Clontarf / Bantry Bay

Data Compilation
&
Estuary Processes Study

FINAL REPORT

Part – II (Chapters 6 -12)

August, 2007

Completed as part of the Clontarf / Bantry Bay Estuary Management Planning Process

The groups that oversee the planning process of the Clontarf/Bantry Bay Estuary Management Plan

Clontarf/Bantry Bay Estuary Management Working Group

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i EXECUTIVE SUMMARY

NSW has over 130 estuaries that vary in size from small coastal creeks and lagoons to large lakes and rivers. Collectively, they are immensely valuable from ecological, social and economic perspective. These estuaries contribute $400 M to the State's economy per annum (DNR 2006). The natural beauty of estuaries attracts many visitors and development, and as a result they are under constant pressure. To improve the management of these estuaries, the NSW Department of Environment & Climate Change (DECC) administers the Estuary Management Program. This program aims to provide a strategic approach to the sustainable management of estuaries and sets out a clearly defined process, culminating in the production and implementation of a comprehensive Estuary Management Plan.

Manly is known to people distinctively for its beaches and foreshore areas. For this reason, it is important that the waters and natural features around these beaches and foreshores are nurtured and protected. In line with efforts of NSW State Government, Manly Council has also embarked on planning and management of coastal and estuarine areas. The importance of coastal and estuarine management has been highlighted in all key policy, strategy, plan and management documents adopted by the Manly Council. Manly Lagoon Estuary Management Plan was adopted back in 1998. Manly Council has, since long, adopted a staged approach to cover the entire Manly foreshore. Coastal Zone Management Plans have been prepared, or are being prepared, for the following areas: Forty Baskets, Little Manly, Manly Cove, North Harbour, Cabbage Tree Bay and Manly Ocean Beach. The preparation of the Clontarf / Bantry Bay Estuary Management Plan will complete the coverage of the entire foreshore.

The Study

One of the key steps in the formulation of the Estuary Management Plan (EMP) is the preparation of an Estuary Processes Study, aimed at determining the baseline condition of the various estuarine processes (eg- physical, biological, chemical) and the interactions between these processes. This document aims to provide information on the baseline conditions in the Clontarf / Bantry Bay section of the Middle Harbour estuary.

To support the formulation of the EMP, the 'Clontarf / Bantry Bay Estuary Management Working Group' was established in May 2006 with representations from the Manly Council, community Precincts, Government organisations, Manly Council's Scientific Advisory Panel, neighbouring councils, community and Aboriginal community. An *Internal Staff Working Group* was also formed to support the development of the Clontarf / Bantry Bay Estuary Management Plan through expert contributions.

An extensive public consultation process and awareness campaign was undertaken through a variety of mechanisms including display panels, Manly Council's webpage, information through Precinct Newsletters, formal questionnaires and organized Field Days.

This study has been developed in-house with contribution from the 'Internal Working Group' under the guidance of the 'Clontarf / Bantry Bay Estuary Management Working Group'. The study report has gone through an extensive peer review including by state agencies.

Study Area

This study area relates to the northern portion of the Middle Harbour (part of the greater Port Jackson / Sydney Harbour) estuary and foreshore that corresponds with the Manly Local Government Area boundary. It covers an area of 350 hectares between Castle Rock and Bantry Bay and includes parts of Balgowlah Heights, Clontarf and Seaforth suburbs. The Spit Bridge, a landmark connecting northern beaches with Sydney, is located halfway along the foreshore of the study area. Population of the study area, according to 2001 census, is 5,873.

The entire study area is covered within the Sydney Harbour Foreshores and Waterways Area and excluded from the legally defined NSW coastal zone. The entire study area is also covered within the 'Sydney Metropolitan Catchment Area'.

The current land use remains predominantly residential development (65.5%), followed by road surfaces (22.0%) and open spaces and parks (10.2%). Pockets of bushland remain scattered throughout the area (which total 18.5 hectares in size), occurring mostly around the immediate estuary foreshore. Manly Scenic Walkway and Harbour to Hawkesbury Walking Tracks run through the study area. The estuary is used actively for walking, swimming, boating, sailing and passive recreation (eg- reading, meditation, picnicking). In addition, the estuary is also popular for kayaking, recreational fishing, sunbathing and walking dogs.

The study area is zoned under both the *Manly Local Environment Plan* 1988 and the *Sydney Regional Environmental Plan - Sydney Harbour Catchments 2005* or simply the Harbour REP. The Manly LEP establishes land use zones within the study area as zone 2 – Residential, 3 – Business Zone, 5 – Special Uses Zone, 6 - Open Space and Zone 8 – National Parks existing. The foreshores and waterways of the study area are located in five of the nine zones under Sydney Harbour REP: W1 (Maritime Waters), W2 (Environment Protection), W5 (Water Recreation), W6 (Scenic Waters – Active Use) and W8 (Scenic Waters – Passive Use).

The study area has a rich history, beginning with extensive Aboriginal occupation, which is evidenced through the many middens that are still present. The area was used extensively by the Aboriginals, known locally as the Gayemal clan of the Guringai tribe. The oldest Aboriginal site known in the Manly LGA is dated to about 4100 years before present. There are 22 recorded Aboriginal sites within the study area. Following European settlement in Sydney, the study area was slowly developed, until improved access made the area more desirable. In 1850 a punt began running from the Spit giving easier access to the north side. Access was further enhanced in 1924 with the opening of the first Spit Bridge. By the 1970s the area was already extensively developed.

Natural Environment – Physical Processes

The estuary within the study area exhibits semidiurnal tidal characteristics, with two high and two low tides each day. The area is not fed by any permanent creeks; however various water courses provide freshwater inflows during and after rain. In periods of wet weather, the estuary becomes stratified with the more buoyant fresh water sitting as a thin layer on the surface of the salt water.

Groundwater is an integral part of the “water cycle” and maintains the dynamics of estuarine and near-shore marine water bodies. The major aquifer class, in the study area, is consolidated porous rocks containing limited quantities of groundwater. However along the foreshores there occurs the aquifer termed ‘unconsolidated sediments’. This aquifer contains significant groundwater resources with a well defined water table that is responsive to recharge events, and even tidal influences in some cases.

Wind waves generated in Middle Harbour are generally less than 0.1m in height. Ocean swell waves penetrate lower Middle Harbour through the heads of Sydney Harbour, and undergo severe refraction and diffraction. The only place in the study area that is subject to waves from a consistent direction is the lower half (Castle Rock Beach to Sandy Bay), where ocean swell waves run along the shore. Sediment has been observed to move along the shore in the same direction, providing possible evidence of a longshore current.

Significant storm events affecting the Middle Harbour area are known to have occurred in April 1893, June 1923 and May-June 1974. The 1974 storm reported wall collapse near Middle Harbour Yacht Club and minor beach erosion at the Spit and Clontarf. The study area experienced waves and high winds from a recent storm on June 9-10, 2007 which resulted in a cruiser washing ashore at Clontarf but no serious erosion. The study area also experienced the impact of a tsunami on May 22, 1960 when a strip 100 yards by 60 yards wide was swept away from Clontarf Reserve Point Park.

From the Spit Bridge to the north western extremity of the study area, the foreshore is predominantly stable rock, with estuarine mud on the sea floor. This area is beyond the normal limit of ocean waves, and is reasonably deep, therefore creating a relatively stable sedimentary environment. However, the lower reaches, from Castle Rock Beach to the Spit Bridge, consists largely of unstable sandy shores, with a mixture of marine sand and estuarine mud on the sea floor. The estuary in this section consists of both a shallow sand bar and a deep channel. The marina at Clontarf lies directly in the path of the sand transport corridor between the tidal delta and Sandy Bay. However, the beach profile appears to have been modified from its natural state, due to the irregular shape of the shoreline between Clontarf Reserve and Sandy Bay. The large sand flat of Sandy Bay

transforms into a narrow beach with a steep drop-off on either side of Clontarf Marina, and then back into a sand flat to the south of the marina. There are many forces impacting on this part of the estuary, creating a complex system.

Natural Environment – Ecological Processes

The ecosystems within the study area are highly fragmented and have signs of the many pressures placed on them through development and high usage.

The marine environment within the study area has a diverse range of habitats. There are significant seagrass beds within the study area: the largest bed is adjacent to Castle Rock Beach and reasonably large meadows exist at Clontarf and Sandy Bay. Compared to the past, large losses of seagrass have been reported. There are several relatively deep holes within the mud basin section that provide habitat, with the deepest located upstream of the Spit Bridge. The mud basin provides habitat for various species, including invertebrates such as worms and molluscs. Over 570 species of fish have been recorded in greater Sydney Harbour, and it is likely that a large proportion of these are also present within the study area. The list includes 3 endangered, 5 vulnerable and 18 protected species.

The intertidal area within the study area has a range of habitats including rocky reefs and platforms, sandy beaches and mudflats, a few remaining mangroves and artificial habitat including seawalls, jetties and pontoons. The entire foreshore of the study area is protected as Intertidal Protected Area (IPA). Many types of algae (eg- red, green, brown) inhabit the intertidal zone, providing a food source for the many grazing invertebrates. Numerous types of invertebrates, such as worms, crabs and molluscs, can be found in the sediment. There is only one small pocket and few individual mangroves remaining within the study area. However, no salt marsh has been identified. A total of 62 species are known to be present in or directly adjacent to (and hence expected to also be in) the study area. The majority of these species are invertebrates. The Little Penguin is often sighted within the study area but no information is available on its nesting place. It feeds in the estuary during the day and nests on land during the night.

The terrestrial environment within the study area has seen the largest change. Bushland reserves occur in a total 18.5 hectares and are scattered throughout the study area. Six reserves have SEPP 19 status under EP&A Act, requiring preparation of management plans. Smaller patches of bushland on both public and private land do exist throughout, and in some places provide corridors between the reserves. There are seven specific vegetation communities present within these reserves. A total of 3 amphibian, 49 birds, 6 mammal and 13 reptile species have been recorded. Grey-headed Flying Fox (*Pteropus poliocephalus*) is the only threatened species recorded.

Human Interventions & Usage

Human activities have altered and modified the natural system of the study area. Foreshore development has been extensive. The first and major foreshore development in the study area happened with the construction of the Spit Bridge in 1924 (which was replaced by the existing bridge in 1958) and some other developments prior to this at the site: first punt operation in 1849, ferry operation in 1880 and tram services in 1900. Seawalls, both public and private, exist throughout the study area. Total length of seawalls is 2.4km, that approximately 46% of the foreshore length. Swimming baths/enclosures, Clontarf Marina and walkways including Manly Scenic Walkway are some other developments on the shore. Public access to foreshore is available at several points. There is no public pontoon/jetty in the study area but one to be constructed soon. There are sailing and yacht clubs providing boating facilities and contributing to estuary use through a number of events including racing, training etc. Manly Council is extracting 1.64 mega litres of groundwater at a depth of 6.1m for irrigation of Clontarf Reserve. Many private properties are also abstracting groundwater. Stormwater now flows through 16.0 km artificial drainage networks. The estuary is used actively for walking, swimming, boating & sailing and passive recreation (eg- reading, meditation, picnicking) with reasonable degree of use for kayaking, recreational fishing, sunbathing and walking dogs. Dogs are allowed on a leash in the Clontarf Reserve. These alterations have all impacted the natural environment.

There exist conflicts between different user groups and the impacts that competing users have on the environment. Examples of some of these conflicts identified include:

- Seawalls for protection of properties versus its damaging impact on natural ecosystem
- Groundwater abstraction and possible saline water intrusion in aquifer
- Beach raking for safety versus its impact on invertebrates
- Dog walking off leash and impact on shore birds
- Powered and sailing boats and their wake impacting on seawalls and beach erosion
- Access to mooring versus their impact on seagrass beds, ability to spread *caulerpa taxifolia*
- Powered boats and the safety aspects for swimmers and kayakers
- Ad hoc boat storage and its impact on amenity and habitat:
- Ad hoc access ways to foreshore for convenience versus destruction of habitat.

Processes & Impacts

With most parts of the Clontarf/Bantry Bay EMP study area being highly urbanised, there is significant pressure placed on water quality health. Despite the reported improvements in water quality recently, pollution is indeed still evident, particularly in times of rain when stormwater transports terrestrial pollutants into the estuary. Loads of pollutants in the estuary from the study area have been estimated at 2250 kg/year of total nitrogen; 260 kg/year of total phosphorus; 180 kg/year of copper, 230 kg/year of lead, 490 kg/year of zinc, and 128,000 kg/year of sediment. Four Gross Pollutant Traps (GPTs) are currently installed in the Clontarf / Bantry Bay Catchments. The Department of Primary Industries has placed a ban on all commercial fishing within Sydney Harbour including the study area, because of the presence of elevated levels of dioxins in fish and crustaceans. Of the three swimming pool/baths, Sangrado bath is the worst in terms of bacterial contamination. There are 5 known sewer overflow locations within the study area.

The study area is used extensively by a variety of vessels, particularly between Castle Rock Beach and Seaforth Bluff. This section of the waterway is the only access between greater Sydney Harbour and upper Middle Harbour, so all vessels wishing to travel between the two must pass through. Boat generated waves over time can cause foreshore erosion and weaken sea walls. They can impact on habitat. Boating can, in addition, impact on water quality via spills, anti-foul paints, littering from boats and from marinas where boats are washed and fixed etc. A No Wash Zone is in place between Clontarf Point and Seaforth Bluff. An 8 knot speed limit zone is also in place, between Clontarf Point and d'Albora Marina (Mosman side of Spit Bridge).

Erosion in the study area occurs along beaches, in front of stormwater outlets, along ad hoc access tracks, and where foreshore protection structures such as seawalls are collapsing. Beach erosion has been experienced at 4 sections of Clontarf Beach and Sandy Bay with varying degrees of severity, and fluctuations over time. Accelerated erosion occurs as a result of the concentration of stormwater flows through artificial drainage networks. The study area, specially the Clontarf Swimming area, also regularly experience siltation. The study area is susceptible to slope and cliff instability, with a large landslip having occurred at Seaforth Crescent in 1956.

An ecosystem health card has also been developed for the study area.

The study area will experience many of the impacts of climate change, with the low lying areas close to the foreshore likely to be subject to more of the impacts than the elevated areas. These impacts are likely to include: sea level rise; increases in extreme weather events; temperature increases; reductions in water availability; altered hydrology and increased flash flooding; and more frequent and more severe droughts (Hennessy et al, 2006).

Community Key Concerns

Concerns of the community were expressed through different means and at different occasions. More directly, a total of 120 survey forms were completed and returned throughout the consultation process. On marine based issues, water pollution, marine flora & fauna and conservation management issues, in broader perspectives, are of high concern of the community. Among land-based issues, pollution, storm water management, terrestrial flora & fauna, conservation management and foreshore walkway issues are of high concern. Climate change issue is also appeared to be of key concern.

Significance and Values of the Estuary

The Clontarf/Bantry Bay estuary is locally significant in its role as a habitat for native animals and plants, a provider of popular recreational resource for locals and visitors alike. The attraction of Clontarf/Bantry Bay is enhanced by its generally good water quality. Because of its scenic beauty and views, foreshores have already become highly sought after residential area. At present, 65% of the foreshore is under residential land use compared to 37% within Manly LGA. The Clontarf/Bantry Bay waterway has a very high economic value and is important to a range of stakeholders, ranging from local retailers to commercial tourism operators, real estate operators, boating services, marinas and support industries.

The study area is rich in Aboriginal cultural heritage giving it significance at the regional and state level. European cultural heritage is also an important feature of the study area with numerous heritage listed sites and buildings including public baths located along the shoreline, including Clontarf, Sangrado and Pickering Point. There exists several floras and fauna recorded as threatened, making the study area important.

The following values reflect attributes, activities and processes that are of importance to the community, and are the qualities on which the study area depends for its attractiveness, desirability, liveability and use.

- aesthetic values associated with a pleasant, appropriate and 'green' landscape character.
- physical values associated with estuary foreshore and processes. For example residents and visitors value being able to access and experience the foreshore and associated views.
- biophysical values associated with the protection and improvement of aquatic, inter-tidal and terrestrial environments. These include estuarine habitat, intertidal habitat, mixed rocky intertidal with sand, sandy beaches, sea grass beds, open forests, urban bush lands and reserves, mangrove forests and wetlands.
- cultural values associated with the area's indigenous and non-indigenous heritage and the identification of significant Aboriginal sites. The Aboriginal Heritage Office has recorded 22 Aboriginal sites within the study area.
- accessibility values associated with convenient access to all public areas. For example people value the ability for all people to access foreshores and enjoy the area.
- recreational values associated with an enjoyable environment for all users, visitors and local residents. For example people value being able to undertake various recreational activities in public places, both on land and on the estuary.
- Economic values associated with a number of economic activities.

Data Gaps & Further Studies Required

There exist various data gaps. These are related to sediment budget & movement, water quality, cliff & seawall stability, groundwater abstraction, loss of seagrass, little penguins and climate change issues. DECC will undertake photogrammetry of sandy shorelines (and possibly further hydro surveys) to better understand sediment processes.

ii ABBREVIATIONS

ANZECC	Australian and New Zealand Environment Conservation Council
AHO	Aboriginal Heritage Office
CBD	Central Business District
CSIRO	Australia's Commonwealth Scientific and Industrial Research Organisation
DCP	Development Control Plan
DDT	Dichlorodiphenyltrichloroethane
DEC	NSW Department of Environment and Conservation
DECC	NSW Department of Environment and Climate Change
DIPNR	The former NSW Department of Infrastructure Planning and Natural Resources
DNR	NSW Department of Natural Resources
DPI	NSW Department of Primary Industries
EIS	Environmental Impact Statement
EMA	Emergency Management Authority
EMP	Estuary Management Plan
EMS	Estuary Management Study
EPI	Environmental Planning Instrument (includes LEP, REP and SEPP)
EPS	Estuary Process Study
EPA	NSW Environment Protection Authority (DEC, recently changed to DECC)
ESD	Ecologically Sustainable Development
GIS	Geographic Information System
GSE	Graduate School of Environment, Macquarie University
IPA	Intertidal Protected Area
IPCC	Inter-Governmental Panel for Climate Change
LEP	Local Environmental Plan
LGA	Local Government Area
MSW	Manly Scenic Walkway
MSB	Maritime Services Board
NHT	National Heritage Trust
NRM	Natural Resources Management
NSW	New South Wales
RAN	Royal Australian Navy
REP	Regional Environmental Plan
SAP	Scientific Advisory Panel (of the Manly Council)
SCCG	Sydney Coastal Council Group
SEPP	State Environmental Planning Policy
SREP	Sydney Regional Environmental Plan
SREPP	Sydney Regional Environmental Planning Policy
UWS	University of Western Sydney
WPA	Wetlands Protection Area

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6. PROCESSES & IMPACTS

This section looks at the extent to which human activities have impacted the estuarine processes in the study area.

6.1 WATER QUALITY

6.1.1 Overview of Water Quality

With most parts of the Clontarf/Bantry Bay EMP study area being highly urbanised, there is significant pressure placed on water quality health. It is important to note in this section that, despite the boundaries of management responsibility between the various government agencies, the Middle Harbour catchment is one large interconnected system. Tidal fluctuations and freshwater flows ensure that water is mixed throughout the estuary (see section 3.2 & 3.3), and the pressures placed on the health of the estuary may originate from any part of the greater Sydney Harbour catchment. Conversely though, these flows that mix the water are also extremely effective in flushing the estuary of contaminants after periods of rainfall.

Historically, water quality in Middle Harbour was good prior to European arrival. Since then, unregulated dumping of waste into waterways, sewage overflows, and poor stormwater management practices resulted in a polluted and unhealthy system. In the early years of settlement around the greater Harbour, untreated sewage (containing both human and industrial waste) was discharged directly onto the foreshore, and mangrove-filled bays were used as unregulated land-fill sites (i.e. - dumping of chemicals and other pollutants) so the land could be reclaimed. Industries such as slaughterhouses, tanneries, pig farms and boiling down works were scattered around the foreshore, with parts of the Harbour turning red on occasions from the blood and offal (Birch and Taylor, 2004). Craig Mcgill (2006), a fishing guide who has fished Middle Harbour for over 30 years, believes that the use of tributyltin in anti-foul paints on the many boats moored in Middle Harbour was alone enough to poison the entire system, devastating populations of intertidal shellfish.

However, anecdotal reports suggest that water quality within Middle Harbour has improved dramatically in recent times. Craig Mcgill reports that, following the ban of tributyltin in anti-foul paints, there was an extraordinary re-population of shellfish such as oysters and mussels throughout the Middle Harbour estuary. Craig also reports that numerous programs run by the Sydney Water, such as the deep-water extension of the ocean outfalls, catchment management programs, and the construction of the North side Storage Tunnel, have all resulted in a dramatic improvement in water quality within Middle Harbour (Mcgill, 2006). Much of the heavy foreshore industry around the greater Harbour has also relocated, making way for relatively less polluting residential development (Birch and Taylor, 2004). Many environmental education programs run by local councils and the state government (particularly the former EPA) have also increased awareness about pollution, and have changed many people's behaviour in regard to pollution prevention.

