Flood Report

Lindfield Learning Village Stage 2 & 3

Schools Infrastructure NSW

100 Eton Road, Lindfield NSW 2070

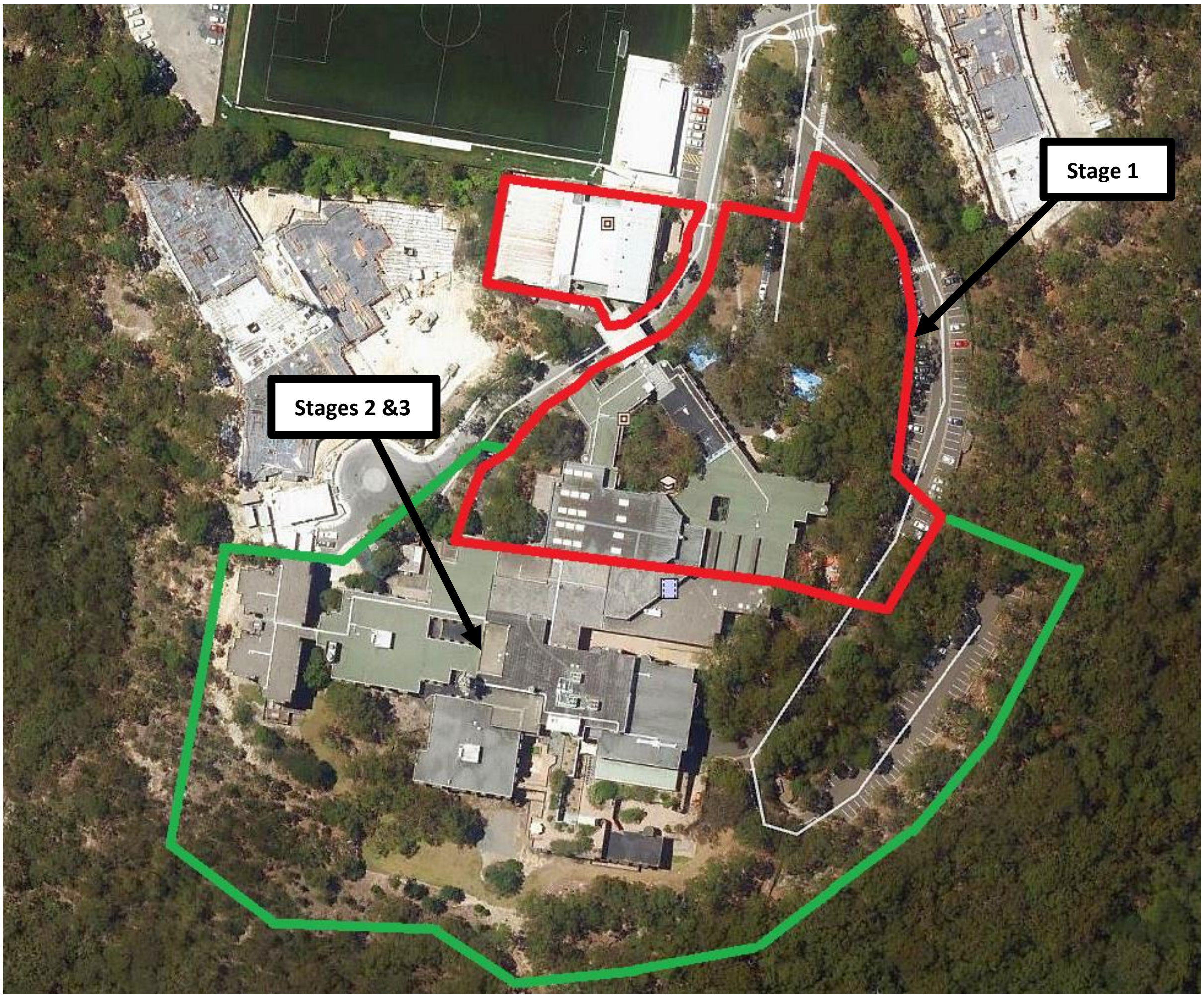
EWFW Pty Ltd

Century House

Level 4, 362 Kent St, Sydney NSW 2000

Phone: 1300 553 654

ABN: 48 130 395 827



DOCUMENT TITLE	Flood Report
PROJECT	Lindfield Learning Village Stage 2 & 3
PROJECT ADDRESS	100 Eton Road, Lindfield NSW 2070
CLIENT	Schools Infrastructure NSW
DOCUMENT VERSION	N
DATE	17/04/2020
EWFW PROJECT REFERENCE	21951.001.R001
File path:	W:\219xx\21951 - Lindfield Learning Village Bus Loop Variation\001 - Design Services\Admin\Reports\Flood Report\21951_Flood Report Rev [N].docx

DOCUMENT VERSION CONTROL					
Rev	Date	Description of Release	Prepared By	Checked By	Approved By
A					
B	15/08/2018	Revised Issue – Draft	S. Bahrow	L DeGioia	D DeGioia
C	30/08/2018	Revised Issue - Draft	S. Bahrow	L DeGioia	D DeGioia
D	30/11/2018	Revised Issue - Draft	S. Bahrow	L DeGioia	D DeGioia
E	31/12/2018	Final Issue	S. Bahrow	L DeGioia	D DeGioia
F	02/01/2019	Final Issue amendments	S. Bahrow	L DeGioia	D DeGioia
G	08/01/2019	Additional Comments added	S. Bahrow	L DeGioia	D DeGioia
H	23/06/2019	Revised for Additional Cleared Areas	S. Bahrow	L DeGioia	D DeGioia
I	11/07/2019	Revised comments	S. Bahrow	L DeGioia	D DeGioia
J	17/07/2019	Revised Comments	S. Bahrow	L DeGioia	D DeGioia
K	18/07/2019	Revised Comments	S. Bahrow	L DeGioia	D DeGioia
L	27/09/2019	Catchment B6 & B7	S. Bahrow	L DeGioia	D DeGioia
M	23/10/2019	Final Issue	S. Bahrow	L DeGioia	D DeGioia
N	17/04/2020	Issued for Final Draft Review	C Veleski	L DeGioia	D DeGioia

EXECUTIVE SUMMARY

This Flood Report has been prepared by EWFW on behalf of School Infrastructure NSW. It accompanies a Response to Submissions Report in support of State Significant Development Application (SSD 16_8114) for Lindfield Learning Village (the site).

On 24 October 2018, the Minister for Planning granted partial development consent to SSD 8114 for Stage 1 construction and operation of a new school for 350 students. The remainder of SSD 8114 is yet to be granted consent and has been subject to further investigation, assessment and engagement with the relevant agencies (DPE, RFS, OEH, TfNSW) and Council.

We understand the Response to Submissions and supporting documents seek approval for the remainder of SSD 8114 as being:

- A contingency for staged construction works:
    - Use of the currently approved Stage 1 administration areas for student occupation.
- Stage 2 of construction:
    - New works to accommodate 1,050 students (including the already approved 350).
    - Repurposing of the Stage 1 works.
    - A loop road around the southern portion of the site for emergency vehicles, buses and drop off and pick up vehicles.
- Stage 3 of construction:
    - New works to accommodate a further 950 students.

The SSD does not seek approval for vegetation management outside the site boundary thus site boundary conditions remain unchanged for stormwater runoff. Any vegetation management or works outside the site boundary is subject to separate approval, thus a separate study should be undertaken to understand change of the behaviour of stormwater runoff.

The primary objective of this study is to define the stormwater behaviour within the site catchment through the establishment of appropriate numerical models. The study has produced information on flows, velocities, levels and extents for a range of stormwater event magnitudes under existing catchment conditions. Specifically, the study incorporates:

- Development and calibration of appropriate hydrologic and hydraulic models utilising DRAINS modelling software.
- Determination of overland flow conditions for a range of design events including the 5%, 2%, 1%, storm event; and
- Presentation of study methodology, results and findings in a comprehensive report incorporating appropriate flood mapping.

Section 5 of this report shows the 5%, 2% and 1% AEP storm event modelling results.

This report meets the criteria's as specified in Ku-ring-gai Council's Development Control Plan 2016 Part 24.

- Assumption was made that the all the drainage system was blocked, for the model
- There is no net increase in the impervious areas without any flow attenuation.

Inundation of the property would be minimal due its location being situated upon the apex of a ridge.

The outcome of the assessment defined the stormwater behaviour along Eton Rd, Shout Ridge, Hamilton Corner, and Dunstan Grove and in particular the investigation of flow level information that will be used to set appropriate planning levels.

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1 INTRODUCTION

1.1 PURPOSE

EWFW Consulting Engineers Pty Ltd (EWFW) has been engaged to undertake a hydrological and hydraulic assessment for the proposed Lindfield Learning Village development (site) at 100 Eton Road, Lindfield. The preparation of this report is based on our understanding of the existing topography of the site and its surroundings, the proposed development works and the constraints surrounding this development.

In undertaking the preparation of this report, EWFW hereby advises that it has no control over any approvals, additional third party requirements, competitive development costs, nor does it have any control over any increase in statutory fees or future availability of external drainage services capacity.

This flood report produced by EWFW is provided on an as is basis of its best judgement and accepted engineering practices at the time of writing.

1.2 SITE LOCATION

The site is located within Ku-ring-gai Council's (Council) local governing area. The site is currently developed with multiple buildings, roads and carparks, landscaped areas and heavily vegetated areas.

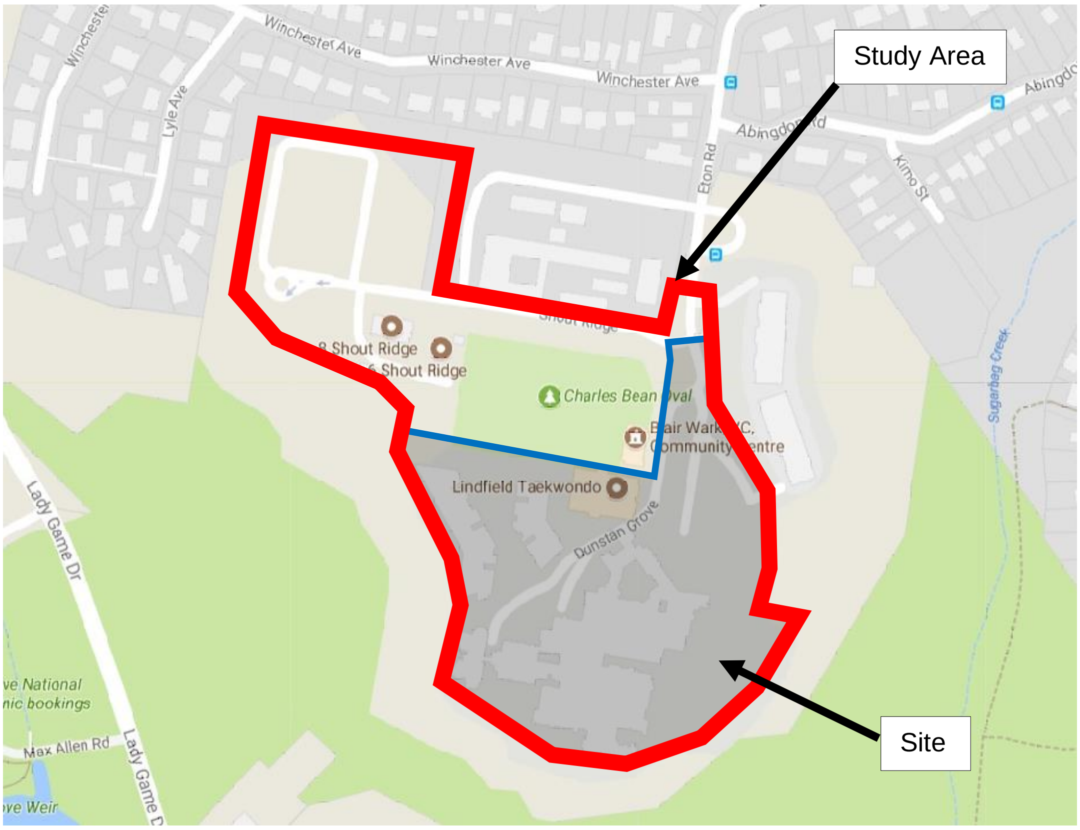

FIGURE 1-1 SITE LOCATION PLAN - *GOOGLE MAPS*

1.3 REFERENCE DOCUMENTS

The following documents have been reviewed in order to develop this report:

TABLE 1-1 REFERENCE DOCUMENTS

Document	Reference
Ku-ring-gai Council Development Control Plan 2016 Part 24	DCP 24
NSW Government Floodplain Development Manual 2005	NSW FDM
Patterson Britton & Partners Pty Ltd Urban Infrastructure Management Strategy 2006	PB UIMS

1.4 GLOSSARY OF TERMINOLOGY

TABLE 1-2 GLOSSARY TABLE

Annual Exceedance Probability (AEP)	The chance of a storm event of a given size occurring in any one year, expressed as a percentage. For example, if a peak flood discharge of 500 m^3/sec has an AEP of 5%, it means that there is a 5% chance (i.e. a 1 in 20 chance) of a peak discharge of 500 m3/s (or larger) occurring in any one year. (see also average recurrence interval)
Australian Height Datum (AHD)	National survey datum corresponding approximately to mean sea level.
Astronomical Tide	Astronomical Tide is the cyclic rising and falling of the Earth's oceans water levels resulting from gravitational forces of the Moon and the Sun acting on the Earth.
Attenuation	Weakening in force or intensity.
Average Recurrence Interval (ARI)	The estimated average time period between random rain events of the same duration and size as a probability of occurring in any one year. For example, if a peak discharge of 500m^3/sec has an average recurrence interval of 20 years based on historical data, it means that there is a 1 in 20 chance of an event occurring in any one year. (see also annual exceedance probability)
Calibration	The adjustment of model configuration and key parameters to best fit an observed data set.
Catchment	The area of land that drains to a point.
Design flood event	A hypothetical flood event representing a specific likelihood of occurrence (for example the 100 year ARI or 1% AEP storm event).
Development	Existing or proposed works that may or may not be impacted by flooding.
Discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic meters per second (m3/s).
Flood	Relatively high stormwater flows, which overtop the natural or artificial banks, and inundate floodplains and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood behaviour	The pattern / characteristics / nature of a flood.
Flood fringe	Land that may be affected by flooding but is not designated as floodway or flood storage
Flood hazard	A source of potential harm or a situation that has potential to cause harm.
Flood level	The height or elevation of floodwaters relative to a datum (typically the Australian Height Datum). Also referred to as "stage".
Flood liable land	see flood prone land
Floodplain	Land that is periodically inundated due to floods. The floodplain includes all land that is susceptible to inundation by the probable maximum flood (PMF) event.
Floodplain management	The co-ordinated management of activities that occur on the floodplain.

Floodplain risk management plan	A document outlining a range of actions aimed at improving floodplain management. The plan is the principal means of managing the risks associated with the use of the floodplain. A floodplain risk management plan needs to be developed in accordance with the principles and guidelines contained in the NSW Floodplain Management Manual. The plan usually contains both written and diagrammatic information describing how particular areas of the floodplain are to be used and managed to achieve defined objectives.
Flood planning levels (FPL)	Flood planning levels selected for planning purposes are derived from a combination of the adopted flood level plus freeboard, as determined in floodplain management studies and incorporated in floodplain risk management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also consider the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of land use and for different flood plans. The concept of FPLs supersedes the "standard flood event" in past NSW FDMs. As FPLs do not necessarily extend to the limits of flood prone land, floodplain risk management plans may apply to flood prone land beyond that defined by the FPLs.
Flood prone land	Land susceptible to inundation by the probable maximum flood (PMF) event. Under the merit policy, the flood prone definition should not be seen as necessarily precluding development. Floodplain Risk Management Plans should encompass all flood prone land (i.e. the entire floodplain).
Flood risk	The potential danger to life and potential damage to property resulting from flooding. The degree of flood hazard varies with circumstances across the full range of flood events.
Flood source	The source of the floodwaters.
Flood storage	Floodplain area that is intended for the temporary storage of floodwaters during a flood event.
Floodway	Area of a floodplain that has an substantial amount of discharge during a flood event.
Freeboard	Factors of safety usually expressed as a height above the adopted flood level thus determine the flood planning level. Freeboard tends to compensate for factors such as wave action, localised hydraulic effects and uncertainties in the design flood levels.
Geomorphology	The study of the origin, characteristics and development of landforms.
Gauging (tidal and flood)	Measurement of flows and water levels during tides or flood events.
Historical flood	A flood that has actually occurred.
Hydraulic	Relating to water flow in rivers, estuaries and coastal systems; in particular, the evaluation of flow parameters such as water level and velocity.
Hydrodynamic	Pertaining to the movement of water.
Hydrograph	A graph showing how a river or creek's discharge changes with time.
Hydrographic survey	Survey of the bed levels of a waterway
Hydrologic	Pertaining to rainfall-runoff processes in catchments
Hydrology	The term given to the study of the rainfall-runoff process in catchments
Hyetograph	A graph showing the distribution of rainfall over time.
Intensity Frequency Duration (IFD) Curve	A statistical representation of rainfall showing the relationship between rainfall intensity, storm duration and frequency (probability) of occurrence.
Isohyets	Equal rainfall contour.
Morphological	Pertaining to geomorphology
Peak flood level, flow or velocity	The maximum flood level, flow or velocity that occurs during a flood event.
Pluviometer	A rainfall gauge capable of continuously measuring rainfall intensity
Probable maximum flood (PMF)	An extreme flood deemed to be the maximum flood likely to occur.
Probability	A statistical measure of the likely frequency or occurrence of flooding.
Riparian	The interface between land and waterway. Literally means "along the river margins"
Runoff	The amount of rainfall from a catchment that actually ends up as flowing water in the river or creek
Stage	See flood level.
Stage hydrograph	A graph of water level over time.

Sub-critical	Refers to flow in a channel that is relatively slow and deep.
Topography	The shape of the surface features of land
Velocity	The speed at which the floodwaters are moving. A flood velocity predicted by a computer flood model is quoted as the depth averaged velocity, i.e. the average velocity throughout the depth of the water column or velocity across the whole river or creek section.
Validation	A test of the appropriateness of the adopted model configuration and parameters (through the calibration process) for other observed events.
Water level	See flood level.

2 OVERLAND FLOW ASSESSMENT APPROACH

2.1 EXISTING CATCHMENT AREAS

The existing site is currently developed and is occupied by multiple buildings, internal road network and carparking system, and landscape areas to which it has a mix of impervious and pervious areas. The site stormwater runoff flows into the Blue Gum Creek drainage system through the existing internal site infrastructure that discharges into Council's stormwater system for drainage conveyance onto Blue Gum Creek.

