OFFICIAL

Application of the Coorong Dynamics Model

Department for Environment and Water
September 2022

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Government of South Australia

Department for Environment and Water

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Foreword

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

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

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

John Schutz
CHIEF EXECUTIVE
DEPARTMENT FOR ENVIRONMENT AND WATER

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Summary

The Coorong is a wetland of local, national and international importance and one of the most significant waterbird habitats in the Murray–Darling system. The condition and value of the Coorong has suffered long-term decline and was further substantially damaged by the Millennium Drought. The long-term accumulation of salt and nutrients in association with low water levels over late spring and summer have prohibited the recovery of the system to a recognisable healthy state (DEW, 2021b).

In response to a number of key knowledge gaps identified in previous Coorong studies and model application, dedicated modelling activities were established within the *Healthy Coorong, Healthy Basin* (HCHB) Trials and Investigations (T&I) Project's Integration component. The modelling has progressed alongside the significant body of research undertaken to address knowledge gaps, and data collected as part of T&I components. This body of work has resulted in significant updates being made to the Department for Environment and Water's (DEW) original Coorong TUFLOW-FV fine resolution hydrodynamic model, which has historically been used to inform Murray Mouth dredging operations. The performance of this model in reproducing the hydrodynamics of the Coorong; water level, salinity and flow has been demonstrated by comparing model outputs against a range of data collected over the period 1 July 2019 to 30 June 2020.

In collaboration with the DEW, the University of Western Australia (UWA) implemented significant improvements to extend both model functionality and the ability to represent complex and dynamic water quality, sediment biochemistry, and ecological habitat processes following extensive model calibration and validation. Collectively, the fine resolution Coorong TUFLOW Finite Volume (FV) hydrodynamic model and the University of Western Australia's (UWA) Aquatic EcoDynamics (AED) model comprising a library of modules and algorithms for simulation of water quality, aquatic biogeochemistry, biotic habitat, and aquatic ecosystem dynamics are referred to as the Coorong Dynamics Model (CDM). The individual models can be configured, coupled, and applied in various ways to address a range of questions.

The updates to the CDM have improved the model representation of external and internal nutrient loads, sediment loads, nutrient fluxes and recycling, and *Ruppia* habitat suitability (UWA, 2022). A set of scenarios run with the DEW Gen1.5 CDM has demonstrated the enhanced functionality and predictive capability of the CDM for a range of hydrodynamic, water quality and biogeochemical parameters in response to changing environmental drivers.

In addition to the significant enhancements made to the CDM, additional models have been developed under other projects within the HCHB Program. The CDM Catalogue comprises the fine resolution detailed CDM, a coarse or rapid Coorong TUFLOW-FV model, and additional fine resolution TUFLOW-FV models calibrated and configured for specific applications. Developed in parallel under the HCHB Program, these models will be harmonised and further updated under subsequent HCHB phases to ensure the CDM Catalogue becomes a sophisticated, flexible and powerful toolkit, containing the best available models for assessing outcomes in the Coorong under HCHB and beyond.

Introduction

The Coorong is a wetland of local, national and international importance and one of the most significant waterbird habitats in the Murray–Darling system. The condition and value of the Coorong has suffered long-term decline and was further substantially damaged by the Millennium Drought. The long-term accumulation of salt and nutrients in association with low water levels over late spring and summer have prohibited the recovery of the system to a recognisable healthy state (DEW, 2021b).

The *Healthy Coorong, Healthy Basin* (HCHB) Program Trials and Investigations (T&I) Project's *Knowledge translation, application, and integration to support site management* component (Integration component) has been designed to consolidate and integrate research developed in the broader T&I Project into model tools and knowledge to inform the management of the Coorong. The HCHB research and monitoring programs have, and continue to, address key knowledge gaps relating to nutrient budgets, paths and dynamics, habitat quality and extent, and more holistic ecosystem assessments. Building on previous studies, these data are critical in the improvement of the models which make up the Coorong Dynamics Model (CDM).

This report summarises the progression of CDM development and application within the Department for Environment and Water (DEW) under HCHB Phase 1. The models comprising the CDM can be configured, coupled, and applied in various ways to address a range of questions. The further improvement and development of the spatially resolved CDM is designed to create fit for purpose Coorong water quality and ecological response models to support decision-making in the HCHB Program and beyond. As a first step towards identifying model improvements, Part A (Sections 2 to 5) of this report details how the original DEW Coorong TUFLOW-FV fine resolution hydrodynamic model was configured and run for a base case hindcast scenario for 1 July 2019 to 30 June 2020 to allow a comparison against a range of data collected, including Coorong water level, salinity data and gaugings undertaken at Parnka Point in 2019-20. The model outputs were also used for other HCHB analyses, for example nutrient budgeting. Additional model scenario assessments were also undertaken to evaluate 2019-20 barrage, Salt Creek operational settings, and the influence of updated bathymetry around Parnka Point.

Part B (Sections 6 to 8) summarises the development and application of the significantly enhanced CDM. Significant model updates made to the Aquatic EcoDynamics (AED) model to reflect the research and data compiled under the various T&I research components has improved the model representation of external and internal nutrient loads, sediment loads, nutrient fluxes and recycling, and *Ruppia* habitat suitability (UWA, 2022). A detailed description of model development, calibration and validation is presented in UWA (2022a, b). Section 8 of this report outlines the adoption of this enhanced functionality and range of outputs via specific scenario modelling and the interpretation of modelled outputs for the DEW Gen1.5 CDM.

In addition to the significant enhancements made to the CDM, additional models have been developed under other projects within the HCHB Program. The CDM Catalogue is comprised of the fine resolution detailed CDM, a coarse or rapid Coorong TUFLOW-FV model, and an additional fine resolution TUFLOW-FV models calibrated and configured for specific applications. Developed in parallel under the HCHB Program, these models will be harmonised and further updated under subsequent HCHB phases to ensure the CDM Catalogue represents the best available toolkit for assessing outcomes in the Coorong under HCHB and beyond. Part C (Sections 9 to 10) of this report details the CDM Catalogue and associated model storage and management implemented under Phase 1 of HCHB.

The CDM has been expanded and significantly improved under various projects of HCHB Phase 1. The improvements extend to both model functionality and the ability to represent complex and dynamic water quality, sediment biochemistry, and ecological habitat processes following extensive model calibration and validation. Collectively, the CDM Catalogue delivered under HCHB Phase 1 represents a sophisticated, flexible, and powerful tool for quantitatively assessing the response of the system to management options and changing environmental conditions over varying spatial and temporal scales. By embedding the CDM into the DEW modelling environment, the modelled scenarios will reduce uncertainties, fill critical knowledge gaps, and facilitate the development of an adaptive management regime to restore the Southern Coorong to the desired state.

Part A – Application of the original DEW TUFLOW-FV hydrodynamic model

1 DEW Coorong TUFLOW-FV model

The fine resolution Coorong TUFLOW-FV hydrodynamic model was originally developed by BMT for the South Australian Government and has been regularly used to inform Murray Mouth dredging operations. Improvements to the model mesh and boundary conditions have occurred over time as part of routine model maintenance and application. Figure 1.1 shows the model domain and boundary condition locations, which are described below.

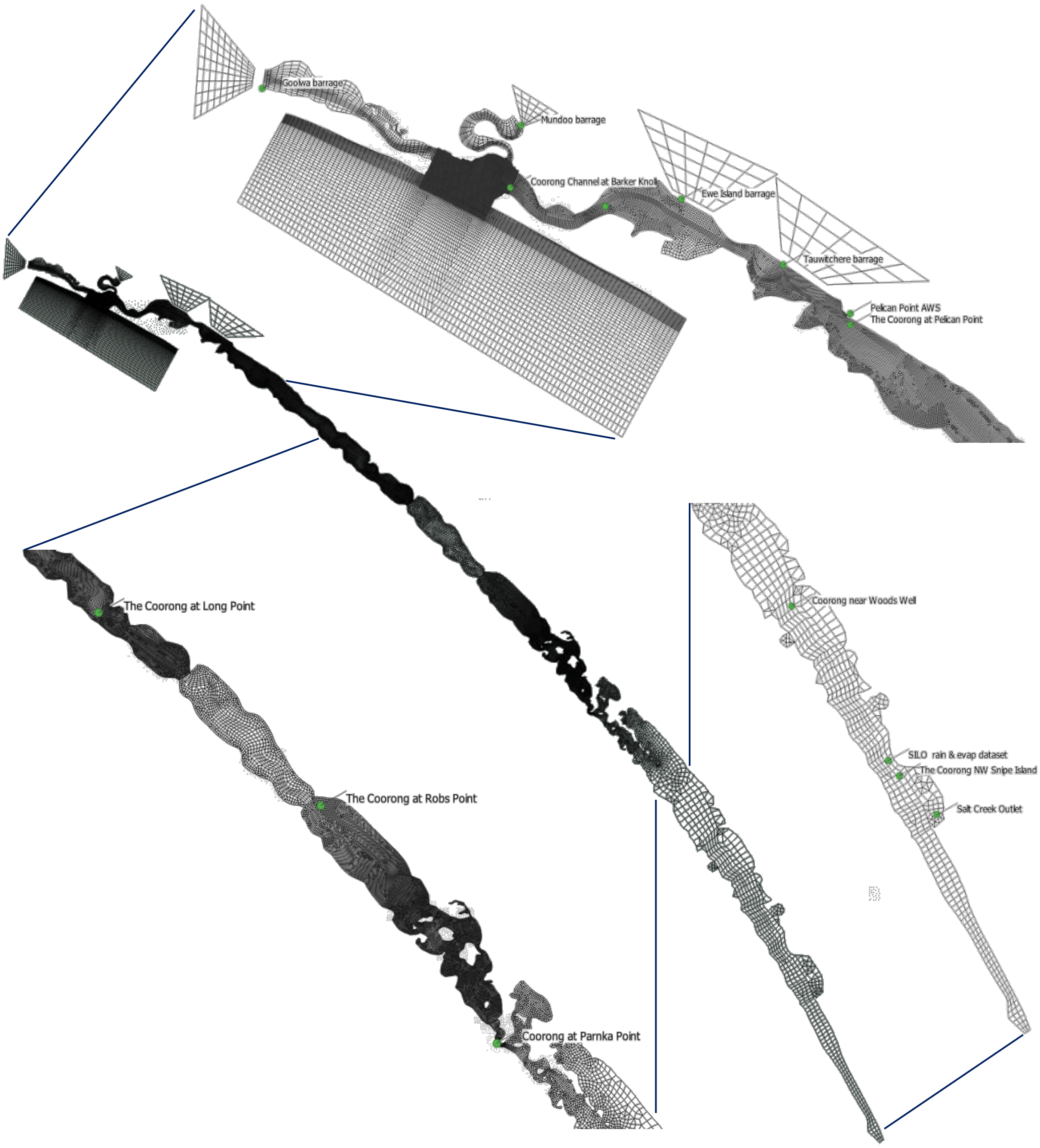


Figure 1.1. Coorong TUFLOW-FV model domain and boundary conditions

2 Model configuration

2.1 Flexible mesh bathymetry

The flexible mesh of the Coorong developed by BMT WBM used for this work extends from the Goolwa Barrage to the southern extent of the Coorong South Lagoon (CSL) and encompasses the Murray Mouth and ocean interface. The model configuration and output evaluation is detailed in BMT (2019).

The two-dimensional mesh was developed using sonar bathymetric data, LiDAR data, aerial photography, and satellite imagery. The bed elevations are based on a 2008 digital elevation model (DEM) of the Coorong. The resolution of the flexible model mesh varies between element sizes of 20 m to 500 m (BMT WBM, 2010).

A number of modifications were made to the mesh for the purpose of base case hindcast scenario modelling:

The bed elevations specified in the cell elevation file dated 7 May 2013 were adopted for all cells in the mesh. This represents the final mesh used in the calibration undertaken by BMT.

The bed elevations around the Murray Mouth region were then modified based on a detailed targeted bathymetric survey undertaken by SA Water dated 31 July 2019 (Figure 2.1).

Following initial testing, further manual modifications were made to the mesh bed elevations to reflect the outcomes of dredging operations designed to open the Tauwitchere channel to the south of the Murray Mouth and improve connectivity with the Coorong North Lagoon (CNL). This was informed by a previous survey (26 February 2019), which reflected dredged bed elevations. The final mesh used for the base hindcast scenario modelling is shown in (Figure 2.2) with the shaded contours reflecting the cell bed elevations.

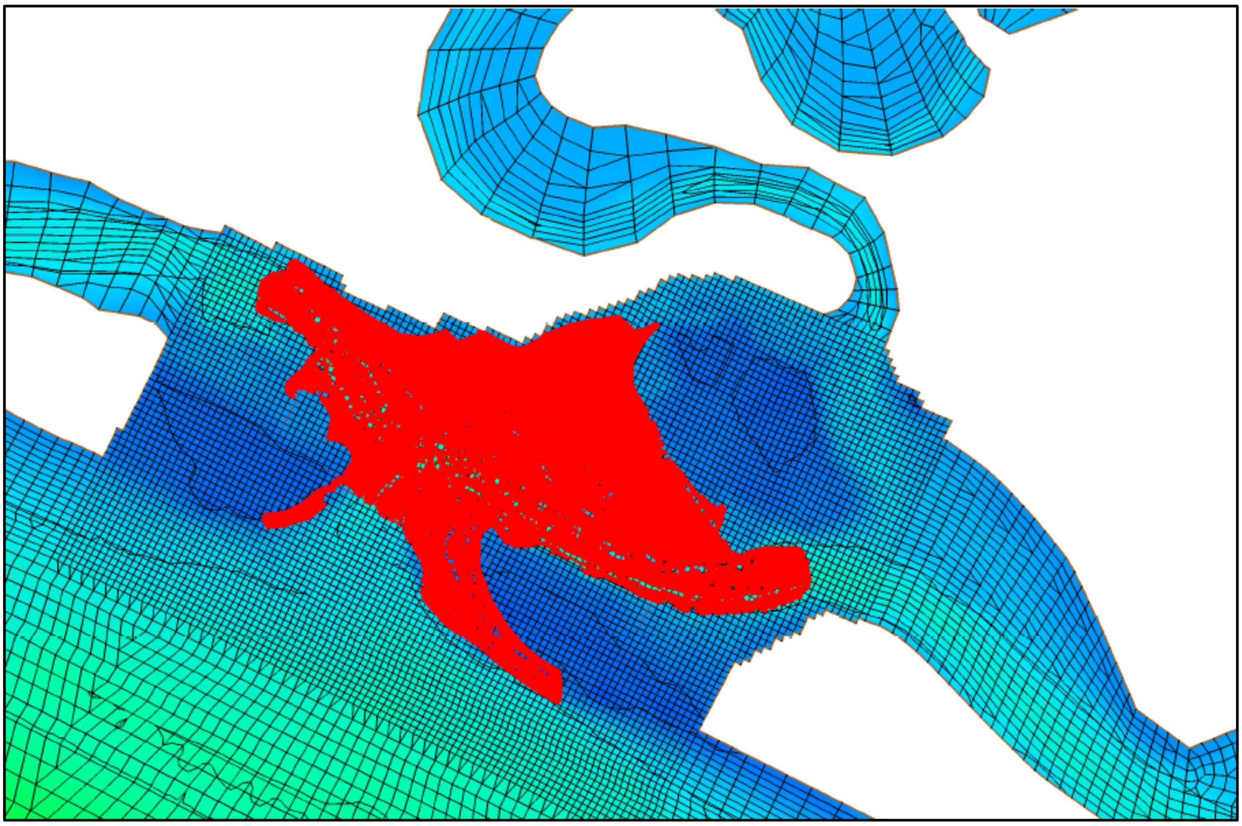


Figure 2.1. Portion of the Coorong TUFLOW-FV flexible fine resolution mesh showing typical extent of a targeted survey in the Murray Mouth and Tauwitchere channel in red

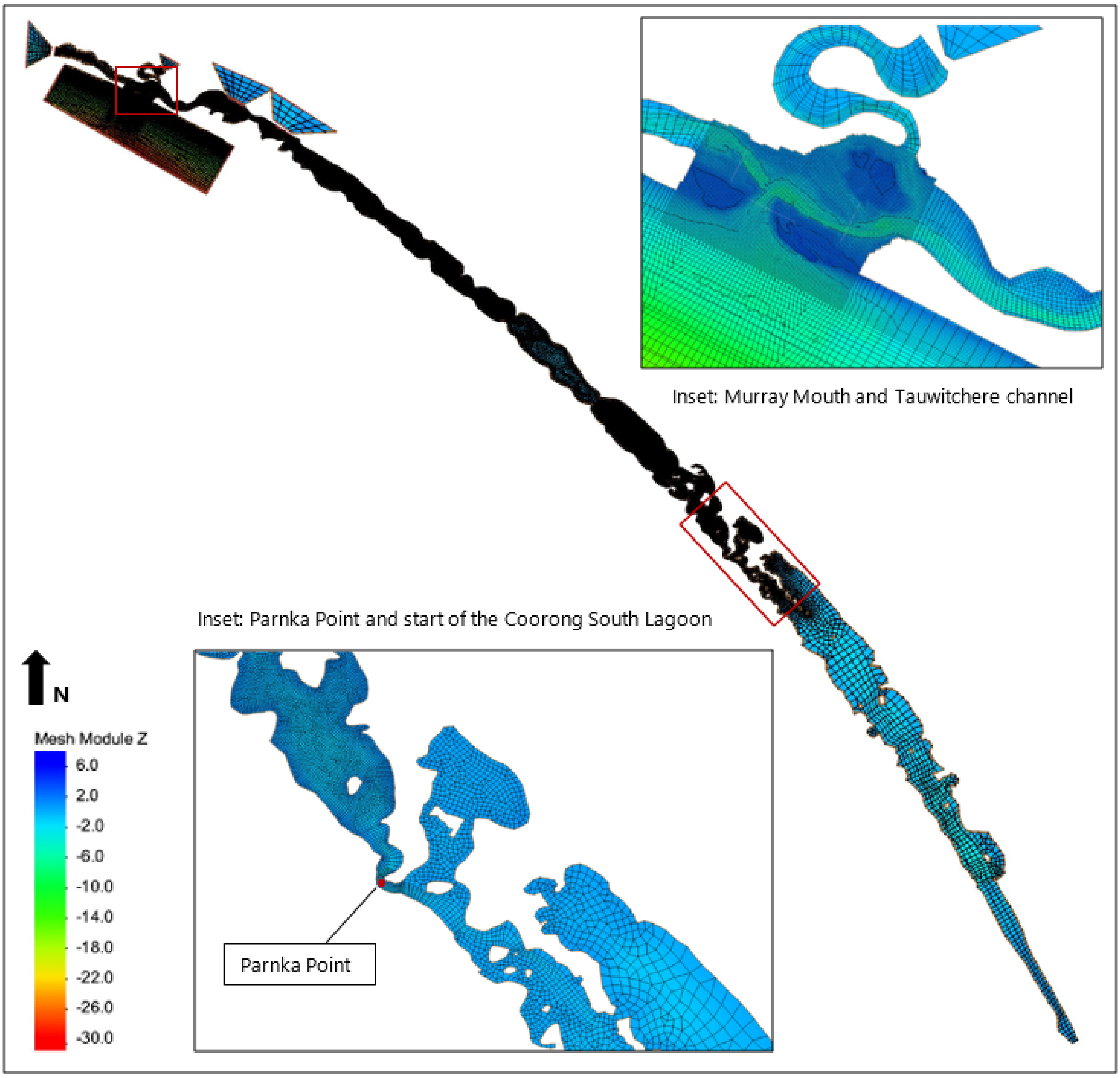


Figure 2.2. Coorong TUFLOW-FV flexible fine resolution mesh showing areas of interest

Nodestrings are sections across the model where control structures can be placed, or where outputs such as flow and fluxes of constituents can be automatically output in model results. Nodestrings were located at key boundaries and points of interest on the mesh to allow the definition of boundary conditions. Additional nodestrings were added at key monitoring sites in the Coorong, including at Parnka Point, to undertake an analysis of the flow and other fluxes moving through the cross-section at these locations. Figure 2.3 and Figure 2.4 show the relevant Coorong monitoring sites within the model mesh boundary. Modelled water level elevation, salinity and tracer concentration (see Section 2.3.4) outputs were recorded at an hourly time step for each of these points, to allow a comparison against observed values, and to provide an indication of the relative contribution of each source of tracer at that point. Similarly, flow, salt and tracer fluxes were exported for the nodestrings at these locations.

Figure 2.3. Coorong North Lagoon monitoring sites and nodestring locations

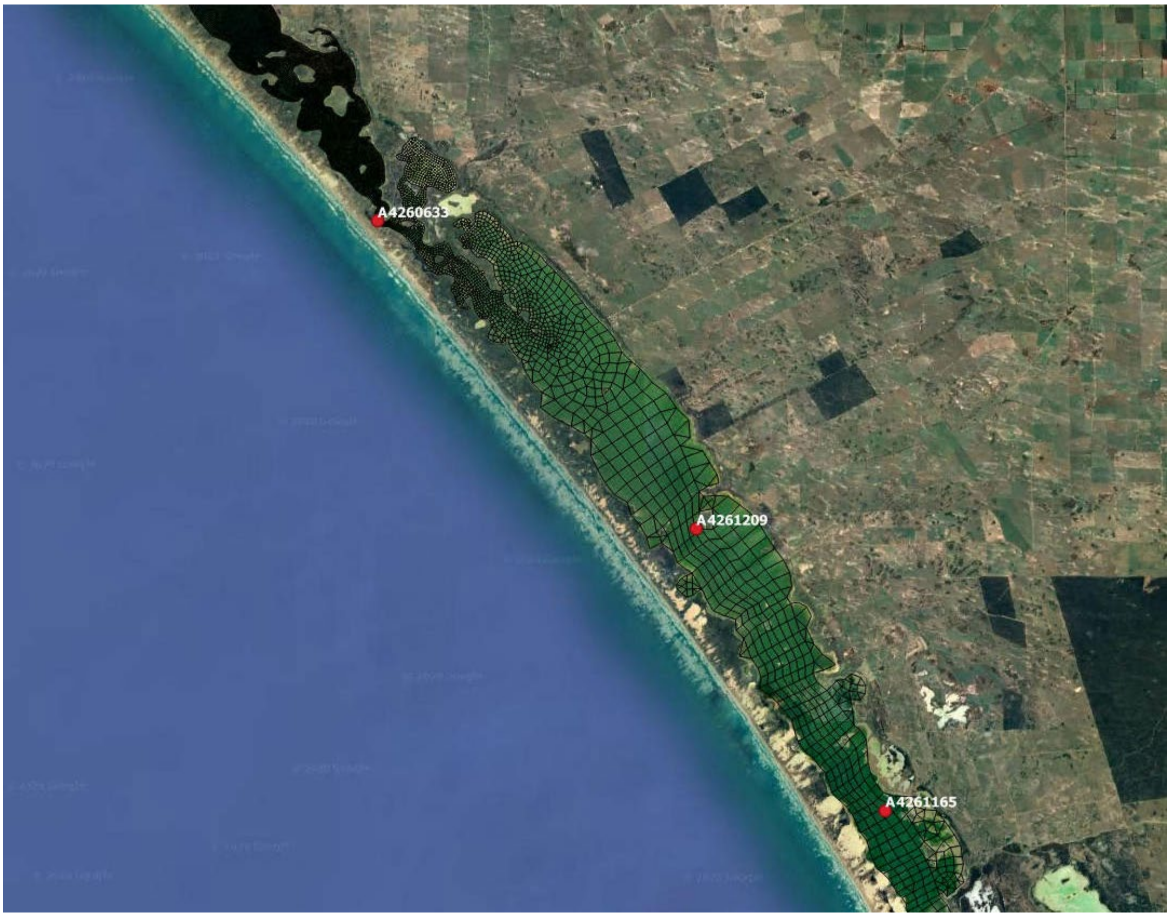


Figure 2.4. Coorong South Lagoon monitoring sites and nodestring locations

2.2 Configuration of the Coorong TUFLOW-FV base case hindcast scenario

The latest available version of TUFLOW-FV (2020.02.034) was used to run a model in two-dimensional hydrodynamic calculation mode between 1 July 2019 and 30 June 2020.

2.2.1 Initial conditions

Initial conditions, which set the starting parameter state values of every cell within the model, were set to a spatially interpolated set of observed values from 1 July 2019.

A series of polygons covering the TUFLOW-FV mesh for the simulation were generated in GIS, drawn as zones corresponding to each monitoring site. An example is shown in Figure 2.5 with the dark outline indicating the division between the zone around site A4261043 and site A4261134, overlaid on the fine resolution mesh. Using an R script, the centroid of each mesh element (cell) within each zone was assigned an initial water level and salinity condition by interpolating between the monitoring sites within the zone (Table 2.1). This approach was used to preserve differences for different water bodies, for example the difference between the ocean salinity and within the estuary.

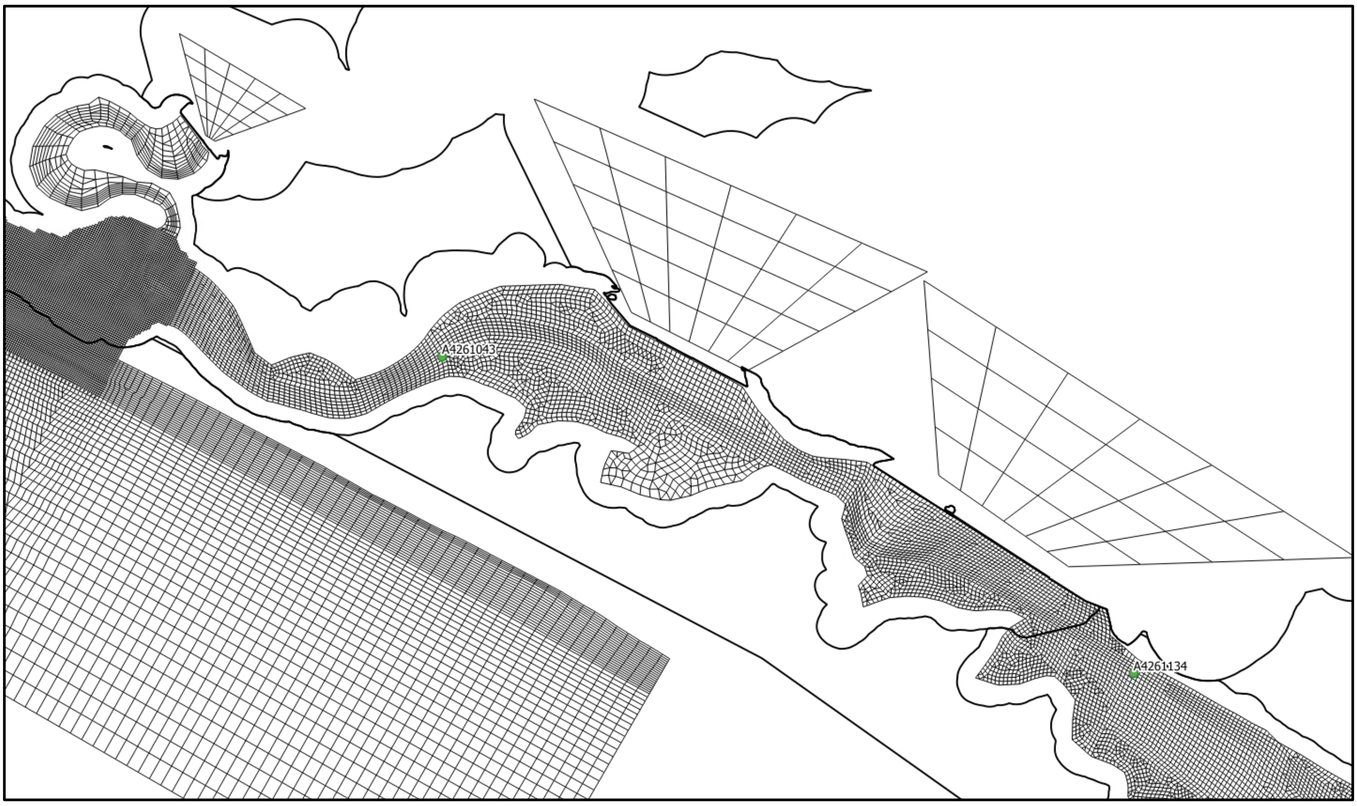


Figure 2.5. Initial conditions polygon zones overlaid on the TUFLOW-FV fine resolution mesh

Daily tide level (m AHD) and salinity (electrical conductivity, EC) data were exported from Hydstra[1] for each of the monitoring sites, and the updated Australian Water Quality Centre (AWQC) equation[2] applied to convert from the electrical conductivity measured at the monitoring stations to Total Dissolved Solids (salinity) in grams per litre (g/L).

Table 2.1. TUFLOW-FV base case hindcast scenario initial conditions for Coorong sites

Site	Name	Water Level (m)	Salinity (EC)	Salinity (g/L)
A4261036	Beacon 12	0.50	47528	33.00
A4261128	Mundoo Channel	0.53	33865	22.12
A4261039	Barker Knoll	0.60	40302	27.11
A4261043	Beacon 1	0.56	53541	38.14
A4261134	Pelican Point	0.47	50687	35.67
A4261135	Long Point	0.54	25471	16.00
A4260572	Robs Point	0.53	67104	50.53
A4260633	Parnka Point	0.48	85150	68.73
A4261209	Woods Well	0.37	105697	91.83
A4261165	Snipe Island	0.41	113015	100.67

2.2.2 Model configuration

All model parameters determined during the previous Coorong model calibration by BMT (2019) were retained in the model control file (Appendix A). These parameters relate to the simulation configuration including the mixing models, global viscosity and diffusivity parameters, and material roughness parameters.

The geometry was defined as per the above modified mesh, but as both the sediment and wave modules were disabled for this scenario, the Murray Mouth bathymetry remained unchanged. This configuration significantly reduces the model run times and still permits relative comparisons of scenarios.

Three conservative tracers, one for barrage inflow, one for ocean inflow, and one for Salt Creek inflows were configured. Passive, or conservative tracers, are commonly used within TUFLOW-FV simulations to represent point source pollutant sources or for flushing studies. In this way, TUFLOW-FV keeps track of the conservative (inert) transport of water quality variables (BMT, 2020). The characteristics of each tracer are specified in a tracer block within the control file, which range in complexity from specifying their inclusion to setting an initial concentration, settling velocity and decay rate for each. In this instance, no specific tracer characteristics were used.

Both point and flux time series outputs were extracted at an hourly time step for the scenario duration. The model outputs were H (water level elevation), SAL (salinity), TRACE_1, TRACE_2, and TRACE_3 (tracer concentrations) time series at selected points along the Coorong, which coincide with observed monitoring data locations. Fluxes (flow, salinity and tracers) across model nodestrings at these locations were also exported.

2.3 Boundary conditions

The boundary conditions referenced in the boundary conditions and barrages files (Appendix B and C) are detailed below. All boundary condition data were compiled for the period 1 July 2019 to 30 June 2020.

[1] At the time of modelling, Hydstra was the Department for Environment's (DEW) water database. This has now been replaced by the Aquarius Time Series software.

[2] At the time of modelling, the updated AWQC equation to convert Electrical Conductivity to Total Dissolved Solids was adopted. Following additional data collection under the T&I Project and a validation of equations, DEW and all researchers have reverted to the previous equation. See Appendix D for details.

2.3.1 Climate

Climate boundary conditions were specified via time series (.csv) files for wind (speed and direction) at a 15-minute time step, and net evaporation at a daily time step.

2.3.1.1 Wind

Observed average wind velocity (km/hr) and direction (degrees) data were downloaded from the Pelican Point AWS site (A4260603) at a 15-minute time step. This was post-processed to generate an input file in the format required by TUFLOW-FV. Wind speed was initially converted to m/s and adjusted to a height of 10 m, and wind direction was converted to radians (relative to East), before both were converted to X and Y velocity components (Figure 2.6).

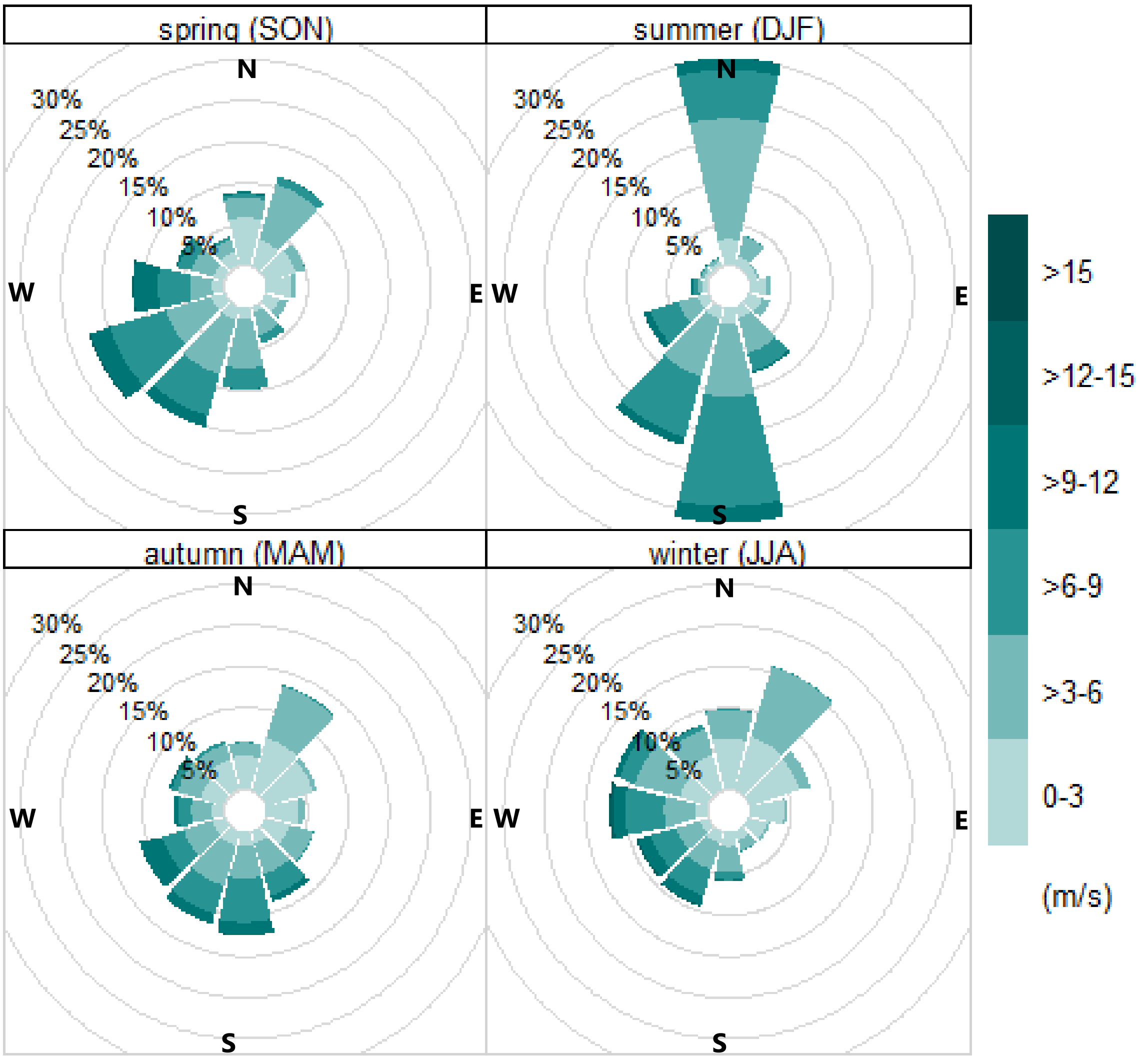


Figure 2.6. Pelican Point AWS (A4260603) 15-minute wind speed and direction used in TUFLOW-FV base case hindcast scenario modelling – 2019-20 seasons

2.3.1.2 Net evaporation

Both rain (mm) and Morton's shallow lake evaporation (mm) were downloaded from the SILO grid data set at a daily time step for a specified grid point (-36.10,139.60) at an elevation of 9.6 m in the mid CSL. Net evaporation (mm/d) was calculated and converted to m/s to generate an input file in the format required by TUFLOW-FV (Figure 2.7). Based on recent modelling undertaken for the region, net evaporation was scaled by 1.09 to account for the bias in the remotely sensed solar radiation data used in the calculation of Morton's Lake evaporation by SILO (DEW, 2021).

Figure 2.7. Daily net evaporation used in TUFLOW-FV base case hindcast scenario

2.3.2 Tide

Victor Harbor tide data were downloaded from the Flinders Ports server at a 15-minute time step and infilled with Barker Knoll (A4261039) tide data where required due to data gaps to generate a continuous tide record in metres for TUFLOW-FV (Figure 2.8). The data were used to prescribe a tidal water level boundary condition at the open boundary offshore of the Murray Mouth. Salinity was set to 35 g/L at this boundary.

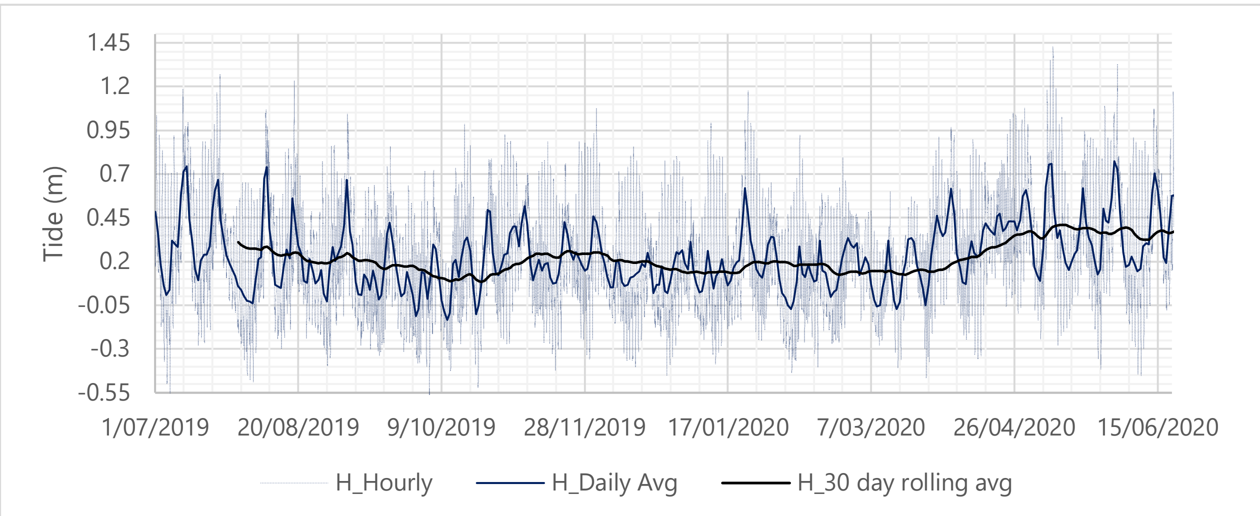


Figure 2.8. Hourly tide record used in the TUFLOW-FV base case hindcast scenario modelling overlaid on the daily and 30-day rolling average tide time series

2.3.3 Salt Creek inflows

Observed flow (m^3/s) and salinity (EC) at Salt Creek flow site (A2390568) was downloaded at a daily time step, and salinity converted to g/L (equivalent to Practical Salinity Unit (PSU) as required by TUFLOW-FV) using the AWQC equation (Figure 2.9). The boundary condition for inflow into the CSL was set at a specific mesh location (377253,600600) in the control file.

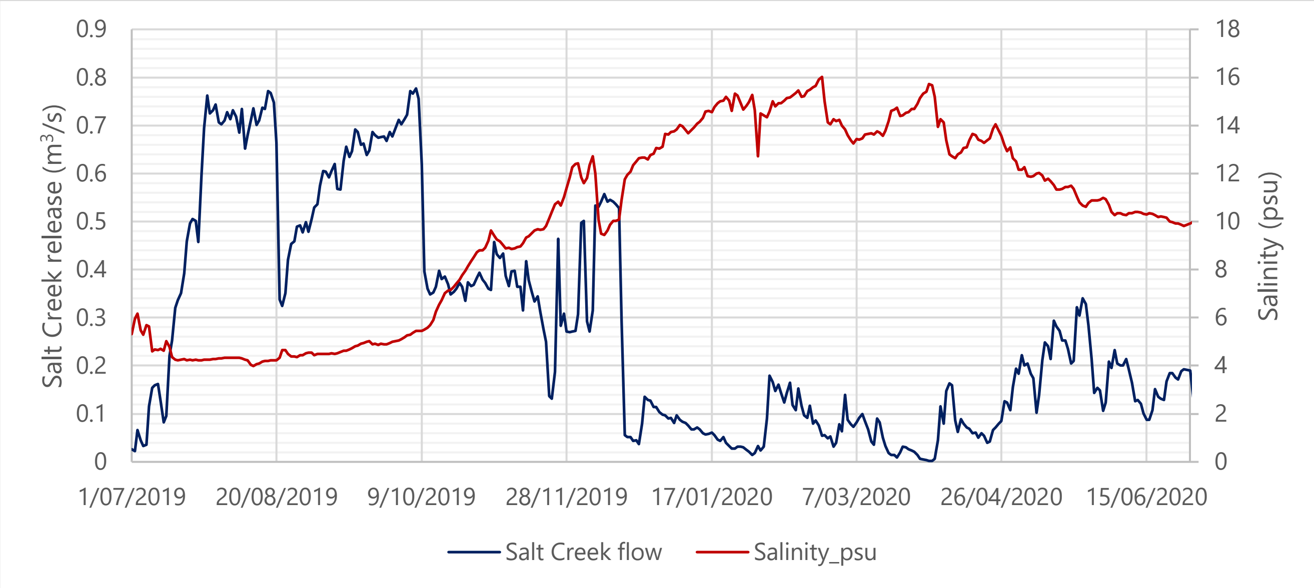


Figure 2.9. Daily Salt Creek releases (flow and salinity) used in the TUFLOW-FV base case hindcast scenario modelling

2.3.4 Tracers

Three conservative (inert) tracers, one for barrage inflow, one for ocean inflow, and one for Salt Creek inflows were specified in the control file tracer block. The conservative tracers were configured to not settle out of the water column, decay over time, or be influenced by other physical inputs such as temperature, light and salinity. However, the default evapo-concentration behaviour was applied whereby tracers are removed with evaporation (BMT, 2020). Tracer 1 was attributed to all barrage inflows and specified in the BarrageCalculator_3Tracers.fvi file in the BC defaults for each of the barrages at the corresponding nodestrings. Tracer 2 was attributed to an ocean source and specified in the BC_Base_002_extended_3Tracers.fvi for the tide and open boundaries at the corresponding nodestrings via the BC defaults. Tracer 3 was attributed to Salt Creek releases (inflow to the Coorong) and was specified in the BC_Base_002_extended_3Tracers.fvi for the Salt Creek inflow at the specific mesh location noted above.

Both point (concentration) and flux outputs were extracted for the three tracers. Point concentrations provide an indication of the relative contribution of the source of each tracer at that point, i.e. a value of 1 indicates the whole element is from that tracer source (barrages, ocean or Salt Creek) while the flux concentrations indicate the relative percentage of flow across that nodestring attributable to each source. Collectively, the tracer outputs provide an indication of the retention or movement of elements within different areas of the Coorong, and the extent to which it flushes.

2.3.5 Barrage flows

Calculated barrage flows (ML/d) were extracted from the Barrage Calculator (DEW, 2021) for Goolwa, Mundoo, Ewe Island, and Tauwitchere barrages at an hourly time step and converted to m^3/s to generate an input file in the format required by TUFLOW-FV (Figure 2.10). The barrage flow input files are all referenced in the BarrageCalculator_3Tracers.fvi file (Appendix C), which in turn is referenced in the TUFLOW-FV control file as a boundary condition.

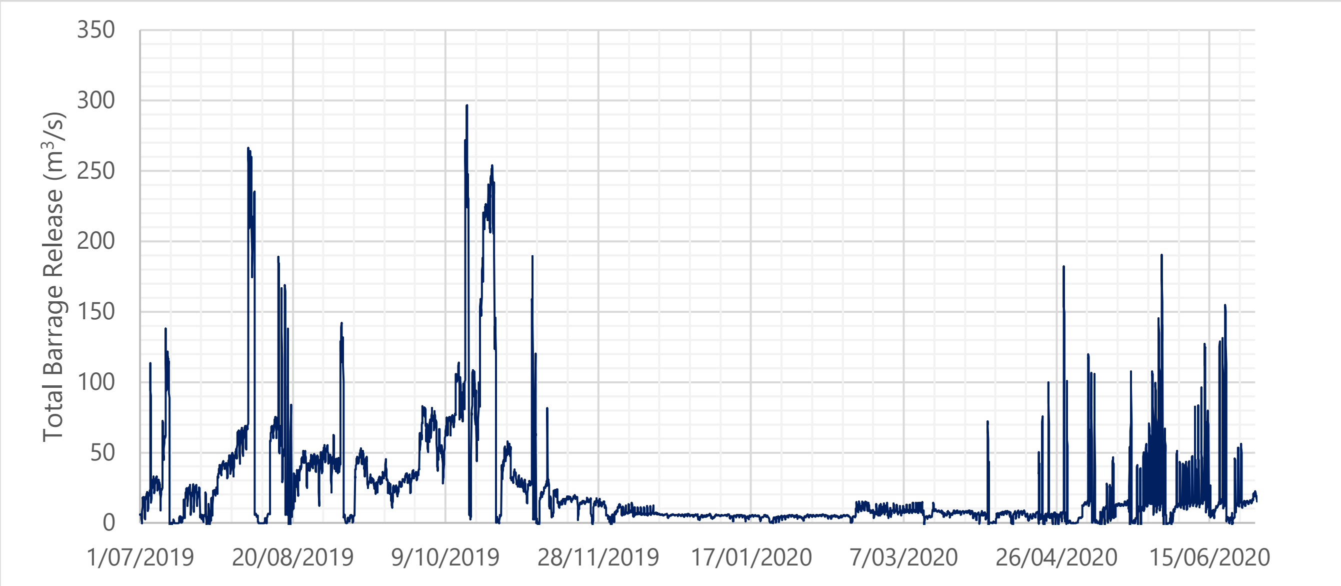


Figure 2.10. Total barrage releases used in the TUFLOW-FV base case hindcast scenario modelling

2.4 Final model and scenario configuration files

Table 2.2 summarises the final model and scenario configuration files used in the base case hindcast scenario modelling.

Table 2.2. TUFLOW-FV final model and scenario configuration files

File type	File name
Initial conditions	Initcons2019.txt
Final 2D mesh	Coorong_20190731with20190226_w_AllNS_1_Renumbered.2dm
Control	V7.12_BarrageCalc_NS_Renum_3Tracers.fvc
Boundary conditions	BC_Base_002_extended_3Tracers.fvi
Barrages	BarrageCalculator_3Tracers.fvi

3 Model validation results

3.1 Water level

Figure 3.1 compares modelled and observed water level at a number of key monitoring sites in the Coorong. The results show that the fine resolution Coorong TUFLOW-FV hydrodynamic model is capable of very closely reproducing observed water level at all sites along the Coorong throughout the modelled period. The relative, albeit minimal, difference between observed and modelled water level is higher in the CNL owing to the greater tidal influence, which is reflected in the variable water level at Beacon 1 (A4261043), Pelican Point (A4261134), Long Point (A4261135) and Robs Point (A4260572). Conversely, the tidal influence is considerably dampened in the CSL, beyond Parnka Point (A4260633) and the modelled water levels at Woods Well (A4261209) and Snipe Island (A4261165) represent the decline in water level following disconnection from the CNL in summer and the increasing influence of net evaporation.