There is limited data available that supports this anecdotal evidence of improvements in water quality. Sydney Water has undertaken population surveys of various intertidal species within Middle Harbour between 1994 and 2005. Two of the sampling sites, Quakers Hat Bay and Sugarloaf Bay, are adjacent to the study area, on the opposite side of the estuary, and are hence expected to exhibit similar water quality characteristics to that of the study area. Due to the simplistic nature in which the Sydney Water surveys were undertaken (visual observations repeated at the same location over time), the results provide an indication only, however, the same methodology was used throughout, so comparisons can be made. Between seven and ten surveys were undertaken on each of the 12 sampling years (see table B7 in the Appendix). All of the results of each year were averaged and graphed chronologically, to see if any trends were evident (see Figures 6.1.1a 6.1.1b). Oysters were used as the indicator species, as they were the most common at the two sites. Both of the sites exhibit a clear trend of an increase in the number of oysters present, supporting the anecdotal evidence of an improvement in water quality in Middle Harbour, and resulting improvement in ecosystem health.

Despite the reported improvements in water quality recently, pollution is indeed still evident, particularly in times of rain when stormwater transports terrestrial pollutants into the estuary. Other point sources of pollution (eg-boats, foreshore industry) also still contribute to the pollution problem. Table 6.1.1 (below) provides a summary

of the common pollutants that are likely to enter Middle Harbour, as well as their likely sources, and impacts on the environment.

Figure 6.1.1a. Oyster populations in Sugarloaf Bay, 1994-2005

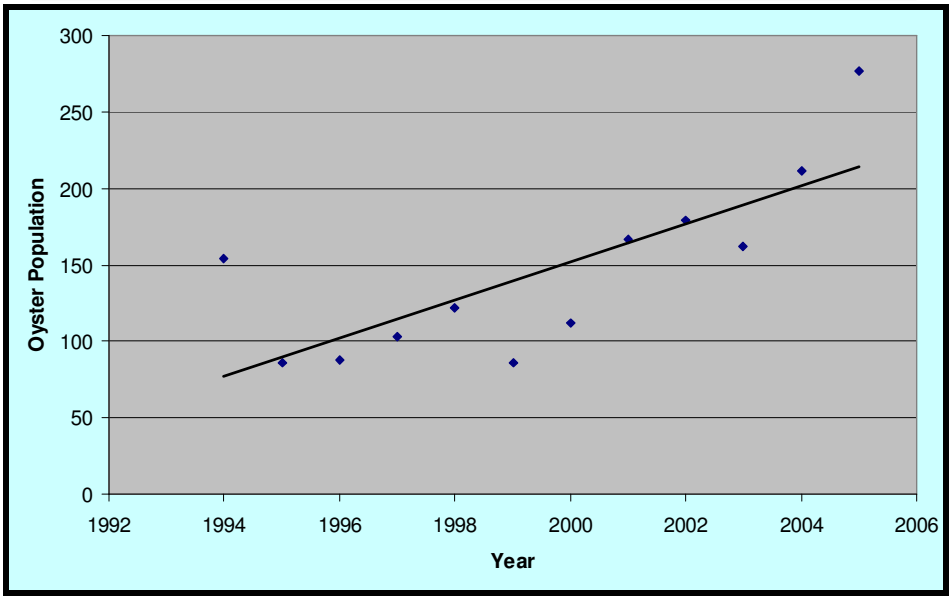


Figure 6.1.1b. Oyster populations in Quakers Hat Bay, 1994-2005

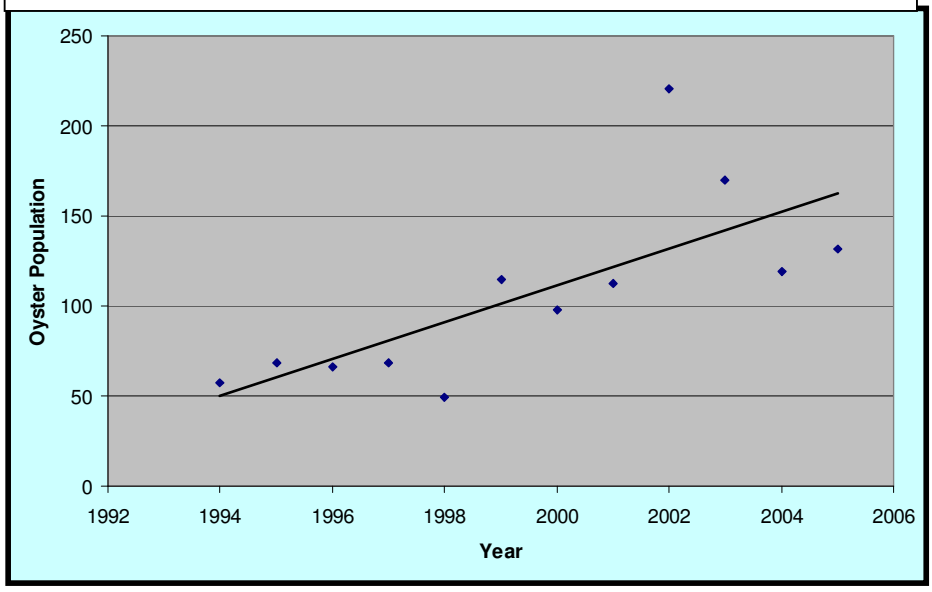


Table 6.1.1 – Pollutants Likely to Enter Middle Harbour

Pollutant Group	Examples	Sources	Impacts
Gross Pollutants	Plastic bags, bottles	Littering, Illegal dumping	Ingestion by marine fauna
Oxygen Demanding Substances	Leaves, twigs	Bushland, roads, residential gardens, stormwater	Reduced dissolved oxygen, marine flora and fauna cannot survive
Oils, greases & hydrocarbons	Car oil, petrol, lubricants	Roads, industrial areas marinas, boats	Marine fauna smothered and/or poisoned
Nutrients	Fertilisers, detergents, sewage	Residential gardens, sports fields, golf courses, sewage leaks/overflows	Algal blooms
Heavy Metals	Lead, copper, zinc	Industrial areas, roads, marinas, boats	Bioaccumulation of heavy metals through the food chain
Pathogens	Faecal coliforms, enterococci	Sewage leaks/overflows, animal faeces	Human infection as a result of pathogens
Sediments	Sand, silt	Construction sites, residential gardens	Smothering of marine flora and fauna; reduced light penetration and ability for marine plants to photosynthesise

Anecdotal evidence is important in helping to understand the history of water quality in a catchment, however a more detailed understanding is necessary to ensure appropriate management actions can be implemented. There are two methods of estimating water quality in a catchment – modelling and monitoring. Both have been undertaken within the study area, and are described below. The modelling described in section 6.1.2 provides information on the pollutant loads produced by the terrestrial catchments within the study area, and the monitoring described in section 6.1.3 provides information on measured water quality within the Middle Harbour estuary itself. However, full report is presented in Appendix C.

6.1.2 Modelled Pollution

Modelling of pollution loads refers to the estimation of pollutant loads from a terrestrial catchment by way of a mathematical equation, incorporating known parameters of the system, and known water quality information in one part of the system or an alternative comparable system. Modelling stormwater pollutant loads generally incorporates the following parameters: volume of stormwater, pollutant concentrations in that stormwater, land use. Volume of stormwater is generally calculated from on-site recorded rainfall, and estimating the percentage that becomes stormwater runoff. Estimating the percentage of rainfall that becomes stormwater is calculated from land-use and hydraulic connectivity (usually measured with the assistance of GIS). Pollutant concentrations in that stormwater are measured on-site by way of water quality sampling and analysis throughout rainfall events at the catchment outlet, or at an alternative comparable system.

Manly Councils Water Cycle Management Team modelled the six catchments within the study area. For this modelling an alternative comparable system had to be used for stormwater pollutant concentration data, due to a lack of data available for the study area. Stormwater pollutant concentrations were attributed from those measured in adjacent catchments in the Manly LGA with similar identified land-uses, for which detailed sampling and analysis has already been undertaken. Extrapolation of these results through the modelling process for the Clontarf / Bantry Bay catchments, along with known rainfall figures, then provided modelled total pollutant loads.

The pollutant loads of total nitrogen (TN), total phosphorus (TP), copper (Cu), lead (Pb), zinc (Zn), and sediment were all estimated. The influence of Manly Councils various current water quality improvement measures were also considered, to provide an estimate of the net pollutant loads that enter Middle Harbour from the study area.

Substantial pollutant loads were estimated from all catchments, with roads and residential land uses contributing the largest load. The water quality improvement measures were estimated to remove significant amounts of pollution; however, high net loads were still estimated to enter Middle Harbour, meaning that further measures are required in the study area. The estimated loads of each pollutant to enter Middle Harbour from the study area were: 2250 kg/year of total nitrogen; 260 kg/year of total phosphorus; 180 kg/year of copper, 230 kg/year of lead, 490 kg/year of zinc, and 128,000 kg/year of sediment.

Table 6.1.2 – Estimated loads of pollutants likely to enter Middle Harbour from six sub catchments of the study area

Catchment Name	Area (sq m)	Pollutant loads (kg/year)					
		Total Nitrogen	Total Phosphorus	Copper	Lead	Zinc	Sediment
Gurney Crescent	319,923	301.46	39.94	21.43	27.73	60.89	16460.12
Bligh Crescent	179,511	206.43	34.78	12.21	15.32	36.77	9569.84
Sangrado Street	428,540	405.23	45.28	31.13	40.76	86.92	23067.18
The Spit	474,719	469.53	47.26	42.51	55.87	112.93	28527.38
Clontarf	610,506	589.68	66.25	48.33	63.23	131.95	34287.20
Castle Rock Reserve	292,324	276.10	27.86	24.13	31.73	64.75	16733.43
Study Area	**2,305,524**	**2248.43**	**261.37**	**179.74**	**234.64**	**494.21**	**128645.00**

Although the above figures are only estimates, they provide a good indication of the scale of pollution entering Middle Harbour from the study area. It is evident that further work needs to be undertaken in the various Clontarf / Bantry Bay catchments to reduce its pollutant contribution to Middle Harbour. Recommended measures on how to reduce pollutant loads, along with further details about the Clontarf / Bantry Bay catchment modelling process, are available in the full report provided by Manly Councils Water Cycle Management Team – see Appendix C.

6.1.3 Measured Pollution

Measured pollution refers to data that has been obtained through taking water samples and analysing them to estimate pollution within a water body. This method of estimating pollutant loads is clearly more accurate than desktop modelling; however, it still has limitations. Firstly, water sampling is undertaken at discreet locations, and these may not be representative of the greater water body within which each sampling location lies. Secondly, the water sampling is only undertaken at a given point in time, and this may not be representative of the average pollutant loads in the given water body.

To date there has been an unco-ordinated approach to managing water quality in the Middle Harbour study area, and as a result, there is only limited water quality data available. The most comprehensive water quality document identified for the study area was the Middle Harbour Catchment Stormwater Management Plan (Willing & Partners, 1999). This document did not use measured water quality data, noting that it was largely not available.

Random grab sampling undertaken for the Spit Bridge Widening Statement of Environment Effects indicated that water quality generally fell within the ANZECC Guidelines recommended for estuarine and marine habitats (GHD, 2003). However, the most comprehensive measured water quality data identified was through the Harbour watch program, run by the Department of Environment and Conservation. The Harbour watch program's key concern is human health relating to the use of harbour waters, and as a result it focuses primarily on bacterial pollution (Department of Environment & Conservation, 2006). Hence, the two major indicators of bacterial contamination, *faecal coliforms* and *enterococci,* are measured at various harbour swimming locations. Faecal coliforms and Enterococci are found naturally in the intestines of humans and therefore also in the sewerage system, so are used to indicate the presence of sewage pollution. Sampling locations within the study area are Gurney Crescent, Sangrado Baths and Clontarf Pool (see Figure 6.1.3a below).

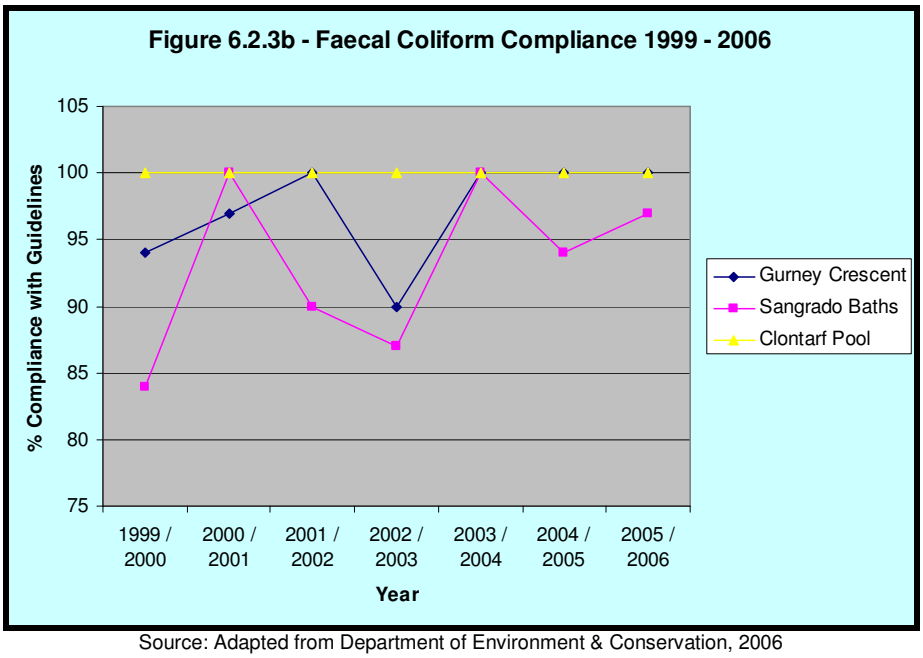
Figure 6.1.3a Harbourwatch sampling Locations within Middle Harbour
Source: DECC 2066

Sampling is undertaken by the DECC at each of the study area sites every six days. A monthly median of the samples from each site is then determined, and monthly reporting indicates if the median was below or above ANZECC guidelines for primary contact (eg- swimming). Figures 6.1.3b and 6.1.3c (below) show the annual level of compliance with ANZECC guidelines for each of the study area sampling sites for *faecal coliforms* and *enterococci* between 1999 and 2006, according to the relevant EPA State of the Beaches Reports.

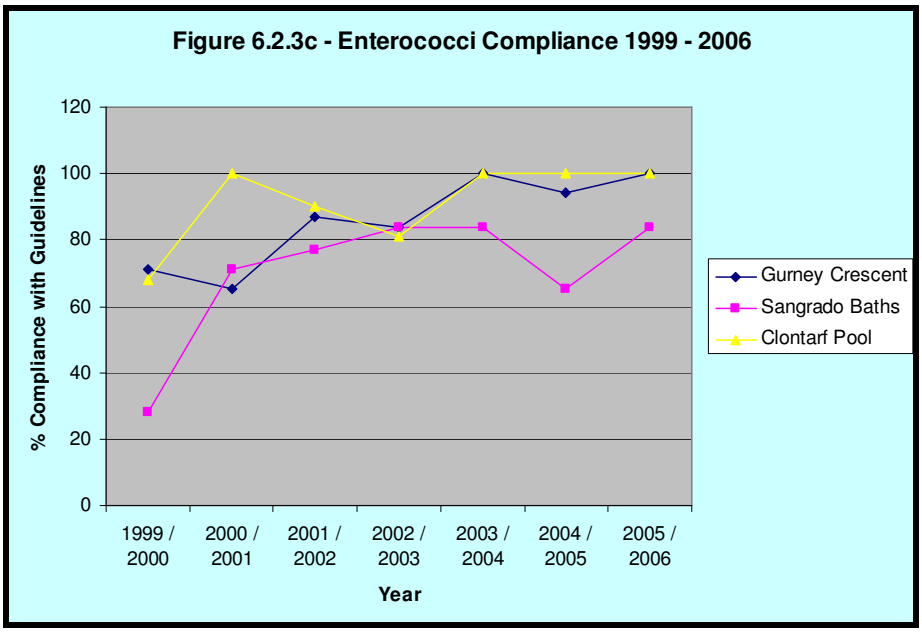
Clontarf pool has the highest level of compliance for both Faecal coliforms and enterococci, most likely due to its proximity to the ocean, and resulting short flushing time (1-5 days, see section 3.2). It showed 100% compliance with the *faecal coliform* guidelines in every year between 1999 and 2006, and 100% compliance with the *enterococci* guidelines on four of the seven years.

Gurney Crescent is next best, with two of the seven years for both *faecal coliform* and *enterococci* showing 100% compliance with guidelines. In 2000/2001, however, it showed less than 70% compliance with *enterococci* guidelines. All other years were relatively good for both indicators, with compliance generally above 80%.

Sangrado Baths is clearly the worst of the three sites, and has a locally renowned history of bacterial contamination. Sangrado Baths lies downstream of Gurney Crescent, and should theoretically be expected to similar or better water quality than Gurney Crescent. The fact that it doesn't may indicate a localised point source of pollution, most likely a sewage leak or overflow. It did have 100% compliance with *faecal coliform* guidelines for two years between 1999 and 2006, but in all of the other years its compliance was lower than the other sites. Compliance with *enterococci* guidelines was much worse, with only three years between 1999 and 2006 above 80% compliance, and one year below 30% compliance.



Source: Adapted from Department of Environment & Conservation, 2006



Source: Adapted from Department of Environment & Conservation, 2006

Although further water quality monitoring data is not available for the study area, there is visual evidence of other types of pollution on occasions. Figure 6.1.3d shows stormwater entering Sandy Bay during a heavy rain event on 12 February, 2007. Visible pollution includes organics, litter and sediment, and likely some dissolved pollutants due to the dark colour of the stormwater. Figure 6.1.3e shows an algal bloom adjacent to Clontarf Marina in 2003. The bloom could have been a result of high nutrient levels due to human activities, but it is also possible that it was a result of natural environmental factors. Figure 6.1.3f shows a sewage leak on the Manly Scenic Walkway, directly above Castle Rock Beach at the south-eastern end of the study area. Figure 6.13g shows a plume of suspended sediment adjacent to Castle Rock Beach, after a burst water main eroded and transported sediment into Middle Harbour from high up in the catchment.

Figure 6.1.3d – Stormwater Pollution at Sandy Bay, 12 February 2007

Figure 6.1.3e - Algal Bloom at Clontarf

Figure 6.1.3f – Sewage Leak on the Manly Scenic Walkway

Figure 6.1.3g – Sediment Plume at Castle Rock Beach, July 2006

6.1.4 Known Designed Sewer Overflow Locations in Clontarf / Bantry Bay Catchments

There are 5 known sewer overflow locations (Figure 6.1.4) within the study area. Detail information of locations is presented in Table 6.1.4.

Figure 6.1.4 Sewage overflow points in the Clontarf / Bantry Bay Catchments

Table 6.1.4: Details of known designed sewage overflow points in the Clontarf / Bantry Bay Catchments

Overflow No.	Catchment	Address	Location	Suburb
SN436OF01	Bligh Crescent	BLIGH CR	IN-ROAD	SEAFORTH
SMSE1OF02	Sangrado Street	SANDGRADO ST	BUSH-NP	SEAFORTH
SMSE1OF01	The Spit	BATTLE BVD	PRIVATE	SEAFORTH
SMCL5OF01	Clontarf	AMIENS RD/HOLMES AVE	IN-ROAD	CLONTARF
SMCL5OF02	Castle Rock Reserve	OGILVY/WEEKES RD		CLONTARF

Source: GIS system, Manly Council

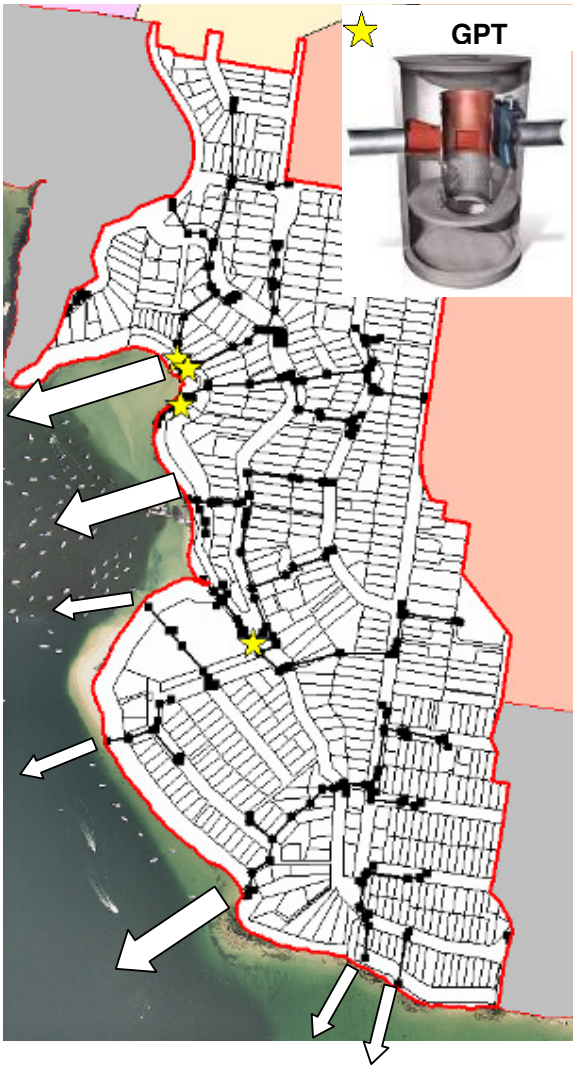
6.1.5 Stormwater Quality Improvement Measures

Manly Council is already implementing the following programmes to reduce pollution loads in the study area. These are:

- Street sweeping
- Installing Gross Pollutant traps and
- Community Education Programs

Street sweeping is currently conducted in the six Clontarf / Bantry Bay Catchments at a frequency of at least once of every twelve weeks, in each catchment. Street sweeping has been shown through scientific research to capture large loads of sediment, gross pollution, and nutrient and metal loads. In the 2005/06 financial year street sweeping in Manly LGA was estimated to prevent 580 tonnes of sediment, and 4.5 tonnes of nutrients from entering Manly waterways. Based on pollutant loads model, it is estimated that street sweeping may have captured up to 303 kg/year of TN, 35 kg/year of TP, 23 – 66 kg/year each of Copper, Lead and Zinc, and 35 tonnes of sediment from the six Clontarf / Bantry Bay Catchments, which is prevented from entering Middle Harbour. Regular sweeping of road surfaces would thus significantly reduce the percentage of loads generated entering stormwater. In addition, beach raking is currently carried out daily on Clontarf beach. This is estimated to provide further capture of gross pollutants not prevented by street sweeping or other pollutant reduction measures.

