Cardno LawsonTreloar

Shaping the Future

TOWRADGI LAGOON ENTRANCE MANAGEMENT POLICY

Report Prepared for

Wollongong City Council

16 April 2007
LJ2578/R2319

Cardno Lawson Treloar Pty Ltd

ABN 55 001 882 873

Level 2, 910 Pacific Highway

Gordon New South Wales

2072 Australia

Telephone: 02 9499 3000

Facsimile: 02 9499 3033

International: +61 2 9499 3000

cltnsw@cardno.com.au

www.cardno.com.au

Document Control

Version	Date	Author		Reviewer	
		Name	Initials	Name	Initials
1	December 2006	Emma Maratea	ERM	Louise Collier	LCC
2	February 2007	Emma Maratea	ERM	Louise Collier	LCC
3	April 2007	Emma Maratea / Tanja Mackenzie	ERM / TJM	Louise Collier	LCC

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ATTACHMENTS

LIST OF ABBREVIATIONS

AHD	Australian Height Datum
ARI	Average Recurrence Interval
BOM	Bureau of Meteorology
CEMP	Contractors Environmental Management Plan
CLT	Cardno Lawson Treloar
DEC	Department of Environment and Conservation (now DECC)
DECC	Department of Environment Climate Change. This recently formed department has absorbed DNR, DEC and some Fisheries functions.
DNR	Department of Natural Resources (now DECC)
DPI	Department of Primary Industries
EEC	Endangered Ecological Community
ESCP	Erosion and Sediment Control Plan
HAT	Highest Astronomical Tide
ICOLL	Intermittently Closed and Open Lake or Lagoon
ILGW	Illawarra Lowlands Grassy Woodland
ISLW	Indian Spring Low Water
mAHD	Metres above Australian Height Datum
NSW	New South Wales
REF	Review of Environmental Factors
SOFF	Swamp Oak Floodplain Forest
SSFCF	Swamp Sclerophyll Forest on Coastal Floodplains
WCC	Wollongong City Council

1. INTRODUCTION

1.1 Towradgi Lagoon Entrance Management Policy

This Entrance Management Policy describes the procedures and responsibilities for mechanical breakouts of the Towradgi Lagoon entrance and the required response of authorities to unassisted breakouts.

1.2 Policy Context

State Rivers and Estuaries Policy

There are a number of State Government Policies and Guidelines supporting the management of estuaries in a manner that promotes the maintenance of natural processes. The objective of the NSW State Rivers and Estuaries Policy is to manage the rivers and estuaries of NSW in ways which:

- slow, halt or reverse the overall rate of degradation in their systems,
- ensure the long-term sustainability of their essential biophysical functions, and
- maintain the beneficial use of these resources.

The NSW Estuary Management Policy (1992) is a component policy of the NSW State Rivers and Estuaries Policy (1992) which advocates the sustainable use and management of estuaries through the production and implementation of Estuary Management Plans. An Estuary Management Committee was established by Wollongong City Council in 2003, to develop and implement Estuary Management Plans for Fairy, Towradgi and Hewitts/Tramway Creeks Estuaries.

The Estuary Management Manual recommends an eight-step process in order to implement an Estuary Management Plan, as follows: -

1. Form an estuary management committee;
2. Assemble existing data (data compilation study);
3. Undertake an estuary processes study;
4. Undertake an estuary management study;
5. Prepare draft estuary management plan;
6. Public review of the draft plan;
7. Adopt and implement the estuary management plan; and
8. Monitor and review the management process as necessary.

The Fairy, Towradgi and Hewitts/Tramway Creeks Estuary Management Plan (Cardno Lawson Treloar, 2005a) has been adopted by Council and is now in the implementation and monitoring stages (Steps 7 and 8).

The development of an entrance management policy for Towradgi Lagoon was an action recommended for implementation as part of the Estuary Management Plan (Cardno Lawson Treloar, 2005a).

Entrance Management Policy

Historically, the Wollongong City Council Works Division has had an informal entrance management policy of opening the entrance of Towradgi Lagoon when resident complaints were received associated with local street flooding in Lake Parade and surrounding areas. An analysis of the maximum water levels at the Towradgi Creek gauge further upstream at Pioneer Road, for the period prior to 2003, shows that the maximum water level generally

has not exceeded 1.75 mAHD. This is consistent with the informal opening strategy previously employed.

This informal entrance management policy ceased in approximately 2003, when the estuary management committee was formed to consider the ecological effects of a mechanical breakout of the entrance. The development of a new policy was identified as an action in the Estuary Management Plan.

1.3 Aims and Objectives

The aim of this Policy is to provide Wollongong City Council, relevant State Government agencies and the community with a detailed procedure for the short- and long-term management of the Towradgi Lagoon entrance.

The specific objectives of this Policy are to:

- Implement a management regime which is consistent with the principles of ecologically sustainable development that consider environmental, social and economic impacts.
- Outline the need, if any, to artificially open the lagoon, and the circumstances under which artificial opening should occur.
- Ensure that entrance opening follows as natural a regime as possible within the constraints of property inundation and flooding of infrastructure.
- Gain broad based community understanding and support for management of the lagoon entrance.
- Deter unauthorised opening of the lagoon.
- Streamline the decision-making and approval process in relation to artificial opening events.
- Provide a mechanism for review and update of this policy, when required
- Ensure the appropriate level of environmental assessment and consultation are undertaken before the lagoon is artificially opened.
- Clarify responsibilities and accountabilities in relation to artificially opening the lagoon.
- Specify when, where and how the lagoon should be artificially opened
- Detail the procedure for monitoring the lagoon entrance after it has opened.
- Provide a cost estimate for the entrance opening works.

Accompanying this Policy is a Review of Environmental Factors (REF), prepared in accordance with the requirements of the Environmental Planning and Assessment Act, 1979, for the assisted breakout of Towradgi Lagoon. The objective of the REF is to detail the environmental impacts of artificially opening the lagoon, particularly on aquatic and fringing terrestrial habitats and associated fauna, and the safeguards necessary to mitigate any environmental impacts.

This Entrance Management Policy and the accompanying Review of Environmental Factors (Cardno Lawson Treloar, 2007) will be regularly reviewed and updated to incorporate new information and address the community and government's changing needs.

1.4 Limitations

Opening of the entrance of the Lagoon will not prevent flooding of property and dwellings in many circumstances. For example, even if the entrance is fully open at the start of a large flood (i.e. it has recently been scoured by a preceding flood) there are existing dwellings that would be expected to be affected by flooding. The Policy aims to reduce (where possible) but not eliminate the impacts of flooding. Further, there may be circumstances (e.g. closed access roads, night, or dangerous sea conditions) where, despite its best endeavours, Council cannot act to mechanically open the entrance of the lagoon at the level indicated in this Policy.

The opening of the entrance during times of flood is only one of a range of floodplain management measures. It should not be considered in isolation as the overall solution to the flood problem. Other management measures for implementation are outlined within the Towradgi Creek Floodplain Risk Management Study and Plan (Bewsher Consulting, 2003b).

1.5 Area to Which This Policy Applies

The study area comprises the tidal waterways, foreshores, the immediate surrounding open space and adjacent lands of Towradgi Creek, including its tributary to the north, referred to in this document as the Parker Road Arm. The limits of the study area are defined at its upstream reaches by the tidal limit (when the entrance is fully open) and Corrimal Beach at the downstream limit. The extent of the study area on the adjacent lands is defined by the 3.5 mAHD contour. This is considered to be beyond the maximum height that the berm could reach and therefore includes all potentially affected lands.

The main waterway (from the beach to Pioneer Rd) is referred to as Towradgi Lagoon. Upstream of the Lagoon is referred to as Towradgi Creek. The tributary to the north of the lagoon area is referred to as the Parker Road Arm.

The study area is shown below in Figure 1.

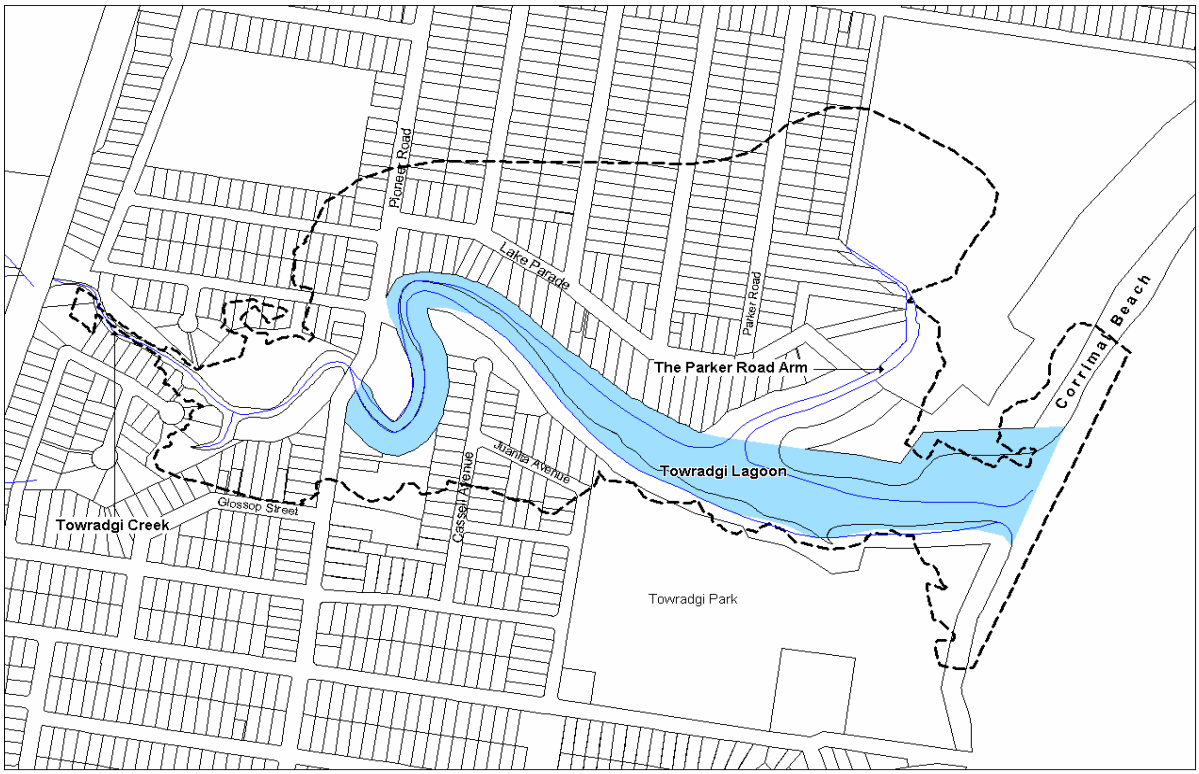


Figure 1 Area to Which the Policy Applies

1.6 Definition of Terms

Figure 2 shows the definition of terms relating to Towradgi Lagoon.

