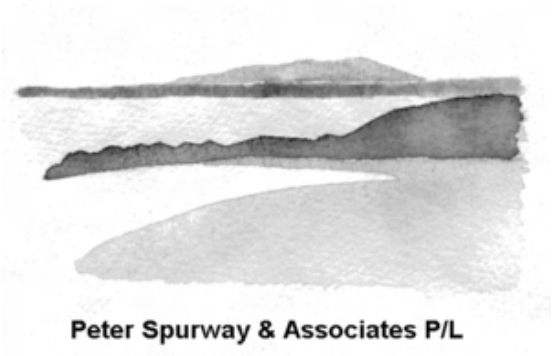

Shoalhaven City Council
Environment - Growth - Community

BURRILL LAKE - INTERIM ENTRANCE MANAGEMENT POLICY

May 2008

Adopted by Council May 2008

Prepared by

Peter Spurway & Associates Pty Limited
495 Bingi Road
Bingi 2537

BURRILL LAKE INTERIM ENTRANCE MANAGEMENT POLICY

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BURRILL LAKE INTERIM ENTRANCE MANAGEMENT POLICY

1 Purpose

This interim policy considers issues related to

- the recent closures of Burrill Lake entrance in 2005 and 2006
- blocking in 2005 of the previous ebb tidal channel across the entrance shoal
- impacts of lake closure on lake ecology, wetlands and water quality
- impacts on tourism / economy, recreation and amenity
- infrastructure levels and intervention levels in Burrill.

It is recommended that until the floodplain risk management plan documents Council's long term policy, a staged trigger approach for entrance management at Burrill Lake, including monitoring and procedural details, be adopted as an interim measure. A final entrance management policy would follow from the development of a Floodplain Risk Management Plan for the locality.

This interim policy should be read in conjunction with the Review of Environmental Factors for the Artificial Opening of Burrill Lake Entrance, which details the potential impacts of entrance openings.

Figure 1 Typical entrance channel configuration (1993 photography)

This Interim Policy and the associated Review of Environmental Factors were adopted by Council in May 2008.

2 Lake Entrance Issues

2.1 Entrance History

A history of entrance closure of Burrill Lake (**Table 1**) reveals that closure has been regular but infrequent. Certainly the lake does close from time to time, and can remain closed for long periods. The frequency of two recurrent closures in January 2005 and August 2006 is possibly uncharacteristic, compared to the historic record. Prior to 2005, the lake was last closed to the sea in 1987, and prior to then, in 1970.

Table 1 - Known and Reported Burrill Lake Closures during the Past 100 Years (updated from Shoalhaven City Council, 2002)

Closure Date	*Comments on closure & reopening*	*Source of Data*	*Authority of data*
1902	Manual opening	McAndrew (1993)	Note in Milton and Ulladulla Times, 26/7/1902
1908	Lake apparently closed for long period	McAndrew (1993)	Historical photograph
1914	Entrance being opened by horse and scoop January 1914	McAndrew (1993)	Historical photograph
1930	Unknown. Reputedly remained opened for 40 years	Smith (1987) pp 100	N Hooper, personal communication
1942	Major flood. Entrance manually opened. Prior to opening, inundation extended as far as the community hall	McAndrew (1993) pp 79	Recollection of Stan Rattey
1944-1986	No closure observed in aerial photos, though entrance heavily shoaled	SCC, Public Works, Patterson Britton and Partners (1992)	DLWC aerial photos
1957 or 58	Closed for approx 1 week. Manually opened by residents across sand dune	Peter Williams	Personal communication
1965-1970	South Coast inlets reported to be often closed in this period	Bentley (1976) quoted in Smith (1987)	
1968	Entrance being opened by manpower and shovels	McAndrew (1993)	Photograph
1970	Closed sporadically for most of 1970. Inlet naturally opened and closed 3 times before staying open	Smith (1987) identifies this as the most recent closure prior to 1987.	Unnamed local resident
1971	Spit breached by big swells		J Downey, pers comm
1974-1977	Breaching of entrance spit by 1974 storms		DLWC aerial photos
March, 1987	Closed for 4 months before apparent natural opening.	Smith (1987). Patterson Britton (1992) suggest lake was manually opened.	Smith personal observation
31 January 2005	Closed for 5 months following coastal storm. Manual opening by SCC on 25 June 2005 at 1.15m AHD	SCC	MHL Water Level records
5 August 2006	Lake was open for 13 months, closure following accretion of beach berm after heavy NE to E swells and lack of ebb channel conveyance.		Community observation
28 March 2007	Manual opening by SCC at 0.99m AHD.	SCC	MHL Water Level records
May / June 2007	Gradual closure followed by manual opening on 17 June at 1.38m AHD after heavy rainfall.	SCC	SCC survey

Figure 2 Entrance on the morning of 26 June 2005 following lake opening at 1.15m AHD the previous day

2.2 Discussion of Recent Lake Behaviour

The lake's two closures on 31st January 2005 and 5th August 2006 are viewed by the local community as unusual events. However they are natural events when viewed in terms of coastal sand dynamics and weather patterns.

The entrance to Burrill Lake, which was last opened on 25th June 2005 (**Figure 2**), finally closed again on 5th August 2006. Closure followed a period of months where the berm prevented egress of lake water at low tide.

Closure has followed a recent period of heavy sand build-up at the southern end of Burrill Beach, aided by a series of north-east to east swells late in July 2006. This was combined with a restricted ebb channel conveyance, probably aided by lower than average rainfall patterns over a period of many years.

Figures 3 and 4 show the changed shoaling pattern inside the lake mouth. The north-south ebb channel in 2001 (**Figure 3**) discharged most of the ebb tide from the lake, whereas the dead-end flood tide ramp in front of the Dolphins Point Tourist Park would have had limited ebb discharge capacity. The configuration of **Figure 3** is most common in the record of historical aerial photography (see **Appendix 1**) which dates back to the 1940s.

The lake entrance, approaching its 2006 closure in **Figure 4,** shows clearly how the beach spit has extended westwards, extending the length of the normal ebb channel. The loss of channel conveyance limited its ability to clear sand introduced into the mouth on flood tides, leading to eventual closure.

Figure 3 Entrance channel February 2001 in its most common location since aerial photograph records of the 1940s

Figure 4 Early 2006 image showing westward growth of shoal and realignment / lengthening of ebb channel

The main ebb channel crossing the entrance shoals was partially infilled by washover deposits a few years ago. This was worsened in March 2006 by easterly swells washing over the beach berm (*E. McLean, pers. comm*.). Washover of sand eroded from the beach face was deposited into the remnant north-south ebb channel (**Figure 5**) completely blocking the normal ebb tidal flow route.

Figure 5 Blockage in north-south ebb channel (August 2006)

This had resulted in a weakened tidal flow diverted to a shallow ebb channel running directly along the Dolphins Point Tourist Park embankment. Some resultant scour at the waterline at the western end of the Dolphins Point Tourist Park, and further west along the reserve, is evident. This is most likely a result of it performing as an ebb channel (**Figure 6)**. The major erosion face on the unprotected embankment is most likely the result of storm wave attack and not from ebb tidal currents.

