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Review of Environmental Factors for Entrance Management of Coila, Tuross, Kianga, Little, Bullengella and Nangudga Lakes

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Eurobodalla Coastal Lakes Entrance Management Policies Review of Environmental Factors

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Synopsis :	This Review of Environmental Factors (REF) supports the development application for implementation of Entrance Management Policies for Coila, Tuross, Kianga, Little, Bullengella and Nangudga Lakes. It describes existing environments and outlines expected impacts of entrance management works.

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1 INTRODUCTION

1.1 Background

Eurobodalla Shire Council assumes responsibility for the management of entrances at a number of coastal lakes throughout the LGA. Entrance management of coastal lakes essentially involves the artificially breakout of the entrance sand berm, releasing built-up waters behind. This is done typically when water levels within the lakes exceed specific ‘trigger’ levels as a precursor to potential detrimental impacts on access and infrastructure around the waterways.

Entrance Management Policies have been prepared for six (6) coastal lakes within the Eurobodalla Shire, namely: Coila, Tuross, Kianga, Little, Bullengella and Nangudga Lakes (refer Figure 1-1). These policies are reproduced in Appendix A. This Review of Environmental Factors (REF) outlines the potential impacts of implementing the Entrance Management Policies on the lake environments, and details the mitigation measures to be adopted in order to minimise potential impacts.

1.2 Existing Policies and Previous Assessments

1.2.1 Coila Lake Entrance Management Policy

The current Coila Lake Entrance Management Plan was adopted by Council in June 2001. The policy describes the levels, procedures and responsibilities for artificial entrance opening, and the response of authorities to natural opening events (ESC, 2001a). The policy describes 13 artificial breaches and 4 natural breaches in the prior 25 years, for reasons including the alleviation of inundation of low lying assets, improving water quality and fish and prawn recruitment into the lake.

The impact to lake ecology from artificial openings below the lake’s natural breakout range has not been assessed. The Policy makes reference to the Aquatic Habitat Management and Fish Conservation Policy and Guidelines (NSW Fisheries, 1998, quoted in ESC, 2001a) which supports minimal interference with estuarine barriers, and allowance for natural opening processes to the greatest extent possible. The Fisheries guidelines (discussed separately in Section 1.2.4) further state there is no support for artificial entrance opening where the water levels pose little threat to public health or safety due to flooding or water quality.

The following considerations were outlined by the Review of Environmental Factors (REF) that supported the Entrance Management Policy (ESC, 2001b):

- There is potential for significant impact upon threatened birds roosting in the berm;
- Impact to lake ecosystems in the short term was considered unlikely, based upon the assumption that an intervention level of 1.85 m AHD is within the natural opening range. Should this assumption be incorrect, it was stated that significant impacts may result to lake ecosystems at the 1.85 m intervention level. A recommendation was made to raise the intervention level when practical, as consistent with the precautionary principle;

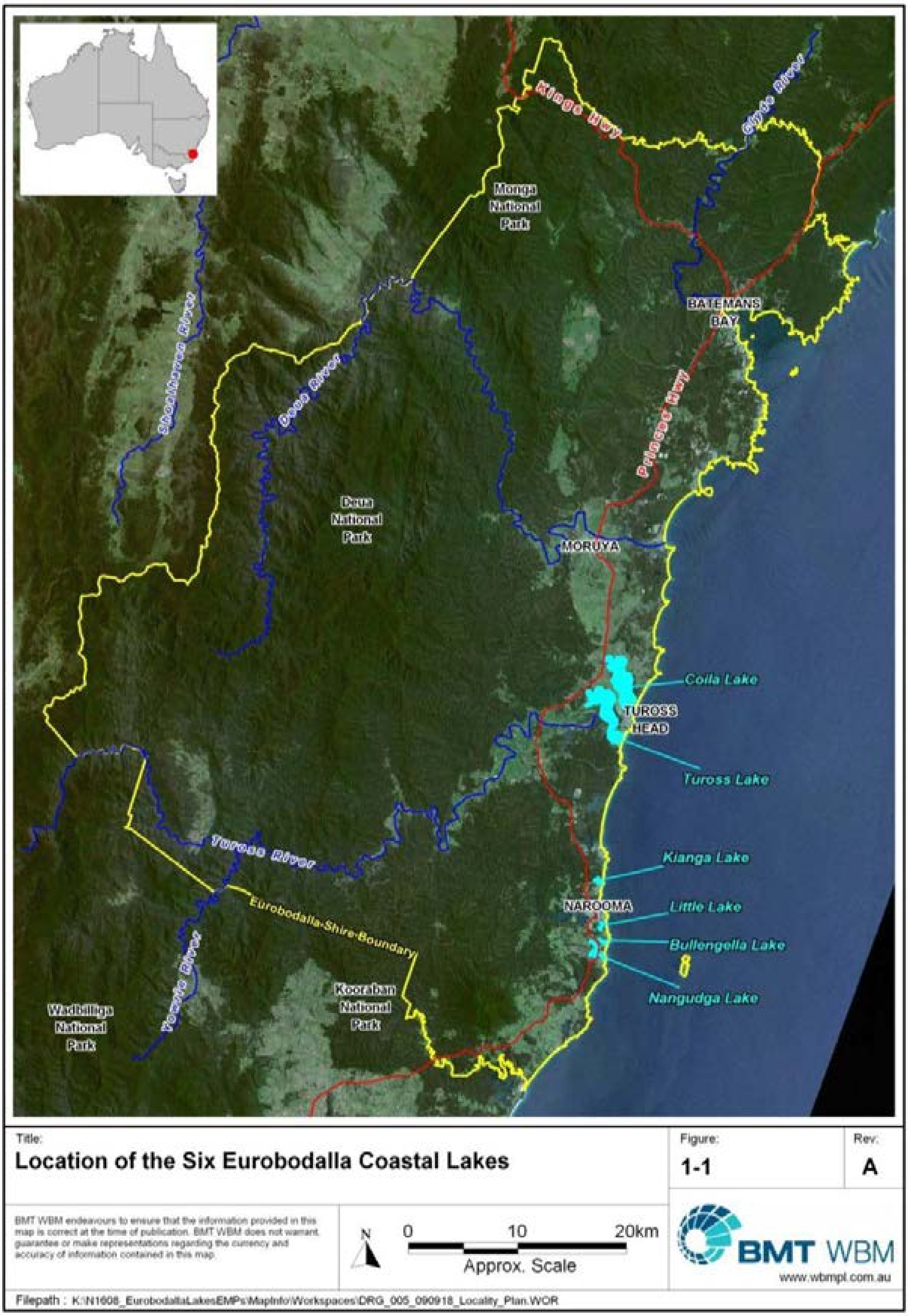

Figure 1-1 Location of the six (6) Eurobodalla coastal lakes

- The likely long term impact to ecosystems from intervention is both a hydrologic and ecologic shift from the natural condition, which may have already begun. It was noted, however, that the new intervention level (1.85 m AHD) is higher than previous levels, and therefore is closer to mimicking a natural regime than conditions over the past 20 years;
- There exist no viable alternatives to artificial opening over the short term that do not cause potential hardship and disruption to the local community. A long term alternative involving progressive removal, relocation or other form of treatment for low lying infrastructure was suggested, which would allow for raising of the intervention level over the long term.

As an outcome of the Entrance Management Policy and REF process, the following mitigation strategies were suggested:

- Monitoring of shorebird breeding activity, particularly Little Tern and Hooded Plover. Excavation of the entrance shall only occur with clearance from NPWS where birds, nests or fledglings are known to be present;
- Measures to progressively remove, relocate or treat low lying infrastructure shall be investigated and implemented;
- Investigation to determine the natural breakout range should be conducted, to better predict the nature and extent of intervention impacts; and
- Assessment and monitoring of peripheral habitats (vegetation communities) to determine shifts in community structure, weed infestation or other impacts from the artificial opening regime.

Coila Lake has been opened just once in accordance with the current entrance management policy, in May 2002. The intent of the policy was to enable progressive increases in the trigger level for opening of the entrance. A new policy should therefore incorporate a trigger level that is higher than RL 1.85m. It is envisaged that greater inundation of the Coila Creek saltmarsh area would reinvigorate the saltmarsh habitat, which has shown limited signs of recovery since the introduction of the existing policy in 2001 (pers. comm., Norm Lenehan, ESC).

1.2.2 Tuross Lakes Entrance Maintenance Dredging

A Review of Environmental Factors for Maintenance Dredging of the Tuross Estuary (GHD, 2003) was completed in April 2003. Maintenance dredging had been proposed in order to open/expand an entrance channel across the Tuross entrance berm. It was stated in the report that a lack of rainfall and subsequent riverine flow over the previous 10 years had resulted in the restriction of tidal range between the ocean and the sea via the constricted entrance channel, reducing tidal range from 1 m to 0.1 m. The reduction in tidal range was of particular concern due to the impact upon the oyster farming industry, in this case threatening the closure of the industry. Water quality from the restricted tidal flow was also viewed as an issue. Thus, the Tuross Estuary / Coila Lakes Management Committee resolved to conduct a review of environmental factors, to determine if artificially opening/expanding the entrance channel was a feasible action to restoring the tidal range.

It was stated in the REF (GHD, 2003) that entrance behaviour was governed by the balance between coastal processes that build up sand at the entrance and fluvial flows that scour the entrance channel. However, the prior 10 years of low flow had allowed coastal processes to dominate, and the entrance was increasingly constricted by marine sand (although, the entrance had not completely closed at this point). While it was understood that this was a natural cyclic process, the impact of entrance constriction or closure over extended periods was now having a significant impact upon the viability of the oyster farming industry in Tuross. It was also noted that ongoing extraction of water was exacerbating entrance constriction by reducing already low base riverine flows. It was also stated by GHD (2003) that closure of the entrance for long periods increased the risk for poor water quality, although the report provided no references for this statement.

Two options were considered: opening of a 40 m by 3 m by 1320 m long channel at the northern end of the entrance; and opening of a 100 m by 3 m by 330 m channel at the southern end of the entrance (at the location of a former flood-conditions breakout channel). Various options for disposal of the dredge spoil were considered, with the placement of material within a former river channel and sand banks immediately south of the entrance considered to be the most suitable option.

The do nothing option was seen as unsatisfactory, because without a flood in the very near future, it was considered that marine sand would continue to be built up at the estuary mouth and this would make it even less likely for a small flood to sufficiently scour the entrance sediments (GHD, 2003). Interestingly, there was no discussion of how long the dredging exercise would actually sustain an open entrance. The work of Rustomji (2007) clearly indicates that artificial breaches do not have sufficient scouring potential to maintain an open entrance for any significant length of time, and tidal ranges may reduce to pre-opening levels within days.

Comments from the then Department of Land and Water Conservation (DLWC, now DECCW), NSW [now DPI] Fisheries, and NPWS largely agreed in their response to the proposal. It was regarded that ecological impacts from the dredging, particularly where unexpected consequences, such as erosion or deposition, and the subsequent impacts upon key ecological habitats (seagrasses, mangroves, SEPP14 wetlands and threatened species) was a major concern. In addition, all options for the placement of dredge spoil were felt to be unsuitable. The 'do nothing' option was therefore considered to require further and better investigation.

1.2.3 Artificial Opening of Lakes within Eurobodalla National Park

An REF has been prepared by DECC (NPWS) in support of entrance management of several coastal lakes within the Eurobodalla National Park. As outlined in the REF, DECC (NPWS) views the opening and closing of the lakes within Eurobodalla National Park to be part of a natural cycle, and prefers that the lakes operate unhindered by human intervention, as consistent with the statutory responsibilities of NPWS for care, control and management of natural and cultural heritage. However, there are factors outside of the control of the NPWS, as they occur within the catchment of the five lakes to which the REF covers, and which necessitate intervention (under certain and controlled conditions).

The REF states that DPI Fisheries (former NSW Fisheries), DECCW (former DIPNR) and Council support the approach of minimum interference, and suggest natural processes be allowed to operate wherever possible. In particular, the problem of inundation of roads, buildings, effluent systems and other public and private property will necessitate artificial opening to alleviate such problems. The REF refers specifically to the act of excavating a channel through the lake entrance barrier with a backhoe, bulldozer or excavator. Inundation may include on-site sewage systems, which would then pollute the lake in question (at Potato Point), stormwater back up at Dalmeny, inundation of access routes, rising saltwater at a vineyard adjacent to Corunna Lake, as well as direct inundation of foreshore houses and sheds (at Mummuga, Potato Point).

The NPWS state explicitly that "flood mitigation is the only circumstance that warrants artificial intervention". The REF outlines the specific conditions under which artificial entrance opening will be undertaken. Options to remove the existing triggers (ie, low lying assets) that currently prompt artificial opening are also outlined. It is the aim of the NPWS that in the medium to long term, intervention shall become unnecessary.

The REF also outlines measures to mitigate potential adverse impacts to flora and fauna communities, hydrology or other natural processes, as well as geology, soils, water quality, Aboriginal sites, and worker and public safety. Monitoring of flora and fauna communities is recommended to determine long-term changes.

The available entrance management options are summarised as:

- non-intervention, with openings only under the natural regime;
- artificial opening at a specified water level;
- maintenance of the entrance berm at a specified level so that breakouts occur at this level;
- regular or irregular artificial opening; and
- engineering works to maintain a permanently open entrance.

All of these activities may have environmental effects.

NPWS (2007) offer significant evidence as to the value of closed lagoons. NPWS (2007) citing Deeley and Paling (1999) claim that:

- Extreme events such as floods and droughts "reset" the biotic communities of estuaries "in a spatial and temporal mosaic";
- Intermediate disturbance hypothesis – mild disturbances bring about the greatest diversity within estuaries. Without such disturbances, biotic communities may progress to one of several possible stable endpoints, depending on which species recruit;
- Salinity may have a profound effect on distribution, abundance and community composition for estuaries. Lagoon opening and closure cycle resets the system, resulting in distinctive ecosystems that reflect the changes in salinity as well as nutrient levels and periods of variable inundation. So, the duration, extent and time of occurrence of a lagoon breakout may determine its ecological significance.

Systems with more frequent opening have a higher ratio of marine to freshwater fish species and invertebrate taxa, whereas systems with more frequent closure have a substantially higher diversity of freshwater fauna.

The REF states "Regular mechanical intervention resulting from the popular idea that coastal lagoons are only healthy when they are open can result in the decline of those fish species unable to cope with continued high salinity". The majority of such species are the smaller, cryptic or rarer resident species, and their loss may go unnoticed while the popular species (especially those species targeted by recreational fishers) continue to be caught. However the loss of such species may affect the overall species diversity, and larger picture of habitat that supports the popular resident species.

The opening event may have different ecological consequences at different geographical locations; or, there may be different ecological consequences in the same location from year to year depending on the other factors which change annually as well. Therefore, NPWS (2007) conclude that opening a lagoon for the purpose of fish recruitment is 'something of a lottery'. Furthermore, the opening may have the reverse effect, as resident fish and prawns are lost to the sea without replacement or augmentation.

Poorly timed artificial or natural breaches may adversely affect the lifecycles of aquatic, terrestrial and amphibious organisms, due to the rate of biological processes that does not match the rapid lake water level drop that follows an opening event. Desiccation and stranding of spawn and larvae for fish, frogs and aquatic invertebrates can cause losses to these species. Where species survive the reduced water level following a breakout, they then must survive an increase in salinity and loss of areas to feed. The exposure and desiccation of shallow feeding areas for water birds, loss of nesting areas and sudden access to eggs and nestlings for water birds may also be adverse.

Over the long term, saltmarsh requires the short to medium length periods of high water level, to maintain the slightly higher salinity soil conditions that prevent the encroachment of freshwater or terrestrial plants (NPWS citing Meehan and West, 2002). But there may be adverse effects due to prolonged high water levels as well. Prolonged high water levels (ie, months) may cause die-off of some saltmarsh species; likewise, terrestrial species may also decompose or die after prolonged immersion. In rare cases, the decomposition of terrestrial vegetation may result in anoxic waters at depth, which, when the lake is opened, may cause fish kills when this water drains into the central basin.

For waterbirds, the high water levels may actually reduce the use of usual feeding grounds where the water becomes too deep. A persistent berm or barrier may prevent the recruitment of marine species that enter lagoons as adults (ie catadromous fish) or juveniles and larvae at particular phases of the year. Likewise, anadromous migration (where fish move out to sea at a certain stage of their life cycle) may also be blocked by the berm.

NPWS concludes it is fluctuating water levels that enable a high level of biodiversity to be maintained, and prevents the establishment of a stable, species poor community dominated by a few communities. NPWS (2007) indicate that "it is important that the entrance behaviour of representatives of each type of estuary is left to natural processes in order to preserve the range of species present, rather than have them all become more broadly marine due to increased frequency of opening".

As stated by NPWS, in spite of the many potentially adverse affects on biota caused by natural opening and closing events, it is interesting that such 'disturbances' within a natural cycle and setting are not destructive at all, but in fact are necessary to sustain such environments.

The decision to open an entrance is to follow a specific flowchart (decision tree) outlined by NPWS (2007). The decision is based on water levels approaching specific trigger levels, or warning heights. When opening, the excavation is to commence at a falling tide, and cease when the channel has a strong outward flow of water. The excavated sand is to be placed on the sides of the channel, and not removed from the site.

Previous assisted openings have shown that when excavation is carried out in the location of the natural entrance channel, the artificial channel will rarely exceed the dimensions or location of the natural channel, reducing the possibility for adverse erosion impacts from opening. While a reasonable long-lasting opening is sought from the activity, a permanent opening is not.

The REF explicitly states the objectives for opening for each of the lakes as:

- relief of high flood levels at causeways, to ensure residents have adequate access;
- prevention of flooding of private property, camping areas and the access to these assets;
- prevention of flooding of houses along the foreshore, and back up of stormwater flooding houses that may not be on the foreshore;
- prevent flooding of access roads for rural properties;
- prevent flooding of outbuildings and on-site sewage systems.

Notice of the openings is to be given to NPWS, MPA, ESC, DECC, and DPI Fisheries, in all but the most urgent situation, where risk of rapid flooding is imminent.

To avoid adverse impacts or disruption to the life cycles of threatened species, the following procedures will be upheld by NPWS (2007):

- Opening the lagoons within water levels experience under their natural opening regimes;
- Undertaking a survey of the entrance barrier and adjacent beaches for breeding bird populations and nests prior to opening;
- Excavation to be undertaken in unconsolidated (unvegetated) sand area only;
- Excavation to be undertaken with the natural channel course; and
- Access with excavation equipment to the site only via established tracks and trails.

It has also been recommended that ‘opportunistic’ surveying of wetland communities (frogs, bird species) be undertaken, to provide better information and decision making regarding entrance opening.

1.2.4 NSW Fisheries Policy for management of intermittently opening coastal lagoons

NSW Fisheries (now known as the Department of Industry and Investment) has established some guiding policies for management of intermittently open coastal lagoons, as documented in *Policy and Guidelines – Aquatic Habitat Management and Fish Conservation 1999*:

a) NSW DPI Fisheries supports minimum interference of estuarine lagoon barriers and natural processes being allowed to operate to the greatest extent possible.

b) NSW DPI Fisheries will not support the artificial opening of a lagoon where there is little threat to public health or safety from flooding or water quality deterioration.

c) NSW DPI Fisheries supports using estuary management planning and environmental assessment processes to analyse the issues relating to opening a particular lagoon, and to reaching consensus about when and under what conditions it can be artificially opened. Proposals for artificial openings which are to be carried out according to the guidelines set down in a management plan are more likely to be approved.

Specific guidelines regarding the management of entrance is also offered by DPI:

- Illegal openings should be guarded against by the erection and maintenance of signs near the lagoon entrance warning people that unauthorized opening is illegal and may result in prosecution.
- The decision to open a lagoon should be made on the basis of factual data, and not speculation or perception. In particular, **factual data** on water levels and the nature and extent of associated flooding impacts, and **quantitative** evidence of changes to relevant water quality parameters (especially nutrient and bacterial levels), should be available. Water levels should be referenced to a standard datum (eg. Australian Height Datum) obtained from appropriately sited staff gauges, or automatic water level recorders.
- In the short term (i.e. Prior to an Estuary Management Plan being formulated and put in place), an interim strategy for each problematic lagoon should be formulated, documented and agreed to. The interim strategy should provide clear rules to guide a decision about where, when and under what conditions to open a lagoon. This plan should be made in consultation with all relevant natural resource management agencies, representatives of local community interest groups and affected landholders. The interim strategy should take account of critical environmental issues.
- If, after due consideration of all the issues involved, breaching is approved, this should be conducted during a falling tide so that the potential for achieving maximum scouring and establishing a long-lasting entrance channel is maximized.
- In the longer term, local councils, government agencies and the local community should aim to lessen the need for artificial manipulations of lagoon entrances by adopting catchment management practices that reduce the inputs of nutrients and pollutants from point and diffuse sources, transferring flood prone land on the margins of lagoons into public ownership, preventing the development of flood-prone lands by adopting appropriate zonings in planning instruments, wherever possible adopting other flood control and management mechanisms (eg. Levees around valuable assets), relocating infrastructure susceptible to flood damage to areas safe from flooding, and implementing community awareness campaigns to heighten appreciation and understanding of the concepts and issues involved.

1.2.5 Tuross and Coila Lakes Entrance Management Plan (WBM, 2005)

The Tuross and Coila Lakes Estuary Management Plan was prepared to provide a program of strategic actions to assist government and other stakeholder groups to sustain healthy estuaries through appropriate waterway, foreshore and catchment management. The Plan is supported by technical and scientific information, and was developed in close consultation with the community and stakeholder representatives.

Management of entrance conditions in both Coila and Tuross Lakes was given a high priority in the Estuary Management Plan. In this regard, specific entrance management objectives were set as follows:

- EM-1: To minimise detrimental effects on the community associated with elevated water levels in Coila Lake by modifying / moving low-lying assets;
- EM-2: To re-establish, as much as practical, the natural water level variation in Coila Lake; and
- EM-3: To maintain a minimum tidal range within the Tuross estuary of 0.3 metres, which allows for sustainability of the local oyster industry, and assists with the natural flushing processes of the estuary.

A series of short-listed strategies were developed and are presented in the Estuary Management Plan. Strategies that specifically address Objectives EM-1, 2 and 3 above include:

- Entr-1: Continue to adopt the current Coila Lake Entrance Management Policy and, as identified in the Policy, flood-proof or relocate low-lying assets around the lake perimeter;
- Entr-2: Investigate and, if appropriate, carry out dredging of the Tuross estuary entrance to reinstate adequate tidal range for oyster farming

In accordance with these strategies, Eurobodalla Shire Council has continued to implement the Coila Lake Entrance Management Policy (2001), which as per the policy, required periodic review and amendment as appropriate. Council has also investigated the value of entrance dredging within the Tuross estuary (refer Section 1.2.2). Given the substantial costs associated with the works, and the potential for the dredged channel to infill under the dynamic coastal conditions, the feasibility of these works has been considered marginal.

1.3 Legislative Requirements

1.3.1 Environmental Planning and Assessment Act 1979

The principal legislation establishing the planning framework in NSW is the *Environmental Planning and Assessment Act, 1979* (EPA Act). The *EPA Act* came into force on 1 September 1980 with the intention of implementing a system of land use control. Approval processes for "development" and "works" in NSW are provided for in Part 3A, Part 4, Part 5 and Part 5A of the *EPA Act*.

Part 3A is used for assessment of major infrastructure or other development that in the opinion of the Minister is of state or regional environmental significance. Specific guidelines have been established outlining the types of projects that would be assessed under Part 3A.

Part 4 of the *EPA Act 1979* lays out the legislative regime for what is commonly known as the standard process for lodgement and consideration of development applications. Essentially Part 4 processes apply where the local authority (Council) is the consent authority. The issue of permissibility is generally found in the Local Environment Plan (LEP) relevant to the Council. The controls for development of particular sites or use are found in Councils LEP and DCP.

Part 5 of the Act applies to an "activity" which is not subject to development control i.e. where a particular proposal does not require development consent under Part 4 of the *EPA Act 1979* but requires approval from a Minister of Public Authority, or is proposed to be carried out by a Minister or

Public Authority. Part 5 only applies to those proposals which are permissible without requiring development consent. Part 5 focuses on the obligation of the “determining authority” to consider the environmental impact of any “activity”. A “determining authority” is the public authority which is proposing to carry out the activity and also any public authority which is required to approve an activity proposed by the person who wishes to carry out the activity.

1.3.1.1 State Environmental Planning Policy (Infrastructure) 2007

SEPP (Infrastructure) 2007 was gazetted on the 1 January 2008 and was prepared to consolidate and update planning provisions relating to infrastructure and government land. The SEPP provides a consistent planning regime for infrastructure and the provision of services across NSW, along with providing for consultation with relevant public authorities during the assessment process. The intent of the SEPP is to support greater flexibility in the location of infrastructure and service facilities along with improved regulatory certainty and efficiency for the State.

The SEPP:

- outlines planning processes for considering classes of public infrastructure and particular infrastructure projects
- exempts some minor public infrastructure from the need for an approval
- clarifies where new infrastructure can be located and provides for additional permissible uses on government land
- requires State agencies constructing infrastructure to consult local councils when a new infrastructure development is likely to affect existing local infrastructure or services.

Development consent for undertaking these works, as set out in the proposed Entrance Management Policies, is exempt from development consent under the Eurobodalla LEP (and thus assessment under Part 4 of the EP&A Act), as the works fall within the scope of provisions outlines in State Environmental Planning Policy (SEPP) Infrastructure 2007 (specifically works for flood mitigation). Relevant approvals still need to be obtained from relevant authorities (see below), and an assessment under Part 5 of the Act is required (including preparation of a Review of Environmental Factors, ie this document).

1.3.1.2 State Environmental Planning Policy 71 – Coastal Protection

SEPP 71 aims to protect and manage the natural, cultural, recreational and economic attributes of the New South Wales coast, protect and improve public access, protect and preserve Aboriginal heritage, visual amenity, beach environments and beach amenity, native coastal vegetation, the marine environment, rock platforms, and manage the coastal zone in accordance with the principles of ecologically sustainable development, ensure development is appropriate for the location, and encourage a strategic approach to coastal management.

SEPP-71 establishes what development is significant coastal development, identifies the procedure for the determination of significant coastal development in terms of the referral process to the Director-General for comment, and identifies master plan requirements for certain development in the coastal zone.

SEPP-71 applies to the area declared as the NSW Coastal Zone under the *Coastal Protection Act, 1979*, which includes the six coastal lakes in question. Further, works associated with implementation of the Entrance Management Policies is to be carried out within “sensitive coastal locations”. As such, these works need to be referred to the Minister for Planning for comment.

1.3.1.3 State Environmental Planning Policy 14 – Coastal Wetlands

SEPP 14 aims to ensure that the coastal wetlands are preserved and protected in the environmental and economic interests of the State. The Policy defines over 1300 areas along the NSW Coastline as wetlands.

The policy identifies that land clearing, levee construction, drainage work and filling requires development consent and that such development is ‘designated development’. Therefore, development applications for such works are required to be accompanied by an Environmental Impact Statement (EIS). The policy identifies that the local council is the consent authority for such work.

Whilst there are a number of SEPP-14 wetlands located within Coila, Tuross and Nangudga Lakes, none of the gazetted wetlands cover the entrance channels where the entrance management works would be undertaken. As such, the provisions of SEPP 14 do not apply directly to this proposal.

1.3.2 Crown Lands Act 1989

The beds of the six coastal lakes, including the entrance channels, are Crown land. Landowner consent from the Department of Lands is therefore required before works on these Crown land parcels can be undertaken. A single licence can be obtained from the Department of Lands covering entrance management of all coastal lakes in the Shire, to be reviewed and renewed concurrently with the review of the individual Policies.

1.3.3 Fisheries Management Act 1994

The aim of the *Fisheries Management Act 1994 and Fisheries Management Amendment Act 1997* is to conserve, develop and share the fishery resources for state benefit of present and future generations. The Acts apply specifically to aquatic flora and fauna primarily fish, invertebrates and some algae. Marine vegetation is protected under the Acts and a permit will be required to destroy or damage marine vegetation, such as mangroves, seagrass and saltmarsh. The Act also includes schedules of endangered aquatic species, populations and ecological communities, which must be considered in the same manner as species listed under the *Threatened Species Conservation Act 1995*.

Section 200 of the FM Act 1994 indicates that dredging can be carried out by a Local Government authority (i.e. Council) without the authority of a permit issued by the Minister of DPI (Fisheries) providing that the works are authorised by the *Crown Lands Act 1989*, or the works have been authorised by another relevant public authority (other than local government authority). This means that consent for the dredging works, if a licence is awarded by another authority (e.g. the issuing of a licence by NSW Department of Lands under the *Crown Lands Act 1989*), will not require a second licence from DPI (Fisheries) under the FM Act 1994. It is a condition of the FM Act, however, that in issuing a licence for the works, other authorities must consult with DPI (Fisheries) regarding the proposal.

1.3.4 Commonwealth Environmental Protection and Biodiversity Conservation Act 1999

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) provides for the protection of matters of national environmental significance, including:

- World Heritage Properties;
- National Heritage Places;
- Wetlands of International Importance;
- Listed Threatened Species and Ecological Communities;
- Listed Migratory Species; and
- Commonwealth Marine Areas.

If an activity has the potential to impact on one or more matters of national environmental significance, an assessment process in accordance with the EPBC Act and Guidelines (Environment Australia 2000) is required. If the assessment concludes that a significant impact is likely, then the activity will be deemed a controlled action and approval for the activity is required from the Commonwealth Department of Environment and Heritage via a detailed referral process, including public exhibition.

The Tuross River Estuary is listed in the Directory of Nationally Important Wetlands, though it is not a Ramsar wetlands. A number of Threatened and Migratory Species and Ecological Communities are found at many of the coastal lakes along the NSW south coast, including those subject to this environmental assessment.

1.3.5 NSW Local Government Act 1993

Under the Local Government Act 1919, Councils had general authority to open coastal lakes and lagoons under Section 352A. Although this provision was not specifically carried through in the Local Government Act 1993, Councils have continued to assume such responsibility on behalf of the interests of the public.

Under the Local Government Act 1993, Council has the authority to enforce penalties on anyone acting contrary to a notice erected on public land or in a bathing place under Section 632(1).

1.3.6 NSW Coastal Protection Act 1979

Consideration needs to be given to Sections 38 and 39 of the Act, requiring concurrence by the Minister for undertaking development works within the coastal zone. The proposed entrance works at the various coastal entrances are within the coastal zone as defined by the Act.

1.3.7 NSW Threatened Species Conservation Act 1995

The Act provides for the identification, conservation and recovery of threatened species and their populations and communities. It also aims to reduce the threats faced by those species. Unless a licence has been obtained under the *National Parks and Wildlife Act 1974* or the *Threatened Species Conservation Act 1995*, or approval under the EPA Act, it is an offence under the *National Parks and Wildlife Act* to harm any animal or plant that is a threatened species, population or ecological community (NPWA s.118(1)(b)).

Threatened species, populations and communities are listed as endangered or vulnerable in Schedules 1 and 2 respectively.

Consideration needs to be given to potential harm or damage to threatened species and listed migratory species, including Little Tern, which have been found around a number of the coastal lakes in question. Transportation of heavy equipment onto some of the entrances may also need to consider potential damage to known Aboriginal sites.

1.3.8 NSW Marine Parks Act 1997

All of the lakes covered by this REF are located within the Batemans Marine Park. Three lakes, Nangudga, Bullengella and Kianga Lakes, are zones completely as Sanctuary Zones (the highest level of protection). Two lakes, Tuross and Little Lakes are zoned completely as Habitat Protection Zones, while Coila Lake is mostly zoned General Use, although the area around Coila Creek is a Sanctuary Zone.

Consent is required from the Minister under the provisions outlined in the Marine Parks Regulations 2009, for undertaking works that will potentially harm marine animals. This includes the artificial opening of the lakes as the definition of marine animals extends to beach invertebrates, which invariably would be destroyed through the excavation process.

1.4 Approvals Required for Implementation of the Entrance Management Policies

The approvals required for implementation of the Entrance Management Policies for the six Eurobodalla Coastal Lakes are summaries in Table 1-1. These approvals are required prior to commencement of entrance management works.

As indicated in Section 1.3.3, a separate licence to dredge does not need to be obtained from DPI (Fisheries), providing that a dredging licence is obtained under the *Crown Lands Act, 1989*.

1.5 Potential Approval Conditions

It is recommended that the approvals provided enable Council to undertake all works necessary to management the entrances, in accordance with the Policies, without any further consent or licence, for a fixed period of five (5) years. After this time, Council should be required to review the Policies and associated environmental impacts before approval and licence renewals are issued.

Table 1-1 Approvals, concurrence and referrals required by proponent

Relevant Act	Approvals Required	Approval Body
Crown Lands Act 1989 (refer Section 1.3.2)	• Approval to carry out activities on Crown Land	Department of Lands
Marine Parks Act 1997 (refer Section 1.3.8)	• Approval to harm marine animals within a Marine Park	Marine Parks Authority
*NSW Fisheries Management Act (*refer Section 1.3.3)	• Permit for destruction of marine vegetation, if applicable.	DPI (NSW Fisheries)
NSW Coastal Protection Act (refer Section 1.3.6)	• Concurrence role	DECCW
SEPP-71 (refer Section 1.3.1.2)	• Referral to Minister	Department of Planning

2 PROPOSED ENTRANCE MANAGEMENT WORKS DESCRIPTION

2.1 Aims / Objectives

The overall aims and objectives of undertaking entrance management works at the six Eurobodalla coastal lakes are:

- To have minimum interference with natural entrance opening processes and minimize impacts on ecological processes;
- To accommodate future climate change, and sea level rise in particular;
- To minimise risks to public safety associated with excessive inundation of foreshores and associated infrastructure;
- To minimise risks to public health associated with excessive bacterial contamination of waters;
- Conserve or enhance the biological diversity and floral and fauna communities of the estuarine lakes systems;
- To facilitate the construction and/or maintenance of essential community infrastructure;
- To determine procedures to be initiated for entrance operations including entrance breakouts;
- To determine key responsibilities for management of the entrance; and
- To detail the procedure for monitoring of lake entrances.

In meeting the above aims and objectives, Council will consider the following:

- Facilitate vertical natural migration of riparian and estuarine ecological communities in response to sea level rise;
- Limit opportunities for ingress and establishment of introduced and invasive species to the estuaries;
- Minimise impacts on local fisheries resources and other ecological species, where possible;
- Enable continued existing use of lands for as long as practical;
- Engage community support for the entrance management policies, and deter unauthorised entrance opening; and
- Time requirements for review of entrance management.

2.2 General Philosophy

Management of the coastal lake entrances will generally accord to the following philosophy.

Initial triggers (if opening today)

⇓

Undertake works to increase initial trigger (to restore a more natural opening regime)

⇓

Revised triggers following works

⇓

Works required to progressively increase trigger in response to future sea level

⇓

Long term trigger targets (incorporating sea level rise at 2100)

For the smaller coastal lakes, the Policies broadly aim for minimal or no opening (ie greater adaptation to closed entrances), but with consideration to potential impacts of future sea level rise. That is, under certain future conditions, opening of the entrance may be the most appropriate adaptation action for climate change mitigation.

2.3 Coila Lake

Coila Lake has an existing entrance management policy, which was adopted by Council in 2001. This policy is due for review.

2.3.1 Constraints

At RL 1.5m AHD private lands are inundated on the western side of the highway. These lands are natural saltmarshes and should be permitted to be inundated on a periodic basis. The landholder has constructed a drainage channel from this land back to Coila Creek to facilitate site drainage (refer Figure 2-1).

Figure 2-1 Constructed drainage channel in lowest lying private lands adjacent to Coila Ck

At RL 1.8m AHD, the stormwater system at the end of Monash Avenue (including a GPT) begins to be inundated. Council has indicated that this is not really a significant constraint and it does not affect backwater drainage for areas upstream, however, prolonged inundation with salt water will potentially damage the stormwater infrastructure. This level will also flood to the edge of the fill batters for the Princes Highway.

At RL 2.0m AHD, the private access road on the north side of Coila Creek is overtopped (same property as the land inundation at RL 1.5m). However, there is an alternative access point across the same land tenure less than 500m north of the constrained road.

At RL 2.2m AHD, small sections of the unformed cycle path along the southern shore of Coila Lake are inundated.

At RL 2.6m AHD, low level flooding of back yards occurs, while at RL 2.8m, some access to urban blocks becomes inundated.

At RL 2.8m AHD, some sections of the constructed cycle path becomes inundated.

At RL 3.0m AHD, the Coila Service Station starts to be inundated. There is a residence attached to the service station, which would also be inundated at this level. Maximum flood level in the past 20 years has reached within about 5 metres of the back door (probably in 1992 when peak lake level reached RL 2.3m).

2.3.2 Policy Outline

Initial trigger	RL 2.0m AHD; or RL 1.80m AHD for more than 3 months.
Primary Works	Establish an alternative temporary access to property north of Coila Creek for use when lake levels are high. Adjust local street drainage and stormwater system on foreshore land adjacent to Coila Lake as necessary (eg backwater flaps)
Revised trigger (following primary works)	RL 2.6m AHD; or > RL 2.5m AHD for more than 3 months
Progressive works	Offer incentives to owners of low-lying private rural property (< RL 3.0m) to accommodate migration of riparian vegetation communities under higher water levels (including sea level rise provisions). Progressive and opportunistic raising of low lying roads, including Princes Highway, allowing for sufficient cross-flow (ie don't impose barriers to habitat migration) Progressive and opportunistic raising or removal of assets and infrastructure around lake fringes (eg sewer manholes) Opportunistic filling of private non-rural property upon future development (for land < RL 3.0mAHD), except where adjacent to SEPP-14 wetlands, and providing no impact on flood behavior, vegetation, etc Progressive raising of minimum floor levels for fringing development (eg Coila service station) through changes to planning instruments. Future minimum floor

	level to be 1 in 100yr flood level + 0.5 metres, assuming entrance breakout at RL 3.2m (which includes provision for sea level rise).
Long term trigger target (ideal 2100 level)	RL 3.0 to 3.3m AHD, with preference for allowing natural breakout wherever possible

Where possible, repetitive artificial openings during summer months should be avoided due to the potential increased threat of introduction of the pest species European Green Crab. In this instance, inundation longer than 3 months may be considered reasonable (but not exceeding 6 months).

2.4 Tuross Lake

2.4.1 Constraints

<u>At RL 0.70m AHD</u>, water starts to overtop the decking of O'Brien's boatshed

<u>At RL 0.83m AHD</u>, water starts to overtop the decking of Laing's boatshed (refer Figure 2-2).

Figure 2-2 Laing's boatshed timber decking (recently reconstructed), and same during Feb 2007 (inset)

BMT WBM

At RL ~1.0m AHD, water starts to inundate farmland surrounding Tuross Lakes and tributaries

At RL 1.11m AHD, water prevents the Sewer Pumping Station next to Redbox Pizza from servicing the low foreshore properties (electrics for the pump station are much higher).

At RL 1.2m AHD, water starts to enter O'Briens boadshed

At RL 1.37m AHD, water starts to overtop the lowest deck of Redbox Pizza

At RL 1.6m AHD, water starts to enter Laing's boatshed

At RL 2.0m AHD, water starts to overtop Hector McWilliams Drive at the Narrows

At RL 2.4m AHD, water overtops flood level of Redbox Pizza residence.

2.4.2 Policy Outline

Initial trigger	Water Level > 0.7m AHD – Council commences to monitor water levels, rainfall and river flows. A relationship between rainfall in the catchment and water level response in the lake is provided in the Policy. Water level > RL 0.8m AHD for 14 days Water level > RL 2.0m AHD; Higher or lower time period triggers may be negotiated with directly affected business owners, during NSW and ACT school holiday periods and Easter holidays.
Works	Convert public access timber decking of commercial premises to floating pontoon type or raise timber decking to floor level of shop.
Revised trigger (following works)	n/a
Progressive works	Offer incentives to owners of low lying properties to accommodate migration of fringing vegetation communities. Progressive and opportunistic raising of Hector McWilliam Drive at the Narrows, and Princes Highway along low-lying section near Trunketabella Creek (ideally to > RL 3.0m AHD). Opportunistic filling of private non-rural property upon future development (for land < RL 3.0m AHD), except where adjacent to SEPP-14 wetlands, and providing no impact on flood behaviour, vegetation, etc Progressive and opportunistic raising or removal of assets around lake fringes (eg Sewage Pumping Station next to Redbox Pizza) Progressive raising of minimum floor levels for fringing development (eg boatsheds precinct) through changes to planning instruments. Minimum floor level to be 1 in 100yr flood level + 0.5 metres, assuming entrance breakout at RL 3.0m AHD.
Long term trigger target (ideal 2100 level)	No artificial opening of entrance preferable. RL 3.0m AHD

2.5 Kianga Lake

2.5.1 Constraints

At RL 1.8m AHD, water enters private properties on the northern side of Lakeside Drive – the lowest area is towards the western end of this road (refer Figure 2-3).

At RL 2.0m AHD, water overtops the access road to Kianga STP.

At RL 2.2m AHD, water overtops the sewage pumping station located on Council land between the lake and the lakeside properties (refer Figure 2-4).

At RL 2.6m AHD, water overtops the Kianga – Dalmeny coastal road on the northern approach to the bridge over Kianga Lake.

Figure 2-3 Low-lying backyards along Lakeside Drive, Kianga

Figure 2-4 Sewage pumping station behind Lakeside Drive properties, Kianga

2.5.2 Policy Outline

Initial trigger	Water level > RL 2.0m AHD Water level > RL 1.80m AHD for 14 days
Works	Infill crevices on rock shelf at headland on southern side of entrance to prevent premature discharge from lake prior to natural breakout of the entrance sand berm. Install a gauge board on Kianga-Dalmeny coastal road bridge indicating level in AHD of authorized breakout by Council.
Revised trigger (following works)	No revised trigger based on rock shelf works
Progressive works	Progressive raising of minimum floor levels for fringing development through changes to planning instruments. Minimum floor level should be 1% AEP flood level + 0.5 metres, assuming entrance breakout at RL 2.8m AHD (representing 100yr planning horizon). Progressive and opportunistic raising of STP access road to > RL 2.8m AHD, allowing for sufficient cross-flow (ie don't impose barriers to habitat migration) Progressive and opportunistic raising or removal of assets around lake fringes (eg sewer pump station) Progressive and opportunistic raising of coastal road to > 2.8m AHD
Long term trigger target (ideal 2100 level)	No artificial opening of entrance preferable. RL 2.8 to 3m AHD. Ultimately, this would require permanent retreat before the year 2100 from lands on the northern side of Lakeside Drive between Nos 25 and 49.

2.6 Little Lake

2.6.1 Constraints

At RL 2.0m AHD, water starts to inundate the edges of the 9th and 15th fairways of the Narooma Golf Course.

At RL 2.2m AHD, water starts to enter the sewer pumping station building off Willcocks Avenue, however, the pumps are located at RL 3.3m AHD.

At RL 2.5m AHD, water starts to overtop Glasshouse Rocks Road.

At RL 3.0m AHD, water extensively inundates the fairways of 8th, 9th, 11th and 15th holes, plus tees of 10th and 16th holes of the Narooma Golf Course.

2.6.2 Policy Outline

Initial trigger	Water level > RL 2.2m AHD
Works	Install signage at entrance indicating that unauthorised openings are illegal with substantial fines under the provisions of the Local Government Act 1993, and install gauge board on post at entrance indicating level in AHD of authorized breakout by Council.
Revised trigger (following works)	No revised trigger following signage
Progressive works	Initially, minor filling and landscaping to provide minimum fairway widths of RL 2.5m AHD, followed by more substantial filling of existing fairways, tees and greens and/or partial course redesign to accommodate reduced widths and allow for vertical migration of saltmarsh (with boardwalks over etc) (may include some clearing of existing fringe vegetation, subject to environmental assessment and appropriate approvals). Progressive and opportunistic flood-proofing of building assets around lake fringes (eg sewer pump station building). Progressive and opportunistic raising of Glasshouse Rocks Road, allowing for sufficient cross-flow (ie don't impose barriers to habitat migration).
Long term trigger target (ideal 2100 level)	No artificial opening of entrance preferable. RL 3.0m AHD.

2.7 Bullengella Lake

2.7.1 Constraints

There are no known constraints to inundation around the foreshores of Bullengella Lake. Surrounding lands are used for grazing only and contain no significant assets or infrastructure.

2.7.2 Policy Outline

The Entrance Management Policy for Bullengella Lake is to retain a natural opening regime.

Artificial openings would be permitted only for emergency management purposes, or to assist in the constructions of essential community services or infrastructure.

2.8 Nangudga Lake

2.8.1 Constraints

<u>At RL 1.2m AHD</u>, water starts to backflow into the drainage system of the Island View Beach Resort.

<u>At RL 1.2m AHD</u>, water starts to inundate private rural small holdings property on the southern side of the highway bridge.

At RL 1.5m AHD, water starts to inundate camping grounds and access roads within the Island View Beach Resort.

At RL 2.2m AHD, water starts to overtop private on-site sewage systems.

At RL 2.2m AHD, water overtops the causeway on the Old Coast Road.

At RL 2.5m AHD, water starts to enter existing private dwellings.

At RL 3.9m AHD, water overtops the Princes Highway road bridge and approaches.

2.8.2 Policy Outline

Initial trigger	Water level > RL 1.3m AHD
Works	Install flap gates to prevent backwater inundation into site. Pump stormwater sump downstream to provide capacity for stormwater capture to minimise site flooding (due to elevated tailwater levels) Provide incentives to rural landowners to accommodate higher lake water levels. Install a gauge board on Princes Highway bridge indicating level in AHD of authorized breakout by Council.
Revised trigger (following works)	Up to water level > RL 2.0m AHD
Progressive works	Opportunistic filling of private non-rural property upon future development (for land < RL 2.5mAHD), except where adjacent to SEPP-14 wetlands, and providing no impact on flood behavior, vegetation, etc Progressive raising of minimum floor levels for fringing development through changes to planning instruments. Minimum floor level should be 1% AEP flood level + 0.5 metres, assuming entrance breakout at RL 2.4m AHD. Progressive and opportunistic raising of causeway on Old Coast Road to RL 2.7m AHD min.
Long term trigger target (ideal 2100 level)	No artificial opening of entrance preferable. RL 2.4m AHD.

3 DESCRIPTION OF EXISTING LAKE ENVIRONMENTS

Available information describing the existing lake environmental varies significantly from one lake to the next. Coila Lake and Tuross Lakes have been studied extensively, resulting in the development of a specific long-term Estuary Management Plan for these lakes. The other lakes, however, have been subject to few environmental assessments, primarily limited to some opportunistic water sampling and broadscale habitat mapping.