Figure 6.1.5 GPT locations in Clontarf



Four **Gross Pollutant Traps (GPTs)** are currently installed in the Clontarf / Bantry Bay Catchments. These capture gross pollution and litter, sediment, and a limited percentage of nutrients and metals present in stormwater, improving the quality of catchment-generated stormwater entering Middle Harbour. All four GPTs are located within the popular swimming and recreation catchment, Clontarf (see Figure 6.1.5). GPTs are not present in any other Clontarf / Bantry Bay Catchments. GPTs are all currently maintained (cleaned out) at least once every 8 weeks, and additionally, immediately after heavy rainfall.

GPTs have been shown through scientific research to capture large loads of sediment, gross pollution, and nutrients and metal loads. Based on pollutant loads model from the *Clontarf* Catchment only, and the percentage of that catchment's stormwater flows through the four GPTs, the GPTs are estimated to capture up to 74.2 kg/year of TN, 8.3 kg/year of TP, 6.1 – 16.6 kg/year each of Copper, Lead and Zinc, and up to 10.5 tonnes of sediment, which is prevented from entering Middle Harbour. Litter loads from the Clontarf catchment are suggested to be well controlled by the existing suite of four GPTs.

Education campaigns to target behaviour in individual residences have been conducted in the past in many precincts in Manly Council. In particular the Sea Change education program has targeted residents in the major central business district precincts. This is important because the greatest source of TN and TP in many urban areas, including the Clontarf / Bantry Bay Catchments is estimated to be residential land-uses. Residents in the Clontarf / Bantry Bay Catchments play a crucial role in preventing these pollutants from entering the stormwater system, and achieving real improvements in water quality.

The Bricks and Water stormwater education program for construction sites has taken place throughout the Manly LGA, including the Clontarf / Bantry Bay study area. This program targets sediment and nutrient runoff from construction sites, which have both been determined as significant pollutants within the study area.

As a result of existing programs, some water quality benefits from Manly Council's general stormwater education are considered to have occurred in the Clontarf / Bantry Bay Catchments. This would be believed to represent a maximum 10% improvement / reduction in stormwater pollutant loads for the purposes of modelling in this report. Community education and responsible community behaviour was thus estimated to have prevented generation of 225 kg/year of TN, 26 kg/year of TP, 18 – 49 kg/year of Cu, Pb, and Zn, and up to 12.8 tonnes of sediment in the six Clontarf / Bantry Bay catchments, which is prevented from entering Middle Harbour.

6.2 SEDIMENT CONTAMINATION

Although the water quality in the greater Sydney Harbour has improved in recent years and is now relatively good, the sediments in parts of the Harbour floor are of extreme concern. Sediments are not as easily flushed of contaminants as water quality, and pollutants tend to accumulate in them over time. Certain pollutants can actually bind or attach to fine sediment (mud) particles, making their dispersal and flushing even more difficult. As discussed in section 6.1 (above), decades of unregulated heavy foreshore industry and poor stormwater management practices have resulted in a toxic array of pollutants finding their way into the Harbour. In 2004 Birch & Taylor published a comprehensive book about the contamination of sediments throughout all areas of Sydney Harbour. They concluded that Sydney Harbour's sediments contain mean concentrations of pollutants such as heavy metals, organochlorin compounds, and polycyclic aromatic hydrocarbons that are among the highest in the world.

Luckily, however, the highest concentrations of these contaminants are not found in the study area. The areas of most concern in Sydney Harbour are the upper reaches of embayment and tributaries, especially those upstream of the Harbour Bridge. Although the study area does contain muddy sediments (which have an affinity for attaching pollutants), it is not close to any major tributary or source of contamination, and is relatively well flushed by tides and currents (see section 3.2). Other parts of Middle Harbour (particularly the bays on the western shore) that do contain tributaries and sources of contamination, muddy sediments, and are poorly flushed, contain much higher levels of contamination (Birch & Taylor, 2004).

In the report by Birch & Taylor (2004) the study area is rarely mentioned, due to its relatively low level of sediment contamination. To this end, the entire study area is categorised as a low priority for attention. Maps provided in the book indicate low levels of copper, lead and zinc in mud-sized sediments upstream of the Spit Bridge. Elevated levels of DDT and dieldrin are indicated in whole sediments upstream of the Spit Bridge, although not to anywhere near the extent of the worst-affected areas. Total organic carbon, organic phosphorus and bioavailable phosphorus are elevated in the fine sediments of Middle Harbour, although again, not to anywhere near the extent of the worst affected areas. The elevated levels of bioavailable phosphorus could be responsible for algal blooms that have been recorded in Middle Harbour (see section 6.1.3).

Although the study area has relatively low sediment contamination, the other areas of contamination are still of concern for the study area, for two main reasons – water quality and bioaccumulation.

As discussed in section 6.1.1, water quality within the study area is influenced by the entire Middle Harbour catchment and to some extent the Sydney Harbour catchment. Contaminants within sediments are able to attach and detach from the sediments depending on other surrounding conditions (eg- temperature, pH, dissolved oxygen), meaning that they can become suspended within the water column. With concerning levels of contaminated sediments in bays of the south-western shore of Middle Harbour, it is possible that water quality within the study area will be adversely affected under certain conditions but would be considered minimal because the study area is well flushed. In the absence of comprehensive water quality data for Middle Harbour (see section 6.1.3) and the study area, it is not possible to determine the extent (or otherwise) of this problem.

Bioaccumulation refers to the ingestion of substances by fauna, and subsequent transfer of those substances up the food chain. Invertebrates living within the sediments, such as yabbies and worms, play an important function in turning and cleaning the sediments, known as bioturbidation. When elevated levels of toxins are found within the sediments, these are ingested by the invertebrates, and then passed up the food chain as they are consumed by predatory fish, and those fish are in turn consumed by larger fish. Birch and Taylor (2004) suggest that toxic chemicals are enriched in fish species within Sydney Harbour due to the contamination of sediments. As fishes move throughout the greater Harbour, this means that affected fish will be found within the study area. In 2006, probably as a result of the release of the findings by Birch & Taylor, testing was undertaken on some common fish species in Sydney Harbour by the Department of Primary Industries (DPI) to determine if toxins were present. They were, and DPI placed a ban on all commercial fishing within Sydney Harbour, stating the presence of elevated levels of dioxins in fish and crustaceans in the Harbour as the reason. Recreational fishing is still permitted, although dietary advice has been issued, stating that limits should be placed on the amount of Harbour caught fish that are consumed. The advice also states that fish caught west of the Harbour Bridge should not be consumed at all (DPI, 2007). The worst affected fish species were generally found where Birch and Taylor (2004) measured the highest levels of sediment contamination. Table 6.2 provides a summary of the dietary advice provided by DPI, regarding the consumption of Harbour caught fish.

Table 6.2: Recommended maximum intake based on eating a single species caught east of the Sydney Harbour Bridge

Species	Number of 150 gram serves	Amounts per month
Prawns	4 per month	600 g
Crab	5 per month	750 g
Bream	1 per month	150 g
Flounder	12 per month	1800 g
Kingfish	12 per month	1800 g
Luderick	12 per month	1800 g
Sand Whiting	8 per month	1200 g
Sea Mullet	1 every 3 months	50 g
Silver Biddie	1 per month	150 g
Silver Trevally	5 per month	750 g
Tailor	1 per month	150 g
Trumpeter Whiting	12 per month	1800 g
Yellowtail Scad	8 per month	1200 g
Squid	4 per month	600 g

Source: NSW Department of Primary Industries, 2007

6.3 BOAT GENERATED WAVES

Limited information is available on boat generated waves specific to the study area. However, the study area is used extensively by a variety of vessels, particularly between Castle Rock Beach and Seaforth Bluff. This section of the waterway is the only access between greater Sydney Harbour and upper Middle Harbour, so all vessels wishing to travel between the two must pass through. Table 6.3 details the wave heights that are produced by various vessels.

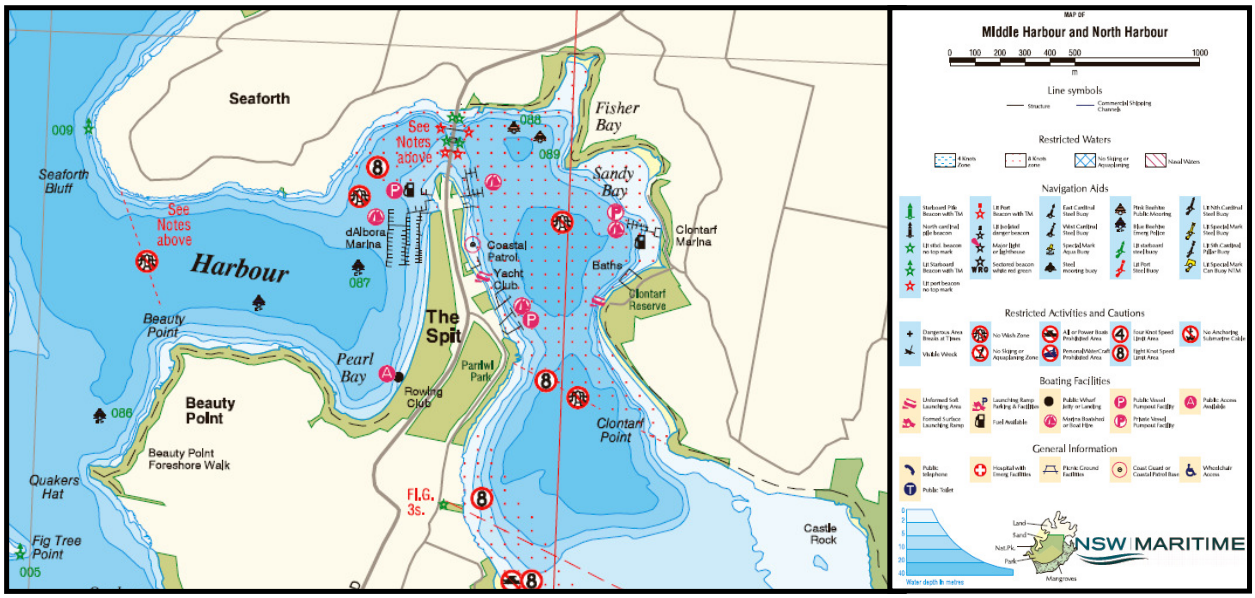
Table 6.3 – Measured Boat Wake Waves for Various Vessel Types

Vessel Type	Maximum Wave Height (m)	Wave Period (sec)
Sydney Ferries (excluding catamaran type)	0.4	2.2
Rivercat	0.3	7.0
Water Taxis	0.5	2.2
15m Motor Cruiser	0.8	3.6
Power Boat	0.4	2.0

Source: (Patterson, Britton & Partners, 2004)

All of the above types of vessels can regularly be observed using the waters of the study area. To manage this large amount of boat traffic, there are two zones of boating restrictions in place (see Figure 6.3a) that in theory should minimise the effects of boat generated waves for certain parts of the study area.

Figure 6.3a – Boating Restrictions within the Study Area



Source: NSW Maritime, 2006

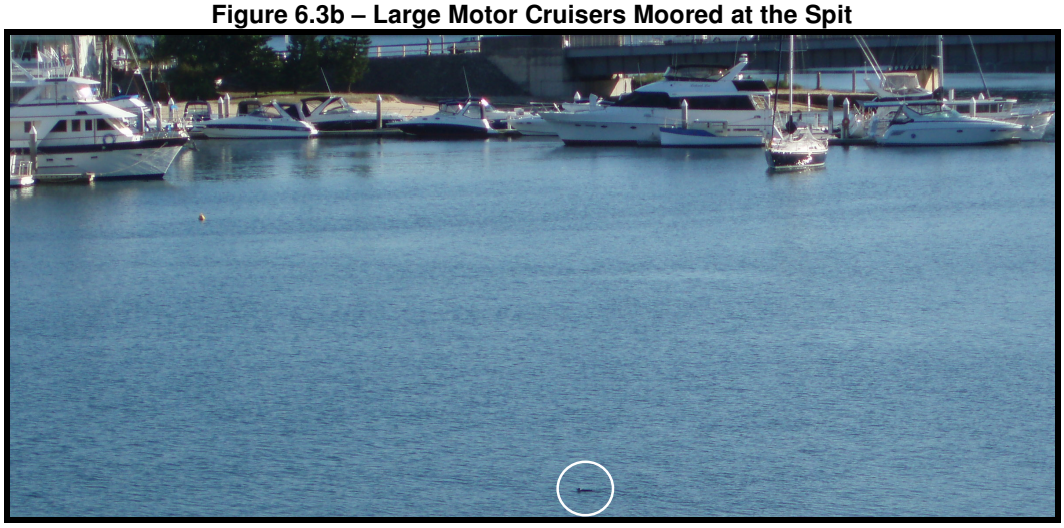
A No Wash Zone is in place between Clontarf Point and Seaforth Bluff. No Wash Zones are designated "where the wash from a vessel is likely to cause damage to the foreshore or vessels, or injury or annoyance to people" (NSW Maritime, 2007). Vessels are required to "travel at a speed which creates minimal wash" (NSW Maritime, 2007). Hence, boat generated waves in this zone should be minimal, with the exception of boats that do not adhere to the restrictions.

An 8 knot speed limit zone is also in place, between Clontarf Point and d'Albora Marina (Mosman side of Spit Bridge). Speed limit zones are designated purely for safety reasons. Safety is a concern in this area because of the large amount of traffic using the waterway (personal communication with Nick Richards of NSW Maritime, 2006). All boats travelling between upper and lower Middle Harbour must pass through this zone, and there are also numerous marina berths and moorings on each side of the channel, along with several other recreational activities that use the waterway. However, the No Wash Zone extends beyond the 8 knot speed limit zone, which means that the speed limit zone will in effect have no impact on boat generated waves in this zone.

No boating restrictions apply for any other parts of the study area, apart from the generic regulations that apply in all waterways. It would hence be subject to boat generated waves of up to, and possibly greater than, 0.8m (see Table 6.3 above). The upper half of the study area beyond Seaforth Bluff (and the boating restrictions) is used extensively by all types of vessels, and is regularly used by boats towing people (water-skiing, wake-

boarding etc). For wake-boarding in particular, there is a desire by participants to have the largest wake possible, enhancing the potential for significant boat generated waves. It has also been noted through community consultation for the Clontarf / Bantry Bay Estuary Management Plan that there has been a general trend towards ownership of increasingly larger motor cruisers in all of Sydney's waterways, which effectively means that larger boat generated waves will be experienced as a result.

Figure 6.3b – Large Motor Cruisers Moored at the Spit



(Note the Little Penguin circled above!)

6.4 EROSION PROCESSES

Erosion is displacement of solids (soil, mud, rock and other particles) by the agents of ocean currents, wind or water by downward or down-slope movement. Erosion is an intrinsic natural process but in many places it is increased by human land use. A certain amount of erosion is natural and, in fact, healthy for the ecosystem. Excessive erosion, however, does cause problems, such as receiving water sedimentation, ecosystem damage and outright loss of soil. In the study area, different types of erosion occur.

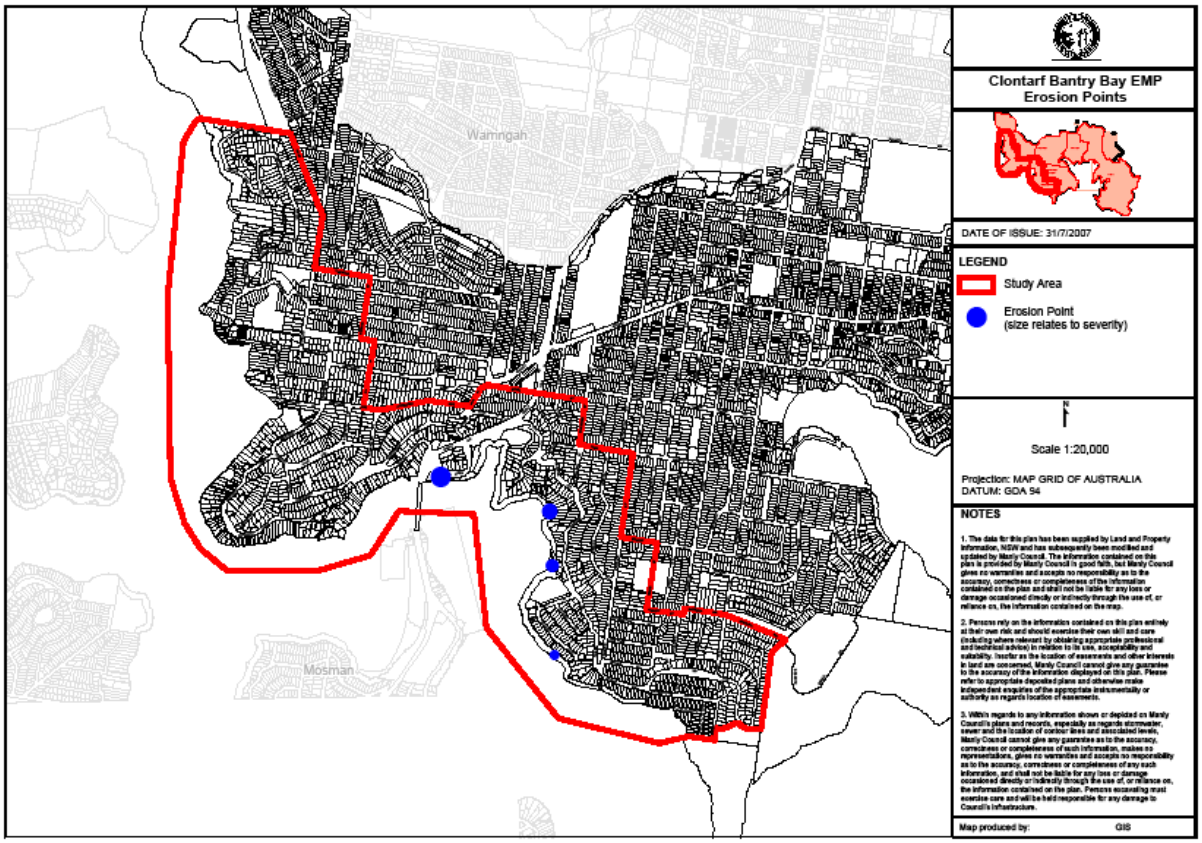
6.4.1 Beach Erosion & Accretion

Sediment processes have been an issue for the Clontarf and Sandy Bay section of the study area since soon after it was developed by Europeans. Foreshore development and recreational activities appear to have interfered with the natural sediment processes of the area, but as described in section 3.7.1 (above), only preliminary conclusions can be drawn from the limited information currently available.

Beach erosion has been experienced in sections of Clontarf Beach and Sandy Bay with varying degrees of severity (Figure 6.4.1a), and fluctuations over time. Outcomes of beach erosion have included the undermining of seawalls and foreshore garden beds, and exposure of buried rocks. It is likely that this erosion is due to the unnatural vertical structures that have been placed where a source of sand would have previously been located and the reflection of wave energy that these structures cause.

Natural beach systems are not static, and beach erosion and accretion occurs constantly over time. Much of the flat areas adjacent to the Clontarf / Sandy Bay foreshore exhibit a sandy substrate, and prior to development of the foreshore, swell waves would have eroded this sand during storms. Swell waves normally approach the beach in a longshore direction, and eroded material is probably dispersed in the deeper water upstream of the tidal delta (see section 3.7.1). It is likely that the tidal delta then becomes the source of sand for beach accretion in calmer wave conditions (GSE, 1990). The vertical structures are built where the natural erosion would have taken place, so in times of higher than normal wave activity, erosion simply begins to undermine the structures

Figure 6.4.1a – Erosion Points within the Study Area



as wave energy is reflected. It is clear that accretion is indeed also taking place, as the photos taken in July and January 2007 show noticeably more sand covering the rocks than the photo taken in December 2006 (see Figures 6.4.1b & 6.4.1c & 6.4.1d).

Not only do the vertical structures built parallel to the beach (eg- the seawalls and garden beds at Clontarf Beach & Sandy Bay) limit the supply of sand to a beach during periods of erosion, they can also actually exacerbate the erosion processes. On a natural beach profile, wave energy in normal (i.e.- calm) conditions is dissipated gradually as it runs up a sloping beach, and is also absorbed as water percolates through the sediment. When waves are instead abruptly stopped by a vertical structure, all of the wave energy is focused in one spot at the base of the wall, resulting in the erosion of sediment (Piorewicz, 2007). At high tide along Clontarf Beach and Sandy Bay, the water level is high enough for this process to occur, as indicated in Figure 6.4.1b.

