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Lake Albert Salinity Investigations

Model Calibration (November 2011 – June 2013) Report

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March 2014

Lake Albert Salinity Investigations

Model Setup and Calibration Report

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Title :	Lake Albert Salinity Investigations – Model Calibration (Nov 2011 – June, 2013) Report
Author :	Rohan Hudson
Synopsis :	This report details the ongoing calibration and validation of a numerical model capable of predicting water level and salinity in the Lower Lakes and Coorong for the 19 month period from: 1st November 2011 to 15th June, 2013.The model includes an accurate representation of the Barrages and can simulate salt mass change in Lake Albert. The model has been developed to assist in aiding management decisions aimed at reducing the salinity in Lake Albert.

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1 Introduction

BMT WBM was commissioned by the South Australian Department of Environment, Water and Natural Resources (DEWNR) to undertake a range of studies aimed at improving the understanding of salinity transport and mixing mechanisms in Lake Albert.

Following a period of severe drought in the Murray Darling Basin, high rainfall through 2010 and early 2011, resulted in significant flows in both the Darling and Murray Rivers for the first time in over a decade. These high flows refilled the Lower Lakes and flushed considerable amounts of salt from Lake Alexandrina. While salinity levels in Lake Albert have been significantly reduced, its terminal nature has prevented complete flushing and salinity levels remain considerably higher than long term pre-drought averages.

In December 2012, an investigation into options for improving Lake Albert's water quality was initiated by the South Australian Government. Potential management actions currently under consideration for the reduction of salinity include:

- Dredging of Narrung Narrows;
- Removal or modification of the Causeway;
- Connection to the Coorong;
- Permanent water level structure in Narrung Narrows; and
- Water level manipulations.

The aim of this investigation is to increase understanding of salinity dynamics within Lake Albert and to provide an assessment of the proposed management options. This report describes the development and calibration of a numerical model capable of simulating the complex Coorong, Lower Lakes and Murray Mouth (CLLMM) system. The calibration period broadly covers the 19 months (1st November 2011 to 15th June, 2013); though due to a lack of field data, the primary calibration period is from 12th December, 2012 to the 15th June, 2013. The report contains an update of information provided in the two previous calibration and validation reports, namely:

- BMT WBM (2011b) which presents the model calibration for the five months between 25th November, 2010 to 1st May, 2011.
- BMT WBM (2012) which presents the model validation for the six months between 1st May to 1st November, 2011.

Additional calibration was undertaken as part of the Lake Albert salinity investigation to further increase confidence in model predictions and also to test whether improvements to the TUFLOW FV model software would alter the performance of the existing models, and their ability to match observed water levels and salt concentrations in the Lower Lakes and Coorong.

1.1 Background

The Lower Lakes (Lake Alexandrina and Lake Albert) are located at the terminus of Australia's largest river system, the Murray-Darling. The Lakes are separated from the Coorong by five barrages (Goolwa, Mundoo, Boundary Creek, Ewe Island and Tauwitchere) built in the 1930's (Figure 1-1). The Coorong is connected to the Southern Ocean (Encounter Bay) at the Murray

Mouth. A detailed background to the study area and recent events is provided in BMT WBM (2013a). An outline of this report is provided below in the following sections.

1.2 Outline of Study and Summary of Previous Reports

This study comprises a number of sub-studies including:

- Preliminary Investigations (i.e. desktop study as outlined in Section 1.2.1);
- Model Calibration (this report);
- Model Scenario Schematisation and Initial Testing (i.e. setup of the model to represent the five proposed management options and initial (12 month) scenario testing; and
- Three year scenario testing (i.e. testing of six scenarios (including the base case) for a range of different environmental conditions to assess the performance of the proposed management options).

1.2.1 Lake Albert Salinity Reduction Study - Preliminary Investigations

The report provides detail of a desktop investigation used to provide an initial assessment of a number of potential management options aimed at improving salinity levels within Lake Albert..

The report contains:

- A description of the environmental characteristics of Lake Albert including a review of long-term water level and salinity data sets, the relationship between lake level (stage), lake surface area and storage volume, a summary of the rainfall and evaporation influences on the system and quantification of changes to mass of salt between April 2011 and February 2013;
- A summary review of previous studies that characterise the hydrodynamics and salinity dynamics of Lake Albert. The review focuses on extracting information that may assist in the assessment of the five management options currently being considered to enhance salt export from Lake Albert. Further relevant details (including figures and summary tables) from the previous studies are presented in Appendix A of the report;
- A conceptual model of the key factors that influence the salinity dynamics of Lake Albert. Quantification of key drivers of salt mass change is provided to assist in the evaluation of the potential management options;
- A description of important features of a numerical model that would be required to accurately quantify the five management options. The report details the benefits of model calibration and validation as well as detailing a suggested matrix of model scenarios. These scenarios will provide an envelope of salinity forecasts, enabling a robust assessment of likely salinity levels in Lake Albert under a range of environmental conditions.
- A summary of key investigation outcomes and relevant conclusions and recommendations;
- Further relevant details of previous reports (including figures and summary tables); and
- A review of the data available for future model scenarios and calibration exercises.

An initial assessment of the proposed management options indicated that a channel connecting Lake Albert to the Coorong capable of transferring 30 GL/month is likely to be able to reduce salinity values within Lake Albert to below 1800 µS/cm within 6 to 12 months of operation. This option would also assist in the reduction of salinity in the Coorong and would be less dependent on Lock 1 flows to be effective.

This report and a number of the references included in the report provide good background to the key hydrodynamic processes and environmental drivers of the Lower Lakes and Coorong system.

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STUDY SITE AREA AND HYDRAULIC CONTROL LOCATIONS	1-1	A

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1.3 Structure of Report

This report documents the study as follows:

Section 1 – provides an introduction to the study and a background to recent events and changes to the Lower Lakes and Coorong.

Section 2 – provides a description of the available datasets including boundary condition data, water level and salinity data and available bathymetry.

Section 3 – provides a description of the model setup including a description of the model components (hydrodynamic (including structures), wave and morphology modules) their interactions and configuration for this project. Details of the model boundary conditions including structure representations and model initial conditions are also provided.

Section 4 – describes the calibration objectives and available calibration parameters. Also described is the importance of suitable barrage/structure representation and a comparison of observed data to model predictions for water levels and salinity at a number of locations throughout the study area. A comparison of model data to Coorong salinity transect collected in late-March, indicates that the model is capable of reproducing observed salinity gradients in the Coorong.

Section 5 – contains a discussion of the achieved model calibration, the suitability of the model for use in other investigations and a discussion of further studies that would increase confidence in model results. It also presents the calculated model barrage discharge and a calculation of changes to salt mass in Lake Albert over the calibration period.

2 Available Data

2.1 Introduction

In order to develop and calibrate a numerical model a sufficient amount of data must be available. The required data can be broken down into that used for model setup and that used in calibration / verification.

Data used for model setup includes:

- Bathymetry data (refer Section 2.3 & 2.4);
- River Murray inflows (refer Section 3.5.1);
- Offshore water levels (tides) (refer Section 3.5.3);
- Direct net rainfall – evaporation (refer Section 3.5.2);
- Wind speed and direction (refer Section 3.5.4);
- Offshore wave data (refer Section 3.5.6);
- Local catchment inflows (refer Section 3.5.7 & 3.5.8);
- Barrage operations (refer Section 0);
- Spatial distribution of salinity (refer Section 3.6.2).

Data used for model calibration / verification includes:

- Water level time-series (see below);
- Salinity time-series (see below);
- A salinity transect along the Coorong (see Section 4.4.4);
- Regular Murray Mouth survey bathymetry data (refer Section 2.4);

An examination of the available data revealed that there is sufficient data for model calibration. While the availability of observed flow (ADCP) dataset could further improve confidence in model calibration, there is sufficient water level and salinity data available to assess the performance of the model.

2.2 DEWNR Water Level and Salinity Data

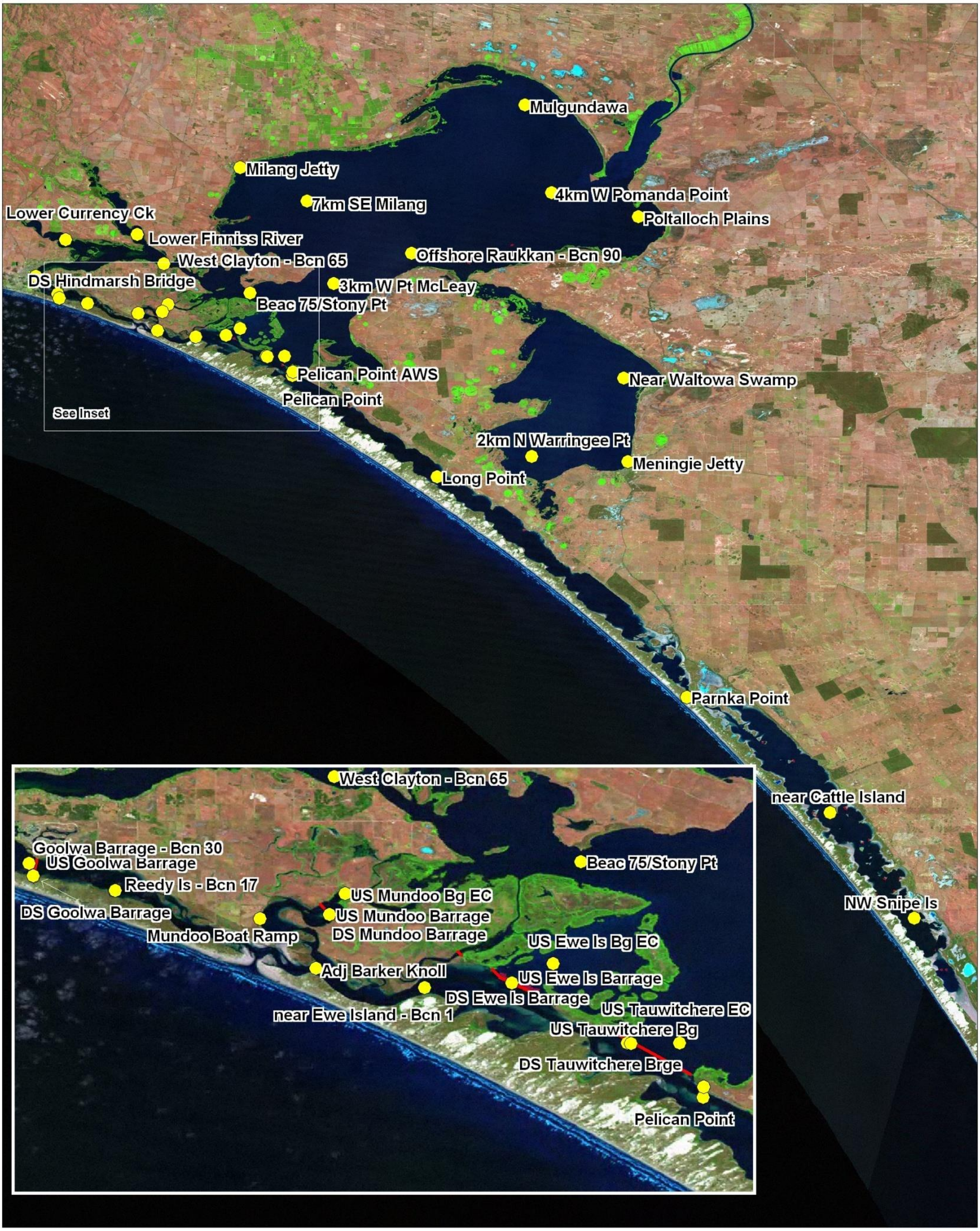
A series of continuous water level and salinity records collected by DEWNR were available for a number of locations in the Lower Lakes and Coorong. A summary of the data quality of the available gauges in the Lower Lakes is presented in Table 2-1 and a list of gauges in the Coorong is presented in Table 2-2. The location of the gauges used in the model calibration is presented in Figure 2-1. Graphs of the observed data (compared to model predictions) are presented in Section 4. A number of adjustments were necessary to ensure data consistency between gauges. These were made by comparing individual gauge data to averages of the surrounding gauges and then adjusting incrementally until daily averaged data of each gauge was within 1-2 cm the adjacent gauges.

Table 2-1 Available Lower Lakes Water Level and Salinity Data

Gauge Number	Name	Type	Comment
A4261153	Waltowa Swamp	WL & EC	Data quality appears to be mostly good
A4260630	Meningie Jetty	WL & EC	Data quality appears to be mostly good
A4261155	Warringee Point	WL & EC	Data quality appears to be good
A4260575	Poltalloch Plains	WL & EC	WL data appears 5cm too high before 1/1/2013
A4261158	4km W Pomanda Point	WL & EC	EC data is ok. WL data appears 5cm too high. Missing or spurious WL data 12/9/2012 – 30/4/2013.
A4260574	near Mulgundawa	WL & EC	Data quality appears to be good. No data supplied after 10/1/2013.
A4261133	Beacon 90 - offshore Raukkan	WL & EC	Data quality appears to be good.
A4260524	Milang Jetty	WL & EC	Data quality appears to be good.
A4261157	7km SE Milang	WL & EC	WL data appears ~2cm too low. Station closed 28/3/2013.
A4261156	3km W Point McLeay	WL & EC	EC data is ok. WL is 4cm too high before 1/1/2013
A4261207	US Tauwitchere Bg EC	EC	Data appears to be good. No data after 12/3/2013
A4260527	Tauwitchere Barrage US	WL	Data quality appears to be good.
A4261206	US Ewe Isl Bg EC	EC	Data quality appears to be ok.
A4261047	Ewe Island Barrage US	WL	Data quality appears to be good.
A4261129	Beacon 75 - 500m South Stony Point	EC	Data is ok. No data after 17/10/2012.
A4261205	US Boundary Ck EC	EC	Not used. Insufficient model resolution in this area.
A4261245	Boundary Creek Barrage US	WL	Not used. Insufficient model resolution in this area.
A4261124	West Clayton - Beacon 65	WL	Data quality appears to be good.
A4261123	DS Hindmarsh Bridge - Bcn 23	WL	Data quality appears to be good
A4261122	Goolwa Barrage - Beacon 20	EC	Data quality appears to be good.
A4261034	Goolwa Barrage US	WL	Data quality appears to be good

Table 2-2 Available Coorong Water Level and Salinity Data

Gauge Number	Name	Type	Comment
A42610525	Goolwa Barrage DS	WL	Data appears to be good.
A4261036	Beacon 17 - Reedy Island	WL & EC	EC data appears spurious in Jan, Feb & May-Jul2012. WL data is good, no data before 17/11/2011.
A4261039	Adjacent Barker Knoll	WL & EC	Data quality appears to be good.
A4261043	Beacon 1 - near Ewe Island	WL & EC	Data quality appears to be ok, spurious WL's occur April-Nov 2012.
A4261044	Boundary Creek Barrage DS	WL	Not used. Insufficient model resolution in this area.
A4261046	Ewe Island Barrage DS	WL	Gauge does not read below 0mAHD. No data after 12/3/2013.
A4261048	Tauwitchere Barrage DS	WL	Data quality appears to be reasonable. Gauge does not read below 0mAHD.
A4261041	Mundoo Barrage DS	WL	WL data is good.
A4261042	Mundoo Barrage US	WL	Data quality appears to be good.
A4261128	Mundoo Boat Ramp	WL & EC	No WL data 26/3-16/5/2012 or EC data 12/4-16/5/2012. Spurious EC data in Nov 2012.
A4261204	Us Mundoo Bg EC	EC	Data quality appears to be good
A4261134	Beacon 19 - Pelican Point	WL & EC	EC data appears to be good. WL data appears 8cm too high. Spurious WL data: 19/1-12/2/2012 & 10/2-27/2/2013. No WL data after 12/3/2013
A4261135	Long Point	WL & EC	EC data appears ok. WL data appears ok,
A4260633	Parnka Point	WL & EC	EC data appears spurious for much of record. WL data appears 8cm too high.
A4261209	near Cattle Island	WL & EC	EC data looks reasonable, though step changes adjustments are noted. WL data appears ok
A4261165	NW Snipe Island	WL & EC	EC data looks reasonable, though step changes adjustments are noted. WL data looks 2cm too low.



Title:
LOCATION OF LEVEL AND SALINITY GAUGES

Figure: 2-1

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2.3 Lake and Coorong Bathymetry Data

Bathymetry for the Lower Lakes and Coorong (excluding the Murray Mouth and South Lagoon) were provided by DEWNR in the form of a 10 metre by 10 metre resolution Digital Elevation Model (DEM).

The DEM was generated by combining the following three (3) datasets:

1. Bed levels in Lakes Alexandrina and Albert, Goolwa and Mundoo Channels were derived from single beam echo soundings undertaken by SA Water during May 2004. These data are expected to have a typical accuracy of +/- 0.1 metre for all bed elevations below -0.25 m AHD;
2. Bed levels in the area to the north of Pomanda Island, including the lower reaches of the Murray River were derived from multi beam echo soundings undertaken by SA Water during November 2006. These data are expected to have a typical accuracy of +/- 0.1 metre for all bed elevations below -0.25m AHD; and
3. LiDAR data covering the fringes of the Lower Lakes and Goolwa Channel captured in April 2008, at a time when the water level was at -0.5 m AHD. This means that ground elevations above -0.5 m AHD are generally reliable for this dataset. The accuracy of the LiDAR data is typically +/- 0.15 m AHD.

Bathymetry of the South Lagoon is based on 22 cross-sections collected sometime prior to 2002 (exact date is unknown). Interpolation of these cross-sections to pick up bathymetric features between the available cross-sections is based on aerial photography collected in February 2008 as detailed in BMT WBM (2010a). Some additional bathymetric data was obtained during salinity surveys on the 22nd April and 16th December, 2009. SA DENR commissioned the collection of additional bathymetry data in the southern half of the Coorong South Lagoon in 2010 which is described in BMT WBM (2010b) and has been used in this study. Bathymetry along the channel connecting the North and South Lagoon (Parnka Point / Hell's Gate area) is based on survey data collected in July and September 2009 and included in a DEM produced by BMT WBM as described in BMT WBM (2009).

The construction of three regulators/bunds at Narrung, Clayton and Currency Creek has altered the bathymetry in these locations. A brief description of the structures including construction, proposed removal dates and the potential influence on bathymetry and hydrodynamics is given below.

Narrung – constructed April 2008, breached in September 2010 with further removal in June and July 2011). Additional survey data collected in October 2011 was provided by DENR and used to update the model mesh elevations in this area.

Clayton – constructed April 2009, partly removed in September 2010 and completely removed by June 2012. It is understood that excavation commenced on Monday 14 November 2011 and was completed by the end of February. Some survey data of the remaining (emergent) structure following removal of the northern half of the structure was provided for use in this study. However, no hydrosuvey of bed levels surrounding the structure were provided which introduces uncertainties into the model.

Currency Creek – constructed in September 2009 and removed in 2013. Measured water levels upstream and downstream of the regulator indicate that there has been significant settlement and erosion of the structure and the design sill level is no longer appropriate. The lack of suitable up-to-date survey data introduces uncertainties into the model for that area.

2.4 Murray Mouth Bathymetry Data

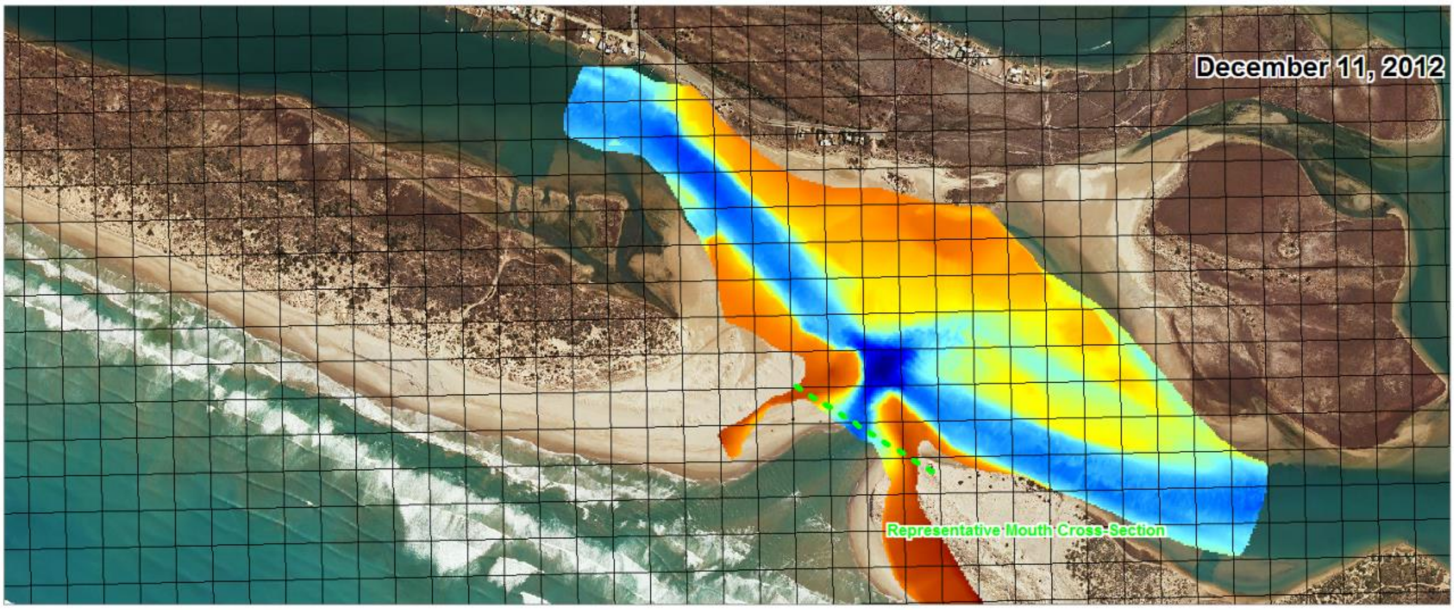
Regular detailed surveys of the Murray Mouth and inner mouth area have been undertaken by SA Water since late 1999 with a frequency of at least 2-3 months since 2001 (DWLBC/BMT WBM, 2008). A Murray Mouth bathymetric survey collected on the 11th December, 2012 is presented in Figure 2-2 and was used for the initial model bathymetry for the model calibration which started on the 12th December, 2012 (which coincides with available initial model conditions).

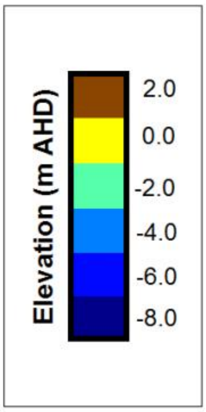
Additional Murray Mouth survey data was taken on the 5th February, 20th March, 7th May and 18th June, 2013. Cross-sections of the Murray Mouth bathymetry for all five dates at the location shown in Figure 2-2 are presented in Figure 4-41.

2.5 Encounter Bay and Offshore Bathymetry Data

Offshore bathymetry for Encounter Bay and the Murray Mouth were based on a combination of the 2005 edition of Geoscience Australia's 250 metre resolution DEM "Australian bathymetry and topography grid" (http://www.ga.gov.au/meta/ANZCW0703013116.html#citeinfo) and the previous offshore mesh adopted in the previous morphology study described in WBM/L&T (2003).

It should be noted that the offshore model mesh uses nearshore bathymetry based on an idealised shore normal beach profile. Aurecon (2009) indicates that some 18 beach cross-shore profiles are available at approximately 10 km intervals between Cape Jaffa and the Murray Mouth however the report does not provide details of when they were collected. While these data were not available for use in this study, it should be considered for use in subsequent studies (where possible).





Title:

Murray Mouth Bathymetry Data, 11 December, 2012

Figure: **2-2**

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N

0 0.5 1km

Approx. Scale

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3 Model Setup

3.1 Model Configuration

The model comprises a combination of hydrodynamics (TUFLOW-FV), waves (SWAN) and morphology (TUFLOW-MORPH). The geometric flexible mesh used by TUFLOW-FV to describe the model area covers the Lower Lakes (Lake Alexandrina and Lake Albert), the Coorong, the Murray Mouth and adjacent coast. The model mesh, which has been developed and applied to many projects is presented in Figure 3-1 and further described in Section 3.3. Due to a lack of sediment data, only a small area of the mesh was defined as being morphologically active, which includes the Murray Mouth, adjacent coastal zone and a section of the Coorong Channel from near Reedy Island to Pelican Point. That region incorporates the main areas where morphological change may affect the propagation of tides into and out of the Coorong.

The SWAN wave model performs calculations on a series of nested grids; these are shown on Figure 3-2. The outermost grid extends offshore to incorporate the deep water location where data were provided by BMT ARGOSS from a global wave model (see Section 3.5.6). Wave model simulations on the outermost grid are executed and the results used to define boundary conditions (waves) on the next smallest (intermediate) grid which is also executed to provide boundary conditions for the innermost (nested) grid. Wave simulations on the innermost grid execute interactively with TUFLOW-FV/MORPH. The nested SWAN simulation passes wave height, direction, period and force conditions to TUFLOW, and TUFLOW passes back resultant bathymetry and currents. This interaction allows representation of the following processes:

- Wave-current interactions;
- Wave generated currents (longshore currents and wave setup);
- Wave stirring of sediments;
- Sediment transport in the direction of waves; and
- Bathymetry updates in both the hydrodynamic and wave models.

The barrages at Goolwa, Mundoo, Ewe Island, Boundary Creek and Tauwitchere have been represented within the TUFLOW-FV model using a special structure element that defines the relationship between flow and a given upstream and downstream water level.

A more detailed description of the hydrodynamic (TUFLOW-FV), wave (SWAN) morphology (TUFLOW-MORPH) model, and structure representation is given below.

Title:

TUFLOW-FV Mesh

Figure: 3.1

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BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 10 20km

Approx. Scale

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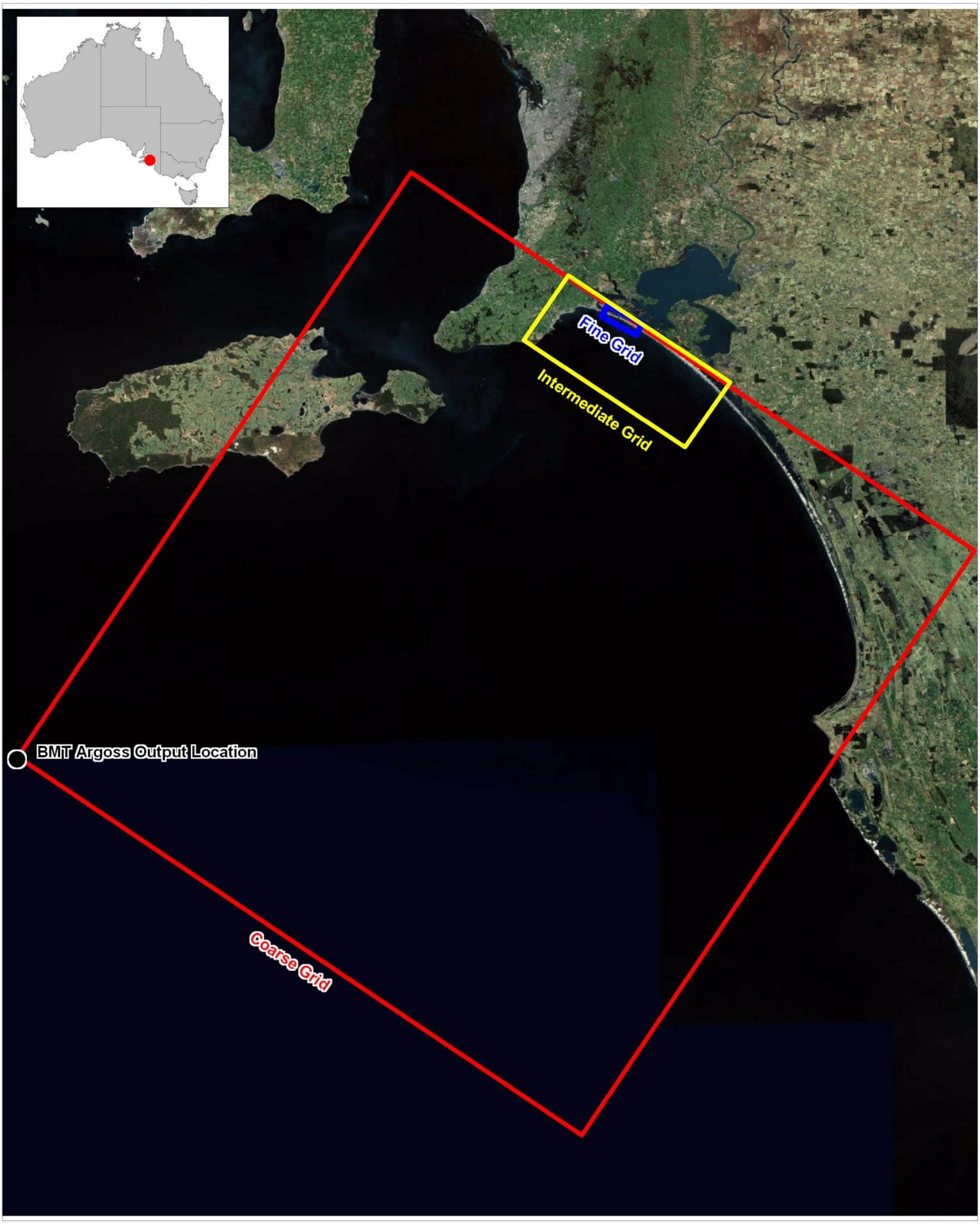

Title:

Location of Coarse, Intermediate and Fine Wave Grids

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0 40 80km

Approx. Scale

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3.2 Model Description

A description of the individual model components and their interaction is given below.

3.2.1 Hydrodynamic Model (TUFLOW-FV)

TUFLOW-FV is a two dimensional finite volume model code that solves the conservative integral form of the non-linear shallow water equations (NLSWE) (i.e. assuming that pressure varies hydrostatically with depth), including viscous flux terms and source terms for Coriolis force, bottom-friction and various surface and volume stresses. The model is currently fully operational as a 2-dimensional NLWSE solver, and has recently been extended to include a 3-dimensional NLSWE solver including baroclinic forcing, which is important for resolving vertical stratification processes.

The scheme is also capable of simulating the advection and dispersion of multiple scalar constituents (e.g. salinity, temperature) within the model domain. Bed friction is modelled using a Manning's roughness formulation and Coriolis force is also included in the model formulation. The spatial domain (or study area extents) is discretised using contiguous, non-overlapping irregular triangular and quadrilateral "cells". Advantages of an irregular flexible mesh include:

- The ability to smoothly resolve bathymetric features of varying spatial scales (e.g. dredged channels adjacent to broad shoaled areas);
- The ability to smoothly and flexibly resolve boundaries such as coastlines; and
- The ability to adjust model resolution to suit the requirements of particular parts of the model domain without resorting to a "nesting" approach.

The flexible mesh approach has significant benefits when applied to study areas involving complex coastlines lakes and rivers, varying bathymetries and sharply varying flow and scalar concentration gradients. TUFLOW-FV presently accommodates a wide variety of boundary conditions, including the water level, flow, net rainfall – evaporation, internal structures, wind, wave stress and salinity boundaries important for the present study. TUFLOW-FV also links to the coastal sediment transport model (TUFLOW-MORPH) to account for the movement of bed sediments through erosion and accretion processes, and is linked to the SWAN wave model to provide dynamic wave radiation stresses.

The assumption of a well-mixed water body can be adequately represented by the two-dimensional TUFLOW-FV hydrodynamic model. The three dimensional processes driven by salinity and / or thermal stratification are not significant issues for this study, even though they might occur from time to time if wind mixing is inadequate to ensure a uniform water column.

3.2.2 Wave Model (SWAN)

The SWAN (Simulating WAves Nearshore) spectral wave model computes irregular waves in nearshore areas, based on variables such as deep water wave conditions, wind, bottom topography, currents and tides. SWAN may be configured to explicitly account for all relevant processes of propagation, refraction, generation by wind, interactions between the waves and decay by breaking and bottom friction with diffraction being included in an approximate manner (DUT, 2011). Wave information as represented by the significant wave height, period and mean direction or the two-dimensional wave spectrum is often required at a coastal location for coastal applications and modelling investigations.

Detailed wave information is not available for the Murray Mouth. While a wave-rider buoy is located at Cape-de-Coudic (near Kangaroo Island), the absence of wave direction data meant that it was unsuitable for the study. Modelled wave data extracted from a regional (WAM) wave model was obtained from BMT ARGOSS for use as the offshore wave boundary condition. A coarse (500 m) wave model was used to transfer the wave data to an intermediate (100 m) wave grid as shown on Figure 3-2. Boundary condition data extracted from this intermediate grid was then used to provide boundary forcing the fine (30 m) grid as part of a dynamic simulation of waves, hydrodynamics and sediment transport. This innermost SWAN simulation passes wave height, direction, period and force information to TUFLOW-FV, and TUFLOW-FV passes back information on updated bathymetry and currents. This interaction allows representation of a range of important processes previously described in Section 3.1.

SWAN simulates the propagation of offshore waves in to the entrance, considering the effects of, bathymetry, currents, bottom friction and wave breaking. Further details of the wave model development including bathymetry, geometry and boundary conditions are provided in the following sections.

3.2.3 Morphodynamic Model (TUFLOW-MORPH)

The morphodynamic model, TUFLOW-MORPH, is an extension of the hydrodynamic model TUFLOW-FV. The morphodynamic component aims to simulate the typical patterns of sediment transport as governed by the hydrodynamics and applied boundary forcing. The processes and characteristics incorporated into the model include:

1. Sediment transport and bed-evolution (sedimentation and erosion);
2. Slumping of unstable slopes;
3. Sediment classes and ability to spatially vary sediment properties according to material type;
4. Bed load transport rates calculated using van Rijn formulation; and
5. Threshold velocity for bed load transport calculated based on Particle size distributions (D10, D50 and D90).

Sediment Transport Calculation

The TUFLOW-MORPH library of sediment transport algorithms was used. The adopted algorithm for this model relies heavily on the latest methods proposed by Van Rijn (2007 a-d). The methods have the following features:

- Bed load is proportional to velocity to the power of ~2.5;
- Suspended load is strongly dependant on particle size and current velocity;
- Suspended load is under-predicted for low flow conditions (<0.6 m/s); and
- The method can calculate rates for multiple sediment fractions.

Using these methods, it has been noted (van Rijn, 2007d) that reasonable validated morphological models can be developed by applying a scaling factor of between 0.25 and 3.0 to the calculated sediment transport rates. For this study, a sediment scale factor of 0.25 was applied to all active morphologic areas though as discussed in Section 4.5 replicating morphologic change was not a focus of the study.

Bed Update Scheme

The integral form of the Exner equation was solved to calculate the change in bed level in each cell at each morphological time step. The sediment fluxes at each of the cell's faces were integrated to obtain the change in bed mass, and divided by the cell area and sediment bulk density to obtain the change in bed level.

The bed load flux at each cell face was determined using an upwinded advection scheme.

3.2.4 Hydrodynamic, Wave and Sediment Model Interactions

The model system adopted by TUFLOW-FV is a combined system of separate hydrodynamic, morphological (sediment) and coastal wave models. A flowchart representing the system is shown in Figure 3-3. The system incorporates the following interactions:

- Passage of hydrodynamics to the morphological model to enable calculation of sediment transport rates;
- Passage of hydrodynamics to the wave model to represent wave-current interactions;
- Passage of wave forces to the hydrodynamic model, driving wave set-up and longshore currents;
- Passage of the wave field (height, period, direction) to the morphological model to calculate wave related sediment transport and stirring effects; and
- Passage of updated bathymetry from the morphological model back to the hydrodynamic and wave models to enable suitably adjusted calculation of the hydrodynamic and wave fields.

As the necessary time step for explicit solution of the bed update scheme is much larger (in the order of minutes) than that for hydrodynamics (typically 5 seconds or less), a morphological time step is specified and governs the frequency with which the sediment transport calculation is undertaken.