The overall site catchment area is identified as 13 sub catchments area comprising of R1, R2, R3, R4, R5, R6, R7, R8 catchments that are parts of internal road network and B1, B2, B3, B4, and B5 catchments that represent the general building catchment areas. The catchment areas are based on a desktop study of existing aerial imagery and maps. The sub catchment areas are as indicated in Figure 2-1.

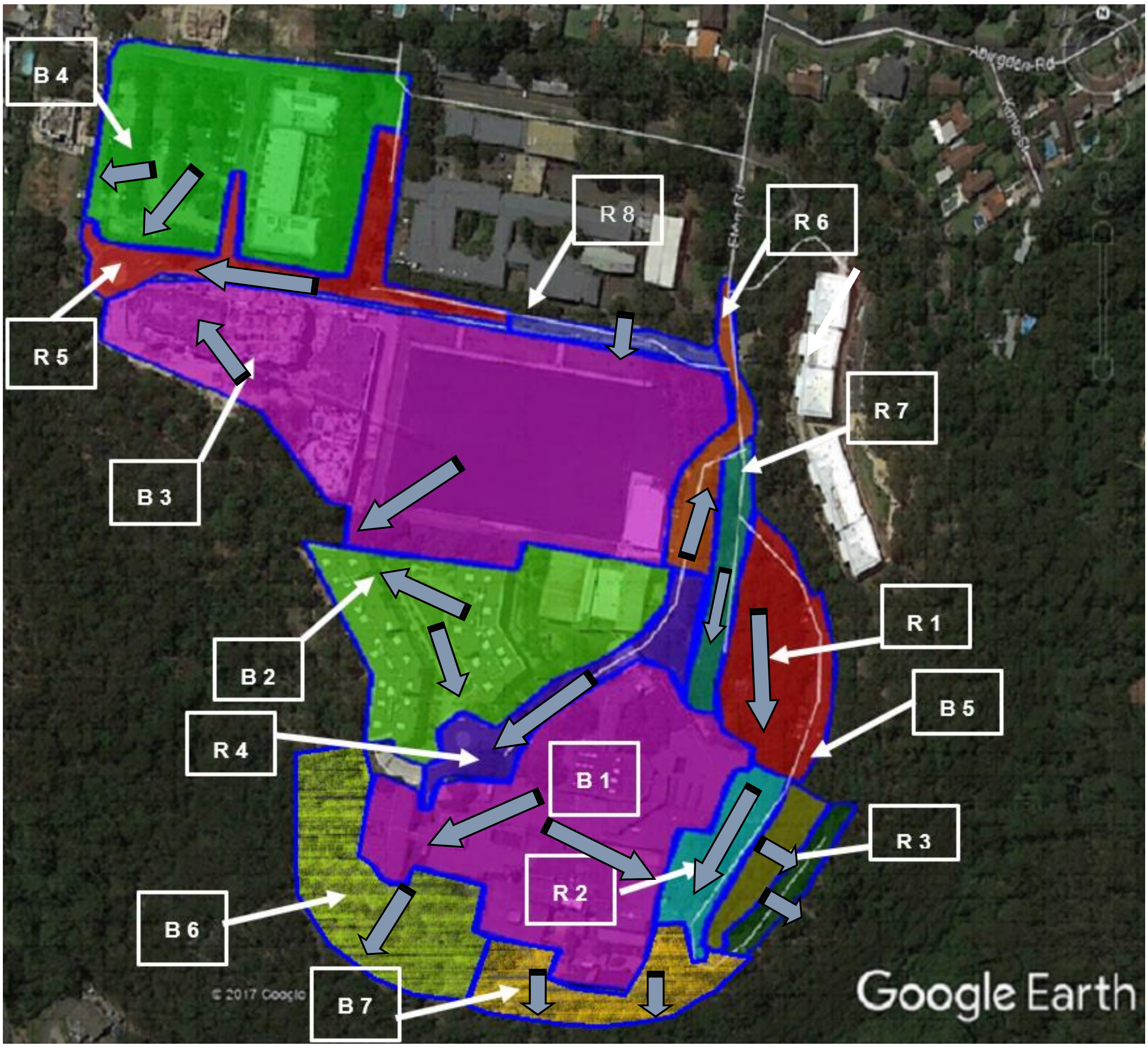

FIGURE 2-1 - CATCHMENT PLAN AND GENERAL SLOPE DIRECTION - *GOOGLE EARTH*

The following has been noted for each catchment, including any assumptions made based on the desktop study.

2.1.1 CATCHMENT R1

The catchment generally grades south and includes a landscape area upstream of the road area. The landscape area runoff flows onto the parking area and further onto the roadway downstream – refer Figure 2-2.

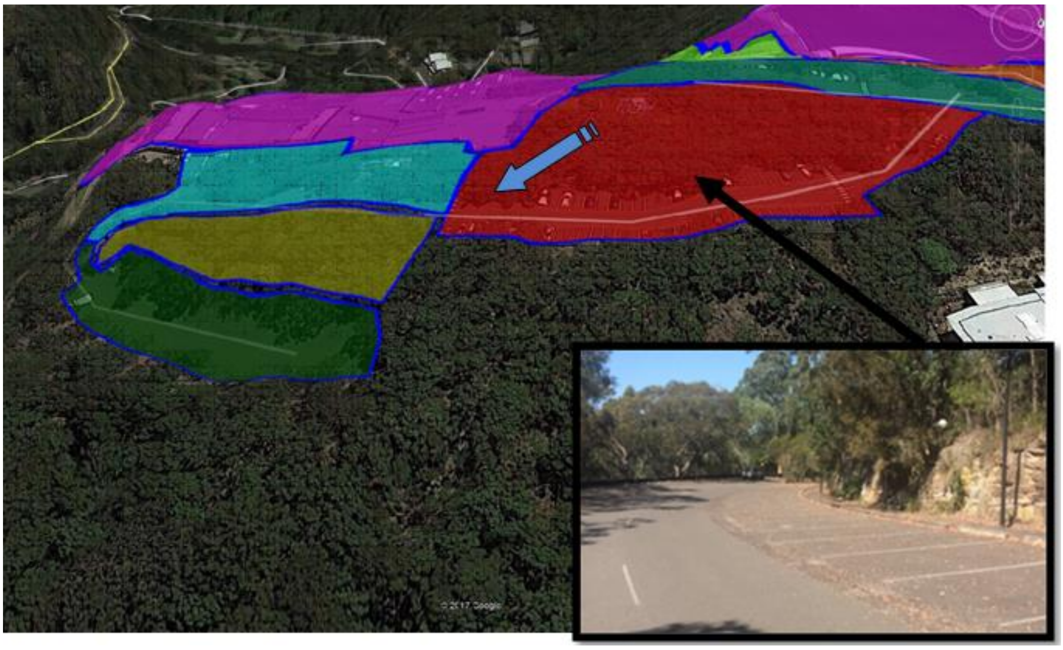

FIGURE 2-2 - CATCHMENT R1

The majority of runoff from catchment R1 discharges into catchment R2 downstream, however a portion also discharges into catchment B5 where the parking is discontinued due to minimal kerb to redirect flows towards catchment R2 – refer Figure 2-3.

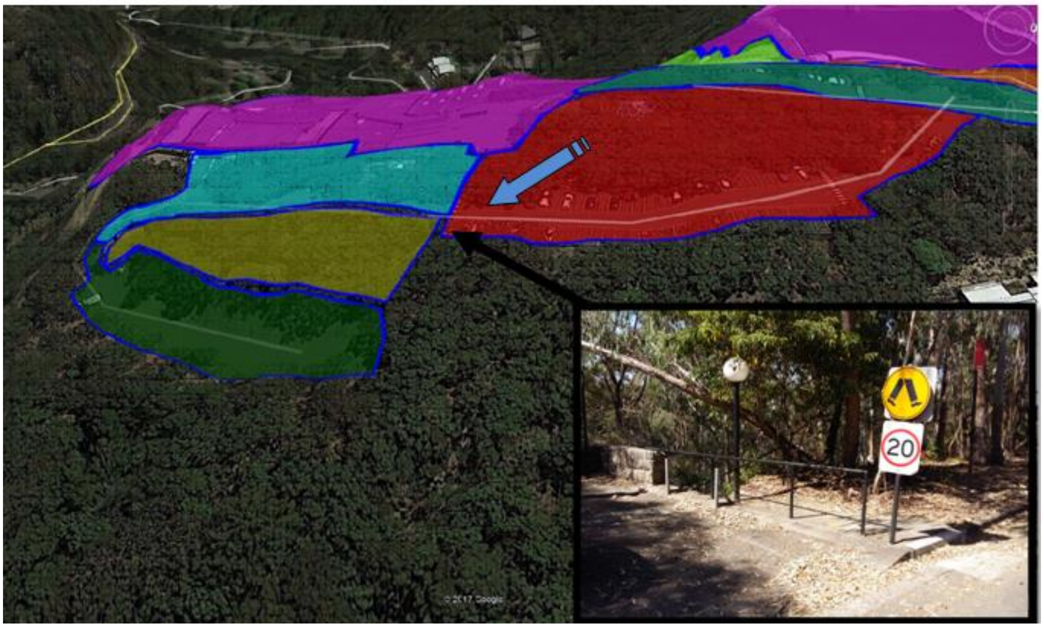

FIGURE 2-3 CATCHMENT R1 DOWNSTREAM

2.1.2 CATCHMENT R2

The catchment generally grades to the south. Runoff within this catchment consists of three parts: runoff from catchment R1, runoff from catchment B1 and runoff generated from the area of catchment R2 – refer

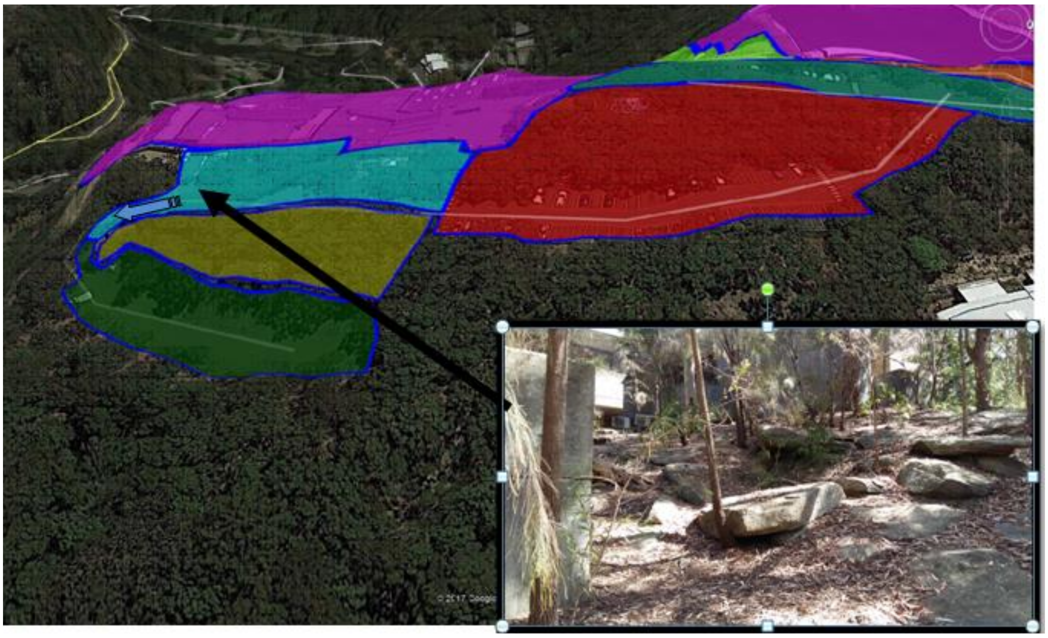

FIGURE 2-4 CATCHMENT R2

The catchment discharges at two locations 50 percent of drains flow into and out of the study area via the culvert that is located at the end of the catchment area and 50 percent of runoff enters to catchment R3.

2.1.3 CATCHMENT R3

The catchment generally grades towards the east. The total runoff of catchment R3 comprises of catchment R3 runoff and upstream R1 and R2 runoff that drain via the low point for discharge to Lane Cove Creek. Catchment B5 is also located upstream, however flows from this catchment are experienced in R3 when there is a pipe blockage.

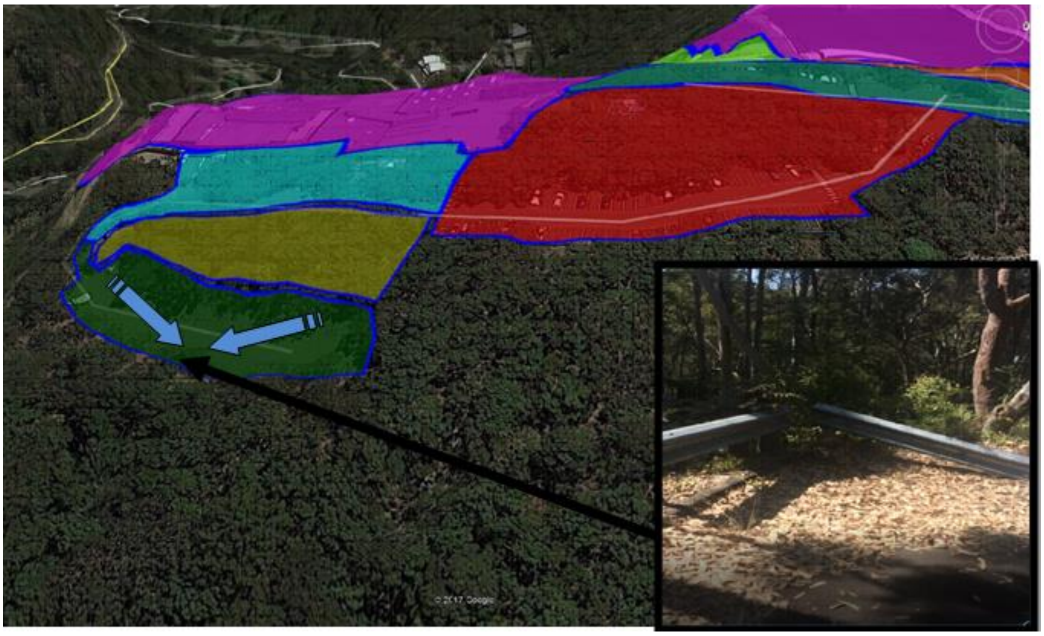

FIGURE 2-5 - CATCHMENT R3

2.1.4 CATCHMENT R4

After discharging 50 percent of catchment B2 runoff and 70 percent of catchment B1 runoff flows into the out of the study area. The remaining flow drains into catchment R4 (see figure 2.11 and 2.12).

At the end, 70 percent of catchment R4 runoff discharges via an existing private property drainage network that is located in the catchment R4 low point and 30 percent discharge to the garden area close to that property (see figure 2.7).

2.1.5 CATCHMENT R5 ASSUMPTIONS

The Existing rain gardens of catchment B4 abstract 30 percent of catchment B4 runoff, then conduct it to outside of the study area and 70 percent of it, discharging to catchment R5 (see figure 2.14). In addition to B4, 30 percent of B3 drains in to R5.

50 percent of discharging catchment R5 runoff, happens via the existing private property drainage network that is located in the lowest level of catchment R5 and the other 55 percent drains via pedestrian wall opening (see figure 2.8)

2.1.6 CATCHMENTS R6 AND R7 ASSUMPTIONS

The catchment R6 and catchment R7 runoff drain in to the low point of them. There is no added flow in these catchments.

2.1.7 CATCHMENT R8 ASSUMPTIONS

The total flow of this catchment discharges to catchment B3 and after that drains into the out of the study area via the lowest level of B3 (see figure 2.10 and 2.13)

2.1.8 CATCHMENT SUMMARY

Base on technical explanation and site observation it is necessary to consider flood level in catchment R1, R2, R3, R4, R5, R6, R7 and R8.