The combination of the vertical structures blocking the natural sand supply of the Clontarf / Sandy Bay flats for times of erosion, and the erosion potential being exacerbated by the presence of the vertical structures, means that erosion is almost certain in this section of the study area. Stormwater erosion can also add to the erosion potential of a given beach (see section 6.4.2 below). It is perhaps only due to the ongoing supply of sand from the tidal delta (i.e. - an external source) that the beach continues to exist. The use of the sand boat ramp at Clontarf Beach, and the daily sand raking undertaken by Manly Council may also influence sediment processes in the area, although the influence is expected to be almost negligible in contrast to the above processes and the ongoing supply of sand from the tidal delta.

Figure 6.4.1b
Beach Erosion at Clontarf Beach, 5/12/2006

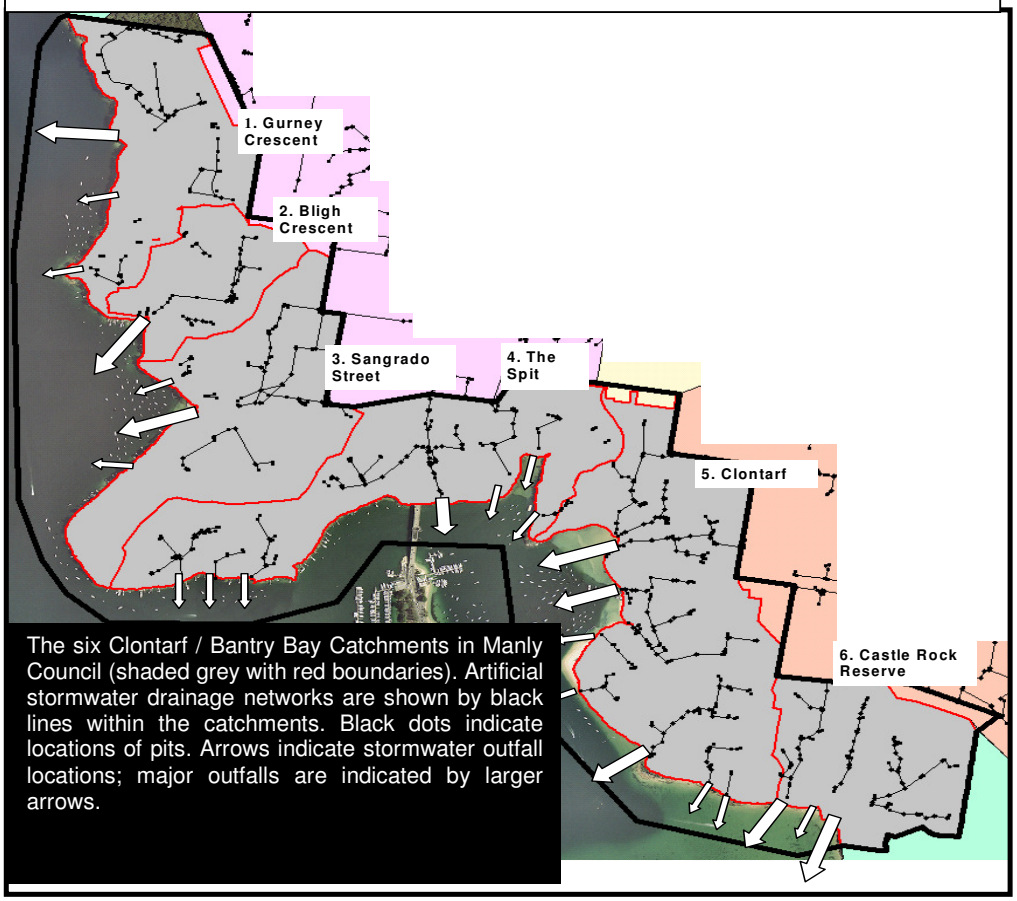
Figure 6.4.1c
Beach Siltation at Clontarf Beach 3/1/2007

Figure 6.4.1d
Beach Siltation at Clontarf Beach 24/7/2007

6.4.2 Stormwater Erosion

Stormwater erosion is a natural process that occurs as a result of rainwater flowing to the lowest point in a catchment and eroding material as it flows. In a natural system, rainwater is dispersed throughout the catchment wherever it falls, and significant erosion is usually limited to large rain events. For the purposes of this section, however, stormwater erosion refers to the accelerated erosion that occurs as a result of the concentration of stormwater flows through artificial drainage networks. The hard artificial surfaces that stormwater travels over and through in urban environments greatly increases its velocity. These high velocity concentrated flows are then directed and released into bushland, watercourses or the foreshore. Often the end of the pipe is surrounded by soft surface material such as soil or sand, which is easily eroded by the large volumes of high velocity rainwater during a storm.

Figure 6.4.2a – Likely stormwater erosion points in the Clontarf / Bantry Bay Catchments



The six Clontarf / Bantry Bay Catchments in Manly Council (shaded grey with red boundaries). Artificial stormwater drainage networks are shown by black lines within the catchments. Black dots indicate locations of pits. Arrows indicate stormwater outfall locations; major outfalls are indicated by larger arrows.

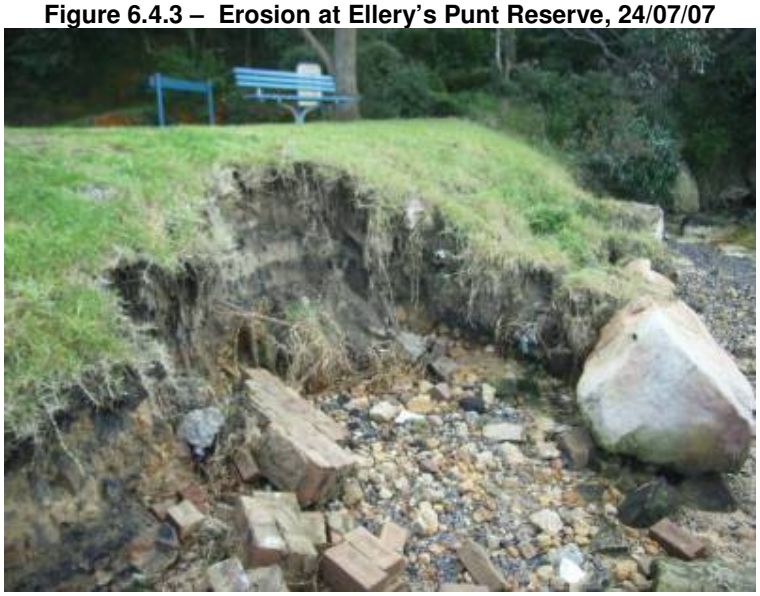
In the study area, the relatively narrow and steep catchment means that nearly all of the major stormwater pipes extend right to Middle Harbour, and discharge either onto the foreshore or directly into the water (see Figure 6.4.2a). The pipes that discharge directly into the water or onto the foreshore, generally pose erosion problems. Some of the pipes direct flows over rock, which provides a stable surface that is not easily eroded, but many of the pipes direct flows over the sandy beaches, which can result in erosion. Figure 6.4.2b shows a stormwater pipe at the rear of the beach in Sandy Bay during a storm in February 2007, with significant erosion resulting from the flows. Large volumes of sand have been removed from the beach, and the base of the seawall has also been exposed, potentially compromising the integrity of the seawall. This can further exacerbate other erosion processes such as those mentioned in section 6.4.1 (above).

Figure 6.4.2b – Stormwater Erosion at Sandy Bay, 12/02/07

6.4.3 Other Erosion

There is also erosion occurring that isn't beach or stormwater erosion. For example, where seawalls are collapsing and foreshores are degraded and undergoing erosion. This is evident in the foreshore directly east of Spit Bridge adjacent to Avona Crescent where there is seawall collapse and foreshore erosion.

Figure 6.4.3 – Erosion at Ellery's Punt Reserve, 24/07/07



Erosion is also a problem in terrestrial areas, where small stormwater pipes from individual residential properties direct stormwater into bushland. Similar to the situation on beaches, the concentrated high velocity flows easily erode the topsoil. This process can take out of nutrient-rich topsoil, expose the roots of vegetation, and smother down slope areas with soil or discharge sediment into the estuary.

6.5 SLOPE & CLIFF INSTABILITY

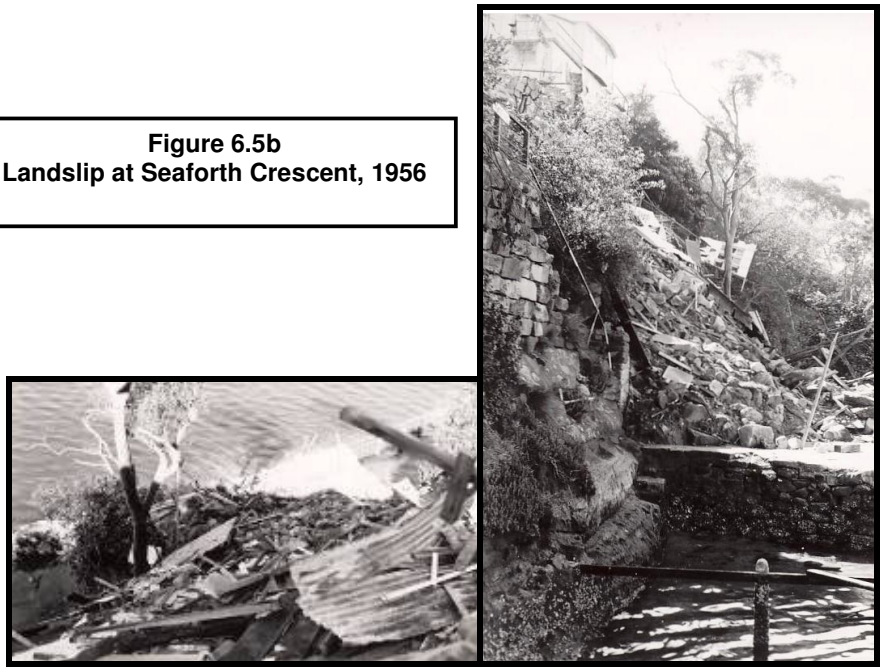
In coastal environments, where the processes of wind, waves, storms and erosion are evident, there is a constant risk that slopes and cliffs may become unstable. The consequences of landslips and rock falls can be

extreme, with risks to both property and life. Although the rocky foreshores in the study area have been described as relatively stable in relation to shorter term estuary processes (section 3.7.1), long term processes such as rock erosion can make slopes and cliffs unstable, to the point of collapse. Further, erosion and waterlogging from terrestrial processes (eg- stormwater flows) can also undermine slopes to the point of collapse.

No formal studies of the potential risks within the study area have been undertaken, although visual observations suggest that there may be risks evident. Figure 6.5a shows a large rock overhang at Clontarf with apparent erosion at its connection with the cliff face, and a regularly used walkway underneath the overhang. Further, history shows that the study area is susceptible to slope and cliff instability, with a large landslip having occurred at Seaforth Crescent in 1956 (Figure 6.5b).

Figure 6.5a – Potentially Unstable Rock face at Clontarf

Figure 6.5b
Landslip at Seaforth Crescent, 1956



Source: Manly Council Library (Local Studies)

As no formal studies have been undertaken, it is not possible to determine the level of risk that is posed by the cliffs and slopes within the study area.

6.6 ECOLOGICAL IMPACTS

6.6.1 Marine

As noted in section 4.1 the marine environment within the study area has a diverse range of habitats, many of which are in relatively reasonable condition. However, there are still many human activities that adversely impact on its health.

Fishing is possibly the most common recreational activity undertaken within the study area. Fisher people are required to obtain a licence from DPI, with revenue rose being used to improve recreational fishing. Various bag and size limits also apply to recreational fisher people for most common fish species. DPI (Fisheries) scientists undertake research into the various species and determine the appropriate bag and size limits to ensure the sustainability of populations. However, not everyone adheres to these regulations, and DPI field officers are required to undertake patrols to enforce the bag and size limits. The impact of the occasional breach of regulations is not likely to be significant, but continued breaches within one locality (i.e. - the study area) could potentially threaten local fish stocks.

Recreational fishing is still permitted despite a ban on all commercial fishing within Sydney Harbour, although dietary advice has been issued, stating that limits should be placed on the amount of Harbour caught fish that are consumed (see Table 5.5). The advice also states that fish caught west of the Harbour Bridge should not be consumed at all (DPI, 2007).

Littering and gross pollutants form stormwater can impact on aquatic life directly e.g. choking on plastic bags, and indirectly through lowering of water quality e.g. garden wastes in stormwater (more details in section 5.4).

Boating is also an extremely popular recreational activity within the study area, but unfortunately it can have detrimental impacts on the marine environment. Anchors, moorings, propellers and hulls can all damage the seafloor and associated seagrass. Also, boating can contribute to water pollution which also degrades the marine environment.

Boat users can potentially impact on many other areas and users of an estuary besides just creating waves. For example, boat generated waves over time can weaken sea walls leading to their collapse; they cause foreshore erosion and can impact on habitat. Boating can impact on water quality via spills, anti-foul paints, littering from boats and from marinas where boats are washed and fixed etc. Boating can impact on swimmers and kayakers in terms of safety e.g. around Clontarf Reserve and their moorings and anchoring impact on seagrasses and amenity.

Moorings are fixed in place with a heavy anchor weight with a chain, rope and buoy attached. The chain drags along the bottom with the current in a circular motion around the anchor, and has the effect of scouring the sea floor. If the mooring is located in a seagrass bed, the scouring will damage or destroy the seagrass within the limit of the chain. There are currently over 200 permanent moorings within the study area. Seagrass friendly moorings are currently being trialled by NSW Maritime, although none are located within the study area (personal communication with Nick Richards of NSW Maritime, 2006).

Anchored boats can have a similar impact on seagrass to that of moorings, with a comparable setup of anchor and chain. They differ in that anchors are not permanent, and can therefore damage a larger area over time, as anchors can be placed over a different patch of the same seagrass bed every time a boat stops. Further, anchors work by embedding themselves in the seabed, and when they are raised they can completely remove seagrass by the roots. Due to this high risk of damaging seagrass, the Fisheries Management Act, 1994 prohibits all anchoring within seagrass beds (DPI, 2007). Castle Rock Beach is one of the most popular day trip location for boats within all of Sydney Harbour (personal communication with Nick Richards of NSW Maritime, 2006), but it is also one of the largest seagrass beds within the study area (see section 4.1.1). This places

significant pressure on the seagrass bed, and likely means that some boat users are contravening the *Fisheries Management Act, 1994*. Options for protection of seagrasses need to be investigated.

Anecdotal evidence, received through the community consultation undertaken for the Clontarf / Bantry Bay Estuary Management Plan, suggests that Clontarf and Castle Rock have experienced large losses in seagrass. These two areas represent the largest stands of seagrass within the study area, so any loss is of extreme concern. West et al (2004) confirms this and states that large losses of seagrass have occurred inside Middle Harbour adjacent to Grotto Point (the tidal delta) and also at Clontarf. A 1981 Seagrass Map of Port Jackson produced for the Catchment Management Authority of the time provides further evidence, and indicates a significant stand of seagrass in Sandy Bay, much larger than that indicated by DPI in the current seagrass map (see Figure 4.1.1b). Further research needs to be undertaken to determine the reason for this loss, and how it can be rectified (see section 7.2).

Humans have also been responsible for introducing a number of exotic species into the marine environment. These exotic species have been introduced in a number of ways, and have had varying impacts on the marine environment.

Probably the most serious of all the introduced species is *Caulerpa taxifolia*. This marine plant is naturally found in tropical and sub-tropical waters (including in Australia) and is also used as a decorative aquarium plant. Through its use as an aquarium plant a cold-tolerant strain was developed, and this was accidentally released into the wild. This unnatural cold-tolerant strain was first recorded in the Mediterranean and California, where it has taken over thousands of hectares of the seafloor and displaced the native seagrasses. It was first recorded in NSW waters in 2000, and has now been recorded in 10 waterways, including Sydney Harbour and the study area (DPI, 2006).

Caulerpa taxifolia is an extremely fast growing and hardy plant, and can tolerate low temperatures, survive for up to 10 days out of the water, colonise on almost any substrate (eg- rock, sand, mud) and recolonise from fragments as small as 1mm. These attributes make it a great concern for the marine environment. *Caulerpa* has been recorded within the study area at Clontarf, and also at other areas in Middle harbour in close proximity to the study area (see Figure 6.6.1). *Caulerpa* populations are known to fluctuate between seasons, and this has certainly been the case at Clontarf, with the population expanding, contracting, and moving location between seasons (DPI, 2006). In regards to *Caulerpa taxifolia*, the community consultation identified a lack of knowledge about this weed species suggesting that education of boat users is crucial.

NSW Department of Primary Industries have been undertaking extensive research into *Caulerpa taxifolia*, to determine the most effective ways of controlling it, and also limiting its spread to other waterways. Various methods of control have been trialled, including:

- Salt Treatment – smothering outbreaks with thick layers of salt to poison the plant
- Matting – covering outbreaks with matting to remove its ability to photosynthesise
- Hand picking – divers remove outbreaks by hand

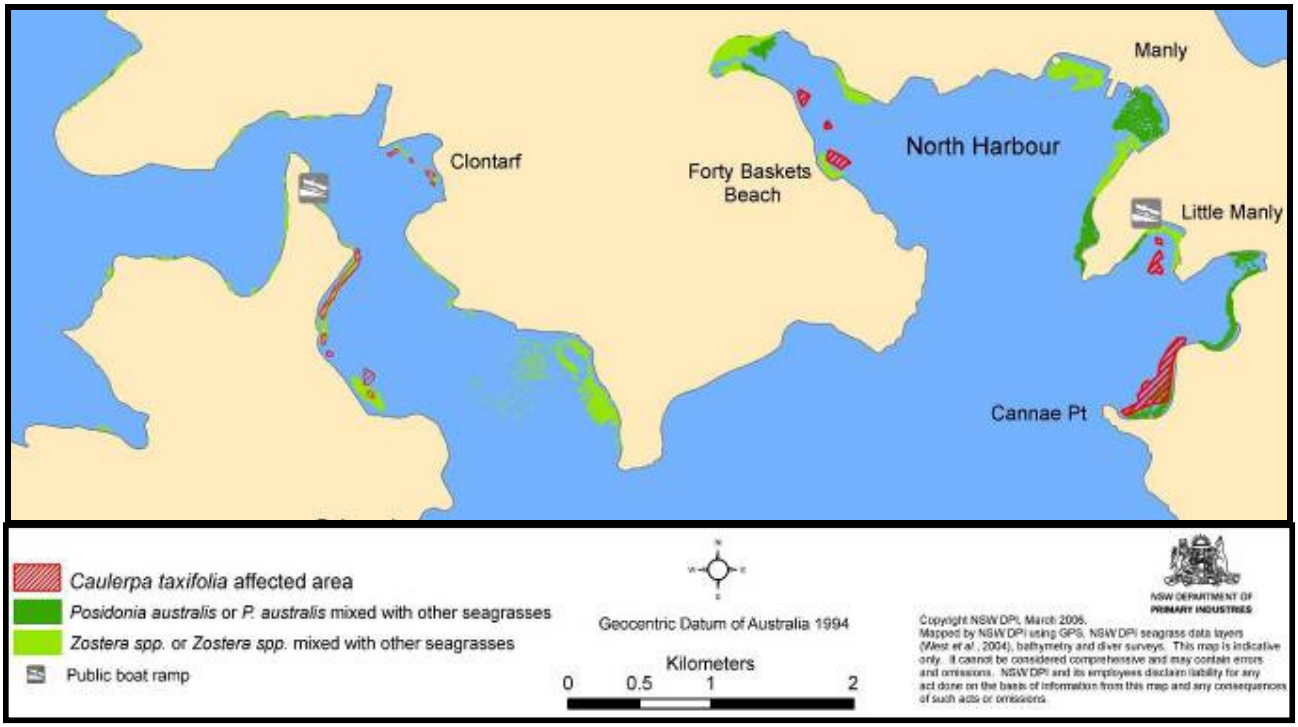
The various methods have had limited success, although none have proven to be completely effective in all situations, and *Caulerpa* continues to pose a serious threat to the marine environment within the study area (DPI, 2006).

Various other exotic species have been introduced into the marine environment, mostly as a result of ballast water in large ships. Ballast water is taken on by these ships while they are in foreign ports to stabilise them during passage. Some of this ballast can then be discharged when they reach their destination, to reach a suitable weight when the return load of cargo is on board. If there are any foreign species within this discharged ballast water, they can be easily discharged into the Harbour.

Australian Museum Business Services (2002) undertook a study into exotic marine species in Sydney Harbour. The aim of this study is to collect baseline data on the occurrence of exotic species in the port of Sydney Harbour utilising the protocol established by AAPMA and CRIMP (Hewitt and Martin, 1996). This adopts a targeted approach with introduced species ranked in three categories.

- Schedule 1 - ABWMAC (Australian Ballast Water Management Advisory Council) target introduced pests.
- Schedule 2 – marine pest species that pose a threat to Australia.
- Schedule 3 – known or likely exotic marine species in Australian waters

Figure 6.6.1 – Known Distribution of Caulerpa taxifolia at Clontarf, March 2006



Source: Department of Primary Industries, 2006

The study recorded a total of 30 species (see Appendix B5).Two species were recorded from the 'Schedule 1 and one species from the 'Schedule 2' list. Little information was available on these pest species, although the report suggested that they were not of great concern. The remaining 27 species were all recorded on the 'Schedule 3' list and were said to be well established within Sydney Harbour, but it was unclear whether they have displaced any endemic species. It is assumed that if these species are present within greater Sydney Harbour, they are likely to be present within the study area.

