Ecological Investigations Findings report – Phase 1, September 2021

Coorong Infrastructure Investigations Project

Department for Environment and Water
September, 2021

DEW Technical report 2021/22

Government of South Australia
Department for Environment and Water

Department for Environment and Water

Government of South Australia

September 2021

81-95 Waymouth St, ADELAIDE SA 5000

Telephone +61 (8) 8463 6946

Facsimile +61 (8) 8463 6999

ABN 36702093234

www.environment.sa.gov.au

Disclaimer

The Department for Environment and Water and its employees do not warrant or make any representation regarding the use, or results of the use, of the information contained herein as regards to its correctness, accuracy, reliability, currency or otherwise. The Department for Environment and Water and its employees expressly disclaims all liability or responsibility to any person using the information or advice. Information contained in this document is correct at the time of writing.

With the exception of the Piping Shrike emblem, other material or devices protected by Aboriginal rights or a trademark, and subject to review by the Government of South Australia at all times, the content of this document is licensed under the Creative Commons Attribution 4.0 Licence. All other rights are reserved.

© Crown in right of the State of South Australia, through the Department for Environment and Water 2019

*Preferred way to cite this publicatio*n

Department for Environment and Water (2021). Ecological Investigations Findings report – Phase 1,CIIP DEW Technical report 2020/21, Government of South Australia, Department for Environment and Water, Adelaide.

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

Acknowledgements

The project team would like to acknowledge the Traditional Custodians of the lands and waters, current land managers, and all Aboriginal and Torres Strait Islander South Australians. As a Department we acknowledge that Aboriginal Nations are the first managers and decision makers of Country and that Country has sustained their culture and economy for thousands of generations. The care, skill and knowledge of Aboriginal Nations has shaped the character of Country across the continent and is seen as an integrated and interdependent cultural landscape

This project is part of the South Australian Government's *Healthy Coorong, Healthy Basin* Program, which is jointly funded by the Australian and South Australian governments.

The work undertaken in the Phase 1 ecological investigations report was part of the Coorong Infrastructure Investigations project. The report was authored by Cristina Vicente, Gareth Oerman and Hugh Wilson.

We thank Dr Daniel Rogers, Dr Jody O'Connor and Dr Matt Gibbs for their support undertaking the Ecological Risk Assessment process and for their input and technical review of this report.

We also thank Dr Michelle Waycott, Dr Luke Mosley, Dr Justin Brookes, Dr Thomas Prowse, Dr Qifeng Ye, Dr Jason Nicol, Dr Sabine Dittmann and Dr Jason Higham for their support and contribution on the Ecological Interpretation process and further input into this report.

An Ecological Investigations Independent Panel Review was established to provide high level technical advice regarding this report. We thank Dr Barry Hart, Dr Roland Cormier, Dr Birgita Hansen, Dr Doug Fotheringham and Dr Ian Webster for their contribution through this panel review.

This project is part of the South Australian Government's *Healthy Coorong, Healthy Basin* Program, which is jointly funded by the Australian and South Australian governments

Contents

List of Figures

List of Tables

List of abbreviations

CIIP	Coorong Infrastructure Investigations Project
CLLMM	The Coorong, Lower Lakes and Murray Mouth
CNL	Coorong North Lagoon
CSL	Coorong South Lagoon
ERAF	Ecological risk assessment framework
HCHB	*Healthy Coorong, Healthy Basin*
HIS	Habitat Suitability Index
LAC	Limits of acceptable change, Ecological Character Description
mAHD	Elevation in metres with respect to the Australian Height Datum
MT	Management thresholds, Ramsar Management Plan
RCT	Resource Condition Targets, Ramsar Management Plan

SEFA	South East Flows Augmentation
Tchla	Total Chlorophyll-a
TN	Total nitrogen
TP	Total phosphorous
TRIX	Trophic Index

Executive Summary

The Coorong Infrastructure Investigations Project is part of the South Australian Government's *Healthy Coorong, Healthy Basin* Program. As part of the *Healthy Coorong, Healthy Basin* Program, the Coorong Infrastructure Investigations Project (CIIP) has been established to investigate the feasibility of long-term infrastructure options for improving the ecological health of the Coorong.

The objective of the Phase 1 ecological investigations for the Coorong Infrastructure Investigations Project (CIIP) was to assess and compare the benefits and risks of the shortlisted infrastructure options (and combinations thereof) to the Coorong ecosystem, with a focus on the Coorong South Lagoon (CSL). Ecological investigations conducted for Phase 1 of CIIP were informed by modelling of Coorong conditions (hydrodynamic, biogeochemical and habitat) under CIIP options and different management scenarios and climate/flow conditions.

Ecological investigations were comprised of two components:

1. Ecological interpretation: A qualitative interpretation of ecological conditions in the Coorong under each CIIP option based upon expert opinion. The ecological interpretation documented the expected response of key ecosystem components (sediment quality, nutrients, aquatic macrophytes, macroinvertebrates and fish) under a CIIP option in the short (<3 years) and long-term (>10 years). The current (2020–21) condition of each key ecosystem component in the Coorong was used as a reference point by which to assess whether the ecosystem component was to improve, remain in a similar condition (neutral) or deteriorate. The magnitude of change from the reference point was also considered (i.e. minor or major).
2. Ecological risk assessment: A semi-quantitative evaluation of changes in level of ecological risk in the Coorong (salinity, water level and nutrients) under a CIIP option with respect to the "no build" case. The ecological risk assessment considered both risk and benefit, with risk measured as a departure from the management objectives for the Coorong as detailed in the *Ramsar Management Plan* and/or the desired state for the Southern Coorong in the *Desired state of the Southern Coorong – discussion paper*. Benefit was measured and defined as a reduction in residual risk under a CIIP option.

This report details the methodology and findings of the ecological investigations for Phase 1 of CIIP. The recommendations and findings from Phase 1 ecological investigations will inform Phase 2 and broader feasibility studies for the CIIP.

A summary of the findings of the Phase 1 ecological investigations are shown below.

Risk to the system	Shortlisted CIIP options can potentially improve the ecological values of the Coorong but they also have the potential to worsen those values. Extreme care should be taken to avoid further detrimental impact to the site, particularly to the Coorong North Lagoon (CNL)
Trade-offs	Ecological interpretation of system responses to CIIP infrastructure found that some options improved the health and condition of the Coorong, however, the Ecological Risk Assessment highlighted that some of these options had trade-offs and had potential to negatively impact parts of the system (i.e. CNL).
Coorong system sensitivity	There seems to be an important system response to slight differences in model assumptions (E.g. pumping in 125 vs pumping in 250), which highlights the importance of CIIP scenario refinement in Phase 2 of the feasibility investigations.

The benefits and risks to the Coorong ecosystem for each CIIP option are summarised below.

CIIP option	Contribution/Benefits	Risks
Lake Albert to Coorong Connector	Modest improvements to flushing and salinity metrics. Benefits may be limited to times when there is sufficient flow in the river. Therefore, benefits are unlikely to be provided under extremely dry conditions.	The system continues to deteriorate due to insufficient flow, especially under extremely dry conditions. Nutrient rich sediments are likely to worsen in Coorong North Lagoon (CNL) and unlikely to improve in the CSL due to additional nutrient loads from Lake Albert and subsequent expected increases in algal biomass. CNL water quality may decline due to additional inputs of high nutrient water from Lake Albert and result in an increase in the extent of the lagoon considered to be in a hyper-eutrophic state.
Coorong Lagoon dredging to improve connectivity	Dredge at targeted locations to remove flow constrictions and subsequently improve connectivity between the CNL and Coorong South Lagoon (CSL). Increased connectivity improves flushing and the export of salt and nutrients. The higher water levels in the CSL over summer are likely to increase the extent of mudflat at a critical time for shorebirds.	Small risk of temporal increases in salinity in the CNL. Water levels in the CSL may decline more rapidly in spring, which could be detrimental to *Ruppia tuberosa* (referred to as Ruppia) reproduction. Potential impact of sediment disturbance during the construction phase and the subsequent potential for long-term impacts (including acid sulphate soils).
A connection between the Coorong South Lagoon and Southern Ocean	This option has the benefit of being independent of water availability in the River Murray or south east drainage network. Pumping water out of the Coorong will export salt and nutrients from the system and draw marine water (lower in salinity, ~35 ppt) in through the Murray Mouth, further reducing salinity in the CNL and CSL. The increased circulation of water between the Coorong and Southern Ocean would reduce water residence time in the CSL.	Pumping water out during the summer/autumn months when water levels are seasonally low, has the negative impact of further reducing these water levels. This impact can be mitigated by (i) only pumping out when water levels are above a specified threshold, (ii) pumping water in as well as out or (iii) via dredging. Pumping ocean water into the Coorong may have a negative impact on the CNL salinity (increase) due high salinity water moving north from the CSL. However, in the longer-term it is expected that the salinity concentrations in the CSL would be

CIIP option	Contribution/Benefits	Risks
	Pumping water into the Coorong helps to dilute and export salt and nutrient rich water from the CSL and through the Murray Mouth. However, the benefits are modest compared to pumping water out.	significantly lower, and therefore, any movement of water from the CSL to CNL may have negligible impact.
Further augmentation of South East Flows to the Coorong	The South East Flows Restoration project (SEFRP) was completed in 2018. The project was responsible for the construction of a channel that diverted flow from the Blackford Drain in the South East drainage network towards the Coorong. Further augmentation of flows from the South East drainage network could divert additional volumes from the Drain L and K catchments into the Coorong.	South East flows augmentation (SEFA) is dependent on rainfall within the catchment, and modelling has determined that the volume of SEFA water entering the CSL would be relatively modest. Volumes of freshwater inflow are insufficient to reach target salinity and nutrient concentrations.
Additional automated barrage gates	Benefits from automated barrage gates would only be experienced at a localised scale in the CNL.	Preliminary modelling indicated even under a range of 'best case' operational scenarios the additional automation of barrage gates would not sufficiently reduce salinity and nutrient concentrations in the CSL.

1. Background

The Coorong, Lower Lakes and Murray Mouth (CLLMM) are located at the terminus of the Murray-Darling Basin in South Australia (Figure 1.1). The Lower Lakes (Lake Alexandrina and Lake Albert) are hydrologically separated from the Coorong by five barrages (Goolwa, Mundoo, Boundary Creek, Ewe Island and Tauwitchere) built in the 1930-40s. Lake Albert is a terminal lake connected to Lake Alexandrina by a narrow channel (the Narrung Narrows), and the Coorong is connected to the Southern Ocean (Encounter Bay) through the Murray Mouth (Figure 1.1).

The CLLMM is a wetland of local, national and international importance and one of the most significant waterbird habitats in the Murray-Darling Basin (Brookes et al. 2018). The site is listed as a Ramsar Wetland of International Importance, and therefore the Australian Government has international obligations to maintain the ecological character of the site (Brookes et al. 2018).

Reductions in inflows have led to the long-term decline in the ecological condition of the Coorong, which was exacerbated by the Millennium Drought (2001–10). Increased inflows to the Coorong following the Millennium Drought were expected to enable the recovery of the Coorong, and while some ecological values have recovered, to date, there has been limited recovery of ecological values in the Coorong South Lagoon (CSL) (Brookes et al. 2018).

A lack of flushing flows has contributed to the CSL becoming a sink for both salt and nutrients, and resulted in its current hypersaline and hypereutrophic state (Mosley et al. 2020) (Figure 1.2). The hypersaline and hypereutrophic state of the CSL in association with low water levels over late spring and summer have prohibited the recovery of the lagoon to a healthy state.

The current condition of the CSL was summarised by DEW (2021a) and Brookes et al. (2021):

- It is degraded and at risk of losing its ecological character and no longer supporting the elements that make it a wetland of local, national and international importance.
- Prolonged hyper-saline and hyper-eutrophic conditions have significantly affected the waterbirds, fish, plants and invertebrates of the CSL.
- Hyper-saline conditions have reduced the abundance and extent of the aquatic plant—*Ruppia tuberosa*, which is an important food source for waterbirds and habitat for other biota, including fish and macroinvertebrates.
- The CSL is experiencing excessive growth of filamentous algae over summer, which interferes with the reproduction of Ruppia. Filamentous algae also aggregate and form large mats that blanket the mudflat and prohibit migratory shorebirds from probing the sediment in search for food.
- The growth of filamentous algae (and other phytoplankton) are stimulated by the release of nutrients (nitrogen and phosphorus) from anoxic and nutrient-rich sediments.

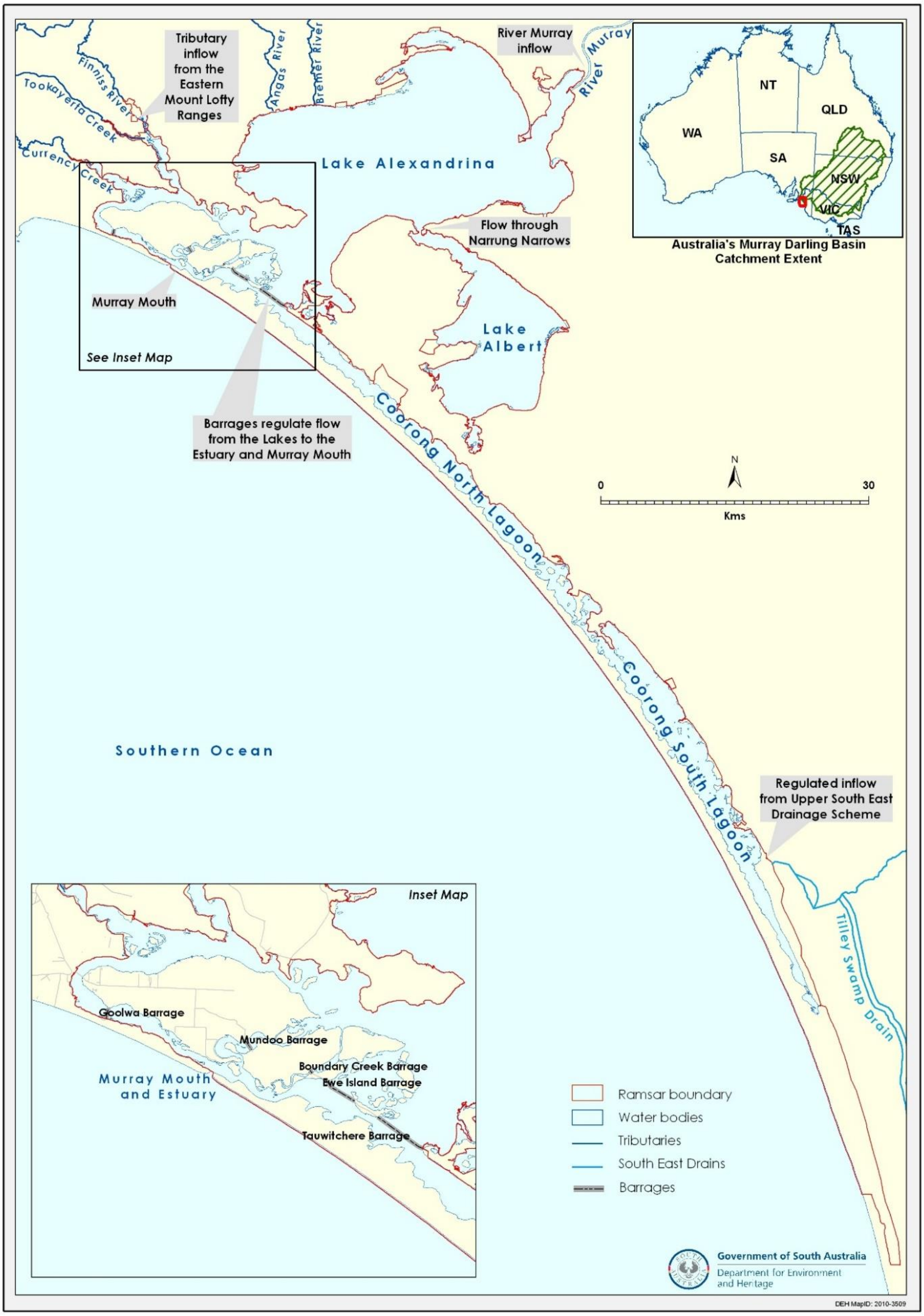


Figure 1.1 Extent of the Lakes (Alexandrina and Albert), Murray estuary and Coorong North and South Lagoons inside the Ramsar site boundary.

1.1 Desired state

The Department for Environment and Water (DEW) have described the desired state of the Southern Coorong (DEW 2021a). The Southern Coorong is another term reflective of the same spatial range as the CSL, and therefore, the Southern Coorong will be referred to as CSL herein. The desired state for the CSL was underpinned by:

- some, but limited historical information of the Coorong when it was a diverse and resilient ecosystem that supported healthy populations of plants, invertebrates, fish and waterbirds,
- existing hydrological and environmental gradients occurring in the Coorong (e.g. presence of fish, macroinvertebrates and aquatic plants within known salinity ranges); and
- scientific understanding of the biotic and abiotic processes governing complex hypersaline estuarine systems.

The desired environmental values, salinity and nutrient conditions, and food web structure are detailed in Table 1.1. A conceptual model of the current and desired states of the CSL is shown in Figure 1.2, which demonstrates the recovery of the CSL from a hypereutrophic state to a mesotrophic (moderate nutrient loads) state. To reach this desired state, short and long term strategies are required to manage water, salinity and nutrients to improve the ecological functioning of the system.

Table 1.1 The desired state for ecosystem elements in the CSL as described by DEW (2021a).

Ecosystem element	Desired state
Environmental value	A resilient and naturally variable system able to withstand environmental variability and to support the environmental values that make it a wetland of local, national and international importance
Salinity	A naturally variable system including some periods of hyper-salinity (>60 g/L) and a range of lower maximum salinities between years
Nutrients	Healthy sediment nutrient cycling and sediment-water fluxes, and mesotrophic conditions defined as moderate levels of chlorophyll-a, nitrogen and phosphorus. Bio-available nutrients are fixated by aquatic plants over phytoplankton, benthic microalgae and filamentous algae.
Food webs	CSL supports functional food webs including: aquatic plant (e.g. *Ruppia tuberosa*) communities, invertebrate, fish and waterbird populations and a more complex resilient food web with multiple trophic levels and productive and diverse biota.

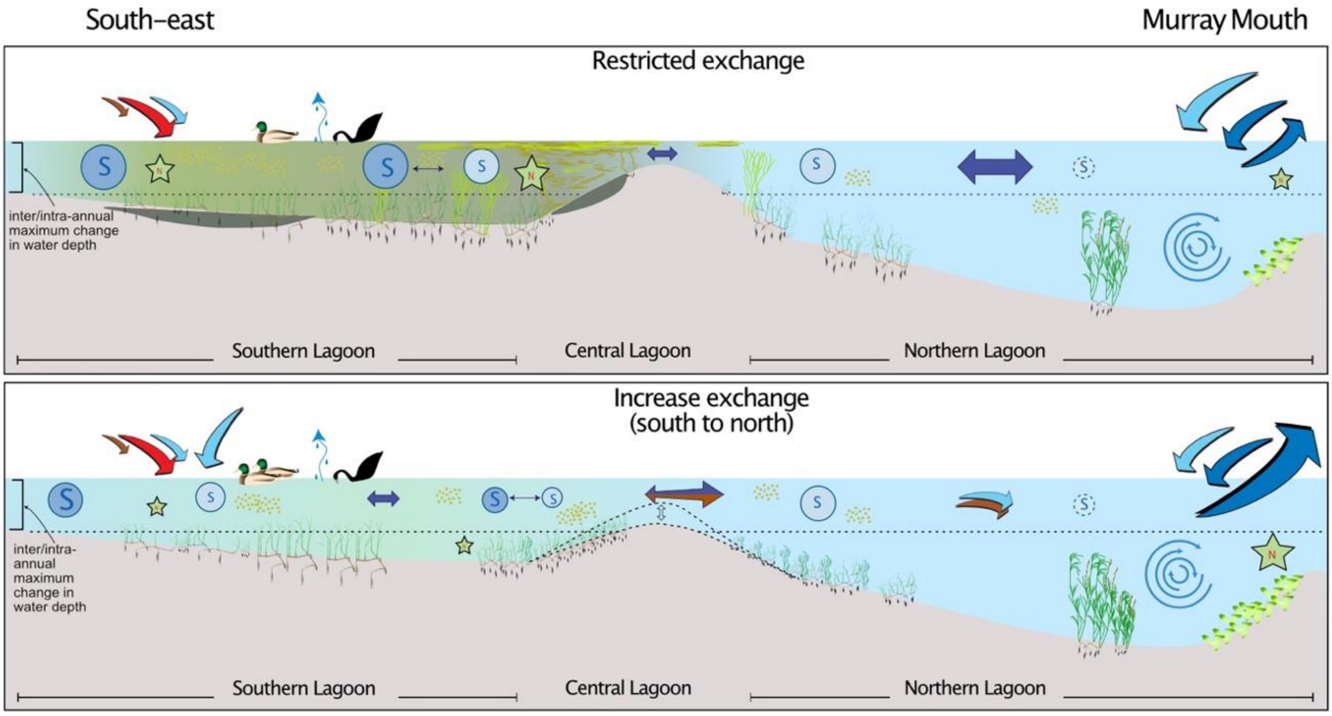


Figure 1.2 Conceptual model of the current (above image) and the desired (below image) state of the CSL. Source: Waycott et al. (2020).

1.2 *Healthy Coorong, Healthy Basin* program

The South Australian and Federal governments have established the *Healthy Coorong, Healthy Basin* (HCHB) program, a $77.7 million 5-year program that aims to support the long-term health of the Coorong by providing evidence-based management options to manage both immediate threats and future conditions anticipated under a changing climate. It is recognised that maintaining the long-term ecological health and resilience of the Coorong may not be achievable through improved knowledge and water resource optimisation alone, and therefore, a number of potential management options have been identified over the years to potentially improve water delivery to, and enhance the ecological health of, the Coorong. Further information about the program is available at https://www.environment.sa.gov.au/topics/coorong/action-plan.

1.3 Coorong Infrastructure Investigations project

As part of the HCHB program, the Coorong Infrastructure Investigations Project (CIIP) has been established to investigate the feasibility of long-term infrastructure options for improving the ecological health of the Coorong.

1.3.1 CIIP management options

A short list of potential management options was developed through options analysis and community consultation in 2020. Options identified for further investigation included:

1. **Lake Albert to Coorong Connector:**
   The objective of this option is to introduce freshwater directly from Lake Albert into the CNL (see discharge point in Figure 1.3), to allow water level cycling to promote the flow of lower salinity water

into the CSL. A target flow rate of 1 GL/d has previously been proposed and this forms the basis of the current feasibility investigations.

2. **Coorong Lagoon dredging to improve connectivity**
   The objective of this option is to enhance connectivity between the Coorong North Lagoon (CNL) and CSL by removing constrictions to flow, thereby improving transfer of water to and from the CSL. Locations identified that may require dredging were Pelican Point (south east of Tauwitchere Barrage) and Parnka Narrows. The dredging alignments modelled (individually and in combination) for management scenarios in this report were:
   - Pelican Point: 2.5 km of dredge length to a 200 m wide profile with an invert level of -1.5 m AHD, and
   - Parnka Narrows: 18.5 km of dredge length centered near Parnka Point to a 200 m wide profile with an invert level of -1.2 m AHD (Figure 1.3).

3. **A connection between the Coorong South Lagoon and Southern Ocean**
   A permanent connection between the CSL and Southern Ocean could take the form of either a pumped connection or a passive connection. This solution would allow either transfer of lower salinity marine water into the CSL and/or transfer of hypersaline water from the CSL to the Southern Ocean. Four broad options are being investigated:
   - Pumping seawater into the CSL to dilute salt and nutrients and export water out of the CSL through the Coorong North Lagoon (CNL) and Murray Mouth to the Southern Ocean.
   - Pumping water out of the CSL to export salt and nutrients to the Southern Ocean, drawing in marine water with lower salinity through the Murray Mouth and CNL, reducing water retention time in the system.
   - A combination of pumping into and out of the CSL from the Southern Ocean.
   - A passive connection between the CSL and the Southern Ocean that would exchange flow in both directions based on relative ocean and CSL water levels (predominantly flow from the Southern Ocean to CSL during summer and vice versa during winter).

   Pumping locations that were used in modelled management scenarios are shown in Figure 1.3.

4. **Further augmentation of South East Flows**
   The objective of this option is to divert additional low salinity flows from the South East Drainage Scheme into CSL via Salt Creek (Figure 1.3).

5. **Additional automated barrage gates**
   As a lower cost and less infrastructure intensive option, consideration has also been given to the addition of a greater number of automated gates within Tauwitchere Barrage to improve control over the discharge of Lake Alexandrina water into the CNL.

   Preliminary modelling (Initial hydrodynamic model scenarios to inform Coorong Infrastructure Investigations project, conducted in 2020) indicated even under a range of 'best case' operational scenarios the additional automation of barrage gates would not sufficiently reduce salinities in the CSL. Positive benefits for barrage automation would only be experienced in localised areas of the CNL.

   The Coorong Partnership community advisory group considered this preliminary modelling at its meeting at Raukkan on 6 May 2021 and endorsed the recommendation from DEW that additional automated barrages should be discounted from further consideration under this specific investigation. Therefore, additional automated barrage gates were not assessed in this report.

