Coorong Infrastructure Feasibility Investigations

Concept Design Report

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The sole purpose of this report and the associated services performed by Kellogg Brown & Root Pty Ltd (KBR) is to **outline the concept design activities completed for the infrastructure options considered for the Coorong Infrastructure Investigations Project Engineering Services** in accordance with the scope of services set out in the contract between KBR and **Department for Environment and Water** ('the Client'). That scope of services was defined by the requests of the Client, by the time and budgetary constraints imposed by the Client, and by the availability of access to the site.

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Revision History

Revision	Date	Comment	Signatures			
			Originated by	Checked by	Technical Approval	Project Approval
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Contents

Abbreviations

1D	One-dimensional
3D	Three-dimensional
4WD	Four-wheel drive
AEP	Annual exceedance probability
AHD	Australian height datum
ALWC	Accelerated low water corrosion
ARI	Average recurrence interval
AS	Australian Standard
ASS	Acid sulphate soil
BESS	Battery energy storage system
BMT	BMT Global Pty Ltd
BOM	Bureau of Meteorology
CD	Chart datum
CIIP	Coorong Infrastructure Investigations Project
CNL	Coorong North Lagoon
CSD	Cutter suction dredge
CSL	Coorong South Lagoon
DCP	Dynamic cone penetrometer
DEW	Department for Environment and Water (SA)
DEH	Department for Environment and Heritage (SA)
DSTE	Design storm tide event
EC	Electrical conductivity (usually measured in µS/cm)
EMD	Estimated maximum demand
EPA	Environment Protection Authority (SA)
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
FNSE	First Nations of the South East
HAT	Highest astronomical tide
HCHB	Healthy Coorong, Healthy Basin
HV	High voltage
HW	Headwater
KBR	Kellogg Brown & Root Pty Ltd

kPag	Kilopascals gauge (internal pressure measurement)
LAC	Lake Albert connector
LAT	Lowest astronomical tide
mAHD	Metres to Australian height datum
MCA	Multi-criteria analysis
MHWN	Mean high water neaps
MHWS	Mean high water springs
ML	Megalitre
MLWN	Mean low water neaps
MLWS	Mean low water springs
MSL	Mean sea level
NAC	Ngarrindjeri Aboriginal Corporation
NAGD	National Assessment Guidelines for Dredging (2009)
NPSH	Net positive suction head
PASS	Potential acid sulphate soil
PLC	Programmable logic controller
ppm	Parts per million
ppt	Parts per thousand
PSD	Particle size distribution
PV	Photovoltaic
PMST	Protected matters search tool
SA	South Australia
SAPN	South Australian Power Networks
SCADA	Supervisory control and data acquisition
SEFRP	South East Flows Restoration Project
SKM	Sinclair Knight Merz Pty Ltd
SLR	Sea level rise
SLS	Serviceability limit state
SPOCAS	Suspension peroxide oxidation combined acidity and sulphur
SWER	Single wire earth return
TDS	Total dissolved solids (usually measured in mg/L or ppm (parts per million))
TW	Tailwater
ULS	Ultimate limit state
VSD	Variable speed drive
WS	Water surface

List of figures

List of tables

1 Introduction

1.1 BACKGROUND

The Coorong lagoons form part of the Coorong and Lakes Alexandrina and Albert Ramsar wetland site and is located at the very downstream end of the River Murray system. It is a long, shallow and brackish to hypersaline coastal lagoon extending around 140 km to the south east from the River Murray Mouth. The Coorong is separated from the Southern Ocean by Younghusband Peninsula, a complex coastal dune barrier system comprising significant areas of cultural heritage, environmental value and biodiversity. In the waters of the Southern Ocean, adjacent parts of the Coorong are South Australian Government Marine Parks and Sanctuary Zone (Encounter and Upper South East). A locality plan of the general area is provided in Figure 1.

The Coorong South Lagoon has become degraded to such a degree that it requires significant intervention to restore its ecological health and reverse the impacts of drought, water extractions and the concentration of nutrients within the lagoons and the lagoon sediments. This degradation has been exacerbated by the Millennium Drought, and the system has been unable to recover at the anticipated rate in the years since the drought ended, even with increased environmental flows and improved water management practices.

The Healthy Coorong, Healthy Basin (HCHB) program, being administered by South Australia's Department for Environment and Water and jointly funded by the Australian and South Australian governments, aims to support the improvement of the ecological health of the Coorong. Central to the program is implementation of intervention measures derived from scientific analysis and monitoring to address both immediate threats and prepare for future threats such as the impacts of climate change.

The Coorong Infrastructure Investigations Project (CIIP) forms part of the HCHB program. As part of the CIIP, Kellogg Brown & Root Pty Ltd (KBR) has been engaged by Department for Environment and Water (DEW) to investigate the engineering feasibility of long-term infrastructure and management regimes. The program aims to improve the ecological health of the Coorong, provide the opportunity for habitat restoration and to sustain the ecosystem for many years to come. These engineering investigations have been completed in parallel with several other studies and consultation processes. These include:

- Hydrodynamic and biogeochemical analysis and scenario testing.
- Community consultation and First Nations engagement.
- Preliminary socioeconomic assessment of the concept designs developed.

The Coorong as a system has a special connection to many community members, and importantly, the Traditional Owners, as a place of recreation, natural beauty, education, and sustainment of livelihoods. DEW is focused on engaging the community in decision-making as part of the CIIP and has sought feedback from the community on preferred options for improvement of the ecological health of the Coorong South Lagoon in particular. This list of options has guided development of the infrastructure options that are assessed in this feasibility and concept design study.

The CIIP Engineering Services engagement has allowed engineering assessment of these shortlisted options, to determine potential suites of infrastructure that will achieve the objectives set by the

HCHB program and provide confidence in the expected outcomes of the infrastructure to be implemented. These shortlisted options selected during 2020 are:

- A connection between the Coorong South Lagoon and the Southern Ocean.
- Coorong lagoon dredging to improve connectivity between the Coorong South Lagoon and Coorong North Lagoon.
- A Lake Albert to Coorong North Lagoon connector.
- Further augmentation of the South East Flows to the Coorong.
- Additional automation of barrage gates at the Tauwitchere barrage.

Figure 1 Coorong location plan
Source: DEW, Healthy Coorong, Healthy Basin Action Plan, 2019

1.2 THIS REPORT

This report presents the concept design process undertaken and the infrastructure options considered to meet the objectives of the CIIP Engineering Services engagement, described below. This report should be read in conjunction with the supplementary documents referenced in this report and those included in the appendices.

Infrastructure design options to achieve the overall program objectives were guided by the following CIIP Engineering Services objectives:

- Achieve the target flow rates and associated scheduling, as informed by the hydrodynamic and biogeochemical analysis and scenario testing (further discussed and summarised in Section 2.1 and Table 2).
- Consideration of constructability (including operations, maintenance, safety) throughout the infrastructure design process.
- Consideration of input from cultural heritage representatives, local stakeholders, landholders and Traditional Owners collaboratively as part of the project design decision making process.
- The design is sufficiently documented to develop a concept level (-20%/+30%) cost estimate, which includes capital, operating and net present value costs for the provided project design life.

DEW is committed to scheduling community forums for sharing information, project updates and receiving feedback, and such forums have taken place during the concept design phase. This report will assist in communicating a project design update to relevant stakeholder and reference groups. It will also be referenced as part of the multi-criteria analysis, which informs selection of more highly preferred infrastructure options for long-term management of the Coorong South Lagoon.

1.3 PREVIOUS PROJECT WORK

The Coorong South Lagoon has been monitored and studied for many years. A significant body of work exists that presents assessments on the state of the Coorong and initiatives for short-term or long-term actions to improve the ecological health of the Coorong South Lagoon. A list of these reports is provided in Section 1.3.1. The relevant sections and findings of these documents have been used as inputs to the current concept design process and built upon where necessary to ensure consistency with current or relevant studies and reporting.

Also, a range of studies and modelling occurred in parallel with concept design activities including, hydrodynamic, ecological, biogeochemical and habitat suitability assessments. The findings of these studies progressively informed concept design selection and development.

1.3.1 Previous reporting

A number of previous reports have been referenced in preparation of the concept design documentation. These previous reports include:

- Preliminary Hydrodynamic Modelling Report, Coorong Temporary Saline Water Discharge (Aurecon August 2009).
- Data Collection, Review and Preliminary Ecological Assessment, Coorong Temporary Saline Water Discharge (Aurecon December 2009).
- Managing Salinity in the Coorong - pumping hypersaline water out of the Southern Lagoon (DEH February 2010).
- Lake Albert and Narrung Narrows Field Investigation Report (SKM 2013).
- Engineering Feasibility of Potential Management Actions, Lake Albert and Narrung Narrows (SKM February 2014).

- Lake Albert Scoping Study Options Paper (DEW 2014).
- South East Flows Restoration Project Augmentation: Preliminary Design Report (Tonkin June 2017).
- Coorong Infrastructure Investigations Technical Review (Tonkin April 2020).
- Coorong Infrastructure Investigations Project Options analysis and shortlisting fact sheet (DEW 2020).
- Healthy Coorong, Healthy Basin Engineering Case Study Review (Jacobs 2021).
- Healthy Coorong, Healthy Basin Coorong Bathymetric Survey (Maritime Constructions April 2021).

This list of previous reports referenced in completion of concept design activities is not exhaustive. Numerous other historical documents and references have been considered (e.g. historical Lake Albert and Coorong lagoon water levels).

1.3.2 Modelling

A series of modelling activities have been completed through the concept design process. The modelling activities that have influenced the concept design development process include:

- a hydrodynamic modelling study (DEW, reference: DEW Technical Report v2.1, December 2020)
- a hydrodynamic, biogeochemical and habitat modelling study (BMT, reference: R.10780.0001.00, May 2021)
- an assessment of climate change impacts on SEFRP yields to Coorong South Lagoon (Julian Whiting, 29 June 2021)
- Phase 2 hydrodynamic modelling scenarios – including long-term (DEW)
- Phase 2 hydrodynamic, biogeochemical and habitat modelling scenarios – including long-term (BMT and University of Western Australia).

Table 1 presents key findings and outcomes from these modelling investigations relevant to concept design.

Table 1 Key findings and outcomes from studies adopted for concept design

Date	Activity	Key findings/outcomes
July 2021	Assessment of climate change impacts on SEFRP yields to Coorong South Lagoon (Julian Whiting, 29 June 2021)	Discontinuation of the South East Flows augmentation concept design option, as it did not provide sufficient reliable yield to achieve the Coorong South Lagoon ecological objectives.
August 2021	Hydrodynamic, biogeochemical and habitat modelling study (completed by BMT, reference R.10780.0001.00, May 2021)	Discontinuation of the Pelican Point dredge alignment, as it did not provide significant benefit to the modelled hydrodynamic results.
August 2021; September 2021	Stage 2 hydrodynamic modelling scenarios	Revision of flow rates within concept design infrastructure options to target equivalent ecological benefits between all options, encouraging like-for-like comparison.
September 2021	Stage 2 hydrodynamic modelling scenarios	Adoption of 10 DN2000 pipes for the passive piped connection between the Southern Ocean and Coorong South Lagoon to achieve target ecological benefits.

Date	Activity	Key findings/outcomes
October 2021	Stage 2 hydrodynamic modelling scenarios	Adoption of operating days for infrastructure informing electrical design and operating cost estimates to achieve target ecological benefits.
November 2021	Stage 2 hydrodynamic modelling scenarios	Confirmation that the circulation concept designs developed (Options 5A and 5B) can allow pump in at the southern location and pump out north of Parnka Point with water level triggers and without dredging of the southern dredge alignment.

2 CIIP infrastructure options summary

2.1 FINAL SELECTED CONCEPT INFRASTRUCTURE OPTIONS

As part of the CIIP Engineering Services engagement, KBR completed an options assessment and concept design for a range of potential infrastructure options. These options are aimed at managing inflows and outflows from the Coorong South Lagoon to improve its ecological health. The designs have been used as inputs to the feasibility assessment reporting and presentation of potential long-term infrastructure and management solutions for the Coorong South Lagoon. The shortlisted options, their associated infrastructure, flow rate and operating conditions are detailed in Table 2.

The concept design drawings produced for each infrastructure option are included within Appendix A. A complete drawing list is provided in Section 12. Further option details are presented in the Options Summary Report (KBR reference: AEG155-TD-WR-REP-0005).

The location and alignment of the infrastructure options is shown in Figure 2. The selection process for the infrastructure alignments considered engineering benefits and constraints (including construction, operation and maintenance), cultural heritage survey findings, and ecological and environmental factors, as outlined in Table 3.

Note that all Southern Ocean infrastructure will be situated within South Australian waters and will not encroach into federal government waters, which is approximately three nautical miles (5.56 km) offshore. Additionally, the infrastructure will not encroach within the Upper South East Marine Park or Sanctuary Zone, which commences adjacent to Salt Creek and runs in a south-easterly direction along the coast.

The alignments described in Table 3 and shown Figure 2 summarise those adopted for the design and as documented within the concept design drawing set (refer to Appendix A).

Table 2 Definition of shortlisted infrastructure options

Option	Description	Maximum daily target flow yield	Operating criteria[2]	Typical flow days per year[1,2]
1A	**Passive open channel connection between Lake Albert and Coorong North Lagoon:** • 1,000 ML/d passive connection between Lake Albert and Coorong North Lagoon via an open channel with regulator structure and fishway.	1,000 ML/d	When flow through barrages is greater than 2,000 ML/d (May to February) or the first 1,000 ML/d scheduled to be released through barrages (March and April).	Between 143 days (with climate change) and 241 days (current).
1B	**Passive piped connection between Lake Albert and Coorong North Lagoon:** • 1,000 ML/d passive connection between Lake Albert and Coorong North Lagoon via seven closed conduits (pipes) with regulator structure.	1,000 ML/d	When flow through barrages is greater than 2,000 ML/d (May to February) or the first 1,000 ML/d scheduled to be released through barrages (March and April).	Between 143 days (current) and 241 days (with climate change).
2	**Dredge Parnka Point:** • 17.5 km long to a target depth of between –1.2 mAHD and –1.4 mAHD centred around Parnka Point to varying widths.	n/a (complementary action)	Permanent operation (24 hours per day, 365 days per year).	Every day (24 hours per day, 365 days per year).
3A	**Intermittent pumped connection out of Coorong South Lagoon – near shore discharge structure:** • 1,000 ML/d pumped connection out of Coorong South Lagoon via pumps on a pontoon structure adjacent to Younghusband Peninsula to a 150 m long jetty discharge structure (within the Southern Ocean).	1,000 ML/d	When water level in Coorong South Lagoon is greater than 0.3 mAHD.	Between 137 days (current) and 189 days (with climate change) at 1000 ML/d.
3B	**Intermittent pumped connection out of Coorong South Lagoon – low visual impact beach discharge structure:** • 1,000 ML/d pumped connection out of Coorong South Lagoon via pumps on a pontoon structure adjacent to Younghusband Peninsula to a beach discharge structure.	1,000 ML/d	When water level in Coorong South Lagoon is greater than 0.3 mAHD.	Between 137 days (current) and 189 days (with climate change) at 1000 ML/d.
3C	**Pumped connection out of Coorong South Lagoon – near shore discharge structure:** • 250 ML/d pumped connection out of Coorong South Lagoon via pumps on a pontoon structure adjacent to Younghusband Peninsula to a 150 m long jetty discharge structure (within the Southern Ocean).	250 ML/d	Permanent operation (24 hours per day, 365 days per year).	Every day at 250 ML/d (24 hours per day, 365 days per year).

Option	Description	Maximum daily target flow yield	Operating criteria[2]	Typical flow days per year[1,2]
3D	**Pumped connection out of Coorong South Lagoon – low visual impact beach discharge structure:** • 250 ML/d pumped connection out of Coorong South Lagoon via pumps on a pontoon structure adjacent to Younghusband Peninsula to a beach discharge structure.	250 ML/d	Permanent operation (24 hours per day, 365 days per year).	Every day at 250 ML/d (24 hours per day, 365 days per year).
4A	**Bi-directional pumped Southern Ocean connection – one location, separate pumping stations, pump in location with caisson structure[3]:** • 350 ML/d bi-directional pumped connection into and out of Coorong South Lagoon via jetty-mounted pumps on a 350 m long jetty in the Southern Ocean with caisson structure and pumps on a pontoon structure in Coorong South Lagoon. • Pumping can only occur in one direction at any one time.	350 ML/d (max out) 350 ML/d (max in)	Pump out 1 May to 30 September then fluctuating between pump in and pump out for the period 1 October to 30 April based on 25 days pump in followed by 23 days pump out.	Every day at 350 ML/d (24 hours per day, 365 days per year) with pump stations alternating.
4B	**Bi-directional pumped Southern Ocean connection – one location, one common pumping station, near shore discharge/intake protected by breakwater:** • 350 ML/d bi-directional pumped connection into and out of Coorong South Lagoon via a common dry-well pumping station positioned within Younghusband Peninsula, with reversible flow pipes and a single set of pumps. • Pumping can only occur in one direction at any one time. • Near shore protected discharge/intake provided in Southern Ocean.	350 ML/d (max out) 350 ML/d (max in)	Pump out 1 May to 30 September then fluctuating between pump in and pump out for the period 1 October to 30 April based on 25 days pump in followed by 23 days pump out.	Every day at 350 ML/d (24 hours per day, 365 days per year) with pumping directions alternating.

Option	Description	Maximum daily target flow yield	Operating criteria[2]	Typical flow days per year[1,2]
5A	**Simultaneous pumped Southern Ocean connection – two locations, separate pumping stations, pump in location with caisson structure[3] on a 350 m long jetty and pump out location to a 150 m discharge jetty with southern dredge alignment:** • 350 ML/d simultaneous pumped connection into and out of Coorong South Lagoon via: – Jetty-mounted pumps on a 350 m long jetty with caisson structure, in the Southern Ocean (pumping in at Woods Well, opposite Fat Cattle Point). – Pumps on a pontoon structure, pumping out to a 150 m discharge jetty (pumping out north of Parnka Point). • Infrastructure positioned at two separate locations allows circulation of flows within Coorong South Lagoon. • Pumping can occur concurrently through each pumping station.	350 ML/d (max out) 350 ML/d (max in)	Intermittent operation for pump in (pump in when Coorong South Lagoon <0.3 mAHD) and permanent operation for pump out (24 hours per day, 365 days per year).	Between 222 days (current) and 166 days (with climate change) at 350 ML/d pump in. Every day at 350 ML/d pump out (24 hours per day, 365 days per year).
5B	**Simultaneous pumped Southern Ocean connection – two locations, separate pumping stations, pump in location with caisson structure[3] on a 350 m long jetty and pump out location to a low visual impact beach discharge structure with southern dredge alignment:** • 350 ML/d simultaneous pumped connection into and out of Coorong South Lagoon via: – Jetty-mounted pumps on a 350 m long jetty with caisson structure, in the Southern Ocean (pumping in at Woods Well, opposite Fat Cattle Point). – Pumps on a pontoon structure, pumping out to a nearshore discharge structure (pumping out north of Parnka Point). • Infrastructure positioned at two separate locations allows circulation of flows within Coorong South Lagoon. – Pumping can occur concurrently through each pumping station	350 ML/d (max out) 350 ML/d (max in)	Intermittent operation for pump in (dependent on Coorong water levels) and permanent operation for pump out (24 hours per day, 365 days per year).	Between 222 days (current) and 166 days (with climate change) at 350 ML/d pump in. Every day at 350 ML/d pump out (24 hours per day, 365 days per year).

Option	Description	Maximum daily target flow yield	Operating criteria[2]	Typical flow days per year[1,2]
6	**Bi-directional piped connection into and out of Coorong South Lagoon, near shore discharge/intake protected by breakwater:** • Bi-directional passive piped connection with flow driven by differing water levels (varying flow rates) between Coorong South Lagoon and the Southern Ocean to a near shore ocean location. • Near shore protected discharge/intake provided in Southern Ocean.	1,620 ML/d into Coorong South Lagoon and 720 ML/d out of Coorong South Lagoon (maximums achieved for 10 DN2000 pipes under 'current' conditions. 3,760 ML/d into Coorong South Lagoon and 880 ML/d out of Coorong South Lagoon (maximums achieved for 10 DN2000 pipes under 'with climate change' conditions).	Permanent operation (24 hours per day, 365 days per year).	Every day (24 hours per day, 365 days per year).

[1] *Refer section 9.2 for further details on operating days and current versus climate change conditions.*

[2] *Operating criteria and typical flow days per year has been drawn from hydrodynamic modelling.*

[3] *A caisson structure is a hollow concrete box structure that is typically floated into position or installed in water using cranage, self-weight, concrete or water ballast, or hydraulic jacks (with or without guide piles).*

Table 3 Selected concept design alignments for each option

Infrastructure option	Applies to option	Concept site location adopted	Justification
Lake Albert connector	Option 1B	Land parcel between Bascombe Bay and Coorong North Lagoon via Seven Mile Road	• Opportunity to use existing road alignment and work with current landowners for a piped solution. • Avoids cultural heritage burial ground. • Makes use of existing alignment.
	Option 1A	Land parcel between Bascombe Bay and Coorong North Lagoon (further north-west of Seven Mile Road)	• Preferred location for open channel solution. • Avoids cultural heritage burial ground.
Dredging between Coorong South Lagoon and Coorong North Lagoon	Option 2	Parnka Narrows	• Dredge dimensions through the Narrows further refined during concept design development to optimise the extent of dredge and ecological benefit.
Coorong South Lagoon to Southern Ocean connector	Option 5A and 5B	North of Parnka Point (approx. 950 m)	• Narrow Coorong South Lagoon crossing between mainland and Younghusband Peninsula. • Existing 4WD vehicle access track nearby. • Site avoids culturally significant locations further south, is adjacent to a known midden.
	Option 3A, 3B, 3C, 3D, 4A, 4B, 5A, 5B and 6	South of Woods Well, opposite Fat Cattle Point on Younghusband Peninsula	• Mains power available (upgrades required), and the closest of all options to reticulated grid power. • Shorter stretch of water from mainland to dunes, compared with other sites. • Younghusband Peninsula is narrow at this location, reducing the required pipe installation through the dunes. • Site avoids known midden and freshwater soak and midden adjacent to the south.

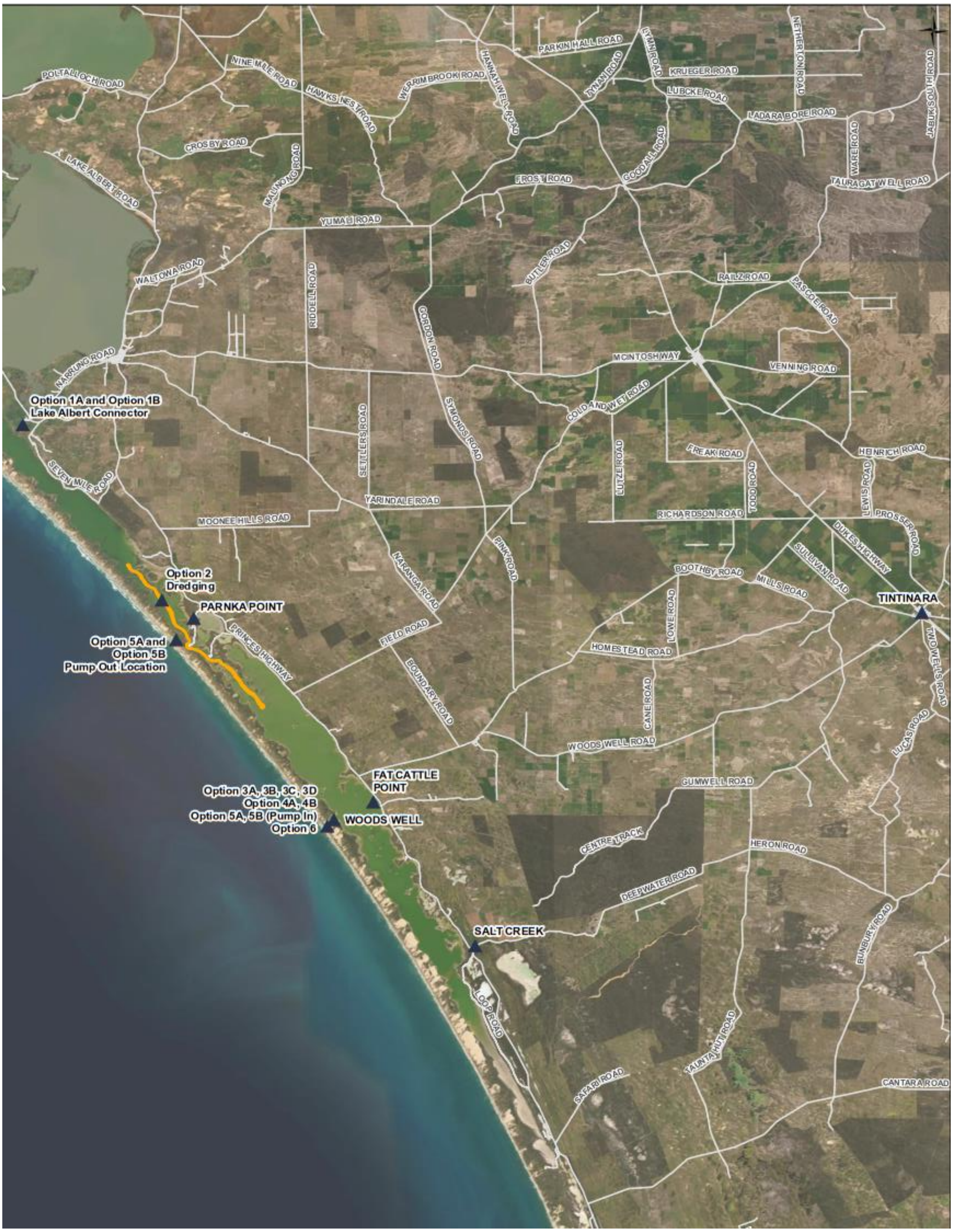


Figure 2 Concept design option locations

2.2 FURTHER ASSESSMENT – COMBINATION OF CONCEPT DESIGNS

To support decision-making and further assessment as part of the CIIP, a multi-criteria analysis (MCA) was undertaken to allow ranking of the full list of infrastructure options. It is important to note that the infrastructure options considered as part of the MCA differ slightly from those presented in Table 2. This has resulted from forming combinations of the above base concept designs (12 separate options) into 15 distinct options, allowing comparison of options that achieve consistent ecological outcomes for the Coorong South Lagoon.

Key considerations in determining these combinations to be assessed through the MCA process include:

- Dredging (Option 2) as a standalone option does not achieve intended ecological outcomes and is therefore discounted from consideration as a standalone infrastructure option
- Dredging (Option 2) in combination with the Lake Albert connector (Option 1A and Option 1B), to enhance connectivity with Coorong South Lagoon maximising the benefit of the Lake Albert connector
- Dredging (Option 2) in combination with a pump out option (Option 3C or Option 3D), allowing the water that is pumped out of Coorong South Lagoon to be replaced with water from the Coorong North Lagoon through improved connectivity mitigating water level impacts to Coorong South Lagoon
- Simultaneous pumped options (Option 5A and Option 5B) are to be considered both with and without the need for dredging of the southern portion of the dredge alignment from Parnka Point. Where dredging is not included, water level controls are added to the ‘pump out’ pumping station to guide operations.

Further details of the options and the MCA process are detailed in the Approach to Multi-criteria Analysis document (KBR reference: AEG155-01-TD-REP-0004) and the Multi-criteria Analysis Outcomes Report (KBR reference: AEG155-01-TD-REP-0006).

3 Concept design process

3.1 DEVELOPMENT OF INFRASTRUCTURE OPTIONS FOR CONCEPT DESIGN

The original scope of works defined within DEW's brief for the project considered infrastructure works to achieve the following five water source connections to the Coorong South Lagoon:

- Lake Albert to Coorong connector.
- Coorong lagoon dredging.
- South East Flows augmentation.
- Connection to the Southern Ocean.
- Additional automated gates at Tauwitchere Barrage.

To achieve these water source connections, KBR developed a list of infrastructure options with six options being endorsed at the concept design selection workshop held on 9 June 2021. These six options were:

- Option 1: Passive connection between Lake Albert and Coorong North Lagoon.
- Option 2: Dredging between Coorong South Lagoon and Coorong North Lagoon.
- Option 3: Pump out of Coorong South Lagoon.
- Option 4: Bi-direction pumped connection into and out of Coorong South Lagoon.
- Option 5: Circulation of Coorong South Lagoon flows via pump in at one location and pump out at another location.
- Option 6: Passive piped connection between Coorong South Lagoon and Southern Ocean.

Changes were made to the scope for the infrastructure options during the development of the concept designs. The changes were based on revised modelling feedback, stakeholder recommendations and technical considerations. Table 4 presents a summary of the key scope changes.

Table 4 Summary of infrastructure option scope changes

Infrastructure option	Scope change	Date of direction
Additional automated gates at Tauwitchere Barrage	Scope to consider this option was excluded from KBR's option selection and concept design development process.	16 April 2021
South East Flows Augmentation	Removal of the South East Flows Augmentation concept following further hydrological assessment, which indicated insufficient reliable yield to achieve the Coorong South Lagoon ecological objectives.	30 June 2021
Dredging between South Lagoon and North Lagoon (Option 2)	Removal of the Pelican Point (near Tauwitchere Barrage) from further consideration within the design for improved connectivity between the Coorong South and North Lagoons.	3 August 2021
All	During the concept design refinement workshop, agreement was reached on revisions to the design flows to be adopted for the infrastructure option concept designs.	11 August 2021

Infrastructure option	Scope change	Date of direction
Lake Albert connector (Option 1), bi-directional pumped connection into and out of Coorong South Lagoon (Option 4) and passive piped connection (Option 6)	Expansion of the previously selected six options to nine options, allowing consideration of two Lake Albert connector alignments (open channel and piped), two bi-directional pumped in and pumped out options (pump station at each end or a common central pump station) and two passive pipe options (one to near shore and the second to closure depth, approximately 4 to 5 km offshore[1]).	11 August 2021
Coorong South Lagoon pump out (Option 3) and Coorong South Lagoon flow circulation (Option 5)	Inclusion of a new concept with a low visual impact beach discharge for the Coorong South Lagoon pump out option, allowing for beach or tidal zone discharge without a jetty structure.	7 September 2021
Bi-directional pumped connection into and out of Coorong South Lagoon (Option 4)	Revision to target flow rates for the bi-directional pumped connection options to 350 ML/d, rather than the previously agreed 500 ML/d, following additional hydrodynamic modelling and assessment.	27 September 2021
Passive piped connection (Option 6)	Removal of passive piped connection to closure depth[1] (approximately 4 to 5 km offshore), considering practicality and constructability of concept.	27 September 2021
Coorong South Lagoon pump out (Option 3)	Inclusion of two additional options, considering reduced discharge flow rate of 250 ML/d rather than the previously agreed 1,000 ML/d.	27 September 2021

[1] The closure depth represents the depth of water at which there is minimal sand in suspension due to wave action and is directly proportional to the offshore significant wave height.

3.2 ALIGNMENT SELECTION CONSIDERATIONS

3.2.1 Early infrastructure alignment considerations

Prior to completing investigative field works, observations taken from initial site visits and stakeholder consultations provided background information to assist in understanding the advantages and disadvantages of the options being considered. Table 5 summarises key observations with respect to engineering design complexities, construction feasibility, environmental impacts and any cultural heritage considerations known at the time. The findings then provided the focus areas for subsequent cultural heritage surveys when developing the preferred site locations in the early phases of the project:

- For Lake Albert connector infrastructure locations, previous studies were considered (refer Section 1.3). Opportunities were sought for alternative alignments within the same corridor between Bascombe Bay and Coorong North Lagoon.
- With Pelican Point dredging removed from at the initial stages of design as per Table 1, the dredging alignment and depth through the Parnka Narrows were further refined to optimise dredging effort whilst not compromising on ecological benefits.
- Potential areas for the Coorong South Lagoon to Southern Ocean connector at the commencement of the project were identified as Round Island, Woods Well, Policeman Point and Salt Creek. At an early site visit, Jack Point (between Policeman Point and Woods Well Road) was also inspected for feasibility. Though all sites varied slightly in terms of Coorong lagoon width and Younghusband Peninsula dune height, the magnitude of these features were substantial in all locations.

Table 5 Key observations with respect to engineering design complexities

Infrastructure option	Site location	Benefits (engineering, construction, environment)	Constraints (engineering, construction, environment)
Lake Albert to Coorong North Lagoon connector	Land parcel between Bascombe Bay and Coorong North Lagoon via Seven Mile Road	Opportunity to use existing road alignment (Seven Mile Road), work with current landholders, and minimise scar on the land.	Known area of cultural significance (Traditional Owners' burial ground) adjacent. Undulating landscape. Visual amenity impacts.
	Land parcel between Bascombe Bay and Coorong North Lagoon (further north-west of Seven Mile Road)	Three-phase power[1] appears available based on overhead powerlines nearby (if needed for a pumped solution). Land is flatter than for the Seven Mile Road option. More visually appealing than Option 1A once completed.	Wider stretch of land to traverse between the bay and the Coorong North Lagoon. Stobie poles[2] along Seven Mile Road (construction challenge) must be avoided/reinstated.
Dredging	Parnka Point (the Narrows)	Improves connectivity between North and South Lagoon (providing ecological benefits).	Large quantum of dredge spoil (millions of cubic metres). Potential disposal options: • Landside: land acquisition and ASS/PASS management. • Landside: existing salt pans on the eastern side of Princes Highway. • Southern Ocean: high wave energy environment, but good mixing potential. • Southern Ocean: temporary beach access shutdown at discrete locations for spoil removal (or potentially the entire 17.5 km dredge length, if required) Cultural heritage considerations, noting a substantial change in the nature of the Coorong lagoon system.
Southern Ocean and Coorong South Lagoon connector	Parnka Point	Younghusband Peninsula dunes are narrow. Narrow Coorong South Lagoon width. Existing 4WD vehicle access track. Favourable water depth at this location. Most feasible to have infrastructure on Younghusband Peninsula side (power cabling to cross the Coorong).	Known area of cultural significance, extending north and south of Parnka Point sand dunes (further cultural heritage surveys required). Sand dunes contain freshwater soaks that must be maintained/protected for wildlife. Camp site inland of Parnka Point – infrastructure may have negative aesthetic impacts. Power requirements and distance from mains power (for pumped solution).

Infrastructure option	Site location	Benefits (engineering, construction, environment)	Constraints (engineering, construction, environment)
	Round Island	Not closely inspected due to access restrictions (low water level).	Not closely inspected due to access restrictions (low water level); however, in general: • Water in the lagoon is shallow. • Coorong South Lagoon width is large at this location. • Islands are present in the Coorong South Lagoon along the alignment. • Power requirements and distance from mains power (for pumped solution) will be challenging.
	Woods Well Road, opposite Fat Cattle Point	Mains power available (upgrades required), and the closest from the mainland to Younghusband Peninsula of all options. Initial indications from First Nation Elders suggest the dunes contain less historical artefacts than around Parnka Point, due to separation from the mainland (generally confirmed via cultural heritage surveys, with a southern alignment proposed). Most feasible to have infrastructure on Younghusband Peninsula side (power cabling to cross the Coorong).	Coorong South Lagoon width is significant. High Younghusband Peninsula dunes. Culturally significant fish traps that are present nearby on the mainland would need to be maintained/protected. Power requirements and distance from mains power (for the pumped solution).
	Jack Point	Indications from First Nation Elders suggest the dunes contain less historical artefacts than around Parnka Point, due to separation from the mainland. Shorter stretch of water from the mainland to dunes, compared with other sites. Most feasible to have infrastructure on Younghusband Peninsula side (power cabling to cross the Coorong)	North Pelican Island is nearby (known pelican breeding ground). High dunes. Culturally significant fish traps that are present nearby on the mainland would need to be maintained/protected. Power requirements and distance from mains power (for the pumped solution).
	Policeman Point	Provides an ideal location for a barge to transport materials across the Coorong South Lagoon. Short width of Coorong South Lagoon. Low dune height on adjacent Younghusband Peninsula.	Culturally significant fish traps that are present nearby on the mainland would need to be maintained/protected. Younghusband Peninsula width is significant. Mellor Island will provide an obstacle when transporting materials across the lagoon. Power requirements and distance from mains power (for the pumped solution).

Infrastructure option	Site location	Benefits (engineering, construction, environment)	Constraints (engineering, construction, environment)
	42 Mile Crossing	Existing access track across Coorong.	Water within Coorong is shallow (less than 300 mm deep). Significant distance from 42 Mile Crossing to the most-suitable alignments further north (approx. 30 km) Potential for waves within the Southern Ocean to meet the dunes, enveloping the beach and any potential access opportunities (at particular times of the year). First Nations Elders were advised of numerous middens, freshwater soaks and fish traps in this area. Within the Upper South East Marine Park area (Southern Ocean side).
	Salt Creek (and further south)	Deep water within the Coorong South Lagoon is ideal for pumping out and conveyance of materials and equipment across Coorong South Lagoon, if required. Narrowness of Coorong South Lagoon. Easiest location to access for 4WD vehicles.	Adjacent to the South East Flows outfalls – risk of flushing out freshwater inflows to the ocean. Younghusband Peninsula width is significant. Number of small islands to avoid during transportation across the Coorong South Lagoon. Within the Upper South East Marine Park Sanctuary Zone (Southern Ocean side) More exposed to public activities, as it is in a higher trafficked part of the Coorong National Park. Power availability is likely to be challenging and it is a greater distance from any existing grid reticulated supply.

[1] Three-phase power is a three phase alternating current power supply system comprising three wires (and a fourth neutral wire) with voltage and currents being 120 degrees out of phase on the three wires producing a stable supply voltage of 415 V.

[2] Stobie poles are overhead power transmission poles between which cable are strung.

3.2.2 Cultural heritage survey findings

During concept design development, cultural heritage surveys were completed to complement the engineering investigation activities as part of determining the preferred infrastructure locations. Table 6 summarises the results of the investigations.

Table 6 Cultural heritage survey findings

Infrastructure Option	Site location	Findings
Lake Albert and Coorong North Lagoon connector	Land parcel between Bascombe Bay and Coorong North Lagoon via Seven Mile Road	• Evenly ranked with Seven Mile Road alternative alignment. • Known burial site situated between alignments (outside alignment footprint).
	Land parcel between Bascombe Bay and Coorong North Lagoon (further north-west of Seven Mile Road)	• Evenly ranked with alternative alignment. • Known burial site situated between alignments (outside alignment footprint).
Dredging	Parnka Point (the Narrows)	• Not surveyed.
Southern Ocean and Coorong South Lagoon connector	Parnka Point (2.5 km north), Younghusband Peninsula	• Avoids all known burial sites. • Midden within site boundary. • Preferred alignment location.
	Parnka Point (1.0 km north), Younghusband Peninsula	• Preferred alignment location. • Midden within site boundary. • Freshwater soak adjacent (outside alignment footprint).
	Round Island	• Removed as potential site location – preferred to site infrastructure within Younghusband Peninsula. • Not surveyed.
	Woods Well Road, opposite Fat Cattle Point	• Midden and freshwater soak within survey boundary (to the south), large freshwater soak to the south of survey boundary. • Preferred alignment of the southern option (though should position infrastructure to the north of the survey area in this location to avoid midden and freshwater soak).
	Jack Point	• Removed as potential site location – preferred to site infrastructure within Younghusband Peninsula. • Not surveyed. • Withdrawn as potential site location.
	Policeman Point	• Known burial site, presence of middens and freshwater soak within survey boundary. • Withdrawn as potential infrastructure site location.

Infrastructure Option	Site location	Findings
	42 Mile Crossing	• Large midden through majority of survey area. • Not preferred.
	Salt Creek	• Removed as potential site location – potential interference with freshwater inflows from Salt Creek outfall, constructed as part of South East Flows Restoration Project. • Not surveyed.

Note the survey investigations considered only the final infrastructure locations and a proportional footprint area surrounding them. An additional cultural heritage survey will be required for construction-associated works including any access tracks, laydown areas, temporary works and more, when these elements are further defined.

3.3 CONSULTATION AND INVESTIGATIONS THROUGH CONCEPT DESIGN DEVELOPMENT

3.3.1 Design basis

A basis of concept design was prepared for the CIIP Engineering Services engagement and is provided in Appendix B (KBR reference: AEG155-01-TD-DBA-0001). This basis of concept design defines design inputs, criteria, assumptions and functional requirements used as the basis for the concept design activities detailed in this report. Of critical importance is the adopted flow metrics, which are also summarised in Table 2. These flows are the key drivers for the magnitude of infrastructure required, which bring with them reflective constructability challenges and associated costs (capital and operating).

3.3.2 Community consultations and site visits

On 2 June 2021 and 3 June 2021, KBR attended the sites under consideration with DEW personnel and First Nations representatives from Ngarrindjeri and First Nations of the South East. The site visit involved traversing sections of Younghusband Peninsula and the proposed Coorong dredging alignment either by foot, or using a vehicle or boat. This two-day site visit also provided an excellent opportunity to discuss elements of importance with First Nations representatives, Coorong National Park Rangers and community members with a strong interest and knowledge of the Coorong system.

On 14 July 2021 and 15 July 2021, KBR participated in four community consultation workshops. A project update was presented at the workshops, including a summary of the scientific and modelling investigations recently completed or currently underway. There was also a presentation from KBR on the likely infrastructure options under consideration throughout concept design and the performance criteria for the proposed multi-criteria analysis process to assist in decision-making on the broader CIIP.

Table 7 outlines some of the key findings or observations from the consultation workshops and the site visits that have been completed.

Table 7 Summary of findings and outcomes from community consultation and site visits

Date	Activity	Key findings/outcomes
2 June 2021	Coorong dredge alignment	The proposed dredge alignment is very narrow in some locations, and zones of rock are present. The proposed dredge alignment is very shallow in some locations, with passage proving challenging even with small draft vessels. Sites of First Nations heritage and significance are present in a range of locations surrounding the sites under consideration for the nominated infrastructure options (e.g. midden sites, burial sites, etc.).
3 June 2021	Southern Ocean to Coorong alignments	The Coorong South Lagoon is extremely wide (>4 km) and shallow in some locations, making pump station options on the highway side of the Coorong challenging in terms of installing conveyance pipework – not only across Younghusband Peninsula but also the width of the Coorong South Lagoon. An appreciation was gained of the steep grade of the beach, the frequently rough seas and changeable access conditions for vehicles along the beach. Site access to Younghusband Peninsula construction or operating sites will be challenging, with four-wheel drive access along unmade tracks possible but not preferable. This requires the likely construction of a barge or boat launch, mooring and retrieval facilities, likely on both sides of the Coorong South Lagoon, to facilitate acceptable construction and ongoing operational and maintenance access. The presence of sites of First Nations heritage and significance in a range of locations adjacent the sites under consideration for the nominated infrastructure options (e.g. fish traps).
3 June 2021	Lake Albert connector alignments	Low undulating hills are present in the vicinity of the two proposed Lake Albert connector alignments. Sites of First Nations heritage and significance are present in a range of locations surrounding the sites under consideration for the nominated infrastructure options (e.g. burial sites). Seven Mile Road was suggested as a possible alignment for Lake Albert connector infrastructure to avoid the requirement for passage across agricultural land (requiring easements) and in proximity to sites of First Nations significance. A high voltage overhead power supply is available along Narrung Road.
3 June 2021	Pelican Point dredge alignment	There is generally good access to this site for construction purposes.

Date	Activity	Key findings/outcomes
14 July 2021 and 15 July 2021	Community consultation workshops in Goolwa, Meningie, Robe and Salt Creek	Support was obtained for discontinuation of the South East Flows Augmentation infrastructure option that had previously reached the short-listing stage. A level of interest in beneficial reuse of dredge spoil was raised by representatives from Coorong District Council. This option could also provide an opportunity for onshore disposal of a portion of the dredge spoil; however, with consideration of how the dredge spoil will be mobilised (i.e. cutter suction dredge), this will require a substantial dewatering process and further environmental and in-situ testing. The community generally agreed with the multi-criteria analysis performance criteria that were presented to them. This included proposing that ecological and environmental criteria have the highest weighting for the option assessment process. Workshop attendees encouraged dedicated consultation with First Nations representatives and landholders on infrastructure options affecting their interests. Workshop attendees provided positive feedback on the potential to create tourism and educational experiences associated with the proposed infrastructure. Impacts to the existing commercial fisheries are particularly important for affected members of the community. The presence of shallow reefs along the proposed dredging alignment should be considered in assessments going forward. Renewable energy should be considered where possible for all infrastructure options requiring a power supply.

3.3.3 Workshops

During the concept design process, two key workshops were held at KBR offices. They provided an opportunity for KBR team members to present an update on concept design progress and to seek the input and guidance of workshop participants in confirming the scope and nature of the infrastructure options to be progressed through concept design.

A summary of the key findings from these two workshops are presented in Table 8.

Table 8 Summary of findings and outcomes from workshops

Date	Activity	Key findings/outcomes
9 June 2021	Concept design selection workshop	Refinement of the concept designs to be progressed to six concepts only. Removal of a passive transfer system driven by the Southern Ocean wave energy to convey water into Coorong South Lagoon owing to constructability, operation and maintenance concerns. Recommendation to minimise installation of on-beach infrastructure as far as possible (e.g. a concrete discharge ramp structure) to reduce the aesthetic and access impacts of the designs.
11 August 2021	Concept design refinement workshop	Addition of three concept design options, increasing the total number of options to nine. Agreement of flow basis for the infrastructure options under consideration. Agreement that pump stations will not be located on the land adjacent the Princes Highway or within the eastern side of the Coorong South Lagoon, as it would be very difficult to install large bore pump discharge pipework across the Coorong, which would be several kilometres long.

3.3.4 Site investigations

KBR either commissioned or gained access to site investigations that would provide specific site information and concept design inputs. A summary of these site investigations along with key findings and outcomes is presented in Table 9.

Table 9 Summary of site investigations completed

Date	Activity	Key findings/outcomes
April 2021	Bathymetric survey of the Coorong lagoons in the vicinity of Parnka Point.	Shallow water has been identified through much of this alignment, with an indication of a centrally deeper channel. This channel has generally been adopted as the dredge alignment for concept design Option 2 with some refinement and optimisation.
May 2021	Access to Mapland topographical information (provided by DEW).	Topographical information and other data to inform the design, specifically locating infrastructure and cross-checking against other information received.
July 2021	Desktop geotechnical investigations for Lake Albert connector (engaged and coordinated by KBR).	Sandy soils identified through all previous investigations with some cementation of layers. Very little clay and shallow topsoil. A low probability of acid sulphate soil (ASS) or potential acid sulphate soil (PASS) from samples collected during previous geotechnical investigations along the terrestrial alignments. Groundwater encountered at around 0 mAHD with some variations up to +/- 1.5 m. There are some construction risks if sheeted calcrete is encountered, and trafficability and ASS/PASS risks when constructing adjacent to or in lacustrine environments.
July 2021	Desktop geotechnical investigations for Coorong dredging (engaged and coordinated by KBR).	Dredging or excavation activities are expected to encounter sands, clays and gravels, with the potential for high strength calcrete layers to be intercepted at all locations. The investigation of the presence and extent of these calcrete layers would be the key consideration of any intrusive or geophysical geotechnical investigation. A high probability of encountering ASS/PASS sediments is expected. Some construction risks if sheeted calcrete is encountered, with potential treatment and disposal activities required where ASS/PASS sediments are encountered.
July 2021	Data elevation model (DEM) of the entire Coorong and south-east region (provided by DEW)	Applied as the topographical survey input for all options (excluding Option 2) prior to receipt of detailed site field investigations within Younghusband Peninsula. Obtained from this information: survey elevation contours and water depths.

Date	Activity	Key findings/outcomes
August 2021	Geotechnical field investigations for Seven Mile Road (Lake Albert connector) (engaged and coordinated by KBR).	Sandy to gravelly soils were encountered with varying fill/topsoil depths. Groundwater was encountered at close to standing water levels within the adjacent water bodies. Carbonate/calcareous soils are present and have the potential to act as collapsing soils when wet leading to extremely poor support for a footing or structure above. Shrink/swell potential is minimal, owing to the sandy and gravelly nature of soils with generally good bearing capacity and minimal settlement for properly founded footings. A hard calcrete layer was encountered at Borehole 1 (Coorong end) at 0.6 m below ground surface, but this could be penetrated by the drill rig after converting the drill to a solid auger (rather than push tube). Such calcrete layers will cause constructability challenges for graders, excavators and backhoes that may be used to construct a channel or pipeline. A permanent cut batter slope should be set to one vertical to three horizontal (1V:3H) or flatter.
August 2021	Geotechnical field investigations for Coorong dredging (engaged and coordinated by KBR).	Coorong water level at Parnka Point was around 0.7 mAHD on 11 August 2021 coinciding with field testing. One DCP test encountered refusal at 1.3 m below bed level (likely a calcrete layer) in 0.8 m water depth (below target dredge depth of –1.2 mAHD plus overdredge allowance). Generally all other sediments were soft, with 0 to 2 blows per 100 mm. A few locations had higher resistance.

Date	Activity	Key findings/outcomes
September 2021	Environmental and acid sulphate soil testing (engaged and coordinated by KBR).	29 soil samples collected from the four Seven Mile Road boreholes were tested. 17 samples collected from the DCP testing within the top 150 mm of sediment along the Coorong dredge alignment were tested (one from each DCP test site). Four samples from the Coorong dredge alignment returned one parameter above the 'waste fill' criteria for arsenic (land based disposal). This was in four grab samples from the DCP testing resulting in the classification of this sediment as 'intermediate waste fill'. Five samples from the Coorong dredge alignment returned one parameter (arsenic) above the National Assessment Guidelines for Dredging (NAGD, 2009) of 20 mg/kg. The determination of suitability for unconfined sea disposal is not made based on whether individual samples exceed the screening level but on the '95% upper confidence limit of the mean' calculated from all analysis results representative of the dredge volume. No samples returned testing results above human health criteria. It is common for sediments in parts of Australia to have naturally high arsenic concentrations as referenced in the NAGD. With samples only collected in the top 150 mm of the proposed dredged material, additional testing is required to fully assess the '95% upper confidence limit of the mean' over the full range of dredge depths once confirmed. Leachate testing was completed for the sample which recorded the highest arsenic concentration, and this did not detect any release of soluble arsenic. This indicates that the arsenic may not be very bioavailable when dispersed in sea water. Unconfined sea disposal of dredged material[1] is considered to likely be permissible but requires further testing over the full dredge extent and depth if this option is considered part of the preferred solutions. Three samples from the entire test suite returned a SPOCAS result (indicating the presence of ASS material). One of these was in BH04 at Seven Mile Road and the other two were from two separate DCP test locations. An ASS management plan will be required for proposed excavation and dredging activities, with disposal/spoil pathways outlined and potential treatment processes defined. With the potential classification of 'intermediate waste fill' for the dredged materials, additional consideration to approvals processes will be essential.

