# Flood Mapping of the River Murray Floodplain in South Australia

DEWNR Technical report 2015/57

Government of South Australia
Department of Environment, Water and Natural Resources

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# Foreword

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

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

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

**Sandy Pitcher**
**CHIEF EXECUTIVE**
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# Contents

## List of Figures



## List of Tables

# Summary

Flood mapping of the River Murray in South Australia was undertaken during 2011 and 2012 to assist in flood preparedness and risk management activities. The flood maps were created using the hydraulic modelling tool MIKE FLOOD which links together hydraulic models representing both one-dimensional (linear) and two-dimensional (grid) representations of the river and floodplain. The models were calibrated to two events (1956 and 1992–93) and validated on a third event (1974).

Flood maps have been produced for the following flow scenarios (megalitres per day):

- 100,000 ML/d
- 120,000 ML/d
- 140,000 ML/d
- 160,000 ML/d
- 180,000 ML/d
- 200,000 ML/d
- 250,000 ML/d
- 300,000 ML/d
- 341,000 ML/d (1956 – highest flood on record)

The model assumes that all inundated areas have stabilised to the given flow conditions. This is often an appropriate assumption, as a review of previous flood events demonstrated that River Murray floods can peak at a steady level for three days or more, and the majority of wetlands are well connected to the river for flows above 100,000 ML/d. However, some wetlands and other backwaters may take some time to fill, potentially weeks and in these cases the flood maps may overestimate inundation in some areas away from the main channel.

The flood maps depict several areas at risk of flooding by overtopping levee banks. It is acknowledged that the banks may fail at lower river heights due to piping or slumping. Assessment of possible bank failure due to these failure mechanisms and the resultant flood impact is beyond the scope of this project. Furthermore, it has been assumed that no works have been undertaken in advance of a flood to raise levee banks or any other temporary works. In some cases there are isolated low spots which are quite narrow, and it may be possible to prevent overtopping occurring in these locations in advance of a coming flood.

# 1 Introduction

## 1.1 Background

The River Murray system extends over five states and a territory (South Australia, Victoria, New South Wales, Australian Capital Territory and Queensland) with a catchment area over one million square kilometres. It is the longest river in South Australia, traversing approximately 600 km across the state from the eastern border with New South Wales and Victoria, to its mouth on the southern coastline.

Details of floods have been recorded on the River Murray since settlement began adjacent to the river in South Australia in the 1880s and 1890s. Major floods since this time include those which occurred in 1917, 1931, 1956 and 1974. The 1956 flood was by far the largest, resulted in extensive inundation of agricultural land and the flooding of hundreds of houses, including significant damage in Mannum and Renmark. Levee banks only narrowly managed to avert the widespread flooding of Renmark.

Flood heights have been recorded at numerous locations along the river since settlement began and flood information for the river exists in several formats. Backwater curves (long section plots of the river showing river distance and water height) show the recorded height for significant flood events dating back to 1917. Aerial photographs taken during the 1956 flood have been used to generate a spatial layer delineating the flood extent, which is now used to define the extent of floodplain and is also used for land use planning purposes. The River Murray Floodplain Inundation Model (RiM-FIM) was created by CSIRO as a tool for environmental flow management (Overton et al. 2006). RiM-FIM consists of a series of inundation maps for the River Murray between Wellington and Hume Dam generated using satellite imagery of historic flood events. In South Australia, RiM-FIM derived inundation extents have been produced up to a flow of 110,000 ML/d. Flood modelling and mapping was undertaken for flows between 100,000 ML/d and 341,000 ML/d (1956 flood) for the Renmark Paringa Council area, commissioned by the council, in 2007. However, for the majority of the River Murray in South Australia, no flood maps exist for flows higher than 110,000 ML/d making it difficult to assess the impact from future flood events.

The River Murray high flow event of early 2011, which peaked at 93,000 ML/d at the South Australian border, was the first high flow event in more than ten years following a period of severe drought. The event revealed both the community's concern regarding their vulnerability to flooding and the reduction in local flood knowledge that has occurred due to the relative infrequency of flooding in recent history. The then Department for Water (DFW) produced flood maps for the forecast flow (90 000 ML/d) and made these available on the WaterConnect website (http://waterconnect.sa.gov.au) prior to the peak arriving. The response from communities and agencies was positive and indicated the need for a wider set of flood maps for flood preparedness purposes.

## 1.2 Aims and objectives

Flood mapping of the River Murray in South Australia was undertaken during 2011 and 2012 to assist in flood preparedness and risk management activities. The maps were developed in response to deficiencies in the coverage of existing information available for flood preparedness and warning, such as:

- Inundation maps of the River Murray in South Australia from the RiM-FIM dataset developed by Overton et al. (2006) go to a maximum flow of 110,000 ML/d
- Information was not available on what flow rate was likely to inundate certain parts of the floodplain, limiting the ability to identify the risk to assets such as housing, infrastructure and levee banks
- There was a considerable gap in level predictions between the two largest floods for which historical records were available, i.e. between 210,000 ML/d (1931 flood) and 341,000 ML/d (1956 flood)
- The 1956 flood line was not representative of current conditions in some locations.

The maps are intended to supplement existing information on river levels, such as that provided by the River Murray backwater curves and SA Water Corporation predictions, rather than being a replacement for these. This report does not consider the frequency of flood events.

# 2 Description of study area

## 2.1 Overview

This flood mapping study covers the South Australian section of the River Murray from the South Australian border to the entrance to Lake Alexandrina (Shown in Figure 2.1). At its downstream extent, the river flows into the shallow and wide Lake Alexandrina, before discharging into the ocean and the Coorong. The Lower Lakes themselves have not been modelled due to the complex interaction of the river mouth and the Coorong, and the effects of winds and tides.

Distances along the river are described by a river kilometre, measured from the mouth of the river, where it discharges to the ocean.

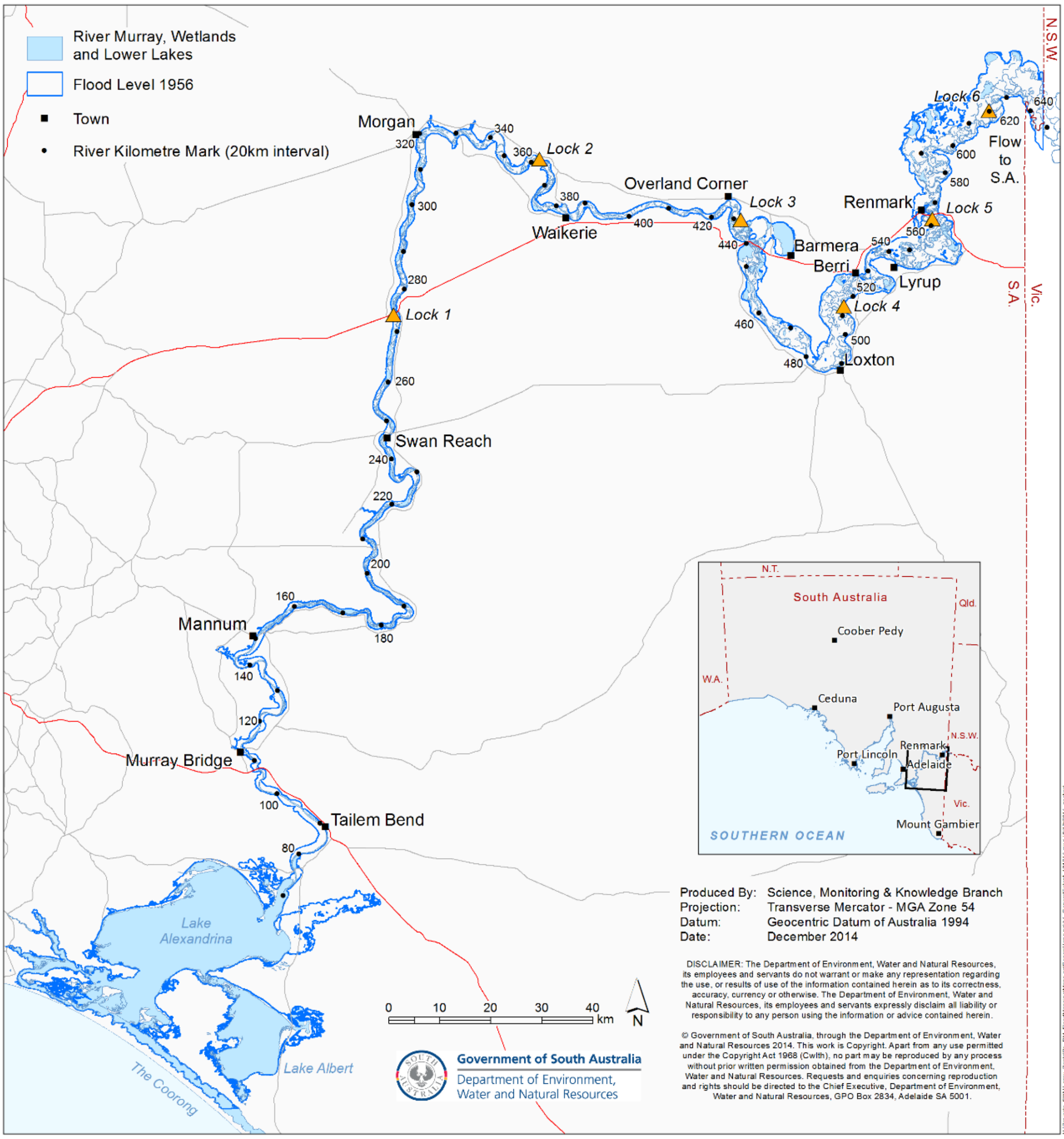



**Figure 2.1 The River Murray in South Australia**

## 2.2 Locks and barrages

There are six weirs constructed on the River Murray in South Australia, to facilitate stable water levels for irrigation and navigation. The weirs contain a lock structure for the passing of boats and each weir is generally referred to by the corresponding lock number (e.g. Lock 1). At low flows the weirs segment the river into a series of pools, within which water levels are held relatively stable for a range of low to moderate flows. There are also five barrages between Lake Alexandrina and the Coorong, which control the level of the lake and flow to the Coorong.

Weir stop logs are added or removed in order to maintain a constant pool level immediately upstream of each lock. However, due to hydraulics, water levels in each reach are not perfectly flat, with the water level increasingly sloped with increased distance upstream from the lock and with increased flow, such that the water level just downstream of each lock has the most variation.

For higher flows the weir structure is fully removed. The flow at which the weir is removed varies for each lock but is between 40,000 and 70,000 ML/d. Once the locks are fully removed, there is little impediment remaining to the river flow. For this study, the minimum flow modelled is well in excess of the flows at which the weirs are removed, so these structures did not need to be included in the modelling.

# 3 Methodology

## 3.1 Modelling approach

The flood maps were created using the hydraulic modelling tool MIKE FLOOD which links together hydraulic models representing both one-dimensional (linear) and two-dimensional (grid) representations of the river and floodplain. This modelling approach was selected due to its ability to model complex flow patterns across the river and floodplain with the two-dimensional model, while also being able to incorporate hydraulic structures such as bridges within the one-dimensional model.

Model development focussed on floods greater than 100,000 ML/d for the following reasons:

1. An existing floodplain inundation model (RiM-FIM) depicts inundation up to a maximum flow of 110,000 ML/d
2. Whilst some shacks may be impacted at lower flows, 100,000 ML/d represents the minimum flow for which other significant development starts to be impacted
3. It is beyond the flow range at which water levels are influenced by the locks and weirs
4. It enables a simpler and efficient model set-up to be adopted which is adequate for representing widespread flow of water across the floodplain.

## 3.2 Model development

### 3.2.1 Model extent

The area of interest for the flood modelling extends more than 500 river kilometres from Lake Alexandrina near the mouth of the River Murray to near the border with New South Wales and Victoria. To improve the efficiency of the modelling, the river floodplain was divided into a series of sections to be modelled separately.

The boundaries of model sections were selected based on several factors including: the location of water level gauges; floodplain elevation, particularly where the flow is confined to the river channel or where the flow direction is linear in a uniform section of floodplain; and model size.

Six sections were defined as follows:

1. Wellington to Mannum
2. Mannum to Lock 1
3. Lock 1 to Morgan
4. Morgan to Overland Corner
5. Overland Corner to Lyrup
6. Lyrup to Murtho.

The extent of each model section is shown in Figure 3.1.