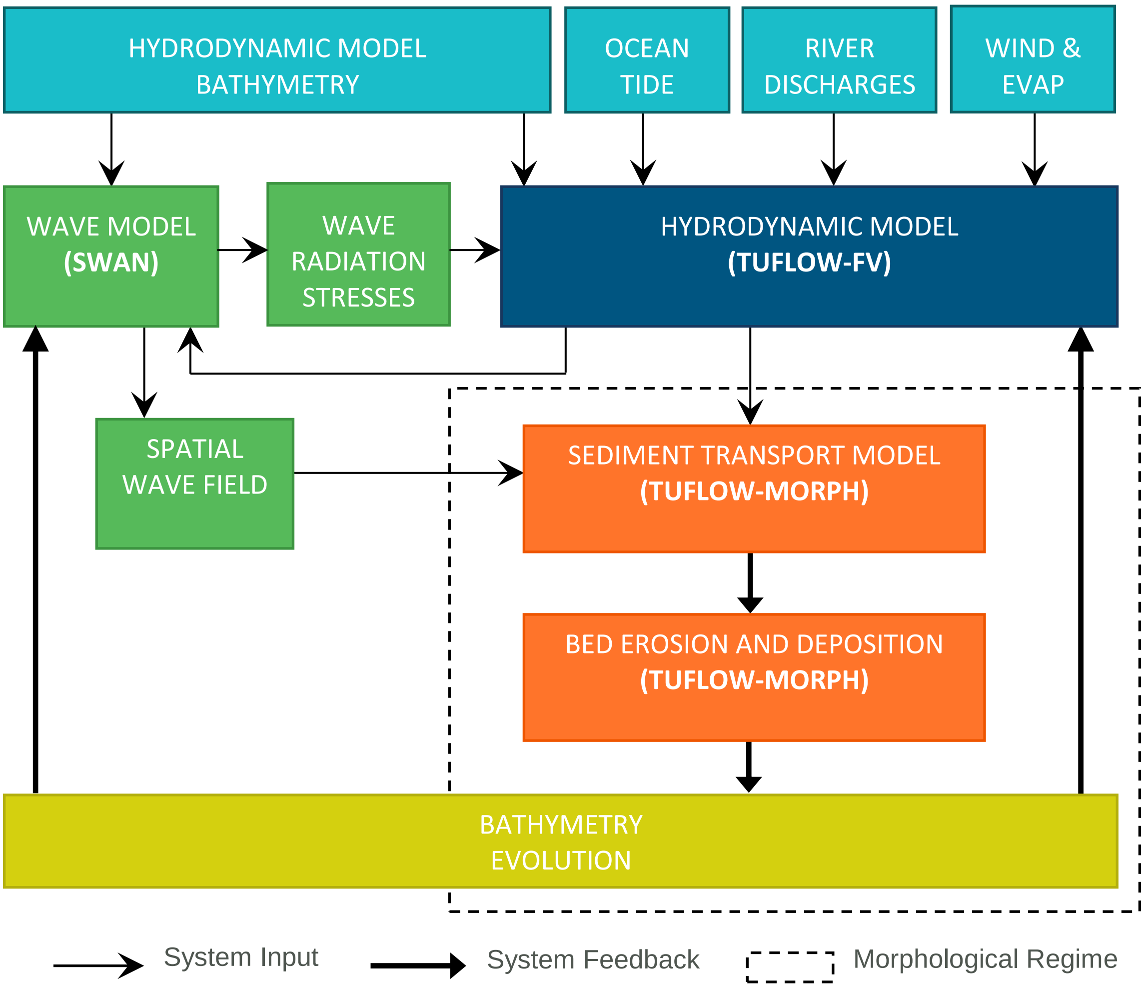


Figure 3-3 Interactions between Hydrodynamic, Wave and Sediment Transport Models

3.2.5 Structure (Barrage) Representation in TUFLOW-FV

Recent code changes to TUFLOW-FV have allowed the representation of a wide range of structures via the inclusion of a node-string based flow control structure. The implementation of the structure involves the use of a structure matrix that defines a given flow for a matrix of upstream and downstream water levels. The level-flow matrix is generated externally using appropriate hydraulic equations for each specific structure. In addition to the use of a flow matrix, a time-series file that defines the percentage the structure is open for a given time-step is also required.

For the Barrages separating the Lower Lakes from the Coorong a broad-crested weir (BCW) structure was deemed to be the most representative hydraulic structure. The hydraulics of a BCW (including an allowance of drowned regimes) is given below based on Bos (1989).

$Q = WFC \times SD \times 1.705 \times WW \times (USWD^{WFE})$ (Equation 1)

Q = total flow across weir (m^3/s)

WFC = weir flow co-efficient = 1.0

WFE = weir flow exponent = 1.5

WW = weir width (see Table 3-2)

USWD = upstream water depth = upstream water level – sill level (see Table 3-2)

SD = submerged discharge ratio (Villemonte formula) = $Q_s/Q = [1 - (h_2/h_1)^{WFE}]^{0.385}$ (Equation 2)

Qs = submerged discharge

Q = free flow discharge

h_2 = downstream head = downstream water level – sill level

h_1 = upstream head = upstream water level – sill level

Equation 1 and Equation 2 were coded into an Excel spreadsheet to generate a matrix of structure flow for a given upstream and downstream water level. The equation show that the flow across the structure is based on the upstream and downstream water levels either side of the structure such that:

- If upstream = downstream water level (WL); flow across the structure = 0 m^3/s
- If upstream WL > downstream WL; flow is positive (i.e. flows from Lake Alexandrina into the Coorong);
- If downstream WL > upstream WL; flow is negative (i.e. flows from the Coorong into Lake Alexandrina); and
- The submerged discharge ratio means that if both the upstream WL and downstream WL are significantly above the sill level, the discharge across the structure is not as efficient (as free surface discharge) so the discharge is scaled back proportionally by the level of submergence.

A drawback of the approach is that the equations do not represent the momentum of the flow and assume that there are insignificant (static) velocities upstream of the structure. This means the approach velocity head ($v^2/2g$) is converted to a static head (i.e. an approach velocity of 1 m/s would generate an additional afflux of ~ 5 cm). However, there is a feedback mechanism which given the greater upstream WL, increases in flow which would tend to reduce the amount of afflux but cannot reduce it down to zero.

Another drawback of the current implementation of the structures in TUFLOW-FV is that the structure matrices are predefined (based on structure width and sill level (see Section 3.3.4, Table 3-2)) and cannot be changed during a simulation. This means that while the proportion of width input time-series (see Section 0) can be used to alter the number of barrages open for a given time-step, the structure sill level cannot be altered dynamically which may occur in reality. This approach is suitable for all barrages apart from Goolwa, which has resulted in a minor reduction in the accuracy of the model calibration currently achieved. It is possible to update the implementation of structures within TUFLOW-FV to overcome this issue although for the current investigation this is not considered necessary.

3.3 Model Extents, Mesh Development and Bathymetry

3.3.1 Background

The flexible mesh used to represent the geometry of the system is shown in Figure 3-1. The mesh has been under continual development and improvement since the original flexible mesh was developed for the Murray River Mouth Morphological Model Development project in 2002 (WBM / L&T, 2003). The mesh and model have been improved and calibrated in a number of subsequent projects as reported in WBM (2006), BMT WBM (2008, 2009a & b, 2010c & e, 2011a & b and 2012).

3.3.2 Further Mesh Improvement

For this project, the mesh (as reported in BMT WBM (2012)) was further refined in a number of areas including:

- Lake Albert – the mesh resolution was further increased to allow for a more accurate assessment of mixing and salinity gradients within the lake, and also to allow for schematisation of a Coorong Connector channel required during the scenario testing phase of this project;
- Lake Alexandrina – minor adjustments (straightening and alignment of elements) were made to improve the mesh, especially the area near Narrung Narrows; and
- Coorong North Lagoon – the mesh resolution was further increased to in the North Lagoon to allow for schematisation of a Coorong Connector channel required during the scenario testing phase of this project.

3.3.3 Comparison of Model to Observed Stage-Area Relationship

A comparison of the stage - volume relationship of the model mesh to measured bathymetry has been made to ensure that the mesh adequately represents the storage characteristic of the Lower Lakes. As shown in Figure 3-4, the stage - volume characteristics of the model mesh is very close to reality with the mesh under-predicting storage by no more than 1 – 2% (~ 30 GL) across the typical operating range of the Lake. This minor under-prediction of stage – volume relationship will result in a difference of approximately 2-3 cm in water levels between the model and actual lake levels, which is within the typical range of accuracy associated with hydrodynamic models.

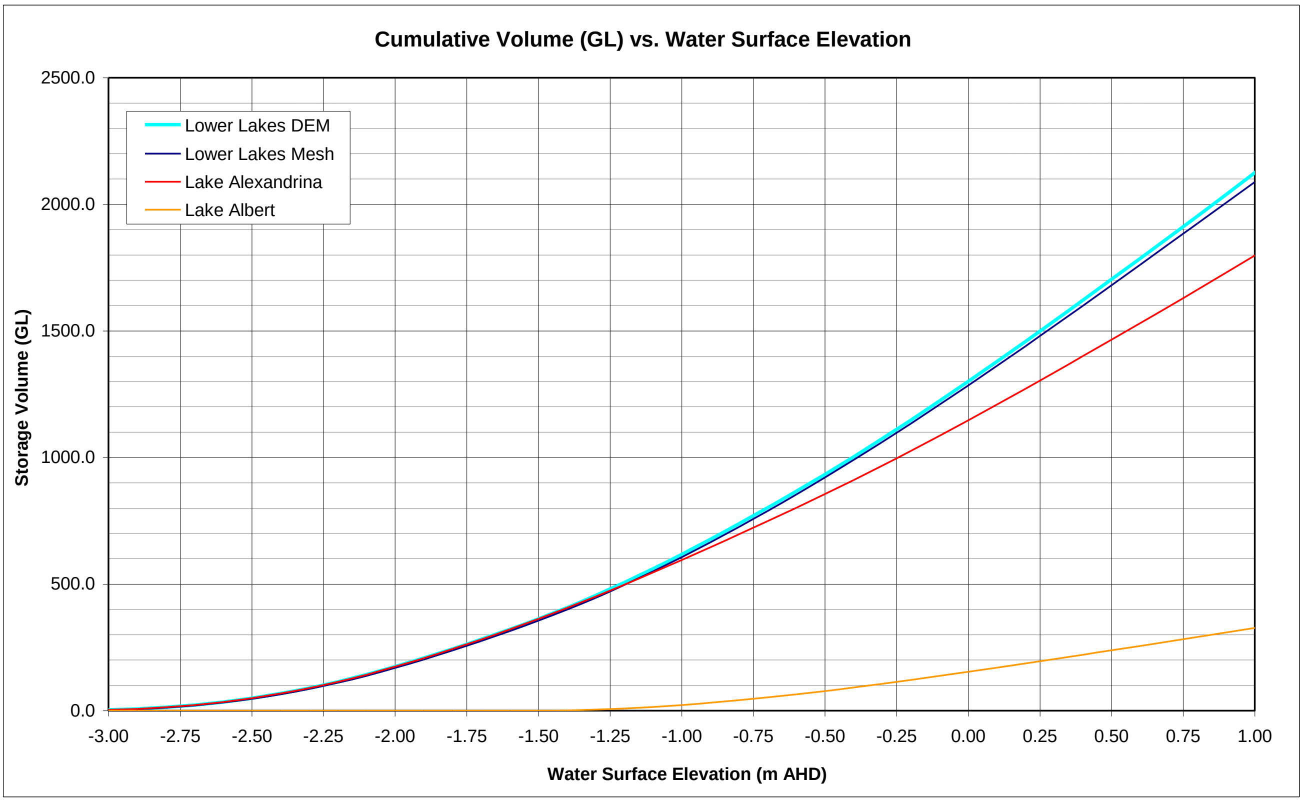


Figure 3-4 Comparison of Mesh to Actual Stage Volume Relationship

3.3.4 Adopted Model Barrage Structures

Table 3-1 provides a summary of the barrage structures and Table 3-2 summarises the adopted hydraulic properties used by the model. A description of the numerical implementation of the barrages discharge calculations were provided in Section 3.2.5. Reported barrage openings, including corrections and adjustment, are presented in Section 0.

Table 3-1 Summary of Barrage Structure Data

Barrage	Openings	Sill Level
Goolwa	128 Gates, total open width = 128 x 3.581m = 458.4m Includes 2 fishways and 5 navigation bays All bays are stop logs	Concrete sill between -1.5 and -3.6 mAHD one log removed = 0.45 mAHD two logs removed = -0.45 mAHD
Mundoo	26 Gates, total open width = 26 x 3.581m = 93.1 m though spindle losses of ~3m give 90m	6 spindles at -1.12 mAHD 9 stop logs at -1.12 mAHD 11 stop logs at -0.81 mAHD
Boundary Creek	6 gates, total open width = 6 x 3.581m = 21.5m	6 stop logs at -1.12 mAHD
Ewe Island	111 gates, total open width = 111 x 3.886m = 431.35m 61 radial gates and 50 stop logs	concrete sill = -0.05 mAHD
Tauwitchere	322 gates, total open width = 322 x 3.886m = 1251.3m 192 radial gates and 130 stop logs (includes 2 fishways)	concrete sill = -0.05 mAHD

Table 3-2 Adopted Hydraulic Properties for Barrages

Barrage	Full Opening Width	Sill Level
Goolwa	458.4m (128 gates)	two logs removed = -0.45 mAHD
Mundoo	90m (26 gates)	-1.0 mAHD
Boundary Creek	21.5m (6 gates)	-1.12 mAHD
Ewe Island	431.35m (111 gates)	-0.05 mAHD
Tauwitchere	1251.3m (322 gates)	-0.05 mAHD

3.4 Adopted Model Bed Roughness

TUFLOW-FV defines model bed roughness using a Manning's '*n*' value. A higher *n* value is used to indicate a rougher surface in which a higher water level gradient is required to convey a given flow. A high Mannings 'n' will also act to reduce water velocity which is associated with reduced erosive forces in active morphodynamic areas.

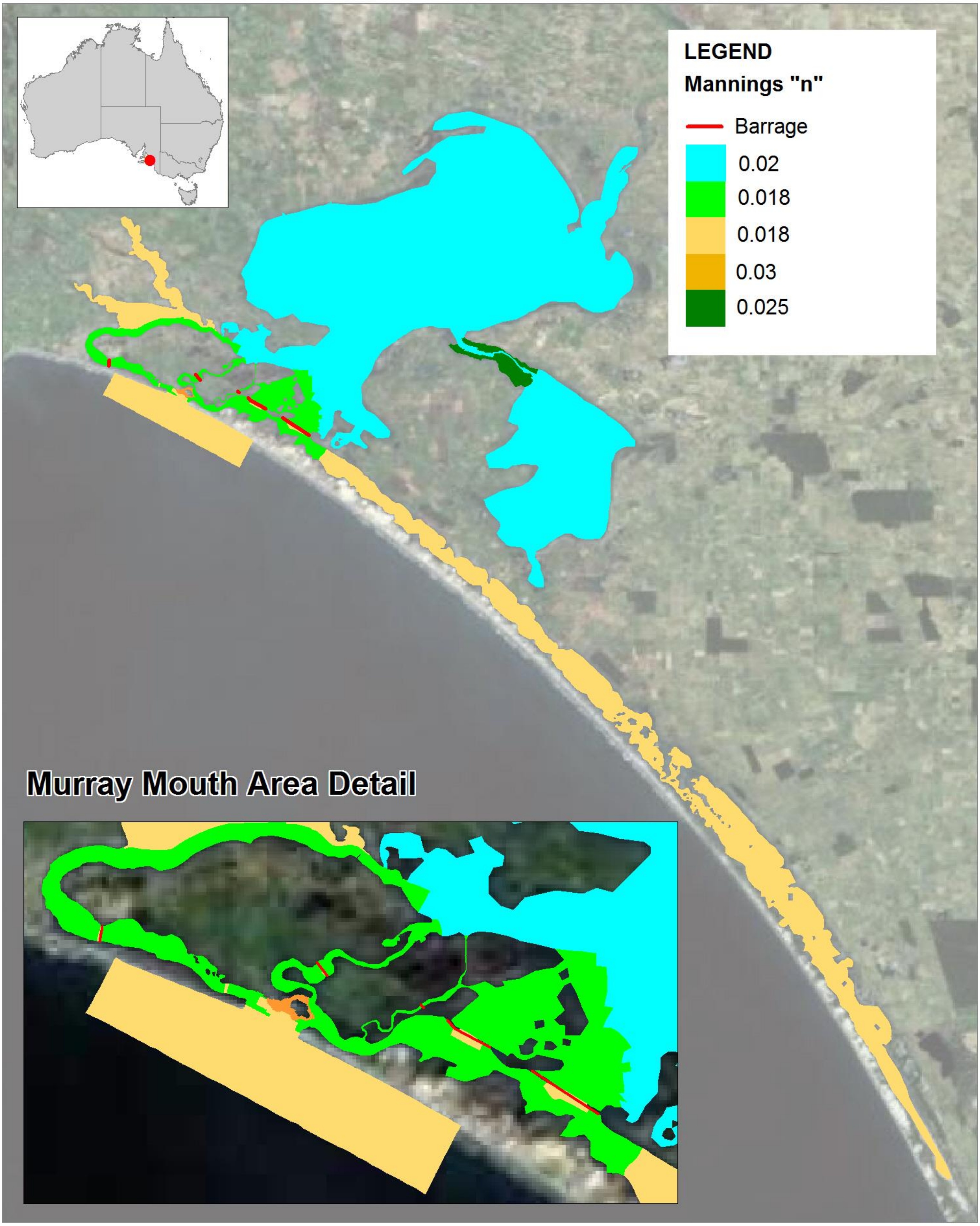
Roughness values were varied within acceptable ranges so that the model was able to best reproduce the observed water levels changes over the calibration period (see Section 4.3). The distribution of adopted/calibrated roughness for the model mesh is presented in Figure 3-5.

3.5 Boundary Conditions

Boundary conditions are used to "drive" model simulations. Observed data is typically used as the model boundary conditions for a calibration run. The suitability and accuracy of the model boundary conditions significantly influences the ability to appropriately calibrate a hydrodynamic model.

Boundary condition data used for the model calibration includes:

- River Murray inflows (refer Section 3.5.1);
- Direct net rainfall – evaporation (refer Section 3.5.2);
- Offshore water levels (tides) (refer Section 3.5.3);
- Wind speed and direction (refer Section 3.5.4);
- Barrage operations/openings (refer Section 0);
- Offshore wave data (refer Section 3.5.6); and
- Local catchment inflows (refer Section 3.5.7 & 3.5.8).



Title:
TUFLOW-FV Mesh Roughness Values

Figure: **3.5**

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3.5.1 River Murray Inflows

Estimates of River Murray flows at Wellington were applied as a boundary condition to the model. The estimates of inflows using the MDBA Source Catchment model (i.e. equivalent to MSM-BIGMOD) at Wellington were provided by DEWNR up to 12 February 2013. The Source catchment model is a daily flow and salinity routing model used to estimate river flow at Wellington based on Lock 1 discharge data and monthly calculations of offtakes and evaporation below Lock 1.

Wellington flow data from 12 February to 1 July, 2013 was estimated by applying a 6 days lag to observed Lock 1 flow data and a 750 ML/day of loss. This method provides a good match to the routing data supplied by DEWNR prior to the 12 February. The simple lag method could be improved upon using the recorded SA Water offtake data which was requested but could not be provided within the required project time-frame. Salinity data applied to the inflows is based on recorded data from the Wellington Ferry Gauge.

Flows and salinity from Lock 1 (Figure 3-6) were applied as an inflow at Wellington, just upstream of the River Murray confluence with Lake Alexandrina. The accuracy of river inflows is important to the model calibration (especially for flows below ~10 GL/Day). The validation period from the 12th December, 2012 consistently experiences flows below 10 GL/Day. For the calibration runs, a reduction in Wellington Ferry inflows of 1 GL/Day for December to April provided an additional allowance for evaporative losses and SA Water offtakes which was required to provide a better match to observed water level data.

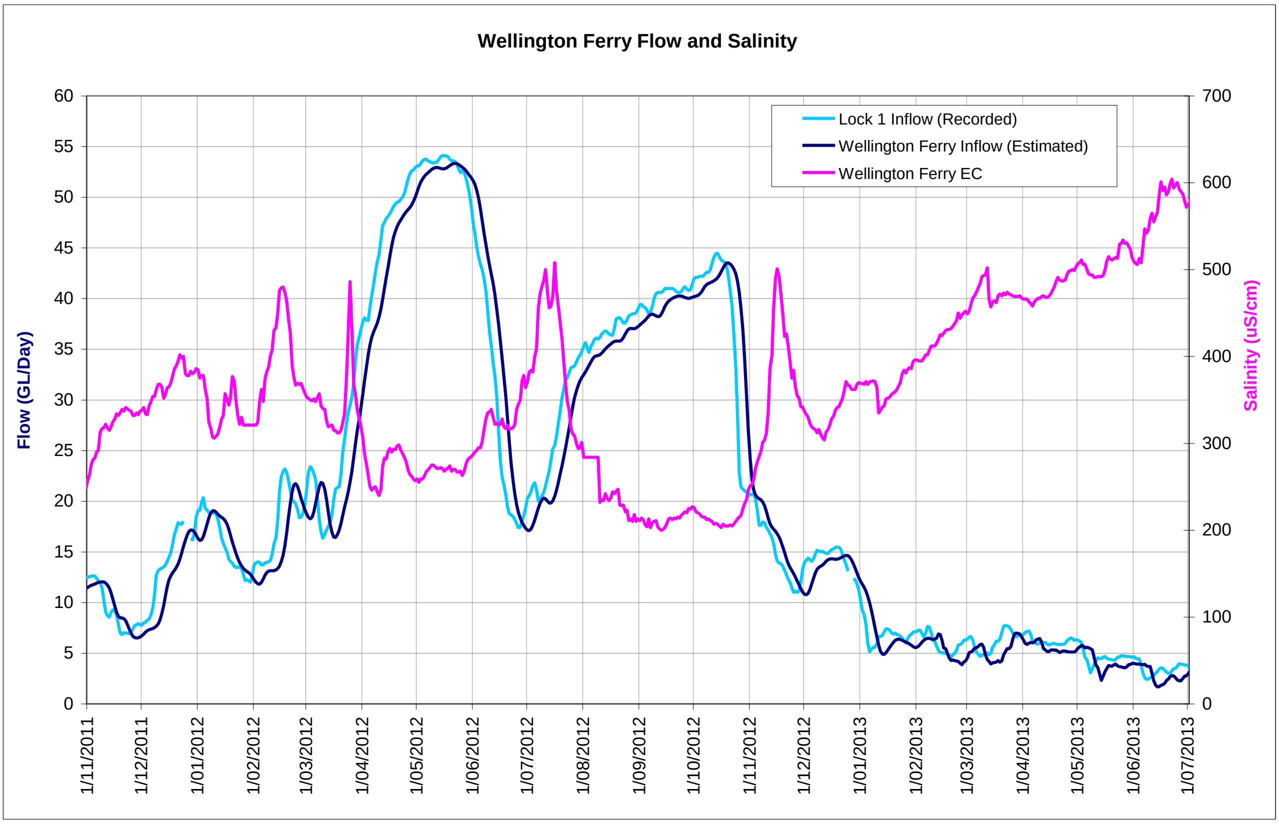


Figure 3-6 Lock 1 Inflow vs Wellington Inflow and Salinity Timeseries

3.5.2 Net Rainfall – Evaporation

Rainfall and evaporation data is applied to the surface of the model. During times of low River discharge, it is an important driver of the system water balance, not only in terms of water levels but also in changes to the concentration of salt. Meteorological data were purchased from the Bureau of Meteorology (BoM) SILO Data Drill data set. The dataset is based on an interpolation of BoM gauges and allows data to be obtained for most locations in Australia. The rainfall and evaporation data were combined to produce a single daily value of net rainfall - evaporation.

In the previous model calibration (BMT WBM, 2011b) data for Lake Alexandrina was successfully applied over the entire model domain. However, during the subsequent validation process (BMT WBM, 2012) it appeared that the use of Lake Alexandrina rainfall and evaporation data only, could not produce an acceptable level of salinity or water level calibration in the Coorong South Lagoon. In order to improve the salinity and water level calibration in the South Lagoon, an additional rainfall data set was purchased. The SILO data used in the TUFLOW-FV model can be seen in Figure 3-7 and is summarised in Table 3-3. A spatially varying input boundary condition of net-evaporation was implemented allowing separate values for Lake and Coorong evaporation inputs to be applied to the model.

A comparison of total rainfall over the ~6 month (12 December 2012 to 17 June 2013) validation period shows that there was 48 mm more rainfall (i.e. nearly 25% more) at the South Lagoon than over Lake Alexandrina. The SILO (Morten's shallow lake) derived estimate of evaporation indicates the there is less than 5% difference in total evaporation (~35 mm). The Lake Alexandrina data indicates 563 mm of net evaporative loss, while the reduced evaporation South Lagoon data set indicates 480 mm (i.e. 17% less) of net evaporative loss over the ~6 month validation period.

Table 3-3 Summary of Total Rain and Evaporation of the Validation Period

	Rain (mm)	Evap (mm)	Net Evap-Rain (mm)
Lake Alexandrina	197	760	-563
Coorong South Lagoon	245	725	-480

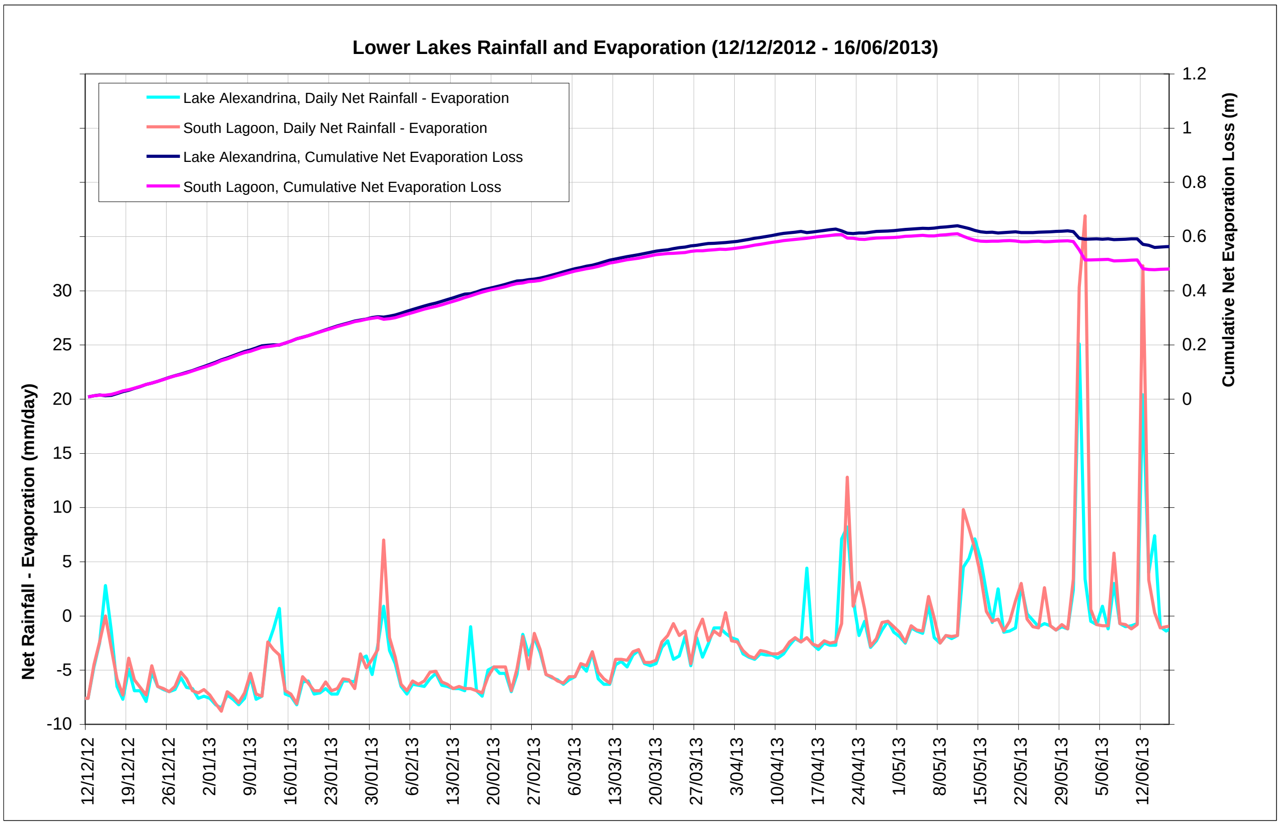


Figure 3-7 Lower Lakes Rainfall and Evaporation Timeseries

3.5.3 Victor Harbour Tides

Tidal (water level) data collected at 2 hourly intervals at Victor Harbour was used to drive the offshore water level boundary in the hydrodynamic model. The gauge which is located approximately 23 km from the mouth of the Murray River (see Figure 1-1) appears to be representative of offshore water levels within Encounter Bay.

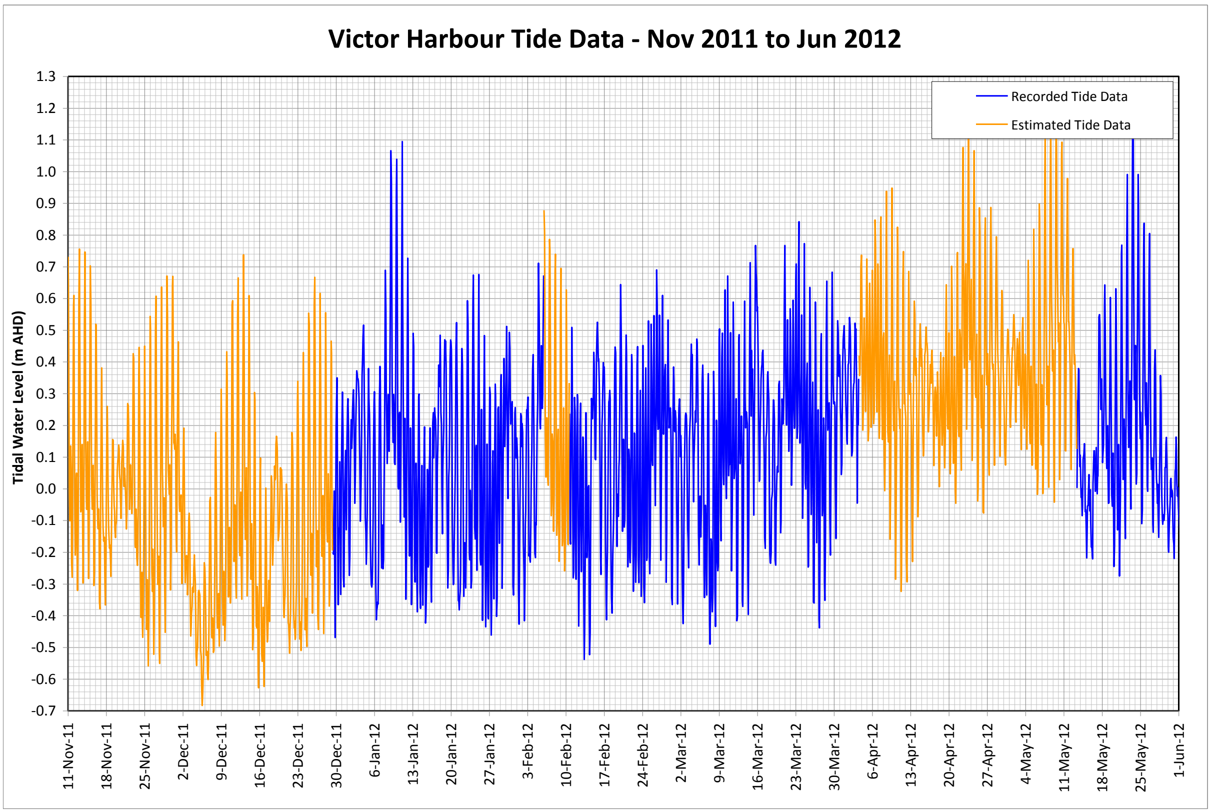
The offshore tidal boundary condition is a key driver of model hydrodynamics. It strongly influences currents and water levels within the Murray Mouth area, the Coorong and during periods of high discharge, water levels in the Lower Lakes. A time-series of the tidal water level data applied during the validation period is presented in Figure 3-8. It should be noted that the Victor Harbour tide gauge failed multiple times over the validation period (on the 19th September, 2011, the 6th February, 2012 and on the 3rd April, 2012). Due to the importance of this boundary condition an estimate of actual tide levels was required as the use of predicted tides alone was found to be unacceptable.

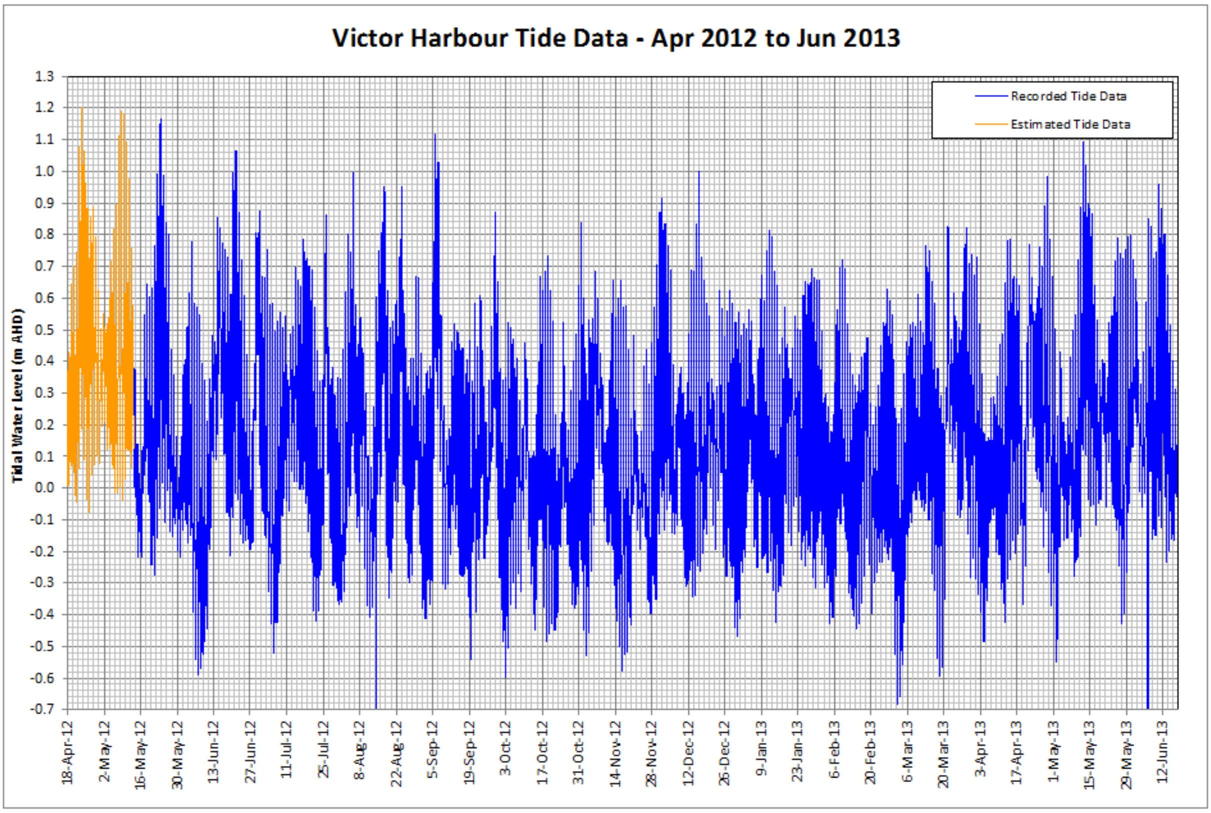
A reasonable estimate of storm surge was calculated using the equation below:

Estimate of Storm Surge / Tidal Anomaly = Average Daily Barker Knoll WL x 1.2 – 0.25 Equation 3

The above estimate is reasonable because daily average water levels tend to be a good estimate of tidal anomaly. The 20% increase in magnitude is required to account for friction losses that occur between offshore and the gauge located inside the mouth, while the 0.25 m reduction in amplitude was required to account for the impact of super-elevation that is typically observed in similar estuaries. This estimate was compared to observed tidal anomaly prior to 19th September and was found to provide a reasonable estimate of observed tides. However, maximum errors ranging between 0.1 to 0.2 metres were evident. During the course of the calibration it was found that this estimate under-predicted tidal levels for the period 1/11 – 29/12/2011 so a correction of +0.1 m was applied. It was also found that during the period 3/4 - 13/5/2012 significant barrage discharge meant that the estimation method would significantly over-predict tidal levels so predicted tides were used for this period (however, the lack of data significantly reduced certainty in the model calibration).

The use of a regional scale offshore hydrodynamic model could potentially be used to provide a better estimate of tidal anomaly or offshore tidal water level which may help increase the accuracy of the model calibration for periods when no tidal data was available.