Date	Activity	Key findings/outcomes
October 2021; November 2021	Geophysical survey in the Southern Ocean for a proposed infrastructure alignment (4 km long x 1 km wide target survey extent) south of Woods Well, opposite Fat Cattle Point.	Marine geophysical surveys have been reported in the geophysical survey report included in Appendix H. Key observations include: • Marine bathymetry captured was generally flat and featureless with no evidence of surface geological expression (e.g. reefs). • No localised magnetic anomalies were identified that may be characteristic of shipwrecks or other large ferrous debris. • Camera drops allowed dense sand clouds moving through the water column to be observed indicating very mobile sands present at seabed level. • Dense benthic habitat (likely seagrass) was present on the seafloor from around 2.3 to 3.2 km offshore at elevations of between –9 and –10.5 mAHD. This indicates that the wave action in this zone is not strong enough to disrupt seagrass growth patterns. As such, it is possible that a seawater intake in this area may not entrain a large amount of sand. The benthic habitat reduces in density at greater depths as light to the ocean floor reduces. Within the near shore environment, no benthic habitat was observed as it is expected to be unable to survive due to the severe wave action. • The presence of seagrass indicates that the wave and current action does not allow deposition of fine sediments in this area, as it would typically smother (and negatively impact) the seagrass beds if allowed to settle out. This would tend to indicate that any fines discharged from the dredging campaign in the near shore environment would be unlikely to settle on the seagrass zone. This offers a level of confidence in the suitability of the proposed near shore disposal pathway for dredged material. • The interpreted seismic refraction shows zones of weaker lagoon sediment or potentially voids (caves) between the R2 and R3 projected reflectors at about –25 mAHD (near shore) to –35 mAHD (offshore). This zone may intersect some of the piles to be installed for jetty structures which could require the pile lengths in these areas to be extended with additional splicing to achieve target capacity. Potentially additional pile length could be allowed for within contingency; however, it is noted that the extent of geophysical survey does not cover the proposed jetty extent (to 300 m offshore). • The zone between the R1 and R2 reflectors at about –5 to –25 mAHD tends to indicate an upper zone of loosely cemented sand which is typically expected to be driveable for piles. Apart from any zones of weaker lagoon sediment or caves present, pile driving is expected to be achievable using a mixture of vibro and impact hammers. This zone should also be appropriate for founding the pump well caisson. • The R2 reflector at about –30 mAHD appears to be stronger calcarenite (cemented sand) combined with potential caves/voids and shouldn't prevent pile driving. • The R3 reflector at about –40 mAHD appears to be the upper surface of harder rock (possibly a basement rock). Piles are not expected to extend to this depth but if they did, they may well meet refusal on this rock.

Date	Activity	Key findings/outcomes
October 2021 and November 2021	Geophysical survey of two terrestrial alignments within Younghusband Peninsula for proposed infrastructure (approximately 800 m long transects) – one opposite Fat Cattle Point (south of Woods Well) and the second around 1 km north of Parnka Point.	Terrestrial geophysical surveys have been reported in the Geophysical Survey Report included in Appendix H. Key observations include: • The Younghusband Peninsula transects appear to indicate loose sand to around –20 mAHD then calcarenite. Some harder (potentially igneous rock) up to about –5 mAHD is present at the Coorong end but this shouldn't intersect proposed pipe depths or alter intended scope at the Coorong end. • Construction of the central pump dry well proposed for Option 4B would appear feasible. • Water table influence is interpreted to occur between 0 mAHD and –5 mAHD. • Bedrock was interpreted to occur at the southern (Woods Well, opposite Fat Cattle Point) transect at between –5 and –20 mAHD.
November 2021	Particle size distribution testing of lagoon sediments from dredge alignment.	Samples of sediments collected within the top 150 mm of lagoon sediments along the proposed dredge alignment was combined to achieve three composite samples for particle size distribution testing. The purpose of this testing was to better understand likely composition of sediments (fines fraction vs coarse fraction) to support future dredged material plume dispersion modelling. It is noted that this sampling was undertaken at only shallow depths and is not representative of the full dredge depth required. It will be necessary to complete deeper sampling in future design phases should dredging be required under the selected infrastructure options. A summary of the particle size distribution test results is presented in Appendix I. The sampled sediments comprise generally fine sands with some (typically less than 10%) fines (particle size < 0.06 mm). It is noted that this sampling is from the top 150 mm and should be considered indicative only. The dredged material plume dispersion modelling (refer section 8.6) has considered a 50/50 split between fines and sands and as such is a conservative approach given the uncertainty of the sediment grading at greater depth.

[1] Dredged material is a fluidised product of lagoon sediment, clays, silts and sands) combined with water to allow hydraulic conveyance of the dredged material from the dredge front to a nominated discharge or disposal location.

The findings presented in the Table 9 have been referenced in the preparation of concept design documentation for the nominated infrastructure options. Relevant reports from the site investigations engaged and coordinated by KBR are presented in the following appendices:

- Appendix C – Lake Albert connector desktop assessment report.
- Appendix D – Lake Albert connector, Seven Mile Road field investigation report.
- Appendix E – Coorong dredge alignment desktop assessment report.
- Appendix F – Coorong dredge alignment field investigation report.
- Appendix G – Environmental and acid sulphate soil testing report.
- Appendix H – Geophysical survey report (marine and terrestrial).
- Appendix I – Particle size distribution test results.

3.3.5 Subject matter expert engagements

Through the concept design, KBR has initiated or participated in a series of engagements with subject matter experts. These engagements have identified a range of considerations necessary to be incorporated within the concept design stage and beyond for the CIIP. Key findings or outcomes from these consultation engagements are presented in Table 10.

Table 10 Record of subject matter expert engagements

Date	Activity	Key findings/outcomes
6 July 2021	Meeting with SA Environment Protection Authority (EPA) to discuss relevant considerations for the CIIP ocean connector and Coorong dredging infrastructure options and associated approvals. EPA attendees included Jackie Agnew, Matt Nelson, David Vaughan, Paris Bates.	General: • To assist in the approval process for any works, EPA representatives advised that any proposal would need to achieve a net environmental benefit. Southern Ocean to Coorong connector: • Approval for an ocean connector would be required under the *Environment Protection Act 1993* (SA) schedule 1 part A, Clause 8(7) – Discharges to Marine or Inland Waters (note that it would not constitute desalination). To approve this, EPA would need modelling and a commitment to ongoing monitoring of environmental health. • A dilution ratio of 40:1 is appropriate for assessments. Modelling of plume dispersion would be required for the worst case scenario (i.e. benign conditions with no wind, etc.). • The infrastructure must pose no navigational hazard. • Any intake would need modelling that ensures that intake velocity issues and potential impacts could be mitigated. Coorong dredging: • Offshore disposal is likely preferred; however, it may be hard to achieve considering dredge methodology, potential spoil disposal location and required haul distance. • Near shore disposal may be problematic due to potential impacts on habitat from ASS and would require modelling. Even with a trace amount of acid, impacts can still be significant. • Disposal to land is likely to be problematic. Geotechnical investigations would confirm the extent of ASS, but it could be impossible to treat on this scale. • For offshore (deep water) disposal, it would need to be past any line of seagrass and would require a habitat assessment to identify where more 'barren' habitats are present.

Date	Activity	Key findings/outcomes
2 August 2021	Discussion with John Herbert, National Business Manager – Underground Technologies, Fulton Hogan.	Working Southern Ocean side (ocean passive and jetty options): • Vehicle access up and down the beach not ideal, but oceanside also challenging. Selected option should minimise beach movements, noting the travel distance, vehicle types, soft sand and varying beach width. • Absolute maximum directional drilling length 3 km. Working within Younghusband Peninsula: • Micro-tunnelling (pipe-jacking) with intermediate jacking an option (700 m per jacking station maximum). • Micro-tunnelling can be completed for pipes up to 3000 mm diameter. Generally recommend this option for larger pipe diameters rather than directional drill. • Vehicles across the Coorong could be either via barge (temporary structures will need to be constructed either side) or potentially a temporary floating or suspended bridge could be installed (likely near Parnka Point) and may be a more affordable option. • Can achieve approx. 6–9 m of pipe laying within Younghusband Peninsula per day. • Pipes would be spaced typically 2–3 m clear distance apart.
4 August 2021	Discussion with Prof. Patrick Hesp, Strategic Professor in Coastal Studies, Flinders University.	• Minimal coastal investigative work has been completed in the Southern Ocean. • Reefs are expected to be present offshore – geophysical survey should assist in identifying location and extent of reefs. • Lack of seagrass and other benthic growth is expected throughout the general near shore area due to the high wave energy climate.
26 August 2021	Discussion with John Herbert, National Business Manager – Underground Technologies, Fulton Hogan.	• Tunnel boring through the Younghusband Peninsula dunes and into deeper ocean water is not a feasible option, due to magnitude of equipment required, structural stability of the native soil, groundwater, and operating challenges handling the plant and equipment. • Traditional cut/fill method or micro-tunnelling (pipe-jacking) feasible pipe installation methods within the Younghusband Peninsula.

Date	Activity	Key findings/outcomes
27 September 2021	Discussion with Shane Fiedler and Sikko Krol, Maritime Constructions	General: • Fuel transport and storage in a sand dune environment will be challenging. • Very difficult to set up construction infrastructure in the dunes. Lots of preparatory work required. Southern Ocean construction: • Jetty construction out from land is achievable. • Offshore breakwater would be marine transport offloading operation. • Distance from shore will impact practicality of building. • Rock in Adelaide will be challenging to procure. May require a five- to seven-year lead time to ensure adequate rock supply. Tetrapods or similar are a suitable alternative for primary armour. • Scour in wave energy will be large and geotechnical conditions need to be understood for breakwater construction. • Building from shore would be more feasible but still challenging considering rock supply and transport. • Interruption to longshore and cross-shore drift patterns is a possibility – flanking may be an issue and could lead to significant dune erosion very rapidly under storm conditions. Dredging: • A cutter suction dredge methodology will be adopted for all proposed dredging. • Dredge production rate allows for 300–500 mm over dredge with approximately 50% of this over-dredge removed. • Allow 400 mm over-dredge with 200 mm removed in addition to the base footprint. • Production rate approximately 40,000–70,000 m^3 per week, but adopt 40,000 m^3 per week owing to uncertainties on disposal locations and likely rate of progress including relocation of dredged material pump stations and disposal pipework. • Continuous operation 24/7 once dredge is mobilised. • Dredging may halt for several days when discharge infrastructure (pipework, pumps) is relocated for the next section. • Dredge mobilisation could be from Goolwa via River Murray mouth which may require some access dredging through shallow water zones noting some flexibility in transporting components of dredge to reduce draft. Alternately, transport of dredge in components via road is possible with establishment of launch facility (hardstands). Good highway access is possible for freighted dredge components.

As part of the constructability advice sought from Maritime Constructions, a concept methodology for the dredging process associated with the construction of infrastructure Option 2 has been prepared. This concept methodology is provided in Appendix J and has been referenced throughout development of the concept designs.

3.4 ENERGY SUPPLY ASSESSMENT

On 22 October 2021, an energy supply assessment workshop was held at KBR. This workshop included participation from DEW and KBR team members and allowed a more detailed analysis of the seven energy supply options presented in section 7 of this report. The objective of this workshop was to:

- Understand the broader DEW and SA Government policy setting regarding renewable energy installations, greenhouse gas emission abatement and future strategies to achieve a zero emissions position for South Australia.
- Provide a summary of the specific elements associated with each energy supply option allowing a comparative assessment.
- Identify and rank top values held by workshop participants considering the broader project, DEW and SA Government perspectives.
- Identify the top-ranked energy supply options to inform whole of life costing and support project decision-making and communication with stakeholders.

As part of the workshop preparation and delivery process, the seven energy supply options (see section 7) were expanded to a suite of 10 options. Through the ranking and assessment process, the workshop participants were able to identify four of the proposed energy supply options as aligning with DEW values, policy, project aspirations and community feedback received to date.

The findings of this energy supply assessment workshop are presented in a technical memorandum (KBR reference: AEG155-C1-S00046), included in Appendix K. Of particular relevance to the concept design process was the conclusion that a grid-connected supply should be considered as the base case for the lifecycle cost estimate process. A range of possible enhancements could be considered to improve the value of this ‘base case’ grid connection to DEW in operation and maintenance of the proposed infrastructure.

3.5 GEOTECHNICAL ASSUMPTIONS

In development of the concept design documentation, a range of assumptions regarding geotechnical conditions expected at the sites under consideration have been made. It is recommended that these assumptions are reviewed as part of future design processes for the preferred infrastructure options with additional geotechnical or geophysical investigation completed to confirm assumptions. Assumptions have included:

- Presence of weakly cemented sand layers through in-situ material likely to be encountered for Lake Albert connector options (Option 1A and Option 1B).
- Groundwater table situated at approximately 0.0 mAHD (with seasonal variation) through in-situ material likely to be encountered for Lake Albert connector options (Option 1A and Option 1B).
- Insoluble and non-erodible cut face within Option 1A channel profile consistent with cemented nature of subsurface layers.
- Composition of approximately 50% fines and 50% coarser materials through the dredged material expected through all areas of dredging with no hard rock inclusions.

- Presence of potential acid sulphate soil materials that will require monitoring, management and treatment through all areas of dredging.
- Groundwater table situated at approximately 0.0 mAHD (with seasonal variation) through in-situ material likely to be encountered within Younghusband Peninsula (Options 3A, 3B, 3C, 3D, 4A, 4B, 5A, 5B and 6).
- Younghusband Peninsula materials comprising sand for the full depth of excavation or trenchless installation required for pipe or pumping station installation (to potentially –10 mAHD).
- Seabed materials comprising sand for the full depth of the piles expected to be driven for jetty construction (to 25 m depth).
- Permanent batter slopes of approximately 1V:4H noting that shallower slopes may be required for sandy materials below water table level where cemented materials are not present (e.g. within Younghusband Peninsula materials).

Recommendations for further geotechnical and geophysical investigation are provided within Section 11 and should be referenced in planning further design phases.

4 Dredging assessments

4.1 DREDGING BETWEEN NORTH AND SOUTH LAGOONS (OPTION 2)

4.1.1 Purpose

The Coorong North Lagoon is naturally less saline than the Coorong South Lagoon, being further upstream and receiving fresher water inflows from Lake Alexandrina (via barrages) and having a permanent connection to the Southern Ocean. The narrow channel constriction between the North and South Lagoons (the Narrows) considerably impedes the southern lagoon's opportunity to receive upstream inflows, particularly during the drier months of the year when Coorong water levels decrease.

An option to improve the ecological health of the South Lagoon is via the introduction of fresher water flows from the northern end of the lagoon system by increasing the connectivity between the North and South Lagoons. This could be achieved via dredging.

At the commencement of the project, a dredge alignment through the Narrows was nominated as 18.5 km long x 200 m wide to –1.2 mAHD, resulting in a total dredge volume of approximately 2.8M m^3. Concept design investigations have partially optimised the dredge alignment (width, depth, path) to reduce the quantity of dredged material whilst maintaining (or improving) the ecological benefits to the South Lagoon provided by the original alignment.

4.1.2 Alternative alignments

Using a bathymetric survey obtained in April 2021, alternative dredge alignments were plotted as shapefiles in GIS, varying in widths, depths and alignment lengths, all with consideration to the natural channel of the Narrows. Constructability input from Maritime Constructions was also sought to consider the minimum dredge equipment operating widths. These alignments were then provided to the DEW hydrodynamic modelling team to determine the level of benefit to the South Lagoon. The alternative alignments considered were:

- Dredge path 1:
  - Weighted towards the natural channels of the lagoon.
  - 17.8 km in length, same start and end point as Dredge path 2.
  - Various dredge widths of 25–50 m, representing –1.6 mAHD and –1.4 mAHD elevations.
  - Alignment avoids two rock walls at the southern section of the lagoon.
- Dredge path 1A:
  - Weighted towards the natural channels of the lagoon.
  - 17.8 km in length, same start and end point as Dredge path 2.
  - Various dredge widths of 50–100 m, representing –1.4 mAHD and –1.2 mAHD elevations.
  - Alignment avoids two rock walls at the southern section of the lagoon.
- Dredge path 2:
  - Considers the natural channels but deviates where a more direct route is present.
  - 17.2 km in length.

  - Various dredge widths of 25–50 m, representing –1.6 mAHD and –1.4 mAHD elevations.
  - Alignment avoids two rock walls at the southern section of the lagoon.
- Dredge path 2A:
  - Considers the natural channels but deviates where a more direct route is present.
  - 17.2 km in length.
  - Various dredge widths of 50–100 m, representing –1.4 mAHD and –1.2 mAHD elevations.
  - Alignment avoids two rock walls at the southern section of the lagoon.

Dredge volumes were not calculated for all four dredge paths options as the hydrodynamic model did not align efficiently with these initial dredge profiles.

4.1.3 Results

Assessments by the DEW hydrological, hydrodynamic and ecological teams has shown that dredging is complementary to other infrastructure options and did not offer significant improvement as a standalone option. Furthermore, assessment of the various dredge alignments above resulted in similar ecological improvements for all options. However, it does appear that a wider dredge profile, as opposed to a deeper one, produces marginally greater improvements (reductions) to salinity levels.

Noting this relationship, the dredge path 2A alignment was selected for further refinement to better align with the hydrodynamic model grid mesh. This was required to improve the level of confidence in the results and minimise instances of over- and underestimation of dredged material. The three other dredge path alignments were not updated to align with the grid mesh. The findings were marginally improved, though generally the improvements are comparable for all levels of connectivity (alignment variations). Because of this rationalisation, the general width of the dredge profile expanded to align with the grid mesh, resulting in widths of greater than 200 m.

The model results suggest that, by nature of the system, an overall increase in connectivity between the North and South Lagoon is sufficient to enhance the benefits of the ecological results seen when coupled with an additional infrastructure option.

The Dredge path 2A alignment is shown in Figure 3, the final dimensions being 17.5 km long x 100 m to 300 m wide x –1.2 mAHD to –1.4 mAHD. Allowing for a 200 mm overdredge during construction, the total dredged volume is estimated to be 2.25M m^3. It is expected that the dredge profile would be trapezoidal in shape avoiding creation of steep banks to each side of the dredge profile. An expected total dredge footprint area of up to 300 ha will be disturbed in completion of dredging activities.

It is noted that in particularly deep sections of the dredge alignment (e.g. in the vicinity of Parnka Point), minimal dredging is required, as the natural channel characteristics provide sufficient connectivity between upstream and downstream water levels.

4.1.4 Further dredge alignment optimisation

The opportunity remains to further optimise the nominated dredge alignment (and subsequent dredged volume) proposed as part of Option 2. It is recommended that this be completed as part of further design optimisation if the Option 2 dredging works are identified through the project decision-making process as being required in any of the preferred or highly favoured concept design options.

Areas for continued optimisation are associated with:

- Reducing dredging depth through areas of wide water (i.e. areas of wide flow at shallow depth).
- Refining the modelling grid mesh along the dredge alignment to allow enhanced representation of the actual dredged alignment and a further narrowing of dredge profile width.
- Increasing dredging depth in areas of softer sediments and decreasing dredging depths in areas of harder sediments.
- Additional geotechnical and geophysical surveys to ascertain extent of softer material deposits for optimal alignment selection.

Note that some additional dredging may be required from a constructability perspective to allow access of floating plant and vessels as well as the dredge itself to the site of the dredge alignment. It is expected that dredging will commence from the north-west and proceed in a south-westerly direction progressively.

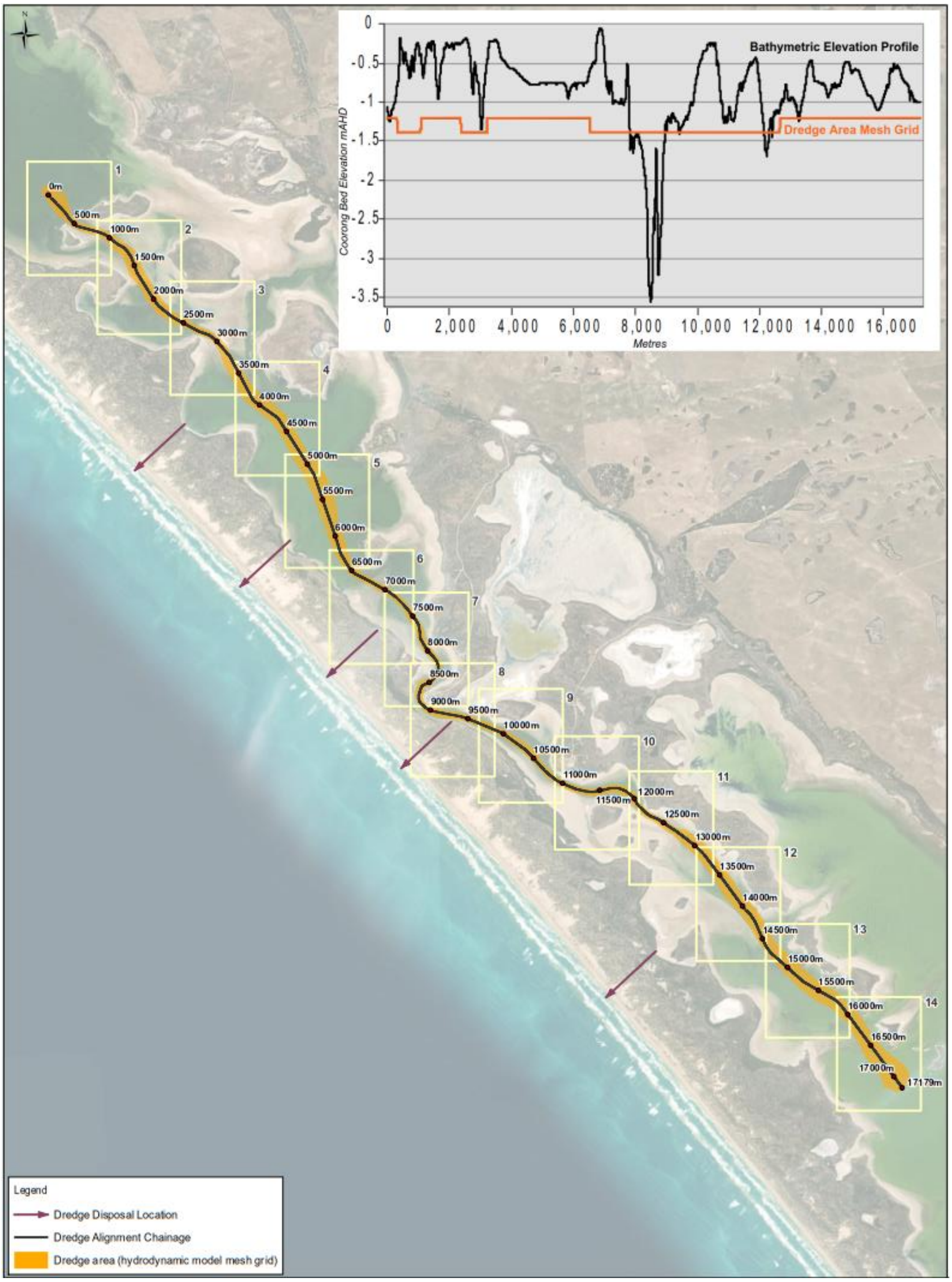


Figure 3 Coorong lagoon dredging alignment (refer drawing AEG155-2000-TD-DRG-CV-1000)

4.1.5 Dredged material disposal

Receiving environment

It is expected that the dredging methodology adopted for this project would utilise a cutter suction dredge method. This process fluidises and removes the sediment through conveyance of a slurry pumped through pipelines to disposal locations. Typically, the volume pumped is around four times the volume of the dredged material to be removed. This therefore requires significant logistical considerations to ensure an appropriate discharge location is identified for receival of this quantum of fluidised dredged material. For the current dredged material volume of 2.25M m^3, a total pumped volume of 10M–15M m^3 could be expected (i.e. a five to seven times bulking factor to produce a fluidised dredged material).

After consideration of advice received from EPA SA during project discussions (refer Table 10) and guidance provided by specialists in marine construction (Maritime Constructions), the option of land-based discharge of dredged material has been discounted, considering:

- The challenges in identifying and purchasing suitable land that could be used for construction of sedimentation basins, including proximity to the dredging works, elevation and grade of available land and the required vegetation clearance and farmland displacement to create a receival site.
- The cost of infrastructure and pumping to reach this identified land along with land acquisition costs.
- The challenges in treating acid sulphate soils (ASS) at this scale should this be encountered in the dredged material, particularly as the dredged material is exposed to air and commences oxidation.
- The challenges associated with on-site material stockpile management, noting the large volumes (e.g. potential dust and erosion issues).
- The cost of construction of sedimentation basins with a large requirement for earthworks to form a series of bunds allowing sediment to fall out of solution progressively as water is cleansed before being returned to the Coorong or another water body/water course.
- The cost of remediating the disposal site following completion of the dredging campaign.
- The likely approvals process to allow land based discharge considering the ongoing environmental implications of land based disposal (e.g. soft silts and clays remaining in a waterlogged state, hypersaline water/retained salt within the sedimentation basins, discharge water monitoring prior to disposal, ASS treatment).

It is noted that the EPA guidance provided indicated consideration of offshore disposal as likely preferred from an environmental approvals perspective. However, considering the cutter suction dredge methodology to be employed, offshore disposal is not considered to be an appropriate disposal pathway. Offshore disposal of dredged material is typically completed via a trailing suction hopper dredge. This is a dredge vessel that collects the dredged product within the vessel hull before transportation to a defined disposal area where it can release the dredged product through opening doors in the vessel's hull to deposit on the seabed. One challenge with this dredge methodology is the vessel draft required to allow a trailing suction hopper dredge to operate effectively (typically 3–4 m of draft required once laden). This is not achievable in the Coorong lagoon environment. A second challenge is navigating the dredge vessel from the site of the dredge to an offshore disposal location requiring passage through the River Murray mouth. This is not a reliably navigable path and adds an extreme challenge to implementation of a safe dredging campaign.

As such, this leaves near shore disposal as the preferred dredged material disposal pathway. This will require further investigation, considering environmental implications such as assessment of impacts on habitat from potential ASS material, hypersaline water and dispersion potential of the high wave energy climate. It is not expected that seagrasses will be encountered in the proposed nearshore disposal area, considering the high wave energy nature of the coastline in the immediate vicinity of the discharge point. Additionally, given the neutralising capacity of the ocean and the intention to prevent exposure of all dredged materials to oxygen (drying and oxidation), effective management of any ASS/PASS inclusions within the dredged material are expected to be adequately managed. Plume dispersion modelling has been completed as part of concept design activities and is reported in section 8.6.

Near shore dredged material disposal methodology

Figure 3 indicates possible dredged material disposal locations as the cutter suction dredge progresses through the Narrows. It is noted that these locations could be varied, depending on the quantum of dredged material to be extracted from specific sections of the alignment. All alignments and pathways through the Younghusband Peninsula dune system will require cultural heritage and environmental survey to ensure items or zones of heritage or environmental value can be adequately managed.

The general dredged material disposal philosophy is as follows:

- The dredge would initially start dredging the alignment heading in a south easterly direction with the pipeline looping behind the dredge and heading south east ahead of the dredge. This would continue until the dredge has passed the discharge point and continue until the pipe has become taut or an opportune distance is reached. The process is then repeated further downstream.
- Each location would have its own nuances that would drive the decision to utilise a floating booster or a land based booster pump/s for any given portion of the dredging. Booster pumps can be synchronised to suit varying dredge productions. Typically booster pumps are required at 0.9–1.5 km from the dredge. If a single onshore booster pump was to be used, discharge points would be required at around 2.4 km centres. If one floating booster pump and one onshore booster pump is adopted, this would allow discharge structures to be placed at around 5 km centres. This latter scenario would require up to five discharge points to be constructed into the Southern Ocean and is the assumed basis for concept design purposes.
- Generally, the pipeline that is required to follow the dredge will be floating. Any pipe that is generally static in its location will be allowed to rest on the seabed. In this way, the pipeline that is in the water is a mobile or active pipeline and the dune crossing pipeline would be considered static.
- Crossing the dune is relatively simple. Using a midsize excavator, 150 m of pipeline (500 mm HDPE or UHMWPE) will be dragged through the most logical crossing location and bolted flange connections would be made to complete the dune crossing. These strings would be floated in from the Coorong side and a tow rope walked ashore for connection to the machine.
- The discharge location itself could be a pipeline propped up at the upper beach on a pile of sand and discharging somewhere above mean sea level (MSL). This is similar to the dredged material disposal methodology for the River Murray mouth dredging. However, this methodology has a greater impact to beach users with an extended exclusion zone required.
- Should the material be required to be pumped directly into the active zone below MSL and closer to lowest astronomical tide (LAT) then piled discharge points will be required. These would be driven using a combination of excavator and tracked telescopic boom crane with pile driving equipment. These would support a prefabricated steel pipeline that would be trenched into the beach up to the upper beach where it would be connected to the dredge line. Several piles may be driven along the steel pipe in the beach crossing with saddles to clamp the pipe into for further restraint should excessive erosion occur. This is the recommended dredged material disposal methodology for concept design purposes.

Additional recommended investigations

It is recommended that some additional particle size distribution testing and an enhanced suite of environmental contaminant testing over the full alignment and range of depths expected to be dredged be undertaken, should this option progress to further consideration. All future testing should be assessed against the National Assessment Guidelines for Dredging (NAGD 2009) in readiness for preparation and submission of environmental approvals documentation for consideration by state and Commonwealth regulators where necessary.

It is noted that low arsenic levels were recorded in 11 of 17 samples collected and tested along the dredge alignment. Of these 11 samples, only five exceeded the screening level. Given the site characteristics and that there are no known sources of heavy metal pollutants, it is not expected that the arsenic detected has resulted from anthropogenic (human activity) sources. As such, further testing of marine sediments will be required also to confirm background levels of arsenic within the natural receiving environment to assist in demonstrating the suitability of the near shore Southern Ocean zone for discharge of the dredged material. This will be completed in future project design phases if dredging is required in any of the preferred or highly favoured infrastructure options.

4.2 ADDITIONAL DREDGING REQUIRED FOR OTHER CONCEPT DESIGN OPTIONS (1A, 1B, 3A, 3B, 3C, 3D, 4A, 5A, 5B AND 6A)

It is noted that dredging will also be required for a range of other purposes associated with the proposed concept design options. This includes:

- Dredging of the hydraulic connection into Lake Albert for Option 1A and Option 1B.
- Dredging of the hydraulic connection into Coorong North Lagoon for Option 1A and Option 1B.
- Dredging of the areas immediately surrounding pontoon-mounted pumps (Options 3A, 3B, 3C, 3D, 4A, 5A and 5B).
- Dredging of a construction and operational barging/navigational alignment across the Coorong South Lagoon in the vicinity of the Southern Ocean connection infrastructure (Options 3A, 3B, 3C, 3D, 4A, 4B, 5A, 5B and 6A) – approximately 4.4 km long, 50 m wide and 1 m deep.

It is expected that a cutter suction dredge methodology will be applied again in all the above instances. Disposal will occur through a similar near shore discharge structure as for the Option 2 capital dredging campaign. It is likely that a separate dredge vessel will be utilised for these smaller dredge alignments.

Where small quantities of dredged material are expected to be generated, there may be an opportunity to explore land-based discharge and treatment of the dredged material for ASS if encountered. This may be considered for the Lake Albert and Coorong North Lagoon dredging necessary to connect these water bodies to Option 1A and Option 1B infrastructure.

4.2.1 Access to dredge site for cutter suction dredge

Several options are possible to allow a cutter suction dredge to be mobilised to the appropriate location for commencement of dredging activities. The dredge could either be sailed from north to south from the Goolwa Channel or alternately launched via crane from a custom-built launch site at a suitable location along the Coorong lagoons.

One challenge with sailing the dredge from Goolwa is that it may encounter shallow sections of the Coorong North Lagoon (e.g. near Pelican Point), which may make travel inefficient. There is the potential need for minor dredging (and possible side casting) of dredged material to allow passage of the vessel. Further survey of the proposed transit route would be required should this mobilisation path be adopted.

For the typical size of cutter suction dredge required for this project, transportation of the vessel in parts could be achieved by road. However, at the launch site, reassembly and construction of crane pads and the like would be required prior to launching the dredge.

The final access arrangements for the dredge to gain access to the dredge alignment will be determined with the dredging contractor, considering:

- The size of the dredge proposed.
- Ease of disassembly, transport and reassembly.

- Identification of a suitable launch site adjacent the highway and on the banks of the Coorong lagoons.
- Likely extent of any dredging requirements on the transit route to the dredge alignment.

5 Access, schedule and constructability

5.1 SITE ACCESS

The provision of site access to all infrastructure locations is an essential consideration for construction and for ongoing operation and maintenance access. Whilst day-to-day attendance at the operating sites will be minimised, there will be routine maintenance and inspections that must occur to ensure ongoing safe and reliable operation of the equipment.

At present it is proposed to retain some of the temporary works required to achieve construction site access as permanent elements, to facilitate operations and maintenance access. Examples are barging points located either side of Coorong South Lagoon and any access tracks, hardstand areas, and other facilities created for vehicle, equipment and crane movements.

Further details on the proposed site access considerations for the Southern Ocean connector options are presented in Appendix A on drawings AEG155-0000-TD-DRG-CV-0400, AEG155-0000-TD-DRG-CV-0401 and AEG155-0000-TD-DRG-CV-0402.

5.2 CONSTRUCTION METHODOLOGY

This section contains a summary of construction methodology considerations for each option, as well as potential challenges and risks. Further details are included in Appendix L for specific construction activities associated with terrestrial and near shore construction. Clarifying commentary to proposed methodologies by KBR are presented within bracketed text.

5.2.1 Constructability considerations to be confirmed as design progresses for preferred options

It is noted that the methodologies presented in Appendix L have been considered in developing the concept designs and supporting capital and operating cost estimates; however, some construction elements still require further design development, investigations and assessments before determining a single preferred construction methodology. It is recommended that this is completed upon selection of the preferred options for further design progression.

These constructability considerations are listed below, along with the assumption that has been adopted for the purposes of producing the concept design and cost estimates:

- Haulage of open channel spoil offsite or formation of a spoil mount on-site for Option 1A (open channel): either approach may be acceptable depending on the haul distance to an appropriate disposal site and the number of truck movements required to dispose of the material. For the purposes of concept design, formation of a spoil mound on-site has been adopted minimising truck movements on regional public roads and risks with placing spoil from construction activities on third party properties and any associated contamination potential.
- Lining of the open channel to minimise soil erosion or retaining it in its natural cut state for Option 1A (open channel): either approach may be acceptable depending on the erosion potential of the native material (which is expected to be low) but will require some additional geotechnical testing (e.g. Emerson Class testing). For the purposes of concept design, an unlined channel has been adopted considering the varying cemented nature of the native material, the one vertical to four horizontal (1V:4H) batters (much less than the expected angle of repose) and the slow flow velocities through the channel (typically less than 0.4 m/s for operating conditions).
- Pipe-jacking (micro-tunnelling) or conventional open trench pipe laying for all pipe options: either approach may be acceptable for pipe installed through deeper sand dune alignments depending on the available footprint for spoil management, the depth of groundwater, the

available area and ease of management of drilling muds, the availability of pipe-jacking equipment capable of installing the required pipe diameters and the equipment required to construct the launch and exit shafts. For the purposes of concept design, conventional open trench pipe laying has been adopted for all pipe installation options.

- Requirement for acquisition or leasing of private property for construction laydown and amenities areas or placement within Minister for Environment and Water land: depending on final construction laydown methodology, it is possible that short-term lease arrangement may be required to facilitate effective laydown of construction plant and materials; however this will be explored further as design progresses. For the purposes of concept design, placement of all construction areas have been assumed to be within Minister for Environment and Water land not requiring any acquisition or leasing of private property with the exception of Options 1A and 1B where some land acquisition will be required.
- Transport of breakwater materials directly across the Coorong or via haulage along ocean beach: either option may be acceptable depending on the likely quantity of daily deliveries and the practicality of hauling via the barge or beach route. Barge movement will require multiple handling points and will be less efficient and somewhat treacherous for the barge moving large rock on a floating steel hull. For the purposes of concept design, stockpiling of rock materials at the southern end of the Coorong South Lagoon has been adopted with haulage along ocean beach to the breakwater construction site.
- Bridge, causeway or barge access across Parnka Point for Options 5A and 5B: any of these three options may be suitable but given the short distance, barging is likely to be inefficient. Construction of a causeway may not be acceptable given interruptions to flow and water level management in the Coorong Lagoons. For the purposes of concept design, a suspended deck structure has been proposed to allow a dedicated construction access route to Younghusband Peninsula.
- Number and location of temporary dredged material disposal pipework through Younghusband Peninsula to near shore discharge structure: the number of locations could vary from four to seven depending on final dredge alignment, expected dredged material quantity, further cultural heritage and environmental assessment of potential pipeline alignments, width of peninsula and placement of floating or land based booster pump stations. For the purposes of concept design, five temporary pipeline alignments have been nominated

As preferred options are selected and concepts are endorsed to commence for further design activities, these items should be reviewed with additional input from landholders, stakeholders, construction contractors, technical personnel, environmental approvals specialists and cultural heritage specialists to confirm the concept design assumptions listed above.

5.2.2 General construction challenges and risks

Construction within the Southern Ocean and Coorong South Lagoon will be challenging, and in some ways unprecedented, depending on the infrastructure option being considered. Design must consider such things as the topography, ground conditions, materials selection, corrosion prevention, cultural heritage and significant sites, weather, wave climate, water levels within the Coorong and sheer scale of the infrastructure being installed. Each chapter of this report discusses associated construction challenges and considerations in further detail; however, more broadly the construction methodology must consider:

- The size of the machinery required to transport the equipment and materials to site and whether this is best transported via vessel (unlikely considering sea state) or freighted along ocean beach (oceanside) or via barge or smaller vessel (across the Coorong) from a logistics hub where trucks, plant and equipment can be delivered adjacent to Princes Highway.

- The requirement for access tracks, barge mooring and loading/offloading infrastructure or a bridge across narrow locations within the Coorong lagoon (e.g. Parnka Point).
- Minimising construction of track that may impact cultural heritage and sensitive flora and fauna sites.
- The size of laydown areas and where they should be best situated (noting the undulating dune environment, cultural heritage locations, native vegetation and protected fauna and flora species).
- Limited beach access due to the high wave energy climate, narrow beach, high dunes, protected bird species and native vegetation.
- The seasonality of water levels within the Coorong and the implications this has on means of transport.
- Avoiding disturbance of fragile dune vegetation where possible, likely with geotextile underlays to all temporary access tracks to minimise the extent of earthworks and disturbance of seed bank in the dune environment.
- Inclusion of revegetation or windblown sand containment to return the dune environment to relative stability as soon as possible after construction activities.
- The high wave energy climate within the Southern Ocean, which limits the number of optimal weather days (anecdotally two weeks of optimal weather in any given year).
- The presence of potentially acid sulphate soils (when dredging for Option 2 and the pumped infrastructure within the Coorong South Lagoon).

5.3 CONSTRUCTION FOOTPRINT

Whilst the construction footprint will vary slightly between sites, a range of standard inclusions are necessary in estimating the construction footprint. The estimated footprint is expected to be typical for a primary construction office, amenities, parking and stockpiling. It is likely though, that individual work fronts may require additional laydown, amenities and parking areas (e.g. a jetty construction work front).

Table 11 presents a summary of expected footprints for key elements of the construction site, not including the area of the works.

Table 12 presents a summary of expected footprints for individual work fronts for specific elements of the construction scope.

Table 11 Construction footprint allowance for construction sites

Construction element	Expected footprint
Site huts and amenities	Adopt a 50 m x 50 m area for various huts, say 2,500 m^2 including walkways between facilities.
Site parking for light vehicles	Allow for 25 vehicles in 5 m x 3 m parking bays with an equivalent area for vehicle manoeuvring, say 750 m^2.
Site parking for heavy vehicles	Allow for 10 vehicles in 10 m x 4 m parking bays, with an equivalent area for vehicle manoeuvring, say 800 m^2.
Laydown area (pipes, steelwork, etc.)	Allow a 100 m x 100 m area for laydown with pipes arriving in 3 m to 12 m lengths, between DN1400 and DN2200 depending on the option, and being stacked single, say 1 ha.
Total	Approximately 1.4 ha, rounded to 2 ha allowing for transit routes, fencing, setback from other site areas, safe walking routes, etc. For Younghusband Peninsula infrastructure options, this could be separated between each side of the Coorong allowing site parking and laydown adjacent to a barge point on each side of the Coorong. For marine construction infrastructure options, an additional 1 ha should be allowed for marine construction equipment and material laydown (e.g. steel, rock, concrete, plant and equipment, etc.). See Table 12 for the jetty construction description.

Table 12 Construction footprint allowance for work front

Construction element	Expected footprint
Pipeline construction	Allow for a 20 m pipe corridor for a pipe between DN1400 and DN2200 with excavator, material stockpile (pipe and backfill) and an access vehicle path assuming trench shoring for an excavation depth of three to four metres.
Pipeline construction – single pipeline (benched) (proposed pipe construction methodology)	For greater excavation depths, benching will likely be required. One vertical to three horizontal (1V:3H) batter slopes could be adopted, but batter slopes may be required to be flatter in some locations, depending on surrounding topography and condition of in-situ material. This will result in an overall excavation width of around 80 m for installation of a single pipe between DN1400 and DN2200 up to 8 m deep with spoil placement, and excavator and vehicle access (nominally 15 m each side of excavation). A significant risk to be managed is access of heavy vehicles and equipment adjacent to any excavation. This may require trench shoring boxes or a greater footprint width to allow separation of construction loads from cut faces.

Construction element	Expected footprint
Pipeline construction – multiple pipelines (benched) (proposed pipe construction methodology)	Where multiple pipelines are required to be installed with appropriate benching at depth (e.g. Option 1B), an excavation width of up to 150 m may be required, allowing an extra 20 m on the width nominated for a single pipeline construction to accommodate the seven separate DN2100 pipes required, and an additional 50 m for temporary stockpile management. A significant risk to be managed is access of heavy vehicles and equipment adjacent to any excavation. This may require trench shoring boxes or a greater footprint width to allow separation of construction loads from cut faces.
Jetty construction – Option 3A, Option 3C, Option 4A, Option 5A and Option 6	Allow for access of a crawler crane (with pile driving hammer) and material deliveries of piles, precast concrete decks, pipe and other steelwork. An equipment handling, stockpiling and amenities construction area may require around 1 ha (100 m x 100 m), positioned within Younghusband Peninsula in the dune environment.
Breakwater construction – Option 4B and Option 6	Allow for access for various cranes, excavators and material deliveries of rock, reinforcement, formwork, etc. Additionally, a concrete batching plant could be utilised for casting of the Tetrapod units, particularly if it is mobilised already for construction of the Option 4B dry-well pump station. An equipment handling, stockpiling and amenities construction area may require around 2 ha (100 m x 200 m), positioned within Younghusband Peninsula in the dune environment.
Pump station construction (on land) – Option 4B	The required building footprint is around 20 m x 30 m. Construction will commence with driving sheet piles on four sides to form the outer forms of the pump station dry-well. The pump station will be situated in an area with a target sand dune level of 5 mAHD, minimising depth of dune excavation required. A switch room is also required to be constructed adjacent to the well, plus construction and permanent access tracks, parking, etc. On this basis, an area of around 7,650 m^2 (85 m x 90 m) will be required, rounded to 1 ha. This allows around 30 m on all sides of the building footprint, with an additional 5 m allowance for construction of the switch room. This additional area is required to allow positioning of a crane pad, concrete batching plant, etc.
Open channel construction – Option 1A	A channel base width of 13.3 m and batter slopes of one vertical to four horizontal (1V:4H), with a minimum of 20 m each side for stockpile management and access through up to 8 m of cut results in a construction footprint of around 120 m. It is possible that the full 200 m width of cultural heritage surveyed alignment is required when considering placement of the spoil mound and provision of access tracks for maintenance and operations.
Trenchless pipe construction – all Southern Ocean connector options (if adopted – option only)	Disturbance to natural surface and the dune system itself will be minimised via this construction methodology; however, launch pits will be required for the trenchless infrastructure (e.g. micro-tunnelling/pipe-jacking equipment). These launch pits may be 15 m x 10 m in size and will require sheet piles to be driven to retain the sand allowing excavation within and installation of required equipment as well as provision of a thrust point for push off. A working area surrounding these pits of 20 m on all sides will be required resulting in a footprint of around 3,000 m^2 (50 m x 55 m).

Construction element	Expected footprint
Dredge alignment – Option 2 and other minor dredging	The footprint requirements for the dredge itself will be minimal, as it is a waterborne craft; however, there will be a need for a range of floating or shore-based booster pump stations, allowing effective disposal of the dredged material through discharge pipework. There will also be the requirement for a mooring facility for tender and support vessels, allowing activities such as personnel movement, refuelling, general maintenance, movement of dredge lines and pump stations. This support area will likely require around 2,500 m^2 (50 m x 50 m) for minor dredging (e.g. Lake Albert connector options) and 1 ha (100 m x 100 m) for capital dredging campaign. For the minor dredging, this area would be required in two locations. For the capital dredging campaign, this area may be required in up to five locations as the dredging operation progresses along the alignment (although this could be centralised, accepting greater distance between dredge front and support area).
Dredged material disposal pipework – Option 2 and other minor dredging	For installation and management of dredged material disposal pipework, around five separate alignments through Younghusband Peninsula will be required. The width of each alignment will be a minimum of 10 m but may increase to 20 m depending on the local site access requirements, length of the alignment through Younghusband Peninsula, avoidance of culturally sensitive materials (e.g. middens), avoidance of environmentally sensitive areas (e.g. freshwater soaks) and the requirement to maintain any additional operational access. This corridor will primarily be used for tracking an excavator along each pipe route to manage the pipework, with frequent excavator movements expected. The final locations will be selected following further cultural heritage survey and confirmation of the dredging methodology, including refinement to dredge alignment and geometry.
Barge mooring and loading points (both temporary and permanent) – all Southern Ocean connector options	Allow a 20 m wide berthing face for barge access x 100 m for laydown, vehicle movement and loading/unloading of barge. This is typically incorporated within the overall construction site footprint calculation presented in Table 11, with around 1 ha allowance on each side of the Coorong for laydown, parking, site accommodation, etc.

Based on the above analysis, Table 13 presents a summary of total area requirements for construction activities. Operation and maintenance activities are also considered. This analysis has been used as the basis for the vegetation disturbance assessment included within Section 10 of this report.

Table 13 Summary of disturbance footprint

Option	Disturbance footprint (ha)
Option 1A	39.5
Option 1B	25.8
Option 2	20.0
Option 3A	10.7
Option 3B	9.7
Option 3C	10.7
Option 3D	9.7
Option 4A	10.7
Option 4B	11.7
Option 5A	28.2
Option 5B	27.2
Option 6	16.2

5.4 CONSTRUCTION RISKS AND MITIGATION MEASURES

Through concept design, a high-level construction risk identification has been completed seeking to identify risks and propose mitigation measures associated with implementation of the proposed works. Table 14 outlines a range of construction risks and aligns these with mitigation measures seeking to minimise the risks posed to construction plant, equipment, materials and personnel. This list is not exhaustive and should be reviewed and updated as further design progresses for the selected concept design options.

Table 14 Construction risks and mitigations measures

Construction risk	Mitigation measures
Ocean construction – jetty	For jetty construction, an ‘over the top’ installation methodology has been adopted to avoid the requirement for floating plant to be present within an open ocean environment.
Caisson construction	As the caisson structure is to be constructed within open water, there will be a requirement to carefully consider the construction methodology adopted and design specific temporary or permanent works to support installation of the structural components. The jetty head could be used to assist installation of the caisson structure or to install temporary or permanent guide piles.

Construction risk	Mitigation measures
Ocean construction – breakwater	For breakwater construction, there will be challenges associated with placement of rock progressively without losing armourstone into the ocean, and management of sand as the rock displaces sand through persistent wave action. It may be appropriate to stage construction over an extended period allowing the placed rock to settle into the environment progressively rather than installing all rock to design level initially. If possible, removal of the cast in-situ concrete topping slab could improve constructability; however, it may require additional rock to construct or acceptance of a greater overtopping flow.
Material haulage on Southern Ocean beach	For breakwater construction, it is expected that rock would be hauled from near Adelaide for the secondary armour. There may be a significant lead time on supply of this rock so early planning will be essential. A stockpile site will likely need to be established at a southern location (e.g. 42 Mile Crossing) to allow laydown of material for transport via Moxy trucks (off-highway six-wheel drive dump trucks) or similar along ocean beach when required. Concerns around mobile sand, high wave energy and tidal effects will need to be managed through surveillance, safe work method statements, etc.
Construction traffic through Younghusband Peninsula	Temporary access tracks are proposed to be constructed for the purposes of allowing construction traffic to traverse the dune environment. These access tracks could be retained as permanent tracks for operation and maintenance purposes where appropriate. Consideration of public access and safety will be necessary.
Trenching and excavation in deep sand profiles	Conventional shore, battering and exclusion of heavy vehicular loads will be required to mitigate potential trench collapse concerns. Another mitigation measure could be to adopt trenchless installation (e.g. pipe-jacking); however, this will require alternative temporary construction works and specialist equipment.
Groundwater management through excavations	Dewatering spear installation will be required around the perimeter of excavations to allow removal of groundwater for construction of open excavations as may be required for the Option 1B pipes, Option 4B dry-well pump station and Option 6 passive pipes.

5.5 PRELIMINARY CONSTRUCTION SCHEDULE (ESTIMATED DURATION OF ACTIVITIES)

Conversations with specialists in marine and civil construction (Maritime Construction and Fulton Hogan) provided guidance on likely construction duration for specific activities. This guidance has been supplemented with other practical knowledge and has been used to outline likely construction durations for the proposed infrastructure options. Some general considerations around the construction schedule are presented in the following sections. Section 5.5.7 provides an estimated duration of activities.

5.5.1 Option 1: Lake Albert connector

The volume of cut expected for construction of the Option 1A open channel is approximately 270,000 m^3 (approximately 1,811 m long). A further 21,000 m^3 of dredging is required to connect the open channel to the adjoining water bodies of Lake Albert and Coorong North Lagoon.

For Option 1A, spoil disposal will be a significant contributor to construction duration, as it depends upon availability of haulage trucks (if offsite disposal is required) and distance to dispose of the spoil. This will constitute a very large number of truck movements along regional roads to a nominated disposal site. For cost estimating purposes, formation of a spoil mound adjacent the channel has been assumed. The opportunity remains to dispose of surplus spoil at another location, preventing wind-blown sand accumulation within the open channel.

For Option 1B, an efficient form of construction would be open cut with stockpiling of material to backfill and cover the seven installed pipes. This excavation method requires around 230,000 m^3 of cut (approximately 1,514 m long) which is then stockpiled and placed back over the pipe once the pipework is installed. Additionally, a further 35,000 m^3 of dredging is required to connect the open channel to the adjoining water bodies of Lake Albert and Coorong North Lagoon.

5.5.2 Option 2: Coorong lagoon dredging

An estimated rate of progress for dredge activities utilising a cutter suction dredge philosophy is around 40,000 m^3 per week (but could increase to 70,000 m^3 per week in ideal conditions). This rate includes an allowance for over dredge and assumed 24/7 dredge operation, 365 days per year. The rate also includes an allowance for downtime associated with relocation of the dredge and dredged material disposal pipework.

The expected volume of dredge spoil to be removed is around 1,700,000 m^3 plus the over dredge quantity. An additional 200 mm of dredge depth has been allowed to determine a total dredge spoil volume of 2,250,000 m^3. The dredging is completed over a footprint area of up to 300 ha.

5.5.3 Option 3: Coorong South Lagoon pump out

Facilitative works will be significant for all Coorong South Lagoon to Southern Ocean connector options – laydown areas will be established each side of the Coorong and the barging points in addition to dredging of the barge route within the Coorong.

