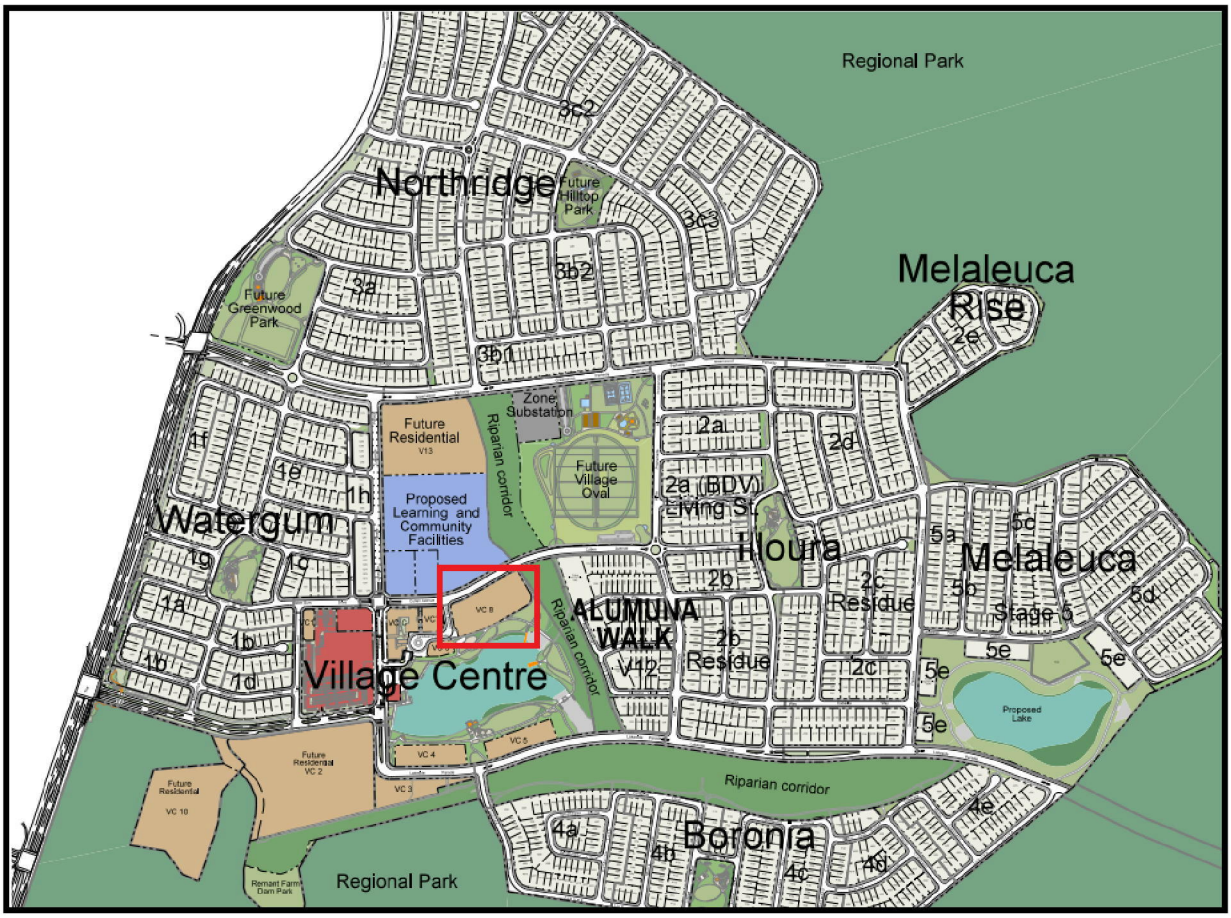
Stormwater Management Strategy

1 Charlotte Street, Jordan Springs

Prepared for:
BENAIAH Pty Ltd



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01	Brent Milton	Philip Byrum	Philip Byrum	30/10/17	Client Approval
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1.0 INTRODUCTION

This Stormwater Management Strategy has been prepared by Orion Consulting Engineers (OCE) to support the residential development of Lot 1 Charlotte St, Jordan Springs (Lot 14 DP1195110).

This site is within the Jordan Springs Western Precinct, is predominantly surrounded by existing development and open space/drainage and drains to the Jordan Springs 'Village Lake'.

This report will demonstrate the existing site is part of an existing development and drainage strategy and formal onsite works for attenuation and quality are not required.

2.0 THE SITE

The site is defined as Lot 14 DP1195110 and is within the existing Village Lake Catchment of Jordan Springs.

The site is, at the time of writing, approximately 8,500 sq.m of open grassland zoned for residential development.

The site has been defined to be within the Jordan Springs Lake (Village Lake) catchment which caters for both On Site Detention and Water Quality requirements. An extract of the Jacobs 2010 'Stormwater Management Report' catchment has been provided below. Refer Appendix A for the Jordan Springs Lake Stormwater Management report (Jacobs 2010).

- **Figure 1 – Location of the proposed Lake (Area 2) and layout of Stages 1 and 2 catchments**

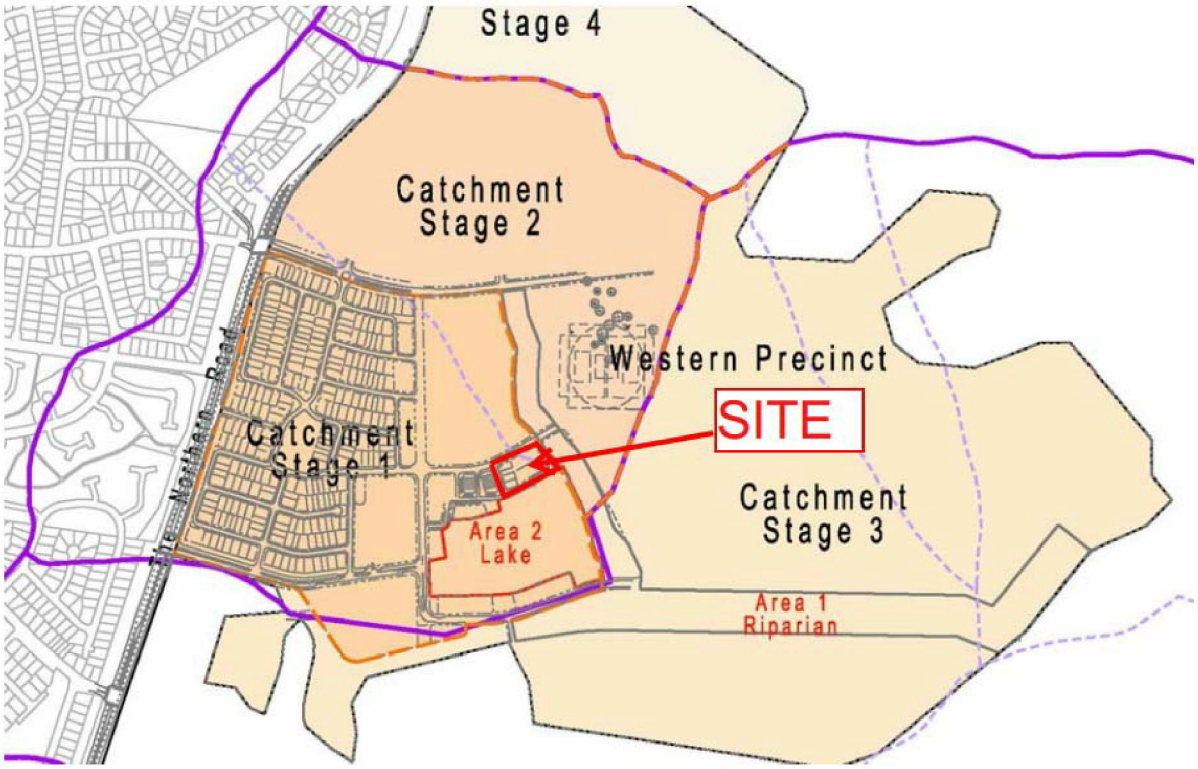


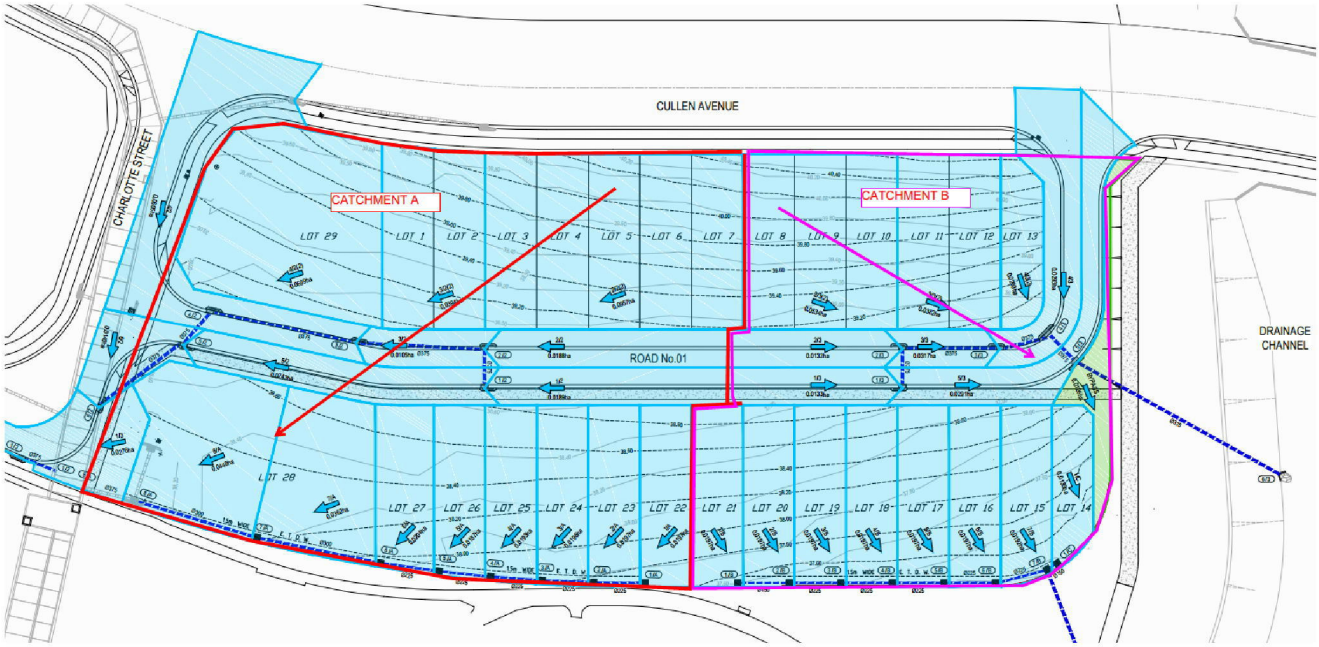
Image 1 – Extract of Jacobs 2010 Stormwater Management Catchment for the Village Lake

3.0 SITE CATCHMENTS

The proposed grading of the site has been developed to match previously approved bulk earthworks levels and grading strategy as part of the overall development of Jordan Springs.

The site will drain in two directions as shown in the image below:

- Catchment A (Western) will drain to the existing Charlotte Street drainage system and GPT. No treatment is proposed for this catchment. All OSD and WSUD requirements will be addressed by existing infrastructure.
- Catchment B (Eastern) will drain directly to the existing Riparian Corridor and Village Lake. Any bypass flows will enter the downstream Riparian Corridor and be directed to the existing 'East Lake' wetland.



3.0 WATER QUALITY

As the site is within an existing development and catchment that drains to a designated Water Quality Wetland, it is not proposed to implement any onsite treatment facilities, apart from trash screens, to address water quality.

To ensure compliance with PCC's WSUD objectives for flows from Catchment B (Northern Road and Lots and Southern IAD line), it is proposed to install trash screens at the outlets to the Riparian Corridor, in lieu of Gross Pollutant traps, to address Water Quality objectives as well as reduce maintenance requirements and access issues.
A MUSIC model has been prepared to demonstrate compliance for Gross Pollutants and Suspended Solids. An extract of the Model and results has been provided below.

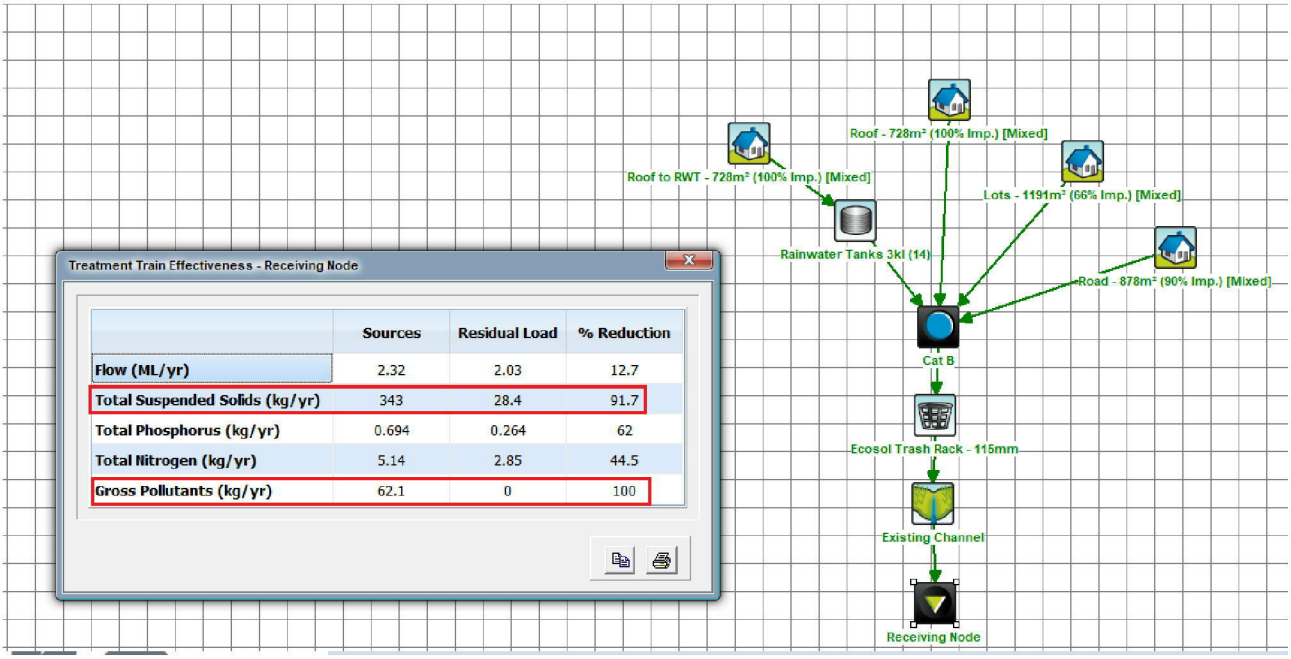


Image 2 – MUSIC model for Catchment B.

The results shown are relevant for Gross Pollutants and Suspended Solids from Catchment B only. The proposal indicates that with the trash screens and vegetated Riparian Corridor, water quality entering the Wetland meets PCC's requirements for treatment of 85% reduction in TSS and 90% reduction in Gross Pollutants.

4.0 WATER QUANTITY

Given the site is within the catchment of an existing residential development and catchment with designated OSD facilities; no OSD is proposed as part of this development.

5.0 TEMPORARY SEDIMENT BASIN

Soil loss for the development has been calculated at less than 150 cubic metres/year.
This volume being under the annual soil loss threshold outlined in Soils and Construction: Volume 1, 4th Edition, March 2014 – Managing Urban Stormwater section 6.3.2 General Recommendations part (d).

6.0 CONCLUSION

The Stormwater management and grading strategy for the Site has prepared considering existing infrastructure and site grading.

Where required, trash screens are proposed at the outlets to the Riparian Corridor to trap Gross Pollutants prior to discharging to the corridor and downstream wetland. Suspended Solids will be dealt with by flows from the site being treated by the existing vegetated Riparian Corridor prior to entering the existing Wetland.

As the site is within an existing residential development, with designated OSD facilities, no onsite OSD system is proposed.

Yours sincerely,

ORION Consulting Engineers Pty Ltd
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BE Civil (Hons), BBus, MBA, Dip Eng Prac, MIEAust, CPEng, NER, RPEQ

APPENDIX A – JACOBS REPORT (2010)

SINCLAIR KNIGHT MERZ

SKM

Delfin

Jordan Springs Lake

STORMWATER MANAGEMENT

Proposed Lake Development Application

Jordan Springs Lake

STORMWATER MANAGEMENT

Proposed Lake Development Application

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Contents

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Executive Summary

This report has been prepared to support the Development Application (DA) of the Jordan Springs Lake at the western Precinct of the Delfin Lend Lease site at St Marys.