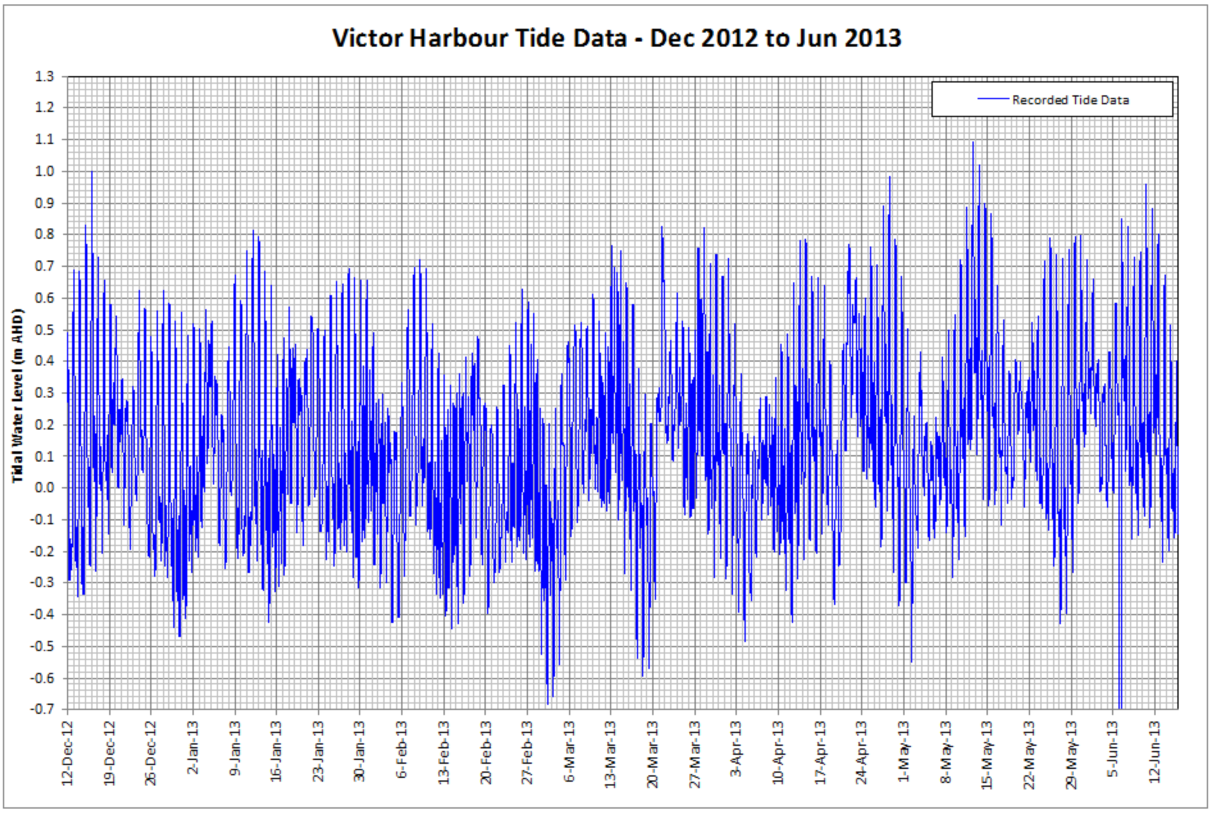


Figure 3-8 Victor Harbour Tidal Water Level Timeseries

3.5.4 Pelican Point Wind Data

The applied wind field is another key driver of short term hydrodynamics (water levels and currents) within the study area. The wind field creates a shear stress on the surface of the water body that pushes the water downwind potentially causing wind setup (and set-down). Wind driven currents and setup can influence circulation between the Coorong's North and South Lagoon and also between Lake Albert and Lake Alexandrina.

Suitable wind speed and direction data for use as a model boundary is collected by DEWNR at the Pelican Point automatic weather station (AWS). The gauge is located just to the east of Tauwitchere Barrage between the Coorong North Lagoon and the southern part of Lake Alexandrina (see Figure 2-1). A time-series of wind speed and direction applied during the validation period is presented in Figure 3-9. It should be noted that a number of spurious readings were corrected by hand.

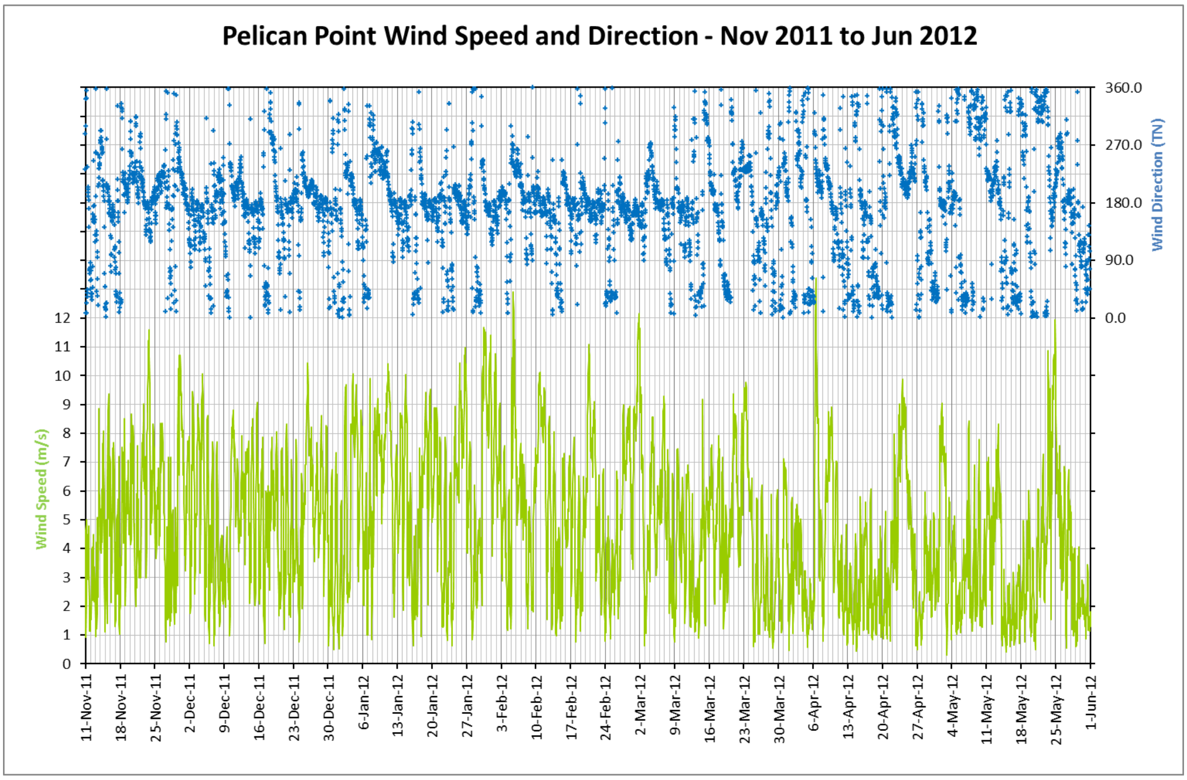


Figure 3-9 Pelican Point Wind Speed and Direction Timeseries

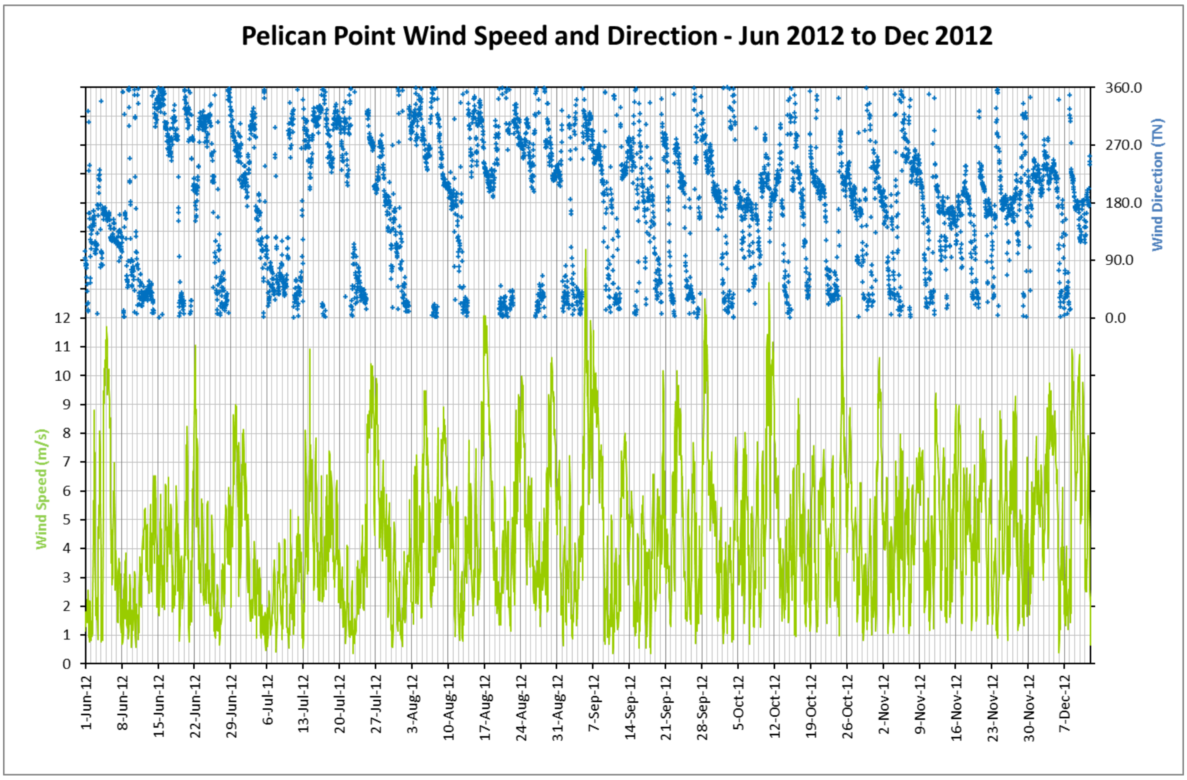


Figure 3-10 Pelican Point Wind Speed and Direction Timeseries

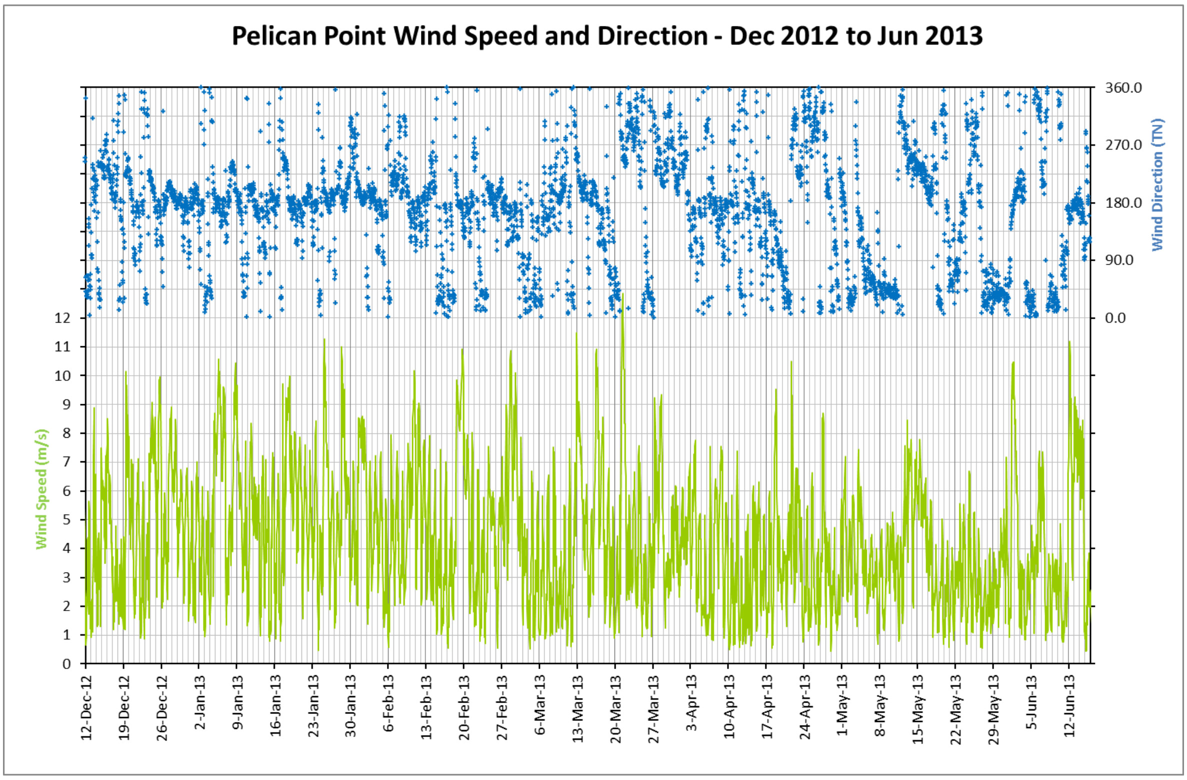


Figure 3-11 Pelican Point Wind Speed and Direction Timeseries

3.5.5 Barrage Representation, Operations and Openings

The following section provides a description of the reported barrage openings including corrections and adjustment to the timings of gate openings. A description of the numerical implementation of the barrages discharge calculations are provided in Section 3.2.5, while a description of the barrage structures and the adopted hydraulic properties used in the model is provided in Section 3.3.4.

The correct implementation and representation of the barrages in the model proved to be of great importance to being able to achieve a suitable model calibration. A spreadsheet recording the date and number of open gates at each of the barrages was provided by SA Water. In addition to this time-series data, a copy of emails detailing any changes to the barrages which is distributed on approximately a monthly basis to Lake Managers (including DEWNR, MDBA, and SA Water representatives) was provided up to the 28th May 2012. These barrage opening emails were used to gain a better understanding of barrages/gate operations and were used to check the time-series data It should be noted that regular updates would be useful to improve model calibration (especially if they contain information regarding the number of logs (and hence approximate sill level) removed from gates at Goolwa.

These checks revealed a small number of inconsistencies between the time-series data and the barrage operations reported in the emails. A graph of the adopted barrage openings and corrected / altered barrage openings for the period 1 November 2011 to 18 June 2013 is presented in Figure 3-12. The graphs show the proportion of all gates open at the structure (i.e. multiply by total number of gates at the barrage to get actual number of open gates). A graph of the adopted barrage openings (in terms of actual gate openings) for the primary calibration period 12 December 2012 to 18 June 2013 is presented in Figure 3-13.

At Goolwa Barrage, the hydraulic property of the structure at a point in time is dependent on the actual number of stop logs removed and the sill level of the highest remaining stop log. This means that in addition to reporting the number of gates that are open, the number of logs removed (or better still the actual sill level in each bay (because of the varying log heights there is no guarantee of actual sill height based on the number of logs removed)) is required. While for the majority of time the number of gates with either one or two stop logs removed was reported in the barrage opening email thread, there was no indication of the actual sill levels meaning the assumptions discussed in Section 3.3.4 needed to be adopted. This resulted in the model operating with two logs removed per gate opening for the entire simulation, when in reality there was a mixture of one and two logs removed per openings.

During periods of low Lake inflow (i.e. for much of the primary calibration period) the operation of the fishways may also have an influence on the system water and salt balance. It is understood that there is a single vertical fishway at Goolwa Barrage, while at Tauwitchere there is a rock ramp, and a small and large slot vertical fishway. While it is understood that the estimated fishway flow is in the order of 30 ML/day (pers. com. Jason Higham, 2012) the accuracy of this figure is unknown. The model assumes that a 5% gate opening allowance for the Goolwa fishway and a 5% opening allowance for the combined vertical fishways at Tauwitchere with an additional 5% allowance for the rock ramp. It appears that at Mundoo and Boundary Creek, a 20% and 10% gate opening setting respectively is available, though again the accuracy of this in terms of flow calculation is unknown.

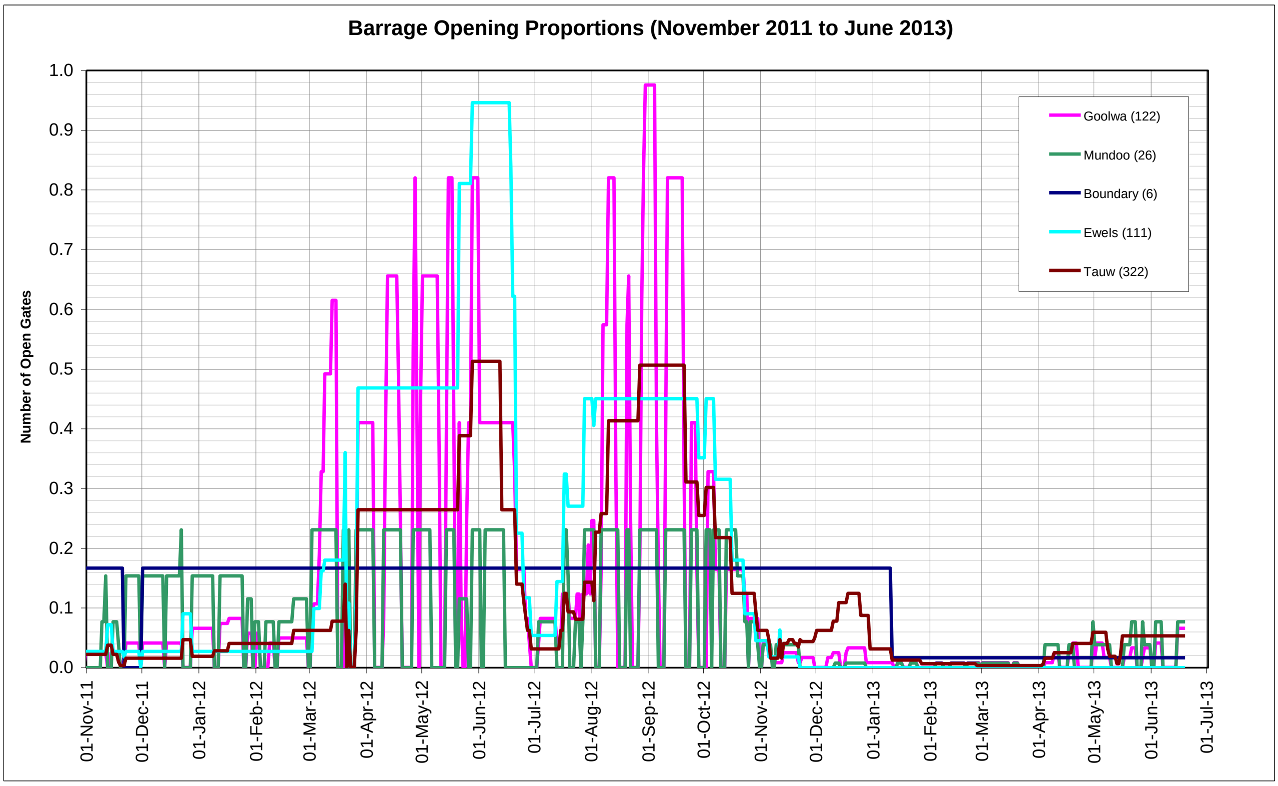


Figure 3-12 Adopted Gate Opening Sequence for Barrages

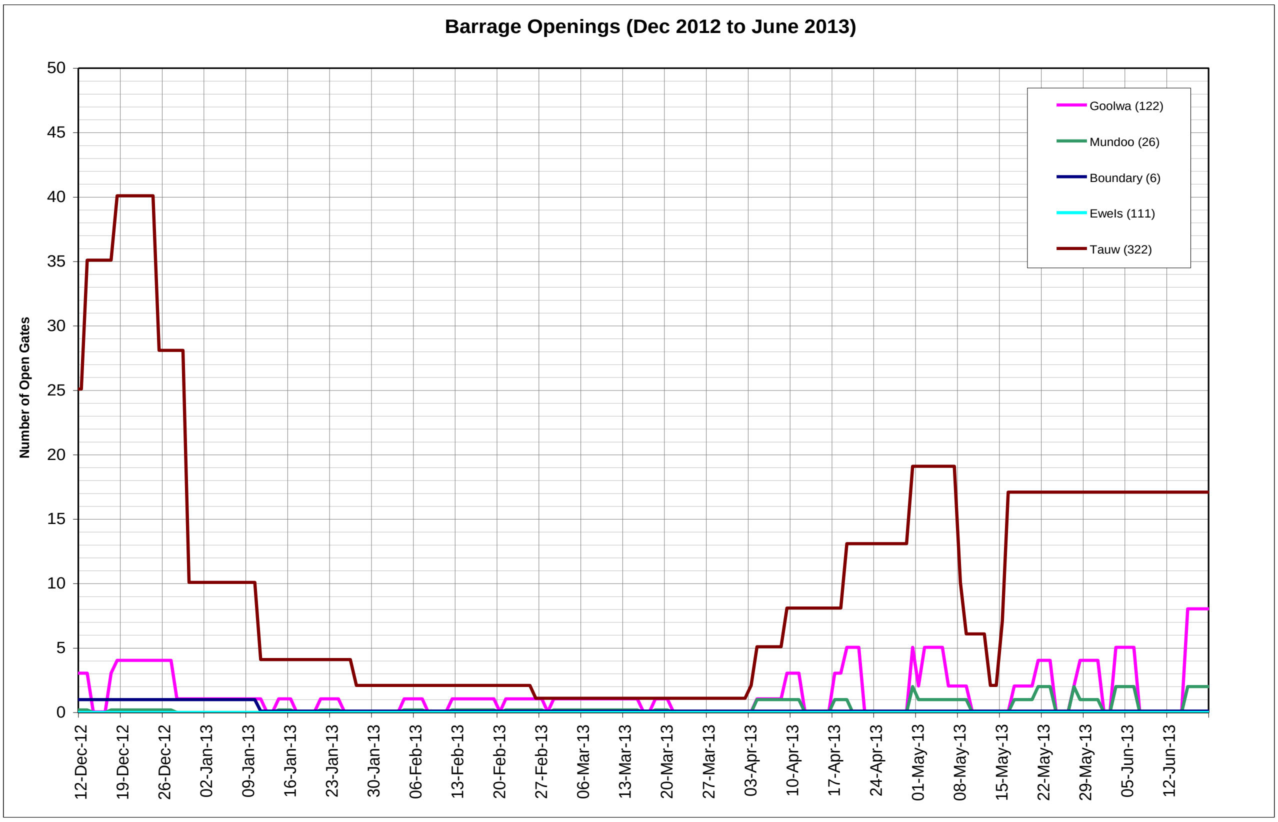


Figure 3-13 Adopted Gate Opening Sequence for Barrages

3.5.6 Offshore Wave Data (BMT ARGOSS)

Modelled wave information for a location offshore of Kangaroo Island (37° S, 136° 15' E) some 280 km south-west from the Murray Mouth (see Figure 3-2) was obtained from BMT ARGOSS for the calibration period at a 3-hour time interval. The BMT ARGOSS modelled wave data was extracted from a regional WAM III wave model with a grid resolution of 1.25° (longitude) x 1.00° (latitude) driven by wind fields from the NCEP final analysis.

A time-series of wave height, wave period and direction for the validation period is presented in Figure 3-14. These data were used as key inputs to the SWAN wave model. The wave model calculated characteristics of the wave field near the mouth, including wave heights, directions, periods and forces, which are applied to the hydrodynamic and morphological models as described in Sections 3.1 and 3.2.

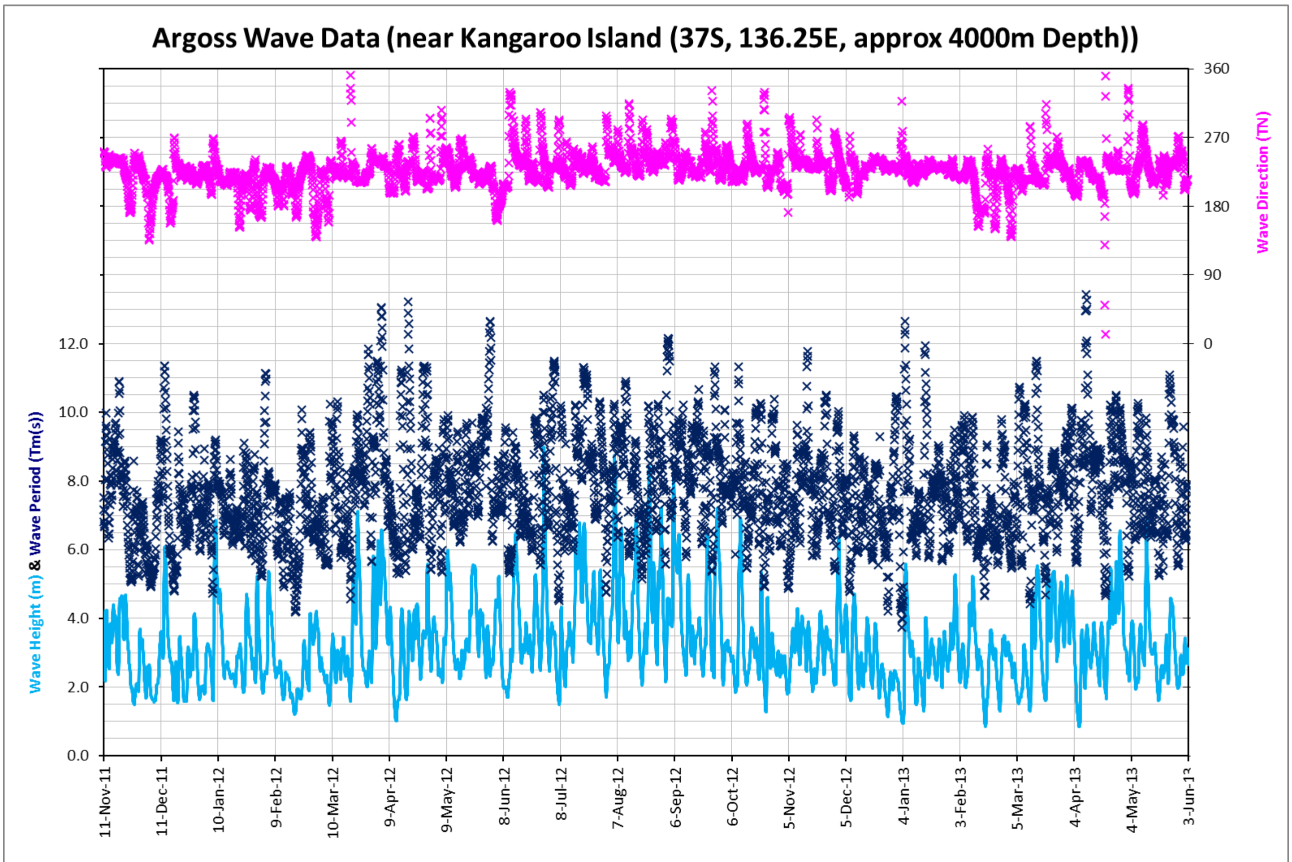


Figure 3-14 Offshore Wave Height, Period and Direction Timeseries

3.5.7 Salt Creek Inflows

The time series of inflow and salinity to the South Lagoon at Morella (Salt Creek) is presented in Figure 3-15. Inflow and salinity data were obtained from DEWNR and are considered to be representative of conditions during the calibration period?

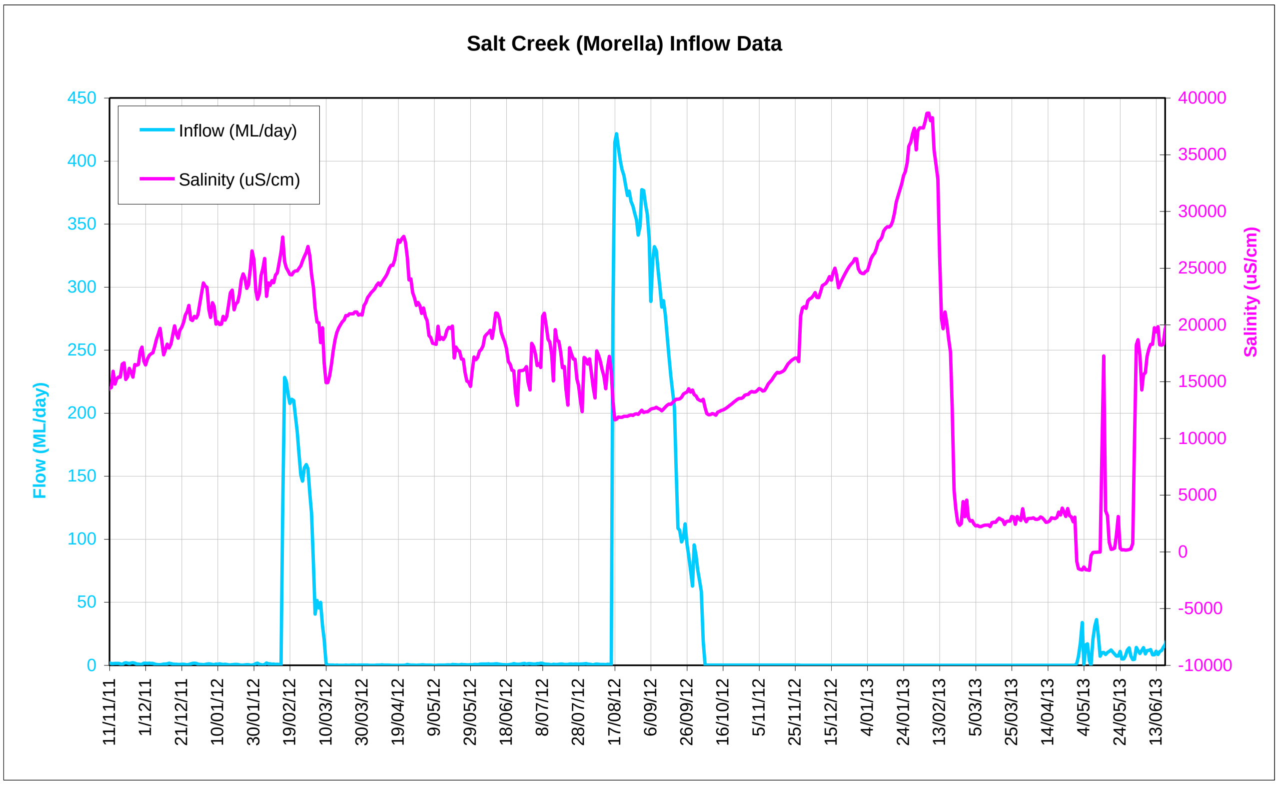


Figure 3-15 Salt Creek Inflow Timeseries

3.5.8 Catchment Inflows

The time series of inflow and salinity into the Finniss River and Currency Creek are presented in Figure 3-16. The Finniss River inflow data is based on flow data from DEWNR gauge A4261208 *(Finniss R DS Cockle Train Railway Crossing)*. It should be noted that while this gauge has been operational since October 2010, flow data is only provided from June 2013 onwards. It also appears that spurious salinity data from September 2012 to April 2013 is contained within the record.

The Currency Creek inflow and salinity data is based on flow data from DEWNR gauge A4261099 (*Currency Creek near Peel Road Cemetery*).

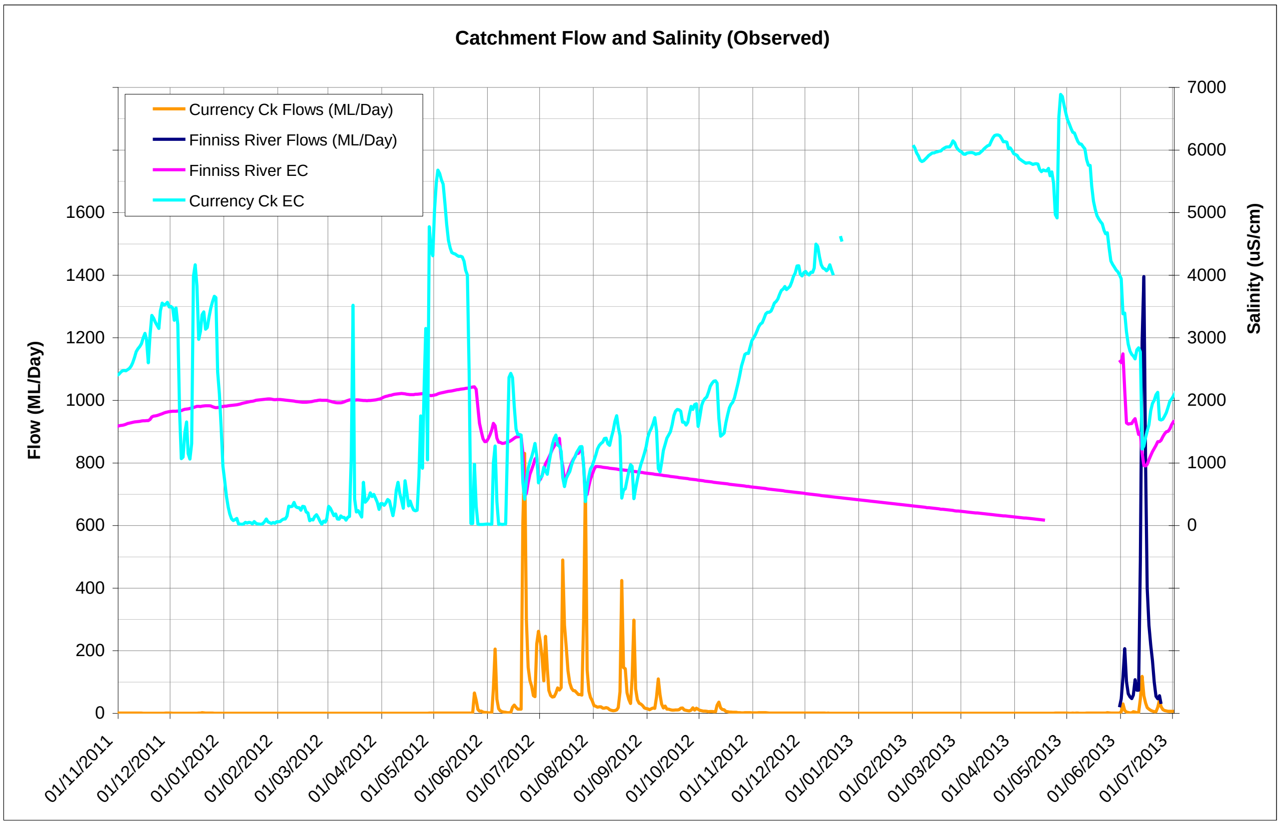


Figure 3-16 Finniss and Currency Creek Inflow Timeseries

3.6 Model Initial Conditions

Initial conditions required by the model include:

- Water level;
- Salinity; and
- Murray Mouth bathymetry.

Details and assumptions for the derivation of initial conditions are provided in the following sections.

3.6.1 Water Levels

The model initial water level defines the starting water level (12th December, 2012) in the model which for the main calibration period. Initial water levels were based on taking an average of DEWNR gauge readings for each area. The Lower Lakes (Alexandrina and Albert), the Coorong's South Lagoon and North Lagoon were set to 0.75 m AHD, 0.0 m AHD 0.1 m AHD respectively.

3.6.2 Salinities

The model's initial salinity was originally based on a gridded Digital Salinity Map (DSM) based on interpolation of spatial salinity survey data and gauge data for the Lower Lakes and North Lagoon (see Figure 3-17). In the Coorong's South Lagoon, where no spatial salinity data was available, the initial salinity was based on the results of the 18th April 2012 calibration run (as presented in Appendix B). These results are a good match to observed gauged salinity data as presented in Figure 4-35 to Figure 4-38. A long-section of Coorong salinity data is presented in Figure 4-40 comparing the adopted initial conditions and the observed salinity data in the North Lagoon. Uncertainty regarding the initial salinity conditions in the Parnka Point area and South Lagoon reduce the ability of the model to match observed salinity data.

A map of the initial model salinity for the start of the calibration period (12th December, 2012) is presented in Figure 3-17. While the use of modelled initial conditions based on the previous model run is appropriate, the availability of a spatial salinity survey dataset at the start of the model simulation for the entire study area would increase confidence in model predictions.

A note on Salinity Conversions

Electrical conductivities above 15,000 µS/cm (~9 ppt) were converted using the below revised Webster formula (as discussed in BMT WBM (2009)). Salinities below this value were converted using the standard Lower Lakes conversion of 1 ppt (~1 kg/m3) = 1667 µS/cm.

