PLANS AND DOCUMENTS
referred to in the ULDA
APPROVAL dated 23/12/11

FLOOD MANAGEMENT PLAN
PARADISE WATERS PRECINCT A

STOCKLAND

NOVEMBER 2010

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

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WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

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Prepared for:

Stockland

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For and on behalf of
Water Technology Pty Ltd

Steve Clark
Director

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1 INTRODUCTION

Stockland Developments Pty Ltd proposes to develop the parcel of land within Ipswich City Council (ICC), and Precinct 7 of Ripley Valley interim Land Use Plan (ILUP), located at South Deebing Creek Road, Deebing Heights. The general location of the subject development site is shown in Figure 1.1.

Water Technology Pty Ltd was requested to provide preliminary advice with regard to a Flood Management Plan (FMP) for the development site.

This plan focuses on Precinct A of the site (refer Figure 1-1). A Master Flood Study is being developed for the whole development site. The Master Study will identify the location and scale of flood detention storage across the whole site to preserve downstream flood behaviour.

Figure 1-1 **Proposed Development Site and Precinct A Locality Plan**

2 SITE CHARACTERISTICS

2.1 Existing Site Characteristics

It is proposed to develop four lots described as Lot 207 on CH31135 and part of an existing unconstructed road reserve within the Ipswich suburb of Deebing Heights. The whole site is currently zoned low density, large lot residential and special opportunity (13 & 14) under the ICC and within Precinct 7 of Ripley Valley ILUP. The total site area is 249.07 ha and 0.79 ha road reserve. The focus of this study is Precinct A, refer Figure 2-1, Figure 2-2 and Figure 2-3 which is 14.24 hectares. It is bounded by South Deebing Creek Road to the west, an unconstructed road to be utilised for Precionct A, to the south by 'Defence Purpose Land' and to the east by similar parcels of land zoned as future residential/conservation. The Centenary Highway extension passes downstream of the development.

Figure 2-3 shows the development site showing proposed land uses and subcatchments in the immediate vicinity. These will be discussed in greater detail in the following section.

The majority of the development discharges into Deebing Creek which flows through the site in a northerly direction. A small proportion discharges through the North West corner of the site to converge with Deebing Creek upstream of the Centenary Highway.

2.2 Proposed Site Characteristics

It is proposed to develop the site predominately for urban residential use. Calculations are based on lot sizes ranging from 260 to 740m^2 classed as Low Density residential.

