Chickiba Lakes
Acid Sulfate Soils and Wetland Management Plan

EWS06-07

Prepared for Ballina Shire Council and funded by the
Northern Rivers Catchment Management Authority

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Executive Summary

This Plan assesses and sets out the requirements for management of any site disturbance associated with infrastructure maintenance (mainly drain clearing), wetland rehabilitation works, and other minor works that may impact on Acid Sulfate Soils (ASS) in the Chickiba Lakes area at East Ballina. The aim of this Chickiba Lakes Acid Sulfate Soils and Wetland Management Plan is to undertake an assessment of the present ASS status of the defined sites, and provide future management recommendations for the Chickiba Lakes area.

The study area is classed as an ASS landscape because elevations are below 5m AHD, ASS soil risk maps predominantly categorise the area as Class 2, the melaleuca forests and tidal lakes of the area are commonly found in ASS landscapes, and the presence of estuarine sediments, geological history and location is favourable for pyrite formation. Assessments were undertaken for five management units to assess in more detail the presence and management of ASS.

The wetlands and waterbodies have been segmented by the clusters of residential areas, sporting fields, and associated infrastructure. Residential housing subdivisions are the dominant land use with stormwater directly discharged from the urban areas into the wetlands and lakes through about thirty stormwater pipes. The adjacent urban developments have drastically changed the natural hydrology of the wetlands.

Visual indicators of ASS impacts were not found during site assessments. However, the northern end of the Chickiba East Wetland featured a hydrogen sulphide smell indicating the possible presence of Potential Acid Sulfate Soil (PASS) conditions.

The soil sampling results for Sites 1 and 2 show that PASS levels were low from the soil surface to 1m depth. The first metre from the soil surface was categorised as containing actual acid sulfate soils. PASS results in the surface layer of organic matter at Site 3 was above the action criteria and therefore would require appropriate management if disturbed. Soil sampling at the three sites provided inconclusive quantitative evidence of the depth of the ASS layer throughout the wetland.

Due to the shallow disturbance from the proposed works, the likely neutralising capacity of the downstream vegetation and waterway, the relatively small size of the wetland, and low level of potential disturbance, it is unlikely that significant negative impacts from ASS would occur downstream of the study area for the proposed works. However, this does not avoid the need for best practice for ASS management, and effective techniques are recommended to manage the proposed works.

It is recommended that the proposed drain clearing be undertaken at the northern side and southern side of Angels Beach Drive at Chickiba East Wetland. This should follow the methodology used for previous drain clearing at this site, i.e. minimal disturbance, careful monitoring, and appropriate liming where indicated. Required liming rates are recommended. In addition, further clearing from the nominal SEPP14 boundary to the open water area is recommended in the interest of remediation of severe damage to the wetland resulting from excessive inundation and water depth.

It is recommended that proposed drain clearing at one site on the south-east side of Chickiba East Wetland be undertaken. Removal of built-up sediments in the drain should not disturb the ASS layer. Removal of weeds and shallow scraping of soil in the stormwater flow path is recommended to improve stormwater management at this site. In addition, future assessment of stormwater drainage redesign during infrastructure renewal is recommended.

It is recommended that erosion works at Chickiba and Prospect Lakes be undertaken. The preferred option is to regrade the slope of the foreshore embankment. This should replicate a gradient of adjacent areas showing no erosion and healthy vegetation cover. Stabilisation of the redesigned bank with salt couch or other desirable native species is recommended.

1. *Introduction*

1.1. Chickiba Lakes Acid Sulfate Soil and Wetland Management Plan

Ballina Shire Council commissioned EcoWater Solutions to undertake an Acid Sulfate Soils and Wetland Management Plan for the Chickiba Lakes study area in the context of planned works in the area. Substantial residential development with associated roads and drainage has been carried out in the study area over the last twenty years, some in low-lying melaleuca wetland areas. This Plan sets out the requirements for management of any site disturbance associated with infrastructure maintenance, wetland rehabilitation works, and other minor works that may impact on acid sulfate soils.

1.2. Acid Sulfate Soils

Acid Sulfate Soils (ASS) occur mainly over low-lying coastal areas, predominantly below 5 metres above Australian Height Datum (AHD). These soils may be found close to the natural ground level but may also be found at depth in the soil profile. ASS is particularly found in coastal wetlands.

Under anaerobic conditions maintained by permanent groundwater, iron sulfides are stable and the pH is often weakly acid to alkaline. ASS only becomes a problem when they are disturbed and exposed to air. When iron sulfides are oxidised, sulfuric acid forms and the soil becomes strongly acidic. Typically, excavating or otherwise removing soils or sediments, manipulating water levels or filling land, causes disturbance of ASS.

The exposure of ASS to oxygen (e.g. by drainage, excavation or filling) usually results in production of sulfuric acid and toxic quantities of iron, aluminium and other heavy metals, in forms that can be released into waterways. These ASS products exert a very high oxygen demand in the water bodies.

The acid also corrodes concrete and steel infrastructure and, together with the metal contaminants, can kill or damage fish, other aquatic organisms, and native vegetation, as well as cause extensive degradation of waterway ecological function (Ahern *et al*., 2002).

All disturbances to the groundwater hydrology or surface drainage patterns in coastal areas below 5 metres AHD, including the subsoil or sediments below 5m AHD where the natural ground level of the land exceeds 5m AHD, should be investigated, and where justified should be designed and managed to avoid potential adverse effects on the natural and built environment (including infrastructure) and human health from ASS (Stone *et al*., 1998).

The elevation of the study area under investigation is below 5m AHD and ASS risks maps classify the area as predominantly Class 2 (Figure 1).

The NSW Acid Sulfate Soil Manual was the guiding document to assess the presence and status of ASS for this management plan.

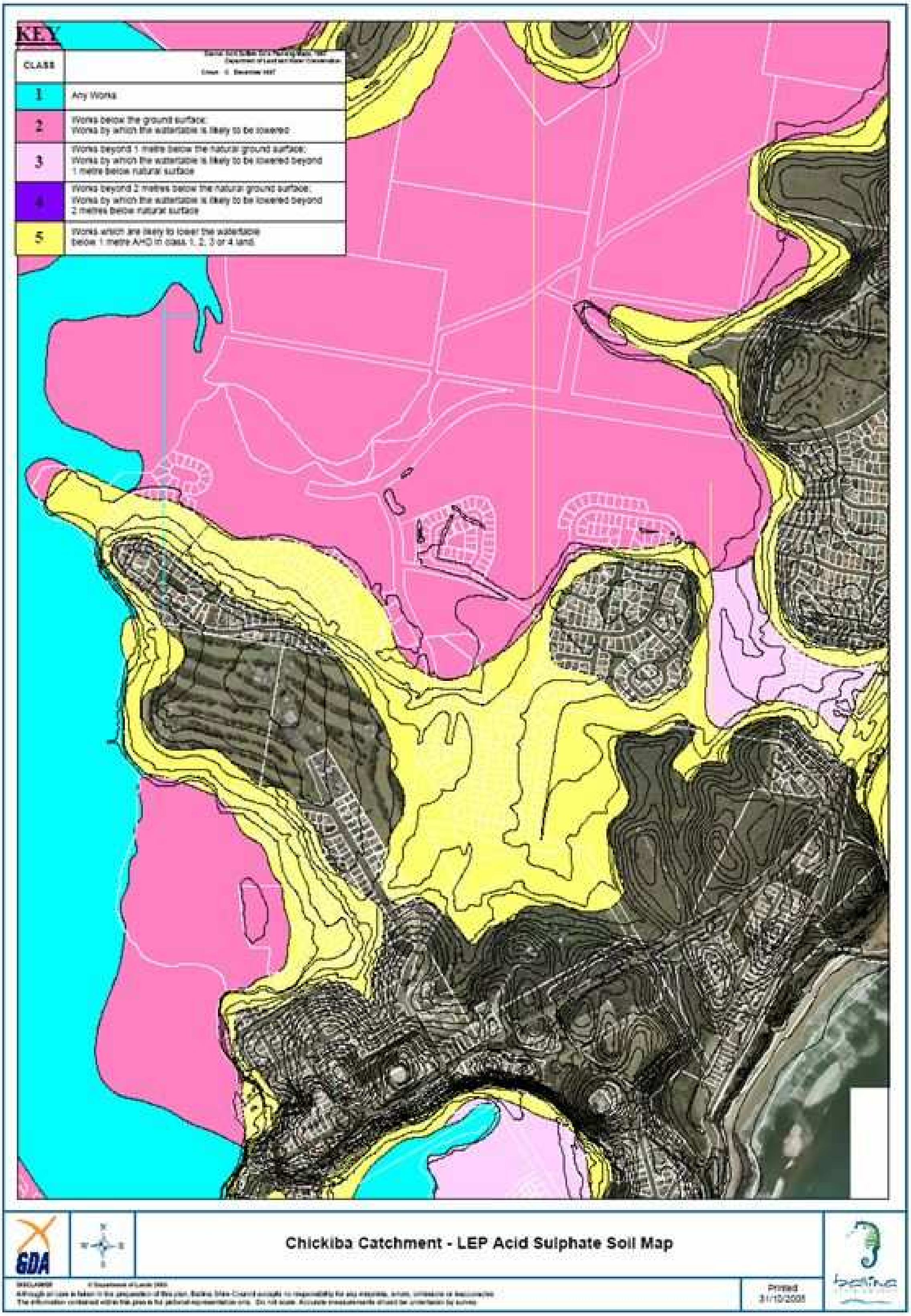

Figure 1: Acid Sulfate Soil Map for the study area.

Project Objectives

The aim of the *Chickiba Lakes Acid Sulfate Soils and Wetland Management Plan* is to undertake an assessment of the present ASS status and provide future management recommendations for the Chickiba Lakes area.

Any works involving the disturbance of ASS must assess the risk associated with disturbance through the consideration of both on-site and off-site impacts. In the Chickiba Lakes area, the possible types of disturbance are drainage works, wetland rehabilitation works, lake maintenance, and minor erosion control works.

To achieve the Plan aim, the following actions were carried out:

- Undertake an assessment of the ASS status of the study area and provide future recommendations for sustainable management.
- Undertake site investigations of the study area and assessment of impacts of any works on ASS and drainage through both desktop assessment and project site inspection
- Undertake soil sampling at designated sites to determine sulphide depth through wetland area. Relate this to the invert levels of the major drains.
- Compile an ASS management plan for the study area covering site characteristics, drainage and flooding, lake pipe discharge and maintenance, lake foreshore erosion, ASS mapping and sampling, land use and infrastructure, identified future earthworks issues relating to ASS, performance indicators and recommended actions and implementation requirements.
- Provide recommendations for wetland ecosystem rehabilitation and preservation in association with ASS drainage.

1.3. Coastal Wetlands

Coastal wetlands in areas undergoing urbanisation are subject to environmental stresses at a number of levels, most notably in their water regime. It is well established that catchment urbanisation can lead to significant changes to the hydrology in, and associated increased pollutant export from, wetlands.

