock 1. The calculations (Figs. 33 and 34) indicate a normalised root mean square value (SRMS) for the whole project area of:

- 1.2% in 1988
- 1.4% in 1995
- 1.0% in 2000
- 1.0% in 2008.

These values are lower than the 5% SRMS range recommended by the *Groundwater flow modelling guideline* (MDBC 2001) and indicate a good fit between modelled and observation data over the time period considered in the analyses.

Note that well WAK 33 has been omitted from the above calculations as it is affected by processes that are not included in this project (i.e. Qualco, Waikerie and Stockyard Basin).

4.3 WATER BALANCE

The model water balance error is less than 0.03% for all times. This is within the criteria of <1% defined in the MDBA *Groundwater flow modelling guideline* (MDBC 2001).

4.4 TRANSIENT MODEL CONFIRMATION

4.4.1 SALT LOADS

The salt load entering the River Murray in the Morgan to Wellington area was calculated using the modelled groundwater flux and groundwater salinity in each model flow budget zone. The zone locations and salinity values are shown in Figures 8 to 11.

Table 4 shows the comparison between the range of modelled salt load and the range of measured Run of River (ROR) salt load for each section of the river during specified years. It can be seen that the range of modelled and measured values are comparable for all sections of the river.

Table 4 Comparison between measured (ROR) and modelled salt load

Location	Years	Measured range (t/d)	Modelled range (t/d)
Morgan to Lock 1	1998, 2001,2002, 2003, 2004, 2005, 2006, 2008	3–33	3–10
Lock 1 to Mannum	2001, 2003	10–12	14–18
Mannum to Murray Bridge	2001, 2003	35–43	39–40
Murray Bridge to Wellington	2001, 2003	22–51	30–35

In January and April 2008, in-stream salinity data was captured at 160 cross sections, approximately 1 km apart, from Lock 1 to Murray Bridge. The objective of the two rounds of data collection was to use this data and gauging station salinity information to calculate the salt load within the reach and to identify salinity hotspots. Further salinity surveys were conducted at weekly intervals between Swan Reach and Mannum in February 2009, with the results to provide more detailed information of salinity spike progression and river flow travel speeds. The model results conform with these in-stream results, which adds confidence and improves the quality of the model results.

4.4.2 RECHARGE VOLUMES

Table 5 below compares the total recharge (including irrigation and rainfall) calculated from the water balance values of Vears and Roberton (2008) compared to the modelled recharge volumes for the irrigation footprints at 1988 and 2007.

Table 5 Comparison between modelled and estimated irrigation recharge

Sub-zone	Water balance estimate (ML/y)		Modelled recharge (ML/y)	
	1988	2007	1988	2007
Morgan to Lock 1	1824	2159	722	1132
Lock 1 to Mannum	3705	2732	1772	3287
Mannum to Murray Bridge	2885*	2804*	4042	4283
Murray Bridge to Wellington	2111*	3058*	3937	4465

* Includes recharge (irrigation drainage) estimates for both highland and floodplain areas. Diversion volumes for floodplain irrigation areas are missing and recharge volumes for the floodplain irrigation area have been estimated using rainfall recharge only.

The differences between calculated accession and the calibrated recharge can be explained by the lack of confidence in the measured diversion volumes. Diversion volumes are also missing for the floodplain area between Mannum to Wellington, which would otherwise account for a large part of the total recharge estimate in this area.

Despite the above mentioned discrepancies, the consistency in the magnitude of the calculated and modelled volumes help provide additional confidence that the total recharge applied in the model is a physically reasonable estimate.

4.4.3 IN-RIVER NANOTEM

Figures 2a and 2b show the 2005 NanoTEM river bed resistivity surveys results between river kilometres 73–191 km, and 191–280 km respectively. It is difficult to draw comparisons between the NanoTEM results and the modelled salt loads because the NanoTEM survey is conducted on a river km by km resolution, yet the model calculates salt loads on a reach by reach scale (i.e. on a much greater scale). The modelled salt loads upstream of Lock 1 are considerably smaller than the other reaches, however the NanoTEM for this area is unavailable so no qualitative comparison can be made. However, a more recent NanoTEM survey may help validate the large salt loads that are modelled post 2005 as a result of the recent drought related river level decline downstream of Lock 1.

5. MODEL SCENARIOS AND PREDICTIONS

The calibrated transient model provides a useful predictive tool to quantify future fluxes of saline groundwater, and the potential impacts of specific stresses on potentiometric heads, over periods that may range from tens to hundreds of years.

The modelling scenarios are summarised in Table 6, and are discussed in detail below. The scenario structure has been developed progressively in response to requests by the state (DWLBC) and the MDBA to:

- Evaluate the impact of various accountable actions, to be recorded on the MDBA Salinity Registers 'A' and 'B', including:
  a. impact of the various pre- and post-1988 actions on the groundwater flux and salt load entering the River Murray
  b. impact of improved irrigation practices IIP and the rehabilitation (RH) of distribution systems
  c. assess the decision about the Salt Interception Scheme (SIS).
- Determine the state and federal responsibility for cost sharing.
- Satisfy the reporting requirements of:
  a. Schedule 'B' of the Murray-Darling Basin Agreement 2008
  b. Basin Salinity Management Strategy 2001–2015 (BSMS)

Table 6 Summary of modelled scenarios and conditions adopted for Morgan to Wellington

Scenario	Name	Model run	Irrigation development area	IIP	RH	SIS
S–1	Natural system	Steady State	None	–	–	–
S–2	Mallee clearance	1920–2106	None (but includes mallee clearance area)	–	–	–
S–3A	Pre-1988, no IIP, no RH	1988–2106	Pre-1988	No	No	–
S–3B	Pre-1988, with IIP, no RH	1988–2106	Pre-1988	Yes	No	–
S–3C	Pre-1988, with IIP and with RH	1988–2106	Pre-1988	Yes	Yes	–
S–4	Current irrigation	1880–2106	Pre-1988 + Post-1988	Yes	Yes	No
S–5	Current plus future irrigation	2006–2106	Pre-1988 + Post-1988 + Future development	Yes	Yes	No

The scenarios include the application of the following important conditions:

Pre-1988 irrigation — Irrigation development area and recharge that occurred prior to January 1988.

Post-1988 irrigation — Irrigation development area and recharge that occurred between January 1988 and end of calendar year 2008.

Future development — Future irrigation development area and recharge (assuming recharge of 100 mm/year) resulting from activation of already allocated (prior commitment) water that is assumed to occur in 2015.

Mallee clearance — Clearance of natural vegetation assumed to commence from the 1920s, resulting in increased recharge to the watertable in dryland areas. It is assumed that no major clearing of native vegetation occurred after 1988.

Improved irrigation practices (IIP) — Advancements in irrigation efficiency include the use of sprinkler and drip systems (replacing flood irrigation via earth channels), and the greatly improved technology, monitoring and management of irrigation systems (from circa early 1990s). These measures have resulted in improvements in efficiency (from ~70% to ~85%) and reduced recharge to the watertable.

Rehabilitation (RH) — Replacement of irrigation channels and gates with pressurised pipes and metered outlets, and transfer of control from State to self-management (e.g. in Mypolonga highland area, RH commenced in the early 1990s) resulting in reduced conveyance losses, which are reflected by reduced recharge to the watertable.

Salt load — For the purpose of a Salinity Register entry, the model result is the annual salt load entering the River Murray based on average river level conditions, as required by MDBA. In general, the salt load is calculated using modelled groundwater flux into the river from the aquifer, multiplied by the groundwater salinity adjacent to the river.

In the Mannum to Wellington area (within floodplain irrigation areas), the salt load in the drains (section 3.7) is one component of the overall salt load results. The salt load discharged into the drains is calculated in a similar way to that for the river, by using groundwater flux from the highland and groundwater salinity adjacent to the salt drain.

Average river level conditions — For the purposes of Salinity Register entry, all model scenarios have involved the use of average river level conditions. An example from this modelling project is that a constant river level of 3.2 m AHD above Lock 1 and 0.7 m AHD below Lock 1 have been used for all times within all model scenarios. Due to drought conditions actual river levels below Lock 1 have declined significantly since 2000. Annual average river levels below Lock 1 were only used during transient calibration.

Note: Within the Mannum to Wellington area, the salt load from the highland into the salt drains is included in the model results for all periods. This is because in the past, seepage water from the highland in the salt drain was pumped into the river regularly. With recent drought conditions, the implementation of tail drains and water use metering, there has been a significant reduction in water diverted into the salt drains and the frequency of the discharge from the salt drains to the river has reduced. A conservative approach has been taken with the assumption (described above) that salt load into the salt drains will continue to discharge into the River Murray on a daily basis in the future. Flux and salt loads from the highland to the salt drains have been presented separately within Appendix B*.*

5.1 SCENARIO–1: NATURAL SYSTEM

The Steady State Scenario–1 models the base groundwater flux and salt load entering the River Murray post-river regulation but prior to irrigation development.

The following conditions are applied to the steady state model:

- Post-regulation of the River Murray. (i.e. with weir pool stage elevations modelled).
- Average river level conditions (i.e. 3.2 m AHD above Lock 1 and 0.7 m AHD below Lock 1)
- Pre-irrigation development.
- Time period equal to steady state.

The results given in Table 7 show the modelled flux and salt load entering the River Murray from the eastern and western side of the river for the four sub-zones for Scenario–1.

Table 7 Modelled groundwater flux and salt load for the four sub-zones within the Morgan to Wellington area (Scenario–1: Natural System)

	Morgan to Lock 1	Lock 1 to Mannum	Mannum to Murray Bridge	Murray Bridge to Wellington
Flux (m^3/d)	391	2953	27	446
Salt load (t/d)	2.8	8.5	0.2	2.7

5.2 SCENARIO–2: MALLEE CLEARANCE

Transient Scenario–2 models the hydrological changes, groundwater flux and salt load entering the River Murray that would be expected to occur due to the clearance of the native mallee vegetation (by comparison with Scenario–1) and the subsequent increase in recharge rates.

The following conditions are applied to the transient model:

- Post-regulation of the River Murray.
- Average river level conditions (i.e. 3.2 m AHD above Lock 1 and 0.7 m AHD below Lock 1)
- No irrigation development.
- Mallee clearance commencing in 1920.
- Within the mallee clearance zones, application of recharge rates >=0.07 mm/year, increasing in some areas to ~29 mm/year after a period of 200 years, with changes (representing lag times) occurring every 10 years (data provided by DEH).
- Outside the mallee clearance zones, application of a recharge rate of 0.07 mm/year and time period equal to 1920–2109.

The results given in Table 8 summarise the predicted flux and salt load entering the River Murray for the four sub-zones. Complete results of the predicted flux of saline groundwater and salt load are given in *Appendix B*. Detailed recharge values applied to Scenario–2 are listed in *Appendix A* (model inputs).

Table 8 Predicted groundwater flux and salt load (Scenario–2: Mallee clearance)

	Year				
	1988	**2000**	**2009**	**2050**	**2109**
Morgan to Lock 1					
Flux (m^3/d)	405	451	498	1447	2756
Salt load (t/d)	2.9	3.3	3.6	10.6	20.5
Lock 1 to Mannum					
Flux (m^3/d)	3165	3235	3264	3522	4229
Salt load (t/d)	9.8	10.1	10.3	11.2	13.7
Mannum to Murray Bridge					
Flux (m^3/d)	2983	3081	3125	3421	4039
Salt load (t/d)	20.4	21.1	21.3	23.4	27.5
Murray Bridge to Wellington					
Flux (m^3/d)	3816	4068	4240	5325	6890
Salt load (t/d)	25.1	26.9	28.1	35.9	47.1

5.3 SCENARIO–3A: PRE-1988, NO IIP, NO RH

Transient Scenario–3A predicts the hydrological changes, groundwater flux and salt load entering the River Murray that would be expected to occur between 1988 and 2109 assuming pre-1988 irrigation development with no mitigation in terms of improvements to irrigation practices (IIP) and rehabilitation (RH).

The following conditions are applied to the transient model:

- The potentiometric head distribution output from the historical model at 1 January 1988 used as the starting point for the prediction run.
- Average river level conditions (i.e. 3.2 m AHD above Lock 1 and 0.7 m AHD below Lock 1)
- 1988 irrigation development area applied between 1988 and 2109.
- Pre-1988 recharge rates and lag times (from the historical model) applied between 1988 and 2109.
- No RH was applied in highland area of Mypolonga.
- Time period is from 1988 to 2109.

The results given in Table 9 summarise the predicted flux and salt load entering the River Murray for the four sub-zones. Complete results of the predicted flux of saline groundwater and salt load are given in *Appendix B*. Detailed recharge values applied to Scenario–3a are listed in *Appendix A* (model inputs).

Table 9 Predicted groundwater flux and salt load (Scenario–3A: Pre-1988, no IIP, no RH)

	Year				
	1988	**2000**	**2009**	**2050**	**2109**
Morgan to Lock 1					
Flux (m^3/d)	391	391	1547	2050	2133
Salt load (t/d)	2.8	2.8	13.9	18.1	18.8
Lock 1 to Mannum					
Flux (m^3/d)	4341	4526	6533	7167	7352
Salt load (t/d)	14.1	14.9	22.6	25.4	26.1
Mannum to Murray Bridge					
Flux (m^3/d)	6225	6489	7133	7406	7478
Salt load (t/d)	43.0	44.8	49.0	50.8	51.3
Murray Bridge to Wellington					
Flux (m^3/d)	4650	4681	6385	6868	6987
Salt load (t/d)	33.1	33.3	43.6	46.8	47.7

5.4 SCENARIO–3B: PRE-1988, WITH IIP, NO RH

Transient Scenario–3B predicts the hydrological changes, groundwater flux and salt load entering the River Murray that would be expected to occur between 1988 and 2109 assuming pre-1988 irrigation development with improvements in irrigation practices (IIP). This scenario evaluates the reduction in salt load (by comparison with Scenario–3A) resulting from the implementation of IIP.

The following conditions are applied to the transient model:

- Potentiometric head distribution output from the historical model at 1 January 1988 used as the starting point for the prediction run until 2109.
- Average river level conditions (i.e. 3.2 m AHD above Lock 1 and 0.7 m AHD below Lock 1)
- 1988 irrigation development area applied between 1988 and 2109.
- IIP—recharge rates decreasing from the early 1990s to the late 2000's, in accordance with calibrated (history match) rates. This assumes an increase in irrigation efficiency after 1988 which is in line with the MDBA definition of IIP for accreditation
- No RH was applied in highland area of Mypolonga.
- Time period is from 1988 to 2109.

The results given in Table 10 summarise the predicted flux and salt load entering the River Murray from the four sub-zones. Complete results of the predicted flux of saline groundwater and salt load are given in *Appendix B*. Detailed recharge values applied to Scenario–3B are listed in *Appendix A* (model inputs).

Table 10 Predicted groundwater flux and salt load (Scenario–3B: Pre-1988, with IIP, no RH)

	Year				
	1988	**2000**	**2009**	**2050**	**2109**
Morgan to Lock 1					
Flux (m^3/d)	391	391	1134	1240	1260
Salt load (t/d)	2.8	2.8	9.9	10.7	10.9
Lock 1 to Mannum					
Flux (m^3/d)	4341	4387	5200	4970	4962
Salt load (t/d)	14.1	14.3	17.4	16.5	16.5
Mannum to Murray Bridge					
Flux (m^3/d)	6225	6219	6228	6106	6108
Salt load (t/d)	43.0	42.9	42.7	41.9	41.9
Murray Bridge to Wellington					
Flux (m^3/d)	4650	4335	4771	4622	4627
Salt load (t/d)	33.1	30.5	32.0	30.8	30.8

5.5 SCENARIO–3C: PRE-1988, WITH IIP AND WITH RH

This scenario tests the reduction in salt load (by comparison with Scenario–3B) resulting from the implementation of rehabilitation (RH). RH has occurred in the highland area of Mypolonga, between the Mannum to Murray Bridge reach.

The following conditions are applied to the transient model:

- The potentiometric head distribution output from the historical model at 1 January 1988 used as the starting point for the prediction run until 2109.
- Average river level conditions (i.e. 3.2 m AHD above Lock 1 and 0.7 m AHD below Lock 1)
- 1988 irrigation development area applied between 1988 and 2109.
- IIP—recharge rates decreasing from the early 1990s to the late 2000's, in accordance with calibrated (history match) rates. This assumes an increase in irrigation efficiency after 1988 which is in line with the MDBA definition of IIP for accreditation.
- RH—recharge rates decreasing from 1990, in accordance with calibrated (history match) RH.
- Time period is from 1988 to 2109.

The results given in Table 11 summarise the predicted flux and salt load entering the River Murray from the four sub-zones. Complete results of the predicted flux of saline groundwater and salt load are given in *Appendix B*. Detailed recharge values applied to Scenario–3C are listed in *Appendix A* (model inputs).

Table 11 Predicted groundwater flux and salt load (Scenario–3C: Pre-1988, with IIP, and with RH)

	Year				
	1988	**2000**	**2009**	**2050**	**2109**
Morgan to Lock 1					
Flux (m^3/d)	391	391	1134	1241	1260
Salt load (t/d)	2.8	2.8	9.9	10.7	10.9
Lock 1 to Mannum					
Flux (m^3/d)	4341	4385	5199	4970	4962
Salt load (t/d)	14.1	14.3	17.4	16.5	16.5
Mannum to Murray Bridge					
Flux (m^3/d)	6225	5848	4993	4457	4441
Salt load (t/d)	43.0	40.3	34.1	30.3	30.2
Murray Bridge to Wellington					
Flux (m^3/d)	4650	4332	4770	4622	4627
Salt load (t/d)	33.1	30.5	32.0	30.8	30.8

5.6 SCENARIO–4: CURRENT IRRIGATION

Transient Scenario–4 predicts the hydrological changes, groundwater flux and salt load entering the River Murray that would be expected to occur between 2009–2109 assuming the current irrigation condition (pre-1988 plus post-1988 irrigation development with IIP and RH). This scenario predicts the likely future salt load if the current conditions remain unchanged in the future, based on the historical events up until the end of calendar year 2008.

The following conditions are applied to the transient model:

- Potentiometric head distribution output from the historical model at 1988 used as the starting point for the prediction run from 1988 to 2109.
- Average river level conditions (i.e. 3.2 m AHD above Lock 1 and 0.7 m AHD below Lock 1)
- Pre-1988 plus post-1988 development area applied up to 2009 and then the areas held constant until 2109.
- IIP—recharge rates decreasing from the early 1990s to the late 2000's, in accordance with calibrated (history match) rates. This assumes an increase in irrigation efficiency after 1988 which is in line with the MDBA definition of IIP for accreditation.
- RH—recharge rates decrease further from the early 1990s, in accordance with calibrated RH.
- Time period is from 1988 to 2109.

The results given in Table 12 summarise the predicted flux and salt load entering the River Murray from the four sub-zones. Complete results of the predicted flux of saline groundwater and salt load are given in *Appendix B*. Figures 35 to 38 show the modelled 'current' salt load

(2009) for each of the four sub-zones: Morgan to Lock 1, Lock 1 to Mannum, Mannum to Murray Bridge and Murray Bridge to Wellington respectively. Detailed recharge values applied to Scenario–4 are listed in *Appendix A* (model inputs).

Table 12 Predicted groundwater flux and salt load (Scenario–4: Current irrigation)

	Year				
	1988	**2000**	**2009**	**2050**	**2109**
Morgan to Lock 1					
Flux (m^3/d)	391	391	1134	2286	2503
Salt load (t/d)	2.8	2.8	9.9	17.8	19.3
Lock 1 to Mannum					
Flux (m^3/d)	4341	4385	5199	8213	9810
Salt load (t/d)	14.1	14.3	17.4	30.0	37.0
Mannum to Murray Bridge					
Flux (m^3/d)	6225	5848	4993	5748	6041
Salt load (t/d)	43.0	40.3	34.1	39.3	41.2
Murray Bridge to Wellington					
Flux (m^3/d)	4650	4332	4770	6504	6848
Salt load (t/d)	33.1	30.5	32.0	43.4	45.8

5.7 SCENARIO–5: CURRENT PLUS FUTURE IRRIGATION

Transient Scenario–5 predicts the hydrological changes, and the (maximum) groundwater flux and salt load entering the River Murray that would be expected to occur between 2009–2109 assuming the current irrigation (pre-1988 plus post-1988 irrigation development with IIP and RH) plus future irrigation growth. This scenario tests the increases in salt load (by comparison with Scenario–4) resulting from future irrigation development. Two zones have been identified for future development upstream of Murray Bridge and Tailem Bend (Fig. 26).

The following conditions are applied to the transient model:

- Potentiometric head distribution output from the historical model at 1988 used as the starting point for the prediction run until 2109.
- Average river level conditions (i.e. 3.2 m AHD above Lock 1 and 0.7 m AHD below Lock 1)
- Pre-1988 plus post-1988 plus future irrigation development area applied between 2009–2109.
- IIP—recharge rates decreasing from the early 1990s to the late 2000's, in accordance with calibrated (history match) rates. This assumes an increase in irrigation efficiency after 1988 which is in line with the MDBA definition of IIP for accreditation.
- RH—Recharge rates decrease further from the early 1990s, in accordance with calibrated RH.
- Recharge from future irrigation development areas operating from 1 January 2015 to 2109, assuming ~85% efficiency. Future irrigation development exists upstream of

Murray Bridge and Tailem Bend only (Fig. 26). Rates are fixed at 100mm/year on the highland area which is consistent with the calibrated rates of Scenario–S4.

- Time period is from 1988 to 2109.

The results given in Table 13 summarise the predicted maximum flux and salt load entering the River Murray from the four sub-zones. Complete results of the predicted flux of saline groundwater and salt load are given in *Appendix B*. Detailed recharge values applied to Scenario–5 are listed in *Appendix A* (model inputs).

Table 13 Predicted groundwater flux and salt load (Scenario–5: Current plus future irrigation)

	Year				
	1988	**2000**	**2009**	**2050**	**2109**
Morgan to Lock 1					
Flux (m3/d)	391	391	1134	2286	2502
Salt load (t/d)	2.8	2.8	9.9	17.8	19.3
Lock 1 to Mannum					
Flux (m3/d)	4341	4385	5199	8213	9790
Salt load (t/d)	14.1	14.3	17.4	30.0	36.9
Mannum to Murray Bridge					
Flux (m3/d)	6225	5848	4993	5748	6065
Salt load (t/d)	43.0	40.3	34.1	39.3	41.3
Murray Bridge to Wellington					
Flux (m3/d)	4650	4332	4770	6504	6895
Salt load (t/d)	33.1	30.5	32.0	43.4	46.2

5.8 COMPARISON OF SCENARIO SALT LOADS

Figures 38 to 42 display the yearly salt loads from 1988 to 2109 for each of the four subzones, and Figure 43 shows the total predicted salt loads entering the River Murray for all scenarios over all four sub-zones between Morgan to Wellington. Details of model results (flux and salt load) for all scenarios are listed in *Appendix B*.

6. SENSITIVITY ANALYSIS

6.1 PREDICTIVE UNCERTAINTY

A combined predictive uncertainty and sensitivity analysis was undertaken to quantify the impact of an incremental variation in aquifer hydraulic parameters, or a stress, on the modelled aquifer response. The purpose of the sensitivity analysis is to quantify the change in the predicted salt load at 2109 due to the uncertainty involved in applying selected parameter values in the model.

The transient model has been calibrated for aquifer hydraulic parameters and recharge, and requires sensitivity testing for issues of major concern and to comply with the MDBA *Groundwater flow modelling guide* (MDBC 2001).

Scenario–5 was selected for all sensitivity tests, as it is a worst-case (full development) scenario of existing irrigation area plus full future irrigation development in the model area.

6.1.1 TEST–1: VARIATION OF LONG-TERM RIVER LEVELS BELOW LOCK 1

The long-term river level below Lock 1 used for all model scenarios from 2010 to 2109 was 0.7 m AHD, which is the average river level. Due to the model's sensitivity to river level, an uncertainty test was carried out for two additional long-term river levels of -0.7 m AHD and 0.1 m AHD downstream from Lock 1 (Fig. 20).

This uncertainty analysis used Scenario 5 under actual annual average river levels to 2009. Only salt load results for the Lock 1 to Wellington section of the river were presented, as salt load above Lock 1 will not be impacted by river levels below Lock 1.

With a falling river level, the watertable gradient toward the river is increased, and this increases the flux and therefore increases salt loads to the river. The model results shown in Figure 49 confirm this process.

A linear equation can be used to approximate the relationship between salt load and river level for any year in the future. These equations have been derived for 2019 and 2109 which are presented in Figure 50. Modelled salt load for each year and for each of the tested river levels are presented in *Appendix C*. This data can be used to interpolate salt loads at different river levels in future years.

6.1.2 TEST–2: VARIATION OF MURRAY GROUP PARAMETERS

This test evaluates the impact of variations in the aquifer hydraulic parameters of the Murray Group Limestone aquifer (specific yield Sy and horizontal conductivity Kh) on the magnitude of the salt load to the river at the modelled year of 2109 (i.e. by running the model 100 years into the future).

Testing was conducted by varying layer 1 aquifer hydraulic parameters by ±15% from the calibrated hydraulic conductivity and specific yield.

Test results (Table 14) indicate that:

- Changes of ±15% to the calibrated Murray Group hydraulic conductivity results in a predicted maximum change of 3.8% in the salt load entering the River Murray 100

years into the future. Figure 51 shows the model sensitivity to changes in horizontal conductivity.

- Changes of ±15% to the calibrated Murray Group specific yield results in a predicted maximum change of 0.9% in the salt load entering the river 100 years into the future. This change is considered insignificant. Figure 51 shows the model sensitivity to changes in specific yield.

The results given in Table 14 indicate that the salt load into the River Murray is only slightly affected by changes in aquifer hydraulic parameters, and this provides confidence in using the calibrated values.

Table 14 Results of sensitivity testing by variation in aquifer and aquitard hydraulic parameters—predicted percentage difference in salt load entering River Murray at 2109

Parameter value	**Kh** (m/d) Murray Group			**Sy (-)** Murray Group			**Kv** (m/d) Ettrick Formation		
	-15%	Calibrated	+15%	-15%	Calibrated	+15%	x1/10	Calibrated	x10
Morgan to Lock 1 Percentage Difference (%)	-1.3	0	1.0	0.7	0	-0.6	0.2	0	0.3
Lock 1 to Upper Mannum Percentage Difference (%)	-5.5	0	5.0	2.4	0	-1.9	0.7	0	0.9
Upper Mannum to Mannum Percentage Difference (%)	-4.3	0	3.8	1.3	0	-1.2	0.4	0	0.5
Mannum to Murray Bridge Percentage Difference (%)	-4.0	0	3.8	0.4	0	-0.3	-0.5	0	3.6
Murray Bridge to Wellington Percentage Difference (%)	-3.8	0	3.7	0.5	0	-0.5	0.0	0	0.4
Total Morgan to Wellington Percentage Difference (%)	-3.8	0	3.5	0.9	0	-0.7	0.0	0	1.4

6.1.3 TEST–3: LEAKAGE FROM ETTRICK FORMATION

In the Morgan to Wellington project area, the vertical flux from the Renmark Group aquifer to the River Murray is considered to be lower than the lateral flux from the Murray Group aquifer. In order to comply with the MDBA guideline (MDBC 2001), the sensitivity to upward leakage by variation of the Kv of the Ettrick Formation (layer 2) was tested and the results are included in this report.

This sensitivity testing was conducted by varying the vertical hydraulic conductivity of the Ettrick Formation (layer 2) by an order of magnitude of the calibrated value and running the model 100 years into the future from 2009.

Test results (Table 14) indicate that changes of an order of magnitude to the calibrated vertical hydraulic conductivity (Kv) for the Ettrick Formation resulted in a predicted maximum change of 0.8% in salt load entering the River Murray 100 years into the future. This is considered insignificant. Figure 52 shows the model sensitivity to changes in Ettrick Formation vertical conductivity.

The comparison of the above three parameters tested (model sensitivity) in the Morgan to Wellington area are shown in Figure 53.

6.1.4 TEST–4: VARIATION OF GROUNDWATER SALINITY

A comprehensive analysis of the existing salinity data has not been evaluated for this region, as has been done for the Pike–Murtho, Berri–Renmark and Pyap to Kingston model projects which compared the adopted salinity values in the model to the statistically determined mean and median salinity values for each flow budget zone. Instead, the salinities of each zone were varied by ±15% of the calibrated salinity value to enable direct comparison with the sensitivity of the Murray Group and Ettrick Formation aquifer parameters tested above.

This test is designed to investigate the uncertainty of the model results (salt loads) to changes in salinity values applied to the model flux zones (Figs. 8 to 11). The test is done outside of the modelling interface, ie the model conditions and fluxes do not change, only the applied salinity values are altered. As salt load is the product of flux and salinity a variation of ±15% in groundwater salinity results in a variation of ±15% in salt load to the river. When compared to Test–2 and Test–3, this result is relatively significant. Figure 53 shows the model sensitivity to changes in salinity values.

7. MODEL UNCERTAINTY

The following factors are considered to be the most important in terms of model accuracy and uncertainty in the results from calculating salt loads.

7.1 FLOODPLAIN PROCESS

The hydrogeology of the highland and floodplain areas is considered to be reasonably well understood and satisfactorily represented in the model, which gives confidence to the estimates of fluxes passing from the highland irrigation areas to the edge of the floodplain. However, the detailed salt flux processes through the floodplains are less well known and were not modelled, although there is satisfactory representation of the floodplain hydrogeology in the model. This is because salt is intercepted and accumulated in floodplains between floods, making discharge of salt from floodplains to the River Murray on a daily basis difficult to predict.

Representation of floodplain processes can be further improved by the use of high resolution and accurate Light Detection and Ranging (LIDAR) data to determine detailed topography of the floodplain. This improved topography data can be used to calculate evapotranspiration more accurately on the floodplain due to a more accurate evapotranspiration surface. Vegetation mapping and detailed salinity distribution analysis on the floodplain can also be used to 'finetune' evapotranspiration parameters on the floodplain.

Evapotranspiration is thought to be one of the most sensitive parameters due to its large potential to intercept flux on the floodplain before it enters the River Murray, which directly impacts modelled salt loads. However, floodplain processes and thus evapotranspiration are not as imperative in the Morgan to Wellington domain due to the following:

- Limited floodplain areas over most of the model domain.
- Floodplain areas that do exist in the project area have extensive drainage systems that keep the groundwater levels generally below river levels and thus the salt loads are reduced in these areas (e.g. downstream area from Mannum). These drainage systems are implemented in the model and tend to minimise the impacts of the model uncertainty of evapotranspiration.

7.2 GROUNDWATER SALINITY

The groundwater salinity values, and the zones which have been applied in the calculation of salt load, represent the best current understanding of the groundwater salinity distribution derived from the analysis of all existing available data (post January 2004) and understanding of the local groundwater system.

Most salinity data used to determine the salinity values of the flux zones in the model domain are located away from the river, except in the Mypolonga area (Fig. 7a). It is suggested that future field investigations should target areas closer to the river to determine more local salinity distributions.

To address the uncertainty of the adopted salinity values in the model, a sensitivity test was conducted with the test results indicating a maximum salt load change of 15% from the

adopted model at 2109 by varying the salinity by ±15%. It is expected that salinity is relatively significant when compared to the other tested parameters.

To help reduce the uncertainty surrounding the adopted salinity values in the model, the Groundwater group of DWLBC compared the modelled salinity values to the 2008 In-stream Salinity Survey, which was used to further refine the salinity values in the model flux zones. Furthermore, the modelled salt loads upstream of Murray Bridge were validated to DWLBC's surface river model. Possible future improvements could include the use of airborne electromagnetic (AEM) imaging to provide a spatial distribution of salinity for the purposes of calculating salt loads to specific reaches. In this case, the AEM can be benchmarked against the measured groundwater salinity values.

7.3 RECHARGE DUE TO IRRIGATION

Model recharge rates and future irrigation areas are considered to be key contributors to model uncertainty. A simplistic approach was adopted for the recharge rates used for the historical modelling. These rates were based on CSIRO's 'rule of thumb' rates and adjusted during the calibration exercise to match observed hydrographs. The resulting recharge volumes due to irrigation were verified against the water balance volumes based on the work of Vears and Roberton (2008) as a reality check.

The SIMPACT model suggests predicted recharge rates of 100 mm/year for the 'future development' predictions in the highland areas between Morgan to Wellington. It is highly likely that there will be changes in irrigation efficiency (that will affect recharge–accession) and irrigated area, and therefore deviations from the assumed development sequence in the future, although these areas are insignificant in size (Fig. 26).

7.4 HYDRAULIC PARAMETERS

As an attempt to quantify the uncertainty associated with the Murray Group Limestone hydraulic parameters, sensitivity analyses were conducted. The percentage change in the model salt loads that is attributable to variations in aquifer and aquitard hydraulic parameters are shown graphically in Figures 51–52. The comparative sensitivity to the parameters is shown in Figure 53.

It should be noted that the aquifer and aquitard hydraulic parameters are considered to be reasonable, and considered as high confidence parameters in comparison to the other parameters discussed above.

7.5 PREDICTED RIVER LEVELS

As previously explained, the model is sensitive to the adopted long-term modelled river levels, with Figure 49 showing that a river level change of only 1 m results in a salt load difference between Lock 1 to Wellington of 150 t/day in 2010.

River levels are one of the most sensitive parameters due to their ability to directly impact watertable gradients and thus fluxes to/from the river. Great care and consideration should be taken when assuming predicted river levels.

8. MODEL LIMITATIONS

The *Groundwater flow modelling guideline* (MDBC 2001), states that: 'It is important to recognise that there is no such thing as a perfect model, and all models should be regarded as works in progress of continuous improvement as hydrogeological understanding and data availability improves. By definition, model limitations comprise relatively negative statements, and they should not necessarily be viewed as serious flaws that affect the fitness for purpose of the model, but rather as a guide to where improvements should be made during work.'

The previously mentioned model uncertainties are not considered to seriously affect the function of the model for predictive purposes. They serve as a guide for where improvements could be made in the future with the availability of additional data or with the improvement of hydrogeological understanding.

The following limitations may introduce a component of error associated with the predictive modelling results:

- The Morgan to Wellington model is a regional groundwater flow model for the purpose listed in earlier sections. Simplifications and assumptions are made for development of the model. Therefore the model should not be used to answer detailed questions at local scales.
- The model layers are a simplified representation of the natural aquifer and aquitard thicknesses and hydraulic parameters, and may not reflect the natural conditions with sufficient accuracy. Currently, the floodplain is represented by a change of aquifer parameters (assumed to be the extent of the Monoman Formation) within the Murray Group Limestone (layer 1) which assumes the floodplain is in direct hydraulic connection with the surrounding Murray Group. This may need to be reviewed with ongoing model refinements in the future.
- According to MDBA requirements, daily pool level fluctuations were not simulated in the model, which results in average values of salt load entering the River Murray being calculated.
- Flood events were not required by the MDBA to be simulated in the model.
- Floodplain processes of salt storage and release were not modelled.
- Groundwater salinities are assumed to remain constant when predicting future salt loads entering the river. However, groundwater salinities will most likely change in the future in response to accessions from flood events, brackish irrigation drainage and/or climate change.
- Model recharge zones and rates are likely to be different in the future to those used in predictive modelling.
- Modelled river levels are likely to vary from those used in predictive modelling.

9. CONCLUSIONS

9.1 MODEL IMPROVEMENTS

In this modelling exercise, Aquaterra and DWLBC have significantly revised and further calibrated the Morgan to Wellington numerical groundwater flow model. This model is an 'impact assessment model of moderate complexity' in the terminology of the MDBA modelling guideline (MDBC 2001). The model accommodates the Morgan to Wellington area within a broad regional context, notably including the aquifer parameters and recharge zones. The model has been accurately calibrated using observed (historical) potentiometric heads. Sensitivity/uncertainty analysis, as specified by the modelling guideline (MDBC 2001), has been undertaken for transient conditions.

The Morgan to Wellington model has been significantly improved by the following actions:

- Model layer structure update based on the AWE 2008 review.
- Grid cell size decreasing from ~300 x 300 m to ~150 x 150 m.
- The model has been calibrated to historical observation hydrographs by building the historical recharge model due to irrigation. Historical irrigation has not been modelled previously.
- Salinity zones have been reviewed and verified against the 2008 In-stream Salinity Survey data and the DWLBC surface water model.

9.2 SALT INTERCEPTION SCHEMES

At the time of writing, no SIS in the Morgan to Wellington area were being considered.

9.3 MODELLING RESULTS

The modelling work has resulted in an improved understanding of the hydrogeology of the aquifer system in the Morgan to Wellington area. The model has been used to predict the flux of saline groundwater (salt load) entering the River Murray under different irrigation practices and development scenarios. Model results (salt loads) can be seen in Figure 43 and in Tables 15 to 18.

Table 15 Predicted salt load (t/day) entering the River Murray (Morgan to Lock 1)

Morgan to Lock 1 Area	Year				
	1988	2000	2009	2050	2109
S–1	2.8	2.8	2.8	2.8	2.8
S–2	2.9	3.3	3.6	10.6	20.5
S–3A	2.8	2.8	13.9	18.1	18.8
S–3B	2.8	2.8	9.9	10.7	10.9
S–3C	2.8	2.8	9.9	10.7	10.9
S–4	2.8	2.8	9.9	17.8	19.3
S–5	2.8	2.8	9.9	17.8	19.3

Table 16 Predicted salt load (t/day) entering the River Murray (Lock 1 to Mannum)

Lock 1 to Mannum Area	Year				
	1988	2000	2009	2050	2109
S–1	8.4	8.4	8.4	8.4	8.4
S–2	9.8	10.1	10.3	11.2	13.7
S–3A	14.1	14.9	22.6	25.4	26.1
S–3B	14.1	14.3	17.4	16.5	16.5
S–3C	14.1	14.3	17.4	16.5	16.5
S–4	14.1	14.3	17.4	30.0	37.0
S–5	14.1	14.3	17.4	30.0	36.9

Table 17 Predicted salt load (t/day) entering the River Murray (Mannum to Murray Bridge)

Mannum to Murray Bridge Area	Year				
	1988	2000	2009	2050	2109
S–1	0.2	0.2	0.2	0.2	0.2
S–2	20.4	21.1	21.3	23.4	27.5
S–3A	43.0	44.8	49.0	50.8	51.3
S–3B	43.0	42.9	42.7	41.9	41.9
S–3C	43.0	40.3	34.1	30.3	30.2
S–4	43.0	40.3	34.1	39.3	41.2
S–5	43.0	40.3	34.1	39.3	41.3

Table 18 Predicted salt load (t/day) entering the River Murray (Murray Bridge to Wellington)

Murray Bridge to Wellington Area	Year				
	1988	2000	2009	2050	2109
S–1	2.7	2.7	2.7	2.7	2.7
S–2	25.1	26.9	28.1	35.9	47.1
S–3A	33.1	33.3	43.6	46.8	47.7
S–3B	33.1	30.5	32.0	30.8	30.8
S–3C	33.1	30.5	32.0	30.8	30.8
S–4	33.1	30.5	32.0	43.4	45.8
S–5	33.1	30.5	32.0	43.4	46.2

9.4 RECOMMENDATIONS

The following work is recommended to address some of the model limitations:

- Install more observation wells closer to the river and, if possible, in floodplain areas to determine/verify current salinities applied in the model, and also to obtain groundwater level data in major irrigation areas where data is absent or sparse.
- Adequate new technologies be considered to improve groundwater salinity information, for example AEM imaging to determine the salinity distribution.
- Further field investigations to resolve conceptual data gaps in key areas.

