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Pearl Beach Lagoon
Condition Study and Community Uses Report

Final Report **September 2014**

GOSFORD CITY COUNCIL

Pearl Beach Lagoon Condition Study and Community Uses Report

Prepared For:	Gosford City council
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Title :	Pearl Beach Lagoon Condition Study and community uses report
Author :	Michelle Fletcher, Jack Sharples, Suanne Richards, Mark Wainwright, Philip Haines
Synopsis :	This draft report includes a Lagoon Condition Study and Community Uses Report for Pearl Beach Lagoon. It is the first stage in the preparation of a Coastal Zone Management Plan for the Lagoon.

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1 INTRODUCTION

1.1 Background

This report is the first stage in the development of a Coastal Zone Management Plan (CZMP) for Pearl Beach Lagoon. It reviews the available information on the present condition of Pearl Beach Lagoon and describes the results from a program of community and stakeholder consultation regarding the lagoon.

The Pearl Beach Lagoon CZMP will provide a list of actions and related implementation details to be carried out by Gosford City Council (Council), other public authorities and potentially the community to address priority management issues affecting Pearl Beach over a defined implementation period. As the CZMP will guide the investment of resources in the estuary, it needs to be based on the best possible information. The process for developing CZMPs, as prescribed by the NSW Government, is described in Section 1.3.

The community has a keen interest in the future management of the Pearl Beach Lagoon, and therefore their values and concerns have been considered and addressed as far as reasonable during preparation of this document.

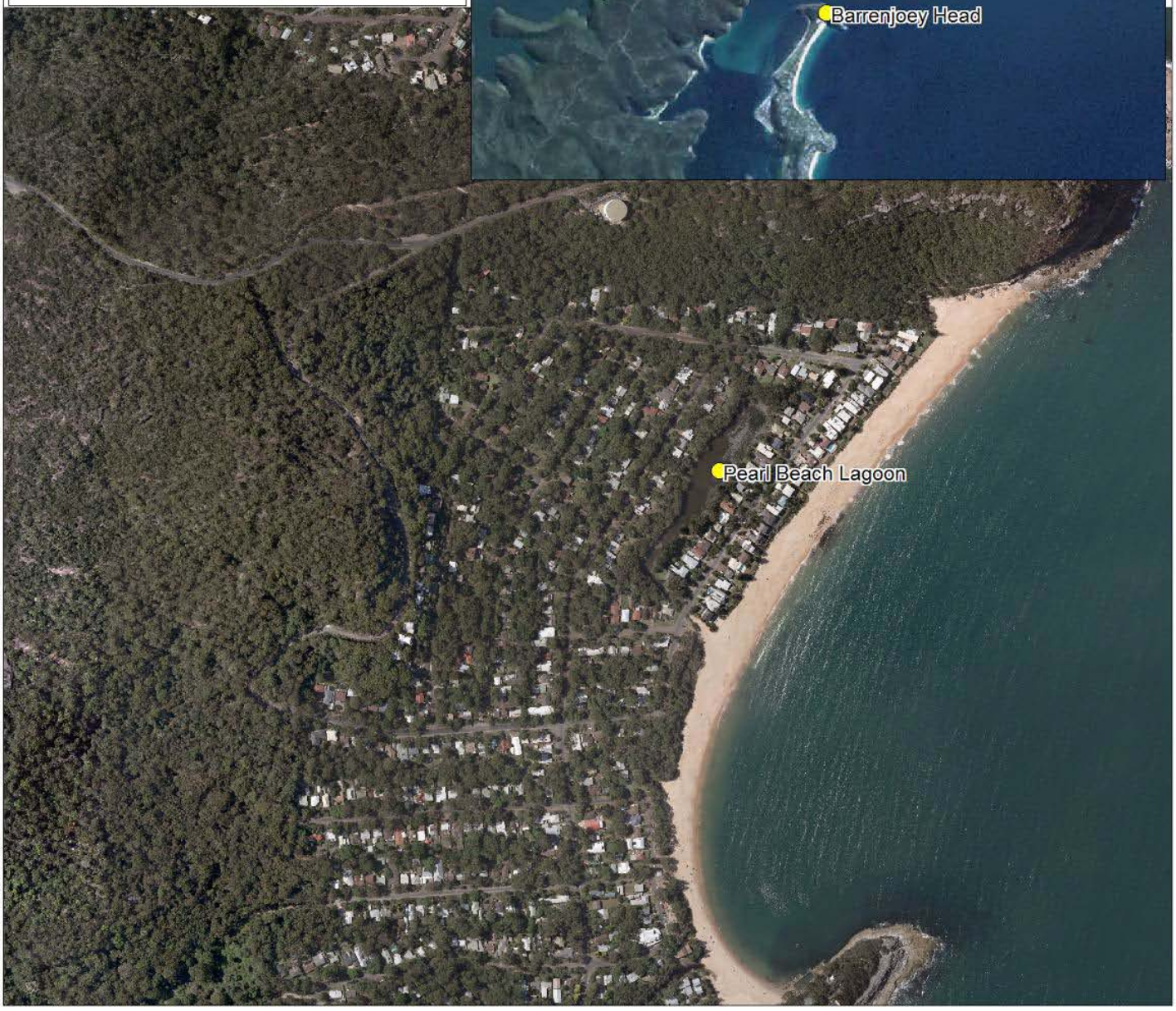
Two new assessments were carried out as part of this stage of the project, covering ecology and catchment characterisation. Information gained from these assessments is integrated into the present report, while specific assessment findings are document in their entirety as Appendices B and C.

1.2 Study Site and Evolutionary Context

Pearl Beach Lagoon (refer Figure 1-1) is a small and mostly closed coastal lagoon on the NSW Central Coast. The lagoon is a dynamic ecosystem that can vary between freshwater, brackish and saltwater environments and has historically, on occasion, been completely dry. It is a unique feature of the local area and there are no comparable environments nearby.

While Pearl Beach Lagoon has been characterised as an Intermittently Closed and Open Lake or Lagoon (ICOLL), it is becoming increasingly characteristic of a freshwater wetland. This is due to the maturity of the lagoon, as described below, and the presence of a weir at the lagoon's entrance as described in Section 2.1.3.

Pearl Beach Lagoon is an example of a coastal lagoon that is nearing a mature stage of geomorphic development, and is slowly transitioning towards a freshwater wetland/floodplain environment. Figure 1-2 illustrates the stages of evolution and maturity for Coastal Lakes/Lagoon in NSW (Roy, 1984). The different stages of maturity reflect the gradual infilling behind the sandy coastal barrier over the past 7,000 years, since the end of the last post-glacial marine transgression. Infilling has occurred predominantly from fluvial sediments. Most recently, this process has been expedited through catchment development, with increased rates of sediment supply to the lagoon and the presence of a weir across the entrance channel, which would help to trap sediments within the waterway.



Title:

Pearl Beach Lagoon Location Map

Figure: 1-1

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Approx. Scale

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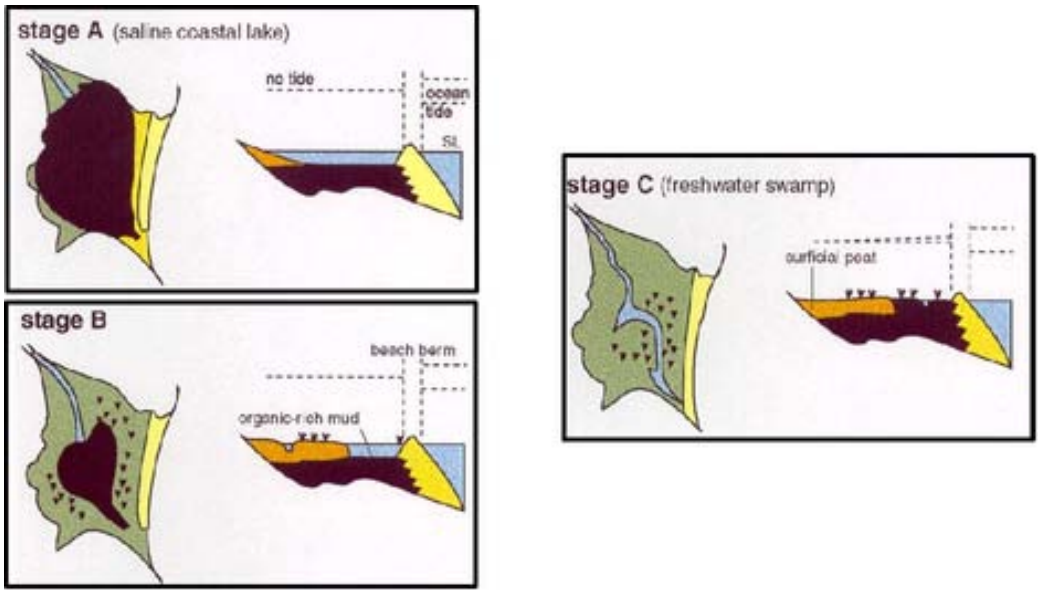


Figure 1-2 Stages of evolution / maturity of coastal lakes in NSW (Roy, 1984)

The Lagoon water body itself covers about 0.8 hectares, while the catchment drains 42.5 hectares. Of this catchment area, almost half is natural bushland.

In the recent past, Pearl Beach Lagoon has been managed by Council as a drainage reserve. The local community has long recognised environmental value in Pearl Beach Lagoon. An outbreak of Avian Botulism in 2010, thought to be related to poor water quality, further motivated Council and the community to improve the health of Pearl Beach Lagoon.

1.3 NSW Coastal Zone Management Framework

Under the *NSW Coastal Protection Act 1979*, a CZMP may be prepared to address risks to estuary health through management actions to maintain, improve or protect estuary values. Therefore, Council with assistance from the NSW Office of Environment and Heritage (OEH) resolved to prepare the Pearl Beach Lagoon CZMP.

Once adopted by Council, the CZMP shall be used to inform other strategic documents that aim to manage and rationalise human activities and development within the catchments, such as Regional Strategies, Local Environmental Plans (LEPs) and Development Control Plans (DCPs). The CZMP will need to be considered when assessing new developments in accordance with Section 79C of the *Environmental Planning and Assessment Act, 1979*.

The CZMP aims to fulfil Council's requirement for applying the principles of Ecologically Sustainable Development (ESD) to Pearl Beach Lagoon and its catchment. The CZMP will also provide an opportunity for future climate change to be considered in the strategic management and planning of the lagoon and surrounding sensitive coastal lands.

Over the past 2 years the NSW Government has introduced various reforms to coastal management, including the release of the *NSW Sea Level Rise Policy Statement (2009)*, reforms to the *Coastal Protection Act 1979* (and other Acts) and new *Guidelines for Preparation of Coastal Zone*

Management Plans (DECCW, 2010). This report and the following Pearl Beach Lagoon CZMP will be consistent with the intent and objectives of these new reforms, as well as the fundamental management principles espoused in the *NSW Coastal Policy 1997* and the previous *Estuary Management Policy 1992*.

1.4 Approach to Lagoon Management

Future management of Pearl Beach Lagoon needs to recognise that many (if not all) of the natural values of the lagoon have been modified by one or more external pressures (e.g. development, construction of the weir, artificial entrance opening). It is now these modified estuary values that are the foundation for present-day environmental and community use. Fundamentally, the principles of management for the lagoon need to be based on either preventing the change in the lagoon ecosystem from exceeding what would be considered an "acceptable level of change", or to reverse change that has indeed exceeded this acceptable level. Management options to meet these principles can target either 'intervention' strategies that reduce impacts of external pressures and associated changes to the natural environment and/or 'adaptation' strategies that essentially modify the use of the lagoon to accommodate other changes. This recognises that it may not be realistic, or even desirable for the lagoon to be returned to a fully natural state. A schematic diagram for the lagoon management process is given in Figure 1-3.

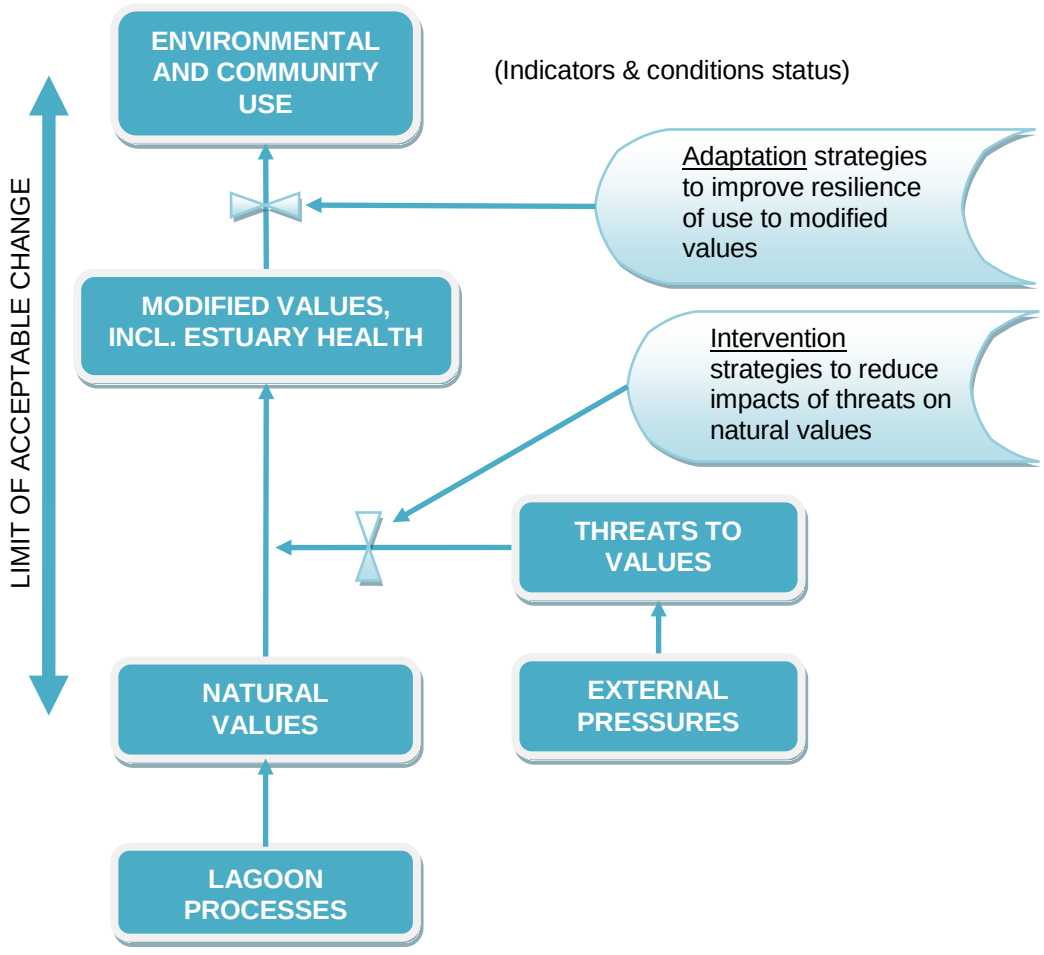


Figure 1-3 Context of Estuary Health Status for the Risk Assessment and Management Plan Preparation

2 LAGOON CONDITION STUDY

Coastal Lagoons are by nature, dynamic and complex ecosystems, forming an ecotone between freshwater and saltwater environments. Most processes occurring within such lagoons are influenced by the condition of the entrance and the state of the catchment (Haines 2008). Both of these primary drivers have been significantly modified for Pearl Beach Lagoon, which has potentially compromised the natural values of the ecosystem.

The following sections describe the present condition of the lagoon as determined from field inspections, a review of the available information and data and specialist ecology and catchment assessments as included as Appendices B and C, respectively.

2.1 Lagoon Entrance Dynamics

2.1.1 Entrance Processes

Anecdotal information from the local community suggests that the entrance channel was originally modified and moved to its present location during the subdivision of land at Pearl Beach. An aerial photograph dated 1941 shows the channel in its present location (refer to Figure 2-5) indicating that the entrance has remained mostly stable for at least the past 70 years.

The entrance to Pearl Beach Lagoon is mostly closed, with beach sands essentially forming a 'dam' across the entrance channel. The lagoon entrance then opens in response to catchment rainfall and associated runoff, which increases water levels within the lagoon until it overtopped the entrance sand berm causing a 'breakout' with the sand berm then scouring away. After the initial discharge of floodwaters from the lagoon, the entrance would remain open for a period of time, allowing some saltwater intrusion into the waterway. It is understood that Pearl Beach Lagoon, on occasion, drained completely, leaving a large exposed area of bed sediments. The frequency of natural lagoon breakouts is unknown.

Overtopping of the entrance berm by ocean storm conditions may also occur infrequently, contributing to the marine sand build-up in the channel and topping up water levels with saline waters.

The entrance channel weir (discussed further in Section 2.1.3) acts as a significant control to the hydrodynamics and entrance dynamics of the lagoon, influencing both freshwater discharges and marine ingress into the waterway. The weir has effectively reduced the volume of saltwater reaching the lagoon, however, the extent of this reduction is unknown.

A concrete block retaining wall (Figure 2-1) constructed in c. 1983 has also been constructed on the north side of the entrance channel. This wall limits further channel migration.