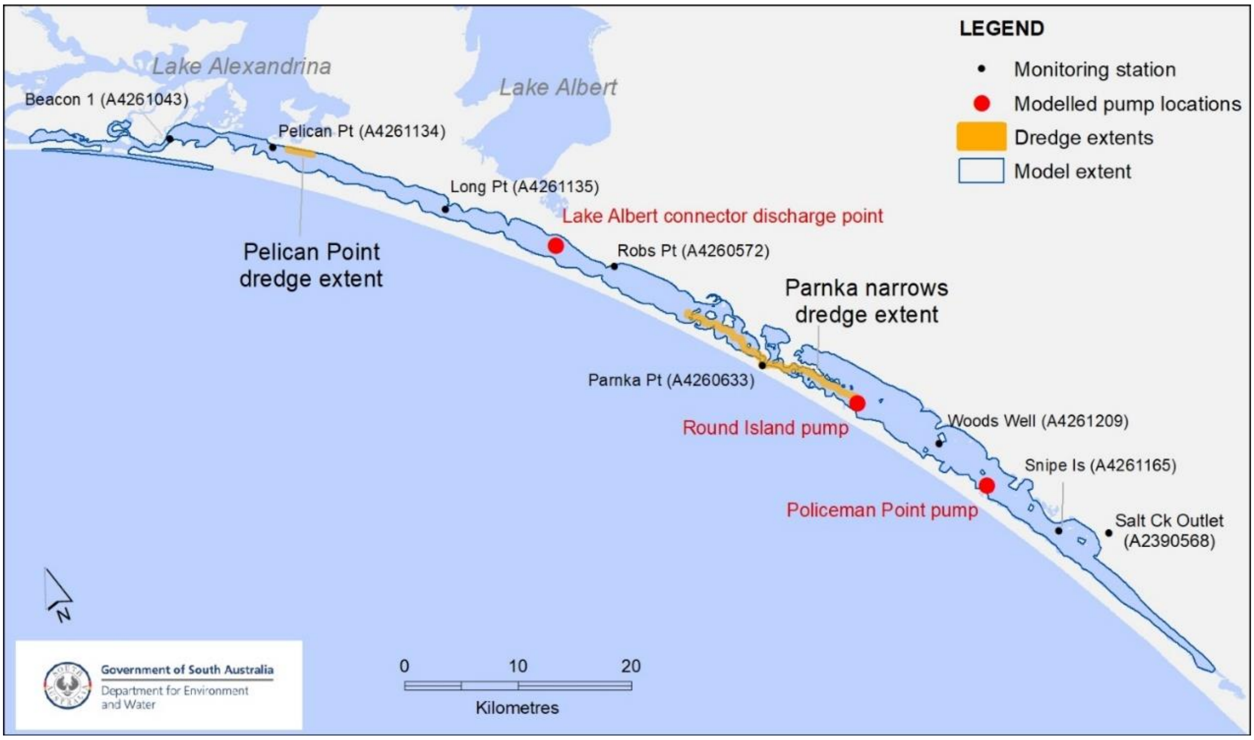


Figure 1.3 Map of the Coorong showing the monitoring stations and location of infrastructure options.

2 Ecological investigations

A key objective of CIIP is to identify the long-term infrastructure options that could improve the ecological health of the Coorong. To meet this objective, ecological investigations were conducted under Phase 1 of CIIP (Figure 2.1).

Ecological investigations conducted for Phase 1 of CIIP were informed by modelling (section 3) of Coorong conditions (hydrodynamic, biogeochemical and habitat) under CIIP options for different management and climate/flow scenarios. Ecological investigations were comprised of two components:

1. Ecological interpretation (section 4): A qualitative interpretation of the modelled ecological conditions in the Coorong under each CIIP option, based upon qualitative expert judgement.
2. Ecological risk assessment (section 5): A semi-quantitative evaluation of changes in level of ecological risk in the Coorong (with respect to the key hydrological and biogeochemical parameters regarding salinity, water level and nutrients) under a CIIP option with respect to the "no build" case.

The ecological interpretation and risk assessment complement one another to form a robust basis from which to evaluate the predicted ability of CIIP options to improve the ecological health of the Coorong. Ecological interpretation is a critical activity in the evaluation of CIIP options as it provides:

- An understanding of the expected ecological responses for key ecosystem components that cannot be quantitatively modelled with the current functionality of the Coorong Dynamics Model or that are only able to be currently simulated with low accuracy.
- A "sanity check" that the modelled results align with our conceptual understanding of the ecosystem.

The ecological risk assessment complements the ecological interpretation as it provides:

- A semi-quantitative approach to the evaluation of CIIP options and therefore personal biases should have limited influence on the results.
- A clear geographic delineation (CSL and CNL) of the benefits and risks (and trade-offs) in the Coorong under each CIIP option.

The findings and recommendations from Phase 1 ecological investigations are presented in section 6.

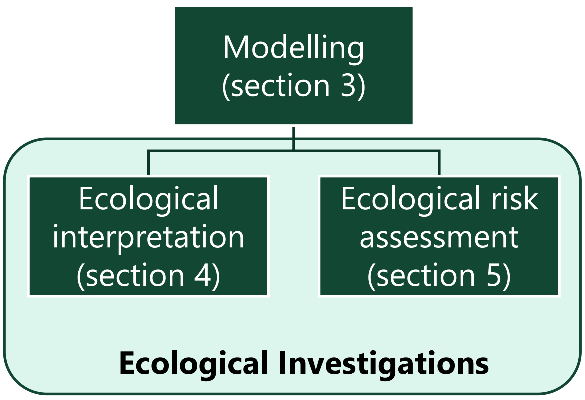


Figure 2.1 Ecological investigations conducted for Phase 1 of CIIP.

3 Modelling

3.1 Model platforms

Hydrological, biogeochemical and ecological models are used by environmental managers to inform management decision-making for aquatic ecosystems, and improve our predictions of future responses to management interventions. A review of all existing hydrodynamic, biogeochemical and ecological models for the Coorong was conducted under Phase One of the Trials and Investigations Project (DEW 2020a), which identified that the Coorong Dynamics Model as the most sophisticated ecosystem model for the Coorong. The Coorong Dynamics Model and its hydrodynamic platform; the TUFLOW-FV model, have been used to support CIIP investigations.

3.1.1 TUFLOW-FV

The TUFLOW-FV model is a two or three-dimensional model that simulates the movement of water and predicts water level and depth, salinity, velocity, temperature, fluxes and Murray Mouth morphology in response to inflows, tides, wind, waves, evaporation and rainfall (BMT 2019). The model is very flexible and to date represents the most detailed hydrodynamic model of the Coorong. A full summary of the TUFLOW-FV Model including its schematisation, outputs and validation are available in BMT (2019) and DEW (2020b).

3.1.2 Coorong Dynamics Model

The Coorong Dynamics Model dynamically links the TUFLOW-FV model with the AED2 Biogeochemistry and Habitat Model (Figure 3.1). The model is used to simulate the hydrodynamic conditions, water clarity (light and turbidity), nutrients (organic and inorganic), chlorophyll-a, filamentous algae and Ruppia habitat quality in the Coorong at high-resolution (Hipsey et al. 2020). A full summary of the Coorong Dynamics Model including its schematisation, outputs and validation are available in Collier et al. (2017), Hipsey et al. (2020) and BMT (2021).

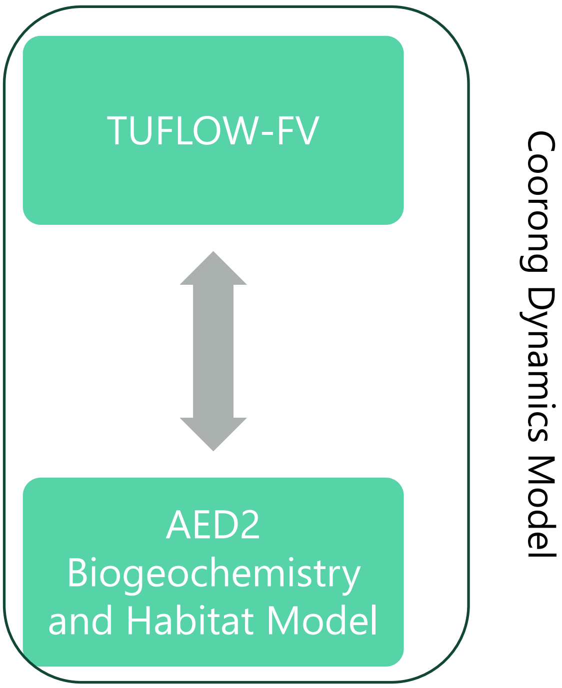


Figure 3.1 Ecological investigations conducted for Phase 1 of CIIP.

3.1.3 Use of models outputs

During 2021, CIIP investigations have used the TUFLOW-FV model and the Coorong Dynamics Model to conduct short-term (three-year) simulations of hydrodynamic, biogeochemical and habitat conditions under a range of management scenarios. The model outputs were used to support the ecological interpretation (see section 4), and ecological risk assessment (see section 5).

3.2 Modelling accuracy and validation

The statistics used to validate the TUFLOW-FV model and Coorong Dynamics Model are described in Table 3.1.

Table 3.1 Description of the statistics used for validation of outputs from the TUFLOW-FV and Coorong Dynamics Model. Source: BMT (2021).

Statistic	Description
Mean Absolute Error (MAE)	The average magnitude of errors between pairs of observations. The MAE will always be smaller or equal to the root mean square error and is considered to be a better measure of the average magnitude as the errors are equally weighted and influence from outliers is minimised.
Root Mean Squared Error (RMSE)	Quantification of the absolute error in the model. This parameter gave an indication of the expected error in the calibration overall. The process of squaring the differences of the model and observed data gives higher weight to the largest.
Coefficient of determination (R^2)	A measure of how close the model and observed data can be represented by a linear regression line. The R-squared value is always between 0 and 1.0 with the higher R-squared value indicating a better model fit.

3.2.1 TUFLOW-FV

Modelled outputs were compared with observed water levels and salinities recorded at seven monitoring stations across the model domain (Table 3.1). Despite some limitation in representing the Murray Mouth dynamics and the subsequent effect in the Murray estuary and CNL, the model is considered to replicate observed conditions well, particularly in the CSL.

Table 3.1 Validation statistics of the TUFLOW-FV model for simulated salinity concentrations and water levels over the Murray estuary and Coorong.

		Salinity			Water level		
Site	**Station**	**MAE**	**RMSE**	**R^2**	**MAE**	**RMSE**	**R^2**
Beacon 1	A4261043	10.8	13.7	0.35	0.13	0.16	0.68
Pelican Point	A4261134	11.7	13.5	0.30	0.13	0.15	0.81
Long Point	A4261135	10.1	11.8	0.35	0.08	0.10	0.88
Robs Point	A4260572	13.5	16.4	0.65	0.08	0.10	0.88

Site	Station	Salinity			Water level		
		MAE	RMSE	R^2	MAE	RMSE	R^2
Parnka Point	A4260633	12.4	17.8	0.69	0.16	0.17	0.95
Woods Well	A4261209	3.2	5.0	0.95	0.09	0.11	0.95
Snipe Island	A4261165	3.7	5.1	0.96	0.08	0.11	0.93

MAE=mean absolute error, RMSE = root mean squared error, R^2 = coefficient of determination.

3.2.2 Coorong Dynamics Model

As the Coorong Dynamics Model uses the TUFLOW-FV model as its hydrodynamic model, the validity of its hydrodynamic outputs will be reflective of that described in section 3.2.1. The biogeochemical outputs (total nitrogen, total phosphorus and total chlorophyll-a) from the Coorong Dynamics Model were validated in BMT (2021) with data collected at Long Pt, Parnka Pt and Snipe Island (Table 3.2). The Coorong Dynamics Model captures temporal and spatial changes in total nitrogen and phosphorus, with simulations of total nitrogen showing high accuracy. At present, the Coorong Dynamics Model shows good agreement of total chlorophyll-a concentrations at Long Point in the CNL, however, the model tends to underestimate concentrations at more southern sites in the system (i.e. Parnka Pt and Snipe Island).

The Ruppia Habitat Suitability Index (HIS) of the Coorong Dynamics Model also simulates reasonably well in the CSL, with the HSI for flowering correlating (R2 =0.44 for 2019) with observed seed densities at the start of the following season. This correlation is weaker when considering the entire extent of the Coorong (R2 =0.22 for 2019) (Hipsey et al. 2021).

Table 3.2 Validation statistics of the Coorong Dynamics model for simulated concentrations of total nitrogen, total phosphorus and total chlorophyll-a over the Coorong.

Site	Station	Total Nitrogen (mg/L)			Total Phosphorus (mg/L)			Total Chlorophyll-a (µg/L		
		MAE	RMSE	R^2	MAE	RMSE	R^2	MAE	RMSE	R^2
Long Point	A4261135	0.20	0.24	0.43	0.039	0.063	-7.02	11.3	20.9	-0.83
Parnka Point	A4260633	0.84	1.04	0.51	0.063	0.079	-0.24	29.2	33.0	-0.78
Snipe Island	A4261165	0.40	0.67	0.44	0.042	0.055	-0.33	39.7	44.8	-2.02

MAE=mean absolute error, RMSE = root mean squared error, R^2 = coefficient of determination.

3.3 Scenarios for modelling

A series of scenarios for each CIIP option and/or combination of operations were defined by DEW to be run through the TUFLOW-FV model and/or the Coorong Dynamics Model. The scenarios that were modelled are summarised in Table 3.3.

The modelled scenarios are simulated for ~3-year periods, with the TUFLOW-FV model simulating the period from 7 May 2013 to 28 January 2016 and the Coorong Dynamics Model simulating the period from 1 July 2017 to 1 July 2020. Simulations run using both the TUFLOW-FV and Coorong Dynamics Model considered a range of flow and climate conditions, including observed, typical and dry conditions. A summary of all the simulations assumptions are presented in Table 3.4 Assumptions for the simulations of CIIP scenarios run by the TUFLOW-FV modeland Table 3.5.

Table 3.3 Description of the scenarios that were run through the TUFLOW-FV model and the Coorong Dynamics Model for each CIIP option or combination of CIIP options.

CIIP option scenario	Description
1.1. Lake Albert Connector realistic	Divert any barrage flow above a total barrage discharge of 2 GL/d and up to a maximum of 1 GL/d through Lake Albert.
1.2 Lake Albert Connector and Dredge	Lake Albert Connector realistic and Dredge as per 2.1
2.1 Dredge	Dredging on targets constrictions at Parnka Point and Pelican Point. Parnka Point channel dimensions; 200m wide, -1.2m AHD deep & 18.5 km long. Pelican Point channel dimensions, 200m side, -1.5m AHD deep & 2.5km long
2.2 Dredge Pelican	Dredge Pelican Pt only
2.3 Dredge Parnka	Dredge Parnka Pt Only
3.1 Constantly pumping in 125	Pumping in 125ML/d Policeman point
3.2 Constantly pumping in 250	Pumping in 250ML/d Policeman point
3.3 Constantly pumping in 500	Pumping in 500ML/d Policeman point
3.4 Constantly pumping out 125	Pumping out 125ML/d Policeman point
3.5 Constantly pumping out 250	Pumping out 250ML/d Policeman point
3.6 Constantly pumping out 250 at Round Island	Pumping out 250ML/d Round Island
3.7 Constantly pumping water in and out	Pumping in 250 ML/d Policeman Point and out 250ML/day Round Island. Locations are 20km apart to enable circulation and mixing of ocean inflows.
3.8 Pumping water out above 0.2m	Pump out only when CSL water level is above 0.2m AHD trigger value. Pump out at Policeman point at 500 ML/d
3.9 Pumping water out above 0.3m	As above but for water level .0.3mAHD
3.10 Pumping water in or out (AHD > 0.3m <0.15m)	Pump out and in 500ML/day at Policeman Point based on water level triggers of >0.3m AHD (pump out) and <0.15m AHD (pump in). There will be a period of no pumping when water level is between trigger values.
3.11 Pumping water in or out (AHD > 0.2m <0.1m)	As above but for water levels out 0.2m AHD and in 0.1m AHD
3.12 Pumping water in or out (AHD > 0.3m <0.15m)	As above but for water levels out 0.3m AHD and in 0.15m AHD
3.13 Passive ocean connector (10 x 1.5m pipes)	Passive exchange flow in both directions based on relative ocean and Coorong water levels. Will predominantly flow from ocean to Coorong during summer and vice versa during winter.
3.14 Passive ocean connector (5 x 1m pipes)	As above but for different pipe configuration
3.15 Passive ocean connector (10 x 1m pipes)	As above but for different pipe configuration

CIIP option scenario	Description
3.16 Passive ocean connector (5 x 0.75m pipes)	As above but for different pipe configuration
3.17 Passive ocean connector (10 x 2m pipes)	As above but for different pipe configuration
3.18 Constantly pumping in 125 and Dredging	Pumping in 125ML/d Policeman point and Dredge as per 2.1
3.19 Constantly pumping in 250 and Dredging	Pumping in 250ML/d Policeman point and Dredge as per 2.1
3.20 Constantly pumping in 500 and Dredging	Pumping in 500ML/d Policeman point and Dredge as per 2.1
3.21 Constantly pumping out 125 and Dredging	Pumping out 125ML/d Policeman point and Dredge as per 2.1
3.22 Constantly pumping out 250 and Dredging	Pumping out 250ML/d Policeman point and Dredge as per 2.1
3.23 Constantly pumping out 500 and Dredging	Pumping out 500 ML/d Policeman point and Dredge as per 2.1
3.24 Constantly pumping out 250 and Dredging only at Pelican Point	Pumping out 250ML/d Policeman point and Dredge as per 2.2
4.1 Further augmentation of South East Flows	(10 GL/y additional)

Table 3.4 Assumptions for the simulations of CIIP scenarios run by the TUFLOW-FV model.

CIIP scenario No	CIIP scenario	Hydro Run No	Inflow	Bathymetry			Pumping		Lake Albert Connector
				Parnka narrows	*Pelican point*	*Mouth*	*Policeman Pt*	*Round Island*	
Do nothing	Basecase	1	Observed	Existing		Existing	None		None
	Dry	2	None	Existing		Existing	None		None
	Climate change	41		Existing		Existing	None		None
	Climate change_bedlift	46	None	Existing		Bed level + 0.24m	None		None
1.1	Lake Albert Connector _ realistic	42	Observed	Existing		Existing	None		1 GL/d conditional
1.2	Lake Albert Connector_ Dredge	4	Observed	Dredge 200m wide to -1.2m	Dredge 200m wide to - 1.5m	Existing	None		1 GL/d
2.1	Dredge	5	Observed			Existing	None		None
2.2	Dredge Pelican	28	Observed	Existing		Existing	None		None
2.3	Dredge Parnka	29	Observed	Dredge 200m wide to -1.2m	Existing	Existing	None		None
3.1	Constantly pumping in 125	6	Observed	Existing		Existing	In 125 ML/d	None	None
3.2	Constantly pumping in 250	7	Observed	Existing		Existing	In 250 ML/d	None	None
3.3	Constantly pumping in 500	8	Observed	Existing		Existing	In 500 ML/d	None	None
3.4	Constantly pumping out 125	9	Observed	Existing		Existing	Out 125 ML/d	None	None
		27	None	Existing		Existing	Out 152 ML/d	None	None
3.5	Constantly pumping out 250	10	Observed	Existing		Existing	Out 250 ML/d	None	None
		26	None	Existing		Existing	Out 250 ML/d	None	None
3.6	Constantly pumping out 250 at Round Island	20	Observed	Existing		Existing	None	Out 250 ML/d	None
3.7	Constantly pumping water in and out	21	Observed	Existing		Existing	Out 250 ML/d	In 250 ML/d	None
3.8	Pumping water out above 0.2m	24	Observed	Existing		Existing	Out 500 ML/d	None	None
3.9	Pumping water out above 0.3m	48	Observed	Existing		Existing	Out 500 ML/d	None	None

CIIP scenario No	CIIP scenario	Hydro Run No	Inflow	Bathymetry			Pumping		Lake Albert Connector
				Parnka narrows	***Pelican point***	***Mouth***	***Policeman Pt***	***Round Island***	
3. 10	Pumping water in or out (AHD > 0.3m <0.15m)	51	Observed	Existing		Existing	Out 500 ML/d	None	None
3.11	Pumping water in or out (AHD > 0.2m <0.1m)	47	Observed	Existing		Existing	Out 500 ML/d	None	None
3.12	Pumping water in or out (AHD > 0.3m <0.15m)	52	Observed	Existing		Existing	Out 500 ML/d	None	None
3.13	Passive ocean connector (10 x 1.5m pipes)	50	Observed	Existing	Existing	Existing	Passive connection		None
3.14	Passive ocean connector (5 x 1m pipes)	30 and 31	Observed	Existing	Existing	Existing	Passive connection		None
3.15	Passive ocean connector (10 x 1m pipes)	33	Observed	Existing	Existing	Existing	Passive connection		None
3.16	Passive ocean connector (5 x 0.75m pipes)	34	Observed	Existing	Existing	Existing	Passive connection		None
3.17	Passive ocean connector(10 x 2m pipes)	49	Observed	Existing	Existing	Existing	Passive connection		None
3.18	Constantly pumping in 125 and Dredging	12	Observed	Dredge 200m wide to -1.2m	Dredge 200m wide to -1.5m	Existing	In 125 ML/d	None	None
3.19	Constantly pumping in 250 and Dredging	13	Observed			Existing	In 250 ML/d	None	None
3. 20	Constantly pumping in 500 and Dredging	18	Observed			Existing	In 500 ML/d	None	None
		14	None			Existing	In 500 ML/d	None	None
3.21	Constantly pumping out 125 and Dredging	15	Observed			Existing	Out 125 ML/d	None	None
3.22	Constantly pumping out 250 and Dredging	19	Observed			Existing	Out 250 ML/d	None	None
		16	None			Existing	Out 250 ML/d	None	None
3.23	Constantly pumping out 500 and Dredging	17	Observed			Existing	Out 500 ML/d	None	None
		?	None			Existing	In 500 ML/d	None	None
3.24	Constantly pumping out 250 and Dredging only at Pelican Point	25	Observed	Existing		Existing	Out 250 ML/d	None	None
4.1	Further augmentation of South East Flows	38 40		Existing	Existing	Existing	None		None

Table 3.5 Assumptions for the simulations of CIIP scenarios run by the Coorong Dynamics Model.

CIIP scenario No	CIIP scenario	BMT run	Hydrology / Climate	Barrage Flow	Salt Creek	Bathymetry			Pumping		Lake Albert Connector	SEFA
						Parnka narrows	*Pelican point*	*Mouth*	*Policeman Pt*	*Round Island*		
Do nothing	Basecase	14	Typical	2000GL/y	40GL/y	Existing	Existing	Existing	None	None	None	None
	Dry	1	Dry	800GL/y	20GL/y	Existing	Existing	Existing	None	None	None	None
1.1	Lake Albert Connector realistic	4	Dry	684GL/y	20GL/y	Existing	Existing	Existing	None	None	116GL/y	None
		17	Typical	1782GL/y	40GL/y	Existing	Existing	Existing	None	None	218GL/y	None
1.2	Lake Albert Connector and Dredge	11	Dry	711GL/y	20GL/y	18.5km-200m - 1.2m (L/W/RL)	2.5km-200m - 1.5m (L/W/RL)	Existing	None	None	116GL/y	None
		24	Typical	1804GL/y	40GL/y			Existing	None	None	218GL/y	None
2.1	Dredge	6	Dry	800GL/y	20GL/y			Existing	None	None	None	None
		19	Typical	2000GL/y	40GL/y			Existing	None	None	None	
3.2	Constantly pumping in 250	13	Dry	800GL/y	20GL/y	Existing	Existing	Existing	In 250 ML/d	None	None	None
		26	Typical	2000GL/y	40GL/y	Existing	Existing	Existing		None	None	None
3.4	Constantly pumping out 125	12	Dry	800GL/y	20GL/y	Existing	Existing	Existing	Out 125 ML/d	None	None	None
		25	Typical	2000GL/y	40GL/y	Existing	Existing	Existing		None	None	None
3.5	Constantly pumping out 250	3	Dry	800GL/y	20GL/y	Existing	Existing	Existing	Out 250 ML/d	None	None	None
		16	Typical	2000GL/y	40GL/y	Existing	Existing	Existing		None	None	None
3.7	Constantly pumping water in and out	8	Dry	800GL/y	20GL/y	Existing	Existing	Existing	Const Out 250ML/y	Const In 250ML/y	None	None
		21	Typical	2000GL/y	40GL/y	Existing	Existing	Existing			None	None
3.8	Pumping water out above 0.2m	9	Dry	800GL/y	20GL/y	Existing	Existing	Existing	500ML/d	None	None	None
		22	Typical	2000GL/y	40GL/y	Existing	Existing	Existing		None	None	None
3. 10	Pumping water in or out (AHD > 0.3m <0.15m)	7	Dry	800GL/y	20GL/y	Existing	Existing	Existing	Out500ML/d - In500ML/d	None	None	None
		20	Typical	2000GL/y	40GL/y	Existing	Existing	Existing		None	None	None
3.13	Passive ocean connector (10 x 1.5m pipes)	2	Dry	800GL/y	20GL/y	Existing	Existing	Existing		None	None	None
		15	Typical	2000GL/y	40GL/y	Existing	Existing	Existing		None	None	None
3.22		10	Dry	800GL/y	20GL/y			Existing		None	None	None

CIIP scenario No	CIIP scenario	BMT run	Hydrology / Climate	Barrage Flow	Salt Creek	Bathymetry			Pumping		Lake Albert Connector	SEFA
						Parnka narrows	*Pelican point*	*Mouth*	*Policeman Pt*	*Round Island*		
	Constantly pumping out 250 and Dredging	23	Typical	2000GL/y	40GL/y	18.5km-200m - 1.2m (L/W/RL)	2.5km-200m - 1.5m (L/W/RL)	Existing	Const Out 250ML/y	None	None	None
4.1	Further augmentation of South East Flows	5	Dry	800GL/y	20GL/y +SEFA	Existing	Existing	Existing	None	None	None	10GL/y
		18	Typical	2000GL/y	40GL/y +SEFA	Existing	Existing	Existing	None	None	None	15GL/y

4 Ecological Interpretation

4.1 Introduction

The ecological interpretation of Coorong Dynamics Model outputs for each CIIP option and scenario was conducted by technical matter experts (Appendix A) that are performing research under the *Trials and Investigations* project of the HCHB program. Ecological interpretation of model outputs is critical to CIIP investigations as it provides a more holistic understanding of how the ecosystem is likely to respond than can currently be quantified with the current functionality of the Coorong Dynamics Model. It also provides an opportunity to check for alignment between conditions simulated by the model (i.e. habitat suitability indices for Ruppia and fish) and those expected to occur based upon an expert's conceptual understanding of the ecosystem.

4.2 Methodology

The ecological interpretation of model outputs followed a six step process.

Step 1 - Modelling

Only the Coorong Dynamics Model was used in the ecological interpretation of ecosystem responses to CIIP Options as the biogeochemical parameters were considered to be critical to provide an understanding of a change in the CSL from a hyper-eutrophic to a mesotrophic state (see section 1.1). The CIIP options and scenarios (and climatic conditions) simulated by the Coorong Dynamics Model are shown in Table 3.3, and the outputs from these model runs are presented in BMT (2021).

Step 2 – Summarise model outputs using the framework for ecological interpretation

The second step is the post-processing of the significant volume of outputs in to a summary table that is both ecologically meaningful and digestible. To achieve this, a *Framework for ecological interpretation* was developed (Appendix B), which presented the modelled results for biogeochemical, biological (habitat suitability indices) and water tracer parameters and used ecologically relevant thresholds to summarise salinity and water level outputs. A rationale for the ecologically relevant thresholds used to summarise salinity and water level outputs has been provided in Appendix C as well as a description of the remaining parameters presented in the ecological interpretation framework.