Revised Webster salinity relationship:

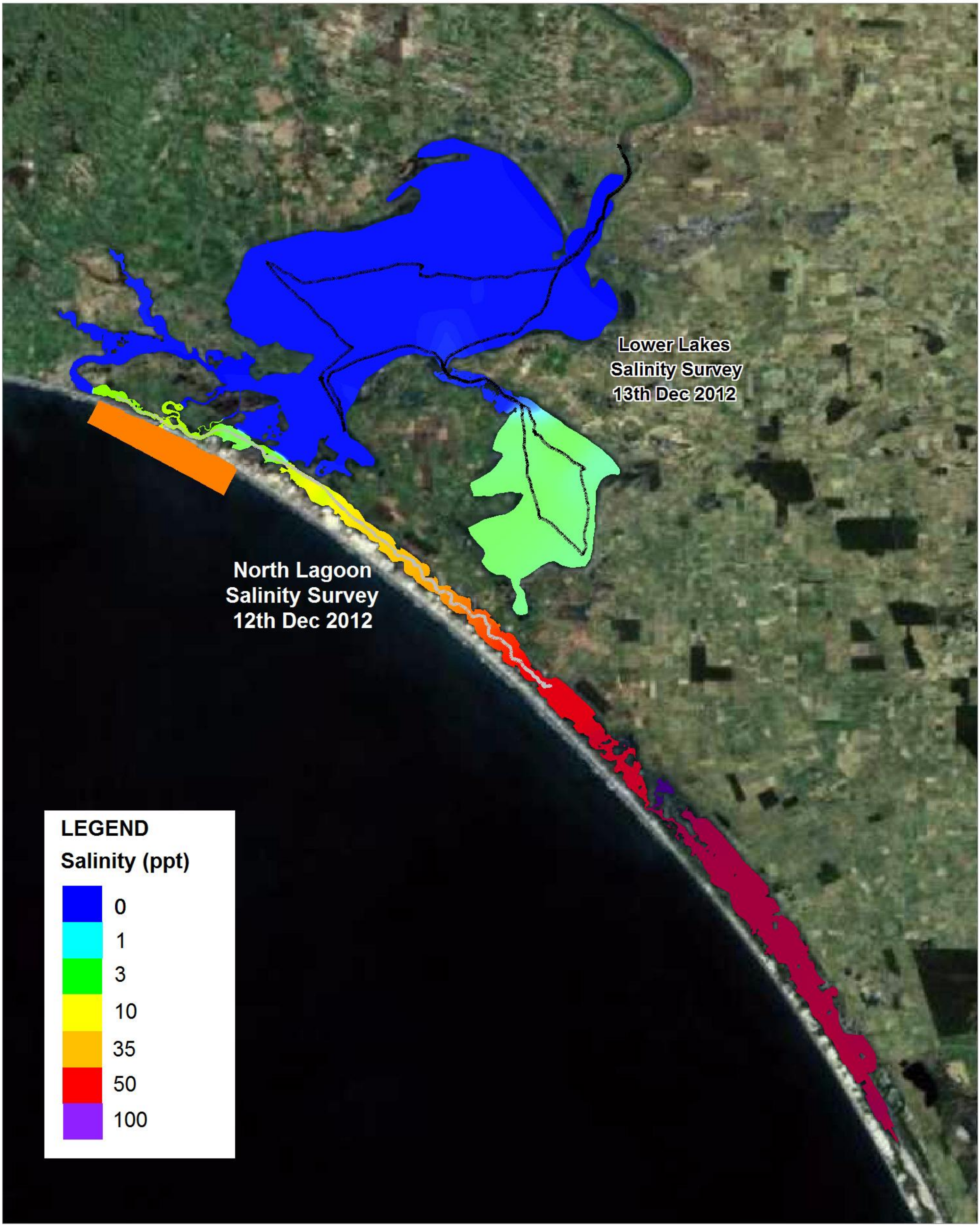
$$Concentration\ (\text{g/L}) = \frac{[0.295 \times EC \times (1 + (0.000238\ \times EC^{0.67}))] \times 1.8055)}{1000} \qquad Equation\ 4$$

Model results were converted from a concentration (ppt) to electrical conductivity (EC) using a derived 3rd order polynomial (shown below) which is based on the above equation.

$$\text{EC}(\mu\text{S/cm}) = 0.00278x^3 - 2.44717x^2 + 1389.61x + 1385.5 \qquad \text{Equation 5}$$

Where: x is salinity in ppt

Note: this should only be used for salinity > 9 ppt



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Initial Model Salinity (12th December 2012)

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0 10 20km

Approx. Scale

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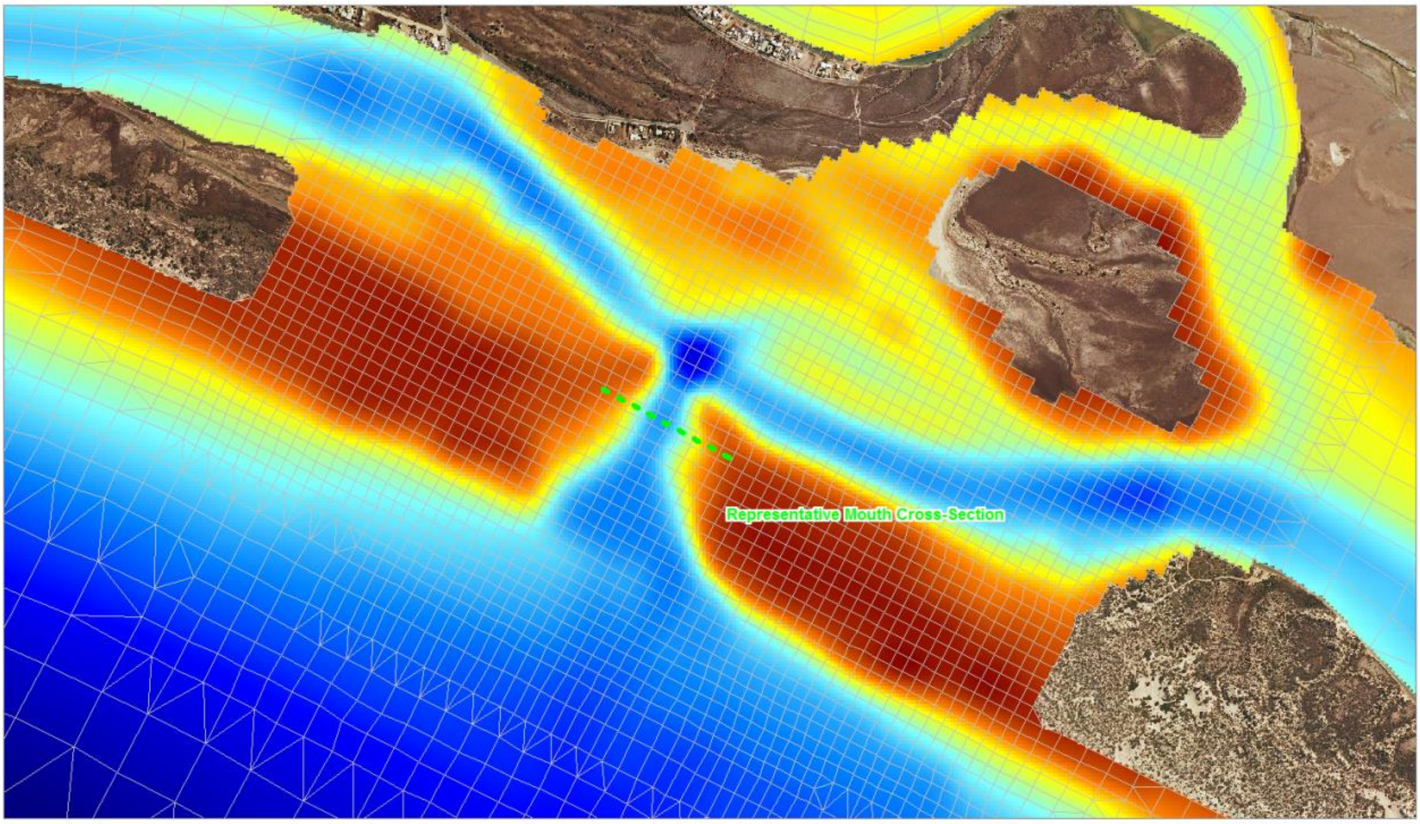
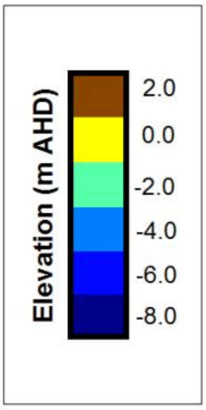
3.6.3 Murray Mouth Bathymetry

The starting Murray Mouth bathymetry was based on the surveyed bathymetry data set from the 11th December, 2012 (see Figure 2-2). Due to a lack of data, the nearshore and offshore bathymetry is based on the model results of the previous calibration which ended on the 1st May, 2011 and is reported in BMT-WBM (2011b). A DEM of the survey data was stamped onto a DEM of the model results and then some adjustments to the mouth bathymetry was undertaken to combine the two datasets. The resultant DEM was then used to determine the elevation of the model mesh as displayed in Figure 3-18. The mesh resolution in the vicinity of the mouth is approximately 40 metres by 40 metres.





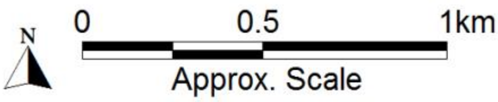
Title:

Initial Murray Mouth Model Bathymetry (12 December 2012)

Figure: **3-17**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.



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4 Model Validation

4.1 Validation/Calibration Process and Objectives

Model validation is typically defined as taking a previously calibrated model and running the model for a different period to that it was calibrated for. Model validation is usually undertaken to ensure that a model has been appropriately calibrated and that it can produce accurate model predictions using different boundary conditions. For a successful model calibration/validation, it is important to have good data sets for both application to the model boundaries and for comparison to predictions (namely water level and salinity) within the model domain (see Sections 2 and 3). Due uncertainty regarding a number to the requirement

Additional model calibration/validation was undertaken as part of the Lake Albert Salinity Reduction Study to increase confidence in model predictions and ensure that the model could reproduce observed salt exchange between Lake Albert and Lake Alexandrina.

An initial model calibration (BMT WBM, 2011b) covered the ~ 5 months between 25th November, 2010 and the 1st May, 2011. During that period, high to very high Lake inflows of 25 – 80 GL/day were recorded. The calibrated model configuration was able to match water levels under those conditions. An additional model validation covering the subsequent 6 months, 1st May to 1st November, 2011 when more moderate flows occurred (i.e. between 10 and 40 GL/day) is presented in (BMT WBM, 2012).

While calibration period broadly covers the 19 months (1st November 2011 to 15th June, 2013); though due to a lack of data the primary calibration period is from 12th December, 2012 to the 15th June, 2013. This primary calibration/validation period covers a period of low lake inflows (<10 GL/day) which makes it ideal for examining salt exchange between the lakes. Two additional calibration runs covering the 1st November 2011 to 1st June, 2012 and 18th April 2012 to 18th April 2013 were also used to check the performance of the model.

For the 1st November 2011 to 1st June, 2012 calibration a lack of tidal data (see Figure 3-8) caused significant difficulties in model calibration, reducing certainty in the calibration process. While for the 18th April 2012 to 18th April 2013 calibration period, high lake inflows (see Figure 3-6) required a lower sill level at Goolwa to pass the lake discharge, however, as this was not recorded it could not be implemented into the model boundary conditions reducing the accuracy of the calibration.

Significant issues encountered during the model validation included:

- Data quality issues with other WL and EC gauges (see Section 2.2);
- Uncertainty regarding sill levels and gate openings at Goolwa Barrage;
- No recent offshore or nearshore (i.e. outside of the Murray Mouth) bathymetry data; and
- A lack of complete spatially varying salinity data for the Coorong South Lagoon at the start of the simulation.

Given the complexity of the model which includes a large spatial extent/coverage with variable environmental conditions, complex hydraulic structures (that represent the operation of the Barrages), sediment transport algorithms and a bed update scheme to represent the morphodynamics of the Murray Mouth, and uncertainty regarding the accuracy of some of the datasets (particularly water level), it is important to consider what an acceptable level of model validation would be for the study.

It is generally accepted that there is a high level of uncertainty with sediment transport models. It was considered that provided the Murray Mouth was modelled as changing at a rate sufficient to enable the model to appropriately match observed water levels in the Coorong and Lower Lakes, a reasonable validation was achieved. Matching the exact bathymetric change of the Murray Mouth was not a primary goal of the validation/calibration task.

Given that an aim of the study is to predict salinity levels within the Lower Lakes and Coorong it was important for the model to be able to closely match observed salinity and water levels at the majority of the gauged data sites within the study area.

The approach to model calibration included:

- Ensuring that the model can approximate observed water levels;
- Ensuring that the model can approximate observed salinity;
- Ensuring that the model can approximate observed salt exchange at Narrung; and
- Ensuring that the model can be used to reasonably estimate barrage discharge;

4.2 Barrage / Structure Calibration

Ensuring the model could calculate appropriate barrage discharge proved to be very important in the development of a suitably calibrated model. Enabling the model to calculate the correct discharge between Lake Alexandrina and the Coorong was important so the model could replicate both water levels in the Lake and Coorong and also discharge through the mouth. As no observed flow datasets were available, there is still some uncertainty regarding the accuracy of the barrage discharge calculations. However, given the model's ability to closely match observed water levels and salinity across the model domain in general, the modelled barrage discharge characteristics are likely to be reasonable.

A lack of sill level data for Goolwa Barrage required a number of model simulations to improve the validation. Even after these adjustments have been made it is likely that differences between modelled and observed water levels can be attributed to the lack of complete information regarding barrage operation (see Section 0).

4.3 Water Level Calibration

Ensuring that the model could replicate observed water level changes was the most important process to address in the model validation. If the model replicates the observed water level changes across all the important model regions, key hydraulic features such as the barrages, Murray Mouth, Narrung Narrows and Hells Gate are likely to be appropriately represented in the model.

Key adjustments required to allow the model to closely match observed water level changes in the system included:

- Access to accurate Lake Inflow and abstraction data (see Section 3.5.1);
- Access to accurate tidal level data (see Section 3.5.3);
- Correcting a number of spurious wind speed records (see Section 3.5.4);
- Correcting or adjusting the timing of gate openings and closures at the Barrages;
- Correcting or adjusting the proportion of Goolwa gate openings to account for unknown sill elevations;
- Applying a spatially varying estimate of net rainfall-evaporation to the Lakes and Coorong (see Section 3.5.2); and
- Correcting/adjusting or ignoring a number of water level gauges which appeared to have errors.

A discussion of the achieved degree of water level calibration for Lake Albert, Lake Alexandrina and the Coorong is provided in the following sections.

4.3.1 Lake Albert

The calibrated model was capable of closely replicating observed water levels in Lake Albert as shown in Figure 4-1 (Meningie), Figure 4-2 (Warringee) and Figure 4-3 (Waltowa). The model predicts short-term (wind driven) and longer term (volumetric) fluctuations. The main deviation between observed and modelled water level occurs may be due to:

- Errors in the reporting (or adoption) of barrage/gate closures and opening; and
- Errors in the calculation of Wellington Inflows discharge.

While the water level in Lake Albert generally follows that of Lake Alexandrina (see Figure 4-4 or Figure 4-5), the constriction along Narrung Narrows means that there is generally a lag between water level changes in the two Lakes and that wind events can cause significant short term water level differences.

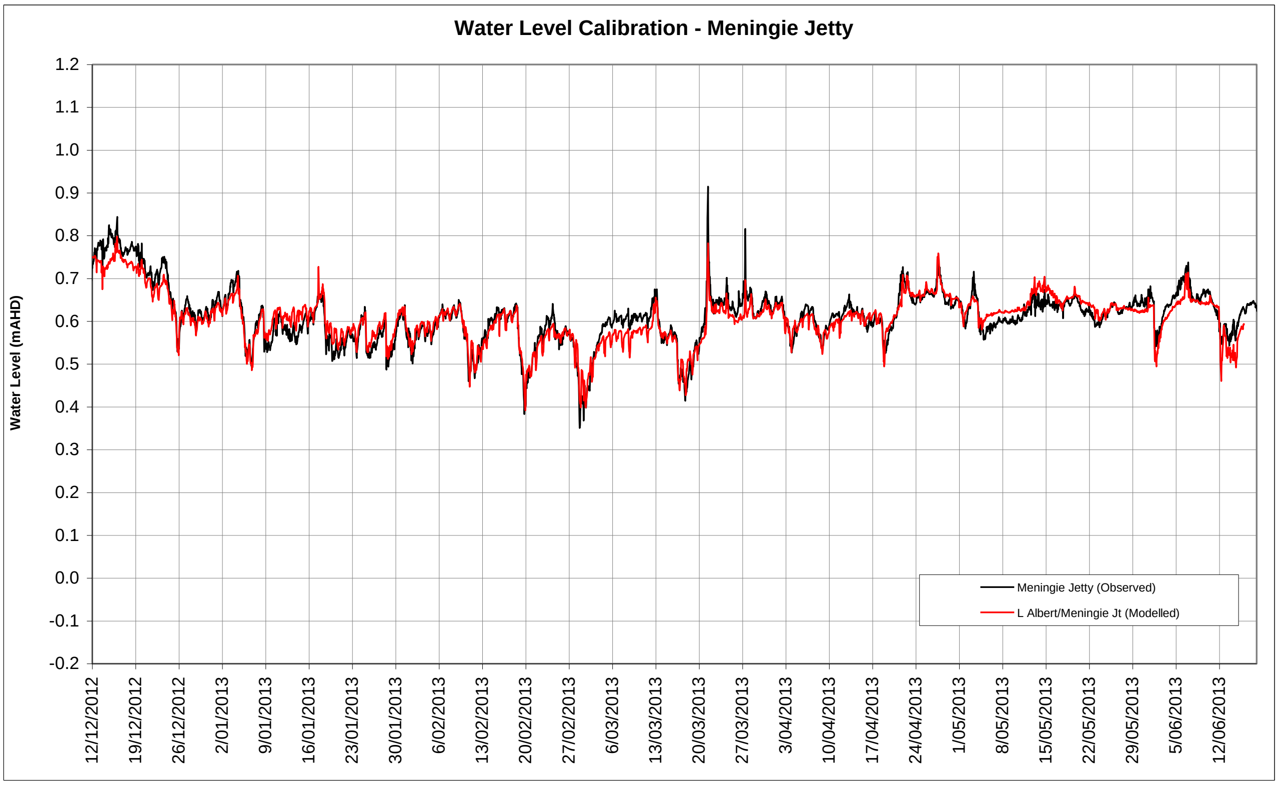

Figure 4-1 Observed and Modelled Water Levels - Meningie

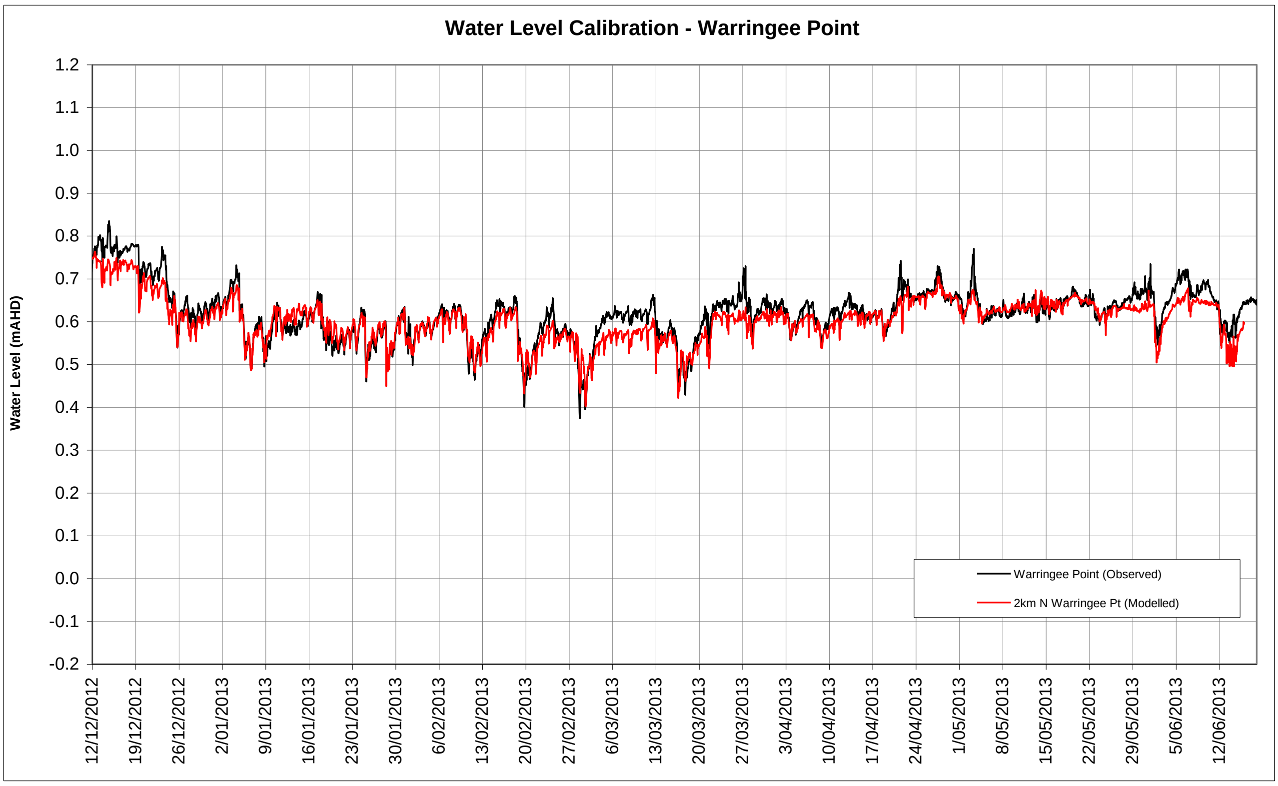

Figure 4-2 Observed and Modelled Water Levels – Warringee Point

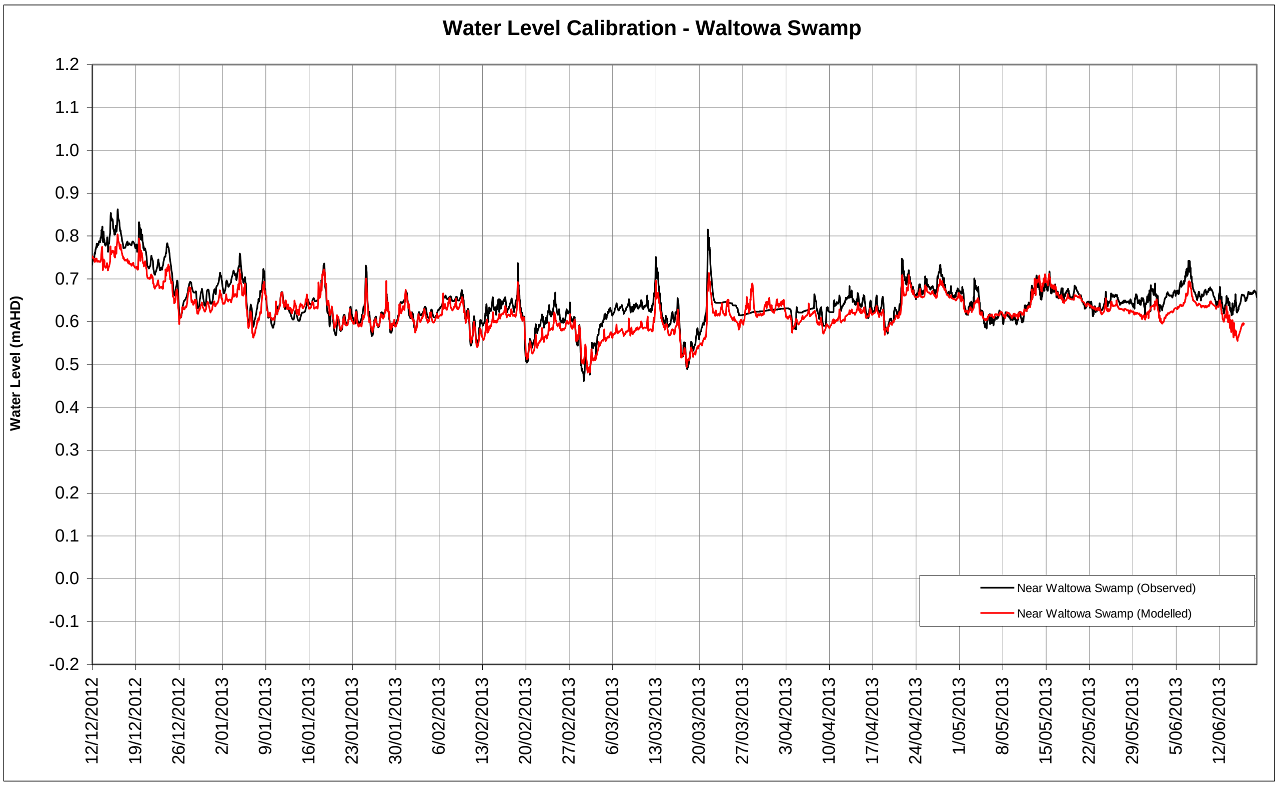

Figure 4-3 Observed and Modelled Water Levels – Waltowa Point

4.3.2 Lake Alexandrina

The calibrated model closely replicated observed water levels in Lake Alexandrina as shown by Figure 4-4 to Figure 4-10. The model is able to closely represent short-term (tide and wind driven) and longer term (volumetric) fluctuations.

Figure 4-4 (West Point McLeay) and Figure 4-5 (Milang) are broadly representative of water levels within Lake Alexandrina. At Upstream Tauwitchere Barrage (Figure 4-6), the water levels closely follow that in Lake Alexandrina, though there is a mild tidal signal, which is difficult to differentiate from possible wind seiches that often have a similar period and magnitude.

The results show that during periods of low inflow (typically in the order of 5 GL/day) and low barrage openings (< 5 gates open) the model is able to closely reproduce observed water level changes which are predominantly influenced by wind shear.

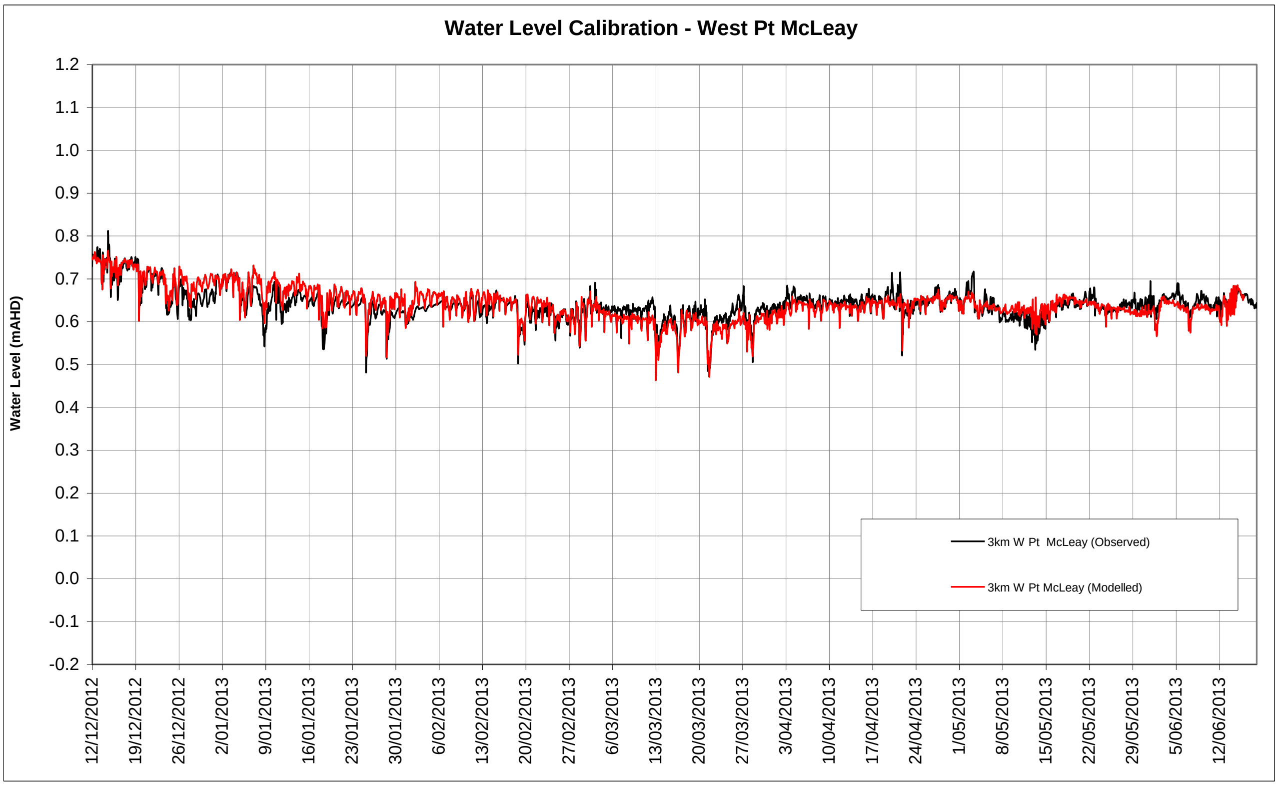

Figure 4-4 Observed and Modelled Water Levels – West Point McLeay

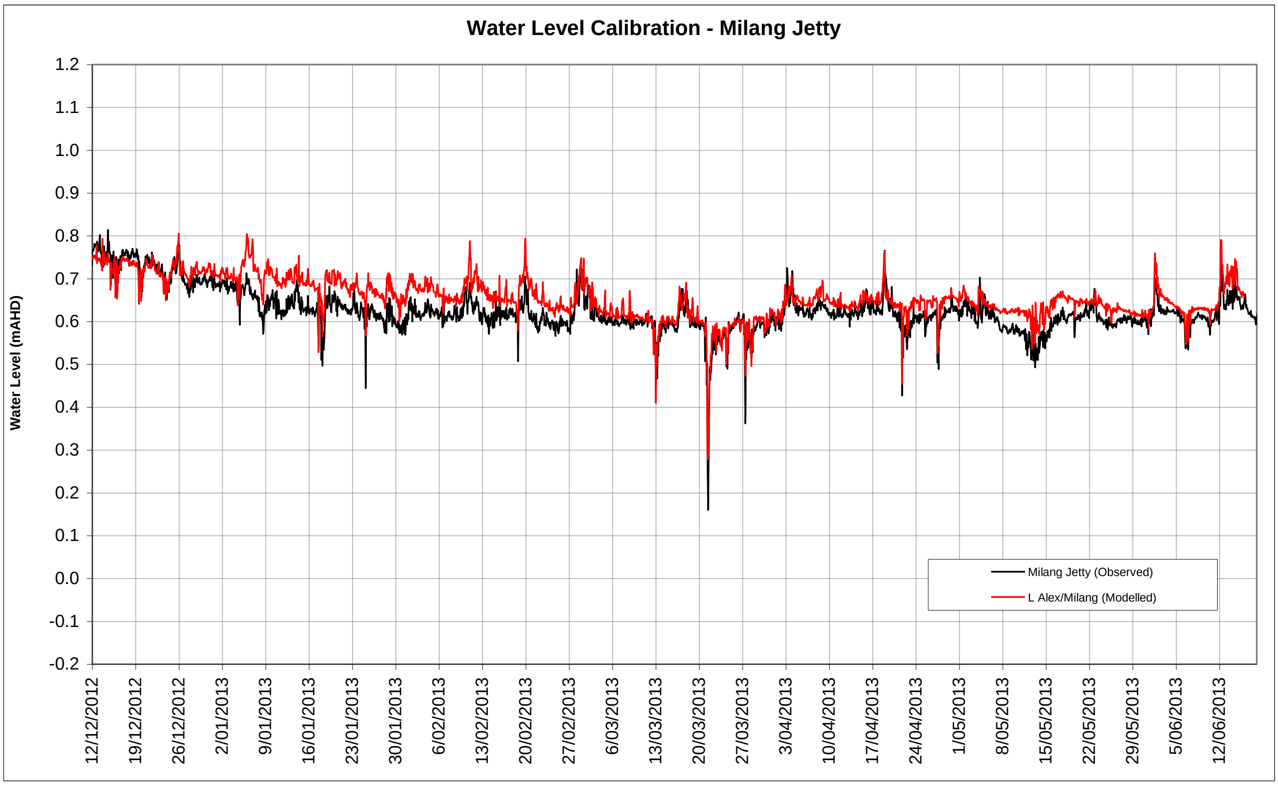

Figure 4-5 Observed and Modelled Water Levels – Milang

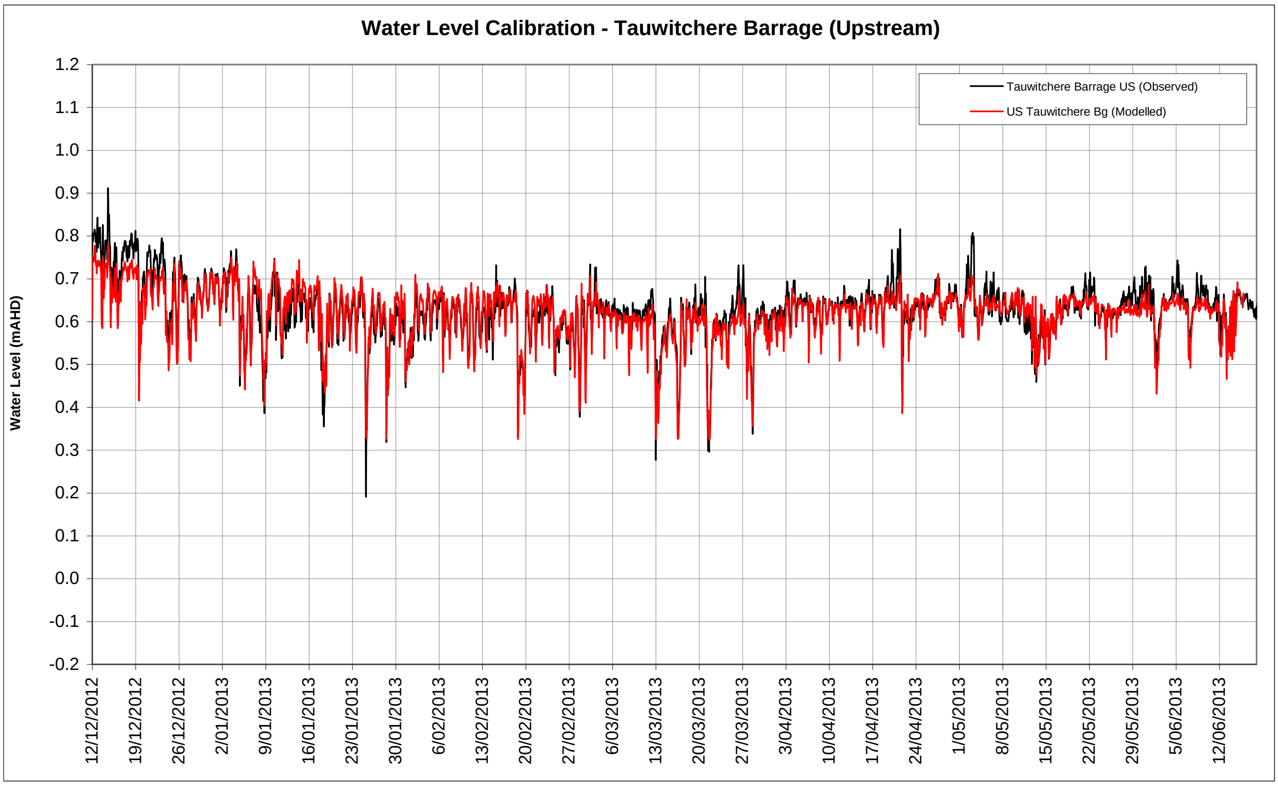

Figure 4-6 Observed and Modelled Water Levels – Upstream Tauwitchere Barrage

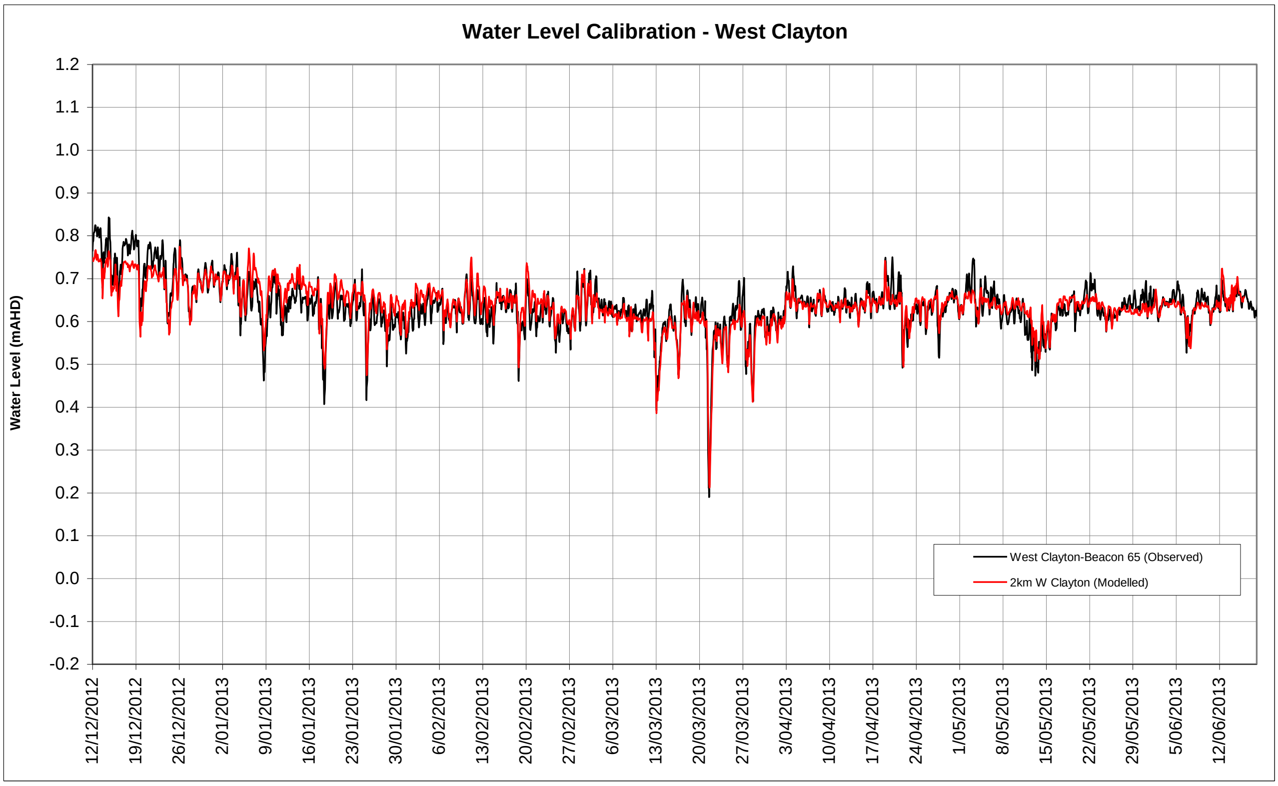

Figure 4-7 Observed and Modelled Water Levels – West Clayton

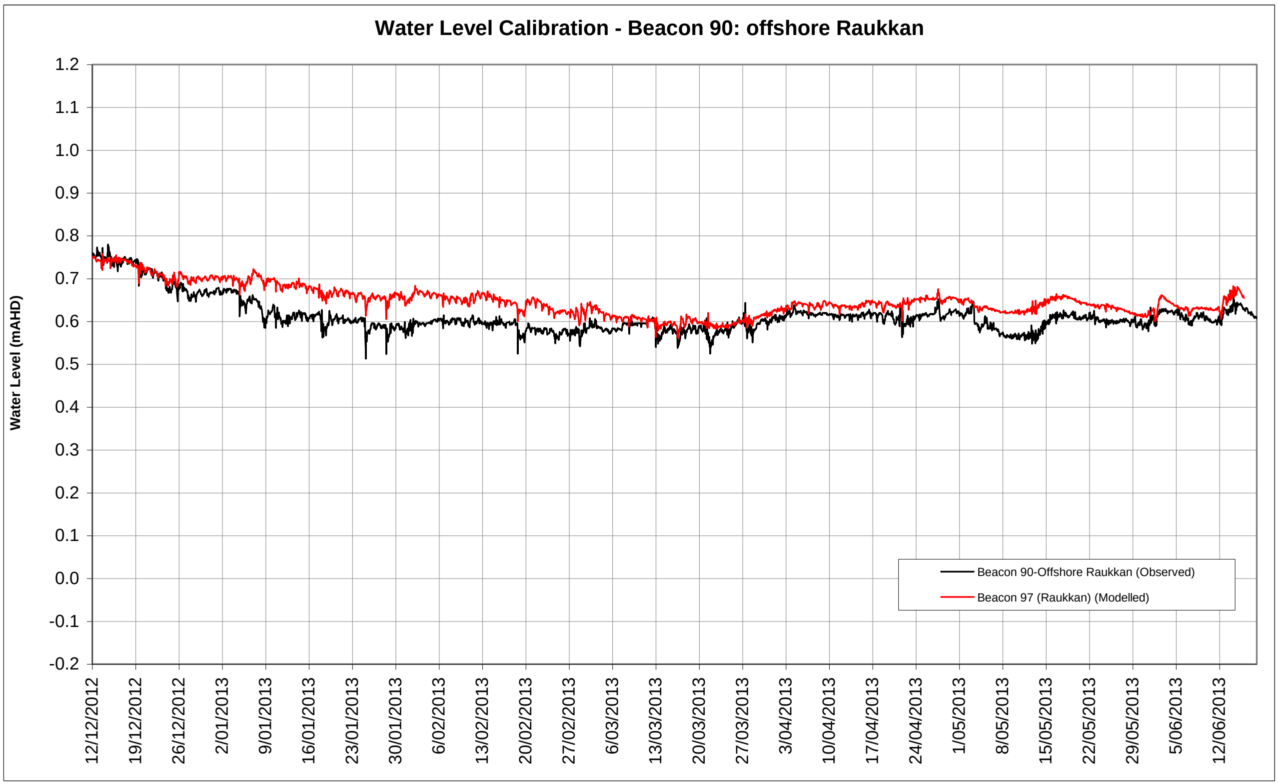

Figure 4-8 Observed and Modelled Water Levels – Beacon 90 (Raukkan)