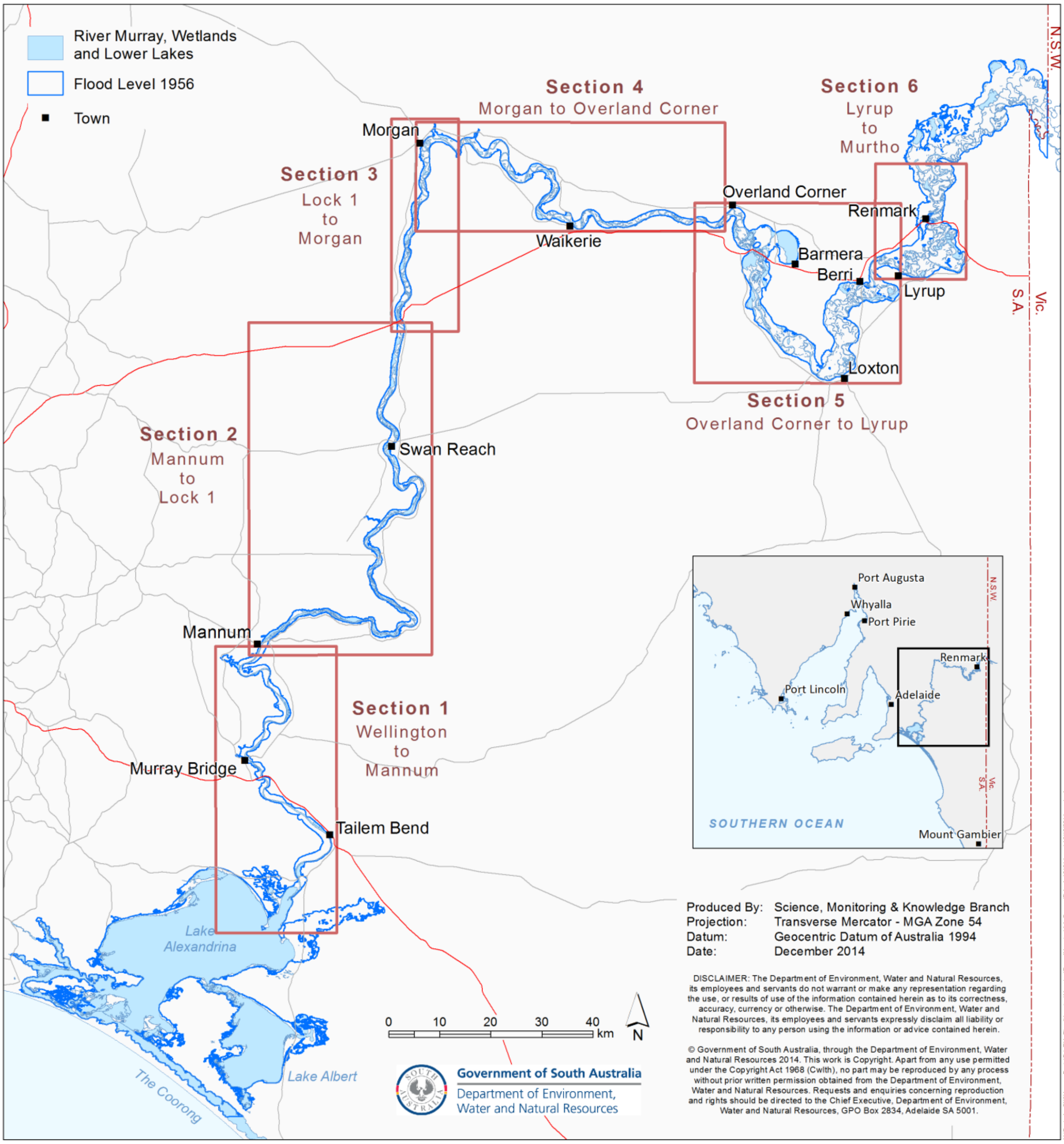



**Figure 3.1 Model sections**

### 3.2.2 Grid size

The selection of the grid size is a critical element in the model development. Since each cell can only have one value, inputs and outputs to the model, such as ground and channel elevation data, flow, velocity and water level, are provided to that degree of resolution. The finer the grid size, the finer the floodplain features that can be modelled. Grid cell size also dictates the resolution of the resulting flood maps. A desired output from the mapping was the ability to identify individual properties or infrastructure at risk of flooding. A smaller grid cell size enables the production of flood maps with finer resolution; however, with smaller cell size comes increased computational time for model runs and larger file sizes. A grid cell size of 15 metres was selected as a balance between being fine enough to adequately represent floodplain features and the preferred resolution of the flood mapping, and computational limitations and reasonable model run time. With a 15 metre grid cell size, each model section had on average approximately 1 million cells.

### 3.2.3 Floodplain and channel elevations

The main River Murray channel was chosen to be modelled using the two-dimensional grid rather than a one-dimensional model element since the channel is wide compared to the resolution of the grid. A modelling 'rule of thumb' states that a flow path can be adequately represented by a grid if typically five or more grid cells, with a minimum of three, cover the width of the channel.

The magnitude of flows modelled as part of this study result in extensive overbank flows across the floodplain which enabled a range of model simplifications to be adopted which would not be appropriate for modelling lower river flows where a greater proportion of the total flow is conveyed by the main channel and floodplain creeks.

One example of model simplification was the representation of small floodplain creeks in the model. It was recognised that many of these smaller channels are too narrow to be adequately represented by the grid. However, since they convey only a small proportion of the total flow, or are completely inundated under flood conditions, adding additional model complexity by representing floodplain channels as one-dimensional elements was not considered necessary. An additional simplification was to disregard small structures on the floodplain such as minor bridge crossings, culverts and wetland regulators where these structures were judged to have minimal influence on water levels during flood events. Larger structures such as earth banks were typically represented in the model. It is acknowledged that the model developed for this study is not well suited to lower flow situations where flows through anabranches and floodplain structures have more of an influence on water levels and flooding extent.

The floodplain and channel elevations in the model have been extracted from a Digital Elevation Model (DEM) of the River Murray and floodplain developed by DEWNR specifically for this project. Two main data sources were used to develop the project DEM: the 2008 River Murray DEM collated by CSIRO (Austin and Gallant, 2010) and bathymetric cross sections of the River Murray channel between Lock 1 and the border, surveyed in the early 1980s.

The floodplain portion of the project DEM and the river channel downstream of Lock 1 are largely based on the 2008 River Murray DEM collated by CSIRO, which stitches together a series of high resolution DEMs of the River Murray floodplain from Chowilla to the Murray Mouth. These were acquired through a range of methods/techniques including LiDAR, orthophotography and manual photogrammetric techniques (floodplain between Lock 1 and Wellington), and sonar (for the river channel downstream of Lock 1 and the Lower Lakes). These data were acquired in 2007–08 except the Chowilla section, which was acquired in 2003.

The 2008 River Murray DEM has a horizontal accuracy of 2 metres and a vertical accuracy of ± 0.15 metres. LiDAR is unable to penetrate standing water, so any area of the floodplain covered by water at the time of acquisition (including the main river channel upstream of Lock 1, wetlands, creeks and anabranches) do not have any elevation data. However, during the drought conditions of 2007–08 when data were collected, there were numerous wetlands that were abnormally dry due to water saving management actions as well as low water levels below Lock 1, so the floodplain and channel elevations of a few normally submerged areas were included in the DEM. The 2008 River Murray DEM is considered to have very good quality data for normally dry areas of floodplain and the river channel and most wetland areas downstream of Lock 1, however it does not contain elevation data for normally wet areas upstream of Lock 1.

A bathymetry for the main river channel upstream of Lock 1 was interpolated from cross-sections of the river obtained in the early 1980s. Cross-section data comprised points generally spaced 10 metres laterally, with cross-sections spaced generally 50 metres longitudinally along the river. It is difficult to ascertain the accuracy of the floodplain and channel elevations created from 1980s survey. The floodplain and channel elevations upstream of Lock 1 were stitched into the 2008 River Murray DEM. Additional interpolation was required to generate elevation data where gaps existed between coverage of the channel and floodplain data.

The LiDAR used to construct the DEM extends 100 metres beyond the 1956 flood extent as defined by the 1956 flood extent dataset, which was derived based on aerial photographs of the actual events. In some locations it was necessary to further extend the DEM where increased areas of flooding have been simulated, for example, in areas where levee banks have been degraded or removed since 1956. For these areas, a 10 metre DEM derived from 1:10,000 contours and floodplain spot height data have been used. As an example, this was undertaken for the area west of the levee banks at Renmark North and the area protected by levee banks at Lyrup.

At the conclusion of the above steps, the River Murray flood mapping DEM was imported into MIKE FLOOD to create the floodplain and channel elevations in the model. A range of additional steps were undertaken within the MIKE FLOOD environment to create model elevations that adequately represented the floodplain features. As part of the import process, the 2 metre DEWNR flood mapping DEM was resampled to a 15 metre grid. Resampled data used as input into the model are accurate to 15 metres horizontally, based on the resolution of the input data. The vertical accuracy of the resampled elevation values would represent an average of the original high resolution elevation values.

Modifications made to floodplain and channel elevations in the model within MIKE FLOOD included:

- **Definition of levee banks.** The resampling process to convert the 2 metre DEM to a 15 metre grid for the model tends to smooth out linear features such as levee banks. Crest heights of the levee banks were separately extracted in GIS, resolved to a 15 metre grid and re-inserted into the hydraulic model grids. This process has been undertaken for all observable banks on the floodplain, including town flood banks, road embankments, causeways and blocking banks. Crest heights derived from the 2 metre DEM from LiDAR are expected to be sufficiently accurate for flood risk assessments, although error margins still need to be considered. No ground survey of crest banks was used for this study.
- **Approximation of wetland and channel depths where no elevation data are available.** There are numerous wetlands and creeks on the floodplain, submerged at normal pool level, for which limited or no elevation data are available (for example, some wetlands only have a single depth measurement in the centre). Since the model is solely used for modelling high flows greater than 100,000 ML/d, these channels are considered to have a minor contribution to flood conveyance. Alterations were made to the floodplain and channel elevations to incorporate best available data, but in many cases assumed depths had to be adopted.
- **Bathymetric survey of Ral Ral Creek.** Ral Ral Creek is one of the larger River Murray anabranches whose path is in a mostly longitudinal direction along the floodplain prior to its confluence with the main River Murray channel. Bathymetric survey of Ral Ral Creek was acquired for this project with elevations manually entered into the two-dimensional grid.
- **Minor creeks under the Sturt Highway between Renmark and Paringa.** Ground survey of the creeks in the vicinity of the bridges was obtained for the project. Bathymetric survey at this location was entered into the model to ensure that the conveyance capacity of this significant constraint was represented in the model.

In selected locations, one-dimensional model elements have been used to represent bridge openings to better represent the flow conditions through the structure. Survey data were obtained for five structures near Renmark: 21stStreet crossing over Bookmark Creek and the four structures along the Paringa Causeway (Sturt Highway between Renmark and Paringa) and bridge structures were inserted into the model at these locations. Other bridge structures, such as the Kingston-on-Murray Causeway, Paringa Bridge, Berri Bridge and Blanchetown Bridge were considered to be sufficiently large that they have not been included in the model explicitly. The lock and weir structures were not inserted into the model since they are fully removed for flows of 100,000 ML/d and above, and the parts of the structure remaining in the river are not considered a significant impediment to flow under flood conditions.

### 3.2.4 Boundary conditions

Boundary conditions describe the water level or flow conditions at the edges of the model. For subcritical flow conditions (such as in this study), incoming flow is specified as the upstream boundary condition and water level is specified as the downstream boundary condition.

MIKE FLOOD is a hydrodynamic model, that is, the flow and water level boundaries applied to the model can be varied over time. For flood studies, it is common practice to model a flow hydrograph which describes the variation of flow during a single flood event. In contrast, this study used the quasi-steady state approach whereby a constant flow rate is applied at the upstream boundary and a constant water level at the downstream boundary for each flow scenario to be modelled. A quasi-steady state approach was adopted for the following reasons: typical inflow hydrographs had not been determined for the River Murray such as through a hydrological study; the width of the floodplain meant that it would take several days of 'model time' for water levels to reach their maximum, leading to very long model run times; and review of previous major flood events, particularly the 1956 flood, demonstrated that it was possible that floods in the River Murray can peak at a steady level for three days or more.