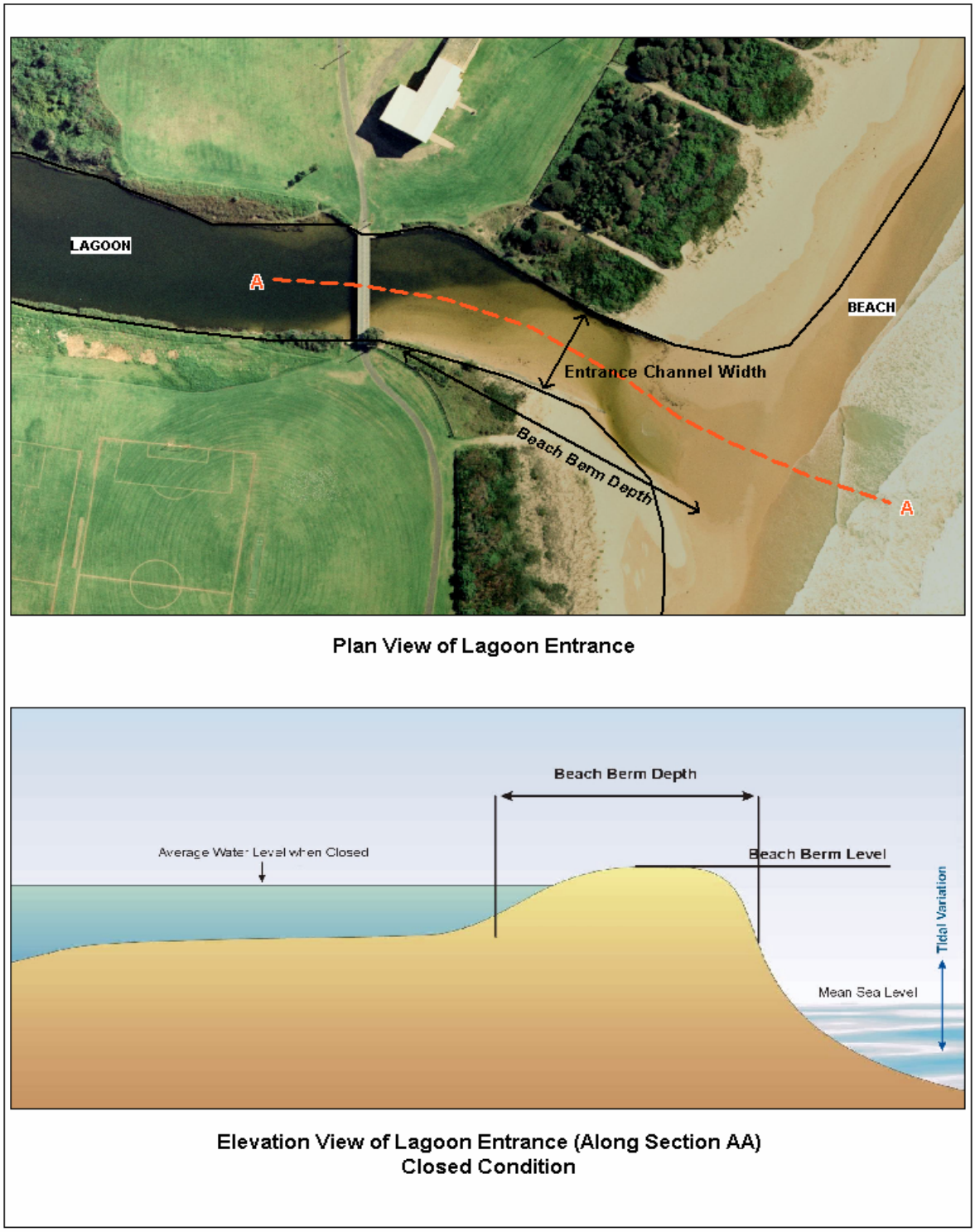


Figure 2 Definition of Terms

1.7 Policy Statement

The Towradgi Lagoon Entrance Management policy seeks to provide Council and the community with a detailed procedure for the short and long term management of the Towradgi Lagoon entrance.

This Policy will be implemented by Wollongong City Council, in consultation with the appropriate State Government Departments.

2. BACKGROUND

Towradgi Lagoon is located near Corrimal Beach, within the northern regions of the Wollongong LGA. Towradgi Lagoon is defined as an Intermittently Closed or Open Lake or Lagoon (ICOLL). ICOLLs are shallow coastal water bodies that are connected intermittently to the ocean. Once open, Towradgi Lagoon tends to remain open for only a few days.

Towradgi Lagoon is typical of many intermittently opening south coast lagoons:

- It is often closed to the sea by a sand bar. Lagoon openings tend to only last a few weeks or months. Sand is deposited in the entrance area by coastal processes (wave and long shore drift action).
- The condition of the lagoon's entrance will play a part in the character of the estuarine ecosystem including the composition of plant and animal species, water quality, and tidal and flooding characteristics.
- It is a popular tourist and recreation area; with tourist visits adding markedly during peak holiday periods to the baseline permanent resident visits.

The Towradgi Lagoon system consists of a main lagoon body with the bed located at approximately -0.3 m AHD (a maximum depth of around -1.0 mAHD). A 'control' on the maximum depth is inferred to occur at the entrance at around 0 mAHD (inferred to be a rock shelf from observations of surrounding rock outcropping, although no information on the actual depth is available for the entrance, or whether the rock is present in the entrance area). Thus, the maximum scour is approximately to 0 mAHD when the entrance is fully open. A large portion of the Lagoon area (including the Parker Road Arm) is located above 0 mAHD and therefore when the entrance opens these areas become exposed, with some areas being exposed and inundated on a tidal basis during the 'open' period. The Parker Road Arm bed is generally above 0.5 m AHD and when the entrance is open the Parker Road Arm is inundated only when the tide level is above 0.5 mAHD (i.e. on a mean high water spring tide).

Towradgi Creek has a catchment area of 7.50km^2, which extends west to the Illawarra escarpment, and is bound by Towradgi Road to the south, and a ridge that runs through Corrimal to Corrimal Beach to the north. Land uses within the Towradgi Creek catchment include residential, business, special use, light industrial, public recreation, environmental protection and state recreation areas. The Towradgi Creek catchment is mostly developed, with the exception of the escarpment and scattered patches of remnant vegetation.

Under present levels of catchment urbanisation, Towradgi Lagoon is receiving greater water input as a result of runoff from urbanised areas, as urbanised areas are far more impervious than natural vegetated areas.

The behaviour of the lagoon entrance can greatly impact on the water level, water quality and ecology of the lagoons. During extended periods of entrance closure and heavy rainfall, water levels within the Lagoon may pose a threat to assets, prompting substantial public pressure on Council to undertake mechanical openings of the Lagoon entrance.

2.1 Lagoon Behaviour

Opening

In the event of a rainfall event occurring, with the entrance closed, water will build up behind the berm until water levels exceed the berm height. The flow will then exceed the berm and start to scour a channel which becomes progressively deeper and wider as the rainfall event continues. The rate of increase of the channel depth and width during the opening will be affected by the ocean tide and wave conditions and the amount of rain that

continues to fall in the catchment. Under fully open entrance conditions at the start of a rainfall event, the catchment flow would exit the lagoon, solely controlled by ocean tide and wave conditions. With sand to scour (i.e. the entrance closed or partly open), the rate of discharge slows as the scouring process occurs. The greater the volume of sand to scour, the longer it takes, except under relatively rare catchment flood conditions.

The breakout frequency for Towradgi Lagoon was assessed from water level time history data. It was found that between 1992 and 2003 the annual breakout frequency varied between 7 and 23 times per year, with an average of 16 breakouts per year (Lawson & Treloar, 2005). During periods of open entrance tidal exchange can occur between the Lagoon and the Ocean. Analysis of water level data by Lawson & Treloar (2005) indicated that approximately 50% of breakouts were followed by tidal exchange.

Bewsher (2003a) report that the mechanism of entrance opening for Towradgi is very efficient, partly due to the revetment works at the entrance (gabion baskets). This suggests that under these conditions the berm now has less time to grow in height because it can be scoured (washed away) more easily.

A comparison of observations of water level data for the nearby Fairy Lagoon system show the average number of breakouts for Towradgi Lagoon are almost twice as frequent as that recorded for Fairy Lagoon, which also suggests the berm at the Towradgi lagoon outlet is more easily scoured. However, no water level data is available for the period prior to entrance stabilisation works (circa 1977) to verify this conclusion. Consequently, any changes to entrance behaviour resulting from the revetment works cannot be directly ascertained.

Water Levels

The water level within ICOLL's, such as Towradgi Lagoon, is generally influenced by inflows and outflows including rainfall, runoff, evaporation, ocean overtopping, the level of the berm where the lagoon breaks out to the sea and percolation losses through the dune barrier and the entrance berm.

At water levels below 2.2 mAHD the water level within Towradgi Lagoon increases rapidly in response to catchment runoff. Above 2.2 mAHD the estuary storage characteristics alter and the storage increases fairly significantly without a significant increase in water level (Cardno Lawson Treloar, 2005b).

Berm height plays a very important role in determining the maximum water level reached in Towradgi Lagoon. Lawson & Treloar (2005) estimated that the minimum berm height prior to breakout based on the lagoon water level would be conservatively 1.75 mAHD for Towradgi Lagoon. This estimate was based on water level data between 1992 and 2003. More recent data suggests that the berm height since 2003 may have increased to levels of the order of 2 mAHD.

Ocean Flooding

The level of ocean at any point in time is subject to the following factors:

- Astronomical Tide
- Barometric Pressure
- Wave/Wind Setup
- Wave Runup
- Medium Term Sea Level Variations (e.g. those associated with climate change)

Estimates of 'design' ocean water level, commonly the 100 year ARI ocean level, for the local region are reported in the flood studies for Hewitts Creek (WCC, 2002) and Towradgi

Creek (Bewsher Consulting, 2003a) and in the Thirroul Flood Study for Hooker Land Development (GHD, 1989).

The estimated 100 Year ARI ocean level for the study area is 2.7 mAHD. GHD (1989) have divided this into 1.6 mAHD for tidal, barometric and wind setup components, +0.8m for wave setup and +0.3m for climate change sea level rise for a 50 year planning period. GHD (1989) have also estimated a 20 Year ARI ocean level of 2.4 mAHD.

The maximum water level associated with oceanic inundation at the Towradgi Creek water level station (Pioneer Road) between 1992 and 2003 was 1.74 mAHD. Thus the 20 Year ARI ocean design level (2.4m AHD, GHD, 1989) has not been exceeded inside the Lagoon since measurements began. Note that if the berm was closed and the berm level is above 2.4m at the time, then the elevated ocean levels would have no effect on the Lagoon level.

Flushing

A 1 Year ARI design storm (24 hour duration) will produce a volume of nearly 6 times the volume of the estuary if the berm is at a height of 1.76m AHD. This multiple will be even greater if the level of the berm is below 1.76 mAHD. This volume of flow will result in a significant displacement of any water held in the estuary at the commencement of the event. This indicates that in the absence of complex hydrodynamic features, complete displacement of the estuary volume is likely to occur in relatively frequent storm events.

Issues such as eutrophication (measured via consideration of the frequency of algal blooms) commonly associated with limited flushing of estuaries, is therefore likely to be influenced by this frequent displacement of the volume of flows entering the estuary.

3. ALTERNATIVES FOR ENTRANCE MANAGEMENT

3.1 Community Feedback

Council sought community feedback on the options available for entrance management. The full details are provided in the Submissions in Reply Report (Wollongong City Council, 2007). Three entrance management options have been identified, they include:

- the do nothing approach,
- assisted opening, and
- berm height management.

A summary of these approaches is provided below. Additional details are provided in the accompanying REF (Cardno Lawson Treloar, 2007).

For the reasons explained below, the Do Nothing Approach is not considered to be a feasible option. Details have also been provided for the Berm Height Management Option. However, the Berm Height Management Option was not the prefered option because of the relative expense and high labour requirements. Assisted opening, or Mechanical Breakout, has been recommended as the preferred approach based on the comments in the Submissions in Reply Report (Wollongong City Council, 2007). Full details are provided in that report.

3.2 Do Nothing Approach

The intention of this approach is to allow the lagoon to open with no assistance. However, the consequences of adopting this approach include the potential to result in nuisance flooding of numerous residential properties (yard and overfloor flooding) and the flooding of local infrastructure (such as Parker Road). However, based on recent observations (particularly following the severe floods of 1998 and 1999), it is expected that in the absence of intervention, an unassisted opening is likely to result in intervention by concerned residents as flood waters rise would take it upon themselves to open the entrance manually. An example of such intervention occurred in 2005 (reported in the Illawarra Mercury) where inundation of Parker Road (associated with a high water level in a closed Lagoon) prompted residents to open the Lagoon.

The impact of not having an adopted entrance management policy is twofold. Firstly, there will be a public perception that both private and public assets are not being adequately protected by Council from flooding. As outlined above, this may result in illegal opening of the lagoon. This could potentially result in the lagoon being mechanically opened more frequently than if an entrance management policy was in place. This could have negative impacts on lagoon ecology and recreational uses.

The second impact is related to the need for the most prudent flood-risk management as within the adopted Floodplain Risk Management Plan (Bewsher Consulting, 2003b). Adopting a do-nothing approach is inconsistent with the adopted Floodplain Risk Management Plan.

