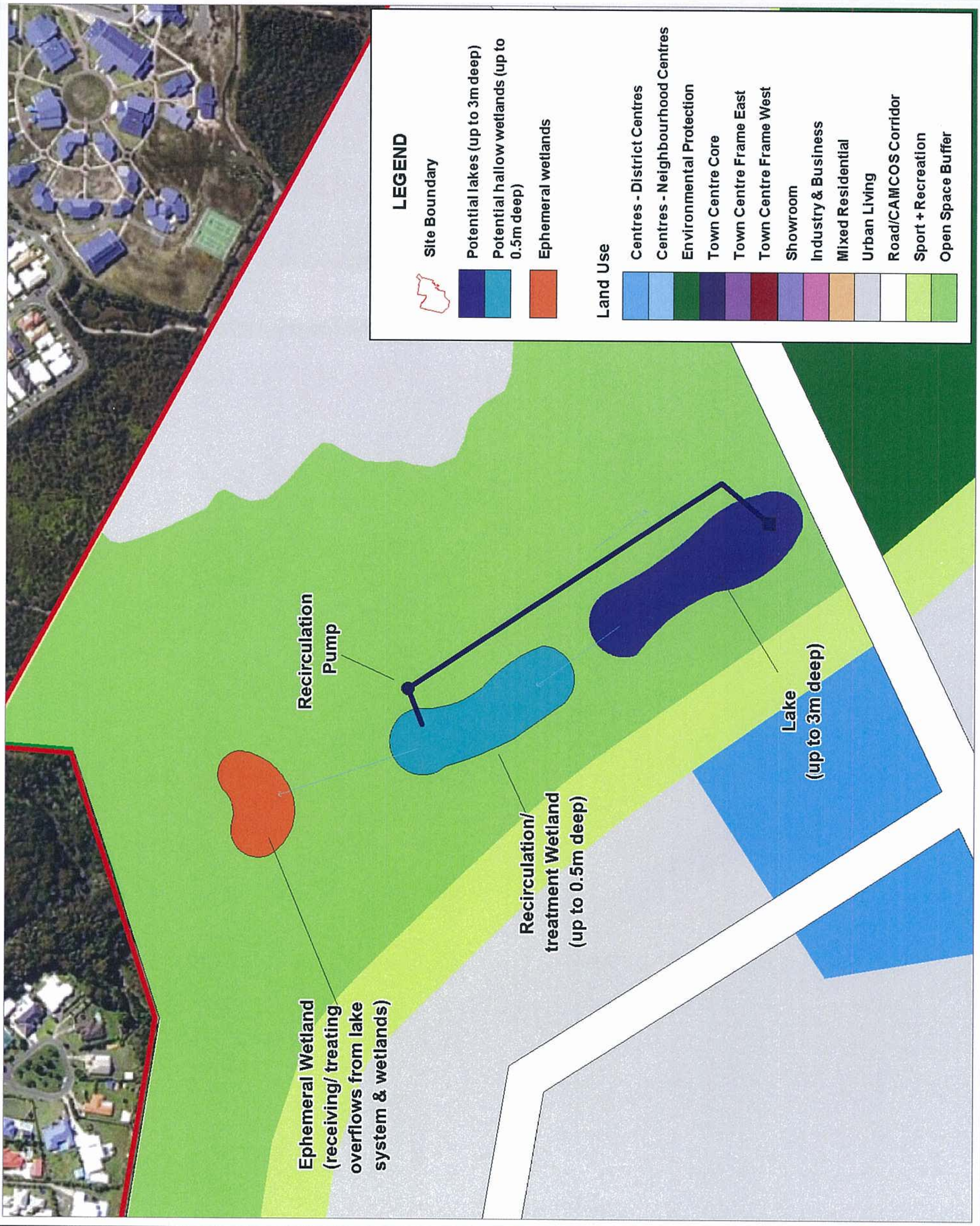


Title:

Indicative Configuration of Potential Lake System C

Figure: H-3

Rev: A

N

0 100 200m

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : I:\B18176_I_AMB_Caloundra_Downs\DRG\IWMP_Rev_5\UW_011_111124_LakeC.wor

Amenity

The potential lake systems will be designed to ensure that they blend into the surrounding environment and enhance site aesthetics. Details of how this will be achieved will be provided in subsequent design stages.

Where practical/ feasible, stormwater outlet structures are to blend into surrounds or are to be obscured from view.

Landscape plans, prepared by a suitably qualified landscape architect/ designer will be provided and details provided regarding plant species, densities and setbacks.

Lake Functional Design

This section includes information in relation to the 'functional design' elements of the potential lake systems, including:

- Quality of inflows;
- Sustaining water levels;
- Organic carbon loads;
- Flushing of lake; and
- Mixing of lake.

Quality of Inflows

The potential lake systems will be considered as 'receiving waterbodies' and, as such, will require stormwater inflows to be pre-treated. Pre-treatment of inflows to the potential lake systems will be provided by a combination of rainwater tanks and 'rain gardens'. These stormwater management measures (and how they will be incorporated into the site) are described further in Sections 4.4.2 and 4.4.3.

These stormwater management measures will provide a very high level of pre-treatment to inflows entering the potential lake systems, and will achieve pollutant load removal rates significantly higher than that required by relevant best practice guidelines (eg. Healthy Waterways (2006), Queensland Government (2009) and DERM (2010)).

Sustaining Water Levels

For any freshwater lake system, the catchment must provide sufficient water to maintain adequate water levels in the lake system (and associated recirculation wetland). Prolonged periods of low water levels (eg due to insufficient catchment inflows) could result in reduced aesthetic values and potential aquatic plant die-off. Mackay City Council (2008) recommends the following:

- Limit the periodic (yearly) water level variation to 0.3-0.4m below normal water level.
- Limit infrequent (1 in 5 years or less frequent) water level variation to 0.5m below the normal water level.