Figure 2-1 Construction of the entrance training wall at Pearl Beach Lagoon (Source Peter Bayliss)

2.1.2 Lagoon Entrance Management

Pearl Beach Entrance is, on occasion, artificially opened by Council to reduce the flood threat along Coral Crescent and adjacent properties. It is understood that a formal procedure for this process does not yet exist. The trigger for opening the lagoon is marked by a white line on the concrete block retaining wall on the northern side of the entrance channel. This line has not been surveyed and its elevation is not known. It is approximately the same height as the top of the culverts (refer Figure 2-2). Council does not routinely monitor the level of water in the entrance channel. Entrance openings are therefore triggered by staff inspections or notification by local residents. The decision by Council to open the lagoon is made based on a combination of the trigger level being reached and the berm being high. It is understood that mechanical openings of this nature occur once or twice a year. Manual openings are carried out by excavator or backhoe depending on the beach / erosion conditions.

Figure 2-2 Culvert on lagoon entrance with arrow indicating entrance opening trigger

A significant catchment rainfall event occurred during the preparation of this study, with 38 mm of rain being recorded at the Gosford rain gauge and 26mm at the Peats Ridge gauge, on June 6 2012. Council used heavy machinery to initiate an artificial opening at around 3:30pm on that day. An extensive photo record of this event was undertaken by local resident Ann Parsons and this is included in Appendix D.

Figure 2-3 Extensive inundated of Melaleuca Swamp Forest around Pearl Beach Lagoon following a large rainfall event on June 6 2012

2.1.3 Entrance Channel Weir

A weir is presently located across the entrance channel of the lagoon. The exact date of construction is not clear, although it is believed to have been around 1990. Mike Allsop (pers. comm.) has explained that the motivations to construct the weir were to prevent:

- Regular drying of the lagoon
- Fish kills resulting from drying
- Odour
- Loss of water bird habitat.
-

The weir is likely to have changed the lagoon conditions and its ongoing role in influencing hydrodynamics, and hence ecology, will be an important consideration for future management.

2.1.4 Odour Prior to Weir Construction

The odour that triggered the weir construction was most likely a result of sulphur reducing bacteria (SRB). In the absence of oxygen, SRB breakdown organic matter, using sulphate, to produce odorous hydrogen sulphide gas (H_2S), carbon dioxide and water.

SRB can only thrive in the absence of oxygen. When oxygen is present, other bacteria will break down the organic matter using more energy efficient processes.

This is a natural process and not a threat to lagoon ecology. High organic loads in catchment runoff as a result of human development increases the frequency and duration of odour events.

Figure 2-4 The weir on the entrance channel (photo taken March 2012)

2.2 Air Photo Comparison

The Coastal Photography Series held by OEH has aerial photography of the study site for a range of dates, from 1941 to the present day. In preparing this report, the available aerial photography has been reviewed. A summary of observations are included as Table 2-1.

Table 2-1Observations from historical aerial photography

Year	Entrance condition	Channel Location	Notable differences to the present day
1941	Closed Coral Crescent (and causeway) present Lagoon not extending beyond Coral Crescent	Similar to present day	Very few houses present. Vegetated (mud flats) in North Eastern corner in the location of present day residential development
1982	Closed, lagoon extending beyond Coral Crescent to berm	Similar to present day	North Eastern corner filled and gently sloping bank now vertical.
1983	Closed, lagoon extending beyond Coral Crescent to berm	Similar to present day	North Eastern corner filled and gently sloping bank now vertical.
2008	Closed; Weir present	Similar to present day	No
2009*	Closed; Weir present	Similar to present day	No

*(Google Earth Image)

While there were not any photographs that showed the lagoon entrance open, two of the photos before the construction of the weir showed the lagoon extending seaward, beyond Coral Crescent to the beach berm.

Figure 2-5 and Figure 2-6 show the lagoon and the catchment for two dates in 1941 and 1982. As can be seen in this photography, by 1982 the development surrounding the lagoon was almost equivalent with the present day.

2.3 Bank Conditions

Anthropogenic modification of the banks and foreshores of Pearl Beach Lagoon has transformed originally gently sloping vegetated banks into to almost vertical banks, with riparian areas dominated by introduced grass species.

Changes to bank slopes can prevent the natural removal of organic material from the lagoon through wind and wave action. Where previously any accumulated wrack on the lagoon foreshores would have undergone aerobic decomposition, the organics are now essentially trapped within waterway, where they are subject the anaerobic processes (and thus generate odour problems).

Construction of the weir has also reduced the variation in water levels, which also limits the potential for wrack to accumulate on the foreshore. The weir has also reduced the saltwater influence on fringing vegetation, with more terrestrial species now dominating the riparian zone.

2.4 Catchment Assessment

2.4.1 General Description

The catchment draining to Pearl Beach Lagoon is 42.5ha. Approximately 20ha of this catchment (approximately 47%) comprises relatively undisturbed natural bushland or lagoon area with the remaining proportion modified by development.

The highest rainfall months are February, March and April. Rainfall statistics are discussed in more detail in Appendix C. Monthly averages sourced from the Peats Ridge Bureau of Meteorology site is shown in Table 2-2. Justification for use of the Peats Ridge data is also included in Appendix C.

Table 2-2 Average Monthly Rainfall over 30 years for Peats Ridge

Month	Average Rainfall (mm)
January	117
February	159.3
March	140.3
April	127
May	95.9
June	105.9
July	66.7
August	78.8
September	73.6
October	90.6
November	107
December	95.2

Bushland areas cover the steeply grading upper catchment areas. Runoff from bushland to the west of the lagoon is intercepted by Pearl Beach Drive and conveyed along this road prior to discharge through culverts as concentrated runoff onto the eastern side of Pearl Beach Drive. Concentrated discharge of runoff may elevate the erosion of soils along the downstream drainage corridors. Runoff from bushland north of Beryl Boulevard drains through residential properties to this street prior to entering a piped drainage system through concrete drainage pits located on the high side of the street. The piped drainage systems discharge into the northern side of the lagoon.

Dwelling construction on steep residential lots within the lagoon catchment may also form a key source of sediment discharged into the lagoon and particularly in circumstances where sediment and erosion controls are inadequate. Typically the highest potential for sediment to be eroded from residential lots occurs during the dwelling construction phase when soils are exposed due to excavation, site clearing and stockpiling of landscaping materials. This potential increases where the development is located on a steep site with highly erodible soils in close proximity to drainage systems inlets. After completion of the dwelling and site landscaping, the land is typically more stabilised and the potential for erosion is significantly reduced.

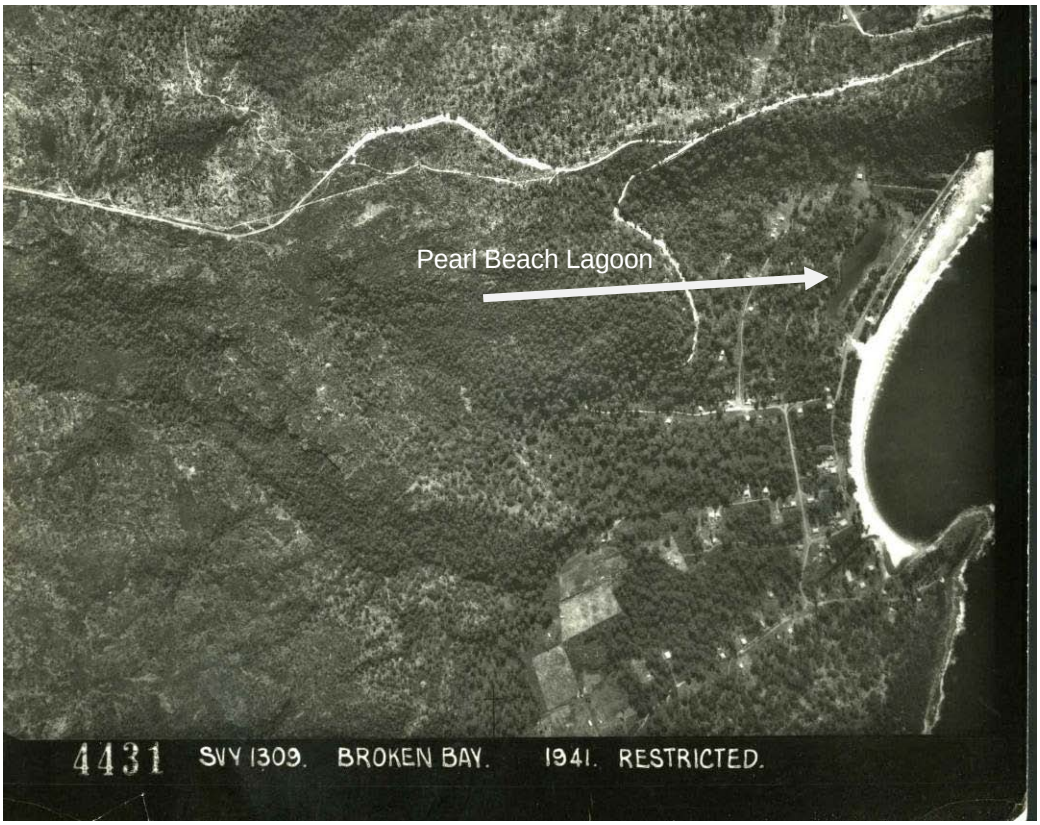


Figure 2-5 Earliest available aerial photography (1941) covering Pearl Beach Lagoon and the surrounding catchment

Figure 2-6 Aerial Photography of Pearl Beach Lagoon and the catchment from 1982.

Maintenance activities within the road reserve may also result in the exposure of soils. If insufficient erosion and sediment controls are in place (particularly protection of inlets to the stormwater drainage system) there is a high potential for eroded soils to discharge into the lagoon. In addition, spilling of landscaping material onto roads during transport or stockpiling provides a source of sediment close to constructed drainage systems.

During severe storms and flood events, the soils within the Pearl Beach Lagoon sub-catchments have been subject to erosion and scouring, even in heavily vegetated areas. The lagoon naturally acts as a sink for these sediments.

Piped stormwater drainage systems through the residential areas convey stormwater runoff (and associated stormwater pollutants) to the lagoon. The streets in the catchment do not have kurb and guttering but are bounded by grass swales. This provides a disconnect between the impervious surfaces and the receiving environment, thus allowing infiltration of stormwater and interception of pollutants. This is very good for the lagoon as it reduces the pollutants reaching the water body.

Figure 2-7 shows the locations of the main stormwater drainage pits and drainage lines in the catchment. These piped stormwater drainage systems will be the primary pathways for the conveyance of sediment from the catchment into the lagoon. Future management of stormwater either entering the stormwater pits or discharging from the outlets is likely to be key to reducing the volume of sediment discharging into the lagoon. The treatment measures indicated on Figure 2-7 are further discussed in Section 5 and Appendix C.

2.4.2 Catchment Modelling

Preliminary catchment modelling has been completed using the MUSIC model to estimate existing catchment loads and estimate the potential for sediment loads to be reduced through the retrofitting of stormwater quality treatment measures along key stormwater drainage lines. The MUSIC modelling process is described in detail in Appendix C and the locations of the modelled treatment measures are shown on Figure 2-7.

MUSIC modelling results for total suspended solids (TSS) are shown in Table 2-2. The modelling results represent the performance of the modelled treatment measures at reducing the load of fine sediment particles (<150µm) conveyed by runoff to Pearl Beach Lagoon. Although not explicitly modelled in MUSIC, the treatment measures would also be effective at capturing a high proportion of coarse grained sediment particles (>150µm). The treatment measures would also capture a proportion of particulate phosphorus and nitrogen loads attached to the fine grained particles provided the measures are regularly maintained.

Table 2-3 MUSIC Modelling Results

Sub-catchment/s Treated	Existing TSS Load (t/yr)	Treated TSS Load (t/yr)	Reduction (t/yr)	% Load Reduction
S3	3.4	1.6	1.8	54%
S1 and S5	5.1	3.8	1.3	24%
S6 and S7	3.2	1.7	1.5	47%
S2 and S4	3.1	1.4	1.7	55%
Totals	**14.8**	**8.5**	**6.3**	**43%**

Whilst a survey of the sediment depth retained in Pearl Beach Lagoon would provide a good indication of the actual sediment loads from the catchment, the modelling results suggest that the quantity of sediment draining to the lagoon from the catchment can be significantly reduced where it is feasible to provide measures along the key drainage lines to intercept runoff.

2.4.3 Groundwater

There is limited information available on groundwater extents within the study area. The Melaleuca Swamp Forest is a Groundwater Dependent Ecosystem (GDE) and as described in Section 4.2.10, groundwater extraction has the potential to impact upon this important Endangered Ecological Community.

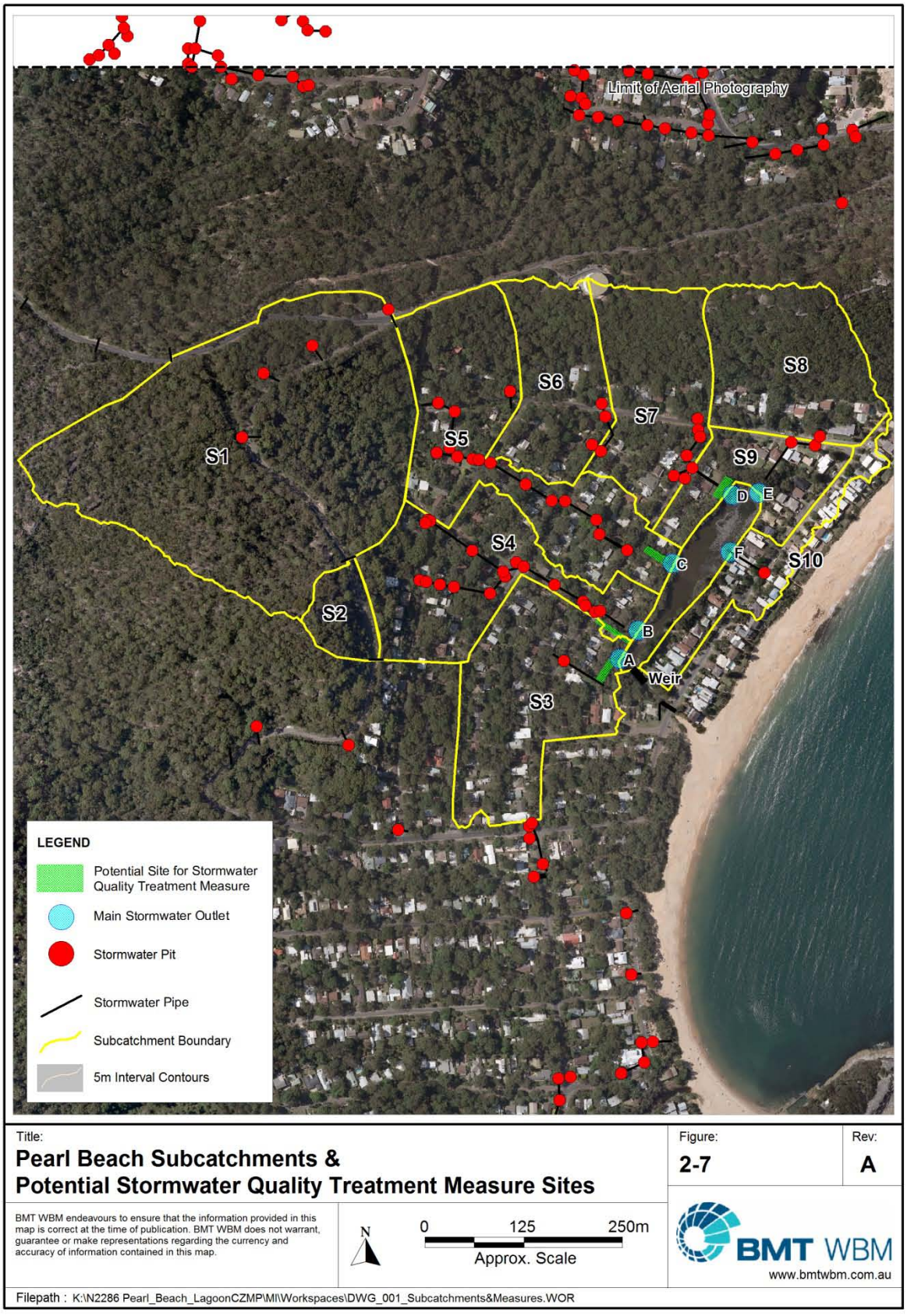


Figure 2-7 Pearl Beach Subcatchments and Treatment Measures

2.5 Lagoon Ecology Assessment

2.5.1 Context

Pearl Beach Lagoon, the current major water body of the Pearl Beach sandplain, lies behind the frontal dune of Pearl Beach in the north of the sandplain. The lagoon is bounded by housing development which encroaches to the edge of the open water in parts. Pearl Beach Village lies within a relatively undisturbed catchment that is mainly situated within Brisbane Water National Park.

Algal blooms are common, particularly following extended periods of closure, where there has been little rainfall or wind.

Prior to development at Pearl Beach, the lagoon was originally only a small soak and was a much smaller wetland than its current extent (Payne et. al., 2010). Historical photos of the mouth of the creek draining the Pearl Beach Lagoon, taken in 1925 (see Payne et. al., 2010, p300), show the lagoon as a narrow, meandering inlet dissecting a sand plain bounded by *Casuarina glauca* (Swamp Oak) and saltmarsh. Some overland flow may have occurred overland towards the Middle Creek subdivision.

Prior to 1941, the lagoon was greatly enlarged by past landowners who removed sediment to raise the levels of their adjoining land (Payne et. al., 2010, p305). As the area developed, the lagoon was seen as a natural feature worth preserving. Thus it was not regularly drained or controlled. It often filled with run-off and spilled onto private property. To prevent this inundation, some land owners are believed to have filled the land to make it “usable. Following enlargement of the lagoon, a weir was constructed near the mouth of the inlet (date of construction unknown) to reduce drying out of the lagoon.

