

PLANS AND DOCUMENTS
referred to in the PDA
DEVELOPMENT APPROVAL



Approval no: DEV2012/403

Date: 19 August 2019

Flagstone City - Stages 2 to 5

Stormwater Management Report

7217/43/R8V2



Prepared for
Peet Flagstone City Pty Ltd

August 2012

Cardno (Qld) Pty Ltd

ABN 57 051 074 992

Level 11 Green Square North Tower

515 St Paul's Terrace

Fortitude Valley Qld 4006

Locked Bag 4006 Fortitude Valley

Queensland 4006 Australia

Telephone: 07 3369 9822

Facsimile: 07 3369 9722

International: +61 7 3369 9822

cardno@cardno.com.au

www.cardno.com.au

Document Information

Prepared for Peet Flagstone City Pty Ltd
Project Name Flagstone City - Stages 2 to 5
File Reference O:\7217-43\WP\R8V2_Stages 2 to 5_SMR\721743_R8V2_Stages 2 to 5_SMP.docx
Job Reference 7217/43/R8V2
Date August 2012

Document Control

Version	Date	Author	Author Initials	Reviewer	Reviewer Initials
1	8 August 2012	S. Walter/A. Vytla/Y. Yan	SW/AV/YY	D. Niven	DN
2	14 August 2012	S. Walter/A. Vytla/Y. Yan	AV/YN	D. Niven	DN

"© 2012 Cardno All Rights Reserved. Copyright in the whole and every part of this document belongs to Cardno and may not be used, sold, transferred, copied or reproduced in whole or in part in any manner or form or in or on any media to any person without the prior written consent of Cardno."

Table of Contents

1	Introduction	1
2	Purpose and Scope of the Report	2
3	Existing Site and Proposed Development	3
3.1	Existing Site Description	3
3.2	Proposed Masterplan Description	3
3.3	Proposed Stage 2 Description	3
3.4	Proposed Stage 3 Description	4
4	Performance Criteria	5
5	Data	6
6	Stormwater Management Strategy	7
6.1	Quantity	7
6.2	Quality	7
7	Water Quality Assessment	9
7.1	Stage 2	9
7.1.1	Approach	9
7.1.2	Results	10
7.2	Stage 3	10
7.2.1	Approach	10
7.2.2	Results	11
7.3.1	Approach	12
7.3.2	Results	13
7.4	Stage 5	13
7.4.1	Approach	13
7.4.2	Results	15
8	Frequent Flow Assessment	16
8.1	Stage 2	16
8.1.1	Approach	16
8.1.2	Results	16
8.2	Stage 3	16
8.2.1	Approach	16
8.2.2	Results	17
8.3	Stage 4	17
8.3.1	Approach	17
8.3.2	Results	17
8.4	Stage 5	17
8.4.1	Approach	17
9	Waterway Stability Assessment	19
9.1	Stage 2	19
9.1.1	Approach	19
9.1.2	Results	19
9.2	Stage 3	20
9.2.1	Approach	20

9.2.2	Results	21
9.3	Stage 4	22
9.3.1	Approach	22
9.4	Results	22
9.5	Stage 5	23
9.5.1	Approach	23
9.5.2	Results	24
10	Stormwater Treatment Device Sizes	26
10.1	Stage 2	26
10.2	Stage 3	26
10.3	Stage 4	27
10.4	Stage 5	28
11	Conclusion	30
12	References	31

Tables

Table 7-1	Modelled Areas	9
Table 7-2	Pollutant Load Reductions	10
Table 7-3	Modelled Areas	11
Table 7-4	Pollutant Load Reductions	12
Table 7-5	Modelled Areas	12
Table 7-6	Pollutant Load Reductions	13
Table 7-7	Modelled Areas	14
Table 7-8	Pollutant Load Reductions	15
Table 8-1	Frequent Flow Assessment	16
Table 8-2	Frequent Flow Assessment	17
Table 8-3	Frequent Flow Assessment	17
Table 8-4	Frequent Flow Assessment	18
Table 9-1	Rational Method Parameters	19
Table 9-2	Rational Method Results	19
Table 9-3	Detention Basin Assumptions	20
Table 9-4	Mitigation Results	20
Table 9-5	Rational Method Parameters	21
Table 9-6	Rational Method Results	21
Table 9-7	Detention Basin Assumptions	21
Table 9-8	Mitigation Results	22
Table 9-9	Rational Method Parameters	22
Table 9-10	Rational Method Results	23
Table 9-11	Detention Basin Assumptions	23
Table 9-12	Mitigation Results	23
Table 9-13	Rational Method Parameters	24
Table 9-14	Rational Method Results	24
Table 9-15	Detention Basin Assumptions	25
Table 9-16	Mitigation Results	25
Table 10-1	Bio-Retention Basin Parameters	26
Table 10-2	Rainwater Tank Parameters	26

Table 10-3	Bio-Retention Basin Parameters	27
Table 10-4	Volume Requirement	27
Table 10-5	Bio-Retention Basin Parameters	27
Table 10-6	Detention Basin Volume Requirement	28
Table 10-7	Rainwater Tank Parameters	28
Table 10-8	Bio-Retention Basin Parameters	28
Table 10-9	Volume Requirement	29

Figures

Figure 1	Site Location and Layout Plan
Figure 2	Stormwater Management Strategy – Stage 2
Figure 3	Stormwater Management Strategy – Stage 3
Figure 4	Stormwater Management Strategy – Stage 4
Figure 5	Stormwater Management Strategy – Stage 5
Figure 6	Catchment Plan – Stage 2
Figure 7	Catchment Plan – Stage 3
Figure 8	Catchment Plan – Stage 4
Figure 9	Catchment Plan – Stage 5

Appendices

Appendix A	Stormwater Management Plan
Appendix B	Maintenance Plans
Appendix C.1	MUSIC Model Schematic and Parameters – Stage 2
Appendix C.2	MUSIC Model Schematic and Parameters – Stage 3
Appendix C.3	MUSIC Model Schematic and Parameters – Stage 4
Appendix C.4	MUSIC Model Schematic and Parameters – Stage 5
Appendix D.1	Rational Method Detailed Calculations – Stage 2
Appendix D.2	Rational Method Detailed Calculations – Stage 3
Appendix D.3	Rational Method Detailed Calculations – Stage 4
Appendix D.4	Rational Method Detailed Calculations – Stage 5

1 Introduction

This stormwater management report has been prepared by Cardno (Water Resources and Coastal), specialist water quality, hydrologic and hydraulic consultants, for Peet Flagstone City Pty Ltd to investigate the stormwater quality management requirements for Stages 2 to 5 of Context Area 1 of the Flagstone West development, located in Logan City Council (LCC) under the Urban Land Development Authority (ULDA). The report has been prepared as a supporting document to accompany the development application for reconfiguring a lot.

The location of the Stages 2 to 5, Context Area 1 and the Masterplan extent is shown on Figure 1. The current structure plan layout and staging plan has been provided by RPS and is included in the reference section of this report. Additional detail of Context Area 1 and more specifically Stages 2 to 5 has also been provided by RPS and is included in the reference section of this report.

This report provides the detail of the stormwater quality management in accordance with the framework defined in Cardno's '*Flagstone City – Context Area 1 Stormwater Management Strategy Report*' dated August 2012 (ref 721743/R9V2) and will minimise the adverse impact of development on the natural water cycle and protect the health of aquatic ecosystems.

The key principles of Water Sensitive Urban Design are as follows:

- protect natural systems;
- integrate stormwater treatment into the landscape;
- protect water quality;
- reduce runoff and peak flows; and
- add value while minimising development costs.

This report provides details on the measures to be adopted to achieve the key stormwater management principles as identified above. Best practice objectives have been adopted for the development to ensure that the key principles can be achieved.

It is recognised that the measures presented in this report represent the current best practice measures by which the nominated objectives can be achieved. As the development will occur in stages over a number of years, it is therefore anticipated that alternate and more effective measures may be developed in the future. Provided that the objectives can still be achieved, the use of improved management techniques is to be encouraged.

The management of the water quantity and site flooding is proposed to be address as a Masterplan solution. This masterplan solution presents an integrated approach to the flooding to provide the most cost effective solution both in terms of construction and on-going maintenance. The details of the flood management are contained in Cardno's '*Flagstone City - Masterplan - Flooding Assessment*' dated August 2012 (ref 721743/R1V2).

2 Purpose and Scope of the Report

The purpose of this report is to evaluate the quality of stormwater associated with the proposed Stage 2, and to demonstrate to the ULDA that an appropriate stormwater quality management strategy can be adopted. The details of the quantity management are contained within the Masterplan report as discussed above.

A stormwater management plan (SWMP) has been appended to this report for possible inclusion in an overall environmental management plan (EMP). The SWMP is a framework of reference to prevent adverse water quality impacts on the environment throughout the construction and operational phases of the development. The SWMP specifically addresses the following elements and issues for both construction and operational phases:

- Operational Policy (Objective);
- Performance Criteria;
- Responsibility;
- Implementation Strategy;
- Monitoring;
- Auditing;
- Reporting;
- Identification of incident or failure; and
- Corrective action;

In particular this report will detail measure to ensure:

- appropriate standards are maintained on all stormwater aspects within the site and that pollution control measures are operating and maintained;
- that the surrounding area is not adversely affected nor unduly disrupted by stormwater during construction, operations and maintenance; and
- there is a unified clear and concise plan for stormwater management throughout every step of the development process.

This report will be in effect throughout construction and until all operational conditions set out in the SWMP are met.

3 Existing Site and Proposed Development

3.1 Existing Site Description

The overall site is approximately 1500ha in area. It is located in an area bounded an existing railway to the east, and forested property to the west. The Real Property description is

- Lot 1 on RP35155
- Lot 2 on RP47120
- Lot 4 on RP45728
- Lot 5 on S312569
- Lot 9 on S312569
- Lot 10 on SL6002
- Lot 873 on SP166448
- Lot 875 on SP146552
- Lot 907 on RP819216
- Lot 908 on RP819216
- Lot 910 on RP857850
- Lot 911 on RP857870
- Lot 988 on CP857841
- Lot 989 on RP854074

The site currently does not have a street address but is located off Homestead Road, which connects to Teviot Road, Jimboomba.

The site is cleared rural land with vegetation maintained along the creeks and gullies that traverse the site. The site drains into Flagstone and Sandy Creeks, or tributaries of these creek systems. Within the site the elevations range from approximately 32 mAHD to 171 mAHD, with a predominate direction of flow in an easterly direction prior to discharging under the existing railway.

An aerial of the current site condition is presented on Figure 1.

3.2 Proposed Masterplan Description

Flagstone City is proposed to be a large master planned mix use development consisting of:

- Residential dwellings;
- Super allotments;
- Mixed use lots;
- Town Centre;
- School;
- Parks (including Regional, district and local facilities); and
- Open Space.

The current structure plan layout and staging plan has been provided by RPS and is included in the reference section of this report.

3.3 Proposed Stage 2 Description

Stage 2 covers an area of approximately 32.3ha. As shown on RPS's Stage 2 layout, included in the reference section of this report, this area is to be developed and will consist of:

- Residential dwellings;
- School;
- Park; and
- a Retirement village.

The management of the stormwater will include the use of Rainwater Tanks and Bio-Retention Systems.

3.4 Proposed Stage 3 Description

Stage 3 covers an area of approximately 56.76 ha. As shown on RPS's Stage 3 layout, included in the reference section of this report, this area is to be developed and will consist of:

- Residential dwellings;
- Community/Child Care Site;
- Parks; and
- Open Space.

The management of the stormwater will include the use of:

- Rainwater Tanks; and
- Bio-Retention Systems.

3.5 Proposed Stage 4 Description

Stage 4 covers an area of approximately 43.63 ha. As shown on RPS's Stage 4 layout, included in the reference section of this report, this area is to be developed and will consist of:

- Residential dwellings;
- Parks; and
- Open Space.

The management of the stormwater will include the use of:

- Rainwater Tanks; and
- Bio-Retention Systems.

Stage 4 basins were designed for the ultimate layout. It considers an additional area of development in the north eastern corner of the site for the design of bioretention and detention basins. This additional development has been excluded in the current layout; however the location and size of the basins illustrated on Figure 4 would remain unchanged and are indicative of the ultimate development.

3.6 Proposed Stage 5 Description

Stage 5 covers an area of approximately 44.59 ha. As shown on RPS's Stage 5 layout, included in the reference section of this report, this area is to be developed and will consist of:

- Residential dwellings;
- Super allotments;
- Parks; and
- Open Space.

The management of the stormwater will include the use of:

- Rainwater Tanks; and
- Bio-Retention Systems.

4 Performance Criteria

A number of objectives have been adopted for Flagstone City with respect to the management of flooding and stormwater quality. The framework of these details is presented in Cardno's '*Flagstone City – Context Area 1 Stormwater Management Strategy Report*' dated August 2012 (ref 721743/R9V2).

The criterion relating to the quality management for Stages 2 to 5 includes:

- protection of stream ecology and geomorphology from impacts of stormwater runoff; and
- adoption of Healthy Waterways '*Concept Design Guidelines for Water Sensitive Urban Design*' (2009) including:
 - Frequent Flow Management;
 - Waterway Stability Management; and
 - Stormwater Management.

Healthy Waterways' guidelines (2009) were considered to provide best practice design criteria for the treatment of runoff from the developed areas. The objectives of relevance to stormwater quality are therefore:

- **Frequent Flow Management** - capture and management of the following design runoff depth (mm/day) from all impervious surfaces:
 - 0 to 40% impervious: Capture first 10mm/d of runoff.
 - > 40% impervious: Capture first 15mm/d of runoff.
- **Waterway Stability Management** - Limit the post developed peak one year ARI event discharge to the pre-developed ARI event discharge; and
- **Stormwater Management** - reduction in pollutant loads:
 - 80% reduction in sediment load;
 - 60% reduction in total phosphorus load;
 - 45% reduction in total nitrogen load; and
 - 90% reduction in gross pollutant load.

5 Data

The assessments detailed in this report are based on the following data:

- Aerial LiDAR survey data obtained from the Department of Environment and Heritage Protection (EHP);
- Site layouts provided by RPS;
- Rainfall Data from the Greenbank Thompson Road station obtained from the Bureau of Meteorology;

6 Stormwater Management Strategy

6.1 Quantity

The management of the water quantity and site flooding is proposed to be address as a Masterplan solution. This strategy will provide an integrated approach to the flooding to provide the most cost effective solution both in terms of construction and on-going maintenance. The details of the flood management are contained in Cardno's 'Flagstone City – Masterplan - Flooding Assessment' dated August 2012 (ref 721743/R1V2).

6.2 Quality

A wide range of stormwater management practices are available to achieve the principles of Water Sensitive Urban Design. All have been shown to be successful when correctly designed, but selection of the most appropriate practices for a particular development is highly dependent on site conditions. The review of these practises is contained in Cardno's 'Flagstone City – Context Area 1 Stormwater Management Strategy Report' dated August 2012 (ref 721743/R9V2). Of the available measures considered the following are considered suitable for Flagstone West:

- rainwater tanks in accordance with Part 25 of the Queensland Development Code;
- gross pollutant traps to collect oil and grease from car park and manoeuvring areas;
- buffer strips;
- grass swales (with or without underlying infiltration systems);
- bio-retention systems;
- detention basins/ sediment basins; and
- constructed wetlands.

Based on the suitable measures and the site constraint elements of Stages 2 to 5, it is proposed to utilise the following treatment measures as shown on Figure 2.

Rainwater Tanks – Stormwater that is collected on the roofs can be directed to rainwater tanks. The rainwater tanks will collect roof runoff for non-potable (or non-drinking) purposes such as:

- Toilet water flushing supply;
- Washing machine cold water taps;
- Landscape irrigation; and
- Lawn watering.



Plate 6.2 – Typical Bio-Retention System



Plate 6.1 – Typical Rainwater Tank

Bio-Retention Systems – The stormwater will be directed to appropriately located and sized bio-retention basins. These systems will improve the water quality by removing:

- Suspended Solids;
- Nutrients; and
- Metals.

The inlet zones of the bio-retention system will include a flow velocity dissipater and sediment forebay to provide protection for the bio-retention basin.

7 Water Quality Assessment

7.1 Stage 2

7.1.1 Approach

The water quality assessments were undertaken utilising MUSIC Version 5.00.11 in accordance with Healthy Waterways 'MUSIC Modelling Guidelines' (Version 1.0 2010).

The catchment extents adopted for the MUSIC model are presented on Figure 6, with the details of the catchment areas and land uses detailed in Table 7-1 below. A schematic of the MUSIC model layout is provided in Appendix C.1.

Table 7-1 Modelled Areas

Catchment Label	Land Use Area (ha)				Rural Residential	Catchment Total Area (ha)
	Urban Roof	Urban Ground	Urban Road	Open Space		
2A	3.77	4.12	3.22	-	-	11.11
2B	1.47	1.47	1.26	-	-	4.19
2C	0.53	0.65	0.45	-	-	1.63
2D	0.98	1.20	0.83	-	-	3.01
2E	2.38	2.64	2.03	-	-	7.05
2F	0.20	0.25	0.17	-	-	0.62
2G	-	-	-	-	4.70	4.70

The rainfall data used in the modelling was the Greenbank Thompson Road station 40659 obtained from the Bureau of Meteorology. A ten year period between 1980 and 1989 was assessed. The potential evapotranspiration details were obtained from the Healthy Waterways 2009 modelling guidelines.

The stormwater quality improvement devices assessed in the MUSIC model include the following treatment devices as discussed above and shown on Figure 6:

- Rainwater tanks; and
- Bio-Retention Systems.

The following assumptions were made in the modelling:

- A 6 minute time step was adopted to ensure accurate assessment of the proposed treatment devices;
- The pollutant generation parameters are adopted from Healthy Waterways 'MUSIC Modelling Guidelines' (Version 1.0, 2010) and can be found in Appendix C.1;
- The following fraction impervious values were adopted in the MUSIC model:

Residential Dwellings

- Roofs = 100%
- Ground = 20%
- Road (including road reserve) = 60%

School and retirement Village

- Roofs = 100%
- Ground = 30%

- Road (including road reserve) = 70%

Park Area

- Ground = 0%

- It was assumed that only half the roof area would discharge to rainwater tanks with all other flows conveyed to the bio-retention area.
- No flow routing was assumed, which provides a conservative estimate of treatment device efficiency;
- Default MUSIC pollutant removal efficiencies were adopted for all treatment devices;
- Each lot was assumed to have a rainwater tank, as recommended by Healthy Waterways 'MUSIC Modelling Guidelines' (Version 1.0 2010) for detached dwellings;
- The reuse of stormwater stored in the rainwater tanks was based on Section 4.2.2 of Healthy Waterways 'MUSIC Modelling Guidelines' (Version 1.0 2010) for detached dwellings and Table A of DNRW's 'Planning Guidelines for Water Supply and Sewerage' (2005) for the School;
- The total daily reuse volume was taken as the sum of the daily non potable demand and irrigation demand.

7.1.2 Results

Table 7-2 below presents the outcomes from the MUSIC modelling compared to the required load based reductions.

Table 7-2 Pollutant Load Reductions

Pollutant	Annual Load (kg/yr)		Load Reduction - Mitigated to Post-Dev (kg/yr)	Percentage Load Reduction - Mitigated to Post-Dev (%)	Required Load Reduction	Meet Load Reduction Requirement ?
	Post-Development	Mitigated				
TSS	24000	4330	19670	82.0%	80%	Yes
TP	46.7	18.7	28.0	60.1%	60%	Yes
TN	278	126	152	54.5%	45%	Yes

The above results indicate that the proposed treatment train is predicted to meet the required water quality load based reductions.

7.2 Stage 3

7.2.1 Approach

The water quality assessments were undertaken utilising MUSIC Version 5.00.11 in accordance with Healthy Waterways 'MUSIC Modelling Guidelines' (Version 1.0 2010).

The catchment extents adopted for the MUSIC model are presented on Figure 7, with the details of the catchment areas and land uses detailed in Table 7-3 below. A schematic of the MUSIC model layout is provided in Appendix C.2.

Table 7-3 Modelled Areas

Catchment Label	Land Use Area (ha)							Catchment Total Area (ha)
	Urban Residential			Commercial			Open Space	
	Roof	Ground	Road	Roof	Ground	Road		
1	4.87	6.37	3.75	-	-	-	0.83	15.81
2	1.42	1.85	1.09	-	-	-	0.02	4.38
3	1.31	1.71	1.01	-	-	-	0.03	4.04
4	3.45	4.51	2.65	0.27	0.11	0.16	0.31	11.45
5	0.49	0.65	0.38	-	-	-	-	1.52

The rainfall data used in the modelling was the Greenbank Thompson Road station 40659 obtained from the Bureau of Meteorology. A ten year period between 1980 and 1989 was assessed. The potential evapotranspiration details were obtained from the Healthy Waterways 2009 modelling guidelines.

The stormwater quality improvement devices assessed in the MUSIC model include the following treatment devices as discussed above and shown on Figure 7:

- Rainwater tanks; and
- Bio-Retention Systems.

The following assumptions were made in the modelling:

- A 6 minute time step was adopted to ensure accurate assessment of the proposed treatment devices;
- The pollutant generation parameters are adopted from Healthy Waterways '*MUSIC Modelling Guidelines*' (Version 1.0, 2010) and can be found in Appendix C.2;
- The following fraction impervious values were adopted in the MUSIC model:
 - Roofs = 100 %
 - Ground = 20 %
 - Road (including road reserve) = 60 %
- It was assumed that only half the roof area would discharge to rainwater tanks with all other flows conveyed to the bio-retention area;
- No flow routing was assumed, which provides a conservative estimate of treatment device efficiency;
- Default MUSIC pollutant removal efficiencies were adopted for all treatment devices;
- Each lot was assumed to have a rainwater tank, as recommended by Healthy Waterways '*MUSIC Modelling Guidelines*' (Version 1.0 2010) for detached dwellings;
- For rainwater tanks, the typical water usage rates for retail areas and public buildings were taken from Table A of DNRW's '*Planning Guidelines for Water Supply and Sewerage*' (2005); and
- Total daily reuse volume was taken as a sum of daily non portable and irrigation demand.

