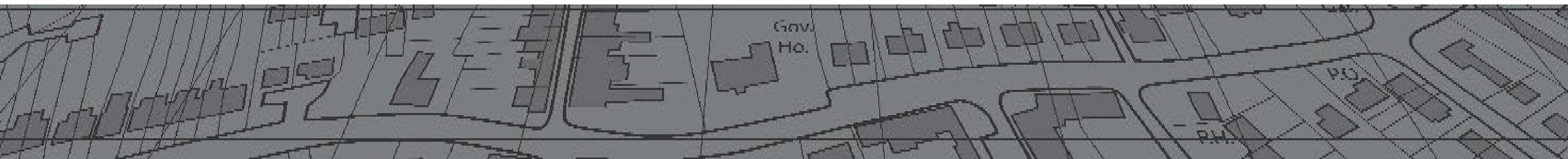
ATTACHMENT 3

Stormwater Management Response



PLANS AND DOCUMENTS referred to in the PDA DEVELOPMENT APPROVAL
Approval no: DEV2022/1290
Date: 08/03/2023

Our Ref: BC-21244
Your Ref: DEV2022/1290

13 October 2022

Department of State Development, Infrastructure, Local Government & Planning
PO Box 15009
CITY EAST, QLD 4002

To Whom it may concern,

RE: DEVELOPMENT APPLICATION DEV2022/1290
PDA Development Permit for a MCU for a Multiple dwelling at 17-19 Weinam Street and 55-61 Hamilton Street, Redland Bay described as Lot 1 on SP169111 and Lot 2 on SP115173

Please find below relevant responses to Item 1 – Stormwater raised by DSDILGP within the Further Issues request issued on 12 October 2022.

The following revised document has been included as an attachment to this letter to provide supporting information:

- Conceptual Stormwater Management Plan (Version 3).

If you would like clarification of any of the information included within this Information Request response, please contact the undersigned.

Yours faithfully

BRAD COMLEY
MSc, BAppSc MEngPrac, NER, RPEQ, CPEng

Attachment A –Conceptual Stormwater Management Plan (Version 3) by BIOME Consulting

FURTHER ISSUES RESPONSE

DEVELOPMENT APPLICATION DEV2022/1290
17-19 WEINAM STREET AND 55-61 HAMILTON STREET, REDLAND BAY

ITEM 1 - STORMWATER

a) Basin B scour protection is not shown on Drawing DWG-313 and should be updated to demonstrate scour protection.

Response

Additional detail has been added to the drawings to show scour protection:

- A note has been added to DWG-300 to nominate scour protection at the discharge headwall from the outlet pipe to the Pitt Street open drain.
- A rock scour has been shown on Section B-B DWG-313 on the downstream side of the proposed high flow weir.

STORMWATER MANAGEMENT

b) It is noted in the SMP that Detention Tank A and Bioretention Basin A2 overflows are designed to sheet flow to Hamilton Street. The weir and passage available for flow are narrow and it appears the flow will channelise. Demonstrate how sheet flow is achieved.

Response

It should be noted that flow will only occur over the emergency weir towards Hamilton Street in a block case scenario. The emergency weir will not engage in a design 1% AEP event.

An additional pit and pipe have been added on the downstream side of the emergency weir to convey flows to Hamilton Street.

Reference to sheet flow to Hamilton Street during a blocked case 1% AEP has been removed.

STORMWATER MANAGEMENT

c) It is noted in the response 'In the post developed case it is proposed that this flow be diverted to the Pitt Street drain approximately 50 m higher than in the predeveloped scenario.' Please clarify.

Response

The referenace to "50 m higher'' was a reference to how far upstream the flow was to be diverted to Pitt Street from the predevelopment case. It is a horizontal length not a vertical hieght.

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In the existing case a small upstream catchment (Catchment B(EXT)) generates flows which enter the site. These flows combine with site flow and discharge to the existing open drain on Pitt Street. In the post devlopment case the Catchment B(EXT) is to be collected upstream of the site and diverted into the Pitt Street drain at a point approxiamately 50 m upstream of where it would have entered the drain in the predevelopment case.

STORMWATER MANAGEMENT

d) Pitt Street Drain Capacity:

i. Table 6.3 does not include catchment B bypass shown in Drawing DWG-201. Please clarify if the non-worsening demonstrated still applies for PD_B.

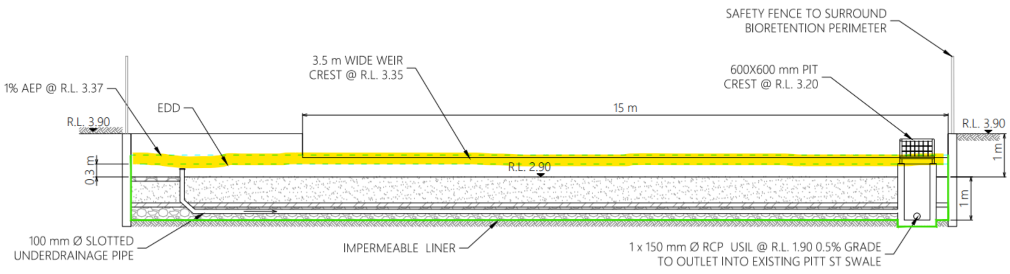
ii. Clarify how mitigation is achieved for PD_B. There are no detention structures shown for PD_B catchments.

iii. The manning's assessment for open channel flow calculation has been done for a flow of 0.04 m^3/s for the Pitt Street channel. However, the flow through the channel should be tested at full flow from the contributing catchments, which is higher.

Response

d) i) Catchment B Bypass was omitted from Table 6.3 in error. Reference to this catchment has now been added. Please note however that all peak discharge values contained in the table were generated via modelling that included Catchment B Bypass.

ii) Mitigation to PD-B is primarily achieved via a reduction in catchment area. Refer to Table 6.3 of the SMP - pre-development catchment 0.46 ha vs post-development catchment 0.38 ha. Modelling has also included a small volume of detention over the extended detention depth of the proposed bioretention basin. Please refer to section A-A on DWG 313.



SECTION A-A (TYPICAL)

iii) The manning's assessment presented in Section 6.1.1 of the report is for the proposed External Catchment B(Ext) diversion requirements. It is not for the exiting Pitt Street drain.

The peak discharge expected from External Catchment B(Ext) in the 1% AEP is 36 L/s. This assessment has been undertaken to set the level of the proposed foot path upgrade and upstream channel to direct flows to Pitt Street. A V-shaped channel with 1:4 batters at a slope of 1:150 will convey 40 L/s at a depth of 140 mm.

An additional Mannings Assessment was undertaken as part of the first IR response for the existing Pitt Street drain. This Mannings assessment was undertaken to determine the potential impact of diverting the 36 L/s of peak flow from Catchment B(Ext) into the existing drain.

As outlined above, in the existing case a small upstream catchment (Catchment B(EXT)) generates flows which enter the site. These flows combine with site flow and discharge to the existing open drain on Pitt Street. In the post devlopment case the Catchment B(EXT) is to be collected upstream of the site and diverted into the Pitt Street drain at a point approximately 50 m upstream of where it would have entered the drain in the predevelopment case.

Based on the dimensions of the existing Pitt Street open drain at this location (V-drain, 1:6 left batter – 1:9.3 right batter, Slope 1:11 and Mannings n of 0.035) the existing channel has been assessed to have a capacity of approximately 0.44 m^3/s (440 L/s) at a depth of 180 mm.

The addition of 0.036 m^3/s (36 L/s) for a length of 50 m is not anticipated to material impact the capacity of the existing channel. Based on a velocity of 1.74 m/s and a surface water width 2.83 m an increase in flow depth of < 8 mm will result.

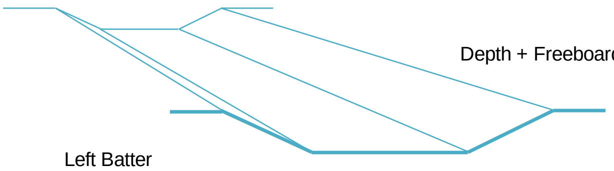
Catchment B(Ext)

Channel Assessment (Pitt Street - Upper Reach @ B(Ext) Outlet)

Mannings Channel Calculator

Design Storm: **0.01 AEP (Design)**

Flow (m^3/s):	0.44	Mannings 'n':	0.035 (Design)
Flow Depth (m)	0.18 (Design)	Channel Slope 1:	11
		Freeboard (m):	0
		Depth + Freeboard (m)	**0.18**



Left Batter	Base Width (m)	Right Batter
Slope 1: 6	0.00	Slope 1: 9.3
Width (m) = **1.152**		Width (m) = **1.674**

	Design		Design
Total Width (m) =	**2.83**	*Pitt St Channel Capacity (m^3/s) =*	**0.44**
Flow Area (m^2) =	**0.254**	Velocity (m/s) =	**1.74**
Hydraulic Radius (m) =	**0.089**	d*v (m^2/s) =	**0.31**

STORMWATER MANAGEMENT

e) The following typos were also identified:
   - Section 6.2.4 refers to Table 6.7 for 'Bioretention Basins A2 and B', this should be Bioretention Basin A1 and B.
   - Table 6.7 notes Basin B, 1% AEP level as 3.40m AHD. However, drawing DWG313 notes it as 3.37m AHD, which is current. Amend table/drawing accordingly.

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Response

- Table 6.7 has been amended to include all basins.

- Table 6.7 notes Basin B, 1% AEP level as 3.40 m AHD. This is correct. This section of the report details the expected peak water level during the sensitively assessment (blocked case).

  Drawing DWG-313 notes the peak water level as 3.37 m AHD. This is correct. This level is the 1% AEP design peak water surface. Not blocked.

PLANS AND DOCUMENTS
referred to in the PDA
DEVELOPMENT APPROVAL

Approval no: DEV2022/1290

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Attachment A

Conceptual Stormwater Management Plan (Version 3) by BIOME Consulting

Stormwater Management Plan

17-19 Weinam Street & 55-61 Hamilton Street, Redland Bay

Palm Lake Works

October 2022
BC-21244

BIOME
WATER AND ENVIRONMENTAL CONSULTING

PLANS AND DOCUMENTS referred to in the PDA DEVELOPMENT APPROVAL

Approval no: DEV2022/1290

Date: 08/03/2023

Queensland Government

Document Control

Project Name	17-19 Weinam Street & 55-61 Hamilton Street, Redland Bay
Project Number	BC-21244
Report Title	Conceptual Stormwater Management Plan
Author	Anna Kleinschmidt BEng, BSc
Reviewed by	Brad Comley
Approved by	Brad Comley .... MSc, BAppSc, MEngPrac, NER, RPEQ (17706), CPESC (8128)

Version Number	Date	Distribution
1	28 April 2022	Palm Lake Works ADG Consulting Engineers
2	24 August 2022	Palm Lake Works ADG Consulting Engineers
3	13 October 2022	Palm Lake Works ADG Consulting Engineers

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Executive Summary

This report has been prepared on behalf of Palm Lake Works and presents a comprehensive review of available Stormwater Quality Improvement Devices (SQID) and stormwater Best Management Practices (BMP) to ensure that the proposed development adequately addresses the management of stormwater quantity and quality during the operational phase of the development.

This version of the Stormwater Management Plan (SMP) – Version 3, has been amended to address the Further Issues raised by the Department of State Development, Infrastructure, Local Government & Planning (DSDLIGP) dated 12 October 2022 (reference DEV2022/1290).

In order to address the management of stormwater quality, three (3) stormwater treatment basins have been proposed. All of the proposed basins will be bioretention systems in planter type boxes, incorporating engineered filter media and planted with relevant plant species to enhance nutrient uptake.

The bioretention system filter areas have been optimised for the treatment of the site's internal catchments such that the required stormwater treatment objectives can be achieved. The proposed design includes bioretention basins with filter areas of 35 m^2, 34 m^2 and 37.5 m^2 within Catchments A1, A2, and B, respectively. It has been demonstrated utilising *MUSIC* Version 6 that this design can achieve pollutant removal efficiencies of 80%, 60%, 45% and 90% for TSS, TP, TN and gross pollutants respectively.

In order to address the management of stormwater quantity, a dedicated detention tank with an estimated detention volume of 70 m^3 has been provided within the north portion of Catchment A2. An additional 3.5 m^3 of detention is provided above the extended detention depth of the bioretention basin within Catchment A2. Modelling of this detention tank and basin and associated outlet structures indicates that pre-developed flows can be maintained for all nominated ARI events at PD-A.

Approximately 6.4 m^3 of detention has been provided above the extended detention depth of the bioretention within Catchment B. The outlets of Bioretention Basin B have been configured to mitigate the increases in flow predicted at PD-B. Modelling of the basin and associated outlet structures indicates that pre-developed flows can be maintained for all nominated ARI events at PD-B.

The level of detail provided within this report is suitable for development assessment only and should not be relied upon for construction purposes. A Detailed Stormwater Management Plan containing detailed engineering designs will be needed to finalise the stormwater concepts presented in this report. Detailed design documentation should be prepared in conjunction with civil operational works.

This report has been reviewed by a Registered Professional Engineer of Queensland (RPEQ), and certification has been provided that if the design parameters set out in this report are included within the development:

- there should be no worsening in peak discharge as a result of the proposed development; and
- stormwater pollutant load reductions in accordance with best practice should be achieved.

PLANS AND DOCUMENTS referred to in the PDA DEVELOPMENT APPROVAL

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Appendix

1 Introduction

This conceptual stormwater management plan has been prepared so as to be considered as part of a Development Application for a Material Change of Use (MCU) over Lot 2 on SP115173 and Lot 1 on SP169111 at 17-19 Weinam Street and 55-61 Hamilton Street (the subject site).

The report has been prepared on behalf of Palm Lake Works and presents a comprehensive review of available Stormwater Quality Improvement Devices (SQID) and stormwater Best Management Practices (BMP) to ensure that the proposed development adequately addresses the management of stormwater quantity and quality during the operational phase of the development.

The level of detail provided within this report is suitable for development assessment only and should not be relied upon for construction purposes. Detailed design documentation should be prepared in conjunction with civil operational works to finalise the stormwater concepts presented in this report.

1.1 Objectives

The overarching objective of this report is to present practical conceptual stormwater designs which can be integrated into the development proposal so as to ensure that the development does not cause an unacceptable impact or nuisance which could result in actionable damage to downstream properties and receiving environments during the operational phase of development. In addition, the report aims to address the requirements of the State Planning Policy – Natural Hazards, Risk and Resilience (Appendix A).

The following objectives are to be achieved.

Operational Phase Objective (Quantity)	Achieve a Lawful Point of Discharge (LPD) for all site catchments in accordance with QUDM (2016).
Operational Phase Objective (Quality)	Stormwater discharged from the site achieves the specified load based reduction targets in accordance Queensland Water Quality Guidelines (2009). For the development site relevant targets are TSS 80%, TP 60%, and TN 45%.

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2 Site Location

The subject site is located within the Redland City Council local area, comprises two (2) allotments, Lot 2 on SP115173 and Lot 1 on SP169111 at 17-19 Weinam Street and 55-61 Hamilton Street, Redland Bay. The site and has a total area of 7,026 m^2 and has street frontage to Pitt Street, Weinam Street and Hamilton Street. Hamilton Street and Weinam Street are currently used as access points.

The existing site consists of a grassed surface over 17-19 Weinam Street and a retirement village over 55-61 Hamilton Street, with multiple buildings and carpark areas.

Refer to Figure 2.1 below which presents a Google map depicting the site's location and surrounding road network.

Figure 2.1 Site Location

2.1 Rainfall

The hydrologic analysis undertaken in this report will rely on Australian Rainfall and Runoff (ARR) temporal pattern and IFD data obtained for the site from the BOM (Table 2.1).

Table 2.1 Adopted Intensity Frequency Data (mm/hr)

Storm Duration	Annual Exceedance Probability (AEP)					
	0.393 (2 yr ARI)	0.181 (5 yr ARI)	0.095 (10 yr ARI)	0.049 (20 yr ARI)	0.02 (50 yr ARI)	0.01 (100 yr ARI)
5 minute	131.0	180.0	213.0	245.0	289.0	322.0
10 minute	107.0	146.0	172.0	196.0	228.0	253.0
15 minute	91.0	124.0	145.0	166.0	193.0	213.0
20 minute	79.3	108.0	127.0	145.0	169.0	187.0
25 minute	70.5	96.1	113.0	130.0	152.0	168.0
30 minute	63.6	86.9	103.0	118.0	138.0	153.0
45 minute	49.9	68.5	81.3	93.9	111.0	124.0
60 minute	41.5	57.3	68.3	79.3	94.1	106.0
90 minute	31.8	44.3	53.0	61.9	74.2	83.9
120 minute	26.3	36.7	44.2	51.8	62.4	70.9
180 minute	20.1	28.3	34.2	40.3	48.8	55.7

3 Existing Case – Hydrological Assessment

xpstorm was utilised to assess the site's existing hydrology and generate hydrographs to represent the stormwater flows expected at the site's existing points of discharge (PD). Modelling was based on existing catchment areas and surface characteristics. Peak discharge rates for nominated Annual Exceedance Probabilities (AEPs) were derived from the output hydrographs. The following sections detail the input parameters used in the *xpstorm* modelling. Catchments have been delineated on Drawing DWG-200 – Appendix B.

3.1 Existing Case – Discharge Locations

Flows from the subject site currently discharge at two (2) Points of Discharge (PD) including:

PD-A Hamilton Street road reserve. Stormwater discharges across the north western and north eastern boundaries of the site at several locations as both piped and overland flow. Flows which discharge across the north western site boundary flow onto the adjacent grassed park area and are conveyed north east to the existing Hamilton Street drainage channel. Flows which discharge across the north eastern boundary are conveyed to Hamilton Street. From the kerb and channel of Hamilton Street stormwater enters Council's network and drains in a north eastern direction.

PD-B The table drain within Pitt Street reserve. Stormwater sheet flows over the north western boundary and through the adjacent grassed park area, and over the south western boundary into the existing table drain. Flows are conveyed to the north.

The existing discharge locations are shown on Drawing DWG-200 – Appendix B.

For hydrological assessment purposes, flows from the site combine with upstream catchments and two (2) Points of Discharge, PD-A and PD-B, will be relied upon for comparison of peak discharge.

3.2 Existing Case – External Catchments

There are two (2) small external upstream catchments that contribute flows directly onto the subject site. These catchments include the external grassed batter of Weinam Street (A(Ext)) and the south western portion of the Weinam Street Road Reserve (B(Ext)). Table 3.1 summarises the characteristics of the identified External Catchments which are also delineated on DWG-200 – Appendix B.

Table 3.1 Existing Case – External Catchment Characteristic

Catchment ID	Area (ha)	Cover (%)	Discharge Condition	PD ID
A (Ext)	0.01	100% - Grassed Batter	Sheet	PD-A
B (Ext)	0.06	82% - Grassed 18% - Footpath	Sheet	PD-B

3.3 Existing Case – Internal Catchments

The subject site has been divided into two (2) internal catchment areas. The characteristic of the site's catchments are detailed in Table 3.2 below and have been delineated on Drawing 200 – Appendix B.

Table 3.2 Existing Case – Catchment Characteristic

Catchment ID		Area (ha)	Cover (%)	Discharge Condition	PD ID
Internal	A	0.30	80 – Buildings/Hardstand 20 – Landscape	Piped/Channel/Sheet	PD-A
	B	0.40	96 – Cleared/grassed 4 – Impervious Driveway	Sheet	PD-B

3.4 Existing Case – *xpstorm* Runoff

The "Laurenson" routing method was applied to *xpstorm* for hydrological calculation and hydrograph generation. The contributing catchment was split into pervious (with 0% impervious fraction) and impervious (with 100% impervious fraction) areas. Adopted parameters for the Laurenson routing method include a Manning's roughness coefficient (n) for impervious and pervious areas respectively. Infiltration uniform losses have been applied to the hydrologic model based on information obtained from the Australian Rainfall and Runoff Data Hub tool (reference: https://data.arr-software.org)..

Temporal Patterns and Rainfall Data

Site specific rainfall and temporal pattern data used in modelling was sourced from the Australian Rainfall and Runoff (ARR) Data Hub (2019). Refer to Appendix C for a summary of the data obtained.

Critical Storm Duration Assessment

The critical storm duration for each catchment was determined utilising the Ensemble Statistics Utility in *xpstorm*. From the critical storm duration, the median storm ensemble was utilised to determine peak flows for each respective catchment. Table 3.3 presents the critical storm duration and chosen median storm ensemble for each of the modelled catchments. Box and Whisker Plots showing the 1% AEP peak flows for the range of durations modelled is contained within Appendix D.

Table 3.3 Existing Case – Critical Storm Assessment

Catchment ID	Critical Storm	Annual Exceedance Probability (AEP)					
		0.393 (2 yr ARI)	0.181 (5 yr ARI)	0.095 (10 yr ARI)	0.049 (20 yr ARI)	0.02 (50 yr ARI)	0.01 (100 yr ARI)
A (Ext)	Duration (min)	30	30	20	15	10	10
	Median Storm	4	6	4	7	7	7
B (Ext)	Duration (min)	90	30	30	30	15	15
	Median Storm	10	4	6	2	1	2
A	Duration (min)	10	10	10	10	10	10
	Median Storm	7	7	1	1	8	8
B	Duration (min)	90	90	45	30	30	25
	Median Storm	7	3	5	8	2	8

The tables below contain the modelling parameters relied upon and present the resulting peak discharges expected for each catchment. The flows reported at PD-A and PD-B represent the combined external and internal catchment inflows at this point.

Table 3.4 Existing Case – *xpstorm* Catchment Details

Catchment ID		Impervious Area		Pervious Area	
		Area (ha)	Slope (%)	Area (ha)	Slope (%)
External	A (Ext)	-	23.3	0.01	23.3
	B (Ext)	0.01	7.5	0.05	7.5
Internal	A	0.11	2.8	0.06	2.8
		0.13	22.0*		
	B	0.01	2.2	0.39	2.2

*represents roof pitch

Table 3.5 Existing Case – Adopted Initial and Continuing Losses

Impervious Area			Pervious Area			
IL (mm)	CL (mm/hr)	Manning's n	AEP	IL (mm)	CL (mm/hr)	Manning's n
0	0	0.014	0.393-0.010	28.0	1.6	0.035

Table 3.6 Existing Case – *xpstorm* Peak Discharge (m^3/s)

Catchment/Point of Discharge	Annual Exceedance Probability (AEP)					
	0.393 (2 yr ARI)	0.181 (5 yr ARI)	0.095 (10 yr ARI)	0.049 (20 yr ARI)	0.02 (50 yr ARI)	0.01 (100 yr ARI)
A (Ext)	0.002	0.003	0.004	0.005	0.007	0.007
B (Ext)	0.011	0.018	0.021	0.027	0.031	0.036
A	0.101	0.126	0.138	0.157	0.184	0.204
B	0.050	0.079	0.100	0.124	0.150	0.171
PD-A	*0.09*	*0.11*	*0.13*	*0.15*	*0.18*	*0.20*
PD-B	*0.06*	*0.09*	*0.18*	*0.14*	*0.17*	*0.20*

3.5 Existing Case – Model Validation (Rational Method)

For validation purposes, peak discharge values were calculated for 0.01 AEP using Rational Method and compared to those generated using *xpstorm.* The comparison is shown in Table 3.7 below and Rational calculations, which are in accordance with QUDM 2016 Section 4, are detailed within Appendix E.

Table 3.7 Existing Case – Peak Flow Validation *xpstorm* vs Rational

Catchment & Point of Discharge ID		*xpstorm* (m^3/s)	Rational (m^3/s)	Difference (%)
External	A (Ext)	0.007	0.007	0.0
	B (Ext)	0.036	0.042	-16.7
Internal	A	0.204	0.245	-20.1
	B	0.171	0.197	-15.2

The peak discharge calculated using Rational method is generally within 20% of the value generated using *xpstorm* for the 1% AEP. The modelling is therefore considered to be appropriately validated.

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4 Proposed Development

The development involves reconfiguring the existing site into a single lot and the construction of multiple residential type dwellings. (Figure 4.1). The five-storey development will include a mix of residential units & townhouses, communal open space, landscape areas, and carparking (including basement).

It should be noted that the development proposes the creation of stormwater treatment areas that are to be managed by a body corporate.

Figure 4.1 Proposed Ground Floor Plan Layout

5 Developed Case – Hydrological Assessment

xpstorm was utilised to assess the site's developed hydrology and generate hydrographs and peak discharge rates at each PD. The following sections detail the parameters used in the *xpstorm* modelling. Catchments have been delineated on Drawing DWG-201 – Appendix B.

5.1 Developed Case – External Catchments

In the developed case the external catchment will remain unchanged.