Table 2-1 Catchments Specification

Catchment No.	Name	Area (ha)	Upstream Level (m)	Downstream Level (m)	Length of biggest runoff (m)	General Slope (%)
1	R 1	0.55	66	61	135	3.7
2	R 2	0.28	61	54	105	6.7
3	R 3	0.17	54	52	75	2.7
4	R 4	0.27	66	53	165	7.9
5	R 5	0.37	69	63	210	2.9
6	R 6	0.2	67	65	150	1.3
7	R 7	0.19	67	66	125	0.8
8	R 8	0.1	67	63	100	1.0
9	B 1	1.691	51	46	59	8.5
10	B 2	1.1	54	43	70	15.7
11	B 3	2.41	62	58	63	6.3
12	B 4	1.25	-	-	-	-
13	B 5	0.21	59	51	32	25

Figure2.6 Catchment R3

Figure2.7 Catchment R4

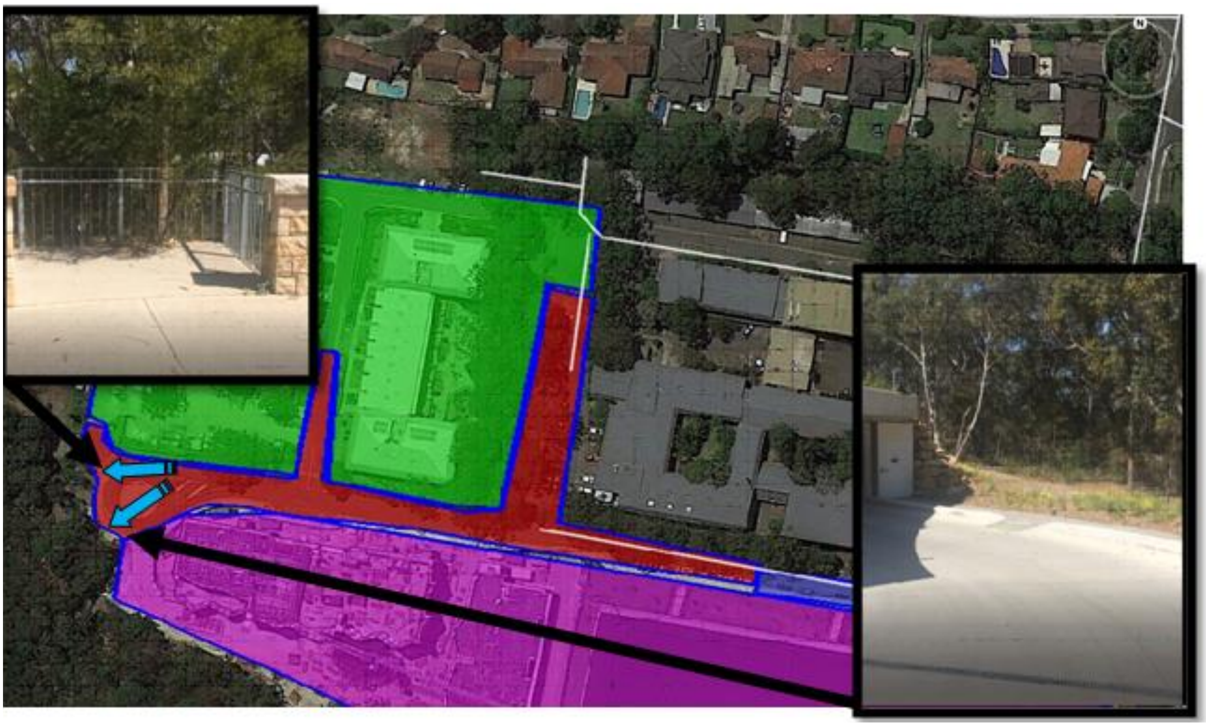

Figure2.8 Catchment R 5

Figure2.9 Catchment R 6 & R 7

Figure2.10 Catchment R 8

Figure2.11 Catchment B1

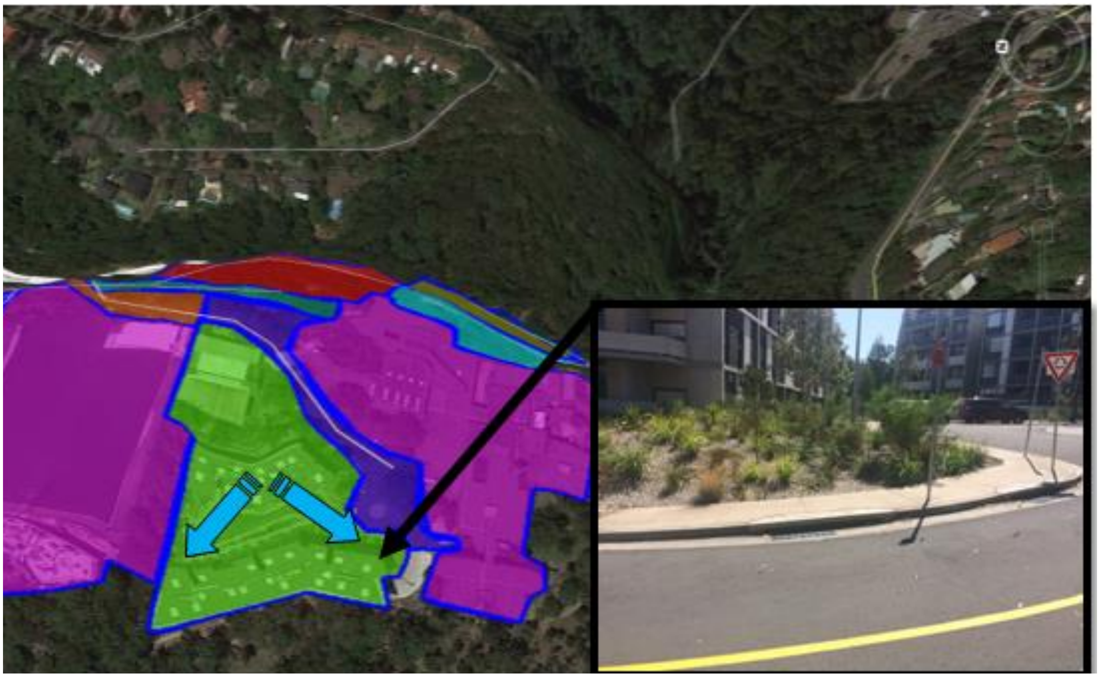

Figure2.12 Catchment B 2

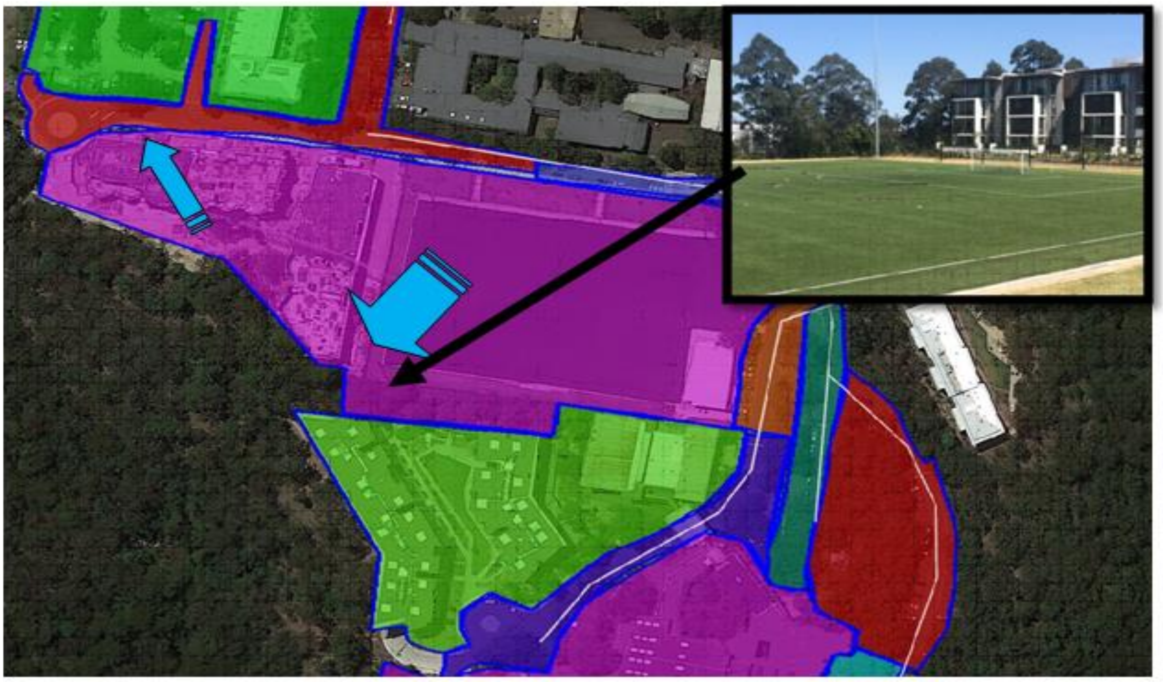

Figure2.13 Catchment B 3

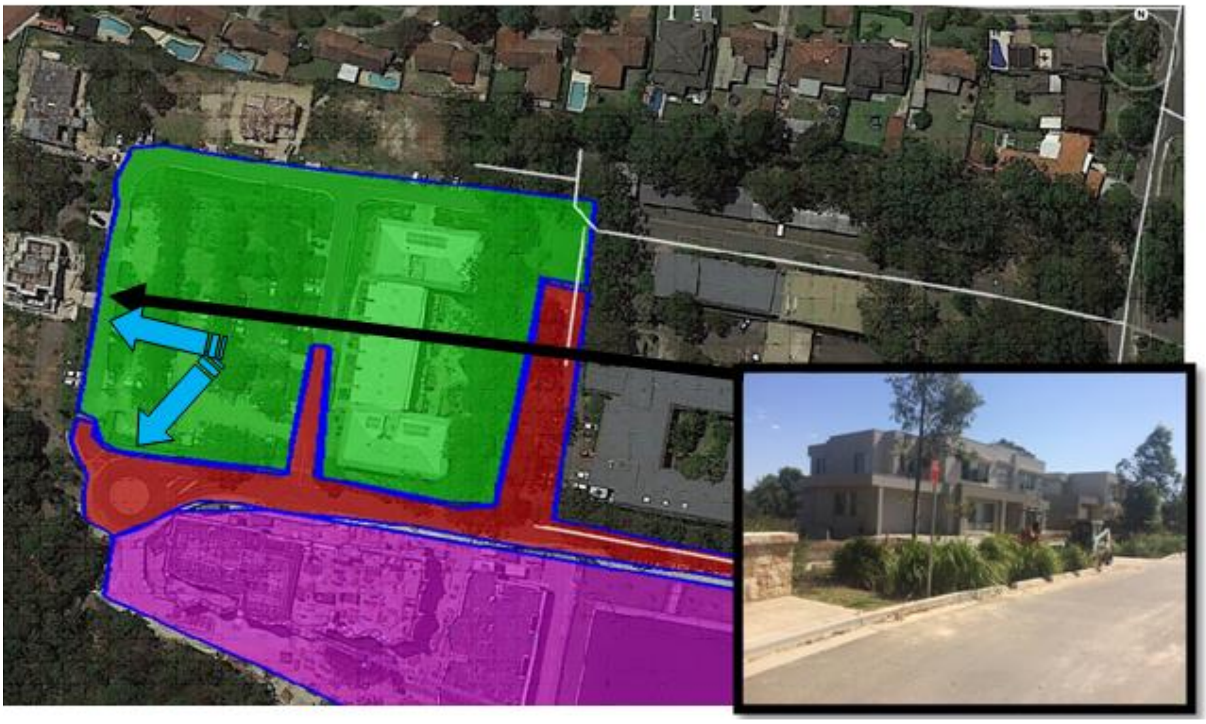

Figure2.14 Catchment B 4

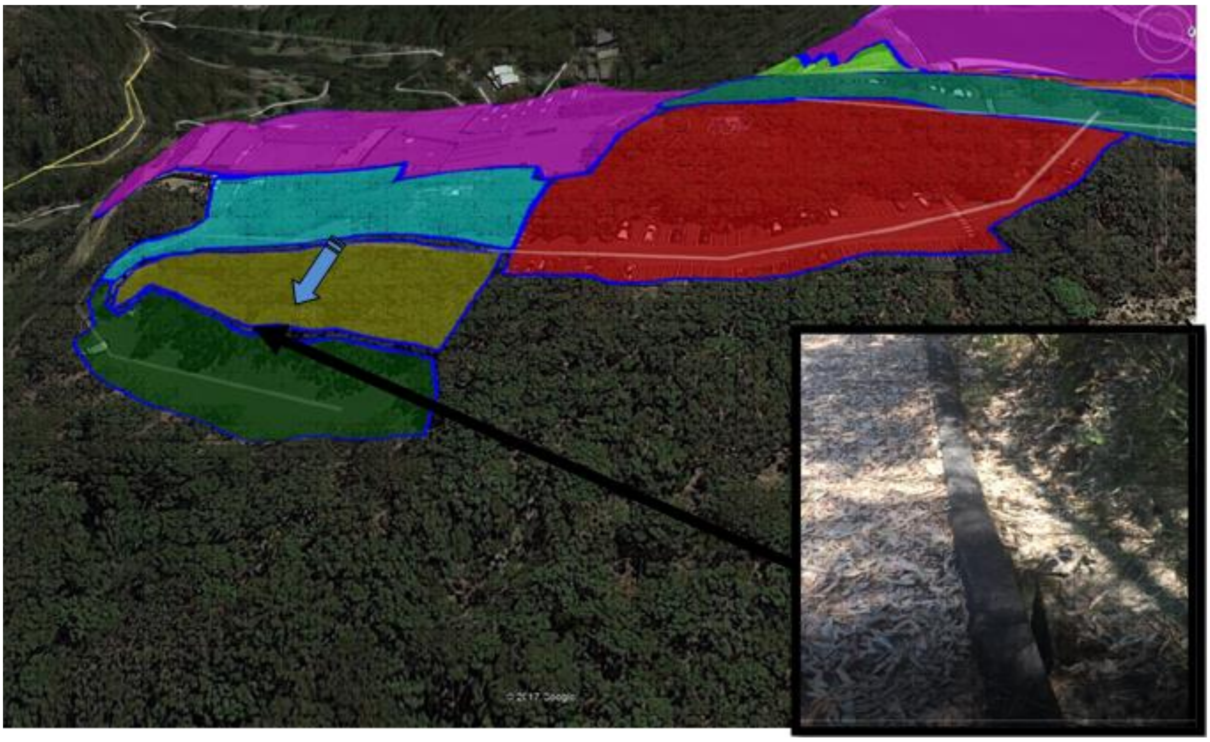

Figure2.15 Catchment B5

2.2 EXISTING STORMWATER DRAINAGE SYSTEM

The site is currently drained via an existing drainage system comprising of below ground pit and pipe network as well as overland flow routes.

It was also noted that the survey picked up pipes blocked with litter and flow alterations by unknown persons

In rainfall events where flows exceed the piped system capacity, surface water runoff is generally conveyed within the road system as uncontrolled flow. When this occurs, there is potential for high hazard flooding conditions resulting from combined high flow velocities and depths.

For the purpose of this study the below ground infrastructure has been modelled as blocked.

There were no open channels within the study area to assist with drainage.

The catchments will be described base on initial assumptions. These assumptions will be checked at the end of report base on model results.

2.3 REVIEW OF AVAILABLE DATA

The data compilation and review was undertaken as the first stage in this flood study in order to consolidate and summarise all of the currently available data, and identify any significant data gaps that may affect the successful completion of the study. This allowed for the missing data to be collected during the initial phases of the study.

The review included:

- Previous studies undertaken within the catchment;
- Available water level, tide and rainfall data; and
- Sydney Water flooding complaints register.
- A complete site survey and a partial drainage infrastructure survey of pit and pipe geometries by Usher Surveyors were given. (It should be noted that all drainage assets was not picked up at time this reporting)

NSW SIX has provided digitally available information such as aerial photography, cadastral boundaries, watercourses, and drainage networks in the form of GIS datasets.

2.3.1 PATTERSON BRITTON STUDY

Stormwater report was prepared by Patterson Britton prepared in July 2006 which has investigated all pertinent aspects of runoff and treatment, to the extent that can be identified, for this site.

This urban infrastructure management strategy has been prepared to support a re-zoning application for the UTS site at Ku-ring-gai. It addresses the following issues:

- Stormwater quality;
- Stormwater quantity;
- Provision of a flooding management plan
- Provision of potable water;
- Provision of sewer reticulation;
- Provision of electricity reticulation;
- Telecommunications services; and

- Geological conditions.

1. Patterson Britton Study Summary (Ku-ring-gai Council, 2006)

A water sensitive urban design approach has been adopted for the proposed rezoning with proposed controls to contribute to the long term improvement in receiving water quality and flow impacts on adjacent bushland. The indicative development scheme and this strategy incorporate a combination of at source controls such as rainwater tanks and bio-retention swales along roadways. Further runoff treatment measures include bio-retention basins, gross pollutant traps and detention tanks. These measures will:

- reduce the number of stormwater outlets;
- improve stormwater quality by reducing runoff pollutant loads significantly below existing rates;
- improve stormwater discharge and reduce peak flow rates in the proposed 50 year ARI to natural 20 year ARI rates; and
- Allow for the reduction of potable water use by 46%.

The beneficial effect of some control measures have not been taken into account in the results presented as part of this assessment. Therefore the level of improvement achieved has been understated. The extent of control measures can be refined at subsequent approval stages in the knowledge that it is feasible to achieve the above objectives.

The proposed conceptual water management strategy for the re-zoning application conforms to best management practice and Councils relevant guidelines. The stormwater quality and quantity control measures proposed in this report will have the combined beneficial effect of improving the existing conditions of the surrounding bushland and the water quality in receiving water bodies.

The servicing of the site has been investigated and confirmation sought from Sydney Water, Energy Australia, AGL, and Telstra that it is possible to service the site. The responses from the service providers support the proposed rezoning application. Water supply is adequate for fire fighting with the provision of a reticulated hydrant supply.

As established in the Parramatta Rail Link EIS, due to the underlying sandstone any settlement beneath the site as a result tunnelling during the construction of the Parramatta Rail Link will have negligible impact on surface buildings or underground service utilities proposed as part of the rezoning application and potential development of the site, and is also not an impediment to rezoning. It is considered that generally, with good engineering design, the site's geological conditions are likely to be suitable for urban development subject to detailed geotechnical investigations.

2. Patterson Britton's Catchments Specifications (Ku-ring-gai Council, 2006)

The adopted hydrologic parameters in Patterson Britton study are shown in below table.

