Bega Valley Shire Council
6 March 2013

FINAL REPORT

Ecological Assessment of the Potential Impacts on Merimbula Lake from Shallow Dunal Exfiltration of Effluent

Merimbula Effluent Management Options Investigation

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Prepared for

Bega Valley Shire Council

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6 March 2013

60102089

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Quality Information

Document	Ecological Assessment of the Potential Impacts on Merimbula Lake from Shallow Dunal Exfiltration of Effluent
	60102089
Ref	p:\60102089_merimbula\8.issued docs\8.1. reports\20130306_Ecological Assessment\ Ecological Assessment of the Potential Impacts on Merimbula Lake from Shallow Dunal Exfiltration of Effluent.docx
Date	6 March 2013
Prepared by	Kathryn Duchatel and Dr Mark Gibbs
Reviewed by	Matthew Renshaw

Revision History

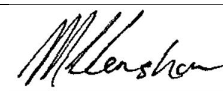
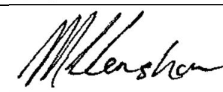
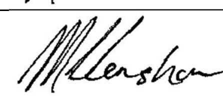
Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
A	14-Jun-2012	Draft for Review	Matthew Renshaw	
B	17-Aug-2012	Draft for Review	Matthew Renshaw	
C	06-Mar-2013	Final	Matthew Renshaw Principal Engineer	

Table of Contents

List of Tables

List of Figures

Executive Summary

Overview

The Merimbula sewerage system services the Bega Valley Shire's coastal towns of Merimbula, Pambula, South Pambula and Pambula Beach.

Bega Valley Shire Council (BVSC) engaged AECOM Australia Pty Ltd (AECOM) to investigate, identify and assess options for the beneficial use of effluent and the disposal of the effluent remaining (i.e. excess effluent that is unable to be beneficially used) from the Merimbula sewage treatment plant (STP). The outcome of the options investigation is to form a strategy for effluent management that provides the greatest benefit to the community and environment, whilst being affordable.

A range of investigations have been undertaken to identify options for the disposal of effluent from the STP including the construction of an exfiltration system within the Merimbula-Pambula dunal system to allow effluent to exfiltrate into the dunal aquifer. This option would result in groundwater near an exfiltration system being recharged by effluent in addition to rainwater and would increase the natural volume and flow of groundwater towards the ocean and the lake.

Groundwater modelling and simulations undertaken by Ian Grey Groundwater Consultanting Pty Ltd (IGGC) has shown that a shallow dunal exfiltration system north of the existing ponds is a viable option for the disposal of effluent from Merimbula STP from a hydraulic loading perspective, both over the long term and during peak discharge times. The modelling for year 2025 estimated effluent disposal volumes via a 400 metre exfiltration trench located within BVSC land in the dunes east of Merimbula airport, predicts that the majority of effluent disposed would flow in groundwater towards the ocean (approximately 81%) and the remainder would flow westward with the natural groundwater flow towards Merimbula Lake.

Further modelling was commissioned by BVSC to assess the potential for phosphorus and nitrogen in effluent to migrate in groundwater to Merimbula Lake and ocean (Merimbula Bay). Four scenarios were modelled with discharge flux rates and typical nitrogen and phosphorus concentrations in groundwater estimated for the identified discharge zones in the bay and lake for each scenario.

The general aim of this study is to investigate and identify the potential ecological impacts to Merimbula Lake of the shallow dunal exfiltration option.

The specific objectives of this study are to:

- Identify aquatic habitats and protected ecological matters in Merimbula Lake.
- Review and interpret modelled nutrient flux data for comparison against background data provided by the Environment Protection Authority (EPA) and additional data where appropriate as found in national and international literature.
- Identify potential impacts associated with modelled nutrient fluxes on the receiving environment of Merimbula Lake.
- Identify likely approvals pathways associated with the shallow dunal exfiltration option.

Potential ecological impacts

Under two of the four scenarios modelled (IGGC 2013 Scenarios 1 & 3) there are no simulated phosphate or nitrate plumes to the Merimbula Lake system. All of the phosphorus and nitrogen in the effluent is adsorbed and denitrified in the groundwater system before it reaches the lake. These scenarios have the least ecological impacts.

Under the scenario that would potentially lead to the most impacts (IGGC 2013 Scenario 2), both dissolved nitrate N and phosphate P would be discharged into the lake at a maximum rate of 3,287 grams/day of dissolved P and 924 grams/day of dissolved N. Under this scenario, the maximum nutrient fluxes would likely lead to enhanced production of both micro-phyto-benthos (micro algae in the sediments) and more visible macro-algae in the near-field or vicinity of the discharge location. It could also be argued however, that the assumption that Scenario 2 is based upon, (i.e. the sediments between the modelled exfiltration trench location and the discharge area in Merimbula Lake have a very low capacity to sorb phosphate and zero capacity for nitrate decay), is unrealistic and therefore it is unlikely that the ecological impacts suggested for this scenario would occur to the same degree and extent as reported.

Under Scenario 2, increased groundwater discharge fluxes with higher than natural concentrations of nitrate and/or phosphate may impact saltmarsh and mangrove vegetation located within the lakeshore zones where the highest concentrations of nutrients in groundwater are likely to be discharged. Little is reported in relation to the sensitivity of these estuarine communities to groundwater impacts although broad interactions are inferred in general information found through literature searches.

If increased nutrients were to be discharged, seagrass meadows in the vicinity of the discharge site may be impacted. Seagrasses are known to respond to increased nutrients; particularly nitrogen through increased growth, which in turn may result in greater quantities of organic matter and hence carbon recycling in these areas. Whilst in some cases, increases in seagrass biomass is seen as advantageous, there are some examples of where excessive seagrass growth is considered to be a negative impact, for example at Tuggerah lakes (Dickenson *et al*, 2006).

In terms of far-field impacts to the greater Merimbula lake system, under the Scenario 2 that leads to the highest nutrient discharge , it is estimated from available information (Roper et al. 2011), that the increased nutrient loading may lead to an overall increase in the mean chlorophyll-*a* concentration from 2.00 µg/L to 2.17 µg/L. This would mean that the trophic status of the lake system would remain within the oligotrophic or nutrient-deficient range.

Approvals

A number of statutory approvals will require consideration for the shallow dunal exfiltration option.

TSC Act: Saltmarsh is listed as an endangered ecological community under the *Threatened Species Conservation Act 1995*. Consultation with NSW Environment Protection Authority's (EPA) Threatened Species Unit is recommended as part of the options development. Where significant impacts are found likely to occur, a Species Impact Statement will need to be prepared.

FM Act: Under the *Fisheries Management Act 1994*, approval is required to harm marine vegetation (e.g. seagrasses and mangroves). In accordance with NSW Department of Primary Industries' (DPI) '*Fish Habitat Protection Plan No.2 Seagrasses'* (DPI, 1997), the discharge of effluent within 50 metres of any seagrass bed will generally not be approved unless special circumstances exist, and effective compensation is provided.

In this case the diffuse discharge of effluent in groundwater would arise from effluent discharged approximately 1,000 metres from seagrass beds and as such, consultation with DPI-Fisheries is recommended to understand whether FMA approval would be required.

Council will also be required to take into consideration the provision of the *NSW Oyster Industry Sustainable Aquaculture Strategy* (DPI, 2006). The Director-General of the DPI requires written notice of any development application that may affect a priority oyster aquaculture area or oyster aquaculture outside such an area.

SEPP 14 – Coastal Wetlands: Under *State Environmental Planning Policy 14* it is likely that the option of shallow dunal exfiltration would be considered a designated development. This means the development application will require consultation and concurrence of the Director-General of the NSW Department of Planning and Infrastructure (DoPI) and an environmental impact statement and be placed on public exhibition for public comment.

SEPP 71 – Coastal Protection: A consent authority must reject development applications that will result in effluent discharge that negatively affects water quality. Consultation with the DoPI should be facilitated if this option is to proceed further.

Protected ecological values

The ecological values of Merimbula Lake have been recognised by its listing on the Directory of Important Wetlands in Australia (ANCA, 1996). The lake supports extensive seagrass meadows, fringing mangrove, and saltmarsh areas, all of which are located within the receiving environment. Seagrasses, mangroves and saltmarsh are defined as 'marine' vegetation protected in NSW by the FM Act. Saltmarsh is listed as an endangered ecological community in NSW under the TSC Act.

The lake fauna is both diverse and abundant, and includes popular estuarine recreational fish species and priority oyster leases. The immediate environment of the subject area (modelled discharge zone) provides habitat for a number of migratory wader bird species protected under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and one endangered species protected under both the EPBC Act and TSC Act.

The subject is also wholly located within the boundary of SEPP 71 – Coastal Protection and partially located within the boundary of a SEPP 14 – Coastal Wetland

1.0 Introduction

1.1 Merimbula sewerage system

The Merimbula sewerage system services the Bega Valley Shire's coastal towns of Merimbula, Pambula, South Pambula and Pambula Beach. The Merimbula STP is located immediately south of Merimbula Airport and adjacent to the Pambula Merimbula Golf Club (PMGC), approximately half way between Merimbula and Pambula, 3.5 km south of Merimbula Main Beach and 2.5 km north of Pambula Beach (Figure 1).

A base population of approximately 7,500 EP (equivalent persons) contributes sewage to the system, predominantly residential with some commercial sources. Sewage inflows increase significantly during summer holiday periods, when the population can increase two-fold. The current total average inflow to the STP is approximately 700 megalitres (ML) per year.

While the permanent population is relatively stable, an average inflow of 900 ML per year has been adopted for this study to allow for future growth potential and to ensure the long term viability and potential impacts of a disposal scheme are adequately assessed. A volume of 500 ML per year for disposal has been adopted, based on future beneficial reuse being approximately 40-50% of total STP inflow for an average rainfall year.

The current strategy for management of effluent from the STP is to meet the demands of an existing automated and priority access irrigation scheme at the PMGC, with the remainder of effluent being released to the environment through existing dunal exfiltration ponds or through discharge to Merimbula Bay via an existing shore-based ocean outfall.

Ocean Outfall

The existing ocean outfall is a 250 mm pipeline from the STP transfer pumping station to a pipe head structure located in the hind dunes at the centre of the beach, between the estuary entrances of Merimbula Lake in the north and Pambula Lake in the south. The pipeline length is approximately 1 km from the STP to the discharge point on the beach. The effluent is discharged just above the normal high water mark (2 mAHD) from where it flows across the beach and into the ocean waters of Merimbula Bay. The pipeline originally extended into the surf zone but was damaged in a large storm event in the 1970s and has not been reinstated.

The periodic occurrence of algae in the ocean waters of Merimbula Bay and the perception of a possible link to effluent disposal attracts media and community attention. Whilst no proven causative link between the algae and the effluent discharge has been established, Council considers the ongoing use of the shore-based ocean outfall inadequate to meet community expectations and has committed to finding an alternative through this investigation.

Dunal Exfiltration Ponds

The existing dunal exfiltration system consists of two ponds located in a disused quarry in the sand dunes east of the STP. The ponds were built and commissioned for effluent disposal in 1986.

Use of the ponds for effluent disposal is determined by the groundwater level near the ponds and season. When the groundwater level at monitoring bore BH10 is below 1.5 mAHD, the ponds may be used. The groundwater level near the ponds is allowed to fall leading up to the summer peak tourist season to enable the ponds to be used instead of the outfall during this time. Once the groundwater level at BH10 rises towards 1.5 mAHD, as a result of dunal exfiltration and/or rainfall, the ponds are taken off-line and the groundwater level allowed to fall away again. Typically the exfiltration ponds have capacity to dispose of about 100 to 250 ML of effluent from the STP each year, depending on rainfall and groundwater levels.

Use of the exfiltration ponds ceased in May 2000, due to concerns that the discharge was impacting on the health of the vegetation in the surrounding dune area. Since 2005, Council has recommissioned the exfiltration ponds to assist in effluent management during the peak summer loading period and to reduce Council's reliance on the shore-based ocean outfall.

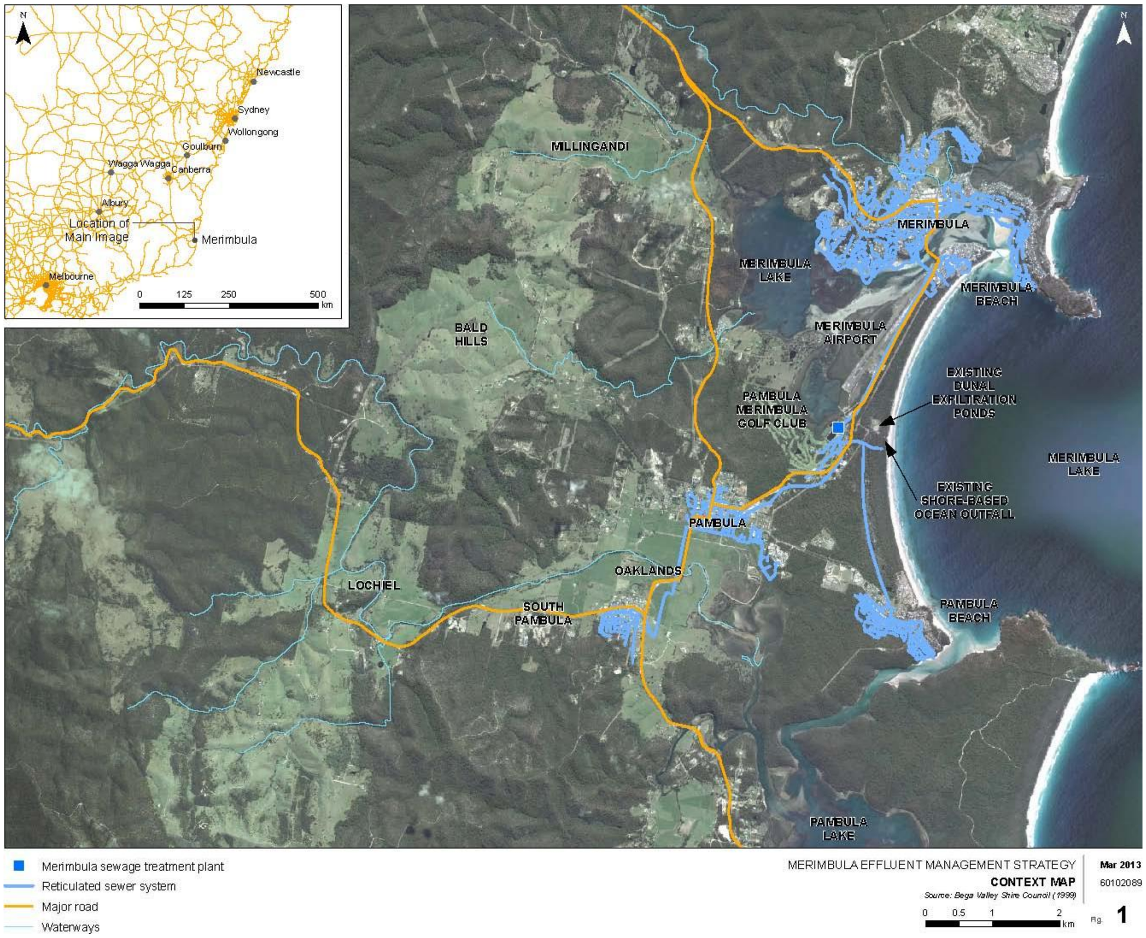


Figure 1 Merimbula Sewerage System and Surrounds

1.2 Options investigation

The 2002-2008 Bega Valley Sewerage Program (BVSP) proposed an upgrade of the STP and the development of a new irrigation scheme for the beneficial reuse of effluent. As a result, a chlorine disinfection system was added to the STP, two existing storage lagoons were upgraded and a pump station and pipeline constructed to deliver effluent to a new storage for irrigation of farmland on a property known as Oaklands on the Pambula River flats. The Oaklands reuse scheme alone however did not resolve the need to continue the disposal of the majority of effluent to the ocean outfall and dunal exfiltration ponds.

BVSC thereafter engaged AECOM to investigate, identify and assess options for the beneficial use of effluent and the disposal of the effluent remaining (i.e. excess effluent that is unable to be beneficially used) from the Merimbula STP. The outcome of the options investigation is to form a strategy for effluent management that provides the greatest benefit to the community and environment, whilst being affordable.

A ‘long list’ of options for beneficial reuse and disposal were identified through review of background reports, publicly available information and consultation with BVSC.

A Focus Group was established by BVSC, comprising agency, council, stakeholder and community representatives to assist with reviewing the options and direction of the investigations. The Focus Group reviewed and short-listed the long-list of options at a facilitated workshop in April 2011. At this workshop the Focus Group:

- Ruled out any options that did not meet the fundamental project objectives and guided further development of preliminary criteria for use in consultation during further Focus Group workshops.
- Short-listed options for beneficial reuse that are largely focused around irrigation, given that there is minimal industry and/or commercial end recipients in the study area. Irrigation options investigated include

agricultural areas (located in South Pambula, Lochiel, Millingandi, and Wolumla) and urban open space areas (located in Pambula).

1.2.1 Effluent Disposal Options

A range of investigations have been undertaken to identify options for the disposal of effluent from the STP. The receiving environments that exist in the study area that have been considered for effluent disposal include:

- Merimbula Bay (ocean)
- Shallow dunal aquifer
- Deep alluvial aquifer
- Pambula River
- Panboola Wetlands
- Merimbula or Pambula Lake.

The 'shallow dunal aquifer disposal' option is the subject of this assessment.

Shallow Dunal Exfiltration

A sufficiently sized exfiltration trench or string of shallow injection wells or bores could be constructed within the Merimbula-Pambula dunal system to allow effluent to exfiltrate into the dunal aquifer. Any shallow dunal exfiltration option would need sufficient capacity to cater for future volumes of effluent unable to be beneficially used.

IGGC (2013) has investigated characteristics of the dunal aquifer hydrogeology and assessed the impacts of a future shallow dunal exfiltration loading on groundwater levels, groundwater flow paths, groundwater quality and on the water quality of the receiving environments Merimbula Lake and the ocean. Options assessed included a 400 m exfiltration trench, or an equivalent line of 9 injection wells at 50 m spacing, in three locations in the dunes: central, BVSC land area and north (near Fishpen).

The results of the IGGC (2013) investigation indicate that the three potential disposal areas are all expected to be viable from a hydraulic loading perspective, with the preferred disposal area being the central part of the dune system due to the greater area and volume of the dunes in this area and the longer groundwater travel times to Merimbula Lake.

Further modelling by IGGC (2013) assessed the potential for phosphorus and nitrogen in effluent to migrate in groundwater to Merimbula Lake and the ocean (Merimbula Bay) from the modelled exfiltration trench located in the BVSC land area. Four scenarios were modelled with discharge flux rates and typical nitrogen and phosphorus concentrations in groundwater estimated for the identified discharge zones in the bay and lake, for each scenario.

1.3 Purpose of this study

During consultation for the options study (8 November 2011), the EPA raised concerns in relation to the potential for shallow dunal exfiltration of effluent to increase the flux of nutrients to Merimbula Lake within the modelled groundwater discharge area and:

- exhaust the existing phosphorus sink in benthic sediments within this area
- increase benthic micro-phyto-benthos (MPB) productivity within this area.

This feedback from the EPA resulted in BVSC engaging AECOM to conduct an additional assessment in relation to the potential impacts of the 'shallow dunal aquifer disposal' option on the ecology of Merimbula Lake within the identified groundwater discharge area.

1.4 Scope of works

This study aims to provide a high level assessment of the potential ecological impacts of the shallow dunal exfiltration option. The focus of this report is on the near field environment where the groundwater discharge is likely to occur although some consideration of the far-field impacts is presented. The scope of works was determined in consultation with BVSC and EPA and includes the following:

1) Background review and compilation of available data.

2) Identification and delineation of aquatic habitats and communities, with consideration to threatened species, communities and populations, and / or other matters protected under national and state environmental legislation that are found to occur, or are likely to occur within the study area.

3) Review and interpretation of modelled nutrient flux data for comparison against natural background benthic fluxes in other estuarine environments provided by EPA and additional data where appropriate as found in national and international literature.

4) Consult with EPA relating to assessment of biogeochemistry data and interpretation.

5) Identify potential impacts and the potential significance of any such impacts.

6) Identify approvals pathways that would be required in proceeding with shallow dunal exfiltration as a part of BVSC's effluent management strategy.

Figure 2 shows the simulated groundwater discharge zones for the ocean and Merimbula Lake as identified through modelling undertaken by IGGC (2013) for an exfiltration trench located in the BVSC land area. The majority of effluent disposed by an exfiltration trench in the location shown will flow in groundwater towards the ocean.

The focus of this assessment is on the ecological impacts within the predicted discharge zones in Merimbula Lake. This is due to the more confined environment of the lake and potential sensitivities of seagrass beds and the habitat they provide as well as oyster aquaculture areas. The 'subject area' relevant to this assessment therefore is limited to the simulated groundwater discharge zones identified within Merimbula Lake through modelling by IGGC (2013), although some consideration is given to impacts on the wider Merimbula Lake system.

For the purposes of identifying approvals pathways associated with the shallow dunal exfiltration option, the following additional areas have also been considered:

- The 'study area' which includes the subject area and any additional areas which may potentially be affected by modelled discharge scenarios into Merimbula Lake.
- The 'locality' is the area within 10 km of the study area, also referred to as the search area for the purpose of data searches in government threatened species databases.

This study has utilised the following data sources:

- Groundwater modelling and simulations to identify discharge zones and forecast potential increased nutrient fluxes to Merimbula Lake undertaken by IGGC (2013).
- Mapping of ecological values within the areas of simulated discharge zones.
- Field surveys, algal sampling and identification, literature reviews and interpretations of Elgin and Associates (2013) - Appendix D
- Consultation with EPA and data provided by the EPA relating to nutrient sediment fluxes collected from estuaries throughout NSW.
- Additional nutrient flux data and relevant research and case studies found through scientific literature review.

Figure 2 Merimbula Lake Study Area

2.0 Environmental setting

2.1 Merimbula Lake

Merimbula Lake is an inlet/lake system comprising a natural entrance and substantial marine delta which opens out into two basins. The lake entrance is permanently open.

Merimbula is located on the northern shore of the lake inlet. The shoreline of the larger medium-depth basin consists of areas of rocky shoreline whilst the shoreline of the smaller shallow basin on the southern side of the estuary is predominantly mangrove lined and sand based. The northern and southern sides of the Lake's entrance are connected via a 250 metre long causeway and short bridge.

The ecological values of the lake have been recognised by its listing on the Directory of Important Wetlands in Australia (ANCA, 1996). The Directory describes wetlands that have qualified as nationally important, based on a range of criteria. The lake is included on the Directory under 'Type A Marine and Coastal Zone wetlands', as it provides a good example of the following wetland types within the South East biogeographic region:

- Subtidal aquatic beds; includes seagrasses.
- Estuarine waters; permanent waters of estuaries and estuarine systems of deltas.
- Intertidal mud, sand or salt flats.
- Intertidal marshes; includes saltmarshes, salt meadows, saltings, raised salt marshes, tidal brackish and freshwater marshes.
- Intertidal forested wetlands; includes mangrove swamps, nipa swamps, tidal freshwater swamp forests.

2.1.1 Hydrodynamics

The Merimbula Lake and estuary system is recognised for its high ecological, amenity and commercial values. The estuary is classified as a wave-dominated barrier estuary according to the Roy et al. (2001) classification. The average depth of the estuary is considered to be 2.6 m and volume of approximately 12,924 ML (Appendix D). The fact that the entrance is relatively wide and remains open allows for substantial flushing of the lake system. Roper et al (2010) estimates the flushing time of the lake system to be about 25.3 days and this acts to maintain a fair standard of water quality (3.3 out of 5; Appendix D; Roper et al. 2011).

Figure 5 in Appendix D shows qualitative estimates of the relative residence times for different parts of the lake system. Inspection of this figure suggests that the location of the predicted discharge of nutrients into the lakes system will be in the region of the lower lake that is hydraulically closest to the ocean. However this southern section of the lake also contains the shallow, and largely enclosed embayments near the golf course that are likely to have longer flushing times by comparison with the larger parts of the lake system. Table 5 in Appendix D contains estimates of the averaged water depths at the site (0.3 m at averaged low tide).

2.2 Protected ecological values

Merimbula Lake supports extensive seagrass meadows and the lake foreshores and tributary streams also support fringing mangrove, saltmarsh and freshwater wetland areas. The lake fauna is both diverse and abundant, and includes popular estuarine recreational fish species and oyster aquaculture operations.

Studies conducted by Day and Hutchings(1984) found a diverse range of macrophytes, macroalgae, invertebrates, fish and bird species within the lake. A complete list of all species sampled and identified is provided in Appendix C.

Estuary habitat mapping (Creese et al. 2009) indicates seagrass to cover 1.64 ha of the lake, with 0.35 ha and 0.59 ha of mangroves and saltmarsh respectively. All three communities are located within the subject area (the area of simulated groundwater discharge from exfiltration) (refer Figure 3).

Seagrasses, mangroves and saltmarsh are defined as 'marine' vegetation protected in NSW by the FM Act. Further, saltmarsh is listed as an endangered ecological community in NSW under the TSC Act.

Appendix D contains details of an investigation at the site and description of the vegetation.

2.2.1 Seagrasses

Seagrasses are aquatic flowering plants that form 'meadows' in near-shore brackish or marine waters, in temperate and tropical regions. Seagrasses are an important link in the critical chain of habitats required for sustainable fisheries production providing nursery habitat for an abundance of fish, crustaceans and molluscs, including many commercially valued species. With the exception of sea turtles and dugongs which graze directly on seagrasses, most of the carbon fixed by seagrasses enters the food web via detritivores rather than through direct consumption.

A wide range of nutrient cycling processes occurs in coastal seagrass communities, and these vary according to seagrass species and the extent of grazing. Seagrasses can support high rates of nitrogen fixation, denitrification and sulfate reduction. Uptake of nutrients by seagrasses (and other benthic plants and algae) can also change the status of sediment from a nutrient source to a nutrient sink. Seagrass meadows also have the potential to influence physical and chemical parameters in the water column (OzCoasts 2012).

Seagrasses also bind sediment which helps to stabilise shorelines against erosion and the baffling effect of seagrasses on water movement causes the deposition of suspended sediment and organic matter. Baffling can also impede the mixing process which destabilises water column stratification, thereby influencing the dissolved oxygen status of bottom waters (OzCoasts 2012).

There are several species of seagrass known to occur within the lake including:

- Varieties of Eelgrass (*Zostera Capricornia*, *Z. muelleri* and *Heterozostera tasmanica*)
- Strapweed (*Posidonia australis*)
- Varieties of Paddleweed (*Halophila ovalis*, and *H.decipiens*).

The site investigation of the site (Appendix D) identified three species of seagrass: *Zostera muelleri* (eelgrass), *Posidonia australis* (strapweed), and *Halophila ovalis* (paddleweed). It was also highlighted that *Posidonia* occurs in only five locations in the Bega Valley, including Merimbula Lake. Appendix D also details that over 60% of the site has seagrass coverage.

2.2.2 Mangroves

Mangroves occur in the seaward edge of the intertidal zone and are inundated by tides on a daily basis. In order to survive in this environment, mangroves have developed specialised root-like structures (pneumatophores), which protrude from the substrate, usually higher than the mean high tide, and act like ‘breathing tubes’ facilitating oxygen transport within the plant.