Figure 6 Dolphin Point Tourist Park showing ebb channel scour at waterline along the upstream reserve

Prior to June 2007, the amount of sand in the lake mouth and on the beach suggested that any eventual lake opening would be difficult to establish. The opening on 17 June 2007 at a high lake level of 1.38m AHD followed very heavy rainfall from an east coast low. The opening was delayed from the previous day due to extremely high seas and wave setup.

The June 2007 opening displayed an interesting comparison between the lower opening in March 2007 at 0.99m AHD. The increased flow energy available at the higher lake level intensified the removal of sand. It mobilised and removed a large volume of sand from the beach spit and the entrance area (see **Figure 7**). Site inspection suggests large volumes of sand were deposited into the southern flood tide channel, reducing the ebb flow along the caravan park. Ebb flows in the main ebb channel was subsequently significantly increased.

Figure 7 View upstream showing wide ebb channel two days after 17 June 2007 opening

2.3 Wave / Tidal Range Records

The lake's tidal range gradually decreases with distance from the entrance. Manly Hydraulics Laboratory recorded tidal ranges on 13th March 2001 (*DPWS - MHL October 2001*). The ocean tidal range of 1.81m decreased to :

- 0.82m at 400m upstream from the entrance,
- 0.67m at the water recorder just upstream of the highway bridge,
- 0.26m near Rackham Crescent,
- 0.21m at The Narrows, and
- 0.21m at the northern end of the lake.

The lake's tidal range varies with the state of the entrance. Ocean swells have impacted the lake's tidal range, evidenced by comparison of offshore wave height / direction and tidal range data analysis since mid 2002 (*E. McLean pers comm*). Wave events over about 4 meters (maximum recorded wave height H_{max}) will reduce the lake's tidal range, regardless of swell direction.

While some periodic recovery of tidal range due to rainfall events is evident in the records summarised in **Table 2**, the range from 2001 has never recovered. As ebb currents decrease the channel is less able to clear accreting sand. And as the entrance shoal spreads westwards, the more the tidal range restricts from channel length increase.

A reduced capacity to flush sand seawards from the immediate entrance area would result. This appears to have been a major factor contributing to the two recent closures.

Table 2 - Ocean swell and Burrill Lake tidal range relationship (E.McLean unpublished)

Time frame	Wave Climate Direction and Height (H_{max})	Resultant Lake Tidal Range (cm)
Late 2001 to mid-2002	minimal	40 to 50
May-June 2003	Some wave activity from East	25 to 30
July 2003	SE swell 5.83m	< 25
Sept 2003	4.9m	
Oct 2003	SE swell	Minimal tidal range
	Rain	Recovery to 30
Late Feb/March 2004	E to SE swells	<25
July 2004	SE swell 6.41m	Sharp reduction
Sept 2004	SSE swell 6.88m	Further reduction
Jan 2005	Persistent E swells	

Time frame	Wave Climate Direction and Height (H_{max})	Resultant Lake Tidal Range (cm)
Late Feb/early March 05	4.3m	Entrance closure
25 June 2005	-	Manual opening, reasonable tidal range
7th Feb 2006	SSE 4.34m	Slight reduction
27 March 2006	E swell 3.3m	Sharp reduction, closed to ebb tides
8 to 10 April 2006	Major SE storm setup	Entrance 'dammed'

2.4 Climate Change and Sea Level Rise

An increase in sea level is predicted in the future due to climate change. Predicted sea level rise covers a range from a low of 2cm to a high of 76cm, with a generally accepted median being a 40cm rise by 2050 (Whetton and Holper 2001).

The range of potential impacts of Sea Level Rise on coastal lakes such as Burrill are reasonably well understood. Flow over the rock bar across the entrance channel would improve as flow depths were to increase. Sea Level Rise could therefore increase the tidal prism in the lake and improve lake flushing while the lake is open. Sea level rise in isolation could also relocate the beach berm landwards and increase berm height, although in a location such as the Burrill entrance there are significant climate change factors that may over-ride these possibilities and prove critical to the entrance behaviour of coastal lakes.

The following effects at Burrill Lake could result from climate change over the next 50 years (*R. Ranasinghe DNR, P Haines WBM Oceanics - pers. comm*.):

- Increased storminess could generate more intense rainfall events to keep the lake open more regularly.
- Reduced total annual rainfall and reduced average streamflow could combine with higher rates of evaporation. This could reduce rainfall inputs overall, to make Burrill Lake more vulnerable to closed entrance conditions.
- The most severe coastal storms on the south coast are generated by weather patterns known as east coast lows. A deeper southwards penetration of east coast lows is predicted. This would change the angle of dominant storm swells hitting the coast. Realignment of beach faces and consequent erosion of the southern end of Burrill Beach would be expected.
- Beach realignment may mean the lake could relocate its entrance landwards. This would shorten the length of the entrance channel. As a result, the lake may be easier to open, if it were to close.
- More frequent and more intense ocean storms would washover larger volumes of sand more often across the beach berm and into the lake entrance channel. This could restrict the ebb channel more frequently.

Some of these climate change scenarios may offset others. For instance, the ebb channel may clear washover sand if it were to have sufficient sustained flow velocity. Conversely more regular washover events may engulf the ebb channel.

The nett effects on an estuary such as Burrill Lake are not well understood and are beyond the scope of this assessment. There is therefore an obvious need to urgently undertake further analysis of these scenarios within a floodplain risk management study. This will facilitate informed strategic decisions to be made about the most appropriate sustainable management and adaptation options in this locality.

3 Lake Ecology

Ecological considerations have historically not influenced decisions about when the Burrill Lake entrance is opened. However, a range of ecological issues need to be considered when planning entrance openings.

3.1 Fauna

There have been few studies on the fish fauna of Burrill Lake. The most recent by West and Jones (2001) sampled between 1997 and 1999 while the lake was open. Full details of the findings are provided in the REF that accompanies this report. The Estuary Processes Study (*WMB July 2002*) notes, with regard to fish species of fisheries value, that six species (Sea Mullet, Luderick, Yellow-fin Leatherjacket, Sand Mullet and Six-spined Leatherjacket) were the most abundant. Of importance to entrance management is the aspect of fish recruitment to the estuary. Recruitment of Luderick was consistent between the sampling years, while recruitment of Yellowfin Bream and Tailor was poor. A large recruitment of Sea Mullet was recorded in one year.

Notably, there were no fish species recorded that are listed as protected marine fauna under the *Fisheries Management Act 1994* or the *Environment Protection and Biodiversity Conservation Act 1999*.

The Estuary Processes Study (*WMB July 2002*) identified a number of potential threatened species that may at times utilise the lake and its catchment. Of relevance to entrance management considerations are threatened shorebirds that may forage or nest in the entrance area. The REF provides more detail of this aspect.

The Little Tern, which is listed as Threatened under the Threatened Species Conservation Act 1995 (TSCA), was last officially recorded at the entrance channel in 1950.Urban growth and activity since that time may have rendered the area unattractive to these birds. However they may still occur as vagrants (*WBM July 2002*). The Pied Oystercatcher (listed as Vulnerable under the TSCA) has been sighted around the entrance in recent years, feeding on the intertidal flats and Burrill Beach.