Generally, with the exception of Parnka Point – a natural constriction point with complex bathymetry – modelled water level is slightly higher than observed throughout the modelled period at all sites. From November onwards, the same discrepancy also applies at Parnka Point. Model inputs such as wind and net evaporation, which have a considerable impact on water levels in the shallow lagoon, are currently represented as point time series inputs. Further improvements to the modelled water level relative to observed during these months may be achieved with a spatially distributed representation of these inputs, based on the additional weather stations that are currently being installed at Parnka Point and Long Point (A4261135), combined with further refinement of the model bathymetry. Despite this, the model accurately captures both the seasonal changes in water level, and changes on more frequent temporal scales.

3.2 Salinity

Figure 3.2 compares modelled and observed salinity at the same key monitoring sites in the Coorong. Modelled salinity is noticeably lower than observed at the Beacon 1 (A4261043) and Pelican Point (A4261134) sites during the winter and spring months. These sites are in close proximity to the barrages, and releases were higher during this period in line with ecological objectives. The difference in modelled and observed salinity reduced from November 2019 onwards, coinciding with a significant reduction in both barrage releases and sea levels.

Modelled salinity tracks very closely to observed at CNL sites Long Point (A4261135), Robs Point (A4260572), and also at Parnka Point (A4260633), despite the complex geometry and flow in this region of the Coorong. On average, the modelled salinity is lower and does not always match the observed salinity peaks throughout the summer months. This and the divergence in modelled and observed salinity in the CSL sites Woods Well (A4261209) and Snipe Island (A4261165) from mid-spring is likely due to the influence of evaporation and the disconnection of the CNL and CSL, with evapotranspiration processes dominating in the CSL from this point onwards. It is anticipated that improved spatial representation of evaporation – derived from additional weather stations currently being installed at Parnka Point (A4260633) and Long Point (A4261135) – and the inclusion of additional model functionality to represent evaporative drivers will improve the modelled salinity outputs along the Coorong.

Ultimately, the model accurately captures the seasonal changes in salinity, and the changes on small temporal scales, which provides confidence in the model's ability to represent the hydrodynamics of the Coorong.

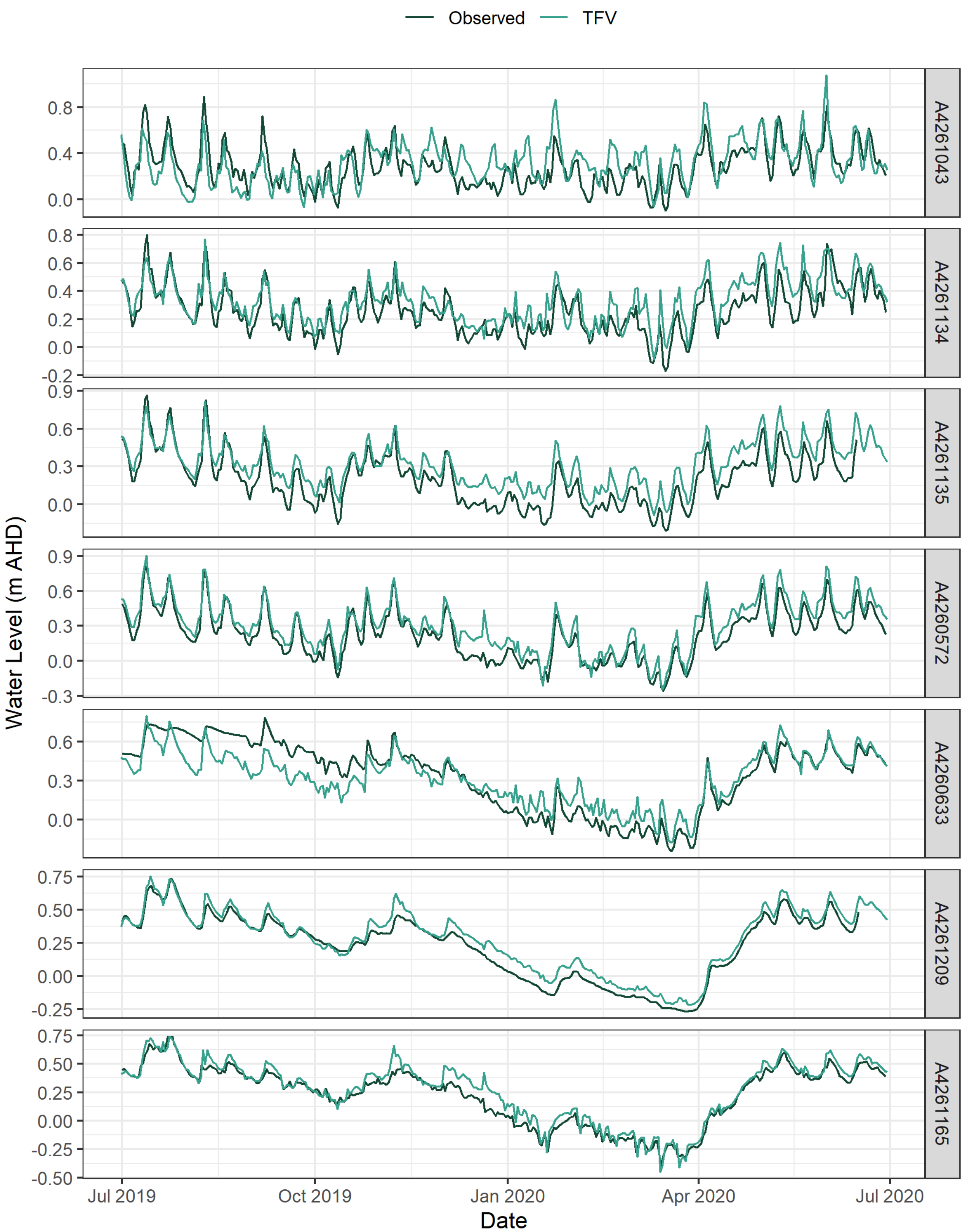


Figure 3.1. Comparison of modelled and observed water level at Coorong monitoring sites – Beacon 1 (A4261043), Pelican Point (A4261134), Long Point (A4261135), Robs Point (A4260572), Parnka Point (A4260633), Woods Well (A4261209) and Snipe Island (A4261165)

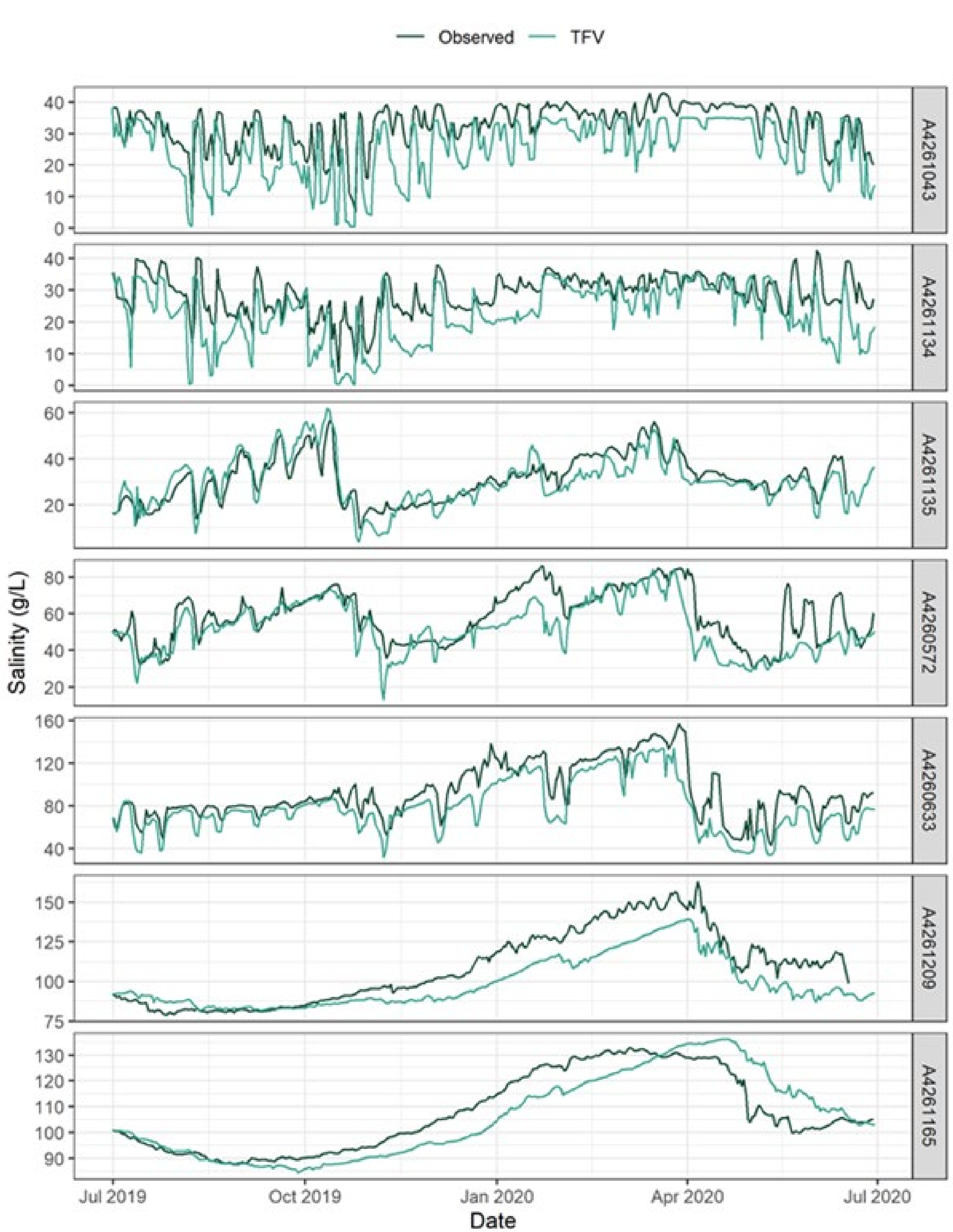


Figure 3.2. Comparison of modelled and observed water level at Coorong monitoring sites – Beacon 1 (A4261043), Pelican Point (A4261134), Long Point (A4261135), Robs Point (A4260572), Parnka Point (A4260633), Woods Well (A4261209) and Snipe Island (A4261165)

3.3 EC Surveys

Modelled salinity was also compared to periodic EC surveys undertaken along the CSL throughout 2019-20. A flow-through cell mounted on the boat continuously recorded just below water surface EC and the location of each data point. For each survey date, the modelled salinity data were extracted from the TUFLOW-FV result file for each mesh cell point closest to the EC survey line. Both modelled and recorded salinity were plotted against Coorong chainage to allow a spatial and temporal comparison. The comparisons are presented in Figure 3.3 to Figure 3.9. Modelled versus recorded salinity values are presented at scales that reflect the variation in salinity at the site. Interpretation of the difference between modelled and recorded salinity should also consider the scale that the results are presented with.

The modelled results compare favourably to the July and August EC surveys along the length of the CSL, but consistently underestimates salinity compared to the monthly EC surveys between October 2020 and January 2020. Despite the discrepancy in the salinity values, the model captures the salinity gradient and pattern along the length of the CSL, which the EC surveys also capture.

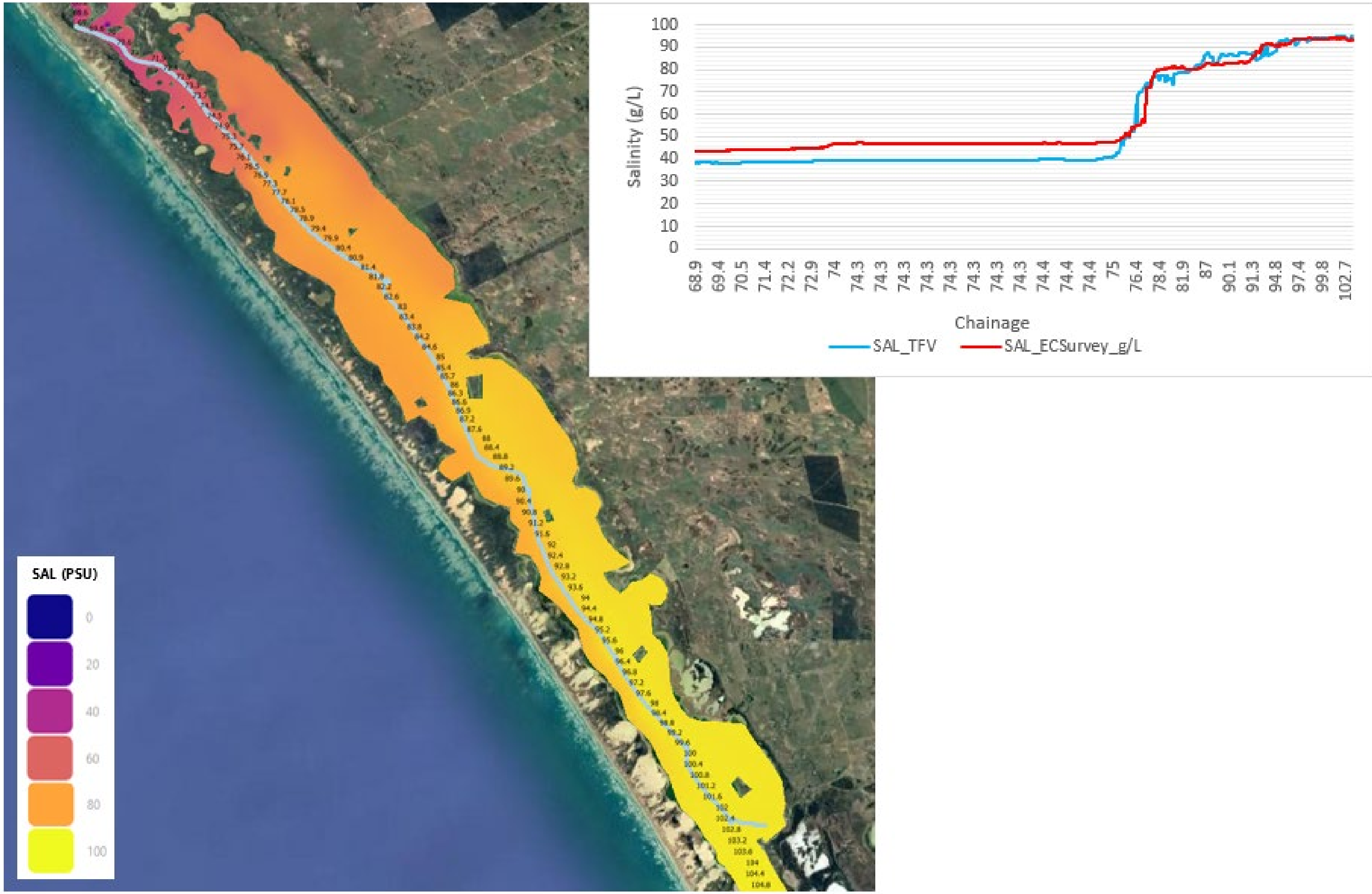


Figure 3.3. Comparison of modelled salinity and EC survey in the CSL – 24 July 2019

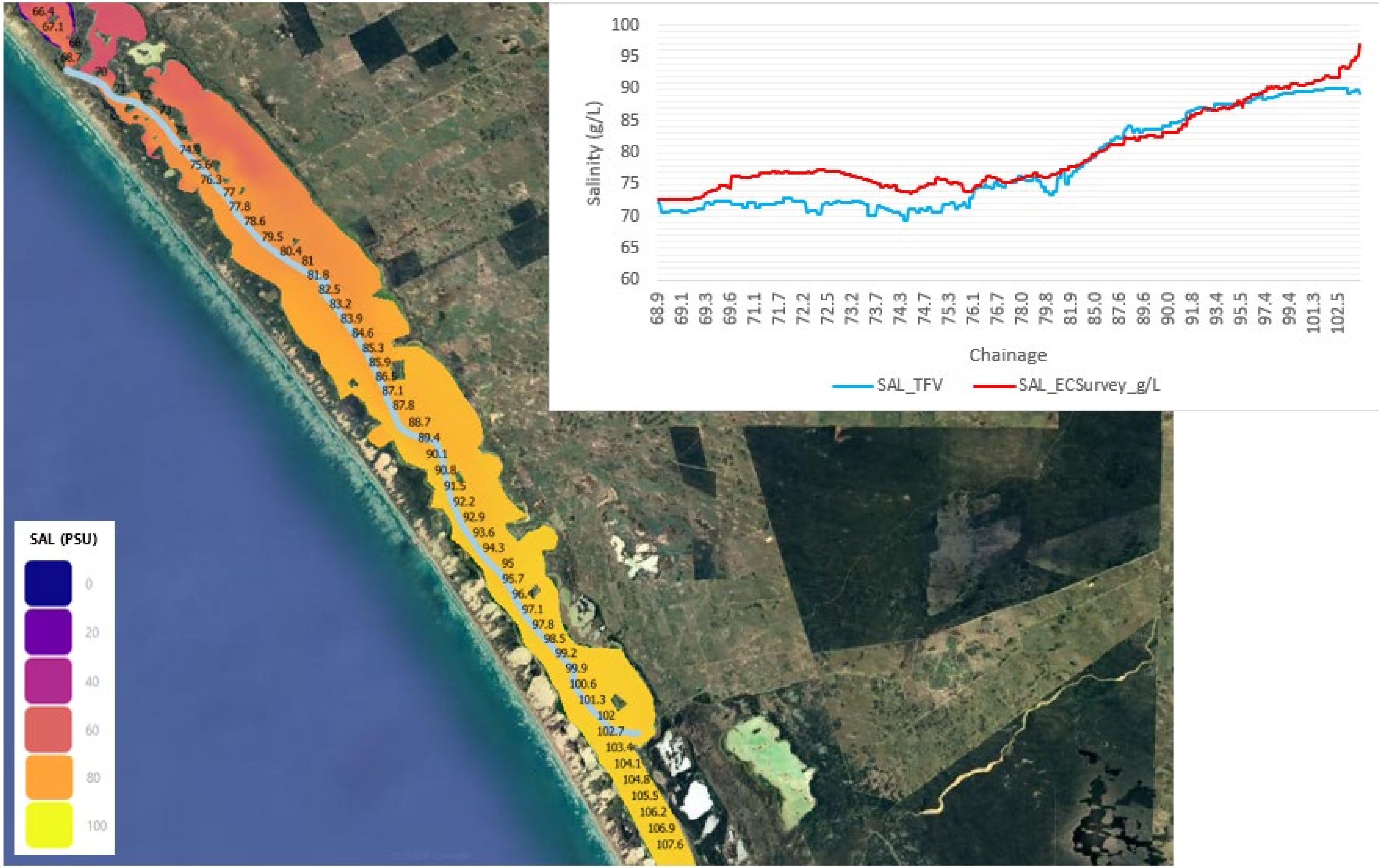


Figure 3.4. Comparison of modelled salinity and EC survey in the CSL – 13 August 2019

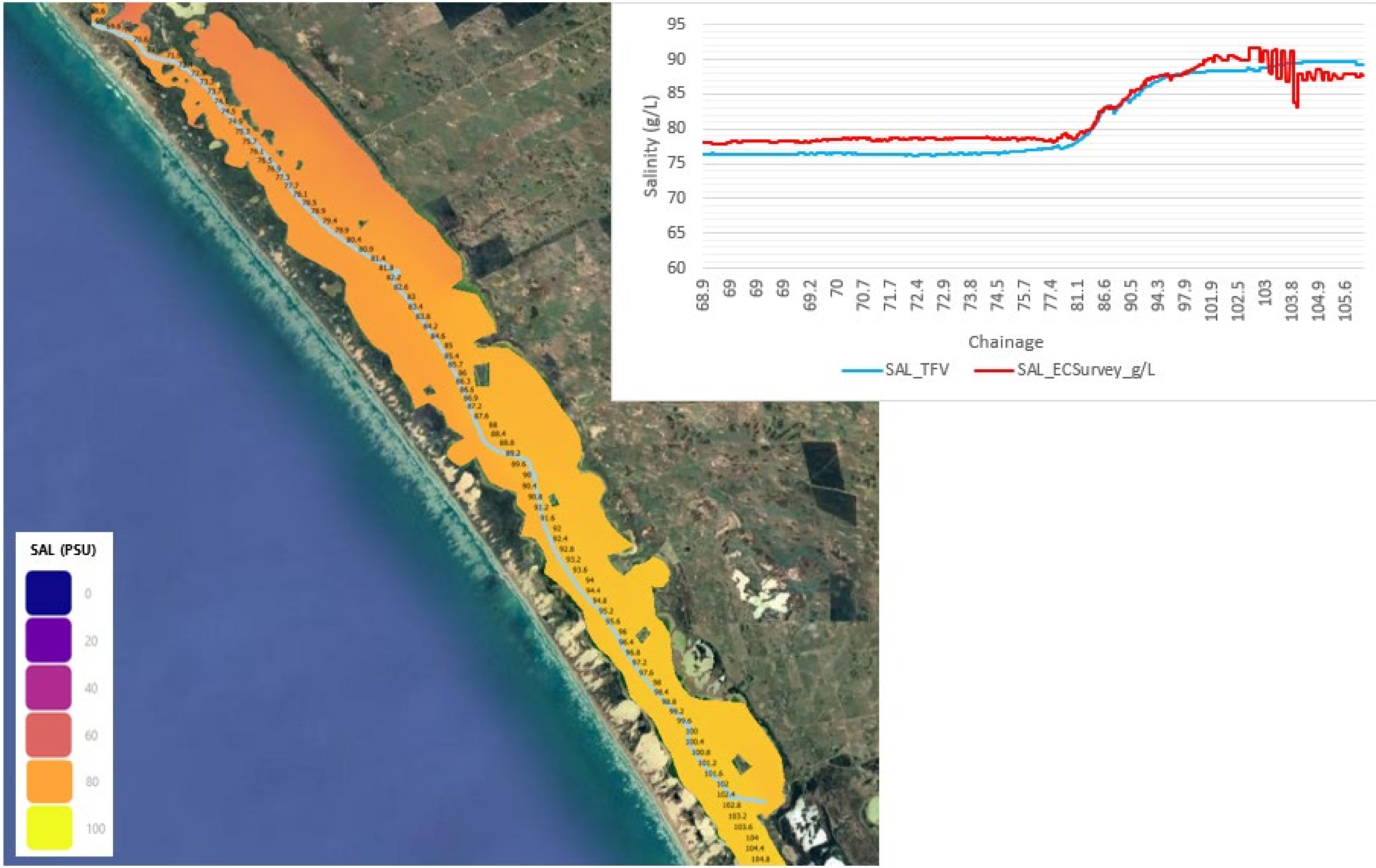


Figure 3.5. Comparison of modelled salinity and EC survey in the CSL – 29 August 2019

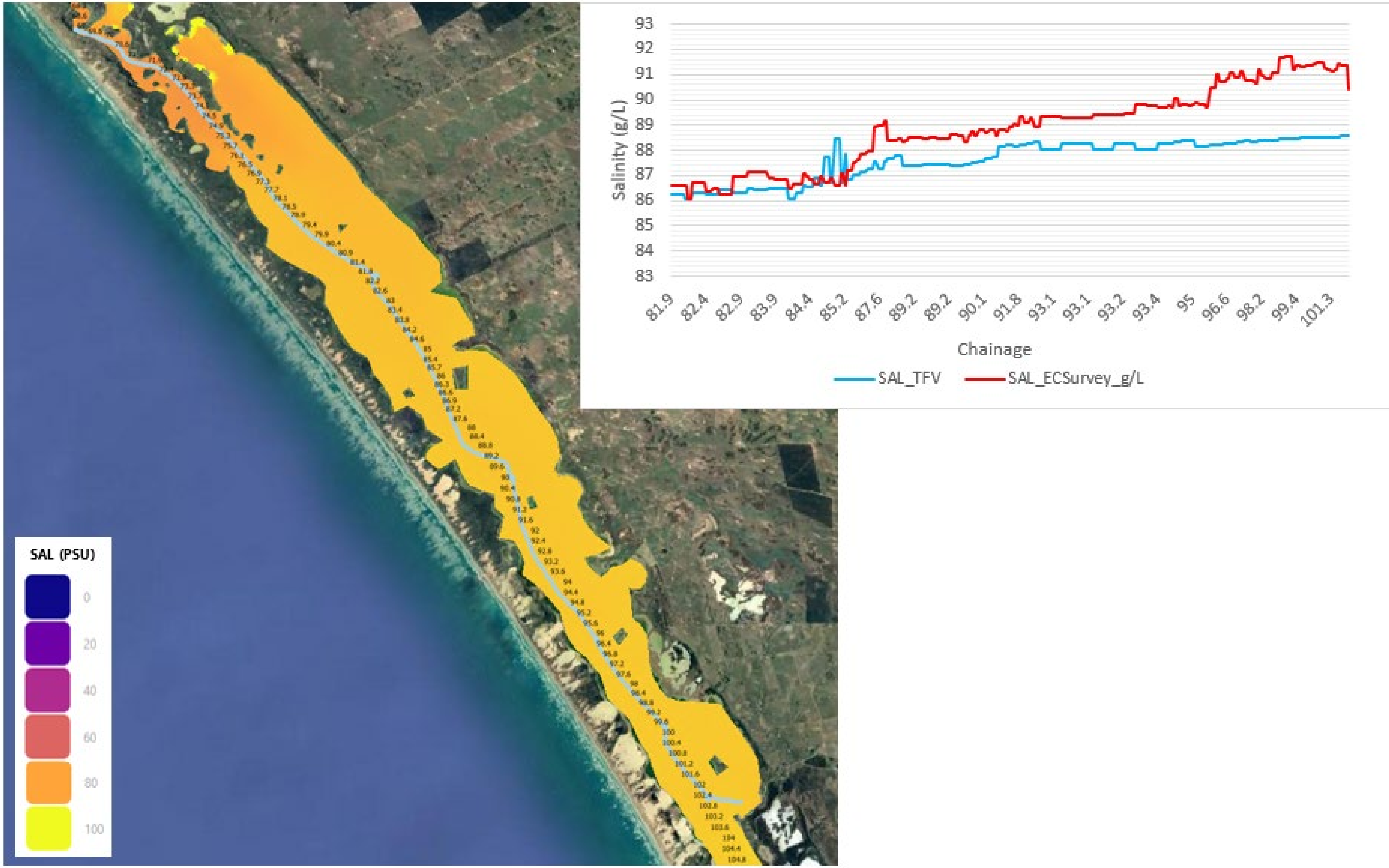


Figure 3.6. Comparison of modelled salinity and EC survey in the CSL – 23 October 2019

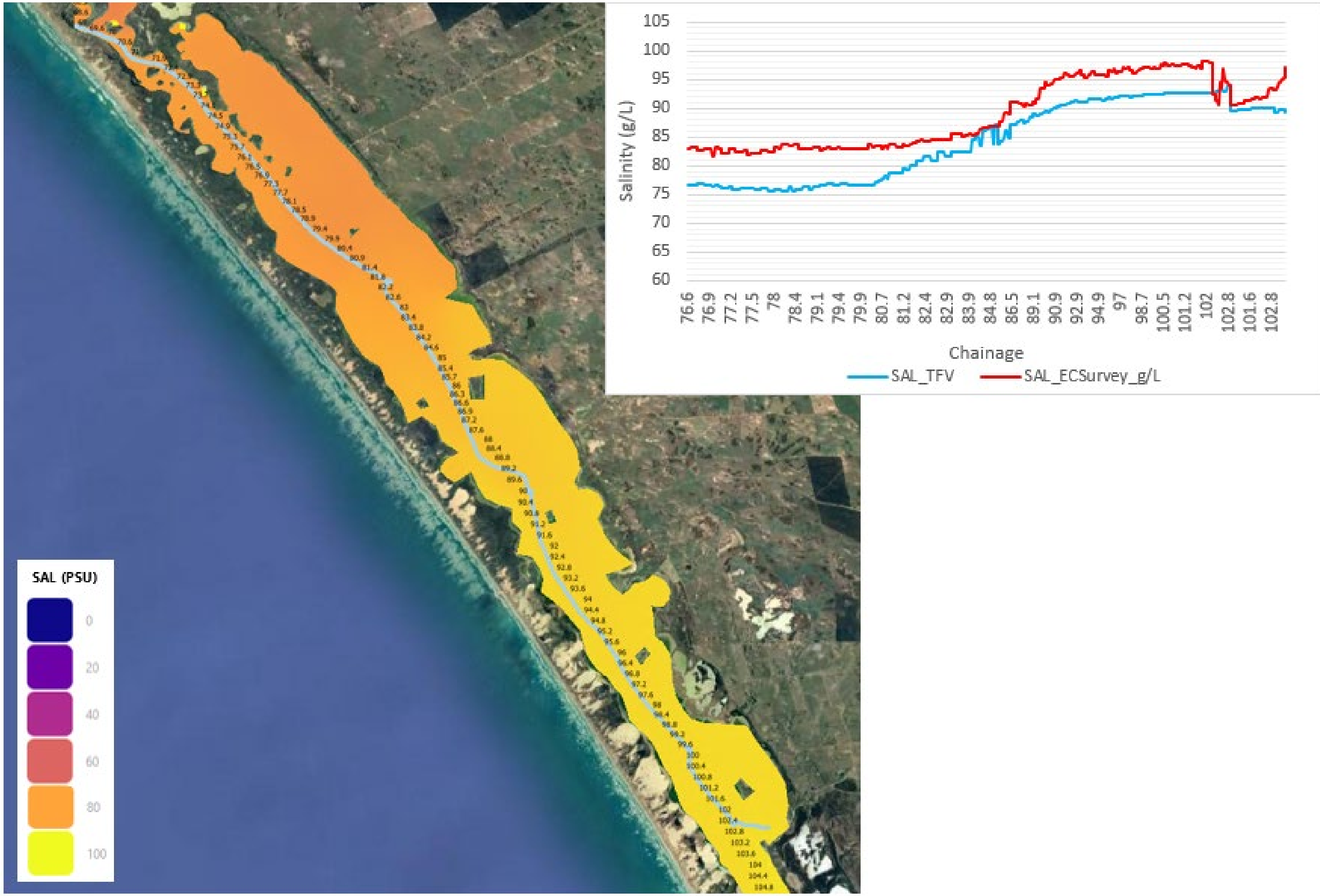


Figure 3.7. Comparison of modelled salinity and EC survey in the CSL – 19 November 2019

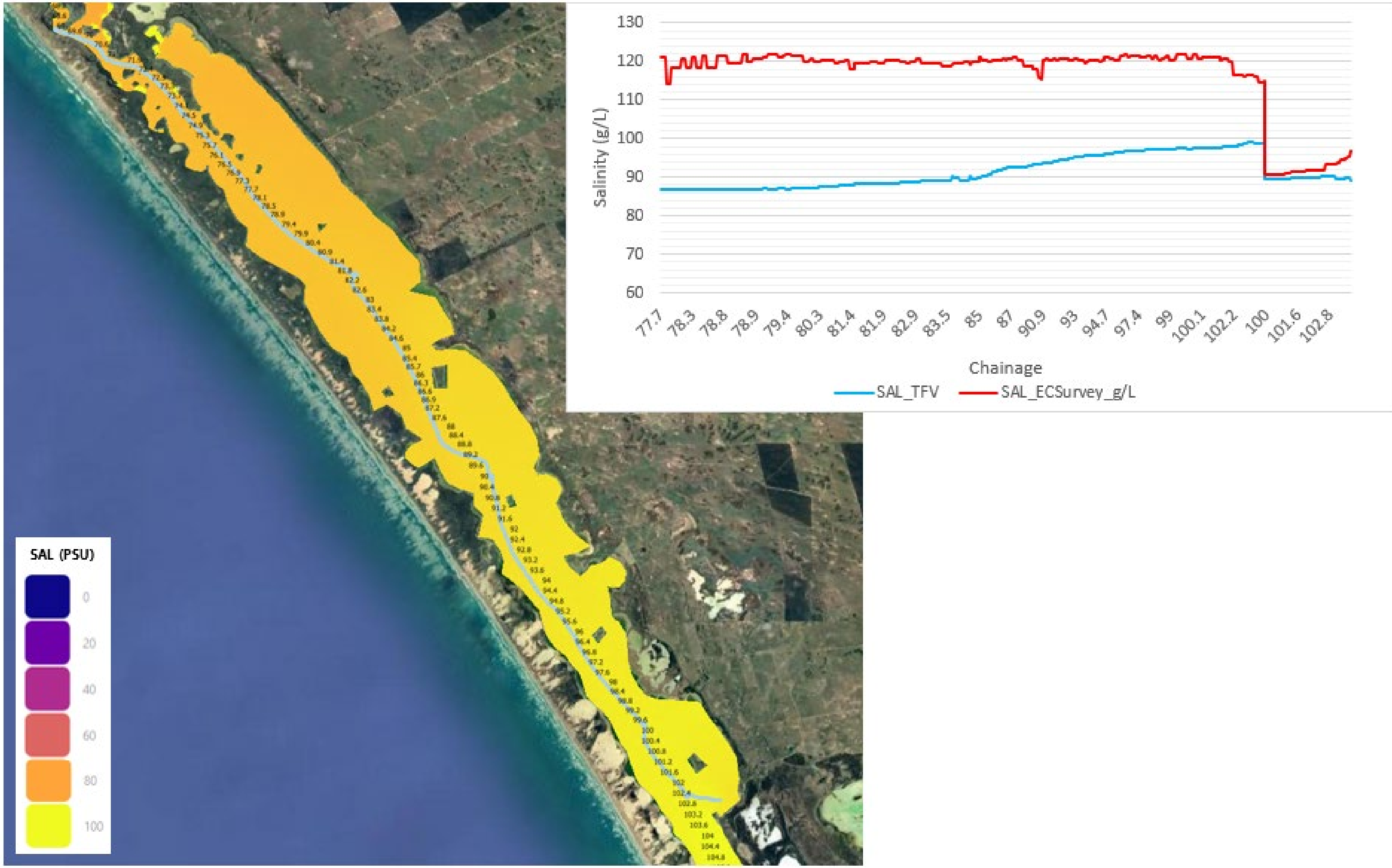


Figure 3.8. Comparison of modelled salinity and EC survey in the CSL - 16 December 2019

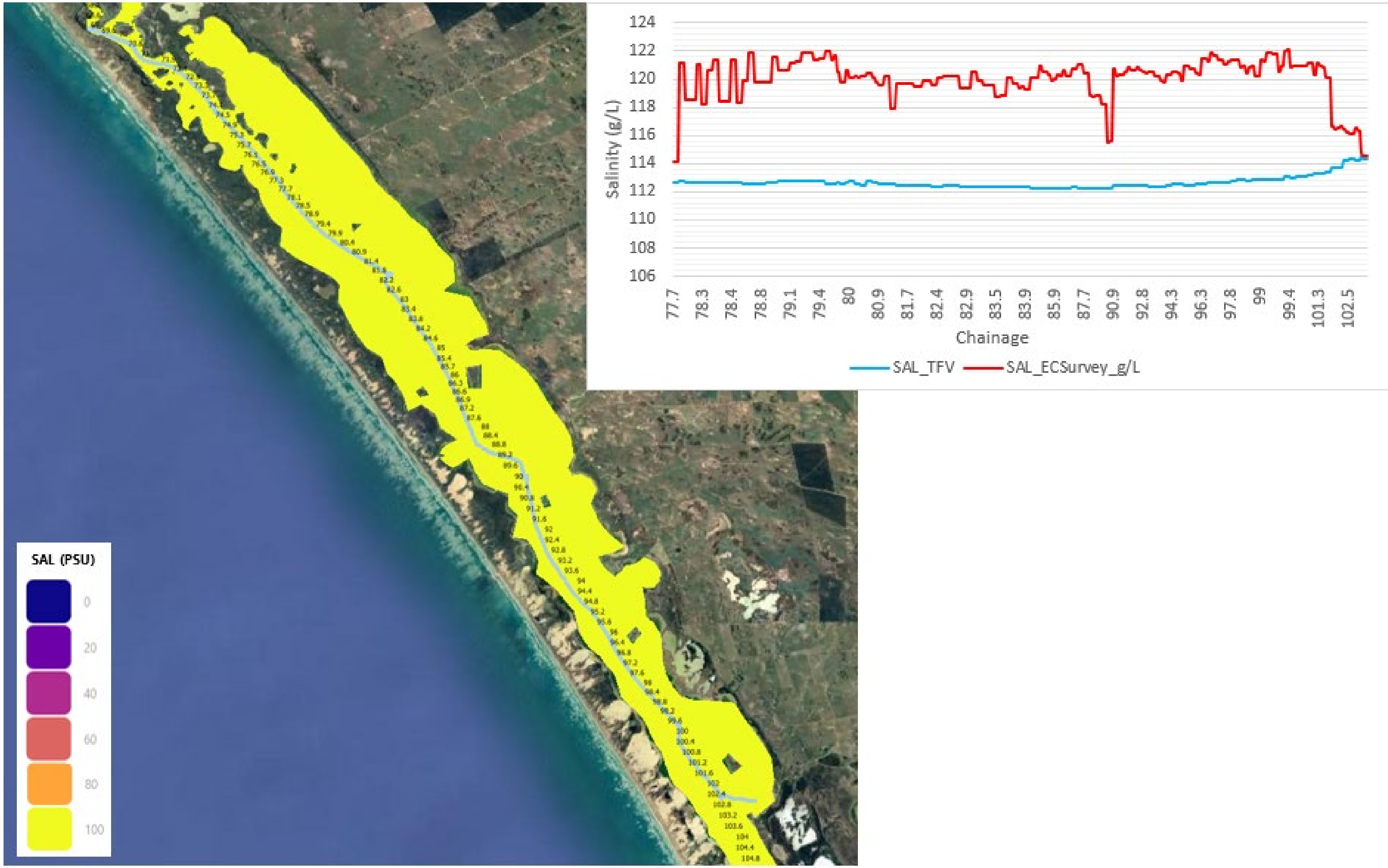


Figure 3.9. Comparison of modelled salinity and EC survey in the CSL – 21 January 2020

3.4 Parnka Point flow gaugings

A number of flow gaugings were undertaken at Parnka Point (A4260633) in the Coorong between July and December 2019, in locations close to where historical gaugings were undertaken in 2010. Flow measurements were taken along transects using an Acoustic Doppler Current Profiler (ADCP), which measured depth, distance and velocity data. To obtain results under various flow and climatic conditions, a total of 21 gaugings were undertaken on different days and times during the 6-month period. The data were post-processed and mean velocity (m/s), total discharge (m^3/s) and maximum velocity (m/s) calculated for each gauging. The difficulties of measuring flow posed by the challenging environment included the considerable effect of wind on the surface velocities, the bi-directional movement of water through the Parnka Point region, and the potential impact of barrage releases and releases from Salt Creek (DEW, 2020), which may increase the uncertainty of individual measurement results.

As described in preceding sections, a nodestring immediately upstream of the Parnka Point monitoring site – approximately 61 km from the Murray Mouth – was added to the TUFLOW-FV mesh so that the flow flux across this nodestring could be exported for comparison against the flow gaugings. The flow direction was set as positive towards Salt Creek to capture flow entering the CSL at Parnka Point, a natural constriction point delineating the CNL from the CSL. The flow record highlights the frequently changing bi-directional flow in the Coorong at Parnka Point. Given the direction of the nodestring, 'positive' flow is flow entering the CSL and 'negative' flow is flow exiting the CSL at Parnka Point, towards the CNL. The flow is equivalent to the total flow rate across the cross-sectional area of the Coorong mesh at the nodestring (transect) located at Parnka Point. A comparison of the total flow rate across this nodestring (NS21) and total gauged discharge from the Parnka Point gaugings is presented in Figure 3.10. This shows the modelled flow rate generally provides an accurate prediction of the measured discharge. This suggests that the model is accurately representing the hydrodynamics of the Coorong, which provides confidence in using modelled results to infer processes/flow at other points in the Coorong.

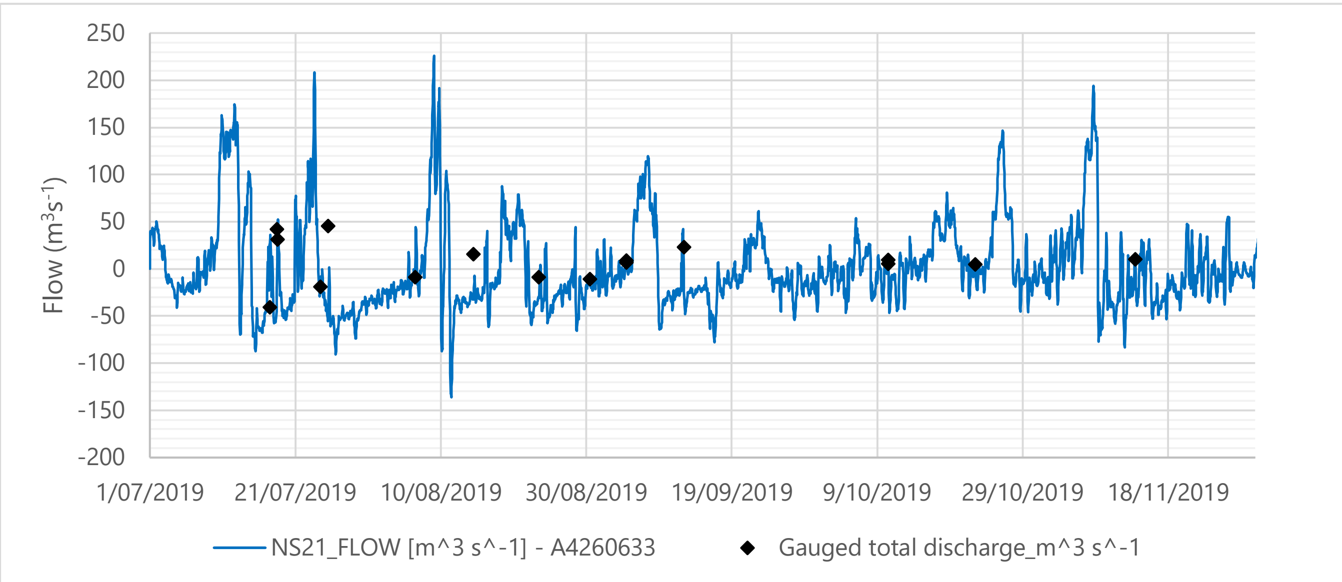


Figure 3.10. Comparison of total gauged discharge at transects around Parnka Point and flow across nodestring 21 (Murray Mouth side of Parnka Point). Note: Nodestring flow direction towards Salt Creek

The model accurately represented the gauged flows undertaken during conditions where the flow measurements were able to be safely performed. There are significant technical and logistical challenges in attempting to undertake gaugings during the highest flow rates, occurring during very high wind events. There are similar challenges in deploying a fixed ADCP to continuously record discharge, with difficulties in identifying a suitable sensor (bottom mounted or side-looking), locating a sensor where the full flow path can be observed, and deriving the velocity-index relationship to derive discharge from the velocity. The flow gauging campaign undertaken in 2019 has provided very useful data on flows at a point in time in the range of up to 50 m^3/s (4,320 ML/d). Given the favourable comparison between the modelled and gauged flows in Figure 3.10, and difficulties in monitoring other flow conditions, there may be limited value in undertaking further flow gaugings at Parnka Point in the short term.

The total flow across a nodestring at Parnka Point was also accumulated at a daily time step, to present the typical flow directions over the year starting in July 2019 (Figure 3.11). The downward slope over the first three months of the period indicates flow towards the CNL as water levels recede from the highest levels over winter, with some short-term flow events back in the other direction. However, the minimal negative cumulative flow during this period confirms that inflow to and outflow from the CSL are almost balanced.

This is followed by flow predominantly back into the CSL between October 2019 and January 2020 driven by evaporation (Figure 2.7) prior to the hydraulic disconnection of the CNL and CSL indicated by the flat slope of the flow curve between January and April 2020. The minimal flows during this period are a function of the constricted conditions between the CNL and CSL at lower water levels. Over this period evaporative losses are dominating and controlling the water level in the CSL and there is no exchange with the CNL. This is further demonstrated by the total flow and relative tracer flux contributions along the Coorong (Section 4) with the residual flow significantly higher in the CSL. From April 2020 onwards, the flow is consistently positive, meaning flow into the CSL from the CNL has resumed as water levels begin to build in the CNL (see Figure 3.1).

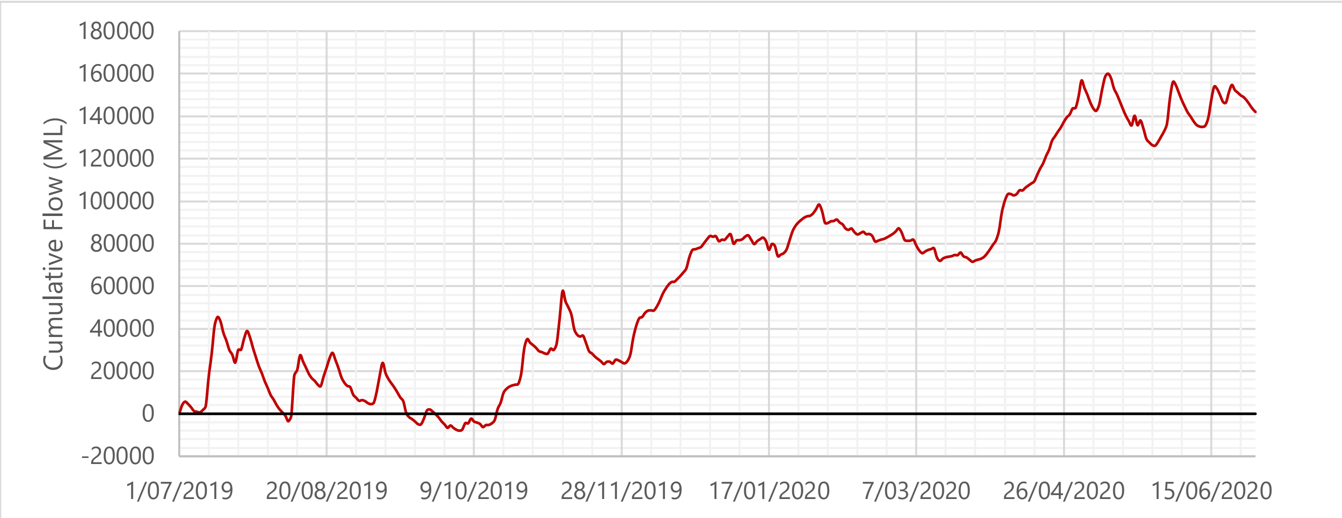


Figure 3.11. Modelled cumulative flow across nodestring 21 at Parnka Point

4 Coorong flow sources using tracers

Tracer outputs provide an indication of the retention or movement of water within different areas of the Coorong. The total flow and tracer fluxes can be used to infer the extent to which the Coorong flushes, or not. As configured for this scenario, the tracers indicate the source of flow into the Coorong from the Murray Mouth end (i.e. barrages or ocean) and the relative contribution of releases from Salt Creek. This information will be used to inform nutrient balances undertaken using water quality data. The results below confirm that the CSL does not flush routinely and the disconnection between the CNL and CSL when water levels diminish is clear in the relative concentrations of the tracers presented below.