7.2.2 Results

Table 7-4 below presents the outcomes from the MUSIC modelling compared to the required load based reductions.

Table 7-4 Pollutant Load Reductions

Pollutant	Annual Load (kg/yr)		Load Reduction - Mitigated to Post-Dev (kg/yr)	Percentage Load Reduction - Mitigated to Post-Dev (%)	Required Load Reduction	Meet Load Reduction Requirement ?
	Post-Development	Mitigated				
TSS	24400	3870	20530	84.1	80	Yes
TP	51.9	20.3	31.6	60.9	60	Yes
TN	321	133	188	58.7	45	Yes

The above results indicate that the proposed treatment train is predicted to meet the required water quality load based reductions.

7.3 Stage 4

7.3.1 Approach

The water quality assessments were undertaken utilising MUSIC Version 5.00.11 in accordance with Healthy Waterways 'MUSIC Modelling Guidelines' (Version 1.0 2010).

The catchment extents adopted for the MUSIC model are presented on Figure 8, with the details of the catchment areas and land uses detailed in Table 7-5 below. A schematic of the MUSIC model layout is provided in Appendix C.3.

These catchments considered for the purposes of this application, the ultimate catchment extents, with the intent to locate these basins within the application extents.

Table 7-5 Modelled Areas

Catchment Label	Land Use Area (ha)							Catchment Total Area (ha)
	Urban Residential			Commercial			Open Space	
	Roof	Ground	Road	Roof	Ground	Road		
1	1.872	2.448	1.440	-	-	-	-	5.76
2	3.195	4.179	2.458	-	-	-	0.538	10.37
3	2.173	2.841	1.671	-	-	-	0.115	6.80
4	6.338	8.288	4.875	-	-	-	1.2	20.70

The rainfall data used in the modelling was the Greenbank Thompson Road station 40659 obtained from the Bureau of Meteorology. A ten year period between 1980 and 1989 was assessed. The potential evapotranspiration details were obtained from the Healthy Waterways 2009 modelling guidelines.

The stormwater quality improvement devices assessed in the MUSIC model include the following treatment devices as discussed above and shown on Figure 8:

- Rainwater tanks; and
- Bio-Retention Systems.

The following assumptions were made in the modelling:

- A 6 minute time step was adopted to ensure accurate assessment of the proposed treatment devices;

- The pollutant generation parameters are adopted from Healthy Waterways 'MUSIC Modelling Guidelines' (Version 1.0, 2010) and can be found in Appendix C.3;
- The following fraction impervious values were adopted in the MUSIC model:
 - Roofs = 100 %
 - Ground = 20 %
 - Road (including road reserve) = 60 %
- No flow routing was assumed, which provides a conservative estimate of treatment device efficiency;
- Default MUSIC pollutant removal efficiencies were adopted for all treatment devices;
- For Rainwater Tanks, The typical water usage rates for retail areas and public buildings were taken from Table A of DNRW's *Planning Guidelines for Water Supply and Sewerage* (2005).
- Total daily reuse volume was taken as a sum of daily non potable demand and irrigation demand.

7.3.2 Results

Table 7-6 below presents the outcomes from the MUSIC modelling compared to the required load based reductions.

Table 7-6 Pollutant Load Reductions

Pollutant	Annual Load (kg/yr)		Load Reduction - Mitigated to Post-Dev (kg/yr)	Percentage Load Reduction - Mitigated to Post-Dev (%)	Required Load Reduction	Meet Load Reduction Requirement ?
	Post-Development	Mitigated				
TSS	28300	4310	23990	84.7	80	Yes
TP	59.0	23.0	36.0	61.0	60	Yes
TN	366	150	215	59.0	45	Yes

The above results indicate that the proposed treatment train is predicted to meet the required water quality load based reductions.

7.4 Stage 5

7.4.1 Approach

The water quality assessments were undertaken utilising MUSIC Version 5.00.11 in accordance with Healthy Waterways 'MUSIC Modelling Guidelines' (Version 1.0 2010).

The catchment extents adopted for the MUSIC model are presented on Figure 9, with the details of the catchment areas and land uses detailed in Table 7-7 below. A schematic of the MUSIC model layout is provided in Appendix C.4.

Table 7-7 Modelled Areas

Catchment Label	Land Use Area (ha)							Catchment Total Area (ha)
	Urban Residential			Commercial			Open Space	
	Roof	Ground	Road	Roof	Ground	Road		
A	2.20	2.88	1.69	-	-	-	0.52	7.28
B	1.21	1.58	0.93	-	-	-	-	3.71
C	1.58	3.17	1.58	-	-	-	-	6.33
D	1.28	1.68	0.99	-	-	-	-	3.95
E	-	-	-	0.74	0.30	0.44	-	1.48
F	4.30	5.63	3.31	-	-	-	1.10	14.34

The rainfall data used in the modelling was the Greenbank Thompson Road station 40659 obtained from the Bureau of Meteorology. A ten year period between 1980 and 1989 was assessed. The potential evapotranspiration details were obtained from the Healthy Waterways 2009 modelling guidelines.

The stormwater quality improvement devices assessed in the MUSIC model include the following treatment devices as discussed above and shown on Figure 9:

- Rainwater tanks; and
- Bio-Retention Systems.

The following assumptions were made in the modelling:

- A 6 minute time step was adopted to ensure accurate assessment of the proposed treatment devices;
- The pollutant generation parameters are adopted from Healthy Waterways 'MUSIC Modelling Guidelines' (Version 1.0, 2010) and can be found in Appendix C.4;
- The following fraction impervious values were adopted in the MUSIC model:
 - Residential 10 dwellings/ha:
 - Roofs = 60%
 - Ground = 100%
 - Road (including road reserve) = 15%
 - Residential 15 dwellings/ha:
 - Roofs = 60%
 - Ground = 100%
 - Road (including road reserve) = 20%
 - Commercial:
 - Roofs = 75%
 - Ground = 100%
 - Road (including road reserve) = 80%
- It was assumed that only half of the roof area would discharge to rainwater tanks with all other flows conveyed to the bio-retention area;
- No flow routing was assumed, which provides a conservative estimate of treatment device efficiency;
- Default MUSIC pollutant removal efficiencies were adopted for all treatment devices;

- Each lot was assumed to have a rainwater tank, as recommended by Healthy Waterways 'MUSIC Modelling Guidelines' (Version 1.0 2010) for detached dwellings;
- For rainwater tanks, the typical water usage rates for retail areas and public buildings were taken from Table A of DNRW's 'Planning Guidelines for Water Supply and Sewerage' (2005); and
- Total daily reuse volume was taken as a sum of daily non portable and irrigation demand.

7.4.2 Results

Table 7-8 below presents the outcomes from the MUSIC modelling compared to the required load based reductions.

Table 7-8 Pollutant Load Reductions

Pollutant	Annual Load (kg/yr)		Load Reduction - Mitigated to Post-Dev (kg/yr)	Percentage Load Reduction - Mitigated to Post-Dev (%)	Required Load Reduction	Meet Load Reduction Requirement ?
	Post-Development	Mitigated				
TSS	18300	3250	15050	82.2	80	Yes
TP	38.4	15.4	23.0	60.0	60	Yes
TN	240	103	137	57.0	45	Yes

The above results indicate that the proposed treatment train is predicted to meet the required water quality load based reductions.

8 Frequent Flow Assessment

8.1 Stage 2

8.1.1 Approach

To assess the amount of runoff that passes through the treatment train systems and whether the frequent flow criterion is satisfied, the methodology presented in the Bligh Tanner and DesignFlow publication '*Stormwater Infrastructure Options to Achieve Multiple Water Cycle Outcomes*' (report for Queensland Water Commission, 2009, p34) was used:

- Use MUSIC to calculate the percentage of annual runoff that the first 15 mm of runoff from impervious areas accounts for (for the 10 year rainfall record);
- Use MUSIC to calculate the proportion of annual runoff that is treated by the treatment train; and
- If the percentage of annual runoff that passes through the treatment train is greater than the percentage of annual runoff that the first 15 mm of runoff accounts for, then the frequent flow objective has been met.

8.1.2 Results

Table 8-1 below presents the results from the frequent flow assessment, which indicates that sufficient volume is provided for the site.

Table 8-1 Frequent Flow Assessment

Parameter	Value
Average annual runoff from site (m ³)	124,800
Average annual runoff produced by first 15 mm of runoff from impervious areas (m ³)	53,400
Proportion of annual runoff produced by first 15 mm of runoff from impervious areas (%)	42.8
Proportion of runoff treated (%)	62.5

8.2 Stage 3

8.2.1 Approach

To assess the amount of runoff that passes through the treatment train systems and whether the frequent flow criterion is satisfied, the methodology presented in the Bligh Tanner and DesignFlow publication '*Stormwater Infrastructure Options to Achieve Multiple Water Cycle Outcomes*' (report for Queensland Water Commission, 2009, p34) was used:

- Use MUSIC to calculate the percentage of annual runoff that the first 15 mm of runoff from impervious areas accounts for (for the 10 year rainfall record);
- Use MUSIC to calculate the proportion of annual runoff that is treated by the treatment train; and
- If the percentage of annual runoff that passes through the treatment train is greater than the percentage of annual runoff that the first 15 mm of runoff accounts for, then the frequent flow objective has been met.

8.2.2 Results

Table 8-2 below presents the results from the frequent flow assessment, which indicates that sufficient volume is provided for the site.

Table 8-2 Frequent Flow Assessment

Parameter	Value
Average annual runoff from site (m ³)	147,957
Average annual runoff produced by first 15 mm of runoff from impervious areas (m ³)	60,783
Proportion of annual runoff produced by first 15 mm of runoff from impervious areas (%)	41.1%
Proportion of runoff treated (%)	58.6%

8.3 Stage 4

8.3.1 Approach

To assess the amount of runoff that passes through the treatment train systems and whether the frequent flow criterion is satisfied, the methodology presented in the Bligh Tanner and DesignFlow publication '*Stormwater Infrastructure Options to Achieve Multiple Water Cycle Outcomes*' (report for Queensland Water Commission, 2009, p34) was used:

- Use MUSIC to calculate the percentage of annual runoff that the first 15 mm of runoff from impervious areas accounts for (for the 10 year rainfall record);
- Use MUSIC to calculate the proportion of annual runoff that is treated by the treatment train; and
- If the percentage of annual runoff that passes through the treatment train is greater than the percentage of annual runoff that the first 15 mm of runoff accounts for, then the frequent flow objective has been met.

8.3.2 Results

Table 8-3 below presents the results from the frequent flow assessment, which indicates that sufficient volume is provided for the site.

Table 8-3 Frequent Flow Assessment

Parameter	Value
Average annual runoff from site (m3)	175,870
Average annual runoff produced by first 15 mm of runoff from impervious areas (m3)	680,11
Proportion of annual runoff produced by first 15 mm of runoff from impervious areas (%)	38.7
Proportion of runoff treated (%)	67.4

8.4 Stage 5

8.4.1 Approach

To assess the amount of runoff that passes through the treatment train systems and whether the frequent flow criterion is satisfied, the methodology presented in the Bligh Tanner and DesignFlow publication '*Stormwater Infrastructure Options to Achieve Multiple Water Cycle Outcomes*' (report for Queensland Water Commission, 2009, p34) was used:

- Use MUSIC to calculate the percentage of annual runoff that the first 15 mm of runoff from impervious areas accounts for (for the 10 year rainfall record);
- Use MUSIC to calculate the proportion of annual runoff that is treated by the treatment train; and
- If the percentage of annual runoff that passes through the treatment train is greater than the percentage of annual runoff that the first 15 mm of runoff accounts for, then the frequent flow objective has been met.

8.5 Results

Table 8-4 below presents the results from the frequent flow assessment, which indicates that sufficient volume is provided for the site.

Table 8-4 Frequent Flow Assessment

Parameter	Value
Average annual runoff from site (m ³)	110,515
Average annual runoff produced by first 15 mm of runoff from impervious areas (m ³)	49,050
Proportion of annual runoff produced by first 15 mm of runoff from impervious areas (%)	44.4
Proportion of runoff treated (%)	62.8

9 Waterway Stability Assessment

9.1 Stage 2

9.1.1 Approach

To determine the volumes required to limit the 1 year post-development flows to the 1 year pre-development conditions a Rational Method assessment of the local catchment as shown on Figure 6 was undertaken, with the volume sized in accordance with Queensland Urban Drainage Manual (2008) (QUDM).

Table 9-1 presents the Rational Method parameters for each of the pre-development and post-developed sub-catchments with the detailed calculations presented in Appendix D.1.

Table 9-1 Rational Method Parameters

Catchment	Pre-Development			Post-Development		
	Area (ha)	Co-Efficient of Runoff (C ₁₀)	Time of Concentration (min)	Area (ha)	Co-Efficient of Runoff (C ₁₀)	Time of Concentration (min)
A	13.03	0.6	16	11.11	0.78	15
G				4.7	0.6	15
B	5.21	0.6	14	4.19	0.78	15
C	1.4	0.6	11	3.30	0.78	10
D	0.68	0.6	11	1.34	0.78	10
E	7.70	0.6	14	7.05	0.78	10
F	0.97	0.6	12	0.62	0.78	10

9.1.2 Results

Table 9-2 presents the peak flows for the 1 year ARI.

Table 9-2 Rational Method Results

Catchment	Pre-Development	Post-Development
	Peak Flow (m ³ /s)	
A	1.17	1.36
G		0.44
B	0.50	0.62
C	0.15	0.48
D	0.07	0.20
E	0.74	1.04
F	0.10	0.09

As the 1 year peak post-development flow from Catchment F is lower than the peak flow under the pre-developed condition, no detention basin is deemed to be required for this catchment.

Table 9-3 presents details for the proposed detention basins. A summary of the mitigation results is presented in Table 9-4.

Table 9-3 Detention Basin Assumptions

Catchment	Outlet Pipe Number/Size	Depth of Weir above EDD of Bio-Retention Basin (m)	Length of Weir (m)	Base Area (m ²)	Basin Volume (m ³)
A & G	1/375	0.7	22	1725	1412
B	1/375	0.55	6.5	333	251
C	1/225	0.7	3	208	230
D	1/225	0.47	5	129	83
E	1/375	0.7	11	425	488
F	-	-	-	-	-

Table 9-4 Mitigation Results

Catchment	Peak Inflow (m ³ /s)	Target Outflow (m ³ /s)	Mitigated Outflow (m ³ /s)	Meet Flow Reduction Requirement ?
A	1.81	1.17	0.29	Yes
B	0.62	0.50	0.28	Yes
C	0.48	0.15	0.14	Yes
D	0.20	0.07	0.06	Yes
E	1.04	0.74	0.72	Yes
F	0.09	0.10	0.09	Yes

9.2 Stage 3

9.2.1 Approach

To determine the volumes required to limit the 1 year post-development flows to the 1 year pre-development conditions a Rational Method assessment of the local catchment as shown on Figure 7 was undertaken.

The required storage volumes for detention basins were determined by a routing of the inflow hydrograph through the basin (stage-storage relationship) and outlet geometry (stage-discharge relationship) until the desired outflow hydrograph is achieved. A triangular hydrograph was assumed for the pre- and post-developed conditions with the peak flows (as per the Rational Method) occurring at the time of concentration.

Table 9-5 presents the Rational Method parameters for each of the sub-catchments with the detailed calculations presented in Appendix D.2.

Table 9-5 Rational Method Parameters

Catchment	Pre-Development			Post-Development		
	Area (ha)	Co-Efficient of Runoff (C ₁₀)	Time of Concentration (min)	Area (ha)	Co-Efficient of Runoff (C ₁₀)	Time of Concentration (min)
1	18.85	0.59	18	15.81	0.84	15
2	3.71	0.59	18	4.37	0.84	15.5
3	4.73	0.59	21	4.04	0.84	16
4	11.62	0.59	19	11.44	0.84	16
5	1.77	0.59	16	1.52	0.84	10

9.2.2 Results

The Rational Method results are summarised in Table 9-6 below.

Table 9-6 Rational Method Results

Catchment	Pre-Development	Post-Development
	Peak Flow (m ³ /s)	
1	1.61	2.09
2	0.32	0.57
3	0.37	0.56
4	0.96	1.47
5	0.16	0.24

Table 9-7 presents details for the proposed detention basins. A summary of the mitigation results is presented in Table 9-8.

Table 9-7 Detention Basin Assumptions

Catchment	Outlet Pipe Number/Size	Depth of Weir above EDD of Bio-Retention Basin (m)	Length of Weir (m)	Base Area (m ²)	Basin Volume (m ³)
1	1/375	0.70	5	1600	1280
2	1/375	0.70	5	343	322
3	1/375	0.67	5	343	304
4	1/375	0.70	5	1600	1221
5	1/375	0.38	5	135	57

Table 9-8 Mitigation Results

Catchment	Peak Inflow (m ³ /s)	Target Outflow (m ³ /s)	Mitigated Outflow (m ³ /s)	Meet Flow Reduction Requirement ?
1	2.31	1.61	0.96	Yes
2	0.62	0.32	0.22	Yes
3	0.57	0.37	0.20	Yes
4	1.61	0.96	0.19	Yes
5	0.26	0.16	0.13	Yes

9.3 Stage 4

9.3.1 Approach

To determine the volumes required to limit the 1 year post-development flows to the 1 year pre-development conditions a Rational Method assessment of the local catchment as shown on Figure 8 was undertaken.

The required storage volumes for detention basins were determined by a routing of the inflow hydrograph through the basin (stage-storage relationship) and outlet geometry (stage-discharge relationship) until the desired outflow hydrograph is achieved. A triangular hydrograph was assumed for the pre- and post-developed conditions with the peak flows (as per the Rational Method) occurring at the time of concentration.

Table 9-9 presents the Rational Method parameters for each of the sub-catchments with the detailed calculations presented in Appendix D.3.

Table 9-9 Rational Method Parameters

Catchment	Pre-Development			Post-Development		
	Area (ha)	Co-Efficient of Runoff (C ₁₀)	Time of Concentration (min)	Area (ha)	Co-Efficient of Runoff (C ₁₀)	Time of Concentration (min)
1	6.19	0.59	23.5	5.76	0.84	16.5
2	18.33	0.59	34.3	10.37	0.84	19.5
3	3.19	0.59	19.3	6.8	0.84	18.5
4	22.07	0.59	34.4	20.7	0.84	20.5

9.4 Results

The Rational Method results are summarised in Table 9-10 below.

Table 9-10 Rational Method Results

Catchment	Pre-Development	Post-Development
	Peak Flow (m ³ /s)	
1	0.46	0.73
2	1.12	1.39
3	0.26	0.81
4	1.35	2.36

Table 9-11 presents details for the proposed detention basins. A summary of the mitigation results is presented in Table 9-12.

Table 9-11 Detention Basin Assumptions

Catchment	Outlet Pipe Number/Size (mm)	Depth above EDD of Bio-Retention Basin (m)	Length of Weir (m)	Base Area (m ²)	Basin Volume (m ³)
1	1/375	0.699	5	590.5	515
2	1/600	0.694	5	1369	1100
3	1/375	0.686	5	812.3	672
4	1/525	0.697	5	3249	2494

Table 9-12 Mitigation Results

Catchment	Peak Inflow (m ³ /s)	Target Outflow (m ³ /s)	Mitigated Outflow (m ³ /s)	Meet Flow Reduction Requirement ?
1	0.73	0.46	0.22	Yes
2	1.39	1.12	0.47	Yes
3	0.81	0.26	0.21	Yes
4	2.36	1.35	0.39	Yes

9.5 Stage 5

9.5.1 Approach

To determine the volumes required to limit the 1 year post-development flows to the 1 year pre-development conditions a Rational Method assessment of the local catchment as shown on Figure 9 was undertaken.

The required storage volumes for detention basins were determined by a routing of the inflow hydrograph through the basin (stage-storage relationship) and outlet geometry (stage-discharge relationship) until the desired outflow hydrograph is achieved. A triangular hydrograph was assumed for the pre- and post-developed conditions with the peak flows (as per the Rational Method) occurring at the time of concentration.

Table 9-13 presents the Rational Method parameters for each of the sub-catchments with the detailed calculations presented in Appendix D.4.

Table 9-13 Rational Method Parameters

Catchment	Pre-Development			Post-Development		
	Area (ha)	Co-Efficient of Runoff (C ₁₀)	Time of Concentration (min)	Area (ha)	Co-Efficient of Runoff (C ₁₀)	Time of Concentration (min)
A	14.00	0.59	17	7.29	0.84	14
B	3.15	0.59	13	3.71	0.84	12
C	2.54	0.59	18	6.33	0.84	12
D	1.95	0.59	18	3.95	0.84	12
E	2.12	0.59	17	1.48	0.84	10
F	1.52	0.59	20	3.91	0.84	12

9.5.2 Results

The Rational Method results are summarised in Table 9-14 below.

Table 9-14 Rational Method Results

Catchment	Pre-Development	Post-Development
	Peak Flow (m ³ /s)	
A	1.23	0.99
B	0.31	0.54
C	0.22	0.37
D	0.17	0.58
E	0.19	0.23
F	0.12	0.57

As the 1 year post-development flows from Catchment A is lower than the flows under the pre-developed condition, no detention basin is deemed required for Catchment A.

Table 9-15 presents details for the proposed detention basins. A summary of the mitigation results is presented in Table 9-16.