Breeding activity by threatened resident and migratory shorebirds (particularly Pied Oystercatcher and Little Tern) should be checked with the NSW Department of the Environment and Climate Change - National Parks and Wildlife Service (NPWS) - prior to artificial lake opening. No excavation work across Burrill Beach should be undertaken without consent from NPWS if birds, nests or fledglings are known to be present. Presence or absence of threatened bird species should be confirmed by NPWS upon request from council. The likely breeding period collectively extends from late August to March in any year.

Figure 8 A pair of Pied Oystercatchers on the lake foreshore - May 2005

3.2 Flora

Six coastal wetlands around the lake are protected under State Environmental Planning Policy No. 14. These are located on the upper estuary on Stoney Creek and the creek delta, in Turpentine Bay and on the West Arm (see **Figure 9**). Common communities are sedges, saltmarsh and Swamp Oak as detailed in **Table 3**. There are no communities of mixed saltmarsh / mangroves, which is consistent with the lake basin's small tidal range.

Table 3 - SEPP 14 Wetlands at Burrill Lake

SEPP 14 Wetland No.	Area (ha)	Major Communities
280	1.12	Swamp Oak, Saltmarsh
281	3.14	Swamp Oak, Saltmarsh, Sedges
283	1.78	Swamp Oak, Sedges
284	16.86	Swamp Oak, Saltmarsh, Sedges
285	21.83	Swamp Oak, Saltmarsh, Sedges
286	11.81	Swamp Oak, Saltmarsh, Sedges

(after WBM July 2002)

In addition, extensive unclassified wetlands (mainly sedges - see **Figure 10** - with some remnant fringing Swamp Oak communities) exist around the Burrill Lake foreshore, mostly located on the estuarine flats in the entrance channel. Small patches of Grey Mangroves exist in low abundance.

Coastal Saltmarsh communities (including sedges and reeds) around the lake are protected under an Endangered Ecological Communities (EEC) listing in the Threatened Species Conservation Act. This classification ("Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South East Corner Bioregions") recognises their limited distribution, regional habitat loss or fragmentation and susceptibility to disturbance.

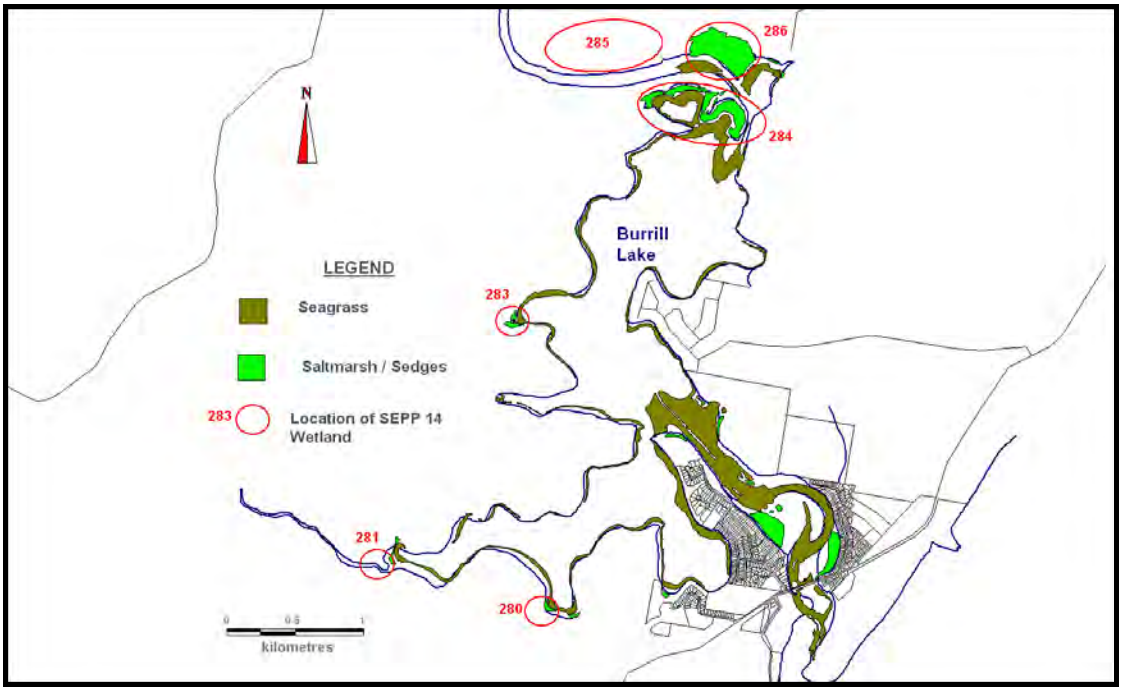

Figure 9 Estuarine Wetland and Seagrass Distribution - Burrill Lake

Swamp Oak Forests around the lake are similarly listed as an EEC ("Swamp Oak Floodplain Forest of the NSW North Coast, Sydney Basin and South East Corner Bioregions"). The remaining area of Swamp Oak Floodplain Forest is likely to represent much less than 30% of its original range due to landclearing, weed invasion and modification of the understorey for parkland.

These wetland systems have developed in response to an estuary with a lake basin tidal range of a few centimetres (*Anderson et al July 1981*). The peripheral wetland areas around the lake basin are narrow. Normal shoreline fluctuations are predominantly from the small tidal range with additional wind and wave setup and wash. Consequently the lake basin shoreline communities are narrow and strongly zoned with regard to elevation above mean tidal lake level.

Figure 10 Sedge community behind houses on Princes Highway

This strong zonation suggests that wetlands around Burrill Lake are not reliant on regular high lake levels. Their structure suggests that routine inundation at tidal lake ranges ensures continued wetland health in the short term. Entrance closure and consequent temporary higher water levels are part of a natural cycle, but historically are rare events. These wetlands have evolved in response to variable water levels over long time scales. A natural entrance regime is most appropriate for the continued health of these wetlands. Threats such as pedestrian activity and fringing urban development would have far greater potential impact on the urban wetlands around the lake than modification of entrance openings under this interim policy.

Verbal evidence of stressed Swamp Oak communities from elevated lake levels would suggest that these communities have colonised to a level determined by a mostly open lake entrance and small tidal range. Remnant Swamp Oak communities around coastal lakes are commonly inundated by natural events such as rainfall and lake closures. There is no available information on the stability of these species when inundated.

3.3 Caulerpa Taxifolia Invasion

Much of the estuary is vulnerable to incursion by the invasive *Caulerpa* seaweed. This weed is listed as a noxious marine vegetation and it presents a serious threat to estuarine ecosystems in NSW. The largest occurrence of the weed on the NSW South Coast occurs on the nearby Conjola estuary system.

It was discovered in Burrill Lake in March 2001, with August 2004 DPI mapping estimating dense coverage of 7.28 hectares mostly in the northern basin (**Figure 11**). There is a sparse coverage of the weed over 34.44 hectares, including parts of the southern basin and the entrance channel above the causeway.