4.1 Source of flow into the Coorong

The flow across a nodestring located at Pelican Point (A4261134), which marks the extent of the barrages furthest from the Murray Mouth and the transition to the Coorong Lagoon, was analysed to determine the total flow and proportional contribution of each tracer flux entering and leaving the Coorong. The residual flow was also calculated as the total flow not attributable to either tracer, representing flow of water that was initialised within the model domain. Flow into the Coorong is indicated by positive total flow, and flow exiting the Coorong by negative total flow (Figure 4.1).

Total flow throughout the July to September 2019 period is predominantly out of the Coorong, as water levels recede from the highest levels over winter and any residual volumes originating in the CNL also flushes out. This coincides with higher barrage releases (Tracer 1) during late winter and early spring (Figure 4.2 and Figure 4.3). The tidal influence is still evident as Tracer 2 (ocean) flux concentrations are contributing as well (Figure 2.8 and Figure 4.3). However, as evaporation volumes increase over the summer months, the total flow between December 2019 and April 2020 is predominantly positive, indicating flow into the Coorong to replace the volume evaporated. The relative impact of the ocean (Tracer 2) increases throughout this period as well, reflecting the re-connection of the CNL and CSL and the increasing magnitude of the high tides (Figure 2.8). The flow reverts to predominantly negative, and back out of the Coorong from May 2020 onwards once water levels reach the winter high level of approximately 0.6 m AHD (see Figure 3.1). From December 2019 onwards, the total flow is entirely attributable to the two tracers, barrages and ocean sources, and there is no residual flow out of the Coorong.

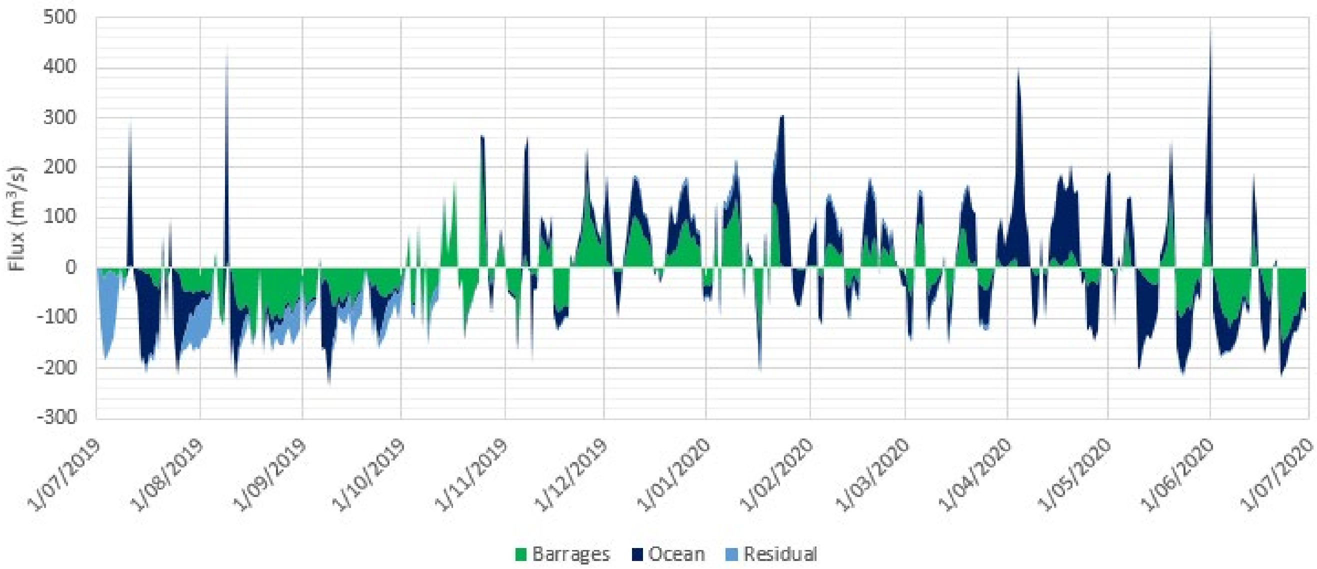


Figure 4.1. Tracer fluxes and residual flow across nodestring located at Pelican Point (A4261134)

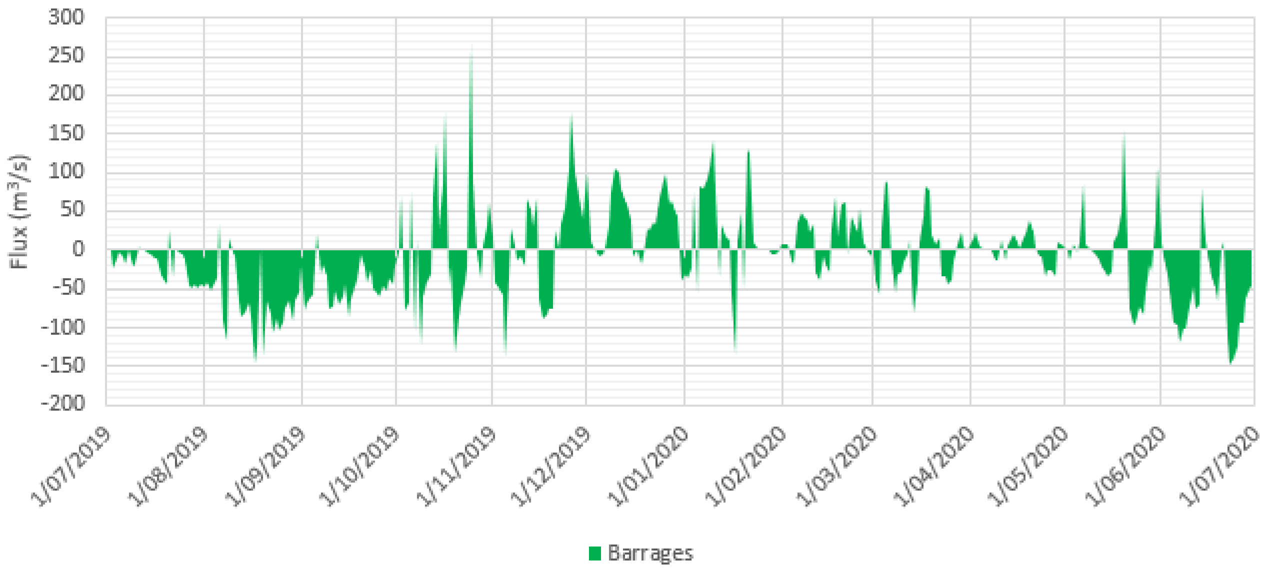


Figure 4.2. Tracer Flux 1 – Barrages at Pelican Point (A4261134)

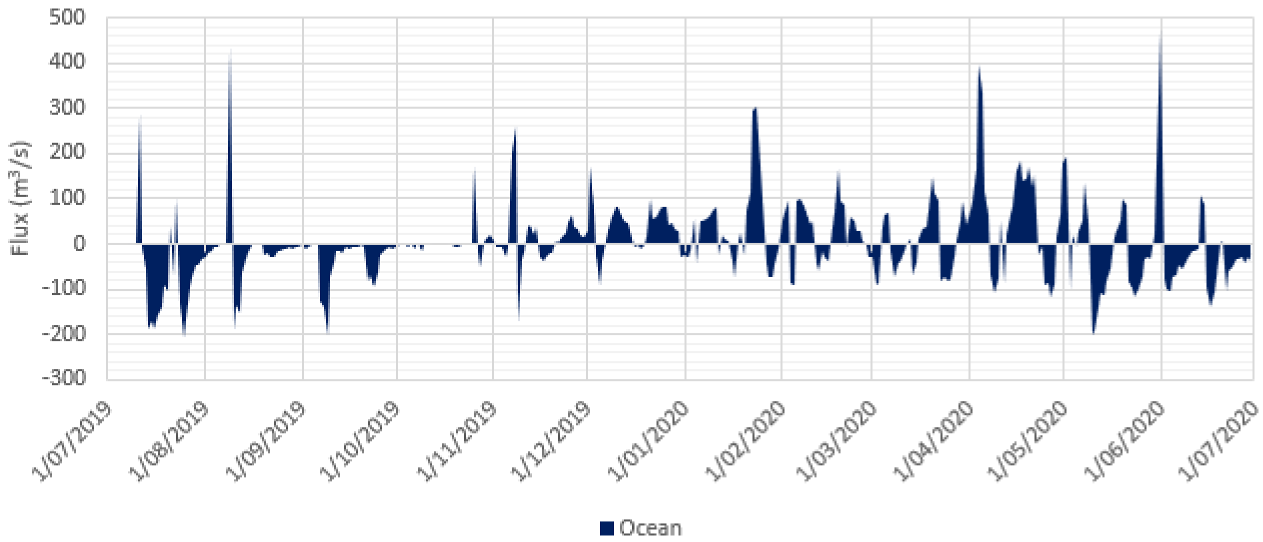


Figure 4.3. Tracer Flux 2 – Ocean at Pelican Point (A4261134)

4.2 Assessing the relative impact of barrage release profiles

To assess the impact of higher barrage flow from Tauwitchere barrage between late-April and late-June in 2020, the total Tauwitchere barrage flow volume for this period was re-distributed to a constant flow rate of 17.26 m^3/s over the period. The re-distributed total barrage flow is presented in Figure 4.4 in red, with the original total barrage flow shown in blue. It should be noted this scenario does not account for the potential for reverse head events requiring the barrages to be shut but does provide an indication of the differences of pulsed versus constant sustained flows for the period considered. The barrage flows for each of the other barrages remained unchanged as they were substantially less than that from Tauwitchere. The model was then run with all other inputs and boundary conditions unchanged.

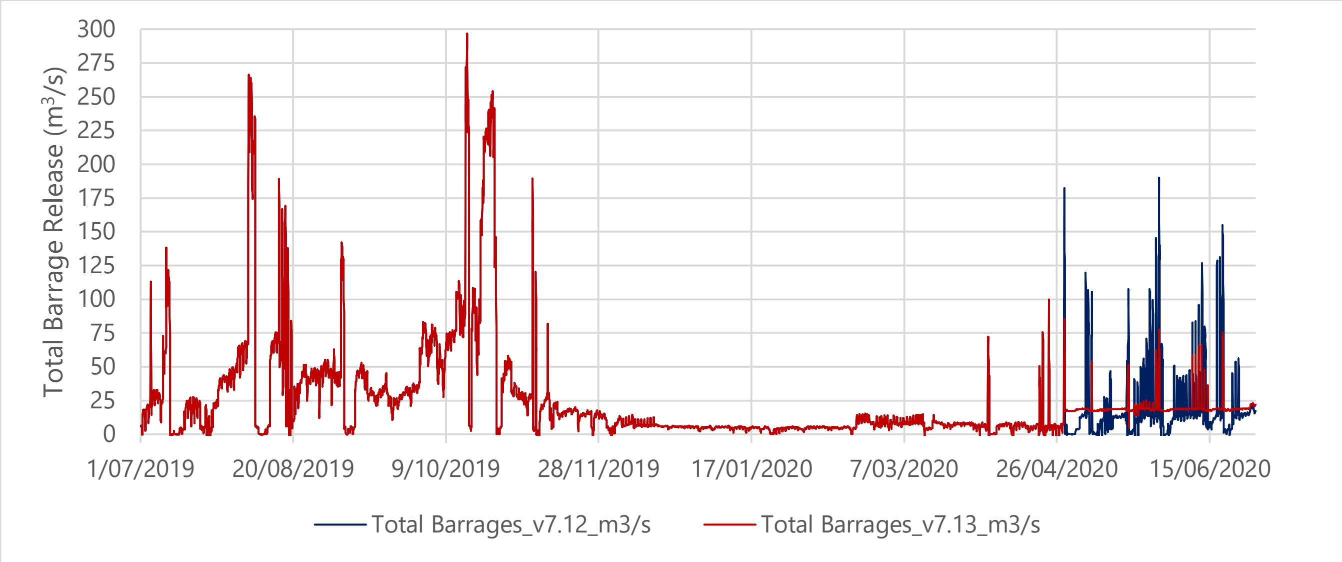


Figure 4.4. Total observed barrage releases – original release profile (blue) and re-distributed release profile (red)

The total flow of Flux 1 (barrages) was compared for the two release profiles at a nodestring at Pelican Point (A4261134), the nearest monitoring site to Tauwitchere barrage. Figure 4.5 presents the period April to June 2020 and shows that the barrage flux is predominantly negative (out of the CNL) from mid-May onwards under both release profiles. The water level at Pelican Point and all sites along the Coorong increases at this time of year (Figure 3.1), which, when combined with a predominant wind direction from the north east (Figure 2.5(d)), acts to push water out of the Mouth rather than into the Coorong. The low barrage releases between pulse events (original release profile) during these months result in a stronger negative flux compared to the constant lower flow rate (re-distributed release profile) at this time of year. The large pulses at the end of May and in mid-June 2020 do result in increased barrage flow past Pelican Point (into the CNL) for a short period.

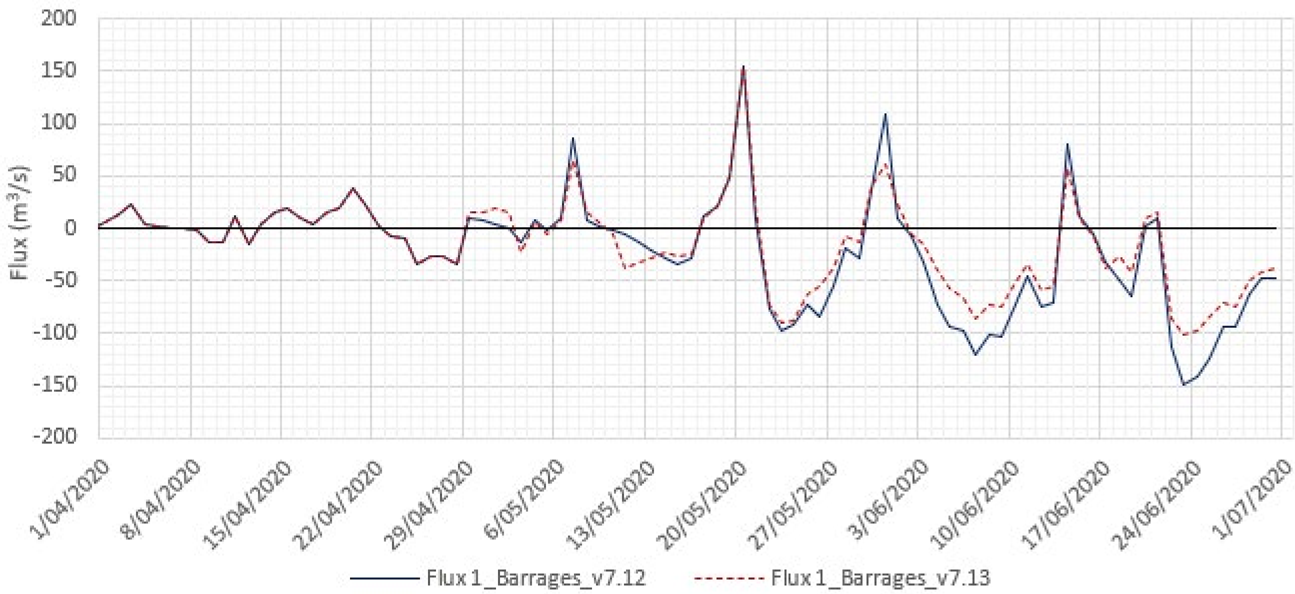


Figure 4.5. Tracer Flux 1 – Barrages at Pelican Point (A4261134). Original release profile (blue) and re-distributed release profile (red)

4.3 Sources of flow within the Coorong

The flow across a nodestring located at Parnka Point (A4260633) was analysed to determine the total flow and proportional contribution of each tracer flux (barrages and ocean) entering and exiting the CSL at Parnka Point. As for Pelican Point (A4261134), the residual flow was also calculated as the total flow not attributable to either tracer. Flow into the CSL is indicated by positive total flow, and flow exiting the CSL by negative total flow.

As shown in Figure 4.6, total flow frequently changes direction due to the complex bathymetry and influence of wind on short term flow direction. The magnitude of the flow range is considerably less at Parnka Point than that at Pelican Point as the distance from the Murray Mouth has dampened the influence of both the barrages and the ocean, and the water level fluctuations are less (Figure 4.6). This is reflected in the minimal Tracer 1 (barrages) and Tracer 2 (ocean) fluxes during the winter and early spring period (Figure 4.7 and Figure 4.8, respectively) compared to the dominant residual flow throughout winter and early-spring, which reflects maintenance of the water volume in the model domain from the start of the simulation (Figure 4.9). The predominantly net positive residual flow into the CSL is also reflected in the cumulative residual plot, highlighting the limited exchange or flushing out of the CSL throughout the summer 2019/20 and the dominance of evaporative fluxes on the mass balance. The net positive residual flux gradually declines as the two lagoons re-connect again in Autumn 2020 and some of the initial water volume in the model domain is flushed out of the CSL and out to the ocean (Figure 4.10).

The influence of higher barrage releases in late-spring 2019 is evident at Parnka Point, albeit at approximately half the magnitude of the equivalent flux at Pelican Point. The increasing high tide levels shown in Figure 2.8, and the re-connection of the CNL and CSL, coincide with the Tracer 2 (ocean) flux increasing as the higher water levels propagate further down the Coorong into the CSL. These higher water levels also transport some barrage flow (Tracer 1) into the CSL, and from April 2020 onwards the total flow is almost entirely attributable to the two tracers representing barrages and ocean sources. However, there is a small residual flow into or out of the CSL representing water that originated in the model domain moving between the lagoons.

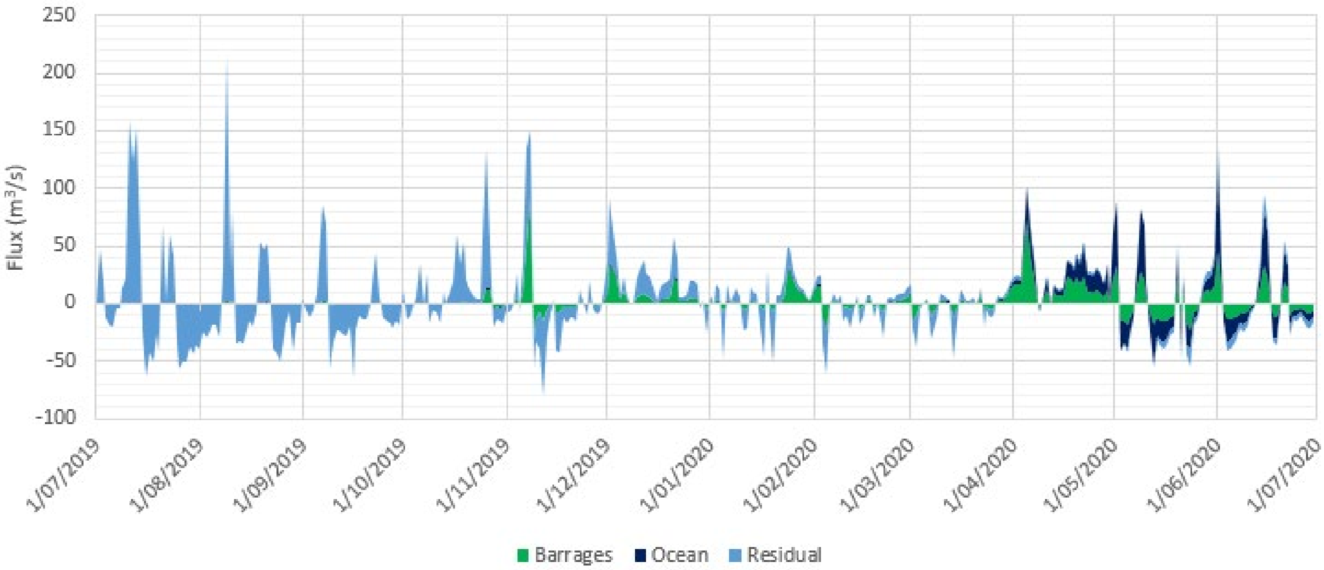


Figure 4.6. Tracer fluxes and residual flow across nodestring located at Parnka Point (A4260633)

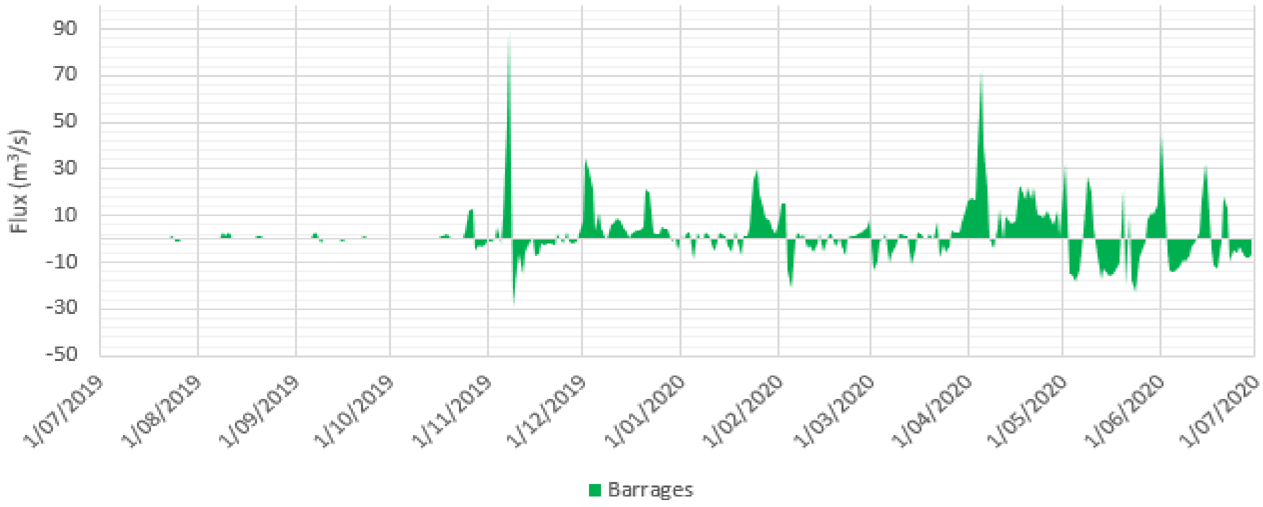


Figure 4.7. Total flux 1 – Barrages at Parnka Point (A4260633)

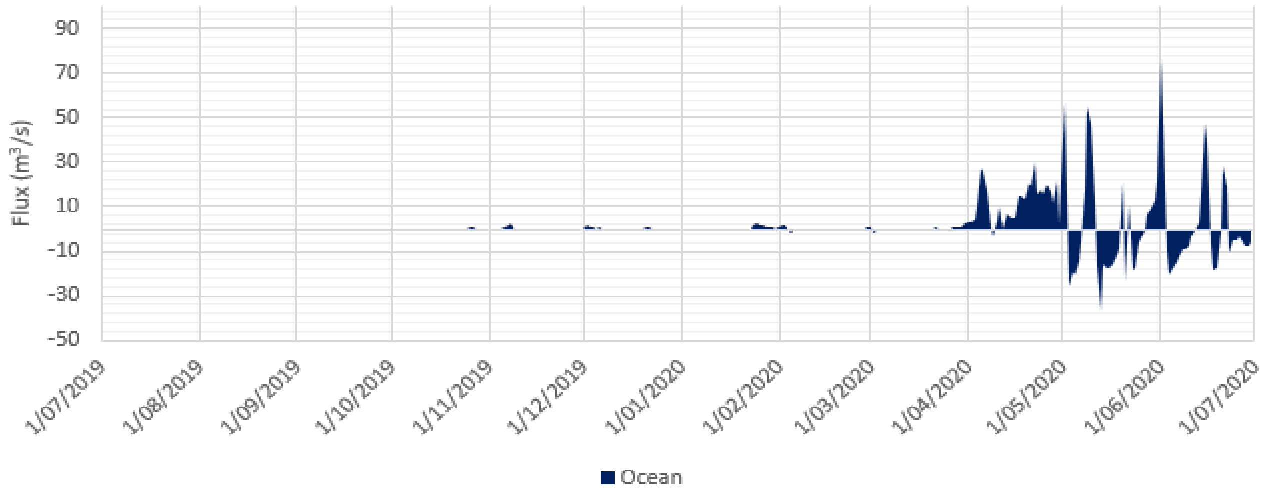


Figure 4.8. Total flux 2 – Ocean at Parnka Point (A4260633)

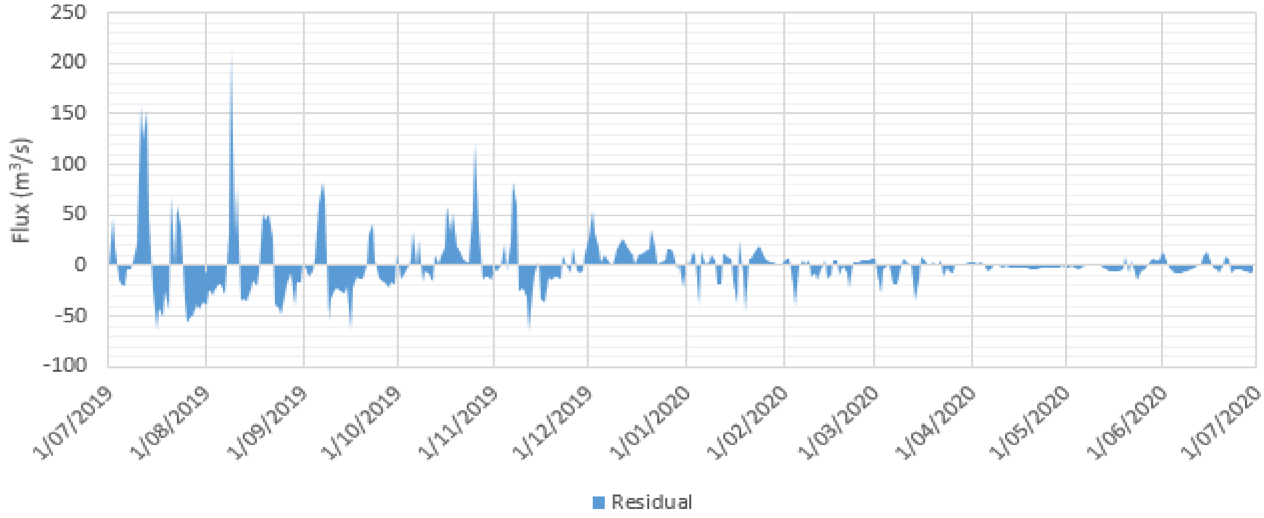


Figure 4.9. Residual flux at Parnka Point (A4260633)

Figure 4.10. Cumulative residual flux at Parnka Point (A4260633)

4.3.1 Influence of Salt Creek inflow on the Coorong South Lagoon

The flow across two nodestrings in the CSL, one located immediately north of the Salt Creek outlet (A2390568) and one located immediately south of this location were analysed to determine the total flow and proportional contribution of each tracer flux at the Southern end of the Coorong. An additional tracer, Tracer 3 was included in the model scenario and was attributed to Salt Creek inflow (Figure 2.9). As for both Parnka Point (A4260633) and Pelican Point (A4261134), the residual flow was also calculated as the total flow not attributable to any of the three tracers. Flow towards the southern CSL is indicated by positive total flow, and flow exiting the southern CSL by negative total flow.

The similar total flow pattern at both nodestrings, as shown in Figure 4.11 and Figure 4.12, highlights that the Salt Creek inflows do not travel in any one predominant direction upon entering the CSL. Rather, the total flow frequently changes direction due to the influence of wind on short-term flow direction, with slightly higher total flow in a northerly direction on average. It is likely the magnitude of the flow range at these locations is greater than Parnka Point due to fewer natural constrictions and deeper water. Despite the proximity to the Salt Creek outlet, Tracer 3 (Salt Creek) fluxes are minimal and therefore the total inflow modelled (Figure 2.9) from the South East drainage system does not have a significant impact on CSL water levels or salinity for the scenario considered. Instead, the dominant residual flow throughout the entire period again highlights the high residence time of water in the southern CSL and the relatively insignificant influence of either barrage releases or the ocean throughout the year in the CSL in this scenario.

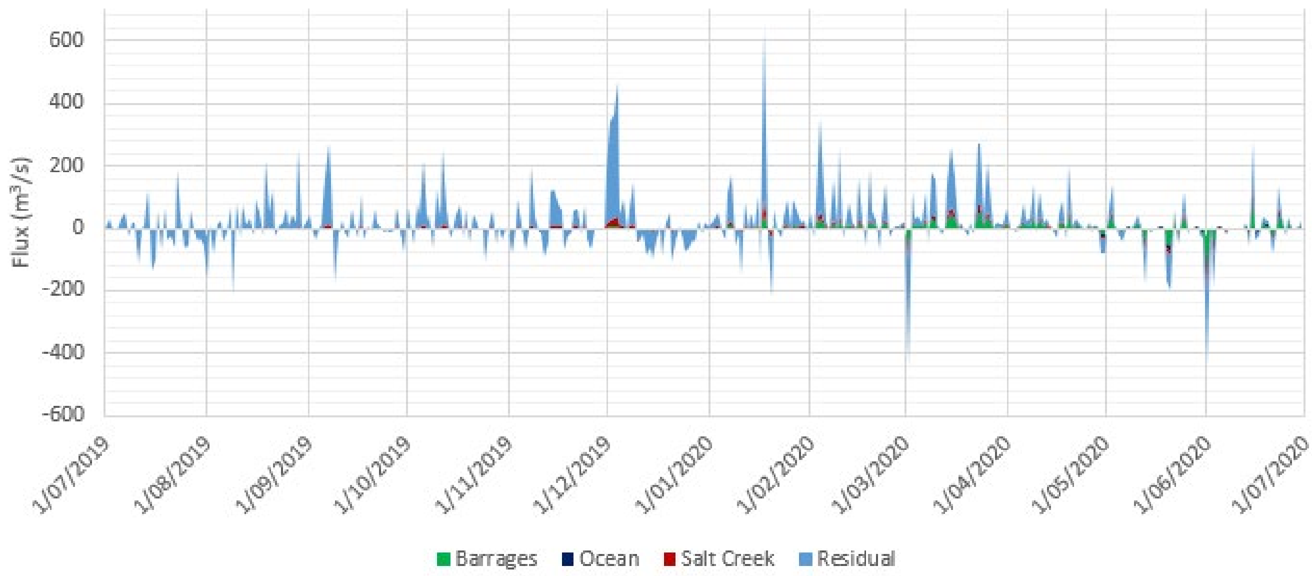


Figure 4.11. Tracer fluxes and residual flow across nodestring located immediately north of the Salt Creek outlet

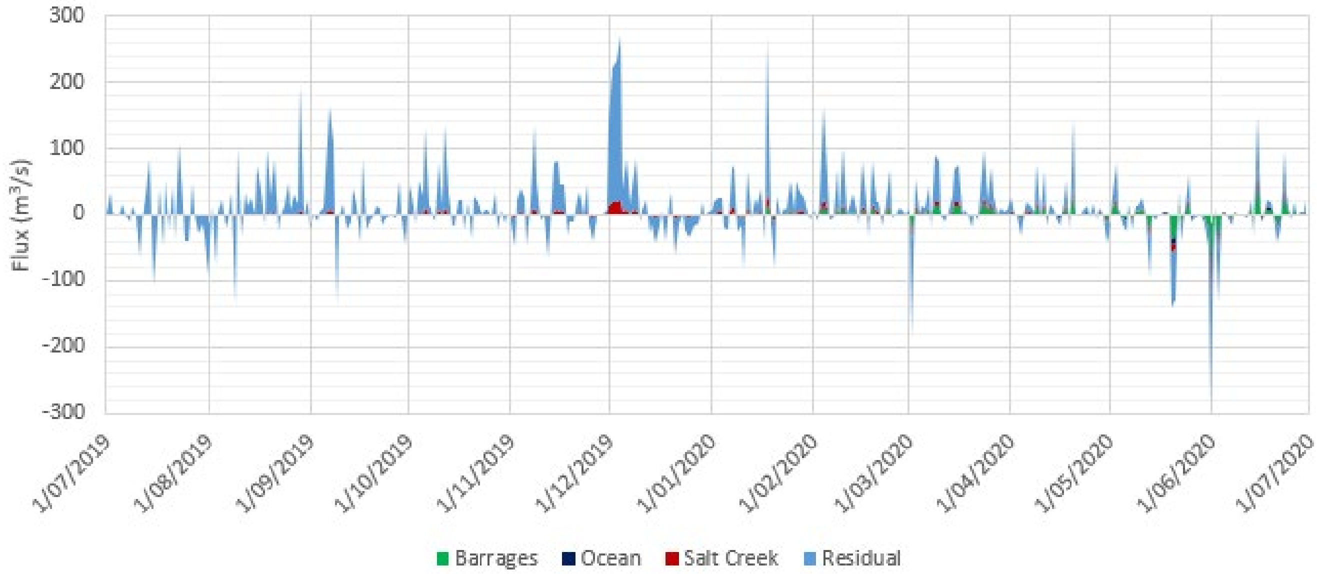


Figure 4.12. Tracer fluxes and residual flow across nodestring located immediately south of the Salt Creek outlet

4.3.2 Tracer 1 (Barrages) concentrations along the Coorong

Figure 4.13 and Figure 4.14 show the relative concentration of each modelled tracer at key monitoring sites in the CNL and CSL. The concentration of Tracer 1, which was attributed to a barrages source, is noticeably higher and more variable at Beacon 1 (A4261043) and Pelican Point (A4261134), which are located in closer proximity to the barrages. Total barrage releases (Figure 2.10) were much higher during the winter and spring months of 2019 due to environmental water delivery for ecological benefit in the Coorong. This barrage release signature, represented by Tracer 1 concentrations, is comparatively delayed and diminished at Long Point (A4261135), Robs Point (A4260572), and Parnka Point (A4260633). Thereafter, the influence is considerably reduced at the CSL sites, Woods Well (A4261029) and Snipe Island (A4261165), which are more than 63 km from the barrages. However, the concentrations confirm that the influence of barrage releases does still extend to these sites due to the constant exchange between CNL and CSL.

4.3.3 Tracer 2 (Ocean) concentrations along the Coorong

At Pelican Point (A4261134) on the Coorong side of Tauwitchere barrage, the two tracers are close to the inverse of each other, i.e. when barrage flow was occurring this was the source of flow into the Coorong, while ocean water became the source with no barrage flow. The relative contribution of ocean sources follows a similar pattern, progressively diminishing with distance from the Murray Mouth and ocean exchange but similarly influenced by the bi-directional flow and re-connection of the CNL and CSL. The concentration of Tracer 2 is highest at Beacon 1 (A4261043) and Pelican Point (A4261134), with the relative influence of the ocean even more pronounced from December 2019 onwards, when barrage releases decreased significantly. However, the dampened tidal signature and thus contribution from ocean sources was evident from Long Point (A4261135) and was at or almost zero by Robs Point (A4260572) in the southern CNL and beyond into the CSL. The increase in Tracer 2 concentrations at Long Point (A4261135) and Robs Point (A4260572) from January 2020 onwards is likely a reflection of the increasing magnitude of the tidal range, particularly the high tide, where higher ocean levels likely force more water further down the Coorong (Figure 2.8). Similarly, the increase in Tracer 2 concentrations at CSL sites, Parnka Point (A4260633), Woods Well (A4261209), and Snipe Island (A4261165) from mid-March 2020 onwards likely reflects the re-connection of the CNL and CSL and the resumption of bi-directional flow and thus oceanic influence in the CSL.

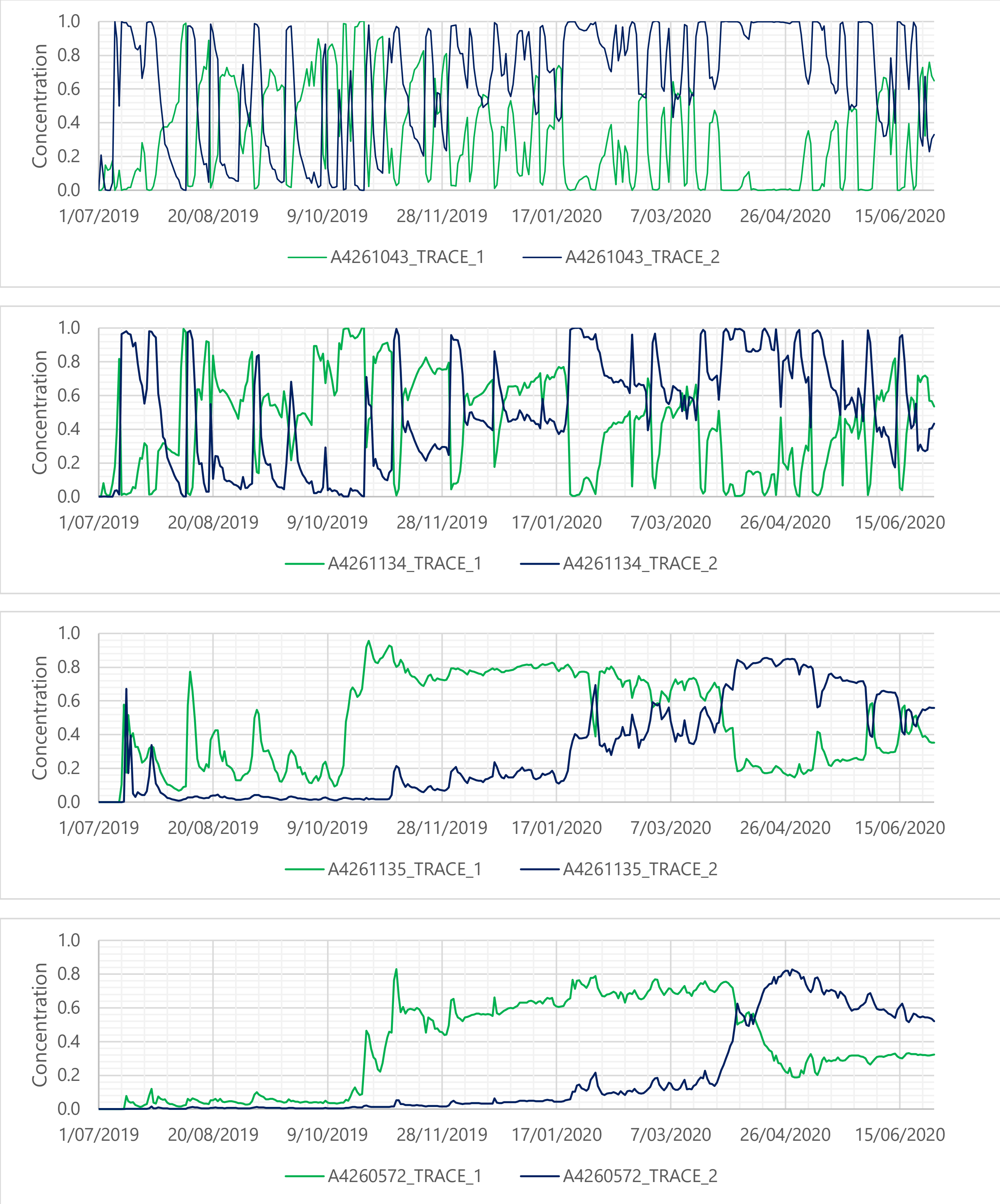
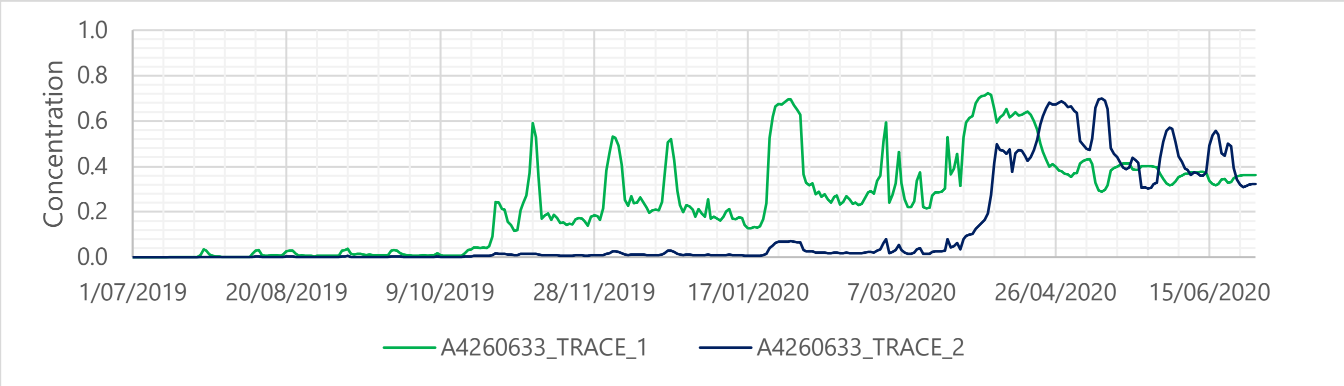
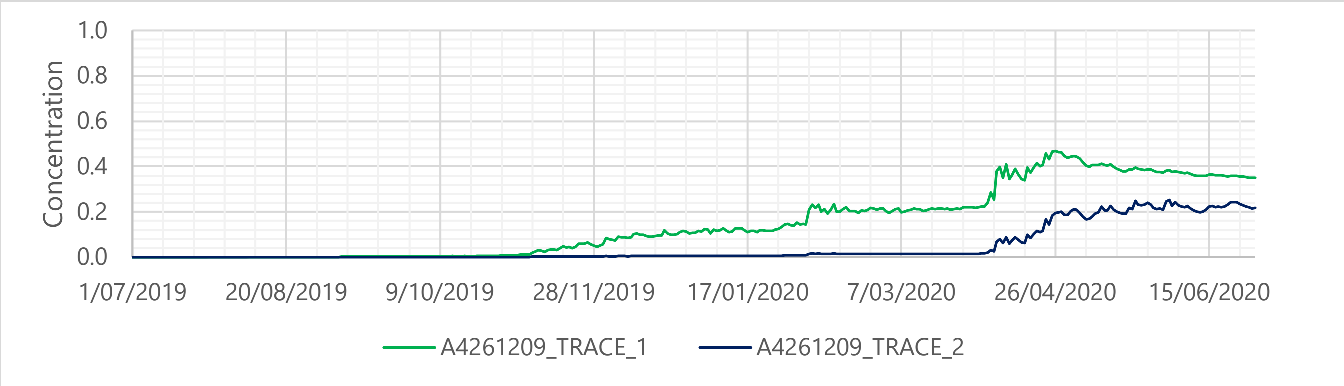


Figure 4.13. Tracer concentrations at monitoring sites in the CNL – Beacon 1 (A4261043), Pelican Point (A4261134), Long Point (A4261135) and Robs Point (A4260572)





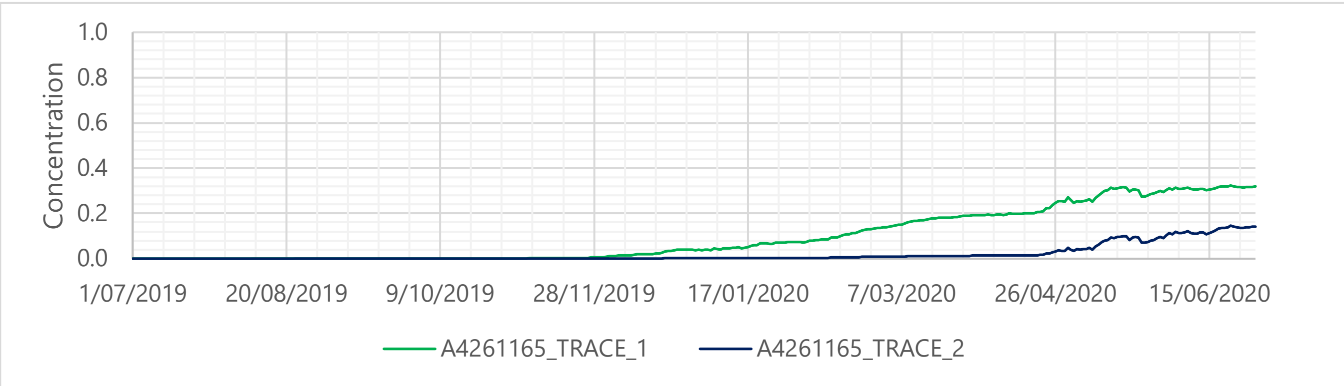


Figure 4.14. Tracer concentrations at monitoring sites in the CSL – Parnka Point (A4260633), Woods Well (A4261209) and Snipe Island (A4261165)

5 Updated bathymetry scenario run

Bathymetric surveys undertaken during March and April 2021 provided updated elevation data for sections of the Coorong either side of and through Parnka Point (A4260633). The bathymetric data collected by Maritime Constructions is shown in Figure 5.1 below and was comprised of:

- Elevation data along 235 transects totalling 135.6 km (blue lines)
- Elevation data along the length (18.6 km) of the deepest part of the main channel between The Needles and Hack Point (red line)

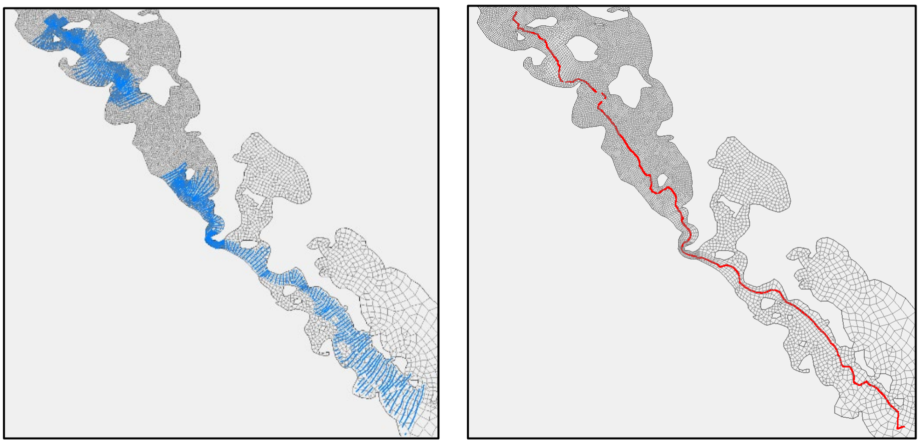


Figure 5.1. Elevation survey data collected around Parnka Point as shown on the TUFLOW-FV model mesh

The TUFLOW-FV fine resolution mesh used in the 2019-20 base case hindcast scenario modelling was updated with elevation data from these surveys using an interpolation method whereby every cell crossed by a survey adopts the z (depth) value from the survey. Where duplicate survey points existed, the z value was over-written by the subsequent survey, in the following order:

- Channel length survey (HCHB_CL_MGA94_AHD_0.75m)
- Transects (HCHB_LBS_MGA94_AHD then HCHB_SBES_MGA94_AHD_0.75m)

The original and updated elevation contours for the respective TUFLOW-FV fine resolution meshes are shown in Figure 5.2. The elevation changes to the mesh across all surveys ranged from -3.36 m to 1.69 m where negative values represent a relative increase (raising) in the bed level elevation, and positive values a relative decrease (lowering) in the bed level elevation. Overall, for the surveyed region there was a decrease in the bed level elevation or increase in depth/channel volume for the total surveyed area (yellow – red in image Figure 5.2c below). However, there was a relative increase in the bed level elevation or decrease in depth/channel volume for the surveyed area through Parnka Point and The Needles (blue in image Figure 5.2c below) and shown in detail in Figure 5.3 relative to the original mesh. This change may be due to more accurate bathymetry rather than a change in channel shape over time. However, the complex bathymetry captured in these surveys highlights the primary challenge to establishing a stable velocity-index relationship to derive discharge from the velocity, as discussed in Section 3.4.