Figure 2-1 **Context Plan**

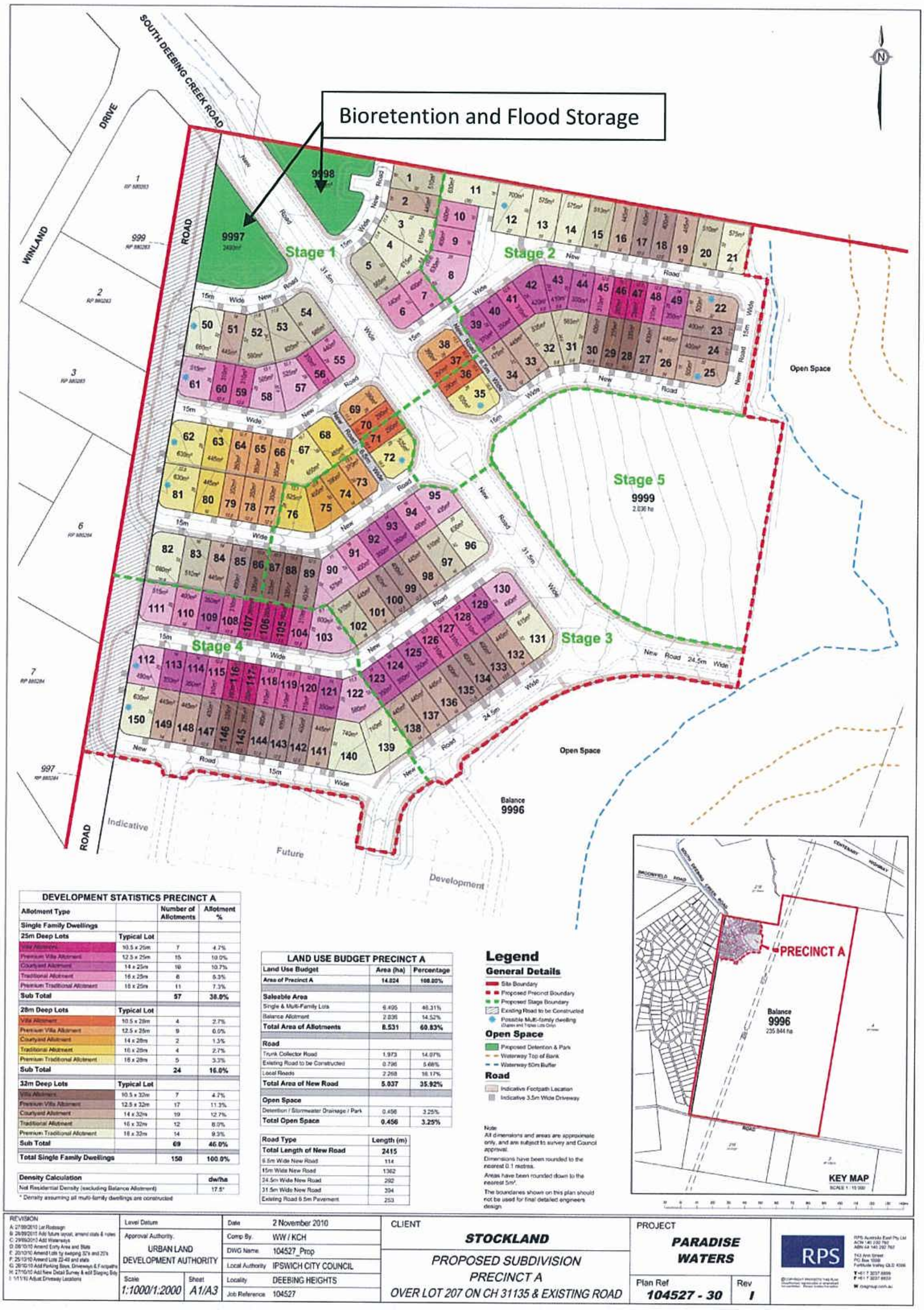

Figure 2-2 **Precinct A Development Plan**

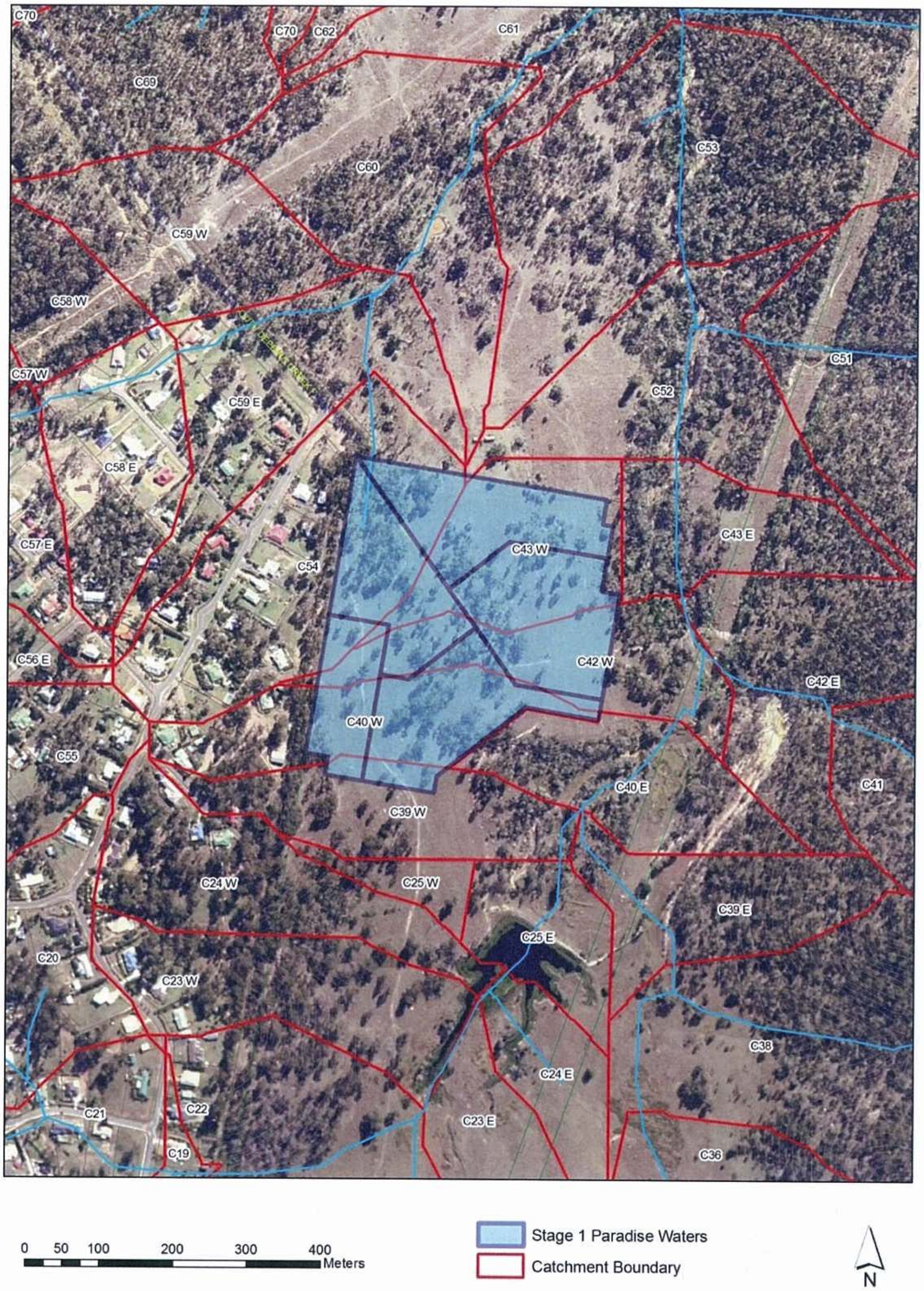

Figure 2-3 **Proposed Development Site Showing Development and RAFTS Model Catchments**

3 DISCHARGE ESTIMATION – EXISTING SITUATION

3.1 Methodology

The 'RAFTS' runoff-routing model (XP Software, 2001) was used to estimate the 1, 2, 5, 10, 20, 50, and 100 year Average Recurrence Interval (ARI) design discharges for the catchment at four downstream reporting locations:

- The downstream boundary of the development site on Deebing Creek.
- The North West boundary of the development site.
- The downstream convergent point of the site discharges, upstream of Centenary Highway.
- Upstream of the Cunningham Highway.

Figure 3-1 and Figure 3-2 show the adopted catchment boundary and RAFTS nodes and links, respectively.

The total catchment area is greater than 500 ha therefore direct estimation of the peak runoff using the "standard" Rational Method was not appropriate. However, given that the existing conditions catchment is predominantly rural, it is acceptable to use the "Stream Velocity (Main Roads) Method" (since the area is less than 25 km^2) (QUDM pg 4-20, technical note 4.06.1). Therefore, the model RAFTS model was checked as follows:

- Rational Method discharges were estimated at Node C117; Deebing Creek directly upstream of the Cunningham Highway (see Figure 3-1). This location was chosen to maximise the catchment area (therefore providing a representative check) while eliminating any confounding influence of the Cunningham Highway.

- Rational Method discharges were estimated for the following conditions:
  - Fully undeveloped: 100% pervious (C10 = 0.66).
  - Fully developed: 100% impervious (C10 = 0.90).

- The RAFTS model was checked and adjusted within normal parameter ranges to match discharges with those estimated using the Rational Method single land use catchment discharges.

- The RAFTS existing and post-development conditions catchment models were created with the RAFTS "two sub-catchment" model, to represent the mix of undeveloped and developed areas within each RAFTS catchment. This was done by modelling the percentage of pervious (RAFTS sub-catch 1) and impervious (RAFTS sub-catch 2) areas. RAFTS parameters were adopted from the single land use checks discussed above.

The following sections provide detail of the modelling. Note the Ipswich City Council has recently completed a Regional Flood Frequency Analysis. This provides design flood estimation for Ipswich. At the time of writing this FMP the Regional Flood Frequency Analysis was not available.

3.2 Adopted Design Rainfalls

Design rainfall patterns and intensities for Ipswich were determined using standard procedures in Australian Rainfall and Runoff (IEAust, 1998).

3.3 Rational Method Design Discharges

The Rational Method was used to estimate design discharges at node C117 (catchment area 1318 ha) (Figure 3-2) for the following scenarios:

- Undeveloped – 100% pervious (C_{10} = 0.66) – the entire catchment is undeveloped.
- Fully Developed - 100% impervious (C_{10} = 0.90) – the entire catchment is equivalent to a CBD.