It is essential that this Plan complements the NSW Department of Primary Industries (previously NSW Fisheries) *Caulerpa taxifolia* Control Plan and is consistent with its control strategies.

This weed can grow in very shallow water, and has been recorded in NSW growing down to a depth of about 10 meters. Variations in lake level of the magnitude covered in the opening policy would have no impact on *Caulerpa*.

The growth and abundance of *Caulerpa* is closely related to high (marine) salinity and warm water temperature (*West & West 2007*). If Burrill Lake were maintained with an open entrance, the dominant marine influences would provide a more favourable environment for *Caulerpa*. Conversely, allowing the lake to operate more naturally with associated intermittently lower salinity (from freshwater inflows) could provide conditions for *Caulerpa* mortality, particularly associated with lower lake temperatures in winter.

It is concluded that the adoption of the Interim Entrance Management Plan could lower the risk of spread of *Caulerpa* on Burrill Lake.

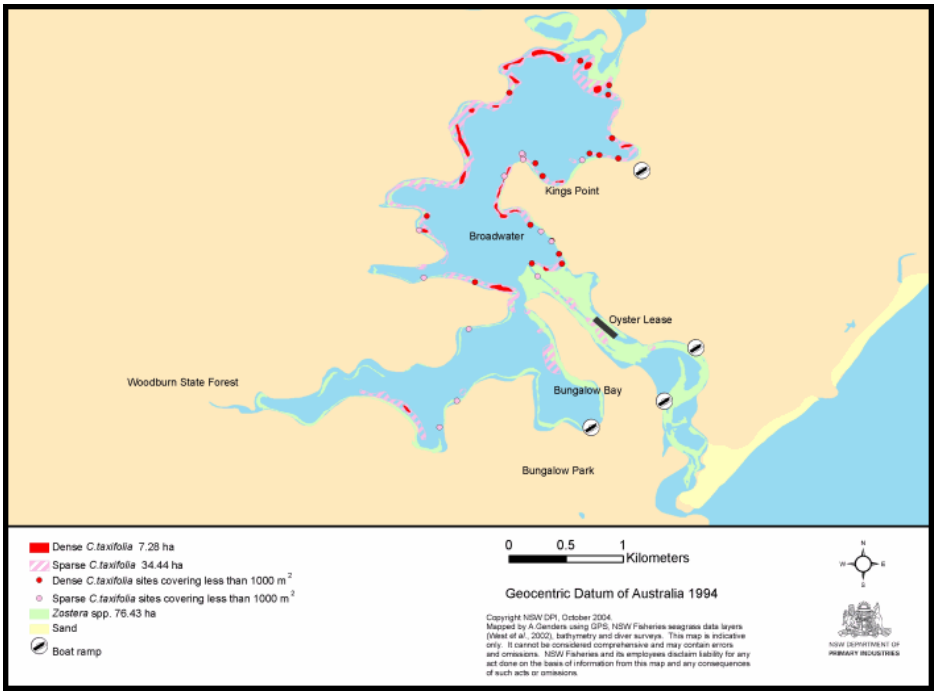

Figure 11 Distribution of Caulerpa in Burrill Lake August 2004 (NSW DPI)

4 Water Quality Issues

While Burrill Lake was closed during the first half of 2005, Shoalhaven City Council carried out monitoring of physio-chemical and bacteriological parameters. Sites were located at the Ski Club and the highway bridge. While aesthetically the water was cloudy, bacterial counts complied with National Recreational Water Quality Guidelines for primary contact. Levels of dissolved oxygen were indicative of a healthy ecosystem. Lake salinity concentrations remained a little less than sea water throughout the body of the lake, consistently at 30 parts per thousand (sea water is about 35 ppt).

Monitoring in September / October 2006 during the most recent closure has shown higher levels of nutrients (nitrates and phosphates) than recorded in 2005. Total Nitrogen was consistently elevated above guideline levels at both sampling locations. Total Phosphorus was slightly elevated at the highway bridge on occasions.

Nutrient levels within Burrill Lake are within an expected range. Control of nutrients at the source (probably mainly from urban runoff) is the most appropriate management action, rather than relying on lake openings for flushing.

Algal blooms in response to elevated nutrient levels in lakes can be a visual issue. Results of potentially high nutrient levels can be seen in **Figure 12** when a bloom of macroalgae appeared along Lake View Drive properties . This level of macroalgae indicates a high level of dissolved nutrients in the water consistent with monitoring results. It would limit sunlight penetration to seagrasses and was observed to prevent waders from feeding.

Figure 12 Mat of macroalgae in shallow water at the western end of Lake View Drive (September 2006)

Levels of Faecal coliforms comply with National Recreational Water Quality Guidelines for primary contact (i.e. swimming).

Levels of Enterococci complied in 2005 with National Recreational Water Quality Guidelines for primary contact but have shown slightly higher levels in 2006 results.

No single result in 2006 would trigger follow-up sampling for further investigation. However combined (median) levels over seven weeks in the period September and October 2006 averaged 75 organisms per 100ml which does not comply with guideline median levels of 35 per 100ml.

Enterococci are a harmless group of bacteria found in the gastrointestinal tract of warm-blooded animals. Enterococci is recognised as the best bacterial indicator for measuring faecal contamination in marine recreational waters. The presence of Enterococci in reasonably consistently moderate numbers at the Burrill Lake Bridge gives reason for further investigation. The levels recorded are not a reason for alarm, nor are they considered a reason for lake opening.

Lake opening would assist in the dilution of dissolved nutrients in the entrance area and central lake basin (*WBM July 2002*). However the flushing time for the southern basin (under tidal conditions) is 80 to 90 days, suggesting that oceanic flushing is a less important mechanism. Pollutants entering the southern basin have a greater potential for water quality degradation (*WBM July 2002*) even when the lake is open to the ocean.

We would conclude overall that while the lake was closed, health-related issues with water quality would not be a reason for lake entrance opening.

Any water quality issue for Burrill Lake is one of source control of nutrients. Sustained public education is suggested to be the best management option to reduce urban nutrient inputs. This would have a long term benefit by addressing the source of water quality issues, rather than attempts by entrance manipulation to remove the indicator of the problem.

5 Community Issues

A number of issues have been raised by community members on health, recreation and lifestyle. These are outlined below.

5.1 Public Boat Ramps

The Maria Avenue boat ramp (**Figure 13**) is usable (albeit with some difficulty due to the low approach road) at lake levels up to 1.1m AHD. However the edges of the ramp are not marked and reportedly one boat trailer has diverted over the western edge, with some difficulty of retrieval. It would be a simple matter to mark the ramp approaches and the western edge to provide orientation when launching and retrieving vessels.

Figure 13 Maria Ave ramp with lake at 0.8m AHD

The Kendall Crescent ramp (**Figure 14)** could also benefit from a safety inspection to sustain its use at high lake levels.

Figure 14 Kendall Cres ramp with lake at 0.8m AHD

5.2 Private Wharves and Jetties

Many lake frontage houses at Burrill Lake have leases over Crown Land for a private jetty. Standards and elevations vary, with these structures having a deck level varying from about 0.75m to 1.3m AHD. (By comparison, the recently constructed Council fishing platforms have been intentionally designed with a bearer level of 1.25m AHD to remain above elevated lake waters.)

