Water Quality Management Plan

North Lakes
Ballina

HEALTH SCIENCE ENVIROMENTAL EDUCATION
ENVIRONMENTAL AUDITOR

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Prepared for: Ballina Shire Council

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EXECUTIVE SUMMARY

The North Lakes Residential Estate was established in 1991 to provide affordable housing on land located at North Creek Road, Balllina. The subdivision is located on the northern outskirts of Ballina and is situated adjacent to North Creek, a saltwater estuary which is a tributary of the Richmond River. Stormwater from the North Lakes Residential Estate catchment drains directly into a series of interconnected constructed stormwater ponds or urban lakes. The constructed urban lakes (referred to as *North Lakes*) collect stormwater runoff from the North Lakes residential development area only. The provision of an embankment wall with a constructed weir overflow arrangement and a reverse flow gate allow controlled interaction with the adjoining wetland and North Creek.

The subdivision was granted approval by Ballina Shire Council in 1991. Residential development has occurred over 5 stages. The subdivision is almost complete with 230 dwellings throughout the five stages. The main aim of providing the constructed urban lakes was to allow for treatment of stormwater runoff prior to discharge into the adjacent State Environmental Protection Policy (SEPP) No. 14 Wetlands. An outcome of the constructed urban lakes is improved amenity in the form of vegetation, water views and bird and aquatic life.

Council and community concerns regarding water quality, maintenance and amenity has triggered the preparation of an overarching Water Quality Management Plan (WQMP) for *North Lakes*. It is envisaged that an overarching Water Quality Management Plan can be used to guide the future management of the system, assist in informing local residents on the lakes purpose and their potential impacts on its operation and assist to inform future planning decisions.

The North Lakes Water Quality Management Plan has considered a broad range of issues including

- water quality, flow, hydrology, algal toxins, bacteria, pesticides, herbicides;
- existing and potential land uses;
- erosion and sedimentation;
- chemical usage and sources;
- nutrient sources;
- aquatic weed control;
- fuel and chemical spills;
- risk management precautions;
- public perceptions; and
- practical, legal, financial etc, issues associated with the management of the constructed urban lakes.

In addition the project team has engaged with local residents through a community consultation process and community education program.

The community consultation process coincided with the preparation and delivery of the technical assessment of the stormwater treatment system.

Through the processes of this study, a number of deficiencies have been identified in the operation and management of the *North Lakes* stormwater system. The main issues to be resolved surround the management and functionality of the lake system. A suite of recommendations are proposed to address the issues identified.

A Site Strategy Plan (SSP) has been prepared. It summarises the key water quality management activities proposed in the Water Quality Management Plan. The SSP should be read in conjunction with Vegetation Management Strategy which includes the Weed Management Plans and Revegetation Plans.

The SSP seeks to address a variety of community preferences for vegetation types and balances the need for vegetation for embankment and water quality improvements with individual preferences for various landscape styles.

Six improvement areas are acknowledged as requiring some measure of remedial action to improve the overall efficiency, performance and management of the North Lakes Residential Estate stormwater system. The six areas are listed below:

- Swale drainage performance
- Land ownership and access rights to open channel hydraulic connection
- Hydraulic connectivity between lake systems
- Outlet weir maintenance
- Vegetation management
- System monitoring

Swale drainage maintenance and performance

To reduce the frequency of inundation and increase the hydraulic efficiency of the swales it is proposed to provide a 50mm diameter perforated pipe wrapped in geotextile down the centre of the swales. Back filling around the drainage pipe with 10mm crushed gravel will ensure that the base of the swales no longer become boggy when wet and importantly are allowed to remain free draining.

Access to allow maintenance of open channel hydraulic connection

To enable effective management between the two urban lakes on land currently owned by the Ballina Racecourse the following actions are required:

- Conduct a survey by a Registered Surveyor to confirm the eastern boundary of 1 Teralgin Place. Following a review of the survey Council should, if necessary, enter into negotiations with the owner of 1 Terlagin Place to remove any structures that encroach on Council's land.
- To enable council to gain access for machinery it is recommended that a small 1metre high retaining wall for a minimum length of 20 metres be constructed at the end of the northern swale off Teraglin Place. The retaining structure would run down the middle of the last 20m of swale and continue around the eastern boundary of no. 1 Teraglin Place. Appropriate landscaping and scour protection works are proposed to be undertaken north of the retaining wall to ensure safe and efficient drainage of the swale remains while also improving the visual amenity of this section of swale (currently due to poor access and continual water logging council is unable to mow this section of the swale and it is consequently overgrown).

  Backfilling would occur south of the proposed retaining wall to create an access way 3m wide to the newly created land parcel. Conceptual details of the proposed access arrangement are provided within the Site Strategy Plan.

- Council should approach the NSW Department of Lands and Ballina Racecourse with a view to entering into an agreement to assume the care, control and management of the triangular portion of land on which the channel exists. In the event that a suitable agreement cannot be reached Council should consider proposing a boundary adjustment to the NSW Department of Lands for the amalgamation of Lot 171 DP 1041678 with Lot 114 DP 852971.

Hydraulic connectivity between lake systems

In order to improve the hydraulic connectivity between the lake systems it is recommended that the two existing 375mm pipes connecting the two urban lakes be removed and the existing open channel be extended to connect the two lakes.

In addition it is recommended that the pipes are replaced with a single 3m wide 500mm deep concrete box culvert which would satisfy both increased hydraulic connectivity and access arrangements to the northern side embankment.

Outlet weir maintenance

In order to retain an effective contingency measure in the event of significant flooding at the site the outlet weir in Lake 1 will be re-commissioned and maintained on a regular basis in accordance with the original design intent as the *single as built* overflow weir.

Vegetation management

The weed management strategy applies to drainage lines and riparian zones within North Lakes Residential Estate. The specific weed management areas are identified on Sheet 2 (Weed Management Plan).

This strategy identifies significant areas of weed infestation and provides general strategies for weed treatment.

Ongoing system monitoring

It is recommended that Council create a log book to record water levels, water flow and asset functionality. A copy of the log should be kept by both Council and by the community association group. The log should record any major water events, water level fluctuations, water flow and a brief account of how elements of the stormwater system (i.e. swales, pits, pipes, macrophyte zone, etc.) are performing and any noticeable change over time. The log book should be updated on a monthly basis to enable analysis of the data and observe long term trends. To complement the log book the production of a monthly photo log would also enable long term changes over time to be observed.

The North Lakes Water Quality Management Plan (WQMP) provides a firm basis for the future management of the North Lakes Residential Estate. The WQMP provides an insight into the mechanisms of this interactive urban water body with the natural system. In addition the WQMP has identified room for improvement and recommends means by which council and the community can better manage this unique community asset in a practical, coherent and sustainable manner.

The recommendations in this report if applied in conjunction with the Vegetation Management Plan and Site Strategy Plan will improve lake amenity, water circulation, accessibility for machinery to undertake maintenance, riparian vegetation and provide better information on the efficacy and effectiveness of *North Lakes*.

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1. Introduction

1.1 Purpose

The purpose of this study is to provide Ballina Shire Council with a suitable management plan for the North Lakes Residential Estate storm water treatment system. The following objectives have been established for the North Lakes Water Quality Management Plan:

- To understand how the stormwater system works and if it is working effectively;
- To provide Council with advice on the most appropriate means to manage the stormwater system and environs;
- To provide information on how the local community can assist in caring for the stormwater system and environs;
- To determine the long term maintenance requirements;
- To satisfy environmental requirements especially with regards to the stormwater quality entering North Creek and the adjoining wetland;
- Integrating with and improving urban landscape and amenity;
- Achieving community acceptance; and
- Ensuring the work is tied in with existing infrastructure and gives due consideration for future infrastructure.

1.2 Locality

The North Lakes Residential Estate was constructed by Ballina Shire Council on low lying degraded grazing land adjacent to a section of North Creek mangrove habitat. The site is located approximately 750m from the Pacific Highway along North Creek Road, 1km from the Ballina Fair Shopping Complex, and 1.5km from Ballina Airport. The locality of the North Lakes Residential Estate is shown in Illustration 1.1.

Illustration 1.1 Site Locality

North Lake Residential Estateand Study Area Extent

N

0 100m 200m

Source: Ballina Shire Council GIS database
Date: August 2008
Ref: TFA North Lakes SWMP.dwg

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1.3 Overview

The North Lakes Residential Estate was established in 1991 to provide affordable housing on land located at North Creek Road, Balllina. The subdivision is located on the northern outskirts of Ballina and is situated adjacent to North Creek, a saltwater estuary which is a tributary of the Richmond River. Stormwater from the North Lakes Residential Estate catchment drains directly into a series of interconnected constructed stormwater ponds or urban lakes. The constructed urban lakes (referred to as *North Lakes*) collect stormwater runoff from the North Lakes residential development area only. The provision of an embankment wall with a constructed weir overflow arrangement and a reverse flow gate allow controlled interaction with the adjoining wetland and North Creek.

The subdivision was granted approval by Ballina Shire Council in 1991. Residential development has occurred over 5 stages. The subdivision is almost complete with 230 dwellings throughout the five stages. The main aim of providing the constructed urban lakes was to allow for treatment of stormwater runoff prior to discharge into the adjacent State Environmental Protection Policy (SEPP) No. 14 Wetlands. The provision of the constructed urban lakes at North Lakes Estate has created an environment allowing greater amenity for residents in the form of increased bird and aquatic life, vegetation variety, water views and a moderated site specific local climate.

In a paper presented by Tony Macalister at the Stormwater Industry Association 1999 Conference, Homebush Bay (Sydney), Tony describes urban lakes as:

> "the construction of dedicated, and typically artificial, lakes within an urban land use setting for the storage, treatment and possible reuse of stormwater entering them." and
>
> "water stored in these lakes is typically reused for non-potable applications such as irrigation and lawn watering, and also often supplies local area amenity benefits, such as aesthetic appreciation and habitat provision.

According to Jillian Pratten (per.com. 2008), Ballina Shire Council's Open Spaces and Reserves Manager, *the stormwater system design was not based on specific design criteria or technical specifications, nor was there a management plan established for the stormwater conveyance or constructed urban lake system.*

Council and community concerns regarding water quality, maintenance and amenity has triggered the preparation of an overarching Water Quality Management Plan (WQMP) for *North Lakes*. It is envisaged that an overarching Water Quality Management Plan can be used to guide the future management of the system, assist in informing local residents on the lakes purpose and their potential impacts on its operation and assist to inform future planning decisions.

To ensure a comprehensive and practical management plan is prepared, the following tasks have been undertaken during the preparation:

1. identify scope of works needed to address the current issues within the catchment;
2. review and consider all relevant information;
3. describe the stormwater treatment system and define its objectives;
4. compare outcomes with stormwater quality guidelines and practices in Councils Stormwater Management Plan;
5. develop a vegetation plan, incorporating a revegetation and weed management plan;
6. address any other issues identified in consultation with Council and residents;
7. identify all of the aspects, specifically associated with water quality;
8. undertake analysis of identified aspects;
9. develop a Site Strategy Plan and

10. prepare and complete the Water Quality Management Plan for North Lakes.

A list of broad issues reviewed during this project includes:

- water quality, flow, hydrology, algal toxins, bacteria, pesticides, herbicides;
- existing and potential land uses;
- erosion and sedimentation;
- chemical usage and sources;
- nutrient sources;
- aquatic weed control;
- fuel and chemical spills;
- risk management precautions;
- public perceptions; and
- practical, legal, financial etc, issues associated with the management of the constructed urban lakes.

Critical to the success of the WQMP will be the engagement of local residents. It is proposed to initiate a community consultation process which will underpin a community education program.

The community consultation process and education program will be co-ordinated and managed to co-incide with the preparation and delivery of the technical assessment of the stormwater treatment system

1.4 Literature Review

Stormwater runoff is an environmental issue more commonly discussed in relation to water quality for receiving waters. It is not only the quality of the water that may be an issue, but also the quantity and local conditions such as tidal position, period since last rainfall event and accumulation of sediment load.

Urbanisation of any stormwater catchment area typically results in a range of water quality impacts derived from landuse changes in the catchment (eg. introduction of impervious area) and the implementation of artificial drainage systems (eg. pipes connecting runoff from impervious areas directly to waterways) (Australian Runoff Quality, 2006). Stormwater from urban areas typically increase the discharge of pollutants to receiving waters through changes to catchment hydraulics and water quality. Stormwater pollutants include: litter, excess nutrients, sediment, high organic loads placing excess oxygen demands on the waterway, hydrocarbons and heavy metals. These pollutants are hydraulically transported from the source through the actions of rainfall on the site or hosing down discharging into receiving water bodies as stormwater.

Environmental consultants WBM undertook the Richmond River Estuary Processes study in 2006. WBM found that the impacts from urban stormwater runoff on the lower Richmond River are likely to be significantly influenced by the mixing and flushing within the estuary due to tidal dynamics and freshwater inputs. In particular, pollutants loads entering the lower estuary from urban areas around Ballina would likely be diluted and dispersed due to tidal impacts (WBM 2006). Hence, any potential impacts due to urban stormwater within the lower estuary are likely to be short-lived (WBM 2006).

Regardless of this, urban centres (such as North Lakes Residential Estate) are located adjacent to water bodies used by residents, visitors and industries such as oyster leases dependent on good estuarine water quality. Any water quality impacts due to urban stormwater or practices within the urban environment that contribute to degraded urban stormwater quality would subsequently be more likely observed by people within these urban areas relative to those occurring on rural areas not frequented by the public (eg. acidic runoff from drainage channels) (WBM 2006).

Therefore, although the impact of stormwater from urban areas to overall estuarine water quality may be negligible, it is still a significant issue to the public and council. Ballina Shire Council actively promotes improved management of urban stormwater through a variety of projects, programs and policies. Examples include installing gross pollutant traps, education programs, drain mapping and more stringent requirements such as *no-net worsening* of stormwater pollution for new urban developments (Ballina Shire Council, 2004).

Whilst stormwater runoff is more commonly discussed in relation to water quality for receiving waters, in the case of the North Lakes Residential Estate with the incorporation of constructed urban lakes, water quality within the urban lakes is of interest also. The ANZECC Water Quality Guidelines identify water quality characteristics relevant to recreational use. Specifically the guidelines identifies three types of recreational use ranging from 'primary contact' i.e. swimming, surfing, to 'secondary contact' i.e. boating or fishing, and 'visual use' limited to passive recreational uses which are pleasant to be around or look at. Table 1.1 below provides an extract from the ANZECC guidelines (2000).

Table 1.1 Water Quality Characteristics relevant to recreational use (Source: ANZECC, 2000)

Characteristics	Primary contact (e.g. swimming)	Secondary contact (e.g. boating)	Visual use (no contact)
Microbiological guidelines	x	x	
Nuisance organisms (e.g. algae)	x	x	x
Physical and chemical guidelines:			
Aesthetics	x	x	x
Clarity	x	x	x
Colour	x	x	x
pH	x		
Temperature	x		
Toxic chemicals	x	x	
Oil, debris	x	x	x

Given the role of North Lakes as a stormwater treatment system or urban lake the *Water Quality Characteristics* relevant to the subject management plan are restricted to Nuisance organisms (e.g. algae), Aesthetics, Clarity, Colour, Oils and debris.

Other sources of poor water quality within the North Creek estuary include acid sulfate runoff from exposed /drained acid sulfate soil areas, release of deoxygenated water from storage areas and urban stormwater runoff containing high levels of suspended sediments, nutrients and potentially faecal coliforms (WBM, 2006).

Good estuary water quality is essential for the health of macro invertebrates and benthic biota within the estuary. Commercial oyster production occurs in North Creek with Mr Geoff Lawler operating an oyster production business on land immediately north of *North Lakes Residential Estate*. Oysters are grown on leases within North Creek with the closest oyster lease approximately 400 metres upstream of *North Lakes Residential Estate*. Water for use in purification of oysters is drawn from the waters edge adjacent to the oyster opening shed in close proximity to the subject Estate.

Available water quality data reveals that the faecal coliform levels in North Creek (near Missingham Bridge) achieved medium value lower than the recommended 14 cfu/100mL, however failed to achieve a 90 percentile limit of <43 cfu/100mL. This is due to the large periodic concentration of faecal coliforms in the lower estuary (WBM 2006). Data for North Creek upstream of Prospect Bridge failed to meet both the 50 percentile and 90 percentile limits (WBM 2006). The contribution of stormwater pollution of the North Creek Estuary through the *North Lakes Residential Estate* is considered to be a fraction of the total pollutant loads and unlikely to significantly affect the greater water quality characteristics.

The water quality in the Richmond River Estuary generally does not meet the Water Quality Objective's of the EPA (2000) and Australian & New Zealand Environment Conservation Council (ANZECC 2000). Regular exceedances of Dissolved Oxygen (DO), pH, turbidity, nutrients, chlorophyll-a and faecal coliforms were observed across all monitoring locations (WBM 2006). These exceedances indicate that many environmental values desired for the Richmond River Estuary may not be achieved, particularly aquatic ecosystems (DO, pH, turbidity, nutrients and chlorophyll-a criteria are typically not met), primary contact (pH, turbidity and faecal coliforms criteria exceeded) and consumption of uncooked, aquatic foods (faecal coliforms exceeded).

A conceptual model of sediment dynamics of the lower Richmond River indicates that tributary streams such as North Creek do not contribute significantly to the sediment load other than clays and silts during rainfall events.

Given the low level and location of the *North Lakes Residential Estate,* rising sea levels due to changing climatic conditions are also of concern. Given the uncertainties in actual magnitude and sea level rate of rise (resulting from the thermal expansion of oceans and melting of glaciers and ice-sheets), the Intergovernmental Panel on Climate Change (IPCC) undertook a comprehensive review of available data and adopted three potential future scenarios. The values are based on the range of model results available and dependent on the future amount of carbon emission produced. The Institute of Engineer's, Australia, National Committee on Coastal and Ocean Engineering recommends that these values be used for planning and design (WBM 2006).

Table 1.2 presents the latest low, mid (best) and high estimates of global mean sea level rise from IPCC (1996) for the years 2040, and 2100, relative to 1990.

Table 1.2 Anticipated Future Sea Level Rise (metres), relative to 1990

Year	Low	Best Estimate	High
2040	0.03	0.12	0.30
2100	0.09	0.48	0.88

The likely impact of these predicted sea level rises would be a general rise in the mean water level in the ocean and the estuary and shoreline recession on the coast.

The rise in mean water level will mean that there will generally be a slightly greater depth of water in the estuary and the tide would be expected to propagate further up the estuary perhaps changing salinity levels (WBM 2006).

1.5 Summary of the Process

Given the time lines involved and the complexities of such a study as the one undertaken here, it is considered prudent to provide an overarching summary of the processes undertaken together with a brief account of the outcomes. Table 1.3 below provides a summary of the process undertaken to prepare the Water Quality Management Plan for the *North Lakes Residential Estate*.

Table 1.3 Process Summary Tasks, Actions and Outcomes

Tasks	Actions	Outcomes
Review of Background material	Past studies undertaken in the catchment; at Southern Cross Industrial Estate and Sovereign Gardens Estate were reviewed. A review of the catchment data from Council's GIS was undertaken with particular reference to catchment area, hydrology, land use; cadastral, topographical. A review of the original design drawings for the subdivision and lake system was undertaken as well as Works as Executed plans for the reticulated sewer and stormwater systems.	The North lakes Stormwater Treatment System is a closed system, independent of the adjacent Southern Cross and Sovereign gardens Estates There was no *hard data* available on water quality design criteria, or historical performance of the stormwater treatment system.
Site Inspection and Project Meetings	A series of 6 site inspections were conducted by members of the project team to: ▪ confirm our understanding of the existing stormwater treatment system and the context of the study area; ▪ photograph important elements; ▪ identify significant land uses and associated impacts on the stormwater treatment system; and ▪ identify broad issues and risks. The project team inspected the site independently and with staff from council and the Department of Primary Industries (Fisheries)	Identified: ▪ partial blockages in the system ▪ the placement of structures on public land ▪ limited access to perimeter of stormwater system ▪ poor access for maintenance ▪ a variety of bank stabilisation techniques ▪ weed species both aquatic and terrestrial ▪ dumped vegetation from gardens on banks ▪ high maintenance and ineffective drainage systems. Confirmed: ▪ Design plans with as constructed elements ▪ Design intent with Council staff ▪ Current Council operational input and procedures ▪ Lake levels likely to fluctuate between 0.5m AHD and 0.94m AHD. ▪ Lake levels were observed to be high (approx. 0.85m AHD) at the time of inspections in April and June.