3.1 Coila Lake

3.1.1 Location and coastal setting

Coila Lake is located 320 km south of Sydney. It is stated in the Coila Entrance Management Policy (EMP) (ESC, 2001a) that the waterway area is ~ 7 km^2 and catchment area is ~ 48 km^2. The catchment largely consist of forested lands, with 25% of the catchment cleared (Spurway et al., 2000). Urban development of the Tuross Head village extends to the southern shores of Coila Lake.

Coila Lake is separated from Tuross Estuary by a bedrock ridge approximately 4 km long and 0.5 – 1 km wide.

The Coila Beach coastline is oriented east to very slightly ESE, with only minor protruding headlands, the largest at Potato Point, and relatively little protrusion of Tuross Head between Tuross and Coila Lakes. Beaches immediately south of Coila are relatively long stretches. This configuration indicates that these compartments are connected under typical south-east wave height conditions, with sediment transport between beaches in a net northerly direction. In this case, sediment to the Coila entrance is supplied from both the nearshore zone (ie cross-shore transport) and from longshore transport processes from the beaches immediately south under modal south-easterly swell waves. That is, it does not require large wave heights (or long period swell) for sediment to be transported between these compartments, and so large quantities of sediment may be transported into Coila entrance relatively quickly and under typical wave heights.

Figure 3-1 shows essential features of Coila Lake, along with bathymetric (ie hydrosurvey) and fringing topographic details.

3.1.2 Hydrology

3.1.2.1 Entrance Behaviour / Characteristics

Coila Lake is typically closed to the ocean, with an entrance berm (or sand bar), formed by the deposition of marine sediments due to longshore and cross-shore sediment transport driven by waves and tides. Open entrance conditions tend to last only a few weeks to months (Spurway et al., 2000; ESC, 2001a). The entrance is more frequently opened by artificial means (mechanical equipment) than by natural rainfall events. Of the 18 openings recorded since March 1975, only four occurred due to natural forces (Spurway et al, 2000; ESC, 2001a) (refer Table 3-1). The lake is reported to be closed for 87% of the time (DECC, 2007).

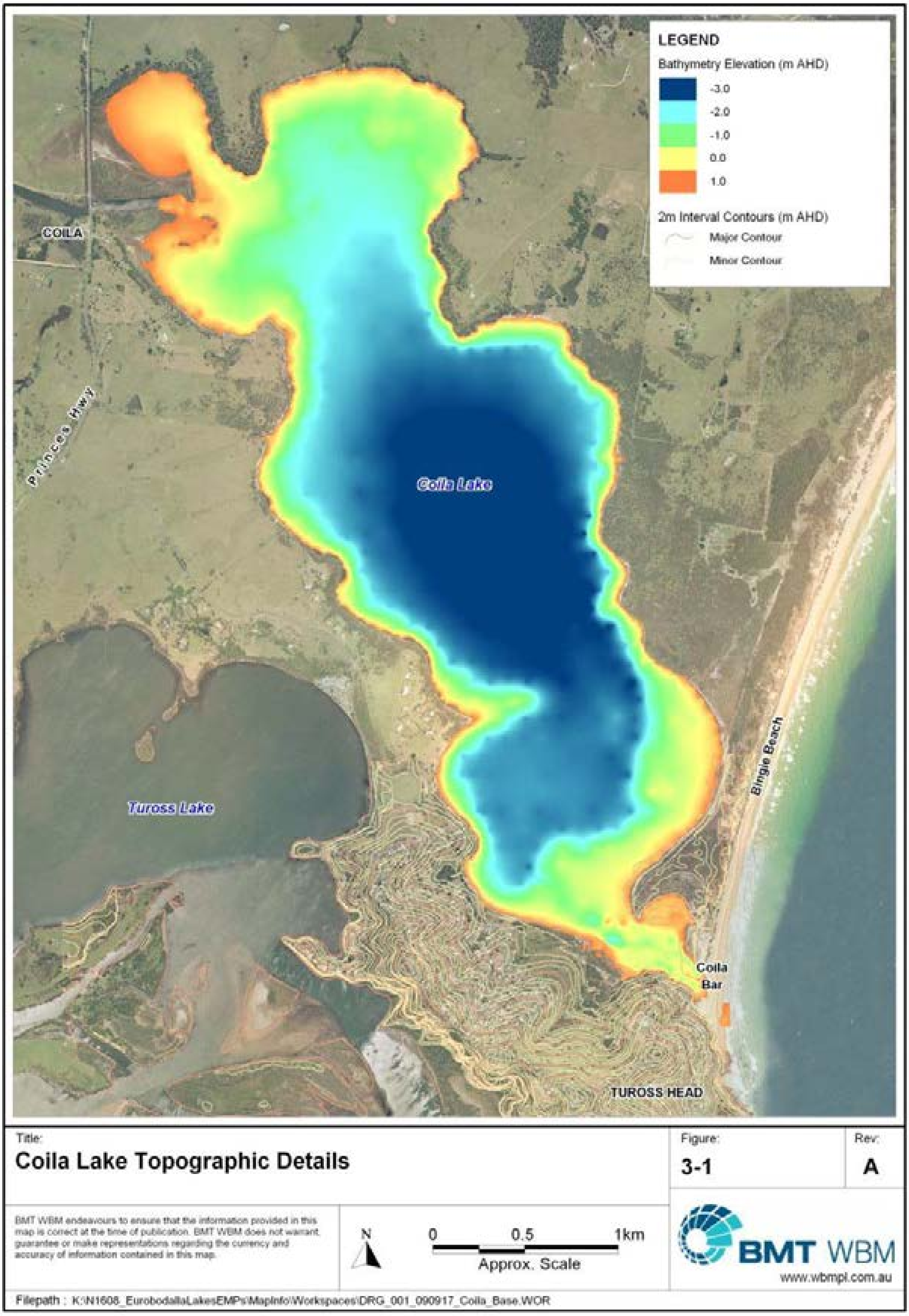

Figure 3-1 Coila Lake Topographic Details

The relative infrequency of natural openings is likely to be in part due to its large waterway area relative to its catchment area. The large lake area enables the lake to accommodate long periods of rainfall without opening, and to survive long periods of evaporation. As described by Brown and Root (2001), the large lake relative to catchment size results in fluvial inflows that are insufficient to overcome the processes of tide and ocean, restricting the lake to being intermittently open.

The Council policy prior to the existing Coila EMP was for artificial opening no lower than 1.5 m AHD. This was done primarily to facilitate recruitment of prawns into the Lake. However, water levels reached 2.2 m for a short period in August 1998, during which there was no undue hardship experienced by residents. Thus, the Estuary Management Committee adopted a new level of 1.8 m AHD, at which lake opening would be considered. The Coila EMP then reviewed such levels, as well as setting out the procedures, responsibilities and required response from the authorities to natural opening events (Spurway et al., 2000).

Table 3-1 Entrance opening conditions, including date, water level, duration of opening and type of opening (natural (N) or artificial (A)), reproduced from Spurway et al., 2000.

Date of Opening	Water level	Type of opening*	Duration of opening (weeks)
March 1975	?	N	35
March 1976	?	N	6
18 Oct 1976	?	N	25
Mid-June 1978	?	A	10
23 Feb 1984	RL 1.96m	A	7
24 July 1985	RL 1.5m	A	2
Nov 1985	RL 1.7m	A	?
23 June 1988	RL 1.7m	A	2
12 Aug 1988	RL 1.2m	A	1.5
28 April 1989	RL 2.1 - 2.2m	A	11
12 June 1990	RL 1.7m	A	10
11 June 1991	RL 2.07m	A	15
11 Feb 1992	RL 2.14m	A	10
5 Dec 1992	RL 2.3m	N	8
16 June 1995	RL 1.62m	A	3
19 August 1998	RL 2.1m	A	2.5
16 November 1999	RL 1.84	A	6.5

Artificial (A), Natural (N)

Brown and Root (2001) report that natural lake opening levels are likely to be between 2.0 and 2.3 m, although this may also depend on the berm level, which is reported to vary between 2.0 and 3.5 m in height.

Spurway et al. (2000) illustrated that the duration of opening was approximately inversely related to the water levels prior to opening. Higher water levels in the lake will enable more effective scouring of an entrance channel, and thus a longer duration of open entrance conditions.

Closure of Coila Lake is driven by ocean swells and waves. Spurway et al. (2000) discuss the relatively fast re-closing of the entrance bar, for instance occurring as quickly as within four days, given the right swell conditions. In January 2000, a 2 m swell closed the entrance overnight, with thousands of cubic metres of sand being transported into the channel to form a bar.

Coila Lake exhibits a very small (almost non-existent) flood tide delta, which is likely due to the lake being rarely open for long enough to initiate any substantial flood tide flows capable of transporting marine sands into the lake to form the delta.

The work of Rustomji (2007) highlights the importance of fluvial flows in allowing entrance closure. That is, while it is wave-driven sediment transport that builds the entrance berm, it is in fact the flow (or lack of flow) out of the entrance mouth that enables wave-driven processes to dominate, and a berm to form. Coila Lake, with its relatively small catchment to waterway size, likely has low flow rates under average rainfall conditions, which enable entrance berm building to occur quickly following a breakout event.

For Coila Lake, swell conditions at the time of opening will also be important, in addition to lake water levels. Berm building swell conditions should be avoided (typically associated with recovery after storms, and so, lower/typical wave heights) as should high ocean levels at the time of opening (to maximise the outflow of water). High swell conditions, while favouring offshore sediment transport, generate higher water levels, and should also be avoided. In reality, the swell conditions over the subsequent weeks after opening are most important (in addition to water level) in determining the length over which the entrance remains open.

3.1.2.2 Water balance

It is noted that predicting rainfall and lake response to imminent rainfall is a key component of an effective opening strategy (Spurway et al., 2000). Daily rainfall runoff modelling was used by Spurway et al. (2000) to determine the average rise in water level for a given rainfall event. The calculations were made for both a dry and wet catchment condition preceding the rainfall, with 'wet catchment' ratios corresponding to 50 mm of rainfall in the preceding 10 days, as shown in Table 3-2. Table 3-2 can then be used to determine the rise in water level relative to the rainfall event, and which may be applicable to the opening regime implemented at the Lake.

Based on an average lake level of 0.93 m AHD, a 1 year ARI rainfall may raise the lake level to 1.75 m AHD, within the range at which artificial breaches may be performed (Brown and Root, 2001).

3.1.2.3 Extractions and Water Use

There has been minimal water extraction from catchment streams and creeks, used mainly for stock watering. An irrigation dam supporting more intensive cattle stocking was recently constructed. It has been suggested that the potential rural demand is likely to remain low, based upon the relatively small rural holdings in the catchment.

A draft Tuross River Macro Water Sharing Plan (DNR, May 2006) lists the Coila Lake catchment, noting a current water extraction entitlement of 8 ML per year, and which cannot be extended to new entitlements under the draft plan. No trade allocations are permitted in Coila Lake catchment, recognising the lake's potential sensitivity to water extraction.

It is suggested that major extractions from the Coila Creek and Cudbugga Creek tributaries may vary the entrance regime of the Lake, and hence over-extraction of from the lake's major sub-catchments is not recommended. The draft water sharing plan appears to provide adequate protection of lake hydrologic inputs in this regard. Protection of minor tributary streams was not indicated, but is possibly unnecessary due to the limited potential for intensive irrigation within the Coila catchment (DECC, 2007).

Table 3-2 Determination of water level rise based on catchment rainfall, reproduced from Spurway et al. (2000) and/or ESC (2001a).

Daily Rain (mm)	Lake Rise/Rainfall Ratio	
	Dry Catchment	Wet Catchment
0-10	1.0	1.0
11-20	1.0	1.0
21-30	1.0	1.1
31-40	1.0	1.1
41-50	1.1	1.4
51-60	1.1	1.9
61-70	1.2	2.8
71-80	1.4	3.6
81-90	1.6	4.2
91-100	1.9	4.7
101-125	2.9	5.1
126-150	3.9	5.8
151-200	4.8	6.5
200-250	5.6	6.8

3.1.3 Water Quality

3.1.3.1 Lake flushing

Lake flushing times were estimated by Spurway et al. (2000). Coila Lake has a theoretical flushing time of six days, however, it is unlikely that water entering the lake on a flood tide becomes fully mixed. Studies of nearby Wagonga Inlet and Lake Illawarra quoted by Spurway et al. (2000) suggest an estimated 20% and 30% of efficiency of entrance exchange respectively. That is, 20–30% of the incoming tidal water remains in the estuary, while 70-80% flows back out unmixed. In this case, a true estimate for flushing time of Coila Lake is likely to be 24-30 days (assuming a mixing efficiency of 20–25%).

More recently, tidal flushing calculations were undertaken by DNR (2006), illustrated in Figure 3-2, indicating that when the entrance is scoured, flushing of Coila Lake may take up to 20-40 days. When the entrance is choked, however, flushing may be over 40 days in the majority of the basin. It should also be noted that the entrance is typically open for between six weeks to a few months, and intermediate to choked conditions are most likely to prevail during this time.

The assimilative capacity, that is the response of the Lake to rainfall inputs, has also been calculated by Spurway et al. (2000). 30 mm of rainfall in the Coila catchment would produce 450 ML of runoff. For an average water level of 0.93 m AHD and total volume of 15,000 ML, 450 ML input would result a 7 cm water level rise and is only 3% of the total volume. A 100 mm rainfall event represents only 10% of Lake volume in this scenario. In response to 400 mm of rainfall in January 1999, Spurway et al. (2000) predicted nearly a 1.4 m rise in the water level.

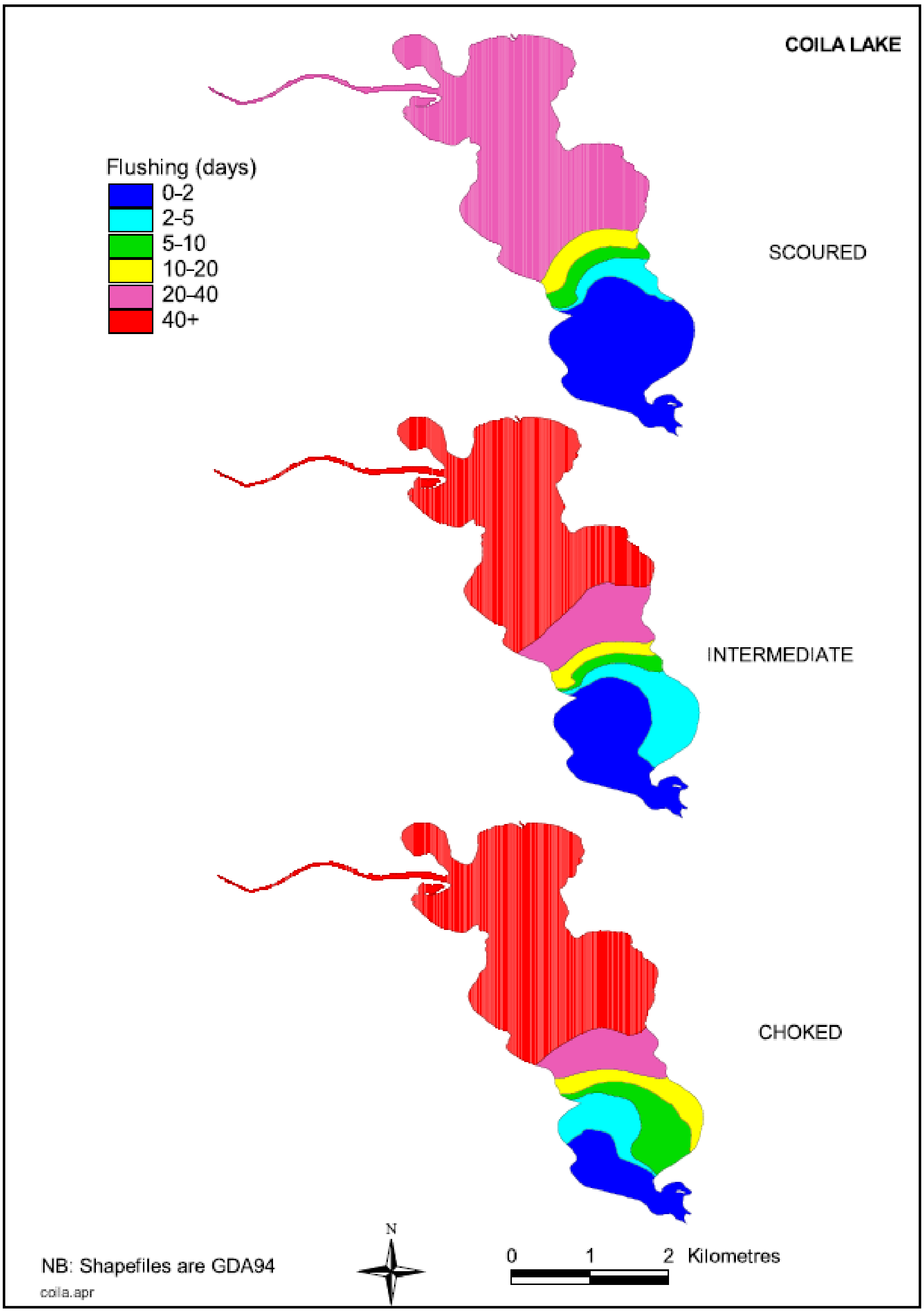

Figure 3-2 Tidal Flushing times for Coila Lake, source DNR 2006

With a large volume per size of catchment, the lake has a large capacity for dilution of inputs. However, the lake also has a high 'trapping efficiency' meaning that it may capture large rainfall inputs (eg, a 1 in 25 year rainfall event) without initiating a breach of the entrance. The effect upon water quality from the trapping and containment of pollutant inputs was not assessed specifically by Spurway et al. (2000). The authors suggest, however, this containment efficiency highlighted the importance of prolonging entrance opening to promote tidal flushing of the lake.

The entrance is mostly closed, which means that all sediments, nutrients and other pollutant inputs entering the system are mostly retained in the lake. It is likely the lake has evolved to internally cycle and process sediments and pollutants under closed conditions. The lake has a deep depositional zone (~2.5 – 3.0 m) in the middle, with shallower zones (~0.3 – 0.6m) to its north and south, and which contain extensive seagrass beds (DECC, 2007). The amount of light reaching the bed results in different environmental processes within the shallow and deep sections. Wind-driven circulation allows for effective mixing of the waters, which would lead to relatively consistent water quality throughout the waterway (WBM, 2005).

3.1.3.2 Nutrients and other pollutants

Around 23% of the catchment is cleared rural land and 1.5% of the catchment is urban lands. These are likely to result in increased sediment and pollutant runoff into the lake, particularly nutrients and faecal coliforms from rural land use, and from Tuross Head urban development. Bingie, a rural residential development, is located to the north of the lake. The remaining forested lands are largely part of Moruya State Forest (DECC, 2007).

The loss of fringing riparian vegetation has assisted in the delivery of sediment, nutrient and pollutants, and meant foreshores are more susceptible to erosion (WBM, 2005). Nutrient and sediment loads to the lake, as modelled by WBM (2004), suggest that land clearing and development has increased total nitrogen loads by 150%, total phosphorous loads by 300% and sediment loads by 400% compared to natural (pre-developed) conditions.

The long cycles during which the lake is closed will have implications for nutrient and sediment management (Spurway et al., 2000). The long flushing times of the lake, even when open, suggests that pollutants entering the lake may be taken up by biota or incorporated by sediments before rather than being flushed to sea. Processes such as denitrification within the bed sediments are expected to be significant in Coila Lake (Robson et al., 2004; Sanderson et al, 2006).

While monitoring of nutrients (total phosphorous and total nitrogen) in Coila Lake typically failed to meet ANZECC guidelines during measurement between March 1995 to May 1996, it was suggested that, based upon evidence at other ICOLLs, the guidelines are likely to be inappropriate for ICOLL systems, as these systems naturally trap nutrients due to their intermittent opening characteristics (Spurway et al., 2000). Further, the ability of the lake to process its nutrient inputs has not been properly examined (DECC, 2007).

<u>Assessment by Baginska et al (2004)</u>

An investigation into land use and nutrient export from catchments into creeks and lakes was undertaken by Baginska et al. (2004) for the Comprehensive Coastal Assessment (CCA). The report estimated loads of total nitrogen and total phosphorous from a catchment, with values for exports based on land uses of Conservation / Bushland / Pasture / Unimproved, Agriculture / Cropping, Agriculture / Pasture Improved, Urban Low Density, Urban Medium Density, Commercial / Industrial / Urban High Density, and Transport & Communication. For Coila Lake, a catchment area of 6214.6 ha, with 0.9 % urban area, was estimated to have a nutrient export potential for total nitrogen loads of 2391.1 kg/year and total phosphorous loads of 296.9 kg/year (Baginska et al., 2004).

Assessment by Sanderson et al (2006)

Sanderson et al (2006) (refer Appendix B) suggest that increased nutrient loads will affect benthic primary production, due to the increase in algal blooms resulting in reduced light availability. With respect to benthic primary production and nutrient loading (taken as a function of the potential export from various catchment land uses multiplied by the catchment area) it was found that Coila Lake was less susceptible to reduction in benthic production, although, this is largely because it has a small catchment to waterway area, and therefore, areal loading rate. Overall, the susceptibility of Coila Lake to adverse change with increased total nitrogen load was concluded to be moderate to high (the authors gave this assessment a low confidence level, based upon amount of useful data, other processes not considered in the assessment, and subjective assessment of the uncertainty in the modelling for the project) (Sanderson et al., 2006).

Assessment by Robson et al (2004)

A biogeochemical model for calculating estuary response to nutrient loading was developed for Coila Lake (and included 13 state variables and over 50 parameters) by Robson et al. (2004). Nonetheless, the model was stated to still not represent all important variables and mechanisms that may be operating in the Lake, and some variables included in the modelling may not be a complete representation of the natural mechanism in the lake. Further, such limitations are likely to be further exacerbated by a lack of available data with which to calibrate the models (Robson et al., 2004). Model inputs included bathymetry, catchment loads, river flows and exchanges within the lake and between the lake and ocean. Outputs from the models were quoted as total nitrogen, as there is insufficient data available to reliably divide the TN into constituents (dissolved inorganic nitrogen (DIN), dissolved organic nitrogen (DON), detritus). Modelling of nutrient cycling by Robson et al (2004) predicts that denitrification in Coila Lake currently balances the input of nitrogen compounds.

A number of typical biogeochemical processes are worth noting. Systems with low nutrient loads will have clear water, so PAR can reach benthic (ie, bottom-attached) primary producers. These primary producers are good at trapping detritus and cycling nutrients released from the sediment back into the sediment. Thus, the feedback of this system assists to maintain clear water. If nutrient load increases too much, growth of phytoplankton or macro-algae in the water column will attenuate light to the benthic primary producers, suppressing their production, and so, the cycling of nutrients back into the sediment, and exacerbating or feeding back to allow phytoplankton/macro-algal blooms (and which further suppresses light to the bottom). Further, the bottom condition becomes less ‘sticky’, allowing detritus to be resuspended into the water column (Robson et al., 2004).

Many (but not all) of the mechanisms for nitrogen sources and sinks scale proportionally to the waterway area. Three bulk nutrient fluxes (or mechanisms) are calculated by the model in three distinct steps: a catchment model gives nutrient load (source term for biogeochemical model); a fluid dynamical model calculates mixing with the ocean, which results in loss/gain of nutrient where nutrients are higher/lower in the lake than the ocean (a sink/source term to the biomodel); and denitrification (the loss of nitrogen as nitrogen gas) is calculated by the biomodel (Robson et al., 2004). Denitrification, and the form of nitrogen as either a form which is able to move with the currents, or a form which is locked and cannot be moved is important in the resultant response to nutrient loading.

The model focuses upon nitrogen, and assumes that nitrogen and phosphorous will change proportionally (Robson et al., 2004). Nitrogen entering an estuary may be removed in one of the following ways: it may be flushed to the ocean, via tidal or other exchanges; it may be buried in the sediments; it may be released to the atmosphere through denitrification; and it may be temporarily removed through uptake by long-lived emergent macrophytes and mangroves. Thus, it is assumed that lakes which are intermittently closed to the ocean will have long residence times for nitrogen, and are likely to suffer adverse impacts at lower nitrogen loads than better flushed (or tidal) estuaries. Conversely, open estuaries typically result from larger catchments, and so, receive correspondingly higher nitrogen loads. In addition, the shape and hydrodynamics of an estuary or lake, including well-flushed sections and poorly flushed basins or creeks, mean individual systems are likely to have a range of possible responses to nutrient loading (Robson et al., 2004).

Robson et al (2004) found that the majority of the upper catchment (forested land use) has nitrogen export of less than 0.025 T/km^2/year, however, nearer to the lake (particularly from Tuross Head village), export increases substantially (refer Figure 3-3). For the entire catchment, the total nitrogen load to Coila Lake is 2391 kg/year. Were the entire catchment to be urbanised, this load would increase to 16560 kg/year, and this value was used in modelling, to determine the impact to Coila as nitrogen loads are increased over a number of consecutive years. That is, if the entire catchment was urbanised, total nitrogen load per unit of waterway area would increase to 2.5 T/km^2/year.

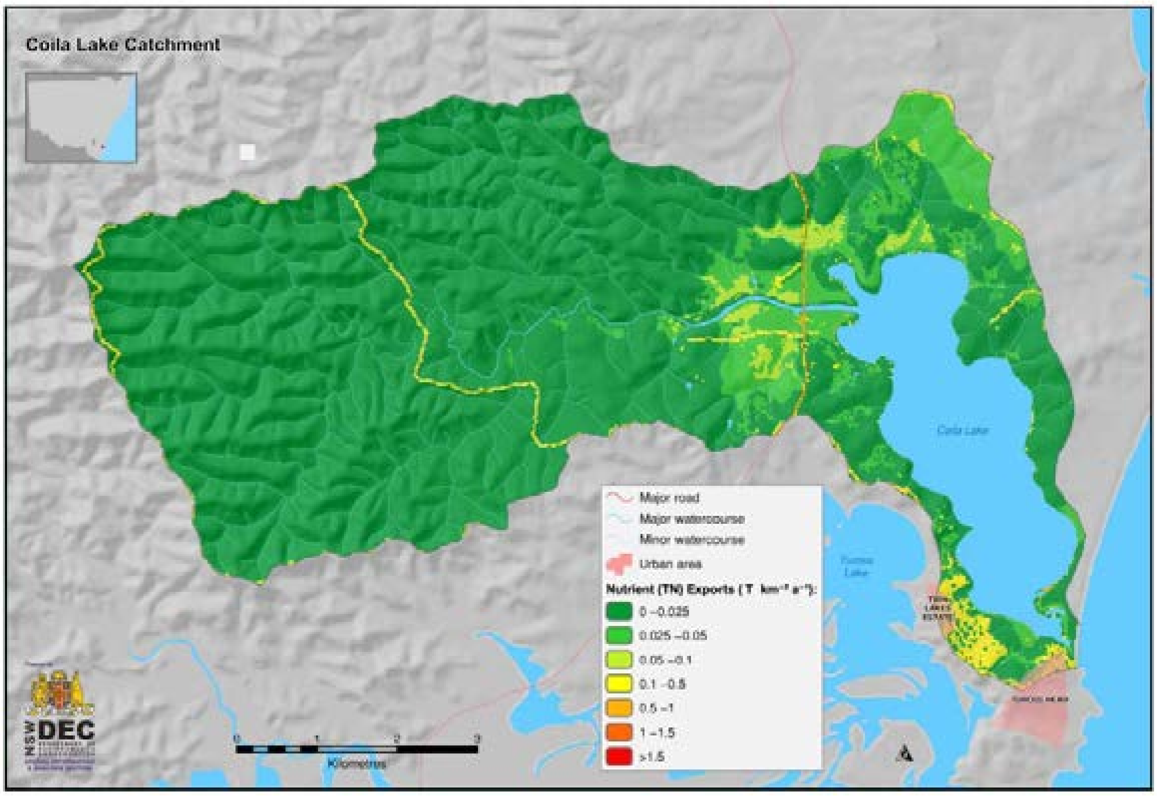

Figure 3-3 Nitrogen loading from the Coila Lake catchment (source: Robson et al., 2004)

Per waterway area, the total nitrogen load into Coila Lake is estimated at 0.3623 T/km^2/year (or, 0.9926 mg/m^2/d). It was found that the nitrogen from the catchment was approximately balanced by denitrification within the lake.

Modelling conducted also determined the response of phytoplankton, seagrass and magroalgae in Coila Lake to increased nitrogen loads. Model results for macroaglae suggests concentrations remain low for nutrient loading at present values to values slightly above the maximum load (ie, and urbanised catchment). Phytoplankton was found to increase only slightly with nutrient loading. Robson et al (2004) conclude that Coila Lake is relatively pristine (and, given the small ratio of catchment area to lake volume, is likely to remain so even with increased nutrients), and suggest seagrass may in fact be nutrient limited in Coila Lake.

It is found in Coila Lake that large rainfall events result in pulses of nutrient which inevitably result in a phytoplankton response without exchange with the ocean. There was insufficient data to calibrate the model, however, it was suggested that given mean concentrations of 3 ug/L of chlorophyll-a at present in Coila lake (Ozestuaries database), there is a possibility for phytoplankton blooms were nitrogen loads increased substantially.

However, the model results suggested that because the area of the catchment is small relative to the waterway, the nitrogen load potential is limited, and so Coila is not highly sensitive to increased nutrient load (even modelling with an entirely urbanised catchment). At present, the majority of the catchment exports low total nitrogen loads (based on largely forested landuse). In fact, given the localised nature of urban areas next to Coila, Robson et al (2004) conclude it would be relatively easy to minimise the nutrient load from these areas into Coila Lake, and preserve it as a 'quasi-pristine oligotrophic system'.

Available water quality data

Available water quality data covering nutrients for Coila Lake are presented in Table 3-3 and Table 3-4.

3.1.3.3 Public Health

In the past, the Coila Lake entrance has not been opened for the purpose of improving recreational water quality, and there is no present evidence to suggest this should change (Spurway et al., 2000).

The Tuross Head Weekly Times has periodically raised concerns about swimming of families with toddlers at the entrance bar, due to a large amount of uncollected dog faeces along the bar at the beach.

3.1.3.4 Odour

Odour is a common cause for complaints by the local community. During low water levels, rotting exposed aquatic vegetation may result in nuisance odours. The exposure of lake sediments may also produce hydrogen sulphide, as a result of the anaerobic breakdown of organic matter by bacteria within the sediment. During high water levels, the inundation of terrestrial vegetation and subsequent rotting has also been the cause of localised odours (Spurway et al., 2000).

Opening the lake at low water levels was not viewed as a necessary response to odour complaints, because this may lead to long term water quality problems where the lake re-closes quickly, and there is a lack of flushing.

Table 3-3 Mean water quality data (1994-1996) for Coila and Tuross Lakes (Source: NSW EPA)

	NOx ug/L	NH3 ug/L	PO4 ug/L	TN ug/L	TP ug/L	temp oC	salinity ms/cm	pH	DO %sat	DO mg/L	turbidity ntu	chl a
Coila Lake												
Dec-94	*	*		*	*	*	*	*	*	*	*	*
Jan-95	*	*		*	*	*	*	*	*	*	*	*
Feb-95	*	*		*	*	*	*	*	*	*	*	*
Mar-95	<10	32		691	24	22.2	21.5	*	105.5	8.1	1.8	*
Apr-95	<10	33		747	32	18.7	22.4	*	118.1	9.6	0	*
May-95	<10	86		890	21	16.5	22.3	*	106.2	9.1	1.9	1.4
Jun-95	<10	14		834	37	14.7	20.6	*	115.1	10.3	1.7	3.1
Dec-95	<2	5	<2	430	25	20.6	26.3	8.6	116.6	7.9	1.7	0.4
Jan-96	<2	6	<2	390	15	23.5	26.9	8.5	92.6	5.9	3.6	3.1
Feb-96	<2	7	3	537	26	23.5	27.7	8.4	93.3	6.5	2.7	2.1
Mar-96	<2	5	4	628	46	22.5	28.3	8.4	94.6	6.1	15.6	3.6
Apr-96	3	14	2	475	32	17.9	27.3	8.1	93.8	6.5	2.6	2.8
May-96	<2	10	<2	638	37	17.6	29.1	8.3	93.9	7.1	1.4	3.6
Tuross Lake												
Dec-94	<10	28		151	24	20.3	34.6	*	104.6	7.7	7	*
Jan-95	<10	10		171	15	23	30.9	*	98.9	7.1	6.8	*
Feb-95	<10	34		340	13	23.5	21.8	*	97.8	7.3	5.9	*
Mar-95	<10	32		358	13	22.9	21.2	*	106.8	8.1	7.2	*
Apr-95	<10	33		204	17	19.5	21.2	*	106.8	8.1	4.1	*
May-95	<10	61		409	13	17	32.4	*	103.8	8.3	4.2	0.8
Jun-95	<10	12		387	20	15.8	28.2	*	112.2	9.4	2.2	0.6
Dec-95	21	7	<2	235	15	19.8	18.1	8.2	111.3	8.1	3.1	1.1
Jan-96	<2	23	2	57	10	23.1	31	8.1	98.6	6.2	5.1	1
Feb-96	2	3	2	113	13	22	32.3	8.1	96.8	6.2	3.8	1.9
Mar-96	28	2	8	112	28	20.7	33.7	8.1	98	6.4	6.8	1.5
Apr-96	2	<2	3	55	17	17.7	32	7.9	101.9	6.9	2.8	1.3
May-96	12	6	2	237	14	18.3	29.8	8.2	98.6	7.1	1	0.6

Table 3-4 Water quality summary data 1995-6 (source: MHL, 1996)

Table 3.2 Coila Lake Water Quality Summary

Parameter	Units	n	Mean	Median	Std Dev	Max	Min
Level (AHD)	m	5969	0.486	0.450	0.118	0.740	0.320
Specific Conductivity	$mScm^{-1}$	5977	44.66	45.40	2.09	48.40	37.60
pH	-	5977	8.29	8.28	0.10	8.57	7.97
Temperature	°C	5977	15.53	15.58	3.46	23.05	9.23
Dissolved Oxygen	mg/L	5977	7.10	7.41	1.81	11.87	1.42

Table 3.3 Water Quality Summary for Coila Lake from 8-3-95 to 26-10-95 (MHL 1996)

Parameter	Units	n	Mean	Median	Std Dev	Max	Min
Level (AHD)	m	5376	0.836	0.430	0.513	1.640	0.120
Specific Conductivity	$mScm^{-1}$	5376	39.11	38.90	5.95	46.20	22.80
pH	-	5376	8.31	8.32	0.15	8.66	7.74
Temperature	°C	5376	15.57	15.84	3.44	24.27	8.77
Dissolved Oxygen	mg/L	5271	6.67	6.89	2.08	13.69	0.34

3.1.4 Sediments

3.1.4.1 Acid Sulfate Soils

Acid sulfate soils are expected to be present around the peripheries of the estuary. Additional, and more prolonged, inundation of these soils, compared to existing conditions, would reduce the oxidation potential of the soils, thus reducing their acid-generating potential, and would also improve the neutralising effect of the marine waters against any acid that is generated.

No acid sulfate soils would be located in the entrance berm where excavations would take place, as this area comprises marine sands only, deposited since the last entrance breakout event.

3.1.4.2 Bank erosion and sedimentation

The large variation in water levels of Coila Lake means that the banks and foreshores of the waterway have stabilised in response to these extreme conditions. Wind waves generated over the surface of Coila Lake are expected to be the main driver for foreshore erosion.

Under high water level conditions, the banks of Coila Creek would become saturated, and may be prone to collapse following sudden water level retreat (ie drawdown).

Given its relatively large waterway size compared to its catchment size, Coila Lake is considered geologically ‘immature’. That is, there has been relatively little infilling of catchment sediments within the paleo-valley formed behind the coastal barriers. Sedimentation within Coila Lake is not considered a big issue. Landward progression of the marine delta has been noted in Coila Lake, however, and is expected to have resulted from entrance intervention over the past few decades, as marine sands are not able to be scoured and advected out of the entrance compartment given the lower hydrostatic head at breakout compared to natural conditions.

3.1.5 Ecology

The estuarine ecosystems of Coila Lake (and other ICOLLs) are strongly influenced by the behaviour of the Lake’s entrance. In this regard, entrance conditions influences water quality, tidal circulation and flooding that in turn determine the composition of flora and fauna communities within the lake (Spurway et al., 2000).

Fringing wetlands are important for the water quality and health of the lake, due to the nutrient cycling performed by the wetlands, which contributes organic material to the estuary, and their provision of habitat to various terrestrial and aquatic flora and fauna.

Wetland communities that fringe Coila Lake (and other ICOLLs) require inundation to maintain their character, extent and biodiversity. In particular, the duration, extent and timing of inundation is highly important to the ecological processes of coastal lakes and lagoons. If regular opening occurs at low water levels, this is likely to degrade fringing wetlands, and reduce fisheries production and other biodiversity over the long term (Spurway et al., 2000). This is an important factor given the high commercial fisheries value of the lake in terms of finfish and crustacean catches.

3.1.5.1 Fringing Wetland Vegetation

Narrow linear patches of saltmarsh fringe the southern and northern extremities of the lake, while more extensive saltmarsh communities surround the north-western area where Coila Creek enters the lake (refer Figure 3-4). In total, an area of 0.343 km^2 of saltmarsh surrounds Coila Lake (NSW DPI, 2006/7). Common saltmarsh species present include *Sarcocornia quinqueflora, Selliera radicans, Baumea* spp., *Juncus krausii* and *Scirpus* spp.

Saltmarsh communities may be fringed by Swamp Oak (*Casuarina glauca*) swamp forest, and linear patches of Swamp Oak swamp forest are also present in some areas along the shore of Coila Lake. Mangrove communities are absent from Coila Lake due to the lack of frequent tidal water level variations.

The saltmarsh communities surrounding the lake to the north and south of Coila Creek are mapped as *State Environmental Planning Policy No 14* (SEPP14) Coastal Wetlands (164a and 164b), and a third SEPP-14 Coastal Wetland (146c) is located near the lake entrance (refer Figure 3-5). The Coila Creek delta wetlands are also listed on the Directory of Important Wetlands in Australia (DIWA). These high ecological value wetlands are under pressure from a range of historical and contemporary catchment activities.

Surrounding terrestrial (i.e. non-wetland) vegetation is largely cleared, featuring sparse patches of sclerophyll forest, wattle scrub and coastal scrub bordering the wetland vegetation. Terrestrial vegetation is more extensive within the eastern area where land has not been subjected to residential or agricultural use.

Degradation of the vegetation communities surrounding Coila Lake has been noted (NSW DPI, 2006/7). As such, a number of local Landcare and other environmental projects have begun to restore riparian buffers in recent years, through fencing, replanting, reshaping of eroded areas and educational signage activities. However, more work is required to increase vegetated buffer widths, preferably to a width of 100 m from mean high water mark to improve biodiversity and habitat linkages (DECC, 2007).

3.1.5.2 Aquatic Vegetation

Seagrass communities composed primarily of *Zostera* are present in Coila Lake, with a smaller proportion of *Ruppia* also present (NSW DPI, 2006/7). These communities are extensive in the south-east and north-west regions of the lake, and narrowly fringe the shallow periphery of the remainder of the lake (refer Figure 3-4). In total, an area of 1.367 km^2 of seagrass is present within Coila Lake (NSW DPI, 2006/7).

DECC (2007) reports that epiphytic algae are common on seagrass fronds, while dense mats of free-floating filamentous macro-algae are also found in shallow sheltered bays in the lake.

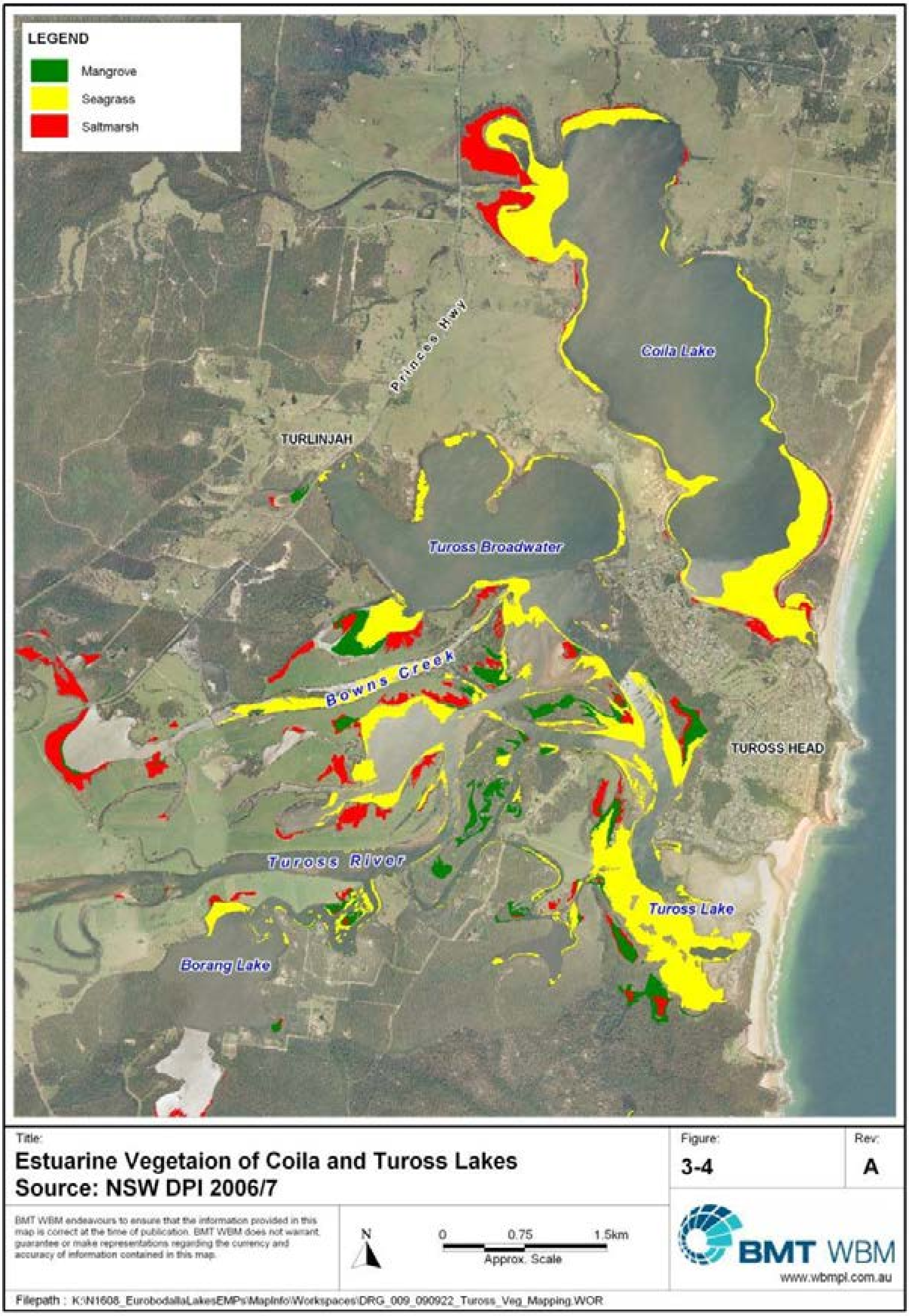

Figure 3-4 Estuarine vegetation of Coila and Tuross Lakes (source: NSW DPI 2006/7).

Figure 3-5 ***State Environmental Planning Policy No 14*** **(SEPP14) Coastal Wetlands of Coila and Tuross Lakes.**

3.1.5.3 Endangered Ecological Communities

In terms of fringing wetland vegetation, the Swamp Oak communities surrounding Coila Lake are an Endangered Ecological Community under the NSW *Threatened Species Conservation Act 1995*, listed as *Swamp Oak floodplain forest of the NSW North Coast, Sydney Basin and South East Corner Bioregions.* The saltmarsh communities surrounding Coila Lake are also an Endangered Ecological Community, listed as *Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South West Corner Bioregions.*

Terrestrial vegetation communities in the vicinity of Coila Lake also include NSW-listed Endangered Ecological Communities. Specifically, two small patches of *Bega Dry Grass Forest* are present behind the Swamp Oak swamp forest in the north-eastern area; and a relatively large patch of *Bangalay Sand forest of the Sydney Basin and South East Corner Bioregions* is present behind the Swamp Oak swamp forest to the east of Coila Lake.

No nationally Threatened Ecological Communities are known to be present in the vicinity of Coila Lake.

3.1.5.4 Threatened Species

The Coila Creek delta wetlands contain the plant species Round-leafed Wilsonia (*Wilsonia rotundifolia*) that is listed as Endangered under the NSW *Threatened Species Conservation Act 1995*. This species inhabits the mid-marsh region of saltmarsh communities, is known from only four locations in NSW, and has been observed to resprout prolifically following a ten month period of inundation in 1999 (Spurway et al., 2000).

Six bird species listed as Threatened under the NSW *Threatened Species Conservation Act 1995* are known to inhabit ecosystems of Coila Lake, namely:

- Hooded Plover (*Thinornis rubricollis*) - Endangered
- Little Tern (*Sterna albifrons*) - Endangered
- Pied Oystercatcher (*Haematopus longirostris*) – Vulnerable
- Lesser Sand Plover (*Charadrius mongolus*) – Vulnerable
- Shy Albatross (*Thalassarche cauta*) – Vulnerable; also listed as Vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)
- Black-tailed Godwit (*Limosa limosa*) – Vulnerable

Additionally, a large proportion of the migratory bird species that utilise Coila Lake habitats are listed as Migratory under the Commonwealth EPBC Act, and/or may be listed under international migratory bird agreements including the Convention on Migratory Species (CMS or Bonn Convention), the China-Australia Migratory Bird Agreement (CAMBA), the Japan-Australia Migratory Bird Agreement (JAMBA) and/or the Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA). Bird species present that are listed under such agreements include, for example, Great Egret (*Ardea alba*), Little Tern (*S. albifrons*) and Crested Tern (*Sterna bergii*).

Three frog species that are listed as Threatened under the NSW *Threatened Species Conservation Act 1995* have been recorded within the region of Coila Lake, but are not likely to occur in habitat directly connected to the lake due to unfavourable saline conditions for these species. These species include:

- Giant Barred Frog (*Mixophyes iterates*) - Endangered; also listed as Endangered under the Commonwealth EPBC Act
- Green and Golden Bell Frog (*Litoria aurea*) – Endangered; also listed as Vulnerable under the Commonwealth EPBC Act
- Giant Burrowing Frog (*Heleioporus australiacus*) – Vulnerable; also listed as Vulnerable under the Commonwealth EPBC Act

An EPBC Protected Matters search identified 30 additional nationally Threatened species that may potentially occur within the region of Coila Lake (DEWHA 2009; noting that this search does not provide records of species known to occur, but rather those potentially occurring due to predictions based on habitats). However, the majority of these species are not considered likely to occur in close proximity to Coila Lake due to the absence of suitable habitat, or may occur but are not dependent on the wetland habitats (refer Table 3-5).