2.5.1.1 Ecological Field Survey

A field survey of the lagoon (the *Study Site*) was conducted on Wednesday 13th June, 2012, to record and describe the current habitat condition and values of the lagoon, and to assess likely implications of the weir on the lagoon’s ecology. It should be noted that the field survey was conducted one week after heavy rainfall and storms which resulted in a breakout. As a result, it is possible that some submerged or floating macrophytic species which may occur within and on the fringes of the lagoon were removed and as a result were not recorded during the survey. Introduced species are denoted with an asterix (*).

Pearl Beach Lagoon lies behind the developed foredune of Pearl Beach and includes open water, fringing sedgeland and Melaleuca wetland habitats. The lagoon is a degraded wetland habitat highly modified from its original condition. Excavation of the original soak, infilling of the banks for adjacent housing and construction of the weir are likely to have significantly altered the original composition and extent of fringing wetlands at Pearl Beach Lagoon. Construction of the weir has reduced the potential range of water levels in the lagoon and has reduced salt water intrusion. As breakouts have become less frequent, lagoon water levels are more influenced by freshwater inputs from the catchment. Species typical of saltmarsh communities have been reduced to the fringes of the lagoon and the infilled banks have been colonised by more terrestrial species tolerant of periodic inundation.

The lagoon provides fringing wetlands and aquatic habitat for local fish, birds and other fauna. The lagoons ecology is likely to be dynamic due to long periods of closure punctuated by periodic breakout. While some estuarine species may be adapted to a wide range of physical variables, others are not, and rapid changes in estuarine assemblages may occur in response to an entrance breakout.

Physiochemical properties of the lagoon are expected to show great temporal variability in response to entrance state. During closed conditions, water quality is primarily influenced by catchment and groundwater inflows after rainfall and so may be brackish or nearer to fresh water. Catchment inflows are a source of nutrients, which are then mixed and dispersed through the lagoon and taken up by primary producers (e.g. algae). During closed conditions, the lagoon may also become hypersaline during drought conditions when evaporation of the lagoon waters concentrates salts and any existing pollutants within the remaining water.

During major coastal events when there is tidal exchange, lagoon water quality may become similar to that in the ocean, subject to the flushing efficiency of the lagoon. The similarity between lagoon and ocean waters will depend upon the time over which the entrance is open.

During both open and closed entrance conditions, lagoon water quality is influenced by accumulation and recycling processes in the sediments, as well as growth and decay of algae. The process of entrance closure and entrance breakout means that it is very difficult to define a typical water quality within the *Study Site*.

2.5.2 Habitats

While in a degraded condition, the lagoon provides food and habitat resources for local fauna, particularly waterbirds. Three habitats were identified at the lagoon: open water, sedgelands and Melaleuca wetland (Figure 2-8). The habitat features of each are described below.

2.5.2.1 Open Water

The lagoon includes approximately 1ha of unvegetated open, shallow water with limited habitat features. No logs, snags, rocks or islands were recorded within the main body of the lagoon. It has been reported a log used as nesting habitat by moorhens was located in the open water, but this was moved to the lagoon edge during the June 6th storm (*pers. comm.* Gosford City Council).

Apart from sedges fringing the banks of the lagoon (refer to section 2.2.2), no instream macrophytes were recorded within the open water during the survey. The storm one week prior to the survey may have removed submerged and floating macrophytes from the main waterbody. In addition, variable salinity and generally poor water quality conditions would repress habitat condition for more estuarine and freshwater macrophyte species.

The open water habitat provides locally important habitat for several local bird species, particularly dusky moorhen (*Gallinulka tenebrosa*). Refer to Appendix A for bird species identified in the area. Maintenance of water quality and habitats within the lagoon will assist in supporting resident birdlife who utilise the *Study Site*.

Figure 2-8 Habitats of Pearl Beach Lagoon

2.5.2.2 Sedgelands

The open water is fringed by a narrow (1-10m wide) band of sedegland dominated by *Juncus krausii* and *Ficinia nodosa*. Both species are salt tolerant and are generally associated with saltmarsh or brackish communities (Harden, 1993). Other species recorded in the sedgelands in isolated patches included *Fimbristylis ferruginea, Juncus usitatus, Cyperus* sp., *Baloskion tenuiculme* and *Baumea articulata*.

The inlet to the lagoon supported a dense groundcover of *Phragmites australis* fringed by *Juncus krausii* and *Ficinia nodosa* over a low cover of *Tetragonia tetragonioides* and *Bacopa monnieri* which extended from the shallow water fringe to the higher banks. Other groundcover species recorded within the inlet included *Stenotaphrum secundatum*, Hydrocotyle bonariensis*, Passiflora* sp.**, Conyza* sp.** and Rumex sp.*.*

The sedgelands fringing the lagoon foreshore provide water quality filters for freshwater runoff from adjacent properties and stabilise the banks from erosion. These fringing communities also provide foraging and nesting habitat for the local bird assemblages. Sedgelands are inhibited from colonising several sections of the lagoon foreshore due to bank infilling and erosion. This is particularly evident along the eastern bank of the *Study Site.*

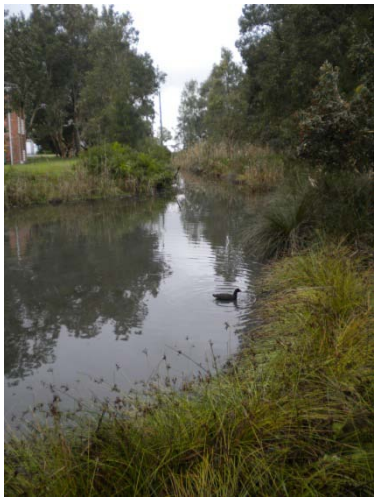


Figure 2-9 Sedgelands Fringing Pearl Beach Lagoon

2.5.2.3 Melaleuca Wetland

Land adjacent to the open water body supported Melaleuca wetland habitat of varying condition. The majority of property owners maintain their lagoon frontages. This generally includes mowing above the level of inundation, planting of garden varieties and turfing to the water's edge in some areas. Regular mowing within the wetland habitat has significantly reduced habitat diversity of the wetland by reducing floristic and structural diversity of the ground and shrub layers and reducing recruitment of canopy species.

Figure 2-10 Melaleuca Wetland Adjacent To Pearl Beach Lagoon

The eastern banks of the lagoon supported a discontinuous, narrow fringe of *Melaleuca quinquenervia* and *Eucalyptus robusta* over a mown groundcover. Other canopy species included *Casuarina glauca, Callistemon* sp., *Melaleuca bracteata,* and *Livistona* sp. and a variety of planted garden varieties including *Schefflera actinophylla**, *Ficus* sp. and *Pinus* sp*..

Figure 2-11 Eastern Banks of Pearl Beach Lagoon

Around the remainder of the lagoon, the wetland canopy was generally dominated by *Melaleuca quinquenervia* (averaging 10-15m in height and approx. 50-70% canopy cover) with sparse emergent *Eucalyptus robusta.* A shrublayer was generally absent except in the south-west of the lagoon which supported the most diverse and intact wetland habitat. At this location, a low, sparse shrublayer of *Acacia longifolia* var. *sophorae, Acacia longifolia* var. *longifolia, Pittosporum undulatum, Breynia oblongifolia, Omalanthus populneus, Livistona* sp. and *Cupaniopsis anarcardioides* was present. Sparse *Crinum pedunculatum* were also recorded.

The groundcover across the Melaleuca wetland habitat was dominated by dense thickets of *Stenotaphrum secundatum**. This species, which tolerates poorly drained soils and high salinity (Cook *et. al*, 2005), formed a very dense groundcover and is likely to have suppressed recruitment of native (and other exotic) groundcovers, shrubs and canopy species. As previously noted regular mowing by adjacent landowners has also reduced recruitment.

The groundcover in the south-western portion of the wetland habitat supported the most diverse and intact groundcover as this area does not appear to be regularly mown. Common groundcovers included, *Juncus krausii, Ficinia nodosa, Fimbristylis ferruginea, Juncus usitatus, Cyperus* sp., and

Baloskion tenuiculme. Isolated *Baumea articulata* and *Scheonoplectus validus* and patches of *Nephrolepis cordifolia* were also recorded in the groundlayer of the wetland at the northern end of the lagoon which is subject to periodic inundation and also does not appear to be regularly mown.

Upslope of the periodic soaks the groundcover was predominantly mown by adjacent landowners. However in the south-west of the lagoon, which was less impacted by adjacent landholders, groundcover species recorded on the landward edge of the wetland included *Imperata cylindrica* and *Cynodon dactylon* with sparse *Paspalum* sp., *Lomandra* sp., *Dianella* sp., *Cyperus* sp., *Asparagus densiflorus**, *Commelina cyanea*, *Conyza* sp*., *Passiflora* sp*., *Hydrocotyle bonariensis*, Rumex sp*.,* and *Viola hederacea*.

Figure 2-12 Melaleuca Wetland with mown groundcover

The Melaleuca wetland plays an important role in providing habitat for local fauna and for trapping nutrients that would otherwise flow into the lagoon. The Melaleuca wetland of Pearl Beach Lagoon is an example of a Swamp sclerophyll forest on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions, which is currently listed as an Endangered Ecological Community in Part 3 of Schedule 1 of the Threatened Species Conservation Act (TSC).

Given the small extent and modified condition of the Melaleuca habitat at Pearl Beach Lagoon and the close proximity of residential development, it is likely that only common and widespread fauna species resilient to modified environments inhabit the lagoon. Threatened fauna such as Grey-headed Flying Fox (*Pteropus poliocephalus*) and Common Blossom Bat (*Sycoyncteris australis*) may visit the lagoon but it is not considered good quality or critical habitat for these species.

2.5.2.4 Wetland Fauna

Refer to Appendix A for bird species identified in the Pearl Beach region. Eighty bird species have been recorded in the Pearl Beach area. The open water and fringing sedgeland habitats provide locally important habitat for several local bird species, particularly dusky moorhen (*Gallinulka tenebrosa*). Other commonly occurring species recorded in the lagoon include wood duck (*Chenonetta jubata*), black duck (*Anas superciliosa*) chestnut teal (*Anas castanea*), grey teal (*Anas gracilis*), royal spoonbills (*Platalea regia*), purple swamphen (*Porphyrio porphyrio*), dusky moorhen (*Gallinula tenebrosa*) and white faced heron (*Egretta novaehollandiae*) (O'Brien, 2010).

Great Cormorant (*Phalacrocorax carbo*), pied cormorant (*Phalacrocorax varius*) and little pied cormorant (*Microcarbo melanoleucos*) have been recorded feeding on eels and fish in the lagoon and roosting and breeding in the surrounding Melaleuca trees (O'Brien, 2010). When the lagoon dries up

several species including the moorhens migrate to regional waterbodies (O'Brien, 2010). Pelicans (*Pelecanus conspicillatus*) are also frequent visitors to the lagoon (O'Brien, 2010). Maintenance of water quality and habitats within the lagoon will assist in supporting resident birdlife who utilise the *Study Site*.

Given the small extent and modified condition of the Melaleuca habitat at Pearl Beach Lagoon and the close proximity of residential development, it is likely that only common and widespread terrestrial fauna species resilient to modified environments inhabit this community. Terrestrial species recorded at Pearl Beach which may occur at the lagoon include ring tailed possum (*Pseudocheirus peregrinus)*, sugar gliders (*Petaurus breviceps*), swamp wallaby (*Wallabia bicolor*) and Eastern water dragon (*Physignathus lesueurii*) (O'Brien, 2010).

In terms of fish species, the weir is highly likely to have disrupted natural fish life-cycles and has created conditions more suitable to habitat generalists particularly the noxious *Gambusia holbrooki*.

2.5.2.5 Threatened Species

Two bird species listed as Threatened under the NSW *Threatened Species Conservation Act 1995* are known to inhabit ecosystems of Pearl Beach, namely Glossy Black Cockatoo (*Calyptorhynchus lathami*) and Barking Owl (*Ninox connivens*) (both listed as Vulnerable). Additionally, four migratory bird species that utilise Pearl Beach area are listed as Migratory under the China-Australia Migratory Bird Agreement (CAMBA) and/ or the Japan-Australia Migratory Bird Agreement (JAMBA). Bird species present that are listed under such agreements include, Wedge-tailed Shearwater (*Ardenna pacifica*), Eastern Great Egret (*Ardea modesta*), White-bellied Sea-Eagle (*Haliaeetus leucogaster*) and Crested Tern (*Thalasseus bergii).* The Glossy Black Cockatoo, Barking Owl, Easter Great Egret and White-bellied Sea Eagle may visit the *Study Site* temporarily but it is not considered good quality or critical habitat for any of these species.

Threatened fauna such as Koalas (*Phascolarctos cinereus*) and spotted tailed quolls (*Dasyurus maculatus*) which have been recorded in the Pear Beach region (O'Brien, 2010) and Grey-headed Flying Fox (*Pteropus poliocephalus*) and Common Blossom Bat (*Sycoyncteris australis*) which potentially occur, may also visit the Melaleuca habitat of the lagoon but it is not considered good quality or critical habitat for these species.

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

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

- Littlejohn's Tree Frog (*Litoria littlejohni)* - Endangered; also listed as Vulnerable under the Commonwealth EPBC Act
- Stuttering Frog (*Mixophyes balbus)* - Endangered; also listed as Vulnerable under the Commonwealth EPBC Act

An EPBC Protected Matters search (refer Appendix B) identified additional nationally Threatened species that may potentially occur within the region of Pearl Beach. However, the majority of these species are not considered likely to occur in close proximity to Pearl Beach Lagoon due to the absence of suitable habitat, or may occur on a temporary basis but are not dependent on the wetland habitats.

2.5.2.6 Summary- Overall Ecological Values

It is likely irregular flushing and sporadic saltwater ingress as a result of the constructed weir, together with poor water quality, siltation and current land management practices, have resulted in the low habitat diversity and quality within the lagoon. However, despite the degraded condition of Pearl Beach Lagoon, the *Study Site* provides the following ecological values:

- Fringing vegetation, including Melaleuca wetland (listed as an Endangered Ecological Communityunder the TSC Act) and sedgelands, which provide habitat for local species.
- Wetland vegetation which reduces the likelihood of bank erosion and acts as a "filter" for catchment runoff before entering the lagoon;
- Open water that supports local birdlife and possible estuarine aquatic species;

Variations in water levels and entrance conditions, which allow for a range of habitat conditions for local birdlife and aquatic species

Despite the degraded condition of Pearl Beach Lagoon, the *Study Site* has local ecological value, notably, open water habitat, Melaleuca wetland listed as Endangered under the TSC Act, and sedgelands, which provide habitat for local birdlife and estuarine species. Key pressures which currently threaten the ecological value of the *Study Site* include sedimentation, pollution, loss of foreshore vegetation and bank erosion. In addition, sea level rise has the potential to reduce the extent of Melaleuca wetland. Several management options addressing water quality improvement and foreshore rehabilitation could enhance the ecological values of the *Study Site*.

Table 5-1 summarises the condition, threats and management objectives for each of the habitats identified at Pearl Beach Lagoon.

Table 2-4Habitat Condition

Habitat	Scale / Condition	Threats	Management Objectives
Open water	1 / Highly disturbed / low value	• Sedimentation • Pollution • Algal blooms	Water quality improvement: • More regular flushing • Educate property owners on pollution and nutrient minimisation • Improve sediment and erosion control in catchment

			• Improve foreshore vegetation
Sedgelands	2 / Slightly to moderately disturbed / moderate value	• Sedimentation • Loss of foreshore (mowing / clearing / bank erosion / bank infilling)	• Improve sediment and erosion control in catchment • Identify foreshore access • Rehabilitate degraded foreshore • Educate property owners on foreshore protection
Melaleuca wetlands	2 / Slightly to moderately disturbed / moderate value	• Climate change – sea level rise • Ground cover removal (mowing / clearing)	• Provide buffers for landward migration • Educate property owners on foreshore protection
No pristine or near natural habitat of high conservation value were identified in the *Study Site*.	3 / Pristine or near natural / high value		

2.6 Water Quality

2.6.1 Context

Water quality is a broad term used to assess a water body's suitability for ecological or recreational uses. It is measured and reported in terms of biological, chemical and physical parameters. Assessing and describing the water quality of an ICOLL such as Pearl Beach Lagoon is challenging due to the dynamic nature of such ecosystems and the paucity of available data (for this site and comparable systems). Changing entrance conditions and the intermittent nature of catchment rainfall events means that monitoring likely misses events and the biological and biogeochemical response that occurs immediately following.

Water watch have been collecting data at Pearl Beach Lagoon for a number of years. For the present study, physical parameters were available for the period between August 1998 and the present.

Water quality guidelines have not been used for comparison at Pearl Beach Lagoon. While there are a number of benchmark guidelines available, such as ANZECC, the applicability of these guidelines to a system as unique as Pearl Beach Lagoon is questionable. Clearly the best approach would be to compare the water quality results with some locally specific guidelines. As such, one of the objectives of the CZMP for the lagoon is to develop a set of lagoon specific water quality guidelines that can be used for assessment purposes.