The base case hindcast 2019-20 scenario was run again with no change to the model configuration aside from the updated mesh bathymetry, and the results are shown below for water level (Figure 5.4) and salinity (Figure 5.5). The change in modelled water level and salinity due to the updated bathymetry was negligible, which is not surprising given the relatively constrained extent of the bathymetric surveys relative to the spatial extent of the Coorong TUFLOW-FV fine resolution mesh. Nonetheless, this provides confidence in all prior 2019-20 scenarios run with the original bathymetry in this region of the Coorong.

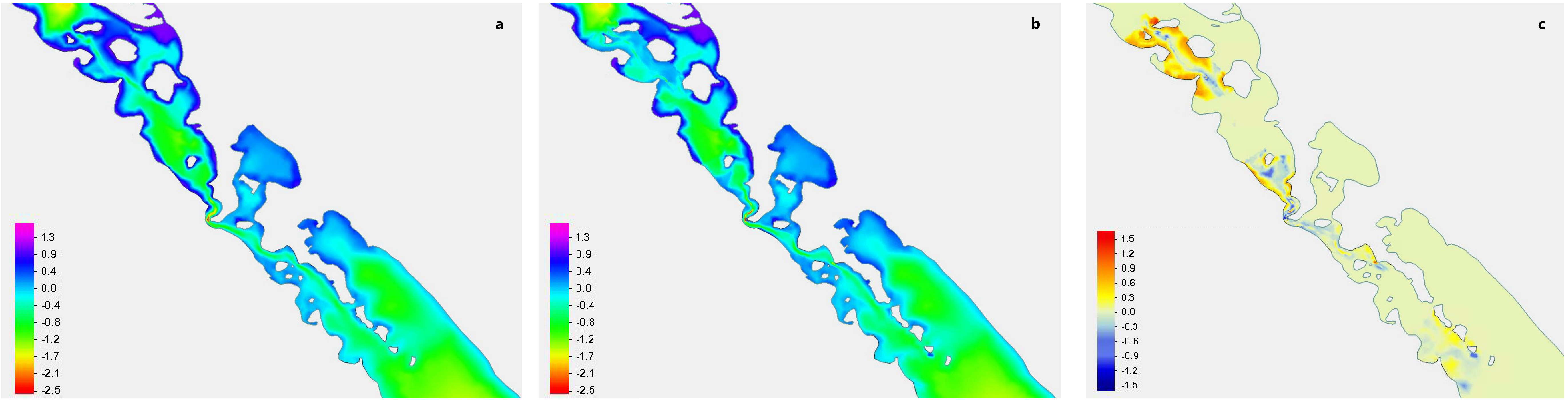


Figure 5.2. Section of TUFLOW-FV fine resolution mesh around Parnka Point (A4260633) showing elevation (z) range - (a) original, (b) updated, and (c) change in elevation following adoption of survey data

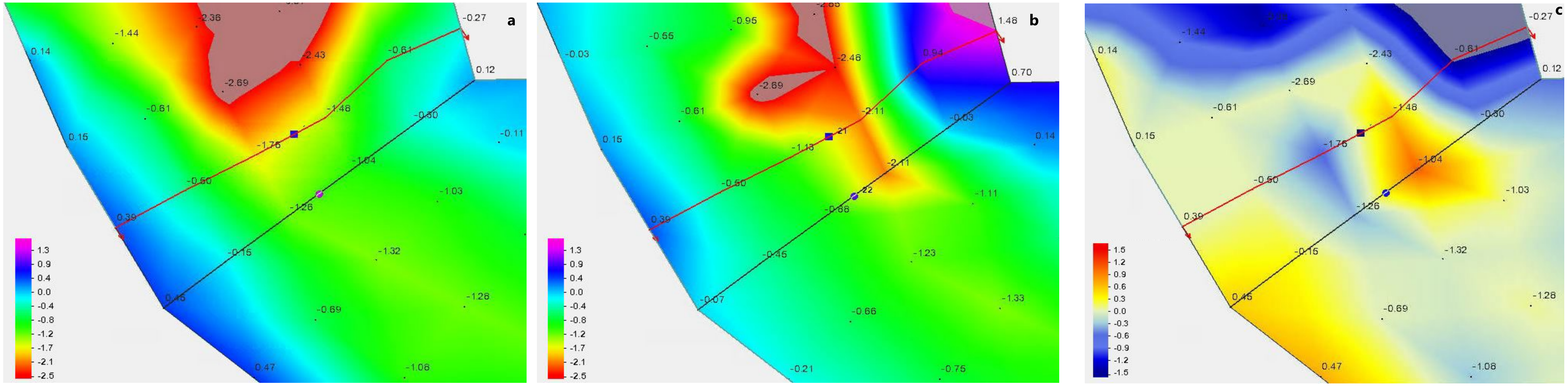


Figure 5.3. Section of TUFLOW-FV fine resolution mesh around Parnka Point (A4260633) showing elevation (z) range, nodestring (red) for results below, and node elevations (m) – (a) original, (b) updated, and (c) change in elevation following adoption of survey data

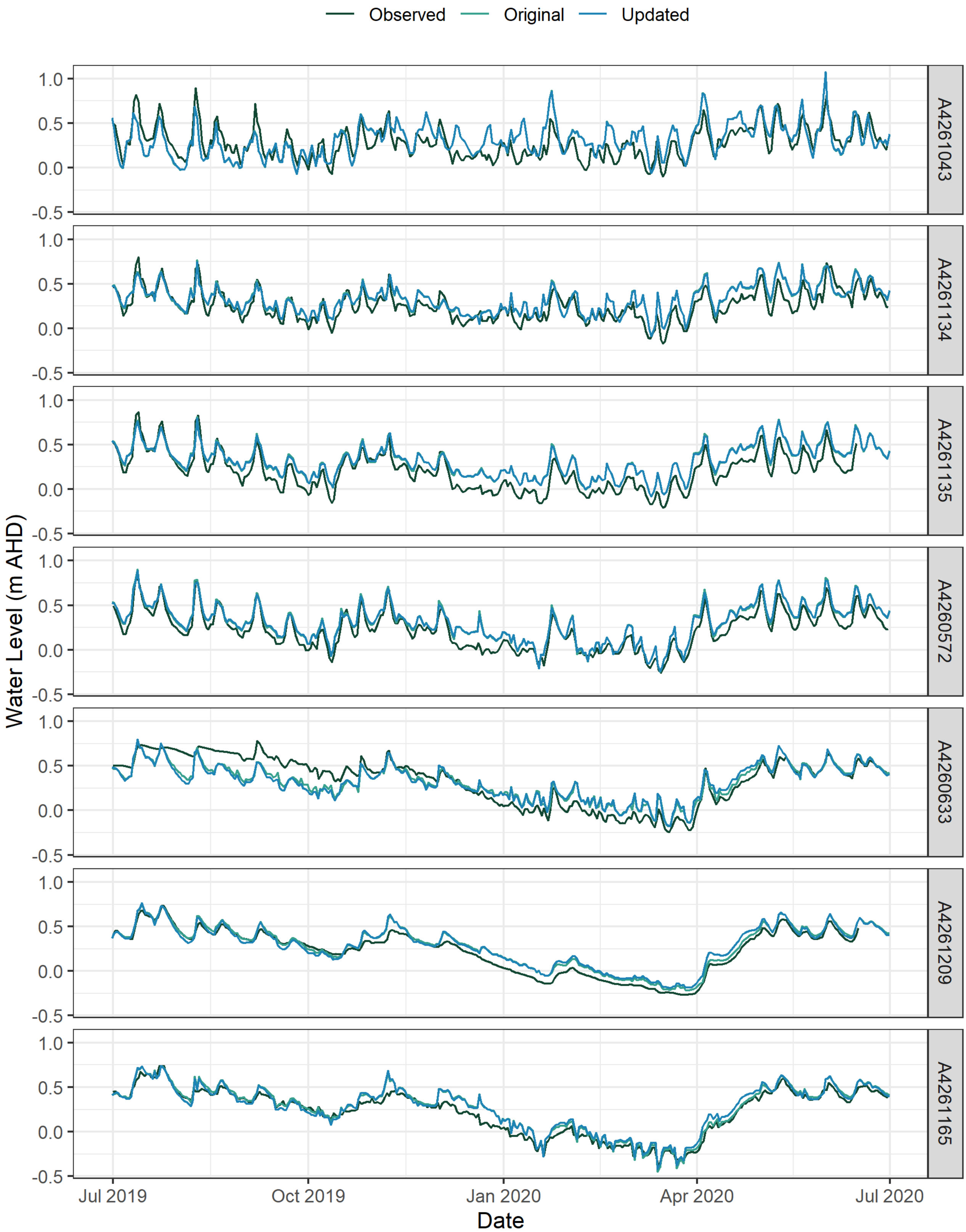


Figure 5.4. Comparison of observed and modelled (original and updated bathymetry) water level at monitoring sites in the Coorong – Beacon 1 (A4261043), Pelican Point (A4261134), Long Point (A4261135), Robs Point (A4260572), Parnka Point (A4260633), Woods Well (A4261209) and Snipe Island (A4261165)

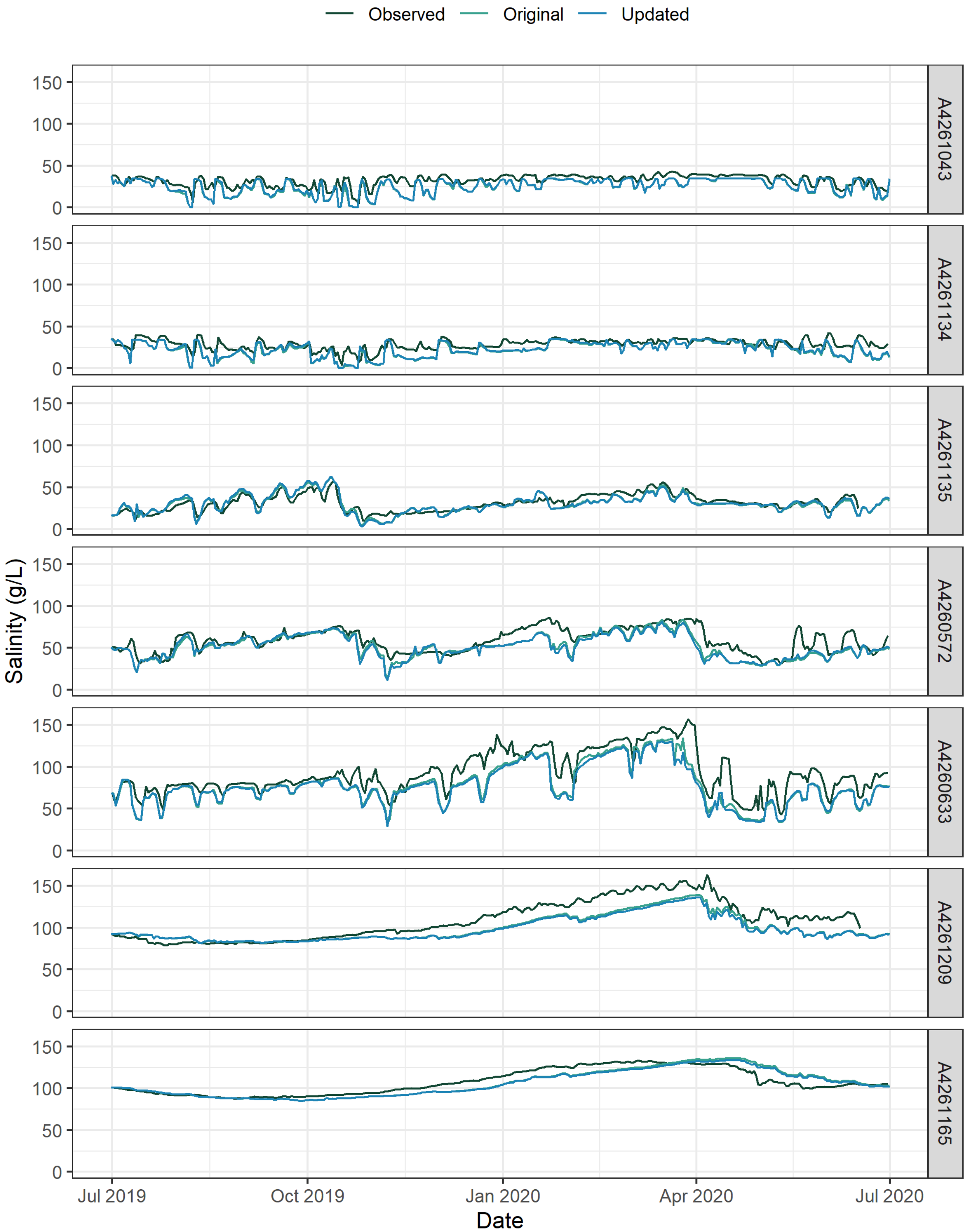


Figure 5.5. Comparison of observed and modelled (original and updated bathymetry) salinity at monitoring sites in the Coorong – Beacon 1 (A4261043), Pelican Point (A4261134), Long Point (A4261135), Robs Point (A4260572), Parnka Point (A4260633), Woods Well (A4261209) and Snipe Island (A4261165)

5.1 Flow volume and sources at Parnka Point

The flow and fluxes across the nodestring at Parnka Point (A4260633) were examined and compared to the original bathymetry model run, given the bathymetric changes implemented for the Coorong and channel through and either side of Parnka Point. As shown in Figure 5.3, the change in node elevations for the nodestring immediately upstream of Parnka Point is predominantly negative, meaning a relative increase/raising of the bed elevation level or a decrease in depth/channel volume across this channel section.

The influence of changes in bed elevation level in terms of flow magnitude show a comparative reduction in total flow across this nodestring for the simulation of 1.160 m^3/s on average, as shown in Figure 5.6. The majority of the flow difference is accounted for by the change in residual flux rather than barrage or ocean sources.

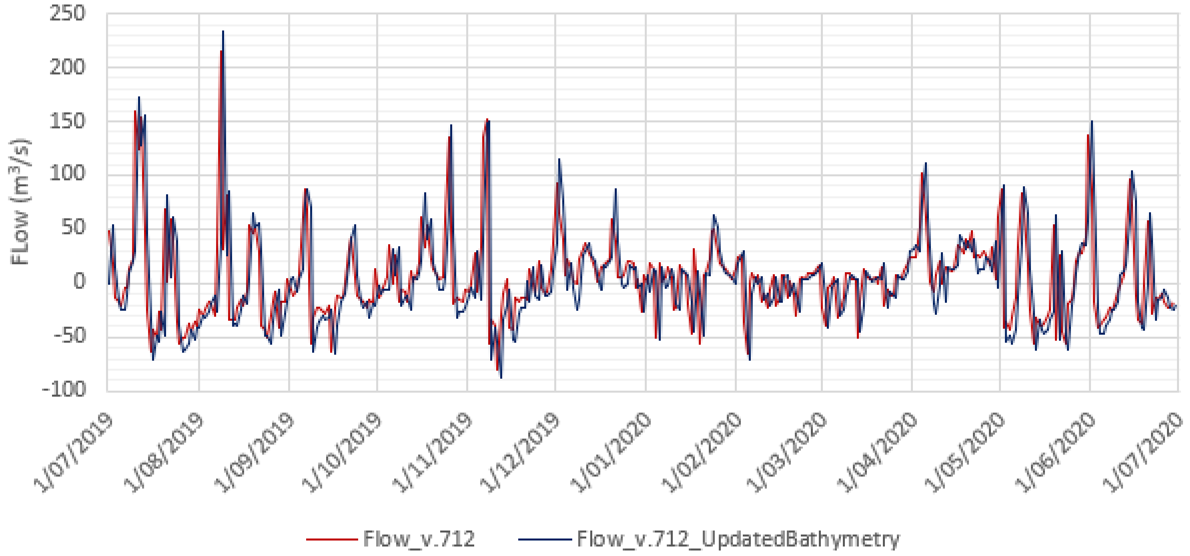


Figure 5.6. Comparison of flow across nodestring located at Parnka Point (A4260633) for original and updated bathymetry scenarios

As for the original 2019-20 model run, the total flow across a nodestring at Parnka Point was also accumulated at a daily time step, to present the typical flow directions over the year (Figure 5.7). For the first three months of the period the total flow was similar to the original bathymetry scenario run. The predominantly downward slope indicates flow direction typically out of the CSL as water levels recede from the highest levels over winter, with some short-term flow events back in the other direction. From November 2019 onwards, the flow is predominantly back into the CSL, aligning with an increase in levels in the CNL.

However, from November 2019 to June 2020, the cumulative flow through Parnka Point is, on average 33,351 ML/d less under the revised bathymetry scenario, which represents a 20% reduction of net flow into the CSL. This is a result of the relatively higher bed elevation level (Figure 5.3c), and therefore reduced channel cross sectional volume for the same water level (Figure 5.4).

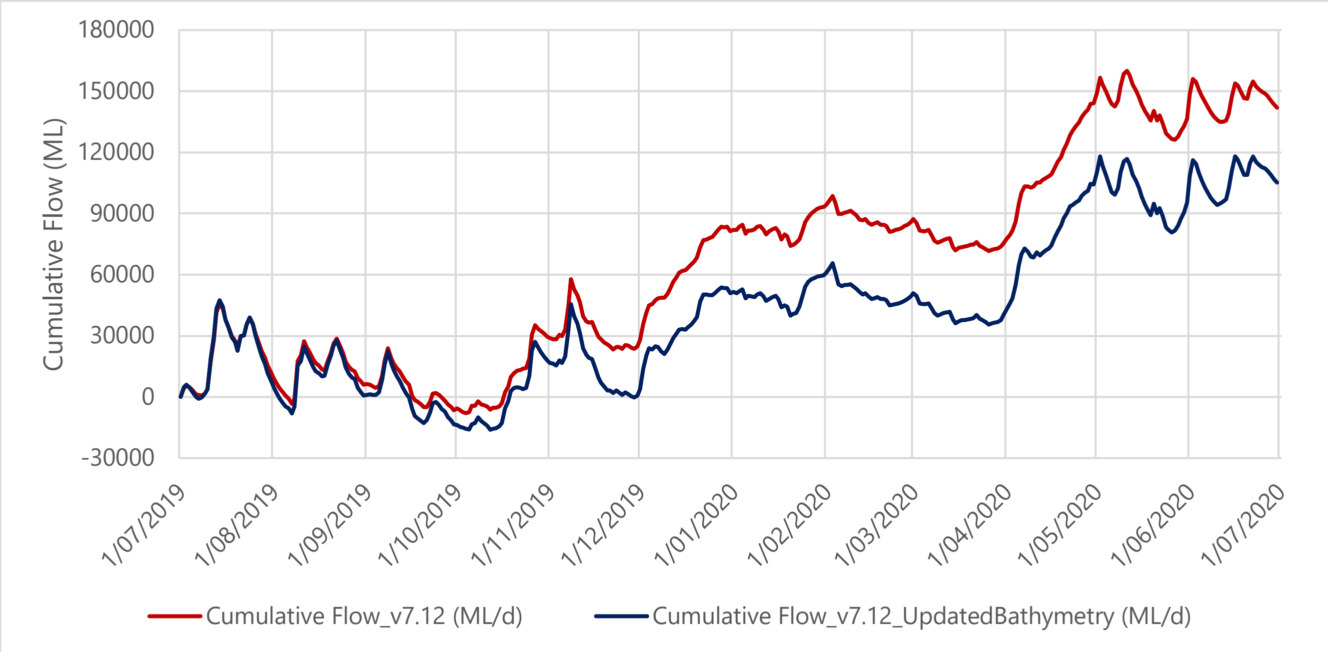


Figure 5.7. Comparison of cumulative total flow across Parnka Point (A4260633) under original and updated bathymetry scenarios

The residual component represents water initially in the model domain at the start of the simulation (1 July 2019) entering or exiting the CSL. The predominantly positive residual flow shown in the cumulative residual plot highlights the limited exchange or flushing of the CSL throughout the summer, which gradually declines as the two lagoons re-connect again in Autumn 2020 (Figure 5.8). As per the reduced cumulative total flow shown in Figure 5.7, the cumulative total residual flow is also less under the updated bathymetry scenario by 29,648 ML/d on average from November 2019 onwards, a result of the reduced cross-sectional area and exchange at Parnka Point. When compared with the reduction in cumulative total flow through this period (33,351 ML/d) under the revised bathymetry scenario, the significance of residual flow is evident.

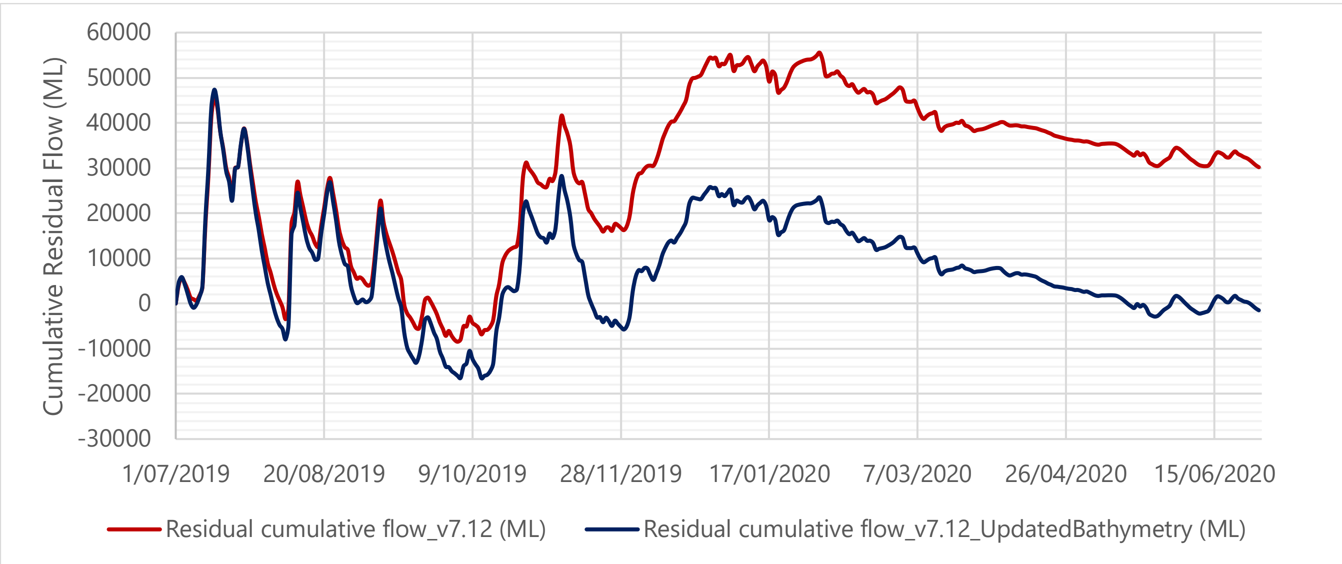


Figure 5.8. Comparison of cumulative residual flow across Parnka Point (A4260633) under original and updated bathymetry scenarios

Part B – Application of the Coorong Dynamics Model

6 The Coorong Dynamics Model

As described in Part A of this report, recent application of the original DEW Coorong TUFLOW-FV model has demonstrated its capability in accurately representing the hydrodynamics of the Coorong. The base case hindcast modelling undertaken for 2019-20 extended beyond the typical historical scenarios, which focused on informing Murray Mouth dredging operations, to include scenarios examining differential barrage releases, bathymetry updates, and modelled flow flux and water source analysis. The expanded range of hydrodynamic modelling outputs informed nutrient budget analysis and the development of initial operational scenarios under Phase 1 of HCHB, highlighting the value of the model in its current state. However, to fully realise the benefits of significant investment in novel research and extensive data collection under HCHB Phase 1, a component of the T&I Project was dedicated to the further development of the Coorong Dynamics Model (CDM). A summary of Coorong hydrological, biogeochemical and ecological models can be found in DEW (2020). Specific prior application of the Coorong TUFLOW-FV modelled coupled with AED2 is described in BMT (2017), Collier et al. (2017), Mosley et al. (2017) and Hipsey et al. (2017).

The CDM is a spatially resolved model to simulate the environmental conditions within the Coorong. It is comprised of a series of models that can be configured, coupled and applied in various ways to address a range of questions. The core of the CDM is the fine resolution Coorong TULOW-FV, and Aquatic EcoDynamics (AED) comprising a library of modules and algorithms for simulation of water quality, aquatic biogeochemistry, biotic habitat, and aquatic ecosystem dynamics. These models can be optionally linked with the Simulating WAves Nearshore (SWAN) wave model. Different levels of model complexity encompassing biogeochemical and ecological components can be applied by parameterising common input files for various scenarios. The CDM is a flexible tool, which can be adapted as required at varying spatial and temporal resolutions to conduct scenarios ranging from short-term operational to long-term restoration and climate change adaptation strategies (UWA, 2022).

Led by the University of Western Australia (UWA) in collaboration with the Department for Environment and Water and T&I researchers, a series of generational model updates significantly improved the CDM under HCHB Phase 1. The scope of this work extended to the improved model representation of external and internal nutrient loads, sediment loads, nutrient fluxes and recycling, and Ruppia habitat suitability (UWA, 2022), thereby enhancing the capability and functionality of the Coorong TUFLOW-FV and AED models, collectively referred to as the CDM. The extensive model calibration and validation means the CDM represents a sophisticated and powerful tool for quantitatively testing and refining the configuration and feasibility of potential infrastructure options and long-term restoration strategies, which will be developed under HCHB Phase 2. Part B of this report summarises these developments (Section 7) and the application (Section 8) of the CDM to scenarios designed to demonstrate the model improvements.

7 Summary of model improvements

7.1 Updates to model boundary conditions

In addition to significant improvements to model capability and functionality undertaken by UWA, which are summarised in Section 7.2, a comprehensive analysis of data sources for model boundary conditions (bc) was undertaken by DEW. A desire to generate a core set of continuous boundary condition data sets extending back to 1 January 1990, for use by each modelling application as required, necessitated a composite approach that utilised both modelled and observed data. Following validation by UWA and BMT, the key boundary condition data sets compiled by DEW and universally adopted by all HCHB Phase 1 modelling were:

- Barrage inflow
- Salt Creek inflow
- Tide

7.1.1 Barrage inflows

Inflows from each of the five River Murray barrages, which include Goolwa, Mundoo, Ewe Island, Boundary Creek and Tauwitchere, are a key boundary condition for the Coorong TUFLOW-FV model. Historically, barrage release time series have been either supplied from the 1D Coorong Hydrodynamic Model (CHM) – which in turn was informed by a water balance method, and later, an Excel macro-driven Barrage Calculator containing weir equations – or TUFLOW-FV derived Lower Lakes/Coorong water level differential calculation.

In 2021 DEW undertook a comprehensive review and calibration of the barrage dimensions and weir equations (DEW, 2021) prior to transitioning the Excel based Barrage Calculator into the Aquarius Time Series (AQTS) database underpinning Water Data SA. As part of this transition, all relevant water and tide level and barrage gate opening data sets were thoroughly validated from January 2011 onwards. The resulting hourly barrage release calculations now represent the point of truth, and the data sets assigned to synthetic barrage sites in Water Data SA (Table 7.1) have been universally adopted as the TUFLOW-FV boundary condition source from January 2011 onwards. Note that the data source preceding 2011 remains as the CHM due to data limitations. The final compiled barrages data set spanning 1 January 1990 to 1 January 2022 at the time of writing is stored in AquaticEcoDynamics/CDM model repository and can be downloaded from Water Data SA.

Table 7.1. Barrage sites in Water Data SA used in CDM boundary conditions (bc) file

Site	Name	Output used in TUFLOW-FV bc file
A4261005	Goolwa Barrage	Discharge.Total Barrage Flow Daily (ML)
A4260526	Mundoo Barrage	Discharge.Total Barrage Flow Daily (ML)
A4260571	Ewe Island Barrage	Discharge.Total Barrage Flow Daily (ML)
A4260570	Boundary Creek Barrage	Discharge.Total Barrage Flow Daily (ML)
A4261006	Tauwitchere Barrage	Discharge.Total Barrage Flow Daily (ML)

7.1.2 Salt Creek inflow

The Salt Creek outlet monitoring station (A2390568) commenced operation in August 2000, recording continuous water level (m) and Electrical Conductivity (EC) data. From this data, discharge (m^3/s) and Total Dissolved Solids (mg/L) are calculated, respectively. Additionally, flow gauging at higher flows undertaken in 2021 informed a rating curve revision, which was applied retrospectively to September 2017 when the current infrastructure configuration was implemented. For the period preceding the installation of the monitoring site, flow and salinity data were derived from modelled outputs. Outputs from a Source hydrological model of the South East drainage network provided a daily flow record at Salt Creek from 1 January 1990 until 10 August 2000. The corresponding salinity record was derived from a 1D CHM model input file, which in turn utilises data from historic monitoring stations (Webster, 2007).

7.1.3 Tide

Historically DEW has downloaded 5-minute tide encoder data (m) recorded at the Victor Harbor (VH) tide gauge (Bureau of Meteorology, 2010) from Flinders Ports[3] secure data network. Hourly values are generated from this data and then gaps patched with tide level data (m AHD) recorded at DEW's Barker Knoll continuous monitoring site (A4261039) (Figure 7.1) to create a complete data set. A datum correction and specific offset were then applied to:

- The VH data to convert it from m LAT to m AHD (- 0.579); and
- A 'Coorong offset' (+ 0.137) VH to Murray Mouth correction to all data, derived from previous Coorong tidal analysis undertaken by Webster (2012).

Due to the varying application of the two corrections over time, BMT undertook a comparison of all tidal data sources when seeking to calibrate a revised fine resolution TUFLOW-FV model for operational scenarios. Investigations undertaken by BMT confirmed that the water level recorded at Barker Knoll (A4261039) was, on average, 0.2 m higher than at VH due to flow through the Murray Mouth and the wave set up through the entrance. This difference confirms that a positive offset of the VH tide data is required to drive the CDM when the wave model is not enabled. However, a parallel process to improve the calibration of the TUFLOW-FV coarse model suggested that the 'Coorong offset' was not required for this model. The final tidal data set considered was provided by the Bureau of Meteorology (BoM) and is also based on the observations recorded at the VH tide gauge. The BoM post-processes the raw VH data by generating hourly values, and the tidal analysis software fills in gaps less than 24 hours in length using the predicted VH tide plus the standard deviation in the residuals for the gauge (residual = observed – predicted). A secondary process used the constituents from the analysis to address any remaining gaps, resulting in a complete tide data set from 1 January 1990 to 1 February 2022. The previously calculated datum must then be applied to convert these values (m) to m AHD at the Murray Mouth[4].

For application to the fine resolution TUFLOW-FV operational model, BMT adopted the VH tide measurements provided by the BoM. Gaps were filled using the VH tide predictions and residuals computed for Barker Knoll and Goolwa with a -4-hour offset, also provided by the BoM. A -0.579 offset was applied to both data sets to convert from m LAT to m AHD. UWA has previously adopted the Barker Knoll monitoring site (A4261039) data as the open boundary tidal boundary condition for the CDM with no datum correction or offsets applied. The intention is for future generations of the CDM to use the VH tide measurements provided by the BoM and gap-filled where necessary.

Figure 7.1. Tide sites used in TUFLOW-FV bc files. Source: GoogleEarth, 2022.

[3] Flinders Ports secure iQuest Data Network login: https://hydrotel.flindersports.com.au/

[4] Pers. Comm. M. Davis, BoM Tidal Service, January 2022. Data and explanation provided via email.

7.2 Updates to model processes and functionality

The updated capability and functionality of the CDM is described in detail by UWA[5] and can be divided into:

- Waves and resuspension
- Resolving metabolism and nutrient cycling
- Resolving sediment biogeochemistry
- Resolving macroalgae dynamics

These improvements are summarised here for the purposes of relating to the application of the CDM in Section 8.

7.2.1 Waves, resuspension and turbidity

The SWAN wave model was coupled to TUFLOW-FV to model sediment resuspension and the resultant impact on water quality. The wave model predicts the spatial pattern of significant wave height and wave periods, which TUFLOW-FV uses to model shear stress at the bed and the rate of sediment resuspension resulting from the combination of wave and current activity (Hipsey et al. 2022). Representing sediment resuspension in the Coorong is critical to predict turbidity of water and in turn the light conditions that influence the dynamics of primary producers (UWA, 2022). As described in UWA (2022b), the SWAN model was applied with a 200 m resolution Cartesian grid and a third-generation simulation mode with a domain extent consistent with the TUFLOW-FV model. The model was forced with Narrung weather station data – the same site used for the TUFLOW-FV meteorological boundary condition – and water depth data derived from the 2008 Coorong DEM (Figure 7.2). Wind data collected at specific field sites (Villa dei Yumpa and Policeman Point) was used for the limited periods it was available.

The resuspension of particulate organic matter is considered in the model by accounting for the maximum resuspension rate, the bottom shear stress generated by current and waves, the critical shear stress of each particle type, and a scaling factor controlling the resuspension rate. The sediment properties of particle size and organic matter fraction were assigned based on sediment survey data collected by the T&I Nutrient Dynamics component (Hipsey et al. 2022). The three suspended sediment types parameterised in the model and the corresponding particle sizes were: clay (< 3.8 microns), silt (>3.8, <186 microns) and sand (> 186 microns), with small particle sizes (<3.8 microns) dominant. A total of 31 sediment zones were created by delineating ten zones along the length of the Coorong, which were further divided into three sub-zones representing deeper water and the two shallower water zones on either side of the deeper water zone (Figure 7.5).

The SWAN wave model was calibrated for the period December 2020 to March 2021 to align with sediment resuspension field studies. This calibration produced reasonable outcomes in the time variation and magnitude of the response of significant wave height. The sediment resuspension processes were calibrated with the SWAN model coupled to the TUFLOW-FV and AED models. This represented the resuspension of particulate organic matter, which was then partitioned into carbon, nitrogen, and phosphorus resuspension rates for the water column. The sedimentation/deposition rate – a function of the estimate settling velocity for each particle size group – was included in the suspended sediment (SS) model. Finally, the feedback between SS, light, and surface heating – where the attenuation of shortwave radiation as it penetrates the water column dictates the intensity and influence of light on the dynamics of primary producers – was represented by dynamically coupling the TUFLOW-FV and AED models. Turbidity was calculated based on the concentration of particulates, and the resulting turbidity predictions generally replicated the variations in turbidity measured at in-situ continuous sites in the Coorong. Corresponding with the field studies, the relatively minor influence of waves on turbidity along the length of the Coorong was evident in the model. The surface water current and interaction with the dynamic

[5] The University of Western Australia has extensively documented the development of the CDM in online model repository documentation (The Coorong Dynamics Model) and in a series of progress reports. All documentation is listed in the references of this report.

ocean interface dominated the resuspension processes in the North Lagoon. Conversely, the effect of waves on the nutrient concentration was relatively small throughout the Coorong. This is supported by the relatively high diffusive nutrient flux findings under calm conditions in the sediment studies, indicating this has a stronger influence than wave induced resuspension events on sediment nutrient release (Hipsey et al. 2022).

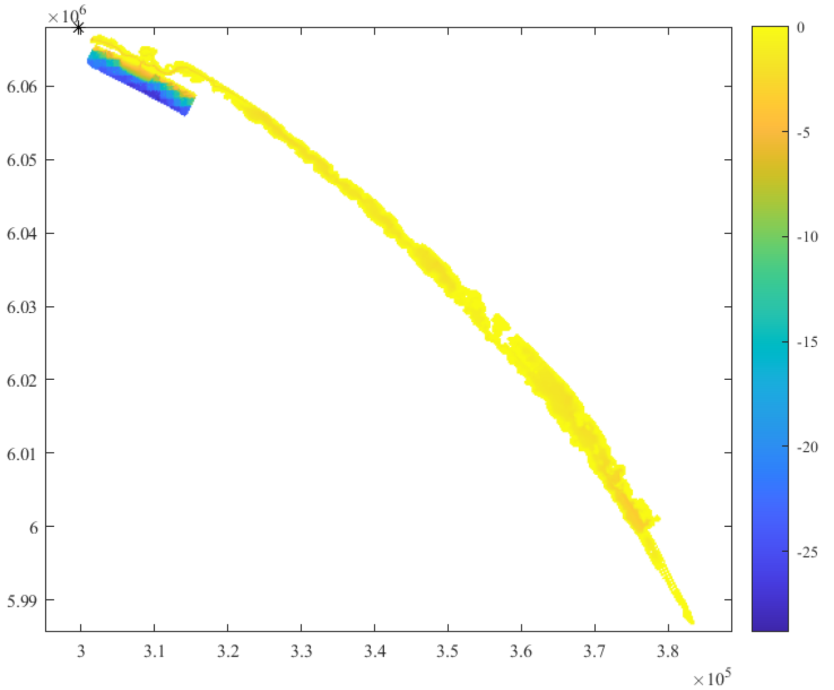


Figure 7.2. Coorong SWAN wave model bathymetry

7.2.2 Resolving metabolism and nutrient cycling – oxygen, nutrients and phytoplankton

Dissolved oxygen

The sediment oxygen demand in the South Lagoon is particularly high due to the nutrient enriched sediments, exacerbated by the high respiratory demands of both phytoplankton and filamentous macroalgae under dark conditions. For this reason, the AED oxygen model (described in 8.1.2) has been configured such that the base oxygen flux rate is specified for each sediment zone, and the sensitivity of sediment oxygen demand to temperature and oxygen concentration of the overlying water is represented. When compared to intensive monitoring at McGrath in the South Lagoon (Mosley et al., 2021), the model captures diel oxygen metabolism and saturation levels well (Hipsey et al. 2022).

Impact of hypersalinity on nitrification and denitrification

The hypersalinity of the Coorong has the potential to impair the nitrification-denitrification process, which acts to remove nitrogen in healthy wetland systems (UWA, 2022). Studies in the Coorong at Parnka Point observed a strong ammonium flux from the sediment and a high ammonium concentration at the sediment surface (Mosley et al., 2021). Based on the finding that the denitrification gene nirK had a strong inverse relationship with salinity in the Coorong (Mosley et al., 2020), a salinity limitation function was applied to nitrification and denitrification rates in the model (UWA, 2022).

Impact of salinity and temperature on phosphorus adsorption-desorption

Suspended particles absorb or desorb phosphate in the water depending on sediment phosphorus contents (Hipsey et al. 2022). Adsorption can vary in response to salinity and temperature. Field studies (Mosley, et al.,

2021) were used to inform the response curve of phosphate (PO_4) adsorption capability of suspended particles to a range of water temperature and salinity conditions implemented in the model (Hipsey et al. 2022).

Nutrient flux at the sediment-water interface (SWI)

Nutrient release from sediment to the water column can occur via nutrient diffusion due to a concentration gradient in calm conditions, or alternatively, due to hydrodynamic processes initiating sediment resuspension (Hipsey et al. 2022). As discussed previously in section 7.2.1, the latter has been found to be relatively minor in the Coorong, and therefore a static sediment flux approach has been adopted in the Generation (Gen) 1.5 CDM. Specifically, the sediment oxygen demand and nutrient flux rates were set based on the outcomes of the sediment field study at Parnka Point (Mosley et al., 2021) and then interpolated across the 31 sediment zones based on sediment particle size and organic matter content. It was assumed that oxygen demand and nutrient flux increased with the organic matter content. The model captures the nutrient gradient along the Coorong, and the very low concentrations of bio-available nutrient fractions within the total pool in both wet and dry periods (Hipsey et al. 2022).

Phytoplankton and Chlorophyll-a dynamics

As summarised by UWA (2022a), previous studies have identified that salinity is the most important driver of both the phytoplankton and microphytobenthos community distributions in the Coorong. The CDM simulates algal biomass (in units of carbon) via four functional groups, each distinct in terms of parameters adopted for environmental dependencies, including salinity tolerance, sedimentation rate, and light sensitivity. Salinity limitation curves are applied to the photosynthesis rate of each group, and the total water column chlorophyll-a is the sum of the four groups. To simulate the biomass of benthic microalgae (microphytobenthos) a single biomass pool is assumed located at the sediment-water interface (SWI), parameterised to respond to the phytoplankton deposited on the sediment, light, resuspension back into the water column, and burial in the deeper sediment. When compared against the chorophyll-a data from continuous Coorong monitoring sites, the CDM adequately represents the phytoplankton biomass and the long-term mean gradient in biomass along the Coorong. Additionally, the model represents the seasonal and high variability in cholorophyll-a throughout the Coorong.

7.2.3 Resolving sediment biogeochemistry

The switch of the Coorong ecosystem from one dominated by aquatic plants to one characterised by eutrophication due to nutrient enrichment has highlighted complex knowledge gaps to be addressed in site management. The representation of sediment condition and its role as a long-term source or sink of nutrients in the CDM has been refined from a simplified static representation to a dynamic, depth-resolved sediment diagenesis model. The extensive work undertaken to significantly upgrade the sediment biogeochemistry in the CDM is described in detail in UWA (2022a) and is summarised here.

The AED model has functions for coupling the bottom most cell of the TUFLOW-FV model to the top-most layer of the sediment layer and this dynamic coupling represents the flux of solid material onto the sediment surface, the concentration of dissolved substances in the bottom water, and the flux of dissolved substances from the top sediment layer. Using sediment survey data, the sediment model has been configured via zones to represent the spatial heterogeneity and sediment characteristics of the Coorong so that this functionality can be applied across the entire model domain. By defining sediment zones independently of the TUFLOW-FV model cells, the overlying water cells can be averaged for the underlying sediment zone and vice versa, which improves computational efficiency without compromising the ability to represent spatial heterogeneity in sediment properties and their fluxes. Figure 7.3 and Figure 7.4 show schematics of this dynamic sediment zone-hydrodynamic model configuration. The sediment model was initially calibrated independently using measured data from six of the 31 zones before being coupled to the water column model.

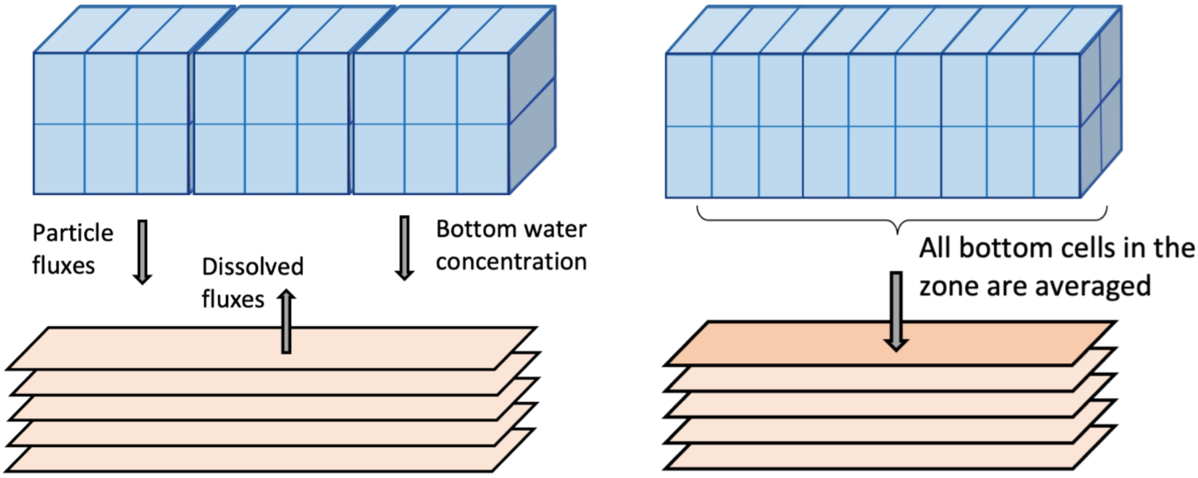


Figure 7.3. Schematic of sediment water coupling in the CDM

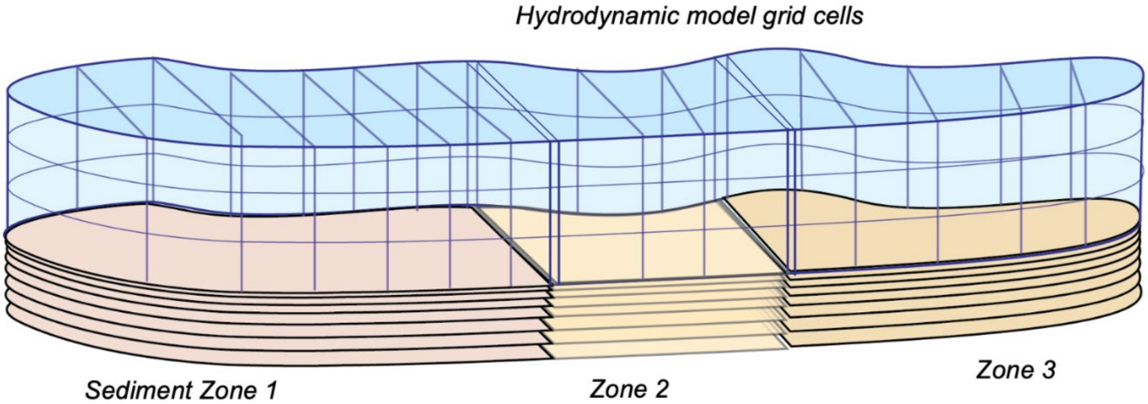


Figure 7.4. Schematic of CDM implementation of sediment zone-hydrodynamic model configuration

The Carbon and Nutrient Diagenesis Model of Boudreau (1996) (CANDI) has been coupled dynamically to the AED model to represent both the physical and chemical processes via 1D sediment profiles that are specified into layers increasing in thickness away from the SWI down to a defined sediment depth. Flux across the SWI was governed by three factors – advection, bioturbation, and bioirrigation – and variables were linked via concentration, dissolved flux, or particle flux to assign the upper sediment boundary condition. By coupling CANDI-AED, the mixing from the water column in the hydrodynamic model with the upper sediment layers captures sediment storage, release, removal of nutrients, and dynamic links with AED modules. Each sediment zone was configured to simulate 42 variables, some constant and others variable across zones, but with all zones resolving local sediment physical and chemical conditions to a depth of 80cm using 50 layers. The development undertaken to improve the representation of processes at the SWI, to account for benthic primary producers, and to account for the effect of hyper-salinity on various biogeochemical processes has significantly expanded the model functionality. The calibrated sediment biogeochemistry model has demonstrated it can resolve the nature of sediment condition throughout the Coorong in response to different sediment organic matter contents and organic matter deposition rates from phytoplankton and filamentous algae.