The assessment focuses on the stormwater management component of the Lake, however it also includes an assessment of bulk earthworks, noise and air issues associated with the construction of the Lake.

The stormwater management component includes an assessment of the required detention volume in the lake to provide peak flow mitigation, and an assessment of water quality.

A maintenance manual has also been prepared to outline the appropriate wetland management strategies for the Lake.

This report is to be read in conjunction with the following stormwater management DA drawings:

DRAWING No	DRAWING TITLE
EN02754-C-001	COVER SHEET
EN02754-C-002	INDEX SHEET AND NOTES
EN02754-C-003	BASIN LAYOUT PLAN
EN02754-C-004	TYPICAL SECTIONS
EN02754-C-005	DETAIL PLANS AND SECTIONS
EN02754-C-006	DETAIL SPILLWAY PLAN
EN02754-C-007	DETAIL SPILLWAY SECTIONS
EN02754-C-008	EROSION AND SEDIMENT CONTROL PLAN (ESCP)
EN02754-C-009	EROSION AND SEDIMENT CONTROL DETAILS
EN02754-C-010	BULK EARTHWORKS PLAN

1. Introduction

1.1. Purpose

The purpose of this report is to support the Jordan Springs Lake DA drawings on Stormwater Management. The main purpose of the Lake is to provide detention, water quality treatment and improve the aesthetic qualities of the area.

The emphasis in this report and associated drawings will be on the Lake area inside the water edge line but will include details on the proposed spillway at the outlet of the Lake. For all areas above the permanent water line, reference is to be made to the Landscaping Plans prepared by Environmental Partnership consultants.

1.2. Site Description of the proposed Lake

The proposed Lake will be located in a future residential area. When built, the wetland will occupy an area of approximately 3.25ha and contain a permanent water body of approximately 55ML. Stormwater collected in the drainage system of the future upstream residential areas will enter the wetland via three inlets shown on the DA drawings.

The wetland will comprise of a deep water zone and a perimeter safety bench macrophyte zone which will consist of reed beds around the perimeter of the wetland. The lake will provide detention, facilitate nutrient suspended solids removal and provide a habitat for wildlife.

The Landscape drawings of the Lake prepared by Environmental Partnership provide the outline of the Lake, the proposed landscaping around the Lake, trees, footpaths and building structures. There are some small differences between the layout of the Lake used in the DA drawings that accompany this report and the Landscape drawings. These differences have been reviewed and they do not have any significant impact on the results presented in this report.

1.3. Stormwater Detention in the Lake

A hydrological assessment has been undertaken to determine peak flow rates for existing conditions at the location of the proposed Lake at its downstream end. This was followed by an assessment of peak flow rates for a fully developed catchment which generated an increase in peak flows. The size of the detention basin and its outlet has been designed to provide sufficient peak flow mitigation such that the peak flows from the fully developed catchment do not exceed current peak flow rates. The detention volume is situated above the permanent water level in the Lake. **Appendix A** – ***Hydrological and Detention Basin Assessment*** provides a more detailed description of the methodology, parameters used and results of the hydrological and detention basin modelling.

1.4. Water Quality Assessment

The water quality objectives for the Jordan Springs Lake are to achieve the target reductions of pollutant loads generated from a fully developed catchment upstream of the Lake. The design criteria and target reductions for new urban areas were obtained from the Penrith City Council *Draft Policy on Stormwater Quality Control' and from the* '*South Creek Stormwater Management Plans'* document.

A water quality assessment was undertaken using the MUSIC model to estimate the reduction in water pollution by the proposed Lake. The main purpose of the modelling was to demonstrate that the proposed water quality management controls (Jordan Springs Lake/water quality pond) would meet the water quality objectives of reducing the annual pollutant loads generated from the future urbanised catchment. **Appendix B – *Water Quality Assessment*** provides a more detailed description of the methodology, parameters used and results of the water quality modelling.

The results of the modelling indicate that the proposed size of the Lake would meet and exceed these objectives.

1.5. Maintenance of the Lake

The proposed Lake will comprise of a deep water zone and a perimeter macrophyte zone which will consist of reed beds around the perimeter of the wetland and open water areas. It will facilitate nutrient and suspended solids removal and provide a habitat for wildlife. Water Quality ponds and wetlands provide a very effective means of treating stormwater in urban areas. However, ongoing maintenance is essential in maintaining the water quality performance of the Lake.

A maintenance manual has been prepared to outline the maintenance and operational requirements associated with the Jordan Springs Lake.

Appendix C – *Maintenance Manual for the Jordan Springs Lake* provides a more detailed description of the required maintenance regime, noxious weeds management and routine inspections of the Lake.

1.6. Water Level in Lake

A water balance assessment has been undertaken to investigate the water levels in the proposed Lake and to estimate the draw down changes to these water levels that will occur for the following two scenarios:

a) Stage1, which is the partial development of the catchment upstream of the Lake; and
b) Stage 2, which is the ultimate development of the catchment upstream of the Lake.

Fifty (50) years of rainfall data from nine (9) nearby weather gauges has been collated, along with long-term evaporation data from the nearest three weather stations in the area. This data has been used in a water balance model to estimate the daily inflows and evaporation losses to which the lake is subjected over this 50 year period of time. The model assesses the resulting effect on water level.

The water balance model results indicate that the drop in water levels would rarely be more than 200mm for Stage 1, and 150mm for the ultimate Stage 2 of the development; however, during a severe drought, the water level could drop down by approximately 300mm to 400mm for Stage 1 and approximately 200mm for Stage 2.

A sensitivity assessment was undertaken to determine any potential significant impacts from climate change. This assessment indicated that the effect of climate change on any additional drops in the lake water levels is not significant. **Appendix D – *Estimation of Water Levels in Jordan Springs Lake*** provides a more detailed description of the methodology, parameters used and results of the water balance assessment.

1.7. Construction phase considerations

There are three considerations that have been addressed for the construction phase of the Lake:

i. Erosion and sediment controls

ii. Bulk Earthworks, and

iii. Noise and air quality assessment

1.7.1. Erosion and Sediment Control for the Lake Area

The erosion of sediment control plan for the construction phase of the Lake has been described on drawing number: EN02754-C-008**.** The plan indicates that external runoff around the construction footprint of the Lake needs to be diverted around and not be allowed to enter the excavated area. Therefore the only runoff entering the construction site will be from direct rainfall, which will be absorbed into the soil; however if significant rainfall fell on the Lake, some dewatering by pumping may be required to the nearby existing sediment basin within two days after any such high rainfall event. Sediment fences will be used at the toe of any fill embankments to avoid sediment export outside the footprint of the Lake's construction area.

1.7.2. Bulk Earthworks for the Lake Area

The bulk earthwork cut and fill volumes have been assessed in a three dimensional model (12D) to estimate the volumes of excavation and amount of fill required. The depth of cut or fill from

existing ground levels has been described on drawing number: EN02754-C-010**.** The volumes of cut and fill have been estimated to be 46700 m3 and 87,000 m3 respectively.

1.7.3. Noise and Air Quality Assessment for the Lake Area

A noise and air quality assessment has been undertaken for the construction phase of the Lake area. This assessment is described in **Appendix E –** ***Noise and Air Assessment***. It provides relevant information on the existing noise environment and air quality, the potential impacts from the construction phase of the Lake, and recommends mitigation measures for any impacts.

Appendix A Hydrological and Detention Basin Assessment

Detention Basin Requirements for Jordan Springs Lake, St Marys

1.1. Purpose

The purpose of this assessment is to provide the methodology and design criteria which have been adopted to calculate stormwater detention requirements in the proposed Jordan Springs Basin/Lake.

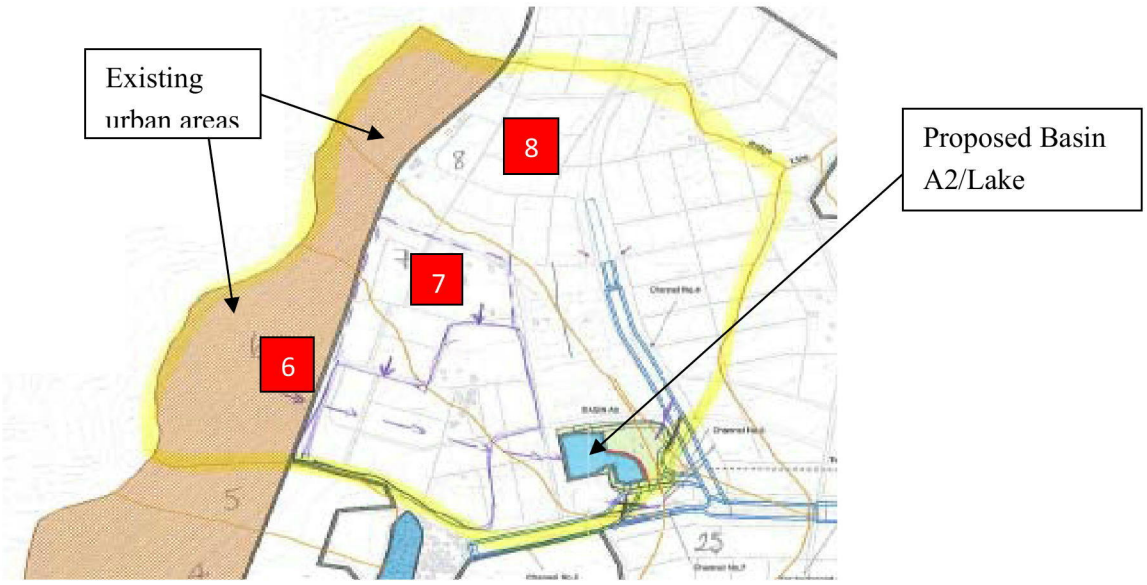
1.2. Introduction

This section summarises work undertaken to assess detention requirements for the development of a catchment upstream of a proposed basin in the Western Precinct, St Marys. It provides details of the hydrological modelling work undertaken to assess the "existing" and 'developed' case.

1.3. Study Area

The study area includes a total catchment area of 109 hectares draining to the proposed detention basin, A2 (catchment shown in yellow) to the south-east corner of the developed area. The existing catchment areas are predominantly rural, with some urban development on the western fringes of the catchment. The developed case has a fully urban catchment. The study area, showing the catchment boundary used in this assessment is shown in **Figure 1.1**

- **Figure 1.1 Study Area showing catchment boundary in yellow**



1.4. Objective

The objective of the assessment is to mitigate the 'with development' peak flows such that the following requirement is met: the mitigated peak flow must be less than the existing peak flow for a range of design storms from 2-100 year average recurrence interval (ARI). In doing this exercise, details will be provided on the required detention volume and outlet configuration.

1.5. Design Criteria (hydrology and detention) and Model Set Up

1.5.1. Catchment Areas

The study area has been divided into three sub-catchments which are labelled catchment 6, 7 and 8 (Figure 1.1)[1]. Delineation of the catchments was undertaken as part of the *St Marys Western Precinct Plan – Water, Soils and Infrastructure Report* (May, 2009). Some minor adjustments were made to catchments 6 and 8 for the current assessment. Total catchment areas and rural/urban areas in each sub catchment are shown in **Table 1.1.**

- **Table 1.1 Sub catchment details**

		Existing		Developed		slope
Sub catchment	Total (ha)	Urban(ha)	Rural (ha)	Urban(ha)	Rural (ha)	
6	32.0	15.4	16.7	32.0	0.0	2.11%
7	28.7	3.8	24.9	28.7	0.0	2.22%
8	48.0	2.6	45.4	48.0	0.0	1.41%

The percentage impervious adopted in the model are as follows;

- Existing Case

Urban Area outside the site – 50% impervious

Rural (within the site) – 5% impervious

- Developed Case

Urban (within the site) – 70% impervious

Rural – 5% impervious (unchanged from existing case)

These values are based on the following assumptions:

- No development will occur in the regional park therefore % impervious does not change;

[1] Sub catchment labelling remains consistent with previous St Mary's studies to avoid confusion.

- Areas allocated for urban development will have varying impervious percentages between 50-70%. For the purpose of the assessment the more conservative, 70% has been adopted for all areas; and
- Existing urban areas external to the site will be unchanged from existing, i.e. 50% impervious.

1.5.2. Rainfall Intensities and Loss Parameters

Penrith City Council IFD data was used in the RAFTS model. A suite of storm durations were input for each ARI rainfall event. IFD data is shown in **Table** below.

- **Table 1.2 Penrith City Council IFD Rainfall Data**

Duration (min)	2yr ARI	5yr ARI	10yr ARI	20yr ARI	50yr ARI	100yr ARI
20	52.82	69.66	79.08	91.89	108.85	121.9
30	42.83	56.47	64.09	74.46	88.19	98.75
60	29.05	38.28	43.43	50.44	59.72	66.86
90	23.04	30.31	34.36	39.89	47.19	52.81
120	19.48	25.6	29	33.65	39.79	44.51
180	15.33	20.12	22.78	26.41	31.21	34.89
360	10.16	13.3	15.04	17.42	20.56	22.97
720	6.75	8.81	9.95	11.51	13.57	15.15

Loss parameters used in the model are as follows:

Impervious Losses;	Initial 1.0mm	Continuing 0.5mm
Pervious Losses;	Initial 10.0mm	Continuing 2.5mm

Bx factor 1.0

The loss parameters are consistent with previous work undertaken by SKM for St Marys, and are consistent with those adopted by JWP in the *Interim Stormwater Management Report* (August 2009).

1.5.3. Roughness Coefficients

Mannings 'n' values adopted in the model for different land uses are provided in **Table 1.3** for the existing and developed case. These values are consistent with previous assessments undertaken.

- **Table 1.3 Roughness values**

Land use	Mannings 'n' value
Existing (pervious)	0.07
Existing (impervious)	0.025
Developed (pervious)	0.015
Developed (impervious)	0.025

1.5.4. Catchment lag times

Catchment lag times have been calculated using the flow path length for the subcatchment and assumed average velocities of the stormwater. The velocities of 2m/s for existing and 1.5m/s for developed have been adopted in the model.

1.6. Model Results

The XP-Rafts model was run for a range of durations from 15minutes – 6 hours to assess and compare the existing case and 'developed with detention' peak flows at the catchment outlet. A comparison of peak flows for the 2 year and 100 year events is are shown in **Table 1.4.**

- **Table 1.4 Peak Flow**

Design Storm (ARI)	Peak flow Existing (m3/s)	Peak flow Developed (m3/s) no detention	Peak flow Developed (m3/s) with detention
2 year	4.9	24.5	4.3
100 year	13.9	55.7	13.3

The results in Table 1.4 indicate that the developed peak flow (with detention) is less than the existing peak flow for the 2 year and 100 year events. The reduction in peak flows are 12% and 4% respectively. There is also a significant reduction in developed peak flows with the detention basin when compared to the unmitigated peak flows.

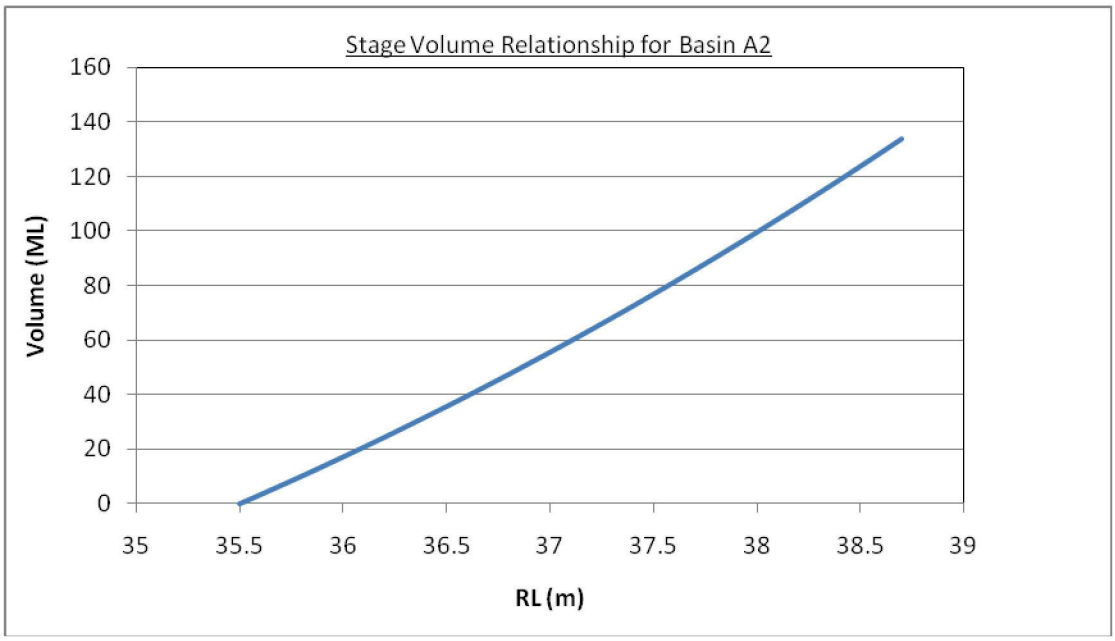
Results indicate that Basin A2 provides adequate detention for the Stage 1 development. Details of the detention basin are provided below.