2.6.2 Dissolved oxygen

As most aquatic organisms require oxygen to survive, understanding the oxygen availability is an important aspect of assessing the lagoon's condition and habitat function. The available data from Waterwatch for the period 1998 to 2012 (Figure 2-13) shows dissolved oxygen levels varies significantly. Low results would generally be the result of high oxygen demand in the lagoon, from organic material decomposition and/or algal respiration. High results (> 100% saturation) would

generally be the result of algal blooms generating large amounts of oxygen during daytime photosynthesis. Snapshot measures of dissolved oxygen such as these are often difficult to interpret in determining lagoon health without accompanying information on other environmental factors, such as antecedent rainfall.

Dissolved oxygen has been monitored through Waterwatch.

2.6.3 pH

Available pH data is presented in Figure 2-14. This shows data that pH is most often approximately neutral, which is largely reflective of freshwater conditions. Periods when pH is greater than 7 would suggest some marine influence and/or alkaline reactions associated with high algal growth. There are few occasions when pH is < 7.

The lagoon bed and immediate foreshore area has been mapped as a High Risk zone for potential Acid Sulphate Soils. Acid sulfate soils are the common name given to naturally occurring sediments and soils containing iron sulfides (principally iron sulfide or iron disulfide or their precursors). The exposure of the sulfide in these soils to oxygen by drainage or excavation leads to the generation of sulfuric acid. The term potential Acid Sulphate Soils describes soils which contain iron sulfides which have not been exposed to air or oxidised.

It is unlikely that Pearl Beach Lagoon would represent a significant acid sulfate soils issue, as the construction of the weir would have largely created a more water-logged groundwater condition that would prevent oxidation of any exposed soils. The potential for Acid sulphate soils to develop will be an important consideration for any management options that interfere with hydrology or involve sediment removal or exposure.

2.6.4 Phosphorus

Phosphorus can be found in dissolved and particulate forms. Particulate phosphorus is commonly attached to suspended sediments and therefore increased trapping of sediment can result in increased phosphorus concentrations in the sediment and water. Suspended sediments conveyed into the lagoon by runoff can settle under the influence of gravity. During periods of elevated water temperature and reduced DO, sediment bound phosphorus may be desorbed from the sediment, and converted to dissolved (and thus bioavailable) phosphorus. The limited aquatic vegetation within the lagoon reduces the potential for phosphorus to be taken up by the rooted plants and converted to biomass. Phosphorus taken up by algae is generally returned to the bottom sediments and water column when the algae dies off and settles, unless the algae is flushed out to sea during an entrance opening event.

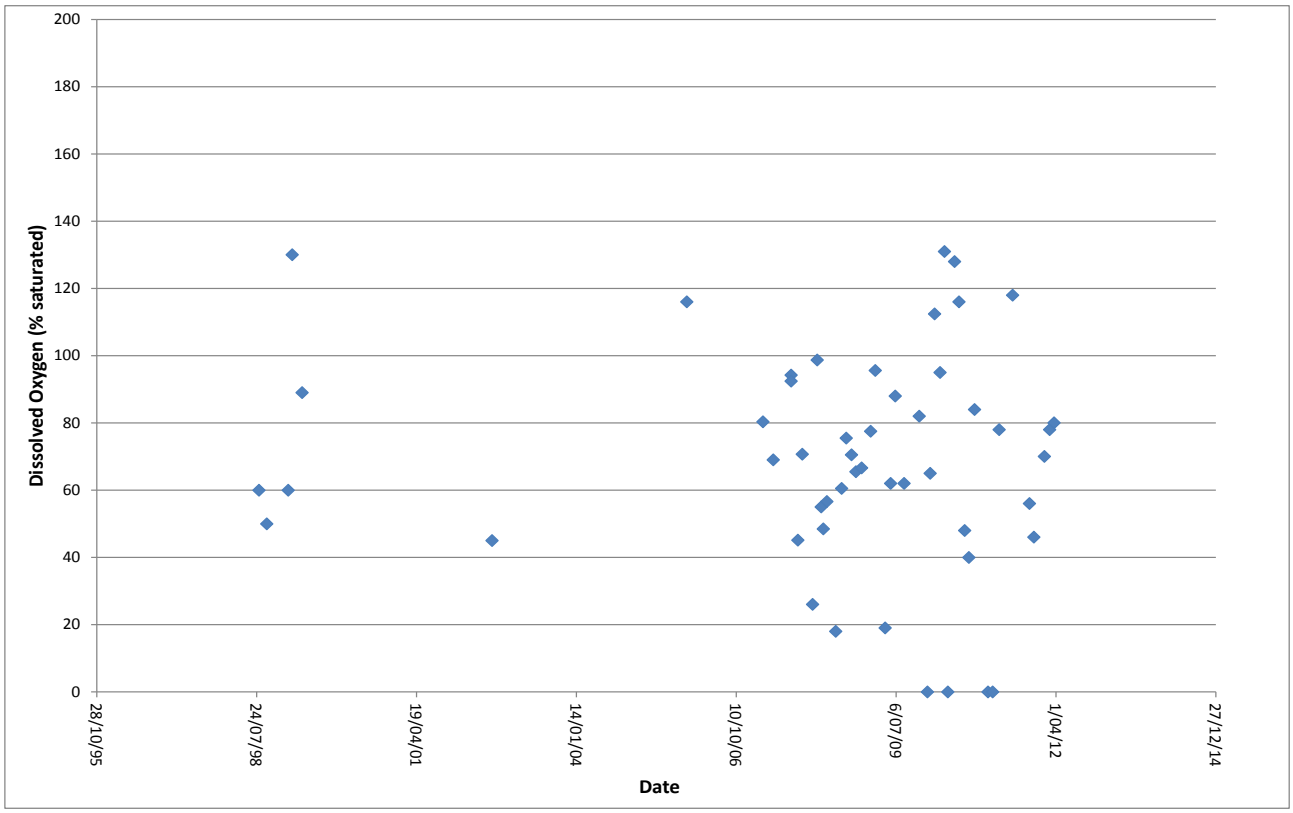


Figure 2-13 Dissolved oxygen concentrations in Pearl Beach Lagoon, as measured by Waterwatch

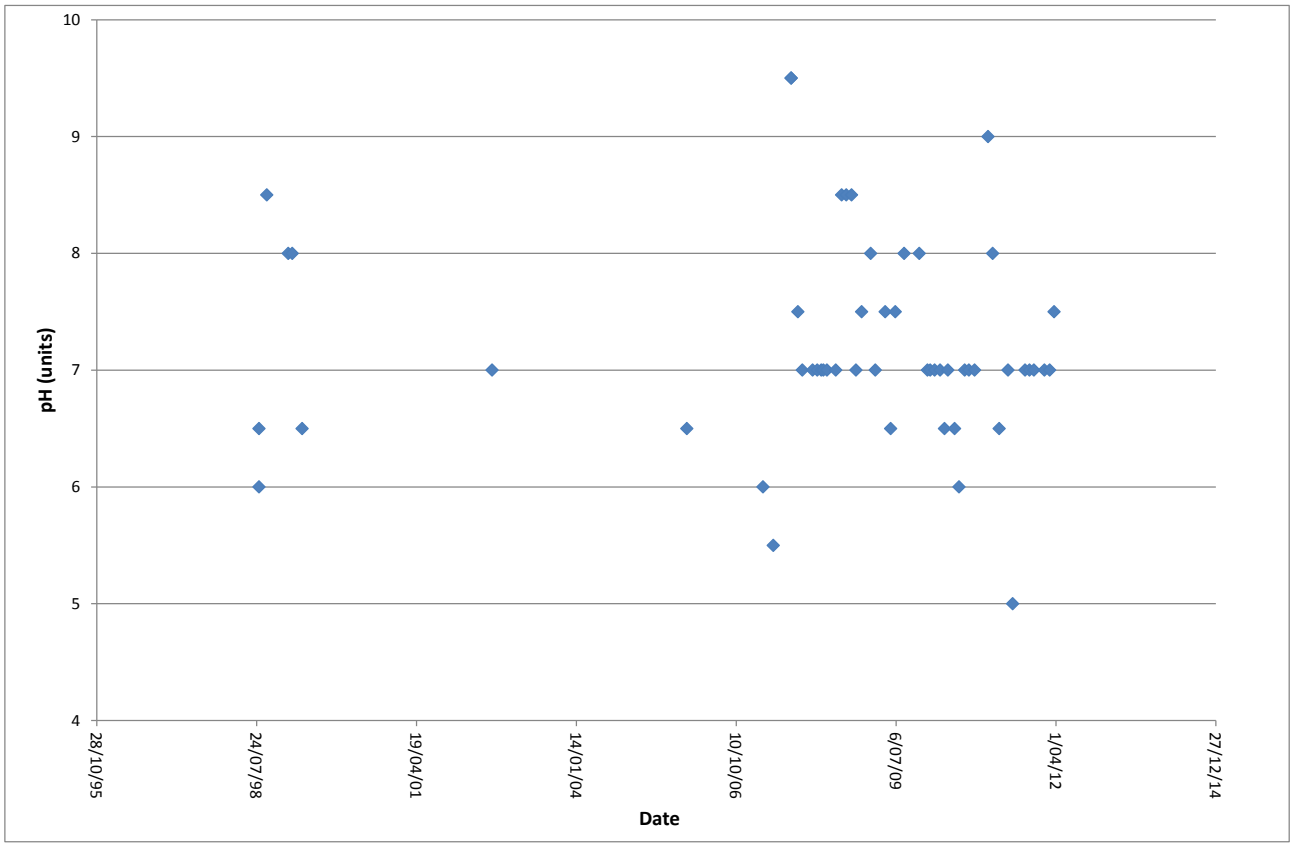


Figure 2-14 pH in Pearl Beach Lagoon, as measured by Waterwatch

Haines (2008) reports that typical phosphorus concentrations within ICOLLs are correlated to the degree of development within the catchment. Water column phosphorus concentrations have also been shown to increase under anoxic conditions.

The concentration of the "available" phosphorus (i.e. filterable reactive phosphorus) has been measured by Waterwatch volunteers at Pearl Beach Lagoon regularly since 2007. Additional water quality sampling was undertaken earlier over the 1998 and 1999 period. Only a limited number of water quality samples were taken during the 2000 to 2006 period.

Monitoring data for available phosphorus over the 2007 to 2012 period (39 samples) are plotted in Figure 2-15. The data shows significant variability in the results. The values recorded are considered very high for a natural waterway, although it is recognised that the confidence in results is limited by the Waterwatch methodology.

Variability in phosphorus could be related to many functions, including catchment runoff events and entrance conditions. There is also potentially seasonal variability in available phosphorus that relates to algal dynamics within the ecosystem, in addition to any sediment-nutrient dynamics associated with adsorption/desorption processes. Another potential source of nutrients to the lagoon, including phosphorus, is faeces from water birds. This can have a significant impact on nutrient balance of a waterbody if the birds feed elsewhere and then only roost on or around the lagoon.

Figure 2-15 clearly indicated that there are periods when available phosphorus levels are very high. It is considered that without intervention, these results will persist in the future, and will continue to contribute to algal blooms and periods of poor water quality.

2.6.5 Nitrogen

Nitrogen exists in water both as inorganic and organic species, and in dissolved and particulate forms. Nitrate is a dissolved bioavailable form of nitrogen. Nitrate has been measured by Waterwatch at Pearl Beach Lagoon on numerous occasions since 2008 (see Figure 2-16).

Nitrate concentrations in Pearl Beach Lagoon are also highly variable, with periods when levels are indeed very high. When combined with high phosphorus concentrations, these nutrient-rich conditions would be ideal for algal blooms. Again, sources of nitrates could relate to catchment runoff and/or local inputs including birds.

2.6.6 E. coli

E.coli is an indicator measure for faecal contamination. It is generally only monitored in recreational waters as it is indicative of the presence of human specific bacteria and other pathogens (e.g. bacteria that cause human gastroenteritis). Limited sampling of E.coli has been undertaken for Pearl Beach Lagoon by Waterwatch since 2011 (Table 2-4). Additional sites were also sampled in February 2012 in response to concerns from residents that the lagoon may be subject to sewage sources of pollution (Table 2-5). This data shows the presence of E.coli, however, counts were not particularly high. It is unknown whether the observed E.coli was from human or animal sources (noting the range of birdlife using the lagoon, and other wildlife present within the catchment).

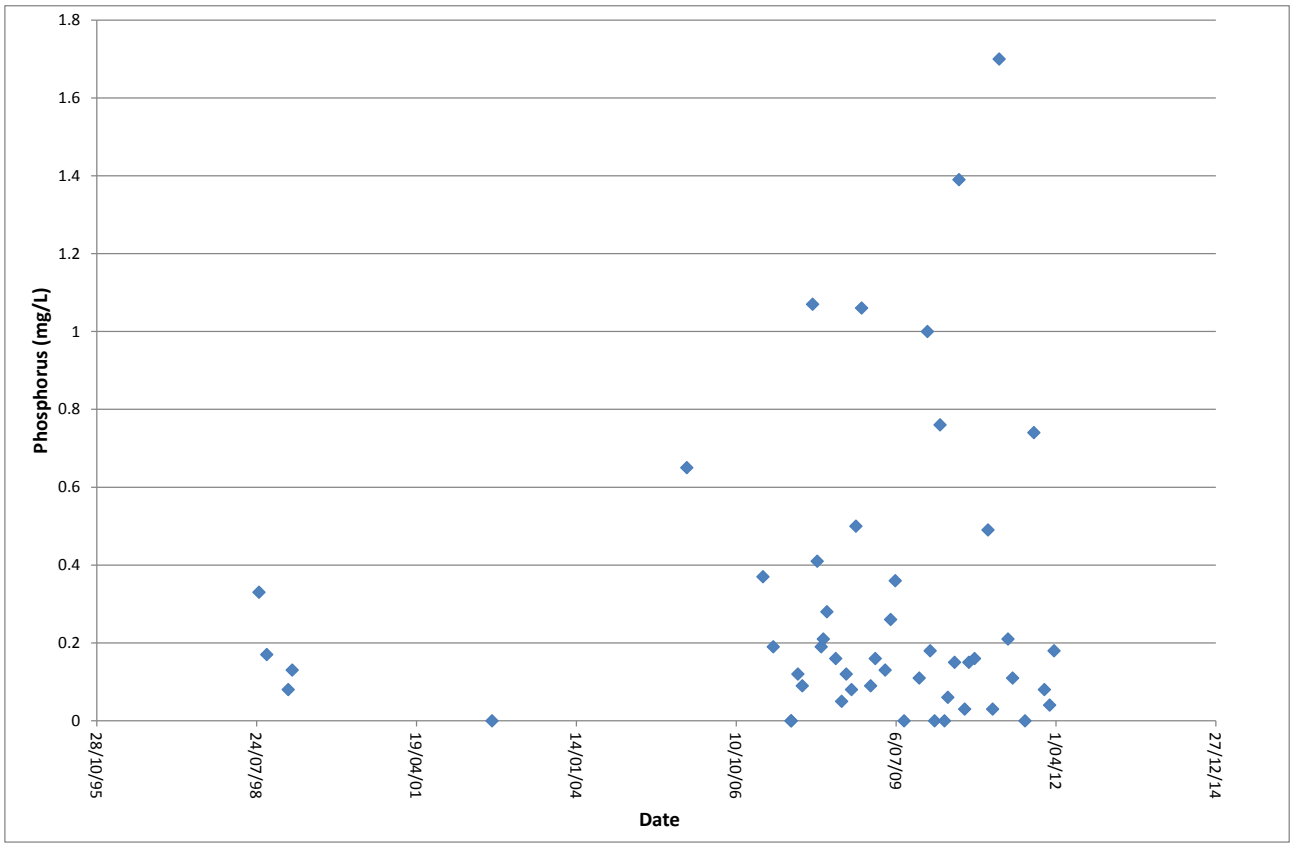


Figure 2-15 Available phosphorus concentrations in Pearl Beach Lagoon, as measured by Waterwatch