Mangrove pneumatophores provide both habitat, and protect shorelines from erosion (in combination with the mangrove tree or shrub itself). Mangrove root systems are efficient at dissipating wave energy (Massel *et al* 1999). Likewise, they slow down tidal water enough that its sediment is deposited as the tide comes in, which are not re-suspended when the tide leaves, except for fine particles (Mazda *et al* 1997). As a result, mangroves build their own environment (Mazda *et al* 2005).

Mangroves provide important habitats for fish, crabs, birds and other animals, providing large amounts of organic matter, which is eaten by many small aquatic animals. In turn, these detritivores provide food for larger carnivorous fish and other animals. Mangrove forests are nursery grounds, feeding areas and shelter sites for fish and support many bird species, including migratory shorebirds which often use mangrove forests as roost sites, and sometimes as foraging sites. Additionally mangrove pneumatophores provide crustacean (e.g. oyster) habitat.

Mangrove communities in the lake are dominated by Grey mangrove (*Avicennia marina*), and less commonly River mangrove (*Aegiceras corniculatum*). Appendix D details that a continuous band of grey mangroves (*Avicennia marina)* were found at the site.

The site inspection (Appendix D) revealed that a saltmarsh community is present between the shoreline and the band of grey mangroves.

Saltmarsh communities typically occur within the intertidal zone from the mean high water (MHW) level and the highest astronomical tide (HAT) and are flooded by larger tides less frequently than mangrove communities (average tidal range 1.6 - 2.0m+).

Saltmarshes are characterised by plant species adapted to surviving in saline, often hypersaline environments, and provide habitats for a wide range of infaunal and epifaunal invertebrates, and low-tide and high-tide visitors such as crabs, shorebirds and fish. Saltmarshes have been found to play an important role as habitat for juvenile species of fish. Common galaxias (*Galaxias maculatus*) deposit their eggs in saltmarsh vegetation and saltmarsh crab larvae are a significant food source for carnivorous fish species. Specific types of crab species are reliant on larger tidal events in which large volumes of larvae are released from the saltmarsh environment (Mazumder 2004).

2.2.3 Aquatic fauna

Fauna that inhabit the lake are numerous – stingrays, stingarees, soldier crabs, birds, fish, worms, eels, seahorses, flutemouths, shrimps, prawns, marine slaters, sea slugs and many recreational fish species.

The lake is a popular recreational fishing area and fishing is an important part of the local economy. Records from weekly fishing reports over two years (Merimbula Big Game and Lakes Angling Club, October 2009 to October 2011) indicate the most frequently caught species are Dusky Flathead, Bream, Whiting, Trevally and Tailor. Salmon, Estuary Perch, Mullet, Garfish, Greasy-back and King prawns and calamari are also commonly reported.

2.2.4 Oyster aquaculture

The lake supports a small but significant oyster farming industry. In 2005/2006, Merimbula Lake produced over 3% of the total NSW production of Sydney Rock Oyster (total value in excess of $1 million). *Saccostrea glomerata* (Sydney rock oyster) and *Crassostrea gigas* (Pacific oyster) are farmed in the Lake and the area also produces Angasi oysters. Areas in the lake that have been leased for oyster aquaculture cover 142.5 ha, with areas currently mapped as priority oyster aquaculture areas covering 125.8 ha[1] (Figure 3).

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[1] does not include 16.4 ha sub-let from the lessees of the Merimbula Airport

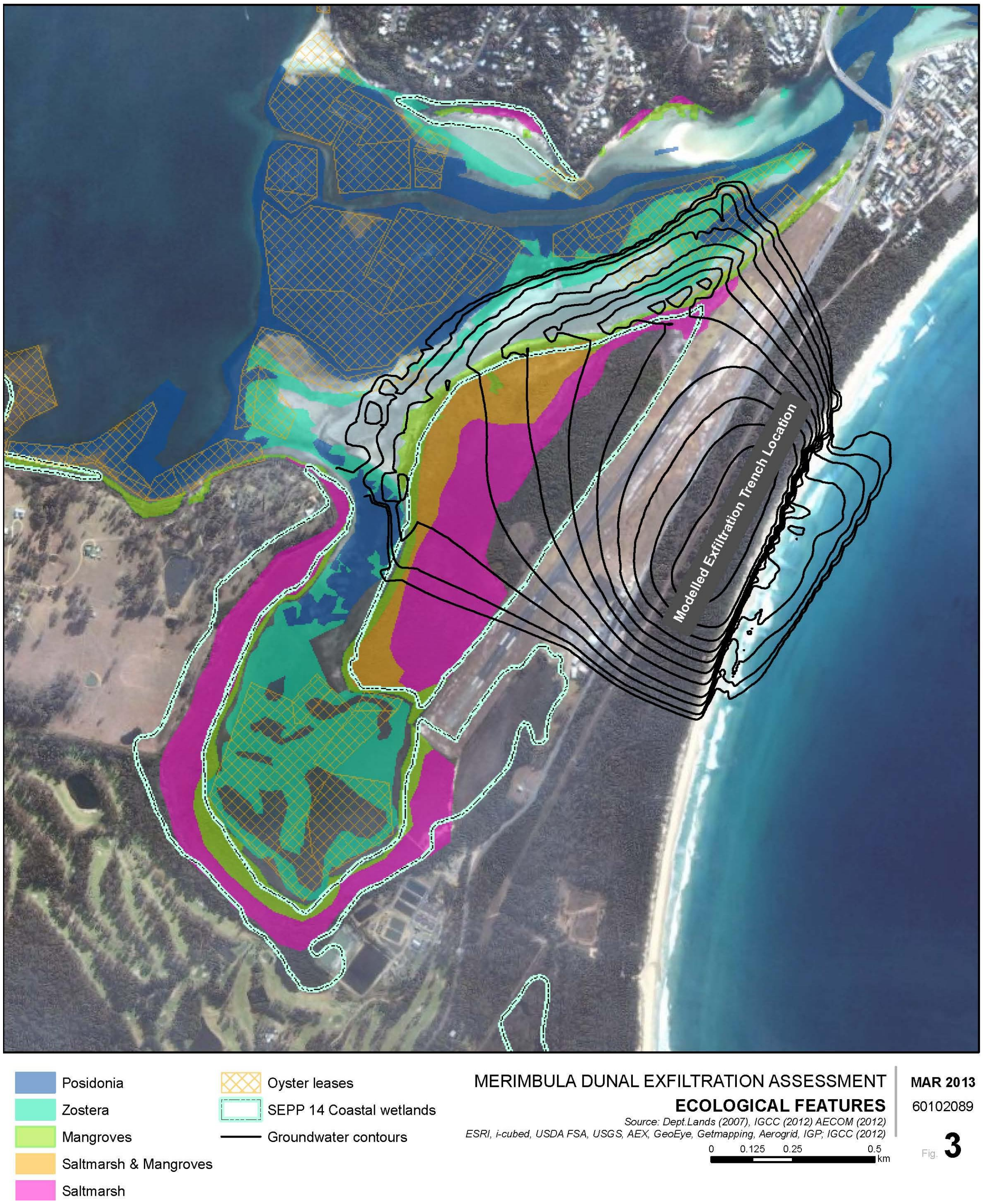

Figure 3 Ecological features of the study area

3.0 Relevant legislation

3.1 Overview

A component of the assessment is to identify statutory approvals that may be required in relation to the option of disposing effluent via shallow dunal exfiltration. The key relevant legislation in relation to the assessment of aquatic ecology of the lake are summarised below:

- Commonwealth legislation
    - *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).
- State legislation
    - *Threatened Species Conservation Act 1995* (TSC Act)
    - *Fisheries Management Act 1994* (FM Act).
- State Environmental Planning Policies
    - State Environment Planning Policy No. 71 Coastal Protection (SEPP 71)
    - State Environment Planning Policy No. 14 Coastal Wetlands (SEPP 14).

As required by commonwealth and state impact assessment guidelines, searches of government databases were undertaken to identify protected matters that have the potential to occur within the locality. The following databases were searched for the assessment:

- The Department of Sustainability, Environment, Water, Population and Community (SEWPaC) Protected Matters on-line search tool for matters of National Environmental Significance (NES) protected under the EPBC Act.
- NSW Wildlife Atlas (OEH) database for threatened species listed under the TSC Act.
- Department of Primary Industries - Fisheries threatened species database for threatened and protected species listed under the FM Act.

As the focus of this assessment is limited to the area in which simulated groundwater discharge would occur in the Merimbula Lake (IGGC 2013), a large number of results returned from database searches are not relevant to this assessment.

Threatened and/or otherwise protected species, populations, or communities that are relevant to this assessment typically occur within shallow tidal areas of estuaries. All lists generated from database searches are provided in Appendix B. Matters of ecological significance relevant to the study area are discussed in the following sections.

Additional sources of information were also searched to gain an understanding of local populations of estuarine flora and fauna. These included local fishing club weekly reports, diving and photographic records found in locally based websites, BVSC's Statement of Environment (SoE) reporting, government marine audits and related reporting.

3.2 Environment Protection and Biodiversity Conservation Act 1999

3.2.1 Matters of National Environmental Significance

Approval under the EPBC Act is required from the Commonwealth Environment Minister if SEWPaC determines the proposal to be a controlled action that would have or is likely to have a significant impact on a matter of NES. The EPBC Act provides protection for eight matters of NES, two of which relate to the locality:

- Threatened Species: 59 (29 birds, 1 fish, 4 frogs, 14 mammals, 3 sharks, 4 turtles, 4 plants).
- Migratory Species: 47 (33 birds, 6 mammals, 4 turtles, 4 sharks).

Of the listed threatened and migratory species, only 10 bird species (one endangered, two vulnerable and seven migratory species) have been recorded within or near the study area (Table 1). The remaining species are either terrestrial, rely on freshwater habitats, or require other habitat features that are not present within the study area (e.g. pelagic or deeper sea species which are highly unlikely to visit the shallower waters of the estuary).

Table 1 Nationally threatened and migratory species recorded within or adjacent to the study area

Species name	Common name	Status	Likelihood of occurrence
BIRDS			
Ardea ibis	Cattle Egret	Migratory	Recorded in study area
Ardenna pacificus	Wedge-tailed Shearwater	Migratory	Recorded from Merimbula Bay
Ardenna tenuirostris	Short-tailed Shearwater	Migratory	Recorded near Pambula Beach & at Berrambool
Botaurus poiciloptilus	Australasian Bittern	Endangered	Recorded from subject area
Diomedea exulans gibsoni	Gibson's Albatross	Vulnerable, Migratory	Recorded from Merimbula Bay
Gallinago hardwickii	Latham's Snipe	Migratory	Recorded from subject area
Haliaeetus leucogaster	White-bellied Sea-Eagle	Migratory	Recorded from subject area
Hydroprogne caspia	Caspian Tern	Migratory	Recorded from Tura Beach
Numenius madagascariensis	Eastern Curlew	Migratory	Recorded from subject area
Numenius phaeopus	Whimbrel	Migratory	Recorded in study area
Thalassarche cauta (sensu stricto)	Shy Albatross, Tasmanian Shy Albatross	Vulnerable, Migratory	Recorded near Pambula Beach

Of the recorded species listed in Table 1, five bird species are considered as having a high likelihood of occurring within the subject area – due to the presence of habitat and / or database records either within or in close proximity to the subject area. These species are listed below along with a brief summary of habitat requirements sourced from Commonwealth threatened species profiles (relevant to the subject area).

- *Botaurus poiciloptilus* Australasian Bittern (Endangered)

  Recorded within the subject area, and described as:

  - Occurring mainly in densely vegetated freshwater wetlands and, rarely, in estuaries or tidal wetlands (the latter mainly in the temperate southeast and southwest).
  - Brackish water is tolerated in estuaries and tidal wetlands, where birds inhabit beds of rushes or reeds in saltmarsh, especially near mouths of creeks or freshwater seepage; sea coasts are avoided.
  - Appears to be capable of moving between habitats as suitability changes.

  Based on the above factors, the subject area provides additional habitat for the species (i.e. by description not preferred habitat), and recorded evidence within the subject area indicate any impacts resulting from shallow dunal exfiltration must consider potential risks to the species.

- *Ardea ibis* Cattle Egret (Migratory)

  Recorded in close proximity to the subject area (i.e. immediately downstream of the causeway and short bridge), and described as:

  - Occurs in tropical and temperate grasslands, wooded lands and terrestrial wetlands.
  - Commonly associated with the habitats of farm animals, particularly cattle, but also pigs, sheep, horses and deer known to follow earth-moving machinery and has been located at rubbish tips.
  - Uses predominately shallow, open and fresh wetlands including meadows and swamps with low emergent vegetation and abundant aquatic flora.
  - Roosts in trees, or amongst ground vegetation in or near lakes and swamps. It has also been recorded roosting near human settlement and industrial areas in Murwillumbah, NSW (Marchant & Higgins 1990).
  - Breeds in colonies in wooded swamps such as mangrove forests (e.g. the lower Adelaide River, Northern Territory), Melaleuca swamps (e.g. Shortland, NSW) and the eucalypt/lignum swamps of the Murray-Darling Basin.

Based on the above factors, the subject area provides habitat for the species (i.e. mangrove forests), and recorded evidence within the subject area indicate any impacts resulting from shallow dunal exfiltration must consider potential risks to the species.

- *Gallinago hardwickii* Latham's Snipe (Migratory)

  Recorded within the subject area, and described as:

  - Usually inhabiting open, freshwater wetlands with low, dense vegetation (e.g. swamps, flooded grasslands or heathlands, around bogs and other water bodies).
  - Sometimes occur in habitats that have saline or brackish water, such as saltmarsh, mangrove creeks, around bays and beaches, and at tidal rivers. These habitats are most commonly used when the birds are on migration.
  - Also occur in various sites close to humans or human activity (e.g. near roads, railways, airfields, commercial or industrial complexes).
  - Foraging habitats are characterised by areas of mud (either exposed or beneath a very shallow covering of water) and some form of cover (e.g. low, dense vegetation).
  - Roost on the ground near (or sometimes in) their foraging areas, usually in sites that provide some degree of shelter, e.g. beside or under clumps of vegetation, among dense tea-tree, in forests, in drainage ditches or plough marks, among boulders, or in shallow water if cover is unavailable.

  Based on the above factors, the subject area provides habitat for the species and recorded evidence within the subject area indicate any impacts resulting from shallow dunal exfiltration must consider potential risks to the species.

- *Haliaeetus leucogaster* White-bellied Sea-Eagle (Migratory)

  Recorded in subject area, but as a wide ranging species records are likely to be aerial based and not necessarily associated with the immediate physical environment of the subject area. Therefore any impacts as a result of shallow dunal exfiltration are unlikely to cause any significant risk of threats to this species.

- *Numenius madagascariensis* Eastern Curlew (Migratory)

  Several records within the subject area were found in government databases, and described as:

  - Most commonly associated with sheltered coasts, especially estuaries, bays, harbours, inlets and coastal lagoons, with large intertidal mudflats or sandflats, often with beds of seagrass.
  - Often recorded among saltmarsh and on mudflats fringed by mangroves, and sometimes use the mangroves.
  - Mainly forages on soft sheltered intertidal sandflats or mudflats, open and without vegetation or covered with seagrass, often near mangroves, and in saltmarsh.
  - Roosts on sandy spits and islets, especially on dry beach sand near the high-water mark, and among coastal vegetation including low saltmarsh or mangroves.
  - Also recorded roosting in trees and on the upright stakes of oyster-racks.

- *Numenius phaeopus* Whimbrel (Migratory)

  Recorded in close proximity to the subject area (i.e. immediately downstream of the causeway and short bridge), and described as:

  - Often found on the intertidal mudflats of sheltered coasts, also found in harbours, lagoons, estuaries and river deltas, often those with mangroves, but also open, unvegetated mudflats.
  - Also use saltflats with saltmarsh, or saline grasslands with standing water left after high spring-tides.
  - Generally forage on intertidal mudflats, along the muddy banks of estuaries and in coastal lagoons, either in open unvegetated areas or among mangroves and sometimes forage on sandy beaches or among rocks.
  - Prefer mudflats with a 10–50% cover of Zostera, followed by areas of sand, mud bare mudflats, and rock platforms.

- The Whimbrel is one of a small group of shorebird species that regularly roost in mangroves and other structures flooded at high tide, often roosting in the branches of mangroves around mudflats and in estuaries and occasionally in tall coastal trees.
- They have also been observed to roost on the ground (sometimes under mangroves or in shallow water), on muddy, sandy or rocky beaches; rocky islets and coral cays.
- Have been once recorded perched on upright stakes attached to oyster racks.

3.3 Threatened Species Conservation Act 1995

The TSC Act outlines the protection of threatened species, populations, ecological communities and critical habitat in NSW. The Act is administered by the NSW Office of Environment & Heritage (OEH). Under section 5A of the EP&A Act, an assessment of significance (7-part test, (DECC) 2007) may be required to determine the likely significance of impacts on threatened species, populations or ecological communities.

NSW database searches returned the following state protected matters for the search area:

- Endangered Ecological Community (EEC): one relevant to study area, Coastal Saltmarsh
- Threatened Species: 42 (24 birds, 1 frog, 13 mammals, 4 plants)

Of these species, those that have been recorded within the study area or in close proximity to the subject area are listed in:

Table 2 Threatened species, communities in NSW recorded within or adjacent to the study area

Species name	Common name	Status	Likelihood of occurrence
VEGETATION			
	Coastal Saltmarsh	EEC	Mapped in subject area
BIRDS			
Botaurus poiciloptilus	Australasian Bittern	Endangered	Recorded from subject area
Haematopus fuliginosus	Sooty Oystercatcher	Vulnerable	Recorded in study area
Haematopus longirostris	Pied Oystercatcher	Endangered	Recorded from subject area
Thinornis rubricollis	Hooded Plover	Endangered	Recorded in study area
MAMMALS			
Dugong dugon	Dugong	Vulnerable	Recorded from Merimbula Bay

- Coastal Saltmarsh

  Present within the subject area (Figure 3). The increased fresh groundwater and nutrient fluxes along the lakeshore may affect this community.

- *Botaurus poiciloptilus* Australasian Bittern (Endangered)

  Discussed under Commonwealth EPBC Act (refer Section 3.2).

- *Dugong dugon* Dugong

  One record was returned for the dugong, which was recorded as a dead specimen found on the beach in Merimbula Bay in 1993. Dugongs are found in abundance throughout north Australian waters, and considered occasional visitors NSW coastal and estuarine waters. Occurrence of the dugong in NSW (in the summer of 2002 / 2003) was associated with warmer water temperatures and large seagrass beds around Wallis Lake, Port Stephens, Lake Macquarie and Brisbane Water (SEWPaC, 2012).

  While the lake provides an abundance of seagrasses for this species, it is considered highly unlikely that the lake's estuarine habitat is of significance to the species due to the following reasons:

  - the study area is considerably further south than past sightings of this species in NSW (as reported by SEWPaC.

- lack of recent records within proximity to the subject area, both in scientific literature and anecdotally.

- *Haematopus fuliginosus* Sooty Oystercatcher

  Recorded in close proximity to the subject area (i.e. immediately downstream of the causeway and short bridge), and described as:

  - Inhabiting marine littoral habitats, including islands, within 50 m of the shoreline.
  - Typically occupies rocky intertidal shorelines, *e.g.* at the base of cliffs and headlands, rock platforms, reefs, outcrops, rock stacks; also sandy beaches near intertidal mudflats or rocks; and occasionally estuaries.
  - Habitat is frequently disturbed by human activities around beaches, headlands and islands.
  - Nest is typically a scrape in sand, gravel, shingle or among rocks above the tideline, usually in bare areas though sometimes amongst wrack.
  - Forages in the intertidal zone mostly for marine invertebrates, especially molluscs, crustaceans and other hard-shelled animals, and above the tideline (on beaches, around stranded seaweed) for other invertebrates at high tide.

- *Haematopus longirostris* Pied Oystercatcher

  Several records within the subject area, and described as:

  - Occupies muddy, sandy, stony or rocky estuaries, inlets and beaches, particularly intertidal mudflats and sandbanks in large marine bays.
  - Habitat of this species is frequently disturbed by human activities on beaches.
  - Nest is typically a scrape in sand, soil, shingle or shellgrit above the tideline, on a beach, lagoon shore, sandbank or sand island in an estuary, between high-water mark and dunes, amongst vegetation or wrack (*e.g.* seaweed, driftwood) or under a shrub, and lined with plant fibres or shells.
  - Forages in the intertidal and wave-wash zone mostly for marine invertebrates, especially bivalve molluscs.

- *Thinornis rubricollis* Hooded Plover

  Recorded in close proximity to the subject area (i.e. immediately downstream of the causeway and short bridge), and described as:

  - Found most often on long stretches of sandy shore, backed by tussock and creeper-covered dunes with nearby inland lakes.
  - Preferred habitat has a wide wave wash zone with beach cast seaweed for feeding, backed by sparsely vegetated sand dunes for shelter and nesting.
  - Individuals also regularly use near-coastal saline and freshwater lakes and lagoons.
  - Forages on beaches, in wave-wash, lagoons and saltpans.

  Based on the above factors the subject area is not likely to provide important habitat for the species.

3.4 Fisheries Management Act 1994

The FM Act provides for the conservation, protection and management of fisheries, aquatic systems and habitats in NSW. The DPI manages the majority of the FM Act, although the EPA has some responsibilities relating to endangered species and habitats. The FM Act applies in relation to all waters that are within the limits of the State, and regulates certain activities that have the potential to impact on aquatic habitats.

3.4.1 Marine vegetation

Under the Part 7 Division 4 of the FM Act, it is an offence to harvest or harm marine vegetation, which includes seagrass, mangroves and saltmarsh. Saltmarsh is also protected as an EEC under the TSC Act (as discussed above).

To assist in the management of seagrasses, development that has the potential to impact on seagrasses is detailed within '*Fish Habitat Protection Plan No.2 Seagrasses*' (DPI,1997) Under this plan, the discharge of effluent within 50 m of any seagrass bed will generally not be approved unless special circumstances exist, and effective compensation is provided. The three locations investigated and modelled (IGGC 2013) for a potential shallow dunal exfiltration of effluent (IGGC, 2013) are all located approximately 1,000 m from the nearest seagrass beds.

3.4.2 Oyster aquaculture

Council would be required to take into consideration the provisions of the *NSW Oyster Industry Sustainable Aquaculture Strategy* (DPI, 2006)*,* in particular the assessment of any development activities that may influence priority oyster aquaculture areas, which includes all oyster leases in Merimbula Lake.

Examples of potential land use incompatibility issues include access to oyster leases being limited by the development or the risk of adverse impacts of the development on water quality and, consequently, on the health of oysters and on the health of consumers of those oysters.

3.5 Coastal protection under SEPPs

There are a number of State Environmental Planning Policies (SEPPs) which regulate development in coastal areas. Their provisions are to be considered by authorities in conjunction with the relevant sections of the *Coastal Protection Act 1979* and the *Environmental Planning and Assessment Act 1979* when an application for development in the coastal zone is being assessed.

3.5.1 SEPP 71 - Coastal Protection

SEPP 71 Coastal Protection is the main SEPP controlling development in the coastal zone. The subject area lies wholly within the coastal area for which SEPP 71. As with all other SEPPs, it is legally enforceable. SEPP 71 provides that a consent authority must reject development applications that will:

- Impede or diminish access to coastal foreshores.
- Result in effluent discharge that negatively affects water quality.
- Involve a discharge of untreated storm water into the sea, a beach, an estuary, or coastal lake or creek.

3.5.2 SEPP 14 - Coastal Wetlands

SEPP 14 Coastal Wetlands aims to protect and preserve coastal wetlands. A number of SEPP 14 wetland areas are mapped within the Lake, and one is located within the modelled groundwater discharge zone as shown in Figure 3.

Under SEPP 14, a person must not clear land, construct a levee, drain land or fill land which is covered by the SEPP except with the consent of the local council and the concurrence (agreement) of the Director-General of Planning. Activities on SEPP 14 wetlands which require development consent are deemed to be designated development, which means the development application must be accompanied by an environmental impact statement and be placed on public exhibition for public comment.

4.0 Shallow Dunal Exfiltration option

4.1 Background

Potential dunal disposal options for Merimbula STP effluent have been identified through consultation with BVSC and a number of previous investigations.

The process of disposal via exfiltration trenches or wells involves vertically downward migration of effluent directly beneath the exfiltration area and a progressive horizontal deflection of streamlines at the water table and at horizons of differing permeability. This recharging process establishes a localised groundwater mound, the geometry of which is constrained by the subsurface permeability distributions and regional flows.

The key focus of this assessment is the potential impact that increased freshwater groundwater flow and increased nutrient concentrations in groundwater (above ambient or background sediment nutrient fluxes) could have on the ecology of Merimbula Lake.

Detailed investigation of other potential contaminants in effluent (such as heavy metals, hydrocarbons, pesticides, faecal coliforms) is beyond the scope of works for this assessment, although considered broadly in relation to relevant approval pathways for this option (refer Section 6.0).

4.2 Numerical modelling

4.2.1 Overview

IGGC (2013) has undertaken numerical groundwater modelling for three locations in the dunes between Merimbula Lake and Merimbula Bay to assess the potential for the disposal of effluent from Merimbula STP.

The IGGC numerical model was developed using the following inputs:

- Analysis of aquifer material for speciated carbon and phosphorus retention index relating to the potential for phosphorus sorption and retardation.
- Analysis of available groundwater quality data from bores located near to the existing exfiltration ponds to determine nitrate decay (dentrification) and phosphorus sorption potential of the dune sediments.
- Water level data for the Merimbula Lake.
- Merimbula Lake and ocean bathymetry data, including the lateral extent of the lake and ocean areas underlain by the shallow aquifer.

The addition of imaginary monitoring wells within the discharge zones to examine contaminant concentrations over time. The modelling showed that all three model exfiltration locations were viable for the disposal of effluent from a hydraulic loading perspective, both over the long term and during peak discharge times.

In particular, the IGGC (2013) modelling for year 2025 estimated effluent disposal volumes from a 400 metre exfiltration trench located within the BVSC land area, predicted that the majority of effluent disposed would flow in groundwater towards the ocean (approximately 81%) and the remainder would flow westward with the natural groundwater flow towards Merimbula Lake.

Further modelling was undertake to assess the potential for phosphorus and nitrogen in the effluent to migrate in groundwater to the ocean (Merimbula Bay) and Merimbula Lake from a 400 m exfiltration trench located within the BVSC land area. Four scenarios were modelled with discharge flux rates and typical nitrogen and phosphorus concentrations in groundwater estimated for the identified discharge zones in the bay and lake for each scenario.

The results of the modelled scenarios are presented as contour maps of predicted final concentrations of phosphate and nitrate and time series graphs of concentration over time (refer Appendix A). Detailed discussion of the model's development, application and modelling results are provided in IGCC (2013) and paraphrased herein.