1.7. Detention Bain details

1.7.1. Basin geometry

A stage-volume relationship has been determined using 3D contour information and inputted into the model to represent the basin geometry. The relationship is shown in **Figure 1.2.**

- **Figure 1.2 Stage-Volume relationship for A2**

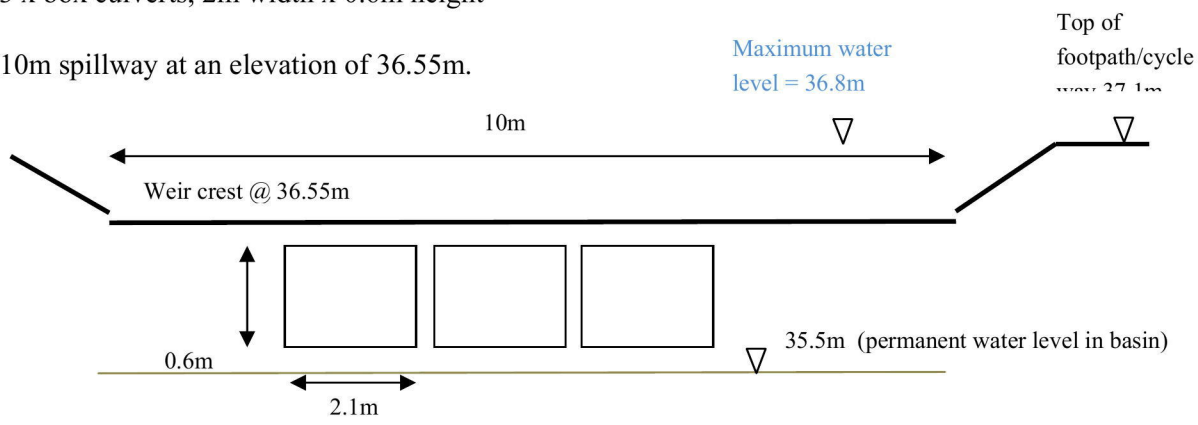


1.7.2. Outlet Configuration

Preliminary model runs have been undertaken assuming the following outlet configuration:

3 x box culverts, 2m width x 0.6m height

10m spillway at an elevation of 36.55m.



Preliminary results for the 2 year and 100 year design events are summarised in **Table 1.5**.

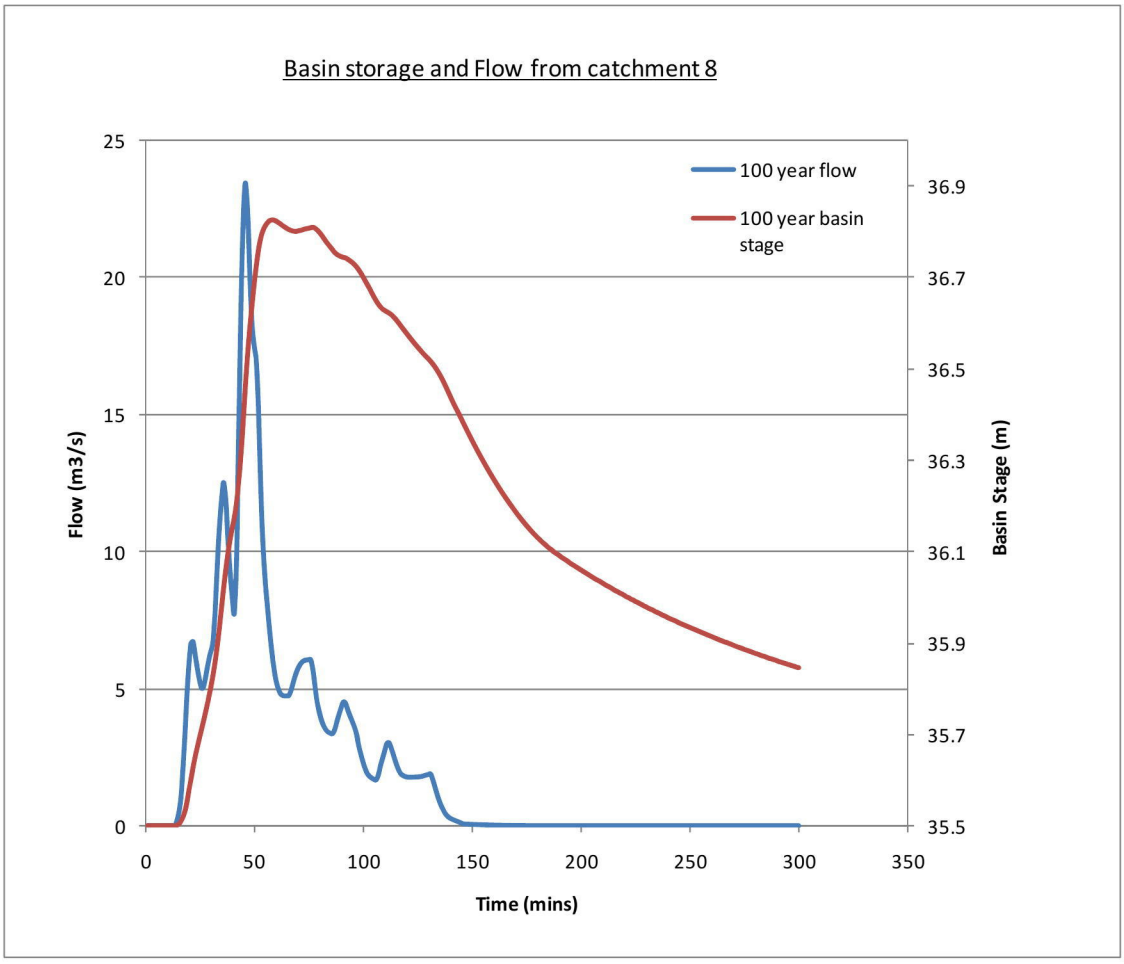
- **Table 1.5 Detention Details**

Design Storm (ARI)	Detention Volume Required (ML)	Maximum Stage (m)	Maximum Depth over weir (mm)
2 year	25	36.2	0
100 year	48	36.8	300

1.7.3. Future inlet into the basin

Preliminary modelling work has been undertaken to assess the potential backwater impacts on the future northern inlet channel carrying flows from Catchment 8 (see **Figure 1.1**). A plot of flows from Catchment 8 and the water level in the basin are provided in Figure 1.3 for the 100 year event.

- **Figure 1.3 Basin storage and flow from Catchment 8**



The peak flow and peak basin stage are not coincident, the basin stage peaks as the flow is receding in the channel, approximately 10 minutes after the peak flow. Preliminary results indicate that the

backwater impact on the channel would be minimal; however, an overflow side flow mechanism will be incorporated into the design of the future open channel through a single spillway of approximately 6m at an RL that is lower than the basin weir RL to ensure that the capacity of the future open channel is maintained and to limit any backwater impact.

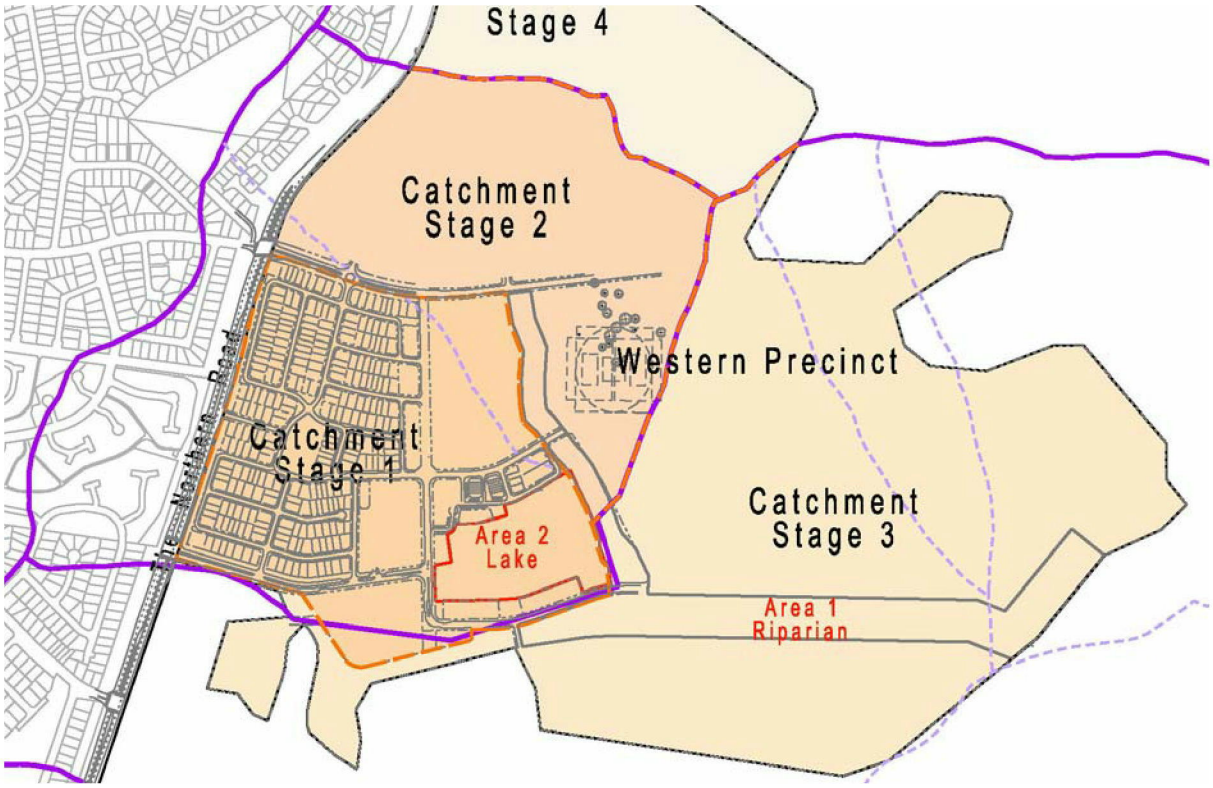
Appendix B Water Quality Assessment

Stormwater Quality Management in Jordan Springs Lake, St Marys

1.1. Purpose

The purpose of this report is to provide a water quality assessment of the proposed Jordan Springs Lake (Area 2 Lake on **Figure 1**). The layout of the proposed development for Stages 1 and 2 of the Western Precinct at St Marys is also shown on **Figure 1.** The runoff generated from the proposed development area of Stages 1 and 2 will receive water quality treatment within the lake prior to discharge into the Riparian corridor (Area 1 in **Figure 1**). This assessment demonstrates that the proposed size of the lake will provide sufficient water quality treatment to meet and exceed the required water quality objectives.

- **Figure 1 – Location of the proposed Lake (Area 2) and layout of Stages 1 and 2 catchments**



1.2. Stormwater Quality Management Objectives

The stormwater quality management objectives for the proposed development are to provide sufficient water quality treatment to reduce the pollutant loads from the proposed development catchments. The objectives that have been used were obtained from the '*South Creek Stormwater*

Management Plans' document and the *'Draft Policy of PCC on Stormwater Quality Control'*. These criteria and water quality objectives for new urban areas are described on **Table 1.**

- **Table 1 - Stormwater Treatment Objectives for New Urban Areas**

	Retention Criteria (Ref PCC)	ESD treatment Objectives (Ref South Creek SMP)
Suspended Solids	80% retention of the load for particles < 0.5mm dia	80% retention of the average annual load
Total Phosphorus	45% retention of the load	45% retention of the average annual load
Total Nitrogen	45% retention of the load	45% retention of the average annual load

Reference: *South Creek Stormwater Management Plan, Stormwater Trust, 2000- Pg60*
Penrith City Council, Draft Stormwater Quality Control Policy, 2005- pg8

1.3. Water Quality MUSIC modelling

A stormwater quality assessment was undertaken using the MUSIC model (Version 4.0) to estimate the reduction in water pollution by the proposed Lake. The main purpose of the modelling was to demonstrate that the proposed water quality management controls (Jordan Springs Lake/water quality pond) would meet the water quality objectives of reducing the annual pollutant loads generated from the future urbanised catchment.

The following data was used in the water quality MUSIC model:

- Pluviograph data for use in the model was obtained from the Bureau of Meteorology for station AWS 67113 at Penrith Lakes for the period December 1998 to November 2002. One year of rainfall data was used with 2001 chosen as the average rainfall year and the model was run at six minute time steps.
- Data from '*Stormwater Flow and Quality and the Effectiveness of Non-Proprietary Stormwater Treatment Measures* (*Monash University and CRC for Catchment Hydrology, 2004)'* and the '*Clean Waterways Program, Stormwater Monitoring Program, Sydney Water 1995'*, was used in the water quality model to represent urbanised conditions. The recommended typical values for suspended solids, total phosphorus and total nitrogen were adopted as the Event Mean Concentrations (EMC) in the model from **Table 2**.
- The proposed surface area of the Lake used in the model is 3.27 ha with a volume of 55.5ML.
- The total catchment area of Stage 1 and 2 is approximately 87 ha.

- **Table 2 - EMC Values adopted for the future Urbanised catchment**

	Base EMC	Storm EMC
TSS mg/L	16	141
TP mg/L	0.14	0.25
TN mg/L	1.0	2.5

1.4. Results

The results for the MUSIC modelling are given in **Table 3**, which provides the annual pollutant loads for Total Phosphorus, Total Nitrogen and Total Suspended Solids at two locations, immediately upstream and downstream of the proposed Lake. The percentage reduction in annual pollutant loads is given on Table 3 and compared to the water quality criteria. The results indicate that the proposed Lake will provide sufficient water quality treatment for the runoff generated from the upstream area to be developed as part of Stages 1 and 2.

- **Table 3 - Pollutant loads from Stages 1 and 2, and reductions achieved by the Lake**

Average Annual Pollutant Loads			Percent reduction	Water Quality Reduction Criteria
Total Phosphorus (kg/yr)	Upstream of water quality pond	93		
	Downstream of water quality pond	42	**54%**	**45%**
Total Nitrogen (kg/yr)	Upstream of water quality pond	851		
	Downstream of water quality pond	446	**47%**	**45%**
Suspended Solids (kg/yr)	Upstream of water quality pond	55×10^3		
	Downstream of water quality pond	8.3×10^3	**85%**	**80%**

A comparison check of the Lake's surface area to the catchment area for Stages 1 and 2 can be used as an approximate method to determine whether this ratio lies within a reasonable range. The commonly accepted range is between 2% and 4%. This ratio for the Jordan Springs Lake and the catchment area of stages 1 and 2 is 3.7%, which is in the higher end of this range. This is considered to be a conservative result.

Maintenance is an essential part of a healthy lake system that continues to provide an aesthetic environment as water quality treatment. A maintenance manual for the Lake has been prepared to provide all essential tasks needed to undertake a good maintenance regime. Refer to **Appendix C.**

1.5. Conclusion

The size of the proposed Jordan Springs Lake provides adequate water quality treatment to the future urbanised area of Stages 1 and 2. The Lake will require adequate maintenance to ensure optimum water quality treatment.

Appendix C - Maintenance Manual for the Jordan Springs Lake

1. Introduction

1.1. Purpose

Wetlands provide a very effective means of treating stormwater in urban areas. However, wetlands constructed in urban environments are subject to external factors and hence, will not behave like natural systems without regular maintenance. Therefore, this Maintenance Manual has been prepared to outline the maintenance and operational requirements associated with the proposed stormwater wetland at Jordan Springs Lake. The main purpose of the wetland is to facilitate water quality treatment and to improve the aesthetic qualities of the area.

1.2. Site Description

The proposed wetland will be located in a future residential area. When built, the wetland will occupy an area of approximately 3.25ha and contain a volume of approximately 55ML. Stormwater collected in the drainage system of the future residential area will enter the wetland via three inlets.

The wetland will comprise of a deep water zone and a perimeter macrophyte zone which will consist of reed beds around the perimeter of the wetland and open water areas. It will facilitate nutrient removal and provide a habitat for wildlife. The open water zone is the deeper part of the wetland without any emergent type macrophytes.

2. Wetland Management

2.1. Wetland Function

Constructed wetland ecosystems are vitally important and regarded as valuable environmental management tools with key qualities being that wetlands:

- Decrease storm-water pollution
- Provide habitat for native flora and fauna
- Act as a buffer for the protection of natural aquatic ecosystems

Wetlands function through a variety of biological, chemical and physical processes which interact to increase nutrient removal and uptake by wetland flora, the breakdown of harmful chemicals in storm water and the action of wetland physical processes which slow down the velocity of running storm water. Wetlands are vitally important and when successfully implemented provide attractive public amenity.