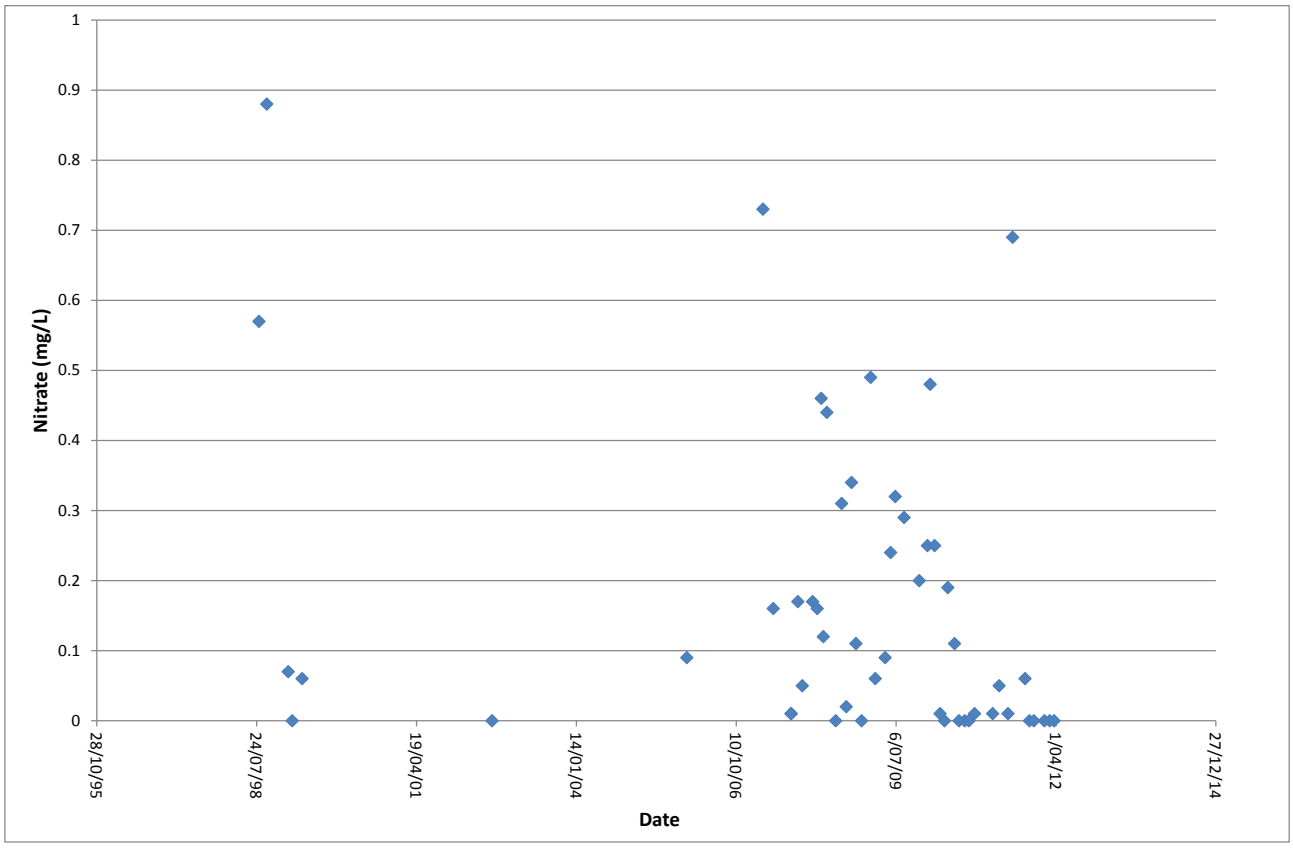


Figure 2-16 Nitrate concentrations in Pearl Beach Lagoon, as measured by Waterwatch

Table 2-5 E.coli results of routine Waterwatch sampling

Date	E.coli (CFU/ 100mL)
2/02/2011	200
2/03/2011	200
12/04/2011	500
7/06/2011	No data
6/07/2011	No data
17/08/2011	300
21/09/2011	400
19/10/2011	No data
16/11/2011	300
20/01/2012	400
22/02/2012	400
21/03/2012	300

Table 2-6 Results of E.coli sampling undertaken by Waterwatch and corresponding rainfall data from the Gosford Gauge

Date	Inlet behind 95 Diamond Road	Inlet behind 75 Diamond Road	Inlet behind 61 Diamond Road	Inlet behind 51 Diamond Road	Rainfall (mm)	Cumulative rain (previous 3 days)
9/02/2012	700	900	1300	Too numerous to count	0	7
15/02/2012	300	400	100	200	0.4	35.2
20/02/2012	2100	4900	5300	3300	27.6	0

The data presented in Table 2-5 shows notably higher E.coli levels during rainfall and runoff conditions. E.coli would be a typical runoff parameter in urban environments, and thus higher levels during rainfall are expected.

The general levels of E.coli are higher than guidelines for primary contact. It would generally be recommended that the community avoid direct contact with the water in Pearl Beach Lagoon, especially for 24 to 48 hours after rainfall. This is typical of most urban waterway environments.

2.7 Sediments

Pearl Beach Lagoon is currently functioning as a large ‘sediment trap’ for sediment runoff from the catchment. Sediment is primarily conveyed into the lagoon as a result of being entrained in surface water flows, such as stormwater runoff. Coarse to medium sized sediment particles will typically settle out rapidly near discharge locations (e.g. stormwater outlets), whilst finer particles will tend to be more widely distributed across the lagoon as they require more time for particles to settle (e.g. 20µm particles will typically require approximately 1 hour to fall 1m in the water column). This results in a typically flat-bottom profile to lagoon.

Very fine colloidal sediments will remain suspended in the water column giving the water a turbid or 'murky' appearance. Wind and other factors causing movement of the water would typically be sufficient to keep these colloidal sediments in suspension.

Plumes of fine sediment can be observed discharging into the Lagoon following catchment rainfall, and understandably of concern to local residents.

Figure 2-17 Stormwater plume observed after rainfall

A photo set submitted through the community consultation is included as Figure 2-18. The photographs show a similar location within the lagoon, characterised by marine sand in 1979 and fluvial sediments in 2010. It is considered that different conditions in 2010 have allowed finer sediment to remain on the foreshore surface of the lagoon. Generally, wave action (including small wind-generated waves) is sufficient to prevent silts from deposition around lagoon fringes. Therefore, it is possible that growth of vegetation around the lagoon has created a more 'depositional environment' within the lagoon that is now more conducive to settlement over the whole waterway area, including the shallow fringe areas.

Figure 2-18 Family photographs showing the presence of marine sand in 1979 and fine silt in 2010 (photos: Ann Parsons)

Periods of open entrance conditions will result in a proportion of finer sediments discharged out of the lagoon, however, it is considered that a large proportion of the total sediment generated from the catchment is retained in Pearl Beach Lagoon. The ability of the lagoon to retain sediments has been increased through the construction of the weir. As the weir truncates the drainage of the lagoon, it limits how much sediment gets scoured and conveyed to the sea during breakout conditions.

Over time it is expected that the lagoon will continue to infill behind the weir until it finds a natural balance between settlement and periodic scour during breakout events. Interestingly, an increase in sea level rise will likely increase the ability of the lagoon to retain sediments further. For this to occur, the weir would have largely been rendered insignificant to hydrodynamic and sediment dynamic processes in the lagoon.

2.7.1 Acid Sulphate Soils

Acid sulphate soils are acidic soil horizons or layers resulting from the aeration of soil materials that are rich in iron sulphides, primarily pyrite (FeS2). When drainage or excavation brings oxygen into these previously waterlogged soils, the pyrite is oxidised to sulphuric acid. Should the production of acid exceed the neutralising capacity of the soils so the pH falls below 4, these soils are known as Actual Acid Sulphate Soils (AASS).

Potential Acid Sulphate Soils (PASS) are waterlogged soils rich in pyrite that have not been oxidised. Any disturbance which admits oxygen will lead to the development of AASS layers. PASS are completely innocuous to the environment if kept under water. AASS generally overlay PASS in Australian coastal environments.

Disturbance of acid sulphate soils in NSW coastal areas has resulted in degradation of lowland environments and estuarine water quality. As a first towards identification and future management of

acid sulphate soils, a series of Acid Sulphate Soil Risk Maps have been prepared by a team of soils surveyors along the coast.

Acid Sulphate Soils Risk mapping information is sourced from the 1997 NSW Department of Land & Water Conservation 1:25000 map series. This has been digitized and incorporated into Councils Geographical Information System. Actual Acid Sulphate Soils were not mapped separately from Potential Acid Sulphate Soils.

The maps predict the distribution of acid sulphate soils based on an assessment of the geomorphic environment. This assessment involved aerial photograph interpretation, extensive field work and laboratory analysis of soil samples.

Figure 2-19 identifies three primary map classes within the Pearl Beach Lagoon catchment:

- High probability of Occurrence of Acid Sulphate Soils
- Low probability of Occurrence of Acid Sulphate Soils
- No known Occurrence of Acid Sulphate Soils

Where there is a probability of occurrence of acid sulphate soils (ASS), the depth to the ASS layer is provided. It is recommended that all land use activities likely to disturb ASS require appropriate investigations and a management plan to avoid environmental degradation.

2.8 Lagoon Sensitivity

Physical characteristics of Pearl Beach Lagoon make it particularly sensitive to catchment inputs and other sources of pollutants (e.g):

- The lagoon is mostly closed, meaning that it acts like a terminal lake such that all inputs to the waterway are retained and assimilated internally whilst ever the entrance is closed.
- The lagoon has a small volume in comparison to the catchment size, meaning that there is little opportunity for dilution of runoff within the waterway. Thus, the quality of the water in the lagoon is generally consistent with the quality of the runoff discharging into it.
- The weir has prevented the lagoon to be fully flushed when the entrance is scoured open. This means that there will always be a residual body of water within the lagoon that remains affected and influenced by catchment runoff. The weir also prevents 'clean' marine water to exchange with the lagoon when the entrance is open following breakout and lagoon discharge. Thus, there is no period within the lagoon hydro-cycle when the lagoon 'resets' to a marine/estuarine condition.

2.9 Data Gaps

A number of data gaps have been identified through the review of background information. The key data gaps are:

- Does the lagoon open naturally? If so, how often?
- What would be appropriate site-specific 'guidelines' for environmental conditions at Pearl Beach Lagoon be? There is limited data to describe it in its natural state and work by Scanes *et al* (2011), on lagoons in the Nadgee Nature reserve, indicates that many of our preconceptions

about the chemical and algal dynamics of infrequently opened coastal lagoons, may need to be re-examined.

- Is the current trigger for artificially opening the entrance appropriate?
- How does the lagoon ecosystem respond to catchment rainfall and pollution events?
- Level of lagoon levels relative to MHWM are not published

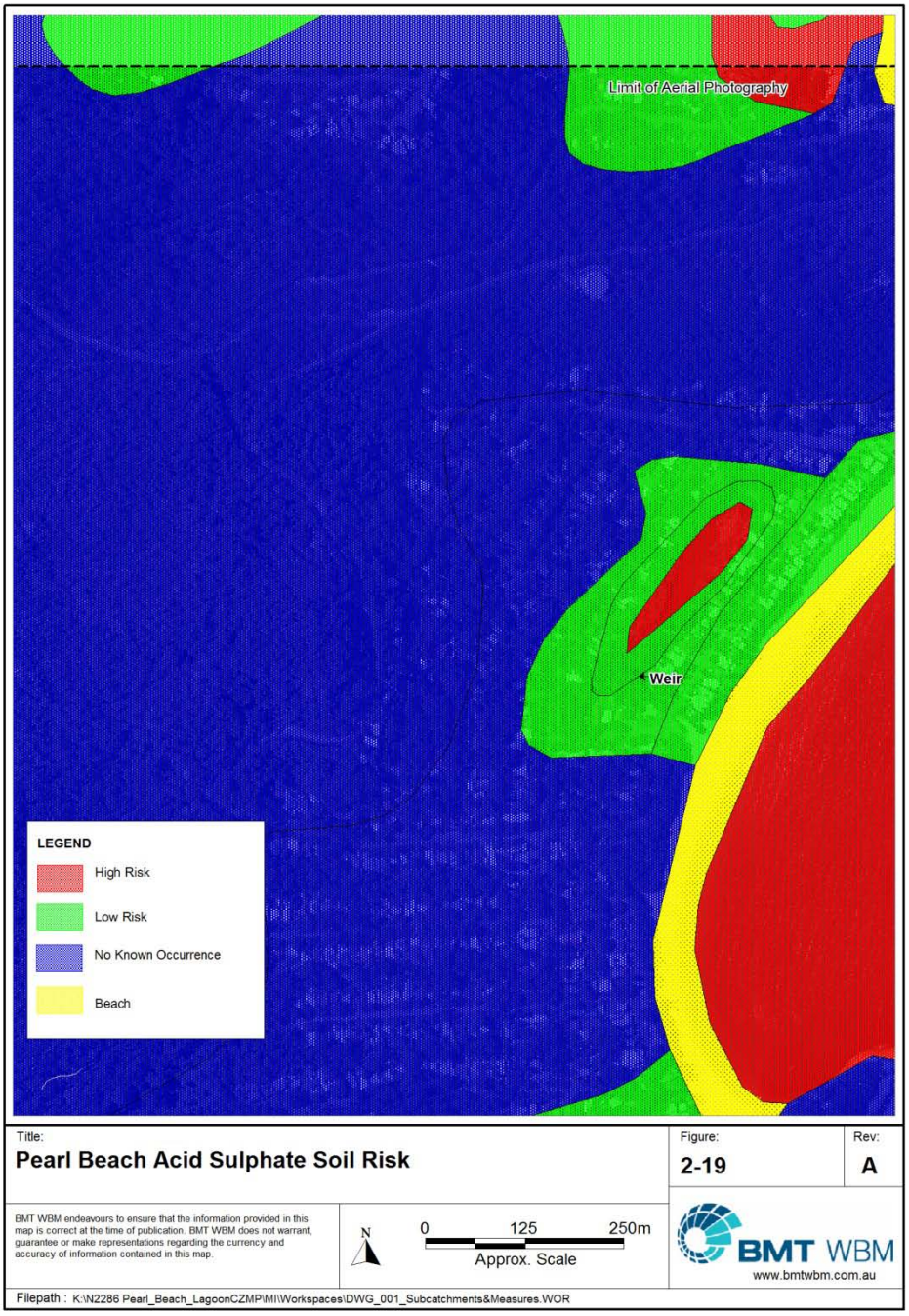


Figure 2-19 Acid Sulphate Soil Risk

3 COMMUNITY USES REPORT

An important aspect of planning for the future of Pearl Beach Lagoon is appreciating the community values, uses and aspirations for the lagoon.

The Pearl Beach community is passionate about the lagoon, it's past and present values and the potential to improve lagoon health into the future. A key challenge for the preparation of the plan will be making sure this enthusiasm can be harnessed and directed towards the best environmental outcomes for the lagoon.

3.1 Community Engagement

The community has been actively engaged throughout this project using the following:

- A community survey distributed via letterbox drop;
- An interactive Discussion Board accessed via Councils web page; and
- A community workshop held on May 17th 2012.

Some 57 registered participants attended the community workshop, and is considered an exceptionally well-attended event of this nature. Some of the attendees have a long history with the lagoon and were able to provide photographs and other information. Over and above the scheduled consultation, community members have provided information and photographs throughout the course of the study. In this regard, special acknowledgement is made for the contribution of Ann Parsons. This information has been useful in preparing the condition study and will also be used to inform the CZMP.

A key aim of the CZMP will be to foster the interest by the community towards a suite of community based actions that will benefit the lagoon such as garden management (for example planting of appropriate species, sediment control and waste disposal), wetland rehabilitation and replanting schemes (such as bushcare) and monitoring programs.

Documentation related to community consultation is included as Appendix A, which also includes photographic submissions by Ann Parsons.

3.2 Cultural and Historical Significance

The community were able to provide a range photographs, reports and anecdotal information. It is understood that the Pearl Beach subdivision was undertaken in 1928 by Clive Staples.

3.3 Zoning and Ownership

Gosford City Council is in the process revising its LEP for consistency with the State's LEP template. The zoning of the Lagoon and its immediate surrounds under the current LEP is shown in Figure 3-1. The Lagoon itself and some of the surrounding land is zoned 5a, and will be changed to RE1. The surrounding residential land is currently 2a, and will be converted to R2 under the new LEP. Within the wider catchment, the large areas of forested land will be converted from 6(a) to E1.

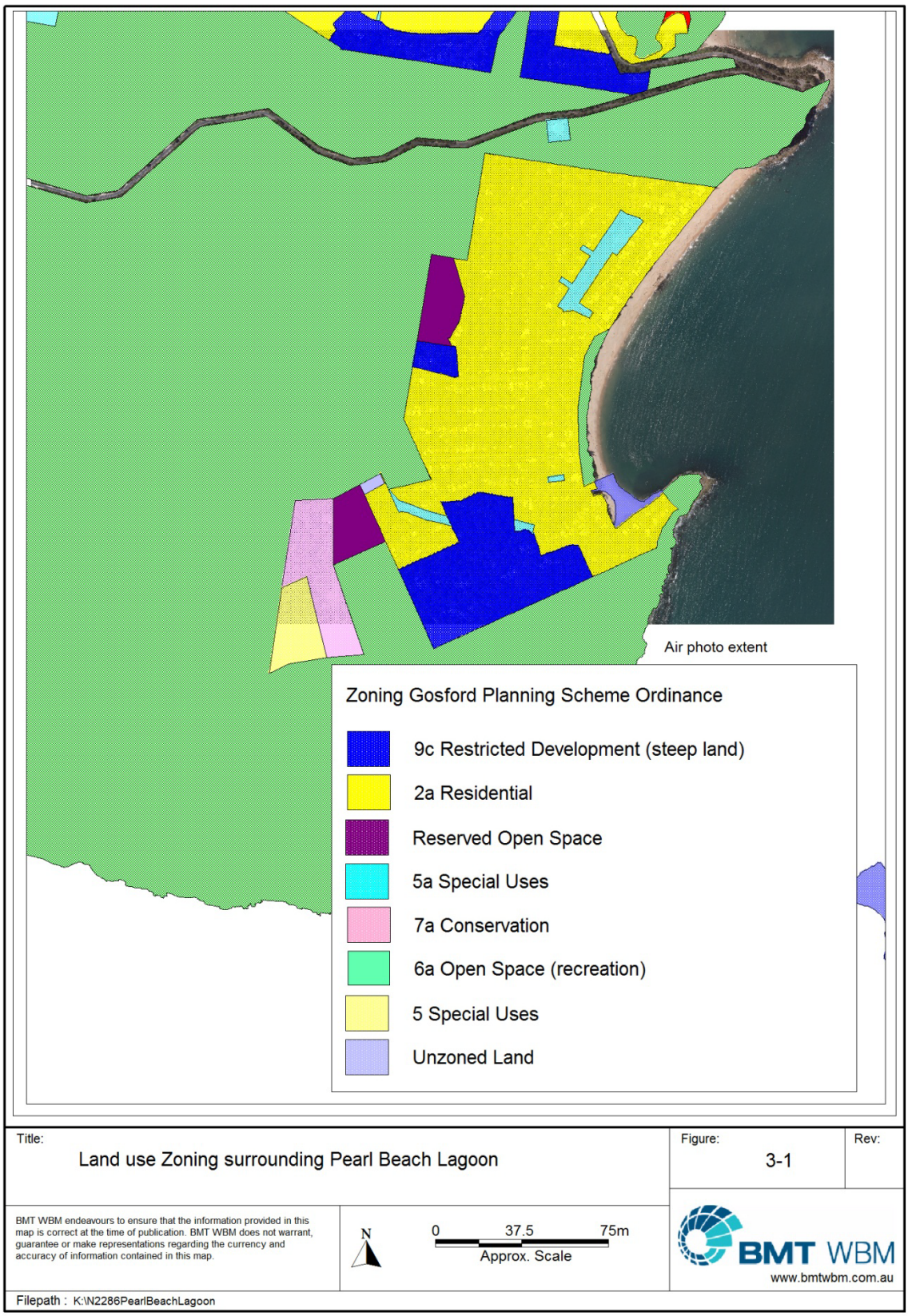


Figure 3-1 Land Use Zoning

3.3.1 Ownership

There is some variation in how land parcels have been drawn in the cadastre surrounding Pearl Beach Lagoon. The land boundaries adjacent to the lagoon foreshore are shown in . As can be seen, while the majority of houses have a parcel of public land between their lot and the lagoon, there are 12 lots along Coral Avenue that extend to the lagoon.