Hydrologic and hydrodynamic characteristics that can affect the environmental value (and ecosystem health) of natural wetlands in urban environments include flood frequency, depth and inundation period, and other flow-duration responses such as velocity increases. Often the “drying” frequency is as important as the inundation frequency in preserving the inherent values of natural Australian wetlands (McComb and Lake, 1990).

Complex interactions between components and alterations to natural cycles and processes, as a result of urbanisation, can result in a wide variety of changes to a natural ecosystem. These threats can impact on physical, chemical and biological attributes of the wetland. Downstream aquatic ecosystems such as estuaries are also impacted by these changes, for example, the possible risk of fish kills through disturbance of acid sulfate soils in natural wetlands.

Threats to wetland function result, primarily, from:

- alterations to hydrology
- physical disturbances as a result of altered hydrology
- alterations to the chemical and physical properties of the substratum (in particular, changes to the wetting and drying pattern)
- direct encroachment on the wetland ecosystem

Land clearing, filling and artificial drainage are typical practices that directly encroach on wetland systems. These threats from urban development can have the following specific impacts on a wetland system:

- redistribution and loss of vegetation communities,
- deterioration of both water and sediment quality within the wetland,
- deterioration of water quality and modification of water volume flowing out of the wetland, and
- loss of individual species and biodiversity or changes to species composition (McComb and Lake, 1990; DLWC, 2000).

In addition, sulfidic soils are particularly found underlying coastal wetlands. Therefore, changes to the hydrologic and hydrodynamic characteristics of a wetland can cause changes to the status of acid sulfate soils.

Importance of Melaleuca Wetlands

Melaleuca wetlands are among the most productive types of ecosystems. They are dynamic, transitional environments that link terrestrial and aquatic ecosystems and are consequently highly variable in their nature. Vegetating the interface between land and water, they provide a number of unique benefits such as:

- Biological diversity
- Nursery and breeding grounds
- Catchment water quality
- Biological productivity
- Nutrient recycling
- Flood mitigation
- Groundwater recharge
- ASS control
- Research and education; and
- Aesthetic, social and cultural values (Adam, 1985).

Melaleuca quinquenervia (paperbark) is the dominant species in north-eastern New South Wales. Prior to European settlement melaleuca wetlands were extensive in distribution, providing wide buffer zones between shorelines, estuaries and coastal rivers, protecting these waterways from sediment loads and nutrient runoff. Clearing of these wetlands for rural activities and more recently for urban development has removed these protective buffer zones (Greenway, 1996).

It is estimated that 50% of freshwater inland and coastal wetlands have been lost since European settlement (Sainty and Associates, 1996). Remaining wetlands are vulnerable to degradation problems affecting both water and land such as water pollution and vegetation clearance. State Environmental Protection Policy Number 14 (SEPP 14) provides some protection for remaining coastal wetlands (NSW EPA, 1997). This policy was introduced in 1985 to conserve wetlands in the face of escalating development pressure on the NSW coast. The Chickiba East Wetland is protected under SEPP 14.

1.4. Legislative and Policy framework

Provisions in Local Environmental Plan

Recent changes to Ballina Shire Council's Local Environmental Plan now require development consent to be obtained for certain works on lands where there is a potential to expose acid sulfate soils, either by excavation or by lowering the water table.

The need for development consent is dependent on the work proposed and the risk class of the land, which is identified on maps held by Council.

SEPP 14 – Coastal Wetlands and other planning instruments

Land mapped by SEPP 14 coastal wetlands defines designated development, pursuant to Section 29 of the *Environmental Planning and Assessment Act*, as:

- Clearing of the land
- Constructing a levee on the land
- Draining the land
- Filling the land

Other instruments are the Regional Environmental Plan and SEPP 26 (Littoral Rainforests) (Stone *et al.*, 1998), and Section 49 Planning Certificates and Acid Sulfate Soils Planning Maps.

2. Chickiba Lakes Management Area

The Chickiba Lakes area consists of a remnant melaleuca wetland that has been divided by past urban development into three parts. The wetland as a whole was fragmented by earlier construction of a sports field in about 1993-4, several residential housing subdivisions and the Southern Cross School. Angels Beach Drive traverses the northern edge of the study area with cleared wetland and salt marsh present on the northern side of the road (private property - see *Consultation* below).

The other areas consist of a natural lake (Chickiba Lake) with rehabilitated bird roost and a constructed lake (Prospect Lake). Figure 2 shows the study area and denotes stormwater drain inlets to wetlands and two drains for which maintenance removal of *Typha orientalis* and *Phragmites australis* is proposed.

The site under investigation has been divided into five management units. These management units have been determined by specific hydrologic characteristics of the areas. The management units are as follows:

Unit 1 – Eastern Chickiba Wetland

Unit 2 – Western Chickiba Wetland (west of Chickiba Sporting Field)

Unit 3 – Chickiba Lake and Southern Cross Wetland

Unit 4 – Prospect Lake

Unit 5 – Property to the north of Angels Beach Drive (Unit 1 drains into this site)

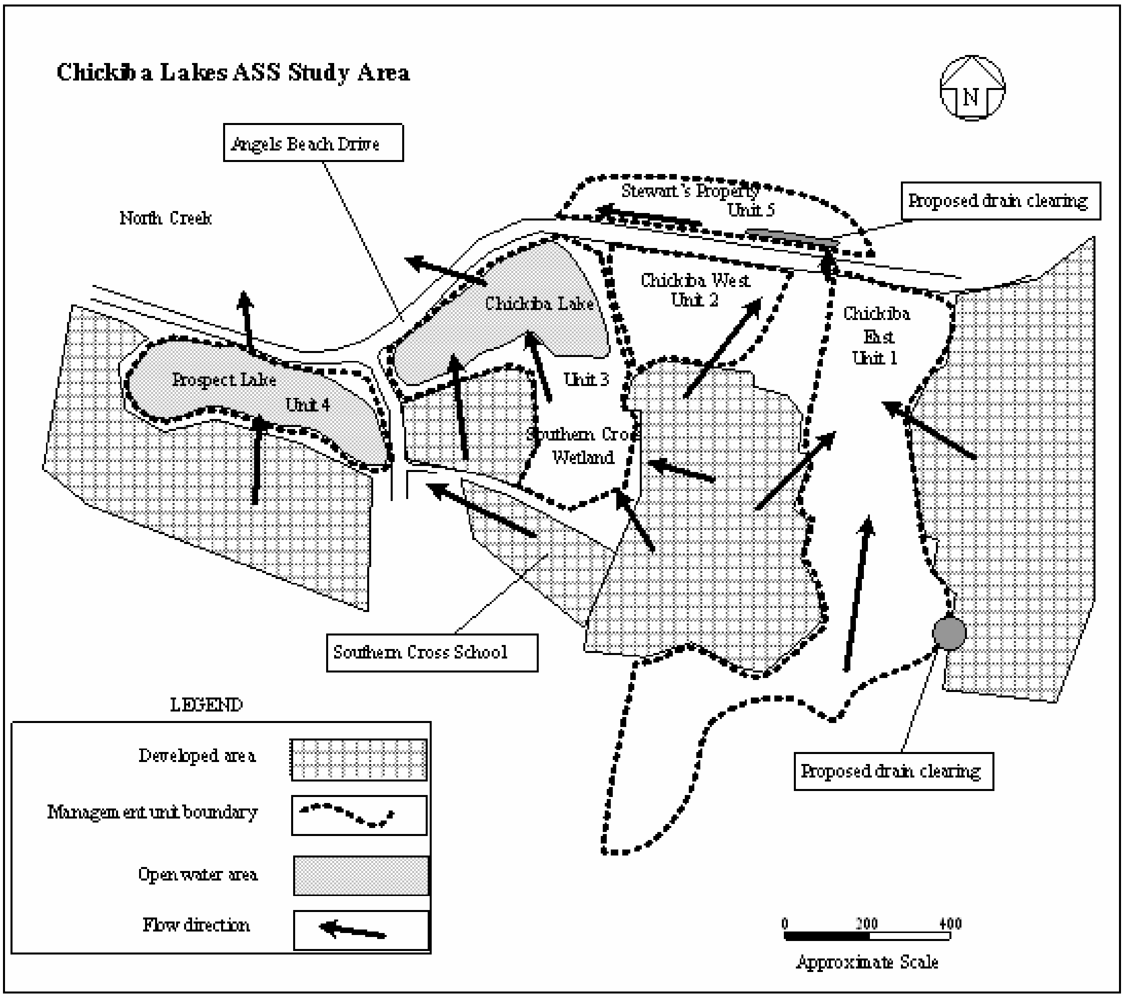

Figure 2: Study area

3. Acid Sulfate Soils at Chickiba Lakes

The study area is considered a potential ASS landscape because elevations are below 5m AHD, ASS soil risk maps predominantly categorise the area as Class 2, melaleuca forests are commonly found on ASS landscapes, and geological history and location is favourable for pyrite formation. Assessments were undertaken for each management unit to assess in more detail the presence of ASS. This involved desktop and visual assessments of the management areas and included ASS sampling in the Chickiba East Wetland.

The following visual indicators for ASS were assessed:

- Unexplained scalding
- Unexplained death or disease in aquatic organisms e.g. fish kills
- Formation of jarosite and other acidic salts in exposed or excavated soils
- Areas of green-blue water or extremely clear water indicating high concentrations of aluminium
- Rust coloured deposits on plants and on the banks of drains, water bodies and watercourses indicating iron precipitates
- Black to very coloured waters indicating de-oxygenation (Stone *et al*., 1998).

None of the abovementioned indicators were found during site assessments. However, the northern end of the Chickiba East Wetland featured a strong hydrogen sulphide smell indicating the possible presence of PASS conditions. This indication is supported by the results from a grab sample. Potential acid sulfate soils in the surface layer of organic matter (see Table 7) were above the action criteria and therefore would require appropriate management if disturbed.

3.1. Previous Site Assessments

3.1.1. North Coast Wetlands Assessment – Chickiba East Wetland

A wetland assessment was undertaken on the 24th of October, 2004. As part of the assessment a Field pH and peroxide test (ASS field kit) was undertaken to determine the likely presence and severity of ASS. The results from the testing are shown in Table 1.

Table 1: pH data table for Chickiba East Wetland.

Sample code	Sample depth (cm)	pH_{field}	pH_{fox}	Reaction rating
1	unknown	5.5	4.0	Moderate
2	unknown	6.0	2.5	High
3	unknown	5.0	3.0	Low
4	unknown	5.0	2.0	Slight

The North Coast Wetlands Assessment for the Chickiba East Wetland has interpreted these results as identifying “high quantities of natural occurring acid currently locked up under pooling water and peat layer”(Brideson, 2003). In addition, vigorous bubbling of sulfide gas was observed during the assessment.

It is important to note that the Field pH and peroxide test can be a useful indicator but not a substitute for laboratory analysis in the identification of ASS. In addition, soils containing high organic matter (such as peat, surface soils, mangrove/estuarine muds, and marine clays) require care to be exercised when interpreting the results as high levels of organic matter and other soil constituents particularly manganese oxides can also cause a reaction (Stone *et al.*, 1998).