2.2. The Role of Vegetation

Vegetation plays an important role in the effective functioning of a wetland. The reed beds and littoral areas in the macrophyte zone enhance the stormwater treatment process by filtering the sediment from the water, facilitating nutrient removal and providing a habitat for wildlife. The reed beds also provide a substrate for microbial biofilms and enhance the transfer of oxygen to the substrate. The open water area provides increased exposure to sunlight, thus increasing the level of water treatment.

The macrophytes to be planted in the wetland will be selected by the landscape Architects at the detailed design stage. A preliminary list of macrophytes supplied by the Landscape Architects includes:

- Eleocharis sphacelata,
- Eleocharis acuta,
- Bolboschoenus fluviatilis
- Bolboschoenus caldwellii
- Baumea rubiginosa,
- Baumea articulata
- Lepironia articulata
- Schoenoplectus validus

- Schoenoplectus mucronatus
- Triglochin procerum
- Ludwigia peploides
- Philydrum lanuginosum
- Juncus usitatus
- Carex appressa
- Cyperus exaltatus
- Gahnia sieberiana
- Lomandra longifolia

2.2.1. Pest Plant Species

A number of undesirable weed species could potentially grow in the wetland. Therefore, maintenance staff must be familiar with the species originally planted in the wetland to enable identification of any foreign plant species. If any introduced weeds are observed, they must be removed as soon as possible to prevent infestation. Undesirable weed species could include *Isolepris prolifera*, Cumbungi *Typha* spp, Salvinia *Salvinia molesta*, Water Hyacinth *Eichhornia crassipes*, Cabomba *Cabomba caroliniana,* Elodea *Elodea canadensis*, Alligatorweed *Alternanthera philoxeroides*, Primrose Willow *Ludwigia peruviana*, Mexican Waterlily *Nymphaea mexicana* and Dense Waterweed *Egeria densa*. For a complete description of these weed species and their controls please refer to **Section 5** of this report.

2.2.2. Algal Growth

Algal blooms tend to develop in warm, nutrient enriched waters. The presence of algae may cause a deterioration in water quality and restrict light penetration into the water column. Algae may grow in the form of filamentous algae, such as *Enteromorpha* sp., *Spirogyra* sp. and *Cladophora* sp., which forms dense floating mats or in the form of blue-green algae, such as *Microcystis* and *Anabaena,* which forms on the surface of the water and in the water column.

Regular monitoring and maintenance of the wetland will help to minimise the likelihood of algal growth. Aquatic plants need to be maintained to enhance nutrient uptake and sediments captured in the sedimentation pond should be regularly removed to prevent the mobilisation of nutrients.

Algal blooms can be prevented using strategies such as:

- changing conditions in the water body so that algae are less likely to bloom (e.g. oxygenation, treating the sediments)
- harvesting macroalgae in shallow water or on beaches to keep the shoreline clean
- increase flushing so that more nutrients are lost from the water body

Algal blooms can be actively managed using the following management techniques (DNR 2010):

- Artificial destratification – altering the thermal layers within a waterbody which may be beneficial for algal blooms.
- Biomanipulation
- Water treatment - Algae can be removed from wetlands using a number of strategies including coagulation using aluminium and ferric iron salts or organic polymers, filtration of the water body, and the use of algicides to remove any algal blooms present.

2.3. Wildlife Management

2.3.1. Wildlife Habitat

Constructed wetlands provide a sanctuary for birds and other animals. Feeding, nesting and breeding activities are enhanced within the wetland area and the abundance and diversity of wildlife can improve the aesthetic characteristics of the wetland basin.

2.3.2. Pest Animal Species

Animal species which could potentially pose a threat to the wetland environment are mosquitoes, mosquito fish, European Carp and introduced waterbirds.

Mosquitoes pose the greatest risk to human health as they may transmit disease. A variety of design and management strategies can be employed to minimise the likelihood of large mosquito populations. These include:

- Creating a water disturbance such as a jet or cascade operated by a submersible pump to disturb the mosquito breeding cycle and kill off populations
- Vary water levels during the breeding cycle to kill populations of mosquitoes
- Implementing a deep wetland design which allows wind wave disturbance and incorporates a steep bank slope to reduce habitat sites.

If present in an artificial wetland mosquito populations can be managed using aerial larvicide application. This application can be conducted by a suitably qualified operator using a hand based applicator or in large scale cases a small helicopter. The application process should be preceded by a pre-treatment survey to determine mosquito abundance and distribution and by a post-treatment survey to determine the success of the larvicide application.

The application of larvicide is heavily dependent upon local weather conditions and environmental characteristics and should only be conducted by a certified operator.

Wetland Maintenance Operations

2.4. Routine Maintenance Tasks

A routine inspection of the wetland is required to be undertaken monthly and after storm events or any other events such as floods, fire and chemical spills that may affect the wetland's function. It is recommended that most items be inspected monthly, however, some items only require attention three-monthly, bi-annually or annually. **Table 1** outlines the frequency at which each item should be inspected and the appropriate maintenance activities associated with that item.

- **Table 1 – Description of Routine Inspection Tasks**

Item	Inspection Frequency	Maintenance Required
Physical		
Debris and litter removal, including at the inlet, outlet and overflow structures	Monthly and immediately after storm events	Hand removal and appropriate disposal of material.
Signage	Monthly	Inspect signs for vandalism. Replace and/or repair signs as necessary.
Sedimentation	Monthly	Remove sediment from the sediment retention area when 0.3m deep using an excavator.
Erosion	Monthly or after storm events	Check the verges and record the location and extent of any erosion. Stabilise erosion sites as necessary.
Water Level	Monthly	Record any changes in water level.
Biological		
Weeds	Monthly or after storm events	Hand removal of any introduced species before the infestation becomes difficult to control.
Mosquitoes	Three-monthly	Check for presence of mosquitoes at dawn and dusk. Check for larvae in pooled water and in shallow sections of the wetland. Check for the presence of invertebrates and small fish, which help to control mosquitoes.
Birds and Other Animals	Three-monthly	Record the presence of animals, including evidence of their existence such as droppings

		or tracks.
Blue-green Algae	Monthly	Check for presence of green surface film, scum, discolouration or new odours.
Water Quality	Bi-annually	Take water samples every 6 months or as necessary, depending on water quality testing results.
Change in Waterplants	Annually	Record diagrammatically the location and abundance of waterplants and compare with original records. Note any discolouration, disease or death.
Replanting	As required	Replace plants as necessary, according to location and abundance of species.

2.5. Maintenance Checklist

A maintenance checklist has been developed which will enable all aspects of the maintenance program, both physical and biological, to be completed and verified. A copy of the maintenance checklist is attached in **Appendix C1**.

Data collected at the wetland should be recorded in a database to assist in the long-term monitoring of the site. Any information recorded in field notes taken during routine inspections and associated maintenance work, as well as results of laboratory testing should be stored in this database. Detailed descriptions of any changes to the wetland will assist management in identifying future needs and maintenance priorities.

2.5.1. Aquatic Vegetation

Over time, there may be some changes in the distribution and abundance of aquatic species found in the wetland. Undesirable plants should be removed by hand as soon as possible to minimise further spreading and to avoid the use of pesticides.

A thorough annual inspection is recommended to document the precise location and abundance of aquatic vegetation, however, any significant changes to the wetland vegetation should be recorded when observed. The results of the inspection should be illustrated diagrammatically and compared with the initial planting guide. The condition of the plants, particularly any signs of disease, pests or stunted growth should also be noted.

2.5.2. Water Quality

Water quality changes can be accessed through physical and chemical testing. Measurements of suspended solids; nutrients including total phosphorus, total nitrogen and ammonia; heavy metals;

hydrocarbons including oils and grease; organics; pathogens including faecal coliforms; oxygen demand; pH and temperature should be recorded bi-annually, after the initial establishment of plants.

2.5.3. Basin Shape and Size

The capacity of the wetland to hold and treat stormwater is dependent upon the shape and size of the basin. Changes to embankment slope and depth may affect the volume of runoff which can be contained in the wetland. Embankments should be inspected monthly to assess any changes which may have occurred as a result of erosion, scouring or changes to vegetation cover. Any changes in water level and basin depth due to changed flow conditions, evaporation or sedimentation should also be recorded.

3. Weed Management

Why are weeds such a problem?

There are many definitions to describe what a weed is. A suitable description of a weed is an unwanted plant growing in a given area which, to reduce its effect on the economy, the environments, human health and amenity requires some form of action control or management action. Weeds are also known as invasive plants. (DEWHA 2010a, NSW DPI 2010). Weeds are among the most serious threats to Australia's natural environment and primary production industries. They displace native species, cause significant land degradation, and reduce farm and forest productivity, and generally interfere with the natural balance of ecological communities (DEWHA 2010b).

3.1. Weed Control Methods

As weeds have such a great economical and environmental impact, appropriate control and management measures are required to minimise any possible weed impacts. The most effective means of weed control is through early detection and eradication where necessary.

3.1.1. Herbicide Use and Safety

As described above weed infestations can be controlled using herbicide supplication. When spraying weed infestations with weeds caution should be used at all times as any 'over-spray' may have negative impacts upon non-target vegetation and the local environment. (The following parameters must be employed when using herbicide to control weed infestation:

- Only licensed operators may undertake herbicide spraying.
- Only use herbicides according to the product label instructions.
- Use only non-residual herbicide (e.g. Biactive Roundup).
- Ensure all Personal Protective Equipment (PPE) is worn; including, overalls, covered shoes, gloves, glasses and mask.)
- Monitor local weather conditions and do not spray on days which are windy, days of rain, or when rain is expected in the proceeding days.

Employees working in the wetland are advised to minimise skin contact with water in the wetland basin. Either waterproof boots, thigh boots or gum boots should be worn at all times. Other protective clothing, sunscreen and insect repellent should be provided by Council for all staff

working in and around the wetland area. The Occupational Health and Safety Act 2000 was established to protect the health, safety and welfare of people at work.

3.2. Common Aquatic Weeds

Common aquatic weeds which may be present include:

- Isolepris prolifera,
- Cumbungi (*Typha* spp,)
- Salvinia (*Salvinia molesta*)
- Water Hyacinth (*Eichhornia crassipes*)
- Cabomba (*Cabomba caroliniana*)
- Elodea (*Elodea canadensis*)
- Alligatorweed (*Alternanthera philoxeroides*)
- Primrose Willow (*Ludwigia peruviana*)
- Mexican Waterlily (*Nymphaea mexicana*) and
- Dense Waterweed (*Egeria densa*)

3.3. Noxious Weeds

The outlet from the Jordan Springs wetland discharges into South Creek which is a tributary of the Hawkesbury River. A list of declared noxious weeds in the control area of Hawkesbury River County Council is included in **Appendix C1**.

4. References

Department of the Environment, Water, Heritage and the Arts 2010a; *"Weeds in Australia - What is a weed?"* Available online:http://www.weeds.gov.au/weeds/what.html Accessed July 2010

Department of the Environment, Water, Heritage and the Arts 2010b; *"Weeds in Australia – Why are weeds a problem?"* Available online:http://www.weeds.gov.au/weeds/what.html Accessed July 2010

Department of the Environment, Water, Heritage and the Arts 2010c; *"Weeds in Australia – Managing weeds?"* Available online:http://www.weeds.gov.au/weeds/what.html Accessed July 2010

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Department of Natural Resources 2007; *Algae: Causes and Control*. Available online: *http://www.dnr.nsw.gov.au/water/algae_causes.shtml.* Accessed August 2010.

NSW Department of Primary Industries 2010; '*Weed Management FAQS'*. Available online: http://www.dpi.nsw.gov.au/agriculture/pests-weeds/weeds/definition/faqs Accessed July 2010.

Sinclair Knight Merz Drawings, 2004, Wetland Pond Planting Schedule, Drawing Number C-010 and Drainage Longitudinal Sections and Schedule, Drawing Number C-006

Sainty, G. and Dalby-Ball, M., 2000*, Maintenance Manual for Water Bodies on the Glen Alpine Golf Course*, Unpublished report to Lend Lease Residential prepared by Sainty and Associates Pty Ltd

Appendix C1 – Noxious Weeds

Weed	Class	Legal requirements
African boxthorn [*Lycium ferocissimum*]	4	The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority
African feathergrass [*Pennisetum macrourum*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
African olive [*Olea europaea subspecies cuspidata*]	4	The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority and the plant may not be sold, propagated or knowingly distributed
African turnipweed [*Sisymbrium runcinatum*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
African turnipweed [*Sisymbrium thellungii*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Alligator weed [*Alternanthera philoxeroides*]	3	The plant must be fully and continuously suppressed and destroyed
Anchored water hyacinth [*Eichhornia azurea*]	1	The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration
Annual ragweed [*Ambrosia artemisiifolia*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Arrowhead [*Sagittaria montevidensis*]	5	The requirements in the Noxious Weeds Act

		1993 for a notifiable weed must be complied with This is an All of NSW declaration
Artichoke thistle [*Cynara cardunculus*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Athel pine [*Tamarix aphylla*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Bathurst/Noogoora/Hunter/South American/Californian/cockle burr [*Xanthium* species]	4	The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority
Bear-skin fescue [*Festuca gautieri*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Black knapweed [*Centaurea nigra*]	1	The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration
Blackberry [*Rubus fruticosus* aggregate species] except cultivars Black satin, Chehalem, Chester Thornless, Dirksen Thornless, Loch Ness, Murrindindi, Silvan, Smoothstem, Thornfree	4	The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority and the plant may not be sold, propagated or knowingly distributed This is an All of NSW declaration
Bridal creeper [*Asparagus asparagoides*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Broomrapes [*Orobanche* species] Includes all Orobanche species except the native O. cernua variety australiana	1	The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration

and O. minor		
Burr ragweed [*Ambrosia confertiflora*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Cabomba [*Cabomba caroliniana*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Cayenne snakeweed [*Stachytarpheta cayennensis*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Chilean needle grass [*Nassella neesiana*]	4	The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority and the plant may not be sold, propagated or knowingly distributed
Chinese violet [*Asystasia gangetica* subspecies *micrantha*]	1	The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration
Clockweed [*Gaura parviflora*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Columbus grass [*Sorghum x almum*]	4	The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority
Corn sowthistle [*Sonchus arvensis*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Crofton weed [*Ageratina adenophora*]	4	The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local

		control authority
Dodder [*Cuscuta* species] Includes All Cuscuta species except the native species C. australis, C. tasmanica and C. victoriana	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
East Indian hygrophila [*Hygrophila polysperma*]	1	The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration
Espartillo [*Achnatherum brachychaetum*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Eurasian water milfoil [*Myriophyllum spicatum*]	1	The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration
Fine-bristled burr grass [*Cenchrus brownii*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Fountain grass [*Pennisetum setaceum*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Gallon's curse [*Cenchrus biflorus*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Giant Parramatta grass [*Sporobolus fertilis*]	3	The plant must be fully and continuously suppressed and destroyed
Glaucous starthistle [*Carthamus glaucus*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Golden dodder [*Cuscuta campestris*]	4	The growth and spread of the plant must be controlled according to the measures specified in

		a management plan published by the local control authority
Golden thistle [*Scolymus hispanicus*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Green cestrum [*Cestrum parqui*]	3	The plant must be fully and continuously suppressed and destroyed
Harrisia cactus [*Harrisia* species]	4	The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority and the plant may not be sold, propagated or knowingly distributed This is an All of NSW declaration
Hawkweed [*Hieracium* species]	1	The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration
Horsetail [*Equisetum* species]	1	The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration
Hygrophila [*Hygrophila costata*]	2	The plant must be eradicated from the land and the land must be kept free of the plant
Hymenachne [*Hymenachne amplexicaulis*]	1	The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration
Italian bugloss [*Echium* species]		See Paterson's curse, Vipers bugloss, Italian bugloss
Johnson grass [*Sorghum halepense*]	4	The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority
Karoo thorn [*Acacia karroo*]	1	The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration
Kochia [*Bassia scoparia*]	1	except B.scoparia subspecies trichophylla

except Bassia scoparia subspecies trichophylla		The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration
Lagarosiphon [*Lagarosiphon major*]	1	The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration
Lantana [*Lantana* species]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Leafy elodea [*Egeria densa*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Lippia [*Phyla canescens*]	4	The plant must not be sold, propagated or knowingly distributed by any person other than a person involved in hay or lucerne production. The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority. This is an All of NSW declaration
Long-leaf willow primrose [*Ludwigia longifolia*]	3	The plant must be fully and continuously suppressed and destroyed
Long-leaf willow primrose [*Ludwigia longifolia*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Ludwigia [*Ludwigia peruviana*]	3	The plant must be fully and continuously suppressed and destroyed
Mexican feather grass [*Nassella tenuissima*]	1	The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration
Mexican poppy [*Argemone mexicana*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with