- Ensure severe water level drawdown (ie. >0.5m below normal water level) does not occur more than once every 20 years (on average).

Spreadsheet-based water balance models of the potential lake systems have been developed to provide an understanding of anticipated water inputs and outputs of the potential lake systems, including inputs from stormwater and outputs due to seepage and evaporation. The model has also been used to assess water level variation and residence (or lake 'turnover') times with comparisons to recommended guideline values for lakes.

A 37-year period of historical climate data was applied. This data period was chosen as it includes all available data from the nearby Caloundra WTP BOM Station. This period obviously included the extended 'drought' period observed in the early 2000's, which may have resulted in less than ideal conditions for lake operation (e.g. extended residence times and low water levels).

Stormwater runoff inputs to the water bodies were sourced from the catchment (MUSIC) model for developed catchment conditions. Historic rainfall data from the nearby Caloundra WTP BOM Station (Station No.: 40496, 1973-2010) was used to calculate direct rainfall inputs (i.e. rainfall direct on to the water surface) and used for the catchment modelling. Daily evaporation losses were based on average monthly pan evaporation rates as recorded by the Nambour DPI BOM station (BOM Station: 040282), which is the closest BOM station that records evaporation data. As a modelling approximation, the lake was assumed to have vertical batters to define the relationship between water surface area (and associated direct rainfall input and evaporation losses) and water volume/ depth. Seepage losses from the lake were assumed to be zero.

The water balance modelling undertaken has demonstrated that the potential lake systems would comply with the above water level variation requirements recommended by Mackay City Council (2008).

The figures below illustrate the predicted water level variation (using historical rainfall data) for the three potential lake systems.

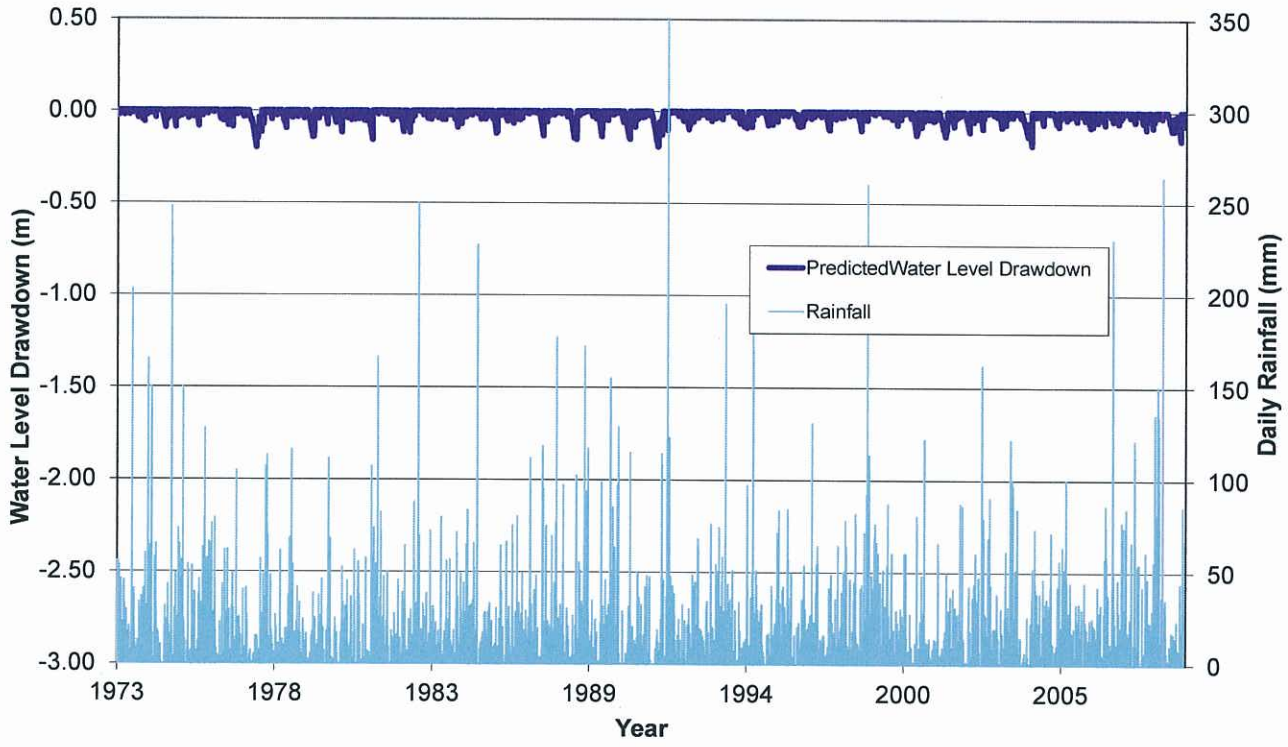


Figure H-4 Time Series Graph of Predicted Water Level Variation in Potential Lake System A (1973 – 2010)