The results from the wetland assessment are indicative and laboratory testing would be required to confirm the presence and severity of ASS at the Chickiba East Wetland.

3.1.2. ASS sampling for the Chickiba Lakes Bird Wading Area

On the 24th of July, 2003, ten samples were taken in the bird wading area at Chickiba Lake. These samples were analysed with the POCAS method and Chromium Reducible Sulphur technique. Figure 3 shows a plan of the Chickiba Lake with the ASS approximate sampling points.

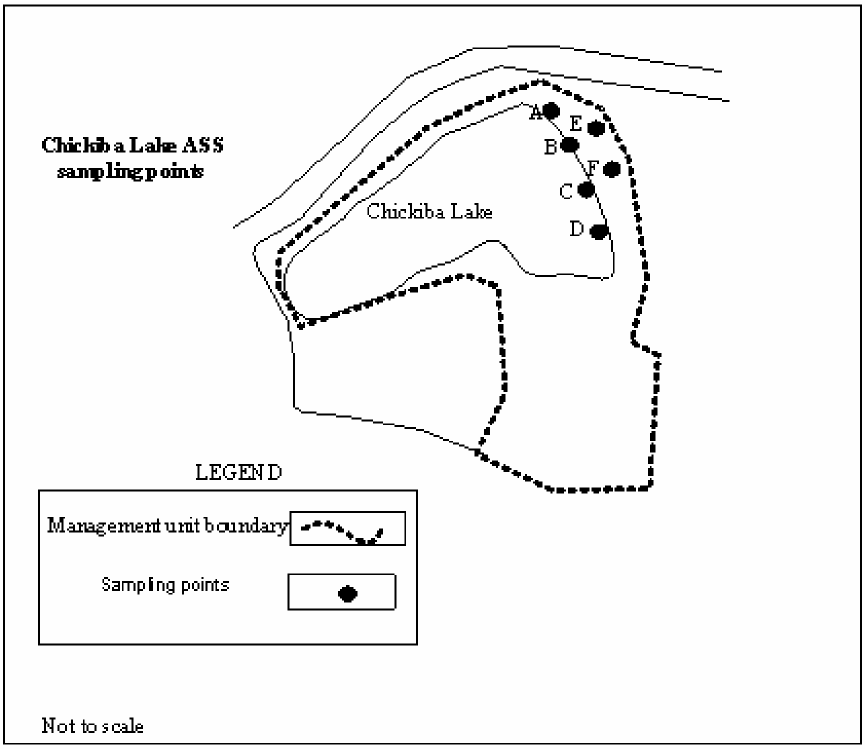

Figure 3: Chickiba Lake area showing ASS sampling points.

The results of the ASS sampling at Chickiba Lake are shown in Table 2. One of the ten samples (Site B, 0.5m depth) was classified as Potential Acid Sulfate Soil. The other samples did not exceed the trigger values set in the NSW Acid Sulfate Soil Manual.

The Total Actual Acidity (TAA) values show Sample A (0.2 and 0.5m depth) and Sample C (0.2m depth) were less than 5.5 and therefore given a calculated liming rate. TAA is a measure of the soil's existing acidity prior to oxidation of sulfidic material. Peat/swamp soils, coffee rock and Podosols, characterised by having high organic matter, may have a significant TAA due to organic acids. These TAA results are inconclusive in identifying the samples taken as Actual Acid Sulfate Soils.

Table 2: Results of Acid Sulfate Soil analysis for bird wading area, Chickiba Lake.

Sample site	**Texture**	**Depth** (m)	**TAA** (pH_{kcl})	**TAA** (mole H/kg)	**Reduced Inorganic Sulfur** (%Scr)	**Potential Acidity Neutralising Calc.** (kg lime/m^3)	**Actual Acidity Neutralising Calc.** (kg lime/m^3)	**Lime calculation** (kg $CaCO_3/m^3$)
Site A	Coarse	0.2	4.79	0.081	0.003	0.1	4.8	4.9
Site A	Coarse	0.5	5.34	0.010	0.006	0.3	0.6	0.9
Site B	Medium	0.2	8.25	0.000	0.006	0.3	0.0	0.3
Site B	**Coarse**	**0.5**	**9.09**	**0.000**	**0.059**	**2.6**	**0.0**	**2.6**
Site C	Medium	0.2	5.06	0.042	0.007	0.3	2.8	3.1
Site C	Coarse	0.5	7.95	0.000	0.008	0.3	0.0	0.3
Site D	Coarse	0.2	6.80	0.000	0.004	0.2	0.0	0.2
Site D	Coarse	0.5	6.20	0.000	0.004	0.2	0.0	0.2
Site E	Medium	0.5	6.55	0.000	0.011	0.5	0.0	0.5
Site F	Coarse	0.5	6.54	0.000	0.002	0.1	0.0	0.1

3.1.3. Chickiba Wetlands Acid Sulfate Soil Management Plan

Preliminary Assessment of site works

A preliminary assessment was undertaken on the 7th of October, 2003 for the proposed drain clearing works at the Chickiba East Wetland discharge drain. The drain is located to the north under Angels Beach Drive into Lot 66.

Preliminary assessment of the works within the outlet drain involved recognition of acid sulfate soil indicators and on-site pH field and pH_{fox} (hydrogen peroxide test). Three soil samples were taken along the course of the drain at 10cm depth for pH testing. At most the Peroxide reaction was only slight with a small change in oxidised pH. No soil surface indicators or water indicators were present (see Appendix 2 for results).

Two soil samples were also taken at each of the three sampling sites at 0cm and 20cm depth. Field notes taken at the time of collection indicated high organic matter levels in the samples. Analysis of the six samples for Total Actual Acidity (TAA) and Total Potential Acidity (TPA) revealed five samples not to be PASS and the one sample at Site 1 (20cm depth) to have a small quantity of PASS.

The laboratory results provided liming rates (kg $CaCO_3$ eq/m^3) based on neutralising calculations (Appendix 2). The quantities of lime required are minimal but were used for the works.

4. Site Characteristics

4.1. Site Description

The area under investigation is located north of the Richmond River estuary and east of North Creek. It is bordered by Angels Beach Drive to the north and residential subdivisions to the south. The undeveloped area is dominated by melaleuca wetlands and the two lakes, Prospect and Chickiba.

The study area is divided into a number of land zones that are described in Table 3 and shown in Figure 4.

Table 3: Land zoning for study area encompassing Units 1-5 (Figure 3).

Unit	Lot No.	Land zoning	Notes
1 2 3 4	Lot 207 DP 851318 Lot 406 DP 755684	6a – open space 7a – environmental protection wetlands 2a – residential living area 1d – rural-land investigation 7L – environmental protection habitat	
5	Lot 66 DP 755684 Lot 306 DP 755884	7a – environmental protection wetlands	Including road reserve and Angels Beach Drive.

Figure 4: Aerial photo of study site with land zoning.

4.2. Geology

The geology of the Ballina Shire is dominated by the volcanic history of the region, the Richmond River system and proximity to the coastal zone. These relate, respectively, to the Alstonville Plateau composed of the iron- and aluminium-rich Mt. Warning volcanics, the alluvial plain areas and the coastal and dunal systems north and south of the Richmond River.

North of the Richmond River, soil-forming processes are generally coastal in influence. Quaternary estuarine alluvial soils are overlain by and/or mixed with Quaternary (Pleistocene) sands. The sands are generally Aeolian, originating from the adjacent beach ridge systems (Morand, 1994). Holocene estuarine conditions and organic matter provided the other elements of the sulfidic soils.

4.3. Climate

The climate of the region is subtropical with relatively high rainfall predominantly in the summer months. The Ballina Shire has a high mean annual rainfall of 1654mm (Australian Bureau of Meteorology, 2006). The majority of rainfall occurs from February to June.

4.4. Catchment Characteristics

The study area lies in a catchment between the dune ecosystems of Shelley and Angels Beach to the east, Chickiba Creek to the north, and North Creek to the west. The area features ecosystems such as mangroves, saltmarsh, melaleuca wetlands, coastal heath and lakes. The highest point in the catchment is slightly higher than 20m AHD and the lowest at sea level (AHD).

A considerable area has undergone urbanisation with six discrete subdivisions. The Ballina Golf Course is located in the south-east corner adjacent to a commercial complex and the Southern Cross School is located south of the Southern Cross Wetland.

4.5. Topography

The lower area is characterized by flat low-lying sediment basins. Shallow water tables fluctuate from above the surface to 100-200cm below the surface. Sediments have accumulated from a number of processes:

- Deposition by suspension from rivers
- Washover sand deposition as extensive sheets
- Aeolian reworking of exposed sand surfaces to produce back dune flats
- Channel-fill deposition of flood tidal delta origin (Morand, 1994).

Slopes are generally 0-1%, relief is 1-2m and elevation is 1-10m. Drains have modified the natural drainage pattern and tidal effects may also impede drainage in some conditions.

4.6. Hydrology

Before urbanisation, the areas less than 5m AHD most likely were frequently flooded up to 1m with 4-6month drying phases. The melaleuca wetland areas would have flooded in high rainfall events and slowly released surface water over a few days to a week into Chickiba Creek. Areas above the 5m AHD elevation line (particularly in the east) are situated on highly permeable sandy soils and therefore minimal surface runoff with higher levels of groundwater recharge would have occurred.

The hydrology has changed considerably due to urban development in the catchment. At present, significant areas of the catchment are impervious (e.g. roads and roofs) which results in less infiltration and higher quantities of surface runoff at discrete points into the melaleuca wetlands.

Figure 5 is a schematic illustration of how the hydrology of natural melaleuca wetlands and wetlands are affected by urbanisation. The arrow thickness estimates the increase quantity of stormwater entering the wetland after catchment urbanisation. In turn, water levels generally rise rapidly in wetlands with adjacent urban development and drying phases are less frequent and shorter in duration. Over time, compositional and structural changes occur in melaleuca wetlands such as the Chickiba Wetlands because of significant changes in hydrology.

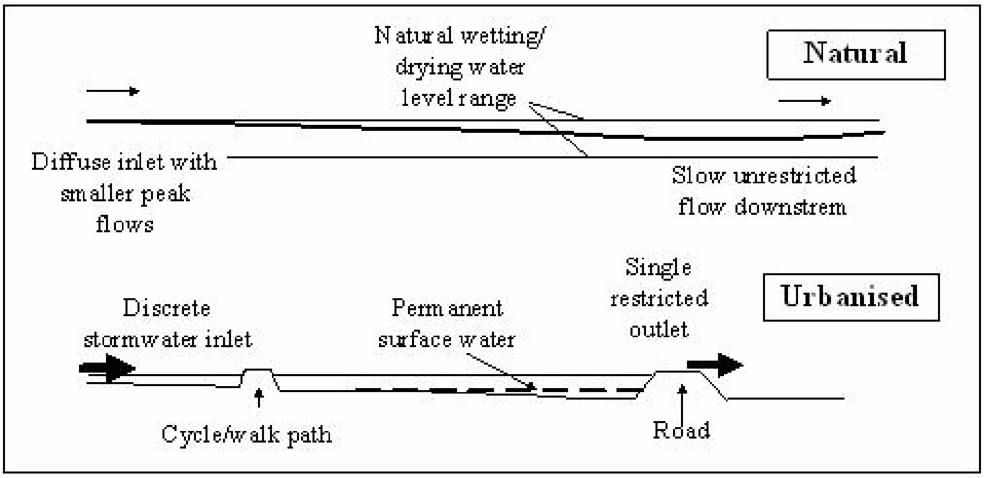

Figure 5: Schematic diagram of Chickiba East Melaleuca Wetlands natural hydrology and hydrologic changes post-urbanisation.