6.6.2 Intertidal Area

Urban development has probably had the greatest impact on the intertidal environment within the study area. Losses of habitat from seawall and foreshore modification such as marinas etc have a big impact on intertidal ecology in the study area. In the past, before their ecological importance was fully understood, mangrove forests were considered unsightly and smelly, and were removed to make way for foreshore development including landfill. With a much better understanding of their vital role in intertidal ecosystems, they are now protected under the Fisheries Management Act, 1994 (Lynch & Burchmore, 2006). It is likely that mangroves were much more extensive within the study area before it was developed, and it is therefore important that not only the remaining population is preserved but also options for any possible expansion investigated.

As noted in section 4.2.1 (above), no salt marsh populations have been found in the study area. Salt marsh is usually found on the landward side of mangroves, so it is likely that populations would have existed within the study area before extensive catchment development took place (Burns & Davey, 2007). The loss of mangroves and potential loss of salt marsh not only means a loss of habitat and source of food, it also means that an important buffer between the terrestrial and marine environment is lost.

As mentioned in section 5.2.1, water pollution has historically had detrimental effects on invertebrates on rocky shores within the study area. As water pollution is still evident within Middle Harbour, it is possible that invertebrate populations are still being affected. However, the limited data available suggests that populations of invertebrates in the intertidal zone may be increasing, regardless of pollution still being evident.

Harvesting species within the intertidal zone may also have impacted on its ecology, although data is not available to confirm this. As noted in section 4.2.1 the entire foreshore of the study area is an Intertidal Protected Area (IPA), and harvesting is not permitted, but the author (Scott Machar, Estuary Management Officer, Manly Council) has observed people collecting yabbies by use of a pump in Sandy Bay. It is not known whether other harvesting (eg- oysters from the rocks) is taking place, although it is certainly possible considering people have been observed collecting yabbies in contradiction to the IPA. This suggests education and enforcement may need to be increased.

The raking of Clontarf Beach and Sandy Bay may also be detrimental to the ecology of the intertidal area, although it is a necessary health and safety procedure (eg- removal of sharps). As mentioned in section 4.2.1, marine debris such as seagrass wrack (not rubbish) washed up on the shore provides an important source of food for a diverse range of invertebrate species, which are an important part of the intertidal food chain. Raking of the beach removes this food source.

6.6.3 Terrestrial

Urban development has been the single largest threat to the terrestrial environment within the study area. Development such as the construction of houses, roads, utilities and recreational facilities removes natural habitat in the footprint of each development.

The loss of natural habitat within the study area since European arrival has been extreme, with the majority of the study area now developed at the cost of the native habitat such as vegetation, rock shelters, mulch, soil and creek lines (see section 5.3.1). Further, some existing properties within the study area are encroaching into the remaining habitat through the extension of lawns and outdoor living areas. The loss of habitat has greatly reduced the carrying capacity of the study area for native wildlife, and natural ecological processes and biodiversity have been threatened (Skelton et al 2004). The fragmentation of natural bush land areas in Manly has reduced the viability of habitat in many bush land reserves to support populations of native fauna.

Some of the impacts and causes of degradation in urban bush land are:

- increased levels of high nutrient stormwater runoff entering bushland, creating ideal conditions for weed growth
- dumped garden refuse and rubbish.
- altered fire regimes - some native plants rely on fire for regeneration
- urban encroachment on reserves
- the impact of domestic pets on flora and fauna
- poisoning trees for views

Impact of high nutrient storm water on Manly Bush land Reserves has been specifically investigated (Skelton et al. 2002). Fifty outlets in 16 reserves, 22 in the study area, were investigated. High nutrient loads were found to occur at 14 of 22 sites located all over the study area (Table 6.6.3). The source of nutrients was not investigated but possible cause included sewage leaks, incorrect use of lawn and garden fertilizer, disposal of dog faeces down the drain etc. (Skelton et al. 2000).

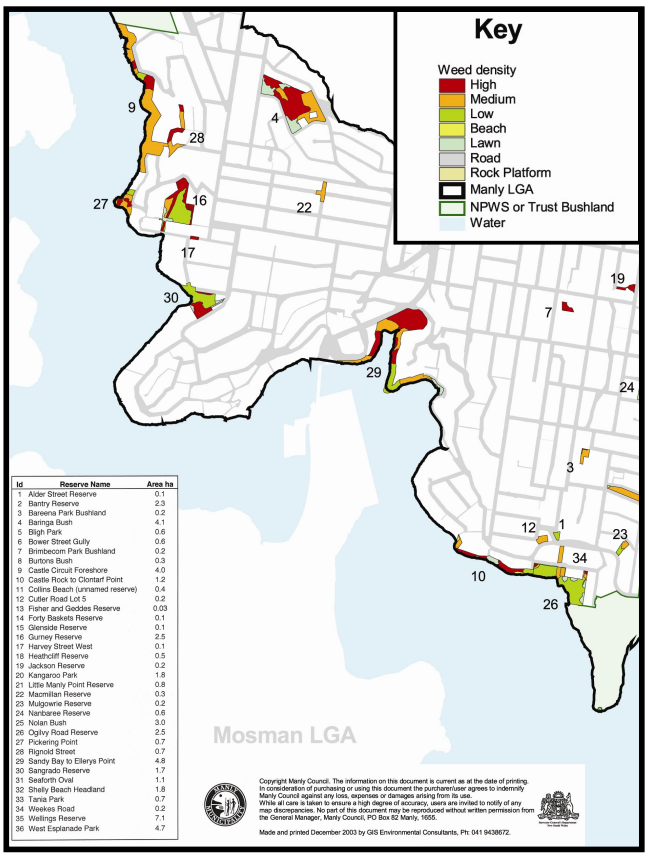
Table 6.6.3: Impact of high nutrient storm water on bush lands at 14 outlets

Reserve	Outlet Reference No.	Outlet Catchment size	litter	Nutrients in Water	Weed Cover	Weed Ecological Severity Score	Deposition Below Outlet	Weeds 5m radius	Severity of Impact on Bushlands
		1=small, 10=large	1=absence, 10=presence	1=low 10=very high	1=no weeds, 10=complete cover	1=no problem weeds 40=many ecologically damaging weeds	1=none, 4=heavily silted	1=degraded bushlands' 5=good bushlands	High value looks bad
Weeks Road	29	8	10	10	10	37	2	1	3.8
Sangrado Park	33	8	10	7	10	25	3	1	3.9
Gurney Reserve	34	4	10	7	10	23	2	1	3.5
	35	2	10	7	10	31	2	1	2.8
	37	2	10	7	10	21	2	1	2.8
Fisher Bay, Spit Rd.	44	8	10	3	10	27	1	1	3.7
	45	2	10	7	10	21	4	1	3.1
	46	4	10	7	10	25	1	1	2.8
Castle Circuit Foreshore	38	4	10	7	10	6	1	1	3.4
	42	8	1	10	4	16	2	3	2.2
	41	2	1	7	10	31	2	1	2.2
	40	2	1	7	10	10	2	1	2.2
	36	4	10	3	7	19	1	2	2.9
Rignold St.	47	8	10	7	10	16	2	1	3.2

Source: Skelton et. al. 2002

There are also many secondary impacts as a result of the development within the study area. The invasion of exotic species is the most notable of these impacts. As indicated in Appendix B, there were 426 species of flora recorded within the study area, and 153 (approximately 36%) of them are exotic. These species have reached bushland areas through escaping from gardens, illegal dumping of garden refuses, dispersion by fauna (eg- birds eating seeds) and illegal plantings. The spread of exotic fauna has also been exacerbated by nutrient pollution from stormwater and sewage overflows (see section 5.2), and the dumping of garden soil. Figure 6.6.3a (below) indicates the density of weeds in each of the Council reserves in the study area. The largest area of high density weeds is in Fisher Bay (part of the Sandy Bay to Ellerys Punt reserve), with scattered high density areas also to the north and south. Of concern is the fact that there is only one reserve in the study area that has been rated entirely as having low weed density – the extremely small 0.1 hectare Alder Street Reserve (Skelton et al, 2004).

Figure 6.6.3a – Weed Densities within the Study Area Reserves



Source: Skelton et al, 2004

Fire is a natural part of the environment, and many species are dependent on regularly spaced fires. Inappropriate fire frequency has also impacted on the terrestrial environment within the study area. Fire is important in many aspects of ecosystem functioning, such as seed germination, nutrient cycling and control of species diversity. Residential development around the bushland reserves means that fires are suppressed, rather than allowed to occur naturally. Back burning takes place in some reserves to reduce the fuel load and reduce the bushfire potential, although this rarely mimics the frequency and intensity of natural fires (Skelton et al, 2004).

Die back is also an issue in parts of the study area. Die back has been recorded across Australia in native vegetation, and can for a number of reasons, such as changes in drainage, insect attack, poisoning and plant pathogens. One particular plant pathogen, *Phytophthora cinnamomi*, is of great concern. *Phytophthora* is a water mould that occurs in soil and causes root rot in a wide variety of plant species, and often results in the death of the infected plant. The pathogen can be spread by water, contaminated soil on tools, cars, and footwear, allowing it to easily infect surrounding plants once it is in an area. It is difficult to determine whether *Phytophthora* is responsible for the death of plants, so a precautionary approach to the management of die back in bushland is recommended (Skelton et al, 2004).

Figure 6.6.3b – Die Back in Bushland above Castle Rock Beach

Informal pathways have also had an impact on the bushland within the study area. Pathways have been illegally made to create access to areas such as beaches, formal walking tracks (eg- Manly Scenic Walkway) and recreation areas, with many originating from private properties. These tracks are often not well constructed, and exacerbate problems such as erosion, compaction of soil, and weed dispersal. As many of the tracks are also on Council land, they pose a liability risk to Council. Figure 6.6.3c illustrates the issue, with an illegal pathway that has been created between a private property and the Manly Scenic Walkway, with resultant erosion at the base of the stairs. Some of the existing ad hoc pathways (e.g. Gurney Crescent) are the only way to the foreshore and are very difficult to traverse. An option may be to improve these paths as formal access ways.

Figure 6.6.3c – Illegal Pathway between Private Property & the Manly Scenic Walkway

Introduced fauna (see Table B9 in Appendix B) have also impacted on the native fauna within the study area. The introduced birds, particularly the Common Myna, have most likely displaced native birds to some degree, although the extent is not known. Displacement occurs through competition for food and nesting sites, and aggressiveness of introduced birds towards natives (Australian Museum, 2007).

Cats were recorded throughout the study area reserves. Cats are renowned as predators of native fauna, and have a preference for mammals and birds around the weight of 200g, although they will also take other species such as reptiles and frogs. Even when a cat attack does not directly kill the intended prey, they carry a disease, *toxaplasmosis* that usually results in death of its opponent through blindness, central nervous system damage or respiratory failure (Skelton et al, 2004).

Domestic dogs were sighted in most of the study area reserves. Dogs impact on native fauna directly by predation and attack when unleashed, but they can also have indirect impacts. The smell of domestic dogs reduces the habitat potential of an area, as native animals become stressed and avoid the areas where the smell is present (Skelton et al, 2004). Parts of the study area, particularly the Manly Scenic Walkway and surrounds, are frequented by dogs being walked, meaning their scent would be nearly always present. Sandy Bay is also regularly used to exercise dogs off leash, which would impact on populations of shore birds that would normally hunt on the sand flat at low tide for food.

Rabbits were recorded in some of the study area reserves. Rabbits cause a myriad of problems, both to other fauna and the environment around them. Rabbits compete with, and often out compete, many native ground dwelling animals for food and shelter. They are extremely mobile and can reproduce rapidly, placing huge pressure on the more territorial and slow reproducing natives. Rabbits eat the seedlings of native plants, reducing the ability of the bush to regenerate, and they also graze on mature plants and damage its protective bark. They create erosion through digging burrows, which can also exacerbate any existing erosion (Skelton et al, 2004).

6.7 ECOSYSTEM HEALTH ASSESSMENT

In conclusion, an assessment has been made in tabular form that allows for an overview of the ecosystem health. Key indicators were chosen from the topics covered in this report. These findings will assist in developing appropriate management actions.

Indicator	Lower half of the study area east of the Spit Bridge	Upper half of the study area west of the Spit Bridge
Water Quality – Aquatic Ecosystem Health Values	??	??
Water Quality – Recreational Ecosystem Health Values	Good. Sample Site showing 100% compliance with the *faecal coliform* guidelines in every year between 1999 and 2006, and 100% compliance with the *enterococci* guidelines on four of the seven years.	Better. Sample sites showing only two of the seven years for both *faecal coliform* and *enterococci* 100% compliance with guidelines.
Erosion	exists as an issue	not a problem
Sedimentation	tidal basin with mixture of marine sand and estuarine mud	stable sedimentary environment,
Wetlands (mangroves and salt marsh)	one individual tree no salt marsh	one small pocket and several individual trees no salt marsh
Seagrasses	reasonably large meadows of seagrass; large losses reported; exotic species exist	exists in isolated patches

Indicator	Lower half of the study area east of the Spit Bridge	Upper half of the study area west of the Spit Bridge
Urban bushlands	scattered, some larger reserves, die back is an issue, exotic species, high density of weed	scattered, some larger reserves, die back is an issue
Fish & fisheries	large number of fish species (fishing banned at present) shark sighted	large number of fish species (fishing banned at present)
Habitat on foreshore structures	selective (poor?) habitats with extensive growth of some species	selective (poor?) habitats with extensive growth of some species
Phytoplankton	Extensive	smaller areas
Zooplankton	??	??
Benthic Macro invertebrates	??	??
Terrestrial fauna	significant number and species	significant number and species

?? No data to make a judgement on the indicator

6.8 THE HAZARDS OF CLIMATE CHANGE

Predictions on the impacts of climate change are varied, but opinions on whether it will occur are not. The Intergovernmental Panel on Climate Change (IPCC), the peak body for climate change science globally, released a report in 2007 titled "Climate Change 2007: The Physical Science Basis". This report states that the earth has warmed as a result of human activities, and that it is "virtually certain" that we will experience "warmer and more frequent hot days and nights over most land areas" into the future (IPCC, 2007). This warmer weather is the catalyst for the many other impacts of climate change. Much of the information now available relates to regional and national scenarios, and only limited information is available for specific localities.

Climate change is likely to have significant impacts on Australia (Preston & Jones 2006). From 1910 to 2004, the Australian–average maximum temperature rose 0.6℃ and the minimum temperature rose 1.2℃, mostly since 1950 (Nicholls and Collins 2006). CSIRO (2006) has recently created simplified scenarios for ten regions of Australia, including NSW. These scenarios for 2030 are suitable for the purpose of an initial assessment of risks and are presented as changes relative to 1990.

Table 6.8: Changes in climate for New South Wales by 2030, relative to 1990

Feature	Low Global Warming Scenario		High Global Warming Scenario	
	Estimate of change	Uncertainty	Estimate of change	Uncertainty
Annual average temperature	+0.6℃	±0.2℃	+1.3 ℃	±0.6℃
Average sea level	+3cm		+17cm	
Average annual rainfall	0%	±6.5%	0%	±15%
Seasonal average rainfall				
Summer	+ 1.5%	±8%	+ 3.5%	±18.5%
Autumn	+1.5%	±8%	+ 3.5%	±18.5%
Winter	-3%	±6.5%	-7%	±15%
Spring	-3%	±6.5%	-7%	±15%
Annual average potential evaporation	+2.4%	±1.9%	+5.6%	±4.4%
Annual average number of hot days (>35℃)	+1 day		+25 days	
Annual average number of cold nights (<0℃)	-5 days		-30 days	

Source: CSIRO, 2006

NSW is likely to become warmer, with more hot days and fewer cold nights. For example, the number of days above 35°C could average 4-7 in Sydney (now 3). In cities, changes in average climate and sea level will affect building design, standards and performance, energy and water demand and coastal planning. Increases in extreme weather events are likely to lead to increased flash flooding, strains on sewerage and drainage systems, greater insurance losses, possible black-outs and challenges for emergency services.

The information below discusses the issue with as much local detail as is currently available.

The study area will experience many of the impacts of climate change, with the low lying areas close to the foreshore likely to be subject to more of the impacts than the elevated areas. These impacts are likely to include: sea level rise; increases in extreme weather events; temperature increases; reductions in water availability; altered hydrology and increased flash flooding; and more frequent and more severe droughts (Hennessy et al, 2006).

Much of the study area contains properties that extend right to the foreshore. Sea levels are expected to rise between 9cm and 88cm by 2100, but they only need to rise marginally for low lying properties to be at risk of inundation. Predictions estimate that for sandy beaches the coastline could retreat 50 – 100 times the distance of the vertical sea level rise (Australian Greenhouse Office, 2007). Hence, a sea level rise of 50cm could result in shoreline recession of 25-50m on sandy beaches. This sandy beach shoreline recession would also be exacerbated by the expected increase in severe weather events (eg- storm surge), to make the threat of inundation for relevant foreshore properties within the study area even more severe. Areas with stable rocky shores will not experience the same shoreline recession, however the frequency of rock falls may increase and the width of the intertidal rock platforms will decrease as the sea migrates inland (Manly Council Scientific Advisory Panel, 2005).

Temperature increases will affect the ability of some ecosystems to function as they currently do. Slight increases in temperature may be enough to change the balance of some vegetation communities, which can then have flow-on effects to the entire surrounding ecosystem. The temperature increases will also affect water availability. Changes in rainfall are expected, and with higher evaporation demand (due to increased temperatures) this will lead to a tendency for fewer run-offs into waterways (Hennessy et al, 2006). This will mean that the already struggling creeks within the study area may be placed under additional stress, further reducing their value as freshwater habitat.

Although there will be a net decrease in water run-off into waterways, the increase in extreme weather events means that the rainfall we do receive will be more intense, and is predicted to lead to more frequent flash flooding, erosion and strains on water infrastructure. The stormwater system is under capacity now, and is broadly designed to cope with 1 in 20 year storms, but these same storms may become as frequent as 1 in 7 year events. Sewer overflows will also become more frequent as a result of the higher intensity storms. Again it will be the low lying parts of the study area that will be most affected by this impact (Manly Council Scientific Advisory Panel, 2005).

Many other impacts (eg bushfires, changes in pest species) may result from the effects of climate change, although they are much harder to predict than those above. Modelling needs to continue on a regional and local level as new information becomes available, to ensure all impacts can be understood (see section 6.6).

Climate Change Forum

On October 29, 2006 Council's Manly Environment Centre conducted a very successful Climate Change Forum titled 'Weathering the Storm'. During this session many views were expressed about what climate change will mean for Manly and some of the management options were outlined.

At Council's Ordinary Meeting of 20 November 2006, Council resolved to adopt a Mayoral Minute entitled Global Warming: Local Solutions - Time for Action, which requires the establishment of a "Climate Change Working Group" to identify likely impacts of climate change and to provide advice on prevention and mitigation strategies.

In addition, Council is in the process to undertake a full review and risk assessment. It is expected that this process will be conducted through a workshop process and a review panel using the recently published guidelines from the Australian Greenhouse Office.

7. INTERACTION BETWEEN PROCESSES

The various estuarine processes occurring in the Clontarf / Bantry Bay study area are related and often dependent on each other. Changes to one process can cause changes to one or several other processes.

The connectivity between various estuarine process and the key issues are presented in Figure 7.0. As can be seen, most processes impact on more than one issue, with some processes affecting all issues. A good understanding of the interactions between the processes and issues is fundamental to a balanced and well guided Estuary Management Plan.