Figure 7.5. Coorong TUFLOW fine resolution mesh showing numbered material zones (green outline) and nodestring locations (red) used in Gen 1.5 CDM scenarios

7.2.4 Resolving macroalgae dynamics

The extensive and detrimental presence of filamentous algae (including *Ulva paradoxa*, *Cladophora* sp. and *Rhizoclonium* sp. (Lewis et al., 2022)) in the Coorong in recent years, often coinciding with the presence of the Ruppia community (defined in Lewis et al., 2022) has prompted a modelling effort to better simulate macroalgae processes and interactions in the Coorong South Lagoon. As described in UWA (2022a), prior to recent model developments, the AED model predicted inorganic and organic nutrients as well as chlorophyll-a. Building on extensive field surveys and data, the specific inclusion of a filamentous algae variable, FA, in the model allows for the representation of Ulva biomass growth and change over time in response to salinity, temperature, light, and phosphorus availability. The Ulva is assumed to attach to a benthic substrate, and is therefore not subject to advection and mixing, but can detach under high stress conditions and become a floating variable subject to transport. The development of a macroalgal 'clump' model to represent the seasonal cycle and associated changes in physiology has aligned the model with recent monitoring, distinguishing age and size into four discrete stages as shown in Figure 7.6. Further data analysis also improved the representation of environmental variable thresholds for light, temperature, and salinity. Four pools were configured to simulate the biomass of filamentous algae, and the total biomass is the total of attached and floating components. The presence of predicted compared with observed Ulva biomass, as captured in the Ulva Habitat Suitability Index (HSI) (Collier et al. 2017), was good for observed filamentous algae density, but less so for predicted biomass and presence. This suggests that the growth controls captured in the 'clump' model are suitable and the model can simulate the spatial extent of filamentous algal biomass accumulation. In general, the macroalgae model in AED captures the broad spatial patterns in environmental drivers that control biomass, with further work to constrain where algae can attach and grow recommended.

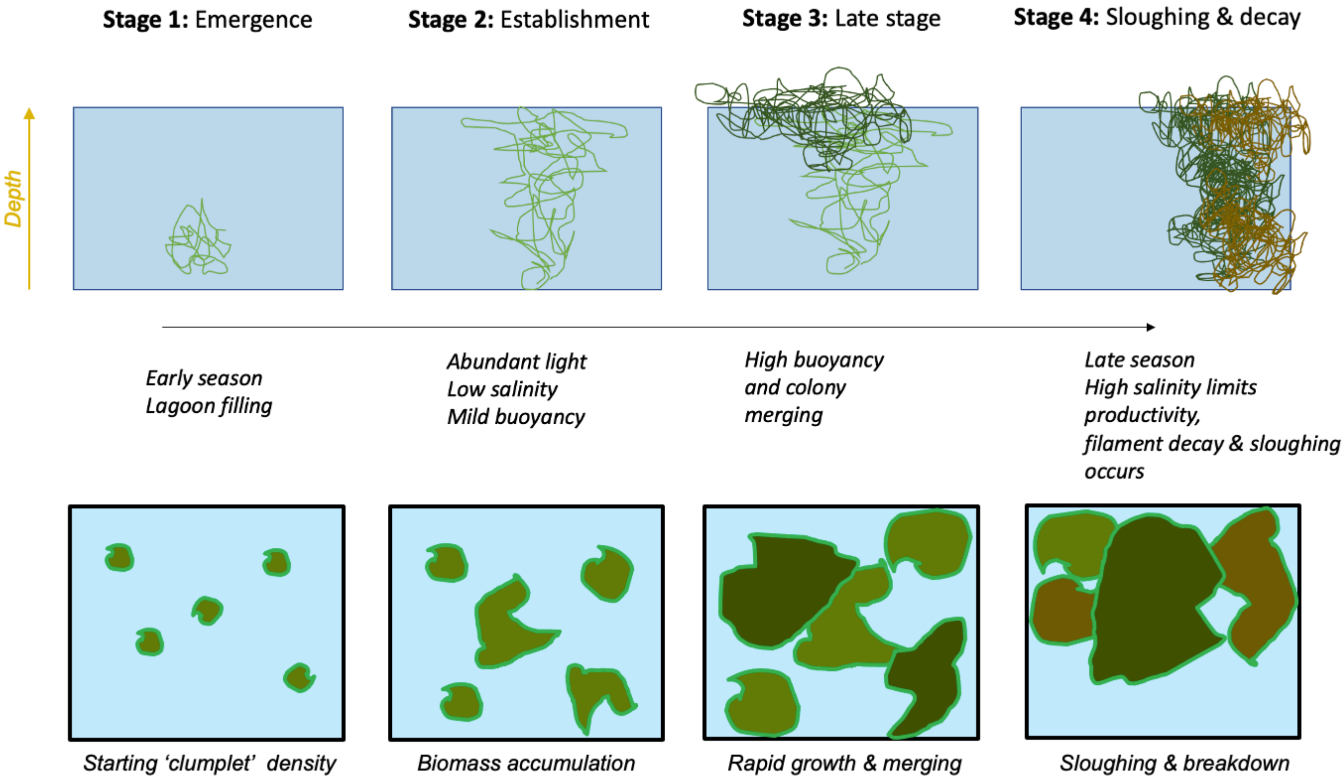


Figure 7.6. Schematic of new life-stage based macroalgal 'clump' model implemented in the CDM (Hipsey et al. 2022)

8 Application of the CDM

To note, the CDM referred to herein is the Generation 1.5 CDM described in Table 9.1 (hchb_Gen1.5_20220523_DEW). This version of the Generation 1.5 CDM was configured by DEW for the purpose of running the scenarios described in this section and preceded the next iteration of the Generation 1.5 CDM (Hchb_tfvaed_Gen1.5_4PFT_MAG), which included additional development by UWA relating to phytoplankton groups and macroalgae.

8.1 CDM set up and configuration

8.1.1 Base case model configuration

The fine resolution flexible two-dimensional mesh of the Coorong, extending from the Goolwa Barrage to the southern extent of the CSL, was derived in the SMS software from the 2008 Coorong DEM, the 2018 1m LiDAR/Sentinel DEM, and the 1999-2019 Murray Mouth surveys. The mesh defining the model domain is ~116 km in length, ~237 km^2 in area and is comprised of 26,250 elements and 21 nodestrings, which allow definition of boundary conditions and analysis of modelled outputs. Additionally, 31 material zones with a material roughness specified for each are defined for the full extent of the mesh (Figure 7.5).

A copy of the CDM TUFLOW-FV base case simulation control file is included in Appendix F, and key parameters are described below. The base case model is set to run from 1 July 2017 to 1 January 2022 and output netcdf files with:

- Key hydrodynamics outputs (water level, water depth, velocity, salinity, temperature, tracer concentrations, wind speed, evaporation, and air temperature).
- Key water quality and biogeochemical diagnostic and concentration outputs.

Simulation configuration settings:

- Both salinity and temperature were specified as modelled parameters, but the dynamic sediment module of TUFLOW-FV was not enabled in the base case model.
- Bottom drag model ==K_s. This specifies the bed boundary resistance (i.e. the bottom roughness values for cells with a material ID) and using a K_s bottom drag model assumes a log-law velocity profile, requiring specification of a roughness length-scale (TUFLOW, 2020). A global bottom roughness length-scale of 0.018 m was applied in the CDM (UWA, 2022).
- Water quality model == EXTERNAL. The external water quality model coupled to TUFLOW-FV (2020.02.034) is the AED (lib aed build 2.0) water quality and habitat model.

Model settings:

- Stability limits == 100, 500. Specifies the maximum water level and maximum velocity, which indicate an unstable model. The simulation will stop if these limits are exceeded (TUFLOW, 2020).
- Cell wet/dry limits == 0.04, 0.04 m. The dry value corresponds to a minimum depth below which the cell is dropped from computations. The wet value corresponds to a minimum depth below which cell momentum is set to zero to avoid unphysical velocities at very low depths (TUFLOW, 2020).

Heat parameters:

- Atmospheric heat calculations were enabled.

- Longwave Radiation Model == 3. This models incident longwave radiation (generated by air) assuming the Stefan-Boltzmann law with a correction for cloud cover following TVA (1972). The method includes water surface reflection of longwave radiation based on albedo. The water temperature is used to compute upwards (outgoing) longwave radiation.
- Shortwave radiation albedo == 0.5. Once computed, shortwave radiation is either reflected from the water surface via specification of the shortwave radiation albedo, or allowed to enter the water column (TUFLOW, 2020).
- Shortwave radiation fractions == 0.500, 0.463, 0.036, 0.001. Fractions of: near-infrared (NIR), photosynthetically active radiation (PAR), ultraviolet A (UVA) and ultraviolet B (UVB) in shortwave radiation, respectively (TUFLOW, 2020).
- Shortwave radiation extinction coefficients == 2.0, 1.2, 2.0, 2.5. Extinction coefficients of: near-infrared (NIR), photosynthetically active radiation (PAR), ultraviolet A (UVA) and ultraviolet B (UVB) in shortwave radiation, respectively (TUFLOW, 2020).
- Bulk Latent Heat Coefficient == 0.0013. Bulk aerodynamic latent heat transfer coefficient under neutral conditions (TUFLOW, 2020).

Turbulence parameters:

- Horizontal momentum mixing model == SMAGORINSKY. The Smagorinsky scheme was applied for the horizontal momentum mixing model (horizontal eddy viscosity calculation method), with a default Smagorinsky coefficient of 0.2 m (TUFLOW, 2020; UWA, 2022b).
- Horizontal scalar mixing model == ELDER. The horizontal non-isotropic scalar diffusivity is calculated according to the Elder model with Global Horizontal Scalar Diffusivity set to 250 m^2/s and a coefficient of 25 (TUFLOW, 2020; UWA, 2022b).
- Vertical mixing model == external. The General Ocean Turbulence Model (GOTM) is a one-dimensional water column model for studying hydrodynamic and biogeochemical processes in marine and limnic waters. The models within GOTM parameterise vertical turbulent fluxes of momentum, heat, and dissolved and particulate matter[6]. The GOTM external turbulence water column model is coupled with TUFLOW-FV with the model settings specified in the gotmurb.nml library. Note: the vertical mixing model only applies when a 3D model configuration is applied, which is not the case for the scenarios described here.

Tracer parameters:

- Passive tracers specified for the following water sources: initial CSL, ocean, barrages, Salt Creek, and water age.

[6] https://gotm.net/about/

8.1.2 Aquatic EcoDynamics (AED) - external water quality and habitat model

The external water quality model AED has been dynamically linked with TUFLOW-FV in the CDM, meaning that water quality and ecosystem properties are updated dynamically in response to changes in hydrodynamic conditions in the Coorong. The AED model simulates the mass balance and redistribution of carbon, nutrients, and sediment (including partitioning between organic and inorganic forms), and resolution of the relevant biotic components. This includes turbidity (particle resuspension and sediment redistribution), chlorophyll-a, and filamentous algae as well as the habitat quality of Ruppia (UWA, 2022). The AED model is comprised of a number of modules that can be connected following general AED configuration (aed.nml in Appendix G), which sets TUFLOW-FV specific settings including the minimum water depth and a range of linkages including physics, light, and initialisation of the benthic variables (AED_IC_OMfrac_MPB.csv and Routing_Tbl.csv). The AED modules enabled in the base case simulation, the AED manual description (Table 3.1 from Hispey, 2022), and base case configuration (aed.nml and Hipsey, 2022) of each are as follows:

NUTRIENT/CHEMISTRY modules:

- 'aed_sedflux'
    - *Description:* An interface module designed to provide spatially variable sediment flux settings to key modules (e.g., OXY, OGM, NUT), and/or link these variables to the dynamic sediment biogeochemistry model (SDG).
    - *Configuration:* Constant 2D, 31 zones to match TUFLOW-FV material zones, initial conditions (concentrations) set for all active zones for the following parameters: Dissolved Oxygen, reactive silica, Ammonium, Nitrogen, Filterable reactive phosphorus, Particulate organic nitrogen, Dissolved organic nitrogen, Particulate organic phosphorus, Dissolved organic phosphorus, Particulate Organic Carbon, Dissolved Organic Carbon, and Dissolved Inorganic Carbon.
- 'aed_macrophyte'
    - *Description:* Simulates benthic habitat and/or growth of macrophytes such as seagrasses in specified sediment zones.
    - *Configuration:* For 20 active zones, macroalgae parameters are defined in a specific library (aed_macrophyte_pars.nml) with a range of settings defined for various general, growth, light, respiration, salinity, Nitrogen, and Phosphorus parameters, for eight species of macrophytes.
- 'aed_noncohesive'
    - *Description:* Defines the properties of select suspended sediment groups and configures sediment resuspension and mass.
    - *Configuration:* For clay (< microns), silt (2-50 microns), and sand (50-2,000 microns) and linked to *Ruppia* variables in the macrophyte parameter library.
- 'aed_tracer'
    - *Description:* Modellers can use the aed_tracer to simulate a dissolved or particulate tracer (subject to transport processes only), or this can be optionally configured to account for decay, sedimentation and/or resuspension. This module also includes an option to simulate water “retention time” where the water age increments once it enters the waterbody.
    - *Configuration:* Retention time tracer enabled.
- 'aed_oxygen'
    - *Description:* Dissolved oxygen (DO) dynamics are simulated, accounting for atmospheric exchange and sediment oxygen demand, and through links to other modules will account for microbial use

during organic matter mineralisation and nitrification, photosynthetic oxygen production and respiratory oxygen consumption, and respiration by other optional biotic components.

- *Configuration:* Initial conditions (concentrations) specified for the following parameters: Oxygen (initial, minimum and maximum), sediment oxygen flux at 20°C, half saturation oxygen controlling oxygen flux, and Arrhenius temperature multiplier for sediment oxygen flux.

- 'aed_silica', 'aed_nitrogen', 'aed_phosphorus', and ‘aed_carbon’
  - *Description:* Modules exist for simulation of inorganic nutrients including phosphorus, nitrogen, carbon, and silica. These modules provide basic nutrient cycling functionality and are designed to be linked with other modules (eg OGM, PHY) in order to provide a more comprehensive depiction of nutrient cycling.
  - *Configuration:* The **carbon module** can be used to simulate both the organic and inorganic pools of carbon and the core variables specified are for Dissolved Inorganic Carbon (DIC), pH, and methane (CH_4). For the **silica module**, an initial concentration is specified followed by sediment flux parameters (reference sediment reactive silica flux at 20°C, half-saturation oxygen concentration controlling silica flux, and Arrhenius temperature multiplier for sediment silica flux). In the **Nitrogen module** configuration, Nitrate (NO_3) and Ammonium (NH_4) are modified by nitrification, denitrification, sediment release, and atmospheric deposition following the specification of initial values for Ammonium, Nitrogen and Nitrous Oxide concentrations. The **Phosphorus module** captures the dissolved phosphate concentration (PO_4) and sorbed phosphate (PO^{ads}_4) and supports processes relating to inorganic phosphorus dynamics.
- 'aed_organic_matter'
  - *Description:* Organic matter variables cover the C, N and P stored in the dissolved and particulate organic matter pools. This module optionally also supports depiction of “labile” vs “refractory” fractions of organic matter, including the breakdown and hydrolysis process, photo-degradation and mineralisation.
  - *Configuration:* Initial concentrations are specified for a set of organic matter variables (Particulate, Dissolved and Refractory Organic Carbon, Particulate, Dissolved and Refractory Organic Nitrogen, Particulate, Dissolved and Refractory Organic Phosphorus, and Coarse particulate organic matter. Parameters were then set relating to breakdown and mineralisation, definitrification, refractory organic matter, light, particle settling, sediment interaction, and flocculation.

BIOLOGY modules:

- 'aed_phytoplankton'
  - *Description:* Highly customisable phytoplankton module for simulating change in algae, cyano-bacteria and chl-a, including phytoplankton production/respiration, nutrient uptake, excretion, vertical movement (eg buoyancy control), and grazing effects. Benthic phytoplankton may also be optionally configured.
  - *Configuration:* Both module level and group-specific parameters are set. Four phytoplankton functional groups are defined (Green, Cryptophytes, Diatom, and Dinoflagellates) relative to their salinity tolerances and the settling method assigned to each. The following variables are set for the benthic phytoplankton group (microphytobenthos, MPB): maximum growth rate, dark respiration rate, constant for light limitation of growth, maximum biomass density, amount of resuspension, zones where MPB active (20). The variables to link to other modules that influence phytoplankton sources and sinks are then specified along with the phytoplankton parameters (aed_phyto_pars_noCom.csv).

- 'aed_macroalgae2'
  - *Description:* Simulates benthic macroalgal growth and sloughing/detachment of macroalgae and its subsequent redistribution within the domain.
  - *Configuration:* For 20 active zones, macroalgae parameters are defined in a specific library (aed_malgae_pars.nml) with a range of settings defined for various general, growth, light, respiration, salinity, Nitrogen, Phosphorus, and Silica parameters, for three types of macroalgae.

SUMMARY modules:

- 'aed_habitat_benthic'
  - *Description:* The high-level Habitat Quality module returns habitat quality metrics based on underlying water condition attributes. The Benthic Habitat component simulates spatially variable benthic habitat and/or growth of macrophytes such as seagrasses in specified sediment zones.
  - *Configuration:* The Ruppia Habitat (HSI) model has been initialised and is linked to the material zones and the ulva (filamentous algae) variables.
- 'aed_totals'
  - *Description:* A summary module, allowing users to "sum-up" component variables from other modules into a total, for example, to compute Total Nitrogen (TN), Total Phosphorus (TP) or Total Suspended Solids (TSS).
  - *Configuration:* Totals have been specified for the following variables: TN, TP, Total Organic Carbon, TSS, and Turbidity.

SEDIMENT model[7]

- 'aed_sed_candi'
  - *Description:* The Carbon and Nutrient Diagenesis Model of Boudreau (1996) (CANDI) has been coupled to the AED model to represent both the physical and chemical processes via 1D sediment profiles that are specified into layers increasing in thickness away from the sediment-water interface (SWI) down to a defined sediment depth.
  - *Configuration:* Dynamic sediment model with eight active zones and a sediment type specified for each. CANDI and geochemistry parameters as well as sediment diagenesis variables defined in external files. Boundary and initial conditions and diagnostic variable outputs (Dissolved Oxygen, Ammonium, and pmol).

A full list of AED simulated model variables is shown in UWA, 2022 (Table 1).

8.1.3 Sediment

The Coorong lagoon is divided into 10 sediment zones along its length, each divided into three material sub-zones to represent the spatial variability in sediment and benthic related variables (Hipsey et al. 2022). One sediment model is run for each of the zones, which are parameterised in terms of sediment quality, porosity, salinity, sulfur, nutrients, oxygen, organic matter, macroinvertebrates, iron and manganese, pH and alkalinity, and the deposition rate (UWA, 2022). The material zones, which each have material roughness specified, are shown in Figure 7.5. The sediment model has not been enabled in the CDM base case or scenarios.

[7] Not enabled in the CDM. The 'aed_sed_candi' configuration in the aed.nml as described above is representative of an earlier phase of model development and the final configuration is represented in the Gen2 CDM, reported by Hipsey et al. 2022)

8.1.4 Boundary conditions

8.1.4.1 Wave model

The generation and configuration of the Simulating WAves Nearshore (SWAN) wave model is described previously in Section 7.2.1. Typically, a separate model run generates the relevant WAVE.nc file, which is referenced in the TUFLOW-FV control file. The SWAN file size is significant (~120 GB), and the inclusion of waves has been found to have a minimal effect on nutrient and phytoplankton predictions. For these reasons, the wave model has not been activated in the CDM scenario runs presented below. A solution will be developed to facilitate wave file transfers and the inclusion of the influence of waves on model runs.

8.1.4.2 Meteorology

The Landscape South Australia Murraylands and Riverland Narrung meteorological site[8] was used as the primary source of meteorological data, supplemented by eight DEW sites that collect continuous meteorological data to address any data gaps in the Narrung site record (Figure 8.7). Hourly data were downloaded from all sites for wind speed and direction, air pressure, air temperature, relative humidity, and solar radiation (Table 8.1).

Table 8.1. Sites used to generate CDM meteorological bc file

Site No.	Site Name	Variables
2778	Narrung	Air temperature, relative humidity, solar radiation, cloud cover, rainfall, wind speed and direction
A4260633	Coorong at Parnka Point	Air pressure, air temperature, relative humidity, solar radiation, wind speed and direction
A4261123	Coorong Channel at Signal Point (Beacon 23)	Wind speed and direction
A4261124	Goolwa Channel 2km West Clayton	
A4261133	Lake Alexandrina at Beacon 97 (offshore Raukkan)	
A4261153	Lake Albert near causeway at Waltowa Swamp	
A4261155	Lake Albert 2km North Warringee Point	
A4261158	Lake Alexandrina 4km West Pomanda Point	
A4261159	River Murray 2km downstream Wellington Ferry	

The meteorological bc file contains hourly data for the following parameters between 1 February 2016 and 1 January 2022. Each time series is referenced in the met.fvc file with any scaling factors applied shown in brackets:

- Wind speed (1.1)
- Wind direction (1.1)
- Air temperature
- Relative humidity
- Solar radiation (0.8)
- Net longwave radiation
- Cloud cover (1.1)
- Precipitation

As described previously in Section 8.1.1 (Heat parameters), the net downward long wave radiation input was calculated using the longwave radiation heat transfer model based on cloud cover. The water temperature is used

[8] https://www.awsnetwork.com.au/station/2778

to compute upwards (outgoing) longwave radiation. The wind stress was calculated using the Wu (1982) wind stress model.

The effect of high salinity in the CSL on evaporation is accounted for via the Vapour Pressure Salinity Parameters included in TUFLOW-FV, described in BMT (2021a) and informed by Webster (2012). The latter describes the derivation of an evaporation factor, dependent on salinity, which accounts for the impact on the saturated vapour pressure at the water surface due to salinity-induced higher water temperatures. As described in Webster (2012), the Dalton relationship represents the evaporation rate as a function of wind speed, vapour pressure in the air, and saturated vapour pressure at the water surface temperature. Salinity affects evaporation by suppressing saturated vapour pressure at the water surface. By reducing the evaporation rate, hyper-salinity increases the water temperature, which in turn enhances the surface vapour pressure. This feedback mechanism determines the impact of salinity on the evaporation rate, and it is this factor which is accounted for in the Vapour Pressure Salinity Parameters. In practice, the implementation of the updated function in TUFLOW-FV reduces the evaporation rate and therefore modelled salinity in the CSL, producing an improved prediction compared to observed data (Hipsey et al. 2022). In addition to this TUFLOW-FV software development, BMT also added a water age tracer to assist in tracking water retention times and CSL flushing metrics, and an evapo-concentrate flag setting to disable the default concentration of the water age tracer with evaporation. This can also be applied to tracers representing pH (BMT, 2021a).

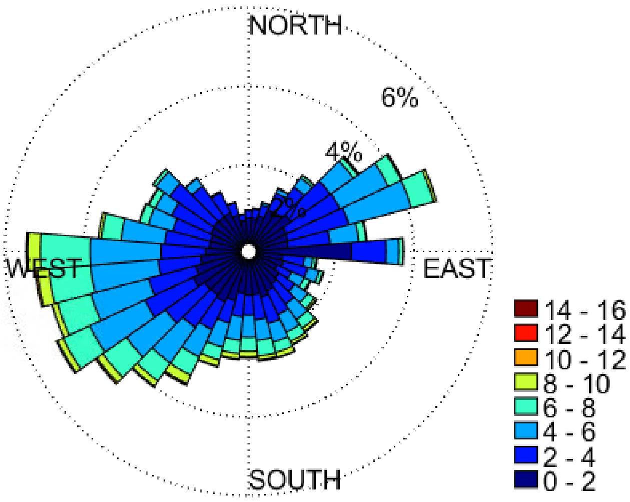


Figure 8.1. Wind speed and direction bc data applied in all CDM scenarios

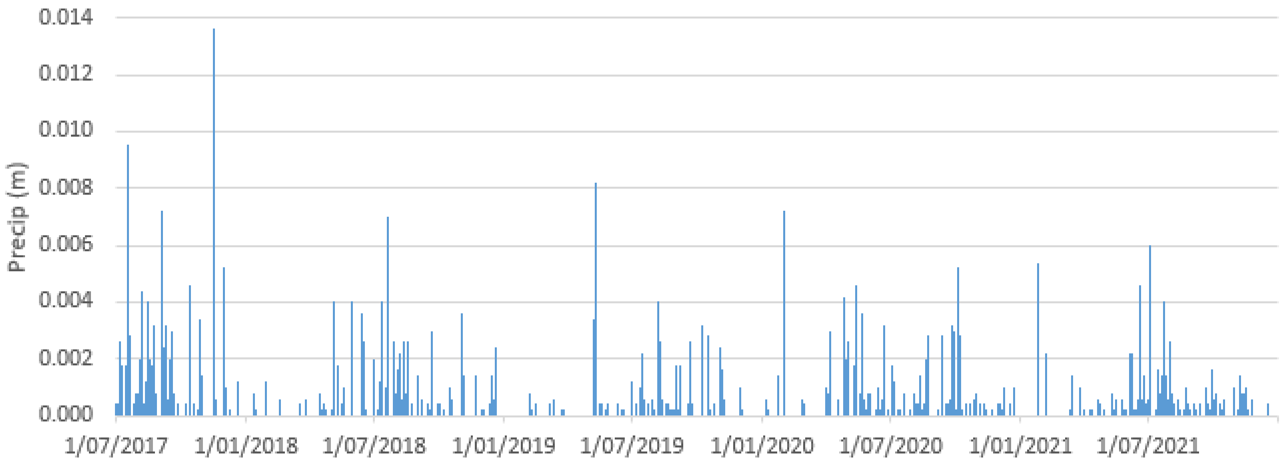


Figure 8.2. Precipitation bc data applied in all CDM scenarios

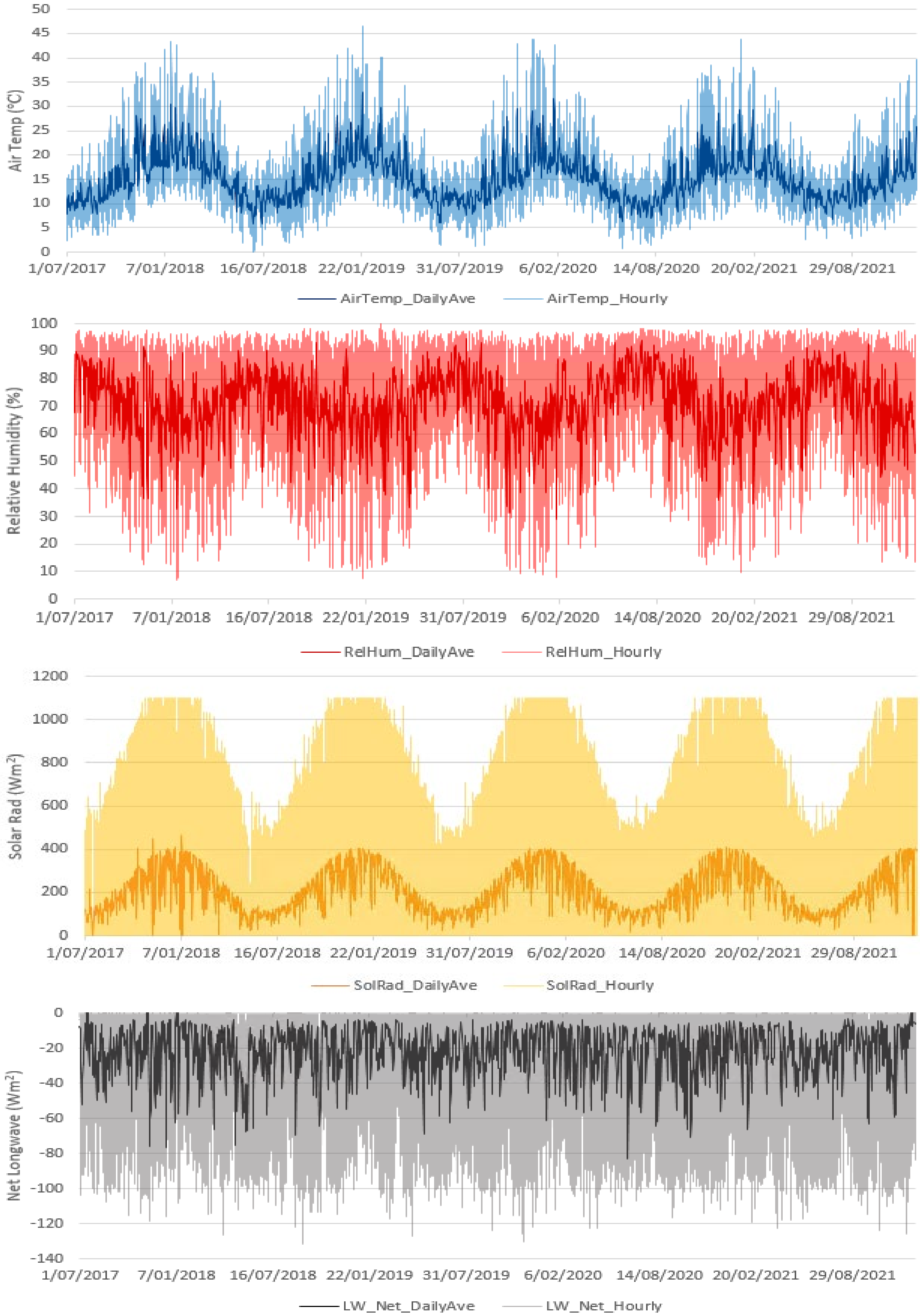


Figure 8.3. Meteorological bc data: air temperature, solar radiation, relative humidity, and net longwave radiation used in all CDM scenarios

8.1.4.3 Flows

Three flow boundaries are defined for the TUFLOW-FV model: tide (water level), barrages (nodestring flow), and Salt Creek (cell inflow).

Tide

As noted previously, the DEW site at Barker Knoll (A4261039) was used to derive a water level (m AHD) time series for tide at a 30-minute time step with no corrections applied (Figure 8.4). Salinity (Total Dissolved Solids (TDS) from EC, g/L, refer to Appendix D) and water temperature (°C) were also downloaded for this site at the same time step. This tide file is then referenced in the flows_basecase.fvc file.

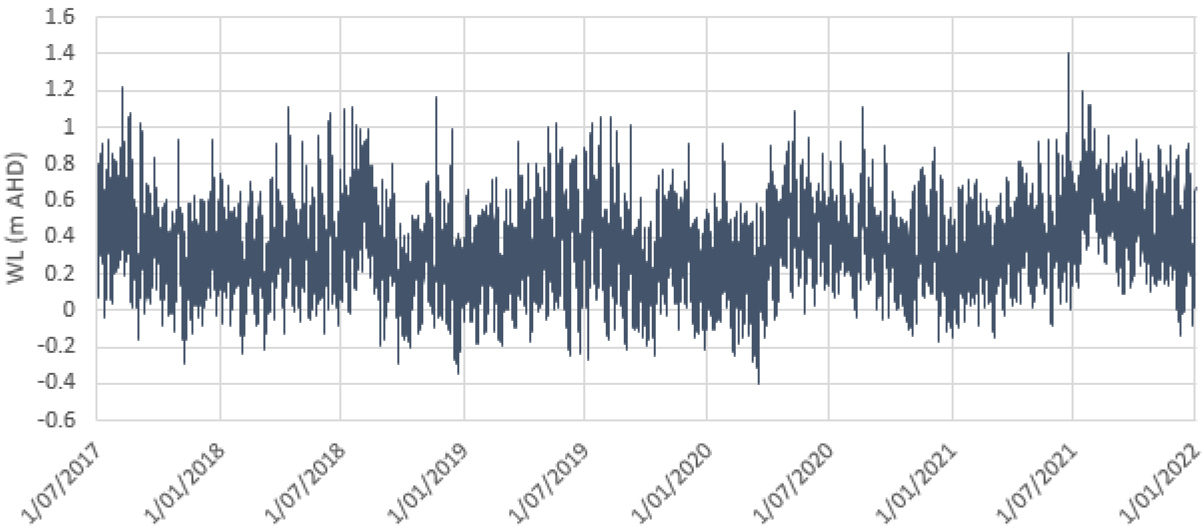


Figure 8.4. Barker Knoll water level data used in CDM tide bc file

Salt Creek

The final flow boundary condition is for the Salt Creek outlet, which is located at the southern end of the CSL. A cell inflow is specified in the flows.fvc file as the X,Y co-ordinates of the DEW site at the Salt Creek outlet (A2390568) and flow data (m^3/s) (Figure 8.5), salinity (TDS from EC, g/L, refer to Appendix D), and water temperature (°C) were downloaded at a daily time step.

Figure 8.5. Salt Creek outlet (A2390568) flow data used in CDM Salt Creek bc file

Barrages

Each of the five barrages are configured as separate nodestrings in the TUFLOW-FV model and the data for each was downloaded from the DEW barrage sites on Water Data SA, as described in Section 7.1.1. Daily total barrage releases (m^3/s) for each barrage are compiled in separate time series files (Figure 8.6), which are then referenced in the flows_basecase.fvc file.

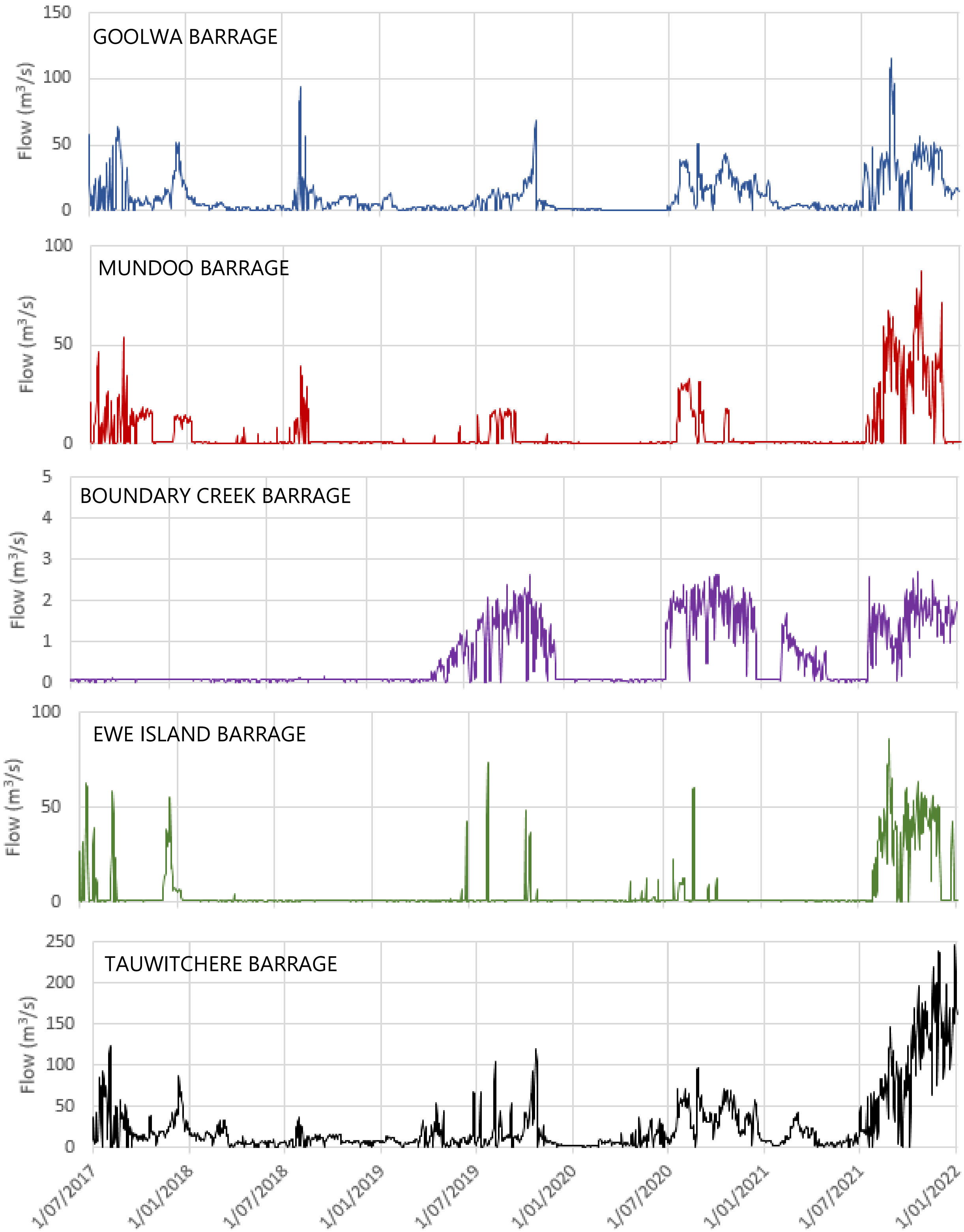


Figure 8.6. Barrage flow data used in CDM barrages bc files

For each of the flow boundaries, the model requires specification of inflow nutrient and salt concentrations, to resolve the external loading into the domain. The variables that must be specified in each inflow boundary condition file are summarised in Table 8.2. Consistent scaling factors are applied to each variable for the barrage flow, and unique ones are applied to each variable for the tide and Salt Creek flow. While observed salinity and water temperature data were available for all flow boundary conditions, the nutrient concentrations were derived from monitoring data and previous modelling.

Table 8.2. Summary of parameters specified at flow boundaries and bc scale

Variable code	Variable name	Units
H	Water Level	m
Q	Flow	m^3/s
Sal	Salinity	PSU
Temp	Temperature	°C
Trace_1	Initial CSL passive tracer	-
Trace_2	Ocean water passive tracer	-
Trace_3	Barrage flow passive tracer	-
Trace_4	Salt Creek passive tracer	-
Trace_5	Water age passive tracer	seconds
SSI	Suspended Sediment (clay, silt, sand)	mg/L
RET	Retention	-
OXY	Dissolved Oxygen	$mmol/m^3$
RSI	Reactive Silica	$mmol/m^3$
AMM	Ammonium	$mmol/m^3$
NIT	Nitrogen	$mmol/m^3$
FRP	Filterable Reactive Phosphorus	$mmol/m^3$
FRP_ADS	Filterable Reactive Phosphorus Sorbed	$mmol/m^3$
DOC	Dissolved Organic Carbon	$mmol/m^3$
POC	Particulate Organic Carbon	$mmol/m^3$
DON	Dissolved Organic Nitrogen	$mmol/m^3$
PON	Particulate Organic Nitrogen	$mmol/m^3$
DOP	Dissolved Organic Phosphorus	$mmol/m^3$
POP	Particulate Organic Phosphorus	$mmol/m^3$
GRN	Phytoplankton (4 functional groups)	$mmol/m^3$
MAG_ULVA	Macroalgae (Ulva - floating)	$mmol/m^3$
IN	Inorganic Nitrogen	$mmol/m^3$
IP	Inorganic Phosphorus	$mmol/m^3$
TOT_TN	Total Nitrogen	$mmol/m^3$
TOT_TP	Total Phosphorus	$mmol/m^3$
TOT_TOC	Total Organic Carbon	$mmol/m^3$

8.1.5 Initial conditions

Initial conditions at 1 July 2017 are specified for each of the 2D mesh elements for water level, wind speed and direction, salinity, air temperature, tracer concentrations, and 20 water quality parameters. Initial conditions were set based on the available observed data nearest to the simulation start date and in the case of missing data, monthly average values derived from historical observations were applied.

8.2 Final CDM base case model and scenario configuration files

Table 8.3 summarises the final model and base case scenario configuration files used in the CDM scenario modelling, and Table 8.4 specifies the base case scenario boundary condition files.

Table 8.3. CDM TUFLOW-FV core model and scenario configuration files

File type	File name
Control	hchb_Gen15_201707_202201.fvc (base case)
Geometry	CoorongBGC_mesh_000.2dm
Nodestrings	2d_ns_CoorongBGC_000_L.shp
Material zones	31_material_zones.shp & Material_Roughness_z31.fvc
Initial conditions	init_conditions_20170701_GEN15_DON3.csv
Outputs	Output_basecase.fvc

Table 8.4. CDM TUFLOW-FV core boundary condition files

Boundary condition	File name
Flows Flows_basecase.fvc	Tide: BK_20120101_20220101.csv Barrages: Boundary_20120101_20220101_v6.csv Ewe_20120101_20220101_v6.csv Goolwa_20120101_20220101_v6.csv Mundoo_20120101_20220101_v6.csv Tauwitchere_20120101_20220101_v6.csv Salt Creek: Salt_Creek_20120101_20220101.csv
Meteorology met.fvc	Narrung_met_20160201_20220101.csv Narrung_rain_20160201_20220101.csv

Figure 8.7. CDM Coorong TUFLOW-FV mesh and boundary condition sites

8.3 Scenarios run and description of boundary conditions

An initial set of scenarios were run with the CDM as described in Table 8.5. All core model and scenario configuration files were as described in Table 8.3 with scenario-specific updates to flow bc files as described in Table 8.5.

Table 8.5. CDM model scenarios

No.	Name	Description/Purpose	Timeframe	Boundary condition updates
01	Basecase	Base case model configuration as summarised in Section 8.2	Jul 2017 – Jan 2022	N/A
02	NoSEFlow	Assess impact of SE Flows (Salt Creek) by setting to zero throughout 2021	Jul 2017 – Jan 2022	Salt Creek flow set to zero throughout 2021
03	Counterfactual (hypothetical no environmental water)	Assess impact of environmental water delivery via the barrages to the Coorong	Jul 2017 – Jul 2021	All environmental water removed from barrage bc files (reduced flow)
04	DesignBarrageFlow (hypothetical annual barrage volume sequence)	Assess impact of annual min barrage flow of 650 GL/y and 3-year rolling average of at least 6,000 GL	Jul 2017 – Jul 2020	Design barrage releases with annual volumes of 2,000 GL (Yr1), 650 GL (Yr2), 3,350 GL (Yr3) based on 2015-16 WY barrage release releases (timing & distribution)
05	NoBarrageFlow	Assess impact of no barrage releases for three consecutive years to compare with scenario 04	Jul 2017 – Jul 2020	Barrage bc files commented out in flows.fvc

8.4 Scenario results

8.4.1 Hydrodynamic – water level, salinity

The modelled hydrodynamic outputs of water level, salinity, and where relevant, tracers, at key Coorong monitoring sites are presented below for each of the scenarios listed in Table 8.5. At the time of running the scenarios, a TUFLOW-FV software bug prevented the modelled flow and tracer fluxes being exported for the scenarios.

Basecase scenario

Figure 8.8 shows the comparison of observed and modelled Basecase water level at key monitoring sites along the Coorong for the period July 2017 to January 2022. The CDM slightly overestimates water level at all sites with the effect slightly larger at the two CSL sites, Woods Well (A4261209) and Snipe Island (A4261165). However, the results show that the CDM is capable of reproducing observed water level at all sites along the Coorong throughout the modelled period, and thereby representing the hydrodynamics of the system.

Figure 8.9 shows the comparison of observed and modelled Basecase salinity at key monitoring sites along the Coorong for the period July 2017 to January 2022. The CDM tends to underestimate salinity at all sites, with the exception of Snipe Island (A4261165) in the southern CSL where the model slightly overestimates salinity. Considerable improvement of the modelled CSL salinity has been achieved in a parallel modelling project undertaken in HCHB Phase 1B (BMT, 2022c) and the re-calibration of the CDM to capture these improvements is a priority in the next phase of HCHB modelling. Ultimately, the model accurately captures the seasonal changes in salinity, and the changes on small temporal scales, which provides confidence in the model's ability to represent the hydrodynamics of the Coorong.