		This is an All of NSW declaration
Miconia [*Miconia* species]	1	The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration
Mimosa [*Mimosa pigra*]	1	The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration
Mossman River grass [*Cenchrus echinatus*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Mother-of-millions [*Bryophyllum* species and hybrids]	3	The plant must be fully and continuously suppressed and destroyed and the plant may not be sold, propagated or knowingly distributed
Noogoora burr [*Xanthium* species]		See Bathurst/Noogoora/Hunter/South American/Californian/cockle burr
Onion grass [*Romulea* species] Includes all Romulea species and varieties except R. rosea var. australis	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Oxalis [*Oxalis* species and varieties] Includes all Oxalis species and varieties except the native species O. chnoodes, O. exilis, O. perennans, O. radicosa, O. rubens, and O. thompsoniae	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Pampas grass [*Cortaderia* species]	3	The plant must be fully and continuously suppressed and destroyed
Parthenium weed [*Parthenium hysterophorus*]	1	The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration
Paterson's curse, Vipers bugloss, Italian bugloss [*Echium* species]	4	The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority
Pellitory [*Parietaria judaica*]	4	The growth and spread of the plant must be

		controlled according to the measures specified in a management plan published by the local control authority
Pond apple [*Annona glabra*]	1	The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration
Prickly acacia [*Acacia nilotica*]	1	The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration
Prickly pear [*Cylindropuntia* species]	4	The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority and the plant may not be sold, propagated or knowingly distributed This is an All of NSW declaration
Prickly pear [*Opuntia* species except *O. ficus-indica*]	4	The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority and the plant may not be sold, propagated or knowingly distributed This is an All of NSW declaration
Privet (Broad-leaf) [*Ligustrum lucidum*]	4	The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority and the plant may not be sold, propagated or knowingly distributed
Privet (Narrow-leaf/Chinese) [*Ligustrum sinense*]	4	The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority and the plant may not be sold, propagated or knowingly distributed
Red rice [*Oryza rufipogon*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Rhus tree [*Toxicodendron*	4	The growth and spread of the plant must be

succedaneum]		controlled according to the measures specified in a management plan published by the local control authority This is an All of NSW declaration
Rubbervine [*Cryptostegia grandiflora*]	1	The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration
Sagittaria [*Sagittaria platyphylla*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Salvinia [*Salvinia molesta*]	3	The plant must be fully and continuously suppressed and destroyed
Sand oat [*Avena strigosa*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Senegal tea plant [*Gymnocoronis spilanthoides*]	1	The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration
Serrated tussock [*Nassella trichotoma*]	4	The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority and the plant may not be sold, propagated or knowingly distributed
Siam weed [*Chromolaena odorata*]	1	The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration
Smooth-stemmed turnip [*Brassica barrelieri* subspecies *oxyrrhina*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Soldier thistle [*Picnomon acarna*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration

Spiny burrgrass [*Cenchrus incertus*]	4	The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority and the plant may not be sold, propagated or knowingly distributed
Spiny burrgrass [*Cenchrus longispinus*]	4	The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority and the plant may not be sold, propagated or knowingly distributed
Spotted knapweed [*Centaurea maculosa*]	1	The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration
St. John's wort [*Hypericum perforatum*]	4	The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority
Texas blueweed [*Helianthus ciliaris*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration
Water caltrop [*Trapa* species]	1	The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration
Water hyacinth [*Eichhornia crassipes*]	3	The plant must be fully and continuously suppressed and destroyed
Water lettuce [*Pistia stratiotes*]	1	The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration
Water soldier [*Stratiotes aloides*]	1	The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration
Willows [*Salix* species] Includes all Salix species except S. babylonica, S. x reichardtii, S. x calodendron	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration

Witchweed [*Striga* species] Includes all Striga species except native species and Striga parviflora	1	The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration
Yellow burrhead [*Limnocharis flava*]	1	The plant must be eradicated from the land and the land must be kept free of the plant This is an All of NSW declaration
Yellow nutgrass [*Cyperus esculentus*]	5	The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with This is an All of NSW declaration

Appendix C2 – Maintenance Checklist

Inspection Checklist

Name ……. Signature ……
……

	Action Required				
Item	**None[1]**	**Soon[2]**	**Urgent[3]**	**Comments[4]**	**Action Taken[5]**
Physical					
Debris and litter					
Signage					
Sedimentation					
Erosion					
Water Level					
Biological					
Weeds					
Mosquitoes					
Birds / Other Animals					
Blue-green Algae					
Water Quality					
Change in Waterplants					
Replanting					

[1] The item is in good condition and no additional maintenance is required

[2] The item is in reasonable condition; however, further maintenance is required prior to the next inspection.

[3] The item is in poor condition and requires immediate action

[4] Describe any additional work required

[5] Describe the date and action taken to rectify the issue

Appendix D Water Level in Lake

Estimation of Water Levels in Jordan Springs Lake, St Marys

4.1. Introduction

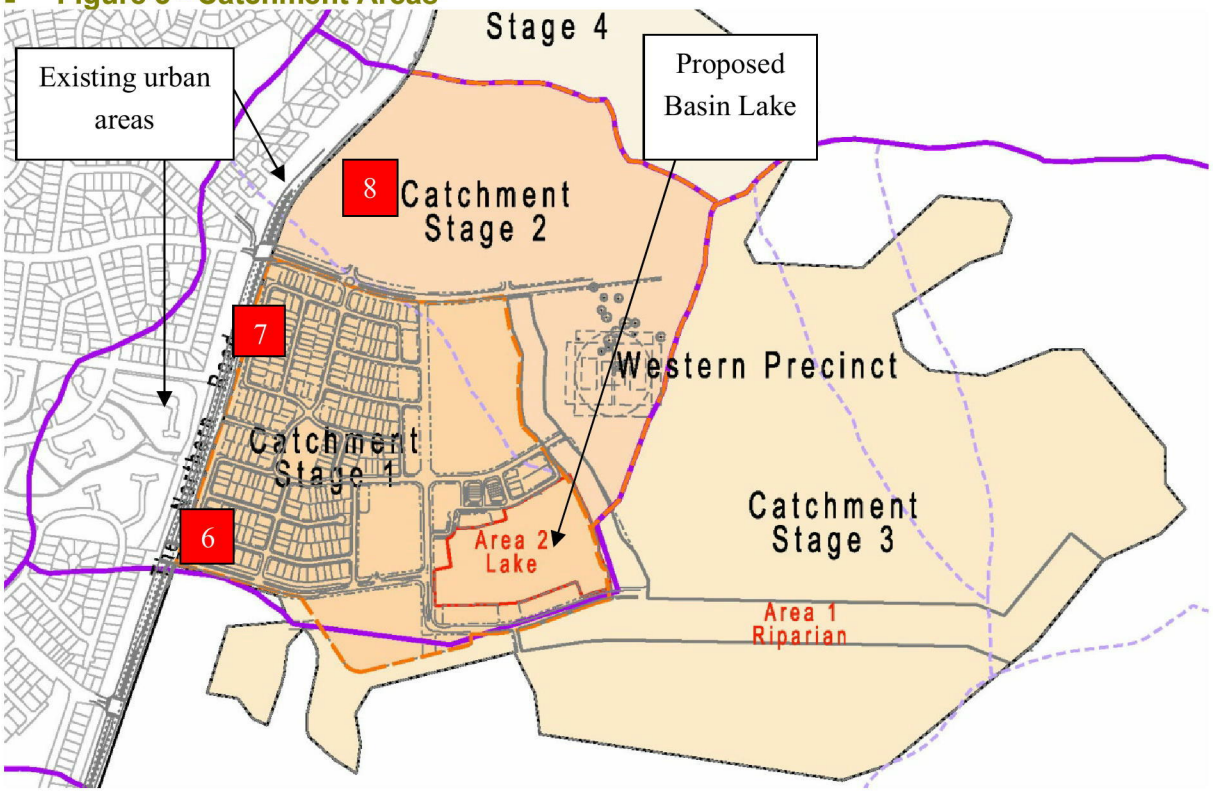
In order to analyse the drop in the water levels of the proposed Jordan Springs Lake at St Marys, which will be built as part of an urban development, a water balance model has been created to estimate the water level drops in the lake.

The study area includes a total catchment area of 109 hectares draining to the proposed basin, (catchments Stage 1 and Stage 2, including the existing urban area). The basin is located to the south-east corner of the developed area. The existing catchment areas are predominantly rural, with some urban development on the western fringes of the catchment. The catchment boundaries used in this assessment are shown in **Figure 1**.

In this assessment two scenarios have been developed. The first is for the development of Stage 1 of the project, where the lake will receive runoff from the existing urban sections of sub-catchments 6 and 7 and the newly developed stage 1 area, ie: including runoff from the undeveloped sections of catchments 6 and 7. The second scenario includes runoff the total catchment draining to the Basin including Stage 2.

For both scenarios, the effect of climate change on the lake's water levels has been analysed by comparing the model using historical rainfall data and factored rainfall data to simulate changed conditions due to climate change.

- **Figure 3 - Catchment Areas**



4.2. Methodology

A simple rainfall model has been created to estimate daily rainfall runoff volumes on the catchments using 50 years of daily recorded rainfall data collated from the most appropriate of 9 nearby rain gauges. Although simplified, the results do not impact significantly on the outcome of the analysis. A reduction of 1.5mm of the initial daily rainfall has been included as a conservative estimate of the absorption of rain into the catchment soil. Further conservative assumptions include the omission of evapotranspiration and the adoption of a small trickle flow value of 0.5L/s for the first scenario and 0.9L/s for the second scenario. An impermeable lining of the lake has also been assumed thus excluding water seepage from the analysis.

CSIRO estimates that by 2030 rainfall in the Hawkesbury-Nepean Catchment will have change d by ±7% from the current long- term average (CSIRO, 2007). Reduced rainfall in the catchment will result in lower water levels in the lake. To analyse this effect, a second model was created for each scenario, in which the daily rainfall data was reduced by 7%.

The assumptions and results of the analyses are discussed herein.

Assumptions and Parameters Used:

- **Table 2 - Rainfall Runoff CCoefficients**

Volumetric Urban Runoff Coefficient (Urban)	**0.3**
Volumetric Runoff Coefficient (Undeveloped)	**0.05**
Initial rainfall losses	**1.5mm/day**
Trickle flow (Stage 1)	**0.5 L/s**
Trickle flow (Stage 2)	**0.9L/s**

- **Table 3 –Stage 1 Catchment Areas**

Catchment	Urban (ha)	Undeveloped (ha)
6	15.4	26.7
7	2.6	
Stage 1 area	16	0
Total	34	26.7

- **Table 4 - Stage 2 Full Development Catchment Areas**

Catchment	Urban (ha)	Undeveloped (ha)
6	32	0
7	28.7	0
8	48	0
Total	108.7	0

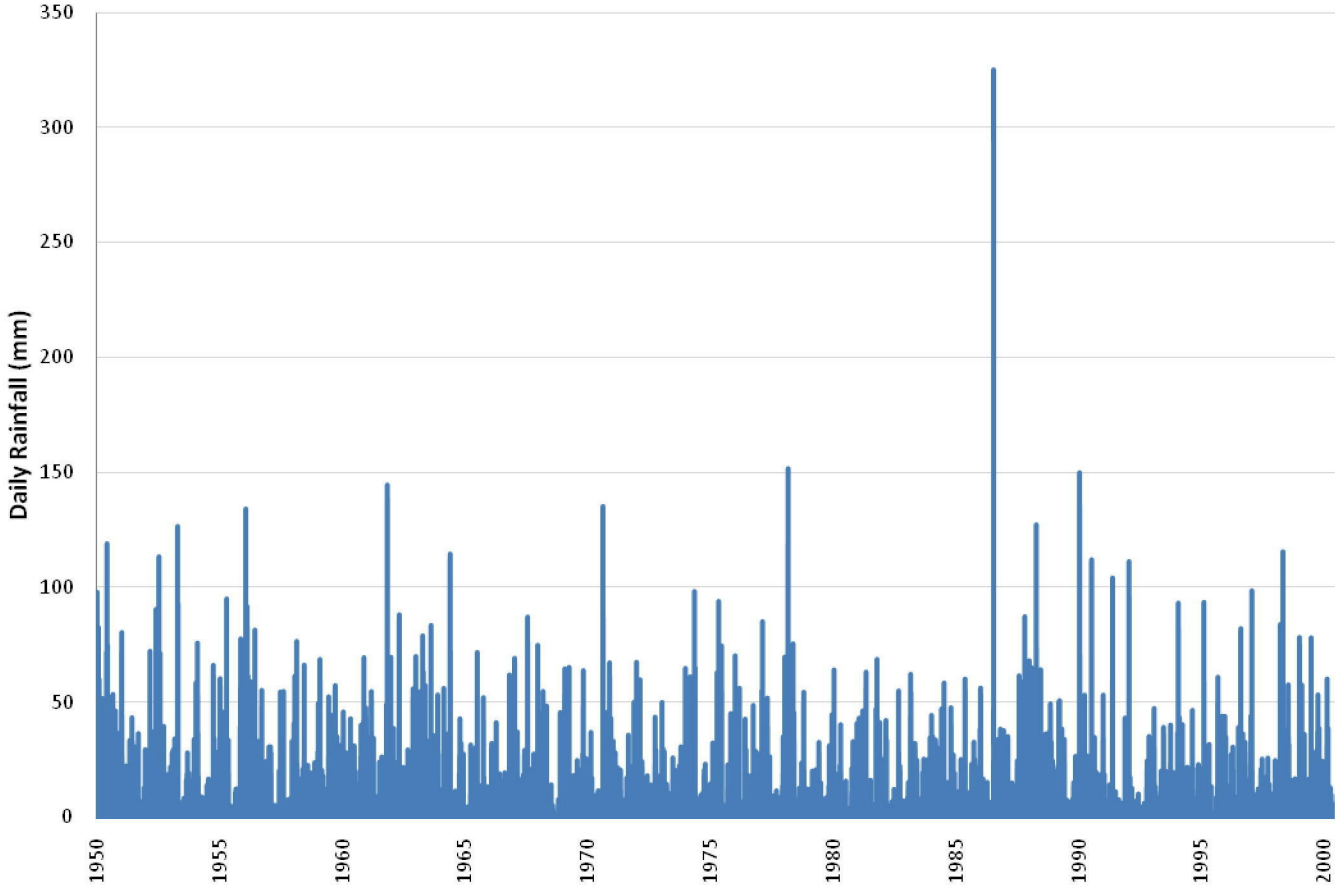
Rainfall Data Stations

Fifty years of data has been taken from the nearest nine weather stations to formulate a daily rainfall volume for the area. The stations are:

- St Marys Mwsdb;
- Quakers Hill Treatment Works;
- Blacktown Kildare Rd;
- Schofields Boundary Rd Post Office;
- Quakers Hill Douglas Rd;
- Box Hill Junction Rd;
- Willmot (Resolution Avenue);
- Minchinbury; and
- Seven Hill Collin St.

