PENRITH LAKES

PENRITH LAKES DEVELOPMENT CORPORATION

WATER MANAGEMENT PLAN: STAGE 2

May 2020

Cover Image: Cranebrook Lake Wetland

WATER MANAGEMENT PLAN: STAGE 2

Prepared by

PENRITH LAKES DEVELOPMENT CORPORATION LTD

89 - 151 Old Castlereagh Road • Castlereagh • NSW 2749
PO Box 457 • Cranebrook NSW 2749
Telephone +61 2 4729 0044 • Facsimile +61 2 4730 1462
Contact: Arthur Ashburn
Email • info@pldc.com.au
Web • http://www.penrithlakes.com.au

Authors	*Qualifications*
Kate Shmidt	MA Environmental Policy and Management (Applied)
Tony Church	PhD (Marine Ecology)
Arthur Ashburn	B Engineering Civil (Hons)

PENRITH LAKES

Supporting documents by:

BMT

NATION PARTNERS

J. WYNDHAM PRINCE
CONSULTING CIVIL INFRASTRUCTURE ENGINEERS & PROJECT MANAGERS

PSM

E2DESIGNLAB

Image: One Tree Lagoon constructed wetland

TABLE OF CONTENTS

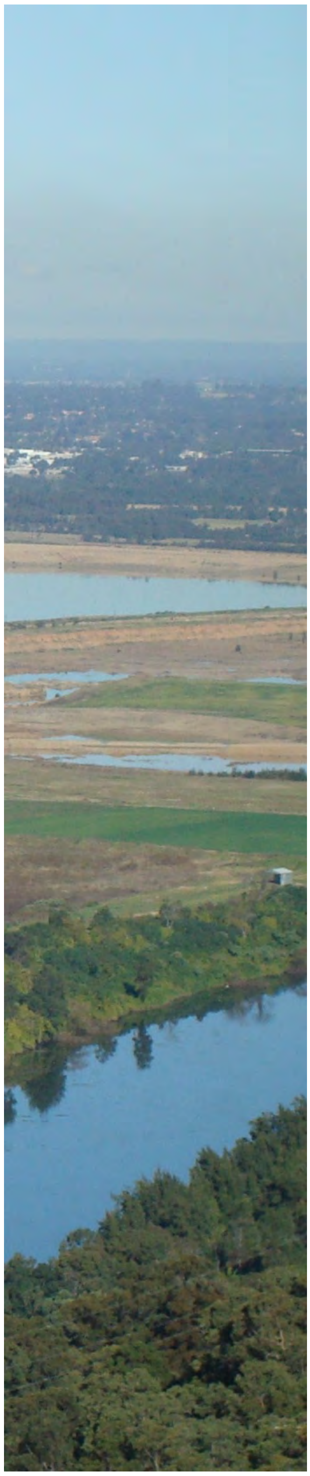
This page was left intentionally blank

1 INTRODUCTION

Penrith Lakes Development Corporation (PLDC), in accordance with the provisions of the 1987 Deed of Agreement (Deed) with the State of New South Wales, is implementing the Penrith Lakes Scheme. A key document described in the Deed and its Schedules is the Water Management Plan, the aim of which was to guide the development and implementation of a unique water based Scheme for western Sydney on completion of extraction activities.

Over the 30 year period, since the inception of the Deed the Water Management Plan has been updated and modified on several occasions, reflecting changes in circumstances, technology, responses to ongoing monitoring results, water management studies and operational experience gained by PLDC through the management of newly formed water bodies.

This Stage 2 Water Management Plan complements the Stage 1 Water Management Plan which was approved in November 2013. Stage 1 of the Water Management Plan investigated the infrastructure required to complete the lakes. Stage 2 details the outcomes of investigations into water quality and water balance and makes recommendations regarding the future operational and water management requirements of the completed Scheme. When approved the combination of these plans will form the final Water Management Plan for delivery of infrastructure and for operating the completed Lakes Scheme over the long term.



1.1 PURPOSE OF THIS REPORT

The delivery of the Water Management Plan has been completed over 2 stages at the request of the Department of Planning, Industry and Environment (DPIE). This document presents the final Stage of the Water Management Plan combining work completed in 2014 (original Stage 2 submission) and the outcomes of the "In-Principle Agreement" between PLDC and DPIE agreed February 2019. The Stage 2 Water Management plan addresses the following:

- Water Quality Criteria
- Groundwater Management
- Stormwater Management
- Ecosystem Development
- Fisheries Management
- Southern Wetlands Design
- Lakes Operations Plan

To adequately address management and water quality performance of the Scheme, PLDC and DPIE have agreed to introduce additional water management infrastructure and have carried out complementary research, including additional water quality and quantity modelling as well as assessment of performance of the redesigned wetlands system in the south of the Scheme.

1.2 FINAL WATER MANAGEMENT PLAN (STAGES 1 & 2)

The 2012 Water Management Plan Stage 1 was conditionally approved on the 5 November 2013 and is included as Appendix 1 of this document.

This Stage 2 document details recommendations for the final lakes and infrastructure requirements to complete the Penrith Lakes Scheme. This submission complies with conditions 7 to 9 of the above mentioned approval.

1.3 THE PENRITH LAKES SCHEME

The Penrith Lakes Scheme is bound to the north by Smith Road, to the east by The Cranebrook Terrace and Castlereagh Rd and to the west and south by the Hawkesbury-Nepean River. Located 60km west of Sydney and 2km north-west of Penrith, the Scheme covers 1,935 hectares within the Penrith LGA with over 11kms of river frontage. The Scheme's location within the greater Sydney region is shown below in Figure 1.

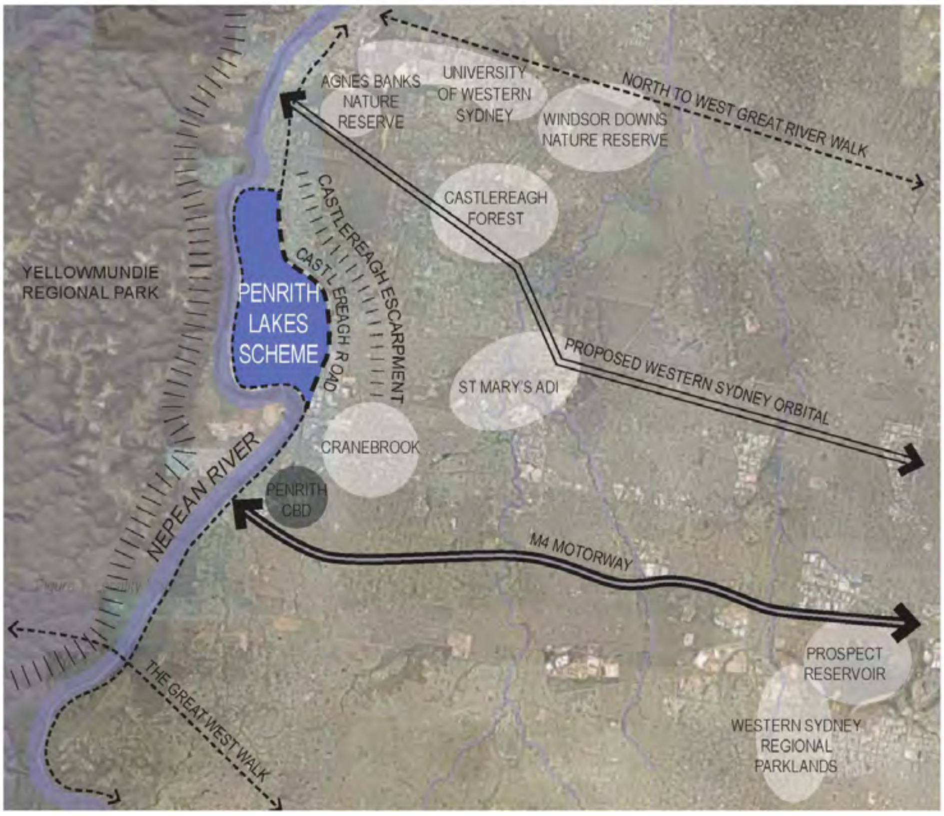


Figure 1: Location of the Penrith Lakes Scheme.

The Penrith Lakes Scheme was envisaged in the 1970's as an innovative rehabilitation project which had its genesis in a joint PLDC and State Government working party. The outcome from the working party was a Regional Environmental Study (RES) completed in 1984 by the Department of Environment and Planning. The key objectives for the RES were:

1) secure the long term orderly extraction of sand and gravel for Sydney's building needs;

and

2) provide significant social, community and environmental benefits for the residents of western Sydney by the creation of a major water-oriented recreation resource.

To give effect to the objectives of both parties as contained in the RES and the 1987 Deed of Agreement (as amended). The Sydney Regional Environmental Plan 11 – The Penrith Lakes Scheme (SREP) was finalised to guide the delivery of the Scheme and establish development objectives for the Scheme's ultimate completion.

The Deed outlines the original intentions for overall water management within the Scheme and is consistent with the preferred Scheme articulated within the RES. The Deed acknowledges that the effect of those intentions were likely to alter over the course of the development and delivery of the Scheme. The Water Management Plan represents the culmination of these changes and establishes the blueprint for completion of the Scheme and achievement of the objectives of both PLDC and Government.

The Stage 1 Water Management Plan, approved in November 2013, details the flood mitigation and reticulation infrastructure to be delivered in the completed Scheme and sets the operating levels for each of the water bodies for the optimum performance of the Scheme during various flood events and normal operating conditions. It also addressed water balance issues in the Cardno Water Balance and Lake Operating Levels Report – August 2012.

The Stage 2 Water Management Plan submission details the water quality and management objectives for the Scheme under its normal operations. It also further refines the water balance investigation carried out by Cardno in Stage 1 and provides information on the final design of the wetlands system and associated infrastructure. Both documents combine to form the completed Water Management Plan for the Scheme.

1.4 DOCUMENT STRUCTURE

The Stage 2 Water Management Plan consists of eleven sections and provides an outline of the Scheme being delivered and further detail on the key approval criteria required to successfully operate the Scheme over the long term.

As a supporting tool for the proposed Scheme, extensive water quality modelling has been undertaken to simulate water quality performance of the Scheme over a 10 year climate sequence from 1985 to 1994. This period is the standard period accepted by Government water agencies for their planning purposes and for consistency has been adopted by PLDC for its modelling and analysis work.

Sections of the Plan are as below:

Section 1 - Introduction

Section 2 - The Scheme

Section 3 - Groundwater Management

Section 4	-	Stormwater Management
Section 5	-	Ecosystem Management
Section 6	-	Fisheries Management
Section 7	-	Water Quality Model
Section 8	-	Water Quality Model Outcomes
Section 9	-	Operational Infrastructure
Section 10	-	Lakes Operations Plan
Section 11	-	Conclusion and Recommendations

Appendices attached to the document include:

Appendix 1: Water Management Plan Stage 1

Appendix 2: Hydrological Modelling of Resized NRPP

Appendix 3: Hydrogeological Assessment

Appendix 4: Water Quality Modelling Report

Appendix 5: Water Quality Model Calibration Results

Appendix 6: Southern Wetlands Design Review

Appendix 7: Southern Wetlands Infrastructure Drawings

Appendix 8: Lakes Operations Plan

Appendix 9: Southern Wetlands Permeability

2 THE SCHEME

The completed Penrith Lakes Scheme as programmed to be completed in 2020 / 2021 will include 723ha of lakes, 32ha of wetlands, and at optimal operating capacity, contains 37.5 gigalitres of water. At the core of the Scheme is a series of interconnected lakes and associated water bodies through which water moves by gravity flow networks from south to north before discharging into the Nepean River in the north. Water for the completed Scheme will be sourced from the surrounding catchment as well as drawing from the Nepean River through a pump and pipeline under an approved water access licence.

The Scheme's water management plan seeks to minimise intervention using either mechanical or chemical means to achieve water quality objectives. The management plan is based on the key principles of:

- water quality management at the source;
- use of detention basins and wetlands to enhance water quality prior to water entering the lakes proper;
- introduction of diverse terrestrial ecosystems; and
- introduction and ongoing management of healthy macrophyte dominated aquatic ecosystems.

A hierarchy of lakes has been adopted by PLDC to deliver operational flexibility to accommodate a wide range of climatic conditions likely to prevail over the life of the Scheme and provide opportunities to optimise the potential to achieve the water quality objectives to support the end water uses.

The recommended hierarchy for recreational lake usage is as follows:

1. Regatta and Warm up Lakes
2. Main Lake B
3. Main Lake A
4. Quarantine Lake
5. Duralia Lake

The Wildlife Lake remains primarily a wildlife habitat for scientific and educational purposes with significant aesthetic value.

Indicative flow paths throughout the Scheme are shown below in Figure 2.

Figure 2: Indicative gravity flow and pumped system across the Scheme.

2.1 SCHEME WATER – DESIGN AND OPERATIONAL OBJECTIVES

The overall objectives for the effective design and long term operation of the completed Scheme are set out below. Over a 30 year period PLDC has investigated and tested the most appropriate system capable of delivering the desired outcomes contained within Schedule 7 of the 1987 Deed of Agreement (Deed) and the 1984 Regional Environmental Study (RES).

The strategic framework set out below includes policies and strategies appropriate to investigating, designing and managing the Scheme's water bodies. The framework has guided the approach PLDC has taken during its tenure as designers, constructors and terrestrial and water managers of the Scheme.

Goal: To achieve as far as practicable the water objectives in Schedule 7 of the Deed.

Key Objectives:

1) Development of Lakes and Foreshores - To design and construct the lakes and foreshores to support the proposed end water uses and associated water quality targets, at the least capital and ongoing recurrent operating costs.
2) Establishment of Ecosystems - To design and implement the key components required to establish a healthy terrestrial and aquatic ecosystem that does not preclude any of the identified end uses of the water.
3) Building in Operational Flexibility - To design processes which maintain adequate depths of water (within the designed operational water level tolerances) for water balance and identified end water use options.
4) Reducing Impacts on Regional Water Resources - To minimise any reduction in Nepean-Hawkesbury river system water quality that may be caused by diversions to the Scheme and to minimise any impacts which the lakes may have on local groundwater tables.