Step 3 - Identification and selection of key ecosystem components

Five ecosystem components were selected during a workshop with internal and external ecologists for the purpose of ecological interpretation of model outputs:

1. Sediment quality
2. Nutrients (water column)
3. Aquatic macrophytes
4. Macroinvertebrates
5. Fish

Each component selected was considered to be critical to the function and recovery of the Coorong ecosystem and were either known or expected to be modelled with a degree of confidence. The notable omission of waterbirds from the list of key ecosystem components was due to their high-level trophic position, meaning that any prediction carried great uncertainty. It was also assumed that the condition of sediments, aquatic macrophytes, macroinvertebrates and fish would subsequently influence the habitat quality for waterbirds in the Coorong, and therefore, it was considered that the ecological responses that affect habitat quality for waterbirds were accounted for indirectly.

Step 4 – Identify important drivers that influence the condition of key ecosystem components

Important drivers that influence the condition of key ecosystem components were identified during a workshop with internal and external ecologists and are presented in Table 4.1. These drivers and interactions between them will be considered by technical matter experts when documenting the expected responses of ecosystem components in *Step 5* and *Step 6*.

Step 5 - Document expected response of each important ecosystem component in the short (<3 years) and long-term (>10 years) for each simulation

Technical matter experts documented their expected ecological response for each important ecosystem component (sediment quality, nutrients, aquatic macrophytes, macroinvertebrates and fish) in the short (<3 years) and long-term (>10 years). The interpretation was based upon directly modelled values (i.e. nutrients in the water column or HSI values) and/or the key drivers (and interactions between them) that influence the condition of the ecosystem component.

Step 6 - Qualitatively assess trend (improvement or deterioration) for each important ecosystem component and each simulation

Technical matter experts documented the expected trend in the condition for each key ecosystem component under each CIIP option and scenario simulation in the short (<3 years) and long-term (>10 years). The current (2020–21) condition of each key ecosystem component was used as a reference point for the trend assessment. Trend was assessed using the following five categories:

1. Major improvement
2. Minor improvement
3. Neutral
4. Minor deterioration
5. Major deterioration

4.3 Results and discussion

A summary of the expected ecological responses and trend (improvement or deterioration) in the short (<3 years) and long-term (>10 years) for key ecosystem components under each CIIP option and scenario simulated is presented in Table 4.1. There was variance in the expected ecological responses between key ecosystem components documented under each CIIP option and scenario. This variation is likely due to genuine differences in how each key ecosystem component would respond and the current condition of each key ecosystem component, as well as knowledge uncertainty (i.e. amount and quality of research), natural uncertainty (i.e. uncertainty due to natural variation) and under or over confidence bias by technical matter experts (Martin et al. 2012).

Table 4.1 Ecological interpretation of ecosystem component responses to CIIP scenarios and climatic conditions.

CIIP Scenario	Conditions	Sediment Quality *Key drivers: sediment nutrient levels, macroalgae, water column nutrients, particle size distribution, macroinvertebrates and aquatic plants*	*Trend*	Nutrients (Water column) *Key drivers: water source (marine, South East or River Murray), connectivity, Ulva, sediment quality.* *Direct values: TN, TP, Tchla, TRIX*	*Trend*	Aquatic macrophytes *Key drivers: Water level, salinity, water clarity, Ulva, nutrients* *Direct values: Ruppia HSI*	*Trend*	Macroinvertebrates *Key drivers: salinity, sediment quality, macroalgae (smothering by algal mats)*	*Trend*	Fish *Key drivers: flows (connectivity), salinity, water quality, food web* *Direct values: Fish HSI, Smallmouth Hardyhead HSI*	*Trend*
Lake Albert Connector realistic	Dry	Short-term trend: sediment nutrient fluxes likely to trigger continuing algal blooms. Deterioration is apparent in CNL also. Long-term trend: anoxic and sulfidic, and organic and nutrient rich sediment conditions will remain dominant throughout CSL and likely to worsen in CNL due to additional nutrient loads from Lake Albert and additional algal biomass created by increased nutrient availability.	Major deterioration	Short-term trend: Sustained nutrient enrichment particularly in summer, increased algal blooms in CNL Long-term trend: Some improvement in CSL predicted due to additional flushing but option is dependent on environmental water availability. CNL water quality will decline and the hyper-eutrophic state will become more widespread due to additional inputs of high nutrient water from Lake Albert. Risks that longitudinal water quality gradient, including salinity, is disrupted.	Major deterioration	Short-term trend: CSL trend is likely to see restricted areas of Ruppia habitat with poor condition including low productivity related to the scale of nutrient loads. Water level improvements during the latter flowering/fruiting period (Summer) might have a positive impact if the levels are maintained to enable flowering/seed set. Lower salinities will offset this water availability due to algal blooms if <90ppt during the late spring/summer period. Long-term trend: Without a net reduction in nutrients the conditions are unlikely to improve to enable long term recruitment of Ruppia community. This is likely to be the compounding impact of poor water and sediment quality, providing ongoing potential for hyper-eutrophic conditions. The conditions during drought periods are likely to lead to worsening outcomes due to lower water inputs and higher nutrients post drought.	Major deterioration	Short-term trend: CSL remains devoid of macroinvertebrates. CNL macroinvertebrates could benefit from lower salinities, but increased macroalgae counter the improvements. Less flushing (longer water age) at Beacon 1 could impact on estuarine macroinvertebrates. Long-term trend: CSL remains in degraded state. CNL macroinvertebrates affected by contradictory drivers, no long-term improvement expected.	Minor deterioration	Short-term trend: Low species diversity in the CSL, largely dominated by single species (Smallmouth Hardyhead) due to high salinity. Reduced salinity in the CNL will likely increase nursery habitat and benefit fish recruitment, but noting potential water quality issue with Lake Albert releases. Long-term trend: Species diversity remained low under dry climate and part of the CSL may not provide suitable habitat for fish, however, under typical hydrology, species diversity may increase with salt tolerant species entering the CSL. Reduced salinity in the CNL will increase nursery habitat and benefit fish recruitment.	Minor deterioration
	Typical		Minor deterioration		Major deterioration		Minor deterioration		Minor deterioration		Neutral
Lake Albert Connector realistic and dredge	Dry		Minor deterioration		Major deterioration	Short-term trend: CSL remains devoid of macroinvertebrates under 'Dry' conditions, some temporary colonisation possible under 'Typical' conditions. CNL macroinvertebrates could benefit from lower salinities. Greater risk of negative effects of macroalgae on macroinvertebrates in CSL and CNL. Less flushing (longer water age) at Beacon 1 could impact on estuarine macroinvertebrates. Long-term trend: CSL remains in degraded state. CNL macroinvertebrates affected by contradictory drivers, no long-term improvement expected.	Major deterioration		Minor deterioration	Short-term trend: Low species diversity in the CSL, largely dominated by single species (Smallmouth Hardyhead) due to high salinity under dry climate, although under typical hydrology, species diversity in the CSL may increase at salinities e.g. 45-54 ppt. Reduced salinity in the CNL will likely increase nursery habitat and benefit fish recruitment, if there are no other water quality issues (e.g. from Lake Albert water releases). Note improved connectivity is generally a positive driver for fish. Long-term trend: Species diversity remained low under dry climate, however, under typical hydrology, species diversity may increase with salt tolerant species entering the CSL. Reduced salinity in the CNL will increase fish nursery habitat and benefit recruitment.	Neutral
	Typical		Minor deterioration		Major deterioration		Minor deterioration		Minor deterioration		Minor improvement
Dredge	Dry	Short-term trend: not likely to be short term improvements due to time lag of response cycles. Long-term trend: potential for long term minor improvement in CSL sediment quality due to slightly reduced organic loadings to sediment as a result of increased connectivity and flushing over summer.	Minor improvement	Short-term trend: some improvement likely in CSL as options maintain channel connectivity between CSL and CNL over summer. Potential short term water quality risks (e.g. turbidity, low dissolved oxygen) due to dredging aspect. Long-term trend: potential for minor long term improvement in CSL water quality, particularly in summer.	Minor improvement	Short-term trend: Some improved opportunity for development of the Ruppia community in extent and condition with the advent of reduced nutrient loads but may/likely be impacted by macroalgal blooms. Long-term trend: Potential improvement to Ruppia habitat suitability and productivity, mainly driven by nutrient reductions. Caveat that concurrent reduction in salinities does not lead to	Minor deterioration	Short-term trend: CSL remains devoid of macroinvertebrates. CNL macroinvertebrates remains unchanged. Macroinvertebrates in CSL and CNL could be impacted by high macroalgal biomass. Long-term trend: CSL remains in degraded state. CNL macroinvertebrates reduced from macroalgal mats	Major deterioration	Short-term trend: Low species diversity in the CSL, largely dominated by single species (Smallmouth Hardyhead) due to very high salinity, although improved connectivity is generally a positive driver for fish. Long-term trend: Abundance of Smallmouth Hardyhead (SMH) likely to decline under continuing dry climate although under typical hydrology, SMH population can be maintained in the CSL due to slightly reduced salinity.	Minor deterioration
	Typical		Minor improvement		Minor improvement		Minor improvement		Major deterioration		Minor deterioration

CIIP Scenario	Conditions	Sediment Quality		Nutrients (Water column)		Aquatic macrophytes		Macroinvertebrates		Fish	
		Key drivers: sediment nutrient levels, macroalgae, water column nutrients, particle size distribution, macroinvertebrates and aquatic plants	*Trend*	*Key drivers: water source (marine, South East or River Murray), connectivity, Ulva, sediment quality. Direct values: TN, TP, Tchla, TRIX*	*Trend*	*Key drivers: Water level, salinity, water clarity, Ulva, nutrients Direct values: Ruppia HSI*	*Trend*	*Key drivers: salinity, sediment quality, macroalgae (smothering by algal mats)*	*Trend*	*Key drivers: flows (connectivity), salinity, water quality, food web Direct values: Fish HSI, Smallmouth Hardyhead HSI*	*Trend*
						macroalgal blooms having a continued negative impact through shading and physical interference with flowering/seed set.					
Constantly pumping in 250	Dry	Short-term trend: minor improvements in CSL due to time lag of response cycles, no improvement in CNL. Long-term trend: sediment quality likely to markedly improve in CSL, however deterioration is possible in CNL also, so therefore only a net "minor improvement" was allocated due to CSL results.	Minor improvement	Short-term trend: rapid short term response due to improved flushing of CSL. However, CNL water quality deteriorates so given "minor deterioration" to reflect this despite CSL improving. Long-term trend: potential for long term response to be different than short term captured in model due to feedback loops and question whether CSL will improve to point where CNL does not deteriorate any further in this scenario.	Minor deterioration	Short-term trend: Some improved opportunity for development of the Ruppia community in extent and condition with the advent of reduced nutrient loads but may/likely be impacted still by macroalgal blooms. Long-term trend: Potential improvement to Ruppia habitat suitability and productivity, mainly driven by nutrient reductions. Caveat that concurrent reduction in salinities does not lead to macroalgal blooms having a continued negative impact through shading and physical interference with flowering/seed set.	Neutral	Short-term trend: CSL remains devoid of macroinvertebrates. CNL macroinvertebrates deteriorate as salinities increase and reduced flushing risks poorer water quality Long-term trend: CSL remains in degraded state, CNL will deteriorate	Major deterioration	Short-term trend: Species diversity remains low in the CSL, largely dominated by single species (Smallmouth Hardyhead) with high salinity (e.g. 79-100) under dry climate. In the CNL, the increased salinity particularly during Jan-May (e.g. to 78 ppt) will negatively impact on fish, leading to a substantial reduction in species diversity, loss of suitable nursery area and reduced fish recruitment. Long-term trend: Species diversity remains low in the CSL, dominated by abundant Smallmouth Hardyhead with high salinity (e.g. 63-79 ppt under typical hydrology). In the CNL, the increased salinity particularly during Jan-May (e.g. to 65 ppt under typical hydrology) will likely reduce species diversity (more dominant by SMH), reduce suitable nursery area and fish recruitment for most estuarine and marine-estuarine opportunistic species.	Major deterioration
	Typical		Minor improvement		Minor improvement		Minor improvement		Major deterioration		Major deterioration
Constantly pumping out 125	Dry	Short-term trend: no significant short term improvements due to time lag of response cycles and internal loadings of nutrients. Long-term trend: potential for long term improvement in CSL sediment quality due to slightly reduced organic loadings to sediment as a result of increased connectivity and flushing, although during the summer period there is lack of flushing. Drying of margins could benefit sediment quality (i.e. reduce anoxia) but create other ecological issues.	Minor improvement	Short-term trend: rapid short term response due to improved flushing and exporting of nutrient and algal rich water from CSL to ocean. Long-term trend: improvement in CSL and CNL water quality, potential for long term response to be stronger than short term captured in model due to feedback loops with restoration of healthier ecosystem function.	Major improvement	Short-term trend: Some improved opportunity for development of the Ruppia community in extent and condition with the advent of reduced nutrient loads but may/likely be impacted still by macroalgal blooms. Long-term trend: Potential improvement to Ruppia habitat suitability and productivity, mainly driven by nutrient reductions. Caveat that concurrent reduction in salinities does not lead to macroalgal blooms having a continued negative impact through shading and physical interference with flowering/seed set.	Neutral	Short-term trend: CSL remains devoid of macroinvertebrates with high salinities and high macroalgal biomass. CNL macroinvertebrates would increase from lower salinities, but high macroalgal biomass counters any improvements. Long-term trend: CSL remains in degraded state and CNL macroinvertebrates decline from macroalgal mats	Major deterioration	Short-term trend: Low species diversity in the CSL, largely dominated by single species (Smallmouth Hardyhead) due to high salinity under dry climate, although under typical hydrology, species diversity may increase due to reduced salinities. Note the water level reduction during summer in the CSL may slightly reduce fish habitat. In the CNL, much reduced salinities will increase nursery habitat area and benefit fish recruitment. Long-term trend: Species diversity remained low under dry climate, however, under typical hydrology, species diversity will increase with salt tolerance species entering the CSL. Reduced salinity in the CNL will increase nursery habitat and benefit fish recruitment.	Minor improvement
	Typical		Major improvement		Major improvement		Minor improvement		Major deterioration		Minor improvement

CIIP Scenario	Conditions	Sediment Quality		Nutrients (Water column)		Aquatic macrophytes		Macroinvertebrates		Fish	
		Key drivers: sediment nutrient levels, macroalgae, water column nutrients, particle size distribution, macroinvertebrates and aquatic plants	*Trend*	*Key drivers: water source (marine, South East or River Murray), connectivity, Ulva, sediment quality.* *Direct values: TN, TP, Tchla, TRIX*	*Trend*	*Key drivers: Water level, salinity, water clarity, Ulva, nutrients* *Direct values: Ruppia HSI*	*Trend*	*Key drivers: salinity, sediment quality, macroalgae (smothering by algal mats)*	*Trend*	*Key drivers: flows (connectivity), salinity, water quality, food web* *Direct values: Fish HSI, Smallmouth Hardyhead HSI*	*Trend*
Constantly pumping out 250	Dry	Short-term trend: minor improvements due to time lag of response cycles. Long-term trend: with lower salinities maintained over long term we would expect significant improvement to macroinvertebrate functions to reducing anoxia and promoting denitrification and reducing sulfide buildup. Major improvement long term.	Minor improvement	Short-term trend: rapid short term response due to improved flushing and drawing more barrage water into CSL. However, reduced summer volume is a risk for high nutrients - would need to avoid lowering water levels too much. Long-term trend: potential for long term response to be stronger than short term captured in model due to feedback loops.	Major improvement	Short-term trend: Salinity reductions should be beneficial to Ruppia flowering and seed lifecycle phases. Reduction in water column nutrients should bring macroalgae load down which would be beneficial to Ruppia. However, risk that macroalgae species could shift but still have shading effect and interfere with flowering/seed set if occurring during late Spring/Summer. Long-term trend: Improvement to productivity, mainly driven by nutrient reductions. Caveat that concurrent reduction in salinities does not lead to macroalgal blooms.	Neutral	Short-term trend: CSL recolonisation can commence driven by lower salinity but at reduced diversity. CNL macroinvertebrates could diversify and become more abundant with lower salinity, but <u>only</u> if macroalgal biomass substantially reduced. Lower water level in summer under this particular scenario is a negative driver. Increase in macroalgae could counter the improvements of macroinvertebrates in both CSL and CNL. Better flushing could be beneficial by improving water quality. Long-term trend: More CSL macroinvertebrate colonisation and further improving trends <u>if</u> reduction in macroalgae biomass under lowered nutrient regime. CNL macroinvertebrates can function as source populations for recolonisation of CSL. CSL macroinvertebrates become similar to existing CNL. Positive feedback on sediment nutrients possible.	Minor improvement	Short-term trend: Increasing species diversity in CSL with reduced salinity. However, lower water level during summer is a negative driver, potentially resulting in some reduction in fish habitat and loss of connectivity. In the CNL, further reduced salinity will increase nursery area and benefit fish recruitment. Long-term trend: Major increase in species diversity, abundance and distribution in the CSL with salinity maintained <60 ppt all year round and <35 ppt during 55% of the year under 'typical hydrology'. With improved habitat conditions, the CSL could provide nursery ground to support the recruitment of many estuarine and marine-estuarine opportunistic fish species. It may contribute to partial commercial fishery.	Minor improvement
	Typical		Major improvement		Major improvement		Major improvement		Minor improvement		Major improvement
Constantly pumping water in and out	Dry	Short-term trend: minor improvements due to time lag of response cycles. Long-term trend: lower salinities maintained over long term would expect significant improvement to macroinvertebrate functions to reducing anoxia and promoting denitrification and reducing sulfide buildup. Major improvement long term.	Minor improvement	Short-term trend: rapid short term response due to improved flushing and drawing more barrage water into CSL. However, reduced summer volume is a risk for high nutrients - would need to avoid lowering water levels too much. Long-term trend: potential for long term response to be stronger than short term captured in model due to feedback loops.	Major improvement	Short-term trend: Some improved opportunity for development of the Ruppia community in extent and condition with the advent of reduced nutrient loads but may/likely be impacted still by macroalgal blooms. Long-term trend: Potential improvement to Ruppia habitat suitability and productivity, mainly driven by nutrient reductions. Caveat that concurrent reduction in salinities does not lead to macroalgal blooms having a continued negative impact through shading and physical interference with flowering/seed set.	Neutral	Short-term trend: CSL could see temporary recolonisation by macroinvertebrates at the northern end with some improvements to water quality, but increased macroalgae could counter their occurrence. CNL macroinvertebrates benefit from better water quality, which is countered by macroalgal biomass. Long-term trend: CSL remains in degraded state, as salinity reductions not low and persistent enough to sustain recolonising macroinvertebrates. CNL macroinvertebrates could diversify and become more abundant with lower salinity, but <u>only</u> if macroalgal biomass substantially reduced.	Minor deterioration	Short-term trend: Increasing species diversity in CSL due to reduced salinity (to e.g. 56-68 ppt). SMH continue to be abundant but other salt tolerant species may enter CSL at times. In the CNL, reduced salinity will increase nursery habitat area and improve fish recruitment and abundance. Long-term trend: Increase in species diversity in the CSL due to reduced salinity, 98% at <60 ppt under 'typical hydrology'. In the CNL, reduced salinity will increase nursery habitat area and improve fish recruitment and abundance.	Minor improvement
	Typical		Major improvement		Major improvement		Minor improvement		Minor deterioration		Major improvement

		Sediment Quality		Nutrients (Water column)		Aquatic macrophytes		Macroinvertebrates		Fish	
CIIP Scenario	Conditions	*Key drivers: sediment nutrient levels, macroalgae, water column nutrients, particle size distribution, macroinvertebrates and aquatic plants*	*Trend*	*Key drivers: water source (marine, South East or River Murray), connectivity, Ulva, sediment quality.* *Direct values: TN, TP, Tchla, TRIX*	*Trend*	*Key drivers: Water level, salinity, water clarity, Ulva, nutrients* *Direct values: Ruppia HSI*	*Trend*	*Key drivers: salinity, sediment quality, macroalgae (smothering by algal mats)*	*Trend*	*Key drivers: flows (connectivity), salinity, water quality, food web* *Direct values: Fish HSI, Smallmouth Hardyhead HSI*	*Trend*
Pumping water out above 0.2m	Dry	Short-term trend: not likely to be short term improvements due to time lag of response cycles. Long-term trend: potential for long term minor improvement in sediment quality due to slightly reduced organic loadings to sediment.	Minor improvement	Short-term trend: short term response due to improved flushing of both CSL and CNL, however much more minor effects predicted relative to higher pump out scenarios. Long-term trend: minor long term improvement in water quality (TN, TP, chlorophyll) predicted relative to higher pump out scenarios.	Minor improvement	Short-term trend: Some improved opportunity for development of the Ruppia community in extent and condition with the advent of reduced nutrient loads but may/likely be impacted still by macroalgal blooms. Long-term trend: Potential improvement to Ruppia habitat suitability and productivity, mainly driven by nutrient reductions. Caveat that concurrent reduction in salinities does not lead to macroalgal blooms having a continued negative impact through shading and physical interference with flowering/seed set.	Neutral	Short-term trend: CSL remains devoid of macroinvertebrates, as salinities to high and the increase in macroalgae would be detrimental. CNL macroinvertebrates would benefit from lower salinities, but macroalgal increase will counter any improvement. Long-term trend: CSL remains in degraded state and CNL declining from macroalgal mats	Major deterioration	Short-term trend: Low species diversity in the CSL, largely dominated by single species (Smallmouth Hardyhead) due to high salinity under dry climate, although under typical hydrology, species diversity may increase due to reduced salinities. Slightly lower salinities in the CNL may increase nursery habitat and benefit fish recruitment. Long-term trend: Species diversity remained low under dry climate, however, under typical hydrology, species diversity may increase with salt tolerant species entering the CSL. Reduced salinity in the CNL will increase nursery habitat and benefit fish recruitment.	Neutral
	Typical		Minor improvement		Minor improvement		Minor improvement		Major deterioration		Minor improvement
Pumping water in or out (AHD > 0.3m <0.15m)	Dry	Short-term trend: sediment nutrient fluxes likely to reduce in CSL. Deterioration is apparent in CNL also. Long-term trend: sediment quality likely to markedly improve in CSL, however deterioration is possible in CNL also so only a net "minor improvement" allocated due to CSL results.	Minor improvement	Short-term trend: rapid short term response due to improved flushing of CSL. However, CNL water quality deteriorates. Long-term trend: potential for long term response to be different than short term captured in model due to feedback loops and question whether CSL will improve to point where CNL does not deteriorate any further in this scenario.	Minor improvement	Short-term trend: Some improved opportunity for development of the Ruppia community in extent and condition with reduced nutrient loads but may be impacted still be macroalgal blooms. Long-term trend: Potential improvement to Ruppia habitat suitability and productivity, mainly driven by nutrient reductions. Caveat that concurrent reduction in salinities does not lead to macroalgal blooms having a continued negative impact through shading and physical interference with flowering/seed set.	Neutral	Short-term trend: CSL remains devoid of macroinvertebrates, as salinity remains high, and macroalgae increase in CSL. CNL macroinvertebrates decrease with the higher salinities, and poorer water quality (nutrients, water level). Long-term trend: CSL remains in a degraded state and macroinvertebrates in CNL deteriorating	Major deterioration	Short-term trend: Species diversity remains low in the CSL, largely dominated by single species (Smallmouth Hardyhead) with salinity at e.g. 73-81 ppt under dry climate. In the CNL, increased salinity particularly during Jan-May (e.g. to 87.5 ppt) will negatively impact on fish, leading to a substantial reduction in species diversity, loss of suitable nursery area and reduced fish recruitment. Long-term trend: Species diversity remains low in the CSL, dominated by abundant Smallmouth Hardyhead with salinity at e.g. 61-69 ppt under typical hydrology. In the CNL, the increased salinity particularly during Jan-May e.g. to 72.3 ppt will likely reduce species diversity (more dominant by SMH), reduce suitable nursery area and recruitment for most estuarine and marine-estuarine opportunistic species.	Major deterioration
	Typical		Minor improvement		Minor improvement		Minor improvement		Major deterioration		Major deterioration
Passive ocean connector (10 x 1.5m pipes)	Dry	Short-term trend: no significant short term improvements due to time lag of response cycles and internal loadings of nutrients. Long-term trend: potential for long term improvement in CSL sediment quality due to slightly reduced organic loadings to sediment as a result of increased connectivity and	Minor improvement	Short-term trend: rapid short term response due to improved flushing and drawing more barrage water into CSL but some deterioration in CNL water quality predicted as poorer water quality enters from CSL under this scenario (so given "minor deterioration" for CNL situation). This strategy more effective in summer when high	Minor deterioration	Short-term trend: Some improved opportunity for development of the Ruppia community in extent and condition with the advent of reduced nutrient loads but may/likely be impacted still by macroalgal blooms. Initial flushing may lead to localised losses. Long-term trend: Potential improvement to Ruppia habitat	Minor deterioration	Short-term trend: CSL remains devoid of macroinvertebrates, as salinities are too high and the macroalgae increase would be detrimental. CNL macroinvertebrates would benefit from lower salinities, but macroalgal increase will counter any improvement. Long-term trend: CSL remains in	Major deterioration	Short-term trend: With slightly reduced salinity, SMH continue to be dominant and abundant in the CSL under dry climate, although other salt tolerant species may enter CSL at times under typical hydrology. In the CNL, reduced salinity will increase nursery habitat and benefit fish recruitment. Long-term trend: Slight increase in species diversity in the CSL due to	Minor improvement