Time of concentration (t_c) was based on the stream velocity method (QUDM pg 4-33) with an average catchment slope of 4-8%, as determined by the spatial analyst program CatchmentSIM. QUDM Table 4.06.5 gives a corresponding assumed stream velocity as 0.9 m/s.

Tables B1 and B2, Appendix B, show the adopted Rational Method calculations. Table 3-1 shows the Rational Method design discharges for the two catchment conditions for the 1, 2, 5, 10, 20, 50 and 100 year ARI design storm events.

Table 3-1 Rational Method Design Discharges to Cunningham Highway

Design Storm Event (ARI Years)	Design Discharge (m^3/s)	
	Fully Undeveloped Catchment (C10 = 0.66)	Fully Developed* Catchment (C10 = 0.90)
1	35.6	48.5
2	49.3	67.2
5	72.3	98.6
10	87.6	119
20	108	147
50	142	194
100	168	230

*'Fully Developed Catchment' refers to a modelled hypothetical scenario where the entire catchment to the Cunningham Highway is modelled as developed and flows are checked against the Rational Method with full impervious conditions.

3.4 Alternate Design Discharge Calculations

Due to the relatively large catchment area, verification of rational method calculations was undertaken. Calculations using the Eastern NSW method (ARR Eq 5.3), Bransby Williams (QUDM eq 4.10 pg 4-320) and Palmen and Weeks (2009) equations were undertaken with results shown below.

Common parameters include:

C_{10} Undeveloped:	0.66
Area:	1318 ha
Stream Length:	7500m
Channel Velocity:	0.9m/s

Table 3-2 Comparison of Discharge Equations (Cunningham Highway)

Discharge Calculation	t_c (mins)	Q100 Design Discharge (m^3/s) (Undeveloped)
Rational Method with Stream Velocity	139	168
Rational Method with Eastern NSW Method	122	186
Bransby Williams	154	156
Palmen & Weeks	N/A	132

The average Q100 Design Discharge for the four methods is 161 m^3/s. Consequently the Rational Method (based on stream velocity) is considered appropriate for use in "calibration" of the Rafts model.

3.5 RAFTS Model Configuration

Deebing Creek catchment was divided into 117 sub-catchments. Tables A1 and A2, Appendix A, show the adopted catchment areas and % imperviousness for existing and developed conditions respectively for the subcatchments in the immediate vicinity of Paradise Waters, Precinct A.

