Consultants Report for Teal Lagoon, Boyter's Lane, Jerseyville NSW

2011

Prepared for Kempsey Shire Council

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THE AUSTRALIAN NATIONAL UNIVERSITY

Contents

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2. Terms of Reference

The purpose of this audit was to undertake a comprehensive assessment of Teal Lagoon; by examining both water chemistry and ecological status either side of the berm against a set of criteria. This study may be used to aid in decisions for the best course of action for Teal Lagoon; regarding a prior set of three options. These options were: 1 Leave the berm as it is; 2 Fix the berm seepage and clean pipes; 3 remove the berm.

3. Executive Summary

A study was undertaken at Teal Lagoon, Jerseyville NSW on behalf of Kempsey Shire Council to investigate management options regarding an existing berm at the site.

The study site has been under the ownership of Kempsey Shire Council since 2002 and was to be used for development of playing fields. Plans to develop the site failed after the site was deemed unsuitable.

Council is now in a position where it owns land inhabited by threatened bird species and several ecological communities but is unable to utilise the area. The diverse birdlife results from the presence of the berm which allows a permanent, shallow lagoon to exist which they can utilise for wading and foraging.

In response to a proposal for an educational learning facility, a walking track has been marked around the land. Apart from this, the current management of the area is relatively stagnant and much of the vegetation and wildlife has been left to develop naturally.

Currently Kempsey Shire Council has a set of management goals for Teal Lagoon; these include:

1. Maintaining a healthy ecosystem for the public and wildlife's wellbeing;
2. Protecting endangered fauna and flora within the Teal Lagoon area; and
3. Providing an educational and recreational area for the members of the public.

Our study provides recommendations for three management options:

- Keep the berm at the site in its current state
- Keep the berm at the site but repair leaks and remove blockages from pipes
- Remove the berm

Each management option has a number of positive and negative for flora, fauna and water quality.

Keeping or repairing the berm would maintain a permanent water body to ensure birds continue to use the system although this may be detrimental for some aspects of water quality. It would also ensure that the small area of salt marsh existing at the site is conserved.

Removing the berm is likely to improve some aspects of water quality and encourage the development of extensive mudflats which will see increases in mangroves and make the site inaccessible in regards to development of a walkway, use for public education and bird watching. Removal of the berm would make the system closer to its natural state prior to human management.

Each of the three management options are feasible but ultimately the suitability is dependent upon which of the management goals are considered to be most valuable.

4. Introduction

4.1 Study Region

The study area is located approximately 450km north of Sydney on the edge of the township of Jerseyville (see Figure 1). It is part of the Macleay River system and lies within the boundaries of the Kempsey Shire (see Figure 2).

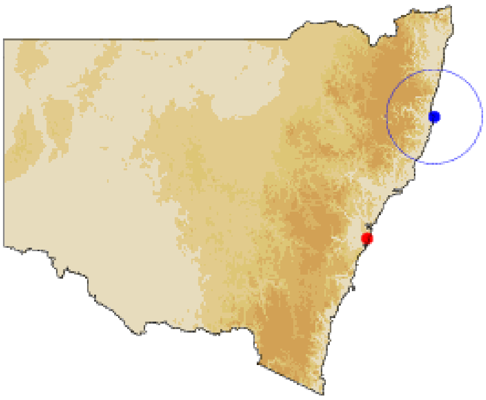

Figure 1 – The location of the study site in relation to New South Wales (BOM 2011)

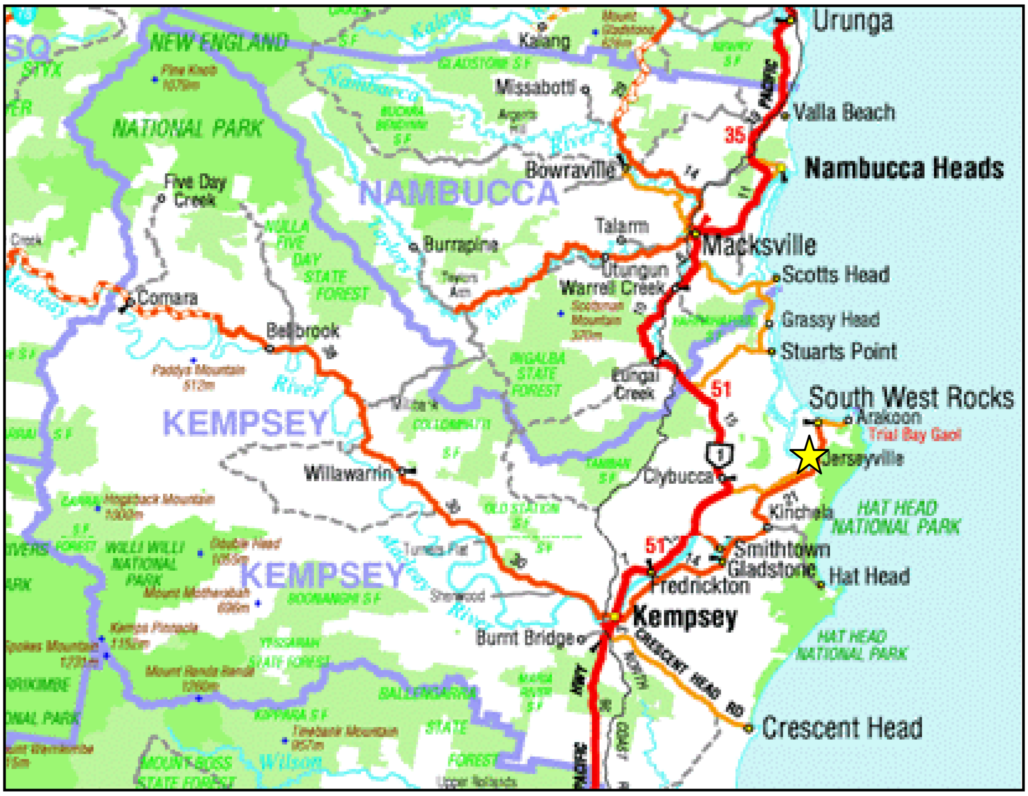

Figure 2 – Map of the area consisting of Kempsey Shire Council. The yellow star marker shows approximate location of the study site (DLG 2010).

The Kempsey Shire is included in the Mid North Coast Region which is currently the most rapidly growing area of all non-metropolitan areas in New South Wales (KSC 2010).It has a population of nearly 30,000, of which 32% is under the age of 25 and only 16% is over the age of 65 (ABS 2010). The area is a popular tourist destination and industry such as production of beef, dairy, seafood, maize, horticulture and timber occurs in the region (KSC 2011; KSC 2010).

Granitoids, metasediments and basalt dominate the underlying geology of the region along with floodplain and estuary sediments (KSC 2011). Soils tend to have moderate to high erodibility in the Macleay River catchment (KSC 2011).

The climate is typical of a coastal site in the southern hemisphere as the region experiences warm summers and cool winters that do not have highly variable ranges due to the temperature regulating effect of the ocean. Precipitation is high averaging over 1200mm annually with the highest rainfall experienced during autumn months (BOM 2011; KSC 2011). Long term average temperatures and rainfall can be seen in Figure 3 which shows a climograph for Smoky Cape Lighthouse (the closest weather station to the study site).

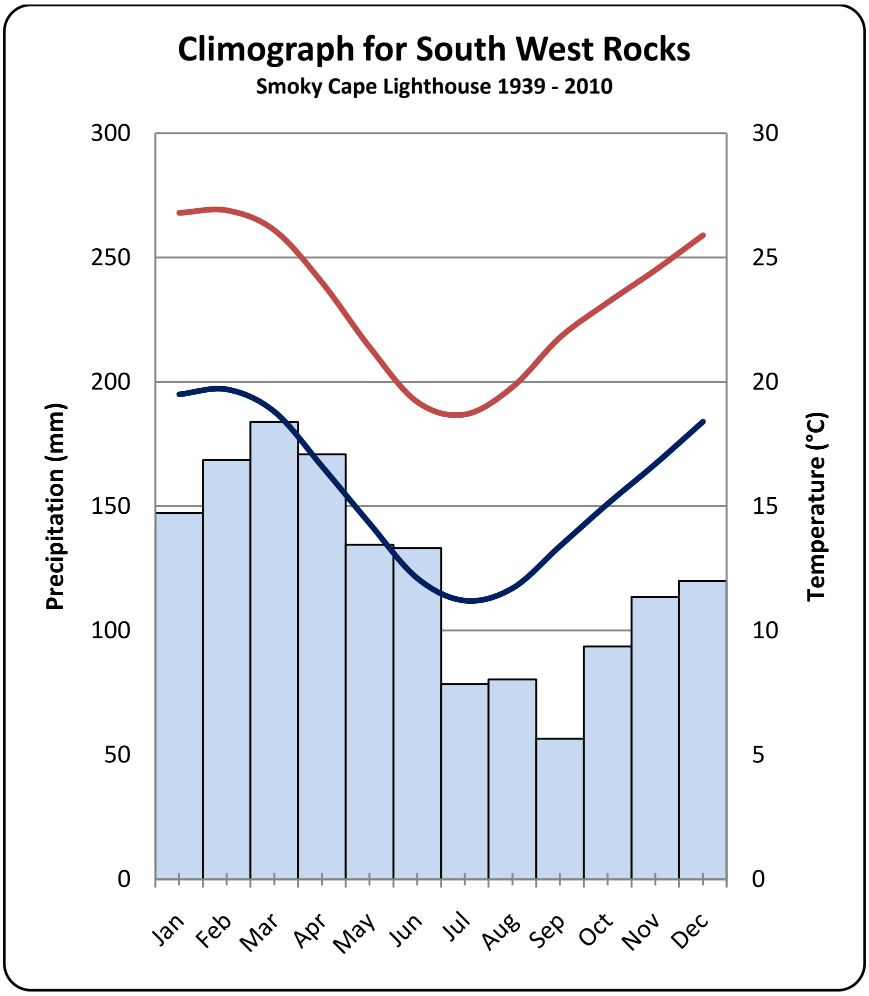

Figure 3 – Climograph for the study region (created from BOM 2011 data)

The region experienced above average rainfall for April 2011 during the period of study which can been seen in Figure 4 but there have been no significant climatic events in the region within the six months prior to the study being undertaken. The Macleay River was affected by flooding during May 2009, peaking at Kempsey at a height of seven metres on the 23rd of May 2009 (KSC 2011), but this is unlikely to have affected the results of the recent study.

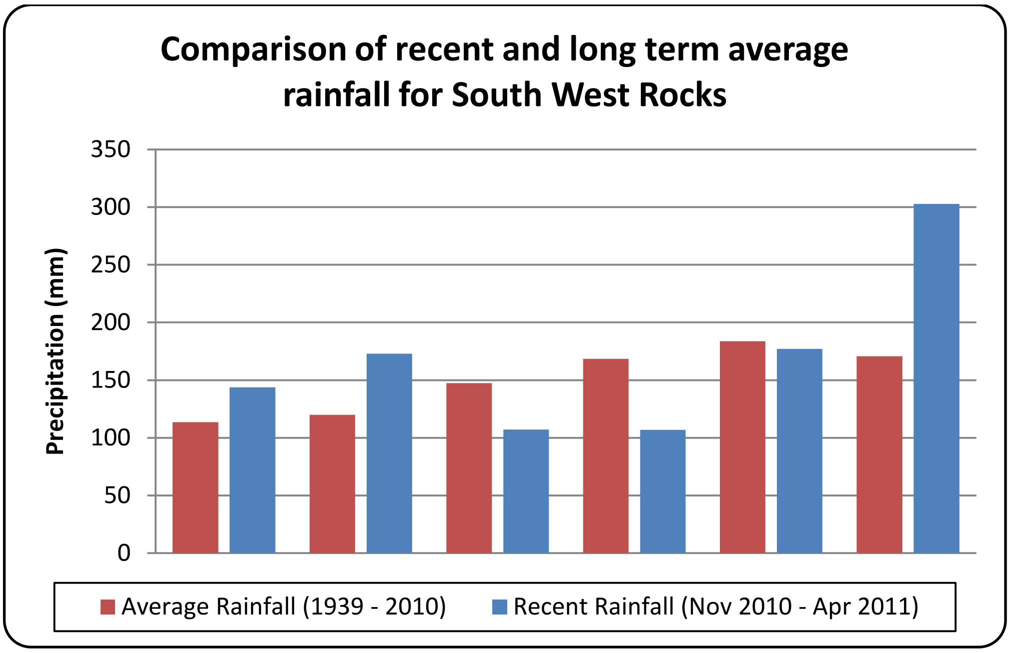

Figure 4 – A comparison of long rainfall averages and recent rainfall for the six months prior to the study being undertaken (created from BOM 2011 data)

Many important and vulnerable ecosystems exist within the Kempsey shire which include estuaries and coastal wetlands such as those at the study site (KSC 2010). Ten endangered ecological communities exist within the Kempsey Shire, including Coastal Saltmarsh while nearly 20% of the shire's fauna species are listed as threatened (KSC 2011).
Major issues being addressed by the Kempsey Shire Council that are occurring in the region surrounding the study site include (KSC 2011):

- reductions in water quality
- acid sulphate soils
- degradation of riparian and wetland zones
- urban stormwater
- threatened species and endangered ecological communities
- noise and air pollution
- erosion and sedimentation
- noxious weeds
- exotic species
- climate change

4.2 Coastal Wetlands

4.2.2 Coastal Wetlands

Teal Lagoon is classified as a coastal wetland. Coastal wetlands have many environmental values including groundwater recharge, water storage and flood mitigation, water filtration, shoreline stabilisation and storm protection, nutrient and sediment retention and export and tourism and recreational amenity (Greenway 2002). They are highly productive systems, centres of biodiversity and are important carbon sinks. Along with these physical characteristics is the cultural significance to indigenous peoples who have utilised them and celebrated their spiritual importance.