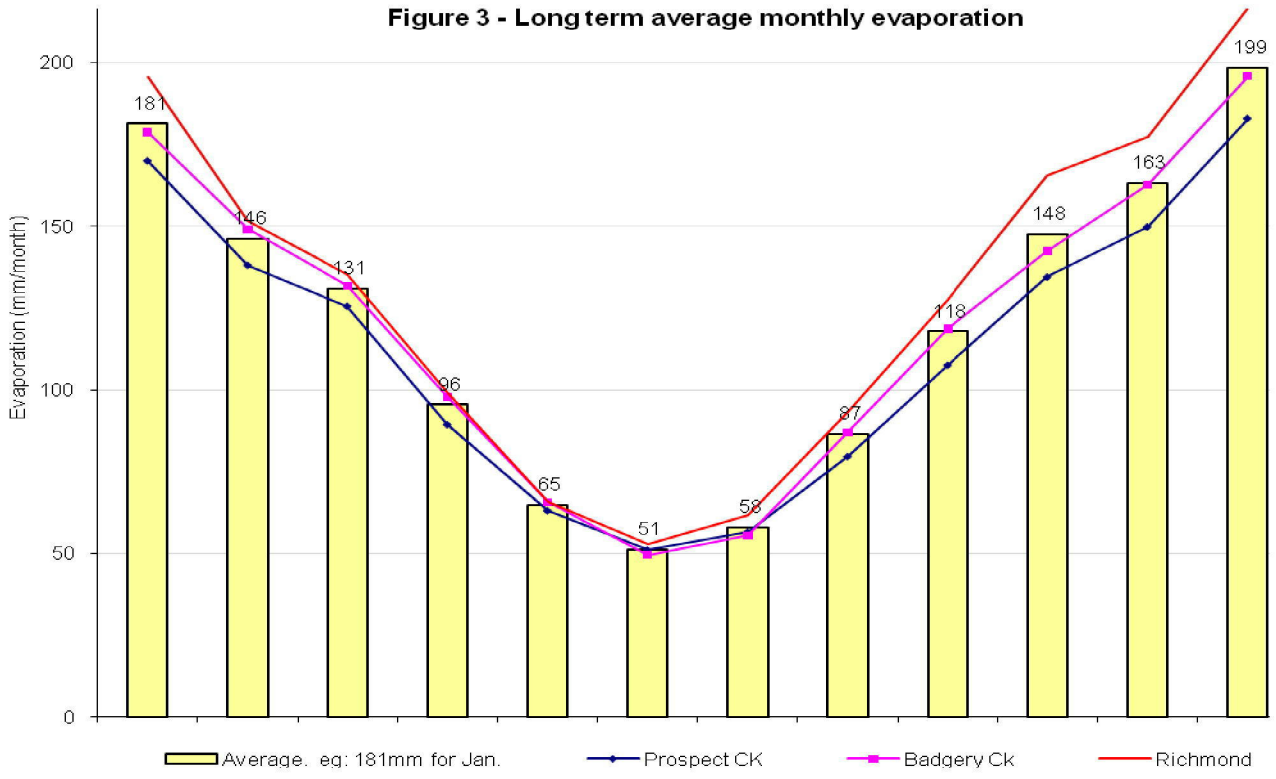
Figure 2 provides the daily rainfall data used in the analysis. The effects of climate change have been simulated by reducing these values by 7%, in accordance with CSIRO's estimated climate change projections (CSIRO, 2007).

Figure 2 -Daily Rainfall Data



Evaporation Data

Monthly evaporation averages have been taken from the long term data of three nearby stations; Prospect Creek, Badgery Creek and Richmond. This has created a monthly evaporation pattern as shown in **Figure 3**.

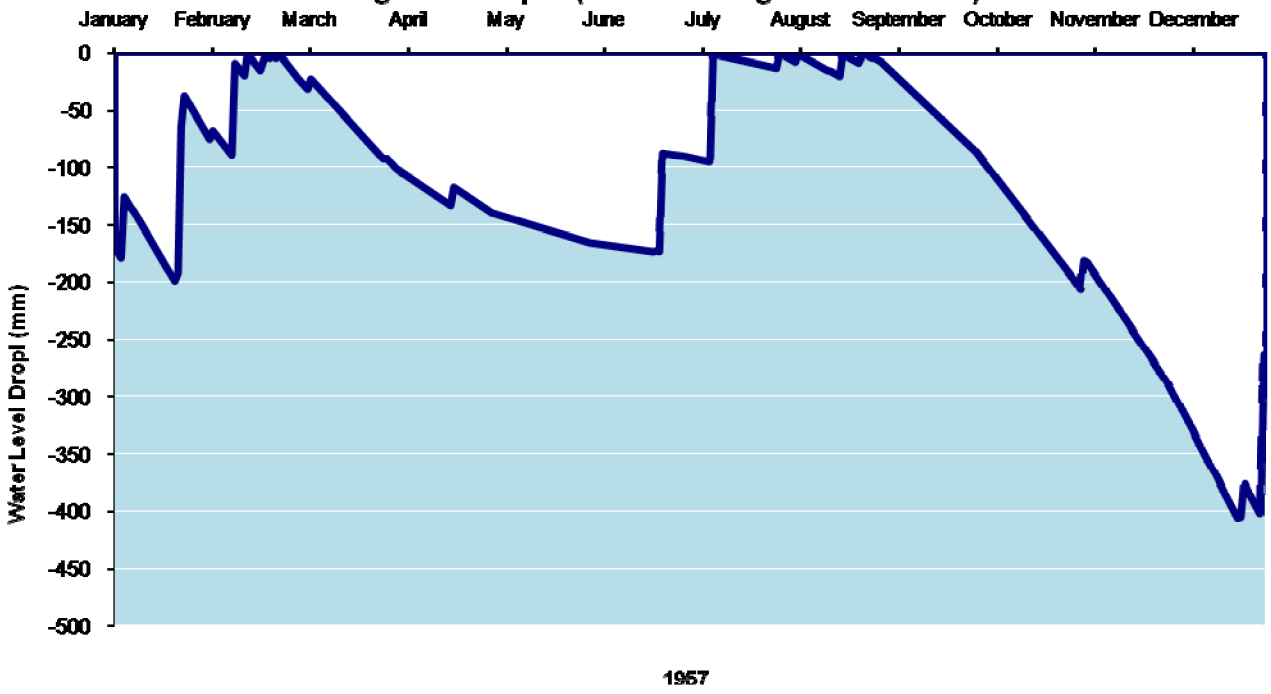


4.3. Results

4.4. Stage 1 Development Results

The water balance model for the 50 year period, without the simulated effects of climate change, calculated a maximum drop in the water level of 406mm. This occurred in December 1957, a particularly dry year. The water dropped to this level for 3 consecutive days. However, the reduced lake level during this exceptionally dry period remained at least 300mm below the normal full level for approximately 22 days. Such low levels were a rare occurrence. The water levels for that year shown in **Figure 4**.

Figure 4 - Water Level Drop from Normal Full Level on a Particularly Dry Year for Stage 1 Developed (Climate Change not Simulated)



For 47% of the 50 year analysis period the lake was more than 99% full. For 76% of the period the drop in water level was less than 50mm.

The effect of climate change reduced the water level to a maximum 409mm for 2 consecutive days in December 1957. The months of December 1957 and January 1958 showed the greatest drop in water levels, with 6 days of water levels lower than 400mm below the normal full level.

For 45% of the 50 year analysis period with climate change simulated, the lake was more than 99% full. For 74% of this period the drop in water level was less than 50mm

Inclusion of climate change in the model increases the drop in water levels, as expected, however these changes are not significant. The change in both maximum and average drop in water levels is 3mm. However, the frequency of drops in water levels of more than 300mm increases by almost 25%.

Table 5 lists the occurrence of a various drops in water level for both the historical rainfall model without climate change, and the model simulating a climate change effect of 7% reduce d rainfall.

Figure 5 shows the water level profile for the entire 50 year period.

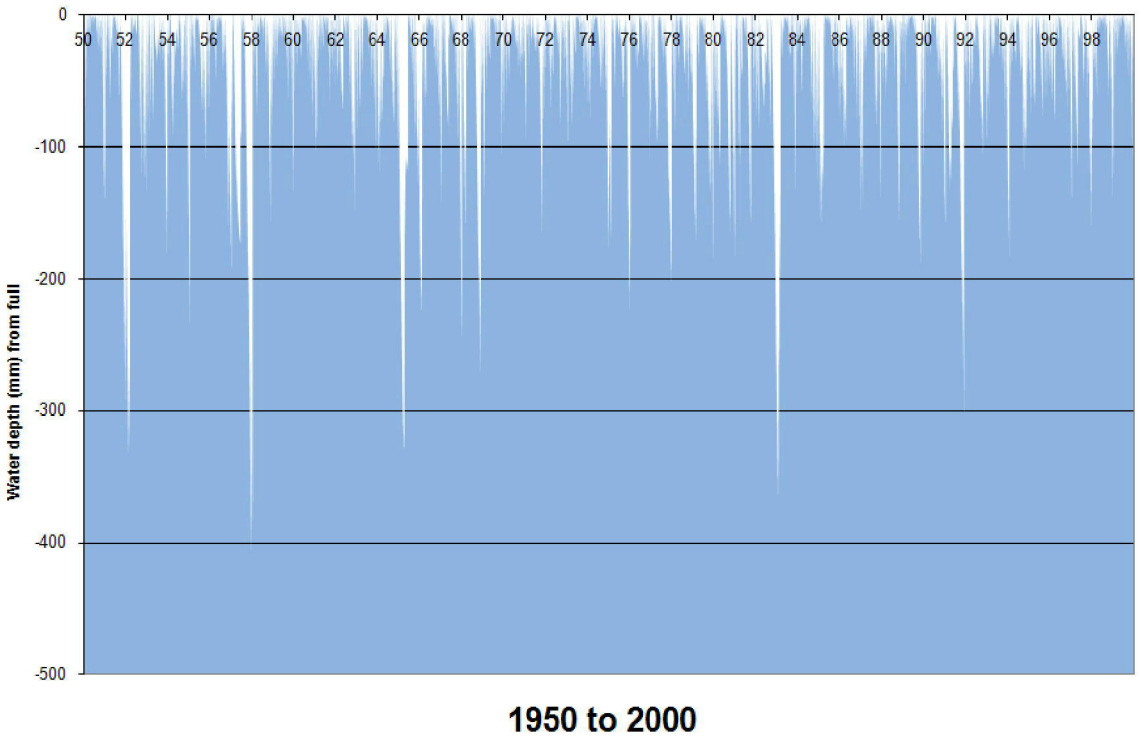
- **Table 5 - Drop in Water Level and Frequency of Occurrence, with and without Effect of Climate Change**

Drop (mm)	No Climate Change Simulated		With Climate change Simulated		Change
	Days in 50 years	Percentage of time	Days in 50 years	Percentage of time	
0	1323	7.2%	1258	6.9%	-5%
1-50	12524	68.5%	12235	66.9%	-2%
50-150	3547	19.4%	3776	20.7%	+6%
150-300	740	4.0%	835	4.6%	+13%
300-400	124	0.7%	153	0.8%	+23%
400+	4	0.02%	6	0.03%	+50%

- **Table 6 - Median, Average and Maximum Drop in Water Levels, with and without Effect of Climate Change**

	No Climate Change	With Climate Change Simulated
Median drop in water level	19 mm	21 mm
Average drop in water level	39 mm	42 mm
Maximum drop in water level	406 mm	409 mm

Figure 5 – Water Level Drop from Normal Full Level for 50 year period for Stage 1 Developed (Climate Change not Simulated)



4.5. Stage 2 Development Results

The water balance model using historical rainfall data for the 50 year period calculated a maximum drop in the water level of 242mm. 11 consecutive days with a water level drop of more than 200mm occurred in December 1957. A further dry period occurred in March 1965, where 3 similar consecutive days occurred. The water levels for the exceptionally dry year of 1957 are given in **Figure 6**.

Figure 6 - Water Level Drop from Full Level for a particularly dry year for Stage 2 Developed (Climate Change not Simulated)

For 9% of the period, the lake was more than 99% full. For 93% of the 50 year period, the lake's water level did not drop more than 25mm below the full level.

The effect of climate change reduced the water level to a maximum 249mm. For 12 consecutive days in December 1957 the drop was greater than 200mm. In March 1965 there were 7 consecutive days with a drop of more than 200mm below the normal full level.

For71% of the 50 year analysis period with climate change simulated, the lake was more than 99% full. For 92% of this period the drop in water level was less than 50mm

Again, the inclusion of climate change in the model increased the drop in water levels. For Stage 2 the inclusion of climate change effects only increased the average drop in water level by 1mm, however the maximum drop increased by 7mm and the frequency of reduced water levels of more than 200m grew by 43%.

Table 7 lists the occurrence of a various drops in water level for both the historical rainfall model without climate change, and the model simulating a climate change effect of 7% reduce d rainfall.

Figure 7 shows the water level profile for the entire 50 year period.

- **Table 7 - Drop in Water Level and Frequency of Occurrence, with and without Effect of Climate Change**

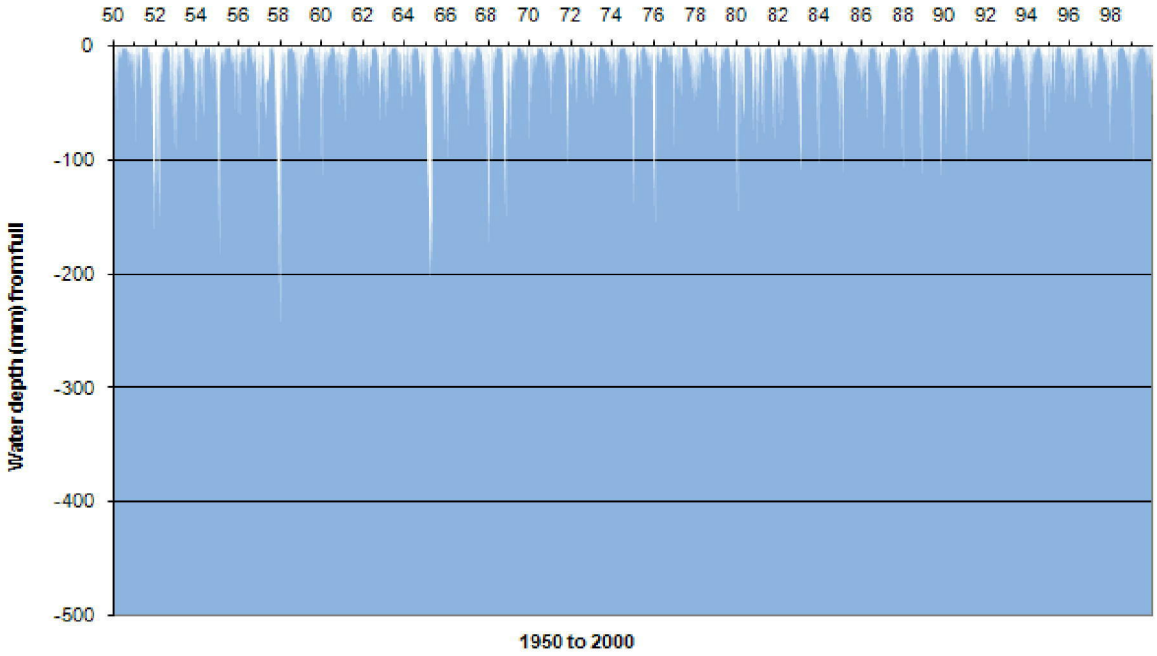
Drop (mm)	No Climate Change Simulated		With Climate Change Simulated		Change
	Days in 50 years	Percentage of time	Days in 50 years	Percentage of time	
0	2398	13.1%	2352	12.9%	-2%
1-25	14621	80.0%	14476	79.2%	-1%
25-49	2255	12.3%	2318	12.7%	3%
50-99	1028	5.6%	1080	5.9%	5%
100-149	258	1.4%	277	1.5%	7%
150-200	86	0.47%	91	0.5%	6%

200-249	14	0.08%	20	0.11%	43%

- **Table 8 - Median, Average and Maximum Drop in Water Levels, with and without the Effect of Climate Change**

	No Climate Change	With Climate change
Median drop in water level	7mm	7mm
Average drop in water level	16mm	17mm
Maximum drop in water level	242mm	249mm

Figure 7 – Water Level Drop from Normal Full Level for 50 year period For Stage 2 Developed (Climate Change not Simulated)



4.6. Conclusions

Without considering the affect of climate change, the water balance model results indicate that the drop in water levels would rarely be more than 200mm for Stage 1 and 150mm for the Ultimate Stage 2 of the development; however, during a severe drought, the water level could drop down by approximately 300 to 400mm for Stage 1 and 200mm for Stage 2.

The effect of climate change on the drop in the lake water levels is not significant; however it does increase the frequency of lower water levels in the lake.

The model provides a simplified calculation for the drop in the water level from the full level for each of the two development scenarios. The results are considered to be accurate to within ±25%.

A temporary drop in the water level of more than 250mm may have some detrimental effect on macrophytes. The water balance model indicates that this would only occur for approximately 1.3% of the time after Stage 1 development without considering climate change, or 1.5% of the time when factoring in reduce rainfall effects due to climate change. Any water level drops of more than 200mm may have an aesthetic impact on the lake.

Appendix E Air and Noise Assessment

Construction Noise, Vibration and Air Quality Assessment

4.1. Project

SKM has been commissioned by Delfin Lend Lease to assess the potential air quality, noise and vibration impacts resulting from the construction of Basin A2 within the area of the Western Precinct of the St Mary's Development in Western Sydney.

Basin A2 is a 3.5 Ha area dam proposed for the south eastern corner of the Western Precinct (refer **Figure 0-4**. The proposed detention volume and wetland area may change as part of this proposal.