5.2 Developed Case – Internal Catchments

The site will undergo earthworks to profile the development area. This stormwater management plan relies on both surface runoff and underground piped drainage to collect minor and major stormwater flows.

Two (2) major post development catchments have been delineated based on the architectural designs by Archidiom. These catchments have been further split into sub-catchments. The characteristic of the site's catchments are detailed in Table 5.1 below and have been delineated on Drawing 201 – Appendix B.

Table 5.1 Developed Case – Catchment Characteristic

Catchment ID		Area (ha)	Cover (%)	Discharge Condition	PD ID
Internal	A1	0.19	100 – Residential Dev	Point & Sheet	PD-A
	A2	0.19	100 – Residential Dev	Point & Sheet	PD-A
	B	0.32	100 – Residential Dev	Point & Sheet	PD-B
	B(Bypass)	0.016	100-Vegetated Batter	Sheet	PD-B

5.3 Developed Case – *xpstorm* Runoff

The "Laurenson" routing method was applied to *xpstorm* for hydrological calculation and hydrograph generation. The contributing catchment was split into pervious (with 0% impervious fraction) and impervious (with 100% impervious fraction) areas. Adopted parameters for the Laurenson routing method include a Manning's roughness coefficient (n) for impervious and pervious areas respectively. Infiltration uniform losses have been applied to the hydrologic model.

The tables below contain the modelling parameters relied upon and present the resulting peak discharges expected for each catchment. The flows reported at each PD represent the combined catchment inflows at this point.

Table 5.2 Developed Case – *xpstorm* Catchment Details

Catchment ID		Impervious Area		Pervious Area	
		Area (ha)	Slope (%)	Area (ha)	Slope (%)
Internal	A1	0.17	22.3	0.02	2.8
	A2	0.18	22.3	0.01	2.8
	B	0.24	2.2	0.064	2.2
	B(Bypass)*	-	-	0.016	50

*vegetated batter

Table 5.3 Developed Case – Adopted Initial and Continuing Losses

Impervious Area			Pervious Area			
IL (mm)	CL (mm/hr)	Manning's n	AEP	IL (mm)	CL (mm/hr)	Manning's n
0	0	0.014	0.393-0.010	28.0	1.6	0.035

Table 5.4 Developed Case – *xpstorm* Peak Discharge (m^3/s)

Catchment/Point of Discharge	Annual Exceedance Probability (AEP)					
	0.393 (2 yr ARI)	0.181 (5 yr ARI)	0.095 (10 yr ARI)	0.049 (20 yr ARI)	0.02 (50 yr ARI)	0.01 (100 yr ARI)
A1	0.070	0.087	0.096	0.109	0.127	0.142
A2	0.075	0.092	0.101	0.115	0.135	0.149
B	0.104	0.130	0.143	0.164	0.192	0.213
B(Bypass)	0.04	0.06	0.07	0.08	0.11	0.012
PD-A	*0.135*	*0.168*	*0.187*	*0.217*	*0.253*	*0.282*
PD-B	*0.107*	*0.131*	*0.145*	*0.170*	*0.207*	*0.229*

5.3.1 Validation of Flows

Table 5.5 illustrates that the peak discharges generated using both methods compare well for the 1.0 % AEP as both hydrological methods are generally within 23.5% of each other for the 1% AEP. The modelling is therefore considered to be appropriately validated.

Table 5.5 Developed Case – Peak Flow Validation *xpstorm* vs Rational

Catchment/Point of Discharge		*xpstorm* (m^3/s)	Rational (m^3/s)	Difference (%)
Internal	A1	0.142	0.163	-14.8
	A2	0.149	0.163	-9.4
	B	0.213	0.263	-23.5

5.3.2 Peak Discharge Comparison (m^3/s) – Existing vs Developed (Unmitigated)

Table 5.6 presents a comparison of the peak discharges expected at each PD. Results indicate increases in peak discharge are expected a PD-A and PD-B as a result of the development.

Table 5.6 Peak Discharge Comparison (m^3/s)

PD	Scenario	Contributing Catchment Area (ha)	Annual Exceedance Probability (AEP)					
			0.393 (2 yr ARI)	0.181 (5 yr ARI)	0.095 (10 yr ARI)	0.049 (20 yr ARI)	0.02 (50 yr ARI)	0.01 (100 yr ARI)
PD-A	Existing	0.31	0.09	0.11	0.13	0.15	0.18	0.20
	Developed (Unmitigated)	0.39	0.14	0.17	0.19	0.22	0.25	0.28
	Difference		**+0.05**	**+0.06**	**+0.06**	**+0.07**	**+0.07**	**+0.08**
PD-B	Existing	0.46	0.06	0.09	0.18	0.14	0.17	0.20
	Developed (Unmitigated)	0.38	0.11	0.13	0.15	0.17	0.21	0.23
	Difference		**+0.05**	**+0.04**	**-0.03**	**+0.03**	**+0.04**	**+0.03**

6 Stormwater Management – Operational Phase

In order to ensure that the operational phase objectives outlined within Section 1.1 of this report can be achieved, a network of stormwater management measures are proposed for inclusion within the development.

To achieve these objectives, both external and internal flows will need to be adequately managed prior to discharge to the site's points of discharge.

6.1 Schematic Design Plan

With consideration given to the existing site characteristics, the proposed development configuration and the range of available stormwater management control measures, a set of conceptual stormwater management designs have been proposed and detailed within the drawing set contained within Appendix B.

6.1.1 External Drainage

A raised foot path and swale has been proposed at the southern boundary of the site which will divert flows (approximately 36L/s) from external catchment B(Ext) west to the existing drainage channel adjacent to Pitt Street.

The location and a typical section of the diversion is shown on drawing DWG 300 (Appendix B).

A manning's assessment has also been undertaken of the proposed diversion as presented in Figure 6.1 below.

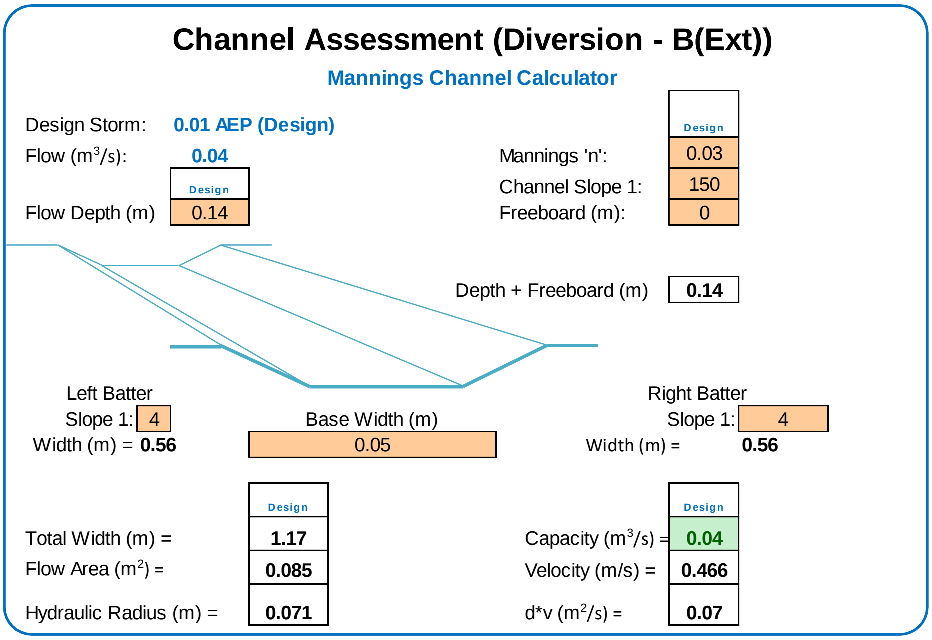

Figure 6.1 Manning's Assessment – B(Ext) Diversion

6.1.2 Internal Drainage

Stormwater flows from the development will be collected and conveyed to stormwater management measures via an internal pipe network. three (3) stormwater treatment basins have been proposed for the management of stormwater. Basins A1, A2 and B will be planter box type bioretention systems for the management of stormwater quality.

6.2 Quantity Control – Detention

The proposed development will result in an increase in impervious and hardstand area and therefore an increase in peak discharge.

A dedicated underground detention tank has been proposed to detain stormwater flows so as to ensure that there is no increase in discharge to PD-A for all nominated AEP's. The underground detention tank is to be located towards the eastern site boundary, underneath the landscaped area. This tank has been sized to detain minor and major flows from Catchment A1 via capturing minor and major outflows from Bioretention Basin A1.

Detention will be provided over the 300 mm extended detention depth of the bioretention basin within Catchment B to mitigate minor flows at PD-B.

6.2.1 *xpstorm* Modelling Parameters

xpstorm has been relied upon to size the required detention measures and develop appropriate outlet configurations.

xpstorm requires a depth area relationship to be defined when modelling an onsite detention (OSD). As an underground detention tank has been proposed for stormwater quantity management, a constant area of 90 m^2 was applied to the storage node A2 within the model. An initial depth of 0.3 m has been applied to the storage node of bioretention Basin B to represent a full extended detention depth at this onset of the modelled storms.

A summary of the total depth-area relationship applied to each storage node of the *xpstorm* model in the post-development (mitigated) scenario is contained in Table 6.1. The dimensions and proposed levels of the outlet structures used to mitigate the developed case peak discharge and achieve the required detention volumes are detailed in Table 6.2

Table 6.1 Modelled Depth Area Relationship

Detention ID	RL (m AHD)	Depth (m)	Surface Area (m^2)
Tank A2 (Primary Chamber)	2.1	0	90
	3.1	1	90
Tank A2 (Secondary Chamber)	2.1	0	1
	3.1	1	1
Bioretention A1	3.4	0	34
	4.1	0.7	34
Bioretention B	2.9	0	37.5
	3.8	0.9	37.5

Table 6.2 Modelled Outlet Structures

Detention Basin ID		Orifice	Outlet Riser(s) & Pipe(s)	Weir
Detention Tank A2	Primary Chamber	1x150 mm @ RL 2.2 m AHD 1x150 mm @ RL 2.9 m AHD	-	1 x 2 m Wide internal weir to Secondary Chamber, crest @ RL 3.1 m AHD
	Secondary Chamber	-	1x 375 mm dia RCP US IL @ RL 2.2 m AHD	-

Bioretention Basin A1	-	1x600x600 mm pit, crest @ RL 3.5 m AHD 1x 225 mm dia Pipe US IL @ RL 2.2 m AHD	1 x 1.6 m wide weir crest @ RL 3.6 m AHD
Bioretention Basin B	-	1x600x600 mm pit, crest @ RL 3.2 m AHD 1x 150 mm dia Pipe US IL @ RL 1.9 m AHD	1 x 15 m wide weir crest @ RL 3.35 m AHD

6.2.2 Modelling Results

The results of *xpstorm* modelling indicate that the inclusion of the underground detention tank along with the proposed catchment delineation and detention provided within Basin B will mitigate the expected increases in peak discharge at the nominated points of discharge location during all nominated ARI events.

Table 6.3 presents a comparison between the expected peak discharges during nominated ARI events for the pre- and post-development mitigated cases at the PDs. Figures 6.2 and 6.3 illustrates a comparison of the outlet hydrographs at PD-A and PD-B respectively where the majority of site flow will ultimately discharge.

Table 6.3 Peak Discharge Comparison (m^3/s) – PD-A & PD-B

PD	Scenario	Contributing Catchments	Contributing Catchment Area (ha)	Annual Exceedance Probability (AEP)					
				0.393 (2 yr ARI)	0.181 (5 yr ARI)	0.095 (10 yr ARI)	0.049 (20 yr ARI)	0.02 (50 yr ARI)	0.01 (100 yr ARI)
PD-A	Pre-Development	Ext A, A	0.31	0.09	0.11	0.13	0.15	0.18	0.20
	Post-Development (Unmitigated)	Ext A, A1, A2	0.39	0.14	0.17	0.19	0.22	0.25	0.28
	Post-Development (Mitigated)	Ext A, A1, A2	0.39	0.07	0.09	0.09	0.10	0.12	0.14
	Difference (Pre vs Post Mitigated)			-0.02	-0.03	-0.04	-0.05	-0.06	-0.06
PD-B	Pre-Development	Ext B, B	0.46	0.06	0.09	0.18	0.14	0.17	0.20
	Post-Development (Unmitigated)	Ext B, B, B(Bypass)	0.38	0.11	0.13	0.15	0.17	0.21	0.23
	Post-Development (Mitigated)	Ext B, B, B(Bypass)	0.38	0.05	0.06	0.07	0.08	0.11	0.15
	Difference (Pre vs Post Mitigated)			-0.01	-0.03	-0.11	-0.06	-0.06	-0.05

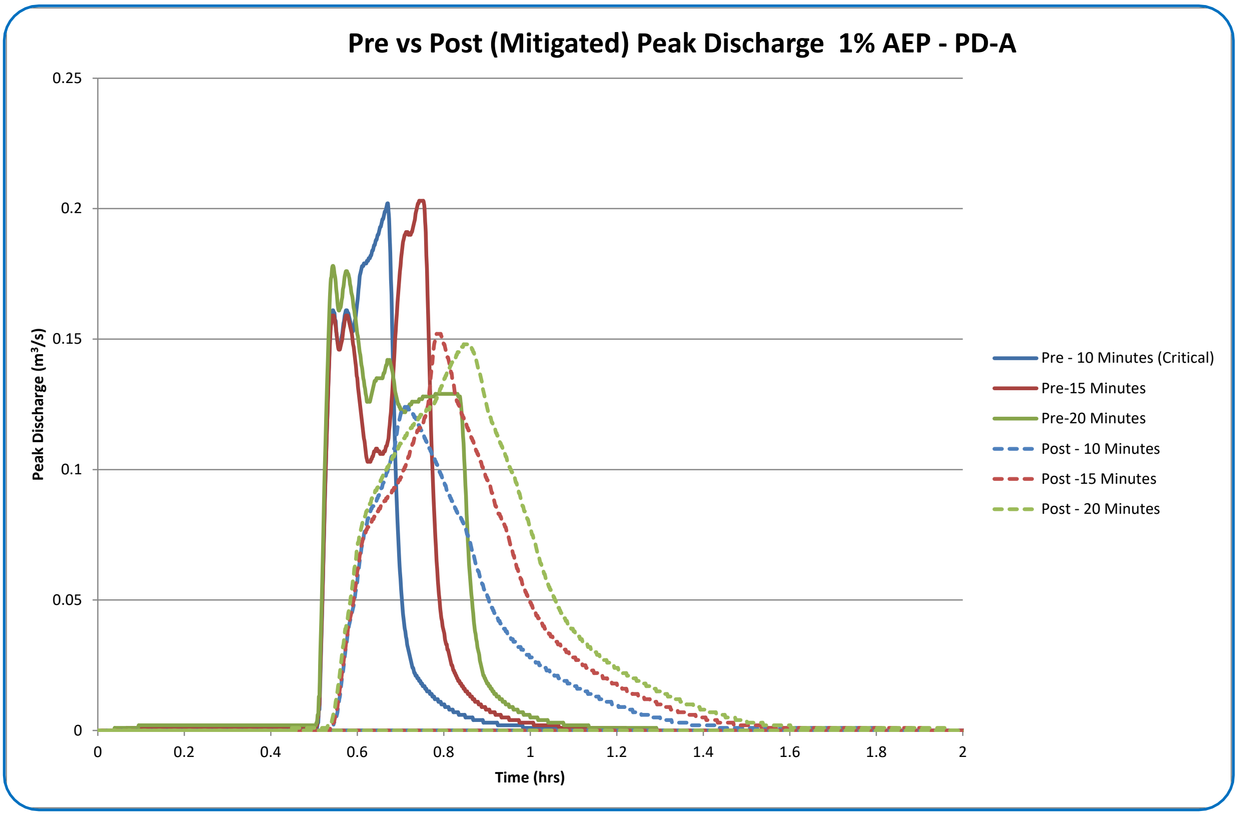

Figure 6.2 Comparison 100 year ARI Hydrography at PD-A

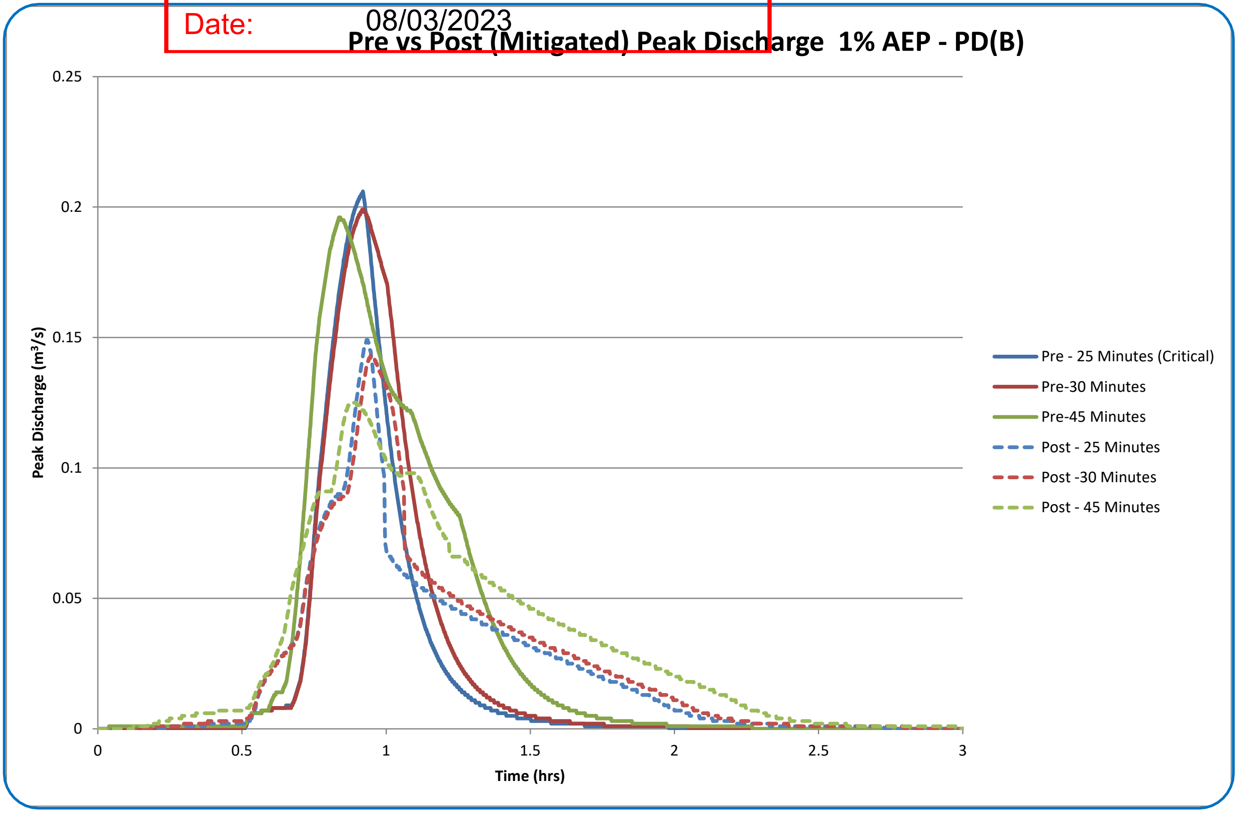

Figure 6.3 Comparison 100 year ARI Hydrography at PD-B

6.2.3 QUDM Minimum Design Safety Standards – Detention Depth

In accordance with the QUDM the depth of water in a detention basin is not to exceed 1.2 m In accordance with the QUDM the depth of water in a detention basin is not to exceed 1.2 m during the 20 year ARI and is to be limited to less than 1.5 m for the 100 year ARI. A freeboard of 300 mm should also be achieved, along with a weir flow depth of no greater than 300 mm.

As Detention Tank A1 is proposed as an underground detention tank, assessment against the QUDM safety design standards is not necessary. Bioretention Basins B1 and B2, however, will be required to meet the above safety requirements.

Table 6.4 – 6.6 below present the peak water levels, depths and volumes expected within the detention tank and bioretention basins during both the 20 year ARI and 100 year ARI's. Based on the *xpstorm* modelling of the proposed post-development scenario, the proposed stormwater management measures will not result in water depths outside the recommended design criteria.

Table 6.4 Detention Storage Details, Depths and Volumes (Detention Tank A)

	0.049 (20 yr ARI)	0.01 (100 yr ARI)
Base Level (m AHD)	2.2	2.2
Top of Tank Level (m AHD)	3.3	3.3
Internal Weir Level (m AHD)	3.1	3.1
Peak Water Surface (m AHD)	3.04	3.14
Peak Depth of Water (m)	0.84	0.94
Peak Volume (m^3)	63.2	70.2

Table 6.5 Detention Storage Details, Depths and Volumes (Bioretention Basin A1)

	0.049 (20 yr ARI)	0.01 (100 yr ARI)
Base Level (m AHD)	3.20	3.20
Top of Bund Level (m AHD)	3.90	3.90
Weir Level (m AHD)	3.60	3.60
Peak Water Surface (m AHD)	3.57	3.60
Peak Depth of Water (m)	0.37	0.40
Peak Volume (m^3) – Exc. EDD	1.1	3.6
Freeboard Achieved (m)	0.33	0.30
Weir Flow Depth (m)	-	-

Table 6.6 Detention Storage Details, Depths and Volumes (Bioretention Basin B)

	0.049 (20 yr ARI)	0.01 (100 yr ARI)
Base Level (m AHD)	2.90	2.90
Top of Bund Level (m AHD)	3.90	3.90
Weir Level (m AHD)	3.35	3.35
Peak Water Surface (m AHD)	3.34	3.37
Peak Depth of Water (m)	0.43	0.52
Peak Volume (m^3) – Exc. EDD	5.0	6.4
Freeboard Achieved (m)	0.56	0.53
Weir Flow Depth (m)	-	0.02

6.2.4 Sensitivity Analysis

In accordance with the requirements of QUDM Section 5.9.3, consideration has been given to the consequences of a fully blocked outlet pipe.

Table 6.7 illustrates the expected peak water levels within the bioretention basins if the proposed pipe outlets became fully blocked. In this event, water levels would increase in the basins with all flow discharging over the basin weirs to Hamilton Street and the Pitt Street channel for basins A1 and B respectively.

Detention Tank A and Bioretention Basin A2 have been designed such that if the piped outlets were to become fully blocked, stormwater would surcharge within the bioretention pit and overflow via the emergency weir located at the north eastern edge of the basin. An emergency overflow pit and pipe system have been proposed directly downstream of the emergency weir to collect and convey overflows from the weir to Hamilton Street as pipe flow.

Table 6.7 Sensitivity Analysis Results for 100 Year ARI Event

Basin	Peak Water Level (m AHD)	Top of Bund (m AHD)	Depth of Weir Flow (m)
A1	3.76	3.90	0.16
A2	3.74	3.90	0.14
B	3.40	3.90	0.05

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Based on the proposed basin and weir configurations, peak water levels would not be expected to exceed the Top of Bund during the 100 year ARI. The expected maximum flow depths over the weirs have been modelled at less than 0.3 m.

6.3 Lawful Point of Discharge

The criteria for determining a Lawful Point of Discharge (LPD) as specified within the Queensland Urban Drainage Manual (2016) is as follows:

(i) Will the proposed development alter the site's stormwater discharge characteristics in a manner that may substantially damage a third party property?

- If not, then no further steps are required to obtain tenure for a lawful point of discharge (assuming any previous circumstances and changes were lawful).
- If there is a reasonable risk of such damage then consider (ii) or (iii).

(ii) Is the location of the discharge from the development site under the lawful control of the local government or other statutory authority from whom permission to discharge has been received? This will include a park, watercourse, drainage or road reserve, stormwater registered drainage easement, or land held by local government (including freehold land).

- If so, then no further steps are required to obtain tenure for a lawful point of discharge
- If not, then consider issue (iii). A land owner or regulator may require that the developer obtain an authority to discharge as described in (iii) in order for the stormwater to ultimately flow to a location described in (ii).

(iii) An authority to discharge over affected properties will be necessary. In descending order of certainty, an authority may be in the form of:

- Dedication of a drainage reserve or park;
- A registered easement for stormwater discharge/works; or
- Written approval.

Each point of discharge has been assessed against the above criteria and it is considered that a Lawful Point of Discharge will be achieved at each discharge location. Provided that the design measures set out in this report are implemented it is not anticipated that substantial damage will be caused to a third party property at any discharge point. Additionally, all discharges will be directed into land under the control of Council.

6.4 Quality Control – Pollutant Reduction

In accordance with the State Planning Policy for Healthy Waters and the Queensland Water Quality Guidelines (2009), treatment measures have been included to achieve the minimum mean annual load based reductions of 80% for Total Suspended Solids (TSS); 60% for Total Phosphorus (TP), 45% for Total Nitrogen (TN), and 90% for Gross Pollutants (GP).