4.2.3 Coastal Wetlands in Australia

Wetlands provide habitats for many fish, crustaceans and molluscs, including species of commercial and recreational value, and therefore are critical to Australia's fishing industries. They are also important feeding, breeding and roosting areas for waterbirds, including migratory species, and refugia for inland species in times of drought. Coastal wetlands provide environments for important ecological communities such as endangered coastal salt marshes. The vegetation in coastal swamps and lagoons is dynamic and can change in response to seasonal fluctuations in water depth. Wetlands have been undergoing significant change since European arrival in Australia. Wetland loss and degradation has occurred mainly due to competing land uses and ignorance of wetland values (Ward et al. 1998).

Australia has 854 wetland sites that are protected the 1997 'Wetlands Policy of the Commonwealth of Australia'. Many NSW coastal wetlands are protected by law. The State Environment Planning Policy (SEAP) #14 protects and preserves these wetlands for environmental and economic interests through both local and state governments. Teal Lagoon is not classified as a SEAP 14 wetland.

4.3 Site Description

Teal Lagoon is located on Boyter's Lane about 3km south of the coastal town of South West Rocks, in the Kempsey shire region on the mid north coast of NSW. Teal Lagoon is one of three estuaries located on Spencers Creek a tributary of the Macleay River. Teal lagoon is a small, tidally influenced estuary of about 25.8ha in area (Berrigan 2008). The wetland lagoon is located on Lots 78, 79 and 802 of Boyter's Lane.

The landscape surrounding the wetlands and the wetlands themselves have been extensively altered. There is a berm across all three inlets which acts to reduce salt water influence within the fresh water lagoon. The berms are connected between the two water bodies through the use of 150mm PVC pipes for fresh water outflow located above the mean low tide height. These originally contained flap gates, however, the current condition of the pipes are blocked. Due to the deterioration of the wall, the lagoon is now tidally influenced through the leaking berm.

Berm Height	1.15 m AHD
Berm Width	~6m base; 3m top
Berm Length	40m
Pipe on Teal Lagoon Side	0.2 m AHD
Pipe of Creek Side	East pipe 0.16m AHD; West pipe 0.01m AHD
Approx Tidal Heights	0.97m AHD
Road Height	1.117m AHD

Figure 5: Characteristics of the berm and Teal Lagoon

The water in teal lagoon is a brackish mixture of freshwater inflow and saltwater and varies between 10-75cm depth (Sandpiper Environmental 2005). The berm acts to restrict water movement, which prevents the lagoon from fully draining at low tide. The surface area of the lagoon is 2.24ha with a strip of littoral habitat located in the centre (Berrigan 2008).

The modification of the site has had major impacts on the hydrology vegetation and habitats on the site. The environment within the lagoon differs from the estuarine habitat downstream. The site is made up of a number of habitats characterised by different hydrological features. Different tides lead to a variation in levels of inundation and water salinity. Environments present include mudflats, saltmarsh, and mangroves. No threatened flora or fauna listed under the *Fisheries Management (Amendments) Act 1997* occur on the site.

Vegetation consists mostly of salt marsh, pasture and grassland, mangroves, and small areas of swamp oak woodland. The area contains two endangered ecological communities. These consist of about 6.6ha of coastal saltmarsh in a good condition, and two small patches making up 2180m^2 of remnant swamp oak floodplain (Berrigan 2008).

The adjacent fresh water body extending into private land consists mostly of weeds and pasture grasses. This fresh water body is hydrologically separate from Teal Lagoon (Sandpiper Environmental 2005). The topography and the disturbance patterns in the area suggest freshwater to the south may have been created by blocking tidal inflow.

The Teal Lagoon wetlands are one of the many important wetlands in the Macleay region. There has been widespread drainage and removal of wetlands from the area over time, making teal Lagoon an important habitat refuge for fauna particularly during dry periods. The large area of permanent brackish water has led to an increase in bird species. Over the past 12 years, 143 species of birds have been identified, 9 of which are listed under NSW TSC Act; and 47 migratory species under Commonwealth Environment Protection and Biodiversity Conservation (EPBC) Act 1999 (Berrigan 2008). Currently the major users of the site are local and regional ornithologists (Berrigan 2008).

The mangroves and mudflat make up 4ha of the site (Berrigan 2008). The mangroves mostly occur in the tidal channel and recent removal of grazing has led to the expansion of the mangrove dominated area. Currently there are some mangroves located within the lagoon concentrated towards the northern end, but still at low densities (<10%) (Walker et al. 2004).

4.4 Management of Teal Lagoon

4.4.1 Pre-settlement management

The Dunghutti people where the first to inhabit the Macleay area, although there is little information available to tell us about their management, if any, of the land at Boyter's Lane.

4.4.2 Pre-government management

With Europeans settling in Macleay from 1835 the landscape started to change. The area known today as Jerseyville, was acquired in 1869 by George Robinson, who later subdivided the land to form a town and run a river-boat service, commuting people between Kempsey and Spencer's Creek, adjacent to Boyter's Lane wetland (KSC 2011). During this time Boyter's Lane was transformed into a highly modified environment. Indigenous trees and vegetation were cleared to make way for dairy farming and beef cattle grazing. It is believed that dairy farming had ceased by the 1950's although many of the structures were left standing and grazing of beef cattle continued.

In the 1950's the farmer constructed a berm across all three inlets from Sullivan's creek. It is noteworthy to mention that some information indicates that is did not occur until the 1960's (Flanagan 2007). The blocking of tidal flow created what is now Teal Lagoon. This instantaneous separation from tidal flow changed the environment from an estuarine influenced system to a fresh or brackish system with limited tidal flux. This style of management resulted in a progressive change of both vegetation and wildlife, particularly in the dieback of mangroves. The berm was made from discarded rubble and of infill taken from a drain constructed at the same time to help remove water from the land for grazing purposes.

In the mid 1990's two PVC pipes (150mm) with small flap gates were installed, allowing water exchange to restore some of the tidal flow and clean up the brackish waters that developed. The flap gates were later damaged and the pipes have since blocked up, however regardless of the inefficient pipes the berm has recently deteriorated allowing tidal flow into the Lagoon.

It is also believed during this period of private ownership, fishing, crabbing and boating were popular in the lower river and Spencers Creek and that local fishers used to source green weed bait from Teal Lagoon (KSC 2011).

4.4.3 Government management

In 2002, Kempsey Shire agreed to purchase the privately owned farm land from the Boyter and the Salmon families of Pelican Island, known today as Boyter's Lane Wetland. This land was to be used for community development and was zoned as Rural 1(a1). This zoning allowed for the construction of playing fields, so long as they were in compliance with relevant zoning of the LEP. This includes conserving, protecting and developing the ascetics and the natural environmental of foreshore reserves. It also includes the development of the land for public recreation to satisfy community needs (Flanagan 2007).

Since the purchase of the property vegetation restoration has been implemented. In total 15,000 native trees, including endemic rainforest trees, small wetland plants and drought tolerant bushes, were planted to provide a suitable environment for wading birds. In June 2006 a buffer vegetation zone was planted between the proposed playing fields and the lagoon. This was to ensure the future impact of lights on invertebrate animal behaviour would not be disturbed. Mangroves were also removed to attract more birds, although they re-established in the mud flats on the estuary due to the combination of favourable tidal conditions and the removal of cattle (Ron Kemsley, per comm).

Between the proposed playing fields and the lagoon, two storm water ponds were constructed to catch runoff and pollutants from the playing fields. Utilizing the new vegetation to filter the water and prevent significant impact on the salt marsh and water communities of Teal Lagoon and estuary system.

With new bird life attracted to the area there was subsequently an increase of local and regional ornithologists. The Rotary club built a bird house, constructed from recycled materials of the old diary. Management of this area has resulted in frequent mowing from the road to the bird house for easy access.

While much work had been progressing to adhere to the environmental aspects of zoning, after a comprehensive assessment of the area, the site was declared a floodplain and deemed unfit for playing fields as it would experience recurring flooding. The council is now in a position where it owns land which contains a prolific bird watching sanction and several ecological communities but unable to utilise the area for its original purpose. They are now faced with a management issue of what to do with this land that now holds environmental implications, most importantly with protecting the established salt marsh community and protected wildlife such as the Grass Owl. There is also an obligation to honour the Japanese treaty in relation to migratory birds.

In response to a proposal for an educational learning facility, a walking track has been marked around the land and is occasionally mowed. Other than this, the current management of the area is fairly stagnant and much of the vegetation and wildlife has been left to develop naturally.

4.5 Current Management Goals.

Currently Kempsey Shire Council has a set of management goals for Teal Lagoon; these include:

- Maintaining a healthy ecosystem for the public and wildlife’s wellbeing;
- Protecting endangered fauna and flora within the Teal Lagoon area; and
- Providing an educational and recreational area for the members of the public.

5. Research

5.1 Flora of Teal Lagoon

5.1.1 Flora Surveys

Over three days in April 2011 a flora survey was completed. This included seven transects, with a $1m^2$ quadrant at every 10m interval. The seven sites where chosen to give a broad representation of the area across a range of vegetation habitats. The boundaries of major plant communities were also mapped to allow comparison to previous studies and aerial photography.

5.1.2 Flora Transects

Seven transects were used to observe the flora around Teal Lagoon (Appendix 1). All transects were done using a $1m^2$ quadrant at every 10m interval. All transect ran from the inside margin of the Mangroves to the planted buffer zone or until deemed adequate. From these dominate species; weed infestation and ground cover were obtained.

Distances from the tidal flow and soil composition seem to be a clear impact on plant habitats. The construction of the berm has altered this tidal effect within the lagoon. This lack of tidal influence may be the reason for the reduction in Mangrove and Salt marsh communities above the berm.

Transect 1, was on the Western side of Teal Lagoon upstream of the berm. It seemed to be a rather healthy site with a mixture of communities, with high ground cover and minimal weeds.

Transect 2, was on the Western side of Teal Lagoon upstream of the berm, near the bird hide. This area seemed to be less ‘natural’ with obvious signs of management such as mangrove removal and the man made storm water wetland at 16m. This area had a larger infestation of weeds, this may be due to the increased disturbance from management.

Transect 3, was on the Eastern side of Teal Lagoon, close to the berm. This area was a high point between two salt marsh areas; ones being affected by reduced tidal flow (above the berm) and the other below the berm. There was a lack of mangroves and the area between the two salt marsh communities had been mown allowing a large infestation of weeds.

Transect 4, was on the Eastern side of Teal Lagoon, opposite the bird hide. This area did contain Mangroves and Casuarina, however it was mainly older trees with all saplings being very small and therefore relatively young. This area contained a zone of planted species, however this area was highly infested with dense weeds. These weeds are starting to invade the more natural areas of the salt marsh, Casuarina and Mangroves; with one Casuarina already being killed by a vine.

Transect 5, was on the Western side of Teal Lagoon, downstream of the berm, near farmland. This area had a clear boundary of each major plant community (Mangroves, Salt Marsh and Kikuyu grassland. The mangroves showed evidence of colonising more area. As you increased the distance from the inside margin of the mangroves the age of the trees decreased, however density generally increased, showing relatively recent dispersion. The salt marsh was also relatively healthy with little weeds. Even the Kikuyu grassland contained little evidence of other weeds.

Transect 6, was on the Western side of Teal Lagoon, downstream of the berm, about halfway between berm and farmland. This area was very similar to transect 5. However, there seemed to be an increased growth in the mangroves from 20m to 30m, this area seemed to be the most productive for the mangroves with increased height and stem density. There was also a larger amount of weed in the Kikuyu grassland with some weeds starting to invade the salt marsh.

Transect 7, was on the Western side of Teal Lagoon, around 10m downstream of the berm. This area very similar to transects 5 and 6. However, it had a larger infestation of weeds, especially vines within the salt marsh and grassland.

It was noted that there was an obvious boundary between plant communities. This seemed to correlate with the distance from the tidal flow and soil composition. The construction of the berm has altered this tidal effect within the lagoon. This lack of tidal influence may be the reason for the reduction in Mangrove and Salt marsh communities above the berm. It was also noted where ever active management was undertaken such as mowing there was a considerable increase in weed infestation.

5.1.3 Major Plant Community Borders

Major plant community borders were recorded using GPS recorded points (Appendix 6). The purpose of this was to allow recording of plant communities in comparison to historical aerial photographs. Due to GPS accuracy error the points recorded was not useful. By comparing the historical aerial photos (Appendix 2, 3, 4) it is obvious there has been an increase of the mangrove area since the shire council started managing the area, especially below the berm, with limited mangrove regrowth above the berm in the lagoon. The most recent photo (2009) shows many small regrowth mangroves below the berm. Our onsite observations show that these areas have now become dense stands with an average height of 1.8m. As stated above the border of these communities seemed to be heavily correlated with tidal flow and soil composition; and any future management decisions regarding the berm may affect these boundaries, which is important especially for the ecologically endangered salt marsh ecosystem.

5.2 Soils of Teal Lagoon

5.2.1 Soils Landscape

Teal Lagoon is best described as part of the 'Clybucca' swamp landscape (Walker *et al, 2004*). This area consists of Holocene alluvial and estuarine infill creating muddy swale swamps, overlying Pleistocene barrier sands (Eddie 2000). These areas usually have high water tables, drain poorly and have a high run-run.

5.2.2 Soil Samples

The results of our soil samples are available in Appendix 7. Due to lack of time we only sampled the sub surface soil at selected points along our vegetation transects. However, we believe it still allowed for comparison with vegetation communities.

The soils sampled range from sandy clay to light clay. The soil samples show all the surface soils contained salinity and were organic. pH ranged from 4.5 to 7.5. Overall, these results show no notable anomalies and are quite standard.

5.3 Fauna of Teal Lagoon

5.3.1 Bird Surveys

Over three days in April 2011 bird surveys were conducted. The surveys were undertaken in order to compare the avian diversity and density of Teal Lagoon to that of the estuary. Surveys were conducted at 7 locations across the Boyter's Lane Wetland site, and covered a broad representation of habitats including salt marsh, shallow open water, bull rush and mangroves. Surveys were taken in the form of a 5 minute settling period followed by a 20 minute survey period. All species landing within the survey site were recorded along with the number of individuals.