Subcatchment	Area (*ha*)	Slope (%)	Impervious (%)
P1	1.16	3.2	75
P2	1.91	1.7	75
P3	1.89	14	70
P4	4.38	12	75
P5*	0.69	11	50
P6*	0.84	8.5	50
P7*	0.21	15	75
P8 *	0.36	11	70
P9 *	0.28	13	50
P10*	0.44	17	40
P11*	0.72	14	40
P12	1.56	21	70
P13	1.1	13	75

Figure 2.16 Assumption of Patterson Britton's Study (Ku-ring-gai Council, 2006)

Catchment Parameters: Proposed Development

3. Patterson Britton's result (Ku-ring-gai Council, 2006)

The result of Patterson Britton's study divides to:

1- Stormwater and Flooding quantity impacts
2- Stormwater quality impacts
3- Water cycle management

The result of the Patterson Britton's study is as below:

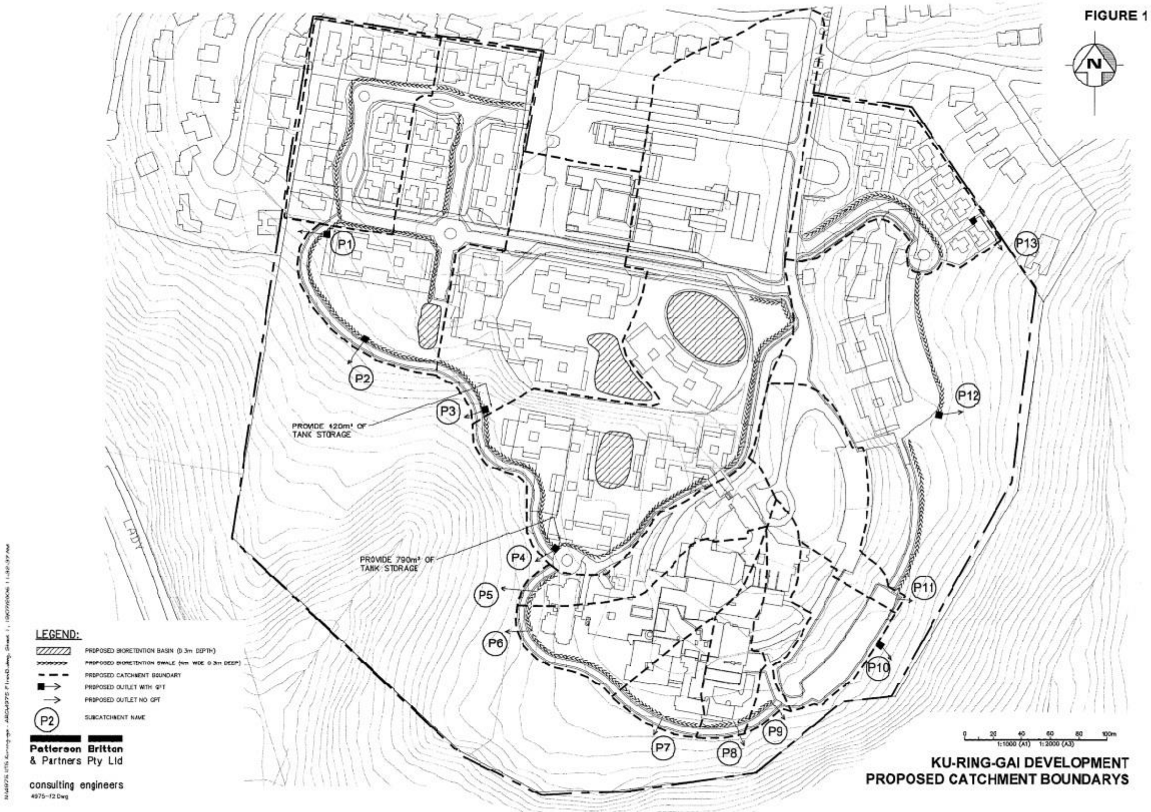

Figure 2.17 Result of Patterson Britton’s Study (Ku-ring-gai Council, 2006)

Proposed Catchment Boundaries

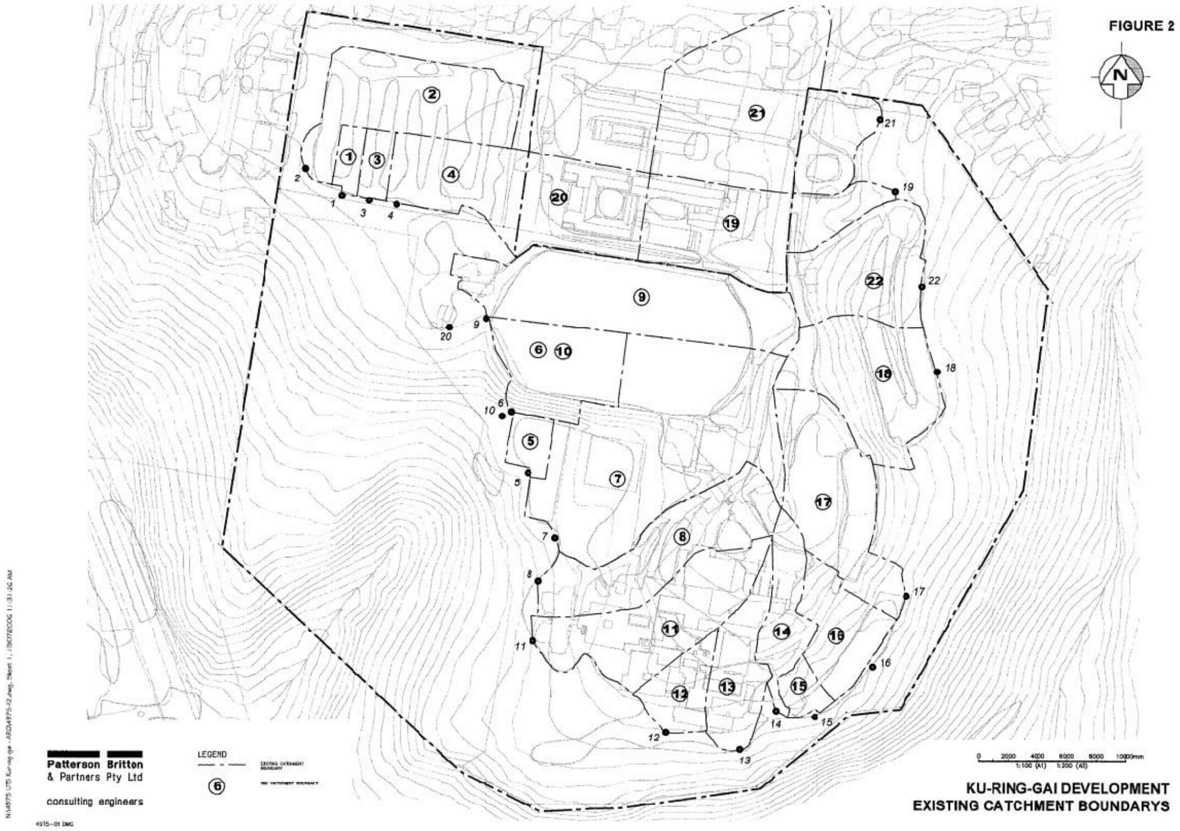

Figure 2.18 Result of Patterson Britton's Study (Ku-ring-gai Council, 2006)

Existing Catchment Boundaries

Outlet Node	Peak flows (m^3/s)			
	$Q_{10\ NATURE}$	$Q_{50\ PROPOSED}$	$Q_{50\ PROPOSED\ TREATED}$	Storage Volume (m^3)
P1 (combined out 1,2,3 and 4)	0.59	0.71	0.59	30
P2 (combined out 20 and 9)	0.64	1.1	0.64	145
P3 (combined out 5 and 10)	0.19	1.17	0.19	800
P4 (out 7)	0.36	2.7	0.36	2150
P10 (out 15 and 16)	0.25	0.27	0.27	
P11 (out 17)	0.4	0.4	0.4	
P12 (combined out 22 and 18)	0.74	0.95	0.74	50
P13 (out 19 and 21)	0.97	0.71	0.71	
Blue Gum Creek	2.4	2.9	2.2	
Little Blue Gum Creek	0.58	0.7	0.6	
College Creek	1.79	6.5	1.8	
Lane Cove River	4.14	9.4	3.9	

Figure 2.19 Result of Patterson Britton's Study (Ku-ring-gai Council, 2006)

OSD Storage Summary

Node / Location	Suspended Solids	Total Phosphorous	Total Nitrogen
	Reduction (%)	Reduction (%)	Reduction (%)
P12 and P13	91	80	72
Little Blue Gum Creek	90	74	50
College Creek	91	81	72
Lane Cove River	84	71	60

Figure 2.20 Result of Patterson Britton's Study (Ku-ring-gai Council, 2006)

Percentage Pollutant load reductions from post untreated post treated.

Node / Location	Pollutant Load (kg/yr)					
	Suspended Solids		Total Phosphorous		Total Nitrogen	
	Existing	Proposed Treated	Existing	Proposed Treated	Existing	Proposed Treated
P1 (combined out 1,2,3 and 4)	3322	236	6.8	1.2	46.1	13.6
P2 (out 9 and 20)	2347	167	5.5	1.1	40.5	11.9
P3 (combined out 5 and 10)	413	136	1.1	0.9	8.2	7.8
P4 (out 7)	875	160	2.4	1.2	17.4	11.5
P5 (out 8)	991	302	2.1	0.9	15.4	7.5
P6 (out 11)	1440	272	1.4	0.9	21.0	8.1
P7 (out 12)	433	74	0.9	0.3	6.2	2.9
P8 (out 13)	690	199	1.4	0.6	9.6	5.2
P9 (out 14)	412	156	0.9	0.4	6.2	4.0
P10 (out 15 and 16)	550	157	1.1	0.8	8.8	7.6
P11 (out 17)	891	915	1.9	1.9	13.9	14.1
P12 (out 18 and 22)	2002	298	4.1	1.5	29.4	15.9
P13 (out 19 and 21)	1540	415	3.5	2.0	23.1	18.7
Blue Gum Creek	**7280**	**2210**	**15.4**	**7.6**	**111**	**68.4**
Little Blue Gum Creek	**3330**	**236**	**6.8**	**1.2**	**46**	**16.6**
College Creek	**5290**	**1040**	**12.5**	**4.9**	**88.6**	**47.2**
Lane Cove River	**15900**	**3480**	**34.6**	**13.7**	**246**	**129**

Figure 2.21 Result of Patterson Britton's Study (Ku-ring-gai Council, 2006)

Performance of Proposed Water Quality Management Strategy

Node / Location	Pollutant Load (kg/yr)					
	Suspended Solids		Total Phosphorous		Total Nitrogen	
	Existing	Proposed	Existing	Proposed	Existing	Proposed
P1 (combined out 1,2,3 and 4)	3322	2260	6.8	4.66	46.1	33
P2 (out 9 and 20)	2347	3510	5.5	7.18	40.5	50.5
P3 (combined out 5 and 10)	413	2940	1.1	6.8	8.2	40.4
P4 (out 7)	875	2900	2.4	7.2	17.4	46
P5 (out 8)	991	862	2.1	1.8	15.4	13.1
P6 (out 11)	1440	1200	1.4	2.5	21	18.4
P7 (out 12)	433	541	0.9	1.1	6.2	7.8
P8 (out 13)	690	689	1.4	1.4	9.6	10.3
P9 (out 14)	412	464	0.9	1	6.2	7.1
P10 (out 15 and 16)	550	620	1.1	1.3	8.8	10
P11 (out 17)	891	930	1.9	1.95	13.9	14.4
P12 (out 18 and 22)	2002	2990	4.1	6.3	29.4	46
P13 (out 19 and 21)	1540	1830	3.47	3.9	23.1	27
Blue Gum Creek	**7280**	**8190**	**15.4**	**17.1**	**111**	**122**
Little Blue Gum Creek	**3330**	**2260**	**6.8**	**4.6**	**46**	**33**
College Creek	**5290**	**11500**	**12.5**	**25.6**	**88.6**	**168**
Lane Cove River	**15900**	**21800**	**34.6**	**47.3**	**246**	**322**

Figure 2.22 Result of Patterson Britton’s Study (Ku-ring-gai Council, 2006)

Annual Pollutant Export Loads – Developed State (No Treatment

	Required OSR DCP 47 (m^3)		Storage Provided			
	1*	2*	OSR Rainwater Tank (m^3)	OSR Bioretention (m^3)	Tank Storage (m^3)	Total Storage Provided (m^3)
P1	43	30	21 (70x0.3)	123	-	144
P2	72	145	109 (363 x0.3)	408	-	517
P3	72	800	92 (306x0.3)	360	420	872
P4	123	2,150	221 (738x0.3)	1,265	787	2,273
P5*	-	-	-	24	-	24
P6*	-	-	-	64	-	64
P7*	-	-	-	48	-	48
P8 *	-	-	-	24	-	24
P9 *	-	-	-	14	-	14
P10*	-	-	-	-	-	-
P11*	-	-	-	-	-	-
P12	44	50	67 (222x0.3)	170	-	237
P13	26	-	20 (65 x0.3)	100	-	120
Total	**380**	**3,175**	**531 (1,770x0.3)**	**2,600**	**1,207**	**4,337**

Figure 2.23 Result of Patterson Britton's Study (Ku-ring-gai Council, 2006)

OSR Storage Summary

2.4 Rainfall Data

There is an extensive network of rainfall gauges across the Sydney area, many of which are operated by the Bureau of Meteorology (BoM). The closest BoM station, located at Abbotsford (Blackwall Point Rd) and Ashfield Bowling Club are close to the catchment. Ashfield Bowling Club rainfall station records continuous rainfall and has a long period of record, commencing in 1894.

Table 2-2 Rainfall stations in the study area (BOM)

Station #	Name	Record Period	Type
066011	Chatswood Bowling Club	1951-2017	Daily
066213	North Ryde Golf Club	2011-2017	Daily
066156	Macquarie Park (Willandra Village)	1970-2017	Daily

2.5 Stream Data

There are no stream gauging data within the study area. This is a common data deficiency in urban catchments. The data is gathered from the nearest station and site visit.

2.6 STORMWATER NETWORK DATA

An extensive network of stormwater infrastructure exists in the study area to provide drainage to Lane Cove Creek. This infrastructure is primarily comprised of a ‘pit and pipe’ stormwater network and does not include open channels as part of the trunk drainage system. Detail of the stormwater drainage network has been compiled from the following sources:

- Survey by Usher & Associates
- Details contained in the Sydney Water Capacity Assessment reports (SWC, 1996)

Dimensions of the various irregular pipes throughout the stormwater drainage network were not provided in an electronic format and the dimensions have been manually digitised from drawings in the Assessment reports. The irregular pipes have been represented in the hydraulic model by calculating the “water depth versus flow area” and the “water depth versus wetted perimeter” values.

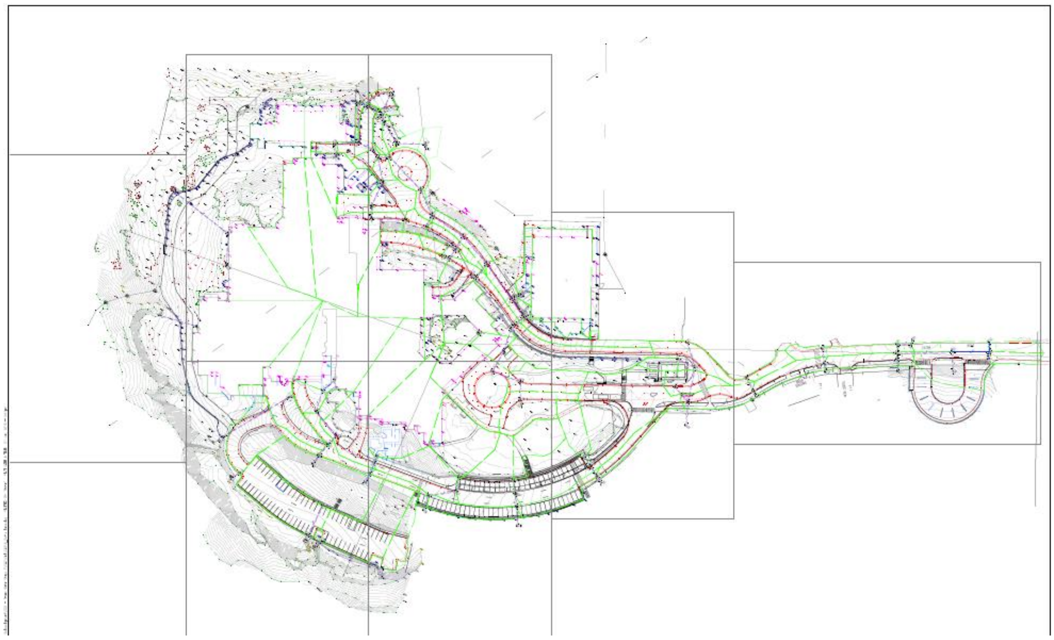

Figure2.24 Stormwater catchment plan

Refer to appendix C

2.7 ESTABLISHING DESIGN FLOOD CONDITIONS

Design floods are statistical-based events which have a particular probability of occurrence. For example, the 1% Annual Exceedance Probability (AEP) event, which is sometimes referred to as the 1 in 100 year Average Recurrence Interval (ARI) flood, is the best estimate of a flood with a peak discharge that has a 1% (i.e. 1 in 100) chance of occurring in any one year.

The design flood conditions form the basis for floodplain management in the catchment and in particular design planning levels for future development controls.

3 OVERLAND FLOW MODEL DEVELOPMENT

3.1 HYDROLOGICAL MODEL DEVELOPMENT

In the absence of long term stream flow data, computer models are usually the most accurate, cost-effective and efficient tools to assess a catchment's flood behaviour. Traditionally, for the purpose of the Flood Study, a hydrologic model and a hydraulic model are developed.

The hydrologic model simulates the catchment rainfall-runoff processes, producing the storm water flows which are used in the hydraulic model.

The hydraulic model simulates the flow behaviour of the drainage network and overland flow paths, producing flood levels, flow discharges and flow velocities.

The site is located atop of arête and run off flows are contained within the existing roadways, as indicated above sections. The existing roadways operate as channelized flows; hence HEC RAS model was used.

The Hec Ras model was used to addressing hydraulic aspects of the channelized flows, of the runoffs thru the various catchments.

Information on the topography and characteristics of the catchment, and channelized flows (roadways) were built into the model.

The Recorded historical flood data, including rainfall and flood levels, are used to compare and validate the model. The model produces as output, water levels, flows rates and flow velocities.

- Development of a hydraulic model follows a relatively standard procedure:
- Discretisation of the catchment, drainage network, flooding, etc.
- Incorporation of physical characteristics (flood levels, structures etc.).
- Try to verify to one or more other historic floods (verification is a check on the model's performance without further adjustment of parameters).

Once model development is complete it may then be used for:

- establishing design flood conditions;
- determining levels for planning control; and
- Modelling development or management options to assess the hydraulic impacts (as part of the flood risk management study).

The hydrological model simulates the rate at which rainfall runs off the catchment. The amount of rainfall runoff from the catchment is dependent on:

- The catchment slope, area, vegetation, urbanisation and other characteristics;
- Variations in the distribution, intensity and amount of rainfall; and
- The antecedent moisture conditions (dryness/wetness) of the catchment.

The hydraulic model utilised 2 computer programs HEC – RAS and Drains to compare flows and runoff.

Drains was used in analysing the drainage pipe networks and the road cross sections for run-off and flow widths. The drains model was adopted due to overland flow analysis with concurrence of the piped drainage infrastructure. Also drains modelled with the multiple ensembles of multiple rain events & intensities (worst case scenario) as required within the ARR 2016 standard.

HEC – RAS was used as a secondary model to verify the drains model. But by ignoring the underground piped network, assuming that the piped network would be blocked or running at capacity.

Road sections was entered as a channelized flow. (Refer to Section 3.4 for details of the HEC – RAS and Drains models setup). The factors given above have been represented in the model by:

- The runoff routing and hydrological response of the catchment within the 1D model is driven by the surface type and underlying topography. Where appropriate, runoff is diverted into pipe domains of the model (more detail is provided in Section 3.4).
- The amount and intensity of rainfall can be varied across the catchment based on available data and information.
- The antecedent moisture conditions are modelled by varying the amount of rainfall which is "lost" into the ground and "absorbed" by storages. For very dry antecedent moisture conditions, there is typically a higher initial rainfall loss.
- Road Flow widths & velocities modelled in HEC RAS and Drains (with the inclusion of the drainage infrastructure) (pipe and pits).

The general modelling approach and adopted parameters are discussed in the following sections.

3.2 RAINFALL DATA

Rainfall information is the primary input and driver of the hydrological model which simulates the catchment's response in generating surface run-off. Rainfall characteristics for both historical and design events are described by:

- Rainfall depth – the depth of rainfall occurring across a catchment surface over a defined period (e.g. 270mm in 36 hours or average intensity 7.5mm/hr); and
- Temporal pattern – describes the distribution of rainfall depth at a certain time interval over the duration of the rainfall event.

Both of these properties may vary spatially across the catchment during any given event and between different events.