4.2.2 Migration scenarios

Four scenarios were modelled to examine existing (8.5 mg/L) and reduced (1.5 mg/L) phosphate concentrations present in discharged effluent from the STP, two K_d values for phosphorus sorption in the sediments and two R values for nitrate decay in the sediments. The parameter K_d is known as the partition (or distribution) coefficient and is an important parameter used to estimate the migration potential of contaminants present in aqueous solutions in contact with surface, subsurface and suspended solids (US EPA 1999). The parameter R represents a first-order decay reaction estimate and was used in the modelling to provide an estimate of nitrate removal by denitrification.

A K_d value of 2.0 for phosphate was obtained from testing of samples of aquifer material collected during the drilling and test production well installation program and is considered to provide a conservative estimate of the P sorption capacity of the dune material in the area assessed for the exfiltration trench modelling. A K_d value of 0.1 was also used to provide a worst-case estimate for phosphate removal.

An R value of 0.002 day^{-1} was obtained from calibration of a simple numeric model of groundwater flow and total inorganic nitrogen concentrations in two groundwater monitoring bores near to the existing effluent ponds and is considered to provide a conservative estimate of the denitrification capacity of the dune material in the area assessed for the exfiltration trench modelling. An R value of 0 was also used to provide a worst-case estimate for nitrate removal and represents zero nitrate removal in groundwater.

Table 3 provides a summary of the 4 scenarios contaminant transport scenarios used in the modelling.

Table 3 Contaminant transport simulation scenarios

Scenario	Effluent Concentration (mg/L)		Kd (mL/g)	R (day^{-1})
	Phosphate as P	Nitrate as N	PO_4	NO_3
Scenario 1	8.5	2.5	2	0.002
Scenario 2	8.5	2.5	0.1	0
Scenario 3	1.5	2.5	2	0.002
Scenario 4	1.5	2.5	0.1	0

The above four scenarios are intended to represent a range of conservative best case and worst case parameters for phosphate and nitrate attenuation. Contaminant transport was simulated for a period of 21,000 days (57 years) for all scenarios. This encompasses the realistic lifespan of an exfiltration discharge system, which is likely to be 20 to 50 years (7,300 to 18,250 days).

Scenario 2 assumes no denitrification capacity and very low phosphorus sorption capacity in the dunal sediments between the modelled exfiltration trench location and the groundwater discharge area in Merimbula Lake. The existence of these conditions is considered unlikely, based on available groundwater quality data collected from bores around the existing exfiltration ponds between 2004 and 2013 (showing that the concentration of phosphate and nitrate in groundwater is significantly lower than the concentration in the effluent disposed to the ponds) and analysis of dune sediment material (IGGC 2013) from 4 locations (providing a mean value Kd value of 11.6 mL/g rather than the very low 0.1 mL/g selected for this scenario). Hence it has been argued in IGGC (2013) that scenario 2 has a low likelihood of occurrence. Furthermore, BVSC intends to reduce phosphate in the effluent to < 1.5 mg/L at through alum dosing at the sewage treatment plant.

Nevertheless, it is important to consider the worst case scenario to ensure extreme possible impacts are assessed.

4.3 Modelling results

4.3.1 Groundwater discharge

Baseline groundwater flow was calculated through modelling of average rainfall conditions without exfiltration and thereafter with exfiltration simulated based on an estimated 2025 average daily effluent discharge loading of 1.4 ML/d. Under natural groundwater flow conditions the model shows the presence of a groundwater divide (recharge mound) extending from the southern area to close to the northern end of the exfiltration trench location. Under simulated groundwater flow conditions the groundwater divide becomes centred on the exfiltration trench with groundwater flowing directly towards the ocean (east-south-east) and towards the lake at its closest point (north-west) The greatest increase in overall net groundwater discharge occurs to the ocean, with a total net increase of 73% higher than under natural conditions. The total net increased discharge to the lake is 7.5% higher than under natural conditions. The time in which groundwater from the exfiltration trench will travel to the lake shore is estimated to be around 7 years, with typical travel times of 12 years or more prior to lake bed discharge. There is a clear decrease in groundwater velocity once the lake shore is reached reflecting the low hydraulic gradient in the shallow aquifer beneath the lake.

4.3.2 Nutrient transport simulation

Typical nutrient concentrations from the model are summarised in Table 4 and predicted phosphate and nitrate concentration distributions are shown in figures from IGCC (2013) provided in Appendix A.

Table 4 Predicted phosphate and nitrate concentrations (Table 13.6 from IGGC 2013)

Scenario	Lake Shore Central	Lake Shore Central	Lake Shore Outer	Lake Shore Outer	Lake Near Shore	Lake Near Shore
	Concentration (mg/L)	Length (m)	Concentration (mg/L)	Length (m)	Concentration (mg/L)	Area (m^2)
Phosphate						
1	0	0	0	0	0	0
2	5	400	1.5	1,400	2.5	287,400
3	0	0	0	0	0	0
4	0.8	400	0.4	1,200	0.3	153,100
Nitrate						
1	0	0	0	0	0	0
2	1.4	400	0.6	1,300	0.8	242,400
3	0	0	0	0	0	0
4	1.4	400	0.6	1,300	0.8	242,400

Note: Lake shore values include the two zones coinciding with the constant head boundary (the central area with greatest flow and highest concentration) and the remainder, and indicate the linear distance along which increased nutrient flux is expected.

Results of the scenarios that are likely to have the least impacts (Scenarios 1 & 3) predict that phosphate or nitrate is unlikely to reach the lake. An increased volume of freshwater will discharge from the lake bed.

Results of scenario that would likely lead to the highest potential impacts (Scenario 2) suggest that phosphate will reach the lake bed along 1,790 m of shoreline (Lake Shore) within 5.5 years and extend 220 m from the shore (Lake Near Shore) with steady state groundwater concentrations reaching up to 2.5 mg/L within 22 years in groundwater discharging from the lake bed (Lake Near Shore).

Table 5 provides a summary of nutrient transport simulation scenarios (i.e. Scenarios 1 to 4) and how the outcomes for each modelled scenario has been interpreted for the purpose of ecological impact assessment.

Table 5 Nutrient transport simulation scenarios

Scenario	Case	STP Upgrade & Effluent Quality	K_d value (PO_4)	R value (NO_3)	Exfiltration induced groundwater constituent breakthrough from lake bed			Scenario outcome
					H_20	Nitrate	Phosphate	
1	= lowest potential impacts	No upgrade and existing effluent quality	2	0.002	Yes	None	None	Increased freshwater only
2	= highest potential impacts	No upgrade and existing effluent quality	0.1	0	Yes	Yes	Yes (High)	Increased freshwater, nitrate and high phosphate flux

Scenario	Case	STP Upgrade & Effluent Quality	K_d value (PO_4)	R value (NO_3)	Exfiltration induced groundwater constituent breakthrough from lake bed			Scenario outcome
					H_2O	Nitrate	Phosphate	
3	= lowest potential impacts	Chemical Dosing to reduce Phosphate as P to 1.5mg/L	2	0.002	Yes	None	None	Increased freshwater only
4		Chemical Dosing to reduce Phosphate as P to 1.5mg/L	0.1	0	Yes	Yes	Yes (Low)	Increased freshwater, nitrate and low phosphate flux

4.4 Nutrient flux data

It is well recognised in international and local scientific literature that estuarine sediments and the biota that reside within play a major role in recycling nutrients. Sediments accumulate organic matter over time and consequently have a large store of nutrients. Depending on the processes occurring, these nutrients may be locked up in the sediments, converted into biologically unavailable forms, or recycled back into the water column in a form that supports ongoing ecosystem functioning.

Microbial breakdown of organic compounds in estuarine sediments is required to mineralise nutrients to a bioavailable form for plants and algae. Mineralised nutrients accumulate in sediment pore-waters and are transported to the overlying water by a number of mechanisms. These include diffusion and a variety of advective mechanisms in which pore-waters and the overlying water are mixed. The term 'flux' is used for when materials are transported from the sediments to the overlying water (RiverScience 2005).

4.4.1 Simulated flux rates

Table 6 shows the simulated nutrient fluxes for the 4 scenarios in units of grams/day..

Table 6 Modelled Nutrient Fluxes from Groundwater in grams per day (Source: Table 13.10 IGGC (2013))

Scenario	Lake Shore	Lake Near Shore	Ocean Shore	Ocean Near Shore	Total Lake
Phosphate Flux (grams per day)					
1	0	0	633	2,744	0
2	2,326	961	770	3,526	3, 287
3	0	0	169	459	0
4	426	90	238	561	516
Nitrate Flux (grams per day)					
1	0	0	207	829	0
2	724	200	713	1,154	924
3	0	0	207	829	0
4	724	200	713	1,154	924

Table 7 shows the simulated nutrient fluxes for the 4 scenarios in units of µmol/m^2/day.

Table 7 Modelled Nutrient Fluxes from Groundwater in µmol/m^2/day (Source: Table 13.11 IGGC (2013))

Scenario	Lake Shore (central)	Lake Shore (outer)	Lake Shore (all)	Lake Near Shore
Phosphate Flux (µmol P/m^2/hr)				
1	0	0	0	0
2	2,307	330	769	10
3	0	0	0	0
4	369	88	158	2
Nitrate Flux (µmol N/m^2/hr)				
1	0	0	0	0
2	646	133	253	3
3	0	0	0	0
4	646	133	253	3

Figure 4 and Figure 5 illustrate the Scenario 2 modelled results for P as phosphate and N as Nitrate plume concentration (mg/L) contours and specific location flux rates (µmol/m^2/hr) across the discharge zones.

Figure 6 and Figure 7 illustrate the Scenario 3 modelled results for P as phosphate and N as Nitrate plume concentrations contours. Flux rates to Merimbula Lake under this scenario are not shown because the modelling has predicted that there will be no nutrient flux to the lake

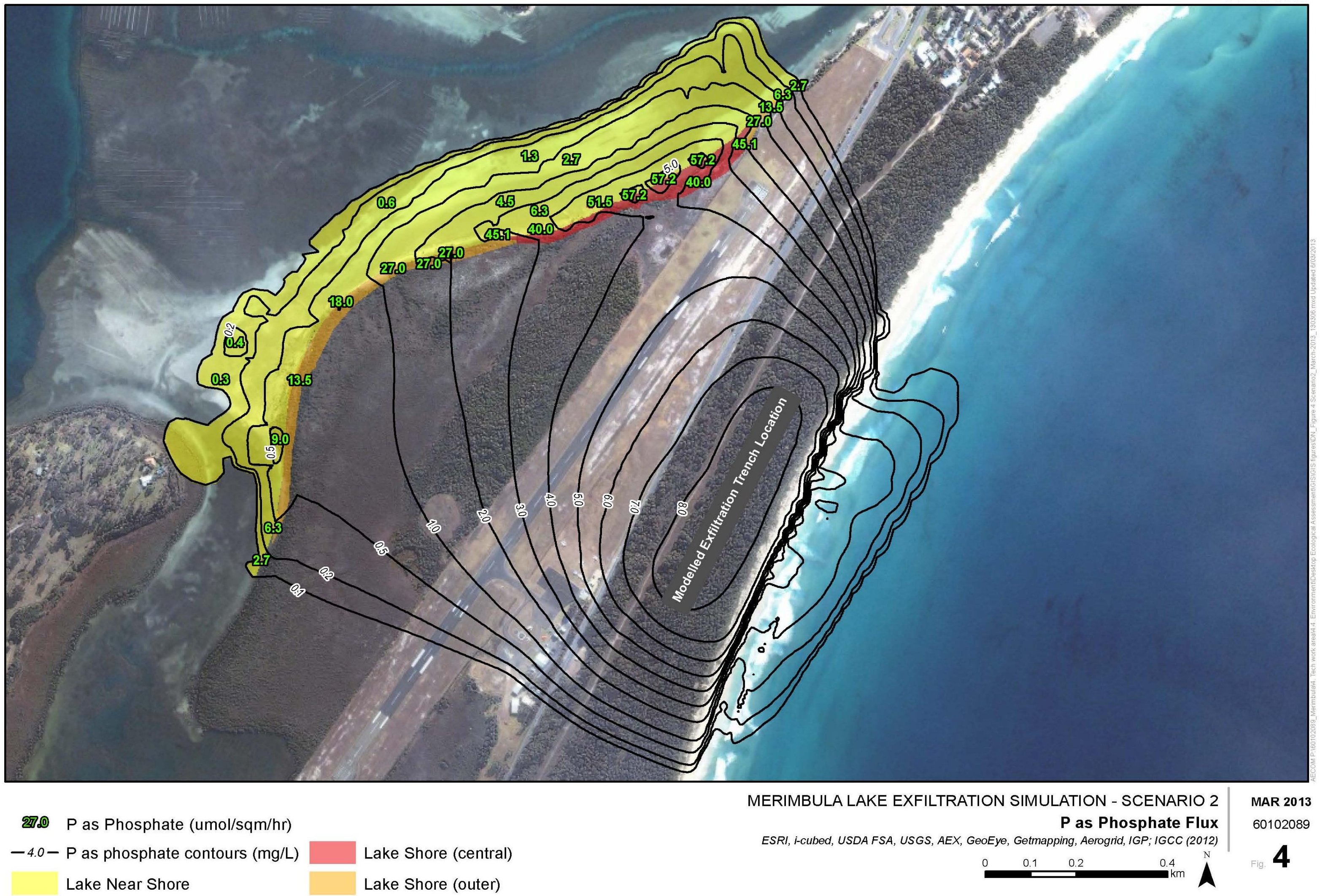

Figure 4 Scenario 2 modelled phosphate flux contour map

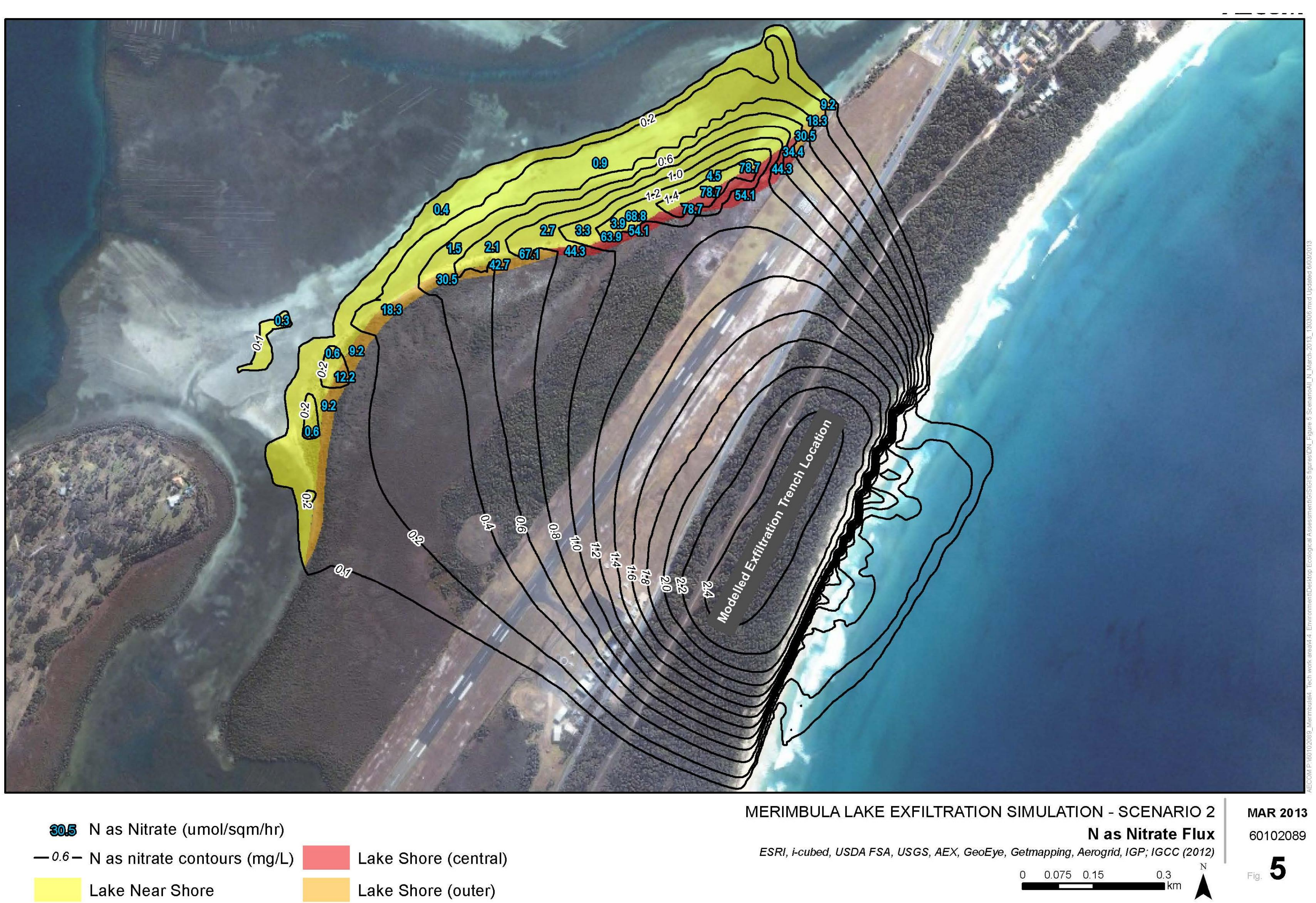

Figure 5 **Scenario 2 modelled nitrate flux contour map**

P as phosphate contours (mg/L)

MERIMBULA LAKE EXFILTRATION SIMULATION - SCENARIO 3
P as Phosphate (mg/L)
ESRI, i-cubed, USDA FSA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGP; IGCC (2012)
0 0.1 0.2 0.4 km
N

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60102089
Fig. **6**

Figure 6 Scenario 3 modelled phosphate flux contour map

N as nitrate contours (mg/L)

MERIMBULA LAKE EXFILTRATION SIMULATION - SCENARIO 3
N as Nitrate (mg/L)
ESRI, i-cubed, USDA FSA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGP; IGCC (2012)
0 0.1 0.2 0.4 km
N

MAR 2013
60102089
Fig. **7**

Figure 7 Scenario 3 modelled nitrate flux contour map

5.0 Impact Assessment

5.1 Preamble

This section provides the results of a combination of both:

- qualitative assessment of the potential near and far-field ecological impacts
- desktop due diligence assessment of matters of ecological significance protected under relevant environmental legislation.

This assessment is qualitative and predictive and is based on:

- simulated discharges of effluent and modelling of groundwater flow and groundwater nutrient transport
- field surveys, algal sampling, literature reviews and interpretations made by Elgin and Associates (Appendix D)
- data provided by the EPA and
- reference to additional data and reporting from relevant and peer reviewed scientific publications.

The steady-state models used by IGGC (2013) were based on average conditions with contaminant transport parameters assumed to be uniform across the model for each scenario. These assumptions are practical requirements of this type of modelling and the results are intended to be indicative only. Actual conditions will vary spatially and temporally and therefore potential impacts will vary spatially and temporally (IGCC 2013).

There remains a considerable knowledge gap which limits the ability for any definitive conclusions to be made. Nevertheless, we believe that the groundwater modelling predictions, field surveys, scientific literature reviews and the objective interpretations made are sufficient to provide a useful insight into the likely impacts of the shallow dunal exfiltration option.

5.2 Potential near-field ecological impacts

The exfiltration option will deliver freshwater and potentially an additional stream of nutrients into the lake system. This discharge would enter the system through the benthic environment firstly, and then release out into the pelagic or water-column environment through benthic-pelagic coupling mechanisms. Hence any nutrients discharged will connect firstly with micro-phyto benthos and then potentially be accessible to benthic and pelagic macro-algae and the shoreline intertidal mangrove and saltmarsh communities.

5.2.1 Benthic micro and macro algal communities

Two of the scenarios suggest that nutrients will be discharged into the lake unless mitigation actions are established. Under these scenarios, areas within any phosphate or especially nitrate plumes may respond to the additional nutrients through the increased growth of benthic microalgae, or micro-phyto benthos (MPB), and macroalgae such as filamentous brown alga. The other two scenarios suggest that only freshwater will enter the lake and hence not result in additional nutrients being discharged,

Benthic algal communities in estuaries are dominated by microscopic algae that live in or on sediment or mud surfaces in mangroves, saltmarsh, sand and mudflat environments.

Major diatom genera found in the sediments of estuaries along the Australian east coast include *Navicula, Nitzschia, Diploneis* and *Amphora*. Other common genera include *Achnanthes, Biremis, Planothidium, Hantzschia* and *Mastologia*. (Green *et al*, in press).

Diatoms respond rapidly to increased nutrient concentrations (in the sediments and water column), and are used widely as indicators of environmental change in marine systems and as indicators of eutrophication in coastal waters. Licursi *et al* (2010) discuss the ecological optima and tolerance ranges of diatoms found on the Argentinean coastline (at a similar latitudes to NSW). A number of genus sampled are found in Lake Merimbula, including: *Achnanthes; Amphora; Hantzschia; and Nitzschia.* Optima and tolerance ranges for 42 species sampled are summarised in Table 8.

Table 8 Optima and tolerance ranges of diatoms along Argentinean coastline in mg/L

	$N\text{-}NO_3$			$P\text{-}PO_4^{-3}$		
	Optima	Low	High	Optima	Low	High
Average	0.745	0.329	1.878	0.249	0.135	0.478
Minimum	0.260	0.060	0.520	0.090	0.040	0.120
Maximum	2.472	1.920	6.360	1.010	0.400	2.540

Comparison with the tolerances shown in Table 8, and simulated concentrations for scenario 2 (up to 1.4 N, 5.0 P; lake Shore Central; Table 4) show that for the cases with nutrient discharges the $N\text{-}NO_3$ concentrations will be suitable for growth of many species of diatoms likely to be present although the available $P\text{-}PO_4^{-3}$ concentrations may actually exceed measured maximum values for some species, in which case more opportunistic species may flourish.

To assess the potential implications of additional nutrient fluxes to benthic micro algal communities, the results of simulated groundwater discharge and nutrient fluxes are considered against natural background benthic fluxes in other estuarine environments. Table 9 provides a summary of nutrient flux data found in literature searches.

Table 9 Summary of nutrient flux data found

Location	PO_4^- µmol/m²/hr	DIP[a] µmol/m²/hr	DIN[b] µmol/m²/hr	NO_x µmol/m²/hr	Source
Australia					
Smiths Lake, NSW	0.03		2.54	0.04	Smith & Heggie 2003
Lake Illawarra, NSW			64.00		Qu et al, 2004
Brunswick, NSW			11.00		Eyre and Ferguson 2005
Wattamolla Lagoon, NSW		0.42			Potts et al 2005
Hewitts Lagoon, NSW		4.00			Potts et al 2005
Tramway Lagoon, NSW		4.01			Potts et al 2005
Towradgi Lagoon, NSW		5.49			Potts et al 2005
Fairy Lagoon, NSW		8.10			Potts et al 2005
Lake Wellington (Gippsland Lakes, VIC)		4.60	56.50		Webster et al 2001
Lakes Victoria & King (Gippsland Lakes) (VIC)		5.90	62.50		Webster et al 2001
Stokes Estuary, WA	3.10			-0.30	Murray et al 2008
Swan River Estuary, WA	28.30				Smith et al 2007
Torbay drainage system, WA	111.50			-3.85	Murray et al 2005, 2007
USA					
Anacostia River, DC	3.65				Bailey et al., 2003
Mobile Bay, AL	9.25				Cowan et al., 1996
Chester River, MD	25.01				Boynton et al., 2003
Potomac River, MD	20.41				Boynton et al., 2003
Pocomoke River, MD	1.74				Boynton et al., 1999
Patuxent River, MD	26.3				Boynton et al., 2003
Fourleague River, MD	-6.67				Teague et al., 1988

South River, NC	14.7				Fisher et al., 1982
San Francisco Bay, CA	0				Hammond et al., 1985
Chesapeake Bay, USA	24.12				Cowan and Boynton 1996
Chesapeake Bay, USA		2.34			Reay et al 2004

[a] *Dissolved Inorganic Phosphorus (DIP) consist largely of the inorganic orthophosphate (PO4) form of phosphorus. Orthophosphate is the phosphorus form that is directly taken up by algae and plants, and the concentration of this fraction constitutes an index of the amount of phosphorus immediately available for algal and plant growth*

[b] *Dissolved Inorganic Nitrogen (DIN) = nitrite + nitrate + ammonia*

Table 7 contains the predicted dissolved N and P fluxes for the simulated scenarios. Table 7 shows that under scenario 2 - the case that has the highest potential impacts yet a low likelihood of occurrence (refer Section 4.2.2), - the flux of nutrients entering into the central lake shore zone are predicted to be up to 2,307 µmol P/m^2/hr for dissolved P, and up to 646 µmol N/m^2/hr for dissolved N at the specific location of peak discharge. At other locations within the lake near shore zone, the flux of nutrients are predicted to be 10 µmol P/m^2/hr for dissolved P, and 3 µmol N/m^2/hr for dissolved N.

Comparison with more widespread and background flux rates as reported in Table 9 from estuaries in NSW and Western Australia is as follows:

- Oxidised nitrogen (N_2 + N_3) ranging from -3.54 to 0.04 µmol/m^2/hr are considerably less than predicted Scenario 2 values for the central lake shore zone (646 µmol/m^2/hr) and lake near shore zones (3 µmol/m^2/hr)
- DIN (N_2 + N_3 + NH_4) ranging from 2.5 to 64.0 µmol/m^2/hr are comparable with the lake near shore Scenario 2 value for nitrate of 3 µmol N/m^2/hr
- DIP (PO_4) ranging from 0.42 to 8.10 µmol/m^2/hr are considerably less than predicted Scenario 2 values for the central lake shore zone (2,307 µmol/m^2/hr) but comparable with the lake near shore Scenario 2 value for phosphate of 10 µmol N/m^2/hr

Under the worst case scenario 2, it can be argued based on the simulated concentrations and fluxes of particularly dissolved N and P that there will be some level of increased production of micro-algae in the near-field receiving environment around the part of the lake shore where the discharge would occur. This is consistent with other studies, for example numerous studies in Victoria and Western Australia, that have demonstrated the importance of nutrients sourced from sediments in promoting nuisance growth of macrophytes and phytoplankton and/or algal blooms (Fredericks *et al.* 1999, Roberts *et al*. 2003, Longmore *et al*. 2003, Murray *et al*., 2005a and 2005b, Murray *et al*., 2008, Smith *et al*., 2007). It might also be the case that the pore water concentrations and discharge concentrations within a near-field mixing zone will exceed ANZECC (2000) default trigger values for South-east Australia slightly disturbed estuaries (of 0.015 mg/L NOx (N_3 + N_2)).

Under mild enrichment conditions, these changes are commonly not visible unless until very high levels of production occur that can then result in visible microbial mats on the seabed. When conditions favour the formation of a benthic microbial mat of algae, the top layer is usually comprised of cyanobacteria or diatoms. Cyanobacterial species such as *Microcoleus chthonoplastes* and *Oscillatora limosa* often dominate the ‘microbial mats’ (Green *et al*, in press).

These mats most commonly occur in regions of low flushing and extended periods of low winds during which vertical mixing in the water-column is reduced. Therefore it is possible, under that some increased microbial production will occur, but not necessarily to the level that would result in visible microbial mats as the majority of the discharge region features stronger flushing.

The development of large colonies of filamentous Cyanobacteria such as the common *Oscillatoria* can also occur in response to higher phosphorus and especially nitrogen levels in the water.