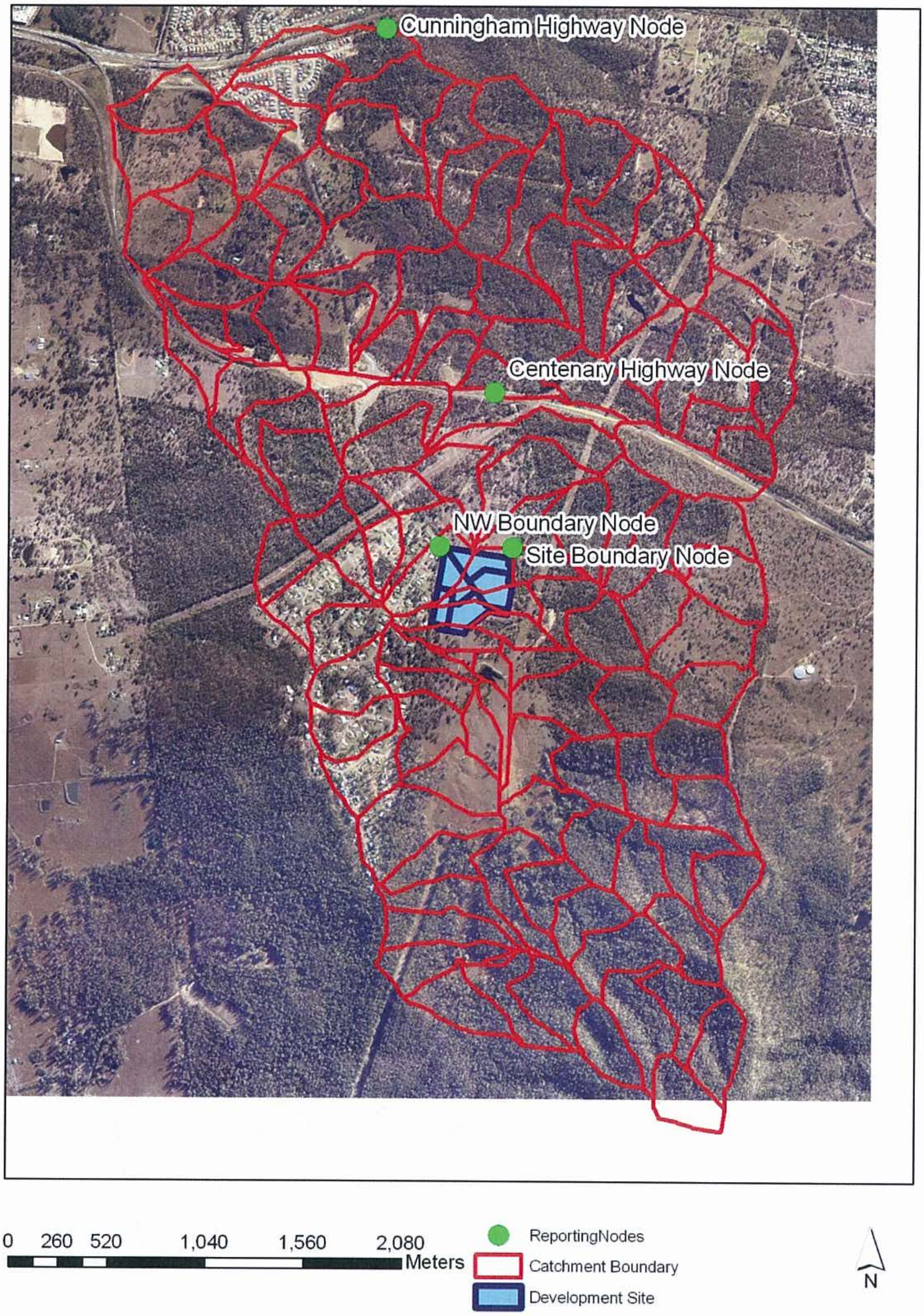

Figure 3-1 **RAFTS Model Layout**

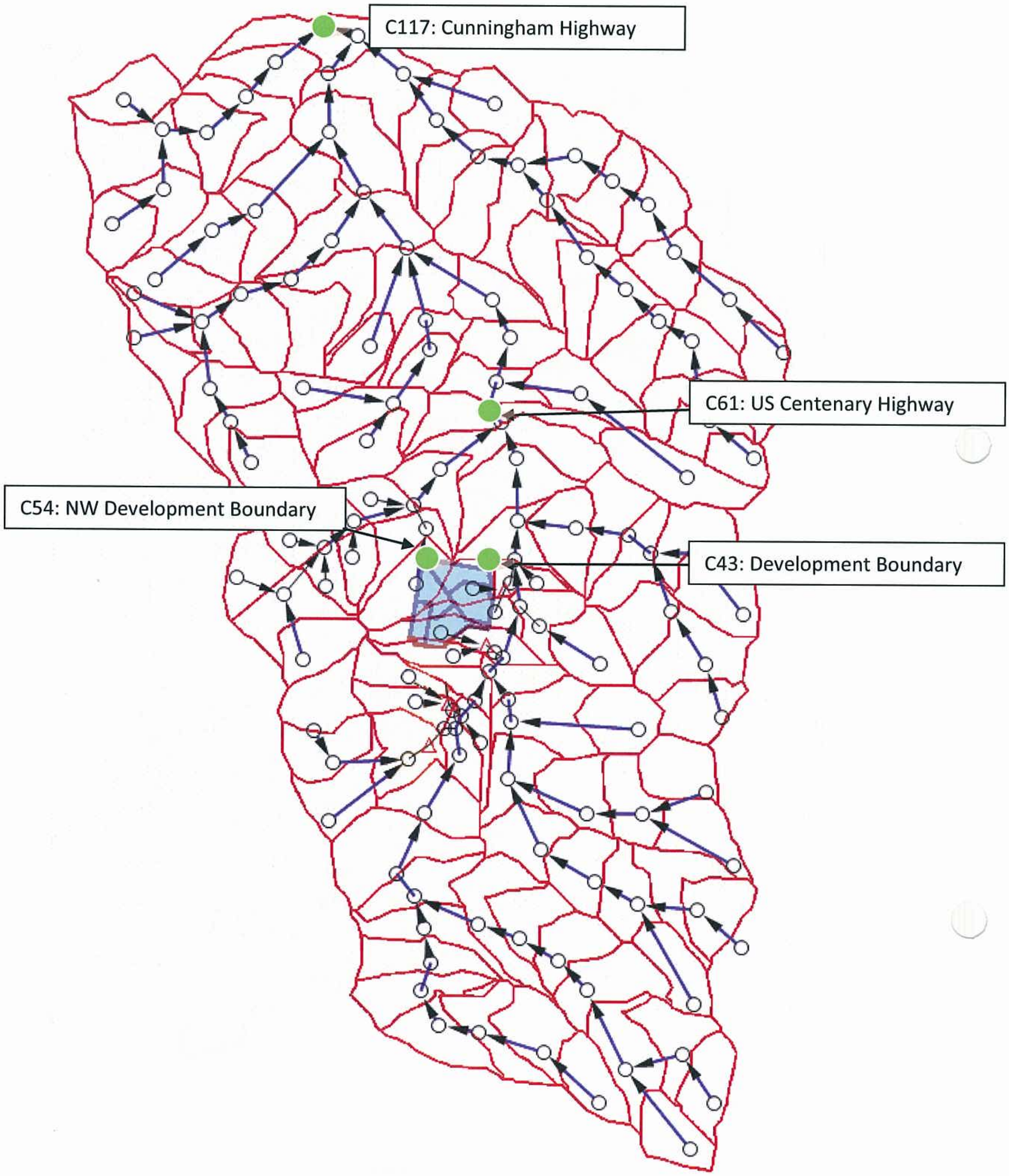

Figure 3-2 **RAFTS Model Nodes and Links (Existing Conditions Model)**

Discharge reporting nodes are highlighted. (Not to scale)

3.6 RAFTS Model Check

The RAFTS model was checked by matching discharges at the Node C117 to those estimated using the Rational Method for the two development scenarios. A range of storm durations were assessed to determine the critical event.

3.6.1 RAFTS Parameters

Table 3-3 shows the adopted RAFTS parameters used in the catchments for the two calibration scenarios. The following is of note:

- Catchment Manning's 'n', % Impervious, Initial Loss, Continuing Loss and Muskingum travel time (k) were adjusted.
- In order to check the fully developed conditions RAFTS models for the different ARI storms different initial and continuing losses were adopted.

Given that the RAFTS model is calibrated, the variation in parameters between different ARIs is considered acceptable.

Table 3-3 RAFTS Catchment Parameters, Undeveloped and Fully Developed Catchment Conditions

RAFTS Parameters	Fully Undeveloped (C10 = 0.7) ARI (Years)			Fully Developed (C10 = 0.90) ARI (Years)		
	1-2	**5 - 20**	**50-100**	**1-2**	**5 - 20**	**50-100**
Catchment Manning's 'n'	0.05	0.05	0.06	0.025	0.025	0.025
% Impervious	0	0	0	90	90	90
Initial Loss (mm)	12	12	15	4	0.5	0.5
Continuing Loss (mm/h)	3	4.5	5	2	0	0
Muskingum K (m/s)	0.9	0.9	1.1	0.9	0.9	1.1

Notes:

1) Storage Coefficient 'Bx' = 1
2) Muskingum n = 0.2
3) Parametres to be re-tested against Regional FFA.

3.6.2 RAFTS Calibration Results

Table 3.4 shows the estimated 1, 2, 5, 10, 20, 50 and 100 year ARI design discharges at node C117 for the two calibration scenarios. The RAFTS model discharges have been adopted for this study.

Table 3-4 Rational Method-RAFTS Results Comparison, Undeveloped & Fully Developed Catchment Conditions – to node 117

Design Storm Event (ARI Years)	Design Discharge (m^3/s)					
	Fully Undeveloped Catchment (C10 = 0.66)			Fully Developed Catchment (C10 = 0.90)		
	Rational Method	RAFTS	Diff (%)	Rational Method	RAFTS	Diff (%)
1	35.6	35.0	-1.6	48.5	51.6	6.3
2	49.3	53.5	8.5	67.2	70.2	4.3
5	72.3	75.7	4.7	98.6	105	6.2
10	87.6	90.8	3.7	119	120	0.3
20	108	111	3.2	147	141	-4.5
50	142	154	8.6	194	197	1.4
100	168	181	7.6	230	223	-2.9

4 DISCHARGE ESTIMATION – PARADISE WATERS PRECINCT A

The results from the RAFTS model calibration scenarios as described in the previous section were used to develop a RAFTS model for existing and Paradise Waters, Precinct A catchment conditions.