Discussion with Government Agencies	The project team made contact with relevant government agencies including ▪ Department of Primary Industries (Fisheries) , Department of Environment, Conservation & Climate Change (DECC), and Catchment Management Authority (CMA) to gain an understanding of their collective view on the current stormwater treatment systems and any concerns, restrictions or comments they may have on measures to improve the management of North Lakes	Department of Primary Industries (Fisheries) Met Pat Dwyer from Fisheries onsite. DPI are supportive of measures to improve water quality impacting on estuary, including improving tidal movements between the stormwater system and the estuary. DECC Discussions with both Scott Ensby & Richard Hagley. Concerned with potential impacts on SEPP 14 wetlands of any proposed works and management of Acid Sulphate Soils and sediment. Generally supportive of means to improve water quality entering the estuary CMA Discussions with Peter Boyd and Roger Stanley. Advised that the CMA funding had been cut by 30% and therefore any funding requests would be unlikely to be successful. Generally happy to be kept informed of any process that improves the water quality entering the estuary.
Community Consultation	A public consultation process was implemented concurrently with the engineering and scientific assessment of the constructed urban lakes. Key tasks in the CC process include: ▪ Community expectations survey sent to all residents and stakeholders in North Lakes ▪ Letter box drop to invite residents to Community Meeting No.1 The aim of the meeting was to explain the goals of the project and to identify the issues and values relevant to the group. Preparation of a draft list of issues and possible management actions ▪ Send to Council for review and comment ▪ Preparation of a preliminary WQMP based upon technical assessment, agreed issues and actions ▪ Distribute a copy of the preliminary management and concept plan to the community & DECC, DPI with notification of the next meeting ▪ Conduct working group meeting 2 ▪ Amend and finalise the management as a 'Draft' ▪ Distribute a copy of the preliminary management to community & DECC,	Community Meeting No.1 Key outcomes ▪ 28 residents attended ▪ Participants keen to see better management of stormwater system ▪ Concerns about lake amenity, water levels, weeds, bank stability, vermin, maintenance and management of the constructed urban lakes ▪ Participants enjoyed wildlife, birds, water body, lack of through traffic, paddling canoe and fishing, being able to walk throughout the estate Community Meeting No.2 Key outcomes ▪ 29 residents attended, 90% of attendees were present at Community Meeting No.1 ▪ Participants were keen to see

	DPI requesting written or telephone comments ▪ Discuss comments with Council and review and amend plan to incorporate comments ▪ Council to send a copy of the revised WQMP to community & DECC, DPI requesting written or telephone comments	recommendations implemented ▪ Individual residents nominated poor water quality near Pipi Place ▪ Bank erosion and stability, including Casuarina root exposure and stability were identified as a concern at the rear of 30 and 32 Edgewater Cove ▪ Erosion and failure of retaining wall at rear of 12 Mulloway Place was nominated as a concern. The resident at this location was seeking the assistance of council with regard to potential failure of the retaining wall structure ▪ Subsequent to the meeting a resident from Pipi Place telephoned concerned about the effect of filling of the drain at the rear of Pipi Place on water hens and land values. Weed infestation in the rear drain was also raised as a matter of concern and as well as trees overhanging at the rear of the neighbouring industrial estate. ▪
Assess stormwater system viability and future management issues	In order to assess the efficacy, efficiency and viability of the existing storm water treatment system we : ▪ Undertook a hydrological assessment of the catchment draining into North Lakes using DRAINS and MUSIC modelling to assess existing water quantity and quality impacts. ▪ Based on the results of hydrological modelling and site inspections, we assessed the effectiveness of the existing water quality measures against Council's Stormwater Management Plan discharge criteria. ▪ Undertook a literature review of contemporary Water Sensitive Urban Design residential developments to assist in identifying potential features for incorporation in the North Lakes stormwater treatment train ▪ Built and ran computer simulation models DRAINS and MUSIC to assess water quantity and quality impacts of any recommended design or system changes resulting from our review of the system. ▪ Based on the results of DRAINS and MUSIC modelling analysis, we assessed the effectiveness of the recommended changes against Council's Stormwater Management Plan discharge criteria.	Results of the site survey were used to generate likely bathometry of the lakes. This revealed: ▪ The potential existence of an isolated deep hole within the first lake immediately upstream of the island. This deep hole (design depth -1.0m AHD, actual depth -2.5m AHD) would likely act as nutrient and temperature trap. ▪ Lakes are deeper (between 200mm and 500mm) in many places than the design levels. ▪ A section of the second lake has been constructed on the Racecourse's land. ▪ Limited accretion appears to have occurred over the current life of the lakes. Results of the DRAINS analysis indicate: ▪ The system has the capacity to capture and retain all storm events up to the 1in 10 yr ARI event without overtopping the weir into North Creek. Lakes levels will likely rise to a maximum of 0.94m during a 1in10 year event. ▪ During a major rainfall event, a 1in100yr event, the lakes will overtop the weir and flow into North Creek. The maximum lake level will rise to 1.0m AHD.

		▪ The pipe and swale system provided for the North Lakes Estate has sufficient capacity to transfer Stormwater flows to the lake system in accordance with Ballina Design principals. ▪ There is no 'additional' capacity within the Nth Lakes Stormwater system for the acceptance of 'additional' catchment areas and no other development within the general area should connect into the North Lakes stormwater system. Results of the MUSIC analysis indicate: ▪ Approximately 90% of total suspended solids, Total Phosphorus and Total Nitrogen generated by the catchment are retained within the lakes systems. ▪ Grassed swales are particularly effective at removing suspended solids. ▪ Swales afford an essential pre-treatment system where they are provided. ▪ Later stage development areas, Stage 3B and 4, produce significantly more TSS (~25%) and TN (~75%) runoff per ML than earlier stages. This is due to the reduced number of swale treatments provided. ▪ The ratio of catchment area verse lake surface area for the two lakes are: Stage 1to 3A (Lake 1) – 11.2 Stage 3B to 4 (Lake 2) – 6.7 ▪ Water quality within Lake 1 was found to be poorer on average than Lake 2. The primary cause is considered to be a direct consequence of larger catchment area/lake surface area ratio for Lake No.1 despite greater pre-treatment occurring within this catchment. A secondary cause stems from the limited tidal interaction occurring in Lake 1.
Prepare Plan for Water Quality & Quantity	Following consideration of a number of options we developed a water quality management plan, based on a single agreed option for stormwater treatment including consideration of: ▪ water flow, quantity and quality; ▪ algal toxins, protozoa, bacteria, pesticides, herbicides; ▪ existing and potential land uses; ▪ erosion; ▪ sedimentation and accretion; ▪ chemical usage and sources; ▪ nutrient sources;	Following a review of the existing situation model outcomes, and taking into account all other design inputs realised to date, potential system improvements were investigated and discussed. Strategies to improve access, improve water quality, improve stormwater maintenance practices, improve vegetation management, visual amenity and public education were considered and developed. Potential stormwater improvement areas were identified and numerous alternate

	▪ aquatic weed control; ▪ fuel and chemical spills; ▪ risk management precautions; ▪ public perceptions; and ▪ practical, legal, financial etc, issues associated with the management of the catchment. ▪ an overall site strategy plan and ▪ water quality management protocols for the preferred system.	strategies were considered for each identified area. The results provided a DRAFT Water Quality Management Plan for the North Lakes system. The proposed system improvements were then remodelled to assess the potential effectiveness in terms of stormwater quality and hydrology. Following consideration and incorporation of comments from Council and the Community a FINAL Water Quality Management Plan has been presented to Council
Prepare Vegetation Management Plan	The vegetation management plan was prepared in concert with the WQMP and includes 2 x A3 plans consisting of a weed location and removal/management plan and a planting/revegetation plan. These plans include: ▪ Identification of problem weed areas. ▪ Identification of areas requiring bank stabilisation via vegetative means. ▪ Notes specifying the appropriate weed control method and a control program (including maintenance activities). ▪ Identification of areas for revegetation. ▪ A list of suitable revegetation plants. ▪ Notes regarding revegetation strategies and a maintenance program.	A Draft Vegetation Management Plan was provided to Council for review. Following consideration and incorporation of comments from Council and Community a FINAL Vegetation Management Plan has been presented to Council
Site Strategy Plan	The site strategy plan: ▪ depicts the 4 stages of the North Lakes residential subdivision and sets the action areas in context. It shows the site catchment and demonstrates an overall strategy for the Water Quality and Vegetation Management Plans.	A Draft Site Strategy Plan was provided to Council for review. Following consideration and incorporation of comments from Council and the Community a FINAL Site Strategy Plan has been presented to Council
Finalise Documents and Handover to Council	After Council and the relevant stakeholders provided their comments and feedback on the Management Plan, the documents were edited, reviewed and finalised. The final reports were sent to Council along with all information gathered during the project.	This FINAL Water Quality Management Plan, incorporating Site Strategy Plan and Vegetation Management Plan handed over to Council.

2. Catchment Characteristics

2.1 Study Area

The study area, including key attributes, as shown in Illustration 2.1, has a total area of approximately 22 ha which comprises a total of 230 dwellings established over five stages. The site is located within the North Creek catchment, a significant coastal waterway that drains an area of land north of the town of Ballina. North Creek drains to the Richmond River and separates the main part of the town from East Ballina and the coastal communities.

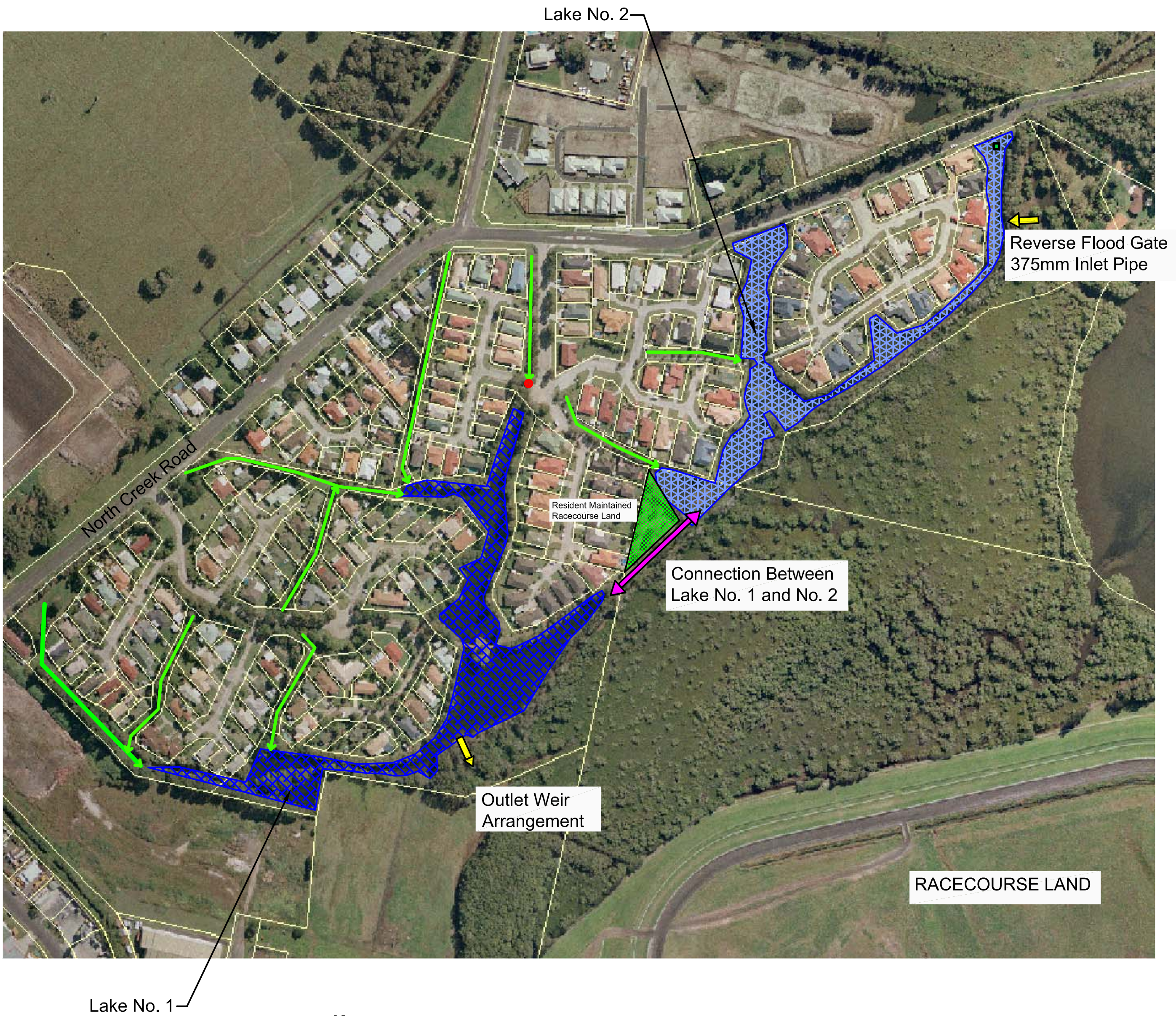
Stormwater from the North Lakes Residential Estate catchment drains via a combination Water Sensitive Urban Design (WSUD) and conventional drainage lines incorporating piped conveyance, grassed swales and the use in one instance of a litter trap. Surface waters generated by the site contribute to one of two interconnected stormwater ponds or constructed urban lakes. The site is relatively flat and low lying with an average elevation in the order of 1.5m AHD. The main topographical features of the site are the urban lakes system, swale drainage network and embankments adjacent to the wetland.

The urban lakes (referred to as *North Lakes*) were installed with the provision of a controlled overflow point (weir) and a reverse flow gate allowing interaction with North Creek. The water level within the lakes fluctuates throughout the seasons from a maximum of 0.94m AHD (weir height) to an estimated minimum of 0.3m AHD. The provision of the reverse flood gate ensures that a mean water level in the order of 0.7 to 0.8m AHD is consistently maintained throughout the year. The reverse flood gate also allows a tidal exchange into the constructed urban lakes to occur.

A wetland area listed as being of state significance and classified as a State Environmental Planning Policy (SEPP) 14 wetland, exists immediately east of the study area. All stormwater from the study area dischargers into the adjoining SEPP14 wetland area which is connected to the North Creek estuary.

Other surrounding land uses include the existing Southern Cross Industrial Estate bordering the site to the south and west, the Ballina Racecourse to the south east and a oyster opening business and oyster leases within North Creek estuary immediately upstream. A recently approved and under construction retirement village, Sovereign Gardens, is provided immediately north of the study area in combination with adjacent farm land, while the Ballina airport is located some distance north of the study area. Surrounding land uses are shown within Illustration 2.1.

Illustration 2.1 Key Site Attributes



Key:

- Drainage Swales
- Lake No. 1
- Lake No. 2
- Trash Rack/GPT
- Existing water level measuring gauge

N

0 100m 200m

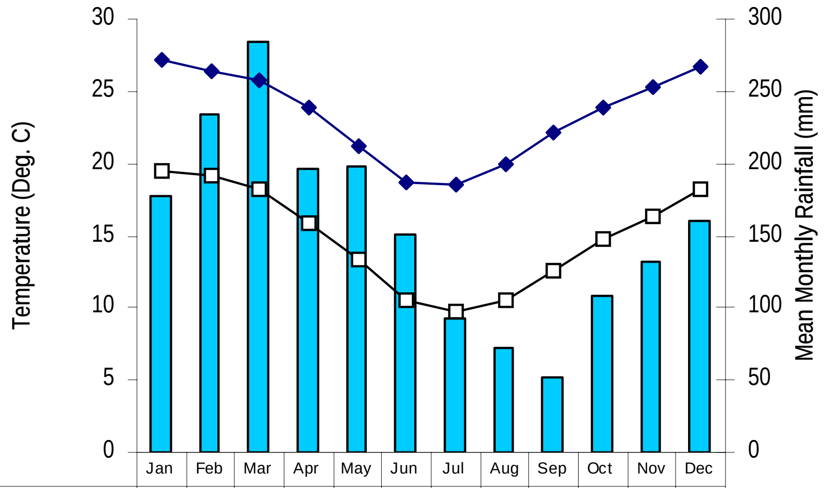
Source: Ballina Shire Council GIS database
Date: August 2008
Ref: TFA North Lakes SWMP.dwg

2.2 Meteorology

The climate is classified as subtropical with no distinctive dry season although we do have fewer rainy days in winter (Koeppen Classification System). The subtropical summer is very humid and very warm.

Our average annual daily temperature is 23.3 degrees Celsius. The warmest summer month is January with an average daily temperature of 27.1 degrees Celsius, whereas the coldest month, July, has a mild daily temperature of 18.5 degrees, with relatively cool nights (9.7oC).

Relative humidity ranges from a high of 81 per cent in February to a low of 63 per cent in September. Approximately 60 per cent of the annual average rainfall (of 1860.9mm) falling in the months of January to May. March is traditionally the wettest month with 283.7mm and September the driest with 52.4mm. The average annual evaporation is 1574.5mm; the mean daily pan evaporation rate is 4.2mm per day (BOM 2007).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean monthly rainfall - mm	177.6	234.3	283.7	196.8	198.6	151.5	91.9	73	52.4	108.3	132.2	160.6
Mean daily max temperature - deg C	27.1	26.4	25.8	23.9	21.2	18.7	18.5	19.9	22.2	23.9	25.3	26.7
Mean daily min temperature - deg C	19.4	19.2	18.2	15.8	13.4	10.6	9.7	10.5	12.5	14.7	16.4	18.2

(Source: BOM 2007)

2.3 Soils

The soils are predominately sandy with some build up of organic material in the forested areas and un-maintained drains. Soil fertility is generally low and is slightly acidic (Maunsell, 2004). Morand (1994) identify the area as being an estuarine soil landscape – Tyagarah (ty). Morand (1994) describes the Tyagarah soil landscape as comprising of a dark coarse sand topsoil with rapid permeability yet loose and often water repellent with a black sandy clay loam 'B' horizon. Morand lists soil limitations for development associated with the soil landscape which include: *very strongly acid, very low water holding capacity, low fertility, foundation hazard and high permeability*

2.4 Groundwater

The groundwater level lies generally at around 0.3 - 0.4m AHD and fluctuates with periods of high rainfall.

2.5 Interaction with North Creek

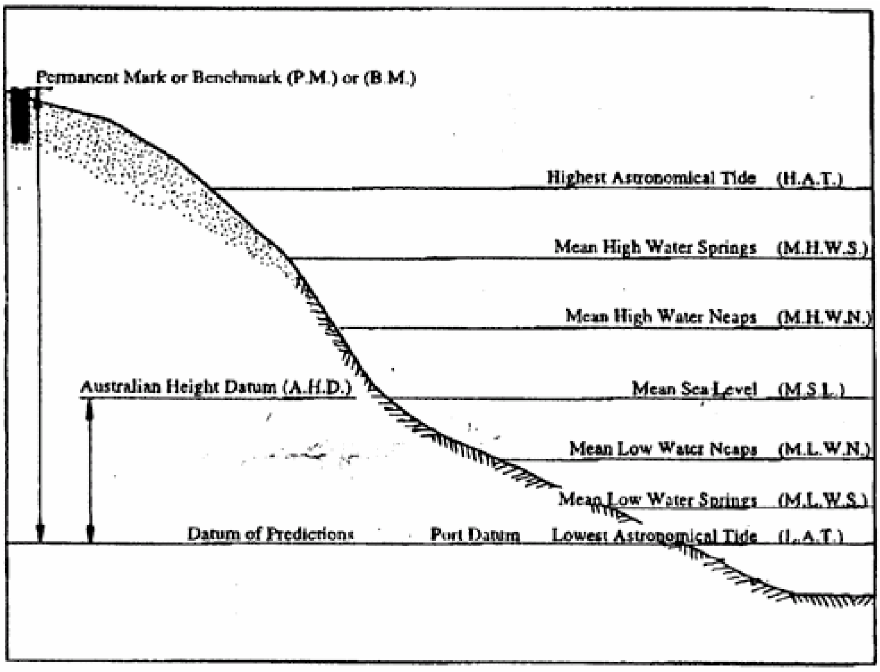
The stormwater system at North Lakes interacts with North Creek through a reverse flood gate arrangement and discharge weir, identified in Illustration 2.1. The reverse flood gate, positioned within the SEPP14 wetland to the north of the North Lakes development area, allows for saline water from North Creek to flow back into *North Lakes* via a single 375mm diameter pipe during high tides. The volume of flow received during each high tide is dependant on the amplitude and length of tide together with the internal lake level.

Key tide heights are provided for Standard Ports. The closest Standard Port to Ballina is the Gold Coast Seaway. Key tidal heights for the Gold Coast Seaway are provided below in Table 2.1. A graphical explanation of the tidal heights and a comparison to the Australian Height Datum (AHD) is also given below in Figure 2.1.