Table 3-5 EPBC Protected Matters search results for Coila Lake

Scientific name	Common name	EPBC Act Status	Likely to occur
Caladenia tessellata	Thick-lipped Spider-orchid	V	Unlikely – does not inhabit saline conditions
Cryptostylis hunteriana	Leafless Tongue Orchid	V	Unlikely – does not inhabit saline conditions
Thesium australe	Toadflax	V	Unlikely – does not inhabit saline conditions
Carcharias taurus (east coast population)	Grey Nurse Shark	CE	Unlikely – marine species
Carcharodon carcharias	Great White Shark	E	Unlikely – marine species
Rhincodon typus	Whale Shark	E	Unlikely – marine species
Dermochelys coriacea	Leatherback Turtle	E	Unlikely – marine species
Prototroctes maraena	Australian Grayling	V	Possible – but generally migrates between freshwater and ocean
Balaenoptera musculus	Blue Whale	V	Unlikely – marine species
Dasyurus maculatus maculatus (SE	Spot-tailed Quoll	E	Possible occasional occurrence – but not dependent on habitats present

mainland population)			
Eubalaena australis	Southern Right Whale	E	Unlikely – marine species
Isoodon obesulus obesulus	Southern Brown Bandicoot	E	Possible occasional occurrence – but not dependent on habitats present
Megaptera novaeangliae	Humback Whale	V	Unlikely – marine species
Potorous tridactylus tridactylus	Long-nosed Potoroo	V	Possible occasional occurrence – but not dependent on habitats present
Pteropus poliocephalus	Grey-headed Flying Fox	V	Possible occasional occurrence – but not dependent on habitats present
Litoria littlejohni	Littlejohn's Tree Frog	V	Unlikely – does not inhabit saline conditions
Anthochaera phrygia	Regent Honeyeater	E	Possible occasional occurrence – but not dependent on habitats present
Diomedea epomophora epomophora	Southern Royal Albatross	V	Possible
Diomedea epomophora sanfordi	Northern Royal Albatross	E	Possible
Diomedea exulans antipodensis	Antipodean Albatross	V	Possible
Diomedea exulans gibsoni	Gibson's Albatross	V	Possible
Lathamus discolor	Swift Parrot	E	Possible occasional occurrence – but not dependent on habitats present
Macronectes giganteus	Southern Giant Petrel	E	Possible
Macronectes halli	Northern Giant Petrel	V	Possible
Neophema chrysogaster	Orange-bellied Parrot	CE	Possible– uses saltmarsh habitats
Rostratula australis	Australian Painted Snipe	E	Possible
Thalassarche bulleri	Buller's Albatross	V	Possible occasional occurrence – but not dependent on habitats present
Thalassarche cauta cauta	Shy Albatross	V	Possible occasional occurrence – but not dependent on habitats present

Thalassarche cauta salvini	Salvin's Albatross	V	Possible occasional occurrence – but not dependent on habitats present
Thalassarche cauta steadi	White-capped Albatross	V	Possible occasional occurrence – but not dependent on habitats present
Thalassarche melanophris impavida	Campbell Albatross	V	Possible occasional occurrence – but not dependent on habitats present

V = Vulnerable, E = Endangered, CE = Critically Endangered

3.1.5.5 Avifauna

The Coila Lake wetlands support a diverse and abundant avifauna community, with 23 bird species previously recorded (Craven 1999 cited in ESC 2001b).

Migratory waders commonly use the entrance area for breeding and nesting, and species such as godwits, knots and curlews feed on the shallow sand flats.

The Coila Lake entrance barrier can be important seabird resting and nesting area, with species such as Silver Gulls and Common Terns reported to rest on the bare sand (ESC 2001b).

3.1.5.6 Fisheries Values

Coila Lake is one of the most intensively commercially fished lakes on the NSW south coast, and is amongst the top five major south coast estuaries for crustacean and finfish catches (WBM, 2002). A primary target species is the Eastern King Prawn (WBM, 2005), while notable habitat for the Greenback Prawn is also present within the Lake (NSW DPI, 2006/7).

3.1.5.7 Batemans Marine Park

As outlined in Section 1.3.8, Coila Lake is mostly zoned General Use under the Batemans Marine Park Zoning Plan, with the area around Coila Creek included as a Sanctuary Zone, the highest level of protection. General Use zonings provide for all forms of recreational fishing and most forms of commercial fishing (except trawling, dredging and long lining). Bag limits, size limits and seasonal closures continue to apply in General Use zones. The only activities permitted in Sanctuary zones are those that do not involve the harming or taking of any plants or animals. All fishing is prohibited in Sanctuary zones so that marine life can continue to thrive and reproduce.

3.1.6 Social Environment

3.1.6.1 Low-lying Infrastructure

The low lying areas surrounding the lake experience inundation during elevated lake water levels. Inundation of Tuross Head stormwater system occurs at water levels of 2.0m AHD and greater. When inundated, the effectiveness of the stormwater system may potentially be compromised. It is noted that private non-rural property around Coila Lake does not become inundated until water levels reach 2.6 m AHD (Spurway et al., 2000). HRC (2002) noted that the acquisition of some residential blocks and a few hectares of one farm surrounding Coila Lake, would remove the need entirely to artificially open the lake because of flooding. Assets at risk of inundation are shown in Table 3-6.

Note that a cycle path has been constructed at RL 2.8m AHD since the identification of these foreshore constraints. Also, a temporary pathway linking with the new path adjacent the saltmarsh at the eastern end of Coila Lake is at RL2.0m AHD. This temporary pathway will be decommissioned following completion of the cycleway link.

Table 3-6 Assets at risk of inundation around Coila Lake, reproduced from Spurway et al. (2000) and/or ESC (2001a)

Lake Level (m AHD)	Asset
1.5	Inundation of pasture on western side of highway
1.8	Inundation of Gross Pollutant Trap (Monash Avenue)
2.0	Flooding of rural access road west of highway
2.0	Surcharge of urban stormwater (Monash Avenue/Marion Close)
2.6	Low level flooding of urban backyards
2.8	Access to urban blocks becomes limited
3.03	Flooding of Coila Service Station
3.5	Princes Highway flooded

3.1.6.2 Recreation

Coila is a popular tourist and recreational area, and the local population increases over the holiday periods. The lake is used for sailing, windsurfing, canoeing, and kayaking. Swimming is also popular in the lake entrance, particularly for families with small children, over summer. There is also a popular cycleway and foreshore walking track through Tuross Head village which overlooks Coila Lake as well as passing along its southern foreshores.

Recreational fishing for prawns is popular when catches are abundant. Recreational fishing is usually concentrated at nearby Tuross Lake, which is a designated Recreational Fishing Haven (while Coila Lake is fished commercially).

3.1.6.3 Economic

Coila Lake is an important area for commercial fishing, being one of five major estuaries on the NSW south coast for catch of crustaceans and finfish (Spurway et al., 2000, quoting Gibbs, 1997). An average of about 33.5 tonnes of fish and crustaceans, including an average of 10 tonnes of Eastern King Prawns are caught annually (WBM, 2002 cited by DECC, 2007). Following a successful prawn recruiting season, Coila Lake can rank as one of the top 12 estuaries in NSW for prawn catch size. Prawn catches vary significantly from one season to the next, dependent on a range of environmental conditions, such as rainfall, tidal flows and entrance condition.

Fish catches also vary significantly between seasons and years, depending on recruitment and the period of time since the lake was last open. Between 1997 and 2002 the average value of the commercial fish catch was $250,000 per year, with a maximum value of $440,000 (in1999/00). In this year, the prawn catch equated to 75% of the catch value, yet accounted for only 45% of the catch by weight, highlighting the value of the Eastern King Prawn to the commercial fishing industry and local economy. Only certain commercial fishers have the right to access Coila Lake, following a zoning process on the estuary.

In the past, prawn recruitment has been used as justification for artificially opening Coila Lake. However, there has been no detailed sampling and analysis of offshore larval populations to accompany the artificial openings, and so no certainty of fish or prawn recruitment following lake opening. Anecdotally, the evidence suggests predicting prawn recruitment is extremely difficult, as the availability of larvae offshore is variable throughout the year. The likely recruitment period for king and school prawns to NSW estuaries is estimated to be September to December (Spurway et al quoting Gibbs, 1997). It is expected that the longevity of an open entrance conditions would have just as much, if not more, benefit for prawn recruitment than specific timing of an opening, and thus a maximum opening duration should be one of the goals of entrance management (Spurway et al., 2000).

Tourism is also an important component of the local economy. Tourism is greatest during the summer months, and usually involves some element of water-based activity. Thus estuaries and coastal lakes such as Coila Lake have a major role in attracting and retaining tourist visitors. Coila Lake may have more variable visitation rates between years, depending on entrance conditions and prawn stocks, however, is still part of the attraction to visitors to the region (DECC, 2007). Facilities such as the foreshore walk and cycleway also add to the appeal for visitors.

Tourism expenditure in the Eurobodalla LGA was $250 million, for the 12 months to September 2004, which equates to 2.6 million visitor nights, the third highest in the state outside of Sydney (DECC, 2007).

Tourism at Tuross Head is significant, and a large proportion of the existing urban housing is used for by weekenders and holidayers, rather than permanent residents. The large increase in population may place pressure upon the natural environment, including a concentration of waterway usage. Tuross Lakes typically receives a larger share of the visitors than Coila Lake.

3.1.7 Cultural Environment

3.1.7.1 Eurobodalla generally

Prior to European Settlement, an Aboriginal land tenure system existed, as explained herein. The Yuin [Djuwin] tribal area is said to extend from the Shoalhaven River in the north to Cape Howe (the Victorian border) in the south and the Great Dividing Range to the west. There are said to be 13 sub-tribal groupings within the Yuin tribal area. The mythological basis to the tribal division involves the mythical ancestor “Bundoola” who had 13 wives, each of which represents a different tribal group. Tribal subgroups of the Yuin who have traditional links in the Eurobodalla include the Walbanga, Bringa and Djirringanj groups. Linguistically, the Eurobodalla Shire is primarily associated with the Dhurga [Thoorga / Durga] language, although the Djirringanj language region covers part of the south and the Thurumba Mudthung language region covering part of the north (Donaldson, 2006).

At the local scale, a number of clan groups exist within each tribal area. In relation to this project (Donaldson, 2006):

- The Terosse [Tuross] group occupy the Tuross area;

- The Bowdally [Bodalla] group are in the Bergalia and Brou Lake area; and
- The Wagunga [Wagonga] and the Noorama [Narooma] people are identified in the Wagonga and Tilba areas, while the Wollaga [Wallaga] group occupy the Tilba, Wallaga Lake and Narooma area.

There are six Local Aboriginal Land Councils, under the NSW Aboriginal Land Rights Act, within the Eurobodalla LGA. Of relevance to this project are (Donaldson, 2006):

- Cobowra [Moruya] LALC;
- Bodalla LALC; and
- Wagonga [Narooma] LALC

The Eurobodalla Aboriginal Cultural Heritage study resulted in the identification of a further 336 places across the Eurobodalla LGA that have special heritage value to Aboriginal people. However, the report acknowledges that Aboriginal cultural heritage values across the region extend to places beyond those identified by the study, as well as there are likely to be many Aboriginal archaeological heritage places from the pre-European and post contact period that have not been recorded or rediscovered. The majority of places outlined in the study related to Aboriginal Heritage post European contact. The report recommended a number of forms of management both for the places identified as well as regions, including:

- registration of places upon DECC's Aboriginal Heritage Information Management System,
- listing of sites and Aboriginal Heritage Conservation Area listing for areas of special significance in Councils LEP.

Aboriginal Culturally Sensitive Lands listing for a number of broader landscapes in the Eurobodalla Shire DCP (including Tuross River and Lake and Potato Point, Coila Lake and 'Black Hill', and possibly, the traditional travelling routes which would encompass the coastal regions in which the remaining lakes are located; and totemic species habitats, which would also include the majority of the lakes as they are bird habitats), and other actions (Donaldson, 2008).

3.1.7.2 Totemism and Ecology

Donaldson (2008) has used the term 'totem' to describe the complex inter-relationship between the Aboriginal people of the Eurobodalla region and the natural world, providing mutual benefits. Donaldson (2008) state that 'traditionally, each Aboriginal group was responsible for the well being of several species'.

There are a number of different categories for totems, including personal, gender, family and clan, tribal and those relating to the specialised powers of 'clever people'. However, through the system of totems, many species were protected, with sanctuary zones or restraints applied to protect habitat areas of totemic species. There were traditional forms of land management or ritual codes, which provided for long term sustainable productivity for a totem (eg, you're not able to eat your totemic species).

For Aboriginal groups in the Eurobodalla region, many of the totemic species are birds, and this is due to the spiritual and mythological happenings/stories of the local Aboriginal people. Some of the known totemic species in the Eurobodalla Shire are listed in Table 3-7. Donaldson (2008) points out that, in addition to the ecological value of protecting species, ‘identification and protection of totemic species and their habitat is a means of valuing a very important element of Aboriginal cultural heritage’.

3.1.7.3 Coila Lake Cultural Significance

As reported in Donaldson (2006), the area known as ‘Black Hill’, on the northern slopes of Coila Lake, has significant cultural and heritage value to the local Aboriginal people. The area was used as a campsite during work, in the early 1900s. The area is also remembered as a place of early conflict between European settlers and the local Aboriginal people. Oral accounts describe a number of possible incidents, including a potential massacre, and mass burial of people struck by Yellow Fever in the late 1800s north of Coila Lake. The ‘Black Hill’ area has a high level of significance to the local Aboriginal people, some of whose ancestors lived there (Donaldson, 2006).

Coila Lake itself has spiritual meaning to the local Aboriginal population (Donaldson, 2007), while Coila Creek is thought to be a place of residence for Aboriginal people (Donaldson, 2006). Former camp areas along Coila Creek and Coila Lake are now on private land, altered by contemporary land development (Donaldson, 2007).

Table 3-7 Aboriginal totemic species in the Eurobodalla Shire (source: Donaldson, 2008)

COMMON NAME	SCIENTIFIC NAME[55]	DHURGA NAME[56]	LOCATION / RANGE
Pacific Black Duck	Anas superciliosa	Umbarra	Wetlands.
Crow	Corvus coronoides	Waagura	Woodlands and open habitats.
Willy Wagtail	Rhipidura leucophrys.	-	Throughout Australia.
Australian Magpie	**Gymnorhina tibicen**	Diriwun	Throughout Australia.
Magpie Lark [Pee Wee].	**Grallina cyanoleuca**	-	Throughout Australia.
Black Swan	**Cygnus atratus**	Gunyung	Wetlands. Less common inland.
White Breasted Sea Eagle	Haliaeetus leucogaster	-	Coastal
Laughing Kookaburra	Dacelo novaeguineae	Gugara	Eastern Australia.
Boobook [Mopoke]	Ninox novaeseelandiae	Googoog	Woodlands.
Bellbird			
Black snake		Murumbul	
Echidna			
Yellow Belly fish			
Goanna			
Grey Thrush		Koori-tu-ku	
Emperor pigeon			
Lyre bird			
Tawny Frog Mouth	Pogargus strigoides	-	Woodlands

Coila Lake has cultural significance to the Aboriginal people for its use as a fishing ground both for food and income, and this includes local fishermen today. The lake is reported to be part of the traditional fishing grounds, especially for prawning (Donaldson, 2006). Fish traps have been described as being used in the area. Donaldson (2006) reports that when there were no fish in Coila Lake, Aboriginal fishers ventured to the adjacent Tuross Lake.

Middens are also located in the vicinity of Coila Lake, providing evidence of food consumption practices and camping areas used over many areas (DECC, 2007). As well as fishing, the older Aboriginal generation also describes trapping rabbits to sell the meat and pelts, and kangaroos to feed the family (Donaldson, 2006). There is reported to be a bora ground (ceremonial ring) on the south-west side of Coila Lake which has substantial cultural importance. The site was used for ceremonies prior to European settlement and during the early period of European contact. The ring lies within what is now private land so local Aboriginal people cannot access the site, which is of major concern to them (Donaldson, 2006; DECC, 2007).

3.2 Tuross Lakes

3.2.1 Location

Tuross Lakes is located 325 km south of Sydney and immediately south of Coila Lake. The catchment area covers approximately 1800km^2, and is mostly uncleared forest, with only 13% of the catchment developed. The waterway area is approximately 14 km^2. The catchment is larger than any other estuary in NSW with a variable entrance condition. The upper catchment is steep, while the lower catchment is relatively flat, with rich alluvial floodplains. The majority of development has occurred upon these low-lying rich alluvial plains, immediately around the estuary (WBM, 2005).

WBM (2005) describe most of the environmental processes within the estuary to be related in some way to the condition of the entrance. Floods tend to push sand out of the entrance, allowing tides to move in and out of the estuary freely; droughts enable the entrance to be heavily shoaled, with ocean processes pushing sand from the beach into the entrance, and the tidal range within the estuary is small.

Tuross River is the main tributary into the estuary, and a number of other small tributaries also flow to the estuary.

Figure 3-6 shows essential features of Tuross Lakes, along with bathymetric (ie hydrosurvey) and fringing topographic details.

3.2.2 Hydrology

3.2.2.1 Entrance Behaviour / Characteristics

The degree of entrance constriction affects the tidal range, lag, current speed, and hence tidal flushing within the estuary. With limited tidal flushing, especially when the entrance is restricted, and the likely input loads from the local catchments, Borang Lake, Trunketabella Lagoon and Bumbo Lake are considered the most sensitive water bodies to potential water quality issues (Brown and Root, 2001).

It has been considered that catchment development has increased the rate of erosion of the catchment, and thus the infilling rate of the estuary and tributaries. Erosion of banks due to the removal of riparian vegetation, and due to boat wake is also occurring (WBM, 2005). Sand build-up at the entrance, however, is the result of coastal processes. The flood-tide delta is indeed made up of marine (beach) sands, rather than terrigenous sediment.

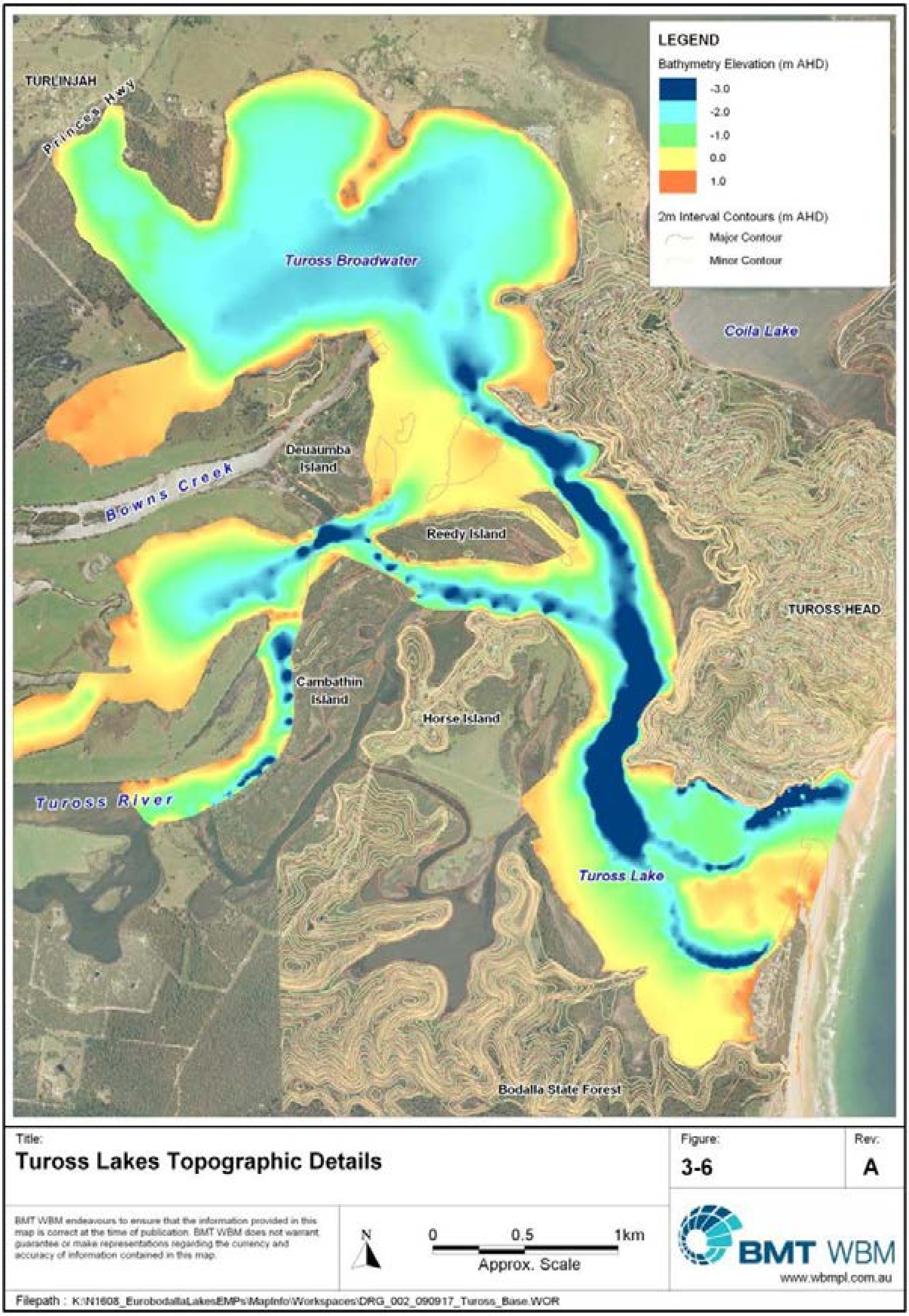

Figure 3-6 Tuross Lakes Topographic Details

With reducing catchment inflows to the lake over the past 15 years, the entrance to Tuross Lakes has actually closed on a number of occasions. Analysis of the water level records (refer Figure 3-7) show that the entrance closed around October 2006, and during the following summer, water levels reduced to less than mean sea level due to evaporation. Significant catchment runoff then occurred in mid February 2007, causing an increase in water level of almost 2 metres (up to 1.83m AHD) before a breakout was initiated by Council in the early hours of the morning of 13/2/07. Further rainfall in June 2007 caused water levels in the lake to again rise rapidly, prompting additional intervention by Council.

The entrance is currently closed (August, 2009), and has been closed since about December 2008. The current height of the entrance berm is approximately 1.8 – 2.0 m AHD and is about 50-60 m wide (pers comm, Norm Lenehan, Apr 2009).

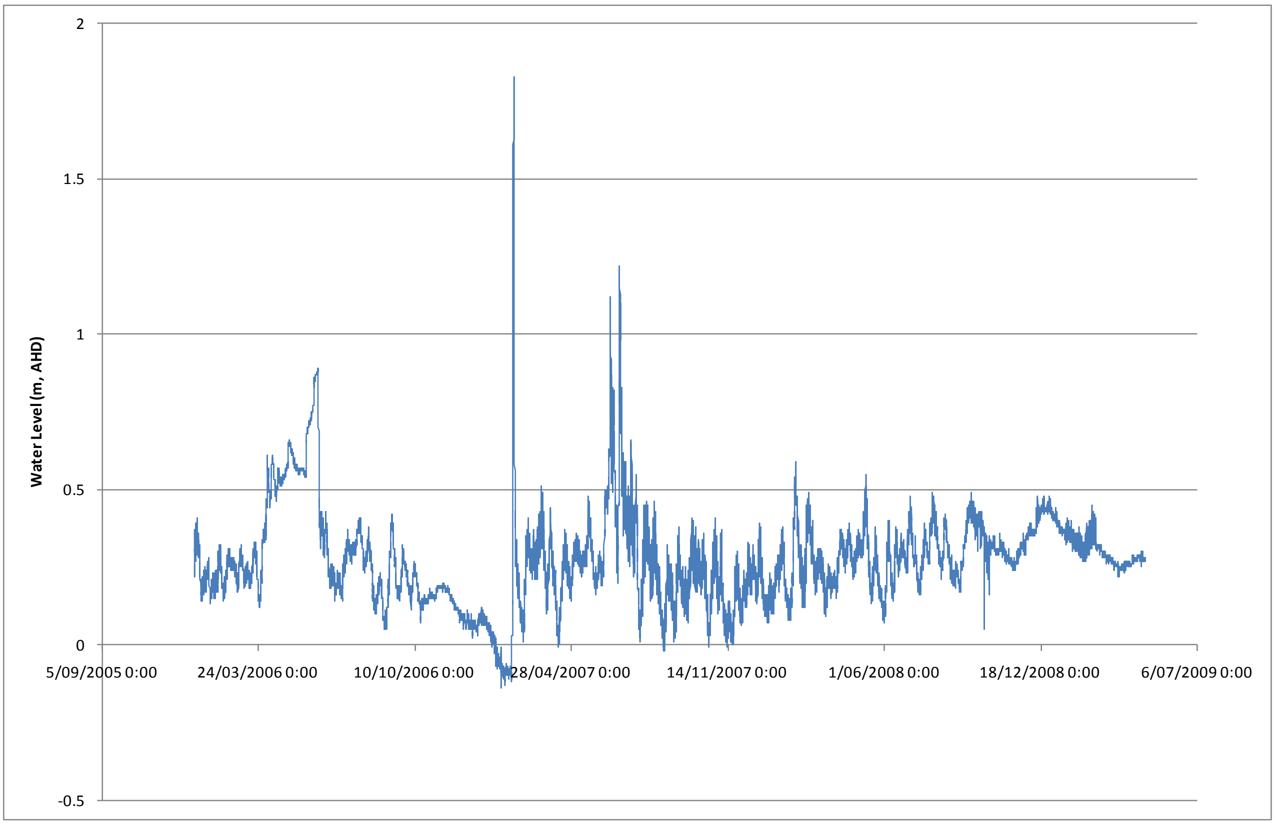

Figure 3-7 Water levels in Tuross Lakes, 2006 - 2009

Historically, the Tuross Lakes entrance has been known to close, but not since the late 19th Century. THWT (15/10/2008) reproduced a letter (a submission to NSW Parliamentary Inquiry, 12 October 1891) by local resident Mr Earnest Hawden regarding Tuross. The following points were indicated in the letter:

- He described the entrance as being 'practicable as a ford' between 1850 and 1860, implying the entrance was frequently closed and highly choked, allowing crossing of the entrance;

- Around 1860 the entrance was completely closed by sand. Around this time, a great flood occurred during a season of heavy and continuous rain (over the colony), which cleared the entrance and left it navigable;
- After this, the lake was used to ship the potato crop grown at Bodalla;
- When the entrance again “suddenly” closed, the crop was lost as it could not be transported;
- Reported seeing the entrance close completely 3 times;
- Described that the entrance could not be relied upon as a navigable channel, he had known it to be ‘fordable’ hundreds of times either on the bar or inner crossing.

Also, historical descriptions of the Tuross Lakes entrance are provided in Gibbney (1989) “Eurobodalla: History of the Moruya District”, as follows:

- The entrance was sealed frequently between 1850 and 1860
- In 1856, a small coaster steamer Mary Jane entered the lake safely and was then trapped for 7 weeks when apparently a ‘flash flood’ sealed the entrance.
- During the 1850s, it was typical for a bullock dray to be taken down the cliff at the north head of Tuross and across the sealed entrance to Bodalla
- A long dry spell caused the entrance to close between 1886 and 1891
- Anecdotal evidence suggested that the southern entrance channel (near Potato Point) was last opened during floods in the 1970s, only remaining open for about three weeks.

3.2.2.2 Water balance

Monthly and annual rainfall data were taken from Bureau of Meteorology (7/5/09), for the Tuross weather station in the upper catchment (elevation of ~970m) (refer Figure 3-8 and Figure 3-9). This data highlights notably fewer peak rainfall events since around 1995 (when the entrance started to constrict). Also, annual rainfall within the upper Tuross catchment has been below long term average most years since 1992, which is markedly different from the period 1946 to 1991.

In combination with fewer ‘scouring’ events over the past 15 years or so, it is generally recognised that for the NSW coastline there have been relatively few erosive storm events over this same period, and many beaches have been observed to be accreting. Both a lack of catchment processes, and a dominance of coastal accretionary processes would be responsible for the progressive shoaling and eventual closure of the Tuross Lakes entrance over the past 15 years.

Rustomji (2007) (refer Appendix B) undertook investigations into the correlation between catchment runoff and entrance condition. Rustomji (2007) showed that coastal processes work to close the entrance, while river flow into the entrance works to keep the entrance open. When there are frequent floods, the entrance channel is maintained open, while when there are fewer floods (and low average river flow), coastal processes can dominate and close the entrance.

Over the past 15 years, the low catchment flows, fewer floods, and accretionary coastal processes have allowed for a large flood tidal delta within the entrance, and closure of Tuross Lakes entrance channel.

3.2.2.3 Water extraction

In accordance with the Tuross Macro Water Sharing Plan, Eurobodalla Shire Council has a licence to extract up to 4 ML/day from the Tuross River to top-up local reservoirs for domestic supplies. When combined with other licensed and riparian use extractions, a total extraction from the river would be about 10 – 20 ML/day. Given the low flows in recent years, however, these extractions have been reduced to zero on many occasions, ie cease to pump (pers comm. Norm Lenehan, ESC, Apr 2009), with the exception of basic landholder rights for domestic and stock watering.

By comparison, evaporation would reduce the volume of water within Tuross Lakes (assuming a closed entrance and no ocean inflow) by about 20 ML/day (averaged annually).

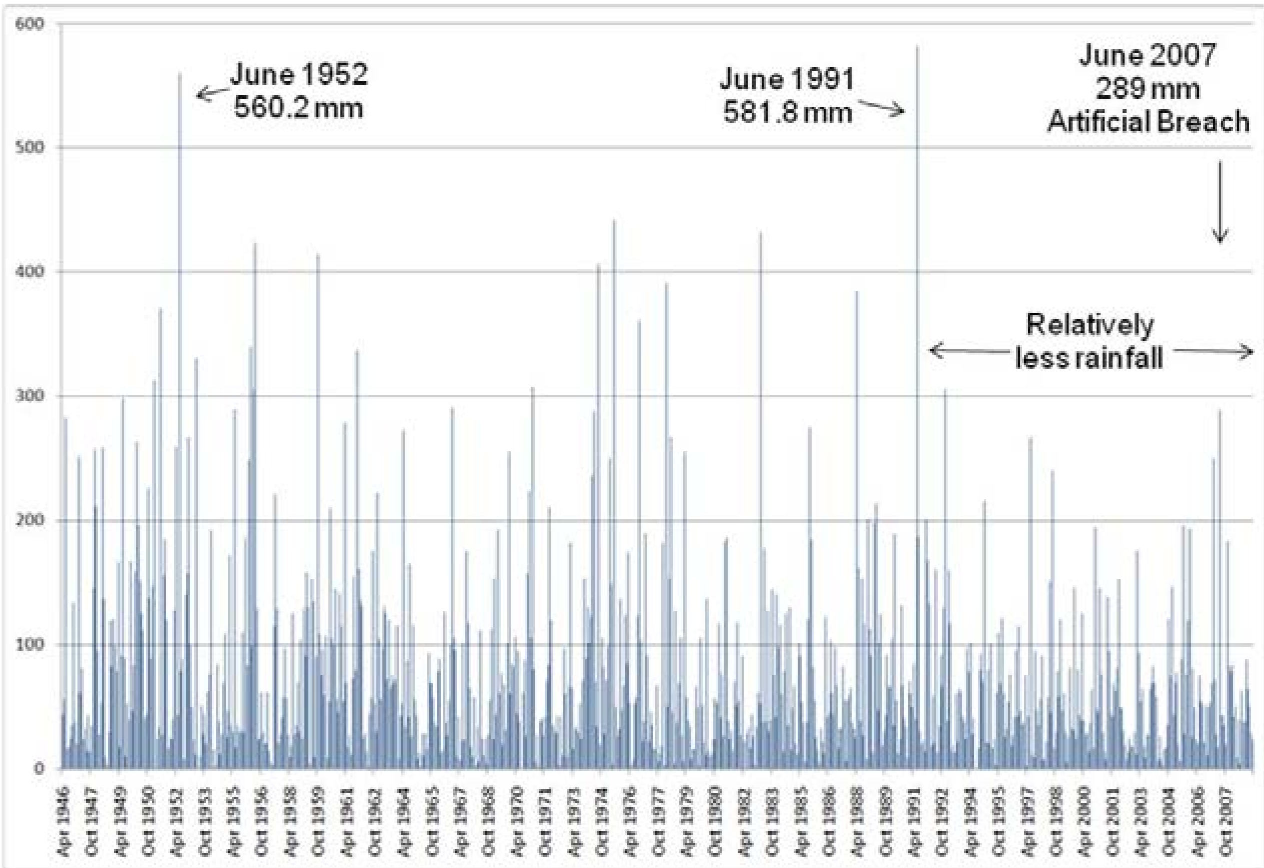

Figure 3-8 Monthly rainfall at Tuross gauge (upper catchment) (mm)

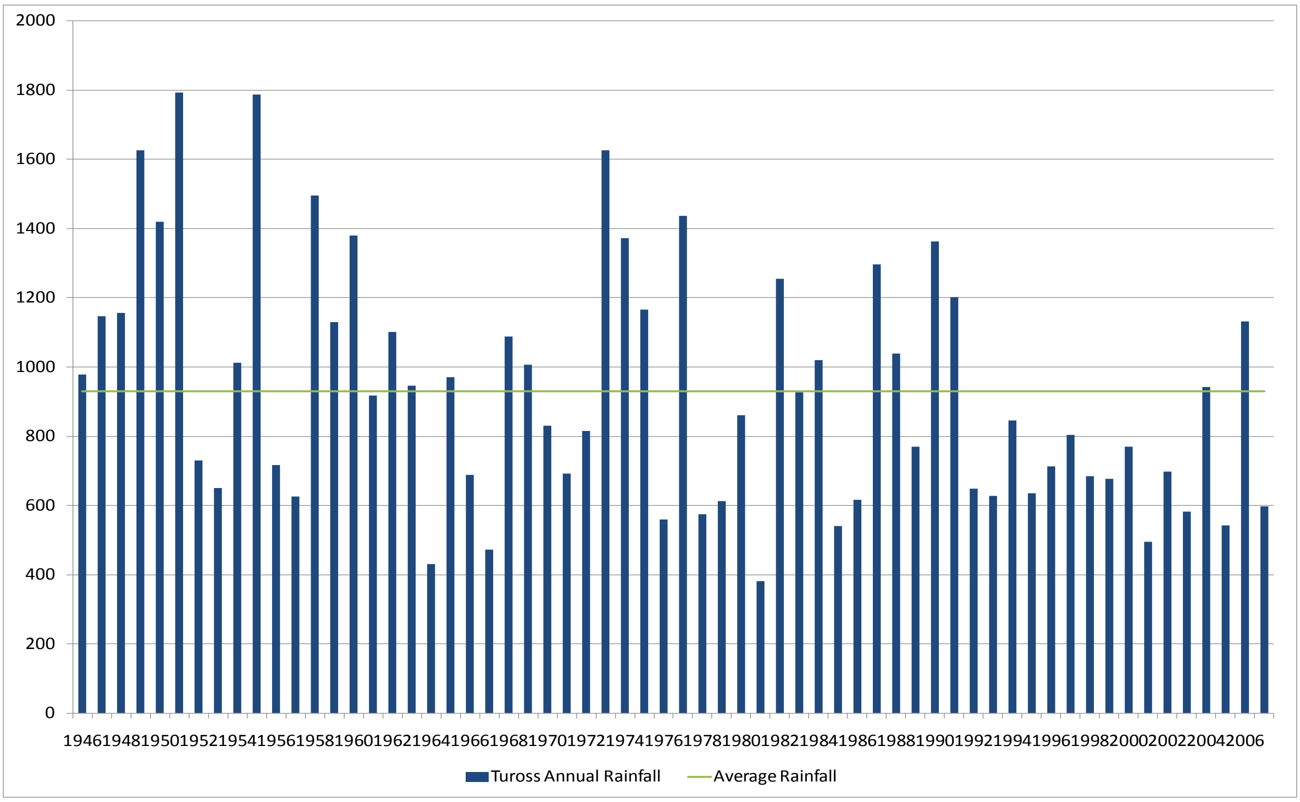

Figure 3-9 Annual rainfall at Tuross gauge (upper catchment) (mm)

3.2.2.4 Flooding

There are three major floods which are commonly noted in the past: 1925, 1934, and 1971. The 1934 flood is thought to have scoured out the southern entrance channel, while the 1971 flood also scoured the southern channel, forming the sand 'islands' within the entrance delta. The 1971 flood reached a level approximately 0.5m metres higher than the February 2007 level, that is, a flood level of around 2.3m AHD.

Floods also occurred in 1991 and 1992. The height of the 1991 flood was comparable to the February 2007 inundation, although these events occurred with an open entrance condition, and thus the flooding / inundation mechanisms were vastly different.

3.2.3 Water Quality

Brown and Root (2001) assessed water quality data, indicating the estuary had large spatial and temporal variability in water quality across its extents. Generally, the estuary was reported to have 'reasonable' levels of dissolved oxygen (DO) and low to medium nutrient concentrations. Faecal coliform levels were of concern in the river upstream of the highway bridge, Trunketabella Creek, west of Horse Island and Smarts Bridge. Borang Lake and south Broadwater had high turbidity, likely due to their potential to capture fine sediments.

Overall, water quality was of greatest concern in Trunketabella Lagoon, which had significantly higher nutrient concentrations (TN consistently above ANZECC guidelines, higher phosphorous, nitrogen and ammonia), as well as high chlorophyll-a, low DO, and high sediments, compared with elsewhere in the estuary. There was found to be little association between rainfall and nutrients (except in Trunketabella Lagoon) or faecal coliforms.

Urban and rural developments within the catchment are expected to have increased the amount and type of nutrients and other contaminants within the estuary. This may include leaching from septic treatment systems, overflows of the reticulated sewerage systems, boating activities, and run off from agricultural properties (WBM, 2005). The increase in inputs over recent times has implications for the natural ability of the estuary to absorb and cycle these inputs (during droughts in particular) and the need for regular monitoring to ensure water quality in the estuary is sustained, including monitoring of aquatic species to indicate signs of stress.

Catchment modelling analysis by Baginska et al (2004) suggest that agriculture / cropping produces approximately 30% of TN loads and 60% of TP loads to the estuary, while transport / communications produces approximately 15% of TN and 25% of TP loads. In contrast, bushland produces about 50% of TN loads and < 10% of TP loads.

Available water quality data for Tuross Lakes was presented in Table 3-3, however, this data is relatively old and does not necessarily reflect the current water quality conditions, particularly as the entrance is now closed.

3.2.4 Sediments

3.2.4.1 Acid Sulfate Soils

Acid sulfate soils are expected to be present around the peripheries of the estuary. Additional, and more prolonged, inundation of these soils, compared to existing conditions, would reduce the oxidation potential of the soils, thus reducing their acid-generating potential, and would also improve the neutralising effect of the marine waters against any acid that is generated.

No acid sulfate soils would be located in the entrance berm where excavations would take place, as this area comprises marine sands only, deposited since the last entrance breakout event.

3.2.4.2 Bank erosion and sedimentation

During previous periods of sustained high water levels within the Tuross Lakes, the creek banks were reported as being saturated, which increased potential for erosion and bank collapse under sudden water level retreat.

Sedimentation within the Tuross Lakes has been noted as a significant issue (WBM, 2005), with some areas losing substantial depth during contemporary times. Catchment erosion, particularly from areas of cleared land, is expected to be the main source of increased sedimentation to the Lakes.

Sediment within the entrance of Tuross Lakes is all marine sands. This material is deposited under the combined action of tides and waves. The non-cohesive sands are dynamic in nature and tend to be redistributed during times of flood. It is expected that during large floods, a large proportion of the marine sands in the entrance channel are actually scoured and transported into the nearshore coastal zone, only to be reworked back into the entrance, or transported alongshore, under the influence of waves and tides.

3.2.5 Ecology

The Tuross estuary is recognised for its ecological importance, with abundant and diverse aquatic and terrestrial habitats providing habitat for numerous Threatened bird species (WBM, 2005). The site is designated as a recreational fishing haven and as such, commercial fishing is prohibited.

3.2.5.1 Fringing Wetland Vegetation

A mosaic of saltmarsh and mangrove communities fringe Tuross Lakes. Mangrove communities are prominent within the eastern section of the lake (i.e. towards the entrance), while saltmarsh communities occur throughout the area (refer Figure 3-4). Mangrove communities are composed of Grey Mangrove (*Avicennia marina*) and River Mangrove (*Aegiceras corniculatum*) (West et al., 1985), and cover a total area of 0.664 km^2 (NSW DPI, 2006/7). Saltmarsh communities cover a total area of 0.802 km^2 (NSW DPI, 2006/7). A small number of Swamp Oak swamp forest communities are also present surrounding Tuross Lakes.

A large proportion of these fringing wetland communities are located in SEPP14 Coastal Wetlands, with 20 discrete SEPP14 wetlands present in the immediate vicinity of the lake (refer Figure 3-5). Additionally, the Tuross River estuary is listed in the DIWA.

Terrestrial vegetation in the surrounding area predominantly includes wet and dry sclerophyll forest, and a small proportion of coastal floodplain woodlands. However, vegetation removal has been extensive such that forests surrounding the lake are mostly sparse, with the exception of the southerly areas where dense vegetation remains.

3.2.5.2 Aquatic Vegetation

Seagrass communities are widespread throughout Tuross Lake, covering a total area of 2.176 km^2 (NSW DPI, 2006/7). In particular, an extensive seagrass meadow is present in the southern section of the lake (closest to the entrance), while seagrass communities in the northern section become increasingly narrower and are restricted to the shallow periphery of the lake (refer Figure 3-4). These seagrass communities are predominantly composed of *Zostera*, with a very small proportion of *Halophila* also present (NSW DPI, 2006/7).

3.2.5.3 Endangered Ecological Communities

There are two NSW-listed Endangered Ecological Communities fringing the Tuross Lakes system. The saltmarsh communities are listed as *Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South West Corner Bioregions* and the Swamp Oak communities are listed as *Swamp Oak floodplain forest of the NSW North Coast, Sydney Basin and South East Corner Bioregions.* However, it is noted that some of these communities surrounding Tuross Lakes require validation as Endangered Ecological Communities (NGH Environmental, 2007). Furthermore, there is a probability that *Freshwater Wetlands on Coastal Floodplains* occurs within the estuarine limits of the Tuross Floodplain.

No terrestrial NSW-listed Endangered Ecological Communities are known to be present in the vicinity of Tuross Lakes.

No nationally Threatened Ecological Communities are known to be present in the vicinity of Tuross Lakes.

3.2.5.4 Threatened Species

The presence of five bird species that are listed as Threatened under the NSW *Threatened Species Conservation Act 1995* is known within the Tuross estuary, namely:

- Little Tern (*Sterna albifrons*) - Endangered
- Hooded Plover (*Thinornis rubricollis*) - Endangered
- Large Sand Plover (*Charadrius leschenaultii*) - Vulnerable
- Pied Oystercatcher (*Haematopus longirostris*) – Vulnerable
- Black-tailed Godwit (*Limosa limosa*) – Vulnerable

Similarly to Coila Lake, a large proportion of the migratory bird species that utilise habitats of the Tuross Lakes are listed under international agreements, including species such as Great Egret and Common Sandpiper.

The Swift Parrot (*Lathamus discolour*), listed as Endangered under NSW and Commonwealth legislation has also been recorded at Tuross Lakes (THWT, various dates). However, their habitat preferences do not directly relate to wetlands but rather predominantly feature Eucalypt woodlands.

An EPBC Protected Matters search identified 33 additional nationally Threatened species that may potentially occur within the region of Tuross Lakes (DEWHA, 2009; noting that this search does not provide records of species known to occur, but rather those potentially occurring due to predictions based on habitats). However, the majority of these species are not considered likely to occur in close proximity to Tuross Lakes due to the absence of suitable habitat, or may occur but are not dependent on the wetland habitats (refer Table 3-8).

Table 3-8 EPBC Protected Matters search results for Tuross Lakes

Scientific name	Common name	EPBC Act Status	Likely to occur
Caladenia tessellata	Thick-lipped Spider-orchid	V	Unlikely – does not inhabit saline conditions
Cryptostylis hunteriana	Leafless Tongue Orchid	V	Unlikely – does not inhabit saline conditions
Thesium australe	Toadflax	V	Unlikely – does not inhabit saline conditions
Carcharias taurus (east coast population)	Grey Nurse Shark	CE	Unlikely – marine species
Carcharodon	Great White Shark	E	Unlikely – marine species

Scientific name	Common name	EPBC Act Status	Likely to occur
carcharias			
Rhincodon typus	Whale Shark	E	Unlikely – marine species
Dermochelys coriacea	Leatherback Turtle	E	Unlikely – marine species
Prototroctes maraena	Australian Grayling	V	Possible – but generally migrates between freshwater and ocean
Balaenoptera musculus	Blue Whale	V	Unlikely – marine species
Dasyurus maculatus maculatus (SE mainland population)	Spot-tailed Quoll	E	Possible occasional occurrence – but not dependent on habitats present
Eubalaena australis	Southern Right Whale	E	Unlikely – marine species
Isoodon obesulus obesulus	Southern Brown Bandicoot	E	Possible occasional occurrence – but not dependent on habitats present
Megaptera novaeangliae	Humback Whale	V	Unlikely – marine species
Potorous tridactylus tridactylus	Long-nosed Potoroo	V	Possible occasional occurrence – but not dependent on habitats present
Pteropus poliocephalus	Grey-headed Flying Fox	V	Possible occasional occurrence – but not dependent on habitats present
Heleioporus australiacus	Giant Burrowing Frog	V	Unlikely – does not inhabit saline conditions
Litoria aurea	Green and Golden Bell Frog	V	Unlikely – does not inhabit saline conditions
Litoria littlejohni	Littlejohn's Tree Frog	V	Unlikely – does not inhabit saline conditions
Anthochaera phrygia	Regent Honeyeater	E	Possible occasional occurrence – but not dependent on habitats present
Diomedea epomophora epomophora	Southern Royal Albatross	V	Possible occasional occurrence – but not dependent on habitats present
Diomedea epomophora sanfordi	Northern Royal Albatross	E	Possible occasional occurrence – but not dependent on habitats present
Diomedea exulans antipodensis	Antipodean Albatross	V	Possible occasional occurrence – but not dependent on habitats present
Diomedea exulans	Gibson's Albatross	V	Possible occasional occurrence – but

Scientific name	Common name	EPBC Act Status	Likely to occur
gibsoni			not dependent on habitats present
Lathamus discolor	Swift Parrot	E	Possible occasional occurrence – but not dependent on habitats present
Macronectes giganteus	Southern Giant Petrel	E	Possible occasional occurrence – but not dependent on habitats present
Macronectes halli	Northern Giant Petrel	V	Possible occasional occurrence – but not dependent on habitats present
Neophema chrysogaster	Orange-bellied Parrot	CE	Possible – uses saltmarsh habitats
Rostratula australis	Australian Painted Snipe	E	Possible
Thalassarche bulleri	Buller's Albatross	V	Possible occasional occurrence – but not dependent on habitats present
Thalassarche cauta cauta	Shy Albatross	V	Possible occasional occurrence – but not dependent on habitats present
Thalassarche cauta salvini	Salvin's Albatross	V	Possible occasional occurrence – but not dependent on habitats present
Thalassarche cauta steadi	White-capped Albatross	V	Possible occasional occurrence – but not dependent on habitats present
Thalassarche melanophris impavida	Campbell Albatross	V	Possible occasional occurrence – but not dependent on habitats present

V = Vulnerable, E = Endangered, CE = Critically Endangered

3.2.5.5 Avifauna

Tuross Lakes supports notable avifauna habitat, with bird breeding activities particularly notable. As outlined above, a number of the bird species that are present are protected under NSW legislation. Shorebird nesting sites at the southern end of the estuary mouth will need to be accounted for in the entrance management policy.