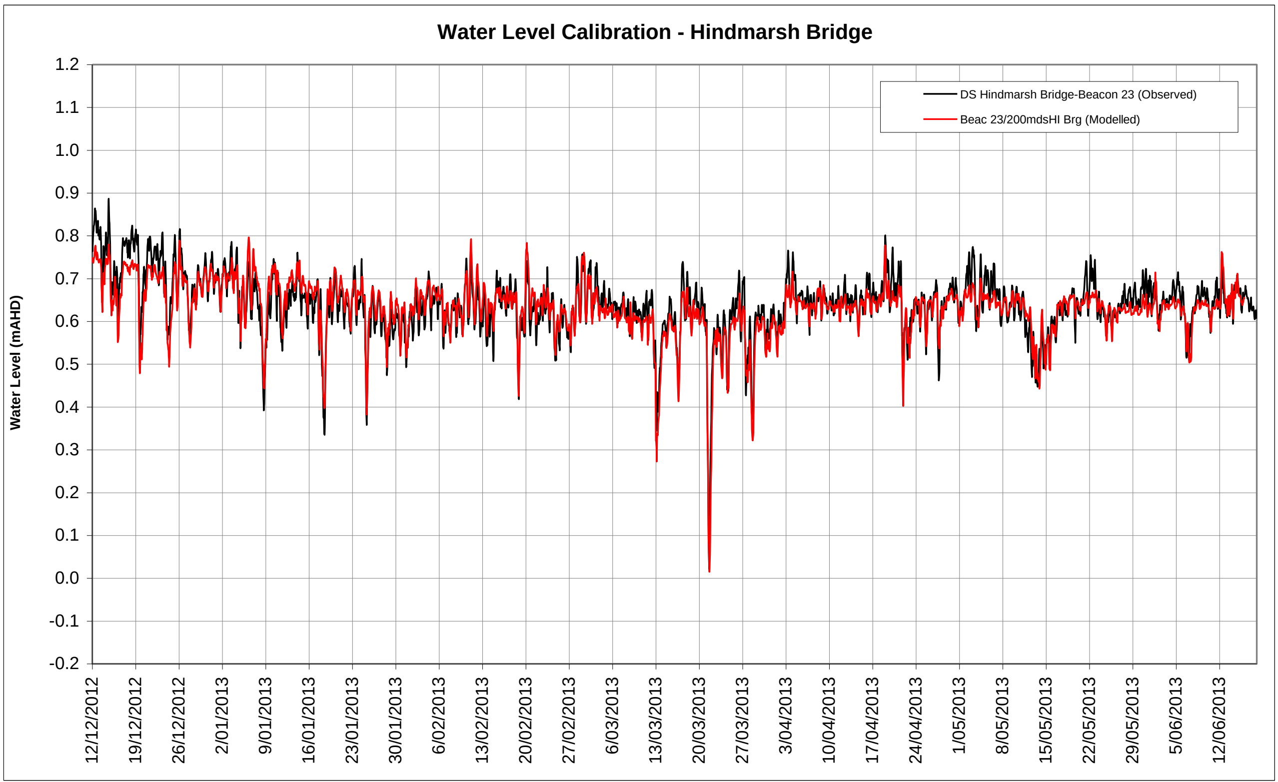

Figure 4-9 Observed and Modelled Water Levels – Hindmarsh Bridge

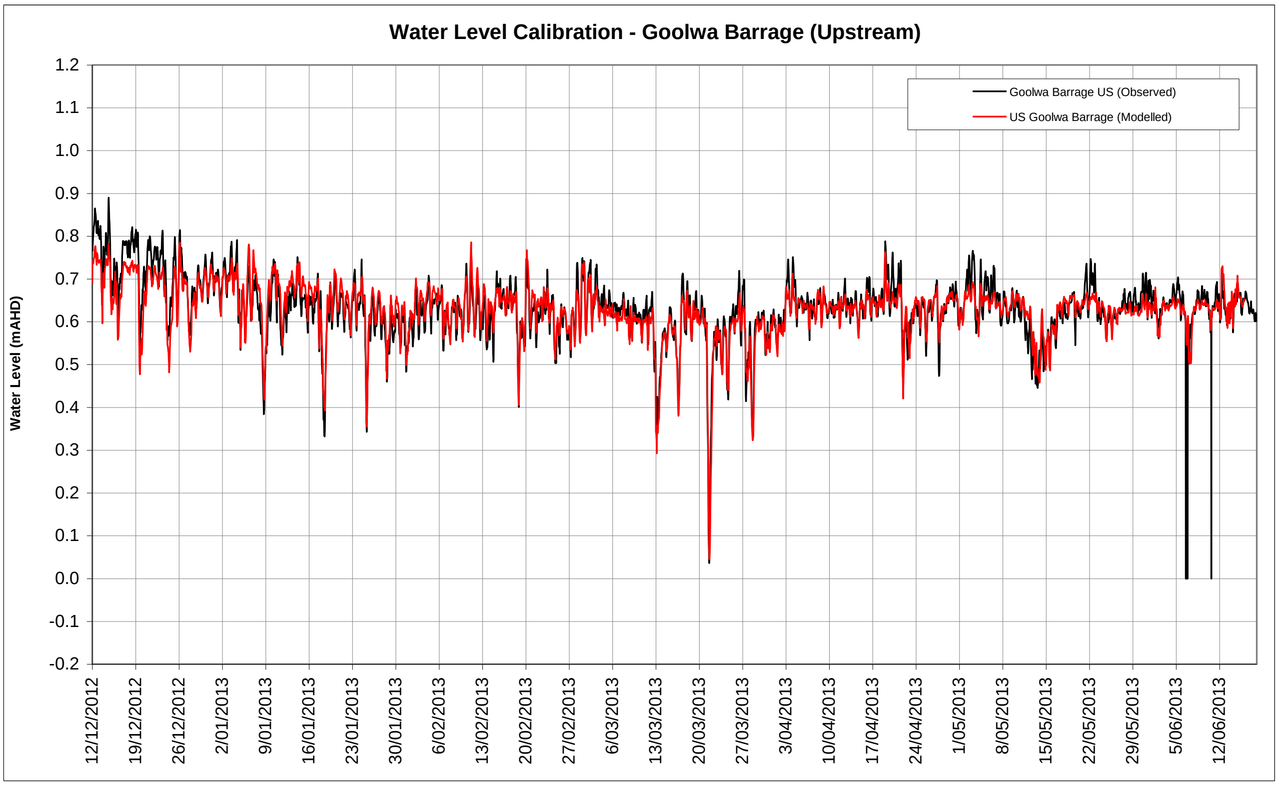

Figure 4-10 Observed and Modelled Water Levels - Goolwa Barrage (Upstream)

4.3.3 Coorong

The calibrated model closely replicates observed water levels along the Coorong as shown in Figure 4-11 to Figure 4-22. The model is able to closely represent short-term (tide and wind driven) and longer term (volumetric) fluctuations. A summary of the water level calibration achieved along the Coorong is presented in Table 4-1.

Table 4-1 Summary of Achieved Water Level Calibration in the Coorong

Gauge	Comment
Goolwa Barrage (Downstream) (Figure 4-11)	Model results closely follow observed water levels indicating a good model calibration.
Beacon 17 (Reedy Island) (Figure 4-12)	Model results closely follow observed water levels indicating a good model calibration.
Barker Knoll (Figure 4-13)	Model results closely follow observed water levels indicating a good model calibration.
Downstream Mundoo Barrage (Figure 4-14)	Model results closely follow observed water levels indicating a good model calibration.
Beacon 1 (near Ewe Island) (Figure 4-15)	Model results closely follow observed water levels indicating a good model calibration.

Gauge	Comment
Downstream Ewe Island Barrage (Figure 4-16)	Model results closely follow observed water levels; however the gauge does not appear to be able to record below 0 m AHD. No data beyond 13/3/2013 was provided at the time of the study.
Downstream Tauwitchere Barrage (Figure 4-17)	Model results closely follow observed water levels. The reduction in the influence of the tides can be clearly seen with tidal fluctuation generally having an amplitude of less than 0.2 m at this location.
Pelican Point (North Lagoon) (Figure 4-18)	By Pelican Point, the tidal amplitude is even further reduced and is now difficult to differentiate from wind seiche. Model results closely follow observed water levels, though a comparison of this gauge to adjacent gauges indicates datum drift during February. No data beyond 13/3/2013 was provided at the time of the study.
Long Point (North Lagoon) (Figure 4-19)	Model results closely follow observed water levels indicating a good model calibration.
Parnka Point (Between Lagoons) (Figure 4-20)	A comparison of this gauge to adjacent gauges indicates the datum needs to be lowered by 8cm. After applying this adjustment, the model is able to fairly closely replicate observed water level changes. The water level at Parnka Point is influenced by both North and South Lagoon water levels, wind setup and the conveyance of the approximately 10 km narrows that connect the two lagoons.
Woods Well (Cattle Island) (South Lagoon) (Figure 4-21)	The Woods Well recorder provides good data on water levels in the South Lagoon as the gauge is less influenced by wind setup and seiching. The calibrated model is able to closely replicate observed water levels which are influenced by the conveyance of water through Hells Gate (which is a function of relative water level, wind conditions, and bathymetry, including potential morphological change, and evaporation).
Snipe Island (South Lagoon) (Figure 4-22)	The model is able to closely replicate observed water level changes at the end of the south lagoon. The influence of wind seiche at this location is more evident than at Woods Well.

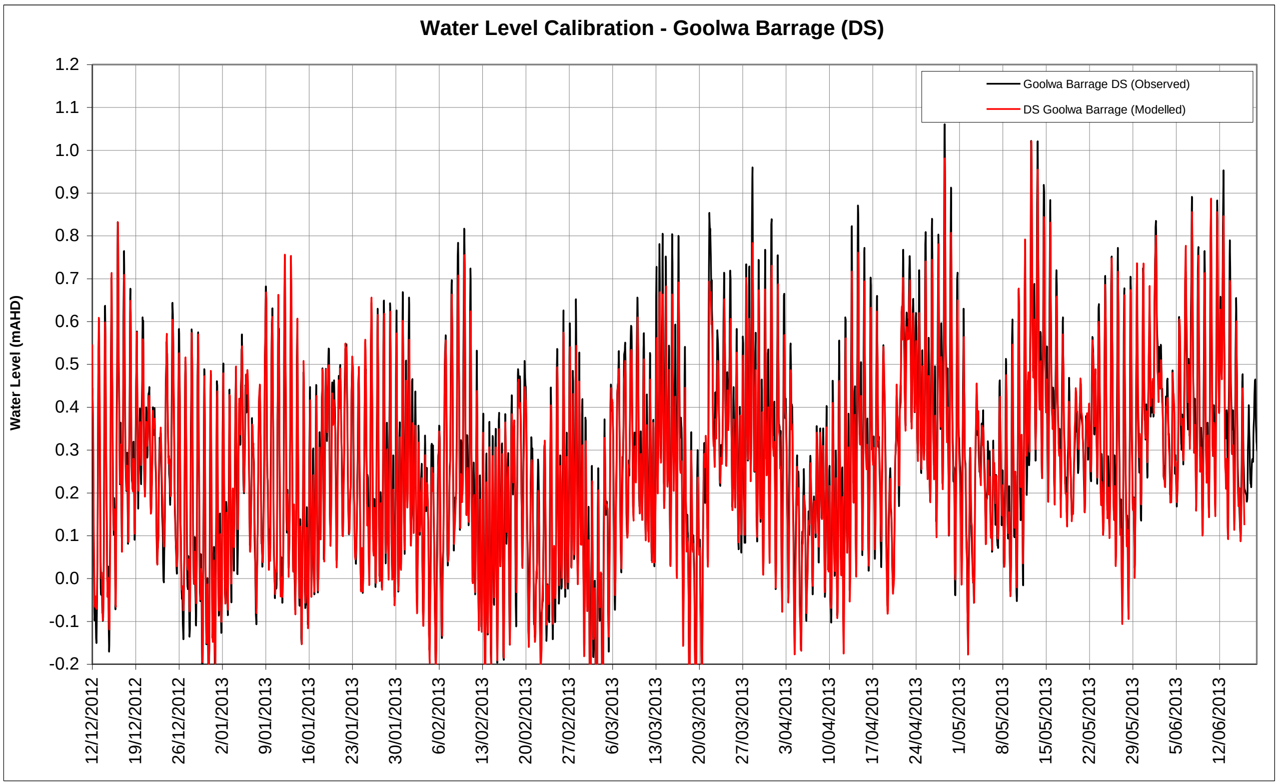

Figure 4-11 Observed and Modelled Water Levels - Goolwa Barrage (Downstream)

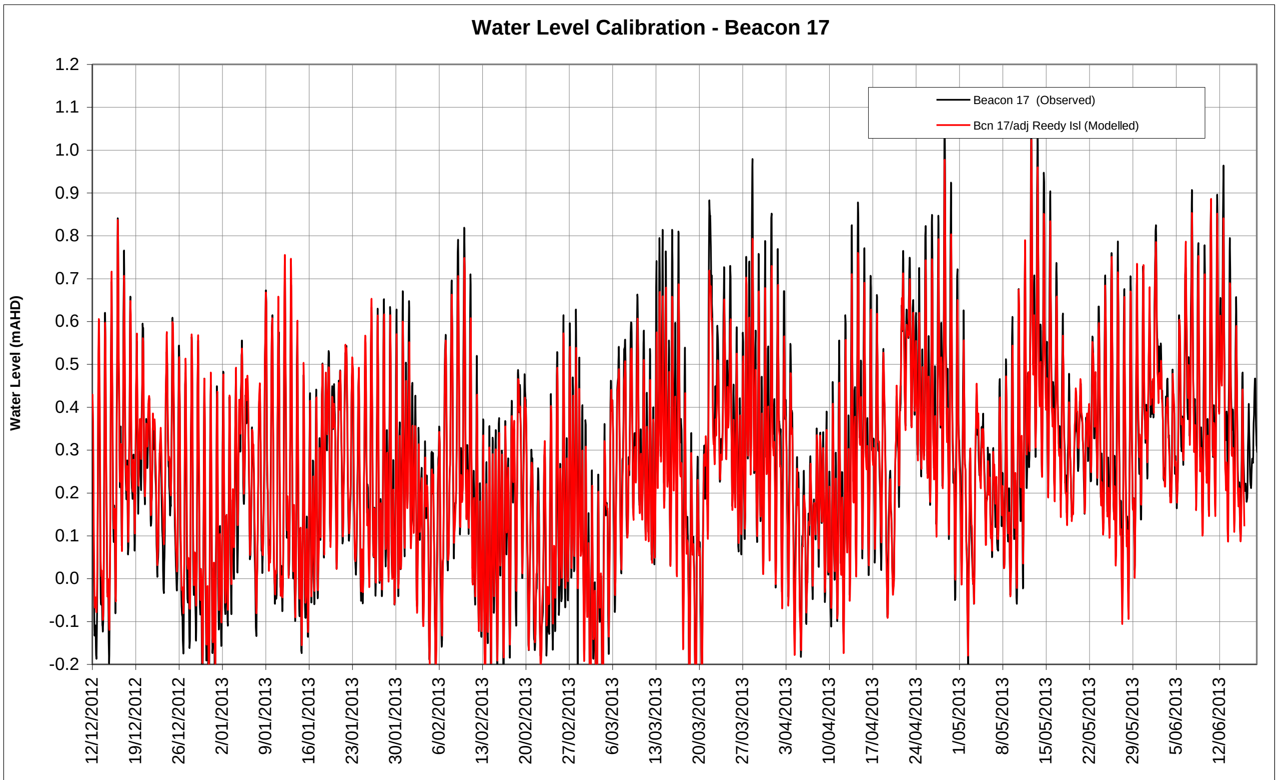

Figure 4-12 Observed and Modelled Water Levels – Beacon 17 (Reedy Island)

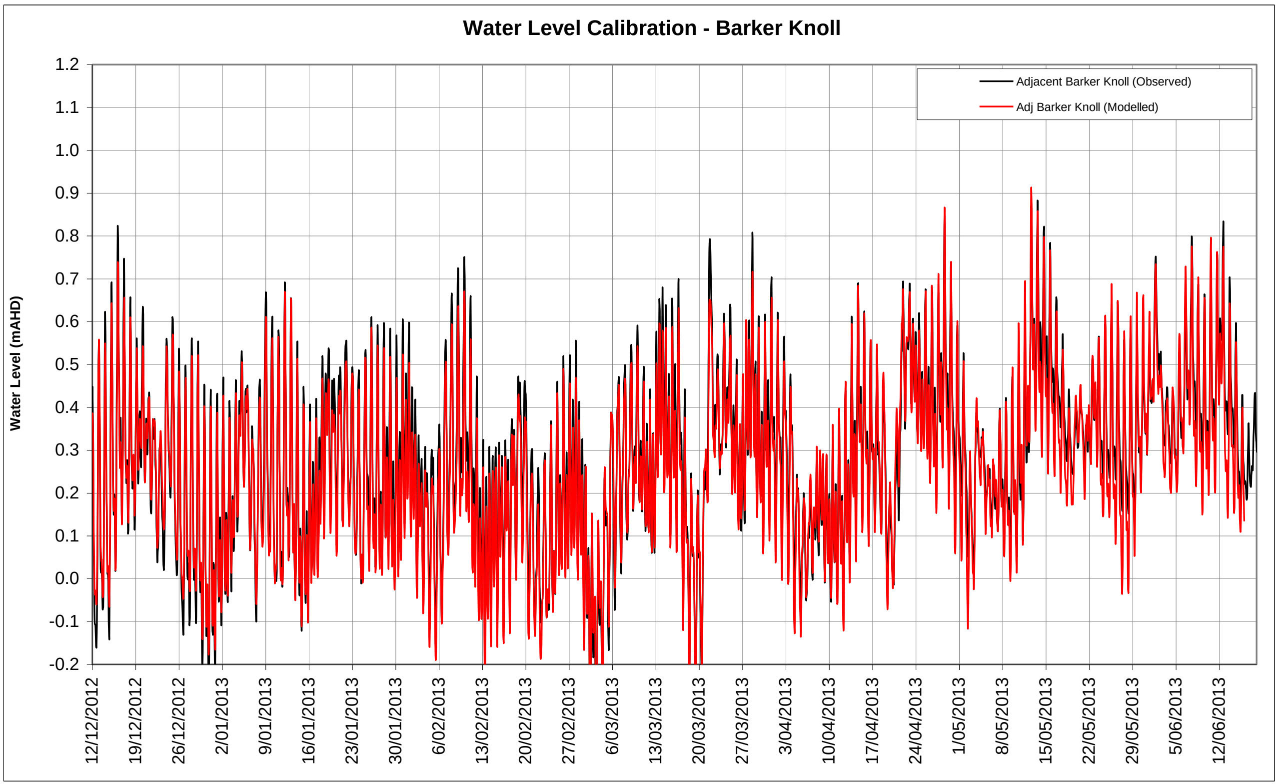

Figure 4-13 Observed and Modelled Water Levels – Barker Knoll

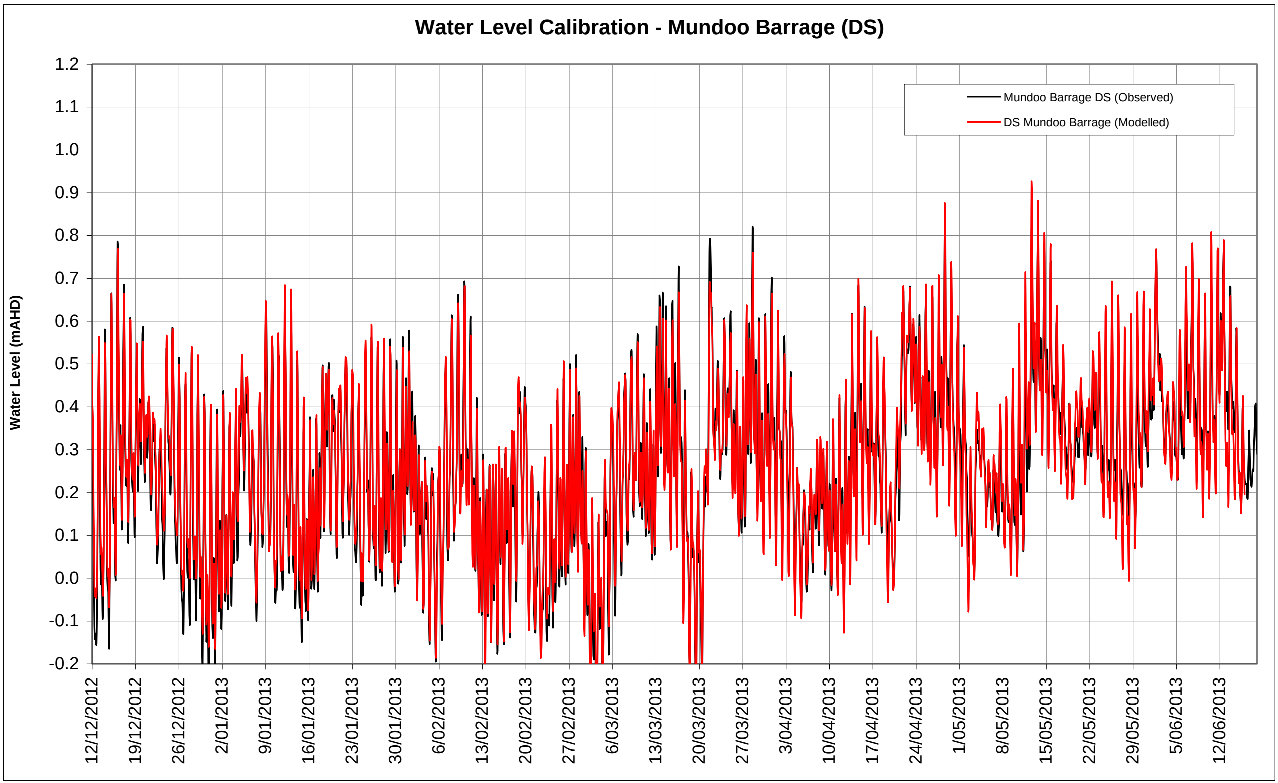

Figure 4-14 Observed and Modelled Water Levels – Downstream Mundoo Barrage

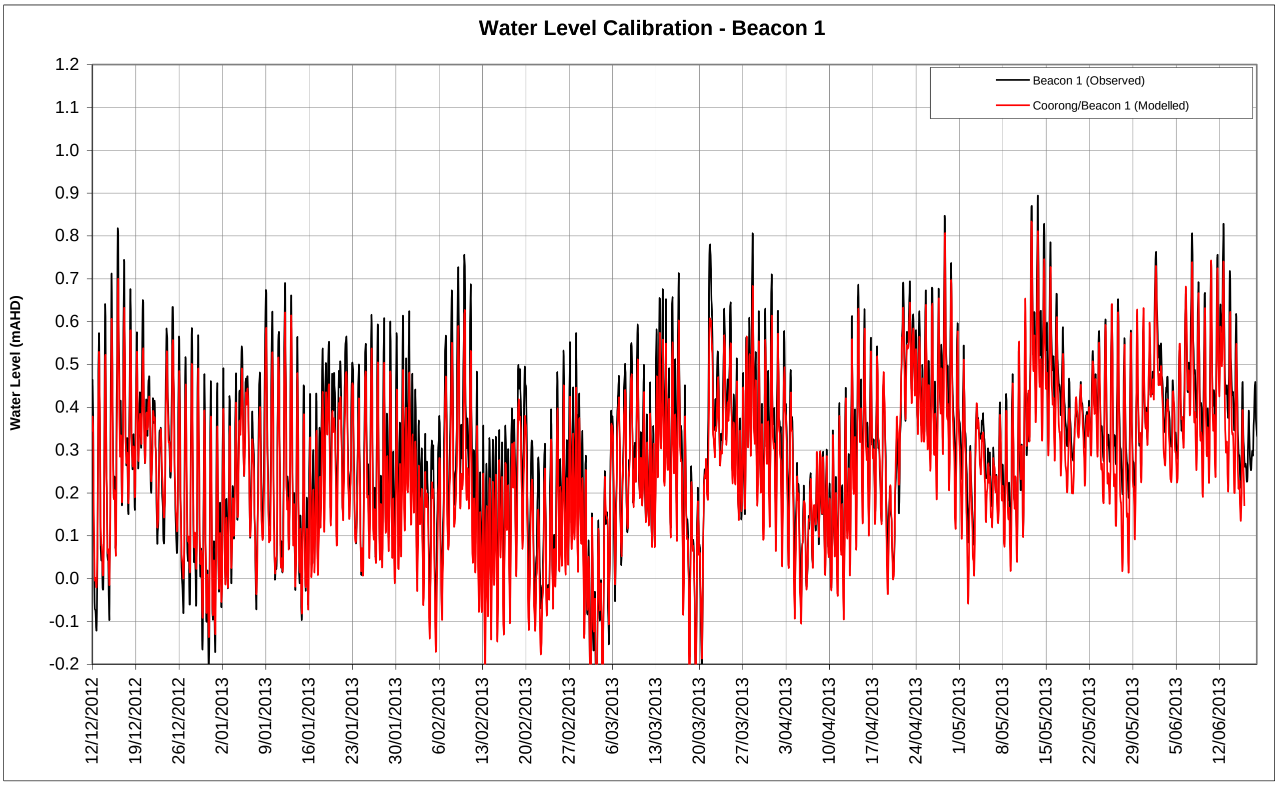

Figure 4-15 Observed and Modelled Water Levels – Beacon 1 (near Ewe Island)

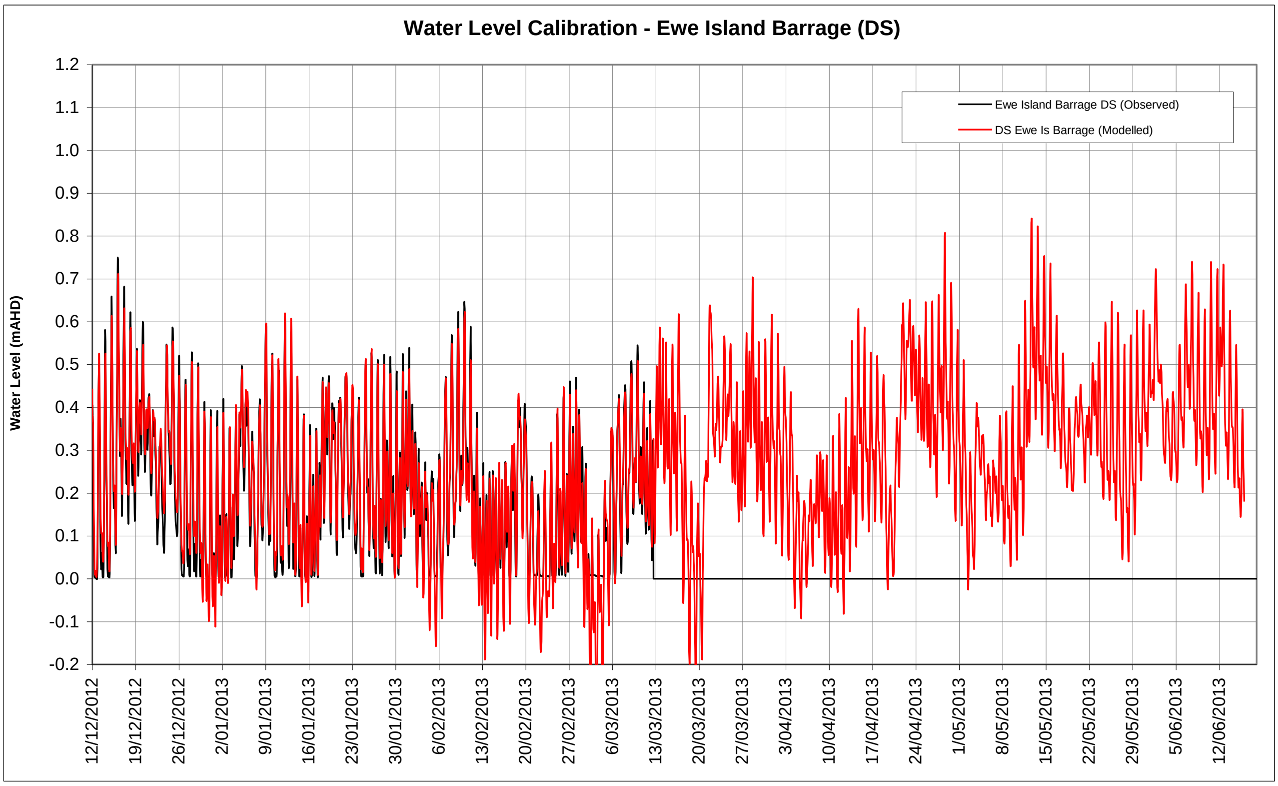

Figure 4-16 Observed and Modelled Water Levels – Downstream Ewe Island Barrage

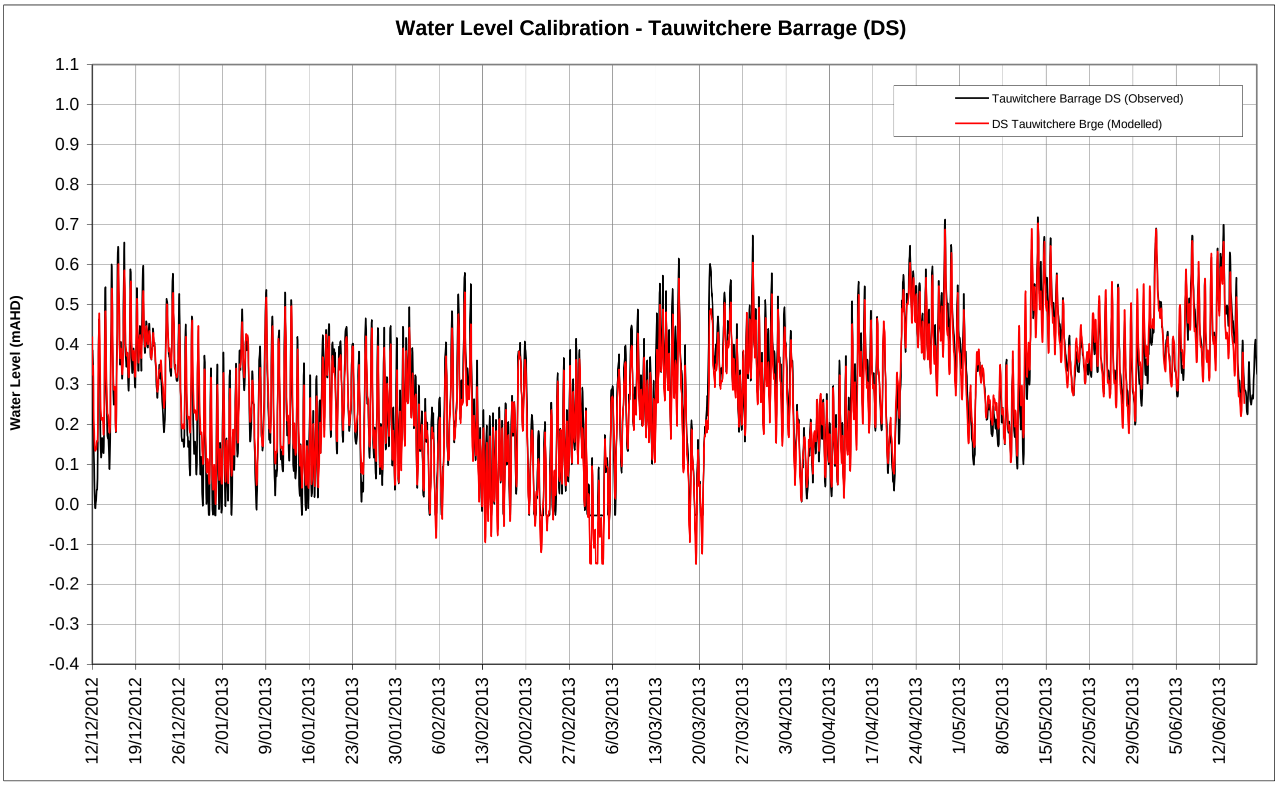

Figure 4-17 Observed and Modelled Water Levels – Downstream Tauwitchere Barrage

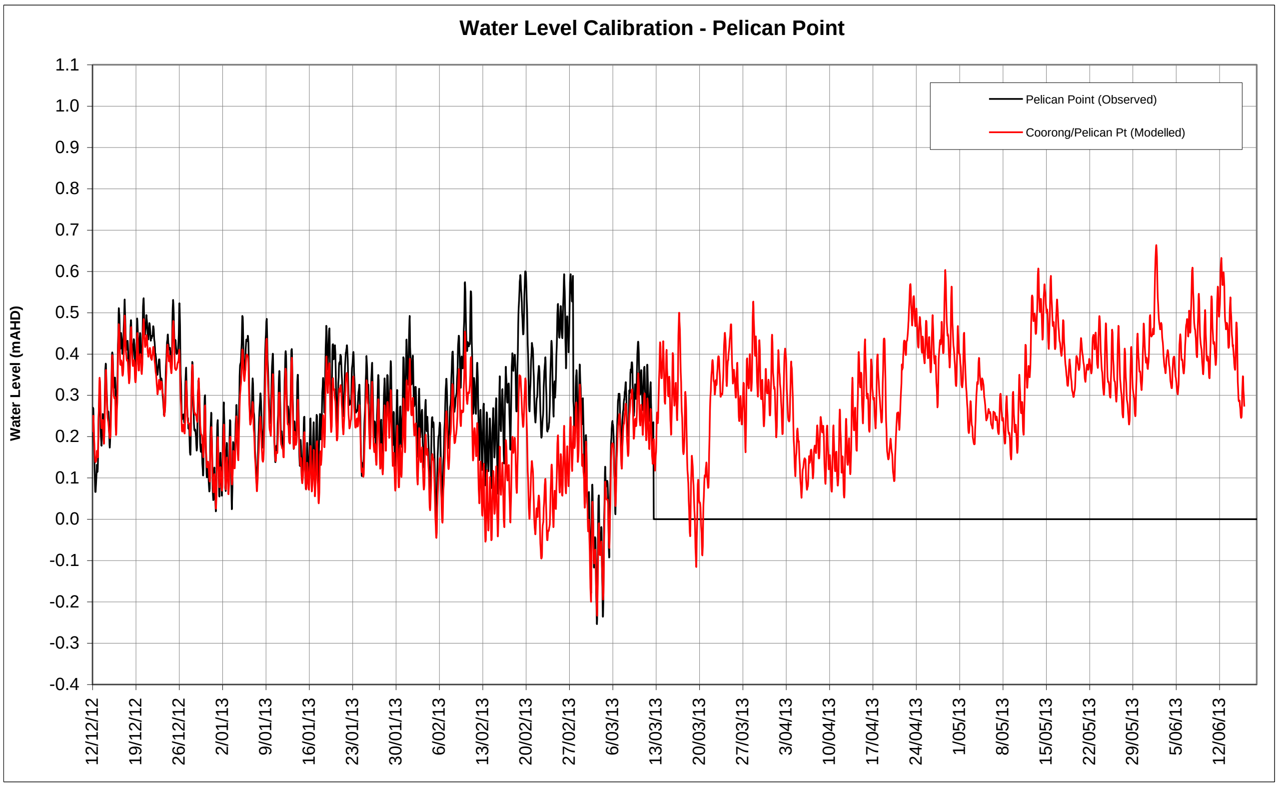

Figure 4-18 Observed and Modelled Water Levels – Pelican Point (North Lagoon)