The Model for Urban Stormwater Improvement Conceptualisation (*MUSIC v6*) has been used to estimate the potential pollutant loads generated by the development and to size the proposed treatment measures. The following sections outline the parameters relied upon within the *MUSIC v6* modelling.

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6.4.1 Rainfall and Evapotranspiration Data

Rainfall and evapotranspiration data has been obtained from the Bureau of Meteorology (BOM) and is summarised within Table 6.8 below.

Table 6.8 Meteorological and Rainfall Runoff Data Reporting

Station	Redlands HRS (40265)
Period	1/01/1997 to 31/12/2006 (10 years)
Time step	6 minute
Mean annual rainfall (mm)	1,088
Evapotranspiration	1,569

6.4.2 Catchment Parameters

The developed site has been modelled as having an Urban Residential land use. Each internal catchment has been split into roof, road and ground level source nodes. Table 6.9 summarises the sub-catchment areas and Drawing DWG-210 – Appendix B presents the sub-catchment delineation. The adopted pollutant export and runoff parameters for each sub catchment are based on data from the Water by Design *MUSIC v6* Modelling Guidelines (2010), as summarised in Tables 6.10 and 6.11.

Table 6.9 *MUSIC v6* Sub-Catchment Areas

Catchment ID	Land Use	Area (ha)	Total Impervious (%)
Catchment A1	Urban Residential – Roof	0.16	100
	Urban Residential – Road	-	100
	Urban Residential – Ground Level	0.03	50
Catchment A2	Urban Residential – Roof	0.15	100
	Urban Residential – Road	-	100
	Urban Residential – Ground Level	0.04	50
Catchment B	Urban Residential – Roof	0.10	100
	Urban Residential – Road	0.04	100
	Urban Residential – Ground Level	0.16	50
Catchment B(Bypass)	Urban Residential – Ground Level	0.02	0
Total (ha)	**-**	**0.70**	

Table 6.10 Rainfall Runoff Parameters

Parameter	All Nodes
Landuse	Residential
Rainfall threshold (mm)	1
Soil storage capacity (mm)	500
Initial storage (% capacity)	10
Field capacity (mm)	200
Infiltration capacity coefficient a	211

Infiltration capacity exponent b	5.0
Initial depth (mm)	50
Daily recharge rate (%)	28
Daily baseflow rate (%)	27
Daily deep seepage rate (%)	0

Table 6.11 Pollutant Export Parameters (log mg/L)

Flow Type	Surface Type	Total Suspended Solids (log_{10} mg/L)		Total Phosphorous (log_{10} mg/L)		Total Nitrogen (log_{10} mg/L)	
		Mean	Std Dev.	Mean	Std Dev.	Mean	Std Dev.
Residential							
Base Flow	Roof	N/A	N/A	N/A	N/A	N/A	N/A
	Road	1.00	0.34	-0.97	0.31	0.20	0.20
	Ground	1.00	0.34	-0.97	0.31	0.20	0.20
Storm Flow	Roof	1.30	0.39	-0.89	0.31	0.26	0.23
	Road	2.43	0.39	-0.30	0.31	0.26	0.23
	Ground	2.18	0.39	-0.47	0.31	0.26	0.23

6.4.3 Treatment Measures

In order to determine the design requirements for the necessary stormwater treatment measures, key "Treatment Nodes" were added to the *MUSIC v6* model. The following sections outline the modelling parameters relied upon for each "Treatment Node".

Bioretention

It is proposed that bioretention measures be incorporated into the development layout to provide the necessary load based reductions. Bioretention systems operate by capturing and retaining water in an extended ponding area (no more than 400 mm deep for a maximum of four (4) days to prevent anaerobic conditions, plant death and insect breeding), before filtering through a soil media. The devices remove pollutants via the following physical processes:

- Sedimentation in the extended detention storage;
- Filtration by filter media;
- Nutrient uptake by biofilms;
- Nutrient adsorption and pollutant decomposition by soil bacteria; and
- Adsorption of metals and nutrients by filter particles (Somes & Crosby, 2007).

In accordance with Water by Design Guidelines, Table 6.12 summarises the treatment node parameters used in the *MUSIC v6* modelling whilst Figure 6.4 provides typical design parameters for the proposed bioretention devices.

Table 6.12 Bioretention Parameters

Bioretention Parameter	Bioretention A1	Bioretention A2	Bioretention B
Drainage Profile (Type 1 = Saturated Zone, Type 2 = Sealed, Type 3 = Conventional, Type 4 = Pipeless)	Type 3	Type 3	Type 3
Surface area (m^2)	35	34	37.5
Extended detention depth (m)	0.3	0.3	0.3

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Filter area (m^2)	35	34	37.5
Unlined filter media perimeter (m)	0.01	0.01	0.01
Saturated hydraulic conductivity (mm/hr)	200	200	200
Filter depth (m)	0.6	0.6	0.6
TN content of filter media (mg/kg)	400*	400*	400*
Proportion of organic material in filter (%)	< 5	< 5	< 5
Orthophosphate content of filter media (mg/kg)	30*	30*	30*
Is the base lined?	Yes	Yes	Yes
Effectiveness of plant TN removal	Effective	Effective	Effective
Overflow weir width (m)	Surface Area/10	Surface Area/10	Surface Area/10
Exfiltration rate (mm/hr)	0.00	0.00	0.00
If an exfiltration rate has been used, have node water balance losses been used in calculation of treatment train effectiveness?	N/A	N/A	N/A
If exfiltration rate has been used, is the exfiltration rate justified?	N/A	N/A	N/A
Underdrain present?	Yes	Yes	Yes
Submerged zone with carbon present?	No	No	No
Depth of submerged zone (m)	N/A	N/A	N/A
Confirmation that K and C* remain default?	Yes	Yes	Yes
Sediment Forebay Required (>2 ha contributing catchment)	No	No	No

*As per Healthy Land and Water Recommendations for MUSICv6 modelling

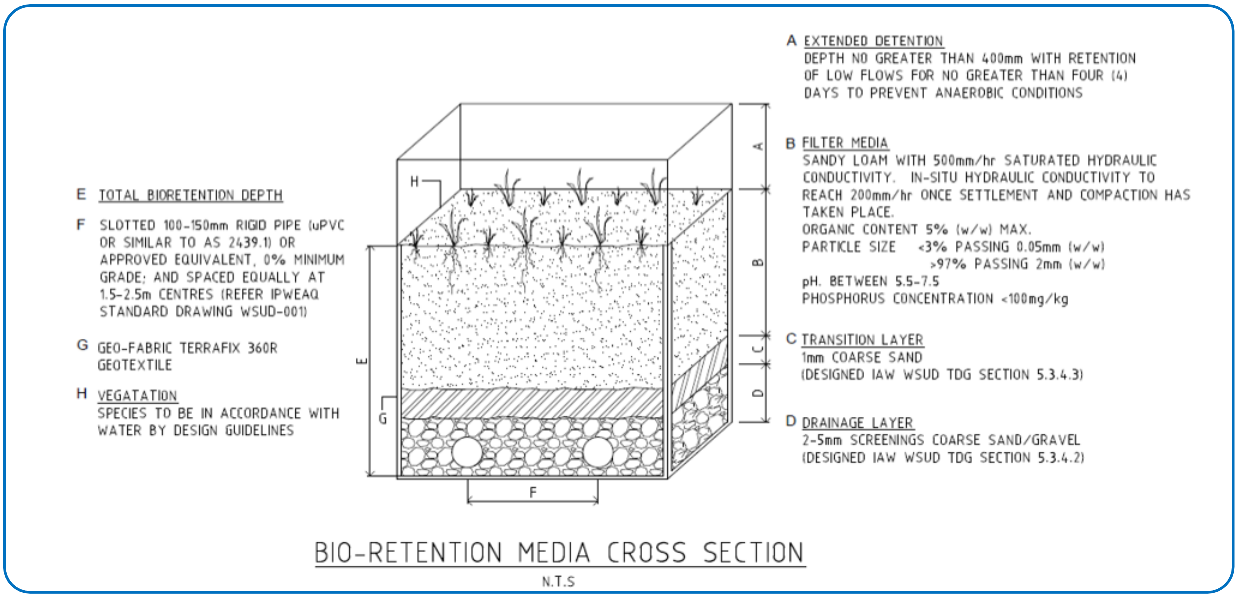

Figure 6.4 Bioretention specifications

Bioretention in Acid Sulfate Soils

The subject site is located within the acid sulfate soils overlay, with much of the site at an elevation of less than 5 m AHD.

It is therefore recommended that geotechnical testing be undertaken onsite for the presence of acid sulfate soils. If it is determined that acid sulfate soils are present where bioretention basins are proposed, a Type 2 sealed bioretention basin should be utilised onsite (instead of the Type 3 conventional). The system would therefore be contained within a unit that would not allow interaction with the adjacent soil environment.

6.4.4 Modelling Results

Results of the *MUSIC v6* modelling are summarised in Table 6.13 and screen captures shown in Figures 6.5 – 6.7. The modelling achieved the required 80%, 60%, 45% and 90% reduction targets for TSS, TP, TN and GP respectively for the rainfall data set simulated.

Table 6.13 Treatment Train Effectiveness

PD ID	Pollutant	Inflows (kg/yr)	Outflows (kg/yr)	Reduction (kg/yr)	Reduction (%)	Water Quality Objective (%)
PD-A	TSS	182.3	35.8	146.5	**80.4**	80
	TP	0.7	0.2	0.5	**72.2**	60
	TN	7.4	3.3	4.1	**55.5**	45
PD-B	TSS	405.4	72.4	333.0	**82.1**	80
	TP	0.8	0.2	0.6	**73.9**	60
	TN	4.9	2.4	2.6	**51.8**	45
Site (Total)	TSS	571.9	105.5	466.4	**81.6**	80
	TP	1.5	0.4	1.1	**72.6**	60
	TN	12.2	5.6	6.6	**54.3**	45

NOTE: All simulations have been run with pollutant export estimation set to “stochastic generation”.

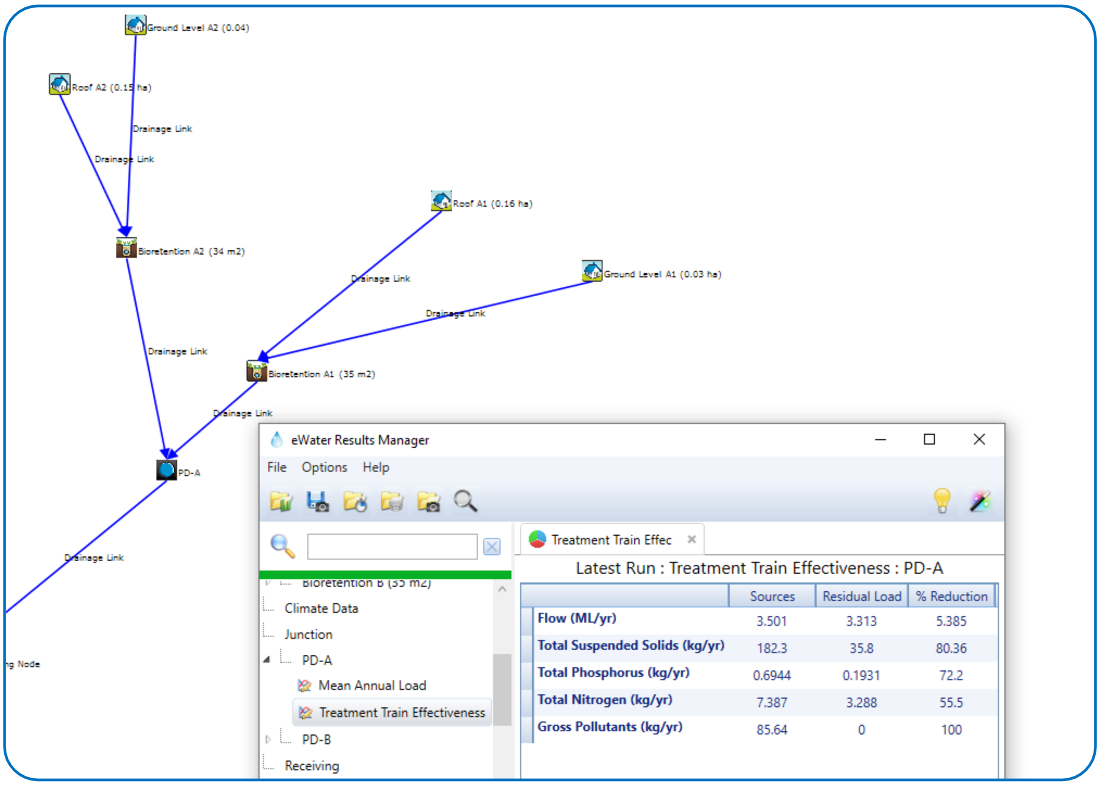

Figure 6.5 Screen Capture of MUSIC Modelling Results (PD-A)

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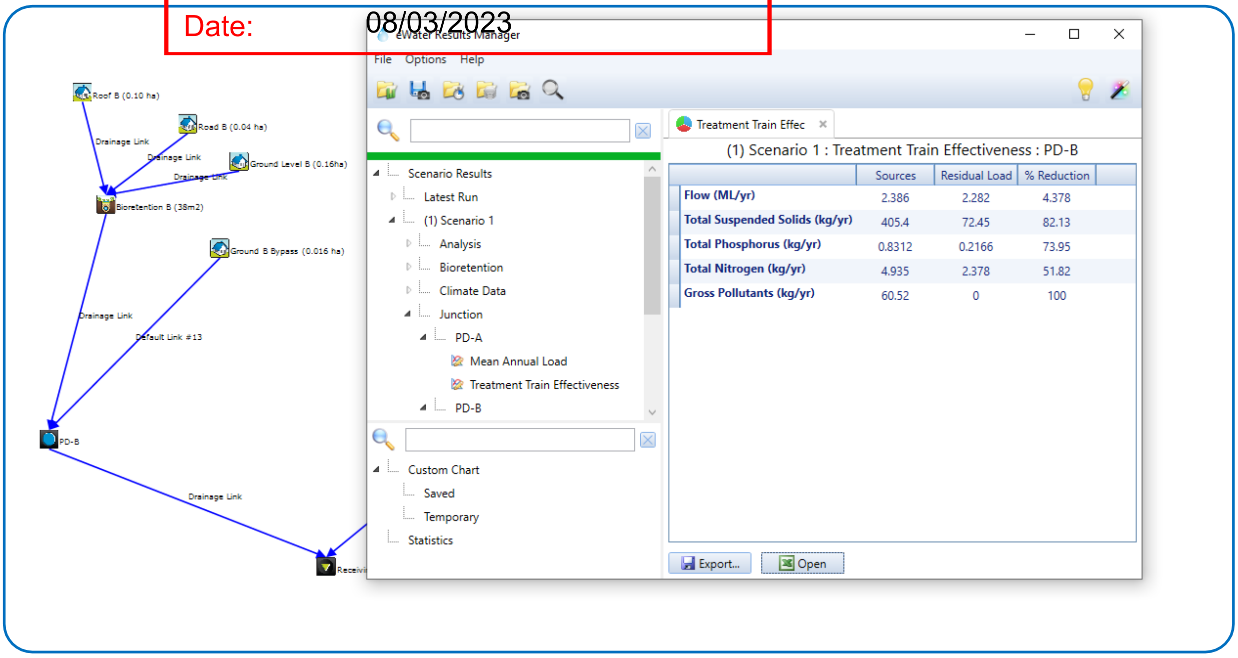

Figure 6.6 Screen Capture of MUSIC Modelling Results (PD-B)

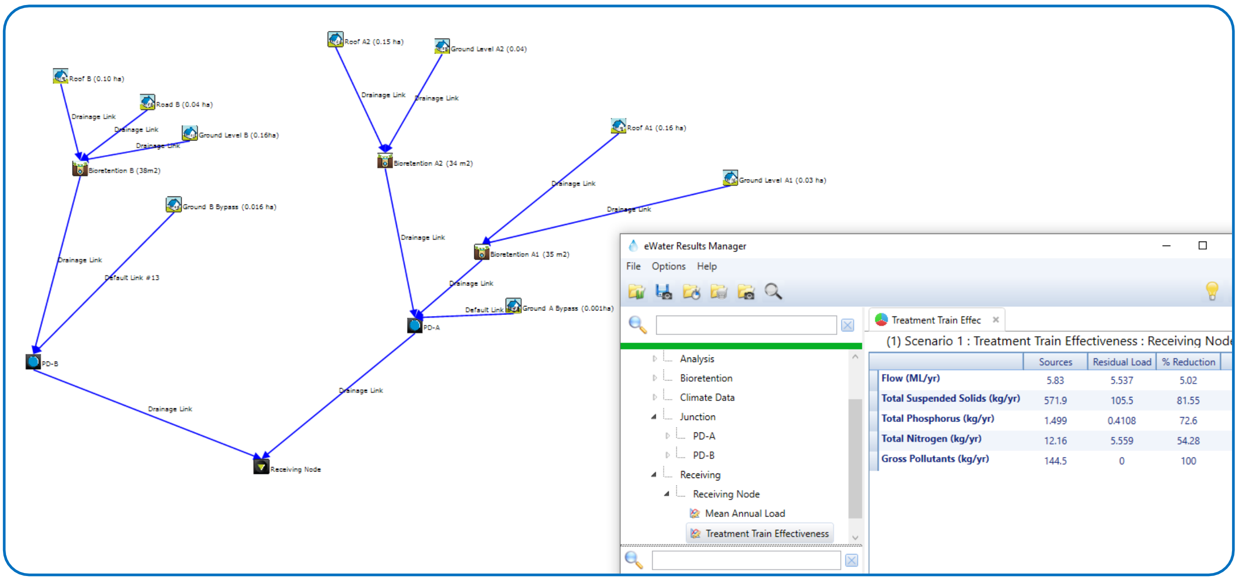

Figure 6.7 Screen Capture of MUSIC Modelling Results (Whole of Site)

6.5 Maintenance Access

The bioretention systems will require regular maintenance, including cleanouts, weeding, and replanting. The bioretention basins, and the surrounds will therefore include the access provisions detailed in Table 6.14 and on drawings -310 to -312 (Appendix B) to facilitate these maintenance activities.

In order to limit public access to the bioretention system, a lockable gate and pool fencing should be provided around the perimeter of the bioretention systems.

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Table 6.14 Maintenance Access Requirements

Access Type	Description	Dimension	Material/Design Requirements
	BIORETENTION FILTER AREA		
Filter Access	Access onto filter and piped inlet point(s) for maintenance and inspections	-	As vertical walls are proposed access is to be via stairs/ladder. Basins are accessed from the internal road (Basin B) via a lockable pool fence gate.
Filter Fencing	Fencing is to be provide around the perimeter of the bioretention to prevent access.	1.8 m high	Pool fencing around entire perimeter
Filter Perimeter	Access Path adjacent to Filter perimeter to allow for maintenance.	>0.75m Wide to min 40% of bioretention perimeter	Access path along one side of the bioretention system to allow easy access on foot. Turf, Gravel, Concrete suitable for foot traffic.
	Underground Detention Tank		
Tank Inlet/Outlet Maintenance Access	Access chamber(s) to be provided to allow inspection/maintenance of tank inlets/outlets	0.9 m x 0.9 m access chamber or as specified by tank manufacturer	As specified by tank manufacturer.

6.6 Bioretention Basin Staged Construction and Establishment

In accordance with the Water by Design Construction and Establishment Guidelines: Swales Bioretention Systems and Wetlands (C & E Guidelines), inflow of sediment-laden runoff during the building stage is a major risk to the successful and long-term functioning of bioretention systems.

During the building phase of developments, sediment can seal the surface of the filter media, move into and clog the filter media and accumulate in the under-drainage. Within the C & E Guidelines, there are four (4) options recommended to overcome the challenges associated with delivering bioretention systems. These generally include the following options:

- Option 1: Surface Protection
- Option 2: Bypass flows and early establishment of vegetation;
- Option 3: Sediment basin and bioretention function; and
- Option 4: Leave as sediment basin.

Any of the above options will ensure adequate protection of the bioretention during the building phase and are suitable for implementation.

It is proposed that Option 4 method for staged construction and establishment of the bioretention system is to be implemented for the proposed development. This method will be progressed in three (3) stages as follows:

Stage 1 Civil Works – earthworks and bulking out of basin followed by the installation of the hydraulic structures;

Stage 2 Building Phase Protection – the system operates as a sediment basin; and

Stage 3 Civil Construction and Landscape Establishment

- when 80-90% of building in the catchment is complete, removal of the accumulated sediment;

- finalisation of civil works and installation of the under-drainage and bioretention media; and
- planting and establishment of vegetation in the bioretention system.

The details of the procedure and order of construction for the Option 4 method are contained within the C & E Guidelines Section 3.10. If an alternative option is found to be more suitable for the site, construction methods and steps should be referenced from the C & E Guidelines.

6.7 Water Quality Monitoring and Maintenance

In order to ensure that the stormwater management measures detailed within this management plan function correctly in the long term and to ensure that impacts to downstream receiving environments are mitigated, appropriate operational phase water maintenance and monitoring is to be undertaken. The following sections detail the minimum requirements for each specific control device.

6.7.1 Operational Phase Water Quality Monitoring

Monitoring during the operational phase will be undertaken to determine the impact of activities on the receiving waters. Surface water quality monitoring is to be undertaken at discharge points from the site. Samples should be collected for TSS, pH, dissolved oxygen (DO), TP, TN and hydrocarbons. Sampling is to be performed in accordance with procedures set out in the Environmental Protection Authority's Water Quality Sampling Manual. A NATA registered laboratory is to be used to analyse the collected samples.

Table 6.15 specifies the sampling parameters and frequencies required. Results of the monitoring program are to be compiled monthly into an ongoing Water Quality Monitoring Report. A copy of the report and monitoring data is to be maintained at all times.

Table 6.15 Operational Phase Water Quality Parameters and Sampling Frequencies

Sampling Parameter	Sampling Frequency
TSS	Water quality monitoring will be completed following a rainfall event of 25 mm or greater in any 24 hour period monthly for a minimum period of 12 months, or as specified by the Local Authority conditions of approval for the development.
pH	
Dissolved Oxygen (DO)	
TN	
TP	
Hydrocarbons	

Table 6.16 sets the water quality criteria for water discharged from the development site.

Table 6.16 Operational Phase Water Quality Discharge Criteria

Water Quality Parameter	Discharge Criteria
TSS	No net deterioration of the downstream receiving environment as a result of discharge from the development.
Turbidity (NTU)	
pH	
DO	
TN	
TP	
Hydrocarbons	

6.7.2 Operational Phase Device Maintenance

In order for each of the proposed stormwater treatment devices to achieve the necessary pollutant removal efficiencies regular maintenance is necessary. Poorly maintained devices will result in under performance and in some instances may cause leaching of pollutants to downstream receiving environments. Based on the proposed treatment train Table 6.17 details appropriate maintenance regimes for each treatment device.

Table 6.17 Operational Phase Device Maintenance Requirements

Treatment Device	Maintenance Action
Bioretention	Routine inspection to identify obvious increased sediment deposition. Remove sediment when flow within the bioretention is impeded or smothering of vegetation occurs.
	Routine inspection of inlet and outlet pit to identify any areas of scour, litter build up or blockages.
	Tilling of the bioretention surface if there is evidence of clogging.
	Regular watering of vegetation until plants are established.
	Removal and management of invasive weeds.
	Removal and replacement of dead and dying vegetation.
	Regular inspection and removal of litter and gross pollutants.
	Resetting (i.e. complete reconstruction) of the bioretention will be required if the flow within the bioretention system is reduced by 25% due to an accumulation of sediment.

All material removed during maintenance, whether solid or liquid, is to be disposed of in a manner that does not cause ongoing soil erosion or environmental harm.

7 Conclusions

The report has been prepared on behalf of Palm Lake Works and presents a comprehensive review of available Stormwater Quality Improvement Devices (SQID) and stormwater Best Management Practices (BMP) to ensure that the proposed development adequately addresses the management of stormwater quantity and quality during the operational phase of the development.

In order to achieve the required quantity and quality operational phase objectives, a single detention tank and four (4) stormwater quality treatment basins (bioretention) are proposed.

The bioretention system filter areas have been optimised for the treatment of the site's internal catchments such that the required stormwater treatment objectives can be achieved. The proposed design includes bioretention basins with filter areas of 35 m^2, 34 m^2, and 37.5 m^2 within Catchments A1, A2, and B, respectively. It has been demonstrated utilising *MUSIC* Version 6 that this design can achieve pollutant removal efficiencies of 80%, 60%, 45% and 90% for TSS, TP, TN and gross pollutants respectively.