For design events, rainfall depths are most commonly determined by the estimation of intensity-frequency-duration (IFD) design rainfall curves for the catchment. Standard procedures for derivation of these curves are defined in Australian Rainfall and Runoff (AR&R) (EA, 1987).

3.3 RAINFALL LOSSES

The antecedent catchment condition reflecting the degree of wetness of the catchment prior to a major rainfall event directly influences the magnitude and rate of runoff.

The total rainfall which falls in an event does not all contribute to run-off. Many precipitation loss processes occur which reduce the effective rainfall converted to run-off. Some rainfall fills depression storages on the ground surface, some is lost by interception from vegetation while some infiltrates into the ground. A conceptual model known as the "Initial Loss – Continuing Loss model" is widely used in Australia and is adopted for this study.

The initial loss component represents a depth of rainfall effectively lost from the system and not contributing to runoff and simulates the wetting up of the catchment to a saturated condition. The continuing loss represents the rainfall lost through soil infiltration once the catchment is saturated and is applied as a constant rate (mm/hr) for the duration of the runoff event.

To determine the correct volume of rainfall run-off, the two most important land categories in this study are roads and roof tops which together represent greater than 55% of the total area.

The remaining land categories for defining rainfall losses have been derived based on the Local Environmental Plan (LEP) Zones.

3.4 HYDRAULIC MODEL

3.4.1 TOPOGRAPHY

The ability of the model to provide an accurate representation of the flow distribution on the floodplain ultimately depends upon the quality of the underlying topographic model. DTM has been derived from the survey and Overlay from SIX database.

The ground surface elevations from the Hec-Ras Sections are extracted directly from the 12d DTM. It is a representation of the ground surface and includes features such as buildings or vegetation. In the context of the overland flow path study, a DTM is important to suitably represent available flow paths, such as roadway flows that are expected to provide significant flood conveyance within the study area.

Owing to some limitations of the SIX data capture method, preparation of the DTM for the upper reaches of study area required additional ground level points and break lines to be defined to ensure a coherent and correct DTM

3.4.2 BUILDINGS

The influence of buildings and other obstacles to the passage of flow in urban floodplains is an important issue in the context of urban floodplain management (Engineers Australia, 2012a). In a typical urban floodplain, some buildings will be elevated on fill and totally obstruct the passage of floodwater; others may be inundated with floodwater ponding inside the building, whilst others may be elevated on piers allowing flow under the building.

Based on a visual assessment of the range of buildings in the UTS Campus the likely minimal effect of buildings on the passage of floodwater, will not flow thru the buildings, upstream and based on this assumption means that floodwater does not pass through and must flow around buildings.

The building footprints across the study area have been based on the footprints provided by GIS. Buildings not contained within GIS imagery of building footprint dataset have been manually defined using available Google aerial photography dated July 2014.

3.4.3 UNDERGROUND CAR PARK

Within the catchment there are numerous underground car parks. In large flood events the car parks may be inundated and act as temporary flood storages if the entrance level is below the flood level. Car parks however are not intended to be inundated in large floods and therefore have not been included in the modelling.

3.4.4 STORM WATER DRAINAGE NETWORK

This study required the modelling of the storm water drainage system across the catchment. Information on the pit and pipe drainage network has been compiled from the survey, and GIS

Pit inlet capacities have been modelled using lintel opening lengths and grate sizes based on the Survey. Pit inlet dimensions have been assumed where data were not available, based on site inspections and nearby pits. Pit inlet curves have been developed using an industry standard approach HEC22 and on laboratory tests by the NSW Department of Main Roads and are considered sufficiently reliable for the purpose of this study.

For the magnitude of events under consideration in the study, the pipe drainage system capacity is anticipated to be exceeded with the major proportion of flow conveyed in overland flow paths. Therefore any limitations in the available pipe data or model representation of the drainage system is expected to have little effect on results (see Section 8 full pit blockage sensitivity analysis).

3.4.5 HYDRAULIC ROUGHNESS

The development of the DRAINS model requires the assignment of different hydraulic roughness (Manning's 'n') zones. These zones are delineated from aerial photography and Survey data identifying different land uses (e.g. vegetation, cleared land, roads, urban areas, etc.) for modelling the variation in flow resistance. The aerial photography supplied by SIX has been used to generate the land use surface types and roughness zones for the study area.

The Manning's 'n' hydraulic roughness values adopted for each land use category are given in Table 3.1.

Table 3-1 Adopted Manning's 'n' hydraulic roughness values

Land Use Category	Manning's '*n*'
Roads	0.015
Public Recreation	0.048
Metro Centre	0.039
Rail Corridor	0.042
General Residential	0.038
Mixed Use	0.04
Commercial Core	0.04
Underground Pipes/Culverts	0.011

3.4.6 BOUNDARY CONDITIONS

The rainfall within the catchments within the hydraulic model was to determine the inflow falling around building has been accounted for in the model by using appropriate boundary features to calculate the runoff from the total catchments, allocating the calculated flow around the perimeter of the building, passing past the building. This method has ensured that all rain falling has been accounted for and represented as contributing to overland flow.

4 DESIGN FLOOD CONDITIONS

4.1 DESIGN FLOOD MODELLING

Design floods are estimated floods used for planning and floodplain management investigations. They are based on having a probability of occurrence specified as either:

- Annual Exceedance Probability (AEP) expressed as a percentage; or
- Average Recurrence Interval (ARI) expressed in years. Refer to Table 5-1 for a definition of AEP and the ARI equivalent.

Table 4.1 Design flood terminology

ARI[1]	AEP[2]	Comments
500 years	0.2%	An estimated flood or combination of floods which represent the worst case scenario with a 0.2% probability of occurring in any given year.
100 years	1%	As for the 0.2% AEP flood but with a 1% probability.
50 years	2%	As for the 0.2% AEP flood but with a 2% probability.
20 years	5%	As for the 0.2% AEP flood but with a 5% probability.
10 years	10%	As for the 0.2% AEP flood but with a 10% probability.
5 years	18%	As for the 0.2% AEP flood but with a 18% probability.
2 years	39%	As for the 0.2% AEP flood but with a 39% probability.
PMF[3]		An estimated flood or combination of floods which represents the Probable Maximum Flood event possible.

1 Average Recurrence Interval (years) 2 Annual Exceedance Probability (%) [3] Probable Maximum Flood

The design events simulated include the PMF event, 0.2% 1%, 2%, 5%, 10%, 18% and 39% AEP events for catchment derived .The 1% AEP flood is generally used as a reference flood for land use planning and control.

In determining the design floods it is necessary to take into account the critical storm duration of the catchment. Small catchments are more prone to flooding during short duration storms while for large catchments longer durations will be critical. For example, considering the relatively small size of the study area catchments, they are potentially prone to higher flooding from intense storms extending over a few hours rather than a couple of days.

Table 4-2 Catchments results

Catchment No.	Name	Area (ha)	Upstream Level (m)	Downstream Level (m)	Length of biggest runoff (m)	General Slope (%)	AEP 1% (Cu.m/s)
1	R 1	0.55	66	61	135	3.7	0.392
2	R 2	0.28	61	54	105	6.7	1.041
3	R 3	0.17	54	52	75	2.7	0.963
4	R 4	0.27	66	53	165	7.9	1.298
5	R 5	0.37	69	63	210	2.9	1.398
6	R 6	0.2	67	65	150	1.3	0.151
7	R 7	0.19	67	66	125	0.8	0.136
8	R 8	0.1	67	63	100	1.0	0.078
9	B 1	1.691	51	46	59	8.5	1.025
10	B 2	1.1	54	43	70	15.7	0.559
11	B 3	2.41	62	58	63	6.3	1.125
12	B 4	1.25	-	-	-	-	0.585
13	B 5	0.21	59	51	32	25	0.098

4.2 Design Rainfall

Design rainfall parameters have been derived using standard procedures defined in *Australian Rainfall and Runoff – a Guide to Flood Estimation* (AR&R) (Pilgrim, DH, 2001) which are based on statistical analysis of recorded rainfall data across Australia. The derivation of location specific design rainfall parameters (e.g. rainfall depth and temporal pattern) for the Ainsworth St catchment is presented herein.

4.3 Rainfall Depths

Design rainfall depth is based on the generation of intensity-frequency-duration (IFD) design rainfall curves utilising the procedures outlined in AR&R (Pilgrim, DH, 2001). These curves provide rainfall depths for various design magnitudes for durations from 5 minutes to 72 hours.

The Probable Maximum Precipitation (PMP) is used in deriving the Probable Maximum Flood (PMF) event. The theoretical definition of the PMP is “the greatest depth of precipitation for a given duration, that is physically possible over a given storm area at a particular geographical location at a certain time of year” (Pilgrim, DH, 2001). The ARI of a PMP/PMF has been estimated using the Generalised Short Duration Method (GSDM) derived by the Bureau of Meteorology. The method is appropriate for durations up to 6 hours and considered suitable for small catchments in the Sydney area.

A range of storm durations from 15 minutes to 9 hours were modelled in order to identify the critical storm duration for design event flooding in the catchment. Table 4-2 shows the average design rainfall intensities based on AR&R adopted for the modelled events.

Table 4.2 Rainfall intensities for design events (mm/h)

Duration	63.2 %	50%	20%	10%	5%	2%	1%
15 min	13.6	15.5	21.8	26.2	30.5	36.2	40.7
25 min	17.1	19.5	27.4	32.8	38.2	45.4	51
30 min	18.4	21	29.3	35.1	40.8	48.5	54.5
45 min	21.3	24.2	33.5	40	46.5	55.4	62.3
1 hour	23.4	26.5	36.5	43.6	50.6	60.3	67.9
1.5 hour	26.7	30.1	41.1	48.9	56.7	67.6	76.3
2 hour	29.4	32.9	44.7	53.1	61.6	73.5	83.1
2.5 hour	31.6	35.4	47.8	56.8	66	78.7	89.1
3 hour	33.7	37.6	50.7	60.2	69.9	83.6	94.6
4 hour	37.3	41.6	56	66.5	77.3	92.4	105
4.5 hour	38.9	43.5	58.5	69.4	80.7	96.6	110
5 hour	40.5	45.2	60.9	72.2	84.1	101	114
6 hour	43.4	48.5	65.4	77.6	90.4	108	123
9 hour	51	57.2	77.5	92.3	108	129	147

5 DESIGN FLOOD RESULTS

5.1 Results Modelling

A range of design flood events were modelled, the results of which are presented and discussed below. The simulated design events included the 2 year ARI, 5 year ARI, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.2% AEP and PMF events for catchment derived flooding.

A range of design event storm durations have been simulated for each event. The design results presented in the remainder of the report represent the maximum values across all durations (peak envelope) for each design event simulated.

5.2 Flooding Overview

Design flood levels have been calculated for the development. The PMF, 1% AEP, 5% AEP and 20% AEP design event levels have been modelled in DRAINS to reach the maximum flood level in every catchment and compare with initial assumptions in section 2.2 results.

After checking results that have been calculated in section 2.2, the initial assumptions are changed. Table of 6.1 is brought based on new assumptions.

In simulating the design flood conditions, flood levels are evaluated in critical location of every catchment including catchments R1, R2, R3, R4, R5, R6, R7 and R8. Because of catchments B1, B2, B3, B4 and B5 conditions, they are not considered as critical locations for flood study.

Table 5-1 the results of flood level assessment

Catchment No.	Name	Area (ha)	AEP 1% (Cu.m/s)	Maximum Depth (mm)	Maximum flow width(m)	Maximum DxV= m/s	Maximum Velocity (m/s)
1	R 1	0.55	0.392	184	5.2	0.42	2.3
2	R 2	0.28	1.041	164	4.7	0.52	3.2
3	R 3	0.17	0.963	129	3.5	0.28	2.1
4	R 4	0.27	1.298	179	5.1	0.58	3.2
5	R 5	0.37	1.398	204	5.7	0.53	2.6
6	R 6	0.2	0.151	111	2.9	0.13	1.2
7	R 7	0.19	0.136	118	3.1	0.11	0.9
8	R 8	0.1	0.078	96	2.3	0.09	0.9

5.3 CATCHMENT FLOOD EVENT

As presented in Section 2.2, a range of durations has been modelled and enveloped for each annual exceedance probability modelled. For complete catchment modelling, it is common for different durations to produce critical flood levels at different locations.

Catchment R1

Modelling the roadway in DRAINS shows that the flood level is not exceeded the kerb top level in this catchment. Therefore, the total flood, drains in to the catchment R2 and there is no upwelling to the outside of study area.

Catchment R2

The results indicate that the flood level is increased in contrast with initial assumptions and up wells the existing kerb top. Considering the flood level, leads to 95% of flooding discharges to catchment R3 and 5% drains in to outside of study area. Also, Catchment R2 has 6.7 slop then the flow is drained with 3 m/s velocity.

Catchment R3

In the catchment R3, all the runoff is gathered to downstream of catchment and then based on depth of flow that is more than kerb height, is discharged to Lane Cove Creek.

Catchment R4

Because of high slop in this catchment (about 8 percent), there is a 3 m/s flow velocity that is fast. That is why, 20 percent of runoff drains into downstream garden via pedestrian way and 80 percent of that into private car park.

Catchment R5

The model results verify maximum depth of flow in this catchment 66 mm higher than kerb height. Therefore, 30 percent of runoff leads to downstream garden via pedestrian opening that is located between walls. And 70 percent of that is discharged to private way drainage network.

Catchment R6 and R7

There is no problem for these catchments. The runoff is discharged by drainage network completely.

Catchment R8

This catchment is located in upstream of playing ground. The results and observation shows that there is problem in this catchment and the storm water is drained to drainage network.

Figure 7-4 shows the 1% AEP critical duration assessment for the catchment. As shown, the majority of the catchment is critical for the 90 minutes and 120 minute duration, with localised upper catchment areas and the Walsh Bay area critical for the 25 minute storm duration.

Table 7-3 shows the differences in flood level for individual storm durations compared with the maximum flood level envelope which combines all durations. The single storm duration which most represents the maximum flood levels across the study area is the 90 minute storm. This duration has therefore been selected as the critical duration for the sensitivity analysis and climate change modelling. For all design event modelling however, all storm durations have been modelled to most accurately produce a peak flood envelope.

Table 5-2 Critical duration assessment (peak flood level difference (m) from maximum envelope)

Location#	015min	025min	030min	045min	060min	090min	120min	180min	270min	360min	540min
H02	-0.07	-0.02	-0.03	-0.04	-0.01	+0.00	+0.00	-0.09	-0.14	-0.20	-0.23
H03	-0.10	-0.03	-0.04	-0.05	-0.01	+0.00	+0.00	-0.11	-0.16	-0.21	-0.25
H04	-0.14	-0.05	-0.05	-0.07	-0.02	+0.00	-0.01	-0.09	-0.14	-0.22	-0.24
H05	-0.17	-0.06	-0.07	-0.06	-0.01	+0.00	+0.00	-0.11	-0.17	-0.24	-0.30
H07	-0.05	-0.02	-0.02	-0.02	-0.01	+0.00	+0.00	-0.06	-0.09	-0.12	-0.13

Refer to Figure 7-1 for the reporting locations

5.4 Tidal Inundation

There is no tidal inundation modelling was undertaken for the 1 year ARI level for Sydney Harbour, which has a level of 1.2 m AHD. This tidal event does not directly pose any flood risk to locations within the study area. It is noted that there is limited sensitivity in Harbour water levels to frequency of design water level

5.5 Super Critcal Flows

As described, sections of the catchment have high velocity flow due to the low hydraulic roughness of the roads which convey the main flow paths and the steepness of the catchment. A catchment of this nature has a tendency to convey supercritical flow which may under-represent the maximum peak water level possible if a hydraulic jump is activated.

For the 1% AEP event, the conjugate depths were calculated for supercritical flow areas. It was found that conjugate flood levels rarely exceed the standard levels by more than 0.35 m.

Mapping and further discussion of conjugate depth analysis is found in Appendix

5.6 Preliminary Hydraulic Catagorisation

There are no prescriptive methods for determining what parts of the floodplain constitute floodway's, flood storages and flood fringes. Descriptions of these terms within the Floodplain Development Manual (NSW Government, 2005) are essentially qualitative in nature. Of particular difficulty is the fact that a definition of flood behaviour and associated impacts is likely to vary from one floodplain to another depending on the circumstances and nature of flooding within the catchment.

The hydraulic categories as defined in the Floodplain Development Manual are:

- Floodway - Areas that convey a significant portion of the flow. These are areas that, even if partially blocked, would cause a significant increase in flood levels or a significant redistribution of flood flows, which may adversely affect other areas.
- Flood Storage - Areas that are important in the temporary storage of the floodwater during the passage of the flood. If the area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges. Flood Storage areas, if completely blocked would cause peak flood levels to increase by 0.1m and/or would cause the peak discharge to increase by more than 10%.
- Flood Fringe - Remaining area of flood prone land, after Floodway and Flood Storage areas have been defined. Blockage or filling of this area will not have any significant effect on the flood pattern or flood levels.

A number of approaches were considered when attempting to define hydraulic categories across the catchment. Approaches to define hydraulic categories that were considered for this assessment included partitioning the floodplain based on:

- Peak flood velocity;
- Peak flood depth;
- Peak velocity-depth product (sometimes referred to as unit discharge);
- Cumulative volume conveyed during the flood event; and
- Combination of the above.

The definition of hydraulic categories that was considered to best fit the application within the catchment was based on a combination of velocity, velocity-depth product and depth parameters. The adopted hydraulic categorisation is defined in Table 7-4 and is consistent with similar study catchments in the City of Sydney LGA (WMAwater, 2012a and 2012b).

Preliminary hydraulic category mapping for the 1% AEP and PMF design events is included in Appendix A (Figure A- 25 to Figure A- 26). It is also noted that mapping associated with the flood hydraulic categories may be amended in the future, at a local or property scale, subject to appropriate analysis that demonstrates no additional impacts (e.g. if it is to change from floodway to flood storage).

Table 5-3 Provisional hydraulic categories

Hydraulic Category	Definition	Description
Floodway	Velocity * Depth > 0.25 m^2/s AND Velocity > 0.25 m/s OR Velocity > 1.0 m/s	Areas and flow paths where a significant portion of floodwaters are conveyed during a flood.
Flood Storage	NOT Floodway AND Depth > 0.2 m	Floodplain areas where floodwaters accumulate before being conveyed downstream. These areas are important for detention and attenuation of flood peaks.
Flood Fringe	NOT Floodway AND Depth < 0.2 m	Areas that are low velocity backwaters within the floodplain. Filling of these areas generally has little consequence to overall flood behavior.