Breeding pairs of Endangered Little Tern have been recorded on Tuross Spit south of the entrance to Tuross Lake (ESC 2001b). Over 2008-9 summer, 56 Little Tern pairs (approximately 17% of the entire NSW breeding population) roosted at Tuross Beach, with an estimated 39 chick reared to fledglings (from an estimated 70 eggs) (THWT, 24/12/08; 31/12/08; 4/3/2009). A number of other species nest at this site. For example, it was the most successful site of Far South Coast over the 2008-9 season for Fairy Terns, and notable breeding success of Pied Oystercatchers was observed over the 2004/5 season (NSW NPWS, 2006).

3.2.5.6 Aquatic Fauna

Three dolphins (an adult pair and infant) have been trapped within Tuross estuary for over eight months. The local community expressed concern for the dolphins, particularly with respect to water quality and food availability. As such, the Tuross Heads Weekly Times (THWT) has reported weekly on the health and safety of the dolphins. Furthermore, NPWS and MPA have regularly monitored the health and safety of the dolphins. To date, no adverse impacts have been observed, as described below.

During November 2008, there was concern that increased rainfall experienced in the catchment would reduce salinity in the lake. However, weekly monitoring indicated that salinity did not drop below levels similar to seawater. The NPWS prepared emergency evacuation plans for the dolphins, should a large flood occur and salinity suddenly decrease. Washover from the sea during high tide or large swells was reported regularly (THWT, various dates Oct 2008 to May 2009), and viewed as a replenishment of seawater for the lake.

Concern for the dolphins was also raised during the January/February 2009 heat waves, as lake temperatures rose to 28^{o}C. Furthermore, the heat wave was reported to evaporate the lake by approximately 5 mm per day (THWT, 18/2/2009), such that high salinity levels were of concern. However, the dolphins remained healthy and it was reported that conditions at 28^{o}C are maintained for dolphins in captivity. Again, monitoring confirmed that salinity levels remained close to ocean conditions.

In relation to food availability, bumper catches of prawns were reported by local fishermen throughout December 2008 and January 2009. In April 2009, sighting and capture of mullet (by fishermen and the dolphins) were recorded. Consequently, fears for lack of sufficient food for the dolphins were allayed. However, it was suggested that fish stocks would decline over winter, placing the dolphins in danger of starvation (THWT 8/4/2009).

Flow across the bar may have recommenced, however the channel is not sufficient to allow the dolphins out of the lake.

3.2.5.7 Fisheries Values

The Tuross estuary was closed to commercial fishing in May 2002 by the NSW Government, establishing it as a 'recreational fishing haven'. Target species for recreational fishing include bream, luderick and mullet.

The opening regime (including mouth closure) may also affect fishery stocks, including where access to the ocean is required as part of the breeding cycle (Rustomji, 2007), although it may be suggested that the reverse may be true for some fish species (see summary by NPWS, 2007).

The entrance of Tuross was reported to close in October of 2008. By December 2008, bumper catches of prawns and other fish were being reported by local recreational fishermen (THWT, 10/12/2008). Likewise, good stocks of fish and mullet were reported during February and April (THWT, 18/2/2009; 8/4/2009). It appears that, in the short term at least, no adverse impacts upon fish stocks occurred due to entrance closure.

In terms of artificial breaching for the purpose of fish recruitment, Rustomji (2007) cites others who have suggested that, without any significant monitoring of fish stocks in the ocean prior to opening, or any monitoring of fish stocks before and after an opening event, there is currently little proof that artificial openings necessarily have a positive impact on fish stocks. That is, artificial openings undertaken for the purpose of improving fish stocks should not be done without monitoring, are not proven to have an impact over the short term, and may even be detrimental over the long term.

3.2.5.8 Batemans Marine Park

As outlined in Section 1.3.8, Tuross Lake is entirely zoned Habitat Protection under the Batemans Marine Park Zoning Plan. Most recreational fishing activities are allowed in habitat protection zones, but some restrictions apply to the collection of bait. Bag limits, size limits and seasonal closures continue to apply. The Tuross Lakes have been established as a Recreational Fishing Haven, and has been closed to commercial fishing since 2002, to improve opportunities for recreational fishing.

3.2.6 Social Environment

3.2.6.1 Low-lying Infrastructure

Key infrastructure at risk of inundation around the Tuross Lakes is summarised in Table 3-9.

Table 3-9 Low-lying Infrastructure around Tuross Lakes

<u>Public</u>	Approximate Level
Sewage pump station (next to Redbox Pizza)	1.11m AHD (with electrics much higher)
Hector McWilliams Drive (only access road servicing Tuross Head) at The Narrows	2.0m AHD
Public road beside boatramp	1.1 – 2.0m AHD
Princes Hwy at Trunketabella Creek	> 2.0m AHD
<u>Private</u>	
O-Briens boatshed	0.7m AHD – decking 1.2m AHD – shop
Laing’s boatshed	0.83m AHD – decking 1.6m AHD – boatshed
Redbox Pizza	1.37m AHD – decking 2.4m AHD – residence
Lakeside Caravan Park (movable cabins)	> 2.0m AHD

3.2.6.2 Community opinions

Tuross Lakes is socially sensitive, and Council receives about a letter per week from the public requesting opening of the entrance (Pers. comm., Norm Lenehan, ESC, 1/4/09). Due to current closure (since December 2008), the recreational fishers believe they may end up with no fish (although, there is no evidence to date of a lack of fish supplies – the THWT has regularly reported good catches of fish and prawns).

Community concerns over the closed condition of the entrance are summarised below from a review of the local newsletter (THWT) and a recent web blog about the entrance condition (see http://turossheadorg.blogspot.com/2009/02/big-questions-about-lake-bar-and.html). These statements are reproduced below directly from the source, and do not necessarily reflect scientific opinion or fact.

From THWT:

- The current closure and volume of sand is believed to be the largest volume in over a century
- Rainfall was suggested to add to the problem, because it will fill the deeper sections of the lake
- Historical floods (1925) occurred into an estuary which had 'depth', and which 'slowed the volume of water'.
- A 'flood level' for the 1925, 1934 and 1971 floods is said to be where the top of the handrail meets the cladding of O'Briens boatshed.
- The present height of the Tuross sand bar is stated to be the height of the window sill at O'Briens boatshed (above the handrail flood level)
- Concerns raised that water levels will reach the height of the sand bar (without a breakout prior to this level) causing a greater amount of flooding than previously seen
- Suggested lowering ('trimming') the sand bar (by 0.8 m) to reduce flooding should a breakout not occur, or heavy rains arrive.
- In addition to the boatsheds, the road at the Narrows is also thought to be 0.6m lower than the present bar height.
- Concerns also raised for the health of the dolphins, if a flood should occur, or otherwise.
- Large concerns about the water extraction by Council from Tuross River for top-up of Deep Creek Dam. There are concerns that pumping from the river will recommence once river flows improve, and this will 'reduce the build-up of water needed to flush the bar if it is opened by a dozer'. Concerns about increased salinity in the lake, and lack of flows for irrigation and environment due to Council pumping.
- The council is described as "pumping vigorously when there is any sign of flow to provide drinking water to the shire". The region is under Level 2 water restrictions at present.
- There are calls for a water sharing/water availability plan to be completed, to improve the flow of water for irrigators, the estuary
- Council has been investigating sources of groundwater to supplement town water supply, however, State government has recently put out a statement about groundwater extraction, which has slowed this investigation.

From Blog:

- A channel of dimensions stated in the dredging REF should be constructed
- "why should Tuross residents pay thousands of dollars to protect one business" ie, the boatshed. The current owners knew the history of flooding when they bought it
- "Despite the lake level plummeting in recent weeks, water quality has held up - an oyster farmer's No.1 priority. Where there was still enough depth, farmers have kept their oysters alive by physically raising and lowering their racks every six weeks."
- Climate change is keeping the lake closed (lack of floods) Council should lobby state government for funds to re-open the lake
- Dredge it to 4 m, or put a breakwall in
- To get it back to the way it was you need to dredge it and take the sand well away (100 m channel to 3 m deep), then re-stock with fish once the dolphins are gone
- Fishing will dry up and oyster industry will be lost if nothing is done. Council with a bulldozer won't be fast enough if it floods

3.2.6.3 Economic Issues

As noted in the Dredging REF (GHD, 2003), there have been requests for entrance channel dredging when the channel is very small to maintain tidal levels for the oyster leases. Oysters are also a socially sensitive issue at Tuross (Pers. comm., Norm Lenehan, ESC, 1/4/09).

Oyster farmers have actually been adapting to the entrance closure, and are currently raising the oyster racks once every 4 to 6 weeks to prevent parasite infestation (pers comm., Michael Taylor, May 2009). Whilst this is not considered a practical long term solution, it is enough to maintain stocks and prevent the oyster farmers from ceasing operations altogether.

Tourism is also a significant and valuable local industry at Tuross. Tourism expenditure in the Eurobodalla LGA at $250 million, for the 12 months to September 2004, which equates to 2.6 million visitor nights, and the third highest in the state outside of Sydney (DECC, 2007).

Tourism at Tuross Head is significant, and a large proportion of the existing urban housing is used for by weekenders and holidayers, rather than permanent residents. The large increase in population may place pressure upon the natural environment, including a concentration of waterway usage. Tuross Estuary typically receives a larger share of the visitors than the adjacent Coila (DECC, 2007).

Anecdotal reports indicate that tourists over the most recent summer season have been disappointed with the condition of the lake (with a closed entrance), with some indicating that they would not return unless the entrance was open. This highlights the importance of the condition of the estuary to the local tourism industry.

Although considered minor in terms of local economics, the Beachcomber Caravan Park at Potato Point has recorded a significant increase in day visitors from Tuross Head who are now able to walk along Tuross Beach since the entrance has closed.

3.2.7 Cultural Environment

Some local Aboriginal people say the whole of Tuross is Aboriginal site (Donaldson, 2006). The entire Tuross River region has been recommended by Donaldson (2007) for access and use of camping areas to be maintained, if necessary. It was also recommended that DCP and LEP instruments take into consideration the ongoing use and access into camping and resource collection areas in the Tuross River region. Many sites of resource collection and camping are still used to present day, and as an opportunity to teach or pass on traditional skills. The heritage study found 336 places of special heritage value to the Aboriginal Community. The key areas of relevance to the Tuross Lake region are described below.

Many families describe working on the many farms along Tuross River, including Coopers Island, and upstream to Nerrigundah in the west (Donaldson, 2007). Nearly half of the heritage places related to seasonal farm industry in the Eurobodalla Shire are located along the Tuross River (Donaldson, 2007). Some families lived at the farm (such as on Coopers Island, or at Tuross Heads) during their seasonal work of picking vegetables, such as peas and beans, on these farms. Others lived elsewhere, including camps on Horse Island (Donaldson, 2006). A number of local Aboriginal families worked on the Spaulding Dairy Farm at Tuross Heads, and lived at the farm (Donaldson, 2006).

Descriptions of past and present use include making spears from the garara stick to fish in the shallow sections of the Tuross River and Lake (Donaldson, 2006).

Blackfellows Point, the region at the southern end of the Tuross Lake entrance, has a long association of Aboriginal use to present day. Families often camped here on the weekends when not working picking vegetables at local farms at Cadgee and along the Tuross River. The area was used frequently by different families, as a campsite, either for holidays or when travelling on route to other locations. There is a traditional campsite next to a freshwater spring amongst the marshland at Blackfellows Point (the freshwater would rise up when the tide was high). Camp could also be found in the sand dunes at Blackfellows Point, or where the caravan park is today. Local Aboriginal people could walk from here to Tuross for supplies, or to Mummuga Lake to visit other families (Donaldson, 2006). The area was also used for teaching, resource collection, meeting and as a spiritual place. The access and use of this area is recommended to be maintained and further, the heritage values should be protected and acknowledged (Donaldson, 2007).

There were three former Aboriginal Reservations in the Tuross and Blackfellows Point areas. One reservation of 56 acres on the southern side of Tuross Lake (northern side of Blackfellows Point) was granted to Richard Bolloway in 1877 (revoked in 1914). In recent years, the Yuin Womens Lore Council meets at this reserve. Another Aboriginal Reservation of 40 acres at Jabarrah / Blackfellows point was granted to Yarraro in 1877 (revoked in 1922). And a reservation of 40 acres on the south bank of Tuross Lake was likely to have been granted to the king 'Neddy' (Donaldson, 2007). These Historical Aboriginal Reservations have historical and cultural significance to Aboriginal people now, as lives were lived and stories told at these places.

3.3 Kianga Lake

3.3.1 Location

Kianga Lake is located further south from Tuross and Coila Lakes, approximately 2.5km north of Narooma. The small coastal village of Kianga is located immediately south of the lake.

Kianga Lake has a small waterway area (0.2 km^2) and catchment (8 km^2), and is typically shallow (< 1m deep). The lake remains closed for the majority of the time.

Figure 3-10 shows essential features of Kianga Lake, along with bathymetric (ie hydrosurvey) and fringing topographic details.

3.3.2 Hydrology

3.3.2.1 Entrance behaviour and inundation

Little is known about the opening regime of this lake. The lake was artificially opened when the RTA were undertaking works on the Kianga – Dalmeny Road. It is understood that when the Kianga STP outfall was constructed in the 1980s, the rock shelf on the southern headland of the Kianga entrance was excavated. Although the excavation was backfilled, it is understood from a number of local residents that part of the backfilled material has been removed over time, allowing the lake to discharge to the ocean through the rock shelf, preventing water levels to build-up and force a substantial entrance breakout.

3.3.3 Water Quality

The lake is typically saline (30 ppt) due to its relatively small freshwater input. A sewage treatment plant is located upon the south-western shore of the Lake, and not surprisingly, the water quality of the lake has been noted as an issue by Council.

A water quality data collection exercise was conducted in Kianga Lake by MHL on 21 August 2002. At the time of the exercise, the water level in Kianga was 1.26 m AHD. Two water quality profiles at selected locations in the lake were taken at assumed high water slack and low water slack. The results indicate that Kianga Lake had minimal tidal range at the time, of 0.1-0.2 m, and as it was undertaken during winter, the lake exhibited very low temperatures. The lake salinity was reasonably low, indicating freshwater inputs had accumulated in the lake, no doubt responsible for the elevated water levels. The water quality results for Kianga Lake taken by MHL are presented in Table 3-10.

Water quality data for Kianga Lake was also collected by Wiecek (2001), as part of a university honours thesis. Wiecek's (2001) data for Kianga Lake suggests generally variable water quality conditions, with typically high nutrient levels, and high chlorophyll-a levels (up to 79ug/L) (refer Table 3-11).

Figure 3-10 Kianga Lake Topographic Details

Table 3-10 Water quality results for Kianga Lake (source: MHL, 2002)

Water Quality Maxima and Minima - Kianga Lake - First Run - 21 August 2002
Low tide slack

Station No.	Time (EST) Low tide	Depth (m)	Density (kg/m3) Mean	Temperatu (DegC) Mean	Salinity (psu) Mean	Dissolved ((% sat) Mean	pH Mean	Backscatte (NTU) Mean	Chlorophy (ug/L) Mean	PAR Mean
1	707	1.2	1001.9	12.66	3.19	97.82	8.25	516.01	3.21	83.1
2	714	0.7	1001.9	12.64	3.19	82.54	7.86	513.68	2.7	162.4
3	721	0.9	1001.9	12.77	3.19	86.49	7.87	513.05	2.68	1440.5
4	727	1	1001.9	12.87	3.19	88.43	7.81	447.53	4.39	127.5
5	734	0.8	1001.9	12.87	3.19	85.16	7.73	509.17	9.28	216.5
6	741	0.9	1001.9	12.63	3.18	89.05	7.89	493.34	12.52	153.1
7	748	0.8	1001.8	12.59	3.06	78.31	7.39	493.52	2.85	262

Water Quality Maxima and Minima - Kianga Lake - Second Run - 21 August 2002
High tide slack

Station No.	Time (EST) High tide	Depth (m)	Density (kg/m3) Mean	Temperatu (DegC) Mean	Salinity (psu) Mean	Dissolved ((% sat) Mean	pH Mean	Backscatte (NTU) Mean	Chlorophy (ug/L) Mean	PAR Mean
1	1308	1.4	1001.8	13.37	3.22	99.36	8.31	458.86	0.38	394.3
2	1313	0.8	1001.7	13.81	3.19	122.34	8.17	468.44	3.4	289.1
3	1318	0.8	1001.7	14.21	3.19	93.34	7.87	349.02	5.73	1666.4
4	1324	0.9	1001.7	14.38	3.18	104	7.93	469.9	5.98	1116.6
5	1333	0.8	1001.7	13.79	3.19	79.65	7.92	475.02	0.21	3080.8
6	1337	0.8	1001.7	14.18	3.17	100.22	8.08	387.62	3.5	2276.9
7	1343	1	1001.8	12.75	3.08	76.54	7.14	510.11	3.07	27

Table 3-11 Water quality data for Kianga Lake, Jan 01 to Oct 01 averaged over three sites within each lagoon (source: Wiecek, 2001).

Collect Date	NH_3 (µg/L)	NO_X (µg/L)	Total inorg. N (µg/L)	Total Nitr. (µg/L)	Ortho phos. (µg/L)	Total Phosph. (µg/L)	Chl-a (µg/L)
Kianga Lake							
January-01	166.7	11.7	178.3	2633.3	12.7	191.7	78.5
March-01	73.3	5.0	78.3	1060.0	10.7	20.3	1.0
April-01	63.3	11.7	75.0	1043.3	5.8	9.8	3.5
May-01	13.3	16.7	30.0	800.0	10.0	11.0	0.7
June-01	43.3	26.7	70.0	1016.7	16.0	34.0	2.8
July-01	20.0	70.0	90.0	776.7	2.5	32.7	2.9
August-01	163.3	6.7	170.0	413.3	12.7	19.0	1.8
October-01	335.0	80.0	415.0	1195.0	46.3	112.5	20.5

3.3.4 Sediments

3.3.4.1 Acid Sulfate Soils

Acid sulfate soils are expected to be present around the peripheries of the lake. Additional, and more prolonged, inundation of these soils, compared to existing conditions, would reduce the oxidation potential of the soils, thus reducing their acid-generating potential, and would also improve the neutralising effect of the marine waters against any acid that is generated.

No acid sulfate soils would be located in the entrance berm where excavations would take place, as this area comprises marine sands only, deposited since the last entrance breakout event.

3.3.4.2 Bank erosion and sedimentation

Sedimentation of the lake is expected to have occurred as a consequence of development within the catchment. The lake is relatively small with no major tributaries. As such, erosion of banks or foreshores is not expected to be an issue.

The sand in the lake entrance is of marine origin, and would have been deposited shortly after the last entrance breakout event. This sand is highly dynamic, and is expected to be scoured and transported into the nearshore zone during the next large flood event.

3.3.5 Ecology

3.3.5.1 Fringing Wetland Vegetation

Mapping of estuarine vegetation by NSW DPI (2006/7) does not show any mangrove or saltmarsh communities to be present (refer Figure 3-11). No SEPP14 Coastal Wetlands or wetlands listed in the DIWA are present in the vicinity of Kianga Lake. The absence of these vegetation communities is likely attributed to the lack of tidal fluctuations.

A small linear patch of Swamp Oak swamp forest is present to the south of Kianga Lake. Terrestrial vegetation surrounding Kianga Lake has largely not been cleared, and consists primarily of sclerophyll forest.

3.3.5.2 Aquatic Vegetation

A seagrass community composed of *Ruppia* species covers most of Kianga Lake (0.113 km^2, refer Figure 3-11). Prolific blooms of green algae such as *Ulva* spp. have previously been noted within the lake.

3.3.5.3 Endangered Ecological Communities

The Swamp Oak swamp forest to the south of Kianga Lake is a NSW-listed Endangered Ecological Community (*Swamp Oak floodplain forest of the NSW North Coast, Sydney Basin and South East Corner Bioregions*).

In terms of terrestrial vegetation, the NSW-listed Endangered Ecological Community *Bangalay Sand forest of the Sydney Basin and South East Corner Bioregions* is present to the east of Kianga Lake.

Figure 3-11 Estuarine vegetation of Kianga Lake (source: NSW DPI 2006/7).

No nationally Threatened Ecological Communities are known to be present in the vicinity of Kianga Lake.

3.3.5.4 Threatened species

The *Atlas of NSW Wildlife* showed no records of Threatened flora or fauna species in close proximity to Kianga Lake (DECC, 2009). It is likely that Threatened bird species may use the site (e.g. those also present at Coila Lake and Tuross Lakes), but sightings have not been recorded on the database.

An EPBC Protected Matters search identified 13 nationally Threatened species that may potentially occur within the region of Kianga Lake (DEWHA, 2009). However, the majority of these species are not considered likely to occur in close proximity to Kianga Lake due to the absence of suitable habitat, or may occur but are not dependent on the wetland habitats (refer Table 3-12).

Table 3-12 EPBC Protected Matters search results for Kianga Lake

Scientific name	Common name	EPBC Act Status	Likely to occur
Cryptostylis hunteriana	Leafless Tongue Orchid	V	Unlikely – does not inhabit saline conditions
Thesium australe	Toadflax	V	Unlikely – does not inhabit saline conditions
Prototroctes maraena	Australian Grayling	V	Possible – but generally migrates between freshwater and ocean
Dasyurus maculatus maculatus (SE mainland population)	Spot-tailed Quoll	E	Possible occasional occurrence – but not dependent on habitats present
Potorous tridactylus tridactylus	Long-nosed Potoroo	V	Possible occasional occurrence – but not dependent on habitats present
Pteropus poliocephalus	Grey-headed Flying Fox	V	Possible occasional occurrence – but not dependent on habitats present
Heleioporus australiacus	Giant Burrowing Frog	V	Unlikely – does not inhabit saline conditions
Litoria aurea	Green and Golden Bell Frog	V	Unlikely – does not inhabit saline conditions
Litoria littlejohni	Littlejohn's Tree Frog	V	Unlikely – does not inhabit saline conditions
Anthochaera phrygia	Regent Honeyeater	E	Possible occasional occurrence – but not dependent on habitats

			present
Lathamus discolor	Swift Parrot	E	Possible occasional occurrence – but not dependent on habitats present
Neophema chrysogaster	Orange-bellied Parrot	CE	Possible – uses saltmarsh habitats
Rostratula australis	Australian Painted Snipe	E	Possible

V = Vulnerable, E = Endangered, CE = Critically Endangered

The EPBC Act Protected Matters Search also revealed that several migratory species that are listed under international agreements may occur within the site, such as Great Egret (*Ardea alba*), Cattle Egret (*Ardea ibis*), Latham's Snipe (*Gallinago hardwickii*), Fork-tailed swift (*Apus pacificus*) and Little Tern (*Sterna albifrons*). The species are also listed as 'Migratory' under the EPBC Act, and Little Tern is Endangered under NSW legislation.

3.3.5.5 Avifauna

Kianga Lake is an important drought refuge for avifauna, and the seagrass beds provide feeding habitat for species including Black Swan (*Cygnus atratus*) and Chestnut Teal (*Anas castanea*).

3.3.5.6 Batemans Marine Park

As outlined in Section 1.3.8, Kianga Lake is included as a Sanctuary Zone in the Batemans Marine Park, the highest level of protection. The only activities permitted in Sanctuary zones are those that do not involve the harming or taking of any plants or animals. All fishing is prohibited in Sanctuary zones so that marine life can continue to thrive and reproduce.

3.3.6 Social / Recreation

3.3.6.1 Low-lying infrastructure

Key infrastructure is located around Kianga Lake. The levels of this infrastructure are outlined in Table 3-13.

Table 3-13 Infrastructure around Kianga Lake

Public	Approximate Level
Sewage pump station (behind Lakeside Blvd)	2.2m AHD
Access road to the Kianga STP	2.0m AHD
Coastal road – Kianga to Dalmeny	2.6m AHD
Private	
Properties on northern side of Lakeside Blvd	Backyards from 1.8m AHD

3.3.6.2 Planning issues

Within the Narooma DCP, no new houses are permitted in the Kianga Urban Expansion Area, due to its impact on scenic quality. Instead, the Dalmeny Urban Expansion Zone is to be targeted for enlarged (ESC, 2005).

The Draft Eurobodalla Local Environment Plan 2009 recognises the principals of the Narooma DCP and proposes limited capacity to expand urban development within the catchment of Kianga Lake.

3.3.7 Cultural Environment

There are no specific references to use of Kianga Lake as part of the Eurobodalla Aboriginal Cultural Heritage Study (Donaldson, 2006, 2007), however, it is highly likely that the lake was used as a camp ground or resource collection site, due to its locality upon the coast. Donaldson (2006) reports upon frequent travelling by foot by Aboriginal people both in the past and the present day along the coastline to different places and areas, camping and collecting food along the way. Kianga Lake is likely to have been utilised in some manner by the local Aboriginal people.

3.4 Little Lake

3.4.1 Location

Little Lake is located 500 m immediately south of Narooma, within the Narooma Golf Course. The entrance to Little Lake is located on Narooma Beach, directly in front of the Surf Life Savings Club.

Little Lake is a small lake of only 0.1 km^2 waterway area and 2.6 km^2 of catchment area. The Lake is reported to be shallow and infilled with marine sands.

Figure 3-12 show essential features of Little Lake, Bullengella Lake and Nangudga Lake, along with bathymetric (ie hydrosurvey) and topographic details, where available.

3.4.2 Hydrology

3.4.2.1 Entrance Behaviour / Characteristics

Little Lake remains closed for the majority of the time. It is possible that some areas of the golf course may be affected by inundation during high lake levels, however, the lake tends to break out naturally, or is artificially opened (by members of the general community) before water levels reach too high.

During a normal rainfall season, the entrance would open naturally (or assisted) about twice. Once opened, the lake remains tidal for about 3 to 4 days before closing.

3.4.2.2 Water balance

There has been little previous work on the water balance of Little Lake. The catchment of Little Lake extends up to the Princes Highway ridgeline, encompassing a large retail development, as well as industrial development along Glasshouse Rocks Road. Dams within the golf course tend to intercept some of the catchment runoff before discharging into the lake. The dams have a capacity of about 35ML, and take about 200mm of rain to fill. Overflows from the dam discharge directly to the lake. Runoff from the Woolworths development discharged directly into the lake.

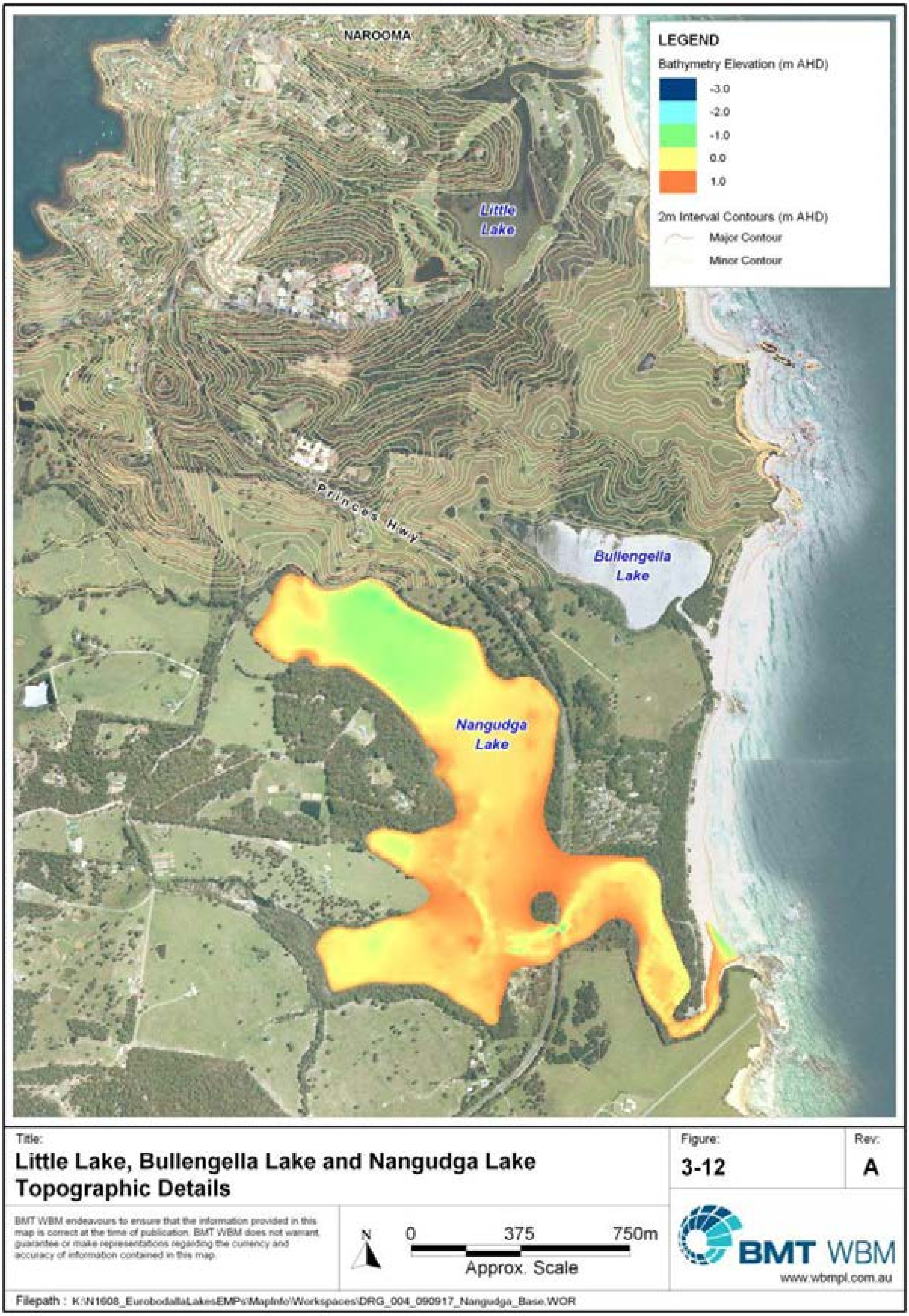

Figure 3-12 Little Lake, Bullengella Lake and Nangudga Lake Topographic Details

3.4.3 Water quality

Given the small size of the catchment which is now largely urbanised, its location within the golf course, and the small waterway area, it is likely that the lake experiences poor water quality from time to time. It is also understood from anecdotal reports that the Sewage Pumping Station overflows into lake about once per year. Despite this, water quality in Little Lake is not considered a significant issue.

Water quality in Little Lake was measured opportunistically during a site visit by BMT WBM personnel in May 2009. Results are summarised in Table 3-14.

Table 3-14 Water quality data for Little Lake (May 2009)

Constituent	Upper bridge	Lower bridge		Entrance
Depth (m)	0.5	0.4	1.6	0.3
Salinity (ppt)	35.6	35.4	35.9	35.2
Temperature (deg. C)	13.7	14.0	14.5	14.9
Turbidity (NTU)	17	0.1	0.8	8
Dissolved oxygen (mg/L)	6.3	6.5	5.8	7.3
ORP	409	401	406	422
pH	7.38	7.5	7.43	7.5

3.4.4 Sediments

3.4.4.1 Acid Sulfate Soils

Acid sulfate soils are expected to be present around the peripheries of Little Lake. Additional, and more prolonged, inundation of these soils, compared to existing conditions, would reduce the oxidation potential of the soils, thus reducing their acid-generating potential, and would also improve the neutralising effect of the marine waters against any acid that is generated. The pH of the water tested to date shown no signs of acidification, and indeed more reflects oceanic conditions, which is slightly alkaline.

No acid sulfate soils would be located in the entrance berm where excavations would take place, as this area comprises marine sands only, deposited since the last entrance breakout event.

3.4.4.2 Bank erosion and sedimentation

A large proportion of the catchment runoff is intercepted by the golf course dams. These dams would act as a sediment trap, limiting the sediment input to the lake from the catchment.

Erosion of the banks or foreshores of Little Lake is not expected to be an issue, given its small size and vegetated fringe.

The sand in the entrance of Little Lake is of marine origin, and would have been deposited shortly after the last entrance breakout event. This sand is highly dynamic, and is expected to be scoured and transported into the nearshore zone during the next large flood event.

3.4.5 Ecology

3.4.5.1 Fringing Wetland Vegetation

Patches of vegetation fringing Little Lake are too small to be detected by the NSW DPI broadscale mapping, although mangroves covering 0.005 km^2 and saltmarsh covering 0.017 km^2 are reported (NSW DPI 2006/7). Saltmarsh species that fringe the upper lake include *Sarcocornia* spp., *Juncus krausii*, and *Sporobolus virginicus*, with *Phragmites australis* also present in some areas. Linear fragments of Swamp Oak swamp forest are present along the northern and south-western shores of Little Lake.

No SEPP14 Coastal Wetlands or wetlands listed in the DIWA are present in the vicinity of Little Lake.

Outside of the golf course boundary, there is a large amount of Coastal Lowlands Spotted Gum – Burrawang Cycad Dry Shrub Dry Forest. There is also a small section of Southern Coastal Hind Dune/Headland Scrub and Beach Strand Grassland, at the far edge of the lake catchment near the cemetery (ESC, 2005).

3.4.5.2 Aquatic Vegetation

A small amount of seagrass is present within Little Lake (0.007 km^2, NWS DPI 2006/7), and is composed of *Ruppia* species (NSW DPI, 2006/7).

3.4.5.3 Endangered Ecological Communities

The saltmarsh communities surrounding Little Lake are a NSW-listed Endangered Ecological Community, listed as *Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South West Corner Bioregions*, however, their coverage is small (0.017km^2 refer Section 3.4.5.1). The Swamp Oak swamp forests are also a NSW-listed Endangered Ecological Community (*Swamp Oak floodplain forest of the NSW North Coast, Sydney Basin and South East Corner Bioregions*).

No terrestrial vegetation communities in the vicinity of Little Lake are known to be NSW-listed Endangered Ecological Communities.

No nationally Threatened Ecological Communities are known to be present in the vicinity of Little Lake.

3.4.5.4 Threatened Species

The *Atlas of NSW Wildlife* had no records of Threatened flora or fauna species in close proximity to Little Lake (DECC, 2009). It is likely that Threatened bird species may use the site (e.g. those also present at Coila Lake and Tuross Lakes), but sightings have not been recorded on the database.

An EPBC Protected Matters search identified 13 nationally Threatened species that may potentially occur within the region of Little Lake (DEWHA, 2009). However, the majority of these species are not considered likely to occur in close proximity to Little Lake due to the absence of suitable habitat, or may occur but are not dependent on the wetland habitats (refer Table 3-15).

Table 3-15 EPBC Protected Matters search results for Little Lake

Scientific name	Common name	EPBC Act Status	Likely to occur
Cryptostylis hunteriana	Leafless Tongue Orchid	V	Unlikely – does not inhabit saline conditions
Thesium australe	Toadflax	V	Unlikely – does not inhabit saline conditions
Prototroctes maraena	Australian Grayling	V	Possible – but generally migrates between freshwater and ocean
Dasyurus maculatus maculatus (SE mainland population)	Spot-tailed Quoll	E	Possible occasional occurrence – but not dependent on habitats present
Potorous tridactylus tridactylus	Long-nosed Potoroo	V	Possible occasional occurrence – but not dependent on habitats present
Pteropus poliocephalus	Grey-headed Flying Fox	V	Possible occasional occurrence – but not dependent on habitats present
Heleioporus australiacus	Giant Burrowing Frog	V	Unlikely – does not inhabit saline conditions
Litoria aurea	Green and Golden Bell Frog	V	Unlikely – does not inhabit saline conditions
Litoria littlejohni	Littlejohn's Tree Frog	V	Unlikely – does not inhabit saline conditions
Anthochaera phrygia	Regent Honeyeater	E	Possible occasional occurrence – but not dependent on habitats present
Lathamus discolor	Swift Parrot	E	Possible occasional occurrence – but not dependent on habitats present
Neophema chrysogaster	Orange-bellied Parrot	CE	Possible – uses saltmarsh habitats
Rostratula australis	Australian Painted Snipe	E	Possible

V = Vulnerable, E = Endangered, CE = Critically Endangered

The EPBC Act Protected Matters Search also revealed that several migratory species that are listed under international agreements may occur within the site, such as Great Egret (*Ardea alba*), Cattle Egret (*Ardea ibis*), Latham's Snipe (*Gallinago hardwickii*), Fork-tailed swift (*Apus pacificus*) and Little

Tern (*Sterna albifrons*). The species are also listed as 'Migratory' under the EPBC Act, and Little Tern is Endangered under NSW legislation.

3.4.5.5 Avifauna

Due to the shallow, saline nature of the lake, Little Lake is an important feeding habitat for waterfowl (DECC, 2008).

3.4.5.6 Fisheries Values

Fish species observed in Little Lake include garfish, bream and mullet.

3.4.5.7 Batemans Marine Park

As outlined in Section 1.3.8, Little Lake is included as a Habitat Protection Zone in the Batemans Marine Park. Most recreational fishing activities are allowed in habitat protection zones, but some restrictions apply to the collection of bait. Bag limits, size limits and seasonal closures continue to apply.

3.4.6 Social Environment

3.4.6.1 Low-lying infrastructure

Some key infrastructure is located around Little Lake. The levels of this infrastructure are outlined in Table 3-16.

Table 3-16 Infrastructure around Little Lake

Public	Approximate Level
Sewage pump station (Off Willcocks Av)	~2.2m AHD, with pumps located at 3.3m AHD
Glasshouse Rocks Road	2.5m AHD
Private	
Inundation of fairway edges (9th and 15th holes)	2.0m AHD
Inundation of various fairways and tees	3.0m AHD

3.4.6.2 Recreation

Little Lake is often used for swimming and other primary recreation activities, given its proximity to the beach and the SLSC. Community members have previously requested opening of Little Lake entrance citing potential health reasons. Opening of the entrance and lowering of water levels, however, exposes sediments, which causes odour.

Community members (particularly kids) have been known to open the lake with shovels (illegally) to initiate a fast outflowing current that is used by boogey boarders, especially around Christmas time.

3.4.6.3 Planning issues

The Narooma Development Control Plan (DCP) area includes Little Lake specifically, with the land surrounding the lake zoned Public Open Space (ESC, 2005). Other coastal lakes and considered through provisions for the rationalisation and manner of development across the whole Eurobodalla Shire.

The golf course is viewed as semi-privatised public open space. There is no development proposed around Little Lake, due to its current and intended future use as a golf course. A public access coastal walkway and cycleway is proposed, to follow the shores of Little Lake. The DCP stipulates controls for flooding and oceanic influences and stormwater for new developments.

The south eastern boundary of Little Lake is classed as public open space, entailing a largely vegetated area with the cemetery within. The cemetery is listed as a Heritage item on the former Eurobodalla Urban LEP (1999) (ESC, 2005).

A number of other environmental constraints upon development (to reduce reliance on potable water, buffers to waterways and sensitive areas, water re-use on site etc) are outlined in the DCP (ESC, 2005).

The plan illustrates the majority of the riparian zone surrounding Little Lake to be “environmental corridor” which, in addition to providing habitat, bank stability and enhancing water quality, shall provide biodiversity linkages by maintaining connectivity for movement of aquatic and terrestrial species (as a corridor) between key destinations of high conservation value.

The plan outlines minimum management/environmental objectives for riparian lands of the ‘environmental corridor’ category, and which applies to Little Lake. These objectives include a minimum core riparian zone (CRZ) width of 40 m from top of bank; additional width of 10 m to counter edge effects, provision of movement continuity (including piered crossings) for terrestrial and aquatic species, re-establishing local native vegetation, the location of services, playing fields and recreational activities outside the CRZ, and treatment of stormwater runoff prior to discharge into the CRZ and additional buffer.

In spite of the environmental protections described above, the original coastal forest surrounding the golf course (and Little Lake) all fall within the settlement boundary of the Narooma township. This coastal forest is described in the plan as ‘unprotected’. Some of this land has been dedicated as new public open space and vegetation to be protected, to continue to provide an environmental corridor. The aim of new public open space is stated to be to “protect vegetation and create pedestrian and habitat corridors from East to West”. However, the plan also indicates that some of this currently vegetated area west of Little Lake will be used for urban development (residential, maximum height of 9 m).

3.4.7 Cultural Environment

There are accounts of use of Little Lake as a camp ground, once the vegetable picking season ended. Little Lake would also have provided a place for camping for Aboriginal people working at the nearby sawmill at Potato Point. Camp grounds have heritage value as places of spirituality, resource collection, and form part of traditional travelling routes (Donaldson 2006, 2007).

3.5 Bullengella Lake

3.5.1 Location

Bullengella Lake is nestled between Little and Nangudga Lakes, surrounded by private lands. There is little information available regarding Bullengella Lake.

The lake has a small waterway and catchment area, which appears to have been modified by clearing for rural use and part of a small industrial estate. The catchment extends up to Narooma High School and the Princes Highway.

Key features of Bullengella Lake and surrounding topography are shown in Figure 3-12.

3.5.2 Hydrology

3.5.2.1 Entrance Behaviour / Characteristics

Anecdotal reports indicate that the entrance of Bullengella Lake was last open in about 1965. The berm prior to that opening was much smaller than the present berm condition.

It is noted from local sources that water levels in the lake vary by about 1.5 metres, responding to rainfall and evaporation, as well as possible percolation through the entrance sands. The present water level is around 0m AHD, indicating that significant rainfall would be required in order to cause an entrance breakout.

The current berm level is very high (likely to be higher than 3m AHD), and is comparable to adjacent incipient dune levels – further highlighting the substantial timeframe since the berm was last breached. The land-side of the entrance berm also contains substantial vegetation, indicating stabilisation of the washover fan.

3.5.2.2 Water balance

Anecdotal reports by local landholders suggest that in the past, the area now occupied by the lake was once used for horticulture (vegetables and an orchard). This apparently was successful until a very high tide event overwashed salt water into the lake basin, killing off the plants. Fencing extending well into the middle of the lake still remains today.

3.5.3 Water quality

Virtually nothing is known about the water quality of Bullengella Lake. Interestingly, local landholders had suspected the water quality to be poor, however, upon testing in May 2009, the results indicate that the water quality was quite reasonable (except from high turbidity, reflective of wind stirring of fine bed sediments).

Surface water quality results that were taken opportunistically during site visit in May 2009 are presented in Table 3-17.

Table 3-17 Bullengella Lake water quality results (May 2009)

Constituent	Upstream end	Downstream end
Salinity (ppt)	11.4	11.3
Temperature (deg. C)	16.4	16.8
Turbidity (NTU)	180	80
Dissolved oxygen (mg/L)	8.3	9
ORP	214	230
pH	8.2	8.25

3.5.4 Sediments

3.5.4.1 Acid Sulfate Soils

Acid sulfate soils may exist around the peripheries and in the bed of the lake. Additional, and more prolonged, inundation of these soils, compared to existing conditions, would reduce the oxidation potential of the soils, thus reducing their acid-generating potential, and would also improve the neutralising effect of the marine waters against any acid that is generated.

3.5.4.2 Bank erosion and sedimentation

Bullengella Lake contains very fine sediments, which emanate H_2S when disturbed. This indicates a high level of organic decomposition within the sediment matrix, however, the water is well oxygenated, given its shallow depth and agitation (and associated oxygen entrainment) through wind stirring.

The gently sloping foreshores are largely unvegetated, or contain patches of salt-tolerant species (saltmarshes). No signs of foreshore erosion are obvious around the lake.

3.5.5 Ecology

3.5.5.1 Fringing Wetland Vegetation

Mapping of estuarine vegetation by NSW DPI (2006/7) does not show any mangrove or saltmarsh communities to be present, although small patches of the saltmarsh species *Sarcocornia* spp. and *Juncus krausii* are present around the foreshores. No SEPP-14 Coastal Wetlands or wetlands listed in the DIWA are present in the vicinity of Bullengella Lake.

The majority of the land surrounding Bullengella Lake is cleared pasture land, with the exception of a small dense stand of South Coast Swamp Oak Forest Complex on the northern boundary of the lake, and a narrow section of dune/headland scrub located between the lake and the beach. Some die-off of Swamp Oak has been observed around the fringes of the lake.

3.5.5.2 Aquatic Vegetation

No details of aquatic vegetation within Bullengella Lake are known, such that the extent of aquatic vegetation is expected to be minimal (i.e. NSW DPI 2006/7 mapping would have detected seagrass had substantial amounts been present).

3.5.5.3 Endangered Ecological Communities

No NSW-listed Endangered Ecological Communities are present in the direct surrounds of Bullengella Lake. However, *Bangalay Sand forest of the Sydney Basin and South East Corner Bioregions* is present in an area to the south of Bullengella Lake (east of Nangudga Lake).

No nationally Threatened Ecological Communities are known to be present in the vicinity of Bullengella Lake.

3.5.5.4 Threatened Species

The *Atlas of NSW Wildlife* showed no records of Threatened flora or fauna species in close proximity to Bullengella Lake (DECC, 2009). It is likely that Threatened bird species may use the site (e.g. those also present at Coila Lake and Tuross Lakes), but sightings have not been recorded on the database.

An EPBC Protected Matters search identified 13 nationally Threatened species that may potentially occur within the region of Bullengella Lake (DEWHA, 2009). However, the majority of these species are not considered likely to occur in close proximity to Bullengella Lake due to the absence of suitable habitat, or may occur but are not dependent on the wetland habitats (refer Table 3-18).