CIIP Scenario	Conditions	Sediment Quality *Key drivers: sediment nutrient levels, macroalgae, water column nutrients, particle size distribution, macroinvertebrates and aquatic plants*	*Trend*	Nutrients (Water column) *Key drivers: water source (marine, South East or River Murray), connectivity, Ulva, sediment quality.* *Direct values: TN, TP, Tchla, TRIX*	*Trend*	Aquatic macrophytes *Key drivers: Water level, salinity, water clarity, Ulva, nutrients* *Direct values: Ruppia HSI*	*Trend*	Macroinvertebrates *Key drivers: salinity, sediment quality, macroalgae (smothering by algal mats)*	*Trend*	Fish *Key drivers: flows (connectivity), salinity, water quality, food web* *Direct values: Fish HSI, Smallmouth Hardyhead HSI*	*Trend*
	Typical	flushing, although over the summer period there is lack of flushing.	Minor improvement	difference in water levels between ocean and CSL. Long-term trend: potential for long term improvement in water quality in CSL, model predicts slight deterioration in CNL for some parameters.	Minor improvement	suitability and productivity, mainly driven by nutrient reductions. Caveat that concurrent reduction in salinities does not lead to macroalgal blooms having a continued negative impact through shading and physical interference with flowering/seed set.	Minor improvement	degraded state and CNL declines from macroalgal mats	Major deterioration	reduced salinity, 81% at <60 ppt under 'typical hydrology'. In the CNL, reduced salinity will increase nursery habitat and benefit fish recruitment.	Minor improvement
Constantly pumping out 250 and Dredging	Dry	Short-term trend: minor improvements due to time lag of response cycles. Long-term trend: lower salinities and flushing maintained over long term would expect significant improvement to sediment quality, including restoring macroinvertebrate functions to reduce severity of sediment anoxia, and promoting denitrification and reducing sulfide build-up. Major improvement long term.	Minor improvement	Short-term trend: rapid short term response due to improved flushing and drawing more barrage water into CSL. Maintains channel connectivity over summer. Potential short term water quality risks (e.g. turbidity, low dissolved oxygen) due to dredging aspect. Long-term trend: potential for major long term improvement in water quality, response may be stronger than model predictions due to feedback loops with improved ecosystem function.	Major improvement	Short-term trend: Some improved opportunity for development of the Ruppia community in extent and condition with the advent of reduced nutrient loads but may/likely be impacted still by macroalgal blooms. Initial flushing may lead to localised losses. Sediment disturbance will lead to localised losses. Long-term trend: Potential improvement to Ruppia habitat suitability and productivity, mainly driven by nutrient reductions. Caveat that concurrent reduction in salinities does not lead to macroalgal blooms having a continued negative impact through shading and physical interference with flowering/seed set.	Minor improvement	Short-term trend: CSL recolonisation can commence driven by lower salinity. CNL macroinvertebrates can diversify and become more abundant with lower salinity, but <u>only</u> if macroalgal biomass substantially reduced. Increase in macroalgae could counter the improvements of macroinvertebrates in both CSL and CNL. Better flushing could be beneficial by improving water quality. Long-term trend: More CSL colonisation by macroinvertebrates and further improving trends <u>if</u> reduction in macroalgae biomass under lowered nutrient regime. CNL macroinvertebrates could function as source populations for recolonisaton of CSL. CSL macroinvertebrates become more diverse and similar to existing CNL. Positive feedback on sediment nutrients possible.	Minor improvement	Short-term trend: Increasing species diversity in CSL with substantially reduced salinity. In the CNL, further reduced salinity will increase nursery area and increase fish recruitment and abundance. Note improved connectivity is a positive driver for fish. Long-term trend: Major increase in species diversity and distribution in the CSL with salinity maintained <60 ppt all year round and <35 ppt during 51% of the year under 'typical hydrology'. With improved habitat conditions, the CSL could provide nursery ground to support the recruitment of many estuarine and marine-estuarine opportunistic fish species. It may contribute to partial commercial fishery.	Major improvement
	Typical		Major improvement		Major improvement		Minor improvement		Minor improvement		Major improvement
SEFA	Dry	Short-term trend: ongoing sediment nutrient fluxes likely to trigger continuing algal blooms and deposition of organic nutrients to sediment. Long-term trend: Long-term trend: anoxic and sulfidic, and organic and nutrient rich sediment conditions will remain dominant throughout CSL and likely to worsen in CNL.	Minor improvement	Short-term trend: Sustained nutrient enrichment particularly in summer as SEFA does not create sufficient flushing to reduce eutrophication. Long-term trend: Some minor long term improvement in CSL water quality predicted by model, no significant change to CNL due to insufficient flushing.	Minor deterioration	Deterioration as per base case	Major deterioration	Short-term trend: CSL remains devoid of macroinvertebrates. Macroinvertebrate recovery in CSL also impacted by higher macroalgae Long-term trend: CSL remains in degraded state. Risk that CNL experiences similar deterioration to CSL.	Major deterioration	Short-term trend: Low species diversity in the CSL, largely dominated by single species (Smallmouth Hardyhead) due to very high salinity. Long-term trend: abundance likely to decline under continuing dry climate in the CSL, although SMH population could be maintained under typical hydrology.	Major deterioration
	Typical		Minor improvement		Minor deterioration		Major deterioration		Major deterioration		Minor deterioration

5 Ecological Risk Assessment

5.1 Introduction

The CIIP Steering Committee agreed that a risk-based approach be used to inform decisions regarding the choice of CIIP options to progress for detailed engineering and construction feasibility. Accordingly, an ecological risk assessment framework (ERAF) (Butcher and Cottingham 2021) was developed to establish the principles and methods of such an approach. The ERAF adopts the relevant Australian Standard for risk (AS/NZS ISO 31000:2020 Risk Management) and DEW's risk management framework for water planning and management (DEWNR 2012).

A key feature of the ISO 31010:2020 standard is that it defines risk as the effect of uncertainty on objectives. Accordingly, the ERAF framed risk and benefit as a function of likelihood and consequence as follows:

- **Benefit** - likelihood of minimal/nil deviation from objectives increased and the likelihood of significant deviation from objectives decreased.
- **Risk** - likelihood of minimal/nil deviation from objectives is decreased and the likelihood of significant deviation from objectives is increased.

For this assessment, "objectives" refer to the management objectives for the Coorong detailed in the *Ramsar Management Plan* (DEW 2021b) or the desired state for the Southern Coorong in the *State of the Coorong* report (DEW 2021c).

Benefit and risk were both assessed by comparing the risk profile of a no-build (basecase) scenario with that under a proposed CIIP option (or combination of options) (Figure 5.1).

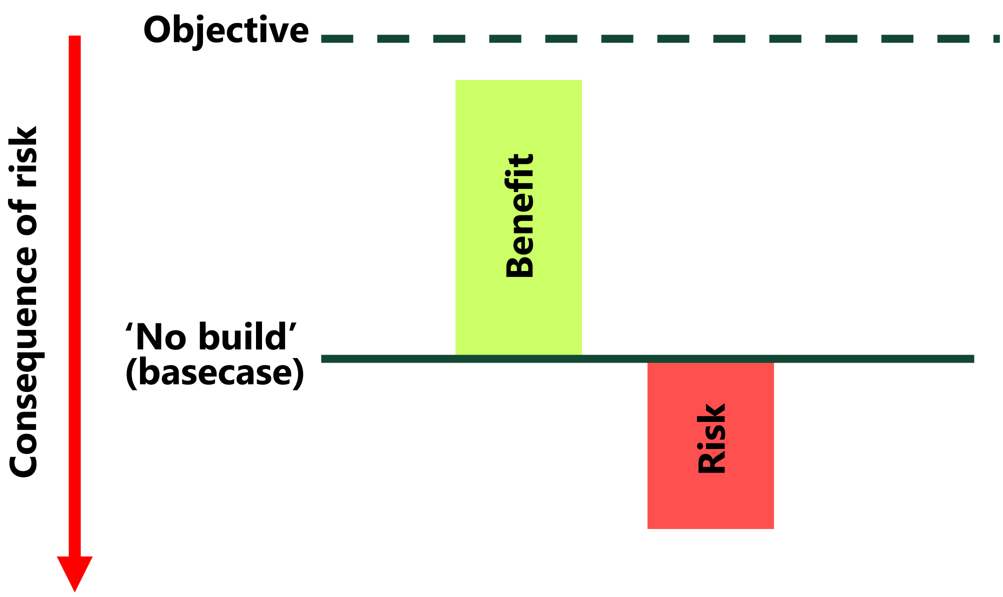


Figure 5.1 Schematic diagram demonstrating how benefit and risk were assessed in the ecological risk assessment.

5.2 Scope

The scope and criteria used for the ERAF assessment were refined and confirmed by the risk assessment team over two workshops. The scope (geographic and temporal limits) and criteria (hazards, CIIP options and climate scenarios) used in the ERAF assessment are detailed in Table 5.1 .

Table 5.1 The scope and criteria used for the ERAF assessment.

ERAF scope/criteria	Description
Geographic area of risks assessed	Coorong South Lagoon, other geographically defined features of the Ramsar site (e.g. Coorong North Lagoon)
Geographic area of risks identified and not assessed	Outside Ramsar site (e.g. Southern Ocean)
Timeframe for benefit/risk assessment	20 year period (2025-45)
Hazards	Hydrology and water quality
	Sediment quality Nutrient cycling
	Productivity
CIIP options	None (i.e. "no-build" control) Pumped ocean connector
	Passive ocean connector
	Dredging (alone and in combination with other options)
	Lake Albert Connector
	South East Flows Augmentation
Climate scenarios	Normal
	Dry
	Extra dry
Miscellaneous scenarios	Sea level rise under climate change (0.24m by 2050)

5.3 Risk pathways

The ERAF establishes the following framework for defining risk pathways:

source of risk (threat/stressor combinations) → event → consequence

Where:

- Threat: the human activities or processes that have impacted, are impacting, or may impact the status of the attribute being assessed (e.g., unsustainable fishing or logging, agriculture, housing developments, etc.)
- Stressor: the altered agents/processes that cause an ecological effect that impacts on the critical components, processes and services which exemplify the site's ecological character. (e.g. increased toxicants or salinity)
- Event: a change in circumstances, arising from a stressor, when a stressor causes a particular level of harm (e.g. when salinity exceeds a particular threshold)

- Consequence: an effect or outcome from an event that in turn affects the achievement of the objectives set for the Coorong South Lagoon. A consequence can itself become a stressor which may lead to a further impact pathway. The level of consequence is assessed using end-points, which are dependent variables that are representative of ecological benefits and consequences.

5.3.1 Risk sources

A total of eight threat/stressor combinations were identified as risks to the Coorong ecosystem (Table 5.2). It was determined that sources of risk relating to the quality of inflows, including toxicants, nutrients and salinity are adequately controlled through existing State and Federal instruments including the Basin Plan, *Environmental Protection* Act 1993 (SA), *Landscapes Act 2019* (SA), *River Murray Act 2003* (SA). Therefore, for the purpose of the ERAF, only the three following threat/stressor combinations are to be considered:

- Climate change: change in precipitation and hydrological regimes causing decreased rainfall and freshwater inflows
- Climate change: change in temperature regimes causing increased temperature
- Natural system modifications: Dams and water management causing reduced freshwater inflows to lagoons

Risks to the quantity (volume) of freshwater inflows (i.e. GL per year) caused by natural system modifications are controlled by both state and Australian government legislation and policy including the Murray-Darling Basin Agreement, Basin Plan 2012 and the *Landscapes Act 2019* (SA). It was determined that there is uncertainty regarding the effectiveness of these controls in this context, particularly climate change as a potential escalating factor over time. These sources of risk are represented by the range of inflow scenarios simulated by the TUFLOW-FV and Coorong Dynamics Model.

Table 5.2 Threat and stressor combinations identified as risks to the Coorong ecosystem. Those marked by an asterisk (*) are to be the focus of the ERAF.

Threat	Stressor
Climate change: Change in precipitation and hydrological regimes*	Decreased rainfall and freshwater inflows*
Climate change: Change in temperature regimes*	Increased temperature*
Natural system modifications: Dams and water management*	Reduced freshwater inflows to lagoons*
Natural system modifications: Dams and water management	Release of toxicants
Natural system modifications: Dams and water management	Increased salinity
Natural systems modifications: Fire & fire suppression	Increased nutrients
Pollution: Agricultural effluents	Increased nutrients
Pollution: Agricultural effluents	Increased salinity

5.3.2 Events

Events, including changes in salinity and water levels, which could cause ecological consequences are simulated by the TUFLOW-FV model and Coorong Dynamics Model.

5.3.3 Consequence

The ERAF defined criteria for five levels of consequence:

1. Insignificant
2. Minor
3. Moderate
4. Significant
5. Very significant

Consequences are defined relative to the ecological objectives defined for the Coorong, with "insignificant consequence" representing the desired ecological state. Minor, and more severe ecological consequences describe increasing departure from this desired state, with "very significant" describing the worst conceivable ecological outcome over the 20 year timeframe relevant for this assessment.

Consequences were assessed through a set of agreed end-points, which can be thought of as the dependent variable of the analysis. These end-points aim to be representative of the ecological benefits and consequences potentially arising from the CIIP options. The following criteria were used to select end-points:

- direct, indirect or assumed surrogate measures of the critical conponents, processes and services (CPS) that form the Ecological Character of the South Lagoon component of the Ramsar site
- related to the identified ERAF "hazards", i.e.:
  - hydrology and water quality
  - sediment quality
  - nutrient cycling
  - productivity
- measurable
- outputs of existing models where possible
- not correlated with other ecological parameters

Using these criteria, five end-points were selected:

1. Salinity in the Coorong South Lagoon
2. Salinity in the Coorong North Lagoon
3. Water level in the Coorong South Lagoon
4. Nutrients in the Coorong South Lagoon
5. Nutrients in the Coorong North Lagoon

Risk assessment end-points 1 to 3 (i.e. salinity and water level) were selected on the basis that they addressed the agreed criteria (above). End-points 4 and 5 (i.e. nutrients) do not address the first criteria (i.e. measure of a critical CPS informing the Ecological Character), yet they were selected as they address the remaining criteria and are key to enable assessment of the recovery of the CSL from a hyper-eutrophic to mesotrophic state and also align with three of the four ERAF hazards (Table 5.1).

Note that the five risk assessment end-points do not consider biota (e.g. waterbirds, fish, *Ruppia* and macroinvertebrates) included as critical CPS in the Ramsar Management Plan and Ecological Character Description.
The risk assessment team omitted biota that are critical CPS as end-points given the following principles:

- There are established causal links between the selected 5 end-points and the remaining ecological parameters

- Causal links between end-points and other ecological parameters are considered by the criteria for consequence severity levels (Table 5.3)
- The selected 5 end-points are direct outputs of existing hydrological and biogeochemical models
- The selected 5 end-points provide sufficient coverage of the four hazards identified by the ERAF, and
- Analysing the effects of CIIP options on the full suite of 23 end-points was impracticable in the context of this assessment.

The risk assessment team established criteria for five consequence levels that ranged from insignificant to very significant for each end-point (Table 5.3).

Table 5.3 Rationale for environmental outcomes reflective of each consequence level (insignificant, minor, moderate, significant, very significant) for each End-point of the ERAF.

End-point	Consequence level	Outcome	Rationale
Coorong South Lagoon water levels	Insignificant	Water levels in the Coorong South Lagoon to be maintained >+0.3 m AHD in June and July, between +0.4 m AHD and +0.2 m AHD from August to December	• Water levels in the South Lagoon of +0.35 m AHD over June and July should provide optimal growth conditions for *R. tuberosa* (DEW 2021c). • Water levels above +0.3 m AHD would help facilitate connectivity and exchange of water between the North and South Lagoon, which could benefit ecosystem function through improved water and sediment quality (e.g. Mosley et al. 2020). • Optimal water levels for *R. tuberosa* (and presumably *A. cylindrocarpa*) reproductive output are approximately +0.25 m AHD as the vast majority (88%) of *R. tuberosa* and *A. cylindrocarpa* plants were distributed between -0.15–+0.15 m AHD in spring 2020 (Oerman 2021) and densities of *R. tuberosa* flowers, seeds and turions are greatest in 0.1–0.4m of water (Kim et al. 2015).
	Minor	Water levels maintained above +0.3 m AHD in June and July, and below +0.2 m AHD from August to December for less than 7 consecutive days.	• Potential for *R. tuberosa* desiccation within core elevation distribution (0.15–+0.15 m AHD, Oerman 2021) before plants have set seed or produced turions (Paton et al. 2019).
	Moderate	Water levels maintained above +0.3 m AHD in June and July, and below +0.2 m AHD from August to December for >7 consecutive days.	• High potential for *R. tuberosa* desiccation within core elevation distribution (0.15–+0.15 m AHD, Oerman 2021) before plants have set seed or produced turions (Paton et al. 2019).
	Significant	Water levels drop below target range from June to December but not below 0 m AHD over this period.	• No connectivity between North and South Lagoons of the Coorong. • Significant desiccation of *R. tuberosa* plants before plants have set seed or produced. Reproductive output (turions and seed) for annual *R. tuberosa* plant is expected to be negligible, however, perennial plants are expected to persist.
	Very significant	Water levels drop below 0 m AHD for > 8 consecutive months	• No connectivity between North and South Lagoons of the Coorong.

End-point	Consequence level	Outcome	Rationale
			• Expected to result in the failed completion of multiple life stages of *R. tuberosa*, loss of annual plants and dependence upon a seed bank for future resilience (DEW 2021c).
Coorong South Lagoon salinity	Insignificant	Average daily salinity in the South Lagoon < 60 ppt year-round	• A variety of macroinvertebrate prey types are available for fish and shorebirds at salinities below 60 ppt (Ye et al. 2021). • The fish community is diverse, abundant and inclusive of both small- and large-bodied species at salinities below 60 ppt (Ye et al. 2019a). • Optimal conditions for *R. tuberosa* germination (10–60 ppt), vegetative growth (30–120 ppt), flowering and seed set (40–63 ppt) (Collier et al. 2017; Asanopoulos and Waycott 2020).
	Minor	Maximum average daily salinities in the South Lagoon are 60-100 ppt	Salinities <100 ppt in the Coorong South Lagoon support: • Suitable conditions for *R. tuberosa* flowering (leading to seed-set) between September and December (optimal: 40–63 ppt, suboptimal: 17–102 ppt; Collier et al. 2017; Asanopoulos and Waycott 2020). • Optimal salinity conditions (full range: 30–122 ppt) for *R. tuberosa* adult plant (vegetative) growth (Collier et al. 2017; Asanopoulos and Waycott 2020). • Suitable conditions for small-mouthed hardyhead recruitment and distribution (Ye et al. 2020), including avoiding lethal effects (i.e. the LC_{50} value is 108 ppt; Lui 1969). • Suitable conditions for larvae of salt-tolerant chironomids (*Tanytarsus barbitarsis*) (Dittmann 2015), including avoiding lethal effects (i.e. LC_{50} value is 97 ppt; Kokkinn 1986).
	Moderate	Average daily salinity in the South Lagoon are > 60 ppt in winter and annual maximum salinity is >100 ppt	• Salinities >60 ppt in winter are sub-optimal (60–85 ppt) or unsuitable (>85 ppt) for *R. tuberosa* germination from seed (Collier et al. 2017). • Salinities >100 ppt exceed or approach the salinity tolerance of small-mouthed hardyhead (108 ppt; Lui 1969), salt-tolerant chironomids (97 ppt; Kokkinn 1986) and flowering and seed set for *R. tuberosa* (Collier et al. 2017).
	Significant	Average monthly salinity exceeds 100 ppt for 6 to 18 consecutive months	• Conditions would have been unsuitable for at least one life stage of *R. tuberosa* (Collier et al. 2017).

End-point	Consequence level	Outcome	Rationale
			• The abundance of chironomid larvae and small-mouthed hardyhead would be expected to become severely reduced and their distributions contracted towards Parnka Pt.
	Very significant	Average monthly salinity exceeds 100 ppt for ≥ 18 consecutive months	• Salinities of >100 ppt for ≥18 consecutive months were recorded at the height of the Millennium Drought (2007–10) and were associated with the extirpation of key food resources (*R. tuberosa*, small-mouthed hardyhead and chironomid larvae) in the South Lagoon (Paton and Bailey 2012: Ye et al. 2020).
Coorong North Lagoon salinity	Insignificant	Average monthly salinity < 45 ppt	Salinities <45 ppt in the Coorong North Lagoon support: • Common macroinvertebrate species with hypermarine salinity tolerances (as shown in brackets) including: polychaete worms *Nephtys australiensis* (50 ppt), *Boccardiella limnicola* (40 ppt) and *Australonereis ehlersi* (50 ppt) and gastropod snails *Salinator fragilis* (45 ppt) and *Hydrobiidae* (45 ppt) (Dittmann et al. 2018). • Preferred habitats for adult greenback flounder: salinities <45 ppt were used by tracked greenback flounder over 91% of the time in the Murray estuary and Coorong (Earl et al. 2017). • Optimal conditions for fertilisation (35–45 ppt) and survival (15–45 ppt) of greenback flounder eggs (as shown in aquaria studies: Hart and Purser 1995). • Suitable conditions for juvenile black bream (0–48 ppt) to survive and grow (as shown in aquaria studies: Partridge and Jenkins 2002). • Conditions that support *Ruppia* flowering and seed bank formation mainly in the southern section of the North Lagoon (optimal: 40–63ppt, suboptimal: 17–102ppt; Collier et al. 2017; Asanopoulos and Waycott 2020).
	Minor	Average monthly salinity > 45 ppt for < 2 months	• Possible contraction of the distribution- and reduction in the abundance, biomass and diversity of common macroinvertebrate species. • Possible contraction of habitat suitable for greenback flounder spawning and recruitment and a reduction in preferred habitat of adult fish. • Possible contraction in habitat for juvenile black bream.
	Moderate	Average monthly salinity > 45 ppt for 2-6 months	• Likely contraction of the distribution- and reduction in the abundance, biomass and diversity of common macroinvertebrate species.

End-point	Consequence level	Outcome	Rationale
			• Conditions likely unsuitable for the spawning and recruitment of estuarine fish (e.g. greenback flounder and black bream).
	Significant	Average monthly salinity > 70 ppt for 6-18 consecutive months	• The below ecological responses to salinities >70 ppt would occur for 6 to 18 consecutive months: • Salinity tolerance of all polychaete species (with the exception of *Capitella capitata* that can occur in low densities in salinities up to 90 ppt) in the Coorong are exceeded. • Loss of an estuarine and marine macroinvertebrate community (Dittmann et al. 2018). • Above or approach the maximum observed field salinities for key estuarine fish, including black bream (60.1 ppt), tamar goby (60.1 ppt), greenback flounder (74.1 ppt) and yelloweye mullet (74.1 ppt) (Ye et al. 2013).
	Very significant	Average monthly salinity > 70 ppt for ≥18 consecutive months	• The below ecological responses to salinities >70 ppt would occur for at least 18 consecutive months: • Salinity tolerance of all polychaete species (with the exception of *Capitella capitata* that can occur in low densities in salinities up to 90 ppt) in the Coorong are exceeded (Dittmann et al. 2018). • Loss of an estuarine and marine macroinvertebrate community (Dittmann et al. 2018) • Above or approach the maximum observed field salinities for key estuarine fish, including black bream (60.1 ppt), tamar goby (60.1 ppt), greenback flounder (74.1 ppt) and yelloweye mullet (74.1 ppt) (Ye et al. 2013).
Coorong South Lagoon nutrients	Insignificant	<1 mg/L Total Nitrogen (TN) and <0.1 mg/L Total Phosphorus (TP) and Chlorophyll a (Chl. *a*) <5 µg/L as per Australian Water Quality Guidelines (2018)	See Appendix D: Interim water quality trigger values for the Coorong
	Minor	Average monthly TN >1 mg/L and/or TP > 0.1 mg/L and/or Chl. *a* >5 µg/L for <2 months	
	Moderate	Average monthly TN >2 mg/L and/or TP > 0.2 mg/L and/or Chl.	

End-point	Consequence level	Outcome	Rationale
		a >10 µg/L for 2-6 consecutive months	
	Significant	Average monthly TN > 3 mg/L and/or TN > 0.3 mg/L and/or Chl. *a* >15 µg/L for 6-18 consecutive months	
	Very significant	Average monthly TN > 3 mg/L and/or TN > 0.3 mg/L and/or Chl. *a* >15 µg/L for ≥18 consecutive months	
Coorong North Lagoon nutrients	Insignificant	<1 mg/L Total Nitrogen (TN) and <0.1 mg/L Total Phosphorus (TP) and Chlorophyll a (Chl. *a*) <5 µg/L as per Australian Water Quality Guidelines (2018)	See Appendix D: Interim water quality trigger values for the Coorong
	Minor	Average monthly TN >1 mg/L and/or TP > 0.1 mg/L and/or Chl. *a* >5 µg/L for <2 months	
	Moderate	Average monthly TN >1 mg/L and/or TP > 0.1 mg/L and/or Chl. *a* >5 µg/L for 2-6 consecutive months	
	Significant	Average monthly TN > 2 mg/L and TN > 0.2 mg/L and/or Chl. *a* >10 µg/L for 6-18 consecutive months	
	Very significant	Average monthly TN > 2 mg/L and TN > 0.2 mg/L and/or Chl. *a*	

End-point	Consequence level	Outcome	Rationale
		>10 µg/L for ≥18 consecutive months	

5.4 Risk analysis

5.4.1 Model simulations

A total of 23 simulations of CIIP scenarios were run for the risk analysis (Table 5.4). The risk analysis considered outputs from both the TUFLOW-FV model and the Coorong Dynamics Model under different inflow conditions from the barrages and Salt Creek and simulation periods (Table 5 5). The range of different inflow conditions aimed to represent natural variability and the sources of risk identified in section 5.3.1. Parameterisation of the TUFLOW-FV model and Coorong Dynamics Model for runs used in the ERAF are detailed in Table 3.4 Assumptions for the simulations of CIIP scenarios run by the TUFLOW-FV modeland Table 3.5.

Table 5.4 CIIP scenarios modelled by the Coorong Dynamics Model and the TUFLOW-FV model for each climate/flow condition.

CIIP option	ID	CIIP scenario	Coorong Dynamics Model – Typical	Coorong Dynamics Model – Dry	TUFLOW-FV – Observed	TUFLOW-FV – Extra Dry
Do nothing		Basecase				
		Dry				
		Climatechange				
		Climatechange_bedlift				
Lake Albert Connector	1.1	Lake Albert Connector realistic	√	√		
	1.2	Lake Albert Connector and Dredge	√	√		
Dredge	2.1	Dredge	√	√	√	
	2.2	Dredge Pelican			√	
	2.3	Dredge Parnka			√	
Ocean Connector	3.1	Constantly pumping in 125			√	
	3.2	Constantly pumping in 250	√	√		
	3.3	Constantly pumping in 500			√	
	3.4	Constantly pumping out 125	√	√		√
	3.5	Constantly pumping out 250	√	√		√
	3.6	Constantly pumping out 250 at Round Island			√	
	3.7	Constantly pumping water in and out	√	√		
	3.8	Pumping water out above 0.2m	√	√		
	3.9	Pumping water out above 0.3m			√	
	3. 10	Pumping water in or out (AHD > 0.3m <0.15m)	√	√		

CIIP option	ID	CIIP scenario	Coorong Dynamics Model – Typical	Coorong Dynamics Model – Dry	TUFLOW-FV – Observed	TUFLOW-FV – Extra Dry
	3.11	Pumping water in or out (AHD > 0.2m <0.1m)			√	
	3.12	Pumping water in or out (AHD > 0.3m <0.2m)			√	
	3.13	Passive ocean connector (10 x 1.5m pipes)	√	√	√	
	3.19	Constantly pumping in 250 and Dredging			√	
	3. 20	Constantly pumping in 500 and Dredging			√	√
	3.22	Constantly pumping out 250 and Dredging	√	√		√
	3.23	Constantly pumping out 500 and Dredging			√	
SEFA	4.1	Further augmentation of South East Flows	√	√	√	

Table 5 5 The simulation periods and inflow conditions for climate category run through the Coorong Dynamics Model and the TUFLOW-FV model.