To achieve the objectives PLDC has adopted the following principal policies and associated strategies.

Policies which relate to the key objective "Development of Lakes and Foreshores" are detailed in the 2012 Water Management Plan Stage 1 submission and are not repeated here.

Policy: *To adopt measures whereby the recommended water quality criteria can be met in the lakes.*

Strategies:

Determine appropriate water detention and holding regimes within the Scheme's treatment trains to deliver optimum outcomes.

Consider catchment inflows and encourage local Government to complete stormwater infrastructure works required to protect the Scheme's lakes from deteriorating water quality from external sources.

Consider the impacts of urban growth in the catchment on the Scheme lakes and encourage local Government to apply water sensitive urban design principles to any development in catchments external to the Scheme.

Monitor appropriate water quality components in the lakes. Identify areas where incomplete horizontal mixing may occur.

Monitor component lakes and detention basins.

Review and update the recommended water quality criteria.

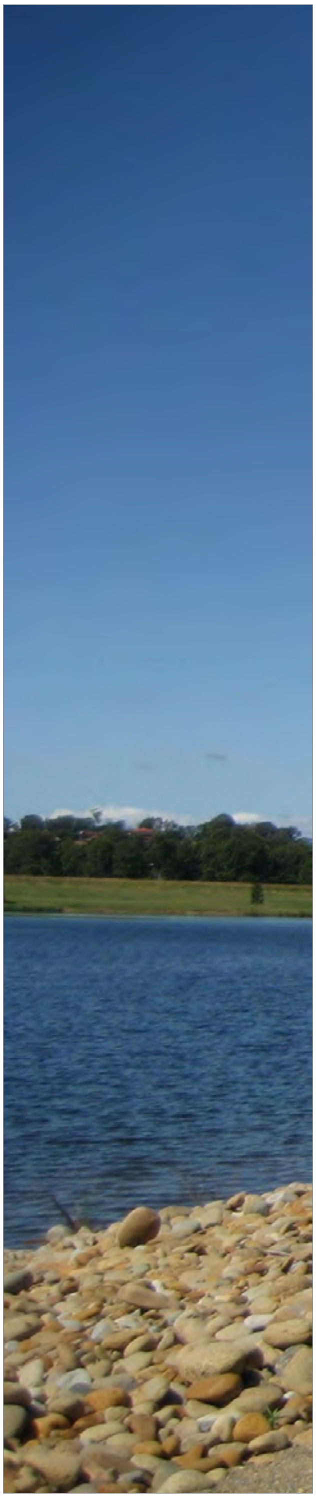
Determine the most appropriate physical, chemical and biological indicators to be monitored.

Confirm the processes which will influence the lakes' water quality in the long term.

Develop a water quality model to assess the performance of the Scheme and simulate final conditions.

Stock the lakes with appropriate fish species to reduce vector populations.

Monitor microbiological and toxicant levels in the lakes.



Policy: *Ensure that water of undesirable quality entering the main lakes is kept to a minimum*.

Strategies:

Investigate the eastern catchment stormwater inflow into to the Scheme and the potential impact on Scheme water quality.

Improve water quality of catchment inflows by selectively pumping excess water from eastern detention lakes into Southern Wetlands for extended detention time.

Selectively pump input water to the lakes from the Nepean River to minimise the risk of undesirable water quality or weed material entering the Lakes.

Establish a program to educate users and neighbours to behave in a manner least likely to impair the lakes' water quality.

Minimise the use of fertilisers and chemicals on areas which drain into the lakes.

Minimise the amount of stormwater entering the lakes from roads and urban areas both within and external to the Scheme area.

Divert stormwater originating from catchment areas outside the Scheme area around the main lakes.

Determine the origins and levels of undesirable water quality components likely to enter the lake system.

Determine relationships between nutrient levels and potential discharge into the Nepean River.

Design building developments within the Scheme area to ensure that the likelihood of discharge of undesirable water quality components is minimised.

Policy: Efficiently manage water through the lake system to minimise operating and recurrent budget.

Strategies:

Adopt a hierarchy of Lakes to ensure optimal safe recreational and public use.

Design outlet pipes to ensure return of water to the Hawkesbury/Nepean River through the gravity system within the Lakes.

Develop an operational plan for the completed lakes.

Model the required maximum amount of water from the Nepean River which would be consistent with maintaining the desired water levels within the lakes.

Determine treatment strategies that have no or minimum impact on the aquatic ecosystem.

Determine the most effective methods for the management of water through the system including use of buffer water storage, series of sluice gates and pumps as designed within the lakes.

Determine and install the most effective means of draining the lakes.

Dispose of material gathered, including weeds, away from the water bodies.

Provide suitable facilities to manage transfer of water through and between lakes.

Policy: *Divert water into Lakes from the Nepean River*.

Diversions are to be effected in accordance with the approved Water Access Licence conditions.

Design and deliver pumping installation and supply lines having due regard to the staged development of the Scheme, cost-effectiveness and long term operating requirements.

2.2 LAKE STRUCTURE

The lakes have been designed to provide optimal operational flexibility in achieving the desired end water uses and maximise public amenity. The ultimate design included wetlands to assist with improving the overall ecosystem performance and water quality and the capacity for significant water storage buffer above the prescribed operating levels approved in the Stage 1 Water Management Plan. Operational flexibility is also optimised through adopting the hierarchy of lakes as set out above. Physical attributes including the size, capacity and recommended water level tolerances of the lakes are provided below in Table 1 and details on the wetlands in Table 2.

.

Table 1: Surface areas, operating water levels, volumes and recommended water level tolerances in the various Scheme water bodies

LAKE	SIZE (HA)	AVERAGE DEPTH (M)	OPERATING LEVEL (M AHD)	VOLUME AT OPERATING LEVEL (GL)	RECOMENDED WATER LEVEL TOLERANCES
Primary Lakes					
Wildlife Lake	110	4-5	10	3.9	-1.00m / +1.00m
Main Lake B	121	6-7	13.5	7.3	-1.00m / +1.00m
Main Lake A	318	5-6	14	17.8	-1.00m / +0.50m
Quarantine Lake	42	6-7	15	2.4	-0.25m / +0.40m
Regatta Lake	80	5-6	15	4.2	-0.25m / +0.40m
Treatment Lakes					
Duralia Lake	13	10-11	18	0.9	-1.50m / +0.90m
Cranebrook Lake	3	10-11	18	0.13	-1.50m / +0.90m
Detention Basins					
Lewis Lagoon	3	5	14	0.08	-1.50m / +1.00m
North Pond	7	4	16.5	0.17	-1.50m / +1.55m
Stilling Basin	0.6	2.5	17.7	0.01	-1.50m / +0.35m
Middle Basin Wetland	5	1-2	17	0.04	-1.50m / +1.05m
Middle Basin	13	4-5	16.0	0.5	-1.50m / +2.05m
Final Basin	7	3-4	15.5	0.07	-1.50m / +2.55m
Lake Totals	723			37.5	

Table 2: Surface areas and recommended water level tolerances of the Scheme wetland systems

WETLANDS	SIZE (HA)	RECOMENDED WATER LEVEL TOLERANCES (M AHD)
Southern Wetlands	23	24.4 – 18
Duralia Wetlands	3.7	19 – 18
Cranebrook Wetlands	2.2	24.5 – 18
Eastern Chain of Ponds	3.6	24 – 17

2.3 END WATER USES AND WATER QUALITY INDICATORS

The completed Primary Lakes as listed in Table 1 have end water uses as set out in Schedule 7 of the Deed. These end water uses are set out below in Table 3.

Table 3: End water uses of the Scheme in the Deed.

LAKE	END WATER USE
Main Lakes A & B	Aesthetic value. Water surface sports - primary and secondary contact. Fishing.
Regatta Lake	Lake water management Water surface sports – secondary contact. Aesthetic value.
Treatment Lake (Duralia Lake)	Lake water management Water surface sports - secondary contact. Aesthetic value.
Wildlife Lake	Lake water management Wildlife habitat including aquatic and shoreline habitat. Scientific and educational. Aesthetic value.
Detention Basin	Lake water management Aesthetic value.

The results of the modelling carried out in Stage 2 indicates that all Primary Lakes will achieve water quality to Primary Contact standard well above 90% of the time and as such could safely accommodate other recreational activities including swimming.

The Deed also lists water quality indicators for Main Lake A and Main Lake B as a guide to achieve the proposed end water uses. As recommended by the NSW Public Health Unit and the NSW Regional Algal Coordination Committee PLDC subsequently adopted the National Health and Medical Research Council Guidelines for Managing Risks in Recreational Waters (NHMRC 2008). As the NHMRC 2008 guidelines are accepted as the appropriate Government standard PLDC believes that these should continue to be used and reviewed by the long term operators for managing recreational uses within the lakes.

Table 4 provides a summary of both the Deed indicators as well as the NHMRC (2008) guidelines to measure water quality performance for Main Lakes.

Table 4: Water quality standards for the Main Recreational Lakes as identified by the 1987 Deed compared to Primary and Secondary water contact requirements under the NHMRC 2008 guidelines.

INDICATOR	1987 DEED STANDARD	PRIMARY CONTACT	SECONDARY CONTACT
Dissolved Oxygen	>90%	>80%	>80%
pH	6.00 - 8.50	5.00 - 9.00	5.00 - 9.00
Temperature	Ambient Variation	16 - 340C	16 - 340C
Salinity	0 - 1000mg/L	N/A	N/A
Suspended Solids	<25mg/L	N/A	N/A
Light Penetration	1.5m	N/A	N/A
Total Nitrogen	<0.7mg/L	N/A	N/A
Total Phosphorus	<0.025mg/L*	N/A	N/A
Bacteriological Indicators	<100 CFU in 80% of samples	<40 CFU Enterococci	<200 CFU Enterococci
Cyanobacteria cell/mL	N/A	<5000 cells/mL Microcystis aeruginosa	<50,000 cells/mL Microcystis aeruginos
Cyanobacterial Biovolume	N/A	<4mm^3/L potentially toxic cyanobacterial biovolume	<10mm^3/L total cyanobacterial biovolume
Cyanobacterial toxins	N/A	<10ug/L Cylindrospermopsis** or Microcystis <20ug/L Saxitoxins**	
Aesthetic quality	No objectionable taints, odours or colours. No visible floating oil, grease scum or other objectionable matter.		
*Based on ratio of total nitrogen to total phosphorus of 14:1. This may vary in accordance with findings of studies detailed in Water Plan **PLDC Specific Guideline provided by the NSW Public Health Unit.			

2.4 CONCEPT DESIGN

When complete the SIRC Lakes, Main Lakes A and B, Duralia Lake (treatment lake),Quarantine Lake and the detention basins (Eastern Lakes, Southern Wetlands) can be characterised by the following:

- a fit-for-purpose landscape, suitable for public recreation and urban uses in accordance with the Construction Principles as defined in the Deed;
- maximum substrate and soil health, conservation and landform stability;
- efficient use of on-site resources;
- minimal ongoing maintenance costs including for the water treatment basins and Wildlife Lake; and
- enhanced biodiversity through the fabrication of foundations of former natural vegetation communities, maximising ecosystem services, landscape function and resilience.

Table 5 summarises the purpose and the character of the main lakes to be used for recreational purposes. The terrestrial recreational activities and water-based activities that could be provided in the longer term are shown in Table 6.

The overall aim for recreational use is to provide a water-based recreational resource for local Western Sydney residents and visitors to enjoy within a pleasant parkland setting and to encourage discovery and appreciation of the area's natural and cultural heritage.

Table 5: Purpose and design character of the main recreation lakes.

SITE	PURPOSE	DESIGN CHARACTER
SIRC Lakes	To optimise public recreation whilst also supporting flood management, ecological water quality improvement and maintenance. To include an International standard Regatta facility.	Reflects a natural open water form. The Warm Up Lake foreshore profiles generally appear natural in gradient. A standard international course, straight with at least 6 operational racing lanes, and at least 3 metres deep at the shallowest point. The course is sheltered from wind as far as possible and has no natural or artificial obstacles (such as woods, buildings, structures) in the immediate neighbourhood of the course that might cause unequal conditions on the water. There are no streams or waves, with the banks designed to absorb rather than reflect waves. For a World Championship or a Regatta World Cup a minimum of 8 racing lanes are available, plus sufficient water width on both sides of the course allowing for both safe traffic patterns and for moving lanes in case of unequal conditions.
Lake A & B	To maximise passive and active recreational activities.	In keeping with the floodplain landscape, foreshore profiles generally appear natural in gradient and planting types/ communities.

Table 6: Suggested terrestrial and water-based activities for the main recreation lakes.

SITE	TERRESTRIAL ACTIVITIES	WATER-BASED ACTIVITIES
SIRC Lakes	Picnic and BBQ areas within the public parklands.	Kayaking/canoeing/Regatta Fishing Beach activities such as swimming in designated areas, sunbathing.
Main Lake A	Exercise stations along walking tracks or within specific play areas and/or parklands. Mountain Bike riding on designated tracks. Attending staged special events. Informal and formal sports. Playing within playgrounds and other areas of interpretive play equipment. Picnic and BBQ areas within the public parklands.	Sailing Special intermittent use of the lakes by power boats including water skiing, wake boarding etc. Windsurfing Wildlife appreciation Designed and constructed to accommodate swimming activities
Main Lake B	Walking and cycling along the Great River Walk and other Heritage Trails. Guided tours of European and possibly Aboriginal Heritage Sites. Camping in designated areas. Picnic and BBQ areas within the public parklands. Horse and dog exercise tracks.	Sailing Fishing Kayaking/canoeing/Regatta Windsurfing Wildlife appreciation Designed and constructed to accommodate swimming activities

Table 7 summarises the purpose and the character of the Wildlife Lake, Eastern Lakes and other water bodies used primarily for wildlife habitat, conservation and water quality management respectively. Table 8 summarises the terrestrial recreational activities and water-based activities adopted by PLDC for modelling purposes and preparation of Two Year Plans.