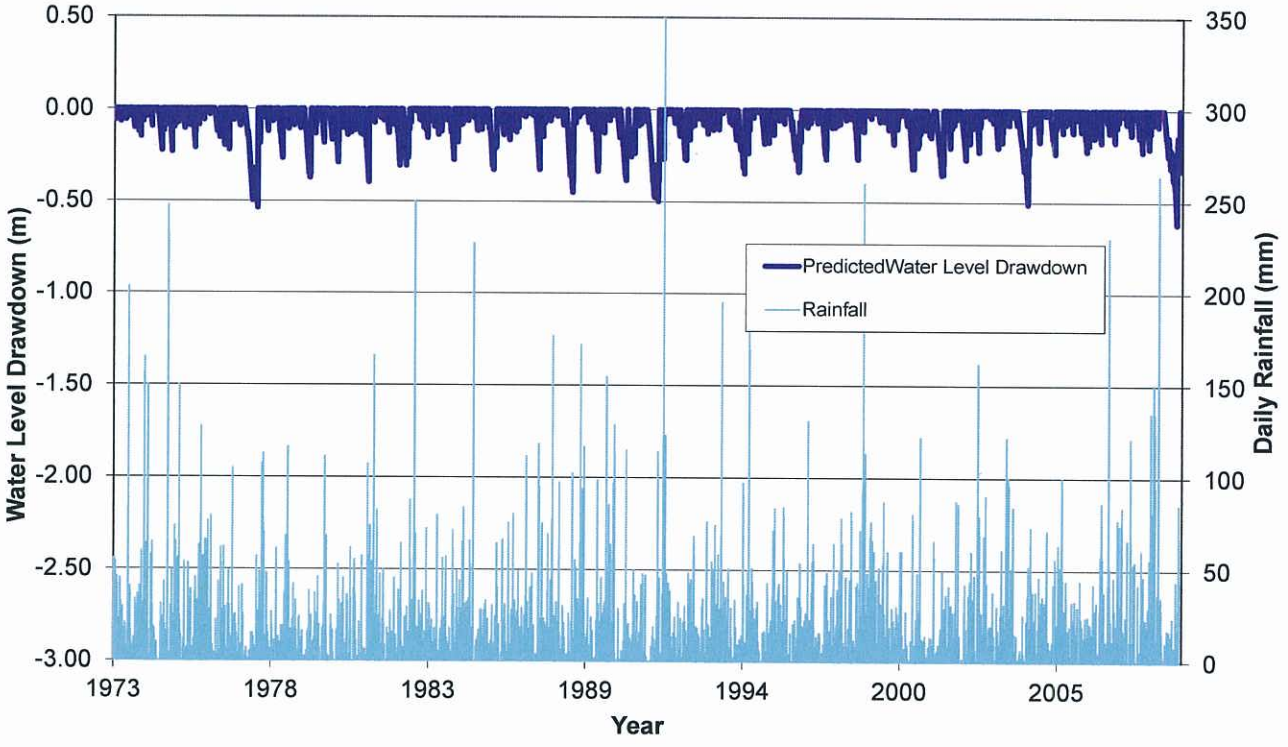


Figure H-5 Time Series Graph of Predicted Water Level Variation in Potential Lake System B (1973 – 2010)

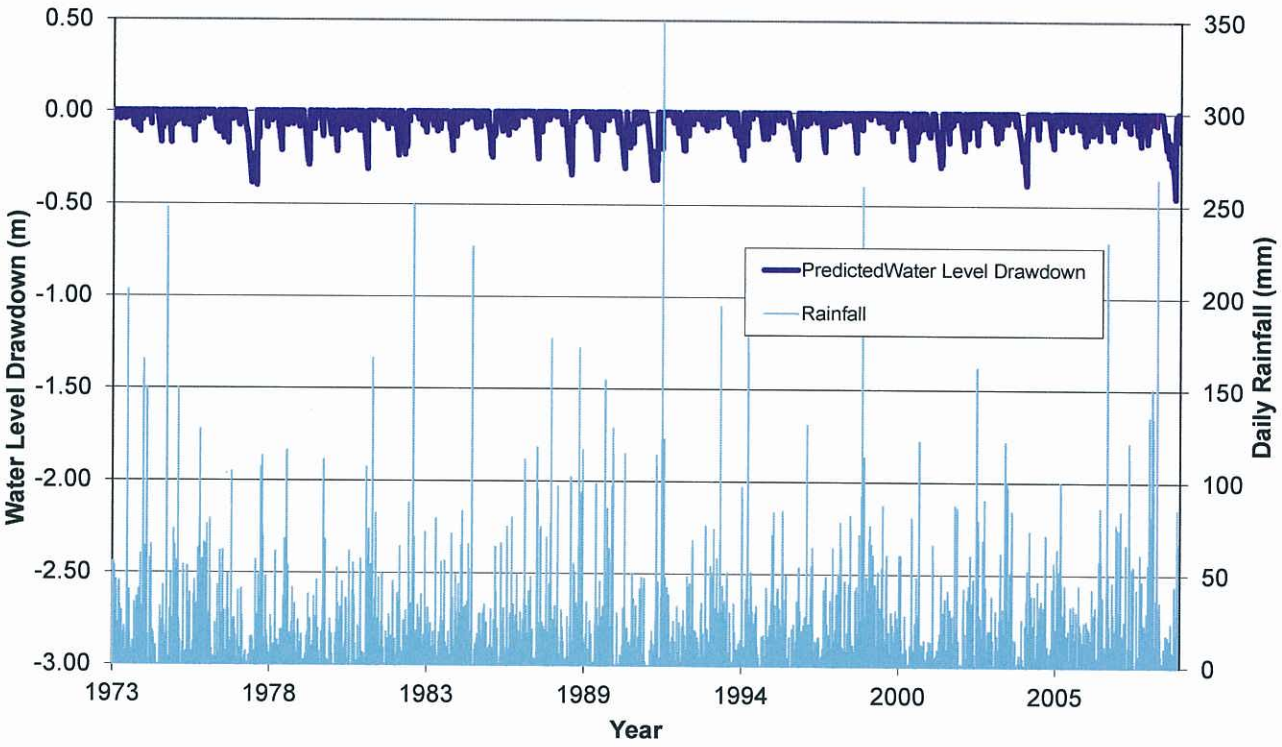


Figure H-6 Time Series Graph of Predicted Water Level Variation in Potential Lake System C (1973 – 2010)

Organic Carbon Loads

Organic carbon is a major contributor of poor water quality within lakes. A significant portion of carbon entering lake systems can come from floating aquatic vegetation growing within the lakes. When this organic carbon decomposes, available oxygen within the lake can be significantly depleted. Furthermore, thick layers of organic material on the lake beds can release significant nutrient supplies to the water column, contributing to algal blooms.