With regards to larger and hence more visible macro-algae, Appendix D highlights that opportunistic filamentous taxa that are commonly epiphytic on the blades of seagrasses may respond to the addition of especially increased nitrogen under the high nitrogen-discharge scenario (Scenario 2). It is difficult to predict exactly how much enhanced productivity could occur as it depends on the extent that these dissolved nutrients make their way into the water-column form the sediments. However, as highlighted in Appendix D at times in the nearby Golf Lakes can at times be covered up to 50% in algae as a result of the combination of low flushing and anthropogenic nutrient inflows.

Appendix D also highlights a lack of hard substrate neat or near the discharge site and hence the biomass of attached broad-leaf macro-algae is constrained by a lack of habitat rather than the availability of nutrients.

5.2.2 Aquatic vegetation

Scenarios 1 and 3 indicate that only the flux of freshwater will increase to the lake receiving environment. Therefore under these scenarios substantive impacts to nutrient cycling and vegetation response would not be expected.

Under Scenario 2 the highest concentrations of nutrients in groundwater discharge are predicted to occur along the lake shore. This is where saltmarsh and mangrove vegetation is located. Little is reported in relation to the sensitivity of these estuarine communities to groundwater impacts although broad interactions are inferred in general information found through literature searches.

Appendix D highlights that a reduction on mean salinity resulting from the freshwater discharge in the saltmarsh community may result in a change in community structure that favours more freshwater tolerant species to proliferate. Similarly, a change in mean salinity in these low flushing communities may also allow mangroves to expand into the saltmarsh community (Rogers and Saintilan 2009).

Further out in the near shore zone, seagrasses are found. Simulated nutrient fluxes are considerably lower here than for along the lakeshore. Seagrass is likely to respond to increased nutrients through increased growth, which in turn may result in greater quantities of organic matter and hence carbon recycling in these areas. Whilst in some cases increases in seagrass biomass is seen as advantageous, there are nearby examples of where excessive seagrass growth is considered to be a negative impact, for example at Tuggerah lakes (Dickenson *et al*, 2006).

The significance of the above risks will be largely dependent on the ability of local hydrodynamics to flush concentrations of nutrients entering the water column out to the ocean. Existing literature suggests that the lake on the whole has very good tidal flushing (Appendix D; Webb, McKeown, 1997). Wind blowing across the lake surface also generates surface and sub-surface currents which assist to maintain water quality within the lake by increasing tidal exchange, vertical mixing and oxygenation (Maunsell | AECOM 2008). This is likely to apply to the subject area helping to reduce the potential risk to aquatic ecosystems.

5.3 Potential far-field ecological impacts

The additional of new bioavailable nutrients into waterways often only results in detectable near-field impacts, as described above and in Appendix D. However, for larger relative nutrient inflows a potential system-wide impact of the addition of nutrient streams into enclosed and semi-enclosed waterways is an increased eutrophication state of the water body as a result of widespread enhanced biological activity.

The lake system represents the receiving environment for existing catchment-derived nutrients, in addition to receiving oceanic nutrients, Roper et al. (2011) reports that 43% of the catchment has been cleared, much of which for agricultural uses and this land use is a source of nutrients into the lake system.

Roper et al. (2011) rates the lake system presently as 'fair' (Appendix D), with a median chlorophyll *a* concentration of 2 µg/L. As illustrated in Figure 8, a comparison with other lake systems in NSW, indicates that the standing phytoplankton population, represented through the chlorophyll a biomass, is good. The water quality in the central lake is below ANZECC guidelines and inspection of water quality data indicates high water quality in many parts of the system (Appendix D).

Two of the scenarios indicate that only the flux of freshwater will increase to the lake shore. The other two scenarios indicate that there could be some discharge of nutrients into the central lake receiving environment. The CERAT (Coastal Eutrophication Risk Assessment Tool; http://www.ozcoasts.gov.au/nrm_rpt/cerat/index.jsp) reports that the present total nitrogen load into Merimbula Lake is 6,433 kg per year. By comparison, Table 8 indicates that under scenario 2, there might be a discharge of 924 g/day of dissolved nitrogen entering the lake environment. This is equivalent to 0.924 kg/day, or 337 kg per year of dissolved nitrogen. However this figure does not include the organic N contribution. Based on the EPA annual return for 2011/2012, the total N discharge was 3.5 tonnes of TN from a volume discharge of 781 ML. Scaling this up to a projected 2025 total volume of 500 ML remaining for disposal after beneficial reuse gives an estimated total N load of 2.25 tonnes TN discharged per year. Assuming 19% (IGGC 2013) of this volume will be directed into the lake, then the total N load into the lake would be 428 kg per year.

This means that for the worst case Scenario 2, the discharge of year 2025 estimated disposal volumes to a 400m exfiltration trench located in BVSC land in the dunes east of the airport would potentially contribute an additional 6.7% of TN to Merimbula Lake.

From the CERAT model, this increased total nitrogen load would increase the mean chlorophyll *a* from 2.00 to 2.17 µg/L. Using standard trophic index scales (Carlson 1977), the lake would remain in an oligotrophic or nutrient deficient condition (0-2.6 µg/L chlorophyll *a*). Furthermore, based on Roper et al. (2011), these values would remain below the monitoring, evaluation and reporting triggers of the NSW Natural Resources Monitoring, Evaluation and Reporting Strategy 2010-2015 (DECCW, 2010).

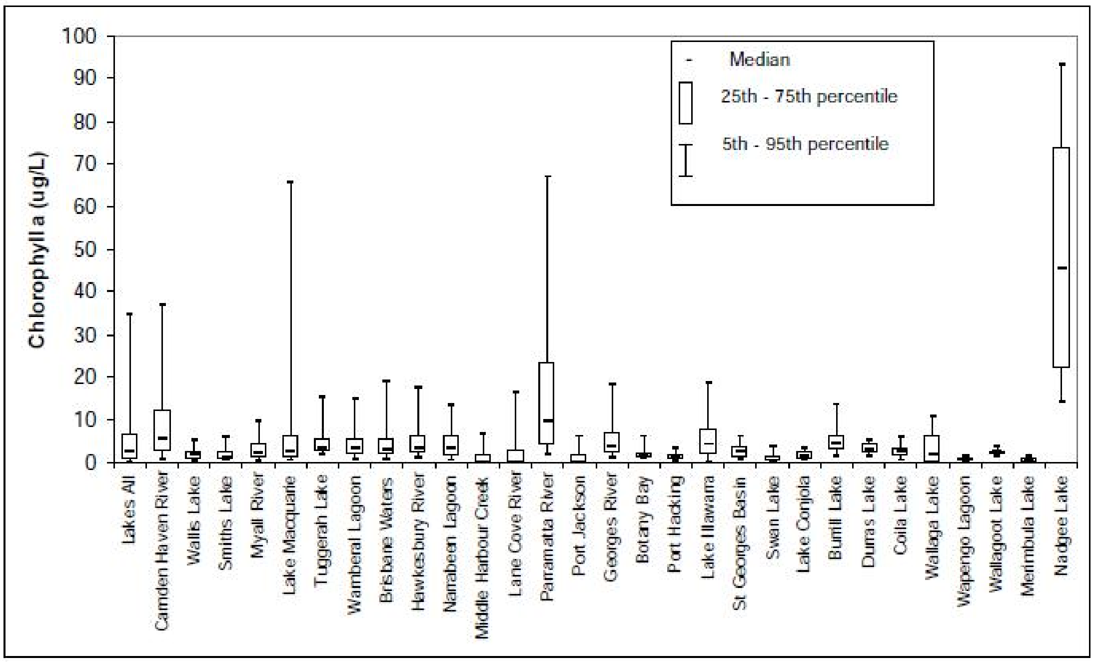

Figure 8 **Comparison of water quality (Chl *a* µg/L) for NSW coastal lakes**

6.0 Approvals

A number of statutory approvals will require consideration in the event that the option of shallow dunal exfiltration was to progress.

6.1 EPBC Act

One endangered and several migratory bird species are reported from within or in near proximity to the subject area and are considered to have a high likelihood of utilising a range of habitat features present, such as saltmarsh, mangroves, seagrass, oyster racks, and non-vegetated substratum.

Any decrease in availability of habitat in the subject area is unlikely to have a significant impact on nationally important habitat for these species. Merimbula Lake is not identified as a key site for migratory shorebirds (as administered under the East Asian-Australasian Flyway Site Network). However the loss of feeding and roosting habitat; human disturbance at roost and feeding sites; and pollution, are listed threats to many shorebirds protected under the EPBC Act.

The EPBC Act is currently under reform, and including SEWPaC consultation for the project is advised.

6.2 TSC Act

Saltmarsh is listed as an endangered ecological community under the TSC Act. As inferred in Sections 5.2 and 3.3, the potential impacts on this community are not clear without further detailed investigation (i.e. ground truthing and delineation of extent of saltmarsh within the subject area, and gaining a better understanding of existing sediment characteristics and groundwater quality). As such, consultation with EPA's Threatened Species Unit is recommended as part of the options development.

6.3 FM Act

In accordance with 'Fish Habitat Protection Plan No.2 Seagrasses' (DPI, 1997), the discharge of effluent within 50 metres of any seagrass bed will generally not be approved unless special circumstances exist, and effective compensation is provided.

In this case the diffuse discharge of effluent in groundwater would arise from effluent discharged approximately 1,000 metres from seagrass beds and as such, consultation with DPI-Fisheries is recommended to understand whether FM Act approval would be required.

6.4 Oyster aquaculture

When considering an application for development that, because of its proposed location, may affect a priority oyster aquaculture area or oyster aquaculture outside such an area, the consent authority must:

1) Give the Director-General of the DPI written notice of the development application and take into consideration any written submissions made in response to the notice within 14 days after notice was given.

2) Take into consideration the provisions of the *NSW Oyster Industry Sustainable Aquaculture Strategy*.

3) Consider any issues that are likely to make the development incompatible with oyster aquaculture and evaluate any measures that the applicant has proposed to address those issues.

This assessment has only considered the effects of simulated nutrient concentrations in groundwater discharge, which are not the major parameters that would be of concern to the DPI. Major factors that would require detailed investigation and consideration would include contaminants that may affect human consumption of oysters (in particular heavy metals, faecal coliforms, pathogens and the like).

Consultation with the DPI will be required, and potentially the NSW Department of Health may also be required.

6.5 State Environmental Planning Policies

Under SEPP 14 – Coastal Wetlands it is likely that the option of shallow dunal exfiltration would be considered designated development. This means the development application will require consultation and concurrence of the Director-General of DoPI and an environmental impact statement and be placed on public exhibition for public comment.

Under SEPP 71 – Coastal Protection a consent authority must reject development applications that will result in effluent discharge that negatively affects water quality. Consultation with the DoPI should be facilitated if this option is to proceed further.

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Appendix A

IGCC figures

Appendix A IGCC figures

IGGC Figures are provided within Appendix D – Supplementary Report (Elgin Associates, 2013)

Appendix B

Government database search results

Australian Government

Department of Sustainability, Environment, Water, Population and Communities

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information about the EPBC Act including significance guidelines, forms and application process details can be found at http://www.environment.gov.au/epbc/assessmentsapprovals/index.html

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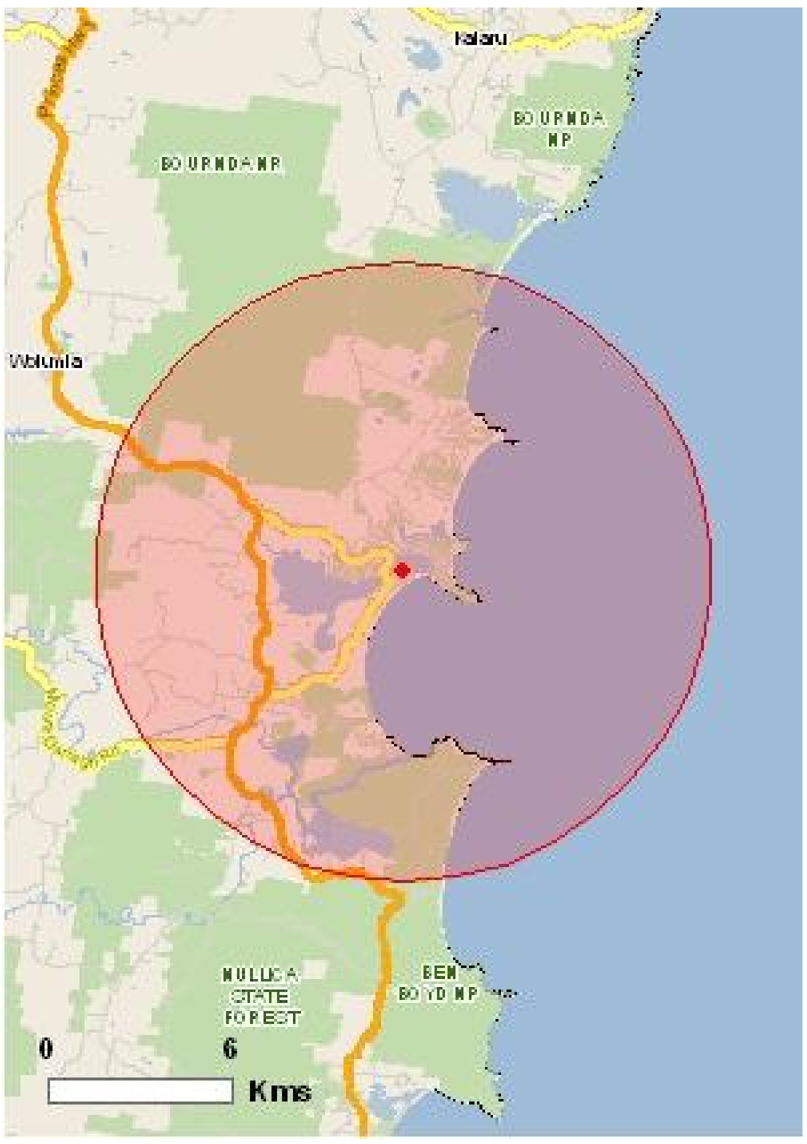

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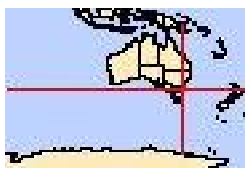

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance - see http://www.environment.gov.au/epbc/assessmentsapprovals/guidelines/index.html

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Areas:	1
Threatened Ecological Communities:	1
Threatened Species:	53
Migratory Species:	47

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place and the heritage values of a place on the Register of the National Estate. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage/index.html

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species. Information on EPBC Act permit requirements and application forms can be found at http://www.environment.gov.

Commonwealth Lands:	1
Commonwealth Heritage Places:	None
Listed Marine Species:	69
Whales and Other Cetaceans:	12
Critical Habitats:	None
Commonwealth Reserves:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have

Place on the RNE:	8
State and Territory Reserves:	4
Regional Forest Agreements:	1
Invasive Species:	13
Nationally Important Wetlands:	3

Details

Matters of National Environmental Significance

Commonwealth Marine Areas [Resource Information]

Approval may be required for a proposed activity that is likely to have a significant impact on the environment in a Commonwealth Marine Area, when the action is outside the Commonwealth Marine Area, or the environment anywhere when the action is taken within the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred

Name
EEZ and Territorial Sea

Threatened Ecological Communities [Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Name	Status	Type of Presence
Littoral Rainforest and Coastal Vine Thickets of Eastern Australia	Critically Endangered	Community likely to occur within area

Threatened Species [Resource Information]

Name	Status	Type of Presence
BIRDS		
Anthochaera phrygia		
Regent Honeyeater [82338]	Endangered	Species or species habitat may occur within area
Botaurus poiciloptilus		
Australasian Bittern [1001]	Endangered	Species or species habitat known to occur within area
Dasyornis brachypterus		
Eastern Bristlebird [533]	Endangered	Species or species habitat known to occur within area
Diomedea epomophora epomophora		
Southern Royal Albatross [25996]	Vulnerable	Species or species habitat may occur within area
Diomedea epomophora sanfordi		
Northern Royal Albatross [82331]	Endangered	Species or species habitat may occur within area
Diomedea exulans amsterdamensis		
Amsterdam Albatross [82330]	Endangered	Species or species habitat may occur within area
Diomedea exulans antipodensis		
Antipodean Albatross [82269]	Vulnerable	Species or species habitat may occur within area
Diomedea exulans exulans		
Tristan Albatross [82337]	Endangered	Foraging, feeding or related behaviour may occur within area
Diomedea exulans gibsoni		
Gibson's Albatross [82271]	Vulnerable	Species or species habitat may occur within area
Diomedea exulans (sensu lato)		
Wandering Albatross [1073]	Vulnerable	Species or species habitat may occur within area
Fregetta grallaria grallaria		
White-bellied Storm-Petrel (Tasman Sea), White-bellied Storm-Petrel (Australasian) [64438]	Vulnerable	Species or species habitat likely to occur within area
Halobaena caerulea		
Blue Petrel [1059]	Vulnerable	Species or species habitat may occur within area
Lathamus discolor		
Swift Parrot [744]	Endangered	Species or species habitat likely to occur within area
Macronectes giganteus		
Southern Giant-Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli		
Northern Giant-Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Neophema chrysogaster		
Orange-bellied Parrot [747]	Critically Endangered	Species or species

Name	Status	Type of Presence
		habitat may occur within area
Rostratula australis Australian Painted Snipe [77037]	Vulnerable	Species or species habitat may occur within area
Sternula nereis nereis Fairy Tern (Australian) [82950]	Vulnerable	Species or species habitat known to occur within area
Thalassarche bulleri Buller's Albatross [64460]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta cauta Shy Albatross, Tasmanian Shy Albatross [82345]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta salvini Salvin's Albatross [82343]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta steadi White-capped Albatross [82344]	Vulnerable	Species or species habitat may occur within area
Thalassarche chrysostoma Grey-headed Albatross [66491]	Endangered	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris impavida Campbell Albatross [82449]	Vulnerable	Species or species habitat may occur within area
FISH		
Epinephelus daemelii Black Rockcod, Black Cod, Saddled Rockcod [68449]	Vulnerable	Species or species habitat may occur within area
Prototroctes maraena Australian Grayling [26179]	Vulnerable	Species or species habitat likely to occur within area
FROGS		
Heleioporus australiacus Giant Burrowing Frog [1973]	Vulnerable	Species or species habitat likely to occur within area
Litoria aurea Green and Golden Bell Frog [1870]	Vulnerable	Species or species habitat likely to occur within area
Litoria littlejohni Littlejohn's Tree Frog, Heath Frog [64733]	Vulnerable	Species or species habitat may occur within area
Mixophyes balbus Stuttering Frog, Southern Barred Frog (in Victoria) [1942]	Vulnerable	Species or species habitat likely to occur within area
MAMMALS		
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Dasyurus maculatus maculatus (SE mainland population) Spot-tailed Quoll, Spotted-tail Quoll, Tiger Quoll (southeastern mainland population) [75184]	Endangered	Species or species habitat may occur within area

Name	Status	Type of Presence
Eubalaena australis		
Southern Right Whale [40]	Endangered	Species or species habitat known to occur within area
Isoodon obesulus obesulus		
Southern Brown Bandicoot (Eastern) [68050]	Endangered	Species or species habitat likely to occur within area
Megaptera novaeangliae		
Humpback Whale [38]	Vulnerable	Congregation or aggregation known to occur within area
Petrogale penicillata		
Brush-tailed Rock-wallaby [225]	Vulnerable	Species or species habitat likely to occur within area
Phascolarctos cinereus (combined populations of Qld, NSW and the ACT)		
Koala (combined populations of Queensland, New South Wales and the Australian Capital Territory) [85104]	Vulnerable	Species or species habitat known to occur within area
Potorous longipes		
Long-footed Potoroo [217]	Endangered	Species or species habitat likely to occur within area
Potorous tridactylus tridactylus		
Long-nosed Potoroo (SE mainland) [66645]	Vulnerable	Species or species habitat may occur within area
Pseudomys fumeus		
Konoom, Smoky Mouse [88]	Endangered	Species or species habitat may occur within area
Pseudomys novaehollandiae		
New Holland Mouse [96]	Vulnerable	Species or species habitat likely to occur within area
Pteropus poliocephalus		
Grey-headed Flying-fox [186]	Vulnerable	Roosting known to occur within area
PLANTS		
Correa baeuerlenii		
Chef's Cap [17007]	Vulnerable	Species or species habitat likely to occur within area
Cryptostylis hunteriana		
Leafless Tongue-orchid [19533]	Vulnerable	Species or species habitat may occur within area
Pomaderris parrisiae		
Parris' Pomaderris [22119]	Vulnerable	Species or species habitat likely to occur within area
REPTILES		
Caretta caretta		
Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area
Chelonia mydas		
Green Turtle [1765]	Vulnerable	Species or species habitat likely to occur within area
Dermochelys coriacea		
Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata		
Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
SHARKS		
Carcharias taurus (east coast population)		
Grey Nurse Shark (east coast population) [68751]	Critically Endangered	Species or species habitat may occur within

Name	Status	Type of Presence
		area
Carcharodon carcharias Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area

Migratory Species

[Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Apus pacificus Fork-tailed Swift [678]		Species or species habitat may occur within area
Ardea alba Great Egret, White Egret [59541]		Species or species habitat may occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered*	Species or species habitat may occur within area
Diomedea antipodensis Antipodean Albatross [64458]	Vulnerable*	Species or species habitat may occur within area
Diomedea dabbenena Tristan Albatross [66471]	Endangered*	Foraging, feeding or related behaviour may occur within area
Diomedea epomophora (sensu stricto) Southern Royal Albatross [1072]	Vulnerable*	Species or species habitat may occur within area
Diomedea exulans (sensu lato) Wandering Albatross [1073]	Vulnerable	Species or species habitat may occur within area
Diomedea gibsoni Gibson's Albatross [64466]	Vulnerable*	Species or species habitat may occur within area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered*	Species or species habitat may occur within area
Macronectes giganteus Southern Giant-Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant-Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Sterna albifrons Little Tern [813]		Species or species habitat may occur within area
Thalassarche bulleri Buller's Albatross [64460]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta (sensu stricto) Shy Albatross, Tasmanian Shy Albatross [64697]	Vulnerable*	Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Thalassarche chrysostoma Grey-headed Albatross [66491]	Endangered	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross [64459]	Vulnerable*	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche salvini Salvin's Albatross [64463]	Vulnerable*	Species or species habitat may occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable*	Species or species habitat may occur within area
Migratory Marine Species		
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Caperea marginata Pygmy Right Whale [39]		Species or species habitat may occur within area
Carcharodon carcharias Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat known to occur within area
Lagenorhynchus obscurus Dusky Dolphin [43]		Species or species habitat may occur within area
Lamna nasus Porbeagle, Mackerel Shark [83288]		Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Congregation or aggregation known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area
Migratory Terrestrial Species		
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat likely to occur within area
Hirundapus caudacutus White-throated Needletail [682]		Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Monarcha melanopsis Black-faced Monarch [609]		Species or species habitat known to occur within area
Myiagra cyanoleuca Satin Flycatcher [612]		Breeding likely to occur within area
Neophema chrysogaster Orange-bellied Parrot [747]	Critically Endangered	Species or species habitat may occur within area
Rhipidura rufifrons Rufous Fantail [592]		Breeding may occur within area
Xanthomyza phrygia Regent Honeyeater [430]	Endangered*	Species or species habitat may occur within area
Migratory Wetlands Species		
Ardea alba Great Egret, White Egret [59541]		Species or species habitat may occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]		Foraging, feeding or related behaviour may occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Foraging, feeding or related behaviour likely to occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Vulnerable*	Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Commonwealth Lands [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Name
Commonwealth Land - Australian Telecommunications Commission

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Apus pacificus Fork-tailed Swift [678]		Species or species habitat may occur within area
Ardea alba Great Egret, White Egret [59541]		Species or species habitat may occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area
Catharacta skua Great Skua [59472]		Species or species habitat may occur within area
Diomedea amsterdamensis Amsterdam Albatross [64405]	Endangered*	Species or species habitat may occur within area
Diomedea antipodensis Antipodean Albatross [64458]	Vulnerable*	Species or species habitat may occur within area
Diomedea dabbenena Tristan Albatross [66471]	Endangered*	Foraging, feeding or related behaviour may occur within area
Diomedea epomophora (sensu stricto) Southern Royal Albatross [1072]	Vulnerable*	Species or species habitat may occur within area
Diomedea exulans (sensu lato) Wandering Albatross [1073]	Vulnerable	Species or species habitat may occur within area
Diomedea gibsoni Gibson's Albatross [64466]	Vulnerable*	Species or species habitat may occur within area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered*	Species or species habitat may occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]		Foraging, feeding or related behaviour may occur within area
Gallinago megala Swinhoe's Snipe [864]		Foraging, feeding or related behaviour likely to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Foraging, feeding or related behaviour likely to occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat likely to occur within area
Halobaena caerulea Blue Petrel [1059]	Vulnerable	Species or species habitat may occur within area
Hirundapus caudacutus White-throated Needletail [682]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Lathamus discolor Swift Parrot [744]	Endangered	Species or species habitat likely to occur within area
Macronectes giganteus Southern Giant-Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant-Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Monarcha melanopsis Black-faced Monarch [609]		Species or species habitat known to occur within area
Myiagra cyanoleuca Satin Flycatcher [612]		Breeding likely to occur within area
Neophema chrysogaster Orange-bellied Parrot [747]	Critically Endangered	Species or species habitat may occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Foraging, feeding or related behaviour likely to occur within area
Rhipidura rufifrons Rufous Fantail [592]		Breeding may occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Vulnerable*	Species or species habitat may occur within area
Sterna albifrons Little Tern [813]		Species or species habitat may occur within area
Thalassarche bulleri Buller's Albatross [64460]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta (sensu stricto) Shy Albatross, Tasmanian Shy Albatross [64697]	Vulnerable*	Species or species habitat may occur within area
Thalassarche chrysostoma Grey-headed Albatross [66491]	Endangered	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross [64459]	Vulnerable*	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche salvini Salvin's Albatross [64463]	Vulnerable*	Species or species habitat may occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable*	Species or species habitat may occur within area
Thinornis rubricollis rubricollis Hooded Plover (eastern) [66726]		Species or species habitat likely to occur

Name	Threatened	Type of Presence within area
Fish		
Heraldia nocturna Upside-down Pipefish, Eastern Upside-down Pipefish, Eastern Upside-down Pipefish [66227]		Species or species habitat may occur within area
Hippocampus abdominalis Bigbelly Seahorse, Eastern Potbelly Seahorse, New Zealand Potbelly Seahorse [66233]		Species or species habitat may occur within area
Hippocampus breviceps Short-head Seahorse, Short-snouted Seahorse [66235]		Species or species habitat may occur within area
Hippocampus minotaur Bullneck Seahorse [66705]		Species or species habitat may occur within area
Hippocampus whitei White's Seahorse, Crowned Seahorse, Sydney Seahorse [66240]		Species or species habitat may occur within area
Histiogamphelus briggsii Crested Pipefish, Briggs' Crested Pipefish, Briggs' Pipefish [66242]		Species or species habitat may occur within area
Histiogamphelus cristatus Rhino Pipefish, Macleay's Crested Pipefish, Ring-back Pipefish [66243]		Species or species habitat may occur within area
Hypselognathus rostratus Knifesnout Pipefish, Knife-snouted Pipefish [66245]		Species or species habitat may occur within area
Kaupus costatus Deepbody Pipefish, Deep-bodied Pipefish [66246]		Species or species habitat may occur within area
Kimblaeus bassensis Trawl Pipefish, Bass Strait Pipefish [66247]		Species or species habitat may occur within area
Leptoichthys fistularius Brushtail Pipefish [66248]		Species or species habitat may occur within area
Lissocampus runa Javelin Pipefish [66251]		Species or species habitat may occur within area
Maroubra perserrata Sawtooth Pipefish [66252]		Species or species habitat may occur within area
Mitotichthys semistriatus Halfbanded Pipefish [66261]		Species or species habitat may occur within area
Mitotichthys tuckeri Tucker's Pipefish [66262]		Species or species habitat may occur within area
Notiocampus ruber Red Pipefish [66265]		Species or species habitat may occur within area
Phyllopteryx taeniolatus Common Seadragon, Weedy Seadragon [66268]		Species or species habitat may occur within area
Solegnathus robustus Robust Pipehorse, Robust Spiny Pipehorse [66274]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Solegnathus spinosissimus Spiny Pipehorse, Australian Spiny Pipehorse [66275]		Species or species habitat may occur within area
Stigmatopora argus Spotted Pipefish, Gulf Pipefish [66276]		Species or species habitat may occur within area
Stigmatopora nigra Widebody Pipefish, Wide-bodied Pipefish, Black Pipefish [66277]		Species or species habitat may occur within area
Stipecampus cristatus Ringback Pipefish, Ring-backed Pipefish [66278]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Urocampus carinirostris Hairy Pipefish [66282]		Species or species habitat may occur within area
Vanacampus margaritifer Mother-of-pearl Pipefish [66283]		Species or species habitat may occur within area
Vanacampus phillipi Port Phillip Pipefish [66284]		Species or species habitat may occur within area
Vanacampus poecilolaemus Longsnout Pipefish, Australian Long-snout Pipefish, Long-snouted Pipefish [66285]		Species or species habitat may occur within area
Mammals		
Arctocephalus forsteri New Zealand Fur-seal [20]		Species or species habitat may occur within area
Arctocephalus pusillus Australian Fur-seal, Australo-African Fur-seal [21]		Species or species habitat may occur within area
Reptiles		
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat likely to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat likely to occur within area

Whales and other Cetaceans [Resource Information]

Name	Status	Type of Presence
Mammals		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area

Name	Status	Type of Presence
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Caperea marginata Pygmy Right Whale [39]		Species or species habitat may occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat known to occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Lagenorhynchus obscurus Dusky Dolphin [43]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Congregation or aggregation known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area

Extra Information

Places on the RNE [Resource Information]

Note that not all Indigenous sites may be listed.