Table 7: Purpose and design character of the Wildlife Lake, the Eastern Lakes and other water bodies.

SITE	PURPOSE	DESIGN CHARACTER
Wildlife Lake	Optimise attractiveness to wildlife, provide suitable habitat and enable scientific research and educational purposes. Retain some historical uses whilst supporting flood management, ecological water quality improvement and maintenance. The design of the Wildlife Lake and its immediate surrounds communicates different layers of history associated with the site through landscape features and interpretation.	Reflect a natural open water form with refuge islands, wetlands and a focus on wildlife habitat. Foreshore profiles generally appear natural in gradient and planting types/ communities. Foreshores are influenced by the geometric nature of the former land grant boundaries as appropriate near Landers Inn. This promotes natural ecological processes while integrating cultural heritage. Topography is constructed with natural resources from within the Penrith Lakes Scheme. Visually integrated within the context of the floodplain and river, including the use of trees of local provenance, shrubs and grasses of the original floodplain.
Eastern Lakes, including Duralia Lake, and other water treatment wetlands	Provide primarily passive recreation whilst also supporting flood management, ecological water quality improvement and maintenance, providing suitable habitat for wildlife and enabling research. Can accommodate some active water surface sports and land based activities with Duralia Lake being suitable for swimming.	Foreshore profiles generally appear natural in gradient and planting types/communities. Topography is constructed with natural resources from within the Penrith Lakes Scheme. Visually integrated within the context of the floodplain and river, including the use of trees of local provenance, shrubs and grasses of the original floodplain.

Table 8: Suggested terrestrial and water-based activities for the Wildlife Lake, Eastern Lakes and other water quality management wetlands.

SITE	TERRESTRIAL ACTIVITIES	WATER-BASED ACTIVITIES
Wildlife Lake	Conservation and research activities. Wildlife appreciation such as bird watching and eco-guided tours associated with the conservation area surrounding the Wildlife Lake. Guided tours of European and possibly Aboriginal Heritage Sites. Pick your own 'Farmers Gate' produce and other activities associated With potential agricultural and/or horticultural interpretation.	Wildlife appreciation Scientific research and educational purposes
Eastern Lakes	Passive recreation walking tracks cycling trails Picnic areas Amphitheatre (Duralia Lake)	Fishing Wildlife appreciation Some water surface sports Swimming in Duralia Lake
Southern Wetlands & Quarantine Lake	Walking and cycling along the Great River Walk Passive recreation Walking tracks Bird watching	Wildlife appreciation Scientific research and educational purposes

3 GROUNDWATER MANAGEMENT

The Penrith Lakes Scheme is located in a topographical depression on the alluvial floodplain of the Nepean River above Quaternary-aged alluvial deposits primarily comprising sand and gravel. Natural groundwater flows through the lower alluvial terrace across the Scheme in a west-northwest direction, ultimately discharging to the Nepean River.

The Scheme will result in a series of lake formations that interact with the natural groundwater flows. Potential risks associated with this interaction include the intrusion of poor water quality into the lakes as well as acting as a local groundwater sink, impacting available water from upstream aquifers. In response to these potential impacts PLDC has conducted several hydrogeological assessments across the Scheme to model and quantify the Scheme's impacts.

To protect surrounding aquifer water extraction licence holders from being affected by the Scheme, PLDC is required to provide alternative water sources to any licence holders that can show they have been impacted by the Scheme. To date PLDC has not been required to provide alternative water resources, and in compliance with part 4 consents, there have not been any adverse impacts on the surrounding aquifer or residents due to the Scheme.

The 2012 Water Balance study undertaken by Cardno as part of the Stage 1 Water Management Plan assessed infiltration rates from previous hydrogeological surveys conducted by PLDC. Cardno concluded that the diversity of weather events across a 100 year period can result in large variations in groundwater infiltration rates from 3.0 to 0.3 Gigalitres a year. Cardno's (2013) water balance model subsequently used a mean of 1.65 Gigalitres a year for groundwater modelling for the 2012 Water Management Plan.

Consistent with Cardno's (2012) model, BMT's (2019) hydrological model for the completed Scheme (inclusive of redesigned Southern Wetlands) used the following methodology to calculate groundwater flows:

- For the eastern lakes, a constant flow of 0.3 GL/yr was applied to Cranebrook Lake only.
- For the western lakes, total groundwater flow was taken to be proportional to annual rainfall, interpolated between a maximum of 2.7 GL/yr and average of 1.3 GL/yr and split between lakes Quarantine Lake to Wildlife Lake, weighted by catchment size.

BMT's Hydrological Modelling of Resized NRPP (2019) is Appendix 2 to this document.

PLDC had also conducted previous investigations into the potential impacts of groundwater on the Scheme by installing three additional bores marked P30, P31 and P35 in Figure 3 as a means of further monitoring groundwater quality and volumes entering from the north-eastern locations of the Scheme. Monitoring data from these bores as well as historical bores were collated and reported by Nation (2014).

Nation (2014) included an assessment of historic reports and assumptions as well as incorporating water quality data previously collected from the bores across the site into their assessment. A key objective for the updated monitoring report was to build a conceptual model and provide details of what assumptions (if any) should be made when incorporating groundwater flows into the future Scheme operations and water quality assessments. The report concluded that even though groundwater would provide a beneficial contribution to the site wide water balance by reducing the need to extract water from the Nepean River, most of it represents a direct infiltration from rainfall and runoff within the Scheme, with less than 1% of the total Scheme volume originating from off-site sources that include potential saline groundwater.

Considering the limited volumetric contribution of off-site sources including potential saline groundwater to the Scheme, accounting for groundwater quality inputs in future water quality assessments was not considered necessary.

Nation's Hydrogeological Assessment report is provided in Appendix 3.

The reports and associated data collated since the Scheme's inception have generally found that there is minimal interaction with surrounding aquifers and a low risk of impacting on the water quality within the Scheme.

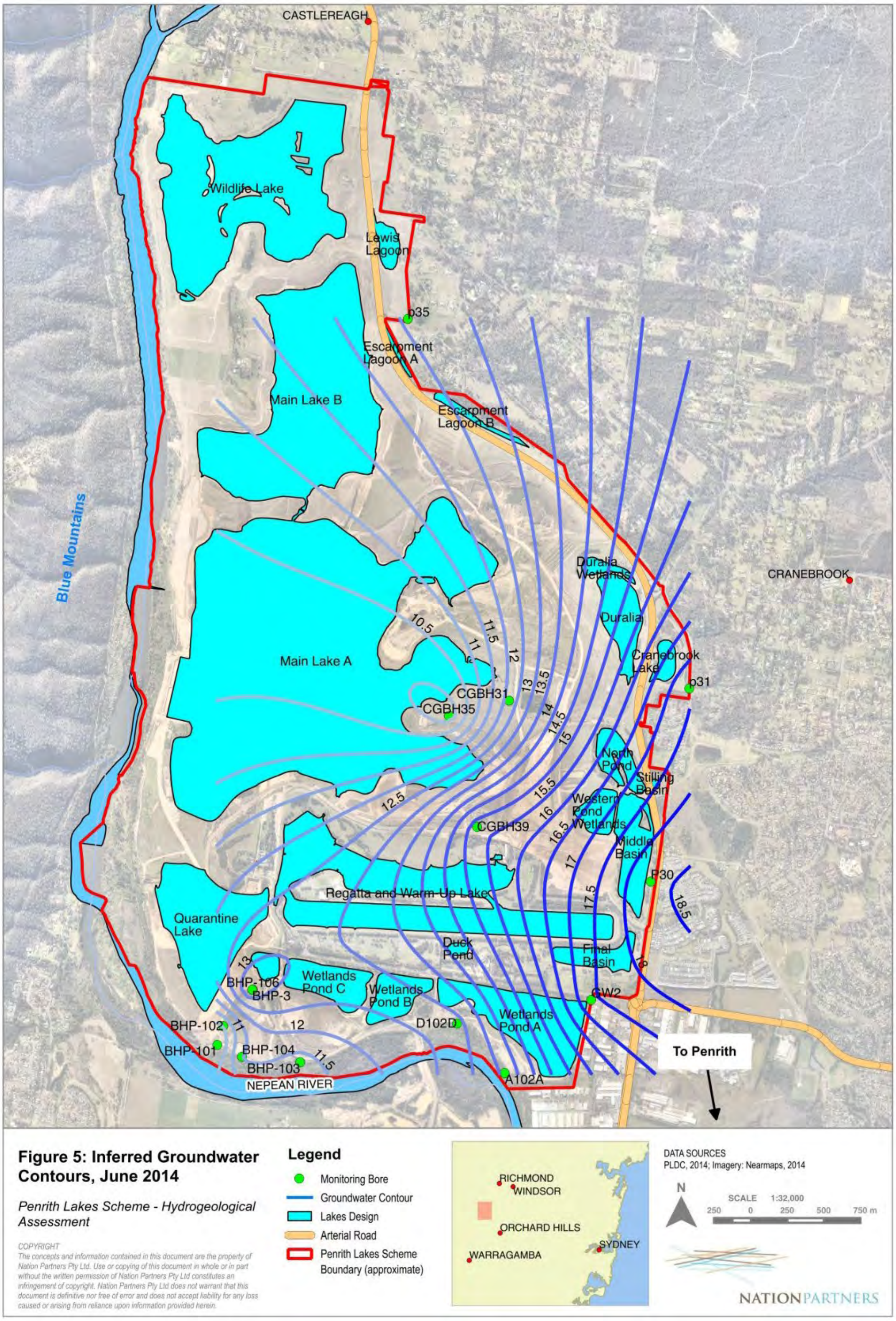


Figure 3: Inferred groundwater contours across the Penrith Lakes Scheme by Nation (2014).

4 STORMWATER MANAGEMENT

The Penrith Lakes Scheme receives stormwater from approximately 3,000 hectares of peri-urban development, dominated by rural residential properties to the north and intensive urbanisation to the south. The stormwater received from these catchments varies dramatically in quality, with water sources typically high in faecal bacteria pollution, particulate nutrients and suspended solids. Left untreated this water is likely to impact on the achievement of water quality to support the desired end uses of the Scheme.

Treatment options employed within the Scheme include treatment wetlands as well as high capacity detention basin systems fitted with sluice gates to increase water residence times. These treatment facilities and an extended period of management have shown to be highly effective in the treatment of stormwater as demonstrated by the historical water quality measurements from the SIRC lakes over the past decade and a half.

Wetland systems located at Duralia and Cranebrook Lake inlets have been developed to filter incoming stormwater prior to entering the lakes. These wetlands were established in 2004 with a wide variety of macrophyte species and have since developed to provide significant water quality and ecology benefits to the lakes. This is evidenced by the continually high water quality and fauna diversity recorded in these lakes. Also a water quality control pond (Lewis Lagoon) has been constructed to improve water quality flowing into the Wildlife Lake.

Ashbolt and Roser (2004) investigated the surrounding catchments and examined residence times required to control the risk of faecal bacteria pollution entering the SIRC lakes. The study concluded that inflows in excess of 43 megalitres from the Scope and Farrell's Creek pose a significant risk of faecal bacteria pollution entering the Scheme. Waters suspected of faecal bacteria pollution are retained in the detention basin system by closing the sluice gates, with the consequential extended residence times aiding in the natural UV disinfection of these waters.

Poor water quality from the surrounding catchment poses a significant risk to the long-term performance of the Scheme. AECOM (2013) were commissioned by Penrith City Council to review the catchment and assess the potential for applying WSUD features to improve water quality. Recommendations made with respect to WSUD could potentially provide significant improvements to the water received in the Penrith Lakes System and should be implemented in full to protect the Scheme. Source management of water quality is seen as critical to the future performance of the Scheme and ongoing achievement of the end use values.

Specifically, the Employment Land located to the east of the Southern Wetlands will ultimately discharge its stormwater into the wetland treatment system once the site is developed. These inflows have been accounted for in the revised wetlands layout as well as the Hydrological Modelling (Appendix 2) and Water Quality Modelling (Appendix 4) of the Scheme. The Employment Land development will be required to treat any stormwater with gross pollutant traps in accordance with WSUD guidelines prior to discharge into the wetland system. The Southern Wetlands will provide all further water quality treatment and on-site detention required to service the proposed Employment Land development in accordance with WSUD guidelines.

Overall, the management of stormwater inflows to the Scheme has been successful in delivering the targeted quality of waters entering the SIRC Lakes and the achievement of the desired end water uses. Recent changes to the design and introduction of the new pump & pipeline connection between Final Basin and Southern Wetlands is expected to further improve the capacity of the Scheme to manage stormwater runoff entering through the Eastern Lakes.

Vigilance will be required in the future as further changes to land use occur in the catchments external to Penrith Lakes and some further deterioration in water quality entering the lakes from those catchments is expected to occur.

5 ECOSYSTEM DEVELOPMENT

Aligned with the original principles of the RES, PLDC has continually promoted the establishment of natural ecosystems and ecological processes. These include promoting in-lake aquatic ecology and establishing submerged and emergent macrophyte assemblages and structural habitat to support various trophic levels within the Lakes. These principles have been implemented and monitored and demonstrate considerable success in the completed and dedicated lakes and water bodies with PLDC applying an adaptive management approach aiming to continually improve the establishment of these ecosystems and processes.

Steps taken by PLDC to promote the development of various ecosystems and associated communities during the different phases of lake formation are summarised below in Figure 4 and expanded upon further through this section of the Plan.

Land forming	•Geotechnical assessment ensuring lake and landform stability •Aquatic habitat structures and macrophyte benches installed
Lake Filling	•Water sourced from pre-established areas •Surrounding landforms designed to complement lakes and treat runoff
Early Aquatic Ecosystem Establishment	•Planting of submerged and emergent macrophytes •Natural propagation allowing for establishment of invertebrates and small fish communities
Ecosystem Stocking	•When the ecosystem is established Australian Bass are stocked into the lakes as a predatory and health indicating species •Macrophyte plantations are assessed and altered as required
Ongoing Monitoring	•Monitoring the established ecosystem ensuring it meets requirements •Monitoring can include assessing water quality, as well as fish, invertebrate, amphibian, bird and macrophyte communities

Figure 4: Summary of ecosystem development stages and key features.