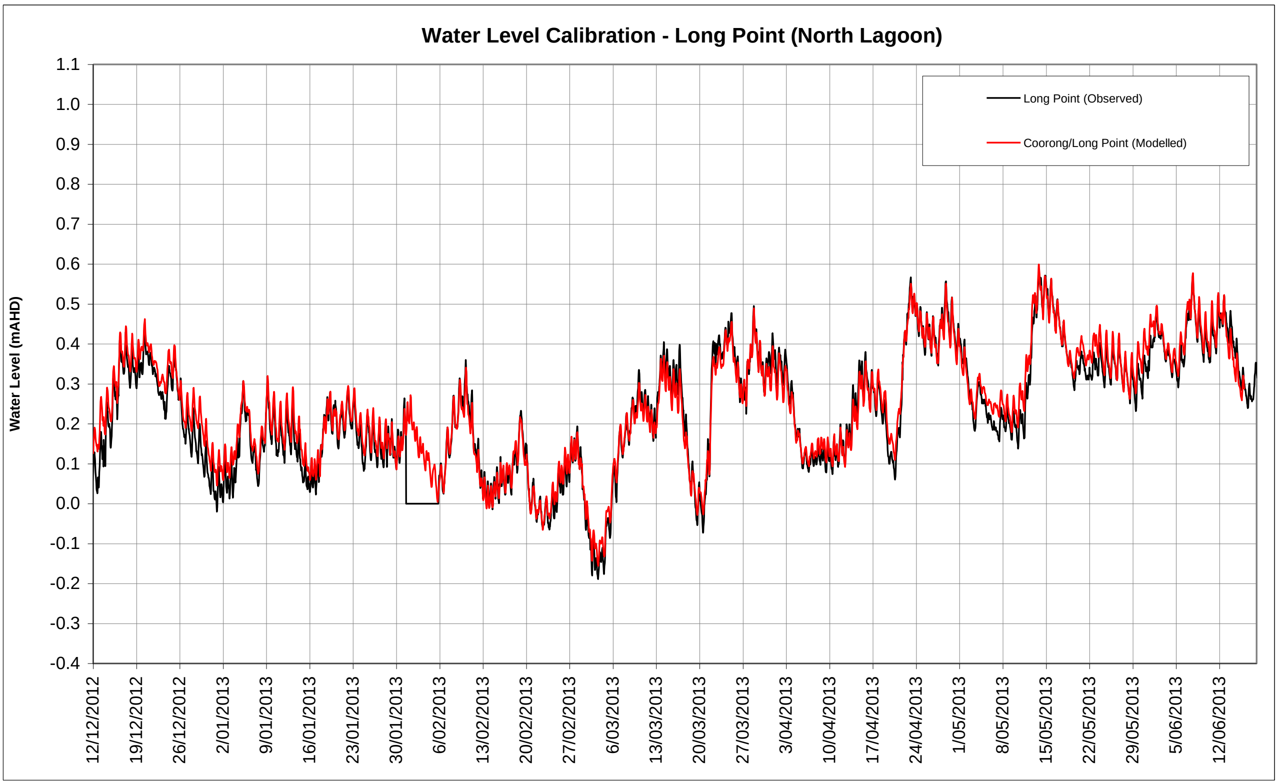

Figure 4-19 Observed and Modelled Water Levels – Long Point (North Lagoon)

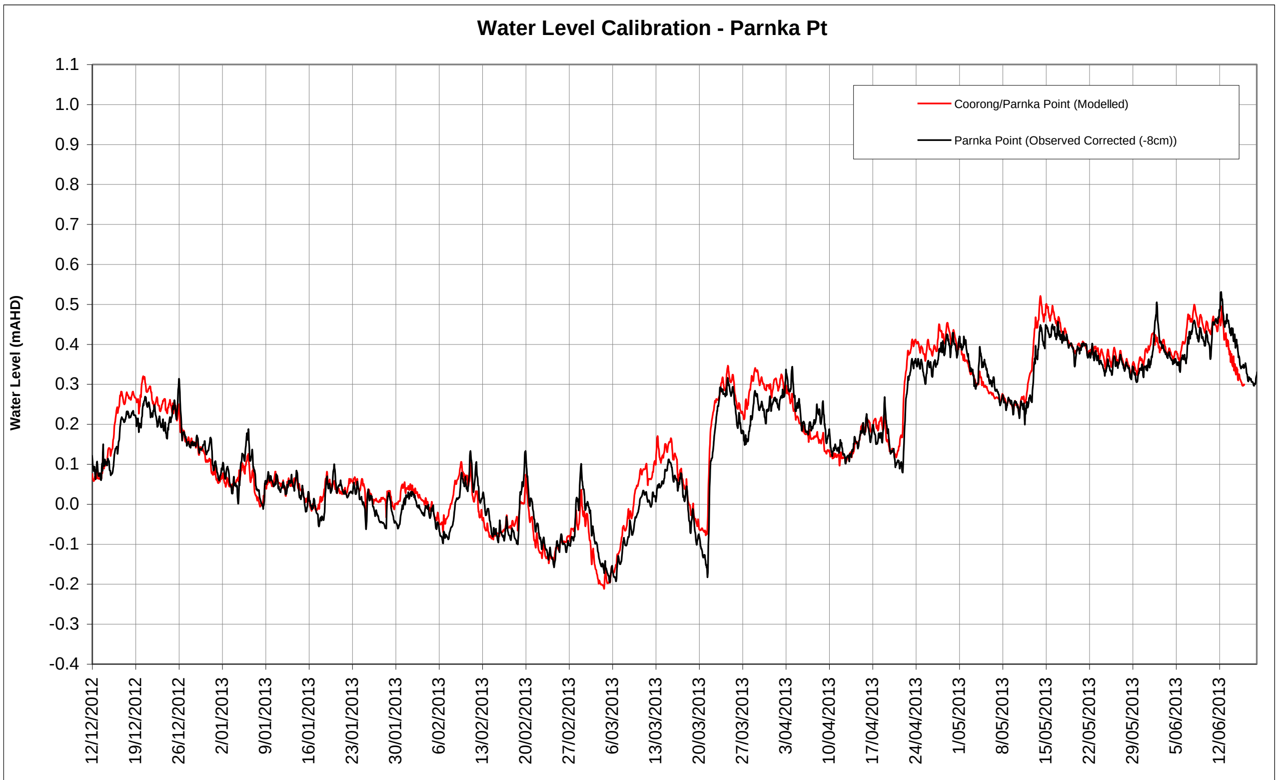

Figure 4-20 Observed and Modelled Water Levels – Parnka Point (Hells Gate)

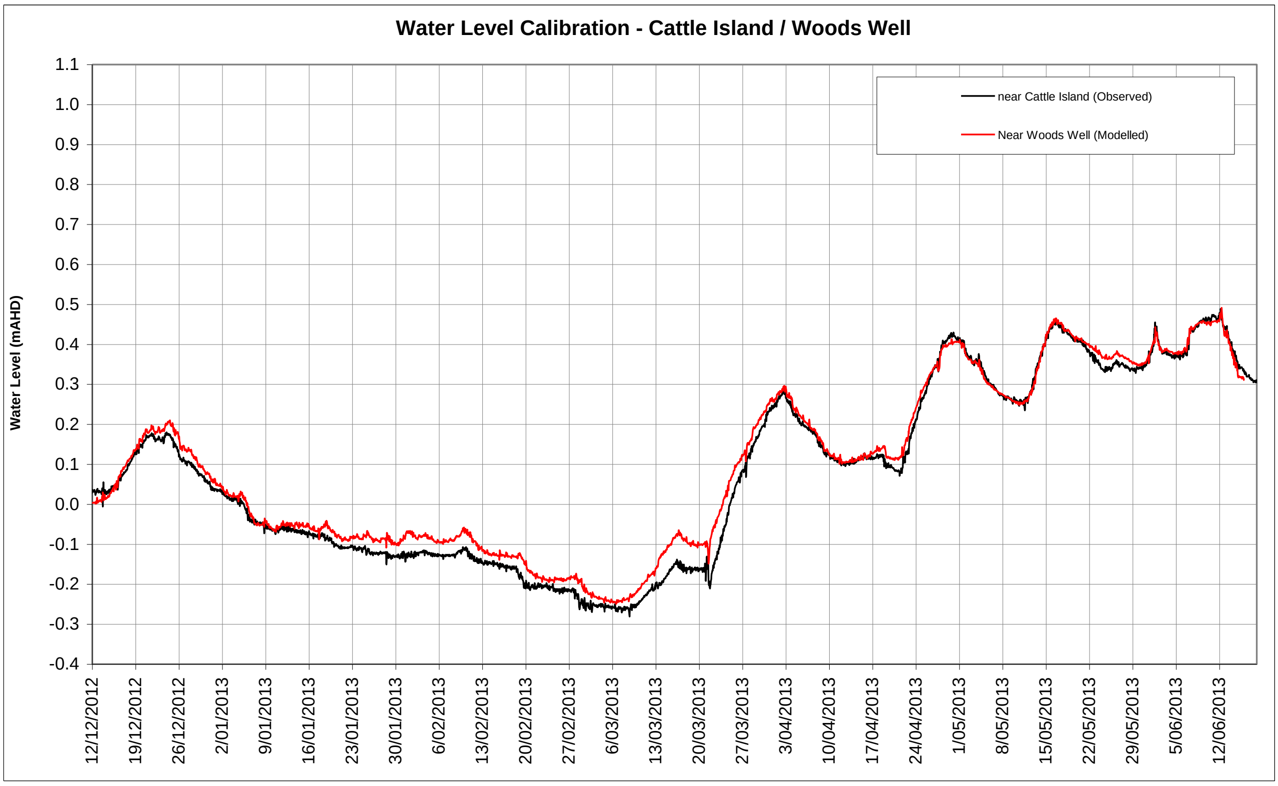

Figure 4-21 Observed and Modelled Water Levels – Cattle Island / Woods Well (South Lagoon)

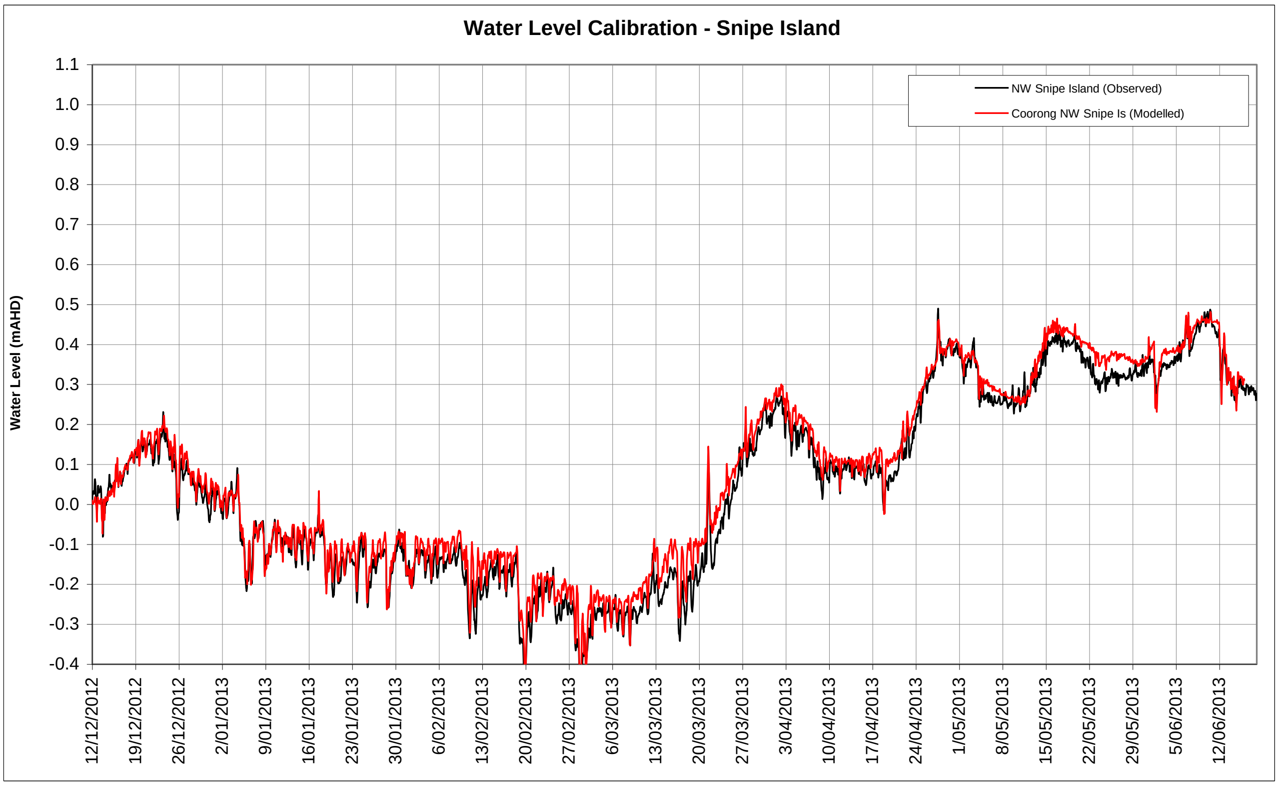

Figure 4-22 Observed and Modelled Water Levels – Snipe Island (South Lagoon)

4.4 Salinity Calibration

Ensuring that the model can replicate observed salinity change is important as a key reason for the development of the model is to assess future changes to salinity in Lake Albert. Therefore, in order to have confidence in future model predictions/forecasts, it is important that the model can replicate/hindcast observed salinity changes.

A number of factors influence the ability of the model to reproduce observed salinity change including:

- Ensuring the model can reproduce the correct movement (hydrodynamics) of water within the system. In the absence of ADCP (flow measurements) ensuring correct water level calibration is the only way to ensure the model can correctly reproduce system hydrodynamics (Section 4.3);
- Correctly specifying the initial conditions – this is important to have a good estimate of the total mass and distribution of salt within the system;
- Correctly specifying lake inflow, lake extraction and barrage outflows (including distribution) was found to be important for reproducing observed salinity levels in the Coorong;
- Correcting specifying rainfall and evaporation; the use of a spatially varying applied net rainfall-evaporation was found to improve the model validation for longer simulations (see Sections 3.5.2); and
- Use of a 2D model – the assumption of a vertically mixed water column is likely to impact the models ability to represent some of the observed salinity variations. However, as the system is shallow and it is exposed to a high degree of wind mixing, the assumption of a well-mixed (vertically homogenous) water column is likely to be appropriate.

A discussion of the achieved degree of salinity calibration for Lake Albert, Lake Alexandrina and the Coorong is provided below. An examination of salinity calibration provides a secondary check that the model is able to adequately calculate the movement of water and also the mixing of salt. Importantly, the model calculates salt concentration which is converted back to an approximate electrical conductivity (EC - µS/cm) using the equation presented in Section 3.6.2. There remains some uncertainty regarding this conversion at high salt concentrations.

4.4.1 Lake Albert

The model's ability to reproduce observed changes in salinity within Lake Albert over the validation period is presented in Figure 4-23 (Meningie Jetty), Figure 4-24 (Waltowa) and Figure 4-25 (Warringee Point). The figures show that the model is able to closely reproduce the magnitude and general timing of observed salinity changes and a good model validation was achieved. This demonstrates that the model is suitable for predicting changes in salinity within Lake Albert and for formulation Lake management options that optimise salt export from Lake Albert.

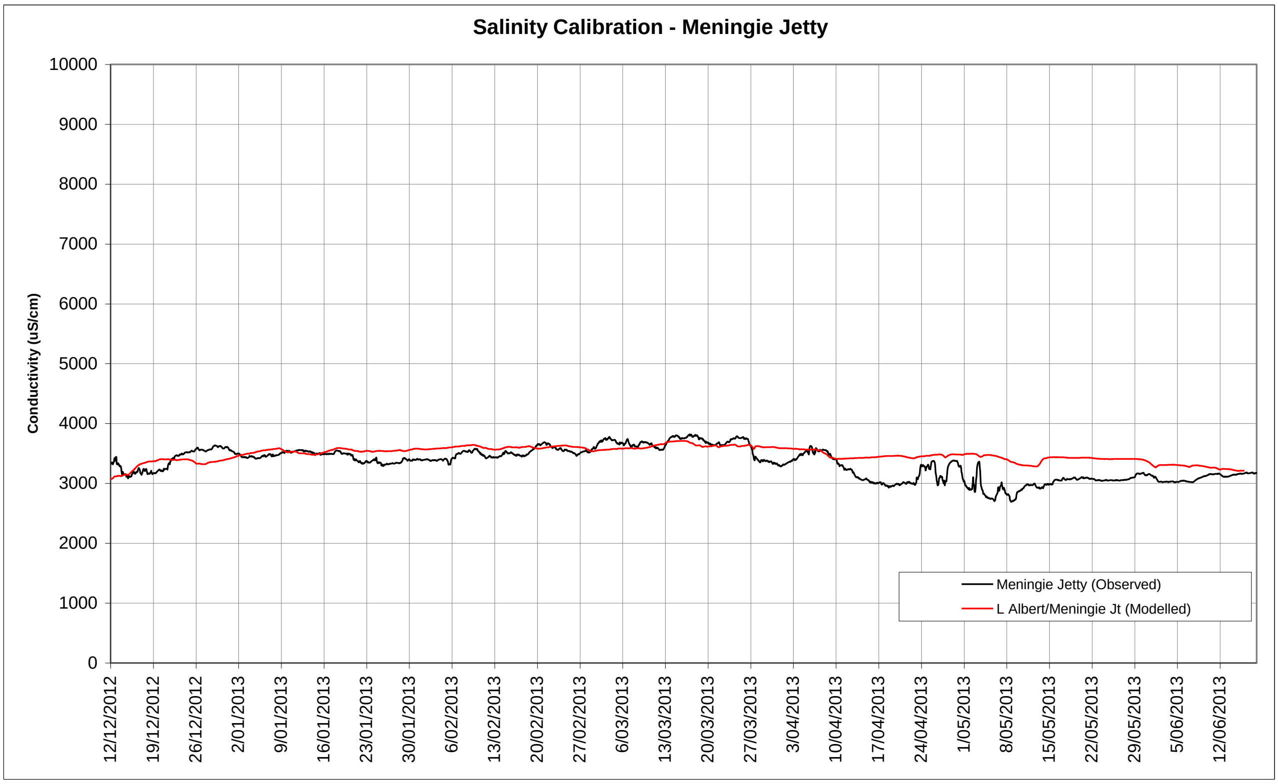

Figure 4-23 Observed and Modelled Salinity – Meningie

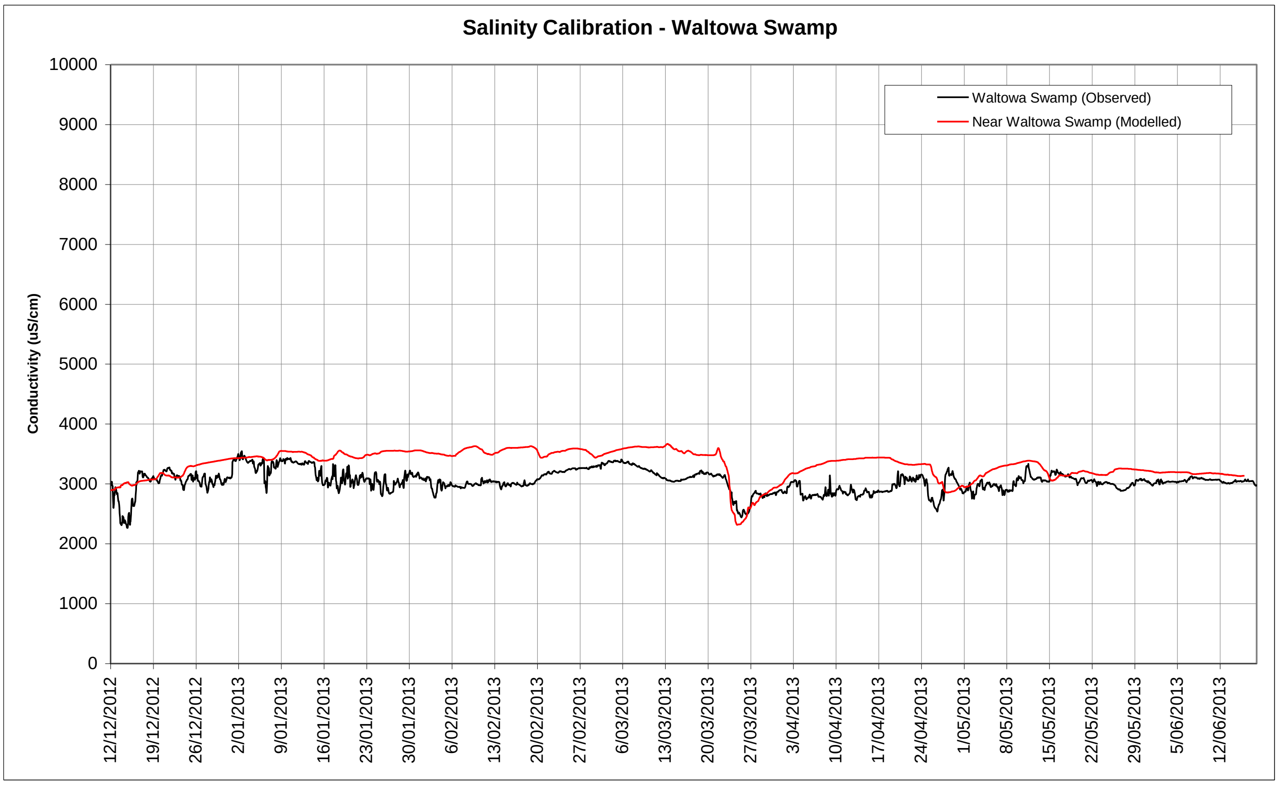

Figure 4-24 Observed and Modelled Salinity – Waltowa Swamp

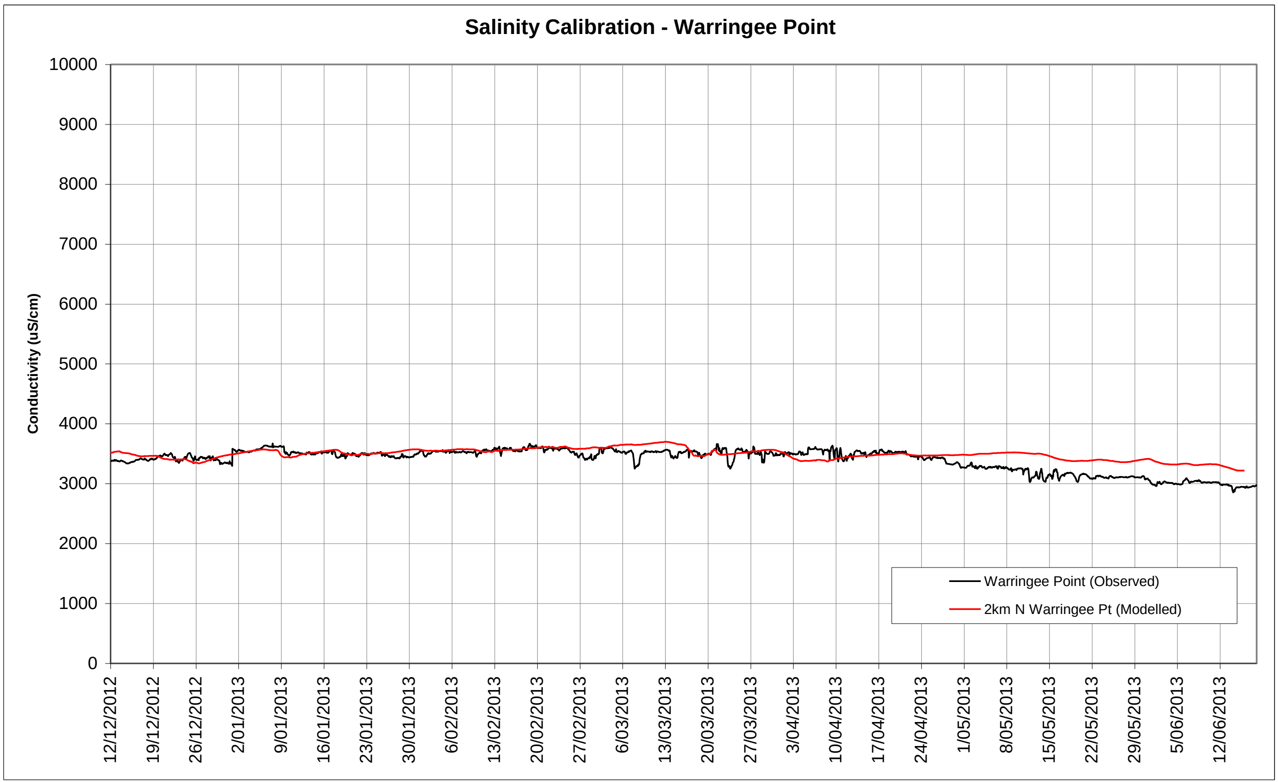

Figure 4-25 Observed and Modelled Salinity – Warringee Point

4.4.2 Lake Alexandrina

The model's ability to reproduce observed changes in salinity over the validation period in Lake Alexandrina is presented in Figure 4-26 (Poltalloch Plains), Figure 4-27 (Mulgundawa), Figure 4-28 (Raukkan - Beacon 90), Figure 4-29 (Upstream Ewe Island Barrage) and Figure 4-30 (Upstream Goolwa Barrage). The model is able to closely replicate observed changes in salinity in the main body of Lake Alexandrina. However, the model is not able to accurately reproduce backflow events at Goolwa or Ewe Island Barrage. This may be due to uncertainties regarding the water balance (i.e. estimates of Lake Inflows and abstractions), the use of a 2D scheme which cannot resolve vertical differences in salinity and uncertainties regarding barrage opening data (i.e. data is of low temporal resolution, no sill level data for Goolwa and no ratings for fishways).

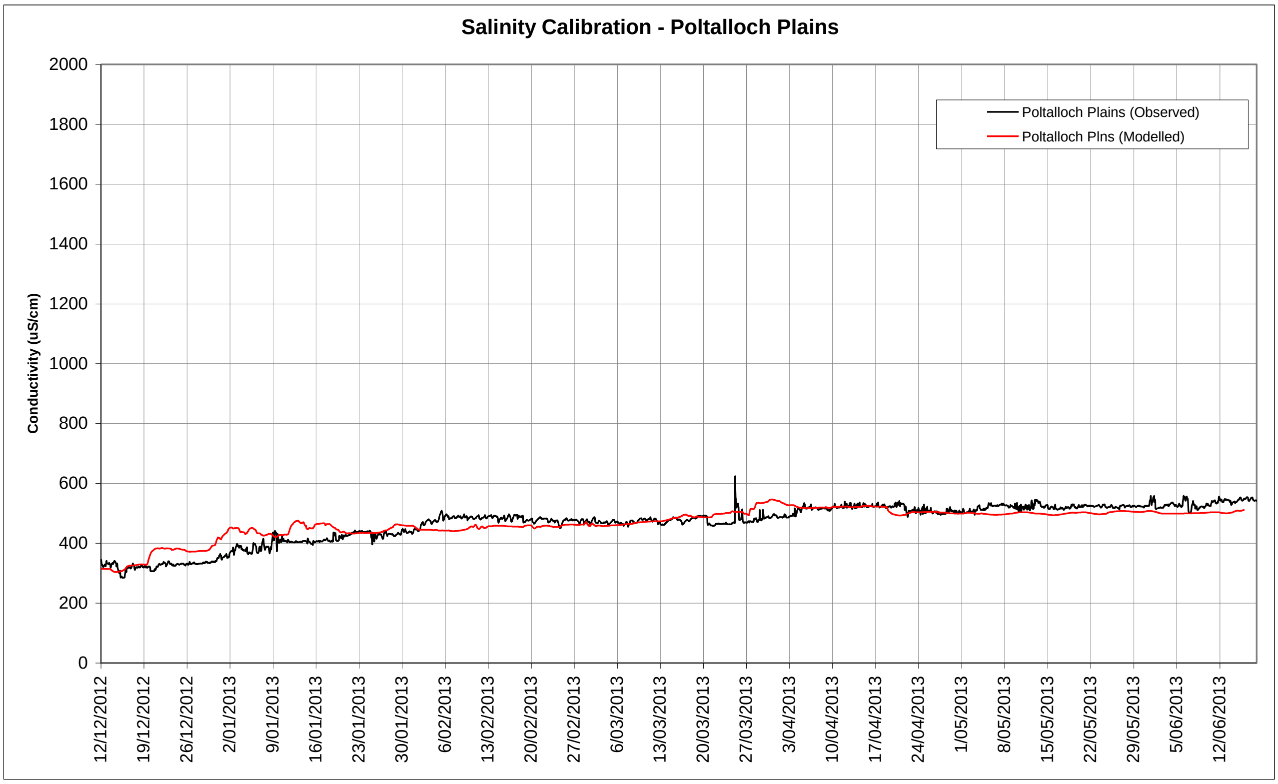

Figure 4-26 Observed and Modelled Salinity – Poltalloch Plains

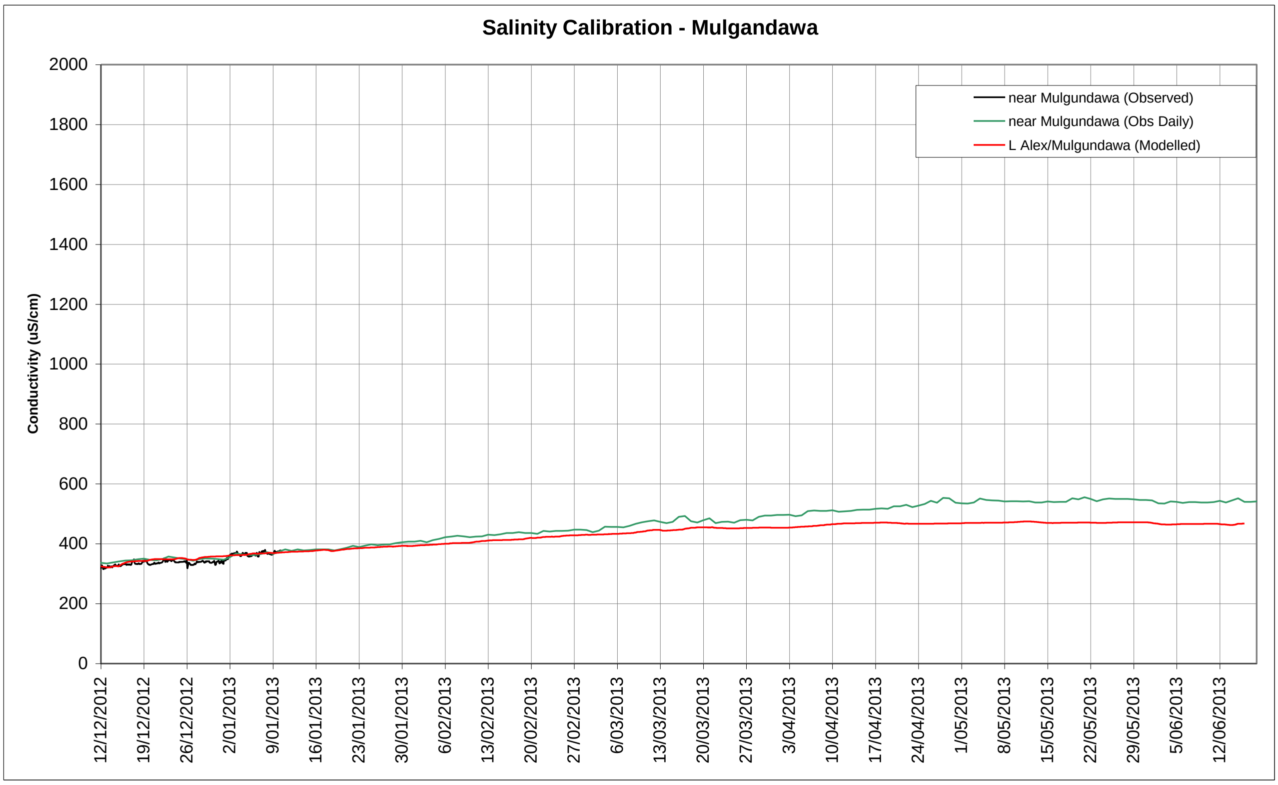

Figure 4-27 Observed and Modelled Salinity – Mulgundawa

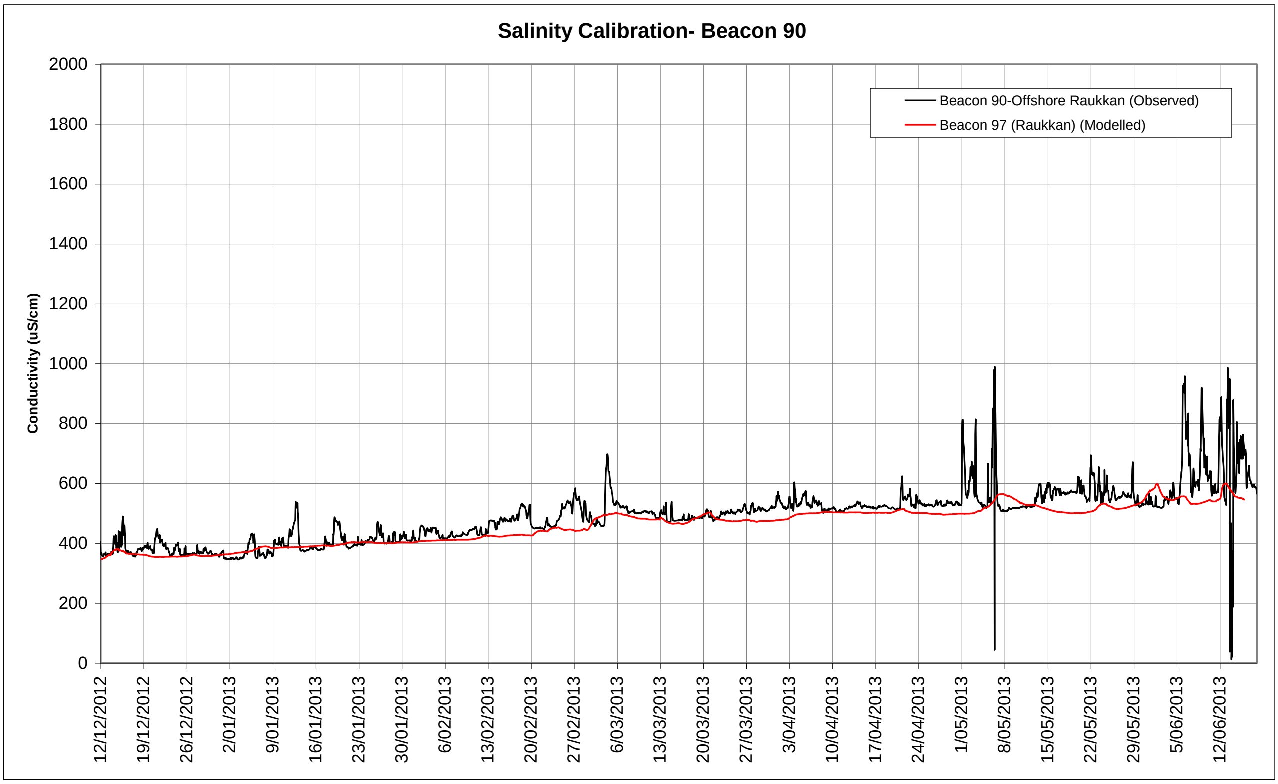

Figure 4-28 Observed and Modelled Salinity – Raukkan (Beacon 90)