4.2. Scope of Assessment

A noise impact assessment has been undertaken to determine potential construction noise impacts at nearby sensitive receivers using the following methodology:

- Identification of nearby noise sensitive receivers;
- Identification of construction noise sources;
- Assessment of potential noise impacts during construction in accordance with the DECC Interim Construction Noise Guideline. Given the proposal is not expected to generate any substantial operational or traffic noise, impacts from these sources have not been assessed against the NSW Industrial Noise Policy and the Environmental Criteria for Road and Traffic Noise respectively
- Recommendation of noise mitigation methods as required.

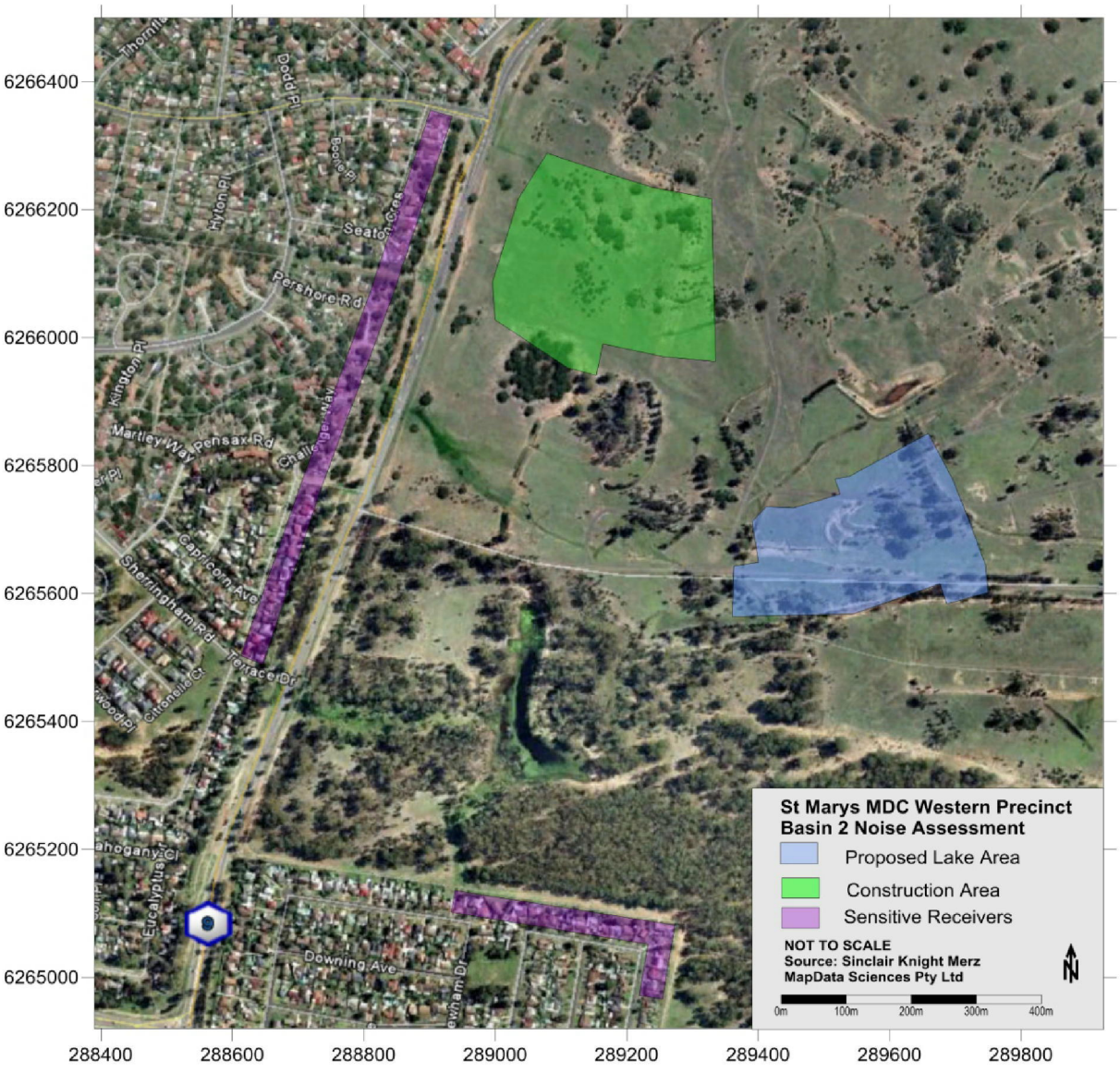
A qualitative air quality assessment will focus on the potential impacts of dust generated during construction. The assessment will consider the following issues:

- Existing local air quality;
- Identification of dust emission sources;
- Local wind patterns for the period of construction;
- Nearby sensitive receivers; and
- Recommend suitable mitigation methods where required.

4.3. Existing Environment

Sensitive receivers in the vicinity of the Development were identified from aerial photography, and are comprised of residential properties located to the west of The Northern Road at Cranebrook, and at Summerfield Circuit in Cambridge Gardens to the south of the proposed location. Both groups of receivers are located at a distance of approximately 750m (refer **Figure 0-4**) from the main Basin site. It is anticipated that the timing for the construction of the Village Lake will likely occur before any future residents move into Stage 1 of Jordan Springs.

▪ Figure 0-4 Site Layout



5. Noise Assessment

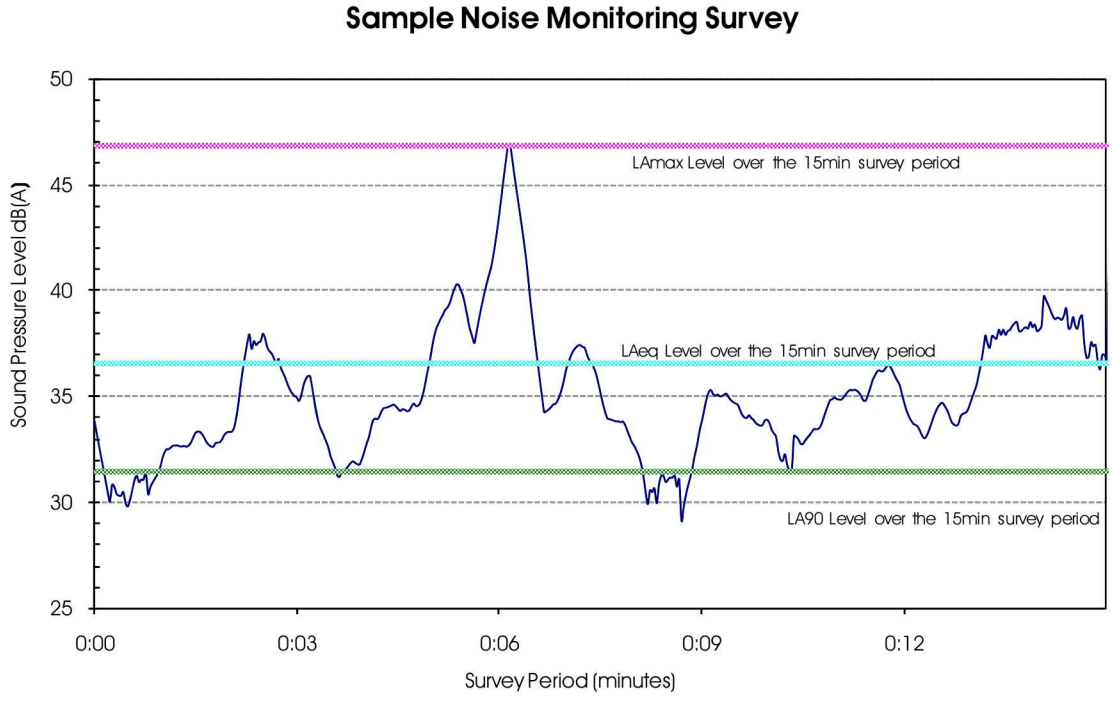
5.1. Environmental Noise Descriptors

Environmental noise is described using the following indices:

- L_{A90} This is the noise level exceeded for 90% of the measurement period. For environmental noise, the interval is usually taken as 15 minutes, thus the LA90 represents the level corresponding to the quietest 90 seconds in a 15 minute period;
- *RBL* Rating Background Level. This is the lowest 10th percentile, of all of the 15 minute LA90 levels within any assessment period (i.e. day, evening or night-time);
- L_{Aeq} The A-Weighted energy averaged sound pressure level over the measurement period. When assessing environmental noise, the assessment period is taken to be 15 minutes (LAeq (15 minutes));
- L_{Amax} The maximum A-weighted noise level for the measurement period.

The L_{A90}, L_{Amax} and L_{Aeq} noise descriptors are shown for a hypothetical 15 minute survey in
Figure 5-1.

- **Figure 5-1: Example of Noise Indices**



5.2. Existing Noise Environment

Noise monitoring was undertaken during August 2008, along the Western Site boundary of the development site. This monitoring data will be used to provide an indication of the acceptability of predicted noise as a result of construction activities.

Table 5-1 Background Noise Monitoring Results

	$L_A$eq(dBA)	L_A10(dBA)	L_A90(dBA)
The Northern Road			
Day	62	65	53
Evening	62	65	53
Night	59	61	38

The residential properties located along The Northern Road are heavily impacted by existing road traffic noise, particularly as a result of heavy vehicles passing along the 80 km/hr speed limited road.

Traffic on The Northern Road would also be audible from Summerfield Circuit, however at a much lower level; in addition the noise environmental at this site would be influenced by typical suburban noise sources such as human activity and local traffic. In the absence of monitored noise data at this location, in order to provide a reference for the assessment of construction noise at Summerfield Circuit, estimated average noise level for areas with low density transportation have been obtained from *AS 1055.3-1997, Acoustics - Description and measurement of environmental noise, Part 3: Acquisition of data pertinent to land use*; these have been set out in **Table 5-2**.

- **Table 5-2 AS 1055.3 Estimated Average Noise Levels (Area Category R2)**

	L_A90(dBA)
Summerfield Circuit	
Day	45
Evening	40
Night	35

5.3. Construction Noise Criteria

The risk of adverse impact of construction noise within a community is determined by the extent of its emergence above the existing background noise level, the duration of the event and the characteristics of the noise. Impacts can then be exacerbated by the proximity of construction to residences or other sensitive land uses and the times of occurrence.

The NSW DECC (2009) has prepared an Interim Construction Noise Guideline (ICNG). The guideline has been developed to assist with the management of noise impacts, rather than to present strict numeric noise criteria for construction activities.

The ICNG recommends standard hours for normal construction work as:

- Monday to Friday 7 am to 6 pm
- Saturday 8 am to 1 pm
- No work on Sundays or public holidays

Categories of work that may be undertaken outside these hours include:

- Delivery of oversized plant or structures
- Emergency work
- Work on essential services and / or considerations of worker safety do not allow work within standard hours
- Work where the proponent demonstrates and justifies a need to operate outside the recommended standard hours. In this case approval must be explicitly given by the approval authority.

The ICNG describes two methods of assessing noise impacts from construction activities. These are:

- the quantitative method, which is suited to major and complex construction projects; and
- the qualitative method, suited to short-term (less than three weeks) works undertaken during standard construction hours.

Construction of the Proposal is anticipated to last for approximately six months, and as such a quantitative method has been used to assess the potential for construction noise impacts.

Table 5-3 outlines management levels for noise at residential receivers and how they should be applied. Restrictions to the hours of construction may apply to activities that generate noise at sensitive receivers above the 'highly noise affected' noise management level. The rating background level (RBL) is used when determining the management level. The RBL is the overall single-figure background noise level measured in each relevant assessment period (during or outside the recommended standard hours).

- **Table 5-3 General Construction Noise Management Levels (NML's)**

Time	Noise Management Level (NML)	Comment
Recommended Standard hours: Monday to Friday 7 am to 6 pm Saturday 8 am to 1 pm No work on Sundays or public holidays	Noise affected (RBL + 10 dB)	The noise affected level represents the point above which there may be some community reaction to noise.
	Highly noise affected	Where the predicted or measured LAeq (15 min) is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to meet the noise affected level.
Outside recommended standard hours	(>75 dB(A))	The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details.

Project specific noise criteria have been determined as follows:

- **Table 5-4 Project Noise Criteria**

Location	RBL	Adjustment	NML - dB(A)
The Northern Road	53	+ 10 dB	63
Summerfield Circuit	45	+ 10 dB	55

5.4. Potential Noise Impacts

Construction activities that may result in noise impacts are most likely to occur during the earthworks stage of the Village Lake. Likely noise levels have been calculated at nominated distances. These calculations are based on measurements of typical noise levels from construction equipment taken from SKM's in house database.

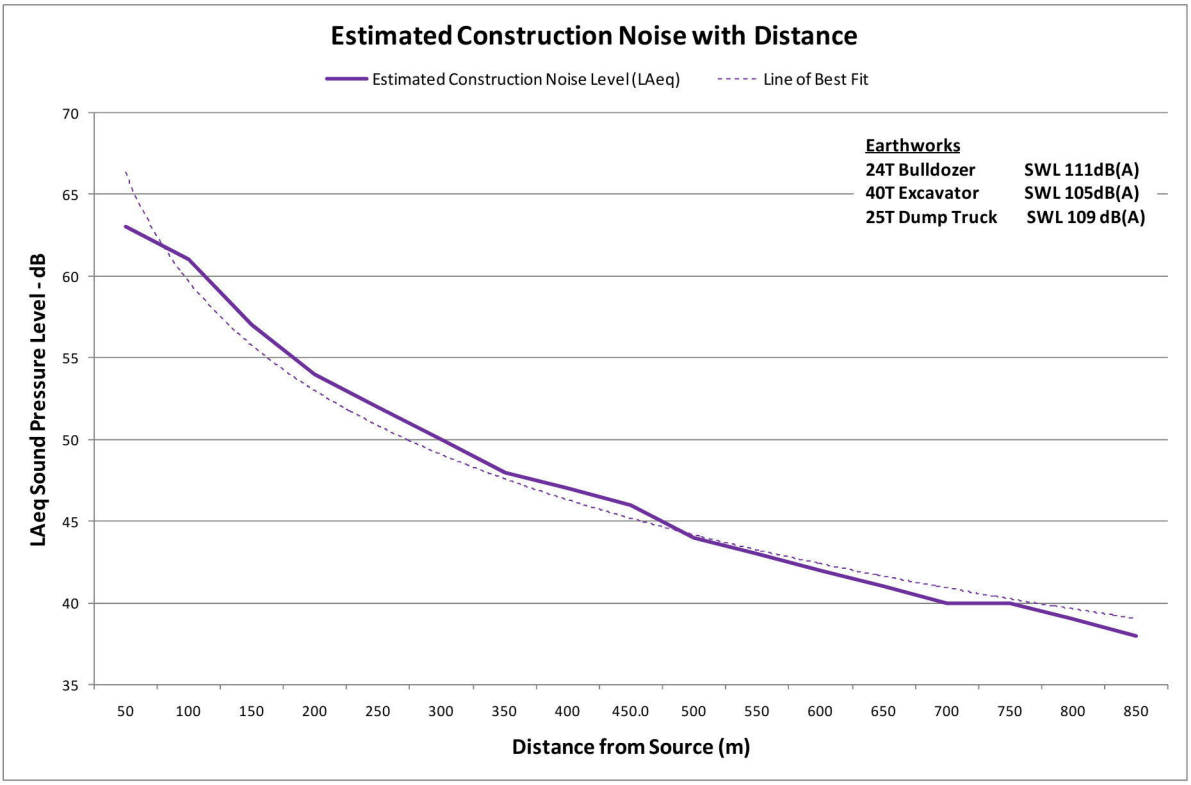
It is noted that these calculations are based on all equipment operating continuously and simultaneously during the period of earthworks, and as such should be seen as an indication of potential maximum noise levels, and unlikely to be maintained for substantial periods of time.

Actual noise levels from the equipment used on site may differ marginally from those in the estimate of potential impacts at the sensitive receiver location however;

these differences are not expected to dramatically alter the conclusions of this report.

Excavation of the lake area is considered to be the major construction task associated with the proposal. Noise predictions at nominated distances from the earthworks have been given in **Figure 5-2**.

- **Figure 5-2 Construction Noise Attenuation**



The calculations above are based on simple attenuation with distance, and do not consider the absorption of noise by local geography, air or vegetation. Meteorological influences are also not considered. As such these calculations should be seen as being at the upper end of predicted noise levels, and may not be reached in actuality.

As discussed in **Section 4.3**, residential properties have been identified at distances of approximately 750m, and as such are likely to be exposed to maximum L_{Aeq} noise levels in the order of 40 dB(A). Noise levels of this magnitude are expected to easily comply with the identified Project NMLs outlined in **Table 5-4**.