Steady state conditions were determined to have occurred when the water level profile at the upstream end of each model had stabilized. It was assumed that if the changes in water level were less than 0.1 m in the last three hours of the model run, then the model had reached the steady state condition.

The quasi-steady state modelling approach is considered to provide a maximum estimate of the extent and depth of flooding on parts of the river floodplain away from the main channel. In some locations, such as wetlands on the outer extent of the floodplain, it can take several days for water to fill floodplain areas to a water level equal to the river channel. For flood peaks that are short in duration, it is possible that these areas on the floodplain away from the main channel will still be in the process of filling as the peak passes, thus never equalising to the same level as the channel. Similarly, areas behind overtopped levee banks have been allowed to fill. This may represent a maximum estimate of the extent or depth of flooding behind levee banks if the flood event is short or actions are taken to stem the inflow over the levee bank.

##### *3.2.4.1 Flow data*

There are no major tributaries to the River Murray in South Australia. Rivers such as the Marne, Bremer, Angas and Finniss Rivers flow into the River Murray from the eastern slopes of the Mount Lofty Ranges, however, their maximum flow and volume is small relative to floods in the Murray. Consequently, the maximum flow from a flood event in the River Murray will decrease, rather than increase, as it moves down the river in South Australia. Reduction of the flood peak will occur through attenuation, that is, the flattening out of the hydrograph through water moving into temporary floodplain storage, as the peak moves down the river. However, since hydrographs of flood events reaching South Australia can have long, flat rises in water level, in many cases very little attenuation of the hydrograph will occur and the flow rate recorded at Lock 1 will be nearly as high as that recorded at the border. The more rapid and 'peakier' the event, the more reduction of peak flow would be expected to occur.

Flow is measured at several locations on the River Murray in South Australia: at the South Australian border (Flow to SA), at each of the Locks and at Lyrup and Overland Corner (see Figure 2.1). Of these locations, Flow to SA has a long flow record and data have been rated well for high flows. The model sections upstream of Overland Corner were calibrated to events based on the flow recorded as Flow to SA, while the model sections between Overland Corner and Wellington were calibrated using recorded flow data at Lock 1.

For a single event, if significant attenuation of the flood peak is expected to occur, it may be appropriate to use a lower flow flood map for the downstream portion of the river.

##### *3.2.4.2 Water level data*

The sources for flood height data were DEWNR's Hydstra database and the SA Water backwater curves. Since the river is modelled as a series of six model sections, it is a requirement that the modelled water levels at each location where the models join will match. The most downstream model was run first, with the upstream water level calculated by the model; sequentially used as the downstream water level boundary condition for the adjacent model section. Where a gauging station was located at the model boundary and a recorded level was available for that flow scenario, recorded levels were used in preference. Historical flood levels were available for up to 35 locations on the SA Water backwater curves and up to 17 water level gauge locations.

At the downstream extent of the study area at Lake Alexandrina, a rating curve compiled from historic flood heights was used to select water levels for the range of flow scenarios.

### 3.2.5 Roughness

Roughness of the river bed or the floodplain affects the flow rate and level of water flowing down a river or over a floodplain. As the roughness of the channel or floodplain increases, the velocity of the water decreases, as does the flow rate for a given depth. The roughness is quantified in the models using a roughness coefficient, with the most commonly used unit being Manning's M (inverse of Manning's n). The smaller the value of the roughness coefficient the rougher the floodplain.

The roughness coefficient value usually forms the main tool which can be adjusted in the calibration process to achieve expected flood levels. Roughness values for the study area were assigned using the same grid format as elevation data. The selection of roughness values for channels and floodplains is a non-exact process. The choice of a suitable roughness value is guided by engineering texts with example photographs of streams and calculated roughness values and by the modeller's previous experience in calibrating models. For river channels, the roughness is dependent on factors such as the bed material (e.g. sand, boulders) and the thickness of vegetation on the banks. For floodplain areas, the roughness is often dependent on the vegetation or land use.

An aerial photograph of the study area was used to identify areas of different roughness and create a roughness coefficient map that can be used in the model. Identification of different vegetation types and land uses (e.g. salt pan, shrubs, brush box trees and agricultural land) was determined from the aerial photographs. An example of a roughness coefficient map is shown in Figure 3.2. The roughness coefficient values generally adopted for this study are presented in Table 3.1. The main channel roughness is expected to be smoother than typical values downstream of Mannum since it is less meandering and shallower than upstream sections. In addition, depending on the density and type of vegetation, roughness values outside of the typical range can be expected.

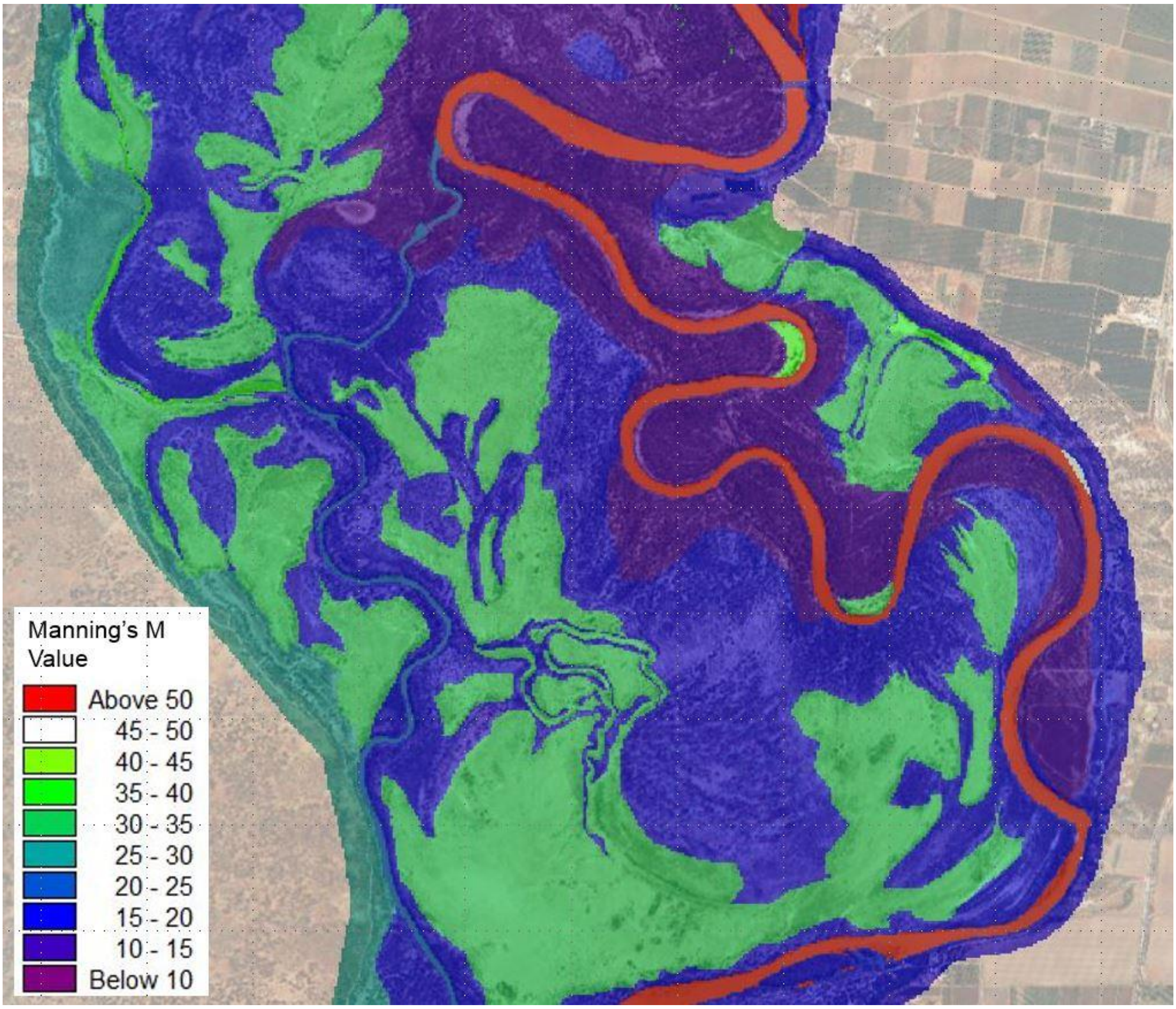



**Figure 3.2 Example of a roughness coefficient map**

**Table 3.1 Roughness coefficient (Manning's M) ranges used for calibration**

| Land use | Manning's M typical ranges | Ranges used for calibration |
|---|---|---|
| River Murray main channel | 40 – 50 | 50 – 60 |
| Minor channels | 20 – 40 | 20 – 40 |
| Agriculture (trees, vines) | 10 – 20 | 15 – 20 |
| Vegetated – small shrubs to medium density large trees | 6.25 – 28.50 | 10 – 20 |
| Salt pan, low-growing vegetation, degraded ground | 15.50 – 28.50 | 25 – 35 |

### 3.2.6 Eddy viscosity

Eddy viscosity is a parameter representing turbulence in the model, and along with the roughness coefficient it controls the distribution and direction of flow in the model. The MIKE model also requires either the "flux based" or "velocity based" eddy viscosity to be specified across the model domain. A velocity based eddy viscosity was used with a distribution of values across the model domain. The following eddy viscosity values were advised by the software developers for this study:

- 4.0 $m^2/s$ for all of the floodplain (recommended range for a 10–100 m grid size model is 1–10 $m^2/s$)
- 0.5 $m^2/s$ for the majority of river channels (upstream of Mannum)
- 0.2 $m^2/s$ for the river channel downstream of Mannum.

## 3.3 Model calibration and validation

The three historic flood events that were selected for calibration and validation were the floods of 1956, 1974 and 1992. These events represent the upper, middle and lower bounds of the flow range being modelled by this study, and for each event observed data were available across a range of gauges.

A summary of flow data used in this study for calibration and verification is provided in Table 3.2. For the section between Lyrup and Murtho, the 1993 event was used instead of 1992 due to better water level data being available from that event in that section of the river. Model sections between Wellington and Overland Corner have been calibrated to recorded flow at Lock 1, while sections between Overland Corner and Murtho are calibrated to the recorded flow at Flow to SA. The 1956 event is calibrated to the same flow throughout since the flow was only measured in one location for this event at Overland Corner. It can be seen that the maximum flow for the 1974 flood reduced by approximately 20,000 ML/d as the peak travelled downstream from the Flow to SA to Lock 1 monitoring site. The measured flow was similar for both locations in 1992.

The hydraulic model was first calibrated to the smallest historical flood event (1992) in order to calibrate parameters for the river channel. The 1956 event was then used to calibrate model parameters for the floodplain. Finally, the 1974 event was used as validation.

Table 3.3 shows the locations for which calibration data were available. The specific level values for the downstream boundary locations are also shown.