Table 9-15 Detention Basin Assumptions

Catchment	Outlet Pipe Number/Size	Depth of Weir above EDD of Bio-Retention Basin (m)	Length of Weir (m)	Base Area (m ²)	Basin Volume (m ³)
B	1/375	0.66	5	274	245
C	1/375	0.68	5	625	524
D	1/375	0.47	5	576	320
E	1/375	0.35	5	215	89
F	1/375	0.36	5	900	350

Table 9-16 Mitigation Results

Catchment	Peak Inflow (m ³ /s)	Target Outflow (m ³ /s)	Mitigated Outflow (m ³ /s)	Meet Flow Reduction Requirement ?
B	0.54	0.31	0.20	Yes
C	0.93	0.22	0.21	Yes
D	0.58	0.17	0.16	Yes
E	0.23	0.19	0.10	Yes
F	0.57	0.12	0.10	Yes

10 Stormwater Treatment Device Sizes

10.1 Stage 2

The bio-retention filter media area was adjusted to reach the performance guidelines outlined previously.

Based on the assessments a 5kL rainwater tank is required on each of the detached dwellings. The tank sizing for the school and retirement village areas has been based on 100kL of tank volume per hectare. The rainwater tank re-use parameters were based on Section 4.2.2 of Healthy Waterways 'MUSIC Modelling Guidelines' (Version 1.0 2010) for detached dwellings and DNRW's *Planning Guidelines for Water Supply and Sewerage* (2005) for the School.

Table 10-1 below provides the bio-retention sizes.

Table 10-1 Bio-Retention Basin Parameters

Parameters	Catchment A	Catchment B	Catchment C	Catchment D	Catchment E	Catchment F	Catchment G
Extended Detention Depth (m)	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Surface Area (m ²)	666	251	198	80	423	37	320
Seepage Loss (mm/hr)	0	0	0	0	0	0	0
Filter Area (m ²)	666	251	198	80	423	37	320
Filter Depth (m)	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Mean Particle Diameter (mm)	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Saturated Hydraulic Conductivity (mm/hr)	200	200	200	200	200	200	200
Depth below underdrain pipe (% of Filter Depth)	0	0	0	0	0	0	0
Overflow Weir Width (m)	17	6.5	2.5	4.6	11	1	4.6

Table 10-2 below provides the Rainwater Tank sizing and re-use values used for the modelling process.

Table 10-2 Rainwater Tank Parameters

Parameters	Tank 2A Lot area	Tank 2A Ret. Village area	Tank 2B Lot area	Tank 2C Lot area	Tank 2D Lot area	Tank 2E Lot area	Tank 2E School area	Tank 2F Lot area
Low Flow By-pass (m ³ /s)	0	0	0	0	0	0	0	0
High Flow By-pass (m ³ /s)	100	100	100	100	100	100	100	100
Volume below overflow pipe (kL)	385	687	440	215	255	290	373	45
Depth above overflow	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Surface Area (m ²)	173	344	220	107.5	128	145	187	23
Overflow pipe diameter (mm)	439	586	469	328	357	381	432	150
Annual Demand: PET – Rain (kL/yr)	7012	2987	1914	5064	2056	5370	1621	951
Daily Demand (kL/day)	16.9	50.6	32.4	9.5	5.1	12.8	27.5	2.0

10.2 Stage 3

Based on the assessments a 5 kL rainwater tank is required on each of the houses. The child care centre in Catchment 4 has assumed a 80 kL rainwater tank.

Table 10-3 below provides the bio-retention sizes with Table 10-4 summarising the 1 year ARI volume requirement.

Table 10-3 Bio-Retention Basin Parameters

Parameter	Catchment 1	Catchment 2	Catchment 3	Catchment 4	Catchment 5
Extended Detention Depth (m)	0.3	0.3	0.3	0.3	0.3
Surface Area (m ²)	850	260	230	680	85
Seepage Loss (mm/hr)	0	0	0	0	0
Filter Area (m ²)	850	260	230	680	85
Filter Depth (m)	0.5	0.5	0.5	0.5	0.5
Mean Particle Diameter (mm)	0.45	0.45	0.45	0.45	0.45
Saturated Hydraulic Conductivity (mm/hr)	200	200	200	200	200
Depth below underdrain pipe (% of Filter Depth)	0	0	0	0	0
Overflow Weir Width (m)	2	2	2	2	2

Table 10-4 Volume Requirement

Catchment	Volume (m ³)
1	1280
2	322
3	304
4	1221
5	57

10.3 Stage 4

Table 10-5 below provides the bio-retention sizes with Table 10-6 summarising the 1 year ARI volume requirement. Additionally Table 10-7 contains the rainwater tank parameters.

Table 10-5 Bio-Retention Basin Parameters

Parameter	Catchment 1	Catchment 2	Catchment 3	Catchment 4
Extended Detention Depth (m)	0.3	0.3	0.3	0.3
Surface Area (m ²)	350	600	400	1200
Seepage Loss (mm/hr)	0	0	0	0
Filter Area (m ²)	350	600	400	1200
Filter Depth (m)	0.5	0.5	0.5	0.5
Mean Particle Diameter (mm)	0.45	0.45	0.45	0.45
Saturated Hydraulic Conductivity (mm/hr)	200	200	200	200
Depth below underdrain pipe (% of Filter Depth)	0	0	0	0
Overflow Weir Width (m)	2	2	2	2

Table 10-6 Detention Basin Volume Requirement

Catchment	Volume (m ³)
1	515.4
2	1100.1
3	671.8
4	2494.1

Table 10-7 Rainwater Tank Parameters

Parameters	Catchment 1	Catchment 2	Catchment 3	Catchment 4
Low Flow By-pass (m ³ /s)	0	0	0	0
High Flow By-pass (m ³ /s)	100	100	100	100
Volume below overflow pipe (kL)	415.58	709.38	482.32	1406.93
Depth above overflow	0.2	0.2	0.2	0.2
Surface Area (m ²)	207.79	354.69	241.16	703.46
Overflow pipe diameter (mm)	820.52	1072	883.95	1509.7
Daily Demand (kL/day)	18.29	31.21	21.22	61.9
Annual Demand (kL/year)	14688	25071.6	17046.8	49725

10.4 Stage 5

Based on the assessments a 5 kL rainwater tank is required on each of the houses. The super allotment in Catchment E has assumed a 222 kL rainwater tank.

Table 10-8 below provides the bio-retention sizes with Table 10-9 summarising the 1 year ARI volume requirement.

Table 10-8 Bio-Retention Basin Parameters

Parameter	Catchment A	Catchment B	Catchment C	Catchment D	Catchment E	Catchment F
Extended Detention Depth (m)	0.3	0.3	0.3	0.3	0.3	0.3
Surface Area (m ²)	400	200	300	200	150	190
Seepage Loss (mm/hr)	0	0	0	0	0	0
Filter Area (m ²)	400	200	300	200	150	190
Filter Depth (m)	0.5	0.5	0.5	0.5	0.5	0.5
Mean Particle Diameter (mm)	0.45	0.45	0.45	0.45	0.45	0.45
Saturated Hydraulic Conductivity (mm/hr)	200	200	200	200	200	200
Depth below underdrain pipe (% of Filter Depth)	0	0	0	0	0	0
Overflow Weir Width (m)	2	2	2	2	2	2

Table 10-9 Volume Requirement

Catchment	Volume (m ³)
B	245
C	524
D	320
E	89
F	350

As discussed previously in Section 9, no detention basin is required for Catchment A.

11 Conclusion

Currently master planning is being undertaken with respect to the Flagstone West area. Water sensitive urban design principles are to be adopted to minimise the negative impact of development on the natural water cycle and protect the health of aquatic ecosystems.

Following the definition of suitable performance criteria with respect to the management of stormwater, the options available for achieving the performance criteria were evaluated. The results of the evaluation are summarised below.

- **Quantity**

The management of the water quantity and site flooding is to be addressed as a Masterplan solution. This strategy presents an integrated approach to the flooding to provide the most cost effective solution both in terms of construction and on-going maintenance. The details of the flood management are contained in Cardno's '*Flagstone City - Masterplan - Flooding Assessment*' dated August 2012 (ref 721743/R1V2).

The above mentioned report provides details on the overall hydrologic and hydraulic models of the Flagstone West area. These models were established to demonstrate no adverse flood impacts downstream of the site due to the proposed Masterplan development.

- **Quality**

A review of available treatment methods indicated several treatment methods were suitable for use. Based on the sites constraints and opportunities, it was determined that the Stages 2 to 5 treatment train is to consist of rainwater tanks and bio-retention systems.

It is expected that the list of appropriate treatment methods will alter over time as technology advances. Provided that the objectives can still be achieved, the use of improved management techniques is to be encouraged.

The objectives relating to the quality management for Stages 2 to 5 includes:

- protection of stream ecology and geomorphology from impacts of stormwater runoff; and
- adoption of Healthy Waterways '*Concept Design Guidelines for Water Sensitive Urban Design*' (2009) including:
 - Frequent Flow Management;
 - Waterway Stability Management; and
 - Stormwater Management.

The modelling detailed in this report confirmed that the proposed development with the proposed treatment train will achieve all of the above objectives; thereby confirming that the environmental values of downstream watercourses can be protected.

12 References

Cardno, 2012, '*Flagstone City – Masterplan - Flooding Assessment*' (ref 721743/R1V2)

Cardno, 2012, '*Flagstone City – Context Area 1 Stormwater Management Strategy Report*' (ref 721743/R9V2)

Department of Natural Resources and Water, 2008, *Queensland Urban Drainage Manual*

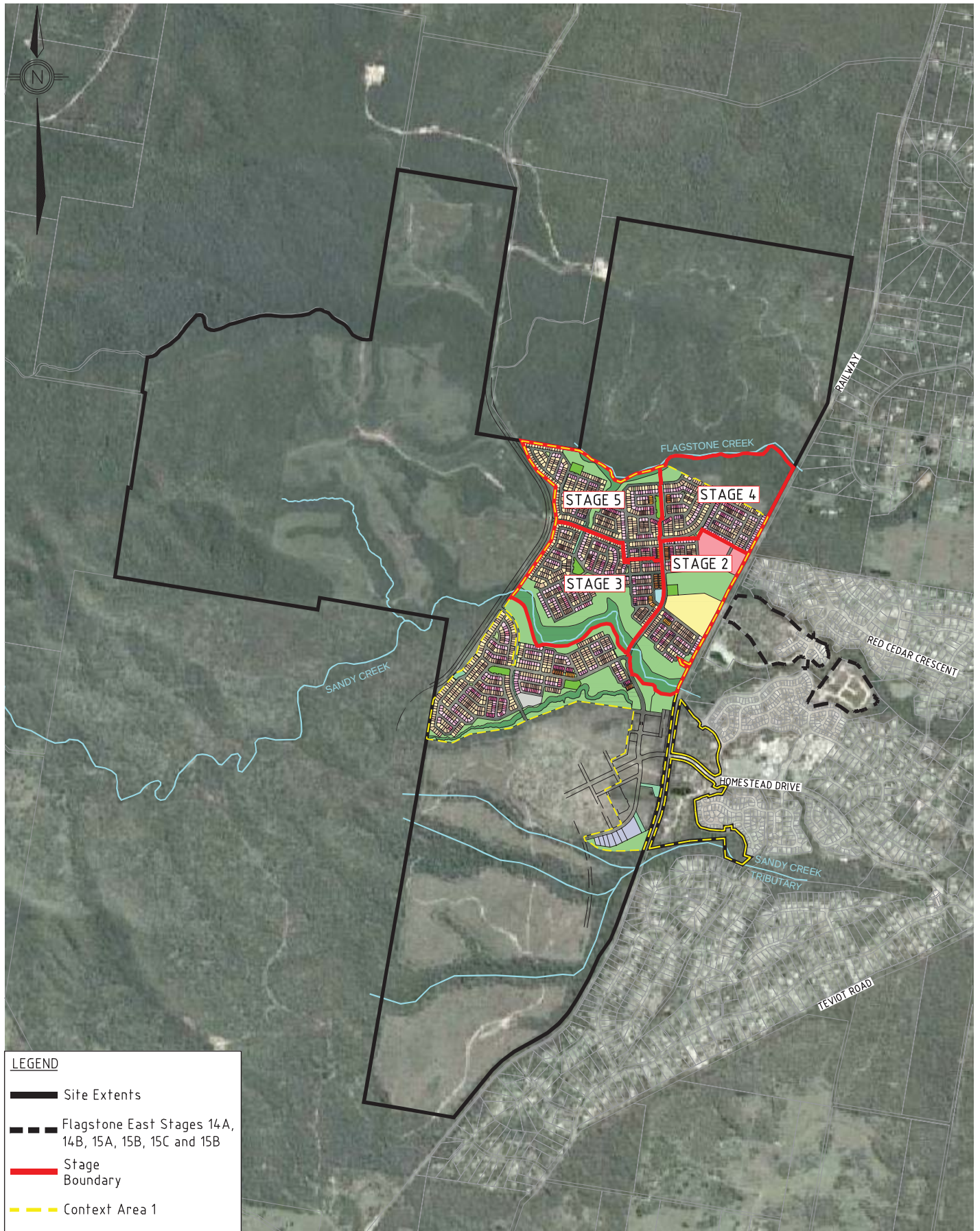
Healthy Waterways, 2009, '*Concept Design Guidelines for Water Sensitive Urban Design*'

Healthy Waterways, 2010, '*MUSIC Modelling Guidelines*' (Version 1.0)

Bligh Tanner and DesignFlow, 2009, '*Stormwater Infrastructure Options to Achieve Multiple Water Cycle Outcomes*' (report for Queensland Water Commission)

FIGURES

- Figure 1 Site Location and Layout Plan
- Figure 2 Stormwater Management Strategy
– Stage 2
- Figure 3 Stormwater Management Strategy
– Stage 3
- Figure 4 Stormwater Management
Strategy – Stage 4
- Figure 5 Stormwater Management
Strategy – Stage 5
- Figure 6 Catchment Plan – Stage 2
- Figure 7 Catchment Plan – Stage 3
- Figure 8 Catchment Plan – Stage 4
- Figure 9 Catchment Plan – Stage 5



Aerial image sourced from Google Earth

© Cardno (Qld) Pty Ltd All Rights Reserved 2012.
Copyright in the whole and every part of this drawing belongs to Cardno (Qld) Pty Ltd and may not be used, sold, transferred, copied or reproduced in whole or in part in any manner or form or on any media, to any person other than by agreement with Cardno (Qld) Pty Ltd.

This document is produced by Cardno (Qld) Pty Ltd solely for the benefit of and use by the client in accordance with the terms of the retainer. Cardno (Qld) Pty Ltd does not and shall not assume any responsibility or liability whatsoever to any third party arising out of any use or reliance by third party on the content of this document.

Rev: 0 | Drawn: J.M. | Checked: D.N. | Date: 24/07/2012

Peet Flagstone City Pty Ltd
CAD FILE: 0:\7217-43\Figures\VR8\Figure 1 - Site Location.dwg
XREF's: 110056-85-Proposal-WP 020812

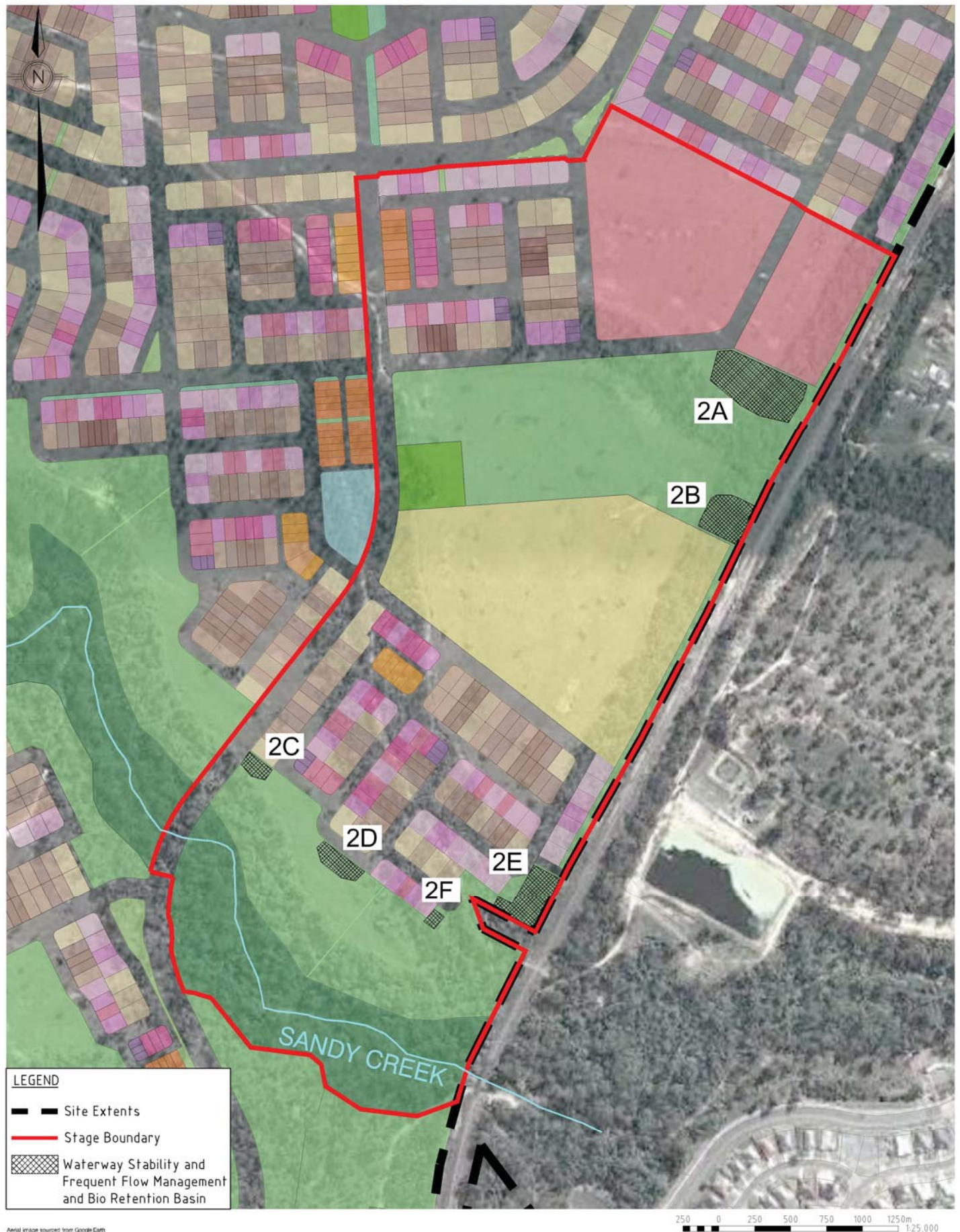
250 0 250 500 750 1000 1250m 1:25,000

Scale 1:25,000 (A3)

FIGURE 1
SITE LOCATION

Project No.: 7217/43

PRINT DATE: 13 August, 2012 - 4:46pm



Aerial image sourced from Google Earth

© Cardno (Qld) Pty Ltd All Rights Reserved 2012.

Copyright in the whole and every part of this drawing belongs to Cardno (Qld) Pty Ltd and may not be used, sold, transferred, copied or reproduced in whole or in part in any manner or form or on any media, to any person other than by agreement with Cardno (Qld) Pty Ltd.

This document is prepared by Cardno (Qld) Pty Ltd solely for the benefit of and use by the client in accordance with the terms of the relevant Cardno (Qld) Pty Ltd does not and shall not assume any responsibility or liability whatsoever to any third party arising out of any use or reliance by third party on the content of this document.