Figure 15 Lake View Road jetties at a lake level of 0.9m AHD

Inundation of these private jetty decks makes them unusable, and hazardous from build-up of algal slime. Decking boards would be expected to warp when drying, and a level of maintenance would be expected to clean and screw down the deck once lake levels recede.

Importantly, those jetties without either handrails or high buffer piles would be a potential hazard to boat navigation. While the inability to use a jetty is not considered sufficient reason to open the lake, issues of navigation safety would need to be addressed.

5.3 Walking Tracks

Walking paths around the lake edge become impassable at lake levels over about 0.6m AHD. This is inconvenient but a minor issue that would not dictate lake openings.

5.4 Mosquitos

There are reports from community members of health risks associated with high lake levels. A number of cases (reportedly 7 in number) of Ross River Fever occurred around the time the lake was elevated in 2005. There is a detriment to the community in terms of social values and quality of life, should a Ross River Fever threat exist.

Ross River virus is a germ that infects people, particularly in rural areas, sometimes causing a flu-like illness with joint pains. The virus is spread by certain types of female mosquitoes which have previously fed on the blood of an infected animal.

The NSW Department of Health fact sheet states that Infections tend to peak in the summer and autumn months. It can be an issue particularly following prolonged heavy rain. DoH recommends protection by the use of insect repellent and loose fitting clothing that covers the arms and legs.

The risk of mosquitoes would always be present in areas with wetlands and sedges, particularly in the warmer months. Tourists can be at risk as they have not been exposed to the virus and have no immunity. Visitors to the area may be less aware of the hazards of mosquitoes than local residents.

Should the urban lake fringes be inundated with shallow waters that provide pools for mosquito breeding, there would be an advantage in opening the lake in the lead-up to the peak summer tourist season.

5.5 Pelican Itch

Pelican itch has been raised by the local community as an issue. Pelican Itch is caused by a parasite known as *Bilharzia.*

Bilharzia has a two-phase development, beginning with the ejection of a swarm of tiny organisms passed in the wastes of their host water birds. These larvae seek their next host, a snail commonly found in local waterways, *Batillaria australis.* The next phase of their development is a free-swimming larval stage, which emerge from the mollusc to go looking for egrets, herons, pelicans etc., to complete their life cycle. During a certain stage of development they will attach to any warm-blooded animal found in sea water, including humans.

These larvae penetrate the skin of humans, where they die, creating small pustules which are very irritating - commonly known as *Pelican* or *Swimmers Itch (Reference OCCI Website).*

There is no evidence that the incidence of Pelican Itch is affected by lake opening / closure events.

6 Commercial Issues

6.1 Tourism

Tourist accommodation operators have reported cancellation of bookings when the lake is closed, and describe the economic effects of a tourism downturn in what is already a seasonal business. Lake closure can detract visitors who identify a closed entrance with cloudy water or odours. At times these issues do arise with all closed coastal lakes, but it is not necessarily always the case. In fact the lake can be a tourist attraction when full, with a variety of abundant birdlife around the lake fringes and offering good fishing opportunities.

Burrill Lake's status as a Recreational Fishing Haven raises its prominence as an attraction to recreational fishing tourists. Whether an entrance opening would provide better or worse recreational fishing is dependent on a number of variables. However it is recognised that a closed lake is not necessarily bad for fishing.

There are compelling economic arguments suggesting that some support to the tourism industry should be shown, without compromising the health of the estuary. Local residents and tourism operators have all requested a degree of certainty in developing the opening policy.

The interim policy attempts to recognise this need for certainty, within the inconsistency of rainfall and a need for a sustainable opening. In particular entrance opening in the lead-up a month prior to peak holiday seasons is permitted, to support the local tourism industry.

6.2 Oyster Farming

All oyster farming activity is carried out in the entrance channel upstream of the highway bridge. One commercial grower operates on the estuary, based on the production of the Sydney Rock Oyster.

The NSW Oyster Industry Draft Sustainable Aquaculture Strategy identifies Burrill Lake as having a historical maximum of 19ha under lease, with 1.1 hectares identified as priority oyster areas. Priority areas are suitable for oyster growing from evaluation against a list of locational, environmental and socio-economic suitability criteria.

Lake opening would have a positive impact on oyster farming. Conversely, low salinity levels and high lake levels can mitigate against oyster production.

7 Burrill Lake Flooding

Shoalhaven City Council is in the process of fulfilling its obligations under the NSW Government's Flood Prone Land Policy, by preparing and implementing a Floodplain Risk Management Plan for Burrill Lake. The flood study has been completed, with a floodplain risk management study to follow.

7.1 Burrill Lake Flood Study

The Burrill Lake Flood Study (WBM 2006) investigated flooding behaviour of the lake and in particular the inlet area. Numerical flood models were developed, calibrated and validated to reproduce recorded flood behaviour in 1971 and 1992.

Design flood behaviour under existing conditions for the full range of floods up to and including the Probable Maximum Flood were also investigated and documented. Two potential flooding mechanisms were investigated. Firstly flooding induced by a range of design rainfall events producing catchment runoff coinciding with normal neap tidal cycles was investigated for the closed entrance surveyed in early 2005. Then flooding induced by a range of elevated design ocean levels coinciding with runoff from 5 year average recurrence interval design rainfall was investigated with the entrance open to the sea.

The dominant flooding mechanism varied with recurrence interval and location, while the range of peak flood levels was typical of an ICOLL. The 5 year average recurrence interval peak flood levels upstream of the causeway were dominated by catchment runoff and were around 2.0 m AHD. The 100 year average recurrence interval peak flood level was dominated by ocean level and were about 2.6 m AHD along the length of the inlet. Peak probable maximum flood levels were dominated by catchment runoff and were about 4.0 m AHD upstream of the causeway.
The flood study also documented other peak flood characteristics such as extent, depth, velocity and hazard across the study area. The models developed in the flood study will be available for use in the floodplain risk management study.

7.2 Burrill Lake Floodplain Risk Management Study and Plan

Following flood study adoption, Council will be in a position to initiate a floodplain risk management study, to develop a plan to manage the full range of foreseeable flood risks likely to arise in the locality into the future.

In addition investigating risks associated with episodic flooding from catchment runoff or elevated ocean levels, the floodplain risk management study will allow Council to also consider means to manage risks associated with the more persistent, if lower level, nuisance flooding during periods of extended entrance closure.

This would allow Council to strategically determine whether entrance management is an appropriate component of a floodplain risk management plan balancing social, economic and ecological outcomes for the community. Based on strategic analysis, Council will be in a position to make informed an decision on whether or not to replace the interim measures discussed further in this document.

8 Options for Management

Management options for the entrance area and future lake openings are discussed below.

8.1 Entrance Channel Re-establishment

It would be prudent to carry out preparatory works to manage large volumes of sand in the entrance shoal, should they accrete to levels seen in September / October 2006. This shoal configuration would prevent a stable ebb channel and restricts tidal range as discussed above.