In order to address the management of stormwater quantity, a dedicated detention tank with an estimated detention volume of 70 m^3 has been provided towards the north western boundary of Catchment A2. Modelling of this detention tank and its associated outlet structures indicate that pre-developed flows can be maintained for all nominated ARI events at PD-A.

Catchment reductions in the post-development case have resulted in subsequent reductions in peak discharge at PD-B for the modelled 50 and 100 year ARI events. The outlets of Bioretention Basin B has been configured to mitigate the increases in flow predicted during lower events at PD-B.

8 RPEQ Certification

I am aware that Council may rely upon the contents and findings of this assessment for the purposes of development assessment. In my opinion, the Council can rely upon the information contained within the report and there are no reservations or qualifications in respect to the information other than set out in the report.

I confirm that if the design parameters set out in this report are included within the development:

- there should be no worsening in peak discharge, as a result of the proposed development that would result in actionable damage to downstream properties; and
- stormwater pollutant load reductions in accordance with best practice should be achieved.

....13.10.22.............................

Brad Comley **RPEQ 17706** **DATE**

9 References

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Water by Design, 2010. MUSIC Modelling Guidelines. South East Queensland Healthy Waterways Partnership, Brisbane, Queensland.

Water by Design, 2014. Bioretention Technical Design Guidelines (Version 1.1), Healthy Waterways Ltd, Brisbane.

PLANS AND DOCUMENTS
referred to in the PDA
DEVELOPMENT APPROVAL

Approval no: DEV2022/1290
Date: 08/03/2023

Queensland Government

Appendix A

State Planning Policy Assessment – Natural Hazards, Risk and Resilience

Assessment Benchmark	Response
Erosion prone areas within a coastal management district	
(1) Development does not occur unless the development cannot feasibly be located elsewhere and is: (a) coastal-dependent development; or (b) temporary, readily relocatable or able to be abandoned development; or (c) essential community infrastructure; or (d) minor redevelopment of an existing permanent building or structure that cannot be relocated or abandoned.	N/A The development is not within a coastal management district, and State Planning Policy mapping does not identify the site as erosion prone.
(2) Development permitted in (1) above, mitigates the risks to people and property to an acceptable or tolerable level.	N/A The development is not within a coastal management district, and State Planning Policy mapping does not identify the site as erosion prone.
Bushfire, flood, landslide, storm tide inundation, and erosion prone areas outside the coastal management district	
(3) Development other than that assessed against (1) above, avoids natural hazard areas, or where it is not possible to avoid the natural hazard area, development mitigates the risks to people and property to an acceptable or tolerable level.	The finished floor levels of the habitable floors have been set above the storm tide level (3.23 m AHD)+300 mm freeboard. Retaining walls are to be constructed so as to ensure that all habitable floors are a minimum level of 4.0 m AHD. The entrance ramp to the basement level
All natural hazard areas	
(4) Development supports and does not hinder disaster management response or recovery capacity and capabilities	Flood free access is available for egress during storm tide events.
(5) Development directly, indirectly and cumulatively avoids an increase in the severity of the natural hazard and the potential for damage on the site or to other properties.	Given that flooding is a consequence of storm tide inundation rather than riverine flooding, flood storage compensation is not considered necessary. The flood storage loss will not impact the storm tide-generated flood level.
(6) Risks to public safety and the environment from the location of hazardous materials and the release of these materials as a result of a natural hazard are avoided	The development is for residential purposes and therefore no hazardous materials are expected to be stored onsite in quantities that would cause risk to the environment.
(7) The natural processes and the protective function of landforms and the vegetation that can mitigate risks associated with the natural hazard are maintained or enhanced.	The site is currently devoid of vegetation with the exception of turf.

Appendix B

Stormwater Management Design Drawings

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PLANS AND DOCUMENTS referred to in the PDA DEVELOPMENT APPROVAL

Queensland Government

Approval no: DEV2022/1290

Date: 08/03/2023

DATE:	13.10.22
PROJECT No. :	BC-21244
DRAWING No. :	DWG 100
REVISION No. :	C

CONCEPTUAL STORMWATER MANAGEMENT DESIGN DRAWINGS

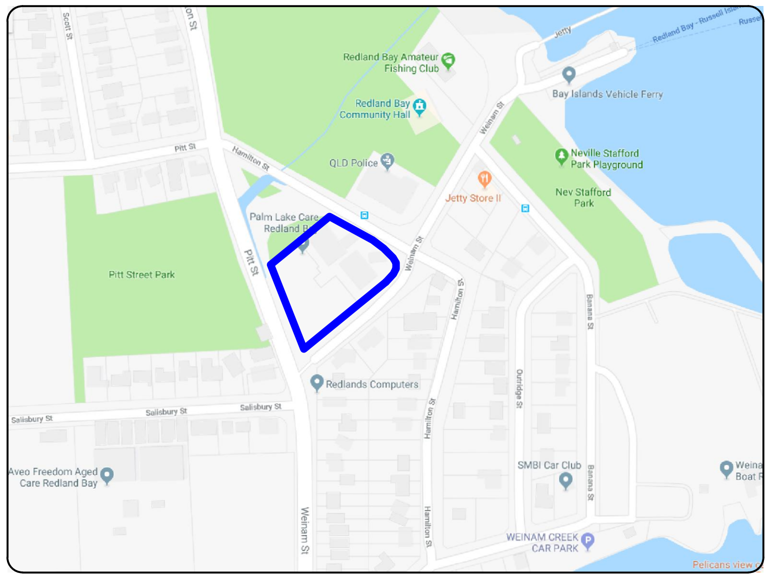
Proposed Residential Development
55-61 Hamilton & 17-19 Weinam Street

for

PALM LAKE WORKS

Project No: BC-21244

October 2022



Site Location

BIOME Consulting Pty Ltd
Unit 30201, Southport Central Tower 3,
9 Lawson St, Southport QLD 4215
PO Box 3469, Australia Fair, Southport
O **07 5532 7779**
M 0415 935 222
E brad@BIOMEconsulting.com.au
W www.BIOMEconsulting.com.au
ABN 86 166 087 476

SCHEDULE OF DRAWINGS

Drawing No.	Drawing Title
DWG-100	LOCALITY AND DRAWING INDEX PLAN
DWG-200	EXISTING CATCHMENT PLAN
DWG-201	DEVELOPED CATCHMENT PLAN
DWG-210	MUSIC CATCHMENT PLAN
DWG-300	OPERATIONAL CONTROL PLAN
DWG-310	UNDERGROUND TANK A LAYOUT & SECTION DETAILS
DWG-311	BASIN A1 LAYOUT & SECTION DETAILS
DWG-312	BASIN A2 LAYOUT & SECTION DETAILS
DWG-313	BASIN B LAYOUT & SECTION DETAILS
DWG-340	BIORETENTION FILTER MEDIUM AND UNDERDRAINAGE TYPICAL DETAILS
DWG-350	BIORETENTION STANDARD NOTES

PLANS AND DOCUMENTS referred to in the PDA DEVELOPMENT APPROVAL

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Date: 08/03/2023

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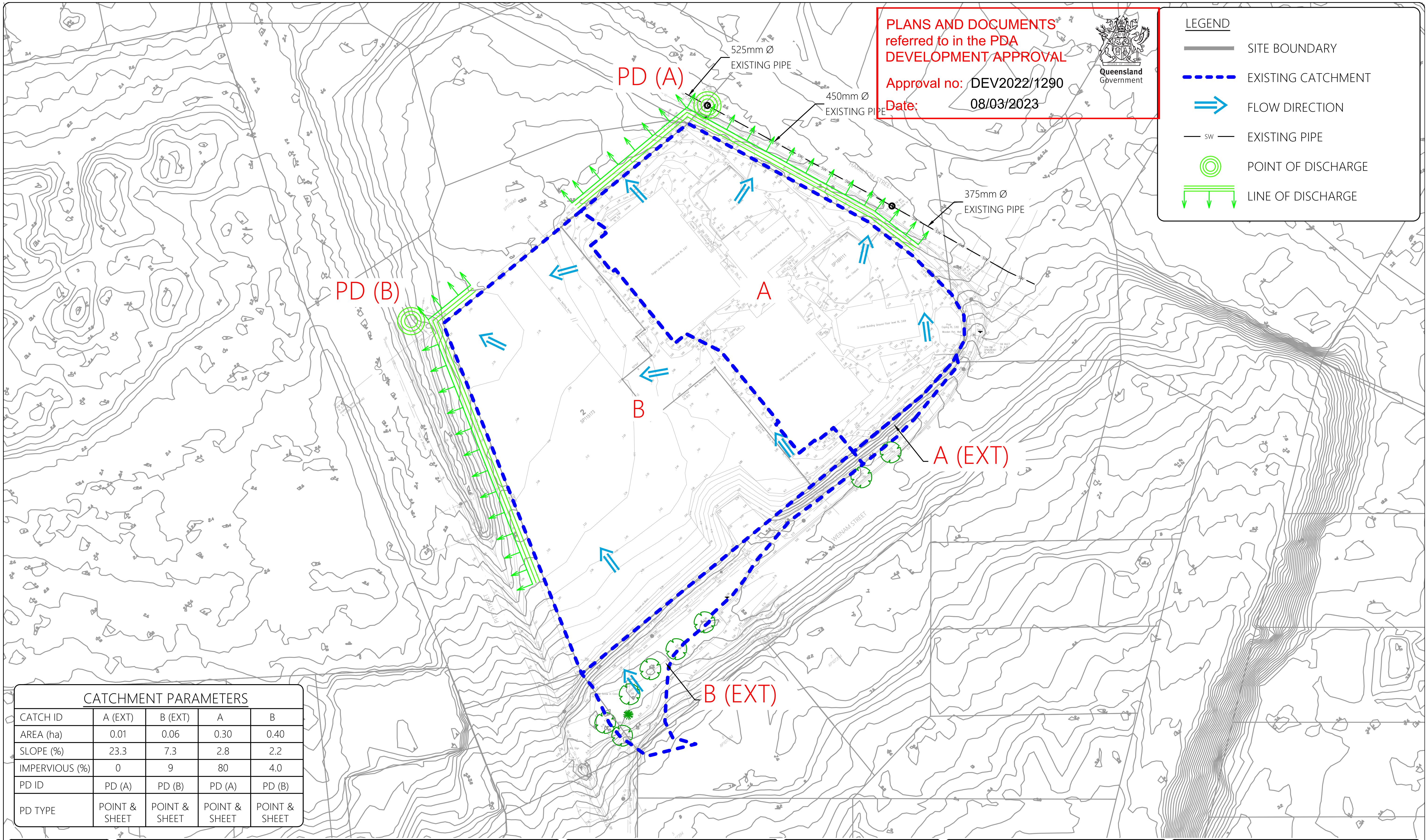

LEGEND

- SITE BOUNDARY
- EXISTING CATCHMENT
- FLOW DIRECTION
- SW EXISTING PIPE
- POINT OF DISCHARGE
- LINE OF DISCHARGE

CATCHMENT PARAMETERS

CATCH ID	A (EXT)	B (EXT)	A	B
AREA (ha)	0.01	0.06	0.30	0.40
SLOPE (%)	23.3	7.3	2.8	2.2
IMPERVIOUS (%)	0	9	80	4.0
PD ID	PD (A)	PD (B)	PD (A)	PD (B)
PD TYPE	POINT & SHEET	POINT & SHEET	POINT & SHEET	POINT & SHEET

DATE
13.10.22

PROJECT No. :
BC-21244

DRAWING No. :
DWG-200

REVISION No. :
C

PROJECT
PROPOSED RESIDENTIAL DEVELOPMENT

DRAWING TITLE
EXISTING CATCHMENT PLAN

CLIENT
PALM LAKE WORKS

ADDRESS:
55-61 HAMILTON & 17-19 WEINAM STREET
REDLAND BAY

DRAFTED BY :	DESIGNED BY :	CHECKED BY:	PAPER SIZE :	SCALE :
TP / KP	AK	BC	A3	1:750

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ACN 166 087 476
RPEQ No. :

VER.	DESCRIPTION	APPR.	DATE
A	ORIGINAL ISSUE		05.04.22
B	FURTHER ISSUES RESPONSE		04.08.22
C	FURTHER ISSUES RESPONSE		13.10.22

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ABN 86 166 087 476

ORIGINAL SCALE BEFORE REDUCTION
10 0 10 20 30 40
1 : 750 (FULL SIZE) (metres)

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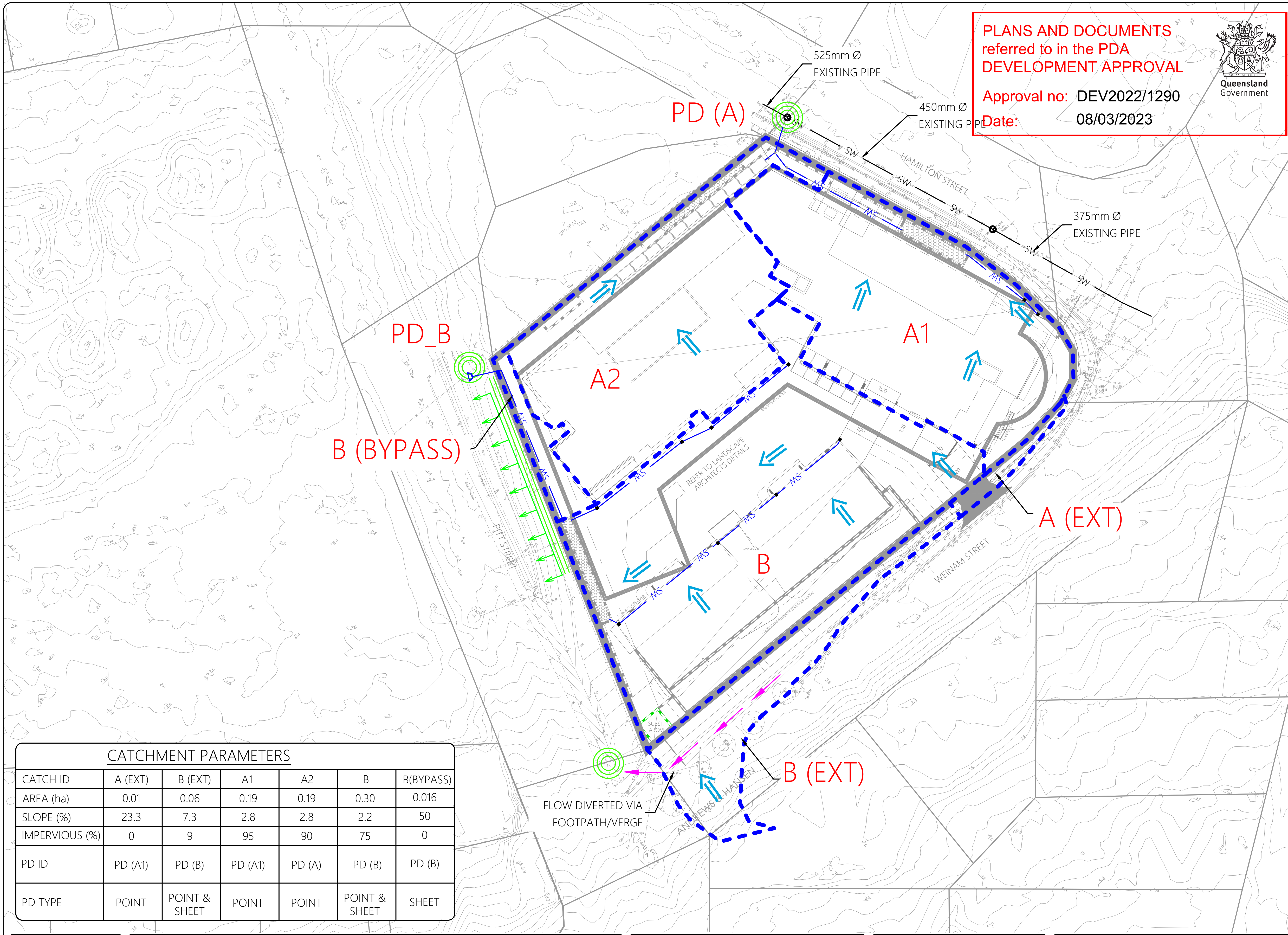

LEGEND

- DEVELOPED CATCHMENT
- FLOW DIRECTION
- EXISTING PIPE
- POINT OF DISCHARGE
- LINE OF DISCHARGE
- INDICATIVE STORMWATER LINE (PIPE/GRATE)

CATCHMENT PARAMETERS

CATCH ID	A (EXT)	B (EXT)	A1	A2	B	B(BYPASS)
AREA (ha)	0.01	0.06	0.19	0.19	0.30	0.016
SLOPE (%)	23.3	7.3	2.8	2.8	2.2	50
IMPERVIOUS (%)	0	9	95	90	75	0
PD ID	PD (A1)	PD (B)	PD (A1)	PD (A)	PD (B)	PD (B)
PD TYPE	POINT	POINT & SHEET	POINT	POINT	POINT & SHEET	SHEET

DATE: 13.10.22

PROJECT No.: BC-21244

DRAWING No.: DWG-201

REVISION No.: C

PROJECT: PROPOSED RESIDENTIAL DEVELOPMENT

DRAWING TITLE: DEVELOPED CATCHMENT PLAN

CLIENT: PALM LAKE WORKS

ADDRESS: 55-61 HAMILTON & 17-19 WEINAM STREET REDLAND BAY

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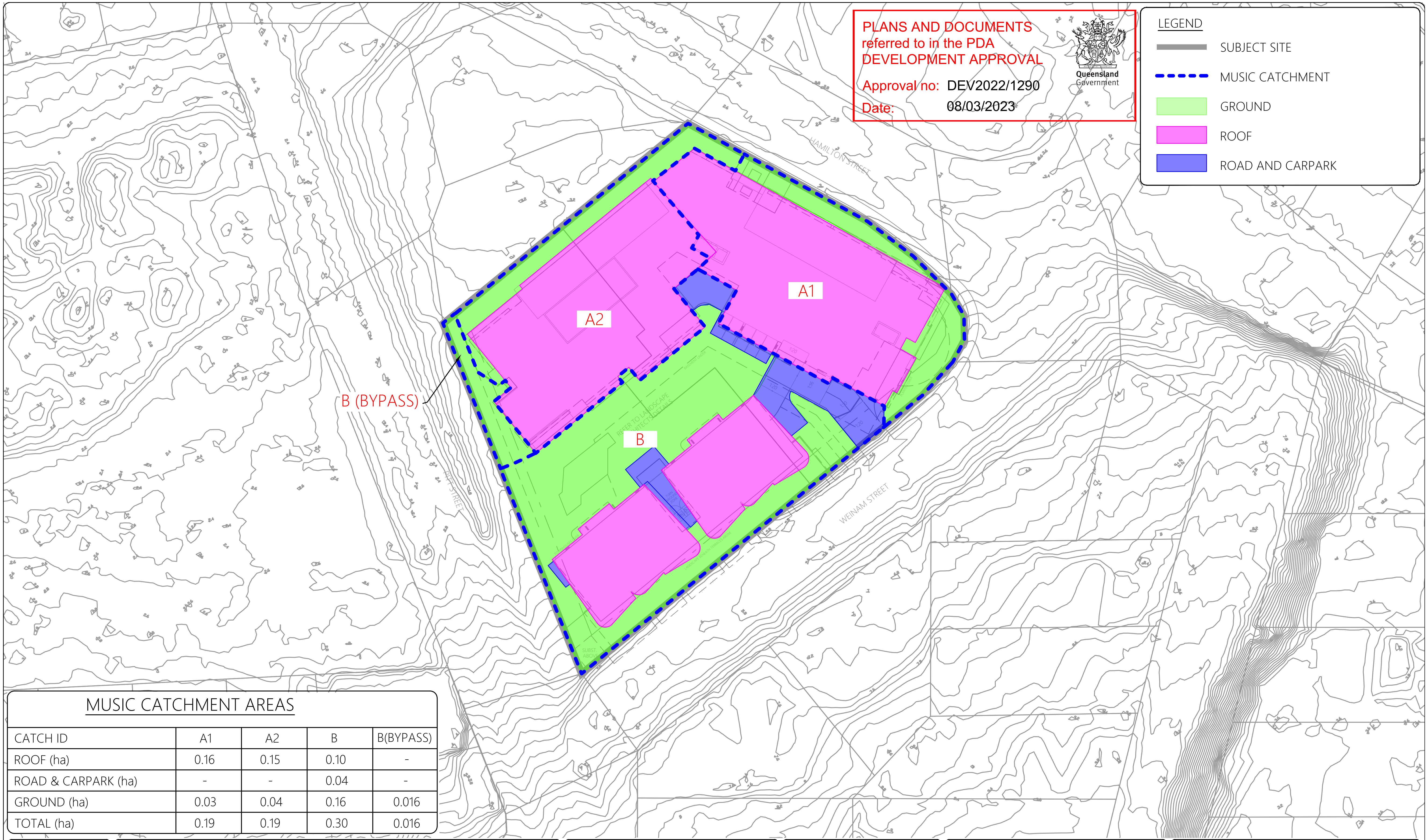

MUSIC CATCHMENT AREAS

CATCH ID	A1	A2	B	B(BYPASS)
ROOF (ha)	0.16	0.15	0.10	-
ROAD & CARPARK (ha)	-	-	0.04	-
GROUND (ha)	0.03	0.04	0.16	0.016
TOTAL (ha)	0.19	0.19	0.30	0.016

DATE
13.10.22

PROJECT No. :
BC-21244

DRAWING No. :
DWG-210

REVISION No. :
C

PROJECT
PROPOSED RESIDENTIAL DEVELOPMENT

DRAWING TITLE
MUSIC CATCHMENT PLAN

CLIENT
PALM LAKE WORKS

ADDRESS:
55-61 HAMILTON & 17-19 WEINAM STREET
REDLAND BAY

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1 : 500 (FULL SIZE) (metres)

CERTIFIED BY

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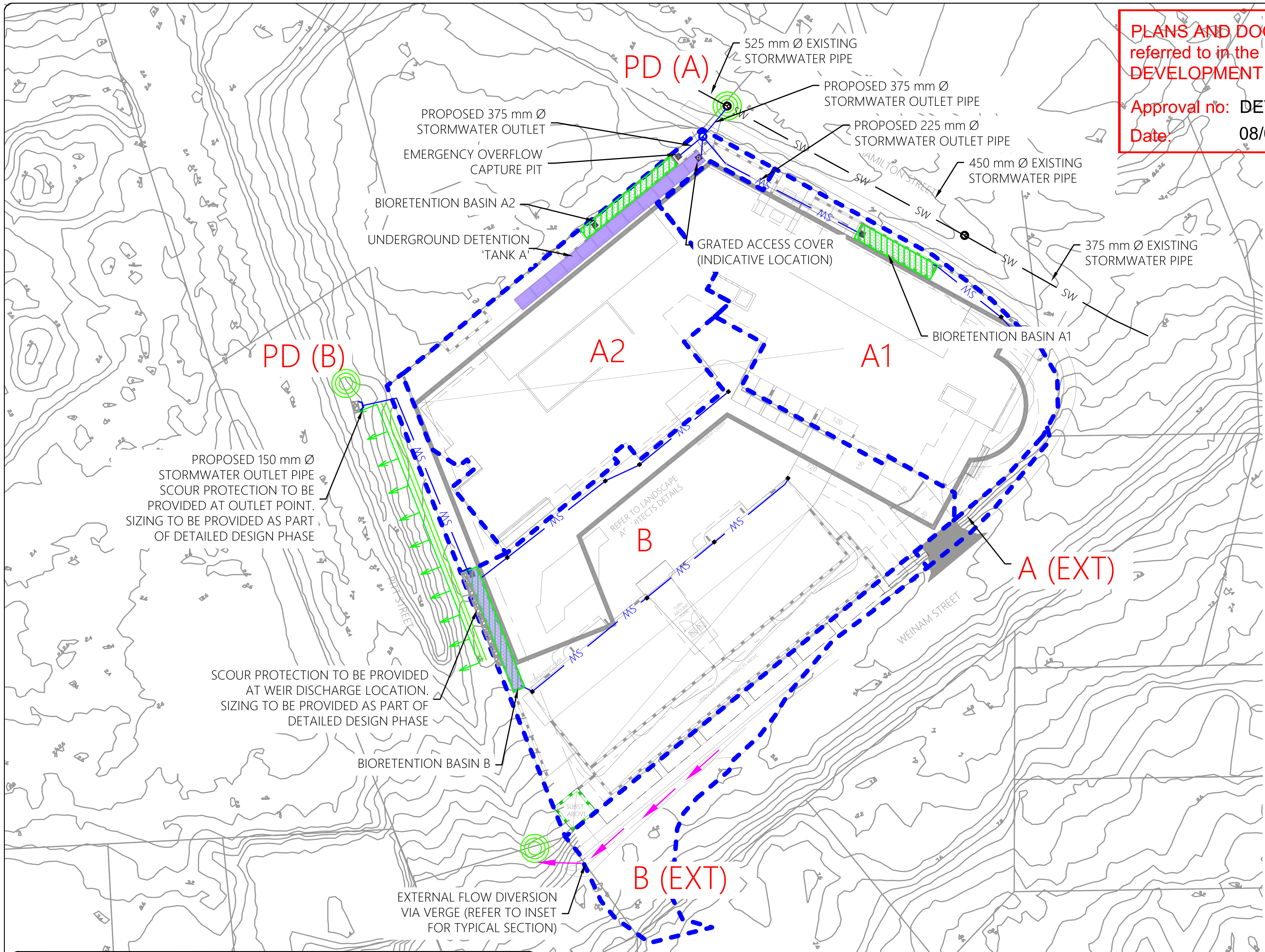

