CONCEPT STORMWATER AND WATER QUALITY MANAGEMENT REPORT

Proposed Development of

46-66 O'CONNELL STREET CADDENS NSW

AUGUST 2020

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ABBREVIATIONS

AEP	Annual Exceedance Probability
AMC	Antecedent Moisture Content
ARI	Average Recurrence Interval
BMP	Best Management Practice
CC	Construction Certificate
CP	Contributions Plan
DA	Development Application
DCP	Development Control Plan
DD	Design Development
DP	Deposited Plan
GPT	Gross Pollutant Trap
IFD	Intensity-Duration-Frequency
ILP	Indicative Layout Plan
LGA	Local Government Area
MUSIC	Model for Urban Stormwater Improvement Conceptualization
OSD	On-Site Stormwater Detention
PMF	Probable Maximum Flood
QUDM	Queensland Urban Drainage Manual
RMS	Roads and Maritime Services
SQID's	Stormwater Quality Improvement Devices
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
WSC	Water Servicing Coordinator
WCMS	Water Cycle Management Strategy Report
WQO	Water Quality Objective
WSUD	Water Sensitive Urban Design

REFERENCED STANDARDS & DOCUMENTATION

The following documents have been used as part of this review:

1. Penrith City Council (2013a). Water Sensitive Urban Design Policy.
2. Penrith City Council (2015). Water Sensitive Urban Design Technical Guidelines.
3. Penrith City Council (2013c), Design Guidelines for Engineering Works for Subdivisions and Developments, in force from 20 May 1997, amended 20 November 2013
4. Penrith City Council (2015), Penrith Development Control Plan 2015.
5. Penrith Local Environmental Plan (Caddens) 2009, Land zoning map
6. MUSIC Model for Urban Stormwater Improvement Conceptualisation, User Guide Version 6.3.

1. INTRODUCTION

1.1. Background

Group Development Services Pty Ltd (GDS) has prepared the engineering earthworks, road, and drainage design for the proposed residential subdivision of the land known as 46-66 O'Connell Street Caddens, referred to as "the site" from hereafter. The site is located within The Penrith City Council (Council) Local Government Area (LGA). Figure 1 shows the location of the development site.

Figure 1-Site Location

At the time of preparing this report, it is understood that none of the adjoining properties are under Development processing and the southern adjoining property has been developed recently. This report has been prepared to support the proposed modification of Development Application to Council.

It should be noted that this stormwater strategy has been based on the road longitudinal grading that was designed. The road grading was assumed to be "frozen" for design purposes. Should the road grading be changed, it may be necessary to re-visit the stormwater management strategy to ensure that it is still relevant.

1.2. Study Scope

The study scope in general, is to produce a stormwater management strategy for redevelopment, which addresses how the development proposes to manage stormwater run-off and address both water quantity and water quality of stormwater flows leaving the site. The following tasks have been undertaken to complete this study:

- Preparation of concept drainage engineering plans.
- Stormwater conveyance for the minor 5 year ARI.
- Major flow management of the 100 year ARI.
- Stormwater detention so that the 2 and 100 year ARI flows are the equivalent of the predeveloped land.
- Produce a concept stormwater strategy design as per the IWCM guidelines.
- Review of standards, codes, policies and relevant Council reports, consultant reports and relevant planning instruments.

2. SITE CHARACTERISTICS

2.1. Location

The site is located within the suburb of Caddens, within The Penrith City Council (Council) Local Government Area (LGA). The region is semi-rural with approximately 12.15 ha in size.

Figure 2- Project area

2.2. Topography

The site is divided into five sub catchment areas and generally grades to north and south through the site. The 2.398 ha of the site drain to the north-west point of the site (Point1). Point 2 is in middle north of the site and collect the 0.671ha overflow of the site. Point 3, 4 and 5 are in north-east, south-east, and south-west sides of the site, respectively. The existing site levels range from 66.5m AHD to 46.0m AHD. The overflow areas for point 3, 4 and 5 are 1.011 ha, 0.420 ha and 7.644 ha, respectively (Fig. 3).

2.3. Water Courses

There is no specified watercourse through the site.

2.4. External Catchments

Based on the site topography, there is no upper catchment for the site Refer to **Appendix C** for the definition of the catchments plan.

2.5. Flooding

The development site is clear of the PMF flood level.

3. STORMWATER DRAINAGE

3.1. Existing Stormwater Drainage

There is currently no major formalised drainage infrastructure in the site. The site overflow hardstand areas are assumed to be drained via overland flow that discharged into the existing street or water course. The site is located on the top of a hill with an elevation of 66.50 m AHD and grades to the north to 50.0 m AHD at an average grade of 7% and to the south down to 46.0 m AHD with an average grade of 6%. The site divided into five sub-catchments. Figure 3 illustrates the site catchment areas and the collecting point for each one. It is assumed, point 2 is the collecting point for the whole catchment 2 (7.644 ha).

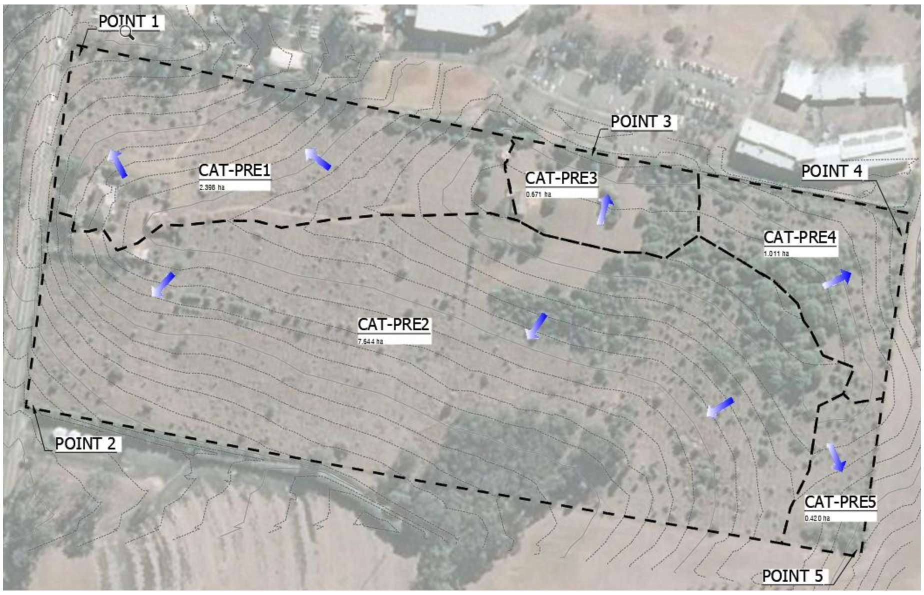

Figure 3- Site catchment areas in pre-development condition

3.2. Site Catchment

As in pre-development condition, the site run-off discharged un-concentrated then in post-developed condition, the site run-off to be conduct into the same discharging points with less and/or same flow rate. There are four discharge points in post-developed condition (No flow at point 3). Also, it is assumed point 2 is the collecting point for CAT2, CAT3, CAT4, PARK and CAT-R-DN catchments (Fig.4). Six different developed sub catchments and three undeveloped areas are defined based on discharging points:

1) The north-western catchment which will discharge into O'Connell street in Post-development condition (CAT1, CAT-R-UP).

2) The south-western catchment which will discharge into O'Connell street in Post-development condition (CAT2, CAT3, CAT4, PARK, CAT-R-DN).

3) The south-eastern catchment which will discharge into point 5 and the outlet and Rip-Rap is placed inside the site to release the run-off to the adjoining property in safe condition (CAT5).

4) The north-eastern catchment which will discharge into point 4 and the outlet and Rip-Rap is placed inside the site to release the run-off to the adjoining property in safe condition (CAT6).

Figure 4- Site catchment areas in post-development condition

Hydrological modelling has been undertaken using the computer software package *DRAINS* for the design of the drainage network. *DRAINS* perform design and analysis calculations for urban stormwater drainage systems and models the flooding behaviour of rural and urban catchments.

The Rainfall Runoff Parameters used in the Drains model were the ILSAX comply with Council's design guidelines.

The site has been modelled as individual nodes. Pre-development input parameters and design flows from the 50% to 1% AEP storm event are summarised in Table 1. A hydraulic assessment of the external catchment conveyance through the site will be conducted during the detailed design. The post-development discharge location is proposed to be the same as the existing catchment.

Table 1- Pre-development and Post-development model parameters and design flows (without OSD)

	Site Catchment (ha)	Fraction impervious (%)	AEP					
			50%	20%	10%	5%	2%	1%
Pre-development model flow (m^3/s)	12.15	2.5	0.501	1.554	2.316	3.149	4.008	4.766
Post-development model flow (m^3/s)	12.15	85	2.515	3.354	3.937	4.501	5.221	5.818

Notes:

- Catchment losses and antecedent moisture conditions (AMC) are in accordance with Council's Engineering Guidelines.
- Rainfall intensity-frequency-duration (IFD) and temporal pattern data is in accordance with Australian Rainfall and Runoff (AR&R) (Appendix A).
- Storm durations considered between 5 minutes and 6 hours.
- Pre-development catchment time of concentration based on sheet flow for the first 50m and minor concentrated flows for the remaining length.
- Post-development catchment time of concentration based on 5-minute property travel time to the road gutter and 1.5 m/s concentrated flow for the remaining length (based on Section 4.6.3 (b) of the *Queensland Urban Drainage Manual (2013)* (QUDM)).
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3.3. Proposed Drainage Strategy

The stormwater drainage design will be carried out in accordance with Council's Engineering Design Guidelines. The piped drainage will be designed to convey the 5-year ARI minor storm event with the road carriageway used to convey excess flows generated in the 100-year ARI major storm event.

The development will introduce an increase in impervious areas consisting of roofs, roads and driveways reducing the potential for infiltration. Additionally, water intercepted by these impervious surfaces will be directed into stormwater system and rapidly conveyed to the catchment outlet increasing the peak flows from the site. To mitigate these potential impacts, on-site detention will be required within the site to attenuate the flows back to the equivalent rural level. It is proposed that detention will be provided through bio-retention basins.

3.4. On-Site Stormwater Detention

To meet Council requirement in terms of stormwater quality and quantity, onsite detention basins are required. Preliminary sizing of the basins has been based on the following criteria:

- Council require post-development peak flows limited to pre-development peak flows for all storms up to and including the 100-year ARI event.
- Basins are not to encroach into the proposed and future road reserve areas.

A preliminary design has been carried out using the *DRAINS* software. For DA purposes, all storms up to and including the 100-year ARI event have been assessed. Final basin areas and volumes are likely to change pending confirmation of design criteria. It is not proposed to attenuate the existing external catchment. A pass-through system is proposed to let this catchment discharge under the site and continue downstream. This system is to be independent of the site's stormwater drainage.

Lots will be required to provide stormwater detention for runoff from the roofs over and above the reuse requirements and will be effective for the 5 and 20-year ARI events. Bio-detention basins will be provided with total storage volume of approximately 31710 m^3 (3.20% of site area). It is proposed that this detention will be located in the site low points.

Preliminary configuration for bio-retention basins is summarized in Tables 2. The analysis shows post-development peak flows have been reduced up to pre-development peak flows whilst achieving the assumed design criteria. Moreover, bio-retention filter media has been provided for water treatment. the bio-retention basins which have been proposed for water treatment have considerable volume. The results are summarised in tables 3 and 4.