5.7 HAZARD CATAGORIES

The NSW Government's Floodplain Development Manual (NSW Government, 2005) defines flood hazard categories are as follows:

- High hazard – possible danger to personal safety; evacuation by trucks is difficult; able- bodied adults would have difficulty in wading to safety; potential for significant structural damage to buildings; and
- Low hazard – should it be necessary, trucks could evacuate people and their possessions; able-bodied adults would have little difficulty in wading to safety.

The key factors influencing flood hazard or risk are:

- Size of the Flood
- Rate of Rise - Effective Warning Time
- Community Awareness
- Flood Depth and Velocity
- Duration of Inundation
- Obstructions to Flow
- Access and Evacuation

The provisional flood hazard level is determined on the basis of the predicted flood depth and velocity. This is conveniently done through the analysis of flood model results. A high flood depth will cause a hazardous situation while a low depth may only cause an inconvenience. High flood velocities are dangerous and may cause structural damage while low velocities have no major threat.

Figures L1 and L2 in the Floodplain Development Manual (NSW Government, 2005) are used to determine provisional hazard categorisations within flood liable land. These figures are reproduced in Figure 6-8. The provisional hydraulic hazard is included in the mapping series provided in Appendix A for the 10%, 5%, 1% AEP and PMF events (Figure A- 27 to Figure A- 30).

Figure 6-8 Provisional flood hazard categorisations

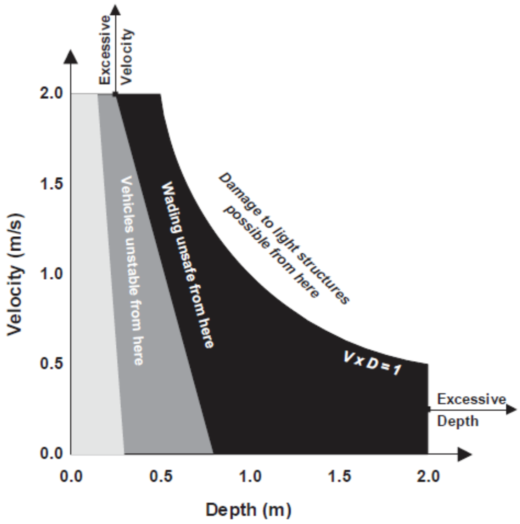

Figure 5.1 Velocity Depth Relationships (L1)

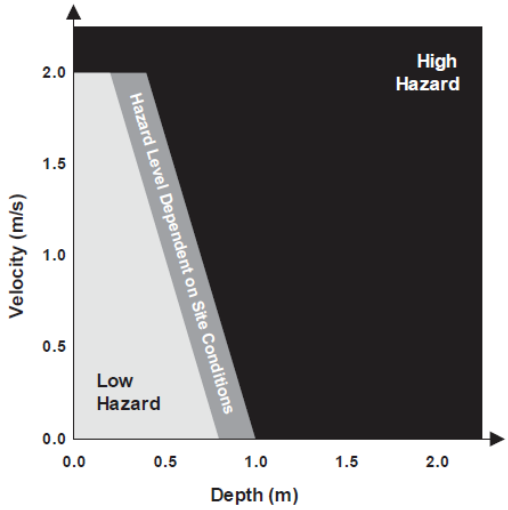

Figure 5.2 Provisional Hazard Categories (L2)

5.8 Flood Response Classification

The NSW Government's Floodplain Development Manual (NSW Government, 2005) requires flood studies and subsequent floodplain risk management studies to address the management of continuing flood risk to both existing and future development areas. Continuing flood risk may vary across a floodplain and as such the type and scale of emergency response does also. To assist the state emergency services with emergency response planning floodplain communities may be classified into the following categories (DECC, 2007):

- High Flood Island – high ground within a floodplain. Road access may be cut by floodwater creating an island. The flood island includes enough land higher than the limit of flooding to provide refuge.
- Low Flood Island – high ground within a floodplain. Road access may be cut by floodwater creating an island. The flood island is lower than the limit of flooding.

- High Trapped Perimeter – fringe of the floodplain. Road access may be cut by floodwater. The area includes enough land higher than the limit of flooding to provide refuge.
- Low Trapped Perimeter – fringe of the floodplain. Road access may be cut by floodwater. The flood island is lower than the limit of flooding.
- Areas with Overland Escape Routes – areas available for continuous evacuation. Access roads may cross low lying flood prone land but evacuation can take place by walking overland to higher ground.
- Areas with Rising Road Access – areas available for continuous evacuation. Access roads may rise steadily uphill away from rising floodwaters. Evacuation can take place vehicle and communities cannot be completely isolated before inundation reaches its maximum, and;
- Indirectly Affected Areas – areas outside the limit of flooding and therefore will not be inundated or lose road access. They may be indirectly affected as a result of flood damaged infrastructure or due to loss of services.

The flood emergency response classification is included in the mapping series provided in Appendix for the full range of design events simulated (Figure A- 37 to Figure A- 43).

5.9 FLOODING CONCLUSIONS

The HecRas model has been applied to derive design flood conditions within the Eton Road / UTS catchments using the design rainfall and tidal conditions described in Section 5. The design events considered in this study include the 2 year ARI, 5 year ARI, 10% AEP (10-year ARI), 5% AEP (20- year ARI), 2% AEP (50-year ARI), 1% AEP (100-year ARI), 0.2% AEP (500-year ARI) and Probable Maximum Flood (PMF) events. The model results for the design events have been presented in a detailed flood catchment. The flood data presented includes design flood inundation, peak flood water levels and peak flood depths.

Provisional flood hazard categorisation in accordance with Figure L2 of the NSW Floodplain Development Manual (2005) has been mapped for the 10% AEP, 5% AEP 1% AEP and the PMF events, in addition to the hydraulic categories (floodway, flood fringe and flood storage) for all modelled design events.

The site is not affected by tidal inundation.

The flood inundation extents derived from the hydraulic modelling are shown in Appendix A.

6 SITE INUNDATION AND FLOOD LEVEL ASSESSMENT & SUMMARY

A flood height assessment has been undertaken to the affected site, to quantify the proposed existing flood conditions and enable assessment of the potential flood height level and mitigation.

The general process for undertaking a flood assessment in the following

- Identifying UTS site subject to flooding assessment;
- Determining current depth of inundation for the flood level for the 1% AEP magnitude;

6.1 FLOOD LEVELS

The flood levels of critical places in every catchment are shown in table 6-1 and figure 6.1.

Name	Location No.	AEP 1% (Cu.m/s)	Maximum Depth (mm)
R 1	1	0.392	184
R 2	2	1.041	164
R 3	3	0.963	129
R 4	4	1.298	179
R 5	5	1.398	204
R 6	6	0.151	111
R 7	7	0.136	118
R 8	8	0.078	96

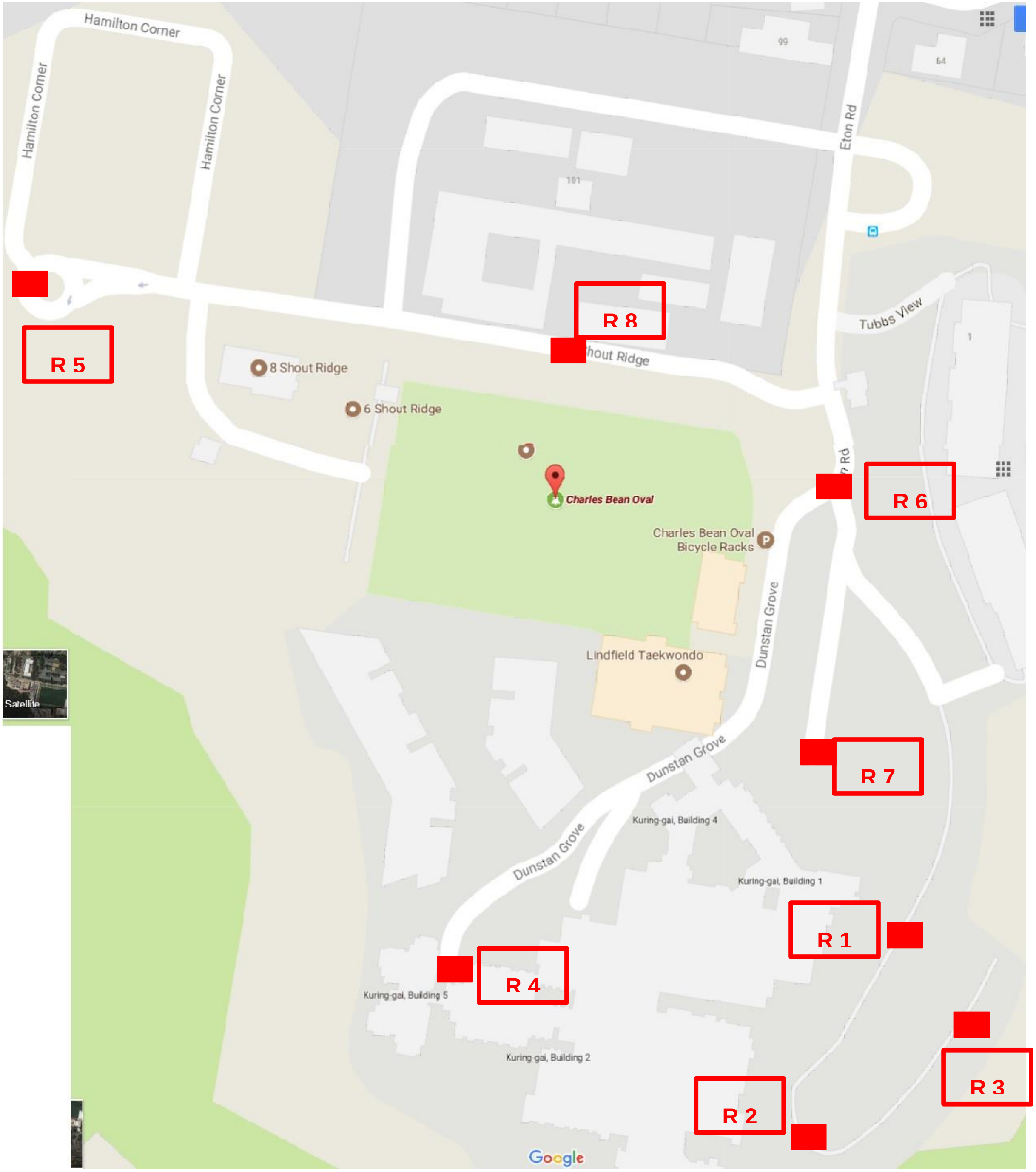

Figure 6.1 Studied Critical Places in UTS site

7 INFORMATION SOURCES, ASSUMPTIONS, & LIMITATIONS AND LIABILITY

7.1 REPORT INFORMATION SOURCES AND PROGRAMS USED.

Table 7.1 Report Information

Document / programs	Version
Water Management Development Control Plan – DCP Part 24R.7 Ku-ring-gai Council	
BOM (Bureau of Meteorology)	
Bureau of Meteorology, 2003. The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method. Commonwealth Bureau of Meteorology.	
Department of Infrastructure, Planning and Natural Resources (DIPNR) 2005. Floodplain Development Manual: the management of flood liable land	
Flood Risk Management-Ku-ring-gai Council Sep 2016	
Regional climate change studies (CSIRO, 2004)	
Flood Risk Management Guide - Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments (DECCW, 2010).	
NSW Department of Environment, Climate Change and Water (DECCW) 2009. NSW Sea Level Rise Policy Statement	
NSW Department of Environment and Climate Change (DECC) 2008. Fort Denison. Sea Level Rise Vulnerability Study. Coastal Unit (DECC)	
Pilgrim, DH (editor). Australian Rainfall and Runoff – A Guide to Flood Estimation. Reprinted ed. 2001 Institution of Engineers, Australia. Barton, ACT. 2001	
WBM Flood Study (2014)	
AR&R (2016) (2001) (1987)	
Flood Emergency Response Planning Classifications (DECC, 2007)	
Drains	2018.09
HEC RAS	5.0.2
12d	Ver. 11

7.2 BOM IFD DURATION TABLE 1987 VALUES

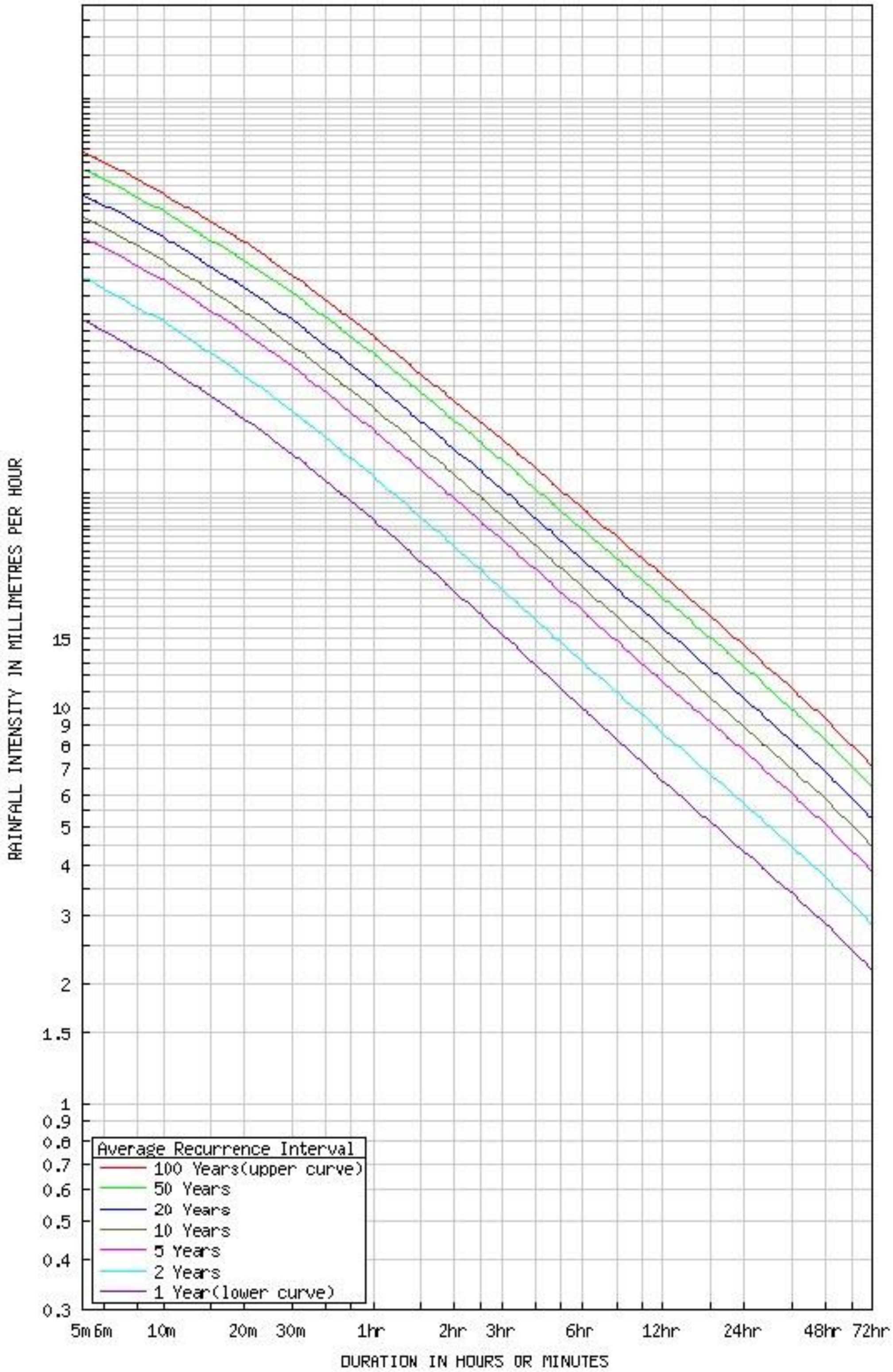

Figure 7.1 IFD duration table.

BOM IFD DURATION TABLE 1987 VALUES

7.3 BOM IFD DURATION TABLE 2017 VALUES

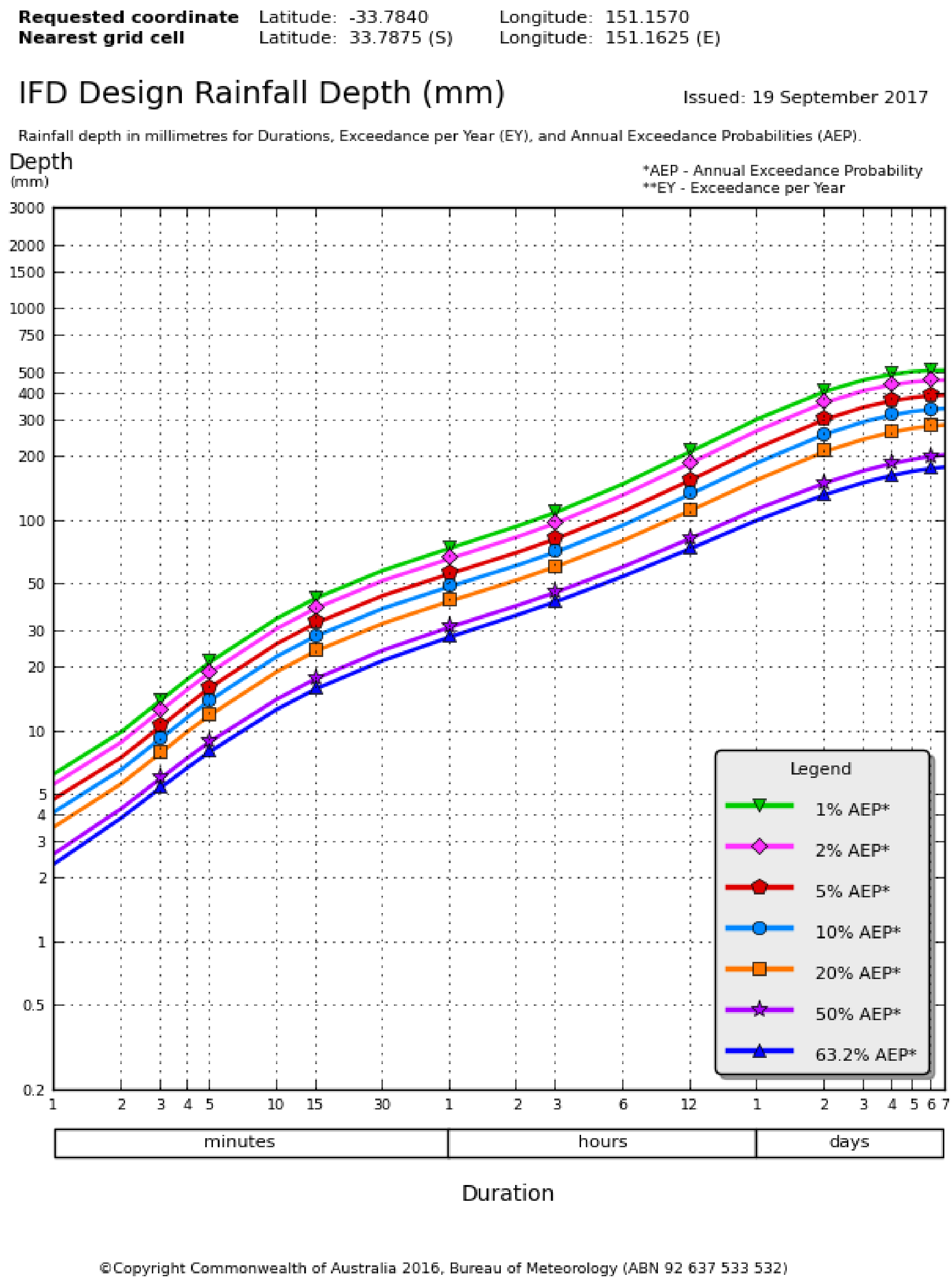

Figure 7.2 IFD duration table.