5.1 LAND FORMING

Landscape plans are developed well in advance of construction and approved via a Two Year Plan process under existing approved development consents. Landscaped features are designed to ensure a wide range of habitats are established providing opportunities for a diverse range of ecosystems. The landscape principles applied to the Scheme aim to optimise the extent and diversity of ecotones. They also provide a link between key habitats and core conservation zones while re-establishing native vegetation from pre-European settlement. Lake foreshores have been designed to, as far as practicable, replicate the historical Nepean floodplain landscape.

These goals are achieved by:

- reinstating Cumberland Plain Woodland vegetation communities and native provenance grasslands across the Scheme;
- designing no greater than 1:6 batters around lake edges with several macrophyte shelves and edge complexity providing various littoral zones within the lake foreshore;
- providing drainage channels that are protected with natural grass swales; and
- establishing habitat enriched with placement of soft woody debris and sandstone structures throughout lake foreshores and lake beds.

5.2 LAKE FILLING

As the Scheme has been established for well over a decade, natural ecosystems have been well established through the detention basin systems and the SIRC lakes. River-sourced water required to fill the remaining recreational lakes enter through the SIRC lakes (unless Quarantine to Lake A by-pass is activated) prior to flowing north into the recreational lakes, transferring with it a large volume of invertebrate biota, juvenile fish and macrophyte propagules and seeds. It is expected this enhancement will significantly reduce the time required for stable ecosystems to establish within the newly formed lakes and that has been the experience to date with the completed and dedicated lakes and water bodies.

Wetland systems have been designed into the Scheme where necessary or desirable to treat water prior to entering the lakes system. The wetland systems function to reduce nutrient and suspended solids loads entering the lakes as well as increase residence time to reduce bacterial contamination. Stormwater drainage from within the Scheme utilises a series of rock or fabric-protected grassed swales, providing water treatment for internal Scheme stormwater flows. The foreshores where practical also contain tree plantings and emergent macrophytes to enhance bank stability and nutrient and sediment retention.

5.3 EARLY AQUATIC ECOSYSTEM ESABLISHMENT

The Scheme relies heavily on the natural propagation of lower trophic biota such as macrophytes, algae and invertebrates. PLDC on-site experience and scientific studies have shown these processes readily take place in the developing lakes and treatment systems, with SIGNAL scores for invertebrates improving through the detention systems and reflective of the water quality achieved within the system.

Aquatic macrophytes are important as primary producers in aquatic food webs and are also critical for nutrient re-cycling within the lakes and in the riparian zone. Different species occupy different parts of the riparian zones of the lakes. Those that can withstand high water regimes and flooding occupy the littoral zones, while those that can withstand prolonged dry periods extend from the upper riparian areas into the terrestrial environments. Others that are totally dependent on water occupy niches within the lakes, either as emergent, submerged, or as floating species. Submerged macrophytes create habit, modify hydraulic conditions, and affect temperature and light conditions in the water column.

Emergent macrophytes and riparian zone plants play an important role in stabilising lake margins and banks; they also slow runoff, filter sediments and take up nutrients entering the lake system.

The riparian zone provides habitat for fauna and a buffer between terrestrial and aquatic ecosystems. Extensive planting has occurred along the margins of the lakes and other water bodies using local native species from relevant Cumberland Plain plant communities. Canopy species provide shading of the lake edge through overhanging branches and sub-canopy, shrub and ground covering species provide faunal habitat, reduce stormwater runoff velocities and assist in reducing the amount of pollution entering the water column.

Aquatic macrophytes respond in various ways to hydrological and edaphic factors and are sensitive to disturbances. Information on the species present and their health is important for management to establish long-term trends and it is therefore necessary to measure levels of recruitment, extent, distribution and abundance of species. Assessments of species composition and community structure are indirect indicators of resilience to change. Noting the presence of noxious aquatic weeds and other undesirable species is important from a due diligence perspective and to reduce the risk of unexpected outbreaks or contamination of other water bodies.

Aquatic macro-invertebrates constitute a major component of aquatic food chains and are common and widely distributed. They rapidly colonise newly formed water bodies from surrounding catchments and landforms as they are sensitive to changes in ecological conditions, particularly physio-chemical stressors, and their use in biological assessments is well established.

5.4 ECOSYSTEM STOCKING

After the ecosystem has established, assessments of the aquatic community are conducted to assess if the water body can support stocks of Australian Bass (*Macquaria novemaculeata*). It is considered beneficial to stock Bass as soon as the ecosystem can support them as they provide a top-order predator and have been shown to control numbers of noxious fish populations such as European Carp (*Cyprinus carprio*) as well as Mosquito fish (*Gambusia holbrooki*).

PLDC has implemented a native fish stocking program since 1996. To date 207,200 Australian Bass fingerlings have been stocked into the Scheme. Some eight native fish species occur in the lakes together with three exotic pest species. The native fish dominate with small bodied species providing food for the larger bodied bass.

5.5 ONGOING MONITORING

PLDC has established an integrated monitoring program to inform a holistic review of the performance of these ecosystems. The monitoring programs undertaken across the Scheme include assessing key indicator species such as macrophytes, macroinvertebrates, amphibians

and fish as well as routine chemical and biological water quality monitoring to assess trends in algal and bacterial populations as well as overall nutrient loading within the lakes.
The integrated monitoring program has demonstrated significant progress in achieving environmental outcomes including:

- constructed lands and static environments showing comparable soil performance - Landscape Function Analysis;
- control and eradication of Salvinia (*Salvinia molesta*), Alligator weed (*Alternanthera philoxeroides*) and Water Hyacinth (*Eichhornia crassipes*);
- 9 native frog species observed around the Scheme;
- 165 bird, 23 mammals and 15 reptile species regularly recorded on site;
- 61 families of macroinvertebrates – showing improved community structures routinely across the Scheme;
- 91% of Total Phosphorus and 73% of Total Nitrogen loads removed from the surrounding peri-urban catchment inflows via the detention basin system*;
- the Sydney International Regatta Centre water quality suitable for Primary Contact 95% of the time since 1996*; and
- Duralia Lake water quality suitable for Primary Contact 95% of the time since 2008*.

*Note: PLDC ceased management and monitoring activities in Eastern Lakes and SIRC in 2014.

6 FISHERIES MANAGEMENT

Additional to the aforementioned ecological benefits of establishing a stable fish community, establishing the Penrith Lakes Scheme as a recreational fishery in Main Lakes A and B is a core end use objective envisaged in the 1987 Deed.

Australian Bass (*Macquaria novemaculeata*) is the only fish species that has been stocked within the Penrith lakes Scheme. Since 1996, 207,200 'fingerling' (approx. 3cm) sized Australian Bass have been stocked into the Penrith Lakes Scheme. These stocking events have been documented and approved by NSW fisheries, including participation in the Dollar for Dollar stocking initiatives.

The fish stocking has provided the SIRC lakes with an opportunity to develop a regular recreational fishing program open to the public currently administered by NSW Fisheries Fishcare volunteers. The venue also successfully hires out the lakes to fishing clubs to conduct fishing competition days for enthusiasts.

Details of fish stocking events post the year 2000 to date as well as total numbers stocked has been provided in Table 9.

Note that PLDC has not undertaken any additional fish stocking of lakes since 2012. It is envisioned that additional fish stocking would occur as required once Scheme wide lake levels are established and all water infrastructure is complete.

Table 9: Australian Bass stocking records across the Penrith Lakes Scheme.

Lakes Stocked	1996	1997	1998	1999	2000	2001	2002	2004	2005	2009	2011	2012	2016	2019	Total
Regatta Lakes	12,000	10,000	12,000	12,000	5,000	7,000	12,000	2,000	6,000	30,000		20,000	5,000	9,000	142,000
Main Lake A					5,000	1,200		4,500	6,000						16,700
Final Basin		2,000						4,000	2,000		2,000				10,000
Middle Basin					2,500				2,000		3,000				7,500
Northern Pond					2,500			5,000	2,000		2,000				11,500
Duralia Lake								6,000	3,000	6,000					15,000
Cranebrook									3,000		1,000				4,000
Duck Pond								500							500
TOTAL	12,000	12,000	12,000	12,000	15,000	8,200	12,000	21,500	24,000	36,000	8,000	20,000	5,000	9,000	207,200

The potential of the completed Scheme to operate as a desirable recreational fishery has been demonstrated by the successes at the SIRC. Considered management of fishing practice will be required if a sustainable fishing community is desired by the completed Scheme operators. This is due to the Australian Bass being a catadromous fish species, unable to breed within the landlocked Scheme.

Additional recreational fish that have populated the lakes include the Eel-Tailed Catfish (*Tandanus tandanus*) and the European Carp (*Cyprinus carpio*). While the Carp is generally not regarded as a sport fish in Australia, recreational fishers are encouraged to target the species and ensure they are euthanized to control carp numbers. All other fish captured on the Penrith Lakes Scheme are required to be released unharmed to maintain the populations.

No provisions are proposed for fish passage in and out of the Scheme under normal operations in the proposed Scheme design. This decision has been made with the concurrence of NSW Fisheries as it reduces the risk of stocked fish leaving the system, while preventing the entry of noxious fish species.

Work by the DIPNR Water Committee (2005) also emphasised the risks associated with fish passage being permitted from the Nepean River as there is a serious risk of the endemic Bullrout (*Notesthes robusta*) fish entering the lakes. The Bullrout is a relative of the scorpion-fish species, with venomous spines which are extremely hazardous in recreational areas.

7 WATER QUALITY MODEL

In preparing the Stage 2 Water Management Plan a predictive computer model was developed for PLDC by BMT for the Scheme simulating final conditions (Appendix 4). The model allowed for extensive monitoring data collected from the Penrith Lakes site spanning well over 10 years, to be incorporated into the modern computer modelling platform. This approach provided a robust, all-inclusive model for testing the efficacy of the Scheme water quality and aquatic ecology systems through a range measured climatic conditions.

This model, originally calibrated and validated in 2014, was used again in 2020 to simulate water movement and quality within the final design of the Penrith Lakes Scheme inclusive of the latest concept design of Southern Wetlands, resized and relocated NRP&P, as well as Final Basin to Southern Wetlands and Quarantine Lake to Lake A connections.

The predictive model is a combination of three individual models, including a catchment model, a hydrodynamic model and a biogeochemical aquatic ecosystem model. The system operations of these models are shown in Figure 5 below.

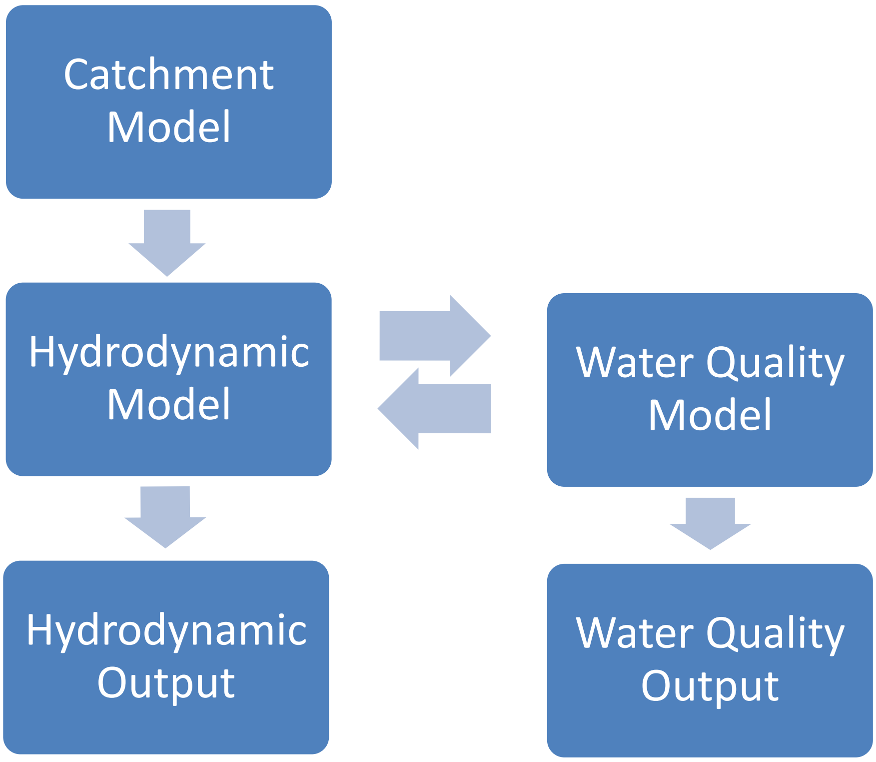


Figure 5: Systems representation of the Water Quality Model.

Preparation of the predictive model involved calibrating the water quality parameters for the updated Scheme model against the original water quality model calibration (BMT WBM 2014). To achieve an acceptable level of calibration, and in absence of flux measurements, benthic sediment flux parameters were adjusted to compensate for the addition of simulated groundwater flows into the Scheme. Refer Appendix 5 Water Quality Calibration Results.

7.1 USES OF A PREDICTIVE MODEL

The predictive model allows for hydraulic and water quality simulations of the individual lakes system as well as an evaluation of the overall operation of the lakes. These simulations cover the climate sequence from 1984 to 1995 which is consistent with other water management modelling undertaken by Government.

The key benefits of the model include the ability to:

- simulate existing water quality;
- envisage water quality performance in the developing lakes well before they are dedicated;
- test a variety of water management options including the validity of additional infrastructure; and
- test at source water management options.

7.2 CATCHMENT MODEL

Catchment boundary conditions were retained from previous modelling works (BMT WBM, 2014). PLDC supplied BMT with the MUSIC (Modelling Urban Stormwater Improvement Conceptualisation) models of the surrounding catchment inflows.