Table 2- Designed Basin Details

Item	Name	Catchment Area (m^2)	Bottom Area (m^2)	Volume (m^3)
1	OSD1	3.019	447	1319
2	OSD2	2.467	250	468
3	OSD3-Up	2.005	256	86
	OSD3-Dn		134	375
4	OSD4	0.815	165	193
5	OSD5	0.390	100	194
6	OSD6	1.229	183	535

Table 3- Site Catchment Outlets Analysis

		Site Area(ha)	Fraction impervious (%)	ARI design flow (m3/s)					
				50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
Point1	Pre-development model	2.398	5	0.098	0.31	0.468	0.62	0.792	0.941
	Post-development model	2.85	85	0.092	0.115	0.224	0.311	0.651	0.896
Point2	Pre-development model	7.655	2	0.293	0.929	1.39	1.93	2.47	2.93
	Post-development model	2.85	85	0.273	0.802	1.251	1.756	2.231	2.734
Point3	Pre-development model	0.671	2	0.053	0.134	0.184	0.228	0.272	0.335
	Post-development model	0	85	-	-	-	-	-	-
Point4	Pre-development model	1.01	2	0.04	0.128	0.194	0.262	0.335	0.395
	Post-development model	2.85	85	0.02	0.024	0.068	0.203	0.229	0.333
Point5	Pre-development model	0.42	2	0.017	0.053	0.08	0.109	0.139	0.165
	Post-development model	2.85	85	0.012	0.012	0.016	0.018	0.02	0.092
Total	Pre-development model	12.15	2.5	0.501	1.554	2.316	3.149	4.008	4.766
	Post-development model	12.15	85	0.397	0.953	1.559	2.288	3.131	4.055

Table 4- Table 4- Maximum volume and water level of on-site detention Basins

BASIN 1 (OSD1)

	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
MAX WATER LEVEL (m)	49.39	49.8	50.07	50.29	50.4	50.46
MAX VOLUME (m3)	553.9	791.6	951.6	1088.4	1162.1	1202.6

BASIN 2 (OSD2)

	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
MAX WATER LEVEL (m)	45.81	46.21	46.29	46.36	46.41	46.45
MAX VOLUME (m3)	281.6	396.8	420.7	441.3	457.3	470.5

BASIN 3-UP (OSD3-UP)

	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
MAX WATER LEVEL (m)	56.25	56.29	56.31	56.32	56.34	56.35
MAX VOLUME (m3)	66	75.7	79.9	83.7	87.9	91.1

BASIN 3-DN (OSD3-DN)

	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
MAX WATER LEVEL (m)	54.22	54.52	54.61	54.66	54.69	54.74
MAX VOLUME (m3)	239.3	308	328	339.5	348.7	359.9

BASIN 4 (OSD4)

	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP

MAX WATER LEVEL (m)	54.27	54.38	54.39	54.4	54.42	54.45
MAX VOLUME (m3)	136.6	158.1	160.4	163.9	167.5	172.4

BASIN 5 (OSD5)

	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
MAX WATER LEVEL (m)	59.78	59.98	60.14	60.3	60.5	60.55
MAX VOLUME (m3)	68.6	94.5	117.7	141.2	173.1	182.2

BASIN 6 (OSD6)

	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
MAX WATER LEVEL (m)	61.93	62.32	62.59	62.64	62.65	62.69
MAX VOLUME (m3)	270.9	383.2	464.3	482.7	485.7	496.2

Based on this assessment, the proposed development will be able to mitigate the peak flow from the site such that it will be less than or equivalent of the pre-developed site and not adversely impact on the downstream lands.

4. STORMWATER QUALITY

4.1. Pollutants of Concern

During the operational (post-construction) phase of a subdivision development, key pollutants which may be of concern in the site's stormwater runoff include:

- Litter
- Sediments
- Nutrients
- Surfactants
- Hydrocarbons

During the construction phase of the development, the typical pollutants that can be expected during this phase are outlined below. Measures should be put in place during the construction phase to mitigate these pollutants.

- Litter
- Sediments
- Hydrocarbons
- Toxic Materials
- pH Altering Substances

4.2. Receiving Waters

The receiving water for the site stormwater drainage is the Killarney Chain of Ponds.

4.3. Environmental Values and Water Quality Objectives (WQO's)

The Water Quality Guidelines for the development have been obtained from Council's DCP which is summarised below in.

- 85% reduction for Total Suspended Solids (TSS);
- 60% reduction for Total Phosphorous (TP);
- 45% reduction for Total Nitrogen (TN); and
- 90% reduction for Gross Pollutants.

4.4. Modelling/Assessment Approach

A quantitative assessment of stormwater runoff quality was considered only for the operational phase of the development.

The pollutants of concern during the construction phase are not readily modelled due to the varying and site-specific nature of construction practices. The pollutant sources are largely dependent on the site practices and the ability of the site to manage them. A Best Management Practice (BMP) approach was adopted in the selection of the construction phase management options.

In order to assess the post-development stormwater discharge concentration of key pollutants from the site, modelling of runoff for the site has been undertaken using the *Model for Urban Stormwater Improvement Conceptualisation (MUSIC) Version 6.3* software package. The site has been assessed using one model for the entire development.

4.5. Water Quality Treatment

Given the site characteristics, the Stormwater Quality Improvement Devices (SQID's) chosen to treat the stormwater discharge in accordance with the WQO's include rainwater tanks with reuse, and bio-retention basin. Refer to Figure 5 for the proposed stormwater quality treatment train used within MUSIC. It is not proposed to provide water quality treatment for the upstream external catchment.

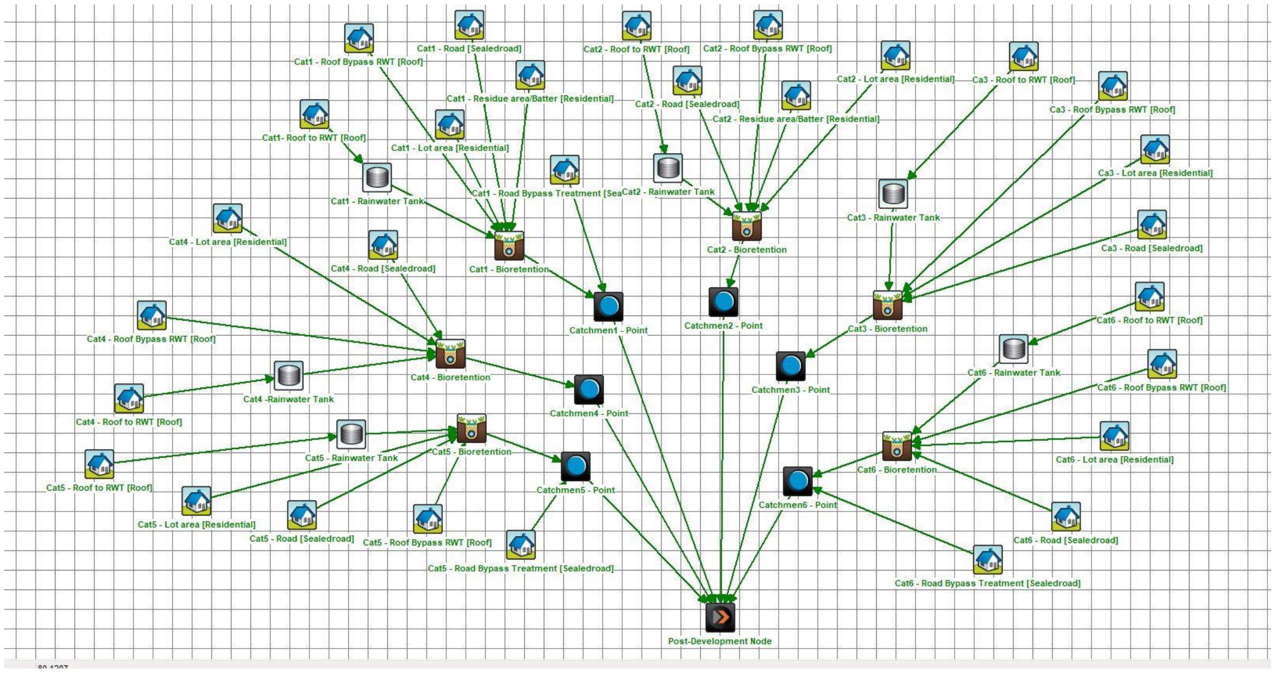


Figure 5- MUSIC Treatment Train.

4.5.1. Rainfall Data

The MUSIC software is capable of utilising rainfall data from a variety of sources based on a range of time steps, such as 6-minute to daily data steps. In accordance with the *Draft MUSIC Modelling Guidelines for New South Wales (2010)* a 6-minute time step has been adopted as this most accurately models such SQID's as rainwater tanks, GPTs, grassed swales and bio-retention basins.

The model runs were based on assessing the Monthly average areal potential evapotranspiration data and rainfall data from the Peats Ridge Bureau of Meteorology (BoM) data (Station No. 067113). This site was selected as it represented the closed BoM station to the Caddens site. The period represented the period where the data was most complete based on the data codes.

4.5.2. Catchment Parameters

The section outlines the MUSIC catchment parameters used to model the site's source nodes and meet the requirement with Penrith council MUSIC link.

For the purposes of the water quality modelling, the following catchment parameters were adopted:

- Impervious fraction of 100% for the roofed and 95% for paved roads reserve.
- Impervious fraction of 50% for open space in lot areas.
- Urban pollutant loads stochastically generated using parameters detailed in Table 3.10 of the Draft MUSIC Modelling Guidelines for New South Wales (BMT WBM, 2010).
- Soil storage and field capacity are the default MUSIC rainfall-runoff parameters as summarised in Table 4-3.

Table 5- MUSIC Rainfall Runoff Parameters (Soil Characteristics)

Parameter	Urban
Rainfall Threshold (mm)	1.0
Soil Storage Capacity (mm)	105
Initial Storage (%)	30
Field Capacity (mm)	70
Infiltration Capacity coefficient - a	150
Infiltration Capacity exponent – b	3.5
Initial Depth (mm)	10
Daily Recharge Rate (%)	25
Daily Baseflow Rate (%)	10
Daily Deep Seepage Rate (%)	0.0

Table 6- MUSIC Base and Storm Flow Concentration Parameters for Source Nodes

Land Use Category	Parameter	TSS (Log10 mg/L)		TP (Log10 mg/L)		TN (Log10 mg/L)	
		Base Flow	Storm Flow	Base Flow	Storm Flow	Base Flow	Storm Flow
Urban – Roofs	Mean	0.32	1.3	-0.82	-0.89	1.1	0.3
	Std. Dev	0.12	0.32	0.19	0.25	170	0.19
Urban– Remaining Ground Area	Mean	0.78	2.15	-0.85	-0.6	0.22	0.3
	Std. Dev	0.17	0.32	0.19	0.25	0.12	0.19
Urban – Roads incl. Verge	Mean	1.2	2.43	-0.85	-0.3	0.11	0.34
	Std. Dev	0.17	0.32	0.19	0.25	0.12	0.19

The above data has been sourced from Tables 3-09 and 3-10 of the *Draft MUSIC Modelling Guidelines for New South Wales (2010)*.

Table 7- MUSIC Catchment Parameters

Catchment Areas	Area (ha)	Lot Number	Lot area(ha)	Road area (ha)	Batter/Residue area (ha)	Bypass Road (ha)	Roof to RWT (ha)	Roof Bypass RWT (ha)	Lot Exclude Roof (ha)
Cat1	3.019	49	1.518	1.2873	0.154	0.060	0.569	0.569	0.380
Cat2	2.467	64	1.6811	0.559	0.2269	0.0	0.630	0.630	0.420
Cat3	2.005	46	1.4393	0.5657		0.0	0.540	0.540	0.360
Cat4	0.815	18	0.5354	0.2796		0.0	0.201	0.201	0.134
Cat5	0.39	3	0.1456	0.1734		0.071	0.055	0.055	0.036
Cat6	1.229	20	0.6606	0.5026		0.066	0.248	0.248	0.165

In lieu of documented guidance, the fraction impervious for the ground level area has been adopted and consistent with the *Water by Design MUSIC Modelling Guidelines (2012)*.

4.5.3. Rainwater Tanks

Rainwater tanks have been provided in accordance with the DCP. Rainwater tanks with 3KL per lot have been modelled.

Table 8- MUSIC Rainwater Tank Parameters

Parameter	Item
Rainwater Tank below pipe (kL)	3
Associated Lots	200
Total Rainwater Tank Volume (kL)	600
Internal Reuse Rate (kL/day/allotment)	0.08

4.5.4. Bio-Retention Basin

The final stage of the MUSIC treatment process is the bio-retention filtration which will consist of a vegetated area that is backfilled with sand around the Subsoil drainage pipes. The final process has been designed to provide sediment and nutrient removal prior to stormwater being transferred into the stormwater system. Table 10 outlines the MUSIC input parameters used for the proposed development.