FIGURES

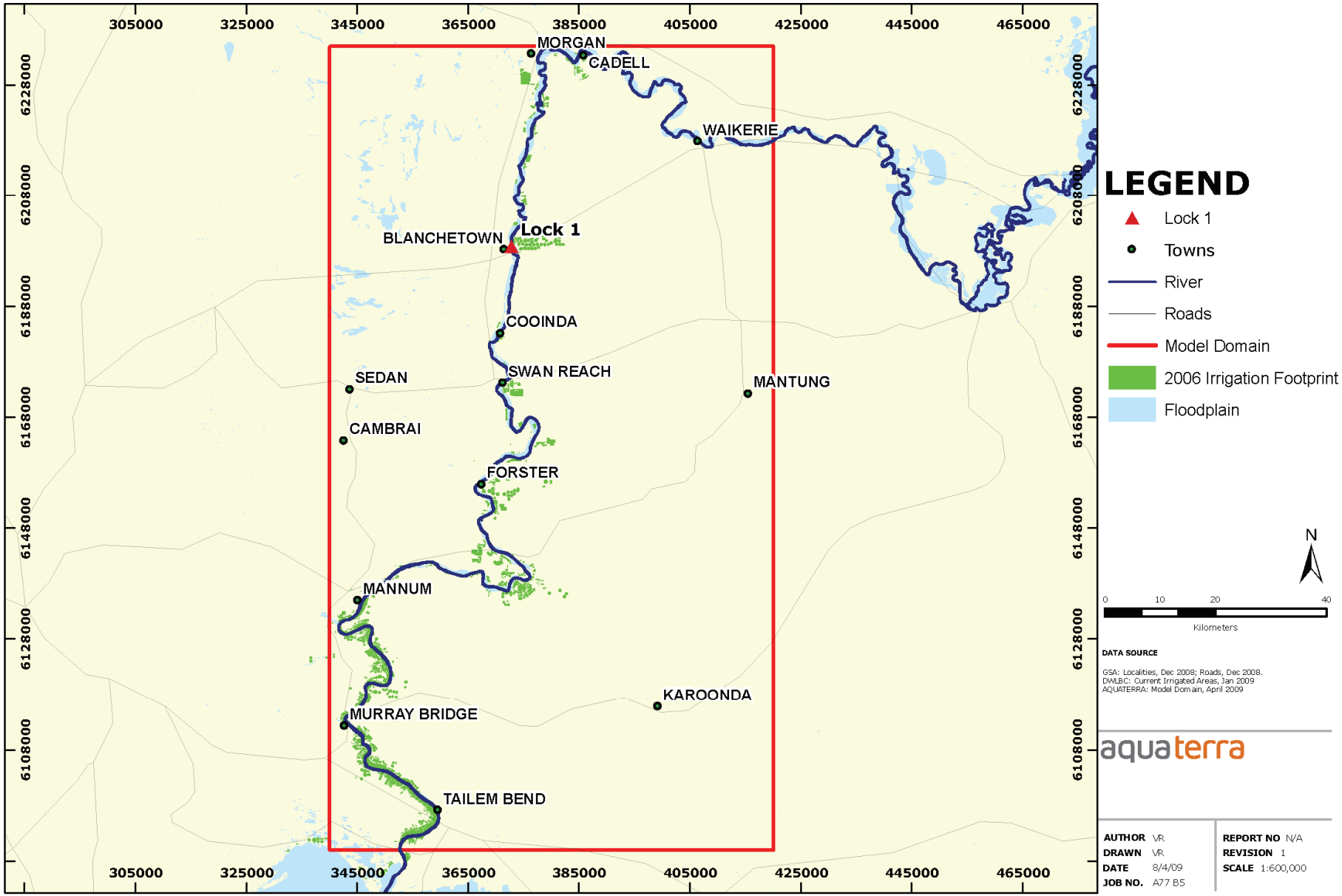


Figure 1. Project location map and model domain

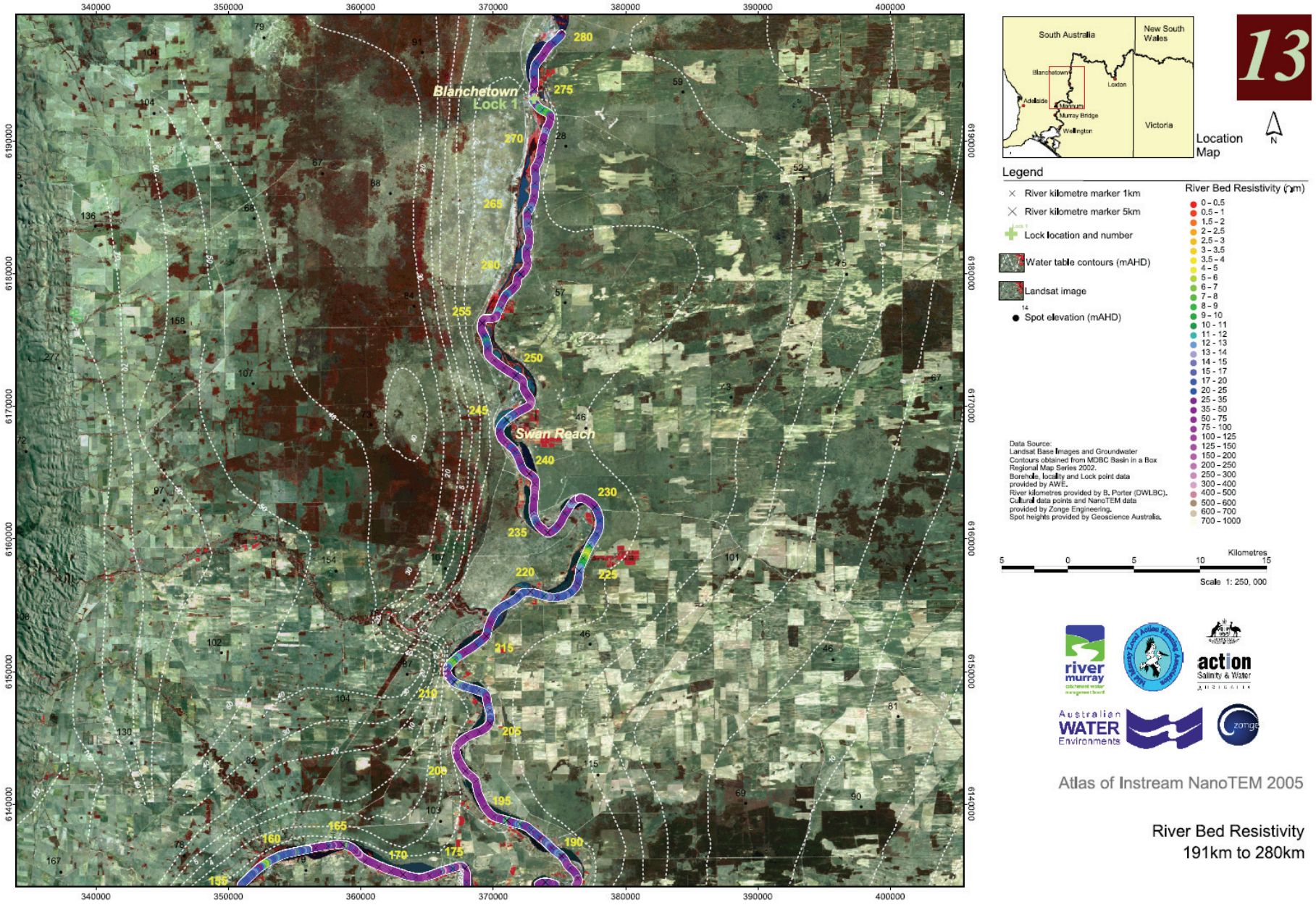


Figure 2b. Aerial photography and NanoTEM results from 192km to 289 km

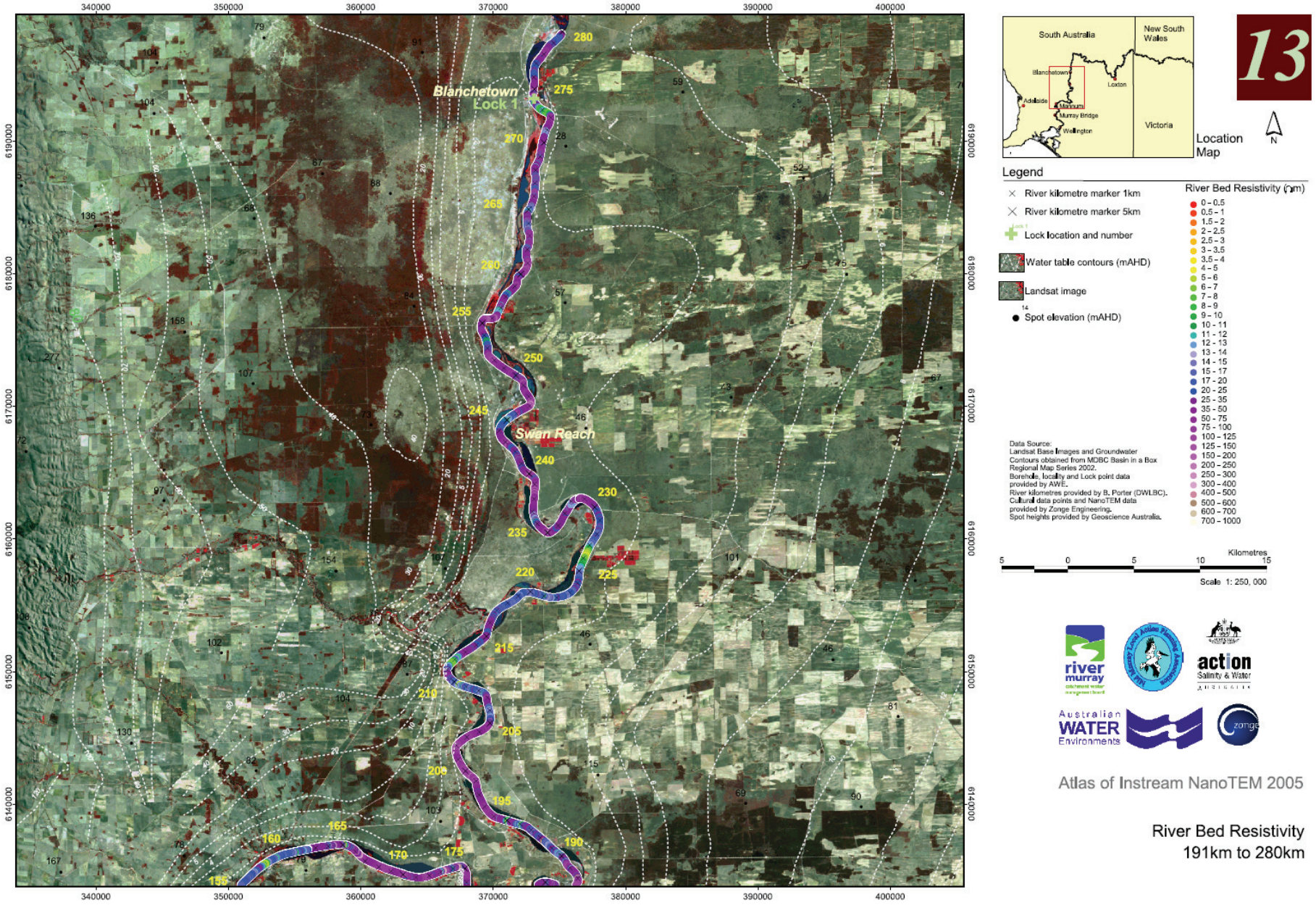


Figure 2b. Aerial photography and NanoTEM results from 192km to 289 km

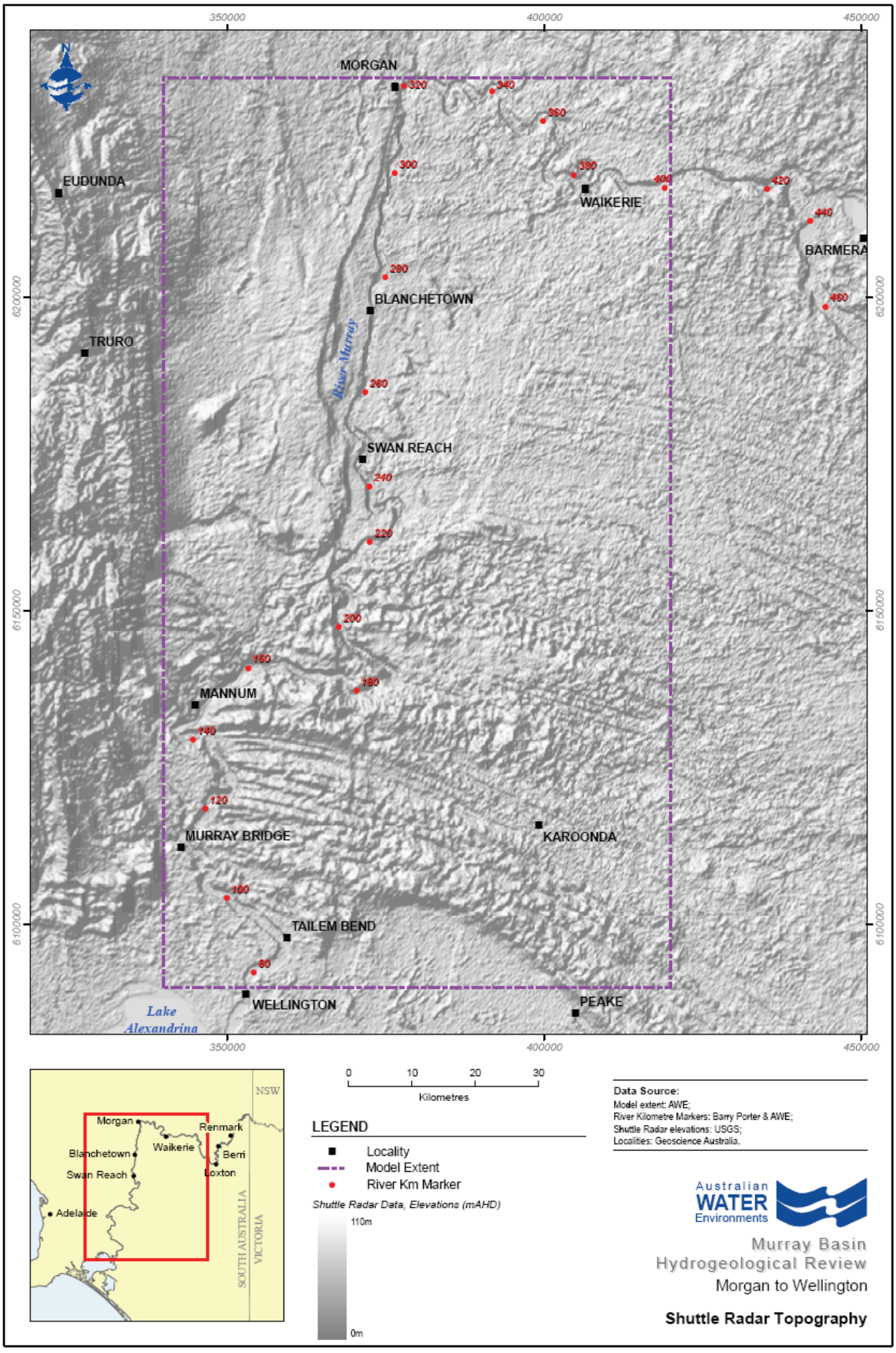


Figure 3. Shuttle Radar Topography

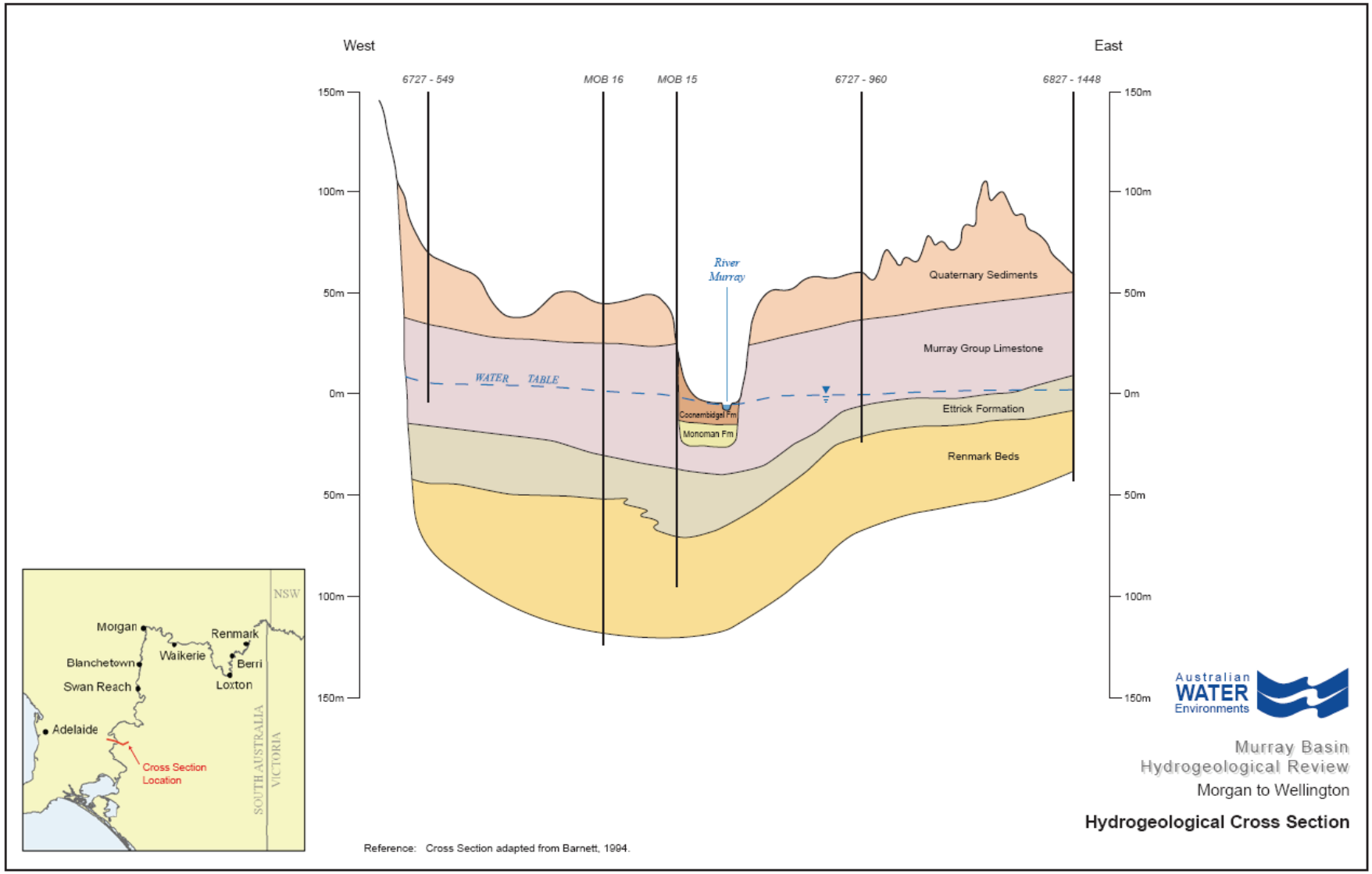
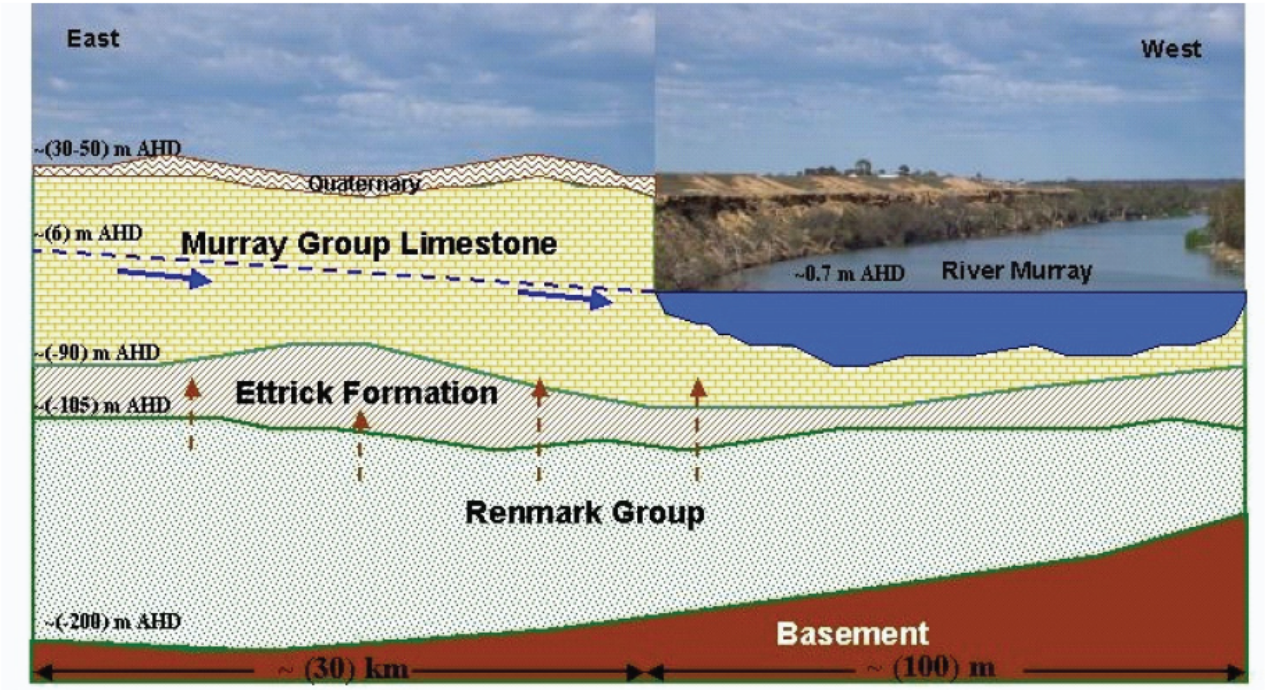


Figure 4. Hydrogeological cross section



Reference: Yan W., Howe B., Howles S., and Armstrong D. 2006. Numerical groundwater models for determining salt loads entering the River Murray in South Australia. Murray Darling Basin Commission Workshop 2006

Murray Basin
Hydrogeological Review
Morgan to Wellington

Conceptual Hydrogeological Cross Section - Riverland District

Australian WATER Environments

Figure 5a. Conceptual Hydrogeological cross section - Riverland District

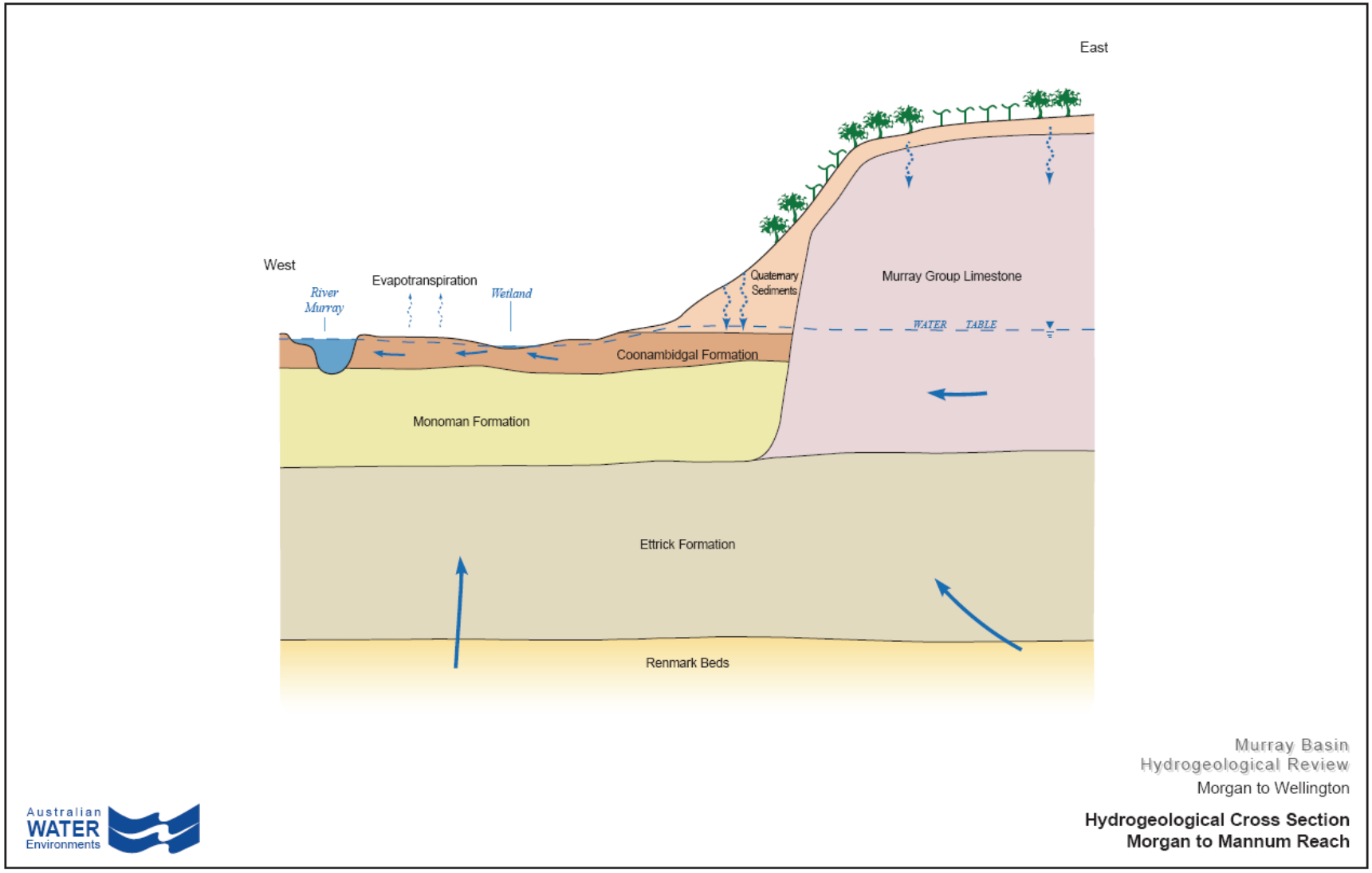


Figure 5b. Conceptual Hydrogeological cross section – Morgan to Mannum Reach

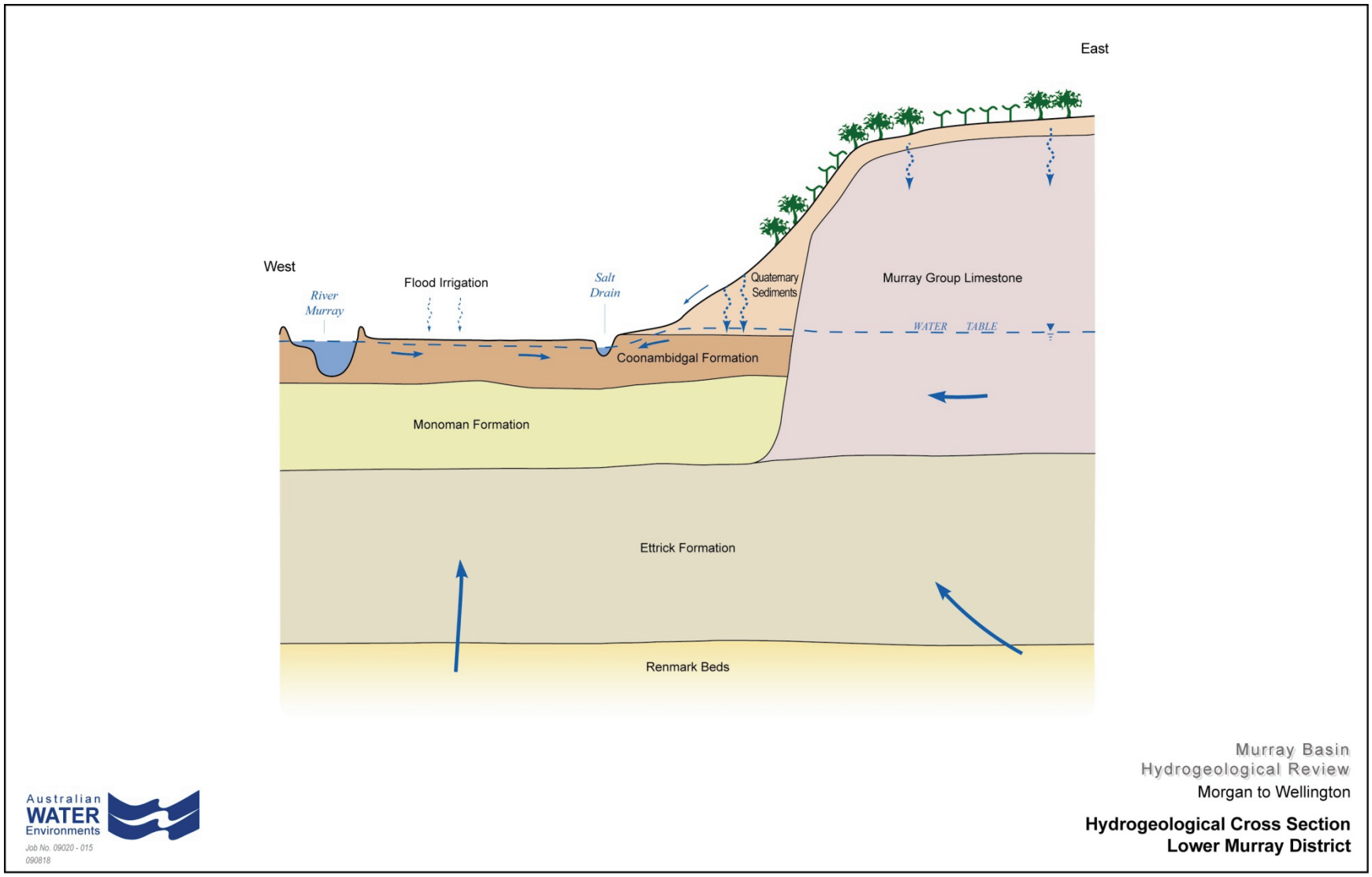


Figure 5c. Conceptual hydrogeological cross section – Mannum to Wellington Reach

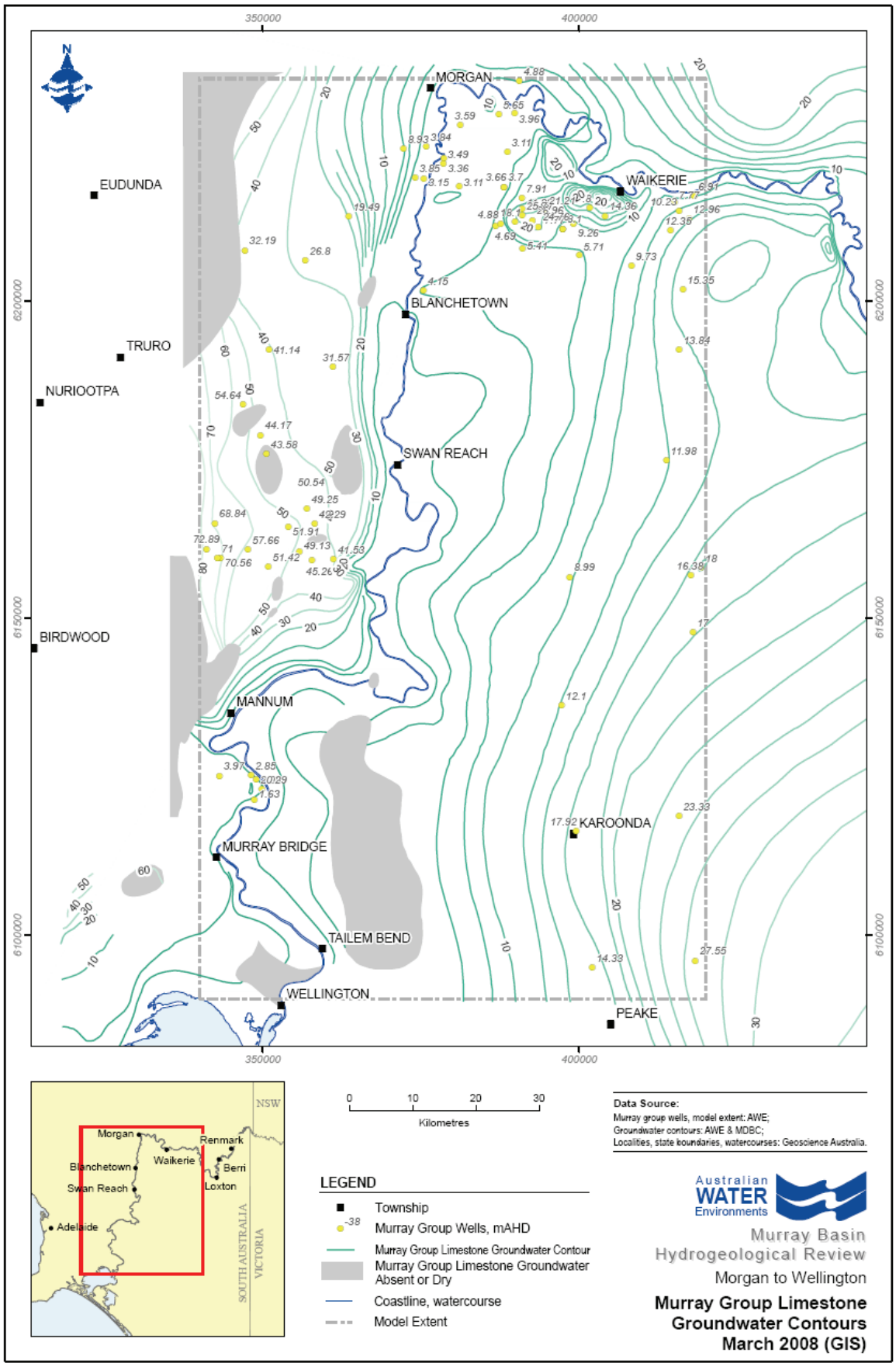


Figure 6a. Murray Group Limestone groundwater contours, March 2008 - GIS

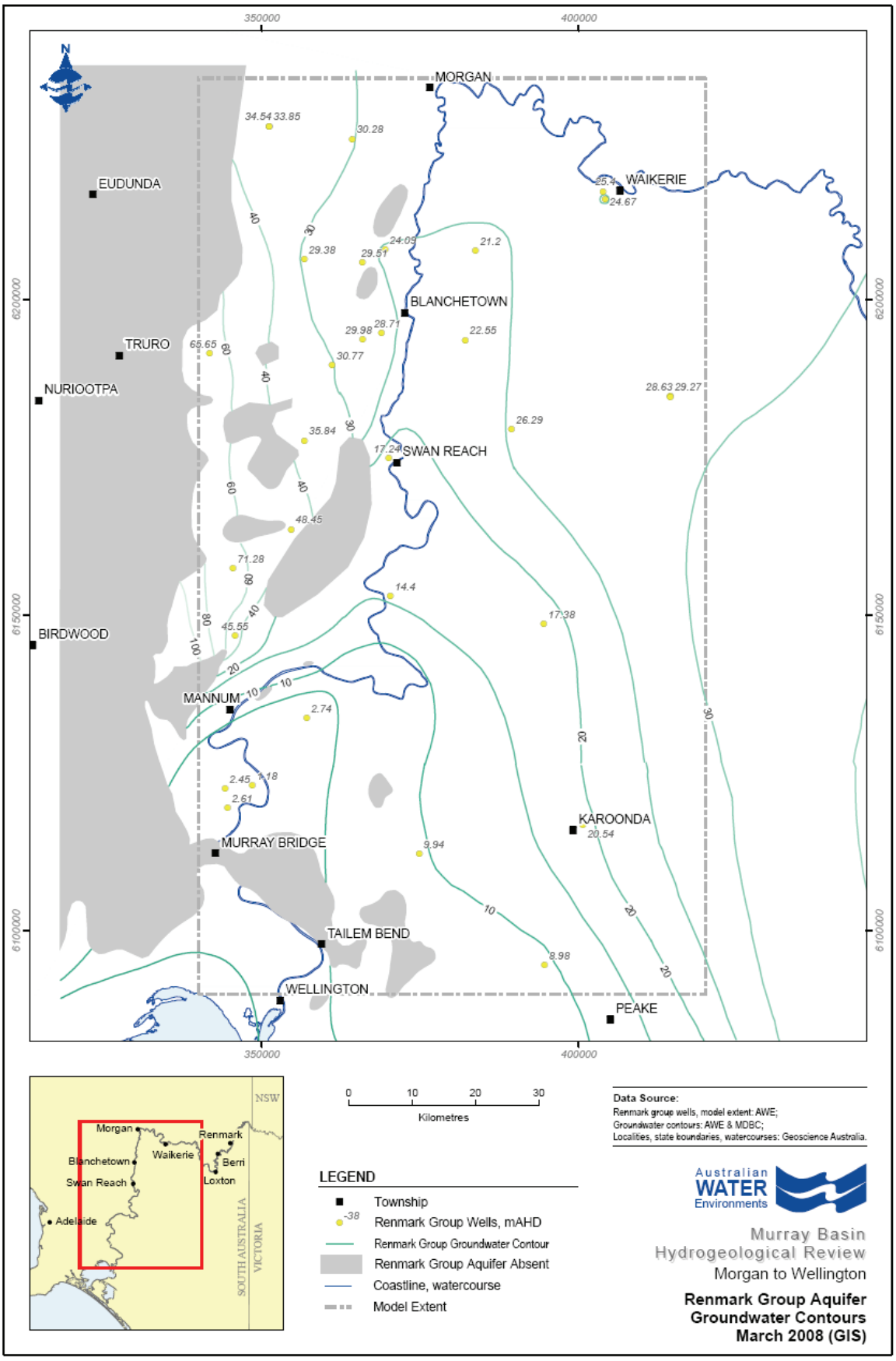


Figure 6b. Renmark Group groundwater contours, March 2008 – GIS

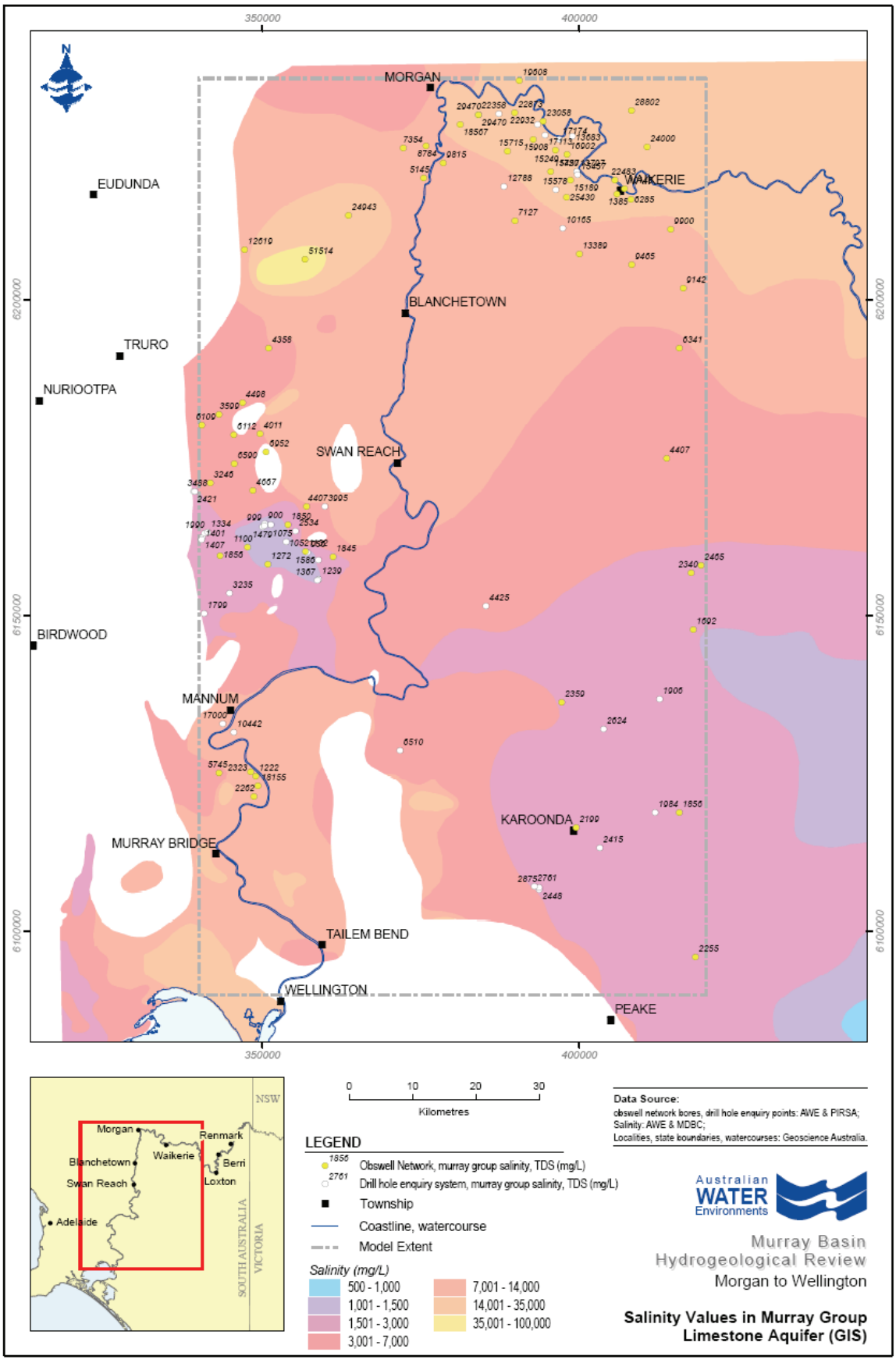


Figure 7a. Salinities in Murray Group Limestone aquifer – GIS

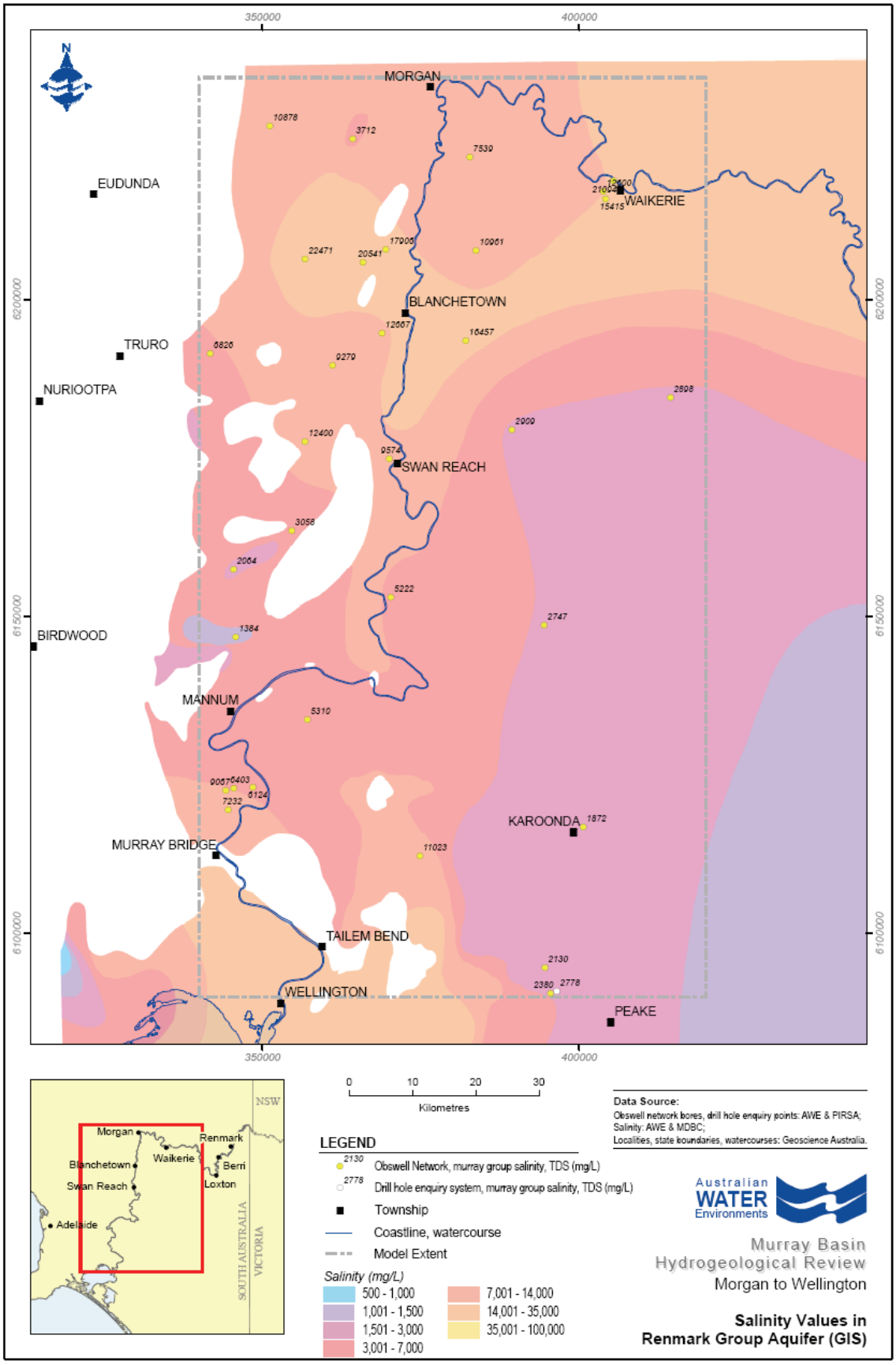


Figure 7b. Salinities in Renmark Group aquifer – GIS

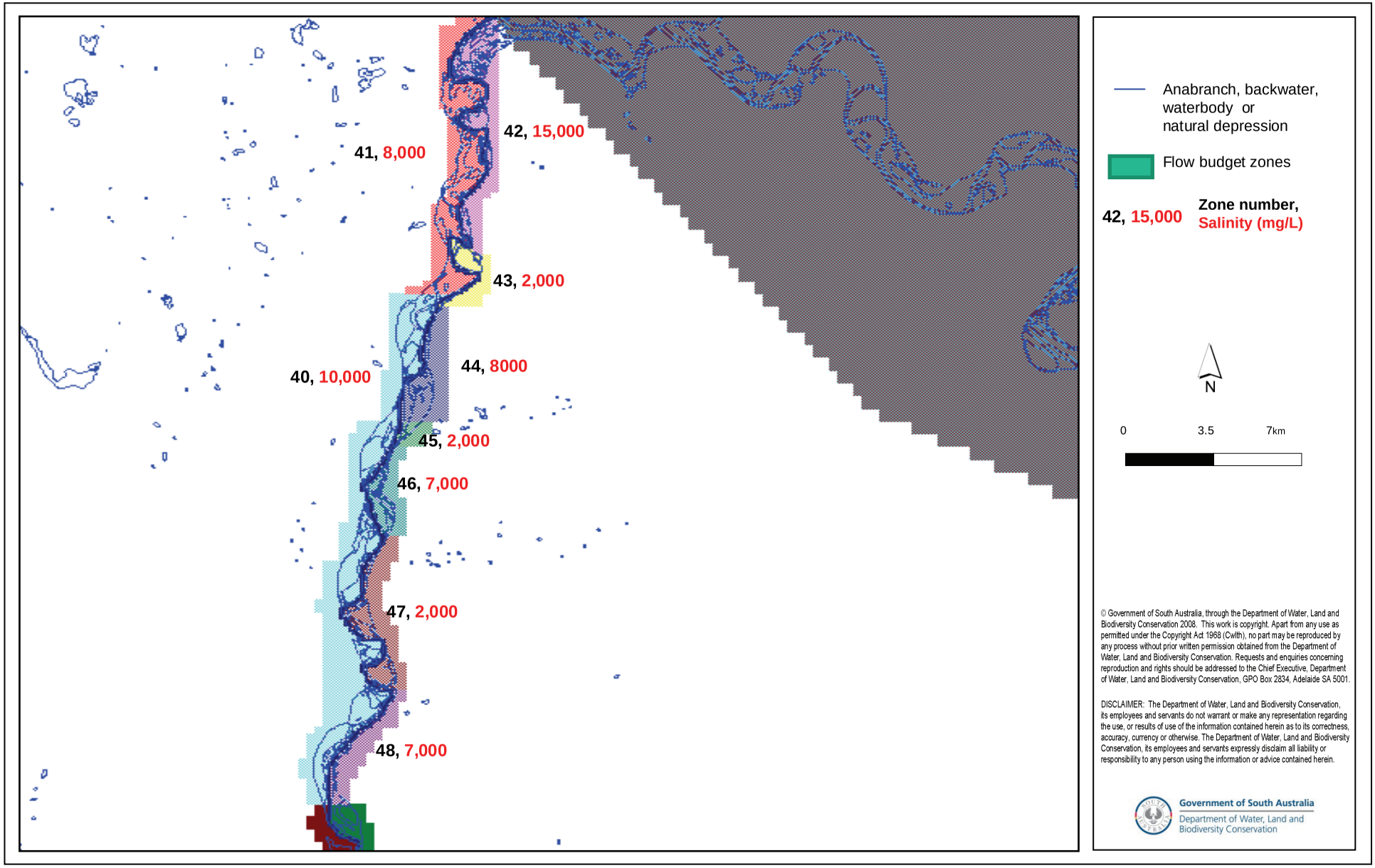


Figure 8. Modelled flow budget salinity zones in the Morgan to Lock 1 area

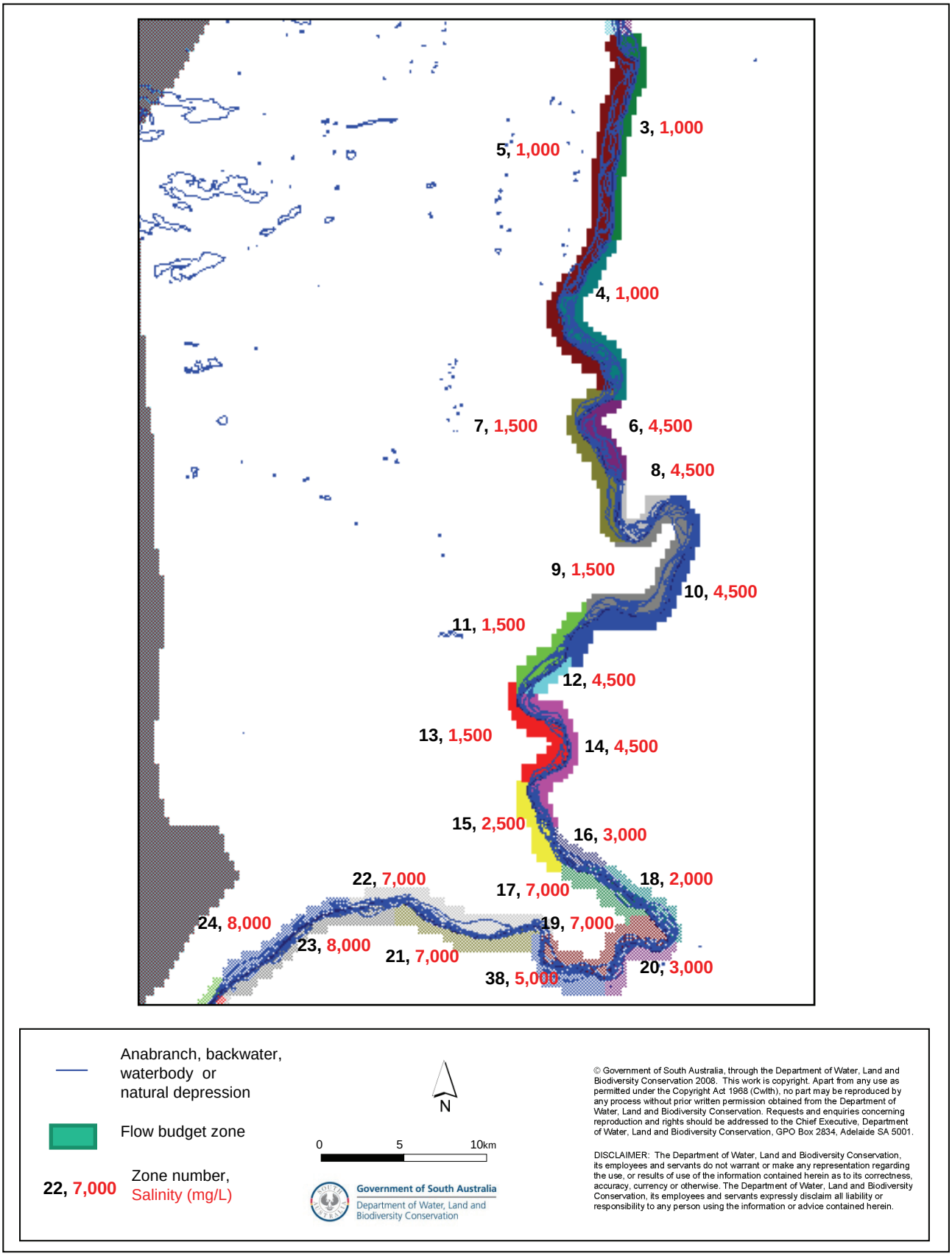


Figure 9. Modelled flow budget salinity zones in the Lock 1 to Mannum area

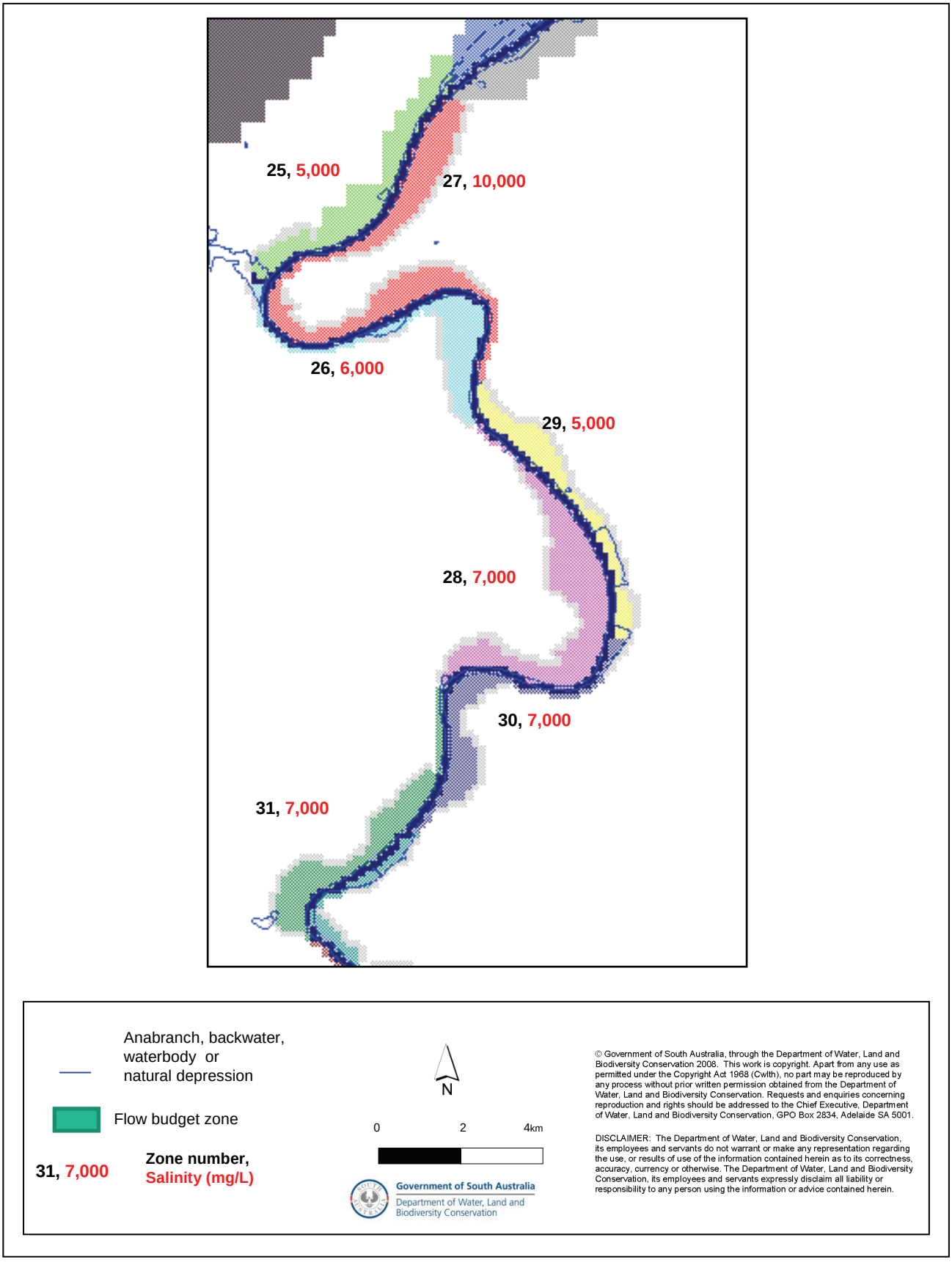


Figure 10. Modelled flow budget salinity zones in the Mannum to Murray Bridge area