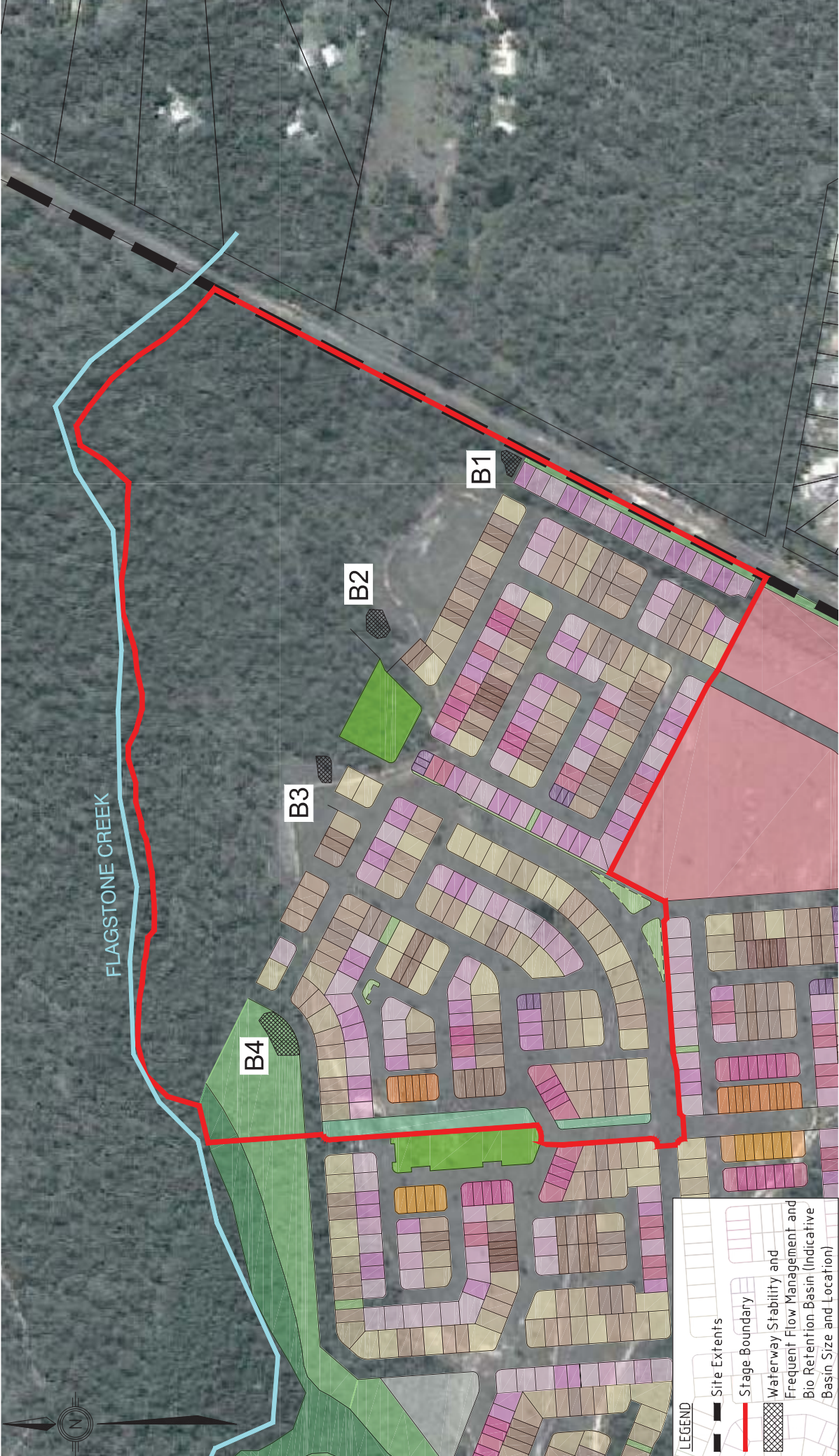
Rev: 0 | Drawn: J.M. | Checked: D.N. | Date: 24/07/2012

Peet Flagstone City Pty Ltd

(AD FILE: 0\7217-43\figures\R8\Figure 2 - Stormwater management strategy-Stage 2.dwg
XREF: 110156-85-Proposal-WP 020812)



- Notes:
- All buildings to include rainwater tanks sized to relevant code requirements
 - Indicative size and location of basins subject to detailed design

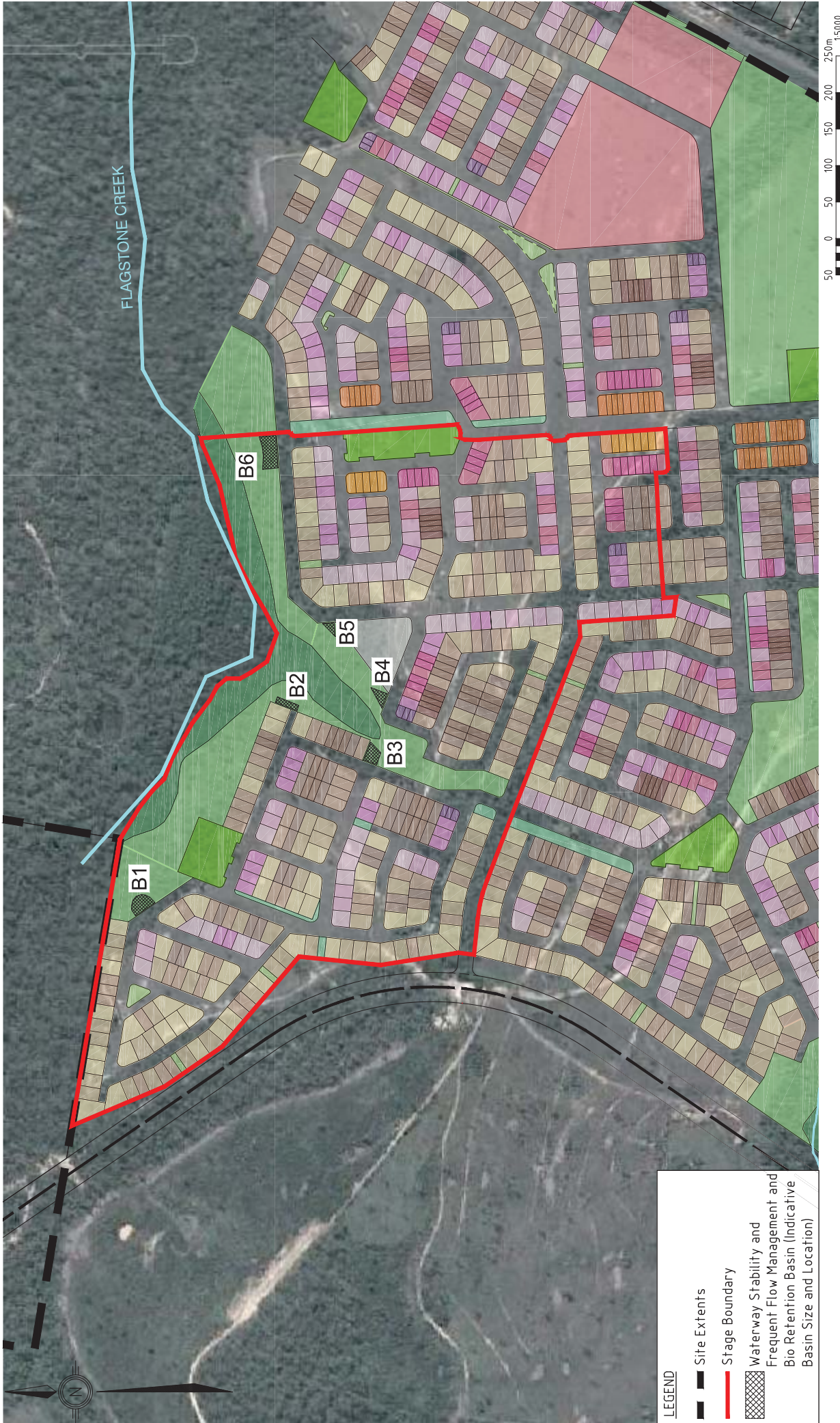


Scale 1:5,000 (A3)

STORMWATER MANAGEMENT STRATEGY - STAGE 4

FIGURE 4

- Notes:
- All buildings to include rainwater tanks sized to relevant code requirements
 - Indicative size and location of basins subject to detailed design



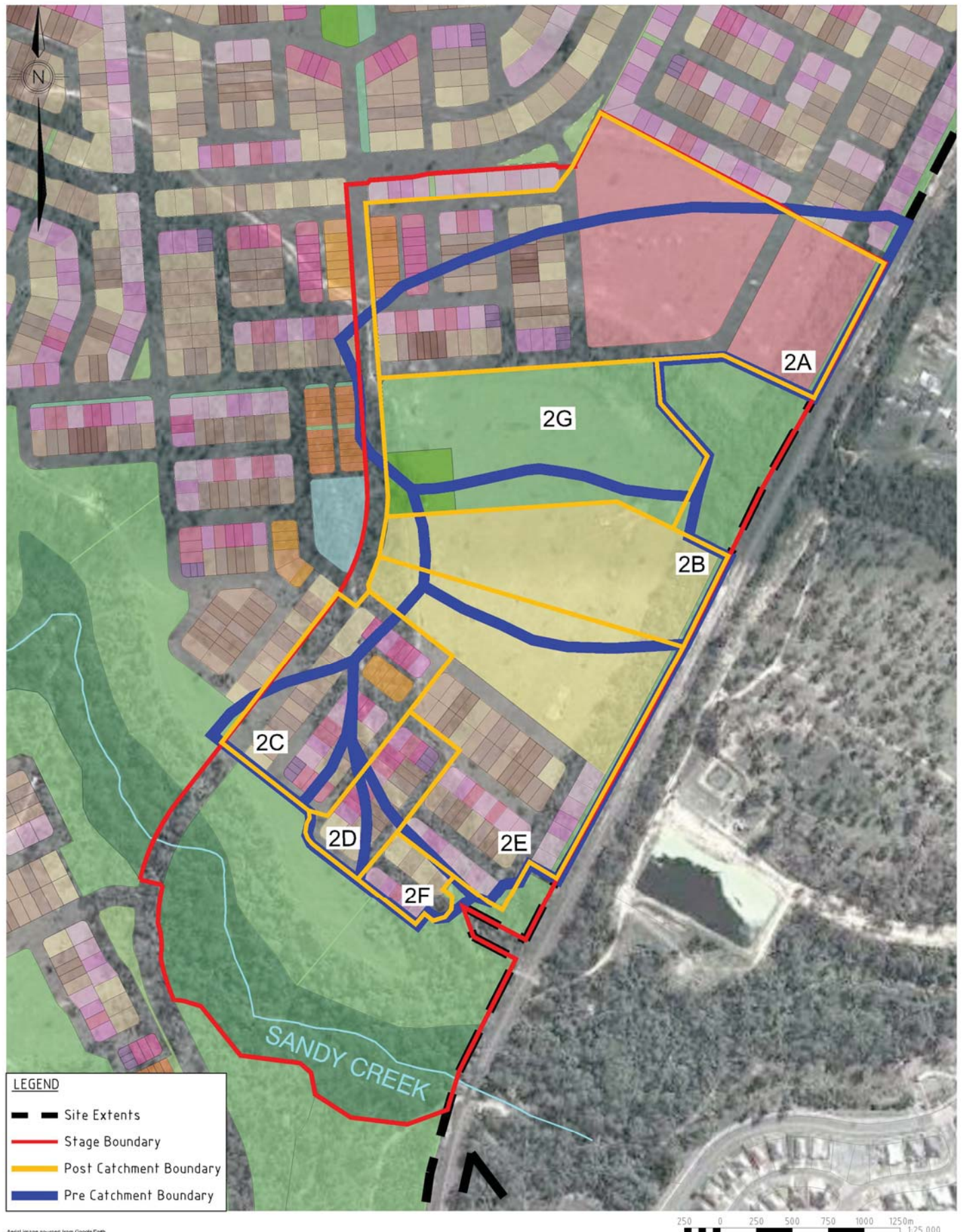
LEGEND

- Site Extents
- Stage Boundary
- Waterway Stability and Frequent Flow Management and Bio Retention Basin (Indicative Basin Size and Location)

- Notes:**
- All buildings to include rainwater tanks sized to relevant code requirements
 - Indicative size and location of basins subject to detailed design

Scale 1:5,000 (A3)

FIGURE 5 STORMWATER MANAGEMENT STRATEGY - STAGE 5



Aerial image sourced from Google Earth

© Cardno (Qld) Pty Ltd All Rights Reserved 2012.
Copyright in the whole and every part of this drawing belongs to Cardno (Qld) Pty Ltd and may not be used, sold, transferred, copied or reproduced in whole or in part in any manner or form or on any media, to any person other than by agreement with Cardno (Qld) Pty Ltd.

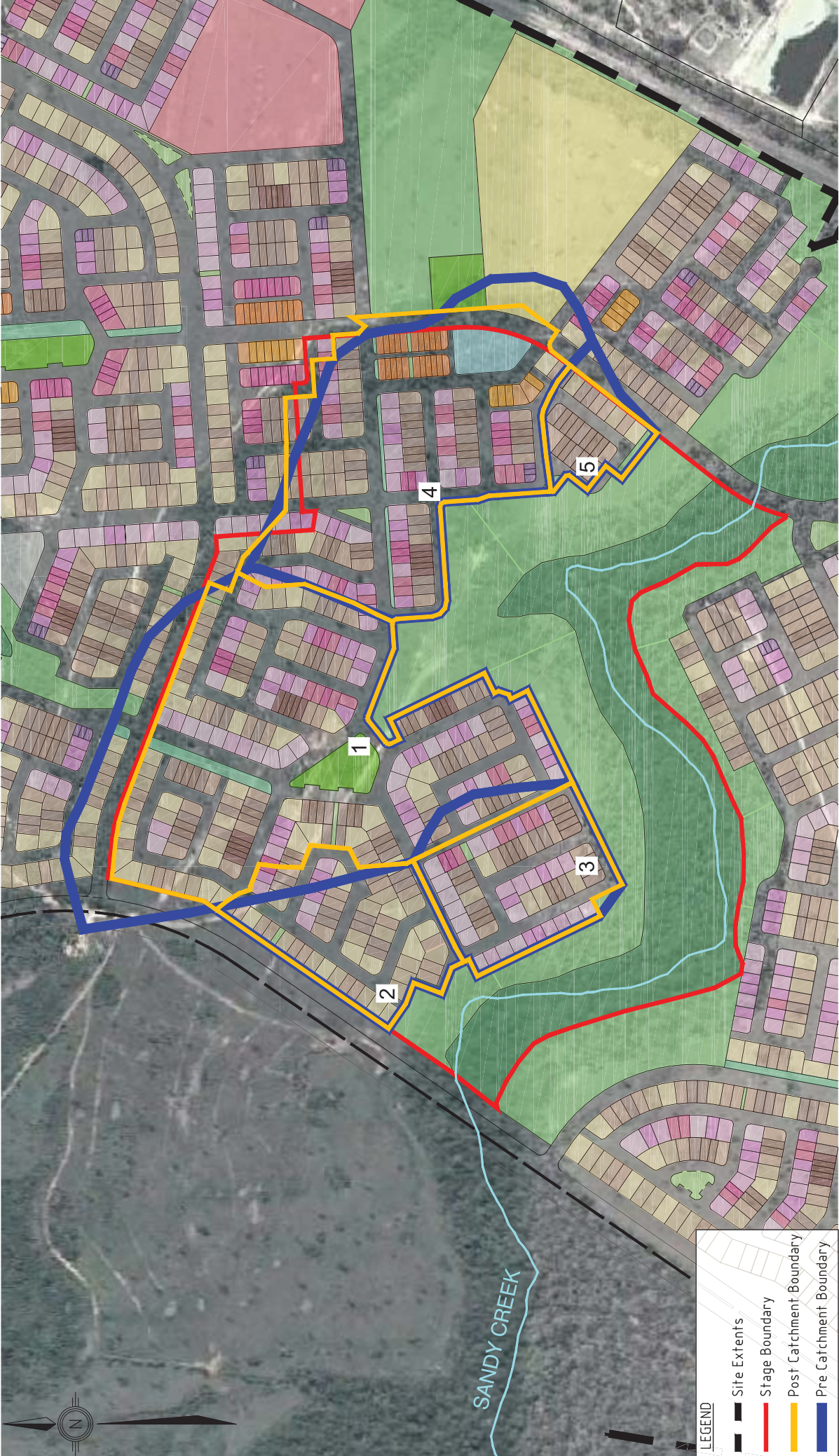
This document is produced by Cardno (Qld) Pty Ltd solely for the benefit of and use by the client in accordance with the terms of the retainer. Cardno (Qld) Pty Ltd does not and shall not assume any responsibility or liability whatsoever to any third party arising out of any use or reliance by third party on the content of this document.

Rev: 0 | Drawn: J.M. | Checked: D.N. | Date: 24/07/2012

Pest Flagstone City Pty Ltd

(A4 FILE: 0:\7217-43\figures\R8\Figure 6 - Catchment plan-Stage 2.dwg
XREF: 1:10056-85-Proposal-WP 020812)

FIGURE 6
CATCHMENT PLAN - STAGE 2
Project No.: 7217/43
PRINT DATE: 13 August, 2012 - 4:53pm



Aerial image sourced from Google Earth

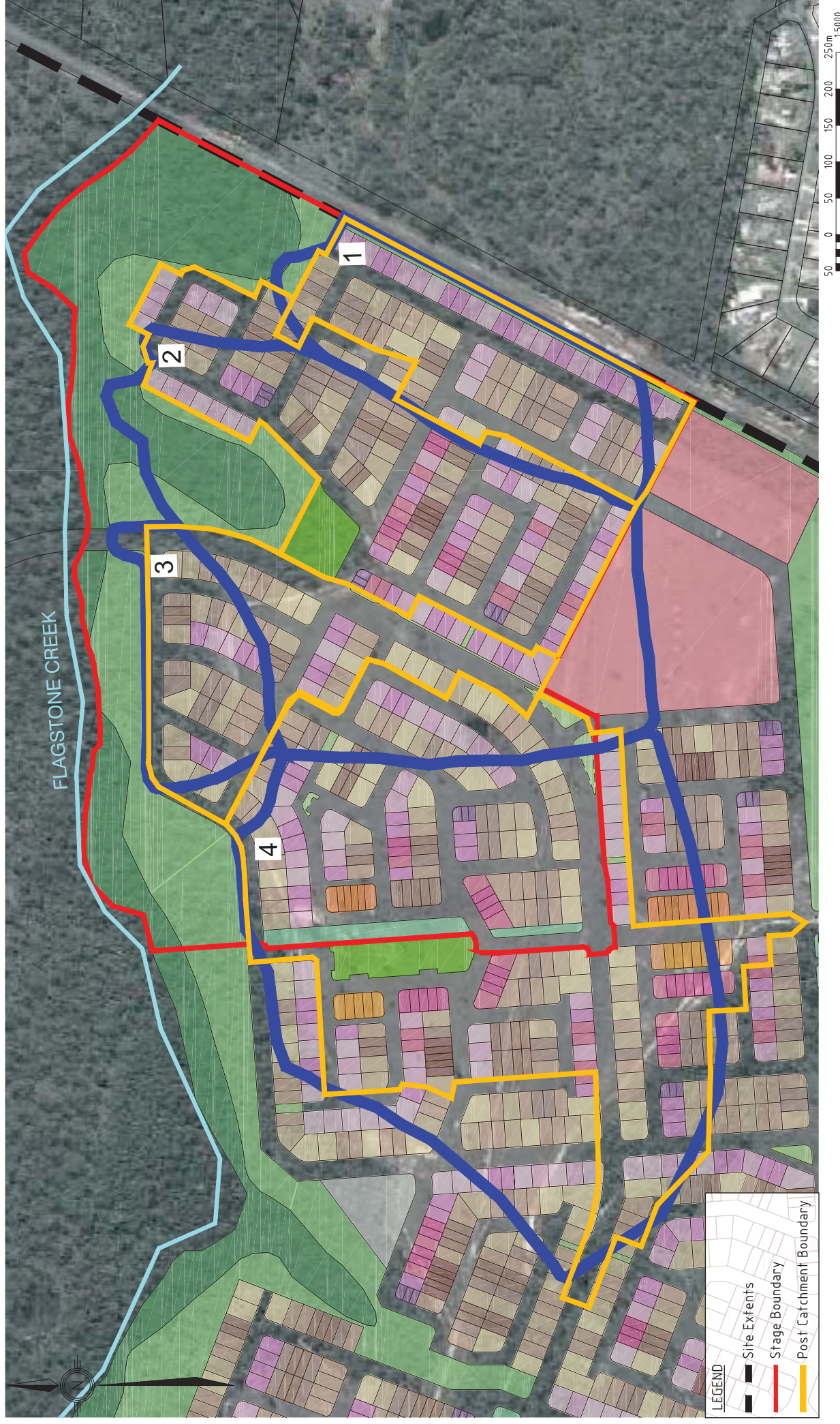
© Cardno (Qld) Pty Ltd All Rights Reserved 2012.
Copyright in the whole and every part of this drawing belongs to Cardno (Qld) Pty Ltd and no part of this drawing may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, or by any information storage or retrieval system, without the prior written permission of Cardno (Qld) Pty Ltd.

This document is produced by Cardno (Qld) Pty Ltd solely for the benefit of and use by the client in accordance with the terms of the relevant Cardno (Qld) Pty Ltd contract. It is not to be used for any other purpose, and no liability is accepted by Cardno (Qld) Pty Ltd for any use or reliance by third party on the content of this document.