5.3.1.1 Bird Survey sites

Surveys conducted on the estuary side of the berm indicated low species diversity (refer to graph 1). This is in contrast to Teal Lagoon which contained twice the number of species. As seen in graph 2, the number of individual birds recorded on the Teal Lagoon side of the berm was triple that of the estuary.

To compare the saline system of Teal Lagoon with that of a freshwater system, a survey was conducted south of Boyter's Lane on the freshwater wetland on private property. The results of this survey as seen in Graph 1 indicated higher species diversity than the estuary, but a lower diversity than Teal Lagoon. If more than one survey of the freshwater wetland was taken, it is likely that more species would be recorded. The species recorded are typical of a freshwater wetland, for example the Purple Swamp Hen and Dusky Moorhen. These freshwater wetland species add to the overall species diversity of the Boyter's Lane Wetland system.

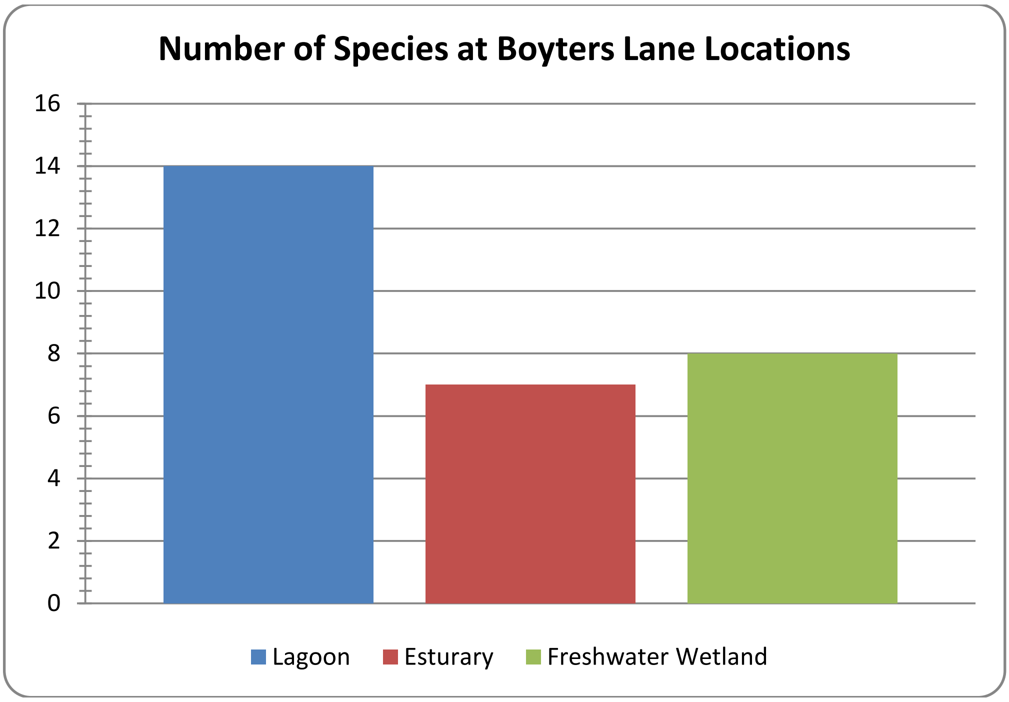

Figure 6- Species diversity across Boyter's Lane Wetland

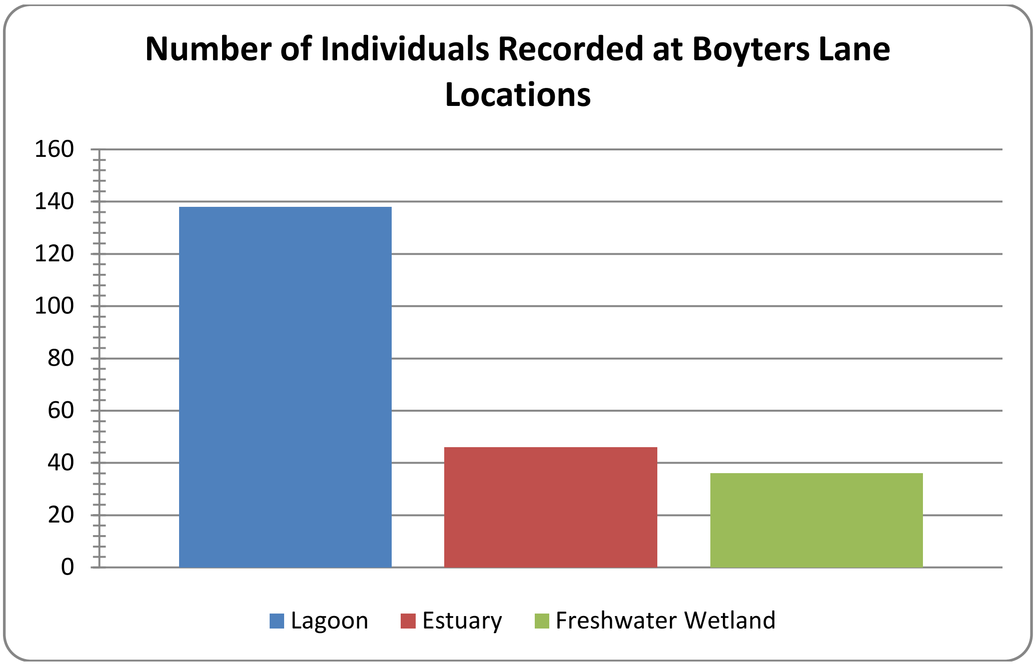

Figure 7- Individual numbers of birds across Boyter's Lane Wetland

The time of year that the surveys were conducted restricted the species that were able to be recorded. Many of the international wading birds known to inhabit the Boyter's Lane Wetland system are migratory. They breed in the northern hemisphere and occur in Australia for only part of the year, usually Spring-Summer, and return north from March to June. To get an accurate view of the avian diversity of Teal Lagoon and the estuary, surveys would have to be taken through summer as well as spring.

Research was conducted on previous Boyter's Lane bird surveys (see appendix 9) in order to view a more accurate long-term view of species diversity. This study was completed by local ornithologist Ken Shingleton. Shingleton has recorded 47 Migratory species listed under the *Commonwealth Environment Protection and Biodiversity Conservation Act (EPBC) 1999*. The site includes the known occurrence of eight species listed under the NSW *Threatened Species Conservation Act (TSC) 1995*. This increases the state importance of the site, although further surveys would be required to assess the extent to which these species rely upon the subject wetland. It is unlikely that Teal Lagoon wetland would be considered as a significant area of habitat under the EPBC Act (Australian Wetlands 2005).

Teal Lagoon is an important habitat for migratory and threatened bird species. It provides potential foraging habitat with protective cover for small and medium sized wading birds in areas such as mangroves, salt marsh and Sea Rush. It also features relatively open habitat on saltmarsh, mudflats and at the edge of mangroves, suitable for large birds such as the endangered Black-Necked Stork (*Ephippiorhynchus asiaticus*) which forages without cover (Lindsey 1992).

The construction of the levee 50 years ago invited wading birds into the new wetland area where they had not previously occupied. These birds prefer the more constant ecosystem of the lagoon over the dynamic tidal estuary. To remove the berm would re-introduce this daily sequence of disturbance and encourage the colonisation of mangroves, which would not be a positive outcome for ducks, shore birds and wading birds. Although this is a relatively small site, given the extensive degradation of coastal wetlands which were previously used by waterbirds, it is important that this site is protected.

5.3.2 Macro Invertebrates Surveys

As 'aquatic invertebrates are an important food source for fish, amphibians and waterbirds' (NSW Government 2011) they can be a useful indicator for biological monitoring. To gain an understanding of the ecological status of Teal Lagoon, a macro invertebrate survey was completed over two days in April 2011. Samples were taken from 6 sites to compare the biodiversity and abundance of macro invertebrates across the two ecological areas of the estuary and the lagoon.

5.3.2.1 Macro Invertebrate sites

Samples of macro invertebrates were taken at 6 sites. Three samples within the waters of the lagoon and three within the waters of the estuary (Appendix 11). All sites samples were gathered using a fine mesh net, sweeping one metre across the water, three times, insuring sediment disturbance for benthic invertebrates. Samples were taken at the inflow, outflow, and midsection of each water body and placed in a white tray. Macro invertebrates were then counted for species type, population number and then documented. To help identify what purpose the macro invertebrates served in the ecosystem, differing species where then divided into three groups;

- Zooplankton - float on the water surface or drift within the water column
- Nekton - able to swim, upper water column
- Benthic - live in or on sediment.

Site one; Samples were taken from the lagoon near the inlet pipe. 3 differing species were identified with a low population averaging 1 per species. They comprised of nekton and benthic species.

Site two; Samples were taken from the lagoon near the midsection. 3 differing species were identified with a medium population averaging 3 per species. They comprised of benthic species only.

Site three; Samples were taken from the estuary near the outlet pip. 4 differing species were identified with a medium population averaging 3 per species. They comprised of nekton and benthic species.

Site four; Samples were taken from the estuary near the midsection. 6 differing species were identified with a low population averaging 1 per species. They comprised of nekton and benthic species.

Site five; Samples were taken from the lagoon near the end of the lagoon. 4 differing species were identified with a very high population averaging 23 per species. They comprised of zooplankton and benthic species.

Site six; Samples were taken from the estuary near the river inlet. 2 differing species were identified with a high population averaging 11 per species. They comprised of zooplankton and benthic species.

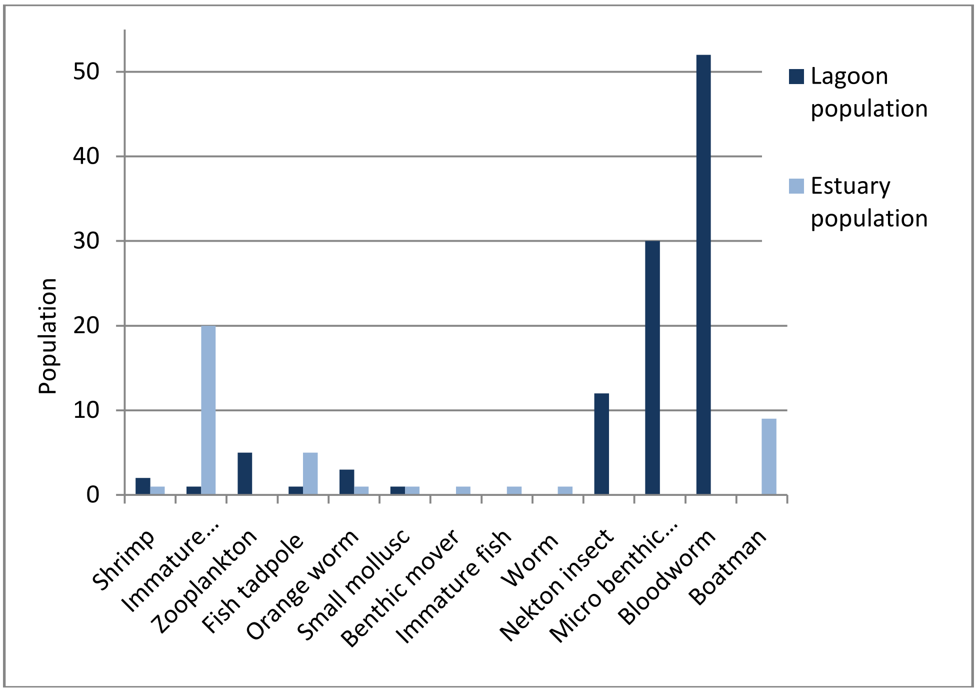

Figure 8 - Comparisons of the lagoon and estuary population densities for macro invertebrates.

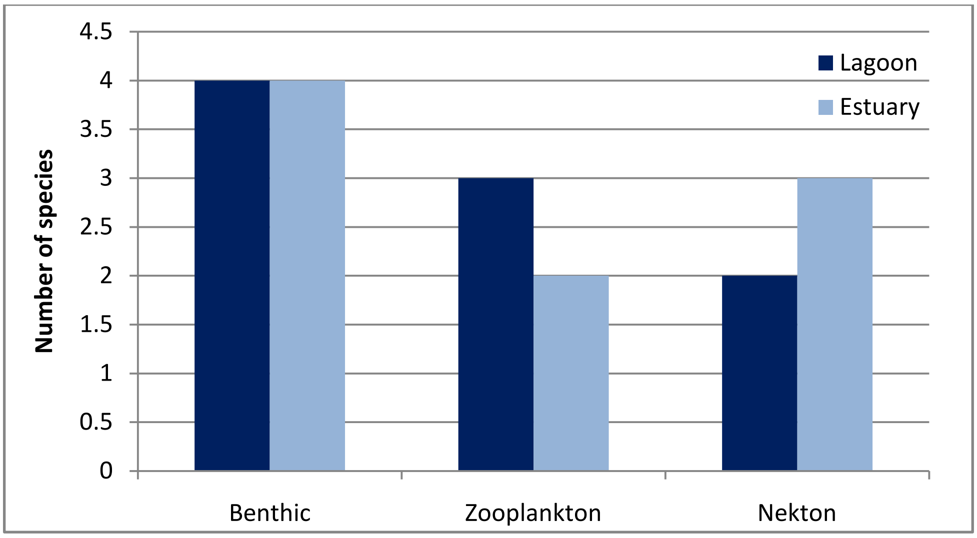

Figure 9 - Comparisons of the lagoon and estuary species richness of macro invertebrates

The biodiversity of an area is a good indicator of how healthy and resilient an ecosystem is and how adaptable it can be to change. From the data collected, the estuary and lagoon indicate that they are both as diverse in species richness as one another and contain differing species that appear to be unique to each ecosystem. Both contain the same number of benthic species with the lagoon favouring zooplankton invertebrates and the estuary favouring nekton invertebrates. Although in general the lagoon has a higher density of population, in particular to its benthic species. As 'aquatic invertebrates are responsible for a large part of the secondary production' (NSW Government, 2011) it is important to understand the invertebrates that occupy the estuary and lagoon and how they support the ecosystem, especially in light of the prolific birdlife that is attracted to the area and most likely dependency on invertebrates as a primary, if not secondary, food source.