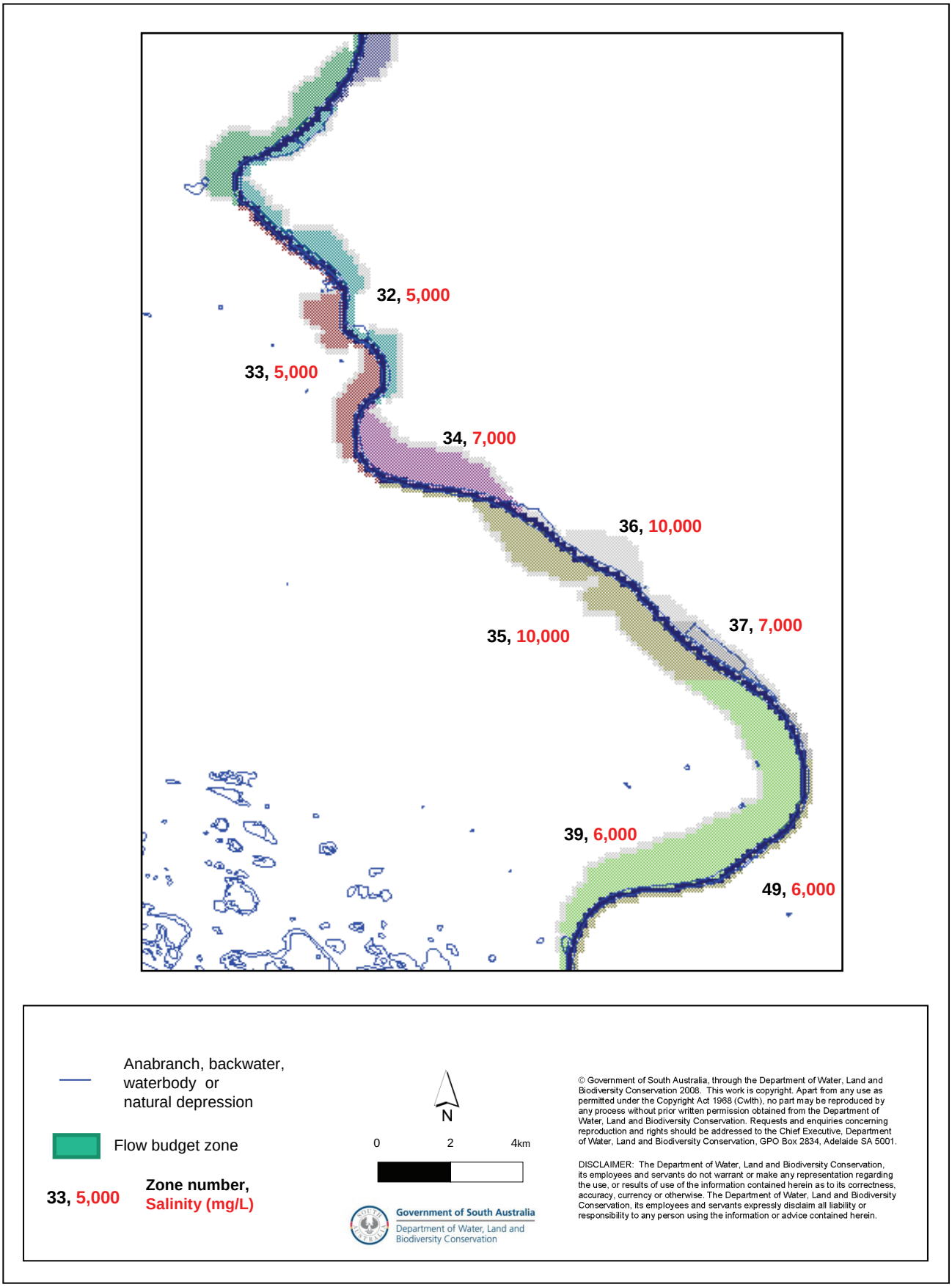


Figure 11. Modelled flow budget salinity zones in the Murray Bridge to Wellington area

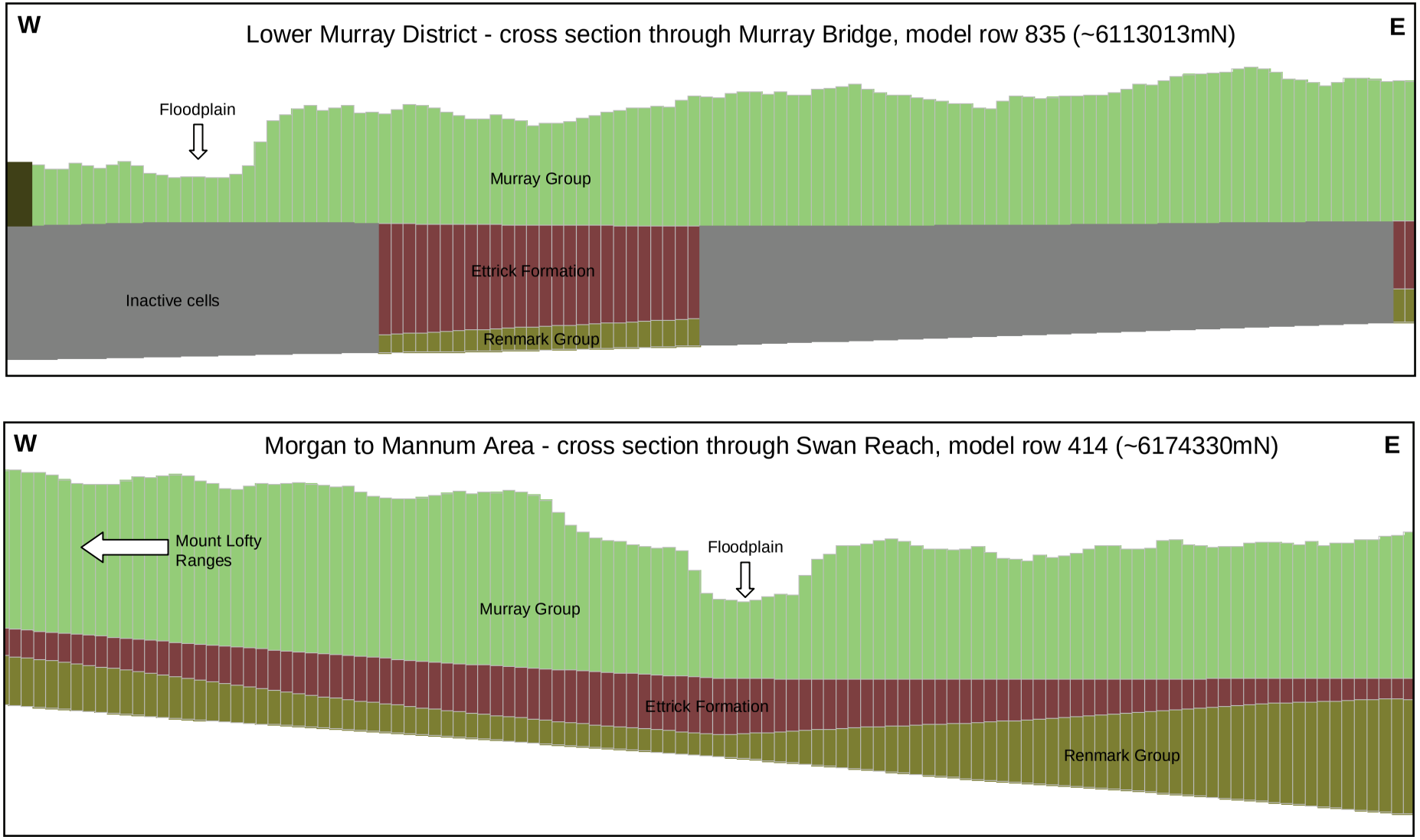


Figure 12. Model cross sections

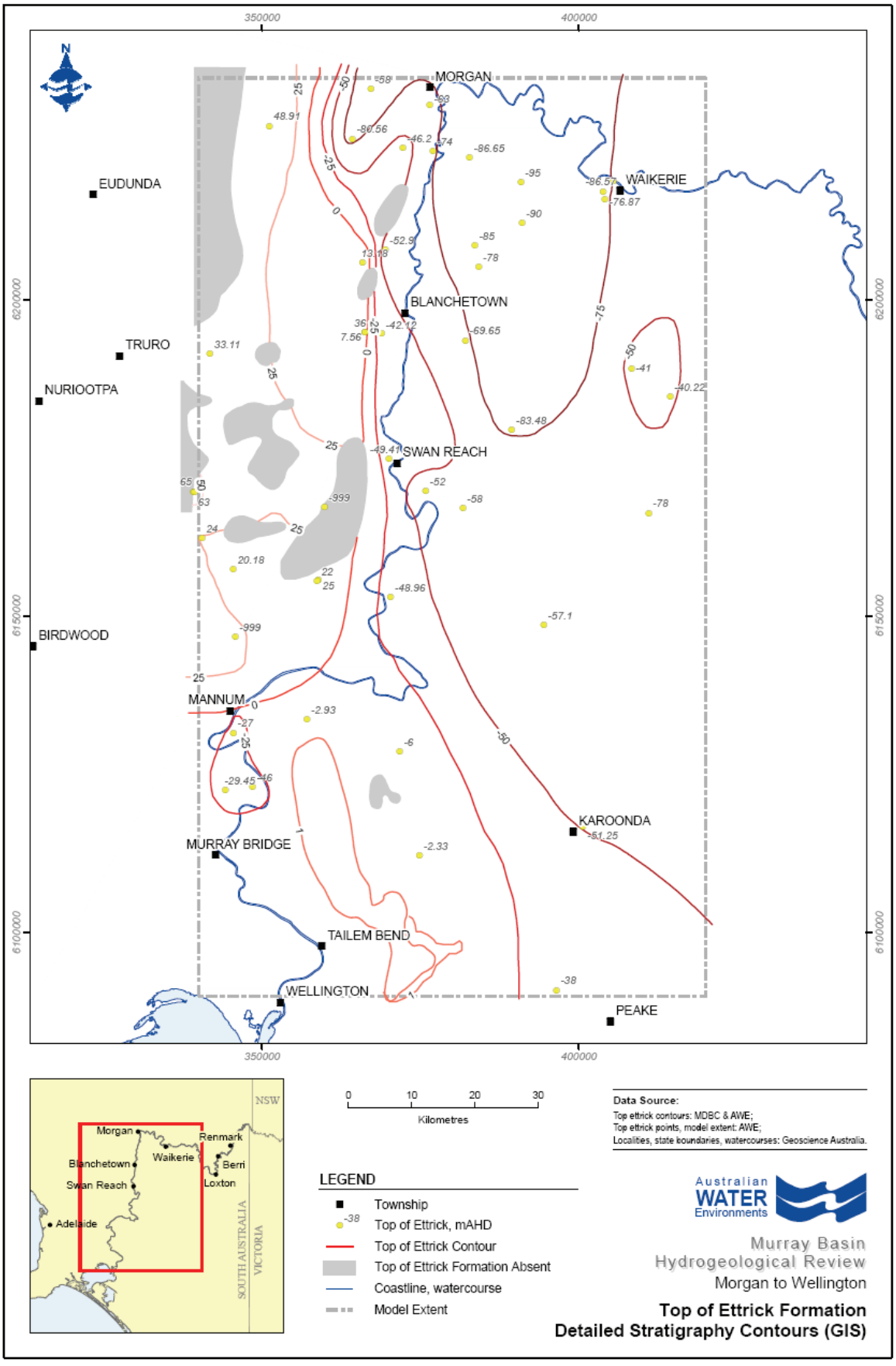


Figure 13. Top of model layer 2 (Ettrick Formation) elevation contours (m AHD)

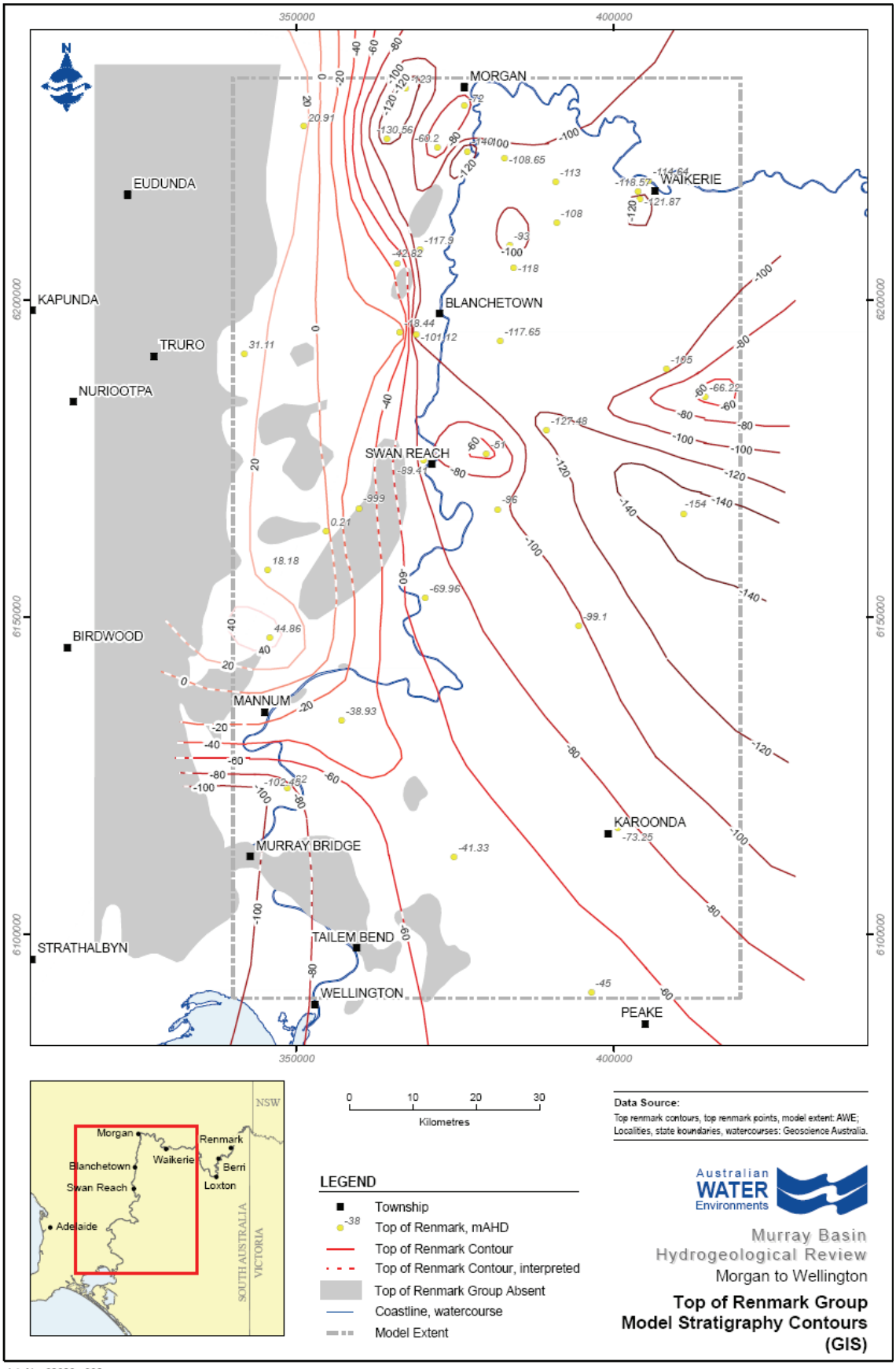


Figure 14. Top of model layer 3 (Renmark Formation) elevation contours (m AHD)

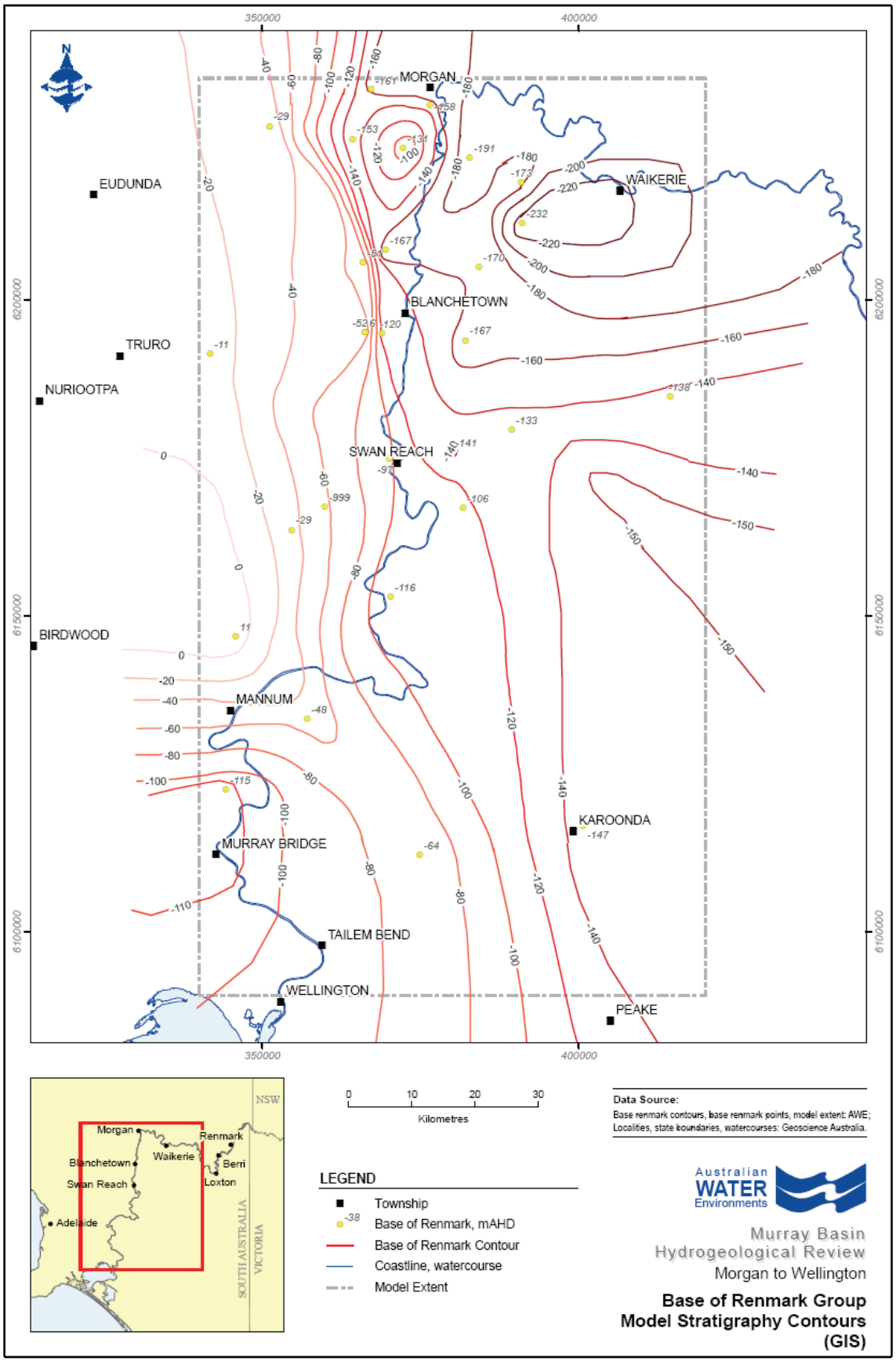


Figure 15. Base of model layer 3 (Renmark Formation) elevation contours (m AHD)

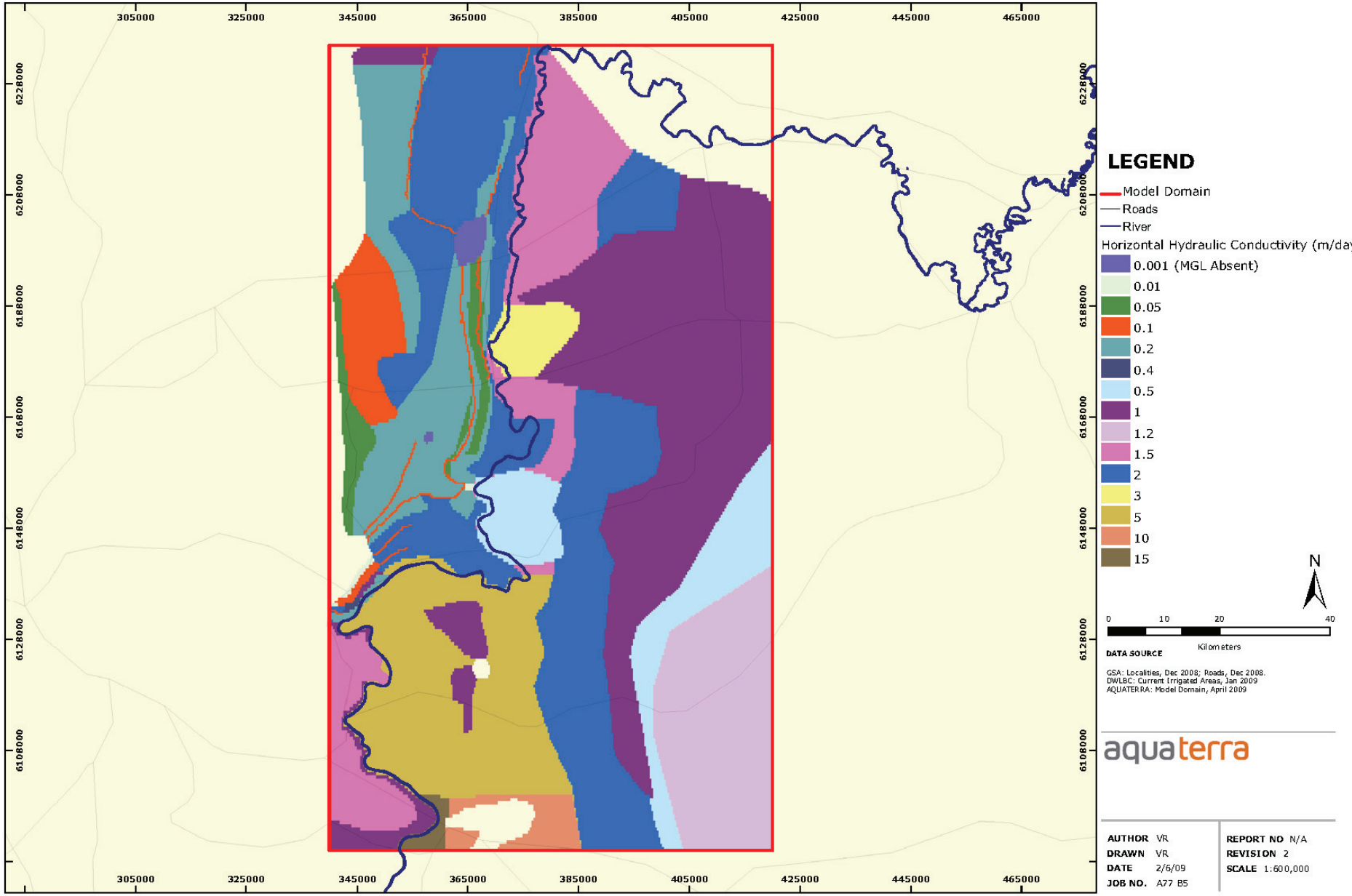


Figure 16. Model horizontal hydraulic conductivity for Murray Group Limestone (layer 1)

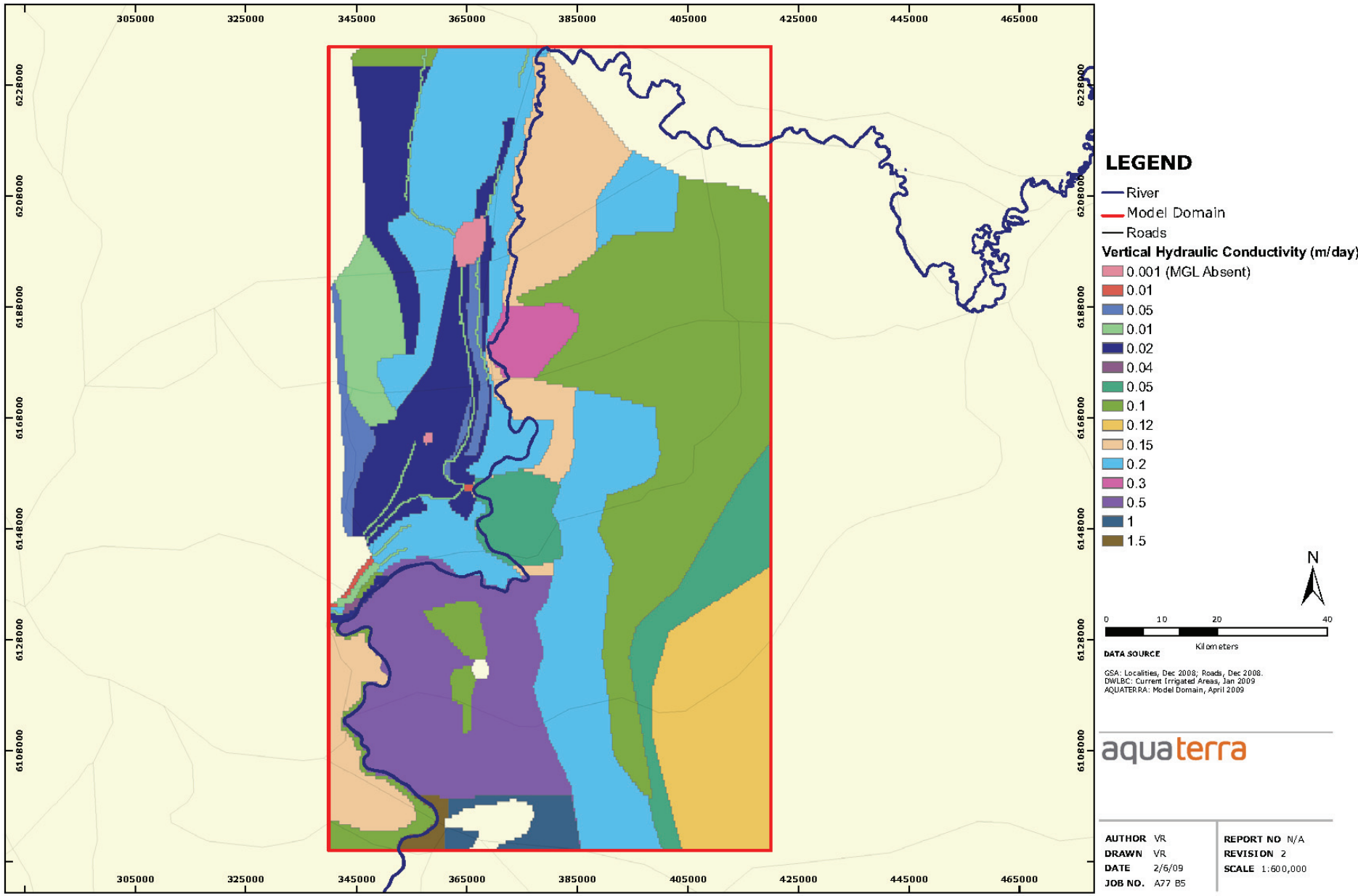


Figure 17. Model vertical hydraulic conductivity for Murray Group Limestone (layer 1)

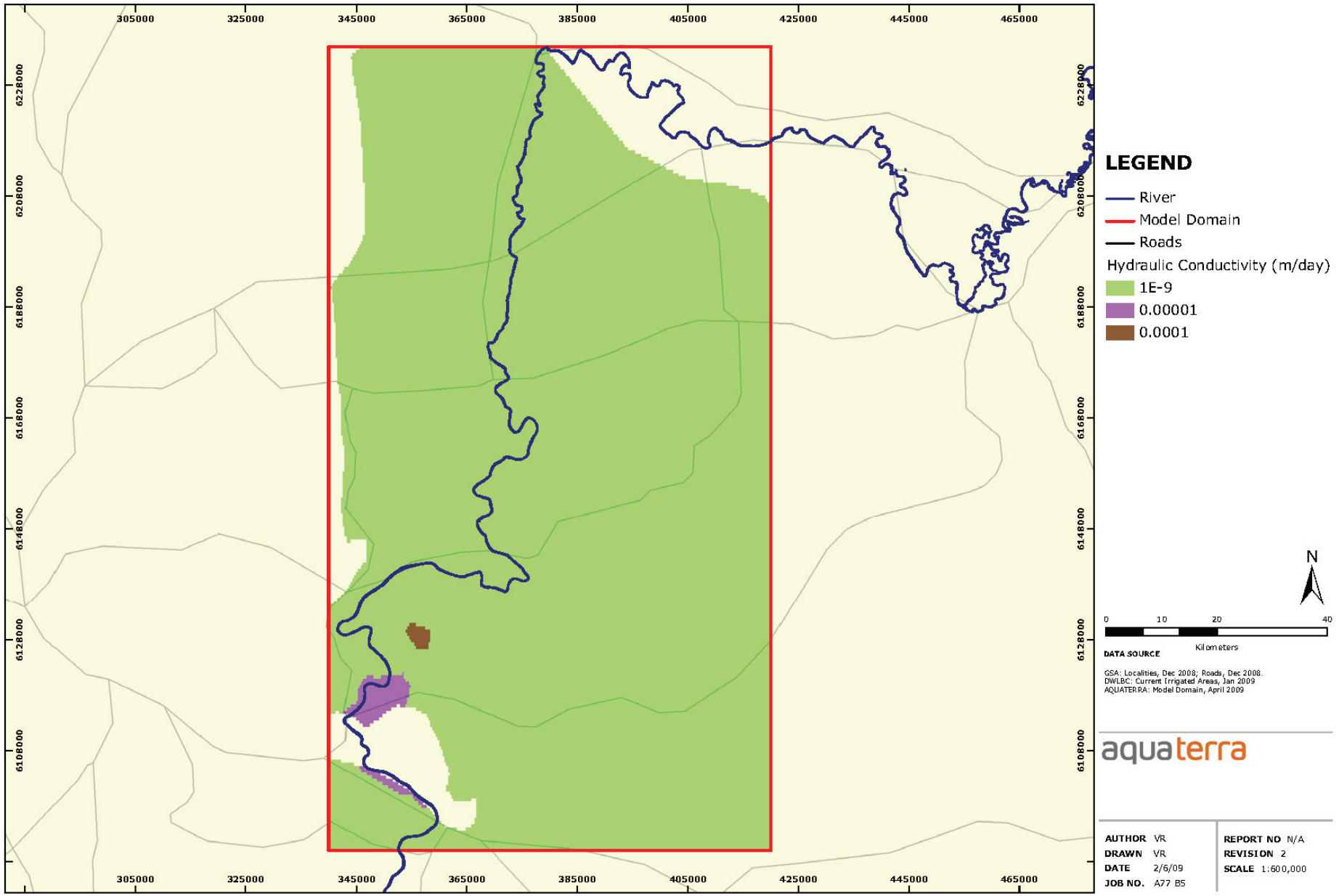


Figure 18. Model vertical hydraulic conductivity for Ettrick Formation (layer 2)

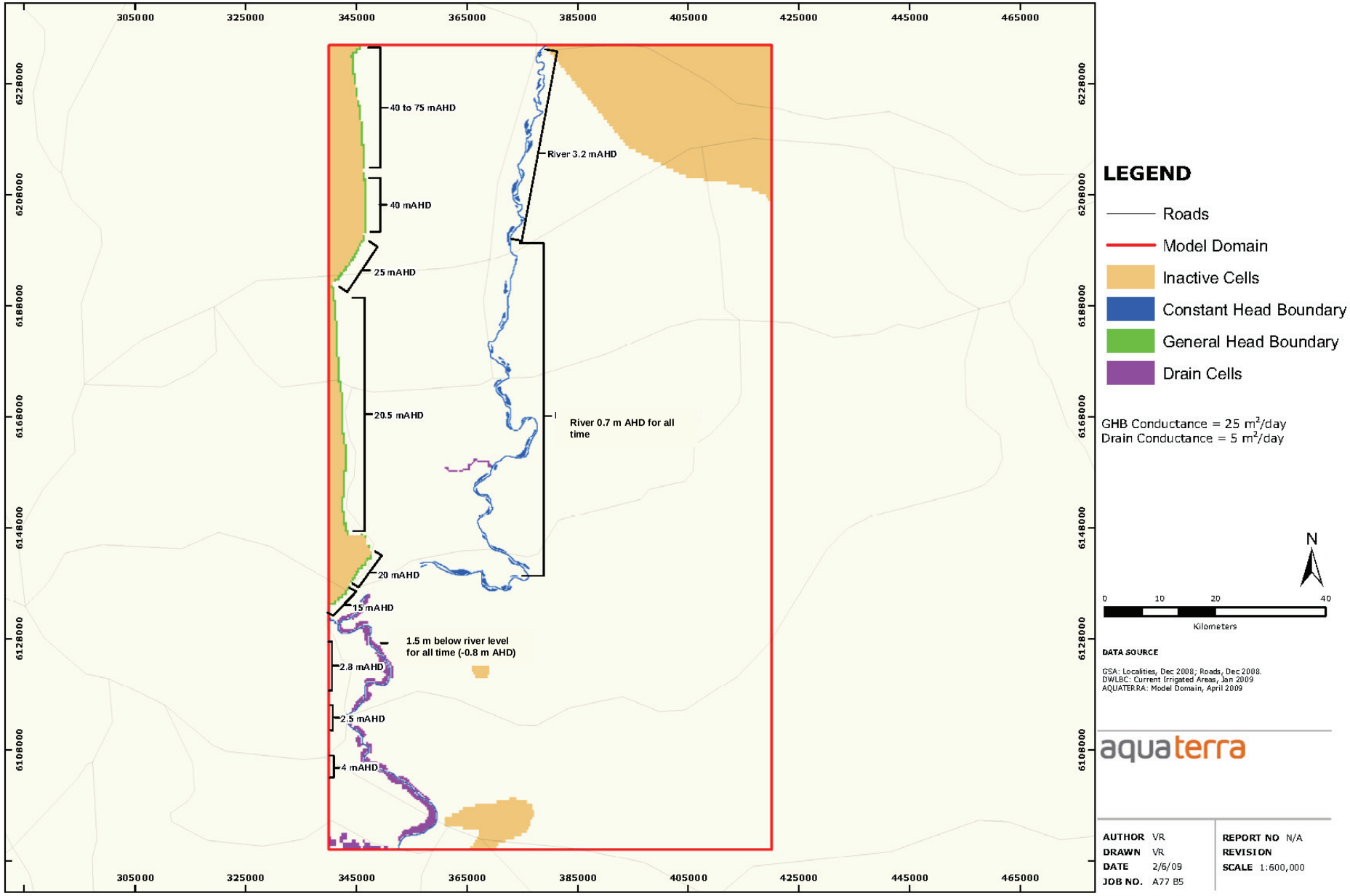


Figure 19. Model boundary conditions (layer 1)

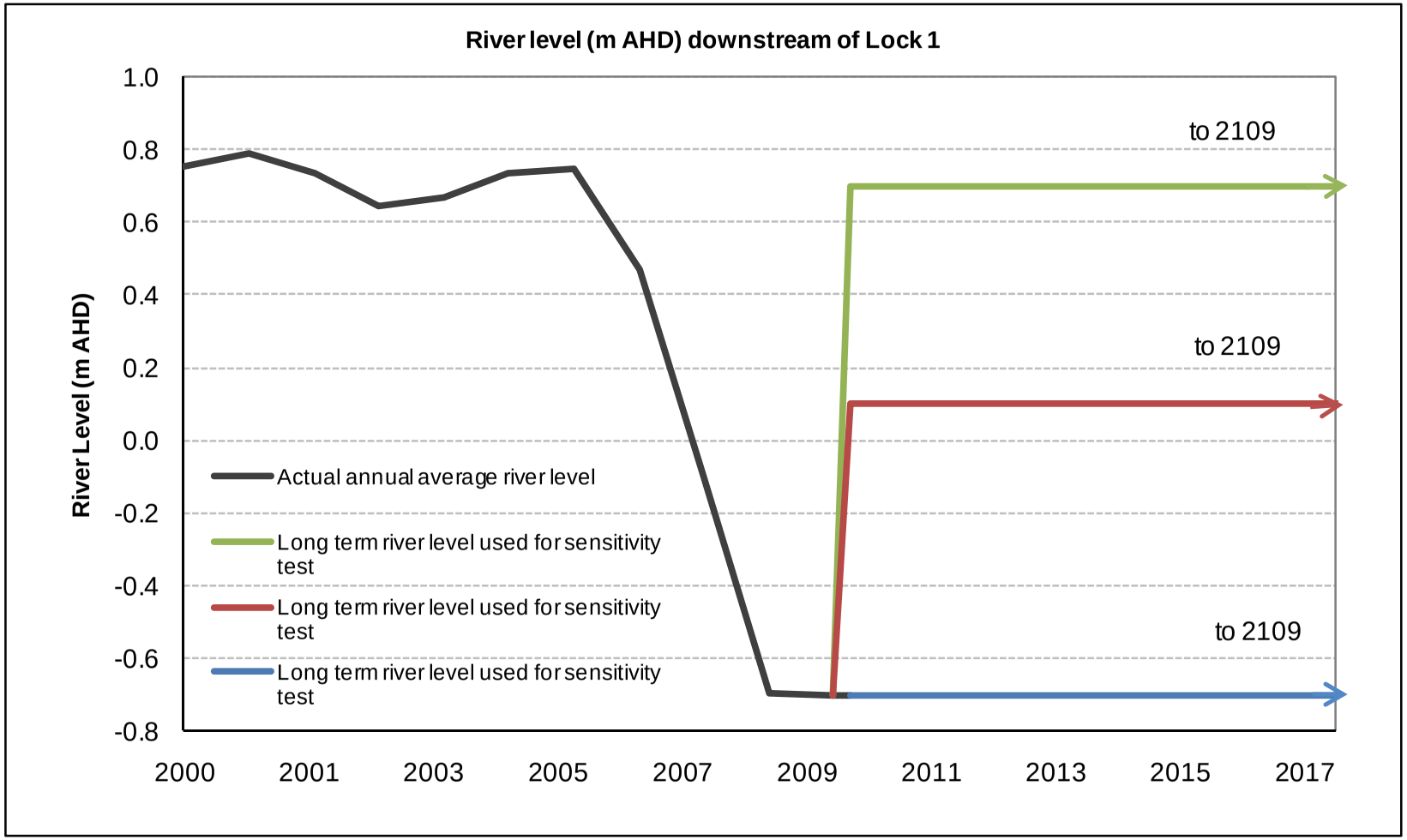


Figure 20. River level (m AHD) downstream of Lock 1

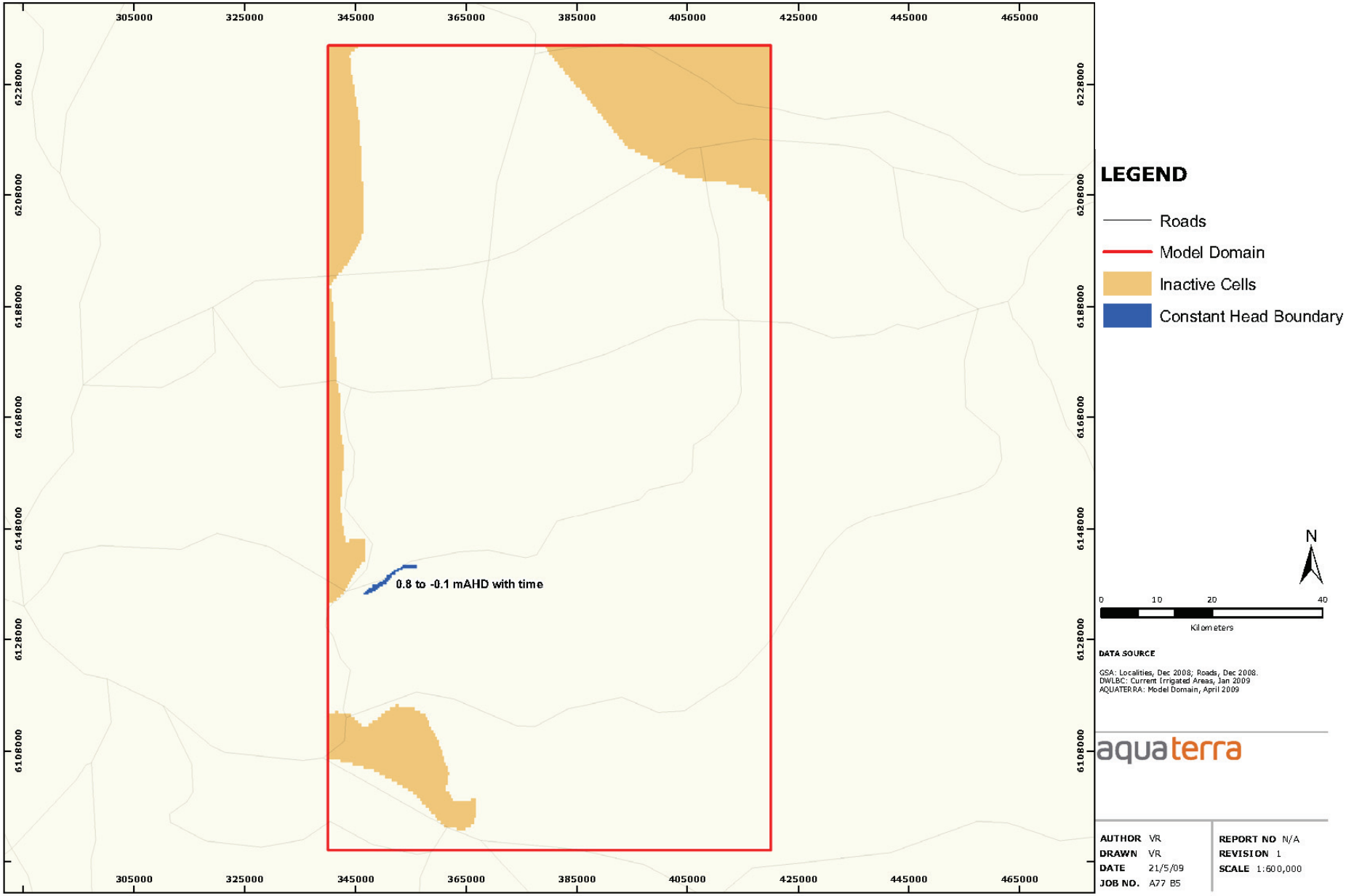


Figure 21. Model boundary conditions (layer 2)

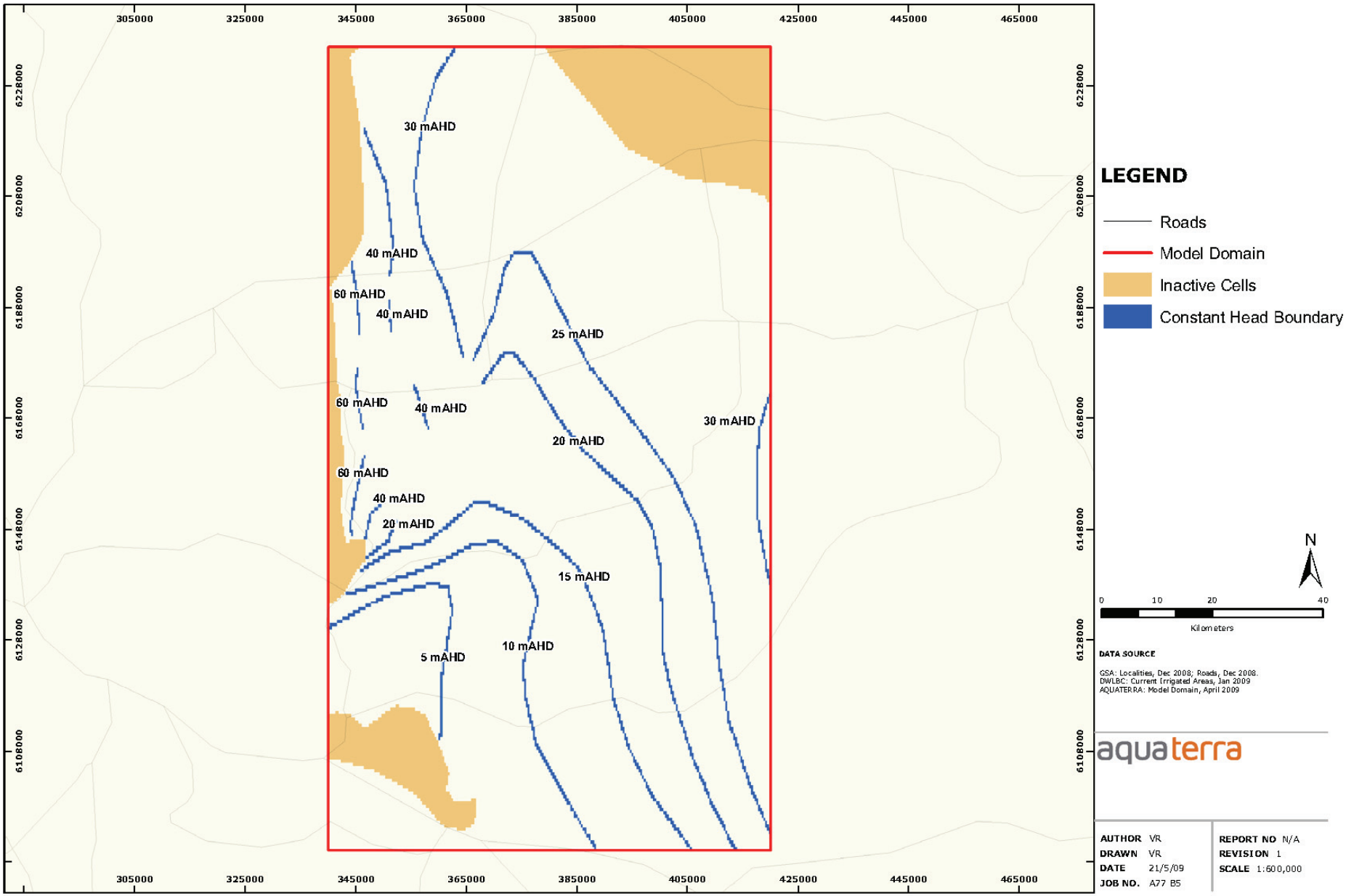


Figure 22. Model boundary conditions (layer 3)

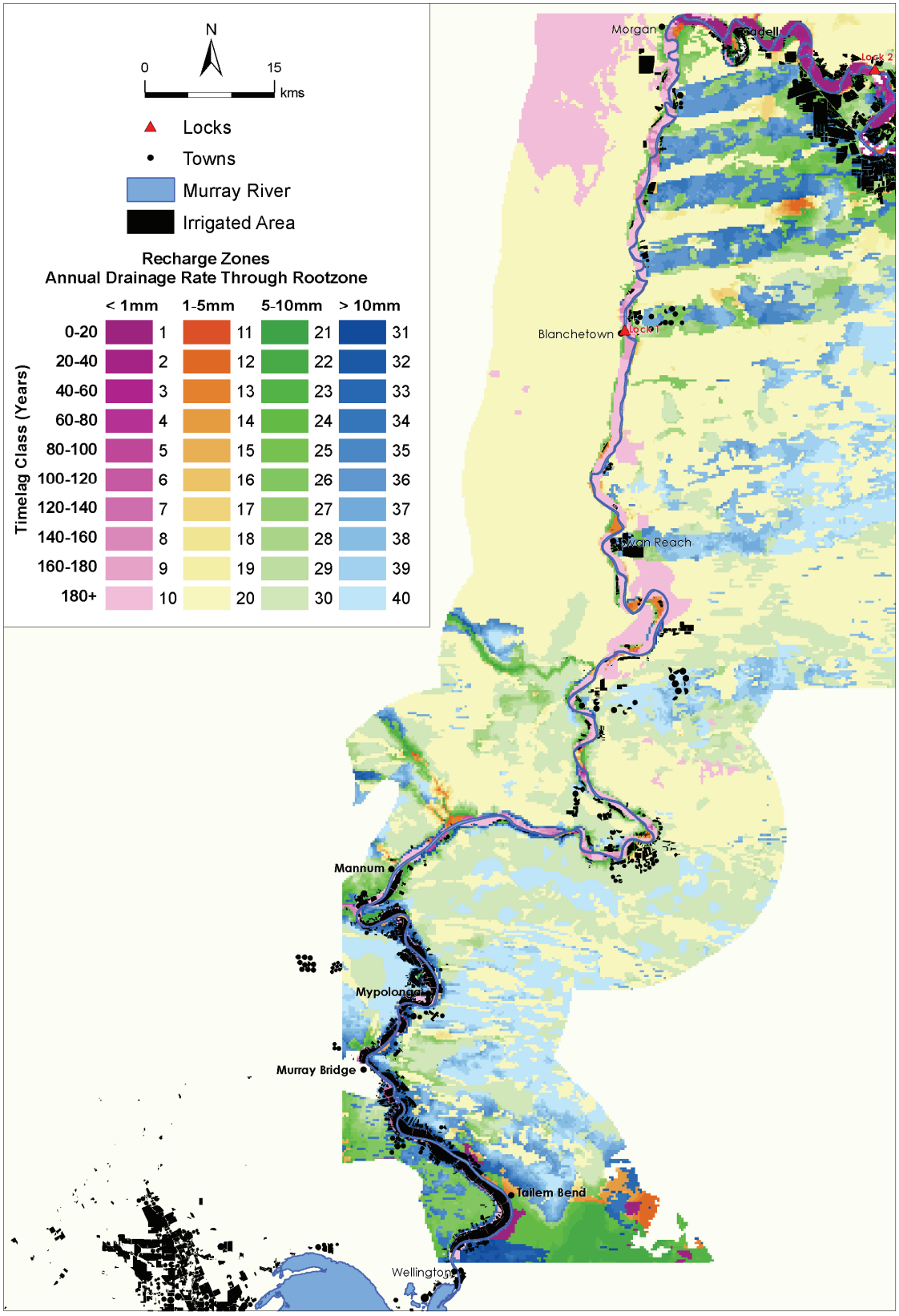


Figure 23. Mallee clearance recharge zones (41 zones) (recharge rates given in *Appendix A*)