Rainfall Depth for Durations, Exceedance Per Year (ey), And Annual Exceedance Probabilities (aep).

7.4 BOM IFD INTENSITIES 2017 vs 1987 VALUES

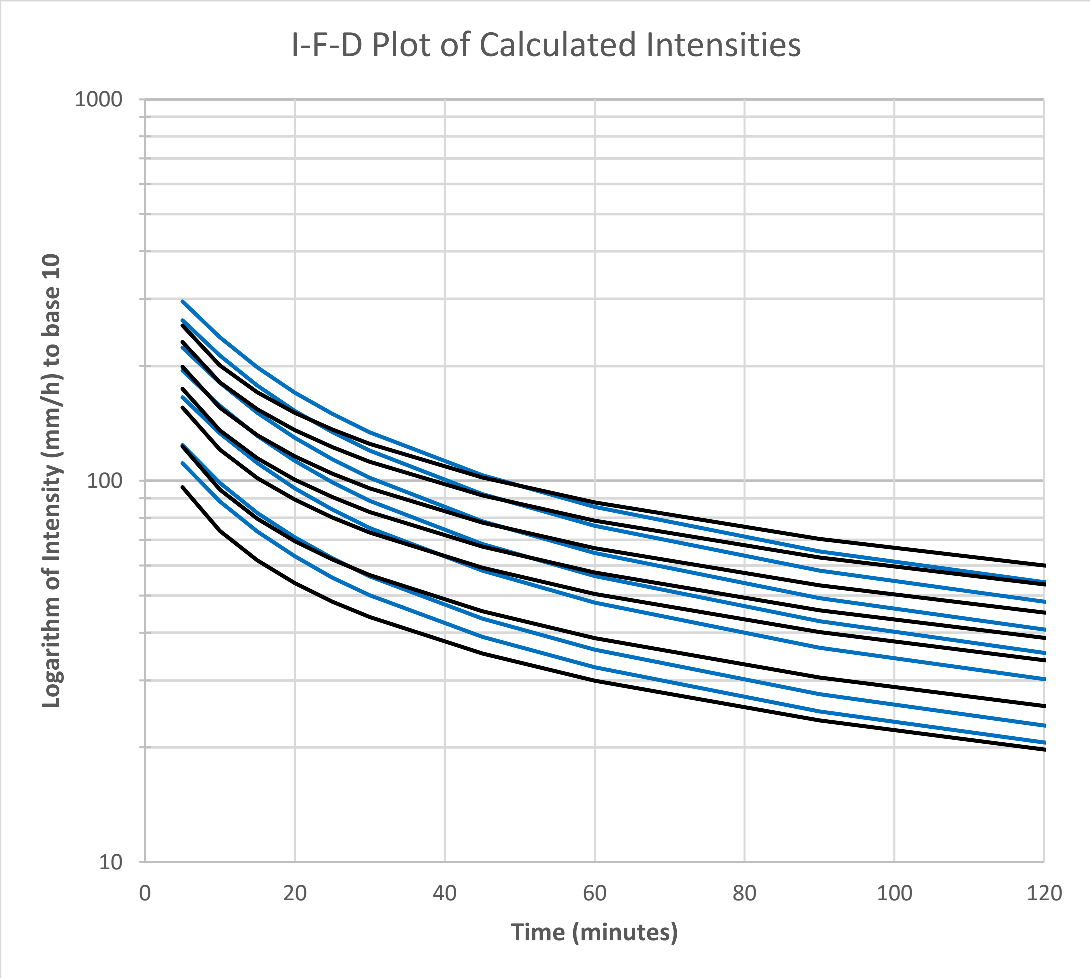

Figure 7.3 IFD duration table.

BOM IFD INTENSITIES 2017 vs. 1987 VALUES

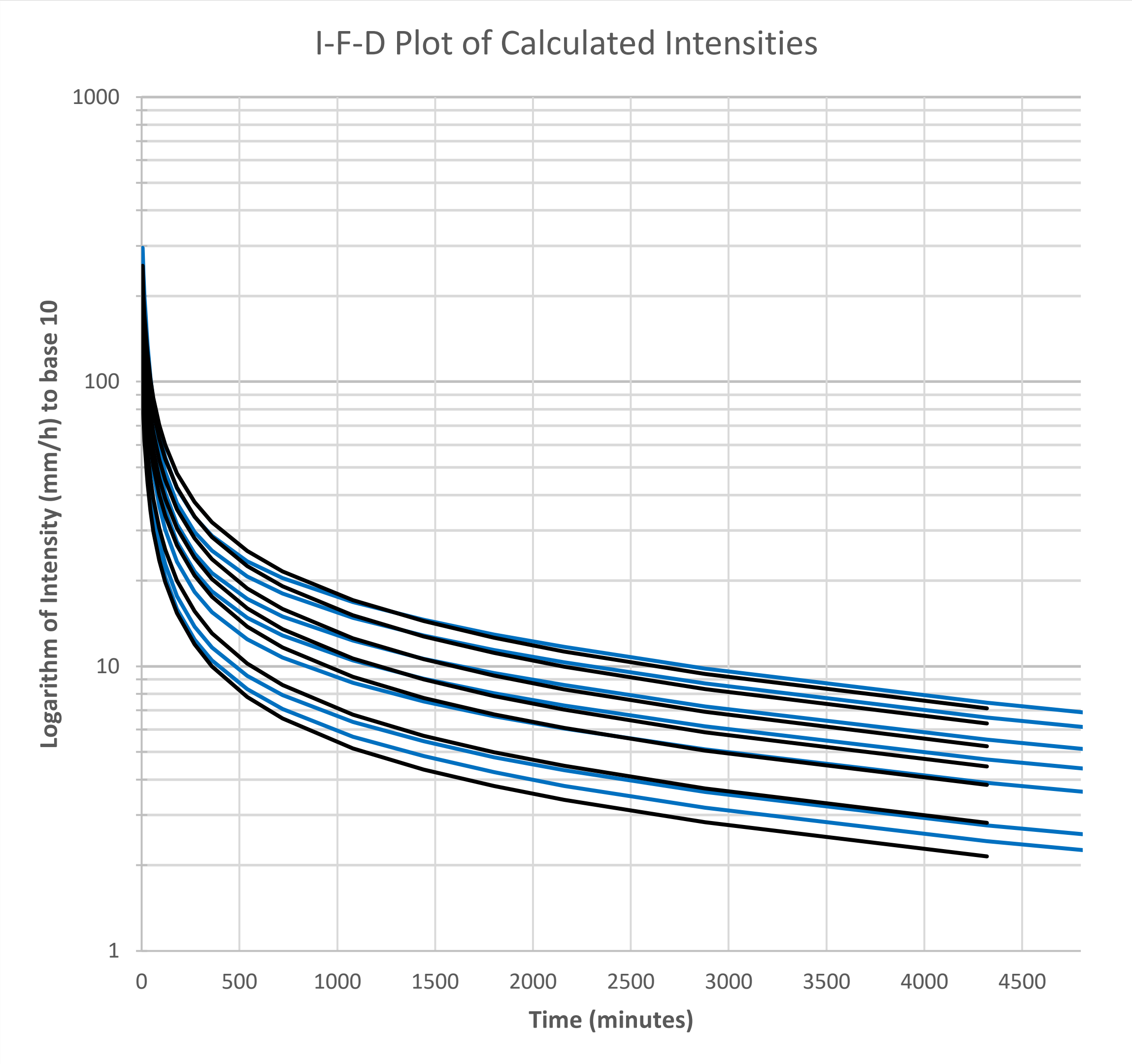

Figure 7.4 IFD duration table.

BOM IFD INTENSITIES 2017 vs. 1987 VALUES

7.5 Model Parameters for Modelling

The values for the Manning's 'n' roughness and rainfall infiltration losses developed for the defined land use categories (refer to Figure 2-4) determined through the model calibration and validation process and adopted for design event modelling are shown in the Table below.

Table 7.2 Report Information

Land Use Category	Manning's *'n'*	Fraction Impervious	Initial Loss (mm)	Pervious Area Infiltration Loss (mm/h)
Roads	0.02	100%	1.0	0.0
Buildings	N/A	100%	1.0	0.0
Public Recreation	0.05	10%	10.0	3.5
Metro Centre	0.04	90%	1.0	2.5
Rail Corridor	0.04	10%	1.0	2.5

General Residential	0.04	90%	1.0	2.5
Mixed Use	0.04	90%	1.0	2.5
Commercial Core	0.04	90%	1.0	2.5

7.6 Assumptions and Limitations

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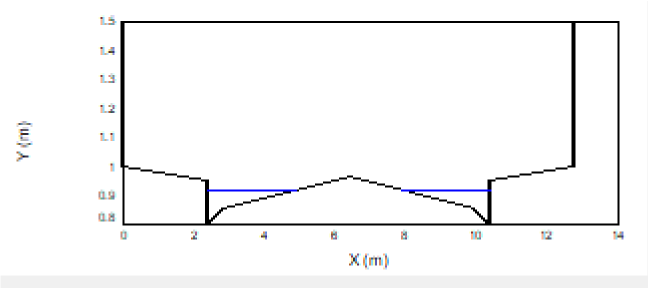
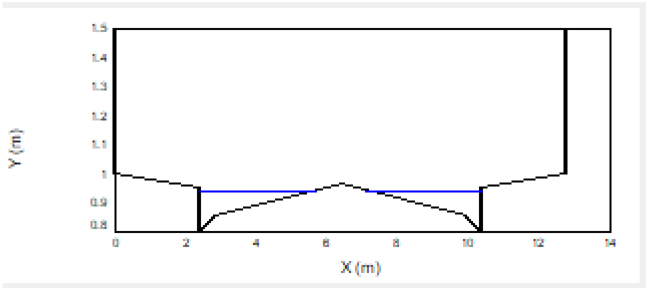
APPENDIX A – HEC-RAS RESULTS

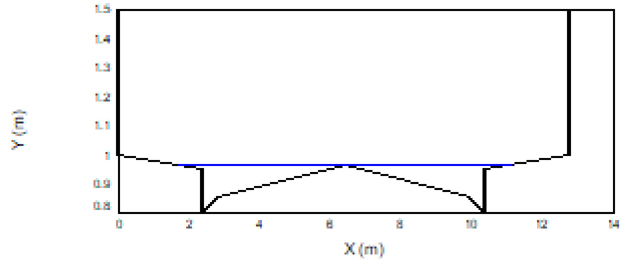
1.1. SECTIONS OF FLOW ROUTES



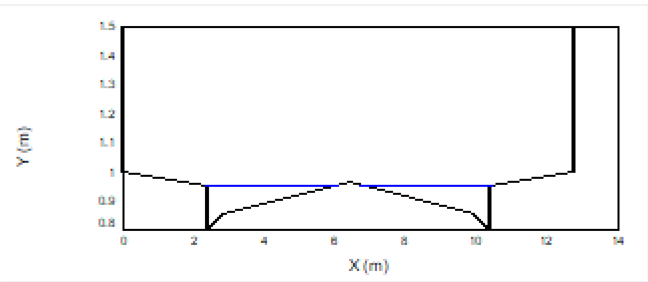
Flow route R 1



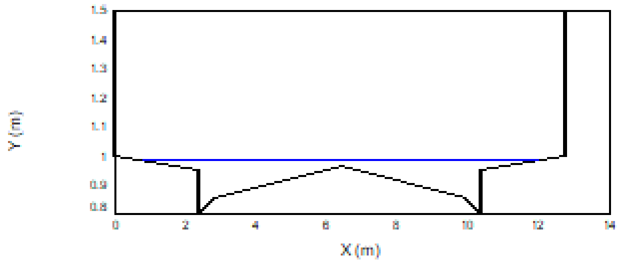
Flow route R 2



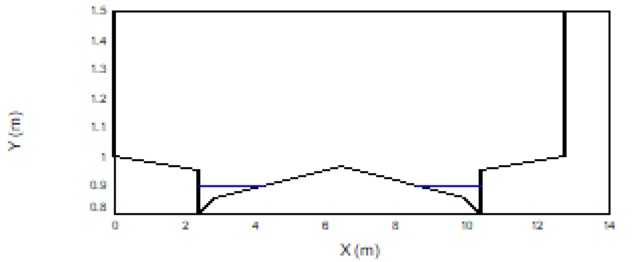
Flow route R 3



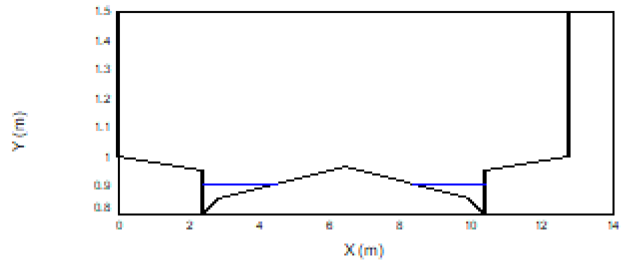
Flow route R 4



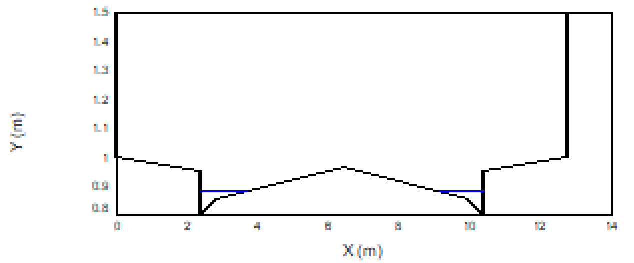
Flow route R 5



Flow route R 6



Flow route R 7



Flow route R 8

1.2. SECTIONS FLOWS & VELOCITIES

CATCHMENT DETAILS

Name	Max Flow Q (cu.m/s)	EIA Max Q (cu.m/s)	Remaining Max Q (cu.m/s)
R' 1	0.392	0.392	0
R' 2	1.041	1.041	0
R' 3	0.963	0.963	0
R' 4	1.298	1.298	0
R' 5	1.398	1.398	0
R' 6	0.15	0.15	0
R' 7	0.136	0.136	0
R' 8	0.078	0.078	0
B1	1.025	1.025	0
B 2	0.599	0.599	0.913
B 3	1.125	0.387	0.785
B 4	0.585	0.301	0.32
B 5	0.098	0.034	0.068

OVERFLOW ROUTE DETAILS

Name	Max Q U/S	Max Q D/S	Safe Q	Max D	Max DxV	Max Width	Max V
OF R1	0.392	0.392	0.815	0.129	0.28	3.45	2.13
OF R2	1.041	1.041	0.605	0.164	0.52	4.71	3.19
OF R3	0.963	0.963	0.892	0.184	0.42	5.2	2.27
OF R4	1.298	1.298	0.559	0.172	0.62	4.89	3.59
OF R6	0.15	0.15	1.099	0.111	0.13	2.85	1.17
OF R7	0.136	0.136	1.287	0.118	0.11	3.06	0.93
OF R8	0.078	0.078	1.201	0.095	0.09	2.29	0.93

APPENDIX B – DRAINS RESULTS

1.3. DRAINS RESULTS & FLOWS

DRAINS results prepared from Version 2018.09

PIT / NODE DETAILS Version 8

Name	Max HGL	Max Pond HGL	Max Surface Flow Arriving (cu.m/s)	Max Pond Volume (cu.m)	Min Freeboard (m)	Overflow (cu.m/s)	Constraint
A-01	62.9		0.013		0.45	0	None
A-02	62.14		0		1.32		None
A-03	61.85		0		1.5		None
A-04	61.63		0		1.53		None
A-05	61.53		0.006		1.49	0	None
A-06	61.45		0				
B-01	62.32		0.012		1.04	0	None
C-01	61.94	62.52	0.041	0.1	0.54		Inlet Capacity
D-01	62.56		0.027		0.61	0.001	Inlet Capacity
D-02	62.5		0.018		0.56	0	Inlet Capacity
D-03	62.34		0.005		0.69	0	None
E-01	63.15		0.025		1.09	0.001	Inlet Capacity
E-02	62.84		0.022		1.35	0	Inlet Capacity
E-03	62.65		0				
F-01	63.63		0.012		1.04	0	None
F-02	63.42		0.025		1.23	0.001	Inlet Capacity
F-03	63.24		0.002				
G-01	64.1		0.037		1.05	0.002	Inlet Capacity
G-02	63.65		0		1.56		None
G-03	63.25		0.034		1.66	0.004	Inlet Capacity
G-04	62.78		0.009				
H-01	63.96	65.38	0.039	0.2	1.38	0	Inlet Capacity
I-01	63.41		0.025		1.56	0.001	Inlet Capacity
J-01	65.93		0.009		0.47	0	None
J-02	65.93		0.038		0.01	0.004	Inlet Capacity
J-03	65.86		0.034		0.09	0	None
J-04	65.52		0.136		0.2	0.004	Inlet Capacity
J-05	65.32	65.6	0.076	3.1	0.23		Inlet Capacity
J-06	61.16		0.025		0.08	0.001	Inlet Capacity
J-07	61.09		0.081		0	0.038	Inlet Capacity
J-08	60.88		0.046		0.2	0.002	Inlet Capacity