These models (incorporating partial catchment development) were not calibrated against the Rational Method as the catchment is not homogeneous.

4.1.1 Catchment Land Use and % Imperviousness

Table 4-1 shows the adopted catchment land use imperviousness.

Table 4-1 Adopted Land Use Imperviousness

Land Use	% Imperviousness	
	Existing Conditions	Developed Conditions
Open Space/Rural	0	0
Existing Rural Residential*	20	20
Paradise Waters (Precinct A)	0	62

*Existing Rural Residential area is located west of the development

4.1.2 RAFTS Model

The RAFTS "two sub-catchment" model was used. That is:

- RAFTS "1st sub-catchment" was used to define the undeveloped (pervious) area of each of the Deebing Creek sub-catchments.
- RAFTS "2nd sub-catchment" was used to define the developed (impervious) area of each of the Deebing Creek sub-catchments.

Calibrated model parameters for the appropriate undeveloped and developed C_{10} and ARI combinations were adopted for each sub-catchment in the RAFTS "two sub-catchment" model.

4.1.3 RAFTS Catchment Areas

Tables A1 and A2 show the area of developed land in each RAFTS sub-catchment for existing and developed conditions respectively. Table 4-2 shows the estimated peak 1, 2, 5, 10, 20, 50 and 100 year ARI design discharges for existing and Paradise Waters Precinct A catchment conditions for the following downstream property boundary locations:

- The downstream boundary of the development site on Deebing Creek.
- The NW boundary of the development.
- The downstream convergent point of the site discharges, upstream of Centenary Highway.
- Upstream of the Cunningham Highway

4.2 Impact of Proposed Site Development: Precinct A

Table 4-2 – Table 4-5 show a comparison of design discharges for the downstream property boundary discharge locations. For Precinct A conditions all increases in peak discharges at downstream locations are within ±1% of existing discharges, with the majority of scenarios experiencing reductions in peak flows.

Table 4-2 Peak Design Discharges for Existing and Paradise Waters Upstream of the Cunningham Highway

ARI (years)	Node C117 US Cunningham Highway		
	Peak Discharge (m^3/s)		Change (%)
	Existing	Precinct A	
1	36.0	36.1	0.4
2	54.7	54.9	0.4
5	77.6	78.0	0.5
10	92.9	93.3	0.5
20	113.7	114.3	0.5
50	156.5	157.8	0.9
100	183.5	185.1	0.9

Table 4-3 Peak Design Discharges for Existing and Developed Conditions Upstream of Centenary Highway

ARI (years)	Node C61 US Centenary Highway		
	Peak Discharge (m^3/s)		Change (%)
	Existing	Precinct A	
1	24.4	24.2	-0.5
2	37.5	37.4	-0.3
5	53.6	53.7	0.1
10	64.2	64.2	-0.0
20	78.8	78.8	-0.1
50	101.9	102.3	0.3
100	119.8	120.0	0.1

Table 4-4 Peak Design Discharges for Existing and Developed Conditions at Development Boundary (Deebing Creek)

ARI (years)	Node C43 Development Boundary		
	Peak Discharge (m^3/s)		Change (%)
	Existing	Precinct A	
1	17.5	17.4	-0.6
2	27.0	26.7	-0.9
5	38.5	38.2	-0.8
10	46.1	45.7	-0.8
20	56.6	56.3	-0.5
50	75.2	74.9	-0.3
100	88.2	87.9	-0.3

Table 4-5 Peak Design Discharges for Existing and Developed Conditions at North West Development Boundary

ARI (years)	Node C43 Development Boundary		
	Peak Discharge (m^3/s)		Change (%)
	Existing	Precinct A	
1	0.7	1.3	83
2	1.2	1.9	51
5	1.9	2.8	43
10	2.4	3.3	38
20	3.0	4.0	35
50	3.2	4.3	34
100	3.9	5.1	31

5 STORMWATER DETENTION REQUIREMENTS

5.1 Precinct A Requirements

The 'XP-RAFTS' runoff-routing model was used to design a detention basin at the North West boundary of the proposed development, as shown in Figure 2-2. Table 5-1 shows the adopted stage storage curve for the basin. Table 5-2 shows the adopted configurations of the wall and spillway. Table 5-3 shows the resulting discharges at the North West boundary have been returned to existing levels. The western side of the entry road will be used for storage to minimise the depth of the system. Refer to Design Flow 'Stormwater Management Plan Paradise Waters Precinct A', Oct 2010 for details. The size of the system will be refined as part of the detailed design.

Table 5-1 Adopted Basin Stage-Storage Curve

Depth (m)	Storage Volume (m^3)
0.0	0
1.2	940
1.4	1100

Table 5-2 Adopted Basin Design Parameters

Design Parameters	Basin
Spillway	
Spillway Elevation (m – nominal datum)	1.2
Spillway Width (m)	2.0
Low Flow Pipe	
Diameter (m)	0.9
Peak Water Levels	
Max 20 year ARI Water Depth (m – nominal datum)	1.2
Max 100 year ARI Water Depth (m – nominal datum)	1.37

Table 5-3 Peak Design Discharges for Existing and Developed Conditions (with mitigation) at North West Development Boundary

ARI (years)	Node C43 Development Boundary			
	Peak Discharge (m^3/s)			Change (%)
	Existing	Precinct A (no mitigation)	Precinct A (mitigation)	
1	0.7	1.3	0.7	-0.4
2	1.2	1.9	1.2	-4.2
5	1.9	2.8	1.9	-2.6
10	2.4	3.3	2.3	-2.9
20	3.0	4.0	2.9	-2.7
50	3.2	4.3	3.2	-0.2
100	3.9	5.1	3.8	-0.9

5.2 Master Flood Management Plan

Work detailed in previous sections indicates that the predicted impact on Deebing Creek peak flows for Paradise Waters Precinct A is nominal (<1%). However, Stockland acknowledges the need to provide stormwater detention measures to ensure that the increase in runoff from increasing urbanisation over the catchment as a whole is addressed. The details of this strategy will be established as part of ongoing Master Flood Management Plan investigations.

There are two broad options for providing detention facilities, these being:

- Provision of site by site (or in this case "off stream") detention facilities, or alternatively
- Provision of regional online scale flood detention facilities.