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Approval no: DEV2022/1290

Date: 08/03/2023

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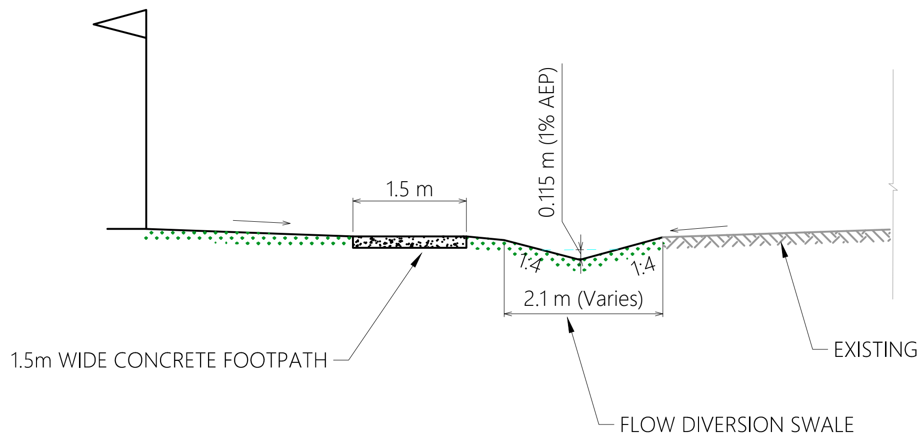
LEGEND

- SUBJECT SITE
- DEVELOPED CATCHMENT
- SW EXISTING PIPE
- SW PIPE DRAINAGE
- BIORETENTION SYSTEM
- ON-SITE DETENTION
- RAISED GARDEN
- WEIR
- PIT



EXTERNAL DIVERSION B(EXT) - TYPICAL

1 : 100 (FULL SIZE) (metres)

TANK & BASIN CHARACTERISTICS

MEASURE ID	TANK A	BASIN A1	BASIN A2	BASIN B
FILTER AREA (m^2)	N/A	35	34	37.5
DETENTION VOLUME (m^3)	70	N/A	3.6	6.4

DATE: 13.10.22

PROJECT No.: BC-21244

DRAWING No.: DWG-300

REVISION No.: C

PROJECT: PROPOSED RESIDENTIAL DEVELOPMENT

DRAWING TITLE: OPERATIONAL CONTROL PLAN

CLIENT: PALM LAKE WORKS

ADDRESS: 55-61 HAMILTON & 17-19 WEINAM STREET REDLAND BAY

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TP / KP	AK	BC	A3	1:750

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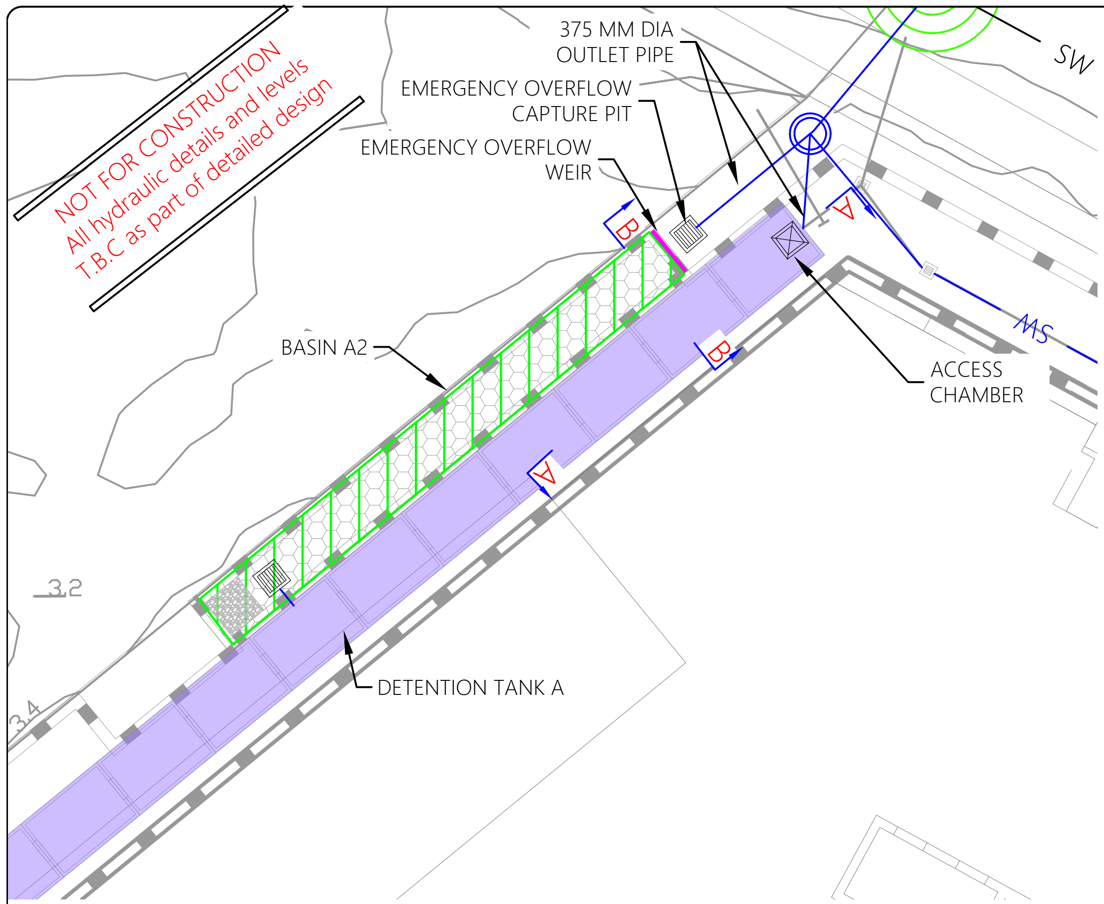

TANK A - PLAN LAYOUT

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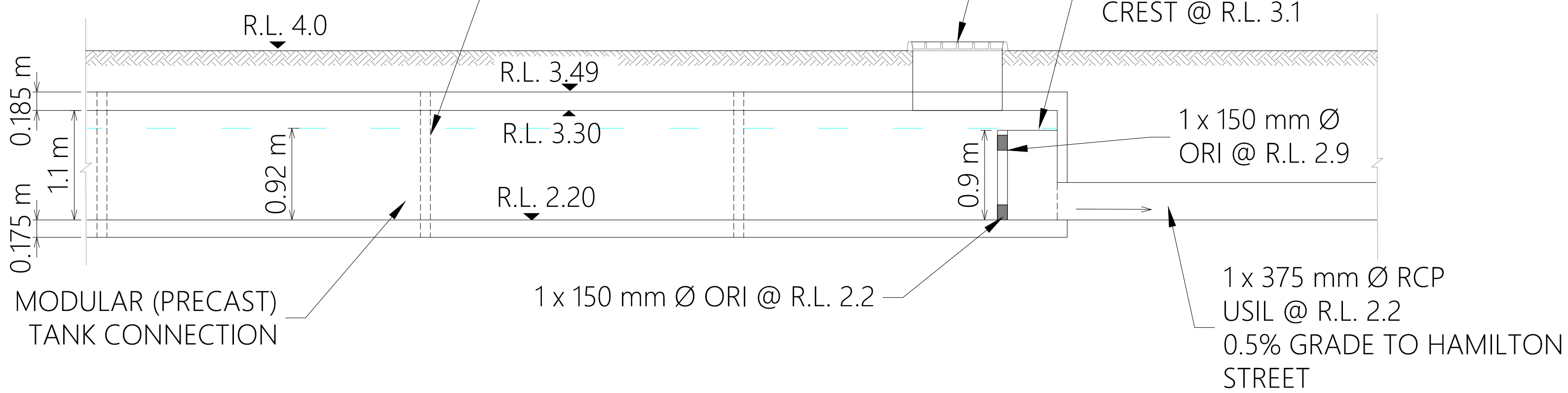

NOTE: ALL LEVELS RELATIVE & SUBJECT TO DETAILED DESIGN

SECTION A-A (TYPICAL)

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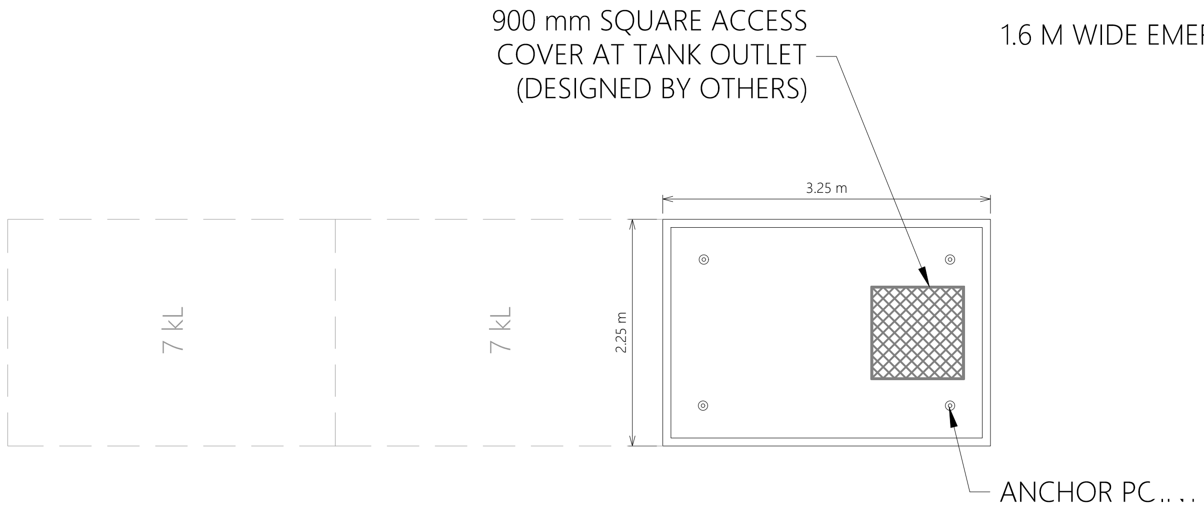
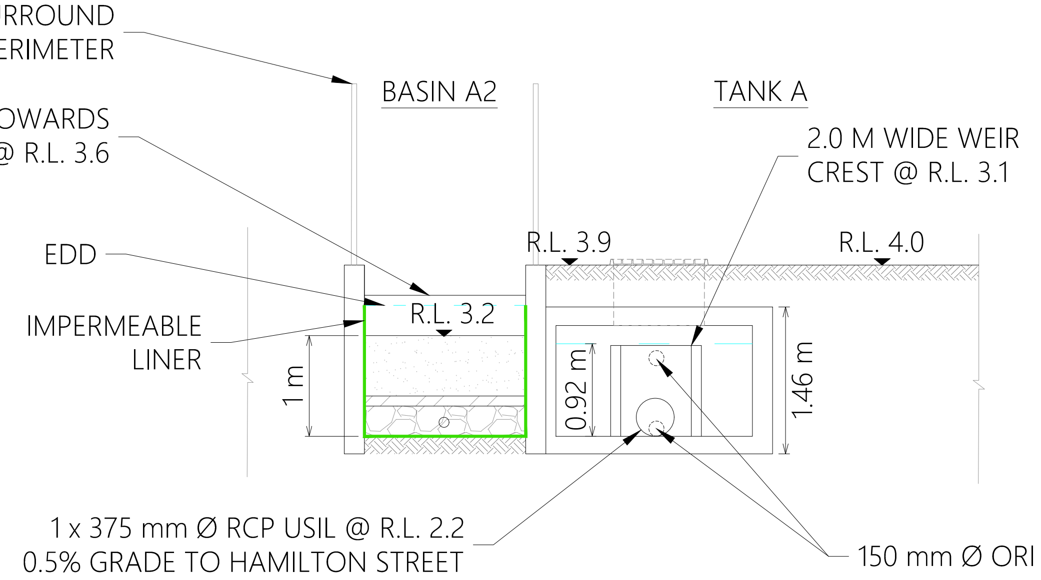


TYPICAL 7KL PRECAST TANK CONFIGURATION

1 : 75 (FULL SIZE) (metres)



NOTE: ALL LEVELS RELATIVE & SUBJECT TO DETAILED DESIGN

SECTION B-B (TYPICAL)

1 : 75 (FULL SIZE) (metres)

DATE	13.10.22
PROJECT No. :	BC-21244
DRAWING No. :	DWG-310
REVISION No. :	C

PROJECT: PROPOSED RESIDENTIAL DEVELOPMENT
DRAWING TITLE: UNDERGROUND DETENTION TANK A TYPICAL DETAILS
CLIENT: PALM LAKE WORKS
ADDRESS: 55-61 HAMILTON & 17-19 WEINAM STREET REDLAND BAY

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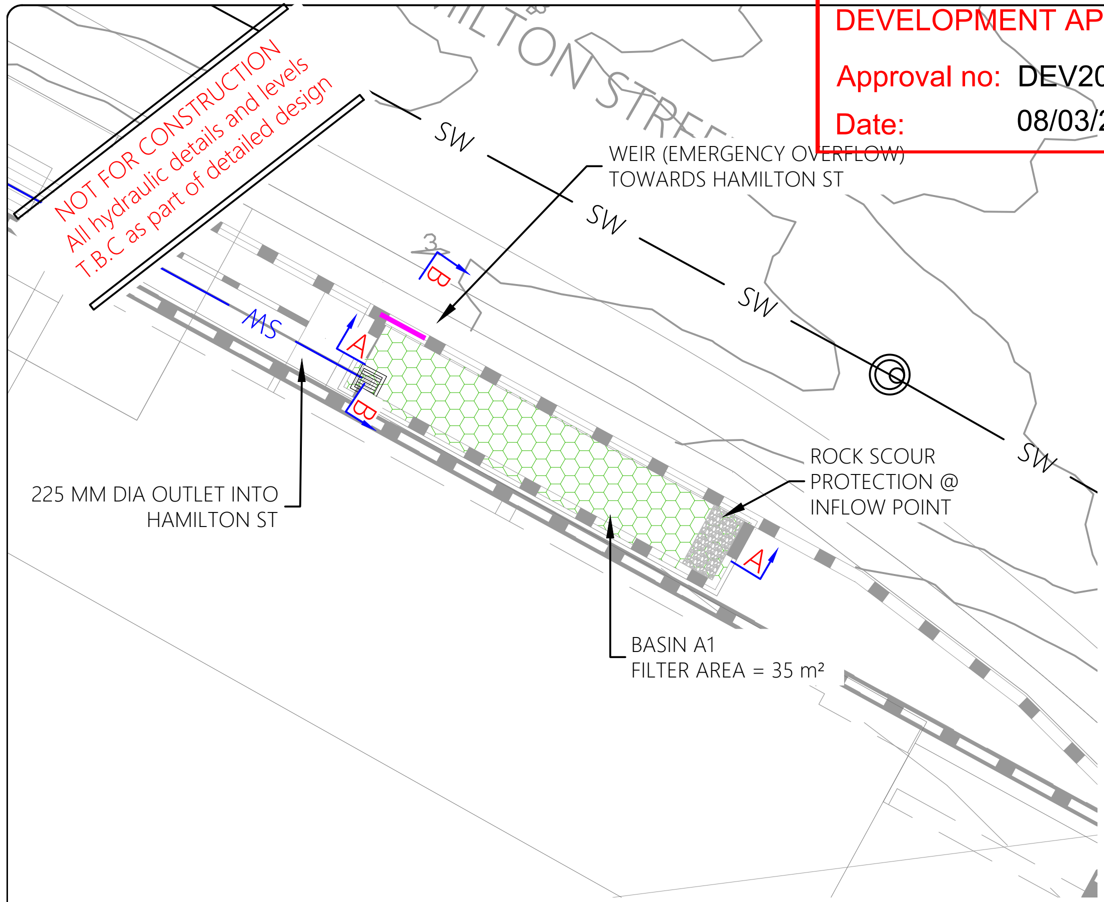
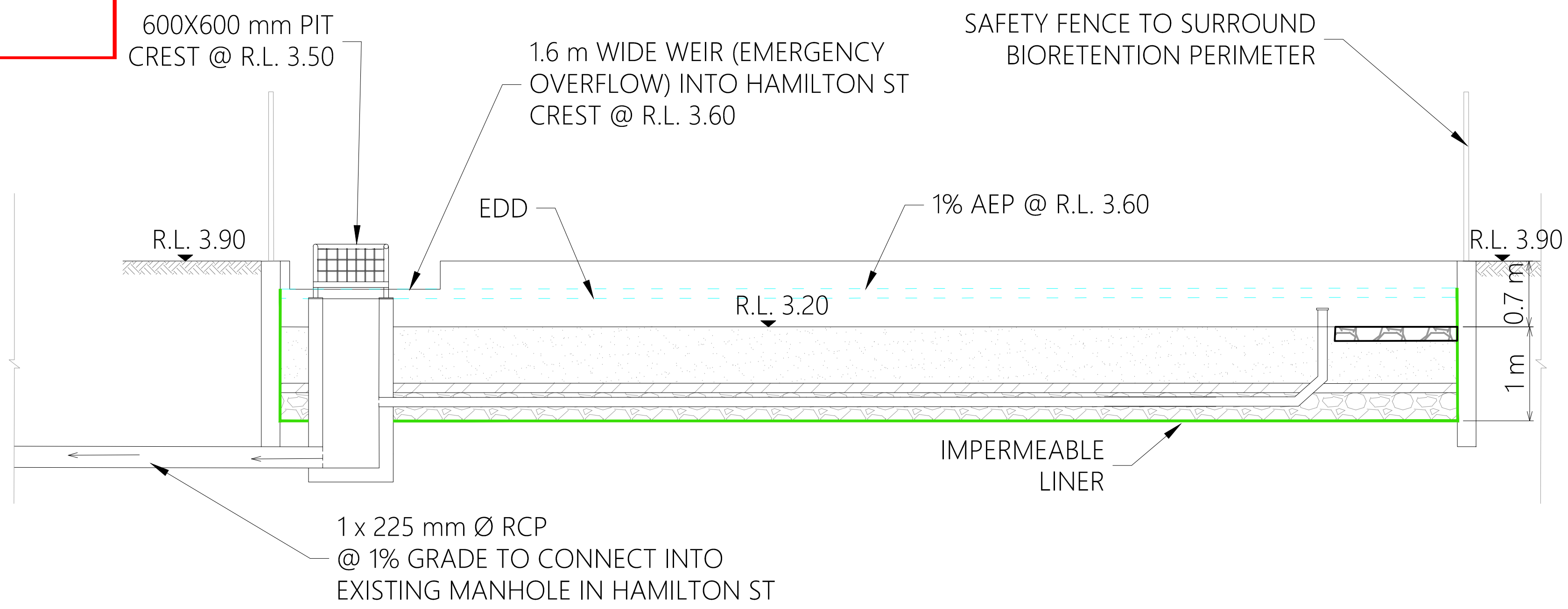


BASIN A1 - PLAN LAYOUT

1 : 250 (FULL SIZE) (metres)



SECTION A-A (TYPICAL)

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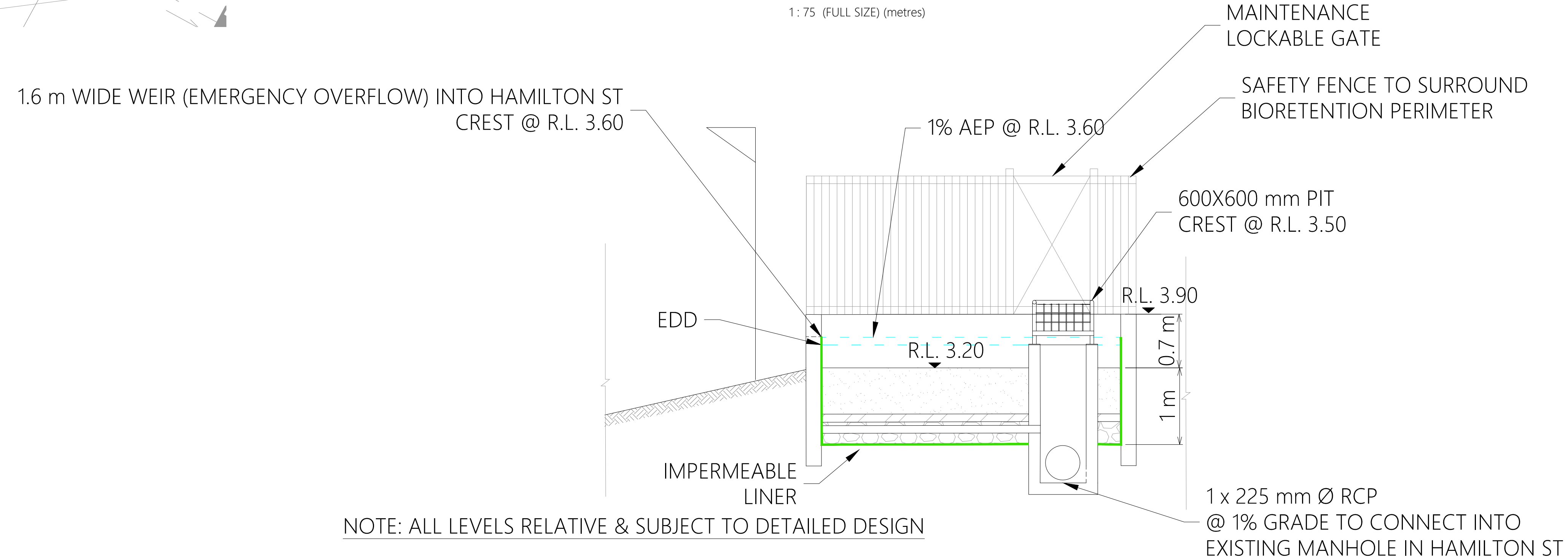

NOTE: ALL LEVELS RELATIVE & SUBJECT TO DETAILED DESIGN

SECTION B-B (TYPICAL)

1 : 75 (FULL SIZE) (metres)

DATE: 13.10.22
PROJECT No.: BC-21244
DRAWING No.: DWG-311
REVISION No.: C

PROJECT: PROPOSED RESIDENTIAL DEVELOPMENT
DRAWING TITLE: BASIN A1 TYPICAL LAYOUT & SECTIONS
CLIENT: PALM LAKE WORKS
ADDRESS: 55-61 HAMILTON & 17-19 WEINAM STREET
REDLAND BAY

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TP / KP	AK	BC	A3	AS SHOWN

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ABN 86 166 087 476

ORIGINAL SCALE BEFORE REDUCTION
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CERTIFIED BY
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DEVELOPMENT APPROVAL