5.4 Water Quality of Teal Lagoon Wetland

5.4.1 Water quality Testing

Water quality data was collected along a transect which spanned from the top of the lagoon closest to Boyter's Lane, across the berm and into the tidal creek at the opposite end of the site (see Figure 10).

Figure 10 - Teal Lagoon, transect marked out along the lagoon and berm

5.4.2 Water quality testing sites

Along the length of the lagoon, ten sites labelled A – K were spaced approximately 20m apart depending upon local accessibility. In the estuary downstream of the berm two sites labelled L and M were chosen. We expected that the water entering and exiting the system during tides would be fairly uniform so decided two sites would be adequate for our purpose. Limited accessibility to the main creek channel due to thick mangroves and extensive mudflats was also a factor which influenced this decision. An additional downstream site called N was chosen for measurement immediately next to the berm while site O was chosen in the freshwater wetlands across the road. Site P was chosen in Spencers creek.

Each site was marked with surveying tape to ensure that the same sites could be returned to for replication of measurements at later tidal stages. All sites were marked with a GPS device which has an error of 5m.

Three measurements for electrical conductivity, pH and dissolved oxygen were taken at sites A – P. Site A – N were measure this way during both incoming and outgoing tides. Turbidity, phosphate and sulphate measurements were also taken at every second site for the lagoon transect (A – K) and also at some downstream sites (L and N). Samples were collected from sites A, K and L and prepared for full lab analysis. Single electrical conductivity measurements were taken upstream and downstream of site P to gauge functioning in the wider system at sites Q and R.

Water data quality was analysed and compared to the ANZECC water quality standards for wetlands to investigate the health of the system.

5.4.3 Dissolved Oxygen

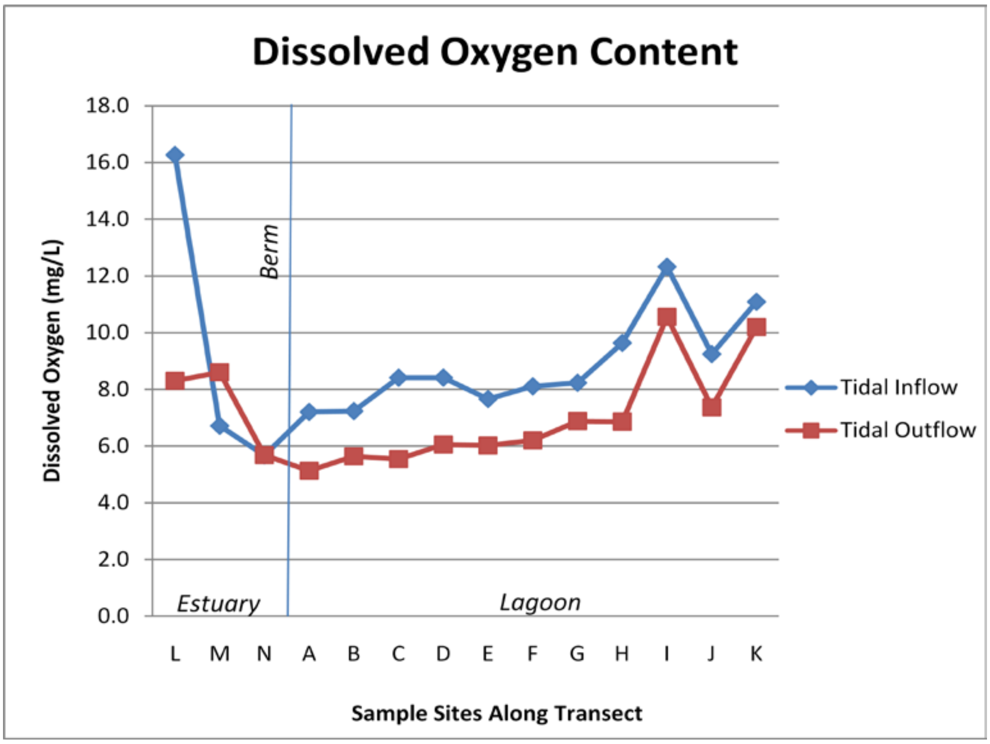

Figure 11 – Average dissolved oxygen content along the transect

From Figure 11 it can be seen that from the berm to the top of the lagoon there is a slight and gradual increase in the dissolved oxygen content of the water. Dissolved oxygen is highest closest to Spencers Creek (site L) during an incoming tide. This was an expected result as change in tidal flow may affect dissolved oxygen (Geoscience Australia 2011). In this case, the tidal inflow contains higher oxygen content than the stagnant lagoon water. This is indicative that during an incoming tide, well mixed surface waters from Spencers Creek which contain higher oxygen enters the system. This is also reflected in the gradual increase in oxygen content on the estuary side of the lagoon.

Dissolved oxygen is at its lowest about the berm. The sites close to the berm (A-C & N) had DO values of around 5mg/L. These values come close to the lower limit for fish growth which is 5-6mg/L (Waterwatch Australia 2005). Levels below 3mg/L are stressful to most organisms (Waterwatch Australia 2005).The low dissolved oxygen content close to the berm can indicate excessive demands on the system, or a build up of organic matter (Geoscience Australia 2011). The rest of the lagoon and estuary system are within the dissolved oxygen ANZECC guidelines for protection of a healthy ecosystem.

Dissolved oxygen is significantly lower at site J than immediately neighbouring sites. This may be explained by the fact that site J was chosen within shallow water amongst mangrove pneumatophores and decomposing organic matter because access to the main channel was not possible due to deep mud. Decomposing organic matter lowers oxygen content in the water (Geoscience Australia 2011) which explains the anomaly at site J. The high dissolved oxygen content at site I is most likely a result of the sample location, which was located in open, shallow waters without decomposing organic matter and not within the main channel of the lagoon. The shallow water may be able to mix better with the air to hold higher oxygen content.

The slight differences in values between the two tidal samples are most likely a reflection on the time of day the samples were taken. The time of measurement affects the amount of oxygen in the water as dissolved oxygen varies diurnally due to photosynthetic organisms being unable to photosynthesise, produce oxygen and release it to the water column overnight (Geoscience Australia 2011).Temperature can also affect oxygen content (Geoscience Australia 2011). Waters at low temperatures can hold more oxygen than warmer waters, however, the temperature of the water remained fairly consistent over the sample period, and probably had minimal effect on the dissolved oxygen content. The amount of oxygen in the water column may also vary with depth (Geoscience Australia 2011) so although care was taken to keep measurement depths similar, any errors in sampling could affect results. Further measurements at different times and depths would give a better understanding of how dissolved oxygen varies between tides and times in the lagoon on both a horizontal and vertical scale.

The dissolved oxygen content of the system could be improved by reducing the catchment nutrient inflow through revegetation, encouraging mixing of surface water with air, allowing tidal inflow and removing excess weeds, particularly floating and submerged vegetation (Geoscience Australia 2011).

5.4.4 Electrical Conductivity

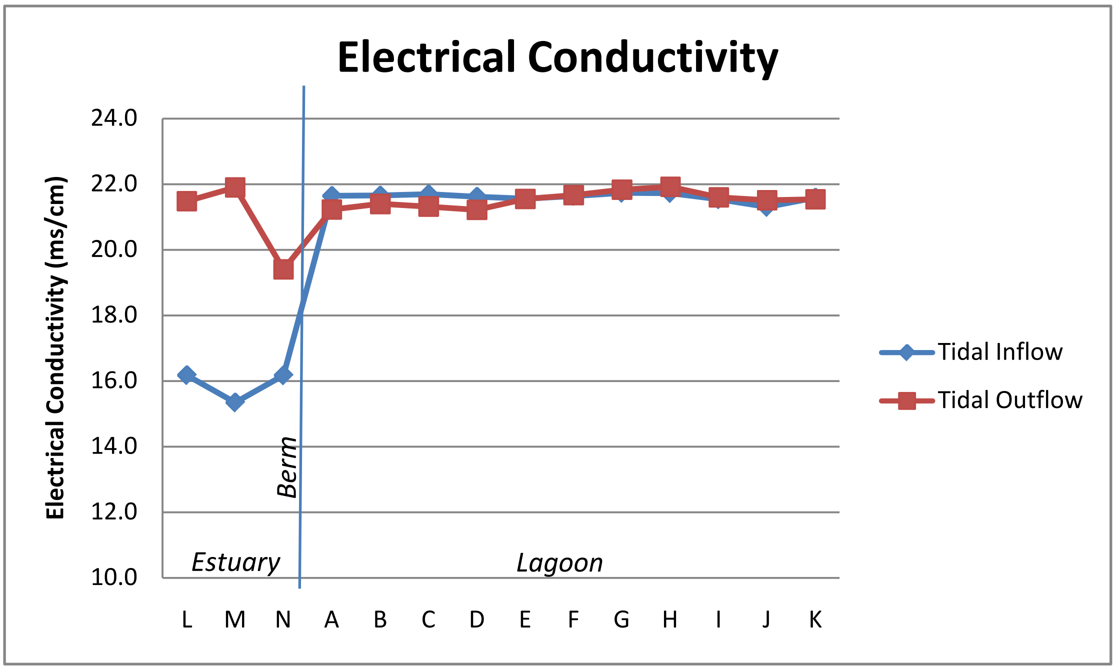

Figure 12 – Average electrical conductivity along the transect

Electrical conductivity is an indicator of salt concentrations in water samples (Geoscience Australia 2011). From Figure 12 it can be seen that the electrical conductivity in the lagoon has a uniform salinity of around 22ms/cm. This is slightly fresher than seawater but is right on the upper limit for healthy lowland systems according to the ANZECC guidelines (2000) which indicate EC should fall between 12.5 and 22ms/cm. The high salinity of the lagoon is most likely a result of evaporation concentrating salts within the permanent, shallow lagoon waters. Restricted outflow from the lagoon during low tide may also result in increased salinity in the water body as salt is continually pushed into the system by tidal activity but cannot escape out the estuary due to the placement of the berm.

The water flowing into the estuary with the tide is fresher water than the lagoon as it has an EC of approximately 16ms/cm. This value falls within the healthy guidelines for an aquatic ecosystem (ANZECC 2000). The fresher water inflow is explained by the fact that a lens consisting of less dense, fresher water exists on the surface of Spencers Creek due to heavy rains in previous months (see Figure 4). Measurements at sites P, Q and R confirmed the presence of this lens. The fresher lens water pushes into the estuary at high tide causing lower EC in incoming estuary water. Water almost completely exits the estuary each time a low tidal phase occurs so there is also little chance for evaporation to concentrate salts in the estuary unlike in the lagoon.

There is a clear, significant leak from the berm during tidal outflow, as the salinity of the estuary water increases to match the out flowing water of the lagoon. The lower end of the berm is slightly influenced by tidal inflow as water is pushed in through the pipes and leaks in the berm; however the upper lagoon remains constant showing that tidal effects are not significant along the entire length of the system.

5.4.5 pH

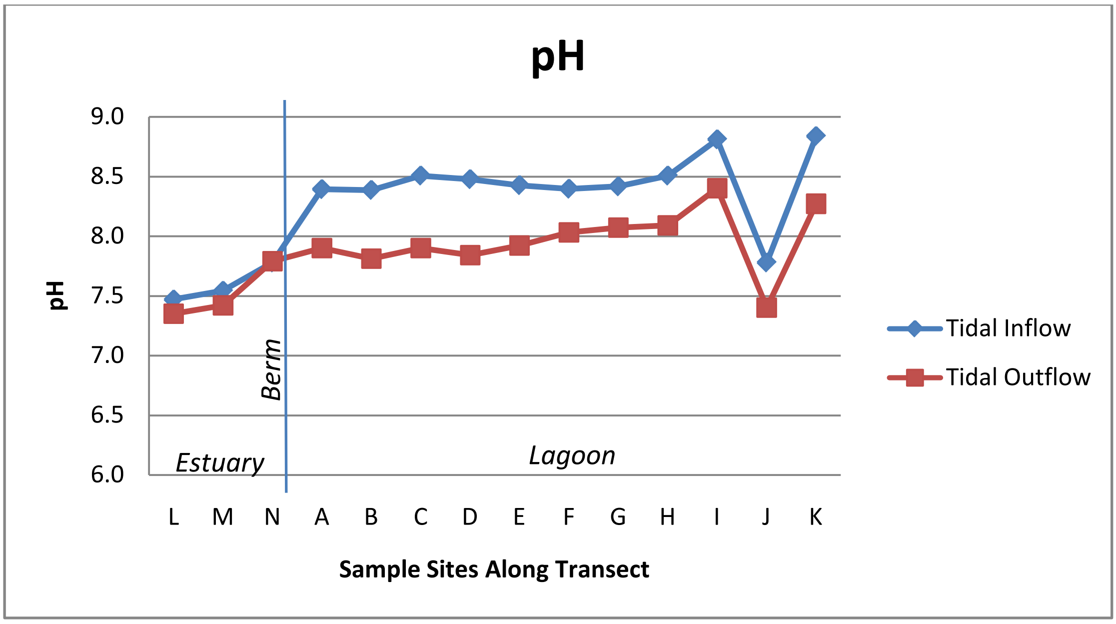

Figure 13 – Average pH along the transect

Figure 13 shows that over the length of the lagoon, there is a slightly increasing gradient in pH values, with the top of the lagoon slightly more alkaline than the waters close the berm. The increasing gradient is likely because pH increases as dissolved oxygen increases (Geoscience Australia 2011). Figure 11 shows that dissolved oxygen is increasing gradually and in a similar way to pH up the lagoon. Most of the values fall within 7 and 8.5 which is described as the healthy range for aquatic ecosystems by ANZECC (2000). Site I and K have slightly higher pH during an incoming tide but these are not considered to be significantly out of range. In terms of pH the lagoon system is functioning and healthy. It does not appear to be affected by Acid Sulphate Soils which are common in the region. The upper areas of the lagoon within the stagnant mangrove water is slightly alkaline. Flushing of the system would drop the pH to more favourable conditions.