Where jetty construction is required, an additional laydown area for marine construction will be required to manage materials and equipment. Furthermore, additional construction equipment will be required (e.g. a 100 t crawler crane) rather than excavators, dump trucks and cranes for pipe installation and general earthworks and access tracks.

5.5.4 Option 4: Bi-directional pumped connection into and out of Coorong South Lagoon (one location)

Option 4A has similar considerations to Option 3 (Section 5.5.3); however, for Option 4B with the breakwater, complexity increases significantly when considering the volume of material required, logistics for hauling the material to the breakwater site and then the equipment and construction methodology to achieve installation.

For the breakwater, a significant lead time may be expected for supply and transport of secondary armour rock and the Tetrapod units (potentially over five years). This may be the time taken for a quarry to win the specified armourstone.

5.5.5 Option 5: Bi-directional pumped connection into and out of Coorong South Lagoon (at two spatially separate locations – one in and the other out)

Option 5 has similar considerations to Option 3 (Section 5.5.3); however, with construction occurring at two locations, additional facilitative works are required to allow construction access to both infrastructure sites.

For power supply considerations, this option now requires provision of two separate power supplies to facilitate operation of the separate pump stations.

5.5.6 Option 6: Passive piped connection into and out of Coorong South Lagoon

With 10 DN2000 pipes required each around 1.0 km in length, the total pipe length to be installed is 10 km. At an indicative installation rate of 6 m to 9 m per day, the expected construction duration for the pipe installation only is around six months per 1.0 km pipe length. The overall construction program could be accelerated by using different construction crews for pipelines within water bodies and using multiple pipe construction crews.

Valve chamber construction will also be challenging and time consuming at the nominated pipe depths. Construction could be completed during pipe installation. Alternatively, a tunnel or gallery structure could be considered in lieu of individual valve pits.

Breakwater construction remains very challenging and with this option having the most extensive breakwater length, a significant construction duration will be expected. Similar challenges to those for Option 4B (listed in Section 5.5.4) again apply.

5.5.7 Summarised expected durations

Table 15 summarises the information presented around construction duration for each option. These durations are expected to apply from award of contract and assuming that procurement of all long lead materials has occurred.

Table 15 Expected duration of construction activities

Option	Expected duration of construction activities (from award of construction contract)
Option 1A	• Three months for dredging activities (can progress in parallel with open channel excavation activities). • Six to nine months for open channel excavation and spoil disposal/spoil mound formation. • Four months for regulator construction (can progress in parallel with open channel excavation activities).
	• Allow nine months for complete construction during drier months of the year.
Option 1B	• Three months for dredging activities (can progress in parallel with open channel excavation activities). • Twelve months for installation of seven DN2100 pipes via open cut methods, including construction of headwalls and backfill of pipe alignment with extensive dewatering. • Four months for regulator construction (can progress in parallel with pipe construction activities).
	• Allow 12 months for complete construction.
Option 2	• Allow up to two years, operating at a 40,000 m^3 per week production rate, including mobilisation and demobilisation.
Option 3A	• Nine months for one construction crew for pipe installation. • Nine months for jetty installation (could be in parallel with pipe installation). • Six months for floating pontoon pump station installation and commissioning.
	• Allow a total of two years, including an allowance for mobilisation, demobilisation, poor weather, etc.
Option 3B	• Nine months for one construction crew for pipe installation. • Three months for beach discharge structure installation (could be in parallel with pipe installation). • Six months for floating pontoon pump station installation and commissioning.
	• Allow a total of 18 months including an allowance for mobilisation, demobilisation, poor weather, etc.
Option 3C	• As for Option 3A, allow a total of two years for construction, including an allowance for mobilisation, demobilisation, poor weather, etc.
Option 3D	• As for Option 3B, allow a total of 18 months for construction including an allowance for mobilisation, demobilisation, poor weather, etc.

Option	Expected duration of construction activities (from award of construction contract)
Option 4A	• One year for one construction crew for pipe installation. • One year for jetty and caisson installation for intake pump station (could be in parallel to pipe installation). • Six months for floating pontoon pump station installation and commissioning. • Six months for jetty-mounted pump station installation and commissioning.
	• Allow two years considering mobilisation, demobilisation, poor weather, etc.
Option 4B	• One year for one construction crew for pipe installation. • One year for breakwater installation (could be in parallel to pipe installation). • Nine months for pump station installation and commissioning.
	• Allow two years considering mobilisation, demobilisation, poor weather, etc. • The lead time to obtain the required size and specification of rock is not included in the above but could potentially be over five years.
Option 5A	• One year for one construction crew for pipe installation; pipes are required at two locations (the second pipe could be installed by a second crew or immediately following the first pipeline). • One year for jetty and caisson installation for the intake pump station (could be in parallel with pipe installation). • Nine months for discharge jetty installation for the near shore discharge structure (could be in parallel with pipe installation). • Six months for floating pontoon pump station installation and commissioning. • Six months for jetty-mounted pump station installation and commissioning.
	• Allow two and a half years, including an allowance for mobilisation, demobilisation, poor weather, etc.
Option 5B	• One year for one construction crew for a single pipe installation; pipes are required at two locations (the second pipe could be installed by a second crew or immediately following the first pipeline). • One year for jetty and caisson installation for the intake pump station (could be in parallel with pipe installation). • Three months for beach discharge structure installation (could be in parallel with pipe installation). • Six months for floating pontoon pump station installation and commissioning. • Six months for jetty-mounted pump station installation and commissioning.
	• Allow two and a half years, including an allowance for mobilisation, demobilisation, poor weather, etc.
Option 6	• Six months for one construction crew installing one pipe. • Five years for one construction crew installing 10 pipes. • Two years for breakwater installation (could be in parallel to pipe installation).
	• Allow up to three years for construction, assuming two pipeline installation crews working concurrently; breakwater installation occurs in parallel. • The lead time to obtain the required size and specification of rock is not included in the above but could potentially be over five years.

Table 15 does not include provision for:

- Construction of the proposed power supply arrangements for each option.
- The detailed design, environmental impact statement and all approvals required before commencement of construction.
- The land acquisition process, where required, for private properties impacted by proposed infrastructure.

The above items may require a period of up to three years to complete. Some overlap is permissible between construction of power supply infrastructure and the proposed infrastructure options.

6 Mechanical and hydraulic design

6.1 MECHANICAL AND HYDRAULIC DESIGN ACROSS THE OPTIONS

Several options detailed in Table 2 include either mechanical equipment such as pumps and valves, or hydraulic structures such as channels and flow regulating structures. This section details the requirements for, and influences on the design, of the mechanical and hydraulic infrastructure.

Table 16 presents a summary of relevant sections for each concept design option, with the section headings as follows:

- Section 6.2 – Lake Albert connector (Options 1A and 1B).
- Section 6.3 – Infrastructure within Coorong South Lagoon (Options 3A, 3B, 3C, 3D, 4A, 5A and 5B).
- Section 6.4 – Infrastructure within Southern Ocean (Options 3A, 3B, 3C, 3D, 4A, 4B, 5A, 5B and 6).
- Section 6.5 – Infrastructure within the Younghusband Peninsula (Option 4B).
- Section 6.6 – Fish exclusion screens.
- Section 6.7 – Pressure surge.

Table 16 Relevant sections for each concept design option

Section	6.2	6.3	6.4	6.5	6.6	6.7
Option 1A	X					
Option 1B	X					
Option 2						
Option 3A		X	X	X	X	X
Option 3B		X	X	X	X	X
Option 3C		X	X	X	X	X
Option 3D		X	X	X	X	X
Option 4A		X	X	X	X	X
Option 4B			X	X	X	X
Option 5A		X	X	X	X	X
Option 5B		X	X	X	X	X
Option 6			X	X		

Section 6.2 details the design and methodology for Options 1A and 1B, for the infrastructure between Lake Albert and Coorong North Lagoon. HEC-RAS modelling was undertaken for these options to determine the required channel dimensions that will provide sufficient flow between the two water bodies.

Design relating to infrastructure located within Coorong South Lagoon is discussed in Section 6.3. Pontoon-mounted pumps were selected as the preferred pumping solution for transferring water out of the Coorong and into the Southern Ocean. This infrastructure within the Coorong South

Lagoon is common to Options 3A, 3B, 3C, 3D, 4A, 5A and 5B and hence the content relates to all these options.

Vertical turbine pumps mounted on a jetty was the preferred design for pumping infrastructure located in the Southern Ocean, as discussed in Section 6.4. This infrastructure is included in Options 4A, 5A and 5B. This section also describes a discharge jetty that is used primarily to support a discharge pipe, for Options 3A and 3C.

Section 6.5 discusses the design process, challenges and risks associated with construction within the Younghusband Peninsula. The discussion is primarily relevant to Option 4B as this option requires significant infrastructure within the Younghusband Peninsula. It is also relevant for the installation of pipelines through the Peninsula for all options.

Section 6.6 discusses fish exclusion screens which are required for all pumping options, as this enables the safe passage of fish across the pump suctions. This was identified as a priority by DEW, and screening has been incorporated into all pump suctions in accordance with manufacturer's guidance. Section 6.7 outlines a preliminary assessment of possible surge events within the pumping systems and how the risk could be mitigated through the design process. These two sections are relevant to all options that require pumping.

6.2 LAKE ALBERT CONNECTOR HYDRAULIC DESIGN (OPTIONS 1A AND 1B)

6.2.1 Overview

An alignment for the connection from Lake Albert to Coorong North Lagoon was selected with consideration to the natural landscape (preference for more open, flatter and relatively unobstructed terrain), the available contour information and the cultural heritage survey results. An overview of the Lake Albert connector Option 1A (channel) and Option 1B (pipes) is shown in Figure 4 and discussed further in the following sections.

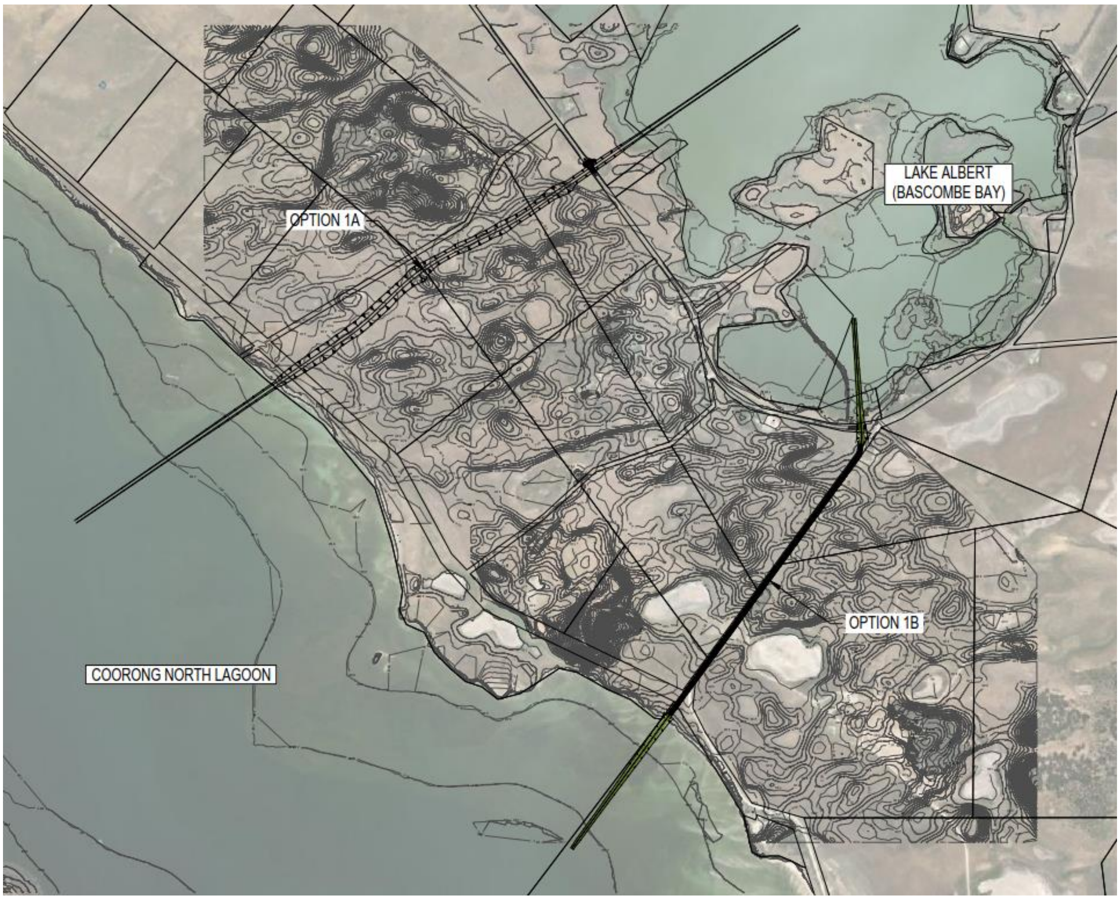


Figure 4 Lake Albert connector: Option 1A channel alignment and Option 1B piped alignment

Option 1A

The channel discharges from Lake Albert (Bascombe Bay) via an inlet flow regulating structure with fishway which sits beneath Narrung Road. On discharge from the flow regulating structure, the channel continues with constant grade and alignment, then discharges into Coorong North Lagoon. Table 17 details the infrastructure proposed for this option. See Section 6.2.2 for discussion on the associated hydraulic design.

The flow regulating structure has rock protection upstream and downstream to assist in minimising erosion potential in areas of concentrated flow. Additionally, the fishway comprises a rock-lined channel, catering for flow velocities and turbulence within the rock riffle fishway.

Table 17 Option 1A scope of works summary

Description	Site location	Water source	Discharge location	Infrastructure scope of works
Lake Albert to Coorong North Lagoon passive connector – channel	Open farmland between Bascombe Bay and Coorong North Lagoon	Lake Albert (Bascombe Bay)	Coorong North Lagoon	• 13.3 m base width trapezoidal channel with one vertical to four horizontal (1V:4H) batter slope, 1,811 m long (landside) plus 2,020 m long channel connection dredging into Lake Albert and Coorong North Lagoon. • Upstream regulator structure: five 2.7 m x 2.7 m reinforced concrete box culverts, two

Description	Site location	Water source	Discharge location	Infrastructure scope of works
				lay-flat gates and five penstocks. • Central sheet pile cut-off wall to regulator structure to ensure seepage mitigation. • Fishway (rock riffle style).

Option 1B

As an alternative to the open channel design of Option 1A, a piped connection between Lake Albert and Coorong North Lagoon was investigated.

The pipes discharge from Lake Albert (Bascombe Bay) via an inlet flow regulating structure that sits beneath Narrung Road. On discharge from the flow regulating structure, the pipes deflect (through a junction pit) to remain within the Seven Mile Road corridor, before discharging into Coorong North Lagoon via an outlet headwall structure. An overview of the selected alignment is shown in Figure 4.

This alignment minimises the length of pipeline that is required to achieve the connection and makes use of the existing unsealed road corridor (Seven Mile Road). Table 18 details the infrastructure proposed for this option. Section 6.2.2 discusses the associated hydraulic design.

Table 18 Option 1B scope of works summary

Description	Site location	Water source	Discharge location	Infrastructure
Lake Albert to Coorong North Lagoon passive connector – pipes	Seven Mile Road corridor between Bascombe Bay and Coorong North Lagoon	Lake Albert (Bascombe Bay)	Coorong North Lagoon	• Seven DN2100 reinforced concrete pipes x 1,514 m long • Upstream regulator structure: five 2.7 m x 2.7 m reinforced concrete box culverts, two lay-flat gates and five penstocks. • Central sheet pile cut-off wall to regulator structure to ensure seepage mitigation. • Junction pit at alignment bend, downstream of regulator structure (approximately 23 m wide x 3–13 m varied length x 4.5 m deep)

6.2.2 Lake Albert connector channel (Option 1A) hydraulic design

Objectives

Hydraulic design was completed for alignment Option 1A using open channel flow hydrological software (HEC-RAS v5.0.7) to simulate one-dimensional uniform flow conditions for varied tailwater levels. The objectives of the analysis were to:

- Determine a suitable trapezoidal channel base width to convey the desired 1,000 ML/d under minimum operating conditions (head differential between Lake Albert and Coorong North Lagoon).

- Consider the actual water levels within Lake Albert and Coorong North Lagoon and therefore the frequency of achieving (or possibly exceeding) the target flow rate of 1,000 ML/d.

Design inputs

A 13.3 m channel base width was adopted within the design, informed by the assessments previously completed for a Lake Albert to Coorong North Lagoon connector in a slightly different alignment to this project (SKM, 2014). Using a different hydraulic modelling program to that here, the study indicated that with this channel base width, using 2011 historical water levels:

- The flow through the channel would be 980 ML/d for Lake Albert and Coorong North Lagoon levels of 0.5 mAHD and 0.3 mAHD, respectively.
- Flow rates often exceeded design discharge (up to double the design flow) at times due to either higher Lake Albert water levels or water level difference between Lake Albert and Coorong North Lagoon being greater than 0.2 m.

Noting the results, applying these design conditions to Option 1A suggested the target flow rate of 1,000 ML/d could be achieved. This included varying the Lake Albert and Coorong North Lagoon water levels but maintaining a +200 mm driving head differential (the minimum considered to provide flow through the channel to the Coorong North Lagoon).

Methodology

The channel cross-sections and surrounding topography were exported directly from civil terrain software (12D) into the HEC-RAS geometry file. The geometry was then manipulated to include an extension at each end of the channel to simulate the large expansion in cross-section as the channel transitions into the Coorong North Lagoon (downstream) and from Lake Albert (upstream).

The model incorporated a bridge and culvert crossing at Narrung Road comprising five 2.7 m wide reinforced concrete box culverts with 2.7 m long culvert legs on a cast in-situ reinforced concrete base. The crossing infrastructure includes flow regulation via penstocks and lay-flat gates, and a fishway (not modelled).

Table 19 and Table 20 summarise the HEC-RAS model parameters adopted for the Lake Albert connector channel and regulator crossing structure, respectively.

Table 19 HEC-RAS model conditions

Parameter	HEC-RAS model input value (channel)
Design flow (target)	11.6 m^3/s (1,000 ML/d)
Base width	13.3 m
Side slope	One vertical to four horizontal (1V:4H)
Manning’s roughness, n	0.035
Cross-section expansion coefficient, k	0.3
Cross-section contraction coefficient, k	0.1
Upstream invert (Lake Albert, Narrung Road culvert crossing)	–1.0 mAHD
Downstream invert (Coorong North Lagoon outfall)	–1.48 mAHD
Channel length (landside)	1,811 m

Table 20 Culvert crossing (Narrung Road) parameters

Parameter	HEC-RAS model input value (upstream culvert crossing)
Structure	5 x 2700 mm wide x 2700 mm high x 12,000 mm long reinforced concrete box culvert
Manning's roughness, n	0.013 (top and bottom)
Cross-section expansion coefficient, k	0.4
Cross-section contraction coefficient, k	1.0

Tailwater levels in the Coorong North Lagoon were set as the boundary condition, investigated in 100 mm increments ranging from -0.4 mAHD up to 1.0 mAHD. An iterative approach was undertaken to determine the flow capacity of the channel for each tailwater condition given an assumed 200 mm driving headwater.

Results

Hydraulic design

The results of the one-dimensional steady-state flow analysis for a trapezoidal channel with 13.3 m base width are summarised in Table 21.

As demonstrated, the design flow of 1,000 ML/d is only achieved for a 200 mm driving headwater when the water surface elevation in Coorong North Lagoon is approximately +0.43 mAHD or higher. Flows of this magnitude can still occur when the tail water condition is below +0.43 mAHD; however, a larger head difference between Lake Albert and the Coorong is required to increase flow depth in the channel.

The results show that the 13.3 m wide trapezoidal channel is sufficient to convey a flow of 1,000 ML/d, with minor head losses anticipated at the regulating structures assuming a culvert configuration commensurate with the five 2.7 m wide reinforced concrete box culverts modelled.

Table 21 Summary of channel flows in Lake Albert connector channel with an approximate 200 mm driving headwater

Coorong North Lagoon water surface elevation (mAHD) (downstream)	Lake Albert water surface elevation (mAHD) (upstream)	LAC Flow rate, Q (m3/s)	LAC Flow rate, Q (ML/d) (measured at CNL outfall)	Velocity (m/s)	Water surface elevation at regulator crossing (m)	Regulator crossing freeboard (m)	Water surface top width at Coorong North Lagoon outfall (m)
-0.40	*-0.21*	*3.6*	*311*	*0.28*	*-0.23*	*1.89*	*19.11*
-0.30	*-0.11*	*4.3*	*372*	*0.29*	*-0.13*	*1.79*	*19.82*
-0.20	*0.01*	*5.2*	*449*	*0.31*	*-0.03*	*1.69*	*20.58*
-0.10	*0.09*	*6.0*	*518*	*0.32*	*0.07*	*1.59*	*21.29*
0.00	*0.19*	*7.0*	*605*	*0.33*	*0.17*	*1.49*	*22.04*
0.10	*0.29*	*7.8*	*674*	*0.34*	*0.26*	*1.40*	*22.71*
0.20	0.39	8.9	769	0.35	0.36	1.30	23.46
0.30	0.49	10.0	864	0.36	0.46	1.20	24.19
0.40	0.59	11.2	968	0.37	0.56	1.10	24.93

Coorong North Lagoon water surface elevation (mAHD) (downstream)	Lake Albert water surface elevation (mAHD) (upstream)	LAC Flow rate, Q (m3/s)	LAC Flow rate, Q (ML/d) (measured at CNL outfall)	Velocity (m/s)	Water surface elevation at regulator crossing (m)	Regulator crossing freeboard (m)	Water surface top width at Coorong North Lagoon outfall (m)
0.50	0.69	12.4	1071	0.38	0.66	1.00	25.65
0.60	0.79	13.6	1175	0.38	0.75	0.91	26.37
0.70	0.89	15.0	1296	0.39	0.85	0.81	27.11
0.80	1.00	16.4	1417	0.40	0.95	0.71	27.84
0.90	1.09	17.8	1538	0.41	1.05	0.61	28.57
1.00	1.19	19.3	1659	0.41	1.15	0.51	29.3

It is noted that transfers from Lake Albert to the Coorong North Lagoon are unlikely to occur for a Lake Albert water level of less than 0.4 mAHD (corresponding Coorong North Lagoon water level of 0.2 mAHD in the table) considering current operating rules applied to Lake Albert. These results are shown in italics within the table.

Erosion protection

Typical velocity in main channel is around 0.4 m/s and lower (for 200 mm driving head scenario, see Table 21), indicating that erosion of sand banks will not typically be expected. Although the native sand layers are expected to be weakly cemented, further testing on solubility or dispersion potential of expected materials should be completed in further stages of design to confirm suitability of an unlined channel.

The batter slope of one vertical to four horizontal (1V:4H) has been selected to allow a stable batter to be achieved at around 14°, substantially less than the angle of repose expected for the native sand present in the channel alignment.

Frequency of occurrence for 1,000 ML/d

As noted, the minimum driving head from Lake Albert was the key engineering constraint for the design of the channel, to ensure the target 1,000 ML/d could be achieved when under the minimum conditions. A supplementary exercise was to consider the frequency of the 1,000 ML/d target occurring and the likelihood of exceeding this flow rate, based on the actual water levels of Lake Albert and Coorong North Lagoon.

Led by the DEW team, a relationship between water levels and available flow was developed and interrogated. Based on historical water levels in the Coorong and Lake Albert from 1 January 2011 to 31 May 2011 it was found that:

- Hydraulic capacity of the channel was greater than 1,000 ML/d approximately 90% of the time based on water level difference between Lake Albert and Coorong North Lagoon.
- The Coorong water level was higher than that in Lake Albert for 1.2% of the time. During these times there would be no discharge from Lake Albert to the Coorong.
- There are other times when there is not enough flow in the River Murray to allow discharge through the Lake Albert open channel.

Channel dimension optimisation (Option 1A)

In assessment of the Lake Albert connector open channel design, a sensitivity check was completed on the spoil volumes expected to be generated in construction of the channel. Table 22 presents a summary of the expected volumes to be generated from either dredging or excavation along the proposed alignment for a narrower and a wider channel width than that adopted. Typically, the variance in spoil volume is within 10% of the 13.3 m width for the terrestrial alignment and within 20% of the 13.3 m base width for the dredged alignment.

Table 22 Option 1A spoil volume

Open channel base width (m)	Dredge volume in Coorong North Lagoon (m^3)	Landside cut volume between Coorong North Lagoon and Lake Albert (m^3)	Dredge volume in Lake Albert (m^3)	Total (m^3)
10.0	10,850	240,069	6,733	257,652
13.3	13,311	267,379	8,348	289,038
16.0	15,324	289,763	9,670	314,757

Considering the practicality of the volume of material to be dredged or excavated under the selected open channel dimensions, it is assumed that spoil generated from the excavation operations to form the channel will be stockpiled adjacent to the open channel. This will require creation of a wider easement but will minimise disposal costs for the surplus spoil. This approach has typically been adopted in creation of similar open channels in the south east of South Australia. Additionally, vegetating these spoil mounds will reduce erosion.

For dredged volumes, it is proposed that the dredged material from a cutter suction dredge process will be managed via land-based dewatering ponds. Clarified water will be returned to the nearest water body. This dredged material disposal method differs to that proposed for the major capital dredging program required as part of the Option 2 concept design and supporting Coorong South Lagoon construction activities.

It is possible that a productive use may be able to be identified for the spoil. This can be explored through further stages of design should Option 1A be selected to progress into future stages of design. This may include road or track construction, filling of low-lying areas or replacement of eroded environments.

6.2.3 Lake Albert connector pipes (Option 1B)

Hydraulic Design

For the Lake Albert connector pipe system, reinforced concrete (RC) pipe was selected as the preferred pipe material. RC pipe was selected due to the cost benefit that RC pipe offers at the sizes required to convey the design flow. The adopted pipe dimensions for RC pipe were taken from the Humes design catalogue and are presented in Table 23. Table 24 lists the hydraulic design parameters adopted to determine the quantity of pipes required to convey the target design flow.

Table 23 Pipe dimensions

Pipe material and size	Outside diameter (mm)	Wall thickness (mm)	Inside diameter (mm)
DN1800 RC Class 4 pipe RRJ (belled socket)	2032.0	122.0	1788.0
DN2100 RC Class 4 pipe RRJ (in wall)	2388.0	194.0	2100.0

Table 24 Hydraulic design parameters for Lake Albert connector piped system (Option 1B)

Parameter	Value
Design flow (target)	11.6 m^3/s (1,000 ML/d)

Parameter	Value
Difference between headwater and tailwater level (target)	200 mm
Upstream invert (Lake Albert, Narrung Road culvert crossing)	-2.00 mAHD
Downstream invert (Coorong North Lagoon outfall)	-2.20 mAHD
Pipe length	1,458 m
Pipe grade (constant)	0.0137%
Specific gravity	1.00
Vapour pressure (kPa)	-98 kPa
Manning's roughness	0.013
Darcy-Weisbach	0.6 mm
Total minor loss coefficient	1.7

Methodology

The flow down the pipe system is governed by the flow condition that creates the largest flow restriction in the pipe – this is either inlet or outlet control (meaning the system is either governed by the headwater or tailwater level). The pipe invert levels were selected such that the pipe will be submerged at the upstream and downstream ends under all operating conditions, which results in an outlet control condition governing the flow in the pipe.

As a result, analysis on the pipe was performed by trialling several different design flow conditions and calculating the resultant headwater based on a tailwater level. This approach means that trial and error is required to determine the required design flow that reaches the target difference in elevation between the water level in Coorong North Lagoon and the water level in Lake Albert (assuming full pipe flow).

While there are many variables that can be altered to change the flow in each pipe, the following were varied to assess the difference in performance along the pipe system:

- Pipe size.
- Number of pipes.

Results

Darcy-Weisbach method

To assess the losses through the network, the Darcy-Weisbach equation was initially used to understand the frictional and minor losses that occur in the pipeline (assuming full pipe flow).

From the analysis it was found that to be able to convey a design flow of 1,000 ML/d down a single pipe and achieve a head differential of 0.2 m between Lake Albert and Coorong North Lagoon, an internal diameter of 4,500 mm in a single pipe arrangement is required. There is no commercially available pipe material which can produce a pipe of this size; hence, a multiple pipe solution was explored.

From discussions with suppliers, a typical upper limiting pipe size that remains economical is DN2100. For pipe sizes larger than DN2100, the haulage costs increase because of the significant increase in pipe weight and therefore the increase in vehicle size required for transport.

When considering DN1800 pipe, it was found that 10 pipes would be required to deliver 1,000 ML/d from Lake Albert to Coorong North Lagoon under the design head differential. When analysing this against DN2100 pipe, it was found that only seven pipes would be required. As a result, seven DN2100 pipes were adopted for the pipe system.

Impact of varying water levels between Lake Albert and Coorong North Lagoon

Similar to the results of the analysis performed for Option 1A, as the differential head increases, a larger flow will be conveyed through the pipe culvert system. The analysis above assumes full pipe flow occurs due to submergence of the inlet and outlet across the range of headwater and tailwater conditions. It is plausible that this will not always be the case. To assess the performance of the system under other scenarios, alternative calculations were completed.

Under rare instances (should Coorong North Lagoon level fall below -0.1 mAHD) it is possible that the tailwater is so low that the outlet at Coorong North Lagoon is not submerged, in which case the flow is governed by inlet control. To assess the flow capacity of the pipe, hydraulic design flow charts were used to assess the required ratio of headwater to pipe diameter to achieve a specified design flow. For seven DN2100 pipes, to achieve a design flow of 1,000 ML/d, each pipe will need to achieve a minimum flow rate of 142 ML/d (assuming each pipe flows equally). Based on this, the headwater to pipe diameter ratio is less than 1, hence the headwater does not need to submerge the pipe to achieve the design flow.

Manning's method

This assessment is further validated by a Manning's equation assessment, which demonstrates that for the design slope of 0.0137% (constant grade between Lake Albert and Coorong North Lagoon), a DN2100 pipe has capacity to flow 2029 L/s, which is greater than 1,643 L/s (142 ML/d). At a design flow of 1,643 L/s, a DN2100 pipe flows approximately 68% full, hence it is expected that to achieve the design flow through the pipe system, the headwater level in Lake Albert needs to be a minimum of 1.43 m above the invert of the outlet. This correlates to a headwater level of -0.572 mAHD (an unlikely scenario).

Recommended infrastructure

The results show that the pipe system is sufficient to convey a flow of 1,000 ML/d, assuming a pipe system configuration commensurate with seven DN2100 RC Class 4 pipes. Table 25 summarises the volume of cut associated with infrastructure option assuming open cut installation. Note this volume may be optimised with the use of pipe-jacking, the application of which is dependent on the preferred contractor method and geotechnical conditions experienced at discrete installation locations (e.g. presence of rock).

Table 25 Option 1B spoil volume

Trench base width (m)	Dredge volume in Coorong North Lagoon (m^3)	Landside cut volume between Coorong North Lagoon and Lake Albert (m^3)	Dredge volume in Lake Albert (m^3)	Total (m^3)
21.3	20,849	231,627	14,569	267,045

6.2.4 Operating philosophy (Option 1A and Option 1B)

The operation of both Option 1A and Option 1B infrastructure will be controlled by the inlet regulator. This regulator comprises two culvert bays with lay-flat gates and three culvert bays each with a vertical penstock. The lay-flat gates are provided to allow automated control of flow rate discharged into the channel or pipe system when control is required to target a specific flow rate and to ensure water is retained within the Lake Albert system. This will be the typical operating philosophy, as a certain flow rate only will be scheduled for discharge each day.

For smaller daily flow rates, a single lay-flat gate may be utilised but for larger flow rates, both lay-flat gates (potentially even with an open vertical penstock) will be required to achieve flow rates in excess of 1,000 ML/d.

The additional culverts with vertical penstocks can be opened when required to allow greater volumes of flow through should this be necessary under certain operating conditions (e.g. a flood scenario). The vertical penstocks are not intended to regulate flow in undershot mode but instead to be either open or closed.

6.2.5 Areas for further work

Volume and scheduling of inflows

The target flow rate from Lake Albert into the Coorong North Lagoon is set at 1,000 ML/d, as a key design basis for the project. This flow rate has been determined from previous studies considering improvements to Lake Albert and is not necessarily for the purpose of improving the Coorong system.

Though it has been determined that greater flow volumes can be achieved for the majority of days, the project is not considering any greater inflows than the 1,000 ML/d at this stage of design. A recommended exercise for later design stages is to optimise the target flow rate specifically for improvements to the Coorong South Lagoon, with consideration given to a range of factors such as:

- Future River Murray water availability upstream into Lake Albert, considering future climate predictions (e.g. available barrage flows).
- Seasonal scheduling of varied flows to maximise Coorong South Lagoon improvements without detriment to Lake Albert (will require more detailed modelling).

Generally, a Lake Albert channel with bed width of 13.3 m and side slopes of 1V:4H is considered accurate enough for concept design purposes. If flows greater than 1,000 ML/d are required more often the channel bed width could be increased. Alternatively, a narrower channel could be adopted if the times when the channel can deliver more than 1,000 ML/d are sufficient to produce acceptable ecological benefits in the Coorong.

Detailing of the fishway

Further design into the fishway is required in later project stages from both ecological and engineering perspectives. At this point in the concept design, the fishway has been included to ensure a cost allocation and as a provision for upstream migration of fish into Lake Albert. Additional work required in the later stages includes definition of:

- Fish species expected to use the fishway.
- The most appropriate position of regularly used lay-flat gates to encourage fish passage upstream.
- The requirement for fish movement and for no environmental implications between the Coorong North Lagoon and Lake Albert.
- Target velocities to suit the specific fish species.
- Any additional regulating requirements (engineering, environmental or other).

6.3 INFRASTRUCTURE WITHIN THE COORONG SOUTH LAGOON (OPTIONS 3A, 3B, 3C, 3D, 4A, 5A AND 5B)

The infrastructure under consideration for installation within the Coorong South Lagoon includes pumps and associated pipes and valves. The options which include infrastructure within the Coorong South Lagoon are as follows:

- Option 3A: Intermittent pumped connection out of Coorong South Lagoon – 150 m long discharge jetty.

- Option 3B: Intermittent pumped connection out of Coorong South Lagoon – low visual impact beach discharge structure.
- Option 3C: Pumped connection out of Coorong South Lagoon – 150 m long discharge jetty.
- Option 3D: Pumped connection out of Coorong South Lagoon – low visual impact beach discharge structure.
- Option 4A: Bi-directional pumped Southern Ocean connection – one location, separate pumping stations, pump in location with caisson structure on 350 m long jetty.
- Option 5A: Simultaneous pumped Southern Ocean connection – two locations, separate pumping stations, pump in location with caisson structure on 350 m long jetty and pump out location to 150 m long discharge jetty
- Option 5B: Simultaneous pumped Southern Ocean connection – two locations, separate pumping stations, pump in location with caisson structure on 350 m long jetty and pump out location to a low visual impact beach discharge structure.

For Option 4B and Option 6, a combined inlet and outlet pipe is required to be provided within the Coorong South Lagoon. The inlet will require a fish exclusion screen and the outlet will include a discharge bypass to avoid pumping back through the fish screen. This arrangement is discussed further in Section 6.4.2.

6.3.1 Infrastructure location

There are several infrastructure options that involve the construction of infrastructure within the Coorong South Lagoon, as identified in Table 2. Two locations were considered for constructing infrastructure within the Coorong South Lagoon, on the eastern side and on the western side, as shown in Figure 5.

Figure 5 Potential infrastructure location within the Coorong South Lagoon

When constructing infrastructure on the eastern side of the Coorong South Lagoon, this could be accomplished through a pump station installed on land adjacent the Princes Highway or within the lagoon on the eastern side. The benefit of these options is that the majority of the materials does not need to be transported across the Coorong South Lagoon; however, the large downside is that the pump station discharge pipeline needs to be installed across the width of the Coorong.

Construction of any large bore pipeline across the Coorong will be very difficult, based on early conversations with Fulton Hogan, and it was subsequently deemed not to be feasible due to construction difficulty and cost implications. In addition, installing a floating pipeline across the Coorong will inhibit north–south boat access, unless the pipe is buried below the Coorong bed.

The benefit of constructing the infrastructure on the western side of the Coorong South Lagoon is that a discharge pipeline is not required to be installed across the Coorong, which would restrict water circulation and create a navigational hazard. Conversely, the main downside of the western side is that all materials required to construct the infrastructure need to be transported to Younghusband Peninsula or across the Coorong South Lagoon.

Beach transport will be difficult, given the extent of haul distance and variable beach conditions. Only select plant will be able to operate on the beach (e.g. Moxy trucks, four-wheel drives (including utility vehicles), crawler cranes and other tracked equipment).

It is proposed that a purpose-built barge system be utilised for hauling most of the plant, equipment and materials across the Coorong South Lagoon. This proposed transport approach could service both construction and ongoing operational needs. Even with the barge system, beach transport of some equipment or materials may still be required however (e.g. rock for breakwaters and large equipment that is unable to be transported via the barge).

These two location options were discussed in detail with Fulton Hogan and presented to DEW at the concept design refinement workshop. It was agreed that constructing infrastructure on the western side of the Coorong South Lagoon was the preferred location due to the implications of installing a large bore pipeline across the Coorong.

6.3.2 Infrastructure type

Several pump types were considered for construction within the western side of the Coorong South Lagoon. Pontoon-mounted pumps were selected after considering water conditions, construction methodology and operational flexibility. A sketch detailing the pontoon-mounted pump design from Option 3A is provided in Figure 6. A jetty extending from Younghusband Peninsula into Coorong South Lagoon with vertical turbine pumps mounted to the end of the structure was also considered. Vertical turbine pumps are most suited to jetty installation given their vertical orientation, positioning of the motor at jetty level and ability to manage net positive suction head requirements with the motor installed at jetty deck level.

For this installation arrangement, the design team determined that the jetty would be a more expensive and challenging option. It is expected that it would require a longer construction period and present other challenges, including achieving the required submergence depth for vertical turbine pumps mounted from a jetty (typically at least 3 m when compared to a pontoon-mounted pump which may only require 1.5 m submergence).

For options with a discharge jetty structure into the Southern Ocean, pumping heads are higher considering the additional static lift when compared to a beach discharge structure. This has typically resulted in selection of a greater number of pumps to deliver the same pumping flow rate or pumps capable of delivering a higher pressure.

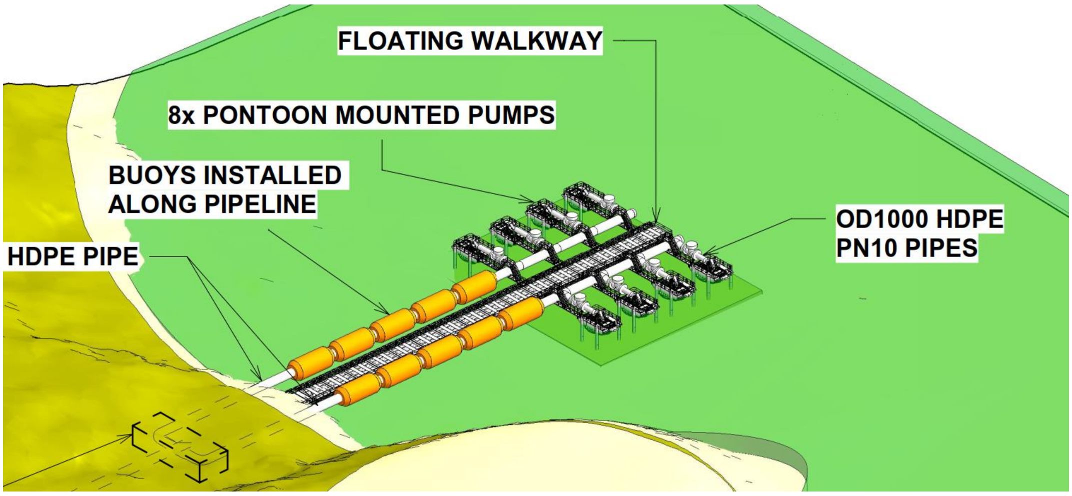


Figure 6 Option 3A pontoon-mounted pump design

Discussions were held with Fulton Hogan comparing a single large pipe with multiple small-bore pipes for the discharge pipework from the pontoon-mounted pumps through Younghusband Peninsula. Using multiple small-bore pipes provides the opportunity to utilise high density polyethylene (HDPE) instead of glass reinforced plastic (GRP) as HDPE is readily available in smaller sizes. In most buried installations, HDPE is preferable due to the inherent flexibility within the pipe compared to GRP, and it reduces the requirements for thrust blocks. However, it was advised that the pipe installation rate is similar per pipe, even at the reduced sizes. Hence, the construction timeline and the amount of dune excavation required for the pipework through the peninsula would be significantly greater when using multiple small-bore pipes.

In addition to construction disadvantages, installing multiple small-bore pipes may increase the ongoing operational costs and effort. For these reasons, a single large-bore pipe through the Younghusband Peninsula has been nominated for the concept designs.

Where infrastructure options require a discharge pipe to be provided within the Coorong South Lagoon allowing a plunging jet to discharge into the water body, a rock mattress will be provided at the discharge point. This rock mattress may be around 10 m x 10 m in footprint area and at least 1 m thick with rock placed on a geotextile to minimise disturbance of lagoon sediments during operation. A cone valve diffuser nozzle will also be installed onto the end of the discharge pipe to dissipate the energy as it leaves the system, reducing the risk of erosion near the rock mattress.

For the passive pipe option (Option 6), up to 20 valve chambers will be required to allow manual isolation of pipes at the nominated pipe depths. Construction could be completed through installation of a single valve pit to each valve (depending on pipe depth and natural surface level at valve location). Alternatively, a tunnel or gallery structure could be considered in lieu of individual valve pits. For concept design purposes, individual valve chambers have been adopted.

Water conditions

The water within the Coorong is shallow, being between 1 and 5 m depth. For pumps to operate effectively without significant dredging to artificially increase the water depth, they need to have the ability to operate in varying water levels and shallow water. Pumps mounted to pontoons will rise and fall with water level to ensure they are always able to operate, provided the water depth achieves the pump submergence criteria (typically less than other pump types). They are also supplied with level sensors to ensure the pumps do not operate in case the water level drops too low.

As the water within the Coorong has minimal wave action, installation of a floating pontoon system is considered appropriate where pontoon-mounted pumps that can rise and fall as water levels fluctuate. Guide piles will need to be installed to keep the pontoons in place, but there will be no issue with stability, as the water is generally calm, with limited wind fetch[1] for wave generation. Pontoons are not suitable in high wave energy environments, which put large forces on the guide piles and the pontoon structure itself.

The water in the Coorong is hypersaline with a salinity much greater than typical seawater. For this reason, all metallic infrastructure installed within the Coorong needs to be supplied with materials that can withstand hypersaline conditions. The main pieces of metallic infrastructure installed within the Coorong are the pontoon structures, fish exclusion screens and valves. Suppliers have recommended that all valves be supplied in either super duplex or Hastelloy stainless steel to accommodate the harsh water conditions. This has been adopted within the cost estimates, which include valves with suitable material specifications. It is noted that after the system has flushed water through the Coorong South Lagoon, for a period, the salinity levels should drop significantly. It may be possible to optimise materials selection based on predicted concentrations in the short term.

Construction methodology

As the proposed location for the pumping infrastructure is the western side of the Coorong South Lagoon (within or adjacent to Younghusband Peninsula), this requires transporting all the required materials and equipment across the Coorong to Younghusband Peninsula. The benefit of pontoon-mounted pumps is that they float and can be towed to the required location with an appropriate vessel, depending on Coorong water depths at the time. This reduces the effort and cost required to transport the pumping infrastructure compared to other options such as a jetty system or concrete pump chamber.

The construction benefit of pontoon-mounted pumps is that they are assembled and delivered as a complete unit. The pontoon is supplied with the required instrumentation and safety features. The only pump-related construction required on-site is connecting the pontoon pipework to the discharge manifold and installing guide piles for the pontoons. The discharge pipework will be installed next to the floating walkway which is supplied with the pump pontoons. This pipework will be HDPE and will be supplied with buoys to assist with floatation of the pipe.

Based on preliminary feedback from pontoon-mounted pump suppliers, the pumps require a minimum of 1.5 m water depth to operate. Fish exclusion screens will be mounted to the pump intakes, as discussed in section 6.6, which increases the required water depth for all pump infrastructure to operate as intended.

As the current Coorong South Lagoon water depths at the proposed pontoon pump locations do not satisfy the pump requirements, it is expected that a local area beneath the pumps will be dredged to a depth of -4.5 mAHD. Approximate dredge areas for each option, shown in Table 26, will be confirmed during detailed design.

Table 26 Approximate dredge areas beneath pontoon pumps

Option	Area (m x m)	Depth (m)	Volume (m^3)
3A	60 x 50	3.5	10,500
3B	50 x 50	3.5	8,750
3C	50 x 25	3.5	4,375
3D	50 x 25	3.5	4,375
4A	60 x 25	3.5	5,250

[1] Wind fetch is the length of unobstructed water over which a wind can travel in a constant direction to generate swell and wave conditions.

Option	Area (m x m)	Depth (m)	Volume (m³)
5A	60 x 25	3.5	5,250
5B	50 x 25	3.5	4,375

The dredged sumps beneath the pontoon pumps will need to be monitored to assess the need for maintenance dredging. It is expected that these sumps may need to be re-dredged occasionally if sediment build-up begins to affect pump performance.

Flexibility

As minimal permanent structures are required for installing the pontoon-mounted pumps, there is a large degree of flexibility once the project is finished. A single pontoon, or multiple pontoons, can easily be disconnected from the common mooring pontoon and transported to the shore using a barge. This provides opportunities to reuse the pumps for different purposes. Minor servicing of the pumps can be undertaken from the pontoons without disconnecting from the common mooring pontoon, however they will need to be transported to the shore for major overhauls.

6.4 INFRASTRUCTURE WITHIN THE SOUTHERN OCEAN (OPTIONS 3A, 3B, 3C, 3D, 4A, 4B, 5A, 5B AND 6)

The infrastructure under consideration for installation within the Southern Ocean includes jetties, discharge structures, and pumps and their associated pipes and valves. The following options include infrastructure within the ocean:

- Option 3A: Intermittent pumped connection out of Coorong South Lagoon – 150 m long discharge jetty.
- Option 3B: Intermittent pumped connection out of Coorong South Lagoon – low visual impact beach discharge structure.
- Option 3C: Pumped connection out of Coorong South Lagoon – 150 m long discharge jetty.
- Option 3D: Pumped connection out of Coorong South Lagoon – low visual impact beach discharge structure.
- Option 4A: Bi-directional pumped Southern Ocean Connection – one location, separate pumping stations, pump in location with caisson structure on 350 m long jetty.
- Option 4B: Bi-directional pumped Southern Ocean connection – one location, one common pumping station, near shore discharge/intake protected by breakwater.
- Option 5A: Simultaneous pumped Southern Ocean connection – two locations, separate pumping stations, pump in location with caisson structure on 350 m long jetty and pump out location to 150 m long discharge jetty.
- Option 5B: Simultaneous pumped Southern Ocean connection – two locations, separate pumping stations, pump in location with caisson structure on 350 m long jetty and pump out location with a low visual impact beach discharge structure.
- Option 6: Bi-directional passive piped connection into and out of Coorong South Lagoon, ocean pipework with breakwater.

For Option 4B and Option 6, a combined inlet and outlet pipe is required to be provided within the Coorong South Lagoon. The inlet will require a fish exclusion screen and the outlet will include a discharge bypass to avoid pumping back through the fish screen. This arrangement is discussed further in Section 6.4.2.

6.4.1 Infrastructure location

Two locations were considered for the pumping infrastructure installed within the Southern Ocean. The two locations were either 300 m from the shoreline, or at the closure depth at approximately the –15 mLAT contour (4 to 5 km offshore).

The closure depth represents the depth of water at which there is minimal sand in suspension due to wave action. It is directly proportional to the offshore significant wave height. Due to the shallow beach profile of the Southern Ocean adjacent to Younghusband Peninsula, the closure depth is located several kilometres from the shore. The closure depth is important to consider when pumping from the Southern Ocean to the Coorong South Lagoon, as entraining sand into the pump suction will result in a significant quantity of sand being deposited from the ocean to the Coorong South Lagoon when pumping for long durations. This sand will also cause wear to the pumps and pipework.

It is estimated that 10,000 to 15,000 m^3 of sand per annum will be transferred from the Southern Ocean to the Coorong South Lagoon when pumping at a rate of 350 ML/d, which is common to Options 4A, 4B, 5A and 5B. This is based on an approximate assessment considering a range of calculation methods resulting in up to 1.5% of the longshore transport volume being captured by the pump inflows and conveyed to the Coorong South Lagoon. When the pump suctions are located past the closure depth, it is expected that significantly less sand will be entrained into the pump system.

The two locations were compared against several factors, including water depth, sand entrainment, constructability and estimated installation cost. After internal discussions, workshops and meetings with construction partners, it was determined that it was more appropriate to install the pumps at the near shore location, due to the construction difficulties that arise when installing infrastructure to the closure depth (including construction duration). Sand entrainment will be managed at the near shore pumping location with the inclusion of a concrete caisson structure, a breakwater structure, or both. The caisson structure is discussed below. The breakwater is discussed further in Section 8.5.2, as this is considered a maritime structure.

Water depth

The Southern Ocean design bed profile is estimated in Figure 30, which shows a near shore profile of 1:100, much shallower than a typical beach. This becomes important for pump types that require a minimum water submergence to operate effectively (e.g. without vortices). Installing pumps at the closure depth ensures that all pump types have sufficient water depth to maintain their minimum submergence as the water depth exceeds 15 m. The water depth at the near shore location is approximately 2 to 3 m, which may not be sufficient to provide the required pump submergence depth depending on the pump type and supplier.

There are design solutions to increase the water depth if this is required at the near shore location, which involve dredging to reduce the bed level and installing a concrete caisson structure to maintain the dredged depth. Dredging will be localised to the approximate footprint of the concrete caisson structure and may involve 'jetting' of the material beneath the structure. This can artificially increase the water depth locally at the dredged location, providing sufficient pump suction submergence, shown in Figure 7.

It is assumed that the caisson will be installed on a flat sand surface, which will be compacted under the weight of the structure. For caisson structure installation, guide piles will be required to facilitate vertical installation of caisson components and ensure structural integrity.

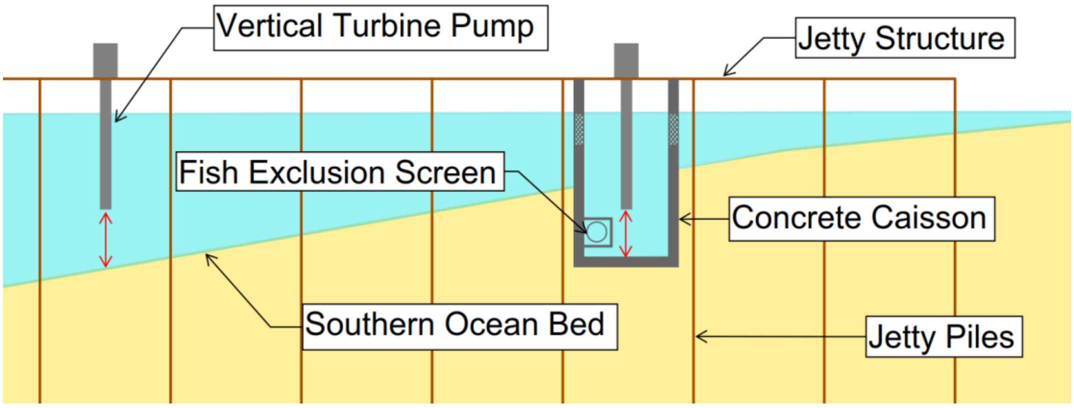


Figure 7 Locally increased water depth design

This construction ensures that a near shore infrastructure location is still viable, while having the benefit that the jetty is shorter than if it was required to extend past the closure depth.