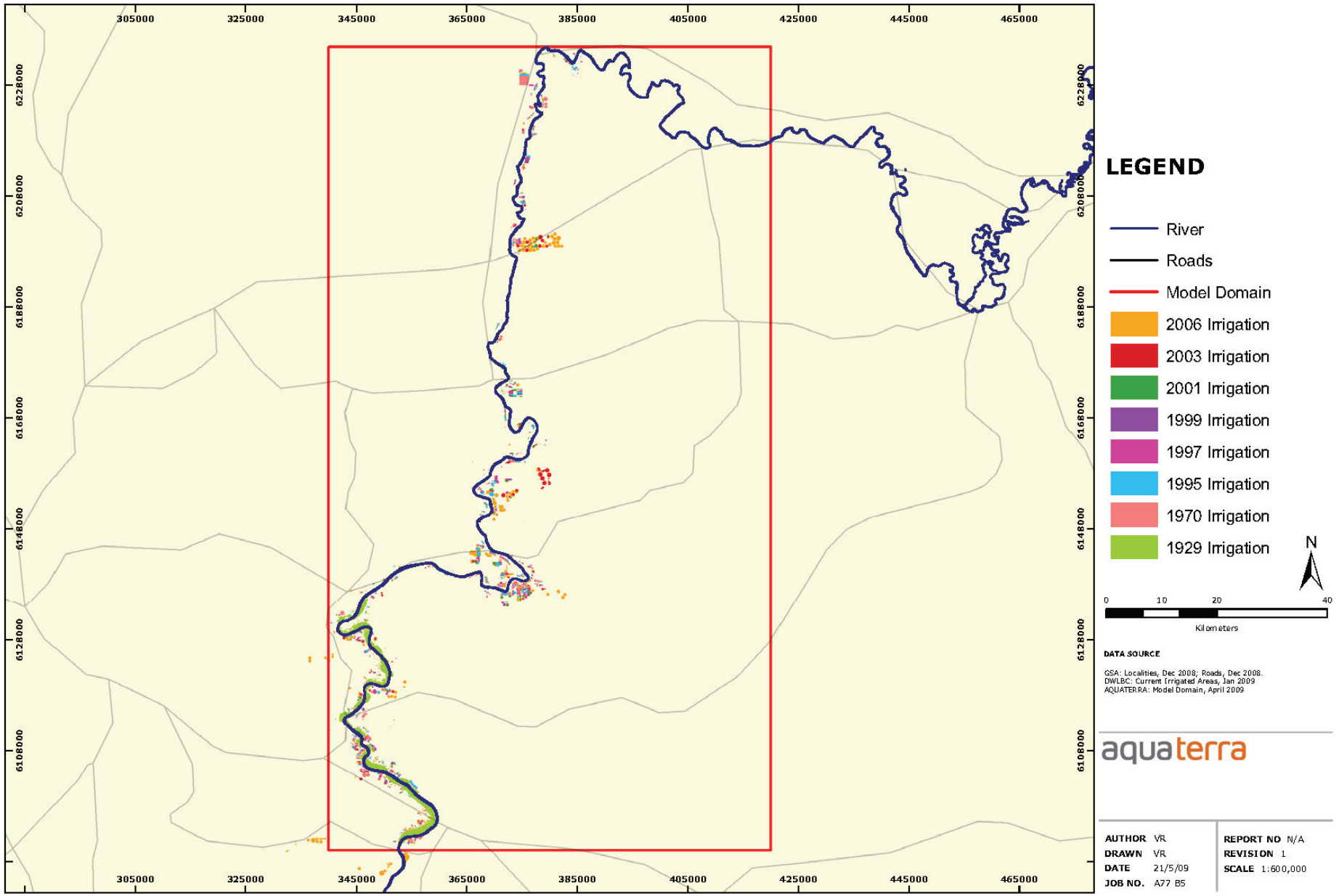


Figure 24. Extent of irrigated areas over time based on GIS coverages

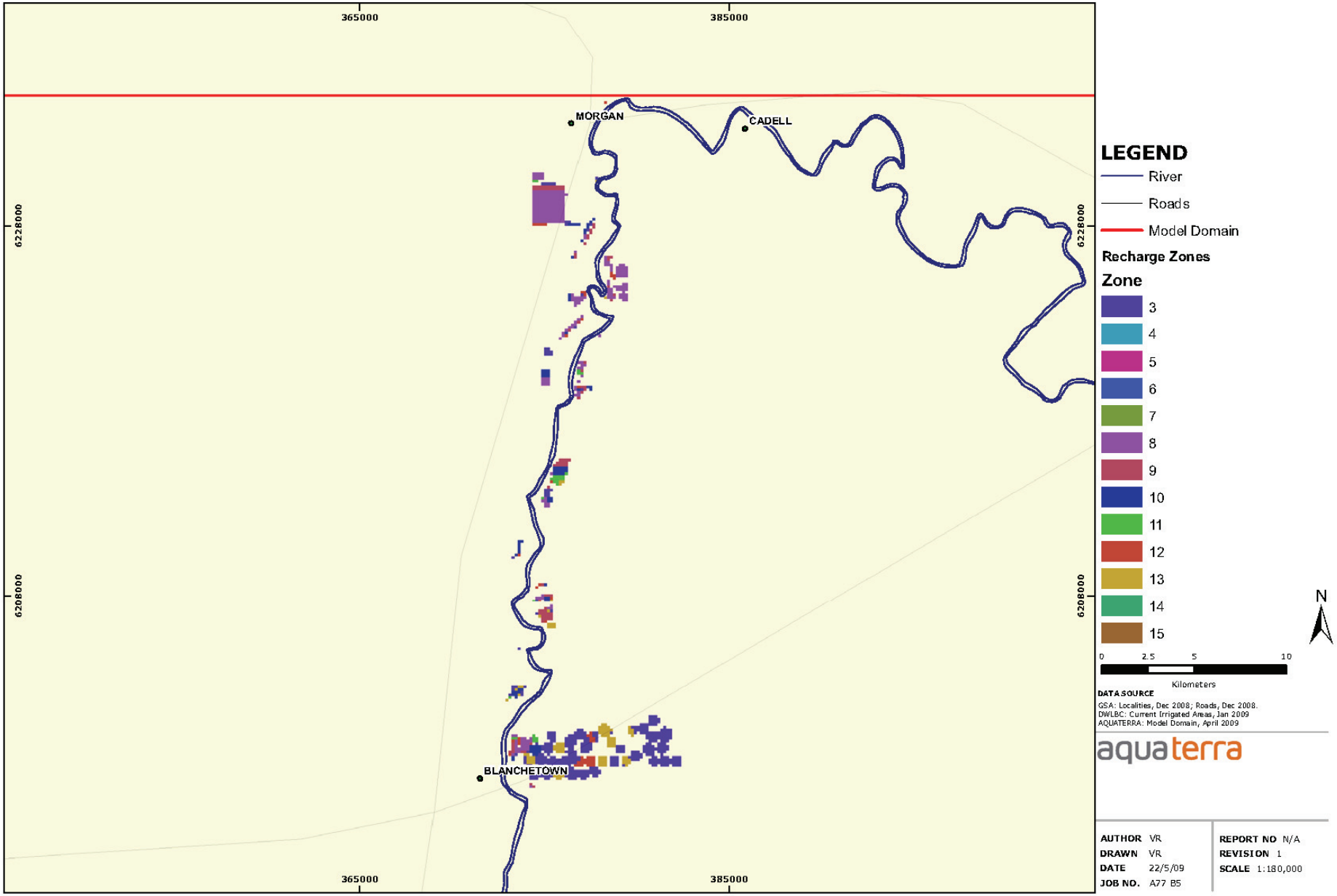


Figure 25a. Model recharge zones in the Morgan to Lock 1 area (recharge rates in each zone against time are listed in *Appendix A*)

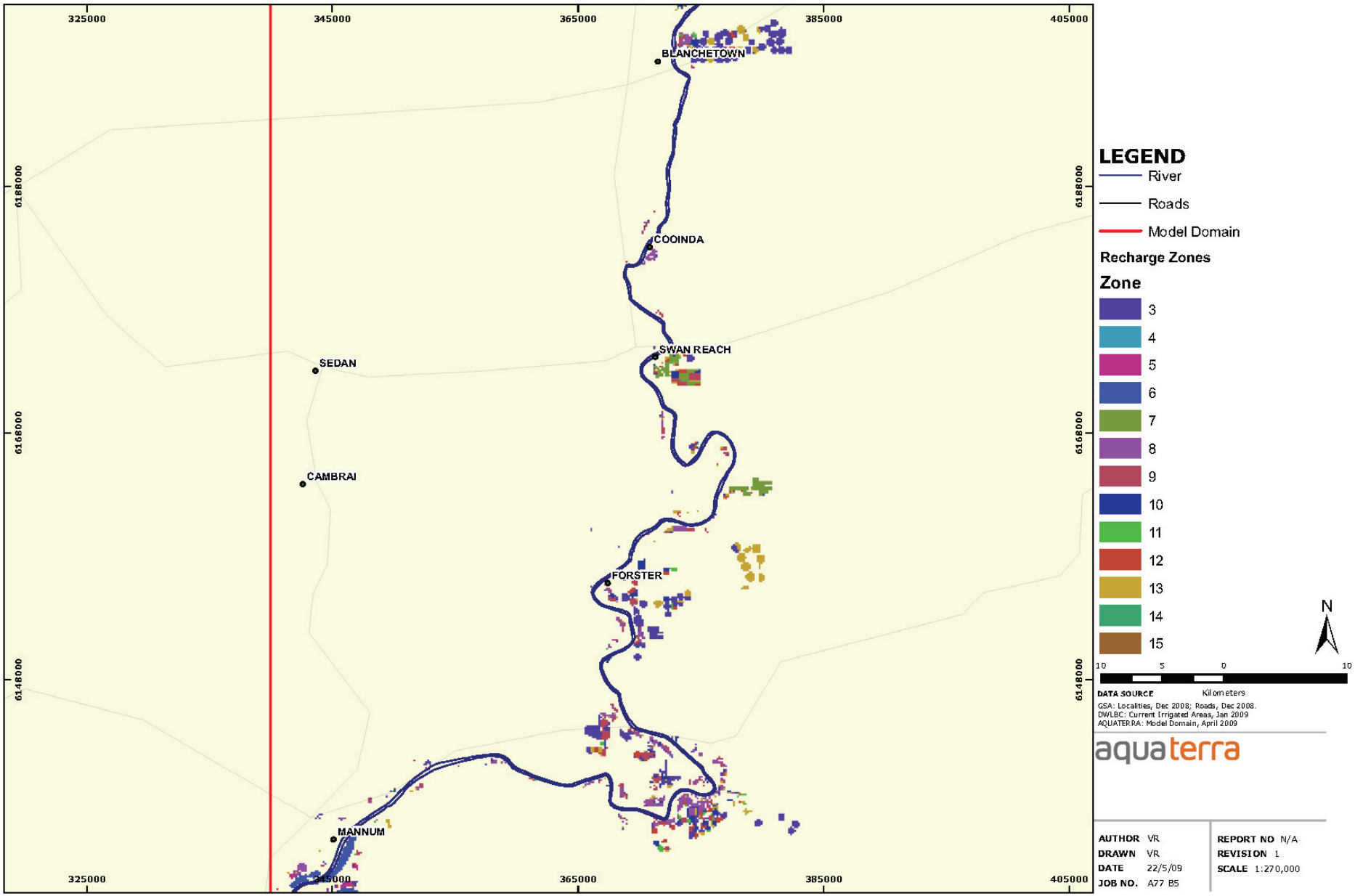


Figure 25b. Model recharge zones in the Lock 1 to Mannum area (recharge rates in each zone against time are listed in *Appendix A*)

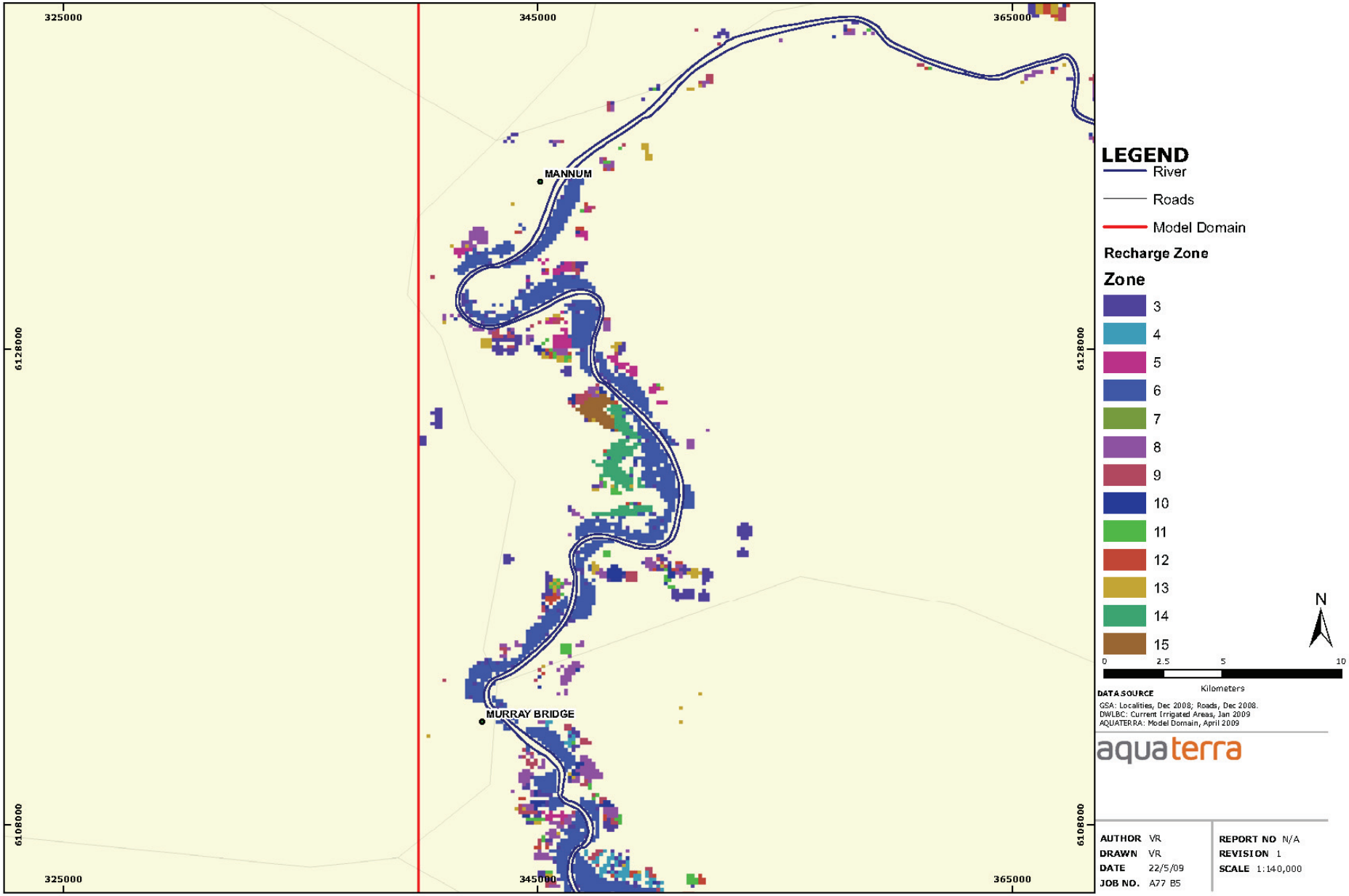


Figure 25c. Model recharge zones in the Mannum to Murray Bridge area (recharge rates in each zone against time are listed in *Appendix A*)

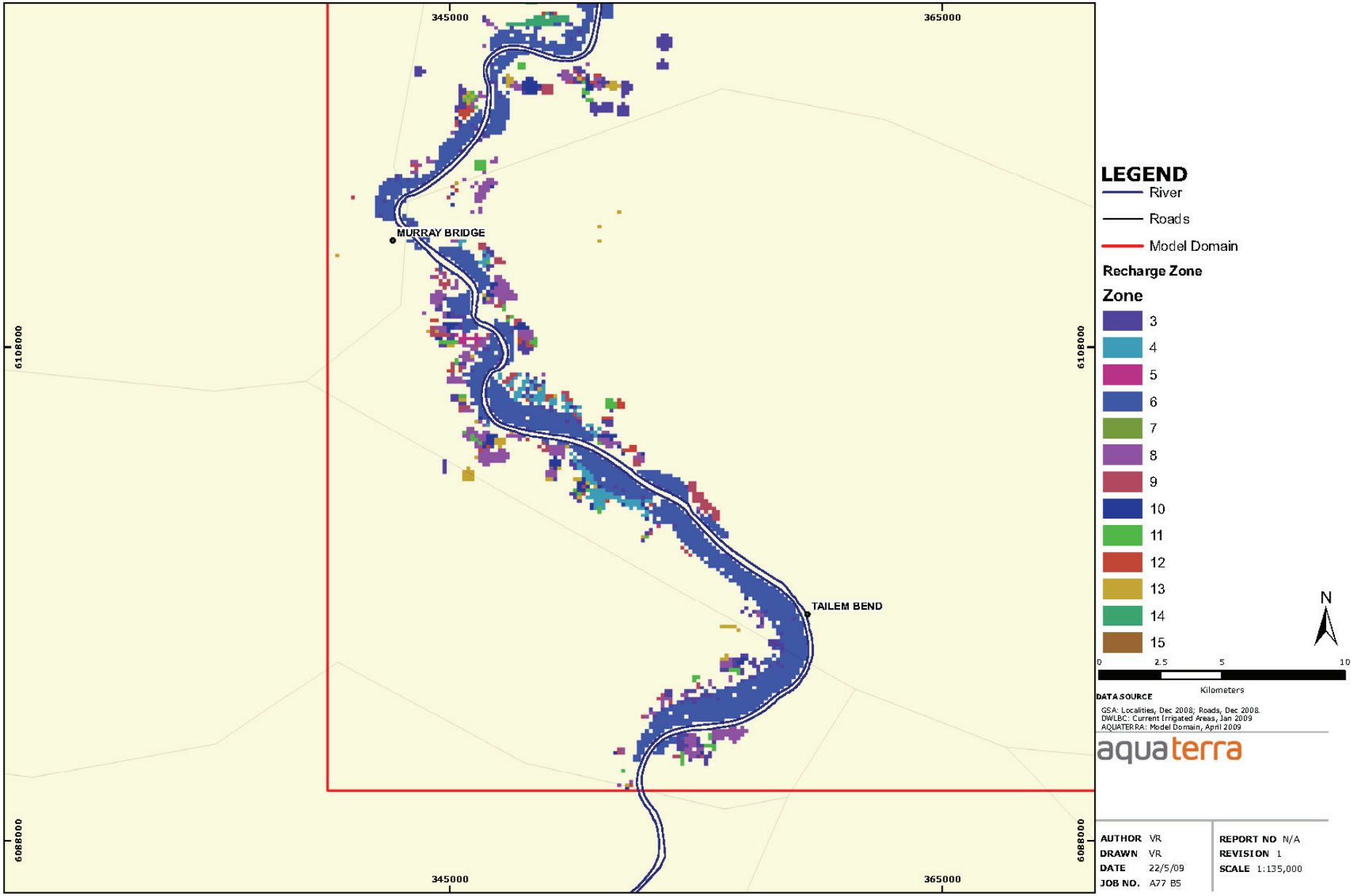


Figure 25d. Model recharge zones in the Murray Bridge to Wellington area (recharge rates in each zone against time are listed in *Appendix A*)

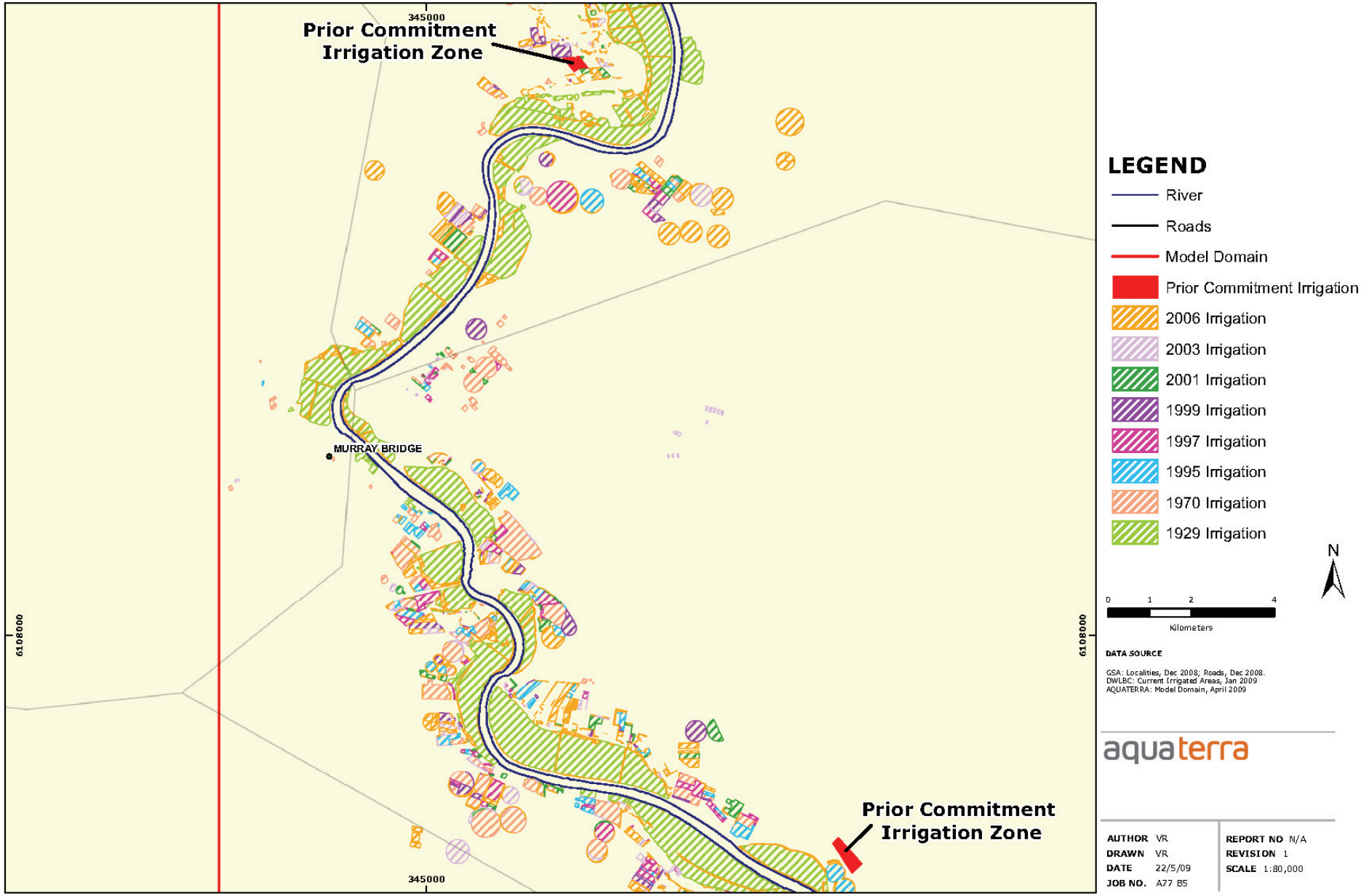


Figure 26. Prior commitment irrigation zones in the Mannum to Wellington area

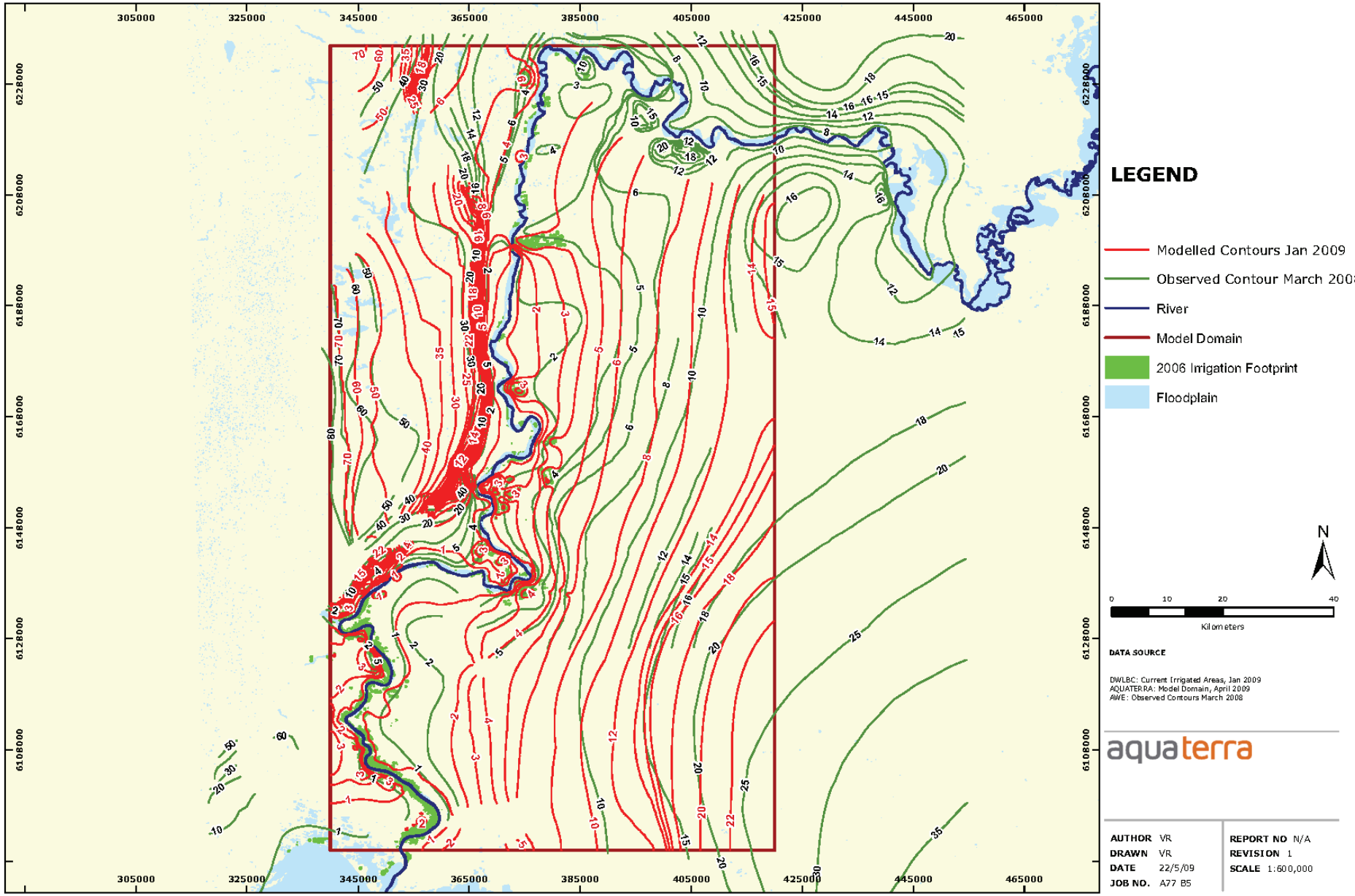


Figure 27. Comparison of observed and modelled Murray Group Limestone potentiometric surface at 2008 (m AHD)

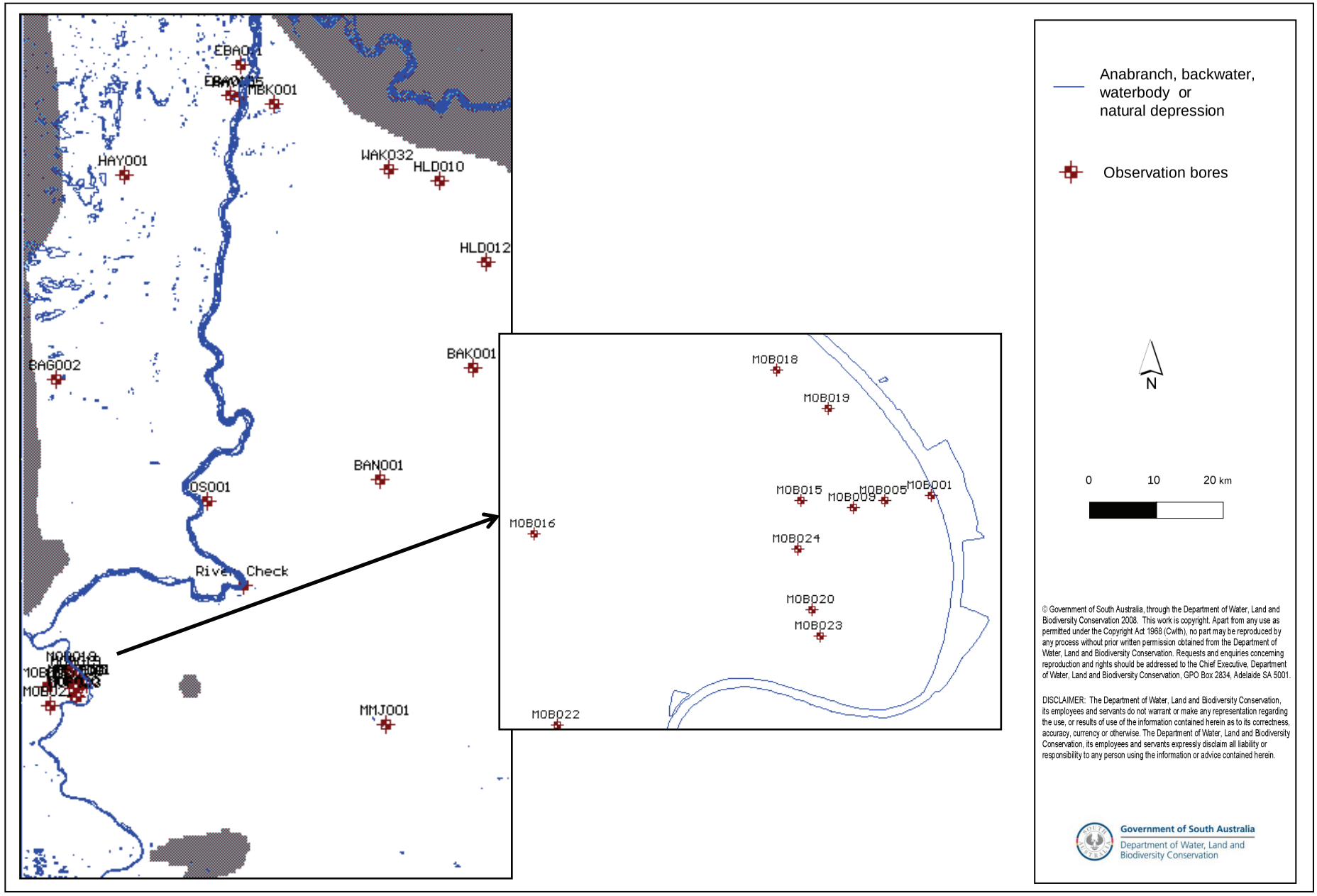
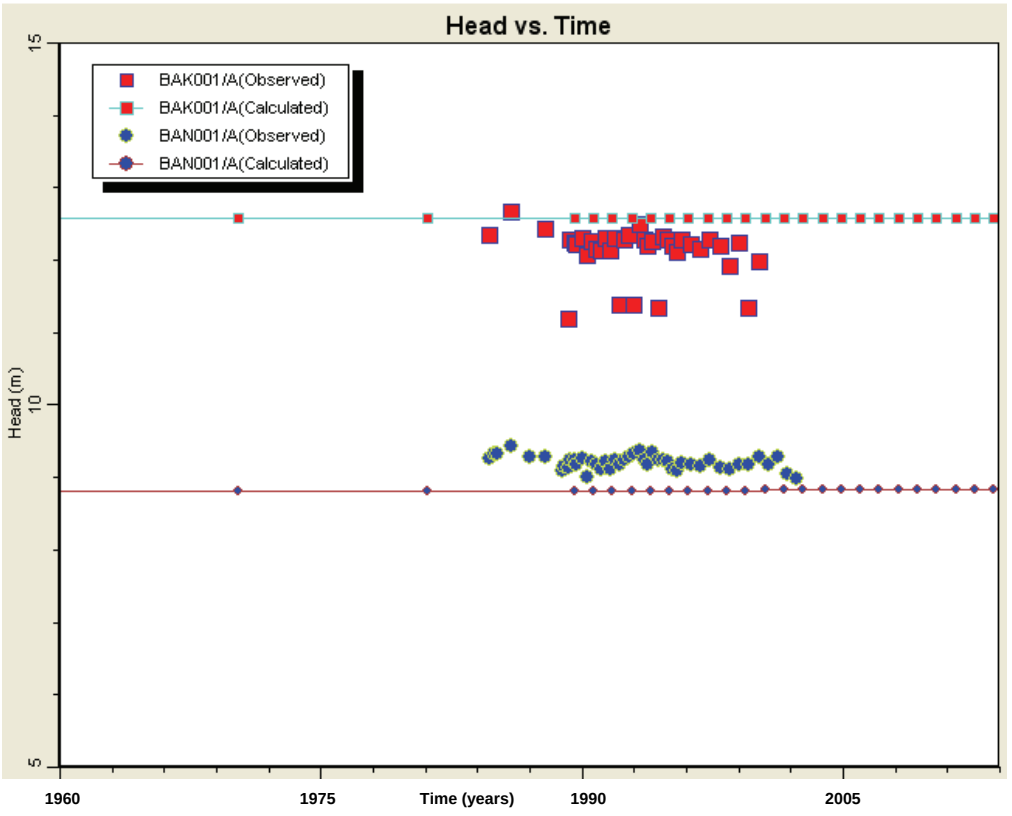


Figure 28. Location of bores used in model calibration



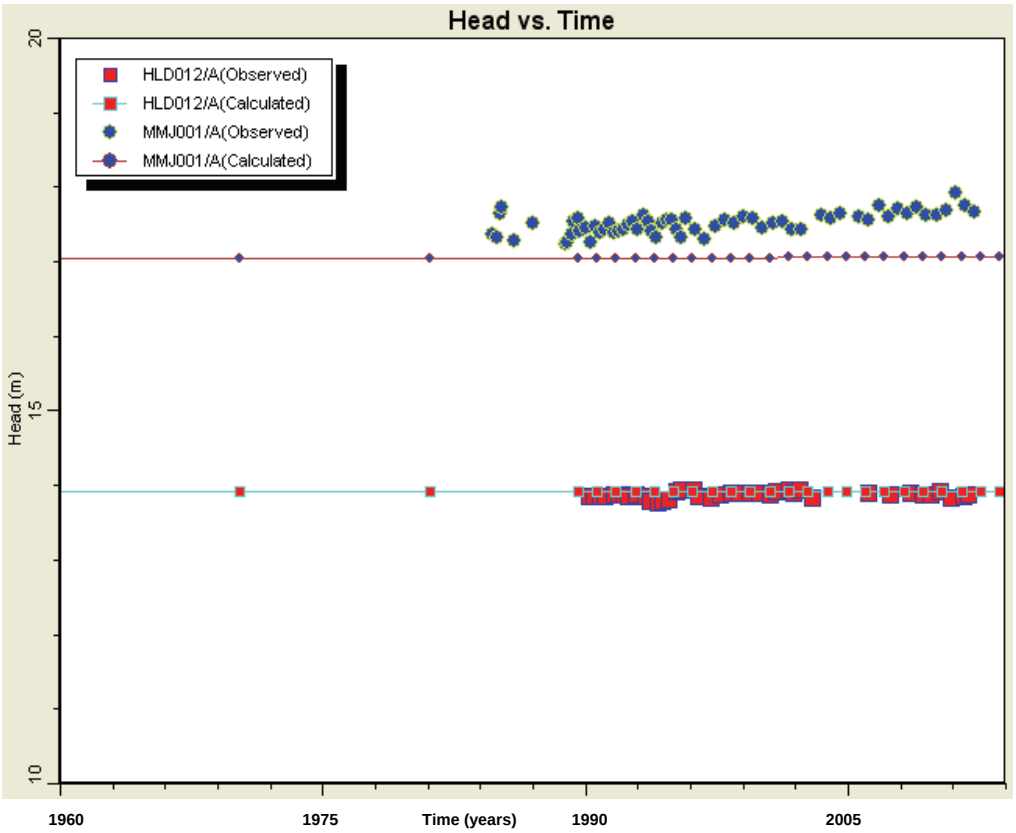
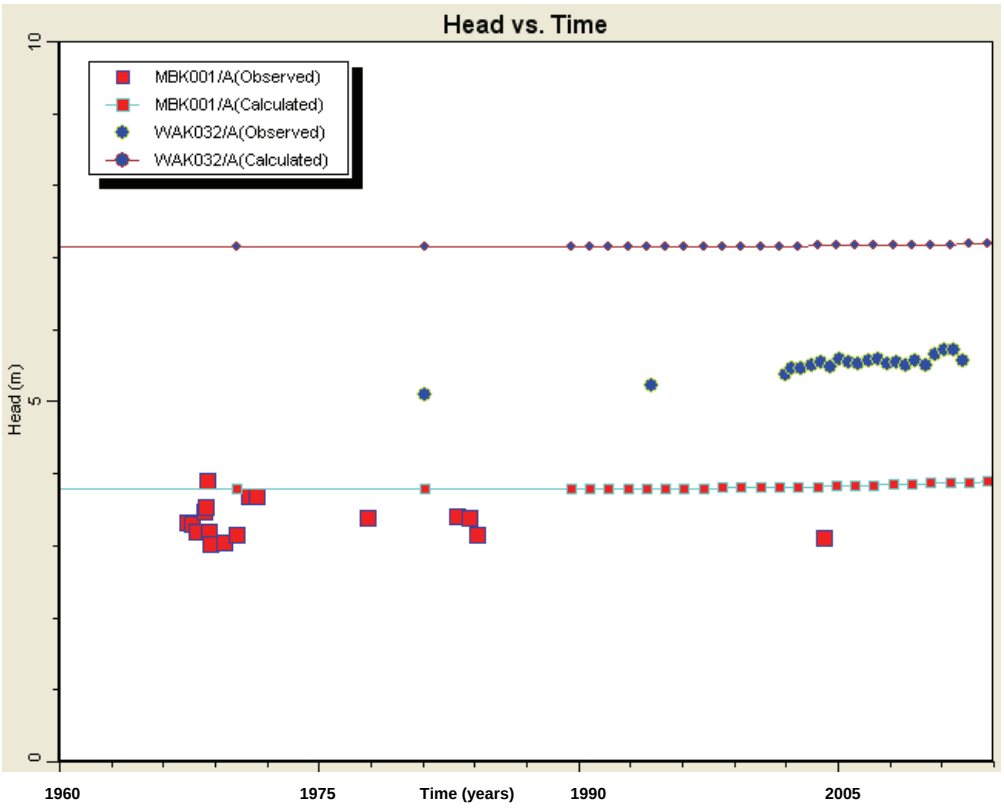


Figure 29a. Modelled vs observed hydrographs (eastern region)



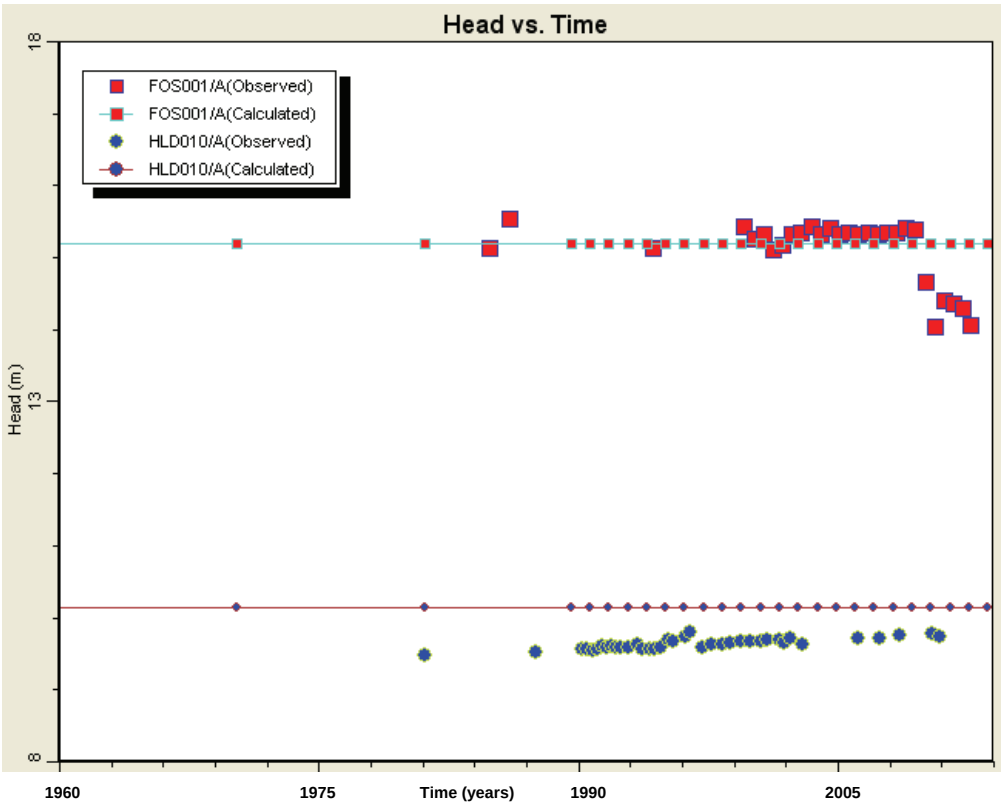
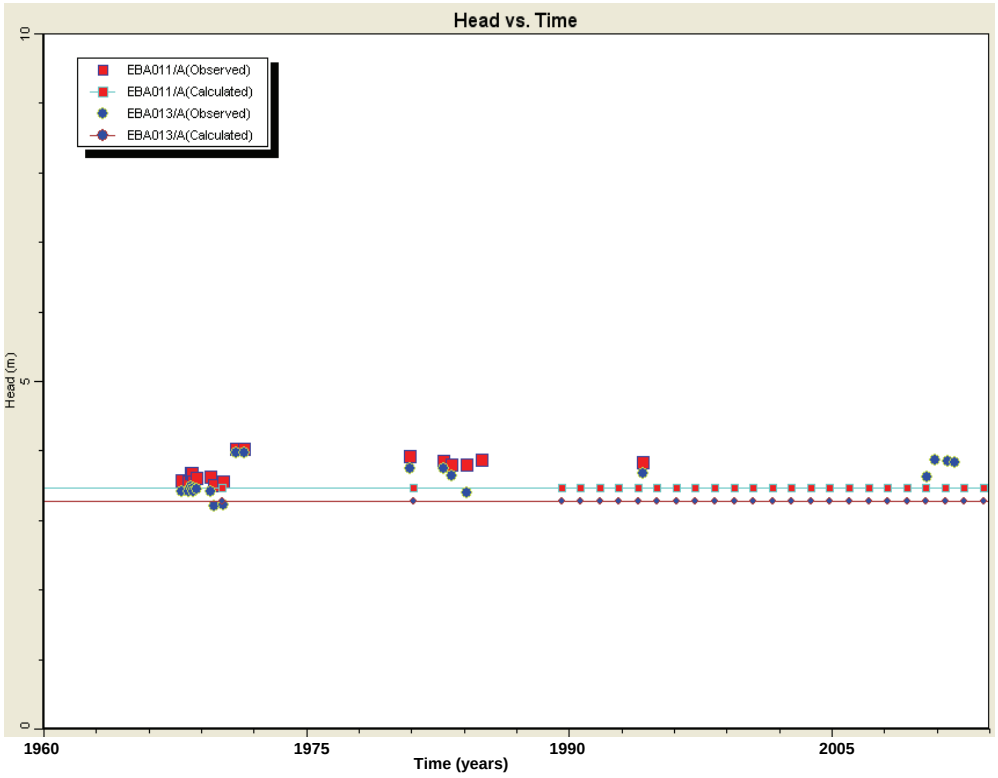


Figure 29b. Modelled vs observed hydrographs (eastern region)



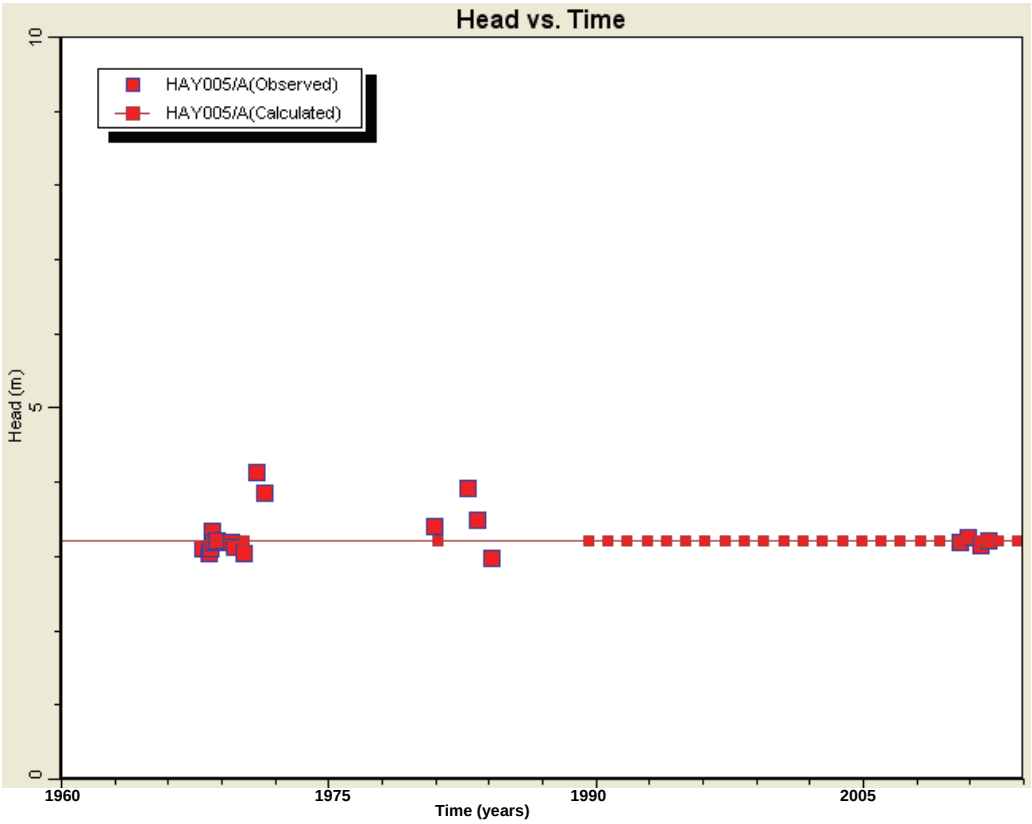
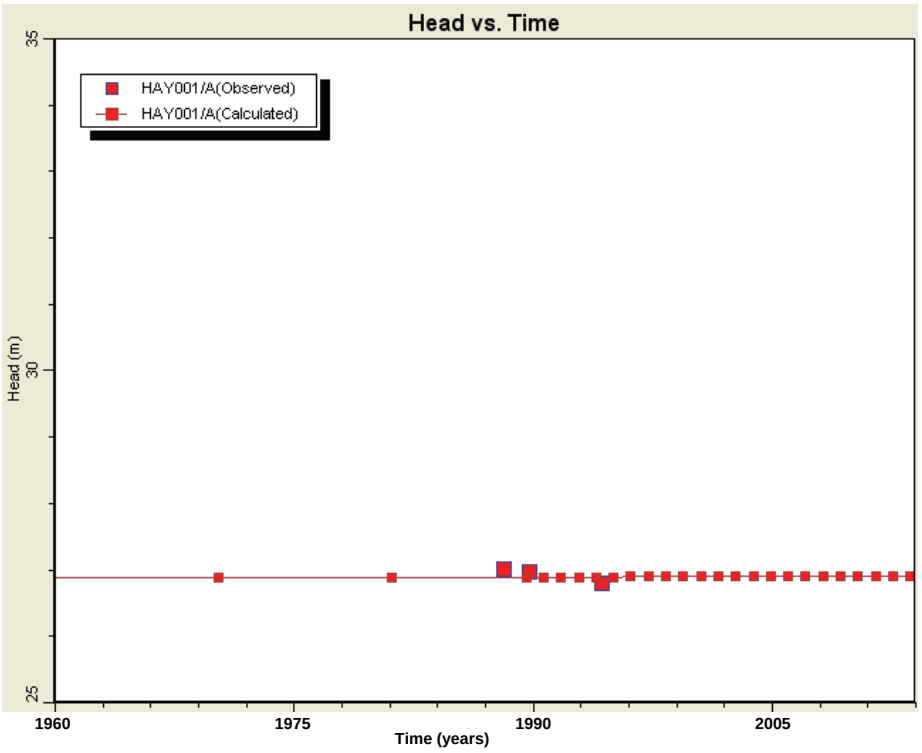