The estuary waters are more acidic than the waters in the lagoon and the pH of water across the whole system is slightly higher during an incoming tide. This is again explained by dissolved oxygen increase as dissolved oxygen is higher within incoming tidal waters due to mixing with air as the water moves along Spencers creek and into the studied system.
The drop in pH at Site J is likely to be a reflection of the sample location amongst the .dense mangroves. The water in this region is stagnant and predominately dominated by rain waterwhich is a possible reason to explain this anomaly. The decomposition of organic matter, which existed at site J, may also be releasing material into the water which is likely to be lowering its pH.

5.4.6 Turbidity

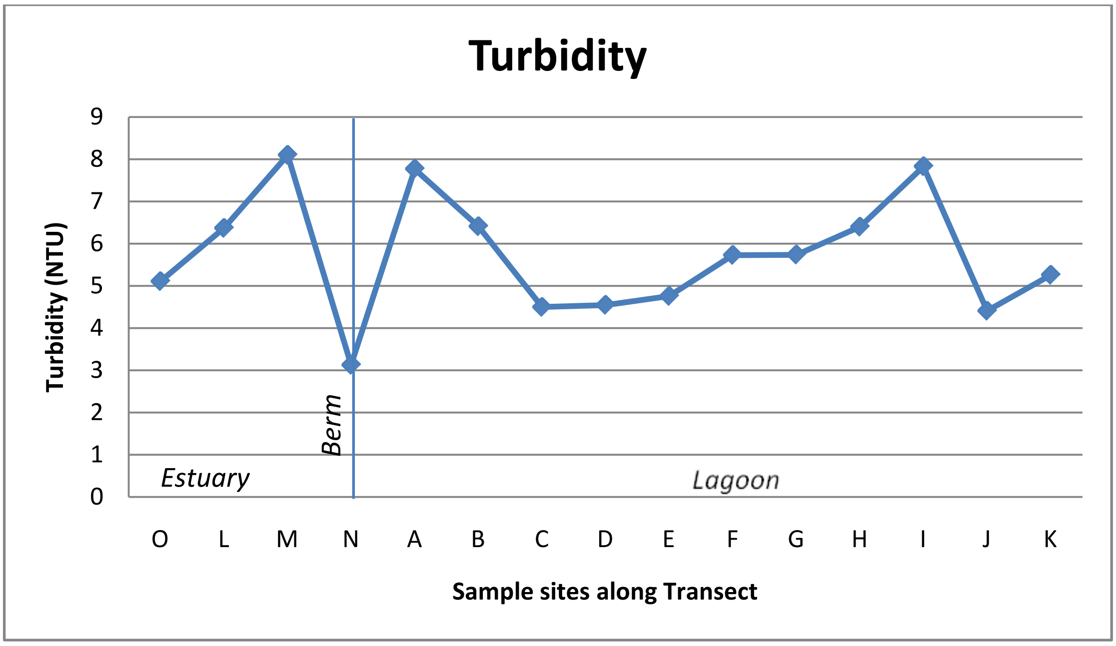

Figure 14 – Measured turbidity along the transect

Turbidity is a measure of water clarity (ANZECC 2000). High turbidity indicates materials such as silt and clay particles are suspended in the water and it can be exacerbated by erosion (Geoscience Australia 2011). Phytoplankton and zooplankton, which are both tiny organisms, also contribute to turbidity (Geoscience Australia 2011). Turbidity is expected to be lower offshore, and higher in estuaries and inshore as it is often wind induced (Geoscience Australia 2011).

Figure 14 shows that the measured turbidity at the site was quite variable. Sites A-K were measured on a outgoing tide. This might explain the increase in turbidity at site A, as water flows towards the berm during outgoing tides and may gain suspended or dissolved sediments as it moves. Sites L - M were measured during incoming tides, and thus reflect the estuarine waters moving in which typically have lower turbidity (as previously mentioned). The low value at site N is most likely an impact of the berm. As the water slows and moves through leaks or pipes in the berm it is able to filter out or allow suspended sediments to drop out of the water column.

The turbidity meter was unable to be calibrated during studies so data for turbidity at the site may only accurately be used for site comparisons. Even though the turbidity measured is for comparative uses only, all values fall within the acceptable guideline range of 0.5-10 NTU for estuaries to maintain a functioning ecosystem (ANZECC 2000).

High amounts of sediment in water can suffocate aquatic organisms, and may reduce their visibility (Geoscience Australia 2011). Turbidity also causes wear and tear on water infrastructure, and makes water unsuitable for drinking (Geoscience Australia 2011). The system is currently healthy in terms of turbidity and these impacts are unlikely unless major rainfall events occur and wash high sediment loads into it.

5.4.7 Sulphate

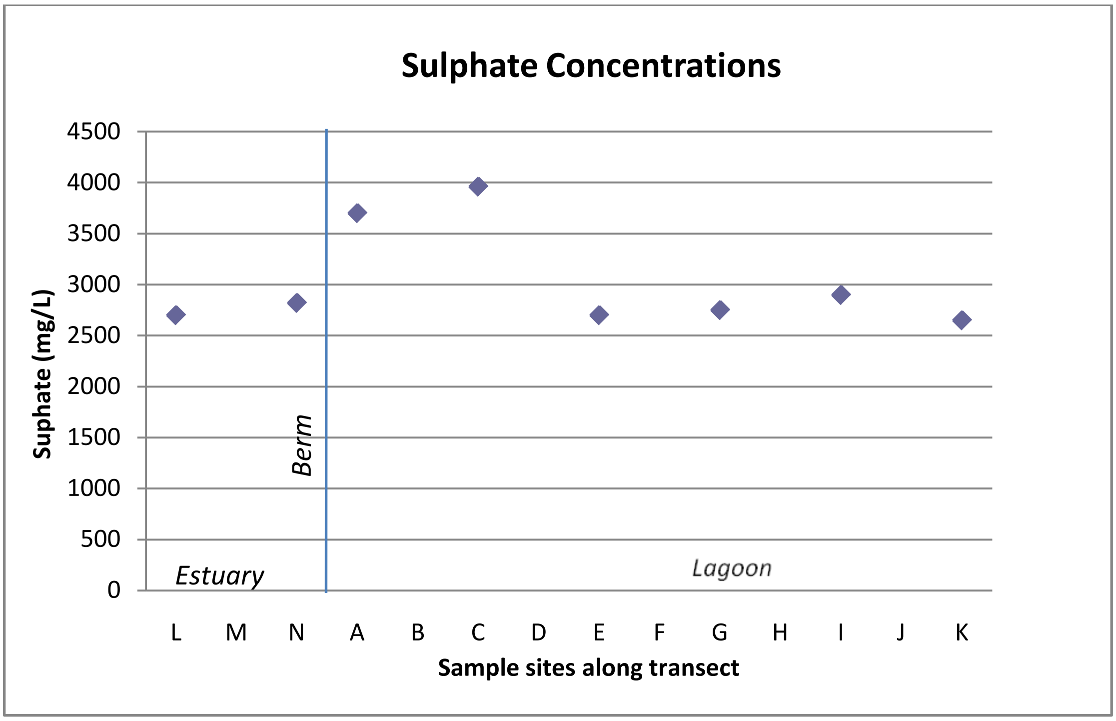

Figure 15 – Measured sulphate along the transect

Figure 15 shows that sulphate measurements ranged between approximately 2500 and 4000 mg/L. The majority of sites were found to have similar amounts of sulphate but site A and C displayed significantly higher values.

There are no ANSECC guidelines for wetland or estuary systems in regards to healthy levels of sulphate for aquatic ecosystems although ANSECC guidelines for safe consumption of water by livestock do exist. The guidelines for sulphate intake for livestick should not exceed 1000 mg/L according to ANSECC (2000). Adverse effects may occur in concentrations between 1000-2000mg/L which include chronic or acute health problems (ANZECC 2000). The sulphate concentration in the system is clearly higher than is recommended for livestock health and therefore it has been assumed that it also also unsuitable for healthy aquatic ecosystems.

It is likely that the amount of sulphate in the system is so high because it has become concentrated as water washes it in from surrounding land used for practices such as agriculture or from erosion sites during rainfall events.

5.4.8 Phosphate

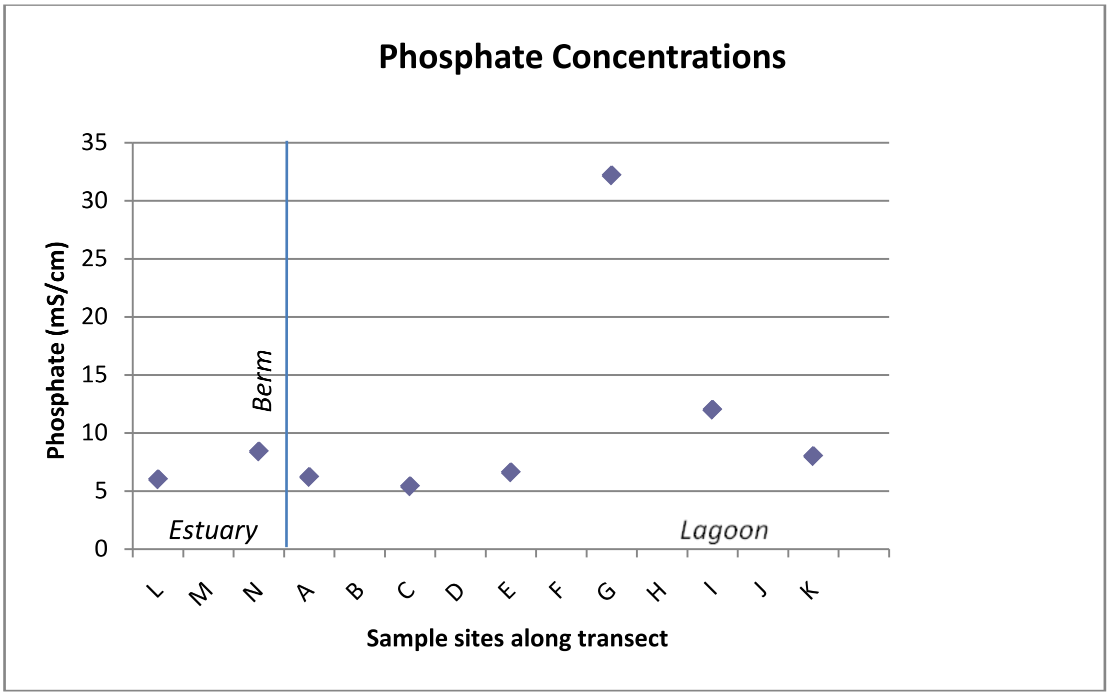

Figure 16 – Measured phosphate along the transect

Figure 16 shows that the phosphate concentrations within the lagoon increase very slightly from the berm to the top of the lagoon. This is expected, as least refreshed water at the top of the lagoon would have a higher build up of nutrients, particularly from feathers and bird droppings which have accumulated in that region. There is a spike in phosphorous concentration at site G which is likely an anomaly resulting from unrepresentative sampling.

The trigger value for total phosphorous is 0.03mg/L according to the ANZECC guidelines (2000). The values measured within the lagoon range between 5-32mg/L which by far exceed the level considered safe for phosphate. This means the system is under stress from excess nutrients.

Phosphate concentration determines plankton growth and the growth of aquatic plants, which in turn determines the availability of food sources larger animals up the trophic pyramid so is therefore important in the system. Although phosphate is required within ecosystems, excess phosphate in the water can lead to nutrient instability and eutrophication (Geoscience Australia 2011). This can lead to periodic blooms, and anoxic waters (Geoscience Australia 2011). High nutrient levels are usually associated with toxicity (Geoscience Australia 2011).

Nutrient loads can be enhanced by human activities such as agricultural runoff, storm and wastewater runoff and eroding soils moving into the system (Geoscience Australia 2011). This is the most likely reason for such high phosphorous concentration within the system. Phosphate also increases with anoxic conditions as well as pH increases and nutrient concentration in estuary systems depends on the flushing rates, the dilution by tidal seawater and the rate of biological uptake (Geoscience Australia 2011) which may further explain the levels found at the study site.

5.4.9 Full laboratory analysis

	Cation/Anion												
Location	**Ba** *(mg/L)*	**Ca** *(mg/L)*	**K** *(mg/L)*	**Mg** *(mg/L)*	**Mn** *(mg/L)*	**Na** *(mg/L)*	**Si** *(mg/L)*	**Sr** *(mg/L)*	**Pr** *(mg/L)*	**Rb** *(mg/L)*	**F** *(mg/L)*	**Cl** *(mg/L)*	**SO_4** *(mg/L)*
Site L	0.015	156	147	476	0.05	3269	2.3	3.1	0.043	0.038	0.63	7480	1012
Site A	0.016	151	140	460	0.048	3162	nd	3.1	0.043	0.036	0.49	7484	996
Site K	0.011	122	112	368	0.073	2579	4.3	2.5	0.036	0.031	1.2	5781	774
Trigger Values	0.7*	1000`		2000`	0.8^						1.5*	0.2*	1000`

*World Health Organisation year? – healthy drinking water guidelines
^ ANZECC year? – healthy aquatic ecosystem guidelines
` ANZECC YEAR? – healthy water for livestock guidelines
Anion analysis carried out on a Diones Series 4500i Ion Chromatograph
Cation analysis carried out on a Varian Vista AX CSS Simultaneous ICPAES

Figure 17 – Lab analysis results for cation and anion concentrations

The results for major cations and anions found during full lab analysis at sites A, K and L are shown in Figure 17. From this figure it can be seen that Ba, Ca, Mn, Mg and F are within the guidelines and Ca is outside the healthy ranges for aquatic ecosystems. High Ca concentration leads to phosphorous deficiency in fauna. For many of the variables guidelines do not exist for wetlands or estuaries so WHO safe drinking water guidelines have been used where possible. Further investigation into the concentration and importance of the cations and anions found is recommended.

5.4.10 Overall Water Quality

Water quality affects the ecological condition of water. The water in the lagoon should be suitable for a broad range of species flora and fauna. The dissolved oxygen content, while low close to the berm, indicates a healthy system. The EC measurements suggest that tidal influence is limited within the lagoon. The pH shows no signs of ASS, and is within the guideline ranges to support a healthy ecosystem. The sulphate and phosphorous concentrations within the lagoon are high and could be causing stress to flora and fauna.