Name	State	Status
Natural		
Yowaka Reserve Proposal	NSW	Indicative Place
Bournda National Park	NSW	Interim List
Ben Boyd National Park	NSW	Registered
Bournda Nature Reserve	NSW	Registered
Indigenous		
Pambula Beach Midden Complex	NSW	Indicative Place
Historic		
Courthouse / Police Station and Cell Block (former)	NSW	Registered
Courunga House, Grounds and Trees	NSW	Registered
School and Residence (former)	NSW	Registered

State and Territory Reserves [Resource Information]

Name	State
Ben Boyd	NSW
Bournda	NSW

Name	State
Bournda	NSW
South East Forest	NSW

Regional Forest Agreements [Resource Information]

Note that all areas with completed RFAs have been included.

Name	State
Eden RFA	New South Wales

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit,

Name	Status	Type of Presence
Mammals		
Felis catus		
Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Oryctolagus cuniculus		
Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Vulpes vulpes		
Red Fox, Fox [18]		Species or species habitat likely to occur within area
Plants		
Asparagus asparagoides		
Bridal Creeper, Bridal Veil Creeper, Smilax, Florist's Smilax, Smilax Asparagus [22473]		Species or species habitat likely to occur within area
Lantana camara		
Lantana, Common Lantana, Kamara Lantana, Large-leaf Lantana, Pink Flowered Lantana, Red Flowered Lantana, Red-Flowered Sage, White Sage, Wild Sage [10892]		Species or species habitat likely to occur within area
Lycium ferocissimum		
African Boxthorn, Boxthorn [19235]		Species or species habitat may occur within area
Nassella neesiana		
Chilean Needle grass [67699]		Species or species habitat likely to occur within area
Nassella trichotoma		
Serrated Tussock, Yass River Tussock, Yass Tussock, Nassella Tussock (NZ) [18884]		Species or species habitat likely to occur within area
Pinus radiata		
Radiata Pine Monterey Pine, Insignis Pine, Wilding Pine [20780]		Species or species habitat may occur within area
Rubus fruticosus aggregate		
Blackberry, European Blackberry [68406]		Species or species habitat likely to occur within area
Salix spp. except S.babylonica, S.x calodendron & S.x reichardtii		
Willows except Weeping Willow, Pussy Willow and Sterile Pussy Willow [68497]		Species or species habitat likely to occur within area
Salvinia molesta		
Salvinia, Giant Salvinia, Aquarium Watermoss, Kariba Weed [13665]		Species or species habitat likely to occur within area
Ulex europaeus		
Gorse, Furze [7693]		Species or species habitat likely to occur within area

Nationally Important Wetlands [Resource Information]

Name	State
Bondi Lake	NSW
Merimbula Lake	NSW
Pambula Estuarine Wetlands	NSW

Coordinates

-36.89331 149.91492

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World Heritage and Register of National Estate properties, Wetlands of International Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

For species where the distributions are well known, maps are digitised from sources such as recovery plans and detailed habitat studies. Where appropriate, core breeding, foraging and roosting areas are indicated under 'type of presence'. For species whose distributions are less well known, point locations are collated from government wildlife authorities, museums, and non-government organisations; bioclimatic distribution models are generated and these validated by experts. In some cases, the distribution maps are based solely on expert knowledge.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Department of Environment, Climate Change and Water, New South Wales
-Department of Sustainability and Environment, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment and Natural Resources, South Australia
-Parks and Wildlife Service NT, NT Dept of Natural Resources, Environment and the Arts
-Environmental and Resource Management, Queensland
-Department of Environment and Conservation, Western Australia
-Department of the Environment, Climate Change, Energy and Water
-Birds Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-SA Museum
-Queensland Museum

- -Online Zoological Collections of Australian Museums
- -Queensland Herbarium
- -National Herbarium of NSW
- -Royal Botanic Gardens and National Herbarium of Victoria
- -Tasmanian Herbarium
- -State Herbarium of South Australia
- -Northern Territory Herbarium
- -Western Australian Herbarium
- -Australian National Herbarium, Atherton and Canberra
- -University of New England
- -Ocean Biogeographic Information System
- -Australian Government, Department of Defence
- -State Forests of NSW
- -Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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Data from the BioNet Atlas of NSW Wildlife website, which holds records from a number of cust
Species listed under the Sensitive Species Data Policy may have their locations denatured (^ ro

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Class	Family	Scientific Name
Amphibia	Hylidae	*Litoria aurea*
Aves	Diomedeidae	*Diomedea gibsoni*
Aves	Diomedeidae	*Thalassarche cauta*
Aves	Procellariidae	*Pterodroma nigripennis*
Aves	Ardeidae	*Botaurus poiciloptilus*
Aves	Accipitridae	*^^Lophoictinia isura*
Aves	Accipitridae	*Hieraaetus morphnoides*
Aves	Accipitridae	*Pandion cristatus*
Aves	Haematopodidae	*Haematopus fuliginosus*
Aves	Haematopodidae	*Haematopus longirostris*
Aves	Charadriidae	*Thinornis rubricollis*
Aves	Cacatuidae	*^^Callocephalon fimbriatum*
Aves	Cacatuidae	*^Calyptorhynchus lathami*
Aves	Psittacidae	*^^Lathamus discolor*
Aves	Psittacidae	*Glossopsitta pusilla*
Aves	Strigidae	*^^Ninox connivens*
Aves	Strigidae	*^^Ninox strenua*
Aves	Tytonidae	*^^Tyto novaehollandiae*
Aves	Meliphagidae	*Epthianura albifrons*
Aves	Neosittidae	*Daphoenositta chrysoptera*
Aves	Pachycephalidae	*Pachycephala olivacea*
Aves	Petroicidae	*Melanodryas cucullata cucullata*
Aves	Petroicidae	*Petroica boodang*
Aves	Petroicidae	*Petroica phoenicea*
Aves	Estrildidae	*Stagonopleura guttata*
Mammalia	Dasyuridae	*Dasyurus maculatus*
Mammalia	Phascolarctidae	*Phascolarctos cinereus*
Mammalia	Petauridae	*Petaurus australis*
Mammalia	Potoroidae	*Potorous tridactylus*
Mammalia	Pteropodidae	*Pteropus poliocephalus*
Mammalia	Vespertilionidae	*Falsistrellus tasmaniensis*
Mammalia	Vespertilionidae	*Miniopterus schreibersii oceanensis*
Mammalia	Vespertilionidae	*Scoteanax rueppellii*
Mammalia	Dugongidae	*Dugong dugon*
Mammalia	Otariidae	*Arctocephalus forsteri*
Mammalia	Otariidae	*Arctocephalus pusillus doriferus*
Mammalia	Balaenopteridae	*Megaptera novaeangliae*
Mammalia	Physeteridae	*Physeter macrocephalus*
Flora	Araliaceae	*Astrotricha sp. Wallagaraugh*
Flora	Rhamnaceae	*Pomaderris bodalla*
Flora	Rutaceae	*Leionema ralstonii*

odians.
ɪunded to 0.1°; ^^ rounded to 0.01°).

Common Name	Legal Status
Green and Golden Bell Frog	E1
Gibson's Albatross	V
Shy Albatross	V
Black-winged Petrel	V
Australasian Bittern	E1
Square-tailed Kite	V
Little Eagle	V
Eastern Osprey	V
Sooty Oystercatcher	V
Pied Oystercatcher	E1
Hooded Plover	E4A
Gang-gang Cockatoo	V
Glossy Black-Cockatoo	V
Swift Parrot	E1
Little Lorikeet	V
Barking Owl	V
Powerful Owl	V
Masked Owl	V
White-fronted Chat	V
Varied Sittella	V
Olive Whistler	V
Hooded Robin (south-eastern form)	V
Scarlet Robin	V
Flame Robin	V
Diamond Firetail	V
Spotted-tailed Quoll	V
Koala	V
Yellow-bellied Glider	V
Long-nosed Potoroo	V
Grey-headed Flying-fox	V
Eastern False Pipistrelle	V
Eastern Bentwing-bat	V
Greater Broad-nosed Bat	V
Dugong	E1
New Zealand Fur-seal	V
Australian Fur-seal	V
Humpback Whale	V
Sperm Whale	V
Merimbula Star-hair	E1
Bodalla Pomaderris	V
Ralston's Leionema	V

Appendix C

Flora and Fauna of Merimbula Lake - 1984

Appendix C Flora and Fauna of Merimbula Lake - 1984

List of aquatic macrophytes and invertebrate animals recorded in Merimbula Lake estuary (1984)

Phylum	Genus-species	Intertidal sandy mud	Rocks *and* oyster racks	Saltmarshes and mangroves	Subtidal
Chlorophyta (Green algae, green seaweeds)	*Acetabularia* sp. Mermaid's cup (?)			Rare	
	Cladophora sp.		Common		
	Codium sp. (arborescent)				Rare
	Codium sp.				Common
	Codium sp. (prostrate)	Rare			
	Ulva intestinalis (formerly Enteromorpha)		Abundant		Abundant
	Ulva lactuca Sea lettuce			Abundant	Abundant
Heterokontophyta (Brown algae, brown seaweeds)	*Colpomenia sinuosa* (ephiphytic) Sinuous ballweed				Common
	Dictyota sp. Forkweed				Common
	Hormosira banksii Neptune's necklace		Abundant		
Rhodophyta (Red algae, red seaweeds)	Sargassum sp.				Fairly common
	Laurencia sp.				Common
	Lophosiphonia sp.				Common
	Polysiphonia sp.				Fairly common
	Thuretia sp.				Rare
Magnoliophyta	Aegiceras corniculatum River mangrove			Fairly common	
	Avicennia marina Grey mangrove			Abundant	
	Halophila ovalis Paddle grass	Abundant			Abundant
	Juncus kraussii Sea rush			Abundant	
	Phragmites australis Common reed			Abundant	
	Sarcocornia quinqueflora Beaded glasswort			Abundant	
	Posidonia australis Strap grass				Abundant
	Bolboschoenus caldwellii (cited as Scirpus maritimus)			Rare	
	Selliera radicans Selliera			Rare	
	Spergularia rubra Sand spurry			Fairly common	

Phylum	Genus-species	Intertidal sandy mud	Rocks *and* oyster racks	Saltmarshes and mangroves	Subtidal
	Sporobolus virginicus Saltwater couch	Common		Common	
	Triglochin striata Streaked arrowgrass			Fairly common	
	Typha sp. Cumbungi			Rare	
	Zostera capricorni Eelgrass	Abundant			Abundant
	Zostera muelleri Eelgrass	Common			
Cnidaria	Actinia ?tenebrosa		Rare		
	?Hydractinia				Fairly common
	?Edwardsiidae	Rare			Rare
Phoronida	*Phoronis albomaculata*	Fairly common			Fairly common
	Phoronis psammophila	Fairly common			Rare
	Phoronopsis harmier	Common			Fairly common
Sipuncula	*Phascolosoma annulatum*	Rare			Rare
Polychaeta: errantia	Ancistrosyllis cf. constricta	Rare			
	Australonereis ehlersi	abundant			
	Brania clavata	rare			
	Ceratonereis pseudoerythraeensis	abundant			common
	Ceratonereis mirabilis	common			fairly common
	Eulalia (Eumid) sanguinea	rare			
	Eunice antennata	rare			rare
	Exogone cf. Verugera	rare			
	Glycera americana	rare			rare
	Glyera tesselata	rare			rare
	Harmothoe praeclara	common			common
	Lumbrineris coccinea	rare			
	Lumbrineris latreilli	common			abundant
	Lumbrineris tetraura	rare			fairly common
	Lysidice natalenis		rare		
	Marphysa macintoshi			rare	
	Marphysa sanguine	rare			Rare
	Nematonereis unicronis	rare			
	Nephtys australiensis	abundant			common

Phylum	Genus-species	Intertidal sandy mud	Rocks *and* oyster racks	Saltmarshes and mangroves	Subtidal
	Nepthys longipes	fairly common			
	Nereis (Neanthes) acuminata				rare
	Nereis (Neanthes) vaalii		rare		
	Ophiodromus sp.	rare			rare
	Paralepidonotus ampulliferus		rare		
	Perinereis nuntia brevicirris	fairly common			
	Perinereis obfuscata	rare			
	Phyllodoce (Anaitides) ?australis	rare			rare
	Pionosyllis ehlersiaeformis				rare
	Platynereis australis	rare			
	Platynereis dumerilii				rare
	Protodorvillea sp. 1	rare			
	Pseudonereis variegata		rare		
	Schistomeringos rudolphi	rare			rare
	Sigalion ovigerum	fairly common			
	Sphaerosyllis semiverrucosa	rare			
	Syllis (Typosyllis) armillaris	rare			rare
	Syllis (Typosyllis) hyaline	rare			
Polychaeta: Sedentaria	*Aonides oxycephala*	rare			Rare
	Armandia intermedia	fairly common			fairly common
	Barantolla lepte	common			common
	Boccardia chilensis		rare		
	Capitella capitata	rare			rare
	Caulleriella tricapillata	rare			
	Chaetopterus variopedatus	rare			
	Cirriformia chrysoderma nuchalis	fairly common			rare
	Cirriformia filigera	abundant			
	Cirriformia tentaculata	fairly common			abundant
	Euclymene trinalis	rare			
	Galeolaria caespitosa		Abundant		
	Heteromastus filiformis	fairly common			fairly common

Phylum	Genus-species	Intertidal sandy mud	Rocks *and* oyster racks	Saltmarshes and mangroves	Subtidal
	Janua (Dexiospira) brasiliensis				abundant
	Janua (Dexiospira) steueri			abundant	
	Magelona cf. pitelkai	rare			fairly common
	Mediomastus californiensis	common			common
	Mesochaetopterus ?saggitttarius				rare
	Terebella sp. nov.	fairly common	rare		
	Notomastus torquatus	fairly common		rare	rare
	Owenia fusiformis	fairly common		rare	
	Phylo felix				rare
	Pista typha	common			common
	Polydora socialis	fairly common			
	Polyophthalmus pictus	rare			
	Pomatoceros caeruleus		rare		rare
	Prionospio (Aquilaspio) aucklandica	rare			common
	Prionospio (Aquilaspio) multipinnulata				rare
	Prionospio (Minuspio) cirrifera	rare			rare
	Pseudopolydora kempi	common			
	Rhinothelepus macer				rare
	Samythella sp.	rare			
	Scoloplos cylindrifer	rare			
	Scoloplos simplex	common			
	Spio pacifica	rare			
	Terebella cf. Ehrenbergi	rare	rare		
Cirripedia	Balanus variegatus var. cirratus		rare		
	Balanus trigonus		rare		
	Chthmalus antennatus		rare		
	Elminius modestus		abundant		
	Tetraclitella purpurascens		fairly common		
Amphipoda	*Aora* MER 312 H			rare	
	Aoroides MER 148 Y	rare		rare	
	Corophium MER 93 K	rare		rare	

Phylum	Genus-species	Intertidal sandy mud	Rocks *and* oyster racks	Saltmarshes and mangroves	Subtidal
	Cymadusa sp.1 MER 93 J	common		abundant	
	Cymadusa sp.2 MER 235 Y			common	
	Exoediceros fossor	abundant			rare
	Exoediceros sp. MER 56 C	rare			
	Eusiridae ? gen MER 301 J			rare	
	Haustoriidae gen. M MER 3 D	fairly common			
	Haustoriidae gen. N MER 163 D	rare			
	Isaeidae MER 249 E	rare			
	Limnoporeia yarrague	rare			
	Maera sp. MER 289 L			rare	
	?Megamphopus MER 93 P	rare		rare	
	Melita MER 42 D	rare		rare	rare
	?Monoculodes MER 195 N	common			
	Oedicerotidae sp. A MER 207 K	fairly common			
	Oedicerotidae sp. C MER 220 Z	fairly common			
	Oedicerotidae sp. 1 MER 275 O	rare			rare
	Oedicerotidae sp. 2 MER 279 D		rare		
	Orchestia chilensis MER 5 A	rare			
	Orchestia sp. 2 MER 96 E	rare			
	Paracalliope sp. MER 24 D	rare			rare
	Phoxecephalidae A MER 241 C	abundant			abundant
	Phoxecephalidae B MER 275 P	abundant			
	?Podoceropsis sp. MER 73 F	rare			rare
	?Talitroides MER 172 A	rare			
	Talorchestia sp. MER 308 B	fairly common			
	Tethygeneia sp.	rare			
	Urohaustorius metungi	abundant			
Isopoda	*Actaccia pallida*	abundant			
	Cirolana cf. arcuata	abundant			

Phylum	Genus-species	Intertidal sandy mud	Rocks *and* oyster racks	Saltmarshes and mangroves	Subtidal
	Deto marina			rare	
	Codonophilus cf. imbricatus				rare
	Ligia australiensis			rare	
	Mesanthura sp. MER 272 Q	rare			
	Nerocila macleayi				rare
	Paridotea ungulate	rare			rare
Mysidacea	*Gastrosaccus dakini*	rare			
Decapoda: Macrura	Alpheus sp.	fairly common			fairly common
	Macrobrachium intermedium				abundant
	Palaemon affinis				rare
	Penaeus plebejus	rare			rare
Decapoda: Anomura	*Callianassa arenosa*	fairly common			rare
	Callianassa australiensis	fairly common			
	Diogenes custos	fairly common			
Decapoda: Brachyura	*Brachynotus spinosus*	rare	rare		
	Carinus ? maenas	rare			rare
	Cyclograpsus audouinii		rare		
	Halicarcinus cf. ovatus	rare			rare
	Halicarcinus paralacustris	fairly common			rare
	Heloecius cordiformis			fairly common	
	Helograpsus haswellianus			common	
	Mictyris longicarpus	abundant			
	Mictyris platycheles	abundant			
	Ovalipes australiensis				rare
	Pachygrapsus laevimanus		rare		
	Paragrapsus laevis	rare			
	Pilumnopeus serratifrons		rare		
	Portunus pelagicus				rare
	Sesarma erythrodactyla			common	
	Thalamita intermedia	rare			
	Thalamita sima				rare
Mollusca: Polyplacophora	*Ischnochiton elongatus crispus*				rare
Bivalvia	*Ambuscintilla*	rare			

Phylum	Genus-species	Intertidal sandy mud	Rocks *and* oyster racks	Saltmarshes and mangroves	Subtidal
	praemium				
	Anadara trapezia	rare			common
	Arthritica helmsi	abundant			rare
	Bankia cf. carinata			common	
	Cyammiomactra cf. symmetrica				rare
	Eumarcia fumigata	common			
	Fluviolanatus amarus	rare			
	Irus crenata	rare			
	Katelysia rhytiphora	rare			rare
	Katelysia scalarina	rare			
	Lasaea australis		rare		
	Laternula creccina	rare			rare
	Mesodesma elongate	rare			
	Musculus cumingianus		rare		
	Mysella sp.	common			common
	Mytilus edulis		rare		fairly common
	Notospisula trigonella	rare			rare
	Ostrea angasi		rare		
	Psammobia donacioides	rare			rare
	Saccostrea commercialis		abundant		
	Solemya velesiana				rare
	Tapes cf. watlingi	rare			
	Tellina (Abranda) modestina				rare
	Tellina (Macomona) deltoidalis	common			common
	Trichomya hirsuta		rare		common
	Wallucina assimilis	common			common
	Xenostrobus securis		fairly common		
Gastropododa: Prosobranchia	*Austrocochlea constricta*	rare	common		fairly common
	Bedeva hanleyi	rare			fairly common
	Bembicium auratum		abundant		
	Bembicium melanostomum		rare		
	Bembicium nanum		common	abundant	
	Bittium lacertinum	rare			abundant
	Patelloida mimula		fairly common		
	Cominella eburnea		rare		

Phylum	Genus-species	Intertidal sandy mud	Rocks *and* oyster racks	Saltmarshes and mangroves	Subtidal
	Diala sp. MER 31 J	fairly common			abundant
	Hydrobia buccinoides	rare			abundant
	Littorina scabra			rare	
	Littorina unifasciata		common		
	Montfortula conoidea		rare		
	Nassarius burchardi	fairly common			common
	Nassarius jonasii	common			fairly common
	Nerita airamentosa		rare		
	Neritina sp. MER 283 K	rare			
	Nodolittorina pyramidalis		rare		
	Patelloida alticostata		rare		
	Polinices (Conuber) sordidus	rare			
	Prothalotia comtessei	rare			fairly common
	Pseudoliotia micans	fairly common			rare
	Pyrazus ebeninus	common			
	Tatea kesteveni			rare	
	Tatea rufilabris	rare			
	Velacumantis australis	rare			
Gastropoda: Opisthobranchia	*Akera soluta*	fairly common			
	Aplysia cf. dactylomela	rare			
	Chemnitzia sp. MER 220 M	rare			
	Cingula spoina	rare			fairly common
	Odostomia sp. MER 219 X	rare			
Gastropoda: Nudibranchia	*Aclis* MER 51 L, 58 P	rare			
Gastropoda: Pulmonata	Ellisiphon cf. denticulatus		rare		
	Ophiocardelus quoyi			fairly common	
	Ophiocardelus sulcatus	rare			
	Onchidella patelloide	rare			
	Salinator fragilis			abundant	
	Salinator solida		rare		
Cephalopoda	*Euprymna stenodactyla*				rare
	Idiosepius notoides				rare
Echinodermata	*Patriella exigua*		rare		
	Amphipholis	rare			rare

Phylum	Genus-species	Intertidal sandy mud	Rocks *and* oyster racks	Saltmarshes and mangroves	Subtidal
	squamata				
	Leptosynapta dolabrifera	rare			rare
	Synaptidae ?gen MER 285 T				rare
Chordata: Ascidiacea			rare		

List of fish recorded in Merimbula Lake (1984)

Scientific name	Common Name	Frequency
Acantholeuteres spilomelanurus	leather jacket	rare
Acanthopagrus australis	yellow fin bream	rare
Acanthopagrus butcheri	black bream	rare
Aldrichetta forsteri	yellow-eyed mullet	rare
Ammotretis rostratus	flounder	rare
Arenigobius befrenatus	goby	rare
Argyrosomus hololepidotus	mulloway	rare
Centropogon australis	fortesque	fairly common
Chrysophrys auratus	snapper	rare
Cheilinus bimaculatus	wrasse	rare
Cristiceps australis	crested weedfish	rare
Enoplosus armatus	oldwife	rare
Favonigobius lateralis	long finned goby	rare
Favonigobius tamarensis	Tamar river goby	rare
Girella tricuspidata	blackfish	common
Gobiopterus semivestitus	transparent goby	rare
Hippocampus abdominalis	seahorse	rare
Hyporhamphus australis	garfish	rare
Lethrinus nematacanthus	scavenger	rare
Meuschenia freycineti	leather jacket	fairly common
Meuschenia hippocrepis	variable leather jacket	rare
Meuschenia trachylepis	MER 105 E	rare
Monacanthus chinensis	fan bellied leather jacket	rare
Mugil cephalus	sea mullet	rare
Mugil georgii	fantail mullet	rare
Mugilidae	juveniles	abundant
Muraenichthys australis	worm eel	rare
Myxus elongatus	sand mullet	rare
Neoodax balteatus	little rock whiting	rare
Nesogobius pulchellus	pretty goby	common
Nesogobius sp. MER 278 T	goby	rare
Ophisurus serpens	snake eel	rare
Parkraemia ornata	ornate goby	rare
Penicipelter vittiger	leather jacket	rare

Scientific name	Common Name	Frequency
Petroscirtes lupus	blenny	rare
Platycephalus fuscus	dusky flathead	common
Platycephalus laevigatus	smooth flathead	rare
Platycephalus marmoratus	marbled flathead	rare
Pomatomus saltatrix	tailor	rare
Pranesus ogilbyi	hardyhead	rare
Pseudogobius olorum	Swan river goby	rare
Redigobius macrostoma	large mouthed goby	rare
Rhabdosargus sarba	tarwhine	rare
Scorpaena cf. cruenta	rock cod	rare
Sillago ciliata	sand whiting	fairly common
Sillago maculate	trumpeter whiting	rare
Stethojulis interrupta	wrasse	rare
Stigmatophora argus	spotted pipefish	abundant
Stigmatophora nigra	pipefish	abundant
Syngnathus phillipi	pipefish	rare
Torquigener glaber	puffer	rare
Torquigener hamiltoni	puffer	rare
Urocampus carinirostris	pipefish	rare
Usacaranx georgianus	trevally	abundant
Vincentia charysurus	cardinal fish	rare

Aquatic birds recorded in 1974-76 in Merimbula Lake (1984)

Scientific name	Common name	Frequency	Habits	Food
Anas superciliosa	black duck	fairly common in spring	dabbler	invertebrates and algae
Ardea novaehollandiae	white faced heron	common in Spring	wader	fish and crustacea
Calidris ferruginea	curlew sandpiper	rare in summer	wader on sand and mud	Invertebrates
Cygnus atratus	black swan	common in spring	swimmer	grazes on Zostera etc
Egretta garzetta	little egret	fairly common in spring	wader	fish and crustacea
Haematopus fuliginosus	sooty oystercatcher	frequent in spring	wader on rocks and oyster racks	invertebrates
Haematopus longirostris	pied oystercatcher	common in spring	wader on sandy mud	mainly crustacean fish
Larus novaehollandiae	silver gull	common in spring	Scavenges on shores and shallows	general carnivore
Limosa lapponica	bar-tailed godwit	common in spring and summer	wader on mud	mainly polychaetes
Numenius madagascariensis	eastern curlew	common in spring and summer	wader on mud in mangroves	invertebrates
Phalacrocarax carbo	black cormorant	common in spring	swimmer and diver	fish
Phalacrocarax melanoleucos	little pied cormorant	common in spring	swimmer and diver	fish
Phalacrocarax sulcirostris	little black cormorant	occasional in spring	swimmer and diver	fish
Sterna bergii	crested tern	common in spring	plunge dives	fish

Appendix D

Supplementary Report (Elgin Associates, 2013)

Ecological Assessment of the Potential Impacts On Merimbula Lake From Dunal Exfiltration Of Effluent

SUPPLEMENTARY REPORT

FINAL REPORT

Prepared for

Bega Valley Shire Council

Zingel Place, Bega

5 March 2013

PROJECT REFERENCE: JN12073

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Reviewed by:	Andrew Roberts	**Date:** 5 March 2013 **Status:** FINAL
Filename:	JN12073_R100c	
Project:	Elgin JN12073 Supplementary Report	

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Record of Report Distribution

Nº of copies	**Status**	**Date**	**Prepared for:**
1 digital	Draft	12 February 2013	BVSC
1 digital	Draft	28 February 2013	BVSC
1 digital	Final	5 March 2013	BVSC

EXECUTIVE SUMMARY

Elgin Associates Pty Ltd (Elgin Associates) was engaged by Bega Valley Shire Council (BVSC) to undertake a supplementary study for the - 'Ecological Assessment of the potential impacts on Merimbula Lake from dunal ex-filtration of effluent'. Information provided in this report specifically reviews the potential impact that increased freshwater and nutrient flux may have on the ecological values of the lake and more specifically, what responses may be expected from estuarine vegetation at the site.