Rev: 0 | Drawn: J.M. | Checked: D.N. | Date: 24/07/2012

Peet Flagstone City Pty Ltd
CAD FILE: 0.1071-43-Flagstone Stages 2 to 5 - Catchment plan-Stage 3.dwg
XREF: 10054-43-Proposed-WP 12002

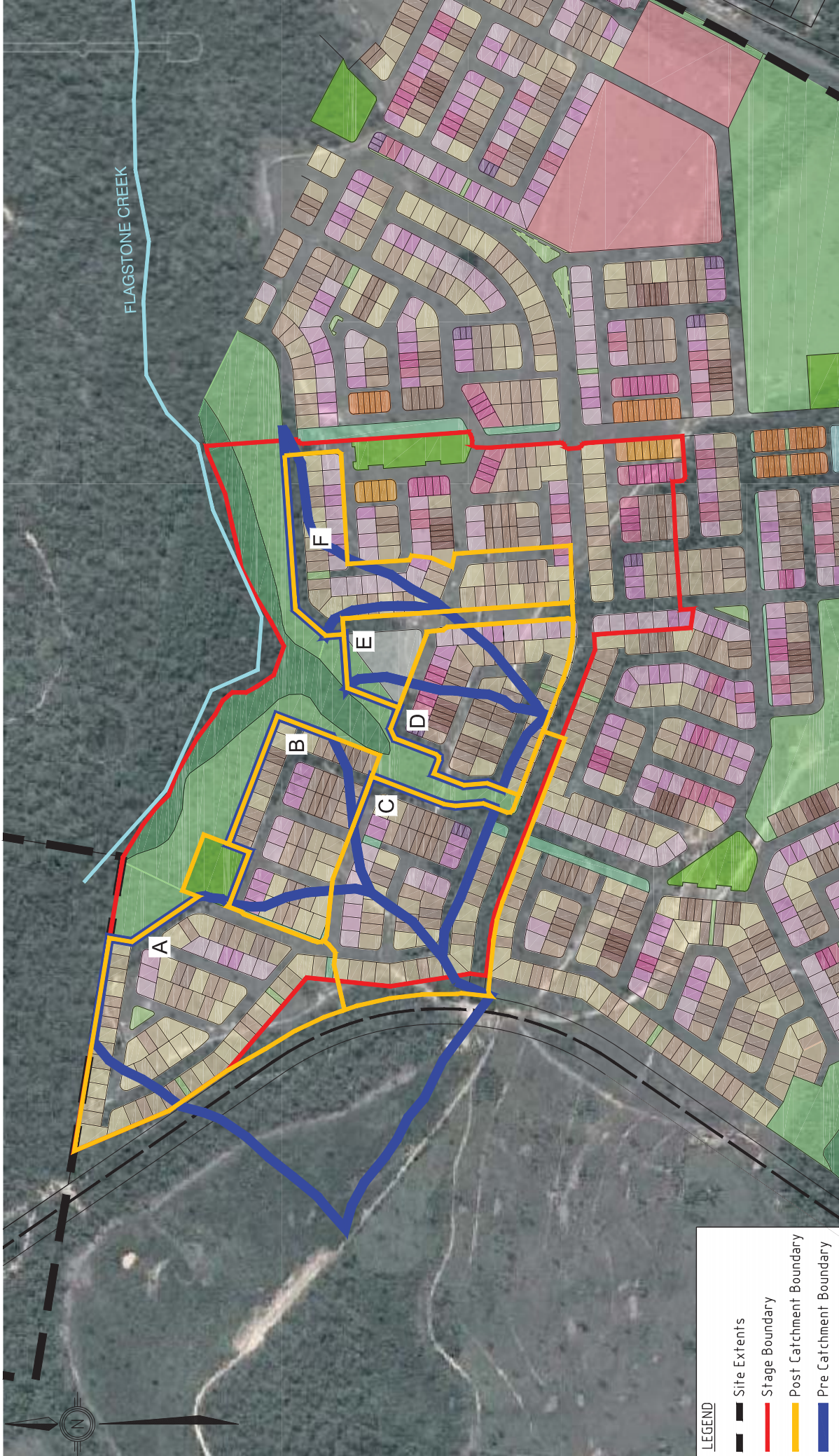
Scale 1:5,000 (A3)
FIGURE 7
CATCHMENT PLAN - STAGE 3
Project No.: 7217/43
PRINT DATE: 07 August, 2012 - 3:36pm



Aerial image sourced from Google Earth
© Cardno (Qld) Pty Ltd All Rights Reserved 2012.
Copyright in the whole and every part of this drawing belongs to Cardno (Qld) Pty Ltd and
no part of this drawing may be reproduced, stored in a retrieval system, or transmitted in
any form or by any means, electronic, mechanical, photocopying, recording, or by any
information storage or retrieval system, without the prior written permission of Cardno (Qld) Pty Ltd.
This document is produced by Cardno (Qld) Pty Ltd solely for the benefit of and use by
the client in accordance with the terms of the relevant Cardno (Qld) Pty Ltd contract. It
does not constitute an offer of any service or product, and no liability is accepted by
Cardno (Qld) Pty Ltd for any loss or damage, whether direct or indirect, arising out of
any use or reliance by third parties on the content of this document.

Rev: 0 | Drawn: J.M. | Checked: D.N. | Date: 24/07/2012
Peet Flagstone City Pty Ltd
CAD FILE: 01/0711-13/Flagstone/Stage 2 to 5 - Catchment plan-Stage 4.dwg
XREF: 10/05/14-15-Proposed-WP 10002

Scale 1:5,000 (A3)
FIGURE 8
CATCHMENT PLAN - STAGE 4
Project No.: 7217/43
PRINT DATE: 14 August, 2012 - 9:42am



LEGEND

Site Extents

Stage Boundary

Post Catchment Boundary

Pre Catchment Boundary

Aerial image sourced from Google Earth

© Cardno (Qld) Pty Ltd All Rights Reserved 2012.
Copyright in the whole and every part of this drawing belongs to Cardno (Qld) Pty Ltd and no part of this drawing may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, or by any information storage or retrieval system, without the prior written permission of Cardno (Qld) Pty Ltd.

This document is produced by Cardno (Qld) Pty Ltd solely for the benefit of and use by the client in accordance with the terms of the relevant Cardno (Qld) Pty Ltd does not warrant, represent or guarantee the accuracy, completeness or reliability of the information or any data or reliance by third party on the content of this document.

Rev: 0 | Drawn: J.M. | Checked: D.N. | Date: 24/07/2012

Peet Flagstone City Pty Ltd
CAD FILE: 0.17071-13 Figures\08 Figure 9 - Catchment Plan-Stage 5.dwg
REF: 10054-10-Proposed-WP 12002

Scale 1:5,000 (A3)
FIGURE 9
CATCHMENT PLAN - STAGE 5

Flagstone City - Stages 2 to 5

APPENDIX

A

Stormwater Management Plan

Stormwater Management Plan

Water Quality Management – Construction Phase

Issue:	Water Quality Management – Construction Phase
Operational Policy:	To provide a set of guidelines to control the severity and extent of erosion and pollutant transport during firstly the earthworks stage, and then construction.
Performance Criteria:	Water discharges off the site are to comply with the Environmental Protection Act to ensure that no detrimental impacts on water quality and aquatic environment occur during the construction phase. The quality of discharge from the site should not exceed the Water Quality Objectives, as follows: Release Criteria pH – 6.5 - 9.0 (range) Suspended Solids < 50mg/L (90th percentile). DO > 80 % saturation or 6 mg/L (90th percentile). Litter – no visible litter washed from site. Hydrocarbons - No visible sheen on receiving waters
Responsibility:	The owner of the property or their appointed representative & the Construction Contractor. The owner will be responsible for the implementation of the control measures and monitoring during the course of all construction activity.
Implementation Strategy:	A detailed erosion and sediment control plan is to be prepared by the project's civil engineers and will incorporate the following: Sediment and erosion control is to be in accordance with the Institution of Engineers Australia 'Soil Erosion and Sediment Control -Engineering Guidelines for Queensland Construction Site (June 1996)', The International Erosion Control Association 'Best Practice Erosion and Sediment Control (2008)' and current local best practice engineering and environmental management.
	Earthworks will be completed in stages with works restricted to the immediate areas.
	Subsequent stages of development should not commence if prior stages are affected by acid sulphate conditions &/or construction phase water quality objectives are not met.
	Prior to the commencement of any stage construction works temporary sediment basins are to be installed as per the details shown in the stages construction phase stormwater management strategy.
	All disturbed site discharge to pass through temporary sediment basins prior to discharge from the site.
Implementation Strategy (Cont'd):	Catch drains should be installed to divert upstream 'clean' water. Silt fences will be placed along the downstream extents of all earthworks. Check dams will be installed at regular intervals along catch drains.
	Drains and bund walls will be topsoiled and vegetated with suitable vegetation as soon as possible.
	Sediment and sludge trapped in the basins will be removed and mixed with topsoil and reused on site for landscaping purposes.
	Clean-up of general site litter on a weekly basis and after significant rainfall events. (>25mm/24hours)
	Landscaping activities and revegetation will occur as soon as possible during/after the construction phase of the development. Only appropriate herbicides and fertilisers are to be used.

Issue:	Water Quality Management – Construction Phase
Monitoring:	Sediment and erosion control measures will be inspected daily by the site manager during periods of rainfall. (>25mm/24hrs) Establishment and growth of vegetation – to be monitored monthly. No occurrence of excessive sediment deposit - to be monitored weekly or daily during periods of heavy rainfall (>25mm/24hrs). No release of construction material and silt from the site – to be monitored weekly or daily during periods of heavy rainfall (>25mm/24hrs). Vegetation established and growing prior to the rainy season. Erosion monitoring immediately following heavy rainfall. (>25mm) Inspection of silt fences and check dams following heavy rainfall. (>25mm/24hrs) Water quality monitoring shall be carried out following a rainfall event (>25mm of rainfall), and prior to discharge water quality monitoring will be conducted on the waters detained in the sediment basins and at the discharge point for the site. The parameters to be tested shall include: • Surface waters: Rainfall Event • Parameters: Temperature, dissolved oxygen, pH, specific conductance, salinity, turbidity, suspended solids and litter. • Water collected in basins: Prior to release • Parameters: pH, suspended solids. Note that additional water quality monitoring may be required if the WQOs are not being met.
Auditing:	Reviews are to be carried out on a monthly basis to assess the implementation strategy. A checklist is to be completed which assesses the strategies listed above.
Identification of Incident or Failure:	Non compliance with agreed performance criteria will be identified by: • Visual inspections identifying: • build up of sediment on and off the site. • Excessive erosion on the site • Release of construction material from the site • Lack of vegetation establishment • Poorly maintained, damaged or failed control devices. • Deteriorated water quality identified by the Environmental Consultant as being attributable to the construction activities.
Corrective Action:	After any identification of incident or failure, the source is to be located immediately and the following measures implemented: • If vegetation growth fails, new vegetation should be planted and established. Vegetation may require supplementary watering & replanting. • If silt fences fail, replace and monitor more frequently. • If gully erosion occurs, fill, vegetate and install velocity dissipation steps. If release of silt and other material off the site occurs, or water quality monitoring indicates levels not within the WQOs, clean up, inspect all treatment techniques, revise designs and review different alternatives and install, otherwise reduce the rate of excavation. If monitored levels within the sediment basins do not conform to the release criteria for: • Suspended solids: flocculate and retest. • pH: add acid if pH is too high or add hydrated lime if pH is too low and retest.

Issue:	Water Quality Management – Construction Phase
Reporting:	Reports will be submitted monthly during the construction of each stage. The reporting will include: • Construction Contractor site managers report; and • Environmental Consultant water quality monitoring report Reporting will identify performance of the implementation strategy, monitoring, identification of incidents/failure and associated corrective action. Reports will be submitted to the owner (or their appointed representative) monthly for submission to Council.

Water Quality Management Operational Phase

Issue:	Water Quality Management – Operational Phase
Operational Policy:	To provide a concise plan to ensure that the water quality in the waterways remain at an acceptable level as specified in the water quality objectives (WQOs) for the site at all times and to ensure that any waters discharged from the site are of an acceptable quality.
Performance Criteria:	Water discharges off the site should be of a quality, which ensures there is no detriment to the downstream environment. Performance criteria for the site are: - 80% reduction in sediment load; - 60% reduction in total phosphorus load; - 45% reduction in total nitrogen load; and - 90% reduction in gross pollutant load.
Responsibility:	The owner of the property or their appointed representative. The owner will be responsible for a period of 12 months after completion of construction.
Implementation Strategy:	A comprehensive conceptual stormwater runoff management system is proposed for the development, comprising local runoff water quality control. Local catchment runoff water quality control is achieved by: • Rainwater Tanks; and • Bio-retention Systems.
	These controls will: • trap coarse sediment and attached nutrients and heavy metals; and • remove nutrients;
	Periodical monitoring of erosion or sediment deposition within treatment devices.
Implementation Strategy (cont'd):	Periodic maintenance of vegetation within the treatment devices. Inspection of basin for clogging.
Monitoring:	Inspect outflow points from the stormwater outlets and treatment trains to ensure that there are no signs of erosive activity or significant sediment deposits. Monitoring shall include inspection of all treatment devices to ensure they are operating efficiently.
Auditing:	Reviews are to be carried out on a monthly basis to assess the implementation strategy. A checklist is to be completed which assesses the strategy against each of the monitoring points above.
Identification of Incident or Failure:	Non compliance with agreed performance criteria will be identified by: • Visual inspections identifying: • build up of sediment and litter on and off the site. • Excessive erosion on the site • Release of construction material from the site • Lack of vegetation establishment • Poorly maintained, damaged or failed control devices. • Deteriorated water quality identified by the Environmental Consultant as being attributable to the site operations.

Issue:	Water Quality Management – Operational Phase
Corrective Action:	Harvesting of vegetation within the bio-retention systems and re-establishment if vegetation is not healthy. If vegetation fails, new vegetation should be planted and established. Vegetation may require supplementary watering and replanting.
	If erosion occurs, fill, vegetated and/or install velocity dissipation. To be in accordance with the Institution of Engineers Australia '<i>Soil Erosion and Sediment Control -Engineering Guidelines for Queensland Construction Site (June 1996)</i>' and the International Erosion Control Association '<i>Best Practice Erosion and Sediment Control (2008)</i>'.
	If release of silt and other material off the site occurs, clean up, inspect all treatment techniques, revise designs and review different alternatives and install.
	If poor water quality continues to occur, inspect all treatment techniques, revise designs and review different alternatives and install.
Reporting:	An Inspection Report for all water quality monitoring shall be submitted to Council, following a monitoring campaign for up to 2 years after the construction phase.

Flagstone City - Stages 2 to 5

APPENDIX

B

Maintenance Plans

1 Introduction

Bio-retention systems are vegetated areas where runoff is filtered through a porous sandy loam filter media as it infiltrates through the system to an arrangement on perforated under-drains and flows to downstream waterways.

Runoff is allowed to temporarily pond to increase the volume of stormwater runoff treated through the bio-retention systems. The temporary ponding level is generally referred to as the extended detention depth.

To protect against possible scour of the bio-retention surface, high flows that exceed the design event are conveyed through an overflow pit or high-flow bypass channel.

2 Function

Bio-retention basins operate by filtering stormwater runoff through densely planted surface vegetation and percolating through a specified filter media. Pollutants within the stormwater runoff are retained through fine infiltration, adsorption and some biological uptake as the runoff percolates through the filter media. The vegetation in a bio-retention system is a vital functional element to the operational effectiveness of the bio-retention system, providing a substrate for biofilm growth within the upper layer of the bio-retention filter media and facilitates the transport of oxygen to the filter media enhancing soil microbiological communities and the biological transformation of pollutants.

Bio-retention basins are not intended to be an infiltration system that discharges the treated stormwater runoff into the surrounding in-situ soils. Bio-retention systems are generally designed to recover stormwater at the base of the filter media in the perforated under-drain and discharge to receiving waters. In order to accommodate this feature an impermeable geotextile fabric is placed between the in-situ soils of the bio-retention walls and base to limit exfiltration to the surrounding soils.

Bio-retention systems can be installed at various scales, including:

- Landscape planter boxes;
- Roadside rain gardens incorporating traffic calming measures;
- Within suburban Parks; and
- At the base of detention basins.

Generally in larger applications a pre-treatment swale or vegetated buffer area is incorporated upstream of the bio-retention system to minimise the maintenance frequency of the bio-retention system.

3 Construction and Establishment

Following the completion of the civil construction phase (i.e. bulk earthworks, roads and services) the site is opened for the build out of each of the individual lots. At this time the works are generally 'uncontrolled' as individual builders not associated with the developer will undertake the individual lot construction. Based on practical experience this stage is usually detrimental to the water quality management and establishment of the water quality treatment devices. The following details a recommended construction and establishment methodology for a bio-retention basin.

3.1 Functional Installation

The Functional Installation of a bio-retention basin occurs at the end of the bulk civil works (i.e bulk earthworks, installation of roads, water, sewage and power services) as part of the landscaping works. The functional installation involves:

- Bulking out and trimming (Basin excavation);
- Installation of the bio-retention basin outlet structures;
- Placement of a geo-textile fabric (between the in-situ basin bed and the drainage layer)
- Installation of the drainage layer and under-drain system;
- Placement of the transition layer and filter media;
- Installation of bio-retention inlet structures;
- Placement of a temporary protective management strategy (Refer to sediment and erosion details below).
- Placement of sediment fences around the boundary of the bio-retention basin to prevent silt entering the filter media and restrict access to the basin.
- The temporary protective management strategies are kept in place throughout the entire construction phase.

3.2 Sediment and Erosion Control

Sediment and Erosion Control involves the placement of temporary protective management strategies for the period where the upstream catchments are not in their final state and are contributing sediment / litter laden waters which may cause the filter media to clog.

3.3 Operational Establishment

Operational Establishment of the bio-retention basin occurs at the completion of the building phase of the development. Operational establishment includes the following works:

- Removal of all accumulated sediment from the sediment fore bay and the basin surface;
- Removal of the temporary turf, topsoil and geotextile fabric;
- Re-profile the bio-retention filter media surface;
- Vegetation of the bio-retention basin in accordance with the landscape design; and
- Regular watering of the vegetation and removal of weeds during the plant establishment phase (generally first two years).

4 Vegetation Establishment

Source: WSUD TDG SEQ 2006 Section 5.5.4

4.1 Weed Control

Conventional surface mulching of bio-retention basins with organic material like tanbark should not be undertaken. Most organic mulch floats and runoff typically causes this material to be washed away with risk of blocking outlet structures. Adopting high plant densities and where necessary applying a suitable biodegradable erosion control matting to the basin batters will help reduce the risk of weed invasion and limit labour intensive maintenance requirements for weed removal. A heavy application of seedless hydro-mulch can also provide short term erosion and weed control prior to planting with nursery stock. No matting or hydro-mulch should be applied to the surface of the bio-retention basin following the construction phase as this will hinder the filtration capacity of stormwater through the filter media.

4.2 Watering

Regular watering of the bio-retention basin vegetation is essential for successful establishment and healthy growth. The frequency of watering to achieve successful plant establishment is dependant upon rainfall, the maturity of the planting stock and the water holding capacity of the soil. The following watering program is generally adequate but should be adjusted (increased) to suit the site conditions:

- Weeks 1-2: 3 Watering campaigns per week;
- Weeks 3-6: 2 Watering campaigns per week; and
- Weeks 7-12: 1 Watering campaigns per week.

After this initial three month watering campaign, watering may still be required, particularly during the first winter (dry period). Watering requirements to sustain healthy vegetation should be determined during ongoing maintenance site visits.

5 Maintenance Requirements

Source: WSUD TDG SEQ 2006 Section 5.6

Vegetation plays a key role in maintaining the porosity of the filter media of a bio-retention basin and strong healthy growth of vegetation is critical to its performance. Therefore the most intensive period of maintenance is during the plant establishment period (first two years) when weed removal and replanting may be required.

Inflow systems and overflow pits require careful monitoring, as these can be prone to scour and litter build up. Debris can block inlets or outlets and can be unsightly, particularly in high visible areas. Inspection and removal of debris should be done regularly, and debris should be removed whenever it is observed on a site. Where sediment forebays are adopted, regular inspection of the forebay is required (3 monthly) with removal of accumulated sediment undertaken as required.

For larger bio-retention basins, it is essential that a maintenance access point is designed or and maintained in the bio-retention basin. The size and complexity of the system will guide its design and may involve provision of a reinforced concrete ramp/ pad for truck or machinery access.

Typical maintenance of bio-retention basin elements will involve:

- Routine inspection of the bio-retention basin profile to identify any areas of obvious increased sediment deposition, scouring from storms, rill erosion of the batters from lateral flows, damage to the profile from vehicles and clogging of the bio-retention basin (generally accompanied by a 'boggy' filter media surface);
- Routine inspection of inflow systems, overflow pits and under-drains to identify and clean any areas of scour, litter build up and blockages;
- Removal of sediment where it is smothering the bio-retention basin vegetation;
- Where a sediment fore bay is adopted, removal of accumulated sediment;
- Repairing any damage to the profile resulting from scour, rill erosion or vehicle damage by replacement of appropriate fill (to match on site soils) and revegetating;
- Tilling of the bio-retention basin surface or removal of the surface layer if there is evidence of clogging;
- Regular watering and irrigation of the basin vegetation until plants are established and actively growing;
- Removal and management of invasive weeds (herbicides should not be used);
- Removal of plants that have died and replacement with plants of equivalent size and species as detailed in the plant schedule;
- Pruning to remove dead or diseased vegetation material and stimulate growth;
- Monitoring and controlling vegetation pests;
- Inspections should be also conducted following any large storm event to check for scour and other damage;
- All maintenance should be carried out only after a reasonably rain free period when the soil in the bio-retention systems is dry; and
- All maintenance works are to be documented using the attached maintenance inspection form.

If a bio-retention system fails to drain adequately after tilling of the basin surface and other remedial maintenance, the bio-retention system may require resetting. Resetting involves the complete reconstruction of the bio-retention system.

5.1 Bio-Retention Typical Maintenance Schedule

SCHEDULE OF SITE VISITS													
Purpose of Visit	Frequency	J	F	M	A	M	J	J	A	S	O	N	D
Routine inspection	12/year	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Annual inspection	1/year				✓								
Routine maintenance	2/year				✓						✓		
Routine clean out of sediment	1 / 2 years				✓								

There are three phases to this maintenance plan which are:

- The establishment phase;
- The inspection and monitoring phase; and
- Cleanout and replacement phase

The above schedule is a guideline only. Routine clean out and maintenance should be scheduled based on the outcome of routine inspection.

ESTABLISHMENT	
1.1	The aim of the establishment phase is to ensure appropriate plant establishment within the bio-retention system through adequate weed control and watering.
1.2	Weed control during the establishment phase focuses on weed growth prevention rather than removal. By adopting high planting densities and if necessary, applying a suitable biodegradable erosion control matting to the basin batters.
1.3	Regular watering of the bio-retention basin vegetation is essential for successful establishment of the selected plants. Each site will need specific watering requirements but as a guide during the first two weeks there will need to be three visits each week, after this (weeks 3-6) there will need to be two visits each week. The third and final period of establishment maintenance (weeks 7-12) there is only one visit each week required. The Bio-retention Basin Maintenance Checklist provides the schedule of visits and a tick box to help monitor what stage of the establishment phase they are in and provides a record as to whether proper establishment has occurred.
INSPECTION	
1.	Routine Inspection
1.1	Routine inspection should be carried out on a regular monthly basis. The purpose of the inspection is to indicate when maintenance of the Bio-retention system is required.
1.2	Inspections should consider items listed on the Bio-retention Basin Maintenance Checklist
2.	Event Inspection
2.1	Following bushfires the bio-retention system shall be inspected for damage to the structure, vegetation and filter media.
2.2	After any significant rainfall events the bio-retention system shall be inspected for damage to the structure, vegetation and filter media.
ROUTINE MAINTENANCE	
1.	Purpose
1.1	Maintenance of the bio retention system involves routine inspections of the bio-retention basin profile to identify any areas of obvious increased sediment deposition or scouring. Based on inspections there should be actions taken to remove dead or diseased vegetation, any litter or foreign objects. Filter Media replacement should occur when necessary and any items from checklist that are noted are to be reported to the site manager.