Table 2.1 Key Tidal Heights

	Tidal Height	Tidal Height (A.H.D)
Highest Astronomical Tide (H.A.T)	1.89	1.04
Mean High Water Springs (M.H.W.S)	1.41	0.56
Mean High Water Neaps (M.H.W.N)	1.15	0.30
Mean Sea Level (M.S.L)	0.85	0.00
Mean Low Water Neaps (M.L.W.N)	0.49	-0.36
Mean Low Water Springs (M.L.W.S)	0.23	-0.57

Figure 2.1 Graphical Comparison of Key Tidal Heights to A.H.D



In order to maintain suitable water quality within the Lakes, sufficient water inflows must be provided to circulate and/or displace stored water within the Lakes. This is termed the exchange rate or turn over rate. In the case of the Lakes at the *North Lakes Residential Estate* the exchange rate is influenced by two sets of inflows; being stormwater runoff and tidal exchanges. The correct balance between these two inflow sources will result in the most efficient stormwater quality control for the two constructed urban lake systems.

2.6 Flood levels

The Ballina area in general has been subject to flooding a number of times. Major floods in the upper reaches of the Richmond River systems in February and March 2001 led to deoxygenation of the water in the lower reaches. Evidence strongly suggested that most fish and crustaceans in these rivers were flushed, migrated actively from the river system or were killed by the anoxic water (NSW Fisheries, 2004).

Richmond River in Flood 2008.
Source: NSW SES photo taken by Michael Bath

The flood combined, with other factors such as summer heat, pasture grasses, drainage channels and sediment, triggered a chain reaction that left the coastal river devoid of oxygen and life (Dawson, 2002).

WBM Oceanics (1996) conducted a detailed flood study for the Ballina area. From this study, the estimated flood levels of various flood events are presented in Table 2.3. The results indicate that the 100 yr flood level on the adjacent Southern Cross Industrial Estate reaches to 1.8m AHD.

Table 2.2 Flood Levels in the vicinity of *North Lakes*

Storm event ARI	Flood levels in AHD
10yr	1.60
20yr	1.67
50yr	1.73
100yr	1.79

Historical accounts from residents living within the North Lakes Estate suggest that the highest water level of the constructed urban lakes has resulted in the submergences of the wooden bridge beam supports for the southern bridge to the island in Lake No. 1. Given that the base of the bridge support is in the order of 0.9m AHD the highest historical level of the lake appears to be in the order of 1.0m AHD.

During the project team field inspections it was also noted that the grassed swales within the initial development stage were inundated with water to an approximate depth of 50mm. An extended period of wet weather preceded the project team site inspection and lake levels were noted to be seasonally high during the inspection.

2.7 Current Study Area Land Management Practices

The current study area is a residential area of predominately single storey dwellings with reticulated sewer, water, power and telecommunication. The development is clearly defined by North Creek Road, the adjacent Wetlands and North Creek itself. The estate is not subject to flow-through traffic.

Activities within the estate reflect those of contemporary residential areas, with the bonus of water front or rear living for some of the residents. Where dwellings abut the constructed urban lakes a number of structural and non-structural approaches have been taken to enhance/protect/stabilise the embankments. These processes have included mown grass, retaining walls, paved areas, rock and pebble revetments and native and introduced riparian vegetation.

Where council is unable to access foreshore areas due to spatial constraints or through inadequate access, the majority of residents have undertaken to ensure the land immediately beyond their residence is maintained in their own fashion. During community consultations it was reported that residents of the *North Lakes Residential Estate* are particularly mindful of the implications of car washing on impervious surfaces and chemical use within yards.

Of particular interest is the triangular section of land behind properties No. 1, 3, 5, 7, 9 and 11 Teraglin Place. These properties back onto land on which the adjacent Racecourse is constructed. The construction of a connecting open swale drainage line hydraulically connecting the two urban lake systems runs across the corner of the racecourse land providing a topographic feature separating the wetland mangrove area from a grassed open woodland area (see Illustration 2.1). While this area remains the property of the racecourse, no attempt to maintain the open woodland section is made by the racecourse management committee. Rather, the residences of the properties which abut the racecourse undertake mowing and maintenance duties.

Given that the land between the two lake systems is not Council owned, no provisions were made for public access to this area. This issue is particularly relevant as appropriate management of the hydraulic connection between the two lake systems is critical to ongoing effective water quality management. Adding to the problems of the lack of suitable access for plant and machinery is the encroachment of paving, fences and other structures over council property by some adjoining neighbours. As a consequence of the above factors it is not currently possible for Council to access the hydraulic connection with any machinery and any maintenance has to be undertaken using hand tools such as spades and wheel barrows.

The Council managed areas include the urban lakes fore-shore area, where accessible, and the swales and parks. Maintenance of council property is undertaken via a combination of mowing, cutting, and pruning combined with weed spraying. As previously noted, there is no specific Council approved/endorsed management plan for *North Lakes Residential Estate*.

A photo plate identifying areas of interest has been compiled and provided below.

Photo Plate A Areas of interest noted during site inspection

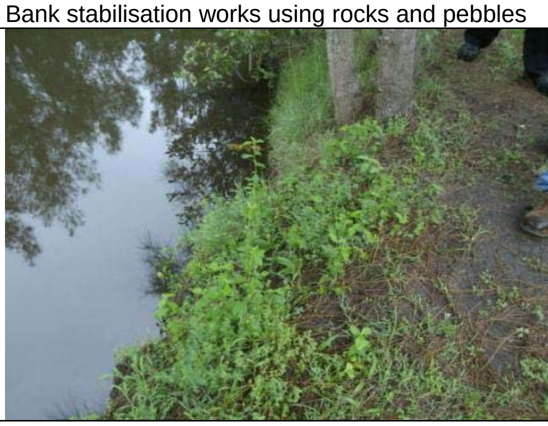
Swale drainage line beside no. 1 Teraglin Place

Land behind Teraglin Place owned by racecourse, maintained by residents and with no access for Council machinery

Water level indicator provided in Lake No. 2

Bank stabilisation works using rocks and pebbles

Typical grass bank edge



Steep sided Lake banks prone to erosion and weed invasion

Publicly accessible lake edge with established reeds.

Suitable signage provided

3. Existing Stormwater Treatment

3.1 Design Intent

Through the process of compiling this report a review of the available design documentation was undertaken. Detailed documentation on the design process and design intent was not a requirement for development when the *North Lakes Residential Estate* was approved. A review of the available information indicates that the design of the system allowed for a stormwater detention function retaining the added increased stormwater runoff volumes and peak flows resulting from the urbanisation of the area. Visual amenity and creating a positive, natural and attractive open space appears to also been a consideration in the establishment of the constructed urban lakes.

3.2 As Built Stormwater Treatment System

The 'as built' stormwater management system at the North Lakes Community closely corresponds to the design plans in all aspects of conveyance, however a few key differences in the lakes outlet structures was noted during the site visits. The main differences in the 'as built' system compared with the design plans are outlined below in Table 3.1.

Table 3.1 As Built Comparison to Intended Design

As Built	Intended Design
Reverse flood gate constructed as one 375mm diameter pipe with tidal flap on lake side. Pipe invert -0.14m AHD, grade ~1%. Minimum tidal height at which the flood gate operates is 0.71m (THD)	Allows for two x 600mm diameter pipes with tidal flaps on lake side. Pipe invert 0.6m AHD, grade not specified. Minimum tidal height at which the flood gate operates is 1.45m (THD)
Allows for a direct hydraulic link between the two urban lakes by the way of an open channel approximately 90m long, 4.0m top width, 3.5m bottom width and maximum depth of approx. 0.6m constrained by two 375mm diameter pipes with invert ~0.35m at southern end of channel	No direct hydraulic link
An outlet structure connecting Lake No. 2 to the wetland, approximately opposite the bridge between stage 3B and stage 4, does not appear to be provided. Limited evidence of a piped outlet does exist in the approximate location however sedimentation and vegetation growth appear to have rendered any piped outlet system in this location ineffective.	Design allows for an outlet structure with emergency flood gate similar to that provided on Lake No. 1. Weir level of 0.9m AHD. Two x 600mm diameter outlet pipes to be provided at invert 0.0m AHD.
A 4m long section of the embankment between Lake No. 1 and the wetland area is significantly lower than the remaining embankment and is acting as weir allowing water transfers between Lake No. 1 and the	Entire embankment between Lake No.1 and wetland and Lake No. 2 and wetland to be constructed to a height of 1.25m AHD.

wetland. The estimated height of the 4m wide low point is 0.85m AHD.	
Outlet structure with emergency flood gate provided off Lake no. 1. Weir structure 1.2m wide by 4m long at a level of 0.94m AHD provided. From inspection it appears that tidal water and stormwater are able to flow into Lake No. 1 as well as out of Lake No. 1 via the weir arrangement. The weir is connected to two x 600mm diameter outlet pipes provided at invert -0.26m AHD. A manual emergency flood gate is provided with an invert level of -0.26m AHD however the gate has remained closed for approximately 8 years and has now rusted shut and cannot be opened.	'Main low level outlet at RL 0.0m AHD' No other design details were found.

The *as built* design features are listed below with their relative impact on the operation of *North lakes* summarized as follows:

The reduced diameter pipe for the reverse flood gate at a fully submerged level has:

- increased the hydraulic back-pressure exerted on the flap gate leading to a tighter seal on the tidal flap preventing stormwater outflows from the lakes. Given that the pipe is designed to allow for saline tidal inflows only, the increased depth of the pipe ensures that no outflow from the lake into North Creek occur via the reverse flood gate pipeline;
- provided an increased depth of the pipe which allows for greater velocities and hydraulic head driving the system. Hence, an equivalent sea water influx rate is achieved using the smaller diameter pipe;
- the increased depth of the pipe compared with the design plans, allows for a longer period over which tidal inflows can occur.

Providing a direct hydraulic link between the two urban lakes ensures

- that the two urban lakes maintain similar water level and operate in unison as the one system rather than two independent systems.

The outlet structure provided for Lake No. 1 allows for water transfers between Lake No.1 and the wetland whilst also ensuring a maximum water level is not exceeded within the urban lake systems, ensuring the risk of flooding to households is abated. The provision of the manual gate valve (now rusted shut and inoperable) would allow for emergency relief in the event of unexpectedly high and rising Lake levels while also allowing for periodic lowering of the lake level in the event of a major contamination event or spill.

Whilst it appears that no outlet structure was constructed for Lake No. 2, or if one was constructed it has become blocked and ineffective, Lake No. 2 is directly connected to Lake No. 1 and Lake No. 1 does have an outlet structure and emergency outlet weir. The provision of the hydraulic link allowed for the omission of the outlet structure for Lake No. 2 with all discharges to the wetland now concentrated through the 4m wide low point in the embankment and the weir arrangement at Lake No. 1.

Changes to the design of the system during its construction and operation have resulted in a real change in the operation and functionality of the urban lakes. While the changes have not been likely to significantly alter or diminish lake water quality the differences from the design to the constructed assets needs to be considered and addressed as part of the broader Water Quality Management Plan for the *North Lakes Residential Estate*.

Photo Plate B Areas modified from design plans to 'As-built' arrangement

	
Reverse flood gate pipe inlet side located on tributary of North Creek. Photo is taken at low tide. Pipe provided is smaller in diameter with a lower inlet level.	Close up photo of reverse flood gate pipe inlet side located on tributary of North Creek. Photo is taken at low tide
	
Manual flood gate provided on main outlet weir within Lake No. 1. Manual flood gate has been locked for approximately 8 years. Design allowed for a similar outlet weir arrangement within Lake No. 2 which was not installed in lieu of the connecting pipes between the two lakes.	Hydraulic connection between the two lakes was provided. The picture above shows Lake No. 1 (top right corner) and Lake No. 2 (bottom left corner). Lakes are connected by 2 x 375mm diameter pipes beneath grassed area shown.

3.3 Water Quality Data

The production and maintenance of a log book to record water quality parameters and/or urban lake water levels for the *North Lakes Residential Estate* has not been kept. As such, no site specific water quality test results for the urban lakes or the discharge waters are available to date. Typical water quality within North Creek has been compiled by WBM in undertaking the Richmond River Estuary Management Plan (WBM, 2006). WBM found that generally the water quality in the Richmond River Estuary does not meet the Water Quality Objective's given by the EPA (2000) and Australian & New Zealand Environment Conservation Council (ANZECC 2000). Regular exceedances of Dissolved Oxygen (DO), pH, turbidity, nutrients, chlorophyll-a and faecal coliforms were observed across all monitoring locations (WBM 2006).

Water quality can be measured through a range of pollutant concentrations within the water column however the measure of suspended solids, total nitrogen and total phosphorus are the main microbiological parameters typically used to describe water quality discharges to an environment such as North Creek Estuary. With regard to the North Lakes which are not intended for any recreational activities where direct contact with water is likely (i.e. swimming), aesthetic water quality parameters (i.e. colour, clarity, and the presences of algae) are important parameters to quantify.

Suspended solids is that material removed from a water sample by filtration under standard conditions. The greatest mass of suspended solids in urban runoff typically occurs in the 1–50 µm particle size range (Collins and Ridgway 1980; Ellis *et al*. 1981; Roberts *et al*. 1988), however larger particles are often observed. Deposition of suspended solids can block pipes, change flow conditions in open channels, and disrupt the habitat of aquatic invertebrates and fish. Turbidity associated with fine suspended solids reduces light penetration and water clarity. Equally important is the association between suspended solids and many other contaminants, including hydrocarbons, heavy metals, and phosphorus (Walesh 1986; Preul and Ruszkowski 1987; Urbonas 1991). Suspended solids have frequently been used as a generic or indicator measure of urban runoff pollution.

Sources of suspended solids include wet and dry atmospheric deposition, wear of roads and vehicles, construction and demolition operations, vegetation, and erosion of pervious areas by wind and water (Pitt 1979; James and Shivalingaiah 1986; Sriananthakumar and Codner 1992)[1]. Typical pollutant runoff concentrations from urban residential subdivisions have been found to vary between 40 mg/L to 400 mg/L (ARQ, 2006) depending on the individual catchment characteristics.

Modelling of the existing system using the computer simulation model MUSIC, indicates that Lake No.1 captures on average 6.27 kg of suspended solids per day while Lake No. 2 captures on average 5.48 kg of suspended solids per day. The difference in sediment accumulation rates described above is primarily due to differences in catchment area size and the ratio of impervious surface area compared with overall catchment area. Average water quality entering and leaving the lakes is estimated through the use of the MUSIC model indicating that 11.2mg/L TSS enters the lakes while 1-4 mg/L exits the lake system. The lakes retain the majority (over 80%) of TSS adding to the sediment on the lakes floor. It is important to note here that a significant concentration of pollutants is removed from storm flows prior to reaching the lakes through the use of grassed swale conveyance systems adopted at the *North Lakes Residential Estate*.

[1] Extracted from Australian Runoff Quality, Chapter 3 Urban Stormwater Pollutant Characteristics.

A second important parameter in estimating lake water quality is associated with the rate at which the water within the lakes is *turned over* or the *residence time*. A system that has a very low turn over rate / high residence time will tend to stagnate and stratify allowing water quality to drop and algal blooms to become more prevalent. A lake with too lower residence time or high turn over rate does not allow sufficient sedimentation time and may experience areas of high velocity increasing the likely occurrence of bank scour or instability. A turn over rate of between 30 and 50 times per year, depending on the lakes summer temperature range, is ideal to reduce the likely occurrence of algal blooms and ensure water quality and an adequate treatment time is maintained within the lake system.

The MUSIC model relies on typical pollutant characteristics for urban developments and as such does not incorporate varying community practices such as car washing, lawn and garden maintenance, construction and renovation, car servicing, chemical storage and use, which are all likely to effect stormwater runoff quality. Results obtained through the MUSIC model should therefore be used primarily as a comparative tool rather than a definitive qualitative measure. In general however the results of the model indicate that water quality within the lakes system would be generally within safe ranges with water quality in Lake No. 1 being slightly poorer than that of Lake No. 2.

3.4 System Survey

Ballina Shire Council's Survey Section was requested to undertake a survey of the system including the lake depths at a number of locations for the purposes of this study. The results of the survey were then used to refine the design plans and generate lake contours levels.

The main outcome from the survey indicated that a deep hole exists within the lake system which was not included in the stormwater design. Immediately north of the island in Lake No. 1 the design bottom level was set at -1.0m AHD. The design depth of approximately 2.0m allowed for the provision of a nutrient and temperature trap. The survey results provided by Council indicate that the bottom level of the lake immediately north of the island in Lake No. 1 is -2.5m AHD resulting in an overall depth of approximately 3.5m.

The survey also allowed for an estimation of the likely sedimentation and accretion rates that have occurred within the system. Sedimentation and accretion is further discussed in section 4.2.3

3.5 Modelling Results

The computer simulation model *DRAINS* was used to provide an understanding of the existing hydraulic capacity of the North Lakes drainage system. *DRAINS* is a program for designing and analysing urban stormwater drainage systems with particular regard to flooding behaviour. *DRAINS* was developed by Bob Stack and Geoffrey O'Loughlin and is distributed by *Watercom Pty Ltd*. The combined hydrological and hydraulic methods in *DRAINS* can be used to design new drainage systems and to analyse established or trial systems. In order to create a model of the North Lakes system a number of assumptions were made. A full list of assumptions made is provided in Appendix C for further reference.

The results of the *DRAINS* analysis indicate that the pipe and swale system provided for the North Lakes Estate has sufficient capacity to transfer all stormwater flows to the lake system in accordance with Ballina Shire Council design principals. That is, all storm flows up to the 1 in 5 year ARI design storm event are safely conveyed via the street drainage system provided. Any flows greater than those specified as the 1 in 5 year event (i.e. major storm flows up to the 1 in 100 year event) must be safely conveyed via nominated overland flow paths without causing undue flooding impacts on residential property.

The *DRAINS* analysis also indicate that the system has the capacity to capture and retain all storm events up to the 1 in 10 yr ARI event raising the lake level to a maximum height of 0.938m AHD without overtopping the weir or embankment into North Creek/wetland[2]. The ultimate detention capacity of the lakes is however heavily dependant on the initial lake levels prior to any storm event. Nevertheless, given mean water levels, the volume and freeboard provided by the two urban lakes is sufficient to ensure that runoff generated by any single storm event, up to the 1 in 10 year event, will not overtop the designated outlet weir.

It was also found through modelling within *DRAINS* that during a major rainfall event, a 1 in 100 year event, the maximum lake level will rise to 1.0m AHD.

Furthermore, it was concluded through running the *DRAINS* model that there is no ‘additional’ capacity within the North Lakes stormwater system for the acceptance of ‘additional’ catchment areas and that no other development within the general area should connect into the North Lakes stormwater system.

A second computer simulation model, *MUSIC*, was run to determine the likely water quality inputs into the North Lakes stormwater system. *MUSIC* (*Model for Urban Stormwater Improvement Conceptualisation)* was developed by the Cooperative Research Centre for Catchment Hydrology and provides the ability to simulate both quantity and quality of runoff from catchments ranging from a single house block up to many square kilometres. Furthermore, the model allows the user to gauge the effect of a wide range of treatment facilities on the quantity and quality of runoff downstream. By simulating the performance of stormwater quality improvement measures, *MUSIC* determines if proposed systems can meet specified water quality objectives.

Results of the *MUSIC* analysis indicate that due to the configuration of the system and lake outlets, approximately 90% of total suspended solids, Total Phosphorus and Total Nitrogen generated by the catchment are retained and accumulate within the two urban lakes. The gradual accumulation of these pollutants over time is described as sedimentation and accretion. The assumed sedimentation rates for the lakes are based on *MUSIC* modelling results of annual suspended solids load in the order of 4,600 kg/yr over the two lakes, a sediment density of 1,750kg/m^3 and a combined lake base area in the order of 10,000m^2. Annual sediment accumulation of approximately 0.25mm per year for the North Lakes can be assumed.

Other conclusions reached through the analysis of the *MUSIC* model indicate that:

- Grassed swales are particularly effective at removing suspended solids.
- Swales afford an essential pre-treatment system where they are provided.
- The ratio of catchment area verse Lake surface area for the two wet basin systems is: Lake No. 1 – 11.2
Lake No. 2 – 6.7
- Water quality within Lake No. 1 was found to be poorer on average than later development stage Lake No. 2. The primary cause is considered a direct consequence of larger catchment area verses the water surface area for Lake No. 1.