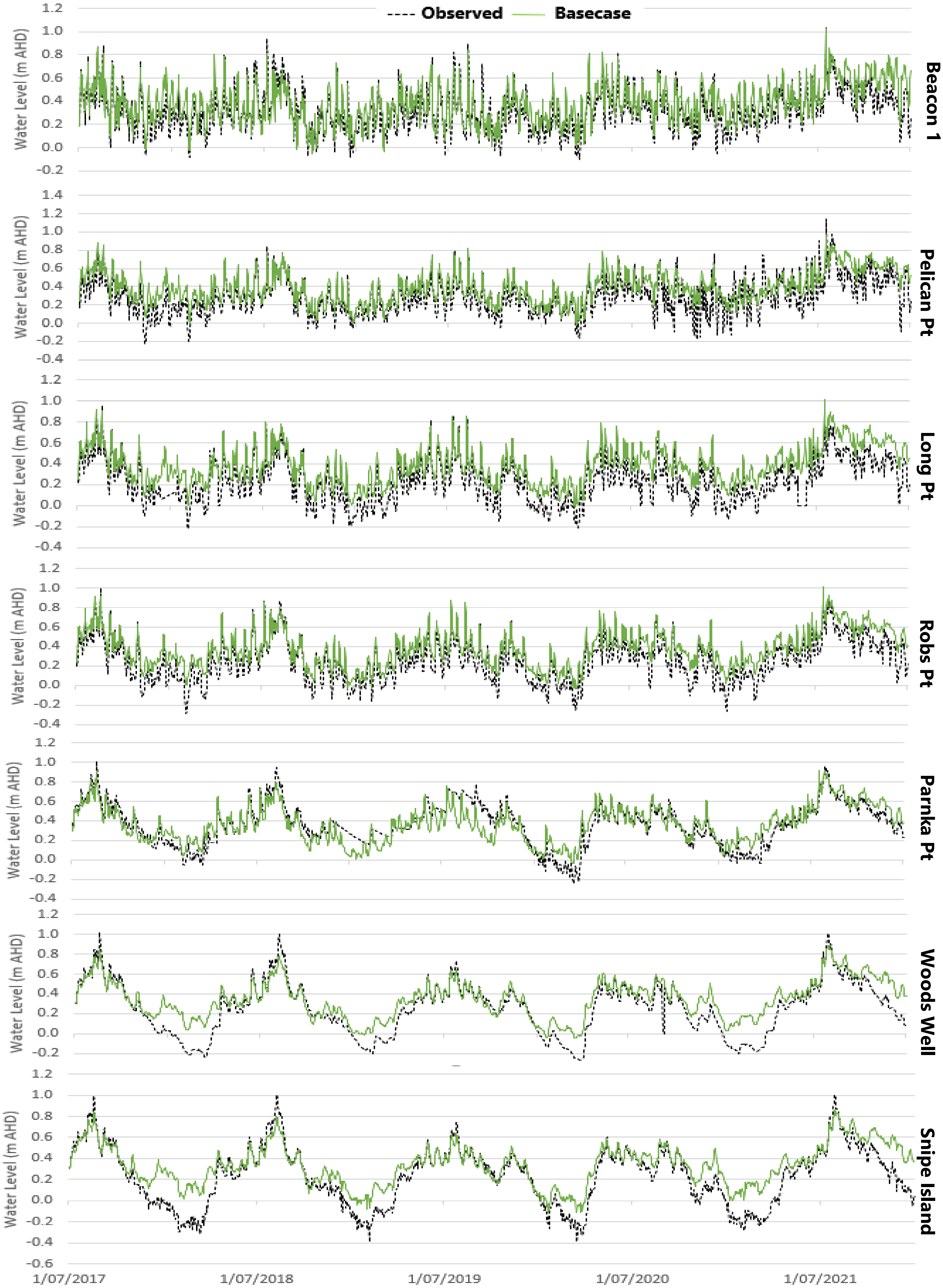


Figure 8.8. Observed and modelled Basecase water level at key Coorong monitoring sites

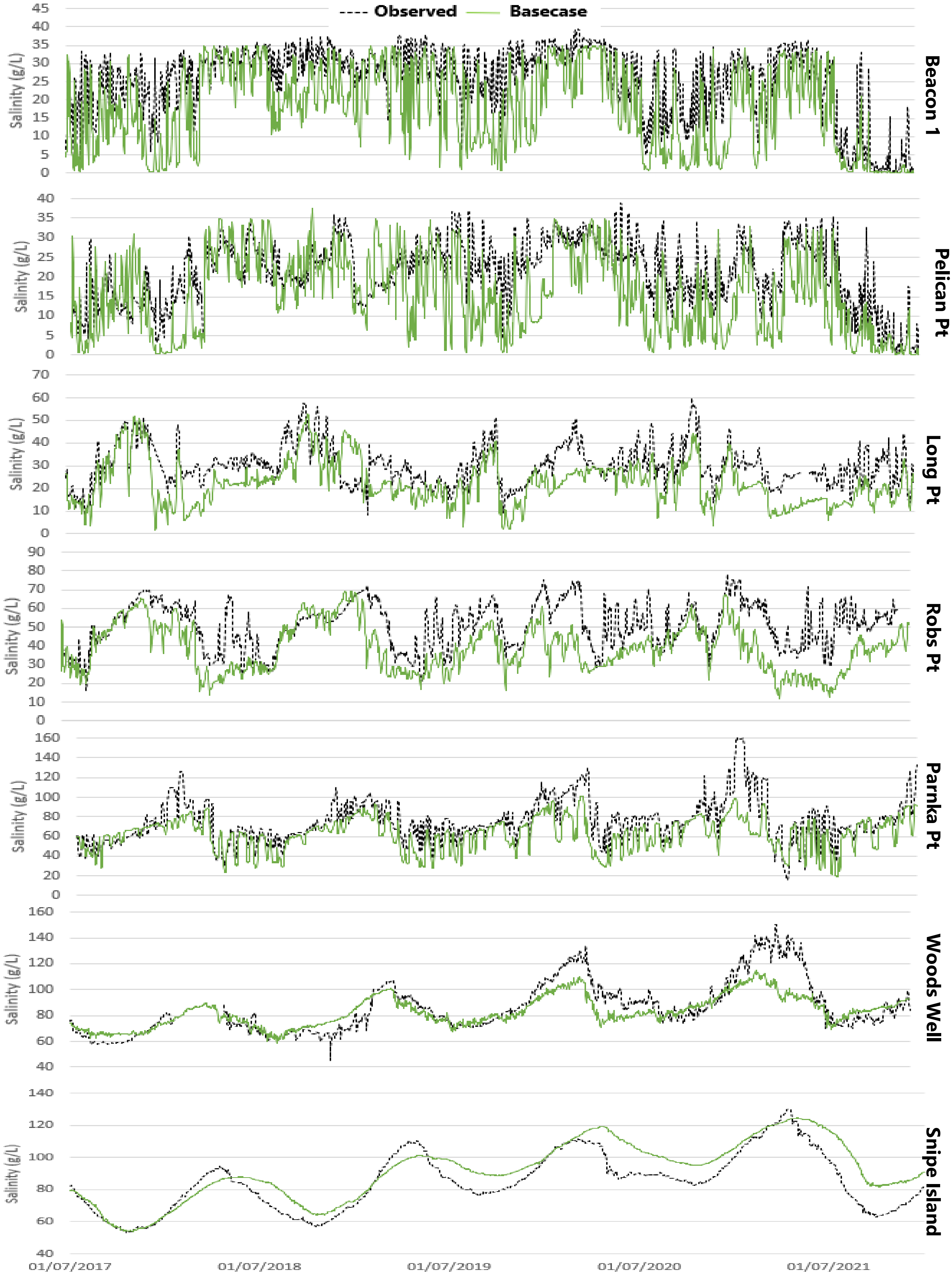


Figure 8.9. Observed and modelled Basecase salinity at key Coorong monitoring sites

NoSEFlow scenario

A reduction in Salt Creek flow in 2021 from 24 GL under Basecase to 0 GL under the NoSEFlow scenario resulted in minimal change in either water level at all sites in the Coorong. When compared to the annual total Salt Creek releases for the historical period 1990 – 2021, the 2021 releases were the fifth highest with 80% of years in this period with releases totalling less than 20 GL. This accords with prior modelling, which also demonstrated minimal impact on water levels (Figure 8.10) attributable to Salt Creek releases.

The impact on salinity (Figure 8.11) was evident at Long Point (A4261135), Robs Point (A4260572), and Parnka Point (A4260633) with a marginal increase under the NoSEFlows scenario in 2021. The impact was most pronounced at the most southerly site, Snipe Island (A4261165), which is approximately 2km north of the Salt Creek outlet. Here the modelled salinity reached 111 g/L at the end of the simulation compared to 91 g/L under the base case, highlighting the relatively localised impact of Salt Creek releases on CSL salinity. This is reinforced by the relative concentration of the Salt Creek modelled tracer at the same sites in the Coorong shown in Figure 8.12, which follows the same pattern as salinity. Of note, the difference in Salt Creek tracer concentration between the base case and the NoSEFlows scenario is more noticeable at Woods Well (A4261209) than the salinity difference at this site.

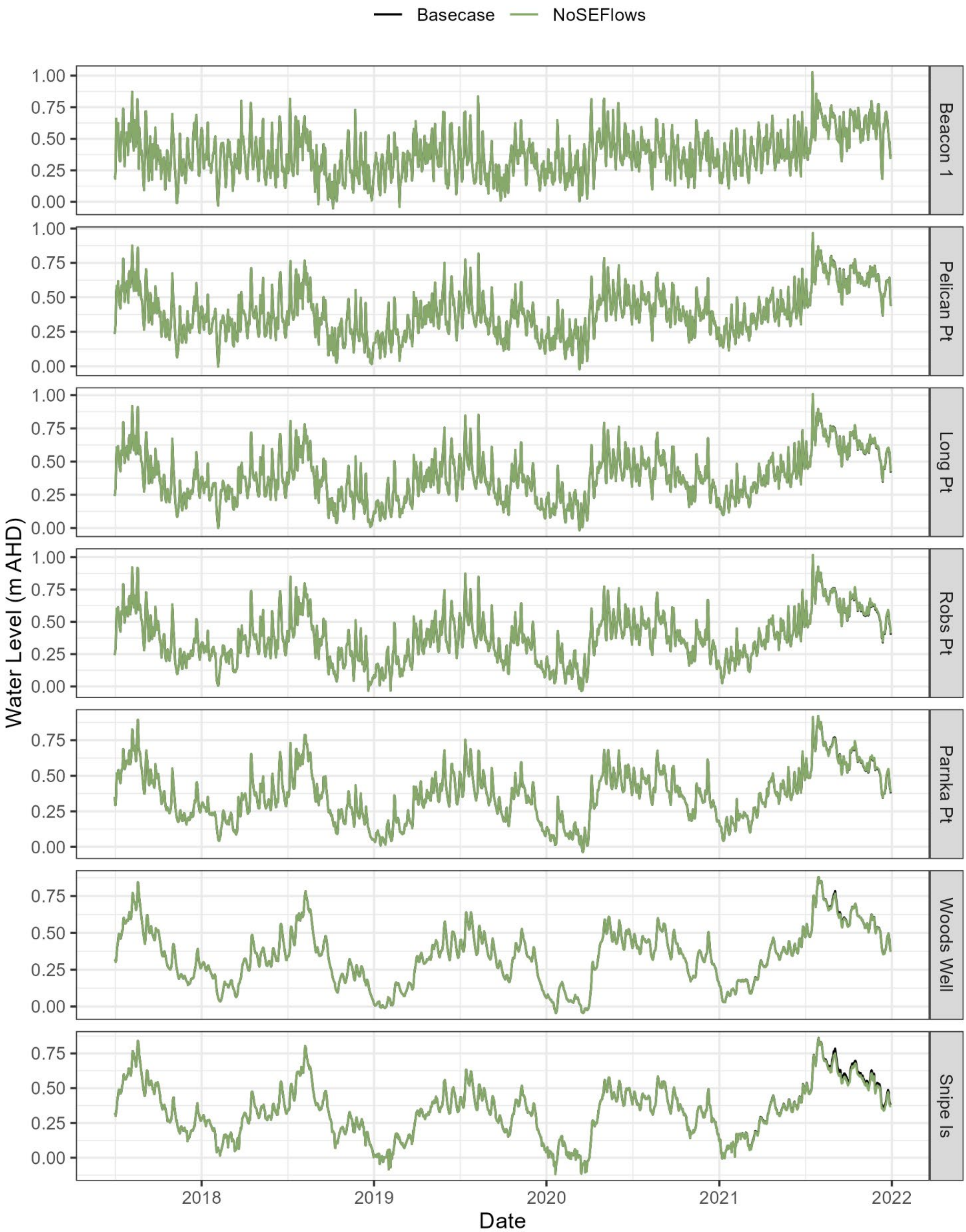


Figure 8.10. Comparison of modelled water level at key Coorong monitoring sites for the Base case and no SE flows (2021) scenario

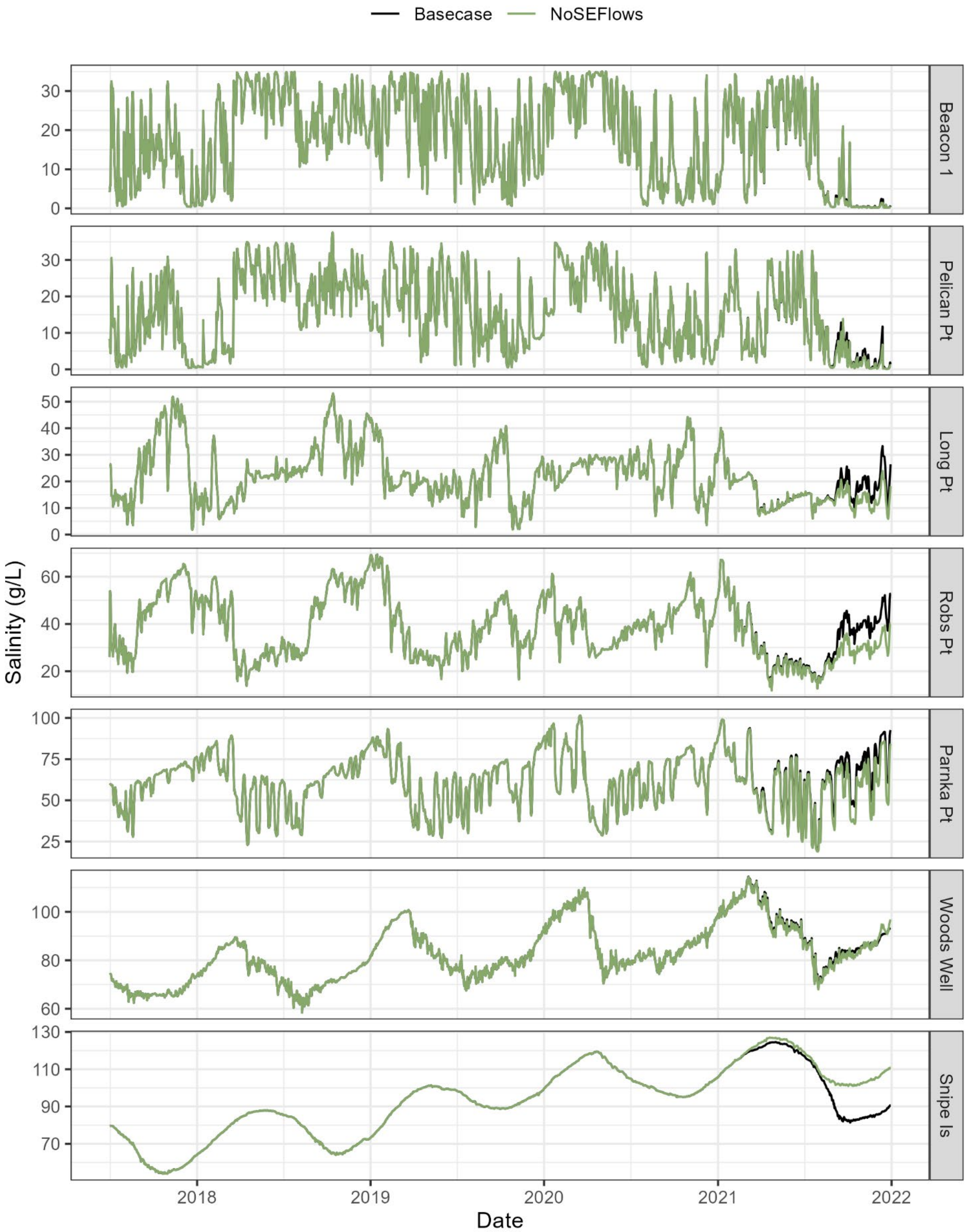


Figure 8.11. Comparison of modelled salinity at key Coorong monitoring sites for the Base case and no SE flows (2021) scenario

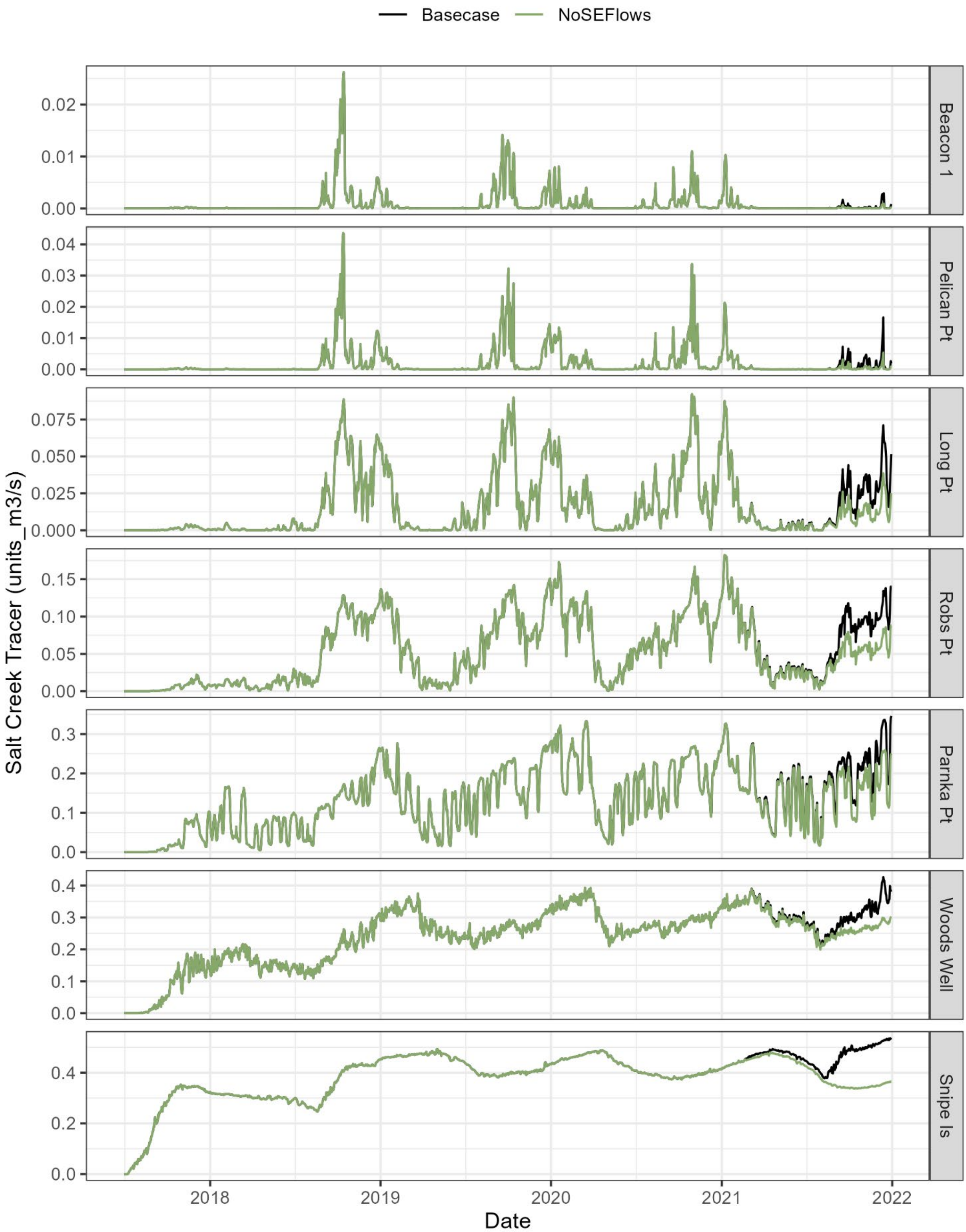


Figure 8.12. Comparison of modelled Salt Creek tracer concentrations at key Coorong monitoring sites for the Base case and no SE flows (2021) scenario

Counterfactual scenario

The total Basecase (with environmental water) and Counterfactual (without environmental water) scenario barrage releases are shown in Figure 8.13 and summarised in Table 8.6. The removal of all environmental water delivery through the barrages (6015 GL or 89 % of total barrage releases) for the period July 2017 to July 2021 resulted in slightly lower water levels at all sites in the Coorong with the impact more noticeable in the CSL, and in 2017-18 when environmental water delivery was highest (Figure 8.14). The influence of the considerable reduction in barrage releases in each year on salinity was much greater at all sites (Figure 8.15). With the exception of Beacon 1 (A4261043) and Pelican Point (A42611324), which are more tidally influenced, the salinity pattern was similar for both scenarios at all other sites, albeit at least 10 g/L more from January 2018 onwards under the Counterfactual scenario. This highlights the relative influence of environmental water in annual barrage releases and in turn, the impact on Coorong salinity at all times of the year.

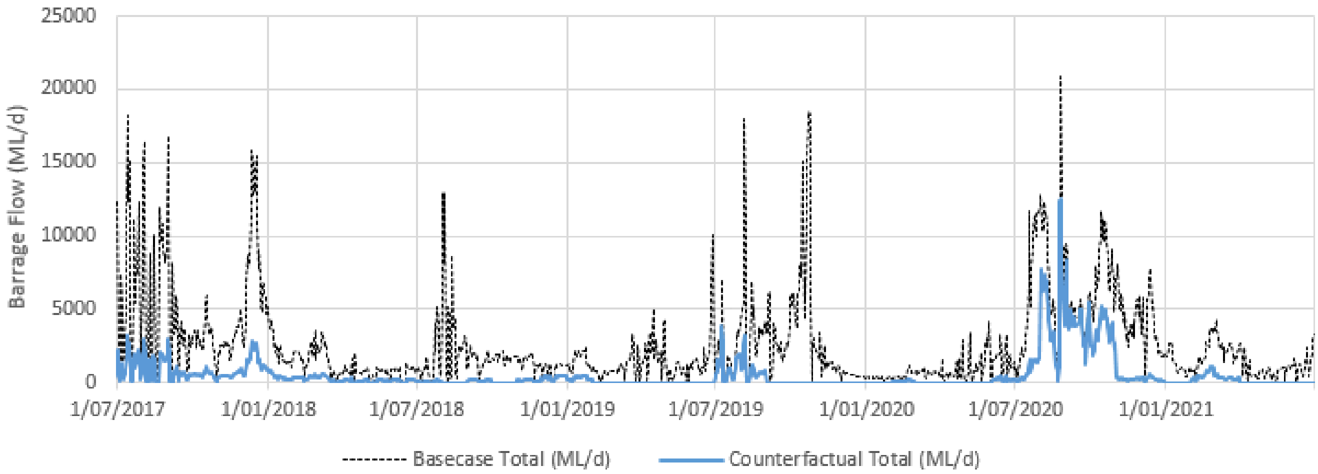


Figure 8.13. Comparison of daily total barrage releases under Basecase and Counterfactual scenarios

Table 8.6. Total annual barrage releases under Basecase and Counterfactual scenarios

Year	Basecase (GL)	Counterfactual (GL)	Ewater (GL) (Difference between Basecase and Counterfactual)
2017/18	1173	202	971
2018/19	572	28	544
2019/20	706	67	639
2020/21	1331	456	875
Total	**3782**	**752**	**3030**

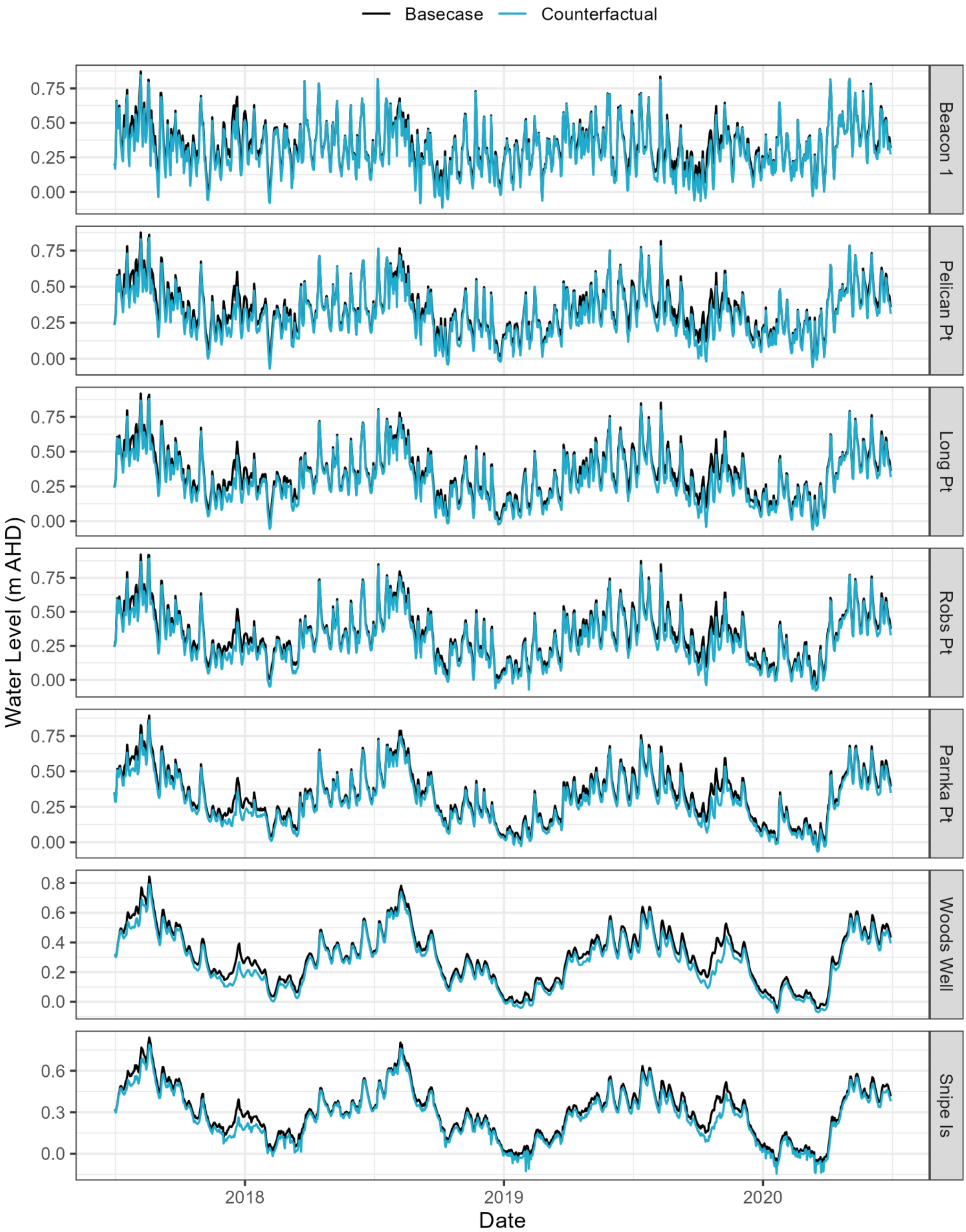


Figure 8.14. Comparison of modelled water level at key Coorong monitoring sites for Base case and Counterfactual scenarios

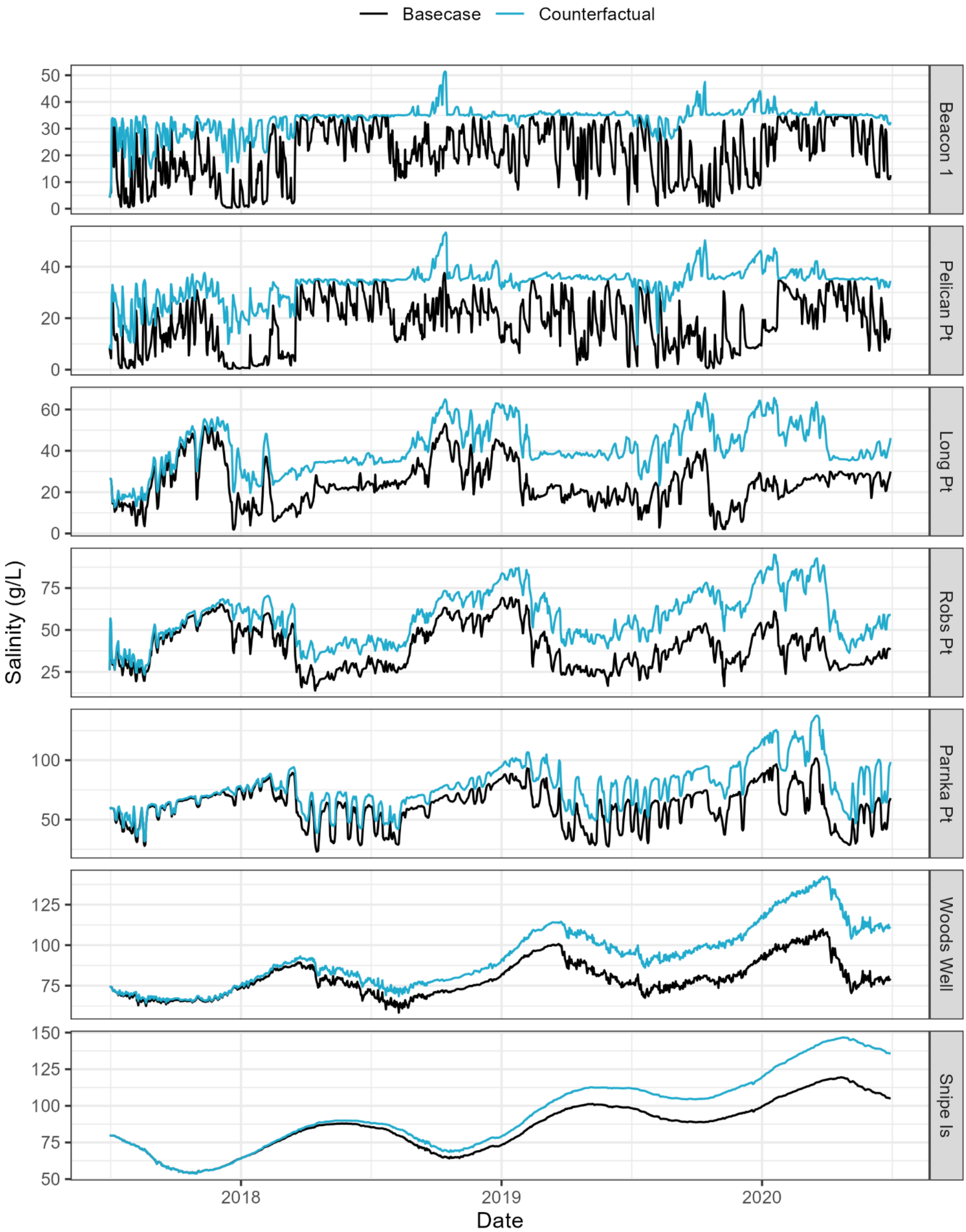


Figure 8.15. Comparison of modelled salinity at key Coorong monitoring sites for Base case and Counterfactual scenarios

Design and No barrage release scenarios

The total Basecase and Design scenario barrage releases, the latter adopting a hypothetical annual barrage volume sequence, are shown in Figure 8.16 and summarised in Table 8.7. The total barrage releases under the Design scenario are nearly three times the magnitude of those under the base case with the biggest difference presenting in the 2019-20 water year. Figure 8.17 shows the modelled water level at all sites in the Coorong for these two scenarios as well as a No Barrages scenario. The influence of the considerably higher releases under the Design scenario is evident in higher modelled water levels at all sites in 2019-20. Unsurprisingly, the No Barrages scenario results in lower water levels at all sites relative to both the Basecase and the Design scenarios, but the difference compared to the Basecase is minimal due to the relatively low total annual barrage releases in that scenario. The Design scenario results in water levels of 0.1 – 0.2 m AHD higher than the Basecase in 2019-20 at all sites confirming the influence of the higher barrage releases extends to the southern CSL.

Table 8.7. Total annual barrage releases under Basecase and Design scenarios

Year	Basecase (GL)	Design (GL)
2017/18	1173	2000
2018/19	572	650
2019/20	706	3350
Total	**2451**	**6000**

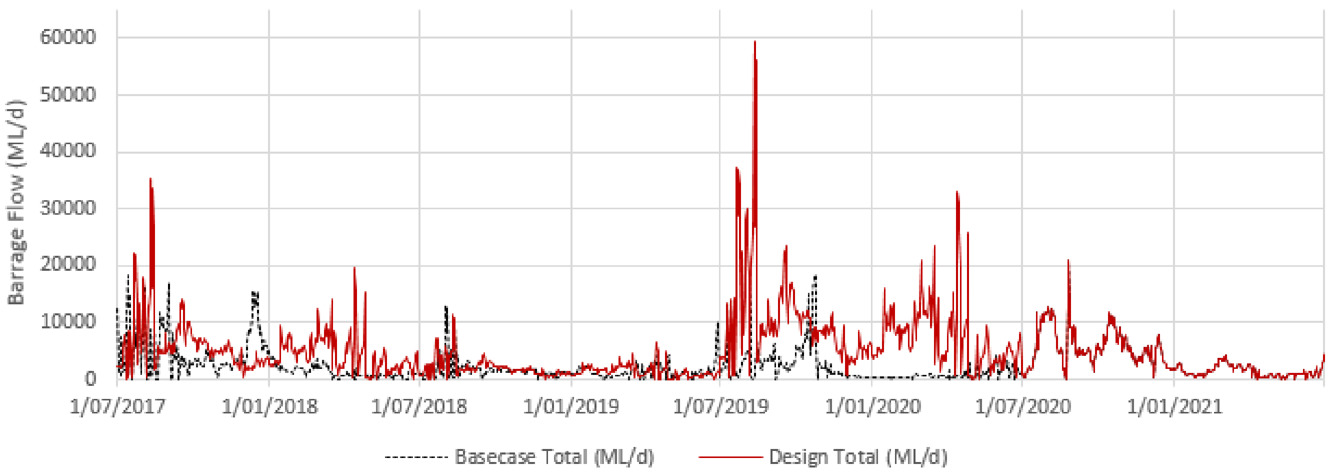


Figure 8.16. Total daily barrage releases under Basecase and Design scenarios

The influence of the higher barrage releases under the Design scenario is considerably greater when compared to the modelled Basecase salinity levels along the Coorong (Figure 8.18). The modelled Design scenario salinities are, up to ~30 g/L lower at the CNL in closer proximity to the barrages and ~20 g/L lower in the CSL. These values increase to ~40 g/L and ~50 g/L, respectively when comparing the No Barrages and Design scenarios.

The relative influence of each of the barrage release flow sequences on the barrage tracer concentrations at each site are shown for the Basecase and Design scenarios in Figure 8.19. Note, the NoBarrages scenario is not shown as the barrage tracer concentrations are zero for this scenario. The concentrations vary considerably at the sites in closest proximity to the barrages, likely due to the greater tidal influence and presence of the ocean water source. The magnitude of the concentrations is maintained along the length of the Coorong, confirming that the relative reduction in salinity under the Design release scenario is attributable to the higher barrage releases, as the other inflow sources (Salt Creek and ocean) are the same for both scenarios. Conversely, the considerably reduced barrage tracer concentrations modelled under the Counterfactual scenario aligns with the noticeably higher salinity levels for this scenario shown in Figure 8.20.

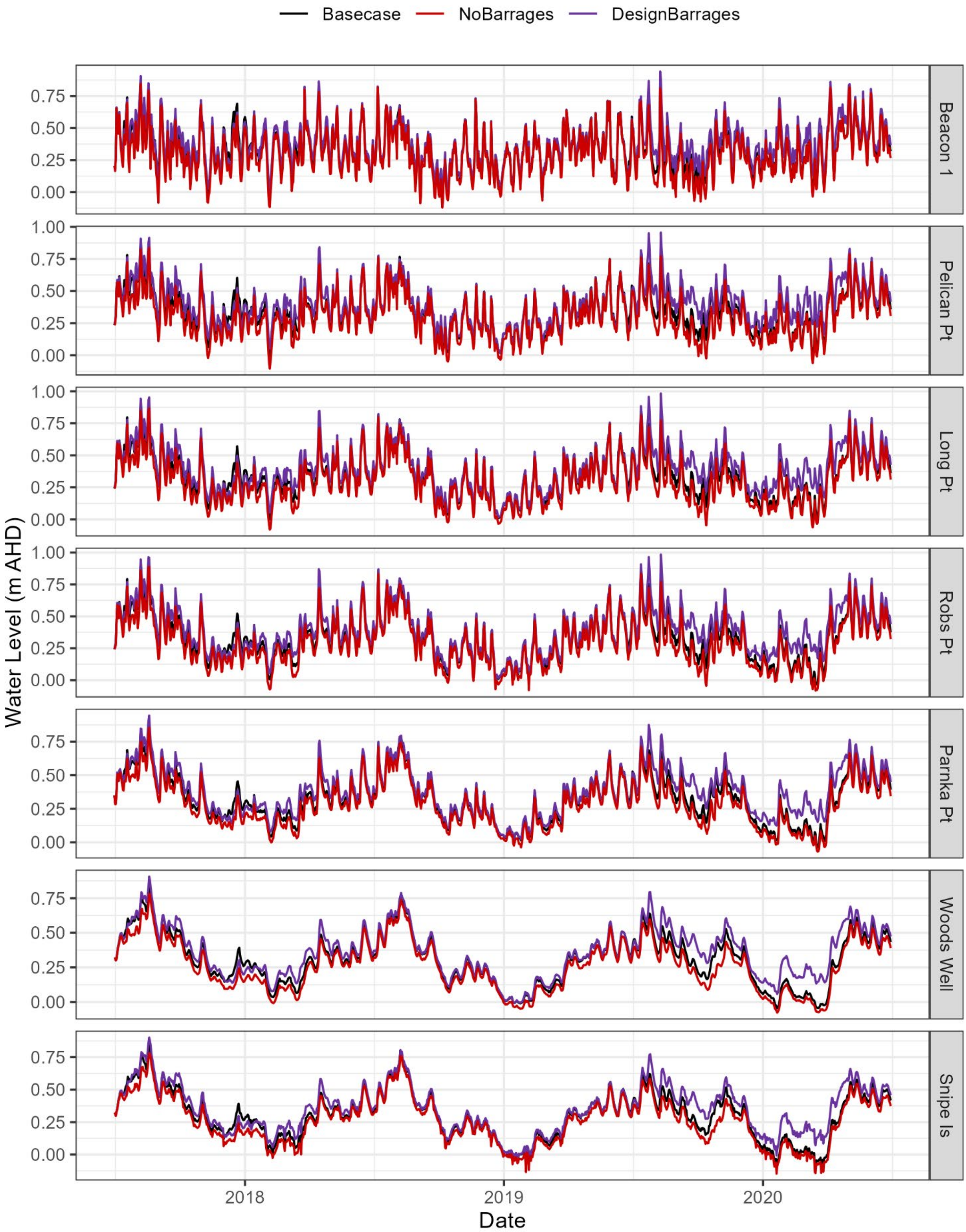


Figure 8.17. Comparison of modelled water level at key Coorong monitoring sites for Basecase, No Barrages and Design Barrages scenarios

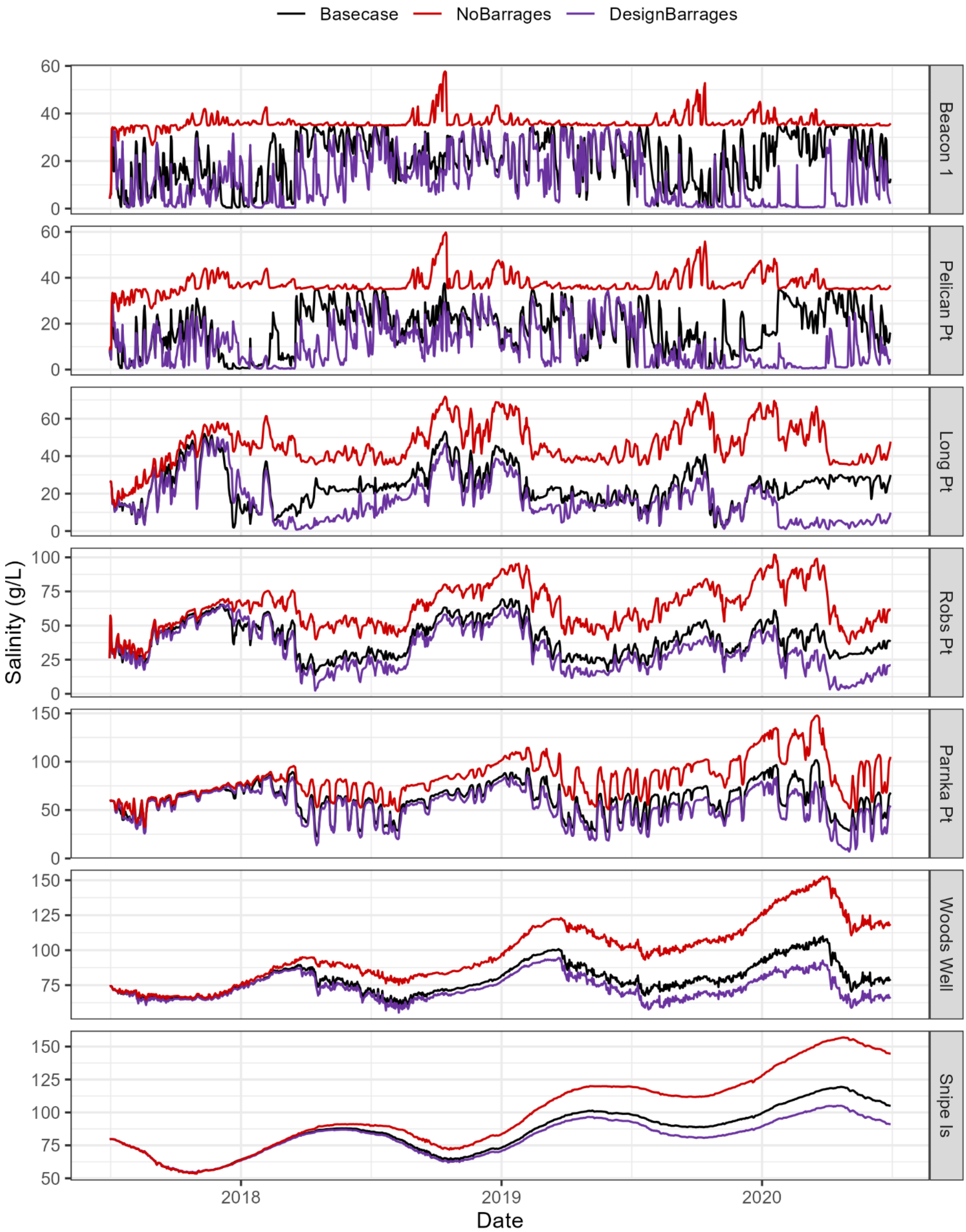


Figure 8.18. Comparison of modelled salinity at key Coorong monitoring sites for the Basecase, No Barrages and Design Barrages scenarios

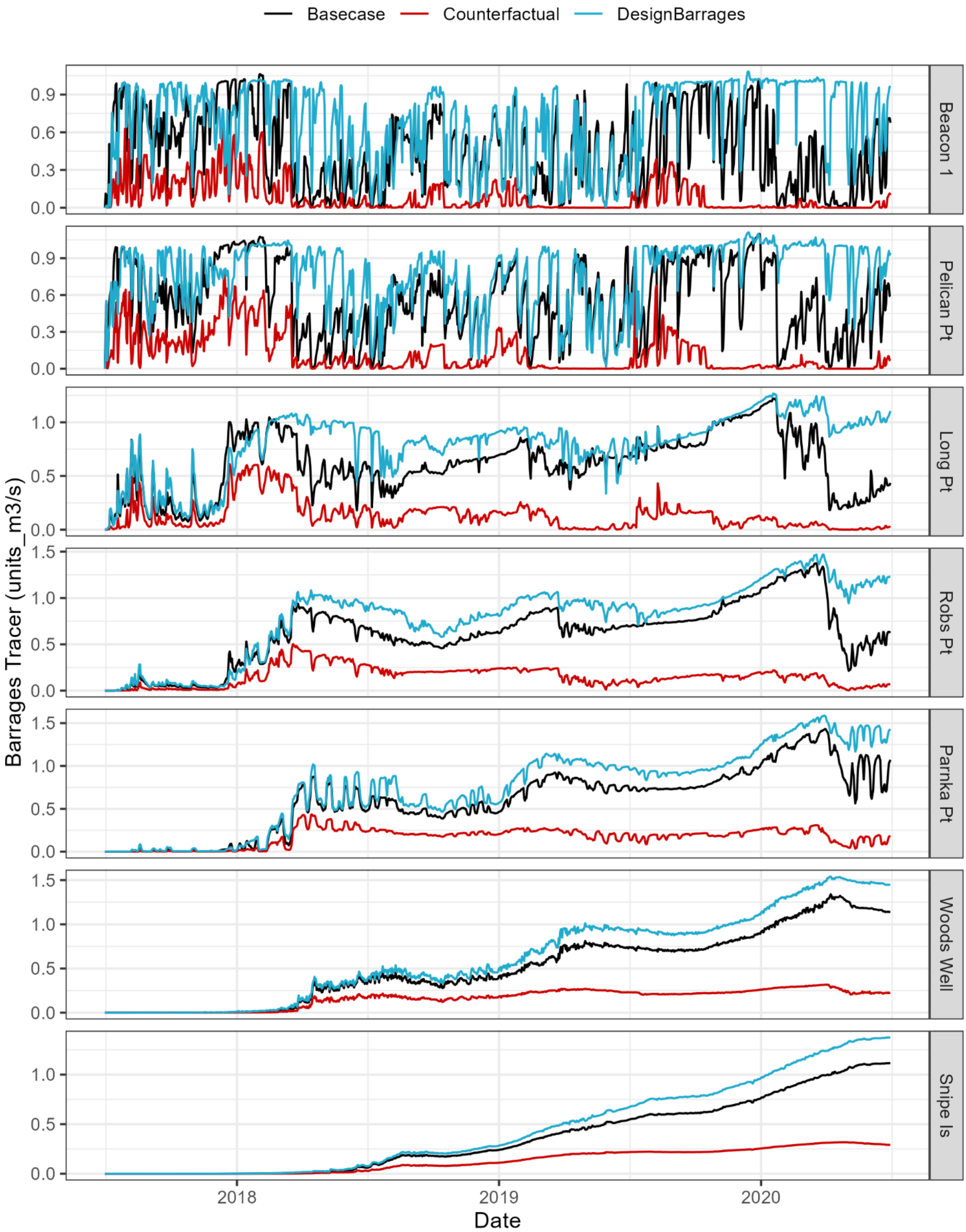


Figure 8.19. Comparison of modelled barrage tracer concentrations at key Coorong monitoring sites for the three barrage flow sequences applied in the scenarios

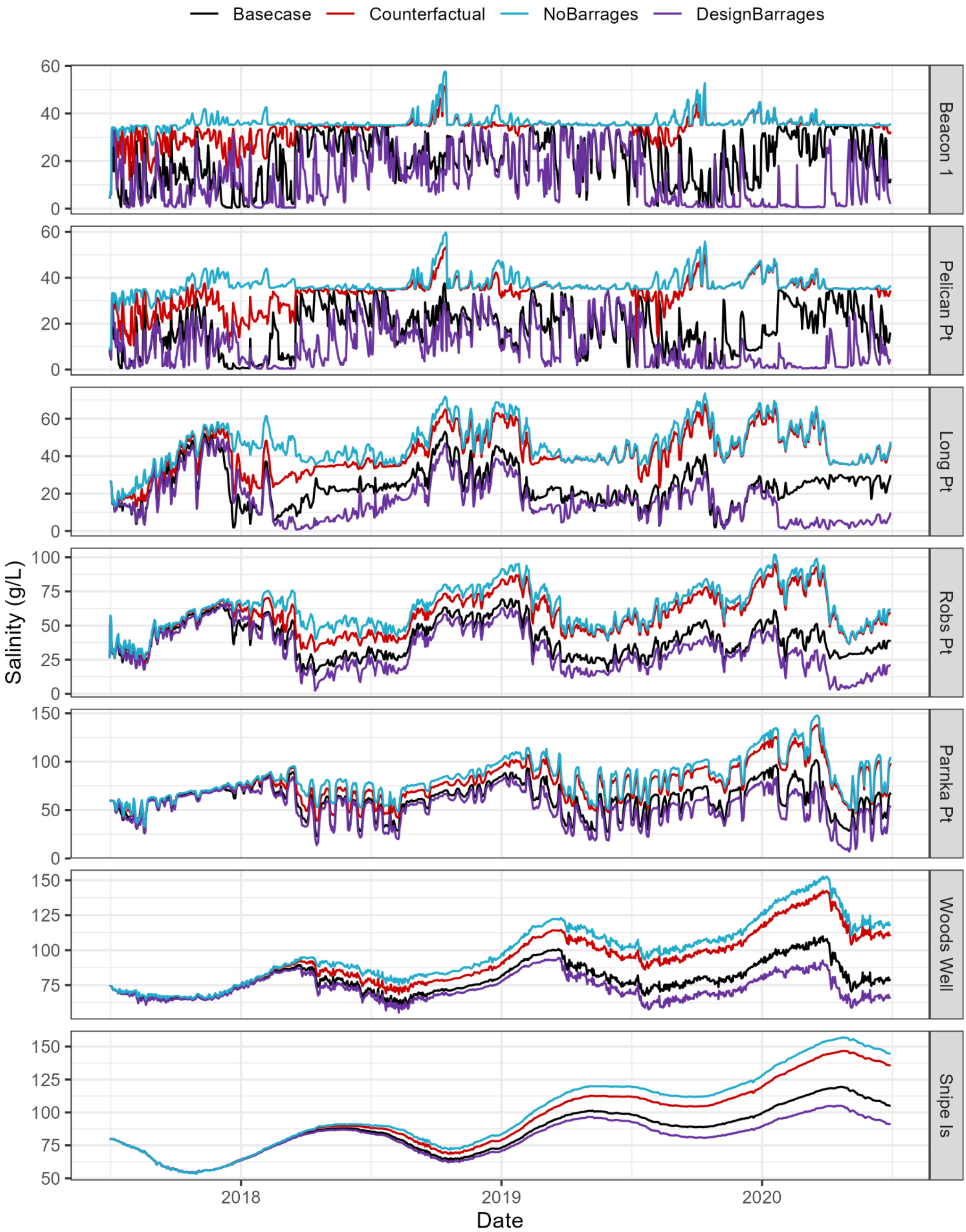


Figure 8.20. Comparison of modelled salinity at key Coorong monitoring sites for all barrage flow sequences applied in the scenarios

8.4.2 Water quality – Total Nitrogen and Total Phosphorus

The Total Nitrogen (TN) concentrations at each of the key Coorong monitoring sites for the Basecase, Counterfactual and Design Barrages scenarios are shown in Figure 8.21 and Figure 8.22. As summarised in section 8.1.2, Nitrate (NO_3) and Ammonium (NH_4) are modified by nitrification, denitrification, sediment release, and atmospheric deposition following the specification of initial values for Ammonium, Nitrogen and Nitrous Oxide concentrations in the Nitrogen module. The TN is the sum of these component variables. For all scenarios, the TN concentrations are more variable at the CNL sites, and the magnitude progressively increases along the Coorong with peaks increasing from ~140 mmol/m^3 to ~400 mmol/m^3. The concentrations are noticeably higher at the Parnka Point (A4260633) site, particularly for the Basecase scenario. Comparing scenarios, the TN concentrations are lowest under the Counterfactual scenario at all sites, and on average, highest under the Design Barrages scenario.