2.	Weed Management
2.1	If weeds have been observed during routine inspection, these weeds should be removed from the bio retention system. Weeding generally involves manual removal of perennial species.
2.2	The aim is to remove the weed including the roots when the weeds are less than 3 months old, otherwise weeds infestation rapidly occurs and is difficult to control.
2.3	Herbicides should not be used as they would contaminate the water in the creek.
2.4	The weeds should be disposed offsite at appropriate waste management facility.
2.5	Replant appropriate plant species, where necessary, in areas that have been extensively weeded.
3.	Litter Management
3.1	Remove and dispose of litter that may be visible around the bio retention system.
4.	Dead or Diseased Vegetation
4.1	Remove or dispose of any dead or diseased vegetation within system.
5.	Filter Media Replacement
5.1	Filter Media replacement is recommended when erosion is evident or system looks unattractive or is not draining in 30 days. Conventional surface mulching with organic material like tank bark, should not be undertaken as most mulch floats and is washed away.
6.	Structural Integrity
6.1	Report any damage to the structure immediately to the civil engineer
6.2	Report significant scour to the civil engineer
6.3	Ensure that the system is draining correctly via visual inspection of a rainfall event. If poor drainage is observed then inspect the outlet pipe for blockage. If the drainage is still poor then contact the civil engineer and arrange for a permeability test to ensure replacement of filter material is not clogged.
EVENT MAINTENANCE	
1.	Purpose
1.1	Event Maintenance of the bio retention system involves undertaking any maintenance to the bio-retention system following an event. Based on the event inspections there should be actions taken to remove dead or diseased vegetation, any litter or foreign objects. Filter Media replacement should occur when necessary and any items from checklist that are noted are to be reported to the site manager. Maintenance is in accordance with the Routine Maintenance guidelines listed above.
CLEANOUT AND REPLACEMENT OF SEDIMENT	
1.	Setup and Prepare Site for Cleanout
1.1	Notify adjacent residents of cleanout at least three days prior to date of cleanout.
1.2	Setup equipment onsite.
2.	Cleanout of Sediment
2.1	The preferred method of cleanout of the bio-retention system is replacing the clogged medium.
2.2	Position the equipment on the side of the system to allow easy access into the bio retention system and transfer of material into adjacent tipper truck. The truck should be positioned so that water from the truck body drains into the bio retention system.
2.3	Drain waste in the truck thoroughly before proceeding to the disposal point.

Flagstone City - Stages 2 to 5

APPENDIX

B1.1

Bio-retention Construction Inspection
Checklist

BIO-RETENTION BASIN CONSTRUCTION INSPECTION CHECKLIST									
Asset ID:					Inspected By:				
					Date:				
Site:					Time:				
					Weather:				
Constructed By:					Site Manager:				
Items Inspected	Checked		Satisfactory		Items Inspected	Checked		Satisfactory	
	Y	N	Y	N		Y	N	Y	N
CONSTRUCTION AND ESTABLISHMENT PHASE									
A). FUNCTIONAL INSTALLATION					Structural Components				
Preliminary Works					15). Location and configuration of inflow systems as detailed in plans				
1). Erosion and sediment control plan adopted					16). Location and levels of overflow pits as detailed in plans				
2). Temporary traffic / safety control measures					17). Under-drain connected to overflow pits as detailed in plans				
3). Location as detailed in plans					18). Concrete and reinforcement as detailed in plans				
4). Basin protected from site runoff					19). Set down to correct level for flush kerbs (rain gardens only)				
Earthworks and Filter Media					20). Kerb opening width as detailed in plans (rain garden only)				
5). Basin bed surface correct shape and slope as detailed in plans									
6). Side slope batters as detailed in plans					B). SEDIMENT AND EROSION CONTROL				
7). Bio-retention dimensions and area as detailed in plans					21). Stabilisation immediately following earthworks and planting of terrestrial landscape around basin				
8). Confirm surrounding soils type with design					22). Silt fences and traffic controls in place				
9). Confirm filter media specifications in accordance with latest FAWB Guidelines					23). Temporary protective turf and topsoil in place				
10). Geotextile fabric placed between in-situ soils and filter media (base and walls)									
11). Under-drain installed as detailed in plans					C). OPERATIONAL ESTABLISHMENT				
12). Drainage layer media as specified					24). Sediment removed from fore bay area				
13). Transition layer media as specified					25). Temporary protective turf, topsoil and geotextile fabric removed				
14). Extended detention depth as detailed in plans					Vegetation				
					26). Planting as designed (species and density)				
					27). Weed removal and watering as required				
FINAL INSPECTION									
1). Confirm levels of the inlets and outlets					6). Check for uneven settling of banks				
2). Confirm structural element sizes					7). Confirm under-drain operational and working				
3). Check side batter slopes					8). Confirm inflow systems operational and working				
4). Check vegetation as designed					9). Confirm maintenance access is provided				
5). Check bio-retention filter media surface flat and free of clogging									
COMMENTS ON INSPECTION									
ACTIONS REQUIRED									
Inspection Officer's Signature:									

Flagstone City - Stages 2 to 5

APPENDIX

B1.2

Bio-retention Maintenance Checklist

BIO-RETENTION BASIN MAINTENANCE CHECKLIST

Asset ID:		Inspected By:	
		Date:	
Site:		Time:	
		Weather:	
Constructed By:		Site Manager:	

Items Inspected	Checked		Satisfactory		Action Required
	Y	N	Y	N	
Sediment accumulation an inflow locations?					
Litter within the basin?					
Erosion at inlet or other key structures?					
Traffic / Vehicle damage present?					
Evidence of illegal dumping (e.g. building waste)?					
Vegetation condition satisfactory (density, weeds etc.)					
Watering of vegetation required?					
Replanting require?					
Mowing / Slashing required?					
Clogging of drainage points (sediment or debris)?					
Evidence of ponding?					
Damage / Vandalism to structures present?					
Surface clogging visible?					
Drainage system inspected?					
Resetting of system require?					

COMMENTS ON INSPECTION**ACTIONS REQUIRED**

Inspection Officer's Signature:

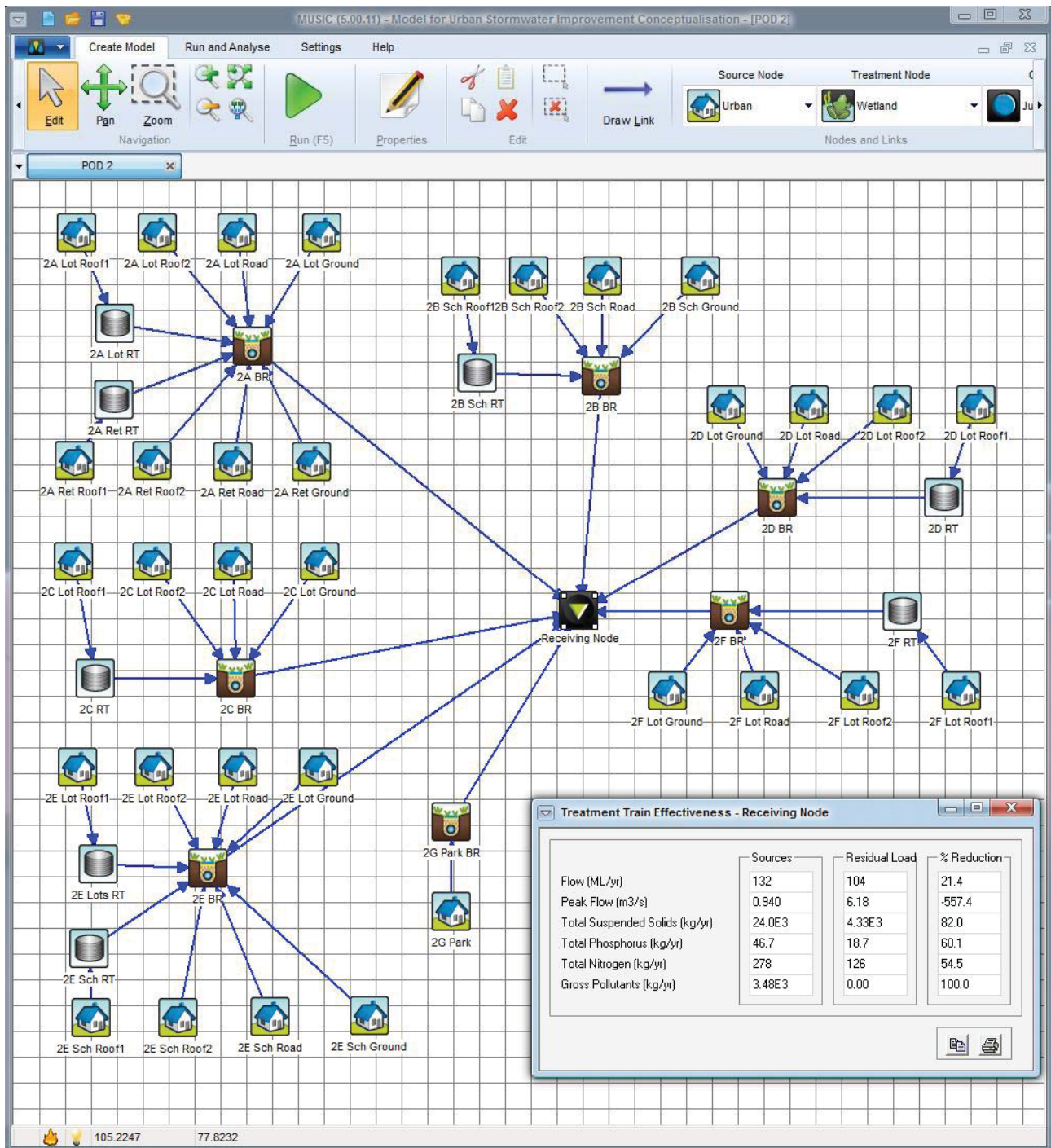
Flagstone City - Stages 2 to 5

APPENDIX

C.1

MUSIC Model Schematic and Parameters
– Stage 2

MUSIC Schematic



MUSIC Parameters (excerpts from Healthy Waterways 'MUSIC Modelling Guidelines' (Version 1.0 2010))

Table 3.5 Typical impervious fraction for split catchment land use (read with Table 3.3)⁷

DEVELOPMENT TYPE	SURFACE TYPE IMPERVIOUS FRACTION (%)		
	ROAD RESERVE	ROOF	GROUND LEVEL
Residential 10 dwellings/ha	60	100	15
Residential 15 dwellings/ha	60	100	20
Residential 40 dwellings/ha	70	100	30
Residential 80+ dwellings/ha	80	100	50
Industrial	75	100	60
Commercial	75	100	80

Table 3.7 Recommended MUSIC rainfall-runoff parameters⁹

PARAMETER	LAND USE			
	URBAN RESIDENTIAL	COMMERCIAL AND INDUSTRIAL	RURAL RESIDENTIAL	FORESTED
Rainfall threshold (mm)	1	1	1	1
Soil storage capacity (mm)	500 ¹⁰	18	98	120
Initial storage (% capacity)	10	10	10	10
Field capacity (mm)	200	80	80	80
Infiltration capacity coefficient a	211	243	84	200
Infiltration capacity exponent b	5.0	0.6	3.3	1.0
Initial depth (mm)	50	50	50	50
Daily recharge rate (%)	28	0	100	25
Daily baseflow rate (%)	27	31	22	3
Daily deep seepage rate (%)	0	0	0	0

Table 3.8 Pollutant export parameters for split catchment land use (log¹⁰ values)

FLOW TYPE	SURFACE TYPE	TSS log ¹⁰ values		TP log ¹⁰ values		TN log ¹⁰ values	
		Mean	St. dev.	Mean	St. dev.	Mean	St. dev.
Urban residential							
Baseflow parameters	Roof	N/A	N/A	N/A	N/A	N/A	N/A
	Roads	1.00	0.34	-0.97	0.31	0.20	0.20
	Ground level	1.00	0.34	-0.97	0.31	0.20	0.20
Stormflow parameters	Roof	1.30	0.39	-0.89	0.31	0.26	0.23
	Roads	2.43	0.39	-0.30	0.31	0.26	0.23
	Ground level	2.18	0.39	-0.47	0.31	0.26	0.23
Industrial							
Baseflow parameters	Roof	N/A	N/A	N/A	N/A	N/A	N/A
	Roads	0.78	0.45	-1.11	0.48	0.14	0.20
	Ground level	0.78	0.45	-1.11	0.48	0.14	0.20
Stormflow parameters	Roof	1.30	0.44	-0.89	0.36	0.25	0.32
	Roads	2.43	0.44	-0.30	0.36	0.25	0.32
	Ground level	1.92	0.44	-0.59	0.36	0.25	0.32
Commercial							
Baseflow parameters	Roof	N/A	N/A	N/A	N/A	N/A	N/A
	Roads	0.78	0.39	-0.60	0.50	0.32	0.30
	Ground level	0.78	0.39	-0.60	0.50	0.32	0.30
Stormflow parameters	Roof	1.30	0.38	-0.89	0.34	0.37	0.34
	Roads	2.43	0.38	-0.30	0.34	0.37	0.34
	Ground level	2.16	0.38	-0.39	0.34	0.37	0.34

Table 3.9 Pollutant export parameters for lumped catchment land uses (log¹⁰ values)

LANDUSE	FLOW TYPE	TSS log ¹⁰ values		TP log ¹⁰ values		TN log ¹⁰ values	
		Mean	St. dev.	Mean	St. dev.	Mean	St. dev.
Urban residential	Baseflow	1.00	0.34	-0.97	0.31	0.20	0.20
	Stormflow	2.18	0.39	-0.47	0.32	0.26	0.23
Industrial	Baseflow	0.78	0.45	-1.11	0.48	0.14	0.20
	Stormflow	1.92	0.44	-0.59	0.36	0.25	0.32
Commercial	Baseflow	0.78	0.39	-0.60	0.50	0.32	0.30
	Stormflow	2.16	0.38	-0.39	0.34	0.37	0.34
Rural residential	Baseflow	0.53	0.24	-1.54	0.38	-0.52	0.39
	Stormflow	2.26	0.51	-0.56	0.28	0.32	0.30
Forest	Baseflow	0.51	0.28	-1.79	0.28	-0.59	0.22
	Stormflow	1.90	0.20	-1.10	0.22	-0.075	0.24
Agriculture	Baseflow	1.00	0.13	-1.155	0.13	-0.155	0.13
	Stormflow	2.477	0.31	-0.495	0.30	0.29	0.26

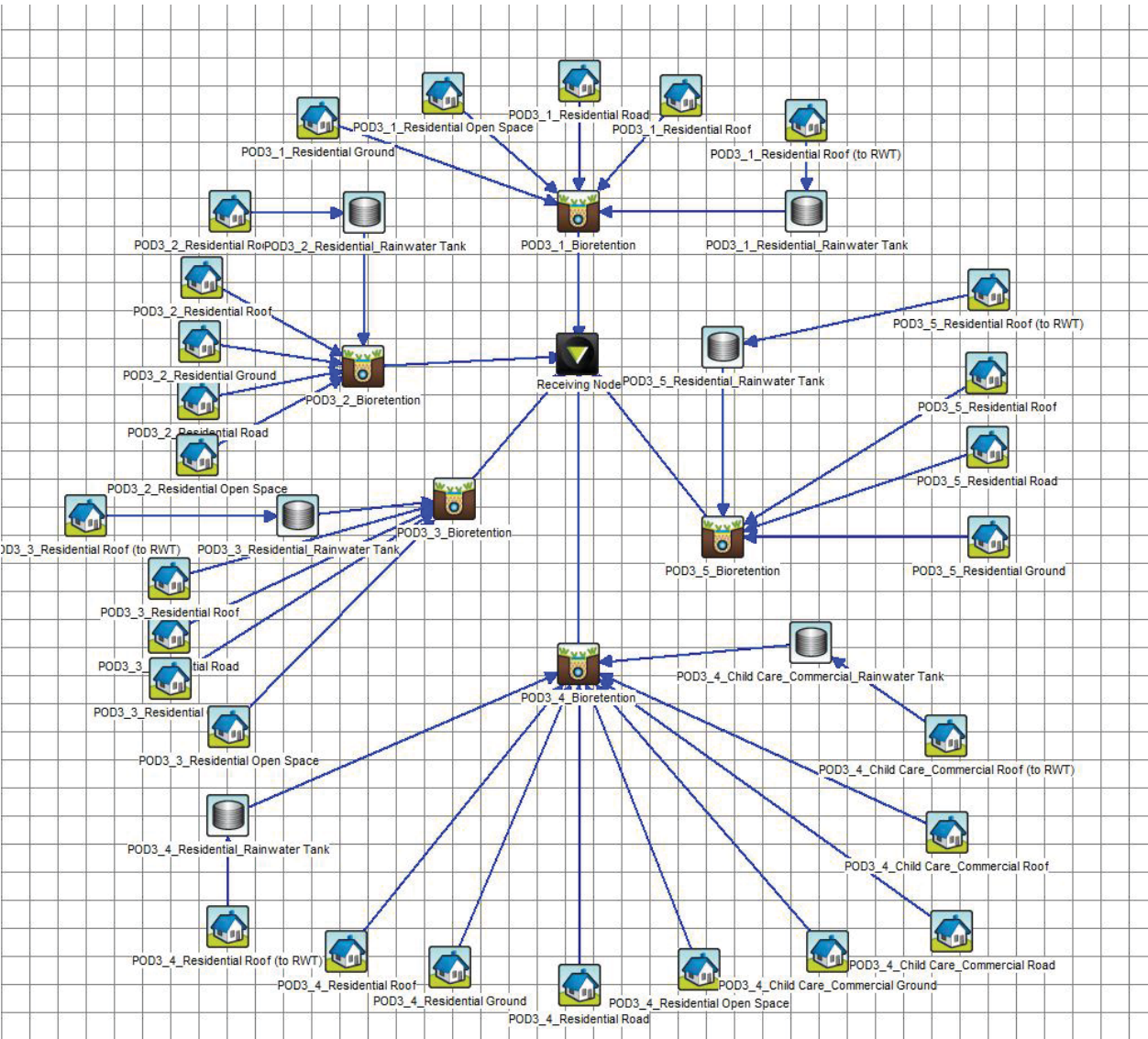
Flagstone City - Stages 2 to 5

APPENDIX

C.2

MUSIC Model Schematic and Parameters
– Stage 3

MUSIC Schematic



MUSIC Parameters (excerpts from Healthy Waterways ‘MUSIC Modelling Guidelines’ (Version 1.0 2010))

Table 3.5 Typical impervious fraction for split catchment land use (read with Table 3.3)⁷

DEVELOPMENT TYPE	SURFACE TYPE IMPERVIOUS FRACTION (%)		
	ROAD RESERVE	ROOF	GROUND LEVEL
Residential 10 dwellings/ha	60	100	15
Residential 15 dwellings/ha	60	100	20
Residential 40 dwellings/ha	70	100	30
Residential 80+ dwellings/ha	80	100	50
Industrial	75	100	60
Commercial	75	100	80

Table 3.7 Recommended MUSIC rainfall-runoff parameters⁹

PARAMETER	LAND USE			
	URBAN RESIDENTIAL	COMMERCIAL AND INDUSTRIAL	RURAL RESIDENTIAL	FORESTED
Rainfall threshold (mm)	1	1	1	1
Soil storage capacity (mm)	500 ¹⁰	18	98	120
Initial storage (% capacity)	10	10	10	10
Field capacity (mm)	200	80	80	80
Infiltration capacity coefficient a	211	243	84	200
Infiltration capacity exponent b	5.0	0.6	3.3	1.0
Initial depth (mm)	50	50	50	50
Daily recharge rate (%)	28	0	100	25
Daily baseflow rate (%)	27	31	22	3
Daily deep seepage rate (%)	0	0	0	0

Table 3.8 Pollutant export parameters for split catchment land use (log¹⁰ values)

FLOW TYPE	SURFACE TYPE	TSS log ¹⁰ values		TP log ¹⁰ values		TN log ¹⁰ values	
		Mean	St. dev.	Mean	St. dev.	Mean	St. dev.
Urban residential							
Baseflow parameters	Roof	N/A	N/A	N/A	N/A	N/A	N/A
	Roads	1.00	0.34	-0.97	0.31	0.20	0.20
	Ground level	1.00	0.34	-0.97	0.31	0.20	0.20
Stormflow parameters	Roof	1.30	0.39	-0.89	0.31	0.26	0.23
	Roads	2.43	0.39	-0.30	0.31	0.26	0.23
	Ground level	2.18	0.39	-0.47	0.31	0.26	0.23
Industrial							
Baseflow parameters	Roof	N/A	N/A	N/A	N/A	N/A	N/A
	Roads	0.78	0.45	-1.11	0.48	0.14	0.20
	Ground level	0.78	0.45	-1.11	0.48	0.14	0.20
Stormflow parameters	Roof	1.30	0.44	-0.89	0.36	0.25	0.32
	Roads	2.43	0.44	-0.30	0.36	0.25	0.32
	Ground level	1.92	0.44	-0.59	0.36	0.25	0.32
Commercial							
Baseflow parameters	Roof	N/A	N/A	N/A	N/A	N/A	N/A
	Roads	0.78	0.39	-0.60	0.50	0.32	0.30
	Ground level	0.78	0.39	-0.60	0.50	0.32	0.30
Stormflow parameters	Roof	1.30	0.38	-0.89	0.34	0.37	0.34
	Roads	2.43	0.38	-0.30	0.34	0.37	0.34
	Ground level	2.16	0.38	-0.39	0.34	0.37	0.34

Table 3.9 Pollutant export parameters for lumped catchment land uses (log¹⁰ values)