Table 9- MUSIC Bio-Retention Basin Parameters

Parameter		Bio-Ret. Basin1	Bio-Ret. Basin2	Bio-Ret. Basin3	Bio-Ret. Basin4	Bio-Ret. Basin5	Bio-Ret. Basin6
Storage	Extended Detention Depth (m)	0.3	0.3	0.3	0.3	0.3	0.3
	Total Area (m^2)	447	250	390	165	100	183
Infiltration	Total Filter Area (m^2)	351	145	166	140	43	160
	Saturated Hydraulic Conductivity (mm/hr)	125	125	125	125	125	125
	Filter Depth (m)	0.5	0.5	0.5	0.5	0.5	0.5
	TN Content of Filter Media (mg/kg)	800	800	800	800	800	800
	Orthophosphate Content of Filter Media (mg/kg)	40	40	40	40	40	40

4.5.5. MUSIC Modelling Results

Based on the proposed stormwater treatment train described within the previous sections of this report Table 10 details the stormwater pollutant reductions achieved.

Table 10- MUSIC Modelling Results

Treatment Train Effectiveness - Post-Development Node

	Sources	Residual Load	% Reduction
Flow (ML/yr)	52.9	50.5	4.4
Total Suspended Solids (kg/yr)	8870	1330	85
Total Phosphorus (kg/yr)	17.8	5.67	68.1
Total Nitrogen (kg/yr)	120	55.6	53.7
Gross Pollutants (kg/yr)	1520	31.9	97.9

5. STORMWATER QUALITY MANAGEMENT PLAN – CONSTRUCTION PHASE

5.1. Objectives

The objective of the Construction Phase Management Plan is to ensure compliance with the DCP. The purpose of the management plan is to prevent the discharge of polluted stormwater off the site and to ensure that the environmental values of receiving waters are maintained or enhanced.

Pollutants typically generated during the Construction Phase are outlined in Table 12.

Table 11- Typical Construction Phase Pollutants

Pollutant	Sources
Litter	Paper, construction packaging, food packaging, cement bags, off-cuts.
Sediment	Unprotected exposed soils and stockpiles during earthworks and building.
Hydrocarbons	Fuel and oil spills, leaks from construction equipment.
Toxic materials	Cement slurry, asphalt prime, solvents, cleaning agents, wash waters (e.g. from tile works).
pH altering substances	Acid sulfate soils, cement slurry and wash waters.

As a guide refer to the *Water by Design Construction and Establishment Guidelines Version 1.1, April 2010*

for the construction and establishment of the proposed stormwater treatment devices.

5.2. Management of Sedimentation & Erosion

A siltation and erosion fence are to be erected. It is expected that the siltation fence along the perimeter of the site will eliminate almost all risk of sediment being washed off the site. Accidental spills of soil or any other material shall be removed immediately if rainfall is likely to occur or at least upon completion of the days' work depending upon the material.

Entry and exit from the site will be restricted to a single stabilised location to minimise the risk of tracking sediment over the site. It is expected that a layer of crushed rock will provide the necessary stabilisation for the access route. A specific area on the site shall be designated for washing down the construction plant. The wash-down area will be contained by earth bunds. There will be no wastewater discharged from the site during construction. The details of the erosion and sediment control devices are to be confirmed during the Construction Certificate phase.

Sediment and erosion control measures, including the design of sediment basins during construction will be in accordance with Managing *Urban Stormwater Soils and Construction, (Landcom 2004)* (The Blue Book).

5.3. Management of Contaminated Soils

The site is not listed as having Acid Sulphate Soils or Contaminated Land. However, in the event that Acid Sulphate Soils or Contaminated Land is found on site, a management plan is to be implemented and maintained by a suitably qualified professional.

5.4. Management of Imported Materials

Any material imported onto the site (including construction materials) will be stockpiled in a location where it cannot contaminate stormwater runoff.

5.5. Monitoring & Maintenance

Silt traps, sediment fences and structural measures should be checked daily during construction, by the Construction Manager. Inspections will ensure the integrity of control structures and other structural measures. Additional inspections will be required immediately following periods of heavy rain. Sediment build-up is to be removed from behind the silt fences and other barriers immediately after each major rainfall event. All noted stormwater treatment devices within this report are to be inspected, maintained, rectified and reported on in accordance with The Council's requirements. Refer to the *Water by Design Maintaining Vegetated Stormwater Assets Version 1 (February 2012)* manual for a guide.

5.6. Responsibility & Reporting

Performance monitoring of all drainage control measures along with erosion and sediment control devices will remain the responsibility of the contractor. Site inspection forms/checklists shall be reported to the Construction Manager following inspection of water quality devices/measures.

The contractor should erect signage at the entrance to the site with contact information (including after-hours contact information). The contractor shall be responsible for the appropriate handling of all complaints.

The contractor is to report on all stormwater quality treatment devices in accordance with The Council's requirements. Refer to the *Water By Design Maintaining Vegetated Stormwater Assets Version 1, February (2012)* manual for a guide.

6. STORMWATER QUALITY MANAGEMENT PLAN – OPERATIONAL PHASE

6.1. Objectives

Water quality objectives for stormwater leaving the developed site under the operational phase are based on reductions in mean annual pollutant loads detailed in Section 13 of this report. Pollutant reduction values are outlined in Table 12.

Table 12-- Operational (Permanent) Water Quality Objectives

Pollutant Indicator	Pollutant Reduction
Total Suspended Solids	85%
Total Phosphorous	60%
Total Nitrogen	45%
Gross Pollutants	90%

6.2. Performance Requirements

Performance requirements for the Management Plan are in accordance with The Council and New South Wales Department of Environment Marine Water Quality Objectives, and notably the following:

- The reduction of dust and particulate matter being washed into the stormwater drainage system; and
- The prevention of hydrocarbons, nutrients, chemicals and heavy metals washed from the stormwater drainage system to the external catchment.

6.3. Management Measures

The majority of the site will either be sealed or landscaped following development. The amount of sediment likely to be generated by a mulched and watered landscape area is considered to be minimal.

Gross pollutants such as paper and plastic waste will be prevented from entering the stormwater drainage system by the installation of grates to all stormwater inlets.

All stormwater pipes will be fully sealed, and no contaminants will be able to enter the stormwater system from the roof catchment area or through infiltration into the stormwater pipes constructed below the ground.

Dust and particulate matter washed into the stormwater system will be reduced by regular sweeping and removal from car parking and vehicle service areas.

Dangerous goods will be stored in properly designed and constructed storage areas as required by the relevant statutory requirements.

All stormwater treatment devices noted within this report are to be inspected, maintained, rectified and reported on in accordance with The Council Requirements Refer to the *Water By Design Maintaining Vegetated Stormwater Assets Version 1 (February 2012)* manual for a guide.

6.4. Monitoring & Maintenance

Table 13- maintenance schedule

Table 14-Typical Maintenance Regime (Source: Water By Design Maintaining Vegetated Stormwater Assets Version 1, 2012)

ASSET TYPE	SUB-TROPICAL		TROPICAL		TEMPERATE
Swales	4 months*	4 months*	4 months*	4 months*	4 months*
Bioretention systems	2 months	4 months	2 months*	4 months	3 months
Constructed wetlands	2 months	3 months	1 month**	3 months	3 months
Sediment basins	2 months	3 months	1 month**	3 months	3 months

*Turf swales will require more frequent mowing
** For tropical climates, monthly inspections are required during the wet season due to the risk of noxious/declared weeds (e.g. Salvania and Para grass)

Figure 4 outlines the required inspected and maintenance frequency for each stormwater treatment device. The site is believed to be within a "Temperate" area. Inspections and maintenance are to be carried out in accordance with the Council, Page 22 - Water Quality Inspection and Maintenance Checklists, for a sample maintenance and inspection procedure checklist for the proposed stormwater quality treatment devices, detailed within this report.

6.5. Bio-Retention Monitoring & Maintenance

The proposed bio-retention basins detailed within the report are to be inspected, maintained, reported on and rectified in accordance with the Council. Refer to the *Water by Design Maintaining Vegetated Stormwater Assets Version 1 (February 2012)* – Section 3.2, Bio-Retention Technical Design Guidelines Version 1, October 2012 and the Facility for Advanced Water Biofiltration Bio-Retention Maintenance Plan for guidance. The filter media located within each bio-retention basin is to be tested in accordance with the FAWB Practice Note 1: In Situ Monitoring of Hydraulic Conductivity (See Appendix E). The resulting filter media hydraulic conductivity is to be assessed against the FAWB recommended filter media hydraulic conductivity chart, shown in Figure 6.

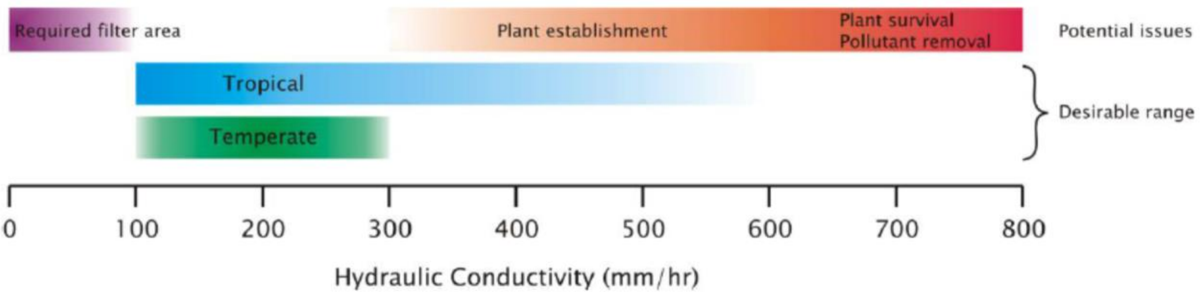


Figure 6- FAWB Recommended Filter Media Hydraulic Conductivity

In the event that the hydraulic conductivity for the filter media is not within the recommended range, the bio-retention system is to be rectified in accordance The Council requirements.

6.5.1. *Maintenance of Raingarden*

In order for a raingarden to work properly, regular inspection and maintenance of its components must be undertaken. In general, a raingarden needs to be checked after a heavy rainfall for blockage or damage and at a minimum of every 3 months. A full inspection should also be carried out one year after construction and then annually.

The maintenance activities proposed in this plan are applicable after the establishment phase of the raingarden. The end of the raingarden's establishment phase can be defined as the time when the raingarden vegetation is suitably established. This would typically be expected 1 to 2 years following planting. Planting should be undertaken when the upstream catchment is fully developed and completely connected to the raingarden.

6.5.2. *Inspection & Maintenance Tasks*

Inspection and maintenance are to be conducted on a regular basis to ensure the raingarden functions as designed. Such checks should be carried out at least on a quarterly basis during the first few years of operating the raingarden. The inspection and maintenance tasks that need to be regularly undertaken to maintain the good condition and to ensure the operation of the raingarden can be grouped into the following categories:

- Filter Media;
- Horticultural; and
- Drainage.

The Inspection and Maintenance Schedule in Section 5 lists what needs to be done and how often they should be undertaken.

6.5.3. *Filter Media Monitoring & Field Testing*

In addition to the required inspection and maintenance tasks, the Facility for Advancing Water Biofiltration (FAWB) recommends field testing of the raingarden's filter media to be carried out at least twice. The first testing is to be conducted after one month following commencement of operation of the raingarden. The second is to be carried out during the second year of operation to assess the impact of vegetation on hydraulic conductivity.

After the second year, hydraulic testing should be undertaken every two years or when there has been a significant change in the catchment characteristics. In-situ hydraulic conductivity testing should be conducted in at least three evenly spaced locations for raingardens that have filter media area of less than $50m^2$. Larger raingardens require additional testing locations for every $100m^2$ of filter media. The in-situ hydraulic conductivity testing procedure is discussed in Practice Note 1: In-situ Measurement of Hydraulic Conductivity (FAWB 2008) included in **Appendix E.**

6.5.4. *Inspection & Maintenance Schedule*

The Inspection and Maintenance Schedule given in Table 15 a checklist in **Appendix F** has been provided to assist to inspection and maintenance of the raingarden. Inspection and maintenance of the raingarden will be the responsibility of developer/owners. All inspection and maintenance tasks should be undertaken by suitably qualified personnel.