5.4.13 Changes in System

Figure 18 - Water quality data from previous audit on Boyter's Lane and Teal Lagoon

Sample	pH	DO (mg/L)
Lagoon (Bird hide)	5.92	8.7
Berm (lagoon side)	6.87	8.21
Estuary (mid)	6.92	8.73
Estuary (Lower)	6.95	8.76
Water analysis sample from 2004 (Lagoon)	7.64	
Typical Saltwater	7.5-8.4	

Two previous water quality investigations are available for comparison in figure 18. The water quality audit conducted in 2004, found the water within the lagoon was acidic. When compared to the present day water, there is a large difference in pH from acidic (6-7) to neutral or alkaline (7-9). This change in pH seems to be an improvement. The sample from the 2004 analysis shows the system is becoming more alkaline.

The dissolved oxygen content from the previous study was higher than the present day content. This is particularly evident for the water at the berm, which was 8.21mg/L, but is currently towards the lower limits for biota survival at 5.13mg/L. This decrease may indicate a decrease in the health of the system.

Connectivity varies in wetland landscapes based on the topography and the degree of disturbances. The movement of water determines the movement of nutrients, organic matter, pH and salinity. Lateral connectivity is the ability for biota, water and materials to move between two distinct systems such as an estuary to a wetland.

Construction of the berm impacts lateral connectivity by stopping the movement of water and by physical stopping the movement of fish.

If marine flushing is prevented, the impacts of catchment development and pollution can be exacerbated. Limiting tidal exchange between the lagoon and the estuary can affect the long term water quality and health of the brackish system. Low level tidal inflow leads to an increase in nutrients. Increasing tidal exchange may reduce nutrient build up and increase invertebrate productivity.

6. Limitations of Research and further research recommendations

6.1 Limitations

The study was limited by our time frame of three days in the field. Due to the limited time, certain sites could not be studied fully. Some samples were replicated three times for each site and each condition (incoming and outgoing), however, other sites were replicated only once or twice. The lack of replication resulted in higher errors as we were unable to average our results with a sufficient sample. This is reflected in some of the graphs, where outliers are evident due to lack of a larger data set. The phosphate sulphate and turbidity measurements were only sampled once at every second site. This means that determining the true readings and patterns for these variables in the system is difficult, as it allows for the presence of anomalies.

The variations between each of the readings were affected by external factors such as the tide, temperature, and time of day. Taking the readings at similar times during the day may have resulted in less variation.

Variation in the readings may also be a result of sampling technique. The depth of the probes and distance from the edge of the bank affect the water quality measurements. Temperature and dissolved oxygen content can vary greatly with depth in the water column. Keeping depth and distance from the edge more constant would allowed higher accuracy of results. It would have been favourable to gather some samples from the centre of the water body. This was beyond the scope of our study. The sample sites were also limited by access due to heavy vegetation and mudflats.

The cost of detailed chemical analysis was also limiting. Due to the costs we were able to only sample three of the most interesting and informative sites. With greater funding a higher level of chemical analysis on the water in the system could have been undertaken.

The anion and cation data was not as useful as we had intended, due to the limited water quality guideline data available. The lack of reliable guidelines was also an issue when analysing some of the other water characteristic measurements. Very little data is available on the water quality standards for wetlands in Australia. Some of the standards used to compare the measurements were based on lowland river systems and estuaries. This makes it difficult to fully assess the health of the lagoon and estuary.

Two readings for SO4 were taken. One set were taken in the field and one set were taken in the lab analysis. Between the two samples there was a large variation in concentration. The readings taken during the field samples were between 2700 and 3700 mg/L while the lab analysis results came back with concentrations between 774 and 1012 mg/L. These differences in concentrations may be a result of the high concentration values as field sampling required high levels of dilution. Further investigation into the sulphate content of the water within the lagoon and estuary would be beneficial.

6.2 Recommendation for further research

6.2.1Further and more comprehensive fauna audit

Due to limitations of time and equipment we were only able to undertake basic bird and macro invertebrate studies. However, even these were not fully representative. For example the bird survey was undertaken in non-migratory time and so some of the protected birds were not detected. We recommend that further surveys are undertaken focusing on insects, spider, crabs, fish and birds during a migratory time frame.

6.2.2 Further soils study

We recommend that further soil studies are undertaken. Due to our lack of time we were only able to do a basic assessment of sub surface soil layers. We recommend that the areas soil profile to be mapped more accurately to minimise risk of disturbing any Acid Sulphate Soils if present.

6.5.3 Further bird study

Further studies into the relationship of invertebrates as a source of food for wading birds would be desirable before making any management changes to the lagoon, as this may affect the food chain that supports the wading bird population. If this is the case then we recommend that more is known about the invertebrate habitat and if they will survive a change in the system.

6.5.4 Further water study

It may be beneficial to conduct further studies on the fresh water influence on the system. Examination of the connectivity between the fresh water wetland across Boyter's Lane may allow some predictions on how the fresh wetlands might be affected by the removal of the berm.

Ongoing monitoring of the water quality on the site is recommended for any of the proposed management options. By investigating the changes in the water and the system processes the wetlands response to management decisions can be better understood. In this way the site can be maintained and action can be taken before the system is degraded.

Studies involving the correlation between water characteristics and vegetation and fauna may also be useful for developing management decisions.

7. Recommendations for berm management

7.1 Option 1: Leave the berm in current state

Positives:

Macro Invertebrates
With the diversity of aquatic invertebrates and the clear separation of species dependent on either lagoon or estuary conditions, it would be desirable to keep both ecosystems to maintain the biodiversity of the area. It is unknown how these invertebrates support the larger ecological diversity of Boyter's Lane that may very well be the foundations for the prolific bird life that is attracted to the area.

Birds
Waders prefer the current state. This provides saltmarsh, bull rush and mangrove foraging habitats with some protective cover for small and medium sized wading birds. Teal Lagoon also offers more open mudflats for larger birds such as the endangered Black necked stork. The gradual colonisation of mangroves under this management could pose a problem for waders, as they are deterred by protruding mangrove pneumatophores and prefer some open areas to forage in.

Society and Economical Value
By leaving the berm as is and maintaining a stable ecosystem for the local fauna and flora an educational base could be set up around Teal Lagoon. This educational base may be beneficial for surrounding schools as part of their science curriculum. This is important as the Kempsey Shire has a young demographic and any environmental education would be valuable.

Also by maintaining this important bird watching area tourism may increase, thus generating more economical stimulation within the Kempsey area, especially during bird migration periods.

Negatives:

Vegetation
The limited tidal influence has seen very small areas of mangrove and salt marsh establishment within the lagoon area. This may be a negative due to the invasion of weeds and loss of important habitats.

Economic Cost
The future costs of repairing an already deteriorating berm will increase. By leaving the berm in its present state and not undergoing any active management the stability of the berm will decrease, this could cause health and safety concerns for the public, especially is a walkway was constructed across the berm. With this continual degradation active management will be

inevitable due to the increase seepage leading to a larger tidal influence and changing the current ecosystems.

Water Quality
In terms of water quality, if the berm is left in place in its current state flushing of the system will not be possible meaning that nutrient and salt loads in the lagoon will remain high and may increase. This can lead to negative effects such as eutrophication and health problems for fauna associated with the system. Judging from changes that have occurred in the system to date, if salinity continues to increase there is a chance that pH will continue to become more alkaline. Dissolved oxygen, turbidity and pH are currently at an acceptable level.

7.2 Option 2: Fix and maintain the berm to stop leakages and unblock the pipes

Positives:

Maintaining Teal Lagoon as an isolated system allows extended periods of elevated water levels in the formation of a permanent water body. During times of drought, the lagoon could provide a drought refugia when inland waterways would have dried up. This is particularly relevant for the Macleay region due to the vast reduction in wetland habitat.

Water Quality
Water quality is not likely to be greatly affected by fixing leaks and cleaning blockages from the pipes in the berm unless the quantity of tidal water entering the lagoon is significantly changed. There is a possibility that the change would lead to better mixing within in the lagoon if greater quantities of fresher estuary water enters the lagoon through unblocked pipes. This may increase dissolve oxygen levels and could encourage lower salinity if an increase in fresher incoming estuary water.

Vegetation
The introduction of a small tidal influence could encourage more establishment of mangroves within the lagoon. This will provide cover for the bird life and introduce more nutrient cycling. However the establishment of mangroves around the bird hide could impede the line of site of bird watchers, reducing visitation and tourism. This problem could be managed by removing any mangroves within this small vicinity, however, this will increase maintenance cost for the area. The introduction of a small tidal influence may also enable more establishment of salt marsh communities. This is important as this is an endangered ecological ecosystem and any increase in area would be significant.

Society and Economical Values
Fixing the berm could facilitate the establishment of a safe educational and recreation walkway. This educational base may be beneficial for surrounding schools as part of their science curriculum. This is important as the Kempsey Shire has a young demographic and any environmental education would be valuable.

Negatives:

Birds
This would encourage mangroves to colonise the Lagoon, at a faster rate than present, leading to a decrease in utilisation of the lagoon by wading birds due to less foraging area available.

Cost
It would cost $30-40,000 to repair and maintain the berm.

7.3 Option 3: Remove the berm

Positives:

Water Quality
Removing the berm would open the system and allow full flushing of the waters. This would stop concentration of nutrient and salts in the permanent water supply as the permanent lagoon would be removed. The pH would not be adversely affected, and the upper section of the lagoon may be brought closer to a healthier alkalinity similar to the estuary and Spencers Creek. Opening the system may also reduce turbidity as estuary waters are typically less turbid than wetlands. By removing the berm, the entire system will be altered towards a more natural, tidally dominated estuary.

On removal of the berm, the lagoon will become tidally dominated. During 2m tides at the coast, the tidal heights at the lagoon will reach 0.97m AHD. These tides will not reach the height of Boyter’s lane road which is at 1.117m AHD. The fresh water body across the road will be protected from flooding of saline waters.

Vegetation
The introduction of a full tidal system would encourage significant regrowth of mangroves. These mangroves may impede into the salt marsh area, however with the introduction of this tidal system it would be expected that the salt marsh area would also increase into the grassland areas, especially in the eastern side of the lagoon. In spite of this the expansion will be impeded by the manmade storm water drains on the western side of Teal Lagoon. If the tidal influence is large enough and the mangroves expand towards the manmade drains the salt marsh area will be very small to nonexistent.

Negatives:

Vegetation
The loss of salt marsh from invasion of mangroves on the western side of the Lagoon would not be a favourable. Other areas of vegetation that has been planted around the bird hide may be negatively affected by the increase in tidal influence.

Birds
Mangroves will colonise Teal Lagoon, to an extent similar to that of the estuary, shrinking suitable foraging areas and changing food availability. Species such as Sharp tailed sandpipers would disappear under this management plan (Shingleton, K, Personal

Communication, May 5 2011). Storks and other waders would also decrease in numbers. Mangroves would also invade the protected salt marsh community.

Society and Economical Value
The removal of the berm will also remove the option of the education and recreational walkway. Therefore, removing and educational and economical benefits.

Also the cost to fully remove the berm is estimated at $20,000.

8. Recommendations for walking track

8.1 Walking Track

From a bird perspective, a walking track would be disruptive. Any increase in human density in or around Teal Lagoon would have a negative effect on avian diversity. Pets would be a danger to birds, especially waders and large birds. Increased car traffic to the site for walking would increase noise pollution, deterring birds from habituating the Lagoon. Litter is likely to increase, putting the birds at more risk of entanglement in rubbish.

If a walking track was to be built, it is preferable to be constructed as far from the banks of Teal Lagoon as possible to avoid disturbance of birdlife. Another bird hide on the opposite side to the existing bird hide could be constructed to allow walkers non-intrusive close up views of the Lagoon.

Birds need to be considered for their economic as well as ecological advantages. Birdwatchers from all over Australia come to this location to see endangered species and rare migrants such as the Lesser Yellowlegs *(Tringa flavipes)* which has only had four confirmed sightings in Australia (Shingleton, K, Personal Communication, May 5 2011). The local economy of the South West Rocks area receives much economic benefit from this wetland and the species it attracts. This must be considered when making management decisions which could influence the presence and activities of rare and endangered species.

In the perspective of vegetation any increase in human activity is likely to introduce more weeds to the area putting pressure on the native plant communities. Any establishment of a walking track would need to not invade the salt marsh community and litter management would be needed. Any active management such as mowing would need to be monitored as not to increase weed density.

In the water quality perspective, turbidity and nutrient runoff may increase if the track is placed too close to the water. It would be necessary that the track be built in areas to reduce these impacts.