3.4 Access and Potential Impacts of Access

Access to the Pearl Beach Lagoon is informal and unrestricted, although somewhat difficult due to the limited public lands surrounding the waterway. Tracks into and around the Lagoon weave between houses and trees from the southern side of the entrance channel, through a stand of *Phragmites australis* to an open grassed area under melaleuca trees. The lagoon may also be accessed via the easements between houses on Diamond Road. From here the route taken is only guided by where existing tracks have trampled vegetation or where mowing has increased accessibility. The eastern foreshore is the least accessible due to private ownership. This unplanned access may interfere with bird breeding and foraging and may also result in trampling of desirable native vegetation.

Figure 3-2 Land Boundaries adjacent to the Pearl Beach Lagoon Foreshore

3.5 Recreational Uses

Unlike other lagoons that may be used for boating, swimming and other active recreational pursuits, Pearl Beach Lagoon is limited to mostly passive land based activities such as bird watching, appreciation of the visual landscape and wetland rehabilitation.

The users include local residents and tourists.

There is a bushcare and dune care group active in the area. It is anticipated that the CZMP will be able to provide specific direction to these groups to maximise rehabilitation opportunities for the lagoon.

Figure 3-3 Access Points

4 VALUES AND THREATS

4.1 Values of Pearl Beach Lagoon

4.1.1 Natural Bushland / Riparian Vegetation

Fringing vegetation, including the Melaleuca wetland (listed as Endangered under the TSC Act) and sedgelands, which provide habitat for local species were identified as a key ecological value of the study site through the ecological assessment (refer to Appendix B). The Melaleuca trees were also identified as a key value at the stakeholder workshop. The role of wetland vegetation in reducing the likelihood of bank erosion and in filtering catchment runoff was also acknowledged in the ecological assessment in Section.

4.1.2 Wetland Fauna

As described in Section 2.5.2. The lagoon is an important habitat for water birds. In summary, the open water and fringing sedgeland habitats provide locally important habitat for several local bird species, particularly dusky moorhen (*Gallinulka tenebrosa*)..

Frogs are also known to be present (including the striped marsh frog) surrounding the lagoon.

4.1.3 Water Quality and Ecological Function

The community generally viewed good water quality to support ecological function as an essential foundation for lagoon health. As discussed in Section 2.6, there is insufficient data to confidently describe the water quality of the lagoon. The confirmation of avian botulism at the site and also the observation of water quality issues, provide sufficient impetus for improving water quality in the future.

The ecology assessment states that maintenance of water quality and habitats within the lagoon will assist in supporting wetland fauna.

4.1.4 Aesthetic Beauty

Most submissions from the community describe the aesthetic beauty of the lagoon. Interestingly, many people commented on the lagoon being beautiful “when it is full of water”.

4.1.5 Public Access Around the Lagoon

Public access for the Pearl Beach Lagoon is limited and informal as described in Section 3.4. While the community does not want to see increased visitation, most respondents to the survey and participants in the workshop valued the current levels of access in and around the lagoon. The desire to formalise this access to reduce impacts to the surrounding wetland was also acknowledged.

4.2 Threats to Lagoon Health and Values

This outline of threats to the Pearl Beach Lagoon is based on the information included in the Lagoon Condition Study (refer to Chapter 2 of this report), the Community Uses Report (refer to Chapter 3 of this report), and input from the stakeholder workshop.

4.2.1 Avian Botulism

It is understood that a catalyst for community concern regarding the condition of Pearl Beach Lagoon was an outbreak of avian botulism in January 2010. This resulted in significant deaths of spoonbills and other water birds.

Avian botulism is a paralytic, disease of birds that results from the ingestion of toxin produced by bacteria. The bacteria *Clostridium botulinum* is the cause of botulism and occurs naturally in the mud/soil of wetlands and lakes around the world. Birds become affected by the disease by ingesting food (insects, maggots, snails, worms etc.) which has consumed or come into contact with the *C. botulinum* bacteria. When this occurs the bacteria then further develops in the bird's digestive system and releases the botulism toxin causing paralysis and mortality (Belmont City Council, 2011).

As the bacterium occurs naturally in wetland soils, the trigger for outbreaks is considered likely to be environmental conditions that encourage bacterial growth (USGS, 2012). *C.botulinium* is an anaerobic bacterium, meaning that it does not grow in the presence of oxygen. The spores can lay dormant in soils until appropriate conditions for germination are present. Conditions that favour proliferation of avian botulism include low levels of dissolved oxygen, high temperatures and high nutrient concentrations. Once environmental conditions return to normal (oxygen levels, increased flushing and stabilised nutrients) the risk of birds becoming infected with botulism reduces.

Gosford Council published a media release

4.2.2 Stormwater Pollution

Under optimal conditions, nitrogen entering the estuary from stormwater would be denitrified and thus converted to nitrogen gas and released to the atmosphere. This process is performed by bacteria within the sediments and is dependent upon the presence of sufficient oxygen. Where excess nutrient loading, the demand for oxygen for this process would not be met, leading to low denitrification rates, with nitrogen thus retained in the water (mostly in the form of ammonia).

There are a number of stormwater discharge points from surrounding houses which flow directly to the lagoon. During the site visits it was noted that the source of these pipes is not known. These pipes are most like conveying roof runoff from surrounding houses and are not considered a significant risk.

4.2.3 Pollution Incidents

A number of suspected pollution incidents have been reported through the community consultation. It is understood that these have been followed up by Council and, where appropriate, fines have been issued. It is recommended that the process for reporting incidents should be clearly communicated to residents and a suitable internal priority placed on it within Council. There is no industry or agriculture with the catchment so pollutants are only sourced from urban landuses (i.e. construction sites, garden products, road runoff etc.)

4.2.4 Catchment Development

All development in the catchment (including road improvement works as well as general landscaping) has the potential to increase sediment and pollutant loads to the lagoon.

4.2.5 Introduced Fauna

There is no evidence that introduced fauna are a significant management issue at the Study Site. Rabbits and foxes may occur, however, these are not known to represent a significant management concern. Domesticated dogs and cats are a threat to birds on the lagoon.

4.2.6 Weed Invasion

Weed invasion was a concern raised by the community through the consultation. The ecological survey conducted for the present study included an audit of weed invasion. No weed species of National Significance, National Environmental Alert List Weeds or species declared under the NSW *Noxious Weeds Act 1993* were identified at the Study Site. In general, weed diversity and distribution across the Study Site was low with the exception of dense *Stenotaphrum secundatum** thickets on the lagoon's edge which have inhibited establishment of a diverse groundlayer of native or exotic species.

Weed species identified during bushcare working bees are listed in Appendix B

4.2.7 Myrtle Rust

Myrtle rust is a disease that affects the Myrtaceae family of plants, which includes many Australian native species such as bottle brush, tea tree and eucalypts. Myrtle rust was first detected in Australia on the Central Coast of New South Wales in April 2010. Observations on the detections in state forests and nature reserves indicate that the disease may have been present in Australia for at least two years.

The fungus that causes Myrtle rust has not been found before in Australia. It belongs to a group of fungi known as the 'guava rust complex'. This complex of diseases is native to South America and is also present in the United States of America (Florida and Hawaii) and Mexico. It is not known how Myrtle rust entered Australia.

Council will be managing this issue through other processes is consultation with the state government and other stakeholders.

4.2.8 The Weir

The weir at Pearl Beach Lagoon may have contributed to the degradation of ecological values by altering the flushing and natural hydro-cycle of the lagoon and changing/exaggerating sedimentation processes. The weir, in combination with past excavation of the lagoon and progressive filling of the foreshores, has created a ponded water environment of consistent water level, which has a relatively low habitat diversity.

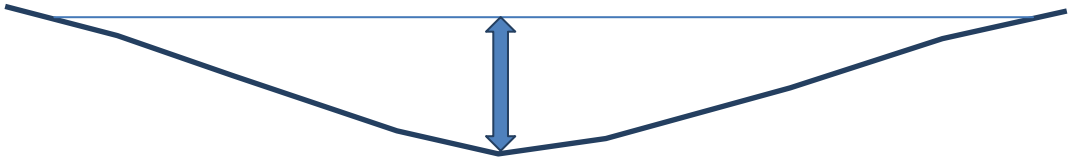
The weir may also have disrupted natural fish life-cycles and has created conditions more suitable to habitat generalists particularly the noxious *Gambusia holbrooki*.

4.2.9 Infilling of Lagoon Foreshores

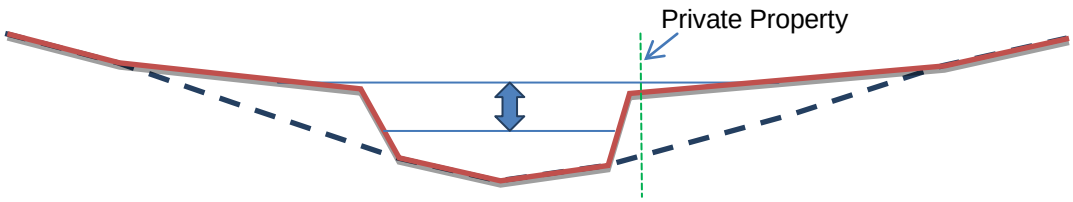
It is unknown to what degree the lagoon foreshores have been filled over the years. Nonetheless, there are some sections of the lagoon that now have relatively short, steep banks into the waterway. As identified previously, gently sloping banks allow organic material and wrack to be washed onto the

shoreline and out of the waterbody, where it can undergo aerobic decomposition. With steep shorelines, the organic material is essentially trapped within the water, where it undergoes anaerobic decomposition, with nutrients returned to the water and sediments, where they can be problematic and are available for further algal growth.

A cross-section schematic of Pearl Beach Lagoon is presented in Figure 4-1 that highlights the changes to the water regime of the lagoon. Under natural conditions the water level variation would have been larger, with most of the foreshores and lagoon bed accustomed to this variability. Under present day conditions, the water level regime has been truncated at both the upper and lower ranges by artificial entrance openings and by the weir, respectively. This was significantly reduced the variability of water levels. In addition, the foreshores have been filled to provide for landscaping of yards, improve grass condition and reducing ponding effects/boggy areas around the lagoon edges. As a result, there is now only a very limited fringe that actually experiences intermittent wetting and drying.



Natural lagoon profile with large WL range and gentle foreshore slopes



Modified lagoon profile with restricted WL range (due to the weir and artificial entrance opening) and steep foreshore slopes (due to progressive filling of backyards)

Figure 4-1 Schematic representation of changes to Pearl Beach Lagoon profile

4.2.10 Climate Change / Sea Level Rise

The expected increase in mean sea level due to future climate change will translate to typically higher water levels within Pearl Beach Lagoon, as the entrance barrier sand levels will increase commensurate with sea level. While the increase in water levels in Pearl Beach Lagoon could be managed to some degree by maintaining the existing artificial entrance breakout level, it is considered that this will become less and less manageable, as the trigger level would approach typical tidal levels.

An increase in the water level of the lagoon will result in additional inundation of the lagoon's foreshore. In response to this, fringing vegetation will tend to migrate landward in an effort to remain within their preferred environmental conditions (including groundwater and surface water inundation). This would include more frequent inundation of yards and grassy areas that are not currently flooded, and would likely start to compromise amenity of private lands fronting the lagoon.

Current projections for shifts in temperature and changes to rainfall patterns (annual, seasonal, extreme) are inconclusive. Furthermore, the understanding of the threshold for severe impacts to species and habitats that exist within and around the lagoon is even less well understood.

Council, at its Ordinary Meeting of 20 August 2013, endorsed a number of climate change scenarios relating to the Central Coast region. The climate change scenarios are intended to present a plausible future state of the climate in the region at different time periods and form the basis for risk assessment in this study.

The scenarios were first published in 2010, in a report commissioned by the Hunter and Central Coast Regional Environmental Strategy (HCCREMS) called, Potential Impacts of Climate Change on the Hunter, Central and Lower North Coast of NSW (HCCREMS, 2010).

This report was informed by a range of different sources, the most significant of which was a detailed analysis of historical climate variability in the Hunter, Central and Lower North Coast region of NSW (Blackmore & Goodwin, 2010). The methodology adopted in the analysis determined projected changes in key climate parameters using a weather typing approach to statistical downscaling from the CSIRO Mk3.5 Global Climate Model.

The scenarios (see Table 4-1) include consideration of future climate as it relates to:

- Sea Level rise and storm surge
- Extreme rainfall, flooding and storms
- Fire weather
- Average and extreme temperatures
- Average rainfall and water availability

The adoption of the regional projections guides Council in proceeding with risk assessment, policy development and strategic planning decisions. Council will incorporate additional and widely accepted scientific information as it becomes available.

Council is currently undertaking an assessment of coastal processes and risk for all beaches including Pearl Beach. This information will assist in building our knowledge in the impact of erosion, recession and coastal inundation which may influence Pearl Beach Lagoon.

Table 4-1Climate Change Scenarios for Gosford

Climate Variable	Current[1] (indicative)	Indicative change[2] (relative to current)		Comments
		2050	2100	
1. Sea level rise and storm surge				
Sea level		↑ 0.4m	↑ 0.9m	Latest projections indicate SLR of up to 1.4m by 2100
Storm tide – max height, 1:100 ARI (average recurrence interval)	1.4m	1.8m	2.3m	Based on NSW design still water levels - excludes wave setup
Storm tide – ARI (1.4 m)	1:100	1:1	na	Limited regional modelling of recurrence intervals has been undertaken to date
2. Extreme rainfall, flooding and storms				
24 hr rainfall intensity (max)	250mm	↑ up to	↑↑	Based on NSW models - Hunter region

		20%		not well represented. Greatest intensity increases likely in Summer
Extreme rainfall frequency (95th %ile)		↑	↑↑	Increases in Summer and Autumn, decrease in Winter.
Flooding - Average recurrence intervals (ARI)		↓ flash	↓↓ flash	Specific projections not available
		↓ riverine	↓↓ riverine	
Maximum wind gust intensity	155 km/hr	↑↓	na	Possible increase in Spring and decrease in Winter
3. Fire weather				
Number of very high and extreme fire danger days	16	↑ up to 24	na	Based on CSIRO projections for one site (Williamtown). Regionally specific projections are not as conclusive, although increased fire danger for Autumn is indicated
Length of fire season		↑	na	Fire season extends further into Autumn
4. Average and extreme temperatures				
Average annual maximum temperature	23	↑ up to 1.5 °C	↑ up to 3.5 °C	Greatest increases in autumn and winter
Days per year > 37 °C	3	↑	↑↑	Specific projections not available
Days per year < 0 °C	1	no change	na	Possible decrease in winter, increases in autumn and spring
5. Average rainfall and water availability				
Average annual	1200 mm	↑ 9%	na	Increases in Summer, Winter and Spring, decrease in Autumn
Summer	350 mm	↑ 22%	na	
Autumn	390 mm	↓ 14%	na	
Winter	200 mm	↑ 19%	na	
Spring	260 mm	↑ 18%	na	
Number of rainy days per year	130	↓	↓	Specific projections not available
Average water balance (rainfall less evaporation)		slight ↓	na	No change in summer, drier in autumn, moister in winter and spring
Annual stream flows		↓ 5-10 %	na	Based on 'mid' scenario for Namoi catchment
Drought frequency	10-20% of months	↑ to 24-28% of months	na	Based on projections for NSW central-north coast

Sources: Blackmore & Goodwin, 2009, 2010; CSIRO, 2007; Macadam, McInnes and O'Grady, 2007; CSIRO, 2007b

4.2.11 Groundwater Extraction

Groundwater extraction was identified as a threat to the Melaleuca wetland through the community consultation. An assessment of the likelihood of this threat undertaken during the catchment assessment indicates that the approximately 10 bores operating in and around the estuary are unlikely to be a threat. Increased runoff to the lagoon and surrounding wetland would be far greater than the volumes of water being extracted from bores.