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[2] assumes the initial lake level prior to any storm event is 0.75m AHD

3.6 Community Feedback

On 28 March 2008 an initial community meeting was undertaken to introduce the North Lakes Water Quality Management Plan and to seek input from the local community

A summary of the issues presented from the community members present is provided below in Table 3.2.

Table 3.2 Community Members Issues/Concerns

Keep Water level at a constant level	Narrow passage between the 2 main lakes causes blockage of water. Previously there was a pipe through the narrow section!! (not confirmed)	Edgewater Cove (Stage 5) banks are being eroded (opposite reverse floodgate)
In Stage 1, southern end, water levels drop as canal dries, causing smell and attracting mossies	Lake level is dependent on getting regular rain	Water comes in through wetland form North Creek during King Tide. Salt water inundates wetland and enters North Lakes via overflow points in Stage 1
Ducks and water hens contribute to scouring of banks and erosion	Some residents have placed bush rocks and pebbles along their banks to stabilize areas, instead of reeds for fear of snakes. Is this a good idea?	BSC staff have sprayed native reeds in the past! Why is this happening? Native reeds filter water pollution , provide bank stabilization and habitat for birds and animals
Dead organic matter alongside lakes causes odour	Tides and winds push rubbish, plastics etc to certain edges of lakes	Weeds are clogging parts of the lake system
Access around the entire lake is restricted, some residents are happy with the existing footpath and access as designed. It seemed to be the view that Council had an inconsistent approach to access and use of public/council land	Reeds are good for bird life	Reeds are bad as they provide harbourage for snakes
Swales: There is a concern that they are holding water and not draining effectively, causing a bog	Better maintenance of the footpath and bridge is required	There is an oily film on the water from time to time
People sometimes wash cars with water entering the stormwater system	Good to have the path within the estate linked to a footpath outside of the estate	Fish kills have occurred from time to time; some fish are known to have had red spot disease
People who back onto the lake do not want the public to be able to walk around	Empty mower clippings on the edge of the lake	BSC maintenance do not pick up clippings in swales which makes its way into

the back of their houses		the lake system
The original slide gate that operated in Stage 1 operated manually to allow water to escape as overflow and enter during king tides. This gate was locked shut by Council to prevent residents altering the gate.		

Following Community Meeting No.2 four residents raised concerns as follows:

- Pipi Place: Low water level and the decaying vegetation on the southern side of the island facing Pipi Place needs cleaning out.
- 30 and 32 Edgewater Cove: Erosion of bank and concerns about bank stability and exposure of Casuarina tree roots. The stability of the Casuarinas is also a concern.
- 12 Mulloway Place. The residents are concerned with bank erosion and failure of retaining wall
- A single letter was received by Council on 4 November 2008. The correspondent was concerned with maintenance of public access to council property, especially foreshore property throughout the estate. Her concern also related to the various methods of managing the riparian zones, use of chemicals, disposal of weeds and grass clippings on the edge of the banks.
- Subsequent to the meeting a resident from Pipi Place telephoned concerned about the effect of filling of the drain at the rear of Pipi Place on water hens and land values. Weed infestation in the rear drain was also raised as a matter of concern and as well as trees overhanging at the rear of the neighbouring industrial estate.

Following the issues being raised the residents were asked to provide some positive things about living at North Lakes. The following matters listed in Table 3.3 were raised.

Table 3.3 Positive Aspects about living at North Lakes

Abundant wildlife	Protects estuary	Quiet, no through traffic
Like being near the water	Like having fish and birds	Being able to walk throughout the whole estate on roads and footpaths
Paddling canoe and fishing	Great for kids to explore; canoe, fish, play with their mates	

3.6.1 Questions from Residents

A number of questions were raised throughout the meeting. The purpose of the meeting was not to address all of these questions, but gain information form the residents about their concerns and issues. Nevertheless the key questions raised are provided below.

1. Are the lakes tidal?
2. How does the water get into North Lakes?

3. Are the lakes silting up?
4. Does any water get into the lake from the original slide gate in Stage 1?
5. Is placing bush rocks and pebbles around the perimeter of the lakes a good option for bank stabilisation?

In addition a number of residents have provided comments/feedback to the project team during our site inspections. Some of the comments voices by residents are listed below:

1. The manual discharge flood gate (weir in Lake No.1) has not been operated in eight years. Prior to that residences would swim over and open the gate periodically when they deemed appropriate.
2. Some residents have been planting reeds along waters edge and on banks.
3. Generally cars within the neighbourhood are washed on the grass rather than on the road surface. Residences enforce/police this throughout the neighbourhood
4. Lake levels fluctuate around 0.5m. The highest level of the lakes is when water touches underside of pedestrian bridge south of the island in Lake No. 1.
5. Water quality within lakes is generally good.
6. Fish population appears healthy
7. Kids fish for eels within lake

4. System Analysis

4.1 System/Treatment Objectives

Chapter 13 of Ballina Shire Councils Development Control Plan has been prepared to address the issues of appropriate stormwater management for new developments within Ballina Shire. Whilst it is acknowledged that the North Creek Estate is not a new development the principals outlined within the planning document will assist to inform the investigation process. The main policy objective of chapter 13 of Ballina Shire's DCP is:

> 'no net increase in the average annual load of key stormwater pollutants and peak discharge flow rates occurs above that occurring under existing conditions.'

Other relevant policy documents include Ballina Shires Council's Urban Stormwater Management Strategy and the NSW Governments State Environmental Planning Policy SEPP 71 'Coastal developments', SEPP 14 Wetlands and the Acid Sulfate Management Manual (ASSMAC 1998). While these documents provide a context for urban Stormwater management and the relevant environmental impacts, specific objectives are not provided for *North Lakes*.

4.2 Current Stormwater System Performance

4.2.1 Hydraulic Capacity / Performance

The stormwater conveyance system at North Lakes caters for the naturally flat grades of the site while also achieving sufficient stormwater conveyance thereby limiting localised flooding. This has been achieved through the combined use of grassed swales together with a pit/pipe network. The road design used throughout the development provides for narrow concrete reverse crown roads where stormwater is conveyed down the centre of the street. Stormwater pits provided within the roadway capture only runoff generated by the roadway as shown in photo. Lots are graded away from the road.

A typical concrete reverse crown road within the North Lakes Estate

The urban design also provides for wide grassed swales or constructed urban lakes at the rear of all lots which allows for all stormwater flows, apart from road runoff but including roof water, to be drained via to the rear of lots and into grassed swales or directly connected to the constructed urban lakes.

The hydraulic capacity of the drainage system has been checked as part of this study and it has been found that the existing combined system of swales and pit/pipes is sufficient to safely convey all minor flows up to the 1 in 10 year design storm event.

The capacity of urban lakes to accept flow is dependant on the lake levels at the time. The high level outlets from the lakes, in the form of discharge weirs, provide sufficient capacity to safely discharge all additional (i.e. storm events greater than 1 in 10yr) stormwater flows safely without allowing lake levels to increase above 1.0m AHD.

An emergency discharge, manually operated gate has also been provided at the weir outlet structure within Lake No. 1. The purpose of this gate allows for adjustment of the lake water level if required while also providing additional outlet capacity in the event of increasing lake water levels. While it has not been operated in approximately 8 years the gate appears to have become rusted in the closed position and it is doubtful if the gate can be opened in its current state.

Looking down at the emergency discharge sluice gate which has become rusted closed over the past few years.

4.2.2 Tidal Exchange

It has been previously noted that the stormwater system at North Lakes interacts with North Creek through a reverse flood gate arrangement and discharge weir. The reverse flood gate, positioned within the SEPP14 wetland to the north of the north lakes development area, allows for saline water from North Creek to flow back into the North Lakes stormwater basins via a single 375mm diameter pipe during high tide. The volume of flow received during each high tide is dependant on the amplitude and length of tide together with the internal lake level.

Through analysis of the data and discussion with residents the internal lake levels are believed to fluctuate with a range between 0.3m and 0.94m AHD. The number of tide events in 2008 for the respective AHD level datum and tidal height datum are presented below in Table 4.1.

Table 4.1 Number of Annual Tidal Events

Tidal Height Datum	Australian Height Datum	Number of tidal events per year
1.865	1.015	0
1.850	1.000	1
1.825	0.975	3
1.800	0.950	11
1.700	0.850	33
1.600	0.750	83
1.500	0.650	164
1.400	0.550	240
1.300	0.450	320
1.225	0.375	380

Tidal heights are also affected by a number of climate variables such as atmospheric low pressure systems, storm surge, sea level rise and river flood heights. When these variable conditions occur during periods of high tides (i.e. greater than 1.7m THD) the number of actual large tidal events is likely to be marginally greater than 33 as shown above in Table 4.1. The affect of these variable conditions could account for an additional tidal increase of:

- 0.09m under a 100yr storm sea surge (Table 4.3 of Ballina Coastline Hazard Study, 2008)
- 0.03m due to a deep atmospheric low pressure cell
- 0.12m in the year 2040 due to anticipated sea level rise

An estimation of the amount, or flux, of saline water back flowing into the constructed urban lakes is critical knowledge in analysing the functionality of the stormwater system. Submerged pipe outlet control nomographs were used to estimate transfer capacity of the 375mm connection pipe under a range of internal lake and tidal levels. **The provision of the reverse flood gate only allows tides which are greater in level than the internal lake to backflow into the lake.** In this way the reverse flood gate assists in maintaining an appropriate lake water level allowing higher tidal influx during dry weather when lake levels are low and reduced tidal influx during wet periods when the lake levels are high.

The connectivity between the two urban lakes is via two 375mm diameter pipes at the southern extreme of Lake No. 2. The location and capacity of these pipes acts as a constriction to the hydraulic connectively of the two lakes. While the pipes have sufficient hydraulic capacity to ensure that water levels within the two Urban Lakes remain closely equivalent, the tidal exchange into Lake No. 1 is considered to be restricted due to this connection. The amount of tidal influx therefore reaching Lake No. 1 is restricted by the two 375mm connecting pipes and the likely amount of tidal inflows reaching Lake No. 1 is considered to be approximately a third of the total potential tidal influx.

A build up of sediment, which has been the subject of previous maintenance by Council at both ends of the pipes, is further evidence of the reduced connectivity between the two lakes.

The percentage inflows of saline tidal water and fresh stormwater into the Urban Lakes are an important consideration. The percentage of tidal inflows compared with stormwater inflows for three various mean lake levels is provided below in Table 4.2.

Table 4.2 Tidal inflows as a percentage of total inflows

Lake	Lake Level m AHD	Average Annual Stormwater Inflows (ML/yr)	Annual Tidal Inflows (ML/yr)	Tidal Inflows as a Percentage of Total Inflows *
No. 1	0.7m	120	45	27%
	0.78m	120	11	8%
	0.9m	120	0.05	0%
No. 2	0.7m	75	91	55%
	0.78m	75	23	25%
	0.9m	75	0.1	0%

* Note: Data based on average rainfall conditions. Annual and seasonal variability in rainfall volumes will vary the tidal inflow percentage accordingly.

Given the direct tidal exchange occurring into Lake No. 2 via the reverse flood gate and the lower stormwater runoff entering lake No. 2 due to the smaller catchment area, the tidal inflows as a percentage of total inflows are significantly greater for Lake No. 2 than Lake No.1. This is likely to be confirmed through measurement of salinity levels within the two lakes. Although not undertaken as part of this study, measurements to confirm these findings would be recommended as part of any further management plan for the Urban Lakes system.

Through analysis of daily tidal flux combined with estimated daily evaporation/seepage losses and rainfall/runoff data, the mean annual lake level can be estimated. Analysis of the tidal range for Ballina and the resulting sea water flux into the North Lakes basins indicates that the likely mean water level of the lakes would be in the vicinity of 0.78m AHD.

4.2.3 Sedimentation and Accretion

Tidal flows and available sediment determine the balance of sedimentation and erosion that occurs across any coastal wetland area or, in this case, tidal constructed urban lake systems. The rate of sedimentation as a result of stormwater flows into the lake has been calculated using the results of the MUSIC water quality model and is estimated to contribute in the order of 0.25mm of sediment to the bottom, of the lakes per year. The rate of sedimentation as a result of tidal inflows is likely to be significantly less than this figure as tidal inflows into the lake system account for only 22% of the mean annual inflows. While water quality entering the lake from tidal influences is better than that from stormwater flows, sedimentation rates from tidal influx would be concentrated within Lake No. 2 likely equating to an additional 0.05mm of sediment per year due to tidal influx.

Given the average depth of the lake is approximately 1.5m, and at the predicted rates of sedimentation, it is conservatively estimated that it would take approximately 5000 years for the lake to *silt up*.

It should also be noted that results from the lake survey undertaken by Council indicate that the lakes are in fact deeper, between 200mm and 500mm, in many places than the design levels indicate. The additional capacity built into the lakes is therefore considered to be sufficient to ensure that future dredging of the lakes due to excess sedimentation remains a remote possibility and is unlikely to be required in the next 100 years.

While these figures are calculated assuming an even distribution of sedimentation across the lakes, sediment will tend to accumulate preferentially in some areas rather than others.

Areas that were noted during the site inspections as risk of preferential sediment accumulation include areas:

- surrounding stormwater pipe outlets,
- of limited water velocity such as the pool at the most northern end of Lake No. 2 near 210 Southern Cross Drive and the pool at the most southern end of Lake No. 2 near 12 Mulloway Place.

By comparing the design plans to recent aerial photography together with field observations it is evident that limited accretion/sedimentation has occurred over the life of the lakes.

4.2.4 Nutrient Sources

The two main nutrient sources are nitrogen and phosphorus.

Nitrogen is an essential nutrient, and may be the limiting nutrient at a site. In such cases, increased nitrogen levels may stimulate further growth and lead to eutrophication of the water body. Sources of nitrogen in the North Lakes Estate stormwater would include garden fertilisers, household cleaning solutions, car washing suds, animal droppings, combustion of fossil fuels (Makepeace et al. 1995), grass clippings, windblown pollen, spores, bacteria, and dust (McKee 1962), fallen leaves, and other plant debris. Rainfall is consistently the main immediate source of nitrogen in urban runoff (Duncan 1995).

Phosphorus is an essential nutrient, and may be the limiting nutrient at a site. Where phosphorus is limiting, an increase may cause excessive and unbalanced growth of plants and algae leading to oxygen depletion (eutrophication). The main sources of Phosphorus in the North Lakes Estate stormwater system would include: garden fertilisers, any household grey water runoff and cleaning product runoff.

An oft-quoted general rule is that Nitrogen is the nutrient limiting plant growth in marine environments, and sometimes in estuaries with low or variable salinity, whereas Phosphorus is generally limiting to plant growth in freshwaters (Enell et al. 1995). However, this simple blanket statement is being challenged as more information becomes available. For example, McComb and Davis (1993) found that the Peel-Harvey Estuary in Western Australia is potentially Nitrogen limited in summer and autumn but Phosphorus limited in winter and spring (ANZECC WQG, 2000).

Modelling indicates that the lakes have a mean total nitrogen concentration in the order of 0.5 mg/L with daily maximum storm flow inputs approaching 4 mg/L. Mean total phosphorus concentration was found to be in the order of 0.05 mg/L with daily maximum storm flow inputs approaching 0.36 mg/L. It can be noted that the daily maximum storm flow input values are in the range of likely runoff values from residential developments and the lake nutrient concentrations are in line with ANZECC (2000) default trigger levels for slightly disturbed estuary systems of 0.3 mg/l and 0.03 mg/L. It should also be noted that while the ANZECC trigger levels provide some guidance, they were developed after considering a diverse range of water and lake systems and natural variability will occur from area to area.

4.2.5 Algal Blooms

Water quality problems for large lakes exhibiting relatively small upstream catchments arise because the water body receives insufficient water inflows to circulate and/or displace the water stored in the lake. Experiences with management of open water bodies have suggested that many algal blooms in water bodies are preceded by extended periods of no or minimal inflows (Australian Runoff Quality, 2006).

Water body residence time (or turnover frequency) analysis can thus be a useful 'first-pass' indicator as to whether the water body is at significant risk of water quality problems (especially associated with algal growth). Many factors influence cyanobacterial growth (Tarczynska *et al*. 2002; Mitrovic *et al*. 2001; Sherman *et al.* 1998; Reynolds 2003) including:

- light intensity
- water temperature
- nutrient concentration
- hydrodynamics
- stratification

- catchment hydrology
- zooplankton grazing
- parasitism.

Melbourne Water undertook research to determine the most appropriate retention times for constructed urban lakes to limit algal blooms. The results published as part of the Melbourne Water Guidelines (2005) indicate that for water bodies with summer water temperatures in the order of 20 degrees, a residence time less than 30 days is appropriate. The residence time of a lake is usually expressed as an annual average and takes no account of the short-term fluctuations in the rainfall which result in a pronounced seasonal variation in the effective residence time.

Assessment of the residence time within the two urban lakes has been undertaken for this study. The two inflows into the lakes comprise stormwater runoff and tidal influx. Tidal influx occurs directly into Lake No. 2 through the reverse flood gate arrangement while the connectivity of the two lakes allows some indirect tidal inflows into Lake No. 1. Tidal inflows into Lake No. 1 have been approximated to be 1/3rd of those into Lake No. 2. Tidal inflows also reduce with increased lake levels. When the lake level is high the majority of inflows will be due to stormwater runoff as described earlier in section 4.2.2.

The annual average residence time is calculated by relating the annual amount of water passing through the lake to the volume of the whole basin. It should be noted that the effective residence time may, however, be influenced by a number of factors such as the timing of stratification, the depth of the thermocline and the variability of the inflows.

In the case of North Lakes, given that tidal inflows decrease with rising lake levels, it can be expected that the annual average residence time will reduce with increased mean lake levels. The likely residence times for the two urban lake systems have therefore been calculated assuming a range of mean lake levels of 0.7m AHD, 0.78m AHD and 0.9m AHD. Results are shown below in Table 4.3.

Table 4.3 North Lakes Average Annual Resident Times for Various Lake Levels

Mean Lake Level	Lake No. 1	Lake No. 2
0.7m	38	24
0.78m	48	41
0.9m	53	54

As can be seen from the above table the annual average resident times for Lake No. 1 are greater than those for Lake No. 2. This is despite the larger catchment area for Lake No. 1. The lower residence times for Lake No. 2 are directly related to the greater tidal inflows into Lake No. 2. This is evident as the water level increase to 0.9m when tidal inflows into the lake become a very small percentage of total inflows (less than 1%) and the resident times for both lakes is in the order of 53 days.

It can also be seen from the table that the residence times for Lake No. 1 is slightly higher than recommended by Melbourne Water at the average water level of 0.7m. However, given that the North Lakes system allows for tidal water to inflow into the lakes, the presence of saline water acts to buffer the longer resident times and limits the occurrence of fresh water algal blooms.

Allowing greater tidal influx into Lake No. 1 by providing a more efficient hydraulic connection between the two lake systems will decrease resident times and increase salinity levels. This will lead to a reduction in the likelihood of algal blooms occurring and improved water circulation.

The Institute of Engineers Australia also suggests that *in pond systems, a crucial design optimisation to limit algal blooms occurring is the sizing of the sedimentation zones relative to organic material (BOD) loading'* (Australian Runoff Quality, 2006). The use of bypass arrangements for extreme storm events, the maintenance of shallow depths promoting efficient surface water re-aeration and transfer of oxygen to sediments, and the promotion of emergent macrophytes to promote the direct transfer of oxygen to macrophyte sediment rhizome zones, are suggested as the principal means of managing the issue of algal blooms.

It was established from the survey data obtained that the depth of the finger zones (narrow extremities) within both lakes are deeper than design plans allowed. In line with the management principles outlined by the Institute of Engineers, reducing the depth of these finger zones to increase the surface water re-aeration rates and the promotion of macrophyte sediment rhizome zones would reduce the likelihood of algal blooms occurring within these sections of the constructed urban lake systems of *North Lakes Residential Estate*.

4.2.6 Use of Chemicals

Many everyday household products and materials contain a diverse range of chemicals, including some which pose a threat to health and the environment. Domestic products containing chemicals include paints; cleaning agents, such as detergents; varnishes; cosmetics; weed killers; insecticides; baits; and wood, pool and pet treatments.

The use of chemicals and fertilisers outdoors may result in these pollutants entering the stormwater drains and into North Lakes. Whilst specific sampling has not been conducted to establish the presence of residual chemicals, there appears to be a reasonable level of awareness and concern by attendees at the Community meeting that inputs into the stormwater system will impact on the quality of the receiving lake system.

The six field inspections by the project team did not reveal any evidence of chemical contamination of the lake system. Nevertheless ongoing education of the community on the use of chemicals and fertilisers, especially external to the home and in the garden should be included in future education of the community to preserve the water quality of the lake system.