**Table 3.2 Summary of flow data used for calibration**

| Section | Model section name | Flow data used for calibration (ML/d) | | |
|---|---|---|---|---|
| | | 1992 event* | 1974 event | 1956 event |
| 1 | Wellington to Mannum | 97,300 | 162,700 | 341,000 |
| 2 | Mannum to Lock 1 | 97,300 | 162,700 | 341,000 |
| 3 | Lock 1 to Morgan | 97,300 | 162,700 | 341,000 |
| 4 | Morgan to Overland Corner | 97,300 | 162,700 | 341,000 |
| 5 | Overland Corner to Lyrup | 95,700 | 181,800 | 341,000 |
| 6 | Lyrup to Murtho | 111,700 | 181,800 | 341,000 |

*1993 upstream of Lyrup

**Table 3.3 The location (River km, see Fig. 2.1) of sites with recorded water level data used for model calibration and validation and downstream water level boundary used for each model section (marked with **)**

| Location | River km | 1992* | 1974 | 1956 |
|---|---|---|---|---|
| **Wellington**** | 80.5 | **1 m** | **1.4 m** | **2.56 m** |
| **Jervois** | 88.3 | | ✓ | ✓ |
| **Monteith** | 101.9 | | ✓ | ✓ |
| **Murray Bridge** | 114.0 | ✓ | ✓ | ✓ |
| **Mypolonga** | 126.0 | | ✓ | ✓ |
| **Mannum**** | 149.8 | **1.56 m** | **3.14 m** | **5.36 m** |
| **Purnong** | 191.8 | | ✓ | ✓ |
| **Swan Reach** | 254.8 | ✓ | ✓ | ✓ |
| **Lock 1**** | 274.3 | **4.85 m** | **6.81 m** | **9.73 m** |
| **Roonka Station** | 282.3 | | | ✓ |
| **Pine Gully** | 298.0 | | | ✓ |
| **Morgan**** | 319.5 | **7.14 m** | **8.57 m** | **11.38 m** |
| **Cadell** | 332.6 | | ✓ | ✓ |
| **Nickalapko** | 338.2 | | | ✓ |
| **Markaranka** | 349.9 | | | ✓ |
| **Lock 2** | 362.1 | ✓ | ✓ | ✓ |
| **Waikerie** | 382.9 | ✓ | ✓ | ✓ |
| **Overland Corner**** | 417.5 | **11.01 m** | **12.73 m** | **15.56 m** |
| **Lock 3** | 431.4 | ✓ | ✓ | ✓ |
| **Kingston Bridge** | 439.6 | | | ✓ |
| **Cobdogla** | 443.3 | | ✓ | ✓ |
| **Loveday** | 446.9 | ✓ | | ✓ |
| **Moorook** | 451.5 | | | ✓ |
| **New Residence** | 462.2 | | | ✓ |
| **Pyap** | 479.9 | | | ✓ |
| **Loxton** | 493.9 | ✓ | ✓ | ✓ |
| **Bookpurnong** | 504.4 | | | ✓ |
| **Lock 4** | 516.2 | ✓ | ✓ | ✓ |
| **Berri** | 525.7 | ✓ | ✓ | ✓ |
| **Lyrup**** | 537.7 | **15.78 m** | | **16.85 m** |
| **Settler's Bend** | 555.1 | | | ✓ |
| **Lock 5** | 562.4 | ✓ | ✓ | ✓ |
| **Renmark** | 567.4 | ✓ | ✓ | ✓ |
| **Murtho** | 570.7 | | | ✓ |

*1993 upstream of Lyrup
**downstream boundary locations

During calibration, the models assumed steady-state flow conditions, which means the water levels in the models are allowed sufficient time to equalise under the specified flow rate (if the changes in water level in the main channel were less than 0.1 m within the last three hours of the model run, the water level is assumed to be stabilized). The water levels simulated to occur for a specific flow rate were then compared to the recorded water levels for that flow rates. The calibration targeted to be within +/- 0.2 m of the recorded level. A summary of the difference in water levels across the calibration points is provided in Table 3.4, where it can be seen that the majority of the points for both the calibration and validation events were within +/- 0.1 m of the recorded level.

**Table 3.4 Calibration and validation statistics for the absolute difference between simulated and recorded water levels (m) for all sites**

| Statistics | Calibration | Validation |
|---|---|---|
| Minimum | 0.00 m | 0.00 m |
| 25th percentile | 0.03 m | 0.00 m |
| Median | 0.06 m | 0.02 m |
| 75th percentile | 0.11 m | 0.03 m |
| Maximum | 0.20 m | 0.21 m |

The modelled and the recorded water levels for Model Section 1 (Wellington to Mannum) and Section 4 (Morgan to Overland Corner) are shown in Figure 3.3 and Figure 3.4 respectively. It can be seen that a good calibration has been achieved for each of the events. Graphs for all sections are presented in Appendix A.

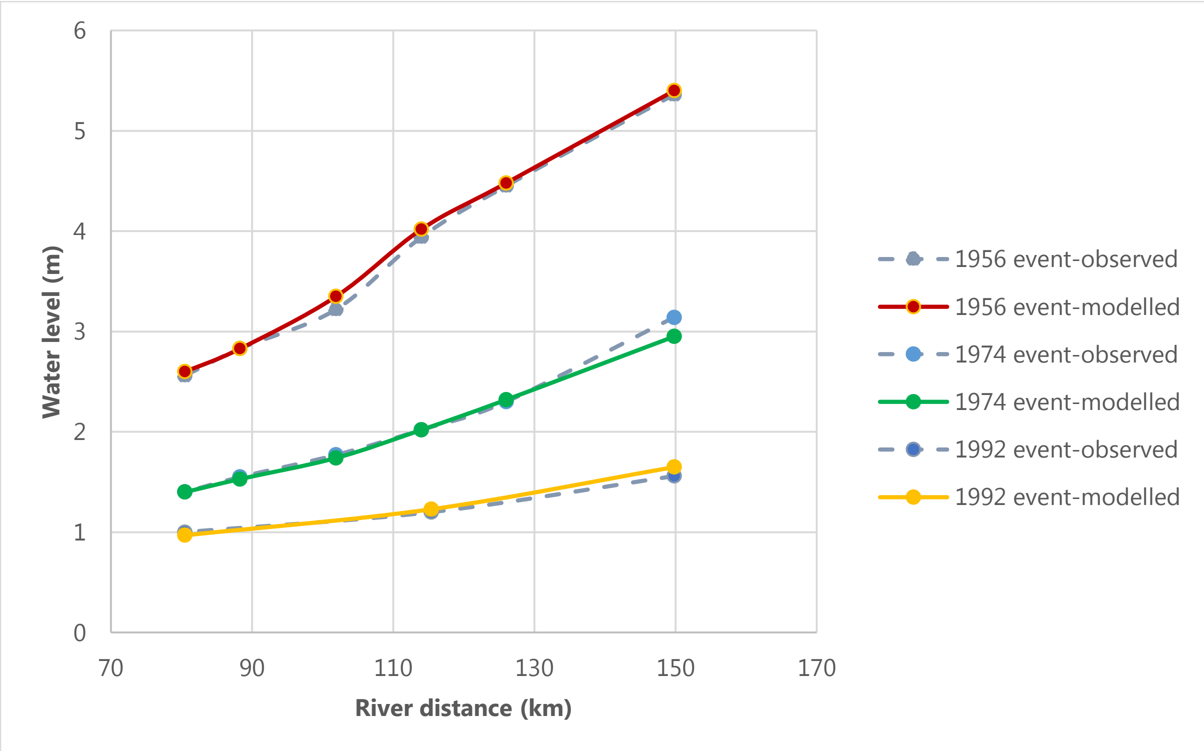



**Figure 3.3 Modelled and recorded water levels for Model Section 1 Wellington to Mannum**

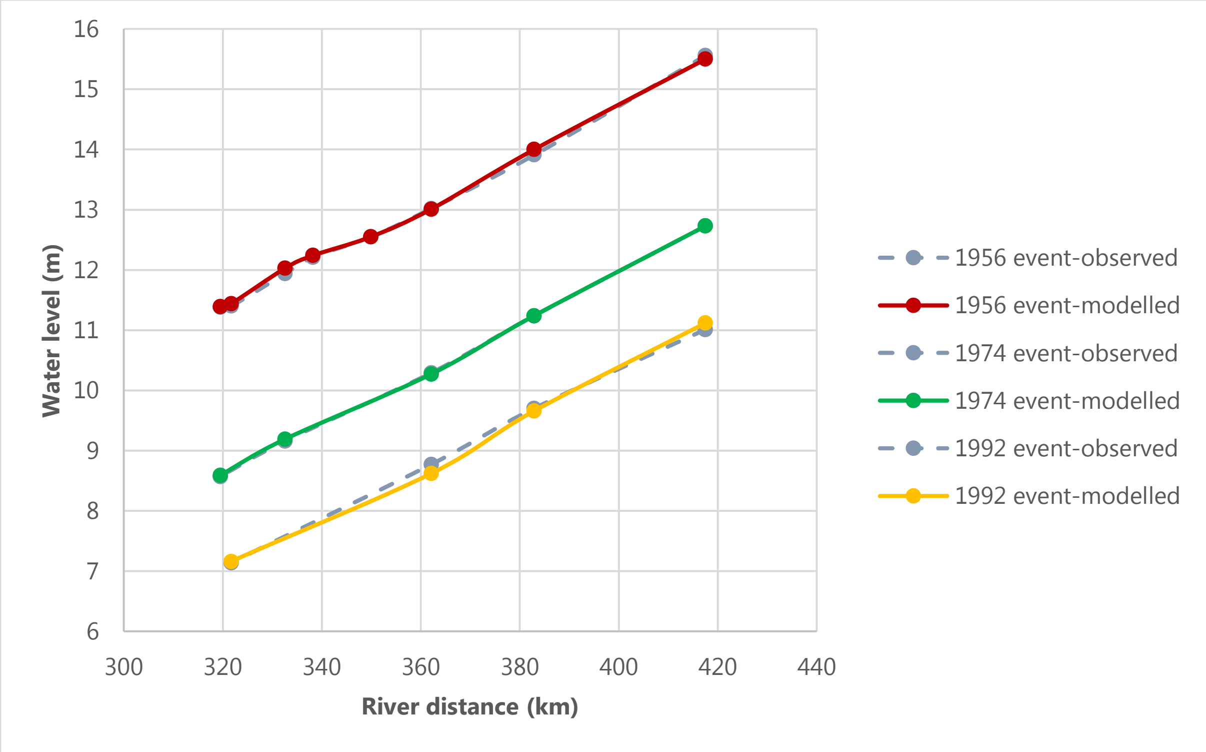



**Figure 3.4 Modelled and recorded water levels for Model Section 4 Morgan to Overland Corner**

## 3.4 Scenario modelling

The calibration process resulted in a set of roughness coefficients for each model section. Using these coefficients, the hydraulic models were run for a range of flow rates and inundation maps were derived for each flow rate. An example of an inundation map of the modelled 250,000 ML/d scenario for a section of the river is shown in Figure 3.6.

Model simulations for the following flow rates were run:

- 100,000 ML/d
- 120,000 ML/d
- 140,000 ML/d
- 160,000 ML/d
- 180,000 ML/d
- 200,000 ML/d
- 250,000 ML/d
- 300,000 ML/d
- 341,000 ML/d (1956 – highest flood on record)

In addition, rating curves for some 14 locations were developed in order to compare the modelled water levels for all scenarios with historical recorded water levels at each location. An example of rating curves for two locations in Model Section 4 (Morgan to Overland Corner) is shown in Figure 3.5. Rating curves for all sections are presented in Appendix B.