The Total Phosphorus (TP) concentrations at each of the key Coorong monitoring sites for the Basecase, Counterfactual and Design Barrages scenarios are shown in Figure 8.23 and Figure 8.24. As summarised in section 8.1.2, the Phosphorus module captures the dissolved phosphate concentration (PO_4) and sorbed phosphate ($PO^{ads}{}_4$) and simulates processes relating to inorganic phosphorus dynamics. The TP is the sum of these component variables and is less variable than the TN at all sites. The TP concentrations are highest in the CNL sites, peaking above 50 mmol/m^3 at Beacon 1 (A4261043) and Pelican Point (A4261134) under the Basecase and Design Barrages scenarios in 2021. However, the majority of values are significantly lower, in the range ~2 mmol/m^3 - ~10 mmol/m^3. The concentrations are highly variable at Parnka Point (A4260633) for all scenarios but more cyclical at the two CSL sites, peaking (~10 mmol/m^3) in late summer in each year of the simulation for all scenarios.

Excluding the significant sediment flux source of nutrients in the Coorong, which are not simulated in these scenarios, Mosley et al. (2021) note the majority of nutrients in the Coorong, especially in the North Lagoon, originate from barrage flow and thus from the River Murray and Lower Lakes. Inputs from the ocean are the next biggest source whereas Salt Creek contributes only a fraction of the nutrients with a localised influence. This accords with the higher TP concentrations at the CNL sites and in 2021 when the highest barrage releases occur for each of the scenarios. Likewise, the Design Barrages scenario produces the highest TN concentrations at all sites and has nearly double the total barrage releases of both the Basecase and Counterfactual scenarios across the simulation period. The relative influence of the barrages, and thus this source of nutrients is dampened in the CSL where TP concentrations are approximately half those modelled at the CNL sites. The seasonal pattern of TN and TP particularly evident in the CSL can be attributed to the apparent flushing of nutrients in winter with better mixing due to increasing water levels resulting in declining TN and TP concentrations. Despite this seasonal influence, the maintenance of nutrients in the CSL due to limited flushing or exchange is evident in the higher average TN and TP concentrations throughout the entire simulation for all scenarios (Mosley et al., 2021).

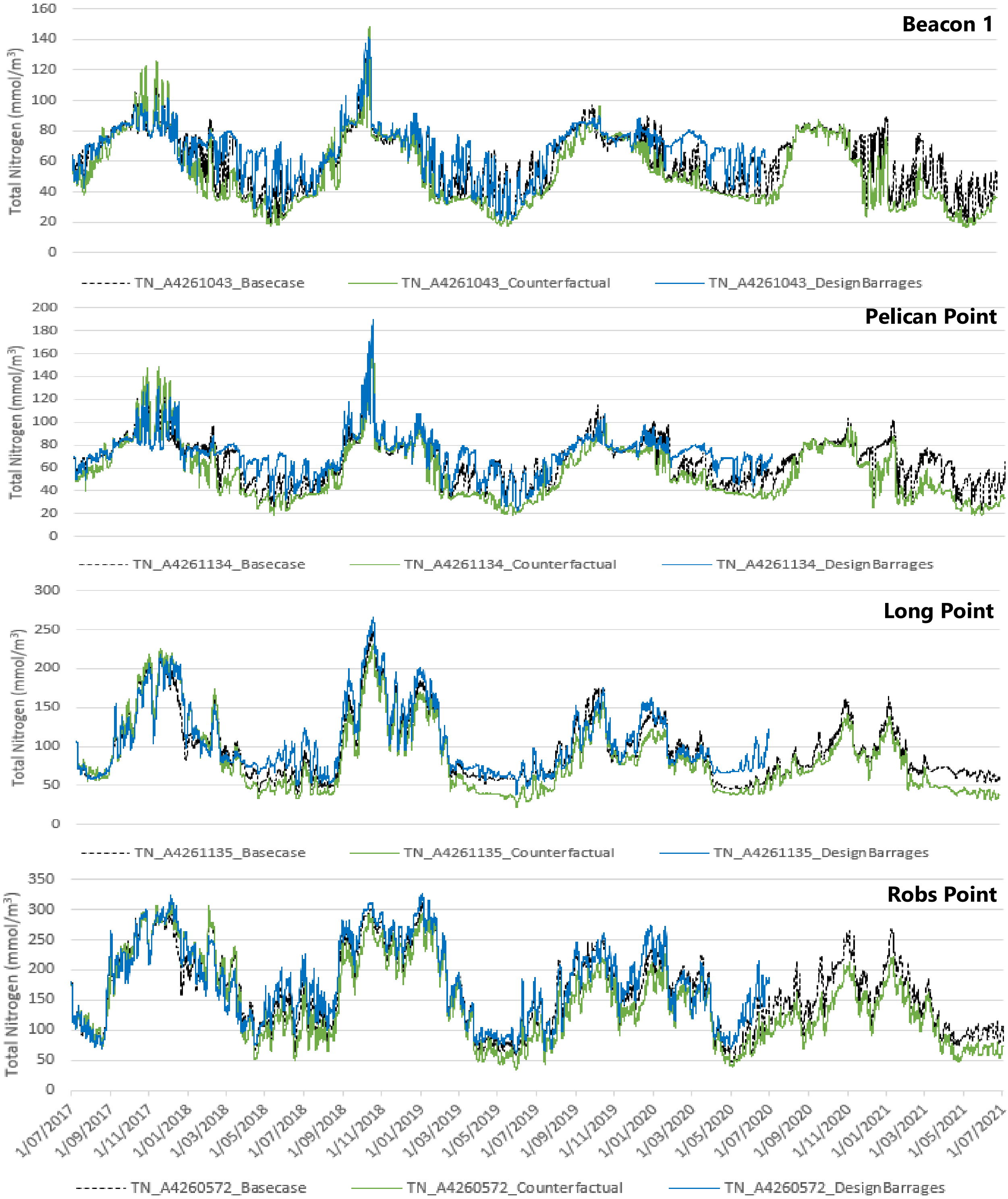


Figure 8.21. Total Nitrogen concentrations at key CNL monitoring sites for Basecase, Counterfactual and Design Barrages scenarios. Note: The Design Barrages scenario was run for a shorter period than the Basecase and Counterfactual scenarios

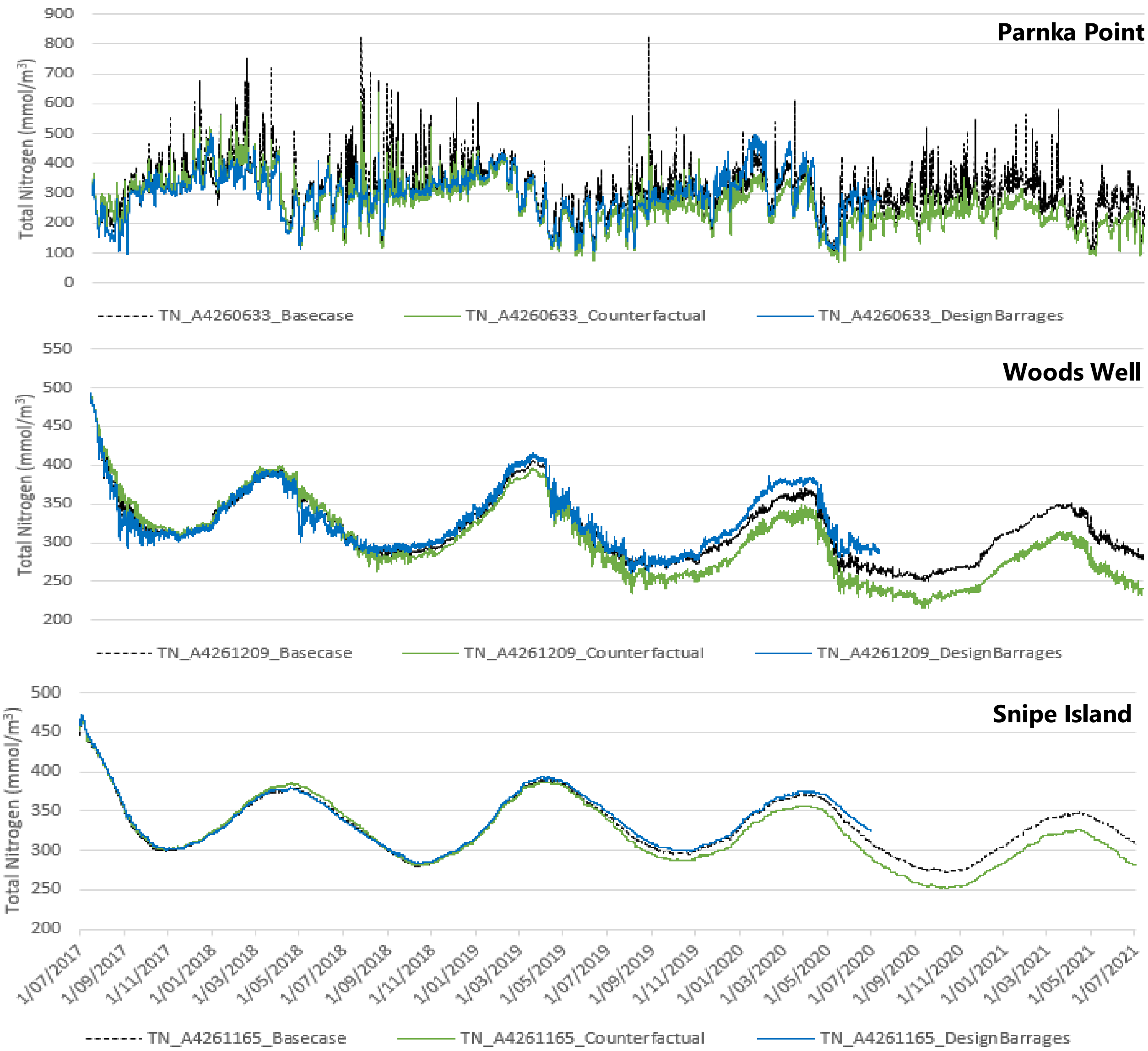


Figure 8.22. Total Nitrogen concentrations at key CSL monitoring sites for Basecase, Counterfactual and Design Barrages scenarios. Note: The Design Barrages scenario was run for a shorter period than the Basecase and Counterfactual scenarios

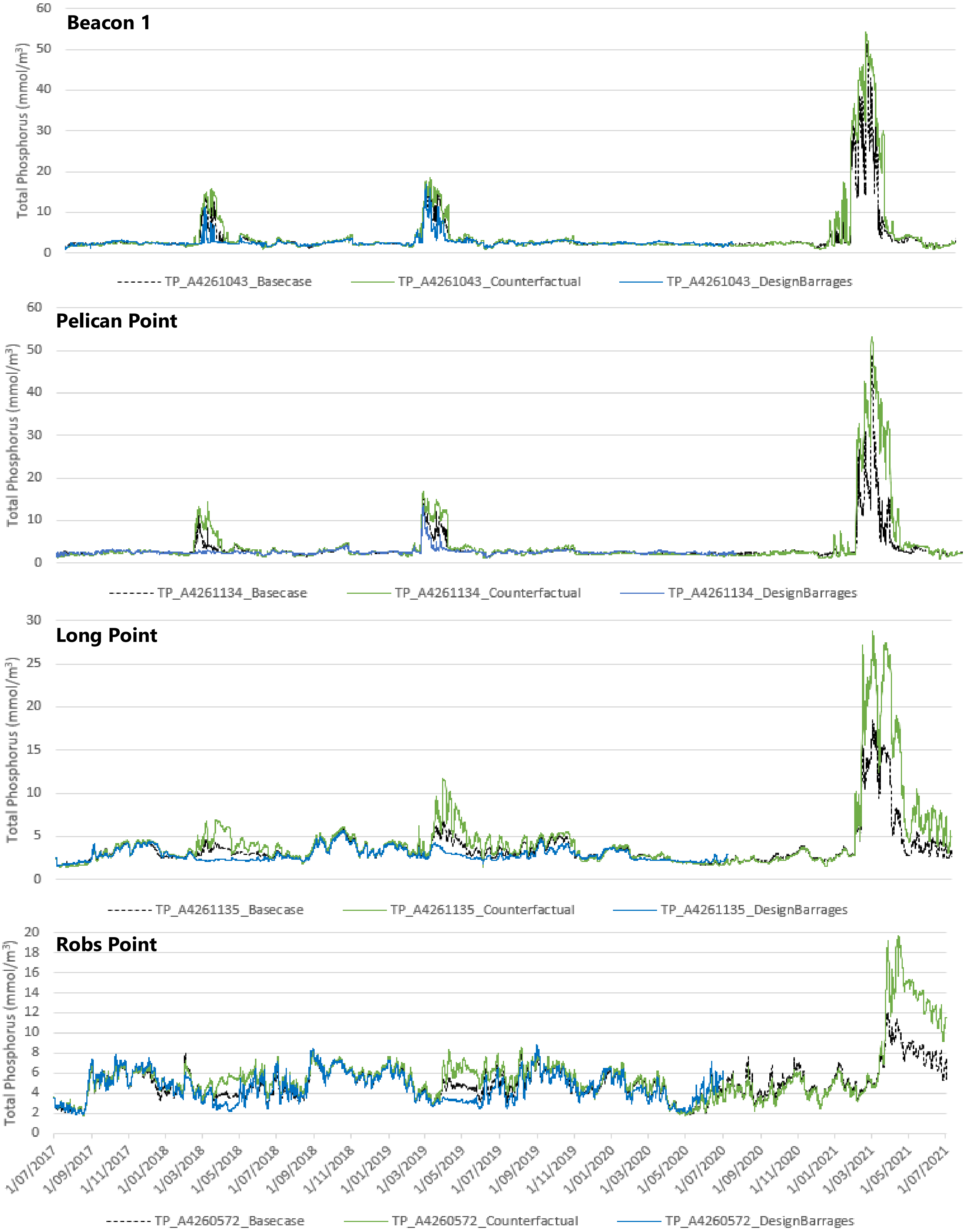


Figure 8.23. Total Phosphorus concentrations at key CNL monitoring sites for Basecase, Counterfactual and Design Barrages scenarios. Note: The Design Barrages scenario was run for a shorter period than the Basecase and Counterfactual scenarios

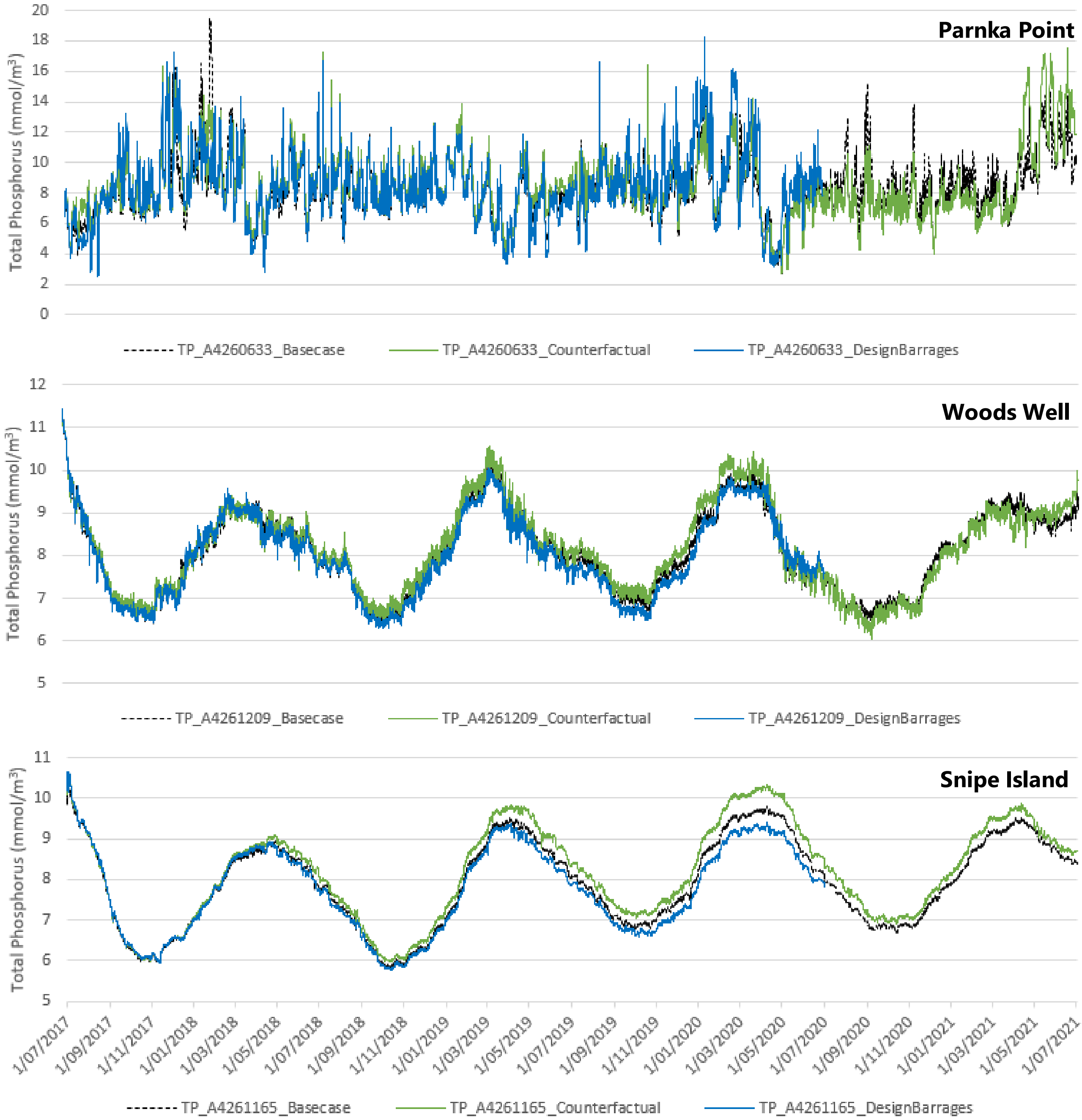


Figure 8.24. Total Phosphorus concentrations at key CSL monitoring sites for Basecase, Counterfactual and Design Barrages scenarios. Note: The Design Barrages scenario was run for a shorter period than the Basecase and Counterfactual scenarios

Part C – The CDM Catalogue

9 The CDM Catalogue

In addition to the significant body of work undertaken as part of the HCHB Integration component to update the CDM, a number of parallel modelling projects have been progressed under complementary HCHB projects. The CDM Catalogue represents the full suite of TUFLOW-FV models applied, improved and developed under HCHB Phase 1. The parallel modelling projects and the phases of model development have resulted in a number of Coorong TUFLOW-FV models with consistent model domains but differing functionality, depending on their configuration and application. This section describes the current catalogue of models, specific improvements delivered, and their application to date beyond that presented in Part B above. HCHB Phases 1B and 2 are intended to deliver continued model improvements and harmonisation across models. This will enhance modelling efficiencies particularly relating to model boundary conditions, and further embed the refined CDM Catalogue into the DEW environment.

Table 9.1. Models comprising the CDM Catalogue at the conclusion of HCHB Phase 1

Model	Model description, configuration and application	Model period
Existing TUFLOW-FV models		
Fine resolution_DEW	Original DEW Coorong mesh (48,968 cells), 2D hydrodynamic model. This is the model applied in the 2019-20 scenario modelling presented in Part A of this report	2013 – 2016
Fine resolution_UWA	UWA Coorong mesh (26,250 cells), 2D hydrodynamics, mesh further optimised for biogeochemical and habitat modelling	
Applied during HCHB Phase 1		
Fine resolution_DEW	Original DEW Coorong mesh (48,968 cells), 2D hydrodynamic model, updated Parnka Point bathymetry. Adopted for CIIP modelling with dredging alignments included and CIIP specific infrastructure configurations	2013 - 2016
Fine resolution_UWA	UWA Coorong mesh (26,250 cells), 2D hydrodynamic model, updated Parnka Point bathymetry and other CIIP scenario specific configurations including initial dredging alignments. Biogeochemical models also applied in CIIP.	2013 - 2016
Developed and applied during HCHB Phase 1		
Coarse model	Coarse resolution Coorong mesh (2,202 cells), 2D hydrodynamic model for faster, long-term simulations investigating water balance and CIIP scenarios. Options for dynamic Murray Mouth functionality.	1990 - 2019
Fine resolution_ops	UWA Coorong mesh (26,250 cells), 2D hydrodynamics, mesh further optimised following bathymetry review with greater resolution in the CNL, Parnka Point, and CSL, re-calibrated (2013 – 2016) and validated (2016 – 2019).	2013 - 2019
CDM Gen 0	UWA Coorong mesh (26,250 cells), 2D hydrodynamics, no surface wave coupling, five sediment zones with statically assigned flux rates based on assumed parameters	2013 – 2019
CDM Gen I – rapid	Coarse mesh (2,202 cells), 2D hydrodynamics, surface wave coupling, five sediment zones with statically assigned flux rates based on assumed parameters	2011 – 2021
CDM Gen I	UWA Coorong mesh (26,250 cells), 3D hydrodynamics, surface wave coupling, 20 sediment zones with statically assigned flux rates, updated based on observed estimates	2019 – 2021
CDM Gen 1.5	a. hchb_Gen1.5_20220523_DEW - UWA Coorong mesh (26,260 cells), as described in Part B of this report. 2D hydrodynamics, 31 sediment zones with statically assigned flux rates. TUFLOW-FV build 2020.02.034, lib aed build 2.0. b. Hchb_tfvaed_Gen1.5_4PFT_MAG – as per (a) but with upgrade to number of phytoplankton groups, and addition of macroalgae. TUFLOW-FV build 2020.03.105, lib aed build 2.0.5b	2017 - 2022
CDM Gen II	Habitat optimised mesh (26,250 cells), 3D hydrodynamics, surface wave coupling, 31 sediment zones with dynamically resolved sediment zones and revised life-stage specific macroalgae model TUFLOW-FV build 2020.03.105, lib aed build 2.0.5b	2017 – 2022

9.1.1 Model meshes

The key distinction between models listed in Table 9.1 is the adoption of either the original or optimised fine resolution mesh, or the coarse resolution mesh. The meshes all share a common Coorong model domain and boundary conditions and are shown in Figure 9.1.

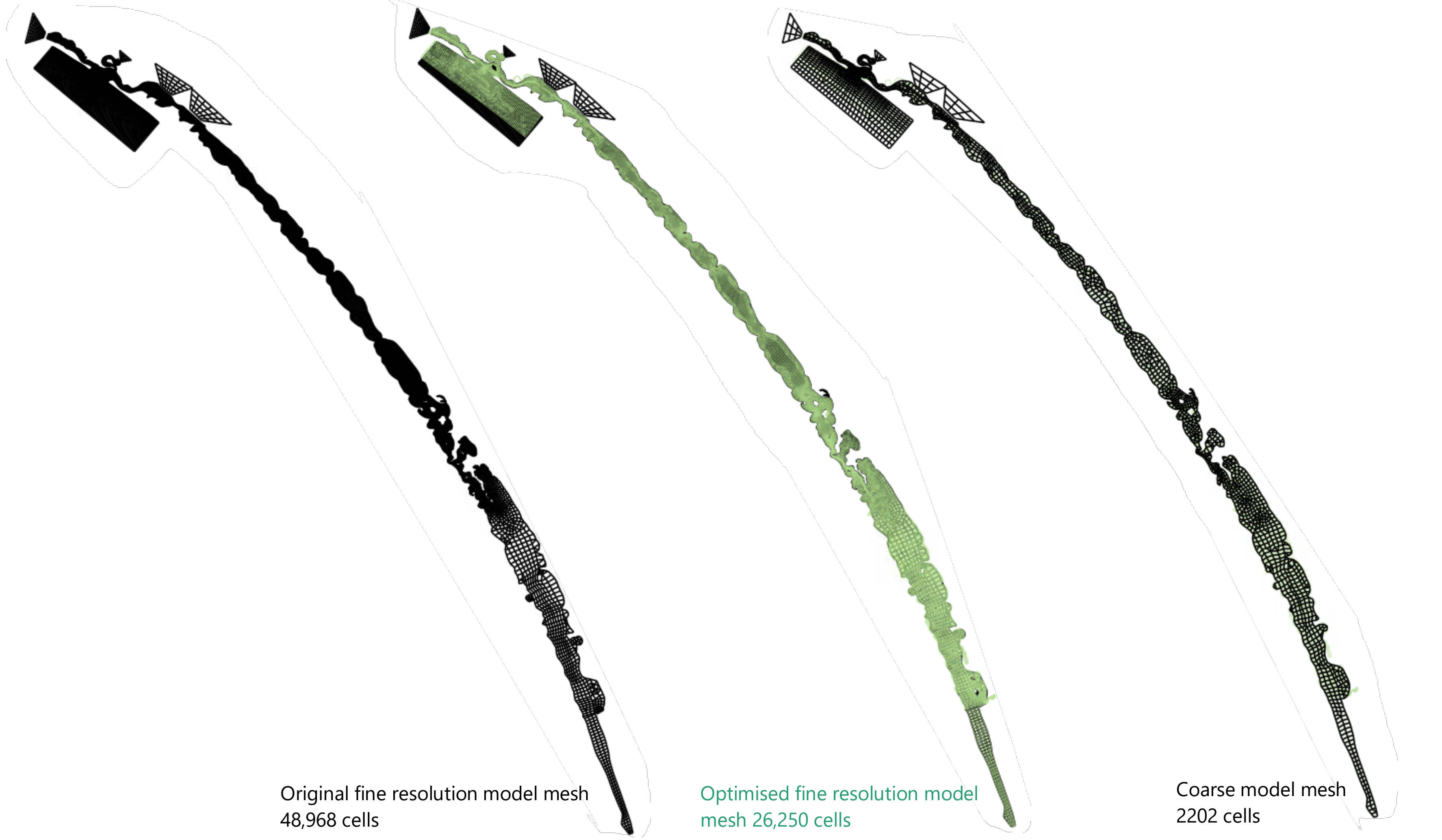


Figure 9.1. Coorong TUFLOW-FV model meshes applied and developed during HCHB Phase 1

9.2 Models delivered through complementary projects

9.2.1 Fine resolution Coorong TUFLOW-FV operational model

As described in BMT (2022a, 2022b) the fine resolution TUFLOW-FV mesh, including modifications and improvements applied in CIIP Phase 2, was further refined by BMT in order to generate an optimised mesh for application to operational scenarios. Specifically, improvements were made to the mesh resolution in the Murray Mouth and CNL, Parnka Point region, and in the CSL following a systematic review of all available bathymetry and Murray Mouth surveys, and the original and updated Coorong DEM. This systematic review and model simulations with varying bathymetry settings confirmed that a model mesh based on the 2018 Coorong DEM update notably reduced model calibration performance, in particular over-predicting CSL salinities. For this reason, it was deemed unsuitable for application to TUFLOW-FV modelling. A composite of the 'master' bathymetry was therefore adopted, based on the original 2008 Coorong DEM and modified to reflect subsequent detailed bathymetry surveys. The resulting updated mesh, with higher resolution in the non-channel areas, has 33,280 cells including a regular gridded static representation of the Murray Mouth. Following calibration, the model effectively demonstrates an improved overall model predictive score. The tide and barrage boundary conditions were also updated using a revised infilled Victor Harbor data set, and the barrage calculator discharge data from Water Data SA barrage sites.

In addition to the model mesh and boundary condition updates, an updated TUFLOW-FV code that retains salt mass in completely dry cells was applied. Previously the code was conservative of scalar mass in wetting and drying areas (e.g. the margins of the lagoons) with the scalar mass being flushed to zero in cells where water depths dropped below a threshold (~1.0e-05 m depth) to avoid calculation errors. When this default was switched off and the dry cells instead retained their salinity mass, the CSL salinity predictions were significantly improved, and therefore this logic was adopted for the model. The re-calibration and application of this model during HCHB Phase 1 has been documented in BMT (2022c).

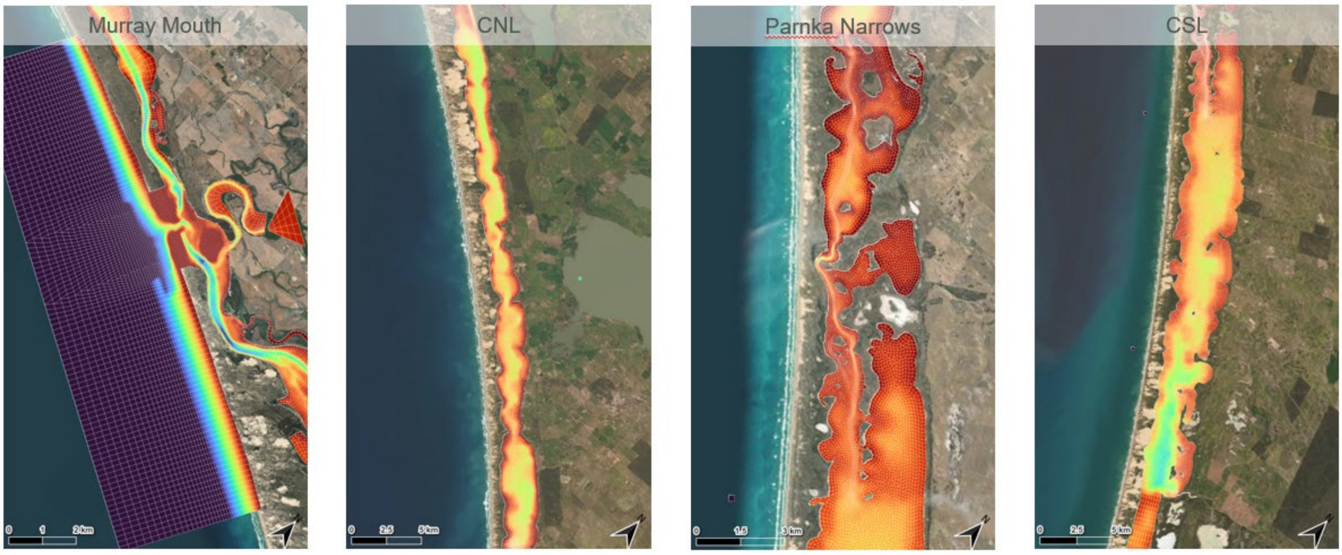


Figure 9.2. Refinement of Coorong TUFLOW-FV fine resolution mesh and adopted bathymetry. Source: BMT, 2022

9.2.2 Development of new morphological update structure in TUFLOW-FV

Previous TUFLOW-FV modelling undertaken by DEW has assumed a static Murray Mouth, adopting recent bathymetry survey elevations at the start of a simulation and with no sediment transport initiated. Under HCHB Phase 1, BMT undertook development of a solution to represent the effect of flow on the morphology of the Murray Mouth under a range of flow conditions, and in response to the interaction with the ocean boundary, without requiring the sediment transport module to be enabled in TUFLOW-FV. Given the continuation of dredging at the Murray Mouth, the ability to represent a specified dredging zone in tandem with natural changes to morphology was also required. In response, BMT (2021a) developed three options for configuring a dynamic Murray Mouth:

1. **Time series bathymetry hindcasts:** A 'timeseries' approach that associates each DEM of the mouth with a specific date and time and linearly interpolates the model bathymetry between these times. This methodology is suitable for hindcast simulations where observed surveys are required to be interpolated between. The inputs include a csv timeseries file that references the relevant bathymetry file for that timestep.

2. **Time series response:** A 'timeseries' approach where the selected DEM is controlled by an input flow timeseries. Each DEM has a flow rate associated with it and based on the applied flow timeseries the DEMs can be interpolated between. This functionality does not instantly apply the interpolated bathymetry but converges towards it based on a user-supplied response rate. This allows areas that are shallower than the 'target' bathymetry to scour quickly, whereas areas that are deeper to infill at a slower rate (or vice-versa). This methodology is suitable for use-cases with a defined flow condition that influences the morphology, such as a total barrage flow timeseries for the Murray Mouth.

3. **Flux sampling response:** Rather than the flow timeseries being specified as a user input, it is sampled from within the model. This requires a specified internal model nodestring across which the flow is to be sampled. This methodology is suitable for cases where the key flow patterns driving morphological response depend on other changes within the model and are not known beforehand. This methodology would be suitable for the Murray Mouth if simulating the barrage flows within the model based on changes in water levels between the Coorong and the Lower Lakes under specified scenarios.

The region of the mesh in which the dynamic structure functionality was applied was defined by a polygon as shown in Figure 9.3. To demonstrate the updated functionality, BMT developed a database of bathymetry states for the zone, reflective of varying flow scenarios and informed by historical bathymetry surveys. These can be applied in model scenarios to represent typical areas of scour and deposition in the Murray Mouth zone.

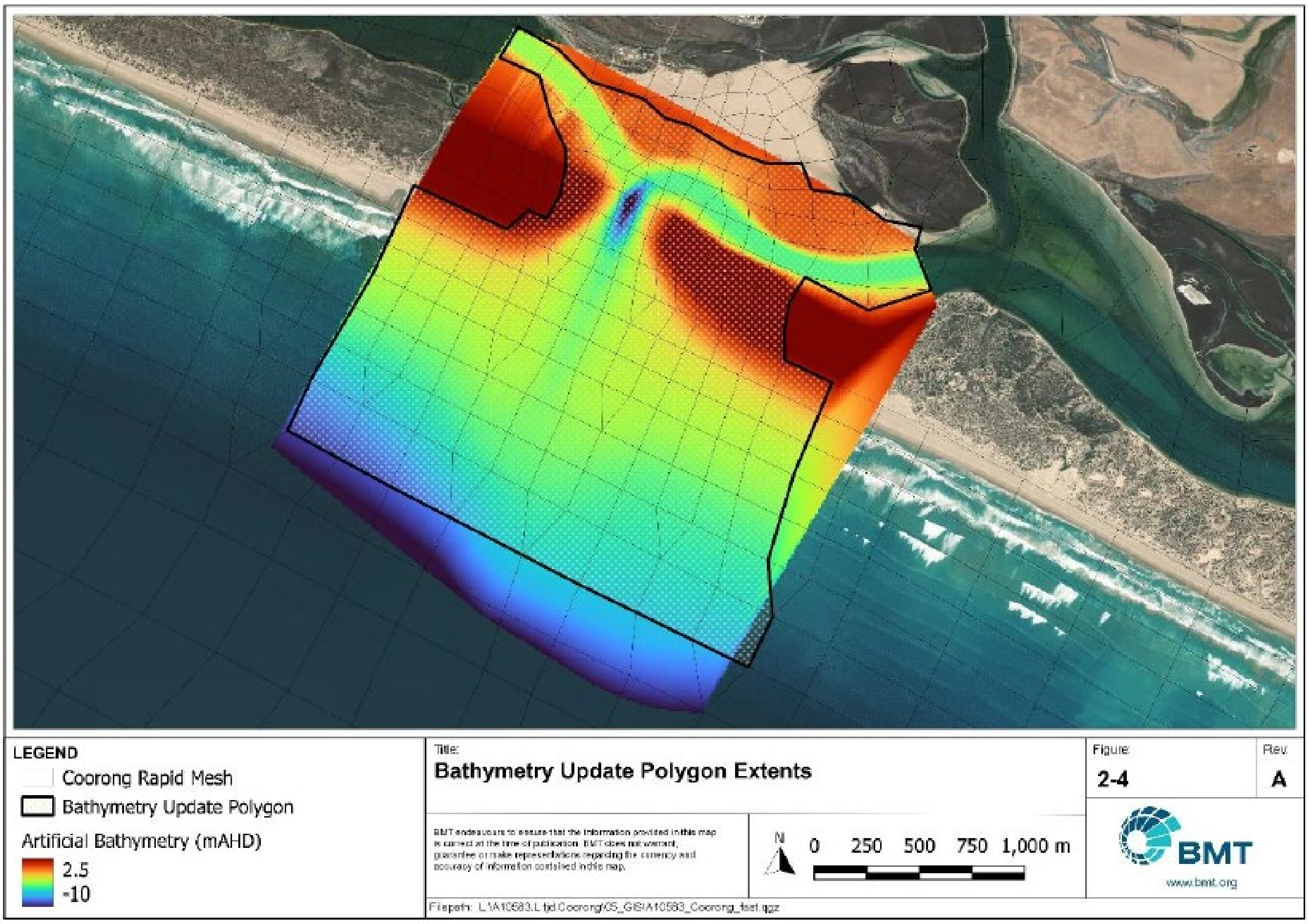


Figure 9.3. Bathymetry update polygon zone defined for dynamic structure functionality. Source: BMT, 2022

9.2.3 Coarse resolution Coorong TUFLOW-FV model

As described in BMT (2021b), a coarse Coorong TUFLOW-FV 2D hydrodynamic model was also developed, calibrated and validated by BMT under the HCHB Phase 1 for application to long-term (~30 years) scenario runs. This coarse resolution model represents the broad scale trends in water level and salinity throughout the Coorong over decadal time periods and is capable of much faster run times than the fine resolution models. The model mesh was developed based on the bathymetry from the fine resolution models, whereby the mean cell elevation was adopted based on a sample of points within each cell. Minimum elevations were instead adopted through the Parnka Narrows region to represent the conveyance between the lagoons at this natural constriction point. The initial Murray Mouth configuration was informed by a bathymetry survey from December 2017 and representative of dredged conditions. The final mesh has 2202 cells (Figure 9.1). The coarse model adopted the updated TUFLOW-FV software functionality described in Section 8.1.4.2 and the updated morphological structure developed by BMT in tandem with the model. The initial model calibration (2013 to 2016) against both the fine resolution model and observed conditions prompted two key model setting changes:

- A larger model roughness was thus adopted for the rapid model: k_s = 0.100 instead of k_s = 0.018 as per the fine resolution model.
- Due to the increased cell size of the rapid model relative to the fine resolution model, an increase to the scalar diffusivity coefficients and limits applied to the Elder scalar transport model was required. The global Horizontal Scalar Diffusivity and coefficient were set to 7000 m^2/s and 700, respectively compared to 250 m^2/s and 25 for the fine resolution model, respectively. The global horizontal scalar diffusivity lower and upper limits set for the coarse model were 1 m^2/s and 50 m^2/s whereas none were set for the fine resolution model.

The model boundary conditions were as per the fine resolution model for inflows (barrages and Salt Creek) and the offshore tidal boundary, but the meteorological boundary conditions were defined using the spatially resolved Bureau of Meteorology Atmospheric High-Resolution Regional Reanalysis for Australia (BARRA)[9] climate model, which has been sub-sampled for application to the Coorong and extends to 2019. The model was validated for the period 2010 to 2019 and full details are provided in BMT (2022b).

Following receipt of the TUFLOW-FV coarse model, DEW undertook an internal re-calibration focusing on the Murray Mouth morphology and the Parnka Narrow bathymetry (DEW, 2021, unpub.). The performance of the Murray Mouth morphology updates was assessed against the Diurnal Tide Ratio (DTR) calculations, generated from observed conditions between 2002 and 2021. The DTR is a measure of the degree of Murray Mouth openness, calculated using the 12-hour tidal signature as a ratio of the values at Tauwitchere and Victor Harbor. Initial analysis indicated that the coarse model typically over-estimated the observed DTR. The re-calibration included more constricted bathymetry, reflective of lower flow scenarios, and a slower corresponding erosion rate, both of which improved the model performance against observed DTR. Secondly, the Parnka Narrows bathymetry was re-sampled to derive higher bed elevations reflective of the natural constriction and reduced conveyance between the lagoons, the influence of which became evident following testing of initial CIIP pumping scenarios. Both 50th and 33rd percentile DEM elevation samples were tested and the 33rd percentile bathymetry configuration recommended following comparison against observed water level and salinity values. The updated calibration of the coarse model has produced a fit for purpose TUFLOW-FV model for application to long-term scenarios.

[9] http://www.bom.gov.au/research/projects/reanalysis/

10 Data and model management

The use of secure, online model and data repositories has been critical in the collaboration and consistent, version-controlled development of models and associated files including boundary conditions and T&I research component data throughout HCHB Phase 1.

10.1 CDM Git repository structure

A shared, private Git model repository (CDM) was created for UWA and DEW to collaborate and to facilitate the storage and tracking of data from various sources including the T&I research components, routine quality monitoring data, other external data provides such as the Bureau of Meteorology (BoM), and continuous monitoring and spatial data stored in DEW databases. The repository structure designed by UWA and maintained collaboratively by UWA and DEW, is shown in Figure 10.1. GitHub Desktop was used within DEW to clone a local copy of the repository and to push data up to the repository.

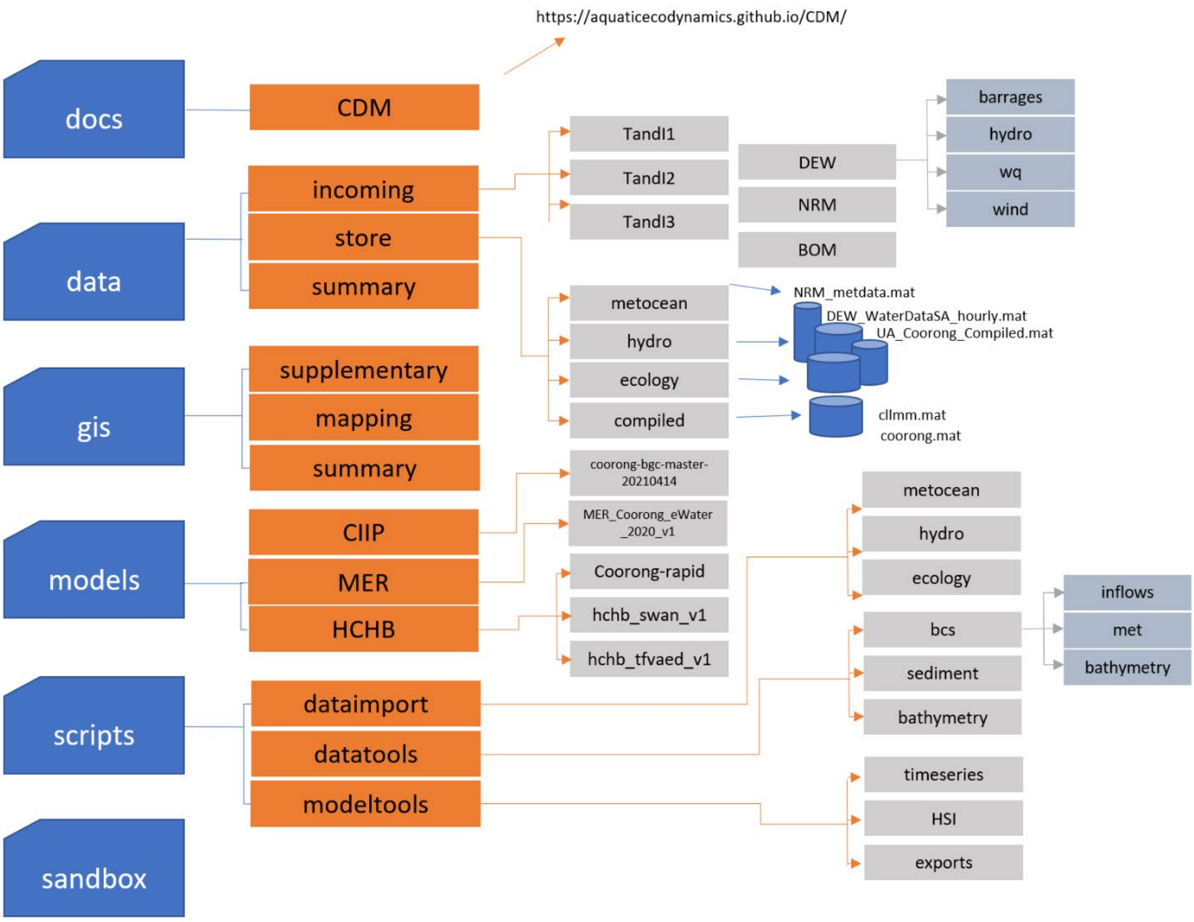


Figure 10.1. CDM model repository structure. Source: Hipsey et al. 2022

10.2 DEW BitBucket model repositories

The CDM Catalogue described in Table 9.1 is in the process of being implemented into the DEW modelling environment via dedicated model repositories housed in the Surface Water team BitBucket account. These model repositories allow for transparent, traceable, and efficient model maintenance, development, and application in tandem with a number of solutions developed under HCHB Phase 1 to store, post-process, and visualise TUFLOW-FV model outputs. GitHub Desktop is used to interact with the online cloud repositories, with local copies stored on the remote servers within the Department.

10.3 Continued model development and validation

Acknowledging the large number of TUFLOW-FV and other models produced under HCHB Phase 1, a process of model harmonisation and integration is planned for the next phases of HCHB. The intention is to:

- Derive consistent model meshes, boundary conditions and post-processing scripts and outputs,
- Identify the fit for purpose application of each model,
- Assess and integrate other specific models developed under Phase 1 including waterbird and food web models, and
- Operationalise the models in the DEW modelling workflow and utilise related solutions for running models and storing and visualising outputs.

Ongoing model development, validation and application will occur as data are collected and knowledge increases to ensure that the models represent the best available science and configuration for all applications.

11 Discussion and summary

This report has summarised the progression of the Coorong TUFLOW-FV model development from a reliable and informative hydrodynamic model to a highly accurate and significantly enhanced CDM, encompassing water quality and ecological response models to support decision-making in the HCHB Program and beyond.

As a first step towards identifying model improvements, the original DEW Coorong TUFLOW-FV fine resolution hydrodynamic model was run for a base case hindcast scenario for 1 July 2019 to 30 June 2020, to allow a comparison against a range of data, including Coorong water level and salinity data and gaugings collected at Parnka Point in 2019-20. The results show that the original model is capable of very closely reproducing the hydrodynamics of the Coorong. The model accurately captures the seasonal changes in water level and salinity, and changes on small temporal scales.

In response to key knowledge gaps identified in previous Coorong studies and model application, dedicated modelling activities were established within the T&I Integration component to progress alongside the significant body of research undertaken to address knowledge gaps, and data collected as part of T&I components. In collaboration with DEW, the UWA implemented significant improvements to extend both model functionality and the ability to represent complex and dynamic water quality, sediment biochemistry, and ecological habitat processes. The updated model was subjected to extensive model calibration and validation. The updates to the AED model have improved the representation of external and internal nutrient loads, sediment loads, nutrient fluxes and recycling, and *Ruppia* habitat suitability (UWA, 2022).