Table 3-18 EPBC Protected Matters search results for Bullengella Lake

Scientific name	Common name	EPBC Act Status	Likely to occur
Cryptostylis hunteriana	Leafless Tongue Orchid	V	Unlikely – does not inhabit saline conditions
Thesium australe	Toadflax	V	Unlikely – does not inhabit saline conditions
Prototroctes maraena	Australian Grayling	V	Possible – but generally migrates between freshwater and ocean
Dasyurus maculatus maculatus (SE mainland population)	Spot-tailed Quoll	E	Possible occasional occurrence – but not dependent on habitats present
Potorous tridactylus tridactylus	Long-nosed Potoroo	V	Possible occasional occurrence – but not dependent on habitats present
Pteropus poliocephalus	Grey-headed Flying Fox	V	Possible occasional occurrence – but not dependent on habitats present

Heleioporus australiacus	Giant Burrowing Frog	V	Unlikely – does not inhabit saline conditions
Litoria aurea	Green and Golden Bell Frog	V	Unlikely – does not inhabit saline conditions
Litoria littlejohni	Littlejohn's Tree Frog	V	Unlikely – does not inhabit saline conditions
Anthochaera phrygia	Regent Honeyeater	E	Possible occasional occurrence – but not dependent on habitats present
Lathamus discolor	Swift Parrot	E	Possible occasional occurrence – but not dependent on habitats present
Neophema chrysogaster	Orange-bellied Parrot	CE	Possible – uses saltmarsh habitats
Rostratula australis	Australian Painted Snipe	E	Possible

V = Vulnerable, E = Endangered, CE = Critically Endangered

The EPBC Act Protected Matters Search also revealed that several migratory species that are listed under international agreements may occur within the site, such as Great Egret (*Ardea alba*), Cattle Egret (*Ardea ibis*), Latham's Snipe (*Gallinago hardwickii*), Fork-tailed swift (*Apus pacificus*) and Little Tern (*Sterna albifrons*). The species are also listed as 'Migratory' under the EPBC Act, and Little Tern is Endangered under NSW legislation.

3.5.5.5 Avifauna

Avifauna of Bullengella Lake is typical of coastal lagoons, including species such as swans and ducks. Furthermore, a Sea Eagle colony of approximately six individuals is also present.

3.5.5.6 Batemans Marine Park

As outlined in Section 1.3.8, Bullengella Lake is included as a Sanctuary Zone in the Batemans Marine Park, the highest level of protection. The only activities permitted in Sanctuary zones are those that do not involve the harming or taking of any plants or animals. All fishing is prohibited in Sanctuary zones so that marine life can continue to thrive and reproduce.

3.5.6 Social Environment

While the beach adjacent to Bullengella Lake ("Hanky Beach") is accessible to the public, Bullengella Lake is essentially landlocked by private freehold title lands. There is no infrastructure at immediate risk of inundation by the lake, and as such, there is unlikely to be any objections to increasing water levels in the future in response to sea level rise.

There is no future development proposed in the vicinity of Bullengella Lake. As outlined in the DCP, any further rural small holding zonings are to be avoided due to the sprawling lot sizes and inadequate tree protection measures, with favour given to compact development types (ESC, 2005).

It is stated within the plan that the Glasshouse Rocks Road industrial estate will not be extended due to environmental constraints and edge of settlement principles (the estate lies on the border of the settlement boundary of Narooma, and is surrounded by original coastal forest) (ESC, 2005).

3.5.7 Cultural Environment

The Glasshouse Rocks, immediately adjacent (seaward and northward) of Bullengella Lake is a significant traditional fishing ground (Donaldson, 2006). In present times, the access road to the Glasshouse Rocks is now privately owned, making it difficult for the local Aboriginal people (particularly the elderly) to access Glasshouse Rocks, and teach the younger generation traditional fishing practises and so on (Donaldson, 2006).

Shell middens are described all along Handkerchief beach and around the headlands, in proximity to Bullengella and Nangudga lake entrances (Donaldson, 2006).

3.6 Nangudga Lake

3.6.1 Location

Nangudga Lake is approximately 2.5 km south of Narooma. The lake overall is very shallow, with only a few deeper backwater sections. Key topographic details and bathymetry of Nangudga Lake are presented in Figure 3-12.

Nangudga Lake has a waterway area of 0.5 km^2 and a catchment area of 12 km^2. The lake is reportedly very shallow, ~ 0.3 m in most locations, although there are a few deeper sections in the back lake section, as well as under the Princes Highway bridge.

3.6.2 Hydrology

3.6.2.1 Entrance Behaviour / Characteristics

This lake is typically closed, but does open occasionally in response to significant rainfall across the catchment. Anecdotal reports from local residents suggest that the lake has been open about 3 times since 2004, and up to 5 times in the last 20 years (or about once every 3 years or so).

Council was responsible for opening the lake on or around 4^{th} August 2005, and again on 14^{th} July 2006 (refer Figure 3-13). A marker on the Princes Highway road bridge was retained indicating the maximum water level prior to these breakouts, this being approximately 1.22m AHD. Council's involvement in other opening events prior to this is unknown.

3.6.2.2 Water balance

High rainfall events can occur over short periods of time, resulting in relatively rapid increases in lake water level (which can subsequently initiate breakout events).

When lake levels are high, water backs up through a sump tank and into the drains within the Island View Beach Resort (refer Figure 3-14). This presents a safety issue, and inundates low-lying camping grounds (which has been mitigated to some degree by converting previous open drains to a covered culvert.

High lake levels also result in inundation of private properties on the southern side of the Princes Highway crossing. This is mostly contained within low-lying paddocks, but potentially surrounds a residence (refer Figure 3-15). Prolonged inundation causes die-off of grasses.

Figure 3-13 Council openings of Nangudga Lake: August 05 (left) and July 06 (right)

Figure 3-14 Backwater inundation of Island View Beach Resort (July 06, prior to breakout)

Figure 3-15 Private property inundation adjacent to lake (July 06, prior to breakout)

3.6.3 Water Quality

Water quality data has been collected from Nangudga Lake by Wiecek (2001) (refer Table 3-19). Water quality in Nangudga Lake is highly variable, with high nutrient levels at times. Water quality profiling was also undertaken by MHL (2002) (refer Table 3-20). Nangudga Lake was closed at the time of the water quality profiling undertaken by MHL on 20 August, 2002. Salinity was at or slightly above ocean conditions, while dissolved oxygen was adequate, and pH was typical for estuaries.

Table 3-19 Water quality data, Nangudga Lake (source: Wiecek, 2001)

Collect Date	NH_3 (µg/L)	NO_X (µg/L)	Total inorg. N (µg/L)	Total Nitr. (µg/L)	Ortho phos. (µg/L)	Total Phosph. (µg/L)	Chl-a (µg/L)
Nangudga Lake							
January-01	136.7	5.0	141.7	670.0	7.3	16.0	n.r.
March-01	100.0	5.0	105.0	976.7	5.3	22.3	2.7
April-01	86.7	11.7	98.3	1113.3	9.7	12.0	6.3
May-01	420.0	26.7	446.7	910.0	11.3	20.3	4.5
June-01	620.0	30.0	650.0	1286.7	11.7	30.0	11.3
July-01	68.3	23.3	91.7	1523.3	2.5	94.0	31.0
August-01	516.7	11.7	528.3	870.0	8.3	14.3	11.8

Table 3-20 Water quality data, Nangudga Lake (source: MHL, 2002)

Water Quality Maxima and Minima - Nangudga Lake - First Run - 20 August 2002
Lake closed. This would represent Low tide slack

Station No.	Time (EST)	Depth (m)	Density (kg/m3) Mean	Temperatu (DegC) Mean	Salinity (psu) Mean	Dissolved (% sat) Mean	pH Mean	Backscatte (NTU) Mean	Chlorophy (ug/L) Mean	PAR Mean
1	748	1	1027.2	12.5	35.9	103.05	8.07	475.57	0.01	1362.1
2	801	1.8	1027.3	12.31	35.92	86.12	7.93	489.38	0	320.1
3	900	0.7	1027.5	12.68	36.36	85.83	8.03	124.18	0	924.7
4	924	1	1027.7	12.7	36.58	91.83	8.18	498.84	2.17	2716.2
5	933	1	1027.8	12.48	36.64	100.97	8.02	504.89	0.41	1191.9

Water Quality Maxima and Minima - Nangudga Lake - Second Run - 20 August 2002
Lake closed, this would be timed with high tide slack.

Station No.	Time (EST)	Depth (m)	Density (kg/m3) Mean	Temperatu (DegC) Mean	Salinity (psu) Mean	Dissolved (% sat) Mean	pH Mean	Backscatte (NTU) Mean	Chlorophy (ug/L) Mean	PAR Mean
1	1256	0.9	1026.6	15.16	35.89	112.85	8.17	525.99	0	2668.9
2	1309	2.2	1027.2	12.58	35.98	85.95	7.94	528.16	0	837
3	1317	0.6	1026.8	15.71	36.33	102.8	8.03	248.11	0.07	3304.2
4	1334	1	1027.4	14.05	36.63	100.04	8.2	515.05	0	1440.1
5	1340	1	1027.4	14.28	36.65	103.38	8.12	404.45	0.76	2305.1

Sediment nutrient analysis has been carried out by PhD student Daniel Spooner (Uni of Canberra). Spooner (2005) demonstrated that the sediments within Nangudga Lake generate high levels of nutrients to the water column. It is this source of nutrients that is expected to drive the macroalgae blooms that dominate the back-lake sections of the Nangudga Lake.

Low water levels within the lake result in significant exposure and desiccation of macroalgae, generating odour issues. During high water levels, swans assemble on the lake to feed on the macroalgae.

The Island View Beach Resort is connected to Council's reticulated sewerage system. Inspection outlets are located in the roadways, however, minimal leaking into the system is expected during periods of high lake inundation.

3.6.4 Sediments

3.6.4.1 Acid Sulfate Soils

Acid sulfate soils may exist around the peripheries and in the bed of the lake. Additional, and more prolonged, inundation of these soils, compared to existing conditions, would reduce the oxidation potential of the soils, thus reducing their acid-generating potential, and would also improve the neutralising effect of the marine waters against any acid that is generated.

3.6.4.2 Bank erosion and sedimentation

Foreshore erosion is not generally noted around Nangudga Lake, given its flat slopes and mostly vegetated fringes.

It is expected that catchment runoff, exacerbated since the catchment has been largely cleared, has accelerated the natural sedimentation of the lake. The sediments in the entrance channel, however, are marine in origin, and would have been deposited mostly since the last significant flood and entrance scouring event. The sediment presently within the entrance berm will be scoured and transported into the coastal nearshore zone, where is will be subject to wave and tide action. A proportion of this sediment will be reworked back into the entrance.

3.6.5 Ecology

3.6.5.1 Fringing Wetland Vegetation

The foreshores of Nangudga Lake are fringed by patches of saltmarsh communities covering a total of 0.146 km^2 (NSW DPI 2006/7, refer Figure 3-16). Species composition of these saltmarsh communities includes *Sarcocornia, Sprorobolus* and *Juncus.* These communities are encompassed by four SEPP-14 Coastal Wetlands (122, 122a, 123, 124) (refer Figure 3-17). No wetlands in the vicinity of Nangudga Lake are listed in the DIWA.

Above the typical high water level of the lake, the vegetation community changes from saltmarsh to Swamp Oak (*Casuarina glauca*). Terrestrial vegetation surrounding the wetland vegetation is sclerophyll forest, with a relatively large community present in the south-west region and narrow, fragmented patches in the remaining areas.

3.6.5.2 Aquatic Vegetation

Seagrass communities composed of *Ruppia* species are present throughout a large proportion of the lake, covering an area of 0.202 km^2 (NSW DPI, 2006/7; refer Figure 3-16).

3.6.5.3 Endangered Ecological Communities

The Swamp Oak communities surrounding Lake Nangudga are a NSW-listed Endangered Ecological Community under the NSW *Threatened Species Conservation Act 1995*, listed as *Swamp Oak floodplain forest of the NSW North Coast, Sydney Basin and South East Corner bioregions.* The saltmarsh communities surrounding Lake Nangudga are also an Endangered Ecological Community, listed as *Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South West Corner Bioregions.*

In terms of terrestrial vegetation, the tall eucalypt forests adjacent to the east of the lake are a NSW-listed Endangered Ecological Community (*Bangalay Sand forest of the Sydney Basin and South East Corner Bioregions*).

No nationally Threatened Ecological Communities are known to be present in the vicinity of Lake Nangudga.

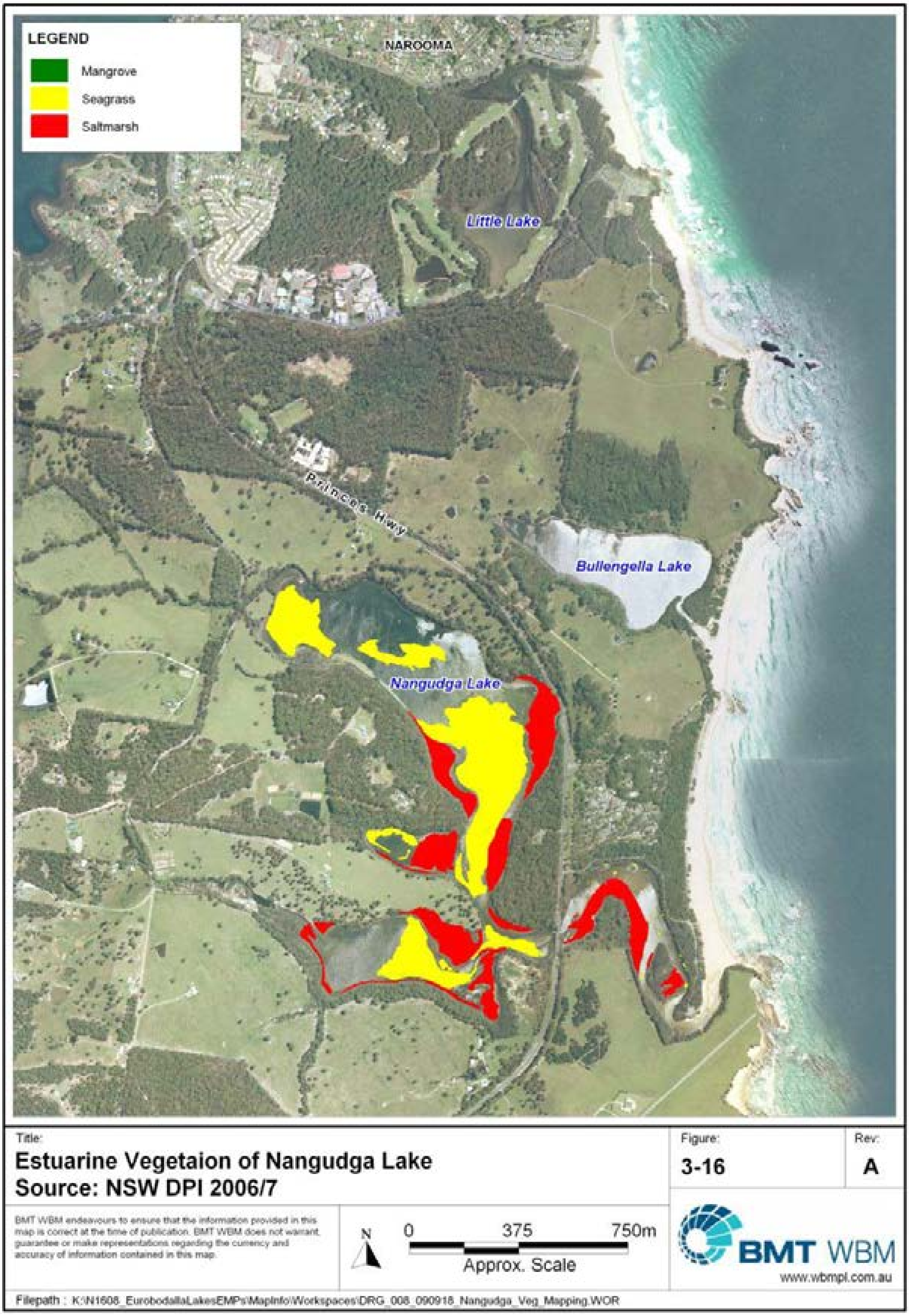

Figure 3-16 Estuarine vegetation of Lake Nangudga (source: NSW DPI 2006/7).

Figure 3-17 ***State Environmental Planning Policy No 14*** **(SEPP14) Coastal Wetlands of Nangudga Lake.**

3.6.5.4 Threatened Species

The *Atlas of NSW Wildlife* showed no records of Threatened flora or fauna species in close proximity to Lake Nangudga (DECC, 2009). However, NSW NPWS (2007) recorded a non-breeding pair of the Vulnerable species Pied Oystercatcher (*Haematopus longirostris*) during the 2006/2007. It is likely that additional Threatened bird species use the site (e.g. those also present at Coila Lake and Tuross Lakes), but sightings have not been recorded on the database.

An EPBC Protected Matters search revealed 12 nationally Threatened species that may potentially occur within the region of Nangudga Lake (DEWHA, 2009). However, the majority of these species are not considered likely to occur in close proximity to Nangudga Lake due to the absence of suitable habitat, or may occur but are not dependent on the wetland habitats (refer Table 3-21).

Table 3-21 EPBC Protected Matters search results for Lake Nangudga

Scientific name	Common name	EPBC Act Status	Likely to occur
Cryptostylis hunteriana	Leafless Tongue Orchid	V	Unlikely – does not inhabit saline conditions
Prototroctes maraena	Australian Grayling	V	Possible – but generally migrates between freshwater and ocean
Dasyurus maculatus maculatus (SE mainland population)	Spot-tailed Quoll	E	Possible occasional occurrence – but not dependent on habitats present
Potorous tridactylus tridactylus	Long-nosed Potoroo	V	Possible occasional occurrence – but not dependent on habitats present
Pteropus poliocephalus	Grey-headed Flying Fox	V	Possible occasional occurrence – but not dependent on habitats present
Heleioporus australiacus	Giant Burrowing Frog	V	Unlikely – does not inhabit saline conditions
Litoria aurea	Green and Golden Bell Frog	V	Unlikely – does not inhabit saline conditions
Litoria littlejohni	Littlejohn's Tree Frog	V	Unlikely – does not inhabit saline conditions
Anthochaera phrygia	Regent Honeyeater	E	Possible occasional occurrence – but not dependent on habitats present
Lathamus discolor	Swift Parrot	E	Possible occasional occurrence – but not dependent on habitats

			present
Neophema chrysogaster	Orange-bellied Parrot	CE	Possible – uses saltmarsh habitats
Rostratula australis	Australian Painted Snipe	E	Possible

V = Vulnerable, E = Endangered, CE = Critically Endangered

The EPBC Act Protected Matters Search also revealed that several migratory species that are listed under international agreements may occur within the site, such as Great Egret (*Ardea alba*), Cattle Egret (*Ardea ibis*), Latham's Snipe (*Gallinago hardwickii*), Fork-tailed swift (*Apus pacificus*) and Little Tern (*Sterna albifrons*). The species are also listed as 'Migratory' under the EPBC Act, and Little Tern is Endangered under NSW legislation.

3.6.5.5 Avifauna

Nangudga Lake is an important feeding habitat for waterfowl and wading birds due to the shallow, saline nature of the waterbody.

3.6.5.6 Invasive Species

A marine pest the European/Green Shore Crab (*Carcinus maenas*) is listed as occurring in Nangudga Lake. The pest crab is not found on open coasts or rocky or sandy coasts, but rather prefers the shallow areas of bays, estuaries, and coastal lakes. The crab is said to compete with native species, feed on native shellfish and other crabs, and has potential impacts on fishing industries and aquaculture. A marine pest alert for the crab has been issued by DPI Fisheries for the affected areas including Nangudga Lake (DPI Fisheries, 2009).

3.6.5.7 Batemans Marine Park

As outlined in Section 1.3.8, Nangudga Lake is included as a Sanctuary Zone in the Batemans Marine Park, the highest level of protection. The only activities permitted in Sanctuary zones are those that do not involve the harming or taking of any plants or animals. All fishing is prohibited in Sanctuary zones so that marine life can continue to thrive and reproduce.

3.6.6 Social Environment

3.6.6.1 Low-lying infrastructure

There is limited ground survey around Nangudga Lake to confirm elevations of private property and low lying infrastructure. In general, inundation impacts have been approximated based on the measured water level of 1.22m AHD immediately prior to the August 2005 breakout event.

The levels of low lying infrastructure around Nangudga Lake are outlined in Table 3-22.

The Caravan Park has previously requested opening to deal with odour/water quality complaints. The caravan park also experiences stormwater flooding and issues (Pers. comm., Norm Lenehan, ESC, 1/4/09).

BMT WBM

Table 3-22 Infrastructure around Nangudga Lake

Public	Approximate Level
Princes Highway (at road bridge)	RL 3.9m AHD
Old Coast Road (at causeway)	RL 2.2m AHD
Hankerchief Beach access road	RL 1.5m AHD
Private	
Inundation of private property on southern side of bridge (eg Gleasons)	1.2m AHD – land 2.5m AHD – dwelling floor
Inundation of camping ground within Island View Beach Resort	~1.2m AHD

3.6.6.2 Economic / Recreational

Nangudga Lake is utilised by visitors to the nearby Ocean View Caravan Park. Visitors mostly utilise the lower reaches of the entrance channel, where water clarity is the best. Other sections of the lake tend to be too weedy for easy access.

Historically the lake has been used for prawning. Visitors to the Caravan Park are directed to Mummaga Lake for prawning, as the Lake is now a Sanctuary Zone of the Batemans Marine Park (and thus recreational and commercial prawning is not permitted).

3.6.6.3 Planning issues

RTA are currently investigating the replacement of the Princes Highway bridge over Nangudga Lake. It is understood that the RTA are using the NSW Government's Sea Level Rise Policy in its design for the new bridge.

There is no specific development proposed in the Nangudga Lake area, as it falls outside of the settlement boundary. In this case, the stipulations upon rural residential / small holdings apply, that is Rural small holding zonings are to be avoided due to the sprawling lot sizes and inadequate tree protection measures, with favour given to compact development types (ESC, 2005). Rezoning of existing rural land surrounding Nangudga Lake to rural residential (1c) is considered inappropriate, due to the impact this may have upon the scenic values of the coast road, in addition to other negative impacts.

3.6.7 Aboriginal Heritage

Nangudga Lake also has cultural significance for use both in the past and to the present day by the local Aboriginal people. Families can recount visits to the lake to fish and catch prawns. Traditional spears made from the garara stick were used to catch fish, including mullet (Donaldson, 2006).

Shell middens are described all along Handkerchief beach and around the headlands, in proximity to Bullengella and Nangudga lake entrances (Donaldson, 2006).

4 ACCOMMODATING CLIMATE CHANGE

4.1 Background

Contributions from increased anthropogenic gas emissions into the Earth's atmosphere and its associated acceleration of the 'greenhouse-effect' and thus rapid climate change are a widely accepted scientific phenomenon. The characteristics of a rapidly changing climate are now being recognised (Steffen, 2006). For example, the past 20 years have been consistently significantly hotter than the 1961-1990 global average (Figure 4-1). The contemporary increase in temperatures globally is reflected also in the Australian climate data.

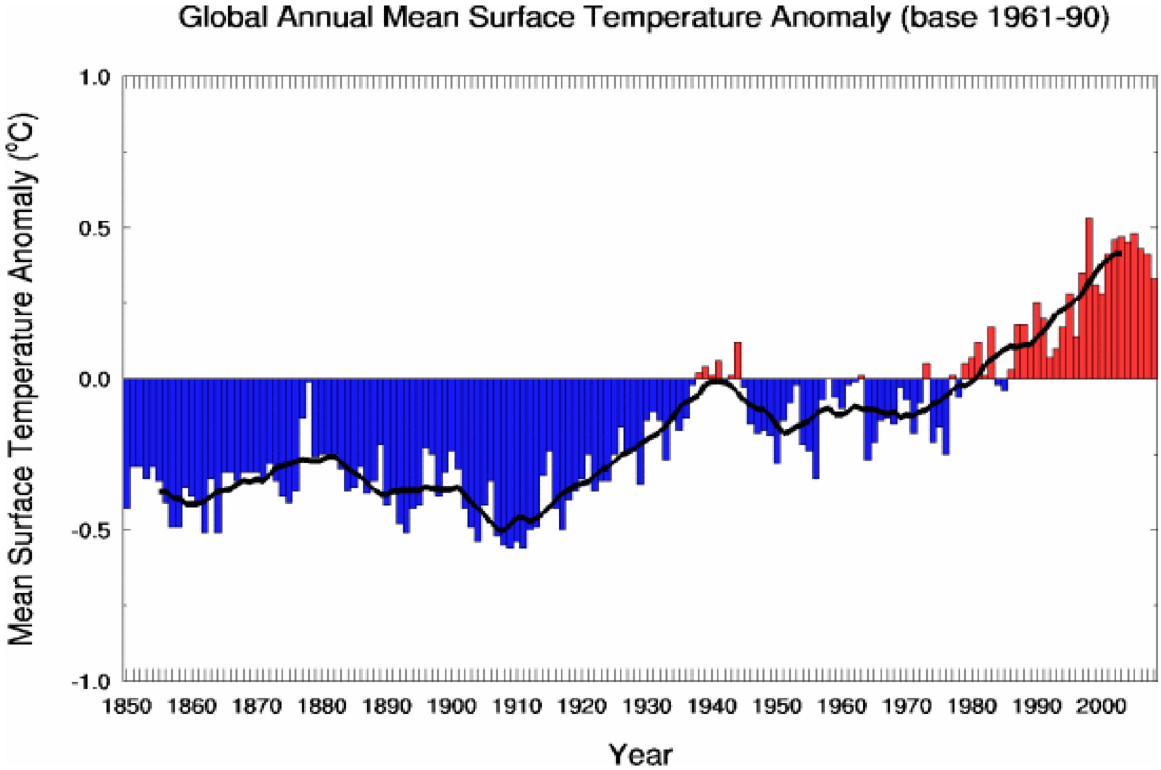

Figure 4-1 Global average temperature variation, 1850 – 2009 compared to 1961-1990 average, black line shows running 11 year average (Source: BoM, 2009)

Increasing air temperatures across the globe in the future will cause a variety of climatic effects, including for example sea level rise, increased atmospheric and ocean temperatures, and changes to rainfall and drought patterns.

Sea level rise is the most accepted of the predictions associated with climate change, however, predictions as to the extent of this rise vary greatly due to the uncertainty of greenhouse gas concentrations in the future and disagreement on the effect of various levels of such gases (Walsh 2004b). Mean sea level, on a global scale, has been increasing over the past century, due primarily to the thermal expansion of the oceans as ocean temperature has increased (Cabanes et al., 2001), as well as glacial melting (Walsh et al., 2002). Over the past 50 years or so, the widely adopted average sea level rise has been approximately 1.8mm/yr (Walsh, 2004; Church et al., 2005). Sea level rise has not occurred consistently, however, with the most recent trend (since the early 1990s) having an accelerated rise of around 3.4 mm/yr, as captured by the TOPEX, and more recently Jason, satellite data.

IPCC (2007) projects an increase in mean sea level of between 0.18 and 0.59m by the end of the 21st century, with the possibility of an additional 0.1 to 0.2m due to ice sheet flow. Further, CSIRO has predicted additional localised sea level rise of up to 0.12m on the east coast of Australia due to thermal effects of the East Australian Current (McInnes et al., 2007) (ie up to 0.91m).

To assist with longer term strategic and land-use planning, the NSW Government has released a *Sea Level Rise Policy Statement* (adopted October 2009), which recommends consideration of a sea level rise of 0.9m by 2100.

It must be recognised and emphasised that projected sea level rise will not stop at the end of this century (the limit of most reasonable projections). Indeed it is reported that the inertia of thermal expansion held within the oceans now will result in continued sea level rise for many centuries or even millennia, regardless of any future controls on CO_2 emissions or global air temperature changes. Thus, sea levels may be several metres higher than present before they once again stabilise, particularly if large land ice masses, such as Greenland, melt (IPCC, 2007). Such circumstances may essentially re-start geomorphic evolutionary processes on the coast, including the landward transgression of coastal barriers and the associated impoundments behind them. Sea level rise in Australia is also likely to be affected by the El Nino Southern Oscillation (ENSO), a decadal cycle characterised by periods of drought and drier weather during the El Nino phase of the cycle, and relatively high rainfall and wetter weather during the La Nina phase. The likely effects of a warmer climate on the ENSO are not currently well understood.

On-going sea level rise beyond our immediate planning horizon prompts the recommendation for adoption of conservative sea level rise estimates, as well as the initiation of a program of adaptation and accommodation of continuously rising seas in the future.

Whilst sea level rise is considered to be the most certain impact of climate change, there is also likely to be a range of other climate impacts pertaining to:

- Temperature (average, extremes);
- Rainfall (average, extremes);
- Evaporation / solar radiation / potential for fire;
- Drought frequency; and
- Wind, wave and storm surge conditions.

4.2 Likely Changes to the Eurobodalla Coastal Climate

Investigations into expected impacts of climate change on the NSW Coastline have been carried out by CSIRO (Macadam et al., 2007; McInnes et al, 2007) on behalf of the NSW Department of Environment and Climate Change. These investigations build on the raft of previous investigations and studies carried out by scientists across the globe (including IPCC), giving specific attention to the

NSW coastline. Two pilot investigation areas for assessment of future climate change impacts upon estuaries were selected: the Clyde River/Batemans Bay estuary; and the Wooli Wooli River estuary.

The CSIRO investigations have given particular attention to the uncertainty of climate response models. In providing predicted outcomes, CSIRO adopted the result of two different regional climate models (CCM2 and CCM3) that were found to have distinctly different responses with regard to wind (considered to be one of the principal climate variables, as it drives a number of processes that influence coastal response). Both regional climate models adopted by CSIRO utilise a future CO_2 emissions rise (from present levels of 370 ppm to 880 ppm by 2100) that is considered sufficiently conservative for a risk averse approach to future decision making (McInnes et al, 2007).

The outcomes of the CSIRO investigations for these pilot investigations are considered a good indication of the likely climate change outcomes for the coastal lakes along the Eurobodalla coastline, and are discussed in detail below.

4.2.1 Average Temperature

Macadam et al (2007) report changes to average temperature based on previous work by Holper et al (2006), scaled by global warming values to produce projections of change for 2030 and 2070. Using the two climate models and a range of global warming values, the daily <u>maximum</u> air temperature at Batemans Bay is likely to increase by between 0.5 and 1.5°C by 2030, and by between 1.1 and 4.6°C by 2070 (annually averaged). The annually averaged daily <u>minimum</u> air temperature is also likely to increase, by between 0.4 and 1.4°C by 2030, and by between 1.0 and 4.3°C by 2070.

4.2.2 Average Rainfall

As for average temperature, average rainfall estimates were determined based on work by Holper et al (2006). The changes in rainfall are given as the change in total quantity of rain falling on a unit area over a year. Macadam et al (2007) reports that by 2030, average annual rainfall will either decrease by 8% or increase by 10% at Batemans Bay, according to the two model simulations, CCM2 and CCM3 respectively. By 2070, annual average rainfall will either decrease by 23% (as per model CCM2) or increase by 30% (as per model CCM3) at Batemans Bay. The scenarios considered by Macadam et al (2007) showed considerable variation, highlighting the lower degree of certainty associated with future rainfall projections.

These widely variable rainfall outcomes are still useful for consideration of the Eurobodalla coastal environment. For example, future planning for water usage would be prudent to accommodate the worst case outcome, ie up to 30% less rainfall by 2070.

4.2.3 Extreme Rainfall Events

Extreme rainfall events have been considered previously by CSIRO (Hennessy et al., 2004). Extreme daily rainfall is predicted to be modified by future climate change (Walsh 2004a,b; Hennessy *et al.*, 2004) with potentially greater storm intensity even if overall precipitation decreases (Walsh, 2004a).

Consideration was given to 1 in 40yr, 1 in 20yr, 1 in 10yr and 1 in 5yr rainfall events. Changes predicted by Hennessy et al. (2004) were averaged across return periods to give a single change for each simulation considered (Macadam et al., 2007). The intensity of extreme rainfall events in the vicinity of Batemans Bay, which may be applied to nearby Eurobodalla, is likely to change by -10 to +10% by the year 2030, and by -10 to 0% by the year 2070 (averaged annually). Typically the intensity of storms is more likely to increase during summer, and decrease during winter.

Extreme rainfall events are particularly important to coastal lakes, as it is these events that typically fill the lakes over short periods of time causing natural breakouts of the entrance. This contrasts to persistent lower intensity rainfall, which typically results in slow increases in water level, which may stay elevated for some time, thus necessitating artificial intervention to minimise public risk.

4.2.4 Drought Frequency

Macadam et al (2007) refer to investigations carried out by Mpelasoka et al (2007), using CSIRO and Canadian Climate Centre modelling. The results of Mpelasoka et al (2007) suggest that the Southeast Coast Drainage Division, containing the Eurobodalla coastline, is likely to have an increase in the frequency of drought of up to 20% by 2030, and up to 40% by 2070. Drought is therefore projected to occur for up to 24% of months per decade by 2030, and up to 28% of months per decade by 2070.

4.2.5 Average Solar Radiation

Average solar radiation was assessed by Macadam et al (2007) based on previous work by Holper et al (2006). The solar radiation was defined as the energy transferred to a unit area by incoming shortwave electromagnetic radiation from the sun. It was assessed that the average solar radiation is likely to increase by between 0.1 and 0.3% by 2030, and by between 0.2 and 0.8% by 2070 (annually averaged). Considerable variability in the average solar radiation was recorded between the different models and global warming scenarios for each of the seasons, with some seasons reporting significantly greater increases (and even decreases) compared to the annual averaged values.

4.2.6 Wind Speed and Direction

McInnes et al (2007) used the CSIRO climate models to determine winds over 40 year periods centred on 1980, 2030 and 2070. A frequency analysis on daily average winds was carried out based on binned wind directions and wind speed classes. On an annual averaged basis, the models showed no difference in wind direction, indicating that any change in wind direction was less than 45° (the resolution of the model). For wind speed however, the percentages of time that winds from the dominant wind direction were within the different wind classes were determined (McInnes et al 2007). The model results indicate only small differences (both positive and negative) in the percentage of time within each wind class for both 2030 and 2070 in the vicinity of Batemans Bay, when considered on an annual and a seasonal basis.

It is noted by McInnes et al (2007) that the wind analysis was conducted for a coarse grid (5^0 boxes) covering the ocean near Batemans Bay, and as such, the results do not represent localised wind conditions that are likely to be experienced on the land. The wind estimates, however, provide the basis of wave height and direction and storm surge predictions, as discussed below.

4.2.7 Wave Height and Direction

The wind speed changes calculated by McInnes et al (2007) were used to estimate changes to the ocean wave climate at Batemans Bay. Winds close to the coast were used to generate a time series of storm waves, while winds offshore were used to generate swell waves – the two time series were then combined.

Storm waves originate most frequently from the south-easterly and southerly directions. Considerable variability in the models was found, with increases and decreases occurring in both climate models for different directions and time periods. However, the CCM3 model predicted an increase in the maximum storm wave height and period from the southerly, easterly and south-easterly directions in 2070 (for Batemans Bay).

The frequency of occurrence of swell waves from the SSE octant decreases in both model outputs, for both 2030 and 2070 (for Batemans Bay). This decrease is thought to possibly relate to the higher frequency of westerly winds at this latitude, as mid-latitude westerlies strength and contract to the south.

4.2.8 Storm Surge

A 50 year return period storm surge level of 0.66m +/- 0.13m was determined for Batemans Bay from extreme sea level residual data using a Generalised Pareto Distribution (GPD) (McInnes et al., 2007). The predicted change in frequency of storm waves was used to modify the GPD parameters. For 2070, the 50 yr return period storm surge increased to 0.68m +/- 0.14m using the CCM3 model, but decreased to 0.65m +/- 0.12m using the CCM2 climate model.

4.2.9 Mean Sea Level

Globally averaged sea level rise is provided by latest IPCC investigations. Using a wide range of scenarios, global average mean sea level is likely to increase by 0.18 to 0.59m by 2095, with potentially an additional contribution of 0.1 to 0.2m from the future rapid dynamic response of the ice sheets (IPCC, 2007). Local variations from this global average are expected. Based on the two CSIRO models, thermal expansion of local seas is predicted to be higher than global average values along the NSW coast. This is associated with stronger warming of the sea surface temperatures and a strengthening of the East Australian Current (McInnes et al, 2007). For the area around Batemans Bay, projected sea level rise is likely to be between 0 and 4cm higher than the global average sea level rise by 2030, and between 0 and 12cm higher than the global average rise by 2070.

An increase in mean sea level would result in an upward and landward translation of ocean beach profiles (Bruun 1962, Dean and Maurmeyer 1983, Hanslow *et al.* 2000), thus causing net shoreline recession (refer Figure 4-2). The changed beach processes will result in a net upward shift in typical berm heights of coastal lake entrances.

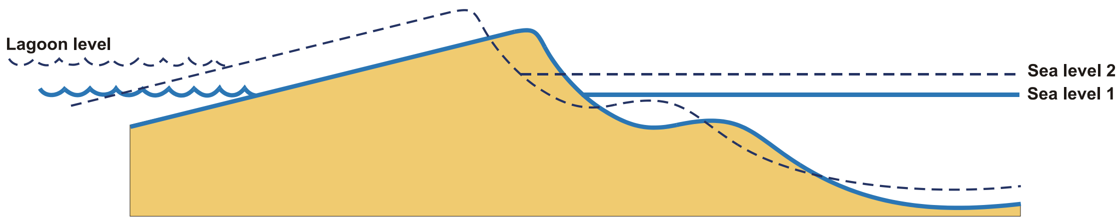

Figure 4-2 Shoreline response to increasing sea level (Hanslow *et al*., 2000)

4.3 Impacts of Climate Change on Eurobodalla Coastal Lakes

The impacts of future climate change are likely to lead to a wide range of environmental responses by coastal lakes within the Eurobodalla Shire. These are likely to manifest throughout the physical, chemical and ecological processes that drive local estuarine ecosystems (see Table 4-1).

A change in entrance berm processes is likely to result from the predicted sea level rise and changes to coastal storm intensity (Haines and Thom, 2007). From this change, a net upward shift in typical berm heights at the entrance may be expected, and therefore flood water levels will need to reach a higher level before inducing a natural breakout to the ocean (Haines, 2006; Haines and Thom, 2007).

Typical water levels within the estuary will increase concurrently with increasing sea levels. This will have repercussions for groundwater tables around the estuary foreshores, as well as for fringing estuarine and freshwater wetland communities and habitats. Planning for foreshore areas around the Eurobodalla coastal lakes will need to cater for the modified lake water levels, and in particular, development in low lying areas should be avoided.

If Council is to maintain a policy of entrance breakouts at the same trigger levels as currently adopted, then more frequent artificial breakouts will be required (as the trigger will be reached more easily in the future). Reduced catchment runoff, however (as a consequence of a reduction in total annual rainfall, coupled with a predicted increase in evaporation due to warmer atmospheric temperatures), may offset this increase in artificial breakouts.

For some lakes, the trigger level will be reached by normal tidal variability, thus necessitating a permanently open entrance in the absence of alternative mitigative or adaptive measures.

The increase in mean water level, reduced catchment runoff and possibly altered entrance breakout frequency is likely to have an impact on the natural sensitivity of the Eurobodalla coastal lakes to external (catchment) inputs (Haines *et al*., 2006). Further, under closed entrance conditions, increase air temperatures are likely to increase typical water temperatures in the estuary. This may degrade water quality, by reducing dissolved oxygen, and changing the solution of various salts and therefore dissolved nutrients, metals and pollutants in the water column. In turn, aquatic species will respond to changes in water chemistry, most notably, algal productivity may increase, causing flow on effects to higher trophic levels of ecology. The distribution of aquatic flora and fauna would also be expected to change in response to higher water temperatures.

BMT WBM

Table 4-1 Environmental response of the Eurobodalla coastal lakes to climate change (adapted from Haines, 2006 and Haines & Thom, 2007)

	Mostly Open Lagoons (eg Tuross Lakes)	*Mostly Closed Lagoons (eg Coila, Kianga, Little, Bullengella and Nangudga Lakes)*
Coastline and entrance morphodynamics	• Recession due to sea level rise • Accretion due to south-to-north longshore sediment drift • Increased intermittent entrance scour due to higher flood intensity Result: may be more open or more closed depending on relativity between factors	• Recession due to sea level rise • Accretion due to south-to-north longshore sediment drift • Reduced intermittent entrance scour due to reduced total rainfall, increased evaporation, and potentially lower head difference for artificial breakouts Result: likely to be increased accretion within entrance, leading to increased period of closure and reduced frequency of natural entrance breakouts.
Hydrodynamics	• Increase in average and storm-related water level within the estuary • Reduced input of total catchment runoff leading to greater average salt penetration into lagoon	• Net increase in low water level by an equivalent amount as sea level • Net increase in natural high water breakout levels • Reduced average input of total catchment runoff leading to a reduced rate of rise of typical water level and fewer entrance breakouts
Sediment dynamics	• Vertical accretion of marine and fluvial deltas reduced wind-driven stirring of bed sediments. • Landward progradation of marine delta • Overall reduced catchment runoff sediment load.	• Vertical accretion of marine and fluvial deltas reduced wind-driven stirring of bed sediments. • Overall reduced catchment runoff sediment load.
Water quality	• Greater water depths in estuary may affect benthic processes. • Higher water temperatures may increase pelagic and benthic primary production and microbial respiration • Overall reduced catchment pollutant runoff loads.	• Reduced breakout frequency leading to reduced potential for purging of pollutant and oceanic flushing. • Higher water temperatures may increase pelagic and benthic primary production and microbial respiration • Overall reduced catchment pollutant runoff loads.
Ecology	• Landward migration of foreshore and estuarine vegetation, if suitable land is available – if not, loss of foreshore and estuarine vegetation • Potential change in distribution and composition of estuarine vegetation communities (e.g. mangroves), higher trophic order consequences of increased phytoplankton (e.g. zooplankton)	• Reduced frequency of breakouts gives more opportunity for benthos community to establish and stabilise • Potential for reduced seagrass due to accretion on fluvial and marine deltas and shoals • Reduced potential for connectivity with ocean

4.4 Council Response to Climate Change

In compliance with the ‘Precautionary Principle’, as espoused by the NSW Coastal Policy as well as other state legislation, management of the Eurobodalla coastal lakes over the next 50 to 100 years needs to accommodate the potential effects of climate change, despite the degree of uncertainty in many areas of climatic predictions. In particular, Objective 2.2 of the Coastal Policy requires the consideration of future climate change in the planning and management of coastal resources and development and promotes a ‘risk averse’ approach to decision making.

Development and implementation of the Entrance Management Policies, which incorporate a progressive increase in breakout trigger level, is considered an appropriate response by Council to climate change. These Policies would, of course, require periodic review, which would incorporate improvements in our understanding of climate processes, and adopt appropriate changes in our response to these.

5 CONSULTATION

Consultation was undertaken with a range of agencies, stakeholder and the general community during the development of the policies and this REF. Key outcomes from this consultation are detailed below. Please note that comments outlined below are provided as a record of consultation and do not necessarily reflect the opinion of the author of this report, nor are they necessarily supported by scientific data or fact.

5.1 Government Agencies

Government agencies consulted through this process include:

- Eurobodalla Shire Council
- NSW Fisheries (Department of Industry and Investment)
- Marine Parks Authority
- Department of Lands
- National Parks and Wildlife Service (Department of Environment, Climate Change and Water)
- Department of Environment, Climate Change and Water (Coasts and Estuaries)

Considerations raised during the consultation with the government agencies include:

Coila Lake

- Access of private property on Coila Creek, and Monash Avenue stormwater and key constraints for Coila Lake
- Have existing policy that included a Crown Lands licence for opening works, currently costs $400/yr
- Pro-fishers need to be notified of an entrance opening to remove nets

Tuross Lakes

- Sand flats in Tuross become exposed, with die-off of benthos and sand-rays
- Recent openings have included consultation with oyster farmers, boatshed operators, and local farmers
- Saturated banks in Tuross lead to potential for collapse
- Minor maintenance dredging has been required at the Tuross boatshed (annually, around Xmas time). There is not real opportunity for an alternative boatramp location in Tuross
- The last decent flush in Tuross was 91 and 92.
- Floodwaters get into sewage system at O'Briens boatshed when water levels are high.
- Floating foreshore structures are preferable to fixed structures, when reconstruction is required
- Foreshore permissive occupancies will eventually be transferred to licences when they come up for transfer (POs are individual based, whereas licences are property based).

Kianga Lake

- Lake drains over rocks, and not through entrance breakout – stems from issues dating back to construction of the ocean outfall
- Periodic opening of the entrance for bridge maintenance

Little Lake

- Little Lake is subject to unauthorised openings by the public
- Swimming occurs in the lake because it is close to the beach and surf club

Bullengella Lake

- Not much is known about Bullengella

Nangudga Lake

- Nangudga Lake has been opened by Council 3 times since 2004. Key constraint is Caravan Park and fringing septics
- RTA have concept plan for new bridge over Nangudga Lake, which incorporated State SLR policy.
- Illegal openings have occurred in the past

General

- New residents have a perception that open entrance means healthy waterways, but open means low water, which can cause odour problems.
- Will review Policies with each LEP review.
- Data collection associated with entrance openings is recommended
- Policies should be used to inform new development
- Openings should be about asset protection, and not trying to maximise fish or prawn populations
- Harming marine animals in Marine Park will require Consent from Minister (refer Section 7 of the regulations) – dredging entrance sands will harm something
- Openings should be avoided in summer if possible to minimise introduction of European Green Crabs into the lakes.
- Actions to specifically favour one species are likely to impact detrimentally on other species
- Future policy reviews should incorporate up-to-date research
- Tern nesting may be an issue under the TSC Act
- Aboriginal sites may be an issue if using heavy equipment on beaches
- The natural variability in ICOLLs is huge, so should try and leave alone if it can be tolerated.
- For smaller lagoons, breakouts can cause fish kills as systems almost completely dry out
- Need simple brochure to explain to public what is and isn't being managed

- Dept of Lands to issue licence for life of the Policy – licence can be renewed as Policy gets renewed
- Single licence can cover all entrances (as same cost)
- Dept of Lands have to consult with Fisheries before issuing licences.
- Potential for harming marine vegetation, including macroalgae, seagrass and mangroves.
- Require physical markers to help with community education

5.2 Other Stakeholders

Other stakeholder consulted during the process included:

- Tuross Coila Lake Estuary Management Committee
- Narooma Golf Course
- Bodalla LALC
- Wagonga LALC
- Cobowra LALC
- Beachcomber Caravan Park (Potato Point)
- Coila Service Station
- Wagonga Inlet Estuary Management Committee
- Island View Beach Resort
- O'Briens boatshed
- Laing's boatshed
- Tuross Beach Holiday Park
- Redbox Pizza
- Oyster farmers (Graham Campbell)

Considerations raised during the consultation with the other stakeholders include:

Coila Lake

- Coila Creek paddocks and access road is main concern
- Not sure what will happen if raise trigger above 1.85m – not yet tested by extended inundation of wetlands etc
- Coila service station use to be really low, but was filled (by about 6 feet) with roadworks over Coila Creek. Council use to open lake at low level to prevent inundation
- House attached to service station hasn't been flooded
- Significant cultural sites around the lake
- Many commercial fishers are Koori. The lake is used to provide fish for the communities
- The lake should be opened once per year for it to be healthy
- Coila prawns generate big dollars for the local economy
- If it is closed all the time, then it is no good for anyone

Tuross Lakes

- Aboriginal communities use to camp around the estuary and gather bush foods, especially in Summer.