4.2.12 Foreshore Management (incl. mowing)

Foreshore vegetation has been impacted by clearing, possibly to enhance views and/or provide lagoon access. Constant mowing of grassed areas prevents the regeneration of native wetland vegetation. In addition to the ecological impacts, the removal and damage of foreshore vegetation enhances the likelihood of bank erosion, and will also impact upon water quality.

Consultation with Council Maintenance Staff carried out through this project indicates that residents are encouraged to mow to the lagoon edge by Council Staff. A clear and consistent message on appropriate foreshore management for these residents needs to be delivered.

4.2.13 Bushfire

Significant bushfires within the catchment can lead to surges in sediment runoff and siltation within the lagoon. During 1998, a significant portion of the Pearl Beach Lagoon catchment experienced a large fire.

4.2.14 Conflicts between lagoon uses

Two key conflicts between lagoon uses are:

- the disruption to bird habitat and breeding posed by dogs being walked around the lagoon
- The conflict between land owners who are mowing and clearing foreshore land to maintain an open grassed area and the planting and other bush regeneration activities being undertaken. Clearing and mowing also conflict with a range of environmental values

4.2.15 Algal Blooms

As noted earlier, algal blooms are a feature of Pearl Beach Lagoon. For example, algal blooms of *Notilucca* were observed in 2011. This algae is a non-toxic dinoflagellate algae that feeds on other algae and fish eggs. It can appear as a pinkish mass as was the case in Pearl Beach Lagoon. While algal blooms are likely to be a natural feature of lagoons such as this, catchment inputs can increase their frequency and they can be considered a threat to lagoon values. Community members have reported a series of recent blooms in September this year (2012).

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5 POTENTIAL MANAGEMENT OPTIONS

5.1 Development of an Initial List of Options

The next stage of this project will be to develop of list of preferred options for the future management of Pearl Beach Lagoon. The next stage will include a multi criteria assessment to evaluate the pros and cons of various options in order to determine what works and actions should be targeted by Council, the community and other stakeholders.

A preliminary list of potential management options has been developed through the course of the assessments described previously, as well as through the community consultation carried out to date. The options considered further as part of the next stage of this project, will include, but not be limited to, those described below.

As outlined in Section 1.4, management of Pearl Beach Lagoon would involve a combination of 'intervention' options and 'adaptation' options. Intervention options aim to reduce the impact of an external pressure or threat so that lagoon values are less impacted than at present. Adaptation options meanwhile aim to help the users of the lagoon (including the community) better accommodate the modified values and conditions of the lagoon.

Intervention Options

- Identify potential sources of nutrients and sediments and liaise directly with land owners to reduce nutrient and sediment runoff within the catchment.
- Improve foreshore structure and habitats. Identify specific locations for improved foreshore access and rehabilitation. Rehabilitation could include restoring a gently sloping foreshore as well as targeted planting.
- Remove the weir to restore a larger water level range and allow periodic flushing (emptying) of the lagoon.
- Modify the weir to provide better control of water levels and thus optimise flooding, aesthetic and ecological objectives
- Education of the residents about the key issues.
- Improved regulation of residential construction activities in the catchment to reduce exposure of soils to erosion from rainfall and runoff.
- Improve maintenance and construction activities within road reserves to ensure that stormwater drainage inlets are protected from the inflow of high sediment volumes.
- Consider providing vegetated filtration measures (e.g. raingardens) in the road reserves adjacent to stormwater inlets to provide filtration of stormwater.
- Investigate the potential for retrofitting sediment traps adjacent to main stormwater outlets into Pearl Beach Lagoon (referFigure 2-7). A preliminary assessment has been carried out to determine the optimum stormwater treatment of the Pearl Beach Lagoon catchment, and is summarised in Table 5-1.

Table 5-1 Summary of Optimum Stormwater Treatment Measures

Sub-catchment/s Treated	Measure Type	Modelled Area (m^2)	Footprint Area (m^2)	Detention Depth (m)	Biofilter Depth (m)
S3	Sediment Basin	175	250	0.45	-
S1 and S5	Sediment Basin	175	250	0.45	-
S6 and S7	Sediment Basin	200	290	0.45	-
S2 and S4	Biofiltration Basin	100	150	0.30	0.45

Adaptation Options

- Consider utilising amphibious machinery (refer to Figure 5-1) to remove organic material and/or remove sediment (and associated nutrients) from the lagoon

Figure 5-1 Amphibious machinery (e.g. TRUXOR) for sediment and weed removal/management

- Increase planting around the fringes of the lagoon with appropriate species for reducing nutrient concentrations (possibly reshape some areas).
- Provide information to private landholders directly adjacent to the lagoon on the habitat values of their frontage, describing the habitat, its importance to the lagoon and options for its protection and management. Correspondence should be targeted to each land holder, letting them know specifically what is on their property, describing its conservation significance and describing actions that should or should not be taken.
- Identify sites where there is the potential for landward migration of wetland vegetation as a result of climate change and prioritise these for rehabilitation works.
- Undertake bank erosion works in areas currently experiencing instability. Foreshore erosion is occurring in relation to human activities, particularly foreshore maintenance. It is better to invest in revegetation works now than to react to erosion of these areas in the future.
- Acquire additional foreshore lands, bringing them into public ownership to maximise opportunities to improve foreshore ecological values and climate change adaptation (likely to be an expensive option).

5.2 Lagoon Entrance Management

Specific recommendations will need to be provided regarding future entrance management of the lagoon, including:

- Reconsider triggers and options for entrance management with ecological benefits.
- Develop an specific opening policy with consideration of the objectives of the CZMP
- Develop a formal procedure for measuring levels and undertaking works.
- Document all openings including other relevant information
- Modification or removal of the weir structure
- Establish a clear link between lagoon water levels and existing assets.
- Consider development controls around the lagoon to ensure minimum floor heights etc.

5.3 Monitoring

The lagoon's ecology and physical parameters are likely to be dynamic due to long periods of closure punctuated by periodic breakout. Potential indicators which may be considered to monitor estuary health at Pearl Beach Lagoon include:

- Water and sediment quality: physio-chemical parameters such as nutrients, microalgae, bacteria, and macrobenthic invertebrates at high and low flow and when the lagoon is opened and closed.
- Macrophyte assemblages as indicators of water quality and ecological condition.
- Foreshore condition in terms of vegetation cover and bank erosion.
- If sewage discharges are suspected, Council is encouraged to sample for faecal sterols (however it is noted that this is not likely as there are no known point sources and all septic systems were decommissioned in the 1980's)
- Event-based inspections and sampling of turbid plumes / discoloration events. The process for reporting incidents should be clearly communicated to residents.

6 WHERE TO FROM HERE?

The next step in the process of preparing a CZMP for Pearl Beach Lagoon will be a stakeholder workshop to help identify lagoon threats and further develop appropriate management strategies. The present document will be background reading for attendees who will include representatives of relevant government agencies, a cross section of Council staff involved in estuary planning and works and other stakeholders invited by Council. Following the stakeholder workshop, a draft CZMP will be prepared that will include recommended actions and implementation information.

This draft CZMP will then be placed on Public Exhibition. Following community feedback and adoption by Council, the plan will be implemented. Implementation will be led by Council but will include input from other government agencies and the local community.

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APPENDIX A: RESULTS OF COMMUNITY CONSULTATION

APPENDIX B: BIRD AND WEED LISTS FOR STUDY AREA

Birds recorded during 15 surveys undertaken by staff of Gosford City Council

Common Name	*Scientific Name*	No of sightings from 15 surveys	EPBC listing	NSW LISTINGS	Jamba	Camba
Australian Brush-turkey	*Alectura lathami*	3				
Australian Wood Duck	*Chenonetta jubata*	4				
Chestnut Teal	*Anas castanea*	1				
Pacific Black Duck	*Anas superciliosa*	3				
Spotted Dove	*Streptopelia chinensis*	1				
Crested Pigeon	*Ocyphaps lophotes*	4				
Topknot Pigeon	*Lopholaimus antarcticus*	1				
Tawny Frogmouth	*Podargus strigoides*	1				
Wedge-tailed Shearwater	*Ardenna pacifica*	1			J	
Australasian Gannet	*Morus serrator*	1				
Little Pied Cormorant	*Microcarbo melanoleucos*	5				
Great Cormorant	*Phalacrocorax carbo*	1				
Little Black Cormorant	*Phalacrocorax sulcirostris*	3				
Pied Cormorant	*Phalacrocorax varius*	1				
Australian Pelican	*Pelecanus conspicillatus*	2				
Eastern Great Egret	*Ardea modesta*	1			J	C
White-faced Heron	*Egretta novaehollandiae*	1				
Royal Spoonbill	*Platalea regia*	1				
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	3				C
Whistling Kite	*Haliastur sphenurus*	3				
Peregrine Falcon	*Falco peregrinus*	1				
Purple Swamphen	*Porphyrio porphyrio*	1				
Dusky Moorhen	*Gallinula tenebrosa*	1				
Crested Tern	*Thalasseus bergii*	4			J	
Silver Gull	*Chroicocephalus novaehollandiae*	4				
Glossy Black-Cockatoo	*Calyptorhynchus lathami*	6		VU		
Galah	*Eolophus roseicapillus*	3				
Long-billed Corella	*Cacatua tenuirostris*	3				
Sulphur-crested Cockatoo	*Cacatua galerita*	3				
Rainbow Lorikeet	*Trichoglossus haematodus*	6				
Scaly-breasted Lorikeet	*Trichoglossus chlorolepidotus*	1				
Musk Lorikeet	*Glossopsitta concinna*	4				
Australian King-Parrot	*Alisterus scapularis*	3				
Eastern Rosella	*Platycercus eximius*	3				
Fan-tailed Cuckoo	*Cacomantis flabelliformis*	1				
Barking Owl	*Ninox connivens*	1		VU		
Southern Boobook	*Ninox novaeseelandiae*	1				
Eastern Barn Owl	*Tyto javanica*	1				
Laughing Kookaburra	*Dacelo novaeguineae*	5				
Superb Lyrebird	*Menura novaehollandiae*	4				
White-throated Treecreeper	*Cormobates leucophaea*	2				
Satin Bowerbird	*Ptilonorhynchus violaceus*	3				
Superb Fairy-wren	*Malurus cyaneus*	1				
Variegated Fairy-wren	*Malurus lamberti*	1				

Rockwarbler	*Origma solitaria*	3				
White-browed Scrubwren	*Sericornis frontalis*	2				
Brown Thornbill	*Acanthiza pusilla*	3				
Spotted Pardalote	*Pardalotus punctatus*	3				
Eastern Spinebill	*Acanthorhynchus tenuirostris*	4				
Lewin's Honeyeater	*Meliphaga lewinii*	3				
Yellow-faced Honeyeater	*Lichenostomus chrysops*	4				
White-eared Honeyeater	*Lichenostomus leucotis*	1				
Noisy Miner	*Manorina melanocephala*	6				
Little Wattlebird	*Anthochaera chrysoptera*	5				
Red Wattlebird	*Anthochaera carunculata*	4				
Scarlet Honeyeater	*Myzomela sanguinolenta*	1				
New Holland Honeyeater	*Phylidonyris novaehollandiae*	2				
White-cheeked Honeyeater	*Phylidonyris niger*	2				
White-naped Honeyeater	*Melithreptus lunatus*	1				
Noisy Friarbird	*Philemon corniculatus*	1				
Eastern Whipbird	*Psophodes olivaceus*	4				
Varied Sittella	*Daphoenositta chrysoptera*	1				
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	1				
Cicadabird	*Coracina tenuirostris*	1				
Golden Whistler	*Pachycephala pectoralis*	3				
Grey Shrike-thrush	*Colluricincla harmonica*	1				
Australasian Figbird	*Sphecotheres vieilloti*	1				
Olive-backed Oriole	*Oriolus sagittatus*	1				
Dusky Woodswallow	*Artamus cyanopterus*	1				
Grey Butcherbird	*Cracticus torquatus*	3				
Australian Magpie	*Cracticus tibicen*	4				
Pied Currawong	*Strepera graculina*	4				
Grey Fantail	*Rhipidura albiscapa*	2				
Australian Raven	*Corvus coronoides*	1				
Leaden Flycatcher	*Myiagra rubecula*	1				
Black-faced Monarch	*Monarcha melanopsis*	1				
Rose Robin	*Petroica rosea*	3				
Silvereye	*Zosterops lateralis*	1				
Welcome Swallow	*Hirundo neoxena*	3				
Red-browed Finch	*Neochmia temporalis*	1				

Birds in addition to the above list for the wider study area

Common Name	Scientific Name
Australasian Grebe	*Tachybaptus novaehollandiae*
Australia Hobby	*Falco lonipennis*
Australian Owlet-nightjar	*Aegotheles cristatus*
Australian White Ibis	*Threskiornis molucca*
Azure Kingfisher	*Alcedo azurea*
Bassian Thrush	*Zoothera lunulata*
Bell Miner	*Manorina melanophrys*
Black Swan	*Cygnus atratus*
Black-browed Albatross	*Thalassarche melanophris*

Black-shouldered Kite	*Elanus axillaris*
Brown Cuckoo-dove	*Macropygia amboinensis*
Brown Falcon	*Falco berigora*
Brown Gerygone	*Gerygone mouki*
Brown Goshawk	*Accipiter fasciatus*
Brown Honeyeater	*Lichmera indistincta*
Brown Quail	*Coturnix ypsilophora*
Brown-headed Honeyeater	*Melithreptus brevirostris*
Brush Bronzewing	*Phaps elegans*
Brush Cuckoo	*Cacomantis variolosus*
Buff-banded Rail	***Gallirallus philippensis*** **
Buff-rumped Thornbill	*Acanthiza reguloides*
Channel-billed Cuckoo	***Scythrops novaehollandiae****
Chestnut-rumped Heathwren	*Hylacola pyrrhopygia*
Collared Sparrowhawk	*Accipiter cirrhocephalus*
Common Bronzewing	*Phaps chalcoptera*
Common Koel	*Eudynanys scolopaccea*
Common Myna	*Acridotheres tristis*
Common Starling	*Sturnus vulgaris*
Common Tern	*Sterna hirundo*
Crimson Rosella	*Platycercus elegans**
Dollarbird	*Eurystomus orientalis*
Double-barred Finch	*Taeniopygia bichenovii*
Eastern Curlew	*Numenius madagascariensis*
Eastern Osprey	*Pandion cristatus*
Eastern Reef Egret	*Egretta sacra*
Eastern Yellow Robin	*Eopsaltria australis*
Emerald Dove	*Chalcophaps indica*
Eurasian Coot	*Fulica atra*
European Goldfinch	*Carduelis carduelis*
Fairy Martin	*Hirundo ariel*
Feral Chicken	***Gallus gallus****
Feral Pigeon	*Columba livia*
Fork-tailed Swift	*Apus pacificus*
Fuscous Honeyeater	*Lichenostomus fuscus*
Grey Goshawk	*Accipiter novaehollandiae*
Grey Teal	*Anus gracillis*
Grey-tailed Tattler	*Heteroscelus brevipes*
Horsfield's Bronze-cuckoo	*Chrysococcyx basalis*
House Sparrow	*Passer domesticus*
Hutton's Shearwater	*Puffinus huttoni*
Intermediate Egret	***Egretta intermedia****
Large-billed Scrubwren	*Sericornis magnirostris*
Lewin's Rail	*Rallus pectoralis*
Little Corella	***Cacatua sanguinea****
Little Eagle	*Hieraaetus morphnoides*
Little Egret	*Egretta garzetta*
Little Friarbird	*Phileom citreogularis*
Little Lorikeet	*Glossopsitta pusilla*
Little Penguin	*Eudyptula minor*
Little Tern	*Sterna albifrons*
Magpie-lark	*Grallina cyanoleuca***
Masked Lapwing	*Vanellus miles***
Mistletoebird	*Dicaeum hirundinacceum*

Nankeen Kestrel	*Falco cenchroides*
Noisy Pitta	*Pitta versicolor*
Northern Mallard	*Anus platyrhynchos**
Oriental Cuckoo	*Cuculus optatus*
Pacific Baza	*Aviceda subcristata*
Pacific Golden Plover	*Pluvialis fulva*
Painted Button-quail	*Turnix varius*
Pallid Cuckoo	*Cuculus pallidus*
Pheasant Coucal	*Centropus phasianinus*
Powerful Owl	*Ninox strenua*
Rainbow Bee-eater	*Merops ornatus*
Red-rumped Parrot	*Psephotus haematonotus*
Red-whiskered Bulbul	*Pycnonotus jocosus*
Regent Honeyeater	*Xanthomyza phrygia*
Restless Flycatcher	*Myiagra inquieta*
Ruddy Turnstone	*Arenaria interpres*
Rufous Fantail	*Rhipidura rufifrons*
Rufous Whislter	*Pachycephala rufiventris*
Sacred Kingfisher	*Todiramphus sanctus*
Satin Flycatcher	*Myiagra cyanoleuca*
Shining Bronze-cuckoo	*Chrysococcyx lucidus*
Short-tailed Shearwater	*Ardenna tenuirostris*
Sooty Oystercatcher	*Haematopus fuliginosus*
Southern Emu-wren	*Stipiturus malachurus*
Spangled Drongo	*Dicrurus bracteatus*
Spotted Quail-thrush	*Cinclosoma punctatum*
Striated Thornbill	*Acanthiza lineata*
Swift Parrot	*Lathamus discolor*
Tawny-crowned Honeyeater	*Phylidonyris melanops*
Tree Martin	*Hirundo nigricans*
Turquoise Parrot	*Neophema pulchella*
Wandering Albatross	*Diomedea exulans*
Wedge-tailed Eagle	*Aquila audax*
Weebill	*Smicrornis brevirostris*
Whimbrel	*Numenius phaeopus*
White-bellied Cuckoo-shrike	*Coracina papuensis*
White-headed Pigeon	*Columba leucomela*
White-necked Heron	*Ardea pacifica**
White-plumed Honeyeater	*Lichenostomus penicillatus*
White-throated Needletail	*Hirundapus caudacutus*
White-winged Chough	*Corcorax melanorhamphos*
White-winged Triller	*Lalage sueurii*
Willie Wagtail	*Rhipidura leucophrys**
Wonga Pigeon	*Leucosarcia picta*
Yellow-billed Spoonbill	*Platalea flavipes*
Yellow-tailed Black-cockatoo	*Calyptorhynchus funereus*
Yellow-throated Scrubwren	*Sericornis citreogularis*
Yellow-tufted Honeyeater	*Lichenostomus melanops*