Figure 5-1 and Figure 5-2 provides an indication of the potential location of these detention facilities.

Figure 5-1 **Possible Flood Detention Location – Structure Plan**

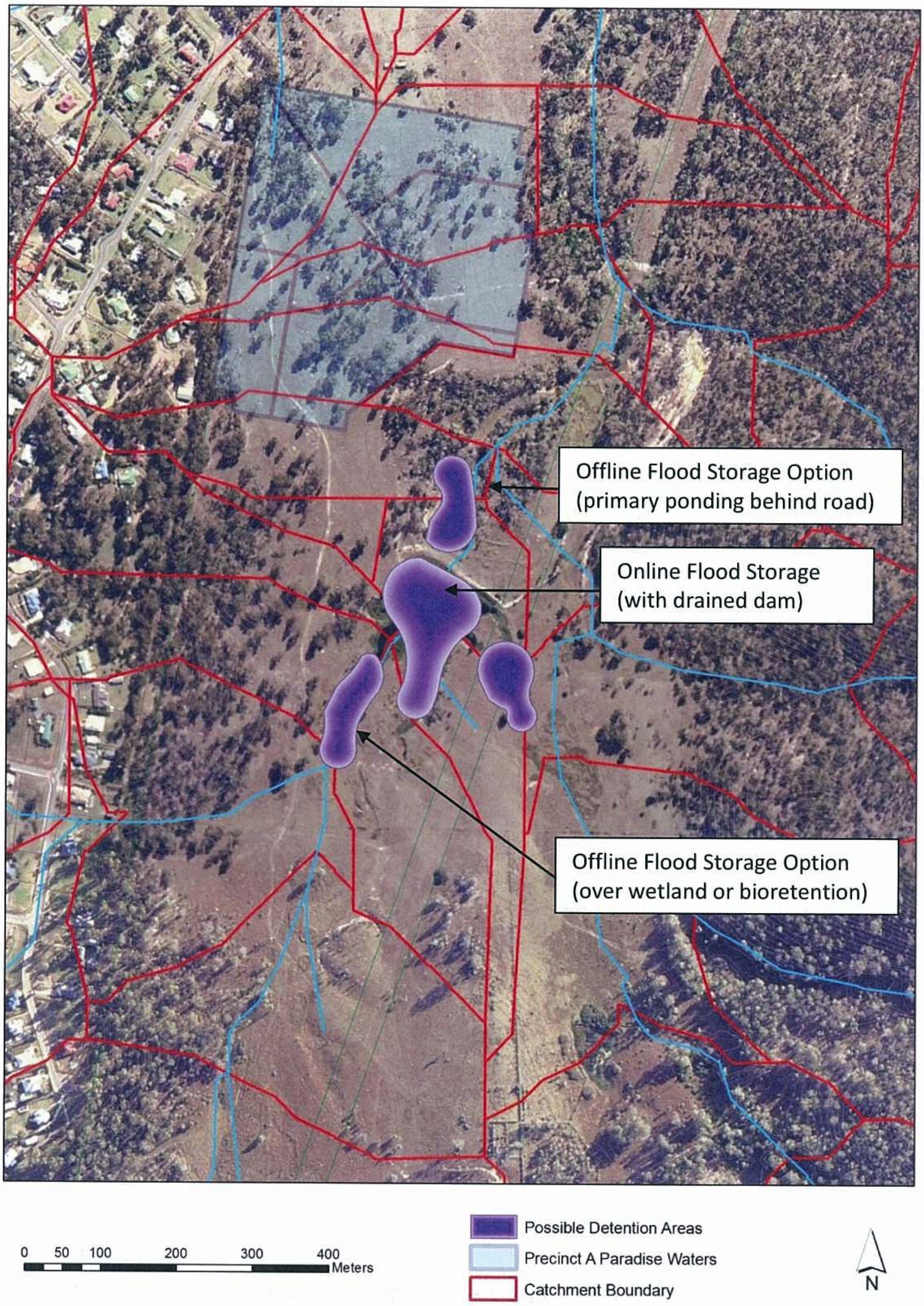

Figure 5-2 **Possible Flood Storage Locations – Context Scale**

6 DESIGN FLOOD LEVEL ESTIMATION

6.1 Methodology

The HEC-RAS hydraulic model (USACE, 2009) was used to estimate the existing 100 year ARI design flood levels across the subject site for existing and post-development site conditions.

6.2 Model Configuration

6.2.1 Cross Sections

Cross sections for the study were developed from field survey. Figure 6-1 shows the locations of the cross sections used in the model.

6.2.2 Adopted Manning's 'n'

The following Manning's 'n' values were adopted for the study:

- Channel: 'n' = 0.045
- Overbank: 'n' = 0.035

Appropriate Manning's 'n' values were selected based upon site inspection and reference to the Brisbane City Council Natural Channel Design Guidelines (BCC, 2003).

6.2.3 Boundary Conditions

Normal depth upstream and downstream boundary conditions were adopted for Deebing Creek and its tributaries. The slopes chosen reflect the approximate slope of the channel beds in the study reaches.

6.2.4 Design Discharges

Table 6-1 shows the adopted design discharges for the 100 year ARI HEC-RAS model for post-development conditions.

6.3 Results

Table C1, Appendix C, and Figure 6-2 show the estimated 100 year ARI design flood levels and extent, respectively, across the subject site for existing conditions.