4.2.7 Aquatic and Embankment Weeds

A survey of weeds was undertaken on 29 April 2008. Threatened plant species were not identified. At the time of inspection the following significant weeds were identified at the site:

Aquatic Weeds

- Alligator Weeds (Alternathera philoxeroides) – small infestations, only observed on embankment edges

Embankments Weeds

- Lantana (Lantana camara)
- Ochna (Ochna serrulate)
- Winter senna (Senna pedula var glabrata)

- Coastal Morning Glory (Ipomea cairica)
- White Passionflower (Passiflora subpeltata)
- Singapore Daisey (Wedelia trilobata)
- Passionfruit (Passiflora edulis)

Other less invasive perennial weeds were also observed.

4.2.8 Community Perceptions

Following the initial community meeting, review of community survey and discussions with community residents it is clear that there are a number of views with regard to the current state of the stormwater lake system and its future management.

The concerns raised revolve around lake water level, lake maintenance, odour from decaying vegetation, bank stabilisation, snakes and vermin, rubbish disposal, weeds and reeds, lack of consistency with public/council access around lake, swales holding water, fish kills, closing of the outlet weir and general water quality.

Feedback from the community has indicated that they like being close to the water enjoy the abundance of bird and fish life, the ability to paddle a canoe, fish and recreate and the fact that the estate is quiet with no through traffic and that they can walk throughout the whole estate on roads and paths.

4.2.9 Practical, legal, financial issues associated with the management of the urban lakes

In terms of the management of the Lake system there is no current management plan. A key component acknowledged by Council previously and confirmed as part of the preparation of this management plan is the need for Council to have adequate access to the Lake system in order to manage the system effectively.

Strategic points of access are required throughout the lake system to ensure that Council has sufficient access for machinery to maintain water flow and maintenance of infrastructure (i.e. outlet weir) throughout the lake. A bottleneck in the drainage channels between Lakes 1 and 2 cannot be accessed with machinery for maintenance by Council. Water quality within the lake system, especially Lake 1 is being affected by the limited hydraulic connectivity between the two lakes at this point.

Attempts by Council to use hand tools to clear this area have had limited and short terms affect and are not a practical nor sustainable practice. In addition there is evidence of structures being built on Council land which is in some cases limiting and restricting access for Council to carry out necessary maintenance of the Urban Lake System.

4.3 Identified Areas for Improvement

4.3.1 Introduction

Through the processes of this study, a number of deficiencies have been identified in the operation and management of the *North Lakes* stormwater system. The main issues to be resolved surround the management and functionality of the swale system, the connectivity between the two lake systems and effective vegetation management. A matter of importance identified by the community representatives and council was the level and quality of water in the system. Our investigations have identified that the water flow, quality and tidal exchange rates are satisfactory. In order to maintain and enhance these key aspects it is imperative that the following matters are addressed.

A Site Strategy Plan (SSP) has been prepared (see Appendix A). It summarises the key water quality management activities proposed in the Water Quality Management Plan. The SSP should be read in conjunction with Vegetation Management Strategy which includes the Weed Management Plans and Revegetation Plans.

The SSP seeks to address a variety of community preferences for vegetation types and balances the need for vegetation for embankment and water quality improvements with individual preferences for various landscape styles.

Swale drainage lines have been constructed at very flat grades (i.e. less than 0.5%) and are prone to ponding, flooding and water logging. Ponded water within the swale limits maintenance operations and can increase the likelihood of vector (i.e. mosquito) habitat. Remediation of the swale system to allow for increased drainage efficiency and improved maintenance arrangements will improve the functionality and performance of these conveyance systems.

Increased connectivity between the two lake systems will result in greater mixing of stored water and allow for greater mixing of tidal waters within Lake No. 1. The current arrangement of two 375mm pipe connecting the two urban lakes does not allow sufficient tidal water transfer between the two lakes. Increasing water transfer efficiency will increase the number of water exchanges per year within Lake No. 1 and increase the salinity levels leading to improved overall water quality and reduced likelihood of algal blooms.

Vegetation along the banks of the urban lakes and within the shallow areas around stormwater discharge points assist the improve water quality by absorbing nutrients and increasing oxidation of sediments. An appropriate vegetation management plan will ensure future management of the Urban Lakes allows for appropriate vegetation management, including weed removal and new plantings

From these three main issues identified six improvement areas are acknowledged as requiring some measure of remedial action to improve the overall efficiency, performance and management of the North Lakes Residential Estate stormwater system. The six areas are listed below:

- Swale drainage performance
- Land ownership and access rights to open channel hydraulic connection
- Hydraulic connectivity between lake systems
- Outlet weir maintenance
- Vegetation management
- System monitoring

4.3.2 Swale drainage maintenance and performance

Given the current situation where swales are often subject to long periods of inundation, maintenance of these assets by Council becomes difficult. Compounding the issue of maintenance are the larger melaleuca trees planted on the edges of the swale. Grass surrounds the majority of the tree trunks requiring Council maintenance workers to spend large amounts of time mowing back and forth, in and around the tree trunks. Time spent mowing around the trees takes away from time available to undertake other maintenance activities in and around the North Lakes Residential Estate. The development of an appropriate planting regime and the construction of planting beds surrounding the tree trunks will reduce the amount of mowable area and enable the grass swales to be mown in a more efficient pattern.

To reduce the frequency of inundation and increase the hydraulic efficiency of the swales it is proposed to provide a 50mm diameter perforated pipe wrapped in geotextile down the centre of the swale. Back filling around the drainage pipe with 10mm crushed gravel will ensure that the base of the swale not longer become boggy when wet and importantly is allowed to remain free draining.

4.3.3 Access to allow maintenance of open channel hydraulic connection

To enable effective management of the two urban lakes, the current capacity and accessibility of the open channel hydraulic connection, located on land currently owned by the NSW Department of Lands and managed by the Ballina Racecourse, needs to be reviewed. In order to address this issue the following staged actions are considered to be required:

- Conduct a survey by a Registered Surveyor to confirm the location of the eastern boundary of no.1 Teralgin Place. Following a review of the survey Council should, if necessary, enter into negotiations with the owner of no.1 Terlagin Place to remove any structures that encroach on Council's land.
- To enable council to gain access to the land at the rear of No. 1 Terlagin Place for machinery, it is recommended that a small 1metre high retaining wall for a minimum length of 20 metres be constructed at the end of the northern swale off Teraglin Place. The retaining structure would align with the middle of the last 20m of swale and continue around the eastern boundary of no. 1 Teraglin Place. Appropriate landscaping and scour protection works are proposed to be undertaken north of the retaining wall to ensure safe and efficient drainage of the swale remains while also improving the visual amenity of this section of swale (currently due to poor access and continual water logging council is unable to mow this section of the swale and it is consequently overgrown). Backfilling the southern side of the proposed retaining wall would create an access way approximately 3meters wide to the land on which the open channel and hydraulic connection exists. Conceptual details of the proposed access arrangement are provided within the Site Strategy Plan.
- Once a strategy for land access has been agreed, Council should approach the NSW Department of Lands and Ballina Racecourse with a view to entering into an agreement to assume the care, control and management of the triangular portion of land on which the channel exists. In the event that a suitable agreement cannot be reached Council should consider proposing a boundary adjustment to the NSW Department of Lands for the amalgamation of Lot 171 DP 1041678 with Lot 114 DP 852971.

4.3.4 Hydraulic connectivity between lake systems

The existing two 375mm pipes connecting the two urban lakes together has insufficient capacity to allow sufficient tidal water flushing to occur between the two lakes. Removal of the pipes and extension of the existing open channel to connect the two lakes would increase tidal flushing of Lake No. 1 leading to improved water quality.

Removal of the pipes and extension of the channel will cut the existing access arrangement to the northern side embankment. Continued access to the northern embankment is considered essential for the future management of the Lakes. Replacement of the pipes with a single 3m wide 500mm deep concrete box culvert would satisfy both increased hydraulic connectivity and access arrangements to the northern side embankment.

4.3.5 Outlet weir maintenance

Maintenance of the outlet weir in Lake 1 is an integral part of the inbuilt contingency for flooding within the North Lakes stormwater system. Whilst the weir has been shut for some extended period and overflows have occurred adjacent to and over the system from time to time since it is important that the weir is operational and maintained.

The weir should be re-commissioned and maintained on a regular basis in accordance with the original design intent as the single as built overflow weir.

4.3.6 Vegetation management

The weed management strategy applies to drainage lines and riparian zones within North Lakes Residential Estate. The specific weed management areas are identified on Sheet 2 (Weed Management Plan in Appendix B). This strategy identifies significant areas of weed infestation and provides general strategies for weed treatment.

4.3.7 Ongoing system monitoring

Stormwater water and salt water interaction between the urban lake system and North Creek is the primary driver that determines water quality and functionality in North Lakes. It is therefore prudent that any future system monitoring is based on this interaction. Traditional assessment of water quality parameters will not provide meaningful data to assist in the future management of the lake system. Ongoing monitoring of water level, stormwater inflows and tidal influx will provide the necessary data to monitor the Lake system functions into the future.

The creation of a log book to record water levels, water flow and asset functionality within the North Lakes Residential Estate is considered to be a vital element to any future WQMP. A greater understanding into the lakes functionality would be provided if a log book of net flows, and water levels were kept. A log could be kept by both Council and by the community association group to record any major water events, water level fluctuations, and a brief account of how elements of the stormwater system (i.e. swales, pits, pipes, macrophyte zone, etc.) are performing and any noticeable change over time. To complement the log book the production of a photo log would also enable long term changes over time to be observed.

To enable water levels to be recorded on a continual basis the provision of two hydrostatic level sensors, one located in each lake system, would be necessary. Data recorded by the hydrostatic level senses could be downloaded on a monthly basis and stored as a computer record. Alternatively, a less technical method would the installation of depth measuring poles in each lake and the monthly recording of lake water levels.

Incoming flows from rainfall can be estimated using the catchment areas, surface conditions and rainfall records. Accurate recording of tidal inflows however may prove more difficult. One method to accurately record tidal inflows could be through the installation of a flow meter within the reverse flood gate pipe. A paddle wheel type flow meter installed within the reverse flood gate pipe, close to the lake end, would fulfil the purpose. The installation of the flow meter would require a small mechanical backhoe to remove surface soil in order to expose the top of the pipe; a small opening would then need to be cut in the pipe to allow the meter to be inserted. The pipe would be resealed and the flow meter connected to a digital readout box. Spoil would then be used to backfill the area on the completion of works. The digital readout box would be pole mounted and capable of storing a months worth of data for later downloading and analysis.

Although minor and temporary in nature this work may involve potential impact/s on the surrounding SEPP 14 Wetland and Acid Sulfate Soils (ASS). It is our view that given the very minor and temporary nature of these works that the environmental impacts can be readily managed with standard ASS and sediment control techniques.

Analysis of soil above the pipeline for Acid Sulfate Soils in accordance with the ASSMAC Manual and the installation of temporary sediment fence controls will minimise any impacts on the immediate environment. Where soils are found to contain Acid Sulfate Material appropriate levels of agricultural lime will be utilised to neutralise the soils to prevent any acidification.

5. Recommendations and Conclusion

The North Lakes Residential Estate was established in 1991 to provide affordable housing on land located at North Creek Road, Balllina. The subdivision is located on the northern outskirts of Ballina and is situated adjacent to North Creek, a saltwater estuary which is a tributary of the Richmond River. Stormwater from the North Lakes Residential Estate catchment drains directly into a series of interconnected constructed urban lakes. The constructed urban lakes (referred to as *North Lakes*) collect stormwater runoff from the North Lakes residential development area only. The provision of an embankment wall with a constructed weir overflow arrangement and a reverse flow gate allow controlled interaction with the adjoining wetland and North Creek.

The subdivision was granted approval by Ballina Shire Council in 1991. Residential development has occurred over 5 stages. The subdivision is almost complete with 230 dwellings throughout the five stages. The main aim of providing the constructed urban lakes was to allow for treatment of stormwater runoff prior to discharge into the adjacent State Environmental Protection Policy (SEPP) No. 14 Wetlands. An outcome of the constructed urban lakes is improved amenity in the form of vegetation, water views and bird and aquatic life.

Council and community concerns regarding water quality, maintenance and amenity has triggered the preparation of an overarching Water Quality Management Plan (WQMP) for *North Lakes*. It is envisaged that an overarching Water Quality Management Plan can be used to guide the future management of the system and assist to inform future planning decisions.

The North Lakes Water Quality Management Plan has considered a broad range of issues including

- water quality, flow, hydrology, algal toxins, bacteria, pesticides, herbicides;
- existing and potential land uses;
- erosion and sedimentation;
- chemical usage and sources;
- nutrient sources;
- aquatic weed control;
- fuel and chemical spills;
- risk management precautions;
- public perceptions; and
- practical, legal, financial etc, issues associated with the management of the constructed urban lakes.

In addition the project team has engaged with local residents through a community consultation process and community education program. The community consultation process and education program, co-ordinated with the preparation and delivery of the technical assessment of the stormwater treatment system at North Lakes Estate, will assist with the current understanding of the system and the long term management of the system by all stakeholders (i.e. Council staff and residents).

Through the processes of this study, a number of deficiencies have been identified in the operation and management of the *North Lakes* stormwater system. The main issues to be resolved surround the management and functionality of the lake system. A suite of recommendations are proposed to address the issues identified.

A Site Strategy Plan (SSP) has been prepared (see Appendix A). It summarises the key water quality management activities proposed in the Water Quality Management Plan. The SSP should be read in conjunction with Vegetation Management Strategy which includes the Weed Management Plans and Revegetation Plans.

The SSP seeks to address a variety of community preferences for vegetation types and balances the need for vegetation for embankment and water quality improvements with individual preferences for various landscape styles.

Six improvement areas are acknowledged as requiring some measure of remedial action to improve the overall efficiency, performance and management of the North Lakes Residential Estate stormwater system. The six areas are listed below:

- Swale drainage performance
- Land ownership and access rights to open channel hydraulic connection
- Hydraulic connectivity between lake systems
- Outlet weir maintenance
- Vegetation management
- System monitoring

5.1 Swale drainage maintenance and performance

To reduce the frequency of inundation and increase the hydraulic efficiency of the swales it is proposed to provide a 50mm diameter perforated pipe wrapped in geotextile down the centre of the swale. Back filling around the drainage pipe with 10mm crushed gravel will ensure that the base of the swale not longer become boggy when wet and importantly is allowed to remain free draining.

5.2 Access to allow maintenance of open channel hydraulic connection

To enable effective management between the two urban lakes on land currently owned by the NSW Department of Lands and managed by the Ballina Racecourse the following actions are required:

- Conduct a survey by a Registered Surveyor to confirm the eastern boundary of 1 Teralgin Place. Following a review of the survey Council should, if necessary, enter into negotiations with the owner of 1 Terlagin Place to remove any structures that encroach on Council's land.
- To enable council to gain access for machinery it is recommended that a small 1metre high retaining wall for a minimum length of 20 metres be constructed at the end of the northern swale off Teraglin Place. The retaining structure would run down the middle of the last 20m of swale and continue around the eastern boundary of no. 1 Teraglin Place. Appropriate landscaping and scour protection works are proposed to be undertaken north of the retaining wall to ensure safe and efficient drainage of the swale remains while also improving the visual amenity of this section of swale (currently due to poor access and continual water logging council is unable to mow this section of the swale and it is consequently overgrown).

Backfilling would occur south of the proposed retaining wall to create an access way 3m wide to the newly created land parcel. Conceptual details of the proposed access arrangement are provided within the Site Strategy Plan.

- Council should approach the NSW Department of Lands and Ballina Racecourse with a view to entering into an agreement assume the care, control and management of the triangular portion of land on which the channel exists. In the event that a suitable agreement cannot be reached Council should consider proposing a boundary adjustment to the NSW Department of Lands for the amalgamation of Lot 171 DP 1041678 with Lot 114 DP 852971.

5.3 Hydraulic connectivity between lake systems

In order to improve the hydraulic connectivity between the lake systems it is recommended that the two existing 375mm pipes connecting the two urban lakes be removed and the existing open channel be extended to connect the two lakes

In addition it is recommended that the pipes are replaced with a single 3m wide 500mm deep concrete box culvert which would satisfy both increased hydraulic connectivity and access arrangements to the northern side embankment.

5.4 Outlet weir maintenance

It is recommended that the outlet weir in lake 1 is re-commissioned and maintained on a regular basis in accordance with the original design intent as the single *as built* overflow weir.

5.5 Vegetation management

The weed management strategy applies to drainage lines and riparian zones within North Lakes Residential Estate. The specific weed management areas are identified on Sheet 2 (Weed Management Plan in Appendix B)

This strategy identifies significant areas of weed infestation and provides general strategies for weed treatment.

5.6 Ongoing system monitoring

It is recommended that Council create a log book to record water levels, water flow and asset functionality. A copy of the log should be kept by both Council and by the community association group. The log should record any major water events, water level fluctuations, water flow and a brief account of how elements of the stormwater system (i.e. swales, pits, pipes, macrophyte zone, etc.) are performing and any noticeable change over time. Log book entries should be made on a minimum of a monthly basis. To complement the log book the production of a monthly photo log would also enable long term changes over time to be observed.

The North Lakes Water Quality Management Plan (WQMP) provides a firm basis for the future management of the North Lakes Residential Estate. The WQMP provides an insight into the mechanisms of this interactive urban water body with the natural system. In addition the WQMP has identified room for improvement and recommends means by which council and the community can better manage this unique community asset in a practical, coherent and sustainable manner.

The recommendations in this report if applied in conjunction with the Vegetation Management Plan and Site Strategy Plan will improve Lake Amenity, water circulation, accessibility for machinery to undertake maintenance, riparian vegetation and provide better information on the efficacy and effectiveness of *North Lakes.*

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A

Site Strategy Plan

Site Strategy

This site strategy applies to drainage lines and riparian zones within the area known as North Lakes, off North Creek Road in Ballina. It summarises key water quality management activities proposed by the North Lakes Water Quality Management Plan (Tim Fitzroy & Associates). This strategy should be read in conjunction with the Vegetation Management Strategy which includes Weed Management Plans and Revegetation Plans (4 sheets).

The strategy seeks to address a variety of community preferences for vegetation types and balance the need for vegetation for embankment and water quality improvements with individual preferences for various landscape styles.

Legend

S Stormwater rectification or management activities (Refer to Site Strategy Plan Sheet 2)

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NORTH LAKES BALLINA
Site Strategy Plan
STORMWATER MANAGEMENT

Stormwater Management Activities

S1 Install rock reinforcing to edges of island and abutments

S2 Install rock retaining to headwall at end of swales and install smaller rock to swale approaches

S3 Swale treatment (Refer to Detail 1)

S4 Negotiate a boundary adjustment with adjoining landowner and construct according to Detail 5.