One being the same model used in the 2014 modelling over the same 95-year period (Cardno, 2012). The other catchment MUSIC model being for the Employment Land directly adjacent to the Southern Wetlands which accounts for the future development of that site.

The two models were merged by BMT and their rainfall and potential evapo-transpiration (PET) extracted for subsequent use in the hydrodynamic (TUFLOW FV) model.

Figure 6: Penrith Lakes Catchment Inflows (not to scale) in Cardno (2012).

The catchment model covers an area of 2094 hectares of adjacent catchment and was calibrated using available time series data to simulate flow and water quality emanating from the adjacent catchments. The performance of the calibration model was then verified against measured data within the lakes and found to be fit for purpose.

7.3 LAKES HYDRODYNAMIC MODEL

The TUFLOW FV hydrodynamic water model was used to simulate the hydrodynamics of the Lakes

Scheme. This includes capturing the effect of flow regulating devices and culverts throughout the Scheme, inflows from catchment MUSIC models and groundwater, water extracted from the Nepean River through the resized Nepean River Pump & Pipeline (NRPP) as well as water pumped from Final Basin to Southern Wetlands, and responses to climatic conditions. The TUFLOW FV hydrodynamic model has been calibrated using a combination of water flows and level telemetry, climatic conditions and thermistor chain data. Further details relating to the Hydrodynamic model is provided in Appendix 2 Hydrological Modelling of the Resized NRPP.

The resized NRPP flows have been modelled to maintain operating lake levels within the Scheme. Historical NRPP pumping rates have been modelled at 1.0m^3/s however this has been reconfigured to pump at a more sustainable 0.2m^3/s to maintain lake levels within the Scheme. The following NRPP pumping rules were applied for the Scheme hydrological modelling:

- The maximum rate of pumping from the Nepean was set at 0.2 m^3/s.
- Pumping was allowed from the Nepean when the flow at Penrith weir was greater than 50 ML/day. During periods of fish migration additional constraints were applied in addition to this rule:
  - The periods of fish migration were from 1 Sep to 30 Nov (Bass migration) and 1 Feb to 30 Apr (Mullet migration).
  - During these periods, pumping could commence only when flow at Yarramundi weir was greater than 500 ML/day.
  - Pumping was set to then cease during fish migration periods when the flow at Yarramundi was less than 350 ML/day.
- Pumping was triggered (subject to the above availabilities) when water levels fell below 15m or 13.5m in Regatta or Lake A, respectively.
- The annual pumped volume in a water year (1 July to 30 June) was capped at 3.3 GL.

The report concluded that both catchment hydrology and representative groundwater inflows will be essential for maintaining the water levels within the Scheme along with pumping from the Nepean River with up to 3.3GL expected to be required most years to maintain lake operating levels.

The effectiveness of the pumping is proved in Scenario 1 of the Hydrological Modelling when Wildlife Lake runs dry during low rainfall periods, while Regatta and Main Lakes are able to operate normally.

Addendum: Hydrological Modelling of the Resized NRPP in Appendix 2.

The rate for pumping between Final Basin and Southern Wetlands will be 0.2 m^3/s and not 0.4 m^3/s as modelled in the Hydrological Modelling of the Resized NRPP (Appendix 2, Table 2-1). The model therefore simulates pumping water between Final Basin and Southern Wetland at twice the rate intended. It should be noted, however, that this would not impact on the total volume of water pumped between the two systems as this is capped by the commence-to-pump (16.5 m AHD) and cease-to-pump (16.0 m AHD) rules.

7.4 LAKES WATER QUALITY MODEL

The AED model (Aquatic Eco Dynamics model, developed by the University of Western Australia) allows for the simulation of the key biogeochemical processes within the Lakes Scheme. A schematic of these processes is shown in Figure 6. The AED model has been calibrated using the suite of in-lake water quality data collected within the existing Lakes Scheme. This data has then been used to define the biogeochemical processes and formulas within AED, replicating the measured performance of the existing lakes Scheme.

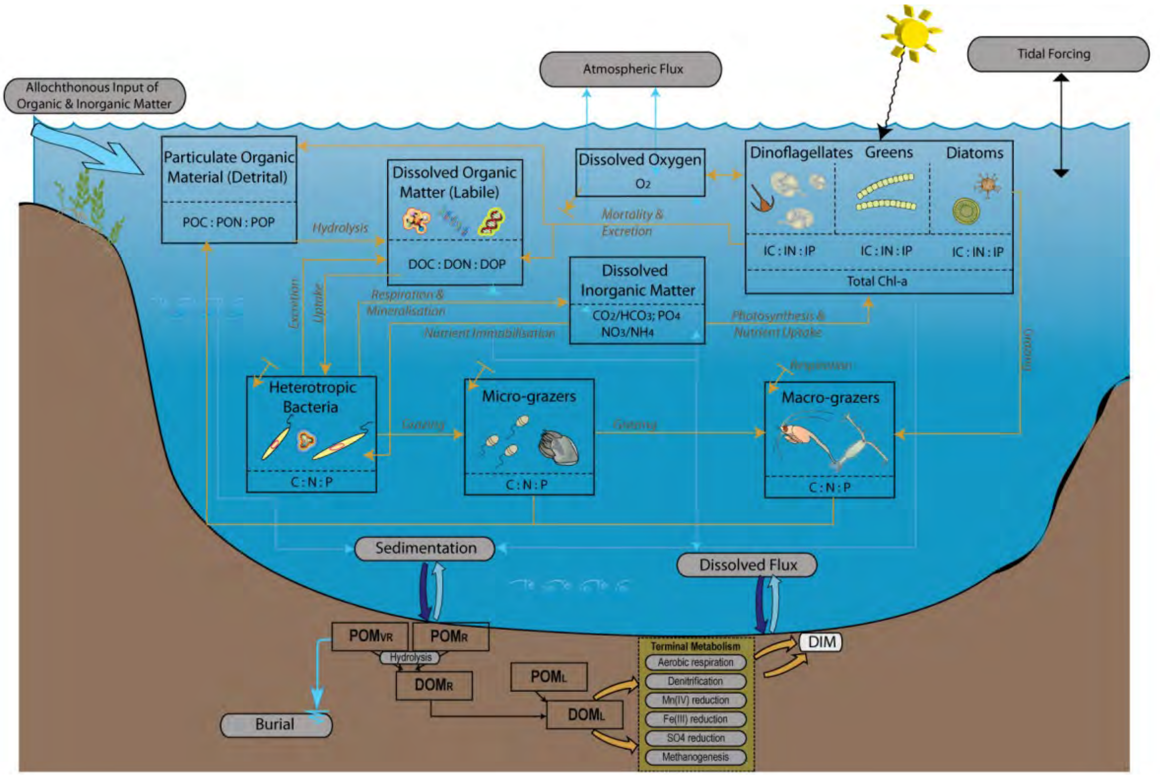


Figure 6: Diagram of AED carbon and nutrient flux pathways

8 WATER QUALITY MODEL OUTCOMES

The water quality model was operated, applying the calibrated parameters from the established lakes and applying these parameters to the proposed 2020 Scheme design. As discussed previously, the 2020 Scheme design has seen a number of changes including an improved design of the Southern Wetlands treatment system as well as additional hydrological connections between Final Basin and Southern Wetlands and Quarantine Lake and Lake A. The model is coupled to the resized Nepean River pump and pipeline hydrological model to permit initial filling and ongoing top-up water pumping when required.

The model has assumed all lakes start at operating level and contain an established ecosystem. The sluice gates across the Scheme have remained permanently open with exception of the Final Basin to Regatta Lake sluice gate connection which position varied depending on whether or not the Final Basin pump and pipeline was in use.

The model simulates a measured 10 year climatic sequence spanning from 1985 to 1994, allowing for the catchment and groundwater inflows, as well as for incidents of both dry and wet climatic sequences. The climatic span also aligns with the modelling undertaken on the Nepean River, allowing for full integration.

Two scenarios were simulated to assess the performance of the revised Southern Wetlands design:

Scenario 1: Pumping of water from Final Basin to the first cell of the Southern Wetlands.
Scenario 2: Allowing water from Final Basin to exit directly to Regatta Lake, thereby bypassing the Southern Wetlands.

Addendum: Penrith Lakes Scheme – Water Quality Model of Southern Wetlands (Appendix 4)

The rate for pumping between Final Basin and Southern Wetlands will be 0.2 m^3/s and not 0.4 m^3/s as modelled in Scenario 1 of the Water Quality Modelling (Appendix 4, Table 2-1). The higher pumping rate modelled simulates pumping water between Final Basin and Southern Wetland at twice the rate intended. It should be noted, however, that this would not impact on the total volume of water pumped between the two systems as this is capped by the commence-to-pump (16.5 m AHD) and cease-to-pump (16.0 m AHD) rules.

Because water is being pumped at twice the rate in Scenario 1 of the model simulations, this may have a variable impact on detention times within the wetlands. That is, depending on the volumetric status of the wetland at any point in time, detention time in the wetlands could be lower than it would have been if the correct flow rate was used. This would mean that the contact time of waters within the wetland would be slightly lower than otherwise so the uptake / assimilation of pollutants could potentially be slightly lower making this a more conservative water quality simulation than if the correct flow rate was used. Thus water quality entering Quarantine Lake could be expected to be slightly improved if the actual flow rate of 0.2m^3/s had been used.

Environmental Value Composite Indices:

The assessment of water quality in the Penrith Lakes Scheme was undertaken using a combination of water quality guidelines including:

- The 1987 Deed of Agreement (DoA).
- ANZECC (2000) Guidelines for Fresh and Marine Water Quality.
- NHMRC (2008) Guidelines for Managing Risks in Recreational Water.

These identified water quality parameters and their associated guideline values formed the basis of the calculation of composite indices for each of the three key environmental values (EVs) presented below:

- Protection of aquatic ecosystems – all lakes (not including the eastern detention basin system).
- Primary Contact Recreation - Regatta Lake, Warm-up Lake, Main Lakes A & B.
- Secondary Contact Recreation – Regatta Lake, Warm-up Lake, Main Lakes A & B.

Thematic maps illustrating the level of protection of the EVs of the primary lakes of the Scheme are presented in Figure 8. Actual percentages are provided below in Table 10.

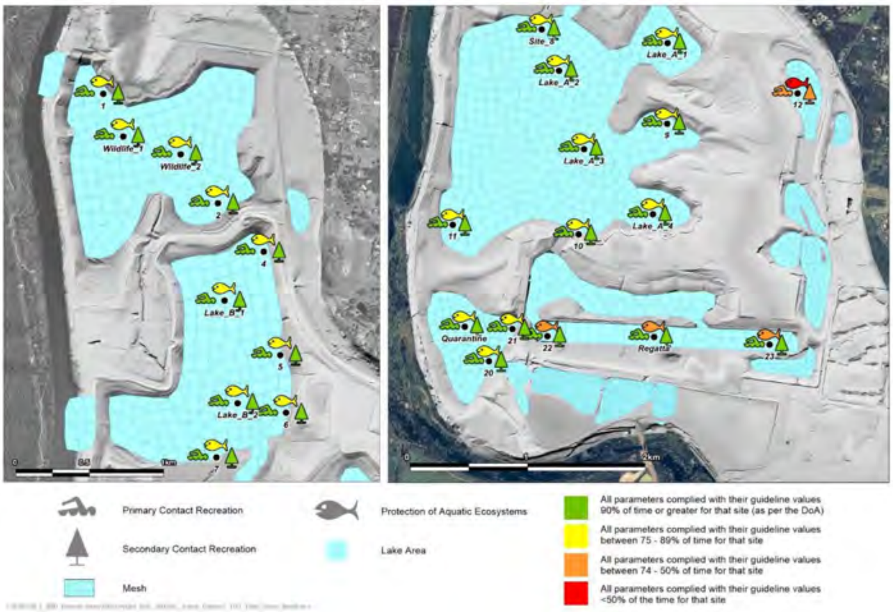


Figure 5-1 Composite Indices of lakes against Environmental Values in Scenario1

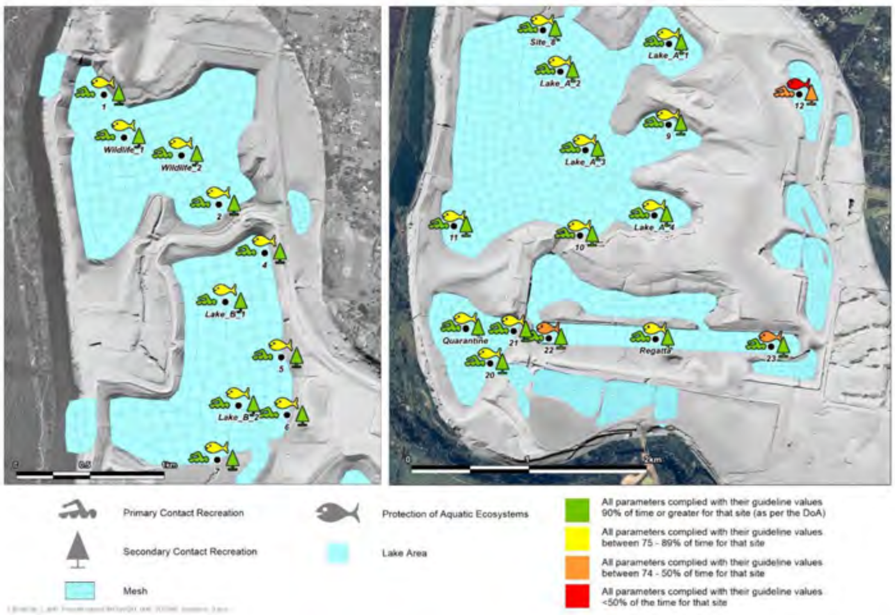


Figure 5-2 Composite Indices of lakes against Environmental Values in Scenario2

Figure 8: Composite Indices of lakes against Environmental Values in Scenarios 1 and 2

Table 10: Composite Indices of Lakes against Environmental Values

Lake Name	Locations of Interest *	Aquatic Ecosystems Scenario 1	Aquatic Ecosystems Scenario 2	Primary Contact Recreation Scenario 1	Primary Contact Recreation Scenario 2	Secondary Contact Recreation Scenario 1	Secondary Contact Recreation Scenario 2
Regatta	Site_22	73	74	99	98	99	98
	Site_23	72	71	98	94	98	94
	Regatta_extra	73	76	99	98	99	98
Lake A	Site_8	83	84	100	100	100	100
	Site_9	80	81	100	100	100	100
	Site_10	81	82	100	100	100	100
	Site_11	85	86	100	100	100	100
	Lake_A_extra_1	82	82	100	100	100	100
	Lake_A_extra_2	83	83	100	100	100	100
	Lake_A_extra_3	82	82	100	100	100	100
	Lake_A_extra_4	82	83	100	100	100	100
Lake B	Site_4	81	82	100	100	100	100
	Site_5	80	80	100	100	100	100
	Site_6	80	81	100	100	100	100
	Site_7	82	82	100	100	100	100
	Lake_B_extra_1	84	84	100	100	100	100
Lake B	Lake_B_extra_2	82	83	100	100	100	100
Duralia	Site_12	29	29	56	56	56	56
Quarantine Lake	Site_20	79	78	NA	NA	NA	NA
	Site_21	76	76	NA	NA	NA	NA
	Quarantine_extra	78	78	NA	NA	NA	NA
Wildlife Lake	Site_1	87	87	NA	NA	NA	NA
	Site_2	85	85	NA	NA	NA	NA
	Wildlife_extra_1	86	86	NA	NA	NA	NA
	Wildlife_extra_2	86	86	NA	NA	NA	NA

* refer Appendix 4, page 31 for measurement location within each Lake

Water quality parameters for the Primary Lakes against EVs in the Penrith Lakes Scheme have been summarised in Table 11 below, detailing the protection levels of the EVs for individual water quality parameters for the Primary Lakes.