Figure 6-1 **HEC-RAS Cross Section Locations**

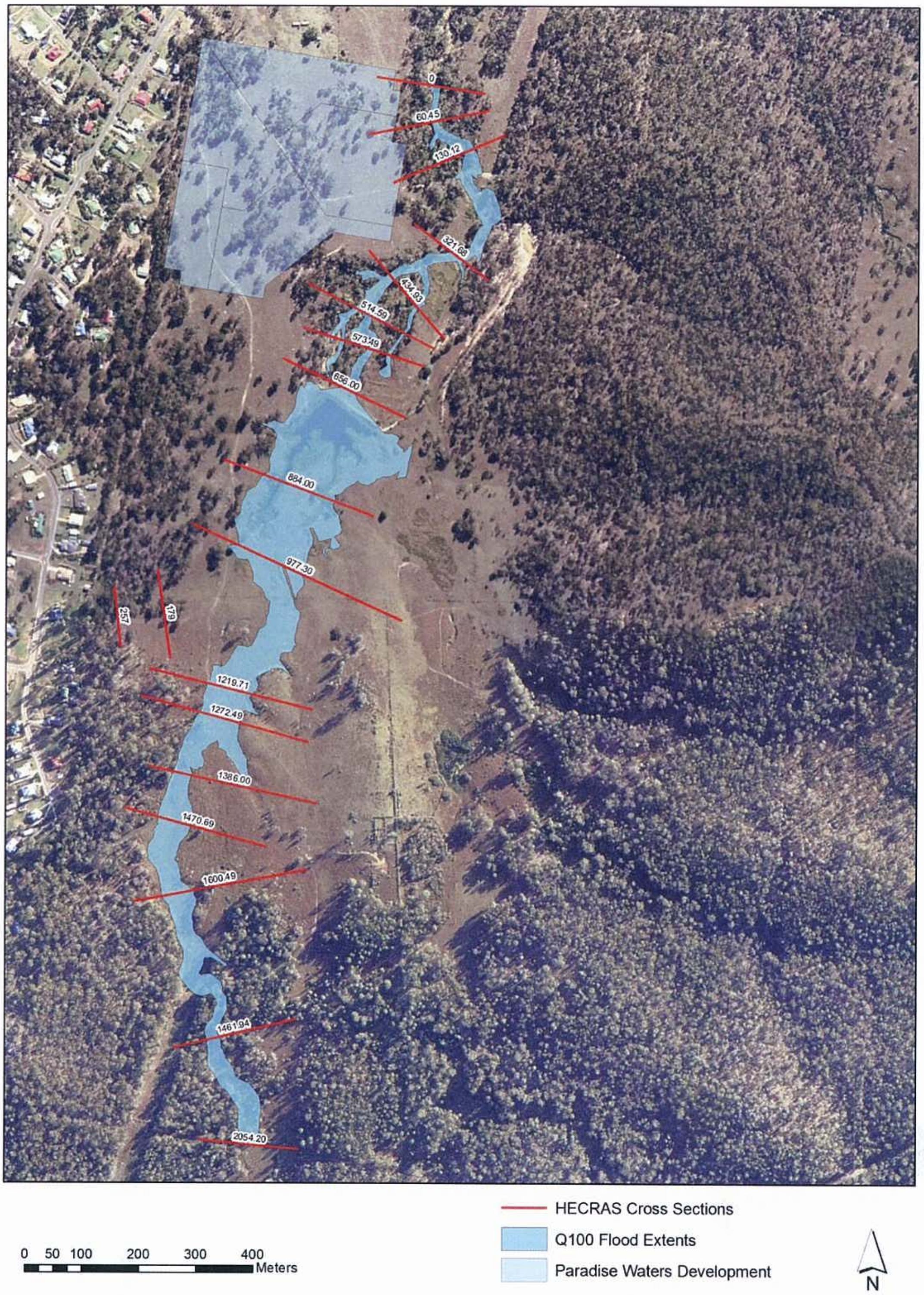

Figure 6-2 **HEC-RAS Q100 Flood Extents**

Figure 6-3 **Context Plan showing Flood Extents**

Table 6-1 Adopted HEC-RAS Design Discharges for Developed Catchment Conditions

Branch	Cross Section	RAFTS Node	100 Yr ARI Discharge (m^3/s)
Deebing Creek	0	D22	88.2
	130.17	C43	87.1
	434.93	C40E	85.6
	514.59	C39	84.1
	573.49	C25E	62.3
	977.30	C23	62.6
	1386.00	C17	53.0
	1600.49	C8	49.1
	1861.94	C7	19.9
	2054.20	C6	17.5
Branch 2	257.00	D22	10.8

7 CONCLUSION

As part of the Paradise Waters Development Precinct A, Stockland proposes to develop the parcel of land located at South Deebing Creek Road, Deebing Heights for predominately urban residential use (150 lots + commercial lot + road + balance land).

Water Technology in collaboration with Design Flow has prepared a preliminary Flood Management Plan for the development.

In general, while the increased urbanisation of catchments within Paradise Waters Precinct A produces increased runoff, the predicted impact on peak Deebing Creek discharges is small.

More specifically:

- The Precinct A proposed works are predicted to have a minor effect on peak flood discharges downstream of the development site.
- Immediately downstream of the development site, peak flows are predicted to reduce slightly.
- There is a slight (<1%) increase in peak flows at the Cunningham Highway.

Stockland is committed to delivering regional and local flood storage on the broader development site. Details of this storage will be defined as part of a Master Flood Study.

8 REFERENCES

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WRC (1994), *Queensland Urban Drainage Manual*, Edition 1-2 November 1994, Water Resources Commission, Department of Primary Industries; Institute of Municipal Engineering Australia, Queensland Division; Brisbane City Council

USACE (2003), *HEC-RAS River Analysis System User's Manual*, V 3.1.1, US Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Centre, California, USA.

XP Software (2001), *XP-RAFTS*, XS Software, Florida, USA

Appendix A

RAFTS Catchment Land Use Areas and Percentage Imperviousness

Table A1 Existing Conditions - RAFTS Catchment Land Use Areas and Percentage Imperviousness

Node	Initial Area (ha)	Exist Rural Residential area (ha)	% Impervious	Exist Area Imperv (ha)	Exist Area Perv (ha)	Undeveloped (ha)	Total Impervious (ha)	Total Pervious (ha)
C17	19.44	5	20%	1	4	14.44	1	18.44
C19	10.5	10.5	20%	2.1	8.4	0	2.1	8.4
C21	10.31	10.31	20%	2.062	8.248	0	2.062	8.248
C20	10.44	10.44	20%	2.088	8.352	0	2.088	8.352
C55	10.13	10.13	20%	2.026	8.104	0	2.026	8.104
C56E	10.47	10.47	20%	2.094	8.376	0	2.094	8.376
C57E	5.28	5.28	20%	1.056	4.224	0	1.056	4.224
C58E	5.19	5.19	20%	1.038	4.152	0	1.038	4.152
C54RR	6.323	6.2	20%	1.24	4.96	0.123	1.24	5.083
C54Dev	4.057	0	20%	0	0	4.057	0	4.057
C59E	7.53	4.4	20%	0.88	3.52	3.13	0.88	6.65
C43W	5.065	0	-	0	0	5.065	0	5.065
C42W	6.94	0.02	20%	0.004	0.016	6.92	0.004	6.936
C40W	5.03	1.6	20%	0.32	1.28	3.43	0.32	4.71
C39W	5.5	0.6	20%	0.12	0.48	4.9	0.12	5.38
C25W	1.3	1.3	20%	0.26	1.04	0	0.26	1.04
C24W	5.28	2	20%	0.4	1.6	3.28	0.4	4.88
C23W	6.315	3	20%	0.6	2.4	3.315	0.6	5.715
C22	10.94	7	20%	1.4	5.6	3.94	1.4	9.54
C18	10.69	1	20%	0.2	0.8	9.69	0.2	10.49