WBM (2001) concludes that the broad-scale configuration of marine sand shoals and tidal channels do not appear to have altered significantly since the 1880's. The current channel pattern (prior to closure) therefore represents a departure from the historical norm, seen in the aerial photography record only once previously (July 1967). The reasons may relate to an extended dry period on the South Coast and resultant reduction in seaward flow components such as fluvial inputs and flood scour.

Without re-establishing the ebb channel alignment to link the lake to the rock shelf, Council would be forced to undertake a longer excavation from further north diagonally across the beach. This channel would be less likely to remain stable than a channel in the lee of the rocks (see **Figure 17** for preferred entrance location in **Section 8.4**).

It is recommended that this north-south ebb channel be reinstated when required, along its original north-south alignment. This channel, estimated 1 to 2 meters deep (WBM 2002) and at least some 20 to 25 meters wide, historically meandered across the shoal towards the outlet at the rocks. It had been previously dredged in 1971 and partially in 1996.

Sand from this excavation could most conveniently be pushed onto the rock shelf, which has been known to have been covered by sand. This would limit the 'leakage' of lake waters (see below). However the rock shelf is at a level of about 0.9m AHD and consequently is influenced periodically by strong wave wash. The likelihood of sand remaining on the shelf for a long period is low, and this would merely represent a temporary storage area. There would also be a slight risk to Council of exposure to litigation from deliberately increasing the lake water level.

It would therefore be preferable to push excavated sand into the flood tide ramp upstream of the Tourist Park. This would replace an ebb shield that has been an historically dominant element for the past 60 years. However this exercise could only be carried out at low lake levels.

A decrease of ebb flow in the Tourist Park (flood tide) channel, concurrent with opening the previous ebb channel, would encourage a more stable entrance configuration.

8.2 Entrance Berm Manipulation

Following lake closure, the entrance berm would be expected to grow by the onshore movement of beach sands. **Figure 16** taken on 8th August 2006 shows a berm in the processes of accretion.

Figure 16 Closed entrance 8th August 2006 looking south

The crest of the berm will naturally rise and fall significantly over fairly short time periods in response to the sea. Experience elsewhere has shown that it is not practical or desirable to attempt to maintain this berm at a level in preparation for a natural breakout. Not only would the work be futile, but it may compromise future lake openings, by allowing more frequent wave wash-over and dumping of sand onto the entrance shoal.

8.3 Rock Shelf Gully

The rock shelf contains a gully (pictured below) which allows ingress of ocean water on higher tides, and also allows escape of lake water as the lake level rises. A section of this gully was reportedly created by blasting in the 1940's. It is not a wholly natural feature.

The control level of the gully is reported by Council at 0.75m AHD. To limit escape of lake waters, this gully could be sandbagged once the lake approached this level. Alternatively it could simply be permanently infilled with concrete. This would assist the lake waters to rise to and stabilise at 0.9m AHD. NSW DPI (Fisheries) has offered no objection to the concreting of the previously blasted section of the gully.

Some concern has been expressed that infilling the gully could expose the community to a greater risk of flooding. The risk would depend on the rate of rainfall - steady rain with the gully filled, would build up the lake level to the shelf level at 0.9m AHD and not present a serious problem. Under normal circumstances council staff are on notice prior to flood risks presenting, and entrance breaching would normally occur before serious inundation.

In heavy rainfall events, the loss of the hydraulic capacity of the gully would be minimal (WMB 2006). Elevated flood waters scour a much larger channel across the entrance shoals. Flood model simulations for the Flood Study (WBM 2006) used an initial lake level of 1.12m AHD - at this level the rock shelf is overtopped and the influence of the gully (whether filled or not) would be insignificant.

In balance the infill of the gully could reduce the period over which the lake is elevated, yet not at sufficient height to open. The infill of the gully is an issue of risk management for council to determine after bearing in mind the full implications. The REF concludes that there are no environmental or lake processes-related reasons why the gully should not be infilled.

8.4 Lake Opening Location

Lake openings should be directed as close to the rock shelf as possible, as depicted on **Figure 17**. Opening the lake at the 2005 (northern) location may be necessary at times to access deeper waters, but council should recognise an opening's reduced permanency at this location.

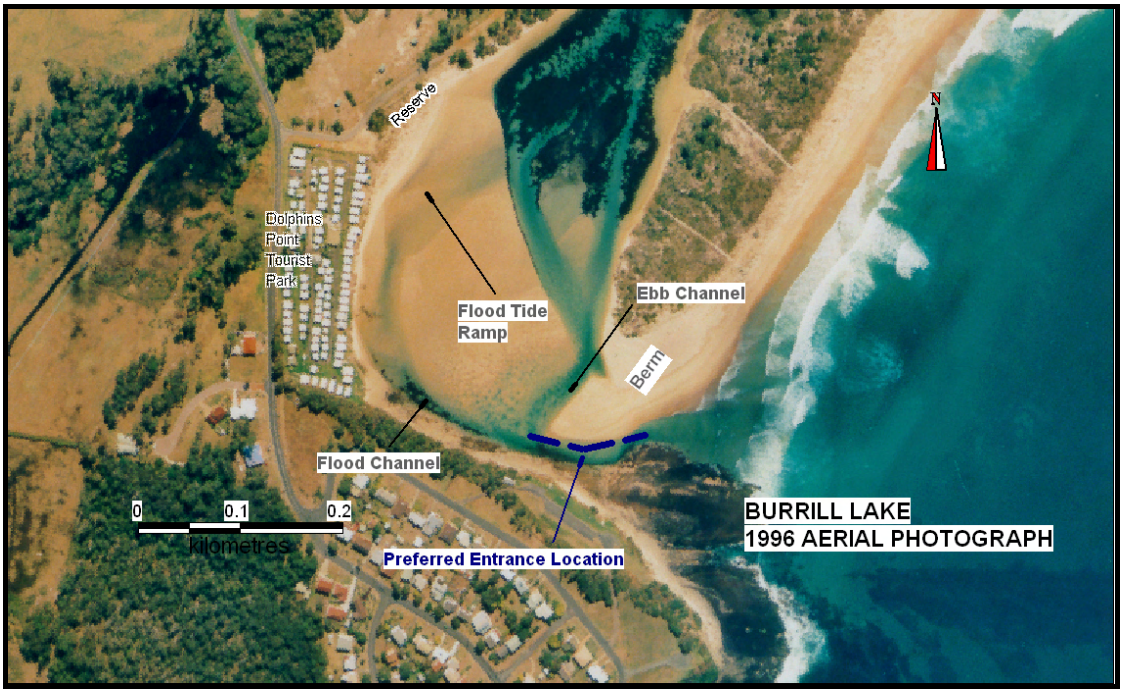

Figure 17 Preferred Entrance Location

9 Critical Asset Levels

This section considers low-level nuisance flooding following rainfall with a closed entrance. As previously discussed, the flood study examined both catchment runoff and ocean induced flooding under existing conditions. While the influence on flood behaviour of the entrance state (i.e. open, shoaled or closed) was not explicitly analysed in the flood study, the floodplain risk management study will provide the opportunity to do so. The risks, whether episodic or persistent, associated with all foreseeable flooding mechanisms, and entrance conditions can be carefully analysed so that strategic decisions can be made about the most appropriate suite of management measures.