- Some areas are used for ceremonies, only known to those who have been initiated
- Opportunities for indigenous work teams should be explored
- There is no concern for inundation of sites around foreshores, as these are flooded often
- Catchment is ‘dry’, so it will take a significant rainfall to ‘wet-up’ the catchment and get reasonable flows
- Inundation of farmland can be tolerated for a period of time, but if it is saltwater /brackish, then greater impacts on ground vegetation.
- Natural things are natural, so need to manage for infrastructure inundation only.
- Road at The Narrows was built-up in 76/77
- Rainfall in catchment provides a couple of days warning of increasing lake levels
- Pontoons (floating decking) should be new DA conditions for boatsheds
- Dolphins are a separate issue
- $10,000 per opening is Council cost
- For Feb 07 event, had about 24 – 48hr warning, so boatsheds were able to limit losses
- Overtopping of decks is OK, but not for extended periods of time – safety concern and loss of trade.
- Breakout didn’t create an entrance channel – only lowered water level. So why is lake left so high if there is no chance of a higher level creating a big entrance channel.
- 07 event was about same height as 91 and 92 flood levels, but 91 and 92 were during open entrance conditions
- 70 years ago the entrance was near Potato Point
- Use to be large trees along the entrance berm to Potato Point, but a gale knocked them flat
- Use to be 3 – 4 floods / yr, with massive logs washing down the river and entering the boatsheds
- Was common for dolphins to be in the lake in the past, as well as penguins (and a platypus once)
- 1971 flood was about 0.5m higher than the June 07 event
- Visitors / tourists have been whinging about the closed entrance – brochures of the area show a lovely open entrance. The open lake is a major drawcard for the area
- Concerns regarding extractions from river and its impact on entrance conditions
- People now walking to Potato Point for coffee, but doesn’t offset lost amenity of no open channel
- Care needs to be taken about inputs to lake as WQ is vulnerable
- Petrol bowsers during flood are a concern
- Water should be allowed to get as high as it can and then go out naturally
- Water quality is not an issue when the entrance is closed – still meets all standards

- Oyster farmers are raising racks as an adaptive measure to the permanent water levels. Can do this for 12 months or so, as it just keeps then alive. They take about 3 – 4 years to grow.
- Use to be 13 or 15 oyster farmers, now there is just 9.
- Last time floods got overbank was in 91 and 92.

Kianga Lake

- Needs flush out, as it stinks

Little Lake

- Hasn't been flushed out for a long time
- Takes 8 inches of solid rain to fill dams before they overflow to the lake
- Kids open the entrance, especially at Xmas
- Pumping station overflows to the lake, on average about once per year
- Not much fertiliser is used on the course, with washdown bays used etc
- Pumping station is first asset to be affected by high water levels
- During normal season, entrance would open a couple of times per year – lake then stays open for about 3-4 days, with tidal flows
- Prawning is done over summer and kids sometime fish in the lake
- Lake contains ruppia (blackfish weed)

Bullengella Lake

- Huge midden on Hanky Beach
- Old Kooris use to get fish from lake, but area is full of brown snakes

Nangudga Lake

- Lake is an asset for visitors, but can be a bit smelly when closed
- When lake is full, water backs up into drains of Holiday Park and floods lower lands (camping ground). If rainfall as well, the site won't drain.
- Has been opened every year for about the past 5 years. Opened naturally by itself once, but Council was all ready to open anyway.
- Wastewater in Caravan Park is connected to sewer, and thus is not an issue, with inspection outlets screwed down in paths
- Park has replaced open drain with a section of closed culvert to limit inundation and safety concerns
- Certain landuses in the catchment are providing more nutrients to the lake
- Surrounding lands contain middens, a burial site and a mythological site

General

- Unless private property is directly affected (eg at Nangudga), then should no nothing

- Other actions outside of the policies should be undertaken to help improve condition of lakes
- Black bream eggs are left high and dry following lake openings – should minimise water level reductions
- Try and avoid openings during black bream spawning period (October onwards)
- Should open at night to allow prawns to escape to the ocean (accommodate biological cycles better)
- Farmers stopping natural flows to the lakes, and creeks are disappearing
- Middens located on most headlands, up high
- Aboriginal site officers should on-site in case heavy machinery disturbs an unregistered site.

5.3 General Community and Landholders

A number of local landholders surrounding the lakes were consulted, while public drop-in sessions were held at Tuross Head and Narooma. A number of feedback forms were completed at the drop-in sessions, and are included in the points below.

Considerations raised during the consultation with the general community include:

<u>Coila Lake</u>

- The lake is 'dead' with no fish and no prawns for years
- Key impact is around Coila Lake foreshores – land at Coila Creek is about same ground level as Tuross Head foreshores
- Current lake level is low, but has been lower in the past
- Emerging navigation hazards with low water levels

<u>Tuross Lakes</u>

- Loss of tourism in the future if the entrance isn't opened
- Tourism dollars filter throughout the local economy
- Options for the entrance should include a commercial (on-going) dredging campaign, and permanent breakwaters
- Extraction impacts by Council, dairy farmers and other irrigators (eg turf farmers)
- Sedimentation in the river, and build-up of sand at the entrance due to catchment clearing
- Location of the entrance breakout is very sensitive
- Channel was opened in wrong location in 2007, as channel migrated to 'Everest' over a couple of days – that alignment should have been used first.
- Humans have altered the natural balance (eg water extraction), so we need to take counter measures to help nature
- We need to maintain a natural tidal entrance to maintain a natural environment

<u>Kianga Lake</u>

- Community generally looks after the lake
- Trigger is private property near the STP road
- Rock barrier at entrance has progressively been removed, which means entrance doesn't fill and breakout due to overtopping over the rocks
- Big floods are required to scour entrance rather than just progressive fill up.

Bullengella Lake

- Vegetables and an orchard were once planted where lake is now – king tide wiped out crops.
- Has fine sediments and smells of rotten egg gas when disturbed
- Used by swans and ducks, and a sea eagle colony is nearby
- Water level has ranged about 1.5m
- Entrance was last opened 44 years ago, but the berm was much lower then

Nangudga Lake

- Lake opens up about every 3 years
- Some conflict with the desire for prawning in the lake and the current MPA zoning, which prevents prawning.
- When lake level is low, macroalgae dies off and produces bad smells
- Swans like to eat the macroalgae when water levels are high
- Can have significant rainfall over short periods of time, which result in rapid WL rise
- Whole lake is very shallow, except for a couple of deeper holes where the pro fishers use to prawn
- Council has opened lake 5 times in last 20 years
- When there is lots of rain, water levels back up onto the paddock and surround sheds and water tanks
- Council has allowed development of low-lying land, so they need to resolve flooding issues
- Filling of low-lying land is an option
- Not many properties around Nangudga are affected
- Recent dry period (last 10 years) has resulted in significant growth of casuarinas around lake fringes
- Drainage from highway contributing to flooding issues
- Opening of entrance next to rocks will provide the greatest effectiveness, with entrance likely to stay open for some months

6 INTERACTIONS BETWEEN THE PROPOSAL AND THE ENVIRONMENT

As the entrance management works essentially involve the same actions across all coastal lakes, the types of impacts of the proposal are essentially consistent (albeit at differing scales). As such, the impacts are discussed generically in the following section, with site-specifics included as necessary.

With respect to Bullengella Lake, the lake entrance is not currently subject to artificial entrance modification, and the proposed Policy will continue this approach. Therefore, for Bullengella Lake, implementation of the Policy will have no net impact on the environment. Rather, the Policy will simply formalise an existing management regime of no intervention.

6.1 Hydrology

The Entrance Management Policies aim to restore more natural hydrologic regimes to the coastal lakes. In the short term, artificial breaching of entrances will be required to protect fringing assets and infrastructure from excessive and/or prolonged inundation, however, the Policies advocate that these 'constraints' be progressively addressed (through modification, removal, etc) to enable higher breakout triggers in the future. The increase in trigger levels is required to a) restore a more natural hydrological regime to the lake, b) reduce demands on Council resources, and c) help to accommodate and adapt to increase sea levels in the future.

6.1.1 Coila Lake

Implementation of the proposed revised version of the Coila Lake Entrance Management Policy will result in relatively minor changes to the hydrology of the lake. The Policy aims for immediate artificial intervention at a level of RL 2.0m AHD, rather than 1.85m in the current policy; or after a period of 3 months at a level > 1.80m AHD, rather than 1.65m in the current policy.

Given the predominantly dry conditions over the past 15 years or so, the last time Coila Lake was opened was in 2002. The current water level of Coila Lake is approximately 0.5m AHD, indicating that significant rainfall would be required in order to threaten foreshore assets and thus impose a need for artificial intervention.

In theory, increasing the current artificial entrance breakout level should have the following effects, albeit relatively minor given that the increase in trigger level is modest at present:

- A hydrologic regime that more resembles a 'natural' regime, being less truncated at the upper range of water levels;
- Longer periods of time between entrance openings, and thus less frequent need for artificial breakout, due to the larger storage capacity held by the lake;
- Increased duration of open entrance conditions, given the larger hydraulic head, which potentially can scour a larger entrance channel.

In the long term, the Entrance Management Policy advocates a progressive increase in entrance intervention level. Further increases in breakout trigger level, beyond RL 2.0m AHD as proposed, would essentially increase the relativity of the above effects.

6.1.2 Tuross Lakes

Unlike the previous century, management of Tuross Lakes now needs to consider the consequences of a closed entrance. Opportunistic development has occurred around the lake fringes taking into account the lake hydrology at the time of the development. With a closed entrance, the lake hydrology is significantly different than under an open entrance.

As the entrance has only recently moved to a more closed condition, the wider environment of Tuross Lakes is still in the early stage of a 'response'. This response would be expected to include a transition to habitats and community structures that more resemble closed coastal lakes, such as Coila Lake. This may include, for example, a reduction of mangroves and macrophytes (seagrass), as these communities may find the highly variable water levels difficult to accommodate (mangroves may be 'drowned' under prolonged high water, while variable photic zones may cause die-back of seagrass).

The proposed action of artificially opening the lake entrance when water levels reach specific triggers (including ultimate level, or extended inundation duration) would essentially limit the magnitude of change in the environment that will inevitably occur if a 'do nothing' approach was adopted. That is, if the entrance was to be left to natural openings only, the lake would be more exposed to extreme variations in water level, prolonged periods of higher water level, and reduced opportunities for tidal exchange. On the other hand, a greater build-up of water behind a closed entrance is likely to result in a more substantial entrance channel once breakout occurs (and thus greater longevity of tidal conditions following breakout), however, it is considered that the duration of flooding from the catchment plays an equally important role in the transport of sediment from the entrance compartment, leading to more open entrance conditions.

The Entrance Management Policy requires that the existing constraints that impose a requirement for opening the entrance be addressed in the future, thus reducing the level of intervention necessary. If the current drier conditions continue over the next few decades, then it can be expected that the hydrology of Tuross Lakes will change naturally from a mostly open coastal lake to a mostly closed coastal lake.

6.1.3 Kianga Lake

There has been relatively little demand for artificially opening Kianga Lake in the past. Water levels have tended to breach the entrance berm before causing inundation of surrounding assets, or have drained slowly across the rock shelf on the southern headland of the entrance.

The works for Kianga Lake include 'plugging' the crevices that allow for the slow drainage of the lake, in an attempt to ensure the lake builds up to a level that breaches the entrance berm, and thus induces a substantial entrance that is capable of flushing out the lake (to a low level) before replacing, to a lesser degree, with marine waters. The slow drainage behaviour across the southern rock shelf is the result of previous human intervention (a consequence of the construction of the Kianga outfall). Therefore, preventing this process is considered a return to a more natural hydrological regime, which will likely include more frequent entrance breakout events (either naturally or artificially). More frequent breakouts will lead to overall lower entrance berm levels (as coastal processes take time to build up the berm, and maximum levels may not be reached before water levels again reach threshold levels).

Overall, the lake will be expected to experience a greater range of water levels, particularly at the upper range, as the maximum level will be determined by the height of the sand berm (rather than the level of the crevices through the rock shelf). Also, the lake is expected to experience more frequent 'dry-out' events following the more frequent entrance breakouts.

6.1.4 Little Lake

The Entrance Management Policy for Little Lake aims to formalise some existing informal procedures for opening the entrance, and also to discourage unauthorised openings.

The key trigger for opening of the entrance is inundation of the golf course (although inundation into the sewer pumping station building will occur first, but will not affect pumping operations).

It is expected that the initial trigger level for opening the Little Lake entrance is indeed near the upper range of natural breakouts. Thus, artificial opening would only be required when berm levels have reached particularly high levels, otherwise natural breakouts could be expected.

The artificial opening of Little Lake would be undertaken well within the natural breakout range for the entrance. Substantial changes to the overall hydrology of the lake as a consequence of the Entrance Management Policy are highly unlikely.

6.1.5 Bullengella Lake

As outlined above, no changes to the hydrological behaviour of Bullengella Lake are proposed as a consequence of implementing the Entrance Management Policy.

6.1.6 Nangudga Lake

The Policy for Nangudga Lake aims to address the current constraints on water levels, whilst establishing a framework for progressively removing these constraints to allow for higher levels in the future. The previous breakout trigger will be adopted as a starting point, whilst works will be encouraged within the Island View Beach Resort to help limit impacts of backwater inundation.

As the entrance to Nangudga Lake is very sheltered, it's natural berm height is not expected to be particularly high. During periods of normal or wet conditions, breakouts would occur relatively often, which would further help to keep berm levels low. During the current dry period, however, assisted breakouts have been required.

The Policy should have no immediate impacts on hydrology as it should not differ significantly from existing conditions and behaviour. Over the long term, however, with higher trigger levels, the entrance should achieve natural breakout more often, returning the hydrology to a more natural regime.

6.2 Water quality

Water quality of intermittently open and closed coastal lakes is highly variable. Water quality is dependent on many factors, including catchment inputs, tidal flushing, and internal assimilative capacities. Water quality tends to be poorer following catchment runoff, especially in systems that have a relatively small waterway compared to the size of the catchment. For larger systems, there is generally more opportunity for internal processing of inputs such as nutrients.

The relatively minor changes to hydrology as discussed above are unlikely to cause significant impacts on the water quality of the coastal lakes.

For Tuross Lakes specifically, under more closed entrance conditions, the water quality will change naturally. This will include, for example, greater variation in salinity (as freshwater inputs will be responsible for causing higher water levels), pH and turbidity. There may also be greater internal processing of catchment nutrients, which may reduce dissolved oxygen levels near the bed.

The artificial opening of Tuross Lakes will tend to limit the range of variability in many water quality parameters, as more frequent openings (even if they don't last very long), can have the effect of 'resetting' the estuarine water quality back to a more marine-influenced condition.

For Kianga Lake specifically, inducing a larger number of entrance breakouts will have the overall effect of increased "flushing-out" of the system. Thus, there will be less opportunity for inputs to accumulate and reprocess within the lake, with more frequent 'purges'. A larger number of 'drying-out' events, however, would cause additional desiccation of macroalgae and macrophytes, which may impart additional oxygen demand on the lake waters.

6.3 Sediments

6.3.1 Acid sulfate soils

No new acid sulfate soils will be exposed as a consequence of the Entrance Management Policies. The proposed excavation works would be confined to the entrance berms of the coastal lakes (excluding Bullengella Lake, as no works are proposed at this lake), which comprise unconsolidated marine sands. These sands are recent deposits and would contain no acid-generating potential.

6.3.2 Bank erosion and sedimentation

There is an increased potential for bank collapse when banks have been inundated for long periods of time (ie the groundwater levels within the banks have adjusted), followed by rapid draw-down. The drainage of groundwater through the bank face increases opportunity for dislodging small or large sods of bank material.

The Entrance Management Policies advocate higher lake water levels, or extended periods of time, before artificial breakouts are induced. In theory, this will increase the potential for bank destabilisation following drawdown. As the change in hydrology is in essence a return to the more natural hydrological regime, it is considered that the potential for bank collapse would be relatively small.

The only exception to this would be Tuross Lakes, which have not been exposed to extensive and prolonged inundation in recent times. The proposed Entrance Management Policy would in fact help to minimise the potential for bank collapse compared to the do nothing scenario, by limiting the maximum height of inundation, and limiting the duration of extended periods of lesser inundation.

6.4 Ecology

The ecological values of the six coastal lakes are likely to be impacted by entrance management actions, with increased water levels, increased water level variability and increased frequency of 'drying-out events' the predominant factors to potentially influence the ecology. Potential ecological impacts of implementation of the Entrance Management Policies are described below, highlighting the relevance of particular impacts to individual lakes where appropriate.

As the Entrance Management Policies aim to restore more natural hydrological regimes to the lakes, the ecological values of the lakes are expected to display an adaptive response as communities revert to those that would have characterised the areas prior to artificial entrance modification. For some lakes, impacts are expected to be negligible as no major hydrological changes are proposed, while noticeable shifts in community composition, structure and/or extent may be observed for other lakes. However, it is noted that the Policies have been developed so as to minimise impacts on ecological processes.

6.4.1 Fringing Wetland Vegetation

The Entrance Management Policies promote higher lake water levels (constrained by inundation impacts), or extended periods of time, before artificial breakouts are induced. As such, fringing wetland vegetation communities are expected to gradually migrate in alignment with the increased water levels. Furthermore, dieback would be expected for terrestrial vegetation that has grown opportunistically due to continuous opening at lower water levels (e.g. Swamp Oak), as these species are typically not able to withstand prolonged inundation under higher lake water levels. However, the majority of the Swamp Oak community on the Coila Creek delta has been observed to survive 10 months of inundation (ESC 2001b).

For lakes under more closed entrance conditions, responses of wetland vegetation communities are expected to include (1) a reduction in the extent of mangroves as mangroves will not be able to withstand prolonged inundation; and (2) an expansion of saltmarsh communities as saltmarsh species are more suited to the re-established hydrological conditions. These impacts are of relevance to Tuross Lakes, noting that the present communities are likely already in a stage of transition as the entrance has recently moved to a more closed condition.

Reductions in the extent of mangroves at Tuross Lakes may in turn impact fauna communities (for example, reduced roosting sites for waterbirds and reduced habitat and food for crustaceans).

6.4.2 Aquatic Vegetation

For lakes under more closed entrance conditions, such as Tuross Lakes, dieback of seagrass communities may occur due to changes in the portion of photic zones as well as the highly variable water levels.

An increased number of 'drying-out' events for a particular lake would likely lead to dieback of seagrass meadows and other macrophyte communities due to desiccation. This is of relevance to Kianga Lake, as the lake is expected to experience more frequent 'drying-out' events following the more frequent entrance breakouts.

Furthermore, a change in composition of seagrass communities may be observed. For example, where increased lake entrance opening is proposed, a gradual replacement of *Ruppia* (which inhabits brackish waters) may be observed in favour of *Zostera* (which inhabits more saline conditions).

In turn, changes in aquatic vegetation may impact on fauna species that rely on these communities. For example, reductions in the extent of macrophytes in Kianga Lake may have an adverse impact on avifauna (e.g. Black Swans) that are reliant on macrophytes as food source.

6.4.3 Threatened Species

Works involved with artificial breaching of entrances will be required to consider disturbance of Threatened species. This is of critical importance with respect to taking into account the breeding season for avifauna that use the entrance, such as the Threatened shorebird nesting sites at the southern end of the Tuross estuary mouth and the nesting sites on the sandy entrance barrier of Coila Lake.

With respect to the Threatened plant species at Coila Lake (*Wilsonia rotundifolia*), higher lake water levels or extended periods of inundation are not expected to have adverse impacts as this species has previously been observed to resprout prolifically following a ten month period of inundation in 1999 (Spurway et al., 2000).

A detailed assessment of potential impacts on Threatened species is provided in Appendix C in the form of eight part tests. Under the *Environmental Planning and Assessment Act 1979*, an Eight Part Test is required to determine "whether there is likely to be a significant effect on threatened species, populations or ecological communities, or their habitats" listed on Schedules 1 or 2 of the *Threatened Species Conservation Act 1995*, and consequently, whether a Species Impact Statement is required.

6.4.4 Endangered Ecological Communities

As described above, the saltmarsh communities surrounding Coila Lake, Little Lake and Nangudga Lake are expected to gradually migrate in response to higher water levels, and saltmarsh communities surrounding Tuross Lakes may expand. Consequently, the area of this Endangered Ecological Community is not expected to substantially decline following implementation of the Entrance Management Policies, but is rather expected to remain approximately the same as current or possibly increase.

The Swamp Oak communities surrounding Coila Lake, Tuross Lakes, Kianga Lake, Little Lake and Nangudga Lake that are an Endangered Ecological Community may experience net loss due to the higher water levels, as these communities are typically not able to withstand long periods of inundation. However, as described above, the Coila Creek Swamp Oak community has previously survived inundation for 10 months (ESC 2001b), such that a situation of no adverse impacts may be possible.

The terrestrial Endangered Ecological Communities (i.e. Bega Dry Grass Forest and Bangalay Sand Forest) are not expected to experience any loss or other adverse impact, due to their terrestrial position within the landscape such that inundation is highly unlikely.

Further assessment of potential impacts to Endangered Ecological Communities is provided in Appendix C in the form of eight part tests.

6.4.5 Invasive Species

6.4.5.1 Caleurpa

Impacts of altered hydrological behaviour on *Caleurpa taxifolia* are expected to be similar to those outlined above for seagrass and other macrophytes, i.e. dieback due to changes in photic zones, highly variable water levels and/or increased frequency of drying-events. However, it is difficult to predict the fate of invasive species to changed conditions, as it is possible that invasive species display a higher degree of plasticity than native species.

Research undertaken by West has shown *C. taxifolia* to be less tolerant of cooler and lower saline conditions (West & West, 2007). Higher breakout levels will typically result in greater dilution, and thus fresher conditions within the lake, prior to breakout, which would tend to be less favourable for *C. taxifolia*. Studies from Lake Conjola indicated that Lake conditions prior to artificial breakouts were cooler and less saline, thus inhibiting *C. taxifolia* growth. The study concluded that entrance management practices may be one factor influencing the success of the species in the lake (West & West, 2007). For Kianga Lake, however, a more frequent breakout regime and greater opportunity for ingress of saline waters would typically make this lake less favourable to *C. taxifolia* encroachment.

6.4.5.2 European Green Crab

As described previously, the European Green Crab favours habitats including shallow areas of bays, estuaries, and coastal lakes. Consequently, Nangudga Lake is likely to remain favourable habitat for this species such that its presence is likely to persist (unless control strategies are put into action). Should this species invade the other lakes, this will not be a direct consequence of implementation of the Entrance Management Policies, but rather natural spread of this species that would likely occur over time as coastal lakes provide a suitable habitat regardless of entrance management.

It is important to recognise that manipulating an entrance to favour (or in this case to disfavour) one particular species may have undesirable consequences on a wide range of other species that also utilise the lake habitats and surrounding environments.

6.5 Social environment

6.5.1 Low-lying infrastructure

The primary objective of Entrance Management Policies is to protect foreshore assets and infrastructure from excessive inundation. These private and public assets and infrastructure are relied upon by the local communities for recreation, access and commerce. Implementation of the Entrance Management Policies is expected to improve the social environment of the lakes by providing some assurance of Council’s role in intervention.

It is not the purpose of the Entrance Management Policies to modify environmental conditions for maximum social or economic gain. Rather, consideration has been given to existing constraints as a means of establishing short-term triggers, however, onus is place on the asset / infrastructure owner in the longer term to modify the asset / infrastructure in order to demand less intervention by Council, and accommodate potential changes manifesting from climate change, including sea level rise.

Ultimately, some areas around the fringes of the coastal lakes may become unsustainable for existing landuses given expected climate change conditions (eg low-lying boatsheds in Tuross, or residential development beside Kianga Lake). In these cases, Council will be required to modify planning instruments accordingly.

6.5.2 Social disruption

The artificial opening of the coastal lakes entrance will involve transportation of earthmoving equipment to the lake entrances. This will have some impact on noise and traffic. Given the infrequent nature of the openings, however, these impacts are expected to be minimal. The perceived benefits of entrance manipulation maintained by the local community would potentially off-set this minor inconvenience.

6.5.3 Safety issues

As has been experienced previously, the excavation of a pilot channel in a coastal lake entrance can attract significant attention with the local community. Safety of the public will need to be addressed by Council to minimise potential for injury and accidents. Specifically:

- Operation of heavy equipment on public land;
- Loading and unloading of equipment on public roads;
- The dangerous and rapidly changing conditions induced following a breakout event, both within the entrance channel and also along the adjacent beach;
- Potential for poor quality water to be discharged onto adjacent beaches.

It is envisaged that signage, staffing for crowd control, and an education program will be necessary to help minimise the potential for accidents arising.

6.6 Cultural environment

The change in hydrology to the coastal lakes is not envisaged to have any detrimental effects on the condition of known site of significance around the lakes, as the change essentially represents a move towards a more natural hydrological regime (which would have typified conditions over the past 6000 years or so).

The proposed excavations will occur within the highly dynamic entrance berm, at locations of previous entrance channels and breakouts. It is highly unlikely that these works would directly or indirectly expose any previous documented or undocumented Aboriginal sites.

Potential impacts may arise, however, where heavy equipment is mobilised across dunes and headlands to access the entrance channels. It is recommended that Aboriginal Site Officers be on-site during the mobilisation of equipment across areas that are considered potentially sensitive. These areas and any proposed access should be discussed individually with representatives of Local Aboriginal Lands Councils.

7 JUSTIFICATION AND ALTERNATIVE OPTIONS

7.1 Do Nothing – No intervention

This option would involve no artificial opening of the coastal lake entrances. Breakouts would occur naturally, and only when water levels within the lakes overtop the height of the entrance sand berm. The consequences of this option would be an increased potential for flooding and inundation of low-lying private and public assets around the foreshores of the lakes.

Low-lying assets have generally been established based on a historic hydrologic regime. Most likely, this historic hydrologic regime incorporated more pro-active management of the entrance berms, although not necessary in a formal sense. Prior to the 1993 version of the Local Government Act, Councils were required to manage the entrances of coastal lakes in order to limit flooding and inundation.

Whilst this scenario would be most ideal from an environmental perspective, as it returns the systems to a natural hydrologic configuration, it would cause significant hardship on private property owners, and may cause significant on-costs for Council, through repairs to public works, such as roads, sewerage systems, etc.

Given the scale of low-lying development, this option is not seen as viable in the short-term, but should be pursued in the longer term through progressive modification and/or relocation of assets and infrastructure.

7.2 Continue Existing Opening Regime

Only Coila Lake has a current formal entrance management policy. Artificial openings of Tuross, Kianga, Little and Nangudga Lakes have followed a largely informal process, the legality of which is questionable. Bullengella Lake has not been subject to artificial opening in the past. It is expected that entrance management works carried out to date have impacted on the natural environment by not allowing lake water levels to reach their natural highest levels. This is expected to have impacted on fringing wetland communities as well as other environmental processes.

The proposed entrance management policies aim to minimise impacts on existing low-lying infrastructure, whilst setting a framework for progressively reducing the need to undertake entrance management works. Continuing with existing formal and informal procedures will address the low-lying infrastructure, but will not enable a return of the environment to a more natural condition. The lack of consideration of the environment and for future climate change under the existing opening regimes (with the exception of Coila Lake), makes this option not viable, especially in the longer term.

7.3 Permanent Entrance Openings

Several estuaries along the NSW coast have been opened permanently through the construction of training walls that extend into the ocean. The closest and most obvious example of this is Wagonga Inlet. Construction of permanent entrances to the coastal lakes would provide some immediate benefit to the low-lying assets and infrastructure, as catchment runoff would be discharged directly to the ocean without significant storage within the lake.

Creating permanent entrances would have profound impacts on the environments of the coastal lakes, with the systems becoming more marinised, and estuarine vegetation along the foreshores retracting to a narrow band surrounding the inter-tidal zone. Permanent entrance would not, however, address the future issue of sea level rise, as lake levels would rise contemporaneously with ocean levels (thus threatening and potentially inundating low-lying assets, especially during king tides or storm surges).

Cost alone would be a significant inhibitor for this option, with permanent entrances likely to cost in the millions of dollars for each lake. The high costs and significant environmental impacts, combined with long term sea level rise consequences, makes this option unviable.

7.4 Higher Trigger Levels

Higher trigger levels are indeed proposed as part of the entrance management policies, but these are to be introduced progressively, and in response to modifications or removal of the low-lying assets and infrastructure. Adopting higher trigger levels at the outset of the policies would result in inundation of the assets and infrastructure when lake levels are high. This is counter-productive to the overall intent of the policies, and as such is not considered a viable alternative.

7.5 Lower Trigger Levels

The trigger levels adopted within the entrance management policies have been selected on the basis of balancing the needs of the community (ie through reduced inundation of assets and infrastructure) with the needs of the environment (ie trying to re-establish more natural conditions within the lakes). Adopting lower trigger levels, whilst likely to be acceptable from a social perspective, would likely have a greater environmental impact – or more correctly, would not enable as substantial environmental improvement over the existing management regime, as it would only achieve an opening for a short period of time before the entrance re-closes.

7.6 Justification for Implementation of Policies

The entrance management policies proposed by Council are considered to address the immediate demands imposed by existing low-lying assets and infrastructure, whilst establishing a framework for reducing the need for such works in the future. The increasing trigger levels advocated by the policies aims to a) restore a more natural hydrological regime to the lake, b) reduce demands on Council resources, and c) help to accommodate climate change and adapt to increase sea levels in the future (refer Section 4).

The works to be undertaken as directed by these policies are considered temporary, as the highly dynamic nature of the coastal lake entrances will rebuild entrance berms in response to coastal and catchment runoff conditions. As such, the policies can be terminated at any time without repercussion of permanent or irreversible environmental change.

8 SUMMARY OF MITIGATION MEASURES AND ENVIRONMENTAL SAFEGUARDS

Outlined in Table 8-1 is a summary of the environmental safeguards and other mitigative measures that are recommended as part of the Entrance Management Policies in order to minimise detrimental impacts on the lake environments and wider community.

Table 8-1 Recommended environmental safeguards

Environmental Issue	Mitigative measure
Loss of benthos due to rapid drawdown	Where possible, open entrance in late afternoon to allow prawns to escape to sea
Recruitment of European Green Crab into lakes	Where possible, avoid opening entrances during the summer months, when the crabs are mobile.
Public safety during opening	Public awareness of risks through appropriate temporary and permanent signage and education
Damage to unregistered Aboriginal site	On-site Aboriginal site officer if machinery is to operate beyond already disturbed tracks and paths.
Disruption to migratory shorebirds	Ensure that the entrance area is regularly monitored during the spring, summer and early autumn to detect breeding activity. If breeding activity is taking place, and an artificial opening is planned, Council will notify the National Parks and Wildlife Service to determine appropriate responses

8.1 Environmental Monitoring

The opportunity exists to undertake monitoring associated with the Entrance Management Policies so that more informed decisions can be made in the future. A number of key conditions should be monitored as part of the Entrance Management Policies, as outlined in Table 8-2.

Table 8-2 Recommended environmental monitoring

Parameter	Details
Berm condition	Berm height and width prior to breakout, both by survey and photo record
Water level	Water level prior to breakout, as well as survey of inundation extents around foreshore (noting impacts on assets and infrastructure)
Water quality	Opportunistic water quality monitoring when lakes are closed and prior to breakout and afterwards

Rainfall	Catchment rainfall prior to breakout, and water level prior to onset of rainfall in order to estimate volumetric runoff
Entrance closure	Date of closure to determine length of opening following breakout

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APPENDIX A: PROPOSED ENTRANCE MANAGEMENT POLICIES

COILA LAKE

ENTRANCE MANAGEMENT POLICY

EUROBODALLA SHIRE COUNCIL

Good Government, better living

COILA LAKE ENTRANCE MANAGEMENT POLICY

1 Policy Name

This policy will be referred to as the *Coila Lake Entrance Management Policy*.

2 Objectives

This Policy will provide a framework that allows Council to pro-actively manage openings of Coila Lake. This Policy aims to:

- Minimise interference with natural entrance opening processes and minimise associated impacts on ecological processes;
- Accommodate future climate change, and sea level rise in particular;
- Minimise risks to public safety associated with excessive inundation of foreshores and associated infrastructure;
- Minimise risks to public health associated with excessive bacterial contamination of waters;
- Conserve or enhance the biological diversity and floral and fauna communities of the estuarine lakes systems;
- Facilitate the construction and/or maintenance of essential community infrastructure;
- determine procedures to be initiated for entrance operations including entrance breakouts;
- determine key responsibilities for management of the entrance; and
- detail the procedure for monitoring of lake entrances.

3 Land to which this Policy applies

This Policy applies to lands located at the ocean entrance of Coila Lake, generally north of Tuross Boulevard, Tuross Head for a distance of about 300 metres.

4 Sea Level Rise Planning Benchmark

Eurobodalla Shire Council has applied the Sea Level Rise planning benchmark determined by the *Sea Level Rise Policy Statement* adopted by the NSW Government in October 2009, of:

- 40cm rise by 2050; and
- 90cm rise by 2100.

This policy is consistent with the most credible information currently available for regional and global sea level rise projections for the two planning periods. This policy is precautionary in considering the uncertainty associated with sea level rise projections and future greenhouse gas emissions.

5 Application of this Policy

Implementing this Policy will ensure that Council:

- Facilitates the vertical natural migration of riparian and estuarine ecological communities in response to sea level rise;
- Limits opportunities for ingress of introduced and invasive species to the estuary;
- Minimises impacts on local fisheries resources and other ecological species, where possible; and
- Enables continued existing use of fringing riparian lands for as long as practical.

The Policy has regard to the existing Tuross / Coila Estuary Management Plan. The Policy also broadly complies with various State Government initiatives for environmental management of coastal lakes, and will be applied with full consideration of the following Federal and State legislation and Policies:

- *Cmwlth Environmental Protection and Biodiversity Conservation Act 1999;*
- *NSW Environmental Planning & Assessment Act 1979;*
- *NSW Local Government Act 1993;*
- *NSW Coastal Protection Act 1979;*
- *NSW Fisheries Management Act 1994;*
- *NSW Crown Lands Act 1989;*
- *NSW Threatened Species Conservation Act 1995;*
- *NSW Marine Parks Act 1997 and Regulations 2009;*
- *State Environmental Planning Policy 71 – Coastal Protection;*
- *State Environmental Planning Policy (Infrastructure) 2007*
- *NSW Coastal Policy 1997;*
- *NSW Flood Prone Land Policy;*
- *NSW Draft Sea Level Rise Policy;*
- *NSW Government's Floodplain Development Manual;*
- *NSW Government's Estuary Management Manual; and*
- *NSW Government's Coastline Management Manual.*

6. Principles

The Coila Lake Entrance Management Policy will be conducted according to the general principles and philosophy set out below.

Open entrance when trigger levels are reached

⇓

Undertake works to enable an increase in trigger levels (to restore a more natural opening regime)

⇓

Revised trigger levels for action based on additional works completed (timeframe: 5 – 10 years)

⇓

Incorporate provisions for increasing triggers at a rate commensurate with sea level rise when undertake works and infrastructure in future

⇓

Establish long term targets for entrance management trigger levels (incorporating sea level rise to 2100)

6.1 Monitoring

Water levels in Coila Lake are monitored on a continuous basis by Manly Hydraulics Laboratory on behalf of the Department of Environment, Climate Change and Water (DECCW), refer:

http://www.mhl.nsw.gov.au/htbin/map_data_display.com?SITE=COIL

Visual gauges are also established at:

- Southern shoreline approximately 100m west of sewage pumping station adjacent to lake entrance

6.2 Entrance breakout

The following conditions are required to initiate an opening of the entrance channel:

- Water levels > RL 2.0m AHD; or
- Water levels > RL 1.80m AHD for more than 3 months

The following procedures should be followed when initiating an entrance opening:

- Relevant authorities shall be informed of the intent to artificially open the entrance (refer Section 9. Contacts list);

- The location of the entrance opening works should be as per shown in Figure C-1;
- The works shall involve the excavation of a pilot channel, approximately 10 metres wide and 2 metres deep, with excavation starting from the ocean end and finishing at the lake edge;
- Final opening of the channel should be timed to coincide with the initial falling stages of the tide to ensure that a good head difference is maintained in the first few hours of opening;
- Outflow from the lake onto the beach may pose a public risk. Council should close the beach in the immediate vicinity of the entrance channel for a period of at least 48 hours, or until significant outflow velocities have abated and lake waters have dissipated across the surf zone.

6.3 Revising breakout levels and works required to achieve levels

This Policy requires the breakout levels to be progressively increased in the future to facilitate adaptation to future climate change (especially sea level rise), and to reduce the on-going need for artificial entrance intervention. Revised breakout levels and the works necessary to achieve these levels are presented in Table 2.

Table 2 –Revised trigger levels and associated works necessary to achieve levels

Revised trigger level	Existing level of constraint	Works to be undertaken	Indicative timeframe
RL 2.6m AHD (or > 2.5m for more than 3 months)	2.0m AHD – private road north of Coila Creek	Establish an alternative temporary access to property north of Coila Creek during times of high lake water level Adjust local stormwater system as necessary (eg backwater flaps)	5 – 10 years
RL 3.0m AHD	2.0m – 3.0m AHD	Provide incentives to rural landowners to accommodate higher lake water levels	10 – 30 years
	2.0m AHD – base of road batter on Princes Highway immediately north of Coila Ck (Coila Ck bridge = 3.5m AHD)	Progressive and opportunistic raising of low lying roads, including Princes Highway at Coila Creek (ideally to > RL 3.0m AHD).	10 – 50 years
	< 1.6m AHD for up to 10 manholes (combined with Tuross Lakes) 2.0m AHD – impacts on local stormwater system in Monash Av	Progressive and opportunistic raising or removal of assets around lake fringes (eg sewer manholes and stormwater system)	10 – 50 years
	2.6m AHD	Opportunistic filling of private non-rural property upon future development (for land < RL 3.0mAHD), except where adjacent to SEPP-14 wetlands, and providing no impact on flood behavior, vegetation, etc	10 – 100 years
> RL 3.0m AHD	3.0m AHD – Coila Service Station	Progressive raising of minimum floor levels for fringing development (eg Coila service station) through changes to planning instruments. Minimum floor level should be 1% AEP flood level + 0.5 metres, assuming entrance breakout at RL 3.2m AHD.	10 – 100 years

6.4 Long term (2100) target for breakout trigger level

This Policy advocates a minimal entrance intervention in the long term, with preference for allowing natural lake breakout wherever possible. A level of between RL 3.0m and 3.3m AHD is considered a target breakout level for the year 2100, with all necessary works to be completed by such time to achieve this target level.

6.5 Review period

This Policy is to be reviewed and revised as necessary every 5 years.

7. Informing the public

Signage is to be maintained regarding the illegal nature of unauthorised opening of the lake. Council has the authority to penalise persons opening the lake without appropriate authorisation under Section 623(1) of the Local Government Act 1993.

Temporary signage should also be erected during a breakout event (natural or artificial) to advise the public of inherent risks and safety issues with associated strong outflowing currents while the lake drains to normal levels.

8. Responsibility

Primary responsibility for implementing this Policy is with Eurobodalla Shire Council, Director of Roads and Recreation.

Alternative responsibility within Eurobodalla Shire Council is the Senior Maintenance Engineer in the event the primary responsibility officer in unavailable.

9. Contacts

All key contacts will be advised of any intention to open the lake prior to undertaking works.

Key contacts regarding implementation of this Policy are:

Eurobodalla Shire Council:	Name: Director Roads & Recreation Phone number: 4474 1000 Mobile phone: 0409 398 358 Email:
Department of Environment, Climate Change and Water (National Parks Unit):	Name: Area Manager, Northern Area Phone number: 4476 0800 After Hours Incident Answering Service : 1800 629 104
Department of Environment, Climate Change and Water – Coast & Estuary Branch	Name: Senior Natural Resource Officer - Coast and Estuaries Phone number: 4224 9630 Mobile phone: 0402 127 205

	Email: Daniel.Wiecek@environment.nsw.gov.au
Department of Industry and Investment (Fisheries):	Name: Fisheries Conservation Manager Phone number: 4478 9103 Mobile phone: 0408 487 083 Email: trevor.daly@industry.nsw.gov.au
Batemans Marine Park:	Name: Manager Phone number: 4476 0800 Mobile phone: Email: batemans@mpa.nsw.gov.au
Eurobodalla Shire Council:	Name: Director Roads & Recreation Phone number: 4474 1000 Mobile phone: 0409 398 358 Email:

10. Authorisation

This Policy was adopted by Council on ....

This Policy commenced on ....

This Policy is due for review on ....

11. Amendments

This Policy was last amended on ....

12. Related Council Policies

a) ESC Interim Sea Level Rise Policy

13. Relevant Legislation

13.1 State Environmental Planning Policy (SEPP) Infrastructure 2007

Development consent for undertaking these works, as set out in the Policy, is exempt from development consent under the Eurobodalla LEP (and thus assessment under Part 4 of the EP&A Act), as the works fall within the scope of State Environmental Planning Policy (SEPP) Infrastructure 2007. Relevant approvals still need to be obtained from relevant authorities (see below), and an assessment under Part 5 of the Act is required (including preparation of a Review of Environmental Factors).

13.2 Local Government Act 1993

Under the Local Government Act 1919, Councils had general authority to open coastal lakes and lagoons under Section 352A. Although this provision was not specifically carried through in the Local Government Act 1993, Councils have continued to assumed such responsibility on behalf of the interests of the public.

Under the Local Government Act 1993, Council has the authority to enforce penalties on anyone acting contrary to a notice erected on public land or in a bathing place under Section 632(1).

13.3 Crown Lands Act 1989

The bed of Coila Lake, including the entrance channel, is Crown land. The area in the vicinity of the entrance, however, is part of under the delegated care and control of Council, being part of Council Reserve 975. Specific landowner consent from the Department of Lands is therefore not required if works are to be carried out by Council. Nonetheless, a Crown lands licence is to be obtained for undertaking similar works at other coastal lake entrances where care and control has not been delegated to Council, and as such, inclusion of Coila Lake entrance within this licencing may be prudent.

13.4 Fisheries Management Act 1994

Within the Fisheries Management Act 1994, reference should be made to Sections 200 and 201, regarding a dredging licence (or the need for Department of Lands to consult with Fisheries in providing a Crown Lands licence), as well as Section 205 in respect to harming of marine vegetation.

13.5 Threatened Species Conservation 1995; and Commonwealth Environmental Protection and Biodiversity Conservation (EPBC) Act 1999

Consideration needs to be given to potential harm or damage to threatened species and listed migratory species, including Little Tern, which are found in the vicinity of Coila/Tuross Lakes. Transportation of heavy equipment onto the entrance will also need to consider potential damage to known Aboriginal sites.

13.6 Marine Park Act 1997

Coila Lake is located within the Batemans Marine Park, zoned General Use, with the exception of areas surrounding the Coila Creek wetlands, which have a Sanctuary Zone. Consent is required from the Minister under the provisions outlined in the Marine Parks Regulations 2009, to open the entrance (on the basis that the works will potentially harm marine animals, including beach invertebrates through the actually physical excavation works).

13.7 Coastal Protection Act 1979

Consideration needs to be given to Sections 38 and 39 of the Act, requiring concurrence by the Minister for undertaking development works within the coastal zone. The proposed entrance works at Coila Lake is within the coastal zone as defined by the Act.

13.8 State Environmental Planning Policy 71 – Coastal Protection

Development proposed within “sensitive coastal locations” needs to be referred to the Minister for comment. Schedule 1 of SEPP-71 specifically lists Coila Lake as a sensitive coastal location, along with most other coastal lakes in NSW.

Title:
Location of Coila Lake Entrance Opening Works

Figure: C-1

Rev: A

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

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0 125 250m

Approx. Scale

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TUROSS LAKES

ENTRANCE MANAGEMENT POLICY

EUROBODALLA SHIRE COUNCIL

Good Government, better living

TUROSS LAKES ENTRANCE MANAGEMENT POLICY

1 Policy Name

This policy will be referred to as the *Tuross Lakes Entrance Management Policy*.

2 Objectives

This Policy will provide a framework that allows Council to pro-actively manage openings of the Tuross Lakes system. This Policy aims to:

- Minimise interference with natural entrance opening processes and minimise associated impacts on ecological processes;
- Accommodate future climate change, and sea level rise in particular;
- Minimise risks to public safety associated with excessive inundation of foreshores and associated infrastructure;
- Minimise risks to public health associated with excessive bacterial contamination of waters;
- Conserve or enhance the biological diversity and floral and fauna communities of the estuarine lakes systems;
- Facilitate the construction and/or maintenance of essential community infrastructure;
- determine procedures to be initiated for entrance operations including entrance breakouts;
- determine key responsibilities for management of the entrance; and
- detail the procedure for monitoring of lake entrances.

3 Land to which this Policy applies

This Policy applies to lands located at the ocean entrance of Tuross Lakes, generally east of Nelson Parade, Tuross Head.

4 Sea Level Rise Planning Benchmark

Eurobodalla Shire Council has applied the Sea Level Rise planning benchmark determined by the *Sea Level Rise Policy Statement* adopted by the NSW Government in October 2009, of:

- 40cm rise by 2050; and
- 90cm rise by 2100.

This policy is consistent with the most credible information currently available for regional and global sea level rise projections for the two planning periods. This policy is precautionary in considering the uncertainty associated with sea level rise projections and future greenhouse gas emissions.

5 Application of this Policy

Implementing this Policy will ensure that Council:

- Facilitates the vertical natural migration of riparian and estuarine ecological communities in response to sea level rise;
- Limits opportunities for ingress of introduced and invasive species to the estuary;
- Minimises impacts on local fisheries resources and other ecological species, where possible; and
- Enables continued existing use of fringing riparian lands for as long as practical.