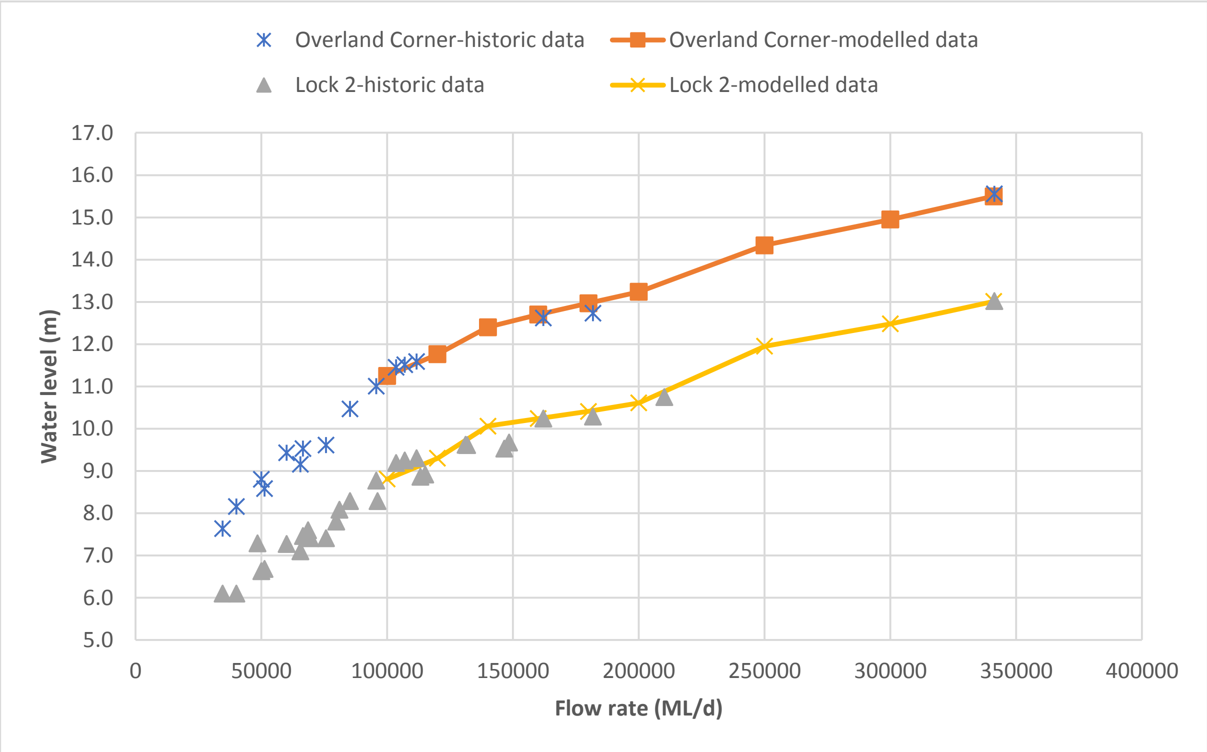



**Figure 3.5 Rating curves for Lock 2 and Overland Corner**

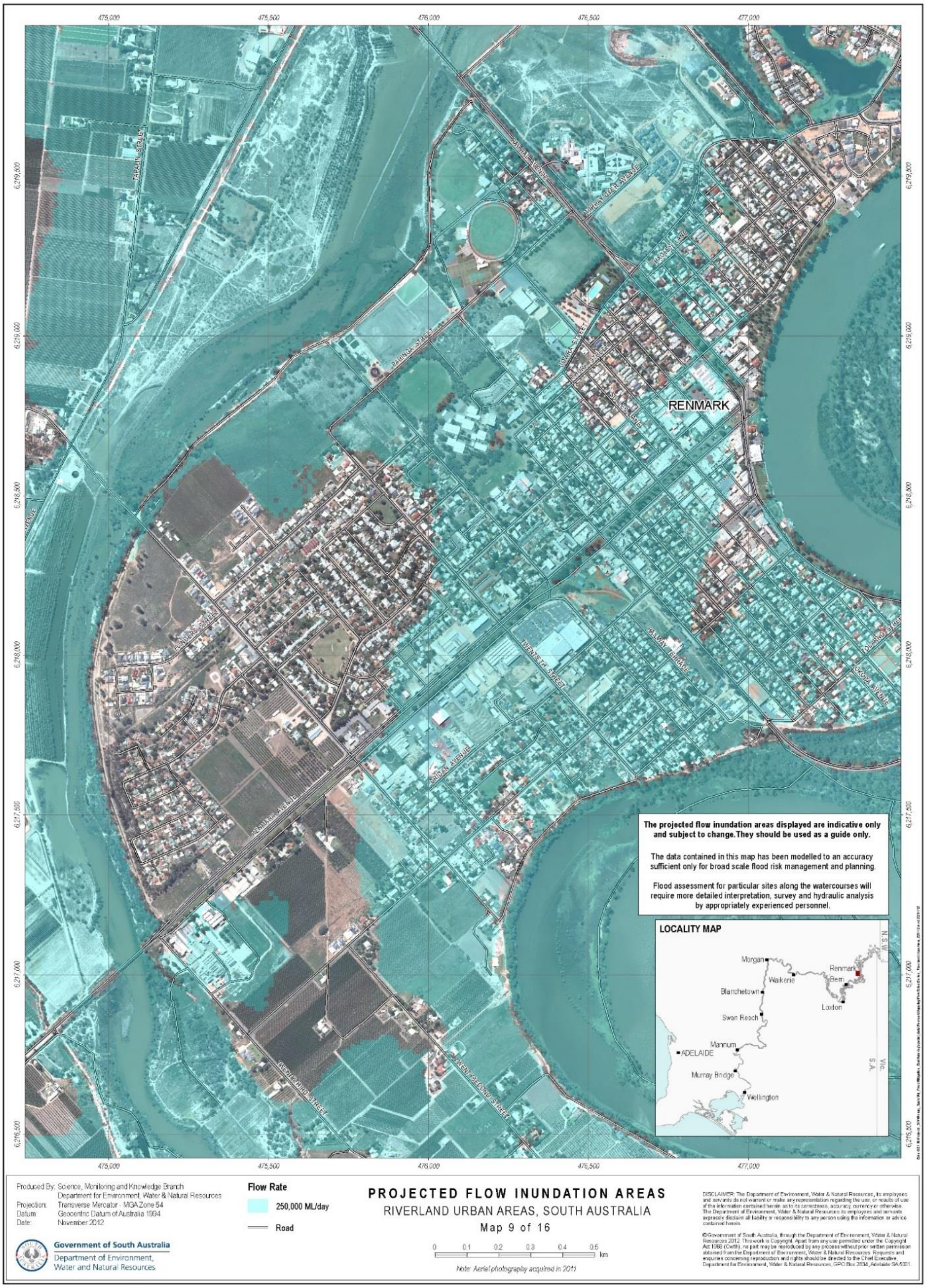



**Figure 3.6 An example of an inundation map of the modelled 250,000 ML/d scenario**

# 4 Considerations for use of flood inundation maps

Some important considerations for use of flood inundation maps are:

- Models use flow rates at Flow to SA (Murtho to Overland Corner sections) and Lock 1 (Overland Corner to Wellington sections). If an actual event significantly attenuates as it travels down the river it may be appropriate to refer to a lower flow flood map at the downstream end of the river. The amount of attenuation varies between events, for example the 1973 event was recorded at 131,100 ML/d (Flow to SA) and 122,000 ML/d (Lock 1), while 1974 recorded 181 800 ML/d (Flow to SA) and 162 700 ML/d (Lock 1).
- A model assumes that all inundated areas have stabilised to the given flow conditions. In most cases this is appropriate as a review of previous flood events demonstrated that floods in the River Murray can peak at a steady level for three days or more and the majority of wetlands are well connected to the river for flows above 100,000 ML/d. However, some wetlands and other backwaters may take some time to fill, potentially weeks, and in these cases the flood maps may overestimate inundation in some areas away from the main channel. The extent to which the inundation is overestimated depends on the shape of the hydrograph (the flatter the peak, the more time the backwaters have to fill to peak water level) and the maximum flow (typically for higher flow rates, the connections between backwaters and the main channel are larger so there is less lag time for the backwaters to fill).
- In some locations (for example in Berri as shown in Figure 4.1) the modelled inundation reaches the edge of coverage of the DEM, consequently the actual extent of inundation will extend past that shown on the flood maps. This situation is made clear on the flood maps using pink lines when the inundation extent reaches the edge of the DEM. In the figure, the hatched area shows the modelled extent of inundation and the rainbow colours are the height-coloured DEM. The exceedance of the modelled inundation extent compared to the 1956 flood line is likely due to data limitations in the DEM and the digitisation of the 1956 flood extent, as well as the influence of actions to reduce the inundation extent during the flood which are not included in the model, such as sandbagging.

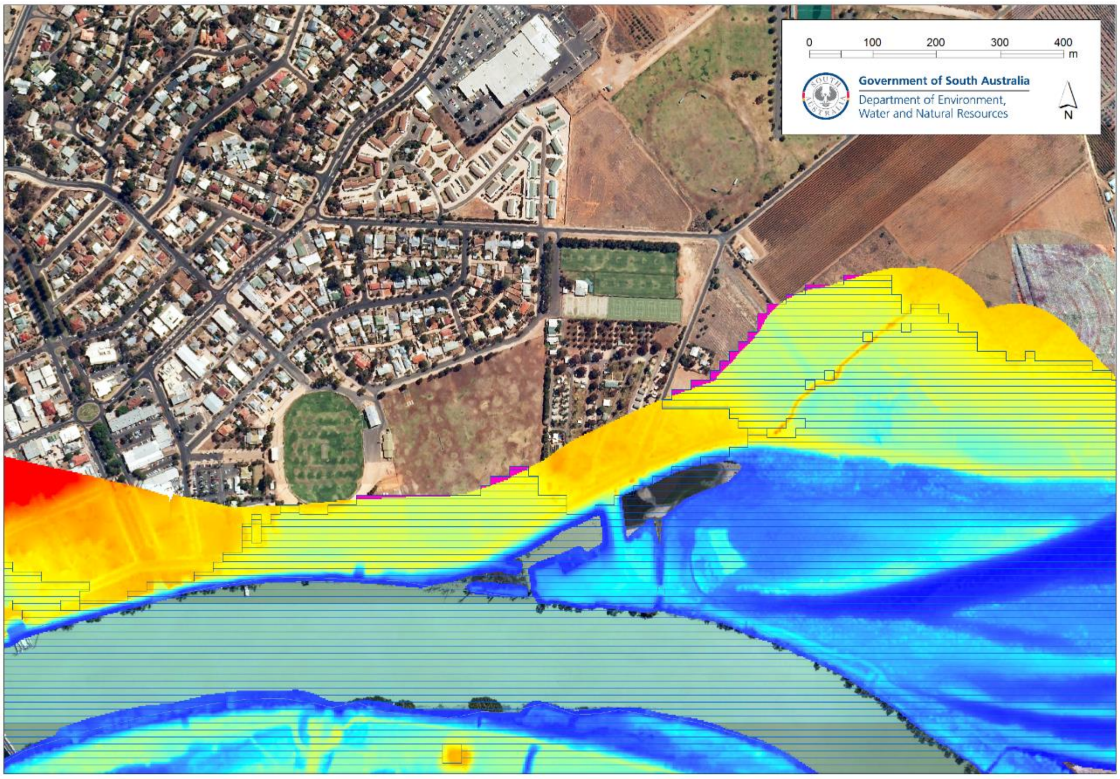



**Figure 4.1 Pink shading indicates where the flood extent has reached the edge of the DEM (1956 flood at Berri) (colour shading is floodplain DEM, hatched is inundation extent)**

The following considerations apply specifically to levee banks:

- The model and flood maps do not take into account freeboard, which is the designed amount of additional height between the top of the levee bank and the maximum water level of the flood for which levee bank is designed to protect against. Typically, levee banks are designed to have between 300 mm and 600 mm of freeboard above the design flood event to enable extra height to protect against the effects of wind, wave action, settlement, erosion, model uncertainty and other variations in levee and water level. The model compares modelled water levels with the ground/levee crest level in the floodplain and channel elevation file and overtopping is shown where the water level exceeds the elevation of the levee. There may be locations where the flood mapping shows that a levee is high enough to protect a location from flooding but the freeboard may actually be very small in that location. In practice, assessment of the adequacy of levee banks would also need to consider freeboard requirements and not only whether the levee is shown as being overtopped in the flood maps. The backwater curves can be used to confirm the expected amount of freeboard for specific levees.
- It has also been assumed that inundated areas behind levee banks have filled to the maximum possible extent. In some cases this may not be valid in real life as actions may be taken to arrest the spread of flooding.
- It has been assumed that no works have been undertaken in advance of a flood to raise levee banks or any other temporary works.
- Crest heights of levees in the model have incorporated ‘low spots’ visible in the 2 metre DEM. In some cases these low spots are quite narrow, and there would be a reasonable expectation that they would be filled in advance of a coming flood. Nonetheless, these have been retained in the model (with inundation allowed to occur behind these points) to highlight where locations of risk occur in the levees. An example is shown in Figure 4.2, where the model shows that a narrow low spot near the treatment ponds can lead to a wide area being inundated. The modelled inundation extent needs to be interpreted with caution.


**Figure 4.2 The modelled flood extent indicates where widespread inundation occurs behind localised overtopping of levee banks (120,000 ML/d flood at Murray Bridge)**

- The flood maps only represent levee bank failure due to overtopping. In reality, the banks may also fail at lower river water level due to piping or slumping. Assessment of possible bank failure due to these failure mechanisms and the resultant flood impact is beyond the scope of this project. Areas at risk due to these failure mechanisms have not been mapped.
- As the inundation dataset is a product derived from a DEM, the polygon outline does not smoothly follow the natural shape of the terrain. It is important that users exercise caution when interpreting the extent. Use of the dataset for analytical purposes at any scale less than the model grid size of 15 m (a map scale of approximately 1:10,000) is not recommended.

# 5 Conclusions

Extensive work has been undertaken to develop flood inundation maps of the River Murray floodplains within South Australia in response to deficiencies in the coverage of existing information available for flood preparedness and warning.

The maps are intended to supplement existing information on river levels, such as that provided by the River Murray backwater curves and SA Water predictions, rather than being a replacement for these.

The models were successfully calibrated and validated against the following flood events:

- 1992–93 event (Flow to SA – 111,700 ML/d)
- 1974 event (Flow to SA – 181,800 ML/d)
- 1956 event (Flow to SA – 341,000 ML/d)

Model results were compared with recorded water levels for each event along the Murray River. An extremely good match was observed for the majority of historical flood events with most results being within 0.1 m of the recorded levels.