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10. Appendices

Appendix 1: Site of Vegetation and Soil Transects

Appendix 2: 1964 Aerial Photo of Teal Lagoon

Appendix 3: 2001 Aerial Photo of Teal Lagoon

Appendix 4: 2009 Aerial Photo of Teal Lagoon

Appendix 5: Vegetation Data

	Waypoint	S	E	% of vegetation	General Veg comments
Transect 1 west U/S					
0	59	S 30.91443	E 153.03770	20 pneumatophores & mangrove trees, 80 water	Mangrove dominated (2 older), lots of organic matter, black ooze, no weeds
10				75 swamp marsh grass, 20 reeds/salt marsh grass, 5 vines	
change @ 15					change from swamp grass to Kikuyu
20				5 daisy weed, 90 kikuyu, 5 vines	Grass dominated, very dense and long.
30				1 daisy weed, 99 kikuyu	> 80cm long and dense. Area looks mowed therefore weeds
38	60	S 30.91450	E 153.03738	90 leaf area x 3 trees (tropical like), 100 leaf litter, garbage, woodchip	No weed no grasses. Edge of buffer zone
Transect 2 west U/S					
0	61	S 30.91562	E 153.03802	10 pneumatophores & saplings, 90 water	1 - 1.5 metres tall with some saplings cut down, sludge deep organic matter
10				90 swamp reefs, 5 weeds, 5 kikuyu	This waypoint was a very managed modified system with banksia, mowed grass and lamandra. The bulrush on the fence line appears natural.
16	62	S 30.91561	E 153.03786	70 kikuyu, 30 runner weed	weed looks like pennywort
Transect 3					
0	63	S 30.91428	E 153.03813	50 salt marsh, 50 salt marsh grass	low lying below waist height, weeds directly following 1 metre with pennywort looking grass.
10				80 weeds (daisy, thistle, vine) 20 kikuyu	no native vegetation
20	64	S 30.91416	E 153.63830	49 salt march, 2 kikuyu, 50 weeds (1 x big rag weed)	edge of the salt march where it starts to slope down
Transect 4					
0	65	S 30.91558	E 153.03899	20 water, 80 mangrove leaf	1 mature mangrove approx. 4m with sucklings & pneumatophores
10				90 veg bull rush, salt march, casuarina dominated, 10 soil	weeds coming in
20				100 thick grasses 0.1 - 30cm tall, daisy weeds & penny worth like plants	
30	66	S 30.91561	E 153.03931	100 coverage, grasses, dandelion, rag weed	2 planted trees
Transect 5					
0	67	S 30.91271	E 153.03561	70 mangrove pneumatophores, 30 water	no leaf
10				90 mangrove leaf cover, pneumatophores, saplings, 30 emerging grass	

20				80 mangrove leaf cover, saplings, 20 sludge mud	1 dominant tree approx. 20 metres
30				70 mangrove leaf coverage, 75 sapling & pneumatophores, 25 sludge	lots of 6ft mangroves
Change @ 36					swamp marsh starting
40				80 swamp grass and swamp brush, 20 soil	
50				100 (50/50) bull rush and grasses, 1 vines	vines entering the system
Change @ 53					edge of the marsh
60				100 kikuyu grass, couch grass near paddock frame	farm might spray for weeds
63	68	S 30.91319	E 153.03537		buffer zone
Transect 6					
0	69	S 30.91320	E 153.03647	75 mangrove pneumatophores, 30 sludge	dead branches, no regrowth
10				40 water with 4 saplings, 60 pneumatophores	
20				60 mangrove leaf, 10 pneumatophores	mangroves 1.8 metres
30				60 mangrove leaf	more established mangroves of approx. 2.5 m tall
40				70 mangrove coverage, 50 grass coverage	mangroves mostly 5 ft tall
Change @ 47				change in vegetation	
50				90 - 50 swamp weed 50 grass	
60				90 - 40 swamp marsh, 60 grasses	
70				59 bull rush, 40 grasses with kikuyu, 1 vines	edge of salt marsh with vine coming through
80				100 grass with pigwort type vine	
Change @97	70	S 30.91372	E 153.03572	buffer zone	
Transect 7					
0	71	S 30.91374	E 153.03729	60 mangrove saplings & pneumatophores	
10				80 mangrove leaf, saplings & pneumatophores	thick density of saplings & pneumatophores. 3 well established mangroves approx. 2.5 m
20				90 mangroves & saplings	mangroves 1.4m very thick density
Change @24				change to salt marsh	
30				50 bull rush, 5 grass	most weeds
40				100 swamp march & vine	one major vine chocking grass casunina tree
50				100 couch, kikuyu, dry grassland, pennywort like plant	
58	72	S 30.91424	E 153.03696		bank of wetland draining pond

Appendix 6: Edge of plant communities data points

Waypoint	S	E	
3	s 30.91427	e 153.03751	
4	s 30.91414	e 153.03743	
5	s 30.91409	e 153.03745	
6	s 30.91395	e 153.0372	
7	s 30.91383	e 153.03709	
8	s 30.91373	e 153.03691	
9	s 30.91372	e 153.03671	
10	s 30.91348	e 153.03622	
11	s 30.91329	e 153.03606	
12	s 30.91328	e 153.03587	
13	s 30.91298	e 153.03546	
14	s 30.91291	e 153.03523	start of private property and lowland forest.
W.P	S	E	Edge of salt marsh and kikuyu west D/S
15	s 30.913	e 153.03531	
16	s 30.91313	e 153.03539	
17	s 30.91336	e 153.0356	
18	s 30.9136	e 153.03603	
19	s 30.91391	e 153.03627	
20	s 30.91401	e 153.03658	
3	s 30.91427	e 153.03751	
W.P	S	E	Edge of Mangroves and salt marsh west U/S
21	s 30.91431	e 153.0376	
22	s 30.91442	e 153.03769	
23	s 30.91455	e 153.03763	
24	s 30.91491	e 153.03792	
25	s 30.91506	e 153.03784	

26	s 30.91516	e 153.03784	
27	s 30.91528	e 153.03789	
28	s 30.91548	e 153.03792	
29	s 30.91566	e 153.03804	
			mangroves removed near hide
30	s 30.91573	e 153.03818	
31	s 30.91594	e 153.03818	
32	s 30.91612	e 153.03818	
33	s 30.91628	e 153.03816	
W.P	S	E	Outer edge of swamp marsh
34	s 30.91609	e 153.03812	
35	s 30.91576	e 153.0381	
36	s 30.91564	e 153.03793	
37	s 30.9153	e 153.0378	from point 35 to 38 marsh cant go west due to stormwater wetland
38	s 30.91494	e 153.03773	
39	s 30.91488	e 153.03773	
40	s 30.91461	e 153.03754	
21	s 30.91431	e 153.0376	
W.P	S	E	Edge of Mangroves and salt marsh East U/S
41	s 30.91404	e 153.03793	
42	s 30.91423	e 153.03812	
43	s 30.91436	e 153.03821	
44	s 30.9146	e 153.03838	
45	s 30.91474	e 153.03857	
46	s 30.91499	e 153.03877	
47	s 30.91517	e 153.03883	
48	s 30.91549	e 153.03906	
49	s 30.91565	e 153.03908	
50	s 30.91607	e 153.03923	

51	s 30.91644	e 153.03952	
W.P	S	E	Edge of salt marsh and kikuyu East U/S
52	s 30.91582	e 153.03923	
53	s 30.91566	e 153.03915	casurinas present
54	s 30.91543	e 153.03909	
55	s 30.91522	e 153.03893	
56	s 30.91496	e 153.03876	
57	s 30.91462	e 153.03862	
58	s 30.91437	e 153.03824	
41	s 30.91404	e 153.03793	

Appendix 7: Soil Data

	Waypoint	S	E	Soil pH	Soil Salinity	Soil IOM	Soil Colour	Soil texture
Transect 1 west U/S								
0	59	S 30.91443	E 153.03770	7.5	y	y	2.5/10y glay	high organic sludge
10				7	y	y	2.5/2/7.5 yr	moist silty clay
change @ 15								
20				5.5	n	y	2.5/3/7.5 yr	moist sandy clay with mottle
30				5	n	y	2.5/3/7.5 yr	moist sandy clay with mottle
38	60	S 30.91450	E 153.03738	4.5	n	y	4/3/5 yr (dry) 2.5/2/8 yr (wet)	moist light clay
Transect 2 west U/S								
0	61	S 30.91562	E 153.03802	7	y	y	2.5/10 y	dark high organic sludge
10				6.5	y	y	2.5/1/5 yr	dark moist silty clay
16	62	S 30.91561	E 153.03786	n/a	n	y	2.5/1/7.5 yr	moist sandy clay
Transect 3								
0	63	S 30.91428	E 153.03813	7.5	y	y	2.5/1/5 yr	moist silty clay
10				5.5	n	y	2.5/2/5 yr	moist sandy clay
20	64	S 30.91416	E 153.63830	5.5	n	y	2.5/2/5 yr	moist sandy clay
Transect 4								
0	65	S 30.91558	E 153.03899	7	y	y	2.5/10 y	high organic
10				6.5	y	y	2.5/2/5 yr	moist silty clay
20				5.5	n	y	2.5/2/5 yr	moist salty clay
30	66	S 30.91561	E 153.03931	5.5	n	y	2.5/2/5 yr	moist salty clay
Transect 5								
0	67	S 30.91271	E 153.03561	7	y	y	2.5/1/2.5 yr	moist silty clay est deposit
10								
20								
30				6.5	y	y	5/10 y glay	moist light sandy clay
Change @ 36								
40				6.5	y	y	2/1/10 yr	moist light clay
50								
Change @ 53								
60				6	y	y	3/2/10 yr	moist loam
63	68	S 30.91319	E 153.03537					
Transect 6								
0	69	S 30.91320	E 153.03647	6.5	y	y	2.5/1/2.5 yr	moist silty clay
10								
20								

30				6.5	y	y	5/10/ y glay	moist light sandy clay
40								
Change @ 47								
50								
60				6	y	y	2/1/10 yr	moist light clay
70								
80				5.5	y	y	2/1/10 yr	moist light clay
Change @97	70	S 30.91372	E 153.03572					
Transect 7								
0	71	S 30.91374	E 153.03729	7	y	y	2.5/1/2.5 yr	moist silty clay
10								
20								
Change @24								
30				6.5	y	y	2/1/10 yr	moist light clay
40								
50				6	y	y	3/2/10 yr	moist loam
58	72	S 30.91424	E 153.03696					

Appendix 8: Bird Survey Data by Joseph Vile collected in April 2011

Bird species	Site 1	Site 2	Site 3	Site 4
Australian White Ibis	40	2	5	
White Faced Heron				
Little Pied Cormorant	1			
Black Winged Stalk	1			
Masked Lapwing	8		2	
Chestnut Teal	6			
Grey Teal	6			
Pacific Black Duck				
Purple Swamp Hen				
Dusky Moorhen				
Laughing Kookaburra				
Magpie Lark	2			
Willy Wagtail	2			
Welcome Swallow	40	10	10	
Superb Blue Wren				5
Golden Headed Cisticola			3	6
Striated Partilote				2
Sacred Kingfisher				
Brahminy Kite			1	
Lagoon/estuary	lagoon	esturary	esturary	esturary
Location	Bird Hide	Buffer 30m from Pvt Prpty	salt marsh, near art wetland	salt marsh, near berm
Date/Time	13/04/2011 6:26	13/04/2011 7:45	13/4/11 8:10	13/4/11 8:45
Comments				

Bird species	Site 5	Site 6	Site 7	total lagoon	total estuary	freshwater wetland
Australian White Ibis				40	7	
White Faced Heron		1	1	1		1
Little Pied Cormorant				1		
Black Winged Stalk				1		
Masked Lapwing			2	8	2	2
Chestnut Teal		18		24		
Grey Teal				6		
Pacific Black Duck		4	6	4		6
Purple Swamp Hen			10			10
Dusky Moorhen			6			6
Laughing Kookaburra			4			4
Magpie Lark			2	2		2
Willy Wagtail				2		
Welcome Swallow		5		40	20	
Superb Blue Wren	4	2	5	6	5	5
Golden Headed Cisticola	2			2	9	
Striated Partilote					2	
Sacred Kingfisher	1			1		
Brahminy Kite					1	
Lagoon/estuary	lagoon	lagoon	Freshwater wetland			
Location	opposite bird hide in bull rush	btwn hide and berm	Across Boyters Ln			
Date/Time	13/04/2011 10:10	14/04/2011 11:35	14/04/2011 10:35			
Comments	interrupted by councillor during survey					
			total # individuals	138	46	36
			total # species	14	7	8

Appendix 9: List of bird sightings at the Boyters Lane Wetland Site by Ken Shingleton from 1991 to 2004

Species Name	Common Name	Species Name	Common Name
Coturnix pectoralis	Stubble Qual	*Lopholaimus antarcticus*	Topknot Pigeon
Coturnix ypsilophora	Brown Quail	*Calyptorhynchus lathami*	Glossy Black-Cockatoo
Dendrocygna eytoni	Plumed Whistling-Duck	*Cacatua roseicapilla*	Galah
Oxyura australis	Blue-billed Duck	*Cacatua tenuirostris*	Long-billed Corella
Cygnus atratus	Black Swan	*Cacatua sanguinea*	Little Corella
Chenonetta jubata	Australian Wood Duck	*Cacatua galerita*	Sulphur Crested Cockatoo
Anas superciliosa	Pacific Black Duck	*Trichoglossus haematodus*	Rainbow Lorikeet
Anas rhynchotis	Australasian Shoveler	*Trichoglossus chlorolepidotus*	Scaly-Breasted Lorikeet
Anas gracilis	Grey Teal	*Platycercus eximius*	Eastern Rosella
Anas castanea	Chestnut Teal	*Cuculus pallidus*	Pallid Cuckoo
Malacorhynchus membranaceus	Pink-eared Duck	*Cacomantis variolosus*	Brush Cuckoo
Aythya australis	Hardhead	*Cacomantis flabelliformis*	Fan-Tailed Cuckoo
Tachybaptus novaehollandiae	Australasian Grebe	*Chrysococcyx basalis*	Horsefields Bronze Cuckoo
Poliocephalus urinatrix	Hoary-headed Grebe	*Chrysococcyx lucidus*	Shinning Bronze Cuckoo
Anhinger melanogaster	Darter	*Eudynamys scolopacea*	Common Koel
Phalacrocorax melanoleucos	Little Pied Cormorant	*Scythrops novaehollandiae*	Channel Billed Cuckoo
Phalacrocorax sulcirostris	Little Black Cormorant	*Centropus phasianinus*	Pheasant Coucal
Phalacrocorax carbo	Great Cormorant	*Hirundapus caudacutus*	White-Throated Needletail
Pelecanus conspicillatus	Australian Pelican	*Dacelo novaeguineae*	Laughing Kookaburra
Egretta novaehollandiae	White-faced Heron	*Todiramphus pyrrhopygia*	Red-backed Kingfisher
Egretta garzetta	Little Egret	*Todiramphus sanctus*	Sacred Kingfisher
Ardea pacifica	White-necked Heron	*Merops ornatus*	Rainbow Bee-eater
Ardea alba	Great Egret	*Eurystomus orientalis*	Dollarbird
Ardea intermedia	Intermediate Egret	*Malurus cyaneus*	Superb Fairy Wren
Ardea ibis	Cattle Egret	*Malurus lamberti*	Varigated Fairy Wren
Nycticorax caledonicus	Nankeen Night Heron	*Malurus melanocephalus*	Red-Backed Fairy Wren
Botaurus poiciloptilus	Ausralasian Bittern	*Pardalotus striatus*	Striated Pardalote
Plegadis falcinellus	Glossy Ibis	*Gerygone mouki*	Brown Gerygone
Threskiornis molucca	Australian White Ibis	*Gerygone levigaster*	Mangrove Gerygone
Threskiornis spinicollis	Straw-necked Ibis	*Acanthiza pusila*	Brown Thornbill
Platalea regia	Royal Spoonbill	*Acanthiza chrysorrhoa*	Yellow-rumped Thornbill
Platalea flavipes	Yellow-billed Spoonbill	*Acanthiza nana*	Yellow Thornbill
Ephippiorhynchus asiaticus	Black-necked Stork	*Anthochaera carunculata*	Red Wattlebird
Pandion haliaetus	Osprey	*Anthochaera chrysoptera*	Little Wattlebird
Aviceda subcristata	Pacific Baza	*Acanthagenys rufogularis*	Spiney-cheecked Honeyeater
Elanus axillaris	Black-Shouldered Kite	*Plectorhyncha lanceolata*	Striped Honeyeater
Lophoictinia isura	Square-tailed Kite	*Philemon corniculatus*	Noisy Friarbird
Haliaster sphenurus	Whistling Kite	*Philemon citreogularis*	Little Friarbird
Haliaster indus	Brahminy Kite	*Manorina melanocephala*	Noisy Miner
Haliaeetus leucogaster	White-Bellied Sea Eagle	*Meliphaga lewinii*	Lewins Honeyeater
Circus approximans	Swamp Harrier	*Lichenostomus chrysops*	Yellow-faced Honeyeater