To minimise the accumulation of organic carbon and the release of nutrients from lake sediments, floating plants must be avoided within the potential lake systems and submerged plants and/or emergent plants encouraged.

Flushing of Lakes

Excessive algal growth is often the largest threat to health of a lake system. The rate of algal growth within lake systems is a function of available nutrients, light, temperature and hydrologic conditions.

Mackay City Council (2008) recommends a maximum residence time for lakes in Queensland of 20 days to minimise the risk of algal blooms. This 'residence time' typically relates to the time in which lake water may be retained within the lake prior to being discharged out of the lake system, typically either:

- Not to be returned to the lake system (eg. to a downstream environment, or for reuse);

- To flow or be pumped into a shallow, densely vegetated wetland environment (for a period adequate to limit the growth of algae and reduced nutrient levels). 'Polished' waters from the wetland can then be returned (eg. pumped) to the lake system.

Using the water balance models for the lake systems, the probability of exceedances of various residence times is given in the figures below. These figures assume that zero pumping of recirculated waters occurs within the lake system.

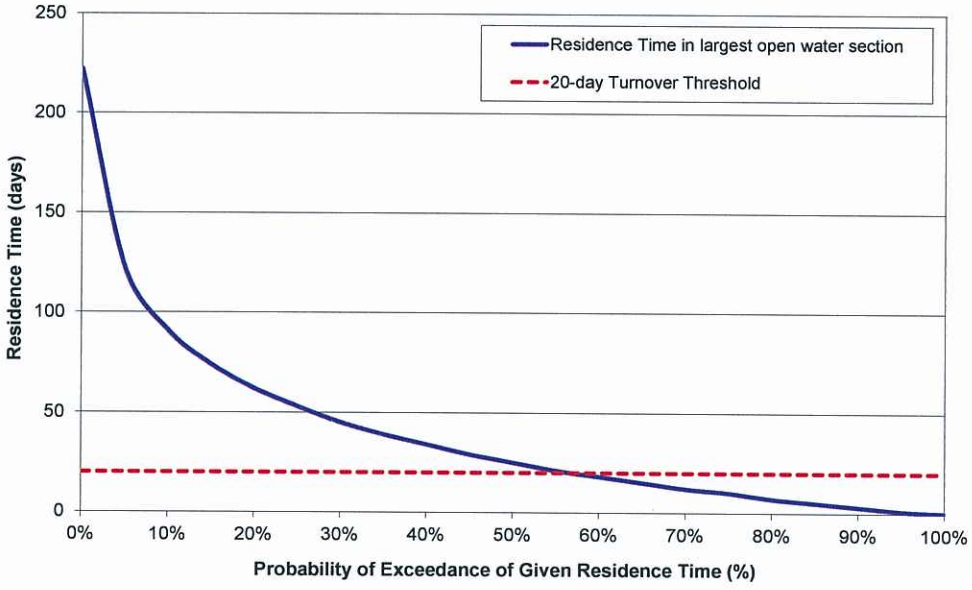


Figure H-7 Probability of Exceedance of Residence Times for Potential Lake System A (1973 – 2010)

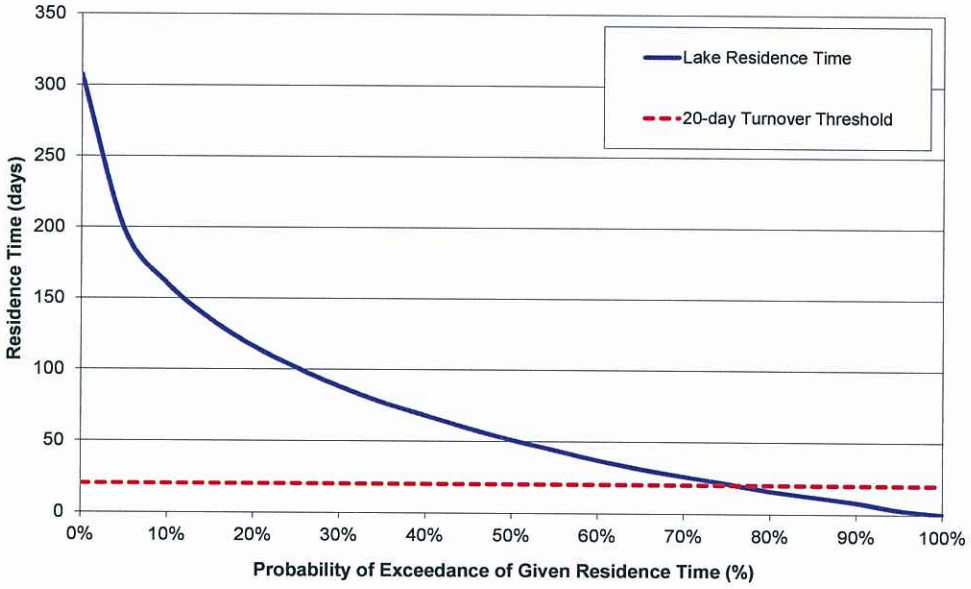


Figure H-8 Probability of Exceedance of Residence Times for Potential Lake System B (1973 – 2010)