Table A2 Paradise Waters, Precinct A - RAFTS Catchment Land Use Areas and Percentage Imperviousness

Node	Initial Area (ha)	Developed Area (ha)	% Impervious	Area Impervious (ha)	Area Pervious (ha)	Exist Rural Residential area (ha)	% Impervious	Exist Area Imperv (ha)	Exist Area Perv (ha)	Undeveloped (ha)	Total Impervious (ha)	Total Pervious (ha)
C17	19.44	0		0	0	5	20%	1	4	14.44	1	18.44
C19	10.5	0		0	0	10.5	20%	2.1	8.4	0	2.1	8.4
C21	10.31	0		0	0	10.31	20%	2.062	8.248	0	2.062	8.248
C20	10.44	0		0	0	10.44	20%	2.088	8.352	0	2.088	8.352
C55	10.13	0		0	0	10.13	20%	2.026	8.104	0	2.026	8.104
C56E	10.47	0		0	0	10.47	20%	2.094	8.376	0	2.094	8.376
C57E	5.28	0		0	0	5.28	20%	1.056	4.224	0	1.056	4.224
C58E	5.19	0		0	0	5.19	20%	1.038	4.152	0	1.038	4.152
C54RR	6.323	0		0	0	6.2	20%	1.24	4.96	0.123	1.24	5.083
C54Dev	4.057	4.057	60%	2.4342	1.6228	0	20%	0	0	0	2.4342	1.6228
C59E	7.53	0		0	0	4.4	20%	0.88	3.52	3.13	0.88	6.65
C43W	5.065	4.065	60%	2.439	1.626	0		0	0	1	2.439	2.626
C42W	6.94	3	60%	1.8	1.2	0.02	20%	0.004	0.016	3.92	1.804	5.136
C40W	5.03	3.27	60%	1.962	1.308	1.6	20%	0.32	1.28	0.16	2.282	2.748
C39W	5.5	0.5	60%	0.3	0.2	0.6	20%	0.12	0.48	4.4	0.42	5.08
C25W	1.3	0		0	0	1.3	20%	0.26	1.04	0	0.26	1.04
C24W	5.28	0		0	0	2	20%	0.4	1.6	3.28	0.4	4.88
C23W	6.315	0		0	0	3	20%	0.6	2.4	3.315	0.6	5.715
C22	10.94	0		0	0	7	20%	1.4	5.6	3.94	1.4	9.54
C18	10.69	0		0	0	1	20%	0.2	0.8	9.69	0.2	10.49

Note: All other nodes assumed at 100% pervious (undeveloped) conditions

Appendix B

Rational Method Calculations

Table B1 Rational Method Calculations, Fully Undeveloped Catchment (C10 = 0.7)

Rational Method Parameters	**Units**	**Design Storm Event (ARI)**						
		1 Year	**2 Year**	**5 Year**	**10 Year**	**20 Year**	**50 Year**	**100 Year**
Catchment Area	ha	1318	1318	1318	1318	1318	1318	1318
Catchment Slope		Hilly (4-8%)	Hilly (4-8%)	Hilly (4-8%)	Hilly (4-8%)	Hilly (4-8%)	Hilly (4-8%)	Hilly (4-8%)
Time of Concentration								
Length	m	7500	7500	7500	7500	7500	7500	7500
Velocity	m/s	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Total Time of Concentration	**min**	**138.9**	**138.9**	**138.9**	**138.9**	**138.9**	**138.9**	**138.9**
Runoff Coefficient (Cy)		0.53	0.56	0.63	0.66	0.69	0.76	0.79
Frequency Factor (Fy)		0.8	0.85	0.95	1	1.05	1.15	1.2
Rainfall Intensity (Iy)	mm/hr	18.6	24.2	31.7	36.5	42.8	51.5	58.5
Discharge	**m^3/s**	**35.6**	**49.3**	**72.3**	**87.6**	**107.9**	**142.1**	**168.3**

Table B2 Rational Method Calculations, Fully Developed Catchment (C10 = 0.9)

Rational Method Parameters	Units	Design Storm Event (ARI)						
		1 Year	2 Year	5 Year	10 Year	20 Year	50 Year	100 Year
Catchment Area	ha	1318	1318	1318	1318	1318	1318	1318
Catchment Slope		Hilly (4-8%)	Hilly (4-8%)	Hilly (4-8%)	Hilly (4-8%)	Hilly (4-8%)	Hilly (4-8%)	Hilly (4-8%)
Time of Concentration								
Length	m	7500	7500	7500	7500	7500	7500	7500
Velocity	m/s	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Total Time of Concentration	**min**	**138.9**	**138.9**	**138.9**	**138.9**	**138.9**	**138.9**	**138.9**
Runoff Coefficient (Cy)		0.72	0.77	0.86	0.90	0.95	1.04	1.08
Frequency Factor (Fy)		0.8	0.85	0.95	1	1.05	1.15	1.2
Rainfall Intensity (Iy)	mm/hr	18.6	24.2	31.7	36.5	42.8	51.5	58.5
Discharge	**m^3/s**	**48.5**	**67.2**	**98.6**	**119.4**	**147.1**	**193.8**	**229.5**

Appendix C

100 year ARI Flood Levels

Table C1 100 Year ARI Design Flood Levels Post-Development Catchment Conditions

River	Reach	River Station	Developed Water Surface Elevation (m AHD)
Deebing Creek	3	0 (DS boundary)	50.6
Deebing Creek	3	60.45	51.1
Deebing Creek	3	130.17	52.2
Deebing Creek	3	321.68	53.5
Deebing Creek	3	434.93	54.8
Deebing Creek	3	514.59	55.6
Deebing Creek	3	573.49	55.8
Deebing Creek	3	656.00	57.0
Deebing Creek	3	884.00	62.9
Deebing Creek	3	977.30	63.9
Deebing Creek	2	179.00	66.6
Deebing Creek	2	257.00	68.2
Deebing Creek	1	1219.71	66.7
Deebing Creek	1	1272.49	67.5
Deebing Creek	1	1386.00	68.7
Deebing Creek	1	1470.69	69.4
Deebing Creek	1	1600.49	70.0
Deebing Creek	1	1461.94	72.8
Deebing Creek	1	2054.20	75.4