5.5. Cumulative Noise Impacts

It is noted that earthworks are likely to be undertaken during the same period in an area located approximately 300m to the north west (refer **Figure 0-4**). The maximum noise level increase at a single receiver location as a result of the Lakes construction works would be in the order of
3 dB (A); that is, a doubling of the noise level. Qualitatively, an increase in noise of 3 dB(A) tends to be indiscernible or noted as a slight noise increase over other construction noise. Construction noise levels subject to an increase of this magnitude would remain within the Project NMLs outlined in **Table 5-4**.

5.6. Recommended Noise Mitigation Measures

Construction noise is not expected to result in noise impacts at surrounding receivers; however the following mitigation measures are considered standard practise for construction sites, and should be considered during all construction activities and adopted wherever they are considered reasonable and feasible in order that noise impacts during construction activities are minimised.

- Construction activities audible at sensitive receivers shall be restricted to the hours of
  7 am and 6 pm Monday to Friday and 8 am to 1 pm on Saturday.
- Arrange the work site to minimise the use of movement alarms on vehicles and mobile plant;
- Examine, and implement where feasible and reasonable, the use of silenced equipment and noise shielding around stationary plant (such as generators), subject to manufacturers' design requirements;
- Ensure road plates (if used) are properly installed and maintained;
- Turn off plant that is not being used.
- Ensure plant is regularly maintained, and repair or replace equipment that becomes noisy;
- Keep staff who receive complaints informed regarding current and upcoming activities;
- Handle complaints in a prompt and responsive manner;
- Where there are complaints about noise from an identified work activity, review and implement, where feasible and reasonable, actions additional to those described above to minimise noise output.

6. Vibration Assessment

6.1. Existing Vibration Environment

No existing vibration sources have been identified in the area of the Development. Heavy vehicle passbys may generate some vibration in the area of The Northern Road, however these impacts are typical unnoticeable at distances beyond 10m. While no works for the project are expected to occur near sensitive receivers, the relevant vibration guidelines and criteria are presented below for completeness. These criteria should be referred to if any works take place near residential areas.

6.2. *Vibration Guidelines*

The effects of vibration can be divided into three main categories:

- Where occupants or users of the building are disturbed or inconvenienced;
- Those in which the building contents may be affected; and
- Circumstances in which the integrity of the building or the structure itself may be prejudiced.

Vibration may be transmitted through the ground or as low frequency pressure waves through the air. There are two types of vibration criteria that are used when assessing impacts. The first is the human comfort criteria, which as the name suggests is designed to minimise impacts that may disrupt day to day activities of humans. The other form of vibration criteria is designed to avoid damage to buildings and structures.

Vibration Guidelines

Human Comfort

Vibration from construction activities with regard to human comfort within a building should comply with the *Department of Environment and Conservation (DEC) Assessing Vibration: A Technical Guideline*. It is not always possible to undertake major infrastructure projects in very close proximity to residential dwellings and comply with the more stringent human comfort criterion. However, this should always be used as the objective to aim for, and be the basis of assessment.

When assessing vibration, the NSW Department of Environment and Climate Change (DECC, formerly the DEC) classifies vibration as one of three types:

- Continuous – Where vibration occurs uninterrupted and can include sources such as machinery and constant road traffic;
- Impulsive – Where vibration occurs over a short duration (typically less than 2 seconds) and occurs less than three times during the assessment period, which is not defined. This may include activities such as occasional dropping of heavy equipment or loading / unloading activities; and
- Intermittent – Occurs where continuous vibration activities are regularly interrupted, or where impulsive activities recur. This may include activities such as rock hammering, drilling, pile driving and heavy vehicle passbys.

Continuous and Impulsive Vibration Criteria

Human sensitivities to vibration differ depending on the direction of movement. For this reason, the criteria outlined below in **Table 6-1**, provides different acceptable levels for vibration based on the direction of movement.

To assess human comfort vibration the measured levels are subjected to a summation and averaging method. This yields a result referred to as a Root Mean Squared Value (rms). This value is measured in m/s^2, and is derived from the acceleration of the measured surface as a result of the induced vibration.

- **Table 6-1 Preferred and maximum weighted rms values for continuous and impulsive vibration acceleration (m/s^2) 1- 80 Hz**

Location	Assessment Period	Preferred Values		Maximum Values	
		Z axis	X + Y axes	Z axis	X + Y axes
Critical Areas	Day + Night time	0.0050	0.0036	0.010	0.0072
Residences	Day time	0.010	0.0071	0.020	0.014
	Night time	0.007	0.005	0.014	0.010
Schools, Churches, Offices	Day + Night time	0.020	0.014	0.040	0.028
Workshops	Day + Night time	0.04	0.029	0.080	0.058

Source: The guidelines are taken from Table 2.2 of the DECC Guidelines.

Intermittent Criteria

Where vibration is classed as intermittent, the DECC uses a vibration dose value (VDV) to assess levels of vibration (refer **Table 6-2**). VDV is calculated using the

acceleration rate of the vibration event and the time over which it occurs. This method is more sensitive to the level of vibration than its duration, and is a measure of the total quantity of vibration perceived. The VDV method is the most suitable for assessing human comfort amenity from intermittent vibration sources.

- **Table 6-2 Acceptable Vibration Dose Values (VDV's) for Intermittent Vibration (m/s$^{1.75}$) 1- 80 Hz**

Location	Day time (7am-10pm)		Night time (10pm-7am)	
	Preferred Value	Maximum Value	Preferred Value	Maximum Value
Critical Areas (eg Hospitals)	0.10	0.20	0.10	0.20
Residential buildings	0.20	0.40	0.13	0.26
Offices, Schools, Churches, etc	0.40	0.80	0.40	0.80
Workshops	0.80	1.60	0.80	1.6

Criteria for Building Structures

When assessing potential vibration impacts on building structures, the velocity and direction of the movement is measured. The measurement is referred to as the Peak Particle Velocity (PPV), presented in mm/s.

Vibration from construction activities, with regard to building damage, is assessed using the German standard DIN 4150: Part 3 – 1999 *Effects of Vibration on Structures* (DIN Guideline). The DIN Guideline values for PPV measured at the foundation of various structures are summarised in **Table 6-3**.

- **Table 6-3 Guideline Values of Vibration Velocity, for Evaluating the Effects of Short Term Vibration DIN 4150**

Line	Type of Structure	Guideline Values for Velocity, v_i (mm/s)			
		Vibration at the Foundation at a Frequency of			Vibration at Horizontal Plane of Highest Floor at all Frequencies
		1 Hz to 10 Hz	10 Hz to 50 Hz	50 Hz to 100 Hz*	
1	Buildings used for commercial purposes, industrial buildings and buildings of similar design	20	20 to 40	40 to 50	40

Line	Type of Structure	Guideline Values for Velocity, v_i (mm/s)			
2	Dwellings and buildings of similar design and/or use	5	5 to 15	15 to 20	15
3	Structures that, because of their sensitivity to vibration, do not correspond to those listed in lines 1 and 2 and are of great intrinsic value (eg buildings that are under a preservation order)	3	8 to 10	8 to 10	8
* For frequencies above 100Hz, at least the values specified in this column shall be applied					

6.3. Potential Vibration Impacts

The prediction of vibration impacts from construction activities is not straight forward as the type and size of equipment, the proximity to a sensitive receiver and the local geology all play a significant role the in the actual vibration levels experienced at a residence. Estimates of vibration levels may be made, however these are based on typical conditions and equipment types. The primary method of ensuring no adverse vibration impacts are encountered is by setting vibration limits and carrying out monitoring where vibration impacts are expected.

In addition the dropping or large rocks onto the ground or when loading trucks can generate impulsive vibration impacts in the area immediately surrounding the impact.

An indication of generally accepted minimum buffer distances is presented in **Table 6-4**. This table identifies distances where the more stringent human comfort criteria are likely to be met. These levels are for reference only and are not to be applied as project specific limits.

- **Table 6-4 Recommended Buffer Distances for Human Comfort Impacts from Ground Vibration**

Equipment Type	Buffer Distances from Sensitive Receiver
Truck movements	10 m
Hydraulic rock breaker	15 m
Vibratory Roller	25 m

It should be noted that this discussion is based on ground borne vibration. In certain instances, vibration may also occur through the air borne transmission of low frequency sound waves. This type of vibration may travel further distances from the construction area than ground borne vibration, and its magnitude and

effects are difficult to predict. As a result, this assessment has considered ground borne vibration only, for which there are assessable guidelines.

Given the minimum separation distance between the site and the nearest receivers is in the order of 750m, vibration impacts are considered to be highly unlikely. In addition no cumulative impacts are predicted as a result of nearby earthworks (refer **Figure 0-4**).

Should the proposal be substantially altered, and construction activities are required within the distances outlined in **Table 6-4**, further assessment of potential vibration impacts should be carried out in accordance with the guidelines in **Section 6.2**. It is noted that should blasting be considered necessary for the Project, further assessment of potential vibration and overblast impacts should be conducted.

6.4. Recommended Vibration Mitigation Measures

No vibration impacts are likely to occur as a result of this project, and as such no vibration mitigation measures have been outlined in this section.

7. Air Quality Assessment

7.1. Overview

The primary air pollution impacts generated during the construction of the project are expected to occur as a result of dust created during earthworks and the storage and transport of spoil and fill.

7.2. Air Quality Legislation

The NSW ambient air quality criteria relevant to this assessment are outlined in the DECCW's *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* (DEC, 2005).

The main pollutant of interest for this project is particulate matter (ie dust). Particulate matter is generally classified according to the size of the particles, and includes particulate matter with equivalent aerodynamic diameter less than or equal to 10 microns, referred to as PM_{10}, and suspended particles of all size, referred to as Total suspended particulates (TSP). The NSW criterion for these parameters is:

▪ PM_{10}	Average annual value	30 ug/m^3
	Maximum 24 hour value	50 ug/m^3
▪ TSP	Monthly 24 hour average	90 ug/m^3

7.3. Existing Air Quality

The greater Sydney metropolitan region has many sources of air pollution, including road traffic, industrial sources, bushfires and domestic wood heaters. Generally the DECCW describes the air quality in the Sydney metropolitan area as good, although there are occasional exceedances of ambient air quality criteria for PM_{10} (small airborne particles that can be inhaled deep into the lungs). These exceedances mainly occur in summer and usually as a result of bushfires or dust storms.

PM_{10} dust levels are monitored at Mamre Road in St Marys by the NSW Department of Climate Change and Water (DECCW). The latest annual data available from this monitoring station shows that 24 hour average PM_{10} dust levels did not exceed either the maximum 24 hour NEPM criteria or the annual average criteria during 2007. It should be noted however that hot, dry and windy days are often precursors to high short-term PM_{10} concentrations but smoke from bushfires

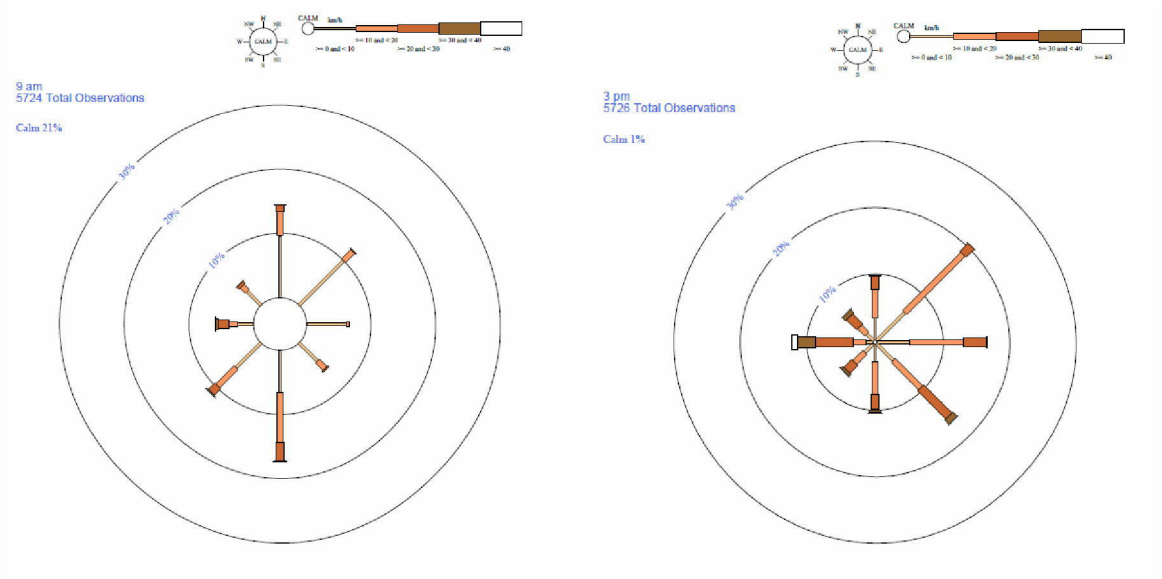
and dust storms can also cause very high levels. Localised construction activities could also contribute to exceedances of particulate matter criteria.

7.4. Meteorology

The western suburbs of Sydney region generally experience a warm temperate climate characterised by warm summers, mild winters, and moderate rainfall throughout the year. The Bureau of Meteorology operates an Automatic Weather Stations (AWS) at Richmond RAAF (Station Id 067105), and these data have been summarised in 7-1 and Figure 7-1, and reviewed below to characterise the conditions in the study area.

Climatic data recorded by the Bureau of Meteorology (BoM) show that the driest months in the region typically occur during winter, with July recording the lowest average monthly rainfall. Afternoon winds are generally from the east and are stronger than morning winds. Morning winds also show much less directional preference. Winds tend to be strongest during spring and summer and weakest in autumn, whilst relative humidity indicates a seasonal pattern, with higher humidity (75 to 80 per cent) from February to July and drier air conditions from July to January.

- **Figure 7-1 Morning and Afternoon Annual Wind Roses**



9am Annual Wind Rose 3pm Annual Wind Rose

- **Table 7-1 Summary of Meteorological Conditions (Richmond AWS)**

Parameter	Summer	Autumn	Winter	Spring
Mean maximum temperature (°C)	29	24	18	25
Mean minimum temperature (°C)	17	12	4	11
Mean rainfall (mm)	87	55	37	62
Mean 9am wind speed (km/h)	9	6	7	10
Mean 3pm wind speed (km/h)	17	14	15	19
Mean 3pm relative humidity (%)	48	51	46	41

7.5. Potential Air Quality Impacts

There would be potential for dust emissions during construction activities. These activities may include excavation of the lake, traffic travelling along unsealed roads, windblown dust from stockpiles, cleared groundcover and topsoil, and the transportation and stockpiling of spoil and construction materials.

The typical meteorological conditions outlined in **Section 7.4** are expected to impact dust generation in the following ways:

- During warmer periods, increased evaporation rates would typically allow dust to form more readily and as such the potential for elevated dust levels typically increases during summer months.
- Afternoon winds may increase dust generation during construction activities, particularly during spring and summer. These winds are likely to be from the east, and as such may potentially result in dust impacts for receivers on Northern Road.
- Decreased humidity during the latter half of the year would increase evaporation rates and lead to drier (and potentially dustier) conditions during these periods.

Given these meteorological influences, the potential for dust impacts is expected to be greatest during the warmer months, particularly during the afternoons. **Figure 7-1** shows that the dominant wind direction in Western Sydney for this time is from the north east to south east, resulting in the potential transport of dust towards receivers on The Northern Road and Summerfield Circuit. As such dust mitigation measures have been recommended below (refer **Section 7.7**).

Mobile vehicle emissions (exhausts) would also occur, as a result of combustion of petroleum products, such as diesel and gasoline. However, at the nearest sensitive receptors, the contribution of emissions from construction related equipment would be minor compared to the emissions generated by vehicles on the Northern Road.

7.6. Cumulative Air Quality Impacts

It is noted that earthworks are likely to be undertaken during the same period in an area located approximately 300m to the north west (refer **Figure 0-4**). The cumulative emission of dust from these two sites may further increase air quality impacts at sensitive receiver locations to the west and south west. As such dust mitigation methods such as those outlined below in **Section 7.7** should be considered at both sites, in particular where meteorological conditions are conducive to the generation and emission of dust.

7.7. Recommended Air Pollution Mitigation Measures

During construction the following measures would ensure that dust emissions are minimised:

- Watering of exposed soils when necessary;
- Water sprays used during dust generating excavation activities;
- Covering of truck loads when removing spoil;
- Clearly identifying and minimising the number of unsealed surfaces;
- Imposing speed limits for vehicles travelling on unsealed surfaces;
- Ensuring heavy vehicles operate only on nominated haulage routes wherever possible;
- Progressive restoration of disturbed areas;
- Maintenance of stockpiles at a height of less than 1.5 metres; and
- Should complaints be received, work shall cease until dust control measures have been implemented as required.

The primary air pollution impacts generated during the construction of the project are expected to occur as a result of dust created during earthworks and the storage and transport of spoil and fill.