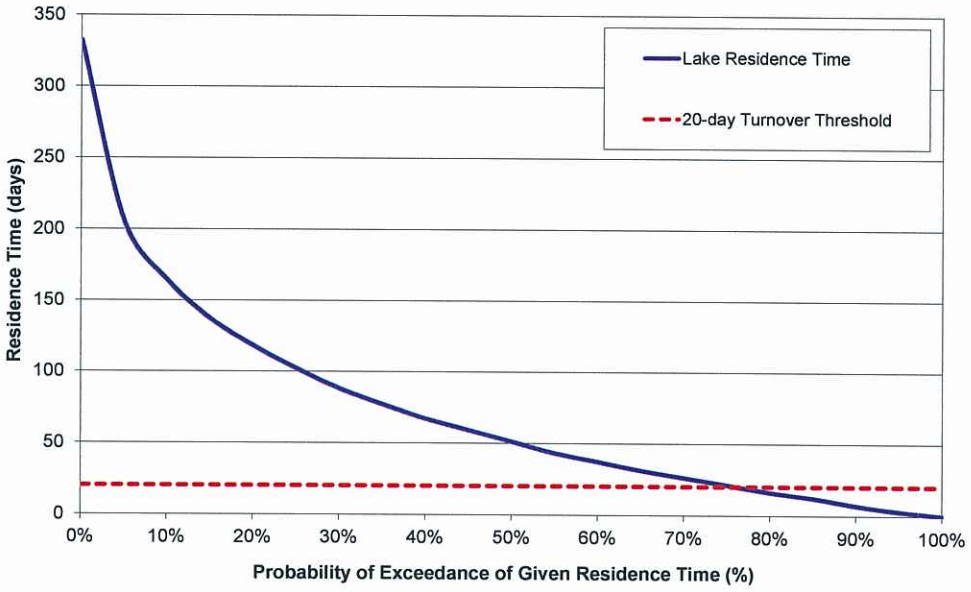


Figure H-9 Probability of Exceedance of Residence Times for Potential Lake System C (1973 – 2010)

As shown by the figures below, the residence times within the potential lake systems would not satisfy Mackay City Council's (2008) 20-day residence time target. To achieve lower residence times within the lake systems (and possibly comply with the 20-day residence time target), lake waters would need to be actively recirculated through a shallow, densely vegetated wetland area.

For lake systems B and C, it is anticipated that lake waters may need to recirculated through an adjacent shallow, densely vegetated wetland area before being returned to the lake system.

For lake system A, it is anticipated that lake waters will need to be recirculated from the downstream end of the lake system to the most upstream end. The shallow, densely vegetated wetland areas will be located within the lake system itself (and not separate to the lake as proposed for lake systems B and C). By incorporating these vegetated areas within the potential lake, the recirculation rate required (for any pumping) will be significantly decreased and can be based on achieving a maximum residence time on only a portion of the potential lake (ie. the largest single area of open water) and not the entire lake area (provided the vegetated areas between open water areas are sufficiently large enough (to provide adequate 'polishing' of lake waters as water traverses through the vegetated areas).

The proposed recirculation design for the potential lake systems is illustrated in Figures H-1 to H-3.

The maximum recirculation rates required for potential lake systems A, B and C required to satisfy a 20-day residence time (in accordance with Mackay City Council (2008)) is approximately 78, 11 and 22 litres/ second respectively. It should be noted that recirculation would need to be continuous over the given 20-day period, but could be reduced through various means including:

- Targeting a lower residence time. The maximum 20-day residence time recommended by Mackay City Council (2008) is anticipated to be highly conservative. If the lake systems were designed and/ or operated to achieve a higher residence time, required recirculation rates would be reduced and the frequency/ timing of recirculation pumping also decreased (eg. only undertaken during extended periods of low rainfall).

- Shallower lake depths and/ or reduced area.

Mixing of Lakes

In deep and poorly mixed water bodies, thermal stratification can develop where a colder deoxygenated bottom layer creates reducing conditions which can release sediment-bound nutrients into the water column. This increase in nutrient concentrations can contribute to algal growth within lake systems.

To avoid the likelihood for stratification, the potential lake systems have a maximum depth of 3m. The base of the lakes will also be as a flat bottom to promote even wind mixing.

Management

Preamble

A management plan will be required for the potential lake system, outlining management strategies to ensure the ongoing sustainability of the lake system. For the purposes of this Integrated Water Management Plan, this section describes some of the key objectives, ongoing tasks/ actions, performance indicators and corrective actions that will likely be required for the management of the proposed lakes within the master-planned community.

The key objectives, ongoing tasks/ actions, performance indicators and corrective actions for the management of the proposed lakes within the community during its operational phase have been discretised into the following categories:

- Water quality;
- Aesthetics and lake ecology; and
- Public safety.

This information is described in the following sub-sections.

It should be stressed that these objectives, actions and indicators are for the operational phase of the potential lakes and upstream catchment (when at least 90% of upstream lots are occupied). Management strategies for the construction phase of the potential lakes will be described as part of the detailed erosion and sediment control plan (E&SCP) being prepared for the construction phase of the site.

Water Quality Management

Objectives

The main objectives associated with lake water quality management during the operational stage of the potential lakes are as follows:

- Preventing environmental harm to lake system ecology and downstream receiving environments; and
- Providing high quality, aesthetically pleasing surrounds.

Ongoing Tasks/ Actions

Key tasks and actions associated with lakes water quality management during the operational stage are as follows:

- *Stormwater Management Measures*: As described in Section 4.4, a wide range of stormwater management measures are proposed for the site. Rainwater tanks and rain gardens will provide pre-treatment to stormwater inflows (prior to discharging into the lake systems). The rain gardens will require regular maintenance, and maintenance plans for these stormwater management measures are provided in Appendix F.
- *Maintenance*: Regular maintenance of the potential lakes will be undertaken in accordance with the indicative maintenance plans for the lakes provided in Appendix G.
- *In-Lake Ecology*: Lake water quality can be seriously affected by the ecology that 'establishes' within the lakes system. Early attention will be given to this issue via active management to ensure the establishment of a viable and suitable lakes ecology, using the following techniques:
  - Stocking the lakes as early as possible with appropriate fish and crustacean species to enable them to establish before the potential entrance of more undesirable species;
  - Development of an appropriate in-lake vegetation establishment program to provide habitat and feed for the lake fauna, and also to minimize the development of unsuitable or weed species in the lake; and
  - Regular monitoring of lake ecology to provide early warning of colonization of pest species in the lakes and to give data that will relate to occasional manipulation of the lakes ecology (e.g. removal of any pest species, restocking).
- *Monitoring*: Monitoring of water quality will be undertaken in accordance with the proposed Water Quality Monitoring Plan (see Appendix I).