# 6 References

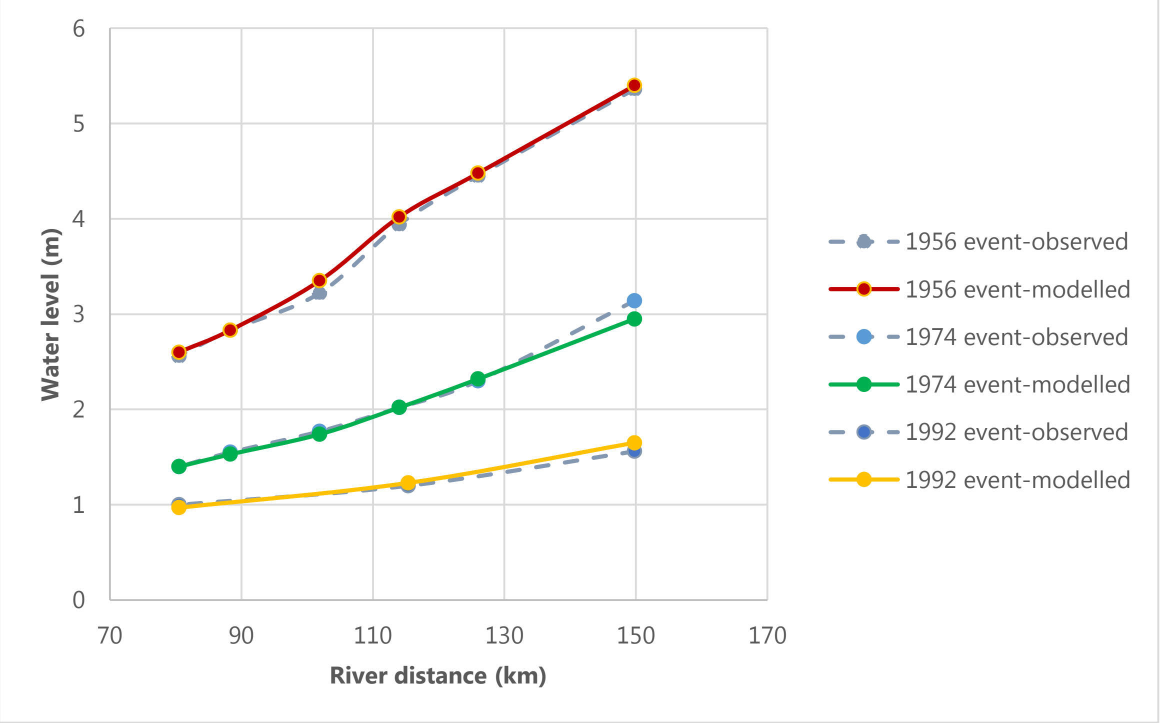
Austin, JM and Gallant, JC (2010). Stitching elevation and bathymetry data for the Murray River and Lower Lakes, South Australia. CSIRO: Water for a Healthy Country National Research Flagship.

Maunsell (2008). Renmark Paringa Flood Mitigation Study. Maunsell Australia in association with Ann Shaw Rungie Consulting.

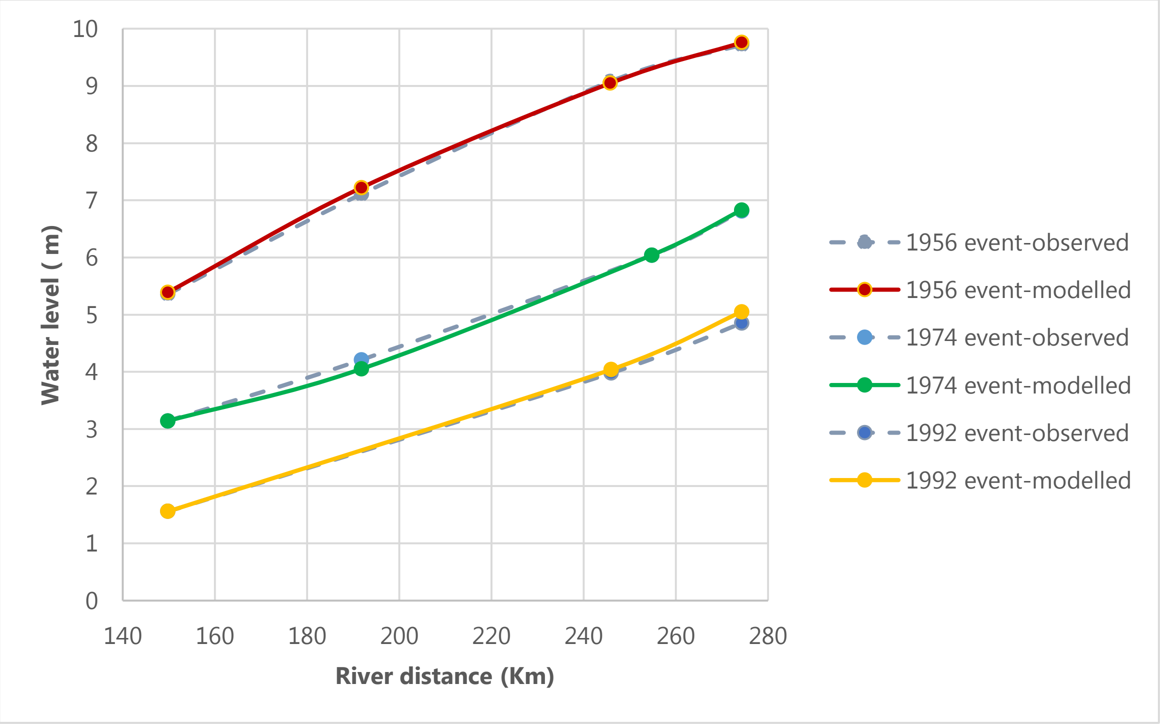
Overton, IC, McEwan, K, and Sherrah, JR (2006). The River Murray Floodplain Inundation Model – Hume Dam to Lower Lakes. CSIRO Water for a Healthy Country Technical Report 2006. CSIRO: Canberra.

# 7 Appendices

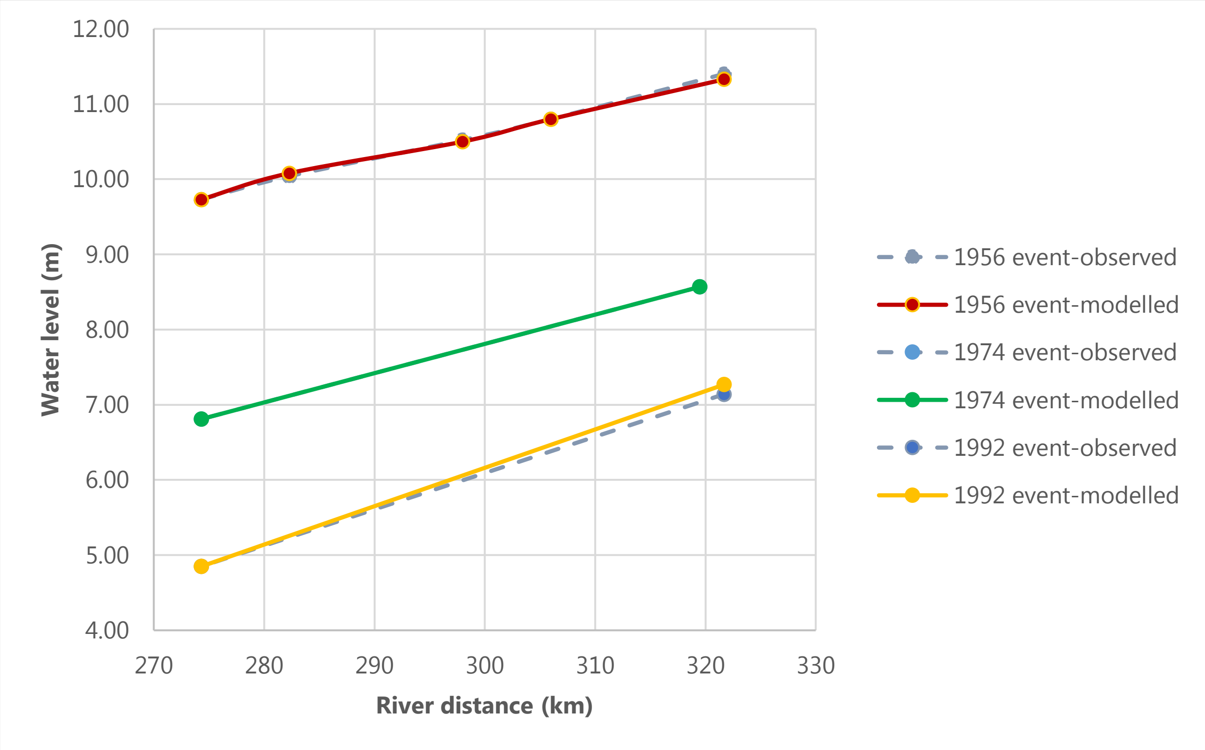
## Appendix A Modelled and recorded water levels