Sand entrainment

As mentioned, there is minimal sand transport past the closure depth. Hence, sand entrainment into the pumps can be reduced when pump suctions are located at or beyond closure depth. By comparison, when pump suctions are located at the near shore areas, sand material is continually entrained throughout the water column due to the wave climate (which provides minimal opportunity to settle sand materials out of suspension). The pump suctions will therefore experience significant sand transport and are very likely to entrain a large quantity of sand over their pumping life if exposed to the open wave climate. Hence, additional infrastructure is required to reduce entrainment of sand material into the system.

In addition to pumps transporting unwanted sand into the Coorong, the design life of the pumps will be reduced if they continuously pump sand. The designs have taken this into consideration and have endeavoured to reduce the quantity of sand that will enter the pumps. It is expected that the design life will not be significantly reduced. During the next stage of design, discussions with pump suppliers can help determine the most appropriate pump materials to maximise the design life of the pumps.

The concrete caisson structure, shown in Figure 7, provides a barrier to reduce the wave energy around the pump suctions. This reduces some of the amount of sand entering the caisson and reduces the quantity of sand entrained into the pumps. Due to the reduced wave energy within the structure, there is opportunity for sand material to fall out of suspension (for removal via slurry pumps) to reduce the sand entrained into the pumps. This construction is a near shore alternative to achieve an equivalent reduction in sand entrainment if the pumps were to be installed beyond the closure depth.

The caisson structure is suitable for options that include pumps mounted on a jetty within the Southern Ocean (Options 4A, 5A and 5B), as the jetty is required to facilitate the construction of the caisson.

For Option 4B, where there are no pumps in the ocean, a jetty is not required. A porous breakwater structure is therefore more suitable to reduce sand entrainment, as a permanent jetty structure would need to be constructed to allow the caisson and buried ocean floor pipework to be installed. Breakwater construction is still a challenging proposition but occurs in a less precise manner than jetty and caisson construction, and will provide improved protection for the buried pipe from wave action.

Construction of a permanent jetty structure and caisson would facilitate the installation of a subsea pipe and could be considered as an alternative in future design stages. For this alternate option, the pipe could be installed at a greater depth, without the need for protection against erosion of the cover to the pipe or installed at shallow depth with provision of rock or other protection. Given the level of effort required to construct this subsea pipe, this may not be a recommended solution and was not considered further at this stage.

Constructability

Fulton Hogan provided guidance on the constructability of near shore infrastructure compared to closure depth infrastructure. There will be challenges in constructing infrastructure at both locations, due to the high wave energy in the Southern Ocean.

The challenge with near shore infrastructure construction is that a concrete caisson or equivalent structure needs to be installed to reduce the wave energy and sand entrainment. Construction is proposed within a highly active surf zone and relatively shallow depths due to the flat bathymetry of the site and has only a limited window for ideal construction conditions. Therefore, the most appropriate construction methodology involves installing the caisson from a jetty. This results in the addition of a jetty just to enable the installation of the caisson, which is a large additional cost. However, much larger challenges are associated with construction of infrastructure to closure depth.

Whether the infrastructure comprises a jetty or a trenched pipeline, the construction becomes very challenging when moving further from the shore. An anticipated pipe installation production rate of 6 to 9 m per day for infrastructure of this magnitude is expected, which would result in construction lasting two to three years for a piped system to closure depth.

Due to the construction challenges and expected pipe production rate, it is recommended that infrastructure be restricted to near shore locations.

Installation cost

The cost to construct the required infrastructure to closure depth will be very significant, due to the length of either trenched pipe or jetty required. The cost of 4 to 5 km of pipe alone is significant, which, combined with the supporting infrastructure, makes it difficult to justify locating infrastructure to reach closure depth.

While the near shore options may require additional infrastructure – such as a concrete caisson – to achieve the required water depth and sand removal, this infrastructure is expected to cost approximately a third the cost of infrastructure constructed to closure depth.

6.4.2 Infrastructure type

Pumping infrastructure

Assessment began with a review of infrastructure to support the proposed pumps. Due to the high wave energy within the Southern Ocean, a permanent and stable structure is required. A jetty is considered the most suitable structure to support the pumps and pipework. This is because of the stability that a jetty can provide in addition to the high expected design life. The jetty deck can also be constructed above maximum wave heights, and construction can occur progressively from shore rather than using floating plant (described in Section 8.5.1). Another advantage is that the jetty also provides reliable, and permanent, access to the pump station location for maintenance, inspection and other operational activities.

Jet pumps were considered as a possible pump type to be supported by a jetty. However, jet pumps operate at high velocities to achieve high suction pressures, are likely to entrain aquatic life and tend to operate at poor efficiency.

Submersible pumps were also considered as a pump type within the Southern Ocean. These pumps are commonly used within water bodies because they can be fully submerged in a permanent installation, creating more ideal net positive suction head (NPSH) conditions. However, the efficiency of the pumps is inferior compared to other pumping options that were able to be installed from a jetty. This is because submersible pumps are more commonly designed for small flow rates and are not readily available at the large flow rates required for this project.

Because these pumps have large drives and are expected to pump for long durations, the ongoing electricity cost is substantial – it is expected to be in the range of millions of dollars annually. For this reason, improving the pump efficiency by only a few percentage points can make significant cost savings to operating costs and reduce environmental impacts.

Vertical turbine pumps were considered, as they are commonly used for seawater pumping, and the pump column can be customised to ensure the pump suction will have sufficient submergence from the high jetty deck height. A suitable vertical turbine pump was selected in consultation with suppliers. It is also available in materials suitable for seawater. Vertical turbine pumps were selected as the most suitable pump type and have been included in the following options:

- Option 4A: Bi-directional pumped Southern Ocean connection – one location, separate pumping stations, pump in location with caisson structure on 350 m long jetty.
- Option 5A: Simultaneous pumped Southern Ocean connection – two locations, separate pumping stations, pump in location with caisson structure on 350 m long jetty and pump out location to 150 m long discharge jetty.
- Option 5B: Simultaneous pumped Southern Ocean connection – two locations, separate pumping stations, pump in location with caisson structure on 350 m long jetty and pump out location with a low visual impact beach discharge structure.

Passive pipework

Option 6 comprises 10 DN2000 pipes installed through Younghusband Peninsula, connecting the Southern Ocean to the Coorong Southern Lagoon. There are no pumps required for this option and hence no power is consumed, making this the most environmentally friendly option from a power perspective. Instead, it relies on differing water levels to promote water exchange between the water bodies. Twenty concrete valve pits are required, which will be manually actuated. Figure 8 depicts the passive pipelines within Option 6.

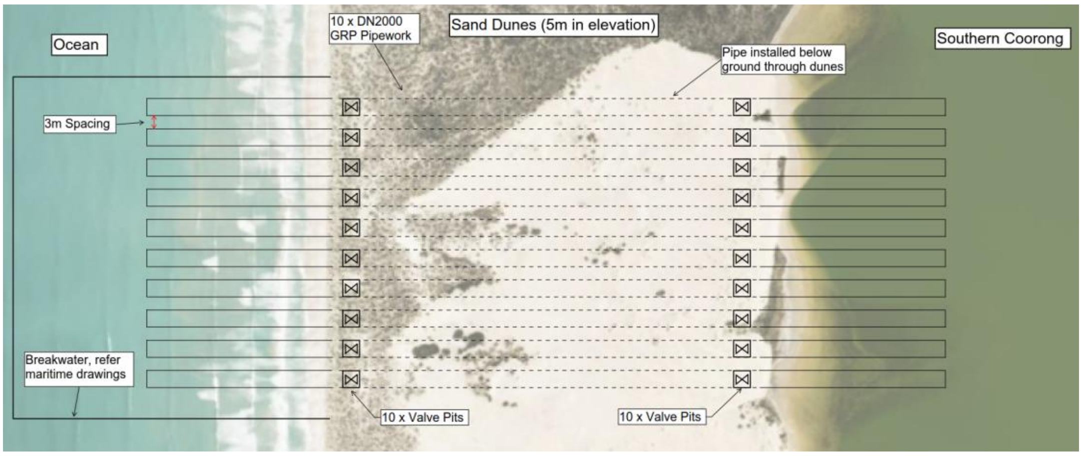


Figure 8 Option 6 site layout sketch

As there is no pumped flow to frequently scour the pipelines, there is an inherent risk of sand entering the pipelines from the Southern Ocean and sediment deposits or marine growth building up within the pipelines. For this reason, sand mitigation infrastructure is required to reduce the risk of sediment build-up, as this will have detrimental impacts to the effectiveness of the design.

A breakwater structure that surrounds the ocean pipelines has been included, as shown in Figure 8. The breakwater structure comprises primary armour (concrete Tetrapod units) and a reinforced concrete crest walkway for required access and inspection or maintenance. The breakwater is intended to provide a permeable wall that dissipates wave energy from the Southern Ocean. This will cause the sand and sediment to drop out of suspension and settle on the ocean floor once it has passed through the breakwater, greatly reducing the likelihood of wave energy transporting the sand and sediment into the pipelines.

The concrete crest wall is provided to increase the effective height of the breakwater to reduce overtopping flows allowing for less sand transfer into the protected water area. The inclusion of the crest wall allows a reduction in the total volume of secondary armour required providing a constructability benefit in reducing the volume of rock to be transported from a quarry.

The breakwater has been designed to a height such that minor overtopping will occur to assist with the flushing of water within the breakwater. The levels of overtopping fall within the allowable limits based on EurOtop II (2016) guidance. This overtopping will occur over the crest wall which has been set at a height to limit the influence of wave action and sand entrainment into the protected water zone, whilst reducing the final volume of secondary armourstone required for breakwater construction.

The pipe intakes are located at an offset to the breakwater area, such that the turbulence created from overtopping does not reach the intakes.

Some movement of sediment through the breakwater is possible, given the porosity of the structure. The amount of material will fluctuate (i.e. with a temporary vacuum created due to drawdown from overtopping water and tidal fluctuations). Most sediment movement through the breakwater is anticipated to be migration of bed materials.

While measures have been taken in the designs to reduce the quantity of sand entering the passive pipework, there will still be a small amount that finds its way into the pipes. Depending on the quantity and size of the particles, this may cause blockages in the long-term that will need to be managed by the operations personnel through jet blasting or pigging. Isolation valves in valve pits have been included at either end of each pipeline to enable the operators to isolate individual pipelines if significant servicing and maintenance is required. Design of these valve pits along with the operating philosophy (manual or actuated) will be reviewed during the next stage of design.

Construction of the passive pipes to the closure depth within the Southern Ocean was considered; however, the constructability and cost implications mentioned in section 6.4.1 are multiplied, due to the number of pipes that would need to be installed past the closure depth. This was immediately ruled out as a viable option, and instead, the breakwater structure was utilised.

Discharge infrastructure

When discharging water into either the Coorong South Lagoon or the Southern Ocean, appropriate discharge structures are required to ensure there are no unnecessary negative impacts to the aesthetics of the area, and access along the Southern Ocean beach can be managed.

Discharging into the Southern Ocean is more difficult than discharging into the Coorong, as installing pipework and discharge structures in the ocean is challenging due to the high wave energy. For this reason, two designs were considered when discharging into the Southern Ocean – one that discharges on the beach (Options 3B and 3D) and another that discharges 100 m into the ocean from a 150 m long jetty discharge structure (Options 3A and 3C). The beach discharge structure was intended as a low visual impact structure (no jetty or breakwater), with a simplified construction process, as it utilises land-side construction techniques in place of more complex marine construction.

Low visual impact shore discharge structure

Discharging onto the shore is much simpler from a constructability perspective, but there are potential access restrictions associated with the beach discharge. A shore discharge design was developed which involves discharging onto a concrete apron with piles to settle the flow and then having the water flow to the ocean over a Flexmat product (a concrete block matting). The Flexmat is partially buried and anchored in place, such that it prevents sand erosion below the mat but also reduces the visual impact to the beach. This design, shown in Figure 9, is included in the following options:

- Option 3B: Intermittent pumped connection out of Coorong South Lagoon – low visual impact beach discharge structure.
- Option 3D: Pumped connection out of Coorong South Lagoon – low visual impact beach discharge structure.
- Option 5B: Simultaneous pumped Southern Ocean connection – two locations, separate pumping stations, pump in location with caisson structure and pump out location with a low visual impact beach discharge structure.

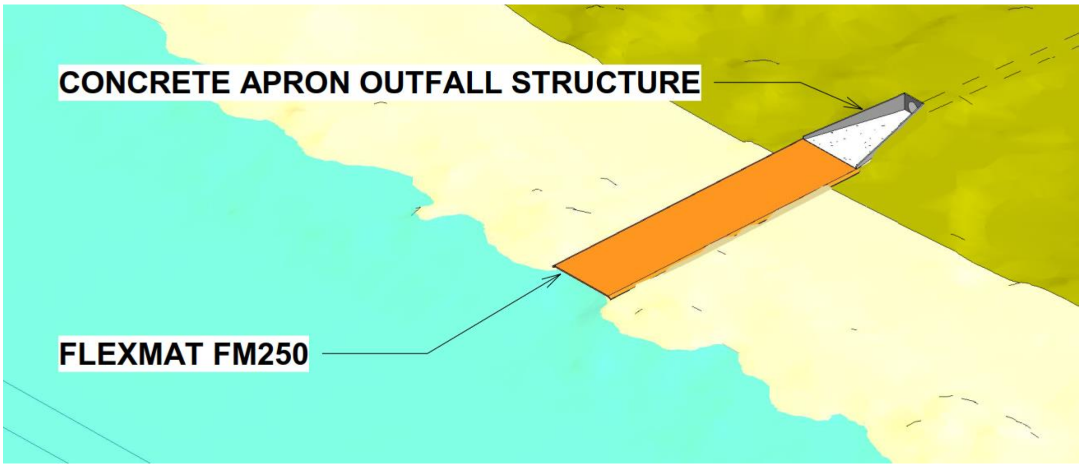


Figure 9 Low visual impact beach discharge structure

Discharge jetty

Discharging into the ocean requires infrastructure to support the discharge pipe 150 m into the Southern Ocean. It was deemed too difficult to bury the pipe directly in a trench out to the discharge location, as most of the pipe would need to be concrete encased to prevent the wave energy from displacing the pipe. A small jetty was included to support the discharge pipe for the options where it was discharging 150 m from the shore. The profile of this jetty is shown in Figure 10 and is present in the following options:

- Option 3A: Intermittent pumped connection out of Coorong South Lagoon – 150 m long discharge jetty.
- Option 3C: Pumped connection out of Coorong South Lagoon – 150 m long discharge jetty.
- Option 5A: Simultaneous pumped Southern Ocean connection – two locations, separate pumping stations, pump in location with caisson structure on 350 m long jetty and pump out location to 150 m long discharge jetty.

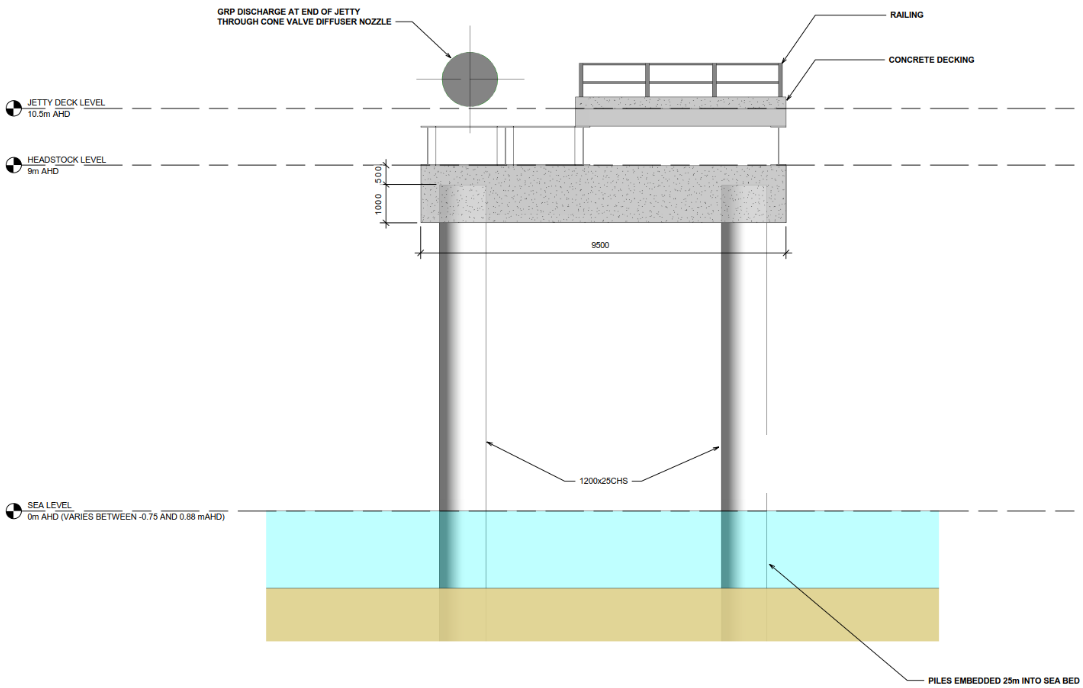


Figure 10 Discharge pipe jetty profile

As shown in Figure 10, a diffuser nozzle is to be installed on the end of the discharge pipework. This nozzle will take the form of a cone valve and is intended to reduce the velocity and energy of the large quantity of water prior to discharging into the ocean. Figure 11 illustrates the function of a cone valve.

Figure 11 Cone valve diffuser nozzle

Buried intake/discharge structure

While it is too challenging to directly install pipework in a trench within the Southern Ocean, a breakwater can be incorporated to reduce the wave energy, which is detailed in Section 8.5.2. When a breakwater is present, trenching pipes in the Southern Ocean becomes feasible. It is expected that a coffer dam could be constructed inside the breakwater in the Southern Ocean with sheet piles driven by excavators on barges, considering Fulton Hogan's advice presented in Appendix L. This would enable discharge pipework from pumps to be trenched in the Southern Ocean in relatively dry conditions to the required depth.

This discharge pipe methodology was adopted for several options, and two variations were designed. While the discharge pipes from pumps are used only for discharge in most options, pipes are used for both intake and discharge for Option 4B. This option comprises a single pipe with each end acting as both an intake and discharge pipeline and the pump station can pump in both directions. For this reason, flooded suctions are required at each end to enable pumping, and the entire pipe will be buried with a different intake/discharge design, shown in Figure 12.

When the structure needs to act as an intake structure, water is drawn through the fish screen end but is unable to enter through the bell mouth, due to a check valve. The fish screen has a large surface area, designed such that the required quantity of water can enter the screen, while reducing the velocity to a suitable level such that fish are not entrained into the screen. When the structure needs to discharge, the check valve adjacent to the fish screen prevents flow in this direction, forcing all flow out of the bell mouth.

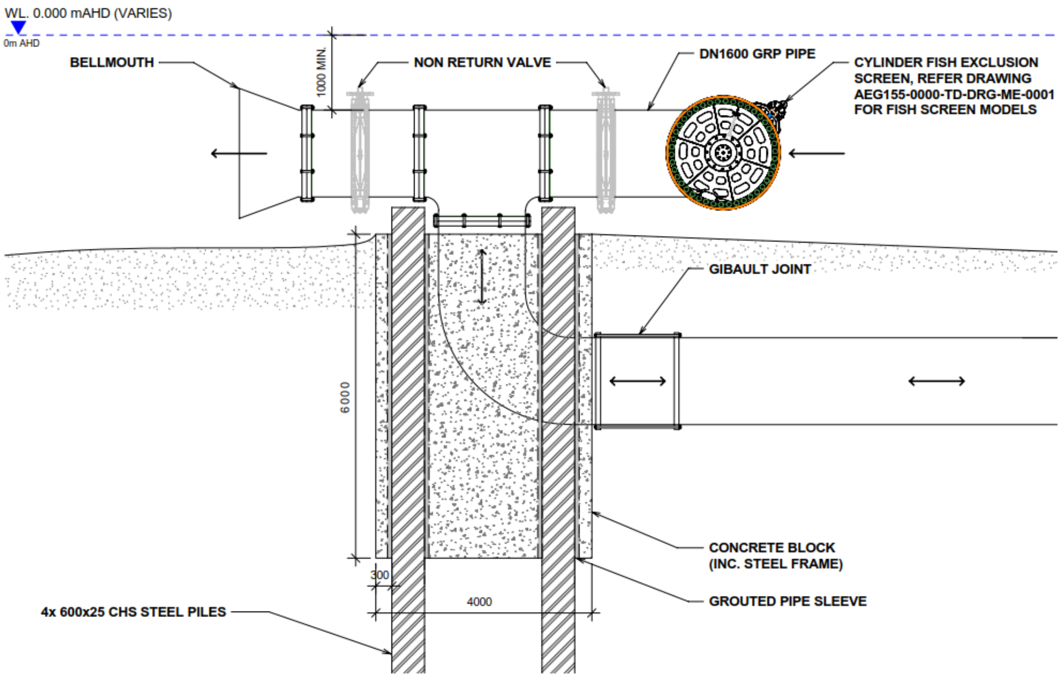


Figure 12 Option 4B intake/discharge structure

These discharge structures are located approximately 100 m from the shore, and the pipes are installed below the Southern Ocean bed between the shore and the structure.

The discharge-only structure design shown in Figure 13 is simpler, requiring only the bell-mouth outlet. A concrete block with steel piles is included to secure the discharge pipe in place and resist wave energy and currents.

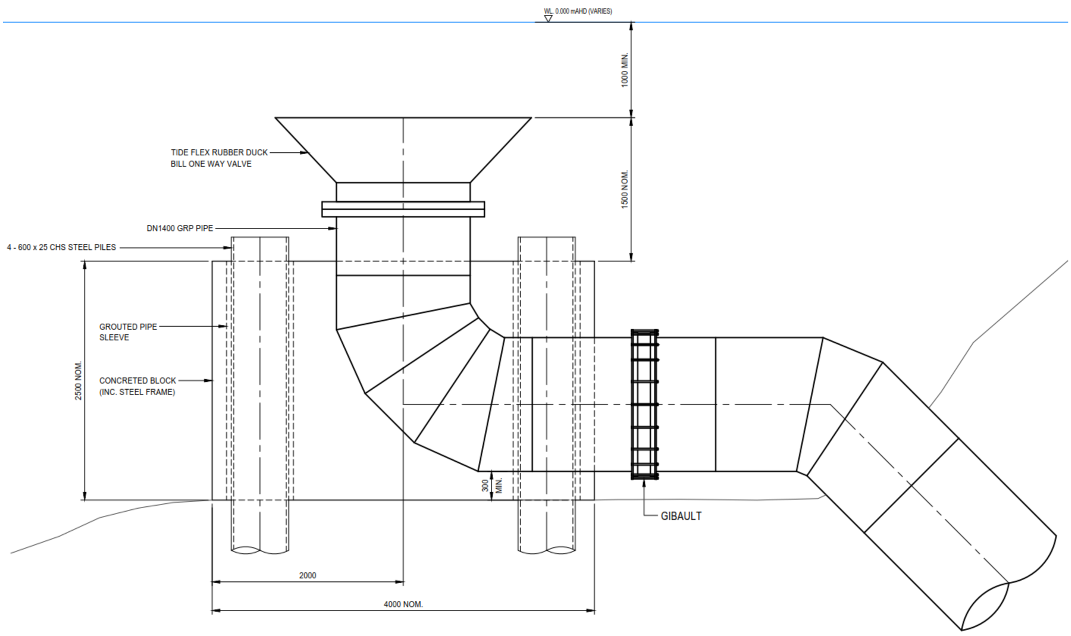


Figure 13 Pumped discharge structure

This discharge structure shown in Figure 13 was adopted for the remaining pump discharge pipes within the Coorong South Lagoon. As there is minimal to no wave energy within the Coorong, this structure does not need to be paired with a breakwater.

The pumped discharge structure is included within the following options:

- Option 5A: Simultaneous pumped Southern Ocean connection – two locations, separate pumping stations, pump in location with caisson structure on 350 m long jetty and pump out location to 150 m long discharge jetty.
- Option 5B: Simultaneous pumped Southern Ocean connection – two locations, separate pumping stations, pump in location with caisson structure on 350 m long jetty and pump out location to a low visual impact beach discharge structure.

It is expected that the velocity within the pipelines provided by the pumps will be sufficient to scour the lines and remove a large quantity of marine growth.

The discharge structure for Option 6 is different in that it is not fed by pumps. The water flow is passive. For this reason the inlet/outlet structure is slightly different, featuring grating to prevent large marine creatures or debris from entering, seen in Figure 14.

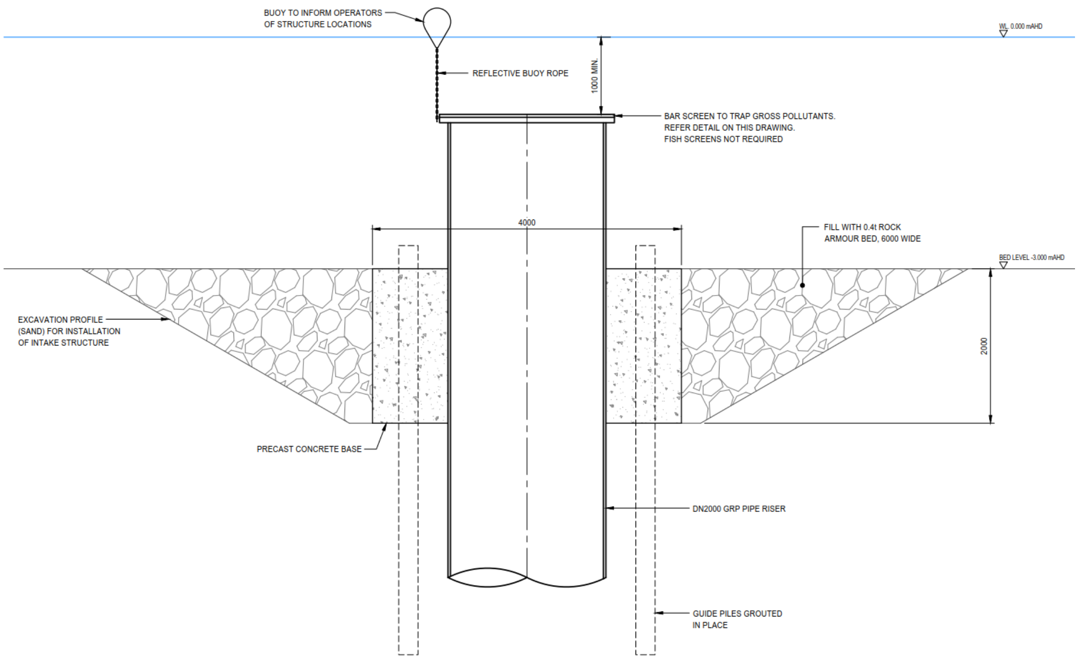


Figure 14 Option 6 inlet/outlet structure

As the discharge structures in Option 6 are reliant on passive flows, it is expected that marine growth will become a concern over time as it will build up on the grating which may require some maintenance.

To access the Option 6 discharge structures for cleaning and maintenance, it is expected that operators will need to travel to the structures on a small vessel within the breakwater structure and clean the structures from the vessel or with the aid of divers in the protected environment behind the breakwater. This exercise may also be required for the protected intake/discharge structures for all options if they are seen to build up with marine growth.

Metallic Infrastructure

The water in the Southern Ocean represents typical seawater which has a salinity that can corrode standard grades of stainless steel. For this reason, all metallic infrastructure installed within the Southern Ocean needs to be supplied with materials that can withstand seawater conditions. The main pieces of metallic infrastructure installed within the Southern Ocean are the fish exclusion screens and valves. Suppliers have recommended that all valves be supplied in either duplex or super duplex stainless steel to accommodate the water conditions. This has been adopted within the cost estimates, which include valves with suitable material specifications.

6.5 INFRASTRUCTURE WITHIN THE YOUNGHUSBAND PENINSULA (OPTION 4B)

At the concept design selection workshop (held 9 June 2021), an option was proposed that comprises a central pump station that allows water to be pumped either into or out of the Coorong. It was determined that the most effective way to do this was to place a pump station within Younghusband Peninsula, with pipework connecting the pump station to both the Southern Ocean and the Coorong South Lagoon whilst managing the reverse flow conditions with valving and pipework. Option 4B takes this approach, with the site layout as illustrated in Figure 15.

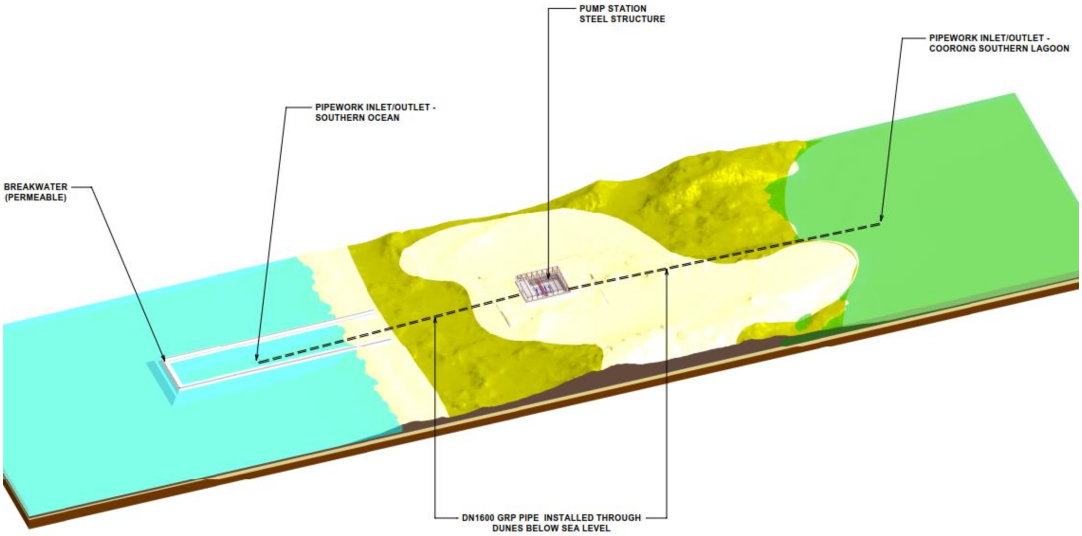


Figure 15 **Bi-directional pump station site layout**

6.5.1 Pumping philosophy

As there is a single pipe connecting the Southern Ocean to the Coorong South Lagoon and the pump station is required to pump in both directions, each pipe acts as both a discharge pipe and a suction pipe depending on the pumping direction. For this reason, a flooded suction is required at both ends of the pipe to best satisfy the NPSH requirements of the pumps. This means the pipework must be submerged within both bodies of water; hence, a breakwater has been included in the Southern Ocean to reduce the sand intake when this pipe acts as a suction pipe and to facilitate construction in a calmer ocean environment.

For a single set of pumps to pump in two directions, careful consideration was given to the pipework and valve arrangement within the pump room, with the resultant arrangement seen in Figure 16.

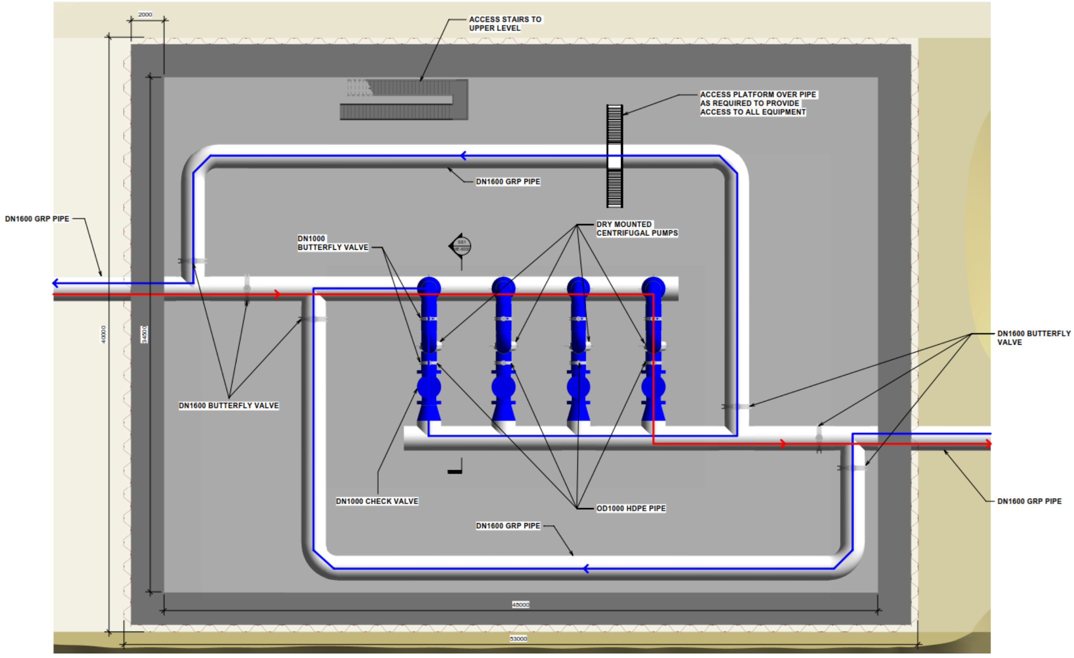


Figure 16 Bi-directional pump station site layout

When pumping from the Coorong to the Southern Ocean, the flow follows the blue path. Certain valves need to be closed and others need to be opened during this operation. When pumping is required to change direction and water is to be transferred from the Southern Ocean to the Coorong, an operator needs to switch the positions of the valves. At present, this is scheduled to be a manual operation, but the necessary valves could be actuated if preferred, allowing fully remote operation.

Centrifugal, dry well mounted pumps were selected for this pumping application considering the efficiency of the pumps, simplicity in installation and operation, and ability to be transported in components (e.g. pump and motor separated) to the pump station site.

The shorter path (red flow path) was chosen for pumping from the Southern Ocean to the Coorong. The reason is that pumping in this direction is more likely to entrain sand, and as this path has the least fittings and bends, there is less chance for sand to fall from suspension and build-up at tees or at valves.

6.5.2 Pump room design

As the pump room is located within Younghusband Peninsula, if the pumps were placed at dune level, the pump centre lines would be at a much higher elevation than the bodies of water it is pumping. When pumps are located above the body of water they are pumping, the available NPSH is reduced and they are at risk of experiencing cavitation[2], which can damage pumps. To increase the available NPSH, the elevation of the pump was reduced until the available NPSH was above the required NPSH of the pump to operate effectively.

Through calculation, it was determined that the pump centreline needs to be located approximately 3 m below sea level to ensure the available NPSH is above the required NPSH. To provide some buffer on the NPSH, the pump room has been located 5 m below sea level. As the dunes are between 5 and 10 m above sea level where the pump room is to be located, this results in at least 30,000 m³ of dune material that needs to be excavated to construct the pump room.

[2] Cavitation in pumps results from the rapid creation and subsequent collapse of air bubbles in a fluid being pumped, which has a detrimental impact to the pump components leading to premature wear and failure.

Preliminary structural design has been undertaken on the pump room to determine basic dimensions and concrete details. Due to the depth of the pump room, the need to retain the surrounding sand and the need to prevent buoyancy of the pump room, the walls are required to be 2.2 m thick and the base slab 2.0 m thick, as illustrated in Figure 17.

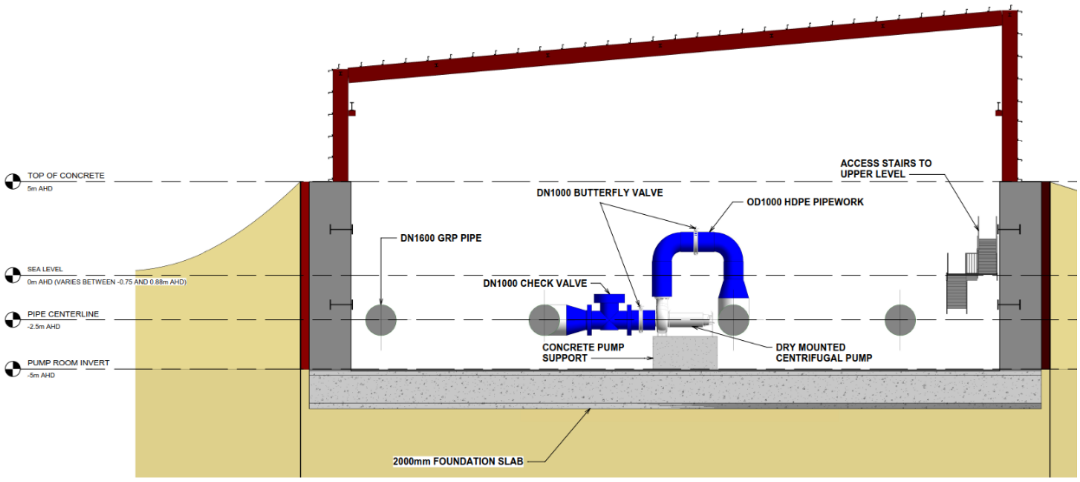


Figure 17 Pump room section

For the pump room to be accessed from ground level, a portal frame structure is required on top of the concrete pump room, with a series of staircases installed to provide access to the pumps from ground level, as shown in Figure 18. A gantry crane for pump and valve removal has been included, along with vehicle access to the pump room within the above-ground building.

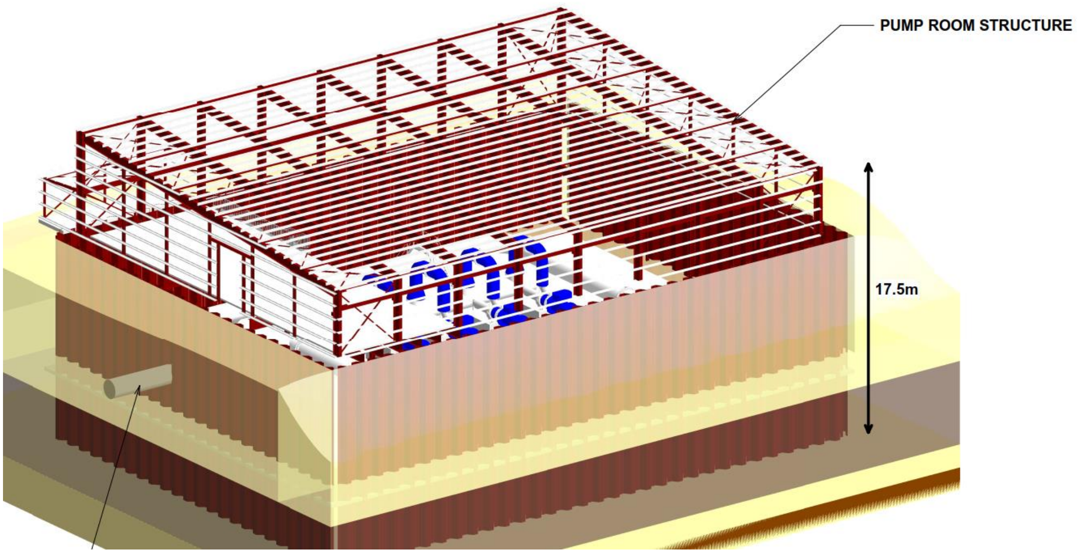


Figure 18 Pump room isometric

6.5.3 Pipelines

Discussions between KBR and Fulton Hogan have identified multiple feasible construction methods to install pipelines through Younghusband Peninsula, each with their own complications and risks. The two options with the most merit are micro-tunnelling (or pipe-jacking) and conventional trenching and backfill.

Micro-tunnelling requires tunnelling pits to be installed within the peninsula to install the required pipe installation equipment. These pits will need to be constructed at depths to suit the pipe installation required across all options. Significant structural reinforcement and dewatering will be required to allow construction. It has also been advised by Fulton Hogan that there are only a small number of micro-tunnelling machines in Australia that can install pipelines around 2 m in diameter. This proves a construction and schedule risk as these machines are often leased for long projects and securing one of these machines for the project lifecycle may prove difficult.

The main advantage of micro-tunnelling is that it can be utilised to install pipelines into the ocean and the Coorong below the bed level, removing some of the costs associated with dewatering when installing pipelines in water bodies. The issue of dewatering will still be encountered within the Younghusband Peninsula when installing the micro-tunnelling pits as these will likely be installed below the groundwater level.

Due to the number of risks and construction challenges with micro-tunnelling, a conventional trenching and backfill methodology to install the pipelines has been proposed in development of the capital cost estimates. This method will result in a large quantity of dune material being excavated and temporarily stockpiled and managed during construction. Despite this challenge, it is still expected that conventional trenching and backfill will be the most suitable pipeline installation method.

6.6 FISH EXCLUSION SCREENS

Fish exclusion screens are to be included on all pump suctions to prevent mortality of aquatic species. Dedicated fish exclusions screens have large surface areas to reduce the velocity of the water as it enters the screen. They typically target an intake velocity of 0.1 m/s. The velocity is reduced to a point where fish can outswim the suction forces created when the pump is operating.

During concept design, KBR consulted with water controls solution business AWMA on the design and supply of suitable fish exclusion screens. AWMA offers three types of fish exclusion screens, as in Figure 19. These screens have a typical aperture width of 2–3 mm, but sizing can be adjusted to suit the project requirements. The screens also come installed with self-cleaning wire brushes that rotate around the screen to clean off debris to prevent clogging the apertures.

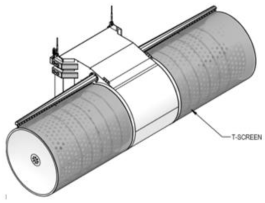
Single Cylinder Screen	T-Screen	Cone Screen
		

Figure 19 AWMA fish exclusion screens

The fish exclusion screens are mounted to the pump suction, which adds length to the pump suction. This will increase the amount of required dredging below the pontoon-mounted pumps as detailed in Section 6.3.2. To reduce the amount of dredging required, cone screens are preferred, as they are the shortest screen type.

For the vertical turbine pumps installed in the Southern Ocean, there is no water depth restriction as the concrete caisson structure will be dredged to provide a suitable water depth. Therefore, cylinder screens or T-screens installed at the caisson inlet have been proposed. They are commonly used and can be manufactured at lengths to suit the project. The proposed installation within the caisson structure is shown in Figure 20.

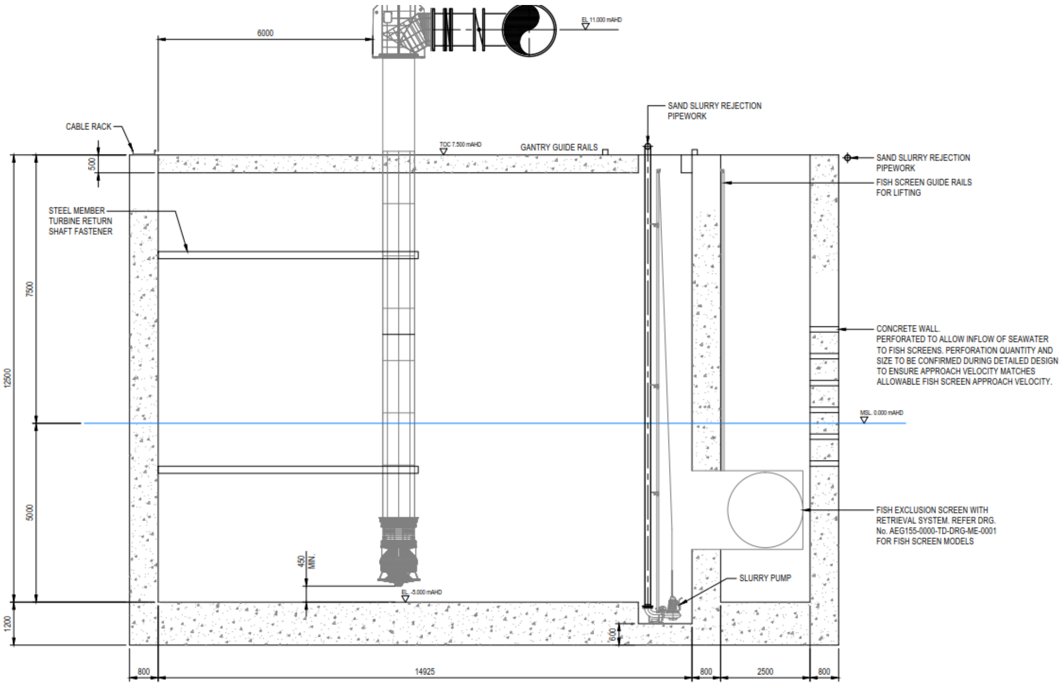


Figure 20 Proposed caisson fish exclusion screen installation

Due to the access difficulties to the fish exclusion screens within the caisson structure, a retrieval system, which is offered by AWMA, has also been included in the design. This will provide operators with the ability to lift the screens to the jetty surface level for cleaning and maintenance activities as required.

As the same pipe is used for intake and discharge for Options 4B and 6, fish screens cannot be installed on these pipes – the fish exclusion screens are not designed to be discharged through. This is not an issue for Option 6, which is a passive system and there is no risk to fish if they enter the pipeline. This only becomes an issue for Option 4B as the pipes on either end of the pump station take the function of both intake and discharge depending on the pumping direction which may entrap and harm aquatic species. As such, the pipework detail shown in Figure 12 was developed.

Bar screens will be provided on the discharge structures as per Figure 21, which will prevent large marine life entering the pipeline for Option 6.

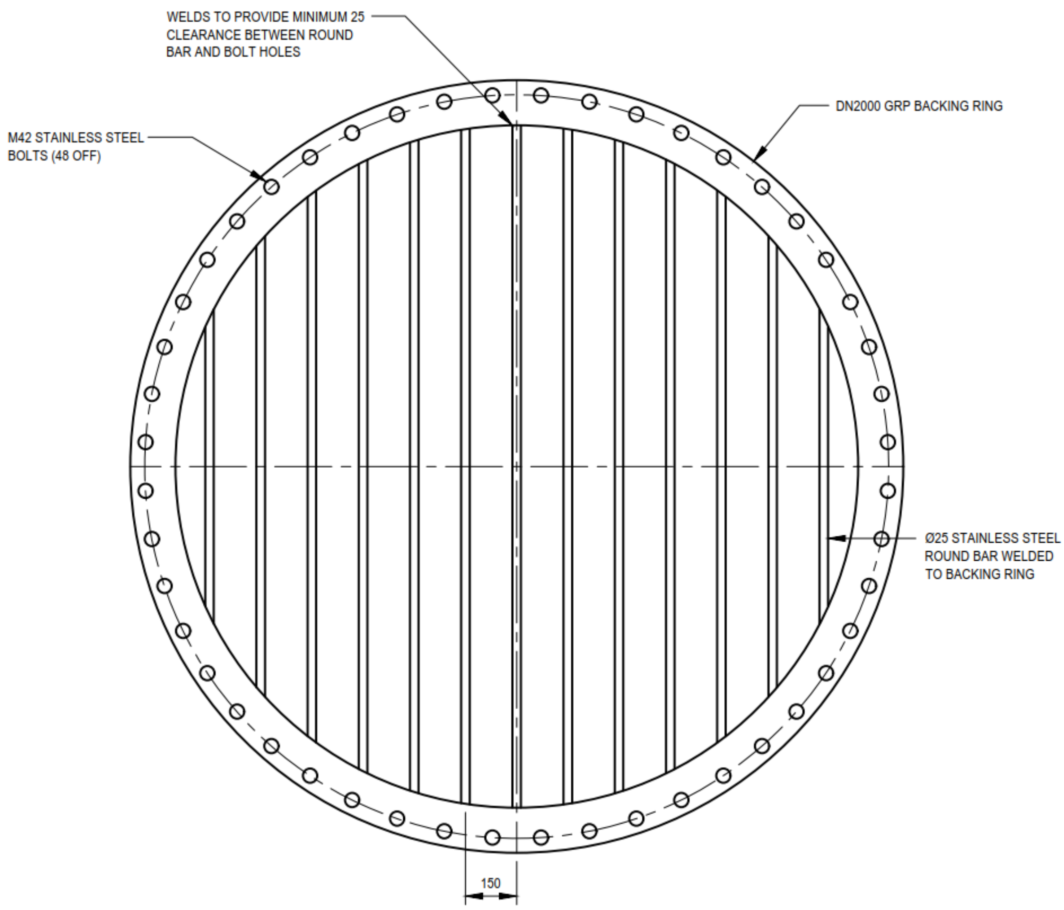


Figure 21 Discharge structure bar screen detail

6.7 PRESSURE SURGE

Pressure surge within the pumped system could arise from rapid valve closure, pump starting or rapid pump stopping under a power failure scenario.

The large valves in the system range between 1,000 and 2,200 mm in diameter, and the time it takes to close the valves is estimated at over 200 seconds, which makes it unlikely that the valve closure will produce significant surge in the system. Valves will be manually actuated and supplied with slow-closing features to ensure the closing duration is not reduced from the estimated 200 seconds. The risk of initiating a pressure surge from rapid valve closure is considered low.

All pumps are to be equipped with variable speed drives (VSD's), which can be used to ramp pump flow both up and down. As such, under normal operating conditions it is expected that the risk of initiating a pressure surge event can be controlled.

In a power failure scenario resulting in a rapid pump stop, the momentum of the pump impeller continuing to turn will assist in mitigating a surge event. If an event was to be initiated, the pipeline length in most of the concept options is approximately 1,500 m and the celerity is approximately 415 m/s for PN10 SN1000 GRP pipe. Upon initiation of a surge event at the pump station, the negative pressure wave will take around four seconds to reach the ocean, and it will take a further four seconds for the positive pressure wave to return. This event could result in a pressure surge of up to 1000 kPag (considering an instantaneous pump stop). Control measures may therefore need to be incorporated in the system to minimise the effects of micro-cavitation – the pipeline will typically be operating at less than 200 kPag and the pipeline will reach vapour pressure (-98 kPag) for a negative surge event of this magnitude.

Options to mitigate surge include bladder surge vessels or a surge-anticipating valve. The bladder surge tank size may be prohibitive; however, an off-line surge anticipating valve that immediately opens in response to an electric signal would be a more compact solution. The pre-opened valve dissipates the returning high pressure wave, eliminating the surge. The valve smoothly closes drip-tight as quickly as the relief feature allows, thereby preventing closing surge. A typical pump station with a surge anticipating valve is shown in Figure 22.