S5 Rubbish/litter removal

S6 Remove garden plantings which obstruct maintenance access

S7 Pipe western end of swale and grass or reshape and plant with macrophytes

S8 Create pedestrian link over swale, flatten swale approach and plant with macrophytes (Refer to Detail 2)

S9 Remove weed, pipe steep swales on approach to headwall and replant steep banks

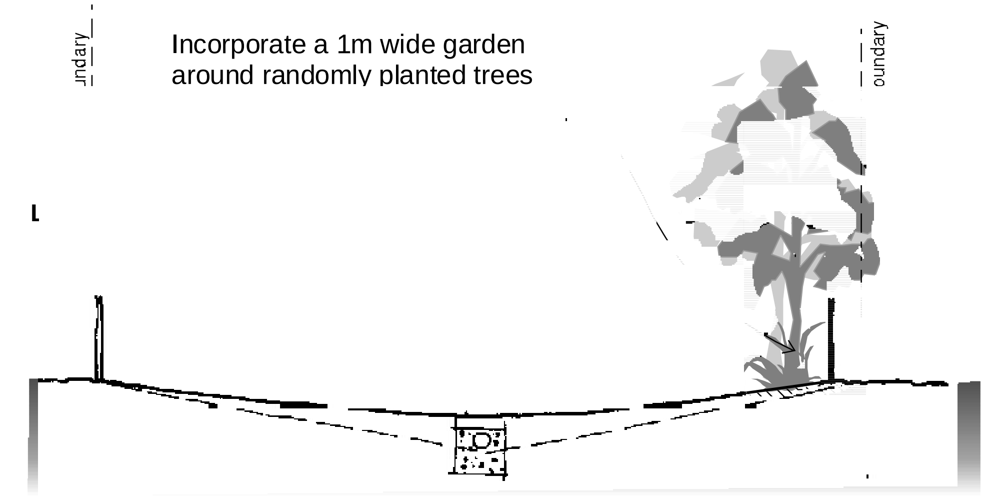
S10 Install rock to culvert entry/exit under pathways and make swales shallower as in detail 1

S11 Construct rock wing walls to outlet and add smaller rock to swale approaches

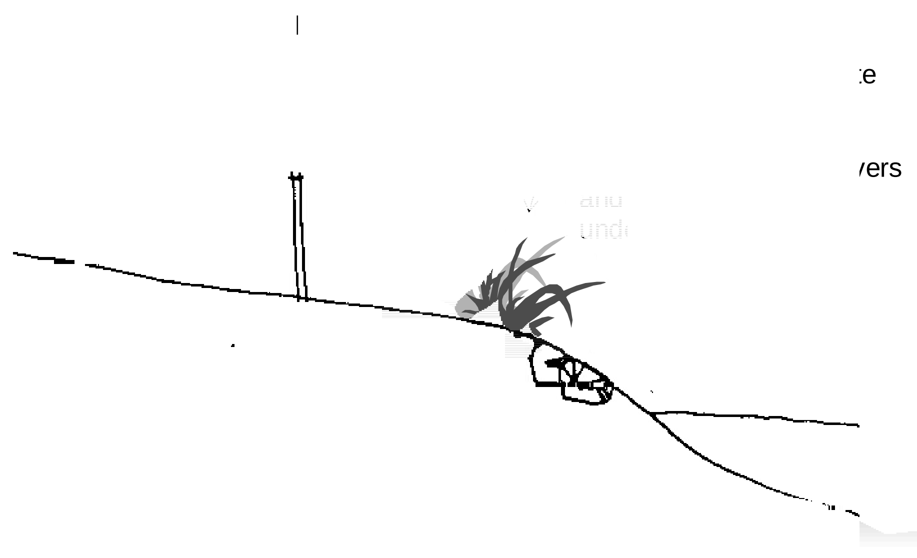
S12 Embankment treatment (Refer to Detail 3)

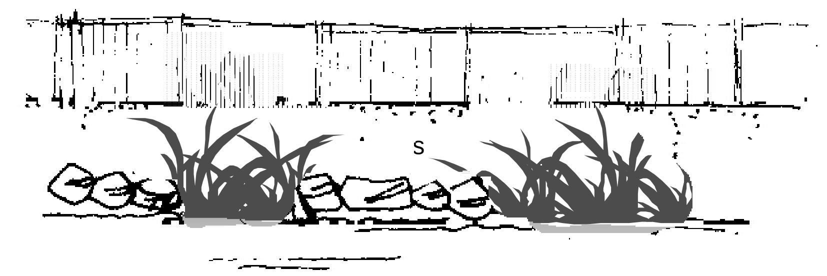
S13 Install rock wing walls to 3m either side of headwall and plant with macrophytes.

S14 Install rock to toe of bank and plant steep embankment edges (Refer to Detail 4)



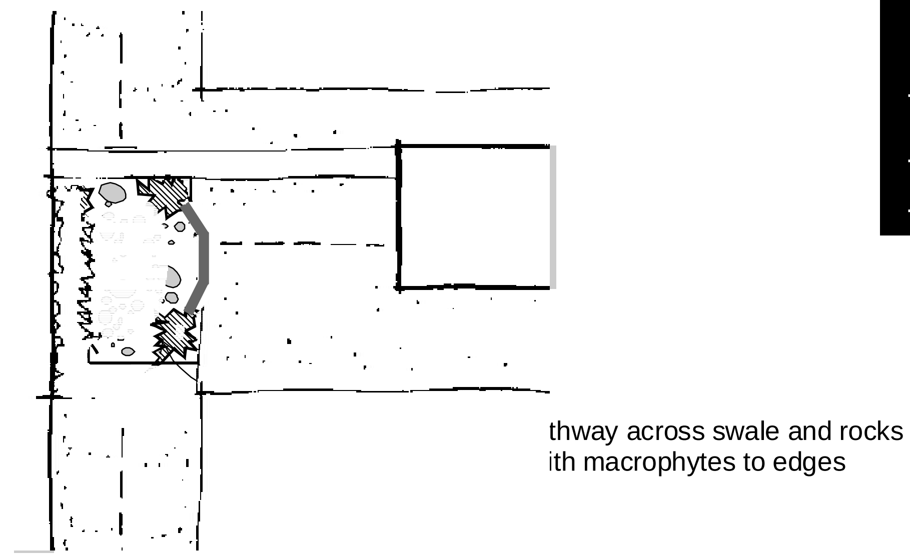
Detail 1: Swale Treatment (S3)



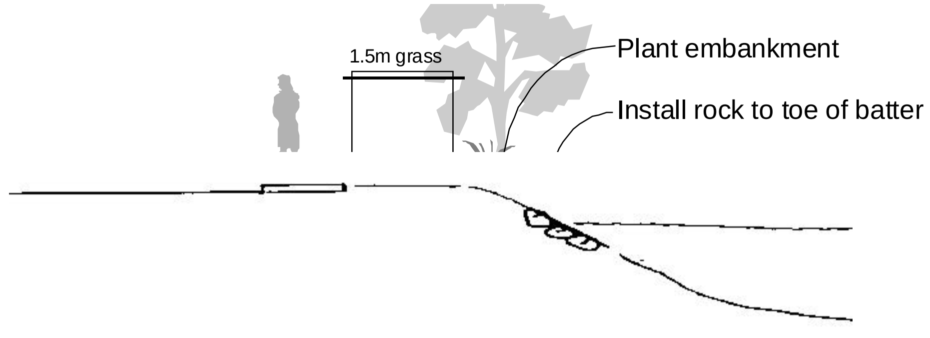


Detail 3: Embankment Treatment (S12)

Note: All details are conceptual treatments only

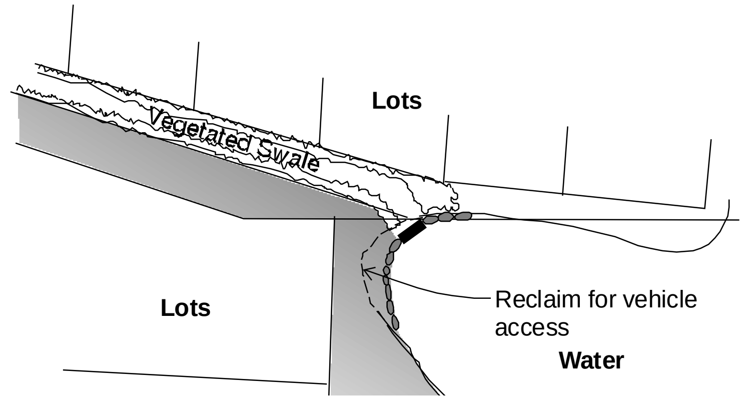


Detail 2: Headwall Treatment (S8)



Detail 4: Bridge Edge Treatment (S14)

- Negotiate boundary adjustment to align with SEPP 14 boundary (hatched)
- Construct retaining wall to provide vehicular access
- Create a swale consisting of a pebble base with low planting to sides
- Install rock wing walls for a distance of approx. 3m either side of the headwall.



Detail 5: Maintenance Access (S4)

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NORTH LAKES BALLINA
Site Strategy Plan Legend and Details 2 of 2
STORMWATER MANAGEMENT

B

Vegetation Management Strategy

Weed Management Area

This weed management strategy applies to drainage lines and riparian zones within the area known as North Lakes, off North Creek Road in Ballina. The specific weed management areas are identified pictorially on Sheet 2 (Weed Management Plan). This strategy identifies significant areas of weed infestation and provides general strategies for weed treatment.

This plan should be read in conjunction with the Weed Management Plan (Sheet 2), the Revegetation Objectives and Notes Plan (Sheet 3), the Revegetation Plan (Sheet 4) and the Overall Site Strategy Plans.

Objectives

- Control all exotic and native weeds on the site that threaten the regeneration of native species or communities.
- Use weed control techniques which minimize the potential for harm to native flora and fauna, and other environmental attributes.
- Allow private garden plantings on public lands to be maintained where they do not inhibit access or threaten native flora or fauna.

Desirable Outcomes (applicable to weed management areas)

- A 50% reduction in the distribution and abundance of exotic weeds after 1 year and a 90% reduction after 5 years.
- An increase in the abundance and diversity of native species present.
- Achievement of 90% canopy cover of native species within 5 years.
- Improved resilience of native vegetation.
- Improved ability to effectively manage and maintain the riparian zones and drainage lines.
- Improved water quality.

Weeds Identified at the Site

A survey of weeds was undertaken on 29 April 2008. This involved a random meandering walk along drainage lines and throughout vegetated areas. Threatened plant species were not identified.

At the time of inspection, the following significant weeds were identified at the site:

Aquatic Weeds
Alligator weed (Alternanthera philoxeroides) - small infestations only observed on embankment edges

Embankment Weeds
Lantana (Lantana camara)
Ochna (Ochna serrulata)
Winter Senna (Senna pendula var glabrata)
Coastal Morning Glory (Ipomea cairica)
White Passionflower (Passiflora subpeltata)
Singapore daisy (Wedelia trilobata)
Passionfruit (Passiflora edulis)

Other less invasive perennial weeds were also observed. Individual treatment techniques have not been specified for these weeds. Treat with a gylphosate or metsulfuron methyl herbicide at the rates recommended by the manufacturer.

Weed Management Actions

Work Zones
Due to there being a low weed diversity, detailed actions for the individual work zones have not been developed. However, target areas for weed management are shown on Sheet 2 (Weed Management Plan).

Prior to commencement of weed control activities the following actions should be undertaken:

- Notify residents of the weed management and work program
- Remove rubbish and litter from the site
- Install information signage about the weed management program
- Install temporary fencing
- Notify residents of any proposed herbicide spraying activities

Weed Treatment

1. Undertake an initial weed treatment using the following techniques:

Alligator weed (Alternanthera philoxeroides)

- Notify Far North Coast Weeds of the location of the weed infestations
- Hand remove weed from embankments and waterway edges taking care to not break up the plant and to remove all plant nodes.
- Bag removed plants

Lantana (Lantana camara)

- Seedlings: Hand pull seedlings (with roots) or cut, scrape and paint stems with Glyphosate (1:1.5).
- Shrubs: Foliar spray or cut down and spray regrowth with Glyphosate (200ml/10L + LI 700 50ml/10L)

Ochna (Ochna serrulata)

- Stems: Cut, scrape and paint with Glyphosate (1:1.5)
- Seedlings and regrowth: Spray with Glyphosate (200ml/10L + LI 700 50ml/10L. A metsulfuron methyl herbicide can also be used (rates vary).

Winter Senna (Senna pendula var glabrata)

- Seedlings: Hand pull seedlings (with roots) or spray with Glyphosate (200ml/10L + LI 700 50 ml/10L
- Shrubs: Cut, scrape and paint with glyphosate (1:1.5)
- Trees: Stem-inject with Glyphosate (1:1.5) collect and bag seeds.
- Trees located near houses or popular public areas: Stem-inject trunk with Glyphosate (1:1.5) collect and bag seeds. Once tree stress is evident cut tree canopy and remove from site.

Coastal Morning Glory (Ipomea cairica)

- Hand remove vine canopy, roll up and bag dry. Cut-scrape and paint larger stems with Glyphosate (1:1.5).

White Passionflower (Passiflora subpeltata)

- Hand pull vine canopy, roll up and bag. Cut-scrape and paint larger stems with Glyphosate at the rate recommended by manufacturer. Spray regrowth seedlings with Glyphosate at the rate recommended by manufacturer.

Singapore daisy (Wedelia trilobata)

- Hand pull or spray with glyphosate (200ml/10L + metsulfuron methyl (1.5gms/10L + Agril 2ml/L)

Passionfruit (Passiflora edulis)

- Hand pull vine canopy, roll up and bag. Cut-scrape and paint larger stems with Glyphosate at the rate recommended by manufacturer. Spray regrowth seedlings with Glyphosate at the rate recommended by manufacturer.

Weed control techniques obtained from various sources including Big Scrub Rainforest Landcare Group.

2. Undertake followup treatments every two months (or as required to control the weed) for 1 year and then as identified by monitoring activities.

General Notes

The weed control techniques noted are appropriate for the level of infestation observed at the time of inspection. If larger outbreaks occur alternative techniques may be required.

Locate all services prior to undertaking any work.

Approvals may be required for use of chemicals near to the SEPP 14 wetland.

Where possible weed spraying activities should be undertaken during the active growing season of the particular species.

All weed control should be undertaken by experienced and qualified bushland regenerators.

Ensure chemicals are used in accordance with the government regulations and the MSD sheet and that the operator has a current Chemical Users Certificate. Some areas are located near to residences and a SEPP 14 Wetland so care should be taken to minimise chemical spray drift.

Monitoring Program

The following monitoring activities should be undertaken for a period of 5 years following completion of the initial weed control works:

1. Maintain records of weed control activities undertaken including date, weather conditions, treatment methods and frequencies.

2. Maintain a 6 monthly photographic record of each Work Zone.

3. Maintain a 6 monthly weed control observation record for each zone which identifies weeds present, approx. % of weed cover, any new weeds, % of native vegetation cover, any new native plants, any impacts from people or animals that may require action (e.g. installation of temporary fencing).

4. Undertake weed control actions if monitoring shows an increase in weed infestation size or if new weeds are identified.

Other Recommendations

Council should encourage the local community to form a Land Care Group (or similar) to assist with vegetation management and monitoring.

Weed Treatment Zones/Actions

W1	General weed treatment required to embankment edges
W2	Remove Alligator weed
W3	Remove Alligator weed and Coastal morning glory amongst trees
W4	General weed treatment
W5	Treat Singapore daisy at discharge point
W6	General weed removal at discharge point and along embankments
W7	Remove Oleander in drainage line
W8	Treat weeds on southern bank (e.g. Winter senna, Lantana, Coastal morning glory, Tobacco an other perennial weeds)
W9	Remove Singapore daisy around pipe and wall
W10	General weed treatment to embankment
W11	Treat weeds including Coastal morning glory, Passionfruit and perennials.

Refer to Sheet 1 for weed treatment methods

Date: July 08 Aerial photography supplied by Ballina Shire Council (2007 - not to scale)

Revegetation Area

This revegetation strategy applies to drainage lines and riparian zones within the area known as North Lakes, off North Creek Road in Ballina. The specific revegetation areas are identified pictorially on Sheet 4 (Revegetation Plan). **The strategy seeks to address a variety of community preferences for vegetation types and balance the need for vegetation for embankment and water quality improvements with individual preferences for various landscape styles** (e.g. mown grass).

Objectives

- Compliment the weed management strategy with a program of vegetation regeneration and revegetation.
- Improved ability to maintain existing and proposed vegetation.
- Stabilise embankments or edges subject to erosion.
- Improve habitat values for native flora and fauna.

Desirable Outcomes

- An increase in the abundance and diversity of native species present.
- Improved ability to effectively manage and maintain the riparian zones and drainage lines.
- Improved water quality.

Revegetation Zones and Actions

Prior to commencement of revegetation activities the following actions should be undertaken:

- Commence implementation of the weed management strategy.
- Notify residents of the revegetation works proposed.
- Remove rubbish and litter from the site.
- Install information signage about the strategy.

Refer to Sheet 4 (Revegetation Plan) for the location of revegetation zones.

General Planting Notes

Plant Stock Type and Size
Where possible all plant stock shall be derived from seed obtained from within 5 kilometres of the subject site. Plant stock shall be native tubes (min. size 125mm x 50mm square) or equivalent. All plants shall be well established, sun hardened, have good form which is consistent with the species or variety and have a healthy root system which shows no evidence of being restricted or damaged.

Planting Rate
Plant trees randomly to achieve a coverage of approximately one plant per two sq.m. The coverage rate above, includes any existing trees located within the rehabilitation area. In addition to this, plant two groundcovers or one shrub per one sq.m.

Services
The plans do not show the location of existing services. Locate and mark on site all services prior to planting. Do not plant within 1 metre of any service line.

Date: July 08

Weed Removal
Remove all weeds in accordance with the Weed Management Strategy. Prior to planting in areas where grass is growing at present spray 1-2 applications of a non-residual herbicide over the area to be planted taking care to prevent spray drift. Apply the herbicide in accordance with the recommendations on the MSD sheet and any government requirements.

Mulch (excluding macrophyte plantings)
Mulch the entire planting area to a depth of 100mm with tea-tree mulch (preferred) or clean mulch bales. Ensure that the mulch is free of seed and deleterious matter.

Protection of Existing Vegetation
Protect all existing trees and native vegetation from any damage.

Protective Bags
Install a protective bag to each plant and secure in place with 3 stakes.

Macrophyte Plantings and Protection
Personnel qualified and experienced with macrophyte planting shall be engaged to do the planting works. Install temporary fencing around the banks of the macrophyte area to protect from animal or bird damage. Install bird deterrents within the planted area if required.

Maintenance
All regeneration and revegetation areas shall be maintained for a period of 5 years or until at least 90% native canopy cover is achieved.

The following maintenance activities shall be undertaken:

<u>0-6 Months</u>
- Watering - weekly or to ensure healthy vigorous growth as determined by the planting season
- Replacement of damaged or failed plants - every 2 months
- Weed control - in accordance with the Weed Management Strategy. Also spray out grass and other perennial weeds within revegetation areas.
- Mulch replenishment - every 2 months
- Removal of litter - every 2 months
- Replacement or correction of plant bags and stakes

<u>6 Months to 5 years</u>
- Watering - vary to ensure healthy vigorous growth as determined by the planting season
- Replacement of damaged or failed plants - every 6 months
- Weed control - in accordance with the Weed Management Strategy. Also spray out grass and other perennial weeds within revegetation areas.
- Mulch replenishment - every 4 months
- Removal of litter - every 2 months
- Replacement or correction of bags and stakes- as required

Monitoring Program

The following monitoring activities should be undertaken for a period of 5 years following completion of the initial weed control works:

1. Initially monitor swamp hen impacts and install bird scare-crows or fencing as appropriate.
2. Maintain records of weed control activities undertaken including date, weather conditions, treatment methods and frequencies.
3. Maintain a 6 monthly photographic record of each Work Zone.
4. Maintain a yearly regeneration observation record for each zone which identifies weeds present, approx. % of weed cover, any new weeds, % of native vegetation cover, any new native plants, any impacts from people or animals that may require action (e.g. Installation of temporary fencing), any threatened species identified, any fauna observed and any new actions required to be taken.