Model	Climatic category	Simulation period	Inflow conditions
Coorong Dynamics Model	Typical	01/07/2017 to 01/07/2020	Barrage flows of 2000 GL/yr and Salt Creek flows of 40 GL/yr
Coorong Dynamics Model	Dry	01/07/2017 to 01/07/2020	Barrage flows of 800 GL/yr and Salt Creek flows of 20 GL/yr
TUFLOW-FV model	Observed	07/05/2013 to 28/01/2016	Observed barrage and Salt Creek inflows. Barrage flows were low, with an annual average of 1524 GL/yr.
TUFLOW-FV model	Extra Dry	07/05/2013 to 28/01/2016	No barrage or Salt Creek inflows

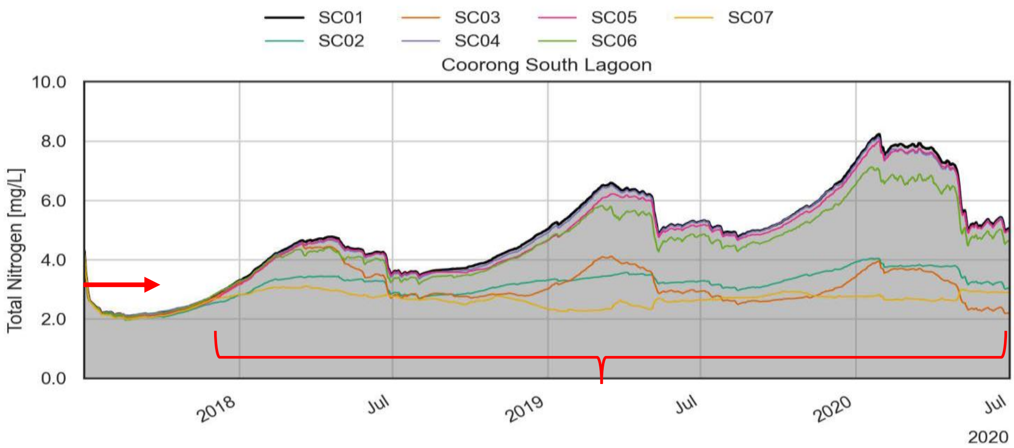
5.5 Assigning likelihood and consequence

Runs of the TUFLOW-FV model and Coorong Dynamics Model simulate the impact of CIIP options on the end-point variables under inflow scenarios that are representative of the identified sources of risk (see section 5.3.1). The risk assessment team established a risk analysis method whereby these model outputs were interpreted according to the consequence criteria (Table 5.3). This interpretation involved visual classification of model outputs into one of five consequence severity levels.

Model predictions were represented as a time-series over the simulation period for the relevant assessment end-point. The risk assessment team compared the model simulations (e.g. Figure 5.2 and Figure 5.3) with key threshold and time periods values identified by the consequence criteria (Table 5.3). Participants assessed the likelihood of each consequence level occurring under the CIIP option and scenario over the simulation period of model runs. When assessing likelihood, participants considered the level of certainty in model predictions and the impact of temporal factors, such as starting conditions and trends over time.

Worked examples of the assessment of risk across consequence levels under a no-build scenario (SC01) for the *Nutrients in the South Lagoon* end-point and the *Salinity in the South Lagoon* end-point are shown in Figure 5.2 and Figure 5.3, respectively.

The likelihood of "very significant" consequence for "*Nutrients in the South Lagoon*" under a no-build scenario (SC01) is 1 while the likelihood of the remaining outcomes is 0 (Figure 5.2). In this case, the time series simulation of Total Nitrogen (mg/L) for SC01 exceeds the 3 mg/L thresholds for over 18 consecutive months and the trend is worsening with time. In contrast, three consequence levels were allocated varying proportions of likelihood for the *Salinity in the South Lagoon* end-point under a no-build scenario (SC01) (Figure 5.3). Salinity continually increases (accounting for seasonal variation) over the first two years of the simulation before stabilising in the final year of the simulation. Although the 100 ppt threshold is exceeded during the simulation, it is unclear as to how long this threshold was exceeded over the simulation and whether it would continue in to the future. Therefore, likelihood was spread over three consequence levels (Moderate, Significant and Very significant), with the total likelihood summing to 1.

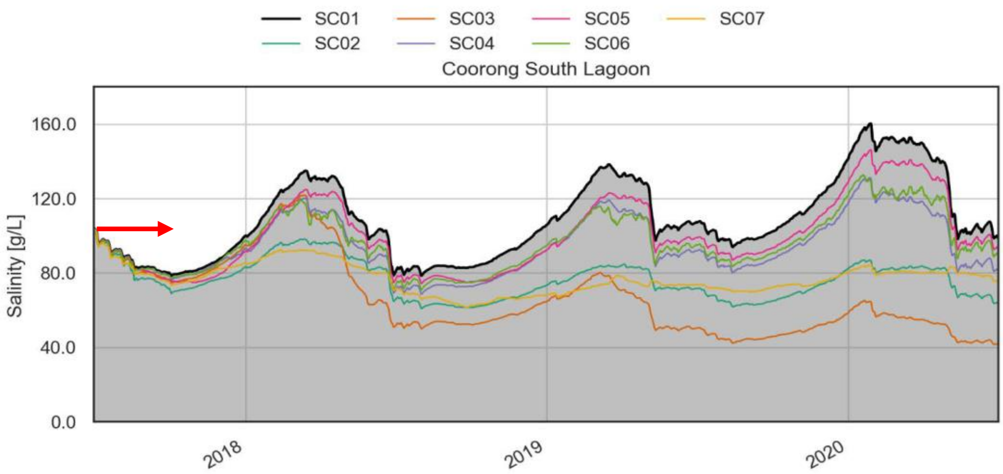


Consequence level	Likelihood observed
Insignificant	0
Minor	0
Moderate	0
Significant	0
Very significant	1

A worked example of the allocation of likelihood to consequence levels (defined in Table 5.3) for the *Nutrients in the South Lagoon* end-point under a no-build scenario (SC01).

The red arrow identifies the 3 mg/L thresholds for Total Nitrogen and the red open bracket shows this threshold was exceeded for over 18 consecutive months, meeting the conditions for the very significant consequence level.

Figure 5.2 A worked example of the allocation of likelihood to consequence levels (defined in Table 5.3).



Consequence level	Likelihood observed
Insignificant	0.0
Minor	0.0
Moderate	0.45
Significant	0.45
Very significant	0.10

A worked example of the allocation of likelihood to consequence levels (defined in Table **5.3**) for the *Salinity in the South Lagoon* end-point under a no-build scenario (SC01). The red arrows identifies the 100 ppt thresholds. As participants were uncertain as to the longevity of the exceedance of the 100 ppt threshold, likelihood were allocated to three consequence levels (Moderate, Significant and Very Significant).

Figure 5.3 A worked example of the allocation of likelihood to consequence levels (defined in Table 5.3).

5.6 Summary of risk assessments

Risk analysis was performed by four members of the DEW risk assessment team. Each of the four participants classified all model scenarios for all end-points. Participants' likelihood scores were aggregated by averaging for each combination of inflow scenario, end-point and consequence level.

The final output of the analysis is a table (e.g. sample thereof in Figure 5.4) where each risk pathway is indexed according to the CIIP option, inflow scenario, end-point variable and geographic location. The "scores" for each pathway were recorded in the orange columns, with each cell representing the likelihood of the consequence level for that column.

D	E	F	G	H	I	J	K	L	M
ario			Run Ids		Risk analysis				
CIIP option	Inflows	End-point	BMT Id	DEW Id	V Sig	Sig	Mod	Minor	Insig
none	Typical	CSL salinity	14		0	0.05	0.95	0	0
none	Typical	CNL salinity	14		0	0.2	0.8	0	0
none	Typical	CSL water levels	14		0	0.2	0.8	0	0
none	Typical	Nutrients	14		0.8	0.2	0	0	0
none	Observed	CSL salinity		1	0	0	0.8	0.2	0
none	Observed	CNL salinity		1	0	0	0.2	0.5	0.3
none	Observed	CSL water levels		1	0.1	0.9	0	0	0
none	Observed	Nutrients		1	0	0	0	0	0
none	Dry	CSL salinity	1		0.2	0.8	0	0	0
none	Dry	CNL salinity	1		0	0	1	0	0
none	Dry	CSL water levels	1		0	1	0	0	0
none	Dry	Nutrients	1		1	0	0	0	0
none	Extra dry	CSL salinity		2	0.8	0.2	0	0	0
none	Extra dry	CNL salinity		2	0	0.3	0.4	0.3	0
none	Extra dry	CSL water levels		2	0.5	0.5	0	0	0
none	Extra dry	Nutrients		2	0	0	0	0	0
none	Climatechange	CSL salinity		41	0	0	0	0.4	0.6
none	Climatechange	CNL salinity		41	0	0	0	0.2	0.8
none	Climatechange	CSL water levels		41	0	0	0	0	1
none	Climatechange	Nutrients		41	0	0	0	0	0
LAC_realistic	Dry	CSL salinity	4		0	0.7	0.3	0	0
LAC_realistic	Dry	CNL salinity	4		0	0	0.8	0.2	0
LAC_realistic	Dry	CSL water levels	4		0	1	0	0	0
LAC_realistic	Dry	Nutrients	4		1	0	0	0	0
LAC_realistic	Typical	CSL salinity	17		0	0	0.2	0.8	0
LAC_realistic	Typical	CNL salinity	17		0	0	0.2	0.4	0.4
LAC_realistic	Typical	CSL water levels	17		0	0.2	0.8	0	0
LAC_realistic	Typical	Nutrients	17		0.5	0.5	0	0	0

Figure 5.4 A sample of the final output showing the allocation of likelihood to consequence levels for each end-point for a given simulation of a CIIP option/scenario and inflow condition.

5.7 Risk evaluation

Risk evaluation is the process to compare the results of the risk analysis with risk criteria to determine the acceptability or tolerability of the level of risk (DEWNR 2012). Risk criteria are usually expressed as a matrix showing that risk is a function of likelihood and consequence Figure 5.5). Consistent with DEWNR (2012), risks were evaluated into one of three levels as shown in Table 5.6 .

Table 5.6 Levels of risk used in the ERAF to evaluate benefit and risk of CIIP options and scenarios.

Level	Description
Low	The risk is acceptable and no further action is required apart from monitoring where necessary.
Medium	The risk may be tolerable under certain conditions – for example, the risk is as low as reasonably practicable (ALARP). Otherwise the risk must be treated to reduce the level of risk.
High	The risk is intolerable and must be treated to reduce the level of risk.

The risk evaluation criteria were configured to align with the desired ecological condition of the Coorong. Therefore, insignificant consequence and rare likelihood are always assigned low risk as indicated by the left-most column and bottom row of the matrix (Figure 5.5).

This risk assessment undertook probabilistic risk analysis, meaning that the output of the analysis step is a probability distribution of consequences. Evaluation of this type of output followed the approach of DEW (2020c):

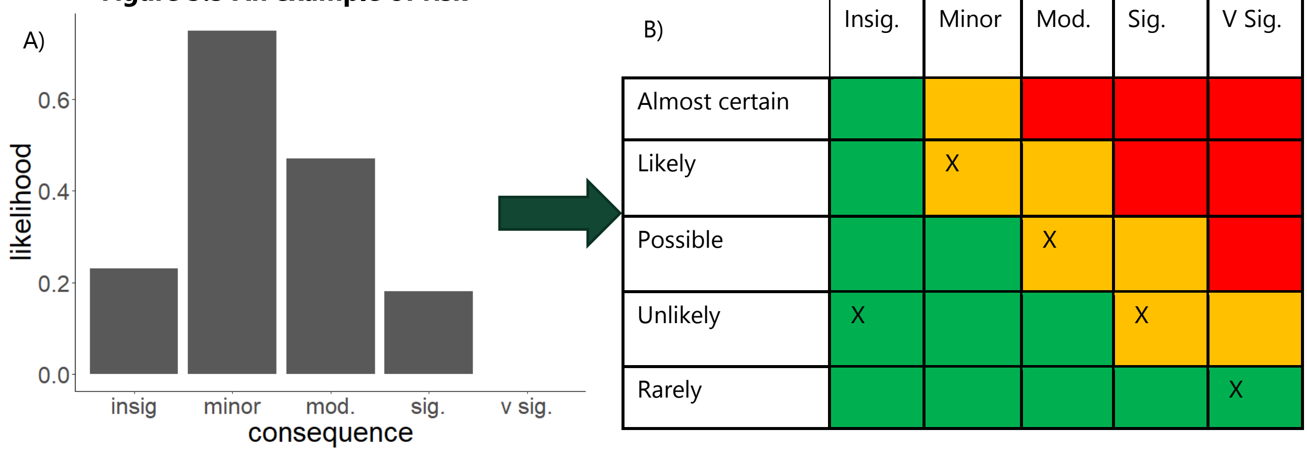
1. Determine likelihood for each consequence, which is the sum of likelihoods having equal or more severe consequence than the current consequence level. For example, the likelihood of a moderate consequence is equal to the sum of the likelihoods for moderate, significant and very significant consequences.
2. Align the quantitative likelihood value (as calculated following the method in Step 1) for each consequence level with a likelihood category as per Table 5.7 .
3. Plot the risk matrix for each consequence level using the categorical likelihoods assigned in Step 2.
4. Record the overall risk rating as the highest risk plotted on the risk matrix.

Table 5.7 A description and categorisation of likelihood that was used in the evaluation of ERAF results.

Category	Description	Likelihood
Rarely	Only occurs in exceptional circumstances	<10% chance
Unlikely	Unusual but not exceptional	10-25% chance
Possible	Less than even chance but not unusual	26-50% chance
Likely	Greater than even chance but not certain	51-90% chance
Almost certain	Expected in all circumstances	91-100% chance

An example likelihood distribution over consequence levels that corresponds with a medium risk is shown in Figure 5.5 where the likelihood distribution over consequence levels (A) are translated to the risk matrix (B) following the categorisation of risk likelihood as shown in Table 5.7 . Risk categories are Low (green), Medium (orange) and High (red), and are defined in Table 5.6 .

Figure 5.5 An example of risk



evaluation for a Medium risk.

5.8 Results

Risk profiles for each CIIP option/scenario, inflow condition and end-point are presented in Appendix E. The risk profile presents the outcomes from the risk and benefit assessment, and includes:

- inherent risk level (i.e. risk assuming “no-build”)
- residual risk level (i.e. risk assuming the CIIP option)
- benefit (i.e. change in risk level caused by the CIIP option), and
- direction (i.e. whether the impact of the CIIP option is positive or negative irrespective of a change in the level of residual risk).

Direction is based on a comparison of the likelihood distribution over consequence levels for the inherent risk (risk assuming no-build) and the residual risk (risk under the CIIP option/scenario). A positive (green) direction value was allocated where the residual risk was lower than inherent risk, and vice versa for a negative (red) direction value. Direction was calculated for all CIIP option/scenario combinations as a general indicator of whether the option was beneficial or detrimental regardless of any changes in the reported level of risk.

Criteria for prioritising CIIP options on the basis of risk and benefit adopted principles agreed at a workshop with DEW representatives from the HCHB program. In essence, the criteria consider the following:

1. Overall benefit, as determined by the proportion of risk pathways for which the level of residual risk is less than the inherent risk.
2. Occurrence of increased risk or negative direction for some risk pathways indicating important trade-offs.

For the purpose of comparing CIIP options, a simple prioritisation was done considering the criteria described in Table 5.8.

The rank of each CIIP option/scenario from Very Low to Very High based on the criteria in Table 5.8, which considers the level of benefit and trade-offs, is summarized in Table 5.9.

CIIP options/scenarios were recommended (pending further investigation) if they provided a level of benefit irrespective of the trade-offs. Commentary has been provided (under Comments) for CIIP options/scenarios where it is considered that trade-offs could be minimised. Other important considerations are also included under Comments.

Table 5.8 Criteria used to rank the effectiveness of CIIP options and scenarios based on the ERAF risk profile.

Option/scenario combinations where:	Rank - effectiveness	Recommendation
No benefit. Residual risk is the same as inherent risk for all risk pathways.	Very low	Not recommended
Low benefit. <40% of risk pathways have reduced level of residual risk and Negative direction for some risk pathways which cannot be mitigated.	Very low	Not recommended
Low benefit. <40% of risk pathways have reduced level of residual risk and Increased risk for one or more risk pathways which cannot be mitigated	Very low	Not recommended
Low benefit. <40% of risk pathways have reduced level of residual risk and	Very low	Not recommended

Option/scenario combinations where:	Rank - effectiveness	Recommendation
Negative direction for one or more risk pathways in the CNL which cannot be mitigated		
Low benefit. <40% of risk pathways have reduced level of residual risk and Any increased risk or negative direction can be mitigated	Low	Recommended pending mitigation strategies
High benefit. >40% of risk pathways have reduced level of residual risk and Any increased risk or negative direction can be mitigated	Moderate	Recommended pending mitigation strategies
High benefit. >40% of risk pathways have reduced level of residual risk and No trade-offs in terms of increased risk or direction	High	Recommended
Maximum benefit. All risk pathways have reduced level of residual risk. The full residual risk profile contains no high residual risks remaining	Very high	Recommended

Table 5.9 The rank of each CIIP option/scenario based in ERAF profile and rank as per Table 5.8.

ID	CIIP option/scenario	Level of benefit	Trade-offs	Rank effectiveness (see Table 5.8)	Recommendation	Comments
1.1	Lake Albert Connector realistic	Minor benefit. Significantly reduced risk (high to low) for CNL salinity under typical inflow scenario. Reduced risk (1 risk category) for CNL salinity under dry and observed scenarios. Reduced risk for CSL salinity under typical and observed inflow scenario.	Negative trajectory for CSL water levels under dry and observed inflow scenarios.	Low	Recommended	Scenario effectiveness relies on water availability as modelled which may not be realistic under extreme drought conditions.
1.2	Lake Albert Connector and Dredge	Major benefit. Significantly reduced risk for CSL and CNL salinity under typical inflows. Reduced risk for CSL and CNL salinity under observed and dry scenarios.	Increased risk (medium to high) for CSL water levels under a typical inflow scenario. Negative trajectory for CSL water levels under observed and dry inflow scenarios.	Moderate	Recommended pending dredging impact mitigation strategy.	Scenario effectiveness relies on water availability as modelled which may not be realistic under extreme drought conditions.
2.1	Dredge	Minor benefit. Reduced risk for CSL salinity under dry, observed and typical inflow scenarios. Reduced risk to CNL salinity under typical inflow scenario.	Negative trajectories for CSL water levels under dry, observed and typical inflow scenarios. Negative trajectory for CNL salinity under dry inflows.	Very Low	Not recommended	Dredging on its own is not considered to be a viable option to reduce risk. However, dredging in unison with another CIIP Option could reduce risk.

ID	CIIP option/scenario	Level of benefit	Trade-offs	Rank effectiveness (see Table 5.8)	Recommendation	Comments
2.2	Dredge Pelican	No benefit Limited set of evidence	Negative trajectories for CNL salinity and CSL water level under observed inflows.	Very Low	Not recommended	Dredging at Pelican Point has no benefit while dredging at Parnka Point only, or dredging at Parnka Point and Pelican Point have the same minor benefits, therefore a more efficient approach is to consider dredging at Parnka only. Concerns remain the impact of sediment disturbance during the construction phase and the subsequent potential for long term impacts (including acid sulphate soils).
2.3	Dredge Parnka	Minor benefit. Reduced risk for CSL salinity under observed inflows. Limited set of evidence	Negative trajectory for CSL water level under observed inflows.	Very Low	Not recommended	
3.1	Constantly pumping in 125	Minor benefit. Reduced risk for CSL salinity under observed inflow scenario. Limited set of evidence	Negative trajectories for over 60% of risk pathways including risk to water levels in the CSL and salinity in the CNL under observed inflows.	Very Low	Not recommended	
3.2	Constantly pumping in 250	Minor benefit. Reduced risk for CSL salinity under dry and typical scenarios.	Negative trajectories for over 50% of risk pathways including water levels in the CSL	Very Low	Not recommended	

ID	CIIP option/scenario	Level of benefit	Trade-offs	Rank effectiveness (see Table 5.8)	Recommendation	Comments
			and salinity and nutrients in the CNL.			
3.3	Constantly pumping in 500	Minor benefit. Reduced risk for CSL salinity under observed inflow scenario. Limited set of evidence	Negative trajectories for over 60% of risk pathways including risk to water levels in the CSL and salinity in the CNL.	Very Low	Not recommended	
3.4	Constantly pumping out 125	Minor benefit. Reduced risk for CNL and CSL salinity under dry and typical inflow scenarios. Reduced risk for CSL salinity under observed inflow scenario.	Increased risk (medium to high) for CSL water levels under typical inflow scenario. Negative trajectories for CSL water levels under dry and observed inflow scenarios.	Low	Recommended pending pump operation strategy	An operation strategy for pumping may help to minimise the impact of receding water levels in the CSL over spring and in to summer. This could be achieved by temporally stopping pumping.
3.5	Constantly pumping out 250	Minor benefit. Significantly reduced risk for CNL and CSL salinity under a typical inflow scenario. Reduced risk for CNL and CSL salinity under a dry inflow scenario. Reduced risk for CSL salinity under observed inflow scenario.	Negative trajectories for CSL water levels under dry, observed and observed inflow scenarios.	Low	Recommended pending pump operation strategy	An operation strategy for pumping may help to minimise the impact of receding water levels in the CSL over spring and in to summer. This could be achieved by temporally stopping pumping.

ID	CIIP option/scenario	Level of benefit	Trade-offs	Rank effectiveness (see Table 5.8)	Recommendation	Comments
3.6	Constantly pumping out 250 at Round Island	Minor benefit. Reduced risk for CSL salinity under observed inflow scenario. Limited set of evidence	Negative trajectory for CSL water levels under observed inflow scenario.	Low	Recommended pending pump operation strategy and further modelling	An operation strategy for pumping may help to minimise the impact of receding water levels in the CSL over spring and in to summer. This could be achieved by temporally stopping pumping. This is same scenario as 3.5 but with pumping station at Round island instead of Policeman Point. Hydrodynamic modelling was not supported by biogeochemical modelling, and therefore, further evidence is required to determine the most beneficial location for pumping out operations.
3.7	Constantly pumping water in and out	Major benefit. Significantly reduced risk for CSL salinity under a typical inflow scenario. Reduced risk for CNL salinity under typical inflow scenario.	Increased risk to CSL water levels under typical inflow scenario (medium to high) Negative trajectories for CSL water levels under a dry inflow scenario.	Moderate	Recommended pending pump operation strategy.	An operation strategy for pumping may help to meet temporal water level targets through independent rates of pumping in and out for different time periods across a year.

ID	CIIP option/scenario	Level of benefit	Trade-offs	Rank effectiveness (see Table 5.8)	Recommendation	Comments
		Reduced risk for CSL and CNL salinity under dry inflow scenario.				
3.8	Pumping water out above 0.2m	Major benefit. Significantly reduced risk for CNL salinity under typical scenario. Reduced risk for CSL salinity under a typical scenario. Reduced risk for CNL and CSL salinity under a dry scenario.	Increased risk to CSL water levels under typical inflow scenario (medium to high) Negative trajectories for CSL water levels under a dry inflow scenario.	Moderate	Recommended pending pump operation strategy.	An operation strategy for pumping may help to minimise the recession of water levels in the CSL over spring and in to summer. This could be achieved by temporally stopping pumping and having short-term surcharges in water level through barrage discharge before critical periods.
3.9	Pumping water out above 0.3m	Minor benefit. Reduced risk for CSL salinity under observed inflow scenario. Limited set of evidence	Negative trajectory for CSL water levels under observed inflow scenario.	Low	Recommended pending pump operation strategy.	An operation strategy for pumping may help to minimise the impact of receding water levels in the CSL over spring and in to summer. This could be achieved by temporally stopping pumping and having short-term surcharges in water level through barrage discharge before critical periods.