Figure 7.0 – Linkages between processes and key issues

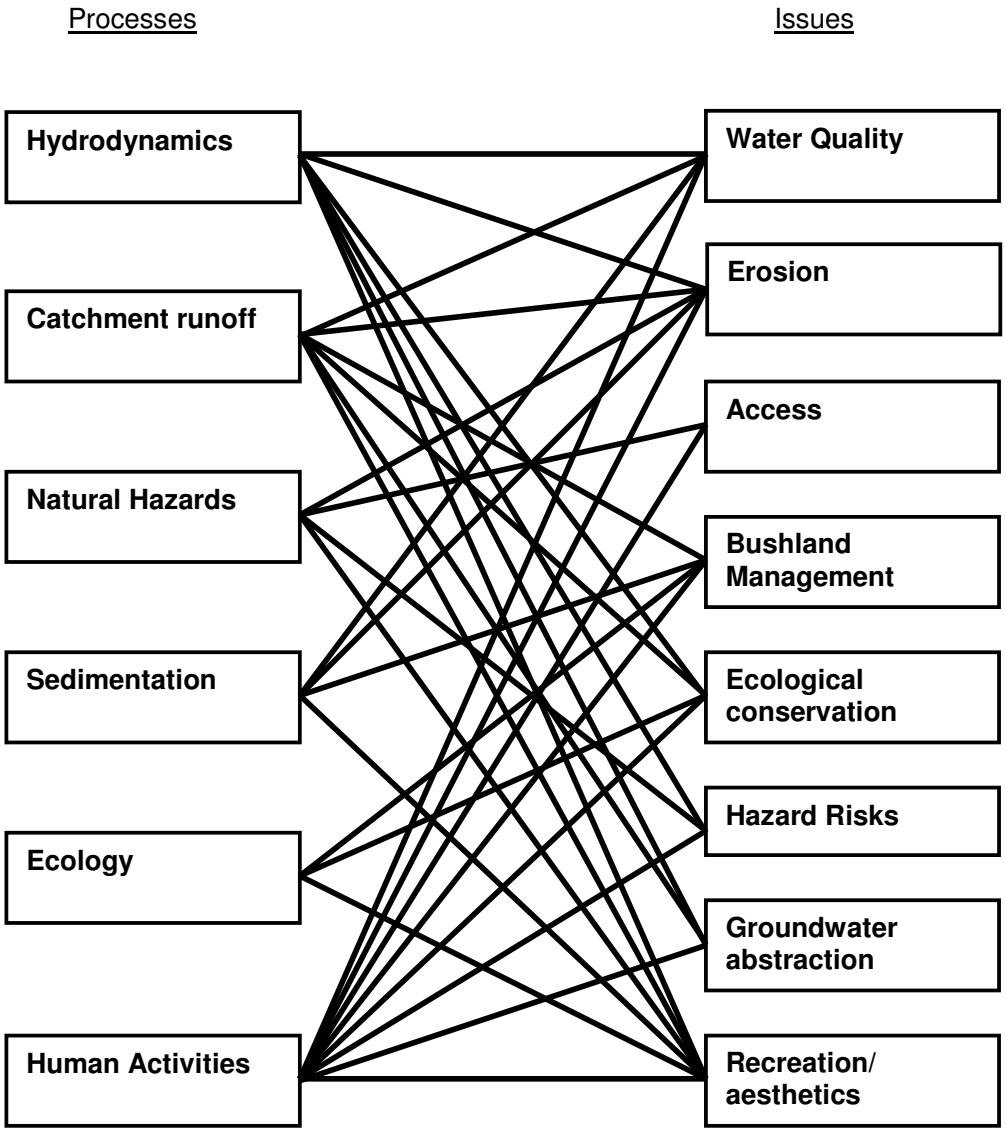


Table 7.0 – Processes Interaction Matrix

Water Quality	Erosion	Access	Bushland Management	Ecological Conservation	Hazard risks	Groundwater abstraction	Recreation/ aesthetics
Hydrodynamics							
Tidal fluctuations and freshwater flows ensure that water is mixed throughout the estuary and may originate from any part of the greater Sydney Harbour catchment. These flows that mix the water are effective in flushing the estuary of contaminants after periods of rainfall.	Hydrodynamics favour a sand transport corridor between the tidal delta and Sandy Bay. However, the beach profile appears to have been modified from its natural state, due to the irregular shape of the shoreline between Clontarf Reserve and Sandy Bay. The large sand flat of Sandy Bay transforms into a narrow beach with a steep drop-off on either side of Clontarf Marina, and then back into a sand flat to the south of the marina. Tidal waves and locally generated wind waves are often the cause of bank erosion			Tidal flushing in the downstream of the estuary favours abundant seagrass	Hydrodynamics of the estuary is impacted by climate change including sea level rise and precipitation.	Over abstraction of groundwater, so close to the estuary, can lead to seawater intruding into the freshwater aquifer. This could render the use of the groundwater unsuitable if contaminated by higher salinity. Local hydrology is affected from modified groundwater systems, with potential impacts on soil moisture and the ability to support vegetation communities	The good tidal flushing downstream of the estuary makes the area ideal for swimming
Catchment runoff							
Stormwater transports terrestrial pollutants into the estuary	Stormwater flowing through artificial drainage networks results in accelerated erosion.	Large volume of catchment runoff can cause foreshore access to be difficult	Stormwater pipes from individual residential properties direct stormwater into bushland, erode the	Large volumes of freshwater inflows can impact on marine species of macrophytes and	Large volumes of stormwater flows remove sand from the base of the seawall and	Hardened catchment due to above ground development can limit the infiltration (supply) of water into	Gross pollutants, sediments and poor water quality of runoff during heavy rainfall or storm events can

Water Quality	Erosion	Access	Bushland Management	Ecological Conservation	Hazard risks	Groundwater abstraction	Recreation/ aesthetics
Poor stormwater management practices have resulted in a toxic array of pollutants in the estuary. Nutrients and bacteria are discharged from sewerage overflows. There are five sewerage overflow points located within the study area. Street Cleaning and GPTs reduce pollutant load			topsoil and discharge sediment into estuary. The spread of exotic fauna in bushlands has been exacerbated by nutrient pollution from stormwater and sewage overflows. Residential development around the bushland reserves means that fires are suppressed. Bushfire is a natural part of the environment, and many species are dependent on regularly spaced fires.	aquatic fauna with low mobility (eg. Molluscs and worms) Leaching of catchment pollutants into the estuary could impact on the overall ecological health of the system Flows from stormwater pipes erode the nutrient-rich topsoil, expose the roots of vegetation, and smother down slope areas with too much soil or discharge sediment into estuary.	potentially compromise the integrity of the seawall.	an aquifer.	reduce recreational usage of the estuary Odour from sewage overflow can have an impact on amenity value of the estuary
Natural hazards							
Storms affect water quality of the estuary	Due to climate change, there will be an increase in intense rainfall and is predicted to lead to more frequent flash flooding and erosion.	A large rock overhanging at Clontarf poses risk over a regularly used walkway	Natural hazards like intense rainfall or storms can damage bushlands	Temperature increases, due to climate change, will affect the ability of some ecosystems to function. Slight increases in temperature may be enough to change the balance of some vegetation communities, which can then have flow-on effects to the entire surrounding	Beach erosion undermines seawalls, foreshore garden beds, and exposes buried rocks. Long term processes such as rock erosion can make slopes and cliffs unstable, to the point of collapse, occurred at Seaforth Crescent in 1956. Properties that		People cannot use the estuary for recreational purposes during and after periods of natural hazards

Water Quality	Erosion	Access	Bushland Management	Ecological Conservation	Hazard risks	Groundwater abstraction	Recreation/ aesthetics
				ecosystem.	extend right to the foreshore face the risk of inundation from sea level rise.		
Sedimentation							
Sediments are not easily flushed and pollutants tend to accumulate in them over time. Certain pollutants can actually bind or attach to fine sediment (mud) particles, making their dispersal and flushing difficult.	Excessive sedimentation is caused by erosion.	Illegal access ways can exacerbate erosion increasing the sediment supply to the estuary		Excessive sedimentation can cause ecosystem damage, such as the smothering of seagrass beds and increase of turbidity that affects light penetration and filter feeders.			Recreational activities interfere with the natural sediment processes. Viability of sailing and fishing in the estuary will be compromised if considerable sedimentation occurs. More exposed sand/mud flats due to excessive sedimentation will impact on aesthetics and general amenity of the estuary.
Ecology							
Ecological habitat can often be used as indicator of the general quality of water. Poor water quality is often characterised by high levels of phytoplankton and/or other forms of algae, combined with low abundance of aquatic fauna Poor water quality can impact on light	Foreshore vegetation is an effective means to prevent bank erosion.	Sensitive and irritant weed species can make access ways less usable.	Urban Bushlands, as it exists in the study area, provide a rich ecological diversity, including both flora and fauna.				Many recreational pursuits around the estuary are reliant on reserve parks, walkways, fishing etc. Many bathers dislike seagrasses as they uncomfortable to walk through

Water Quality	Erosion	Access	Bushland Management	Ecological Conservation	Hazard risks	Groundwater abstraction	Recreation/ aesthetics
penetration to seagrass beds whereas higher nutrient load can result in excessive epiphytic growth.							
Human activities							
Highly urbanised study area placed significant pressure on water quality health. Education programs have increased awareness about pollution, and have changed many people's behaviour in regard to pollution prevention. Boats and foreshore industry also contribute to the pollution problem. Boating impact water quality via spills, anti-foul paints, littering from boats and from marinas where boats are washed and fixed.	Bank erosion can be exacerbated by the construction of foreshore seawalls, particularly if these are poorly designed and constructed Erosion of some foreshores has also been caused by boat launching at undesignated locations. Boat generated waves create foreshore erosion.	Walkways/access roads, if not well constructed, exacerbate problems such as erosion, compaction of soil, and weed dispersal.	Urbanisation has encroached into bushlands. The loss of habitat has greatly reduced the carrying capacity of the study area for native wildlife, and natural ecological processes and biodiversity have been threatened Of 426 species of flora recorded within the study area, 153 (approximately 36%) are exotic. These have reached bushland areas through escaping from gardens, illegal dumping of garden refuses, dispersion by fauna (eg- birds eating seeds) and illegal plantings. In the past, people cleared mangrove forests to make way for foreshore development including landfill	Many human activities adversely impact on ecological health Human activities responsible for introducing a number of exotic species into the marine environment, the most serious being *Caulerpa taxifolia*. Recreational fishing can reduce the abundance and diversity of species within the estuary. Boat generated waves can impact on habitat. Moorings and anchoring of boats impact on seagrasses.	Boat generated waves over time can weaken sea walls leading to their collapse	Residential bores, often unlicensed, creating over abstraction of groundwater.	The raking of Clontarf Beach and Sandy Bay is detrimental to the ecology of the intertidal area, although it is a necessary health and safety procedure for recreational use (eg- removal of sharps). Marine debris such as seagrass wrack (not rubbish) washed up on the shore provides an important source of food for a diverse range of invertebrate species. Boating can impact on swimmers and kayakers in terms of safety e.g. around Clontarf Reserve. Conflicts arise between the various recreational pursuits

8. COMMUNITY CONSULTATIONS & KEY CONCERNS

A vital part in the estuary management planning process is community involvement and action. Hence, the estuary management planning process requires widespread community awareness, cooperation and action. This section provides a brief outline of the awareness campaign and consultation process undertaken in the development of the Clontarf / Bantry Bay Estuary Management Plan.

8.1 METHODOLOGY

There are various ways in which the development of the Estuary Management Plan (EMP) were marketed to the community, and various methods by which the community were consulted about their issues of concern or interest. These are summarized below.

8.1.1 Marketing the EMP Development

Display Panels: A series of A3 Display Panels were created to assist in marketing the EMP development. They were designed and used for various events and displays. The panels incorporated pictures to enhance visual appeal and assist in promoting messages, and covered:

- How Manly Council is protecting our coastal zone
- The Clontarf / Bantry Bay EMP study area
- The EMP development process
- Potential Issues

Displays / Survey Return Sites: Several displays were set up at key locations to promote the development of the EMP and to encourage people to provide input. These locations also provided facilities for people to pick up and return surveys. Locations were:

- Balgowlah Heights Bowling Club
- Balgowlah RSL Club
- Wakehurst Golf Club
- Seaforth Bowling Club
- Clontarf Marina
- Clonnys on the Beach
- Manly Library

Displays on Hop, Skip & Jump Buses: An A4 laminated poster was created (based on the A3 Display Panels) and displayed on the door of all the four Freebie Hop, Skip & Jump buses to reach as many people as possible. The poster simply called for people to 'have a say' about the future management of the Clontarf / Bantry Bay area, and listed the locations that they could pick up a survey (i.e. - the above-listed commercial premises). It also pointed them to the website for further information.

Webpage: A webpage was created on Manly Council's website (www.manly.nsw.gov.au) to allow easy access to information relevant to the plan. The page contained general information about the development of the EMP, but also included other features, such as:

- Links to the surveys, so people could print off and filled out
- An email hyperlink, so people can email the Estuary Management Officer directly
- Updates on the status of the EMP development

Precinct Newsletters: Articles were regularly sent to the Precinct groups for inclusion in their monthly newsletter. Articles featured in Precinct newsletters were:

- Clontarf Precinct, July 06 – Calling for information and people's views
- Clontarf Precinct, August 06 – Calling for nominations to represent the Precinct on the Estuary Management Working Group
- Balgowlah Heights Precinct, August 06 – Calling for information and people's views

Presentations at Council Committee Meetings: Presentations were made at following relevant Council Committee meetings promoting the development of the EMP, and calling for submissions (every committee member of the given committees were provided with a survey to complete).

- Manly Sustainability Strategy Management Group
- Manly Social Plan Implementation Committee
- Manly Scenic Walkway Committee
- Manly Access Committee

8.1.2 Methods for Community Consultation

Survey: Two survey forms were produced to assist people in providing input into the development of the EMP – a comprehensive survey and a brief survey. The comprehensive survey dealt with broad issues as well as specific issues relevant to the study area, and was designed for people who wanted to provide significant input into the EMP development. The brief survey dealt with broad issues only, and was designed for people who would like to have input without spending much time. As the broad issues were common in both surveys, results were combined for the purposes of analysis and reporting.

The survey forms were distributed through various means (as mentioned above), and were emailed or posted to people upon request. A total of 120 filled in survey forms were returned.

Email: People were able to email the Estuary Management Officer to:

- Seek information about the EMP development
- Provide comments for input into the EMP development

Post & Fax: People were able to send in comments in writing by:

- Post: PO Box 82, Manly, 1655
- Fax: 9976 1400

Field Days: Two community consultation field days were held within the study area –Clontarf Reserve (October 21, 2006) and Seaforth (November 12, 2006). The Seaforth field day was held as part of the Seaforth Centennial Event. Field days were aimed to reach many people in a short period of time, by providing an accessible, visible, and interesting stall, along with other attractions. The days were undertaken in partnership with the relevant Precinct group, to assist with promotion and organisation.

8.2 ISSUES OF CONCERN

A total of 120 survey forms were completed and returned throughout the consultation process. Responses to the questionnaire identified a diverse range of uses, values and provided confirmation of activities and issues of importance within the study area. The following information has been summarised from the findings of the questionnaire distributed to the local community.

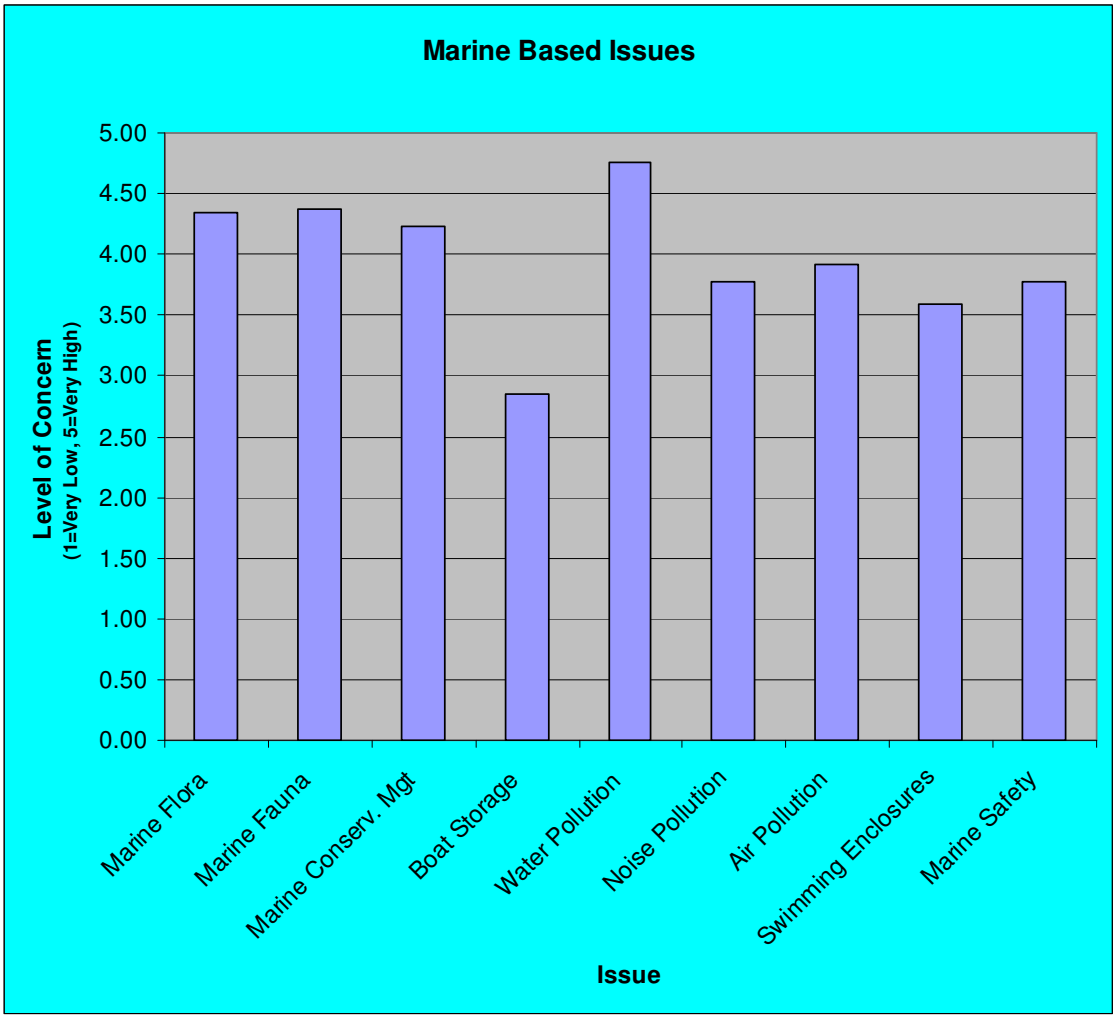
The survey forms contained 27 questions around three major groups, marine, land and coastal hazard/risk based issues. Respondents were asked to prioritize each issue on a scale of 1 (very low) to 5 (very high).

This section reports concerns raised directly by community through different formats.

8.2.1 Marine based issues

There were opportunities to prioritize nine marine based issues: marine flora, marine fauna, marine conservation management, boat storage, water pollution, noise pollution, air pollution, swimming enclosures and marine safety.

Figure 8.2.1: Level of Community Concerns on Marine based Issues



Water pollution, marine flora & fauna and conservation management issues, in broader perspectives, are of high concern. Details of these concerns are summarized below:

Water pollution: Storm water, sewage overflows, litter and boat effluent disposal are of high priority. Uncontrolled stormwater flow and sewage are threat to the long term ecology of the area. Some sewage still goes directly into Bantry Bay. Dog faeces are also flowing to waterways. More stormwater traps / filters are required including regular inspection of gross pollutant traps. There is need to cut down sewage and all forms of effluent into water and in to beaches

Marine flora: Sea grasses and *Caulerpa taxifolia* are of common concerns. Rosevilles sea grass was covered to create a picnic area and Tunks Park / Cammeray has also lost its sea grasses due to siltation. Drainage and runoff are upsetting both marine and shore based vegetation balance and helping exotic infestation. There is need to keep weeds down to allow fish to feed and penguins to thrive. There are complaints about Marinas and other installations destroying native marine flora.

Marine fauna: Little penguins, seahorses & sea dragons, fish species and marine invertebrates are of high priority. There is need of a good ecosystem for a clean environment. Looking after sea life (flora and fauna) would always be extremely important. Marine growth / seahorses are linked. More help from Fisheries will be needed to combat illegal fishing practices. There should be stricter controls on private development on and near shoreline.

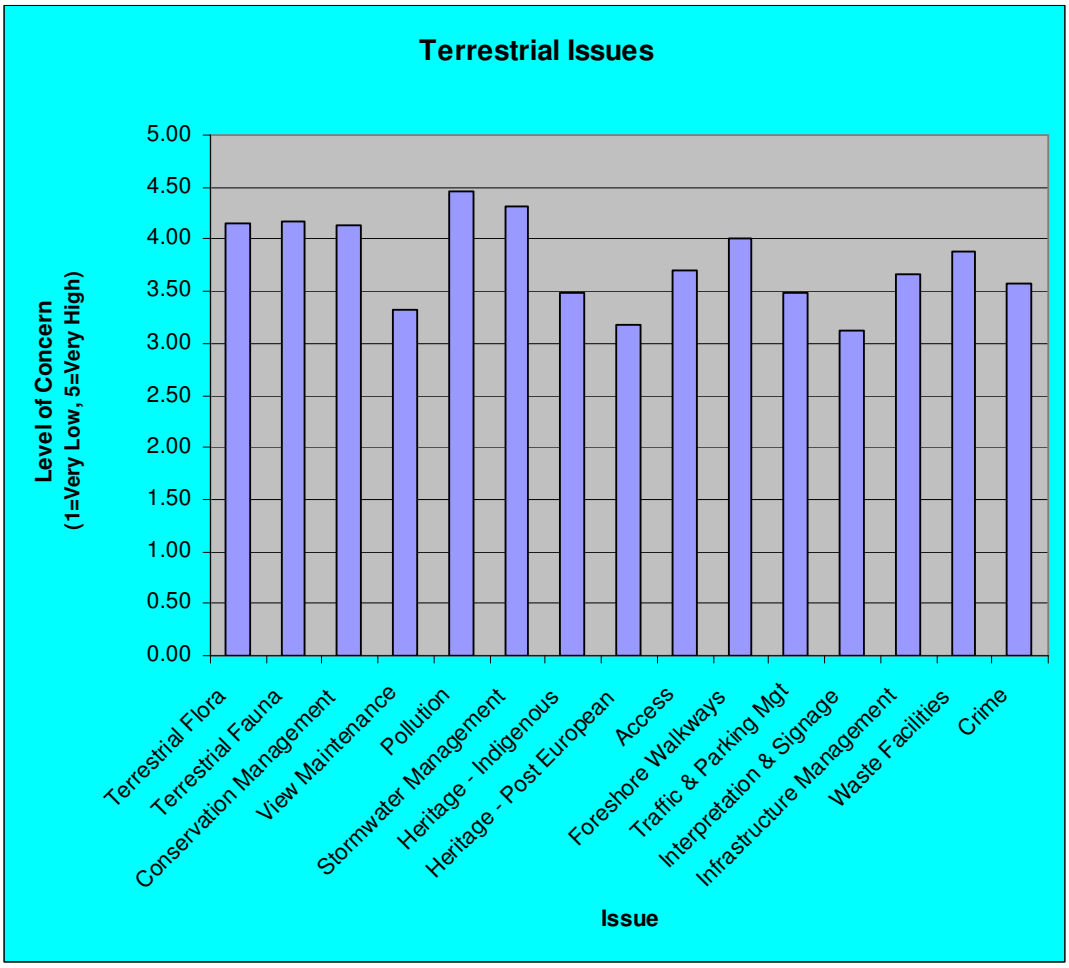
Conservation management: intertidal protection is of high priority. Litter seems to be a huge problem, especially plastic materials in water. The public needs to be educated to be vigilant about rubbish and encouraged to pick up rubbish that they see before it gets to the estuary. To cut down pollutants, rubbish traps would be good

Others: Boats stored on Sandy Bay should be removed as they restrict use of grass area. Consider a modest user pay storage arrangement to eliminate abandoned dinghies and provide better and safer access for genuine and active boat users. There is conflicting concerns about to restrict or increase number of moorings. More moorings are required for Clontarf beach and Garigal "Bantry Bay" residents. Protect swimming and marine area by providing boundary and access. Present Jetski ban should be retained. Do not allow noisy boating such as speed boats and water skiing which are dangerous. 8 knots limit should be maintained for Clontarf beach. There should be efforts to upgrade boat user awareness of safe and courteous use. Sangrado reserve is wonderful and should be maintained in its natural state, it is very much used by walkers and dog owners. It is a family orientated area and there should be accessibility for less mobile people. Clontarf pool is highly valued to the community and should be well maintained. It is silting up and should be dredged. Water is polluted and a drain exists from Clontarf Park into pool through a dangerous lift-up gate. This pool should be improved so that more people will use it for swimming. At present, there are lots of oysters.