4.7.Fauna and Flora

The vegetation of the area under investigation is predominantly Broad-leaved paperbark forests that adjoin the Chickiba sports field and a number of surrounding urban developments. The native plants Bangalow palms (*Archontophoenix cunninghamiana*), black wattle (*Acacia melanoxylon*), and cunjevoi (*Alocasia macrorrhiza*) exist in some areas, and a number of garden escapees such as lantana (*Lantana camara*) and *Impatiens* are found on the fringes of the paperbark wetlands or in areas of disturbance.

Due to urban encroachment in the wetland and development in the surrounding areas the Chickiba East Wetland has experienced drastic changes to natural wetland hydrology. This change is most noticeable at the bottom of the wetland where surface water to an estimated depth of 80cm is permanent. This has caused species change in the SEPP 14 wetland with *Typha orientalis* and *Phragmites australis*, with some *Lepironia articulata*, colonising in areas of permanent to semi-permanent water.

The Chickiba Lakes waterbodies are tidal and therefore salt species predominate. These include salt couch (*Sporobolus virginicus*) and patches of grey mangroves (*Avicenna marina*). Chickiba Lakes has a bird roosting site for a variety of migratory shorebirds that include such species as the Pacific Golden Plover, Eastern Curlew, Curlew Sandpiper, Terek Sandpiper and Grey-tailed Tattler.

4.8.Current land use

The wetlands and waterbodies have been segmented by the clusters of residential areas, sporting field, and associated infrastructure. Residential housing subdivisions are the dominant land use with stormwater directly discharged from the urban areas into the wetlands and lakes through almost thirty stormwater pipes of varying size and condition.

4.9.Drainage and Flooding

A drain has been constructed along the western edge of the Eastern Chickiba Wetland. In other areas stormwater pipes discharge directly into the melaleuca wetlands and lakes. Stormwater flows leave the study area by three routes: through a stormwater pipe at the Chickiba Eastern Wetland, located under Angels Beach Drive, and under two bridges for Chickiba Lake and Prospect Lake. The stormwater flows into the wetlands and lakes are shown as arrows in Figure 2. Figure 6 shows an aerial photo of the study area.

Figure 6: Aerial photograph of the study area.

5. *Chickiba Lakes Management Units*

5.1. Chickiba East Wetland

The eastern wetland drains a catchment of about 50 hectares extending from the south, from just west of Black Head. Angels Beach Drive separates the wetland on the south side of the road from the cleared wetlands and salt marsh complex on the north side (private property). The wetland is classified under SEPP 14 legislation, and as 7A Zone under Ballina Shire Council's Local Environmental Plan. The main features of this wetland section are shown in Figure 7. The "Open Water" zone marked is characterised by an absence of plants but the water is usually covered in the small native fern *Azolla*.

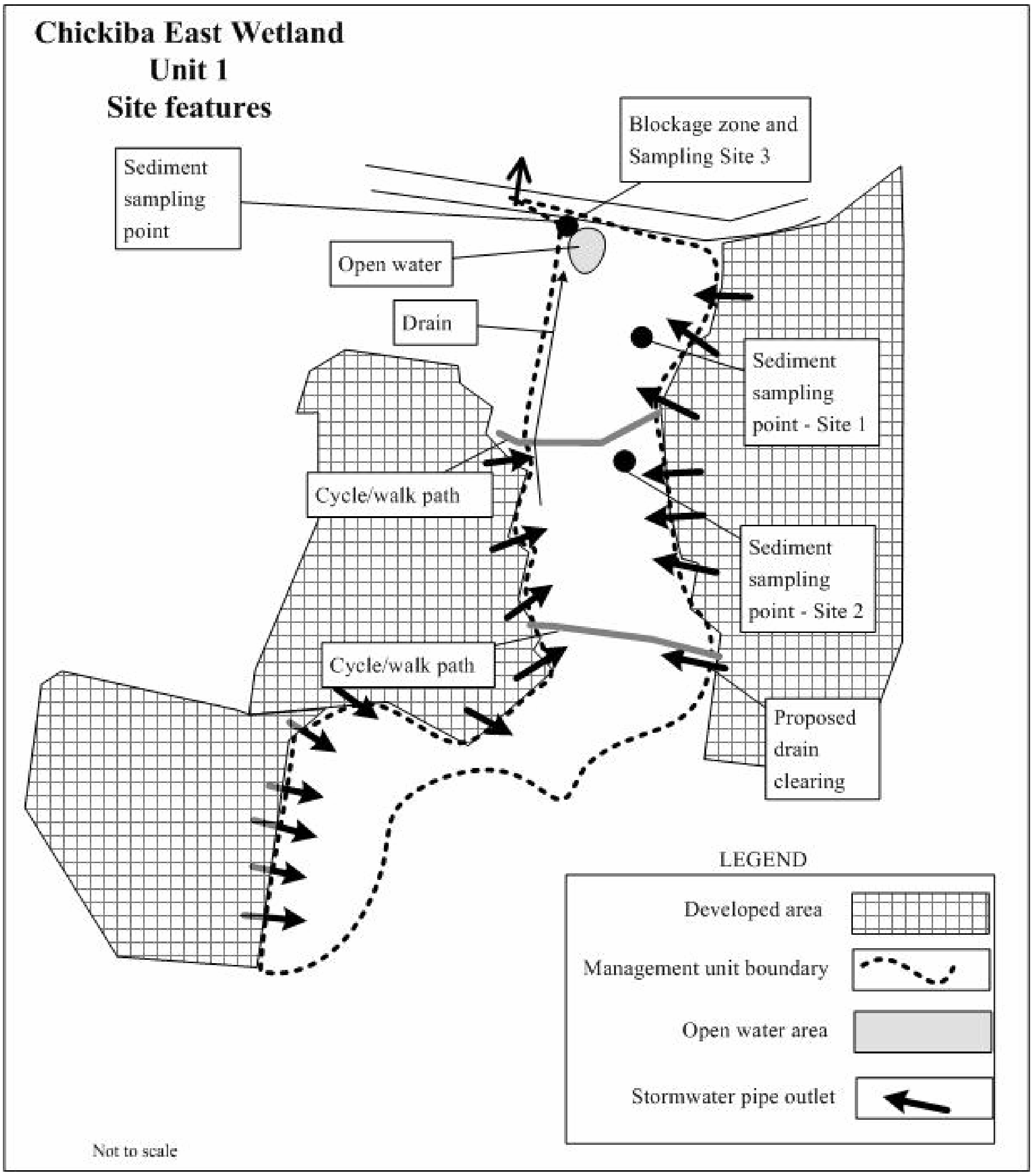

Figure 7: Main features of the Eastern Chickiba Wetland.

During 2002, the Chickiba East Wetland was assessed for ecological health and condition (Brideson, 2002). Comments had also been received from the community about the obvious dieback of the melaleuca forest which could be seen easily from Angels Beach Drive.

The assessment found that the northern part of the wetland was in very poor condition due to changes in the hydrological regime (see Plates 1 and 2). Substantial volumes of untreated stormwater runoff were flowing into the wetland, and outflows were restricted.

This process had led to a change in species and conditions in the wetland. *Typha* and *Phragmites* were found to dominate the lower areas of the wetland, and were choking the culverts and drains that were constructed to allow water to flow out of the wetland.

Phragmites and Typha are native species, but in this context are an indicator of damage because these reeds would not normally grow so densely in this wetland under the melaleuca canopy. Anecdotal evidence and observation of the similar landscape nearby suggest the wetland was dominated by melaleucas. Fallen trees and instances of windthrow were common, indicating waterlogging of the melaleuca forest.

Plate 1: Typha and Phragmites dominating the Eastern Chickiba Wetland. Sparse melaleuca canopies in the background.

Plate 2: Open water zone with Azolla cover in Chickiba East Wetland.

Site inspections indicate that drainage of surface waters is inhibited mainly by *Typha* and *Phragmites* blocking the drain outlet added to the build-up of slowly decomposing organic matter at the bottom edge of the melaleuca wetland and in the drain. This build-up of material is likely to have caused a choke point at the bottom edge of the wetland that precludes surface water naturally draining. Conditions are dangerous for personnel for site inspection in places because of the depth of water and fallen trees.

In March 2004, after preparation of a Review of Environmental Factors and approval from the Department of Infrastructure, Planning and Natural Resources, part of the drain was carefully cleared of some of the reeds. Monitoring of water levels and vegetation condition was undertaken on a monthly basis by Council staff to assess the success of the drain clearing in restoring the wetland.

It was noted that increased flow velocity occurred in the drain after clearing and some reduction in water level occurred, however, it was not practical to monitor water level changes after the removal of reeds from the drain (J. Brideson, pers comm.). Repeating the reed clearing of the drain will be required to aid in rehabilitating the wetland, although a risk of ASS disturbance is incurred by the potential lowering of the water table.

In addition, it is considered that clearing of the blocking organic matter from within the "bottleneck" of the wetland outlet is required to allow a decrease in water depth for safe access to allow closer inspection of the physical situation.

One method of achieving this is to install an interim water control structure in the outlet drain at about the point previously designated as the nominal limit of works so that clearing could be extended upstream to where it would become effective in lowering the damaging water depth.

Such a structure would not be permanent, but would be adjustable, low-cost, and removable. A sandbag weir can be used in this situation (Figure 10). This weir would allow water depth to be maintained while further drain clearing occurred, after which the depth could be lowered by removing sandbags.

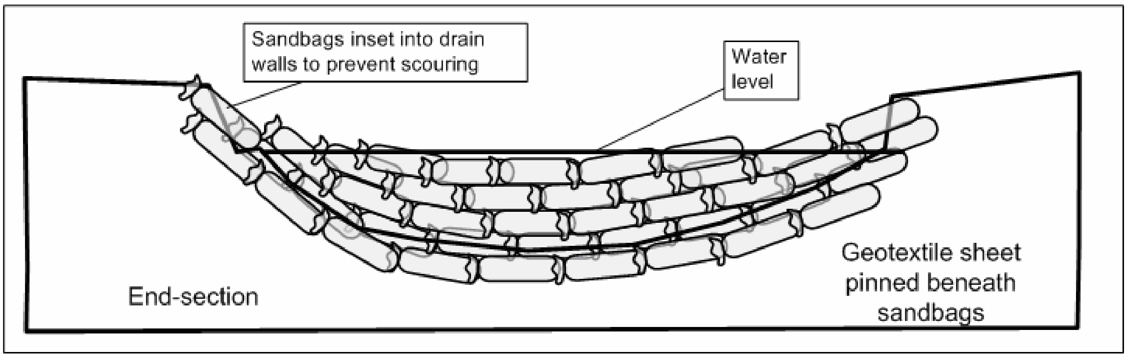

Figure 8: Simple diagram of sandbag weir.