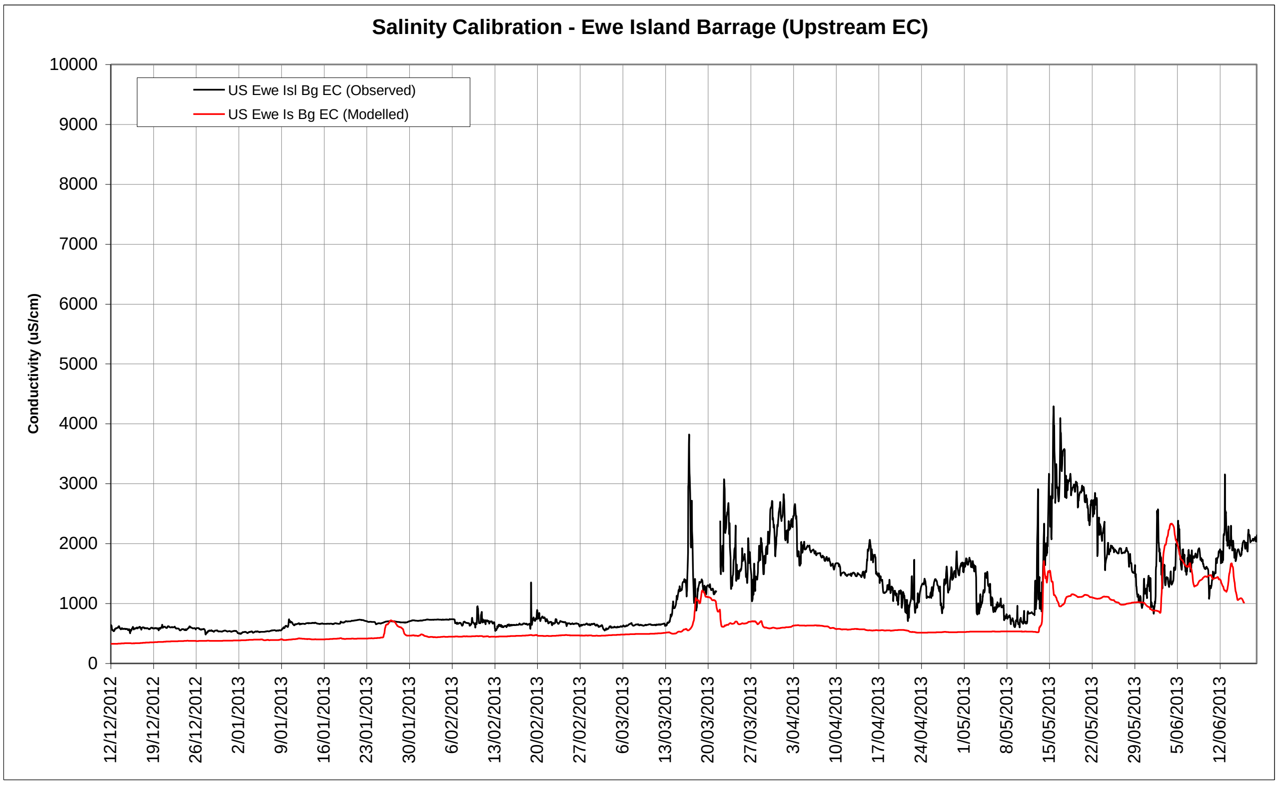

Figure 4-29 Observed and Modelled Salinity – Ewe Island Barrage (Upstream)

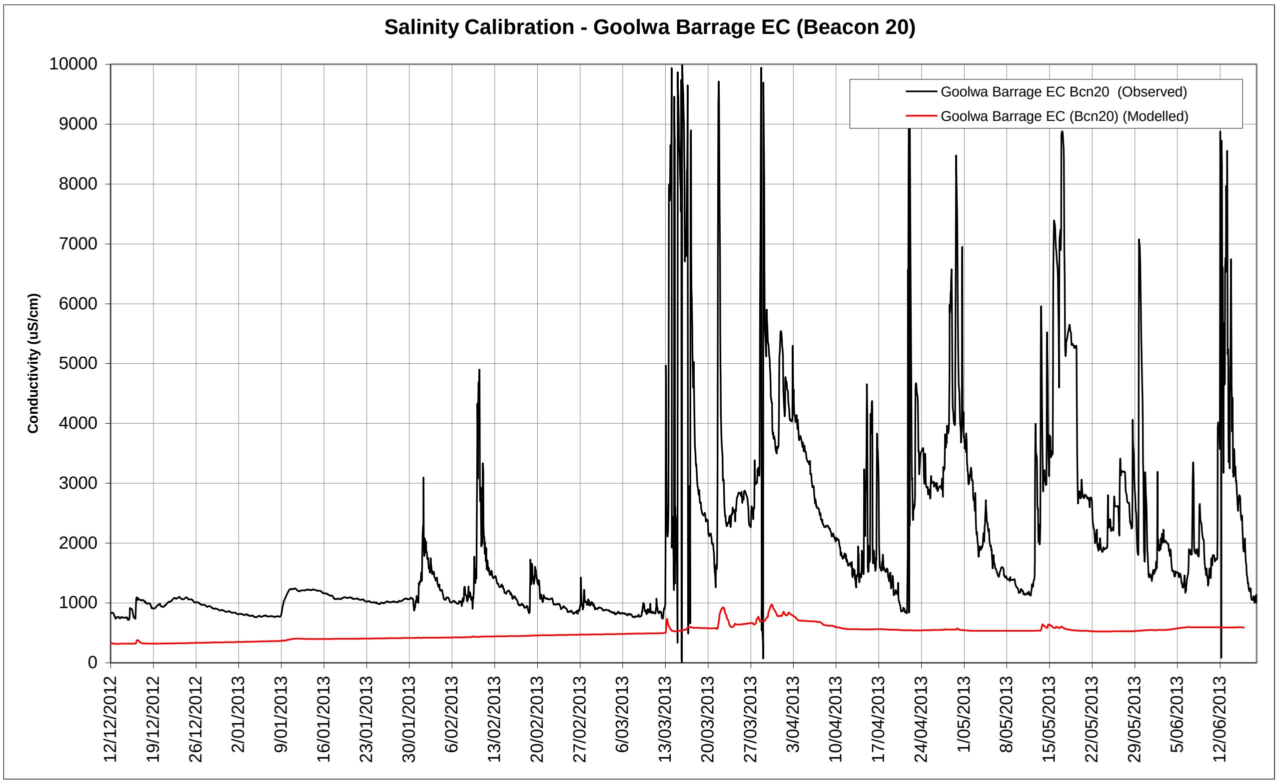

Figure 4-30 Observed and Modelled Salinity – Goolwa Barrage (Upstream)

4.4.3 Coorong

The model's ability to reproduce observed changes in salinity over the validation period along the Coorong is presented in the following nine figures and summarised in Table 4-2.

The model replicates the majority of the observed salinity changes in the Coorong over the validation period, though uncertainty in the water balance of the Lower Lakes and uncertainty regarding barrage operations means that salinity levels in Goolwa and Tauwitchere Channel downstream of the barrages were not always reproduced accurately by the model. An example of this is that modelled salinity levels at Reedy Island (Figure 4-31) are generally half that observed, while there a a number of periods (in March to May) when modelled salinity levels at Barker Knoll Figure 4-32 are higher than observed.

It should also be noted that there is a degree of uncertainty between the accuracy of the electrical conductivity gauges at high salinity and also the conversion between electrical conductivity and concentration at high salinity (see Section 3.6.2 for conversion method).

Table 4-2 Summary of Achieved Salinity Calibration in the Coorong

Gauge	Comment
Beacon 17 (Reedy Island) (Figure 4-31)	The model is able to reproduce the timing of changes in salinity, however, the model under-predicts the observed salinity levels indicating the model is releasing too much flow at Goolwa Barrage. This may be due to uncertainty regarding barrage operation (i.e. sill level, gate location, timing and fishway operation) or the water balance of the Lower Lakes (i.e. uncertainty regarding lake inflows and abstractions).
Barker Knoll (Figure 4-32)	The model is able to replicate the majority of salinity response at this location (near the Murray Mouth). However, during a number of periods in March to May the model does not predict reductions in salinity. This is likely to be due to errors in predicting the flow split between the eastern (i.e. Goolwa and Mundoo) barrages and the western (i.e. Ewe Island and Tauwitchere) barrages and the above mentioned water balance issue.
Beacon 1 (near Ewe Island) (Figure 4-33)	The model is able to replicate the majority of observed salinity changes at this location. The larger than observed salinity drops during January are likely to be due to the above mentioned water balance issues.
Pelican Point (North Lagoon) (Figure 4-34)	At Pelican Point the model is able to reproduce the majority of the observed salinity fluctuations. Differences are likely to be due to the above mentioned water balance issues, which act to push salt back into the North Lagoon.
Long Point (North Lagoon) (Figure 4-35)	The model is able to reasonable replicate observed salinity behaviour at Long Point in the Coorong's North Lagoon. The model under-predicts salinity through much of the simulation is likely to be due to the above mentioned water balance issue.
Parnka Point (Between Lagoons) (Figure 4-36)	Gauge issues at Parnka Point mean that the observed data set is likely to be spurious for much of the simulation period. In May and June the model is able to reproduce the timing of salinity changes.
Woods Well (Cattle Island) (South Lagoon) (Figure 4-37)	The model is able to closely simulate much of the observed salinity behaviour in the South Lagoon (especially consider some potential gauge issues (i.e. vertical, "step" salinity changes)).
Snipe Island (South Lagoon) Figure 4-38	The model is able to closely simulate much of the observed salinity behaviour in the South Lagoon at Snipe Island (especially consider some potential gauge issues and uncertainty regarding the conversion between conductivity and concentration). The observed drop in salinity in late-April may be a gauge error (i.e. there is a step change in reported salinity).

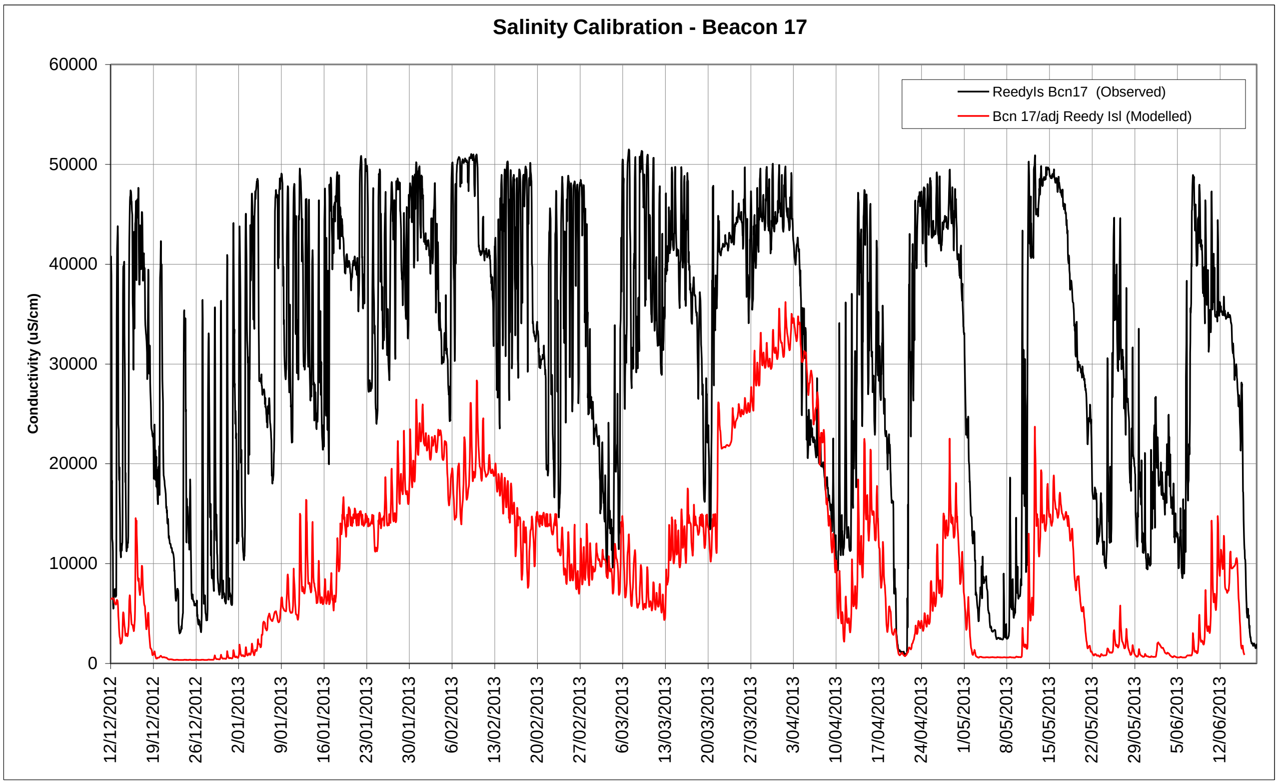

Figure 4-31 Observed and Modelled Salinity – Beacon 17 (Reedy Island)

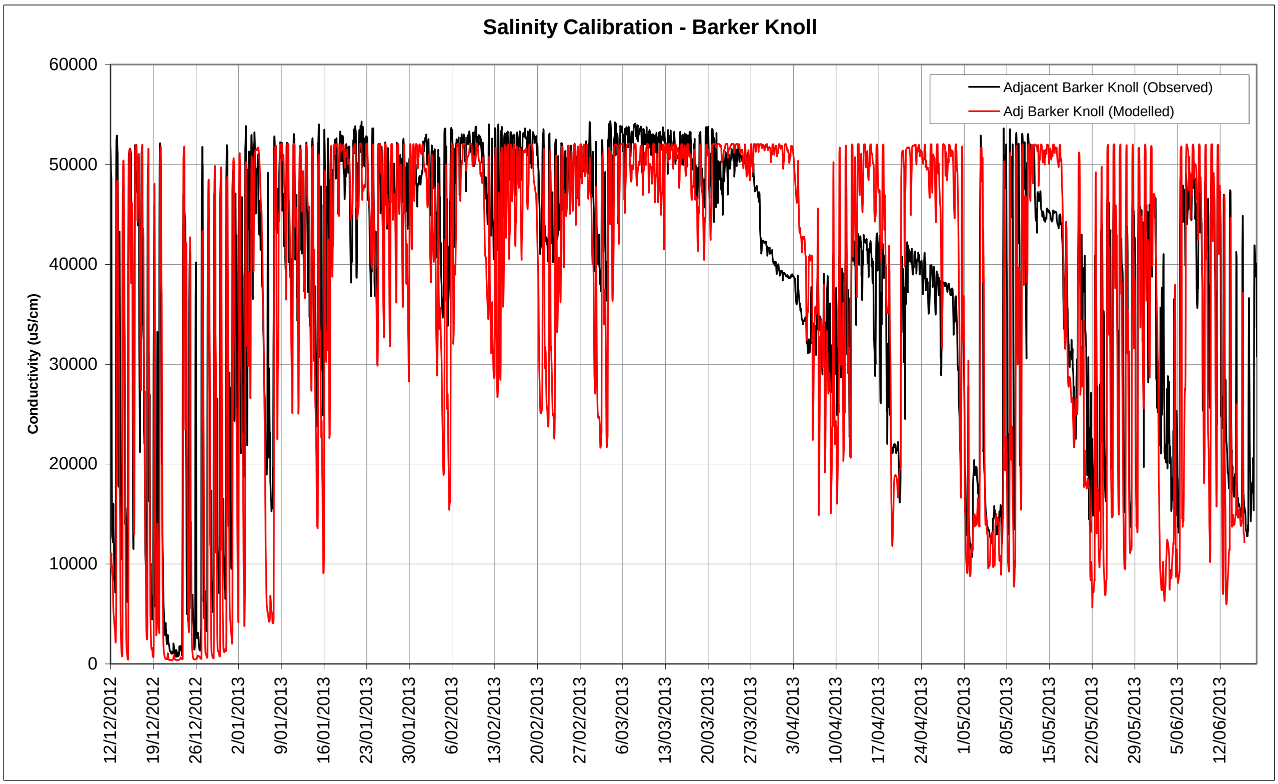

Figure 4-32 Observed and Modelled Salinity – Barker Knoll

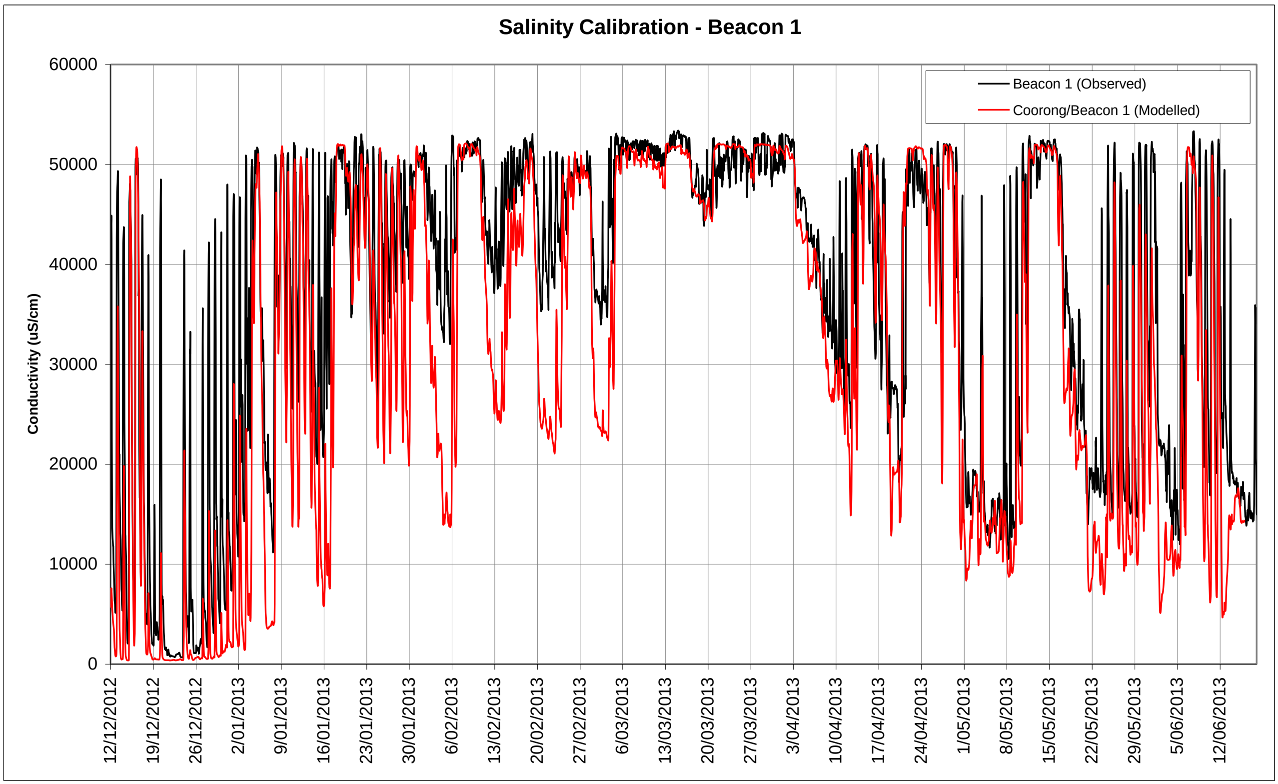

Figure 4-33 Observed and Modelled Salinity – Beacon 1 (near Ewe Island)

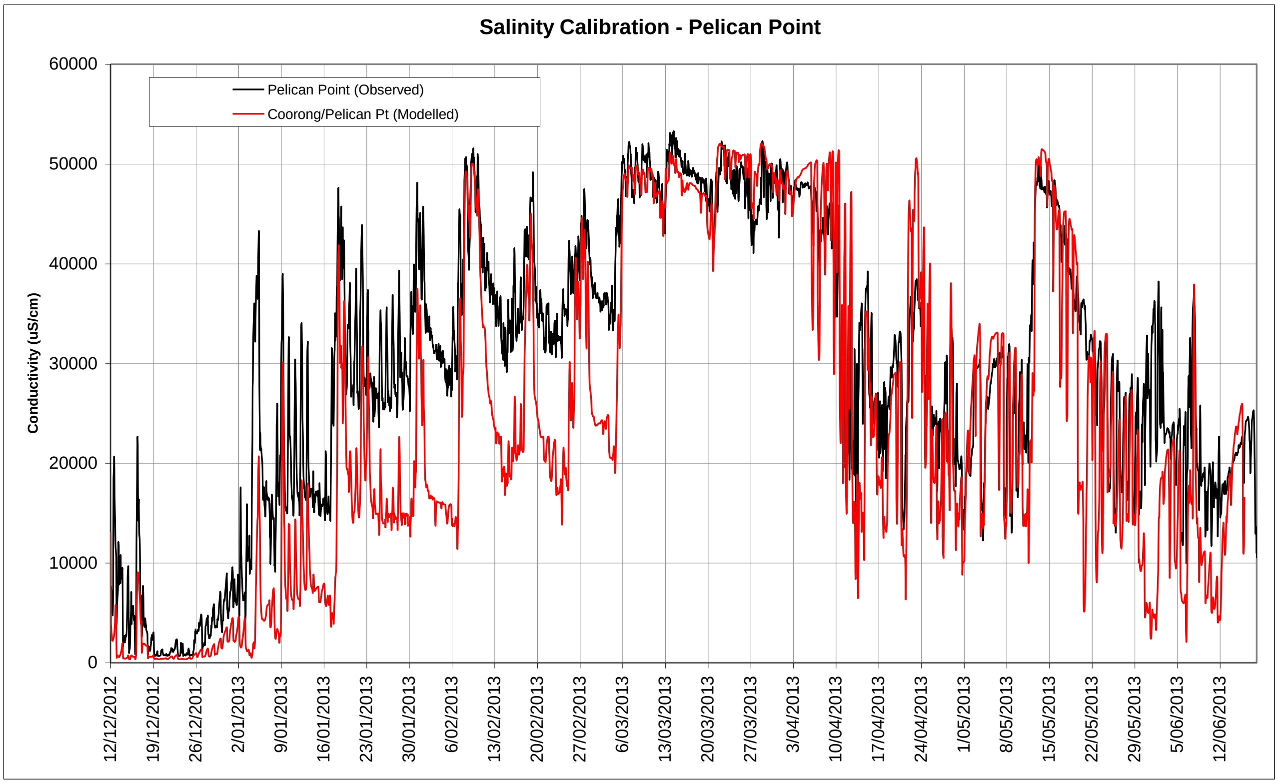

Figure 4-34 Observed and Modelled Salinity – Pelican Point (North Lagoon)

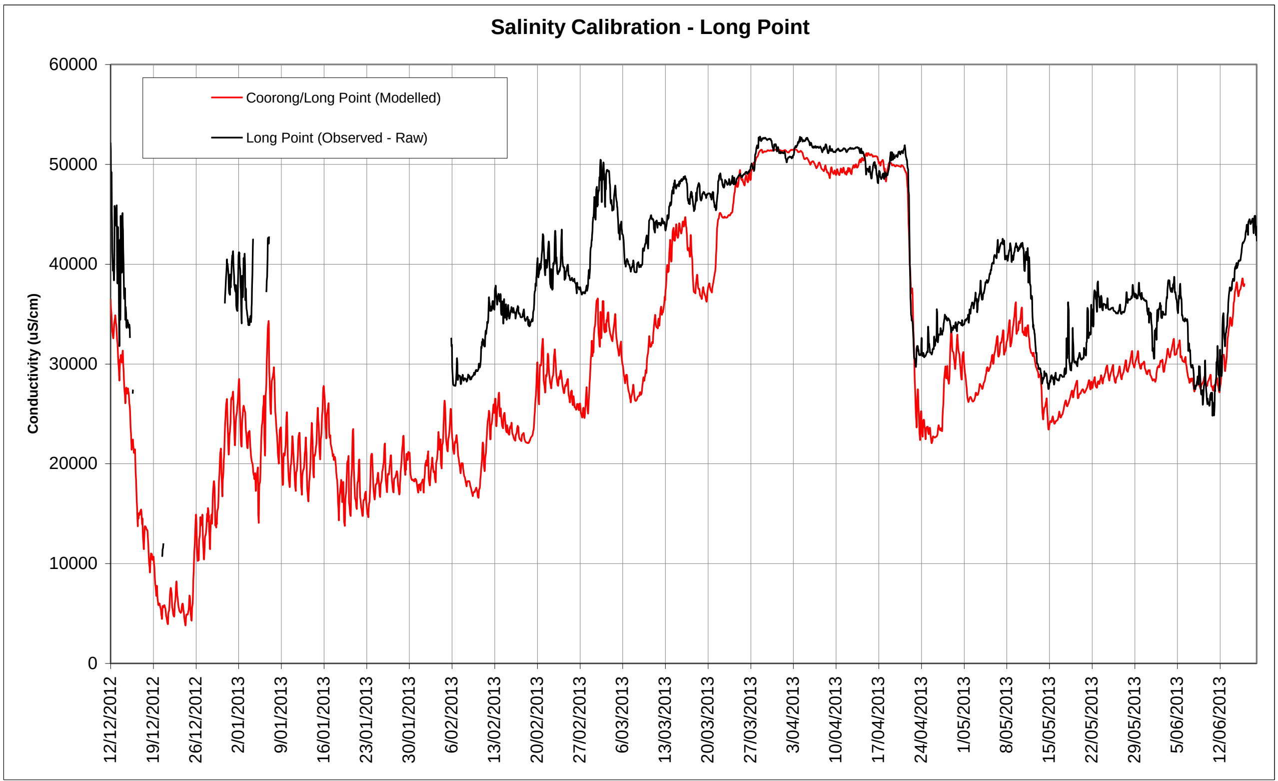

Figure 4-35 Observed and Modelled Salinity – Long Point (North Lagoon)

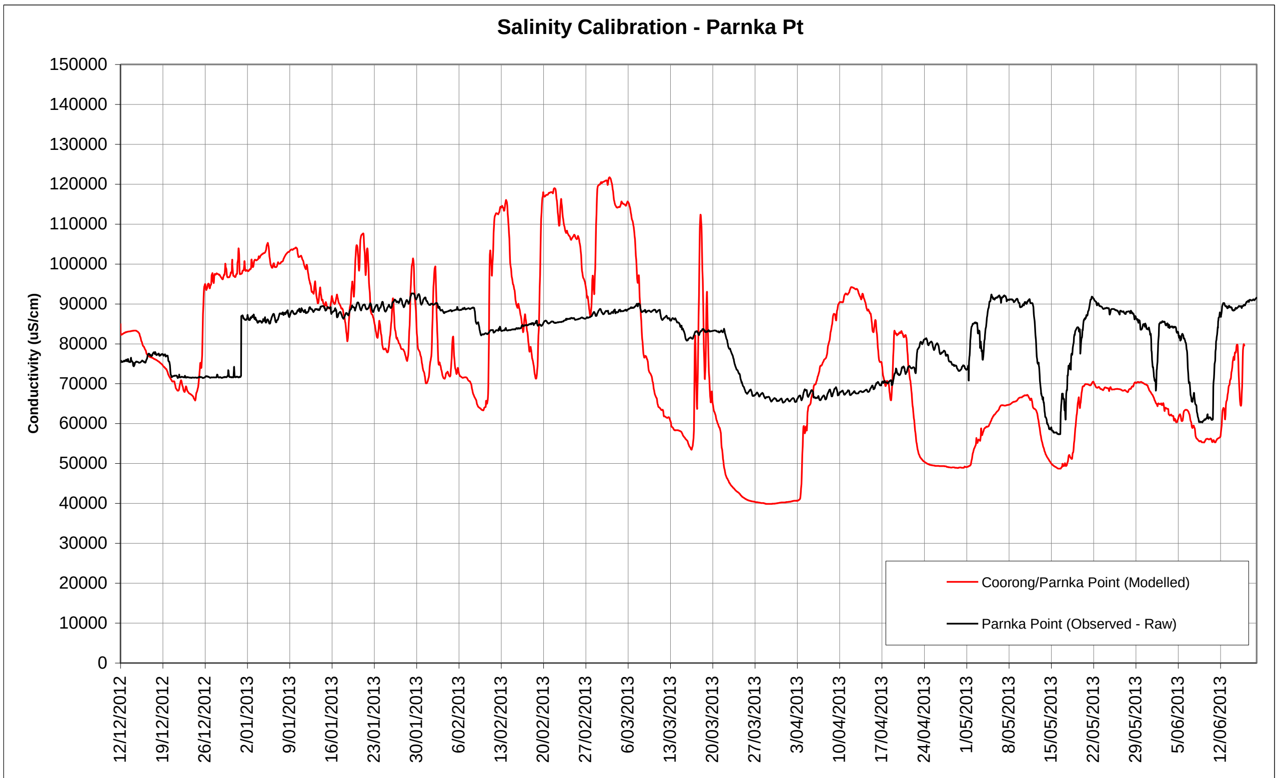

Figure 4-36 Observed and Modelled Salinity – Parnka Point (Hells Gate)

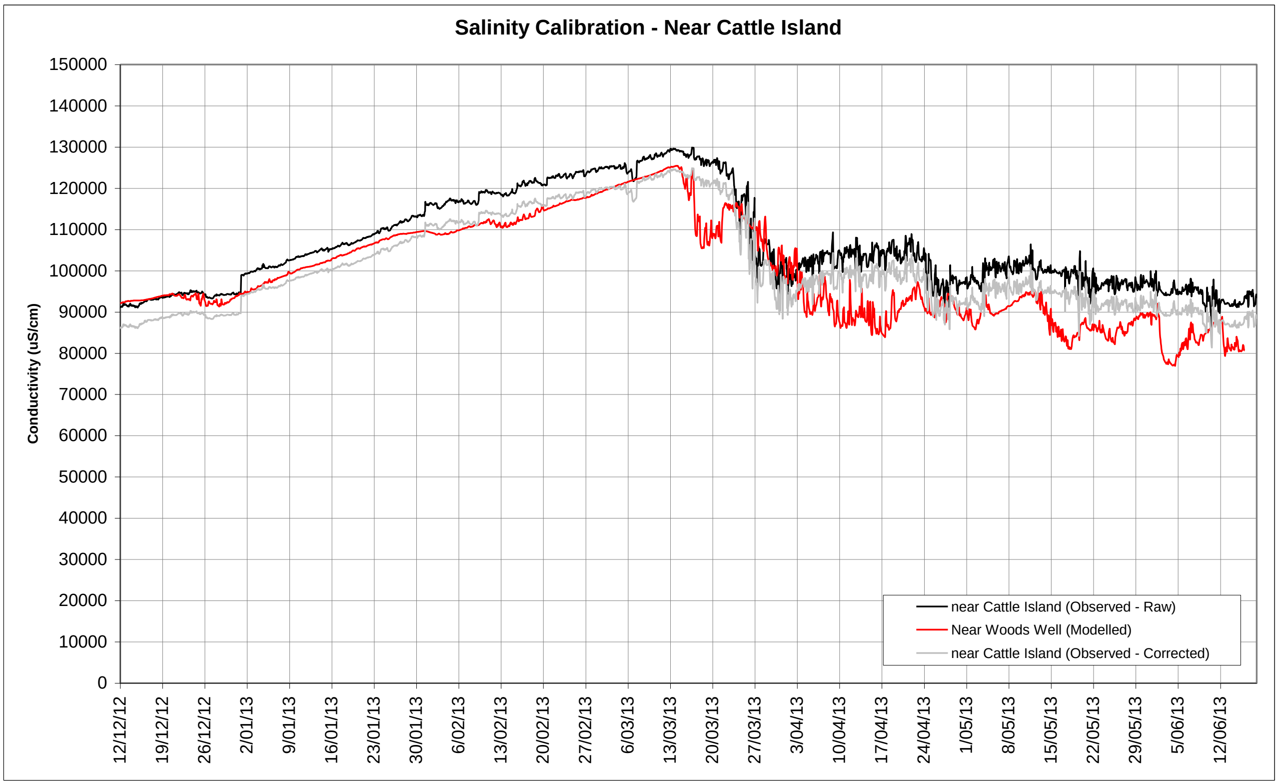

Figure 4-37 Observed and Modelled Salinity – Cattle Island / Woods Well (South Lagoon)

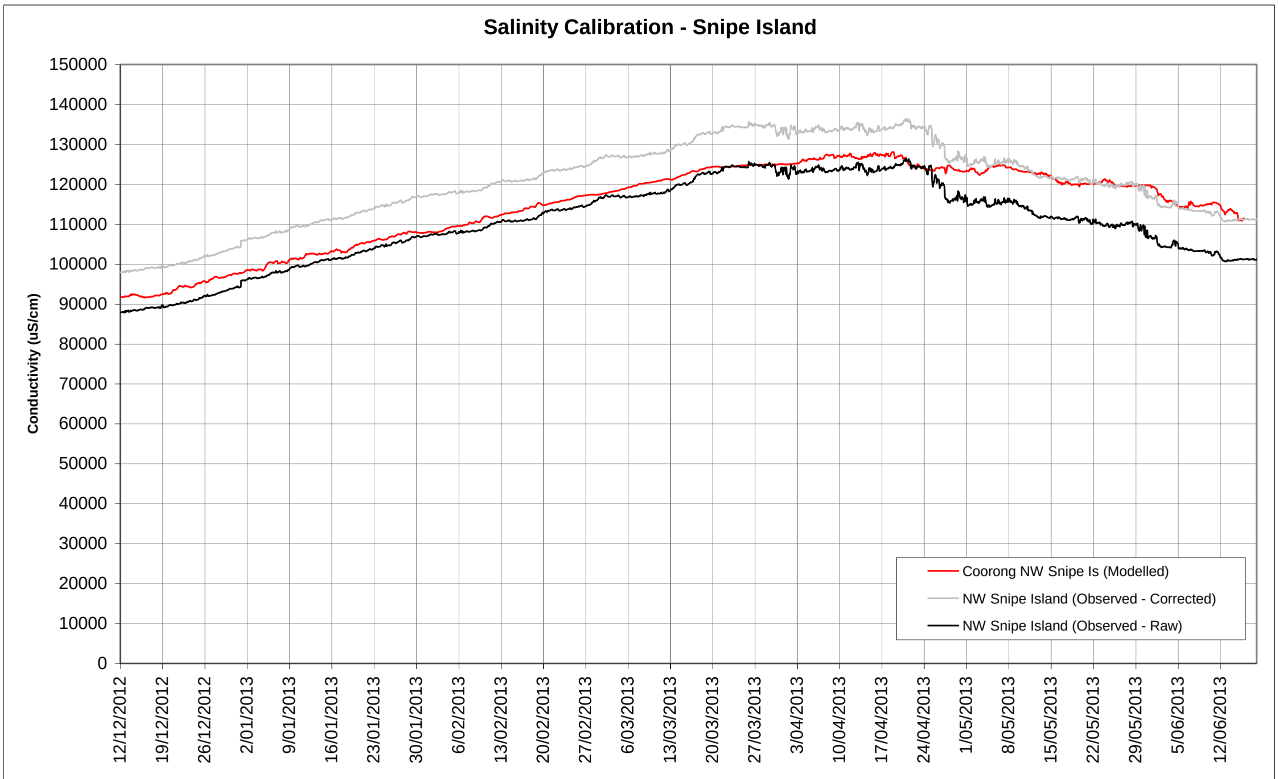

Figure 4-38 Observed and Modelled Salinity – Snipe Island (South Lagoon)

4.4.4 Coorong Salinity Long-Section

Salinity results are also presented for a 120 km long-section (transect) of the Coorong starting at Goolwa Barrage (0 km) and ending at the end of the South Lagoon (past Sandspit Point). An indication of bathymetry along the Coorong and key locations is presented in Figure 4-39. The North Lagoon is typically defined as the reach between 22 and 64 km, while the South Lagoon is located between 80 and 120 km. The shallow narrows between two Lagoons, often referred to as Hells Gate, is located between 65 and 80 km. The Murray Mouth is approximately 8 km from Goolwa Barrage along the transect (long-section).