Performance Indicators

Relevant guideline levels for water quality constituents to be achieved in the receiving waterways and potential lake system are described in Appendix I.

Corrective Actions

In the event of lake water quality not meeting the design criteria and objectives described earlier, there are several courses of corrective action that are potentially available, as follows:

- Prior to the commencement of any corrective actions, further investigation into the likely source of poor water quality should be undertaken, especially that current maintenance practices are being properly implemented as per the maintenance plans.
- Total Nitrogen, Total Phosphorus, Chlorophyll-a – consider enhancing the shallow wetlands and rain gardens. Review and possibly improve catchment management practices. If stratification occurs, elevated nutrient and chlorophyll-a measurements may be due to anoxic sediments in the bottom depths of the lake system (or wetlands) and sediment removal may need to be considered.
- Total Suspended Solids, Secchi Depth – ensure that Erosion and Sediment Controls are in place and are consistent with relevant best practice guidelines. As for the parameters above, improved/

enhanced stormwater management measures and lake system macrophyte zones should also be considered.

- Dose the lakes with proprietary products such as Phoslock (although it should be stressed that no dosing of proprietary products should be conducted without advice from a suitably qualified consultant).

Aesthetics and Ecosystems

Objective

To provide for aesthetically pleasing lake systems that augments the amenity of the site and the protection of aquatic ecosystems by ensuring suitable water quality, morphology, foreshore design and proper function of lake system infrastructure.

Tasks/ Actions

- *Infrastructure Management*: Lake systems infrastructure (eg. inlet/ outlet structures) will be inspected as part of the lake system maintenance plan (see Appendix G).
- *Water Quality Management*: See previous sub-section.
- *Macrophyte Management*: On occasions, areas within the planted macrophyte zones of the lake systems may need to be harvested for aesthetic reasons. Harvesting does not need to be undertaken to improve water quality (i.e. nutrient uptake) as this has not been found to improve performance to any significant degree. Macrophyte management is outlined in the indicative lake system maintenance plan (see Appendix G).
- *Ecological Surveys*: We would recommend six-monthly ecological surveys of the lake systems undertaken by a suitably qualified consultant within the first few years of operation (ie. post construction). These surveys will include the following assessments:
  - Benthic fauna using standard assessment schemes;
  - Weed Surveys – visual; and
  - Fish surveys – qualitative only, indicating potential presence or absence of key species.
- *Fauna Management*: If exotic fish species are identified within the lake system, techniques approved by appropriate regulatory authorities (eg. Department of Primary Industries and Fisheries) may need to be implemented to remove pest species, and the lake system restocked with appropriate native fish species (based on consultation with the Department of Primary Industries and Fisheries). Any introduced species such as ducks and geese will be removed as soon as practicable after identification.

Performance Indicators

- Relevant guideline levels for water quality constituents to be achieved in the receiving waterways and lake system are described in Appendix G;
- Exotic Fish are managed so that populations are controlled at low levels;
- Other nuisance fauna (i.e. birds) are removed within one week of detection.

Public Safety

Objective

To minimise any risk to the health and safety of the public.

Design/ Management Actions

Key design actions recommended procedures for the operational phase of the site to minimise risks to public health and safety include the following:

- *Design Features*: The conceptual design of the lakes, wetlands, and stormwater management measures will need to undertaken with due consideration to minimising risks to public health and safety (eg. gently sloping and densely vegetated batters for the lakes, fencing for steep batters).
- *Hazard Management*: Lake infrastructure will also be regularly inspected to minimise potential hazards. Physical hazards such as litter, debris and submerged macrophytes will be managed through ongoing maintenance of the lake systems. An indicative maintenance plan for the lake system is provided in Appendix G.
- *Water Quality Monitoring*: As described in Appendix I, water quality monitoring will be undertaken to identify any potential risks to public safety due to poor water quality. Lake Infrastructure to minimise potential hazards and continued monitoring for compliance with secondary contact recreation water quality guidelines.
- *Ecological Monitoring*: As described in the previous sub-section, ecological surveys will be undertaken, which will identify any potential risks to public health and safety due to lake ecology.
- *Reporting*: Incidents should be recorded as part of the overall Workplace Health and Safety Program.

Performance Indicators

Health and safety risks minimised.

Corrective Actions

Corrective actions will need to be specific to any incidents that may occur.

Monitoring

A water and sediment quality monitoring programme will be developed and implemented for the proposed lake systems. The preliminary monitoring programme for the lake systems is described in Appendix I.

Maintenance

Appendix G provides an indicative maintenance plan for the proposed lake systems (including the shallow wetlands).

APPENDIX I: PRELIMINARY WATER QUALITY MONITORING PROGRAMME

This appendix provides a proposed water quality monitoring programme. This programme should be considered preliminary only. A detailed water quality monitoring programme will be prepared for the proposed master-planned community.

The proposed water quality monitoring programme for the Caloundra South site includes the following:

- Telemetered monitoring with turbidity sensor;
- Event-based and ambient water quality monitoring within Bells Creek North, Bells Creek South and Lamerough Creek;
- Ecosystem health monitoring of Bells Creek (and Pumicestone Passage); and
- Lake water (and sediment) quality monitoring.

This proposed monitoring programme is anticipated to be 'beyond best practice', consistent with the over-arching stormwater management strategy proposed for the site. This programme will allow for any incidences of poor water quality and/ or ecosystem health to be quickly identified and their cause remedied (if appropriate) augmenting the protection of downstream ecosystems.

The following sections provide further information in relation to the proposed monitoring strategy.

Telemetry Monitoring

Telemetered sensors will be placed downstream of areas being developed. Should these turbidity sensors detect turbidity levels in site runoff which exceeds predefined threshold levels, alarm signals will be sent to Stockland/site construction personnel so that they can investigate the cause of the elevated turbidity levels and undertake appropriate corrective actions.