Plant Schedule

A: Planting on steep embankments

B: Planting at the edge of swales along boundaries

C: Low planting for embankments and erosion prone areas near the water line

D: Macrophytes or plantings within inundated areas

Botanical name	Common name	A	B	C	D
Alocasia brisbanensis	Cunjevoi	■	■	■	
Acronychia imperforata	Beach acronychia	■			
Acmena smithii 'dwarf'	Lilly pilly	■	■		
Alpinia caerulea	Native ginger	■	■		
Alectryon coriaceus	Beach alectryon	■			
Austromyrtus dulcis	Midgen berry	■	■	■	
Callistemon salignus	White bottlebrush	■			
Callistemon viminalis	Coastal bottlebrush	■			
Casuarina glauca	Swamp oak	■			
Commersonia bartramia	Brown kurrajong	■			
Cordyline rubra	Red fruited Palm Lilly	■	■		
Cordyline stricta	Palm Lilly	■	■		
Cupaniopsis anacardioides	Tuckeroo	■			
Cryptocarya triplinervis	Three veined cryptocarya	■			
Cyathea cooperi	Tree fern	■			
Dianella caerulea	Blue flax lilly	■	■	■	
Dianella congesta	Coastal flax lilly	■	■	■	
Glochidion sumatrama	Cheese tree	■			
Isolepis nodosa	Knobby club rush	■	■	■	
Lomandra hystrix	Matt rush	■	■	■	
Lophostemon suaveolens	Swamp box	■			
Macaranga tanarius	Macaranga	■			
Mallotus philippensis	Red kamala	■			
Melaleuca quinquenervia	Swamp paperbark	■			
Macrophytes					
<u>Emergent Zone 1 (0-0.3m below WL)</u>					
Carex appressa	Tall sedge				■
Juncus usitatus	Common rush				■
Schoenoplectus mucronatus	Star club rush				■
<u>Emergent Zone 2 (0.3-1m below WL)</u>					
Baumea articulata	Jointed twig rush				■
Baumea rubiginosa	Soft twig rush				■
Schoenoplectus validus					■

Revegetation Zones/Actions

R1	Construct 1m wide garden along swale edge and boundaries around existing Trees
R2	Macrophyte planting
R3	Low planting along water edges
R4	Macrophyte planting
R5	Macrophyte planting at discharge point
R6	Not Used
R7	Macrophyte planting at discharge point
R8	Planting to steep embankment on southern side of channel
R9	Low planting to island crossing abutments where weeds to be removed and macrophytes at discharge point
R10	Plant around Melaleucas for easier maintenance
R11	Plant steep embankments around headwall and GPT near Bonito Place. Plant macrophytes to boggy area at base of headwall.
R12	Replant steep banks around wall with low groundcovers.
R13	Spray out lawn and plant low groundcovers to steep banks between walls and water.
R14	Low groundcover planting to eroding banks (Refer to detail on Strategy plan)
R15	Macrophyte plantings at discharge point
R16	Low groundcover planting to steep and eroding banks (Refer to detail on Strategy plan)
R17	Low planting plus Casuarina glauca (Refer to detail on Strategy Plan)

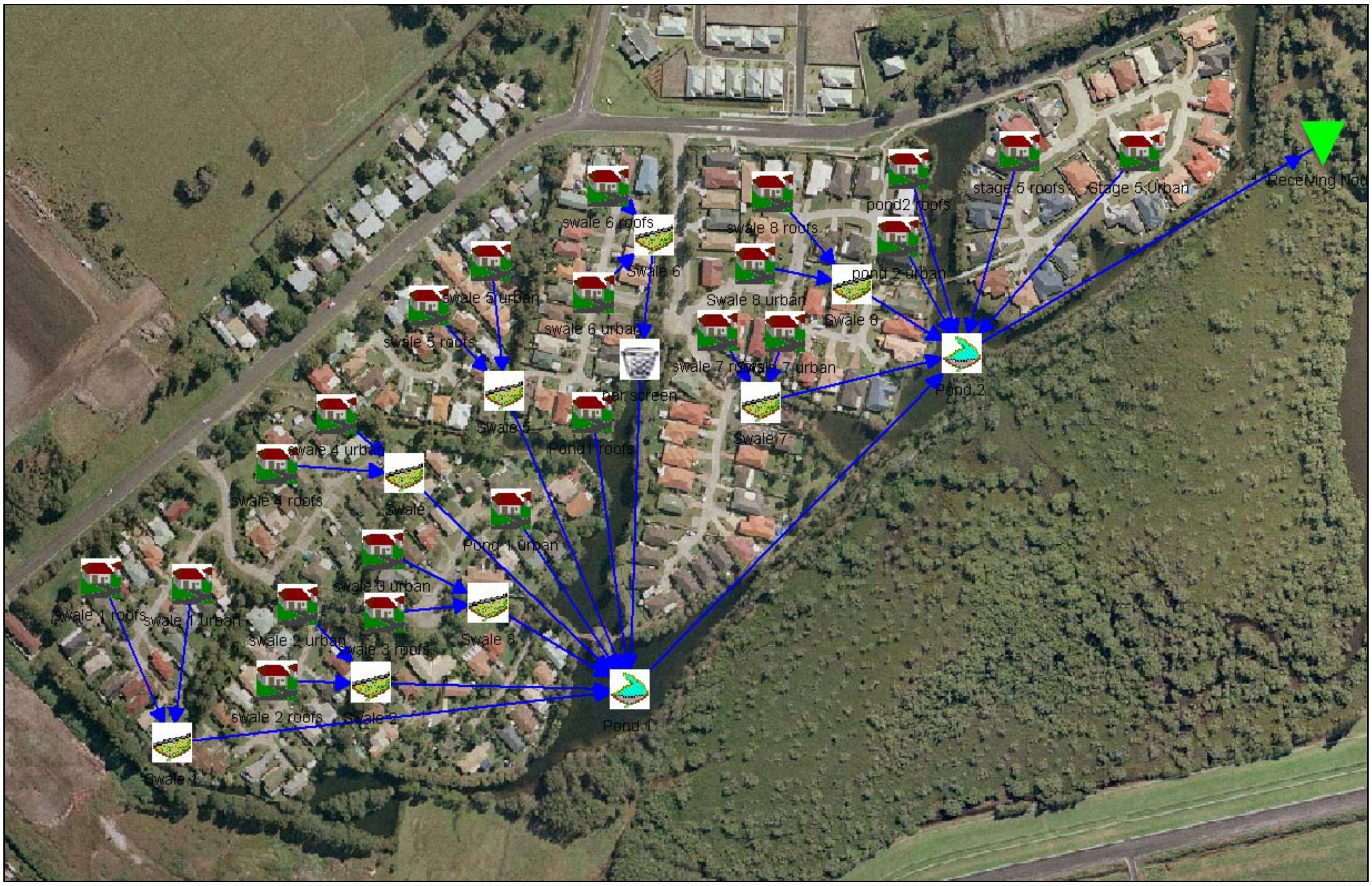
Date: July 08 Aerial photography supplied by Ballina Shire Council (2007 - not to scale)

C

Modelling Results and Assumptions

MUSIC (version 3)

Model Layout:



Assumptions:

Rainfall data	Brisbane 1980 - 1990
Evapo-transpiration data	Alstonville daily averages
Urban Roof Source Nodes	
Impervious percentage	100%
Rainfall threshold	1 mm/day
TSS mean storm flow	1.3 log mg/L
TN mean storm flow	0.26 log mg/L
TP mean storm flow	-0.89 log mg/L
Estimation method	Stochastically generated
Urban Area Source Nodes	
Effective impervious area	0.33 * actual impervious area
Soil Storage capacity	400mm

Initial storage	25%
Field capacity	200mm
Infiltration coefficient a	50.0
Infiltration coefficient b	1.00
Groundwater initial depth	1000mm
Daily Recharge rate	25%
Daily Baseflow rate	0%
Daily deep seepage rate	0%
Impervious area rainfall threshold	1 mm/day
TSS Mean Base flow	0.1 log mg/L
TSS mean storm flow	2.18 log mg/L
TP mean base flow	-0.97 log mg/L
TP mean storm flow	-0.47 log mg/L
TN mean base flow	0.2 log mg/L
TN mean storm flow	0.26 log mg/L
Estimation method	Stochastically generated
Swales	
Bed slope	0.5%
Base width	3.0m
Top width	6.0m
Depth	0.5m
vegetation height	0.1m
seepage loss	0.3mm/hr
Bar screen	
Low flow bypass	0.0 m3/s
High flow bypass	100 m3/s
TSS input	1000 mg/L
TSS output	1000 mg/L
TP input	5 mg/L
TP output	5 mg/L
TN input	50 mg/L
TN output	50 mg/L
GP input	15 mg/L
GP output	7.5 mg/L
Pond properties	
Low flow bypass	0 m3/s
High flow bypass	500 m3/s
Surface area	Taken from design plans/ aerial photography and survey data
Extended detention depth	Taken from design drawings/survey results
Permenant pool volume	Calculated
Seepage loss	0.3 mm/hr
Evaporation loss as percentage of Pan Evap.	100%

MUSIC Results:

Lake No. 1
Mean Annual Loads

	Inflow	Outflow	%reduction
Flow (ML/yr)	58.0	13.0	77.5
Total Suspended Solids (kg/yr)	2550	310	87.9
Total Phosphorus (kg/yr)	10.2	1.56	84.7
Total Nitrogen (kg/yr)	102	17.9	82.5
Gross Pollutants (kg/yr)	324	0.00	100.0

Lake No. 2
Mean Annual Loads

	Inflow	Outflow	%reduction
Flow (ML/yr)	37.5	5.28	85.9
Total Suspended Solids (kg/yr)	2020	93.2	95.4
Total Phosphorus (kg/yr)	6.80	0.543	92.0
Total Nitrogen (kg/yr)	66.1	6.21	90.6
Gross Pollutants (kg/yr)	292	0.00	100.0

Model Limitations

MUSIC is an aid to decision-making. It enables users to evaluate conceptual designs of stormwater management systems to ensure they are appropriate for their catchments.

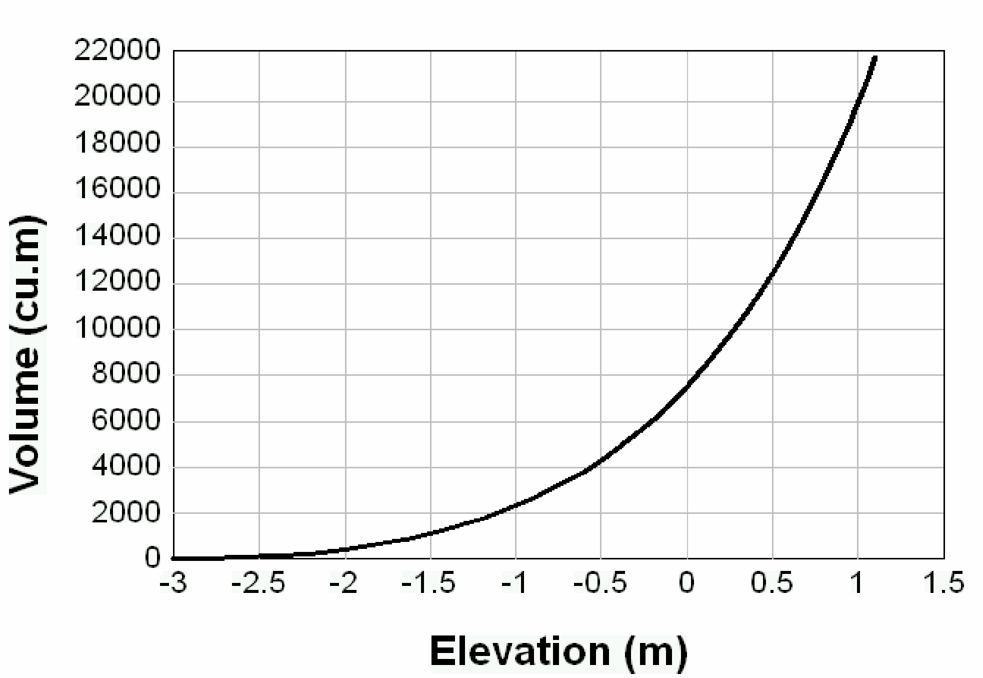
The evaluation of the effectiveness of a stormwater management system is based on a risk-based approach associated with examination of (i) the long-term frequency in which the receiving aquatic ecosystem is subjected to exposure of pollutant concentrations above a pre-specified threshold level and/or (ii) the long-term mean annual pollutant load delivered to the receiving waters. MUSIC is designed to simulate stormwater systems in urban catchments and to operate at a range of temporal and spatial scales suitable for catchment areas from 0.01 km2 to 100 km2. Modelling time steps can range from 6 minutes to 24 hours to match the range of spatial scale.

MUSIC is **not** a detailed design tool; it does not contain the algorithms necessary for detailed sizing of structural stormwater quantity and/or quality facilities. MUSIC should be viewed as a conceptual design tool.

MUSIC should be only one of several tools used in Water Sensitive Urban Design because factors other than stormwater quality (e.g. land and soil characteristics, amenity, passive recreation, and landscape design) also influence Water Sensitive Urban Design. MUSIC does not currently incorporate all aspects of stormwater management that decision-makers must consider. Hydraulic analysis for stormwater drainage, indicators of ecosystem health, and the integration of urban stormwater management facilities into the urban landscape are currently omitted from the model.

DRAINS model Assumptions for North Lakes Estate Ballina:

HYDROLOGICAL MODEL	
Paved depression storage:	2mm
Supplementary depression storage	2mm
Grassed depression storage	5mm
Soil Type	2
RAINFALL DATA	
2yr 1 hour rainfall intensity	47.5
2yr 12hour rainfall intensity	9.2
2yr 72hour rainfall intensity	3.2
50yr 1 hour rainfall intensity	86.7
50yr 12hour rainfall intensity	18.7
50yr 72hour rainfall intensity	7.0
Skewness (G)	0.02
F2 factor	4.4
F50 factor	17.0
RAINFALL EVENTS	
Minor Storms	*Major Storms*
1yr 10min storm, zone 3	10yr 1hour storm, zone 3
1yr 30min storm, zone 3	10yr 2hour storm, zone 3
1yr 1hour storm, zone 3	10yr 4.5hour storm, zone 3
1yr 2hour storm, zone3	10yr 6hour storm, zone3
5yr 30min storm, zone 3	100yr 1hour storm, zone 3
5yr 1hour storm, zone 3	100yr 2hour storm, zone 3
5yr 2hour storm, zone 3	100yr 6hour storm, zone 3
5yr 3hour storm, zone3	100yr 12hour storm, zone3
GENERAL	
Pipe friction formula	Manning's n
Pipe Lengths and Inverts	Referenced from Design Drawings
Pit Inverts and surface levels	Referenced from Design Drawings
Minimum pit freeboard	150mm
Minimum fall across pits	30mm
All pits modelled as 600x600 grated inlet sag pits	
All lots assumed to be developed	
Roof Area, Paved Area and Impervious (i.e. Grassed) Area calculated from 2007 aerial photography supplied by Ballina Shire Council	

<table>
<tr><td colspan="2">Lake Data</td></tr>
<tr><td>Lake No. 1 initial volume</td><td>16600m^3</td></tr>
<tr><td colspan="2">Lake No. 1 Volume vs Storage Graph

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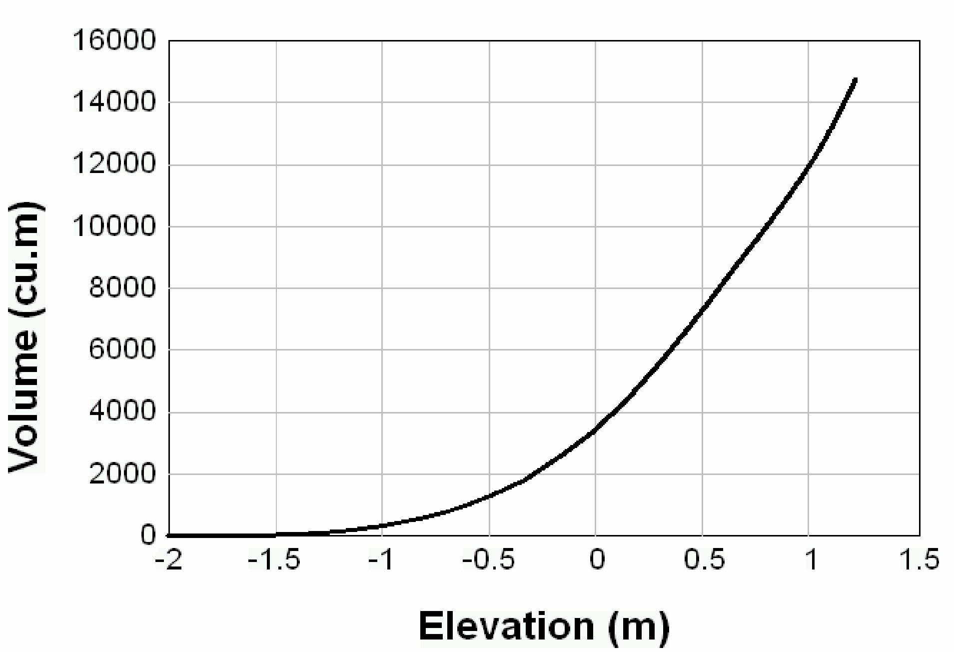
<tr><td colspan="2"></td></tr>
<tr><td>Lake No. 2 initial volume</td><td>9500m^3</td></tr>
<tr><td colspan="2">Lake No. 2 Volume vs Storage Graph

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</table>

Results:

Minor storm events

DRAINS results prepared 11 August, 2008 from Version 2007.19							
PIT / NODE DETAILS							
Name	*Max HGL*	*Max Pond HGL*	*Max Surface Flow Arriving(cu.m/s)*	*Max Pond Volume(cu.m)*	*Min Freeboard(m)*	*Overflow (cu.m/s)*	*Constraint*
Pit1	1.73	2.01	0.038	0.1	0.27		None
N77	1.71		0				
N85	1.71		0.088				
N90	1.69		0.104				
N83	1.54		0				
Pit2	1.56	1.91	0.037	0.1	0.34		None
Pit3	1.37		0.028		0.52	0.001	Inlet Capacity
Pit4	1.25	1.8	0.022	0.1	0.54		None
Pit7	1.48	1.91	0.028	0.1	0.42	0	None
Pit6	1.41	1.86	0.024	0.1	0.44		None
Pit5	1.25	1.81	0.011	0.1	0.55		None
Pit8	1.77	2.01	0.029	0.1	0.23		None
N100	1.82		0.048				
N99	1.65		0				
Pit9	2.4	2.4	0.043	2	-0.1	0.031	Outlet System
Pit10	2.4	2.39	0.046	0.2	-0.1	0	Outlet System
Pit11	1.67	2.01	0.045	0.1	0.33	0	None
Pit12	1.68	2.01	0.007	0.1	0.32	0	None
Pit13	1.33	1.81	0.043	0.1	0.47		None
Pit14	1.84	2.21	0.043	0.1	0.36		None
N98	1.82		0.147				
N104	1.19		0				
Pit15	1.7	2.21	0.043	0.1	0.5		None

Pit16	1.68	1.85	0.112	1	0.12		None
Pit18	1.43	1.91	0.042	0.1	0.47		None
Pit19	1.33	2	0	0	0.67		None
Pit21	2.21	2.17	0.136	0.1	-0.29	0	Outlet System
Pit24	2.01	1.9	0.069	1	-0.16	0	Outlet System
Pit25	2.07	2.02	0.088	0.1	-0.23	0	Outlet System
Pit26	1.35	1.88	0.04	0.1	0.51		None
Pit30	1.65	1.66	0.137	0.1	0		Outlet System
Pit32	1.15		0		0.48	0	None
Pit33	1.15	1.52	0.053	0.1	0.36		None
Pit34	1.47	1.72	0.087	0.1	0.24		None
N78	1.94		0.131				
N91	1.76		0.162				
N93	1.54		0.182				
N101	2.03		0.302				
N102	2.04		0.203				
N105	1.86		0.132				
N122	1.83		0.115				
SUB-CATCHMENT DETAILS							
Name	*Max Flow Q (cu.m/s)*	*Paved Max Q (cu.m/s)*	*Grassed Max Q (cu.m/s)*	*Paved Tc (min)*	*Grassed Tc (min)*	*Supp. Tc (min)*	*Due to Storm*
Cat1	0.038	0.038	0	6.98	0	0	AR&R 10 year, 1 hour storm,
Cat9	0.088	0.043	0.046	2	4	0	AR&R 10 year, 1 hour storm
Cat19	0.104	0.033	0.071	2	4	0	AR&R 10 year, 1 hour storm
Cat27	1.259	0.858	0.513	0	12	5	AR&R 10 year, 1 hour storm
Cat91	1.141	0.778	0.465	0	12	5	AR&R 10 year, 1 hour storm
Cat4	0.037	0.037	0	7.34	0	0	AR&R 10 year, 1 hour storm
Cat24	0.028	0.028	0	5.07	0	0	AR&R 10 year, 1 hour storm
Cat31	0.022	0.022	0	3.56	0	0	AR&R 10 year, 1 hour storm
Cat35	0.028	0.028	0	3.56	0	0	AR&R 10 year, 1 hour storm

Cat38	0.024	0.024	0	2.79	0	0	AR&R 10 year, 1 hour storm
Cat41	0.011	0.011	0	2.18	0	0	AR&R 10 year, 1 hour storm
Cat44	0.029	0.029	0	6.42	0	0	AR&R 10 year, 1 hour storm
Cat54	0.048	0.036	0.015	7	18	2	AR&R 10 year, 1 hour storm
Cat69	0.043	0.028	0.017	3	8	2	AR&R 10 year, 1 hour storm
Cat66	0.025	0.017	0.009	3	8	2	AR&R 10 year, 1 hour storm
Cat60	0.045	0.045	0	6.42	0	0	AR&R 10 year, 1 hour storm
Cat63	0.007	0.007	0	2.79	0	0	AR&R 10 year, 1 hour storm
Cat72	0.043	0.043	0	4.84	0	0	AR&R 10 year, 1 hour storm
Cat75	0.043	0.043	0	4.84	0	0	AR&R 10 year, 1 hour storm
Cat77	0.147	0.113	0.042	8	12	2	AR&R 10 year, 1 hour storm
Cat86	0.043	0.043	0	4.84	0	0	AR&R 10 year, 1 hour storm
Cat88	0.112	0.087	0.032	8	12	2	AR&R 10 year, 1 hour storm
Cat83	0.042	0.042	0	4.84	0	0	AR&R 10 year, 1 hour storm
Cat110	0.136	0.11	0.032	4	12	2	AR&R 10 year, 1 hour storm
Cat107	0.069	0.048	0.025	8	12	2	AR&R 10 year, 1 hour storm
Cat113	0.088	0.07	0.023	4	12	2	AR&R 10 year, 1 hour storm
Cat104	0.04	0.04	0	4.84	0	0	AR&R 10 year, 1 hour storm
Cat94	0.137	0.112	0.032	8	12	2	AR&R 10 year, 1 hour storm
Cat101	0.053	0.034	0.02	5	6	2	AR&R 10 year, 1 hour storm
Cat98	0.087	0.067	0.022	3	8	2	AR&R 10 year, 1 hour storm
Cat6	0.131	0.082	0.062	7	18	2	AR&R 10 year, 1 hour storm
Cat15	0.162	0.085	0.093	7	12	2	AR&R 10 year, 1 hour storm
Cat21	0.182	0.095	0.104	7	12	2	AR&R 10 year, 1 hour storm
Cat57	0.302	0.236	0.086	8	20	2	AR&R 10 year, 1 hour storm
Cat47	0.203	0.143	0.078	7	18	2	AR&R 10 year, 1 hour storm
Cat80	0.132	0.102	0.037	8	12	2	AR&R 10 year, 1 hour storm
Cat48	0.115	0.065	0.064	7	18	2	AR&R 10 year, 1 hour storm
Outflow Volumes for Total Catchment (9.40 impervious + 12.0 pervious = 21.4 total ha)							