3.3 Mechanical Breakout

The modification of the Towradgi Lagoon entrance system and the modification of the local catchment through the process of urbanisation have altered the natural (Pre-European) opening conditions. Given the flood risks to property and infrastructure in the Towradgi Lagoon floodplain, the entrance may need to be mechanically opened from time to time. The advantage of an Entrance Management Policy, is that it provides certainty for all

affected stakeholders and the wider community of when, where, how and under what conditions Towradgi lagoon will be mechanically opened.

The lagoon entrance would be opened only when a pre-defined set of criteria are met. These criteria include a 'trigger' lagoon water level and berm height coupled with the prediction of continuing rainfall and therefore an expected further increase in lagoon water levels. There would also be an emergency 'trigger' level which would result in immediate opening of the lagoon even if continuing rainfall is not predicted. This emergency level would be defined by the level of the lowest critical asset.

Once all the criteria are met, a mechanical breakout of the lagoon entrance is initiated. This would involve the deployment of equipment, such as a 4WD backhoe, to dig a 'pilot' channel (a narrow, shallow channel to facilitate the commencement of outflow from the Lagoon). Details of the means of access of equipment to the beach are outlined in Section 3.5. The pilot channel would be approximately 1m wide and to a depth such that the base of the pilot channel meets the lagoon water level. Once the pilot channel has been created, the machinery is removed from the beach and water in the lagoon will start to flow through the pilot channel, the flow will increase as it scours the channel deeper and wider. The mechanism of the scour process is natural from this point onwards, driven by ocean tidal behaviour and catchment inflow. This generally results in a three phase process, taking of the order of 4 - 6 hours and is described in Gordon (1981 and 1990).

Generally a mechanical breakout is initiated on the first suitable high tide. However, during the consultation period of this study, it was noted that there is considerable community concern about over-scouring of the entrance during an opening and the consequent exposure of the estuarine sediments and the impacts on recreational usage and visual amenity. As such, it is suggested that the mechanical breakouts should occur on the first available mid-outgoing tide. This may limit the efficiency of scour during the opening but is dependant on catchment rainfall conditions. This should be undertaken as a trial and review of this process should be undertaken during the next review of this policy.

It should be noted that whilst opening the entrance on the mid-outgoing tide was the preferred action by the community, the community also voiced concerns about accumulating sediments within the lagoon. Should scour of the entrance be limited to reduce scour depth, it is also likely that the scour and removal of sediments within the main body of the lagoon may also be limited. This may artificially increase the accumulation of sediments within Towradgi Lagoon over time.

3.4 Berm Height Management

The berm height at the entrance of the lagoon can be managed such that it does not exceed a pre-determined level. This is sometimes known as maintaining a 'dry notch' (i.e. a low or 'saddle' point in the beach adjacent to the entrance which the Lagoon can preferentially flow across). The purpose of the notch is to dispense with the need to mechanically open the Lagoon when a flood arrives. If maintained correctly, the notch would breach without intervention when the Lagoon water level reaches the appropriate level. The flow from the Lagoon to the ocean will increase as it scours the channel deeper and wider (ie the same three phase process described above by Gordon, 1981 and 1990).

Managing the berm height to sustain the presence of the 'dry notch' would involve regular monitoring of the berm height via regular survey and/or the use of observation height markers. A combination of lagoon water levels and volume of the overall sand berm would be considered to determine if a berm 'shaping' to maintain the notch is required. The 'shaping', potentially to be undertaken on frequent basis (ie of the order of monthly or bi-monthly dependent on coastal processes), would be undertaken using some form of sand moving machinery, such as a bulldozer or excavator. As part of the 'shaping' process, the required depth of sand would be moved from the entrance to a location on the beach (close

to the entrance) and spread out to 'match in' with the existing beach profile such that the sand remains in the beach system.

Berm height management would be expected to involve more frequent access of machinery onto the beach than the mechanical opening approach (Section 3.3). Therefore there may be increased impacts associated with access and machinery. A formalised access path (Section 3.5) would be required to limit the erosion impacts on the bank. Under the mechanical breakout option, a less formal access path may be suitable.

3.5 Access Path Alternatives

In addition to the feedback provided on the alternatives outlined above, the Submissions in Reply Report (Wollongong City Council, 2007) also provided Community feedback on the alternatives available for the access path that will be used by machinery accessing the beach. To prevent erosion of the banks of the Lagoon and the coastal dune system, and to minimise the generation of sediments being delivered to the lagoon, an access of some form will be required for the Mechanical Breakout option (Section 3.3).

Several alternatives have been assessed for the proposed access path, which are described in the REF (Cardno Lawson Treloar, 2007).

- The installation of an 'inlaid rubber grid', a proprietary product, for the grassed portions of the access path would allow for turf to grow within or on top of the pavers. The use of such products would minimise erosion impacts associated with the movement of machinery. Additionally, this would minimise fragmentation by allowing the growth of grasses, and would reduce any visual impacts. Such a product would have to be used in tandem with a flexible plank decking, similar to that used for sand dunes, where sand is encountered on the access path.

- Another option for stabilising and defining the access path is to implement a formal gravel access path for 4WD backhoes to gain access to the entrance area of the Lagoon. This option would help minimise disturbance of the southern bank of Towradgi Lagoon associated with the movement of machinery. This will most likely take the form of a gravel-based path, lined with geofabric, with a base of approximately 200 – 300mm deep. Concerns associated with this form of path include the fragmentation of riparian vegetation and visual impacts.

- It may be possible to use a transportable access stabilisation product. This would also help minimise erosion and avoid fragmentation. This would involve the use of a portable rubber stabilisation structure that can be rolled out prior to machinery accessing the Lagoon entrance, to protect sensitive areas. The main issue associated with the use of a portable temporary structure is that it may take time to set it up. This will be an issue during mechanical breakout, as the process of laying out the temporary structure will be time consuming, and water levels may be rising rapidly.

Concerns were raised in the Submissions in Reply Report (Wollongong City Council, 2007) regarding formalisation of a designated access path. As outlined above, the major concern with not creating a formalised access path for machinery to use during mechanical opening of the Lagoon is that there will be increased erosion of the banks of the Lagoon, as there will be no stabilised, designated access route, which may result in machinery using several entrance and exit points, spreading the risk of erosion. In addition, the mechanical breakout activity is time critical. Therefore, a transportable access stabilisation product is not recommended. A permanent access point alleviates this time pressure. With these concerns in mind, the grassed inlaid rubber grid may be the preferable option for the access point. However, a formal access path is not necessary for the policy to be implemented. This matter may be considered by Council and clarified at a later date.

4. DETERMINATION OF TRIGGER LAGOON WATER LEVEL

4.1 Inundation

The amount of inundation experienced by the land surrounding Towradgi Lagoon (including the Parker Road Arm) varies with lagoon levels. Inundation extents were assessed for a range of lagoon levels (1.4mAHD to 3mAHD). A trigger level greater than 2mAHD is considered inappropriate due to road, property and over floor flooding in Parker Road. Also water level records show that the lagoon very rarely exceeds 2 mAHD. Therefore, the inundation extents for lagoon levels of 1.6 mAHD, 1.8 mAHD and 2 mAHD are shown below in Figure 3 to provide a representation of various inundation extents which could be experienced. It should be noted that limited survey was available for the Parker Road Arm to produce this mapping. However, survey downstream of Lake Parade shows fairly significant inundation of surrounding land at 2 mAHD. Ground survey for properties on Parker Road show that property inundation would be expected to occur after levels in the Lagoon exceed 1.8 mAHD. Figure 3 shows that the reserve at the rear of properties in Juanita Avenue is inundated to some degree at 1.6 mAHD and is significantly inundated at 2 mAHD. Anecdotal evidence in the local area suggests that there is no property inundation at 1.6 mAHD. However, not all affected residents were available during the consultation period to confirm this observation. In addition, the results of the modelling should be treated with caution due to the limited survey used. Nonetheless, for the purposes of this report, it has been assumed that there is some degree of property inundation at 1.6 mAHD.

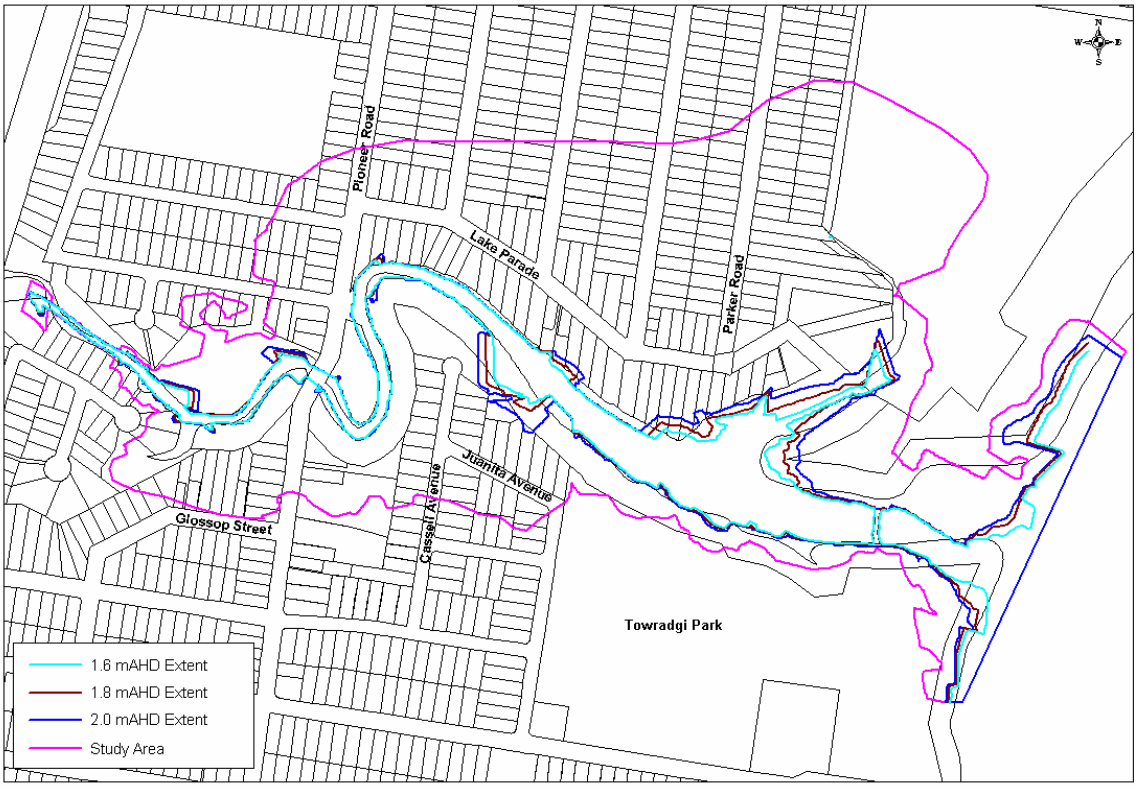


Figure 3 Comparison of 1.6 mAHD and 2 mAHD Extent

A review of the potential inundation extents would suggest that a trigger level of 1.6 mAHD would be the most desirable. At this level some property inundation occurs. However, the majority of residential properties are protected and no street flooding or overfloor flooding occurs. It may be possible that inundation of properties up to approximately 1.7 mAHD could be tolerated for a short time. However, due to the rate of rise of lagoon water levels during a rainfall event this level would very quickly be exceeded and assets may be

impacted. A trigger level of 1.6 mAHD allows for a longer response time. This issue is discussed further in Section 4.5.

4.2 Asset Assessment

A detailed asset assessment is provided in the accompanying Review of Environmental Factors (Cardno Lawson Treloar, 2007). The outcome of this assessment found that the inconvenience of inundation to a level of 1.6 mAHD could be tolerated. No access roads, stormwater pits surcharging or floor levels would be impacted upon at this level and only minor property inundation would be experienced. At lagoon levels of 1.8 mAHD significant property inundation would occur along the Parker Road Arm and some stormwater pits on Lake Parade and Parker Road would be expected to be inundated (grate levels of 1.64 mAHD and 1.7 mAHD), resulting in drainage issues along the street.