LANDUSE	FLOW TYPE	TSS log ¹⁰ values		TP log ¹⁰ values		TN log ¹⁰ values	
		Mean	St. dev.	Mean	St. dev.	Mean	St. dev.
Urban residential	Baseflow	1.00	0.34	-0.97	0.31	0.20	0.20
	Stormflow	2.18	0.39	-0.47	0.32	0.26	0.23
Industrial	Baseflow	0.78	0.45	-1.11	0.48	0.14	0.20
	Stormflow	1.92	0.44	-0.59	0.36	0.25	0.32
Commercial	Baseflow	0.78	0.39	-0.60	0.50	0.32	0.30
	Stormflow	2.16	0.38	-0.39	0.34	0.37	0.34
Rural residential	Baseflow	0.53	0.24	-1.54	0.38	-0.52	0.39
	Stormflow	2.26	0.51	-0.56	0.28	0.32	0.30
Forest	Baseflow	0.51	0.28	-1.79	0.28	-0.59	0.22
	Stormflow	1.90	0.20	-1.10	0.22	-0.075	0.24
Agriculture	Baseflow	1.00	0.13	-1.155	0.13	-0.155	0.13
	Stormflow	2.477	0.31	-0.495	0.30	0.29	0.26

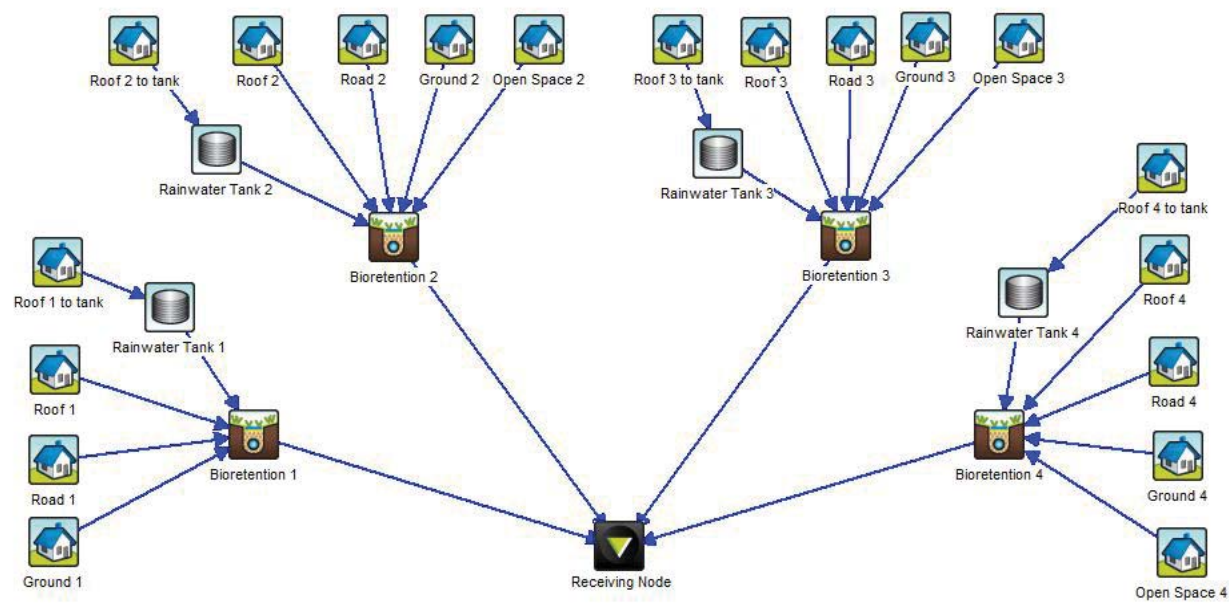
Flagstone City - Stages 2 to 5

APPENDIX

C.3

MUSIC Model Schematic and Parameters
– Stage 4

MUSIC Schematic



**MUSIC Parameters (excerpts from Healthy Waterways 'MUSIC Modelling Guidelines'
(Version 1.0 2010))**

**Table 3.5 Typical impervious fraction for split catchment land use
(read with Table 3.3)⁷**

DEVELOPMENT TYPE	SURFACE TYPE IMPERVIOUS FRACTION (%)		
	ROAD RESERVE	ROOF	GROUND LEVEL
Residential 10 dwellings/ha	60	100	15
Residential 15 dwellings/ha	60	100	20
Residential 40 dwellings/ha	70	100	30
Residential 80+ dwellings/ha	80	100	50
Industrial	75	100	60
Commercial	75	100	80

Table 3.7 Recommended MUSIC rainfall-runoff parameters⁹

PARAMETER	LAND USE			
	URBAN RESIDENTIAL	COMMERCIAL AND INDUSTRIAL	RURAL RESIDENTIAL	FORESTED
Rainfall threshold (mm)	1	1	1	1
Soil storage capacity (mm)	500 ¹⁰	18	98	120
Initial storage (% capacity)	10	10	10	10
Field capacity (mm)	200	80	80	80
Infiltration capacity coefficient a	211	243	84	200
Infiltration capacity exponent b	5.0	0.6	3.3	1.0
Initial depth (mm)	50	50	50	50
Daily recharge rate (%)	28	0	100	25
Daily baseflow rate (%)	27	31	22	3
Daily deep seepage rate (%)	0	0	0	0

Table 3.8 Pollutant export parameters for split catchment land use (log¹⁰ values)

FLOW TYPE	SURFACE TYPE	TSS log ¹⁰ values		TP log ¹⁰ values		TN log ¹⁰ values	
		Mean	St. dev.	Mean	St. dev.	Mean	St. dev.
Urban residential							
Baseflow parameters	Roof	N/A	N/A	N/A	N/A	N/A	N/A
	Roads	1.00	0.34	-0.97	0.31	0.20	0.20
	Ground level	1.00	0.34	-0.97	0.31	0.20	0.20
Stormflow parameters	Roof	1.30	0.39	-0.89	0.31	0.26	0.23
	Roads	2.43	0.39	-0.30	0.31	0.26	0.23
	Ground level	2.18	0.39	-0.47	0.31	0.26	0.23
Industrial							
Baseflow parameters	Roof	N/A	N/A	N/A	N/A	N/A	N/A
	Roads	0.78	0.45	-1.11	0.48	0.14	0.20
	Ground level	0.78	0.45	-1.11	0.48	0.14	0.20
Stormflow parameters	Roof	1.30	0.44	-0.89	0.36	0.25	0.32
	Roads	2.43	0.44	-0.30	0.36	0.25	0.32
	Ground level	1.92	0.44	-0.59	0.36	0.25	0.32
Commercial							
Baseflow parameters	Roof	N/A	N/A	N/A	N/A	N/A	N/A
	Roads	0.78	0.39	-0.60	0.50	0.32	0.30
	Ground level	0.78	0.39	-0.60	0.50	0.32	0.30
Stormflow parameters	Roof	1.30	0.38	-0.89	0.34	0.37	0.34
	Roads	2.43	0.38	-0.30	0.34	0.37	0.34
	Ground level	2.16	0.38	-0.39	0.34	0.37	0.34

Table 3.9 Pollutant export parameters for lumped catchment land uses (log¹⁰ values)

LANDUSE	FLOW TYPE	TSS log ¹⁰ values		TP log ¹⁰ values		TN log ¹⁰ values	
		Mean	St. dev.	Mean	St. dev.	Mean	St. dev.
Urban residential	Baseflow	1.00	0.34	-0.97	0.31	0.20	0.20
	Stormflow	2.18	0.39	-0.47	0.32	0.26	0.23
Industrial	Baseflow	0.78	0.45	-1.11	0.48	0.14	0.20
	Stormflow	1.92	0.44	-0.59	0.36	0.25	0.32
Commercial	Baseflow	0.78	0.39	-0.60	0.50	0.32	0.30
	Stormflow	2.16	0.38	-0.39	0.34	0.37	0.34
Rural residential	Baseflow	0.53	0.24	-1.54	0.38	-0.52	0.39
	Stormflow	2.26	0.51	-0.56	0.28	0.32	0.30
Forest	Baseflow	0.51	0.28	-1.79	0.28	-0.59	0.22
	Stormflow	1.90	0.20	-1.10	0.22	-0.075	0.24
Agriculture	Baseflow	1.00	0.13	-1.155	0.13	-0.155	0.13
	Stormflow	2.477	0.31	-0.495	0.30	0.29	0.26

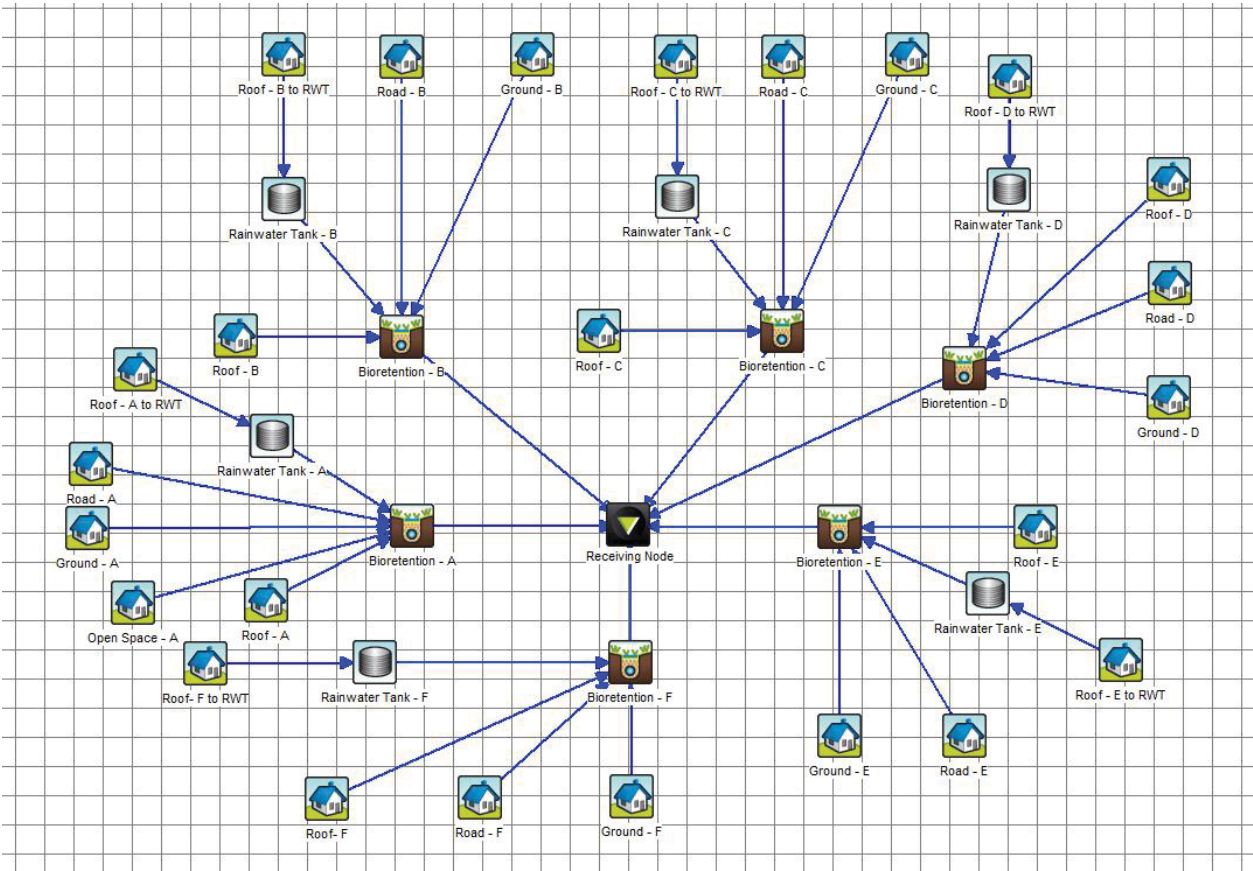
Flagstone City - Stages 2 to 5

APPENDIX

C.4

MUSIC Model Schematic and Parameters
– Stage 5

MUSIC Schematic



MUSIC Parameters (excerpts from Healthy Waterways 'MUSIC Modelling Guidelines' (Version 1.0 2010))

Table 3.5 Typical impervious fraction for split catchment land use (read with Table 3.3)⁷

DEVELOPMENT TYPE	SURFACE TYPE IMPERVIOUS FRACTION (%)		
	ROAD RESERVE	ROOF	GROUND LEVEL
Residential 10 dwellings/ha	60	100	15
Residential 15 dwellings/ha	60	100	20
Residential 40 dwellings/ha	70	100	30
Residential 80+ dwellings/ha	80	100	50
Industrial	75	100	60
Commercial	75	100	80

Table 3.7 Recommended MUSIC rainfall-runoff parameters⁹

PARAMETER	LAND USE			
	URBAN RESIDENTIAL	COMMERCIAL AND INDUSTRIAL	RURAL RESIDENTIAL	FORESTED
Rainfall threshold (mm)	1	1	1	1
Soil storage capacity (mm)	500 ¹⁰	18	98	120
Initial storage (% capacity)	10	10	10	10
Field capacity (mm)	200	80	80	80
Infiltration capacity coefficient a	211	243	84	200
Infiltration capacity exponent b	5.0	0.6	3.3	1.0
Initial depth (mm)	50	50	50	50
Daily recharge rate (%)	28	0	100	25
Daily baseflow rate (%)	27	31	22	3
Daily deep seepage rate (%)	0	0	0	0

Table 3.8 Pollutant export parameters for split catchment land use (log¹⁰ values)

FLOW TYPE	SURFACE TYPE	TSS log ¹⁰ values		TP log ¹⁰ values		TN log ¹⁰ values	
		Mean	St. dev.	Mean	St. dev.	Mean	St. dev.
Urban residential							
Baseflow parameters	Roof	N/A	N/A	N/A	N/A	N/A	N/A
	Roads	1.00	0.34	-0.97	0.31	0.20	0.20
	Ground level	1.00	0.34	-0.97	0.31	0.20	0.20
Stormflow parameters	Roof	1.30	0.39	-0.89	0.31	0.26	0.23
	Roads	2.43	0.39	-0.30	0.31	0.26	0.23
	Ground level	2.18	0.39	-0.47	0.31	0.26	0.23
Industrial							
Baseflow parameters	Roof	N/A	N/A	N/A	N/A	N/A	N/A
	Roads	0.78	0.45	-1.11	0.48	0.14	0.20
	Ground level	0.78	0.45	-1.11	0.48	0.14	0.20
Stormflow parameters	Roof	1.30	0.44	-0.89	0.36	0.25	0.32
	Roads	2.43	0.44	-0.30	0.36	0.25	0.32
	Ground level	1.92	0.44	-0.59	0.36	0.25	0.32
Commercial							
Baseflow parameters	Roof	N/A	N/A	N/A	N/A	N/A	N/A
	Roads	0.78	0.39	-0.60	0.50	0.32	0.30
	Ground level	0.78	0.39	-0.60	0.50	0.32	0.30
Stormflow parameters	Roof	1.30	0.38	-0.89	0.34	0.37	0.34
	Roads	2.43	0.38	-0.30	0.34	0.37	0.34
	Ground level	2.16	0.38	-0.39	0.34	0.37	0.34

Table 3.9 Pollutant export parameters for lumped catchment land uses (log¹⁰ values)

LANDUSE	FLOW TYPE	TSS log ¹⁰ values		TP log ¹⁰ values		TN log ¹⁰ values	
		Mean	St. dev.	Mean	St. dev.	Mean	St. dev.
Urban residential	Baseflow	1.00	0.34	-0.97	0.31	0.20	0.20
	Stormflow	2.18	0.39	-0.47	0.32	0.26	0.23
Industrial	Baseflow	0.78	0.45	-1.11	0.48	0.14	0.20
	Stormflow	1.92	0.44	-0.59	0.36	0.25	0.32
Commercial	Baseflow	0.78	0.39	-0.60	0.50	0.32	0.30
	Stormflow	2.16	0.38	-0.39	0.34	0.37	0.34
Rural residential	Baseflow	0.53	0.24	-1.54	0.38	-0.52	0.39
	Stormflow	2.26	0.51	-0.56	0.28	0.32	0.30
Forest	Baseflow	0.51	0.28	-1.79	0.28	-0.59	0.22
	Stormflow	1.90	0.20	-1.10	0.22	-0.075	0.24
Agriculture	Baseflow	1.00	0.13	-1.155	0.13	-0.155	0.13
	Stormflow	2.477	0.31	-0.495	0.30	0.29	0.26

Flagstone City - Stages 2 to 5

APPENDIX

D.1

Rational Method Detailed Calculations –
Stage 2

Project Title: **Flagstone - Stage 2**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **SW**

Check: **DNN**

Date: **3/8/2012**

Page: **Page 1 of 13**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Existing Catchment A

Variable	Value	Unit
Area	13.03	ha
f_i	0.000	Fraction
C_{10}	0.590	Fraction

Catchment Discharges for Existing Catchment A

Adopted Time: **16** Minutes (or 0.27 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	68.7	88.2	111.3	125.1	143.9	169.0	188.6
Discharge	1.17	1.60	2.26	2.67	3.23	4.15	4.83

Project Title: **Flagstone - Stage 2**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **SW**

Check: **DNN**

Date: **3/8/2012**

Page: **Page 2 of 13**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Existing Catchment B

Variable	Value	Unit
Area	5.21	ha
f_i	0.000	Fraction
C_{10}	0.590	Fraction

Catchment Discharges for Existing Catchment B

Adopted Time:		14		Minutes (or 0.23 hours)			
Variable	ARI (Years)						
	1	2	5	10	20	50	100
f _y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	73.1	93.8	118.3	132.9	152.8	179.4	200.1
Discharge	0.50	0.68	0.96	1.13	1.37	1.76	2.05

Project Title: **Flagstone - Stage 2**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **SW**

Check: **DNN**

Date: **3/8/2012**

Page: **Page 3 of 13**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Existing Catchment C

Variable	Value	Unit
Area	1.4	ha
f_i	0.000	Fraction
C_{10}	0.590	Fraction

Catchment Discharges for Existing Catchment C

Adopted Time: **11** Minutes (or 0.18 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	81.3	104.3	131.4	147.5	169.6	199.0	221.8
Discharge	0.15	0.20	0.29	0.34	0.41	0.52	0.61

Project Title: **Flagstone - Stage 2**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **SW**

Check: **DNN**

Date: **3/8/2012**

Page: **Page 4 of 13**
Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Existing Catchment D

Variable	Value	Unit
Area	0.68	ha
f_i	0.000	Fraction
C_{10}	0.590	Fraction

Catchment Discharges for Existing Catchment D

Adopted Time: **11** Minutes (or 0.18 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	81.3	104.3	131.4	147.5	169.6	199.0	221.8
Discharge	0.07	0.10	0.14	0.16	0.20	0.25	0.30

Project Title: **Flagstone - Stage 2**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **SW**

Check: **DNN**

Date: **3/8/2012**

Page: **Page 5 of 13**
Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Existing Catchment E

Variable	Value	Unit
Area	7.7	ha
f_i	0.000	Fraction
C_{10}	0.590	Fraction

Catchment Discharges for Existing Catchment E

Adopted Time: **14** Minutes (or 0.23 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	73.1	93.8	118.3	132.9	152.8	179.4	200.1
Discharge	0.74	1.01	1.42	1.68	2.03	2.60	3.03

Project Title: **Flagstone - Stage 2**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **SW**

Check: **DNN**

Date: **3/8/2012**

Page: **Page 6 of 13**
Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Existing Catchment F

Variable	Value	Unit
Area	0.97	ha
f_i	0.000	Fraction
C_{10}	0.590	Fraction

Catchment Discharges for Existing Catchment F

Adopted Time: **12** Minutes (or 0.20 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	78.3	100.5	126.6	142.2	163.4	191.8	213.8
Discharge	0.10	0.14	0.19	0.23	0.27	0.35	0.41

Project Title: **Flagstone - Stage 2**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **SW**

Check: **DNN**

Date: **3/8/2012**

Page: **Page 7 of 13**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Developed Catchment A

Variable	Value	Unit
Area	11.11	ha
f_i	0.600	Fraction
C_{10}	0.780	Fraction

Catchment Discharges for Developed Catchment A

Adopted Time: **15** Minutes (or 0.25 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	70.8	90.9	114.7	128.9	148.2	174.0	194.1
Discharge	1.36	1.86	2.62	3.10	3.75	4.82	5.61

Project Title: **Flagstone - Stage 2**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **SW**

Check: **DNN**

Date: **3/8/2012**

Page: **Page 8 of 13**
Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Developed Catchment B

Variable	Value	Unit
Area	4.19	ha
f_i	0.600	Fraction
C_{10}	0.780	Fraction

Catchment Discharges for Developed Catchment B

Adopted Time: **10** Minutes (or 0.17 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	84.7	108.6	136.7	153.5	176.4	206.9	230.6
Discharge	0.62	0.84	1.18	1.39	1.68	2.16	2.51

Project Title: **Flagstone - Stage 2**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **SW**

Check: **DNN**

Date: **3/8/2012**

Page: **Page 9 of 13**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Developed Catchment C

Variable	Value	Unit
Area	3.3	ha
f_i	0.600	Fraction
C_{10}	0.780	Fraction

Catchment Discharges for Developed Catchment C

Adopted Time:		10		Minutes (or 0.17 hours)			
Variable	ARI (Years)						
	1	2	5	10	20	50	100
f _y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	84.7	108.6	136.7	153.5	176.4	206.9	230.6
Discharge	0.48	0.66	0.93	1.10	1.32	1.70	1.98

Project Title: **Flagstone - Stage 2**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **SW**

Check: **DNN**

Date: **3/8/2012**

Page: **Page 10 of 13**
Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Developed Catchment D