Approval no: DEV2022/1290
Date: 08/03/2023

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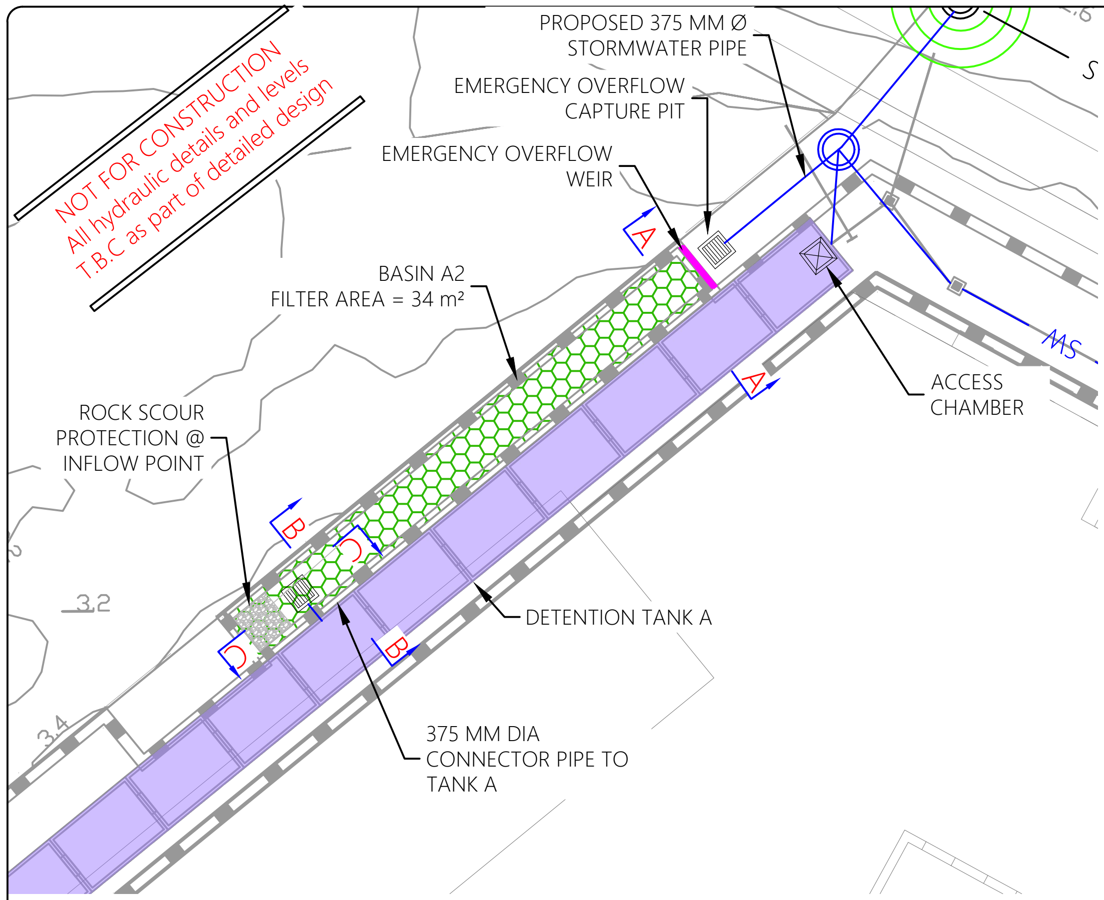

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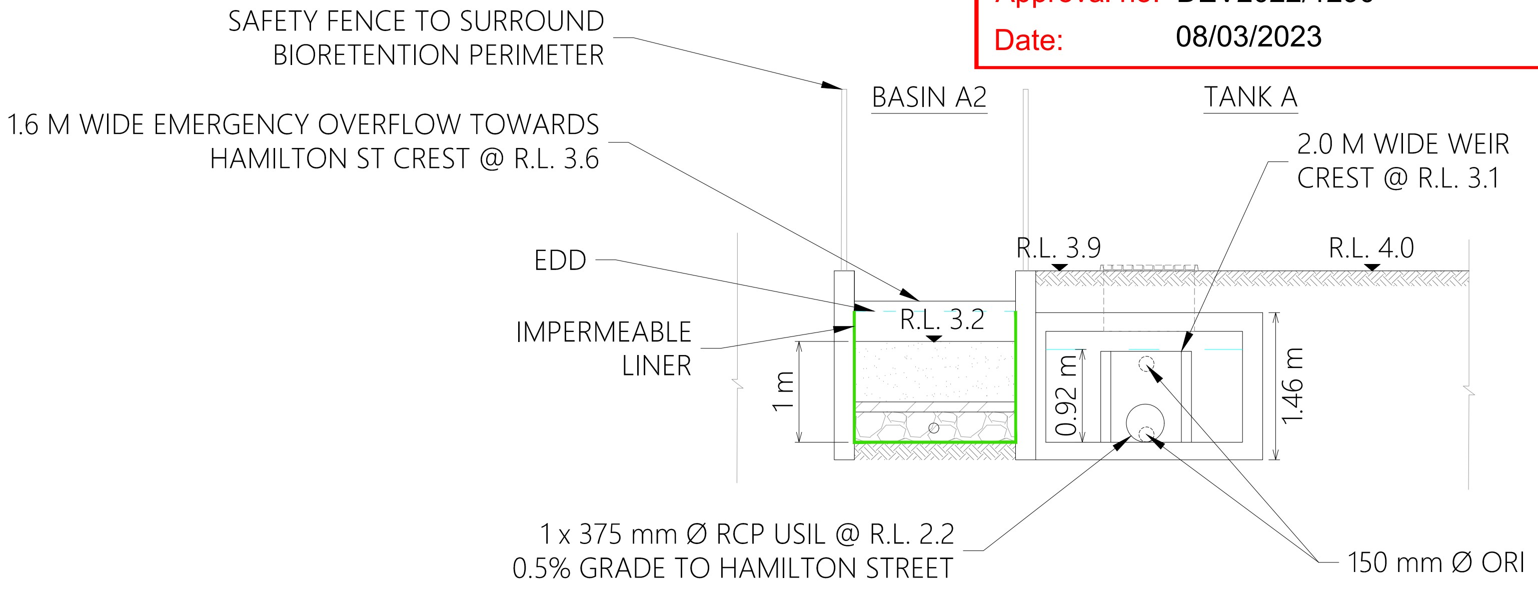

NOTE: ALL LEVELS RELATIVE & SUBJECT TO DETAILED DESIGN

SECTION A-A (TYPICAL)

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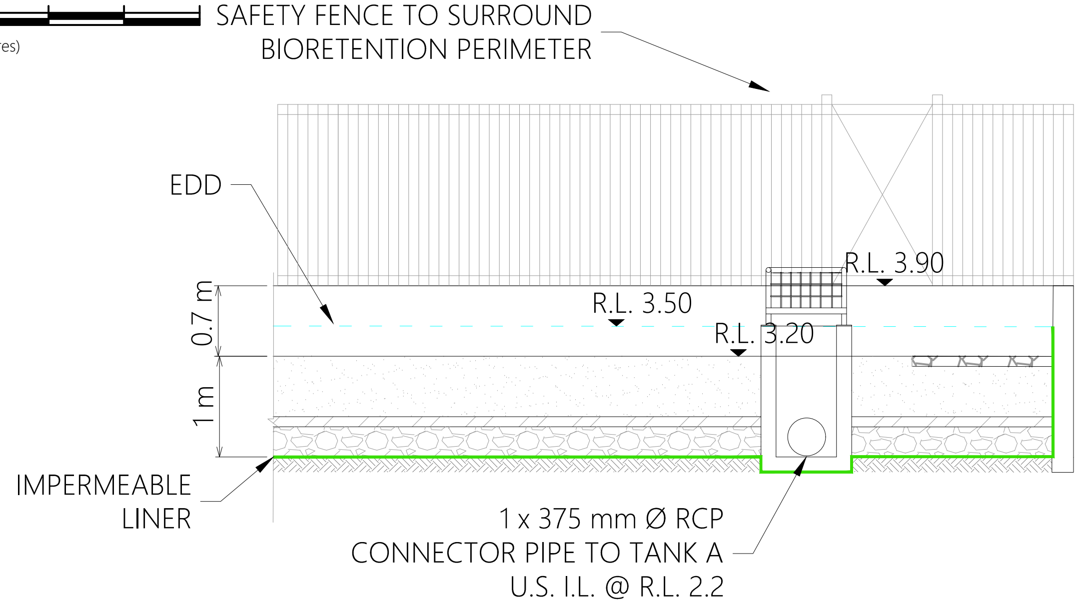
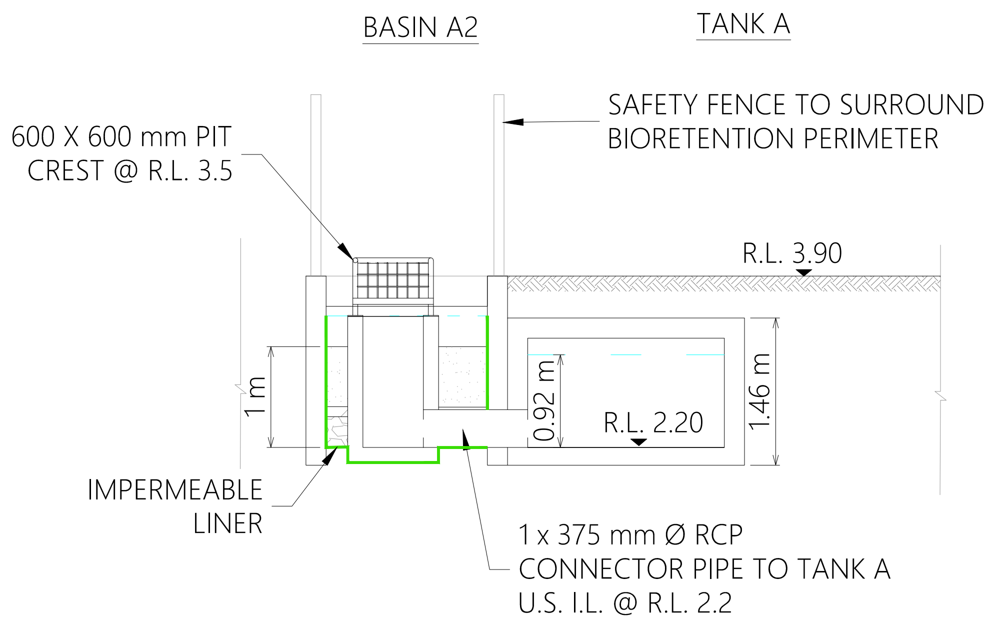


SECTION C-C (TYPICAL)

1 : 75 (FULL SIZE) (metres)



SECTION B-B (TYPICAL)

1 : 75 (FULL SIZE) (metres)

DATE: 13.10.22
PROJECT No.: BC-21244
DRAWING No.: DWG-312
REVISION No.: C

PROJECT: PROPOSED RESIDENTIAL DEVELOPMENT
DRAWING TITLE: BASIN A2 TYPICAL LAYOUT & SECTIONS
CLIENT: PALM LAKE WORKS
ADDRESS: 55-61 HAMILTON & 17-19 WEINAM STREET REDLAND BAY

DRAFTED BY:	DESIGNED BY:	CHECKED BY:	PAPER SIZE:	SCALE:
TP / KP	AK	BC	A3	AS SHOWN

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ORIGINAL SCALE BEFORE REDUCTION
1 : 250 (FULL SIZE) (metres)
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PLANS AND DOCUMENTS referred to in the PDA DEVELOPMENT APPROVAL

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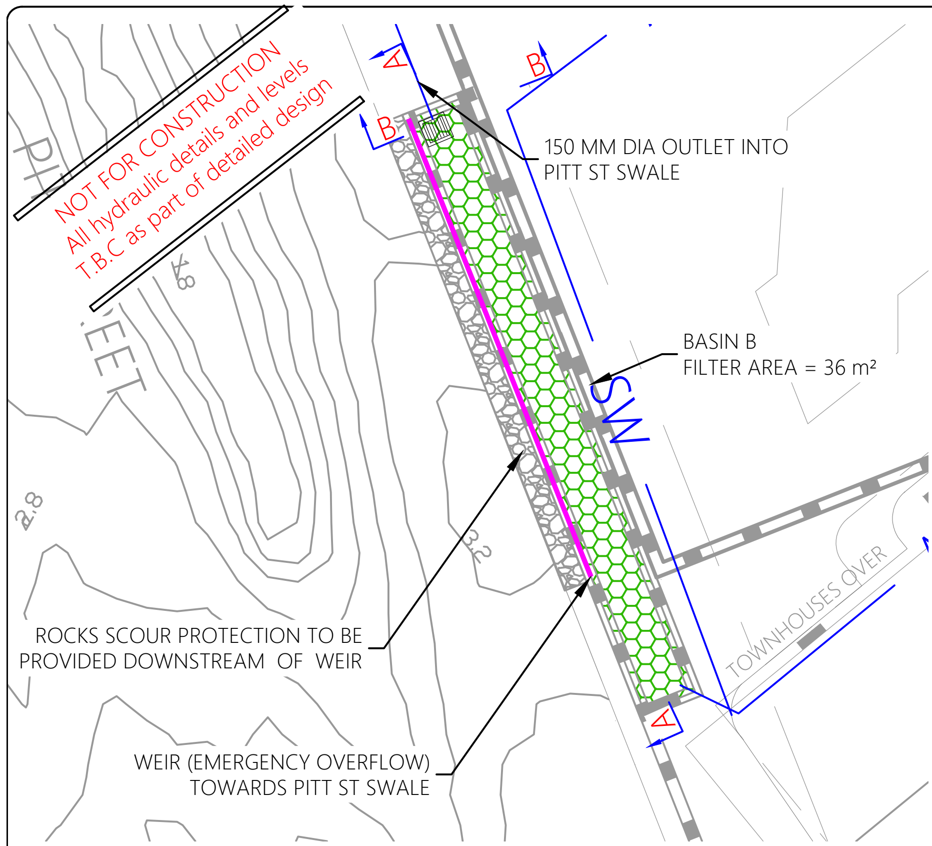
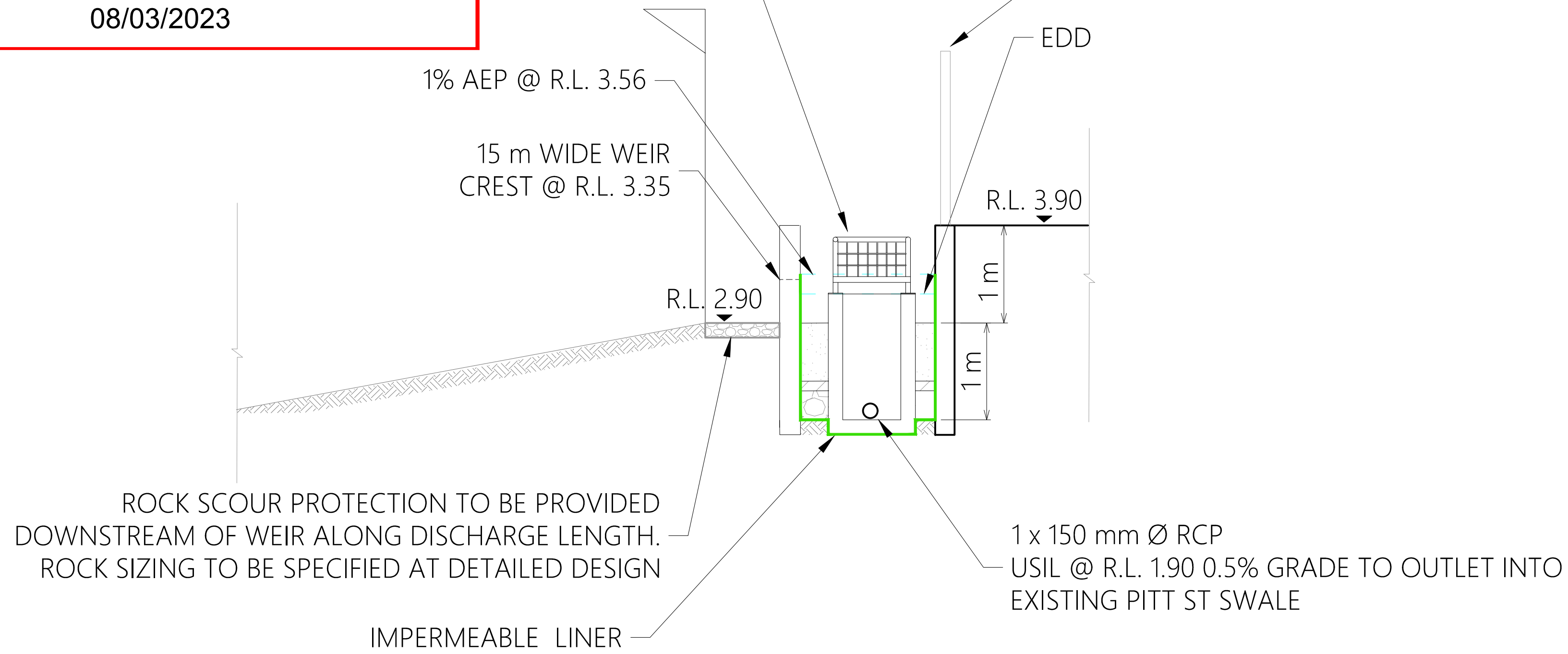
Approval no: DEV2022/1290

Date: 08/03/2023



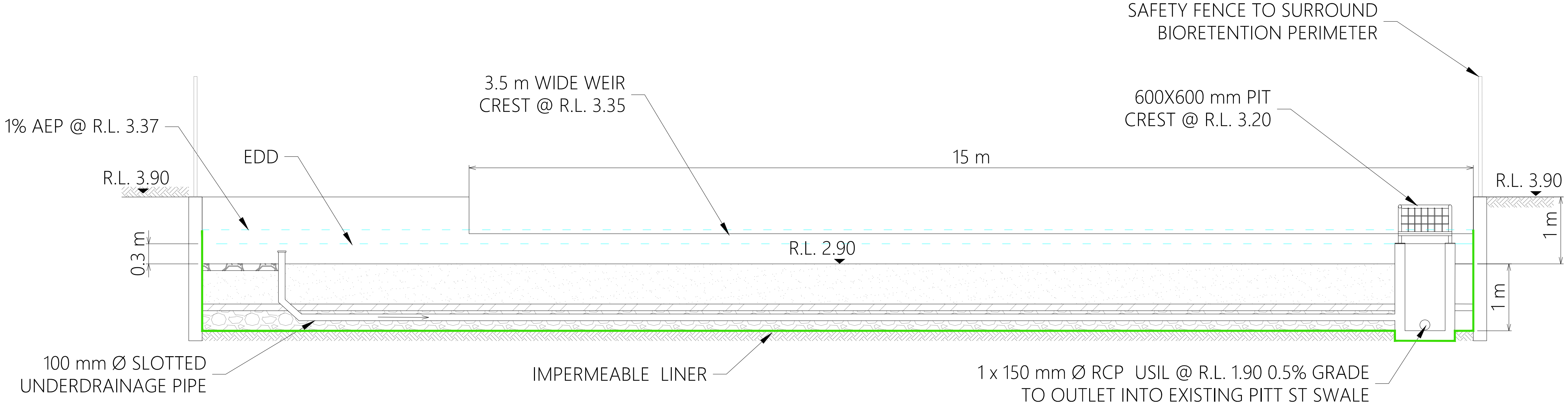
BASIN B - PLAN LAYOUT

1 : 250 (FULL SIZE) (metres)



SECTION B-B (TYPICAL)

1 : 75 (FULL SIZE) (metres)



SECTION A-A (TYPICAL)

1 : 75 (FULL SIZE) (metres)

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DRAWING TITLE: BASIN B TYPICAL LAYOUT & SECTIONS

CLIENT: PALM LAKE WORKS

ADDRESS: 55-61 HAMILTON & 17-19 WEINAM STREET REDLAND BAY

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ORIGINAL SCALE BEFORE REDUCTION

1 : 250 (FULL SIZE) (metres)

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NOT FOR CONSTRUCTION
All hydraulic details and levels
T.B.C as part of detailed design

PLANS AND DOCUMENTS
referred to in the PDA
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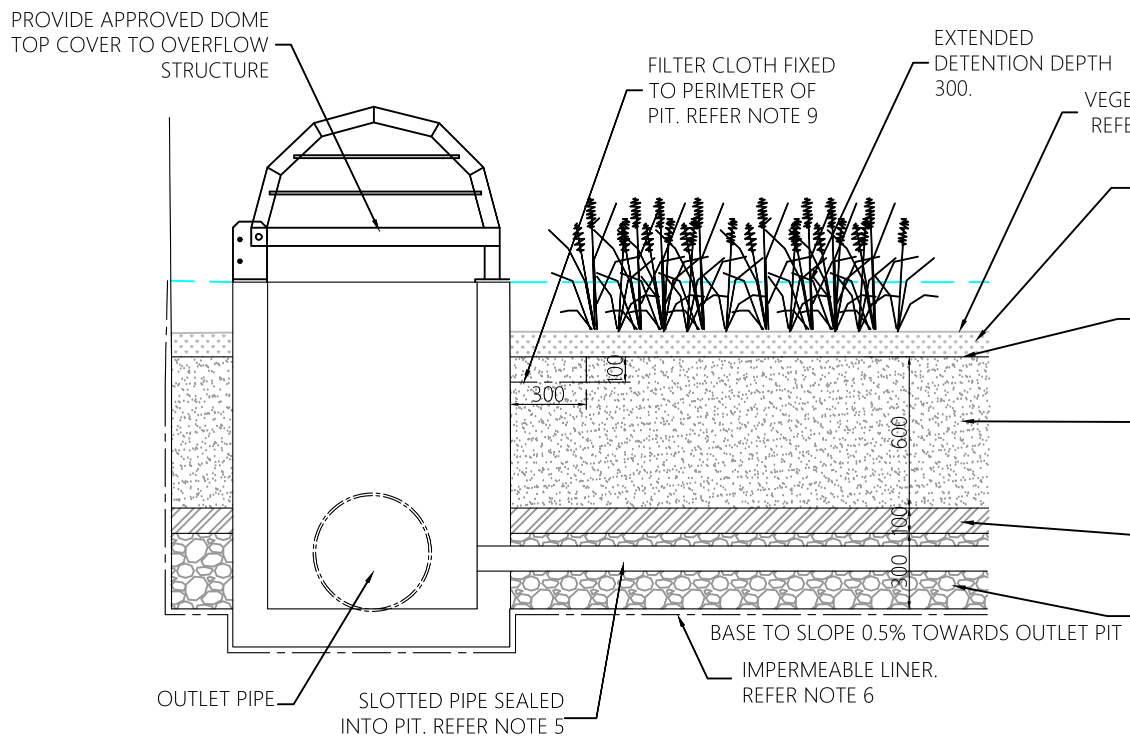
Approval no: DEV2022/1290

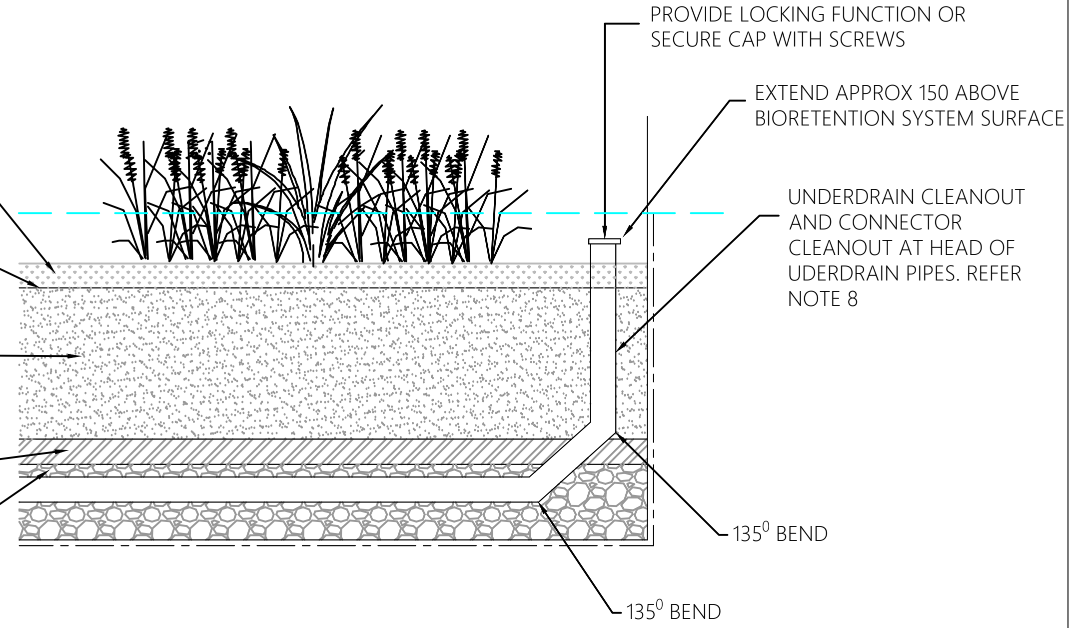
Date: 08/03/2023

Queensland Government



BIORETENTION MEDIA (TYPE 3-CONVENTIONAL) CROSS SECTION

N.T.S



BIORETENTION BASIN SUBSOIL DRAIN CLEANOUT (TYPE 3-CONVENTIONAL)

N.T.S

NOTES (IN ACCORDANCE WITH IPWEAQ STANDARD DRAWINGS DS-070 AND DS-073):

1. BIORETENTION SYSTEM SURFACE. SURFACE LEVEL IS TOP OF FILTER MEDIA. SURFACE TO BE MULCHED AND PLANTED AS PER THE 'BIORETENTION TECHNICAL DESIGN GUIDELINES' (WATER BY DESIGN).
2. FILTER MEDIA SPECIFICATION SHALL BE IN ACCORDANCE WITH THE 'ADOPTION GUIDELINES FOR STORMWATER BIOFILTRATION SYSTEMS (CRC FOR WATER SENSITIVE CITIES) AND THE BIORETENTION TECHNICAL DESIGN GUIDELINES (WATER BY DESIGN). BIORETENTION HYDRAULIC CONDUCTIVITY SHALL BE IN ACCORDANCE WITH PRACTICE NOTE 1: IN SITU MEASUREMENT OF HYDRAULIC CONDUCTIVITY' (FAWB). THE NUMBER OF SAMPLES TO BE TESTED SHALL BE IN ACCORDANCE WITH THE 'CONSTRUCTION AND ESTABLISHMENT GUIDELINES - SWALES, BIORETENTION SYSTEMS AND WETLANDS' (WATER BY DESIGN).
3. CONSTRUCTION TOLERANCES SHALL BE IN ACCORDANCE WITH THE 'CONSTRUCTION AND ESTABLISHMENT GUIDELINES -SWALES, BIORETENTION SYSTEMS AND WETLANDS' (WATER BY DESIGN)
4. TRANSITION LAYER AND DRAINAGE LAYER. DEPTHS AND SPECIFICATION TO BE IN ACCORDANCE WITH THE 'BIORETENTION TECHNICAL DESIGN GUIDELINES' (WATER BY DESIGN)
5. UNDERDRAIN. SLOTTED RIGID PIPE LAID FLAT. PIPE SHOULD NOT BE INSTALLED WITH A FILTER SOCK SURROUNDING PIPE. UNDERDRAIN PIPES SHALL BE SEALED INTO PITS USING GROUT OR OTHER APPROVED WATERTIGHT SEAL.
6. IMPERMEABLE LINER. IMPERMEABLE LINER AS PER "BIORETENTION TECHNICAL DESIGN GUIDELINES" (WATER BY DESIGN).
7. VEGETATED BATTER. SLOPE AND PLANTING TO BE IN ACCORDANCE WITH 'BIORETENTION TECHNICAL DESIGN GUIDELINES' (WATER BY DESIGN).
8. INSPECTION/CLEANOUT POINT. VERTICAL SOLID PIPE SECTION ATTACHED TO THE END OF EACH UNDERDRAIN IN ACCORDANCE WITH THE 'BIORETENTION TECHNICAL DESIGN GUIDELINES'(WATER BY DESIGN)
9. FILTER CLOTH TO BE FIXED TO PERIMETER OF PIT TO AVOID RUNNELLING OF WATER BETWEEN PIT AND SOIL INTERFACE. BEGIN FILTER CLOTH 100 ABOVE SURFACE. EXTEND TO 100 BELOW SURFACE. CONTINUE 300 HORIZONTALLY INTO FILTER MEDIA.
10. FOR GENERAL DESIGN AND CONSTRUCTION NOTES REFER TO DS-078
11. ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE NOTED.