ID	CIIP option/scenario	Level of benefit	Trade-offs	Rank effectiveness (see Table 5.8)	Recommendation	Comments
3. 10	Pumping water in or out (AHD > 0.3m <0.15m)	Minor benefit. Reduced risk for CSL salinity and CSL water levels under a dry inflow scenario. Reduced risk for CSL salinity under a typical inflow scenario.	Negative trajectories for CNL nutrients and CNL salinity under a dry inflow scenario. Negative trajectory for CSL salinity under a typical inflow scenario.	Low	Recommended pending pump operation strategy.	An operation strategy for pumping may help to minimise the export of salt and nutrients from the CSL to the CNL. This can be achieved by managing the CSL in isolation from the CNL when water levels drop below the sill height of the CSL (~+0.2 m AHD).
3.11	Pumping water in or out (AHD > 0.2m <0.1m)	Minor benefit. Significantly reduced risk for CSL salinity under observed inflow scenario. Limited set of evidence	Negative trajectory for CSL water levels under an observed inflow scenario.	Low	Recommended pending pump operation strategy.	An operation strategy for pumping may help to promote connectivity between the CNL and CSL over late-autumn to spring and meet target water levels over spring and early summer (+0.2–+0.4 m AHD). This can be achieved by adjusting the water level thresholds for pumping in and out at different times of the year.
3.13	Passive ocean connector (10 x 1.5m pipes)	Minor benefit. Reduced risk for CNL and CSL salinity under dry and typical inflow scenarios.	Negative trajectory for CSL water levels under dry and observed scenarios.	Low	Recommended pending mitigation strategies	Scenario will need mitigation strategy for water level in the CSL

ID	CIIP option/scenario	Level of benefit	Trade-offs	Rank effectiveness (see Table 5.8)	Recommendation	Comments
		Reduced risk for CSL salinity under observed inflow scenario.				
3.22	Constantly pumping out 250 and Dredging	Major benefit. Significantly reduced risk for CNL salinity, CSL salinity under dry and typical scenarios. Significantly reduced risk for CSL salinity under observed scenario. Reduced risk to CNL salinity under extra dry and observed scenarios.	Increased risk to CSL water levels under typical inflow scenario. Negative trajectory for CSL water levels under dry and extra dry scenarios.	Moderate	Recommended pending pump operation strategy and dredging impact mitigation strategy.	An operation strategy for pumping may help to minimise the recession of water levels in the CSL over spring and in to summer. However, due to the dredged constriction between the CSL and CNL, changes in pumping operation are expected to have relatively minor impact in minimising the impact of water recession in the CSL over spring and in to summer. Concerns remain the impact of sediment disturbance during the construction phase and the subsequent potential for long term impacts (including acid sulphate soils).
3.23	Constantly pumping out 500 and Dredging	Major benefit.	Negative trajectory for CSL water levels under	Moderate	Recommended pending pump operation strategy	An operation strategy for pumping may help to minimise the recession of

ID	CIIP option/scenario	Level of benefit	Trade-offs	Rank effectiveness (see Table 5.8)	Recommendation	Comments
		Significantly reduced risk for CSL salinity under observed inflow scenario. Reduced risk for CNL salinity under observed inflow scenario. Limited set of evidence	observed inflow scenario.		and dredging impact mitigation strategy.	water levels in the CSL over spring and in to summer. However, due to the dredged constriction between the CSL and CNL, changes in pumping operation are expected to have relatively minor impact in minimising the impact of water recession in the CSL over spring and in to summer. Concerns remain the impact of sediment disturbance during the construction phase and the subsequent potential for long term impacts (including acid sulphate soils).
4.1	Further augmentation of South East Flows	Minor benefit. Reduced risk for CSL salinity under typical and dry scenarios. Reduced risk for CNL salinity under typical scenario.	Negative trajectory for CNL salinity and CSL water levels under the dry scenario.	Very low	Not recommended	

6 Findings and recommendations

- Risk to the system: Shortlisted CIIP options can potentially improve the ecological values of the Coorong but also have the potential to worsen those values. Extreme care should be taken to avoid further detrimental impact to the site, particularly to the CNL.
- Trade-offs: Ecological interpretation suggested that some options may deliver only improvements to the system but the Ecological Risk Assessment process highlighted that even those options can have trade-offs.
- System sensitivity: There seems to be an important system response to slight differences in model assumptions (E.g. pumping in 125 vs pumping in 250), which highlights the importance of CIIP scenario refinement in Phase 2 of the feasibility investigations.
- The ecological interpretation and risk assessment concluded that the following CIIP options and scenarios have limited or no benefits to the system and are likely to cause trade-offs that cannot be mitigated, and therefore, they are not recommended:
    - Further augmentation of South East Flows
    - Dredging as a standalone option
    - All the pumping options with constant flow into the southern lagoon
- Lake Albert Connector: Ecological interpretation of this CIIP option suggested that a moderate benefit could be achieved, however, the risk assessment identified major risks to the system from this option. The effectiveness of this CIIP option relies on water availability, which may not be realistic under extreme drought conditions.
- Dredging on its own is not considered to be a viable option to reduce risk. However, dredging in unison with another CIIP Option could benefit the system. Dredging at Pelican Pt was determined to provide no benefit, and therefore, if dredging is to occur it should only take place at Parnka Pt.
- Mitigation strategies: Scenarios that pump water out the South Lagoon appeared to be the most effective and beneficial CIIP option. However, none of the CIIP scenarios modelled provided a benefit to the system without associated risks and trade-offs. An operation strategy for pumping will need to be developed and tested to avoid or minimise trade-offs. This may include:
    - temporarily stopping pumping (either in or out depending on the scenario)
    - independent rates of pumping in and out at different time periods or water level thresholds
    - temporarily stopping pumping and having short-term surcharges in water level through barrage discharge before critical periods.
- Pumping location: further evidence is required to determine the most beneficial location for pumping out operations.

7 References

Asanopoulos C and Waycott M (2020) *The growth of aquatic macrophytes (Ruppia tuberosa spp. and Althenia cylindrocarpa) and the filamentous algal community in the southern Coorong*, Goyder Institute for Water Research Technical Report Series No. 20/13.

Bice C, Furst D, Lamontagne S, Oliver R, Zampatti B and Revill A (2016) *The influence of freshwater discharge on productivity, microbiota community structure and trophic dynamics of the Murray estuary: evidence of freshwater derived trophic subsidy in the sandy sprat, Goyder Institute for Water Research Technical Report Series No. 15/40, Adelaide, South Australia.*

BMT (2019) *Murray Mouth Model Status Report*, BMT Eastern Australia Pty Ltd.

BMT (2021) *Coorong Infrastructure Investigations Project: Hydrodynamic, Biogeochemical and Habitat Modelling Study,* Report prepared by BMT Commercial Australia for the SA Department of Environment and Water, Adelaide.

Brookes J, Dalby P, Dittmann S, O'Connor J, Paton D, Quin R, Rogers D, Waycott M & Ye Q (2018). *Recommended actions for restoring the ecological character of the South Lagoon of the Coorong*. Goyder Institute for Water Research Technical Report Series No. 18/04, Adelaide, South Australia. ISSN: 1839-2725.

Brooks J, Aldridge K, Hipsey M, Busch B, Ye Q, Gibbs M and Paton D (2021) Ecological condition of the Lower Lakes and Coorong, In: Hart, B.T., Bond, N.R., Byron, N., Pollino, C.A. and Stewardson, M.J. (eds.), *Murray-Darling Basin, Australia: Its Future Management*, Elsevier, Oxford, 95-107.

Butcher R and Cottingham P (2021) *Coorong Infrastructure Investigation Project (CIIP) Ecological Risk Assessment Framework*, Report prepared for the SA Department of Environment and Water, Adelaide

Collier C, van Dijk K, Erftemeijer P, Foster N, Hipsey M, O'Loughlin E, Ticli K and Waycott M (2017) *Optimising Coorong Ruppia habitat. Strategies to improve habitat conditions for Ruppia tuberosa in the Coorong (South Australia) based on literature review, manipulative experiments and predictive modelling*, University of Adelaide, DEWNR, University of Western Australian and DAMCO Consulting.

Delroy LB (1974) 'The food of waterfowl (Anatidae) in the southern Coorong saltwater habitat of South Australia', *South Australian Ornithologist*, 26.

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

DEW (2020b) *Initial hydrodynamic model scenarios to inform Coorong Infrastructure Investigations project*, SA Department of Environment and Water, Adelaide.

DEW (2020c) *Assessment of risks to groundwater dependent ecosystems in the Far North Prescribed Wells Area*, Technical report 2020-07, Government of South Australia, Department for Environment and Water, Adelaide.

DEW (2021a) State of the Southern Coorong, desired state and overall recommendations for how to achieve it. Department for Environment and Water, South Australia [in preparation].

DEW (2021b) *Ecological Character Description 2015 Coorong and Lakes Alexandrina and Albert Wetland Ramsar site,* Department for Environment and Water, South Australia [in preparation].

DEW (2021c) *The Coorong and Lakes Alexandrina and Albert Wetland (Yarluwar-Ruwe) Ramsar Site Management Plan*, Department for Environment and Water, South Australia [in preparation].

DEWNR (2012) *Risk Management Framework for Water Planning and Management*, Government of South Australia, Department for Environment, Water and Natural Resources, Adelaide.

Dittmann S (2015) *Macroinvertebrate monitoring, analysis and synthesis for Coorong and Murray Mouth locations. Progress report and preliminary response to "Condition of the RAMSAR site since listing" July 2015, Interim Report for the Department of Environment, Water and Natural Resources.*

Dittmann S, Rolston A and Baring R (2018) 'Estuarine and lagoon macro-invertebrates – patterns and processes', in Mosley L, Ye Q, Shepherd S, Hemming S, Fitzpatrick R (eds), *Natural History of the Coorong, Lower Lakes, and Murray Mouth Region (Yarluwar-Ruwe),* Royal Society of South Australia, 332–348.

Earl J, Fowler A, Ye Q and Dittmann S (2017) 'Complex movement patterns of greenback flounder (*Rhombosolea tapirina*) in the Murray River estuary and Coorong, Australia,' *Journal of Sea Research*, 122:1–10.

Giatas G and Ye Q (2016) *Conceptual food-web models for the Coorong: A focus on fishes and the influence of freshwater inflows*, SARDI (Aquatic Sciences), SARDI Publication No. F2016/000124-1, Research Report Series No. 892.

Haddy J and Pankhurst N (2000) 'The effect of salinity on reproductive development, plasma steroid levels, fertilisation and egg survival in black bream', *Acanthopagrus butcheri*, *Aquaculture*, 188:115–131.

Hart P and Purser G (1995) 'Effects of salinity and temperature on eggs and yolk sac larvae of greenback flounder (*Rhombosolea tapirina* Günther, 1862)', *Aquaculture* 136, 221-230.

Hindell J, Jenkins G and Womersley B (2008) 'Habitat utilisation and movement of black bream Acanthopagrus butcheri (Sparidae) in an Australian estuary', *Marine Ecology Progress Series* 366, 219–229.

Hipsey M, Busch B, Huang P and Gibbs M (2020) *Coorong Dynamics Model sensitivity tests and gap identification*, Goyder Institute for Water Research Technical Report Series No. 19/35.

Hipsey M, Huang P, Paraska D, Zhai S, Busch B, Sims C and Gibbs M (2021) *The Coorong Dynamics Model*, accessed on 20 Sep. 21 at https://aquaticecodynamics.github.io/CDM/index.html.

Hobbs T, O'Connor J and Gibbs M (2019) *Improved elevation and bathymetry models for the Coorong.* A Healthy Coorong, Healthy Basin project, DEW Technical report 2019/23, Government of South Australia, Department for Environment and Water, Adelaide.

Hossain M, Ye Q, Leterme S and Qin J (2016) 'Spatial and temporal changes of three prey-fish assemblage structure in a hypersaline lagoon: the Coorong, South Australia', *Marine and Freshwater Research* 68(2):282–292.

Kim D, Aldridge K, Ganf, G and Brookes J (2015) 'Physicochemical influences on Ruppia tuberosa abundance and distribution mediated through life cycle stages' *Inland Waters* 5(4), 451-460.

Kokkinn M (1986) *A control strategy for* 'Tanytarsus barbitarsis' *Freemann (Diptera, Chironomidae), a small-scale pest organism / M. J. Kokkinn,* PhD thesis, Department of Zoology, University of Adelaide.

Lui L (1969) 'Salinity tolerance and osmoregulation in *Taenomembrus microstomus* (Gunther, 1861) (Pisces: Mugiliformes: Atherinidae) from Australian salt lakes', *Australian Journal of Marine and Freshwater Research,* 20:157–162.

Martin T, Burgman M, Fidler F, Kuhnert P, Low-Choy S, McBride M and Mengersen K (2012) 'Eliciting expert knowledge in conservation science', *Conservation Biology*, 26(1), 29–38.

Mosley L, Priestly S, Brookes J, Dittmann S, Farkas J, Farrel M, Ferguson A, Gibbs M, Hipsey M, Huang J, Lam-Gordillo O, Simpson S, Teasdale P, Tyler J, Waycott M and Welsh D (2020) *Coorong water quality synthesis with a focus on the drivers of eutrophication, Goyder Institute for Water Research*, Adelaide, South Australia.

Mosley L, Teasdale P, Huang L, Welsh D, Erler D, Ferguson A, Brookes J, Keneally C, Chilton D, Dittmann S, Lam-Gordillo O, Southgate M and Simpson S (2021b) *Activity 1.3: Nutrient cycle and fluxes*, Goyder Institute for Water Research.

Mosley L, Welsh D, Waycott M, Dittmann S, Lam-Gordillo O and Simpsons S (2021a) *Activity 1.4: Nutrient removal options,* Goyder Institute for Water Research.

Mosley LM, Priestley S, Brookes J, Dittmann S, Farkaš J, Farrell M, Ferguson AJ, Gibbs M, Hipsey M, Huang J, Lam-Gordillo O, Simpson SL, Teasdale PR, Tyler JJ, Waycott M, Welsh DT (2020) *Coorong water quality synthesis with a focus on the drivers of eutrophication.* Goyder Institute for Water Research Technical Report Series No. 20/10.

Oerman G (2021) *Elevation distribution of Ruppia tuberosa and Althenia cylindrocarpa in the southern Coorong*. Department for Environment and Water, Government of South Australia.

Partridge G and Jenkins G (2002) 'The effect of salinity on growth and survival of juvenile black bream (*Acanthopagrus butcheri*)', *Aquaculture* 210(1), 219–230.

Paton D and Bailey C (2012) *Annual monitoring of* Ruppia tuberosa *in the Coorong region of South Australia, July 2011*, report for DEWNR, University of Adelaide.

Paton D, Paton F and Bailey C (2018) Waterbirds of the Coorong, Lower Lakes and Murray Mouth', in Mosley L, Ye Q, Shepherd S, Hemming S, Fitzpatrick R (eds), *Natural History of the Coorong, Lower Lakes, and Murray Mouth Region (Yarluwar-Ruwe)*, Royal Society of South Australia, 371–399.

Paton DC, Paton FL & Bailey CP (2019) *Monitoring of Ruppia tuberosa in the southern Coorong, summer 2018-19*. The University of Adelaide.

Waycott M, McDougall A and O'Loughlin E (2020) *Experimental testing of Coorong filamentous algal growth with increasing temperature and salinity*, Goyder Institute for Water Research, Adelaide, South Australia.

Ye Q, Bucater L and Short D (2015) *Fish response to flows in the Murray estuary and Coorong during 2013/14*, South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2014/000786-1, SARDI Research Report Series No. 884. 91pp.

Ye Q, Bucater L and Short D (2015) *Fish response to flows in the Murray estuary and Coorong during 2013/14*, South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2014/000786-1, SARDI Research Report Series No. 884. 91pp.

Ye Q, Bucater L, Lorenz Z, Giatas G and Short D (2019b) *Monitoring salt wedge conditions and black bream (*Acanthopagrus butcheri*) recruitment in the Coorong during 2017–18*, SARDI (Aquatic Sciences), SARDI Publication No. F2018/000425-1, Research Report Series No. 1012.

Ye Q, Bucater L, Short D and Giatas G (2020) *Coorong fish condition monitoring 2008-2019: Black bream (*Acanthopagrus butcheri*), greenback flounder (*Rhombosolea tapirina*) and smallmouth hardyhead (*Atherinosoma microstoma*) populations*, SARDI (Aquatic Sciences), SARDI Publication No. F2011/000471-6, Research Report Series No. 979.

Ye Q, Dittmann S, Baring R, Bucater L, Nitschke J, Newbery A, Pyke W, Schroder L and Kent J (2021) *Healthy Coorong, Healthy Basin – phase one Trials and Investigations project* Component Component 3 –

Restoring a functioning Coorong food web. *Activity 3.3: Investigate food resource abundance, productivity, biomass, energy content and availability, and the influence of key environmental factors. Interim Report*. Goyder Institute for Water Research, Adelaide, South Australia.

Ye Q, Dittmann S, Giatas G, Baring R, Nitschke J, Bucater L and Furst D (2019a) *The current state of food resources supporting waterbird and fish populations in the Coorong, Goyder Institute for Water Research Technical Report Series No. 19/33*.

Ye Q, Earl J, Bucater L, McNeil D, Noell C and Short D (2013) *Flow related fish and fisheries ecology in the Coorong, South Australia*, Final Report, South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2009/000014-2. SARDI Research Report Series No. 698. 84pp.

8 Appendices

A. Subject matter experts for Ecological Interpretation of modelling outputs

Sediment quality	Associate Professor Luke Mosley University of Adelaide
Nutrients (water column)	Associate Professor Luke Mosley University of Adelaide
Aquatic macrophytes	Professor Michelle Waycott *Chief Botanist, Head of Science and Conservation* Botanic Gardens and State Herbarium *Professor of Plant Systematics* School of Biological Sciences The University of Adelaide
Macroinvertebrates	Professor Sabine Dittmann (PhD) Professor in Marine Biology Flinders University College of Science & Engineering
Food chain (fish)	A/Professor Qifeng Ye Principal Scientist – Science Leader (Inland Waters and Catchment Ecology) South Australian Research and Development Institute – SARDI (Aquatic Sciences) Department of Primary Industries and Regions

B. Ecological Interpretation framework

This ecological interpretation framework was developed to guide experts in their judgement of expected responses by ecosystem components (sediment quality, nutrients, aquatic macrophytes, macroinvertebrates and fish) to CIIP options/scenarios and climatic conditions in the short (<3 years) and long-term (>10 years).

				Salinity			Water level				Biogeochemical					Biological				Tracers			
				%	%	%	%	%	%	%	µg/L	mg/L	mg/L	mg/L	mg/L	g DW/m²	km²	km²	km²	days	%	%	%
CIIP Option	CIIP Scenario	BMT Simulation	Water station	<35 ppt (year-round)	<60 ppt (year round	<100 ppt (year-round)	>-0 m & <+0.8 AHD	>0.3 m AHD (April to July)	+0.2 +0.4 m AHD (August to December)	0.0 – +0.2 m AHD (January to March)	TCHLA	TP	TN	TSS	TRIX	ULVA (TMALG)	Ruppia HSI (sexual >0.5)	All Fish HSI	Smallmouth Hardyhead HSI	Water Age	South Lagoon Initial tracer	Barrage tracer	Salt Creek tracer
Do nothing	Basecase Dry	Dry	Beacon 1	94%	100%	100%	65%				8.74	0.11	1.28	21.30	6.52					17	0	33	0
			Long Pt	67%	100%	100%	75%				1.51	0.14	1.74	0.79	5.91					106	7	51	3
			Parnka Pt	3%	28%	83%		56%	14%	3%	7.93	0.28	4.55	3.31	7.33					272	43	80	21
			Snipe Is	0%	0%	0%		51%	15%	0%	15.80	0.41	6.71	6.65	8.41					432	91	92	53
			CNL_Region	18%	93%	100%	85%				3.68	0.19	2.47	1.74	6.50	16.10	12.2	49.1	58.7	159	17	60	8
			CSL_Region	0%	0%	18%		70%	21%	33%	11.57	0.38	6.22	4.86	7.96	0.91	2.3	10.5	26.4	383	78	92	43
	Basecase Typical	Typical	Beacon 1	100%	100%	100%	71%				8.56	0.14	1.54	17.02	6.65					15	0	52	0
			Long Pt	97%	100%	100%	84%				1.70	0.18	2.10	0.83	6.15					100	6	75	6
			Parnka Pt	7%	49%	92%		61%	17%	6%	4.80	0.32	4.48	2.00	7.13					275	37	107	42
			Snipe Is	0%	0%	62%		56%	9%	0%	13.48	0.38	6.24	5.67	8.32					404	66	103	92
			CNL_Region	51%	100%	100%	90%				2.58	0.23	2.73	1.23	6.55	27.01	9.5	55.7	61.3	158	15	86	16
			CSL_Region	0%	0%	68%		76%	51%	47%	9.85	0.37	5.92	4.15	7.88	2.27	12.2	42.4	78.7	367	59	109	76
Lake Albert Connector	Lake Albert Connector _realistic	Dry	Beacon 1	95%	100%	100%	65%				8.61	0.11	1.31	21.19	6.52					23	1	33	0
			Long Pt	93%	100%	100%	77%				3.64	0.12	1.87	1.96	6.21					90	6	62	3
			Parnka Pt	4%	54%	94%		56%	14%	6%	4.17	0.23	4.01	1.75	6.95					238	33	101	18
			Snipe Is	0%	0%	29%		53%	14%	0%	14.75	0.36	6.76	6.20	8.36					424	78	120	52
			CNL_Region	57%	100%	100%	88%				4.75	0.15	2.35	3.20	6.56	27.59	12.4	57.0	60.1	127	12	75	6
			CSL_Region	0%	0%	55%		72%	22%	38%	10.52	0.33	6.14	4.42	7.87	1.57	8.9	22.5	50.4	369	66	118	41
		Typical	Beacon 1	100%	100%	100%	71%				8.51	0.13	1.58	17.04	6.63					21	1	52	1
			Long Pt	100%	100%	100%	86%				5.54	0.13	2.18	2.96	6.46					80	4	83	5
			Parnka Pt	54%	94%	100%		61%	18%	12%	1.49	0.19	3.53	0.63	6.55					222	21	121	32
			Snipe Is	0%	38%	100%		58%	9%	0%	8.91	0.25	4.91	3.75	7.92					376	45	124	83
			CNL_Region	100%	100%	100%	92%				6.29	0.15	2.55	4.59	6.68	26.21	4.3	62.2	62.3	113	7	96	11
			CSL_Region	0%	64%	100%		77%	52%	63%	5.62	0.24	4.60	2.38	7.38	17.27	21.4	78.3	87.2	331	38	129	66
Lake Albert Connector and dredge	Lake Albert Connector _realistic + dredge	Dry	Beacon 1	93%	100%	100%	65%				8.56	0.11	1.31	21.50	6.51					24	1	32	1
			Long Pt	75%	100%	100%	77%				3.94	0.12	1.80	2.25	6.23					92	6	55	4
			Parnka Pt	2%	56%	99%		53%	12%	43%	4.11	0.21	3.60	1.73	7.05					237	29	91	18
			Snipe Is	0%	0%	57%		51%	14%	0%	14.10	0.33	6.18	5.92	8.29					412	64	114	47
			CNL_Region	41%	100%	100%	90%				4.79	0.14	2.23	3.28	6.57	29.96	12.4	57.8	60.6	127	11	67	7
			CSL_Region	0%	0%	91%		73%	21%	76%	9.73	0.30	5.41	4.09	7.76	3.39	9.9	35.6	74.9	350	52	110	36
		Typical	Beacon 1	100%	100%	100%	71%				8.55	0.13	1.56	17.45	6.62					21	1	51	1
			Long Pt	100%	100%	100%	88%				5.82	0.13	2.07	3.30	6.45					79	4	77	6

				Salinity			Water level				Biogeochemical					Biological				Tracers			
				%	%	%	%	%	%	%	*µg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*g DW/m²*	*km²*	*km²*	*km²*	*days*	%	%	%
CIIP Option	CIIP Scenario	BMT Simulation	Water station	*<35 ppt (year-round)*	*<60 ppt (year round*	*<100 ppt (year-round)*	*>-0 m & <+0.8 AHD*	*>0.3 m AHD (April to July)*	*+0.2 +0.4 m AHD (August to December)*	*0.0 – +0.2 m AHD (January to March)*	*TCHLA*	*TP*	*TN*	*TSS*	*TRIX*	*ULVA (TMALG)*	*Ruppia HSI (sexual >0.5)*	*All Fish HSI*	*Smallmouth Hardyhead HSI*	*Water Age*	*South Lagoon Initial tracer*	*Barrage tracer*	*Salt Creek tracer*
			Parnka Pt	53%	100%	100%		61%	18%	48%	2.17	0.18	3.33	0.93	6.74					219	18	114	31
			Snipe Is	0%	70%	100%		60%	11%	15%	6.47	0.24	4.48	2.72	7.76					365	36	125	76
			CNL_Region	100%	100%	100%	93%				6.25	0.15	2.42	4.61	6.66	26.60	5.6	62.4	62.4	114	7	88	11
			CSL_Region	0%	100%	100%		88%	46%	58%	4.19	0.22	4.17	1.78	7.23	18.16	22.1	84.6	87.5	315	30	127	59
Ocean connector	Constant_ Out250	Dry	Beacon 1	94%	100%	100%	65%				9.05	0.11	1.24	22.30	6.53					13	0	31	0
			Long Pt	98%	100%	100%	75%				1.87	0.12	1.39	0.97	5.86					67	0	44	0
			Parnka Pt	72%	100%	100%		55%	14%	3%	0.97	0.17	1.96	0.41	6.11					165	3	62	2
			Snipe Is	0%	54%	100%		50%	15%	0%	8.30	0.27	3.51	3.48	7.82					335	20	88	22
			CNL_Region	100%	100%	100%	87%				2.37	0.13	1.57	1.23	6.09	25.86	11.0	60.0	60.0	100	1	50	1
			CSL_Region	0%	93%	100%		66%	20%	0%	4.93	0.24	2.98	2.07	7.12	18.57	22.4	71.3	80.1	271	14	80	13
		Typical	Beacon 1	100%	100%	100%	71%				8.80	0.14	1.50	17.83	6.66					11	0	49	0
			Long Pt	100%	100%	100%	84%				2.52	0.16	1.84	1.20	6.22					62	0	68	0
			Parnka Pt	98%	100%	100%		60%	16%	5%	0.84	0.23	2.58	0.35	6.28					173	5	98	6
			Snipe Is	0%	100%	100%		55%	9%	0%	4.89	0.31	3.77	2.06	7.70					325	19	120	41
			CNL_Region	100%	100%	100%	91%				2.29	0.18	2.05	1.13	6.33	26.11	0.0	61.8	61.8	99	1	78	2
			CSL_Region	55%	100%	100%		75%	48%	0%	3.15	0.29	3.42	1.34	7.12	19.93	19.1	82.0	84.3	271	13	117	26
	Pump in or out reverse @500	Dry	Beacon 1	87%	100%	100%	66%				8.27	0.12	1.35	19.98	6.53					25	1	35	1
			Long Pt	10%	67%	100%	72%				1.92	0.18	2.41	0.95	6.46					185	16	52	9
			Parnka Pt	0%	2%	89%		52%	15%	49%	8.19	0.19	3.55	3.42	7.17					270	27	30	20
			Snipe Is	0%	0%	100%		53%	14%	11%	11.21	0.15	2.55	4.72	7.62					283	22	14	27
			CNL_Region	0%	31%	100%	84%				5.70	0.20	3.17	2.57	6.85	9.53	6.1	36.8	54.8	228	22	47	14
			CSL_Region	0%	0%	100%		78%	36%	85%	8.40	0.16	2.76	4.01	7.29	7.22	7.3	57.4	86.5	263	23	19	22
		Typical	Beacon 1	99%	100%	100%	71%				8.19	0.15	1.62	15.99	6.65					22	1	55	1
			Long Pt	38%	90%	100%	83%				1.62	0.20	2.49	0.79	6.35					169	13	74	15
			Parnka Pt	0%	18%	100%		60%	18%	56%	5.66	0.20	3.26	2.36	7.07					266	24	50	36
			Snipe Is	0%	43%	100%		58%	13%	23%	7.62	0.14	2.23	3.23	7.39					267	19	22	45
			CNL_Region	17%	63%	100%	90%				4.29	0.22	2.95	1.93	6.79	17.75	12.5	50.5	62.0	215	18	69	24
			CSL_Region	0%	16%	100%		91%	74%	71%	6.27	0.16	2.56	3.12	7.15	12.86	18.8	76.7	88.6	257	21	31	39
	Pump_Constant _In250_Out250	Dry	Beacon 1	95%	100%	100%	66%				8.76	0.11	1.26	21.30	6.52					17	0	32	0
			Long Pt	95%	100%	100%	76%				1.50	0.13	1.51	0.79	5.82					96	1	46	1
			Parnka Pt	10%	92%	100%		57%	14%	6%	1.30	0.16	2.01	0.61	6.24					186	6	51	4
			Snipe Is	0%	15%	100%		54%	14%	0%	10.43	0.21	2.95	4.37	7.75					310	19	49	21
			CNL_Region	66%	100%	100%	87%				2.39	0.14	1.71	1.21	6.15	26.03	14.4	59.4	60.4	132	3	50	2
			CSL_Region	0%	58%	100%		74%	22%	39%	6.49	0.18	2.45	3.16	7.12	15.48	21.0	73.3	83.5	242	13	45	13
		Typical	Beacon 1	100%	100%	100%	71%				8.57	0.14	1.53	17.03	6.65					14	0	51	0