This information includes:

- Confirmation of and description of vegetation communities at the site;
- Qualitative discussion regarding the hydrodynamics of Merimbula Lake;
- The current ecological condition and surface water quality of Merimbula Lake;
- Factors that could influence the response of vegetation communities to increased nutrient flux; and
- Local case study of increased nutrient supply to an estuarine setting.

IGGC (2013) modelled groundwater flow mass balance for year 2025 estimated effluent disposal volumes via a 400 metre exfiltration trench located within BVSC land in the dunes east of Merimbula airport. Model outcomes predict a net increase in groundwater discharge to Merimbula Lake of approximately 7.5%, occurring within an area of approximately 28,000 m^2 on the eastern side of the lake. Under scenarios 2 and 4 of the four scenarios modelled by IGCC (2013) using year 2025 estimated effluent disposal volumes, steady state concentrations of nitrogen (mostly as bioavailable NO_3) and phosphorous (mostly as bioavailable PO_4) were predicted to be discharged from the lake bed after 15 to 27 years, respectively. Under scenarios 1 and 3 neither nitrate nor phosphate from effluent reach the lake in groundwater within the 57 year modelled period.

For scenarios 2 and 4, tidal flushing will dilute and reduce the concentration of nitrogen and phosphorous discharging within groundwater within the identified discharge plume area and transport these nutrients to other regions of the lake. Nevertheless, this discharge of nutrients from sediment porewater would represent a new continuous supply of inorganic N and P in bioavailable forms that has the potential to further stimulate existing levels of primary production at the site and within the lake generally. A potentially vulnerable area of the lake to increased supply of bioavailable nutrients is the backwater Golf Course Lake due to its reduced capacity for flushing and estimated longer water residence times

TABLE OF CONTENTS

LIST OF TABLES, DRAWINGS & APPENDICES

LIST OF TABLES (IN TEXT)

LIST OF TABLES (ATTACHED)

LIST OF FIGURES (ATTACHED/IN TEXT)

LIST OF APPENDICES

LIST OF ABBREVIATIONS AND ACRONYMS

ANZECC	Australia and New Zealand Environment Conservation Council
BVSC	Bega Valley Shire Council
Chl a	chlorophyll a
DO	Dissolved oxygen
DECCW	NSW Department of Environment and Climate Change Water
EC	Electrical conductivity
FRP	Filterable Reactive Phosphate (*also known as* ortho-phosphate)
K_d	Partition coefficient
Km^2	Kilometers squared
m^2	Metres squared
mg/L	Milligrams per litre
NH_4^+	ammonium
NOx	Oxides of nitrogen including nitrate (NO_3^-)and nitrite (NO_2^-)
NTU	Nephelometric Turbidity Units
K_d	Partition coefficient
OEH	NSW Office of Environment and Heritage
pH	Measure of the acidity or alkalinity of a solution
SEPP	State Environment Protection Policy
STP	Sewage treatment plant
t	Tonne
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen (all organic forms of nitrogen)
TN	Total Nitrogen (all forms of N)
TP	Total Phosphorous (all forms of P)
TSS	Total Suspended Solids
µg/L	Micrograms per litre
µM	Micromolar
N/A	Not Applicable

GLOSSARY

bioturbation	reworking of sediment causing displacement and mixing of sediment particles and porewater through burrowing activity
bioirrigation	the process of benthic organisms flushing their burrows with overlying water
flux	*in context of this report* - the rate of transport of materials from the sediments to the overlying water column (refer Fick's Law)
K_d	Partition distribution coefficient – a parameter used to estimate the migration potential of contaminants present in aqueous solutions in contact with surface, subsurface and suspended solids.
microphytobenthos	the microscopic, photosynthetic eukaryotic algae and cyanobacteria that live on seafloor habitats ranging from wave swept beaches to detritus-laden backwater lagoons.
thallus	the algal body; also used in relation to other simply constructed, non-vascular plants; *plural* thalli**.**

INTRODUCTION

Elgin Associates Pty Ltd (Elgin Associates) was engaged by Bega Valley Shire Council (BVSC) to undertake a supplementary study to support the - 'Ecological Assessment of the potential impacts on Merimbula Lake from dunal ex-filtration of effluent' study being undertaken by AECOM consultants.

This supplementary study provides information regarding the vegetation communities and algal taxa present in the area, referred to herein as 'the site', that modelling by IGGC (2013) shows may be affected by the discharge of nutrient-enriched groundwater should effluent disposal by dunal exfiltration proceed within the dunes east of Merimbula airport. Particular attention is given to algal communities present at the site and in the lake more broadly, as prolific algal growth is typically the first indication of excess nutrients becoming a problem. Finally, the potential impacts of increased nutrient flux on the ecology of Merimbula Lake is considered given the data available and patterns observed in estuarine settings elsewhere in the region and in Australia more broadly.

1.1 Background

BVSC engaged AECOM in 2009 to investigate, identify and assess options for the beneficial use of effluent and disposal of that proportion of flows unable to be beneficially used (excess effluent) from the Merimbula sewage treatment plant (STP). The outcome of the options investigation is to form a strategy for effluent management that provides the greatest benefit to the community and environment, whilst being affordable.

A range of investigations have been undertaken to identify options for the disposal of effluent from the STP including the construction of an exfiltration system within the Merimbula-Pambula dunal system to allow effluent to exfiltrate into the dunal aquifer. This option would result in groundwater near an exfiltration system being recharged by effluent in addition to rainwater resulting in an increase in the natural volume and flow of groundwater towards the ocean and the lake.

Groundwater flow modelling (IGGC 2013) for year 2025 estimated effluent disposal volumes via a 400 metre exfiltration trench located within BVSC land in the dunes east of Merimbula airport indicates that the majority of effluent disposed would flow in groundwater towards the ocean (approximately 81%) and the remainder would flow westward towards Merimbula Lake. Further modelling was undertaken by IGGC (2013) to assess the potential for phosphorous (P) and nitrogen (N) in effluent to migrate in groundwater to Merimbula Lake and the ocean. Four scenarios were modelled with discharge flux rates and typical nitrogen and phosphorous concentrations in groundwater estimated for the identified discharge zones in the bay and lake for each scenario. The potential ecological impacts on the vegetations communities within predicted discharge zones is the subject of this supplementary report.

The approximate location of the ex-filtration trench used by IGGC (2013) for the groundwater flow and water quality modelling assessment is shown in Figure 1 with groundwater flow directions (drawn conceptually) and the area of the lake that was investigated during this study outlined.

Figure 1. Overview of the area of investigation in relation to the Merimbula STP, the existing dunal exfiltration ponds and the location of the exfiltration trench used for the modelling assessment.

1.2 Summary of IGGC (2013) modelling

A brief summary of the IGGC (2013) groundwater model output for year 2025 estimated effluent disposal volumes via a 400 metre exfiltration trench located as shown in Figure 1 is presented here to provide context for this report.

Four scenarios were modelled to examine existing (8.5 mg/L) and reduced (1.5 mg/L) phosphate concentrations present in discharged effluent from the STP, two K_d values for phosphorus sorption in the sediments and two R values for nitrate decay in the sediments. The outcomes of modelled K_d and R values are summarised conceptually in terms of best and worse cases below:

K_d 0.1 mL/g-------------------------|------------------------ K_d 2.0 mL/g	
Low P sorption capacity	Some P sorption capacity
R 0.0 day $^{-1}$---------------------------|------------------------ R 0.002 day $^{-1}$	
No denitrifcation	Some denitrification
worse case	***best case***

The K_d value of 2.0 was obtained from testing of the dune sediments in the central dune region and is considered to provide a conservative estimate of the P sorption capacity of the dune material in the area of the exfiltration system shown in Figure 1. The K_d value of 0.1 is considered to provide a worst-case estimate for phosphate removal (IGGC 2013).

The R value of 0.002 was obtained from calibration of a simple numeric model of groundwater flow and total inorganic nitrogen concentrations in two groundwater monitoring bores near to the existing effluent ponds. It represents a conservative first-order decay reaction estimate of nitrate removal by denitrification. The R value of 0 is considered to provide a worst-case estimate for nitrate removal (IGGC 2013).

Models were based on a 57 year simulation as this encompasses the realistic lifespan of an exfiltration system, that is likely to be 20 to 50 years (IGGC 2013).

The four scenarios modeled were:

Scenario 1	High P as Phosphate in effluent (8.5 mg/L) and Low K_d (2.0), R (NO_3) = 0.002
Scenario 2	High P as Phosphate in effluent (8.5 mg/L) and Very Low K_d (0.1), R (NO_3) = 0
Scenario 3	Low P as Phosphate in effluent (1.5 mg/L) and Low K_d (2.0), R (NO_3) = 0.002
Scenario 4	Low P as Phosphate in effluent (1.5 mg/L) and Very Low K_d (0.1), R (NO_3) = 0

1.2.1 Groundwater Discharge to Receiving Waters

Effluent disposal via an exfiltration trench in the location shown in Figure 1 results in an overall increase in net groundwater discharge to receiving waters. For year 2025 estimated disposal volumes in this location, the greatest increase in groundwater discharge would occur to the ocean, with a total net increase 73% higher than under natural conditions. The total net increased discharge to the lake is estimated at 7.5% higher than under natural conditions. Modelling estimates groundwater to travel from the exfiltration trench to the lakeshore in approximately 7 years, with typical travel times of 12 years or more prior to lake-bed discharge. There is a clear decrease in groundwater velocity once the lakeshore is reached reflecting the low hydraulic gradient in the shallow aquifer beneath the lake (IGGC 2013).

1.2.2 Nutrient Transport and Flux

IGGC (2013) model output included figures showing typical N and P concentrations in groundwater that can be expected for the identified discharge zones (shore and near-shore) in the lake and ocean for each scenario. Figures showing nutrient concentration pathlines and the areas of the lakeshore affected are contained in Appendix A.

Under scenarios 1 and 3, where a conservative decay reaction estimate for nitrate removal (R = 0.002) and a conservative phosphorous sorption capacity of the sediments (K_d = 2.0) is assumed, modelling shows nitrate and phosphate from effluent disposal does not reach the lakeshore, irrespective of P concentration being 8.5 mg/L or 1.5 mg/L in effluent.

However, under scenario 2, where no decay rate for nitrate (R = 0) is assumed and the phosphorous sorption capacity of the sediments is assumed very low (K_d = 0.1), nitrate and phosphate is predicted to reach the lakeshore and discharge from the lake-bed. Scenario 2 represents a "worse-case" and predicts that nitrate will reach the lake-bed along 1,700 m of shoreline within 3 years with the discharge plume extending up to 250 m from the shore and reach a steady state discharge concentration of 0.8 mg/L within the near shore zone within 15 years. Phosphate is predicted to reach the lake-bed along 1,800 m of shoreline within 5.5 years with the discharge plume extending up to 220 m from the shore and reach a steady state discharge concentration of 2.5 mg/L within the near shore zone within 27 years.

For all scenarios, an increased volume of freshwater will also discharge from the lake-bed. Predicted nutrient discharge concentrations, the lake area affected determined from the modelling and equivalent flux rates are summarised in Table 1 (below).

Table 1. Predicted phosphate and nitrate concentrations for modelled discharge zones and equivalent flux rates (based on data from Table 13.6, 13.10 & 13.11 in IGGC 2013).

Scenario	Lake Shore[1]			Lake Near Shore		
	Mean conc. (mg/L), Length (m)	Nutrient flux rate[2] (g/day)	Nutrient flux rate[2] (µmol/m^2/hr)	Mean conc. (mg/L), Area (m^2)	Nutrient flux rate (g/day)	Nutrient flux rate (µmol/m^2/hr)
Phosphate (as P)						
1	0 mg/L, 0 m	0	-	0 mg/L, 0 m^2	0	-
2	5 mg/L, 400 m *1.5 mg/L, 1,400 m*	2,326	769	2.5 mg/L, 287,400 m^2	961	10
3	0 mg/L, 0 m^2	0	-	0 mg/L, 0 m^2	0	-
4	0.8 mg/L, 400 m *0.4 mg/L, 1200 m*	426	158	0.3 mg/L, 153,100 m^2	90	2
Nitrate (as N)						
1	0 mg/L, 0 m^2	0	-	0 mg/L, 0 m^2	0	-
2	1.4 mg/L, 400 m *0.6 mg/L, 1,300 m*	724	253	0.8 mg/L, 242,400 m^2	200	3
3	0 mg/L, 0 m^2	0	-	0 mg/L, 0 m^2	0	-
4	1.4 mg/L, 400 m *0.6 mg/L, 1,300 m*	724	253	0.8 mg/L, 242,400 m^2	200	3

Note:

[1] Lake Shore values provided represent inner and outer (*values italicized*) zones, coinciding with the constant head boundary (the central area with greatest flow and highest concentration) and the remainder, and indicate the linear distance along which increased nutrient flux is expected.

[2] Nutrient flux rate (as g/day and) represents total sum for both inner and outer lakeshore zones.

1.3 Assessment of Ecological Impact

In order to assess the relative impact of each of the simulated nutrient transport scenarios on the Lake's ecology, the scenarios may be ordered in terms of best to worse case scenarios as follows:

	Scenario	Outcomes
Best Case	1 & 3	increased freshwater flux only
	4	increased freshwater, nitrate and low phosphate flux
Worse Case	2	increased freshwater, nitrate and high phosphate flux

An assessment of ecological impact for each of these cases is being undertaken by AECOM (report *in prep*.). The purpose of this supplementary report is to provide additional data regarding the potential impact that increased freshwater and nutrient flux may have on the ecological values of the lake and more specifically, what responses may be expected from estuarine vegetation at the site.

1.4 Scope of Work

In order to provide more site-specific information regarding how the vegetation communities and algae at the site may respond to increased levels of nutrients (N and P) due to groundwater discharge, the following scope of work was undertaken:

1) Background review of the IGGC (2013) report, and review relevant data regarding ecological condition of Merimbula Lake;

2) Conduct a site inspection to confirm what vegetation communities (saltmarsh, mangrove, seagrass and algae) and species are specifically present at the 'site';

3) Conduct a literature review regarding the vegetation communities and species found at the site, with qualitative discussions that include a focus on potential impacts of increased P and N nutrients; and

4) Preparation of this report containing the findings of the site inspection and literature review.

2.1 Site Inspection

A field inspection of the site was undertaken after review of the following information:

- IGGC report (IGGC 2013);
- estuarine vegetation mapping for Merimbula Lake (Creese *et al.* 2009); and
- modelled nutrient (N and P) pathlines (IGGC 2013) showing the areas of the lake likely to be affected by increased concentrations of nutrients discharged via groundwater.

Review of this information informed the site inspection by defining the site boundary as shown in Figure 2 (attached). The extent of the site boundary was based on the nutrient distribution pathlines for the worse case scenario (*i.e.* Figures 9b and 9e in Appendix A). Estuarine habitat mapping by Creese *et al.* (2009) provides the most current assessment of vegetation distribution for Merimbula Lake including the site area.

Inspections were carried out from a small workboat with wading of most areas required due to the shallow depths encountered. The site inspections consisted of a combined haphazard and transect survey approach. Qualitative observations were recorded haphazardly over the site with detailed inspections conducted along six transects situated across the site area. Transect locations were spaced approximately 300 – 400 m apart and determined largely by the vegetation communities mapped by Creese *et al.* (2009). Transect locations with regard to the mapped vegetation communities are shown on Figure 3 (attached) with coordinates provided in Table 2.

Table 2. Transect coordinates

Transect	Location	Start	End
A1	Backwater entrance	36°54’21.16” S 149°53’37.11” E	36°54’30.02” S 149°53’36.14” E
A2	Backwater entrance	36°54’21.96” S 149°53’40.21” E	36°54’31.63” S 149°53’38.65” E
B	Flood-ebb delta	36°54’09.32” S 149°53’38.78” E	36°54’14.89” S 149°53’45.45” E
C	Flood-ebb delta	36°54’02.72” S 149°53’52.02” E	36°54’8.94” S 149°53’58.21” E
D	Flood-ebb delta	36°53’57.01” S 149°54’10.50” E	36°54’4.45” S 149°54’13.53” E
E	Flood-ebb delta	36°53’52.45” S 149°54’20.43” E	36°53’58.31” S 149°54’24.41” E

Qualitative observations recorded during the inspection included:

- confirmation of mapped vegetation communities including seagrass, mangrove and saltmarsh communities;
- diversity of algal taxa present;
- presence of natural or artificial hard substrata that may be readily colonised by algae; and
- presence of faunal burrows in benthic sediments.

GPS was used to locate the extent of the site and transect locations. Vegetation communities and algal taxa encountered were photographed with samples of macroalgae collected for further identification as required. A list of all saltmarsh, mangrove, seagrass and algal species present at the site during the field inspection as well as macroalgal taxa known to occur seasonally, though not encountered during the field inspection are presented in Section 3.1.2.

2.1.1 Algal samples

Whole algal thalli were collected by hand into clean plastic containers with seawater, collection details logged and stored on ice. Samples were examined under light microscope at x200 and x400 magnification to determine genus and species identity where possible with portions of sample collections set aside for preservation as voucher specimens.

2.1.2 Voucher specimens

Voucher specimens representative of each sample collection were preserved with 4% formalin-seawater solution in 5 ml vials and or pressed on herbarium paper to be lodged at the National Herbarium of NSW.

2.1.3 Field photos

Images of vegetation types, substrates and macroalgae observed at the site were recorded using a waterproof Panasonic Lumix FT-3 camera.

2.2 Desktop Review

A literature review was undertaken for each of the vegetation communities and algal taxa found during the site inspection with a focus on responses to elevated levels of N and P nutrients. Factors considered for this review included:

- Physiological constraints *i.e.* species growth limited by N or P?
- Nutrient uptake rates *i.e.* slow growing versus fast growing species
- Is the species an indicator of excessive nutrient inputs? *i.e.* fast growing species known to form blooms?

Locally relevant case study of an estuarine setting where excess nutrient inputs have occurred and the ecological consequences that have likely arisen due to those historical inputs is presented (*i.e.* Racecourse Creek, Bega River estuary).

RESULTS AND DISCUSSION

3.1 Site Inspection

A field inspection of the site was conducted on 21 December 2012 during ebb tidal conditions. According to tidal charts, low tide of 0.67 mAHD occurred at approximately 11:20 am at Merimbula bridge (~90 mins after tide predictions for Fort Dension, 08:50 am). Observations regarding substrates, vegetation type and occurrence of macroalgae were recorded along six transects as shown in Figure 4. Mangrove and saltmarsh habitats were inspected briefly to determine the most common taxa though transect surveys through these habitats were not specifically undertaken. Field images recorded during the site inspection and descriptions of vegetation communities and habitats are presented in Appendix B and support the information contained in the sections below.

3.1.1 General Observations

The site, as defined in Figure 2, is approximately 0.41 km^2 in area and part of the marine-tidal delta of the estuary. Greater than 50% of that area is characterised by sand-flats (0.23 km^2 in area) that are either devoid of- or sparsely vegetated with seagrass.

3.1.2 Seagrass

Three seagrass species were recorded at the site including *Posidonia australis* (strapweed), *Halophila ovalis* (paddleweed) and *Zostera muelleri* (eelgrass). While *Zostera* and *Halophila* are relatively common seagrasses, Merimbula Lake represents one of only five locations in the Bega Valley where *Posidonia* occurs. The other locations being Twofold Bay, Pambula Lake, Kianniny Bay and Bermagui River.

Sand flats where seagrasses are absent is due to regular exposure at low tide. Sand-flats that are sparsely vegetated, comprising the seagrasses *Halophila ovalis* and *Zostera muelleri* are exposed less frequently and become more densely vegetated with increasing water depth. The larger seagrass *Posidonia australis* is present at the deeper, permanently submerged, areas of the site.

The current distribution of *Posidonia* at the site is accurately represented by vegetation mapping in Figure 3 (from Creese *et al.* 2009). In contrast, the current distribution of the small seagrass *Halophila ovalis* is not accurately represented in Figure 3. *Halophila* is typically less than 7 cm high and was common across the site with discrete patches present in tidal channels close to the shoreline. The vegetation mapping depicted in Figure 3 is based on aerial imagery and field survey data that is now a decade-old. *Halophila* and *Zostera* are relatively fast growing seagrasses and patch sizes may vary on a yearly basis. In contrast, *Posidonia* is a slow growing seagrass and variation in patch sizes may only be detected over time-scales of decades or longer.

Mapping seagrass patches at the site was not part of this project scope. However, a seagrass landscape (including sparse and dense meadows) is conservatively estimated to cover more than 30% of the site area that is shown to be unvegetated in Figure 3. Overall, it is estimated that a seagrass landscape (including sparse and dense meadows) may cover as much as 0.25 km^2, approximately 60% of the site. A quantitative assessment would need to be undertaken to accurately assess seagrass cover at the site.

3.1.3 Mangrove and Saltmarsh

A continuous band of grey mangroves (*Avicennia marina*) are present along the site shoreline. The specialised peg roots (pneumatophores) extend as much as 8 m from the shoreline into the intertidal zone. Sediments beneath the mangrove canopy are grey in color and release a sulphide odour when disturbed indicative of high organic content in the sediments.

Saltmarsh community occurs immediately behind the mangroves above the mean high water mark. The most conspicuous species in this community include samphire (*Sarcocornia quinqueflora*), coastal speargrass (*Austrostipa stipoides*), sea rush (*Juncus krausii*) and shrubby samphire (*Tecticornia arbuscula*). The saltmarsh community within the predicted discharge zone (as modelled in IGGC Figs 13.11b and 13.11f) covers approximately 0.54 km^2. The most dominant species within the community would appear to be shrubby samphire (*Tecticornia arbuscula*) with coastal speargrass (*Austrostipa stipoides*), and sea rush (*Juncus krausii*) found adjacent to the mangroves and along drainage channels. Field images of mangrove and saltmarsh habitat at the site are contained in Appendix B.

3.1.4 Macroalgal assemblages and substrates

Substrates at the site include sand flats, seagrass meadows, shell beds and oyster lease infrastructure (ropes, posts and baskets), each providing opportunities for the colonisation of macro- and microalgal assemblages.

A variety of macroalgae were present across the site, epiphytic on seagrass and attached to available natural and artificial hard substrata. While not quantitatively assessed, macroalgal epiphyte loads on seagrass were more conspicuous and appeared greater at the southern end of the site (Transects A1, A2 and B) compared to the northern end of the site (Transects C, D and E). The dominant epiphytic taxa on seagrass included four species of red algae (*Laurenica majuscula* var. *elegans*, *Centroceras clavulatum, Spyrida filamentosa* and *Polysiphonia infestans*) and two species of brown algae (*Dictyota alternifida* and *Dictyota dichotoma*). A full list of algal taxa recorded at the site is provided in Table 3 (attached).

The occurrence of natural hard substrates at the site is limited to the area in the vicinity of Transect B where old shell beds have been exposed and extend from 0.5 m depth to the lake shore. Oysters have also colonised the available hard substrate in this area. Artificial hard substrata at the site include the ropes, posts and floating baskets of the oyster leases located at the site margins. The green alga *Codium* and brown alga *Dictyota* had a preference for the ropes. Beyond the site boundary, the availability of hard substrates in Merimbula Lake is relatively limited. Rocky shore areas are scattered around the lake margins though majority of these areas are intertidal and do not favour the establishment of macroalgal assemblages. Subtidal rocky habitats do exist in the vicinity of the causeway and at the estuary entrance where larger macroalgal taxa such as the brown alga *Sargassum* sp. are common. However, although the lake environment is marine (salinity typically >34 ppt) it does not support kelps beds due to the lack of suitable rocky hard substrata.

3.1.5 Microalgal assemblages and substrates

Microalgal assemblages include pelagic (suspended in water column) phytoplankton and benthic microalgae, also known as the microphytobenthos. Phytoplankton at the site would be transient due to the strong tidal flows across the site. In contrast, a benthic microalgal assemblage would be ever-present creating biofilms on most substrates. This includes the sandy sediments where aggregations of benthic microalgae were noted around faunal burrows in the vicinity of Transect B (Appendix B – Plate 3). While this algal assemblage was not specifically examined, it is likely to consist mostly of diatoms (Class Bacillariophyceae). As water depths at the site are shallow and water clarity high, the microphytobenthos would play an important role in nutrient turnover at the site. Indeed, the pelagic and benthic microalgal assemblages represent an important component of the primary production and nutrient cycling for all parts of the estuary.