A further issue involves a stormwater pipe outlet situated on the wetland eastern boundary (Figures 2), and proposed for clearing. The pipe invert is about one meter below ground level, and the outlet has a very limited dissipation zone (Plate 3). The grade line of this stormwater pipe appears to be inappropriate for the development.

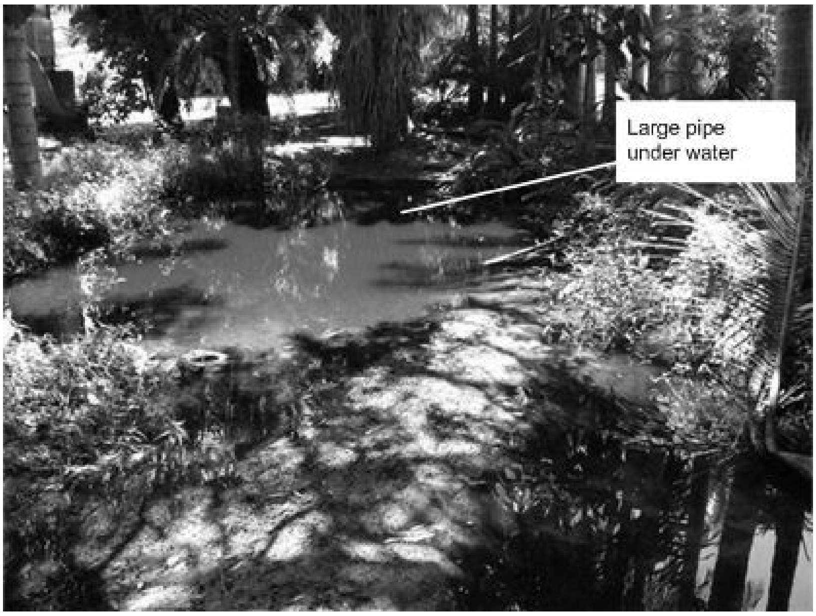

Plate 3: Position of pipe below water.

The ground-level outlet discharge area is a weed-infested (mainly Lantana and umbrella trees) clearing within the melaleuca forest. There is some regrowth of small Bangalow Palms in the drainage path. The following points are relevant:

- The need for interim clearing of the discharge path in the interest of residents' safety and amenity is clear
- The proposed area for clearing has been cleared in the past and is presently covered in weeds
- There are no visible signs of ASS impacts from past operations
- Clearing of weeds is likely to involve only surface soil disturbance
- Deeper clearing to extend the ponded area is likely to increase ASS impacts, problems of mosquitos, possible algal blooms, and damage to the forest
- The weed infestation probably results from the clearing itself allowing sunlight into the wetland
- A longer term sustainable strategy could include assessment of re-design of the drainage system in this area, including employment of Water Sensitive Urban Design principles. In the short term, re-planting of melaleucas with interim weed control may provide an efficient stormwater discharge path with shading of weeds.

5.1.1. Acid Sulfate Soil Assessment

The ASS assessment of the Chickiba Melaleuca Wetland followed the *NSW Acid Sulfate Soil Manual* (1998), the *Guidelines for sampling and analysis of lowland Acid Sulfate Soils (ASS) in Queensland* (1998), and *Acid Sulfate Soils Laboratory Methods Guidelines* (2004).

This assessment was undertaken to provide a foundation for the effective management of the impact of reinstating more natural water levels on the ASS status of the site. Reductions in water levels are required to rehabilitate the melaleuca wetland and this action has the potential for a negative impact on downstream aquatic ecosystems by the possible production of ASS by-products.

Preliminary assessment within the Chickiba wetland involved inspection for ASS indicators, and onsite soil pH (field) and oxidised pH field-testing using Hydrogen Peroxide.

For the ASS assessment, six soil samples were taken from within the Chickiba wetland area on December 12, 2005 and tested for the presence of acid sulfate using the Chromium Reduced Sulphur technique, as laid out in the Acid Sulfate Soils – Laboratory Methods Guidelines by Ahern *et al*., (2004) and recommended by Michael Wood, Richmond River County Council (pers comm., 2005)

Difficulties were encountered in sampling at one bore site below the cycle/walk path as originally planned. The depth of permanent water found at the designated site made it impracticable for soil sampling.

Safety issues were also identified for this borehole that was under fairly deep opaque water with fallen trees. Therefore, samples were taken at the nearest site possible and a grab sample from the permanent water was added to the sampling.

5.1.1.1. Acid Sulfate Soil Sampling Methodology

Two bore holes were dug at strategic points in the Eastern Chickiba Melaleuca Wetland. The sample positions were chosen in the landscape to reflect practical access constraints as well as the likelihood of intersecting ASS if present. The sampling protocol followed the sequence of:

- Using auger to dig bore hole.
- Samples taken at 0-10, 25, 50, 75, and 100cm.
- All samples were tested for pH_{field} and pH_{fox} in the field.
- Samples at 0-10, 50, and 100cm were placed in a sealed bag and stored on ice.
- Samples were then taken to the Environmental Analysis Laboratory at SCU for analysis using the Chromium Reducible Sulfur suite.

5.1.1.2. Acid Sulfate Soil Field Analysis

An Acid Sulfate Soils Field Kit was used to determine pH_{field} and pH_{fox} immediately after the soil samples were extracted. The following table shows the results of the field analysis.

Table 4: pH_{field} and pH_{FOX} results from the Eastern Chickiba Wetland.

Sample site	Sample code	Sample depth (cm)	pH_{field}	pH_{fox}	Reaction rating
1	1a	0-10	6.39	4.1	Low
	1b	25	6.2	4.8	Low
	1c	50	5.9	5.3	No reaction
	1d	75	4.96	4.6	No reaction
	1e	100	4.9	4.7	No reaction
2	2a	0-10	4.6	4.6	No reaction
	2b	25	4.78	4.25	No reaction
	2c	50	5.15	4.5	No reaction
	2d	75	6.0	4.9	Low
	2e	100	6.1	4.6	Low

Soil characteristics for each sample taken from the Eastern Chickiba Wetland are shown in the following tables. The soils are generally characteristic of wetland environments, and ASS landscapes. Indicators of ASS conditions would include iron oxides or jarosite on soil surfaces, and characteristic plants.

Table 5: Soil characteristics at sample sites in the Eastern Chickiba Wetland.

Soil Sample	1a	1b	1c	1d	1e
Depth (cm)	0-10	25	50	75	100
Texture	Sandy clay	Sandy clay	Sandy clay	Sandy clay	Sandy clay
Structure	massive	massive	massive	massive	massive
Colour	dark grey	dark grey	dark grey	brown	brown
Water table	at surface	-	-	-	-
Presence of ASS indicators	absent	absent	absent	absent	absent
Presence of $CaCO_3$ e.g. shell grit	absent	absent	absent	absent	absent
General Comments	Wet soil with high root density		Low root density	-	Some fine roots, 20-30% sand

Table 6: Soil characteristics at sample sites in the Eastern Chickiba Wetland.

Soil Sample	2a	2b	2c	2d	2e
Depth (cm)	0-10	25	50	75	100
Texture	Organic silty clay	Organic silty clay	Silty clay	Sandy	Sandy
Structure	massive	massive	massive	single grained	single grained
Colour	dark brown	dark brown	dark brown	grey/yellow	grey/yellow
Water table	-	15cm below soil surface -	-	-	-
Presence of ASS indicators	absent	absent	absent	absent	absent
Presence of $CaCO_3$ e.g. shell grit	absent	absent	absent	absent	absent
General Comments	Wet soil with high root density	-	Low root density, organic matter found	-	-

5.1.1.3. Acid Sulfate Soil Laboratory Results

Laboratory results from Site 1 and 2 are shown in Table 7. The results show that samples tested for reduced inorganic sulfur percentages (%Scr) were below the trigger value of 0.06 (medium texture). This indicates that Potential Acid Sulfate Soils (PASS) were low.

Net acidity results show samples were above the action criteria set at 36 mol H^+/tonne. Therefore, samples are classified as actual ASS according to the Acid Sulfate Soil Manual action criteria.

The results for Site 3 (Table 7) show reduced inorganic sulfur percentages (%Scr) that triggers the action criteria. This grab sample from the sediment surface of the open water area has a pH of 7.99 and no actual acid sulfate soil is present in the sample due to a TAA result of 0.

Table 7: Acid Sulfate Soils laboratory results.

Sample site	**Texture**	**TAA** (pH_{kcl})	**TAA** (mole H^+/tonne)	**Reduced Inorganic Sulfur** (%Scr)	**Reduced Inorganic Sulfur** (mole H^+/tonne)	**Net Acidity** (mole H^+/tonne)	**Lime calculation** (kg $CaCO_3/m^3$)
Method No.		*23A*	*23F*	*22B*	*a- 22B*		
Site 1a	Medium	4.38	170	0.026	16	186	7
Site 1b	Medium	4.49	40	0.005	3	43	5
Site 1c	Medium	4.45	60	0.008	5	65	7
Site 2a	Medium	3.41	380	0.022	14	394	8
Site 2b	Medium	3.89	105	0.031	19	124	12
Site 2c	Medium	4.10	65	0.014	9	74	8
Site 3	**Coarse**	**7.99**	**0**	**0.053**	**33**	**33**	**5**

5.1.1.4. ASS Summary and implications

The results show that PASS levels were low from the soil surface to 1m depth. The first meter from the soil surface was categorised as containing actual acid sulfate soils under the action criteria set by the NSW Acid Sulfate Soils Manual, however the relatively high pH_{field} values of 4.6 to 6.4, low Reduced Inorganic Sulfur levels (Table 7), the permanently high water table, and the presence of high organic acidity commonly found in low-lying coastal wetlands indicate that the sample results were most likely anomalous and related to natural organic acidity and therefore have a low ASS risk.

Site 1 was located on the edge of the open water area (adjacent to the installed piezometer) due to difficulties of sampling and safety issues in the permanent water. Therefore, a further grab sample was also taken from the edge of the permanent water at the northern end of the drain in the wetland. A hydrogen sulfide smell was evident at that point during site assessment, and the Reduced Inorganic Sulfur results from that sample indicate that PASS exists in the surface sediment layer.

The most likely explanation of this result is that the surface sulfur developed from the lowering of natural water levels by drainage during construction of surrounding developments in the 1980's, followed by permanent inundation, with anaerobic conditions, as obstructions to outflows developed with the construction of the road, sport fields, and the growth of reeds and rushes in place of melaleucas.

The implication of these findings is that although a low risk of ASS impacts exists, any changes in water level and/or disturbance of sediment at the northern end of the wetland will require appropriate ASS management. This would involve a maximum liming rate of

2.7kg $CaCO_3/m^3$ for sediment removed in drain clearing outside of the wetland and a liming rate of 5kg $CaCO_3/m^3$ for drain clearing undertaken within the Chickiba East Wetland.