6.5.5. *Workplace Health and Safety*

All raingarden maintenance activities shall be undertaken in a manner that minimises the workplace health and safety risk to maintenance personnel and the general health and safety of the public.

It is important that the maintenance staff:

- Comply with Council's Workplace Health and Safety (WH&S) policy and risk management processes;
- Have a thorough knowledge of the workplace, health and safety risks (i.e. able to identify and reduce any workplace hazards and risks) associated with maintenance activities (e.g. working in close proximity to traffic);
- Are equipped with adequate personal safety protection equipment; and
- Are aware of public health and safety risks associated with maintenance activities (e.g. undertaking maintenance activity during a significant rain event).

6.5.6. *The Developer's Responsibilities*

The developer will be responsible for all soil and water management until at least 12 months[3] after more than 90 percent of a catchment is stabilised. Thereafter, any subdivision-scale water quality structure would be transferred to owners/ building management. A method of transfer is given in *Water by Design (2012a)*. A copy of this document is freely available from www.waterbydesign.com.au.

Although they may be built during the subdivision construction, the bioretention swales should not be activated until at least 90 percent of their catchment is stabilised (i.e. more than 90 percent is covered with hard surfaces or is vegetated). This is to prevent them from becoming clogged by excessive sediment.

6.5.7. *The Council's Responsibilities*

Council would ultimately become responsible for the trunk drainage of Railway Road. The bioretention swales would require ongoing maintenance under developer/owner responsibility. to the requirements of *Water by Design (2012b).* A copy of this document is freely available from www.waterbydesign.com.au.

6.5.8. *The owners' Responsibilities*

The rainwater tank collection system (gutters, pipes, rainwater tanks, pumps and valves)/bio-retention basin and sediment basin would be maintained by owners committee/building management. They would require periodic inspection and maintenance, but the requirements are not great. Periodically all inlets, outlets and pumps for stability and operational performance should be inspected.

The tanks would be fitted with a back-flow prevention valve such that mains water can be used when the tank level falls below 5 percent. The valve must be checked annually by a registered plumber to the requirements of AS/NZS 2845.1:2010.

Table 15- Inspection and Maintenance Schedule

Raingarden Element	Potential Concerns	Inspection	Frequency	Maintenance Required
FILTER MEDIA TASKS				
Filter Media	Sediment deposition	Check for accumulation of sediments near inlets.	4 times per year and after all major storm events	Remove sediment build-up from inlet areas.
Filter Media	Holes or scour	Check for holes, erosion and scour.	4 times per year and after all major storm events	Infill any holes in the filter media. Provide energy dissipation (e.g. rocks and pebbles at inlet) if necessary.
Filter Media	Filter media surface porosity	Inspect for the accumulation of an impermeable layer (such as oily or clayey sediment) that may have formed on the surface of the filter media. A symptom may be that water remains ponded in the raingarden for more than a few hours after a rain event.	4 times per year and after all major storm events	Repair minor accumulations by raking away any mulch on the surface and scarifying the surface of the filter media between plants.
Filter Media	Litter control	Check for litter (including organic litter e.g. mulching, decaying leaves) in and around treatment areas.	4 times per year and after all major storm events	Remove both organic and anthropogenic litter to ensure flow paths and infiltration through the filter media are not hindered.
HORTICULTURAL TASKS				
Raingarden Vegetation	Pests and diseases	Assess plants for disease, pest infection, stunted growth or senescent (i.e. ageing) plants.	4 times per year and after all major storm events	Treat or replace as necessary. Any noticeable issues with the vegetation should be referred to an appropriate landscape architect and/or ecologist.
Raingarden Vegetation	Uprooting of plants Maintain original plant densities	Reduced plant density reduces pollutant removal and infiltration performance. Planting should be evenly spaced to help prevent scouring due to a concentration of flow. Infill planting: between 6 and 10 plants per square metre should (depending on species) be adequate to maintain a density where the plant's roots touch.	4 times per year and after all major storm events	Provide rocks or pebbles to dissipate flows and prevent uprooting of plants. Any noticeable issues with the vegetation should be referred to an appropriate landscape architect and/or ecologist.

Raingarden Element	Potential Concerns	Inspection	Frequency	Maintenance Required
Raingarden Vegetation	Weeds	It is important to identify the presence of any rapidly spreading weeds as they occur. The presence of such weeds can reduce dominant species distribution and diminish aesthetics. Weed species can also compromise the system's long-term performance.	4 times per year and after all major storm events	Inspect for and manually remove weed species. Application of herbicide should be limited to a wand or restrictive spot spraying due to the fact that raingardens directly drain to downstream watercourses.
Raingarden Vegetation	Lack of water	Check for plant condition (e.g. stunted growth, unhealthy appearance). Filter media could also reveal flaking or cracks.	4 times per year and after all major storm events	Irrigate following extended dry periods.
DRAINAGE TASKS				
Outlet Structure (Inlet to Raingarden)	Accumulation of sediment/litter	Check for vegetation overgrowth and build-up of sediments and litter.	2-3 times per year and after all major storm events	Trimming of vegetation. Removal of sediment/litter.
Outlet Structure (Inlet to Raingarden)	Excessive scouring Uprooting vegetation	Check for signs of scouring or erosion and uprooted vegetation.	2-3 times per year and after all major storm events	If excessive scour and plant dislodgement are observed the designer should be contacted to discuss remedial action.

Raingarden Element	Potential Concerns	Inspection	Frequency	Maintenance Required
Subsoil Drainage	Blockage of subsoil drainage Inefficient operation of subsoil drainage	Ensure that perforated pipes are not blocked to prevent filter media and plants from becoming waterlogged. A small steady clear flow of water may be observed discharging from the perforated pipe at its connection into the downstream pit some hours after rainfall. Note that smaller rainfall events after dry weather may be completely absorbed by the filter media and not result in flow. Remote camera (e.g. CCTV) inspection of pipelines for blockage and structural integrity could be useful.	2-3 times per year and after all major storm events	Rod and flush subsoil drainage lines to prevent build-up of sediment.
Detention Control Pit	Excess vegetation surrounding the pit limiting flows through the pit	Check for vegetation over growth covering overflow grates and weirs.	2-3 times per year and after all major storm events	If excess vegetation is present this should be trimmed back.
Detention Control Pit	Blockage of orifice controls	Check for build-up of sediments and litter inside pit blocking the orifices. Check condition of trash guards.	2-3 times per year and after all major storm events	Pit to be cleaned to ensure the operation of the orifice controls.
Earth Bund	Breaches, erosion, bund stability RHS pipes blocked	Check for signs of potential breaches, erosion and scouring of the bund. Check for blockage in RHS pipes.	2-3 times per year and after all major storm events	Repair damaged sections of the bund to ensure no inflows escaping from the raingarden. Eroded sections to be reinstated and replanted with grass. Rod and flush blocked RHS pipes.

Raingarden Element	Potential Concerns	Inspection	Frequency	Maintenance Required
Sediment Pit	Accumulation of sediments & debris Blockage and damage in lid	Check for build-up of sediments and litter inside pit. Check condition of grated pit lid.	2-3 times per year and after all major storm events	Accumulated sediments and debris to be removed in order for the sedimentation pit to function. Repair lid if required.
Flow Spreader	Accumulation of sediments & debris Dislodgement of pipe	Check for build-up of sediments and litter inside pipe. Check placement / alignment of pipe.	2-3 times per year and after all major storm events	Accumulated sediments and debris to be removed and pipe secured or stabilised in order for the flow spreader to function.

7. CONCLUSION

The proposed Stormwater Management Plan for 46-66 O'Connell Street Caddens consists of a conventional pit and pipe system to convey surface flows through the development to the bio-detention basins, water quality treatment and filtration devices. Detention is provided via six open bio-detention basins with total volume of 3171 m^3 (3.20% of developed area).

Due to pollutant loads created by the development, water quality treatment is required to comply with council guidelines. A water quality treatment train has been provided to treat pollutant runoff before discharging into the downstream catchment. It is recommended that bio retention basins with total filter media area of 1005 m^2 (1.01% of developed area) and rainwater tank per lot to be installed to minimise the development potential impacts on water quality on the surrounding environment and to detain surface runoff back to pre-developed flows.

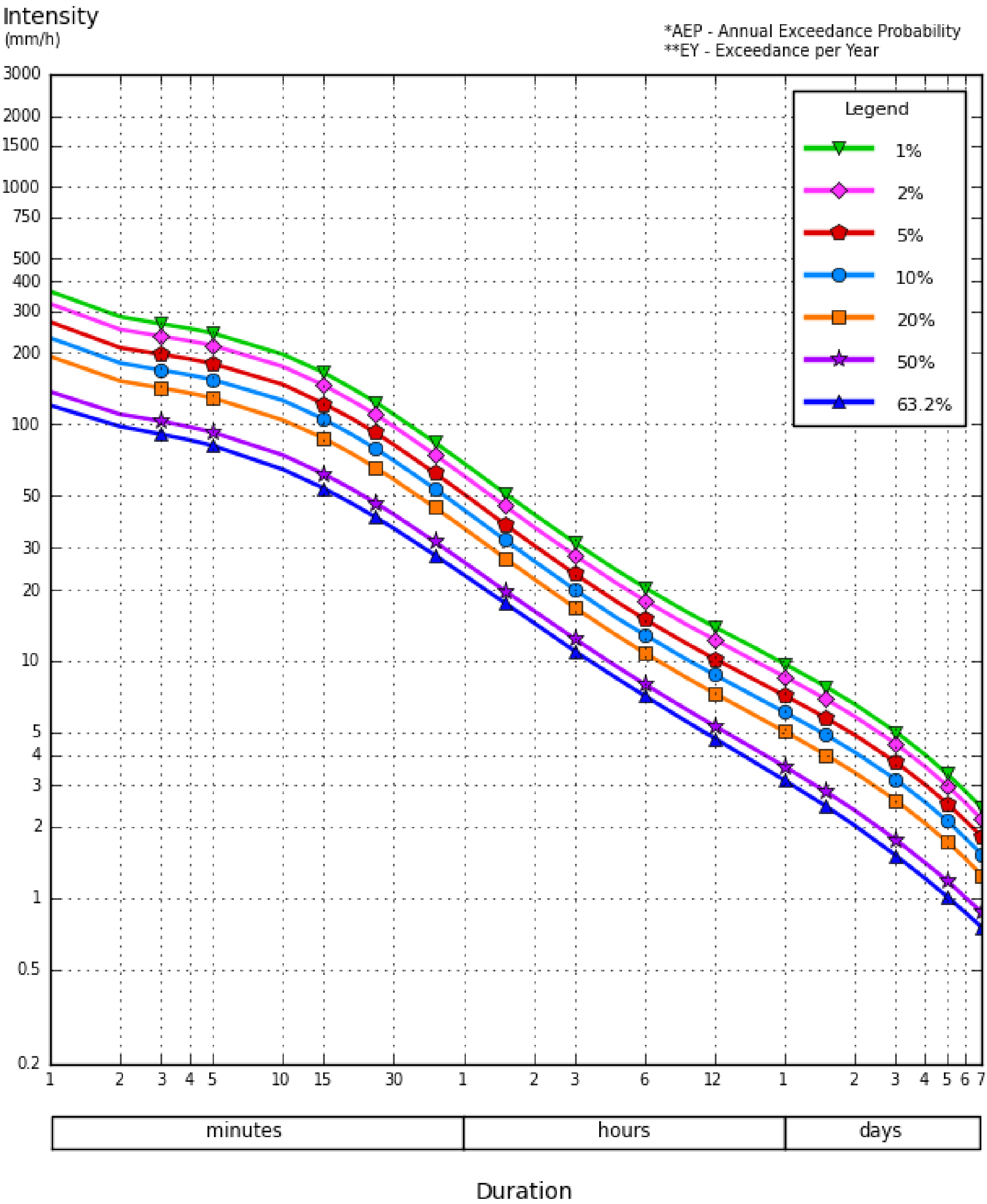
APPENDIX A IFD TABLE AND CHART

IFD Design Rainfall Intensity

Latitude: -33.25 33.2375 (S)]

Longitude: 151.444 151.4375(E)]

Rainfall intensity (mm/h) for Durations, Exceedance per Year (EY), and Annual Exceedance Probabilities (AEP).