Figure 30. Modelled vs observed hydrographs (northern region)



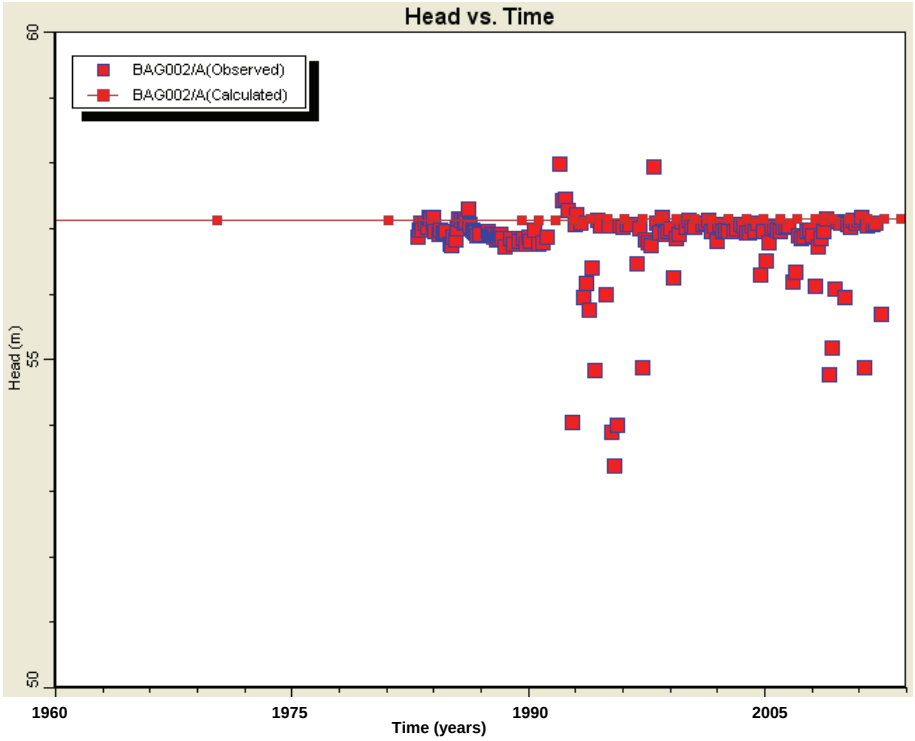
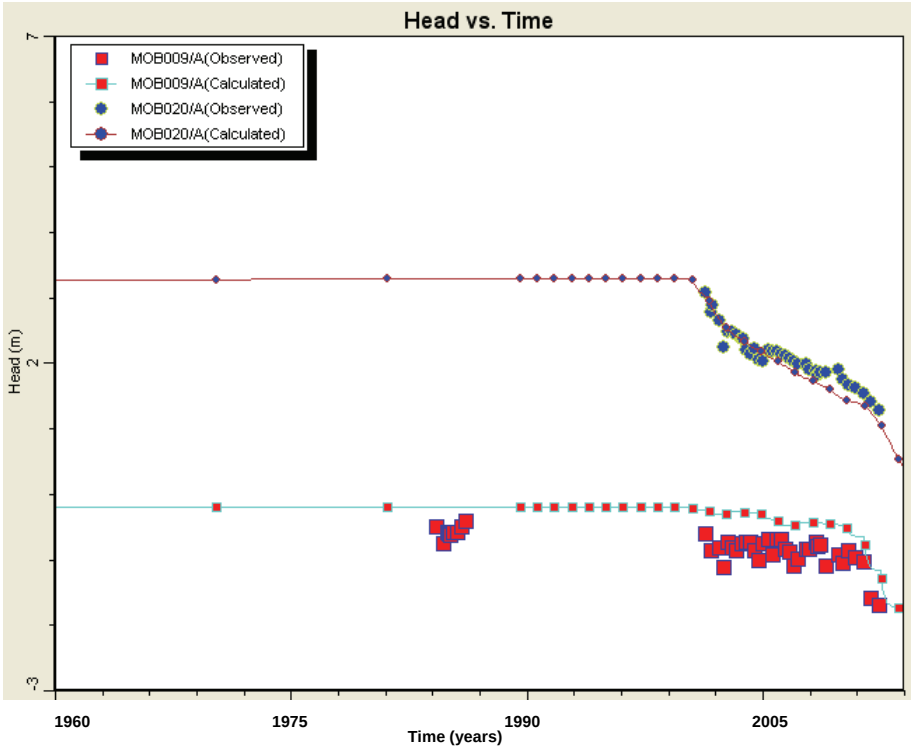


Figure 31. Modelled vs observed hydrographs (northern region)



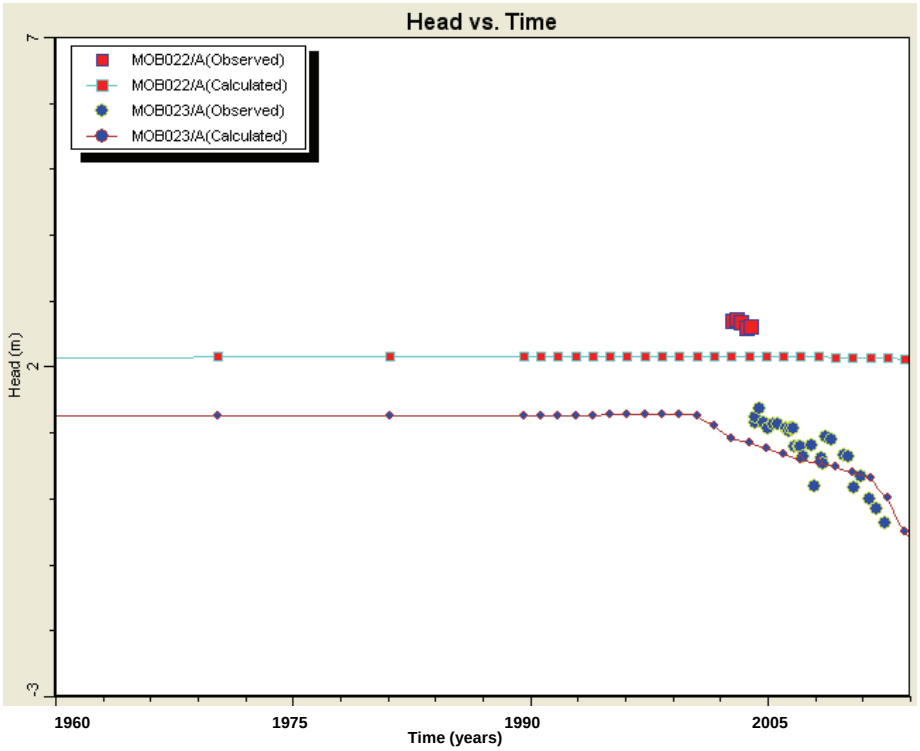
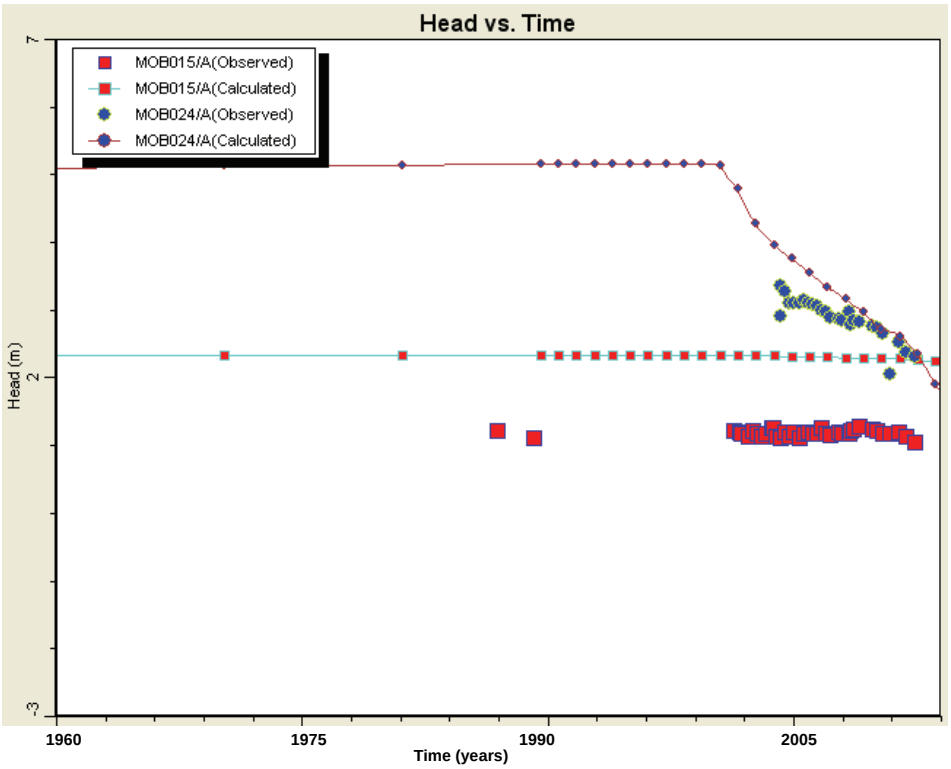


Figure 32a. Modelled vs observed hydrographs (south of Mannum)



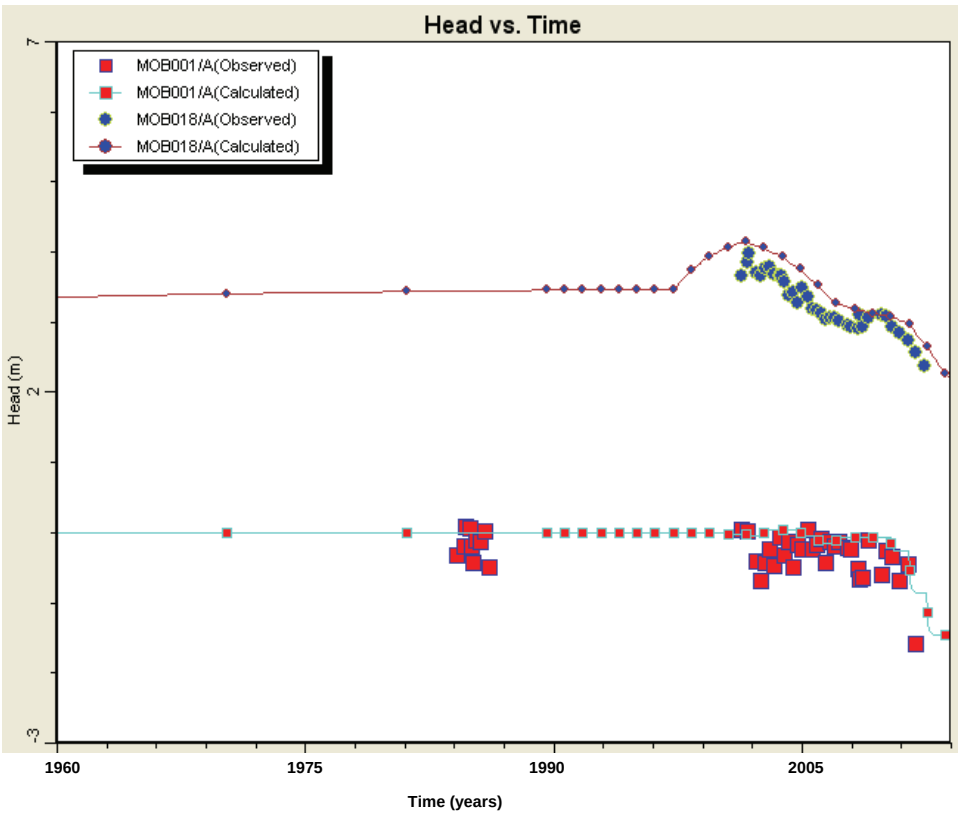
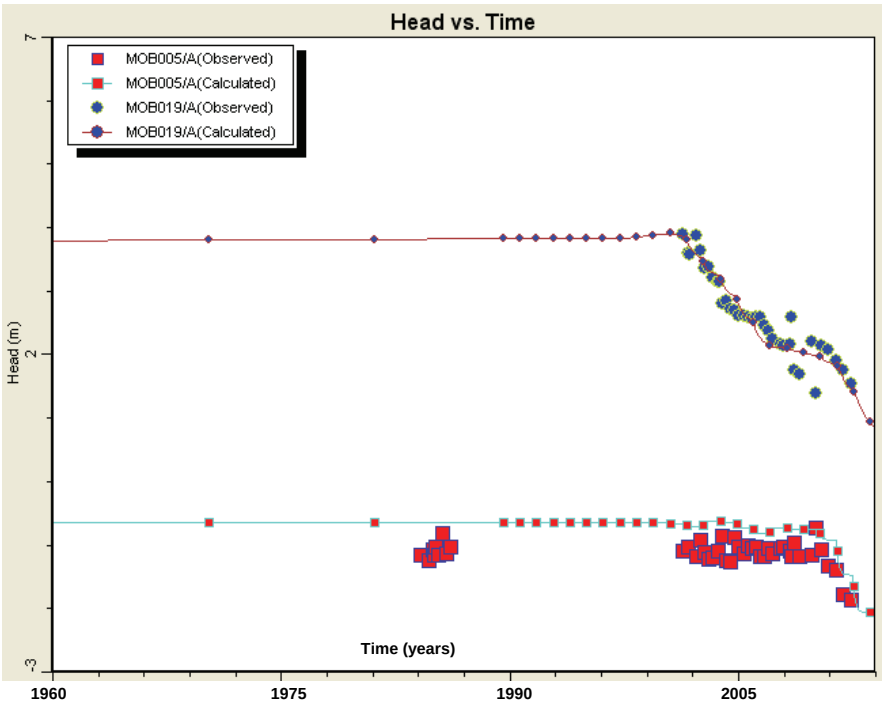


Figure 32b. Modelled vs observed hydrographs (south of Mannum)



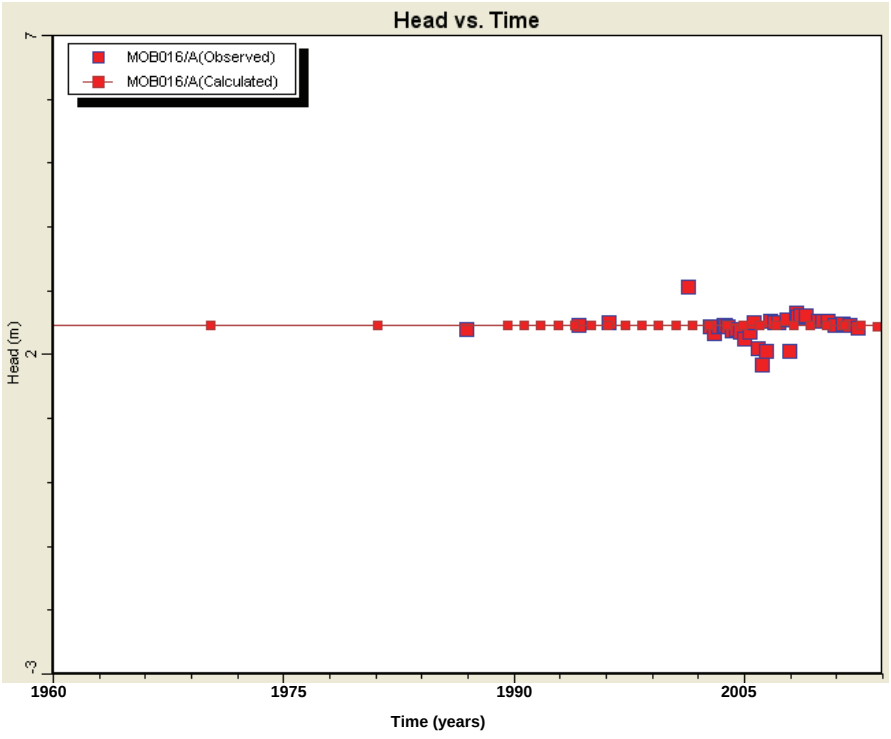
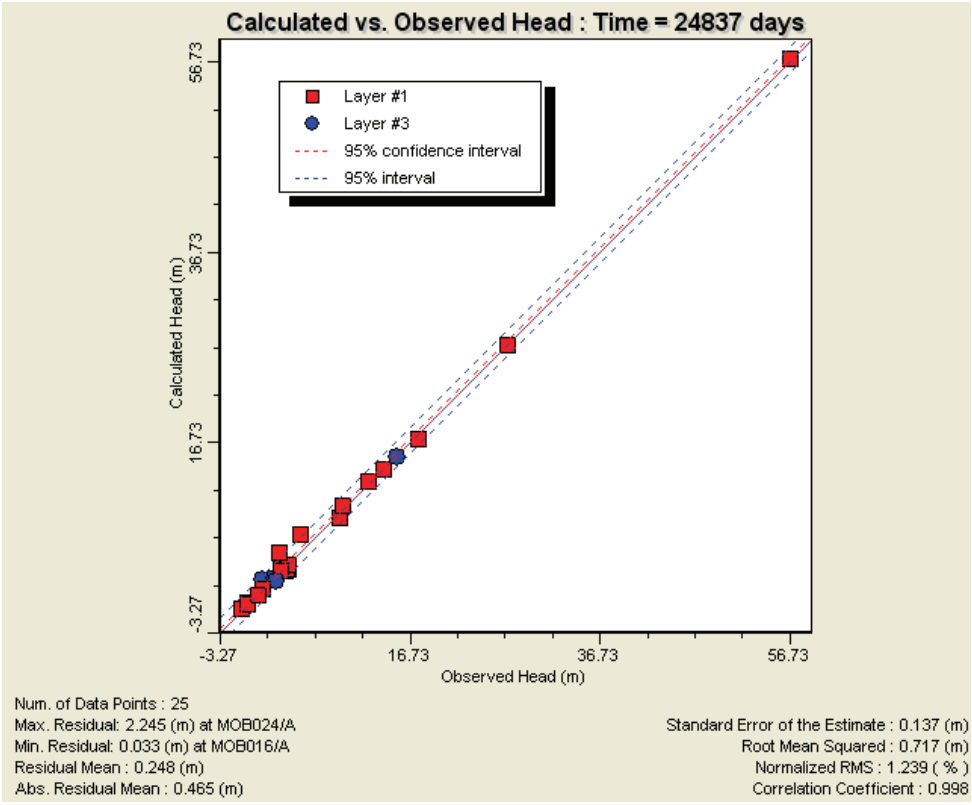


Figure 32c. Modelled vs observed hydrographs (south of Mannum)



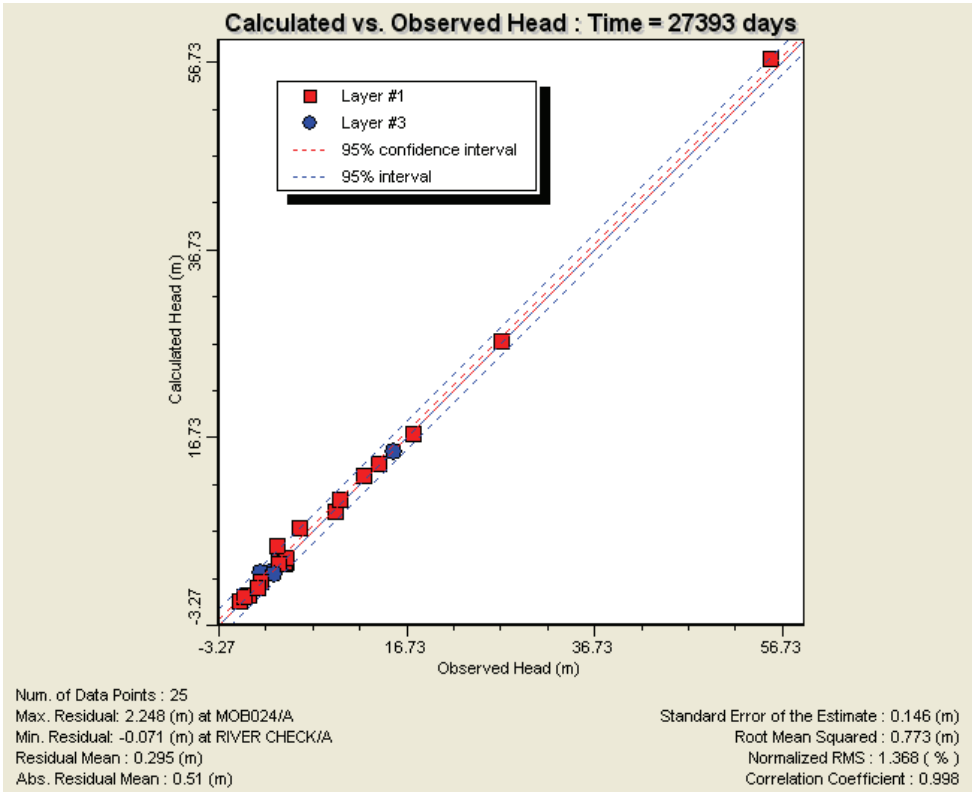
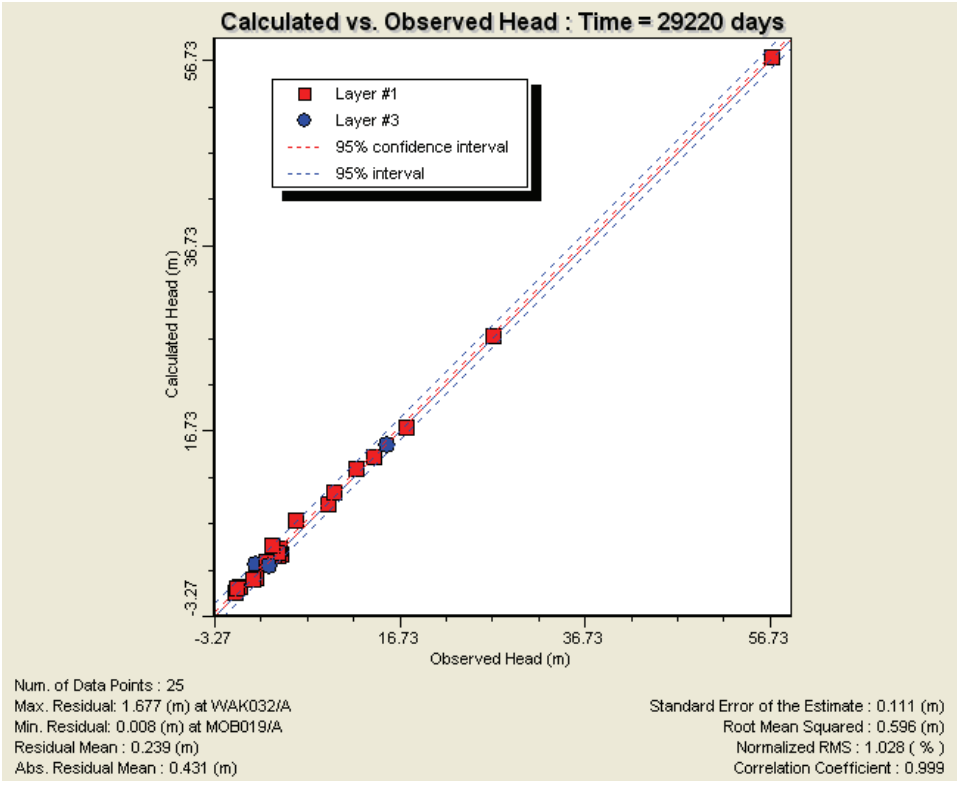


Figure 33. Modelled normalised RMS% values at years 1988, and 1995.



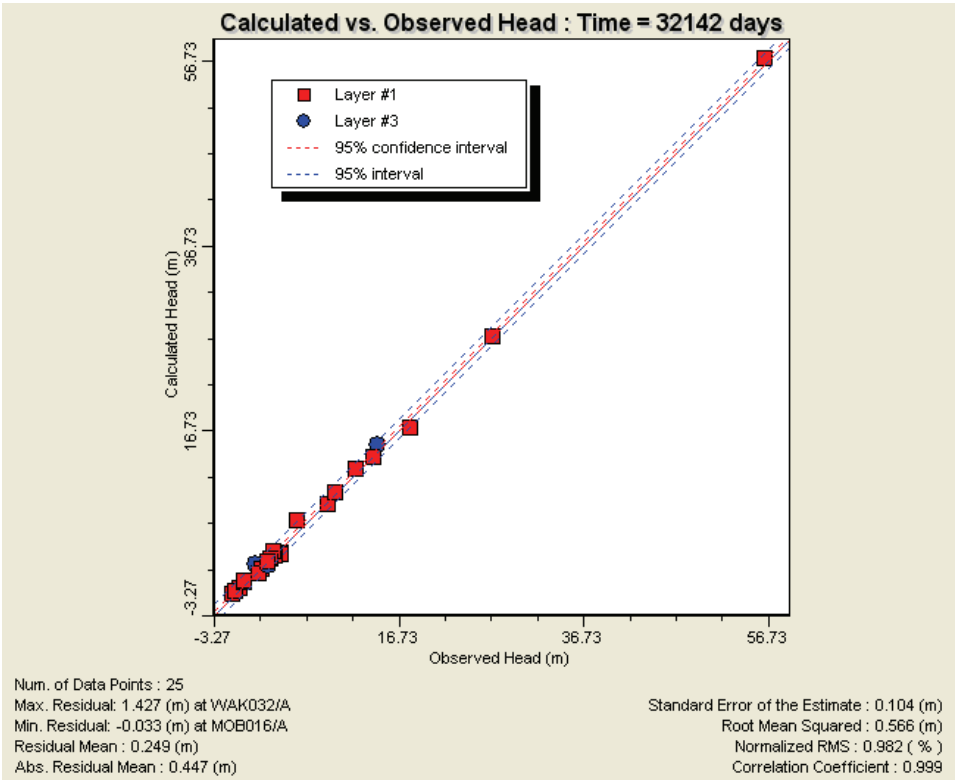


Figure 34. Modelled normalised RMS% values at years 2000 and 2008

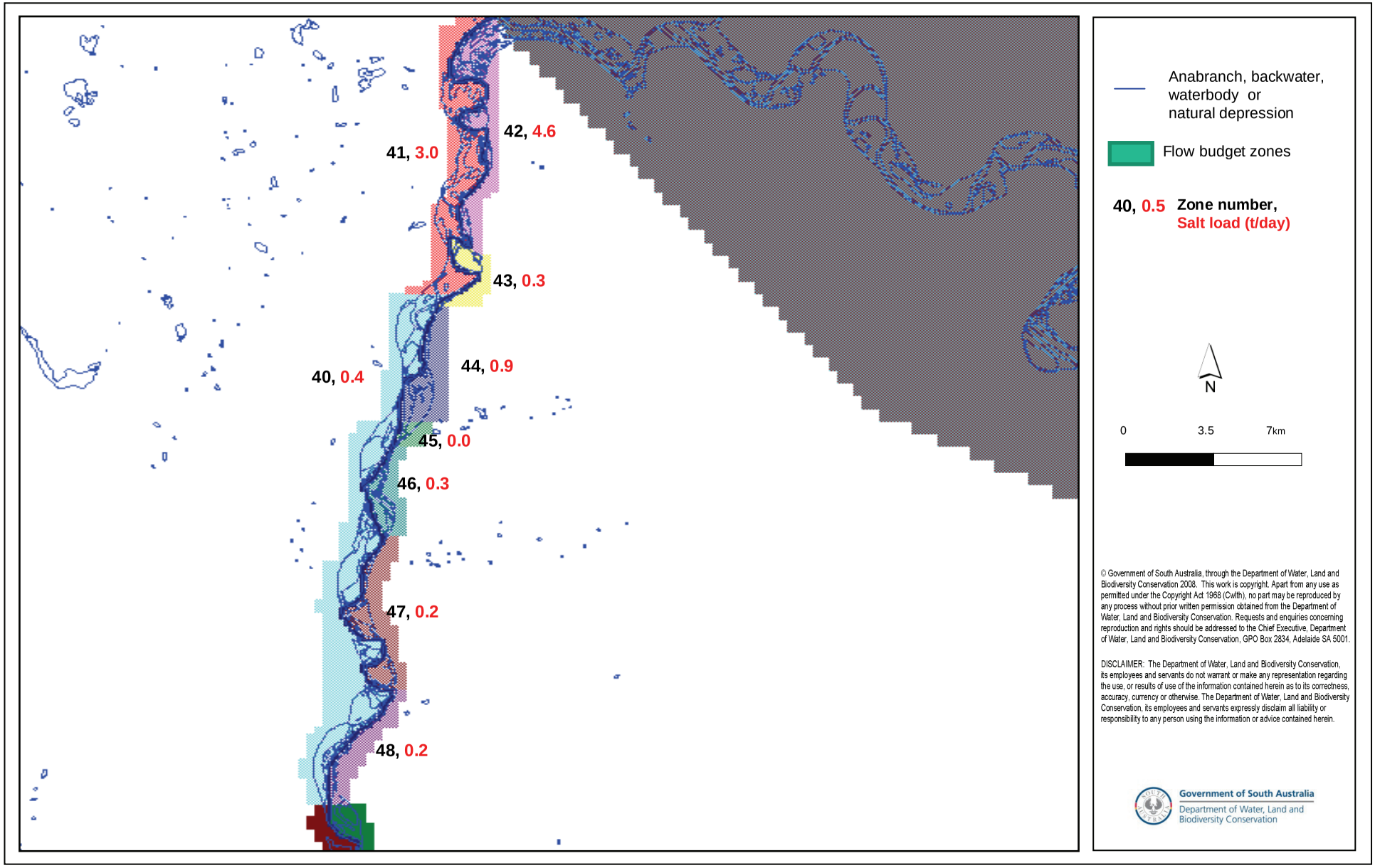


Figure 35. Model flow budget zones and modelled annual average salt load at 2009 (t/day) in the Morgan to Lock 1 area

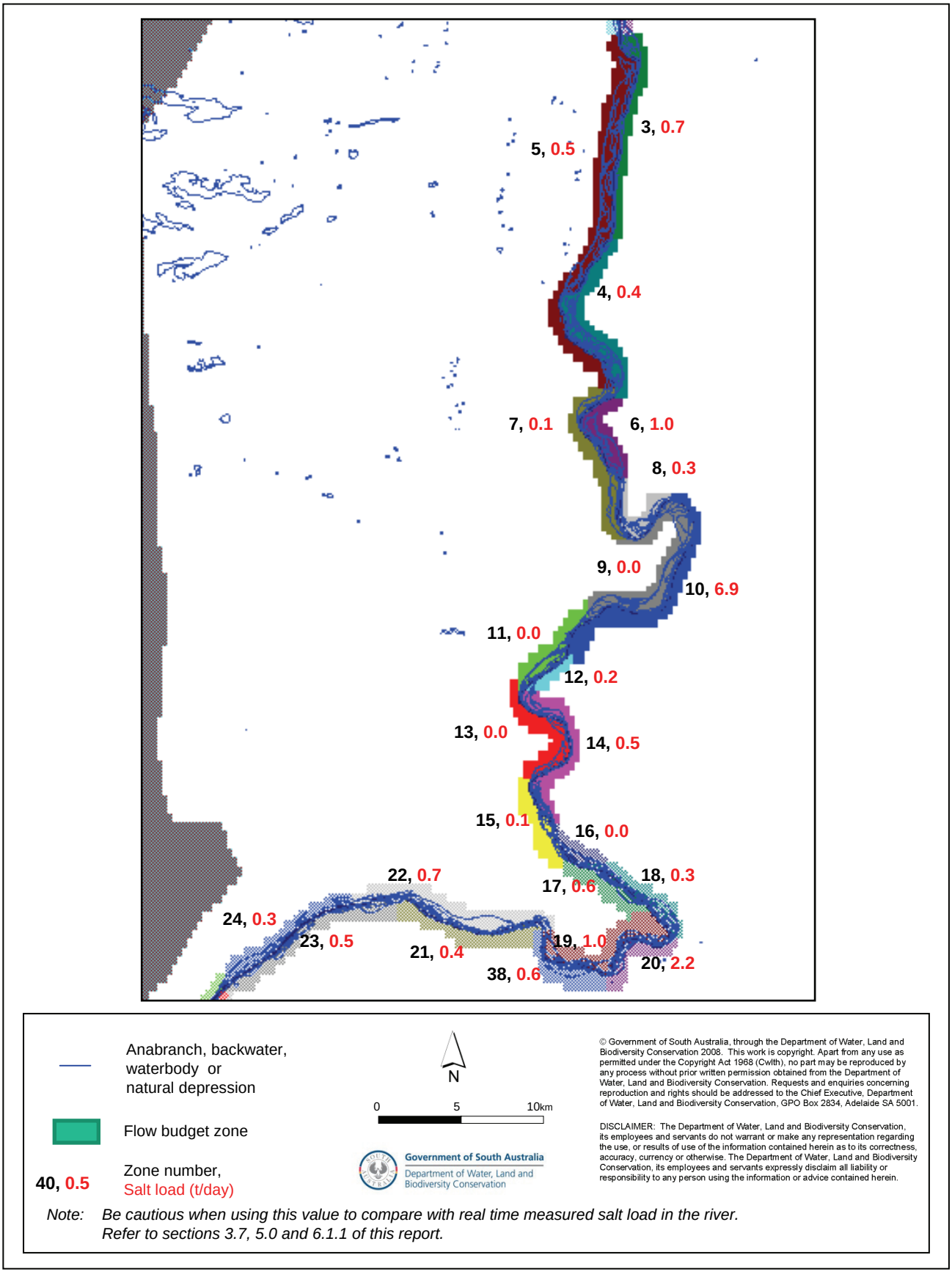
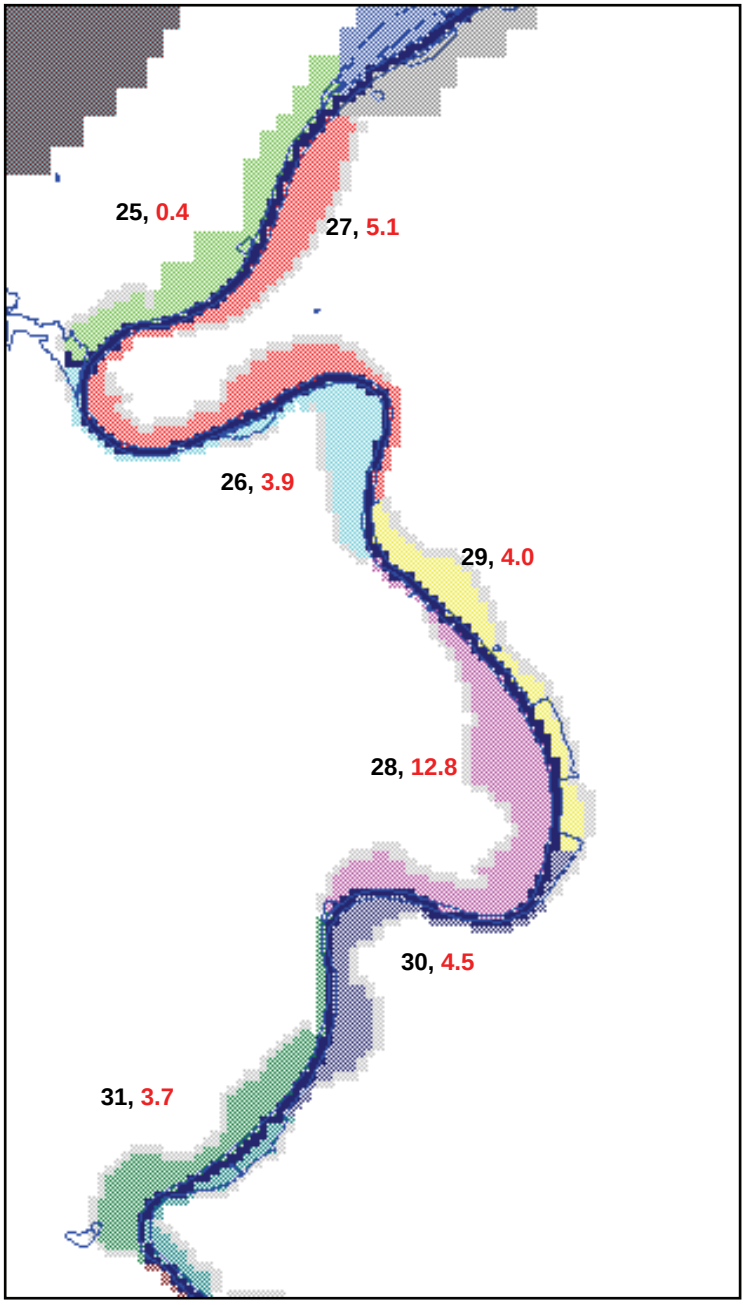


Figure 36. Model flow budget zones and modelled annual average salt load at 2009 (t/day) in the Lock 1 to Mannum area



Anabranch, backwater, waterbody or natural depression

Flow budget zone

40, 0.5 Zone number, Salt load (t/day)

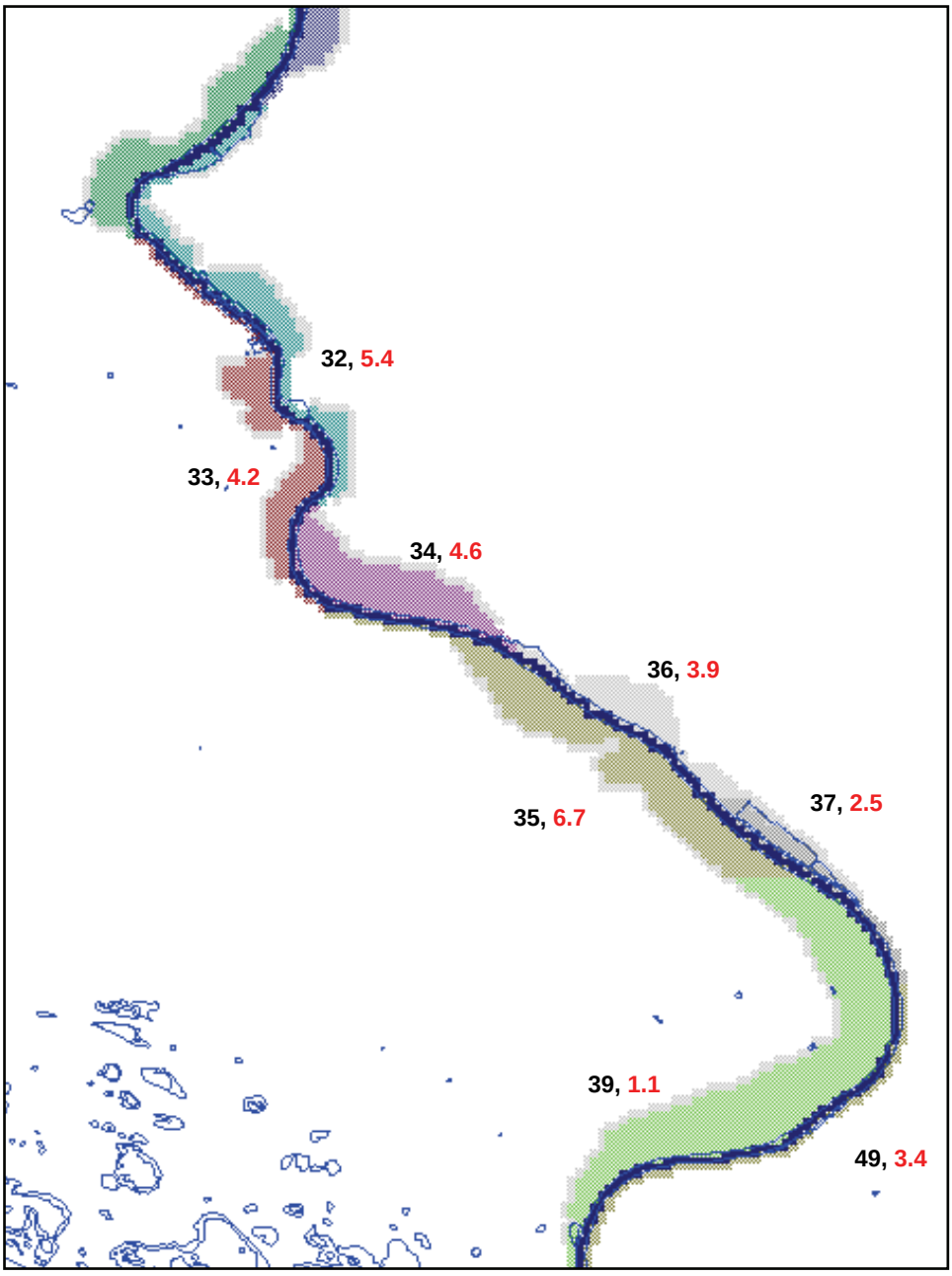
N

0 2 4km

Government of South Australia
Department of Water, Land and Biodiversity Conservation

Note: Be cautious when using this value to compare with real time measured salt load in the river. Refer to sections 3.7, 5.0 and 6.1.1 of this report.

Figure 37. Model flow budget zones and modelled annual average salt load at 2009 (t/day) in the Mannum to Murray Bridge area



Anabranch, backwater, waterbody or natural depression

Flow budget zone

Zone number,
Salt load (t/day)

31, 6.8

N

0 2 4km

Government of South Australia
Department of Water, Land and Biodiversity Conservation

Note: Be cautious when using this value to compare with real time measured salt load in the river. Refer to sections 3.7, 5.0 and 6.1.1 of this report.