Table 11: Protection Levels of the Environmental Values for individual water quality parameters

Primary Lakes	Locations of Interest *	DO saturation (%)		TN (mg/L)		Chlorophyll a (µg/L)		Cyanobacteria		Enterococci		NOx		NH4		FRP	
		Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Regatta / SIRC	Site 22	73	74	97	97	96	96	100	100	99	98	60	38	1	1	100	99
	Site 23	72	71	94	94	94	94	99	99	98	94	61	42	2	3	99	99
	Regatta extra	73	76	97	97	96	96	100	100	99	98	60	39	1	1	99	99
Main Lake A	Site 8	83	84	100	100	99	99	100	100	100	100	99	99	89	88	42	50
	Site 9	80	81	100	100	97	97	100	100	100	100	100	100	89	88	42	50
	Site 10	81	82	100	100	99	99	100	100	100	100	99	99	88	97	43	51
	Site 11	85	86	100	100	99	99	100	100	100	100	99	99	89	88	43	51
	Lake A extra 1	82	82	100	100	97	97	100	100	100	100	100	100	93	90	39	42
	Lake A extra 2	83	83	100	100	99	99	100	100	100	100	99	99	89	88	42	50
	Lake A extra 3	82	82	100	100	99	99	100	100	100	100	99	99	89	88	43	51
	Lake A extra 4	82	83	100	100	98	98	100	100	100	100	100	100	89	88	42	49
Main Lake B	Site 4	81	82	100	100	95	95	100	100	100	100	95	95	93	93	31	35
	Site 5	80	80	100	100	95	95	100	100	100	100	95	95	93	93	32	35
	Site 6	80	81	100	100	95	95	100	100	100	100	95	95	93	92	32	36
	Site 7	82	82	100	100	95	95	100	100	100	100	95	95	93	93	32	35
	Lake B extra 1	84	84	100	100	95	95	100	100	100	100	95	95	93	93	31	34
	Lake B extra 2	82	83	100	100	95	95	100	100	100	100	95	95	93	93	32	35
Duralia	Site 12	90	90	29	29	78	78	100	100	56	56	68	68	1	1	99	99
Quarantine	Site 20	79	78	94	94	99	99	100	100	100	100	88	95	34	64	99	99
	Site 21	76	76	96	96	100	100	100	100	100	100	87	95	34	64	100	100
	Quarantine extra	78	78	95	95	99	99	100	100	100	100	88	95	34	63	100	99
Wildlife	Site 1	87	87	95	95	94	94	100	100	100	100	96	96	77	76	60	60
	Site 2	85	85	95	95	92	92	100	100	100	100	96	96	79	78	62	62
	Wildlife extra 1	86	86	95	95	94	94	100	100	100	100	96	96	77	77	61	61
	Wildlife extra 2	86	86	96	96	93	93	100	100	100	100	96	96	78	77	61	61

* refer Appendix 4, page 31 for measurement location within each Lake

The simulations suggest that all Primary and Secondary Contact Recreation and the majority of Protection of Aquatic Ecosystem EVs (with exception of DO saturation parameter on the western side of scheme) are met throughout the Scheme under the composite index measures. The redirection of Final Basin outflow into the Southern Wetlands increases EV compliance of Regatta Lake.

<u>Southern Wetlands</u>

A revised layout and bathymetry for the Southern Wetlands was provided to BMT (Figure 9) and included in the modelling. The Southern Wetlands were configured to function as a nutrient sink with pollutant assimilation rates developed by E2 Design Lab specifically for this modelling exercise. The full report reviewing the efficiency of the re-configured Southern Wetlands can be found in Appendix 6.

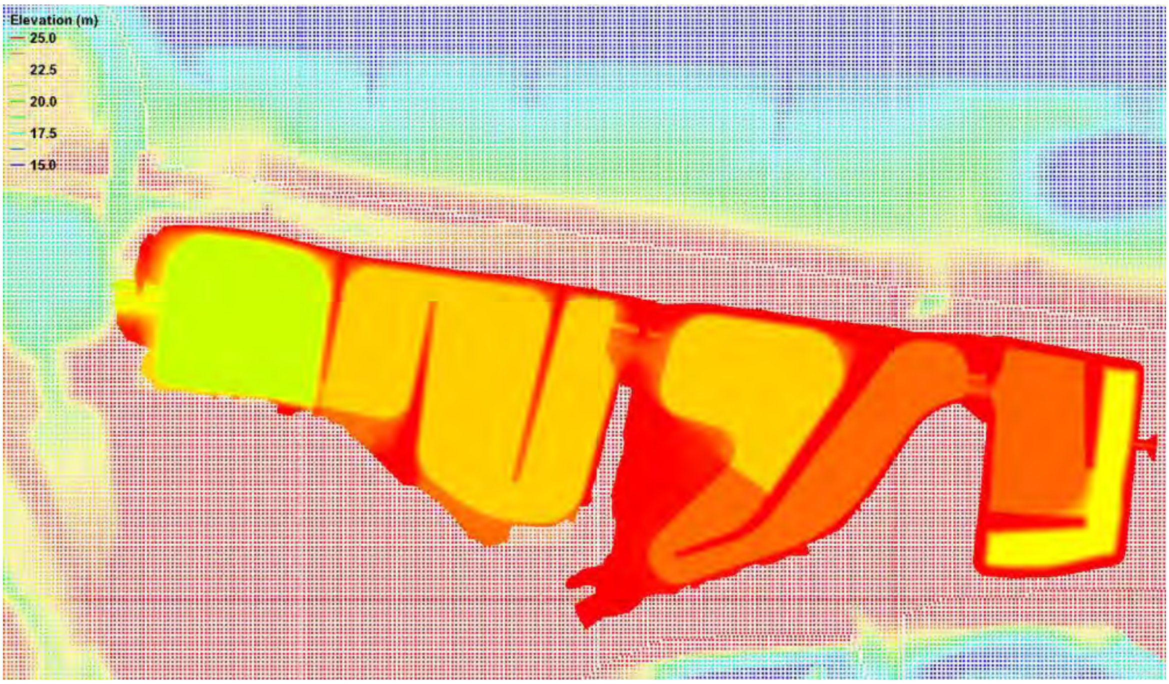


Figure 9: Updated digital elevation model for the Southern Wetlands.

To quantify the effectiveness of the revised Southern Wetlands system, pollutant fluxes at the entrance and exit of the Southern Wetlands were extracted from the model, compared and the percent reduction calculated. Nutrient loads are presented in Table 12 as annual average tonnes of TSS, TN, TP and algal carbon, and as CFU for Enterococci.

Table 12: Annual pollutant load reduction through Southern Wetlands.

<table>
<tr><th rowspan="2">Protection Value</th><th rowspan="2">Pollutant Load (tonnes/year)</th><th colspan="2">Entrance</th><th colspan="2">Exit</th><th colspan="2">Percent reduction</th></tr>
<tr><th>Scenario 1</th><th>Scenario 2</th><th>Scenario 1</th><th>Scenario 2</th><th>Scenario 1</th><th>Scenario 2</th></tr>
<tr><td rowspan="2">Aquatic Ecosystems</td><td>TSS</td><td>28.8</td><td>6.6</td><td>17.1</td><td>2.7</td><td>41%</td><td>55%</td></tr>
<tr><td>TN</td><td>2.5</td><td>1.5</td><td>0.3</td><td>0.2</td><td>87%</td><td>98%</td></tr>
</table>

Protection Value	Pollutant Load (tonnes/year)	Entrance		Exit		Percent reduction	
		Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2
	TP	0.15	0.03	0.005	0.001	97%	98%
	Algae	2.0	0.40	1.7	0.33	17%	24%
Primary Contact Recreation	Cyanobacteria	1.7	0.20	0.78	0.15	55%	26%
	Enterococci	8.95E+12	8.66E+12	0.65E+12	0.26E+12	93%	97%
Average						65%	67%

The model outcomes see the quality of water leaving the Southern Wetlands is improved in both scenarios. Water quality parameters such as TN, TP, Enterococci, and TSS show compliance with the respective guideline values at the exit from Southern Wetlands in both scenarios.

The percent reduction in pollutant loads through the Southern Wetlands were slightly greater in Scenario 2 due to the lower flow rates (i.e. no pumping from Final Basin) and increased retention times. In other words, more contact time allowed for greater pollutant removal.

The pollutant loads exiting the Southern Wetlands in Scenario 1 were greater than Scenario 2 due to the significantly higher pollutant loads entering the system as a result of Final Basin pumping directly to the wetlands (note Addendums to Appendix 2 and 4 regarding pumping rate). Absolute pollutant loads are therefore difficult to compare between scenarios at the exit of the Southern Wetlands.

Overall, the water quality simulation provides a high degree of confidence that the revised 2020 Scheme design is suitably sized and equipped to achieve the desired water quality objectives and lake end uses. The model demonstrates the effectiveness of the designed treatment lakes and wetlands and reticulation system to achieve a significant improvement in water quality through the system, ultimately 'polishing' the source water to reach the desired water quality in the Primary Lakes.

Further breakdown of the water quality model results have been provided in the BMT "Water Quality Modelling Report" included in Appendix 4.

9 OPERATIONAL INFRASTRUCTURE

The overall goal for the Scheme is to construct and maintain recreational lakes and aquatic ecosystems that are resilient to normal disturbance events at minimum capital and operating cost. PLDC has taken an adaptive management approach to achieving this goal with a commitment to continual improvement. The day to day management of the lakes and water bodies by PLDC over the past 20 years have been part of a continuous process of testing, learning and understanding the various behaviours. This has allowed PLDC to adapt its approach for the differing climatic conditions and, where appropriate, refine operational infrastructure and management procedures for future operations.

As part of PLDC's testing it has trialled the use of aeration devices to determine whether they are effective in destratifying the lakes system to assist in meeting the end use objectives. Experience gained at the Scheme has shown that the existing aeration devices are ineffective in that they have been unable to prevent or 'treat' cyanobacterial blooms in the eastern detention basin system. PLDC has also used thermistor chains to gain valuable information and scientific data about stratification and temperature and correlate these with lakes and water body behaviour and performance. The data obtained by PLDC has been used in the calibration of the water quality model. It is considered thermistor chain monitoring will no longer be required by future water managers.

Furthermore, in response to the changes to the State Environment Planning Policy (Penrith Lakes Scheme) Amendment 2017 (the 'SEPP') that effectively rezoned 47 hectares of the land originally allocated for the wetlands system in the south of the Scheme for employment purposes, PLDC in consultation with DPIE have developed a revised design of the water supply and treatment system that is schematically represented in Figure 10 and includes the following:

- New location and more realistic water supply design of the Nepean River Pump and Pipeline (NRPP);
- Installation of a new pump and pipeline system that allows excess water from Final Basin to be pumped into the Southern Wetland system to extend detention time of catchment inflows prior to them entering any of the recreational lakes. The Final Basin pump and pipeline will allow for pumping at $0.2m^3/s$;
- Improved design of Southern Wetlands treatment system, inclusive of several sluice gates and strategically placed berms that increase the length to width ratio of wetland cells, capable of treating water pumped from both the Nepean River, Final Basin and adjacent Employment Land;
- Manually operated sluice gate between Quarantine Lake and Warm-up Lake;
- Inclusion of the Quarantine Lake to Lake A channel with a manually operated sluice gate that can be activated by the water manager to divert water from Quarantine Lake into the main lakes (A and B) by-passing the SIRC lakes if required.