DATE
13.10.22

PROJECT No. :
BC-21244

DRAWING No. :
DWG-340

REVISION No. :
C

PROJECT
PROPOSED RESIDENTIAL DEVELOPMENT

DRAWING TITLE
BIORETENTION – FILTER MEDIUM & UNDERDRAINAGE DETAILS

CLIENT
PALM LAKE WORKS

ADDRESS:
55-61 HAMILTON & 17-19 WEINAM STREET
REDLAND BAY

DRAFTED BY :	DESIGNED BY :	CHECKED BY:	PAPER SIZE :	SCALE :
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Queensland Government

BIORETENTION SYSTEM SPECIFICATION

1. Referenced documents.
The following documents are incorporated into this specification by reference:
1.1. Standards
1.1.1. AS 1289- Methods of Testing Soils for Engineering Purposes
1.1.2. AS 1289.5.4.1-2007- Soil Compaction and Density Tests-Compaction Control Test-Dry Density Ratio, Moisture Variation and Moisture Ratio
1.1.3. AS 1289.5.7.1-2006 - Soil Compaction and Density Tests - Compaction control Test-Hilf Density Ratio and Hilf Moisture Variation (rapid method)
1.1.4. AS 2758 - Aggregates and Rock for Engineering Purposes
1.1.5. AS 4419 - Soils for Landscaping and Garden Use
1.1.6. AS 4454 - Composts, Soil Conditioners and Mulches
1.2. Other publications
1.2.1. Guidelines for Soil Filter Media in Bioretention Systems (FAWB) - the current version of the guideline can be found at http://www.Monash.edu.au/FAWB/
1.2.2. Construction and Establishment Guidelines - Swales, Bioretention systems and Wetlands (Water by Design) http://waterbydesign.com.au/ceguide/
1.2.3. Transferring Ownership of Vegetated Stormwater Assets (Water by Design) http://waterbydesign.com.au/transferguide/
1.2.4. Transferring Ownership of Vegetated Stormwater Assets (Water by Design) http://waterbydesign.com.au/transferguide/
1.2.5. Bioretention Technical Design Guidelines (Water by Design) http://waterbydesign.com.au/techguide/
1.2.6. Water Sensitive Urban Design Field Guide (Water by Design)

2. Abbreviations and definitions
2.1. The bioretention system specification consists of the following abbreviations and definitions:
2.2. Filter soil layer which acts as a pollutant filter and supports plant growth.
2.3. Impermeable liners: the liner that prevents water movement between the filter and the surrounding soils and defines the edge of the system.
2.4. Transition layer: layer to separate filter layer from the drainage layer to avoid migration of soils from the filter to the drainage layer
2.5. Drainage layer relatively free d raining layer to convey infiltrated water to the underdrainage.
2.6. Under-drains: slotted drains collect treated stormwater from the drainage layer at the base of the bioretention system.

3. Test methods and standards
3.1. The following test methods and standards are to be used as specified in the above guidelines when conducting tests associated with this specification:
3.2. The hydraulic conductivity of potential filter media shall be measured using the ASTM F1815-11 method
3.3. Particle size distribution: AS1289.3.6.1 - 1995
3.4. Soils for landscaping and garden use: AS4419 - 2003.

4. Materials
4.1. Materials shall meet the required specifications detailed in Section 8 Filter media, Section 9 Transition layer, Section 10 Drainage layer, Section 11 Under drainage. Section 12 Permeable liner. Section 13 Impermeable liner end section 14 landscaping of this document.
4.2. All materials must be certified by the supplier with certification and delivery supply dockets shall be provided on request to certify the material delivered is the material tested.

5 Timing and erosion and sediment control
5.1. The timing of civil and landscape works for bioretention systems must be carefully planned to ensure that both the bioretention system and the downstream waterways, are not impacted by stormwater and sediment (e.g. through best practice erosion and sediment control). In particular, the drainage layer, transition layer and filter media must not be placed until the risk of high sediment loading from upstream construction activities has been mitigated. The construction sequence must be approved by the superintendent
5.2. Erosion and sediment control during construction must be delivered in accordance with all legislative requirements including, where required, the preparation of site-specific ESC plan/s in accordance with current Best Practice Erosion and Sediment Control (e.g. IECA 2008, or later version).

6. Earthworks and hydraulic structures
6.1. The construction of hydraulic structures must ensure the design levels are achieved. Bunds/ embankments surrounding the system shall be at correct levels. The below table summarises the construction tolerances for each element of a typical bioretention system.
6.2. Bioretention systems tolerances

Bioretention element	Tolerance (unless specified otherwise)
Hydraulic structures	+/-25 mm (+/-15 mm for streetscape systems)
Earthworks	+ / - 50 mm
Underdrainage	+/-25 mm
Drainage and transition layers	+ 25 mm
Surface level	+/- 25mm +/- 40mm for filter media >300m² provided the average extended detention requirement is within 25mm of the design requirement.
Embankments and bunds	- 25 mm, + 50 mm

7. Maintenance access.
Maintenance access is provided in accordance with the design drawings.

8. Filter media
8.1. Materials
A fundamental part of bioretention systems is the filter media. The main role of the filter media is to support vegetation and remove pollutants. Filter media should be loamy sand that has high permeability when compacted. It should not contain any rubbish or deleterious material. The loamy sand should contain some organic matter to improve water-holding capacity and plant health, but it should be low in nutrient content. The filter media must be compliant with AS 4419 - Soils for Landscaping and Garden Use, and meet the following requirements:

Parameter	Test method in accordance with	Requirement
Saturated hydraulic conductivity	ASTM f1815 -11	50 - 500 mm/hr (200 preferred)
pH	AS 4419	5.5 - 7.5
Electrical conductivity	AS 4419	<1,2 dS/m
Nitrogen content	AS 4419	<800 mg/kg
Phosphorus content	AS 4419	<40 mg/kg
Organic content	AS 4419	3%-10%. Where organic content Is below this threshold, the filter media may be ameliorated by adding 50mm of compost and tining it into the top 150mm of filter media.
Particle size distribution	AS 1289.3.6.1 - 1995	Clay & silt 3-6% (<0.05mm) Very fine sand 5-30% (0.05-0.15mm) Fine sand 10-30% (0.15-0,25mm) Medium to coarse sand 40-60% (0.25 -1.0mm) Coarse sand 7-10% (1.0-2.0mm) Fine gravel <3% (2.0-3.4%)

Source: Guidelines for Soil Filter Media in Bioretention Systems (FAWB) and Bioretention Technical DEsign Guidelines (Water by Design)
Filter media must be free of weeds and propagates. Other characteristics of the filter media required for plant growth should be confirmed with a soil analysis or confirmed with a horticulturist/landscape architect.
8.2. Testing frequency
Suitable filter media can be delivered to site or imported sand can be ameliorated to meet the above specification. In either case, the media shall be tested against the above parameters at one sample per 500m³ of filter media. For soil supplied to site, testing must be undertaken on the actual material to be delivered to the bioretention system. The supplier and contractor will be responsible for ensuring the filter media meets the specification and the correct material is delivered to site prior to installation.
8.3. Installation and compaction
When installing, the following specifications shall be applied:
8.3.1. Filter media shall be installed and compacted in two lifts for depths of over 500mm. Compaction shall be light and even across the surface.
8.3.2. The top surface of the drainage layer, transition layer and the filter media layer shall be level and free from localised depressions to ensure even distribution of stormwater flows across the surface and prevent localised ponding.
8.3.3. Filter fabric must not be used between drainage layer, transition layer and the filter media layers or wrapped around the under-drainage

9. Transition layer
9.1. Transition layers prevent filter media migrating into the drainage layer.
9.1.1. Materials
9.1.1.1. Transition layer shall be minimum thickness of 100 mm coarse sand unless otherwise specified (typically 1mm particle size diameter) with <2% fines.
9.1.1.2. A particle size distribution for the sand shall be obtained to ensure that it meets the following criteria (VicRoads).
9.1.1.3. D15 (transition layer) =< 5x D85 (filter media)
9.2 Testing
A sample of the proposed transition layer is to be provided to the superintendent for approval prior to installation. The superintendent may require the transition layer to be tested to ensure its particle size.

10. Drainage layer
Drainage layers convey infiltrated water into the slotted under-drainage pipes.
10.1. Materials
10.1.1. Drainage layer shall be comprised of fine gravel (nominal 2-5mm) with <2% fines and a minimum saturated hydraulic conductivity of 400mm/hr. The depth of the drainage layer shall ensure at least 50mm of aggregate cover over all perforated under-drainage pipes.
10.1.2. A particle size distribution for the gravel shall be obtained to ensure that it meets the following bridging criteria (VicRoads): D15 (drainage layer) =< 5xD85 (transition layer)
10.2. Testing
A sample of the proposed drainage layer is to be provided to the superintendent for approval prior to installation. The superintendent may require the drainage layer to be tested to ensure its particle size.

11. Under-drainage
11.1. Materials
Either slotted rigid pipe (HDPE or similar) or ag-pipe can be used for under-drainage as specified in the construction drawings. When installing, the following specifications shall be considered:
11.1.1. Typically 100mm-slotted hdpe pipe is the preferred type of rigid pipe.
11.1.2. The slots in the pipe shall not allow the drainage layer aggregate to freely enter the pipe (under-drainage with slot width of 2mm or smaller is preferred).
11.1.3. Under-drainage pipes must not be surrounded by any geofabric or sock.
11.2. Installation
11.2.1. The maximum spacing of under-drains for blo-retentlon systems <100m² is 1.5m from centre to centre. For bioretention systems >100 m² the maximum spacing can be increased to 2.0-2.5m if specified in the construction drawings.
11.2.2. The under-drains shall be sloped towards the outlet pit (min. 0.5% longitudinal grade) and the base of filtration trench shall be free from localised depressions. For bioretention systems with a saturated zone a 0% pipe grade is acceptable.
11.2.3. All junctions and connections shall be appropriately sealed.
11.2.4. Under-drainage pipes shall be sealed into the overflow pit
11.2.5. All under drainage pipes to have raised dean out points constructed from non-slotted pipes which extend to 150mm above filter media surface

12. Permeable liner (where specified)
12.1. A permeable geotextile liner fabric must be used to line the outside of the bioretention system.
12.2. The liner must extend at least 500mm beyond the top of the sides and must be keyed into batter and covered by at least 200mm of topsoil.
12.3. The liner must be resistant to all soil acids and alkalis, resistant to microorganisms and comply with the requirements of AS 3706.12 and AS 3706.13.

13. Impermeable liner (where specified)
13.1. Materials
Liner options include day, geosynthetic bentonite day liners or high-density poly ethylene (HDPE) liners. Refer to the project drawings for liner details.
13.2. Installation
Installation must be in accordance with manufacturers specifications and design drawings and achieve the following:
13.2.1. The liners shall be keyed into the batters and to the embankments.
13.2.2. Liners must be sealed around protrusions such as outlet pipes.
13.2.3. Must achieve a maximum permeability of 1 x10^{-9}m/s

14. Landscaping
14.0. Refer to landscape design drawings.
14.1. Batter slopes must have min 200mm topsoil which must be tested by a NATA-accredited laboratory in accordance with AS 4419.
14.2. Subsoils to be cultivated to 150mm prior to placing topsoil on batter slopes.
14.3. Planting densities and species must be consistent with the landscape design drawings. No substitutions should be made unless approved by the superintendent.
14.4. Plants supplied to site must:
14.4.1. Be grown in clean, weed-and pest-free conditions;
14.4.2. Be well developed, sun-hardened and contain a fully established root ball that does not crumble when removed from its container.
14.4.3. Be at least 200mm high
14.4.4. Show no sign of pest and disease
14.4.5. Show no signs of nutrient deficiency
14.4.6. Be free from weeds
14.4.7. Be clearly labelled
14.4.8. Be supplied in a container that is at least 90mm high x 50mm wide
14.5. Preparing filter media: unless specified otherwise, each plant must receive at least 10 g of slow-release native fertilizer in granular or tablet form. Pre-hydrated water crystals may be applied at 1-2% by weight
14.6. Mulch must be applied in accordance with the design drawings, be applied prior to planting, provide coverage of the soil and not exceed 75mm thickness, and be kept 50 mm dear of plant stems. Unless otherwise specified, mulch should be fine sugar cane mulch secured in place by a loose weave jute net pinned at 500mm centres.
14.7. Filter media surface and plant stock are to be watered immediately prior to planting. Unless otherwise specified, plants should be planted in clumps of the same species, and large monocultures avoided.
14.8. Plant method must minimise soil compaction and ensure that all roots are covered by at least 10-20mm of soil, avoid covering plant crowns.
14.9. Unless specified otherwise, the following irrigation schedule applies during plant establishment (at 2.5 - 5L per plant per week)
- Week 1 -5 five waterings per week
- Week 6-10 three waterings per week
- Week 11-15 two waterings per week
- Thereafter as required to sustain plants until successful establishment
14.10. Replanting must occur during the establishment period if less than 90% of plants survive.
14.11. Successful plant establishment in bioretention systems is considered when the plants are robust and self-sustaining, and meet the following criteria.
- Vegetation must cover at least 90% of the bioretention surface with mulch covering the remainder (< 10% mulch visible from above)
- Average groundcover plant height must be greater than 500mm.
- Plants must be healthy and free from disease.
- No weeds or litter to be present.

15. Certification and chain of custody
15.1. The following certification and the chain of custody applies to bioretention media:
15.1.1. The supplier and contractor are responsible for ensuring the bioretention media meets the specifications outlined in these guidelines and that the correct material is delivered to site. The supplier must arrange for testing of the filter media by a soil laboratory certified for the methods in accordance with the requirements listed above. On the basis of the testing, the soil laboratory and supplier must certify the material meets these specifications. The supplier must provide the certification and laboratory test results to the contractor with the supply docket.
15.1.2. The contractor provides a copy of the supplier's certification, test results and supply docket to the site superintendent or bioretention designer for review.
15.1.3. Following review of the certification, test results and the supply docket, the site superintendent or bioretention designer approves installation of the bioretention media.
15.1.4. The relevant sections of the bioretention media sign-off form as per the construction and establishment guidelines (Water by Design) should be completed and signed. This sign-off form is provided as part of the construction certification by the site superintendent or bioretention designer.

16. Hold points
16.1. The following hold points must be observed in accordance with the most recent Water by Design construction checklists and superintendent approval is required for works to proceed:
16.1.1. Prestart meeting
16.1.2. Completion of hydraulic structures and under-drainage
16,1.3. Prior to placing filter media
16.1.4. After placement of filter media (prior to applying mulch and planing).

17. Compliance testing (for on-maintenance or off-maintenance)
17.1. Compliance testing must be in accordance with chapter 5 of Transferring Ownership of Vegetated Stormwater Assets (Water by Design). Checklists must be completed and signed by the superintendent.

Disclaimer:It is the responsibility of the certifying registered professional engineer to ensure these standard notes are adapted to the specific needs of the project. It is expected that additional drawing notes would be required to cover other important project issues (e.g. Workplace Health and Safety, Environmental Protection, Erosion and Sediment Control, etc). Healthy waterways, IPWEA and all contributors to this document accept no liability for the use, misuse or any omission or inaccuracy in this document.

DATE
13.10.22
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C

PROJECT
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Date: 08/03/2023

Appendix C

ARR Data Hub Summary Output

PLANS AND DOCUMENTS referred to in the PDA DEVELOPMENT APPROVAL

Approval no: DEV2022/1290

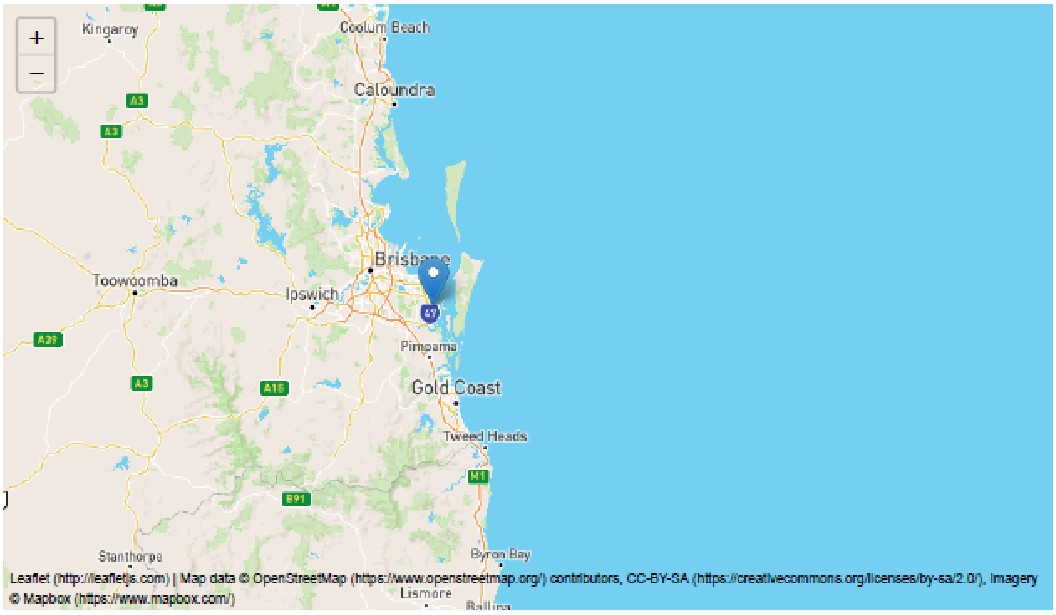
Date: 08/03/2023

Queensland Government

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	153.307
Latitude	-27.617
Selected Regions (clear)	
Storm Losses	show
Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show



Data

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

ID	1557.0
Storm Initial Losses (mm)	28.0
Storm Continuing Losses (mm/h)	1.6

Layer Info

Time Accessed	18 March 2022 02:24PM
Version	2016_v1

PLANS AND DOCUMENTS referred to in the PDA DEVELOPMENT APPROVAL
Queensland Government
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Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/ECnorth.zip)

code	ECnorth
Label	East Coast North

Layer Info

Time Accessed	18 March 2022 02:24PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-27.617273&longitude=153.307171&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	18 March 2022 02:24PM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	2.8 (0.067)	6.0 (0.105)	8.4 (0.122)	10.6 (0.134)	9.6 (0.102)	9.4 (0.089)
90 (1.5)	4.4 (0.093)	10.9 (0.165)	15.2 (0.191)	19.4 (0.208)	15.5 (0.139)	12.6 (0.100)
120 (2.0)	7.7 (0.147)	14.1 (0.192)	18.3 (0.207)	22.4 (0.216)	22.5 (0.181)	22.6 (0.160)
180 (3.0)	13.2 (0.218)	24.1 (0.284)	31.3 (0.305)	38.2 (0.316)	46.5 (0.317)	52.7 (0.315)
360 (6.0)	16.3 (0.211)	30.3 (0.276)	39.5 (0.296)	48.4 (0.306)	76.6 (0.397)	97.7 (0.442)
720 (12.0)	14.5 (0.144)	25.8 (0.179)	33.4 (0.189)	40.6 (0.193)	61.2 (0.239)	76.7 (0.261)
1080 (18.0)	12.5 (0.106)	19.8 (0.116)	24.7 (0.118)	29.4 (0.118)	54.3 (0.179)	73.1 (0.210)
1440 (24.0)	2.5 (0.019)	11.1 (0.058)	16.7 (0.071)	22.1 (0.079)	34.0 (0.099)	42.9 (0.109)
2160 (36.0)	1.0 (0.006)	7.8 (0.035)	12.3 (0.045)	16.6 (0.050)	37.1 (0.092)	52.5 (0.113)
2880 (48.0)	0.0 (0.000)	5.6 (0.023)	9.4 (0.031)	13.0 (0.036)	22.1 (0.049)	28.9 (0.056)
4320 (72.0)	0.0 (0.000)	1.5 (0.005)	2.4 (0.007)	3.3 (0.008)	11.0 (0.021)	16.7 (0.028)

Layer Info

Time Accessed	18 March 2022 02:24PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Location

Label: 17-19 Weinam

Latitude: -27.6173 [Nearest grid cell: 27.6125 (S)]

Longitude: 153.3072 [Nearest grid cell: 153.3125 (E)]

IFD Design Rainfall Intensity (mm/h)

Issued: 18 March 2022

Rainfall intensity for Durations, Exceedance per Year (EY), and Annual Exceedance Probabilities (AEP).
FAQ for New ARR probability terminology

	Annual Exceedance Probability (AEP)						
Duration	**63.2%**	**50%#**	**20%***	**10%**	**5%**	**2%**	**1%**
1 min	162	184	250	296	339	397	440
2 min	135	153	213	255	298	357	404
3 min	127	144	199	237	276	329	371
4 min	121	137	189	224	259	307	344
5 min	116	131	180	213	245	289	322
10 min	94.9	107	146	172	196	228	253
15 min	80.4	91.0	124	145	166	193	213
20 min	70.1	79.3	108	127	145	169	187
25 min	62.3	70.5	96.1	113	130	152	168
30 min	56.2	63.6	86.9	103	118	138	153
45 min	44.0	49.9	68.5	81.3	93.9	111	124
1 hour	36.6	41.5	57.3	68.3	79.3	94.1	106
1.5 hour	28.0	31.8	44.3	53.0	61.9	74.2	83.9
2 hour	23.1	26.3	36.7	44.2	51.8	62.4	70.9
3 hour	17.6	20.1	28.3	34.2	40.3	48.8	55.7
4.5 hour	13.5	15.4	21.9	26.5	31.4	38.2	43.7
6 hour	11.2	12.9	18.3	22.3	26.4	32.1	36.8
9 hour	8.70	9.99	14.3	17.4	20.7	25.3	29.0
12 hour	7.28	8.38	12.0	14.7	17.5	21.4	24.5
18 hour	5.68	6.55	9.47	11.6	13.8	16.9	19.4
24 hour	4.75	5.49	7.97	9.78	11.7	14.3	16.4
30 hour	4.12	4.77	6.95	8.55	10.2	12.5	14.4
36 hour	3.66	4.25	6.20	7.64	9.13	11.2	12.9
48 hour	3.02	3.50	5.14	6.35	7.61	9.35	10.8
72 hour	2.25	2.62	3.86	4.78	5.76	7.11	8.21
96 hour	1.80	2.09	3.08	3.83	4.63	5.72	6.62
120 hour	1.50	1.73	2.55	3.18	3.85	4.76	5.50
144 hour	1.28	1.48	2.16	2.70	3.27	4.03	4.66
168 hour	1.11	1.28	1.87	2.32	2.82	3.47	4.00

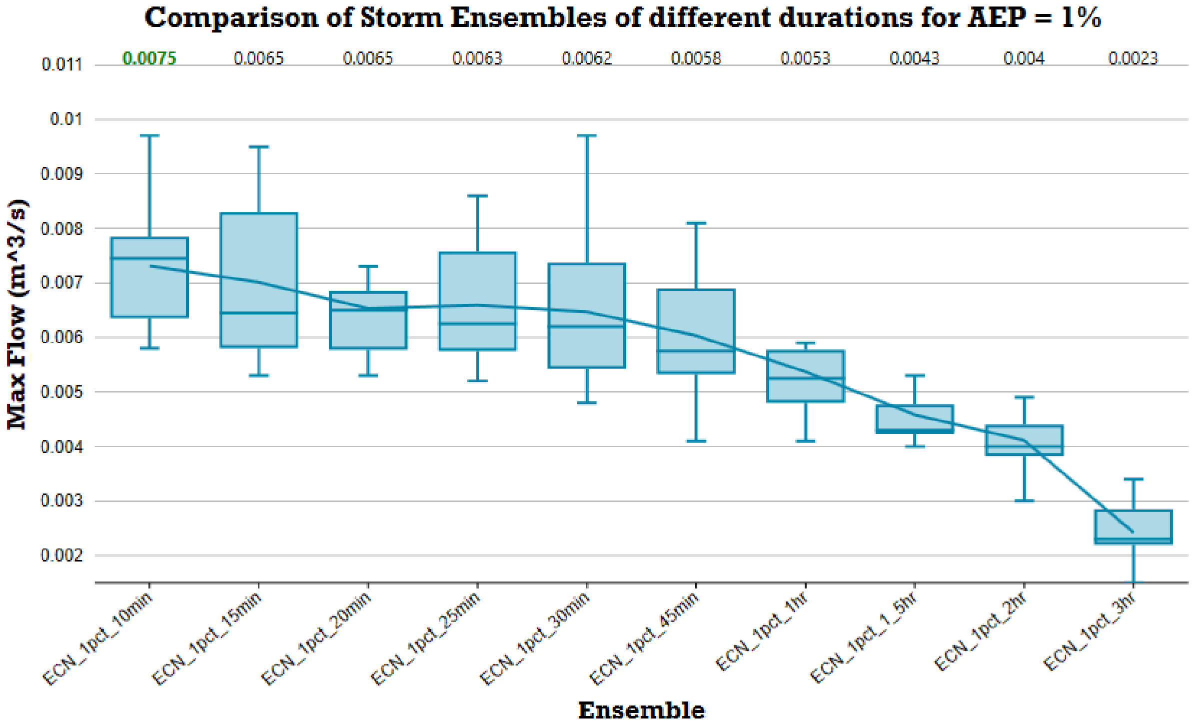
Note:
The 50% AEP IFD **does not** correspond to the 2 year Average Recurrence Interval (ARI) IFD. Rather it corresponds to the 1.44 ARI.
* The 20% AEP IFD **does not** correspond to the 5 year Average Recurrence Interval (ARI) IFD. Rather it corresponds to the 4.48 ARI.