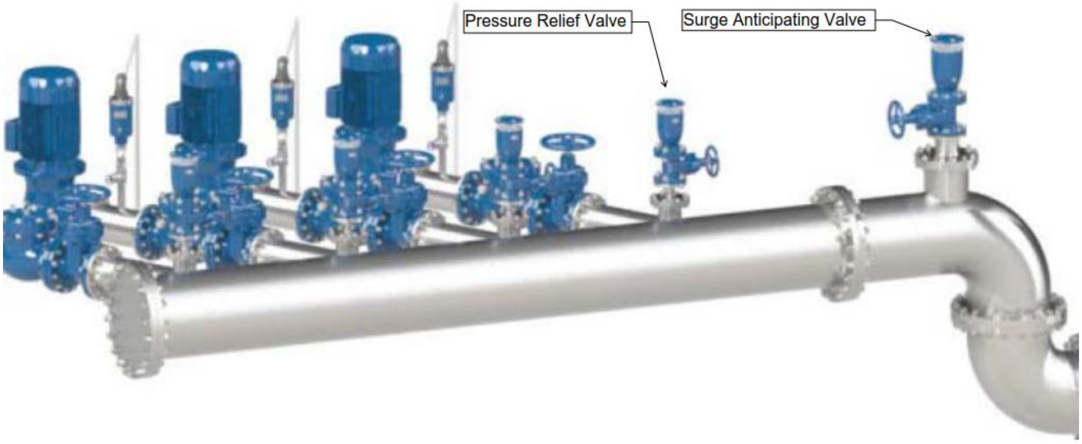


Figure 22 Surge-anticipating valve arrangement

Detailed surge analysis of the ultimately selected options will be required as design progresses forward. This will ensure that appropriate protection measures can be incorporated within the installed infrastructure and control system to minimise the occurrence and severity of any pressure surge events.

7 Electrical and communication design

7.1 GENERAL DESCRIPTION

From a power supply and electrical reticulation perspective, the Coorong is a unique site, which will require an innovative approach during the design and construction phases. Elements that promote this uniqueness are distance to existing power infrastructure, difficulty of access to Younghusband Peninsula and a wide expanse of relatively shallow water to reach the power demand site.

The traditional method in electrical design is to locate a power supply or have South Australian Power Networks (SAPN) provide a grid connection as near as practical to the load. In this situation, the majority of pumping infrastructure will be located on Younghusband Peninsula and it has been anticipated that:

- Younghusband Peninsula is unsuitable for establishing a renewable power supply on the Peninsula, given it forms part of the Coorong National Park (considering previous project experience, First Nations significance of the sites and amenity value of the national park).
- SAPN will only provide a service point (one or more) on the mainland (i.e. north-eastern side of the Coorong lagoons) adjacent to Princes Highway.

Therefore, the power supply will need to be located on the mainland and power reticulated across the Coorong South Lagoon and Peninsula to the pumping infrastructure.

On the basis that pumping infrastructure must have the ability to operate 24 hours per day, the following power supply options have been considered:

- A grid connection.
- A grid connection supplemented by a renewable energy source.
- Renewable energy systems (wind or solar) with either battery or diesel generator backup.

Depending on the pumping option, electrical reticulation will include a combination of:

- Underground cables – across the mainland and peninsula.
- Submarine cable under the Coorong South Lagoon.
- Electrical infrastructure on the mainland and peninsula.
- Cables along jetties and pontoons.

7.2 POWER REQUIREMENTS

The numerous options considered in this report require power predominantly for:

- System monitoring and communications.
- Pump loads.

Table 27 summarises the estimated maximum demand (EMD) of each pumping option. While all power supplies are required on the Peninsula, the closest point on the mainland has been nominated as the location where the power will reticulate from.

Table 27 EMD for each option

Option	Location – relative to the mainland	Requirements for power	EMD (kW)
1A	Lake Albert	System monitoring and communications	2
1B	Lake Albert	System monitoring and communications	2
2	Parnka Point	Not applicable	0
3A	South of Woods Well, opposite Fat Cattle Point	System monitoring, communications and pump loads	2820
3B	South of Woods Well, opposite Fat Cattle Point	System monitoring, communications and pump loads	1140
3C	South of Woods Well, opposite Fat Cattle Point	System monitoring, communications and pump loads	570
3D	South of Woods Well, opposite Fat Cattle Point	System monitoring, communications and pump loads	500
4A	Pump out – south of Woods Well, opposite Fat Cattle Point	System monitoring, communications and pump loads	1020
	Pump in – south of Woods Well, opposite Fat Cattle Point	System monitoring, communications and pump loads	1250
4B	Combined pump station – south of Woods Well, opposite Fat Cattle Point	System monitoring, communications and pump loads	250
5A	Pump out – north of Parnka Point	System monitoring, communications and pump loads	920
	Pump in – south of Woods Well, opposite Fat Cattle Point	System monitoring, communications and pump loads	1250
5B	Pump out – north of Parnka Point	System monitoring, communications and pump loads	480
	Pump in – south of Woods Well, opposite Fat Cattle Point	System monitoring, communications and pump loads	1250
6	South of Woods Well, opposite Fat Cattle Point	System monitoring and communications	2

7.3 POWER SUPPLY OPTIONS

Power supply options typically comprise one or a combination of the following:

- SAPN grid connection – as a primary supply or secondary supply to a renewable energy system.
- Renewable energy system – as a primary supply.
- Secondary systems – diesel generation or batteries.

7.3.1 SAPN grid connection

Existing SAPN infrastructure

Preliminary correspondence with SAPN has identified SAPN electrical distribution infrastructure in and around the Coorong district. Table 28 summarises the distribution infrastructure and approximate distances to the pumping locations.

Table 28 Distribution infrastructure and approximate distances to the pumping locations

Infrastructure description	Comment	Distance from Fat Cattle Point (km)	Distance from Parnka Point (km)
19 kV overhead SWER (single wire earth return)	Only low voltage (LV) single phase and LV two phase supplies are available from this infrastructure.	2	4
33 kV overhead – single phase	Only LV single phase and LV two phase supplies are available from this infrastructure.	25	Not available[1]
33 kV overhead – three phase	Three phase supply is available – service size is subject to discussions with SAPN.	50	25

[1] SAPN service to Parnka Point is via a 19 kV SWER service only. SAPN is not expected to extend a 33 kV SWER to this location.

SAPN is likely to limit services from the 19 kV SWER and 33 kV single phase systems to 25 kVA; therefore, these services are only suitable for supply to monitoring and communications equipment located on the mainland.

A 33 kV three phase supply is essential for the pumping loads.

SAPN connection details

If an SAPN connection is required as per Table 28, SAPN will carry out the following work:

- 19 kV and 33 kV single phase: an overhead extension, with a transformer and LV service on the terminal pole.
- 33 kV three phase: an overhead extension, with a high voltage (HV) service on the terminal pole.

All service connections to the SAPN system must be in accordance with the SAPN service and installation rules.

7.3.2 Minor power supplies

At some sites the electrical load will be limited to the level required for monitoring and communications purposes – refer to Table 27 for details on those sites. The indicative load at each of these sites is in the order of approximately 2 kW.

Where monitoring and communications systems are established on the mainland, the following options exist for this power supply:

- SAPN single phase service.
- Solar with battery backup.

However, where monitoring and communication systems are established on the Peninsula, a power supply is best achieved via a solar system with battery backup.

7.3.3 Major power supplies

Table 29 summarises options for supplying the large electrical demand at the pumping sites. The intention is for the primary source to meet the full demand of the pump loads. The secondary supply is only there to supplement the primary source when the primary source cannot meet the demand of the pump loads. This is likely to occur at night and during days of low irradiance levels (in the case of solar photovoltaic (PV)) and when wind strength is low (in the case of wind turbines).

Table 29 Options for supplying the large electrical demand at the pumping sites

Option	Primary source		Secondary source	
	Description	Details	Description	Details
P1	SAPN	SAPN to provide a grid-connected three phase HV supply.	n/a	n/a
P2	Solar	Grid-connected solar PV array, sized to supply the entire pumping load during a typical winter's day.	SAPN	SAPN to provide a grid-connected three phase HV supply.
P3	Solar	Off-grid solar PV array, sized to supply pump load during a typical winter's day.	Diesel Generator	Multiple diesel generators sized to supply the entire pumping load.
P4	Solar	Off-grid solar PV array, sized to supply pump load and charge batteries during a typical winter's day.	Battery energy storage system (BESS)	Battery energy storage system relies on a full daily charge from the solar PV array.[1]
P5	Wind	Grid-connected wind turbines, sized to supply the entire pumping load.	SAPN	SAPN to provide a grid-connected three phase HV supply.
P6	Wind	Multiple wind turbines suitable for off-grid operation, sized to supply the entire pumping load.	Diesel Generator	Multiple diesel generators sized to supply the entire pumping load.
P7	Wind	Multiple wind turbines suitable for off-grid operation.	BESS	Battery energy supply system relies on a regular charge from the wind turbines.[1]

[1] Battery capacity sizing has been based on the renewable primary source being able to fully charge the batteries on a regular basis and at least once per day.

7.3.4 Renewable energy sources

The installation of a renewable energy source will require an area on the mainland. The area would ideally be located directly across the Coorong from the proposed pump stations and will therefore most likely be on a private property. Detailed site selection has not been undertaken as part of the concept design activities. An alternative would be to locate the renewable energy source elsewhere along the transmission line. This would incur additional connection costs and require a separate agreement with SAPN as DEW could not use SAPN infrastructure to transmit its renewable energy to the grid connection point.

Table 30 provides an indicative guide on the footprint required for two of the renewable energy options described in Table 29 and their application to two infrastructure options, Options 3A and 4B. Option 3A represents the highest power demand option whilst Option 4B represents the lowest.

Table 30 Application to infrastructure Options 3A and 4B

Infrastructure option	Power option	Energy source	EMD[1] (kW)	Possible configuration[2]	Footprint	
					(m^2)	ha
3A	P2	Solar	2820	7000 x 400 W solar PV panels	75,000	7.5
	P5	Wind	2820	3 x 4 MW turbines	2,400,000	240

Infrastructure option	Power option	Energy source	EMD[1] (kW)	Possible configuration[2]	Footprint	
					(m^2)	ha
4B	P2	Solar	250	630 x 400 W solar PV panels	6,300	0.63
	P5	Wind	250	2 x 0.5 MW turbines	200,000	20

[1] In the absence of site-specific wind monitoring, a capacity factor of 25% has been adopted to ensure the maximum demand can be supplied.

[2] Performance of solar PV panels has been based upon an assumed irradiance level of 1 kW/m^2.

7.4 POWER RETICULATION

Since the power supply will be located on the mainland, there is a requirement to reticulate supply to the pumps installed on pontoons or jetties off the Peninsula. A major component of the reticulation will be a HV submarine cable installed across the Coorong South Lagoon. The cable could either be:

- Trenched into the floor of the lagoon, or
- Laid on the floor of the lagoon with appropriate mechanical protection.

The reticulation system across the peninsula will vary according to the pumping option selected. Figure 23 is a general summary of the expected reticulation.

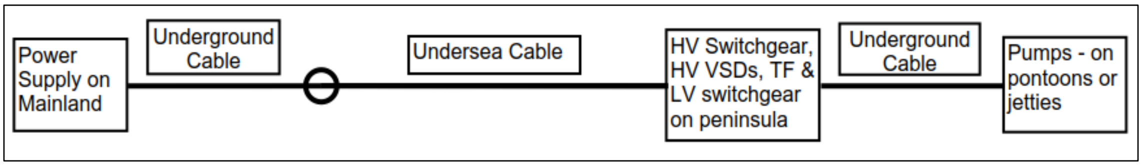


Figure 23 Expected electrical reticulation

As submarine cables are specifically made to suit an application, it may be prudent to have fibre optics included in the cable to assist with communications between the Peninsula and mainland. This should be considered as an option in future phases of design.

7.5 CONSTRUCTABILITY

The following items are likely to present difficulties during the construction phase and therefore it is recommended they be thoroughly explored during future design phases to mitigate the risk of any issues during construction.

7.5.1 Submarine cable

It is envisaged that conventional methods for transporting and laying of the submarine cable may not be appropriate for this location. The lagoon is relatively shallow, and access via water is severely restricted. This is likely to result in:

- The submarine cable having to be transported by road to the site (normally completed by ship).
- A barge (or vessel with a relatively small draft) being used for the cable installation. Note that barging is likely to be required for construction equipment and transport of construction materials associated with the infrastructure proposed on the Peninsula. As such, this barge could be used for a dual purpose.

One consideration with a submarine cable is ensure provision of adequate protection against damage from any other activities within the Coorong South Lagoon. The submarine cable could be laid directly on the bed of the Coorong South Lagoon or it could be trenched (dredged) into the bed. Whilst there is no specific minimum depth of submergence for the cable to provide appropriate protection, a safety in design assessment and risk assessment will be required as part of future design stages to develop an appropriate installation solution.

7.5.2 PV mounting systems

While the concept design has been based on a PV array being mounted on a fixed angle, numerous alternatives exist for mounting solar panels in other configurations. The availability of suitable land and the geotechnical characteristics of the selected land are two major factors that should be considered in the final mounting configuration.

7.6 TECHNICAL ISSUES TO RESOLVE

While the options presented in this report should all be considered further, a significant amount of technical work is required to confirm the requirements for a technical solution that complies with all the regulatory demands. As the design progresses, it is expected that particular attention will need to be given to the following items.

7.6.1 SAPN technical requirements

SAPN will impose technical requirements on a grid connection, and it is likely those requirements will be assessed at the point of common coupling. They will include:

- Maximum number of motor starts.
- Maximum voltage drop (or a limit on motor starting current).
- Maximum harmonic voltage distortion.
- Power factor limits.

7.6.2 Variable speed drives (VSD’s)

Individual VSD’s have been nominated on all pumps to ensure the pumps operate at their nominated speed and to help reduce starting currents. Where pumps are grouped together and operate at synchronous speed, it may be possible to rationalise on the number of VSD’s by installing a synchronous transfer system.

A synchronous transfer system allows for the installation of a single VSD, which is used to start every motor. A programmable logic controller (PLC) controls the starting sequence, and each motor is started individually by the VSD and transferred across to the normal supply when the motor reaches synchronous speed. This process repeats until all motors have started.

7.6.3 System redundancy

To provide a power reticulation system with a higher level of reliability, it is generally necessary to install additional infrastructure. This additional infrastructure is not essential for the operation of the reticulation system but helps to ensure the continuity of power if parts of the essential infrastructure fail. However, the additional infrastructure normally results in higher capital and maintenance costs, and generally a financial evaluation is carried out to confirm the feasibility of additional infrastructure. This may therefore require evaluation that would also consider the criticality of demand and assess the impact of power outages in the event of equipment failure.

The reticulation systems shown and discussed in this report do not include additional infrastructure proposed for redundancy purposes.

7.6.4 System capacities

The outputs of the renewable primary sources and their ability to charge the BESS has been based on generic capacities. Further investigation and/or system modelling is required to confirm the ability of each source to meet the intended operating strategy.

It should be noted that the output of the BESS's is limited to supplying overnight power and that the BESS must be recharged at least once a day. If the renewable energy source is unable to provide a regular recharge, then the renewable source may have to be increased in size.

7.6.5 Wind turbines

According to the state planning guidelines, the Coorong is not an area where wind turbines are envisaged. Therefore, it could be expected that approval for a wind turbine in this area may be difficult to obtain. There are also typically large land requirements for wind turbines to ensure that shielding and disturbance to wind patterns do not impact on the generation potential of each turbine. This is the primary reason for the large footprint requirements associated with a wind turbine system, as presented in Table 30.

However, provided a sufficient buffer is allowed, a wind turbine located adjacent to the Coorong may have a greater possibility of gaining the necessary approvals.

7.7 ENERGY CONSUMPTION AND GREENHOUSE GAS EMISSIONS

Table 31 summarises the annual energy consumption and greenhouse gas emissions for the infrastructure options, when supplied totally from the South Australian electricity grid.

Table 31 Annual energy consumption and greenhouse gas emissions for the infrastructure options

Option	Annual energy consumption (kWh)	Annual greenhouse gas emissions (t eCO_2)
1A	5,300	2
1B	5,300	2
2	0	0
3A	11,100,000	3,860
3B	4,500,000	1,560
3C	5,000,000	1,740
3D	4,400,000	1,520
4A	9,600,000	3,350
4B	2,200,000	750
5A	13,800,000	4,840
5B	10,000,000	3,480
6	10,100	4

Note:

1. *Energy consumption is based on the operating hours in Table 2, the operating power of the pumps and includes an allowance for distribution system power losses (nominally 5%).*
2. *Greenhouse gas emissions have been calculated in accordance with the Australian Government National Greenhouse Accounts Factors (August 2021) and are based on 0.35 kg CO_2-e per kWh.*

7.8 PROPOSED COMMUNICATION AND CONTROL SYSTEMS

To ensure that pumping infrastructure is operating as intended, several measures will be taken to monitor the operation of pumps and valves.

7.8.1 Pump monitoring

Key parameters will be monitored during pump operation to ensure the pumps are healthy and operating within their boundaries. The approach will be to include appropriate instrumentation. The typical arrangement for pumps with submerged discharges shown in Figure 24.

Pump monitoring is only required for options that include pumps, being:

- Option 3A:Intermittent pumped connection out of Coorong South Lagoon – 150 m long discharge jetty.
- Option 3B: Intermittent pumped connection out of Coorong South Lagoon – low visual impact beach discharge structure.
- Option 3C: Pumped connection out of Coorong South Lagoon – 150 m long discharge jetty.
- Option 3D: Pumped connection out of Coorong South Lagoon – low visual impact beach discharge structure.
- Option 4A: Bi-directional pumped Southern Ocean connection – one location, separate pumping stations, pump in location with caisson structure on 350 m long jetty.
- Option 5A: Simultaneous pumped Southern Ocean connection – two locations, separate pumping stations, pump in location with caisson structure on 350 m long jetty and pump out location to 150 m long discharge jetty.
- Option 5B: Simultaneous pumped Southern Ocean connection – two locations, separate pumping stations, pump in location with caisson structure on 350 m long jetty and pump out location with a low visual impact beach discharge structure.

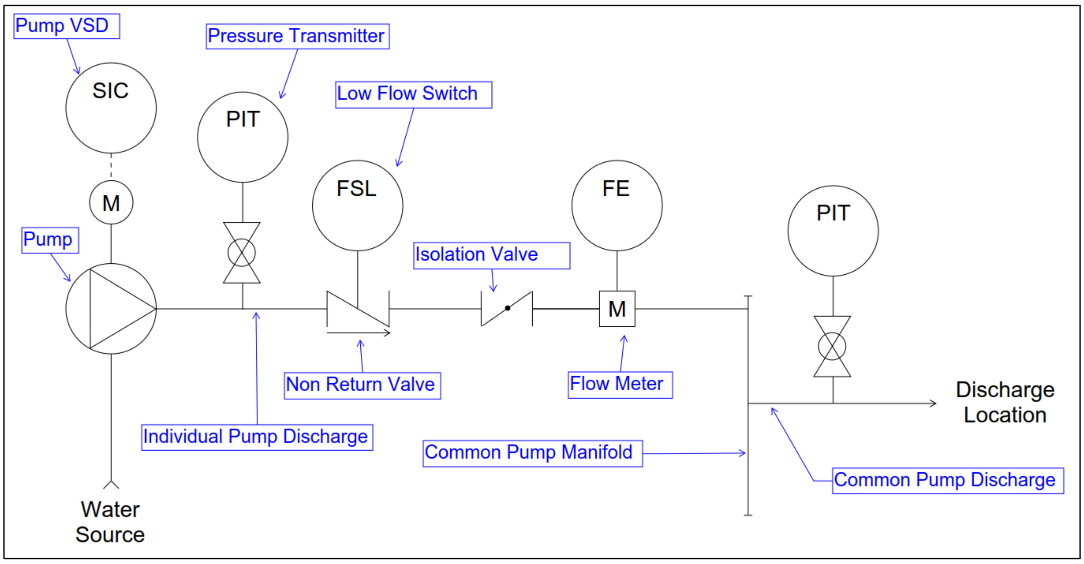


Figure 24 Typical arrangement for pump operation control

VSD’s will be included on all pumps to ensure they are operating efficiently if the conditions change, and the pumps need to adapt either flow rate or discharge pressure. Pressure transmitters will monitor the pressure on both the individual pump discharge pipes and the common pump discharge pipeline.

The non-return valve will prevent backflow, and the low-flow switch mounted to the non-return valve will shut off the pump if it is running but no flow is being recorded. This can occur when there is a blockage further down the line that prevents the water from passing and if the pump can be damaged if it continues to operate in these conditions. The isolation valve is used to isolate the line when maintenance needs to occur.

A flow meter will be incorporated to track both the instantaneous flow rate and the cumulative flow passing through each pump to track how well the pumps are performing against the expected performance. This will also assist DEW to determine how the salinity is changing in accordance with the quantity of water being transferred.

The instrumentation and control requirements will be reviewed through detailed design and may change based on discussions with suppliers. Suppliers may have their own control systems which will need to be integrated with any additional requirements. Discussion with pump and mining services business Weir have identified that its pontoon-mounted pumps come fitted with low water level switches, and similar provisions are expected from other suppliers.

7.8.2 Water body monitoring

To measure the success of the project, the salinity of the Coorong Southern Lagoon should be monitored. It is proposed that salinity analyser poles are installed a suitable distance from the pumping locations where water is discharged into the Coorong, with the current long-term monitoring poles retained within the Coorong lagoons.

7.8.3 Communication

All data recorded from instrumentation will be recorded and used to inform operating procedures through the SCADA system. Alarms and fault readings will have the ability to be transmitted to nominated mobile numbers. This will also allow remote monitoring and control.

A cloud/web-based SCADA system would be ideal for this unmanned pumping infrastructure, as there are limited 3G and 4G services available in the area. Further investigation is required to ensure these services are entirely suitable for use.

If existing service capacity is not sufficient, an alternate option would be to establish a Telstra NBN connection on land (adjacent to the Princes Highway) and provide a suitable ethernet connection via buried fibre cable or directional antenna to a fixed land-based receiver alongside any pontoon-mounted system (Telstra NBN availability checked at 9270 Princess Highway and is available). Alternative NBN technologies may reduce the need to install fibre or antennae to get internet to where it is required but requires further investigation.

Xylem provide a web-based SCADA and controller system called PumpView by Multitrode which that would be ideal for this application. Other bespoke control systems could also be applied but may incur extra engineering costs to design.

8 Maritime structures

Several options require marine infrastructure solutions to be constructed on the Southern Ocean shoreline and within the offshore area. These options are:

- Option 3A: Intermittent pumped connection out of Coorong South Lagoon – 150 m discharge jetty.
- Option 3B: Intermittent pumped connection out of Coorong South Lagoon – low visual impact beach discharge structure.
- Option 3C: Pumped connection out of Coorong South Lagoon – 150 m long discharge jetty.
- Option 3D: Pumped connection out of Coorong South Lagoon – low visual impact beach discharge structure.
- Option 4A: Bi-directional pumped Southern Ocean connection – one location, separate pumping stations, pump in location with caisson structure on 350 m long jetty.
- Option 4B: Bi-directional pumped Southern Ocean connection – one location, one common pumping station, near shore discharge/intake protected by breakwater.
- Option 5A: Simultaneous pumped Southern Ocean connection – two locations, separate pumping stations, pump in location with caisson structure on 350 m long jetty and pump out location to 150 m long discharge jetty.
- Option 5B: Simultaneous pumped Southern Ocean connection – two locations, separate pumping stations, pump in location with caisson structure on 350 m long jetty and pump out location with a low visual impact beach discharge structure.
- Option 6: Bi-directional passive piped connection into and out of Coorong South Lagoon, ocean pipework with breakwater.

The following sections describe the infrastructure solutions identified, with consideration of the coastal conditions of the foreshore and near shore area of the Southern Ocean. Description of the mechanical and pumping elements associated with these options is presented in section 6 of this report.

8.1 METOCEAN CONDITIONS

8.1.1 Astronomical tide

Limited tidal level information is available for the site. The proposed tide planes are adopted from Cape Jaffa (SA_TP012) and were provided by the Bureau of Meteorology (BOM). The Cape Jaffa site is 100 km south of the project site and is the nearest, non-estuarine tidal station located near the Coorong. The Cape Jaffa tidal information therefore represents the best available information to relate tide and land levels and is presented in Table 32.

Table 32 Southern Ocean tidal plane

Tidal plane	mCD / mLAT	mAHD
Highest Astronomical Tide (HAT)	1.623	0.876
Mean High Water Springs (MHWS)	1.215	0.468
Mean High Water Neaps (MHWN)	0.932	0.185

Tidal plane	mCD / mLAT	mAHD
Mean Sea Level (MSL)	0.747	0.000
Mean Low Water Neaps (MLWN)	0.562	-0.185
Mean Low Water Springs (MLWS)	0.279	-0.468
Lowest Astronomical Tide (LAT) / Chart Datum (CD)	0.00	-0.747

The site has small tidal range, varying from a 0.37 m range (neaps) to 0.94 m range (spring tides). A timeseries of water surface elevations for a representative one-month period is provided in Figure 25 for reference (generated using the Mike21 global tide model), with comparison to the approximated high and low water levels within the Coorong. These water levels generate only a small amount of hydraulic head between the Southern Ocean and Coorong, which fluctuates with the daily tides (see Figure 25).

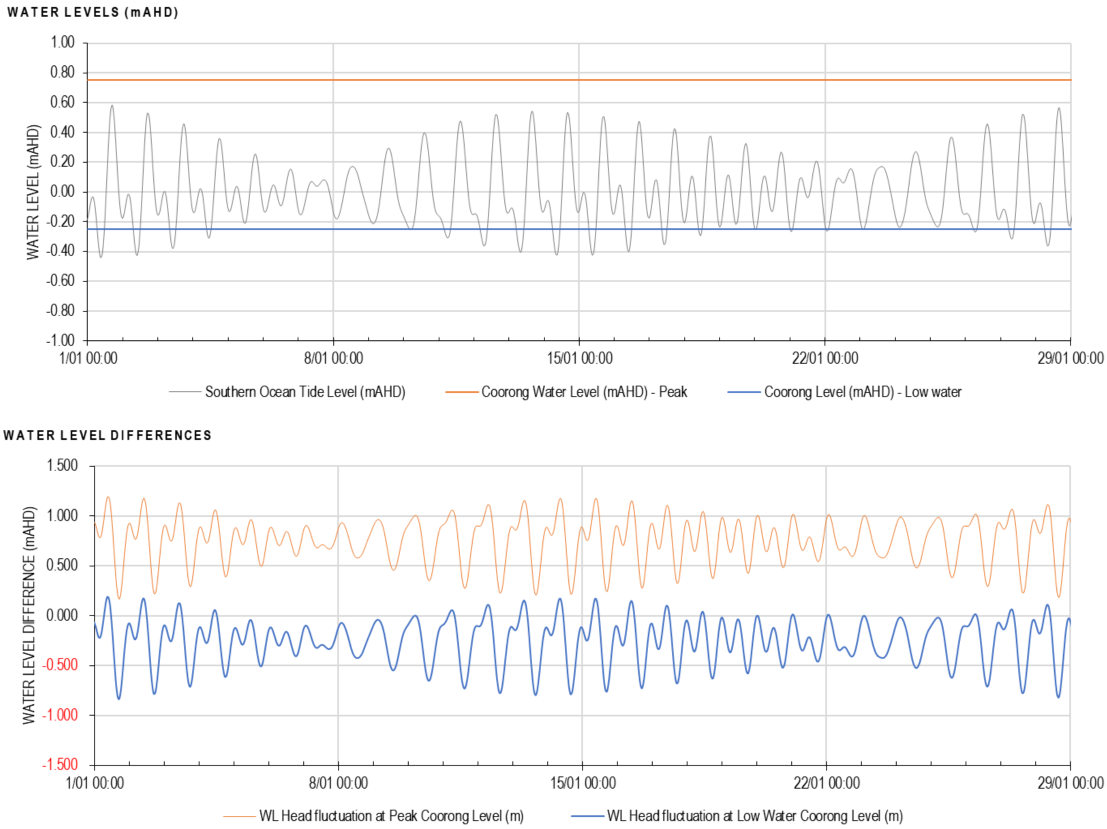


Figure 25 Southern Ocean water levels (top) and water level fluctuations (static peak and low water Coorong levels) (bottom)

8.1.2 Design water levels

Table 33 presents the design water levels applied to design elements on the marine side (i.e. beach and near shore zone of the Southern Ocean).

Table 33 Design water levels

Water level condition	Elevation	Source
Ambient water level condition	MSL = +0.747 mLAT	Cape Jaffa Tidal Planes supplied by the Bureau of Meteorology National Tide Centre (BOM, 2021).
Design storm tide event (DSTE) still water level	Extreme water level condition (100-year average recurrence interval (ARI) or 1% annual exceedance probability (AEP)): DSTE = +2.200 mLAT	Masterplan SA et al. (2005) Cape Jaffa anchorage Environmental Impact Statement (EIS), prepared for Kingston District Council and Cape Jaffa Development Company Pty Ltd.

Sea level rise to end of design life has also been considered over the life of the proposed structures. A 1.0 m sea level rise has been adopted and is applied in addition to the levels in Table 33, in accordance with the South Australian Coast Protection Board Policy (2016) – 29 July 2016.

8.1.3 Waves

The site has an uninterrupted fetch across the Southern Ocean, generating very large, highly energetic waves.

Hindcast wave data was sourced from a wave model called NOAA Wavewatch III global model (ST4) (location [-36.5,139.5]) to obtain design ARI wave conditions for the site. Hindcast data covered the period from January 1993 to January 2021. Design wave conditions are provided in Appendix B.

Further observed wave data is also available from BOM from the Cape du Couedic wave rider station (located approximately 180 km to the west of the site). Figure 26 shows a storm event captured over a period during May 2021. Offshore significant wave heights of up to 6 m were observed during the May 2021 event and is a relatively frequent condition in the Southern Ocean (less than a 10-year ARI return period). These conditions may also persist for several days and was a key consideration in the design of marine infrastructure at the site.

The conditions in Figure 26 correspond to an observed south-westerly (SW) approach direction and correlates well with the predominant SW wave conditions from the hindcast data source.

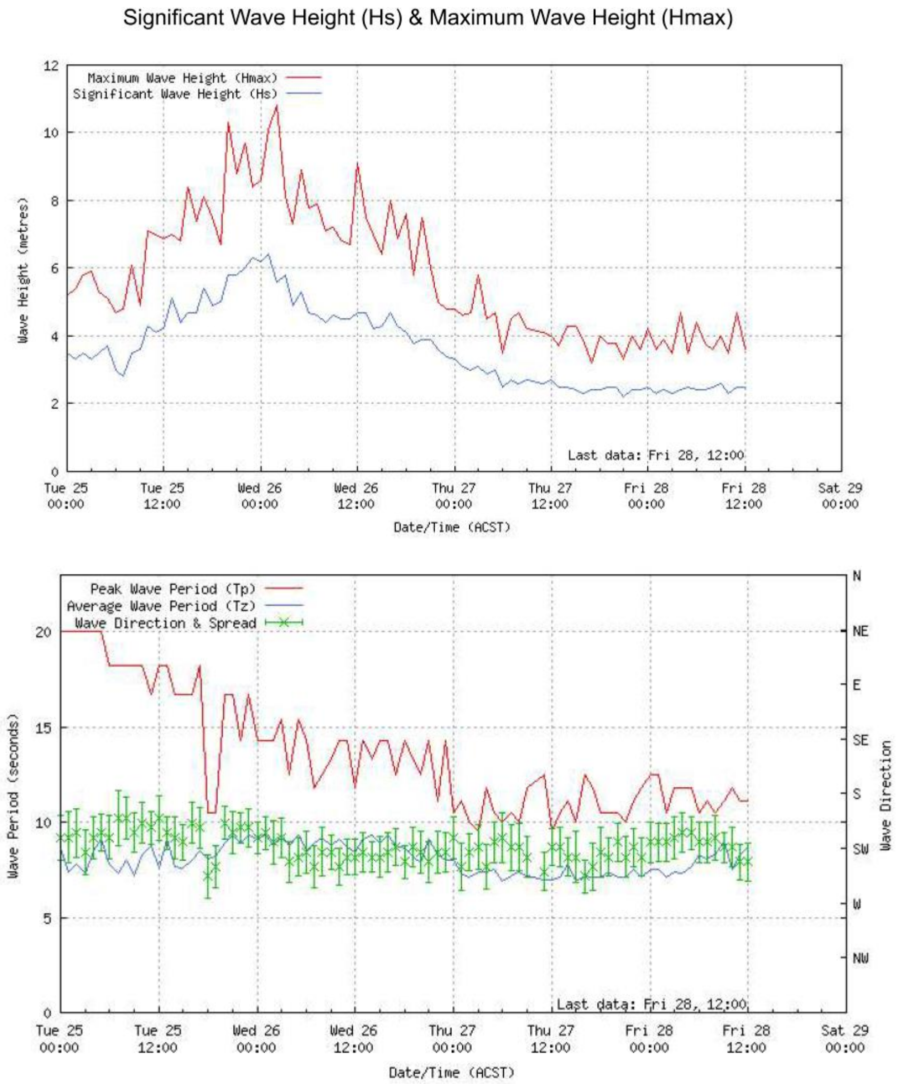


Figure 26 Cape du Couedic wave rider data (25 - 29 May 2021)

The design event is a function of the design working life of the structure, and the importance level (which considers the level of importance of a structure – for example, if it is a temporary structure, normal maritime structure or 'special' structure). For a design working life of 100 years in combination with an importance level of 2 (for normal marine structures) in accordance with AS 4997 (Guideline for the Design of Marine Structures), the design wave event is 1/1000 years.

Table 34 summarises the design wave heights adopted for concept design purposes.

Table 34 Design wave heights

Water level condition	Wave conditions
Ambient water level condition (serviceability limit state (SLS))	• Significant wave height, Hs = 2.00 m • Peak wave period, Tp = 13.00 s
Design wave event (ultimate limit state (ULS))	Design offshore wave condition (1000-year ARI or 0.1% AEP): • Significant wave height, Hs = 9.36 m • Peak wave period, Tp = 25.85 s

Wave rider buoys are suggested to collect site-specific data for detailed design purposes.

8.2 BEACH DESIGN PROFILE

The collection of bathymetric survey information through geophysical survey was completed through the latter stages of concept design. In lieu of this information, a 'design beach (and bed) profile' was established before, combining supplied LiDAR data capture and available chart information in the public domain. The following sections describe the sources of information used to develop a synthetic design beach profile. The design beach profile was later compared against the surveyed bed profile as a validation exercise (see Section 7.2.4).

8.2.1 LiDAR data capture

LiDAR survey information covering the dunes and intertidal area was available from a 1 m LiDAR survey provided by the South Australian Government. The LiDAR survey was captured during 2018. Table 35 provides details of the LiDAR data capture.

Table 35 2018 LiDAR data capture

Parameter	Description
Dataset ID	Elevation – South East Coastline LiDAR 2018 (no. 2212)
Date of capture	22 May to 24 August 2018
Resolution	1 m spacings
Accuracy	Vertical accuracy: +/-15 cm (95% confidence interval); horizontal accuracy: +/-50 cm (95% confidence interval)
Vertical datum	AHD (Ausgeoid09)

A cross-section was taken through the sand dune at the proposed Woods Well (opposite Fat Cattle Point) infrastructure location (shown in Figure 27) where coastal infrastructure is intended for construction [139.514, -36.0335]. The proposed location for the infrastructure has been selected considering engineering, ecological, access and cultural heritage considerations.

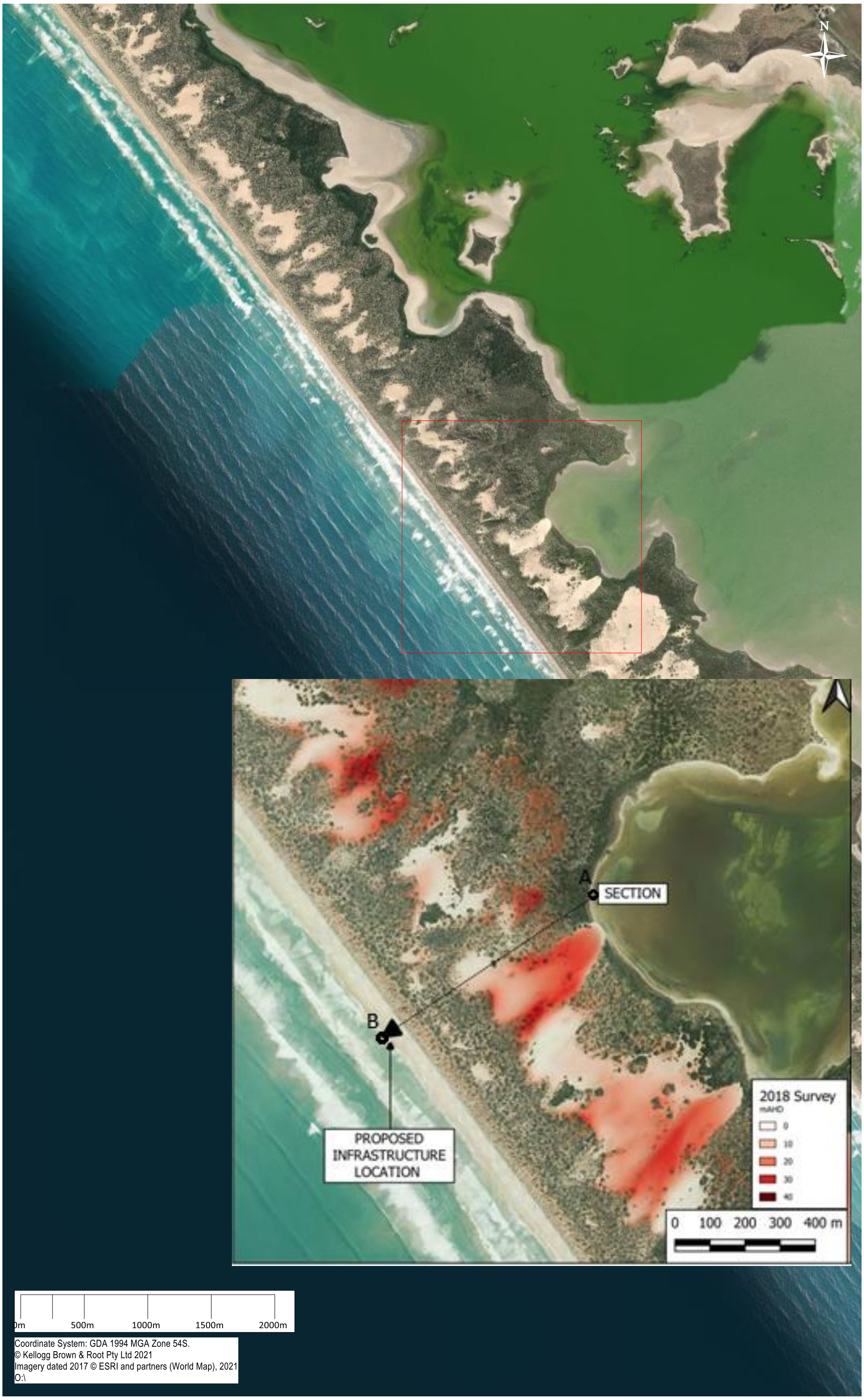


Figure 27 Typical cross-section location for marine infrastructure design

The survey section captures the dune from the Coorong lagoon near Woods Well, opposite Fat Cattle Point (CH0). The survey data ends approximately 51.0 m offshore from the toe of the dune[3] (approximately CH700, shown in the cross-section in Figure 28). An average one vertical to 19 horizontal (1V:19H) or 5% slope was taken between the end of the data at CH650 m out to CH700 m which is at zero LAT (0.769 mAHD). This section is shown in Figure 28, represented by the blue dashed segment.

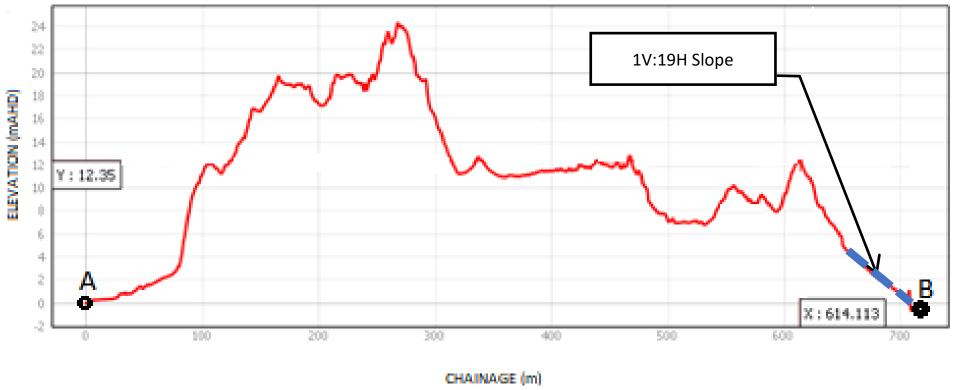


Figure 28 2018 survey section (mAHD)

8.2.2 Chart data

Navigational charts were reviewed to provide an understanding of the offshore bathymetry near the site. Publicly available chart information was sourced using Navionics (an extract is shown in Figure 29). The chart bathymetry is referenced to chart datum (CD) which is equivalent to lowest astronomical tide (LAT).

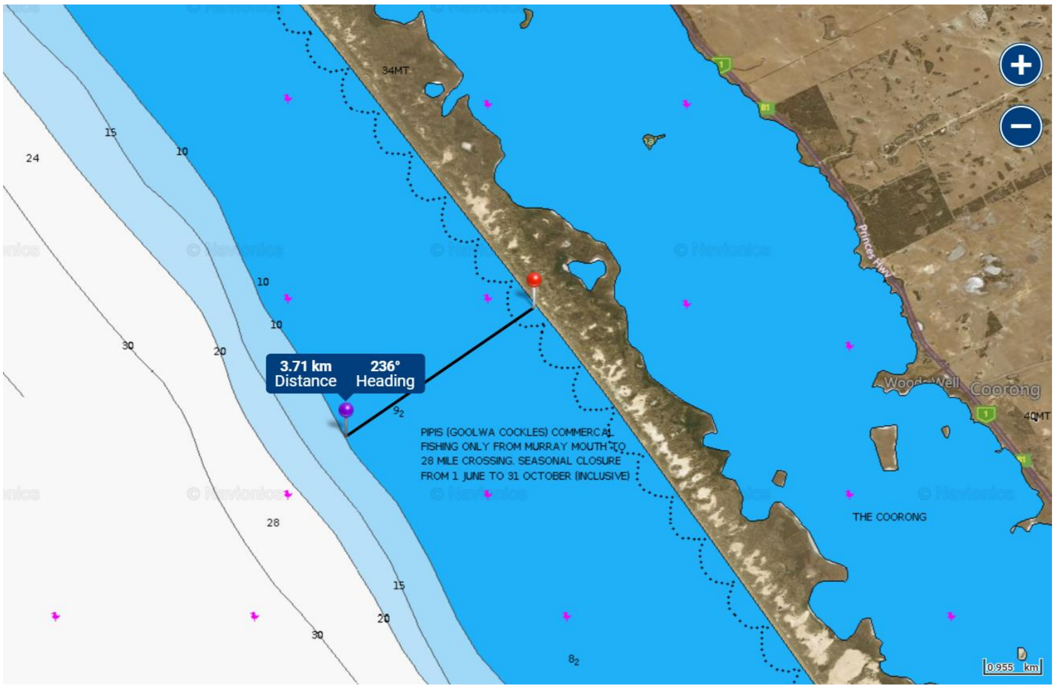


Figure 29 Chart bathymetry (Navionics web app, 2021) near Woods Well (depths to metres chart datum)

[3] The dune toe is where a sand dune meets the prevailing beach profile (i.e. the intersection of the beach and the base of a dune).

The bathymetry shown on the charts indicates wide, expansive flat bathymetry and relatively uniform coastline close to the site. The 10 mCD (chart datum) (or 10.769 mAHD) contour is reached at 3.7 km offshore. This represents a 1:400 bed profile.

8.2.3 Design bed profile

Data from Section 8.2.1 and Section 8.2.2 was combined to develop a 'design bed profile'. The development of this continuous bed profile enabled an estimation of the distances offshore for infrastructure options, and an assessment of shoreline changes (e.g. cross-shore erosion assessments). This assumed bed profile was reviewed against bathymetric survey collected as part of the geophysical survey and is discussed in Section 8.2.4.

The design bed profile comprised the following:

- **Dune and intertidal area**: A one vertical to 19 horizontal (1V:19H) slope applies in the intertidal beach zone (down to a level of 0.0 mAHD), which is consistent with the surveyed beach profile from the LiDAR data capture in 2018 (see Section 8.2.1).
- **Near shore zone:** For vertical elevations between 0 and -5 mAHD, the bed profile was assumed a one vertical to 100 horizontal (1V:100H) profile, determined as a stable beach slope for the wave climate and sand grain size (assumed based on calculations using Vellinga, 1990, discussed in Section 8.3.1).
- **Offshore:** The offshore profile was established using the contours provided on the navigational charts (Section 8.2.2).

Figure 30 presents the design bed profile.

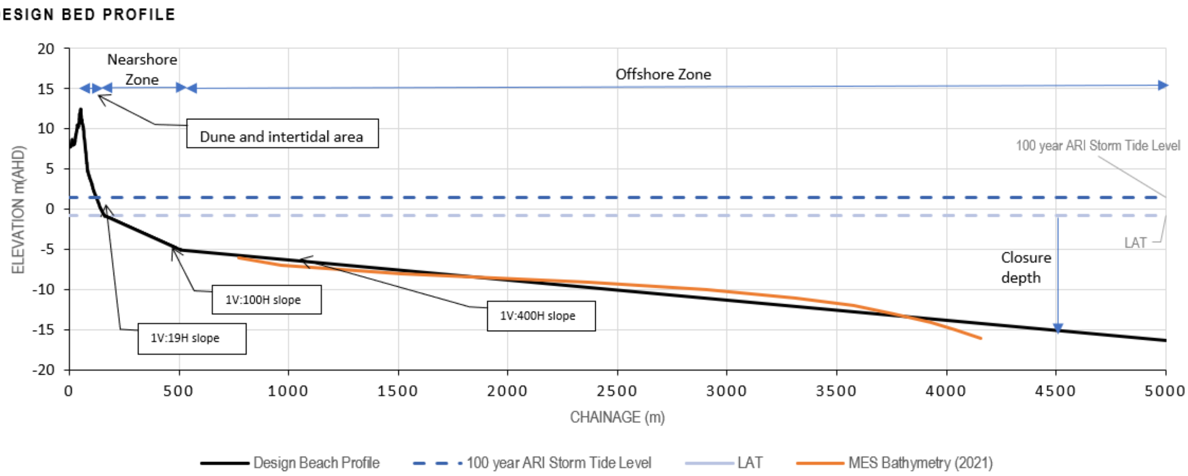


Figure 30 Design bed profile extending offshore

On this basis, to reach a depth of -5 mAHD (required for the pump submergence), an extension of approximately 500 m offshore from the dune toe must be travelled. As this depth is substantial, inclusion of a caisson structure was proposed to reduce the jetty length necessary to achieve pump submergence.

8.2.4 Comparison of bathymetric survey data to design bed profile

Bathymetric survey data was collected by Marine and Earth Sciences (2021) to confirm the beach profile compared with design. The data provided covers a 1 km wide section of coastline. Due to limitations in the collection of data (the zone of breaking waves at the time of survey), the survey coverage extended from approximately 750 m offshore, to just over 4 km offshore.

A comparison is provided in Figure 30 (shown in orange).

Overall, the data shows similarities to the assumed beach profile used for design. The design bed profile has been applied to the areas inshore on the basis that levels are unknown to date. Further investigation may be possible in future design phases; however, all modelling and assessment completed as part of concept design has adopted the design bed profile presented in Figure 30.

8.3 SHORELINE CHANGES

The beach morphology assessed within a 1 km range of the potential project site [139.514, -36.0335] was analysed using image photogrammetry. A library of nine aerial images capturing the Coorong that dates back to 1978 was provided to KBR.

The analysis was conducted by processing the aerial images to produce a georeferenced shape file of the coastline's dune toe for each aerial image. The distance between the coastline's dune toe to a baseline position ('nominal point') was used to measure the horizontal changes and represents a quantifiable advancement or retreat of the coastline in an area close to the primary infrastructure site. For the purposes of this study, this nominal point was used to represent typical conditions at each of the nominated coastal infrastructure sites, as the coastline changes between each site are minimal. The GIS processing can be seen in Figure 31 and Table 36.

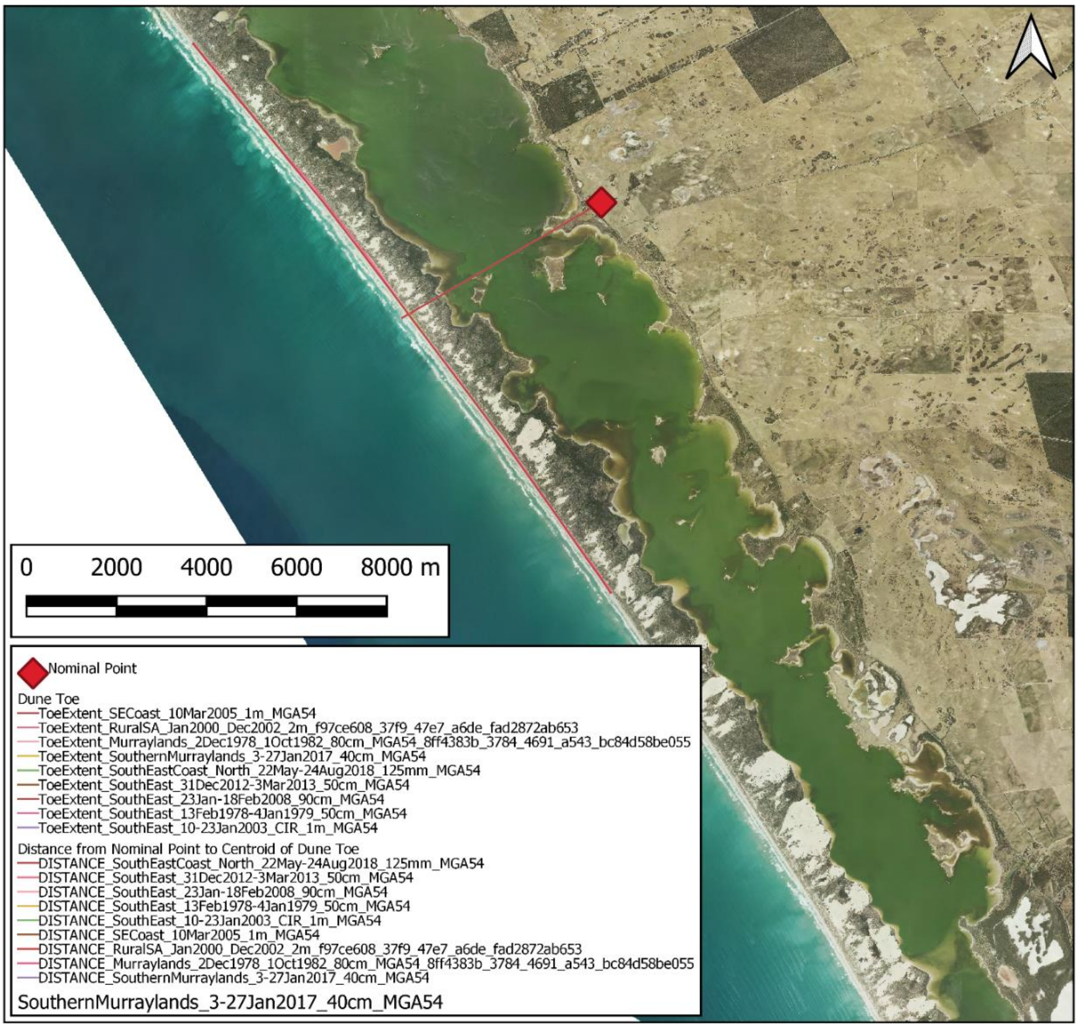


Figure 31 Change in dune toe position

Results show that the shoreline at this location is retreating by an average of 0.1 m annually from a base date of 1979 (by comparing only the 1979 and 2018 surveys), although there is a fluctuation in short-term results, with shoreline changes ranging from +10 m of accretion in one month to –0.7 m of retreat in one month, averaged (see Table 36). These fluctuations are due to continual erosion and redistribution of the beach, resulting from varied storm conditions year to year and seasonally.