*Sited recently

**Have had chicks this year

Kindly provided by Ann Parsons

Weeds Identified during Bushcare Working Bees

Common name	Scientific name	
African daisy	*Osteospermum ecklonis*	
Arum lily	*Zantedeschia aethiopica*	
Beach pennywort	*Hydrocotyle bonariensis*	
Blackberry	*Rubus fruticosus aggregate*	Weed of National Significance
Blackberry nightshade	*Solanum nigrum*	
Blue Heliotrope	*Heliotropium amplexicaule*	
Blue Morning	*Glory Ipomoea indica*	
Buffalo Grass	*Stenotaphrum secundum*	
Canna	*Canna indica*	
Cape gooseberry	*Physalis peruviana*	
Cassia	*Senna pendula*	
Clivia	*Clivia miniata*	
Coastal Morning Glory	*Ipomoea cairica*	
Cobbler's peg,Farmers friend	*Bidens pilosa*	
Conyza sp	*Fleabane*	
Coreopsis	*Coreopsis lanceolata*	
Couch	*Cynodon dactylon*	
Couch	*Cynodon dactylon*	
Cucumber	*Cucumis sativus*	
Dandelion	*Taraxacum officinale*	
English Ivy	*Hedera helix*	
Fleabane	*Conyza albida*	
Gazania	*Gazania linearis*	

Ground Asparagus	*Asparagus aethiopicus*	Weed of National Significance
Hibiscus		
Japanese Honeysuckle	*Lonicera japonica*	
Lantana	*Lantana camara*	Weed of National Significance
Lesser Quaking Grass	*Briza minor*	
Lion's tail	*Leonotis leonurus*	
Montbretia	*Crocosmia crocosmiiflora*	
Ochna	*Ochna serrulata*	
Paddy's Lucerne	*Sida rhombifolia*	
Pampas Grass	*Cortaderia selloana*	
Paspalum	*Paspalum dilatatum*	
Passionfruit	*Passiflora edulis*	
Pennywort	*Hydrocotyle bonariensis*	
Quaking Grass	*Briza maxima*	
Sweet pea Shrub	*Polygala myrtifolia*	
Tomato	*Solanum lycopersicum*	
Yucca		

Kindly provided by Ann Parsons

APPENDIX C: CATCHMENT MODELLING

1 MUSIC MODEL DEVELOPMENT

1.1 Modelling Approach

Preliminary stormwater quantity and quality modelling was undertaken using the Model for Urban Stormwater Improvement and Conceptualisation (MUSIC) to estimate runoff volumes and loads of common stormwater pollutants including Total Suspended Solids (TSS), Total Phosphorus (TP) and Total Nitrogen (TN) draining to Pearl Beach Lagoon to assist with identifying management actions.

MUSIC was designed to continuously simulate urban stormwater systems over a range of temporal and spatial scales utilising historically representative rainfall data. MUSIC is considered within the industry to be an appropriate conceptual design tool for the assessment and sizing of stormwater treatment measures.

The hydrologic algorithm in MUSIC is based on the model developed by Chiew & McMahon (1997). The model simplifies the rainfall-runoff processes and requires input of the following variables to perform the hydrological assessment:

- Rainfall data (time steps varying from 6 minutes to 1 days);
- Potential evapotranspiration rates;
- Catchment parameters (area, % impervious and pervious areas);
- Impervious and pervious area parameters (rainfall threshold, soil and groundwater parameters); and
- Storm event and base flow stormwater pollutant concentrations.

MUSIC can be utilised for comparison of alternative scenarios that adopt the same base inputs. Although the magnitude of the estimates may not be equivalent to actual site conditions (due to limitations in available data for a particular site), the relative differences between scenarios is expected to be appropriate for supporting decision making.

The MUSIC modelling approach applied to assist in estimating flow volumes and pollutant loads discharging to the Pearl Beach Lagoon from the contributing catchment is described in the following sections.

1.2 Meteorological Input Data

The meteorological template includes the rainfall and areal potential evapotranspiration data. It forms the basis for the hydrologic calculations within MUSIC.

A Bureau of Meteorology (BoM) continuously recording pluviograph rainfall station is located at Peats Ridge (Waratah Road) approximately 26.1km from Pearl Beach. Pluviograph data are available for the 1981 to 2010 period for this station (however years 1992 to 1996 have some data

missing). An additional long term BoM rainfall station is located at Woy Woy (Everglades Country Club) approximately 4.3km from Pearl Beach. Data are available from this station for the 1964 to 2012 period. Comparison of the Peats Ridge and Woy Woy rainfall data shows that the mean annual rainfall (MAR) is approximately 1271mm and 1274mm respectively for each site. Rainfall data for Pearl Beach were also sourced from interpolated average annual rainfall data grids prepared by the Bureau of Meteorology, and the average annual rainfall was estimated at approximately 1267mm. Based on these comparisons, the Peats Ridge pluviograph data were deemed suitable and adopted for modelling.

Pluviograph rainfall data for Station 61351 Peats Ridge were sourced and reviewed for the 1981 to 2010 period to identify a continuous period of good quality data with an average annual rainfall similar to long-term conditions. Review of the Peats Ridge rainfall data indicated that the 1982 to 1991 period was relatively free of data gaps and accumulated rainfall data. The mean annual rainfall for this period is 1270mm which is similar to the long-term mean annual rainfall.

Interpolated data from SILO (DataDrill) were obtained for Pearl Beach to provide an indication of long term daily rainfall distribution. For the 1982 to 1991 period and the SILO data the mean annual number of days where the rainfall exceeds 1mm, 5mm, 10mm, 25mm, 50mm and 100mm were calculated. These were compared to confirm that the daily distribution of annual rainfall for the 1982 to 1991 period was similar to expected average conditions at Pearl Beach. The correlation was found to be reasonable as observed in Figure 1-1.

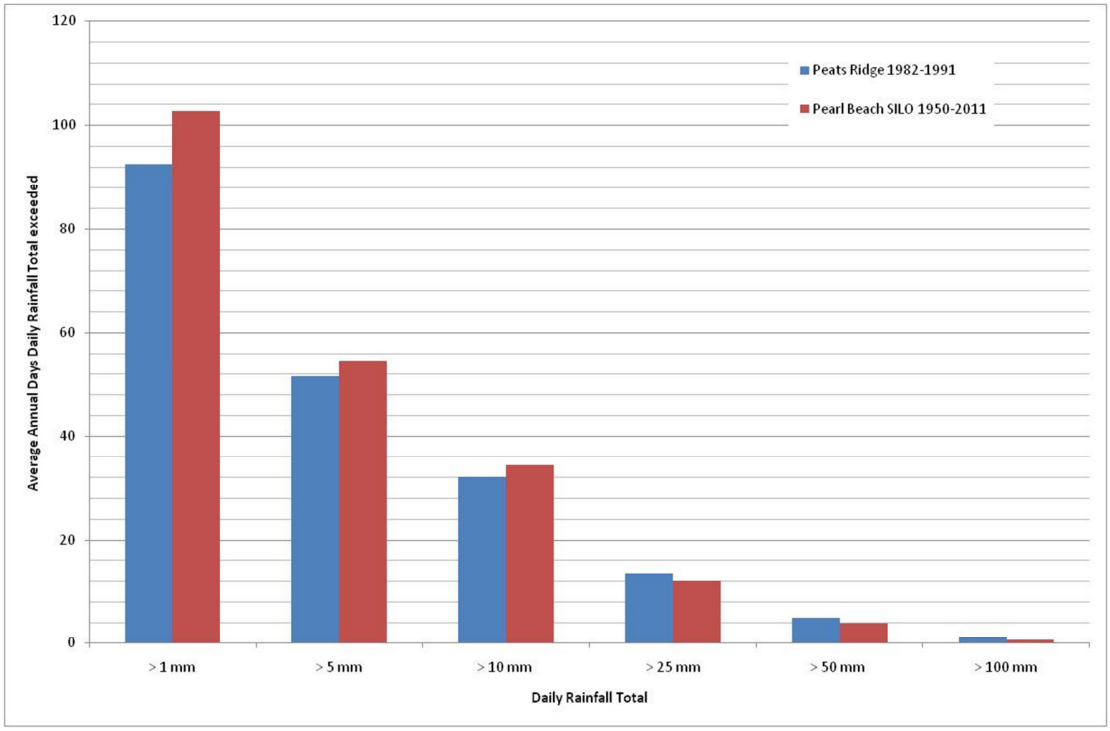

Figure 1-1 Daily Rainfall Distribution Comparison

Average monthly areal potential evapotranspiration (PET) rates adopted for the MUSIC modelling are summarised in Table 1-1. These values were obtained from BoM gridded data. A 6 minute modelling time step was adopted for the MUSIC modelling.

Table 1-1 Adopted Average Monthly Areal PET Rates

Month	Mean monthly areal PET (mm)
January	182
February	142
March	138
April	90
May	57
June	44
July	46
August	62
September	89
October	130
November	154
December	167

1.3 Sub-catchments

The Pearl Beach Lagoon study catchment was divided into a number of smaller sub-catchments considering topography and natural/constructed (kerb and pipe stormwater drainage) water courses. These sub-catchments are shown in **Error! Reference source not found.**.

Geographical Information System (GIS) data were utilised to estimate the total impervious areas (TIA) within each sub-catchment and estimate the proportion of these areas directly connected to the constructed drainage system. Impervious areas included roads, roofs and paved areas (i.e. driveways, patios and paths). A sample of residential lots in Pearl Beach was digitised in detail using GIS to estimate typical roof and paved areas within each lot. The estimated lot impervious areas were extrapolated to estimate total lot imperviousness for each Pearl Beach Lagoon sub-catchment. In addition, forest / bushland regions were digitised based on Council land use zoning data. Land use types were used to assign event and dry weather stormwater quality characteristics.

Residential lots were assumed to have an average roof area of 230m^2. The remaining lot area was assumed to comprise a mix of hard and soft landscaping surfaces. Average lot hard landscaping was assumed to be 60m^2. All landscaping was assumed to be disconnected from the constructed drainage system due to lack of kerb and guttering within Pearl Beach. Additionally, directly connected road and roof proportions were reduced to reflect the lack of kerb / guttering.

The total area, surface types, land uses and estimated directly connected impervious areas (DCIA) are summarised in Table 1-2.

Table 1-2 Summary of Sub-catchment Land Uses and Areas

Sub-catchment ID	Total Area (ha)	DCIA (%)	Impervious Surfaces (% of sub-catchment)			Pervious Surfaces (% of sub-catchment)	
			Roads	Roofs	Landscaped	Landscaped	Bushland
1	12.53	2%	4%	0%	0%	0%	96%
2	0.85	6%	15%	0%	0%	0%	85%
3	4.40	17%	8%	27%	7%	58%	0%
4	4.13	13%	5%	21%	6%	68%	0%
5	5.40	12%	6%	19%	5%	51%	19%
6	2.80	9%	5%	15%	4%	38%	37%
7	3.53	9%	5%	14%	4%	35%	43%
8	3.70	5%	2%	8%	2%	19%	68%
9	2.11	13%	3%	24%	6%	66%	0%
10	1.78	24%	6%	42%	11%	40%	0%

1.4 Rainfall-Runoff Parameters

Modelling of the rainfall-runoff process in MUSIC requires the definition of two impervious surface parameters and eight pervious surface parameters. These parameters can be estimated through a calibration and validation exercise for a particular catchment.

The average annual runoff fraction (ARF) was estimated for the site applying methods derived by Fletcher et al. (2004) for NSW catchments. The work by Fletcher et al. (2004) provides guidance on estimating surface runoff proportions for 100% pervious catchments/sites based upon the local mean annual rainfall (MAR). It represents the proportion of rainfall that is typically converted to runoff for a particular catchment/site. Based on a MAR of 1270mm, it is estimated that the ARF would be 30%.

Runoff modelled within MUSIC includes surface runoff and base flow components. For this study, a base flow index (BFI) of 0.3 was adopted as being representative of the hydrologic conditions for the Pearl Beach Lagoon catchment. This results in 21% of the total runoff volume being sourced from surface runoff, with the remaining 9% contributed by base flow. Additional pervious area parameters were then estimated based on MacLeod (2008). The adopted MUSIC hydrologic parameters are summarised in Table 1-3.

Table 1-3 MUSIC Rainfall-Runoff Parameters

Impervious Area Parameters	
Rainfall Threshold (all impervious surfaces, mm)	1.0
Pervious Area Parameters	
Soil Storage Capacity (mm)	350
Initial Storage (% of capacity)	30
Field Capacity (mm)	185
Infiltration Capacity Coefficient – a	150
Infiltration Capacity Exponent - b	3.5
Groundwater Properties	
Initial Depth (mm)	10
Daily Recharge Rate (%)	25
Daily Baseflow Rate (%)	10
Daily Deep Seepage Rate (%)	0

1.5 Runoff Quality Parameters

The MUSIC input stormwater constituent concentrations were adopted from those recommended for NSW in Fletcher et. al. (2005). The normalised values presented within that report were converted to logarithmic values for input to MUSIC.

Mean values for each parameter were calculated from the 'typical' values presented in Fletcher et. al. (2005). The existing default standard deviation values in MUSIC were adopted. This approach was consistent with that adopted for scenario modelling in Fletcher et. al. (2005). The adopted log_{10} values are summarised in Table 1-4 and Table 1-5. Residential concentration values were adopted for all urban land use nodes.

Table 1-4 Storm flow concentrations for MUSIC modelling in NSW (log_{10})

	TSS		**TP**		**TN**	
	mean	std. dev	mean	std. dev	mean	std. dev
Residential	2.15	0.32	-0.60	0.25	0.30	0.19
Forest	1.60	0.20	-1.10	0.22	-0.05	0.24

Table 1-5 Base flow concentrations for NSW MUSIC modelling in NSW (log_{10})

	TSS		**TP**		**TN**	
	mean	std. dev	mean	std. dev	mean	std. dev
Residential	1.20	0.17	-0.85	0.19	0.11	0.12
Forest	0.78	0.13	-1.52	0.13	-0.52	0.13

1.6 Treatment Measures

The modelled treatment measure sizes are summarised in Table 1-6.

Table 1-6 Treatment Measure Sizes

Sub-catchment/s Treated	Measure Type	Modelled Area (m^2)	Footprint Area (m^2)	Detention Depth (m)	Biofilter Depth (m)
S3	Sediment Basin	175	250	0.45	-
S1 and S5	Sediment Basin	175	250	0.45	-
S6 and S7	Sediment Basin	200	290	0.45	-
S2 and S4	Biofiltration Basin	100	150	0.30	0.45

APPENDIX D: PHOTO RECORD OF ELEVATED OCEAN WATER EVENT

Northern end of Pearl Beach

Storm Apr 2009

A. Beach front properties on Coral Cres where sand dunes have been severely eroded and vegetation designed to hold the bank removed by the sea.
(Photo taken next to 62 Coral Cres).

Storm Oct 2009

B. Waves have come into the back garden of 62 Coral Cres as seen by the wet sand outline.

Middle of Pearl Beach where the ocean links up with the Pearl Beach Wetland (lagoon)

Storm Oct 2009

C. Next to 4 Coral Cres

D. 13 Agate Ave across the road from 4 Coral Cres
Drain full of sea water leading to Pearl Beach Wetland (lagoon)

E. Reeds (Phragmites australis) and Rushes (Juncus kraussii) help trap polluted sediment from flowing into the lagoon and help remove excess nutrients

F. Sea water coming into Pearl Beach lagoon with the Swamp mahogany – paperbark (Melaleuca quinquenervia) Ecological Community in the background. The natural understorey includes native reeds (Phragmites australis) and sea rush (Juncus kraussii).

16 Feb 2009 after heavy rain

G. 57 Diamond Rd Pearl Beach. Water from the lagoon is on the back boundary of the property. Seawater coming into the lagoon at the point could flood this and nearby properties which has happened historically and affect the Swamp mahogany – paperbark (Melaleuca quinquenervia) Ecological Community.

Pearl Beach Lagoon photos

Dec 1979
White sand around the lagoon

May 2010
Now there is silt

Some of the lagoon's birds
Pacific Black Ducks Our Royal spoonbill Dusky moorhen's nest Cormorant

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12 Dec 2009

Many birds died including our Royal Spoonbill

Silt build up and algae.
Northern end of lagoon

Southern end of lagoon

30 Jan 2010
Pink algae

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