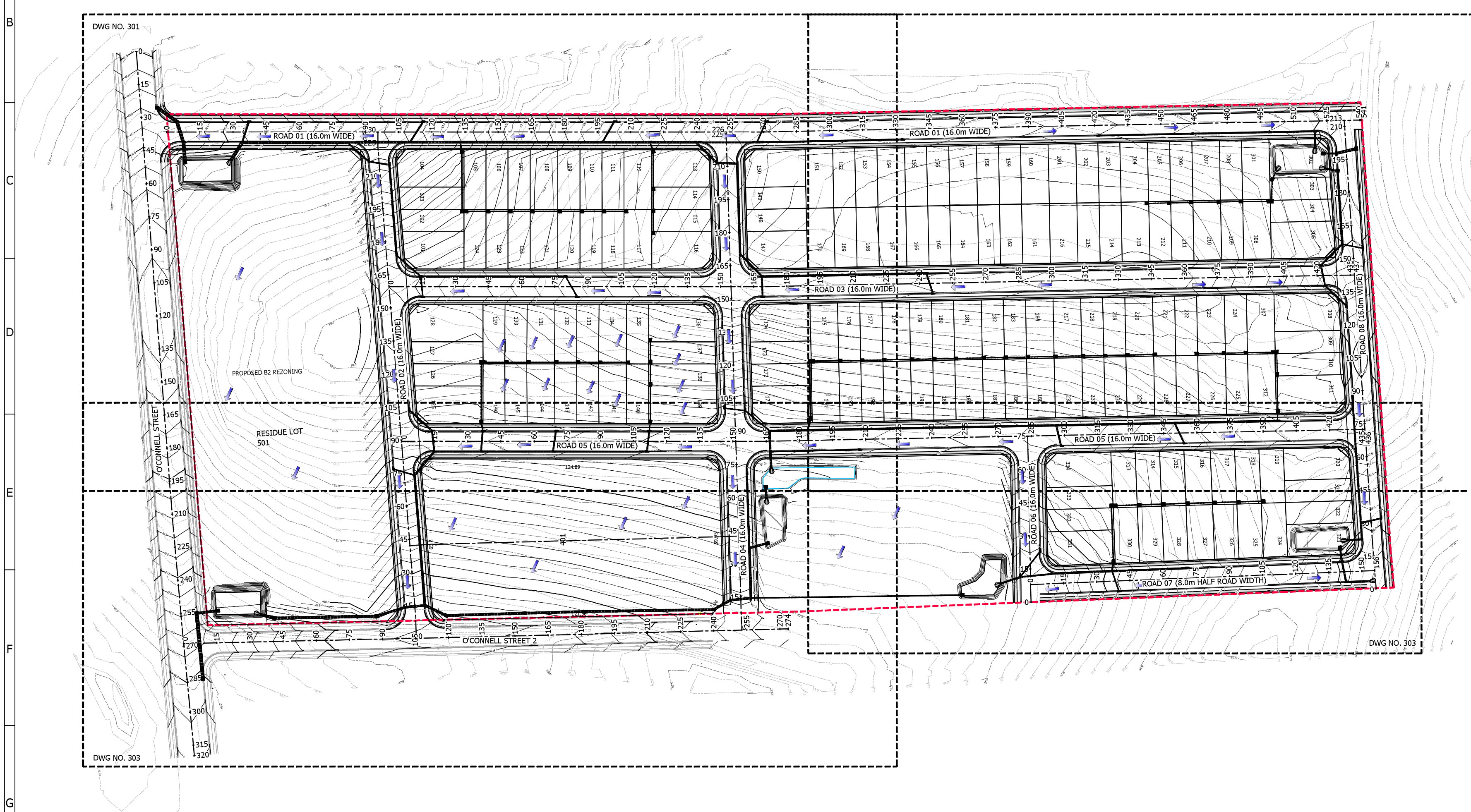


Intensity-Frequency-Duration Table

Rainfall intensity in mm/hr for various duration and Average Recurrence Interval

	Annual Exceedance Probability (AEP)						
Duration	**63.2%**	**50%#**	**20%***	**10%**	**5%**	**2%**	**1%**
1 min	120	137	193	231	270	322	363
2 min	97.7	110	152	181	210	251	284
3 min	90.6	103	142	169	197	235	265
4 min	85.5	97.1	135	161	188	224	253
5 min	81.1	92.4	129	154	180	215	242
10 min	64.4	74.0	104	126	147	175	197
15 min	53.6	61.6	87.2	105	122	146	165
20 min	46.0	52.9	74.7	89.9	105	125	141
25 min	40.5	46.5	65.5	78.8	92.0	110	124
30 min	36.3	41.6	58.4	70.2	81.9	97.8	110
45 min	28.0	31.9	44.5	53.4	62.2	74.3	83.8
1 hour	23.1	26.2	36.4	43.5	50.7	60.6	68.4
1.5 hour	17.6	19.8	27.2	32.5	37.8	45.2	51.1
2 hour	14.5	16.3	22.2	26.5	30.8	36.8	41.7
3 hour	11.0	12.4	16.8	20.0	23.3	27.9	31.6
4.5 hour	8.51	9.53	12.9	15.3	17.9	21.4	24.3
6 hour	7.12	7.98	10.8	12.9	15.0	18.0	20.4
9 hour	5.58	6.27	8.54	10.2	11.9	14.3	16.2
12 hour	4.71	5.31	7.29	8.73	10.2	12.3	13.9
18 hour	3.71	4.22	5.87	7.06	8.28	9.94	11.3
24 hour	3.13	3.58	5.03	6.07	7.14	8.58	9.70
30 hour	2.73	3.13	4.45	5.39	6.35	7.62	8.61
36 hour	2.44	2.81	4.01	4.88	5.75	6.90	7.79
48 hour	2.02	2.34	3.38	4.12	4.87	5.83	6.57
72 hour	1.51	1.76	2.58	3.16	3.74	4.47	5.02
96 hour	1.21	1.41	2.07	2.54	3.01	3.59	4.03
120 hour	1.01	1.18	1.72	2.11	2.50	2.97	3.33
144 hour	0.864	1.00	1.46	1.78	2.11	2.51	2.81
168 hour	0.754	0.873	1.25	1.53	1.82	2.15	2.41

APPENDIX B PLAN OF SUBDIVISION



LEGEND

- LIMIT WORKS - CURRENT APPLICATION
- DESIGN CONTOUR - MAJOR (62.0)
- DESIGN CONTOUR - MINOR
- EXISTING MAJOR CONTOUR
- EXISTING MINOR CONTOUR
- PROPOSED STORM WATER PIPE
- PROPOSED INTERALLOTMENT STORM WATER PIPE
- FUTURE STORM WATER PIPE
- EXISTING STORM WATER PIPE
- PROPOSED INTERALLOTMENT PIT
- PROPOSED GRATED GULLY STORM WATER PIT
- PROPOSED SAG GRATED GULLY STORM WATER PIT
- SWALE PIT
- KG — 150mm KERB AND GUTTER
- MK — MODIFIED KERB AND GUTTER
- CK — CASTELLATED KERB
- RKG — ROLL KERB AND GUTTER
- MRKG — MODIFIED ROLL KERB AND GUTTER
- GP — GARBAGE PAD (1.7m x 0.8m)
- SWALE
- VEHICLE CROSSINGS

CONTOUR INTERVAL - 0.5m

PRELIMINARY ISSUE
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REVISION	DESCRIPTION	BY	DATE
A	ISSUED FOR DA ENGINEERING APPROVAL	D.T.	31/07/2020

SITE DESCRIPTION
SUBDIVISION OF LOT 3 DP 1103503

THIS PLAN IS PRELIMINARY ONLY AND IS SUBJECT TO AMENDMENTS AND CHANGES DUE TO FURTHER INVESTIGATION, LATENT FINDS, UNKNOWN SITE CONDITIONS, SURVEYING AND LOCAL COUNCIL STATE AND FEDERAL GOVERNMENT AUTHORITIES RECOMMENDATIONS AND APPROVALS.
REPORTS AND INFORMATION REQUIRED TO FINALISE THIS PLAN WILL INCLUDE BUT WILL NOT BE LIMITED TO ARCHAEOLOGY, HERITAGE, CONTAMINATION, ECOLOGY, ZONING, DWELLING DENSITIES, CONSCIENTIOUS OBJECTION, GEOTECHNICAL, ADJOINING LANDOWNERS, REFERAL AUTHORITIES, FLOODING AND WATERWAYS, SEWERAGE, WATER SUPPLY, ELECTRICITY, TELECOMMUNICATION.

BAR SCALES 0 10 20 30 40 — 1:1000 AT A1

NOTE: BOUNDARY AND LOT DIMENSIONS, ALIGNMENTS AND AREAS ARE PROVISIONAL AND ROUNDED TO NEAREST DECIMAL PLACE. AS SUCH THESE AREA ARE SUBJECT TO FINAL SURVEY.

SURVEY	HEIGHT DATUM	LGA	AUTHORITY REFERENCE
-	AHD	PENRITH CITY COUNCIL	DA20/0143
DESIGN	CHECKING	DA No.	DATE
H.E.	W.M.	DA 20/0143	02/04/2020
DRAWN	CHECKING	CC No.	DATE
D.T.	W.M.	-	-

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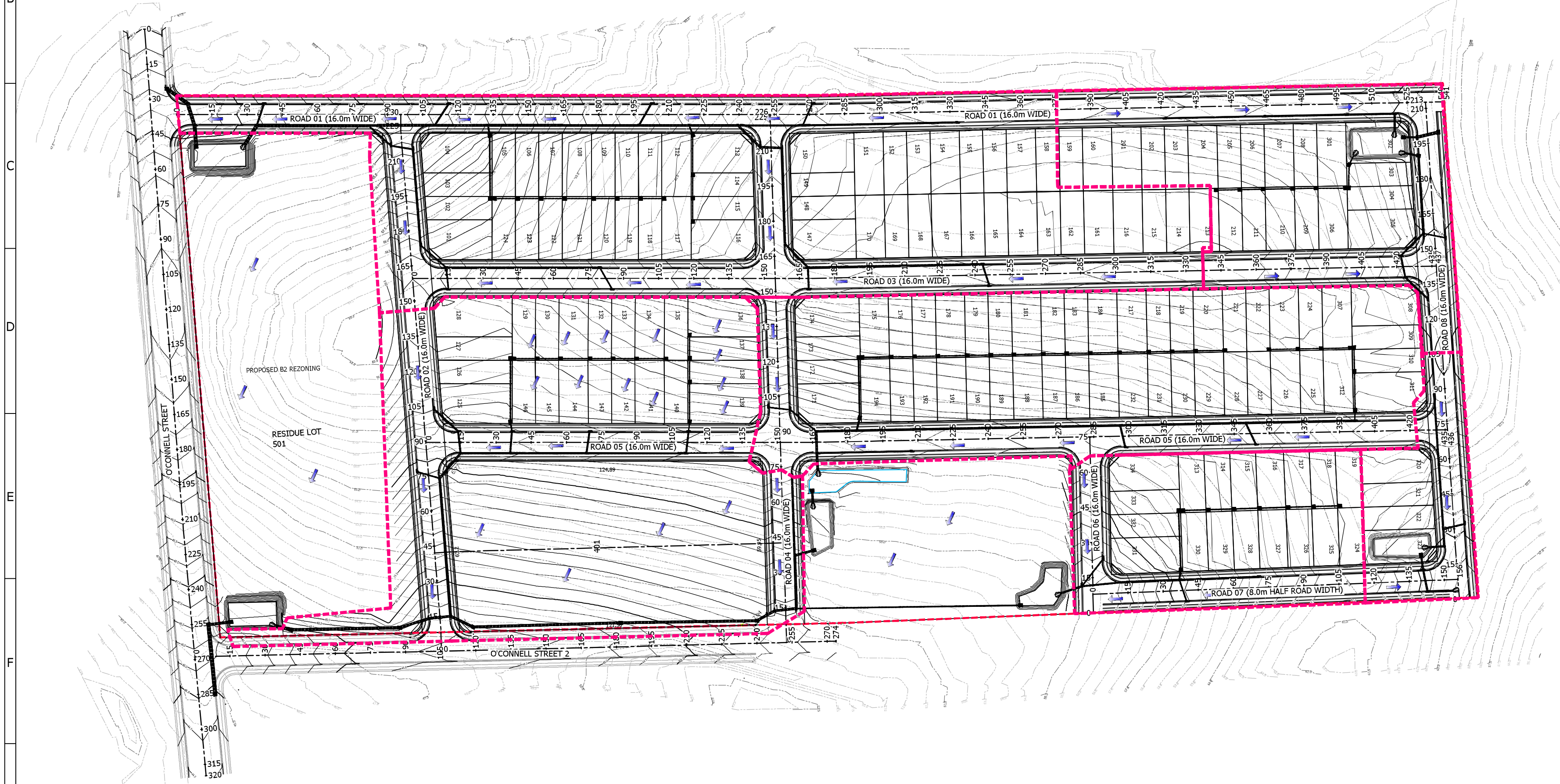
PROJECT
46 O'CONNELL STREET CADDENS
DA ENGINEERING