A set of scenarios focusing on changes to the key environmental management levers of barrage and Salt Creek releases run in the CDM has demonstrated the enhanced functionality and predictive capability of the CDM for a range of hydrodynamic and water quality parameters. This application of the CDM represents the first step in operationalising the significantly enhanced modelling capability developed under HCHB in the DEW modelling environment. Future scenarios will continue to test various model configurations and functionality and the application of evolving post-processing and interpretive tools will further enhance the contribution of the CDM to informing decision making and site management.

In addition to the significant enhancements made to the CDM, additional models have been developed under other projects within the HCHB Program. The CDM Catalogue comprises the fine resolution detailed CDM, a coarse or rapid Coorong TUFLOW-FV model, and additional fine resolution TUFLOW-FV models calibrated and configured for specific applications. Developed in parallel under the HCHB Program, these models will be harmonised and further updated under subsequent HCHB phases to ensure the CDM Catalogue represents the best available toolkit for assessing outcomes in the Coorong under HCHB and beyond.

The CDM has been expanded and significantly improved under various projects of HCHB Phase 1. Collectively, the CDM Catalogue delivered under HCHB Phase 1 represents a sophisticated, flexible, and powerful toolkit for quantitatively assessing the response of the system to management options and changing environmental conditions over varying spatial and temporal scales. By operationalising the CDM in the DEW modelling environment, the modelled scenarios will reduce uncertainties, fill critical knowledge gaps, and facilitate the development of an adaptive management regime to restore the Southern Coorong to the desired state.

12 Appendices

A. TUFLOW-FV control file for 2019-20 base case hindcast modelling

```
! Murray Mouth morpho response investigations
! Includes Waves & Morphology
!TIME COMANDS

!____________________________________________________

time format == ISODATE
use restart file time == 0
timestep limits == 0.1, 25.0 ! Min and Max Timesteps
display dt == 900.
cfl external == 0.9
cfl internal == 0.9

start time == 01/07/2019 00:00:00
end time == 01/07/2020 00:00:00

Hardware == GPU
Device ID == 3

! SIMULATION CONFIGURATION
!____________________________________________________
include salinity == 1,1
momentum mixing model == SMAGORINSKY
scalar mixing model == SMAGORINSKY
spatial order == 1,1
horizontal gradient limiter == LCD
bottom drag model == ks
wave parameters == 0.8, 0.1

!MODEL PARAMETERS
!____________________________________________________
display depth == 1.0e-4
stability limits == 50.,50.         ! (were much higher)
cell wet/dry depths == 1.0e-3, 1.0e-1
global horizontal eddy viscosity == 0.2
global horizontal scalar diffusivity == 0.2
g == 9.81
reference density == 1025.
latitude == -35.8
include wave stress == 0
include stokes drift == 0
echo geometry == 0

!SEDIMENT PARAMETERS
!____________________________________________________
include sediment == 0,0
!sediment control file == ../../sed_control/MM_MORPH_008_linux.sed
```

```
!GEOMETRY
!_______________________________________________________________
geometry 2d == ../../geo/Coorong_20190731with20190226_w_AllNS_1_Renumbered.2dm ! New mesh modified by
MG from 31-07-2019 to open MM with NS at all monitoring sites, nodes re-numbered
!Cell elevation file == ../../surveys/CI_006_Z_IC_20130507.txt

material == 1  ! sand
  bottom roughness == 0.05
end material
material == 2  ! super high density at boundaries
  bottom roughness == 1.0
  horizontal eddy viscosity == 1.0
  spatial reconstruction == 0
end material
material == 3  ! Coorong Channels
  bottom roughness == 0.001
end material
material == 4  ! Upstream of Barrages
  bottom roughness == 1.0
  Bed elevation limits == 5,5
  spatial reconstruction == 0
end material

!three conservative tracers, one for barrage inflow, one for ocean inflow and one for SE inflows
NTracer == 3

Tracer == 1
End tracer

Tracer == 2
End tracer

Tracer == 3
End tracer

!BOUNDARY CONDITIONS
!_______________________________________________________________

include == ../../bc/BC_Base_002_extended_3Tracers.fvi
include == ../../bc/BarrageCalculator_3Tracers.fvi

!bc == wave_coupled, ../../../SWAN/input/SWAN_DESI_20130507_20131015.swn
!  sub-type == 2
!end bc

!INITIAL CONDITIONS
!_______________________________________________________________

initial condition 2d == ../../surveys/Initcons2019.txt

!OUTPUT COMMANDS
!_______________________________________________________________
```

```
output dir == ../../output/

output == netcdf
        output parameters == h,d,sal,v,TRACE_1,TRACE_2,TRACE_3
        output interval == 86400
end output

Output == points
        Output points file == ../../geo/points/CLLMM_Gauges_2006_2008_POINTS_updated.csv
        Output parameters == H,sal,TRACE_1,TRACE_2,TRACE_3
        Output interval == 86400
end output

output == flux
output interval == 86400
end output

!write restart dt == 24.0
```

B. Boundary condition file – 2019-20 base case hindcast modelling

```
!BC_Base

! Wind
bc == W10, atmos/Wind_20190701_20191231.csv
            bc header == TIME, W10_X, W10_Y
end bc

! MSLP attempt at csv
! bc == MSLP, atmos/MSLP_20190701_20191231.csv
!  bc header == TIME, MSLP_hPa
!end bc

! MSLP_Grid from template
!grid definition file == atmos/MSLP_20121101_20160901.nc
!  grid definition variables == utm_x, utm_y
!  grid definition label == mslp
!end grid

!bc == MSLP_GRID, mslp, atmos/MSLP_20121101_20160901.nc
!  bc header == time,mslp
!  bc update dt == 3600.
!  bc scale == 0.01
!  bc time units == hours
!  bc reference time == 01/01/1990 00:00
!end bc

! Evaporation
bc == QG, atmos/NetEvap_20190701_20191231.csv
   bc header == TIME,Net_evap_m_per_s,zeros,tracer1,tracer2,tracer3
            bc default == 0, 0, 0, 0, 0,0
            bc scale == -1.09, 0
            sub-type == 2 ! sub-type == 2 flow is applied as a source term, distributed across a nodestring by cell
width
                                                  ! Note: BC is specified as a reflective wall with a source distributed along the
internal boundary cell
end bc

! Tide
bc == WL, 5, tide/Tide_20190101_20200731.csv
  sub-type == 1 ! sub-type == 1 flows is applied as a flux and distributed across a nodestring by cell width
  bc header==  TIME,H,Sal,tracer1,tracer2,tracer3
  BC default == 0,35,0,1,0
end bc

! Open boundaries - shorenormal offshore ......
bc == WL, 4, tide/lateral_boundaries_extended.csv !4 = nodestring specified boundary
  bc header==  TIME,zeros,Sal,tracer1,tracer2, tracer3
  BC default == 0,35,0,1,0,0
end bc

bc == WL, 6, tide/lateral_boundaries_extended.csv !2 = nodestring specified boundary
```

```
  bc header==  TIME,zeros,Sal,tracer1,tracer2, tracer3
  BC default == 0,35,0,1,0,0
end bc

! Inflows
bc == QC,  377253,6000600, catchment/Salt_creek_inflow_toJul2020.csv !377253,6000600 means BC is applied to the cell that this co-ordinate falls within (Salt Creek)
  bc header== TIME,Q,Sal,tracer1,tracer2,tracer3
        BC default == 0, 0, 0, 0, 1
end bc
```

C. Barrage boundary file – 2019-20 base case hindcast modelling

```
! Base Barrage
! Goolwa barrage
bc == Q, 7, barrage/BarrageFlowCalculator_04August2020.csv
        sub-type == 2
        bc header== Time,Q_Goolwa,Sal,tracer1,tracer2,tracer3
        BC default == 0, 0, 1, 0, 0
        bc scale== 1, 1, 1, 1, 1
end bc

! Mundoo barrage
bc == Q, 8, barrage/BarrageFlowCalculator_04August2020.csv
        sub-type == 2
        bc header== Time,Q_Mundoo,Sal,tracer1,tracer2,tracer3
        BC default == 0, 0, 1, 0, 0
        bc scale== 1, 1, 1, 1, 1
end bc

! Ewe_Isl barrage
bc == Q, 9, barrage/BarrageFlowCalculator_04August2020.csv
        sub-type == 2
        bc header== Time,Q_EweIs,Sal,tracer1,tracer2,tracer3
        BC default == 0, 0, 1, 0, 0
        bc scale== 1, 1, 1, 1, 1
end bc

! Tauwitchere barrage
bc == Q, 3, barrage/BarrageFlowCalculator_04August2020.csv
        sub-type == 2
        bc header== Time,Q_Tauwitchere,Sal,tracer1,tracer2,tracer3
        BC default == 0, 0, 1, 0, 0
        bc scale== 1, 1, 1, 1, 1
end bc
```

D. Salinity equation: EC to TDS

The Total Dissolved Solids (TDS) from EC equation agreed between DEW and SA Water for universal adoption across surface water sites in the DEW database for all instances of the parameter **TDS from EC.Calculated from Corrected EC** and other reporting is shown in Equation 1. This equation reflects updated field data collected under HCHB and is consistent with prior Australian Water Quality Centre analysis.

$$TDS\ (in\ mg/L) = 0.548(EC) + 2.2 \times 10^{-6}(EC)^2 - 2.06 \times 10^{-12}(EC)^3$$

Where EC = EC corrected uS/cm @ 25°C

E. TUFLOW-FV control file for CDM base case scenario modelling

```
! Coorong BGC Model
!_______________________________________________________

 Hardware == GPU

! GIS
!_______________________________________________________
GIS format == shp
shp projection == ../../model/gis/shp/projection.prj
GIS Projection Check == WARNING

! TIME COMANDS
!_______________________________________________________
time format == ISODATE
start time == 01/07/2017 00:00:00
end time ==  01/01/2022 00:00:00

timestep limits == 0.1, 15
display dt == 3600.
cfl external == 0.9
cfl internal == 0.9

! SIMULATION CONFIGURATION
!_______________________________________________________
include salinity == 1,1
include temperature == 1,1
include sediment == 0,0
spatial order == 1,2
horizontal gradient limiter == LCD
vertical gradient limiter == MC
bottom drag model == ks
equation of state == UNESCO

water quality model == EXTERNAL
external water quality model dir == ../../external/AED/
```

```
! MODEL PARAMETERS
!_______________________________________________________________
stability limits == 100.,500.
cell wet/dry depths == 4.0e-2, 4.0e-2
g == 9.81
reference density == 1025.
latitude == -35.8
Wind Stress Params == 0., 0.8E-03, 50., 4.05E-03

! HEAT PARAMETERS
!_______________________________________________________________
include heat == 1,0
LONGWAVERADIATIONMODEL == 3
Shortwave radiation albedo == 0.05
Shortwave radiation fractions == 0.500, 0.463, 0.036, 0.001
Shortwave radiation extinction coefficients == 2.0, 1.2, 2.0, 2.5
Bulk Latent Heat Coefficient == 1.3e-3 ! Default 1.3e-3

! TURBULENCE PARAMETERS
!_______________________________________________________________
momentum mixing model == SMAGORINSKY
scalar mixing model == ELDER
vertical mixing model == external
external turbulence model dir == ../../external/GOTM/
global horizontal eddy viscosity == 0.2
global horizontal scalar diffusivity == 250.0,25.0

! TRACER PARAMETERS
!_______________________________________________________________
Ntracer == 5
tracer == 1 ! Initial CSL passive tracer - initial concentration 100 in CSL
end tracer
tracer == 2 ! Ocean water passive tracer - concentration 100 at ocean boundaries including pump connections
end tracer
tracer == 3 ! Barrage flow passive tracer - concentration 100 in barrage flow
end tracer
tracer == 4 ! Salt Creek passive tracer - concentration 100 in salt creek flow
end tracer
tracer == 5 ! Water age passive tracer - initial concentration 0 and all inflow concentrations 0
  water age == 1
end tracer

! GEOMETRY
!_______________________________________________________________
geometry 2d == ../../model/geo/mesh/CoorongBGC_mesh_000.2dm
echo geometry == 1

Read GIS Nodestring == ../../model/gis/shp/2d_ns_CoorongBGC_000_L.shp

!Read GIS Mat == ../../model/gis/shp/2d_mat_CoorongBGC_001_R.shp
!include == ../../model/material/Coorong_BGC_materials_001.fvm
Read GIS Mat == ../../model/gis/shp/31_material_zones.shp
include == ../../model/material/Material_Roughness_z31.fvc
```

```
! STRUCTURES
!______________________________________________________________
structure logging == 0

! BOUNDARY CONDITIONS
!______________________________________________________________

include == .\include\flows_basecase.fvc
include == .\include\met.fvc

!! Wave model
!!
!grid definition file ==
/Projects2/CDM/Coorong_swn_20170101_20220101_UA_Wind_200g_2000w/04_results/WAVE.nc
!grid definition variables == x,y
!grid definition label == SWAN_waves_regional
!ENDGRID
!bc == Wave, SWAN_waves_regional,
/Projects2/CDM/Coorong_swn_20170101_20220101_UA_Wind_200g_2000w/04_results/WAVE.nc
!  bc header == time,hs,tps,thetap
!  bc reference time == 01/01/1970 00:00
!  bc time units == seconds
!end bc

! INITIAL CONDITIONS
!______________________________________________________________
Initial Condition 2D == ../../BC/Initial/init_conditions_20170701_GEN15_DON3.csv

! OUTPUT COMMANDS
!______________________________________________________________
include == .\include\output_basecase.fvc

!Write Check Files  == ./log/check/
```

F. Aed.nml for CDM base case scenario modelling

```
!
! solution_method     (1: Euler's Method)
! link_bottom_drag    (T/F: AED variables included/excluded in TFV bottom drag)
! link_surface_drag   (T/F: AED variables included/excluded in TFV surface drag)
! link_water_density  (T/F: AED variables included/excluded in TFV density calculation)
! link_water_clarity  (T/F: AED variables included/excluded in TFV light extinction)
! base_par_extinction (Kw; /m)
! ext_tss_extinction  (T/F: TFV SS concs included/excluded in Kd calculation)
!
&aed_bio
   !-- AED configuration flags
   solution_method =  1
   do_limiter      = .true.
   display_minmax  = .false.
 ! display_cellid  = 1000
 ! do_2d_atm_flux  = .true.
 ! do_particle_bgc = .false.
   glob_min = -1e38
   glob_max =  1e38
   min_water_depth =  0.0401
   n_equil_substep = 12
   !-- Linkages with host model: PHYSICS
   link_bottom_drag = .false.
   link_surface_drag = .false.
   link_water_density = .false.
   link_wave_stress = .true.
   !-- Linkages with host model: LIGHT
   link_ext_par = .false.
   link_water_clarity = .false.
   base_par_extinction = 0.2
   ext_tss_extinction = .false.
   tss_par_extinction = 0.02
   !-- Linkages with host model: RIPARIAN
   link_solar_shade = .false.
   link_rain_loss = .false.
   !-- Benthic variable initialisation
   init_values_file = '../../external/AED/AED_IC_OMfrac_MPB.csv'
!   route_table_file = '../../external/AED/Routing_Tbl.csv'
/

!-------------------------------------------------------------------------------
! aed_models  :  List of AED modules to be simulated
!-------------------------------------------------------------------------------
!
! List here the available aed modules to be included in the simulation.
!       It is important they are listed in the correct order so dependencies
!       can be set during the model set-up phase.
!
! For further detail about available AED modules visit:
!       http://aquatic.science.uwa.edu.au/research/models/AED/
!
```

```
! NOTE: This example only includes CORE modules without all values and options
!       configured. Refer to the web-links for summary tables of modules
!       parameters, and refer to AED+ documentation for details of
!       configuration of the PLUS modules.
!
!-------------------------------------------------------------------------------
&aed_models
   models =
      !-->  NUTRIENT/CHEMISTRY modules  <--!
           'aed_sedflux',
           'aed_macrophyte',
           'aed_noncohesive',
           'aed_tracer',
           'aed_oxygen',
       !off 'aed_carbon',
           'aed_silica',
           'aed_nitrogen',
           'aed_phosphorus',
           'aed_organic_matter',
       !off 'aed_seddiagenesis',
       !off 'aed_geochemistry',
      !-->  BIOLOGY modules  <--!
           'aed_phytoplankton',
           'aed_macroalgae2',
      !     'aed_habitat_benthic'
       !off 'aed_geochemistry',
       !off 'aed_zooplankton',
       !off 'aed_bivalve',
       !off 'aed_macrophyte',
       !off 'aed_pathogens',
      !-->  RIPARIAN modules  <--!
       !off 'aed_land',
       !off 'aed_ass',
       !off 'aed_vegetation',
      !-->  SUMMARY modules  <--!
           'aed_totals',
       !   'aed_seddiagenesis:za',
       !   'aed_test:za',
/

!###############################################################################
! SDF: aed_sedflux - AED sedflux interface module
!
! If TFV is host, this allows spatially variable fluxes, based on Materials
!
!-------------------------------------------------------------------------------
&aed_sedflux
  sedflux_model = 'Constant2D'
!   sedflux_model = 'dynamic2d'
/
&aed_sed_const2d
n_zones = 31    ! check match to TFV material zones
active_zones = 11,12,13,21,22,23,31,32,33,41,42,43,51,52,53,61,62,63,71,72,73,81,82,83,91,92,93,101,102,103,104
```

```
Fsed_oxy = -8.4,-43.2,-8.4,-6.24,-23.2,-8.4,-27.88,-47.6,-8.4,-0.24,-57.6,-0.24,-45.8,-57.6,0,-6.6,-63.52,-6.6,-6.6,-22.2,-6.6,-6.6,-40.24,-6.6,-0.12,-40.24,-0.12,-42.04,-43.68,-22.04,0
Fsed_rsi = -1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10,-1.0e+10
Fsed_amm =
10.4554,18.1749,10.4554,9.7385,17.2183,9.9051,12.2313,15.1251,9.3549,8.2450,16.2926,8.2450,5.4257,6.0943,-2.2500,5.0640,9.3408,5.0640,5.0640,5.6880,5.0640,5.0640,7.2096,5.0640,4.8048,7.2096,4.8048,4.8816,5.3472,4.8816,4.8000
Fsed_nit = -0.0057,-0.0136,-0.0057,-0.0055,-0.0136,-0.0057,-0.0090,-0.0123,-0.0057,-0.0050,-0.0148,-0.0050,-0.0097,-0.0148,-0.0060,-0.0056,-0.0145,-0.0056,-0.0056,-0.0069,-0.0056,-0.0056,-0.0100,-0.0056,-0.0050,-0.0100,-0.0050,-0.0052,-0.0061,-0.0052,-0.0050
Fsed_frp = 0.1231,0.5441,0.1231,0.1127,0.3401,0.1231,0.3135,0.4525,0.7231,0.0838,0.3248,0.0838,0.1231,0.1567,-0.0640,0.1145,0.3149,0.1145,0.0640,0.0844,0.0640,0.0640,0.0844,0.0640,0.0647,0.0664,0.0647,0.0719,0.1155,0.0719,0.0643
Fsed_pon =
0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000
Fsed_don =
0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000
Fsed_pop =
0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000
Fsed_dop =
0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000
Fsed_poc =
0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000
Fsed_doc =
0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000
Fsed_dic =
0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000,0.0000
/

!-------------------------------------------------------------------------------
!###############################################################################
! aed_macrophyte - AED macrophyte model
!-------------------------------------------------------------------------------
&aed_macrophyte
   num_mphy = 1
   the_mphy = 3
   n_zones  = 20
   active_zones = 11,13,21,23,31,33,41,43,51,53,61,63,71,73,81,83,91,93,101,103
   simStaticBiomass = .true.
   simMacFeedback = .false.
   dbase = '../../external/AED/aed_macrophyte_pars.nml'
/

!###############################################################################
```

```
! TRC: aed_noncohesive
!
! Refer to the below link for module settings & parameter details:
! http://aquatic.science.uwa.edu.au/research/models/AED/aed_tracer.html
!
!-------------------------------------------------------------------------------
&aed_noncohesive
  !-- Select SS groups and their properties !SS1: clay < 2 microns; SS2: silt 2-50 microns; SS3: sand 50-2000
microns
   num_ss     = 3
   ss_initial = 1,1,1
   Ke_ss      = 0.063,0.06,0.057
  !-- Configure sediment resuspension
   settling   = 1
   w_ss       = -0.06,-2.825,-135.13
   d_ss       = 2e-6,1e-5,6e-5
   rho_ss     = 1.5e3,1.6e3,1.8e3
  !-- Configure sediment resuspension
   resuspension       = 2
   epsilon            = 0.02
   tau_0              = 0.05,0.15,0.50 !0.01,0.015,0.0212
   tau_r              = 1.0
   Ktau_0             = 0.000
   macrophyte_link_var = 'MAC_ruppia'
  !-- Configure sediment mass
   simSedimentMass      = .true.
   fs                   = 0.36,0.05,0.59
   sed_porosity         = 0.6
/

!###############################################################################
! TRC: aed_tracer
!
! Refer to the below link for module settings & parameter details:
! http://aquatic.science.uwa.edu.au/research/models/AED/aed_tracer.html
!
!-------------------------------------------------------------------------------
&aed_tracer
  !-- Optional retention time tracer
   retention_time = .true.
  !-- Select number of tracers and their decay/sedflux/light properties
   num_tracers = 0
   decay = 0,0
   Fsed = 0,0
/

!###############################################################################
! OXY: aed_oxygen - AED oxygen model
!
! Refer to the below link for module settings & parameter details:
! http://aquatic.science.uwa.edu.au/research/models/AED/aed_oxygen.html
!
!-------------------------------------------------------------------------------
```

```
&aed_oxygen
   oxy_initial       = 225.0
   Fsed_oxy          = -40.0
   Ksed_oxy          = 100.0
   theta_sed_oxy     =   1.08
   Fsed_oxy_variable = 'SDF_Fsed_oxy'
   oxy_min           = 0
   oxy_max           = 500
  !diag_level        = 1
/

!###############################################################################
! CAR: aed_carbon - AED carbon model
!
! Refer to the below link for module settings & parameter details:
! http://aquatic.science.uwa.edu.au/research/models/AED/aed_nutrient.html
!
!-------------------------------------------------------------------------------
&aed_carbon
   !-- DIC & pH
    dic_initial = 1600.5
    Fsed_dic = 14.0
    Ksed_dic = 20.0
    theta_sed_dic = 1.08
   !Fsed_dic_variable='Fsed_dic'
    pH_initial = 7.5
    atmco2 = 390e-6
    co2_model = 1
    alk_mode = 1
    ionic = 0.1
    co2_piston_model = 1
   !-- CH4
    ch4_initial = 27.6
    Rch4ox = 0.01
    Kch4ox = 0.5
    vTch4ox = 1.08
    Fsed_ch4 = 0.5
    Ksed_ch4 = 100.0
    theta_sed_ch4 = 1.08
    methane_reactant_variable = 'OXY_oxy'
   !Fsed_ch4_variable = 'Fsed_ch4'
    atm_ch4 = 1.76e-6    !atm
    ch4_piston_model = 1
/

!###############################################################################
! SIL: aed_silica
!
! Refer to the below link for module settings & parameter details:
! http://aquatic.science.uwa.edu.au/research/models/AED/aed_nutrient.html
!
!-------------------------------------------------------------------------------
&aed_silica
```

```
  rsi_initial = 12.5
  Fsed_rsi = 0.
  Ksed_rsi = 50.0
  theta_sed_rsi = 1.08
  silica_reactant_variable='OXY_oxy'
 !Fsed_rsi_variable = 'SDF_Fsed_rsi'
/

!###############################################################################
! NIT: aed_nitrogen - AED nitrogen model
!
! Refer to the below link for module settings & parameter details:
! http://aquatic.science.uwa.edu.au/research/models/AED/aed_nutrient.html
!
!-------------------------------------------------------------------------------
&aed_nitrogen
 !-- Initial values
  amm_initial      = 12.7
  nit_initial      = 23.5
  n2o_initial      = 23.5
 !-- Nitrification
  Rnitrif          =  0.1
  Knitrif          = 78.1
  theta_nitrif     =  1.08
  nitrif_reactant_variable = 'OXY_oxy'
  simNitrfSal      = .true.
  simNitrfpH       = .false.
  nitrif_ph_variable = ''
  Rnh4o2           = 0.000001
  Rno2o2           = 0.000001
 !-- N2O reactions
  simN2O           = 0
  Rn2o             = 0.05
  Kpart_ammox      = 1.0
  Kin_deamm        = 1.0
  atm_n2o          = 0.32e-6    ! atm
  n2o_piston_model = 4
 !-- Annamox
  Rnh4no2          = 0.000001
  kanammox         = 0.001
  Kanmx_nit        = 2.0
  Kanmx_amm        = 2.0
 !-- De-nitrification
  Rdenit           = 0.26
  Kdenit           = 2.0
  theta_denit      = 1.08
  Rdnra            = 0.01
  Kdnra_oxy        = 2.0
 !-- Sediment fluxes
  Fsed_amm         =   3.5
  Ksed_amm         =  25.0
  Fsed_nit         =  -4.5
  Ksed_nit         = 100.0
```

```
   Fsed_n2o        =   0.0
   Ksed_n2o        = 100.0
   theta_sed_amm     = 1.08
   theta_sed_nit    = 1.08
   Fsed_amm_variable='SDF_Fsed_amm'
   Fsed_nit_variable='SDF_Fsed_nit'
  !Fsed_n2o_variable='SDF_Fsed_n2o'
  !-- Atmospheric deposition
   simDryDeposition = .false.
   atm_din_dd       = 0.05
   simWetDeposition = .true.
   atm_din_conc     = 1.6
/

!###############################################################################
! PHS: aed_phosphorus - AED phosphorus model
!
! Refer to the below link for module settings & parameter details:
! http://aquatic.science.uwa.edu.au/research/models/AED/aed_nutrient.html
!
!-------------------------------------------------------------------------------
&aed_phosphorus
  !-- Initial value
   frp_initial = 0.29
  !-- Sediment flux
   Fsed_frp = 0.08
   Ksed_frp = 80.0
   theta_sed_frp = 1.08
   phosphorus_reactant_variable ='OXY_oxy'
   Fsed_frp_variable ='SDF_Fsed_frp'
  !-- PO4 adsorption
   simPO4Adsorption = .true.
   ads_use_external_tss = .false.
   po4sorption_target_variable ='NCS_ss1'
   PO4AdsorptionModel = 1
   Kpo4p = 0.1
   ads_use_pH = .false.
   Kadsratio= 1.0
   Qmax = 1.0
   w_po4ads = -9999     ! Note: -9999 links PO4-ad settling to target_variable
  !-- Atmospheric deposition
   simDryDeposition = .false.
   atm_pip_dd = 0.00
   simWetDeposition = .true.
   atm_frp_conc = 0.10
/


!###############################################################################
! OGM: aed_organic_matter - AED organic matter model
!
! Refer to the below link for module settings & parameter details:
! http://aquatic.science.uwa.edu.au/research/models/AED/aed_organic_matter.html
```

```
!
!-------------------------------------------------------------------------------
&aed_organic_matter
  !-- Initial concentrations for OM variables (mmol/m3)
    poc_initial  =  78.5
    doc_initial  =  39.9
    pon_initial  =   8.3
    don_initial  =   1.3
    pop_initial  =   8.3
    dop_initial  =   1.5
    docr_initial = 350.0
    donr_initial =  13.0
    dopr_initial =   3.0
    cpom_initial = 100.0
  !-- Breakdown and mineralisation (basic pool)
    Rpoc_hydrol  =   0.005
 !-off   Rdoc_minerl  =   0.001
    Rdom_minerl  =   0.0015
    Rpon_hydrol  =   0.005
 !-off   Rdon_minerl  =   0.005
    Rpop_hydrol  =   0.005
 !-off   Rdop_minerl  =   0.001
    theta_hydrol =   1.08
    theta_minerl =   1.08
    Kpom_hydrol  =  31.25
    Kdom_minerl  =  31.25
    simDenitrification = 1
    dom_miner_oxy_reactant_var = 'OXY_oxy'
   !dom_miner_no2_reactant_var = 'NIT_no2'
   !dom_miner_n2o_reactant_var = 'NIT_n2o'
   !dom_miner_fe3_reactant_var = 'GEO_feiii'
   !dom_miner_so4_reactant_var = 'GEO_so4'
   !dom_miner_ch4_reactant_var = 'CAR_ch4'
    doc_miner_product_variable = ''
    don_miner_product_variable = 'NIT_amm'
    dop_miner_product_variable = 'PHS_frp'
    dom_miner_nit_reactant_var = 'NIT_nit'
    f_an = 1.
    K_nit            = 10.0
   !Kin_denitrat       = 20.0
   !Kin_denitrit       =  0.297
   !Kin_denitrous      =  0.205
   !Klim_denitrit      =  1
   !Klim_denitrous     =  1
   !Kpart_denitrit     =  1
  !-- Refractory organic matter (optional)
    simRPools    = .false.
    Rdomr_minerl = 0.0001
    Rcpom_bdown  = 0.0001
    X_cpom_n     = 0.0005
    X_cpom_p     = 0.0001
  !-- Light related parameters
    KeDOM        = 0.000005
```

```
  KePOM        = 0.00096
  KeDOMR       = 0.10000   ! = 1 (assuming KeDOMR is applied to CDOM in /m)
  KeCPOM       = 0.00096   ! = 0.08 (/m)/(mg/L)  /83.3  (mmol/m3)/(mg/L)
  simphotolysis = .false.   ! .true.
 !photo_fmin
  photo_c      = 0.75
!-- Particle settling parameters
  settling     =  1 !3
  w_pom        = -0.02
  d_pom        =  1e-5
  rho_pom      = 1.2e3
  w_cpom       = -0.01
  d_cpom       =  1e-5
  rho_cpom     = 1.4e3
!-- Sediment interaction parameters (basic model)
  resuspension = 2
  resus_link   = 'NCS_resus'
  sedimentOMfrac = 0.0245
  Xsc = 0.5
  Xsn = 0.05
  Xsp = 0.005
  Fsed_doc = 0.0
  Fsed_don = 0.0
  Fsed_dop = 0.0
  Ksed_dom = 80
  theta_sed_dom = 1.08
 ! Fsed_poc_variable = 'SDF_Fsed_poc'
 ! Fsed_pon_variable = 'SDF_Fsed_pon'
 ! Fsed_pop_variable = 'SDF_Fsed_pop'
          Fsed_doc_variable = 'SDF_Fsed_doc'
  Fsed_don_variable = 'SDF_Fsed_don'
  Fsed_dop_variable = 'SDF_Fsed_dop'
!-- DOM Flocculation
 simFlocculation = 1
 Rdom_floc = 0.001
 Kdom_floc = 500
 dom_floc0 = 1500 !DOC conc where floc kicks in
 dom_flocS = 50   !Salinity KSal
          !-- Other options
 extra_diag = .true. !.true.
 diag_level = 10
/


!-------------------------------------------------------------------------------
!###############################################################################
! aed_phytoplankton - AED phytoplankton model
!-------------------------------------------------------------------------------
&aed_phytoplankton
!-- Configure phytoplankton groups to simulate
  num_phytos = 4
  the_phytos = 1,2,3,4
```

```
  settling =   1,1,1,1
!-- Benthic phytoplankton group (microphytobenthos)
  do_mpb = 1
  R_mpbg = 1.5
  R_mpbr = 0.15
  I_Kmpb = 100.
  mpb_max = 3600.
  resuspension = 0.0,0.0,0.5,0.0 !0.45   to be check
  resus_link   = 'NCS_resus'
  n_zones = 20
  active_zones = 11,13,21,23,31,33,41,43,51,53,61,63,71,73,81,83,91,93,101,103
!-- Set link variables to other modules
  p_excretion_target_variable='OGM_dop'
  n_excretion_target_variable='OGM_don'
  c_excretion_target_variable='OGM_doc'
  si_excretion_target_variable=''
  p_mortality_target_variable='OGM_pop'
  n_mortality_target_variable='OGM_pon'
  c_mortality_target_variable='OGM_poc'
  si_mortality_target_variable=''
  p1_uptake_target_variable='PHS_frp'
  n1_uptake_target_variable='NIT_nit'
  n2_uptake_target_variable='NIT_amm'
  si_uptake_target_variable='SIL_rsi'
  do_uptake_target_variable='OXY_oxy'
  c_uptake_target_variable=''
!-- General options
! dbase = '../../external/AED/aed_phyto_pars_4PFTs.nml'
 dbase = '../../external/AED/aed_phyto_pars_noCom.csv'
 extra_diag = .false.
 !zerolimitfudgefactor = ??
  min_rho = 900.
  max_rho = 1200.
/
!-------------------------------------------------------------------------------
!###############################################################################
! aed_macroalgae - AED phytoplankton model
!-------------------------------------------------------------------------------
&aed_macroalgae
   num_malgae = 1
   the_malgae = 1
   settling =   5
   slough_stress = 0.5
   n_zones = 20
   active_zones = 11,13,21,23,31,33,41,43,51,53,61,63,71,73,81,83,91,93,101,103
   p_excretion_target_variable='OGM_dop'
   n_excretion_target_variable='OGM_don'
   c_excretion_target_variable='OGM_doc'
   si_excretion_target_variable='SIL_rsi'
   p_mortality_target_variable='OGM_pop'
   n_mortality_target_variable='OGM_pon'
   c_mortality_target_variable='OGM_poc'
   si_mortality_target_variable=''
```

```
  p1_uptake_target_variable='PHS_frp'
  n1_uptake_target_variable='NIT_nit'
  n2_uptake_target_variable='NIT_amm'
  si_uptake_target_variable='SIL_rsi'
  do_uptake_target_variable='OXY_oxy'
  c_uptake_target_variable=''
  simMalgHSI = 1
  extra_debug = .true.
  dbase = '../../external/AED/aed_malgae_pars.nml'
/


!&aed_macroalgae
!   num_malgae = 1
!   the_malgae = 1
!   settling =   5
!   slough_stress = 0.5
!   n_zones = 5
!   active_zones = 1,2,3,4,5
!  !-- benthic sloughing & detachment
!   simSloughing    = 0                    ! CGM sloughing based on decay
!   slough_stress   = -1.5                 ! CGM trigger value for sloughing
!   resuspension    = 0.01                 ! rate of detachment
!   tau_0           = 0.1                  ! critical stress for detachment
!  !-- macroalgae feedback & linking setup
!   simMalgFeedback = .true.
!   p_excretion_target_variable ='OGM_dop'
!   n_excretion_target_variable ='OGM_don'
!   c_excretion_target_variable ='OGM_doc'
!   p_mortality_target_variable ='OGM_pop'
!   n_mortality_target_variable ='OGM_pon'
!   c_mortality_target_variable ='OGM_poc'
!   p1_uptake_target_variable   ='PHS_frp'
!   n1_uptake_target_variable   ='NIT_nit'
!   n2_uptake_target_variable   ='NIT_amm'
!   do_uptake_target_variable   ='OXY_oxy'
!   c_uptake_target_variable    ='' !CAR_dic
!  !-- advanced settings
!   simMalgHSI      = 1
!   dtlim           = 900
!   diag_level      = 10
!   dbase = '../../external/AED/aed_malgae_pars.nml'
!/


!###############################################################################
! HAB: aed_habitat - AED habitat index models
!
! Refer to the below link for module settings & parameter details:
! http://aquatic.science.uwa.edu.au/research/models/AED/aed_habitat.html
!
!-------------------------------------------------------------------------------
&aed_habitat_benthic
```

```
    simRuppiaHabitat  = .true.
    extra_diag        = .true.
    rhsi_falg_link  = 'MA2_ulva_ben'
    rhsi_salg_link  = 'MA2_ulva'
/


!###############################################################################
! aed_totals
!-------------------------------------------------------------------------------
&aed_totals
   TN_vars =  'NIT_nit',
           'NIT_amm',
           'OGM_don',
           'OGM_pon',
           'PHY_grn',
                                'PHY_crypt',
                                'PHY_diatom',
                                'PHY_dino'
   TN_varscale = 1.0, 1.0, 1.0, 1.0, 0.15, 0.15, 0.15, 0.15
   TP_vars =  'PHS_frp',
           !'PHS_frp_ads',
           'OGM_dop',
           'OGM_pop',
           'PHY_grn',
                                'PHY_crypt',
                                'PHY_diatom',
                                'PHY_dino'
   TP_varscale = 1.0, 1.0, 1.0, 0.01, 0.01, 0.01, 0.01
   TOC_vars = 'OGM_doc',
           'OGM_poc',
           'PHY_grn',
                                'PHY_crypt',
                                'PHY_diatom',
                                'PHY_dino'
   TOC_varscale = 1.0, 1.0, 1.0, 1.0, 1.0, 1.0
   TSS_vars = 'NCS_ss1',
           'NCS_ss2',
           'NCS_ss3',
           'OGM_poc',
           'PHY_grn',
                                'PHY_crypt',
                                'PHY_diatom',
                                'PHY_dino'
   TSS_varscale = 1,1,1,0.1,0.1,0.1,0.1,0.1       !,  <vector same length as TSS names>
   !TSS_varscale = 1,1,1,0.024,0.024          !,  <vector same length as TSS names>
   Turb_vars = 'NCS_ss1',
            'NCS_ss2',
            'NCS_ss3',
                                 'OGM_poc',
            'PHY_grn',
                                 'PHY_crypt',
                                 'PHY_diatom',
```

```
                                 'PHY_dino'     !, .... ! Matt
   Turb_varscale = 1,1,1,0.024,0.024,0.024,0.024,0.024
/


!###############################################################################
! aed_sed_candi
!-------------------------------------------------------------------------------
&aed_sediment
   sediment_model = 'DYNAMIC'
/

&aed_sed_candi
  !-- Time things --!
   spinup_days = 20
   driver_dt   = 900     ! 3600
   substep     = 8       ! 0.25 ! 94 works
  !-- Zones details  --!
   n_zones = 8
   active_zones =  1,3,4,6,7,8,30,31  ! Material zones to be activated
 ! zone_types   =  1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1   ! Sediment "type" in each
  !-- General setup options  --!
   dbase        = '../../external/AED/aed_candi_params.csv'    ! tuflow version
   vars_files   = '../../external/AED/sdg_vars.csv'           ! tuflow version
   geochem_file = '../../external/AED/aed_geochem_pars.dat'    ! tuflow version
  !-- Boundary Conditions  --!
   swibc_mode    = 0   ! previously ibc2
   deepbc_mode   = 1   ! previously ibbc
   swibc_file    = '../../external/AED/aed_sediment_swibc.dat'  ! tuflow version
   deepbc_file   = 'aed_sediment_deepbc.dat'
   swibc_filevars   = '' ! 'oxy', 'nit', 'amm', 'frp', 'poml'   ! from_bc_file
   deepbc_filevars = '' ! ,OXY_oxy,                            ! use_deep_bc
   flux_scale = 1
  !-- Initial Conditions  --!
   SolidInitialUnit = 'mmolLsolid'
   OMInitMethodL = 'LI_I'
   OM_topL = 1
   OM_minL = 0.9
   OM_cfL = 0.6
   InitMinDepthL = 99
   OMInitMethodR = 'LI_I'
   OM_topR = 1
   OM_minR = 0.9
   OM_cfR = 0.6
   InitMinDepthR = 99
   POMVR = 0.3
  !-- Outputs  --!
   diag_level = 10
   output_profiles = .TRUE.
 !  morevariables = 'FO2'
   output_diag_vars    = 'oxy','amm','poml'
   n_ddpths = 1
   output_diag_depths = 1.0
```

13 Units of measurement

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

Name of unit	Symbol	Definition in terms of other metric units	Quantity
day	d	24 h	time interval
degree Celsius	°C		temperature
gigalitre	GL	10^6 m^3	volume
gram	g	10^{-3} kg	mass
hour	h	60 min	time interval
kilometre	km	10^3 m	length
litre	L	10^{-3} m^3	volume
megalitre	ML	10^3 m^3	volume
metre	m	base unit	length
milligram	mg	10^{-3} g	mass
millimetre	mm	10^{-3} m	length
minute	min	60 s	time interval
second	s	base unit	time interval
year	y	365 or 366 days	time interval

13.2 Shortened forms

AED Aquatic EcoDynamics – library of modules and algorithms for simulation of aquatic ecodynamics

AHD Australian Height Datum (m)

AWQC Australian Water Quality Centre

bc Boundary condition

BMT BMT Limited – maritime-oriented design and technical consulting firm

BoM Bureau of Meteorology, Australia

CDM Coorong Dynamics Model

CHM Coorong Hydrodynamics Model

CNL Coorong North Lagoon

CSL Coorong South Lagoon

DEM Digital Elevation Model

DEW Department for Environment and Water

DO Dissolved Oxygen

DTR Diurnal Tide Ratio

EC Electrical Conductivity (µS/cm)

HCHB	*Healthy Coorong, Healthy Basin* Program
LiDAR	Light Detection and Ranging (remote sensing data)
PSU	Practical Salinity Unit
SILO	Database of Australian climate data from 1889 to the present
T&I	Trials and Investigations Project (HCHB)
TDS	Total Dissolved Solids
TN	Total Nitrogen
TP	Total Phosphorus
UWA	University of Western Australia

14 Glossary

Aquatic macrophyte — Any non-microscopic plant that requires the presence of water to grow and reproduce

Barrage — Specifically any of the five low weirs at the mouth of the River Murray constructed to exclude seawater from the Lower Lakes

Bioturbation — The disturbance of sediment by living organisms

Denitrification — The microbial process in which nitrates and nitrites are reduced or removed from soil, water, or air by their conversion into nitrogenous gases

EC — Electrical conductivity; 1 EC unit = 1 micro-Siemen per centimetre (µS/cm) measured at 25°C; commonly used as a measure of water salinity as it is quicker and easier than measurement by TDS

Eutrophication — Degradation of water quality due to enrichment by nutrients (primarily nitrogen and phosphorus), causing excessive plant growth and decay

Filamentous algae — The green filamentous algal community which occurs in the Coorong, consisting of *Ulva paradoxa*, *Rhizoclonium* sp. and *Cladophora* sp. (Lewis et al., 2022)

m AHD — Defines elevation in metres (m) according to the Australian Height Datum (AHD)

Millennium Drought — An Australian drought which impacted the Murray–Darling Basin over the period 1996-2010, and substantially impacted the Coorong over the period 2001-2010

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

Nitrification — The process by which bacteria in soil and water oxidise ammonia and ammonium ions and form nitrites and nitrates

Ruppia Community — The multi species assemblage that has become established across the southern Coorong and includes *Ruppia tuberosa*, *Althenia cylindrocarpa* along with an as yet unresolved species of *Ruppia* (Lewis et al., 2022)

SA Water — South Australian Water Corporation (Government of South Australia)

15 References

BMT WBM Pty Ltd. (2010). *Coorong salinity modelling*. Coorong Pumping EPBC Referral Appendix F1, SA MDB NRM Board, Adelaide.

BMT WBM (2017). *Coorong Options Assessment*. Brisbane: BMT WBM Pty Ltd.

BMT (2019). *Murray Mouth Model Status Report*. Report to SA Water, August 2019.

BMT (2020). *TUFLOW FV User Manual Build 2020.01.*

BMT (2021a). Software developments summary. Report to Department for Environment and Water.

BMT (2021b). Coorong Rapid Model Development. Report to Department for Environment and Water, R.A10583.001.03

BMT (2022a). *Model calibration status and scenario assumptions.* Memo to Department for Environment and Water.

BMT (2022b). *Coorong Model Development* and *Release Window* – Power point provided to Department for Environment and Water.

BMT (2022c). *Coorong Barrage Release Windows Investigations*. Report to Department for Environment and Water, R.A.11650.

Bureau of Meteorology (2010). *Metadata for Tidal Data Exchange (Victor Harbor)*.

Collier, C., van Diijk, K., Erftemeijer, P., Foster, N., Hipsey, M., O'Laughlin, E., Ticli, K. and Waycott, M. (2017). *Optimising Coorong Ruppia habitat: Analysis of management strategies to improve habitat conditions for Ruppia tuberosa in the Coorong (South Australia) based on literature review, manipulative experiments and predictive modelling*. Adelaide.

DEW (2020). *Summary of Coorong hydrological, biogeochemical and ecological models.* DEW Technical Report 2020/39, Government of South Australia, Department for Environment and Water, Adelaide.

DEW (2020, unpub). *Summary report Parnka Point flow gaugings 2019, for the Healthy Coorong, Healthy Basin, Phase 0 Project.* Government of South Australia, Department for Environment and Water, Adelaide.

DEW (2021a). *Methodology for calculating flow through the barrages.* DEW Technical report 2021/04, Government of South Australia, Department for Environment and Water, Adelaide.

DEW (2021b). *State of the Southern Coorong – Discussion paper*. Government of South Australia, Department for Environment and Water, Adelaide.

DEW (2021, unpub). *Coorong fast model recalibration*. Government of South Australia, Department for Environment and Water, Adelaide.

DEW (2022). *Coorong decision-making framework, supporting ecosystem based management*, DEW Technical Report 2022/15, Government of South Australia, Department for Environment and Water, Adelaide.

Hipsey, M.R., Busch, B.D., Aldridge, K.T. (2017). Coorong Investigations Project: Ruppia habitat changes in response to augmented South East Flows scenarios and a regulating structure. AED Report #R39, The University of Western Australia, Perth.

Hipsey, M.R., Huang, P., Zhai, S., Busch, B., Paraska, D., Sims, C. (2022). The Coorong Dynamics Model. Zenodo: DOI: 10.5281/zenodo.

Hipsey, M.R., ed. (2022) *Modelling Aquatic Eco-Dynamics: Overview of the AED modular simulation platform*. Zenodo repository. DOI: 10.5281/zenodo.6516222.

Lewis, R., Waycott, M., O'Loughlin, E.J., Urgl, C., van Dijk, K.J., Calladine, A. and Nicol, J. (2022). *Distribution and seasonality of the Ruppia dominated aquatic macrophyte community and filamentous algae in the southern Coorong*. Goyder Institute for Water Research Technical Report Series No. 22/09.

Mosley, L.M., Hamilton, B. Busch, B. Hipsey, M. and Taylor, B. (2017). *Assessment and modelling of the effects of the 2013-2016 Morella Basin releases on Coorong water quality*. Report to the Department of Environment, Water and Natural Resources (DEWNR). University of Adelaide, South Australia.

Mosley, L., Teasdale, P., Huang, L., Welsh, D., Erler, D., Ferguson, A., Brookes, J., Keneally, C., Chilton, D, Dittman, S., Lam-Gordillo, O., and Southgate, M. (2021). *Activity 1.3: Nutrient cycling and fluxes. Annual Investigations Report: Sediment quality, nutrient cycling and fluxes (2021).* Adelaide.

TUFLOW FV User Manual Build 2020.01.

UWA (2022). *The Coorong Dynamics Model: Resolving nutrient cycling and habitat dynamics in the Coorong Lagoon, South Australia (Progress Report)*. The University of Western Australia, Perth.

Webster, I.T. (2007). *Hydrodynamic modelling of the Coorong*. Water for a Healthy Country National Research Flagship, CSIRO.

Webster, I.T. (2012) *The Application of Hydrodynamic Modelling to Assess the Impact of Supplementary Flow Releases on Coorong Water Levels and Salinities*: Water for a Healthy Country National Research Flagship.

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Environment and Water