Figure 38. Model flow budget zones and modelled annual average salt load at 2009 (t/day) in the Murray Bridge to Wellington area

Annual Salt Loads for Morgan to Lock 1 (t/day)

Time	S-1	S-2	S-3A	S-3B	S-3C	S-4	S-5
1988	2.8	2.9	2.8	2.8	2.8	2.8	2.8
1989	2.8	2.9	2.8	2.8	2.8	2.8	2.8
1990	2.8	3.0	2.8	2.8	2.8	2.8	2.8
1991	2.8	3.0	2.8	2.8	2.8	2.8	2.8
1992	2.8	3.0	2.8	2.8	2.8	2.8	2.8
1993	2.8	3.1	2.8	2.8	2.8	2.8	2.8
1994	2.8	3.1	2.8	2.8	2.8	2.8	2.8
1995	2.8	3.1	2.8	2.8	2.8	2.8	2.8
1996	2.8	3.1	2.8	2.8	2.8	2.8	2.8
1997	2.8	3.1	2.8	2.8	2.8	2.8	2.8
1998	2.8	3.1	2.8	2.8	2.8	2.8	2.8
1999	2.8	3.1	2.8	2.8	2.8	2.8	2.8
2000	2.8	3.3	2.8	2.8	2.8	2.8	2.8
2001	2.8	3.3	7.2	7.2	7.2	7.2	7.2
2002	2.8	3.4	9.1	8.9	8.9	8.9	8.9
2003	2.8	3.4	10.3	9.7	9.7	9.7	9.7
2004	2.8	3.4	11.2	10.1	10.1	10.1	10.1
2005	2.8	3.5	11.9	10.4	10.4	10.4	10.4
2006	2.8	3.5	12.5	10.4	10.4	10.4	10.4
2007	2.8	3.5	13.0	10.4	10.4	10.4	10.4
2008	2.8	3.6	13.5	10.0	10.0	10.0	10.0
2009	2.8	3.6	13.9	9.9	9.9	9.9	9.9
2010	2.8	3.8	14.3	9.9	9.9	9.9	9.9
2011	2.8	3.9	14.6	10.0	10.0	10.0	10.0
2012	2.8	4.0	14.9	10.0	10.0	10.0	10.0
2013	2.8	4.1	15.1	10.1	10.1	10.1	10.1
2014	2.8	4.2	15.4	10.1	10.1	10.1	10.1
2015	2.8	4.3	15.6	10.2	10.2	10.2	10.2
2016	2.8	4.4	15.8	10.2	10.2	10.2	10.2
2017	2.8	4.4	16.0	10.3	10.3	10.3	10.3
2018	2.8	4.5	16.1	10.3	10.3	10.3	10.3
2019	2.8	4.5	16.3	10.3	10.4	10.4	10.4
2020	2.8	4.9	16.4	10.4	10.4	10.4	10.4
2021	2.8	5.1	16.5	10.4	10.4	10.4	10.4
2022	2.8	5.3	16.7	10.4	10.5	10.5	10.5
2023	2.8	5.4	16.8	10.5	10.5	10.5	10.5
2024	2.8	5.5	16.9	10.5	10.5	11.2	11.2
2025	2.8	5.7	16.9	10.5	10.5	11.5	11.5
2026	2.8	5.8	17.0	10.5	10.6	12.0	12.0
2027	2.8	5.9	17.1	10.5	10.6	12.4	12.4
2028	2.8	6.0	17.2	10.6	10.6	12.9	12.9
2029	2.8	6.1	17.2	10.6	10.6	13.2	13.2
2030	2.8	6.5	17.3	10.6	10.6	13.8	13.8
2031	2.8	6.7	17.4	10.6	10.6	14.2	14.2
2032	2.8	7.0	17.4	10.6	10.7	14.5	14.5
2033	2.8	7.2	17.5	10.6	10.7	14.7	14.7
2034	2.8	7.4	17.5	10.7	10.7	14.9	14.9
2035	2.8	7.5	17.6	10.7	10.7	15.3	15.3
2036	2.8	7.7	17.6	10.7	10.7	15.6	15.6
2037	2.8	7.8	17.7	10.7	10.7	15.8	15.8
2038	2.8	8.0	17.7	10.7	10.7	16.1	16.1
2039	2.8	8.1	17.8	10.7	10.7	16.3	16.3
2040	2.8	8.5	17.8	10.7	10.7	16.5	16.5
2041	2.8	8.8	17.8	10.7	10.7	16.7	16.7
2042	2.8	9.0	17.9	10.7	10.7	16.9	16.9
2043	2.8	9.2	17.9	10.7	10.7	17.1	17.1
2044	2.8	9.4	17.9	10.7	10.7	17.2	17.2
2045	2.8	9.6	18.0	10.7	10.7	17.3	17.3
2046	2.8	9.8	18.0	10.7	10.7	17.4	17.4
2047	2.8	10.0	18.0	10.7	10.7	17.5	17.5
2048	2.8	10.1	18.0	10.7	10.7	17.6	17.6
2049	2.8	10.3	18.1	10.7	10.7	17.7	17.7
2050	2.8	10.6	18.1	10.7	10.7	17.8	17.8
2051	2.8	10.9	18.1	10.7	10.7	17.9	17.9
2052	2.8	11.1	18.1	10.7	10.7	18.0	18.0
2053	2.8	11.3	18.2	10.8	10.8	18.0	18.0
2054	2.8	11.5	18.2	10.8	10.8	18.1	18.1
2055	2.8	11.7	18.2	10.8	10.8	18.1	18.1
2056	2.8	11.9	18.2	10.8	10.8	18.2	18.2
2057	2.8	12.1	18.3	10.8	10.8	18.2	18.2
2058	2.8	12.2	18.3	10.8	10.8	18.3	18.3
2059	2.8	12.4	18.3	10.8	10.8	18.3	18.3
2060	2.8	12.7	18.3	10.8	10.8	18.4	18.4
2061	2.8	12.9	18.3	10.8	10.8	18.4	18.4
2062	2.8	13.1	18.4	10.8	10.8	18.5	18.5
2063	2.8	13.3	18.4	10.8	10.8	18.5	18.5
2064	2.8	13.5	18.4	10.8	10.8	18.5	18.5
2065	2.8	13.7	18.4	10.8	10.8	18.6	18.6
2066	2.8	13.9	18.4	10.8	10.8	18.6	18.6
2067	2.8	14.1	18.4	10.8	10.8	18.6	18.6
2068	2.8	14.2	18.5	10.8	10.8	18.7	18.7
2069	2.8	14.4	18.5	10.8	10.8	18.7	18.7
2070	2.8	14.6	18.5	10.8	10.8	18.7	18.7
2071	2.8	14.8	18.5	10.8	10.8	18.7	18.7
2072	2.8	15.0	18.5	10.8	10.8	18.8	18.8
2073	2.8	15.2	18.5	10.8	10.8	18.8	18.8
2074	2.8	15.4	18.5	10.8	10.8	18.8	18.8
2075	2.8	15.5	18.6	10.8	10.8	18.8	18.8
2076	2.8	15.7	18.6	10.8	10.8	18.9	18.9
2077	2.8	15.9	18.6	10.8	10.8	18.9	18.9
2078	2.8	16.0	18.6	10.8	10.8	18.9	18.9
2079	2.8	16.2	18.6	10.8	10.8	18.9	18.9
2080	2.8	16.4	18.6	10.8	10.8	18.9	18.9
2081	2.8	16.6	18.6	10.8	10.8	19.0	19.0
2082	2.8	16.7	18.6	10.8	10.8	19.0	19.0
2083	2.8	16.9	18.6	10.8	10.8	19.0	19.0
2084	2.8	17.1	18.7	10.8	10.8	19.0	19.0
2085	2.8	17.2	18.7	10.8	10.8	19.0	19.0
2086	2.8	17.4	18.7	10.8	10.8	19.1	19.0
2087	2.8	17.5	18.7	10.9	10.9	19.1	19.1
2088	2.8	17.7	18.7	10.9	10.9	19.1	19.1
2089	2.8	17.8	18.7	10.9	10.9	19.1	19.1
2090	2.8	18.0	18.7	10.9	10.9	19.1	19.1
2091	2.8	18.1	18.7	10.9	10.9	19.1	19.1
2092	2.8	18.3	18.7	10.9	10.9	19.1	19.1
2093	2.8	18.5	18.7	10.9	10.9	19.2	19.1
2094	2.8	18.6	18.7	10.9	10.9	19.2	19.2
2095	2.8	18.7	18.7	10.9	10.9	19.2	19.2
2096	2.8	18.9	18.7	10.9	10.9	19.2	19.2
2097	2.8	19.0	18.7	10.9	10.9	19.2	19.2
2098	2.8	19.2	18.8	10.9	10.9	19.2	19.2
2099	2.8	19.3	18.8	10.9	10.9	19.2	19.2
2100	2.8	19.5	18.8	10.9	10.9	19.2	19.2
2101	2.8	19.6	18.8	10.9	10.9	19.2	19.2
2102	2.8	19.7	18.8	10.9	10.9	19.3	19.2
2103	2.8	19.9	18.8	10.9	10.9	19.3	19.3
2104	2.8	20.0	18.8	10.9	10.9	19.3	19.3
2105	2.8	20.2	18.8	10.9	10.9	19.3	19.3
2106	2.8	20.3	18.8	10.9	10.9	19.3	19.3
2107	2.8	20.4	18.8	10.9	10.9	19.3	19.3
2108	2.8	20.5	18.8	10.9	10.9	19.3	19.3
2109	2.8	20.5	18.8	10.9	10.9	19.3	19.3

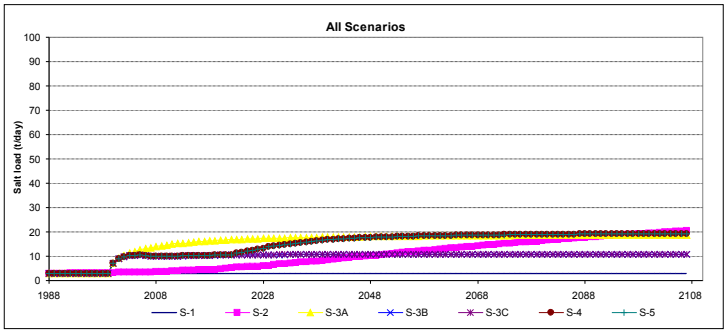
Scenario	Name	Model Run	Irrigation development area	IIP	RH	SIS
S-1	Natural system	Steady State	None	-	-	-
S-2	Mallee clearance	1920 - CY100	None (but includes Mallee clearance area)	-	-	-
S-3A	Pre-1988, no IIP, no RH	1988 – CY100	Pre-1988	No	No	-
S-3B	Pre-1988, with IIP, no RH	1988 – CY100	Pre-1988	Yes	No	-
S-3C	Pre-1988, with IIP and with RH	1988 – CY100	Pre-1988	Yes	Yes	-
S-4	Current irrigation	CY – CY100	Pre-1988 + Post-1988	Yes	Yes	No
S-5	Current plus future irrigation	CY – CY100	Pre-1988 + Post-1988 + Future development	Yes	Yes	No

IIP = improved irrigation practices
RH = Rehabilitation of irrigation distribution networks
SIS = Salt interception scheme
CY = current year
CY100 = 100 yrs from the current year

The tables below are designed to help MDBC choose the correct inputs to BIGMOD and show the impact of each of the individual accountable actions.

Accountable actions (t/day)

	Debits					Credits
	S2 - S1	S3A - S2	S4 - S3B	S4 - S3C	S5 - S4	S3A - S4
2000	0.4	-0.4	0.0	0.0	0.0	0.0
2005	0.7	8.5	0.0	0.0	0.0	1.6
2006	0.7	9.0	0.0	0.0	0.0	2.1
2007	0.7	9.5	0.0	0.0	0.0	2.7
2008	0.7	9.9	0.0	0.0	0.0	3.5
2009	0.8	10.3	0.0	0.0	0.0	4.0
2010	1.0	10.4	0.0	0.0	0.0	4.3
2011	1.1	10.6	0.0	0.0	0.0	4.6
2012	1.2	10.8	0.0	0.0	0.0	4.8
2013	1.3	11.0	0.0	0.0	0.0	5.1
2014	1.4	11.2	0.0	0.0	0.0	5.2
2015	1.5	11.3	0.0	0.0	0.0	5.4
2016	1.5	11.4	0.0	0.0	0.0	5.6
2017	1.6	11.6	0.0	0.0	0.0	5.7
2018	1.7	11.7	0.0	0.0	0.0	5.8
2019	1.7	11.8	0.0	0.0	0.0	5.9
2020	2.0	11.6	0.0	0.0	0.0	6.0
2021	2.3	11.5	0.0	0.0	0.0	6.1
2022	2.4	11.4	0.0	0.0	0.0	6.2
2023	2.6	11.4	0.0	0.0	0.0	6.3
2024	2.7	11.3	0.8	0.7	0.0	5.6
2025	2.9	11.3	1.0	1.0	0.0	5.4
2026	3.0	11.2	1.5	1.5	0.0	5.0
2027	3.1	11.2	1.8	1.8	0.0	4.8
2028	3.2	11.2	2.3	2.3	0.0	4.3
2029	3.3	11.1	2.6	2.6	0.0	4.0
2030	3.7	10.8	3.2	3.2	0.0	3.5
2031	3.9	10.6	3.5	3.5	0.0	3.2
2032	4.1	10.5	3.8	3.8	0.0	3.0
2033	4.3	10.3	4.0	4.0	0.0	2.8
2034	4.5	10.2	4.2	4.2	0.0	2.7
2035	4.7	10.1	4.6	4.6	0.0	2.3
2036	4.9	9.9	4.9	4.9	0.0	2.1
2050	7.8	7.5	7.1	7.1	0.0	0.3
2100	16.6	-0.7	8.4	8.4	0.0	-0.5



Summary of predicted salt load (t/day) entering the River Murray from Morgan to Lock 1

	1988	2000	2009	2050	2109
S-1	2.8	2.8	2.8	2.8	2.8
S-2	2.9	3.3	3.6	10.6	20.5
S-3A	2.8	2.8	13.9	18.1	18.8
S-3B	2.8	2.8	9.9	10.7	10.9
S-3C	2.8	2.8	9.9	10.7	10.9
S-4	2.8	2.8	9.9	17.8	19.3
S-5	2.8	2.8	9.9	17.8	19.3

Register A & B accountable debits and credits for the Morgan to Lock 1 Reach (t/day) Figure 39

Annual Salt Loads for Lock 1 to Mannum (t/day)

Time	S-1	S-2	S-3A	S-3B	S-3C	S-4	S-5
1988	8.4	9.8	14.1	14.1	14.1	14.1	14.1
1989	8.4	9.8	14.1	14.1	14.1	14.1	14.1
1990	8.4	9.9	14.2	14.2	14.2	14.2	14.2
1991	8.4	9.9	14.2	14.2	14.2	14.2	14.2
1992	8.4	10.0	14.3	14.3	14.3	14.3	14.3
1993	8.4	10.0	14.3	14.3	14.3	14.3	14.3
1994	8.4	10.0	14.4	14.4	14.4	14.4	14.4
1995	8.4	10.0	14.5	14.5	14.5	14.5	14.5
1996	8.4	10.0	14.6	14.6	14.6	14.6	14.6
1997	8.4	10.0	14.6	14.6	14.6	14.6	14.6
1998	8.4	10.0	14.7	14.6	14.6	14.6	14.6
1999	8.4	10.0	14.8	14.5	14.5	14.5	14.5
2000	8.4	10.1	14.9	14.3	14.3	14.3	14.3
2001	8.4	10.2	17.9	17.1	17.1	17.1	17.1
2002	8.4	10.2	19.4	18.3	18.3	18.3	18.3
2003	8.4	10.2	20.4	18.7	18.7	18.7	18.7
2004	8.4	10.2	21.0	18.8	18.8	18.8	18.8
2005	8.4	10.2	21.5	18.7	18.7	18.7	18.7
2006	8.4	10.3	21.8	18.5	18.5	18.5	18.5
2007	8.4	10.3	22.1	18.3	18.3	18.3	18.3
2008	8.4	10.3	22.4	17.7	17.7	17.7	17.7
2009	8.4	10.3	22.6	17.4	17.4	17.4	17.4
2010	8.4	10.4	22.8	17.2	17.2	17.2	17.2
2011	8.4	10.4	23.0	17.1	17.1	17.1	17.1
2012	8.4	10.4	23.1	17.0	17.0	17.0	17.0
2013	8.4	10.4	23.2	17.0	16.9	16.9	16.9
2014	8.4	10.4	23.4	16.9	16.9	16.9	16.9
2015	8.4	10.4	23.5	16.8	16.8	16.8	16.8
2016	8.4	10.5	23.6	16.8	16.8	16.8	16.8
2017	8.4	10.5	23.7	16.8	16.7	16.7	16.7
2018	8.4	10.5	23.8	16.7	16.7	16.7	16.7
2019	8.4	10.5	23.9	16.7	16.7	16.7	16.7
2020	8.4	10.6	24.0	16.7	16.6	16.6	16.6
2021	8.4	10.6	24.1	16.6	16.6	16.6	16.6
2022	8.4	10.6	24.1	16.6	16.6	16.6	16.6
2023	8.4	10.6	24.2	16.6	16.6	16.6	16.6
2024	8.4	10.6	24.3	16.6	16.6	17.4	17.4
2025	8.4	10.6	24.3	16.6	16.6	17.7	17.7
2026	8.4	10.7	24.4	16.6	16.6	18.2	18.2
2027	8.4	10.7	24.5	16.6	16.6	18.6	18.6
2028	8.4	10.7	24.5	16.6	16.6	19.0	19.0
2029	8.4	10.7	24.6	16.6	16.6	19.3	19.3
2030	8.4	10.8	24.6	16.6	16.5	19.9	19.9
2031	8.4	10.8	24.7	16.6	16.5	20.3	20.3
2032	8.4	10.8	24.7	16.5	16.5	21.2	21.2
2033	8.4	10.8	24.8	16.5	16.5	21.8	21.8
2034	8.4	10.8	24.8	16.5	16.5	22.2	22.2
2035	8.4	10.9	24.9	16.5	16.5	23.4	23.4
2036	8.4	10.9	24.9	16.5	16.5	24.2	24.2
2037	8.4	10.9	24.9	16.5	16.5	24.9	24.9
2038	8.4	10.9	25.0	16.5	16.5	25.5	25.5
2039	8.4	10.9	25.0	16.5	16.5	26.0	26.0
2040	8.4	11.0	25.1	16.5	16.5	26.5	26.5
2041	8.4	11.0	25.1	16.5	16.5	27.0	27.0
2042	8.4	11.0	25.1	16.5	16.5	27.4	27.4
2043	8.4	11.1	25.2	16.5	16.5	27.8	27.8
2044	8.4	11.1	25.2	16.5	16.5	28.2	28.2
2045	8.4	11.1	25.2	16.5	16.5	28.5	28.5
2046	8.4	11.1	25.2	16.5	16.5	28.8	28.8
2047	8.4	11.1	25.3	16.5	16.5	29.2	29.2
2048	8.4	11.1	25.3	16.5	16.5	29.5	29.5
2049	8.4	11.2	25.3	16.5	16.5	29.7	29.7
2050	8.4	11.2	25.4	16.5	16.5	30.0	30.0
2051	8.4	11.3	25.4	16.5	16.5	30.3	30.3
2052	8.4	11.3	25.4	16.5	16.5	30.5	30.5
2053	8.4	11.3	25.4	16.5	16.5	30.8	30.8
2054	8.4	11.4	25.5	16.5	16.5	31.0	31.0
2055	8.4	11.4	25.5	16.5	16.5	31.2	31.2
2056	8.4	11.4	25.5	16.5	16.5	31.4	31.4
2057	8.4	11.4	25.5	16.5	16.5	31.6	31.6
2058	8.4	11.4	25.5	16.5	16.5	31.8	31.8
2059	8.4	11.4	25.6	16.5	16.5	32.0	32.0
2060	8.4	11.5	25.6	16.5	16.5	32.2	32.2
2061	8.4	11.6	25.6	16.5	16.5	32.4	32.4
2062	8.4	11.6	25.6	16.5	16.5	32.6	32.6
2063	8.4	11.6	25.6	16.5	16.5	32.7	32.7
2064	8.4	11.7	25.7	16.5	16.5	32.9	32.9
2065	8.4	11.7	25.7	16.5	16.5	33.1	33.1
2066	8.4	11.7	25.7	16.5	16.5	33.2	33.2
2067	8.4	11.7	25.7	16.5	16.5	33.4	33.2
2068	8.4	11.8	25.7	16.5	16.5	33.5	33.4
2069	8.4	11.8	25.8	16.5	16.5	33.7	33.5
2070	8.4	11.9	25.8	16.5	16.5	33.8	33.6
2071	8.4	11.9	25.8	16.5	16.5	33.9	33.8
2072	8.4	11.9	25.8	16.5	16.5	34.1	33.9
2073	8.4	12.0	25.8	16.5	16.5	34.2	34.0
2074	8.4	12.0	25.8	16.5	16.5	34.3	34.1
2075	8.4	12.0	25.8	16.5	16.5	34.4	34.3
2076	8.4	12.1	25.9	16.5	16.5	34.5	34.4
2077	8.4	12.1	25.9	16.5	16.5	34.7	34.5
2078	8.4	12.1	25.9	16.5	16.5	34.8	34.6
2079	8.4	12.2	25.9	16.5	16.5	34.9	34.7
2080	8.4	12.2	25.9	16.5	16.5	35.0	34.8
2081	8.4	12.3	25.9	16.5	16.5	35.1	35.0
2082	8.4	12.3	25.9	16.5	16.5	35.2	35.1
2083	8.4	12.4	25.9	16.5	16.5	35.3	35.2
2084	8.4	12.4	26.0	16.5	16.5	35.4	35.3
2085	8.4	12.5	26.0	16.5	16.5	35.5	35.3
2086	8.4	12.5	26.0	16.5	16.5	35.5	35.4
2087	8.4	12.5	26.0	16.5	16.5	35.6	35.5
2088	8.4	12.6	26.0	16.5	16.5	35.7	35.6
2089	8.4	12.6	26.0	16.5	16.5	35.8	35.7
2090	8.4	12.7	26.0	16.5	16.5	35.9	35.8
2091	8.4	12.7	26.0	16.5	16.5	36.0	35.8
2092	8.4	12.8	26.0	16.5	16.5	36.0	35.9
2093	8.4	12.9	26.0	16.5	16.5	36.1	36.0
2094	8.4	12.9	26.0	16.5	16.5	36.2	36.1
2095	8.4	12.9	26.1	16.5	16.5	36.3	36.1
2096	8.4	13.0	26.1	16.5	16.5	36.3	36.2
2097	8.4	13.0	26.1	16.5	16.5	36.4	36.2
2098	8.4	13.1	26.1	16.5	16.5	36.5	36.3
2099	8.4	13.1	26.1	16.5	16.5	36.5	36.4
2100	8.4	13.2	26.1	16.5	16.5	36.6	36.4
2101	8.4	13.3	26.1	16.5	16.5	36.6	36.5
2102	8.4	13.4	26.1	16.5	16.5	36.7	36.5
2103	8.4	13.4	26.1	16.5	16.5	36.8	36.6
2104	8.4	13.5	26.1	16.5	16.5	36.8	36.7
2105	8.4	13.5	26.1	16.5	16.5	36.9	36.7
2106	8.4	13.6	26.1	16.5	16.5	36.9	36.8
2107	8.4	13.6	26.1	16.5	16.5	37.0	36.8
2108	8.4	13.7	26.1	16.5	16.5	37.0	36.9
2109	8.4	13.7	26.1	16.5	16.5	37.0	36.9

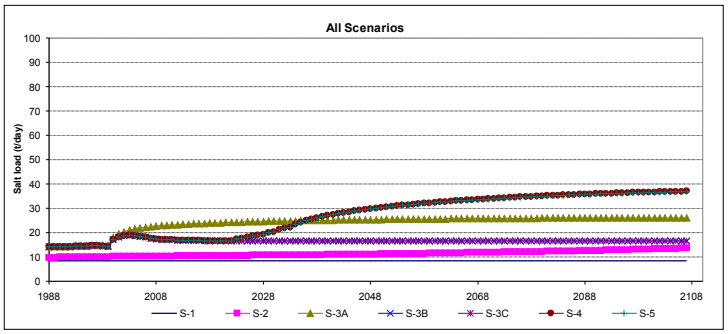
Scenario	Name	Model Run	Irrigation development area	IIP	RH	SIS
S-1	Natural system	Steady State	None	-	-	-
S-2	Mallee clearance	1920 - CY100	None (but includes Mallee clearance area)	-	-	-
S-3A	Pre-1988, no IIP, no RH	1988 – CY100	Pre-1988	No	No	-
S-3B	Pre-1988, with IIP, no RH	1988 – CY100	Pre-1988	Yes	No	-
S-3C	Pre-1988, with IIP and with RH	1988 – CY100	Pre-1988	Yes	Yes	-
S-4	Current irrigation	CY – CY100	Pre-1988 + Post-1988	Yes	Yes	No
S-5	Current plus future irrigation	CY – CY100	Pre-1988 + Post-1988 + Future development	Yes	Yes	No

IIP = improved irrigation practices
CY = current year
RH = Rehabilitation of irrigation distribution networks
CY100 = 100 yrs from the current year
SIS = Salti interception scheme

The tables below are designed to help MDBC choose the correct inputs to BIGMOD and show the impact of each of the individual accountable actions.

Accountable actions (t/day)

	Debits					Credits
	S2 - S1	S3A - S2	S4 - S3B	S4 - S3C	S5 - S4	S3A - S4
2000	1.7	4.7	0.0	0.0	0.0	0.5
2005	1.8	11.2	0.0	0.0	0.0	2.7
2006	1.9	11.6	0.0	0.0	0.0	3.3
2007	1.9	11.9	0.0	0.0	0.0	3.9
2008	1.9	12.1	0.0	0.0	0.0	4.7
2009	1.9	12.3	0.0	0.0	0.0	5.2
2010	2.0	12.4	0.0	0.0	0.0	5.6
2011	2.0	12.6	0.0	0.0	0.0	5.9
2012	2.0	12.7	0.0	0.0	0.0	6.1
2013	2.0	12.8	0.0	0.0	0.0	6.3
2014	2.0	12.9	0.0	0.0	0.0	6.5
2015	2.0	13.1	0.0	0.0	0.0	6.7
2016	2.1	13.2	0.0	0.0	0.0	6.9
2017	2.1	13.2	0.0	0.0	0.0	7.0
2018	2.1	13.3	0.0	0.0	0.0	7.1
2019	2.1	13.4	0.0	0.0	0.0	7.2
2020	2.2	13.4	0.0	0.0	0.0	7.3
2021	2.2	13.5	0.0	0.0	0.0	7.4
2022	2.2	13.5	0.0	0.0	0.0	7.5
2023	2.2	13.6	0.0	0.0	0.0	7.6
2024	2.2	13.6	0.8	0.8	0.0	6.9
2025	2.2	13.7	1.1	1.1	0.0	6.6
2026	2.3	13.7	1.6	1.6	0.0	6.2
2027	2.3	13.8	2.0	2.0	0.0	5.9
2028	2.3	13.8	2.4	2.4	0.0	5.5
2029	2.3	13.9	2.7	2.7	0.0	5.3
2030	2.4	13.9	3.3	3.3	0.0	4.8
2031	2.4	13.9	3.7	3.8	0.0	4.4
2032	2.4	13.9	4.6	4.7	0.0	3.5
2033	2.4	13.9	5.2	5.2	0.0	3.0
2034	2.4	14.0	5.7	5.7	0.0	2.6
2035	2.5	14.0	6.8	6.8	0.0	1.5
2036	2.5	14.0	7.7	7.7	0.0	0.7
2050	2.8	14.1	13.5	13.5	0.0	-4.6
2100	4.8	12.9	20.1	20.1	-0.2	-10.5



Summary of predicted salt load (t/day) entering the River Murray from Lock 1 to Mannum

	1988	2000	2009	2050	2109
S-1	8.4	8.4	8.4	8.4	8.4
S-2	9.8	10.1	10.3	11.2	13.7
S-3A	14.1	14.9	22.6	25.4	26.1
S-3B	14.1	14.3	17.4	16.5	16.5
S-3C	14.1	14.3	17.4	16.5	16.5
S-4	14.1	14.3	17.4	30.0	37.0
S-5	14.1	14.3	17.4	30.0	36.9

Register A & B accountable debits and credits for the Lock 1 to Mannum Reach (t/day) Figure 40

Annual Salt Loads for Mannum to Murray Bridge (t/day)

Time	S-1	S-2	S-3A	S-3B	S-3C	S-4	S-5
1988	0.2	20.4	43.0	43.0	43.0	43.0	43.0
1989	0.2	20.4	43.0	43.0	43.0	43.0	43.0
1990	0.2	20.6	43.0	43.0	43.0	43.0	43.0
1991	0.2	20.7	43.0	43.0	43.0	43.0	43.0
1992	0.2	20.7	43.0	43.0	43.0	43.0	43.0
1993	0.2	20.8	43.0	43.0	43.0	43.0	43.0
1994	0.2	20.8	43.1	43.1	43.1	43.1	43.1
1995	0.2	20.8	43.5	43.5	43.5	43.5	43.5
1996	0.2	20.8	44.0	44.0	44.0	44.0	44.0
1997	0.2	20.9	44.3	44.3	44.3	44.3	44.3
1998	0.2	20.9	44.5	44.0	44.0	44.0	44.0
1999	0.2	20.9	44.7	43.6	42.2	42.2	42.2
2000	0.2	21.1	44.8	42.9	40.3	40.3	40.3
2001	0.2	21.1	46.4	43.9	40.2	40.2	40.2
2002	0.2	21.2	47.1	44.2	39.3	39.3	39.3
2003	0.2	21.2	47.6	44.2	38.2	38.2	38.2
2004	0.2	21.2	48.0	44.1	37.6	37.6	37.6
2005	0.2	21.3	48.3	44.0	37.0	37.0	37.0
2006	0.2	21.3	48.5	43.8	36.1	36.1	36.1
2007	0.2	21.3	48.7	43.5	35.7	35.7	35.7
2008	0.2	21.3	48.9	43.2	35.1	35.1	35.1
2009	0.2	21.3	49.0	42.7	34.1	34.1	34.1
2010	0.2	21.5	49.1	42.5	33.4	33.4	33.4
2011	0.2	21.6	49.2	42.3	32.9	32.9	32.9
2012	0.2	21.6	49.4	42.2	32.6	32.6	32.6
2013	0.2	21.7	49.4	42.2	32.2	32.2	32.2
2014	0.2	21.7	49.5	42.1	32.0	32.0	32.0
2015	0.2	21.7	49.6	42.1	31.7	31.7	31.7
2016	0.2	21.7	49.7	42.0	31.5	31.5	31.5
2017	0.2	21.8	49.8	42.0	31.3	31.3	31.3
2018	0.2	21.8	49.8	42.0	30.9	30.9	30.9
2019	0.2	21.8	49.9	41.9	30.8	30.8	30.8
2020	0.2	21.9	49.9	41.9	30.7	30.7	30.7
2021	0.2	22.0	50.0	41.9	30.7	30.7	30.7
2022	0.2	22.1	50.1	41.9	30.6	30.6	30.6
2023	0.2	22.1	50.1	41.9	30.6	30.6	30.6
2024	0.2	22.1	50.1	41.9	30.6	31.0	31.0
2025	0.2	22.2	50.2	41.9	30.5	31.2	31.2
2026	0.2	22.2	50.2	41.9	30.5	31.7	31.7
2027	0.2	22.2	50.3	41.9	30.5	32.0	32.0
2028	0.2	22.2	50.3	41.9	30.5	32.3	32.3
2029	0.2	22.2	50.3	41.9	30.5	32.6	32.6
2030	0.2	22.4	50.4	41.9	30.4	33.1	33.1
2031	0.2	22.5	50.4	41.9	30.4	33.4	33.4
2032	0.2	22.5	50.4	41.9	30.4	33.9	33.9
2033	0.2	22.6	50.5	41.9	30.4	34.2	34.2
2034	0.2	22.6	50.5	41.9	30.4	34.5	34.5
2035	0.2	22.6	50.5	41.9	30.4	35.6	35.6
2036	0.2	22.7	50.5	41.9	30.4	36.3	36.3
2037	0.2	22.7	50.6	41.9	30.4	36.8	36.8
2038	0.2	22.7	50.6	41.9	30.4	37.2	37.2
2039	0.2	22.7	50.6	41.9	30.4	37.5	37.5
2040	0.2	22.9	50.6	41.9	30.4	37.8	37.8
2041	0.2	22.9	50.7	41.9	30.4	38.0	38.0
2042	0.2	23.0	50.7	41.9	30.4	38.2	38.2
2043	0.2	23.0	50.7	41.9	30.4	38.4	38.4
2044	0.2	23.1	50.7	41.9	30.4	38.6	38.6
2045	0.2	23.1	50.7	41.9	30.4	38.7	38.7
2046	0.2	23.1	50.8	41.9	30.4	38.8	38.8
2047	0.2	23.2	50.8	41.9	30.4	39.0	39.0
2048	0.2	23.2	50.8	41.9	30.3	39.1	39.1
2049	0.2	23.2	50.8	41.9	30.3	39.2	39.2
2050	0.2	23.4	50.8	41.9	30.3	39.3	39.3
2051	0.2	23.4	50.8	41.9	30.3	39.3	39.3
2052	0.2	23.5	50.9	41.9	30.3	39.4	39.4
2053	0.2	23.5	50.9	41.9	30.3	39.5	39.5
2054	0.2	23.6	50.9	41.9	30.3	39.6	39.6
2055	0.2	23.6	50.9	41.9	30.3	39.6	39.7
2056	0.2	23.6	50.9	41.9	30.3	39.7	39.8
2057	0.2	23.7	50.9	41.9	30.3	39.8	39.9
2058	0.2	23.7	50.9	41.9	30.3	39.8	40.0
2059	0.2	23.7	51.0	41.9	30.3	39.9	40.0
2060	0.2	23.9	51.0	41.9	30.3	39.9	40.1
2061	0.2	23.9	51.0	41.9	30.3	40.0	40.2
2062	0.2	24.0	51.0	41.9	30.3	40.0	40.2
2063	0.2	24.1	51.0	41.9	30.3	40.1	40.3
2064	0.2	24.1	51.0	41.9	30.3	40.1	40.3
2065	0.2	24.1	51.0	41.9	30.3	40.2	40.3
2066	0.2	24.2	51.0	41.9	30.3	40.2	40.4
2067	0.2	24.2	51.0	41.9	30.3	40.3	40.4
2068	0.2	24.2	51.1	41.9	30.3	40.3	40.5
2069	0.2	24.3	51.1	41.9	30.3	40.3	40.5
2070	0.2	24.4	51.1	41.9	30.3	40.4	40.5
2071	0.2	24.5	51.1	41.9	30.3	40.4	40.6
2072	0.2	24.6	51.1	41.9	30.3	40.4	40.6
2073	0.2	24.6	51.1	41.9	30.3	40.5	40.6
2074	0.2	24.7	51.1	41.9	30.3	40.5	40.7
2075	0.2	24.7	51.1	41.9	30.3	40.5	40.7
2076	0.2	24.8	51.1	41.9	30.3	40.6	40.7
2077	0.2	24.8	51.1	41.9	30.3	40.6	40.8
2078	0.2	24.9	51.1	41.9	30.3	40.6	40.8
2079	0.2	24.9	51.2	41.9	30.3	40.7	40.8
2080	0.2	25.0	51.2	41.9	30.3	40.7	40.9
2081	0.2	25.1	51.2	41.9	30.3	40.7	40.9
2082	0.2	25.2	51.2	41.9	30.3	40.7	40.9
2083	0.2	25.3	51.2	41.9	30.3	40.8	40.9
2084	0.2	25.4	51.2	41.9	30.3	40.8	41.0
2085	0.2	25.4	51.2	41.9	30.3	40.8	41.0
2086	0.2	25.5	51.2	41.9	30.3	40.8	41.0
2087	0.2	25.5	51.2	41.9	30.3	40.8	41.0
2088	0.2	25.6	51.2	41.9	30.3	40.9	41.0
2089	0.2	25.6	51.2	41.9	30.3	40.9	41.1
2090	0.2	25.8	51.2	41.9	30.3	40.9	41.1
2091	0.2	25.9	51.2	41.9	30.3	40.9	41.1
2092	0.2	26.0	51.2	41.9	30.3	40.9	41.1
2093	0.2	26.1	51.2	41.9	30.3	41.0	41.1
2094	0.2	26.2	51.2	41.9	30.3	41.0	41.1
2095	0.2	26.2	51.2	41.9	30.3	41.0	41.2
2096	0.2	26.3	51.2	41.9	30.3	41.0	41.2
2097	0.2	26.4	51.3	41.9	30.3	41.0	41.2
2098	0.2	26.5	51.3	41.9	30.3	41.0	41.2
2099	0.2	26.5	51.3	41.9	30.3	41.1	41.2
2100	0.2	26.7	51.3	41.9	30.3	41.1	41.2
2101	0.2	26.8	51.3	41.9	30.3	41.1	41.2
2102	0.2	26.9	51.3	41.9	30.2	41.1	41.3
2103	0.2	27.0	51.3	41.9	30.2	41.1	41.3
2104	0.2	27.1	51.3	41.9	30.2	41.1	41.3
2105	0.2	27.2	51.3	41.9	30.2	41.1	41.3
2106	0.2	27.3	51.3	41.9	30.2	41.1	41.3
2107	0.2	27.4	51.3	41.9	30.2	41.2	41.3
2108	0.2	27.5	51.3	41.9	30.2	41.2	41.3
2109	0.2	27.5	51.3	41.9	30.2	41.2	41.3

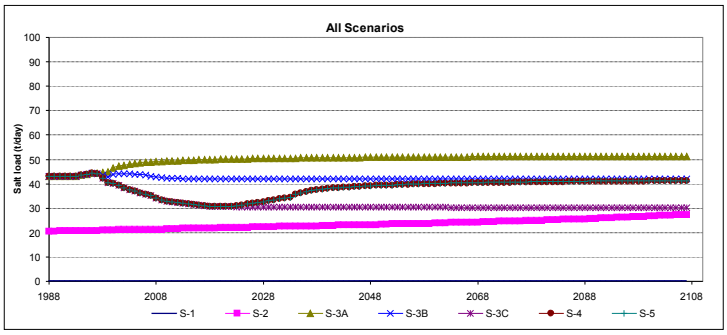
Scenario	Name	Model Run	Irrigation development area	IIP	RH	SIS
S-1	Natural system	Steady State	None	-	-	-
S-2	Mallee clearance	1920 - CY100	None (but includes Mallee clearance area)	-	-	-
S-3A	Pre-1988, no IIP, no RH	1988 – CY100	Pre-1988	No	No	-
S-3B	Pre-1988, with IIP, no RH	1988 – CY100	Pre-1988	Yes	No	-
S-3C	Pre-1988, with IIP and with RH	1988 – CY100	Pre-1988	Yes	Yes	-
S-4	Current irrigation	CY – CY100	Pre-1988 + Post-1988	Yes	Yes	No
S-5	Current plus future irrigation	CY – CY100	Pre-1988 + Post-1988 + Future development	Yes	Yes	No

IIP = improved irrigation practices
RH = Rehabilitation of irrigation distribution networks
SIS = Salti interception scheme
CY = current year
CY100 = 100 yrs from the current year

The tables below are designed to help MDBC choose the correct inputs to BIGMOD and show the impact of each of the individual accountable actions.

Accountable actions (t/day)

	Debits					Credits
	S2 - S1	S3A - S2	S4 - S3B	S4 - S3C	S5 - S4	S3A - S4
2000	20.9	23.7	-2.6	0.0	0.0	4.5
2005	21.1	27.0	-7.0	0.0	0.0	11.3
2006	21.1	27.2	-7.6	0.0	0.0	12.3
2007	21.1	27.4	-7.8	0.0	0.0	13.0
2008	21.1	27.5	-8.1	0.0	0.0	13.8
2009	21.1	27.7	-8.6	0.0	0.0	14.9
2010	21.3	27.6	-9.1	0.0	0.0	15.7
2011	21.4	27.7	-9.4	0.0	0.0	16.3
2012	21.4	27.7	-9.7	0.0	0.0	16.8
2013	21.5	27.8	-9.9	0.0	0.0	17.2
2014	21.5	27.9	-10.1	0.0	0.0	17.6
2015	21.5	27.9	-10.3	0.0	0.0	17.9
2016	21.5	28.0	-10.5	0.0	0.0	18.2
2017	21.6	28.0	-10.7	0.0	0.0	18.5
2018	21.6	28.1	-11.1	0.0	0.0	18.9
2019	21.6	28.1	-11.1	0.0	0.0	19.1
2020	21.7	28.0	-11.2	0.0	0.0	19.2
2021	21.8	28.0	-11.2	0.0	0.0	19.3
2022	21.9	28.0	-11.3	0.0	0.0	19.4
2023	21.9	28.0	-11.3	0.0	0.0	19.5
2024	21.9	28.0	-10.9	0.4	0.0	19.1
2025	22.0	28.0	-10.7	0.7	0.0	19.0
2026	22.0	28.0	-10.2	1.2	0.0	18.5
2027	22.0	28.1	-9.9	1.5	0.0	18.3
2028	22.0	28.1	-9.5	1.9	0.0	18.0
2029	22.0	28.1	-9.3	2.2	0.0	17.7
2030	22.2	28.0	-8.8	2.7	0.0	17.3
2031	22.3	27.9	-8.5	2.9	0.0	17.0
2032	22.3	27.9	-8.0	3.5	0.0	16.5
2033	22.4	27.9	-7.6	3.9	0.0	16.2
2034	22.4	27.9	-7.4	4.1	0.0	16.0
2035	22.4	27.9	-6.3	5.2	0.0	15.0
2036	22.5	27.9	-5.6	5.9	0.0	14.2
2050	23.2	27.5	-2.6	8.9	0.0	11.6
2100	26.5	24.6	-0.8	10.8	0.2	10.2



Summary of predicted salt load (t/day) entering the River Murray from Mannum to Murray Bridge

	1988	2000	2009	2050	2109
S-1	0.2	0.2	0.2	0.2	0.2
S-2	20.4	21.1	21.3	23.4	27.5
S-3A	43.0	44.8	49.0	50.8	51.3
S-3B	43.0	42.9	42.7	41.9	41.9
S-3C	43.0	40.3	34.1	30.3	30.2
S-4	43.0	40.3	34.1	39.3	41.2
S-5	43.0	40.3	34.1	39.3	41.3

Register A & B accountable debits and credits for the Mannum to Murray Bridge Reach (t/day) Figure 41

Annual Salt Loads for Murray Bridge to Wellington (t/day)

Time	S-1	S-2	S-3A	S-3B	S-3C	S-4	S-5
1988	2.7	25.1	33.1	33.1	33.1	33.1	33.1
1989	2.7	25.2	33.1	33.1	33.1	33.1	33.1
1990	2.7	25.5	33.1	33.1	33.1	33.1	33.1
1991	2.7	25.8	33.1	33.1	33.1	33.1	33.1
1992	2.7	25.9	33.2	33.2	33.2	33.2	33.2
1993	2.7	26.0	33.2	33.2	33.2	33.2	33.2
1994	2.7	26.1	33.2	33.2	33.2	33.2	33.2
1995	2.7	26.2	33.2	33.2	33.2	33.2	33.2
1996	2.7	26.3	33.2	33.2	33.2	33.2	33.2
1997	2.7	26.4	33.3	33.3	33.3	33.3	33.3
1998	2.7	26.4	33.3	32.7	32.7	32.7	32.7
1999	2.7	26.5	33.3	31.5	31.4	31.4	31.4
2000	2.7	26.9	33.3	30.5	30.5	30.5	30.5
2001	2.7	27.1	37.6	34.0	34.0	34.0	34.0
2002	2.7	27.3	39.4	35.0	35.0	35.0	35.0
2003	2.7	27.5	40.6	35.2	35.2	35.2	35.2
2004	2.7	27.6	41.5	35.1	35.1	35.1	35.1
2005	2.7	27.7	42.1	34.7	34.7	34.7	34.7
2006	2.7	27.8	42.6	34.2	34.2	34.2	34.2
2007	2.7	27.9	43.0	33.6	33.6	33.6	33.6
2008	2.7	28.0	43.4	32.6	32.6	32.6	32.6
2009	2.7	28.1	43.6	32.0	32.0	32.0	32.0
2010	2.7	28.5	43.9	31.7	31.6	31.6	31.6
2011	2.7	28.7	44.1	31.5	31.4	31.4	31.4
2012	2.7	28.9	44.3	31.3	31.3	31.3	31.3
2013	2.7	29.1	44.5	31.2	31.2	31.2	31.2
2014	2.7	29.3	44.7	31.1	31.1	31.1	31.1
2015	2.7	29.4	44.8	31.1	31.0	31.0	31.0
2016	2.7	29.5	44.9	31.0	31.0	31.0	31.0
2017	2.7	29.6	45.1	31.0	31.0	31.0	31.0
2018	2.7	29.7	45.2	31.0	30.9	30.9	30.9
2019	2.7	29.8	45.3	30.9	30.9	30.9	30.9
2020	2.7	30.2	45.4	30.9	30.9	30.9	30.9
2021	2.7	30.4	45.5	30.9	30.9	30.9	30.9
2022	2.7	30.7	45.5	30.9	30.9	30.9	30.9
2023	2.7	30.8	45.6	30.9	30.9	30.9	30.9
2024	2.7	31.0	45.7	30.9	30.9	32.4	32.4
2025	2.7	31.2	45.8	30.9	30.8	32.9	32.9
2026	2.7	31.3	45.8	30.8	30.8	33.9	33.9
2027	2.7	31.5	45.9	30.8	30.8	34.4	34.4
2028	2.7	31.6	46.0	30.8	30.8	35.1	35.1
2029	2.7	31.7	46.0	30.8	30.8	35.5	35.5
2030	2.7	32.0	46.1	30.8	30.8	36.1	36.1
2031	2.7	32.2	46.1	30.8	30.8	36.5	36.5
2032	2.7	32.5	46.2	30.8	30.8	37.2	37.2
2033	2.7	32.7	46.2	30.8	30.8	37.5	37.5
2034	2.7	32.9	46.3	30.8	30.8	37.8	37.8
2035	2.7	33.0	46.3	30.8	30.8	39.4	39.4
2036	2.7	33.2	46.4	30.8	30.8	40.2	40.2
2037	2.7	33.4	46.4	30.8	30.8	40.8	40.8
2038	2.7	33.5	46.4	30.8	30.8	41.2	41.2
2039	2.7	33.6	46.5	30.8	30.8	41.5	41.5
2040	2.7	33.9	46.5	30.8	30.8	41.8	41.8
2041	2.7	34.2	46.6	30.8	30.8	42.1	42.1
2042	2.7	34.4	46.6	30.8	30.8	42.3	42.3
2043	2.7	34.6	46.6	30.8	30.8	42.5	42.5
2044	2.7	34.8	46.7	30.8	30.8	42.6	42.6
2045	2.7	35.0	46.7	30.8	30.8	42.8	42.8
2046	2.7	35.2	46.7	30.8	30.8	42.9	42.9
2047	2.7	35.3	46.7	30.8	30.8	43.1	43.1
2048	2.7	35.5	46.8	30.8	30.8	43.2	43.2
2049	2.7	35.7	46.8	30.8	30.8	43.3	43.3
2050	2.7	35.9	46.8	30.8	30.8	43.4	43.4
2051	2.7	36.1	46.9	30.8	30.8	43.5	43.5
2052	2.7	36.4	46.9	30.8	30.8	43.6	43.6
2053	2.7	36.6	46.9	30.8	30.8	43.7	43.7
2054	2.7	36.8	46.9	30.8	30.8	43.8	43.8
2055	2.7	37.0	47.0	30.8	30.8	43.9	44.0
2056	2.7	37.2	47.0	30.8	30.8	43.9	44.2
2057	2.7	37.3	47.0	30.8	30.8	44.0	44.3
2058	2.7	37.5	47.0	30.8	30.8	44.1	44.4
2059	2.7	37.7	47.1	30.8	30.8	44.1	44.5
2060	2.7	37.9	47.1	30.8	30.8	44.2	44.5
2061	2.7	38.1	47.1	30.8	30.8	44.3	44.6
2062	2.7	38.4	47.1	30.8	30.8	44.3	44.7
2063	2.7	38.6	47.1	30.8	30.8	44.4	44.8
2064	2.7	38.8	47.2	30.8	30.8	44.4	44.8
2065	2.7	39.0	47.2	30.8	30.8	44.5	44.9
2066	2.7	39.2	47.2	30.8	30.8	44.5	44.9
2067	2.7	39.4	47.2	30.8	30.8	44.6	45.0
2068	2.7	39.6	47.2	30.8	30.8	44.6	45.0
2069	2.7	39.7	47.3	30.8	30.8	44.7	45.1
2070	2.7	39.9	47.3	30.8	30.8	44.7	45.1
2071	2.7	40.2	47.3	30.8	30.8	44.8	45.2
2072	2.7	40.4	47.3	30.8	30.8	44.8	45.2
2073	2.7	40.6	47.3	30.8	30.8	44.9	45.3
2074	2.7	40.8	47.3	30.8	30.8	44.9	45.3
2075	2.7	41.0	47.4	30.8	30.8	44.9	45.4
2076	2.7	41.2	47.4	30.8	30.8	45.0	45.4
2077	2.7	41.4	47.4	30.8	30.8	45.0	45.4
2078	2.7	41.5	47.4	30.8	30.8	45.0	45.5
2079	2.7	41.7	47.4	30.8	30.8	45.1	45.5
2080	2.7	41.9	47.4	30.8	30.8	45.1	45.6
2081	2.7	42.1	47.4	30.8	30.8	45.1	45.6
2082	2.7	42.3	47.5	30.8	30.8	45.2	45.6
2083	2.7	42.5	47.5	30.8	30.8	45.2	45.7
2084	2.7	42.7	47.5	30.8	30.8	45.2	45.7
2085	2.7	42.9	47.5	30.8	30.8	45.3	45.7
2086	2.7	43.1	47.5	30.8	30.8	45.3	45.7
2087	2.7	43.3	47.5	30.8	30.8	45.3	45.8
2088	2.7	43.5	47.5	30.8	30.8	45.3	45.8
2089	2.7	43.6	47.5	30.8	30.8	45.4	45.8
2090	2.7	43.8	47.5	30.8	30.8	45.4	45.9
2091	2.7	44.0	47.6	30.8	30.8	45.4	45.9
2092	2.7	44.2	47.6	30.8	30.8	45.4	45.9
2093	2.7	44.4	47.6	30.8	30.8	45.5	45.9
2094	2.7	44.6	47.6	30.8	30.8	45.5	45.9
2095	2.7	44.8	47.6	30.8	30.8	45.5	46.0
2096	2.7	45.0	47.6	30.8	30.8	45.5	46.0
2097	2.7	45.1	47.6	30.8	30.8	45.6	46.0
2098	2.7	45.3	47.6	30.8	30.8	45.6	46.0
2099	2.7	45.5	47.6	30.8	30.8	45.6	46.0
2100	2.7	45.7	47.6	30.8	30.8	45.6	46.1
2101	2.7	45.9	47.6	30.8	30.8	45.6	46.1
2102	2.7	46.1	47.6	30.8	30.8	45.7	46.1
2103	2.7	46.2	47.7	30.8	30.8	45.7	46.1
2104	2.7	46.4	47.7	30.8	30.8	45.7	46.1
2105	2.7	46.6	47.7	30.8	30.8	45.7	46.2
2106	2.7	46.8	47.7	30.8	30.8	45.7	46.2
2107	2.7	46.9	47.7	30.8	30.8	45.7	46.2
2108	2.7	47.1	47.7	30.8	30.8	45.8	46.2
2109	2.7	47.1	47.7	30.8	30.8	45.8	46.2

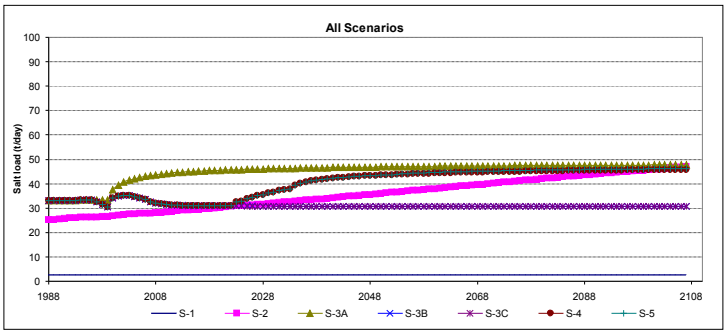
Scenario	Name	Model Run	Irrigation development area	IIP	RH	SIS
S-1	Natural system	Steady State	None	-	-	-
S-2	Mallee clearance	1920 - CY100	None (but includes Mallee clearance area)	-	-	-
S-3A	Pre-1988, no IIP, no RH	1988 – CY100	Pre-1988	No	No	-
S-3B	Pre-1988, with IIP, no RH	1988 – CY100	Pre-1988	Yes	No	-
S-3C	Pre-1988, with IIP and with RH	1988 – CY100	Pre-1988	Yes	Yes	-
S-4	Current irrigation	CY – CY100	Pre-1988 + Post-1988	Yes	Yes	No
S-5	Current plus future irrigation	CY – CY100	Pre-1988 + Post-1988 + Future development	Yes	Yes	No

IIP = improved irrigation practices
RH = Rehabilitation of irrigation distribution networks
SIS = Salt interception scheme
CY = current year
CY100 = 100 yrs from the current year

The tables below are designed to help MDBC choose the correct inputs to BIGMOD and show the impact of each of the individual accountable actions.