STORMWATER DRAINAGE PLAN - SHEET 1

PROJECT REFERENCE	DATE OF ISSUE	REVISION No.	SHEET SIZE	DRAWING NUMBER
P00361	31/07/2020	A	A1	300

FILE LOCATION: C:\USERS\MARK\GROUP DEVELOPMENT SERVICES\GDS TEAM - DOCUMENTS_2 CURRENT PROJECTS\P00361 46-66 O'CONNELL ST CADDENS\4. ENGINEERING\4. DA ENGINEERING\P00361-46-66 O'CONNELL ST CADDENS-DA ENG-REV A_DRAINAGE.DWG -DWG NO: 300 -(Plot with----)- PLOT DATE: 8/1/2020 4:33 PM

APPENDIX C CATCHMENT PLANS



LEGEND

- LIMIT WORKS - CURRENT APPLICATION
- DESIGN CONTOUR - MAJOR
- DESIGN CONTOUR - MINOR
- EXISTING MAJOR CONTOUR
- EXISTING MINOR CONTOUR
- PROPOSED STORM WATER PIPE
- PROPOSED INTERALLOTMENT STORM WATER PIPE
- FUTURE STORM WATER PIPE
- EXISTING STORM WATER PIPE
- PROPOSED INTERALLOTMENT PIT
- PROPOSED GRATED GULLY STORM WATER PIT
- PROPOSED SAG GRATED GULLY STORM WATER PIT
- SWALE PIT
- SWALE
- GARBAGE PAD
- ROAD PAVEMENT WIDENING
- TABLE DRAIN
- VEHICLE CROSSINGS
- CATCHMENT BOUNDARY
- CONTOUR INTERVAL - 0.5m

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REVISION	DESCRIPTION	BY	DATE
A	ISSUED FOR DA ENGINEERING APPROVAL	D.T.	31/07/2020

SITE DESCRIPTION
SUBDIVISION OF LOT 3 DP 1103503

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BAR SCALES 0 10 20 30 40 — 1:1000 AT A1

NOTE: BOUNDARY AND LOT DIMENSIONS, ALIGNMENTS AND AREAS ARE PROVISIONAL AND ROUNDED TO NEAREST DECIMAL PLACE. AS SUCH THESE AREA ARE SUBJECT TO FINAL SURVEY.

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www.gdsland.com.au

PROJECT
46 O'CONNELL STREET CADDENS
DA ENGINEERING

STORMWATER CATCHMENT PLAN

PROJECT REFERENCE	DATE OF ISSUE	REVISION No.	SHEET SIZE	DRAWING NUMBER
P00361	31/07/2020	A	A1	304

FILE LOCATION: C:\USERS\MARK\GROUP DEVELOPMENT SERVICES\GDS TEAM - DOCUMENTS_2 CURRENT PROJECTS\P00361 46-66 O'CONNELL ST CADDENS\4. ENGINEERING\4. DA ENGINEERING\P00361-46-66 O'CONNELL ST CADDENS-DA ENG-REV A_DRAINAGE.DWG -DWG NO: 304 -(Plot with:----)- PLOT DATE: 8/1/2020 4:35 PM

APPENDIX D MUSICLINK REPORT

PENRITH CITY COUNCIL

music link

MUSIC-*link* Report

Project Details		Company Details	
Project:	46-66 O'connell Street Caddens-Stormwater report	**Company:**	Group Development Services
Report Export Date:	8/17/2020	**Contact:**	Hamed Esfahani
Catchment Name:	oconnell Caddens	**Address:**	
Catchment Area:	10.037ha	**Phone:**	02 - 99801000
Impervious Area*:	87.07%	**Email:**	hamed@gdsland.com.au
Rainfall Station:	67113 PENRITH		
Modelling Time-step:	6 Minutes		
Modelling Period:	1/01/1999 - 31/12/2008 11:54:00 PM		
Mean Annual Rainfall:	691mm		
Evapotranspiration:	1158mm		
MUSIC Version:	6.3.0		
MUSIC-link data Version:	6.33		
Study Area:	Penrith		
Scenario:	Penrith Development		

* takes into account area from all source nodes that link to the chosen reporting node, excluding Import Data Nodes

Treatment Train Effectiveness		Treatment Nodes		Source Nodes	
Node: Post-Development Node	**Reduction**	**Node Type**	**Number**	**Node Type**	**Number**
Flow	4.42%	Rain Water Tank Node	6	Urban Source Node	29
TSS	85%	Bio Retention Node	6		
TP	68.1%				
TN	53.7%				
GP	97.9%				

Comments

Passing Parameters

Node Type	Node Name	Parameter	Min	Max	Actual
Bio	Cat1 - Bioretention	Hi-flow bypass rate (cum/sec)	None	99	90
Bio	Cat1 - Bioretention	PET Scaling Factor	2.1	2.1	2.1
Bio	Cat2 - Bioretention	Hi-flow bypass rate (cum/sec)	None	99	90
Bio	Cat2 - Bioretention	PET Scaling Factor	2.1	2.1	2.1
Bio	Cat3 - Bioretention	Hi-flow bypass rate (cum/sec)	None	99	90
Bio	Cat3 - Bioretention	PET Scaling Factor	2.1	2.1	2.1
Bio	Cat4 - Bioretention	Hi-flow bypass rate (cum/sec)	None	99	90
Bio	Cat4 - Bioretention	PET Scaling Factor	2.1	2.1	2.1
Bio	Cat5 - Bioretention	Hi-flow bypass rate (cum/sec)	None	99	90
Bio	Cat5 - Bioretention	PET Scaling Factor	2.1	2.1	2.1
Bio	Cat6 - Bioretention	Hi-flow bypass rate (cum/sec)	None	99	90
Bio	Cat6 - Bioretention	PET Scaling Factor	2.1	2.1	2.1
Post	Post-Development Node	% Load Reduction	None	None	4.42
Post	Post-Development Node	GP % Load Reduction	90	None	97.9
Post	Post-Development Node	TN % Load Reduction	45	None	53.7
Post	Post-Development Node	TP % Load Reduction	60	None	68.1
Post	Post-Development Node	TSS % Load Reduction	85	None	85
Rain	Cat1 - Rainwater Tank	% Reuse Demand Met	80	None	99.9677
Rain	Cat2 - Rainwater Tank	% Reuse Demand Met	80	None	99.9677
Rain	Cat3 - Rainwater Tank	% Reuse Demand Met	80	None	99.9677
Rain	Cat4 -Rainwater Tank	% Reuse Demand Met	80	None	99.9677
Rain	Cat5 - Rainwater Tank	% Reuse Demand Met	80	None	97.2422
Rain	Cat6 - Rainwater Tank	% Reuse Demand Met	80	None	99.9677
Urban	Ca3 - Lot area	Area Impervious (ha)	None	None	0.18
Urban	Ca3 - Lot area	Area Pervious (ha)	None	None	0.18
Urban	Ca3 - Lot area	Total Area (ha)	None	None	0.36
Urban	Ca3 - Road	Area Impervious (ha)	None	None	0.538
Urban	Ca3 - Road	Area Pervious (ha)	None	None	0.027
Urban	Ca3 - Road	Total Area (ha)	None	None	0.566
Urban	Ca3 - Roof Bypass RWT	Area Impervious (ha)	None	None	0.54
Urban	Ca3 - Roof Bypass RWT	Area Pervious (ha)	None	None	0
Urban	Ca3 - Roof Bypass RWT	Total Area (ha)	None	None	0.54
Urban	Ca3 - Roof to RWT	Area Impervious (ha)	None	None	0.54
Urban	Ca3 - Roof to RWT	Area Pervious (ha)	None	None	0
Urban	Ca3 - Roof to RWT	Total Area (ha)	None	None	0.54
Urban	Cat1 - Lot area	Area Impervious (ha)	None	None	0.19
Urban	Cat1 - Lot area	Area Pervious (ha)	None	None	0.19
Urban	Cat1 - Lot area	Total Area (ha)	None	None	0.38
Urban	Cat1 - Residue area/Batter	Area Impervious (ha)	None	None	0.023
Urban	Cat1 - Residue area/Batter	Area Pervious (ha)	None	None	0.130

Only certain parameters are reported when they pass validation

Node Type	Node Name	Parameter	Min	Max	Actual
Urban	Cat1 - Residue area/Batter	Total Area (ha)	None	None	0.154
Urban	Cat1 - Road	Area Impervious (ha)	None	None	1.225
Urban	Cat1 - Road	Area Pervious (ha)	None	None	0.061
Urban	Cat1 - Road	Total Area (ha)	None	None	1.287
Urban	Cat1 - Road Bypass Treatment	Area Impervious (ha)	None	None	0.057
Urban	Cat1 - Road Bypass Treatment	Area Pervious (ha)	None	None	0.002
Urban	Cat1 - Road Bypass Treatment	Total Area (ha)	None	None	0.06
Urban	Cat1 - Roof Bypass RWT	Area Impervious (ha)	None	None	0.569
Urban	Cat1 - Roof Bypass RWT	Area Pervious (ha)	None	None	0
Urban	Cat1 - Roof Bypass RWT	Total Area (ha)	None	None	0.569
Urban	Cat1- Roof to RWT	Area Impervious (ha)	None	None	0.569
Urban	Cat1- Roof to RWT	Area Pervious (ha)	None	None	0
Urban	Cat1- Roof to RWT	Total Area (ha)	None	None	0.569
Urban	Cat2 - Lot area	Area Impervious (ha)	None	None	0.21
Urban	Cat2 - Lot area	Area Pervious (ha)	None	None	0.21
Urban	Cat2 - Lot area	Total Area (ha)	None	None	0.42
Urban	Cat2 - Residue area/Batter	Area Impervious (ha)	None	None	0.033
Urban	Cat2 - Residue area/Batter	Area Pervious (ha)	None	None	0.193
Urban	Cat2 - Residue area/Batter	Total Area (ha)	None	None	0.227
Urban	Cat2 - Road	Area Impervious (ha)	None	None	0.532
Urban	Cat2 - Road	Area Pervious (ha)	None	None	0.026
Urban	Cat2 - Road	Total Area (ha)	None	None	0.559
Urban	Cat2 - Roof Bypass RWT	Area Impervious (ha)	None	None	0.63
Urban	Cat2 - Roof Bypass RWT	Area Pervious (ha)	None	None	0
Urban	Cat2 - Roof Bypass RWT	Total Area (ha)	None	None	0.63
Urban	Cat2 - Roof to RWT	Area Impervious (ha)	None	None	0.63
Urban	Cat2 - Roof to RWT	Area Pervious (ha)	None	None	0
Urban	Cat2 - Roof to RWT	Total Area (ha)	None	None	0.63
Urban	Cat4 - Lot area	Area Impervious (ha)	None	None	0.067
Urban	Cat4 - Lot area	Area Pervious (ha)	None	None	0.067
Urban	Cat4 - Lot area	Total Area (ha)	None	None	0.134
Urban	Cat4 - Road	Area Impervious (ha)	None	None	0.266
Urban	Cat4 - Road	Area Pervious (ha)	None	None	0.013
Urban	Cat4 - Road	Total Area (ha)	None	None	0.28
Urban	Cat4 - Roof Bypass RWT	Area Impervious (ha)	None	None	0.201
Urban	Cat4 - Roof Bypass RWT	Area Pervious (ha)	None	None	0
Urban	Cat4 - Roof Bypass RWT	Total Area (ha)	None	None	0.201
Urban	Cat4 - Roof to RWT	Area Impervious (ha)	None	None	0.201
Urban	Cat4 - Roof to RWT	Area Pervious (ha)	None	None	0
Urban	Cat4 - Roof to RWT	Total Area (ha)	None	None	0.201