Sediment and materials removed should be managed according to the NSW ASS Manual, i.e. the most favoured option is to bury the material in anaerobic conditions, preferably below the water table. Other options include rapid oxidation and neutralization under controlled conditions.

5.1.2. Recommended Actions

The recommendations for the Chickiba East Wetland are provided for three time scales – short-term, medium-term and long-term.

Short-term

- Begin a careful removal of accumulated vegetation in the drain outside of the SEPP 14 wetland as carried out previously in 2002, beginning at the Angels Beach Drive culvert
- Consider an EIS, REF or appropriate document to allow further ASS management, exotic vegetation control and hydrological remediation measures into the SEPP 14 boundary
- Assess placement of a water control structure such as a sandbag weir at a point outside the nominal SEPP14 wetland boundary to enable more control over the level of water in the northern zone of the wetland
- Undertake further removal of accumulated vegetation and build-up of sediment in the outlet zone of the wetland
- Consult with the NSW Department of Planning regarding options
- Locate a photo monitoring point at the bottom of the wetland in order to document changes in wetland structure and composition over time
- Consider addressing stormwater impacts (pollutants and stormflows) on the wetland with on-ground works and associated management plans.

Medium-term

- Following lowering of unnatural water depths in the wetland, wait and observe for natural regeneration as a first option;
- Consider planting melaleucas and other shading vegetation along Angels Beach Drive drain to reduce severe terrestrial weed (e.g. Para grass) problem through shading;
- Consult with nearby residents;
- Consider the need for better stormwater management.

Long-term

- Assess feasibility of widening and/or shallowing drain to restore better wetland function;
- Assess natural regeneration rate and weed infestation;

- Recognise damage to wetland from partial clearing, cycle/walk path, road, inundation, weeds, and apply remediation strategies over time in response to results of works.

5.1.3. Implementation Requirements

The proposed works consist of strategic stages to accomplish a common environmental objective of lowering the surface water levels within the wetland to near natural flow levels. Each stage should be conducted with a sufficient time span to allow the hydrological and ecological conditions to effectively change and adapt to the natural conditions. Included in the implementation requirements are recommendations to effectively manage ASS on the site.

Stage 1

The proposed works within the first stage entail the removal of reeds in the drain near the road culvert on both sides of Angels Beach Drive. This involves a 30m long section of the drain parallel to Angels Beach Drive on the south side and a section of drain on the north side of Angels Beach Drive. The works will involve the removal of the reeds (*Typha* and *Phragmites*) and weeds that currently grow in and block the drain and culvert on either side of Angels Beach Drive.

Stage 2

It is recommended that once Stage 1 is complete that a temporary water level control structure such as a sandbag weir be installed to retain water levels close to present levels. Removal of a further 35m section of reeds in the drain as far as the open water area would then allow inspection and assessment of the blockage area downstream of the open water area.

Water levels could then be lowered by removing sandbags from the weir a layer at a time under controlled conditions. Visual and instrument survey would then be more practical, following which a more detailed plan for water table control could be devised. It is recognised that removal of vegetation further upstream to the open water will incur constraints associated with the SEPP 14 Policy. However, the SEPP 14 wetland has been severely degraded by the identified process of excessive inundation and water depth, and unless these processes are remediated the degradation is likely to continue.

An excavator should remove the reeds and weeds using a reed bucket as in the previous operation, allowing sediment and water to filter through holes, thus remaining in the drain. It is expected that some accumulated sediment from the drain substrate will be attached to the reed roots as they are removed.

Monitoring Locations

The depth gauge and 75mm piezometer currently installed at the upper end of the wetland will monitor surface waters and groundwater levels. However, due to the distance between this monitoring location and the staged works it is recommended that a depth gauge be installed at the bottom of the wetland adjacent to the area of works.

The open water area dominated by *Azolla* (see Plate 2) is located 6 metres into the wetland from the western corner and the drain there would be a suitable location for a depth gauge.

Photo monitoring should continue, especially of the open water zone and area of *melaleuca* dieback.

Water Quality Monitoring
Monitoring of pH levels near the road culvert in drain should continue. Monitoring of pH following reed removal is essential, and should continue while any changes to water level are being effected. A general pH level of at least 5.5 would be desirable, but prior pH testing would establish baseline values from which substantial deviation would require remediation such as greater liming, or a higher water table.

Monitoring Frequency
After works are completed the depth gauges should be monitored fortnightly and the water quality monthly, while photographs should be taken at 3 monthly intervals from designated photograph points.

Performance indicators
The photo points, depth gauge, piezometer, and visual assessments will provide an indicator of performance. In the short-term water levels need to be reduced to between the soil surface and 100mm below the surface at the northern end of the wetland. Therefore, permanent surface water and open water areas will recede to or below the surface level. Following this action, longer term performance indicators should include the improved health of the melaleuca trees and natural regeneration after the reeds die back to a more natural balance.

Contingency procedures
A possible extreme event would be a large flood washing out the water control structure. In this event, simple replacement of the structure (recommended sandbags) within two weeks will prevent any serious ASS impacts.

If natural regeneration over the long term does not occur even though the water levels recede to recommended levels then it may be advisable to plant melaleuca seedlings in bare areas.

5.1.4. Acid Sulfate Soil Mitigation Strategies

Consideration of alternative methods to be used for the proposed works (such as more outlets beneath Angels Beach Drive) has indicated this staged procedure of works and installation of water control structure is the best option for environmental management to restore the natural health of the wetland and appropriately manage Acid Sulfate Soils. Monitoring of works by an environmental officer is recommended to ensure effective management. This requires water quality testing and visual assessments.

5.2. Chickiba Wetland (western)

The western wetland (Plate 4 and Figure 12) drains a catchment of about 20 hectares extending from the south. The Angels Beach Drive separates the wetland on the south side of the road from the cleared wetlands and salt marsh complex on the north side.

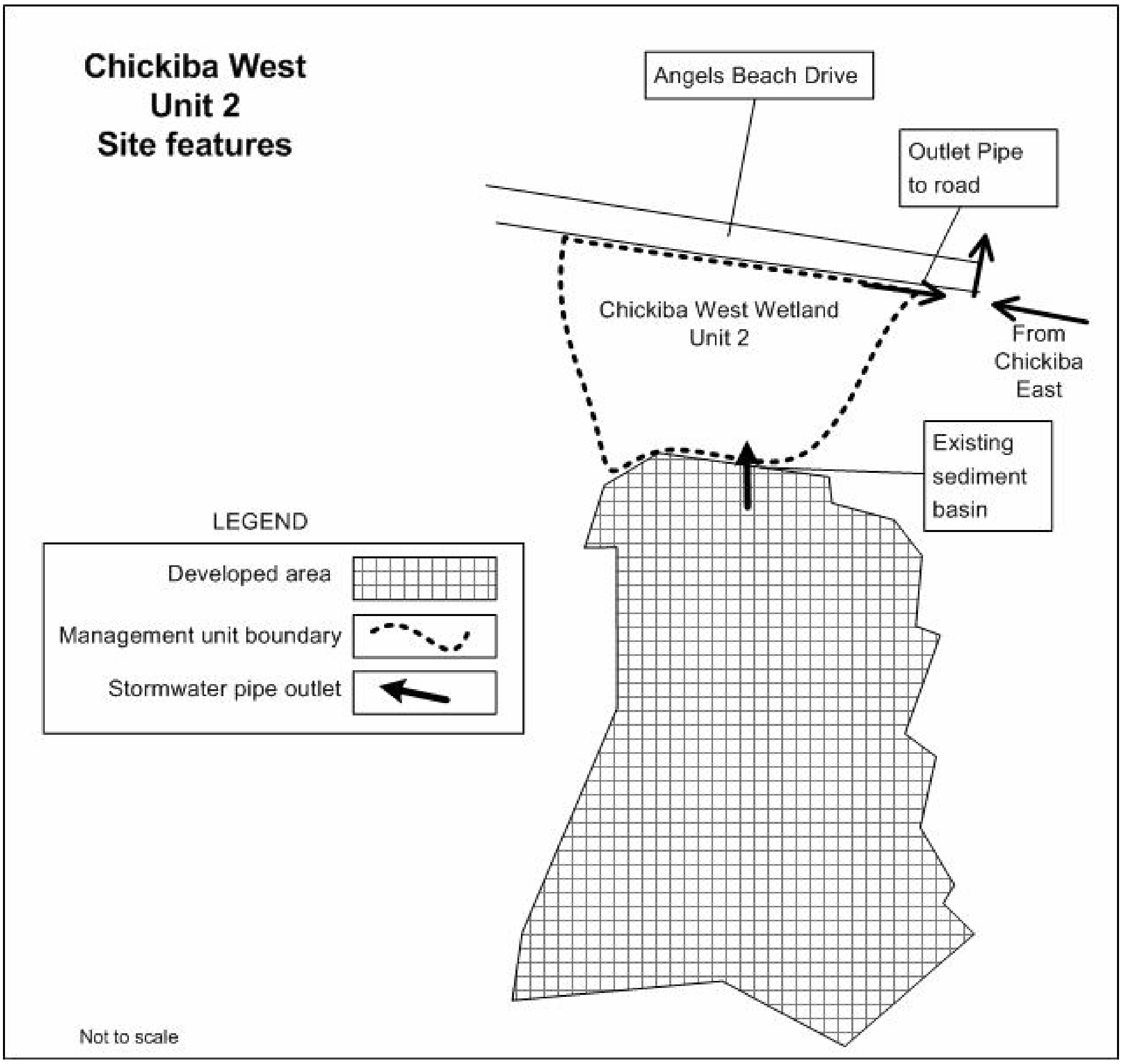

Figure 9: Chickiba West Wetland features

The Chickiba West wetland is classified as 6A Zone – open space under Ballina Shire Council's Local Environmental Plan.

Plate 4: Chickiba West Wetland from the sports field, looking southwest.

The Chickiba West Wetland has been reduced, confined, and fragmented from the other wetlands in the complex by the construction of the Chickiba Sporting Field, by fill placed between the wetland and Chickiba Lake, the Angels Beach Drive to the north, and urban development above the wetland. This has created a rectangular wetland with one discrete inlet and one discrete outlet. Due to the urbanisation above the wetland, increases in peak discharges from storm events are common due to increases in impervious areas and therefore increased runoff and reduced infiltration to groundwater.

5.2.1. Qualitative ASS assessment

A desktop and initial site assessment of the Chickiba West Wetland was undertaken. The presence of Acid Sulfate Soils are most likely present at this wetland because elevations are below 5m AHD, ASS soil risk maps predominantly categorise the area as Class 2 (Figure 1), melaleuca forests are commonly found in ASS landscapes, and the presence of estuarine sediments, geological history and location is favourable for pyrite formation (Stone et al., 1998). No visual indicators of ASS except for the presence of melaleucas were found.

It is suggested that soil sampling be undertaken to quantify the presence and status of ASS at this site if any future proposed works are likely to disturb any potential acid sulfate soils.