The Policy has regard to the existing Tuross / Coila Estuary Management Plan. The Policy also broadly complies with various State Government initiatives for environmental management of coastal lakes, and will be applied with full consideration of the following Federal and State legislation and Policies:

- *Cmwlth Environmental Protection and Biodiversity Conservation Act 1999;*
- *NSW Environmental Planning & Assessment Act 1979;*
- *NSW Local Government Act 1993;*
- *NSW Coastal Protection Act 1979;*
- *NSW Fisheries Management Act 1994;*
- *NSW Crown Lands Act 1989;*
- *NSW Threatened Species Conservation Act 1995;*
- *NSW Marine Parks Act 1997 and Regulations 2009;*
- *State Environmental Planning Policy 71 – Coastal Protection;*
- *State Environmental Planning Policy (Infrastructure) 2007*
- *NSW Coastal Policy 1997;*
- *NSW Flood Prone Land Policy;*
- *NSW Draft Sea Level Rise Policy;*
- *NSW Government's Floodplain Development Manual;*
- *NSW Government's Estuary Management Manual; and*
- *NSW Government's Coastline Management Manual.*

6. Principles

The Tuross Lakes Entrance Management Policy will be conducted according to the general principles and philosophy set out below.

Open entrance when trigger levels are reached

⇓

Undertake works to enable an increase in trigger levels (to restore a more natural opening regime)

⇓

Revised trigger levels for action based on additional works completed (timeframe: 5 – 10 years)

⇓

Incorporate provisions for increasing triggers at a rate commensurate with sea level rise when undertake works and infrastructure in future

⇓

Establish long term targets for entrance management trigger levels (incorporating sea level rise to 2100)

6.1 Monitoring

Water levels in Tuross Lakes are monitored on a continuous basis by Manly Hydraulics Laboratory on behalf of the Department of Environment, Climate Change and Water (DECCW), refer:

http://www.mhl.nsw.gov.au/htbin/map_data_display.com?SITE=TURO

Visual gauges are also established at:

- Volunteer Coastal Patrol jetty

Rainfall within the Tuross catchment is monitored by the Bureau of Meteorology at the following sites:

- Belowra (Event-based Radio Telemetry System)
- Eurobodalla (pluvio)
- Bodalla (pluvio)

Refer http://www.bom.gov.au/hydro/flood/nsw/rain_river.shtml

6.2 Entrance breakout

The following conditions are required to initiate an opening of the entrance channel:

- Water levels > RL 2.0m AHD; or
- Water levels > RL 0.80m AHD for 14 days, or
- Higher or lower time period triggers may be negotiated with directly affected business owners, during NSW and ACT school holiday periods and Easter holidays

Diligent monitoring of water levels will occur once water levels exceed 0.7m AHD and the entrance is closed. Table 1 provides an approximate relationship between rainfall in the catchment and increases in water level in Tuross Lakes.

Table 1 – Volumetric characteristics of Tuross Lakes

Runoff volume (ML) = rainfall (mm) x area receiving rainfall (km^2) x 0.2	
Contributing runoff volume (ML)	Approx. water level increase in estuary (m)
2,600	0.2
6,500	0.5
13,000	1.0
19,500	1.5
26,000	2.0

Example:

50mm of rain falling over 1,200km^2 will produce ~12,000ML of runoff. If the entrance is closed, this runoff volume will potentially increase estuary water levels by almost 1.0m. If the initial water level was RL 0.5m AHD, then peak water levels would reach about RL 1.5m AHD.

Notes:

1. This relationship is considered approximate and has been provided largely for indicative purposes only. The increase in water level will actually be dependent on the starting water level. A more detailed stage-volume relationship can be established using LiDAR data, when available.
2. Runoff co-efficient of 0.2 is typical of a large catchment (ie > 1,000km^2) and assuming a relatively dry catchment condition. For a wet catchment, the runoff coefficient would be higher, but under such circumstances, the entrance would likely already be open due to previous rainfall and flow conditions.
3. For simplicity, a linear interpolation can be adopted between values in the table.
4. Rainfall across the catchment is to be determined with reference to the following Bureau of Meteorology gauges, and associated assumed contributing catchment areas:
   a. Belowra (ERTS) 1200 km^2
   b. Eurobodalla 400 km^2
   c. Bodalla 200 km^2

The following procedures should be followed when initiating an entrance opening:

- Relevant authorities shall be informed of the intent to artificially open the entrance (refer Section 9. Contacts list);
- The location of the entrance opening works should be as per shown in Figure T-1;
- The works shall involve the excavation of a pilot channel, approximately 10 metres wide and 2 metres deep, with excavation starting from the ocean end and finishing at the lake edge;
- If the entrance is opened at a low level (< RL 1.0m AHD), there may be a need to provide on-going mechanical assistance to maintain an open entrance conditions until normal water levels are re-established. This may include additional excavations (eg using a long reach excavator);
- Final opening of the channel should be timed to coincide with the initial falling stages of the tide to ensure that a good head difference is maintained in the first few hours of opening;
- Outflow from the lake onto the beach may pose a public risk. Council should close the beach in the immediate vicinity of the entrance channel for a period of at least 48 hours, or until significant outflow velocities have abated and lake waters have dissipated across the surf zone.

6.3 Revising breakout levels and works required to achieve levels

This Policy requires the breakout levels to be progressively increased in the future to facilitate adaptation to future climate change (especially sea level rise), and to reduce the on-going need for artificial entrance intervention. Revised breakout levels and the works necessary to achieve these levels are presented in Table 2.

6.4 Long term (2100) target for breakout trigger level

This Policy advocates a minimal entrance intervention in the long term, with preference for allowing natural lake breakout wherever possible. A level of RL 3.0m AHD is considered a target breakout level for the year 2100, with all necessary works to be completed by such time to achieve this target level.

6.5 Review period

This Policy is to be reviewed and revised as necessary every 5 years.

Table 2 –Revised trigger levels and associated works necessary to achieve levels

Revised trigger level	Existing level of constraint	Works to be undertaken	Indicative timeframe
RL 1.5m AHD	0.7m AHD – O'Briens 0.83m AHD – Laing's 1.37m AHD - Redbox	Convert timber decks of commercial premises to floating pontoon type	5 – 10 years
RL 2.0m AHD	~1.0 – 2.0m AHD	Return of low-lying private property (< RL 2.0m AHD) to public ownership upon opportunistic future sub-division (pending LEP lot sizes and zoning)	10 – 30 years
	1.11m AHD for continued operation of SPS next to Redbox Pizza Other manholes within Tuross Head	Progressive and opportunistic raising or removal of assets around lake fringes (eg Sewage Pumping Station)	10 – 30 years
RL 3.0m AHD	2.0m AHD – Hector McWilliam Drive 2.3m AHD – Princes Highway between Trunketabella Ck and Tuross River bridge	Progressive and opportunistic raising of Hector McWilliam Drive at the Narrows, and Princes Highway along low-lying section near Trunketabella Creek (ideally to > RL 3.0m AHD).	10 – 50 years
	~ 1.5 – 3.0m AHD	Opportunistic filling of private non-rural property upon future development (for land < RL 3.0mAHD), except where adjacent to SEPP-14 wetlands, and providing no impact on flood behavior, vegetation, etc	10 – 100 years
	1.2m AHD – O'Briens 1.6m AHD – Laing's 2.4m AHD - Redbox	Progressive raising of minimum floor levels for fringing development (eg boatsheds precinct) through changes to planning instruments. Minimum floor level should be 1% AEP flood level + 0.5 metres, assuming entrance breakout at RL 3.0m AHD.	10 – 100 years

7. Informing the public

Signage is to be maintained regarding the illegal nature of unauthorised opening of the lake. Council has the authority to penalise persons opening the lake without appropriate authorisation under Section 623(1) of the Local Government Act 1993.

Temporary signage should also be erected during a breakout event (natural or artificial) to advise the public of inherent risks and safety issues with associated strong outflowing currents while the lake drains to normal levels.

8. Responsibility

Primary responsibility for implementing this Policy is with Eurobodalla Shire Council, Director of Roads and Recreation.

Alternative responsibility within Eurobodalla Shire Council is the Senior Maintenance Engineer in the event the primary responsibility officer in unavailable.

9. Contacts

All key contacts will be advised of any intention to undertake entrance works prior to the activities.

Key contacts regarding implementation of this Policy are:

Eurobodalla Shire Council:	Name: Director Roads & Recreation Phone number: 4474 1000 Mobile phone: 0409 398 358 Email:
Department of Environment, Climate Change and Water (National Parks Unit):	Name: Area Manager, Northern Area Phone number: 4476 0800 After Hours Incident Answering Service : 1800 629 104
Department of Environment, Climate Change and Water – Coast & Estuary Branch	Name: Senior Natural Resource Officer - Coast and Estuaries Phone number: 4224 9630 Mobile phone: 0402 127 205 Email: Daniel.Wiecek@environment.nsw.gov.au
Department of Industry and Investment (Fisheries):	Name: Fisheries Conservation Manager Phone number: 4478 9103 Mobile phone: 0408 487 083 Email: trevor.daly@industry.nsw.gov.au
Batemans Marine Park:	Name: Manager Phone number: 4476 0800

	Mobile phone: Email: batemans@mpa.nsw.gov.au
Department of Lands:	Name: Team Leader Environment Phone number: 4428 9127 Mobile phone: Email: Grant.Merinuk@lands.nsw.gov.au
Oyster Farmers	Name: Greg Woodforde (1) Phone number: 4473 9187 Name: Campbell's Oyster Farm (2) Phone Number: 4473 8492 Name: Glenn Jones (3) Phone Number: 4473 6999

10. Authorisation

This Policy was adopted by Council on ....

This Policy commenced on ....

This Policy is due for review on ....

11. Amendments

This Policy was last amended on ....

12. Related Council Policies

a) ESC Interim Sea Level Rise Adaptation Policy

13. Relevant Legislation

13.1 State Environmental Planning Policy (SEPP) Infrastructure 2007

Development consent for undertaking these works, as set out in the Policy, is exempt from development consent under the Eurobodalla LEP (and thus assessment under Part 4 of the EP&A Act), as the works fall within the scope of State Environmental Planning Policy (SEPP) Infrastructure 2007. Relevant approvals still need to be obtained from relevant authorities (see below), and an assessment under Part 5 of the Act is required (including preparation of a Review of Environmental Factors).

13.2 Local Government Act 1993

Under the Local Government Act 1919, Councils had general authority to open coastal lakes and lagoons under Section 352A. Although this provision was not specifically carried through in the Local Government Act 1993, Councils have continued to assumed such responsibility on behalf of the interests of the public.

Under the Local Government Act 1993, Council has the authority to enforce penalties on anyone acting contrary to a notice erected on public land or in a bathing place under Section 632(1).

13.3 Crown Lands Act 1989

The bed of Tuross Lake, including the entrance channel, is Crown land. Landowner consent from the Department of Lands is therefore required before works on the Crown land can be undertaken. A single licence can be obtained from Lands covering entrance management of all coastal lakes in the Shire, to be reviewed and renewed concurrently with the review of this Policy.

13.4 Fisheries Management Act 1994

Within the Fisheries Management Act 1994, reference should be made to Sections 200 and 201, regarding a dredging licence (or the need for Department of Lands to consult with Fisheries in providing a Crown Lands licence), as well as Section 205 in respect to harming of marine vegetation.

13.5 Threatened Species Conservation 1995; and Commonwealth Environmental Protection and Biodiversity Conservation (EPBC) Act 1999

Consideration needs to be given to potential harm or damage to threatened species and listed migratory species, including Little Tern, which nests along the entrance berm of Tuross Lakes. Transportation of heavy equipment onto the entrance will also need to consider potential damage to known Aboriginal sites.

13.6 Marine Park Act 1997

Tuross Lake is located within the Batemans Marine Park, zoned Habitat Protection Zone. Consent is required from the Minister under the provisions outlined in the Marine Parks Regulations 2009, for open the entrance (on the basis that the works will potentially harm marine animals, including beach invertebrates through the actually physical excavation works).

13.7 Coastal Protection Act 1979

Consideration needs to be given to Sections 38 and 39 of the Act, requiring concurrence by the Minister for undertaking development works within the coastal zone. The proposed entrance works at Tuross Lakes is within the coastal zone as defined by the Act.

13.8 State Environmental Planning Policy 71 – Coastal Protection

Development proposed within "sensitive coastal locations" needs to be referred to the Minister for comment. Schedule 1 of SEPP-71 specifically lists Tuross Lakes as a sensitive coastal location, along with most other coastal lakes in NSW.

Title:
Location of Tuross Lakes Entrance Opening Works

Figure: T-1

Rev: A

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

N

0 125 250m
Approx. Scale

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Filepath : K:\N1608_EurobodallaLakesEMPs\MapInfo\Workspaces\DRG_012_091105_Tuross_Entrance.WOR

KIANGA LAKE

ENTRANCE MANAGEMENT POLICY

EUROBODALLA SHIRE COUNCIL

Good Government, better living

KIANGA LAKE ENTRANCE MANAGEMENT POLICY

1 Policy Name

This policy will be referred to as the *Kianga Lake Entrance Management Policy*.

2 Objectives

This Policy will provide a framework that allows Council to pro-actively manage openings of Kianga Lake. This Policy aims to:

- Minimise interference with natural entrance opening processes and minimise associated impacts on ecological processes;
- Accommodate future climate change, and sea level rise in particular;
- Minimise risks to public safety associated with excessive inundation of foreshores and associated infrastructure;
- Minimise risks to public health associated with excessive bacterial contamination of waters;
- Conserve or enhance the biological diversity and floral and fauna communities of the estuarine lakes systems;
- Facilitate the construction and/or maintenance of essential community infrastructure;
- determine procedures to be initiated for entrance operations including entrance breakouts;
- determine key responsibilities for management of the entrance; and
- detail the procedure for monitoring of lake entrances.

3 Land to which this Policy applies

This Policy applies to lands located at the ocean entrance of Kianga Lake, east of the Kianga – Dalmeny coastal road.

4 Sea Level Rise Planning Benchmark

Eurobodalla Shire Council has applied the Sea Level Rise planning benchmark determined by the *Sea Level Rise Policy Statement* adopted by the NSW Government in October 2009, of:

- 40cm rise by 2050; and
- 90cm rise by 2100.

This policy is consistent with the most credible information currently available for regional and global sea level rise projections for the two planning periods. This policy is precautionary in considering the uncertainty associated with sea level rise projections and future greenhouse gas emissions.

5 Application of this Policy

Implementing this Policy will ensure that Council:

- Facilitates the vertical natural migration of riparian and estuarine ecological communities in response to sea level rise;
- Limits opportunities for ingress of introduced and invasive species to the estuary;
- Minimises impacts on local fisheries resources and other ecological species, where possible; and
- Enables continued existing use of fringing riparian lands for as long as practical.

The Policy broadly complies with various State Government initiatives for environmental management of coastal lakes, and will be applied with full consideration of the following Federal and State legislation and Policies:

- *Cmwlth Environmental Protection and Biodiversity Conservation Act 1999;*
- *NSW Environmental Planning & Assessment Act 1979;*
- *NSW Local Government Act 1993;*
- *NSW Coastal Protection Act 1979;*
- *NSW Fisheries Management Act 1994;*
- *NSW Crown Lands Act 1989;*
- *NSW Threatened Species Conservation Act 1995;*
- *NSW Marine Parks Act 1997 and Regulations 2009;*
- *State Environmental Planning Policy 71 – Coastal Protection;*
- *State Environmental Planning Policy (Infrastructure) 2007*
- *NSW Coastal Policy 1997;*
- *NSW Flood Prone Land Policy;*
- *NSW Draft Sea Level Rise Policy;*
- *NSW Government's Floodplain Development Manual;*
- *NSW Government's Estuary Management Manual; and*
- *NSW Government's Coastline Management Manual.*

6. Principles

The Kianga Lake Entrance Management Policy will be conducted according to the general principles and philosophy set out below.

Open entrance when trigger levels are reached

⇓

Incorporate provisions for increasing triggers at a rate commensurate with sea level rise when undertake works and infrastructure in future

⇓

Establish long term targets for entrance management trigger levels (incorporating sea level rise to 2100)

6.1 Monitoring

Water levels in Kianga Lake are monitored visually using gauge-plates located at:

- Kianga – Dalmeny coastal road bridge (to be installed, refer schedule of works in REF)

6.2 Entrance breakout

The following conditions are required to initiate an opening of the entrance channel:

- Water levels > RL 2.0m AHD; or
- Water levels > RL 1.8m AHD for 14 days

The following procedures should be followed when initiating an entrance opening:

- Relevant authorities shall be informed of the intent to artificially open the entrance (refer Section 9. Contacts list);
- The location of the entrance opening works should be as per shown in Figure K-1;
- The works shall involve the excavation of a pilot channel, approximately 2-5 metres wide and 1 metre deep, with excavation starting from the ocean end and finishing at the lake edge;
- Final opening of the channel should be timed to coincide with the initial falling stages of the tide to ensure that a good head difference is maintained in the first few hours of opening;
- Outflow from the lake onto the beach may pose a public risk. Council should close the beach in the immediate vicinity of the entrance channel for a period

of at least 48 hours, or until significant outflow velocities have abated and lake waters have dissipated across the surf zone.

6.3 Revising breakout levels and works required to achieve levels

This Policy requires the breakout levels to be increased in the future to facilitate adaptation to future climate change (especially sea level rise), and to reduce the on-going need for artificial entrance intervention. Revised breakout levels and the works necessary to achieve these levels are presented in Table 2.

Table 2 –Revised trigger levels and associated works necessary to achieve levels

Revised trigger level	Existing level of constraint	Works to be undertaken	Indicative timeframe
RL 2.8m AHD	1.8 – 2.8m AHD – private properties along Lakeside Dr, Kianga	Progressive raising of minimum floor levels for fringing development through changes to planning instruments. Minimum floor level should be 1% AEP flood level + 0.5 metres, assuming entrance breakout at RL 2.8m AHD.	10 – 50 years
		Ultimately, retreat from lands on northern side of Lakeside Drive between Nos 25 and 49.	50 – 100 years
	2.0m AHD – access road to Kianga STP	Progressive and opportunistic raising of STP access road to > 2.8m AHD, allowing for under-flow as appropriate	10 – 50 years
	2.2m AHD for sewage pump station	Progressive and opportunistic raising or removal of assets around lake fringes (eg sewer pump station)	10 – 50 years
	2.6m AHD – Kianga-Dalmeny coastal road on northern bridge approach	Progressive and opportunistic raising of coastal road to > 2.8m AHD	10 – 50 years

6.4 Long term (2100) target for breakout trigger level

This Policy advocates a minimal entrance intervention in the long term, with preference for allowing natural lake breakout wherever possible. A level of between RL 2.8m and 3.0m AHD is considered a target breakout level for the year 2100, with all necessary works to be completed by such time to achieve this target level.

6.5 Ancillary works

Ancillary entrance management works are also required to improve the effectiveness of entrance breakouts. The following works are to be carried out concurrently with implementation of entrance breakout protocols:

a) Infill crevices in the rock shelf headland on the southern side of Kianga entrance to prevent discharge from the lake prior to breakout of the entrance sand berm. These crevices have formed following excavation of the rock shelf as part of the Kianga ocean outfall works.

   Location: The location of the rock infill is shown in Figure K-1.

   Method: Rock infill is to use concrete, capable of withstanding marine environment and high wave activity. Concrete is to be keyed into existing rock to ensure integrity and maintain minimum height.

   Minimum height: Concrete infill is to have a crest elevation comparable with adjacent rock shelf levels (approximately RL 1.5m AHD).

   Aesthetics: Additives should be used in the concrete to match existing rock colour, while the infill should avoid straight edges wherever possible.

   Approval: Consent required under the *Fisheries Management Act 1994*.

6.6 Review period

This Policy is to be reviewed and revised as necessary every 5 years.

7. Informing the public

Signage is to be maintained regarding the illegal nature of unauthorised opening of the lake. Council has the authority to penalise persons opening the lake without appropriate authorisation under Section 623(1) of the Local Government Act 1993.

Temporary signage should also be erected during a breakout event (natural or artificial) to advise the public of inherent risks and safety issues with associated strong outflowing currents while the lake drains to normal levels.

8. Responsibility

Primary responsibility for implementing this Policy is with Eurobodalla Shire Council, Director of Roads and Recreation.

Alternative responsibility within Eurobodalla Shire Council is the Senior Maintenance Engineer in the event the primary responsibility officer in unavailable.

9. Contacts

All key contacts will be advised of any intention to undertake entrance works prior to the activities.

Key contacts regarding implementation of this Policy are:

Eurobodalla Shire Council:	Name: Director Roads & Recreation Phone number: 4474 1000 Mobile phone: 0409 398 358 Email:
Department of Environment, Climate Change and Water (National Parks Unit):	Name: Area Manager, Northern Area Phone number: 4476 0800 After Hours Incident Answering Service : 1800 629 104
Department of Environment, Climate Change and Water – Coast & Estuary Branch	Name: Senior Natural Resource Officer - Coast and Estuaries Phone number: 4224 9630 Mobile phone: 0402 127 205 Email: Daniel.Wiecek@environment.nsw.gov.au
Department of Industry and Investment (Fisheries):	Name: Fisheries Conservation Manager Phone number: 4478 9103 Mobile phone: 0408 487 083 Email: trevor.daly@industry.nsw.gov.au
Batemans Marine Park:	Name: Manager Phone number: 4476 0800 Mobile phone: Email: batemans@mpa.nsw.gov.au

10. Authorisation

This Policy was adopted by Council on ....

This Policy commenced on ....

This Policy is due for review on ....

11. Amendments

This Policy was last amended on ....

12. Related Council Policies

a) ESC Interim Sea Level Rise Policy

13. Relevant Legislation

13.1 State Environmental Planning Policy (SEPP) Infrastructure 2007

Development consent for undertaking these works, as set out in the Policy, is exempt from development consent under the Eurobodalla LEP (and thus assessment under Part 4 of the EP&A Act), as the works fall within the scope of State Environmental Planning Policy (SEPP) Infrastructure 2007. Relevant approvals still need to be obtained from relevant authorities (see below), and an assessment under Part 5 of the Act is required (including preparation of a Review of Environmental Factors).

13.2 Local Government Act 1993

Under the Local Government Act 1919, Councils had general authority to open coastal lakes and lagoons under Section 352A. Although this provision was not specifically carried through in the Local Government Act 1993, Councils have continued to assumed such responsibility on behalf of the interests of the public.

Under the Local Government Act 1993, Council has the authority to enforce penalties on anyone acting contrary to a notice erected on public land or in a bathing place under Section 632(1).

13.3 Crown Lands Act 1989

The bed of Kianga Lake, including the entrance channel, is Crown land. Landowner consent from the Department of Lands is therefore required before works on the Crown land can be undertaken. A single licence can be obtained from Lands covering entrance management of all coastal lakes in the Shire, to be reviewed and renewed concurrently with the review of this Policy.

13.4 Fisheries Management Act 1994

Within the Fisheries Management Act 1994, reference should be made to Sections 200 and 201, regarding a dredging licence (or the need for Department of Lands to consult with Fisheries in providing a Crown Lands licence), as well as Section 205 in respect to harming of marine vegetation.

13.5 Threatened Species Conservation 1995; and Commonwealth Environmental Protection and Biodiversity Conservation (EPBC) Act 1999

Consideration needs to be given to potential harm or damage to threatened species and listed migratory species. Transportation of heavy equipment onto the entrance will also need to consider potential damage to known Aboriginal sites.

13.6 Marine Park Act 1997

Kianga Lake is located within the Batemans Marine Park, as a Sanctuary Zone, representing the highest level of protection in the Park. Consent is required from the Minister under the provisions outlined in the Marine Parks Regulations 2009, to open the entrance (on the basis that the works will potentially harm marine animals, including beach invertebrates through the actually physical excavation works).

13.7 Coastal Protection Act 1979

Consideration needs to be given to Sections 38 and 39 of the Act, requiring concurrence by the Minister for undertaking development works within the coastal zone. The proposed entrance works at Kianga Lake is within the coastal zone as defined by the Act.

13.8 State Environmental Planning Policy 71 – Coastal Protection

Development proposed within “sensitive coastal locations” needs to be referred to the Minister for comment. Schedule 1 of SEPP-71 specifically lists Kianga Lake as a sensitive coastal location, along with most other coastal lakes in NSW.

Title:
Location of Kianga Lake Entrance Opening Works

Figure: **K-1** Rev: **A**

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

N

0 75 150m
Approx. Scale

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LITTLE LAKE

ENTRANCE MANAGEMENT POLICY

LITTLE LAKE ENTRANCE MANAGEMENT POLICY

1 Policy Name

This policy will be referred to as the *Little Lake Entrance Management Policy*.

2 Objectives

This Policy will provide a framework that allows Council to pro-actively manage openings of Little Lake. This Policy aims to:

- Minimise interference with natural entrance opening processes and minimise associated impacts on ecological processes;
- Accommodate future climate change, and sea level rise in particular;
- Minimise risks to public safety associated with excessive inundation of foreshores and associated infrastructure;
- Minimise risks to public health associated with excessive bacterial contamination of waters;
- Conserve or enhance the biological diversity and floral and fauna communities of the estuarine lakes systems;
- Facilitate the construction and/or maintenance of essential community infrastructure;
- determine procedures to be initiated for entrance operations including entrance breakouts;
- determine key responsibilities for management of the entrance; and
- detail the procedure for monitoring of lake entrances.

3 Land to which this Policy applies

This Policy applies to lands located at the ocean entrance of Little Lake, immediately adjacent to the Narooma Surf Life Saving Club.

4 Sea Level Rise Planning Benchmark

Eurobodalla Shire Council has applied the Sea Level Rise planning benchmark determined by the *Sea Level Rise Policy Statement* adopted by the NSW Government in October 2009, of:

- 40cm rise by 2050; and
- 90cm rise by 2100.

This policy is consistent with the most credible information currently available for regional and global sea level rise projections for the two planning periods. This policy is precautionary in considering the uncertainty associated with sea level rise projections and future greenhouse gas emissions.

5 Application of this Policy

Implementing this Policy will ensure that Council:

- Facilitates the vertical natural migration of riparian and estuarine ecological communities in response to sea level rise;
- Limits opportunities for ingress of introduced and invasive species to the estuary;
- Minimises impacts on local fisheries resources and other ecological species, where possible; and
- Enables continued existing use of fringing riparian lands for as long as practical.

The Policy broadly complies with various State Government initiatives for environmental management of coastal lakes, and will be applied with full consideration of the following Federal and State legislation and Policies:

- *Cmwlth Environmental Protection and Biodiversity Conservation Act 1999;*
- *NSW Environmental Planning & Assessment Act 1979;*
- *NSW Local Government Act 1993;*
- *NSW Coastal Protection Act 1979;*
- *NSW Fisheries Management Act 1994;*
- *NSW Crown Lands Act 1989;*
- *NSW Threatened Species Conservation Act 1995;*
- *NSW Marine Parks Act 1997 and Regulations 2009;*
- *State Environmental Planning Policy 71 – Coastal Protection;*
- *State Environmental Planning Policy (Infrastructure) 2007*
- *NSW Coastal Policy 1997;*
- *NSW Flood Prone Land Policy;*
- *NSW Draft Sea Level Rise Policy;*
- *NSW Government's Floodplain Development Manual;*
- *NSW Government's Estuary Management Manual; and*
- *NSW Government's Coastline Management Manual.*

6. Principles

The Little Lake Entrance Management Policy will be conducted according to the general principles and philosophy set out below.

Open entrance when trigger levels are reached

⇓

Undertake works to enable an increase in trigger levels (to restore a more natural opening regime)

⇓

Revised trigger levels for action based on additional works completed (timeframe: 5 – 10 years)

⇓

Incorporate provisions for increasing triggers at a rate commensurate with sea level rise when undertake works and infrastructure in future

⇓

Establish long term targets for entrance management trigger levels (incorporating sea level rise to 2100)

6.1 Monitoring

Water levels in Little Lake are monitored visually using gauge-plates located at:

- Little Lake entrance (to be installed, refer schedule of works in REF)

6.2 Entrance breakout

The following conditions are required to initiate an opening of the entrance channel:

- Water levels > RL 2.2m AHD.

The following procedures should be followed when initiating an entrance opening:

- Relevant authorities shall be informed of the intent to artificially open the entrance (refer Section 9. Contacts list);
- The location of the entrance opening works should be as per shown in Figure L-1;
- The works shall involve the excavation of a pilot channel, approximately 2-5 metres wide and 1 metre deep, with excavation starting from the ocean end and finishing at the lake edge;

- Final opening of the channel should be timed to coincide with the initial falling stages of the tide to ensure that a good head difference is maintained in the first few hours of opening;
- Outflow from the lake onto the beach may pose a public risk. Council should close the beach in the immediate vicinity of the entrance channel for a period of at least 48 hours, or until significant outflow velocities have abated and lake waters have dissipated across the surf zone.

6.3 Revising breakout levels and works required to achieve levels

This Policy requires the breakout levels to be increased in the future to facilitate adaptation to future climate change (especially sea level rise), and to reduce the on-going need for artificial entrance intervention. Revised breakout levels and the works necessary to achieve these levels are presented in Table 2.

Table 2 –Revised trigger levels and associated works necessary to achieve levels

Revised trigger level	Existing level of constraint	Works to be undertaken	Indicative timeframe
RL 2.5m AHD	2.0 – 2.5m AHD – edges of fairways along 9th and 15th holes	Minor filling and landscaping to provide minimum fairway widths of RL 2.5m AHD	10 – 50 years
	~2.2m AHD – Sewage Pumping Station building off Willcocks Av, although pumps at 3.3m AHD	Progressive and opportunistic flood-proofing of buildings around lake fringes (eg sewer pump station building)	10 – 30 years
RL 3.0m AHD	< 3.0m AHD – fairways of 8th, 9th, 11th and 15th holes, plus tees of 10th and 16th.	Substantial filling of existing fairways tees and greens and/ or partial course redesign to accommodate reduced widths and allow for vertical migration of saltmarsh (with boardwalks over etc) (may include some clearing of existing fringe vegetation, subject to environmental assessment and appropriate approvals)	30 – 100 years
	2.5m AHD – Glasshouse Rocks Road	Progressive and opportunistic raising of road to > 3.0m AHD	50 – 100 years

6.4 Long term (2100) target for breakout trigger level

This Policy advocates a minimal entrance intervention in the long term, with preference for allowing natural lake breakout wherever possible. A level of approximately RL 3.0m AHD is considered a target breakout level for the year 2100, with all necessary works to be completed by such time to achieve this target level.

6.5 Review period

This Policy is to be reviewed and revised as necessary every 5 years.

7. Informing the public

Little Lake is particularly vulnerable to unauthorised openings due to the typically narrow nature of the entrance berm. Signage is to be maintained regarding the illegal nature of unauthorised opening of the lake. Council has the authority to penalise persons opening the lake without appropriate authorisation under Section 623(1) of the Local Government Act 1993.

Temporary signage should also be erected during a breakout event (natural or artificial) to advise the public of inherent risks and safety issues with associated strong outflowing currents while the lake drains to normal levels.

8. Responsibility

Primary responsibility for implementing this Policy is with Eurobodalla Shire Council, Director of Roads and Recreation.

Alternative responsibility within Eurobodalla Shire Council is the Senior Maintenance Engineer in the event the primary responsibility officer in unavailable.

9. Contacts

All key contacts will be advised of any intention to undertake entrance works prior to the activities.

Key contacts regarding implementation of this Policy are:

Eurobodalla Shire Council:	Name: Director Roads & Recreation Phone number: 4474 1000 Mobile phone: 0409 398 358 Email:
Department of Environment, Climate Change and Water (National Parks Unit):	Name: Area Manager, Northern Area Phone number: 4476 0800 After Hours Incident Answering Service : 1800 629 104
Department of Environment, Climate Change and Water – Coast & Estuary	Name: Senior Natural Resource Officer - Coast and Estuaries

Branch	Phone number: 4224 9630 Mobile phone: 0402 127 205 Email: Daniel.Wiecek@environment.nsw.gov.au
Department of Industry and Investment (Fisheries):	Name: Fisheries Conservation Manager Phone number: 4478 9103 Mobile phone: 0408 487 083 Email: trevor.daly@industry.nsw.gov.au
Batemans Marine Park:	Name: Manager Phone number: 4476 0800 Mobile phone: Email: batemans@mpa.nsw.gov.au

10. Authorisation

This Policy was adopted by Council on ....

This Policy commenced on ....

This Policy is due for review on ....

11. Amendments

This Policy was last amended on ....

12. Related Council Policies

a) ESC Interim Sea Level Rise Policy

13. Relevant Legislation

13.1 State Environmental Planning Policy (SEPP) Infrastructure 2007

Development consent for undertaking these works, as set out in the Policy, is exempt from development consent under the Eurobodalla LEP (and thus assessment under Part 4 of the EP&A Act), as the works fall within the scope of State Environmental Planning Policy (SEPP) Infrastructure 2007. Relevant approvals still need to be obtained from relevant authorities (see below), and an assessment under Part 5 of the Act is required (including preparation of a Review of Environmental Factors).

13.2 Local Government Act 1993

Under the Local Government Act 1919, Councils had general authority to open coastal lakes and lagoons under Section 352A. Although this provision was not specifically carried through in the Local Government Act 1993, Councils have continued to assumed such responsibility on behalf of the interests of the public.

Under the Local Government Act 1993, Council has the authority to enforce penalties on anyone acting contrary to a notice erected on public land or in a bathing place under Section 632(1).

13.3 Crown Lands Act 1989

The bed of Little Lake, including the entrance channel, is Crown land. Landowner consent from the Department of Lands is therefore required before works on the Crown land can be undertaken. A single licence can be obtained from Lands covering entrance management of all coastal lakes in the Shire, to be reviewed and renewed concurrently with the review of this Policy.

13.4 Fisheries Management Act 1994

Within the Fisheries Management Act 1994, reference should be made to Sections 200 and 201, regarding a dredging licence (or the need for Department of Lands to consult with Fisheries in providing a Crown Lands licence), as well as Section 205 in respect to harming of marine vegetation.

13.5 Threatened Species Conservation 1995; and Commonwealth Environmental Protection and Biodiversity Conservation (EPBC) Act 1999

Consideration needs to be given to potential harm or damage to threatened species and listed migratory species. Transportation of heavy equipment onto the entrance will also need to consider potential damage to known Aboriginal sites.

13.6 Marine Park Act 1997

Little Lake is located within the Batemans Marine Park, as a Sanctuary Zone, representing the highest level of protection in the Park. Consent is required from the Minister under the provisions outlined in the Marine Parks Regulations 2009, to open the entrance (on the basis that the works will potentially harm marine animals, including beach invertebrates through the actually physical excavation works).

13.7 Coastal Protection Act 1979

Consideration needs to be given to Sections 38 and 39 of the Act, requiring concurrence by the Minister for undertaking development works within the coastal zone. The proposed entrance works at Little Lake is within the coastal zone as defined by the Act.

13.8 State Environmental Planning Policy 71 – Coastal Protection

Development proposed within “sensitive coastal locations” needs to be referred to the Minister for comment. Schedule 1 of SEPP-71 specifically lists Little Lake (near Narooma) as a sensitive coastal location, along with most other coastal lakes in NSW.

Title:

Location of Little Lake Entrance Opening Works

Figure: **L-1**

Rev: **A**

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Approx. Scale

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BULLENGELLA LAKE

ENTRANCE MANAGEMENT POLICY

EUROBODALLA SHIRE COUNCIL

Good Government, better living

BULLENGELLA LAKE ENTRANCE MANAGEMENT POLICY

1 Policy Name

This policy will be referred to as the *Bullengella Lake Entrance Management Policy*.

2 Objectives

This Policy will provide a framework that allows Council to pro-actively manage the entrance of Bullengella Lake. This Policy aims to:

- Minimise interference with natural entrance opening processes and minimise associated impacts on ecological processes;
- Accommodate future climate change, and sea level rise in particular;
- Minimise risks to public safety associated with excessive inundation of foreshores and associated infrastructure;
- Minimise risks to public health associated with excessive bacterial contamination of waters;
- Conserve or enhance the biological diversity and floral and fauna communities of the estuarine lakes systems;
- Facilitate the construction and/or maintenance of essential community infrastructure; and
- determine key responsibilities for management of the entrance.

3 Land to which this Policy applies

This Policy applies to lands located at the ocean entrance of Bullengella Lake.

4 Sea Level Rise Planning Benchmark

Eurobodalla Shire Council has applied the Sea Level Rise planning benchmark determined by the *Sea Level Rise Policy Statement* adopted by the NSW Government in October 2009, of:

- 40cm rise by 2050; and
- 90cm rise by 2100.

This policy is consistent with the most credible information currently available for regional and global sea level rise projections for the two planning periods. This policy is precautionary in considering the uncertainty associated with sea level rise projections and future greenhouse gas emissions.

5 Application of this Policy

Implementing this Policy will ensure that Council:

- Facilitates the vertical natural migration of riparian and estuarine ecological communities in response to sea level rise;
- Limits opportunities for ingress of introduced and invasive species to the estuary;
- Minimises impacts on local fisheries resources and other ecological species, where possible; and
- Enables continued existing use of fringing riparian lands for as long as practical.

The Policy broadly complies with various State Government initiatives for environmental management of coastal lakes, and will be applied with full consideration of the following Federal and State legislation and Policies:

- *Cmwlth Environmental Protection and Biodiversity Conservation Act 1999;*
- *NSW Environmental Planning & Assessment Act 1979;*
- *NSW Local Government Act 1993;*
- *NSW Coastal Protection Act 1979;*
- *NSW Fisheries Management Act 1994;*
- *NSW Crown Lands Act 1989;*
- *NSW Threatened Species Conservation Act 1995;*
- *NSW Marine Parks Act 1997 and Regulations 2009;*
- *State Environmental Planning Policy 71 – Coastal Protection;*
- *State Environmental Planning Policy (Infrastructure) 2007*
- *NSW Coastal Policy 1997;*
- *NSW Flood Prone Land Policy;*
- *NSW Draft Sea Level Rise Policy;*
- *NSW Government's Floodplain Development Manual;*
- *NSW Government's Estuary Management Manual; and*
- *NSW Government's Coastline Management Manual.*

6. Principles

Bullengella Lake is not to be opened artificially unless for emergency purposes or for facilitating the construction of essential community services / infrastructure. The no-intervention approach is to remain despite a potential increase in berm heights, and thus increase in lake water level to initiate a natural entrance breakout as a consequence of future sea level rise.

If the entrance is to be opened artificially (for emergency purposes or essential services only), then it is to follow best practice for environmental management, including appropriate consultation with agencies before undertaking the works (if feasible). Appropriate actions to reduce public risks associated with an artificial breakout shall be undertaken.

6.1 Review period

This Policy is to be reviewed and revised as necessary every 5 years.

7. Informing the public

Temporary signage should be erected during a breakout event (natural or artificial) to advise the public of inherent risks and safety issues with associated strong outflowing currents while the lake drains to normal levels.

8. Responsibility

Primary responsibility for implementing this Policy is with Eurobodalla Shire Council, Director of Roads and Recreation.

Alternative responsibility within Eurobodalla Shire Council is the Senior Maintenance Engineer in the event the primary responsibility officer in unavailable.

9. Contacts

Key contacts regarding implementation of this Policy are:

Eurobodalla Shire Council:	Name: Director Roads & Recreation Phone number: 4474 1000 Mobile phone: 0409 398 358 Email:
Department of Environment, Climate Change and Water (National Parks Unit):	Name: Area Manager, Northern Area Phone number: 4476 0800 After Hours Incident Answering Service : 1800 629 104
Department of Environment, Climate Change and Water – Coast & Estuary Branch	Name: Senior Natural Resource Officer - Coast and Estuaries Phone number: 4224 9630 Mobile phone: 0402 127 205 Email: Daniel.Wiecek@environment.nsw.gov.au
Department of Industry and Investment (Fisheries):	Name: Fisheries Conservation Manager Phone number: 4478 9103 Mobile phone: 0408 487 083 Email: trevor.daly@industry.nsw.gov.au
Batemans Marine Park:	Name: Manager Phone number: 4476 0800

	Mobile phone: Email: batemans@mpa.nsw.gov.au

10. Authorisation

This Policy was adopted by Council on ....

This Policy commenced on ....

This Policy is due for review on ....

11. Amendments

This Policy was last amended on ....

12. Related Council Policies

a) ESC Interim Sea Level Rise Policy

13. Relevant Legislation

13.1 State Environmental Planning Policy (SEPP) Infrastructure 2007

Development consent for undertaking these works, as set out in the Policy, is exempt from development consent under the Eurobodalla LEP (and thus assessment under Part 4 of the EP&A Act), as the works fall within the scope of State Environmental Planning Policy (SEPP) Infrastructure 2007. Relevant approvals still need to be obtained from relevant authorities (see below), and an assessment under Part 5 of the Act is required (including preparation of a Review of Environmental Factors).

13.2 Local Government Act 1993

Under the Local Government Act 1919, Councils had general authority to open coastal lakes and lagoons under Section 352A. Although this provision was not specifically carried through in the Local Government Act 1993, Councils have continued to assumed such responsibility on behalf of the interests of the public.

Under the Local Government Act 1993, Council has the authority to enforce penalties on anyone acting contrary to a notice erected on public land or in a bathing place under Section 632(1).

13.3 Crown Lands Act 1989

The bed of Bullengella Lake, including the entrance channel, is Crown land. Landowner consent from the Department of Lands is therefore required before works on the Crown land can be undertaken. A single licence can be obtained from Lands covering entrance management of all coastal lakes in the Shire, to be reviewed and renewed concurrently with the review of this Policy.

13.4 Fisheries Management Act 1994

Within the Fisheries Management Act 1994, reference should be made to Sections 200 and 201, regarding a dredging licence (or the need for Department of Lands to consult with Fisheries in providing a Crown Lands licence), as well as Section 205 in respect to harming of marine vegetation.

13.5 Threatened Species Conservation 1995; and Commonwealth Environmental Protection and Biodiversity Conservation (EPBC) Act 1999

Consideration needs to be given to potential harm or damage to threatened species and listed migratory species. Transportation of heavy equipment onto the entrance will also need to consider potential damage to known Aboriginal sites.

13.6 Marine Park Act 1997

Bullengella Lake is located within the Batemans Marine Park, as a Sanctuary Zone, representing the highest level of protection in the Park. Consent is required from the Minister under the provisions outlined in the Marine Parks Regulations 2009, to open the entrance (on the basis that the works will potentially harm marine animals, including beach invertebrates through the actually physical excavation works).

13.7 Coastal Protection Act 1979

Consideration needs to be given to Sections 38 and 39 of the Act, requiring concurrence by the Minister for undertaking development works within the coastal zone. Any entrance works at Bullengella Lake would be within the coastal zone as defined by the Act.

13.8 State Environmental Planning Policy 71 – Coastal Protection

Development proposed within “sensitive coastal locations” needs to be referred to the Minister for comment. Schedule 1 of SEPP-71 specifically lists Bullengella Lake as a sensitive coastal location, along with most other coastal lakes in NSW.

NANGUDGA LAKE

ENTRANCE MANAGEMENT POLICY

EUROBODALLA SHIRE COUNCIL

Good Government, better living

NANGUDGA LAKE ENTRANCE MANAGEMENT POLICY

1 Policy Name

This policy will be referred to as the *Nangudga Lake Entrance Management Policy*.

2 Objectives

This Policy will provide a framework that allows Council to pro-actively manage openings of Nangudga Lake. This Policy aims to:

- Minimise interference with natural entrance opening processes and minimise associated impacts on ecological processes;
- Accommodate future climate change, and sea level rise in particular;
- Minimise risks to public safety associated with excessive inundation of foreshores and associated infrastructure;
- Minimise risks to public health associated with excessive bacterial contamination of waters;
- Conserve or enhance the biological diversity and floral and fauna communities of the estuarine lakes systems;
- Facilitate the construction and/or maintenance of essential community infrastructure;
- determine procedures to be initiated for entrance operations including entrance breakouts;
- determine key responsibilities for management of the entrance; and
- detail the procedure for monitoring of lake entrances.

3 Land to which this Policy applies

This Policy applies to lands located at the ocean entrance of Nangudga Lake.

4 Sea Level Rise Planning Benchmark

Eurobodalla Shire Council has applied the Sea Level Rise planning benchmark determined by the *Sea Level Rise Policy Statement* adopted by the NSW Government in October 2009, of:

- 40cm rise by 2050; and
- 90cm rise by 2100.

This policy is consistent with the most credible information currently available for regional and global sea level rise projections for the two planning periods. This policy is precautionary in considering the uncertainty associated with sea level rise projections and future greenhouse gas emissions.

5 Application of this Policy

Implementing this Policy will ensure that Council:

- Facilitates the vertical natural migration of riparian and estuarine ecological communities in response to sea level rise;
- Limits opportunities for ingress of introduced and invasive species to the estuary;
- Minimises impacts on local fisheries resources and other ecological species, where possible; and
- Enables continued existing use of fringing riparian lands for as long as practical.

The Policy broadly complies with various State Government initiatives for environmental management of coastal lakes, and will be applied with full consideration of the following Federal and State legislation and Policies:

- *Cmwlth Environmental Protection and Biodiversity Conservation Act 1999;*
- *NSW Environmental Planning & Assessment Act 1979;*
- *NSW Local Government Act 1993;*
- *NSW Coastal Protection Act 1979;*
- *NSW Fisheries Management Act 1994;*
- *NSW Crown Lands Act 1989;*
- *NSW Threatened Species Conservation Act 1995;*
- *NSW Marine Parks Act 1997 and Regulations 2009;*
- *State Environmental Planning Policy 71 – Coastal Protection;*
- *State Environmental Planning Policy (Infrastructure) 2007*
- *NSW Coastal Policy 1997;*
- *NSW Flood Prone Land Policy;*
- *NSW Draft Sea Level Rise Policy;*
- *NSW Government's Floodplain Development Manual;*
- *NSW Government's Estuary Management Manual; and*
- *NSW Government's Coastline Management Manual.*

6. Principles

The Nangudga Lake Entrance Management Policy will be conducted according to the general principles and philosophy set out below.