8.2.2 Land based issues

There were opportunities to prioritize 15 land based issues: terrestrial flora, terrestrial fauna, conservation management, view maintenance, pollution, storm water management, heritage – indigenous, heritage- post European, access, foreshore walkways, traffic & parking management, interpretation & signage, infrastructure management, waste facilities and crime.

Figure 8.2.2: Level of Community Concerns on Land based Issues



Pollution, storm water management, terrestrial flora & fauna, conservation management and foreshore walkway issues, in broader perspectives, are of high concern. Details of these concerns are summarised below:

Pollution: Litter is a huge problem, especially glass on beaches in Clontarf. Motor vehicle emissions are bad during Spit Bridge openings. Building and renovating activity from 7am and earlier has turned parts of the suburb into an industrial zone.

Stormwater management: Discharge issue is of high priority. More regular usage of Clontarf Reserve sprinkler pumps at night from groundwater spears needed. Piping is too obtrusive. Investment is needed to fix blocked storm water from Church point to Manly Wharf. Storm water re-use may be the only way to control the adverse impact of storm water.

Terrestrial flora: Protection of rare and endangered species, weed management and vandalism issues are of high concern. New settlement leads to loss of species; regeneration provides a chance to recover. Plant more native trees. Although the bush is fantastic but the views are very special too. Not all bush needs to be preserved at look outs. Maintain reasonable canopy so that view loss through growth is minimized. Residents should be engaged in landscape decisions regarding loss of views. Loss of views to homeowners should not be incentive to illegal poisoning / lopping. People should be prosecuted who damage, poison or cut down trees. Protect and maintain as much bush land as possible

Terrestrial fauna: Little Penguins and Feral animals (including birds) are of priority concern. There is need to establish and maintain a proper balance of native and non native animals. There is need for control of rats / rabbits, spiders, insects (sand fly), termites, feral cat and tick. Any action to reduce feral birds would benefit the natural area.

Conservation management: There are conflicting opinions about beaches or bay to be leashed or unleashed dog area. Sandy Bay is a popular unleashed dog area. There is call for swimming area for dogs. At least, current unleashed dog areas should be maintained. However, there is need for increased signage regarding droppings and additional dog bag stands. An education program is needed for responsible dog ownership and management.

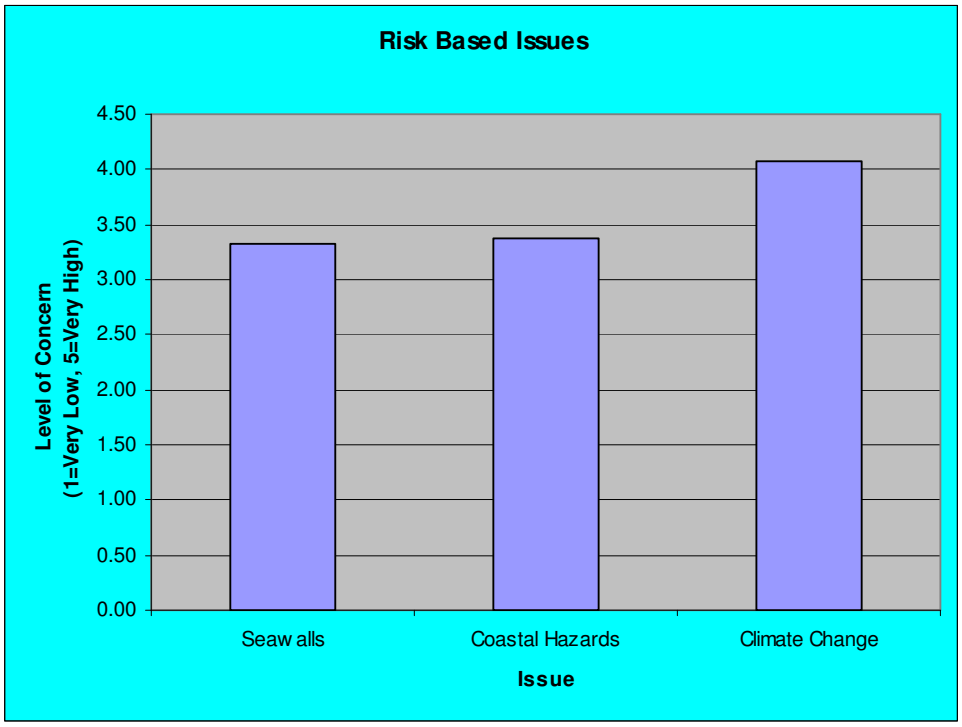
Foreshore walkways: Track maintenance is of prime concern. Passive enjoyment by walking and sitting is a right for ratepayers and the public. A proper waterfront / shoreline walkway is needed to join the Spit Bridge and Bantry Bay, thus linking to other tracks. This would not require the destruction or harm to anyone's jetty, just the 'permissive' use of the right to cross individuals land. Council should definitely take a program to construct a walkway from the Spit to Bantry Bay. This walkway should be low intervention track keeping as natural as possible. Regular maintenance is needed including weed management, litter maintenance and inspections for hazards such as broken steps.

Others: There are lots of natural history as well as historical sites, buildings, structures in the area. Aboriginal heritage signage should be increased. However, there is dilemma: should this heritage be kept a secret in order to protect it - then how would people appreciate these heritage sites? An overhaul of traffic management is needed around Ethel Street - Sydney Rd, including pedestrian crossing in Ethel St and policing of parking in surrounding streets i.e. parking right to edge of street corners. Mismanagement of castle circuit placement and traffic lights. These should have been installed at Lister Ave intersection. This was original plan before council changed this without any community consultation. Need a crossing in Ethel Street before someone is hit and hurt. Hop skip and jump is a great innovation. More park and ride will encourage public transport habit. Bike paths required to Clontarf Reserve. More public space should be developed for aesthetic value and enjoyment. Facilities needed could be taps, bubblers, shade, rain shelters, rails on steps, telephones, toilets, accessible toilets / showers / seating / pathways / parking / ramps / rails. Many of recreational infrastructures are used by visitors rather than locals. Maintenance is still important. As this is high traffic area in summer, it is important that bins and recycling are well managed. Dog litter bags should be replenished more frequently. Vandalism in Clontarf Park would be reduced if the gates are locked regularly. Council should take graffiti removal more seriously. Well lit and designed public places will help in dissuading opportunistic crime.

8.2.3 Coastal hazards/risk based issues

There were opportunities to prioritize three coastal hazards/risk based issues: seawalls, coastal hazards and climate change.

Figure 8.2.3: Level of Community Concerns on Coastal hazards/risk based Issues



Climate change issue, in broader perspectives, is of high concern. Details of this and other concerns are summarized below:

Climate change: Global warming is the priority concern. It is happening. Long term large scale measures are needed. Council's efforts and investments should be part of a national initiative on climate change.

Others: Overdevelopment of shoreline will degrade marine and intertidal environment. Reduce beach erosion where possible and maintain beach sand.

9. SIGNIFICANCE & VALUES OF THE ESTUARY

This section summarises the special features and unique qualities of the Clontarf/Bantry Bay estuary area that make it significant from a local, regional, and national level. This is based on the feedback from community consultation, as well as the research and data collection collated for this study.

9.1 SIGNIFICANCE OF THE ESTUARY

The identified characteristics indicate significance of the study area which is of existing and perceived future local or regional significance.

9.1.1 Local Significance

The Clontarf/Bantry Bay estuary is locally significant in its role as a habitat for native animals and plants, a provider of popular recreational resource for locals and visitors alike. The attraction of Clontarf/Bantry Bay is enhanced by its generally good water quality. This results in numerous primary and secondary contact recreational pursuits, including swimming, sailing, kayaking, diving, sail boarding, kite-surfing, water skiing and boat and shore fishing, which are immense value to locals and visitors alike.

Given its scenic beauty the estuary is highly attractive and people want to be near it, look at it, or be on it. For these reasons, recreational visitation and use of the waterway is extremely high with significant “flow on” effects for the local and regional economies. Its deep waters are very attractive to the boating community. It is one of the most intensively used waterways in NSW.

Because of its scenic beauty and views, foreshores have already become highly sought after residential area. At present, 65% of the foreshore is under residential land use compared to 37% within Manly LGA.

The Clontarf/Bantry Bay waterway has a very high economic value and is important to a range of stakeholders, ranging from local retailers to commercial tourism operators, real estate operators, boating services, marinas and support industries.

9.1.2 State and Regional Significance

The study area is rich in Aboriginal cultural heritage giving it significance at the regional and state level. The AHO has recorded 22 Aboriginal sites within the study area (personal communication, AHO) including 16 middens. European cultural heritage is also an important feature of the study area with numerous heritage listed sites and buildings including public baths located along the shoreline, including Clontarf, Sangrado and Pickering Point.

At the regional level, the study area has significance for its natural habitat. In recognition of the diverse array of habitat types that are still found in Middle Harbour, the NSW State Government, under its Sydney Regional Environmental Plan (Sydney Harbour Catchment) 2005, has zoned large parts of the study area as Environmental Protection, which aims to “provide for the protection, rehabilitation and long term management of the natural and cultural values of the waterways and adjoining foreshores (NSW Department of Infrastructure, Planning & Natural Resources, 2005). In addition, the entire foreshore of the study area is protected as an Intertidal Protected Area (IPA) under the Fisheries Management Act, 1994 due to the significance of the remaining rocky habitats and intertidal species. Large areas of the study area have also been designated as a Wetlands Protection Area (WPA) by the NSW State Government, despite the absence of salt marsh and only a few remaining mangroves. This area is designed to allow for future growth, as well as preserving and protecting the existing populations (NSW Department of Infrastructure, Planning & Natural Resources, 2005).

There exists several floras and fauna recorded as threatened, making the study area important. The entire study area has regional significance as it is covered within the Sydney Harbour Foreshores and Waterways Area and the Sydney Metropolitan Catchment Area.

9.2 VALUES OF THE ESTUARY

It is also important to gain an appreciation of the multiple features and values of the area. The following values reflect attributes, activities and processes that are of importance to the community, and are the qualities on which the study area depends for its attractiveness, desirability, liveability and use. These values were derived from the community consultation that was undertaken from the start of August to the end of October, 2006, to assist in the development of the Clontarf / Bantry Bay Estuary Management Plan.

- **aesthetic values** associated with a pleasant, appropriate and 'green' landscape character. For example the consultation process identified that the community values the more natural characteristics of the area. Areas that hold specific scenic value include:
    - Clontarf Reserve
    - Duke of Edinburgh Reserve
    - Sandy Bay
    - Sangrado Reserve
    - Castle Rock Beach
    - Ellerys Punt Reserve

  Some of these areas together are proposed to be called as 'Eco Corner' of Manly.
- **physical values** associated with estuary foreshore and processes. For example residents and visitors value being able to access and experience the foreshore and associated views.
- **biophysical values** associated with the protection and improvement of aquatic, inter-tidal and terrestrial environments. These include estuarine habitat, intertidal habitat, mixed rocky intertidal with sand, sandy beaches, sea grass beds, open forests, urban bush lands and reserves, mangrove forests and wetlands. The consultation process identified that the community highly values the preservation of natural bushland, seagrass and water quality. The Clontarf / Bantry Bay estuary supports habitats of regional and state conservation value including species and communities listed under the *Threatened Species Conservation Act* 1995, *Environment Protection and Biodiversity Conservation Act 1999*, *Fisheries Management Act 1994,* and/or State Environmental Planning Policies.
- **cultural values** associated with the area's indigenous and non-indigenous heritage and the identification of significant Aboriginal sites. The entire Clontarf / Bantry Bay study area was used extensively by the Aboriginals, known locally as the Gayemal clan of the Guringai tribe, who spent much of their time on the foreshores of Sydney Harbour (Aboriginal Heritage Office, 2007). The Aboriginal Heritage Office has recorded 22 Aboriginal sites within the study area (personal communication, AHO). This includes the following types (there can be more than one feature at one site):

    - Shelters with midden
    - open middens
    - Rock Engravings
    - Shelter with Art
    - Burial
    - Shelter with potential archaeological deposit
    - set of grinding grooves

  A list of heritage items of the study area is presented in Chapter 2.
- **values associated with the sustainable use and management** of resources, lands and the estuary. The consultation identified that the community would like to ensure that the area be used and managed in a way that will ensure that these values are preserved in the future.
- **accessibility values** associated with convenient access to all public areas. For example people value the ability for all people to access and enjoy the area.
- **recreational values** associated with an enjoyable environment for all users, visitors and local residents. For example people value being able to undertake various recreational activities in public places, both on land and on the estuary. The attraction of Clontarf/Bantry Bay is enhanced by its generally good water quality. This results in numerous primary and secondary contact recreational pursuits, including swimming, sailing, kayaking, diving, sail boarding, kite-surfing, water skiing and boat and shore fishing. The foreshores

around are also used for numerous recreational pursuits, including walking / jogging, dog exercise, bird watching, scenic enjoyment / nature appreciation and picnicking.

- **lifestyle values** associated with a safe environment. For example people value being able to enjoy the area knowing that it is safe and will not affect their health
- **values associated with effectively maintained infrastructure and services**. For example people identify that well maintained facilities and services contribute to the experience of the area.
- **community involvement values** associated with appropriate consultation. That is, people recognise the area as public land for the enjoyment of the local community and visitors and value being able to provide input into the future direction and management of the area.
- **Economic values** associated with a number of economic activities**.** The area is important to a range of stakeholders, ranging from local retailers to commercial tourism operators, boating services, marinas and support industries. Commercial fishing had been one of the key economic activities of the study area but has remained banned since October 2006. However, recreation fishing is allowed with some restrictions. NSW Fisheries has carried out a recreational fishing survey of NSW (NSW Fisheries, 2002), which indicates that there are almost half a million recreational anglers in Sydney, many of whom would utilise this estuary from time to time. Total expenditure of Sydney recreational anglers could be in the order of $150 - $250 million per year. Manly is a visitor's destination in Australia and attracts approximately 6 million visitors per year. It has very positive impact on local economy. Recently, attention has been drawn towards ecotourism to market natural, heritage and cultural showcases existing in Manly and selling 'Manly – more than a beach'. The Clontarf/Bantry Bay area offers many opportunities.

10. DATA GAPS & FURTHER STUDIES REQUIRED

Various gaps in available data were uncovered through the community consultation that was undertaken for the Clontarf / Bantry Bay Estuary Management Planning process, and the research and preparation of this document. Issues were identified through the community consultation, and then data relating to each issue was sought. The data gaps where sufficient information was not available are listed below and prioritised as presented, along with the suggested method of obtaining the data. This prioritisation is also based on considered implementability within the available time period.

10.1 SEDIMENT BUDGET & MOVEMENT

The broad issue of sediment movement (both erosion and accretion) in the Castle Rock Beach to Spit Bridge section of the study area is a significant issue according to the results of community consultation and findings of this study. Individual issue such as beach erosion has been identified, and, according to some limited research that was undertaken in the early 1980s for Clontarf Marina, it is likely that sediment processes throughout this area are linked.

Hence, a comprehensive study of the entire system needs to take place, to understand the sediment budget and movement throughout the lower reaches of the Middle Harbour estuary. DECC (formally DNR) have agreed to undertake photogrammetry and if required, additional hydro survey of the study area. This data will then need be assessed to improve the understanding of sedimentary processes.

As these surveys are yet to start, it is likely that any results will be used to inform the management of the study area once they are finalised. Hence, the following sections in this report will be based initially on the limited information available from the Clontarf Marina report, but will be considered as 'draft' until the results of the surveys can verify (or otherwise) the information presented.

- 4.7 Sediment Budget & Movement
- 6.1 Foreshore Development
- 6.5 The Hazards of Climate Change

It must be noted that the results of the surveys may possibly also affect other sections of this report, depending on the results obtained.

10.2 WATER QUALITY

There is a lack of data available on water quality within Middle Harbour and the study area. Modelled stormwater pollutant loads have provided an insight into the likely pollutant contribution of the study area catchments, and Harbour watch data has provided information on bacterial pollution within the estuary. However, this is the extent of the data currently available.

It would be useful to calibrate the modelled pollutant loads from the study area catchments by undertaking stormwater quality monitoring at key locations, to provide more certainty as to the pollutants of concern. It would also be useful to undertake more comprehensive water quality monitoring within the estuary itself (i.e. - other than just bacteria), to determine the end result of the cumulative impact of all pollutant sources, and the health of the estuary. Water quality monitoring should be done in collaboration with adjoining councils.

One of the most important aspects would actually be to monitor condition indicators to actually understand the 'health' of the system, pressure indicators such as pollutant loads do not necessarily have a direct relationship with condition and are not often good surrogates.

10.3 SLOPE, CLIFF AND SEAWALL STABILITY

Investigation into the risks posed by slope and cliff instability within the study area needs to be undertaken by a qualified geotechnical expert. It is recommended that a geotechnical study be undertaken around the entire

study area foreshore, identifying the high, medium and low risk hazards, with provision of design and cost estimates for remediation of high risk hazards.

It is also recommended that suitably qualified engineers be engaged to investigate the stability of the seawalls within the study area, with particular emphasis on those below The Spit, where properties are subject to ocean swell waves and storm activity. Investigation should look at the construction, condition, and future stability of each wall, and include both visual observation and excavation of test pits at the base of each. Issues of seawalls on private property would have to be resolved to determine if these should be included in any investigation.

10.4 GROUNDWATER EXTRACTION AT CLONTARF

Many private properties along the beachfront at Clontarf display signs indicating that they are extracting groundwater for residential irrigation purposes. Manly Council is also extracting groundwater for irrigation of Clontarf Reserve. It was found from a sample that six out of the seventeen private properties did not have the appropriate licence (personal communication with Wayne Connors, NSW Department of Water & Energy) to extract groundwater.

Research needs to be undertaken to determine exactly how many properties are extracting groundwater (preferably throughout the entire study area), and the quantities that are being extracted. Further investigation then needs to be undertaken, in conjunction with DECC, to measure recharge rates of the aquifer at Clontarf (and potentially other areas, if required), to determine if the current yields are sustainable. Once the sustainability of the current situation is determined, DECC should be approached to take appropriate actions to resolve licensing issues.

10.5 LOSS OF SEAGRASS AT CASTLE ROCK BEACH & CLONTARF

Community consultation and previous seagrass studies indicate that there has been a significant loss of seagrass at both Castle Rock and Clontarf. The extent of seagrass loss, and reason for the loss, needs to be determined, and so appropriate management options can be formulated. Further insight may be gleaned from analysis of historical aerial photos.

10.6 LITTLE PENGUINS IN MIDDLE HARBOUR

As noted in section 5.2.2 it is unknown whether the Little Penguins that are sighted in Middle Harbour are from the Endangered North Head population, or whether they are from a separate population nesting in Middle Harbour. Anecdotal evidence has suggested that there may be Penguins nesting under the Spit Bridge, although this has not been confirmed. Research needs to be undertaken to establish where the Middle Harbour Penguins are nesting, as any nests in the area may need protecting. This should be followed up with the National Parks and Wildlife Section of the Department of Environment and Climate Change.

10.7 CLIMATE CHANGE

The predicted effects of climate change on a regional level are now relatively well understood (although still with large ranges in predicted impacts). However, the impacts on specific localities are generally not yet well documented. This is the case for the Clontarf / Bantry Bay study area. GIS programs can be used to model outcomes such as the landward extent of various sea level rise scenarios. Regional predictions will provide broad understanding of the impacts, but models for specific localities will need to be generated to effectively manage climate change at a local level. It is recommended that such modelling takes place for the Clontarf / Bantry Bay study area, so that the impacts can be better estimated, and appropriate management options can be identified.