5.2.2. Impacts of Stormwater on the Chickiba West Wetland

One impact of increased stormwater runoff into and possibly restricted drainage out of the wetland is shown in Plate 5. A number of melaleuca trees have fallen over which is most likely due to more frequent wetter periods and shorter drying cycles.

Plate 5: Windthrow in the Chickiba West Wetland.

Given the situation in the Chickiba West Wetland, with uncontrolled stormwater inputs and the possibly restricted outlet, similar impacts of varying degrees to those in the Chickiba East Wetland may be expected over time as the wetland degrades from excessive inundation and other factors such as nutrient loads.

A step-by-step process is recommended to effectively manage the long-term health of the Chickiba West Wetland. Firstly, the wetland should be protected from increased stormwater peak flows and nutrients.

Integrating Water Sensitive Urban Design (WSUD) principles and technologies into the catchment will provide retention and treatment benefits that assist in reducing the impact of increased stormwater into the wetland. Reduction of flows near the source, and discharge controls such as sedimentation basins, extended detention basins, and constructed wetlands, retrofitted to the urban landscape may be very effective in protecting the health of the Chickiba Lakes. Some examples are given below in the section *Stormwater Management*.

5.3. Chickiba Lake and "Southern Cross" Wetland

The features of the Chickiba Lake and associated wetland area are shown in Figure 15.

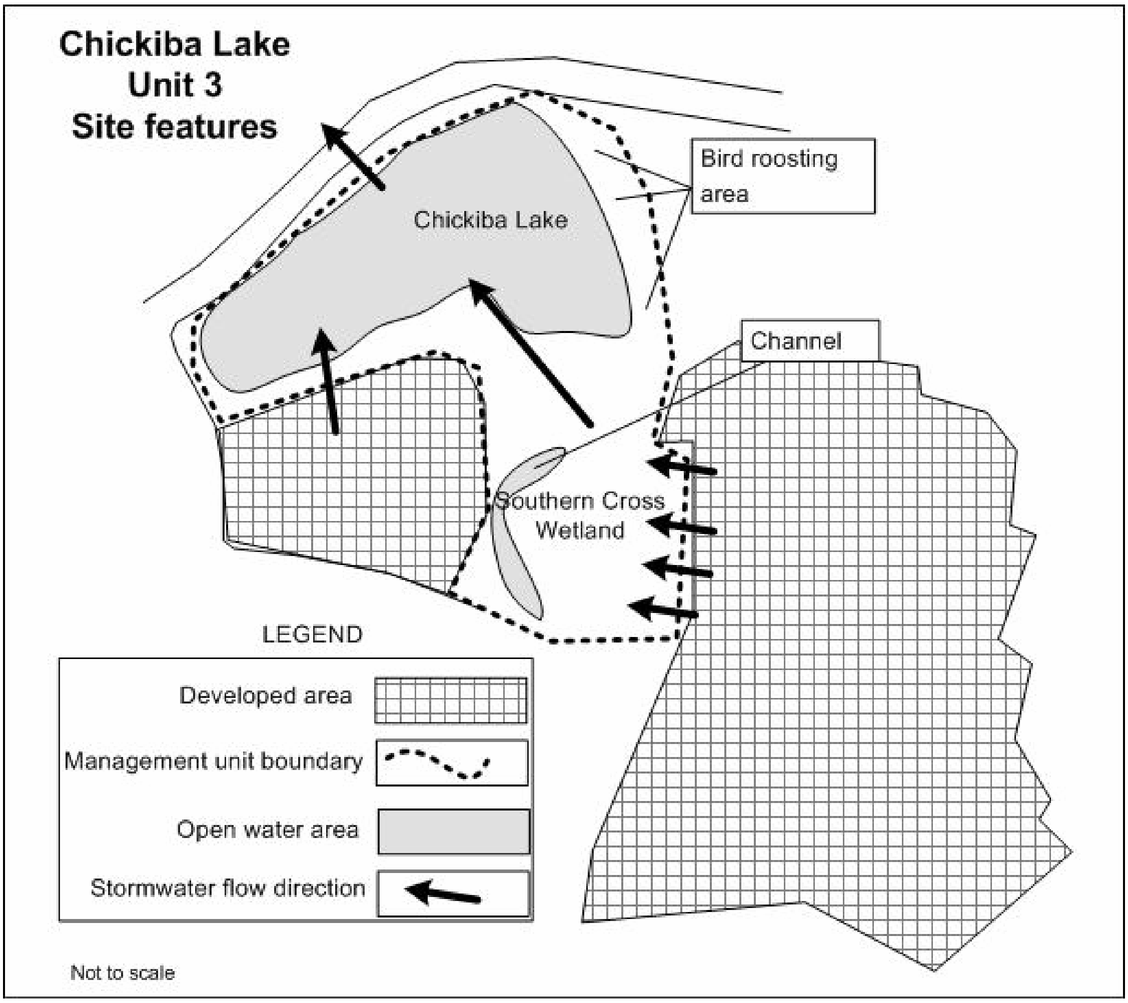

Figure 10: Chickiba Lake and surrounds

5.3.1. Southern Cross Wetland

A desktop and initial site assessment of the Southern Cross Wetland was undertaken. Acid Sulfate Soils are most likely present at this wetland because elevations are below 5m AHD, ASS soil risk maps predominantly categorise the area as Class 2 (Figure 1), melaleuca forests are commonly found in ASS landscapes, and the presence of estuarine sediments, geological history and location is favourable for pyrite formation (Stone et al., 1998). No visual indicators of ASS except for the presence of melaleucas were found.

It is suggested that soil sampling be undertaken to quantify the presence and status of ASS at this site if any future proposed works are likely to disturb any potential acid sulfate soil layer.

5.3.2. Chickiba Lake

ASS assessment

See section 3.1.2 ASS sampling for the Chickiba Lakes Bird Wading Area for details of previous ASS investigations undertaken at the Bird Wading Area to the north of Chickiba Lake.

It is suggested that further soil sampling be undertaken to quantify the presence and status of ASS at this site if any future proposed works are likely to disturb any potential acid sulfate soil layer.

Lake Foreshore Erosion

Lake foreshore erosion at Chickiba Lake has been identified by Council as an issue. Tidal movement of water in the lake has apparently caused a number of sections along the bank to erode, in particular the areas shown in Plates 6 and 7. After site investigation two main options have been identified to protect the foreshore banks from erosion. These are:

1. Reshaping the foreshore bank to a suggested low batter followed by replanting bank with salt couch, *Phragmites* spp., and/or *Juncus krausii*. This will stabilize the bank as shown in Plate 8. It is recommended that the slope for the erosion areas replicate the area of salt couch shown in Plate 8. A topographic survey is also recommended.
2. Hardening the bank with concrete training walls, large logs, gravel baffles, or alternative erosion reduction measures.

Option 1 is recommended.


Plate 6: Erosion area along the foreshore bank at Chickiba Lake.


Plate 7: Second erosion area along the foreshore bank at Chickiba Lake.

Plate 8: Area of salt couch stabilising the bank

Lake Pipe Discharge and Maintenance
Stormwater discharge into the lake is likely to be causing longer term damage to the lake ecology through nutrients and regular introduction of unnaturally high flows. The flushing efficiency of the lake inlet/outlet would require detailed assessment to gain a deeper understanding of processes and impacts, but a best practice approach is to reduce discharges whenever possible. The most sustainable approach is to carry out WSUD assessment - rainwater tanks, preservation of natural systems, and 'ecotechnology' such as constructed wetlands where possible.

5.4.Prospect Lake

Prospect Lake is located at East Ballina and is part of a constructed lake system that drains into Chickiba Creek. Prospect Lake is a popular swimming spot for local residents of the adjoining residential area as well as students from the nearby high school and triathlon club.

Qualitative ASS assessment
A desktop and initial site assessment of the Chickiba West Wetland was undertaken. The Acid Sulfate Soils are most likely present at this constructed lake because elevations are below 5m AHD, ASS soil risk maps predominantly categorise the area as Class 2 (Figure 1), estuarine sediments are present, and the geological history and location is favourable for pyrite formation (Stone et al., 1998).

It is suggested that soil sampling be undertaken to quantify the presence and status of ASS at this site if any future proposed works are likely to disturb any potential acid sulfate soils.

Lake Foreshore Erosion

Lake foreshore erosion has also been identified as an issue at Prospect Lake. Tidal movement of water in the lake has caused sections along the bank to erode, in particular the areas shown in Plate 9. After site investigation a number of options are recommended to protect the foreshore banks from erosion. These are:

1. Reshaping the foreshore bank to a designed V:H ratio replicating adjacent areas of no erosion and healthy vegetation. This should be followed by replanting bank with appropriate species such as salt couch, *Phragmites*, or *Juncus krausii*. This will stabilize the bank as shown in Plate 8.
2. Hardening the bank with concrete training walls, large logs, gravel baffles, or alternative erosion reduction measures.

Potential costs for these options approximate to \$6-\$10/m^2 for reshaping and planting, and \$100/m for concrete walls.

Plate 9: Area of erosion at Prospect Lake.

Lake Pipe Discharge and maintenance

Stormwater discharge into the lake is likely to be causing longer term damage to the lake ecology through nutrients and regular introduction of unnaturally high flows (Plate 10). The flushing efficiency of the lake inlet/outlet would require detailed assessment to gain a deep understanding of processes and impacts, but a best practice approach is to reduce discharges whenever possible. The sustainable approach is to carry out most WSUD assessment - rainwater tanks, preservation of natural systems, and ecotechnology such as constructed wetlands where possible.

Opportunities exist at the site for retrofitting rainwater tanks on nearby houses, swale technology during infrastructure upgrade, and constructed wetlands. See Section 6 for more details on stormwater management using Water Sensitive Urban Design.

Plate 10: Stormwater pipes discharging into Prospect Lake

5.5. Property to north of Angels Beach Drive

Council proposes to remove vegetation from a shallow drain on the north side of Angels Beach Drive. The drain is located on a 20m wide crown road reserve that runs parallel to Angels Beach Drive (40m wide) on one side and Dr P. Stewart's land on the other side (Ballina Shire Council, 2006). The works and subsequent potential changes to drainage patterns incurred the requirement to consult this landowner.

Report of on-site meeting with Dr. Peter Stewart, owner of property north of Angels Beach Drive (Stewarts Property, Unit 5) regarding drain line proposed for clearing.

David Pont met with Dr. Stewart on his property in February of 2006. The proposed drain clearing was discussed, as were other issues relating to drainage on the property, particularly regarding water management at the western end of the drain line, closer to Chickiba Creek.

The drainage issues in this area have implications for the quantity and management of water from the Chickiba wetlands and urban areas on the south side of Angels Beach Drive. The following main points of discussion are reported:

- Dr. Stewart authorises the drain clearing works as described for the purpose of facilitating infrastructure management
- he would like consultation if any substantive changes to the plan are proposed
- he is concerned about the present drainage arrangements on the property near the road - particularly salt intrusion onto the property, and blocked drains nearer to Chickiba Creek. These issues however overlap with recent interaction with NSW Fisheries regarding removal of floodgates.
- In general Dr. Stewart desires a fresher water regime on the land near the road, with less salt.
- Dr. Stewart stated that there is uncertainty regarding past boundary alignments and fences during road and drainage construction and he would like resolution of the exact boundary.