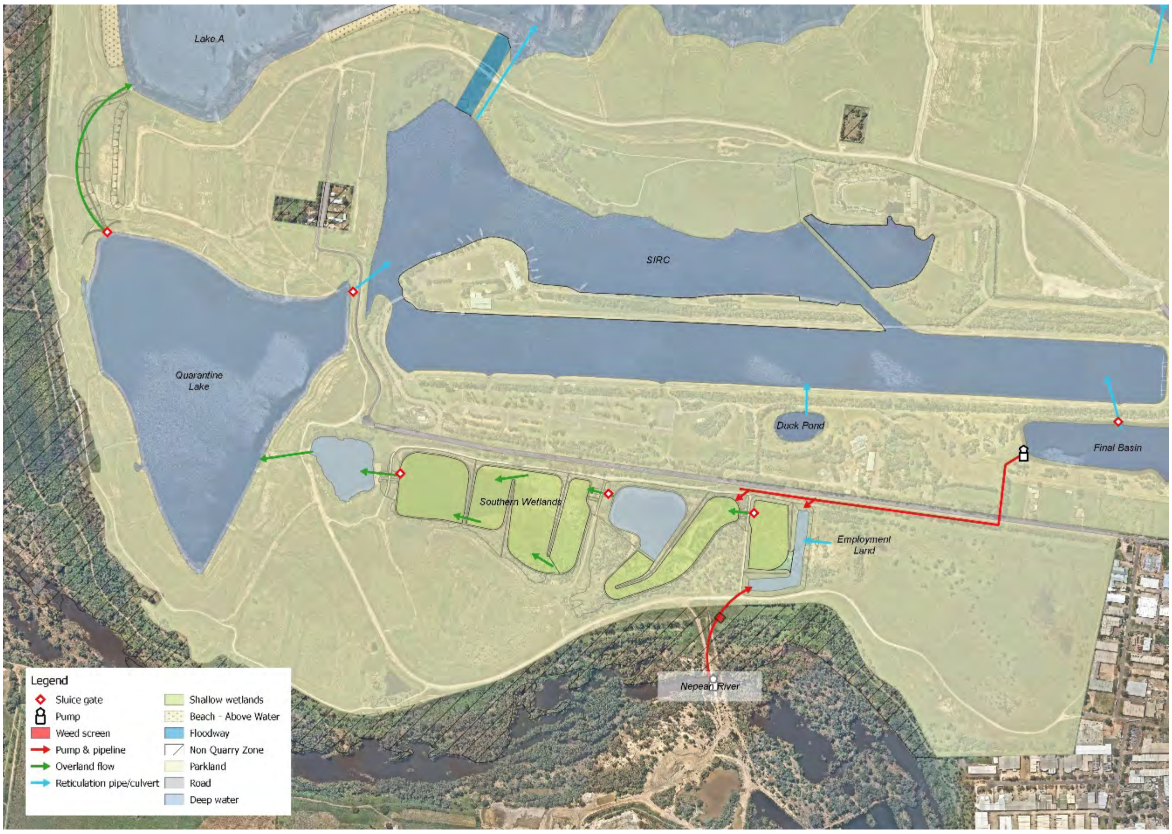


Figure 10: Revised design of water supply and treatment system in the South.

The revised location of the NRPP is to be at the existing BMG Causeway ('Boral Bridge') infrastructure allowing for pumping directly into the eastern most Cell of the Southern Wetlands through a weed structure. The NRPP will be constructed to undertake the initial filling of the lakes system as well as for the ongoing top up to maintain lake levels.

The inlet side of the pumps will have mesh screens fitted to ensure large weeds and fish are not pumped from the river into the Scheme. There will also be a weed structure constructed prior to discharge into the Southern Wetlands system which will ensure removal of smaller weeds pumped from the Nepean River prior to entering the lakes system.

The pumping rate and rules for the NRRP will be as follows (as per Hydrological Modelling pumping rules detailed in Section 7.3):

- The maximum rate of pumping from the Nepean for lakes top up 0.2 m^3/s.
- Pumping can commence from the Nepean when the flow at Penrith weir is greater than 50 ML/day. During periods of fish migration additional constraints are applied in addition to this rule:
    - The periods of fish migration are from 1 Sep to 30 Nov (Bass migration) and 1 Feb to 30 Apr (Mullet migration).
    - During these periods, pumping will commence only when flow at Yarramundi weir is greater than 500 ML/day.
    - Pumping will cease during fish migration periods when the flow at Yarramundi is less than 350 ML/day.

To enable the initial filling of the lakes, PLDC has applied for a Specific Purpose Access Licence (SPAL). During the initial lake filling campaign, the NRPP pumping rate and rules, as per the licence application, will be as follows:

- The maximum rate of pumping from the Nepean for lake filling 0.5 m^3/s (43.2ML/day).
- Pumping can commence from the Nepean River to the lakes when the total river flow exceeds 500 ML/day at Yarramundi Gauge.
- Pumping must cease when the total Nepean River flow drops below 350 ML/day at Yarramundi Gauge.
- Environmental flows cannot be pumped. When pumping occurs, the remaining flow in the Nepean River must exceed the environmental flows

The revised NRPP design and configuration will allow for both the lake filling and ongoing top up scenarios.

Further details of changes to the wetlands design can be found in Southern Wetlands Design Review in Appendix 6, engineering drawings of the new infrastructure are attached as Appendix 7 and the hydrological modelling of the resized NRPP is presented in Appendix 2.

Due to the water quality model results set out in Appendix 4 of this submission and 20 years of water monitoring and management by PLDC there is a high degree of confidence that the currently proposed lake designs and infrastructure will deliver a Scheme that meets the desired targets for water quality and associated end water uses and that no further infrastructure is warranted.

The proposed Scheme will contain all operational infrastructure as detailed in Stage 1 of the Water Management Plan, as well as the more recent changes to water supply, reticulation system and Southern Wetland system described above.

10 LAKES OPERATIONS PLAN

10.1 OVERVIEW

The Lakes Operations Plan guides the day to day management of both the quantity and quality of water entering the lakes system as well as the passage of water throughout the Scheme. The plan provides background information on the lakes system, documents the goals for water quality and aquatic ecosystem health and outlines procedures for management of various parts of the Scheme. It documents how water movement through the system is controlled and how water quantity, water quality and aquatic ecosystem health are monitored. Response plans determining specific decisions and actions to be taken, such as during high water levels, cyanobacteria blooms, bacteria (faecal) contamination, and low dissolved oxygen, are also included.

The Lakes Operations Plan meets the evolving requirements of water quality and water balance management across the Scheme and is progressively updated as the Scheme develops. The Scheme-wide Lakes Operations Plan accompanies this document and can be found in Appendix 8.

10.2 WATER LEVEL MANAGEMENT

Table 2 and were approved in the Stage 1 Water Management Plan. The recommended tolerances in operating levels set for these lakes has been included, with tolerances based on operational requirements and ecological considerations depending on their purpose and provide the added protection of providing buffer water storage to reduce the need to top up the lakes from the Nepean River.

The monitoring and management of the lakes water levels is assisted by the use of the numerous sluice gates and level monitoring stations (automatic and manual) across the scheme. Monitoring stations collect real time data of water levels (accurate to 0.01m) and water temperature profiles. Water level stations are currently located in the Final Basin, Middle Basin, North Pond and Duralia Lake. The system is designed to alert water managers via SMS when alarm levels are triggered. Water volumes can then be managed accordingly to maintain operational levels. Water levels of other lakes are monitored by recording the manual depth gauges levels located in convenient location around the lakes.

10.3 WATER QUALITY MANAGEMENT

10.3.1 Flows and Quality

Stormwater and run-off water entering the Scheme through the eastern detention basin system can contain high concentrations of bacterial contaminants, sediment loads together with nutrients and other pollutants, including gross pollution and organic material including weeds.

An inflow monitoring station was installed by PLDC to provide information on the potential for bacterial contamination. Discharge from the Stilling Basin into the North Pond was measured over a weir by means of a Cipoletti notch, developed by Manly Hydraulics Laboratory (MHL) and made available to PLDC from the MHL website. PLDC used a guide of >43 000m^3 water (43ML) within 72 hours as a trigger for potential faecal bacteria inflows into the system from the surrounding catchment. This trigger was developed through the work of Ashbolt and Roser (2004). An SMS alert was sent to water managers when this threshold had been reached and, provided storage was available in the detention basins, water was consequently withheld from the SIRC lakes.

A sluice gate installed between Final Basin and SIRC lakes also allows highly turbid water to be held back during intense rainfall events so residence time is extended to allow sediment and other water quality improvements to occur prior to water entering the SIRC lakes. This gate is very effective in isolated rainfall events. With prolonged rainfall a considerable storage volume must be retained and water levels may increase by up to 2.55m above normal operating level in the Final Basin.

Prolonged storage in Final Basin however impacts adversely on both emergent and submerged macrophytes; therefore a pump and pipeline will be installed on the western bank of Final Basin that will allow pumping of excess water directly to the Southern Wetlands. This will increase detention time of the catchment inflows by travelling through the Southern Wetlands system. The pump is designed to operate at a rate of 0.2 m^3/s. Careful and vigilant management is required if optimal outcomes are to be achieved in this part of the Scheme.

10.3.2 Management of Weeds and Silt

Floating weed booms located in North Pond, Middle Basin, Final Basin, and Warm-up Lake aid in confining floating noxious weeds. They are also present in Lewis Lagoon, Wildlife Lake, Quarantine Lake and Main Lake A. A combined weed boom and silt curtain is present in the Final Basin and acts as a barrier to prevent weeds, rubbish and sediment entering the SIRC lakes. The silt curtain is less effective in severe rainfall events when lake levels rise and the boom can be bypassed at the lake's edge. Careful monitoring is required in this regard.

10.3.3 Monitoring of Recreational Water Quality

In order to meet the recreational water quality goals, monitoring of various physio-chemical and biological variables is undertaken on a regular basis.

Sampling is carried out at monthly intervals and after rainfall events in the SIRC lakes and in the detention basins and the eastern ancillary lakes. Techniques employed follow standard water quality sampling protocols.

The physio-chemical variables measured include: pH, Dissolved Oxygen, Turbidity, Total Suspended Solids, algae, nutrients (Nitrogen - Ammonium N, NOX, TN; Phosphorus – SRP, TP), and includes depth profiles of the water column for temperature, dissolved oxygen and pH.

The biological variables measured include algae and cyanobacteria, the species composition and

abundance (cell counts) of phytoplankton assemblages and bio-volumes of Cyanobacteria (blue-green algae) are measured. The microbial indicators of Faecal Coliforms and Enterococci are also measured. The monitoring results are provided to the NSW Department of Health and SIRC venue management to ensure that proper action is taken in circumstances where water quality results represent a danger to venue patrons and the general public.

10.3.4 Algal Response Plan

For the period that PLDC agreed to maintain water quality in the Eastern Lakes and SIRC a draft Algal Response Plan specific to the management of the SIRC and Penrith White Water Stadium (PWS) was adopted. The plan was developed to ensure an adequate monitoring regime was in place to alert users of public waterways of the potential toxins present in the water body for safe usage. The plan was developed in conjunction with NSW Office of Water and the NSW Department of Health, as well as SIRC and PWS. This plan is included in the Lakes Operation Plan (Appendix 8).

This plan informs all stakeholders of their responsibilities and outlines specific testing and response requirements and should be updated by the future operators of the Scheme to ensure ongoing compliance.

10.3.5 Aquatic Weed Response Plan

Aquatic weeds adversely impact on the ecological functioning of the lake systems as well as having negative effects on recreational use and aesthetic amenity. The adverse impacts of invasive species are largely due to their ability to rapidly colonise areas, often forming mono-specific stands, which lead to displacement of native species and alterations to habitat. The dominance of these species usually results in losses of biodiversity (both plants and animals) and degradation of the ecosystem.

From the list of most problematic, difficult-to-control aquatic invasive species in the Sydney basin, the highest threat for the water bodies within the Scheme are the emergent Alligator Weed (*Alternanthera philoxeroides*), the submergent Egeria (*Egeria densa*), Cabomba (*Cabomba caroliniana*) and Elodea (*Elodea canadensis*), and the floating Water Hyacinth (*Eichhornia crassipes*) and Salvinia (*Salvinia molesta*) species. All of these species (except Cabomba) are abundant either in the Hawkesbury-Nepean River or on its floodplain in which the Scheme is located. Some, like Alligator Weed, Water Hyacinth and Salvinia are relatively common in the upstream Cranebrook and Londonderry catchments.

A monitoring and control program has been developed in order to manage exotic weed species within the scheme. Weed species targeted as part of this program include any noxious or environmental weed scheduled under the Biosecurity Act 2015. Currently priority weeds include Willows (Black (*Salix nigra*), Crack (*Salix fragilis*) and their associated hybrids), Peruvian Water Primrose (*Ludwigia peruviana*), Water Hyacinth, Salvinia, Sagittaria (*Sagittaria platyphylla*), Spiny Rush (*Juncus acutus*) and Alligator Weed.

10.4 AQUATIC ECOSYSTEM MANAGEMENT

Monitoring programs focused initially on the recreation water quality values and on surveys of submerged macrophytes and fish populations. The monitoring program was reviewed and revised by an expert panel in 2009 and monitoring now focuses more clearly on site management objectives so that environmental quality information obtained and changes over time can better inform the decision making process (ALS 2009). It was advised that macro-invertebrates and amphibians are to be included in the surveys sand more detailed information on emergent macrophytes is gathered. The monitoring has also been targeted more closely on the SIRC lakes, detention basins, and the eastern ancillary lakes and water bodies.

The key monitoring programs include:

10.4.1 Fish Populations

Fish populations are a good indicator of aquatic ecosystem health as they occupy key roles in aquatic ecosystem function. They are considered to be a proven and cost effective method of assessing ecosystem health. Regular fish monitoring also allows PLDC to respond in a timely manner to any potential invasions or population increases of pest fish such as European Carp.

Surveys of fish populations used to occur on annual or biennial basis at the SIRC lakes, detention basins, and eastern ancillary lakes using current fish sampling protocols (electro-fishing, panel gill netting, bait trapping). Species composition and abundance of fish was recorded and changes over time analysed. The abundance of the exotic pest species was carefully assessed to ensure they did not become dominant within any of the lakes, with Australian Bass being effectively stocked to predate on juvenile carp to control populations. As the remainder of the lakes come online and are transferred to Government it is suggested that the fish monitoring programme expands to cover these lakes as well.

10.4.2 Macrophytes

Monitoring of the aquatic macrophytes at Penrith Lakes had been undertaken since the 1990s, focusing initially on the recreational lakes and issues relating to their use.