				Salinity			Water level				Biogeochemical					Biological				Tracers			
				%	%	%	%	%	%	%	µg/L	mg/L	mg/L	mg/L	mg/L	g DW/m²	km²	km²	km²	days	%	%	%
CIIP Option	CIIP Scenario	BMT Simulation	Water station	<35 ppt (year-round)	<60 ppt (year round	<100 ppt (year-round)	>-0 m & <+0.8 AHD	>0.3 m AHD (April to July)	+0.2 +0.4 m AHD (August to December)	0.0 – +0.2 m AHD (January to March)	TCHLA	TP	TN	TSS	TRIX	ULVA (TMALG)	Ruppia HSI (sexual >0.5)	All Fish HSI	Smallmouth Hardyhead HSI	Water Age	South Lagoon Initial tracer	Barrage tracer	Salt Creek tracer
			Long Pt	100%	100%	100%	85%				1.76	0.17	1.88	0.86	6.14					89	2	70	2
			Parnka Pt	39%	99%	100%		61%	17%	9%	1.36	0.20	2.34	0.63	6.40					187	7	72	9
			Snipe Is	0%	68%	100%		58%	9%	0%	6.62	0.21	2.80	2.79	7.57					296	16	61	37
			CNL_Region	100%	100%	100%	91%				2.34	0.18	2.09	1.14	6.34	26.36	8.4	61.3	62.0	129	3	74	4
			CSL_Region	0%	98%	100%		77%	51%	61%	4.75	0.20	2.52	2.43	7.08	18.17	23.9	83.3	86.8	240	12	61	24
	Pump_Out250 _above0.2m	Dry	Beacon 1	95%	100%	100%	65%				8.85	0.11	1.26	21.57	6.53					15	0	32	0
			Long Pt	94%	100%	100%	75%				1.57	0.13	1.59	0.83	5.87					93	3	50	1
			Parnka Pt	6%	60%	96%		53%	14%	5%	2.69	0.24	3.20	1.12	6.71					244	21	80	12
			Snipe Is	0%	0%	56%		47%	15%	0%	13.93	0.37	5.80	5.85	8.30					413	54	99	41
			CNL_Region	41%	100%	100%	86%				2.53	0.17	2.01	1.27	6.28	27.86	13.6	58.5	60.2	142	7	59	4
			CSL_Region	0%	0%	67%		63%	21%	38%	9.76	0.34	5.15	4.10	7.77	5.56	12.9	37.8	71.1	360	45	97	31
		Typical	Beacon 1	100%	100%	100%	71%				8.64	0.14	1.53	17.20	6.66					13	0	51	0
			Long Pt	100%	100%	100%	84%				1.89	0.17	1.93	0.92	6.21					81	2	72	2
			Parnka Pt	45%	91%	100%		60%	18%	9%	1.23	0.28	3.33	0.52	6.60					235	18	108	22
			Snipe Is	0%	25%	100%		57%	12%	0%	10.05	0.35	4.86	4.23	8.09					381	42	113	69
			CNL_Region	100%	100%	100%	91%				2.34	0.21	2.35	1.14	6.42	26.98	7.3	60.8	61.9	131	6	85	7
			CSL_Region	0%	59%	100%		76%	52%	60%	6.44	0.34	4.49	2.72	7.55	16.10	17.5	71.9	86.3	336	35	117	53
	Pump_Constant_Out125	Dry	Beacon 1	94%	100%	100%	65%				8.92	0.11	1.25	21.82	6.53					14	0	32	0
			Long Pt	97%	100%	100%	75%				1.67	0.13	1.49	0.87	5.86					82	1	47	1
			Parnka Pt	12%	87%	100%		56%	14%	4%	1.53	0.21	2.59	0.64	6.44					209	14	72	7
			Snipe Is	0%	0%	72%		52%	15%	0%	13.61	0.34	5.31	5.71	8.23					382	47	95	34
			CNL_Region	90%	100%	100%	86%				2.43	0.15	1.81	1.23	6.19	27.73	13.0	59.2	60.2	124	5	55	2
			CSL_Region	0%	2%	99%		69%	20%	10%	8.97	0.31	4.50	3.76	7.63	8.70	15.4	46.0	70.1	323	36	90	24
		Typical	Beacon 1	100%	100%	100%	71%				8.69	0.14	1.52	17.43	6.65					13	0	50	0
			Long Pt	100%	100%	100%	84%				2.10	0.17	1.92	1.01	6.21					77	2	72	2
			Parnka Pt	55%	96%	100%		61%	16%	6%	1.10	0.27	3.14	0.46	6.51					218	15	106	18
			Snipe Is	0%	43%	100%		56%	9%	0%	9.07	0.35	4.69	3.82	8.05					365	38	118	61
			CNL_Region	100%	100%	100%	91%				2.36	0.20	2.29	1.15	6.40	26.33	5.5	61.2	61.8	124	5	83	6
			CSL_Region	0%	70%	100%		76%	51%	35%	5.61	0.34	4.27	2.37	7.46	17.67	19.8	72.9	85.4	317	31	120	45
	Pump_Constant_In250	Dry	Beacon 1	88%	100%	100%	65%				8.37	0.11	1.34	20.35	6.52					26	2	33	1
			Long Pt	20%	73%	100%	72%				1.74	0.16	2.17	0.86	6.36					158	16	46	9
			Parnka Pt	0%	3%	60%		56%	15%	8%	8.75	0.22	4.25	3.65	7.30					279	36	39	25
			Snipe Is	0%	0%	93%		55%	14%	0%	13.38	0.18	3.43	5.66	7.84					287	32	17	31
			CNL_Region	2%	32%	100%	83%				5.50	0.19	3.07	2.48	6.78	11.32	7.8	35.5	49.4	207	24	46	14
			CSL_Region	0%	0%	80%		77%	36%	76%	10.17	0.19	3.61	4.72	7.50	1.47	0.4	35.5	76.4	274	33	23	28
		Typical	Beacon 1	100%	100%	100%	71%				8.26	0.14	1.59	16.24	6.64					22	1	53	1

				Salinity			Water level				Biogeochemical					Biological				Tracers			
				%	%	%	%	%	%	%	µg/L	mg/L	mg/L	mg/L	mg/L	g DW/m²	km²	km²	km²	days	%	%	%
CIIP Option	CIIP Scenario	BMT Simulation	Water station	*<35 ppt (year-round)*	*<60 ppt (year round*	*<100 ppt (year-round)*	*>-0 m & <+0.8 AHD*	*>0.3 m AHD (April to July)*	*+0.2 +0.4 m AHD (August to December)*	*0.0 – +0.2 m AHD (January to March)*	*TCHLA*	*TP*	*TN*	*TSS*	*TRIX*	*ULVA (TMALG)*	*Ruppia HSI (sexual >0.5)*	*All Fish HSI*	*Smallmouth Hardyhead HSI*	*Water Age*	*South Lagoon Initial tracer*	*Barrage tracer*	*Salt Creek tracer*
			Long Pt	41%	97%	100%	82%				1.50	0.18	2.22	0.73	6.28					150	11	63	16
			Parnka Pt	2%	15%	98%		61%	18%	29%	7.61	0.21	3.66	3.18	7.20					275	26	47	45
			Snipe Is	0%	31%	100%		60%	14%	0%	9.01	0.15	2.46	3.84	7.48					268	21	18	52
			CNL_Region	14%	74%	100%	89%				4.28	0.20	2.80	1.93	6.73	16.66	12.9	48.9	60.7	202	18	61	27
			CSL_Region	0%	14%	100%		78%	53%	94%	7.44	0.17	2.84	3.56	7.25	9.26	16.0	69.0	88.0	265	23	27	48
Passive ocean connector	10x1.5m pipes	Dry	Beacon 1	96%	100%	100%	66%				8.65	0.11	1.29	20.80	6.53					16	0	34	0
			Long Pt	88%	100%	100%	76%				1.34	0.14	1.70	0.72	5.87					103	3	55	1
			Parnka Pt	2%	52%	100%		55%	13%	44%	4.12	0.24	3.26	1.72	6.88					255	18	73	12
			Snipe Is	0%	0%	100%		52%	15%	0%	12.39	0.22	3.51	5.22	7.90					313	27	46	27
			CNL_Region	35%	100%	100%	87%				2.50	0.18	2.14	1.24	6.34	26.88	13.7	57.4	60.4	156	7	64	4
			CSL_Region	0%	0%	100%		70%	20%	83%	8.83	0.23	3.48	4.05	7.50	7.11	11.3	57.1	84.5	287	25	54	21
		Typical	Beacon 1	100%	100%	100%	71%				8.54	0.14	1.55	16.82	6.66					13	0	53	0
			Long Pt	100%	100%	100%	85%				2.03	0.18	2.02	0.97	6.20					81	1	77	2
			Parnka Pt	44%	97%	100%		60%	17%	49%	1.11	0.27	3.16	0.46	6.54					237	12	106	18
			Snipe Is	0%	81%	100%		57%	12%	9%	6.54	0.22	2.99	2.77	7.62					299	19	67	44
			CNL_Region	100%	100%	100%	91%				2.29	0.21	2.40	1.11	6.44	26.87	8.8	61.4	62.0	133	4	90	5
			CSL_Region	0%	97%	100%		82%	48%	82%	4.68	0.25	3.13	2.26	7.22	18.14	23.3	82.8	87.0	279	18	83	34
Dredge	Dredge	Dry	Beacon 1	94%	100%	100%	65%				8.64	0.11	1.27	21.55	6.52					19	1	32	0
			Long Pt	60%	100%	100%	75%				1.95	0.14	1.68	1.07	5.98					98	7	47	4
			Parnka Pt	2%	27%	86%		53%	11%	40%	6.78	0.26	3.98	2.83	7.31					268	36	73	20
			Snipe Is	0%	0%	23%		50%	14%	0%	14.88	0.37	6.16	6.25	8.35					422	72	90	48
			CNL_Region	6%	90%	100%	88%				3.19	0.17	2.27	1.61	6.44	20.68	12.6	52.0	59.2	152	15	54	8
			CSL_Region	0%	0%	53%		70%	16%	77%	10.73	0.34	5.55	4.51	7.86	0.99	4.9	19.4	47.0	368	60	87	38
		Typical	Beacon 1	100%	100%	100%	71%				8.50	0.14	1.53	17.37	6.64					16	0	50	1
			Long Pt	92%	100%	100%	86%				2.20	0.17	1.99	1.12	6.19					94	6	68	7
			Parnka Pt	4%	65%	100%		60%	16%	45%	3.36	0.28	3.78	1.41	7.08					269	30	99	40
			Snipe Is	0%	0%	88%		57%	11%	6%	12.65	0.36	5.58	5.32	8.24					396	53	106	85
			CNL_Region	59%	100%	100%	92%				2.69	0.21	2.51	1.34	6.49	28.69	11.9	59.2	61.9	151	13	78	17
			CSL_Region	0%	0%	100%		83%	42%	66%	8.69	0.35	5.10	3.66	7.75	7.71	13.7	61.1	86.7	355	46	108	69
Ocean connector and dredge	Pump_Constant_Out250_Dredge	Dry	Beacon 1	93%	100%	100%	65%				8.98	0.11	1.22	22.66	6.53					14	0	30	0
			Long Pt	93%	100%	100%	74%				2.48	0.11	1.38	1.31	5.94					61	0	42	0
			Parnka Pt	32%	100%	100%		53%	12%	39%	1.54	0.16	1.96	0.64	6.35					174	5	57	4
			Snipe Is	0%	57%	100%		51%	14%	0%	7.80	0.26	3.32	3.27	7.75					340	18	82	21
			CNL_Region	93%	100%	100%	88%				2.49	0.13	1.53	1.35	6.10	25.88	11.5	60.4	60.4	96	1	46	1
			CSL_Region	0%	96%	100%		72%	16%	76%	4.60	0.22	2.79	1.93	7.07	16.81	20.8	79.2	84.3	271	12	74	13
		Typical	Beacon 1	100%	100%	100%	70%				8.75	0.13	1.48	18.17	6.64					12	0	48	0

				Salinity			Water level				Biogeochemical					Biological				Tracers			
				%	%	%	%	%	%	%	µg/L	mg/L	mg/L	mg/L	mg/L	g DW/m²	km²	km²	km²	days	%	%	%
CIIP Option	CIIP Scenario	BMT Simulation	Water station	<35 ppt (year-round)	<60 ppt (year round	<100 ppt (year-round)	>-0 m & <+0.8 AHD	>0.3 m AHD (April to July)	+0.2 +0.4 m AHD (August to December)	0.0 – +0.2 m AHD (January to March)	TCHLA	TP	TN	TSS	TRIX	ULVA (TMALG)	Ruppia HSI (sexual >0.5)	All Fish HSI	Smallmouth Hardyhead HSI	Water Age	South Lagoon Initial tracer	Barrage tracer	Salt Creek tracer
			Long Pt	100%	100%	100%	85%				2.83	0.15	1.74	1.40	6.23					59	1	63	1
			Parnka Pt	97%	100%	100%		61%	16%	45%	1.23	0.22	2.48	0.51	6.48					181	5	89	9
			Snipe Is	1%	100%	100%		59%	10%	6%	4.78	0.30	3.60	2.01	7.66					326	16	115	39
			CNL_Region	100%	100%	100%	92%				2.42	0.17	1.94	1.25	6.29	26.35	4.5	62.0	62.0	97	2	71	3
			CSL_Region	51%	100%	100%		84%	41%	67%	3.09	0.27	3.21	1.32	7.09	19.32	20.9	86.5	86.6	268	12	108	25
SEFA	SEFA	Dry	Beacon 1	94%	100%	100%	65%				8.73	0.11	1.28	21.28	6.52					18	0	33	0
			Long Pt	66%	100%	100%	75%				1.51	0.14	1.76	0.79	5.92					108	7	50	5
			Parnka Pt	3%	29%	85%		56%	14%	3%	7.83	0.28	4.55	3.27	7.32					273	41	77	32
			Snipe Is	0%	0%	19%		52%	15%	0%	15.00	0.37	6.46	6.31	8.36					417	81	82	76
			CNL_Region	18%	95%	100%	85%				3.67	0.18	2.48	1.73	6.51	16.31	13.3	48.8	57.6	162	17	59	12
			CSL_Region	0%	0%	45%		71%	21%	35%	11.10	0.36	6.07	4.67	7.91	0.91	2.7	15.5	40.5	375	71	84	63
		Typical	Beacon 1	100%	100%	100%	71%				8.55	0.14	1.55	16.99	6.65					15	0	52	1
			Long Pt	98%	100%	100%	84%				1.68	0.18	2.10	0.82	6.14					103	6	74	9
			Parnka Pt	10%	65%	99%		61%	17%	6%	2.97	0.29	4.00	1.24	6.93					275	33	100	58
			Snipe Is	0%	0%	90%		57%	9%	0%	11.56	0.32	5.22	4.87	8.14					385	53	88	117
			CNL_Region	55%	100%	100%	90%				2.57	0.22	2.68	1.23	6.50	28.81	9.6	56.3	61.8	162	14	84	23
			CSL_Region	0%	1%	100%		76%	51%	55%	8.40	0.33	5.06	3.56	7.73	11.94	14.9	63.2	86.5	356	49	96	99

C. A description/rationale for the use of each parameter in the ecological interpretation framework, including the measure calculated for each parameter.

Component	Parameter	Measure	Description/Rationale for use
Salinity	<35 ppt (year-round)	% of days below 35 ppt over simulation period	Salinities 35 ppt support: • High abundances of macroinvertebrates and fishes in the Murray Mouth and upper North lagoon (Dittmann 2015; Giatas & Ye 2016; Ye et al. 2019a) • Habitat for sandy sprat (Hossain et al. 2016) and the crab *Paragrapsus gaimardii* (Ye et al. 2019a), which are key prey species for fish and waterbirds (Giatas & Ye 2016) • Black bream, which are most abundant in areas where salinities range from 15–25 ppt, particularly during the spawning period (Hindell et al. 2008). Studies in aquaria have determined the survival of black bream eggs to be optimal at salinities from 15–35 ppt and that physical abnormalities in larvae were lowest from eggs that were incubated at salinities from 15–35 ppt (Haddy and Pankhurst 2000). Salt wedge habitats (salinity stratification at the freshwater and marine interface) are important for black bream recruitment, and favourable salinities (15–30 ppt) and haloclines (>10 ppt) were likely present during the successful recruitment event in the Murray estuary in 2017/18 (Ye et al. 2019b). • Conditions that were considered favourable to the recruitment of goby species (Ye et al. 2015) • Enhanced recruitment of estuarine fish species, including small-mouthed hardyhead, Tamar goby, sandy sprat and yelloweye mullet as a result of freshwater flows (Ye et al. 2015) that increase estuarine productivity (Bice et al. 2016).
Salinity	<60 ppt (year-round)	% of days below 60 ppt over simulation period	Salinities <60 ppt support: • A variety of macroinvertebrate prey types are available for fish and shorebirds at salinities below 60 ppt (Ye et al. 2021) • Macroinvertebrate communities that can positively affect nutrient cycling and fluxes are still present in the Murray estuary and northern North Lagoon where salinities are below 60 ppt (Mosley et al. 2021a). • The fish community is diverse, abundant and inclusive of both small- and large-bodied species at salinities below 60 ppt (Ye et al. 2019a). • Optimal conditions for R. tuberosa germination (10–60 ppt), vegetative growth (30–120 ppt), flowering and seed set (40–63 ppt) (Collier et al. 2017; Asanopoulos and Waycott 2020). • The abundance of the denitrification gene in bacteria has a strong inverse relationship with salinity in the Coorong, particularly where salinities exceed 80 ppt in the southern South Lagoon (Mosley et al. 2021b).
Salinity	<100 ppt (year-round)	% of days below 100 ppt over simulation period	Salinities <100 ppt support: • Suitable conditions for *R. tuberosa* flowering (leading to seed-set) between September and December (optimal: 40–63 ppt, suboptimal: 17–102 ppt; Collier et al. 2017; Asanopoulos and Waycott 2020). • Optimal salinity conditions (full range: 30–122 ppt) for R. tuberosa adult plant (vegetative) growth (Collier et al. 2017; Asanopoulos and Waycott 2020). • Suitable conditions for small-mouthed hardyhead recruitment and distribution (Ye et al. 2020), including avoiding lethal effects (i.e. the LC50 value is 108 ppt; Lui 1969). • Suitable conditions for larvae of salt-tolerant chironomids (*Tanytarsus barbitarsis*) (Dittmann 2015), including avoiding lethal effects (i.e. LC50 value is 96.9 ppt; Kokkinn 1986).
Water level	CNL: >0 m AHD and <+0.8 m AHD	% of days where water levels in the CNL are between 0 and +0.8 m AHD over simulation period	A water regime where levels fluctuate seasonally between 0.0 m AHD in autumn and +0.8 m AHD in winter are expected to provide: • Conditions for *Ruppia tuberosa* and *Althenia cylindrocarpa* growth in the central North Lagoon and for growth and reproduction in the southern sections of the North Lagoon. • Connectivity with the South Lagoon (i.e. water levels above +0.2 m AHD, M Gibbs. Pers. Comm. 2021) to support the passage of fish between the Coorong lagoons and *R. tuberosa* and *A. cylindrocarpa* growth and reproduction in the South Lagoon. • Protection of mudflat habitats from long-term exposure that otherwise makes them uninhabitable for certain benthic macroinvertebrates (i.e. polychaetes) (Dittmann et al. 2018). • Extensive mudflat availability at low (~+0.1m AHD) water levels (Hobbs et al. 2019) from mid-summer to autumn that provides foraging habitat for shorebirds.
Water level	CSL: >0.3 m AHD (April to July)	% of days where water levels in the CSL are >+0.3 m AHD over simulation period	A water regime where levels in the CSL are above +0.3 m AHD over April to July would be expected to: • Facilitate connectivity and exchange of water between the CNL and CSL, which could benefit ecosystem function through improvements to water and sediment quality (e.g. Mosley et al. 2020). • Support condition favourable to the winter growth of *Ruppia tuberosa* and *Althenia cylindrocarpa*. Most (88%) *R. tuberosa* and *A. cylindrocarpa* plants in spring 2020 occurred at elevations between -0.15 and +0.15 m AHD in the South Lagoon (Oerman 2021). As *R. tuberosa* (and presumably *A. cylindrocarpa*) had greatest shoot densities in water depths of 0.2 to 0.6 m (Kim et al. 2015), water levels in the South Lagoon of +0.35 m AHD over June and July should provide optimal growth conditions.

Component	Parameter	Measure	Description/Rationale for use
Water level	CSL: +0.2 to +0.4 m AHD (August to December)	% of days where water levels in the CSL are between +0.2 m AHD and +0.4 m AHD over simulation period	A water regime where levels in the CSL are between +0.4 m AHD and +0.2 m AHD from August to December would be expected to: • Maintain water levels from September to December that are critical to successful *R. tuberosa* (and presumably *A. cylindrocarpa*) sexual (seed) and asexual (turions) reproduction (Collier et al. 2017). Optimal water levels for *R. tuberosa* (and presumably *A. cylindrocarpa*) reproductive output are approximately +0.25 m AHD as the vast majority (88%) of *R. tuberosa* and *A. cylindrocarpa* plants were distributed between -0.15 to +0.15 m AHD in spring 2020 and densities of *R. tuberosa* flowers, seeds and turions are greatest in 0.1–0.4m of water (Kim et al. 2015). This optimal water level (m AHD) for *R. tuberosa* and *A. cylindrocarpa* needs to be confirmed by field data and new digital elevation model information collected for shallow water environments. • Provide shallow water habitats for waterbirds that congregate from late spring (Delroy 1974) and occur in their highest numbers over summer and autumn (Paton 2010). Waterbird activity is concentrated in shallow water habitats (Paton et al. 2018), which become greatly reduced as water levels exceed +0.4 m AHD (Hobbs et al. 2019).
Water level	CSL: 0.0 to +0.2 m AHD (January to March)	% of days where water levels in the CSL are between 0 m AHD and +0.2 m AHD over simulation period	A water regime where levels in the CSL are between +0.4 m AHD and +0.2 m AHD from August to December would be expected to: • Provide expansive areas of mudflat from mid-summer to autumn for shorebirds to forage, as the extent of such habitat are optimal at water levels of +0.1–+0.2 m AHD (Hobbs et al. 2019).
Biogeochemical	Total Chlorophyll-a (TCHLA)	Average Total Chlorophyll-a over the final year of simulation	Total chlorophyll-a is the sum of all planktonic algal groups (cyanobacteria, green algae and diatoms) (Hipsey et al. 2020). Processes that planktonic algae groups influence and are influenced by are photosynthesis, nutrient uptake, respiration and sedimentation (Hipsey et al. 2020). This parameter helps to track the progression of lack thereof from a hyper-eutrophic to mesotrophic state.
Biogeochemical	Total Nitrogen (TN)	Average Total Nitrogen over the final year of simulation	Total nitrogen is the sum of all nitrogen state variables (dissolved organic, particulate organic, ammonium and nitrate). Processes that impact these nitrogen state variables are algal uptake and mortality/excretion, nitrification, denitrification, sediment flux, organic mineralization, photolysis, breakdown and settling (Hipsey et al. 2020). This parameter helps to track the progression of lack thereof from a hyper-eutrophic to mesotrophic state.
Biogeochemical	Total Suspended Solids (TSS)	Average TSS over the final year of simulation	A measure of the amount of suspended sediment in the water column and therefore is a measure of water clarity. Water clarity is considered to be an important determinant in the depth to which aquatic plants can grow and also influence the vigour of plants (Collier et al. 2017).
Biogeochemical	Trophic Index (TRIX)	Average measure of TRIX over the final year of simulation	The trophic index (TRIX) assesses the degree of eutrophication in the Coorong, and is calculated based upon the concentrations of chlorophyll-a, dissolved oxygen, total nitrogen and total phosphorus (Mosley et al. 2020). As TRIX incorporates measures of nutrients and chlorophyll-a, it helps to represent recovery of nutrient dynamics in the South Lagoon from a hyper-eutrophic to mesotrophic state.
Biological	ULVA (TMALG)	Average dry weight density (g DW/m^2)	Average biomass of macroalgae across the CNL and CSL over the final year of simulation. Macroalgae cover is a key factor that influences the condition of the Coorong, especially the CSL as it affects: • the reproductive success of *R. tuberosa* • nutrient cycling in the sediment, and • the accessibility and quality of foraging habitat (mudflat) for shorebirds.
Biological	Ruppia HSI (Sexual >0.5)	Extent (Km^2) of habitat for sexual reproduction (seed production) that has a suitability rating over 0.5.	A literature review by Collier et al. (2017) determined thresholds for salinity, temperature, light, water depth and algal biomass for each life stage of the *R. tuberosa* lifecycle. These ecological thresholds were used to parameterise the Ruppia Habitat Suitability Model (Collier et al. 2017), which can be coupled with the Coorong Dynamics Model (DEW 2020a) to determine the habitat suitability for each *R. tuberosa* life stage and across the life cycle under different management scenarios. The outputs in the framework Ruppia HSI (sexual >0.5) is the extent (Km^2) of habitat for sexual reproduction (seed production) that has a suitability rating over 0.5.
Biological	All Fish HSI	Average yearly total habitat	The Fish HSI area was calculated as average yearly total extent for all fish species, with each of the seven species weighted equally. A diverse fish community is a key biological attribute of the desired state of the Southern Coorong (DEW 2021a).

Component	Parameter	Measure	Description/Rationale for use
		extent (Km^2) for all fish species)	
Biological	Smallmouth Hardyhead HSI	Average yearly total habitat extent (Km^2)	The Smallmouth Hardyhead HSI was calculated as average yearly total extent of habitat for the species. The Smallmouth Hardyhead is a key food resource for piscivorous fish and waterbirds in the Coorong, especially the South Lagoon (Giatas and Ye 2016).
Water Tracer	Water Age	Annual averaged water age (days)	The water age tracer represented the average age of water at each point in space and time in the model from the commencement of the simulation (i.e. the water age from on the first day was set to 0).
Water Tracer	South Lagoon Initial tracer	Annual average	The South lagoon initial tracer represents how the water in the South Lagoon flushes and evapo-concentrates.
Water Tracer	Barrage tracer	Average Barrage water tracer concentration during the final simulation year	The concentration of barrage water. The concentration of barrage water is treated similarly to dissolved constituents (e.g. salt) and therefore can evapo-concentrate.
Water Tracer	Salt Creek tracer	Average Salt Creek water tracer concentration during the final simulation year.	The concentration of Salt Creek water. The concentration of Salt Creek water is treated similarly to dissolved constituents (e.g. salt) and therefore can evapo-concentrate.