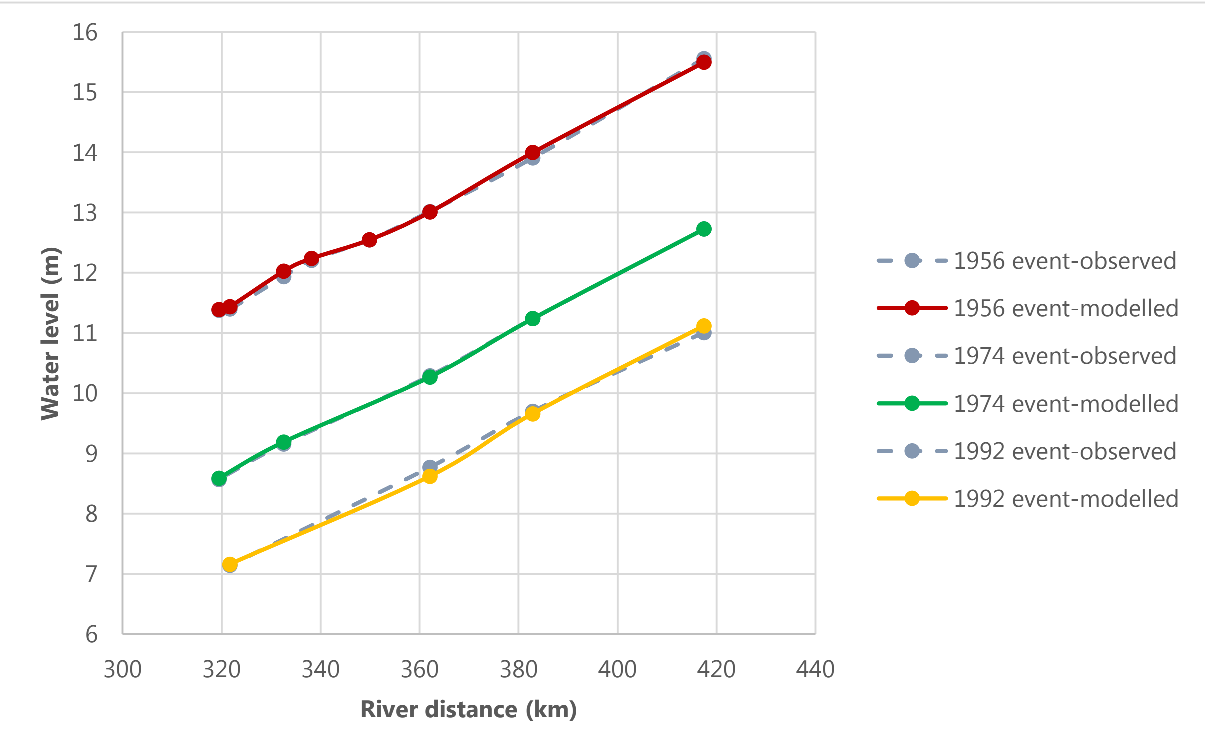

**Model Section 1. Wellington to Mannum**



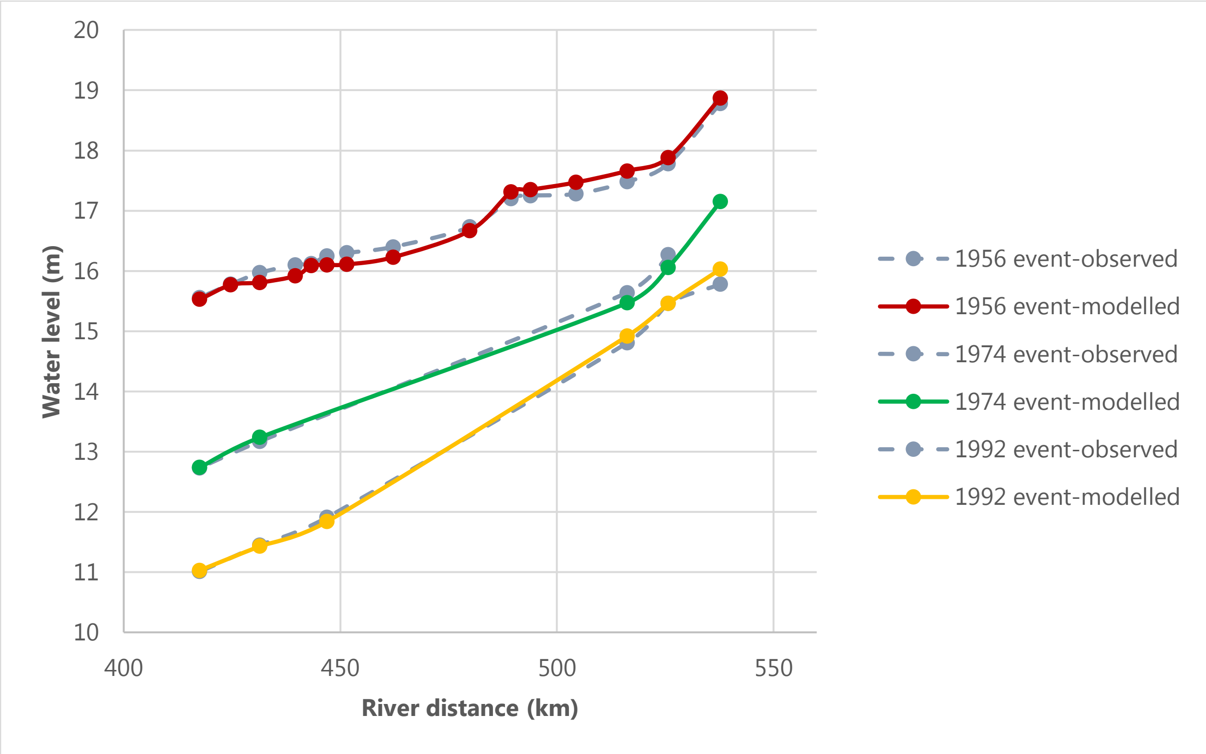

**Model Section 2. Mannum to Lock 1**



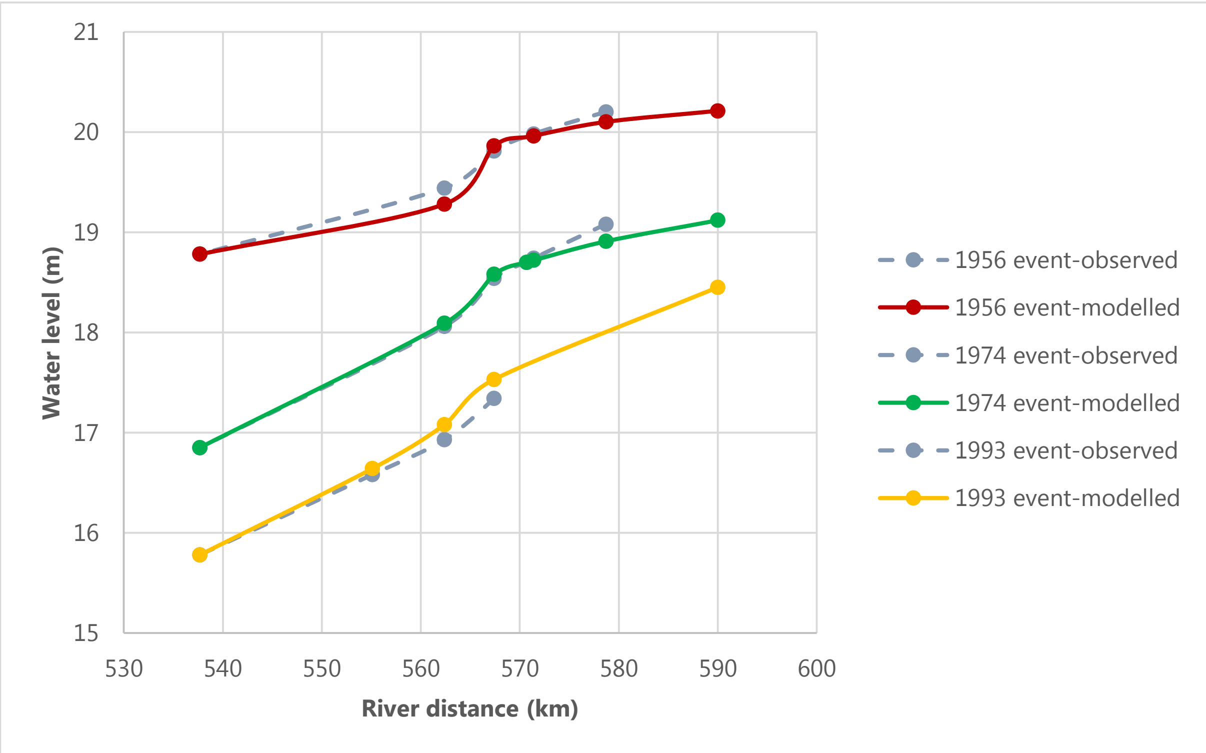

**Model Section 3. Lock 1 to Morgan**




**Model Section 4. Morgan to Overland Corner**

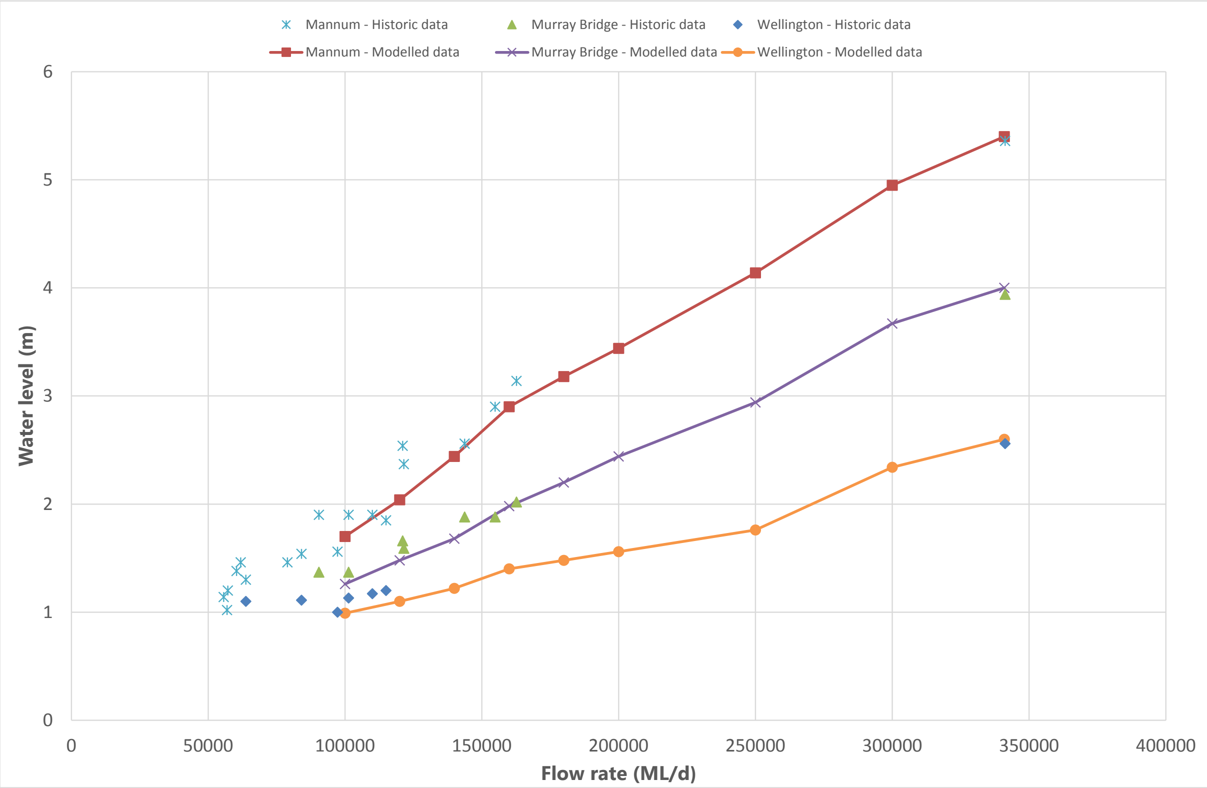



**Model Section 5. Overland Corner to Lyrup**

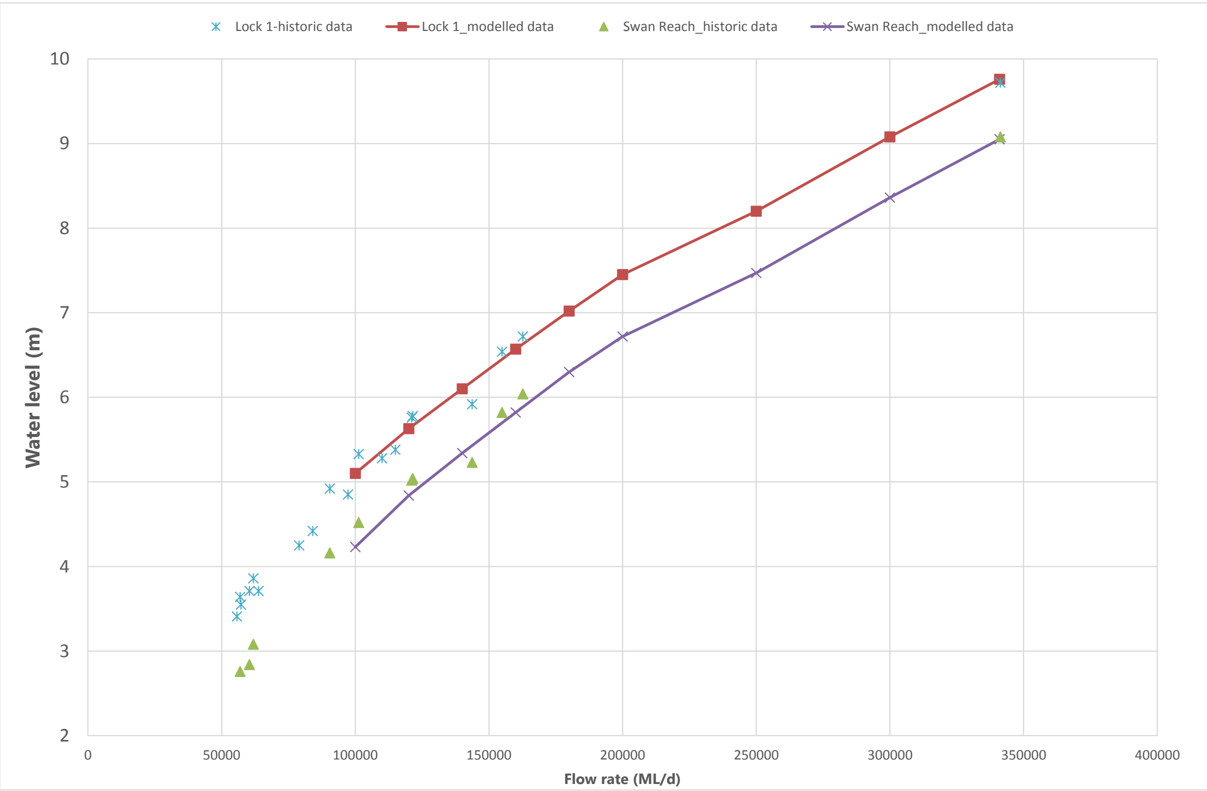



**Model Section 6. Lyrup to Murtho**

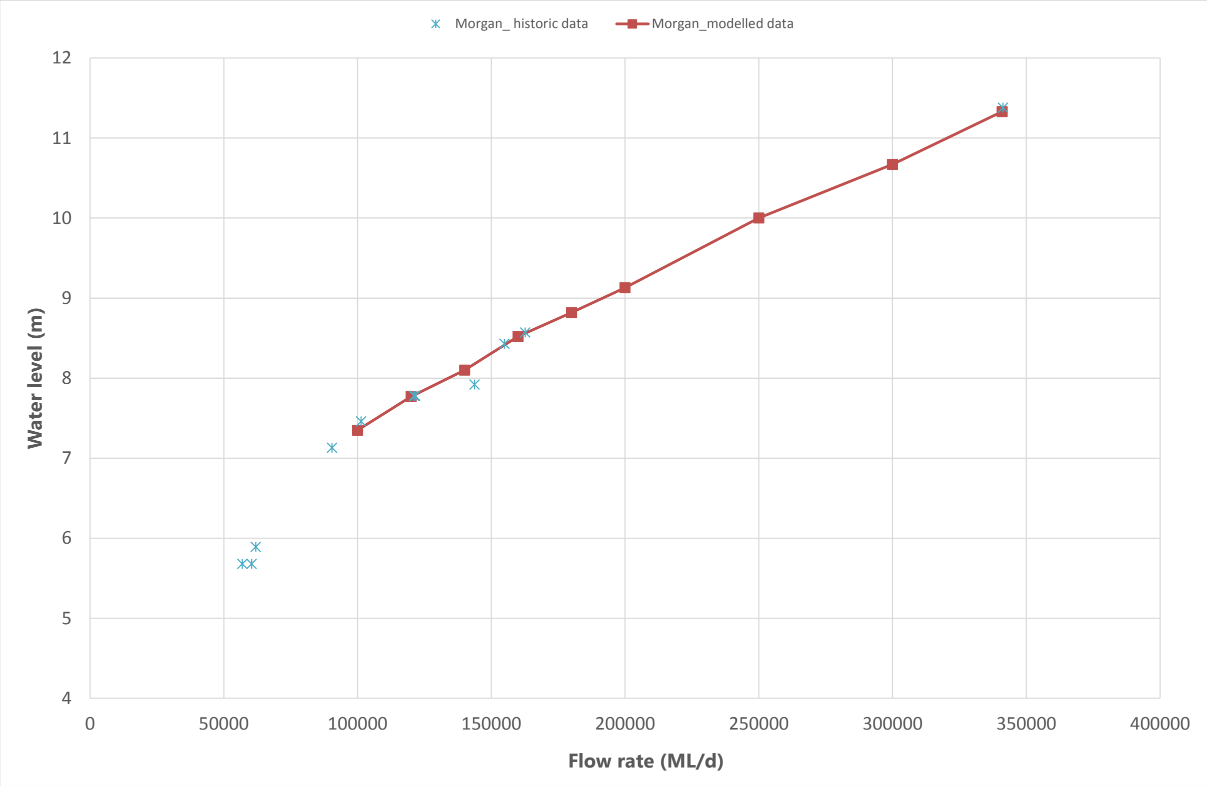