In the past the area around Towradgi Lagoon has experienced stormwater and sewerage overflows. The sewerage issue has not been assessed as part of this Policy, due to the provision of the wet weather pumping station currently under construction by Sydney Water.

It is assumed that services and infrastructure such as underground cables and pipe networks would have been designed to withstand any groundwater pressure as a result of lagoon levels of 1.6 mAHD as this level has regularly been achieved within the Lagoon.

4.3 Historic Water Levels

A water level gauge has been operated on the downstream side of the Pioneer Road (near Blue Divers) on Towradgi Creek since February 1992. An analysis of water level data from Towradgi Creek for the period 1992 to 2003 indicates that the water level at the gauge has ranged from 0.51m AHD to 4.32m AHD during the 11 year monitoring period (Lawson & Treloar, 2005).

In addition to the water level data provided for the 1992 to 2003 period, MHL provided the top 10 maximum water level records for the last three years. These records are shown in Table 1. This period represents the time after the cessation of the informal entrance management policy (as discussed in Section 1.2). In contrast with the data provided for 1992 till 2003, which represents the period when the informal policy was in practice, the 2003 to 2006 data shows that the lagoon exceeded 1.6 mAHD on a number of occasions, with maximum water level of 1.94 mAHD recorded in June 2004.

It should be noted that the water level gauge was not operational during a period of observed inundation in June 2005. Residents observed the lagoon levels on the 25 June 2005 to be of the order of 1.96 mAHD (Ray Robinson, *pers comm to WCC*.). This level is supported by the fact that Parker Road was inundated (The Illawarra Mercury, dated 27 June 2005). The Parker Road crossing has a level of 1.94 mAHD.

Table 1 Maximum Recorded Towradgi Lagoon Water Levels (2003 – 2006)

Level (mAHD)	Date	Time
1.67	21-Feb-03	09:00
1.74	18-Apr-03	22:00
1.72	27-Jun-03	20:00
1.79	17-Aug-03	12:00
1.82	3-Oct-03	06:00
1.70	25-Oct-03	19:00

Level (mAHD)	Date	Time
1.66	21-Nov-03	22:00
1.71	24-Feb-04	21:00
1.74	27-Feb-04	03:00
1.94	11-Jun-04	03:00
1.75	18-Jul-04	05:00
1.70	17-Aug-04	20:00
1.71	19-Sep-04	23:00
1.82	22-Mar-05	17:00
1.82	23-Mar-05	07:00
1.71	28-Mar-06	08:00
1.75	9-Apr-06	07:00
1.73	2-Jun-06	20:00
1.78	22-Jun-06	08:00
1.87	18-Jul-06	13:00

A review of water level data both during and after the implementation of the informal entrance management policy shows that without mechanical breakouts, the lagoon levels have been observed to rise to a level which causes inundation of roads, stormwater infrastructure, properties and potentially overfloor flooding.

4.4 Recreation

Towradgi Lagoon has a high recreational value to the local community and to visitors to the area. A number of the recreational activities identified in Towradgi Lagoon are water based activities, such as kayaking, canoeing and small boat sailing. These activities require the Lagoon to have sufficient depth to facilitate the activities.

The average bed level in the Lagoon is approximately -0.3 mAHD (with some section at 0 mAHD). If it is assumed that water based recreational activities require a minimum depth of approximately 1.5 metres, it would be undesirable to undertake a mechanical breakout at less than 1.5 mAHD. If the trigger level for Towradgi Lagoon were to be set at this value, the recreational value of the lagoon would be expected to be significantly reduced.

To maximise recreational values the trigger level should therefore be greater than 1.5 mAHD.

4.5 Rate of Rise

Due to the nature of the catchment and rainfall patterns in the area, the rate of rise of lagoon water levels in response to rainfall is fairly high. This means that during a rainfall event the lagoon level could potentially be significantly higher than the trigger level by the time a mechanical breakout had occurred.

The rate of rise for Towradgi Lagoon was calculated using catchment size (750ha), rainfall intensity on the catchment, runoff and the lagoon volume (varies with depth).

Based on a bathymetric analysis and a review of the character of the 24 hour duration (the critical duration for volume) for the 1 Year ARI design event, the rate of rise, once the lagoon levels exceed 1.3 mAHD, is on average 0.37 m/hr. This value increases at lower levels due to the limited lagoon storage capacity. At high lagoon water levels, the water spreads out into a larger area allowing a greater volume of water to be stored. The rate of rise at various lagoon water levels above 1.3 mAHD is shown below in Figure 4.

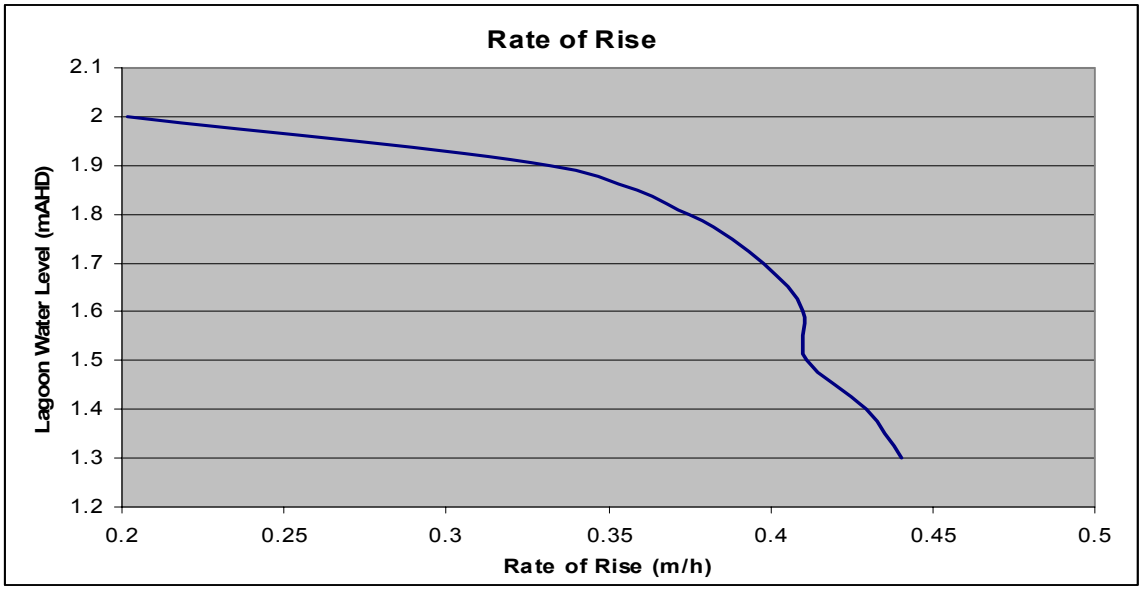


Figure 4 Rate of Rise of Towradgi Lagoon Levels

The high rate of rise within Towradgi Lagoon, even for relatively frequent events such as the 1 Year ARI Storm, indicates the need to ensure the selected trigger level allows for enough time for additional rise of lagoon levels before significant damages are experienced. It also highlights the need to establish an alert level which will indicate that lagoon levels may rise and reach the trigger level. This will allow additional time to mobilise machinery, if required.

Based on the Parker Road crossing level of 1.94 mAHD and overfloor flooding occurring at levels greater than 1.97 mAHD, the lagoon would need to be opened at 1.9 mAHD to protect these assets. If the rate of rise is 0.37 m/hr, and a 2 hour duration is required to initiate a mechanical breakout, the procedure to mechanically breakout would need to be mobilised when the lagoon levels reached approximately 1.2 mAHD. However, it is not considered practical to send an alert every time the lagoon reaches levels greater than 1.2 mAHD as water level records suggest that the lagoon is higher that 1.2 mAHD over 25% of the time.

Whilst the rate of rise within the lagoon would suggest that an alert level is necessary, the Flood Study (Bewsher, 2003a) states that during large rainfall events (5 Year ARI and greater) the lagoon and berm levels do not impact upon peak flood levels in properties adjacent to the lagoon. This is due to the limited storage area in the lagoon and the relatively large catchment size compared to the Lagoon size. This results in an efficient entrance breakout mechanism.

It should be noted that should heavy rainfall occur in the catchment and Lagoon levels were to rise above 1.6 mAHD before a mechanical breakout could occur, the lagoon would most likely only be above levels of 1.6 mAHD for a relatively short period of time (i.e. the time taken for the lagoon to drain back down to 1.6 mAHD, of the order of a few hours.

Based on the assessment of the rate of rise in Towradgi Lagoon and the assumptions in the Flood Study (Bewsher, 2003a) it is considered that an alert level of 1.4 mAHD would be appropriate for Towradgi Lagoon. However, if heavy rainfall is predicted in the catchment, close observations of the lagoon level should be undertaken on a regular basis (at least hourly). This should be done even at levels less than 1.4 mAHD to ensure timely mobilisation of a 4WD backhoe.

A trigger level of 1.6 mAHD would allow for additional rise of lagoon waters before significant impacts occurred on private and public assets.

4.6 Ocean Levels

If ocean levels were greater than the trigger level and the Lagoon entrance was opened, ocean waters would flow into the lagoon, rather than the lagoon draining, and the lagoon level would rise. Therefore, an assessment has been undertaken of Highest Astronomical Tides (commonly referred to as King Tides), historical tide data and predicted ocean levels in storm conditions.

It should be noted that all ocean levels below are reported in mAHD, ocean levels for navigation purposes are often reported from the Lowest Astronomical Tide (LAT) which is approximately 1m below 0 mAHD, resulting in tide levels reported as 1m higher than those in mAHD.

The highest astronomical tide (HAT) or King Tide for the region is 1.17 mAHD. While HAT is the highest level of normal tides inundation may exceed this level (eg storm surges). If the trigger level is set above this level, a king tide event will not increase lagoon levels when the lagoon entrance in opened.

Due to the extensive data set from tide gauges such as Fort Denison (operational since the late 1880's), recorded water levels can be reported in terms of the probability of exceedance of a specific level at some locations. For example, the water level that is exceeded for only 1% of the time at Fort Denison is ~1.0 mAHD. This level would relate to ocean levels at Towradgi Lagoon. As described above, if the trigger level is set above 1.0 mAHD, the ocean level will not increase lagoon levels if an assisted opening is undertaken.

The maximum water level associated with oceanic inundation at the Towradgi Creek water level station (Pioneer Road) between 1992 and 2003 was 1.74 mAHD.

The estimated 100 Year ARI ocean level for the study area is 2.7 mAHD. GHD have divided this into 1.6 mAHD for tidal, barometric and wind setup components, +0.8m for wave setup and +0.3m for climate change sea level rise for a 50 year planning period. GHD (1989) have also estimated a 20 Year ARI ocean level of 2.4 mAHD. These values are estimates for the beach not within the lagoon. Wind and wave setup would not be able to propagate through the entrance at these same heights. Therefore, the resulting lagoon levels as a result of elevated ocean levels would be significantly lower.

An assisted opening will only be undertaken when ocean levels are below the lagoon levels.

4.7 Floodplain Risk Management Plan

The Flood Study (Bewsher, 2003a) did not utilise a closed entrance condition within the hydraulic modelling, which was used to determine flood planning levels. However, the Towradgi Creek Floodplain Risk Management Plan (Bewsher, 2003b) recommends entrance management as a flood mitigation measure. It recommends that the trigger level be set at a maximum of 2 mAHD.

4.8 Berm Height

Berm height plays a very important role in determining the maximum water level reached in Towradgi Lagoon. Lawson & Treloar (2005) estimated that the minimum berm height prior to breakout based on the lagoon water level would be conservatively 1.75 mAHD for Towradgi Lagoon. This estimate was based on water level data between 1992 and 2003.

More recent data suggests that the berm height since 2003 may have increased to levels of the order of 2 mAHD.

When the lagoon water levels exceed the berm height an unassisted opening is initiated. As such, if the berm height is not significantly higher than the trigger level, a mechanical breakout may not be necessary. A review of the inundation extent and asset assessments undertaken in the REF (Cardno Lawson Treloar, 2007) and anecdotal evidence from community feedback would indicate that a lagoon water level of up to approximately 1.75 mAHD could be tolerated for an extended period of time (of the order of several days). Levels higher than this could only be tolerated for a short period of time (less than 1 day).