A long-section of salinity in the Coorong showing the original initial conditions (for 12 December, 2012 based on observed data in the North Lagoon and modelled data for the remainder of the Coorong) and a comparison of the observed and modelled salinity transect data for the 18th March, 2013 is presented in Figure 4-40. The graph shows that the model is able to reasonably replicate the spatial distribution of salinity along the Coorong on the 18th March 2013. The figure shows that discharge from Goolwa Barrage appears to be over-predicted and that reducing barrage discharge improves salinity calibration along Goolwa Barrage. The figure also shows that by adding an additional 2 GL/day offtake to the lake the model is able to better replicate observed salinity levels in the vicinity of Long Point.

Differences between observed and modelled salinity levels in the South Lagoon (i.e > 75 km) are likely to be due to a lack of data to accurately specify the initial model salinity on the 12 December, 2012, with observed salinity data being only available for the North Lagoon (< 60 km). The model is also unable to represent the pool of slightly “fresher water” between Snipe Island and Sand Spit Point which may have been due to local catchment runoff or ground water inputs.

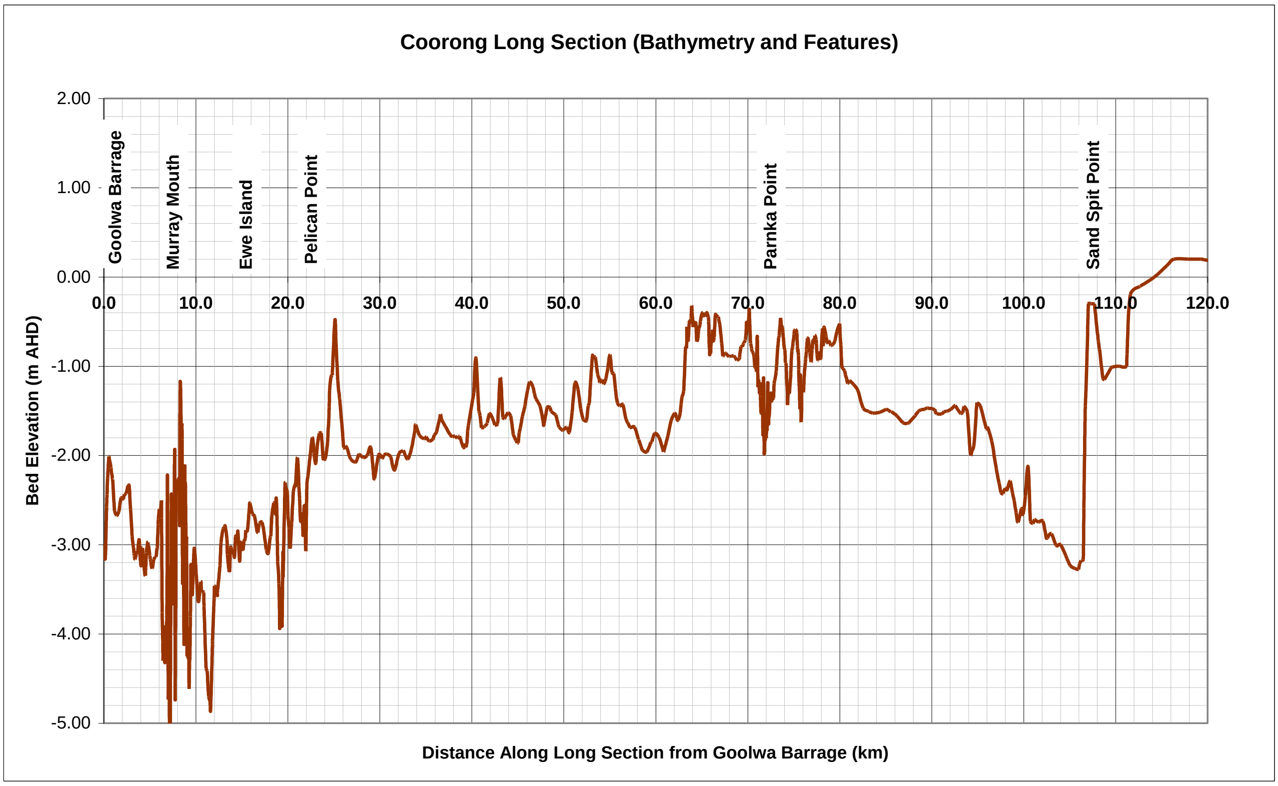

Figure 4-39 Bathymetry and Locations along the Coorong Long Section

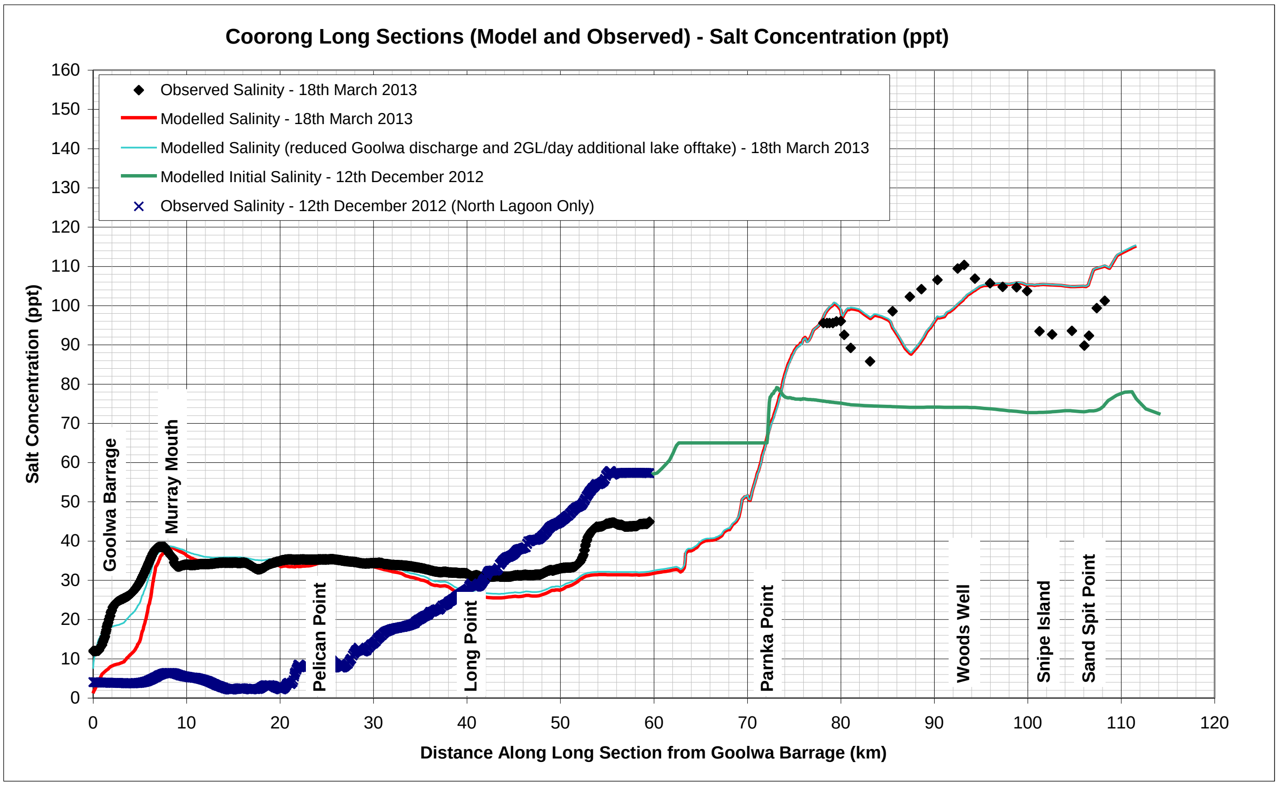

Figure 4-40 Observed and Predicted Salinity along the Coorong including Initial Salinity

4.5 Morphology Validation

Morphological validation was considered to be of less importance for the Lake Albert calibration/validation study provided that the model was able to match Lake and Coorong water levels. Observed changes to a representative Murray Mouth cross-section (see Figure 2-2) are shown in Figure 4-41, while the model predictions of morphologic change are shown in Figure 4-42. The cross-sectional areas of the observed and modelled mouth bathymetries were calculated and are presented in Table 4-3. The calculations of cross-sectional area are from 0 mAHD downwards and were calculated using trapezoidal integration.

When interpreting the model's cross-sectional shape it is important to realise that the mesh resolution in the mouth area is only 40 metres by 40 metres. Given the initial mouth width is approximately 200 metres, a degree of schematisation was necessary. The difference in initial cross-sectional area is due to requirement for the morphological model to interpolate gridded bathymetry data and slump to a stable position (considering mesh resolution) which results in a wider and shallower cross-section.

A comparison of Figure 4-41 (observed cross-sectional change) to Figure 4-42 (modelled cross-sectional change) shows that, while the model simulates channel migration to the west, it does not reproduce the change in channel cross-section (see Table 4-3). This is likely to be due to the model resolution but may also be due inaccuracies in the models ability to accurately represent all sediment transport processes. A lack of regular offshore bathymetry data also means that the accuracy of initial bathymetry or offshore processes cannot be verified.

This inaccuracy in cross-sectional area does not appear to prevent the model accurately predicting water levels or salinity within the system, as the mouth is not a key hydraulic control during the validation period.

However, as the model was able to closely replicate observed water levels and salinity with the Lower Lakes and Coorong, further model enhancements were not warranted. While further changes to mesh resolution may improve the accuracy of the morphological ability of the model, significant increases in model run time would make long term simulations of the system more costly and may only result in minor improvements to water level or salinity predictions.

Table 4-3 Observed vs Modelled Murray Mouth Cross-Sectional Area

Survey	Modelled (m^2)	Observed (m^2)
12-Dec	439.0	501.3
5-Feb	444.8	506.2
20-Mar	446.9	371.8
7-May	445.6	303.9
16-Jun	439.1	237.2

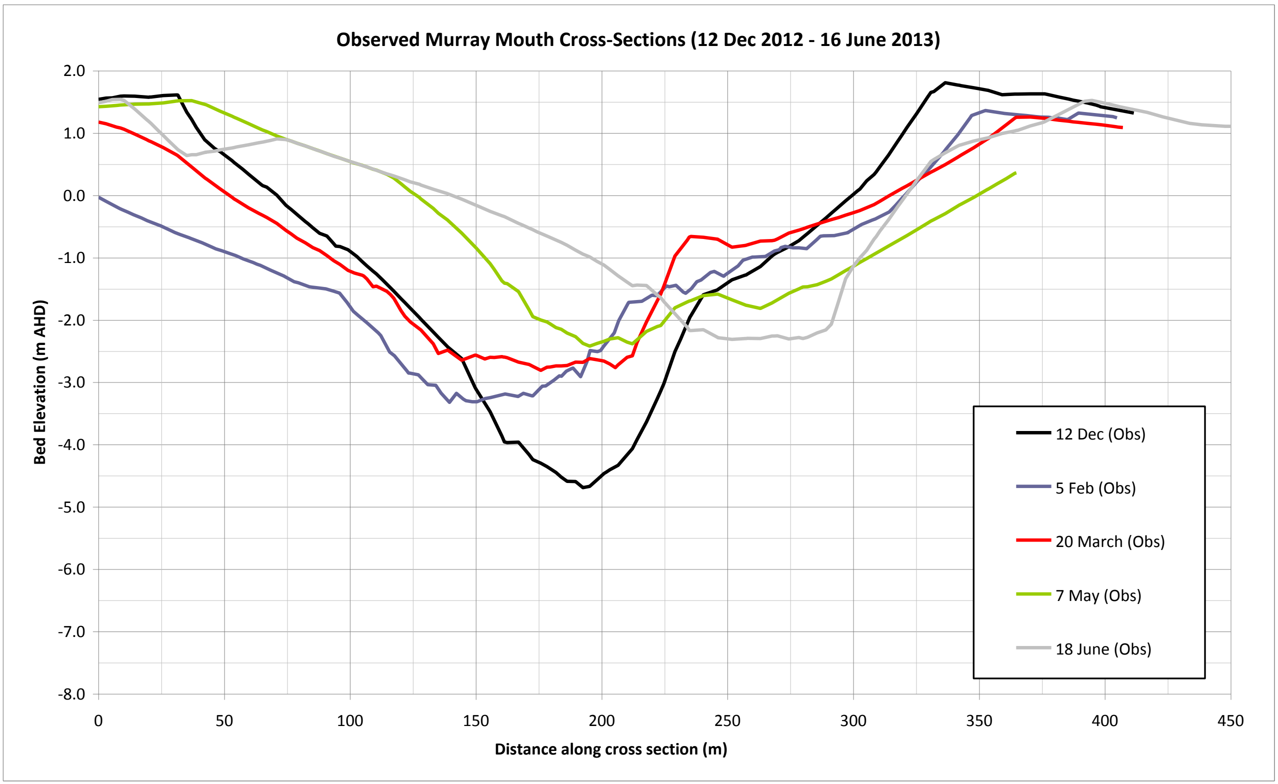

Figure 4-41 Observed Murray Mouth Cross-Sections

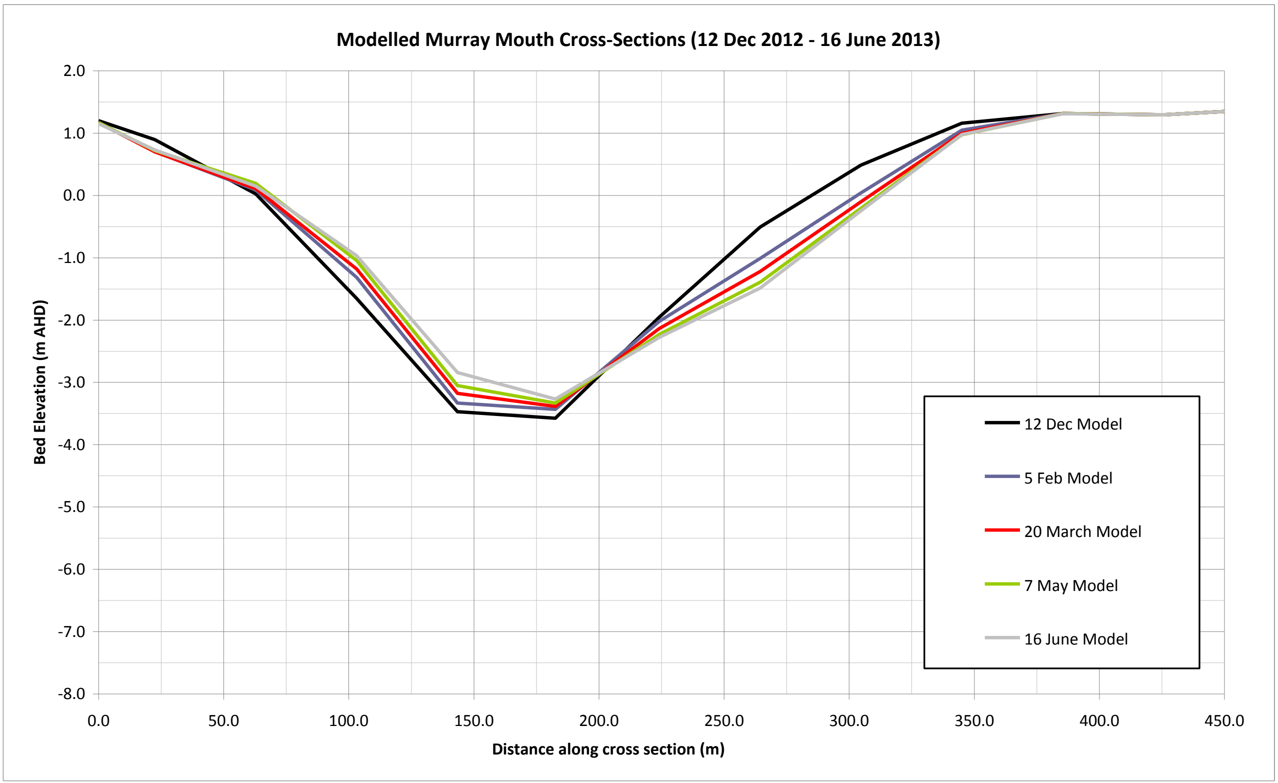

Figure 4-42 Modelled Murray Mouth Cross-Sections

5 Discussion

5.1 Calculation of Barrage Discharge

Current estimates of barrage discharge are 200-400 ML/day/gate and do not account for tidal influence, or a range of other factors. The calibrated model is able to accurately calculate barrage discharge as presented in Figure 5-1. The impact of daily tidal fluctuations is clearly apparent as are a number of backflow events. The difference between Lake Inflow (at Wellington) and barrage outflow during January, February and March is also evident, with Lake inflows typically being ~5 GL/day and barrage outflows only ~1 GL/day. This leaves ~4 GL/day loss to evaporation losses (a 5 mm/day net evaporation demand will remove ~4.1 GL/day of water from the Lower Lakes) and extractions.

Figure 5-2 presents the daily averaged value of modelled total barrage inflow in addition to the estimated barrage discharge provided by SA Water in the barrage operation spreadsheet. The graph shows that there are often differences between the predicted discharge and the actual discharge. These data could be further analysed to provide better estimates of barrage discharge for use in lake management operations. Absence of recorded sill level data at Goolwa, and gauge data for fishways also contributes to the discrepancy between SA Water estimates of barrage discharge and model calculations.

5.2 Calculation of Volume and Salt Mass Fluxes

The use of a finite volume numerical model such as TUFLOW-FV allows the accurate calculation of water volume or salt mass in model regions (areas), or changes in water volume or salt mass over time past a single cell or number of cell faces (i.e. calculate the volume or salt mass flux between areas of interest).

A time-series of modelled and observed salt mass change in Lake Albert is presented in Figure 5-3. From the graph the effect of wind driven seiches on salt export can be seen, with typically 80-90% of the exported salt returning to Lake Albert as the lake water levels return to an equilibrium position. A comparison of modelled salt mass export to observed salt mass export (based on salinity transect data – refer to BMT WBM (2013a)) shows that the model is able to closely reproduce the observed rates of salt mass change. The model predicts that in 6 months some 60,800 tonnes of salt is exported, while observed data indicates that that 64,000 tonnes is exported from Lake Albert. When interpreting the observed salt mass data it is important to understand the influence of the adopted lake water level on the salt mass calculation. At a lake salinity of 3000 µS/cm a 3 cm difference in water level will produce a 10,000 tonnes salt mass difference. This is the reason for the observed salt mass on the 19th March being considerably lower than the adjacent data points. The ability of the model to closely replicate observed changes to salt mass in Lake Albert give further confidence in the models ability to evaluate proposed management options to reduce salinity levels in Lake Albert.

The difference in salt concentration between Lake Albert (~3000 µS/cm) and Lake Alexandrina (~400-600 µS/cm), and the available wind transport and mixing means that despite evaporative demand drawing approximately 65 GL of water into Lake Albert, approximately 60,000 tonnes of salt is exported from Lake Albert over the 6 month simulation period (see Figure 5-4). It is interesting to note that while 40,000 tonnes of salt is lost from mid-May to mid-June this does not alter salt concentrations at Waltowa or Meningie until mid-July (see River Murray Data website).

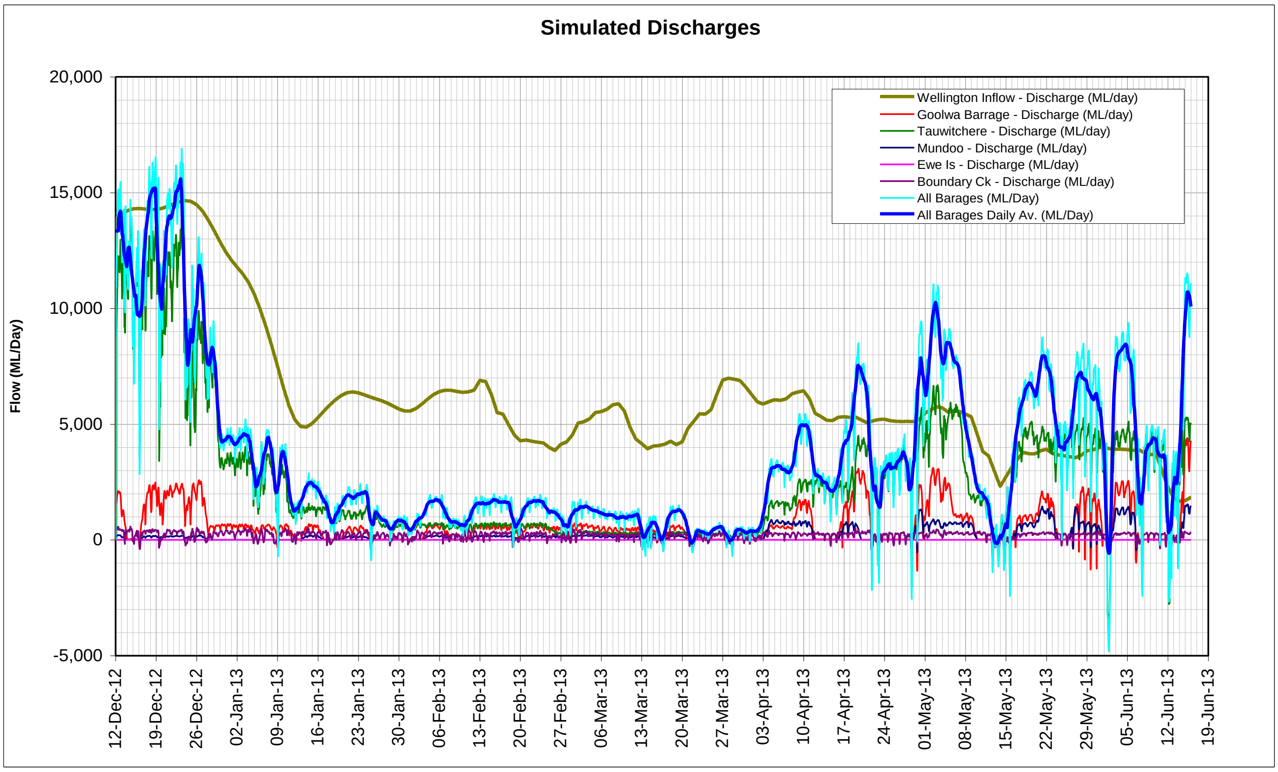

Figure 5-1 Modelled Barrage Discharge

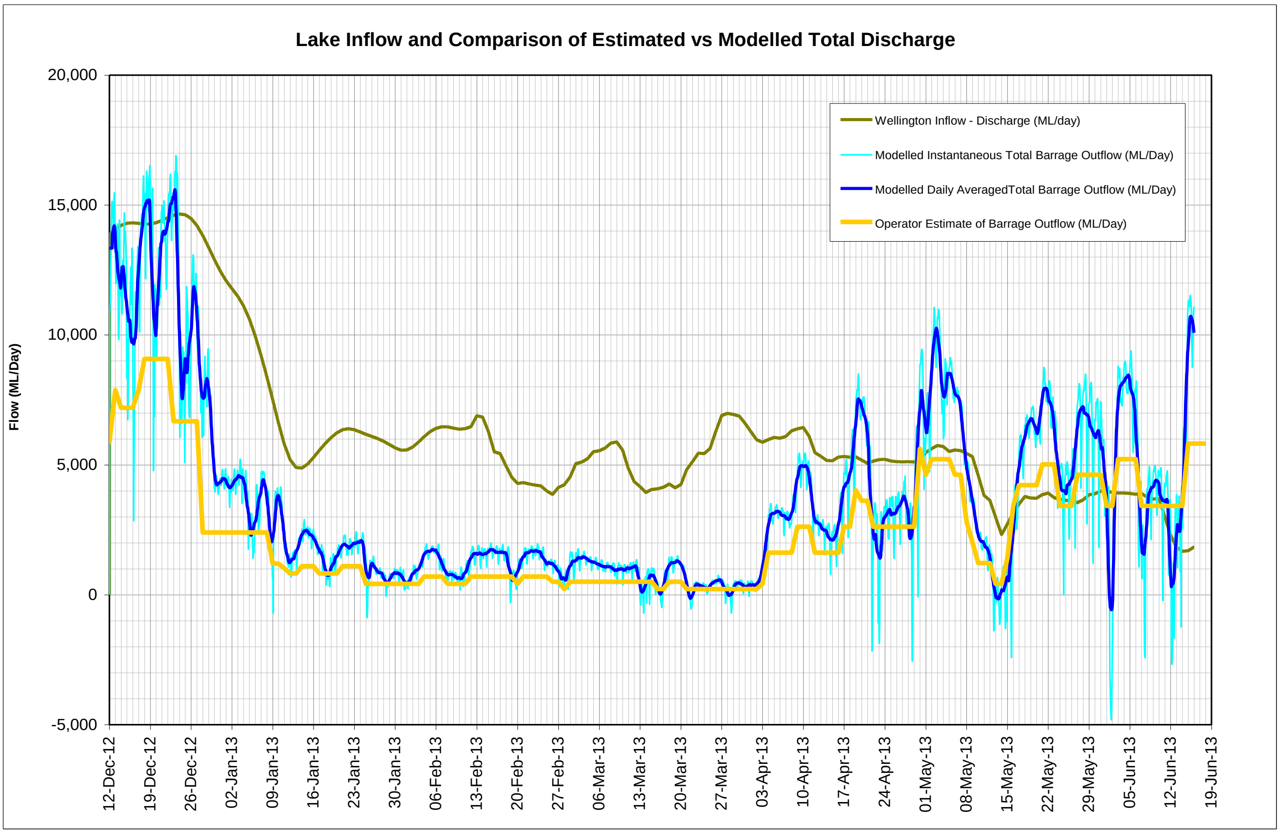

Figure 5-2 Comparison of Modelled and Estimated Total Barrage Discharge

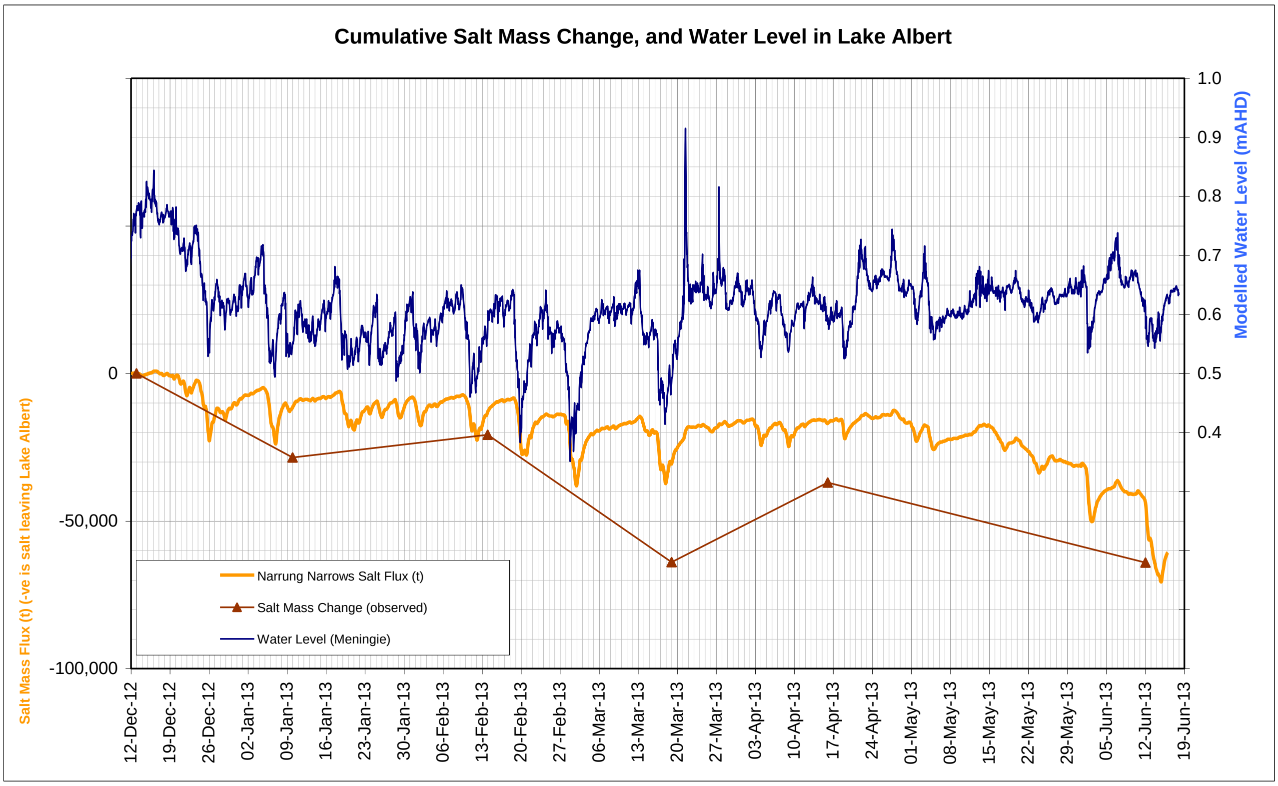

Figure 5-3 Modelled Salt Mass Change in Lake Albert

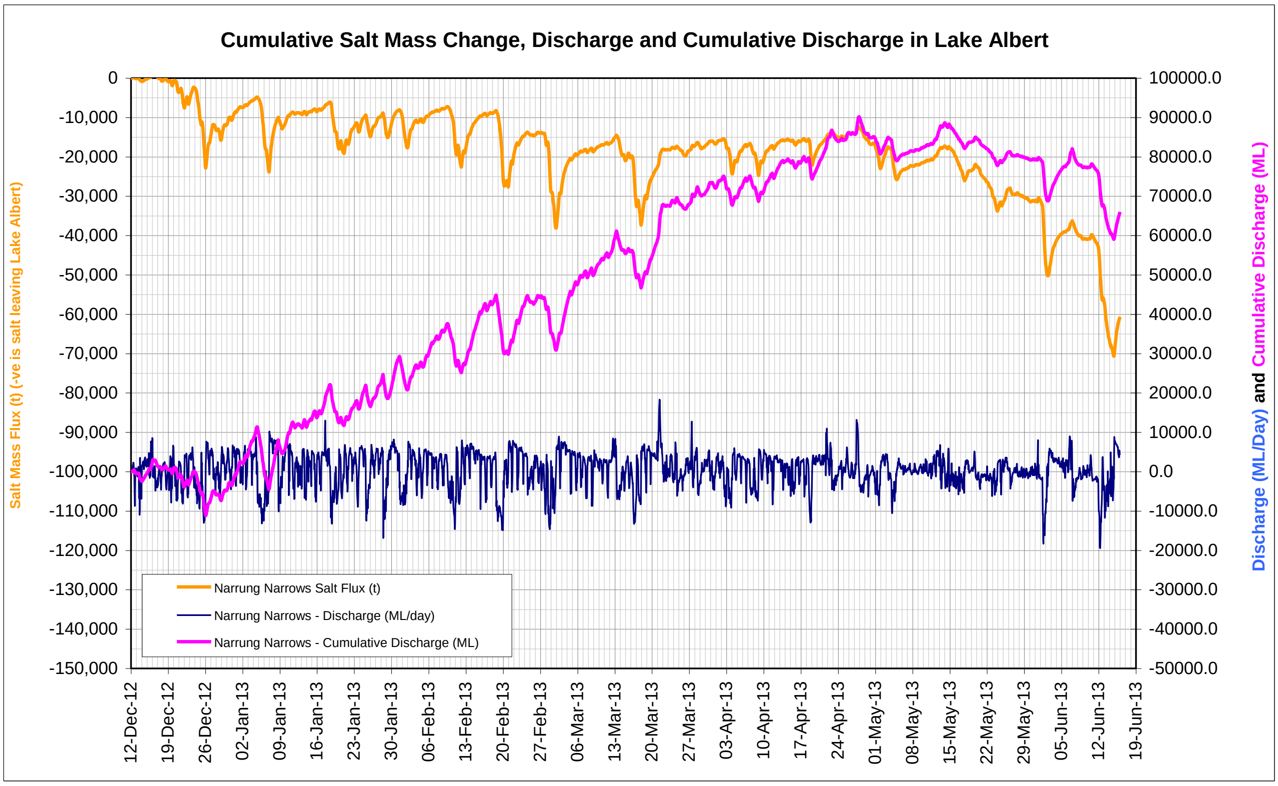

Figure 5-4 Modelled Salt Mass Change, Discharge and Volume Change in Lake Albert

5.3 Status of Model Calibration and Suggested Improvements

As presented in Section 4, a good model validation was achieved, with the model being able to closely predict observed water level and salinity variations across the study area as well as observed changes to salt mass in Lake Albert during the six validation period (12/12/2012 – 16/6/2013). The validation demonstrates that the model can be used to calculate both discharge at the five Barrages (see Section 5.1) and also changes in salt mass in Lower Lakes and Coorong (see Section 5.2). However, it is important to understand the limitations of the existing model as well as potential improvements that would be possible through further model development and calibration/validation. These include:

- More frequent collection of salinity transects along the Coorong and Lake Albert to provide better estimates of initial conditions for salinity;
- Inclusion of River between Lock 1 and Wellington (especially at lower flows);
- Inclusion of abstractions (SA Water and Irrigation) (especially at lower flows);
- Ability to model variable barrage sill levels. This is required to be able to better represent Goolwa Barrage, where the removal of individual stop logs defines the structure sill level. This would require the collection/reporting of suitable barrage data information;
- Increased model resolution in the Murray Mouth to better predict morphological change; and
- Use of a 3-dimensional model representation to better predict salt spikes in the Coorong and also morphological change.

It is important to note that ongoing management of the system requires that the model be updated to reflect a number of changes including:

- Update of bathymetry in Goolwa, Mundoo and Tauwitchere Channels to reflect potential morphological changes during the recent periods of high system flows.

A number of the above improvements would require the collection of up-to-date bathymetry survey data. The collection of sediment data within the Murray Mouth (particularly the flood tide delta) would also be beneficial to future model calibration/validation exercises. In addition to this bathymetric survey data offshore of the Murray Mouth and in the nearshore zone along Encounter Bay would be useful.

6 Conclusions

A numerical model of the Lower Lakes, Coorong and Murray Mouth was developed and calibrated for the period 12th November 2010 to 1st May 2011 (BMT WBM, 2011b) and subsequently validated for the six months from 1st May to 1st November, 2011 (BMT WBM, 2012). The calibration study presented here focuses on a six month period (12 December 2012 to 16 June 2013) of Lower Lake inflows and focuses on the models ability to accurately calculate salt export from Lake Albert.

A good level of model validation (including comparison to water levels, salinity and salt mass) has been achieved. Model accuracy could be improved with the use of variable sill geometry at the barrages, though this would require the collection of actual sill level data at Goolwa Barrage. A finer grid resolution at the Murray Mouth is likely to improve the ability of the model to better reproduce observed morphologic change at the Murray Mouth; however, additional offshore data would also be required to reduce uncertainty in model predictions.

The model's ability to reasonably replicate observed water levels and salinities during the calibration period, give confidence in the model's ability to predict future changes to water level and salinity for future conditions (provided they are not too different to those of the validation or calibration period). The model can be confidently applied to evaluate a range of management options (i.e. water level manipulation targets) aimed at reducing salinity within Lake Albert as well as predicting future conditions based on a reasonable estimate of future inflows and an appropriate set of climatic conditions.

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