Figure I-1 Photos of Telemetered Water Quality Monitoring Infrastructure

Ambient Water Quality Monitoring

As described in Section 2.3, a baseline water quality monitoring program was designed and implemented within the Caloundra South site to help characterise the site in its current (pre-development) condition.

BMT WBM's reports "*Caloundra Downs: Baseline Monitoring Program – Final Report*" and "*Caloundra Downs Stormwater Quality Management Master Planning Assistance*" describes the methodology used and provides a summary of the data that has been collected between May 2008 and October 2010.

It is recommended that this monitoring program be re-commenced during the construction phase and operational phases of the development. This will allow a comparison between 'pre-development' catchment conditions – and those experienced during the construction and operation of the site. As for the telemetry monitoring, this will allow any incidences of deteriorated water quality (relative to the 'pre-development' catchment) to be identified and subsequently investigated (and, if appropriate, remedied).

Ecosystem Health Monitoring

An Ecosystem Health Monitoring Program (EHMP) is currently being undertaken throughout South East Queensland. This EHMP is one of the most comprehensive marine, estuarine and freshwater monitoring programs in Australia. It delivers a regional assessment of the ambient ecosystem health (or pulse) for each of South East Queensland's (SEQ) 19 major catchments, 18 river estuaries, and Moreton Bay, highlighting where the health of our waterways is getting better or worse. The EHMP is managed by Healthy Waterways on behalf of its various partners and is implemented by a large team of experts from the Queensland Government, universities and CSIRO.

As part of this EHMP, ecosystem health monitoring is currently undertaken within Pumicestone Passage, including a site immediately downstream of Bells Creek.

It is proposed that similar ecosystem health monitoring be undertaken within locations (approximately two or three sites) within Bells Creek downstream of the site. Healthy Waterways may be able to extend their EHMP to include these monitoring locations. Alternatively, similar (if not identical) methodologies be employed by others to allow between Bells Creeks and Pumicestone Passage ecosystem health monitoring data to be correlated.

This ecosystem health monitoring in Bells Creek (and Pumicestone Passage) will provide a further level of ecosystem assessment, again allowing any incidences of changed ecosystem health to be identified (and, if appropriate, investigated and remedied).

Lake Water and Sediment Quality Monitoring

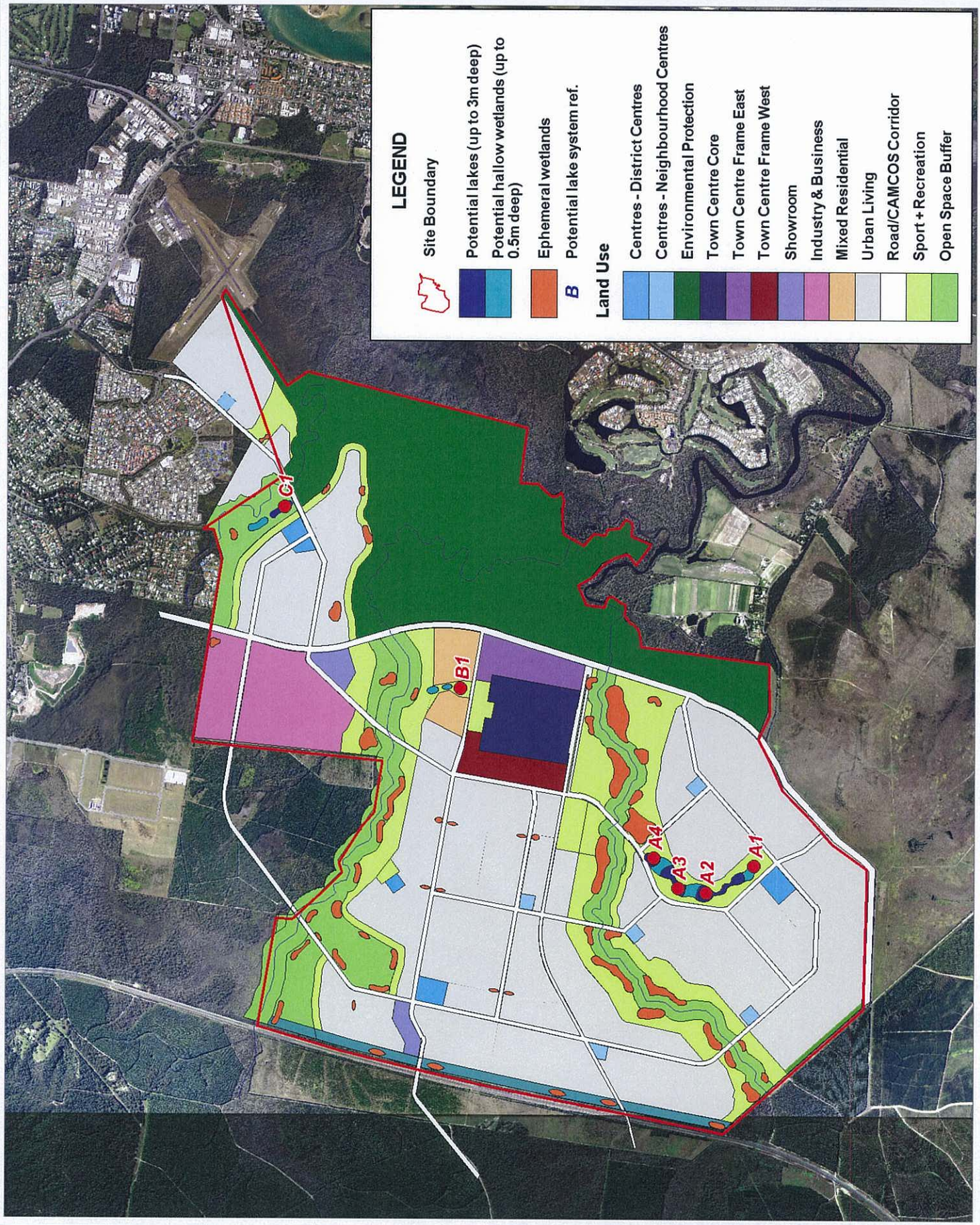
Water and sediment quality monitoring is proposed for the potential lake systems within the master-planned community. Table H-1 provides a summary of the recommended parameters, frequency and locations for water quality monitoring within the proposed lake system. Figure I-2 illustrates the location of the recommended monitoring locations.