It is therefore recommended that a berm trigger level of 1.75 mAHD should be incorporated into the opening procedure.

4.9 Trigger Level

It is recommended that the Towradgi Lagoon Entrance Management Policy define the Towradgi Lagoon trigger level to be set at **1.6 mAHD**. Based on the fast response in lagoon water levels to rainfall in the catchment, it is also recommended that an alert trigger level should be provided; this level should be set at **1.4 mAHD**.

It should be noted that for an opening to occur the lagoon water levels should not only exceed 1.6 mAHD but rainfall must be falling in the catchment or be expected to fall, such that Lagoon levels will continue to rise, these conditions should also be coupled with a berm height level greater than 1.75 mAHD.

An emergency trigger level should also be set at **1.85 mAHD**. The emergency trigger level is a level at which the Lagoon should be opened even if no rainfall is predicted. The lagoon level may reach this level slowly (e.g. through very small rainfall events or topping up of the Lagoon from ocean levels overtopping the berm). As such, the criteria for undertaking an opening may not be fulfilled. The emergency trigger level allows for the Lagoon to be opened even in dry conditions so that inundation of properties and assets does not occur over a significant period of time.

5. LAGOON OPENING PROCEDURE

5.1 Lagoon Opening Decision Making

The logic behind this policy relates to the threat to flooding of private property and public assets if the lagoon entrance is closed and the water level reaches the threshold level of 1.6 mAHD and heavy rain occurs. An asset assessment for the study area is provided in the Review of Environmental Factors (Cardno Lawson Treloar, 2007). At levels below 1.6 mAHD, there is increased opportunity to plan an opening. As such, once water levels reach 1.4 mAHD and rainfall is predicted, monitoring of water levels is to be undertaken so that an opening can be planned for in the event of water levels reaching 1.6 mAHD.

The water level in the Lagoon is monitored at 15 minute intervals at Pioneer Road and reported publicly at the following website:

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

It is important to note that while the data is regularly logged, the information on this webpage is normally only updated on a daily basis, usually between 4 – 6am.

Rainfall in the locality can be monitored via routine checks of the local rainfall gauge at Russell Vale. The data from this gauge is also reported publicly at the following website:

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

As for the water level data, it is important to note that the information on this webpage is normally only updated on a daily basis, usually between 4 – 6am.

As part of this policy, systems will be implemented to ensure an alarm is created in the monitoring system to send an automated fax or telephone a pre-registered list of telephone numbers (provided in Attachment A1) with a recorded message when the threshold levels have been exceeded.

- A “standby” message should be issued at **1.4 mAHD**.
- An action or “go” message should be issued at **1.6 mAHD**.
- A “no delay” message should be issued at **1.85 mAHD**.

The “standby” alarm to be triggered when the level reaches 1.4 mAHD is to indicate to Council that an opening may be prudent and ensure that adequate resources are available to undertake an opening. The “go” alarm initiates the active opening procedure which includes a first phase of checking predicted rainfall in the catchment and berm elevations. Then, if necessary, the second stage of mechanically opening the entrance. The “no delay” alarm triggers an immediate opening of the lagoon, irrelevant of predicted rainfall or berm height.

The following summarises conditions under which the lagoon entrance can be mechanically opened.

a. If the level of the lagoon reaches 1.85 mAHD it shall be opened as soon as conditions permit (see Section 5.3 for a description of those conditions);
b. If the level of the lagoon reaches 1.6 mAHD and rainfall is continuing in the catchment or expected in the following 24 hours (details of rainfall prediction is provided below) and the berm height is greater than 1.75 mAHD (to be determined from a marker to be placed at the entrance), the entrance shall be opened on the top of the first available mid outgoing tide without delay; or

c. When the lagoon reaches a level of 1.4 mAHD and heavy rain is predicted and water levels are likely to exceed 1.6 mAHD overnight, works staff shall be placed on standby to open the lagoon without delay.

There may be occasions when safety issues preclude a mechanical breakout proceeding, for example, during severe ocean storms.

It should be noted that the estimated time to mobilise a 4WD backhoe and operator is of the order of one hour during business hours and two hours during non-business hours.

Predicted rainfall patterns can be accessed via the following Bureau of Meteorology (BOM) web pages:

South East Districts Forecast: - http://www.bom.gov.au/products/IDN10061.shtml#ILL

Example of Data found on this website:

Australian Government Bureau of Meteorology

Home | About Us | Contacts | Help | Feedback |

SEARCH

Global | Australia | NSW | Vic. | Qld | WA | SA | Tas. | ACT | NT | Ant. |

Learn About Meteorology | Weather & Warnings | Climate | Hydrology | Numerical Prediction | About Services | Registered User Services |

- Select district from: NR | MNC | HUN | NT | ILL | SC | CT | ST | NWS | CWS | SWS | RIV | UW | LW

IDN10061
Australian Government Bureau of Meteorology
New South Wales

SOUTH EAST DISTRICTS FORECAST

Issued at 5:15am on Friday the 8th of December 2006

For the period through to Monday
IDN1006101

ILLAWARRA

Warning summary

Forecast for Friday
Morning drizzle patches on ranges then fine and partly cloudy day. Mild. Northeast to southeast winds.

```
Wollongong : Mostly fine, partly cloudy.     Max:   23
Nowra :      Mostly fine, partly cloudy.     Max:   24
Bowral :     Mostly fine, partly cloudy.     Max:   25
```

Forecast for Saturday
Early drizzle patches then fine. Mild. Light to moderate east to northeast winds.

```
Wollongong : Mostly fine, partly cloudy.     Min:   15  Max:   24
```

Forecast for Sunday
Fine. Warm day. Fresh north to northeast winds.

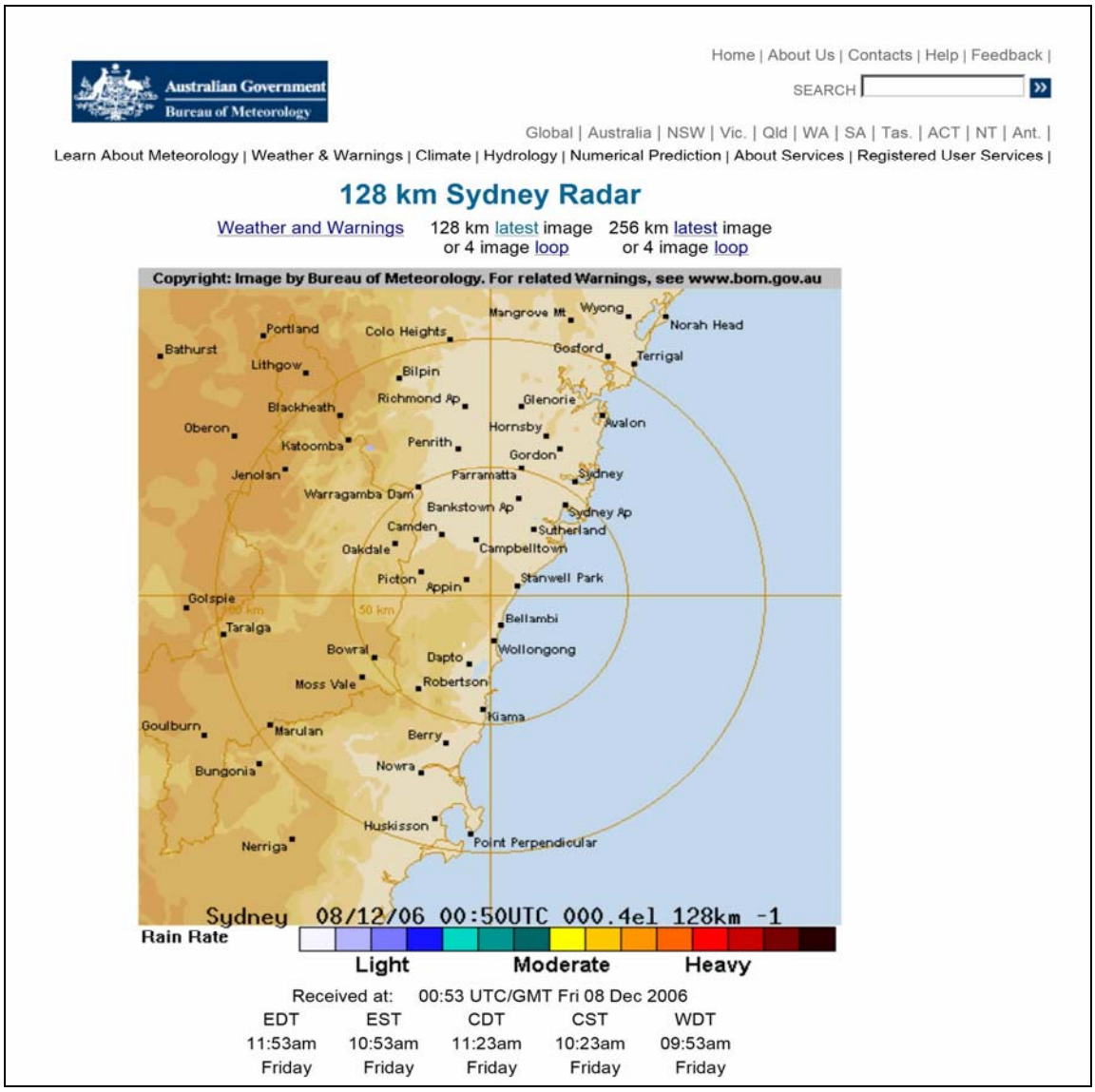
```
Wollongong : Fine.                           Min:   16  Max:   26
```

Forecast for Monday
Fine day. Isolated afternoon showers and thunderstorms more likely in the south. Warm to hot day. Fresh north to northeast winds ahead of a late southerly change.

```
Wollongong : Chance afternoon shower/thunderstorm.  Min:   17  Max:   31
```

128km Sydney Radar - http://mirror.bom.gov.au/products/IDR033.shtml

Example of Data found on this website:



Once a decision has been made to undertake a mechanical breakout, advice to DPI (NSW Fisheries), DECC and the local media should be issued advising of the breakout with details of the opening (including proposed timing and reasons for opening) and of potential health impacts on recreational swimmers on the adjacent beach areas for the following three days (a list of contacts is provided in Attachment A2). Failure to notify the public about the health and safety hazards could result in Council being liable for any incidents.

A flowchart summarising the decision-making process is provided as Attachment B.

5.2 Responsibility for Opening

Wollongong City Council is responsible for lagoon opening, should intervention be necessary. The Council officer responsible for carrying out specific on site assessment in accordance with the REF (Cardno Lawson Treloar, 2007), consultation and any subsequent decision to open the lagoon (as per Attachment B), is the Floodplain Strategy Manager. This officer will also be responsible for the monitoring function detailed in Section 5.4 and Attachment D.

The Council officer responsible for plant management and on-site control is the Division Engineer – Central Depot. The procedures and assessments outlined in this document, including a copy of Attachment C showing the entrance location and copies of the entrance monitoring sheet (Attachment D), will be made available to the Division Engineer – Central Depot to ensure the opening is made in the correct location and to the dimensions required.

5.3 Procedures

Once the decision has been made to undertake a mechanical breakout, the following breakout procedure should be undertaken.