Variable	Value	Unit
Area	1.34	ha
f_i	0.600	Fraction
C_{10}	0.780	Fraction

Catchment Discharges for Developed Catchment D

Adopted Time:		10 Minutes (or 0.17 hours)					
Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	84.7	108.6	136.7	153.5	176.4	206.9	230.6
Discharge	0.20	0.27	0.38	0.45	0.54	0.69	0.80

Project Title: **Flagstone - Stage 2**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **SW**

Check: **DNN**

Date: **3/8/2012**

Page: **Page 11 of 13**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Developed Catchment E

Variable	Value	Unit
Area	7.05	ha
f_i	0.600	Fraction
C_{10}	0.780	Fraction

Catchment Discharges for Developed Catchment E

Adopted Time:		10		Minutes (or 0.17 hours)			
Variable	ARI (Years)						
	1	2	5	10	20	50	100
f _y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	84.7	108.6	136.7	153.5	176.4	206.9	230.6
Discharge	1.03	1.41	1.98	2.34	2.83	3.63	4.23

Project Title: **Flagstone - Stage 2**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **SW**

Check: **DNN**

Date: **3/8/2012**

Page: **Page 12 of 13**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Developed Catchment F

Variable	Value	Unit
Area	0.62	ha
f_i	0.600	Fraction
C_{10}	0.780	Fraction

Catchment Discharges for Developed Catchment F

Adopted Time:		10 Minutes (or 0.17 hours)					
Variable	ARI (Years)						
	1	2	5	10	20	50	100
f _y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	84.7	108.6	136.7	153.5	176.4	206.9	230.6
Discharge	0.09	0.12	0.17	0.21	0.25	0.32	0.37

Project Title: **Flagstone - Stage 2**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **SW**

Check: **DNN**

Date: **3/8/2012**

Page: **Page 13 of 13**
Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Developed Catchment G

Variable	Value	Unit
Area	4.7	ha
f_i	0.000	Fraction
C_{10}	0.590	Fraction

Catchment Discharges for Developed Catchment G

Adopted Time: **15** Minutes (or 0.25 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	70.8	90.9	114.7	128.9	148.2	174.0	194.1
Discharge	0.44	0.60	0.84	0.99	1.20	1.54	1.79

Flagstone City - Stages 2 to 5

APPENDIX

D.2

Rational Method Detailed Calculations –
Stage 3



Project Title: **Flagstone Stage 3**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **YY**

Check: **DNN**

Date: **2/08/2012**

Page: **1 of 10**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Existing Catchment 1

Variable	Value	Unit
Area	18.85	ha
f_i	0.000	Fraction
C_{10}	0.590	Fraction

Catchment Discharges for Existing Catchment 1

Adopted Time: **18** Minutes (or 0.30 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	65.0	83.4	105.4	118.5	136.3	160.1	178.7
Discharge	1.61	2.19	3.09	3.66	4.42	5.69	6.62

Project Title: **Flagstone Stage 3**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **YY**

Check: **DNN**

Date: **2/08/2012**

Page: **2 of 10**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Developed Catchment 1

Variable	Value	Unit
Area	15.8125	ha
f_i	0.800	Fraction
C_{10}	0.840	Fraction

Catchment Discharges for Developed Catchment 1

Adopted Time: **15** Minutes (or 0.25 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	70.8	90.9	114.7	128.9	148.2	174.0	194.1
Discharge	2.09	2.85	4.02	4.75	5.74	7.38	8.53

Project Title: **Flagstone Stage 3**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **YY**

Check: **DNN**

Date: **2/8/2012**

Page: **3 of 10**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Existing Catchment 2

Variable	Value	Unit
Area	3.71	ha
f_i	0.000	Fraction
C_{10}	0.590	Fraction

Catchment Discharges for Existing Catchment 2

Adopted Time: **18** Minutes (or 0.30 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	65.0	83.4	105.4	118.5	136.3	160.1	178.7
Discharge	0.32	0.43	0.61	0.72	0.87	1.12	1.30

Project Title: **Flagstone Stage 3**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **YY**

Check: **DNN**

Date: **2/8/2012**

Page: **4 of 10**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Developed Catchment 2

Variable	Value	Unit
Area	4.37	ha
f_i	0.800	Fraction
C_{10}	0.840	Fraction

Catchment Discharges for Developed Catchment 2

Adopted Time: **15.5** Minutes (or 0.26 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	69.8	89.5	113.0	127.0	146.0	171.5	191.3
Discharge	0.57	0.78	1.09	1.29	1.56	2.01	2.32

Project Title: **Flagstone Stage 3**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **YY**

Check: **DNN**

Date: **2/8/2012**

Page: **5 of 10**
Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Existing Catchment 3

Variable	Value	Unit
Area	4.73	ha
f_i	0.000	Fraction
C_{10}	0.590	Fraction

Catchment Discharges for Existing Catchment 3

Adopted Time: **21** Minutes (or 0.35 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	60.3	77.4	97.8	110.1	126.7	148.9	166.2
Discharge	0.37	0.51	0.72	0.85	1.03	1.33	1.55

Project Title: **Flagstone Stage 3**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **YY**

Check: **DNN**

Date: **2/8/2012**

Page: **6 of 10**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Developed Catchment 3

Variable	Value	Unit
Area	4.04	ha
f_i	0.800	Fraction
C_{10}	0.840	Fraction

Catchment Discharges for Developed Catchment 3

Adopted Time: **16** Minutes (or 0.27 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	68.7	88.2	111.3	125.1	143.9	169.0	188.6
Discharge	0.52	0.71	1.00	1.18	1.42	1.83	2.12

Project Title: **Flagstone Stage 3**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **YY**

Check: **DNN**

Date: **2/8/2012**

Page: **7 of 10**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Existing Catchment 4

Variable	Value	Unit
Area	11.62	ha
f_i	0.000	Fraction
C_{10}	0.590	Fraction

Catchment Discharges for Existing Catchment 4

Adopted Time: **19** Minutes (or 0.32 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	63.3	81.3	102.7	115.5	132.9	156.1	174.2
Discharge	0.96	1.32	1.86	2.20	2.66	3.42	3.98

Project Title: **Flagstone Stage 3**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **YY**

Check: **DNN**

Date: **2/8/2012**

Page: **8 of 10**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Developed Catchment 4

Variable	Value	Unit
Area	11.44	ha
f_i	0.800	Fraction
C_{10}	0.840	Fraction

Catchment Discharges for Developed Catchment 4

Adopted Time: **16** Minutes (or 0.27 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	68.7	88.2	111.3	125.1	143.9	169.0	188.6
Discharge	1.47	2.00	2.82	3.34	4.03	5.19	5.99



Project Title: **Flagstone Stage 3**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **YY**

Check: **DNN**

Date: **2/8/2012**

Page: **9 of 10**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Existing Catchment 5

Variable	Value	Unit
Area	1.77	ha
f_i	0.000	Fraction
C_{10}	0.590	Fraction

Catchment Discharges for Existing Catchment 5

Adopted Time: **16** Minutes (or 0.27 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	68.7	88.2	111.3	125.1	143.9	169.0	188.6
Discharge	0.16	0.22	0.31	0.36	0.44	0.56	0.66

Project Title: **Flagstone Stage 3**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **YY**

Check: **DNN**

Date: **2/8/2012**

Page: **10 of 10**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Developed Catchment 5

Variable	Value	Unit
Area	1.52	ha
f_i	0.800	Fraction
C_{10}	0.840	Fraction

Catchment Discharges for Developed Catchment 5

Adopted Time: **10** Minutes (or 0.17 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	84.7	108.6	136.7	153.5	176.4	206.9	230.6
Discharge	0.24	0.33	0.46	0.54	0.66	0.84	0.97

Flagstone City - Stages 2 to 5

APPENDIX

D.3

Rational Method Detailed Calculations –
Stage 4

Project Title: **Flagstone**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **AV**

Check: **KTC**

Date: **1/8/2012**

Page: **1 of 9**
Rainfall Data Used

Location: **Flagstone, QLD**

AR&R Vol 2 1987 Parameters

Skewness	0.17
F2	4.39
F50	17.12

Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
1	44.56	83.37
12	7.13	13.63
72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Existing Catchment 1 Conditions

Variable	Value	Unit
Area	6.190	ha
C_{10}	0.59	Fraction
f_i	0.000	

Catchment Discharges for Existing Catchment 1 Conditions
Adopted Time: **23.5** Minutes (or 0.39 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	57.0	73.3	92.6	104.2	120.0	141.1	157.5
Discharge	0.46	0.63	0.89	1.06	1.28	1.65	1.92

Project Title: **Flagstone**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **AV**

Check: **KTC**

Date: **1/8/2012**

Page: **2 of 9**
Rainfall Data Used

Location: **Flagstone, QLD**

AR&R Vol 2 1987 Parameters

Skewness	0.17
F2	4.39
F50	17.12

Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
1	44.56	83.37
12	7.13	13.63
72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Developed Catchment 1 Conditions

Variable	Value	Unit
Area	5.760	ha
C_{10}	0.84	Fraction
f_i	0.800	

Catchment Discharges for Developed Catchment 1 Conditions
Adopted Time: **16.5** Minutes (or 0.28 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	67.7	86.9	109.7	123.4	141.9	166.7	185.9
Discharge	0.73	0.99	1.40	1.66	2.00	2.58	2.98

Project Title: **Flagstone**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **AV**

Check: **KTC**

Date: **1/8/2012**

Page: **3 of 9**
Rainfall Data Used

Location: **Flagstone, QLD**

AR&R Vol 2 1987 Parameters

Skewness	0.17
F2	4.39
F50	17.12

Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
1	44.56	83.37
12	7.13	13.63
72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Existing Catchment 2 Conditions

Variable	Value	Unit
Area	18.330	ha
C_{10}	0.59	Fraction
f_i	0.000	

Catchment Discharges for Existing Catchment 2 Conditions
Adopted Time: **34.3** Minutes (or 0.57 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	46.8	60.1	76.2	85.9	98.9	116.5	130.1
Discharge	1.12	1.54	2.17	2.58	3.12	4.02	4.69



Cardno Lawson Treloar

Project Title: **Flagstone**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **AV**

Check: **KTC**

Date: **1/8/2012**

Page: **4 of 9**

Rainfall Data Used

Location: **Flagstone, QLD**

AR&R Vol 2 1987 Parameters

Skewness	0.17
F2	4.39
F50	17.12

Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
1	44.56	83.37
12	7.13	13.63
72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Developed Catchment 2 (Rural) Conditions

Variable	Value	Unit
Area	2.280	ha
C_{10}	0.59	Fraction
f_i	0.000	

Catchment Discharges for Developed Catchment 2 (Rural) Conditions

Adopted Time: **20.9** Minutes (or 0.35 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	60.4	77.6	98.1	110.3	127.0	149.2	166.5
Discharge	0.18	0.25	0.35	0.41	0.50	0.64	0.75

Project Title: **Flagstone**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **AV**

Check: **KTC**

Date: **1/8/2012**

Page: **5 of 9**
Rainfall Data Used

Location: **Flagstone, QLD**

AR&R Vol 2 1987 Parameters

Skewness	0.17
F2	4.39
F50	17.12

Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
1	44.56	83.37
12	7.13	13.63
72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Developed Catchment 2 (Site) Conditions

Variable	Value	Unit
Area	10.370	ha
C_{10}	0.84	Fraction
f_i	0.800	

Catchment Discharges for Developed Catchment 2 (Site) Conditions
Adopted Time: **19.5** Minutes (or 0.33 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	62.5	80.3	101.4	114.1	131.3	154.2	172.1
Discharge	1.21	1.65	2.33	2.76	3.33	4.29	4.96



Cardno Lawson Treloar

Project Title: **Flagstone**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **AV**

Check: **KTC**

Date: **1/8/2012**

Page: **6 of 9**

Rainfall Data Used

Location: **Flagstone, QLD**

AR&R Vol 2 1987 Parameters

Skewness	0.17
F2	4.39
F50	17.12

Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
1	44.56	83.37
12	7.13	13.63
72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Existing Catchment 3 Conditions

Variable	Value	Unit
Area	3.190	ha
C_{10}	0.59	Fraction
f_i	0.000	

Catchment Discharges for Existing Catchment 3 Conditions

Adopted Time: **19.3** Minutes (or 0.32 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	62.8	80.7	101.9	114.6	131.9	155.0	172.9
Discharge	0.26	0.36	0.51	0.60	0.72	0.93	1.08

Project Title: **Flagstone**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **AV**

Check: **KTC**

Date: **1/8/2012**

Page: **7 of 9**
Rainfall Data Used

Location: **Flagstone, QLD**

AR&R Vol 2 1987 Parameters

Skewness	0.17
F2	4.39
F50	17.12

Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
1	44.56	83.37
12	7.13	13.63
72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Developed Catchment 3 Conditions

Variable	Value	Unit
Area	6.800	ha
C_{10}	0.84	Fraction
f_i	0.800	

Catchment Discharges for Developed Catchment 3 Conditions
Adopted Time: **18.5** Minutes (or 0.31 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	64.1	82.3	104.0	117.0	134.6	158.1	176.4
Discharge	0.81	1.11	1.57	1.86	2.24	2.88	3.33

Project Title: **Flagstone**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **AV**

Check: **KTC**

Date: **1/8/2012**

Page: **8 of 9**
Rainfall Data Used

Location: **Flagstone, QLD**

AR&R Vol 2 1987 Parameters

Skewness	0.17
F2	4.39
F50	17.12

Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
1	44.56	83.37
12	7.13	13.63
72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Existing Catchment 4 Conditions

Variable	Value	Unit
Area	22.070	ha
C_{10}	0.59	Fraction
f_i	0.000	

Catchment Discharges for Existing Catchment 4 Conditions
Adopted Time: **34.4** Minutes (or 0.57 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	46.7	60.1	76.1	85.7	98.8	116.3	129.9
Discharge	1.35	1.85	2.61	3.10	3.75	4.84	5.64

Project Title: **Flagstone**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **AV**

Check: **KTC**

Date: **1/8/2012**

Page: **9 of 9**
Rainfall Data Used

Location: **Flagstone, QLD**

AR&R Vol 2 1987 Parameters

Skewness	0.17
F2	4.39
F50	17.12

Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
1	44.56	83.37
12	7.13	13.63
72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Developed Catchment 4 Conditions

Variable	Value	Unit
Area	20.700	ha
C_{10}	0.84	Fraction
f_i	0.800	

Catchment Discharges for Developed Catchment 4 Conditions
Adopted Time: **20.5** Minutes (or 0.34 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	61.0	78.3	99.0	111.4	128.2	150.6	168.1
Discharge	2.36	3.22	4.54	5.38	6.50	8.37	9.66

Flagstone City - Stages 2 to 5

APPENDIX

D.4

Rational Method Detailed Calculations –
Stage 5



Project Title: **Flagstone Stage 5**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **YY**

Check: **DNN**

Date: **2/08/2012**

Page: **1 of 12**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Existing Catchment A

Variable	Value	Unit
Area	14	ha
f_i	0.000	Fraction
C_{10}	0.590	Fraction

Catchment Discharges for Existing Catchment A

Adopted Time: **17** Minutes (or 0.28 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	66.8	85.7	108.2	121.7	140.0	164.4	183.4
Discharge	1.23	1.67	2.36	2.79	3.37	4.34	5.05



Project Title: **Flagstone Stage 5**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **YY**

Check: **DNN**

Date: **2/08/2012**

Page: **2 of 12**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Developed Catchment A

Variable	Value	Unit
Area	7.29	ha
f_i	0.800	Fraction
C_{10}	0.840	Fraction

Catchment Discharges for Developed Catchment A

Adopted Time: **14** Minutes (or 0.23 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	73.1	93.8	118.3	132.9	152.8	179.4	200.1
Discharge	0.99	1.36	1.91	2.26	2.73	3.51	4.05

Project Title: **Flagstone Stage 5**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **YY**

Check: **DNN**

Date: **2/8/2012**

Page: **3 of 12**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Existing Catchment B

Variable	Value	Unit
Area	3.15	ha
f_i	0.000	Fraction
C_{10}	0.590	Fraction

Catchment Discharges for Existing Catchment B

Adopted Time: **13** Minutes (or 0.22 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	75.6	97.0	122.2	137.3	157.9	185.4	206.7
Discharge	0.31	0.43	0.60	0.71	0.86	1.10	1.28

Project Title: **Flagstone Stage 5**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **YY**

Check: **DNN**

Date: **2/8/2012**

Page: **4 of 12**

Rain Fall Data Used:

Location: Flagstone, QLD			
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)
Skewness	0.17	1	44.56
F2	4.39	12	7.13
F50	17.12	72	2.00
			i_{50} (mm/hr)
			83.37
			13.63
			4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Developed Catchment B

Variable	Value	Unit
Area	3.71	ha
f_i	0.800	Fraction
C_{10}	0.840	Fraction

Catchment Discharges for Developed Catchment B

Adopted Time: **12** Minutes (or 0.20 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	78.3	100.5	126.6	142.2	163.4	191.8	213.8
Discharge	0.54	0.74	1.04	1.23	1.49	1.91	2.20

Project Title: **Flagstone Stage 5**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **YY**

Check: **DNN**

Date: **2/8/2012**

Page: **5 of 12**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Existing Catchment C

Variable	Value	Unit
Area	2.54	ha
f_i	0.000	Fraction
C_{10}	0.590	Fraction

Catchment Discharges for Existing Catchment C

Adopted Time: **18** Minutes (or 0.30 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	65.0	83.4	105.4	118.5	136.3	160.1	178.7
Discharge	0.22	0.30	0.42	0.49	0.60	0.77	0.89

Project Title: **Flagstone Stage 5**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **YY**

Check: **DNN**

Date: **2/8/2012**

Page: **6 of 12**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Developed Catchment C

Variable	Value	Unit
Area	6.33	ha
f_i	0.800	Fraction
C_{10}	0.840	Fraction

Catchment Discharges for Developed Catchment C

Adopted Time: **12** Minutes (or 0.20 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	78.3	100.5	126.6	142.2	163.4	191.8	213.8
Discharge	0.93	1.26	1.78	2.10	2.53	3.26	3.76

Project Title: **Flagstone Stage 5**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **YY**

Check: **DNN**

Date: **2/8/2012**

Page: **7 of 12**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Existing Catchment D

Variable	Value	Unit
Area	1.95	ha
f_i	0.000	Fraction
C_{10}	0.590	Fraction

Catchment Discharges for Existing Catchment D

Adopted Time: **18** Minutes (or 0.30 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	65.0	83.4	105.4	118.5	136.3	160.1	178.7
Discharge	0.17	0.23	0.32	0.38	0.46	0.59	0.69

Project Title: **Flagstone Stage 5**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **YY**

Check: **DNN**

Date: **2/8/2012**

Page: **8 of 12**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Developed Catchment D

Variable	Value	Unit
Area	3.95	ha
f_i	0.800	Fraction
C_{10}	0.840	Fraction

Catchment Discharges for Developed Catchment D

Adopted Time: **12** Minutes (or 0.20 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	78.3	100.5	126.6	142.2	163.4	191.8	213.8
Discharge	0.58	0.79	1.11	1.31	1.58	2.03	2.35

Project Title: **Flagstone Stage 5**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **YY**

Check: **DNN**

Date: **2/8/2012**

Page: **9 of 12**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Existing Catchment E

Variable	Value	Unit
Area	2.12	ha
f_i	0.000	Fraction
C_{10}	0.590	Fraction

Catchment Discharges for Existing Catchment E

Adopted Time: **17** Minutes (or 0.28 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	66.8	85.7	108.2	121.7	140.0	164.4	183.4
Discharge	0.19	0.25	0.36	0.42	0.51	0.66	0.76

Project Title: **Flagstone Stage 5**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **YY**

Check: **DNN**

Date: **2/8/2012**

Page: **10 of 12**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Developed Catchment E

Variable	Value	Unit
Area	1.48	ha
f_i	0.800	Fraction
C_{10}	0.840	Fraction

Catchment Discharges for Developed Catchment E

Adopted Time: **10** Minutes (or 0.17 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	84.7	108.6	136.7	153.5	176.4	206.9	230.6
Discharge	0.23	0.32	0.45	0.53	0.64	0.82	0.95

Project Title: **Flagstone Stage 5**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **YY**

Check: **DNN**

Date: **2/8/2012**

Page: **11 of 12**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Existing Catchment F

Variable	Value	Unit
Area	1.52	ha
f_i	0.000	Fraction
C_{10}	0.590	Fraction

Catchment Discharges for Existing Catchment F

Adopted Time: **20** Minutes (or 0.33 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	61.8	79.3	100.2	112.7	129.7	152.4	170.1
Discharge	0.12	0.17	0.24	0.28	0.34	0.44	0.51



Project Title: **Flagstone Stage 5**

Subject: **Rational Method Hydrology Calculations**

Job No.: **7217-43**

Designer: **YY**

Check: **DNN**

Date: **2/8/2012**

Page: **12 of 12**

Rain Fall Data Used:

Location: Flagstone, QLD				
AR&R Vol 2 1987 Parameters		Time (hrs)	i_2 (mm/hr)	i_{50} (mm/hr)
Skewness	0.17	1	44.56	83.37
F2	4.39	12	7.13	13.63
F50	17.12	72	2.00	4.27

Column and Variable Definition

Variable	ARI (years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20

Catchment Data for Developed Catchment F

Variable	Value	Unit
Area	3.91	ha
f_i	0.800	Fraction
C_{10}	0.840	Fraction

Catchment Discharges for Developed Catchment F

Adopted Time: **12** Minutes (or 0.20 hours)

Variable	ARI (Years)						
	1	2	5	10	20	50	100
f_y	0.80	0.85	0.95	1.00	1.05	1.15	1.20
Intensity	78.3	100.5	126.6	142.2	163.4	191.8	213.8
Discharge	0.57	0.78	1.10	1.30	1.57	2.01	2.32