During the 1970s, Middleton – located on the Fleurieu Peninsula north of the River Murray mouth and Coorong – had a well-documented shoreline recession where the dune toe retreated by 45 m. Although Middleton is over 100 km away from the proposed site that was analysed, the same magnitude of dune movement is documented in the aerial photogrammetry results. This large shift is also observable in the photogrammetry results between 1979 and 1982 (by comparing Murraylands_2Dec1978-1Oct1982_80cm_MGA54.gpkg to the SouthEast_13Feb1978-4Jan1979_50cm_MGA54.gpkg baseline).

Literature speculates that this large dune recession in the late 1970’s and early 1980’s is possibly due to tectonic subsidence and in the years preceding the 1970’s the dune stabilises (Bourman et al. 2000) and is not necessarily associated with typical erosion and deposition processes. Another possible cause could be a slight rotation of the shoreline owing to temporal (decadal) changes in wave direction, as occurs regularly on beaches in eastern Australia (Short and Trembanis, 2004). The switch in littoral transport direction also noted by Bourman et al. (2000) would also support rotation.

For design purposes, long-term average shoreline changes of -0.1 m/year (or 10 m of shoreline retreat over a 100-year design life) has been considered, unless shorter-term cross-shore transport (described in Section 8.3.1) governs.

Table 36 Shoreline photogrammetry results

Aerial image reference[1]	Month	Month	Year	Distance from nominal point (m)	Difference between each survey interval (m)	Cumulative change since baseline date (1979) (m)	Months since last image	Cumulative months since first image	Monthly (m/month) change between each survey[2]	Monthly (m/month) change from baseline date (1979)	Annual (m/year) change from baseline date (1979)
SouthEast_13Feb1978-4Jan1979_50cm_MGA54.gpkg	January	1	1979	5119.3							
Murraylands_2Dec1978-1Oct1982_80cm_MGA54.gpkg	October	10	1982	5089.5	–29.8	–29.8	45	45	–0.66	–0.66	–7.95
RuralSA_Jan2000-Dec2002_2m.gpkg	December	12	2002	5103.0	13.5	–16.3	242	287	0.06	–0.06	–0.68
SouthEast_10-23Jan2003_CIR_1m_MGA54.gpkg	January	1	2003	5113.8	10.8	–5.5	1	288	10.80	–0.02	–0.23
SECoast_10Mar2005_1m_MGA54.gpkg	March	3	2005	5115.8	2.0	–3.5	26	314	0.08	–0.01	–0.13
SouthEast_23Jan-18Feb2008_90cm_MGA54.gpkg	February	2	2008	5115.2	–0.6	–4.1	35	349	–0.02	–0.01	–0.14
SouthEast_31Dec2012-3Mar2013_50cm_MGA54.gpkg	March	3	2013	5110.7	–4.5	–8.6	61	410	–0.07	–0.02	–0.25
SouthernMurraylands_3-27Jan2017_40cm_MGA54.gpkg	January	1	2017	5112.1	1.4	–7.2	46	456	0.03	–0.02	–0.19
SouthEastCoast_North_22May-24Aug2018_125mm_MGA54.gpkg	August	8	2018	5115.3	3.2	–4.0	19	475	0.17	–0.01	–0.10

[1] *Where two dates are present within aerial image file name, the second of the two dates has been assumed as the date of image capture.*

[2] *A positive (+ve) value indicates that the shoreline advanced (accretion) towards the ocean. A negative (-ve) value indicates that the shoreline retreated (eroded) landward.*

8.3.1 Cross-shore transport

The cross-shore transport was estimated using Vellinga's method (Centre for Civil Engineering Research and Codes (CUR) 1989, 'Guide to the assessment of the safety of dunes as a sea defence' Report 140). Vellinga's method assumes no volume loss in the beach profile, which is reasonable, since industry experts have established that the system is generally well established and stabilised, with no volume of material being removed from the coastal system, but instead being captured via the formation of sand bars and redistributed to the shoreline during storm events (evidenced by no noticeable accumulation sites along the coastline). Inputs to this analysis include the assumed beach profile shown in Section 8.2.3 and the offshore deep-water ambient wave conditions (Section 8.1.3).

Cross-shore transport is likely highly variable and episodic at the site, with a continual process of erosion and redeposition (re-establishment of the shore) over time expected, due to the reversal of longshore transport processes (to a nearly 'net zero' movement), circulations from rips and the reworking of the beach due to ambient events.

Results from the analysis (in Figure 32) show that at 0.0 mAHD the beach profile erodes by approximately 25 m horizontally from the initial beach profile (based on a combined 100-year ARI storm tide event, sea level rise and 1000-year ARI wave height, presented in Section 8.1). A vertical erosion of 2 m at the dune toe was also estimated. These rates of shoreline change correspond well to observed changes in the aerial imagery analysis in Section 8.3. It is noted, however, that this is representative of a single low-frequency event, and higher rates of long-term shoreline change are plausible (such as the 45 m erosion observed historically at Middleton).

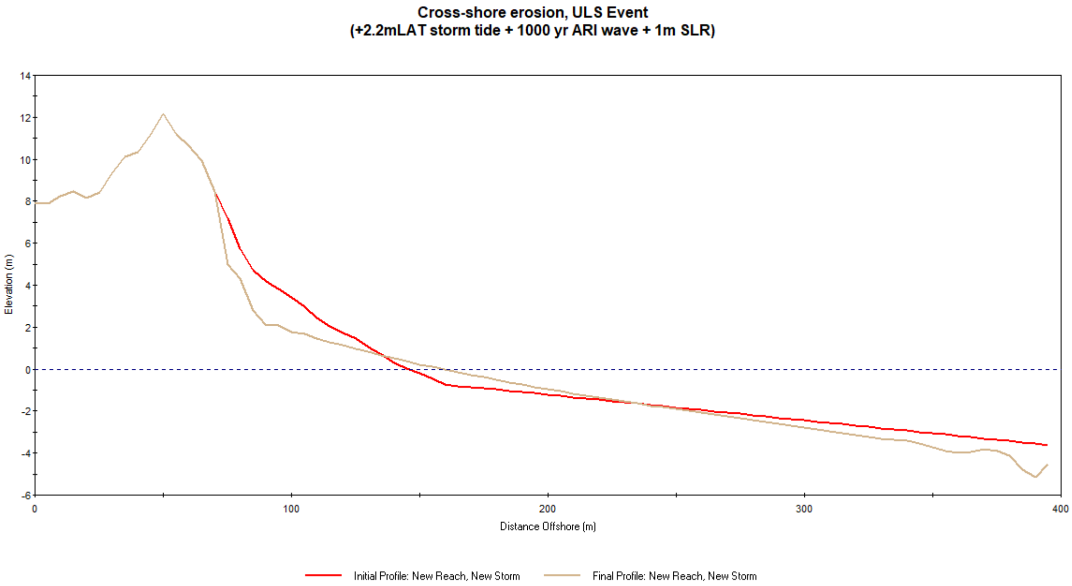


Figure 32 Cross-shore erosion assessment

Initial calculations for cross-shore transport are taken into consideration for potential design options. These calculations are a function of the near shore depth, such as an open discharge channel from Coorong to the ocean or jet pumps located in the surf zone. These considerations include:

- Piled support for structures located on the beach (for example Option 3B), to minimise vulnerability to shoreline changes/erosion.
- Extension of the breakwater into the foreshore. Nominally a 50 m extension is allowed for, buried within the foreshore and dunes (conservatively allowing for approximately two ULS wave erosion events during the life of the structure).

8.3.2 Longshore transport

A literature review of longshore transport of the Coorong was conducted as a part of preliminary calculations.

A number of studies have attempted to estimate rates of longshore sand transport along the Sir Richard Peninsula based on hindcasting models. The results range from net 260,000 m^3 per year to the east between 1940 and 1990, with a 1,000,000 m^3 per year westerly reversal in 1941–42, as well as other reversals noted (Chappell, 1991). Bourman et al. (2000) conclude that swell waves may transport sand from the River Murray mouth west along the beach to Goolwa, while storm waves transport it in the opposite direction.

At best, these results are inconclusive. Sediment is predicted to be transported east and west, and Bourman et al. (2000) concluded that there is a net westerly transport towards the River Murray mouth, based on the westerly migration of the mouth and the recurved nature of the western inlet shoreline.

It is the opinion of this study that the long term average net longshore sand transport along the Sir Richard and Younghusband peninsulas is close to zero, with the possibility of slight switching in direction causing alternating eroding and accretion to manifest itself along Middleton beach, as a form of beach rotation. This study believes that the long term average gross longshore sand transport is about 1,000,000 m^3/year.

The net drift is defined as the south setting drift *minus* the north setting drift and gross drift is defined as the south setting drift *plus* the north setting drift.

The longshore drift at any one time is the averaged effect of vigorous rip and feeder currents which are essentially circular in plan. Even on days when the calculated longshore drift is zero because the wave approach angle is 90 degrees to the shoreline alignment, there will be vigorous mixing of any discharge plumes due to these rip and feeder currents. This mixing has been represented in the discharge modelling with high lateral turbulent diffusivity values (e.g. 100 m^2/s vs 1. 0 m^2/s in the open ocean).

If climate change induces a slight change in swell wave direction and/or the intensity and frequency of westerly storms, these would affect the direction and rates of longshore transport, which would impact shoreline stability.

The literature review addressed multiple studies conducted over the past three decades and concludes that the Coorong longshore transport is incomprehensible. Local academic research experts were also consulted during the study (e.g. Professor Patrick Hesp). They advised that the Coorong is a high wave energy climate with a well-established beach morphology; however, the longshore transport is still being studied.

Preliminary calculations undertaken using the CERC formula (Rijn 2002) were utilised to estimate a gross transport rate. A gross transport rate of 1,000,000 m^3 per year was adopted for concept design purposes, calculated from the ambient wave conditions in Table 34. This value is consistent with the literature studies (order of magnitude) and may be considered a conservative assumption for this level of investigation.

8.4 CLOSURE DEPTH

A key consideration in the design of marine infrastructure solutions is the exclusion of sand. The site is characterised by a wide active surf zone (between 500 m and 2000 m in width) due to the flat bed profile and persistent high-energy wave climate. This zone is highly turbulent and facilitates the rapid suspension and movement of sand, which ultimately can find its way into the proposed intake/outfall system.

Ideally, the intake/outfall systems would be located far enough offshore to minimise the impacts of sand either being entrained at the intake, or from blocking the outfall. This location offshore is the theoretical ‘closure depth’.

The closure depth represents the depth of water at which there is minimal sand transport due to wave action and is directly proportional to the offshore significant wave height. Using the ambient offshore significant wave height (Table 34), the closure depth is beyond the –15 mLAT contour. From the sources discussed in Sections 8.2.3 and 8.2.4, this closure depth is therefore 4 to 5 km offshore of the coastline.

Where the intake and/or outfall structure cannot be located at this distance offshore, additional sand maintenance measures are considered necessary. Based on the assessment of longshore transport described in Section 8.3.2, a high-level estimate of the sand that could be moved annually through a pumped or piped system is 10,000–15,000 m^3. This volume would result in a noticeable accumulation that would require regular maintenance and removal were it to be deposited within the Coorong South Lagoon.

8.5 MARITIME INFRASTRUCTURE OPTIONS

Multiple infrastructure solutions have been designed to a concept level and can be augmented to suit new functional requirements that develop during later design phases. A summary of each infrastructure solution and its main design variables is provided below.

8.5.1 Jetty

A jetty structure is proposed for both intake and outfall processes under:

- Option 3A: Intermittent pumped connection out of Coorong South Lagoon – 150 m long discharge jetty.
- Option 3C:Pumped connection out of Coorong South Lagoon – 150 m long discharge jetty.
- Option 4A: Bi-directional pumped Southern Ocean Connection – one location, separate pumping stations, pump in location with caisson structure on 350 m long jetty.
- Option 5A: Simultaneous pumped Southern Ocean connection – two locations, separate pumping stations, pump in location with caisson structure on 350 m long jetty and pump out location to 150 m long discharge jetty.
- Option 5B: Simultaneous pumped Southern Ocean connection – two locations, separate pumping stations, pump in location with caisson structure on 350 m long jetty and pump out location with a low visual impact beach discharge structure.

A jetty is not proposed under Option 4B and Option 6.

The jetty design comprises precast concrete deck units, steel members and steel piles to enable ‘over the top’ construction. The design was selected to reduce construction time since the location is considered remote and the environment is severe compared to other options that involve construction within the wave climate (for example breakwater construction). The jetty has short spans (11 m) to facilitate construction via a cantilevered method.

Initial considerations included the extension of the jetty beyond the closure depth (–15 mLAT contour) to minimise the intake of sand, thereby reducing maintenance requirements and the need for more sophisticated sediment exclusion mechanisms to prevent the transport of excess sand to the Coorong. However, to reach the closure depth, a 4 to 5 km long jetty would be required. A jetty of this length is comparable to the Lucinda Jetty in Queensland (at 5.7 km length), making it one of the longest jetties in the southern hemisphere. As such, this ‘long jetty’ option was deemed unfeasible in early concept screening due to the length.

A 350 m long jetty (300 m into ocean and 50 m into dune system) is currently proposed for economy. Additional protection to inhibit sand entrainment will be provided through the inclusion of a caisson structure for pump in options (Options 4A, 5A and 5B).

The jetty will extend into the highly active surf zone of the Southern Ocean. This is beneficial for dispersing higher salinity outflows pumped from the Coorong but requires a robust design at the intake to achieve sand exclusion.

The jetty will therefore comprise the following design elements:

- It will have short spans (11 m), to minimise the size of the cantilever pile guide and facilitate construction.
- It is founded on tubular steel piles.
- The deck comprises precast concrete headstocks, steel beams and precast concrete deck. It will be at least 4.5 m wide (single lane), to suit construction and maintenance cranes and to provide additional deck width, which will allow pipework to be run at jetty level.
- Where an intake is required on the jetty, a precast reinforced concrete caisson structure is proposed at the jetty head. This caisson provides an enclosure for fish exclusion screens (T-screens or cylinder screens), slurry pumps (required to extract sand that washes into the caisson from the surf zone) and the intake pump shafts (to protect from wave impact loads).
- The width of the jetty is a function of the pumping flow rate requirements. The jetty width must be able to accommodate the intake and outfall pipework, power cabling, clear width of jetty to enable over the top construction, and safe maintenance access.
- The top elevation of the jetty headstock is required to be +9 mAHD. This has been selected based on maintaining a safe airgap between the underside of the structure and the storm tide, wave crest levels (in a ULS event) with allowance for sea level rise over the life of the structure. Considerations were also made to allow for vehicles to drive along the beach and under the jetty on the shoreline to maintain current access amenity.
- The head of the jetty is wider than the typical jetty cross-section, to hold the pumps and auxiliary machinery supported over the caisson structure (and could be widened further to allow vehicle turnaround). Jetty head dimensions should be reviewed during future design phases.

It is assumed that public access to a jetty structure will be permitted (unless the facility is manned to prevent public access). Without a manned access point, gated or fenced access points cannot guarantee continued closure (i.e. if unpermitted access is gained, the access could remain open until such time as the jetty is revisited in the next maintenance schedule). Given the remoteness of the site, provision of a security presence was considered unfeasible, and as such, handrailing has been provided to either facilitate public access, or if other preventative measures (such as gated access) are breached.

All fixings and handrails have been specified as duplex stainless steel grade 2205 to meet the required design life of 50 years.

Fish exclusion screens are proposed to stop fish and other aquatic species from being drawn into the pumps, and so minimise mortality rates associated with the pumping infrastructure. It is also anticipated that the fish screens will provide some assistance in minimising the sand intake into the system. Discussions with suppliers have indicated that super duplex grade 2507 stainless steel will be required for the construction of the fish exclusion screens.

A secondary slurry pump system is also proposed for settled sand removal within the caisson structure.

The jetty structure may be marked with a lighted beacon or marker as required. The requirement for markers will follow recommendations in *IALA Recommendation 0139 on the Marking of Man-Made Offshore Structures* (2013, ed 2.1). No provisions for vessel berthing will be incorporated in the jetty due to the severe wave climate.

Access to the jetty structure will be achieved through construction of an earthen abutment and embankment to form an access track matching in at top of structure level. Stabilisation of abutment and embankment will be required through placement of rocks or vegetation to avoid wind-blown erosion.

8.5.1.1 Construction considerations

Jetty construction is proposed using a single crane plus a canti-traveller[4] (or similar). It is a common method of constructing typical pile and deck jetty structures that has been used successfully in similar construction projects across Australia and internationally. The canti-traveller can hold the pile in position, guide the pile and support the pile being driven.

The canti-traveller can utilise the full width of the jetty span, as it provides a cantilevered work platform (i.e. is not limited only to the 4.5 m accessway nominated on the drawings). The 4.5 m width is sized to enable access for the crawler crane back to the land-side once constructed and provides access for maintenance cranes that may be required to maintain the pumps and components at the head of the jetty structure.

In developing a construction methodology, the following was considered:

- Construction requires over the top construction only (no construction via vessels is proposed due to the severe metocean conditions and shallow depths). Construction will utilise a crawler crane and canti-traveller (cantilevered mobile construction platform).
- Over the top construction enables construction above the metocean climate. The elevation of the jetty is selected to be above the storm surge plus wave heights to prevent overtopping during construction and operation.
- No divers to aid in construction due to the severe metocean conditions.
- The connection between steel pipes and headstock is a reinforced in-situ concrete plug and designed to allow fast construction.
- Construction loads must not exceed that of the operating loads; otherwise, the span and possibly girder design may change. The contractor must consider its construction plant carefully as the clear width is limited to 4.5 m to manage jetty capital costs.
- The Southern Ocean coastline is not frequently accessed by marine traffic. Primary navigation routes are >30 km offshore and presents a low risk of interaction with marine traffic during construction and commissioning of the jetty. Navigational changes will be advised through issuance of a notice to mariners for both construction activities and any permanent marine structures.
- Construction of the caisson jetty head is proposed using precast elements, to be stacked over pile guides. The base of the caisson, which is required to be installed at approximately -5 mAHD, would require ‘jetting’ in of precast elements approximately 300 m offshore from the shoreline to achieve the required submergence depths of the pumps. Otherwise, an increased jetty length would be required at a minimum to the -5 mAHD contour (between 500 m and 1 km offshore). The final caisson invert level will be confirmed after making the final selection of pumps and receiving guidance from the supplier.

[4] A canti-traveller is a purpose-built working platform structure that installs piles into the seabed using an ‘over-the-top’ cantilevered construction method.

8.5.1.2 Maintenance

The jetty option has been selected with minimal maintenance in mind for the structure although several elements of the intake/outfall systems will require maintenance (discussed further in section 9).

Corrosion protection

Paintings and coatings to provide corrosion protection are not considered feasible, given:

- The aggressive metocean climate.
- Likely abrasion of any wetted infrastructure by sand impacting lifespan of any applied coating.
- Difficulties with recoating applications in the field.
- The high frequency of maintenance required (which presents difficulties given the remoteness of the site, and low number of days per year which offer good conditions for application).

Provision of cathodic protection via the use of anodes affixed to submerged steelwork is unlikely to be feasible as these anodes will require periodic replacement. This is an operation typically completed with the aid of divers; a high risk and undesirable operation in the Southern Ocean.

Corrosion protection on the ocean side therefore relies on a corrosion allowance to the external face of the piles. This corrosion allowance is an additional thickness considered in structural design of steel members and elements. The corrosion rate varies from 0.04 to 0.1 mm per year for most jetty structure components with reference to Australian Standards. This allowance is intended to cover all corrosion types (e.g. uniform (surface) corrosion, accelerated low water corrosion, etc.). While reliance on this additional allowance minimises the ongoing maintenance requirement of the structure, given the 100-year design life, this can equate to an additional thickness of 8 to 10 mm (when considering a corrosion rate of 0.1 mm per year), meaning an increase in member sizes and the capital cost. Alternate corrosion prevention measures could be considered through detailed design for the selected infrastructure option.

In addition to (or in lieu of) a corrosion allowance, corrosion prevention measures such as an impressed current cathodic protection system could be considered to enhance durability of any jetty infrastructure. This can be assessed as part of detailed materials design considerations completed in future design phases.

Fish screen maintenance

Fish screens, while they have a self-cleaning mechanism (mechanical scraper/rake), will require regular maintenance. Fish screens are typically a fine 2–3 mm mesh grating that requires cleaning because they become fouled with marine growth or debris. Cleaning can be completed by blasting with chlorinated water or compressed air. Allowance for maintenance vehicle access is provided to enable safe vehicle and crane access to the head of the jetty. Fish screens will be 2507 super duplex stainless steel for marine applications.

Following supplier recommendations, a screen retrieval system (gantry and rail system) is to be installed on the jetty head, to enable access to screens out of water for regular inspections and maintenance. This will also prevent the need for diver access for the replacement of anodes and cleaning. Indicatively, anode replacement in seawater will be required after several months.

8.5.2 Breakwater

The key difficulties in designing marine infrastructure solutions are the ability for the solution to:

- Keep sand from blocking the intake and outfall.
- Withstand the wave loads for a persistent, high wave energy condition, in addition to the significant storm conditions likely to affect the Southern Ocean coastline.

To overcome these challenges, an enclosed breakwater solution was proposed for Options 4B and 6 (passive pipes). The enclosed breakwater can provide a protected environment from the high wave energy climate. It also minimises sand ingress into the system, mainly the suspended source of sediment generated in the surf zone.

Design

The breakwater cross-section extension comprises a dual layer of primary armour overlaying a permeable rock core (see Option 4A and Option 6 drawings in Appendix A for details). This differs from a conventional breakwater, which has multiple layers of armour and a fine, granular core which typically has low permeability and is difficult to construct in high wave climates (due to loss of material).

No geotextile filter layer was proposed due to constructability constraints associated with the active Southern Ocean wave climate.

The breakwater structure has been designed to maintain its structural integrity during the ULS environmental conditions while allowing pedestrian safe volumes of overtopping.

The primary armour, 16 t Tetrapod units, has been sized using the Hudson (1961) equation for 5% damage criteria during the ultimate design event. Secondary armour has been sized as a proportion of the mass of the Tetrapod armour units in accordance with the CUR Rock Manual (1999).

The breakwater design has the following key features:

- **The crest is 4.5 m wide**: A concrete crest pathway is provided to facilitate access of vehicles and small to mid-sized cranes (as required) for maintenance and inspection.
- **The breakwater crest level is +3.43 mAHD**: This elevation was selected based on the following:
  - Wave climate offshore of the breakwater is depth-limited. Wave climate is governed by the water depth. To achieve an internal depth to -5 mLAT (-5.747 mAHD) inside the breakwater structure, the breakwater therefore requires a crest level of +3.43 mAHD to account for an acceptable level of overtopping in the given wave climate (inclusive of sea level rise over the life of the structure).
  - Overtopping volume is 1 to 20 L/s/m for pedestrian access in ambient wave conditions. The EurOtop Overtopping Manual offers guidance on limiting volumes to safe amounts for pedestrians. A limiting overtopping volume of 1 to 20 L/s/m is required in accordance with this manual. While public access may not necessarily be provided, periodic pedestrian and vehicle access for maintenance crews will be required. The crest is therefore set to achieve this criterion under ambient ('typical') wave conditions (inclusive of sea level rise).
- **Primary armour placement is on the lee- and front-sides of the breakwater**: Given the severe wave climate at the site, it is anticipated that the structure will be frequently overtopped during storms (i.e. a SLS or 1-year ARI storm events and above). Primary armouring is therefore required on the front- and lee-sides of the breakwater.
- **Breakwater extent (frontal width) is a function of the overtopping flow rate**: The width of the U-shaped breakwater is a function of both the overtopping volume under SLS environmental conditions and the footprint of the pipework. The overtopping of the breakwater will be one of the mechanisms that will introduce new water into the enclosed breakwater basin and provide a supply of clean ocean water for the Coorong intake at high tide.
- **The footprint of the breakwater is approximately 50 m wide**: This footprint is based on the slope of armour units being one vertical to 1.5 horizontal (1V:1.5H), the water depth (governed by pump submergence requirements), and the width of a crest access path to facilitate actions such as maintenance or emergency access.

- **The toe of the rock revetment**: The revetment's toe detail provides protection against scour, undermining, revetment over-steepening, and failure. Rock toe protection in front of the concrete units at the base of the structure is proposed. Use of rock at the toe is generally preferred over concrete armour units to avoid structural overload of the units (i.e. the mass of the slope crushing the toe units). Additionally, slender units typically rely on their interlocking for stability (as opposed to mass) and therefore may perform inadequately on a flat base. It is intended that over time the toe will be buried due to the natural build-up of sediment.
- **The porosity of the breakwater**: The breakwater has been designed using a single-sized underlayer to promote flow through the breakwater structure. The exchange of water is related to the tidal prism available.

  Option 4B is approximately 130 m of breakwater shore-parallel face and may contribute up to 2,600 L/s in an ambient storm event. Option 6 is approximately 50 m width of breakwater along the shore-parallel face and may contribute up to 1,000 L/s in a storm event in addition to tidal exchanges. It is noted that for Option 6 the footprint of the pipework governs the breakwater footprint design.

  It is noted that flow through the porous structure will also contribute to the exchange of water.

Alternatively, the length of the breakwater's frontal face could be reduced by considering other methods to flush the waters enclosed by the breakwater such as box culverts or weirs through the breakwater structure.

The breakwater structure will terminate approximately 50 m shoreward of the coastline to allow for shoreline recession (in line with section 8.3). This 50 m section is proposed to transition to tie into the existing beach levels at the foot of the dune, enabling beach access to continue along the coastline or via a constructed access path through the dunes bypassing the breakwater.

Materials selection

Initially the cross-section was designed with >10 t rock primary armour units (average mass). This average mass will represent a range of rock sizes. For a select grading, this could mean that up to 15 t rock material may be required (based on a standard grading size per Australian Standard AS 2758.6 *Guidelines for the Specification of Armourstone*). This option was discounted based on the challenges in sourcing and transporting rock of this size, in the quantities required and of the high quality needed for placement in the marine environment (discussed further below).

Armourstone for use on breakwaters (either as primary or secondary armour) is susceptible to more severe environmental conditions than general armourstone. Larger rock armour is also increasingly susceptible to defects and damages compared with small rock armour sizes. This includes:

- Susceptibility to hydraulic forces (i.e. wave action) causing rocking/motion which could displace armour or result in breakdown of the armour material in-situ.
- Weathering, including cyclic wetting/drying, abrasion (such as from sand) and salt attack

The rock durability (physical and chemical properties) and the low incidence of defects (joints, cleavage, shear planes or fracturing) are important to ensure the armour can withstand the environmental conditions in the marine environment without significant loss of size during the life of the structure, which would result in a loss in breakwater stability in high-energy conditions. Recovery of suitable sized rock with minimal defects from a quarry source may therefore be low (as low as 10% of the quarried volume), with a large proportion of material recovered being unsuitable under the tight specifications required.

Prefabricated concrete units can be a cost-effective option where suitable quality rock of the required size and quality is unavailable. A Tetrapod concrete primary armour unit was therefore selected on the basis that the units could be cast on-site (or nearby) and transported more efficiently, and the unit size is smaller than rock while still passing the same ultimate design conditions. Sizing of these Tetrapod units are likely to be in the 16 t range for an installation to a water depth of 5 m.

It is assumed that periodic maintenance would help to maintain the coastline against significant shoreline retreat over the life of the structure. The breakwater structure can also be upgraded over time, should further retreat warrant extension into the dune zone further than initially allowed for, through the placement of additional rock.

8.5.2.1 Construction considerations

Breakwater structures can be constructed using plant exclusively from land or from water. It is likely that, due to the severe metocean conditions, only land-based construction methods can be utilised in this application.

A typical breakwater cross-section is constructed by first dumping the core material; then placing the armour layers. This process will typically require placement in 'sections' to minimise loss of underlayer materials.

Some key considerations in assessing the constructability of the breakwater include:

- Difficulties in the production and transport of rock armour to the quantities and specifications required for the marine environment. Initial estimates suggest that over 10 t rock armour units would be required as primary armour, facilitating the decision to instead implement concrete armour unit construction (e.g. Tetrapod units) due to difficulties in sourcing this type of material. While concrete armour units can be utilised for primary armour, a large quantity of high-quality rock will still be required for the core and toe of the breakwater structure. It is likely the closest available suitable rock source is in Adelaide. Transporting this size rock to site will take a significant amount of time, and during the transport of the rock it may be fractured and become unusable.
- Marine-grade armourstone is typically a low-production product due to the high specifications required and as such takes a significant lead time to source and stockpile prior to construction.
- The wave environment is high energy with large wave heights and long sweeping wave periods. Contractors will need to carefully consider their machinery capabilities and stability during lifting operations. This is particularly important for the breakwater, as construction duration is expected to be longer than other options.
- The concrete armour units can be transported to site or cast on-site. Either way, it is economically efficient to have a consistent amount of the units ready for placement at the same speed that they are being placed on the breakwater. This reduces the amount of space required for stockpiling the units and reduces the amount of time the units are exposed to the construction environment before being positioned within the breakwater.

8.5.2.2 Maintenance

Normal maintenance of the breakwater structure is expected over the functional design life to maintain the integrity of the structure. Allowable damages up to 5% of the primary armour layer are considered acceptable over the life of the structure.

The structure is considered effective to manage high volumes of sand in suspension within the near shore zone; however, the porosity of the structure still allows the movement of bed sands into and out of the structure. Due to the calm conditions inside the breakwater, there is a reduced mobilisation of material, leading to accumulation over time. Periodic maintenance of sand within the breakwater will be required to manage the levels of sand within the structure. Maintenance may involve slurry pumping (or very small suction dredging) of the sand periodically.

An allowance for approximately 50 m of shoreline retreat has been incorporated in the design; however, it is anticipated that periodic management of sand via manual bypassing will also be required, both to minimise erosion impacts, and to maintain a continual movement of sand along the coastline. This could involve movement of accumulated sand via excavators and dump trucks or installation of temporary slurry pumps and pipelines to bypass sand from one side of the breakwater to the other side.

8.5.3 Subsea pipeline

Subsea pipeline installation was initially considered for all options on the basis that:

- A directionally drilled or trenched pipeline offers the advantage of not being exposed to the severe environmental conditions experienced at site.
- Aesthetically no substantial changes across the near shore zone (except for pump stations and auxiliary systems that may be required for the system).

A conventional subsea pipeline was initially considered in early concept screening however, conventional subsea pipelines were identified as being susceptible to the build-up of sand and are difficult to maintain for sand removal. Consequently, intake and outfall infrastructure would be required to be located at a distance beyond the depth of closure (discussed in Section 8.4), and thus a pipeline of over 4–5 km from the shoreline would be required (up to 8 km from the Coorong).

Several construction options were considered to install the subsea pipeline; however, the installation of a submerged pipeline was deemed unfeasible in early concept screening. As such no concept design options incorporate a subsea pipeline due to the following:

- **Difficulties in constructability**: in total three different construction techniques were reviewed for a subsea pipeline option. Each presented unique challenges in the execution of the work (discussed below):
  - **Floating pipe installation**: a floating pipe installation involves the installation of a 'string' of pipes which are floated into place (by towing from the shoreline) and weighted to the seabed using concrete collars. Due to the significant wave climate, the concrete collars attract high wave loads and concrete collars alone are insufficient to fix the pipeline to the bed. The pipeline therefore requires concrete encasement or burial. Vessel access is also limited for ocean placement because of the severe metocean condition.
  - **Trench installation**: to bury or concrete encase the pipeline, trenching may be required. Trenching involves the construction of a temporary sheet-piled jetty structure, excavation and placement of the pipeline, and then backfilling or concrete encasing the pipeline. This method of construction is high-cost (requiring the construction of a temporary construction jetty or similar) and is not feasible within the surf zone or in deeper offshore areas.
  - **Directionally drilled pipe installation**: directionally drilled installation would enable the pipe to be buried below the seabed. Directionally drilling a pipe 4 - 5 km offshore is unfeasible and exceeds the limits of current directionally drilled pipe installations considering industry advice.
- **Material cost**: the cost of materials is high, due to the number, size and lengths of pipe required.
- **Maintenance**: maintenance of the system would be required frequently to ensure sand and marine growth is excluded from the system. Due to the severe metocean climate, access via divers or vessels for maintenance is unsafe. At present, no remotely operated flushing or clearing systems of the scale required are known. Marine growth maintenance would typically require chlorine dosing (as is used in desalination plants). The cost associated with chlorination

and de-chlorination is high, and there is opposition to utilising chemical treatments given the sensitivities of the site; therefore, this option was not considered further.

A modified version of the subsea pipeline was therefore considered for a passive piped system (Option 6), with a subsea intake/outfall system being considered in combination with the shoreline breakwater structure. This combined solution provides the advantage of:

- Maintaining current foreshore amenity for access (as pipelines are buried through the dune and foreshore). It is noted that breakwater infrastructure is proposed for Option 6 also which will have a greater amenity impact, but alternate access tracks could be provided behind or over the breakwater minimising this impact.
- Reducing the intake of sand anticipated due to the presence of the breakwater structure.
- Minimising the exposure to the severe metocean environment because of the location within the breakwater, thereby simplifying the construction and maintenance activities.
- Reducing distances for pipeline burial, to be within the existing capability of directional drilling or micro-tunnelling (pipe-jacking) installations or trench installation.

The intake/outfall structure is proposed to be a precast concrete structure, installed on guide piles and fitted with a grillage structure. Due to the low flows proposed through the passive system (Option 6) fish screens will not be provided. Only gross pollutant screens are proposed. Some sand intake would be expected and will require periodic maintenance for removal (via slurry pumping or similar). These elements are described further in Section 6.4.2.

8.5.3.1 Construction considerations

The following construction considerations were identified in consultation with Fulton Hogan, which may provide some constraints on construction operations and installation techniques:

- A drill rig located on land will feed the drill head and connect additional drill shafts. Once the drill head has breached the seabed at the desired location, an offshore support vessel is required to feed the pipe as the drill rig pulls the pipeline back from land. An alternate approach is to install the pipe via micro-tunnelling/pipe-jacking from a launch site on Younghusband Peninsula and then construct the discharge/intake structure as the tunnelled pipe breaches the seabed.
- The type of available drilling/tunnelling equipment is limited due to the high wave energy environment.
- The maximum length of a directionally drilled pipeline is 3,000 m and around 700 m for a micro-tunnelled pipe.
- A trenched pipeline requires a trenching rig, which is usually located on land or sometimes from a support vessel or temporary jetty structure depending on pipeline length, prevailing ocean conditions and depth of installation required. The trenching rig is required to plough a segment of the bed and place a pipe into this ploughed segment. Unlike the directionally drilled pipeline, a trenched pipeline is not limited in length. An alternate construction methodology would be similar to that used for outfall pipelines (e.g. for wastewater treatment plants) where temporary sheet piling is installed adjacent to provide protection for pipe installation with pipe segments welded or jointed on land and progressively fed into a trench between these sheet piles within a trench excavated from the temporary jetty.
- Once the trenched pipeline has been laid, it may be left uncovered on the seabed, or it may need to be buried (subject to pipe uplift loads). If the pipe is left uncovered, it will be exposed to wave motions, vessel anchor drag and fishing nets. As such, a buried trenched pipeline is the preferred option. To bury the pipeline, backfilling of the pipe trench, or concrete encasement would be required.

To concrete encase the pipeline, dewatering of segments would be necessary. Due to the challenging wave climate and water depth, this option is not feasible to bury the pipeline, particularly in considering trenching to closure depth (i.e. –15 mLAT on the ocean side).

The 'uncovered' option was also considered; however, given the high wave energy climate, an uncovered pipeline would be subject to very high uplift forces within the surf zone and was at risk of damage. Installation via vessel was also unfeasible given the site conditions (shallow depth compared to the high wave energy conditions).

In considering this, construction of the trenched pipeline was not considered further in concept screening without installation of a breakwater. The breakwater should be constructed in the near shore environment to minimise material quantities (pipe and armourstone) and to maximise pipe installation methodologies available.

8.5.3.2 Maintenance

Key maintenance considerations include:

- Maintenance of sand to prevent blockages of the intake/outfall (see also section 8.5.3).
- Periodic maintenance of the pipe 'grillage' to clear blockages and marine growth.

8.5.4 Beach discharge outfall

For Option 3 (Coorong pump-out only), a 'lower cost' outfall solution with lower visual impact was considered, modelled off a conventional outfall pipe system. This option involves discharging a significant volume of water from the Coorong onto the foreshore and is included in Option 3B, Option 3D and Option 5B.

Key challenges in designing the system included:

- The high flow rate of water that could be expected to be pumped through the outfall (particularly for Option 3B).
- Scour of the foreshore area.

The beach discharge option comprises the following:

- Culvert with headwall, apron and wingwalls; structures would be founded on piles to prevent settlement or erosion of the structure over time.
- Installation of Flexmat to protect the foreshore from significant erosion due to the high outflows. The Flexmat system can be traversed by vehicles (if needed); although, due to safety, access to the foreshore in the vicinity of the outfall is recommended to be excluded, and a bypass road through the dunes provided, on the grounds that:
  - Following significant discharging or a storm event conditions the site may be significantly altered (e.g. movement of the Flexmat, significant scour holes) and unsafe for traversing.
  - It is unsafe for vehicles or pedestrians during discharging.
- Culvert fitted with heavy concrete collars to resist uplift with discharges at LAT.
- Culvert that may also be fitted with a tideflex valve to minimise sand ingress into the outfall pipe due to normal dune formation processes (applied to Options 3B, 3D and 5B).

8.5.4.1 Construction considerations

A key advantage of the beach discharge is that it eliminates the need for construction within the Southern Ocean environment, with all works proposed within the beach and intertidal area. Construction would follow conventional civil construction techniques for trenching and follow either in-situ or precast installation of headwalls, aprons and piling equipment required for foundations.

8.5.4.2 Maintenance

While the outfall option offers a lower-cost solution for initial construction, the beach discharge outfall solution will require frequent inspection and maintenance to ensure the condition remains safe. Flexmat has the benefit of being flexible, so as to conform with the beach during sand movements, but may also be susceptible to movement, erosion or dislodgement during frequent severe storm events (e.g. 5- or 10-year ARI events).

Frequent inspection and closure of the beach may also be required for forecast storm events or during discharging to prevent access to the site. Due to the remoteness of the site, this may be unfeasible, or require remote surveillance and closure systems to be implemented and staffed.

8.6 PLUME DISPERSION MODELLING – BRINE AND DREDGED MATERIAL

The hypersaline outfall discharge flows from the Coorong are intended to be discharged into the coastal margins of the Southern Ocean. To do this efficiently, whilst minimising environmental impacts, an offshore outfall was initially considered. However, due to the high cost and complexities in constructability and materials requirements (discussed in the sections above), several alternative nearshore discharge options have been considered. High-level conceptual hydrodynamic modelling has therefore been undertaken to investigate the performance of these near shore discharges. The comparisons of dilution performance between selected near shore and shoreline discharge options are presented in the following sections.

The investigations use mid- to far-field modelling to predict the dilution of salinity as a result of diffusion in the near shore environment. Mixing close to the discharge was not modelled in detail.

Dispersion of Option 2 (Coorong lagoon dredging) dredged material disposal into the near shore zone was also modelled. This dredged material is from proposed channel deepening and creation works in the Coorong lagoon.

The modelling described herein is uncalibrated. Field data collection and calibrated modelling investigations will be needed to further explore the near shore disposal options for both hypersaline flows and dredged material, to better support environmental impact studies. A more detailed examination should be completed for the preferred infrastructure option(s).

8.6.1 Modelling approach

The hydrodynamic computer model Delft3D-FLOW was used to model the dispersion of the brine and fine sediment discharges. This software solves the unsteady shallow water equations in two dimensions, vertically averaged. The following scenarios were modelled:

- Mixing of hypersaline (brine) water discharge plumes into the Southern Ocean: this brine is sourced from the Coorong, at flow rates varying from 250 to 1,000 ML/d. Even though this brine is heavier than seawater, it is assumed that it will be fully mixed through the water column at the outfalls, because it is in the surf zone in shallow water that is only about 3 m deep.
- The release and settlement of dredged material in the Southern Ocean: this sediment comes from the proposed dredging of channels in the Coorong and adjacent areas. The dispersion of the fine sediment fraction (silts and clays) was simulated using the Deflt3D Lagrangian particle tracking module PART. Coarse sediments (e.g. sand) were assumed to settle close to the outfall and then be dispersed by longshore drift. This dispersion was modelled using an analytic solution of the single line diffusion model of beach evolution.

The brine discharge modelling considered the following scenarios:

- Near shore plunging jet discharge through a cone valve approximately 300 m seaward of the low water mark.
- Discharge at the water's edge.
- Near shore submerged pipe discharge inside a beach lagoon created by a U-shaped breakwater approximately 100 m seaward of the low water mark. The breakwater prevents burying of the inlet/outlet by drifting sand, whilst allowing diffusion of a diluted brine-plume through the porous breakwater structure. The breakwater porosity will be about 40% assuming a narrow rock grading.

The near shore dredged material disposal scenario assumes an outfall approximately 20 m seaward of the low water mark. Near shore dredged material disposal is based on a typical mid-sized (i.e. 400 mm delivery pipe diameter) cutter suction dredge (CSD) with a production rate of 40,000 m^3 per week of sediment plus water at the in-situ density in the dredged channels. This corresponds to a flow rate in the dredge delivery pipe of about 280,000 m^3 per week sediment plus water (for a seven times bulking factor).

The following sections provide a summary of the modelling inputs, assumptions and outputs.

8.6.2 Model development

A localised Delft3D hydrodynamic model of the surf zone was developed in the vicinity of the proposed brine discharge location. The location adopted for the modelling is the southern location indicated in Figure 2 for the Options 3A, 3B, 3C, 3D, 4A, 4B, 5A, 5B and 6. The same model was used for simulating the dispersion of the fine sediment fraction of the dredged material for the disposal methodology proposed for construction of Option 2.

A separate modelling approach was adopted for the coarse-grained dredged material which is documented in Section 8.6.4.2.

8.6.2.1 Grid and bathymetry

The model conservation of mass and force plus momentum equations are solved over a single-layer (2D) rectilinear grid using the finite difference method. The model domain provides coverage of approximately 10 km along the shore and 1,000 m across the shore, with cell sizes of about 25 m x 25 m in plan (16,000 cells). The model domain is shown in Figure 33. The 1,000 m width is about the width of the wave zone.

The model bathymetry relied on digitised data from publicly available chart information (discussed in Section 8.2.2) and is presented in Figure 34.

Figure 33 Model grid

Note: The grid lines are shown in dark blue. This figure should be magnified for them to be visible.

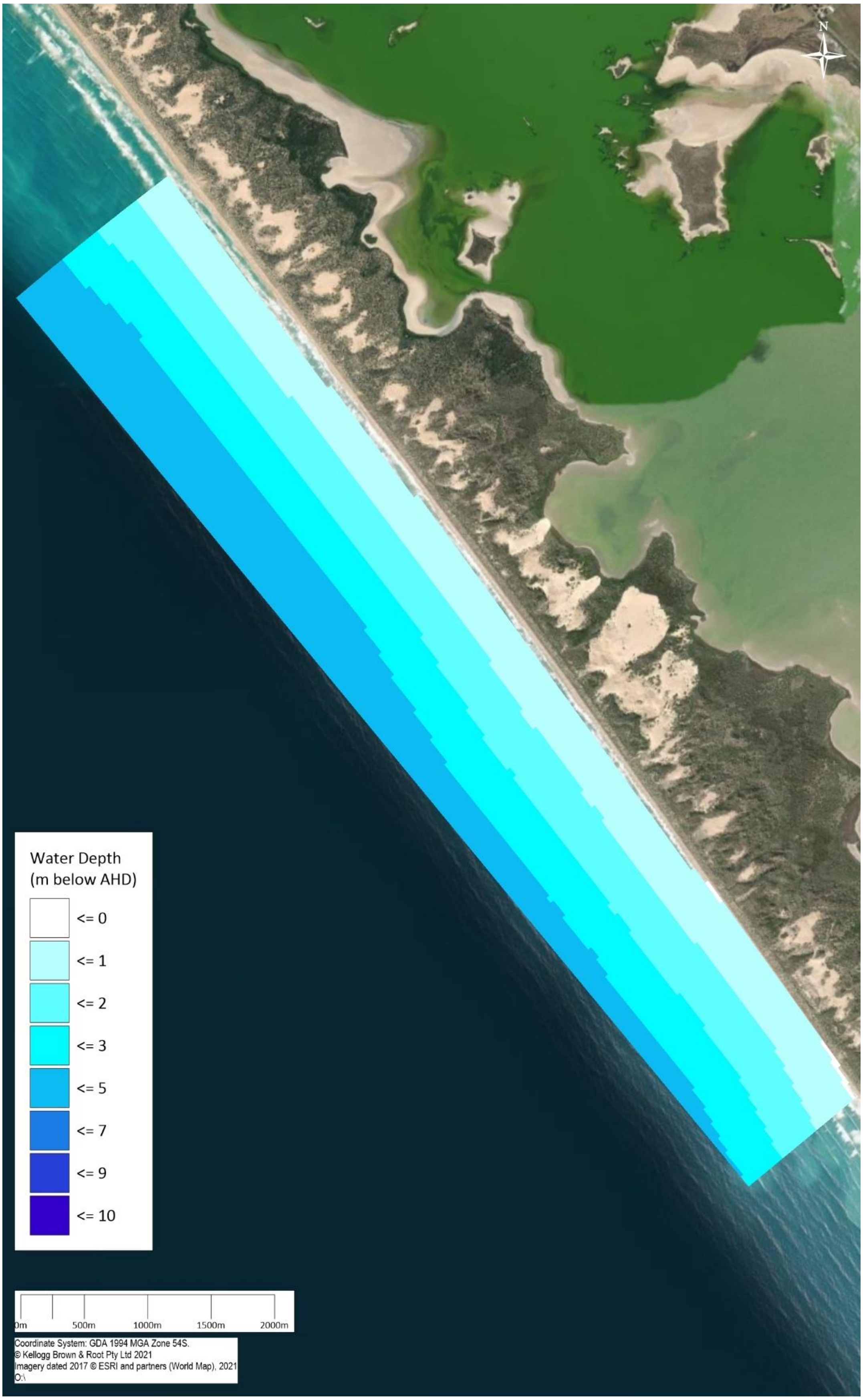


Figure 34 Model bathymetry

8.6.2.2 Flow structures

Modelling did not incorporate structures such as the jetty piers or fish screens as these features are at small scale from a far-field dispersion perspective.

8.6.2.3 Model setup

Modelling assumed no tidal water level movements, steady currents input at the cross-shore boundaries used to simulate the long shore currents, and a steady brine or dredged material input.

The model was developed based on the following key criteria:

- **Full mixing over the water depth at the brine or dredged material outfall assumption**: an appropriate criterion for deciding whether vertical mixing of a brine/dredged material discharge will occur is the Richardson number, which is the ratio of buoyancy forces to turbulent forces in a fluid:
  - $Ri = g * (\partial\rho/\partial z) / (\rho * (\partial u/\partial z)^2)$.
  - If Ri > 1.0 then the process is dominated by buoyancy forces (i.e. stratified flow is expected). If Ri < 1.0 then the process is dominated by turbulence forces (i.e. stratified flow cannot exist). The indicative Ri in the Southern Ocean surf zone at the Coorong is about 0.01, which <<< 1.0 (i.e. a brine/dredged material discharge will very quickly be mixed over the full water depth). As the Ri in the surf zone is <<< 1.0 use of a vertically averaged 2D model is appropriate.
- **Surf zone lateral turbulent mixing**: according to Inman et al., the lateral eddy diffusivity in the surf zone is about 10 m^2/s cross-shore and 100 m^2/s longshore. These values are based on considerations of the Prandtl mixing lengths (Vennard & Street 1976) in the surf zone. For example, if the rip cells are about 200 m apart and the longshore current velocity is about 0.5 m/s then an eddy diffusivity of about 200 x 0.5 = 100 m^2/s is indicated. The model therefore applied a lateral longshore turbulent diffusivity of 100 m^2/s.
- **Flow boundary conditions**: the model is driven by a wave radiation stress-induced longshore velocity boundary condition with a cross-shore profile assumed to be similar to Bruun's mean current velocity method (Bruun 1963). Figure 35 shows the longshore velocity profile adopted for the modelling using Bruun's method.
  A velocity of 0.2 m/s was added to these values to represent tidal and wind driven currents. This value is typical of a 6 m/s westerly wind.
  This longshore current corresponds to an estimated long-term average gross longshore sand drift rate of 1M m^3 per year on this part of the Younghusband Peninsula ocean beach. This rate is generated by a 'morphological' wave height of Hs = 2 m with a breaking wave approach angle of about 10 degrees north or south of normal. This 'morphological wave' estimate was derived from the NOAA NCEP Wave Watch III data combined with a longshore drift rate estimated using the CERC equation (van Rijn 2002).
  This average flow rate is representative of 'modal' sea conditions where advection of the plumes along the coast is modest compared to vigorous cross-shore mixing due to surf-zone rip cells and feeder currents. This mixing is modelled by using high lateral eddy diffusivities, as discussed above. Direct modelling of surf-zone combined rip, feeder and longshore currents is still a research topic.

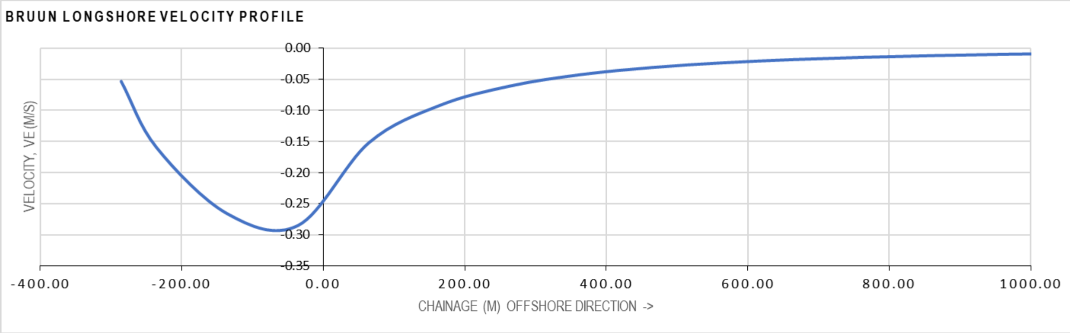


Figure 35 Longshore current velocity profile due to waves (calculated using Bruun 1963)

Note: Positive velocities flowing to the north; negative to the south.

8.6.3 Model scenarios

8.6.3.1 Brine discharge

Table 37 describes the brine discharge scenarios modelled to represent the possible range of options. These scenarios are various combinations of near shore and shoreline discharges for 'high' and 'low' discharges, consistent with the options and target flow yields listed in Table 2 and described in previous sections.