Table I-1 Summary of Recommended Water Quality Monitoring Plan

Parameter	Unit	Water Quality Objectives*	Monitoring Frequency	Monitoring Locations
Water Quality Monitoring				
Physical Monitoring				
Temperature	°C	-	Monthly	A1-A4, B1, C1. Recorded 0.3m from surface and every 0.5m from surface til lake bottom.
Salinity	ppt	-		
Conductivity	mS/cm	-		
Dissolved Oxygen	mg/L	-		
Dissolved Oxygen	% Sat.	90 – 110		
pH	-	6.5 – 8.5		
Turbidity (NTU)	NTU	<20		
Chemical Analyses				
Total Suspended Solids	mg/L	-	Monthly	A1-A4, B1, C1 Recorded 0.3m from surface and 1m from lake bottom.
Total Nitrogen	mg/L	<0.35		
Oxidised Nitrogen	mg/L	<0.01		
Ammonia Nitrogen	mg/L	<0.01		
Total Phosphorus	mg/L	<0.01		
Filterable Reactive Phosphorus	mg/L	<0.005		
Chlorophyll-a	µg/L	<5		
Faecal Coliforms	org./ 100mL	<1000 (& 80th %ile <4000)		
Enterococci^	org./ 100mL	<230 (& Max. <700)		
Heavy Metals & Pesticides				
Cadmium	µg/L	<2	Six-monthly	A1-A4, B1, C1 Recorded 0.3m from surface and 1m from lake bottom.
Copper		<5		
Nickel		<5		
Lead		<150		
Zinc		<20		
Organochlorine and Organophosphorus pesticides	Below detectable limits			
Sediment Quality Monitoring				
Cadmium	mg/kg (dry weight)	<10	Annually	A1-A4, B1, C1
Copper		<270		
Nickel		<220		
Lead		<60		
Zinc		<410		

*: Objectives are median values unless otherwise stated. These objectives are based on the recommended values for 'freshwater lakes/ reservoirs' in South East Queensland, as given in DERM (2009) and ANZECC (2000).

Six-monthly consolidated lake water quality monitoring reports will be prepared and submitted to Sunshine Coast Council for review. Any corrective action undertaken will also be reported immediately to Council.



Title:

Proposed Lake Water Quality Monitoring Locations

Figure: **I-2**

Rev: **C**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 1 2km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : I:\B18176_I_AMB_Caloundra_Downs\DRG\IWMP_Rev_5\UW_014_120524_LakeWQMonitoring_RevC.wor

APPENDIX J: SITE WATER BALANCE

An indicative water balance has been developed for the Caloundra South site (both prior to and with development). This appendix describes the applied methodology and subsequent results.

Methodology

This site water balance has been derived through a combination of three methods:

- Interrogating the 'node water balance' modules of the MUSIC models developed for this project (See Section 4.3 for a description of the MUSIC modelling methodlogy);
- Interrogating Urban Developer modelling conducted of the site for Stockland by BMT WBM to guide stormwater harvesting assessments; and
- Interrogating water balance models of the lakes (described in Appendix H).

The MUSIC models provided much of the water balance, including rainfall, runoff generated and outputs such as evapotranspiration (from the catchment, rain gardens and ephemeral wetlands). Urban Developer modelling provided guidance as to the quantities of stormwater able to be harvested from the site and the difference between the MUSIC flows and the extractions due to stormwater harvesting gives the resultant site discharges (to receiving waterways). The water balance models provided the estimated evaporation rates from the lakes (as the lakes have not previously been included in the MUSIC modelling – because they are not considered a key part of the stormwater 'treatment train').

The water balance was derived using the same meteorological period (1st January 1997 to 31st December 2006) as previously applied to the MUSIC modelling (consistent with the time periods recommended by Water by Design's (2010) "*MUSIC Modelling Guidelines*").

Two scenarios were assessed:

- Existing site (prior to development); and
- Developed site with proposed Integrated Water Management strategy.

Rainfall-runoff and pollutant export characteristics for the existing (pre developed) site have been developed based on the data collected as part of BMT WBM's load based water quantity and quality monitoring program at the Caloundra South site. This is described further in our response to Item 4.

Results

The results of the water balance assessment of the Caloundra South site are given in Table I-1.

Table I-1 Indicative Water Balance for the Caloundra South Site

Water Cycle Element (ML/year)	Existing Site	Developed site
Rainfall	31 856	
Evapotranspiration from catchment	21 262	16 814
Flow generated	10 494	17 371
Extraction from rainwater tanks	-	1 231
Evapotranspiration from assets	-	2 528
From rain gardens	-	*721*
From ephemeral wetlands	-	*1594*
From lakes	-	*213*
Stormwater Harvesting and Reuse (from ephemeral wetlands)	-	2336
Discharge to waterways	**10 606**	**11 276**

The water balance results given in Table I-1 indicate that, if unmanaged, the proposed development would result in a significant increase in the amount of flow generated within the site.

The results also indicate, however, that the proposed stormwater management strategy will significantly decrease the flow volume that would otherwise be discharged to the waterways. There is subsequently predicted to be little, if any, change in regard to the annual average volumes of runoff from the site. Water quality modelling (undertaken by BMT WBM and described separate to this report) that integrates catchment sourced stormwater flows with water quality in Bells Creek and Pumicestone Passage has shown that this will not cause any detectable change in salinity or water quality levels in Bells Creek or Pumicestone Passage.