3.1.6 Faunal burrows

Faunal burrows occur in the lower intertidal zone across the site and evidence of bioturbation was widespread. Burrowing fauna include crustaceans (crabs and shrimp), worms and bivalves and burrows may reach depths of 0.4 m. Faunal burrows increase the sediment-water interface and there is a wealth of evidence that burrowing activity (bioturbation) and the flushing of burrows by fauna (bioirrigation) can enhance the porewater-seawater exchange and thereby the release of nutrients from the bed, which may support primary production (Santos *et. al.* 2012). Aggregations of microalgae around burrows in the vicinity of Transect B indicate this is likely to be occurring at the site. At high densities, burrowing fauna may be the dominant process of porewater advective exchange (Santos *et al.* 2012). This could be important mechanism for enhancing the release of nutrients from the lake-bed to be flushed away from the immediate site by tidal currents.

3.1.7 Tidal Flows and Hydraulic Mixing

Water depths across the site ranged from 0 to 0.6 m (at low tide of 0.67 mAHD) with average water depth considered to be ~0.3 m. Tidal flows across the shallow sand flats were strong (not measured) though tidal flows were clearly attenuated in the densely vegetated *Posidonia australis* seagrass meadows. *Posidonia* meadows were generally located beyond the outer margins of the site (*i.e.* the predicted nutrient discharge area) with the exception of the entrance to Golf Course Lake and Transect E at the northern end of the site (refer Figure 3). Therefore the vast majority of the site is subject to strong tidal flows and due to the shallow depths would be well mixed. In addition to tidal flows, wind advection would also play a role to mix and homogenize the waters overlying the site sediments.

Owing to its wide and deep entrance, Merimbula Lake has exceptionally good tidal flushing and it has been estimated that weekly tidal flows through the entrance are equivalent to approximately twice the total volume of the lake (Webb, McKeown and Associates 1997). Information regarding the tidal prism of Merimbula Lake is available on the NSW Office of Environment and Heritage website (OEH 2013). The tidal prism is the volume of water (cubic metres per second) moving past a fixed cross section of the estuary during each flood tide or ebb tide (*i.e.* slack water to slack water) (OEH 2013). The tidal prism varies according to tide heights with largest tidal volumes discharged during spring tides. For Merimbula Lake, a tidal prism for a tide of approximately 0.5 mAHD was measured at the causeway on 25 October 2003 (MHL 2003) and is contained in

Appendix C. The tidal prism shows that peak discharge of ~140 m^3/sec^{-1} flowed through the causeway during the ebb tide while peak flows during the subsequent flood tide reached ~160 m^3/sec^{-1} . Assuming this tidal prism is representative of an average tide, the volume of lake water transported during average tidal flows may be estimated with moderate confidence (± 20% error) in the absence of real-time data using the tidal prism provided by MHL (2003).

It is estimated that roughly 1,512 ML of lake water was transported through the causeway during the ebb tide with approximately 1,728 ML flowing back through the causeway and into top lake during the flood tide on 25 October 2003 (Table 4). Note that these estimated volumes represent one ebb and one flood tide on the 25 October 2003. Tidal prism will vary throughout the year and on a daily basis due to tidal asymmetry.

Table 4. Estimated tidal discharge at Merimbula causeway, 25 October 2003 (based on coarse analysis of tidal prism MHL 2003).

Tide state	Estimated average discharge (m^3/sec^{-1})	Estimated Tidal range (m)	Estimated Tide duration (hrs)	Estimated total volume discharge[1] (m^3 per tide)	Estimated total volume discharge (ML per tide)
Ebb flow	60	0.5	7	1,512,000	1,512
Flood flow	80	0.48	6	1,728,000	1,728

Note: [1] Estimated total volume discharge is the product of *estimated average discharge* x *tide duration*.

When these estimated discharge volumes are considered with regard to the total volume of the estuary, estimated at 12,924 ML (Roper *et al.* 2011), a conservative approximation of the number of tidal cycles required to discharge or flush the estuary volume may be estimated by dividing the total lake volume by the tidal discharge volume.

Using the ebb discharge volume (ML),

12,924 / 1,512 = 8.5 tidal cycles (equivalent to 4.3 days) will discharge a volume of water equivalent to the estimated volume of the lake.

Taking a conservative approach, the total volume of Merimbula Lake is likely to be discharged over a 5-day period. However, this is a simplistic interpretation based on the tidal prism data available and assumptions made. Flushing time will vary across the lake areas as well as three dimensionally and while a volume, equivalent to the total lake volume, is likely to be flushed over a 5-day period, this does not mean all lake waters are flushed over that period.

Roper *et al.* (2011) estimate the flushing time for the entire estuarine water body at 25.3 days based on the predicted tidal prism of 1752 ML, equivalent to 14% of the volume of the lake. This estimate of flushing time adopted a typical tidal exchange efficiency coefficient of 0.15 (*Refer* Appendix 9 in Roper *et al.* 2011).

RESULTS AND DISCUSSION

Based on the analysis of Roper *et al.* (2011), it can be assumed that all areas of Merimbula Lake will be flushed over a 25-day period with areas closest to the entrance likely to be flushed over shorter time periods. In absence of three-dimensional modelled data, flushing times for identified areas of Merimbula Lake may be generalised from shortest to longest duration in the following order:

- Shortest flushing time - marine tidal delta (incorporating the 'site')
- Medium flushing time - central basin
- Longest flushing time - golf course lake backwater

The areas of the lake where these generalised flushing duration times are estimated is shown in Figure 5 below.

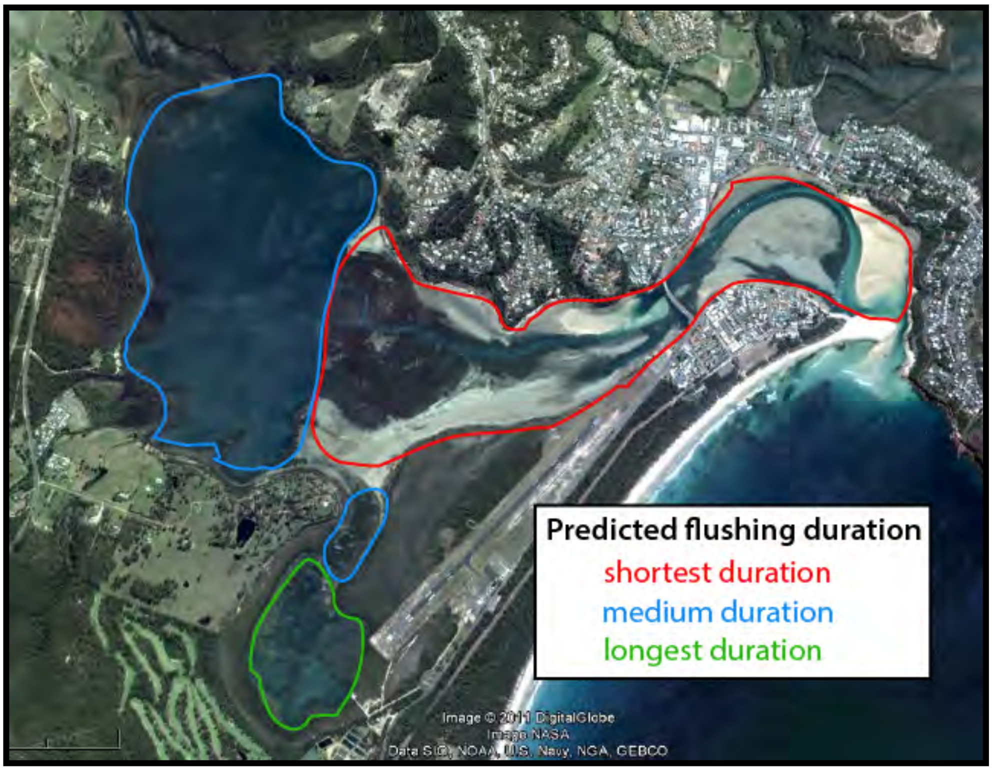

Figure 5. Generalised flushing duration periods estimated for areas of Merimbula Lake (*i.e.* high flushing capacity = shortest duration, low flushing capacity = longest duration).

The area in which nutrients will discharge from the lake-bed is part of the marine-tidal delta and this area is predicted to have a shorter flushing duration (*i.e.* will be completely flushed over shorter time scale) compared to the central basin and the golf course lake backwater. The volume of water overlying the sediments at the site is estimated to range between 123 and 246 ML based on estimated average depths of 0.3 m and 0.6 m at low and high tide respectively (Table 5). It is likely that the total volume of water overlying the sediments at the site would be completely flushed on a daily basis. This prediction is based on the tidal observations recorded at the site during the field investigation and the estimated volumes of water discharged during an average tidal cycle. However, the degree of tidal exchange is an important consideration with regard to nutrient concentrations and other pollutants and understanding what percentage of estuarine water is exchanged with oceanic water during a range of tidal conditions and what residual estuarine water is retained in the system would require hydrodynamic modeling.

Table 5. Estimated water volumes overlying sediments at the site at mean low and mean high tide.

Tide state	Site area (km^2)	Estimated average depth (m)	Estimated Volume (m^3)	Estimated Volume (ML)
Mean Low tide	0.41	0.3	123,000	123
Mean High tide	0.41	0.6	246,000	246

Unit conversions: 1 km^2 = 1,000,000 m^2, 1 m^3 = 0.001 ML

3.2 Current ecological condition of Merimbula Lake

An understanding of the current ecological condition of Merimbula Lake is required before a realistic assessment of what potential impacts may result from an increased flux of nutrients and freshwater discharge. Estuarine ecological condition in NSW is currently assessed using 10 indicators representing elements of the structure, function and composition of estuarine ecosystems and are summarised in Table 6 below.

Table 6. Environmental indicators adopted by the state-wide MER program to assess estuarine ecological health (Roper *et al.* 2011).

Issue	Indicator
Eutrophication	microalgal abundance as phytoplankton determined by chlorophyll *a*;
	macroalgal abundance
	water clarity as turbidity
Habitat Availability	extent of seagrass
	extent of mangroves
	extent of saltmarsh
Fish Assemblages	species diversity and composition
	species abundance
	nursery function
	trophic integrity

3.2.1 2010 State of Catchments Report (DECCW 2011)

Most recently, a State of the Catchments (SOC) 2010 report (DECCW 2011) was published that provides the latest assessment of ecological condition/health of estuaries and coastal lakes and the pressures acting upon them in the Southern Rivers region including Merimbula Lake. Much of this assessment was based on MER data collected up to 2009. The assessment provided Merimbula Lake with an overall condition index of 3.3 (out of 5), rated as being fair based on four of seven estuarine health indicators applicable to Merimbula Lake. Levels of chlorophyll *a* were rated as good, extent of seagrass and fish assemblages rated as fair, and extent of saltmarsh rated as poor. The overall assessment was provided with medium confidence as some of the data was greater than three years old and data regarding turbidity or macroalgae was not available.

The assessment also provided Merimbula Lake with an overall pressure index of 3.0 (out of 5), rated as having moderate pressure in terms of indicators – cleared land, population, sediment and nutrient inputs, extractive fishing, freshwater flows, disturbed habitat and tidal flows. Among the indicators considered, nutrient inputs, disturbed habitat and tidal flows were rated as moderate pressures while cleared land, population and sediment inputs were deemed to be exerting the highest pressure on the condition of the estuary.

3.2.2 Surface Water Quality of Merimbula Lake

Ecological condition is also largely determined by water quality. Consistent high levels of nutrients may create conditions for prolific micro- and macroalgal growth, diminishing water clarity and affecting the ability of seagrass meadows to function efficiently. Seagrass meadows are a critical component of estuarine systems, and loss of seagrass habitat may have consequences at higher trophic levels. Background levels of nutrients for surface waters of Merimbula Lake are available for the central basin, golf course lake backwater and the ocean entrance. Mean values for a range of nutrient parameters, chlorophyll *a* and indicators of water clarity are summarised in Table 7.

The central basin is characterised by low mean nutrient concentrations typically well below the guidelines for the protection of aquatic ecosystem health. Mean levels of chlorophyll *a* range from 1.1 to 1.3 µg/L and water clarity is very high with turbidity less than 0.5 ntu. In contrast, Golf Course Lake is characterised by higher mean nutrient levels with some bioavailable forms of nitrogen exceeding guideline values. Consequently, Golf Course Lake has a higher abundance of microalgae (as indicated by chl *a*) and diminished water clarity compared to the central basin. This water quality data supports the prediction (Figure 5, above) that Golf Course Lake is not as well flushed and has longer water residence times than the central basin and the marine tidal delta. The data also support anecdotal reports from oyster growers that highest oyster growth rates can be achieved in Golf Course Lake owing to the higher microalgal biomass.

Overall, water quality of the estuary is considered high with low nutrient levels and high water clarity largely due to the lake's high flushing capacity that allows waters to be well mixed over most areas of the lake.

Table 7. Mean water column nutrients and properties for Merimbula Lake
(*note* - shaded mean values indicate guideline value has been exceeded)

	NH_4^+ (µg/L)	NOx (µg/L)	TKN (µg/L)	TN (µg/L)	TP (µg/L)	FRP (µg/L)	Chl a (µg/L)	TSS (mg/L)	Turbidity (ntu)
ANZECC guideline[1]	15	15	-	300	30	5	4	-	0.5-10
MER guideline[2]	-	-	-	-	-	-	3.6	-	5.7
Central Basin[3]	7.6	17	175	196	9	2.4	1.1	-	0.2
Central Basin[4]	~28	-	-	223	9	-	1.3	18	-
Golf Course Lake[4]	~50	-	-	393	28	-	3.4	31	-
Entrance[5]	-	-	-	194	-	-	2.7	1.4	-

Note:

[1] WQOs for protection of Estuarine Aquatic Ecosystems in Bega River Catchment - based on ANZECC/ARMCANZ 2000 guidelines (http://www.environment.nsw.gov.au/ieo/Bega/index.htm) for slightly disturbed ecosystems in SE Australia (ANZECC Table 3.3.2)

[2] Chlorophyll a and turbidity trigger level adopted by the NSW MER program (Roper *et al.* 2011)

[3] Mean values calculated from 2012 data (Elgin Associates 2013)

[4] Mean values calculated from 2005-2008 data (BVSC 2013)

[5] Mean values calculated from 2002 data (Ozcoasts 2013)

3.3 Response of vegetation communities to increased nutrient flux

The primary concern with the worst case modeled increase in nutrient flux and freshwater discharge from the lake bed is whether that will have a negative impact on the ecological values of the lake over the life of an exfiltration trench. An assessment of factors that could influence potential impact is discussed in the sections below in terms of how the vegetation communities may respond to increased nutrient flux and freshwater discharge.

3.3.1 Nutrient limitation

Nitrogen is widely considered to be the limiting nutrient for plant and algal growth in the marine and estuarine environment and a large body of evidence now supports this trend (Lobban and Harrison 1994, Howarth and Marino 2006, Smith 2006), with P the second most limiting nutrient (Lobban and Harrison 1994). Consequently, efforts to minimise the effects of eutrophication in coastal areas have focused on the management of N inputs. In contrast, P is the limiting nutrient in freshwater systems and excess inputs of P are typically the cause for eutrophication and algal blooms, commonly of cyanobacterial taxa that have the capacity to fix atmospheric nitrogen (N_2).

Understanding the nutrient demands of a plant or algae will help to predict its response to increased nutrient availability. A desktop review of literature regarding the physiology of algae and of specific studies investigating the responses of seagrass and saltmarsh to increased nutrients allow some general predictions to be considered here.

The nutrient demands (ratio of N:P) required by one plant or algal species may be quite different from the nutrient ratio required by another species. One species may be N-limited, while another species may be P-limited. The nutrient supply rate is also important in determining the magnitude or degree of nutrient limitation. If the concentration of a nutrient is low, but the supply rate is slightly less than the uptake rate by the plant or algae, then the plant or algae will only be slightly limited. Furthermore, the rates of nutrient turnover by a species and capacity to store nutrients will also influence how a species may respond to increased nutrient availability.

In general, model predictions by IGCC (2013) for the worst case scenario indicate that effluent disposal to an exfiltration trench in the location shown in Figure 1 would result in addition of N and P nutrients and freshwater to receiving Lake waters at the site. Under scenarios modelled by IGCC, steady state concentrations of N (scenarios 2 and 4 - mostly as bioavailable NO_3) and P (scenarios 2 and 4 - mostly as bioavailable PO_4) were predicted to be discharged from the lake bed after 15 to 22 years, respectively. For all of these scenarios, efficient tidal flushing will effectively dilute and reduce these concentrations and transport nutrients to other regions of the lake. However, this discharge of nutrients from sediment porewater would represent a new continuous supply of inorganic N and P in bioavailable forms that would have the potential to further stimulate existing levels of primary production within the lake. For the different ecological communities identified at the site, their limitation to N or P nutrients are noted where information from the literature was available.

3.3.2 Benthic and Pelagic microalgae

Benthic microalgae comprising mostly of diatoms but also of other taxa including marine cyanobacteria contribute a significant fraction of the total primary production in estuarine systems where water clarity is high. They form biofilms over the sediment surface binding sediment particles and stabilise sediments against erosion. In this way, benthic microalgae can influence estuarine morphology. Aggregations of benthic microalgae were conspicuous at the southern end of the site around faunal burrows though they would be present across the entire site. Diatom nutrient requirements generally follow the Redfield ratio of elements carbon, nitrogen and phosphorous (C:N:P), which is 106:16:1 (by atoms). Therefore in an environment where supplies of inorganic N and P are continuous, enhanced productivity of benthic microalgae may result, and a large proportion of available nutrients assimilated.

Pelagic microalgae would be transient at the site due to the strong tidal flows. However, as nutrient concentrations would be diluted and transported away from the site on a daily basis, increased phytoplankton biomass may become evident in other areas of the estuary where water residence times are longer such as the central basin and Golf Course Lake. As microalgal abundance of lake surface waters is typically low (chlorophyll *a* mean concentrations of 1.1-1.3 µg/L), a response by the pelagic microalgal community to further nutrient inputs would be measurable as chlorophyll a concentrations above current background levels.

3.3.3 Macroalgae

The occurrence of macroalgae at the site is limited by available hard substrates for attachment. Consequently, majority of macroalgal taxa at the site are epiphytic on the leaf blades of seagrasses with the most dominant species being small and filamentous (*Centroceras, Polysiphonia, Spyridia, Laurencia*). A filamentous thallus provides a high surface area: volume ratio and filamentous algae typically have a high propensity for nutrient uptake and fast growth rates (Lobban and Harrison 1994). The epiphytic species observed during the site inspection were annual species with a preference for growth in spring to summer and disappearing altogether during the cooler seasons. In contrast, larger perennial algae observed at the site such as *Hormosira, Codium, and Cystoseira* would be present throughout the year. These types of algae are slow growing species that have a greater capacity to store nitrogen though their local abundance at the site is limited due to a lack of available hard substrate.

An increased nutrient flux to the site and a continuous supply of inorganic nutrients more generally will favour the growth of fast growing macroalgae, typically of filamentous or foliose forms, that can grow attached to seagrasses. As such, epiphytic loads on seagrasses are likely to increase at the site throughout the year. The ability of seagrass to photosynthesise may be directly affected by increased epiphyte loads through shading.

Prolific growth of two macroalgal taxa is already known to occur in Merimbula Lake on a seasonal basis. Blooms of the brown alga *Colpomenia sinuosa* have occurred each winter since 2007 (*N. Yee,* pers. obs. 2007-2012). The alga grows attached to the leaf blades of *Posidonia* until it reaches a size that cannot resist the drag forces of tidal flows and is torn from its seagrass substrate. Thalli of *Colpomenia* wash up along the shoreline of the lake in early summer and are further washed out to Merimbula Bay where it aggregates on the seafloor and begins to decompose. Blooms of the finely branched calcareous alga *Jania micrarthrodia* have been reported in summer though on an irregular basis. *Jania* is also an epiphyte of *Posidonia* and once detached from the seagrass may be transported from the lake to the bay environment during ebb tidal flows where large biomass aggregate on the seafloor. Aggregations of drift algae were not present at the site due to the strong tidal flows and an increase in nutrient flux will not alter this. However, short-term aggregations of drift algae may occur in slow flow areas of the lake before being flushed out of the estuary altogether. Images of these algal taxa forming blooms in Merimbula Lake are contained in Appendix D.

The triggers that cause the prolific growth of *Colpomenia* and *Jania* are not understood. However, the regular seasonal occurrence of blooms in Merimbula Lake suggest any additional inputs to existing levels of nutrients may encourage the prolific growth of other algal taxa whose nutrient demands are not currently being addressed.

3.3.4 Saltmarsh

There have been few studies in Australia that have examined the responses of temperate coastal saltmarsh to nutrient enrichment. However, a number of long-term studies in America have shown that nutrient enrichment to *Spartina* (smooth cordgrass) coastal wetlands resulted in an overall loss of wetland vegetation (Deegan *et al.* 2012). For most plants increased N generally stimulates higher rates of leaf growth and development, while P is more important for the production of flowers and fruiting. Deegan *et al.* (2012) demonstrated that nutrient enrichment resulted in increased above ground plant-biomass, with a concomitant decrease or no-change to below ground biomass. The increased leaf matter subsequently results in higher rates of microbial decomposition of the organic matter within the sediments. The combination of root loss and increased rates of microbial decomposition reduced soil strength that led to increased erosion during tidal flows. This resulted in reduced geomorphic stability, creek bank collapse and overall losses of *Spartina* habitat that was replaced by large areas of unvegetated mud. However, the saltmarsh communities of southern Australia are very different floristically to the *Spartina* coastal wetlands of the northern hemisphere.

A study by Boon and Cain (1988) examined the sediments and rates of nitrogen cycling in a samphire (*Sarcocornia*) saltmarsh community in southern Australia. The sediments were found have a very high inorganic N:P ratio (>100:1) suggestive of a high limitation of bioavailable phosphate in that setting. The rate of nitrogen cycling during the decomposition of plant matter (*i.e.* conversion of organic nitrogenous compounds to inorganic bioavailable forms) is closely linked to the presence of P in freshwater sediments (Sjogren and Little 1982) and a similar situation may exist in marine settings (Boon and Cain 1988). Assuming saltmarsh sediments at the site are also characterised by a high N:P ratio, an increased liberation of inorganic nitrogen to stimulate further plant growth may result from increased levels of phosphate in shallow groundwater. The resultant higher primary productivity of the saltmarsh may feedback and in turn alter saltmarsh sediment chemistry where the ratio of inorganic N:P is lowered with an associated increase in organic content. With forecast rise in sea levels, an organic-rich sediment with higher levels of inorganic P may favour the encroachment of mangroves into the saltmarsh area.

An increased discharge of freshwater to the saltmarsh may lead to more brackish water conditions providing less saline-tolerant saltmarsh species opportunities to establish or expand their distribution.

3.3.5 Seagrass

The seagrass landscape of Merimbula Lake consists of three species: *Posidonia australis, Zostera marina* and *Halophila ovalis*. All three seagrasses are present at the site in various patch sizes and shoot densities with *Posidonia* confined to the deeper water margins of the site while *Halophila* and *Zostera* occupy the shallow, near shore areas where nutrient flux is expected to be greater. Seagrasses obtain majority of their nutrients from the sediments via the roots, though they are also able to uptake inorganic N from the water column through their leaves (Pedersen *et al.* 1997, Gobert *et al.* 2005) and highest rates of productivity (*i.e.* nutrient uptake) typically occur during the warmer months. The nutrient requirements of seagrasses is similar to that of macroalgae, with a C:N:P ratio of approximately 480:27:1 (Eyre and Ferguson 2002). In a temperate estuarine environment with sandy sediments where inorganic P is accessible, it is the availability of nitrogen that generally limits the growth of seagrasses.

Local seagrass productivity would benefit from an increased flux of both inorganic N and P, though the proportion of nutrients assimilated by seagrasses would likely be less than the total proportion assimilated by faster growing algal species including the benthic and pelagic microalgae, and macroalgal epiphytes. Declines in seagrass habitat have occurred around the world due to competition with algae for resources, shading effects due to epiphyte loads and indirectly through reduced light levels in the water column associated with increased phytoplankton biomass (Collings *et al.* 2006). However, the primary concern for seagrass at the site is direct competition with algae for nutrients and potentially greater epiphyte loads. Water clarity is expected to remain high due to the strong tidal flows at the site.

3.4 Local case study of increased nutrient supply to an estuarine setting

Racecourse Creek is a shallow backwater section of the Bega River estuary where flushing and water movement is restricted. Coincidentally, Racecourse Creek is also adjacent to sources of continual nutrient input via surface runoff from the Tathra golf course that uses reclaimed water from the Tathra STP as well as groundwater discharge characterised by elevated levels of nutrients. In 2008, an extensive mixed species macroalgal bloom was present in Racecourse Creek covering as much as 50% of the waterbody (Elgin Associates 2009). Over 14 algal taxa were recorded from the bloom with dominant bloom species including the green algae *Ulva intestinalis* (as *Enteromorpha intestinalis*) and *Chaetomorpha valida*, and the blue-green alga *Oscillatoria* sp. (Elgin Associates 2009). The seagrass in Racecourse Creek had heavy epiphyte loads and were completely smothered either by surface rafts or by decomposing sub-surface algal rafts. Persistent smothering as observed in 2008 would have a negative outcome for the seagrass in the long-term. Water quality data collected during 2008 showed that high levels of bioavailable forms of N and P were present throughout the year and combined with low tidal flushing due to river entrance closure/restriction, presented ideal conditions for the development and persistence of blooms of opportunistic and fast growing algal species.

Widespread blooms of opportunistic algal taxa are not unlikely to be realised at the site due to the high degree of tidal flushing. However, Golf Course Lake is an area of the estuary that is vulnerable to increased nutrient concentrations due to its reduced capacity for flushing. During flood tides a proportion of water flowing across the site would be transported into Golf Course

Lake in addition to shallow groundwater discharge. The backwater would be supplied with regular pulses of nutrients in bioavailable forms to feed the growth of algae and seagrasses.

CONCLUSIONS

This supplementary report provides information regarding the vegetation communities at the site and discussion of thepotential impacts that proposed dunal exfiltration may have on the ecological values of Merimbula Lake. This information includes:

- Confirmation of and description of vegetation communities at the site;
- Qualitative discussion regarding the hydrodynamics of Merimbula Lake;
- The current ecological condition and surface water quality of Merimbula Lake;
- Factors that could influence the response of vegetation communities to increased nutrient flux; and
- Local case study of increased nutrient supply to an estuarine setting.