Only certain parameters are reported when they pass validation

Node Type	Node Name	Parameter	Min	Max	Actual
Urban	Cat5 - Lot area	Area Impervious (ha)	None	None	0.073
Urban	Cat5 - Lot area	Area Pervious (ha)	None	None	0.073
Urban	Cat5 - Lot area	Total Area (ha)	None	None	0.146
Urban	Cat5 - Road	Area Impervious (ha)	None	None	0.164
Urban	Cat5 - Road	Area Pervious (ha)	None	None	0.008
Urban	Cat5 - Road	Total Area (ha)	None	None	0.173
Urban	Cat5 - Road Bypass Treatment	Area Impervious (ha)	None	None	0.067
Urban	Cat5 - Road Bypass Treatment	Area Pervious (ha)	None	None	0.003
Urban	Cat5 - Road Bypass Treatment	Total Area (ha)	None	None	0.071
Urban	Cat5 - Roof Bypass RWT	Area Impervious (ha)	None	None	0.055
Urban	Cat5 - Roof Bypass RWT	Area Pervious (ha)	None	None	0
Urban	Cat5 - Roof Bypass RWT	Total Area (ha)	None	None	0.055
Urban	Cat5 - Roof to RWT	Area Impervious (ha)	None	None	0.055
Urban	Cat5 - Roof to RWT	Area Pervious (ha)	None	None	0
Urban	Cat5 - Roof to RWT	Total Area (ha)	None	None	0.055
Urban	Cat6 - Lot area	Area Impervious (ha)	None	None	0.0825
Urban	Cat6 - Lot area	Area Pervious (ha)	None	None	0.0825
Urban	Cat6 - Lot area	Total Area (ha)	None	None	0.165
Urban	Cat6 - Road	Area Impervious (ha)	None	None	0.478
Urban	Cat6 - Road	Area Pervious (ha)	None	None	0.024
Urban	Cat6 - Road	Total Area (ha)	None	None	0.503
Urban	Cat6 - Road Bypass Treatment	Area Impervious (ha)	None	None	0.062
Urban	Cat6 - Road Bypass Treatment	Area Pervious (ha)	None	None	0.003
Urban	Cat6 - Road Bypass Treatment	Total Area (ha)	None	None	0.066
Urban	Cat6 - Roof Bypass RWT	Area Impervious (ha)	None	None	0.248
Urban	Cat6 - Roof Bypass RWT	Area Pervious (ha)	None	None	0
Urban	Cat6 - Roof Bypass RWT	Total Area (ha)	None	None	0.248
Urban	Cat6 - Roof to RWT	Area Impervious (ha)	None	None	0.248
Urban	Cat6 - Roof to RWT	Area Pervious (ha)	None	None	0
Urban	Cat6 - Roof to RWT	Total Area (ha)	None	None	0.248

Only certain parameters are reported when they pass validation

APPENDIX E IN-SITU MEASUREMENT OF HYDRAULIC CONDUCTIVITY (FAWB 2008)

Table 14- Inspection and Maintenance Schedule

Raingarden Element	Potential Concerns	Inspection	Frequency	Maintenance Required
FILTER MEDIA TASKS				
Filter Media	Sediment deposition	Check for accumulation of sediments near inlets.	4 times per year and after all major storm events	Remove sediment build-up from inlet areas.
Filter Media	Holes or scour	Check for holes, erosion and scour.	4 times per year and after all major storm events	Infill any holes in the filter media. Provide energy dissipation (e.g. rocks and pebbles at inlet) if necessary.
Filter Media	Filter media surface porosity	Inspect for the accumulation of an impermeable layer (such as oily or clayey sediment) that may have formed on the surface of the filter media. A symptom may be that water remains ponded in the raingarden for more than a few hours after a rain event.	4 times per year and after all major storm events	Repair minor accumulations by raking away any mulch on the surface and scarifying the surface of the filter media between plants.
Filter Media	Litter control	Check for litter (including organic litter e.g. mulching, decaying leaves) in and around treatment areas.	4 times per year and after all major storm events	Remove both organic and anthropogenic litter to ensure flow paths and infiltration through the filter media are not hindered.
HORTICULTURAL TASKS				
Raingarden Vegetation	Pests and diseases	Assess plants for disease, pest infection, stunted growth or senescent (i.e. ageing) plants.	4 times per year and after all major storm events	Treat or replace as necessary. Any noticeable issues with the vegetation should be referred to an appropriate landscape architect and/or ecologist.
Raingarden Vegetation	Uprooting of plants Maintain original plant densities	Reduced plant density reduces pollutant removal and infiltration performance. Planting should be evenly spaced to help prevent scouring due to a concentration of flow. Infill planting: between 6 and 10 plants per square metre should (depending on species) be adequate to maintain a density where the plant's roots touch each other.	4 times per year and after all major storm events	Provide rocks or pebbles to dissipate flows and prevent uprooting of plants. Any noticeable issues with the vegetation should be referred to an appropriate landscape architect and/or ecologist.

Raingarden Element	Potential Concerns	Inspection	Frequency	Maintenance Required
Raingarden Vegetation	Weeds	It is important to identify the presence of any rapidly spreading weeds as they occur. The presence of such weeds can reduce dominant species distribution and diminish aesthetics. Weed species can also compromise the system's long-term performance.	4 times per year and after all major storm events	Inspect for and manually remove weed species. Application of herbicide should be limited to a wand or restrictive spot spraying due to the fact that raingardens directly drain to downstream watercourses.
Raingarden Vegetation	Lack of water	Check for plant condition (e.g. stunted growth, unhealthy appearance). Filter media could also reveal flaking or cracks.	4 times per year and after all major storm events	Irrigate following extended dry periods.
DRAINAGE TASKS				
GPT Unit	Filling of gross-pollutant trap	Check amount of accumulated litter/gross pollutants in GPT.	2-3 times per year and after all major storm events	Regular pump-out of trapped material as per manufacturer's specification.
GPT Unit	General blockage	Visual inspection for build-up of sediments and litter.	2-3 times per year and after all major storm events	Removal of sediment/litter causing blockage.
Outlet Structure (Inlet to Raingarden)	Accumulation of sediment/litter	Check for vegetation overgrowth and build-up of sediments and litter.	2-3 times per year and after all major storm events	Trimming of vegetation. Removal of sediment/litter.
Outlet Structure (Inlet to Raingarden)	Excessive scouring Uprooting vegetation	Check for signs of scouring or erosion and uprooted vegetation.	2-3 times per year and after all major storm events	If excessive scour and plant dislodgement are observed the designer should be contacted to discuss remedial action.

Raingarden Element	Potential Concerns	Inspection	Frequency	Maintenance Required
Subsoil Drainage	Blockage of subsoil drainage Inefficient operation of subsoil drainage	Ensure that perforated pipes are not blocked to prevent filter media and plants from becoming waterlogged. A small steady clear flow of water may be observed discharging from the perforated pipe at its connection into the downstream pit some hours after rainfall. Note that smaller rainfall events after dry weather may be completely absorbed by the filter media and not result in flow. Remote camera (e.g. CCTV) inspection of pipelines for blockage and structural integrity could be useful.	2-3 times per year and after all major storm events	Rod and flush subsoil drainage lines to prevent build-up of sediment.
Detention Control Pit	Excess vegetation surrounding the pit limiting flows through the pit	Check for vegetation over growth covering overflow grates and weirs.	2-3 times per year and after all major storm events	If excess vegetation is present this should be trimmed back.
Detention Control Pit	Blockage of orifice controls	Check for build-up of sediments and litter inside pit blocking the orifices. Check condition of trash guards.	2-3 times per year and after all major storm events	Pit to be cleaned to ensure the operation of the orifice controls.
Earth Bund	Breaches, erosion, bund stability RHS pipes blocked	Check for signs of potential breaches, erosion and scouring of the bund. Check for blockage in RHS pipes.	2-3 times per year and after all major storm events	Repair damaged sections of the bund to ensure no inflows escaping from the raingarden. Eroded sections to be reinstated and replanted with grass. Rod and flush blocked RHS pipes.

Raingarden Element	Potential Concerns	Inspection	Frequency	Maintenance Required
Sediment Pit	Accumulation of sediments & debris Blockage and damage in lid	Check for build-up of sediments and litter inside pit. Check condition of grated pit lid.	2-3 times per year and after all major storm events	Accumulated sediments and debris to be removed in order for the sedimentation pit to function. Repair lid if required.
Flow Spreader	Accumulation of sediments & debris Dislodgement of pipe	Check for build-up of sediments and litter inside pipe. Check placement / alignment of pipe.	2-3 times per year and after all major storm events	Accumulated sediments and debris to be removed and pipe secured or stabilised in order for the flow spreader to function.

APPENDIX F RAINGARDEN INSPECTION & MAINTENANCE CHECKLIST

CONDITION ASSESSMENT AND PERFORMANCE EVALUATION OF BIORETENTION SYSTEMS

PRACTICE NOTE 1: *In Situ* Measurement of Hydraulic Conductivity

Belinda Hatt, Sebastien Le Coustumer

April 2008

The Facility for Advancing Water Biofiltration (FAWB) aims to deliver its research findings in a variety of forms in order to facilitate widespread and successful implementation of biofiltration technologies. This Practice Note for *In Situ* Measurement of Hydraulic Conductivity is the first in a series of Practice Notes being developed to assist practitioners with the assessment of construction and operation of biofiltration systems.

1. SCOPE OF THE DOCUMENT

This Practice Note for *In Situ* Measurement of Hydraulic Conductivity is designed to complement FAWB's Guidelines for Soil Filter Media in Bioretention Systems, Version 2.01 (visit http://www.monash.edu.au/fawb/publications/index.html for a copy of these guidelines). However, the recommendations contained within this document are more widely applicable to assessing the hydraulic conductivity of filter media in existing biofiltration systems.

For new systems, this Practice Note ***does not*** remove the need to conduct laboratory testing of filter media prior to installation.

2. DETERMINATION OF HYDRAULIC CONDUCTIVITY

The recommended method for determining *in situ* hydraulic conductivity uses a single ring infiltrometer under constant head. The single ring infiltrometer consists of a small plastic or metal ring that is driven 50 mm into the soil filter media. It is a constant head test that is conducted for two different pressure heads (50 mm and 150 mm). The head is kept constant during all the experiments by pouring water into the ring. The frequency of readings of the volume poured depends on the filter media, but typically varies from 30 seconds to 5 minutes. The experiment is stopped when the infiltration rate is considered steady (i.e., when the volume poured per time interval remains constant for at least 30 minutes). This method has been used extensively (e.g. Reynolds and Elrick, 1990; Youngs *et al.*, 1993).

Note: This method measures the hydraulic conductivity at the surface of the soil filter media. In most cases, it is this top layer which controls the hydraulic conductivity of the system as a whole (i.e., the underlying drainage layer has a flow capacity several orders of magnitude higher than the filter media), as it is this layer where fine sediment will generally be deposited to form a "clogging layer". However this shallow test would not be appropriate for systems where the controlling layer is not the surface layer (e.g. where migration of fine material down through the filter media has caused clogging within the media). In this case, a 'deep ring' method is required; for further information on this method, please consult FAWB's report "Hydraulic performance of biofilter systems for stormwater management: lessons from a field study", available at www.monash.edu.au/fawb/publications/index.html.