Submerged macrophytes were surveyed at the SIRC lakes, detention basins, and eastern ancillary lakes every two years. Echo-sounding technology was employed in 2011, combined with spot diving to gather information on species composition, abundance, distribution and extent, and changes over time. Overall plant health was noted and the presence and abundance of any invasive and highly undesirable species is recorded.

Emergent macrophytes and riparian zone taxa were surveyed at the SIRC lakes, detention basins, eastern ancillary lakes and their associated lagoons. A monthly walk-through of the perimeter of all lakes was undertaken to check the health of riparian areas and the presence of any invasive noxious weed species. An annual survey of all riparian zones was undertaken also using a series of line transects from the shore to 1-1.5m depth.

Similar to the fish monitoring, it is recommended that all lakes are added to the regular macrophyte surveys once they are in service. Changes over time of species composition, abundance and

percentage cover, distribution and extent of submerged and shoreline macrophyte vegetation should be recorded. The presence of invasive and highly undesirable species should also be recorded.

10.4.3 Macro-invertebrates

While benthic macro-invertebrates (those that live in stream or lake-bed sediments) are the most commonly used indicators, the sampling and laboratory analyses of these organisms is labour-intensive, and hence, expensive. Initially ‘edge’ macro-invertebrates were surveyed, using rapid assessment techniques in order to obtain a ‘picture’ or ‘signature’ of macro-invertebrate community structure. Site-specific macro-invertebrate details for the different water bodies allow a SIGNAL-2 score and an EPT Index to be calculated. In situ water quality sampling and physical habitat assessments are also carried out at the monitoring sites enabling the macro-invertebrate data to be interpreted more fully.

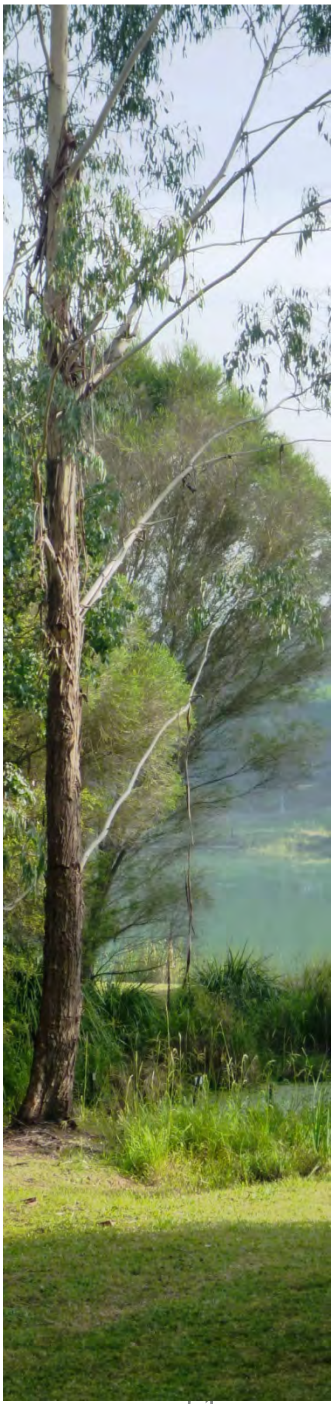
Building a ‘baseline’ of macro-invertebrate community structure will assist in monitoring changes over time within the marginal lake environments and provide information on habitat quality that may reflect impacts from external or local catchment activities.

Sites are suggested to be surveyed twice yearly (autumn and spring) in the detention basins, eastern ancillary lakes and their associated water bodies. Five marginal sites will be designated at each lake and water body and standard sampling protocols for Rapid Bio-Assessment followed. Species composition and abundance data will be collected to enable SIGNAL-2 and EPT Indices to be calculated.

10.4.4 Amphibian Populations

Amphibians provide both a primary and secondary consumer role within the aquatic ecosystems. They prey on a variety of invertebrates and are also prey to other species such as various birds. Amphibian populations are regarded as excellent indicators of environmental conditions, particularly in regards to ecological changes in relation to water quality, habitat fragmentation and water regime. Monitoring amphibians is relatively inexpensive, non-destructive and it is considered that it would be a useful component to the Penrith Lakes Integrated Ecological Health Monitoring Program.

Amphibians at the detention basins and eastern ancillary lakes and their associated water bodies were surveyed annually using call playback and spot-lighting techniques. Species composition and abundance of frogs, abundance of tadpoles and changes over time can be documented. A possibility of allowing interested environmental and/or educational groups to conduct independent monitoring with results submitted to the scheme managers for assessment could also be considered.



10.5 LANDSCAPE MANAGEMENT

The SIRC lakes are a proven recreational attraction for a wide variety of community activities, such as regattas, white water rafting, triathlons, cycling, running and fishing events, as well as various community gatherings and organised events. As the area develops as a regional recreation resource a variety of different management regimes will need to be implemented including regional open space, local open space, and water management.

Regional open space management will apply to the bushland, woodland, grassland and other mass planted parts of the Scheme. Many of these areas are designed to become self-sustaining and maintenance would be expected to be less than that of a public park.

Local open space management will apply to camp sites, public parks, picnic areas and beaches where a higher expected volume of usage would require higher-intensity maintenance. Such areas would not form a major part of the Scheme and would be located where access was readily available. Use, access and therefore maintenance requirements can be regulated through careful operational management policies and practices.

The management and maintenance of the lakes within the Scheme would need to balance recreational needs with the capacity to monitor and maintain ecological values and ensure cost-effective management and maintenance.

PLDC is developing Landscape Management Plans for the completed landforms and remnant landscapes to direct their ongoing management and these will provide information to assist the development of future Management Plans and Maintenance Programs.

Technical Specifications have also been developed and outline how a particular task or operation should be carried out to ensure current industry standards and guidelines are met. They cover a range of activities including weed management (both aquatic and terrestrial), land surface stabilisation, land rehabilitation and maintenance works amongst others.

10.6 COMPLETED LAKES OPERATIONS PLAN

The completed Lakes Operations Plan forms part of this WMP Stage 2 submission and is attached in Appendix 8. It has to be noted though that the Lakes Operations Plan will always be a living document based on an adaptive management approach and will require to be continually improved based on the growing knowledge gained from practical day to day management of completed water bodies within the Scheme.

11 CONCLUSION AND RECOMMENDATIONS

11.1 CONCLUSION

The Scheme is being implemented under the Deed, SEPP (Penrith Lakes) 1989, development consents and other relevant approvals. The Water Management Plan is being submitted to the Secretary, Department of Planning, Industry and Environment under Condition 27 of DA4.

The Plan has been submitted in two (2) stages. Stage 1 was submitted on 17 August 2012 and approved by the Director-General, Department of Planning and Infrastructure on 15 November 2013. This Stage 2 WMP submission focuses primarily on the resultant water quality outcomes, water balance and operational requirements for the short and long term management of water taking into consideration the infrastructure that was delivered in the Stage 1 WMP, as well as the infrastructure changes under the In-Principle Agreement between PLDC and DPIE (2019). The Stage 2 WMP simulates the water quality inflows from the eastern catchment, models water quality through the established ecosystems and treatment pathways before and after water enters the gravity flow system inherent in Stage 1 and provides for optimal flexibility in management regimes available to the long term managers to achieve the end water uses set out in Schedule 7 of the Deed.

In completing Stage 2 of the Plan, PLDC and its consultants have relied on the Stage 1 approval as the basis for developing the suite of assumptions underpinning the detailed analysis and modelling which has been undertaken over a period of more than 24 months. The water quality modelling provides a scientific prototype of the Scheme's lakes, wetlands and detention basins to inform the preparation of the Stage 2 documentation. Additionally, reliance has also been placed on PLDC's extensive on-site experience as the primary water managers of the Eastern Lakes detention basin, wetland treatment system and the water quality outcomes of the SIRC lakes. This experience has been invaluable in testing and verifying in a practical sense the results and outputs of the theoretical modelling.

PLDC has also, where relevant to the Stage 2 WMP, considered the recommendations of a number of previously commissioned studies which detail highly technical component parts of water bodies and aquatic plant ecology. The modelling work undertaken has also used contemporary eastern catchment and Hawkesbury Nepean River inflow data provided by Government and Sydney Water.

This Stage 2 Water Management Plan has been prepared in consultation with Government water agencies, NSW Department of Health, OSL and Department of Planning, Industry and Environment. A number of workshops were held during the Stage 2 Water Management Plan preparation period and progressive feedback from the analysis and modelling work was shared with the relevant stakeholders. This modelling completes a trial of interim bodies for a period of 10 years and effectively simulates final conditions including the redesigned Southern Wetlands system, demonstrating the Scheme design is fit for purpose and capable of achieving the desired water quality outcomes.

The Stage 2 Water Management Plan as submitted:

1) provides a robust and cost-effective management regime for the day to day operation of the Scheme to best achieve the end water uses defined in Schedule 7 of the Deed;
2) optimises the water quality objectives for the Scheme without the need for chemical intervention or frequent accessing of water from the Nepean River;
3) provides management options for the expected range of climatic conditions from dry to wet periods;
4) supports the hierarchy of lakes for recreational uses proposed in the approved Stage 1 Water Management Plan;
5) minimises ongoing capital and operational costs for the long term management and operation of the Scheme;
6) confirms the terrestrial and aquatic ecosystems as designed and constructed by PLDC as suitable to achieve the water end uses;
7) is consistent with the recommendations contained in the DIPNR Water Committee Report 2005; and
8) optimises the flexibility for recreational uses of the Scheme and allows a practical and cost effective staging of opening up the Scheme to public use.

The Stage 2 Water Management Plan also acknowledges that as a State Significant Site water licensing is required only for extraction of water from the Nepean River to fill the lakes and for ongoing “topping up” of the lakes. In 2019 PLDC applied for the relevant water access licence, Specific Purpose Access Licence (SPAL), to allow for initial filling of the lakes and is currently working on modification of the existing NRPP development consent to allow for its resizing and relocation.

The ongoing top up of the lakes from the NRPP is expected to be undertaken using existing Water Access Licences (3.3GL) to maintain operational levels. It is expected that most years will require up to the 3.3GL to offset evaporation.

This submission appends the relevant technical and analytical reports prepared by independent experts upon which the outcomes and recommendations contained in Stage 2 Water Management Plan have been arrived at by PLDC.

The Stage 2 Water Management Plan completes PLDC’s requirements for lodgement under Condition 27 of DA4 and satisfies the conditions of the In-Principle Agreement between PLDC and DPIE.

11.2 RECOMMENDATIONS:

It is recommended that the Secretary of the Department of Planning, Industry & Environment approves and adopts this Stage 2 Water Management Plan.

It is further recommended that following specific recommendations be approved:

a) the Wildlife Lake and surrounding precinct continues to be managed as a core conservation zone - applying the maintenance principles of natural asset management;
b) consistent with the results of the water quality modelling and the importance of the terrestrial and aquatic ecology in achieving the ultimately desired Scheme water

objectives, the filling of the lakes system be completed as soon as practically possible;

c) the protocols for water management of SIRC and Eastern Lakes under the Eastern Lakes Operations Plan be implemented by SIRC and the water manager for recreational purposes;

d) Penrith City Council be urged by the State Government to immediately install the appropriate stormwater infrastructure connecting to existing Scheme infrastructure in the eastern catchment which has a direct impact on the quality of water inflows into the SIRC Lakes;

e) Penrith City Council be urged by the State Government to immediately impose relevant WSUD features as a condition in any consent issued by Council for development in the eastern catchment; and

f) Government, Scheme managers and operators agree to generally adopt the monitoring regime and operational programs contained in the Scheme-wide Lakes Operations Plan based on the contents of Section 10 of this submission.

12 REFERENCES

ANZECC 2018. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at www.waterquality.gov.au/anz-guidelines ALS 2009, Review of Aquatic Macrophyte Monitoring Program for the Penrith Lakes Scheme. Report prepared for the Penrith Lakes Scheme.

Ashbolt N. & Roser D. (2004). Review of Penrith Lakes Water Quality Monitoring Program. Public Health: Review of Historic Data and Proposed Risk Management based Monitoring Framework. Report prepared for the Penrith Lakes Development Corporation Ltd. Centre for Water and Waste Technology, The University of New South Wales.

Cardno (2013) Water Balance and Lake Operating Levels – Addendum Report. Report prepared for Penrith Lakes Development Corporation.

IEP. 2005, *Penrith Lakes Water Principles and Water Plan Peer Review Stage 1 & 2 Review*, Report by the Independent Expert Panel for Penrith Lakes Water Committee,

Nation (2014) Penrith Lakes Scheme – Hydrogeological Assessment. Report prepared for the Penrith Lakes Development Corporation.

National Health and Medical Research Council (2008) Guidelines for Managing Risks in Recreational Water, National Health and Medical Research Council of Australia, Canberra, ACT.

WBM BMT (2014) Penrith Lakes Schemes – Numerical Assessment of Thermal Stratification in Main Lake A. Report prepared for Penrith Lakes Development Corporation.

13 APPENDICIES

APPENDIX 1: WATER MANAGEMENT PLAN STAGE 1 (CARDNO, 2012)

APPENDIX 2: HYDROLOGICAL MODELLING OF RESIZED NRPP (BMT R.B23771.001.02, 2019)

APPENDIX 3: HYDROGEOLOGICAL ASSESSMENT (NATION PARTNERS, 2014)

APPENDIX 4: WATER QUALITY MODELLING REPORT (BMT R.B24088.001.02, 2020)

APPENDIX 5: WATER QUALITY MODEL CALIBRATION RESULTS (BMT M.B24088.001.PLS2012, 2019)

APPENDIX 6: SOUTHERN WETLANDS DESIGN REVIEW (E2 DESIGN LAB, VERSION 2, 2019)

APPENDIX 7: SOUTHERN WETLANDS INFRASTRUCTURE DRAWINGS (JWP 11008808CC01-23, 100-114, 200-212; 16880-S1-S8 A, 2019)

APPENDIX 8: LAKES OPERATIONS PLAN (PLDC, 2020)

APPENDIX 9: SOUTHERN WETLANDS PERMEABILITY (PSM 2541-286L REV1, 2019)