11. REFERENCES

- Aboriginal Heritage Office, *Aboriginal Heritage*, online, cited 11/01/07, www.Aboriginalheritage.org
- Afferent Media, *Balgowlah Online*, online, cited 12/10/06, www.balgowlahonline.com.au
- Australian Greenhouse Office, *Living With Climate Change: An Overview of Potential Climate Change Impacts on Australia*, online, cited 6/2/07, www.greenhouse.gov.au/impacts/overview/index.html
- Australian Museum, *Full Fact Sheet List*, online, cited 16/01/07, www.amonline.net.au/factsheets/
- Australian Museum Business Services, 2002, *Port Survey for Introduced Marine Species – Sydney Harbour: Final Report*, Sydney Ports Corporation, Sydney
- Birch, Gavin & Taylor, Stuart, 2004, *The Contaminant Status of Sydney Harbour Sediments: A Handbook for the Public and Professionals*, Geological Society of Australia, Sydney
- Braithwaite, David, 02/04/2007, *Sydney All Clear After Tsunami Warning,* Sydney Morning Herald
- Broadleaf Capital International, Marsden Jacob Associates, 2006, *Climate Change Impacts & Risk Management: A guide for Business and Government*, Australian Greenhouse Office, Department of Environment and Heritage, Australian Government, Canberra
- Bryant, Edward, 1980, *Bathymetric Changes in Three Estuaries of the Central New South Wales Coast*, Australian Journal of Marine and Freshwater Research, 1980, 31: 553-571
- Bulleri, F., Chapman, M. G. and Underwood, A. J. 2005, *Intertidal assemblages on seawalls and vertical rocky shores in Sydney Harbour, Australia.* Austral Ecology (2005) 30, 655–667)
- Burns, Cassie & Davey, Greg, *Fishnote – Salt marsh*, online, cited 31/01/2007, www.fisheries.nsw.gov.au/__data/assets/pdf_file/5046/Saltmarsh-Fishnote-dec11.pdf
- Champion, G & S, 2006, *North Shore to Manly*, unpublished monograph
- Chapman, M.G. & F. Bulleri, 2003, *Intertidal seawalls: new features of landscape in intertidal environments.* Landscape and Urban Planning, Vol. 62, pp. 159-172
- Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management, *Estuary Assessment Framework for Non-Pristine Estuaries – Estuary 37 (Port Jackson),* online, cited 14/09/06, http://dbforms.ga.gov.au/pls/www/npm.ozest.show_mm?pBlobno=9071#search=%22estuary%20assessment%20framework%20for%20non-pristine%20estuaries%20port%20jackson%22
- CSIRO, 2006. *Climate change scenarios for initial assessment of risk in accordance with risk management guidance.* Prepared for Australian Greenhouse Office, May 2006.
- Edgar, Graham, 2001, *Australian Marine Habitats in Temperate Waters*, Reed New Holland, Sydney
- EMA. Disaster Database, cited 05/07/07 http://www.crimeprevention.gov.au/ema/emadisasters.nsf/54273a46a9c753b3ca256d0900180220/0b687e7e25f2a345ca256d3300057d0c?OpenDocument
- Foster, D. N.; Gordon A.D & N. V. Lawson. 1975. *The Storms of May-June 1974, Sydney, N.S.W.* Paper presented at the 2nd Australian Conference on Coastal & Ocean Engineering, 1-11pp.
- Frew, Wendy, 30/10/2006, *Sydney's Vanishing Future*, Sydney Morning Herald

- GHD, 2003, *Proposed Widening of the Spit Bridge over Middle Harbour: Statement of Environmental Effects / Review of Environmental Factors*, NSW Roads and Traffic Authority, Sydney

- GSE, 1990, *Clontarf Marine Services Marina Extension Environmental Impact Statement*, Clontarf Marine Services, Graduate School of the Environment, Macquarie University.

- Gray, C.A., McElligott, D.J., Chick, R.C., 1996. *Intra- and interestuary differences in assemblages of fishes associated with shallow seagrass and bare sand.* Journal of Marine and Freshwater Research 47, 723-735.

- Harris, Peter, & O'Brien, Phil, 1998, *Australian Ports – Environmental Data & Risk Analysis Phase 1: Literature Review*, Australian Quarantine Inspection Service, Canberra

- Henderson, C W T, date indecipherable, Harbour Havoc when Gale Hit, *The Manly Daily,* date & page number unknown

- Hennessy, Kevin, Macadam, Ian, Whetton, Penny, CSIRO Marine & Atmospheric Research, 2006, *Climate Change Scenarios for Initial Assessment of Risk in Accordance with Risk Management Guidance*, Australian Greenhouse Office, Department of Environment and Heritage, Australian Government, Canberra

- Intergovernmental Panel on Climate Change, *Climate Change 2007: The Physical Science Basis - Summary for Policymakers*, online, cited 5/2/07, www.ipcc.ch/SPM2feb07.pdf

- Kennedy, David, 2002, *Estuarine Beach Morphology in Microtidal Middle Harbour, Sydney*, Australian Geographical Studies 40(2): 231-240

- Lafferty, K.D. 2001. Disturbance to Wintering Western Snowy Plovers. Biological Conservation 101:315-325.

- Lau, Connie, 2006, *Subregional Planning (presentation)*, unpublished

- Lawson and Treloar, 2003, *Pittwater Estuary Process Study*, Lawson and Treloar, Gordon

- Lord, Doug, Watson, Phil, Coates, Bruce, Hanslow, David, 2006, *Coastal Zone Management Planning under the New South Wales Coastal Protection Act (1979)*, Proceedings from NSW Coastal Conference 2006, Coffs Harbour

- Lynch, Peter, Burchmore, Jenny, NSW Department of Primary Industries, *Fishcare – Our Mangrove Forests*, online, cited 13/07/06, www.fisheries.nsw.gov.au/aquatic_habitats/aquatic_habitats/fishcare_-_our_mangrove_forests

- Lynch, Peter, Burchmore, Jenny, Johnson, Tom, NSW Department of Primary Industries, *Fishcare - Saving Our Seagrasses Fishnote DF/29*, online, cited 13/07/06, www.fisheries.nsw.gov.au/aquatic_habitats/aquatic_habitats/fishcare_-_saving_our_seagrasses_fishnote

- Manly Council, 1988, *Manly Local Environment Plan*, Manly Council

- Manly Council, 1998, *Manly Scenic Walkway Plan of Management*, Manly Council

- Manly Council, 2001, *2001 Census Analysis for the Manly Local Government Area*, Manly Council

- Manly Council, 2002, *Manly's Sustainability Strategy: Blueprint for the Future*, Manly Council

- Manly Council, 2004, *Plans of Management for Seaforth Oval, Keirle Park and Tania Park*, Corporate Planning & Strategy Division, Manly Council

- Manly Council, 2006, *Bushland News – February 2006*, Manly Council, Manly
- Manly Council, 2006, *Surfing the Future: A Vision for the Manly Local Government Area for 2025*, Manly Council, Manly
- Manly Council, 2006, *Unmade Road Reserves in Manly: Summary – Ecological Importance*, Manly Council, Manly
- Manly Council, 2007, *LEP, DCP's + Policies*, online, cited 08/01/2007, www.manly.nsw.gov.au/sp/PlanningDocs.aspx?PageID=518
- Manly Council, *Manly Council – Regional Significance*, online, cited 05/10/2006, http://www.manly.nsw.gov.au/Regional-Significance.html
- Manly Council, year unknown, *It's all About Dogs* (brochure), Manly Council, Manly
- Manly Council, year unknown, *Native Plant Guide – Manly Coastal*, Manly Council, Manly
- Manly Council, year unknown, *Potentially Contaminated Sites Register*, Manly Council, Manly
- Manly Council Scientific Advisory Panel, 2005, *The Enhanced Greenhouse Effect: Local Climate Change in the 21st Century*, Manly Council, Manly
- Manly Hydraulics Laboratory, *New South Wales Tide Glossary*, online, cited 17/10/2006, http://www.mhl.nsw.gov.au/www/tide_glossary.htmlx#SEM
- Martin, Bob, Minister for Mineral Resources and Minister for Fisheries, 1996, Letter to Dr Peter Macdonald, Member for Manly
- McAteer, John, 2006, *Seaforth Moth Sailing Club*, unpublished
- Mcgill, Craig, *Sydney's Middle Harbour*, online, cited 04/10/06, www.fishnet.com.au/default.aspx?id=234&articleId=3856
- McIntosh, Edgar, 1988, *Recollections by Former Manly Municipal Engineer*, online, cited 5/2/07, www.manly.nsw.gov.au/Recollections---Reminiscences-about-Manly.html
- McLoughlin, Lynette, 2000, *Shaping Sydney Harbour: sedimentation, dredging and reclamation 1788-1990's,* Australian geographer, 31(2): 183-208
- Middle Harbour Catchment Management Committee, 1996, *Middle Harbour Catchment Management Committee: Strategic Plan*, Middle Harbour Catchment Management Committee
- Moreira, J. 2006, *Patterns of occurrence of grazing molluscs on sandstone and concrete seawalls in Sydney Harbour (Australia)*. Molluscan Research 26(1):51-60)
- Natural Resource Management Ministerial Council, 2006, *National Cooperative Approach to Integrated Coastal Zone Management – Framework and Implementation Plan*, Australian Government, Department of Environment and Heritage, Canberra
- Noxious Weeds Committee – Sydney North, *Stop the Spread – Noxious Weeds are Spoiling our Environment* (brochure), Noxious Weeds Committee – Sydney North
- NSW Department of Environment & Conservation, *Beachwatch & Harbour watch State of the Beaches 2005-2006*, online, cited 03/01/07, www.environment.nsw.gov.au/beach/ar2006/

- NSW Department of Environment & Conservation, *Nature and Conservation*, online, cited 2/2/07, www.nationalparks.nsw.gov.au/npws.nsf/content/wildife+corridors

- NSW Department of Infrastructure, Planning & Natural Resources, 2005, *Sydney Harbour Catchment: Sydney Regional Environment Plan*, NSW Government Department of Infrastructure, Planning & Natural Resources

- NSW Department of Infrastructure, Planning & Natural Resources, 2005, *Sydney Harbour Foreshores and Waterways Area: Development Control Plan*, NSW Department of Infrastructure, Planning & Natural Resources

- NSW Department of Infrastructure, Planning & Natural Resources and Waterways Authority, 2004, *Boat Storage Policy for Sydney Harbour*, Department of Infrastructure, Planning and Natural Resources, Sydney

- NSW Department of Natural Resources, *Accessing Bore Water / Groundwater*, online, cited 06/12/06, www.dnr.nsw.gov.au/water/pdf/bore_drilling_factsheet.pdf

- NSW Department of Natural Resources, Annual Report 2005-06, Coastal & Floodplain Management, online, cited 01/05/07, http://www.dnr.nsw.gov.au/aboutus/pdf/coast_floodplains.pdf

- NSW Department of Natural Resources, *Acid Sulphate Soil*, online, cited 05/10/06, http://www.dnr.nsw.gov.au/soils/sulfate.shtml

- NSW Department of Natural Resources, *Estuaries in NSW*, online, cited 11/09/06, www.dnr.nsw.gov.au/estuaries

- NSW Department of Primary Industries, *Caulerpa taxifolia*, online, cited 13/07/06, www.fisheries.nsw.gov.au/threatened_species/general/content/fn_caulerpa1.htm

- NSW Department of Primary Industries, *Estuarine Habitats*, online, cited 13/07/06, www.fisheries.nsw.gov.au/aquatic_habitats/estuarine

- NSW Department of Primary Industries, *Fish Habitat Protection Plan No 2: Seagrasses*, online, cited 15/01/07, www.fisheries.nsw.gov.au/__data/assets/pdf_file/5050/protplan_2.pdf

- NSW Department of Primary Industries, *Fishing in Sydney Harbour*, online, cited 15/2/07, www.dpi.nsw.gov.au/fisheries/sydney-harbour-closure

- NSW Department of Primary Industries, *Intertidal Protected Areas*, online, cited 14/09/06, www.fisheries.nsw.gov.au/marine_protected_areas/ipa

- NSW Department of Primary Industries, *Pacific Oyster – Crassostrea gigas*, online, cited 26/07/06, www.fisheries.nsw.gov.au/threatened_species/general/content/fn_pacific_oyster.htm

- NSW Department of Primary Industries, *Policy & Guidelines - Aquatic Habitat Management and Fish Conservation 1999 Update*, online, cited 14/09/06, www.fisheries.nsw.gov.au/aquatic_habitats/aquatic_habitats/policy__and__guidelines

- NSW Department of Primary Industries, Recreational Fishing, online, cited 19/2/07, http://www.fisheries.nsw.gov.au/recreational

- NSW Fisheries, 2004, *NSW Control Plan for the noxious marine weed Caulerpa taxifolia in NSW Waters*, NSW Fisheries

- NSW Government, 1992, *Estuary Management Manual*, NSW Government

- NSW Maritime, 2006, *Moorings in the Manly LGA*, unpublished
- NSW Maritime, *Boating Handbook*, online, cited 2/1/2007, www.maritime.nsw.gov.au/sbh.html
- NSW Maritime, *Boating Map For Port Jackson – Sydney, Middle And North Harbours*, online, cited 14/09/06, www.maritime.nsw.gov.au/maps.html#sydney
- NSW National Parks & Wildlife Service, 1998, *Garigal National Park Plan of Management*, NSW National Parks & Wildlife Service, Sydney
- NSW National Parks & Wildlife Service, 1998, *Sydney Harbour National Park Plan of Management*, NSW National Parks & Wildlife Service, Sydney
- OzEstuaries, *Beach & Dune Indicators*, online, cited 6/2/07, www.ozestuaries.org/oracle/ozestuaries/indicators/In_beach_dune_area_f.html
- OzEstuaries, *Benthic Invertebrates,* online, cited 14/09/06, www.ozestuaries.org/indicators/benthic_inverts.jsp
- OzEstuaries, *Glossary of Terms*, online, cited 21/12/06, www.ozestuaries.org/glossary.jsp
- OzEstuaries, *Port Jackson*, online, cited 28/06/06, www.dbforms.ga.gov.au/pls/www/npm.ozest.report
- Parliamentary Counsel's Office, 2007, *State Environmental Planning Policy No 19—Bushland in Urban Areas*, online, cited 5/2/2007, www.legislation.nsw.gov.au/viewtop/inforce/epi+014+1986+FIRST+0+N/?fullquery=(((%22state%22%20AND%20%22environmental%22%20AND%20%22planning%22%20AND%20%22policy%22)))
- Patterson Britton & Partners Pty Ltd, 1999, *Northern Beaches Stormwater Management Plan*, Northern Beaches Stormwater Management Plan Committee, Sydney
- Patterson, Britton & Partners, 2004, *Davis Marina to Manly Point Coastline Hazard Definition Study*, Manly Council, Manly
- Piorewicz, Jurek, *Proceedings of the Public Workshop "Beach protection: risk and management"*, Yeppoon, 7 February 2002, online, cited 7/2/07, www.coastal.crc.org.au/pdf/beach_protection_yeppoon_feb02.pdf
- Pittock, Barrie, 2003, *Climate Change: An Australian Guide to the Science and Potential Impacts*, Australian Greenhouse Office, Canberra
- Richards, Russell, Scheltinga, David, Barchiesi, Donna, 2006, *Local Government Authority NRM Information Fact sheets*, Cooperative Research Centre for Coastal Zone, Estuary & Waterway Management, Queensland
- Ryan, D., Brooke, B., Bostock, H., Smith, J., Buchanan, C., and Skene, D., 2006, *Report on sediment characteristics, sub-bottom profiles, backscatter data and seabed morphological classification*, Coastal CRC Coastal Water Habitat Mapping Project, Milestone CG 6.01, 71 pp.
- Ryan, David, Heap, Andrew, Radke, Lynda & Heggie, David, 2003, *Conceptual Models Of Australia's Estuaries And Coastal Waterways: Applications For Coastal Resource Management*, Geoscience Australia, ACT
- Sharpe, Alan, 2004, *Pictorial Memories – Manly to Palm Beach*, Kingsclear Books, Alexandria
- Skelton, Nick, Donner, Erica & Wong, Purdey, 2004, *Flora and Fauna of Manly Council's Bushland Reserves*, GIS Environmental Consultants

- Skelton, Nick, Gilson, Tony & Donner, Erica, 2002, *Stormwater Impact on Manly Bushland Reserves*, GIS Environmental Consultants, North Curl Curl

- Smith, Tim, 2001, *Australian Estuaries : a framework for management*, Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management, Queensland

- SCCG, 2006. Sydney Coastal Councils Region Groundwater Management Handbook - A Guide for Local Government. First Edition. Sydney Coastal Councils Group and Groundwater Working Group. Sydney, September.

- Sydney Fish Finder, *Sydney Fish Finder Forum*, online, cited 15/2/07, www.sydneyfishfinder.com.au/sffforum

- Sydney Harbour Federation Trust, 2004, *Phytophthora & Vegetation Dieback in Sydney Harbour's Bushland* (brochure), Sydney Harbour Federation Trust, Sydney

- Sydney Water, 2005, *Environmental Indicators Compliance Report (volume 1-2) – Sydney Water Annual Report 2005*, Sydney Water, Sydney

- Taylor, S, Birch, G, Links, F, 2004, *Historical Catchment Changes and Temporal Impact on Sediment of the Receiving Basin, Port Jackson, New South Wales*, Australian Journal of Earth Sciences, 51:233-246

- The Ecology Lab Pty Ltd, 2002, *Aquatic Habitats in the Vicinity of Clontarf Marina – Ecological Audit, 2002*, Clontarf Marina, Clontarf

- Thomas, K. R.G. Kvitek, and C. Bretz. 2003. Effects of Human Activity on the Foraging Behaviour of Sanderlings (*Calidris alba*). Biological Conservation 109:67-71.

- Turner, Lynne, Tracey, Dieter, Tilden, Jan, Dennison, William, 2004, *Where River Meets Sea: Exploring Australia's Estuaries*, Cooperative Research Centre for Coastal Zone, Estuary & Waterway Management, Queensland

- Underwater Research Group, *Research & the URG*, online, cited 19/01/07, www.urgdiveclub.org.au

- University of Western Sydney, 2005, *Sustainable Coastal Tourism for Manly,* Tourism Research for Healthy Futures for Manly Council.

- West, G., Williams, R., & Laird, R., 2004, *Distribution of Estuarine Vegetation in the Parramatta River and Sydney Harbour, 2000*, NSW Department of Primary Industries, Nelson Bay

- West, R.J., King, R.J., 1996. *Marine, brackish, and freshwater fish communities in the vegetated and bare shallows of an Australian coastal river*. Estuaries 19, 31-41.

- Willing & Partners, 1999, *Middle Harbour Catchment Stormwater Management Plan*, Middle Harbour Stormwater Management Committee, Sydney

12. GLOSSARY

Sources:
[1] = Australian Government, Department of Environment & Heritage, 2007
[2] = OzEstuaries, 2006
[3] = Department of Environment & Climate Change, 2007

Accretion[2]	When average (small) swell waves deliver sediment back to the shoreline
Aeolian[2]	The erosion, transport, and deposition of material by wind, and work best when vegetation cover is sparse, or absent.
Benthic[2]	Pertaining to the seafloor (or bottom) of a river, coastal waterway, or ocean.
Catchment[2]	The area of land which collects and transfers rainwater into a waterway.
Corridor[3]	Lines of native vegetation connecting separate habitat areas that are essential for maintaining biodiversity. Corridors enable fauna to access larger habitats by encouraging mobility between areas. Corridors may also assist native plant species to spread and colonise new areas over time.
Diffraction[1]	The "spreading" of waves into the lee of obstacles such as breakwaters by the transfer of wave energy along wave crests. Diffracted waves are lower in height than the incident waves.
Estuary (definition 1)[3]	The tidal portions of river mouths, bays and coastal lagoons, irrespective of whether they are dominated by hyper saline, marine or fresh water conditions
Estuary (definition 2) [3]	a semi enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage
Fetch[2]	The horizontal distance over which a wind blows in generating waves.
Flushing[2]	Exchange of water between an estuary or coastal waterway and the ocean.
Intertidal[2]	The environment between the level of high tide and low tide.
Mud[2]	Fine sedimentary material, typically comprising both inorganic (mineral) and organic material.
Organic Material[2]	Once-living material (typically with high carbon content), mostly of plant origin.
Refraction[1]	The tendency of wave crests to become parallel to bottom contours as waves move into shallower waters. This effect is caused by the shoaling process which slows down waves in shallower waters.
Seagrass[2]	Marine flowering plants which generally attach to the substrate with roots.
Seawalls[1]	Walls built parallel to the shoreline to limit shoreline recession.
Sediment Budget[1]	An accounting of the rate of sediment supply from all sources (credits) and the rate of sediment loss to all sinks (debits) from an area of coastline to obtain the net sediment supply/loss.
Semi-diurnal Tide[1]	Tides with a period, or time interval between two successive high or low waters, of about 12.5 hours. Tides along the New South Wales coast are semi-diurnal.
Shoreline Recession[1]	A net long term landward movement of the shoreline caused by a net loss in the sediment budget.
Spring Tide[2]	A tide greater than the mean tidal range. Occurs about every two weeks, when the Moon is full or new.
Storm Surge[1]	The increase in coastal water level caused by the effects of storms. Storm surge consists of two components: the increase in water level caused by the reduction in barometric pressure (barometric setup) and the increase in water level caused by the action of wind blowing over the sea surface (wind setup).
Swell Waves[1]	Wind waves remote from the area of generation (fetch) having a uniform and orderly appearance characterised by regularly spaced wave crests.
Turbidity[2]	The condition resulting from the presence of suspended particles in the water column which attenuate or reduce light penetration.
Wave Height[1]	The vertical distance between a wave trough and a wave crest.
Wind Waves[1]	The waves initially formed by the action of wind blowing over the sea surface. Wind waves are characterised by a range of heights, periods and wavelengths. As they leave the area of generation (fetch), wind waves develop a more ordered and uniform appearance and are referred to as swell or swell waves.