2.1 Selection of monitoring points

For bioretention systems with a surface area less than 50 m^2, *in situ* hydraulic conductivity testing should be conducted at three points that are spatially distributed (Figure 1). For systems with a surface area greater than 50 m^2,an extra monitoring point should be added for every additional 100 m^2. It is ***essential*** that the monitoring point is flat and level. Vegetation should not be included in monitoring points.

Figure 1. Spatially distributed monitoring points

2.2 Apparatus

The following is required:

- 100 mm diameter PVC rings with a height of at least 220 mm. The bottom edge of the ring should be bevelled and the inside of the ring should be marked to indicate 50 mm and 150 mm above the filter media surface (Figure 2).
- 40 L water
- 100 mL, 250 mL and 1000 mL measuring cylinders
- Stopwatch
- Thermometer

- Measuring tape
- Spirit level
- Hammer
- Block of wood, approximately 200 x 200 mm

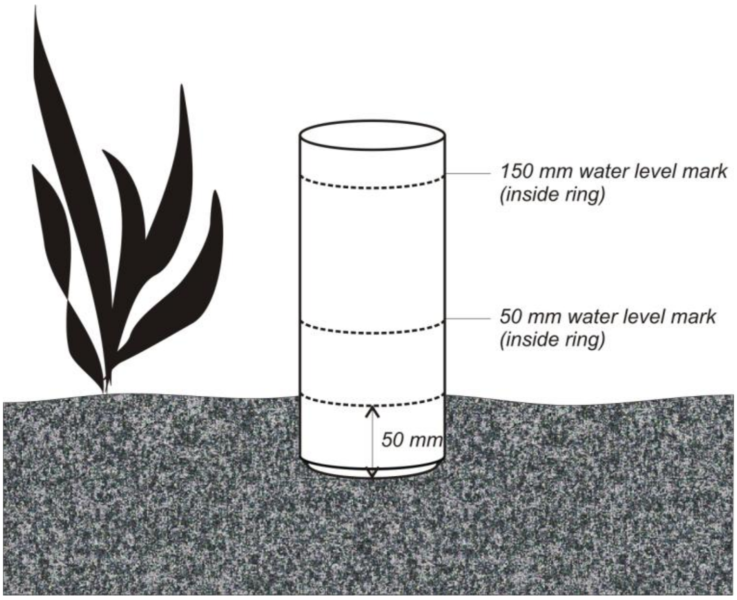

Figure 2. Diagram of single ring infiltrometer

2.3 Procedure

a. Carefully scrape away any surface covering (e.g. mulch, gravel, leaves) ***without disturbing*** the soil filter media surface (Figure 3b).

b. Locate the ring on the surface of the soil (Figure 3c), and then place the block of wood on top of the ring. Gently tap with the hammer to drive the ring 50 mm into the filter media (Figure 3d). Use the spirit level to check that the ring is level.

   Note: It is ***essential*** that this the ring is driven in slowly and carefully to minimise disturbance of the filter media profile.

c. Record the initial water temperature.

d. Fill the 1000 mL measuring cylinder.

e. Using a different pouring apparatus, slowly fill the ring to a ponding depth of 50 mm, taking care to minimise disturbance of the soil surface (Figure 3f). Start the stopwatch when the water level reaches 50 mm.

f. Using the 1000 mL measuring cylinder, maintain the water level at 50 mm (Figure 3g). After 30 seconds, record the volume poured.

g. Maintain the water level at 50 mm, recording the time interval and volume required to do so.

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Note: The time interval between recordings will be determined by the infiltration capacity of the filter media. For fast draining media, the time interval should not be greater than one minute however, for slow draining media, the time between recordings may be up to five minutes.

Note: The smallest measuring cylinder that can pour the volume required to maintain a constant water level for the measured time interval should be used for greater accuracy. For example, if the volume poured over one minute is 750 mL, then the 1000 mL measuring cylinder should be used. Similarly, if the volume poured is 50 mL, then the 100 mL measuring cylinder should be used.

h. Continue to repeat Step f until the infiltration rate is steady i.e., the volume poured per time interval remains constant for at least 30 minutes.

i. Fill the ring to a ponding depth of 150 mm (Figure 3h). Restart the stopwatch. Repeat steps e – g for this ponding depth.

Note: Since the filter media is already saturated, the time required to reach steady infiltration should be less than for the first ponding depth.

j. Record the final water temperature.

k. Enter the temperature, time, and volume data into a calculation spreadsheet (see "Practice Note 1_Single Ring Infiltration Test_Example Calculations.xls", available at www.monash.edu.au/fawb/publications/index.html, as an example).

2.4 Calculations

In order to calculate K_{fs} a 'Gardner's' behaviour for the soil should be assumed (Gardner, 1958 in Youngs *et al.*, 1993):

$$K(h) = K_{fs} e^{\alpha h} \qquad \text{Eqn. 1}$$

where *K* is the hydraulic conductivity, *α* is a soil pore structure parameter (large for sands and small for clay), and *h* is the negative pressure head. K_{fs} is then found using the following analytical expression (for a steady flow) (Reynolds and Elrick, 1990):

$$K_{fs} = \frac{G}{a}\left(\frac{Q_2 - Q_1}{H_2 - H_1}\right) \qquad \text{Eqn. 2}$$

where *a* is the ring radius, H_1 and H_2 are the first (50 mm) and second (150 mm) pressure heads, respectively, Q_1 and Q_2 are the steady flows for the first and second pressure heads, respectively, and *G* is a shape factor estimated as:

$$G = 0.316\frac{d}{a} + 0.184 \qquad \text{Eqn. 3}$$

where *d* is the depth of insertion of the ring and *a* is the ring radius.

G is nearly independent of soil hydraulic conductivity (i.e. K_{fs} and *α*) and ponding, if the ponding is greater than 50 mm.

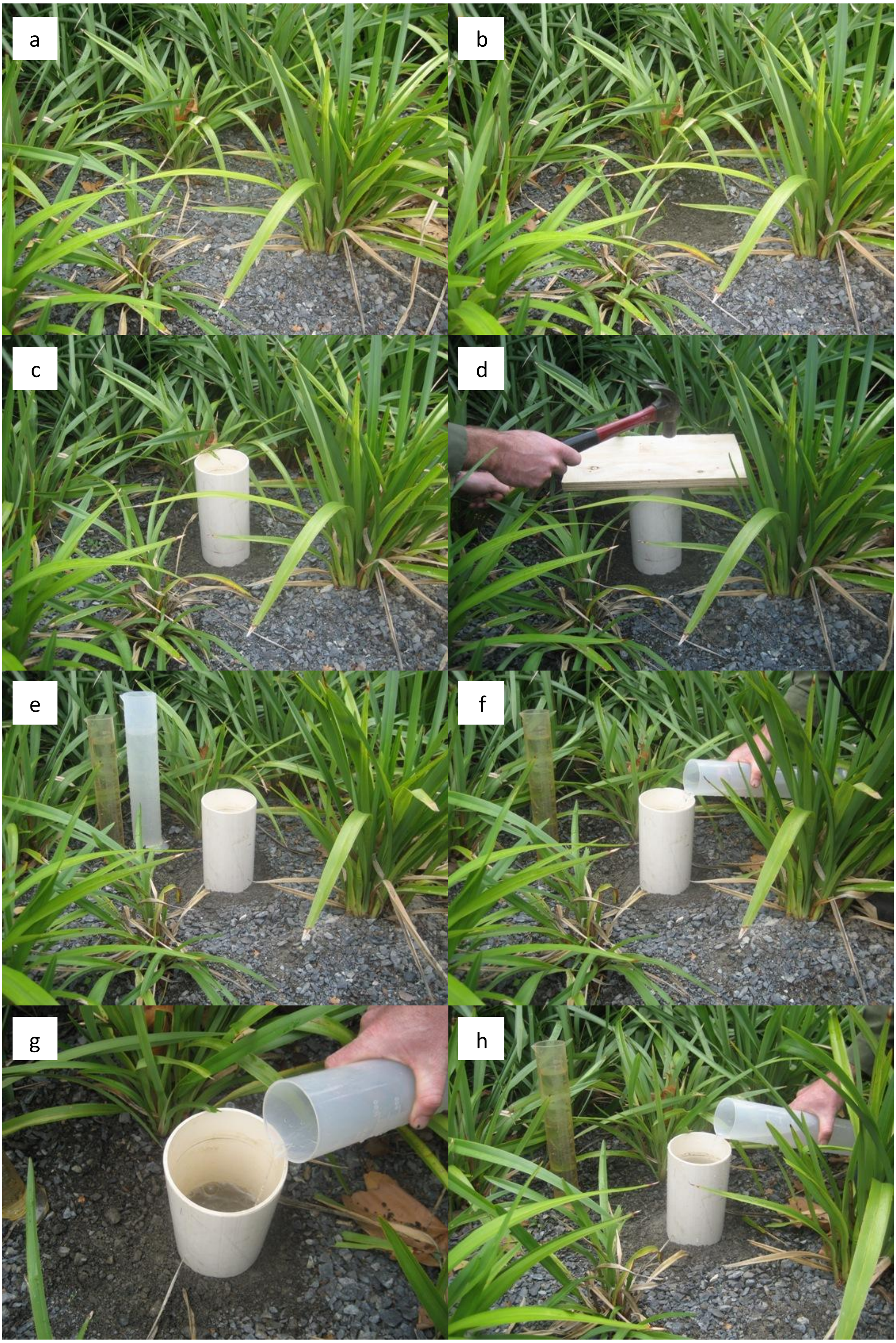

Figure 3. Measuring hydraulic conductivity

The possible limitations of the test are (Reynolds *et al.*, 2000): (1) the relatively small sample size due to the size of the ring, (2) soil disturbance during installation of the ring (compaction of the soil), and (3) possible edge flow during the experiments.

3 INTERPRETATION OF RESULTS

This test method has been shown to be relatively comparable to laboratory test methods (Le Coustumer *et al.*, 2008), taking into account the inherent variability in hydraulic conductivity testing and the heterogeneity of natural soil-based filter media. While correlation between the two test methods is low, results are not statistically different. In light of this, laboratory and field results are deemed comparable if they are within 50% of each other. In the same way, replicate field results are considered comparable if they differ by less than 50%. Where this is not the case, this is likely to be due to a localised inconsistency in the filter media, therefore additional measurement should be conducted at different monitoring points until comparable results are achieved. If this is not achieved, then an area-weighted average value may need to be calculated.

4 MONITORING FREQUENCY

Field testing of hydraulic conductivity should be carried out at least twice: (1) One month following commencement of operation, and (2) In the second year of operation to assess the impact of vegetation on hydraulic conductivity. Following this, hydraulic conductivity testing should be conducted every two years or when there has been a significant change in catchment characteristics (e.g., construction without appropriate sediment control).

REFERENCES

Gardner, W. R. (1958). Some steady-state solutions of the unsaturated moisture flow equation with application to evaporation from a water table. *Soil Science* **85**: 228-232.

Le Coustumer, S., T. D. Fletcher, A. Deletic and M. Potter (2008). Hydraulic performance of biofilter systems for stormwater management: lessons from a field study, Melbourne Water Corporation.

Reynolds, W. D., B. T. Bowman, R. R. Brunke, C. F. Drury and C. S. Tan (2000). Comparison of tension infiltrometer, pressure infiltrometer, and soil core estimates of saturated hydraulic conductivity. *Soil Science Society of America journal* **64**(2): 478-484.

Reynolds, W. D. and D. E. Elrick (1990). Ponded infiltration from a single ring: Analysis of steady flow. *Soil Science Society of America journal* **54**: 1233-1241.

Youngs, E. G., D. E. Elrick and W. D. Reynolds (1993). Comparison of steady flows from infiltration rings in "Green and Ampt" and "Gardner" soils. *Water Resources Research* **29**(6): 1647-1650.

Single Ring Infiltration Test

Site: ____

Date: ____

Constant water level = 50 mm		
Time (min)	Volume (mL)	Q (mL/s)

Constant water level = 150 mm		
Time (min)	Volume (mL)	Q (mL/s)

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