1. The procedure is to be planned so that where possible the actual opening of the lagoon occurs at the mid outgoing tide, except for decision-making process A (Attachment B), where the opening of the lagoon occurs shortly after the tide turns from high to low, for the lower tide of the day (given the diurnal nature of the tides).
2. A mechanical opening should not be undertaken if wave conditions are dangerous i.e. if H_{sig} is greater than 4m. Wave heights can be accessed at http://www.bom.gov.au/marine/waves.shtml.
3. A mechanical opening should only be undertaken when high tides are predicted to be less than the lagoon levels. Ocean tide information in the form of predicted tides can be accessed at http://www.mhl.nsw.gov.au/www/sydp_tide.htmlx - note that the datum for this prediction is ISLW not AHD).
4. The Figure provided in Attachment C shows the recommended access point for the 4WD backhoe operator to access the beach and the recommended orientation of the excavated channel and location of the material excavated from the pilot channel. The location and orientation of the recommended pilot channel has been selected by considering available historical data from Council. White pole markers be placed in Corrimal Beach Park upstream of the footbridge in clear view from the entrance, to direct the 4WD backhoe operator as to the most appropriate pilot channel location and orientation.
5. The opening should be sufficient for scouring flow to develop (i.e. with a velocity of greater than 0.4 m/s). The 4WD backhoe operator is to dig a 'pilot' channel from the ocean-ward end toward the lagoon approximately a bucket-width wide (commonly 2m or less) with the bed graded to the ocean. The last section of the channel (at the lagoon end) should be opened at the time of the next possible mid outgoing tide. Ocean tide information in the form of predicted tides can be accessed at http://www.mhl.nsw.gov.au/www/sydp_tide.htmlx - note that the datum for this prediction is ISLW not AHD). Initiation of a breakout at this time is likely to result in the most effective and sustained mechanical breakout due to the increasing head difference through the course of the breakout.
6. Where access to the internet is not available (due to power loss associated with a storm event), checking of a water level marker (a 'tide board') at a visible location from the footbridge at the entrance (to be installed on the upstream side of the footbridge) should be undertaken.
7. The volume of sand to be excavated for the pilot channel is expected to be small. This sand will be retained on the beach and may be washed into the channel as it expands laterally. The location for placement of the excavated sand is shown on the Figure provided in Attachment C. Excavated sand is not to be removed from the beach area.
8. Possible contamination of the adjacent surf beach should be considered while the lagoon is emptying, for at least the first 3 days. Appropriate action should be taken to protect public health and safety at the site while excavation equipment is operating.

5.4 Entrance Monitoring

5.4.1 Mechanical Breakouts

When mechanical breakouts have been carried out, monitoring of the entrance should be undertaken to determine the efficiency of the opening and to provide data for use in a possible future flood study. Council's Floodplain Strategy Manager will be responsible for this monitoring function.

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

- level of lagoon prior to opening
- date and time of opening
- location and length of excavation
- approximate width and depth of channel (recorded at least hourly)
- ocean swell conditions (wave height and direction)
- preceding rainfall
- date of closure and cause
- digital photographs.

If possible, photographs at later time intervals after breakout initiation has occurred are to also be made, at least until the lagoon has emptied to tidal conditions.

If possible, an estimate of depth and peak flow velocity coincident with ocean low tide should be made; photographs of the water surface should also be made at each time interval. Comment should be made on apparent depth, velocity and width variations along the channel.

The information is to be recorded on a standard monitoring sheet (Attachment D).

It is also recommended that monitoring currently being undertaken by Wollongong City Council continues, and that monitoring plan recommended in the Further Processes Study (CLT, 2005b) be implemented (See Appendix D of the REF, Cardno Lawson Treloar, 2007). This monitoring plan is to be supplemented with the monitoring requirements provided in Table 2.

5.4.2 Unassisted Breakouts

Monitoring will also include unassisted breakouts, where possible, recording the prior lagoon level, time and date of opening, the date of lagoon closure, and any other relevant comments. Responsibility for monitoring is assigned to Council. The information is to be recorded on a standard monitoring sheet (Attachment D), which is to be completed for every entrance opening, whether mechanical or unassisted.

As part of this policy, systems will be implemented to ensure an alarm is created in the monitoring system to send an automated fax or telephone a pre-registered list of telephone numbers (provided in Attachment A1) with a recorded message when the threshold levels have been exceeded. These contacts will also be notified by an automated fax when an unassisted breakout has occurred. This will be identified by a sudden drop in lagoon levels over a short period of time.

5.5 Entrance Berm Clearance

The berm height and depth at some lagoon entrances can build up to such a volume that a mechanical breakout would be hindered and the length of time it would take to open the entrance would be substantially increased. The increased time to undertake a mechanical

breakout can result in significant inundation and damages incurred around the Lagoon. Therefore, it may be necessary, in some cases, to undertake an entrance berm clearance. Entrance berm clearance would involve the redistribution of built up sand from the entrance to the surrounding beach area. This would increase the likelihood of an unassisted breakout and reduce the amount of time required to undertake a mechanical breakout.

Towradgi Lagoon entrance is considered to be an “efficient” entrance, in that it opens fairly regularly and has limited sand build up. Therefore, due to the nature of the entrance at Towradgi Lagoon, entrance berm clearance is not likely to be required or recommended.

6. SUMMARY OF ENVIRONMENTAL ISSUES AND RECOMMENDED SAFEGUARDS

A summary of the proposed safeguards is provided below in Table 2.

Table 2 Summary of Environmental Issues and Recommended Safeguards

Environmental Issues	Recommended Safeguards
Geology, Soils and Topography Issues will largely be associated with erosion and sedimentation during the construction of the access path.	• An ESCP would be prepared and implemented for the construction of the access path in accordance with *Managing Urban Stormwater – Soils and Construction* (the Blue Book) (NSW Department of Housing, 2004) as part of the Contractors Environmental Management Plan (CEMP) for the site and approved by Council's Superintendent before works commence. • Regular inspection of the work site would be undertaken for the duration of construction of the access path to ensure that the ESCP is implemented and maintained.
Climate There are no immediate issues associated with climate. However, the impact of climate change and associated sea level rise may impact on entrance management in the future, especially with regards to berm location.	• The impacts of sea level rise on berm location should be assessed during subsequent Entrance Management Policies.
Water Quality There is uncertainty as to the impact of the Entrance Management Policy on water quality within Towradgi Lagoon.	• Monitoring of water quality as recommended by CLT (2005b) (Appendix D) to assess the impact of the Entrance Management Policy.
Assets Flooding as a result of heavy rainfall and a closed Lagoon entrance can have a detrimental impact upon surrounding assets such as infrastructure, commercial and residential properties, roads and recreational areas.	• The implementation of this policy is the key mitigation measure. Options for asset raising associated with increased trigger levels are outline in Section 8.3.
Lagoon Ecology Seven part tests indicate that the proposed Entrance Management Policy is unlikely to have a significant impact upon endangered ecological communities and threatened species that are likely to occur within Towradgi Lagoon. However, there is a need to gauge the impact of the proposed policy on terrestrial and aquatic flora and fauna is necessary to improve future policies through adaptive management.	• Implementation of monitoring programmes as recommended in CLT (2005b) to assess the impact of the Entrance Management Policy upon flora, fauna and important habitats such as seagrass beds riparian vegetation, mangroves and wetlands (Appendix D).

Environmental Issues	Recommended Safeguards
Commercial and Recreational Fishery There is a need to gauge the impact of the proposed policy on commercial and recreational fish species within the Lagoon.	• Monitoring of commercial and recreational fish species, which could be incorporated in the monitoring of aquatic fauna.
Tree Failure Trees fringing on the banks of Towradgi Lagoon have the potential to pose a hazard.	• Monitoring of trees that have potential for tree failure could be incorporated in monitoring for erosion and sedimentation that have been recommended in CLT (2005b).
Air Quality Minor localised air quality issues associated with the operation of machinery for the construction of an access path may occur.	• The generation of exhaust particle dust would be minimised during the construction of the access path and assisted breakout of the Lagoon by using well maintained machinery and operating in an efficient manner.
Noise and Vibration Minor noise and vibration impacts may be experienced during the construction of the access path.	• Construction of the access path should take place during winter when recreational use of the area will be lowest.
Indigenous Heritage Several known indigenous heritage items are located within areas surrounding Towradgi Lagoon. Construction of the access path may disturb such items. Additionally, if the proposed policy was to lead to increased erosion, this may result in the exposure of indigenous heritage items within the Lagoons banks.	• An indigenous heritage assessment for the proposed access path should be undertaken prior to construction. • Erosional impacts upon the Lagoon banks should be incorporated into the erosion and sediment monitoring recommended in CLT (2005b).
Non-Indigenous Heritage	• No specific requirements.
Hazards Large machinery may pose a hazard to pedestrians and motorists using Towradgi Park and its facilities during the construction of the access path and assisted opening of the Lagoon.	• Signage should be erected warning pedestrians and motorists during both the construction works and an assisted breakout.

7. PRELIMINARY COST ESTIMATE

The capital cost of implementing the Towradgi Lagoon Entrance Management Policy is of the order of $33,000 and the recurrent cost of the works is of the order of $29,000/year. Presuming a discount rate of 7% and a life of the works to be 50 years the net present value of the policy is approximately $433,222.

A breakdown of the estimated costs is shown in Table 3.

Table 3 Preliminary Cost Estimates (Capital and Recurrent Costs)

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT
Capital Costs					
1	Establishment of water level alarm system, with automated messaging	Item	3,000	1	$ 3,000
2	Establishment of pole marker to determine berm height	Item	500	1	$ 500
3	Establishment of local benchmark for 4WD backhoe operator	Item	2,000	1	$ 2,000
4	Establishment of pole markers in Corrimal Beach Park to Guide 4WD backhoe	Item	500	2	$ 1,000
5	Establishment of access path for 4WD backhoe	Item	16,300	1	$ 16,300
6	Establishment of monitoring and reporting processes with Works Division	Item	2,000	1	$ 2,000
	GST (10%)				$ 2,480
	Contingency (20%)				$ 5,456
	Total				**$ 32,736**
				Approximately	**$ 33,000**
Recurrent Costs (Annual)					
1	4WD backhoe Mobilisation and Labour	Item	2,000	5	$ 10,000
2	Observations of Entrance Before and After Mechanical Breakout and Transfer to Lagoon Book	Item	500	5	$ 2,500
3	Contact with DECC and DPI	Item	100	5	$ 500
4	Contact with Community and Media to advise of beach swimming restrictions	Item	500	5	$ 2,500
5	Ongoing costs associated with water level alarm system	Item	1,000	1	$ 1,000
6	Two attendants / observers to accompany 4WD backhoe	Item	1,000	5	$ 5,000
	GST (10%)				$ 2,150
	Contingency (20%)				$ 4,730
	Total				**$ 28,380**
				Approximately	**$ 29,000**

8. RECOMMENDATIONS

8.1 Infrastructure and Monitoring Systems

The following infrastructure and monitoring systems should be implemented as part of this Policy:

- Council should contact DECC to have an alarm system, with automated messaging, developed and activated.
- A water level marker should be placed at a visible location from the footbridge (to be installed on the upstream side of the footbridge). This will assist with determining water levels in the event of a mechanical breakout if access to the internet is lost. The water level marker should also be accompanied by clear signage which outlines this Policy and the marker should have a clear mark at 1.6 mAHD (the trigger level). This will inform residents of the Policy and the level at which Council will undertake a mechanical breakout.
- White pole markers should be placed in the dune system adjacent to the entrance (on the northern side) to direct the 4WD backhoe operator to the most appropriate pilot channel location and orientation. These should be constructed from fairly sizable poles with a diameter greater than 20cm and the top half of the poles painted white. The two poles should be located relatively close to each other. Given the poles are located in an open space it is recommended they be integrated for community education (e.g. with design flood levels or decorative information with a heritage theme). The size of the poles in intended to prevent vandalism.

8.2 Review and Update of This Policy

This Policy and the associated REF (Cardno Lawson Treloar, 2007) should be reviewed every five years or in response to legislation changes. Review of the policy will include analysis of all monitoring data collected over that period to ensure that predictions and assumptions outlined in the current REF (2007) are correct. Also included will be a review of the intervention level in relation to infrastructure present at that time. As outlined in the REF, implementation also involves Wollongong City Council investigating and, where possible, implementing measures to progressively remove, relocate or otherwise treat items of low-lying infrastructure so that it no longer represents a constraint and the intervention level can be progressively raised. As such, if any of the assets listed in the REF are removed or modified, the intervention level will be amended accordingly.

It has been recommended in this current Policy that a mechanical opening should occur on the mid-outgoing tide. This has been included due to community concerns about excessive berm scour and complete draining of the Lagoon (exposing the bed of the Lagoon). It is recommended that this procedure be monitored during the implementation of this Policy. It may be prudent to undertake a few openings at the high tide to compare the scour and drainage. During the review and update of this policy, this procedure should be reviewed for its effectiveness and any impacts on reducing the removal of accumulated sediments in the lagoon.