This page was created at **13:29** on **Friday 18 March 2022 (AEST)**

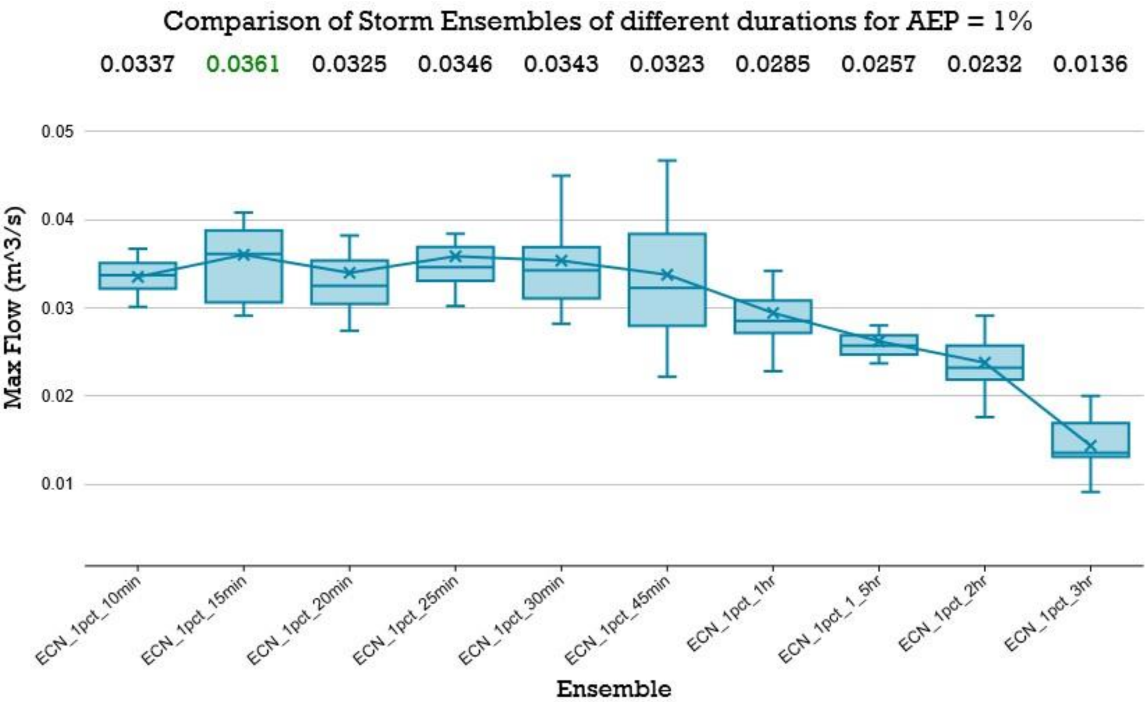
Appendix D

1 % AEP Box and Whisker Plots for Modelled Durations

Catchment A (EXT)



Catchment B (EXT)



PLANS AND DOCUMENTS
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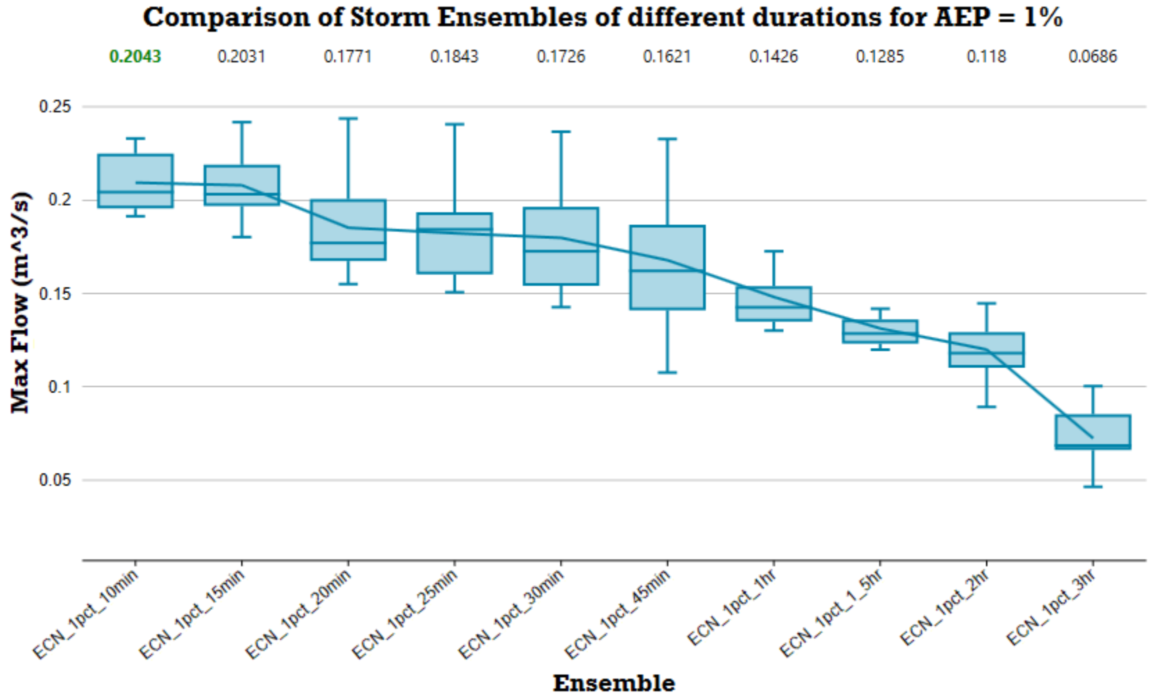
DEVELOPMENT APPROVAL

Approval no: DEV2022/1290

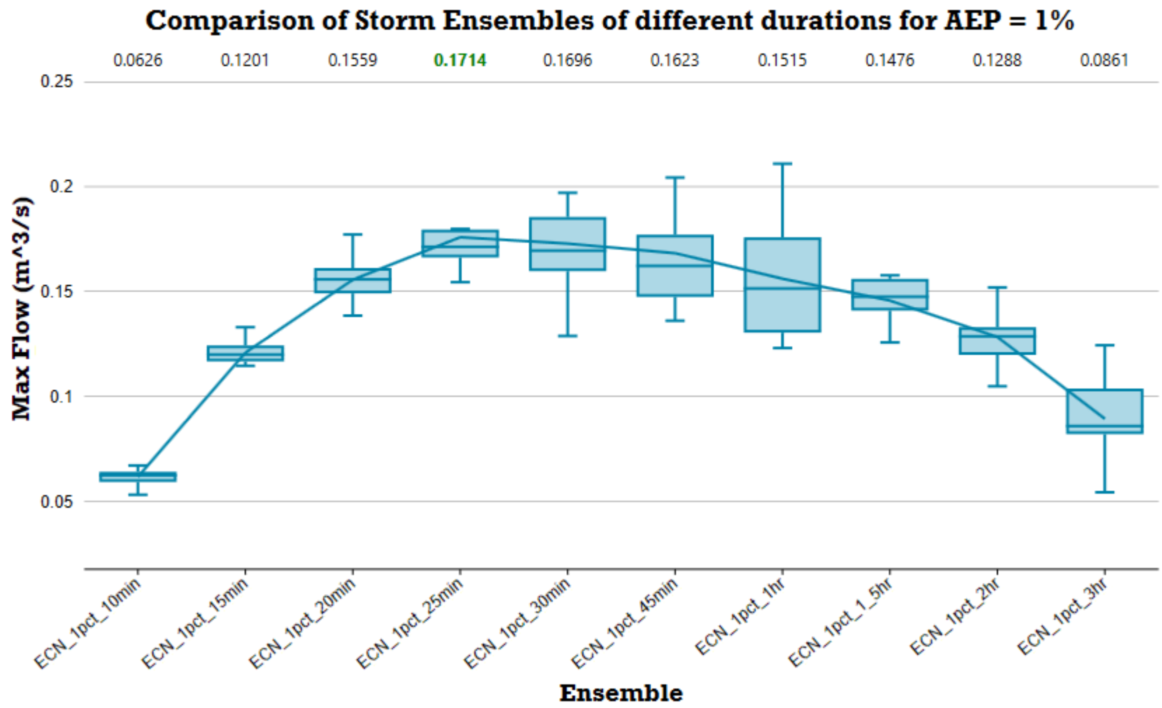
Date: 08/03/2023

Queensland Government

Catchment A



Catchment B



PLANS AND DOCUMENTS
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Queensland Government

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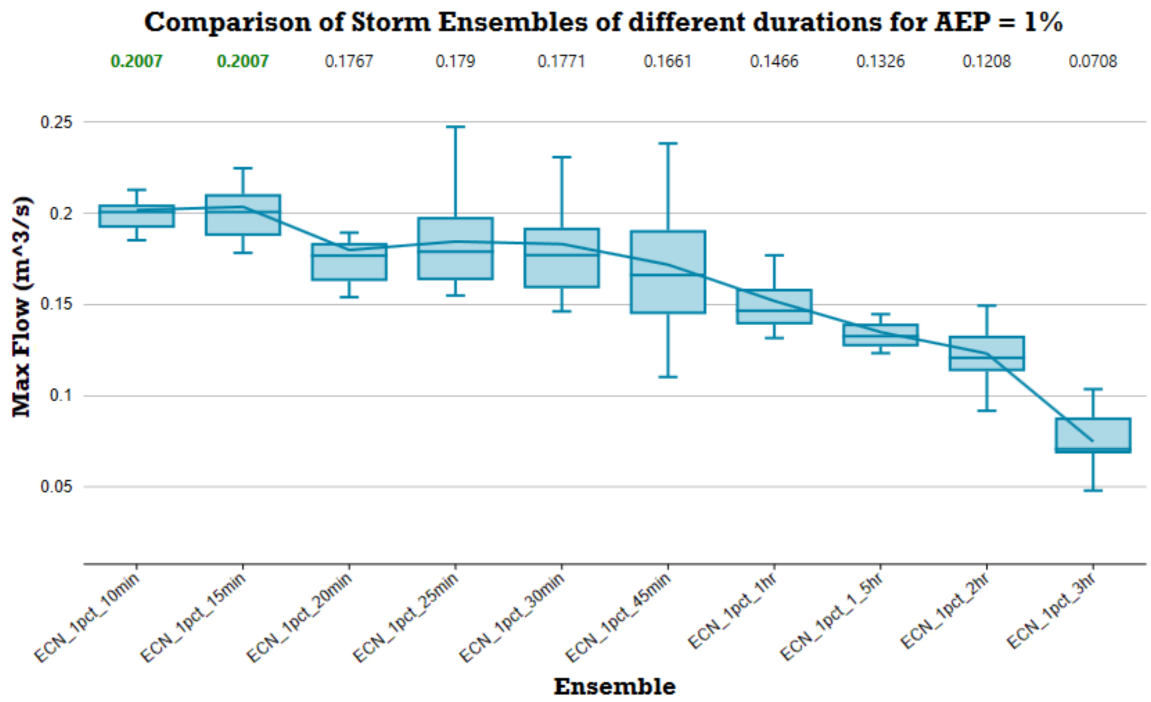
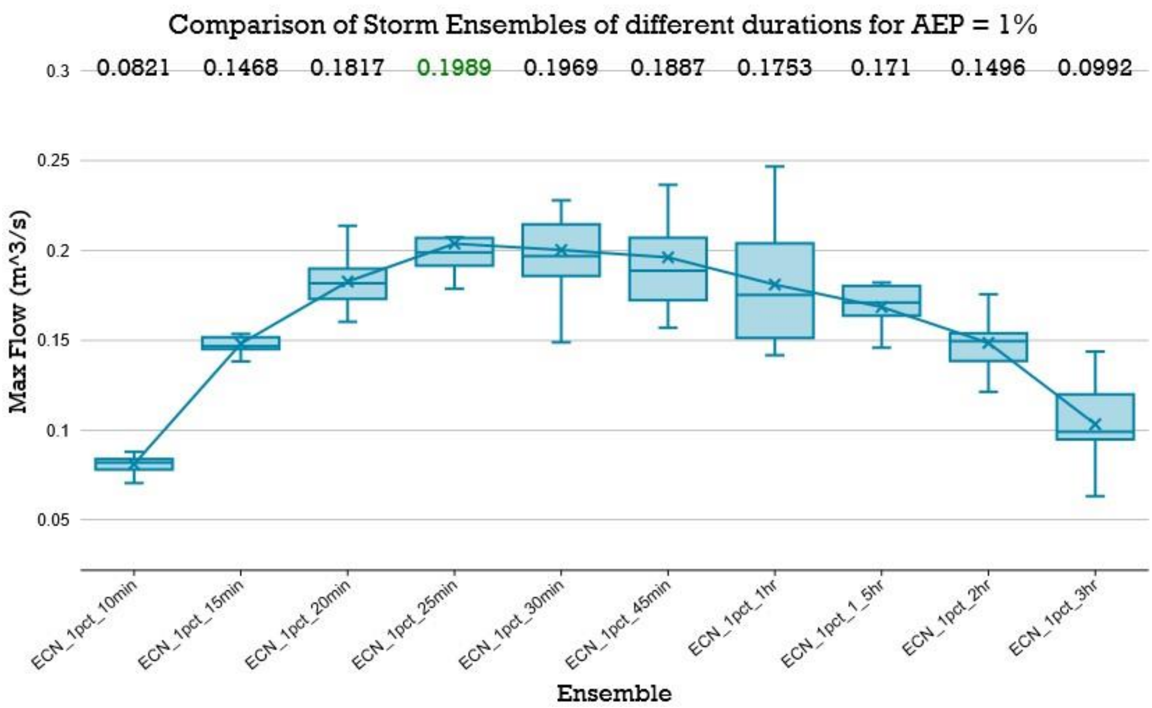
PD-A



PD-B



Appendix E

Rational Method Model Validation

The Rational Method has been relied upon to validate the flows reported within *xpstorm* for both the pre and post development cases. In accordance with QUDM 2016 Section 4, the Rational Method provides a simple means of estimating peak discharge and is therefore considered suitable for validation purposes. Equation 4.2 from QUDM has been relied upon.

$$Q_y = (C_y \, . \, {}^{t}I_y \, . \, A)/360$$

where:

Q_y	=	peak flow rate (m^3/s) for annual exceedance probability (AEP) of 1 in '*y*' years
C_y	=	coefficient of discharge for AEP of 1 in '*y*' years
A	=	area of catchment (ha)
${}^{t}I_i$ '*y*'	=	average rainfall intensity (mm/h) for a design duration of '*t*' hours and an AEP of 1 in years
t	=	the nominal design storm duration as defined by the time of concentration (t)

Coefficient of Discharge

Based on the infiltration characteristics of the internal and external catchments, the following discharge coefficients have been calculated using the method presented within Book 8 of Australian Rainfall and Runoff (1998) and based on Equation 4.3 from QUDM (2016).

$$C_y = F_y \, . \, C_{10}$$

where:

C_y	=	coefficient of discharge for AEP of 1 in '*y*' years
F_y	=	frequency factor for AEP of 1 in '*y*' years
C_{10}	=	10 year discharge coefficient value for Tables 4.5.3 and 4.5.4 of QUDM

Fraction impervious (f_i) values for the existing and developed catchments were derived from aerial photography and development plans, respectively. Using these values, and the local ${}^{1}I_{10}$ (1 hour rainfall intensity for the 10 year ARI) value sourced from BOM, the C_{10} for each catchment was determined and utilised to calculate the runoff coefficients for each nominated event.

The fraction impervious and coefficient of discharge values for the nominated AEP's for the existing case and developed case are contained within Tables E.1 and E.2, respectively.

Table E.1 Coefficient of Discharge – Existing Case

Catchment ID		f_i	C_2	C_5	C_{10}	C_{20}	C_{50}	C_{100}
External	A (Ext)	0.09	0.58	0.65	0.68	0.72	0.78	0.82
	B (Ext)	0.07	0.58	0.64	0.68	0.71	0.78	0.81
Internal	A	0.80	0.70	0.78	0.83	0.87	0.95	0.99
	B	0.04	0.57	0.64	0.67	0.70	0.77	0.80

Table E.2 Coefficient of Discharge – Developed Case

Catchment ID		f_i	C_2	C_5	C_{10}	C_{20}	C_{50}	C_{100}
Internal	A1	0.01	0.76	0.85	0.89	0.93	1.00	1.00
	A2	0.01	0.75	0.84	0.88	0.92	1.00	1.00
	B	0.01	0.70	0.78	0.83	0.87	0.95	0.99

Time of Concentration

The time of concentration (t_c) for each catchment was calculated in accordance with Section 4.6 of QUDM (2016).

A standard inlet time of concentration of 5 min has been adopted within the relevant developed catchments as per Table 4.6.2 of QUDM.

The time of concentration (t_c) for the overland flow length within the undeveloped catchments and the relevant developed catchments was estimated using Friend's Equation for overland flow (QUDM Section 4.6.6).

$$t_c = (107nL^{0.333})/S^{0.2}$$

where:

t_c	=	Time of concentration (min)
n	=	Horton's roughness value (estimated using QUDM Table 4.6.5)
L	=	Overland sheet flow path length (m)
S	=	Slope (%)

For channel flow, times where estimated using Manning's equation as provided in the Technical notes for Figure 4.6 of QUDM, shown below:

$$t_c = 0.025L/S^{0.5}$$

where:

t_c	=	Time of concentration (min)
L	=	Length of gutter flow (m)
S	=	Slope (%)

Tables E.3 and E.4 below present the parameters relied upon to calculate the time of concentration (t_c) to the discharge point of each catchment (site's PD) for the existing and developed case, respectively.

Table E.3 t_c Parameters – Existing Case

Parameter	External		Internal	
	A (Ext)	B (Ext)	A	B
Standard Inlet Time				
t_c (min)	-	-	5	-
Sheet Flow				
Flow Length (m)	10	20	-	85
Horton's Roughness Value	0.035	0.035	-	0.035
Slope (%)	25.0	7.3	-	2.2
t_c (min)	4.2	6.8	-	14.0
Channel Flow				
Flow Length (m)	-	-	-	-
Velocity (m/s)	-	-	-	-
Slope (%)	-	-	-	-
t_c (min)	-	-	-	-
Pipe Flow				
Flow Length (m)	-	-	110	-
Velocity (m/s)	-	-	1.0	-
Slope (%)	-	-	0.0	-
t_c (min)	-	-	1.8	-
TOTAL t_c (min)	**4.2**	**6.8**	**6.8**	**14.0**

Table E.4 t_c Parameters – Developed Case

Parameter	Internal		
	A1	A2	B
Standard Inlet Time			
t_c (min)	5	5	5
Sheet Flow			
Flow Length (m)	-	-	-
Horton's Roughness Value	-	-	-
Slope (%)	-	-	-
t_c (min)	-	-	-
Channel Flow			
Flow Length (m)	-	-	-
Velocity (m/s)	-	-	-
Slope (%)	-	-	-
t_c (min)	-	-	-
Pipe Flow			
Flow Length (m)	60	60	100
Velocity (m/s)	1.0	1.0	1.0
Slope (%)	1.0	1.0	1.0
t_c (min)	1.0	1.0	1.7
TOTAL t_c (min)	**6.0**	**6.0**	**6.7**

Rainfall Intensity

Based on the calculated t_c for each catchment, Intensity-Frequency-Duration data (IFD) has been obtained from the Bureau of Meteorology for nominated AEP's and the existing and developed cases are presented in Tables E.5 and E.6, respectively.

Table E.5 Rainfall Intensity (mm/h) – Existing Case

Catchment ID		I_2	I_5	I_{10}	I_{20}	I_{50}	I_{100}
External	A (Ext)	131.0	180.0	213.0	245.0	289.0	322.0
	B (Ext)	122.3	167.6	198.1	227.2	266.8	296.9
Internal	A	122.2	167.6	198.0	227.1	266.7	296.7
	B	94.1	128.2	150.2	171.8	199.7	220.7

Table E.6 Rainfall Intensity (mm/h)– Developed Case

Catchment ID		I_2	I_5	I_{10}	I_{20}	I_{50}	I_{100}
Internal	A1	126.2	173.2	204.8	235.2	276.8	308.2
	A2	126.2	173.2	204.8	235.2	276.8	308.2
	B	123.0	168.6	199.3	228.6	268.6	299.0

Peak Discharge

Based on the above parameters, estimates of the expected peak discharge generated for the site's existing and developed catchments for nominated AEP's have been calculated, and are presented in Tables E.7 and E.8, respectively.

Table E.7 Peak Discharge (m^3/s) – Existing Case

Catchment ID		Annual Exceedance Probability (AEP)					
		0.393 (2 yr ARI)	0.181 (5 yr ARI)	0.095 (10 yr ARI)	0.049 (20 yr ARI)	0.02 (50 yr ARI)	0.01 (100 yr ARI)
External	A (Ext)	0.00	0.00	0.00	0.00	0.01	0.01
	B (Ext)	0.02	0.03	0.03	0.04	0.05	0.06
Internal	A	0.07	0.11	0.14	0.16	0.21	0.24
	B	0.06	0.09	0.11	0.13	0.17	0.20

Table E.8 Peak Discharge (m^3/s) – Developed Case

Catchment ID		Annual Exceedance Probability (AEP)					
		0.393 (2 yr ARI)	0.181 (5 yr ARI)	0.095 (10 yr ARI)	0.049 (20 yr ARI)	0.02 (50 yr ARI)	0.01 (100 yr ARI)
Internal	A1	0.05	0.08	0.10	0.12	0.15	0.16
	A2	0.05	0.08	0.10	0.11	0.15	0.16
	B	0.08	0.12	0.15	0.18	0.23	0.26