Species Name	Common Name	Species Name	Common Name
Accipiter fasciatus	Brown Goshawk	*Lichmera indistincta*	Brown Honeyeater
Accipiter cirrhocephallus	Collared Sparrowhawk	*Phylidonyris nigra*	White-Cheecked Honeyeater
Aquila audax	Wedge-tailed Eagle	*Acanthorhynchus tenuirostris*	Eastern Spinebill
Hieraaetus morphnoides	Little Eagle	*Myzomela sanguinolenta*	Scarlet Honeyeater
Falco longipennis	Australian Hobby	*Pachycephala pectoralis*	Golden Whistler
Falco peregrinus	Peregrine Falcon	*Pachycephala rufiventris*	Rufous Whistler
Falco cenchroides	Nankeen Kestrel	*Colluricincla harmonica*	Grey Shrike Thrush
Grus rubicunda	Brolga	*Myiagra rubecula*	Leaden Flycatcher
Gallirallus philippensis	Buff-Banded Rail	*Myiagra cyanoleuca*	Satin Flycatcher
Rallus pectoralis	Lewins Rail	*Grallina cyanoleuca*	Magpie-lark
Porzana fluminea	Australian Spotted Crake	*Rhipidura rufifrons*	Rufous Fantail
Porzana tabuensis	Spotless Crake	*Rhipidura fuliginosa*	Grey Fantail
Porphyrio porphyrio	Purple Swamphen	*Rhipidura leucophrys*	Willie Wagtail
Gallinula tenebrosa	Dusky Moorhen	*Dicrurus bracteatus*	Spangled Drongo
Fulica atra	Eurasian Coot	*Coracina novaehollandiae*	Black-Faced Cuckoo Shrike
Gallinago hardwickii	Latham's Snipe	*Lalage sueurii*	White-winged Triller
Limosa limosa	Black-tailed Godwit	*Oriolus sagittatus*	Olive Backed Oriole
Limosa lapponica	Bar-tailed Godwit	*Sphecotheres viridis*	Figbird
Numenius minutus	Little Curlew	*Artamus leucorynchus*	White-Breasted Woodswallow
Numenius phaeopus	Whimbrel	*Cracticus torquatus*	Grey Butcherbird
Numenius madagascariensis	Eastern Curlew	*Cracticus nigrogularis*	Pied Butcherbird
Tringa stagnatilis	Marsh Sandpiper	*Gymnorhina tibicen*	Australian Magpie
Tringa nebularia	Common Greenshank	*Strepera grucelena*	Pied Currawong
Tringa glareola	Wood Sandpiper	*Corvus tasmanicus*	Forest Raven
Actitis hypoleucos	Common Sandpiper	*Corvus orru*	Torresian Crow
Calidris canutus	Red Knot	*Sericulus chrysocephalus*	Regent Bowerbird
Calidris ruficollis	Red-necked Stint	*Anthus novaeseelandiae*	Richard's Pipit
Calidris acuminata	Sharp-tailed Sandpiper	*Neochima temporalis*	Red-Browed Finch
Calidris ferruginea	Curlew Sandpiper	*Lonchura castaneothorax*	Chestnut-Breasted Mannikin
Irediparra gallinacea	Comb-crested Jacana	*Dicaeum hirundinaceum*	Mistletoebird
Himantopus himantopus	Black-winged Stilt	*Hirundo neoxena*	Welcome Swallow
Pluvialis fulva	Pacific Golden Plover	*Hirundo nigicans*	Tree Martin
Elseyornis melanops	Black-fronted Dotterel	*Hirundo ariel*	Fairy Martin
Erythrogonys cinctus	Red-kneed Dotterel	*Acrocephalus stentoreus*	Clamorous Reed-Warbler
Vanellus miles	Masked Lapwing	*Megalurus timoriensis*	Tawny Grassbird
Larus novaehollandiae	Silver Gull	*Megalurus gramineus*	Little Grassbird
Streptopelia chinensis	Spotted Turtle Dove	*Cisticola exilis*	Golden-Headed Cisticola
Columba leucomela	White-Headed Pigeon	*Zosterops lateralis*	Silvereye
Ocyphaps lophotes	Crested Pigeon	*Sturnus vulgaris*	Common Starling
Geopelia striata	Peaceful Dove	*Acridotheres tristis*	Common Myna
Geopelia humeralis	Bar Shouldered Dove		

Appendix 10: Macro Invertebrate Data

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Shrimp	1	1		1		
Immature shrimp	1		6	1		13
Shrimp like		5				
Tadpole	1		4	1		
Orange caterpillar		3	1			
small mollusc			1		1	
ground mover				1		
blue tinged shrimp/fish				1		
segregated worm clear				1		
surface bug					12	
pin sized jumping bug					30	
Bloodworm					52	
Boatman						9
Average populatoin	1	3	3	1	23.75	11
Lagoon/estuary	lagoon	lagoon	estuary	estuary	lagoon	estuary
South	30.91409	30.91404	30.91404	30.91377	30.91576	30.91271
East	153.03784	153.03793	153.03793	153.03728	153.0381	153.03561
Comments;	Near pipe		est. site near pipe		near bird house.	low tide close to river
Time	12.30pm	1.30pm				

Appendix 11.1: Water quality data for lagoon transect

				12.4.11 Tidal inflow					**13.4.11 Tidal inflow**								
SITE	**Coordinates**	**Site details**	**Photo**	**Time**	**pH**	**EC (ms/cm)**	**DO (mg/L)**	**Temp (°C)**	**Time**	**pH**		**EC (ms/cm)**		**DO (mg/L)**		**Temp (°C)**	
A	**30.91406 S 153.03799 E**	Open, Small mangroves on edge, grassy, close to berm	499	*13.00*	8.46	21.94	8.7	21.7	*1.53*	8.35	8.37	21.56	21.43	6.47	6.45	23.9	24
B	**30.91418 S 153.03815 E**	Open, grassy, few small mangroves, cleared	500		8.46	21.88	8.94	24	*1.56*	8.36	8.34	21.58	21.5	6.37	6.4	24.5	25.1
C	**30.91441 S 153.03824 E**	Young mangroves, pneumataphores, grassy	501		8.46	21.84	9.4	24.4	*2.00*	8.53	8.53	21.64	21.59	8.25	7.59	24.9	25
D	**30.91461 S 153.03842 E**	Salt marsh on edges, medium mangroves, partial shading, more pneumataphores, scum and feathers	502		8.55	21.79	10.29	24.3	*2.10*	8.45	8.43	21.52	21.54	7.4	7.56	24.6	24.4
E	**30.91475 S 153.03857 E**	Salt marsh on edges, medium mangroves, partial shading, more pneumataphores, scum and feathers, slightly deeper	503	*13.20*	8.6	21.72	9.96	23.7	*2.07*	8.36	8.32	21.48	21.47	6.48	6.55	24.2	25.1
F	**30.91494 S 153.03870 E**	Scum and feathers, small mangroves, grassy behind	504	*13.25*	8.45	21.69	9.89	24	*2.15*	8.38	8.36	21.66	21.57	7.3	7.14	25.7	25.8
G	**30.91505 S 153.03883 E**	Little mangroves, scum, open	505/506	*13.33*	8.45	21.71	10.25	24.6	*2.19*	8.39	8.41	21.77	21.72	7.04	7.41	25.5	25.8
H	**30.91527 S 153.03893 E**	medium mangroves, scum, partial shade, grasses	507	*13.40*	8.5	21.76	11.19	24.8	*2.23*	8.51	8.51	21.71	21.71	8.43	9.3	26	26
I	**30.91578 S 153.03816 E**	15m of swamp, mars and then mangroves, smelly, profuse pneumataphores, test within open channel	508/509	*13.50*	8.92	21.4	15.7	26.3	*2.30*	8.69	8.82	21.6	21.61	10.6	10.68	26	26
J	**30.91614 S 153.03855 E**	Edge of mangroves, shaded, not in channel	512		7.56	21.06	9.53	23.3	*2.38*	7.75	8.03	21.4	21.45	9.5	8.71	24.6	24.5
K	**30.91620 S 153.03864 E**	Closer to channel, open mangroves, grasses, shallow	513	*14.03*	8.63	21.35	11.33	27	*2.41*	8.92	8.96	21.74	21.68	10.7	11.24	26	26.1

Appendix 11.2: Water quality data for lagoon transect

	Average Tidal inflow				**13.4.11**	**Tidal outflow**			
SITE	**pH**	**EC (ms/cm)**	**DO (mg/L)**	**Temp (°C)**	**Time**	**pH**	**EC (ms/cm)**	**DO (mg/L)**	**Temp (°C)**
A	8.39	21.64	7.21	23.20	*10.15*	7.9	21.23	5.13	21
B	8.39	21.65	7.24	24.53	*10.25*	7.81	21.4	5.64	21.4
C	8.51	21.69	8.41	24.77	*10.3*	7.9	21.32	5.54	21.3
D	8.48	21.62	8.42	24.43	*10.33*	7.84	21.22	6.05	20.9
E	8.43	21.56	7.66	24.33	*10.36*	7.92	21.55	6.02	20.4
F	8.40	21.64	8.11	25.17		8.03	21.67	6.2	20.6
G	8.42	21.73	8.23	25.30		8.07	21.83	6.88	20.6
H	8.51	21.73	9.64	25.60		8.09	21.92	6.86	20.5
I	8.81	21.54	12.33	26.10		8.4	21.6	10.56	20.9
J	7.78	21.30	9.25	24.13		7.4	21.51	7.37	17.8
K	8.84	21.59	11.09	26.37	*11.15*	8.27	21.54	10.2	20

Appendix 12: Data for additional water quality sites

13.4.11 Tidal inflow

SITE	Coordinates	Site details	Photo	Time	pH			EC (ms/cm)			DO (mg/L)			Temp (°C)		
O	S30.91666 E153.03943	Across road freshwater swamp, covered with weed, exotic reeds and grasses	576/574		6.81	6.36	6.23	0.847	0.861	0.924	2.54	0.67	2.38	22.6		
Q	S30.92503 E153.03809	next to bridge, upstream of study site, spencers creek	588					10.98								
P	S30.91691 E153.04175	Spencers creek, muddy/rocky bank with mown grass, mangroves either side of site, upstream of study site	583/584	*7.19*	7.52	7.39	15.3	15.35	15.45	4.79	4.2	4.95	23.7			
L	S30.91270 E153.03552	Shaded, close to channel curve, full mangroves, swampy mud		*12.55*	7.51	7.45	7.45	16.31	16.39	15.82	7.59	7.29	7.15	23.6	25.2	
M	S30.91295 E153.03613	Shaded, close to channel curve, full mangroves, swampy mud, open, 5 metres upstream		*13.13*	7.58	7.52	7.53	15.56	15.61	14.85	7.04	6.33	6.78	25.7	25.4	25.5
N	S30.914 E153.03784	Estuary, downstream of berm, still some outflow from lagoon through pipes		*14.50*	7.9	7.73	7.71	16.12	16.17	16.21	5.85	5.78	5.4	25.7	25.7	25.4
R	S30.89728 E153.01645	Spencers creek entrance to Macleay river, near boat ramp, mangroves	592					39.1	40.1							

13.4.11 Tidal Inflow averages | **13.4.11 Tidal outflow**

SITE	pH	EC (ms/cm)	DO (mg/L)	Temp (°C)	Time	pH	EC (ms/cm)	DO (mg/L)	Temp (°C)
O	6.47	0.88	1.86	22.60					
Q		10.98							
P	10.07	11.86	10.95						
L	7.47	16.17	16.27	24.40	*12.01*	7.35	21.5	8.3	19.3
M	7.54	15.34	6.72	25.53		7.42	21.9	8.6	22.6
N	7.78	16.17	5.68	25.60	*13.42*	7.79	19.40	5.68	25.77
R		39.60							

Appendix 13: Water quality data

Site	Turbidity (NTU)	Phosphate (mg/L)	Sulphate (mg/L)
P	5.11		
L	6.37	6	2700
M	8.1		
N	3.13	8.4	2820
A	7.77	6.2	3700
B	6.41		
C	4.5	5.4	3960
D	4.55		
E	4.76	6.6	2700
F	5.73		
G	5.74	32.2	2750
H	6.4		
I	7.83	12	2898
J	4.41		
K	5.26	8	2650
O	23.1		