Several data sets have not been available during the preparation of this Policy. The following data sets should be collected for use in the review and update of this Policy:

- Accurate survey of Parker Road.
- Accurate survey of the Parker Road Arm and surrounding land.
- Details of upgraded sewerage infrastructure.

8.2.1 Climate Change

The impact of climate change should be assessed in subsequent reviews of the Entrance Management Policy.

Engineers Australia (2004) provide an engineering estimate for projected sea level increases as a result of the 'greenhouse effect' to 2100 with a central figure of 0.5 m (a range of 0.1 – 0.9 m). These estimates are produced from a range of scenarios. Engineers Australia (2004) also report a central projected sea level rise for a 20 year planning period (i.e. to 2030) to be of the order of 0.1 m.

The response of berm heights to sea level change has been discussed by Hanslow et al. (2003). In summary, it is believed that increased sea level will lead to beach recession, which will be accompanied by landward and upward movement of beach berms (Dean and Maurmeyer, 1983 and SCOR, 1991, referenced in Hanslow et al 2003). Therefore, climate change may result in berm height at the entrance Towradgi Lagoon becoming progressively higher. The implications this has for the entrance management policy is that it will need to be receptive to such change if it may occur.

There are very limited quantitative studies to produce likely rainfall patterns under climate change scenarios. Hennessy et al (2004) considered events from the 1 in 5 year event through to a 1 in 40 year event for the whole of NSW for a 1 day event duration and a 3 day event duration and found that there are likely to be increases in 1 day event rainfall (~10%) out to 2070 in spring, summer and autumn and decreases in winter. These durations are notably longer than the critical duration for the Towradgi Lagoon floodplain and as such the estimates are not reliable for application to the study area. No other reliable estimates relating to impacts on rainfall associated with climate change are available at this stage.

8.3 Options for Increasing Trigger Levels

At lake levels beyond 1.6 mAHD, there would be an expectation that natural breaching of the berm would be imminent, with a very small likelihood of Council intervention being required, unless the berm level is set substantially higher than 1.6 mAHD preventing a natural breaching. This policy investigates ways to progressively raise the intervention level beyond 1.6 mAHD.

The review of assets and asset levels within the Study Area (provided in the accompanying REF, Cardno Lawson Treloar 2007) indicates that Lake Parade and Parker Road would limit the trigger level being raised any higher than 1.9 mAHD. The floor level survey also indicates that overfloor flooding becomes likely at this level. Floor levels could be raised in the future. However, raising of Lake Parade and Parker Road is likely to be an expensive and complex exercise. Lagoon levels may inundate the pits causing drainage issues. Any future increase in the trigger level will need to involve a review of the drainage issues. Unless stormwater infrastructure is upgraded the invert levels of the pits is likely to limit any future raising of the trigger level.

Nuisance flooding of roadways is the primary limiting factor to an increase in the Towradgi Lagoon trigger level. Preliminary assessment of the inverts suggests that stormwater pit lip levels at Parker Road and Lake Parage are 1.64 mAHD and 1.7 mAHD respectively. When the lagoon level rises above 1.64 mAHD there will be nuisance flooding of these roads. At the emergency trigger level of 1.85 mAHD the extent of road inundation is only to gutter depth and so the road is still passable. For this reason, the emergency trigger level of 1.85 mAHD. Property inundation is considered to be the second limiting factor to an increase in trigger levels. At 1.6 mAHD only very limited property inundation is occurring, most of which is on public land. Residential private property inundation starts to become increasingly significant at levels greater than 1.6 mAHD, with overfloor flooding expected to commence at 1.97 mAHD.

As discussed in Section 4.5, due to the nature of the catchment and rainfall patterns in the area, the high rate of rise within the lagoon is a significant factor in determining trigger levels for Towradgi Lagoon. As such, any raising of the trigger level must take into consideration the rate of rise of the lagoon and the limited response time available during a rainfall event.

If property inundation could be alleviated via mechanisms such as levees or bunding without impacting on flood levels, the trigger level could potentially be raised to a maximum of 1.9 mAHD. Above which, Lake Parade and Parker Road becomes inundated completely.

9. REFERENCES

Bewsher Consulting Pty Ltd (2003a) *Addendum to Towradgi Creek Flood Study Following August 1998 Flood – Final Report*. Prepared for Wollongong City Council.

Bewsher Consulting Pty Ltd (2003b) *Towradgi Creek, Wollongong, Floodplain Risk Management Study and Plan.* Prepared for Wollongong City Council.

Cardno Lawson Treloar, (2005a), *Fairy, Towradgi and Hewitts/Tramway Creeks Estuary Management Study and Plan,* Prepared for Wollongong City Council.

Cardno Lawson Treloar, (2005b), *Fairy, Towradgi and Hewitts/Tramway Creeks Estuary Management Study and Plan – Further Processes Study,* Prepared for Wollongong City Council.

Cardno Lawson Treloar, (2007), *Towradgi Lagoon Entrance Management Policy – Review of Environmental Factors,* Prepared for Wollongong City Council.

Engineers Australia (2004) '*Guidelines for Responding to the Effects of Climate Change in Coastal and Ocean Engineering*', The National Committee on Coastal and Ocean Engineering.

Eurobodalla Shire Council (2000), *Coila Lake Entrance Management Policy and Review of Environmental Factors – Draft.*

Figgis, H. F. (2001) *A Baseline Water and Sediment Quality Study of Wollongong's Northern Streams*, Prepared for Wollongong City Council.

GHD, (1989), *Hooker Land Development Thirroul Flood Study.*

Gordon, A. D., (1981) *The Behaviour of Lagoon Inlets,* 5th Australian Conference on Coastal and Ocean Engineering, Perth, November 1981, Institute of Engineers Australian Publication No 81/16, pp 54-58.

Gordon, A. D., (1990) *Coastal Lagoon Entrance Dynamics,* 22nd International Conference on Coastal Engineering ASCE Delft, July 1990.

Hanslow, D.J., Davis, G.A., You, B.Z. and Zastawny, J. (2003) Berm Height at Coastal Lagoon Entrances in NSW. *Proceedings*, 10th NSW Coastal Conference

Hennessy, K., McInnes, K., Abbs, D., Jones, R., Bathols, J., Suppiah, R., Ricketts, J., Rafter, T., Collins, D., and Jones, D., (2004) *Climate Change in New South Wales,* Consultancy report for the New South Wales Greenhouse Office.

Lawson & Treloar, (2005) *Fairy, Towradgi and Hewitts/Tramway Creeks Data Analysis and Review Study,* Prepared for Wollongong City Council.

Lewis, B. J. (2003) *An Assessment of Water Quality and Indicator Suitability for Two Urban Coastal Lagoons in the Illawarra*. Honours Thesis, Department of Environmental Sciences, University of Wollongong.

NSW Government, (1992) *Estuary Management Manual.*

NSW Water Resources Council, (1993) *The NSW State Rivers and Estuaries Policy.* New South Wales Government

Shiau, C., (1996) *Fairy Creek Lagoon Water Quality Improvement and Ecosystem Enhancement Study*. Project Report Submitted to Wollongong City Council.

Wollongong City Council, (2002) *Hewitts Creek Floodplain Risk Management Study and Plan.*

Wollongong City Council (2007) *Submissions in Reply Report. Fairy Lagoon Entrance Management Policy and Review of Environmental Factors. Towradgi Lagoon Entrance Management Policy and Review of Environmental Factors.*

ATTACHMENT A

Contact List

ATTCHMENT A1
TOWRADGI LAGOON ENTRANCE MANAGEMENT POLICY AUTOMATED CONTACT LIST – TRIGGER LEVELS EXCEEDED

An automated email, fax or telephone message should be sent to the contacts listed below via an alarm as part of the monitoring system.

- A standby message is to be issues when lagoon levels reach 1.4 mAHD.
- An action or “go” message is to be issued when lagoon levels reach 1.6 mAHD.

Division Engineer – Central Depot
Wollongong City Council (Works and Services)
Fax: (02) 4227 7815

Floodplain Strategy Manager
Wollongong City Council (Design)
Fax: (02) 4228 8153

Manager, Environmental Projects
Wollongong City Council
Fax: (02) 4229 9197

Co-ordinator Beach Services
Wollongong City Council (Recreation and Natural Resources)
Fax: (02) 4226 5140

ATTACHMENT A2
TOWRADGI LAGOON ENTRANCE MANAGEMENT POLICY CONTACT LIST – DECISION TO OPEN THE LAGOON HAS BEEN MADE

Once the decision to open the lagoon entrance has been made, the following contacts should be advised of the breakout with details of the opening (including proposed timing and reasons for opening) and of potential health impacts on recreational swimmers on the adjacent beach areas for the following three days.

Division Engineer – Central Depot
Wollongong City Council (Works and Services)
Fax: (02) 4227 7815

Floodplain Strategy Manager
Wollongong City Council (Design)
Fax: (02) 4228 8153

Co-ordinator Beach Services
Wollongong City Council (Recreation and Natural Resources)
Fax: (02) 4226 5140

Media Relations Officer
Wollongong City Council (Communications and Public Relations)
Fax: (02) 4227 7580

Communications and Public Relations Officer
Wollongong City Council (Communications and Public Relations)
Fax: (02) 4227 7580

Natural Resource Project Officer – Coasts and Estuaries
NSW Department of Natural Resources
Fax: (02) 4224 9651

Fisheries Conservation Manager – South Coast
NSW Dept. of Primary Industries (Fisheries)
Fax: (02) 4472 7542