Accountable actions (t/day)

	Debits					Credits
	S2 - S1	S3A - S2	S4 - S3B	S4 - S3C	S5 - S4	S3A - S4
2000	24.2	6.5	0.0	0.0	0.0	2.9
2005	25.0	14.4	0.0	0.0	0.0	7.4
2006	25.1	14.8	0.0	0.0	0.0	8.4
2007	25.2	15.1	0.0	0.0	0.0	9.4
2008	25.3	15.3	0.0	0.0	0.0	10.8
2009	25.4	15.6	0.0	0.0	0.0	11.7
2010	25.8	15.4	0.0	0.0	0.0	12.3
2011	26.0	15.4	0.0	0.0	0.0	12.7
2012	26.2	15.4	-0.1	0.0	0.0	13.0
2013	26.4	15.4	0.0	0.0	0.0	13.3
2014	26.6	15.4	0.0	0.0	0.0	13.6
2015	26.7	15.4	0.0	0.0	0.0	13.8
2016	26.8	15.4	0.0	0.0	0.0	13.9
2017	26.9	15.4	0.0	0.0	0.0	14.1
2018	27.0	15.4	0.0	0.0	0.0	14.2
2019	27.1	15.4	0.0	0.0	0.0	14.4
2020	27.5	15.2	0.0	0.0	0.0	14.5
2021	27.7	15.0	0.0	0.0	0.0	14.6
2022	28.0	14.9	0.0	0.0	0.0	14.7
2023	28.1	14.8	0.0	0.0	0.0	14.8
2024	28.3	14.7	1.6	1.6	0.0	13.3
2025	28.5	14.6	2.1	2.1	0.0	12.9
2026	28.6	14.5	3.0	3.0	0.0	12.0
2027	28.8	14.4	3.5	3.5	0.0	11.5
2028	28.9	14.4	4.2	4.2	0.0	10.9
2029	29.0	14.3	4.6	4.7	0.0	10.5
2030	29.3	14.1	5.3	5.3	0.0	10.0
2031	29.5	13.9	5.7	5.7	0.0	9.6
2032	29.8	13.7	6.3	6.3	0.0	9.0
2033	30.0	13.6	6.7	6.7	0.0	8.7
2034	30.2	13.4	7.0	7.0	0.0	8.4
2035	30.3	13.3	8.6	8.6	0.0	6.9
2036	30.5	13.2	9.4	9.4	0.0	6.1
2050	33.2	10.9	12.6	12.6	0.0	3.4
2100	43.0	1.9	14.8	14.8	0.4	2.0



Summary of predicted salt load (t/day) entering the River Murray from Murray Bridge to Wellington

	1988	2000	2009	2050	2109
S-1	2.7	2.7	2.7	2.7	2.7
S-2	25.1	26.9	28.1	35.9	47.1
S-3A	33.1	33.3	43.6	46.8	47.7
S-3B	33.1	30.5	32.0	30.8	30.8
S-3C	33.1	30.5	32.0	30.8	30.8
S-4	33.1	30.5	32.0	43.4	45.8
S-5	33.1	30.5	32.0	43.4	46.2

Register A & B accountable debits and credits for the Murray Bridge to Wellington Reach (t/day) Figure 42

Annual Salt Loads for Entire reach bwt Morgan to Wellington

Time	S-1	S-2	S-3A	S-3B	S-3C	S-4	S-5
1988	14.1	58.3	92.9	92.9	92.9	92.9	92.9
1989	14.1	58.3	93.0	93.0	93.0	93.0	93.0
1990	14.1	59.0	93.1	93.1	93.1	93.1	93.1
1991	14.1	59.4	93.2	93.2	93.2	93.2	93.2
1992	14.1	59.6	93.3	93.3	93.3	93.3	93.3
1993	14.1	59.8	93.3	93.3	93.3	93.3	93.3
1994	14.1	60.0	93.4	93.4	93.4	93.4	93.4
1995	14.1	60.1	94.0	94.0	94.0	94.0	94.0
1996	14.1	60.3	94.6	94.6	94.6	94.6	94.6
1997	14.1	60.4	95.0	95.0	95.0	95.0	95.0
1998	14.1	60.5	95.3	94.1	94.1	94.1	94.1
1999	14.1	60.5	95.6	92.4	90.9	90.9	90.9
2000	14.1	61.3	95.8	90.5	87.9	87.9	87.9
2001	14.1	61.8	109.1	102.2	98.5	98.5	98.5
2002	14.1	62.1	115.1	106.3	101.4	101.4	101.4
2003	14.1	62.3	119.0	107.8	101.8	101.8	101.8
2004	14.1	62.5	121.7	108.2	101.6	101.6	101.6
2005	14.1	62.7	123.8	107.8	100.8	100.8	100.8
2006	14.1	62.9	125.5	107.0	99.4	99.4	99.4
2007	14.1	63.0	126.9	105.8	98.0	98.0	98.0
2008	14.1	63.2	128.1	103.5	95.4	95.4	95.4
2009	14.1	63.3	129.2	102.0	93.4	93.4	93.4
2010	14.1	64.1	130.1	101.3	92.2	92.2	92.2
2011	14.1	64.6	130.9	100.9	91.4	91.4	91.4
2012	14.1	65.0	131.7	100.6	90.9	90.9	90.9
2013	14.1	65.3	132.3	100.4	90.4	90.4	90.4
2014	14.1	65.6	133.0	100.3	90.1	90.1	90.1
2015	14.1	65.9	133.5	100.1	89.8	89.8	89.8
2016	14.1	66.1	134.1	100.0	89.5	89.5	89.5
2017	14.1	66.3	134.5	100.0	89.2	89.2	89.2
2018	14.1	66.5	135.0	99.9	88.9	88.9	88.9
2019	14.1	66.7	135.4	99.9	88.8	88.8	88.8
2020	14.1	67.5	135.7	99.9	88.7	88.7	88.7
2021	14.1	68.1	136.1	99.9	88.6	88.6	88.6
2022	14.1	68.6	136.4	99.9	88.6	88.6	88.6
2023	14.1	69.0	136.7	99.9	88.6	88.6	88.6
2024	14.1	69.3	137.0	99.9	88.5	92.1	92.1
2025	14.1	69.7	137.2	99.9	88.5	93.4	93.4
2026	14.1	70.0	137.5	99.9	88.5	95.8	95.8
2027	14.1	70.2	137.7	99.9	88.5	97.3	97.3
2028	14.1	70.5	137.9	99.9	88.5	99.3	99.3
2029	14.1	70.8	138.2	99.9	88.5	100.6	100.6
2030	14.1	71.6	138.4	99.9	88.4	102.9	102.9
2031	14.1	72.2	138.6	99.9	88.4	104.3	104.3
2032	14.1	72.8	138.8	99.9	88.4	106.7	106.7
2033	14.1	73.2	139.0	99.9	88.4	108.3	108.3
2034	14.1	73.7	139.1	99.9	88.4	109.4	109.4
2035	14.1	74.1	139.3	99.9	88.4	113.6	113.6
2036	14.1	74.4	139.4	99.9	88.4	116.3	116.3
2037	14.1	74.8	139.6	99.9	88.4	118.3	118.3
2038	14.1	75.1	139.7	99.9	88.4	120.0	120.0
2039	14.1	75.4	139.9	99.9	88.4	121.4	121.4
2040	14.1	76.2	140.0	99.9	88.4	122.7	122.7
2041	14.1	76.9	140.1	99.9	88.4	123.8	123.8
2042	14.1	77.4	140.3	99.9	88.4	124.8	124.8
2043	14.1	77.9	140.4	99.9	88.4	125.7	125.7
2044	14.1	78.4	140.5	99.9	88.4	126.6	126.6
2045	14.1	78.8	140.6	99.9	88.4	127.3	127.3
2046	14.1	79.2	140.7	99.9	88.4	128.0	128.0
2047	14.1	79.6	140.8	99.9	88.4	128.7	128.7
2048	14.1	80.0	140.9	99.9	88.4	129.3	129.3
2049	14.1	80.3	141.0	99.9	88.4	129.9	129.9
2050	14.1	81.1	141.1	99.9	88.4	130.5	130.5
2051	14.1	81.7	141.2	99.9	88.4	131.0	131.0
2052	14.1	82.3	141.3	100.0	88.4	131.5	131.5
2053	14.1	82.8	141.4	100.0	88.4	132.0	132.0
2054	14.1	83.2	141.5	100.0	88.4	132.4	132.4
2055	14.1	83.7	141.6	100.0	88.4	132.9	133.0
2056	14.1	84.1	141.6	100.0	88.4	133.3	133.6
2057	14.1	84.5	141.7	100.0	88.4	133.7	134.1
2058	14.1	84.9	141.8	100.0	88.4	134.0	134.5
2059	14.1	85.3	141.9	100.0	88.4	134.4	134.9
2060	14.1	86.0	142.0	100.0	88.4	134.7	135.2
2061	14.1	86.6	142.0	100.0	88.4	135.1	135.6
2062	14.1	87.1	142.1	100.0	88.4	135.4	135.9
2063	14.1	87.6	142.2	100.0	88.4	135.7	136.2
2064	14.1	88.1	142.2	100.0	88.4	136.0	136.5
2065	14.1	88.5	142.3	100.0	88.4	136.3	136.8
2066	14.1	89.0	142.4	100.0	88.4	136.6	137.1
2067	14.1	89.4	142.4	100.0	88.4	136.9	137.3
2068	14.1	89.8	142.5	100.0	88.4	137.1	137.5
2069	14.1	90.2	142.5	100.0	88.4	137.4	137.8
2070	14.1	90.8	142.6	100.0	88.4	137.6	138.0
2071	14.1	91.4	142.7	100.0	88.4	137.9	138.3
2072	14.1	91.9	142.7	100.0	88.4	138.1	138.5
2073	14.1	92.4	142.8	100.0	88.4	138.3	138.7
2074	14.1	92.9	142.8	100.0	88.4	138.5	139.0
2075	14.1	93.3	142.9	100.0	88.4	138.7	139.2
2076	14.1	93.7	142.9	100.0	88.4	138.9	139.4
2077	14.1	94.1	143.0	100.0	88.4	139.1	139.6
2078	14.1	94.5	143.0	100.0	88.4	139.3	139.8
2079	14.1	94.9	143.1	100.0	88.4	139.5	140.0
2080	14.1	95.6	143.1	100.0	88.4	139.7	140.2
2081	14.1	96.1	143.2	100.0	88.4	139.9	140.4
2082	14.1	96.6	143.2	100.0	88.4	140.1	140.6
2083	14.1	97.1	143.2	100.0	88.4	140.2	140.7
2084	14.1	97.6	143.3	100.0	88.4	140.4	140.9
2085	14.1	98.0	143.3	100.0	88.4	140.5	141.1
2086	14.1	98.4	143.4	100.0	88.4	140.7	141.2
2087	14.1	98.9	143.4	100.0	88.4	140.8	141.4
2088	14.1	99.3	143.4	100.0	88.4	141.0	141.5
2089	14.1	99.7	143.4	100.1	88.4	141.1	141.7
2090	14.1	100.3	143.5	100.1	88.4	141.3	141.8
2091	14.1	100.8	143.5	100.1	88.4	141.4	141.9
2092	14.1	101.3	143.5	100.1	88.4	141.6	142.1
2093	14.1	101.8	143.6	100.1	88.4	141.7	142.2
2094	14.1	102.3	143.6	100.1	88.4	141.8	142.3
2095	14.1	102.7	143.6	100.1	88.4	141.9	142.4
2096	14.1	103.2	143.7	100.1	88.4	142.1	142.5
2097	14.1	103.6	143.7	100.1	88.5	142.2	142.6
2098	14.1	104.0	143.7	100.1	88.5	142.3	142.7
2099	14.1	104.4	143.7	100.1	88.5	142.4	142.8
2100	14.1	105.0	143.8	100.1	88.5	142.5	142.9
2101	14.1	105.6	143.8	100.1	88.5	142.6	143.0
2102	14.1	106.1	143.8	100.1	88.5	142.7	143.1
2103	14.1	106.6	143.8	100.1	88.5	142.8	143.2
2104	14.1	107.1	143.9	100.1	88.5	142.9	143.4
2105	14.1	107.5	143.9	100.1	88.5	143.0	143.5
2106	14.1	108.0	143.9	100.1	88.5	143.1	143.6
2107	14.1	108.4	143.9	100.1	88.5	143.2	143.7
2108	14.1	108.8	143.9	100.1	88.5	143.3	143.8
2109	14.1	108.8	143.9	100.1	88.5	143.3	143.8

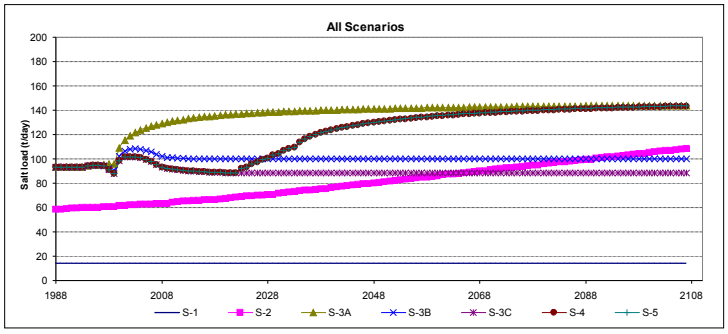
Scenario	Name	Model Run	Irrigation development area	IIP	RH	SIS
S-1	Natural system	Steady State	None	-	-	-
S-2	Mallee clearance	1920 - CY100	None (but includes Mallee clearance area)	-	-	-
S-3A	Pre-1988, no IIP, no RH	1988 – CY100	Pre-1988	No	No	-
S-3B	Pre-1988, with IIP, no RH	1988 – CY100	Pre-1988	Yes	No	-
S-3C	Pre-1988, with IIP and with RH	1988 – CY100	Pre-1988	Yes	Yes	-
S-4	Current irrigation	CY – CY100	Pre-1988 + Post-1988	Yes	Yes	No
S-5	Current plus future irrigation	CY – CY100	Pre-1988 + Post-1988 + Future development	Yes	Yes	No

IIP = improved irrigation practices
RH = Rehabilitation of irrigation distribution networks
SIS = Salt interception scheme
CY = current year
CY100 = 100 yrs from the current year

The tables below are designed to help MDBC choose the correct inputs to BIGMOD and show the impact of each of the individual accountable actions.

Accountable actions (t/day)

	Debits					Credits
	S2 - S1	S3A - S2	S4 - S3B	S4 - S3C	S5 - S4	S3A - S4
2000	40.5	33.5	-2.6	0.0	0.0	7.1
2005	49.8	46.6	-7.0	0.0	0.0	8.5
2006	50.3	46.1	-7.6	0.0	-0.1	9.5
2007	71.4	42.1	-7.9	0.0	0.0	4.7
2008	138.0	33.3	-8.5	0.0	0.0	-4.4
2009	189.0	35.8	-9.2	0.0	0.0	0.4
2010	149.1	53.6	-9.8	0.0	0.0	20.9
2011	130.7	47.5	-10.2	0.0	0.0	16.6
2012	119.9	44.8	-10.6	0.0	0.0	15.2
2013	112.7	43.2	-10.9	0.0	0.0	14.7
2014	107.6	42.1	-11.2	0.0	0.0	14.5
2015	103.7	41.3	-11.4	0.0	0.0	14.4
2016	100.6	40.7	-11.6	0.0	0.0	14.4
2017	98.2	40.2	-11.9	0.0	0.0	14.5
2018	96.1	39.8	-12.2	0.0	0.0	14.7
2019	94.4	39.4	-12.3	0.0	0.0	14.7
2020	93.6	38.3	-12.4	0.0	0.0	14.8
2021	92.8	37.6	-12.3	0.0	-0.1	14.7
2022	92.0	37.1	-12.5	0.0	-0.1	14.6
2023	91.2	36.7	-12.5	0.0	-0.1	14.7
2024	90.6	36.4	-8.9	3.8	-0.1	10.9
2025	90.0	36.1	-7.6	5.2	-0.1	9.6
2026	89.4	35.9	-5.7	7.1	-0.1	7.0
2027	88.9	36.1	-4.1	8.5	-0.1	5.9
2028	88.4	36.5	-2.5	10.1	-0.1	4.4
2029	88.0	36.8	-1.7	10.9	-0.1	3.6
2030	88.3	36.5	0.1	12.8	-0.1	1.7
2031	88.4	36.3	1.1	13.7	-0.1	0.8
2032	88.4	36.2	3.2	15.8	-0.1	-1.3
2033	88.3	36.2	4.3	17.0	-0.1	-2.5
2034	88.3	36.1	5.1	17.8	-0.1	-3.3
2035	88.2	36.1	9.3	21.9	-0.1	-7.4
2036	88.2	36.1	11.8	24.4	-0.1	-9.9
2050	90.7	32.5	22.9	35.6	0.0	-21.0
2100	108.9	11.3	31.8	44.6	0.7	-29.8



Summary of predicted salt load (t/day) entering the River Murray from Morgan to Wellington

	1988	2000	2009	2050	2109
S-1	14.4	14.4	14.4	14.4	14.4
S-2	60.5	54.9	203.4	105.1	126.7
S-3A	94.9	88.4	239.2	137.6	134.1
S-3B	94.9	83.8	248.0	135.7	132.2
S-3C	94.9	81.2	238.8	123.0	119.4
S-4	94.9	81.2	238.8	158.6	164.7
S-5	94.9	81.2	238.7	158.5	165.4

Register A & B accountable debits and credits for Morgan to Wellington (total) Figure 43

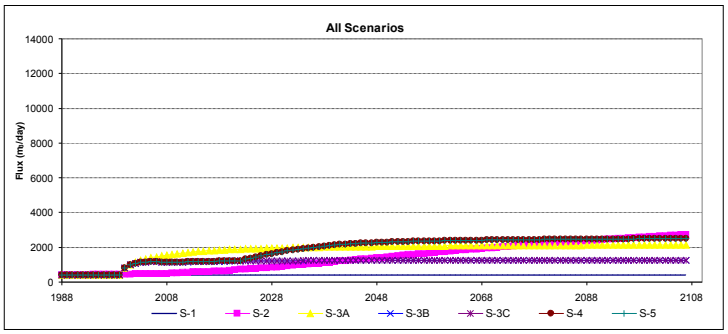
aquaterra

Annual Flux for Morgan to Lock 1 (m^3/day)

Time	S-1	S-2	S-3A	S-3B	S-3C	S-4	S-5
1988	391	405	391	391	391	391	391
1989	391	405	391	391	391	391	391
1990	391	414	391	391	391	391	391
1991	391	418	391	391	391	391	391
1992	391	420	391	391	391	391	391
1993	391	423	391	391	391	391	391
1994	391	424	391	391	391	391	391
1995	391	426	391	391	391	391	391
1996	391	428	391	391	391	391	391
1997	391	429	391	391	391	391	391
1998	391	430	391	391	391	391	391
1999	391	432	391	391	391	391	391
2000	391	451	391	391	391	391	391
2001	391	460	811	810	811	811	811
2002	391	467	1008	983	983	983	983
2003	391	472	1138	1075	1075	1075	1075
2004	391	478	1236	1127	1128	1128	1128
2005	391	482	1315	1156	1157	1157	1157
2006	391	487	1384	1170	1170	1170	1170
2007	391	491	1445	1171	1171	1171	1171
2008	391	495	1498	1138	1138	1138	1138
2009	391	498	1547	1134	1134	1134	1134
2010	391	530	1589	1139	1139	1139	1139
2011	391	548	1628	1145	1147	1147	1147
2012	391	562	1664	1151	1154	1154	1154
2013	391	574	1696	1158	1161	1161	1161
2014	391	586	1725	1164	1169	1169	1169
2015	391	596	1752	1171	1175	1175	1175
2016	391	606	1775	1177	1181	1181	1181
2017	391	615	1796	1182	1187	1187	1187
2018	391	624	1816	1187	1193	1193	1193
2019	391	633	1835	1193	1198	1198	1198
2020	391	674	1850	1197	1202	1202	1202
2021	391	703	1865	1201	1205	1205	1205
2022	391	726	1878	1204	1208	1208	1208
2023	391	747	1890	1207	1211	1211	1211
2024	391	766	1902	1210	1213	1323	1323
2025	391	784	1912	1212	1216	1368	1368
2026	391	801	1922	1214	1219	1447	1447
2027	391	817	1932	1217	1221	1497	1497
2028	391	832	1940	1219	1224	1578	1578
2029	391	847	1948	1221	1226	1625	1625
2030	391	893	1957	1224	1228	1707	1707
2031	391	928	1964	1226	1230	1749	1749
2032	391	958	1971	1228	1231	1808	1808
2033	391	986	1978	1230	1233	1843	1843
2034	391	1011	1984	1231	1234	1870	1870
2035	391	1034	1990	1233	1234	1927	1927
2036	391	1057	1994	1235	1235	1969	1969
2037	391	1078	1999	1235	1235	2008	2008
2038	391	1098	2005	1236	1236	2044	2044
2039	391	1118	2009	1236	1236	2077	2077
2040	391	1163	2014	1236	1237	2107	2107
2041	391	1199	2018	1237	1237	2134	2134
2042	391	1231	2022	1237	1237	2158	2158
2043	391	1261	2026	1238	1238	2179	2179
2044	391	1288	2030	1238	1238	2199	2199
2045	391	1314	2033	1238	1239	2217	2217
2046	391	1339	2037	1239	1239	2233	2233
2047	391	1362	2040	1239	1239	2248	2248
2048	391	1385	2043	1240	1240	2262	2262
2049	391	1406	2046	1240	1240	2275	2275
2050	391	1447	2050	1240	1241	2286	2286
2051	391	1481	2053	1241	1241	2297	2297
2052	391	1511	2055	1241	1241	2307	2307
2053	391	1539	2058	1242	1242	2316	2316
2054	391	1566	2061	1242	1242	2325	2325
2055	391	1591	2064	1242	1242	2333	2333
2056	391	1615	2066	1243	1243	2341	2341
2057	391	1639	2068	1243	1243	2349	2349
2058	391	1662	2071	1243	1244	2355	2355
2059	391	1684	2073	1244	1244	2362	2362
2060	391	1718	2075	1244	1244	2368	2368
2061	391	1748	2078	1245	1245	2374	2374
2062	391	1776	2080	1245	1245	2380	2379
2063	391	1802	2082	1245	1245	2385	2385
2064	391	1827	2084	1246	1246	2390	2390
2065	391	1851	2086	1246	1246	2395	2395
2066	391	1874	2087	1246	1246	2400	2399
2067	391	1896	2089	1247	1247	2404	2404
2068	391	1918	2091	1247	1247	2409	2408
2069	391	1939	2093	1247	1248	2413	2412
2070	391	1969	2094	1248	1248	2417	2416
2071	391	1996	2096	1248	1248	2420	2420
2072	391	2020	2097	1249	1249	2424	2423
2073	391	2044	2099	1249	1249	2428	2427
2074	391	2067	2101	1249	1249	2431	2430
2075	391	2089	2102	1250	1250	2434	2434
2076	391	2111	2104	1250	1250	2437	2437
2077	391	2132	2105	1250	1250	2441	2440
2078	391	2153	2107	1251	1251	2444	2443
2079	391	2173	2108	1251	1251	2446	2446
2080	391	2199	2109	1251	1251	2449	2449
2081	391	2223	2110	1252	1252	2452	2452
2082	391	2245	2111	1252	1252	2455	2455
2083	391	2267	2113	1252	1252	2457	2457
2084	391	2289	2114	1253	1253	2460	2460
2085	391	2309	2115	1253	1253	2462	2462
2086	391	2330	2116	1253	1253	2465	2464
2087	391	2349	2117	1254	1254	2467	2467
2088	391	2369	2118	1254	1254	2469	2469
2089	391	2388	2119	1254	1254	2471	2471
2090	391	2411	2120	1255	1255	2473	2473
2091	391	2433	2120	1255	1255	2475	2475
2092	391	2454	2121	1255	1255	2477	2477
2093	391	2474	2122	1255	1256	2479	2478
2094	391	2494	2123	1256	1256	2481	2480
2095	391	2513	2124	1256	1256	2483	2482
2096	391	2532	2125	1256	1256	2485	2483
2097	391	2551	2125	1257	1257	2487	2485
2098	391	2569	2126	1257	1257	2489	2486
2099	391	2588	2127	1257	1257	2490	2488
2100	391	2608	2127	1258	1258	2492	2490
2101	391	2628	2128	1258	1258	2493	2491
2102	391	2648	2129	1258	1258	2495	2493
2103	391	2667	2130	1259	1259	2496	2494
2104	391	2685	2130	1259	1259	2498	2496
2105	391	2703	2131	1259	1259	2499	2498
2106	391	2721	2132	1259	1259	2501	2499
2107	391	2739	2132	1260	1260	2502	2500
2108	391	2756	2133	1260	1260	2503	2502
2109	391	2756	2133	1260	1260	2503	2502

Scenario	Name	Model Run	Irrigation development area	IIP	RH	SIS
S-1	Natural system	Steady State	None	-	-	-
S-2	Mallee clearance	1920 - CY100	None (but includes Mallee clearance area)	-	-	-
S-3A	Pre-1988, no IIP, no RH	1988 – CY100	Pre-1988	No	No	-
S-3B	Pre-1988, with IIP, no RH	1988 – CY100	Pre-1988	Yes	No	-
S-3C	Pre-1988, with IIP and with RH	1988 – CY100	Pre-1988	Yes	Yes	-
S-4	Current irrigation	CY – CY100	Pre-1988 + Post-1988	Yes	Yes	No
S-5	Current plus future irrigation	CY – CY100	Pre-1988 + Post-1988 + Future development	Yes	Yes	No

IIP = improved irrigation practices
RH = Rehabilitation of irrigation distribution networks
SIS = Salt interception scheme
CY = current year
CY100 = 100 yrs from the current year



Summary of predicted flux (m^3/day) entering the River Murray from Morgan to Lock 1

	1988	2000	2009	2050	2109
S-1	391	391	391	391	391
S-2	405	451	498	1447	2756
S-3A	391	391	1547	2050	2133
S-3B	391	391	1134	1240	1260
S-3C	391	391	1134	1241	1260
S-4	391	391	1134	2286	2503
S-5	391	391	1134	2286	2502

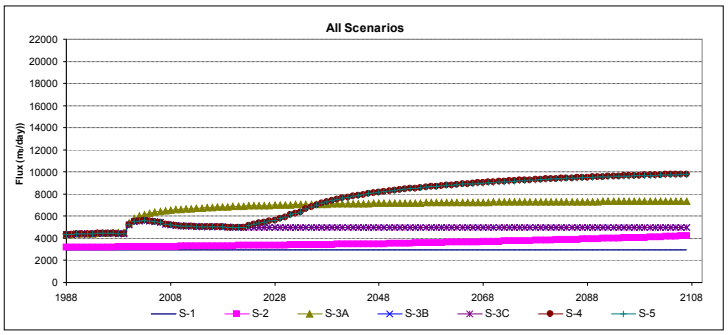
Modelled flux (m^3/day) entering the River Murray in the Morgan to Lock 1 Reach Figure 44

Annual Flux for Lock 1 to Mannum (m^3/day)

Time	S-1	S-2	S-3A	S-3B	S-3C	S-4	S-5
1988	2953	3165	4341	4341	4341	4341	4341
1989	2953	3166	4352	4352	4352	4352	4352
1990	2953	3187	4366	4366	4366	4366	4366
1991	2953	3195	4377	4377	4377	4377	4377
1992	2953	3200	4390	4390	4390	4390	4390
1993	2953	3203	4400	4400	4400	4400	4400
1994	2953	3206	4410	4410	4410	4410	4410
1995	2953	3208	4433	4433	4433	4433	4433
1996	2953	3211	4454	4454	4454	4454	4454
1997	2953	3212	4474	4474	4474	4474	4474
1998	2953	3214	4493	4467	4467	4467	4467
1999	2953	3216	4509	4429	4428	4428	4428
2000	2953	3235	4526	4387	4385	4385	4385
2001	2953	3242	5399	5199	5199	5199	5199
2002	2953	3247	5781	5477	5476	5476	5476
2003	2953	3250	6004	5576	5576	5576	5576
2004	2953	3253	6155	5592	5592	5592	5592
2005	2953	3256	6265	5562	5562	5562	5562
2006	2953	3258	6352	5502	5503	5503	5503
2007	2953	3260	6422	5423	5424	5424	5424
2008	2953	3262	6481	5276	5276	5276	5276
2009	2953	3264	6533	5200	5199	5199	5199
2010	2953	3280	6577	5154	5151	5151	5151
2011	2953	3287	6616	5125	5117	5117	5117
2012	2953	3292	6653	5102	5093	5093	5093
2013	2953	3295	6685	5082	5074	5074	5074
2014	2953	3299	6715	5067	5057	5057	5057
2015	2953	3301	6744	5053	5045	5045	5045
2016	2953	3304	6769	5042	5034	5034	5034
2017	2953	3306	6793	5032	5025	5025	5025
2018	2953	3308	6815	5024	5016	5016	5016
2019	2953	3311	6837	5016	5010	5010	5010
2020	2953	3327	6855	5011	5005	5005	5005
2021	2953	3335	6873	5005	5001	5001	5001
2022	2953	3340	6890	5001	4997	4997	4997
2023	2953	3344	6906	4998	4994	4994	4994
2024	2953	3348	6922	4995	4991	5179	5179
2025	2953	3351	6936	4992	4989	5258	5258
2026	2953	3354	6950	4990	4986	5374	5374
2027	2953	3357	6963	4988	4984	5469	5469
2028	2953	3359	6976	4986	4982	5563	5563
2029	2953	3362	6988	4984	4980	5641	5641
2030	2953	3381	7001	4982	4979	5784	5784
2031	2953	3390	7012	4980	4977	5890	5890
2032	2953	3396	7023	4978	4976	6110	6110
2033	2953	3401	7034	4977	4975	6252	6252
2034	2953	3406	7045	4976	4974	6361	6361
2035	2953	3410	7055	4975	4974	6638	6638
2036	2953	3413	7063	4974	4974	6841	6841
2037	2953	3417	7071	4973	4973	7011	7011
2038	2953	3420	7081	4973	4973	7159	7159
2039	2953	3423	7089	4973	4973	7290	7290
2040	2953	3445	7098	4972	4972	7407	7407
2041	2953	3456	7105	4972	4972	7515	7515
2042	2953	3464	7113	4972	4972	7614	7614
2043	2953	3470	7121	4972	4972	7706	7706
2044	2953	3476	7128	4971	4971	7792	7792
2045	2953	3481	7135	4971	4971	7872	7872
2046	2953	3486	7141	4971	4971	7947	7947
2047	2953	3490	7147	4971	4971	8019	8019
2048	2953	3494	7154	4970	4971	8087	8087
2049	2953	3499	7161	4970	4970	8151	8151
2050	2953	3522	7167	4970	4970	8213	8213
2051	2953	3534	7173	4970	4970	8272	8272
2052	2953	3543	7179	4970	4970	8329	8329
2053	2953	3551	7184	4969	4969	8383	8383
2054	2953	3558	7190	4969	4969	8434	8434
2055	2953	3565	7196	4969	4969	8485	8485
2056	2953	3571	7201	4969	4969	8533	8533
2057	2953	3576	7206	4969	4969	8580	8580
2058	2953	3582	7211	4968	4968	8624	8624
2059	2953	3587	7216	4968	4968	8666	8667
2060	2953	3611	7221	4968	4968	8709	8709
2061	2953	3624	7226	4968	4968	8750	8750
2062	2953	3635	7231	4968	4968	8789	8789
2063	2953	3644	7235	4967	4967	8828	8826
2064	2953	3652	7240	4967	4967	8865	8863
2065	2953	3660	7244	4967	4967	8902	8898
2066	2953	3668	7247	4967	4967	8937	8933
2067	2953	3675	7251	4967	4967	8971	8929
2068	2953	3682	7255	4967	4967	9004	8963
2069	2953	3688	7259	4966	4966	9036	8996
2070	2953	3711	7262	4966	4966	9068	9028
2071	2953	3725	7266	4966	4966	9097	9058
2072	2953	3737	7270	4966	4966	9126	9087
2073	2953	3748	7273	4966	4966	9155	9116
2074	2953	3758	7277	4966	4966	9182	9144
2075	2953	3767	7281	4966	4966	9209	9172
2076	2953	3776	7284	4965	4965	9235	9199
2077	2953	3784	7288	4965	4965	9261	9226
2078	2953	3793	7291	4965	4965	9285	9253
2079	2953	3801	7294	4965	4965	9310	9278
2080	2953	3823	7296	4965	4965	9333	9304
2081	2953	3839	7299	4965	4965	9357	9328
2082	2953	3853	7301	4965	4965	9380	9352
2083	2953	3865	7305	4964	4965	9402	9375
2084	2953	3877	7308	4964	4964	9424	9397
2085	2953	3888	7310	4964	4964	9445	9419
2086	2953	3898	7312	4964	4964	9465	9439
2087	2953	3909	7315	4964	4964	9484	9460
2088	2953	3919	7317	4964	4964	9504	9479
2089	2953	3929	7318	4964	4964	9523	9498
2090	2953	3952	7321	4964	4964	9542	9517
2091	2953	3969	7322	4964	4964	9560	9535
2092	2953	3985	7325	4963	4963	9578	9553
2093	2953	3999	7326	4963	4963	9596	9568
2094	2953	4013	7328	4963	4963	9614	9583
2095	2953	4026	7330	4963	4963	9630	9598
2096	2953	4039	7332	4963	4963	9647	9612
2097	2953	4051	7334	4963	4963	9662	9626
2098	2953	4063	7336	4963	4963	9678	9640
2099	2953	4075	7337	4963	4963	9694	9654
2100	2953	4099	7339	4963	4963	9708	9668
2101	2953	4119	7341	4963	4963	9721	9683
2102	2953	4137	7342	4962	4963	9736	9697
2103	2953	4153	7344	4962	4962	9748	9711
2104	2953	4169	7345	4962	4962	9761	9726
2105	2953	4185	7347	4962	4962	9773	9740
2106	2953	4200	7349	4962	4962	9786	9754
2107	2953	4215	7350	4962	4962	9797	9768
2108	2953	4229	7352	4962	4962	9810	9781
2109	2953	4229	7352	4962	4962	9810	9790

Scenario	Name	Model Run	Irrigation development area	IIP	RH	SIS
S-1	Natural system	Steady State	None	-	-	-
S-2	Mallee clearance	1920 - CY100	None (but includes Mallee clearance area)	-	-	-
S-3A	Pre-1988, no IIP, no RH	1988 – CY100	Pre-1988	No	No	-
S-3B	Pre-1988, with IIP, no RH	1988 – CY100	Pre-1988	Yes	No	-
S-3C	Pre-1988, with IIP and with RH	1988 – CY100	Pre-1988	Yes	Yes	-
S-4	Current irrigation	CY – CY100	Pre-1988 + Post-1988	Yes	Yes	No
S-5	Current plus future irrigation	CY – CY100	Pre-1988 + Post-1988 + Future development	Yes	Yes	No

IIP = improved irrigation practices
RH = Rehabilitation of irrigation distribution networks
SIS = Salt interception scheme
CY = current year
CY100 = 100 yrs from the current year



Summary of modelled flux (m^3/day) entering the River Murray from Lock 1 to Mannum

	1988	2000	2009	2050	2109
S-1	2953	2953	2953	2953	2953
S-2	3165	3235	3264	3522	4229
S-3A	4341	4526	6533	7167	7352
S-3B	4341	4387	5200	4970	4962
S-3C	4341	4385	5199	4970	4962
S-4	4341	4385	5199	8213	9810
S-5	4341	4385	5199	8213	9790

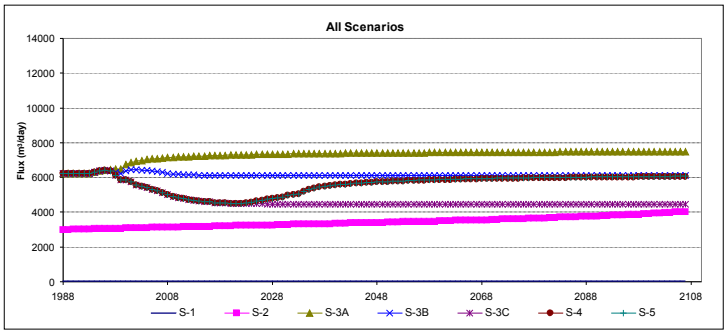
Modelled flux (m^3/day) entering the River Murray in the Lock 1 to Mannum Reach Figure 45

Annual Flux for Mannum to Murray Bridge (m^3/day)

Time	S-1	S-2	S-3A	S-3B	S-3C	S-4	S-5
1988	27	2983	6225	6225	6225	6225	6225
1989	27	2985	6227	6227	6227	6227	6227
1990	27	3013	6230	6230	6230	6230	6230
1991	27	3025	6232	6232	6232	6232	6232
1992	27	3033	6234	6234	6234	6234	6234
1993	27	3038	6236	6236	6236	6236	6236
1994	27	3042	6238	6238	6238	6238	6238
1995	27	3045	6308	6308	6308	6308	6308
1996	27	3048	6367	6367	6367	6367	6367
1997	27	3051	6410	6410	6410	6410	6410
1998	27	3053	6444	6367	6367	6367	6367
1999	27	3055	6468	6313	6111	6111	6111
2000	27	3081	6489	6219	5848	5848	5848
2001	27	3093	6734	6387	5856	5856	5856
2002	27	3101	6849	6430	5737	5737	5737
2003	27	3107	6924	6437	5581	5581	5581
2004	27	3111	6979	6427	5494	5494	5494
2005	27	3115	7021	6406	5406	5406	5406
2006	27	3118	7056	6378	5291	5291	5291
2007	27	3121	7086	6345	5231	5231	5231
2008	27	3123	7111	6291	5133	5133	5133
2009	27	3125	7133	6228	4993	4993	4993
2010	27	3149	7152	6194	4899	4899	4899
2011	27	3160	7170	6174	4830	4830	4830
2012	27	3167	7186	6160	4777	4777	4777
2013	27	3173	7200	6148	4732	4732	4732
2014	27	3178	7213	6140	4689	4689	4689
2015	27	3181	7226	6133	4656	4656	4656
2016	27	3185	7237	6127	4620	4620	4620
2017	27	3188	7248	6123	4588	4588	4588
2018	27	3190	7258	6120	4540	4540	4540
2019	27	3193	7267	6117	4524	4524	4524
2020	27	3215	7275	6115	4514	4514	4514
2021	27	3226	7283	6113	4506	4506	4506
2022	27	3234	7290	6111	4501	4501	4501
2023	27	3240	7297	6110	4495	4495	4495
2024	27	3245	7304	6110	4490	4548	4548
2025	27	3249	7310	6109	4486	4578	4578
2026	27	3252	7316	6108	4482	4650	4650
2027	27	3255	7321	6108	4478	4684	4684
2028	27	3258	7327	6108	4475	4738	4738
2029	27	3261	7332	6107	4472	4776	4776
2030	27	3283	7337	6107	4470	4843	4843
2031	27	3294	7342	6106	4468	4881	4881
2032	27	3302	7347	6106	4466	4961	4961
2033	27	3308	7351	6106	4464	5015	5015
2034	27	3313	7355	6106	4463	5053	5053
2035	27	3317	7360	6106	4463	5196	5196
2036	27	3321	7363	6106	4462	5301	5301
2037	27	3325	7366	6106	4462	5377	5377
2038	27	3328	7371	6106	4461	5437	5437
2039	27	3331	7374	6106	4461	5486	5486
2040	27	3351	7378	6106	4461	5526	5526
2041	27	3363	7380	6106	4460	5561	5561
2042	27	3371	7384	6106	4460	5591	5591
2043	27	3377	7387	6106	4459	5618	5618
2044	27	3383	7390	6106	4459	5642	5642
2045	27	3387	7393	6106	4458	5664	5664
2046	27	3392	7395	6106	4458	5683	5683
2047	27	3396	7398	6106	4458	5701	5701
2048	27	3399	7401	6106	4457	5718	5718
2049	27	3403	7403	6106	4457	5733	5733
2050	27	3421	7406	6106	4457	5748	5748
2051	27	3432	7408	6106	4456	5761	5761
2052	27	3441	7410	6106	4456	5774	5774
2053	27	3447	7413	6106	4455	5786	5786
2054	27	3453	7415	6106	4455	5797	5797
2055	27	3458	7417	6106	4455	5807	5815
2056	27	3463	7419	6106	4454	5817	5832
2057	27	3467	7421	6106	4454	5827	5846
2058	27	3472	7423	6106	4454	5836	5856
2059	27	3475	7425	6106	4454	5844	5866
2060	27	3493	7428	6106	4453	5853	5875
2061	27	3505	7429	6106	4453	5861	5884
2062	27	3514	7431	6106	4453	5868	5891
2063	27	3522	7433	6106	4452	5876	5899
2064	27	3528	7435	6106	4452	5883	5906
2065	27	3534	7436	6106	4452	5889	5913
2066	27	3540	7438	6106	4451	5896	5920
2067	27	3545	7439	6106	4451	5902	5926
2068	27	3550	7441	6106	4451	5908	5932
2069	27	3555	7442	6106	4450	5914	5938
2070	27	3572	7444	6106	4450	5920	5944
2071	27	3585	7445	6106	4450	5925	5949
2072	27	3596	7447	6106	4450	5930	5954
2073	27	3605	7448	6106	4449	5935	5959
2074	27	3613	7450	6106	4449	5940	5964
2075	27	3621	7451	6106	4449	5945	5969
2076	27	3627	7452	6106	4449	5950	5974
2077	27	3634	7454	6106	4448	5954	5978
2078	27	3640	7455	6106	4448	5958	5983
2079	27	3646	7456	6106	4448	5962	5987
2080	27	3664	7457	6106	4447	5966	5991
2081	27	3679	7458	6106	4447	5970	5995
2082	27	3692	7459	6106	4447	5974	5999
2083	27	3703	7460	6106	4447	5978	6003
2084	27	3713	7461	6107	4446	5981	6006
2085	27	3723	7462	6107	4446	5985	6010
2086	27	3732	7463	6107	4446	5988	6013
2087	27	3740	7464	6107	4446	5991	6016
2088	27	3748	7465	6107	4446	5994	6019
2089	27	3756	7466	6107	4445	5997	6022
2090	27	3776	7466	6107	4445	6000	6025
2091	27	3794	7467	6107	4445	6003	6028
2092	27	3809	7468	6107	4445	6006	6030
2093	27	3823	7469	6107	4444	6009	6033
2094	27	3835	7469	6107	4444	6012	6035
2095	27	3847	7470	6107	4444	6014	6037
2096	27	3859	7471	6107	4444	6017	6039
2097	27	3870	7471	6107	4444	6019	6041
2098	27	3880	7472	6107	4443	6021	6044
2099	27	3890	7473	6107	4443	6024	6046
2100	27	3913	7473	6107	4443	6026	6048
2101	27	3934	7474	6107	4443	6028	6050
2102	27	3952	7475	6107	4442	6030	6053
2103	27	3969	7475	6107	4442	6032	6055
2104	27	3985	7476	6107	4442	6034	6057
2105	27	3999	7476	6108	4442	6036	6059
2106	27	4013	7477	6108	4442	6038	6061
2107	27	4027	7478	6108	4442	6039	6063
2108	27	4039	7478	6108	4441	6041	6065
2109	27	4039	7478	6108	4441	6041	6065

Scenario	Name	Model Run	Irrigation development area	IIP	RH	SIS
S-1	Natural system	Steady State	None	-	-	-
S-2	Mallee clearance	1920 - CY100	None (but includes Mallee clearance area)	-	-	-
S-3A	Pre-1988, no IIP, no RH	1988 – CY100	Pre-1988	No	No	-
S-3B	Pre-1988, with IIP, no RH	1988 – CY100	Pre-1988	Yes	No	-
S-3C	Pre-1988, with IIP and with RH	1988 – CY100	Pre-1988	Yes	Yes	-
S-4	Current irrigation	CY – CY100	Pre-1988 + Post-1988	Yes	Yes	No
S-5	Current plus future irrigation	CY – CY100	Pre-1988 + Post-1988 + Future development	Yes	Yes	No

IIP = improved irrigation practices
RH = Rehabilitation of irrigation distribution networks
SIS = Salt interception scheme
CY = current year
CY100 = 100 yrs from the current year



Summary of predicted flux (m^3/day) entering the River Murray from Mannum to Murray Bridge

	1988	2000	2009	2050	2109
S-1	27	27	27	27	27
S-2	2983	3081	3125	3421	4039
S-3A	6225	6489	7133	7406	7478
S-3B	6225	6219	6228	6106	6108
S-3C	6225	5848	4993	4457	4441
S-4	6225	5848	4993	5748	6041
S-5	6225	5848	4993	5748	6065

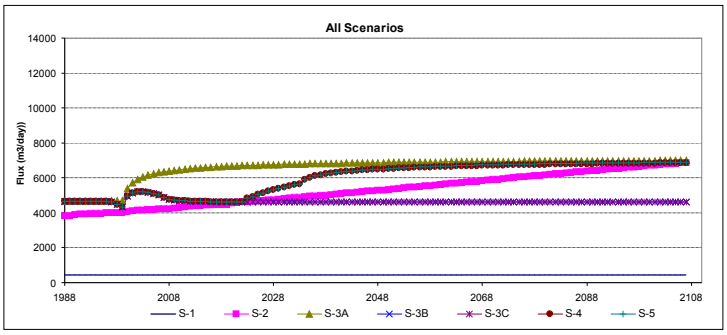
Modelled flux (m^3/day) entering the River Murray in the Mannum to Murray Bridge Reach Figure 46

Annual Flux for Murray Bridge to Wellington (m^3/day)