The current entrance management policy recommends opening at a lake level of 1.25 m AHD. The floodplain risk management study will provide an opportunity to analyse the utility of entrance management for flood mitigation. Analysis can focus on the timing and effectiveness of previous openings particularly in relation to the peak level at the time of opening eg June 2005 at RL 1.15 m AHD and April 2007 at RL 0.99 m AHD.

The main hazards associated with inundation at levels above RL 1.0 m AHD are:

- The potential for sustained inundation to reduce soil bearing capacity leading to footing failure and building damage
- Road pavement failure due to prolonged saturation
- Traffic incidents associated with flooded roads eg Balmoral Road

Preliminary discussion of issues is provided in the following sections. While further analysis to determine sustainable long term responses can be carried out in the floodplain risk management study, an interim entrance management policy is required until a strategic floodplain risk management plan is available.

9.1 Road Inundation

Figure 18 shows inundation of Balmoral Road at about 1.05m AHD in early June 2005. Water backs up stormwater drains and runs along the kerb and onto the roadway. This road is the only road in and out of the southern area of Burrill Lake and the locality shown is some 50 meters from the Princes Highway intersection. This is an unsustainable situation to manage for any length of time beyond a day or so. The traffic safety issue would be of concern specifically in peak tourist season where visitors to the area may not be familiar with flood potential, particularly at night.

Storm flaps on the pipe outlets from the Balmoral Road stormwater system could not be relied on to floodproof the roadway for a lengthy period of inundation. Their installation at this location is not a practical option as the stormwater pipe outlets sit alongside concrete retaining walls at the lake bed.

Figure 18 Balmoral Road looking east towards Princes Hwy intersection - June 2005 (lake level approx 1.05m AHD)

Inundation of Thistleton Drive in **Figure 19** shows an area, well removed from the lake, affected by a compromised stormwater system. The invert of the grassed swale drain at this location (concrete pit cover is visible in the figure below) is 0.95m AHD. The road level is about 1.1m AHD. Thistleton Drive is not a busy road and access from either direction is available. The traffic safety issue could be managed by signage. Storm flaps on pipe outlets would not assist in this case as the issue appears related to flat pipeline grade / limited capacity under a high tailwater (lake) level. Stormwater flaps would only serve to decrease pipeline capacity.

Figure 19 Thistleton Drive (cnr. Ronald Ave) - June 2005 (stormwater backing up from surcharged pipes after heavy rainfall)

While these issues suggest merit in lower entrance intervention levels in the short term, the Floodplain Risk Management Study will allow strategic examination of the sustainability of the existing road network.

9.2 Footing / Underfloor Inundation

Figure 20 shows a Burrill Lake residence with footing pads under some 250mm of water.

Figure 20 Water below lake frontage residence June 2005

While this locality appears to be one of the lowest residential under-floor surface levels (without the house floor being inundated), at least four other residents report similar experiences.

While potential for prolonged underfloor ponding may promote lower entrance intervention levels in the short term, the Floodplain Risk Management Study can strategically examine sustainable development modifications and/or controls for the locality.

9.3 Sewerage System

There are no issues with inundation of the town sewerage system at lake levels up to 1.25m AHD. The lowest pump stations at Burrill Lake are sited at 1.435m and 1.51m AHD.

Sewerage maintenance staff consider the extra inundation at the June 2005 level did not increase pumping hours. It can be inferred that this level of inundation did not cause infiltration into the system.

9.4 Intervention Level - Conclusions

Interim conclusions on the intervention level for Burrill Lake are that:

1. Underfloor areas of a number of houses are inundated at elevated lake levels around 1.0m AHD. Inundation for a lengthy period has the potential to cause loss of foundation strength and impact on structural integrity. Geotechnical advice should be sought to determine if this issue is a critical determinant of intervention, based on the local soils around Burrill Lake.
2. The capacity of the stormwater system is compromised with progressive backing up of lake waters. At lake levels above about 0.95m AHD lake

waters commence to overflow into the kerb at the sag point in Balmoral Road and into the swale drain at the intersection of Thistleton Drive/ Ronald Avenue.

3. Resultant inundation of Balmoral Road at lake levels above 1.05m AHD requires appropriate emergency signage to manage traffic safety. This level of inundation is unacceptable for a lengthy period at this location, which forms the only route from the nearby Princes Highway into this part of the village.
4. Inundation of grass swale drains in the sag on Thistleton Drive commences at a level of 0.95m AHD. By 1.1m AHD the whole road cross-section is covered. While alternative routes are available to most residents, a number of houses on the corner of Ronald Avenue would have difficult driveway access.
5. Geotechnical advice should be sought on the implications of extended periods of elevated lake levels on damage to road pavement.
6. Road raising should be investigated under the Floodplain Risk Management Study.
7. A number of houses around the lake frontage incur considerable inconvenience by inundation of part or all of backyards at lake levels above 1.0m AHD. Residents comment that they would benefit from more certainty on the likely timing to open the lake.
8. Other local issues such as the inundation of private jetties and public boat ramps have implications for safe navigation that could be managed by improved marker piles and channel markers. These issues are not considered critical for entrance intervention.
9. An acceptable interim option may be that an intervention level for lake opening is lowered coming into peak tourism periods such as the Christmas and Easter holidays. This could avoid inconvenience and traffic safety issues for the peak tourist season when they are of biggest concern.

The Burrill Lake Floodplain Risk Management Study will further examine management options for these issues. This will permit the development of a strategic medium to long term opening policy.

10 Interim Opening Policy Recommendations

In line with the conclusions of this report, and in order to proactively manage the entrance of Burrill Lake, the following interim recommendations for a lake opening policy are made. The Burrill Lake Floodplain Risk Management Study will further examine management options for these issues. This will permit the development of a strategic medium to long term opening policy.

The village of Burrill Lake has infrastructure so low that special consideration to a staged lake opening procedure is recommended. Large numbers of lake frontage properties are at such low elevation that any form of flood-proofing by filling or revetment raising does not appear to be an option.

10.1 Interim Lake Opening Policy

The following summarises conditions under which the lake entrance can be breached.

1. Conditions that are essential before mechanical lake opening occurs are:

a) Lake water level at or exceeding **1.20 m AHD** initiates an immediate entrance opening at any time on the first available high tide

OR

b) If the lake reaches and stabilises at a level between **1.10m and 1.20m AHD**, a planned opening shall be made under suitable conditions defined by Point 2 below.

OR

c) If the lake level reaches and stabilises at a level between **1.00 m and 1.10 m AHD** and it is within one month prior to or at the time of the Christmas or Easter holiday periods, a planned opening shall be made under suitable conditions defined by Point 2 below

AND

d) Non-breeding season for threatened shorebirds, or clearance from NPWS has been obtained (see Point 4 below).