Storm	*Total Rainfall cu.m*	*Total Runoff cu.m (Runoff %)*	*Impervious Runoff cu.m (Runoff %)*	*Pervious Runoff cu.m (Runoff %)*
AR&R 10 year, 1 hour storm,	14155.02	6552.62 (46.3%)	4987.22 (80.4%)	1565.41 (19.7%)
AR&R 1 year, 1 hour storm,	7978.28	2742.98 (34.4%)	2742.98 (78.4%)	0.00 (0.0%)
AR&R 5 year, 1 hour storm,	12653.73	5293.69 (41.8%)	4441.77 (80.1%)	851.93 (12.0%)

PIPE DETAILS

Name	*Max Q (cu.m/s)*	*Max V (m/s)*	*Max U/S HGL (m)*	*Max D/S HGL (m)*	*Due to Storm*
Pipe39	0.038	0.4	1.715	1.706	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
Pipe163	0.209	0.9	0.991	0.988	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
Pipe40	0.037	0.4	1.553	1.545	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
Pipe41	0.027	1.1	1.292	1.005	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
Pipe42	0.022	1.1	1.183	1.005	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
Pipe43	0.028	1.1	1.405	1.405	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
Pipe44	0.052	1.4	1.289	1.254	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
Pipe45	0.063	1.5	1.124	1.005	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
Pipe46	0.029	0.3	1.769	1.819	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
Pipe47	0.026	1.4	2.42	2.4	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
Pipe48	0.044	2.4	2.002	1.674	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
Pipe49	0.087	0.9	1.624	1.676	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
Pipe50	0.092	0.8	1.636	1.655	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
Pipe52	0.043	1.1	1.243	1.043	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
Pipe51	0.043	0.4	1.833	1.824	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
Pipe55	0.322	1.8	1.186	1.005	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
Pipe56	0.043	0.4	1.686	1.68	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
Pipe57	0.157	1.7	1.525	1.291	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
Pipe58	0.042	1.1	1.342	1.326	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
Pipe59	0.042	1.1	1.244	1.044	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
Pipe69	0.115	1	2.138	2.011	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
Pipe70	0.254	2.4	1.686	1.213	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3

Pipe71	0.076	0.7	2.041	2.011	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
Pipe74	0.04	1	1.273	1.043	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
Pipe130	0.137	1.6	1.467	1.196	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
Pipe61	0	0	1.149	1.149	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
Pipe62	0.053	1.1	1.061	1.003	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
Pipe60	0.087	1.4	1.334	1.064	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
CHANNEL DETAILS					
Name	*Max Q (cu.m/s)*	*Max V (m/s)*	*Chainage (m)*	*Max HGL (m)*	*Due to Storm*
swale 1.2	0.168	0.6	0	1.706	AR&R 10 year, 1 hour storm
		0.1	35	1.706	
swale 1.3	0.251	0.1	0	1.706	AR&R 10 year, 1 hour storm
		0.3	35	1.687	
swale 1.5	0.509	0.4	0	1.687	AR&R 10 year, 1 hour storm,
		0.3	35	1.545	
Crk38	0.545	0.5	0	1.545	AR&R 10 year, 1 hour storm,
		1.2	10	1.005	
Crk62	0.394	0.5	0	1.819	AR&R 10 year, 1 hour storm,
		0.3	70	1.585	
Crk67	0.787	0.3	0	1.655	AR&R 10 year, 1 hour storm,
		1.3	20	1.005	
Crk73	0.322	0.2	0	1.824	AR&R 10 year, 1 hour storm,
		1	105	1.186	
swale1	0.131	0.1	20	1.892	AR&R 10 year, 1 hour storm,
		0.5	105	1.711	
swale 1.4	0.162	0.1	0	1.757	AR&R 10 year, 1 hour storm,
		0.2	108	1.687	
Crk34	0.182	0.1	0	1.541	AR&R 10 year, 1 hour storm,
		0.9	90	1.005	
Crk55	0.302	0.6	0	2.025	AR&R 10 year, 1 hour storm,
		0.4	200	1.585	

Crk58	0.203	0.1	0	2.041	AR&R 10 year, 1 hour storm,
		0.2	200	1.768	
Crk70	0.132	0.7	0	1.86	AR&R 10 year, 1 hour storm,
		0	100	1.824	
Crk81	0.115	0.1	0	1.829	AR&R 10 year, 1 hour storm,
		0.1	185	1.768	

OVERFLOW ROUTE DETAILS

Name	*Max Q U/S*	*Max Q D/S*	*Safe Q*	*Max D*	*Max DxV*	*Max Width*	*Max V*	*Due to Storm*
OF4	0.329	0.329	2.702	0.085	0.05	6.23	0.63	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
OF16	0.213	0.213	2.702	0.065	0.03	6.17	0.53	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
OF18	0.001	0.001	0.565	0.015	0	0.59	0.26	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
OF8	0	0	0.256	0	0	0	0	
OF6	0.031	0.031	0.256	0.023	0.01	7.63	0.35	AR&R 10 year, 1 hour storm, average 66 mm/h, Zone 3
OF26	0	0	0.256	0	0	0	0	
OF28	0	0	1.072	0	0	0	0	
OF34	0	0	1.072	0	0	0	0	
OF22	0	0	1.072	0	0	0	0	
OF24	0	0	1.072	0	0	0	0	
OF20	0	0	1.072	0	0	0	0	
OF1	0	0	0.565	0	0	0	0	

DETENTION BASIN DETAILS

Name	Max WL	MaxVol	Max Q Total	Max Q Low Level	Max Q High Level		
pond no.1	1	19891.2	0.538	0.209	0.329		
pond no.2	0.99	12063.5	0.213	0	0.213		

Run Log for 080724 modified.drn run at 14:14:08 on 11/8/2008							
No water upwelling from any pit.							
Freeboard was less than 0.15m at Pit30, Pit25, Pit24, Pit21, Pit16, Pit10, Pit9							

Results:
Major Storm Events

PIT / NODE DETAILS							
Name	*Max HGL*	*Max Pond HGL*	*Max Surface Flow Arriving (cu.m/s)*	*Max Pond Volume (cu.m)*	*Min Freeboard (m)*	*Overflow (cu.m/s)*	*Constraint*
Pit1	1.78	2.01	0.041	0.1	0.22		None
N77	1.76		0				
N85	1.76		0.112				
N90	1.74		0.138				
N83	1.59		0				
Pit2	1.6	1.91	0.04	0.1	0.3		None
Pit3	1.37		0.029		0.52	0.001	Inlet Capacity
Pit4	1.25	1.8	0.023	0.1	0.54		None
Pit7	1.48	1.91	0.029	0.1	0.42	0	None
Pit6	1.41	1.86	0.025	0.1	0.44		None
Pit5	1.26	1.81	0.011	0.1	0.54		None
Pit8	1.77	2.01	0.031	0.1	0.23		None
N100	1.9		0.064				
N99	1.73		0				
Pit9	2.4	2.4	0.053	2	-0.1	0.048	Outlet System
Pit10	2.4	2.4	0.075	0.2	-0.1	0.041	Outlet System
Pit11	1.81	2.01	0.082	0.1	0.19	0	None
Pit12	1.69	2.01	0.007	0.1	0.31	0	None
Pit13	1.33	1.81	0.044	0.1	0.47		None

Pit14	1.88	2.21	0.044	0.1	0.32		None
N98	1.87		0.19				
N104	1.33		0				
Pit15	1.79	2.21	0.044	0.1	0.41		None
Pit16	1.78	1.86	0.145	1.1	0.02		None
Pit18	1.43	1.91	0.043	0.1	0.47		None
Pit19	1.33	2	0	0	0.67		None
Pit21	2.22	2.23	0.158	0.1	-0.3	0.077	Outlet System
Pit24	2.2	1.9	0.282	1	-0.35	0	Outlet System
Pit25	2.14	2.15	0.104	0.1	-0.3	0.137	Outlet System
Pit26	1.36	1.88	0.042	0.1	0.51		None
Pit30	1.74	1.69	0.178	0.1	-0.09		Outlet System
Pit32	1.16		0		0.47	0	None
Pit33	1.16	1.52	0.058	0.1	0.35		None
Pit34	1.57	1.72	0.101	0.1	0.15		None
N78	2.03		0.224				
N91	1.85		0.288				
N93	1.65		0.323				
N101	2.09		0.402				
N102	2.11		0.287				
N105	1.91		0.171				
N122	1.91		0.202				
SUB-CATCHMENT DETAILS							
Name	*Max Flow Q (cu.m/s)*	*Paved Max Q (cu.m/s)*	*Grassed Max Q (cu.m/s)*	*Paved Tc (min)*	*Grassed Tc (min)*	*Supp. Tc (min)*	*Due to Storm*
Cat1	0.041	0.041	0	7.11	0	0	AR&R 100 year, 2 hours storm
Cat9	0.112	0.044	0.068	2	4	0	AR&R 100 year, 2 hours storm
Cat19	0.138	0.035	0.104	2	4	0	AR&R 100 year, 2 hours storm
Cat27	1.471	0.89	0.797	0	12	5	AR&R 100 year, 2 hours storm
Cat91	1.333	0.806	0.722	0	12	5	AR&R 100 year, 2 hours storm

Cat4	0.04	0.04	0	7.48	0	0	AR&R 100 year, 2 hours storm
Cat24	0.029	0.029	0	5.17	0	0	AR&R 100 year, 2 hours storm
Cat31	0.023	0.023	0	3.63	0	0	AR&R 100 year, 2 hours storm
Cat35	0.029	0.029	0	3.63	0	0	AR&R 100 year, 2 hours storm
Cat38	0.025	0.025	0	2.85	0	0	AR&R 100 year, 2 hours storm
Cat41	0.011	0.011	0	2.22	0	0	AR&R 100 year, 2 hours storm
Cat44	0.031	0.031	0	6.54	0	0	AR&R 100 year, 2 hours storm
Cat54	0.064	0.04	0.04	7	18	2	AR&R 100 year, 2 hours storm
Cat69	0.053	0.029	0.033	3	8	2	AR&R 100 year, 2 hours storm
Cat66	0.03	0.018	0.017	3	8	2	AR&R 100 year, 2 hours storm
Cat60	0.048	0.048	0	6.54	0	0	AR&R 100 year, 2 hours storm
Cat63	0.007	0.007	0	2.85	0	0	AR&R 100 year, 2 hours storm
Cat72	0.044	0.044	0	4.93	0	0	AR&R 100 year, 2 hours storm
Cat75	0.044	0.044	0	4.93	0	0	AR&R 100 year, 2 hours storm
Cat77	0.19	0.126	0.084	8	12	2	AR&R 100 year, 2 hours storm
Cat86	0.044	0.044	0	4.93	0	0	AR&R 100 year, 2 hours storm
Cat88	0.145	0.096	0.064	8	12	2	AR&R 100 year, 2 hours storm
Cat83	0.043	0.043	0	4.93	0	0	AR&R 100 year, 2 hours storm
Cat110	0.158	0.114	0.073	4	12	2	AR&R 100 year, 2 hours storm
Cat107	0.102	0.053	0.06	8	12	2	AR&R 100 year, 2 hours storm
Cat113	0.104	0.072	0.053	4	12	2	AR&R 100 year, 2 hours storm
Cat104	0.042	0.042	0	4.93	0	0	AR&R 100 year, 2 hours storm
Cat94	0.178	0.124	0.071	8	12	2	AR&R 100 year, 2 hours storm
Cat101	0.058	0.035	0.026	5	6	2	AR&R 100 year, 2 hours storm
Cat98	0.101	0.07	0.042	3	8	2	AR&R 100 year, 2 hours storm
Cat6	0.224	0.089	0.174	7	18	2	AR&R 100 year, 2 hours storm
Cat15	0.288	0.092	0.223	7	12	2	AR&R 100 year, 2 hours storm
Cat21	0.323	0.103	0.25	7	12	2	AR&R 100 year, 2 hours storm
Cat57	0.402	0.261	0.218	8	20	2	AR&R 100 year, 2 hours storm
Cat47	0.287	0.156	0.196	7	18	2	AR&R 100 year, 2 hours storm
Cat80	0.171	0.113	0.076	8	12	2	AR&R 100 year, 2 hours storm
Cat48	0.202	0.071	0.164	7	18	2	AR&R 100 year, 2 hours storm

Outflow Volumes for Total Catchment (9.40 impervious + 12.0 pervious = 21.4 total ha)							
Storm	*Total Rainfall cu.m*	*Total Runoff cu.m (Runoff %)*	*Impervious Runoff cu.m (Runoff %)*	*Pervious Runoff cu.m (Runoff %)*			
AR&R 10 year, 2 hours storm	18401.53	8172.49 (44.4%)	6530.16 (80.9%)	1642.33 (15.9%)			
AR&R 100 year, 2 hours storm	27023.21	16343.22 (60.5%)	9662.74 (81.6%)	6680.48 (44.0%)			
AR&R 100 year, 2 hours storm	41435.6	25031.19 (60.4%)	14899.57 (82.0%)	10131.62 (43.5%)			
PIPE DETAILS							
Name	*Max Q (cu.m/s)*	*Max V (m/s)*	*Max U/S HGL (m)*	*Max D/S HGL (m)*	*Due to Storm*		
Pipe39	0.041	0.4	1.766	1.759	AR&R 100 year, 2 hours storm		
Pipe163	0.209	0.9	1.074	1.066	AR&R 10 year, 2 hours storm		
Pipe40	0.04	0.4	1.595	1.587	AR&R 100 year, 2 hours storm		
Pipe41	0.028	1.1	1.294	1.106	AR&R 100 year, 2 hours storm		
Pipe42	0.023	1.1	1.185	1.106	AR&R 100 year, 2 hours storm		
Pipe43	0.029	1	1.411	1.411	AR&R 100 year, 2 hours storm		
Pipe44	0.054	1.4	1.292	1.26	AR&R 100 year, 2 hours storm		
Pipe45	0.065	1.5	1.127	1.106	AR&R 100 year, 2 hours storm		
Pipe46	0.031	0.3	1.765	1.898	AR&R 100 year, 2 hours storm		
Pipe47	0.028	1.5	2.424	2.4	AR&R 100 year, 2 hours storm		
Pipe48	0.045	2.4	2.082	1.805	AR&R 100 year, 2 hours storm		
Pipe49	0.121	1.1	1.713	1.688	AR&R 100 year, 2 hours storm		
Pipe50	0.126	1.1	1.649	1.728	AR&R 100 year, 2 hours storm		
Pipe52	0.044	1.1	1.246	1.106	AR&R 100 year, 2 hours storm		
Pipe51	0.044	0.4	1.875	1.869	AR&R 100 year, 2 hours storm		
Pipe55	0.396	1.8	1.331	1.106	AR&R 100 year, 2 hours storm		
Pipe56	0.044	0.4	1.782	1.778	AR&R 100 year, 2 hours storm		

Pipe57	0.181	1.9	1.571	1.311	AR&R 100 year, 2 hours storm
Pipe58	0.043	1.1	1.344	1.331	AR&R 100 year, 2 hours storm
Pipe59	0.043	1.1	1.247	1.106	AR&R 100 year, 2 hours storm
Pipe69	0.117	1.1	2.223	2.197	AR&R 100 year, 2 hours storm
Pipe70	0.283	2.6	1.693	1.224	AR&R 100 year, 2 hours storm
Pipe71	0.089	0.8	2.164	2.197	AR&R 100 year, 2 hours storm
Pipe74	0.042	1.1	1.275	1.066	AR&R 100 year, 2 hours storm
Pipe130	0.176	1.8	1.624	1.233	AR&R 100 year, 2 hours storm
Pipe61	0	0	1.162	1.162	AR&R 10 year, 2 hours storm
Pipe62	0.058	1.1	1.069	1.066	AR&R 100 year, 2 hours storm
Pipe60	0.101	1.5	1.356	1.086	AR&R 100 year, 2 hours storm
CHANNEL DETAILS					
Name	*Max Q (cu.m/s)*	*Max V (m/s)*	*Chainage (m)*	*Max HGL (m)*	*Due to Storm*
swale 1.2	0.25	0.6	0	1.759	AR&R 100 year, 2 hours storm
		0.1	35	1.758	
swale 1.3	0.31	0.1	0	1.758	AR&R 100 year, 2 hours storm
		0.3	35	1.741	
swale 1.5	0.664	0.4	0	1.741	AR&R 100 year, 2 hours storm
		0.4	35	1.587	
Crk38	0.699	0.5	0	1.587	AR&R 100 year, 2 hours storm
		1.2	10	1.106	
Crk62	0.572	0.5	0	1.898	AR&R 100 year, 2 hours storm
		0.4	70	1.6	
Crk67	1.079	0.3	0	1.728	AR&R 100 year, 2 hours storm
		1.3	20	1.106	
Crk73	0.396	0.4	0	1.869	AR&R 100 year, 2 hours storm
		1	105	1.331	
swale1	0.224	0.2	20	1.982	AR&R 100 year, 2 hours storm
		0.5	105	1.765	
swale 1.4	0.288	0.1	0	1.853	AR&R 100 year, 2 hours storm

		0.1	108	1.741			
Crk34	0.323	0.1	0	1.647	AR&R 100 year, 2 hours storm		
		1.1	90	1.106			
Crk55	0.402	0.6	0	2.09	AR&R 100 year, 2 hours storm		
		0.4	200	1.6			
Crk58	0.287	0.1	0	2.114	AR&R 100 year, 2 hours storm		
		0.4	200	1.771			
Crk70	0.171	0.7	0	1.91	AR&R 100 year, 2 hours storm		
		0	100	1.869			
Crk81	0.202	0.1	0	1.913	AR&R 100 year, 2 hours storm		
		0.1	185	1.771			
OVERFLOW ROUTE DETAILS							
Name	*Max Q D/S*	*Safe Q*	*Max D*	*Max DxV*	*Max Width*	*Max V*	*Due to Storm*
OF4	1.358	2.702	0.199	0.22	6.53	1.09	AR&R 100 year, 2 hours storm
OF16	0.892	2.702	0.154	0.14	6.41	0.93	AR&R 100 year, 2 hours storm
OF18	0.001	1.931	0.015	0	0.61	0.25	AR&R 100 year, 2 hours storm
OF8	0	7.665	0	0	0	0	
OF6	0.048	7.665	0.026	0.01	8.83	0.41	AR&R 100 year, 2 hours storm
OF26	0.041	7.665	0.026	0.01	8.53	0.38	AR&R 100 year, 2 hours storm
OF28	0	1.945	0	0	0	0	
OF34	0	1.945	0	0	0	0	
OF22	0.077	1.945	0.149	0.13	1.19	0.87	AR&R 100 year, 2 hours storm
OF24	0	1.945	0	0	0	0	
OF20	0.137	1.945	0.185	0.19	1.48	1	AR&R 100 year, 2 hours storm
OF1	0	1.931	0	0	0	0	
DETENTION BASIN DETAILS							

Name	*Max WL*	*MaxVol*	*Max Q Total*	*Max Q Low Level*	*Max Q High Level*
pond no.1	1.11	21847	1.567	0.209	1.358
pond no.2	1.07	12967.4	0.892	0	0.892

Run Log for 080724 modified.drn run at 14:40:37 on 11/8/2008

Upwelling occurred at Pit25

Freeboard was less than 0.15m at Pit34, Pit30, Pit24, Pit21, Pit16, Pit10, Pit9