D. Interim water quality trigger values for the Coorong

Luke Moseley, University of Adelaide, 25 May 2021
Proposed interim water quality trigger values to ensure components, processes and services (CPS) are maintained in the Coorong in regard to nutrients (nitrogen and phosphorus) and chlorophyll a (indicator of green micro-algae/phytoplankton concentration) are shown in Table 8.1. The approach taken to develop these was to first consider the Australian Water Quality Guidelines (AWQG 2018) for nutrients and chlorophyll *a* in seawater or estuarine water (Table 8.2). Estuary trigger values of total nitrogen (TN) < 1 mg/L, total phosphorus (TP) <0.1 mg/L, and chlorophyll a < 5 µg/L are proposed to be used for the Coorong but the TN and TP are also the same for marine waters (Table 8.1).

Given the reverse estuary type, restricted morphology, and occurrence of hypersaline conditions in the Coorong, applying these default guidelines derived for salinities greater than 35 psu is somewhat problematic. However one simple principle that can be applied is that the total nutrient or chlorophyll concentration in the Coorong water should not increase above that expected via evapo-concentration of seawater on an annual cycle (i.e. evapo-concentration over spring-summer period). For example, given the AWQG (2018) value for TN is 1 mg/L in marine waters (Table 8.2), if doubling the marine salinity of 35 psu occurs to reach 70 psu, TN should be < 2 mg/L (i.e. doubling of AWQG 2018 value of 1 mg/L). This approach was applied to derive the interim values in Table 8.2) while remaining internally consistent with the salinity thresholds and exceedance durations that have been proposed. For example, for salinity a “very significant” consequence is categorised when salinities are >100 psu for ≥18 months in the South Lagoon. Correspondingly for TN a “very significant” consequence was set at >3 mg/L TN for ≥18 months, which is approximately 3 times the AWQG (2018) TN value (to reflect the corresponding salinity of >100 psu is approaching 3 times seawater salinity). Using this approach the limits of acceptable change (LAC) are set at TN>3 mg/L and/or TP>0.3 mg/L and/or Chlorophyll a > 15 µg/L for ≥18 months for the South lagoon, and TN>2 mg/L and/or TP>0.2 mg/L and/or Chlorophyll a > 10 µg/L for ≥18 months for the North lagoon.

How the existing water quality data compares to these values is shown in Figure 8.1 and Figure 8.2 respectively. The current water quality in the Coorong is often largely in excess of the interim guideline values (Oliver et al. 2015, Mosley et al. 2020), particularly for TN and chlorophyll (Figure 8.1 and Figure 8.2). The consequence is that the interim guidelines proposed suggest the CPS are in the “very significant” range currently due to excessive nutrient and chlorophyll levels, particularly in the South Lagoon. This is considered reasonable given that algae and nutrients are acknowledged as major issues presently harming the Coorong ecological health (Mosley et al. 2020, Waycott 2020a,b).

Historical data near the time of Ramsar site declaration shows water quality not inconsistent with these interim trigger values and much improved from current conditions. For example in 1982-1983 the mean TP concentration along the entire Coorong was 0.08 mg/L and chlorophyll a values were also typically <10 µg/L (Geddes and Butler 1984). This period was during low flow conditions so likely represents poorer water quality than average conditions at the time. Hence setting trigger values more consistent with earlier water quality data when less eutrophication was present aligns with a resource condition target (RCT, Table 8.1), and CPS of the Coorong around the time of Ramsar site declaration.

The proposed Coorong trigger values in Table 8.1 should be considered interim values until the current nutrient and algal components of the *Healthy Coorong, Healthy Basin* Trials and Investigations are completed in 2022. Following completion of this research these values should be reviewed.

Table 8.1 Proposed trigger values for nutrients and chlorophyll in CPS

CPS (from RaMP)	Consequence level	Outcome
1.1.3 Coorong South Lagoon water levels	Insignificant	Water levels in the CSL to be maintained >+0.3 m AHD in June and July, between +0.4 m AHD and +0.2 m AHD from August to December (part of RCT)
	Minor	Water levels maintained above +0.3 m AHD in June and July, and below +0.2 m AHD from August to December for less than 7 consecutive days.
	Moderate	Water levels maintained above +0.3 m AHD in June and July, and below +0.2 m AHD from August to December for >7 consecutive days.
	Significant	Water levels drop below target range from June to December but not below 0 m AHD over this period.
	Very significant	Water levels drop below 0m AHD for > 8 consecutive months (LAC exceeded)
1.2.2 Coorong South Lagoon salinity	Insignificant	Average daily salinity in the South Lagoon < 60 ppt year-round
	Minor	Maximum average daily salinities in the South Lagoon are 60-100 ppt
	Moderate	Average daily salinity in the South Lagoon are > 60 ppt in winter and annual maximum salinity is >100 ppt
	Significant	Average monthly salinity exceeds 100 ppt for 6 to 18 consecutive months
	Very significant	Average monthly salinity exceeds 100 ppt for ≥ 18 consecutive months (LAC exceeded)
1.2.2 Coorong North Lagoon salinity	Insignificant	Average monthly salinity < 45 ppt (RCT)
	Minor	Average monthly salinity > 45 ppt (RCT) for < 2months
	Moderate	Average monthly salinity > 45 ppt for 2-6 months
	Significant	Average monthly salinity > 70 ppt for 6-18 consecutive months
	Very significant	Average monthly salinity > 70 ppt for ≥18 consecutive months (LAC exceeded)
Coorong South Lagoon Nutrients	Insignificant	<1 mg/L Total Nitrogen (TN) and <0.1 mg/L Total Phosphorus (TP) and Chlorophyll a (Chl. *a*) <5 µg/L as per Australian Water Quality Guidelines (2018)(RCT)
	Minor	Average monthly TN >1 mg/L and/or TP > 0.1 mg/L and/or Chl. *a* >5 µg/L for <2 months
	Moderate	Average monthly TN >2 mg/L and/or TP > 0.2 mg/L and/or Chl. *a* >10 µg/L for 2-6 consecutive months
	Significant	Average monthly TN > 3 mg/L and/or TN > 0.3 mg/L and/or Chl. *a* >15 µg/L for 6-18 consecutive months
	Very significant	Average monthly TN > 3 mg/L and/or TN > 0.3 mg/L and/or Chl. *a* >15 µg/L for ≥18 consecutive months (LAC exceeded)
Coorong North Lagoon Nutrients	Insignificant	<1 mg/L Total Nitrogen (TN) and <0.1 mg/L Total Phosphorus (TP) and Chlorophyll a (Chl. *a*) <5 µg/L as per Australian Water Quality Guidelines (2018)(RCT)
	Minor	Average monthly TN >1 mg/L and/or TP > 0.1 mg/L and/or Chl. *a* >5 µg/L for <2 months
	Moderate	Average monthly TN >1 mg/L and/or TP > 0.1 mg/L and/or Chl. *a* >5 µg/L for 2-6 consecutive months
	Significant	Average monthly TN > 2 mg/L and TN > 0.2 mg/L and/or Chl. *a* >10 µg/L for 6-18 consecutive months

	Very significant	Average monthly TN > 2 mg/L and TN > 0.2 mg/L and/or Chl. *a* >10 µg/L for ≥18 consecutive months (LAC exceeded)

Table 8.2 Default Australian Water Quality Guideline (2018) trigger values for physical and chemical stressors for south central Australia — low rainfall areas — for slightly disturbed estuarine and marine ecosystems.

Trigger values are used to assess risk of adverse effects due to nutrients, biodegradable organic matter and pH in various ecosystem types.

Ecosystem type	Chl. A (µg/L)	TP (mg/L)	TN (mg/L)
Estuarine	5	0.1	1
Marine	1	0.1	1

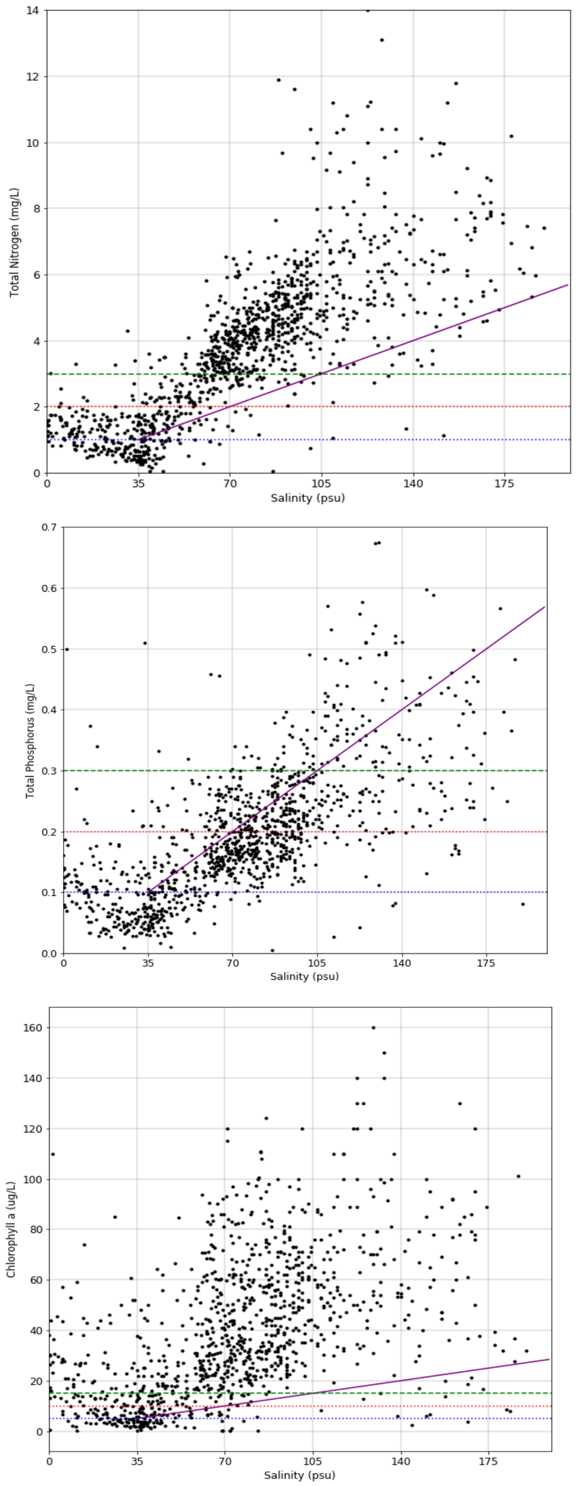


Figure 8.1 TN, TP and chlorophyll a versus salinity in the Coorong.

The proposed thresholds for TN (1, 2, 3 mg/L), TP (0.1, 0.2, 0.3 mg/L) and Chlorophyll a (5, 10, 15 µg/L) respectively are shown as the horizontal lines on the plots. The diagonal line represents the AWQG (2018) guideline extrapolated to higher salinity as described in the text (e.g. doubling

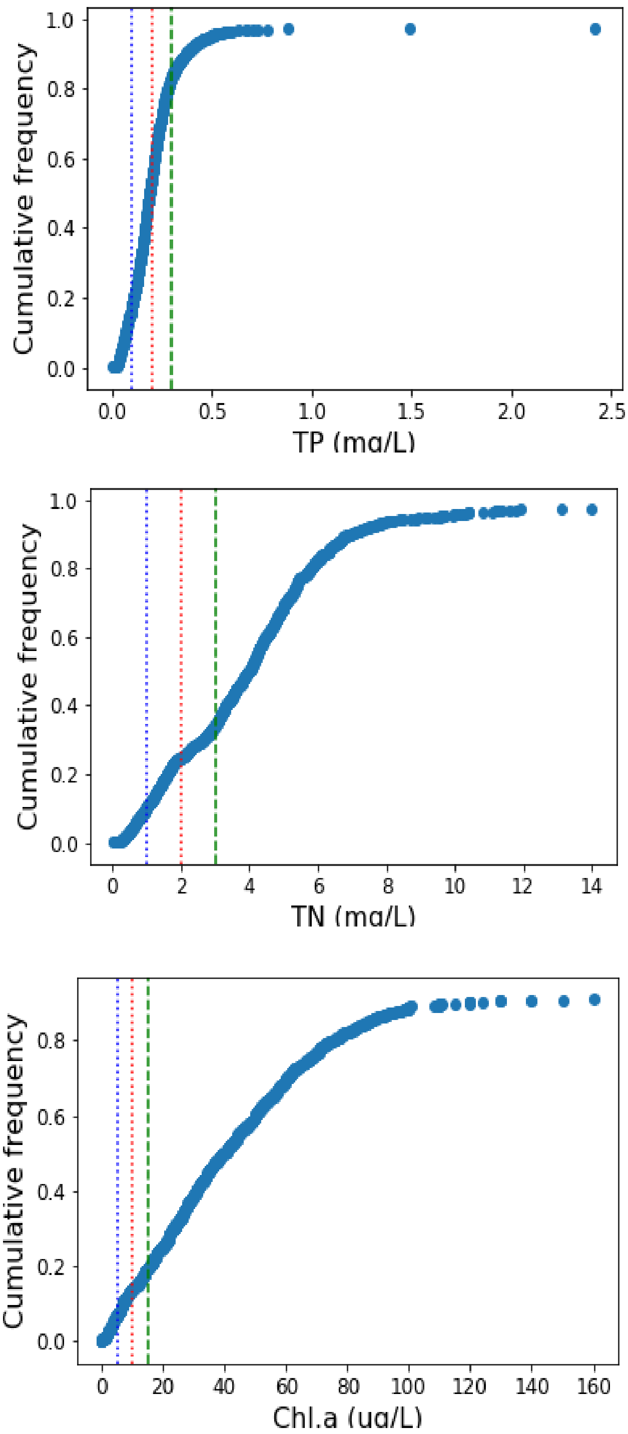


Figure 8.2 Cumulative frequency plots.

The proposed thresholds for TN (1, 2, 3 mg/L), TP (0.1, 0.2, 0.3 mg/L) and Chlorophyll a (5, 10, 15 µg/L) respectively are shown as the vertical lines on the plots.

References

AWQG (2018). Australian Water Quality Guidelines. Canberra. https://www.waterquality.gov.au/guidelines

Geddes MC and Butler AJ (1984). Physicochemical and biological studies of the Coorong lagoons, South Australia and the effect of salinity on the distribution of the macrobenthos. Transactions of the Royal Society of South Australia 108, 51–62.

Mosley LM, Priestley S, Brookes J, Dittmann S, Farkaš J, Farrell M, Ferguson AJ, Gibbs M, Hipsey M, Huang J, Lam-Gordillo O, Simpson SL, Teasdale PR, Tyler JJ, Waycott M, Welsh DT (2020) Coorong water quality synthesis with a focus on the drivers of eutrophication. Goyder Institute for Water Research Technical Report Series No. 20/10, Adelaide, South Australia. ISSN: 1839-2725.

Oliver RL, Mosley L and Lorenz, Z. (2015) Utilizing the Coorong, Lower Lakes and Murray Mouth water quality and microalgae monitoring data to evaluate indicators for the Ecological Character Description. CSIRO Land and Water Flagship, Australia.

Waycott, M, O'Loughlin, E, Foster, N, McGrath, A, Jones, A and Van Dijk, KJ (2020a). Distribution and dynamics of filamentous green algae and the *Ruppia* aquatic plant community in the Southern Coorong. *Goyder Institute for Water Research Technical Report Series No. 20/02*, Adelaide, South Australia.

Waycott, M (2020b). *Healthy Coorong, Healthy Basin – phase one Trials and Investigations project Component 2 – Investigating the drivers and controls of filamentous algae and restoration of aquatic plants in the Coorong. 2.7.1 Annual Report: Nutrient dynamics of primary producers* pp. 1-14, University of Adelaide, Goyder Institute for Water Research, Adelaide, South Australia.

E. The risk profile for CIIP options/scenarios across a range of inflow conditions.

The inherent risk that assumes a no-build scenario (Pre) is compared against the residual risk (Post) under a CIIP option/scenario for each end-point. Risk was categorised as low (green), medium (orange) and high (red). The Benefit column highlights where the CIIP option/scenario changed the risk level, with a positive change of one category shown in light green and a positive change of two categories shown in dark green. If the CIIP option/scenario caused a negative change in the risk category this was marked in orange. Direction shows the impact of the CIIP option/scenario irrespective of a positive of negative change in the risk level, a positive change is shown in green and a negative change in red.

CIIP option/scenario	Inflow condition	End-point	Pre	Post	Benefit	Direction
10 x 1.5m pipes	Dry	CNL Nutrients				
10 x 1.5m pipes	Dry	CNL salinity				
10 x 1.5m pipes	Dry	CSL Nutrients				
10 x 1.5m pipes	Dry	CSL salinity				
10 x 1.5m pipes	Dry	CSL water levels				
10 x 1.5m pipes	Observed	CNL salinity				
10 x 1.5m pipes	Observed	CSL salinity				
10 x 1.5m pipes	Observed	CSL water levels				
10 x 1.5m pipes	Typical	CNL Nutrients				
10 x 1.5m pipes	Typical	CNL salinity				
10 x 1.5m pipes	Typical	CSL Nutrients				
10 x 1.5m pipes	Typical	CSL salinity				
10 x 1.5m pipes	Typical	CSL water levels				
Constantly In500_Dredge	Extra dry	CNL salinity				
Constantly In500_Dredge	Extra dry	CSL salinity				
Constantly In500_Dredge	Extra dry	CSL water levels				
Constantly In500_Dredge	Observed	CNL salinity				
Constantly In500_Dredge	Observed	CSL salinity				
Constantly In500_Dredge	Observed	CSL water levels				
Constantly Out250_Dredge	Dry	CNL Nutrients				
Constantly Out250_Dredge	Dry	CNL salinity				
Constantly Out250_Dredge	Dry	CSL Nutrients				
Constantly Out250_Dredge	Dry	CSL salinity				
Constantly Out250_Dredge	Dry	CSL water levels				
Constantly Out250_Dredge	Extra dry	CNL salinity				
Constantly Out250_Dredge	Extra dry	CSL salinity				
Constantly Out250_Dredge	Extra dry	CSL water levels				
Constantly Out250_Dredge	Observed	CNL salinity				

CIIP option/scenario	Inflow condition	End-point	Pre	Post	Benefit	Direction
Constantly Out250_Dredge	Observed	CSL salinity				
Constantly Out250_Dredge	Typical	CNL Nutrients				
Constantly Out250_Dredge	Typical	CNL salinity				
Constantly Out250_Dredge	Typical	CSL Nutrients				
Constantly Out250_Dredge	Typical	CSL salinity				
Constantly Out250_Dredge	Typical	CSL water levels				
Constantly Out500_Dredge	Observed	CNL salinity				
Constantly Out500_Dredge	Observed	CSL salinity				
Constantly Out500_Dredge	Observed	CSL water levels				
Constantly_In125	Observed	CNL salinity				
Constantly_In125	Observed	CSL salinity				
Constantly_In125	Observed	CSL water levels				
Constantly_In250	Dry	CNL Nutrients				
Constantly_In250	Dry	CNL salinity				
Constantly_In250	Dry	CSL Nutrients				
Constantly_In250	Dry	CSL salinity				
Constantly_In250	Dry	CSL water levels				
Constantly_In250	Typical	CNL Nutrients				
Constantly_In250	Typical	CNL salinity				
Constantly_In250	Typical	CSL Nutrients				
Constantly_In250	Typical	CSL salinity				
Constantly_In250	Typical	CSL water levels				
Constantly_In250_Out250	Dry	CNL Nutrients				
Constantly_In250_Out250	Dry	CNL salinity				
Constantly_In250_Out250	Dry	CSL Nutrients				
Constantly_In250_Out250	Dry	CSL salinity				
Constantly_In250_Out250	Dry	CSL water levels				
Constantly_In250_Out250	Typical	CNL Nutrients				
Constantly_In250_Out250	Typical	CNL salinity				
Constantly_In250_Out250	Typical	CSL Nutrients				
Constantly_In250_Out250	Typical	CSL salinity				
Constantly_In250_Out250	Typical	CSL water levels				
Constantly_In500	Observed	CNL salinity				
Constantly_In500	Observed	CSL salinity				
Constantly_In500	Observed	CSL water levels				
Constantly_Out125	Dry	CNL Nutrients				

CIIP option/scenario	Inflow condition	End-point	Pre	Post	Benefit	Direction
Constantly_Out125	Dry	CNL salinity				
Constantly_Out125	Dry	CSL Nutrients				
Constantly_Out125	Dry	CSL salinity				
Constantly_Out125	Dry	CSL water levels				
Constantly_Out125	Observed	CNL salinity				
Constantly_Out125	Observed	CSL salinity				
Constantly_Out125	Observed	CSL water levels				
Constantly_Out125	Typical	CNL Nutrients				
Constantly_Out125	Typical	CNL salinity				
Constantly_Out125	Typical	CSL Nutrients				
Constantly_Out125	Typical	CSL salinity				
Constantly_Out125	Typical	CSL water levels				
Constantly_Out250	Dry	CNL Nutrients				
Constantly_Out250	Dry	CNL salinity				
Constantly_Out250	Dry	CSL Nutrients				
Constantly_Out250	Dry	CSL salinity				
Constantly_Out250	Dry	CSL water levels				
Constantly_Out250	Observed	CNL salinity				
Constantly_Out250	Observed	CSL salinity				
Constantly_Out250	Observed	CSL water levels				
Constantly_Out250	Typical	CNL Nutrients				
Constantly_Out250	Typical	CNL salinity				
Constantly_Out250	Typical	CSL Nutrients				
Constantly_Out250	Typical	CSL salinity				
Constantly_Out250	Typical	CSL water levels				
Constantly_out250Round	Observed	CNL salinity				
Constantly_out250Round	Observed	CSL salinity				
Constantly_out250Round	Observed	CSL water levels				
Dredge	Dry	CNL Nutrients				
Dredge	Dry	CNL salinity				
Dredge	Dry	CSL Nutrients				
Dredge	Dry	CSL salinity				
Dredge	Dry	CSL water levels				
Dredge	Observed	CNL salinity				
Dredge	Observed	CSL salinity				

CIIP option/scenario	Inflow condition	End-point	Pre	Post	Benefit	Direction
Dredge	Observed	CSL water levels				
Dredge	Typical	CNL Nutrients				
Dredge	Typical	CNL salinity				
Dredge	Typical	CSL Nutrients				
Dredge	Typical	CSL salinity				
Dredge	Typical	CSL water levels				
DredgeParnka	Observed	CNL salinity				
DredgeParnka	Observed	CSL salinity				
DredgeParnka	Observed	CSL water levels				
DredgePelican	Observed	CNL salinity				
DredgePelican	Observed	CSL salinity				
DredgePelican	Observed	CSL water levels				
Lake Albert Connector dredge	Dry	CNL Nutrients				
Lake Albert Connector dredge	Dry	CNL salinity				
Lake Albert Connector dredge	Dry	CSL Nutrients				
Lake Albert Connector dredge	Dry	CSL salinity				
Lake Albert Connector dredge	Dry	CSL water levels				
Lake Albert Connector dredge	Observed	CNL salinity				
Lake Albert Connector dredge	Observed	CSL salinity				
Lake Albert Connector dredge	Observed	CSL water levels				
Lake Albert Connector dredge	Typical	CNL Nutrients				
Lake Albert Connector dredge	Typical	CNL salinity				
Lake Albert Connector dredge	Typical	CSL Nutrients				
Lake Albert Connector dredge	Typical	CSL salinity				
Lake Albert Connector dredge	Typical	CSL water levels				
Lake Albert Connector realistic	Dry	CNL Nutrients				
Lake Albert Connector realistic	Dry	CNL salinity				

CIIP option/scenario	Inflow condition	End-point	Pre	Post	Benefit	Direction
Lake Albert Connector realistic	Dry	CSL Nutrients				
Lake Albert Connector realistic	Dry	CSL salinity				
Lake Albert Connector realistic	Dry	CSL water levels				
Lake Albert Connector realistic	Observed	CNL salinity				
Lake Albert Connector realistic	Observed	CSL salinity				
Lake Albert Connector realistic	Observed	CSL water levels				
Lake Albert Connector realistic	Typical	CNL Nutrients				
Lake Albert Connector realistic	Typical	CNL salinity				
Lake Albert Connector realistic	Typical	CSL Nutrients				
Lake Albert Connector realistic	Typical	CSL salinity				
Lake Albert Connector realistic	Typical	CSL water levels				
Pump in and out 0.2-0.1	Observed	CNL salinity				
Pump in and out 0.2-0.1	Observed	CSL salinity				
Pump in and out 0.2-0.1	Observed	CSL water levels				
Pump in and out 0.3-0.15	Dry	CNL Nutrients				
Pump in and out 0.3-0.15	Dry	CNL salinity				
Pump in and out 0.3-0.15	Dry	CSL Nutrients				
Pump in and out 0.3-0.15	Dry	CSL salinity				
Pump in and out 0.3-0.15	Dry	CSL water levels				
Pump in and out 0.3-0.15	Typical	CNL Nutrients				
Pump in and out 0.3-0.15	Typical	CNL salinity				
Pump in and out 0.3-0.15	Typical	CSL Nutrients				
Pump in and out 0.3-0.15	Typical	CSL salinity				
Pump in and out 0.3-0.15	Typical	CSL water levels				
Pump out above 0.2m	Dry	CNL Nutrients				
Pump out above 0.2m	Dry	CNL salinity				
Pump out above 0.2m	Dry	CSL Nutrients				
Pump out above 0.2m	Dry	CSL salinity				
Pump out above 0.2m	Dry	CSL water levels				
Pump out above 0.2m	Typical	CNL Nutrients				
Pump out above 0.2m	Typical	CNL salinity				

CIIP option/scenario	Inflow condition	End-point	Pre	Post	Benefit	Direction
Pump out above 0.2m	Typical	CSL Nutrients				
Pump out above 0.2m	Typical	CSL salinity				
Pump out above 0.2m	Typical	CSL water levels				
Pump out above 0.3m	Observed	CNL salinity				
Pump out above 0.3m	Observed	CSL salinity				
Pump out above 0.3m	Observed	CSL water levels				
SE_1975_Augment	Dry	CNL Nutrients				
SE_1975_Augment	Dry	CNL salinity				
SE_1975_Augment	Dry	CSL Nutrients				
SE_1975_Augment	Dry	CSL salinity				
SE_1975_Augment	Dry	CSL water levels				
SE_1975_Augment	Typical	CNL Nutrients				
SE_1975_Augment	Typical	CNL salinity				
SE_1975_Augment	Typical	CSL Nutrients				
SE_1975_Augment	Typical	CSL salinity				
SE_1975_Augment	Typical	CSL water levels				

Government
of South Australia

Department for
Environment and Water