Table 37 Summary list of scenarios

Scenario	Layout	Brine discharge location	Discharge flow rate[1]
1	Option 3A	150 m long jetty discharge	1000 ML/d
2	Option 3C		250 ML/d
3	Option 3B	Low visual impact beach discharge (shoreline discharge)	1000 ML/d
4	Option 3D		250 ML/d
5	Options 4A and 5A	350 m long jetty discharge	350 ML/d
6	Options 4B and 6	Discharge within breakwater structure	350 ML/d[2]

[1] *Brine discharge scenarios are modelled for average flow rates assuming continuous discharge to assess cumulative salinity results.*

[2] *For Option 6, discharge flow rate could vary between 0 ML/d and 880 ML/d. 350 ML/d has been adopted as an average flow rate for modelling purposes.*

All modelled scenarios conservatively assumed a constant discharge salinity of 165 parts per thousand (ppt), following the upper limit described in Appendix B and modelled by DEW. As operation of the infrastructure continues, it is expected that the salinity within the Coorong South Lagoon will trend down to below 60 ppt. This reducing salinity will improve mixing rates and the dispersion of high salinity discharges to reach background levels nearer to the discharge point.

Note that the modelled scenarios have not included assessment of nutrient dispersion within the marine environment.

8.6.3.2 Dredged material discharge

Sediment characterisation

Some limited sediment characterisation data of the material to be dredged within the Coorong was available for this study. Particle size distribution (PSD) and laboratory analysis data from the sediment quality survey undertaken by University of Adelaide from 11 March to 13 March 2020 was made available to KBR (Mosley 2020). This information provides an indication of the properties of the surface layer of sediments that might be dredged (i.e. from the top 2 to 5 cm of sediment). It is acknowledged that the dredging will disturb much deeper layers of sediment that were not sampled.

The PSD indicates a significant fines (i.e. clay) fraction in the upper surface layers of the bed of the Coorong. These fines were modelled in Delft3D PART, assuming a settling velocity of 0.5 mm/s. This is typical of a flocculated clay in the marine environment.

Sedimentation and re-suspension of these fine sediments was not modelled. It was assumed that the combined wave-current bed shear stresses are well above the inception shear stress for deposition. This is a reasonable assumption for a sandy beach surf zone environment that has no fine sediment.

Sediment source

Industry advice (Maritime Constructions) indicates that hydraulic dredging by a 400 to 500 mm CSD is a suitable method for dredging the proposed 2.25M m^3 of dredged material from the channels in the Coorong. Dredged material will be delivered to a near shore disposal site within the Southern Ocean via hydraulic pumping in the form of a slurry. It is understood that the CSD method has been successfully utilised locally, with previous dredging of the River Murray mouth entrance, north of the proposed dredging site.

A 40,000 m^3 per week dredging production rate was assumed based on industry advice. This is the volume of the combined sediment and water at the in-situ bulk density in the Coorong. This in-situ bulk density is assumed to be 1.45 t/m^3 which is 700 kg/m^3 of solids and 750 kg/m^3 water. The solids are assumed to be 50% fines and 50% sand. This means that about 20 kg/s of fines and 20 kg/s of sand (coarser particles) are discharged into the ocean. It is assumed that this discharge occurs 24 hours per day, seven days per week. In practice, dredging will halt from time to time for moving the dredge and maintenance, but for the purpose of this modelling, these comparatively short breaks do not affect the far-field dispersion indications.

The actual slurry flow rate into the sea (solids plus water) will be about 0.463 m^3/s (for a bulking factor of seven), being 455 kg/s water and 40 kg/s solids. Assuming a slurry delivery pipe velocity of 3.5 m/s, a 400 mm pipe diameter would be required as indicated above. High slurry pipe velocities are used to prevent plugging of the pipe.

It is anticipated that the outfall will be relocated every few kilometres along the beach as the channel dredging progresses. On average between 320,000 and 450,000 m^3 of material might be discharged at each of five to seven outfall locations, over durations of about 2 to 3 months, with about 18 months of dredging anticipated in total, including stoppages. It is possible that some locations might be used for longer periods (e.g. six months), and mobilisation and demobilisation periods are in addition to dredging operations.

8.6.4 Outcomes

8.6.4.1 Salinity

Modelling results for the six discharge scenarios (see Table 37) are shown in Figures 36 to 41. The modelling assumes an initial seawater salt concentration of 35 ppt and a constant open ocean boundary salinity of 35 ppt. This boundary condition allows the transport of salt across the boundary. All Figures 36 to 41 display an elevated salinity gradient near the open ocean boundary. This gradient is expected because the open ocean boundary is located at the edge of the surf zone, where the lateral turbulent diffusivity drops significantly. Future more detailed modelling should extend further out to sea to better understand the effect of this reduction in diffusivity.

Based on KBR's past work on aquaculture ponds, salinities above 40 ppt are lethal to most marine organisms. Using the 40 ppt isohaline as a criterion, the findings show that the higher discharge rates (Figures 36 and 37, Scenarios 1 and 2, 1,000 ML/d) have the largest impacted zone.

When comparing the near shore jetty discharge scenarios (Figures 36 and 37, Scenarios 1 and 2, Options 3A and 3C) to the shoreline discharges on the beach (Figures 38 and 39, Scenarios 3 and 4, Options 3B and 3D), higher salinity concentrations are evident for the beach discharge structure locally around the discharge.

For the extended jetty discharge (Figure 40, Scenario 5, Options 4A and 5A) very low peak salinity is recorded but the 40 ppt isohaline appears comparable in size to the 250 ML/d discharge scenarios (Figures 37 and 39, Scenarios 3 and 4, Options 3C and 3D).

The discharge within the breakwater structure (Options 4B and 6) produces higher salinities within the breakwater compared with the other scenarios modelled, with the porous breakwater structure not having much effect on the far field dispersion of the plume in the short-term. In reality, there will be mixing and exchange due to tide and wave impacts to help disperse this salinity. A separate assessment of the turn-over time within the breakwater structure lagoon was undertaken to determine the flushing. A rapid turnover time of a couple of days is indicated (i.e. no water quality problem inside this lagoon is indicated).

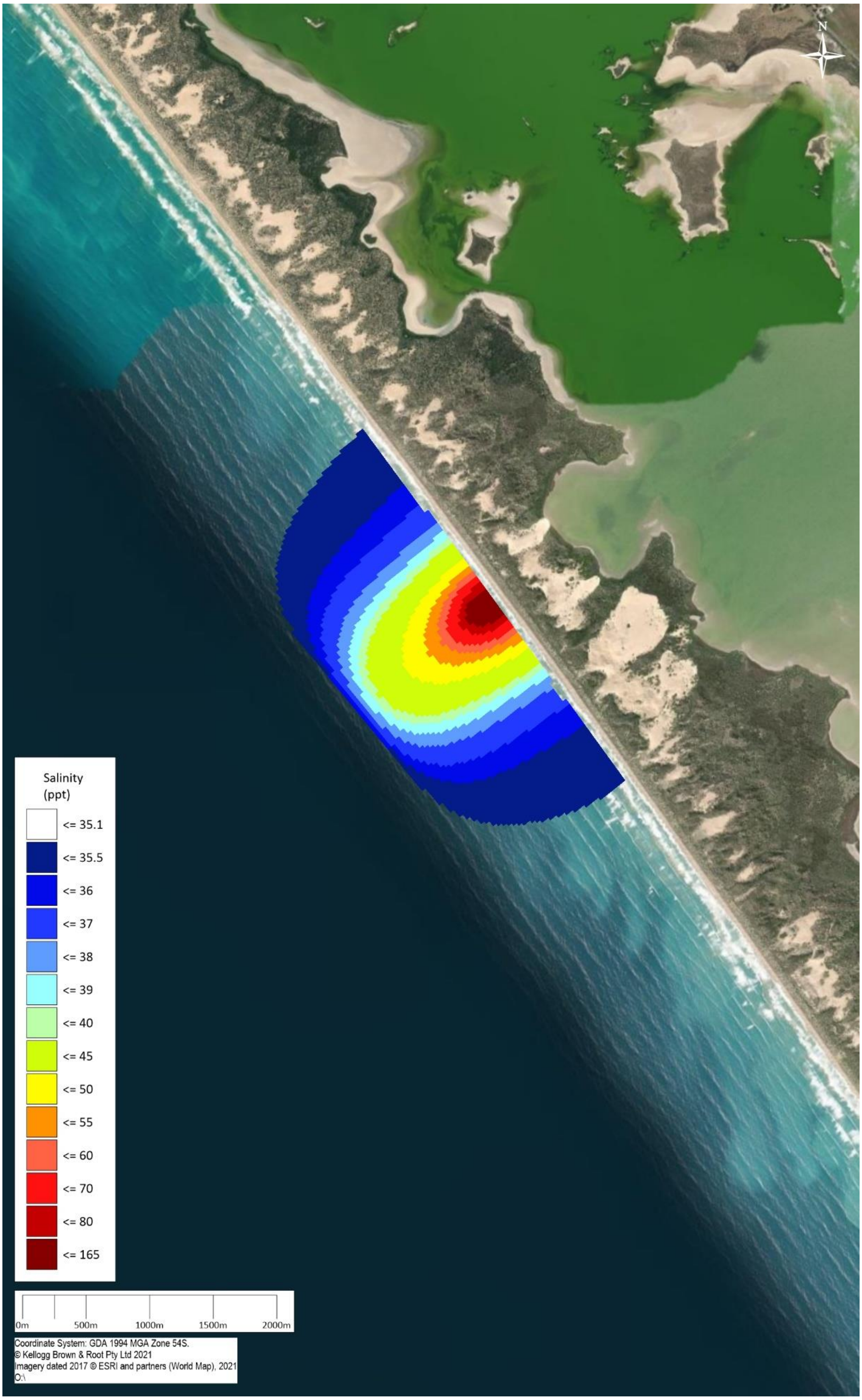


Figure 36 Scenario 1, Option 3A: Near shore outfall; 1000 ML/d, 165 ppt salinity (background at 35 ppt)

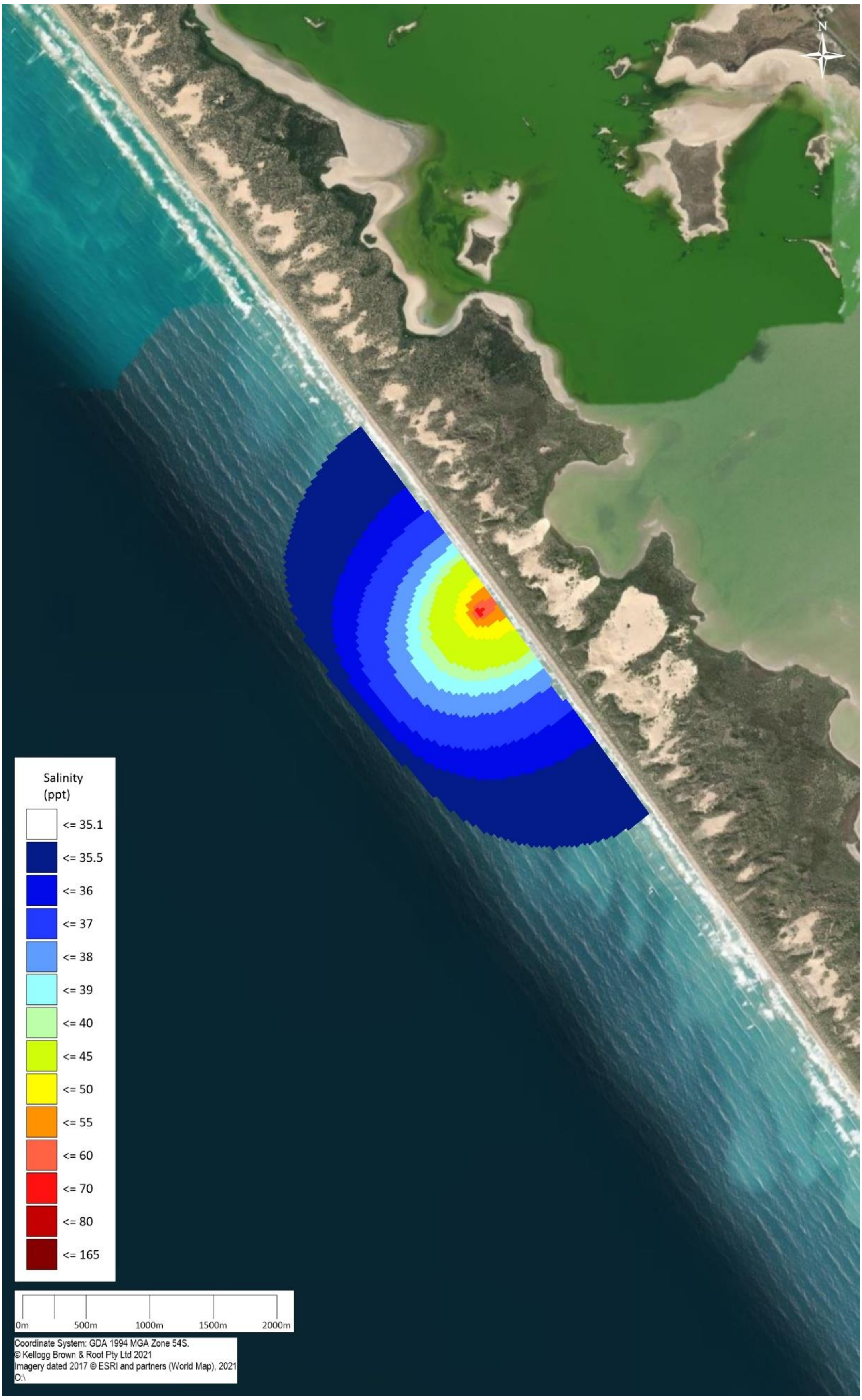


Figure 37 Scenario 2, Option 3C: Near shore outfall; 250 ML/d, 165 ppt salinity (background at 35 ppt) (discharge <100 m from shoreline)

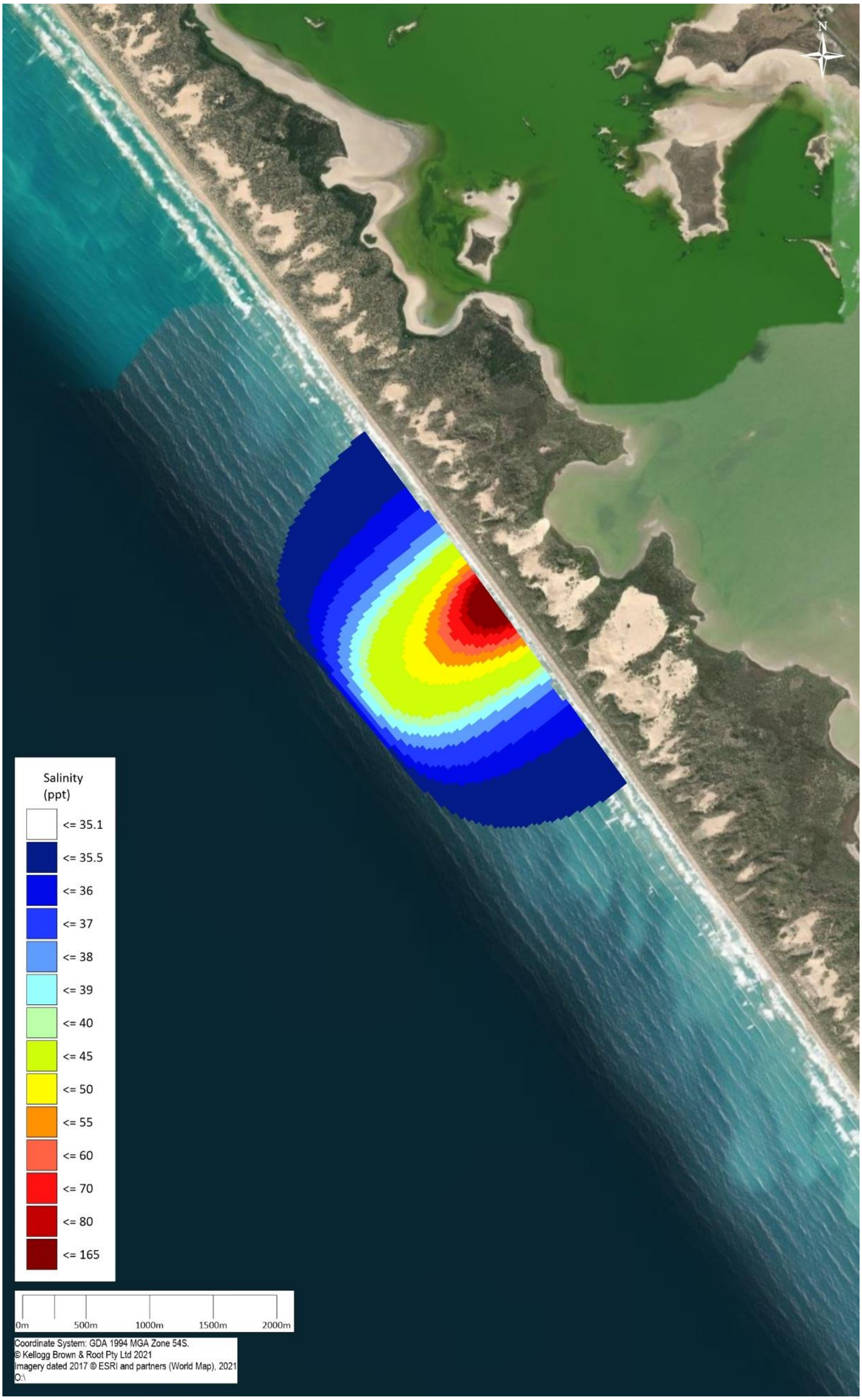


Figure 38 **Scenario 3, Option 3B: Shoreline outfall; 1000 ML/d, 165 ppt salinity (background at 35 ppt) (discharge at shoreline)**

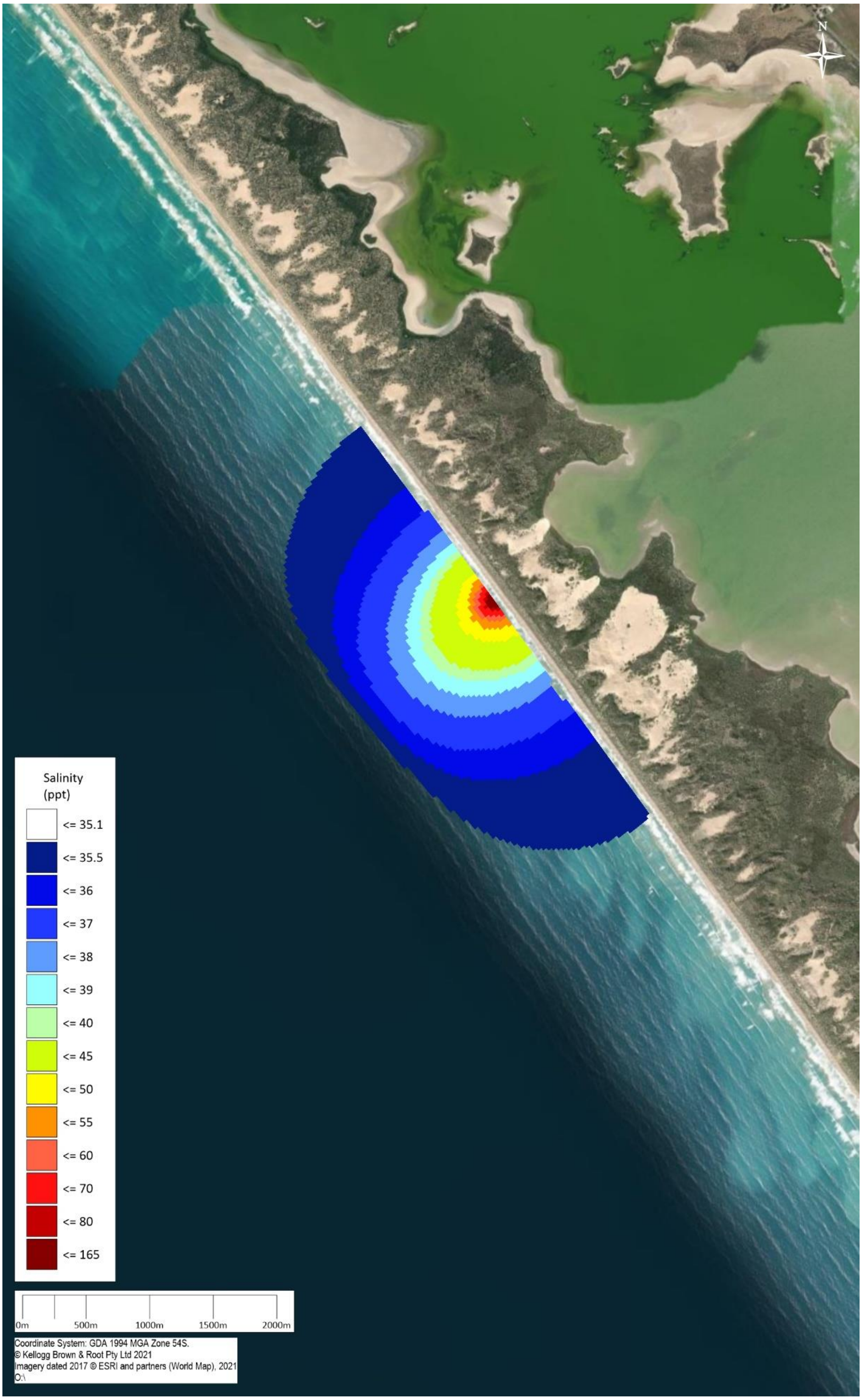


Figure 39 Scenario 4, Option 3D: Shoreline outfall; 250 ML/d, 165 ppt salinity (background at 35 ppt) (discharge at shoreline)

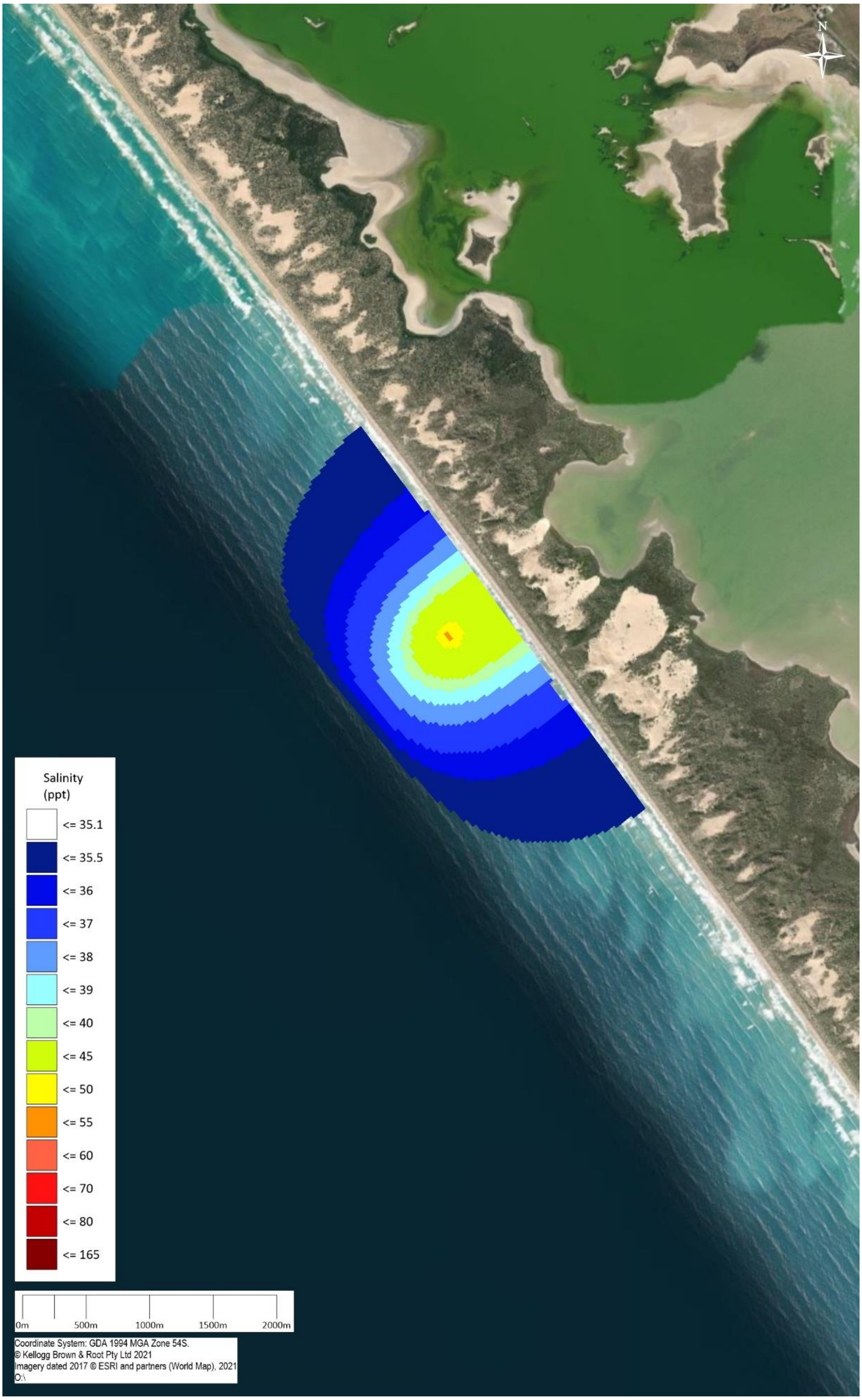


Figure 40 Scenario 5, Options 4A and 5A: Jetty-based outfall; 350 ML/d, 165 ppt salinity (background at 35 ppt) (discharge 300 m from shoreline)

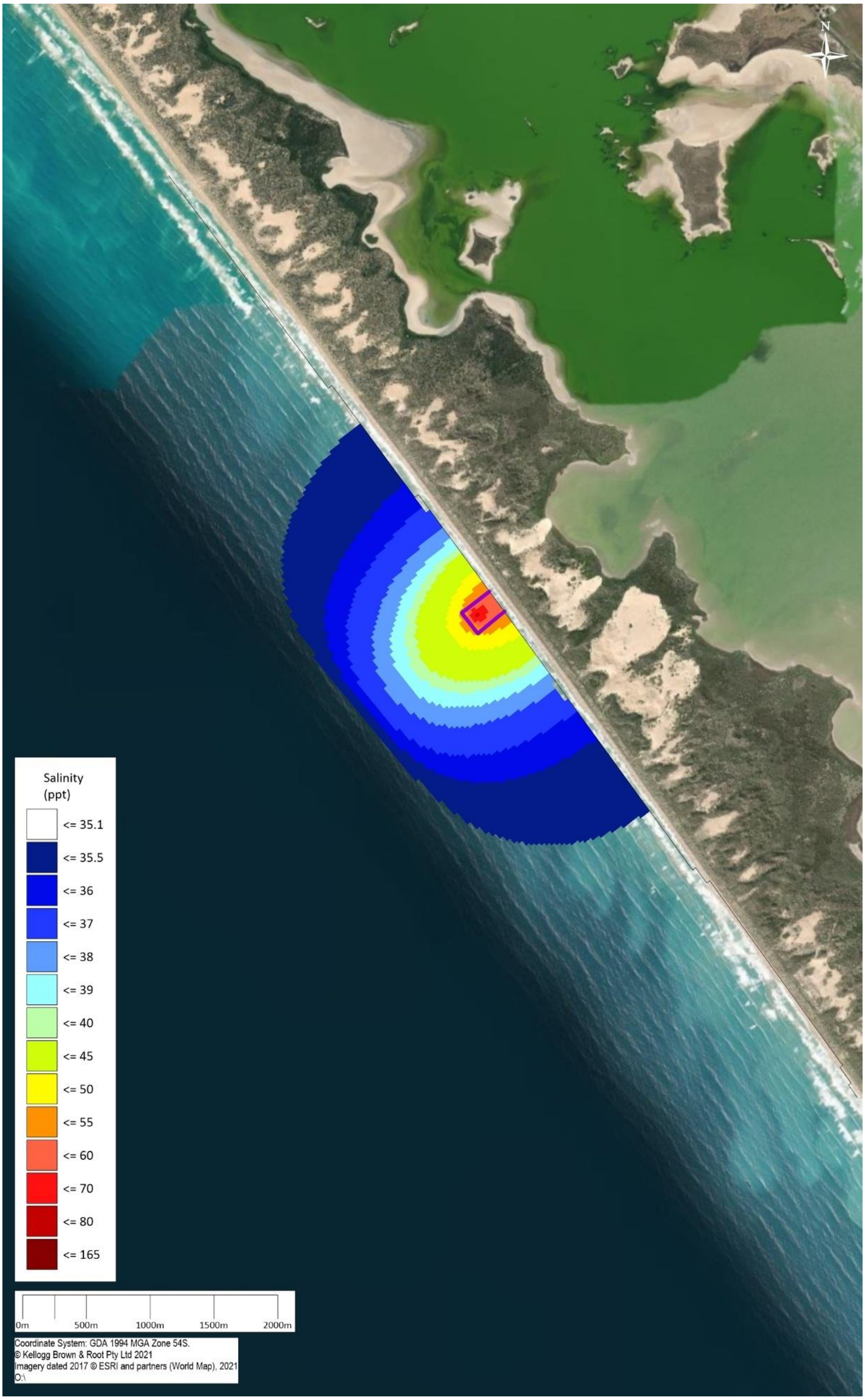


Figure 41 Scenario 6, Options 4B and 6: Discharge into a lagoon created by a U-shaped breakwater; 350 ML/d, 165 ppt salinity (background at 35 ppt) (discharge approximately 100 m from shoreline)

The findings show that under all scenarios, under steady state conditions, the 165 ppt brine discharge is diluted to 36 ppt (i.e. 1 ppt above background) within approximately 1.0 km of the source location under lower flow scenarios (250 and 350 ML/d, Figures 37, 39 and 40). For the 1,000 ML/d scenarios (Figures 36 and 38), the brine discharge is diluted to 36 ppt within approximately 1.3 km of the source location.

Options 4A and 5A jetty discharges (Figure 40) promote the greatest mixing, with the plume diluted to 1 ppt above background within approximately 700 m from the outfall. This improved mixing compared to the other scenarios is due to the outfall being in deeper water.

For Options 4B and 6 (Figure 41) have the inclusion of the breakwater and demonstrate plume dilution to 1 ppt above background within approximately 1.2 km of the outfall. The salinity within the breakwater is marginally higher than other near shore jetty disposal options (Figures 37 and 40) but substantially less than the 1000 ML/d discharge options and beach discharge (Figures 36, 38 and 39). This demonstrates that the breakwater does not have a significant retention effect of salinity within the breakwater minimising the potential for circulation of the hypersaline Coorong South Lagoon water.

As expected, the shape of the plume is roughly symmetric about the outfall, due to cross-shore mixing by rips being more important than the longshore drift under the modal conditions modelled. Under wave conditions with a larger approach angle, more advection up or down the coast is expected. These conditions are not common because the swells approaching the site from the Southern Ocean mostly come from a narrow band of directions (see NOAA NCEP Wave Watch III offshore data).

8.6.4.2 Dredged material

The discharge of this material has been assessed in two parts:

1. Discharge of the fine fraction modelled using the Lagrangian particle tracking model Delft3D-PART: fines are assumed to be 50% of the total sediment discharged. The modelling assumed that all this sediment is transported in suspension, as the bed shear stresses are too high to allow for deposition.
2. Discharge of coarse-grained material (i.e. sand) on the shoreline: this material is considered to create a localised 'beach fill' at the discharge point. It is assumed that 50% of the total sediment discharged will be coarse-grained. This discharge is assumed to deposit close to the outfall, with subsequent movement along the coast north and south in a mixture of bed and suspended load. This movement was modelled using an analytic solution of the single line diffusion equation for a rectangular beach fill source .

Discharge of fine materials

Figure 42 shows a modelled suspended sediment plume after 21 days, following a continuous discharge of 20 kg/s fine sediment (i.e. 40,000 m^3 per week dredging, at 50% fines content).

The output of the modelling is provided following a simulated three weeks of dredging; however, the model reaches a 'steady state' condition after approximately 12 hours, after which the change in the plume is minimal.

The modelling indicates suspended sediment concentration up to 200 mg/L (0.2 g/L) above background within a 'mixing zone' of about 100 m from the outfall. The modelling indicates strong dispersion of the fines beyond this initial mixing zone, with concentrations of approximately 0.1 g/L (100 mg/L) above background within 200 m of the discharge location. Background turbidity due to breaking wave action might be 0.025 g/L (25 mg/l). The concentrations above background are further reduced to below 0.06 g/L (60 mg/L) within approximately 1.5 to 2 km from the discharge point.

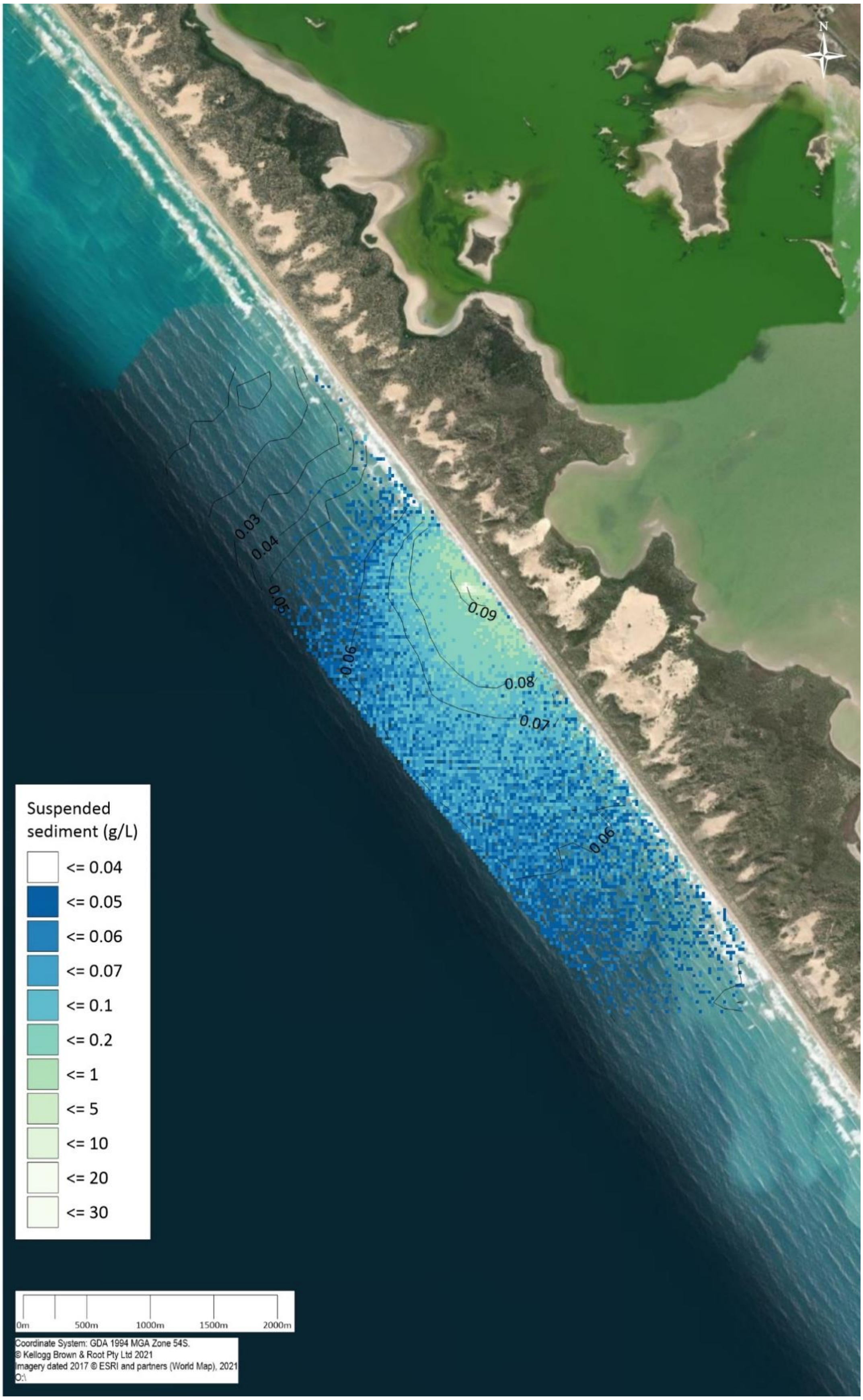


Figure 42 Option 2: Dredged material discharge into the Southern Ocean – suspended sediment concentrations in g/L above background due to 20 kg/s fine sediment discharge at the end of 21 days continuous discharge

Discharge of coarse-grained materials

Given the significant volume of coarse material (i.e. sand) anticipated to be dredged, it is expected that the coastline will be modified locally at the discharge point for the duration of dredging. An assessment of shoreline changes due to the discharge of the sand fraction of the dredged material was undertaken using an analytic solution of the single line diffusion equation of beach evolution. This method of analysis is appropriate for assessment of the movement of the sand fraction on a beach not affected by other freshwater or saline flows (i.e. not in proximity to a river mouth).

An instantaneous beach fill at the outfall of 200 m x 30 m by 17 m thick was assumed, which is about 100,000 m^3. The 17 m thickness is an assumed beach berm[5] elevation of 2 m plus the closure depth of 15 m. The nearshore 'closure depth' is the depth beyond which sand movement due to wave action is minimal. This instantaneous beach fill volume is not seen in the field and the dimensions are indicative only to approximately equal the volume of sands that are being deposited at a particular location.

At the near shore discharge point, a shallow volcano shaped mound of coarse particles is expected to form but this mound will be quickly eroded by the wave action and currents in the near shore zone. The sand once mobilised will be drawn out as far as closure depth whilst leaving an approximate 30 m headland connected to the beach. From this headland, the resulting progradation is expected to follow the existing bed profile approximately out to closure depth.

This is about 160,000 t of sand at a beach dry density of 1.6 t/m^3 (i.e. a porosity of 40%, which is typical of ocean beaches), which is about three months' worth of dredging assuming a dredged sand particle discharge rate of 20 kg/s. This prismatic beach fill assumption uses the Bruun rule, which states that the movement of the shoreline when modelled as a rectangular prism is the same as the movement of the actual sloping beach profile provided this profile does not change as the beach accretes or erodes.

High and low gross longshore sand transport rates scenarios were examined. The assumed low rate was 100,000 m^3 per year and the high rate was 1,000,000 m^3 per year gross. These scenarios represent conservative extremes over a one-month period, based on the NOAA NCEP Wave Watch III offshore wave data transformed to the shore using straight parallel contour refraction and shoaling approximation, and the longshore drift estimated using the CERC equation. The extent of the prograded shoreline movement will vary due to fluctuations in the wave climate. The upper and lower envelopes of the modelled shoreline change is provided in Figure 43 and Figure 44.

[5] Beach berm is a nearly horizontal ridgeline formed on the beach due to landward accretion of the coarsest fraction of beach material (sand).

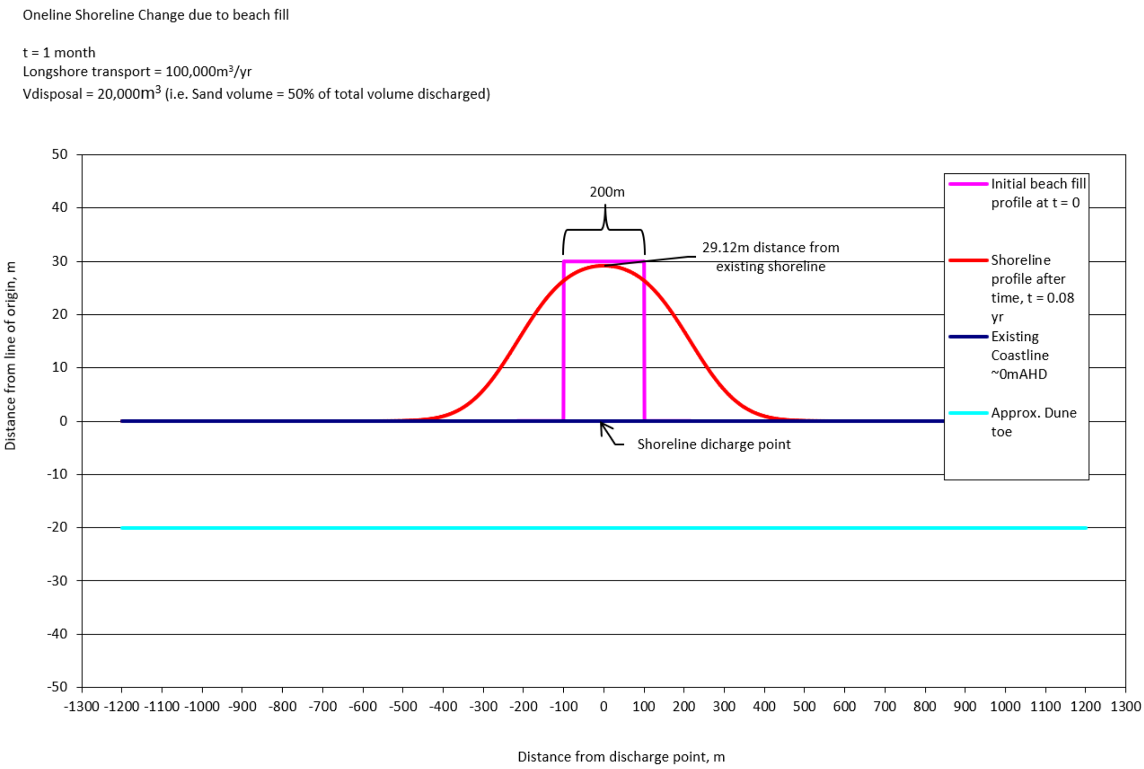


Figure 43 **Shoreline change after one month, using the single line diffusion model: 100,000 m³ per year gross longshore sand transport rate assumption starting after three months' of dredged material discharge at 40,000 m³ per week; 50% sand, 50% clay, sand fraction only modelled**

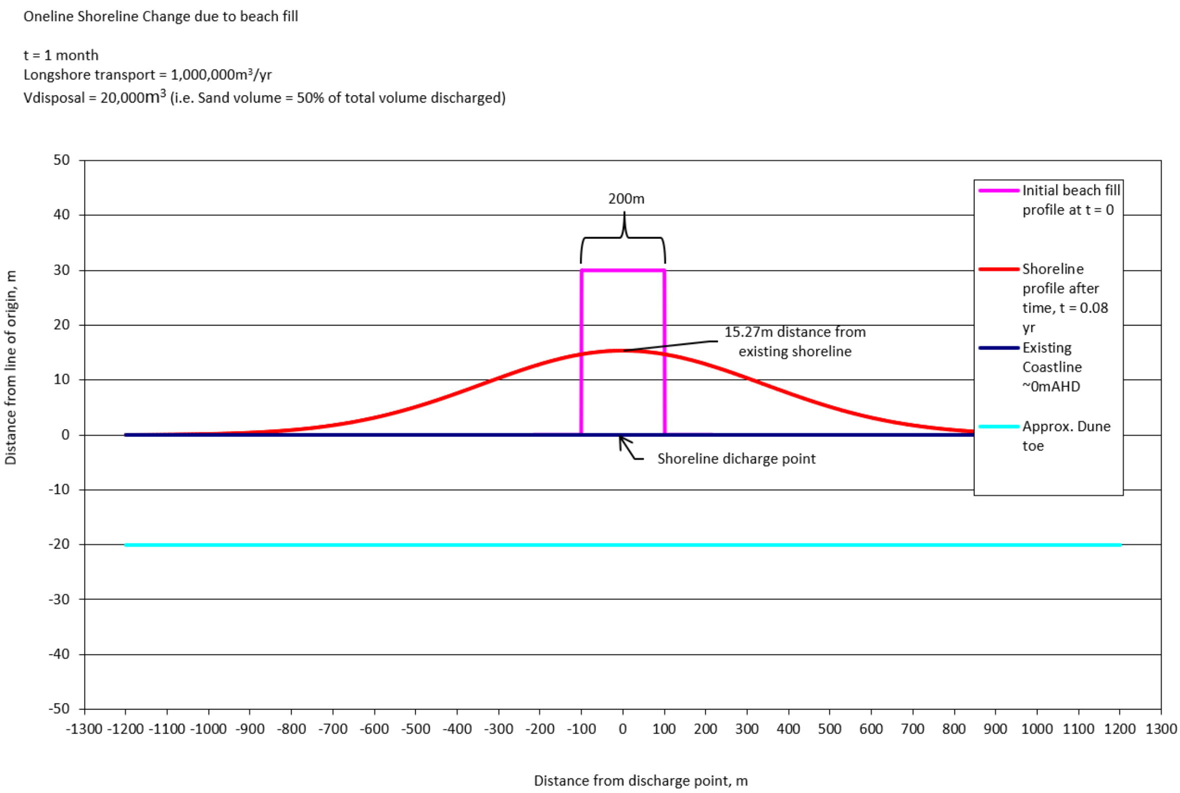


Figure 44 **Single line diffusion model shoreline change after one month: 1,000,000 m³ per year gross longshore sand transport rate assumption starting after three months' of dredged material discharge at 40,000 m³ per week; 50% sand, 50% clay, sand fraction only modelled**

Figure 45 shows the modelled shoreline change over a one-year period that indicates a return of the shoreline profile to close its initial condition. The realised timing for this 'return' is subject to the management and number of discharge locations that will be used when dredging plus the wave climate at that time.

Figures 43 to 45 inclusive show the modelled location of the shoreline if the beach profile remains the same (i.e. the 'Bruun Rule'). Under the Bruun Rule, the beach is not elevated. It simply progrades due to the placement of the dredged sand and regrades as this sand erodes naturally. A 30 m prograded beach after one month is very small compared to the scale of the beach.

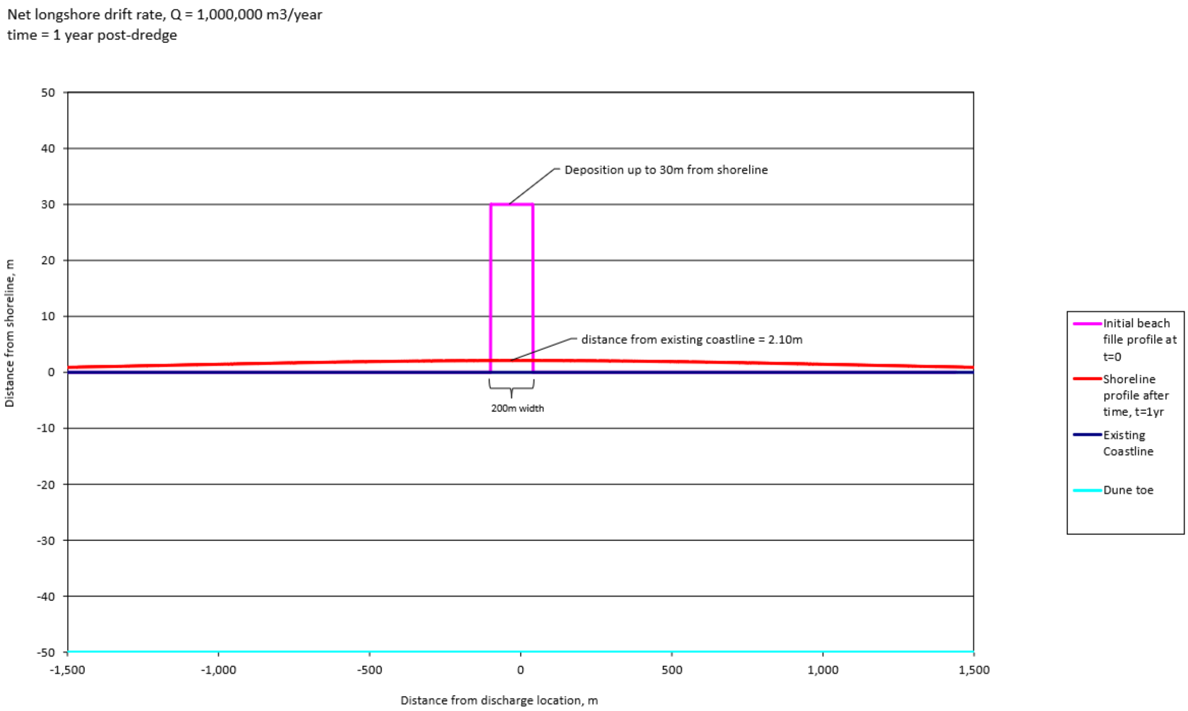


Figure 45 Single line diffusion model shoreline change after 12 months: 1,000,000 m³/year gross longshore sand transport rate assumption starting after three months' of dredged material discharge at 40,000 m³ per week; 50% sand, 50% clay, sand only modelled.

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9 Operations and maintenance

9.1 SAFETY

Safety in design has been considered throughout concept design development. Importantly, this considers construction, operation, maintenance and decommissioning activities. Several initiatives to protect the safety of personnel conducting construction, operation and maintenance activities have been included within design details as follows:

- Guardrails have been provided each side of Narrung Road, allowing a protected zone for maintenance and operation of the penstocks and lay-flat gates associated with the regulator (Options 1A and 1B).
- All jetty infrastructure has been designed with a deck height of +10.5 mAHD and a headstock height of +9 mAHD to maintain a safe airgap between the ULS wave crest levels and the headstock.
- Vehicle access has been provided along the jetty infrastructure to allow cranes and other operational vehicles access to the pumps, pipes and valves on the jetty.
- Hand railing has been provided to all jetty infrastructure, as public access is highly likely.
- The expected sea level rise associated with climate change has been considered in setting jetty and infrastructure levels.
- Construction access tracks will be retained through Younghusband Peninsula to facilitate operations and maintenance activities.
- Barge access points each side of the Coorong South Lagoon will be retained to allow mooring of vessels for the transfer of personnel, vehicles and equipment across Coorong South Lagoon and to avoid the need for four-wheel drive access from the south of Younghusband Peninsula.
- A gantry crane system has been provided within the Option 4B pump room for valve and pump installation/removal and maintenance activities. Other sites will likely require a crane access pad where frequent cranage is required (e.g. at barging points).
- Appropriate delineation and warning signs will be provided where beach conditions change because of the proposed infrastructure.
- Jetty access ladders at appropriate spacings will be provided as per AS 4997 Cl 3.4.5 for emergency use.
- Access platforms within the Option 4B pump room have been provided to enable safe access over large bore pipes (Option 4B).
- Infrastructure within the Southern Ocean has been designed such that it will not require diver access for operation and maintenance in open waters.
- Placement of cathodic protection anodes on wetted jetty elements or the use of coatings to protect steelwork have been avoided; however, this introduces another challenge around effective corrosion prevention to be applied for the project infrastructure (corrosion allowance has been incorporated for concept design purposes).
- Longshore drift (and erosion of sand adjacent structures) could affect personnel safety where undermining occurs which will require periodic inspection from operations personnel prior to commencing specific operations (i.e. regular surveillance and inspection of sand movement with possible manual sand bypassing/management if required).