Key points from the findings include:

- A range of ecological communities is present at the site including saltmarsh, mangrove, intertidal sand flats, and seagrass meadows. Three seagrasses occur at the site including *Posidonia*, *Zostera* and *Halophila*. Estuarine habitat mapping (Creese *et al.* 2009) of Merimbula Lake accurately depicts the current distribution of *Posidonia* at the site but underestimates the distribution of *Halophila* and *Zostera* which occur over much of the shallow waters depicted in mapping as being unvegetated. Overall, it is estimated that a seagrass landscape (including sparse and dense meadows) may cover as much as 0.25 km^2, or approximately 60% of the site as defined in Figure 2.
- A variety of macroalgae were encountered during the site inspection with majority being epiphytes of seagrass. Leaf blades of seagrasses represent the most abundant available substrate for colonisation by macroalgae. The dominant epiphytic taxa on seagrass included four species of red algae (*Laurenica majuscula* var. *elegans*, *Centroceras clavulatum, Spyrida filamentosa* and *Polysiphonia infestans*) and two species of brown algae (*Dictyota alternifida* and *Dictyota dichotoma*) representing the summer epiphyte flora. In winter, the dominant epiphyte is known to be the brown alga *Colpomenia sinuosa* that has shown prolific growth in winter each year since (at least) 2007. The calcareous red alga *Jania micrarthrodia* is also known to proliferate in Merimbula Lake on an irregular seasonal basis.
- The availability of natural hard substrates for algal attachment was limited to a small area in the form of an exposed shell bed. Larger perennial macroalgal species such as the brown algae *Cystoseria* and *Hormosira* and the green alga *Codium* occurred in this area. In addition to macroalgae, aggregations of benthic microalgae were noted on the sandy sediments associated with faunal burrows. At high densities, burrowing fauna may be the dominant process of porewater advective exchange (Santos *et al.* 2012). This could be an important mechanism for enhancing the release of nutrients from the lake bed to be flushed away from the immediate site by tidal currents.
- Merimbula Lake has a high capacity for tidal flushing due to its wide and deep ocean entrance that promotes efficient tidal exchange and mixing of lake waters. It is estimated that weekly tidal flows through the entrance are equivalent to approximately twice the total volume of the lake (Webb, McKeown and Associates 1997). Strong tidal flows were observed

over the sand flats at the site with flows attenuated over the *Posidonia* seagrass meadows. The site is part of the marine tidal delta and it is predicted that the site would be completely flushed on a daily basis effectively diluting and transporting nutrients discharged from sediments away from the site.

- The current ecological condition of the Lake based on MER indicators of eutrophication - microalgal abundance (as chlorophyll *a*) and water clarity (as turbidity) is rated as good. Surface water quality data collected over all seasons from 2005-2008 and 2012 show water clarity is consistently high with turbidity typically less than 0.5 ntu. Nutrient levels of the central basin are typically low and consequently microalgal abundance is also low with mean concentrations of chlorophyll a between 1.1-1.3 µg/L. However, surface water quality data show levels of nutrients and microalgae are higher in the backwater of Golf Course Lake likely due to the longer water residence times in this area of the estuary.

IGGC (2013) groundwater flow mass balance modelling for year 2025 estimated effluent disposal volumes via a 400 metre long exfiltration trench in the location shown in Figure 1 predicts a net increase in groundwater discharge to Merimbula Lake of approximately 7.5%, occurring within an area of approximately 28,000 m^2 on the eastern side of the lake. Under scenarios modelled by IGCC, steady state concentrations of N (scenarios 2 and 4 - mostly as bioavailable NO_3) and P (scenarios 2 and 4 - mostly as bioavailable PO_4) were predicted to be discharged from the lake bed after 15 to 22 years, respectively. Under scenarios 1 and 3 neither nitrate nor phosphate from effluent reach the lake in groundwater within the 57 year modeled period.

For scenarios 2 and 4, tidal flushing will dilute and reduce the concentrations of nitrogen and phosphorous discharging within groundwater within the identified discharge plume area and transport these nutrients to other regions of the lake. Nevertheless, this discharge of nutrients from sediment porewater would represent a new continuous supply of inorganic N and P in bioavailable forms that has the potential to further stimulate existing levels of primary production at the site and within the lake generally. A potentially vulnerable area of the lake to increased supply of bioavailable nutrients is the backwater Golf Course Lake due to its reduced capacity for flushing and estimated longer water residence times.

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LIMITATIONS

Elgin Associates Pty Ltd has prepared this report for the sole use of Bega Valley Shire Council in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 28 November 2012.

The methodology adopted and sources of information used by Elgin Associates are outlined in this report. Elgin Associates has made no independent verification of this information beyond the agreed scope of works and Elgin Associates assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to Elgin Associates was false.

This report was prepared between December 2012 and March 2013 and is based on the conditions encountered and information reviewed during that period up to the time of preparation. Elgin Associates disclaims responsibility for any changes that may have occurred after this time. Opinions and recommendations contained in this report are based upon information gained during desktop study and fieldwork and information provided from government authorities' records and other third parties. The information in this report is considered to be accurate at the date of issue and reflects at the site at the dates sampled. This document and the information contained herein should only be regarded as validly representing the site conditions at the time of the fieldwork unless otherwise explicitly stated in a preceding section of this report.

This report should be read in full together with all other reports referenced by this report. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties.

Table 3. Macroalgae recorded during the site inspection

Table 3. Macroalgae recorded during the site inspection and other taxa recorded in Merimbula Lake but not observed at the site.

Taxon	Recorded in Transect	Notes
Red algae (Phylum Rhodophyta)		
Laurencia majuscula var. elegans	A, B, C, D, E	A conspicuous red alga, highly branched, epiphytic on *Posidonia australis* seagrass. Abundant.
Centroceras clavulatum	A, B, C, D, E	A small, filamentous red, epiphytic on *Halophila* and *Zostera* seagrass. Abundant.
Spyridia filamentosa	A, B, C, D, E	A filamentous red alga, epiphytic on all seagrasses. Common.
Polysiphonia infestans	A, B, C	A small filamentous red alga, epiphytic on all seagrasses. Abundant.
*Polycerea nigrescens**	-	A small filamentous red alga, epiphytic on *Posidonia*.
*Jania micrarthrodia**	-	A finely branched, calcareous red alga, epiphytic on *Posidonia*. Common in spring and summer.
Brown algae (Class Phaeophyceae)		
Dictyota alternifida	A, B	Commonly found attached to shell fragments or epiphytic on *Posidonia australis, Halophila ovalis* seagrass.
Dictyota dichotoma	A	Commonly found attached to shell fragments or epiphytic on *Posidonia australis, Halophila ovalis* seagrass.
Hormosira banksii	A, B,	Intertidal and shallow sub-tidal. Attached to shell fragments and also unattached, scattered amongst seagrass.
Colpomenia sinuosa	E	Epiphyte of *Posidonia* seagrass. Found throughout the lake where *Posidonia* grows and blooms in winter to early spring. Proliferates annually during winter.
Cystoseira trinodis	B, C	A large conspicuous species attached to shell fragments, common in shallow waters at the site.
*Sargassum sp.**	-	A
*Asperococcus bullosus**	-	A membranous brown alga with an elongate and hollow thallus, epiphytic on *Posidonia* seagrass.
Green algae (Phylum Chlorophyta)		
Codium fragile	B, C	Attached to rock, shells, and oyster lease infrastructure.

Note:

* Commonly recorded in Merimbula Lake though not encountered at the site on 21 December 2012.

ATTACHED FIGURES

Figure 2. Study Site

Figure 3. Estuarine vegetation and survey transects inspected

Figure 4. Survey Transects

North

0 175 350
Metres

Key:
- location of simulated discharge monitoring wells
- 0.1 phosphorous (mg/L) pathlines - Scenario 2 (high P, low Kd)
- 0.1 nitrogen (mg/L) pathlines
- study area investigated

Client: Bega Valley Shire Council

elgin associates

Project: Merimbula Lake Ecological Assessment Supplementary Report

Title: Study Site

Designed: NY	Checked: AR	Date: FEB 2013	Figure 2	Rev. A
Drawn: LF	Approved: AR	Status: FINAL		A4

North

0 300 600
Metres

Legend
- Posidonia
- Zostera/Halophila
- Saltmarsh
- Mangrove/Saltmarsh
- Mangrove

Client:
Bega Valley Shire Council

elgin associates

Project:
Merimbula Lake Ecological Assessment Supplementary Report

Title:
Estuarine vegetation & survey transects inspected

Designed: NY	Checked: AR	Date: Feb 2013	Figure 3	Rev. A
Drawn: LF	Approved: AR	Status: FINAL		A4

Key:

- study area investigated
- A1 — transect location
- ★ representative habitat at this location

Client: Bega Valley Shire Council

elgin associates

Project: Merimbula Lake Ecological Assessment Supplementary Report

Title: Survey Transects

Designed: NY	Checked: AR	Date: Dec 2012	Figure 4	Rev. A
Drawn: LF	Approved: AR	Status: Draft		A4

APPENDIX A

IGGC (2013) - Figures 13.11a – 13.11f

Figure 13.11a: Phosphate Concentrations in Groundwater, Scenario 1 (High Effluent PO_4=8.5 mg/L; Low P Sorption Capacity, *Kd*=2.0 mL/g)

Figure 13.11b: Phosphate Concentrations in Groundwater, Scenario 2 (High Effluent PO_4=8.5 mg/L; Very Low P Sorption Capacity, Kd=0.1 mL/g)

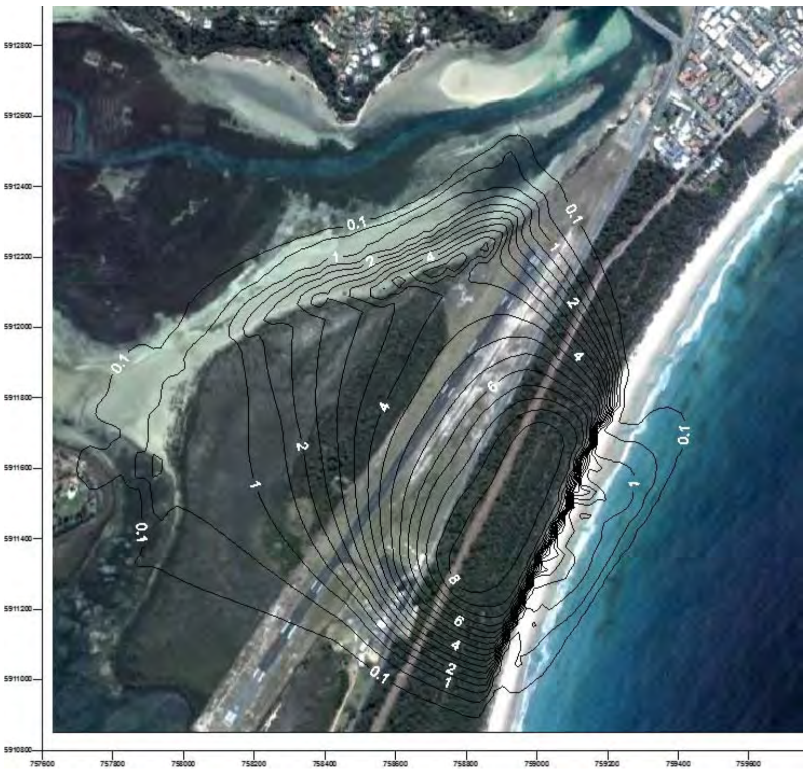
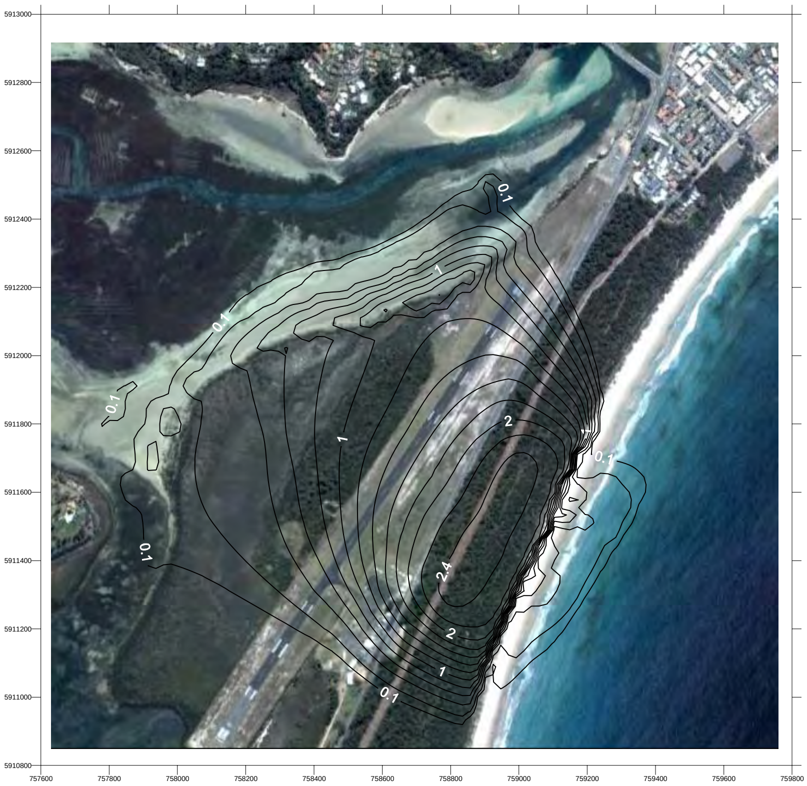


Figure 13.11c: Phosphate Concentrations in Groundwater, Scenario 3 (Low Effluent PO_4=1.5 mg/L; Low P Sorption Capacity, *Kd*=2.0 mL/g)

Figure 13.11d: Phosphate Concentrations in Groundwater, Scenario 4 (Low Effluent PO_4=1.5 mg/L; Very Low P Sorption Capacity, *Kd*=0.1 mL/g)

Figure 13.11e: Nitrate Concentrations in Groundwater, Scenarios 1 and 3 (Moderate N Decay Rate Constant R=0.002 day^{-1})

Figure 13.11f: Nitrate Concentrations in Groundwater, Scenarios 2 and 4 (Zero N Decay Rate Constant R=0 day^{-1})



APPENDIX B

Images from Field Inspection, 21 December 2012

Plate 1.	Mangrove and Saltmarsh habitat
Plate 2.	Transects A1 and A2 – entrance to backwater
Plate 3.	Transect B – natural hard substrates
Plate 4.	Seagrass epiphyte loads at Transects A & B – southern end of site
Plate 5.	Seagrasses at Transects C, D & E – northern end of the site
Plate 6.	Micrographs of macroalgal epiphytes on segrasses

Plate 1. Mangrove and Saltmarsh habitat

a) A band of the grey mangrove (*Avicennia marina)* occupy the high intertidal zone along the entire lakeshore at the site. **b)** Mangrove leaf litter, pneumatophores (specialised root structures) and drift algae are found below the mangrove canopy. **c)** Mangrove sediments are typically grey in colour, contain high silt and organic content relative to the estuarine sand flats and have a sulphide odour when disturbed. Faunal burrows are common in the mangrove sediments created by range of invertebrates including the red-fingered marsh crab (*Sesarma erythrodactyla*). **d)** Saltmarsh plants occupy the higher ground immediately behind the band of mangroves with samphire (*Sarcocornia quinqueflora*) common. **e)** Narrow bands of coastal speargrass (*Austrostipa stipoides*) and sea rush (*Juncus krausii*) are found immediately behind the mangroves and along the drainage channels. **f)** Shrubby samphire (*Tecticornia arbuscula*), a medium sized shrub is the most conspicuous saltmarsh plant at the site.

Plate 2. Transects A1 and A2 – entrance to backwater

a) Large areas of sand flats become exposed at low tide at the entrance to the backwater. **b)** The view South overlooking the main channel that opens into a deeper backwater section of Merimbula Lake that is adjacent to the Merimbula golf course and the Merimbula STP. **c)** The large seagrass *Posidonia australis* is abundant throughout the main channel that acts to slow the velocity of tidal flows. **d, e)** Epiphyte loads (of macroalgae) on the leaf blades of *Posidonia australis* appear to be greater in the vicinity of Transect A1 and A2 compared to other areas of the site. **e)** A close-up image of the red alga *Laurencia* sp., a common epiphyte of *Posidonia australis* throughout Merimbula Lake. **f)** The smaller seagrass *Halophila ovalis* is also widespread in this area covered with macroalgal epiphytes and drift algae such as *Hormosira banksia*.

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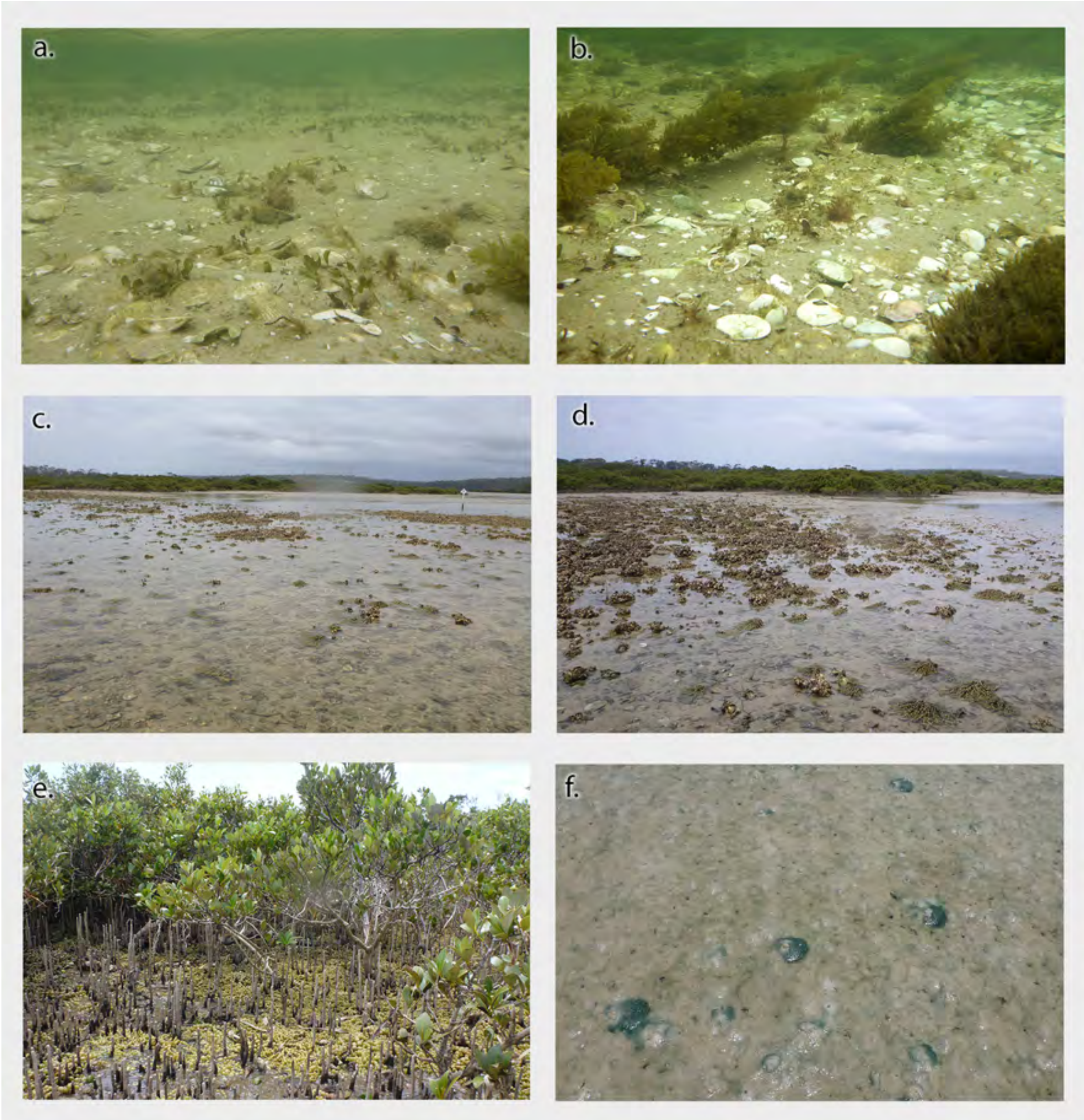


Plate 3. Transect B – natural hard substrates

a, b) Exposed shell beds in the vicinity of Transect B represent the only natural hard substrata at the site. Larger brown macroalgae such as *Sargassum* spp. and *Cystoseira trinodis* are common in the subtidal zone of this area attached to the dead shells. **c, d)** The exposed shell beds extend from the shallow subtidal zone to the intertidal zone where oysters have naturally recruited to form large clumps. **e)** The brown alga *Hormosira banksii,* is abundant among the mangrove roots along the lakeshore in vicinity of Transect B. **f)** The shallow sand flats are characterised by faunal burrows and evidence of bio-turbation. Aggregations of benthic microalgae (dark green patches in photo) were conspicuous around the entrance of some burrows.

Plate 4. Seagrass epiphyte loads at Transects A & B – southern end of site

a, b) The seagrass landscape of shallow waters at the site is composed predominantly of the smaller paddleweed (*Halophila ovalis*) and stunted eelgrass (*Zostera muelleri*). Seagrasses at the southern end of the site are affected by heavier loads of macroalgal epiphytes compared to the northern end of the site. **c)** Close-up image of fine filamentous epiphytes on paddleweed leaf blades. Dominant epiphytes included the red algae *Centroceras clavulatum*, *Polysiphonia infestans* and *Spyridia filamentosa*. **d)** Larger brown algae including *Dictyota dichotoma* and *Dictyota alternifida* (circled) were also common epiphytes of seagrasses at the southern end. **e, f)** The broad leaf blades of *Posidonia australis* were characterised by moderate to heavy loads of macroalgal epiphytes, mostly of the red alga *Laurenica* sp.

Plate 5. Seagrasses at Transects C, D & E – northern end of the site

a, b) The large seagrass *Posidonia australis* had relatively light epiphyte loads in the vicinity of Transects C, D and E compared to Transects A and B. **c)** The brown alga *Colpomenia sinuosa* was a common epiphyte of *Posidonia* leaf blades in the deeper waters at the northern end of the site. **d)** The seagrass landscape of paddleweed (*Halophila ovalis*) and eelgrass (*Zostera muelleri*) generally had lighter loads of macroalgal epiphytes at northern end of site. **e, f)** Large areas of benthos surveyed at Transects C, D and E comprised sparse patches of seagrass with larger seaweeds such as *Cystoseira trinodis* occasionally present. A number of sea hares (*Aplysia sydneyensis*) were grazing at the northern end of site (Image E).

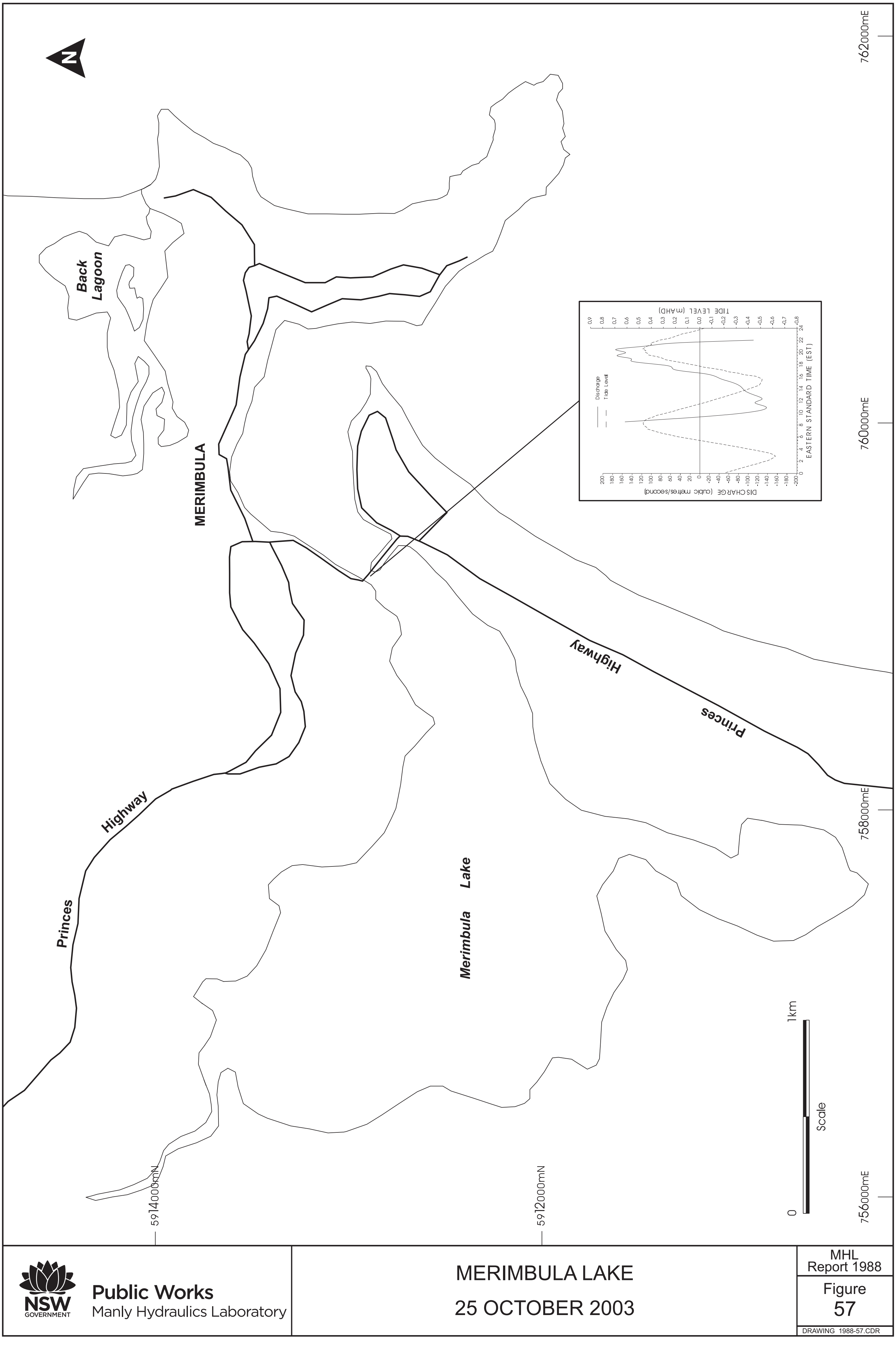
Plate 6. Common macroalgal epiphytes of seagrasses at the site

a-d) Red alga *Centroceras clavulatum*. Images show the mass of microscopic erect filaments attached to the seagrass leaf blade (a), by a network of prostrate filaments and rhizoids (b). Branches are dichotomously branched with involute apices and a ring of pericentral cells gives the alga a banded appearance. **e & f)** Red alga *Polysiphonia infestans*. Images show reproductive tetrasporangia developing in spiral series along an upper branch of a tetrasporophyte (e), and spermatangial branches developing near the branch apex of a gametophyte (f).

APPENDIX C

Merimbula Lake Tidal Prism

25 October 2003, at Causeway



Public Works
Manly Hydraulics Laboratory

MERIMBULA LAKE

25 OCTOBER 2003

MHL Report 1988

Figure 57

DRAWING 1988-57.CDR

APPENDIX D

Examples of macroalgal blooms in Merimbula Lake

APPENDIX D

Plate 1. Macroalgae known to proliferate seasonally in Merimbula Lake

a, b) The finely branched and articulated coralline red alga *Jania micrathrodia* (bleached white in images – typically a light pink colour) has been known to proliferate in shallow, slow flow areas of Merimbula Lake during early summer where its primary substrate for attachment are the leaf blades of the seagrass *Posidonia australis (photos taken in January 2011)*.

c, d) The membranous brown alga *Colpomenia sinuosa* proliferates during winter in Merimbula Lake where it becomes the dominant epiphyte on the seagrass *Posidonia australis* (*photos taken in September 2008*). Once the alga reaches a large size it is typically torn from its substrate due to the drag forces of the tidal flows and washes up along the shoreline of the lake or further washed out to Merimbula Bay.