Manager Illawarra
NSW DEC (EPA)
Fax: (02) 4224 4110

Manly Hydraulics Laboratory
Fax: (02) 9948 6185

Catchment Impact Manager
Sydney Water
Fax: (02) 4223 3477

News Editor
Mercury
Fax: (02) 4221 2338 TEL: (02) 4221 2207

ATTACHMENT B

Entrance Opening Decision Making Flowchart

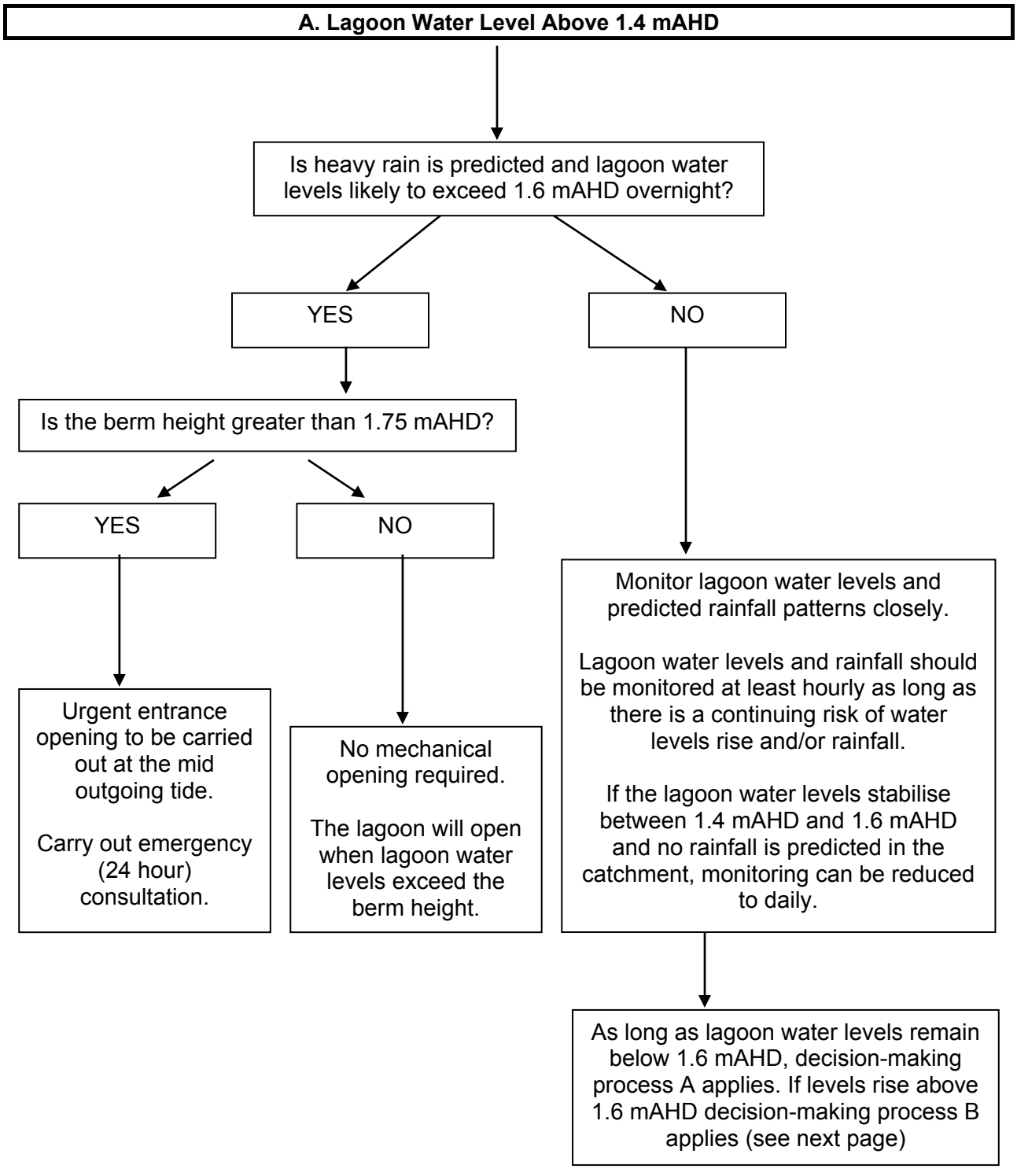
TOWRADGI LAGOON ENTRANCE OPENING DECISION MAKING FLOWCHART

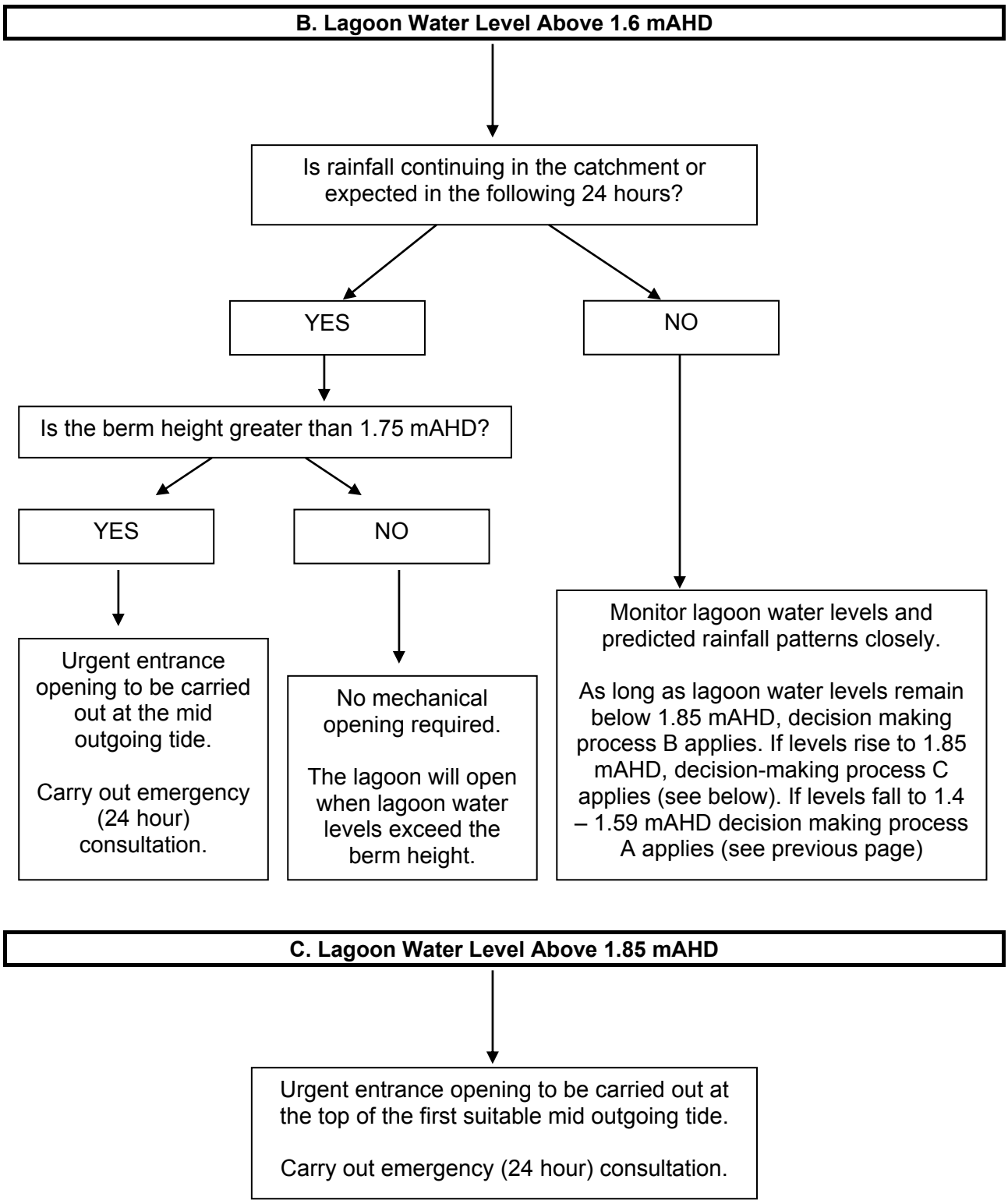
Reference should be made to Manly Hydraulic Laboratory's website for water level and rainfall data:

- Water Level: http://www.mhl.nsw.gov.au/htbin/map_data_display.com?SITE=TOWR
- Rainfall: http://www.mhl.nsw.gov.au/htbin/map_data_display.com?SITE=RUSS

Reference should be made to the Bureau of Meteorology's website for wave height data:

- Wave Height: http://www.bom.gov.au/marine/waves.shtml



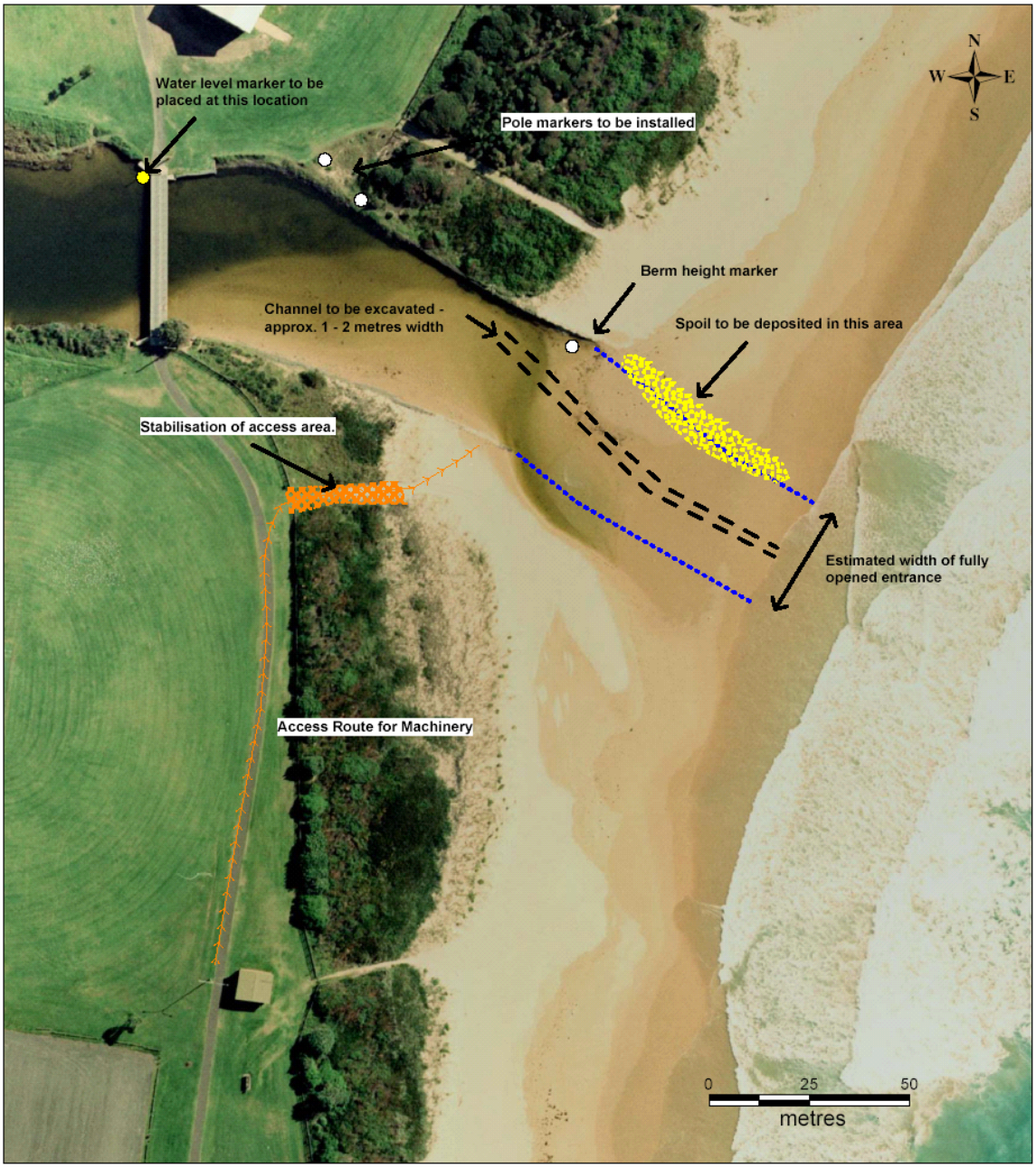


NOTE: 24 hour emergency consultation involves issuing advice to DPI (NSW Fisheries), DECC and the local media, advising of the breakout with details of the opening (including proposed timing and reasons for opening) and of potential health impacts on recreational swimmers on the adjacent beach areas for the following three days. A list of department contacts is provided in Attachment A.

ATTACHMENT C

Towradgi Lagoon Entrance Opening Diagram

TOWRADGI LAGOON ENTRANCE OPENING DIAGRAM



ATTACHMENT D

Towradgi Lagoon Entrance Breakout Monitoring Sheet

TOWRADGI LAGOON ENTRANCE BREAKOUT MONITORING DATA SHEET

Opening Date	Unassisted (U) or Mechanical (M)	Height of Dune (m)	Location of Breach
Approximate Wave Height (m)	**Approximate Wave Direction**	**Preceding Rainfall (mm)**	**Approximate Wind Direction**

Lagoon Water Level (mAHD)	Time	Channel		
		Length (m)	Width (m)	Depth (m)
Initial Breach				
Ongoing Channel Development				
Full Breakout				

Closure Date _____

Additional Information _____

_____

_____

_____

_____

Note: Ongoing channel development should be noted at least hourly if possible or when sudden changes occur.

TOWRADGI LAGOON ENTRANCE BREAKOUT MONITORING DATA SHEET (EXAMPLE)

Opening Date	Unassisted (U) or Mechanical (M)	Height of Dune (m)	Location of Breach
17 September 06	M	0.6m	Middle of Berm
Approximate Wave Height (m)	**Approximate Wave Direction**	**Preceding Rainfall (mm)**	**Approximate Wind Direction**
1m	SE	12mm in preceding week	NE

Lagoon Water Level (mAHD)	Time	Channel		
		Length (m)	Width (m)	Depth (m)
Initial Breach				
1.65	10:25 am	10m	1.5m	0.5m
Ongoing Channel Development				
1.6	10:40 am	10m	2m	0.8m
1.4	11:30 am	15m	4m	1m
1	12:30 pm	15m	10m	1m
0.5	1:45 pm	15m	10m	1.1m
Full Breakout				
0	3 pm	15m	12m	1.6m

Closure Date 20 October 2006

Additional Information _____

Note: Ongoing channel development should be noted at least hourly if possible or when sudden changes occur.