# Appendix B Rating curves



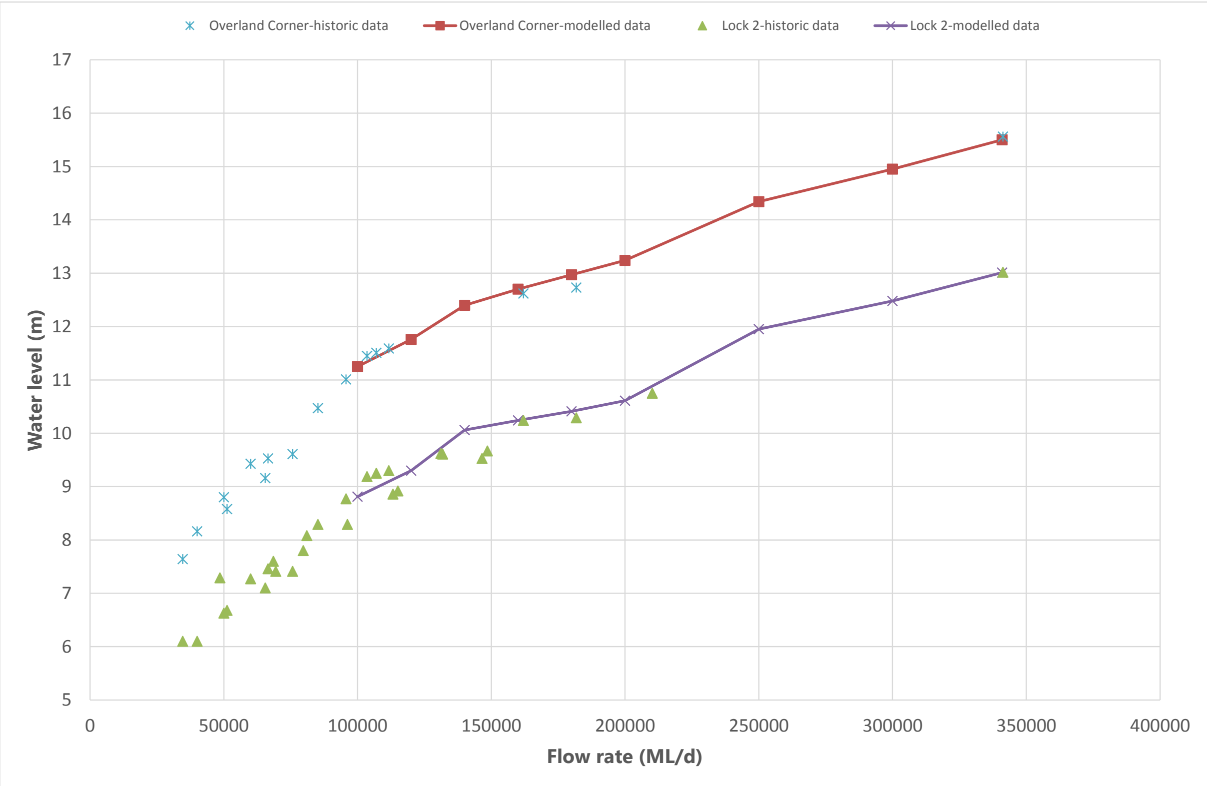

**Rating curves for Wellington, Murray Bridge and Mannum**



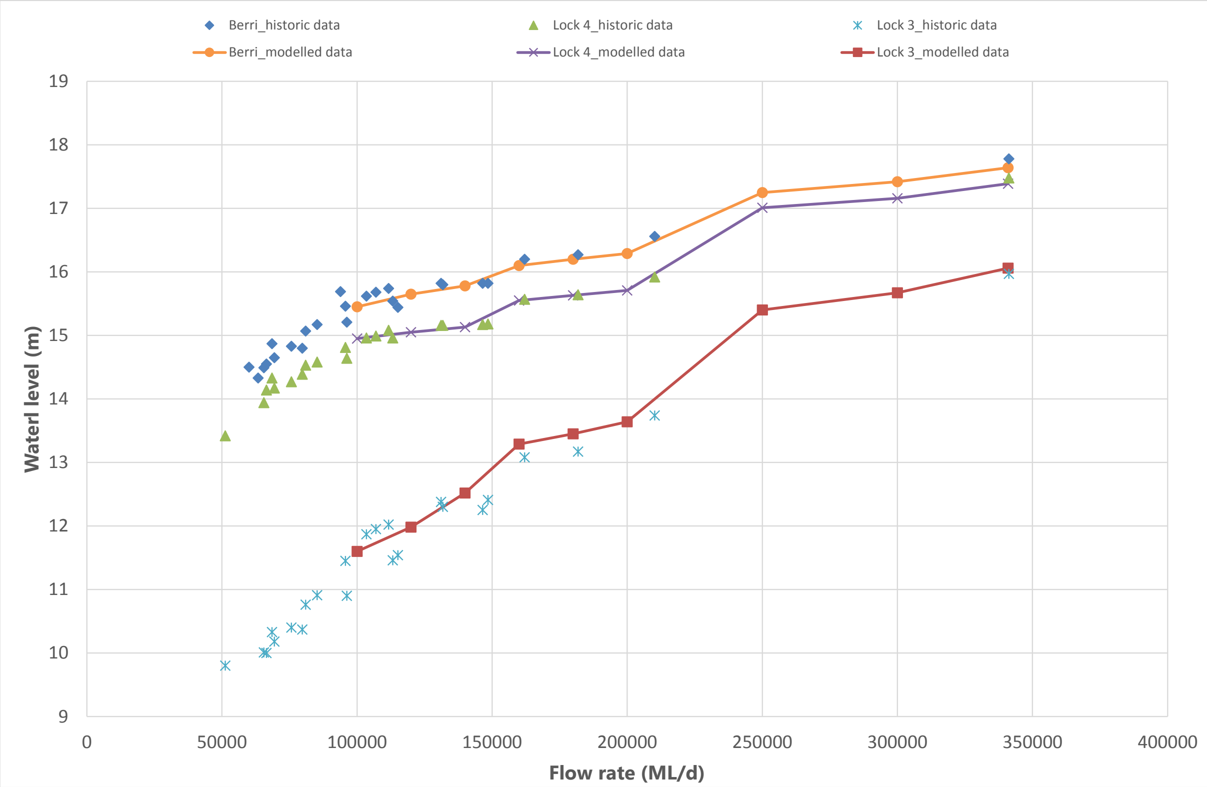

**Rating curves for Swan Reach and Lock 1**



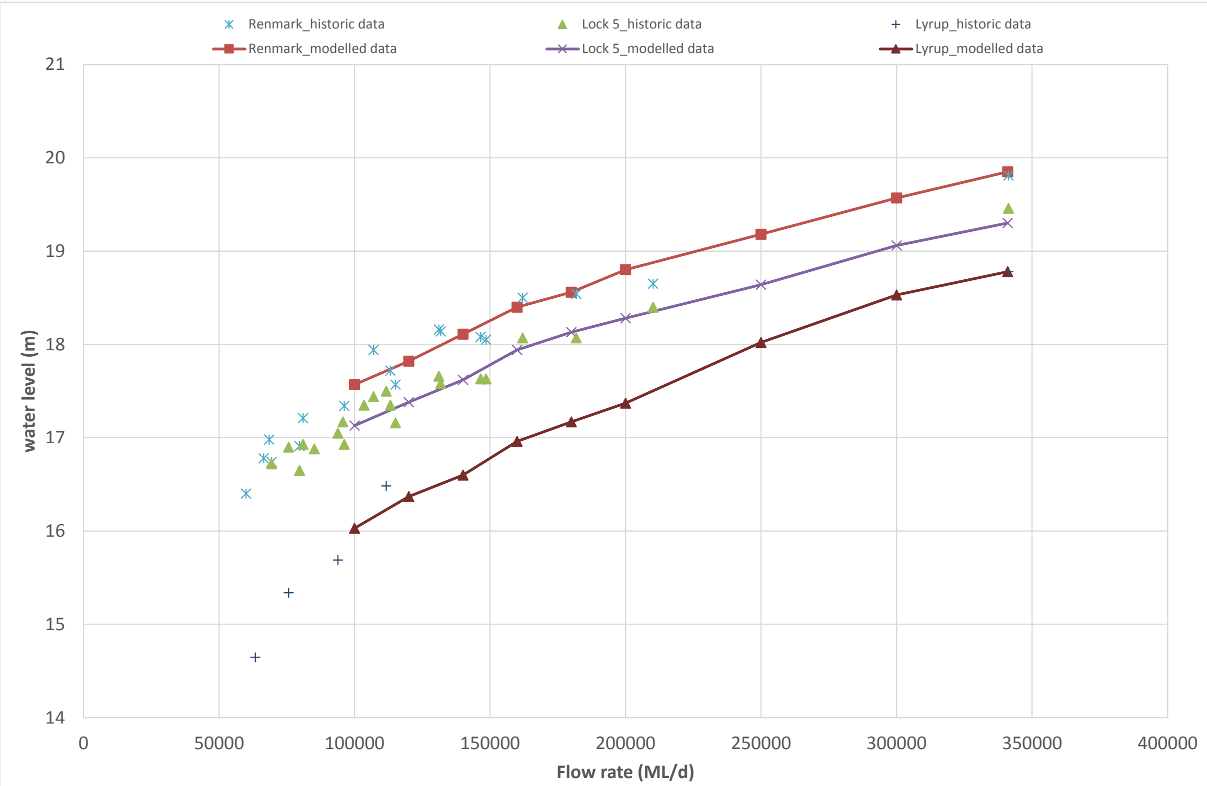

**Rating curves for Morgan**




**Rating curves for Lock 2 and Overland Corner**




**Rating curves for Lock 3, Lock 4 and Berri**




**Rating curves for Lyrup, Lock 5 and Renmark**

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Department of Environment, Water and Natural Resources