2. The following conditions are required for a planned opening to maximise the opportunity for effective entrance scour and flushing. (This may result some delay in an opening to await suitable conditions.)

a) Moderate to heavy rainfall is ongoing or predicted in the catchment
b) Relatively large ocean tidal range (greater than 1.0 m) with opening to coincide with a falling tide
c) Slight ocean swell
a) High Barometric pressure.

3. Council outdoor staff are to be alerted at a lake level of **0.85m AHD** that an opening may be imminent, pending further rainfall.

4. A check for the presence and breeding activity of threatened resident or migratory shorebirds (particularly Pied Oystercatcher and Little Tern) must be made with the Parks and Wildlife Group of DECC prior to artificial lake opening. No excavation work across Burrill Beach is to be undertaken without consent from NPWS if birds, nests or fledglings are known to be present. Presence or absence of threatened bird species should be confirmed by NPWS upon request from council. The likely breeding period collectively extends from late August to March in any year.

5. A set of gauge plates over the full lake height range are to be installed at the southern end of the Princes Highway bridge in Apex Park and at the Kendall Crescent boatramp, both sites relating lake level to AHD for consistency. The gauges should be marked with the minimum lake opening levels in accordance with this interim policy.

10.2 Additional Policy Recommendations

The section of channel in the entrance rock shelf detonated in the 1940's could optionally be permanently backfilled by concrete, suitably coloured to blend with the rock shelf. This would provide opportunity for the lake to refill after a closure earlier than if the gully were to remain. Clarification of the additional flood risk caused by maintaining a slightly higher lake level when closed should be sought. Council's determination whether to proceed with this option should take into account additional flood risk, if any.

Inspection of the north-south ebb channel behind Burrill Beach should occur following any ocean swell with maximum wave height (H_{max}) greater than 4 meters. Following these events, if there is evidence of overtopping flow and sand accretion in the ebb channel, the lake tidal range should be verified to assess if ebb flows have significantly reduced. If so, reinstatement of the channel capacity by excavation should be considered.

Safe use of the waterway should be considered as it will operate at higher lake levels for more of the time. All public boat ramps around Burrill Lake should be suitably marked to define orientation for safe use at all lake levels. Submerged private jetties without handrails are a navigation hazard at high lake levels. Council should approach NSW Maritime for financial assistance to install channel markers in critical locations for safer boat navigation at all lake levels.

10.3 Prediction of Lake Level Response to Rainfall

Analysis of historical records of Burrill Lake's response to rainfall is of limited use - lake response is masked by the lake being open to the ocean. Residents have noted that after rainfall, the following day will experience a sustained normal high tide level in the lake. However when the lake is closed it is important to the working of the proposed policy to have a feel for how far the lake would rise following a rainfall event.

Prediction of Burrill Lake's response to rainfall is complicated by the large catchment area and the variable landuses in the catchment. Trends from Ulladulla daily rainfall records and lake level data display a marked variation in response to moderate

rainfall events, possibly as the Ulladulla rainfall is not always representative of rainfall in the whole Burrill catchment. Another reason is the variable nature of rainfall losses which over a large catchment such as this will have a major effect on resultant runoff to the lake.

As a theoretical approximation, the lake can rise about **350mm in height** as a result of **daily rainfall of 100mm** over the whole catchment. This approximation uses variable runoff coefficients for urban, rural and forested land and can be used to estimate the expected rise in lake waters following rainfall. However it should be recognised that the many variables discussed above will vary the lake response.

10.4 Interim Policy Review

The Interim Policy and REF should be reviewed in two (2) years in response to the development of the Burrill Lake Floodplain Risk Management Study and Plan.

10.5 Entrance Monitoring

Artificial Openings

When artificial openings have been carried out, monitoring of the entrance is to be undertaken (**Sheet 1**). Council's Natural Resources and Floodplain Manager and the Coastal Estuaries Officer will be responsible for coordination of this monitoring function. Monitoring is to be carried out by Council with assistance from Committee members as appropriate.

For each opening attempt, the following data will be recorded :

- level of lake immediately prior to opening
- date and time of opening
- location and length of initial excavation
- approximate progressive width and depth of channel until stable (over two to three days)
- ocean swell conditions (wave height and direction) over two to three days
- preceding and subsequent rainfall
- date of subsequent closure and cause if evident
- digital photographs of opening and breakout development

Natural Openings

Monitoring will include natural entrance breakouts, recording the prior lake level, time and date of natural opening, the date of lake closure, and any other relevant comments. Monitoring is to be carried out by Council staff with assistance from Committee members.

The information is to be recorded on a standard monitoring sheet (**Sheet 1**), which should be completed for every entrance opening, whether artificial or natural.

10.6 Lake Opening Procedure

Responsibility for Opening

The Council officer responsible for carrying out specific on-site assessment in accordance with the REF, consultation and any subsequent decision to open the lake is the Manager Natural Resources Unit. In his absence, decision making responsibility will fall to the Coastal Estuaries Officer, the Director of City Services or the regional Maintenance Engineer, in that order.

The Council officer responsible for plant management and onsite control is the Regional Maintenance Engineer, or in his absence the Maintenance Supervisor. The procedures and assessments outlined in this document will be made available to the Regional Maintenance Engineer.

Procedures

The procedure is to be planned so that where possible the final breaching of the beach berm occurs shortly after the tide turns from high to low. The location of the opening is to be to the immediate north of the rock shelf. This is the most frequent natural entrance location determined from aerial photographs and past experience.

The opening should be sufficient for scour flow to develop. The preferred pilot channel size is 2 m wide with the bed graded to the ocean. An excavator would access the entrance along the route specified in the REF as shown in **Figure 21**. It will cut the channel, pushing the excavated sand as far as is feasible from the cut face. Normally excavation will commence at the ocean, working back to the lake. This procedure could be reversed, leaving a ‘plug’ of sand at the lake edge, should high seas hamper excavation at the ocean.

The possibility of possible contamination of adjacent surf beaches should be considered while the lake is emptying, for at least the first seven (7) days.

Appropriate action should be taken to protect public health and safety at the site while excavation equipment is operating. Under OH&S legislation, the activity of excavating a channel between the lake and the ocean requires a clear Safe Work Method statement. Given the nature of the "work" and identified hazards, a clear description of operation would address issues such as induction of operators, the use of public access barriers, temporary signage and hazards management.

Figure 21 Preferred excavator access route to entrance

SHEET 1 - BURRILL LAKE - ENTRANCE OPENING MONITORING DATA SHEET

Page ..... of ……..

Opening Date	Natural (N) or Artificial (A)	Height & Width of Beach Berm (m)		Location of Breach	Time & Date	Lake Level (m AHD)	CHANNEL DETAILS		
							Alignment	Width (m)	Depth (m)
					Initial Breach Dimensions (** indicates photograph taken)				
Wave Height	Wave Direction	Rainfall		Wind Direction	Ongoing Channel Development (over 2 to 3 days):				
					Full Breakout Final Dimensions:				

Closure Date -

Initial wave height / direction ..... Preceding rainfall .....Tide ……

Initial wind strength / direction ..... Follow-up rainfall ……

Cause of closure ……

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