Open entrance when trigger levels are reached

⇓

Undertake works to enable an increase in trigger levels (to restore a more natural opening regime)

⇓

Revised trigger levels for action based on additional works completed (timeframe: 5 – 10 years)

⇓

Incorporate provisions for increasing triggers at a rate commensurate with sea level rise when undertake works and infrastructure in future

⇓

Establish long term targets for entrance management trigger levels (incorporating sea level rise to 2100)

6.1 Monitoring

Water levels in Nangudga Lake are monitored visually using gauge-plates located at:

- Princes Highway road bridge (gauge plate to be installed – refer schedule of works in REF)

6.2 Entrance breakout

The following conditions are required to initiate an opening of the entrance channel:

- Water levels > RL 1.3m AHD

The following procedures should be followed when initiating an entrance opening:

- Relevant authorities shall be informed of the intent to artificially open the entrance (refer Section 9. Contacts list);
- The location of the entrance opening works should be as per shown in Figure N-1;
- The works shall involve the excavation of a pilot channel, approximately 2 metres wide and 1 metre deep, with excavation starting from the ocean end and finishing at the lake edge;

- Final opening of the channel should be timed to coincide with the initial falling stages of the tide to ensure that a good head difference is maintained in the first few hours of opening;
- Outflow from the lake onto the beach may pose a public risk. Council should close the beach in the immediate vicinity of the entrance channel for a period of at least 48 hours, or until significant outflow velocities have abated and lake waters have dissipated across the surf zone.

6.3 Revising breakout levels and works required to achieve levels

This Policy requires the breakout levels to be increased in the future to facilitate adaptation to future climate change (especially sea level rise), and to reduce the on-going need for artificial entrance intervention. Revised breakout levels and the works necessary to achieve these levels are presented in Table 2.

6.4 Long term (2100) target for breakout trigger level

This Policy advocates a minimal entrance intervention in the long term, with preference for allowing natural lake breakout wherever possible. A level of approximately RL 2.4m AHD is considered a target breakout level for the year 2100, with all necessary works to be completed by such time to achieve this target level.

6.5 Review period

This Policy is to be reviewed and revised as necessary every 5 years.

7. Informing the public

Signage is to be maintained regarding the illegal nature of unauthorised opening of the lake. Council has the authority to penalise persons opening the lake without appropriate authorisation under Section 623(1) of the Local Government Act 1993.

Temporary signage should also be erected during a breakout event (natural or artificial) to advise the public of inherent risks and safety issues with associated strong outflowing currents while the lake drains to normal levels.

8. Responsibility

Primary responsibility for implementing this Policy is with Eurobodalla Shire Council, Director of Roads and Recreation.

Alternative responsibility within Eurobodalla Shire Council is the Senior Maintenance Engineer in the event the primary responsibility officer in unavailable.

Table 2 –Revised trigger levels and associated works necessary to achieve levels

Revised trigger level	Existing level of constraint	Works to be undertaken	Indicative timeframe
RL 1.7m AHD	~1.2 - 1.4m AHD, camping grounds and access road within Holiday Park	Flap gates to prevent backwater inundation into site. Pump stormwater sump downstream to provide capacity for stormwater capture to minimise site flooding (due to elevated tailwater levels)	2 – 5 years
RL 2.0m AHD	~1.2 – 2m AHD – private rural lands on southern side of bridge	Provide incentives to rural landowners to accommodate higher lake water levels	10 – 30 years
RL 2.4m AHD	~1.2 - 1.4m AHD, camping grounds and access road within Holiday Park	Opportunistic filling of private non-rural property upon future development (for land < RL 2.5mAHD), except where adjacent to SEPP-14 wetlands, and providing no impact on flood behavior, vegetation, etc	10 – 100 years
	2.2m AHD	Progressive and opportunistic raising of causeway on Old Coast Road to RL 2.7m AHD min.	30 – 100 years
	~2.5m AHD - Rural residences	Progressive raising of minimum floor levels for fringing development through changes to planning instruments. Minimum floor level should be 1% AEP flood level + 0.5 metres, assuming entrance breakout at RL 2.4m AHD.	30 – 100 years

9. Contacts

All key contacts will be advised of any intention to undertake entrance works prior to the activities.

Key contacts regarding implementation of this Policy are:

Eurobodalla Shire Council:	Name: Director Roads & Recreation Phone number: 4474 1000 Mobile phone: 0409 398 358 Email:
Department of Environment, Climate Change and Water (National Parks Unit):	Name: Area Manager, Northern Area Phone number: 4476 0800 After Hours Incident Answering Service : 1800 629 104
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Department of Industry and Investment (Fisheries):	Name: Fisheries Conservation Manager Phone number: 4478 9103 Mobile phone: 0408 487 083 Email: trevor.daly@industry.nsw.gov.au
Batemans Marine Park:	Name: Manager Phone number: 4476 0800 Mobile phone: Email: batemans@mpa.nsw.gov.au

10. Authorisation

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This Policy commenced on ....

This Policy is due for review on ....

11. Amendments

This Policy was last amended on ....

12. Related Council Policies

a) ESC Interim Sea Level Rise Policy

13. Relevant Legislation

13.1 State Environmental Planning Policy (SEPP) Infrastructure 2007

Development consent for undertaking these works, as set out in the Policy, is exempt from development consent under the Eurobodalla LEP (and thus assessment under Part 4 of the EP&A Act), as the works fall within the scope of State Environmental Planning Policy (SEPP) Infrastructure 2007. Relevant approvals still need to be obtained from relevant authorities (see below), and an assessment under Part 5 of the Act is required (including preparation of a Review of Environmental Factors).

13.2 Local Government Act 1993

Under the Local Government Act 1919, Councils had general authority to open coastal lakes and lagoons under Section 352A. Although this provision was not specifically carried through in the Local Government Act 1993, Councils have continued to assumed such responsibility on behalf of the interests of the public.

Under the Local Government Act 1993, Council has the authority to enforce penalties on anyone acting contrary to a notice erected on public land or in a bathing place under Section 632(1).

13.3 Crown Lands Act 1989

The bed of Nangudga Lake, including the entrance channel, is Crown land. Landowner consent from the Department of Lands is therefore required before works on the Crown land can be undertaken. A single licence can be obtained from Lands covering entrance management of all coastal lakes in the Shire, to be reviewed and renewed concurrently with the review of this Policy.

13.4 Fisheries Management Act 1994

Within the Fisheries Management Act 1994, reference should be made to Sections 200 and 201, regarding a dredging licence (or the need for Department of Lands to consult with Fisheries in providing a Crown Lands licence), as well as Section 205 in respect to harming of marine vegetation.

13.5 Threatened Species Conservation 1995; and Commonwealth Environmental Protection and Biodiversity Conservation (EPBC) Act 1999

Consideration needs to be given to potential harm or damage to threatened species and listed migratory species. Transportation of heavy equipment onto the entrance will also need to consider potential damage to known Aboriginal sites.

13.6 Marine Park Act 1997

Nangudga Lake is located within the Batemans Marine Park, as a Sanctuary Zone, representing the highest level of protection in the Park. Consent is required from the

Minister under the provisions outlined in the Marine Parks Regulations 2009, to open the entrance (on the basis that the works will potentially harm marine animals, including beach invertebrates through the actually physical excavation works).

13.7 Coastal Protection Act 1979

Consideration needs to be given to Sections 38 and 39 of the Act, requiring concurrence by the Minister for undertaking development works within the coastal zone. The proposed entrance works at Nangudga Lake is within the coastal zone as defined by the Act.

13.8 State Environmental Planning Policy 71 – Coastal Protection

Development proposed within "sensitive coastal locations" needs to be referred to the Minister for comment. Schedule 1 of SEPP-71 specifically lists Nangudga Lake (near Narooma) as a sensitive coastal location, along with most other coastal lakes in NSW.

Title:

Location of Nangudga Lake Entrance Opening Works

Figure: N-1

Rev: A

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

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Approx. Scale

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APPENDIX B: REVIEW OF KEY RELEVANT LITERATURE

Flood and drought impacts in the opening regime of Tuross Lakes (Rustomji, 2007)

Interaction of terrestrial and marine influences controls the opening regime of the estuary. During floods, the estuary is filled and the estuary mouth is scoured, allowing for greater tidal exchange with the ocean and greater tidal range inside the estuary. During low river flow, combined with evaporative losses from the estuary and low ocean wave activity, the estuary mouth may close completely.

The fewer flood-driven scour events since 2000 explains the congested to closed state of the estuary mouth. Hydrologic variability has resulted in large variations in the estuary's opening regime. This variability in the opening regime is likely to be enhanced in the future due to predicted hydrologic changes due to climate change.

It is both the flood-tide delta as well as the coastal barrier (or entrance berm) which restrict the flow of seawater through the mouth, resulting in reduced tidal amplitudes within the estuary. [ie the flood tide delta restricts by reducing tidal velocities, not just the closed mouth]

The coastal barrier may be breached due to floodwaters from the river increasing the estuary water level above the height of the barrier, and scouring a channel.

There is also evidence at Tuross that the barrier may be breached due to erosion from a large coastal storm, which occurred during the May 1974 storms.

More commonly, there is overwash into the estuary due to high ocean water levels (storm surge) and waves during a coastal storm (but this doesn't result in a breach of the entrance). The predominant force for entrance opening is high lake water levels due to floods.

Rustomji (2007) cites Jones and West (2005) as indicating that the effects of artificial opening of the estuary may be unpredictable [ie, not always the desired or a good outcome]; and cites Pollard (1994) as indicating that in some cases there are negative impacts upon seagrass beds and fish populations resulting from artificial opening. Further, formulation of management guidelines is frequently hampered by a lack of information about the natural or characteristic opening regime of the estuary.

"Longer term changes in the opening status of the estuary [is] attributable to decadal-scale hydrologic variability".

The study finds that it is the effects of "highly variable precipitation and run-off rates" that alter the estuary's opening regime, while coastal processes play less of a role in opening. (more important for closure).

Tuross is defined as a wave-dominated estuary, which are defined as having a "supra-tidal berm or barrier at their mouth, a sandy flood-tide delta extending into a central mud-basin lagoon and at their landward ends, a river with prograding floodplain" (Rustomji, 2007 citing Thom et al. 1981; Dalrymple et al. 1992).

Tuross has a surface area of 13.3 km^2. The estuary geomorphic features include a prograding birdsfoot river delta, central mud basin, a flood tide [sand] delta, and a coastal barrier composed of quatzose marine sand. The Tuross River catchment is described as predominantly forested with agriculture [clearing] at the headwaters of the catchment and on the lower valley floodplains.

Lower catchment mean monthly rainfall is 60-140 mm, and mean annual rainfall of 800-1000 mm. Regional peak daily rainfall of 200-360 mm have been recorded, and which typically results in flooding.

The largest recorded flood was in 1992 with a peak daily mean flow discharge of 1590 m3/s (water level estimated at +2.0 m AHD). Other large floods (exceeding 1400 m3/s) occurred in 1991 (water level estimated at +1.7 m AHD) and 1978. Largest flood in living memory occurred in 1971, with levels approx +3 m AHD reported.

The berm (which would have been partially eroded from 1971 flood anyway) was completely eroded during the 1974 storms with high seas and large waves. Mouth still largely open by 1975 (observed in satellite imagery).

Historically, breaches have occurred at the southern end, recent breaches have occurred at the northern end.

The cross sectional area of the estuary mouth inferred from tidal observations (ie tidal range). Rustomji (2007) illustrated (with equations) that daily tidal (water level) range (as recorded by the gauge inside the estuary) is directly linked with the openness of the estuary mouth: when the expression of the tidal range within the estuary is large, the estuary mouth may be inferred as being in a relatively open state; when the tidal range is minimal to none, the mouth may be inferred to be partially to fully closed. Also used water level measurements (where they were persistent of systematic) to infer a minimum berm elevation.

Rustomji examined the offshore wave climate. Longshore sediment transport, which allows for the building of the entrance berm, is variable and dependant upon the wave climate. Under ENSO, it is typically observed that net northerly transport is increased under predominant SE swell. During La Nina, net northerly transport is weakened with an increase in E to NE swells, and in addition, gross transport to the south during these conditions may erode northern ends of coastal barriers.

Rustomji (2007) found that wave climate and ENSO co-variance has decreased since the late 1990s, with inter-annual variation not evident over the last 3 – 7 years. In this case, the recent opening regime of Tuross is found to be unlikely to have been affected by ENSO-driven variation in the offshore wave climate. (Implying that closure is not *controlled* by wave climate, even though this is the *mechanism* of closure).

“The decline in tidal range [between 1994 and 1997] indicates that the Tuross estuary mouth became increasingly constricted (though not completely sealed) by both tidal and wave activity, supporting a perched estuarine water level and the absence of major floods prevented scouring of the estuary mouth”. What is important here is that swell wave conditions (and which are not necessarily being affected by ENSO, although still likely to be variable at an annual scale) are resulting in berm building, but without flood flows, there is no scouring and therefore the entrance becomes constricted.

In addition, actions by council to breach the estuary were short lived, even if the mouth remained open. Rustomji (2007) reports tidal range in the estuary returning to pre-breach levels within 4 months of opening the estuary (June 2006 opened, November 2006 water level range the same). Over that period, there had been only a marginal increase in daily water level range. While river flow inputs were roughly matched by daily evaporation, estuarine water levels were contributed to by wave spillover, retained within the estuary. However, following the artificial breach in June 2006, river inputs again fell below daily evaporation, and there was no contributing wave spillover. The mouth fully closed and the water level in the estuary fell to -0.11 m AHD.

Following a flood in February 2007 (11^{th} – 13^{th}), the council again opened the entrance. The flood was relatively small, and eroded only a small channel through the berm. Within 8 days of the artificial breach, the water level range was again constricted to < 0.1 m, even though the mouth was open. It was apparent that the opening did not erode a large enough amount of the flood tide delta to enable sufficient exchange across the estuary mouth. That is, even if the mouth is open, if the cross sectional area of the channel is small and/or the flood-tide delta remains large, the estuarine tidal range will remain limited.

Rustomji (2007) concludes that floods are the principal mechanism for opening the estuary mouth. During drier periods, tidal and wave activity is further enabled to build the berm, reducing the cross sectional area available for tidal exchange (even as the mouth may remain open). Over the long term, with the complete erosion of the barrier during the 1974 storm waves and water levels being an exceptional event, it is concluded that marine processes are of lesser importance. Hydrology dominates the opening regime, thus inter-decadal variation in flood activity affects the scouring frequency [and effectiveness of scouring] of the estuary mouth.

Floods fill the estuarine lagoon, raising the water level until a breach of the barrier is initiated.

Typical maximum pre-breach water levels of 1.5 to 3.0 m AHD are indicated from the historical data.

Under non-flood conditions, mean water levels typically range from 0.1 – 0.4 m AHD.

Therefore, a 1.5 m increase in water level is required to initiate a breach. That is, assuming a typical pre-flood water level of ~0.25m AHD, a 1.5 m water level increase provides potentially 2 m hydraulic head at the estuary mouth at low tide between estuary and ocean.

Based on a predicted flow (>19.5 x 10^6 m3) required to increase water levels by 1.5 m, the following conclusions are drawn from the rainfall run off models:

- There is strong inter-annual to inter-decadal variability in flood activity
- 1901-1944 was a drier period with an estimated ~5-15 scour events per decade
- The 1950s exhibited a marked increase in rainfall and so, flood activity, and likewise, a dramatic increase in the minimum number of scour events is estimated.
- After the 1950s, there has been a decreasing trend in the number of scour events per decade. The period since 2000 has no estimated scour events.

Following a flood, entrance closure processes (ie, waves and tides) recommence within days. Following a major natural breach, it may take as long as 2-5 years for the entrance to constrict to decrease daily tidal range to ~0.2 m. In contrast, breaching by relatively small floods, or the artificial breaches of Tuross in June 2006 and February 2007, resulted in only a small and short lived impact upon tidal range within the estuary.

Rustomji (2007) notes that it is not just the channel dimensions or capacity through the berm, but the presence and size of the flood tide delta which restricts the tidal range. The flood-tide delta may reach an elevation close to MSL and cover several km^2 in area. Small floods lack the water capacity to erode the flood tide delta, in addition to scouring the channel.

Rustomji (2007) schematic model description:

- Under normal flow conditions, the moderate stream flow is typically sufficient to keep the mouth open in Tuross.
- Under drought conditions, wave and tidal activity enlarges the flood-tide delta, and water exchange is restricted. During autumn and winter, water levels may rise above mean sea levels as a result of wave activity building the barrier and wave spillover into the estuary. During summer, falling wave heights and enhanced onshore sediment transport may close the estuary mouth completely. High evaporation and low river flow during summer will result in lowering of estuarine water levels (possibly below sea level).
- Under flood conditions, flood waters will breach the entrance barrier and scour a channel. “Erosion and transport of the flood-tide delta sediments out of the estuary is related to flood size and duration”

Future regimes due to climate change:

- A predicted increase in the magnitude of extreme rainfall events in combination with a decrease in annual rainfall is expected to result in a more variable river flow regime.
- Not considering changes in sea level and coastal storm activity, and its potential impact upon coastal barriers, the predicted changes to rainfall and subsequent river flow would mean that future floods are larger, scouring a greater entrance channel, but the reduced river inflow between floods would mean that entrance closure between floods would occur more quickly.

Response of Estuaries and Coastal Lakes to Total Nitrogen Loading (Sanderson et al, 2006).

Sanderson et al., (2006) make some general comments about nutrient exchange in coastal lakes. Biologically active nitrogen may enter a coastal lake / estuary from the catchment, ocean and atmosphere. Under certain conditions, the process of denitrification will enable dissolved inorganic nitrogen to be converted to nitrogen gas (and lost to the atmosphere).

When the entrance of the estuary/lagoon/lake is open, nitrogen will be exchanged with the ocean.

In certain conditions, some organisms can fix nitrogen gas from the atmosphere for biological use.

It is thought that, increased total nitrogen loads from the cathcment, where all else remains equal, may shift a system towards a higher eutrophic state. There may be some ability for the denitrification process to balance the nitrogen load, but a sufficiently increased load may be too large to be processed by the denitrification process (ie, there are likely to be limits to any natural denitrification process), and which shall result in more anoxic conditions at the sediment water interface and an increased availability of nutrients for phytoplankton blooms. Increased nutrient loads can also increase light attenuation in the water column [due to increased phytoplankton populations clouding water?], damaging benthic macrophytes (seagrass). These issues may occur even when there is tidal exchange in the lake/ estuary.

In addition to increased nutrient loading, modified catchments also result in increased sediment loads, acidic runoff, and pollutants such as pesticides and herbicides entering the lake / estuary. Introduced exotic species will also affect the native biota, particularly where such species are better adapted to the changed water conditions from changed catchment runoff. Hydrologic mechanisms (water volumes and velocities) may also be modified by a modified catchment. All of these factors may have negative affects, and reduce the health, structure and function of lake / estuary ecosystems.

Nitrogen was assessed, as, of all the macronutrients, nitrogen is considered to be the most significant control on primary production in coastal lakes and estuaries. Nitrogen comes in a variety of chemical forms, and is easily transferred from one form to another. In the case of coastal lakes, actual measurements of each of the potential forms is rarely available, and typically, total nitrogen is calculated, which gives the overall nitrogen balance. The CCA study assigned a particular total nitrogen load per unit of land area according to land use. Runoff into the lakes was determined using flow gauges, rainfall and water level measurements.

Depth is also a key consideration, as this determines light availability for benthic primary production. Depth / bathymetry also governs/controls hydrodynamic conditions (ie, tidal mixing, fluvial flow and mixing).

A number of key assumptions about nutrients in coastal lakes were made, and which may apply to the lakes here:

- Denitrification is difficult to measure and highly variable. However, the study assumed that a lake with a larger area will denitrify more than a lake with a smaller area
- Primary production is dependant upon incoming photosynthetically active radiation (PAR) – and again, the larger the lake area, the greater the PAR
- The amount of nutrient arriving from the catchment depends upon the land use (ie, export rate per unit area is greatest for dairy farms and urban developments and lowest for undisturbed native vegetation) and the area (size) of the catchment.
- Thus, the areal loading rate will depend upon the input of nitrogen (ie, export rate times area) divided by the area of the lake (which will limit the ability of the lake to dentrify, as larger lakes have higher denitrification rates)
- And so, the degree of eutrophication will increase with an increase in the areal loading rate. The study states that systems with a high areal loading rate require high exchange or flushing with the ocean to avoid eutrophication.
- The biogeochemical model used in the study treats denitrification as a function of sediment respiration. The efficiency of denitrification increases to a point (said to be 6.65 mg-N/m2/day), after which the efficiency drops off, resulting in a larger proportion of decomposing detritus becoming dissolved inorganic matter, reducing oxygen levels in the sediment, and compromising water quality.

- Thus, where exchange is limited, denitrification then becomes key in determining the WQ of the system. Coila is suggested to have input loads below the denitrification efficiency limit, and so may still increase its efficiency with increased inputs (there is still a buffer).
- The frequency of opening is seen to be a scale of ratio of catchment area to waterway area – so Coila, with a small catchment to waterway ratio will open less frequently.
- Likewise, the nutrients will be flushed from the system more quickly where the ratio of catchment to waterway area is large – again, Coila will then be flushed more slowly, and retain inputs more readily, allowing the nutrient load to be available for use by the biota.
- Having said this, the small catchment to waterway area, it is argued by Sanderson et al (2006), means that lakes such as Coila are less sensitive to nutrient input (and so, better able to cycle the nutrients) because there is less runoff and so, less nutrient input (and Coila additionally is on its way up the denitrification efficiency scale).
- A simple assumption to determine the effectiveness of benthic primary production (seagrass, microphytobenthos) was based upon light availability. They assumed a highly simplified model with one variable representing material in the water column that attenuates light and the variable increases with nitrogen loading, and which then comes back to areal loading rates for each estuary [there are some more calculations in there, but really, this is what they have assumed]. That is, apart from existing bathymetric constraints which limit light availability at depth at present this assumption basically means that light availability, and so, benthic primary production, reduces as nitrogen loads increase (and there was no consideration of water level also limiting light availability). Not surprisingly, then, the critical value for benthic production in this assumption is entirely dependant upon areal loading rate, and therefore, lakes with a low rate have a higher/ more viable benthic primary production.

APPENDIX C: EIGHT (8) PART TESTS FOR ASSESSMENT OF IMPACTS TO THREATENED SPECIES AND ENDANGERED COMMUNITIES

Eight part test for Threatened Avifauna

This eight part test is for Threatened avifauna known to occur at Coila Lake and Tuross Lakes (Hooded Plover, Pied Oystercatcher, Little Tern, Lesser Sand Plover and Black-tailed Godwit), and Shy Albatross known to occur at Coila Lake.

1. In the case of a threatened species, whether the life cycle of the species is likely to be disrupted such that a viable population of the species is likely to be placed at risk of extinction.

The life cycles of Threatened avifauna species within the areas of interest could potentially be disrupted by actions associated with entrance management (e.g. direct disturbance of Little Tern breeding sites at the southern end of the Tuross estuary). However, the Entrance Management Policies have taken this into consideration and specified that disruption to activities such as breeding should be mitigated. Furthermore, direct disruptions will be over a short-term period, such that the life cycles of Threatened avifauna species will not be significantly compromised. Therefore, the risk of Threatened avifauna population extinction within the areas of interest is highly unlikely.

2. In the case of an endangered population, whether the life cycle of the species that constitutes the endangered population is likely to be significantly compromised.

No Endangered populations have been recognised for the Threatened avifauna species within the area of interest.

3. In relation to the regional distribution of the habitat of a threatened species, population or ecological community, whether a significant area of known habitat is to be modified or removed.

No areas of Threatened avifauna habitat will be removed. A proportion of habitat may be modified through changed hydrological behaviour; however, these modifications are representative of natural variability as the Entrance Management Policies aim to restore more natural hydrological regimes to the lakes.

4. Whether an area of known habitat is likely to become isolated from currently interconnecting or proximate areas of habitat for a threatened species, population or ecological community.

The proposed activity will not affect the connectivity of habitat for Threatened avifauna within the areas of interest, nor will it fragment habitats such that they may become progressively isolated.

5. Whether critical habitat will be affected.

No critical habitat for Threatened avifauna species has been listed within the areas of interest.

6. **Whether a threatened species, population or ecological community, or their habitats, are adequately represented in conservation reserves (or similar protected areas) in the region.**

The Threatened avifauna and their habitats are not well represented in conservation reserves on a regional scale; however, the proposal will not reduce the amount of Threatened avifauna habitat.

7. **Whether the development or activity proposed is of a class of development or activity that is recognised as a threatening process.**

Yes.

8. **Whether any threatened species, population or ecological community is at the limit of its known distribution.**

No Threatened avifauna species are at their limit of known distribution within the areas of interest.

Conclusion

The Entrance Management Policies proposed for Coila Lake and Tuross Lakes is highly unlikely to have any significant adverse impacts on the Threatened avifauna populations or their habitats.

Eight part test for *Wilsonia rotundifolia*

This eight part test is for *Wilsonia rotundifolia*, an Endangered flora species present at Coila Lake.

1. **In the case of a threatened species, whether the life cycle of the species is likely to be disrupted such that a viable population of the species is likely to be placed at risk of extinction.**

The life cycle of *W. rotundifolia* will not be disrupted through entrance management of Coila Lake, such that the population is highly unlikely to be placed at risk of extinction.

2. **In the case of an endangered population, whether the life cycle of the species that constitutes the endangered population is likely to be significantly compromised.**

The life cycle of *W. rotundifolia* will not be disrupted through entrance management of Lake Coila.

3. **In relation to the regional distribution of the habitat of a threatened species, population or ecological community, whether a significant area of known habitat is to be modified or removed.**

No area of *W. rotundifolia* habitat will be removed. An area of habitat may be subject to occasional inundation due to increased water levels. However, the position of this species in the mid-marsh zone of saltmarsh communities means that a large proportion of habitat is not expected to be impacted. Furthermore, *W. rotundifolia* is a saltmarsh species that is able to withstand, and possibly benefit from, inundation events (Spurway et al. 2000).

4. Whether an area of known habitat is likely to become isolated from currently interconnecting or proximate areas of habitat for a threatened species, population or ecological community.

The proposed activity will not affect the connectivity of *W. rotundifolia* habitat, nor will it fragment habitats such that they may become progressively isolated.

5. Whether critical habitat will be affected.

No critical habitat has been listed for this species.

6. Whether a threatened species, population or ecological community, or their habitats, are adequately represented in conservation reserves (or similar protected areas) in the region.

The species itself is not well represented within conservation reserves, largely due to the limited distribution of the species. However, saltmarsh habitat is adequately represented in conservation reserves.

7. Whether the development or activity proposed is of a class of development or activity that is recognised as a threatening process.

Yes

8. Whether any threatened species, population or ecological community is at the limit of its known distribution.

The *W. rotundifolia* population at Lake Coila is not at the limit of its known distribution.

Conclusion

The Entrance Management Policy proposed for Coila Lake is highly unlikely to have any significant adverse impacts on the *W. rotundifolia* population or its habitat.

Eight part test for wetland Endangered Ecological Communities

This eight part test is for the two wetland Endangered Ecological Communities known to be present within the project area, specifically:

- *Swamp Oak floodplain forest of the NSW North Coast, Sydney Basin and South East Corner Bioregions* - present surrounding Coila, Tuross, Kianga, Little and Nangudga Lakes.
- *Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South West Corner Bioregions* – present surrounding Coila, Tuross, Little and Nangudga Lakes.

1. In the case of a threatened species, whether the life cycle of the species is likely to be disrupted such that a viable population of the species is likely to be placed at risk of extinction.

Not applicable as this relates to threatened species; however, it is noted that the life cycles of species constituting the wetland Endangered Ecological Communities are highly unlikely to be disrupted, such that the viability of these Endangered Ecological Communities is not expected to be impacted.

2. In the case of an endangered population, whether the life cycle of the species that constitutes the endangered population is likely to be significantly compromised.

Not applicable as this relates to threatened species (and see above).

3. In relation to the regional distribution of the habitat of a threatened species, population or ecological community, whether a significant area of known habitat is to be modified or removed.

No area of the wetland Endangered Ecological Communities will be removed. Although certain areas of Endangered Ecological Communities may be subject to occasional inundation due to increased water levels, these vegetation communities are able to withstand, and possibly benefit from, inundation events (e.g. see Spurway et al. 2000).

4. Whether an area of known habitat is likely to become isolated from currently interconnecting or proximate areas of habitat for a threatened species, population or ecological community.

The proposed activity will not affect the connectivity of wetland Endangered Ecological Communities habitat, nor will it fragment habitats such that they may become progressively isolated.

5. Whether critical habitat will be affected.

No critical habitat will be affected.

6. Whether a threatened species, population or ecological community, or their habitats, are adequately represented in conservation reserves (or similar protected areas) in the region.

The wetland Endangered Ecological Communities are represented in conservation reserves and similar protected habitats; however, it is also to be noted that the proposal will not reduce the extent of any Endangered Ecological Communities.

7. Whether the development or activity proposed is of a class of development or activity that is recognised as a threatening process.

No

8. Whether any threatened species, population or ecological community is at the limit of its known distribution.

Neither of the wetland Endangered Ecological Communities are at the limit of their known distribution.

Conclusion

The Entrance Management Policies proposed for the relevant lakes (i.e. Coila, Tuross, Kianga, Little and Nangudga Lakes) are highly unlikely to have any significant adverse impacts on the wetland Endangered Ecological Communities.

Eight part test for terrestrial Endangered Ecological Communities

This eight part test is for the two terrestrial (i.e. non-wetland) Endangered Ecological Communities known to be present within the project area, specifically:

- *Bega Dry Grass Forest* - present in the vicinity of Coila Lake.
- *Bangalay Sand forest of the Sydney Basin and South East Corner Bioregions* – present in the vicinity of Coila, Kianga, Bullengella and Nangudga Lakes.

1. In the case of a threatened species, whether the life cycle of the species is likely to be disrupted such that a viable population of the species is likely to be placed at risk of extinction.

Not applicable as this relates to threatened species; however, it is noted that the life cycles of species constituting the terrestrial Endangered Ecological Communities are highly unlikely to be disrupted, such that the viability of these Endangered Ecological Communities is not expected to be impacted.

2. In the case of an endangered population, whether the life cycle of the species that constitutes the endangered population is likely to be significantly compromised.

Not applicable as this relates to threatened species (and see above).

3. In relation to the regional distribution of the habitat of a threatened species, population or ecological community, whether a significant area of known habitat is to be modified or removed.

No area of the terrestrial Endangered Ecological Communities will be removed. Furthermore, the position of the Endangered Ecological Communities in the landscape is such that inundation is highly unlikely and consequently no impacts to these communities are expected.

4. Whether an area of known habitat is likely to become isolated from currently interconnecting or proximate areas of habitat for a threatened species, population or ecological community.

The proposed activity will not affect the connectivity of terrestrial Endangered Ecological Communities habitat, nor will it fragment habitats such that they may become progressively isolated.

5. Whether critical habitat will be affected.

No critical habitat will be affected.

6. Whether a threatened species, population or ecological community, or their habitats, are adequately represented in conservation reserves (or similar protected areas) in the region.

The terrestrial Endangered Ecological Communities are represented in conservation reserves and similar protected habitats; however, it is also to be noted that the proposal will not reduce the extent of any Endangered Ecological Communities.

7. Whether the development or activity proposed is of a class of development or activity that is recognised as a threatening process.

No

8. Whether any threatened species, population or ecological community is at the limit of its known distribution.

Neither of the terrestrial Endangered Ecological Communities are at the limit of their known distribution.

Conclusion

The Entrance Management Policies proposed for the relevant lakes (i.e. Coila, Kianga, Bullengella and Nangudga Lakes) are highly unlikely to have any significant adverse impacts on the terrestrial Endangered Ecological Communities.

APPENDIX D: COMMUNITY BROCHURES

Managing the Coila Lake Entrance

An Entrance Management Policy for long term sustainability

Why manage the entrance?

Coila Lake is an important natural waterway. It's ecology and habitats have adapted to it's unique behaviour of sometimes being open and sometimes being closed to the ocean.

Urban and rural development around the foreshores of the lake means that flooding may occur when lake levels are high and the entrance is closed. In accordance with Coila Lake Entrance Management Policy, Council will artificially open the entrance of the lake when foreshore flooding becomes excessive.

In an effort to minimise future artificial intervention, the Policy also targets flood risk management around the foreshores. In time, it is hoped that all significant development around the lake's edges has been raised, relocated or flood-proofed so that the lake entrance can be left to open more naturally.

Future climate change, and sea level rise in particular, also means that Council needs to start planning carefully for future development on low-lying lands surrounding all coastal lakes and estuaries in the Shire, including Coila Lake.

In brief

1. Coila Lake entrance will be opened when:
   - Water level reaches 2.0m AHD(*), or
   - Water level exceeds 1.8m AHD for > 3 months
2. Authorities will be notified before opening the entrance
3. A pilot channel will be excavated (~10m wide and 2m deep) to initiate entrance breakout
4. The trigger level for entrance opening will be increased progressively in the future in response to sea level rise

(*) AHD = Australian Height Datum. Zero AHD is approx. mean sea level

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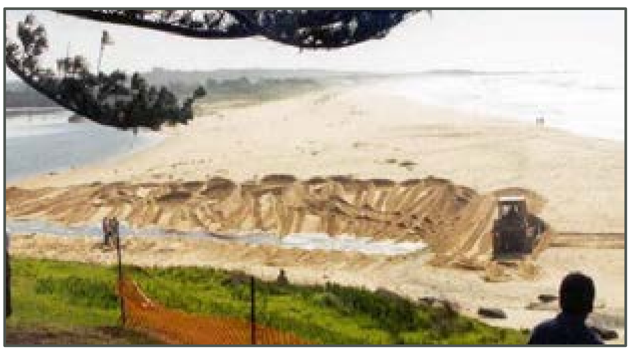

Next steps

Open entrance when required, as per the Entrance Management Policy	Now
Establish alternative access for the private rural track north of Coila Creek to allow lake levels to reach 2.6m AHD	5-10yrs
Provide incentives to rural landowners to accommodate higher lake levels	10-30yrs
Progressive and opportunistic raising of low lying roads	10-50yrs
Progressive and opportunistic raising or removal or flood-proofing of foreshore assets, such as stormwater and sewerage infrastructure to a level above 3.0m AHD	10-50yrs
Progressive raising of minimum floor levels for new development around Coila Lake, taking into account sea level rise, flood planning guidelines and minimal entrance intervention	10-100yrs

Want more information?

Contact Eurobodalla Shire Council
Coastal and Flood Management Policy Officer
Norm Lenehan 4474 1374
Vulcan Street, Moruya

January 2010

Managing the Tuross Lakes Entrance

Why manage the entrance?

Over the past 10 – 15 years, the NSW south coast has experienced severe drought. Because of the reduced flow from the catchment, the entrance of Tuross Lakes is now subject to closure – a condition that has not been experienced since the late 1800s.

When the entrance is closed, due to sand build-up across the beach, local rainfall can increase water levels in the lake. As the height of the sand berm can be high (more than 2m above mean sea level), the water levels in the lake need to be high before the lake entrance can break-out naturally.

If lake levels get high (because of a closed entrance), but not high enough to cause an entrance break-out, then rural properties and development around the foreshores will be inundated, potentially for a long time if there is no further rainfall to initiate a break-out.

A policy is required whereby the entrance is artificially opened if water levels get too high and start to impact on the welfare of the community. A policy is also required so that Council can start planning carefully for future climate change, and sea level rise in particular. This would include ensuring that appropriate future development in not placed in vulnerable areas around lake foreshores.

In brief

1. Tuross Lakes entrance will be opened when:
   - Water level reaches 2.0m AHD(*), or
   - Water level exceeds 0.8m AHD for > 2 weeks
   - Levels and durations may be negotiable during holiday periods
2. Close monitoring of water levels and catchment rainfall will commence when water levels > 0.7m AHD
3. Authorities will be notified before opening the entrance
4. A pilot channel will be excavated (~10m wide and 2m deep) to initiate entrance breakout
5. Trigger levels for entrance opening will be increased progressively in the future in response to sea level rise

(*) AHD = Australian Height Datum. Zero AHD is approx. mean sea level

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Next steps

Open entrance when required, as per the Entrance Management Policy	Now
Convert timber decks of commercial properties to floating pontoons to allow for sustained higher water levels (up to 1.2m AHD)	5-10yrs
Progressive and opportunistic raising or removal of foreshore assets, such as sewage pump station	10-30yrs
Progressive and opportunistic raising of low lying roads, including Hector McWilliams Drive at the Narrows, to allow for future water levels up to 3.0m AHD	10-50yrs
Opportunistic filling of private non-rural properties, unless adjacent to SEPP-14 wetlands	10-100yrs
Progressive raising of minimum floor levels for new development around Tuross Lakes, taking into account sea level rise and a future closed entrance condition	10-100yrs

Want more information?

Contact Eurobodalla Shire Council
Coastal and Flood Management Policy Officer
Norm Lenehan 4474 1374
Vulcan Street, Moruya

January 2010

Frequently Asked Questions about Tuross Lakes entrance

Why is the entrance closed?

The entrance has closed recently because there is not enough water flowing out of the Tuross River catchment to keep the entrance open. This is because of the long drought across the NSW south coast, which has persisted for more than 10 years.

Has pumping from the river been a factor in its closure?

There is some licenced extractors in the Tuross River, including Council. However, extractions cease when river flows become low. The total amount of extraction from the river (when permitted) is generally small compared to river flows, and less that what would evaporate from the lake surface.

Where does the sand in the entrance come from?

The sand in the entrance is all *marine sand*. This means that it comes from the beach and nearshore ocean environment. Marine sand is slowly pushed from south to north along the coastline between Potato Point and Tuross Head. The sand in the entrance is not from soil erosion within the catchment.

Can we keep the entrance open all the time?

Tuross Lakes is an Intermittently Closed and Open Lake or Lagoon (ICOLL for short). There are more than 100 ICOLLs along the NSW coast, mostly occurring on the south coast. ICOLLs are sometimes open and sometimes closed, depending on the prevailing catchment and ocean conditions.

To keep Tuross Lakes open permanently would require twin breakwaters at the entrance, such as at Wagonga Inlet (Narooma), or a permanent dredging program, such as at Tuggerah Lakes (The Entrance). Both of these options would likely be very costly, requiring significant funding from all levels of Government.

Why can't we open the entrance at lower levels?

One of the key objectives of artificially opening the entrance is to induce significant scouring as the water rushes out of the lake. This scouring creates an entrance channel that can then stay open for while allowing tidal flushing and exchange between the ocean and the lake. Scouring of a channel will only occur when the water level in the lake is much higher than the ocean level. That is, there is a 'head' of water to scour out the entrance.

If the entrance was to be opened when the lake levels were low, there would be little scouring and only a small channel would form. Sand would like fill this channel and re-close the entrance very quickly (within days).

What about the dolphins?

Three dolphins (2 adults and a juvenile) have been trapped in Tuross Lakes since it last closed in late 2008. State authorities (DECCW and DII-Fisheries) are keeping a close eye on the dolphins. To date, they have maintained good health.

What about the oyster farms?

Farming oysters in Tuross Lakes has been getting harder over the past decade or so. With a closed entrance, farmers have resorted to manually lifting racks out of the water on a periodic basis to prevent parasite attack (something that the tide use to do naturally). Although it requires extra effort, the oyster farms are able to continue, largely due to the good water quality that is preserved within Tuross Lakes.

What about the mangroves?

Mangroves around the shores of Tuross Lakes have been under stress for a number of years. When water levels remain high, their peg roots (pneumatophores) become submerged. As the trees 'breathe' through these roots, they effectively drown under continued high water. When the lake returns to tidal conditions with an open entrance, the mangroves should return to good health.

What about fish stock?

There is no recruitment of fish stock from the ocean when the entrance is closed. But there is also reduced predation by bigger fish. Research has found that ICOLLs that are mostly closed typically have fewer species of fish, but the fish are generally in higher numbers and are larger in size.

Will climate change and sea level rise make the situation worse?

Longer and more frequent dry spells along with reduced annual rainfall are expected with future climate change. Therefore, closed entrance conditions may become more common in the future.

Projected sea level rise will result in higher sand levels at the entrance when it is closed. This means that lake levels will need to be even higher in the future in order to initiate effective break-out channels.

The Eurobodalla coastline is considered one of the most sensitive parts of the country to future sea level rise given the large number of coastal lakes and estuaries, and their fringing low-lying coastal lands.

Managing the Kianga Lake Entrance

An Entrance Management Policy for long term sustainability

Why manage the entrance?

Kianga Lake is a small and sensitive coastal lake, located between Kianga and Dalmeny. It is mostly covered by seagrass and is gazetted a Sanctuary Zone in the Batemans Marine Park.

The extensive seagrass beds, combined with widespread macroalgae, means that the lake can have a foul smell when the water levels are low.

It is desirable to restore the natural opening cycle of Kianga Lake so that it gets regular flush-outs and limits the build-up of decaying organic matter. The prolonged drought experienced in South East NSW over the past decade or so, however, has limited the number of natural break-out events in recent years.

Further, development has occurred around the foreshores of the lake, which becomes vulnerable to inundation when lake levels are high.

A policy is required that allows the entrance of Kianga Lake to be opened artificially when lake levels are too high. A policy is also required for Council to start considering future climate change and its potential impacts on low lying coastal environments such as Kianga Lake.

In brief

1. Kianga Lake entrance will be opened when:
   - Water level reaches 2.0m AHD(*), or
   - Water level exceeds 1.8m AHD for > 2 weeks
2. Authorities will be notified before opening the entrance
3. A pilot channel will be excavated (~2 - 5m wide and 1m deep) to initiate entrance breakout
4. The trigger level for entrance opening will be increased progressively in the future in response to sea level rise

(*) AHD = Australian Height Datum. Zero AHD is approx. mean sea level

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Next steps

Open entrance when required, as per the Entrance Management Policy	Now
Install a gauge board within the lake near the road bridge that clearly indicates the trigger level	Now
Infill crevices in rock shelf on the southern side of entrance to prevent premature lake discharge	As funding permits
Progressive and opportunistic raising of STP access road and Dalmeny coast road to allow lake levels up to 2.8m AHD	10-30yrs
Progressive and opportunistic raising or removal of foreshore assets (eg sewage pumping station) to allow lake levels up to 2.8m AHD	30-100yrs
Progressive raising of minimum floor levels for fringing development, with ultimate retreat from lowest lying properties	10-100yrs

Want more information?

Contact Eurobodalla Shire Council
Coastal and Flood Management Policy Officer
Norm Lenehan 4474 1374
Vulcan Street, Moruya

January 2010

Managing the Little Lake Entrance

An Entrance Management Policy for long term sustainability

Why manage the entrance?

Little Lake is located behind the ocean beach at Narooma, surrounded by the Narooma Golf Course. For most of the time, the entrance of Little Lake is closed, meaning that there is no regular exchange of water between the lake and the ocean.

When the entrance is closed, rainfall and local catchment runoff can fill the lake. The water level in the lake has to be quite high before it overtops the entrance sand berm and spills to the ocean. If rainfall fills the lake without the entrance opening naturally, then some sections of Narooma Golf Course can be inundated. At very high levels, Glasshouse Rocks (cemetery) Road can also be flooded.

A policy is required that allows the entrance of Little Lake to be opened artificially when lake levels are high. A policy is also required for Council to start considering future climate change and its potential impacts on low lying coastal environments such as around Little Lake.

In brief

1. Little Lake entrance will be opened when water level reaches 2.2m AHD(*)
2. Authorities will be notified before opening the entrance
3. A pilot channel will be excavated (~2 - 5m wide and 1m deep) to initiate entrance breakout
4. Council will close the immediate beach area during break-out due to hazardous outflow currents and potential poor water quality.
5. The trigger level for entrance opening will be increased progressively in the future in response to sea level rise

(*) AHD = Australian Height Datum. Zero AHD is approx. mean sea level

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Next steps

Open entrance when required, as per the Entrance Management Policy	Now
Install a gauge board within the lake near the entrance that clearly indicates the trigger level	Now
Minor filling and landscaping along the edges of 9th and 15th fairways to allow for lake levels up to 2.5m AHD	10-50yrs
Progressive and opportunistic flood-proofing of foreshore assets, such as the sewage pumping station building	10-30yrs
Filling of existing fairways, tees and greens, and/or partial course redesign to allow for lake levels up to 3.0m AHD	30-100yrs
Progressive and opportunistic raising of Glasshouse Rocks Road up to 3.0m AHD	50-100yrs

Want more information?

Contact Eurobodalla Shire Council
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Bullengella Lake Entrance Management Policy

What is the policy about?

Bullengella Lake is a small coastal lake that sits behind Handkerchief Beach, just south of Narooma. It is surrounded by private rural lands.

It is understood that Bullengella Lake hasn't been opened to the ocean for a number of decades. The large sand dunes at the entrance suggests that water levels in the lake would have to be very high before the entrance breaks-out and the lake spills into the ocean.

A policy is required to ensure that the entrance of Bullengella Lake is not artificially opened without giving due consideration to the need for opening, or the environmental impacts of such action. A policy is also required for Council to start considering future climate change and its potential impacts on low lying coastal lands.

In brief

Bullengella Lake is not to be opened artificially unless for emergency purposes or for facilitating the construction of essential community services / infrastructure.

Want more information?

Contact Eurobodalla Shire Council
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Managing the Nangudga Lake Entrance

An Entrance Management Policy for long term sustainability

Why manage the entrance?

Nangudga Lake is located to the south of Narooma. It is mostly shallow and opens to the ocean occasionally, following significant rainfall. The lake is gazetted a Sanctuary Zone in the Batemans Marine Park.

The Island View Holiday Park is located next to the lake, on low-lying land. When lake levels are high, water can back up into the Holiday Park through the drainage system. Some low-lying private lots and associated residences are also located around the shores of the lake.

The lake has been artificially opened in the past in order to relieve the impacts of flooding around the foreshores. This has generally been done by Council in a reactive manner.

A formal policy is required that allows the entrance of Nangudga Lake to be opened artificially when lake levels are too high. A policy is also required for Council to start considering future climate change and its potential impacts on existing and future development in low lying coastal environments such as around Nangudga Lake.

In brief

1 . Nangudga Lake entrance will be opened when water level reaches 1.3m AHD(*)

2. Authorities will be notified before opening the entrance

3. A pilot channel will be excavated (~2m wide and 1m deep) to initiate entrance breakout

4. The trigger level for entrance opening will be increased progressively in the future in response to sea level rise

(*) AHD = Australian Height Datum. Zero AHD is approx. mean sea level

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Next steps

Open entrance when required, as per the Entrance Management Policy	Now
Install a gauge near the road bridge that clearly indicates the trigger level	Now
Install flapgates to prevent backwater into Holiday Park and a stormwater sump pump, to allow lake levels up to 1.7m AHD	2-5yrs
Provide incentives to rural landholders to accommodate lake levels up to 2.0m AHD	10-30yrs
Opportunistic filling of private non-rural land, except adjacent to SEPP-14 wetlands to allow lake levels up to 2.4m AHD	30-100yrs
Progressive raising of the Old South Coast Road to 2.7m AHD	30-100yrs
Progressive raising of minimum floor levels for new development, taking into account an ideal trigger level of 2.4m AHD	30-100yrs

Want more information?

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