- Fish screen installations have been provided on rails within the Southern Ocean to allow lifting of the fish screens for cleaning and inspection.
- Slurry pumps within the caisson structure have been included to allow agitation and removal of any sand that accumulates on the structure floor.
- Access to breakwater top has been provided via the concrete accessway to allow maintenance and inspection access beyond the crest wall. The crest wall increases the effective breakwater height whilst limiting overtopping flows (and sand entrainment) and providing a protected area for pedestrian or vehicle access as may be required during calmer sea states.
- Pontoon pumps will allow the entire pumping unit to be decoupled from the pipework and floating walkway and towed to the other side of the Coorong, allowing removal from the water and transport via truck for overhaul and maintenance operations, rather than completing maintenance activities over water (with N+1 pumps provided allowing standby capacity within pump stations).
- Public access in the vicinity of pumping infrastructure will require signage and lighting to alert watercraft to in-water pump stations and submarine cables (within Coorong South Lagoon).
- Public access along the beach with dredged material disposal pipework will require temporary exclusion areas and a possible bypass track for vehicles to minimise public interaction with operation and maintenance activities.
- Public access along the beach in the vicinity of permanent infrastructure (e.g. jetty or breakwater) will likely require a separate bypass access track around infrastructure into the dune environment.

As one or more preferred options are selected, it is recommended that further design stages commence with another 'safety in design' assessment. It will be important that these further assessments focus on:

- Fish screen access and maintenance.
- Corrosion prevention methodologies proposed.
- Inspection, maintenance and ultimate replacement of valves and valve components.
- Inspection, maintenance and ultimate replacement of pumps and pump components.
- Site access requirements for a range of vehicles (including nomination of final design vehicles) including consideration of turnaround requirements on jetty infrastructure.
- Effective cleaning methods for removal of marine growth or settled solids from within the pipelines.

9.2 OPERATING PLANS

A key element of the operating plan is confirmation of operating times and durations expected for the infrastructure proposed for each option. This affects not only design considerations but also energy supply and operating cost assessment. Table 38 presents a summary of the adopted operating times developed from the detailed hydrodynamic modelling undertaken by DEW.

Current conditions represent model results that assume current Lower Lakes operating rules and Murray Darling Basin water recovery for the Lower Lakes in accordance with the broader Murray Darling Basin Plan. These conditions have been applied over the period 1990 to 2020 as part of the extended hydrodynamic modelling completed.

Climate change conditions represent model results that assume predicted 2050 climatic conditions.

With infrastructure expected to be constructed through the mid- 2020s, the life cycle cost analysis to be completed as part of the concept design process extends over a period of 25 years. This closely aligns with the current and future predicted (2050 climate change) conditions and was a key reason for nomination of the average operating days in Table 38.

Table 38 Operating days

Option	Operating days (current conditions)	Operating days (climate change conditions – 2050)	Operating days (adopted average or everyday)
1A	241 days	143 days	192 days
1B	241 days	143 days	192 days
2	n/a	n/a	365 days
3A	137 days	189 days	163 days
3B	137 days	189 days	163 days
3C	n/a	n/a	365 days
3D	n/a	n/a	365 days
4A	n/a	n/a	350 ML/d out 1 May to 30 September, then fluctuating between in and out for the period 1 October to 30 April, based on 25 days pump in followed by 23 days pump out.
4B	n/a	n/a	350 ML/d out 1 May to 30 September, then fluctuating between in and out for the period 1 October to 30 April based on 25 days pump in followed by 23 days pump out.
5A	350 ML/d in over 222 days 350 ML/d out over 365 days	350 ML/d in over 166 days 350 ML/d out over 365 days	350 ML/d in over 194 days 350 ML/d out over 365 days
5B	350 ML/d in over 222 days 350 ML/d out over 365 days	350 ML/d in over 166 days 350 ML/d out over 365 days	350 ML/d in over 194 days. 350 ML/d out over 365 days.
6	n/a	n/a	365 days

9.3 OPERATING FLEXIBILITY

Typically, pumps will be installed with VSD's to allow staged ramp-up and ramp-down of pumped flows and operation at differing flow rates (if required).

Flows over regulator structures will also be controllable via the use of the lay-flat gates to target specific release flow rates.

In general, remote monitoring and control is expected to be made available for operators. The degree of actuation for these large diameter valves across the concept design options will be required to be assessed in future design stages. At present, large diameter valves are generally nominated as manual operation only.

10 Preliminary environmental risk review

10.1 DESKTOP REVIEW

A preliminary desktop review of existing environmental characteristics associated with each of the concept design options has been undertaken to establish the potential presence of terrestrial and marine/estuarine species and communities of conservation significance occurring within the vicinity of each proposed option.

Database searches were undertaken as part of the desktop review process and included:

- *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) Protected Matters Search Tool (PMST) – Department of Agriculture, Water and the Environment (DAWE) (Appendix M).
- NatureMaps, Enviro Data SA, NatureMaps 3.0, Department for Environment and Water, Government of South Australia.
- Seamap Australia – National Marine Benthic Habitat Map.
- Atlas of Living Australia.

In addition, other data and reports were reviewed to inform the assessment of environmental values and potential impacts associated with the construction and operation of each concept design option.

10.2 LIMITATIONS

This body of work represents an environment risk identification process and a preliminary review. It is preliminary in nature and is not intended to replace the need for an environmental impact assessment for the construction and operational phases of the final selected infrastructure options(s). Further field studies and investigation with associated reporting will still be required to develop the project's environmental impact statement to support achievement of environmental approvals associated with the project.

No project-specific terrestrial or marine and estuarine field surveys have been completed to date. This risk review is limited to desktop review of available databases, reports and information within the public domain relevant to the terrestrial sites and marine/estuarine environment of the Coorong and adjacent open ocean.

The tables outlined in Appendix N represent the predicted potential impacts based upon available data and relevant studies. It is recognised that as the detailed design process progresses, the proposed works will become better defined, enabling site-specific field assessments and site-specific management measures to be further developed to address potential environmental impacts. The risks identified are likely to change once field investigations are available to inform an assessment, and more information regarding design and construction methodology is available. However, this initial preliminary review highlights critical issues related to each of the proposed concept design options.

10.3 ENVIRONMENTAL VALUES OF THE COORONG

The Coorong is a long, shallow saline lagoon that stretches over 100 km and is separated from the Southern Ocean by a narrow sand dune barrier. It marks the termination of Australia's longest river, the Murray. The nearby Lake Alexandrina and Lake Albert comprise fresh to brackish/saline waters, while the Coorong consists of the saline north and south estuarine lagoons, saline marshes. There are also areas at the southern end where waters are hypersaline.

With its diversity of ecological features, the site provides a wide range of habitats for many flora and fauna species. It is an internationally renowned breeding area for the Australian pelican and habitat for ducks, swans, cormorants, terns, grebes and numerous species of migratory birds.

Key environmental values associated with the project area include:

- **Ramsar wetland of international importance**: the Coorong, including Lake Alexandrina and Lake Albert, is recognised under the Ramsar Convention as a wetland of international importance. The wetlands associated with the Coorong provide habitat for many local species and migratory birds. All infrastructure options currently being considered are located within the Ramsar site.
- **Listed threatened and migratory species**: the Coorong provides critical habitat for many state and nationally listed threatened flora and fauna species. It supports more than 200 species of birds, as well as many migratory shorebirds that arrive each summer. A number of marine mammals and sharks are also known to periodically utilise the ocean waters adjacent to the Coorong.

The Environment Protection and Biodiversity Conservation Act Protected Matters Search Tool (EPBC PMST) report identified a number of species as potentially occurring within the area, including**:**

- 55 threatened fauna species listed under the EPBC Act that may occur or may have habitat that occurs within the vicinity of the project area.
- 63 migratory fauna species listed under the EPBC Act that may occur or may have habitat that occurs within the project area, of which 26 are also listed as threatened.
- 100 marine species listed under the EPBC Act that may occur or may have habitat that occurs within the project area.
- 14 whales and other cetaceans (namely dolphins) that may occur or may have habitat that occurs within the project area, five of which are also listed as threatened species under the EPBC Act.

  A large proportion of the species identified by the PMST as having the potential to occur within the project area are considered unlikely to occur, as they have specific habitat requirements that are absent from the project area. For example, a number of listed whales, petrels and albatross are generally associated with offshore oceanic waters beyond the project area.

  Some key listed (threatened or migratory) fauna species that may utilise the project area or be a transient visitor to the area include:

- **Birds**: Hooded plover (hooded dotterel) (*Thinornis Cucullatus*), Far Eastern curlew (*Numenius madagascariensis*), Curlew sandpiper (*Calidris ferruginea*), Red Knot (*Calidris canutus*), Great Knot (*Calidris tenuirostris*), Bar-tailed Godwit (*Limosa lapponica*), Fairy tern (*Sterna nereis*), Australian painted-snipe (*Rostratula australis*), White bellied sea-eagle (*Haliaeetus leucogaster*), Red-necked stint (*Calidris ruficollis*), Greater crested tern (*Thalasseus bergii*), Orange-bellied parrot (*Neophema chrysogaster*).
- **Mammals**: Blue whale (*Balaenoptera musculus*), Southern Right Whale (*Eubalaena australis*), Humpback Whale (*Megaptera novaeangliae)* (and the long-nosed fur-seal (*Arctocephalus forsteri*), Australian Sea-Lion (*Neophoca cinerea*), Bottle nose Dolphin (*Tursiops truncatus s. str.*), common Dolphin (*Delphinus delphis*) listed as 'Marine').
- **Ray finned fishes and molluscs** Murray Hardyhead (*Craterocephalus fluviatilis*), Murray Cod (*Macculochella peelii*) and some locally important species which are not listed such as mulloway (*Argyrosomus japonicus*), bream (*Acanthopagrus butcheri*), salmon (*Arripis trutta*), mullet (*Aldrichetta forsteri*), flathead (*Pseudaphritis urvillii*), snapper *(Chrysophrys auratus)* and the Goolwa Cockle (*Plebidonax deltoide*s).

- **Sharks**: Great White Shark (*Carcharodon carcharias*).
- **Vegetation communities**: the native vegetation communities which would be affected by the options being considered are (Nature Map):
  - Grassland: comprising low coastal species including spinifex, shrubs and sedges. This community is located on the frontal dune system.
  - Rushland/Sedgeland: comprising Melaleuca (and other) shrubs with sedge understory and predominantly located in swampy areas such as along the Cooroy lagoon shoreline.
  - Coastal Shrubland: Tall Leucopogon shrubland with Lepidosperma sedges.

These vegetation communities are present in the terrestrial areas affected by all of the options, apart from Options 1A and 1B, where native vegetation has been almost entirely replaced by agriculture.

Some of the main flora species that occur along the Coorong dunal system include:

- Saltbush (*Atriplex sp.*), Samphire (*Tecticornia sp.)*, Native pigface (*Carpobrotus rossii*), Seablite (*Suaeda australis*), Coast Beard-heath (*Leucopogon parviflorus*), Coast wattle (*Acacia sophorae*), Coast Daisy Bush (*Olearia axillaris*), Coastal sword-sedge (*Lepidosperma gladiatum*), small-leaved mint-bush (*Prostanthera serpyllifolia*), knobby club-rush (*Ficinea nodosa*), Small-leaved clematis (*Clematis microphylla*), Hairy spinifex (*Spinifex sericeus*), Coast everlasting (*Ozothamnus turbinatus*), Cushion bush (*Leucophyta brownie),* Sea celery (*Apium prostratum*), Swamp paperbark (*Melaleuca ericifolia*).
- **Threatened ecological communities**: the EPBC PMST identified three listed threatened ecological communities (TECs) that may occur within the project area. These include:
  - *Buloke Woodlands of the Riverina and Murray-Darling Depression Bioregions*: this community is unlikely to occur within the sand dunes between the Coorong and the Southern Ocean.
  - *Plains mallee box woodlands of the Murray Darling Depression, Riverina and Naracoorte Coastal Plain Bioregions:* this community may occur within the project area, particularly towards the southern end of the Coorong South Lagoon.
  - *Subtropical and Temperate Coastal Saltmarsh:* this community may occur within the vicinity of the project area, particularly within the southern lagoon where samphire habitats and estuarine sedges occur.
- **Intertidal habitats within the Coorong**: the Coorong South Lagoon supports intertidal samphire habitats and estuarine sedgeland/rushland.
- **Coastal dunes**: low lying shrubland and grassland dominate the coastal dune vegetation. Vegetation on the coastal dunes is fragile and easily damaged (which can result in the shifting of sands and destabilisation of the dune system).
- **Marine habitat**: the inshore marine waters occur within an active high wave energy environment. The high wave energy sandy habitats associated with the inshore marine waters are typically dominated by worms and within Younghusband Peninsula, the Goolwa Cockle. Seagrass beds are scarce along most of the coast because of the high wave energy and active sand transport processes that occur along the majority of the coastline. The nearest significant seagrass habitats are located near Victor Harbour to the north and Kingston South East to the south. Coarse sands overlying low platform limestone reef dominate the Coorong offshore marine areas.
- **Protected areas**: the Coorong National Park (a state national park) was established in 1996 and covers both the north and south lagoons. The wetlands within this part of the national park form a complex ecosystem of freshwater, estuarine and hypersaline waterbodies. The Martin

Washpool Conservation Park is located near Salt Creek. Both the Encounter and Upper South East Marine Parks (State Marine Parks) border the Coorong National Park. The Encounter Marine Park and sanctuary zone are located to the north of Younghusband Peninsula, with the Upper South East Marine Park and sanctuary zone located towards the very southern end of the Coorong, south of Salt Creek. The Murray Marine Park is also nearby, although located further offshore.

- **Recreational and commercial fisheries**: the Coorong South Lagoon and the oceanside of the Coorong are popular areas for recreational fishers. Key species fished include mulloway, bream, salmon, mullet, flathead and snapper. The coastal marine waters adjacent to Younghusband Peninsula are considered a significant part of the commercial fisheries industry. Target commercial fisheries species include the Goolwa Cockle and Mulloway.
- **Visual amenity**: the Coorong and open ocean side of Younghusband Peninsula is an area of significant natural biodiversity with visual amenity value.

10.4 ENVIRONMENTAL RISK REVIEW PROCESS

10.4.1 Methodology

A preliminary environmental risk review was undertaken following the identification of concept design options. The risk review process is based on the concept that the level of risk of the environmental issue is related to the consequence of the issue and the likelihood of the issue occurring. This approach is consistent with the Australian Standard for risk management AS/NZS 4360:2004 which ensures that the review process is repeatable.

A version of the risk review tool has been used to provide a preliminary analysis of the extent of impacts, identify appropriate management measures and identify where further assessment may need to be undertaken.

Risk level was determined using the standard risk matrix in Table 39. The definitions for the likelihood and consequence ratings are shown in Table 40 and Table 41, respectively. Note that these definitions are indicative and have been adopted from standard risk assessment methodologies. They do not attempt to represent the policy position of project stakeholders.

Table 39 Risk review matrix

Likelihood rating	Consequence rating				
	Insignificant	Minor	Moderate	Major	Severe
Almost Certain	Low	Medium	High	Very High	Very High
Likely	Low	Medium	High	High	Very High
Possible	Low	Medium	Medium	High	High
Unlikely	Low	Low	Medium	Medium	High
Rare	Low	Low	Low	Medium	Medium

Table 40 Likelihood definitions

Rating	Description
Almost certain	Very high probability of the consequence occurring. Expected to occur in most circumstance (occurs multiple times within a year, or incident is clearly imminent).
Likely	High probability of the consequence occurring. Probably occurs in most circumstances (expected to occur approximately once per year).

Rating	Description
Possible	Even probability of consequence occurring. Could occur at some time (likely to occur approximately once every five years).
Unlikely	Low probability of consequence occurring. Not expected to occur (likely to occur approximately once every 5–10 years)
Rare	Very low probability of consequence occurring. Exceptional circumstances only (likely to occur with less frequency than once every 10 years).

Table 41 Consequence definitions

Rating	Description
Severe	Serious permanent/persistent and irreversible damage to the environment. Widespread serious permanent effect.
Major	Notable damage to the environment from which it will take more than 10 years to recover with long-term evidence of the incident resulting. Wider spread, moderate to long-term effect.
Moderate	Moderate but repairable damage that will take up to 10 years to recover. Localised, short-term to moderate effect.
Minor	Minor damage to the environment that is immediately contained on-site. It will take less than two years for the resource to fully recover. Localised, short-term effect.
Insignificant	Negligible damage that is contained on-site, and the damage is fully recoverable with no permanent effects, taking less than six months to fully recover. No impact or no lasting effect.

10.4.2 Environmental risk review findings

The preliminary environmental risk review process considered the following environmental aspects for each concept design option:

- Coastal/lake processes (currents, tides, wind and wave conditions).
- Marine processes (currents, tides, wind and wave conditions).
- Sediment characteristics.
- Water quality.
- Flora.
- Fauna.
- Noise.
- Visual amenity.
- Energy emissions.

Based on the information currently available, a summary of the residual risk of impact on the above environmental aspects for each concept design option, addressing both construction and operational activities, is presented in Tables 42 and 43. Note that each residual impact category is accompanied by a number that represents the number of identified impacts assessed as having that level of residual risk.

A detailed breakdown of the preliminary risk review undertaken for each proposed option, covering both construction and operational activities, are provided in Appendix N.

In consideration of the outcomes of the risk review process, all pumped/passive pipeline connections to the Southern Ocean are considered to be very similar in terms of construction-related impacts on the environment. The passive pipe connections between Lake Albert and the Coorong have some additional impact risks with regard to sediment and erosion control and water quality issues. Overall, the preliminary risk review process indicates that for all options, key construction-related impacts include the potential impacts associated with sediment characteristics, water quality, flora, fauna and ambient noise levels.

The findings of the preliminary risk review for the operation of each concept design indicate that key environmental impacts are likely to include potential adverse effects on marine coastal processes, water quality, fauna, visual amenity and energy emissions. The pumped/passive pipeline connections to the Southern Ocean, which involve supporting infrastructure such as a breakwater or jetty, and those which require an energy supply are likely to involve a greater risk of impact than those options that do not require such infrastructure and do no rely on external energy sources.

Table 42 Construction: Preliminary environmental impact review – Residual risks

Option	Coastal/Lake processes (currents, tides, wind and wave conditions)	Marine processes (currents, tides, wind and wave conditions)	Sediment characteristics	Water quality	Flora	Fauna	Noise	Visual amenity	Energy emissions
1A	Low (1)	Nil	High (1) Medium (1)	High (1) Medium (1) Low (1)	Medium (1) Low (3)	Medium (1) Low (1)	Medium (1)	Low (1)	Low (1)
1B	Low (1)	Nil	High (1) Medium (1)	High (1) Low (1)	Medium (1) Low (3)	Medium (1) Low (1)	Medium (1)	Low (1)	Low (1)
2	Low (2)	Low (1)	Medium (1) Low (1)	Medium (1) Low (5)	Low (4)	Medium (2) Low (3)	Medium (1)	Low (1)	Low (1)
3A	Nil	Low (1)	High (2) Low (2)	Low (5)	High (1) Medium (1) Low (3)	Medium (1) Low (2)	Medium (1)	Low (1)	Low (1)
3B	Nil	Low (1)	High (1) Low (2)	Low (5)	High (1) Medium (1) Low (3)	Medium (1) Low (2)	Medium (1)	Low (1)	Low (1)
3C	Nil	Low (1)	High (2) Low (2)	Low (5)	High (1) Medium (1) Low (3)	Medium (1) Low (2)	Medium (1)	Low (1)	Low (1)
3D	Nil	Low (1)	High (1) Low (2)	Low (5)	High (1) Medium (1) Low (3)	Medium (1) Low (2)	Medium (1)	Low (1)	Low (1)
4A	Nil	Low (1)	High (2) Low (2)	Low (5)	High (1) Medium (1) Low (3)	Medium (2) Low (4)	Medium (1)	Low (1)	Low (1)
4B	Nil	Low (1)	High (2) Low (2)	Low (5)	High (1) Medium (1) Low (3)	Medium (1) Low (3)	Medium (1)	Low (1)	Low (1)
5A	Nil	Low (1)	High (2) Low (2)	Low (5)	High (1) Medium (1) Low (3)	Medium (2) Low (3)	Medium (1)	Low (1)	Low (1)

Option	Coastal/Lake processes (currents, tides, wind and wave conditions)	Marine processes (currents, tides, wind and wave conditions)	Sediment characteristics	Water quality	Flora	Fauna	Noise	Visual amenity	Energy emissions
5B	Nil	Low (1)	High (2)	Low (5)	High (1)	Medium (2)	Medium (1)	Low (1)	Low (1)
			Low (2)		Medium (1)	Low (3)			
					Low (3)				
6	Nil	Low (1)	High (2)	Low (5)	High (1)	Medium (1)	Medium (1)	Low (1)	Low (1)
			Low (2)		Medium (1)	Low (3)			
					Low (3)				

Table 43 Operations: Preliminary environmental impact review – Residual risks

Option	Coastal/Lake processes (currents, tides, wind and wave conditions)	Marine processes (currents, tides, wind and wave conditions)	Sediment characteristics	Water quality	Flora	Fauna	Noise	Visual amenity	Energy emissions
1A	Low (1)	Nil	Medium (1)	Medium (4)	Low (1)	Medium (1) Low (1)	Low (1)	High (1)	Low (1)
1B	Low (1)	Nil	Nil	Medium (2) Low (1)	Nil	Low (1)	Low (1)	Low (1)	Low (1)
2	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
3A	Low (1)	Medium (1)	Nil	Medium (2)	Low (1)	High (1) Medium (1) Low (1)	Low (1)	High (1)	High (1)
3B	Low (1)	Medium (1)	Nil	Medium (2)	Low (1)	High (2) Low (1)	Low (1)	Medium (1)	High (1)
3C	Low (1)	Medium (1)	Nil	Medium (2)	Low (1)	High (1) Medium (1) Low (1)	Low (1)	High (1)	High (1)
3D	Low (1)	Medium (1)	Nil	Medium (2)	Low (1)	High (2) Low (1)	Low (1)	Medium (1)	High (1)
4A	Low (1)	Medium (1)	Nil	Medium (2)	Low (1)	High (1) Medium (1) Low (1)	Low (1)	High (1)	High (1)
4B	Low (1)	High (1)	Nil	Medium (2)	Low (1)	Medium (1) Low (2)	Low (1)	High (1)	High (1)
5A	Low (1)	Medium (1)	Nil	Medium (2)	Low (1)	High (2) Medium (1)	Low (1)	Very High (1)	High (1)
5B	Low (1)	Medium (1)	Nil	Medium (2)	Low (1)	High (2) Medium (1)	Low (1)	High (1)	High (1)
6	Low (1)	High (1)	Nil	Medium (2)	Low (1)	Medium (2)	Low (1)	High (1)	Low (1)

11 Recommended further investigations

11.1 FURTHER STUDIES AND INVESTIGATIONS

Through the concept design process, a range of information gaps have been identified. Where necessary, available reference information or engineering judgement has been used to allow completion of the concept design activities described in this report. However, upon selection of the more highly favoured options through the multi-criteria analysis process, these options should be reviewed against some recommended studies and investigations that will identify the beneficial and productive further studies to support decision-making for the CIIP and HCHB program.

These further recommended studies and investigations include:

- Geophysical survey along the proposed dredge alignment within the Coorong lagoons to identify if zones of harder material (e.g. cemented sands or sheet calcrete) are present along the proposed dredge alignment associated with concept design Option 2.
- Further refinement of the proposed dredge alignment to further optimise the width, depth and extent of dredging required to achieve the required connectivity associated with concept design Option 2. This will include both enhanced hydrodynamic modelling, which utilises a finer mesh through the proposed dredge alignment, and trial of a range of dredge widths, depths and extents.
- Further refinement of the extent of dredging required for the southern dredge alignment supporting concept design Option 5A and Option 5B (or confirmation of elimination of this dredging element by including water level controls to achieve stable pump operation).
- Investigation into the expected frequency and volume of dredge maintenance activities over the life span of the project (expected to be minimal and only targeted areas where significant accumulation has occurred).
- Collection of bathymetry data within the near shore zone between HAT and 750 m into the Southern Ocean (the gap between marine and terrestrial geophysical surveys completed to date).
- Further geotechnical and environmental sampling and testing over the full depth of excavation expected for Lake Albert connection construction activities (e.g. bearing capacity, native soil modulus, Emerson Class assessment, environmental contaminant sample collection and testing, etc.).
- Further geotechnical testing and environmental sampling and testing over the full depth of dredging expected to be required (e.g. particle size distribution testing, environmental contaminant sample collection and testing, etc.).
- Further dredge plume dispersion modelling at the site of any proposed dredging (i.e. within Coorong South Lagoon) and at the dredged material disposal sites once further geotechnical information is known, to support the environmental approvals process.
- Further hypersaline plume and dredged material disposal plume modelling in the Southern Ocean, to support environmental impact assessments, including calibration of models with further field data (in particular dredged material properties).
- Further geotechnical testing within Younghusband Peninsula at sites of proposed infrastructure, to identify factors such as presence and depth of groundwater, horizontal and vertical bearing pressures, native soil modulus, CBR, slope stability analysis, solubility, dispersion potential and other engineering design parameters.

- Further investigation into water availability from Lake Albert and seasonal scheduling of varied flows to maximise Coorong South Lagoon improvements without detriment to Lake Albert and in considering climate change impacts.
- Further solubility and dispersion potential testing of native sand on Option 1A open channel alignment, to confirm suitability of an unlined channel.
- Consultation with landholders potentially impacted by Options 1A and 1B infrastructure, as well as those landholders in the vicinity of proposed infrastructure located within Younghusband Peninsula.
- Noise modelling of pump operation and sound pressure levels to the nearest receptors in accordance with EPA SA guidelines and advice.
- Further assessment of access and egress routes with the landholder of the Option 1A site, to determine if a second access culvert is required elsewhere along the channel (i.e. for land management, First Nations cultural access or emergency scenarios).
- Identification of target fish species to utilise the Option 1A fishway and undertake design activities to confirm the suitability of the proposed rock riffle fishway.
- Review and refinement of the environmental approvals pathway required for the selected concept designs to inform future engineering and environmental studies and assessments.
- Initiation of environmental impact assessment processes for the preferred concept design options, building upon the preliminary environmental impact reviews completed as part of concept design. This will include a detailed range of further studies comprising both field and technical modelling investigations (e.g. deployment of a wave rider buoy to collect metocean data (in both Southern Ocean and Coorong South Lagoon), additional dispersion modelling, additional dredged material sampling, benthic and terrestrial communities' surveys, etc.) and an EPBC self-assessment to define Commonwealth approvals requirements.
- Completion of traffic volume and transport route assessment to better understand any road infrastructure upgrades, high risk areas, control measures, to be applied through construction to manage vibration and heavy vehicle/passenger vehicle interaction and establishment of load limits and necessary detour routes.
- Further cultural heritage surveys to inform finalisation of infrastructure alignments (in particular, those through Younghusband Peninsula, including temporary pipeline alignments for dredged material disposal pipework).
- Flora, fauna and other ecological assessments for the proposed infrastructure alignments (also supporting the EPBC self-assessment process).
- Further investigation into the feasibility of a synchronous transfer system for pumped options to enable a single VSD to be installed instead of a VSD on each pump.
- Submission of a formal request to SAPN for provision of a connection to the locations required for pumping infrastructure, allowing confirmation of likely supply and augmentation costs necessary for the project.
- Detailed engineering survey of proposed areas where infrastructure is required.
- Further design activities focused on the more highly favoured options, to assist in refinement of the required scope of works and confirmation of expected capital cost of proposed infrastructure. Elements to consider include piping support details, pressure surge mitigation measures, thrust block design and further site layout details including provision of power supplies (if required), buried services routing and additional multi-disciplinary design and analysis.

- Confirmation of a preferred operational philosophy for large valves, including consideration of actuation and the ability to remotely operate valves (particularly for Options 4A, 4B and 6).
- Assessment of land acquisition requirements for construction purposes (e.g. laydown, permanent access provisions, etc.) and any complementary project activities (e.g. solar panel installation).
- Assessment of construction methodologies to be applied for pipeline constructions (e.g. trenchless installation vs. conventional open trench pipe laying), as final pipe material selection is completed, jointing methodologies are understood and construction equipment requirements are better defined.
- Further socioeconomic assessment and modelling building upon preliminary investigations, and with a focus on developing a cost benefit analysis for the project for the finally recommended infrastructure option.
- Consideration of available renewable energy supplies from nearby projects or development of a renewable energy project, in exploration of development of a power purchase agreement (PPA) for dedicated renewable energy supply for power demands on this project.

11.2 ITEMS IDENTIFIED FOR INVESTIGATION DURING DETAILED DESIGN

Throughout concept design, a range of additional design activities have been identified that will be required to be investigated and addressed during detailed design activities for the selected infrastructure option. A summary of these items is provided in Table 44.

Table 44 Items to be investigated through detailed design

Item	Detailed design activities	Option(s)
1	Investigation of power infrastructure requirements with SAPN.	All pumped options
2	Sensitivity analysis of roughness coefficient for pipe head loss considering sediment accumulation, marine growth, etc.	All piped options
3	Sensitivity analysis of minor loss coefficients for pipe head loss.	All piped options
4	Consider mobile sand and sediment removal scrapers or pumps to assist in desilting of the caisson structure. Also consider installation of a sump or plinth to better manage any settled sand or sediment.	All caisson structure options
5	Further development of a maintenance strategy for management of marine growth to pipe outlets.	All submerged discharge options
6	Consider pipe jointing types to allow for expected relative pipe movement between fixed (i.e. jetty mounted) pipework and in ground pipework.	All pumped options with jetty
7	Optimisation of pipework arrangement in dry well within Younghusband Peninsula considering bend angles, pipe elevations and minor losses.	Option 4B
8	Further development of access arrangements for buried valves in passive system.	Option 6
9	Definition of design vehicle, vehicle loading and turning circle assessment for all access roads.	All options
10	Assessment of haul routes to infrastructure sites and consideration of impacts on traffic volume and management within townships, vehicle safety (e.g. site distances for traffic entry/exit) and standard of construction of frequently used roads.	All options

Item	Detailed design activities	Option(s)
11	Definition of target fish species and review of fishway design parameters for these target species.	Option 1A
12	Review of adopted batter slopes for open channel design, trenching or excavation for both temporary and permanent installation.	All options
13	Geophysical survey (continuous marine seismic refraction) of all dredge alignments to identify and avoid firmer layers of proposed dredged material.	All dredging options
14	Further development of pipework installation strategy (open cut trenching or trenchless installation) including pipe material, pipe class, jointing methods and available pipe diameters.	All piped options
15	Optimisation of dredged alignment and profile after development of a finer hydrodynamic model mesh and additional modelling and analysis.	All dredging options
16	Assessment of dredge access paths for mobilisation of equipment and temporary construction works required to facilitate dredging activities.	All dredging options
17	Assessment of maintenance dredging requirements within the Coorong for dredged pockets surrounding pump infrastructure.	All Coorong pumped options
18	Further assessment of pipe fouling (marine growth) and potential treatment or management options.	All piped options
19	Investigation of beneficial reuse of spoil from open channel construction rather than creation of a spoil mound.	Option 1A
20	Investigation of impact to pump design life for operation with expected suspended sediment concentration.	All pumped options
21	Final selection of all pumps to allow preparation of datasheets and optimisation of pump station dimensions and arrangement.	All pumped options
22	Engagement of SAPN to provide detailed technical requirements associated with provision of the proposed power supply.	All pumped options
23	Assessment of redundancy requirements for power supply infrastructure (no redundancy is proposed at present).	All pumped options
24	Investigation of the need to provide vessel berthing facilities to ocean jetty (not currently included considering risk profile).	All jetty options
25	Investigation of specific screen cleaning methods for fish screens to minimise manual maintenance activities.	All pumped options
26	Further assessment of environmental aggressivity and final material selection for proposed equipment and infrastructure.	All options
27	Further assessment of preferred submarine cable installation method and required minimum depth of water installation to manage damage or impact risks.	All pumped options
28	Further assessment of head loss through fish screens.	All pumped options
29	Completion of a secondary armourstone sourcing study to confirm preferred supply quarry.	Options 4B and 6

Item	Detailed design activities	Option(s)
30	Further assessment of requirement for crest wall to breakwater to assist in efficient use of armourstone and improved management of overtopping flows.	Options 4B and 6
31	Further design development and construction methodology assessment for caisson structure.	All caisson structure options
32	Further assessment of sand entrainment into ocean pumps to assess infrastructure implications and consider sediment control measures to minimise entrainment.	All Southern Ocean pumped options
33	Confirmation of horizontal orientation of all butterfly valves.	All pumped options
34	Confirmation of effective operation of all non-return valves considering provision of counterweights to control valve closure.	All pumped options
35	Design of specific air release points from all pipelines ensuring full pipe flow can be achieved efficiently.	All pumped options
36	Further assessment of scour depth in the seabed adjacent the caisson structure to ensure undermining does not occur.	All caisson structure options
37	Further assessment of pontoon restraint and guide piles including pile material, number of piles and mechanical connection details with pontoon.	All Coorong pumped options
38	Further assessment of flotation of all structures once final dimensions, weights and sizes are known including variance in groundwater level under sea level rise conditions.	All options
39	Further assessment of communications infrastructure (e.g. wireless) to allow remote monitoring and operation.	All options
40	Further assessment of access track routes and requirement for erosion protection infrastructure to access jetty and pontoon infrastructure from the dunes.	All pumped options
41	Design of rock mattress dissipation structure beneath Coorong South Lagoon pump in discharge infrastructure.	All Southern Ocean pumped options
42	Further assessment of dredge pocket depth surrounding pontoon pumps in the Coorong South Lagoon.	All pumped options
43	Further assessment of Flexmat anchorage and energy dissipation at beach discharge outlet.	All beach discharge pumped options (low visual impact)
44	Further assessment of the requirements for fish screens in Southern Ocean pumped options given operational and maintenance challenges with fish screens within the caisson structure or protected by a breakwater.	All Southern Ocean pumped options
45	Detailed surge analysis of all pumped pipelines and design of mitigation measures.	All pumped options
46	Detailed thrust and anchor restraint analysis and design for all pumped pipelines.	All pumped options
47	Deployment of wave rider buoys to collect metocean data in both Coorong South Lagoon and Southern Ocean.	All options
48	Consider inclusion of vehicle turnaround bay at end of jetty infrastructure.	All jetty options

Item	Detailed design activities	Option(s)
49	Optimisation of perforations within caisson structure stilling well to minimise sand entrainment and collection of other floating matter (e.g. seaweed).	All caisson structure options
50	Further assessment of rate of corrosion to be allowed in jetty infrastructure and application of cathodic protection or other corrosion prevention methods.	All jetty options
51	Further assessment of breakwater geometry ensuring pipework can be accommodated without risk of damage to pipe through operation.	Option 4B
52	Further assessment of pipeline installation within Southern Ocean for breakwater options.	Options 4B and 6
53	Consider range of expected discharge flow rates for passive pipe, brine-plume dispersion modelling.	Option 6
54	Define permanent vehicle bypass tracks around Ocean Beach infrastructure to allow separation of public use of the beach in the vicinity of infrastructure (e.g. beach discharge).	All Southern Ocean connector options
55	Safety in design, and risk assessment and mitigation activities for complex elements of the selected infrastructure (e.g. submarine cable installation arrangement, operational access to infrastructure, jetty or breakwater access, public safety implications, etc.).	All options
56	Optimisation of the deck height and span adopted for jetty elements considering material supply, detailed construction methodology, operational access requirements, etc.	All jetty options
57	Design of all pavements based following CBR testing and analysis of results.	All options
58	Define parking requirements for construction, operation and maintenance vehicles and ensure they can be accommodated within proposed access tracks and hardstand areas (as well as any specific heavy vehicle/equipment operational requirements – e.g. a crane).	All options
59	Consider installation of fauna crossings, landholder access crossing and emergency services access crossings over Lake Albert connector channel infrastructure.	Option 1A
60	Consider automation of valve opening and closing for discharge valves on jetty and pontoon structures and for valves within the dry well pump station allowing for remote flow reversal.	Options 4A and 4B
61	Consider automation of buried valves opening and closing in passive system.	Option 6

Whilst extensive, this list of detailed design considerations is not exhaustive. A complete and thorough detailed design process will be required for the selected infrastructure option to ready the project for construction and delivery.

11.3 ALTERNATIVE OPTION CONSIDERATIONS

Through completion activities for the concept design, several alternate (hybrid) options have been identified as being of potential merit, building on the concept design scope completed to date. These are intended to draw together favourable elements of different options and have been proposed through workshop discussion or constructability reviews. The opportunity remains to develop the hybrid options further, to improve option metrics and optimise the designs. These options include:

- Construction of the Option 1B piped connector along the Option 1A open channel alignment, avoiding the requirement for bends in the pipeline, the overhead electrical supply present along Seven Mile Road, and temporary traffic diversions.
- Replacement of the Option 4B breakwater with a jetty and caisson structure as for Option 4A (potentially shorter in length) but retaining the central pumping well.

Further design development could occur on these options if any of the base concept design options are considered to be favoured through the project decision-making process.

12 Concept design drawing list

A list of the concept design drawings produced across the 12 concept design options developed are presented in Table 45. The full set of concept design drawings is provided in Appendix A.

Table 45 Concept design drawing list

Drawing Number	Drawing Title	Description
AEG155-0000-TD-DRG-CV-0001	Sitewide	Project Key Plan
AEG155-0000-TD-DRG-CV-0200	Sitewide	Typical Jetty General Arrangement
AEG155-0000-TD-DRG-CV-0201	Sitewide	Typical Jetty Section
AEG155-0000-TD-DRG-CV-0300	Sitewide	Typical Discharge Jetty General Arrangement
AEG155-0000-TD-DRG-CV-0301	Sitewide	Typical Discharge Jetty Section
AEG155-0000-TD-DRG-CV-0400	Sitewide	Construction Access - Option 5 (North)
AEG155-0000-TD-DRG-CV-0401	Sitewide	Construction Access - Options 3,4,5,6 Sheet 1
AEG155-0000-TD-DRG-CV-0402	Sitewide	Construction Access - Options 3,4,5,6 Sheet 2
AEG155-0000-TD-DRG-CV-0600	Sitewide	Passive Intake/Outfall Structure - Section
AEG155-0000-TD-DRG-CV-0700	Sitewide	Nearshore Discharge Structure Details
AEG155-0000-TD-DRG-CV-0800	Sitewide	Typical Trench Details
AEG155-0000-TD-DRG-CV-0900	Sitewide	Breakwater Details
AEG155-0000-TD-DRG-CV-1000	Sitewide	Caisson Structure General Arrangement
AEG155-0000-TD-DRG-CV-1001	Sitewide	Caisson Structure Section
AEG155-0000-TD-DRG-ME-0001	Sitewide	Fish Screen Detail
AEG155-1000-TD-DRG-CV-0001	Option 1A - Lake Albert Connector - Channel	Cover Sheet and Drawing List
AEG155-1000-TD-DRG-CV-0002	Option 1A - Lake Albert Connector - Channel	Options Key Plan
AEG155-1000-TD-DRG-CV-1000	Option 1A - Lake Albert Connector - Channel	Plan and Longitudinal Section Sheet 1 of 4
AEG155-1000-TD-DRG-CV-1001	Option 1A - Lake Albert Connector - Channel	Plan and Longitudinal Section Sheet 2 of 4
AEG155-1000-TD-DRG-CV-1002	Option 1A - Lake Albert Connector - Channel	Plan and Longitudinal Section Sheet 3 of 4

Drawing Number	Drawing Title	Description
AEG155-1000-TD-DRG-CV-1003	Option 1A - Lake Albert Connector - Channel	Plan and Longitudinal Section Sheet 4 of 4
AEG155-1000-TD-DRG-CV-7000	Option 1A - Lake Albert Connector - Channel	Inlet Regulating Structure - Site Plan
AEG155-1000-TD-DRG-CV-7001	Option 1A - Lake Albert Connector - Channel	Inlet Regulating Structure - Elevation
AEG155-1000-TD-DRG-CV-7100	Option 1A - Lake Albert Connector - Channel	Channel Cross Section Ch. 1850
AEG155-1500-TD-DRG-CV-0001	Option 1B - Lake Albert Connector - Pipes	Cover Sheet and Drawing List
AEG155-1500-TD-DRG-CV-0002	Option 1B - Lake Albert Connector - Pipes	Options Key Plan
AEG155-1500-TD-DRG-CV-1000	Option 1B - Lake Albert Connector - Pipes	Plan and Longitudinal Section Sheet 1 of 3
AEG155-1500-TD-DRG-CV-1001	Option 1B - Lake Albert Connector - Pipes	Plan and Longitudinal Section Sheet 2 of 3
AEG155-1500-TD-DRG-CV-1002	Option 1B - Lake Albert Connector - Pipes	Plan and Longitudinal Section Sheet 3 of 3
AEG155-1500-TD-DRG-CV-7000	Option 1B - Lake Albert Connector - Pipes	Inlet Regulating Structure - Site Plan
AEG155-1500-TD-DRG-CV-7100	Option 1B - Lake Albert Connector - Pipes	Cross Section Ch. 1800
AEG155-2000-TD-DRG-CV-0001	Option 2 - Parnka Narrows Dredge	Cover Sheet and Drawing List
AEG155-2000-TD-DRG-CV-1000	Option 2 - Parnka Narrows Dredge	Key Plan
AEG155-2000-TD-DRG-CV-1001	Option 2 - Parnka Narrows Dredge	Plan - Sheet 1 of 14
AEG155-2000-TD-DRG-CV-1002	Option 2 - Parnka Narrows Dredge	Plan - Sheet 2 of 14
AEG155-2000-TD-DRG-CV-1003	Option 2 - Parnka Narrows Dredge	Plan - Sheet 3 of 14
AEG155-2000-TD-DRG-CV-1004	Option 2 - Parnka Narrows Dredge	Plan - Sheet 4 of 14
AEG155-2000-TD-DRG-CV-1005	Option 2 - Parnka Narrows Dredge	Plan - Sheet 5 of 14
AEG155-2000-TD-DRG-CV-1006	Option 2 - Parnka Narrows Dredge	Plan - Sheet 6 of 14
AEG155-2000-TD-DRG-CV-1007	Option 2 - Parnka Narrows Dredge	Plan - Sheet 7 of 14
AEG155-2000-TD-DRG-CV-1008	Option 2 - Parnka Narrows Dredge	Plan - Sheet 8 of 14
AEG155-2000-TD-DRG-CV-1009	Option 2 - Parnka Narrows Dredge	Plan - Sheet 9 of 14
AEG155-2000-TD-DRG-CV-1010	Option 2 - Parnka Narrows Dredge	Plan - Sheet 10 of 14
AEG155-2000-TD-DRG-CV-1011	Option 2 - Parnka Narrows Dredge	Plan - Sheet 11 of 14
AEG155-2000-TD-DRG-CV-1012	Option 2 - Parnka Narrows Dredge	Plan - Sheet 12 of 14
AEG155-2000-TD-DRG-CV-1013	Option 2 - Parnka Narrows Dredge	Plan - Sheet 13 of 14
AEG155-2000-TD-DRG-CV-1014	Option 2 - Parnka Narrows Dredge	Plan - Sheet 14 of 14

Drawing Number	Drawing Title	Description
AEG155-3000-TD-DRG-CV-0001	Option 3A - 1000 ML/d CSL Pump Out (Jetty Discharge)	Cover Page
AEG155-3000-TD-DRG-CV-1000	Option 3A - 1000 ML/d CSL Pump Out (Jetty Discharge)	Key Plan
AEG155-3000-TD-DRG-CV-1001	Option 3A - 1000 ML/d CSL Pump Out (Jetty Discharge)	Plan - Sheet 1
AEG155-3000-TD-DRG-CV-1002	Option 3A - 1000 ML/d CSL Pump Out (Jetty Discharge)	Plan - Sheet 2
AEG155-3000-TD-DRG-CV-1003	Option 3A - 1000 ML/d CSL Pump Out (Jetty Discharge)	Jetty Sections - Sheet 1
AEG155-3000-TD-DRG-ME-6001	Option 3A - 1000 ML/d CSL Pump Out (Jetty Discharge)	Pump Station Sections - Sheet 1
AEG155-3100-TD-DRG-CV-0001	Option 3B - 1000 ML/d CSL Pump Out (Nearshore Discharge)	Cover Page
AEG155-3100-TD-DRG-CV-1000	Option 3B - 1000 ML/d CSL Pump Out (Nearshore Discharge)	Key Plan
AEG155-3100-TD-DRG-CV-1001	Option 3B - 1000 ML/d CSL Pump Out (Nearshore Discharge)	Plan - Sheet 1
AEG155-3100-TD-DRG-CV-1002	Option 3B - 1000 ML/d CSL Pump Out (Nearshore Discharge)	Plan - Sheet 2
AEG155-3100-TD-DRG-ME-6001	Option 3B - 1000 ML/d CSL Pump Out (Nearshore Discharge)	Pump Station Sections - Sheet 1
AEG155-3200-TD-DRG-CV-0001	Option 3C - 250 ML/d CSL Pump Out (Jetty Discharge)	Cover Sheet
AEG155-3200-TD-DRG-CV-1000	Option 3C - 250 ML/d CSL Pump Out (Jetty Discharge)	Key Plan
AEG155-3200-TD-DRG-CV-1001	Option 3C - 250 ML/d CSL Pump Out (Jetty Discharge)	Plan - Sheet 1
AEG155-3200-TD-DRG-CV-1002	Option 3C - 250 ML/d CSL Pump Out (Jetty Discharge)	Plan - Sheet 2
AEG155-3200-TD-DRG-CV-1003	Option 3C - 250 ML/d CSL Pump Out (Jetty Discharge)	Jetty Sections
AEG155-3200-TD-DRG-ME-6001	Option 3C - 250 ML/d CSL Pump Out (Jetty Discharge)	Pump Station Sections
AEG155-3300-TD-DRG-CV-0001	Option 3D - 250 ML/d CSL Pump Out (Nearshore Discharge)	Cover Page
AEG155-3300-TD-DRG-CV-1000	Option 3D - 250 ML/d CSL Pump Out (Nearshore Discharge)	Key Plan
AEG155-3300-TD-DRG-CV-1001	Option 3D - 250 ML/d CSL Pump Out (Nearshore Discharge)	Plan - Sheet 1
AEG155-3300-TD-DRG-CV-1002	Option 3D - 250 ML/d CSL Pump Out (Nearshore Discharge)	Plan - Sheet 2

Drawing Number	Drawing Title	Description
AEG155-3300-TD-DRG-ME-6001	Option 3D - 250 ML/d CSL Pump Out (Nearshore Discharge)	Pump Station Section
AEG155-4000-TD-DRG-CV-0001	Option 4A - Bi-Directional Two Pump Stations	Cover Page
AEG155-4000-TD-DRG-CV-1000	Option 4A - Bi-Directional Two Pump Stations	Key Plan
AEG155-4000-TD-DRG-CV-1001	Option 4A - Bi-Directional Two Pump Stations	Plan - Sheet 1
AEG155-4000-TD-DRG-CV-1002	Option 4A - Bi-Directional Two Pump Stations	Plan - Sheet 2
AEG155-4000-TD-DRG-ME-6000	Option 4A - Bi-Directional Two Pump Stations	Pontoon Pump Section
AEG155-4000-TD-DRG-ME-6001	Option 4A - Bi-Directional Two Pump Stations	Jetty Pump Section
AEG155-4100-TD-DRG-CV-0001	Option 4B - Bi-Directional One Pump Station	Cover Page
AEG155-4100-TD-DRG-CV-1000	Option 4B - Bi-Directional One Pump Station	Key Plan
AEG155-4100-TD-DRG-CV-1001	Option 4B - Bi-Directional One Pump Station	Plan - Sheet 1
AEG155-4100-TD-DRG-CV-1002	Option 4B - Bi-Directional One Pump Station	Plan - Sheet 2
AEG155-4100-TD-DRG-CV-1003	Option 4B - Bi-Directional One Pump Station	Plan - Sheet 3
AEG155-4100-TD-DRG-CV-1004	Option 4B - Bi-Directional One Pump Station	Piping Section
AEG155-4100-TD-DRG-ME-6000	Option 4B - Bi-Directional One Pump Station	Pump Station Section
AEG155-4100-TD-DRG-ME-6002	Option 4B - Bi-Directional One Pump Station	Pump Station Isometric View - Sheet 1
AEG155-4100-TD-DRG-ME-6003	Option 4B - Bi-Directional One Pump Station	Pump Station Isometric View - Sheet 2
AEG155-5000-TD-DRG-CV-0001	Option 5A - Simultaneous Pump In, Pump Out on Jetty	Cover Page
AEG155-5000-TD-DRG-CV-1000	Option 5A - Simultaneous Pump In, Pump Out on Jetty	North Location Key Plan
AEG155-5000-TD-DRG-CV-1001	Option 5A - Simultaneous Pump In, Pump Out on Jetty	North Location Plan - Sheet 1
AEG155-5000-TD-DRG-CV-1002	Option 5A - Simultaneous Pump In, Pump Out on Jetty	North Location Plan - Sheet 2
AEG155-5000-TD-DRG-CV-1004	Option 5A - Simultaneous Pump In, Pump Out on Jetty	South Location Key Plan

Drawing Number	Drawing Title	Description
AEG155-5000-TD-DRG-CV-1005	Option 5A - Simultaneous Pump In, Pump Out on Jetty	South Location Plan - Sheet 1
AEG155-5000-TD-DRG-CV-1006	Option 5A - Simultaneous Pump In, Pump Out on Jetty	South Location Plan - Sheet 2
AEG155-5000-TD-DRG-CV-6000	Option 5A - Simultaneous Pump In, Pump Out on Jetty	Pontoon Pump Section
AEG155-5000-TD-DRG-CV-6001	Option 5A - Simultaneous Pump In, Pump Out on Jetty	Jetty Pump Section
AEG155-5100-TD-DRG-CV-0001	Option 5B - Simultaneous Pump In, Pump Out to Near Shore	Cover Page
AEG155-5100-TD-DRG-CV-1000	Option 5B - Simultaneous Pump In, Pump Out to Near Shore	North Location Key Plan
AEG155-5100-TD-DRG-CV-1001	Option 5B - Simultaneous Pump In, Pump Out to Near Shore	North Location Plan - Sheet 1
AEG155-5100-TD-DRG-CV-1002	Option 5B - Simultaneous Pump In, Pump Out to Near Shore	North Location Plan - Sheet 2
AEG155-5100-TD-DRG-CV-1003	Option 5B - Simultaneous Pump In, Pump Out to Near Shore	South Location Key Plan
AEG155-5100-TD-DRG-CV-1004	Option 5B - Simultaneous Pump In, Pump Out to Near Shore	South Location Plan - Sheet 1
AEG155-5100-TD-DRG-CV-1005	Option 5B - Simultaneous Pump In, Pump Out to Near Shore	South Location Plan - Sheet 2
AEG155-5100-TD-DRG-ME-6000	Option 5B - Simultaneous Pump In, Pump Out to Near Shore	Pontoon Pump Section
AEG155-5100-TD-DRG-ME-6001	Option 5B - Simultaneous Pump In, Pump Out to Near Shore	Jetty Pump Section
AEG155-6000-TD-DRG-CV-0001	Option 6 - Passive Pipework CSL In/Out With Breakwater	Cover Page
AEG155-6000-TD-DRG-CV-1000	Option 6 - Passive Pipework CSL In/Out With Breakwater	Key Plan
AEG155-6000-TD-DRG-CV-1001	Option 6 - Passive Pipework CSL In/Out With Breakwater	Plan - Sheet 1
AEG155-6000-TD-DRG-CV-1002	Option 6 - Passive Pipework CSL In/Out With Breakwater	Plan - Sheet 2
AEG155-6000-TD-DRG-CV-5000	Option 6 - Passive Pipework CSL In/Out With Breakwater	Piping Section