Time	S-1	S-2	S-3A	S-3B	S-3C	S-4	S-5
1988	446	3816	4650	4650	4650	4650	4650
1989	446	3821	4651	4651	4651	4651	4651
1990	446	3874	4654	4654	4654	4654	4654
1991	446	3905	4656	4656	4656	4656	4656
1992	446	3927	4658	4658	4658	4658	4658
1993	446	3945	4659	4659	4659	4659	4659
1994	446	3960	4661	4661	4661	4661	4661
1995	446	3972	4665	4665	4665	4665	4665
1996	446	3983	4669	4669	4669	4669	4669
1997	446	3993	4672	4672	4672	4672	4672
1998	446	4002	4675	4605	4605	4605	4605
1999	446	4010	4678	4460	4458	4458	4458
2000	446	4068	4681	4335	4332	4332	4332
2001	446	4104	5387	4948	4946	4946	4946
2002	446	4132	5700	5137	5135	5135	5135
2003	446	4154	5898	5200	5199	5199	5199
2004	446	4173	6037	5198	5198	5198	5198
2005	446	4190	6140	5157	5157	5157	5157
2006	446	4204	6220	5091	5091	5091	5091
2007	446	4217	6285	5007	5006	5006	5006
2008	446	4229	6339	4858	4859	4859	4859
2009	446	4240	6385	4771	4770	4770	4770
2010	446	4296	6424	4725	4722	4722	4722
2011	446	4334	6459	4699	4693	4693	4693
2012	446	4364	6490	4681	4674	4674	4674
2013	446	4388	6517	4666	4661	4661	4661
2014	446	4410	6542	4656	4650	4650	4650
2015	446	4429	6565	4648	4644	4644	4644
2016	446	4446	6586	4642	4638	4638	4638
2017	446	4462	6604	4637	4634	4634	4634
2018	446	4476	6622	4634	4630	4630	4630
2019	446	4489	6639	4630	4628	4628	4628
2020	446	4539	6652	4628	4626	4626	4626
2021	446	4576	6666	4626	4625	4625	4625
2022	446	4606	6678	4625	4624	4624	4624
2023	446	4632	6690	4624	4624	4624	4624
2024	446	4656	6701	4624	4623	4838	4838
2025	446	4677	6711	4623	4623	4909	4909
2026	446	4697	6721	4623	4622	5052	5052
2027	446	4715	6731	4622	4622	5128	5128
2028	446	4732	6740	4622	4622	5235	5235
2029	446	4748	6748	4622	4622	5302	5302
2030	446	4791	6757	4622	4622	5392	5392
2031	446	4826	6765	4622	4622	5447	5447
2032	446	4857	6772	4622	4622	5540	5540
2033	446	4885	6780	4622	4622	5595	5595
2034	446	4910	6787	4622	4622	5637	5637
2035	446	4934	6794	4622	4622	5884	5884
2036	446	4956	6799	4622	4622	6016	6016
2037	446	4977	6805	4622	4622	6103	6103
2038	446	4997	6811	4622	4622	6168	6168
2039	446	5015	6817	4622	4622	6220	6220
2040	446	5053	6823	4622	4622	6263	6263
2041	446	5087	6827	4622	4622	6300	6300
2042	446	5118	6833	4622	4622	6332	6332
2043	446	5147	6838	4622	4622	6361	6361
2044	446	5174	6842	4622	4622	6387	6387
2045	446	5200	6847	4622	4622	6411	6411
2046	446	5224	6851	4622	4622	6432	6432
2047	446	5248	6855	4622	4622	6453	6453
2048	446	5270	6860	4622	4622	6471	6471
2049	446	5292	6864	4622	4622	6488	6488
2050	446	5325	6868	4622	4622	6504	6504
2051	446	5358	6872	4623	4623	6519	6519
2052	446	5389	6876	4623	4623	6534	6534
2053	446	5419	6879	4623	4623	6547	6547
2054	446	5447	6883	4623	4623	6560	6560
2055	446	5474	6887	4623	4623	6572	6586
2056	446	5500	6890	4623	4623	6583	6606
2057	446	5524	6894	4623	4623	6594	6622
2058	446	5548	6897	4623	4623	6605	6635
2059	446	5572	6900	4623	4623	6614	6647
2060	446	5603	6904	4623	4623	6624	6658
2061	446	5635	6906	4623	4623	6633	6669
2062	446	5666	6909	4623	4623	6642	6679
2063	446	5696	6912	4623	4623	6650	6688
2064	446	5725	6915	4623	4623	6658	6697
2065	446	5752	6918	4623	4623	6666	6706
2066	446	5779	6920	4623	4623	6674	6714
2067	446	5805	6922	4623	4623	6681	6722
2068	446	5830	6925	4624	4624	6688	6729
2069	446	5854	6928	4624	4624	6695	6737
2070	446	5885	6930	4624	4624	6702	6743
2071	446	5916	6932	4624	4624	6708	6750
2072	446	5946	6935	4624	4624	6714	6756
2073	446	5975	6937	4624	4624	6720	6762
2074	446	6003	6940	4624	4624	6725	6768
2075	446	6031	6942	4624	4624	6731	6774
2076	446	6057	6944	4624	4624	6736	6780
2077	446	6083	6946	4624	4624	6741	6786
2078	446	6108	6948	4624	4624	6746	6791
2079	446	6132	6950	4624	4624	6751	6796
2080	446	6162	6952	4624	4624	6756	6802
2081	446	6192	6953	4625	4625	6760	6807
2082	446	6220	6955	4625	4625	6765	6811
2083	446	6249	6957	4625	4625	6769	6816
2084	446	6276	6959	4625	4625	6774	6820
2085	446	6302	6961	4625	4625	6778	6825
2086	446	6328	6962	4625	4625	6782	6829
2087	446	6353	6963	4625	4625	6785	6833
2088	446	6377	6965	4625	4625	6789	6837
2089	446	6401	6966	4625	4625	6793	6841
2090	446	6430	6967	4625	4625	6797	6844
2091	446	6458	6968	4625	4625	6800	6847
2092	446	6485	6970	4626	4626	6804	6850
2093	446	6512	6971	4626	4626	6807	6854
2094	446	6539	6972	4626	4626	6811	6857
2095	446	6564	6973	4626	4626	6814	6859
2096	446	6590	6975	4626	4626	6817	6862
2097	446	6614	6976	4626	4626	6820	6865
2098	446	6638	6977	4626	4626	6823	6868
2099	446	6662	6978	4626	4626	6826	6871
2100	446	6690	6979	4626	4626	6829	6873
2101	446	6718	6980	4626	4626	6831	6876
2102	446	6744	6981	4626	4626	6834	6879
2103	446	6769	6982	4626	4626	6836	6882
2104	446	6795	6983	4627	4627	6839	6884
2105	446	6819	6984	4627	4627	6841	6887
2106	446	6844	6985	4627	4627	6843	6890
2107	446	6867	6986	4627	4627	6845	6893
2108	446	6890	6987	4627	4627	6848	6895
2109	446	6890	6987	4627	4627	6848	6895

Scenario	Name	Model Run	Irrigation development area	IIP	RH	SIS
S-1	Natural system	Steady State	None	-	-	-
S-2	Mallee clearance	1920 - CY100	None (but includes Mallee clearance area)	-	-	-
S-3A	Pre-1988, no IIP, no RH	1988 – CY100	Pre-1988	No	No	-
S-3B	Pre-1988, with IIP, no RH	1988 – CY100	Pre-1988	Yes	No	-
S-3C	Pre-1988, with IIP and with RH	1988 – CY100	Pre-1988	Yes	Yes	-
S-4	Current irrigation	CY – CY100	Pre-1988 + Post-1988	Yes	Yes	No
S-5	Current plus future irrigation	CY – CY100	Pre-1988 + Post-1988 + Future development	Yes	Yes	No

IIP = improved irrigation practices
RH = Rehabilitation of irrigation distribution networks
SIS = Salt interception scheme
CY = current year
CY100 = 100 yrs from the current year



Summary of modelled flux (m^3/day) entering the River Murray from Murray Bridge to Wellington

	1988	2000	2009	2050	2109
S-1	446	446	446	446	446
S-2	3816	4068	4240	5325	6890
S-3A	4650	4681	6385	6868	6987
S-3B	4650	4335	4771	4622	4627
S-3C	4650	4332	4770	4622	4627
S-4	4650	4332	4770	6504	6848
S-5	4650	4332	4770	6504	6895

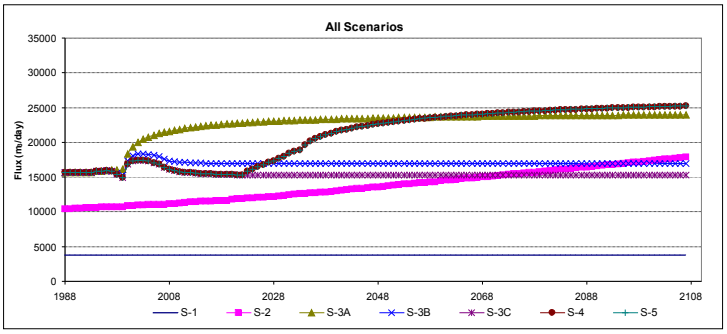
Modelled flux (m^3/day) entering the River Murray in the Murray Bridge to Wellington Reach Figure 47

Annual Flux (m^3/day) for Entire reach bwt Morgan to Wellington

Time	S-1	S-2	S-3A	S-3B	S-3C	S-4	S-5
1988	3816	10368	15606	15606	15606	15606	15606
1989	3816	10378	15622	15622	15622	15622	15622
1990	3816	10488	15640	15640	15640	15640	15640
1991	3816	10543	15655	15655	15655	15655	15655
1992	3816	10580	15672	15672	15672	15672	15672
1993	3816	10609	15686	15686	15686	15686	15686
1994	3816	10632	15699	15699	15699	15699	15699
1995	3816	10652	15797	15797	15797	15797	15797
1996	3816	10670	15881	15881	15881	15881	15881
1997	3816	10685	15947	15947	15947	15947	15947
1998	3816	10700	16003	15830	15830	15830	15830
1999	3816	10712	16046	15593	15387	15387	15387
2000	3816	10835	16087	15331	14956	14956	14956
2001	3816	10899	18332	17344	16812	16812	16812
2002	3816	10946	19338	18027	17331	17331	17331
2003	3816	10984	19964	18288	17432	17432	17432
2004	3816	11015	20406	18344	17411	17411	17411
2005	3816	11042	20741	18281	17281	17281	17281
2006	3816	11066	21012	18141	17056	17056	17056
2007	3816	11089	21238	17946	16833	16833	16833
2008	3816	11109	21429	17563	16406	16406	16406
2009	3816	11127	21597	17333	16096	16096	16096
2010	3816	11255	21742	17213	15911	15911	15911
2011	3816	11329	21873	17143	15786	15786	15786
2012	3816	11385	21992	17093	15698	15698	15698
2013	3816	11431	22099	17055	15627	15627	15627
2014	3816	11472	22195	17028	15565	15565	15565
2015	3816	11508	22287	17005	15519	15519	15519
2016	3816	11541	22368	16988	15472	15472	15472
2017	3816	11571	22441	16975	15434	15434	15434
2018	3816	11599	22511	16965	15379	15379	15379
2019	3816	11625	22578	16956	15359	15359	15359
2020	3816	11756	22631	16951	15346	15346	15346
2021	3816	11839	22686	16945	15337	15337	15337
2022	3816	11906	22737	16942	15330	15330	15330
2023	3816	11963	22783	16940	15323	15323	15323
2024	3816	12014	22829	16938	15318	15887	15887
2025	3816	12061	22869	16937	15313	16113	16113
2026	3816	12104	22909	16936	15309	16524	16524
2027	3816	12144	22948	16935	15305	16778	16778
2028	3816	12182	22982	16935	15302	17115	17115
2029	3816	12217	23017	16934	15300	17344	17344
2030	3816	12347	23051	16934	15298	17727	17727
2031	3816	12438	23083	16934	15296	17968	17968
2032	3816	12513	23113	16934	15295	18419	18419
2033	3816	12579	23143	16935	15293	18704	18704
2034	3816	12639	23171	16935	15293	18921	18921
2035	3816	12695	23198	16935	15293	19646	19646
2036	3816	12747	23219	16936	15292	20128	20128
2037	3816	12796	23241	16936	15292	20499	20499
2038	3816	12843	23267	16936	15292	20808	20808
2039	3816	12888	23289	16937	15292	21072	21072
2040	3816	13012	23312	16937	15292	21304	21304
2041	3816	13105	23331	16937	15291	21509	21509
2042	3816	13184	23352	16937	15291	21695	21695
2043	3816	13255	23372	16937	15291	21865	21865
2044	3816	13321	23390	16937	15291	22020	22020
2045	3816	13382	23408	16938	15291	22164	22164
2046	3816	13440	23424	16938	15290	22296	22296
2047	3816	13496	23440	16938	15290	22421	22421
2048	3816	13549	23458	16938	15290	22538	22538
2049	3816	13599	23474	16938	15290	22647	22647
2050	3816	13715	23491	16939	15290	22751	22751
2051	3816	13805	23506	16939	15290	22849	22849
2052	3816	13884	23520	16939	15289	22943	22943
2053	3816	13956	23534	16939	15289	23032	23032
2054	3816	14024	23549	16940	15289	23116	23116
2055	3816	14088	23564	16940	15289	23197	23218
2056	3816	14149	23576	16940	15289	23275	23312
2057	3816	14207	23590	16940	15289	23350	23395
2058	3816	14263	23602	16941	15289	23420	23470
2059	3816	14318	23615	16941	15289	23487	23542
2060	3816	14425	23628	16941	15289	23553	23610
2061	3816	14513	23639	16941	15289	23617	23676
2062	3816	14591	23651	16942	15288	23679	23738
2063	3816	14664	23662	16942	15288	23739	23798
2064	3816	14732	23673	16942	15288	23796	23855
2065	3816	14798	23684	16942	15288	23852	23911
2066	3816	14860	23693	16943	15288	23906	23966
2067	3816	14921	23701	16943	15288	23959	23981
2068	3816	14980	23712	16943	15288	24009	24033
2069	3816	15037	23722	16944	15288	24058	24083
2070	3816	15137	23730	16944	15288	24106	24131
2071	3816	15222	23739	16944	15288	24150	24177
2072	3816	15299	23749	16945	15288	24194	24221
2073	3816	15372	23757	16945	15288	24238	24265
2074	3816	15441	23767	16945	15288	24279	24306
2075	3816	15507	23776	16945	15288	24320	24348
2076	3816	15571	23785	16946	15288	24358	24390
2077	3816	15633	23794	16946	15288	24396	24430
2078	3816	15693	23800	16946	15288	24433	24470
2079	3816	15752	23808	16947	15288	24469	24508
2080	3816	15849	23814	16947	15288	24504	24546
2081	3816	15933	23821	16947	15288	24539	24582
2082	3816	16011	23826	16948	15288	24574	24617
2083	3816	16084	23834	16948	15288	24606	24651
2084	3816	16155	23842	16948	15288	24638	24683
2085	3816	16222	23848	16949	15288	24669	24716
2086	3816	16288	23854	16949	15288	24699	24745
2087	3816	16351	23859	16949	15288	24727	24775
2088	3816	16414	23864	16950	15289	24756	24803
2089	3816	16474	23868	16950	15289	24785	24832
2090	3816	16569	23874	16950	15289	24812	24860
2091	3816	16654	23878	16951	15289	24839	24885
2092	3816	16733	23884	16951	15289	24866	24910
2093	3816	16808	23888	16951	15289	24892	24932
2094	3816	16881	23892	16952	15289	24917	24955
2095	3816	16951	23898	16952	15289	24941	24976
2096	3816	17019	23902	16952	15289	24966	24996
2097	3816	17086	23906	16953	15289	24987	25016
2098	3816	17151	23910	16953	15289	25011	25037
2099	3816	17215	23914	16953	15289	25034	25058
2100	3816	17312	23919	16954	15289	25054	25079
2101	3816	17399	23922	16954	15290	25073	25101
2102	3816	17481	23926	16954	15290	25095	25121
2103	3816	17559	23930	16955	15290	25113	25142
2104	3816	17634	23934	16955	15290	25132	25163
2105	3816	17707	23938	16955	15290	25148	25184
2106	3816	17778	23942	16956	15290	25168	25204
2107	3816	17847	23945	16956	15290	25184	25224
2108	3816	17915	23949	16956	15290	25202	25243
2109	3816	17915	23949	16956	15290	25202	25252

Scenario	Name	Model Run	Irrigation development area	IIP	RH	SIS
S-1	Natural system	Steady State	None	-	-	-
S-2	Mallee clearance	1920 - CY100	None (but includes Mallee clearance area)	-	-	-
S-3A	Pre-1988, no IIP, no RH	1988 – CY100	Pre-1988	No	No	-
S-3B	Pre-1988, with IIP, no RH	1988 – CY100	Pre-1988	Yes	No	-
S-3C	Pre-1988, with IIP and with RH	1988 – CY100	Pre-1988	Yes	Yes	-
S-4	Current irrigation	CY – CY100	Pre-1988 + Post-1988	Yes	Yes	No
S-5	Current plus future irrigation	CY – CY100	Pre-1988 + Post-1988 + Future development	Yes	Yes	No

IIP = improved irrigation practices
RH = Rehabilitation of irrigation distribution networks
SIS = Salt interception scheme
CY = current year
CY100 = 100 yrs from the current year



Summary of modelled flux (m^3/day) entering the River Murray from Morgan to Wellington

	1988	2000	2009	2050	2109
S-1	3816	3816	3816	3816	3816
S-2	10368	10835	11127	13715	17915
S-3A	15606	16087	21597	23491	23949
S-3B	15606	15331	17333	16939	16956
S-3C	15606	14956	16096	15290	15290
S-4	15606	14956	16096	22751	25202
S-5	15606	14956	16096	22751	25252

Modelled flux (m^3/day) entering the River Murray in the Morgan to Wellington Reach (total) Figure 48

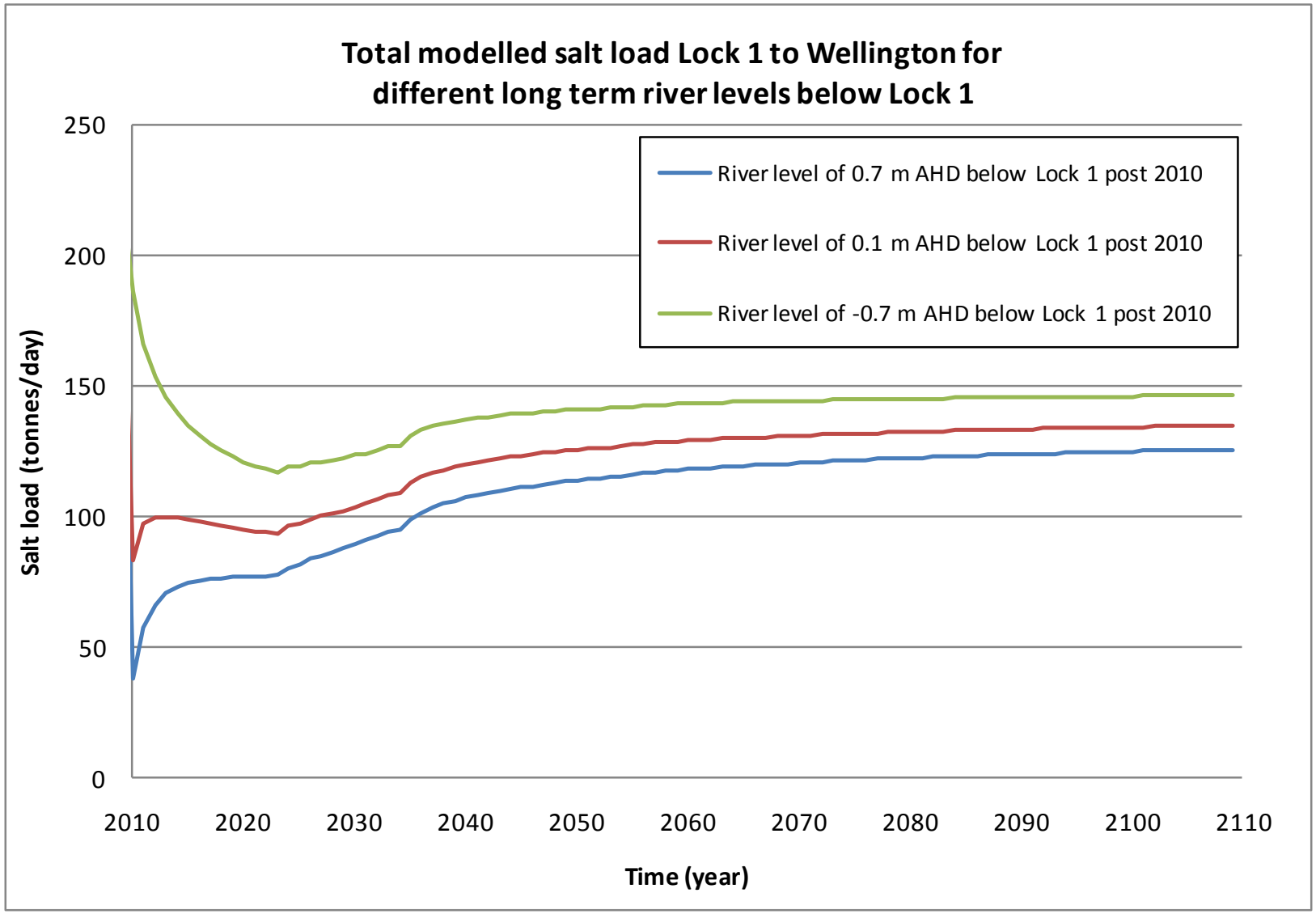


Figure 49. Modelled salt load (t/day) entering the River Murray between Lock 1 and Wellington under different long term river levels (below Lock 1 and post 2010)

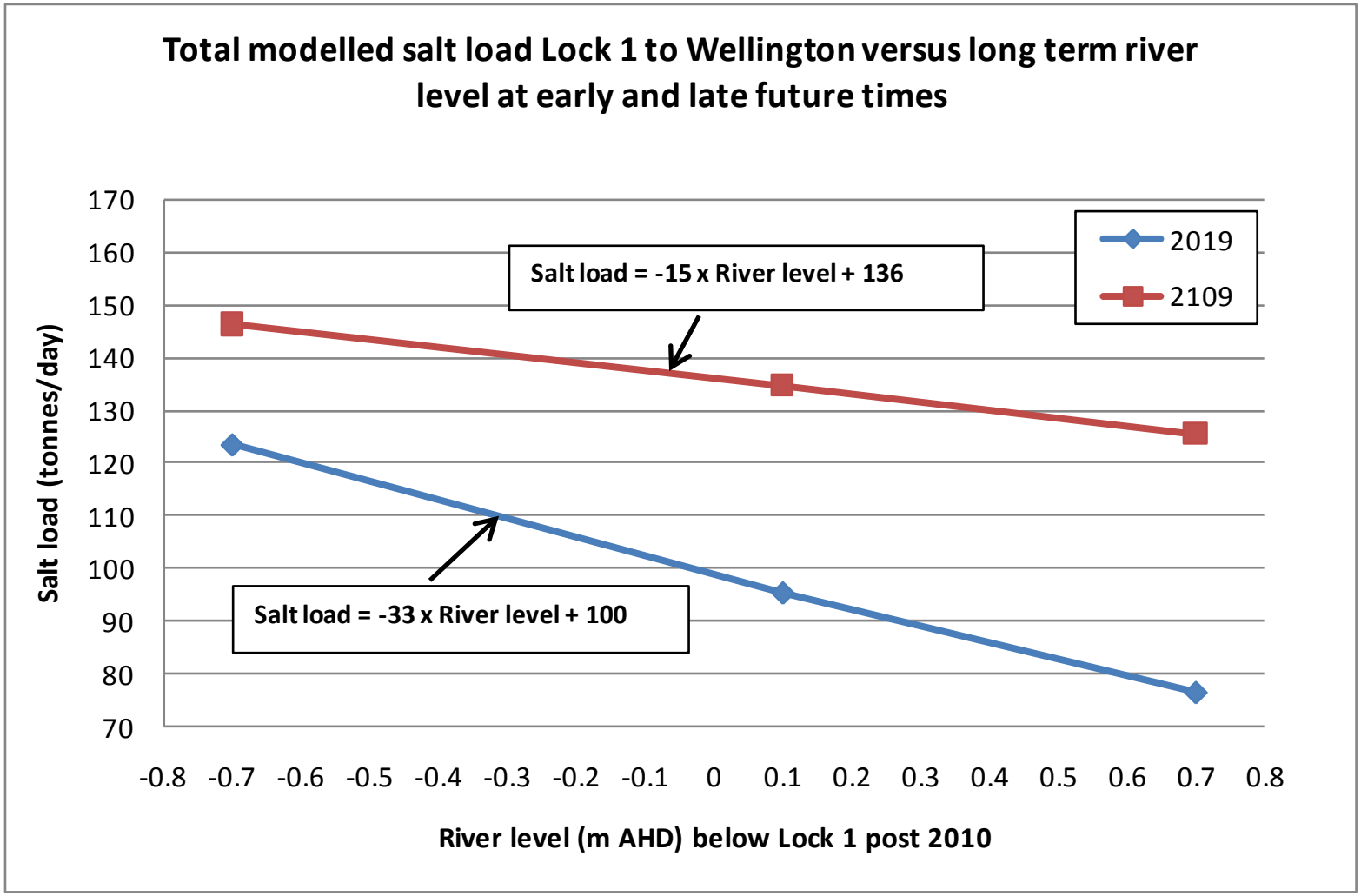
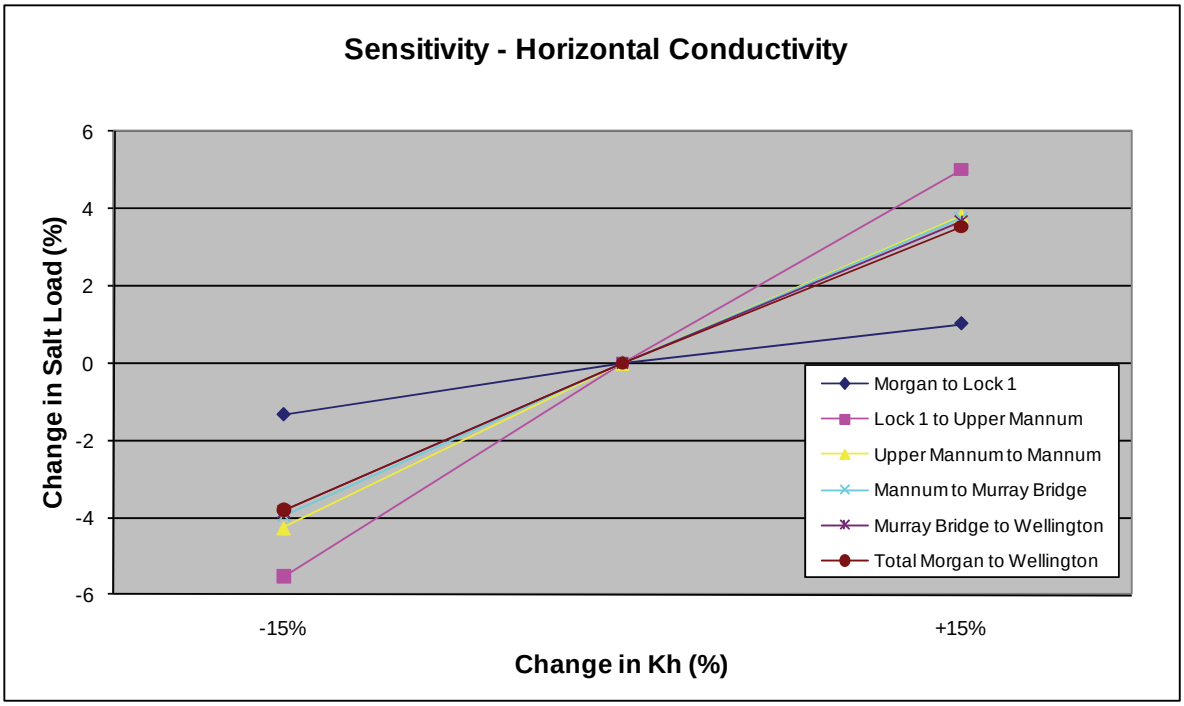


Figure 50. Modelled salt load (t/day) entering the River Murray between Lock 1 and Wellington versus long term river level (below Lock 1 and post 2010)



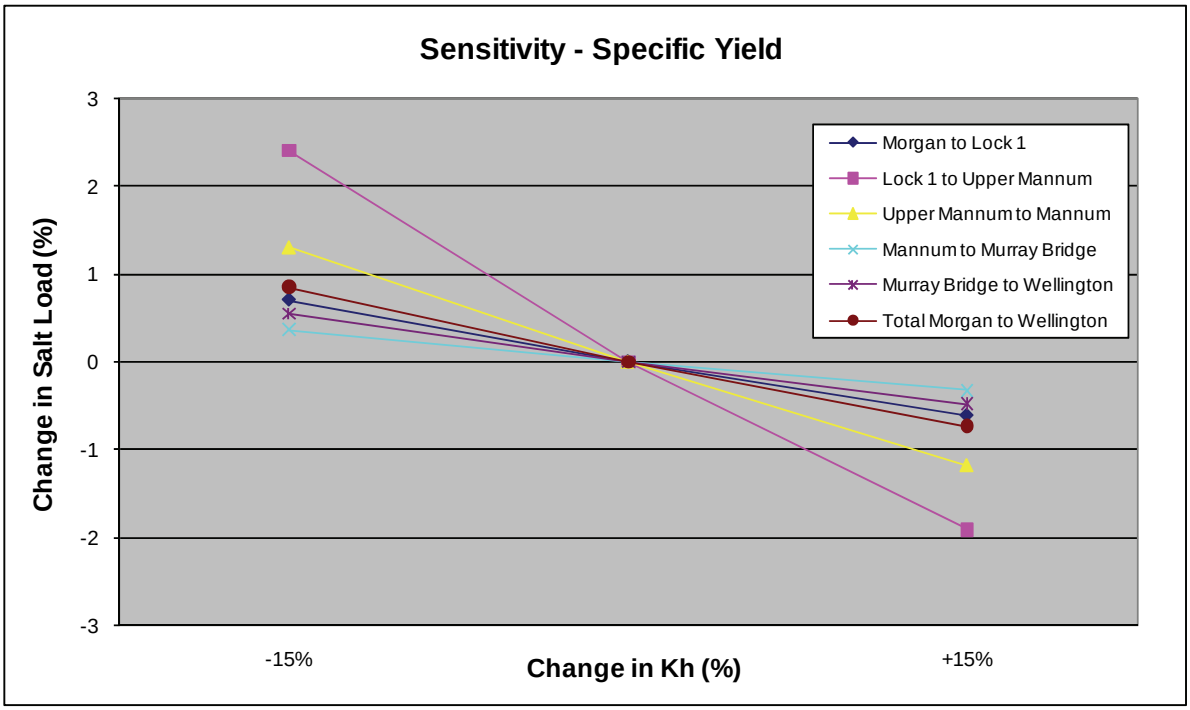


Figure 51. Predicted salt load for Sensitivity Test 2

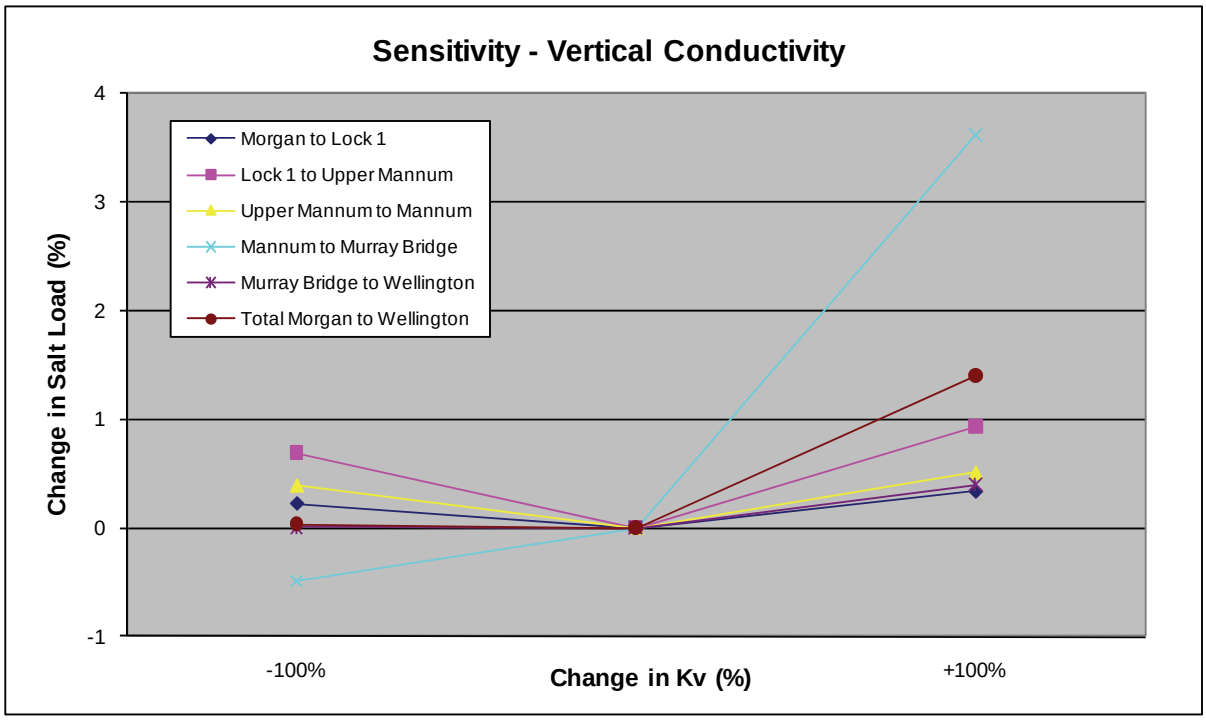


Figure 52. Predicted salt load for Sensitivity Test 3

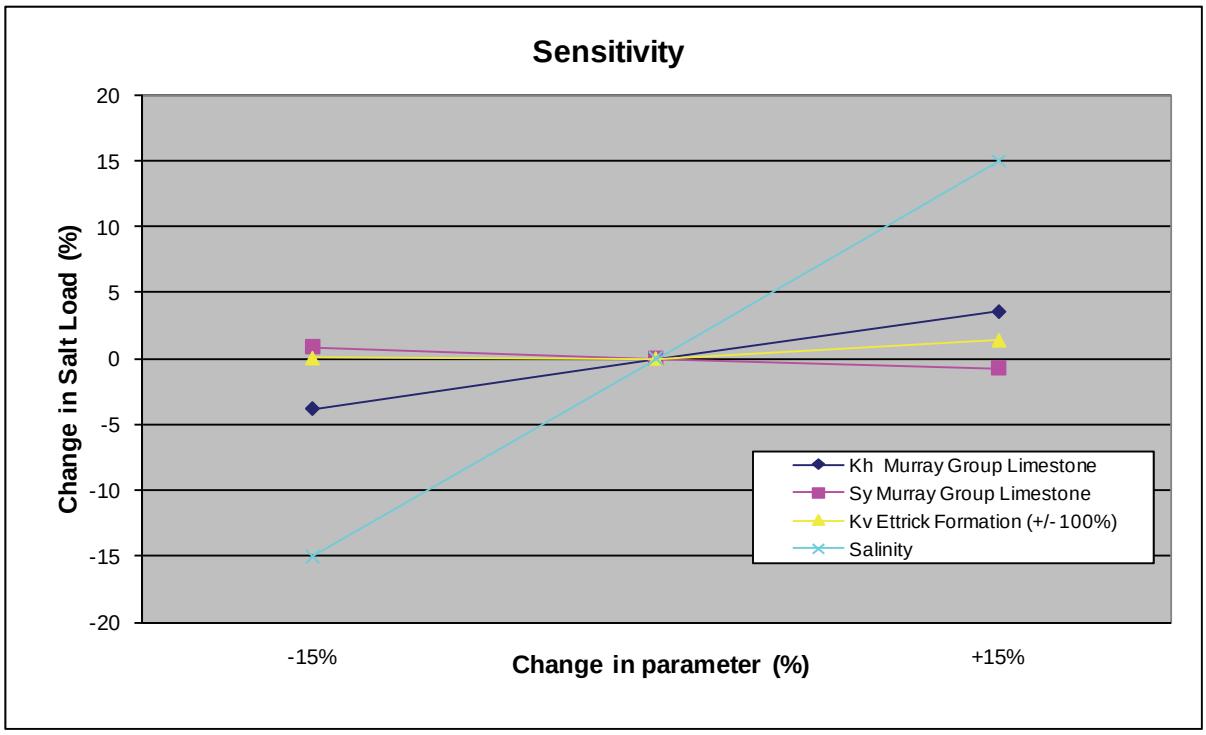


Figure 53. Comparative model sensitivity of the parameters tested

UNITS OF MEASUREMENT

Units of measurement commonly used (SI and non-SI Australian legal)

Name of unit	Symbol	Definition in terms of other metric units	Quantity
day	d	24 h	time interval
gigalitre	GL	10^6 m^3	volume
gram	g	10^{-3} kg	mass
hectare	ha	10^4 m^2	area
hour	h	60 min	time interval
kilogram	kg	base unit	mass
kilolitre	kL	1 m^3	volume
kilometre	km	10^3 m	length
litre	L	10^{-3} m^3	volume
megalitre	ML	10^3 m^3	volume
metre	m	base unit	length
microgram	µg	10^{-6} g	mass
microlitre	µL	10^{-9} m^3	volume
milligram	mg	10^{-3} g	mass
millilitre	mL	10^{-6} m^3	volume
millimetre	mm	10^{-3} m	length
minute	min	60 s	time interval
second	s	base unit	time interval
tonne	t	1000 kg	mass
year	y	365 or 366 days	time interval

Shortened forms

~	approximately equal to
AHD	Australian Height Datum
EC	electrical conductivity (µS/cm)
Kh	horizontal hydraulic conductivity (m/d)
Kv	vertical hydraulic conductivity (m/d)
Ss	specific storage (/m)
Sy	specific yield (-)
pH	acidity
TDS	total dissolved solids (mg/L)

GLOSSARY

Anabranch — A branch of a river that leaves the main stream.

Aquifer — An underground layer of rock or sediment that holds water and allows water to percolate through

Aquifer, confined — Aquifer in which the upper surface is impervious and the water is held at greater than atmospheric pressure. Water in a penetrating well will rise above the surface of the aquifer

Aquifer test — A hydrological test performed on a well, aimed to increase the understanding of the aquifer properties, including any interference between wells, and to more accurately estimate the sustainable use of the water resource available for development from the well

Aquifer, unconfined — Aquifer in which the upper surface has free connection to the ground surface and the water surface is at atmospheric pressure

Aquitard — A layer in the geological profile that separates two aquifers and restricts the flow between them

Basin — The area drained by a major river and its tributaries

Benchmark — Points of reference from which change can be measured

Bore — See *well*

BSMS — Basin Salinity Management Strategy developed by Murray-Darling Basin Authority

CSIRO — Commonwealth Scientific and Industrial Research Organisation

DEH — Department for Environment and Heritage (SA)

DES — Drillhole Enquiry System

EC — Abbreviation for electrical conductivity. 1 EC unit = 1 micro-Siemen per centimetre (µS/cm)

ELMA — Environmental Land Management Allocation

Evapotranspiration (ET) — The total loss of water as a result of transpiration from plants and evaporation from land, and surface water bodies

Floodplain — Of a watercourse means: (a) the floodplain (if any) of the watercourse identified in a catchment water management plan or a local water management plan; adopted under Part 7 of the Water Resources Act 1997; or (b) where paragraph (a) does not apply — the floodplain (if any) of the watercourse identified in a development plan under the Development Act 1993, or (c) where neither paragraph (a) nor paragraph (b) applies — the land adjoining the watercourse that is periodically subject to flooding from the watercourse.

Future irrigation development — Future irrigation development area and recharge (assuming recharge of 100 mm/year) resulting from activation of already allocated water that is assumed to occur after the current year

GIS (geographic information system) — Computer software allows for the linking of geographic data (for example land parcels) to textual data (soil type, land value, ownership). It allows for a range of features, from simple map production to complex data analysis.

Groundwater — See *underground water*

Hydrogeology — The study of groundwater, which includes its occurrence, recharge and discharge processes and the properties of aquifers (see *hydrology*)

Hydrology — The study of the characteristics, occurrence, movement and utilisation of water on and below the earth's surface and within its atmosphere (see *hydrogeology)*

IAG-Salinity — Independent Audit Group for Salinity

Infrastructure — Artificial lakes; or dams or reservoirs; or embankments, walls, channels or other works; or buildings or structures; or pipes, machinery or other equipment

Irrigation — Watering land by any means for the purpose of growing plants

Irrigation season — The period in which major irrigation diversions occur, usually starting in August–September and ending in April–May

Improved irrigation practices (IIP) — Commencing in the mid 1990s when flood irrigation via earth channels was replaced by sprinkler and drip irrigation systems, thus increasing irrigation efficiency (70–85%) and reducing recharge to the groundwater table

Lag time — Time (years) taken for recharge to reach the groundwater table. Lag time is affected by depth to groundwater table and the presence and properties of aquitards.

Lake — A natural lake, pond, lagoon, wetland or spring (whether modified or not) and includes: part of a lake; and a body of water declared by regulation to be a lake; a reference to a lake is a reference to either the bed, banks and shores of the lake or the water for the time being held by the bed, banks and shores of the lake, or both, depending on the context

Land — Whether under water or not and includes an interest in land and any building or structure fixed to the land

Licence — A licence to take water in accordance with the Water Resources Act 1997 (see *water licence*)

Mallee clearance — Clearance of natural vegetation

MDB – Murray-Darling Basin

MDBA — The Murray-Darling Basin Authority is responsible for planning the integrated management of water resources of the Murray-Darling Basin

Model — A conceptual or mathematical means of understanding elements of the real world which allows for predictions of outcomes given certain conditions. Examples include estimating storm runoff, assessing the impacts of dams or predicting ecological response to environmental change.

Modelled result — Output from the calibrated model (e.g. a potentiometric head distribution) that can be compared to observed data

Natural recharge — The infiltration of water into an aquifer from the surface (rainfall, streamflow, irrigation etc.) (See *recharge area*)

Permeability — A measure of the ease with which water flows through an aquifer or aquitard

PIRSA — (Department of) Primary Industries and Resources South Australia

Post-1988 irrigation — Irrigation development area and recharge that occurred between 1 January 1988 and the current year

Pre-committed water — Water allocation that has been approved but is not yet being used

Pre-1988 irrigation — Irrigation development area and recharge that occurred prior to 1 January 1988

Predicted result — Output from the prediction model has been used to determine the future result of a particular scenario

Recharge — Irrigation drainage and/or rainfall infiltration reaching the groundwater table

Recharge area — The area of land from which water from the surface (rainfall, streamflow, irrigation, etc.) infiltrates into an aquifer (See *natural recharge*)

Rehabilitation (RH) — Replacement of leaky concrete water distribution channels with pipelines resulting in reduced transportation losses, which are reflected by reduced recharge to the groundwater table

SIS — Salt Interception Scheme designed to intercept the (maximum) groundwater flux and salt load resulting from the pre-1988, post-1988 and future irrigation development

Surface water — (a) water flowing over land (except in a watercourse), (i) after having fallen as rain or hail or having precipitated in any another manner, (ii) or after rising to the surface naturally from underground; (b) water of the kind referred to in paragraph (a) that has been collected in a dam or reservoir.

Underground water (groundwater) — Water occurring naturally below ground level or water pumped, diverted or released into a well for storage underground

WAP — Water Allocation Plan

Water licence — A licence granted under the Act entitling the holder to take water from a prescribed watercourse, lake or well or to take surface water from a surface water prescribed area. This grants the licensee a right to take an allocation of water specified on the licence, which may also include conditions on the taking and use of that water. A water licence confers a property right on the holder of the licence and this right is separate from land title.

Water table — The saturated–unsaturated interface within the ground.

Water body — Water bodies include watercourses, riparian zones, floodplains, wetlands, estuaries, lakes and groundwater aquifers.

Watercourse — A river, creek or other natural watercourse (whether modified or not) and includes: a dam or reservoir that collects water flowing in a watercourse; and a lake through which water flows; and a channel (but not a channel declared by regulation to be excluded from the this definition) into which the water of a watercourse has been diverted; and part of a watercourse.

Well — (a) an opening in the ground excavated for the purpose of obtaining access to underground water; (b) an opening in the ground excavated for some other purpose but that gives access to underground water; (c) a natural opening in the ground that gives access to underground water.

REFERENCES

Allison GB, Cook PG, Barnett SR, Walker GR, Jolly ID and Hughes MW, 1990, 'Land clearance and river salinisation in the western Murray Basin, Australia', in *Journal of Hydrology*, 119, pp. 1–20

Aquaterra, 2007, 'Mallee zone 5-year rolling salinity review—hydrogeological modelling for Victoria and NSW, B-Register 'Legacy of History' Assessments, Eastern Mallee Model version 1 (EM1)', prepared for the Murray Darling Basin Commission

Aquaterra, 2009, 'Sunraysia sub-regional groundwater flow model (EM2.2) final report, Eastern Mallee model version 2.2 (EM2.2)' (in prep)

Australian Water Enviornments (AWE) 2008, 'Review and update of hydrogeological information for the Morgan to Wellington model area', prepared by Australian Water Environments Pty Ltd for the Department of Water, Land and Biodiversity Conservation, Adelaide

Barnett SR, 1991, *Renmark Hydrogeological Map (1:250 000 scale)*, Department of Mines and Energy, Adelaide

Barnett SR, Yan W, Watkins NR, Woods JA and Hyde KM, 2001, *Groundwater modelling to predict future dryland salt loads to the River Murray in South Australia*, Report DWR 2001/017, Department for Water Resources, Adelaide

Barnett S and Yan W, 2006, *Review of mallee clearing saltloads to the River Murray in SA—2005*, Report DWLBC 2006/08, Department of Water, Land and Biodiversity Conservation, Adelaide

Berens V, Hatch M, James-Smith J and Love A, 2004, 'In-stream geophysics aiding the hydrogeological investigation for the Loxton salt interception scheme, SA', in *Proceedings: Inaugural Australasian Hydrogeology Research Conference, November 2003, Melbourne*

Bureau of Meteorology, 2001, Climatic atlas of Australia—Evapotranspiration

Bureau of Meteorology, 2008, Commonwealth of Australia, http://www.bom.gov.au/

Cook PG, Leaney FW and Miles M, 2004, *Groundwater recharge in the north-east Mallee Region, South Australia,* CSIRO Land and Water Technical Report No 25/04

Drexel JF and Preiss WV (eds), 1995, *The geology of South Australia, Vol. 2, The Phanerozoic*, Bulletin, 54, Geological Survey, Adelaide

Environment Protection Authority, 2005, 'Cowirra surface irrigation reuse trial May 2005', Department for Environment and Heritage, South Australia

Evans WR and Kellet JR, 1989, 'The hydrogeology of the Murray Basin, southeastern Australia', in *BMR Journal of Australian Geology and Geophysics*, 11, pp. 147–166

Holland K, Jolly ID, Tyerman S, Mansforth L, Telfer A and Walker GR, 2001, 'Interception of groundwater discharge by floodplain in the lower River Murray: Implications for river salinity', *8th Murray Darling Basin Groundwater Workshop, 2001*

Jolly I, Overton I and Smitt C, 2003, 'Options analysis for salinity management in the Lower Murray of South Australia, Milestone 5: Historical reconstruction of the impact of the Mypolonga, Toora and Mobilong Highland irrigation areas on the Lower River Murray and its floodplain', CSIRO, Australia

McDonald MG and Harbaugh AW, 1988, 'A modular three-dimensional finite-difference groundwater flow model', Techniques of water-resources investigations of the United States Geological Survey, Modelling techniques book 6

Mid Murray Local Action Planning (LAP) Committee, 2000, 'The Mid Murray local action plan', viewed 29 September 2008, http://www.midmurraylap.org.au/

Morton FI, 1983, 'Operational estimates of areal evapotranspiration and their significance to the science and practice of hydrology', *Journal of Hydrology*, 66, pp. 1–76

Murray-Darling Basin Commission (MDBC), 2001, *Groundwater flow modelling guideline*, August 2001

Murray-Darling Basin Commission (MDBC), 2005, Basin Salinity Management Strategy Operational Protocols, Appendix 3.11 http://www.mdbc.gov.au/subs/dynamic_reports/bsms_op_protocols/HTML/lib/pdf/appendix3-11.pdf

Rammers N, Hill T and Yan W, 2005, *Regional disposal strategy—Renmark Group deep injection: Phase 1 desktop study*, Report DWLBC 2005/29, Department of Water, Land and Biodiversity Conservation, Adelaide

Rural Solutions, 2004, 'Groundwater modelling of Salt Interception Schemes in the Woolpunda-Cadell reach of the River Murray, Volume 2, Appendices', prepared for the Department of Water, Land and Biodiversity Conservation, Adelaide

Thorburn PJ, Hatton TJ and Walker GR, 1993, 'Combining measurements of transpiration and stable isotopes of water to determine groundwater discharge from forests', *Journal of Hydrology*, 150, pp. 563–587

Vears L and Roberton C, 2008, 'Review and update of irrigation and recharge information for the Morgan to Wellington regional groundwater model', Department of Water Land and Biodiversity Conservation, Adelaide

Yan W, Georgiou J, Howe B, Armstrong D and Barnett S, 2007, *Berri–Renmark numerical groundwater model 2007, Vol. 1 – report and figures*, Report DWLBC 2007/30, Department of Water Land and Biodiversity Conservation, Adelaide

Yan W, Howles SR and Hill AJ, 2005, *Loxton numerical groundwater model 2004*, Report DWLBC 2005/16, Department of Water Land and Biodiversity Conservation, Adelaide

Yan W, Morgan L, Georgiou J, Evans S and Vears L, 2009, Morgan to Wellington numerical groundwater model 2009, Vol. 1 – report and figures, Report DWLBC 2009/22, through Department of Water, Land and Biodiversity Conservation, Adelaide.

Yan W and Stadter M, 2008, *Pyap to Kingston numerical groundwater model 2008, Vol. 1 – report and figures*, Report DWLBC 2008/19, Department of Water Land and Biodiversity Conservation, Adelaide