The drain location has been assessed by Ballina Shire Council and defined as part of the 20m wide crown road reserve that runs parallel to Angels Beach Drive (40m wide). It is recommended that further consultation between affected parties and Council should still be undertaken in relation to any drain works as the drain is close to Dr Stewart's land.

6. Stormwater Management Options - Water Sensitive Urban Design (WSUD)

Since the late 1990's there has been an increasing number of initiatives to manage the urban water cycle to protect downstream aquatic ecosystems. These initiatives are underpinned by key sustainability principles of water consumption, water recycling, and environmental protection. Urban stormwater managed both as a resource and for the protection of downstream aquatic ecosystems is a key element of WSUD (Melbourne Water, 2005).

In response to the changes in stormwater management, Ballina Shire Council has implemented Development Control Plan No.13 Stormwater Management (DCP 13). Based on the principles of Environmentally Sustainable Development (ESD) and the Urban Storm Water Strategy, Ballina Shire Council (BSC) has adopted the stormwater management objective for new urban developments that there shall be no net increase in the average annual load of key stormwater pollutants and peak discharge flow rates, above that occurring under existing conditions. This condition specifically applies to all sites that have a sensitive receiving environment (Gilbert and Sutherland, 2004).

However, a large portion of Ballina Shire is already developed to some level, and the major opportunities for the inclusion of WSUD will come as part of the redevelopment and 'retro-fitting' of existing areas. Some design limitations apply to incorporating WSUD into existing developments, however the opportunities and costs associated with retro-fitting are not considered major constraints to the implementation of WSUD control measures. Included in DCP 13 is the objective of effectively protecting sensitive areas such as SEPP 14 wetlands from adverse of impacts of urban stormwater.

The study area under investigation has a number of opportunities to retrofit WSUD technologies to protect the health of the SEPP 14 wetlands. Examples are given below.

Rainwater Tanks
Mains water is treated to drinking standard, though in reality only a small percentage of the drinkable water entering a house is used for drinking purposes. Uses such as toilet flushing, hot water, laundry and outside utilises about 90% of the total domestic water. These uses do not require high quality water, and can therefore be supplied by sources such as rainwater and stormwater. This can significantly save money from water supply as well as reducing stormwater flows from the property. (WSUD, Practice Note 4)

Rainwater tanks are considered beneficial source controls as they act as detention systems for storing rainfall that would normally have to be conveyed to a point of discharge, reduce the amount of stormwater that requires treatment, and reduce the demand for potable water supply to households. The tank water can be used for toilet flushing, hot water in laundry, kitchen, and bathroom, and for all outdoor uses.

Constructed Stormwater Wetlands
Constructed wetland systems are shallow, extensively vegetated water bodies that use enhanced sedimentation, fine filtration, and pollutant uptake processes to remove pollutants from stormwater. Water levels rise during rainfall events and outlets are configured to slowly release flows, typically over three days, back to dry weather water levels (Melbourne Water, 2005; DLWC, 1998). An example of such stormwater wetlands is the Airforce Beach wetlands at Evans Head, NSW (Plate 11).

Throughout the study area suitable sites for constructed wetlands are limited, given the tendency for stormwater pipes to be located low in the environment, discharging either into the lakes or the natural wetlands. However, some outlets such as the stormwater pipe located near Southern Cross School (Plate 12) provides an opportunity for a constructed wetland to help reduce nutrients, sediments and excessive peak flows of water from entering the receiving environment.

Plate 11: Example of a constructed stormwater wetland in a residential situation (location: Evans Head, NSW)

Plate 12: Stormwater pipe in elevated position near Southern Cross School - suitable for a constructed wetland treatment system

Sedimentation Basin
There are two practical options for sediment basins: they are either relatively deep open water bodies, generally permanently holding water at a depth that is not preferred by wetland plants, or drying basins such as ephemeral wetlands. Both have advantages and disadvantages. They mainly provide sedimentation of suspended solids and diffuse the stormwater energy entering the wetland.

Swales
Swales are open, vegetated channels that remove suspended solids and sediment in stormwater. The density and height of the vegetation within the swales determine the removal efficiency, with thicker vegetation (such as long grass, sedges or reeds) slowing water velocities and removing more solids than thinner, shorter vegetation (such as mown grass) (CRC Catchment Hydrology, MUSIC V.3 Manual, 2005).

Swales can be incorporated into the broader Chickiba Lakes area, by removing segments of stormwater pipes and constructing swales as a replacement mode of stormwater conveyance. This retrofitting practice can be limited by the depth of the pipes, so detailed investigations of the location of pipes earmarked to be removed must be carried out.

Buffer Strips
Buffer strips are densely vegetated troughs that specialize in heavy sediment removal from urban stormwater and runoff. Buffer strips are typically integrated with other stormwater management systems to serve as a 'buffer' between impervious areas of a catchment and a treatment device or receiving waters (creek, stream or wetland).

Buffer strips feature vegetation that stands taller than the maximum treatment flow water levels under normal conditions. This vegetation is capable of withstanding and slowing design flow velocities of stormwater or runoff entering the buffer strip, promotes an even distribution to encourage effective retention of coarse sediments, and is to be of sufficient density to provide good filtration. As well as contributing to improving the quality of recycled stormwater, buffer strips also contribute to the aesthetic value and visual amenity of the area.

7. Conclusion
Although limited funding was available to provide a comprehensive ASS sampling regime the study area is classed as an ASS landscape. Combined ASS samples taken during this study and previous assessments show three samples out of twenty three were above the trigger values for PASS. The ASS results show that actual ASS was present in some areas. The results highlight the spatial variability of acid sulfate soils. The sampling regime did not provide conclusive results on the status and variability of ASS (due to available funds and the large area under study). However, this does not preclude the need for best practice of ASS management for site disturbances. This Management Plan recommends management practices to address the proposed disturbances of ASS.

8. References

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Appendix 1

Pipe numbers	East Chickiba **1**	East Chickiba **2**	East Chickiba **3**	East Chickiba **4**	Southern Cross School Wetland **5**	Southern Cross School Wetland **6**
Pipe diameter	900mm	900mm	375mm	900mm	Pipe (a) 600 (b) 375	375
Present condition	Clear but vegetation building up	Clear water, no algae, drain mostly clear of vegetation, and some scouring	Dry, weed infested, and drain half blocked	Permanent water, drain invert at low level in environment, weeds, possible mosquito breeding area, and sediment building up in deep pool	Erosion, loose rocks covering pipe, and 30m swale connects pipe to wetland	Grass covering pipe, may have small flows during storm events
Slope below pipe outlet	1%	0%	0%	-	2%	3%
Sensitive vegetation	Cunjevoi (*Alocasia brisbanensis*)	-	Bangalow Palm	-	No native vegetation	-
Weeds	*Typha orinetalis*, impatience	Impatiens	Ragweed, lantana	Impatience and wandering jew	Grass	Grass
Organic loads	Median	-	-		-	-
Sand loads	-	-	High		-	-

Pipe numbers	Southern Cross School Wetland **7**	Chickiba West **8**	Chickiba East **9**	Chickiba East **10**	Chickiba East **11**
Pipe diameter	750mm	Pipe (a) 400mm (b) 900mm	500mm	*Not able to find stormwater discharge pipe*	*Smothered by wandering jew.*
Present condition	Overgrown, blocked by grass/weeds	Weed infested mainly para grass	No head wall on pipe, broken end	*Lost in lantana*	*Located along swale drain.*
Slope below pipe outlet	0%	0%	0%	*Good site for constructed stormwater wetland*	*Improvements - Shallow and widen.*
Sensitive vegetation	Melaleucas	Wattles	Melaleucas, Bangalow palm		
Weeds	Grass, impatience	Para grass	Senna, and lantana		
Organic loads	-	-	-		
Sand loads	-	Heavy sediment build-up (sand/silt)	-		

Appendix 2

Preliminary Works – results of ASS soil analysis

The following tables shows the ASS results obtained for previous drain clearing at the drain located to the north of Chickiba East Wetland.

Sample site	**Texture**	**Reduced Inorganic Sulfur** (%Scr)	**TAA** (pH_{kcl})	**TAA** (mole H^+/kg	**TPA** (pH_{kcl})	**TPA** (mole H^+/kg)	**TPA (kg** (H_2SO_4/tonne)
Site 1a	Medium	0.016	5.01	0.000	5.01	0.026	1.3
Site 1b	**Medium**	**0.081**	**3.81**	**0.000**	**3.81**	**0.155**	**7.6**
Site 2a	Medium	0.006	4.42	0.002	4.42	0.078	3.8
Site 2b	Medium	0.006	5.49	0.000	5.49	0.001	0.0
Site 3a	Medium	0.007	3.22	0.032	3.22	0.289	14.2
Site 3b	Medium	0.020	3.14	0.040	3.14	0.310	15.2

Sample site	**Texture**	**Lab. Bulk Density** (DW/m^3)	**Neutralising calculation** (kg lime/m^3) Based on CRS	**Neutralising calculation** (kg lime/m^3) Based on NAGP	**Neutralising calculation** (kg lime/m^3) Based on TAA	**Neutralising calculation** (kg lime/m^3) Based on TPA	**Comments**
Site 1a	Medium	0.53	0.3	.	0.0	0.7	Not PASS
Site 1b	Medium	0.73	1.8	-5.8	0.0	5.5	YES PASS but ve NAGP
Site 2a	Medium	0.79	0.1	.	0.1	3.0	Not PASS
Site 2b	Medium	0.70	0.1	.	0.0	0.0	Not PASS
Site 3a	Medium	0.1	0.1	.	0.9	7.9	Not PASS
Site 3b	Medium	0.3	0.3	.	0.9	6.8	Not PASS

The following table shows the field results of pH ASS field testing.

Sample code	**Sample depth (cm)**	**pH_{field}**	**pH_{fox}**	**Reaction rating**	**Mottles, iron & jarosite stains**
1	10	6.5	inconclusive	None	Not present
2	10	6.2	5	Slight	Not present
3	10	6.2	5.5	Slight	Not present

Chickiba Wetlands Works Neutralising Calculation Summary

The following table shows the liming rates required for previous drain clearing at the drain located to the north of Chickiba East Wetland. It is recommended that 2.7kg/m^3 of lime be used in any future drain clearing at this site.

Sample Site and depth (cm)	Neutralising Calculation Kg Lime/m^3 **(based on %Scr)**	**Neutralising Calculation Lime/m^3 (based on TAA)**	**Final Neutralising Calculation Lime/m^3 (%Scr +TAA) x 1.5 safety factor**
Sample 1a – Ocm	0.3	0.0	0.45
Sample 1b – 20cm	1.8	0.0	2.7
Sample 2a - 0cm	0.1	0.1	0.3
Sample 2b – 20cm	0.1	0.0	0.15
Sample 3a - 0cm	0.1	0.9	1.5
Sample 3b – 20cm	0.3	0.9	1.8