J-09	59.82		0.151		0.6	0.005	Inlet Capacity
J-10	58.83		0.085		0.15	0.001	Inlet Capacity
J-11	56.79		0.03		1.02	0	None
J-12	55.67		0.011		0.6	0	None
J-13	54.33		0.008		0	0.035	Outlet System
J-14	52.97		0.119		0	0.166	Outlet System
J-15	52.42		0.225		0	0.22	Outlet System
J-16	51.63		0.295		0.36	0.155	Inlet Capacity
J-17	51.06		0.015		0.98	0	None
J-18	48.91		0				
K-01	57.31		0.124		0.57	0.013	Inlet Capacity
K-02	57.02		0.166		0.85	0.03	Inlet Capacity
K-03	56.91		0		0.99	0	None
L-01	59.36		0.042		1.08	0.001	Inlet Capacity
L-02	58.84		0.035		0	0.041	Outlet System
L-03	58.84		0.029		0.13	0.002	Inlet Capacity
M-01	54.05		0.032		1.24	0	None
M-02	54.03	54.66	0.151	2.2	0.48	0	Inlet Capacity
M-03	53.65	54.67	0.014	0.1	1	0	Inlet Capacity
M-04	53.05		0.028		0.59	0.002	Inlet Capacity
N-01	52.46		0.003		1.62	0	None
N-02	52.44		0.008		1.34	0	None
N-03	52.11		0.007		1.12	0	None
N-04	50.64		0.008		1.38	0	None
N-05	49.47		0.009		1.96	0	None
N-06	48.87		0.033		0.86	0	None
N-07	48.65		0.001				
O-01	49.04		0.231		1.39	0.008	Inlet Capacity
O-02	48.62		0.016				
P-01	57.4	57.93	0.049	0.5	0.48	0	Inlet Capacity
Q-01	62.6	64.22	0.025	0.2	1.59	0	Inlet Capacity
Q-02	61.68		0		2.22	0	None
Q-03	61.03		0		2.95	0	None
Q-04	60.73		0				
R-01	60.32	61.87	0.031	0.2	1.52	0	Inlet Capacity
R-02	60.19		0.066		1.52	0.005	Inlet Capacity
R-03	60.07		0.024		1.76	0	None
R-04	59.9		0				
S-01	59.69		0.056		0.92	0.003	Inlet Capacity
S-02	59.28		0.076		1.18	0.004	Inlet Capacity
S-03	59.06		0.037		1.02	0	None
S-04	58.85		0				

T-01	58.23	0.085	0.83	0.006	Inlet Capacity
T-02	57.92	0.009	1.02	0	None
T-03	57.53	0.002	1.4	0	None
T-04	57.14	0			
U-01	58.82	0.066	1.73	0.004	Inlet Capacity
U-02	58.41	0.073	1.48	0.004	Inlet Capacity
U-03	57.72	0.032	1.08	0.001	Inlet Capacity
U-04	56.98	0.099	1.27	0.021	Inlet Capacity
U-05	56.63	0.052	1.56	0	None
U-06	55.61	0.013	2.48	0	None
U-07	54.34	0			
V-01	53.3	0.082	1.67	0.005	Inlet Capacity
V-02	51.5	0.009			
W-01	50.69	0.049	0.64	0	None
W-02	50.59	0			
X-01	50.76	0.404	0.78	0.061	Inlet Capacity
X-02	50.17	0.129	0.34	0.008	Inlet Capacity
X-03	49.84	0.014			
Y-01	48.76	0.06	1.9	0.003	Inlet Capacity
Y-02	48.32	0.006			
Z-01	49.45	0.022	2.28	0	Inlet Capacity
Z-02	49.06	0.001			
Z1-01	61.15	0.087	4.25	0.005	Inlet Capacity
Z2-01	60.09	0.059	0.97	0.003	Inlet Capacity
Z3-01	55.68	0.119	0.6	0	None
Z4-01	53.77	0.021	1.03	0	None
Z5-01	51.13	0.021	1.01	0.001	Inlet Capacity
Z5-02	51.1	0.006	1.15	0	None
Z6-01	52.92	0.045	1.05	0.003	Inlet Capacity
Z6-02	52.39	0.037	1.16	0.002	Inlet Capacity
Z6-03	50.38	0.007			
Z7-01	51.38	0.196	0.61	0.025	Inlet Capacity
Z7-02	48.41	0.035			

SUB-CATCHMENT DETAILS

Name	Max Flow Q (cu.m/s)	EIA Max Q (cu.m/s)	Remaining Max Q (cu.m/s)	EIA Tc (min)	Remaining Tc (min)	Due to Storm
Cat a-01	0.009	0.009	0	5	6	1% AEP, 5 min burst, Storm 1
Cat a-05	0.003	0.003	0	5	6	1% AEP, 5 min burst, Storm 1
Cat b-01	0.008	0.008	0	5	6	1% AEP, 5 min burst, Storm 1
Cat c-01	0.03	0.009	0.021	5	6	1% AEP, 20 min burst, Storm 10

Cat d-01	0.018	0.018	0	5	6	1% AEP, 5 min burst, Storm 1
Cat d-02	0.011	0.011	0	5	6	1% AEP, 5 min burst, Storm 1
Cat93108	0.002	0.002	0	5	6	1% AEP, 5 min burst, Storm 1
Cat e-01	0.017	0.017	0	5	6	1% AEP, 5 min burst, Storm 1
Cat e-02	0.015	0.015	0	5	6	1% AEP, 5 min burst, Storm 1
Cat f-01	0.008	0.008	0	5	6	1% AEP, 5 min burst, Storm 1
Cat93121	0.017	0.017	0	5	6	1% AEP, 5 min burst, Storm 1
Cat g-01	0.025	0.025	0	5	6	1% AEP, 5 min burst, Storm 1
Cat g-03	0.022	0.022	0	5	6	1% AEP, 5 min burst, Storm 1
Cat h-01	0.029	0.029	0	5	6	1% AEP, 5 min burst, Storm 1
Cat i-01	0.017	0.017	0	5	6	1% AEP, 5 min burst, Storm 1
Cat j-01	0.007	0.001	0.006	5	6	1% AEP, 20 min burst, Storm 8
Cat j-02	0.025	0.014	0.013	5	6	1% AEP, 20 min burst, Storm 10
Cat j-03	0.023	0.012	0.013	5	6	1% AEP, 20 min burst, Storm 10
Cat j-04	0.065	0.053	0.019	5	6	1% AEP, 20 min burst, Storm 3
Cat j-05	0.017	0.014	0.005	5	6	1% AEP, 20 min burst, Storm 3
Cat93240	0.017	0.014	0.005	5	6	1% AEP, 20 min burst, Storm 3
Cat j-07	0.054	0.054	0	5	6	1% AEP, 5 min burst, Storm 1
Cat j-08	0.022	0.022	0	5	6	1% AEP, 5 min burst, Storm 1
Cat9 j-09	0.006	0.006	0	5	6	1% AEP, 5 min burst, Storm 1
Cat j-10	0.017	0.017	0	5	6	1% AEP, 5 min burst, Storm 1
Cat j-11	0.007	0.007	0	5	6	1% AEP, 5 min burst, Storm 1
Cat j-12	0.008	0.008	0	5	6	1% AEP, 5 min burst, Storm 1
Cat j-13	0.006	0.006	0	5	6	1% AEP, 5 min burst, Storm 1
Cat j-14	0.022	0.022	0	5	6	1% AEP, 5 min burst, Storm 1
Cat j-15	0.007	0.007	0	5	6	1% AEP, 5 min burst, Storm 1
Cat j-16	0.006	0.006	0	5	6	1% AEP, 5 min burst, Storm 1
Cat j-17	0.007	0.007	0	5	6	1% AEP, 5 min burst, Storm 1
Cat k-01	0.084	0.084	0	5	6	1% AEP, 5 min burst, Storm 1
Cat k-02	0.034	0.034	0	5	6	1% AEP, 5 min burst, Storm 1
Cat l-01	0.028	0.028	0	5	6	1% AEP, 5 min burst, Storm 1
Cat l-02	0.019	0.019	0	5	6	1% AEP, 5 min burst, Storm 1
Cat l-03	0.019	0.019	0	5	6	1% AEP, 5 min burst, Storm 1
Cat m-01	0.007	0.007	0	5	6	1% AEP, 5 min burst, Storm 1
Cat m-02	0.115	0.115	0	5	8	1% AEP, 5 min burst, Storm 1
Cat m-03	0.011	0.011	0	5	8	1% AEP, 5 min burst, Storm 1
Cat m-04	0.02	0.02	0	5	8	1% AEP, 5 min burst, Storm 1
Cat n-01	0.002	0.001	0.001	5	6	1% AEP, 20 min burst, Storm 10
Cat n-02	0.005	0.003	0.002	5	6	1% AEP, 20 min burst, Storm 10
Cat n-03	0.005	0.003	0.002	5	6	1% AEP, 20 min burst, Storm 10
Cat n-04	0.005	0.003	0.003	5	6	1% AEP, 20 min burst, Storm 10
Cat n-05	0.006	0.003	0.003	5	6	1% AEP, 20 min burst, Storm 10
Cat93339	0.022	0.022	0	5	6	1% AEP, 5 min burst, Storm 1
Cat o-01	0.008	0.008	0	5	6	1% AEP, 5 min burst, Storm 1

Cat p-01	0.005	0.005	0	5	6	1% AEP, 5 min burst, Storm 1
Cat q-01	0.017	0.009	0.009	5	6	1% AEP, 20 min burst, Storm 10
Cat r-01	0.023	0.003	0.021	5	6	1% AEP, 20 min burst, Storm 8
Cat r-02	0.047	0.047	0	5	6	1% AEP, 5 min burst, Storm 1
Cat r-03	0.018	0.018	0	5	6	1% AEP, 5 min burst, Storm 1
Cat s-01	0.042	0.005	0.037	5	6	1% AEP, 20 min burst, Storm 8
Cat s-02	0.043	0.043	0	5	6	1% AEP, 5 min burst, Storm 1
Cat s-03	0.021	0.021	0	5	6	1% AEP, 5 min burst, Storm 1
Cat t-01	0.064	0.008	0.056	5	6	1% AEP, 20 min burst, Storm 8
Cat u-01	0.047	0.047	0	5	6	1% AEP, 5 min burst, Storm 1
Cat u-02	0.047	0.047	0	5	6	1% AEP, 5 min burst, Storm 1
Cat u-03	0.018	0.018	0	5	6	1% AEP, 5 min burst, Storm 1
Cat u-04	0.073	0.009	0.065	5	6	1% AEP, 20 min burst, Storm 8
Cat u-05	0.014	0.014	0	5	8	1% AEP, 5 min burst, Storm 1
Cat u-06	0.008	0.008	0	5	8	1% AEP, 5 min burst, Storm 1
Cat v-01	0.059	0.059	0	5	6	1% AEP, 5 min burst, Storm 1
Cat93202	0.034	0.022	0.015	5	8	1% AEP, 20 min burst, Storm 10
Cat x-01	0.063	0.004	0.059	5	6	1% AEP, 20 min burst, Storm 8
Cat93194	0.06	0.06	0	5	8	1% AEP, 5 min burst, Storm 1
Cat y-01	0.046	0.012	0.035	5	8	1% AEP, 20 min burst, Storm 8
Cat z-01	0.015	0.007	0.008	5	6	1% AEP, 20 min burst, Storm 10
Cat z1-01	0.064	0.064	0	5	6	1% AEP, 5 min burst, Storm 1
Cat z2-01	0.044	0.044	0	5	6	1% AEP, 5 min burst, Storm 1
Cat z3-01	0.01	0.01	0	5	6	1% AEP, 5 min burst, Storm 1
Cat z4-01	0.016	0.016	0	5	8	1% AEP, 5 min burst, Storm 1
Cat z5-01	0.016	0.016	0	5	8	1% AEP, 5 min burst, Storm 1
Cat z5-02	0.005	0.005	0	5	8	1% AEP, 5 min burst, Storm 1
Cat z6-01	0.036	0.036	0	5	6	1% AEP, 5 min burst, Storm 1
Cat z6-02	0.03	0.03	0	5	6	1% AEP, 5 min burst, Storm 1
Ca z7-01	0.156	0.156	0	5	6	1% AEP, 5 min burst, Storm 1

PIPE DETAILS

Name	Max Q	Max V	Max U/S	Max D/S	Due to Storm
	(cu.m/s)	(m/s)	HGL (m)	HGL (m)	
P A-01	0.009	1.07	62.901	62.819	1% AEP, 5 min burst, Storm 1
P A-02	0.017	0.56	62.138	61.855	1% AEP, 10 min burst, Storm 8
P A-03	0.044	0.83	61.855	61.626	1% AEP, 20 min burst, Storm 10
P A-04	0.072	1.24	61.546	61.529	1% AEP, 20 min burst, Storm 10
P A-05	0.075	1.39	61.51	61.445	1% AEP, 20 min burst, Storm 10
P B-01	0.008	1.34	62.325	62.148	1% AEP, 5 min burst, Storm 1
P C-01	0.029	0.84	61.898	61.855	1% AEP, 20 min burst, Storm 10
P D-01	0.017	0.63	62.556	62.498	1% AEP, 5 min burst, Storm 1
P D-02	0.028	0.98	62.498	62.341	1% AEP, 5 min burst, Storm 1

P D-03	0.03	2.07	62.341	62.087	1% AEP, 5 min burst, Storm 1
P E-01	0.016	1.69	63.149	62.843	1% AEP, 5 min burst, Storm 1
P E-02	0.031	1.73	62.839	62.648	1% AEP, 5 min burst, Storm 1
P F-01	0.008	0.53	63.629	63.423	1% AEP, 20 min burst, Storm 10
P F-02	0.024	1.75	63.423	63.238	1% AEP, 5 min burst, Storm 1
P G-01	0.023	0.62	64.101	63.646	1% AEP, 20 min burst, Storm 1
P G-02	0.048	1.7	63.646	63.255	1% AEP, 5 min burst, Storm 1
P G-03	0.082	2.32	63.247	62.775	1% AEP, 5 min burst, Storm 1
P H-01	0.029	0.85	63.957	63.646	1% AEP, 5 min burst, Storm 1
P I-01	0.016	0.54	63.407	63.247	1% AEP, 20 min burst, Storm 1
P J-01	0.007	0.17	65.928	65.927	1% AEP, 20 min burst, Storm 8
P J-02	0.024	0.59	65.879	65.861	1% AEP, 20 min burst, Storm 10
P J-03	0.045	1.1	65.658	65.524	1% AEP, 20 min burst, Storm 8
P J-04	0.104	0.97	65.366	65.32	1% AEP, 20 min burst, Storm 10
P J-05	0.119	2.9	64.279	61.161	1% AEP, 20 min burst, Storm 10
P J-06	0.134	1.26	61.111	61.091	1% AEP, 20 min burst, Storm 10
P J-07	0.163	1.53	60.924	60.878	1% AEP, 20 min burst, Storm 8
P J-08	0.23	2.27	60.106	59.821	1% AEP, 20 min burst, Storm 8
P J-09	0.281	2.68	59.621	58.83	1% AEP, 5 min burst, Storm 1
P J-10	0.321	3.01	57.96	56.788	1% AEP, 5 min burst, Storm 1
P J-11	0.433	2.74	56.412	55.674	1% AEP, 10 min burst, Storm 1
P J-12	0.461	2.88	54.835	54.33	1% AEP, 20 min burst, Storm 8
P J-13	0.43	2.62	53.46	52.968	1% AEP, 5 min burst, Storm 1
P J-14	0.325	1.98	52.49	52.423	1% AEP, 2 hour burst, Storm 9
P J-15	0.427	2.6	51.706	51.628	1% AEP, 5 min burst, Storm 1
P J-16	0.451	2.75	51.258	51.056	1% AEP, 20 min burst, Storm 10
P J-17	0.469	4.25	49.987	48.911	1% AEP, 10 min burst, Storm 10
P K-01	0.071	1.45	57.236	57.025	1% AEP, 5 min burst, Storm 1
P K-02	0.093	0.87	56.925	56.907	1% AEP, 20 min burst, Storm 8
P K-03	0.107	1	56.817	56.788	1% AEP, 10 min burst, Storm 1
P L-01	0.027	0.96	59.326	58.839	1% AEP, 5 min burst, Storm 1
P L-02	0.036	0.5	58.838	58.838	1% AEP, 10 min burst, Storm 2
P L-03	0.053	0.5	58.831	58.83	1% AEP, 5 min burst, Storm 1
P M-01	0.007	0.43	54.05	54.033	1% AEP, 5 min burst, Storm 1
P M-02	0.12	1.53	53.859	53.715	1% AEP, 5 min burst, Storm 1
P M-03	0.13	2.68	53.635	53.116	1% AEP, 5 min burst, Storm 1
P M-04	0.162	1.52	52.542	52.423	1% AEP, 5 min burst, Storm 1
P N-01	0.002	0.23	52.455	52.444	1% AEP, 20 min burst, Storm 10
P N-02	0.007	1.03	52.444	52.198	1% AEP, 20 min burst, Storm 10
P N-03	0.012	2.21	52.111	51.049	1% AEP, 20 min burst, Storm 10
P N-04	0.017	1.37	50.618	50.509	1% AEP, 20 min burst, Storm 10
P N-05	0.025	1.03	49.46	48.869	1% AEP, 20 min burst, Storm 3
P N-06	0.043	2.46	48.801	48.65	1% AEP, 20 min burst, Storm 2
P O-01	0.148	3.16	48.893	48.617	1% AEP, 10 min burst, Storm 7

P P-01	0.016	2.05	57.4	57.027	1% AEP, 20 min burst, Storm 3
P Q-01	0.017	2.64	62.571	61.808	1% AEP, 20 min burst, Storm 10
P Q-02	0.017	2.3	61.661	61.183	1% AEP, 20 min burst, Storm 10
P Q-03	0.016	2	61.033	60.733	1% AEP, 20 min burst, Storm 10
P R-01	0.023	0.59	60.316	60.194	1% AEP, 20 min burst, Storm 8
P R-02	0.059	1.16	60.127	60.072	1% AEP, 20 min burst, Storm 10
P R-03	0.073	1.61	60.057	59.902	1% AEP, 20 min burst, Storm 10
P S-01	0.04	2.06	59.688	59.371	1% AEP, 20 min burst, Storm 3
P S-02	0.079	1.29	59.206	59.057	1% AEP, 20 min burst, Storm 10
P S-03	0.097	1.76	58.988	58.848	1% AEP, 20 min burst, Storm 10
P T-01	0.06	2.05	58.199	57.918	1% AEP, 20 min burst, Storm 10
P T-02	0.063	2.14	57.918	57.687	1% AEP, 20 min burst, Storm 10
P T-03	0.063	2.96	57.53	57.135	1% AEP, 20 min burst, Storm 10
P U-01	0.043	0.71	58.822	58.414	1% AEP, 5 min burst, Storm 1
P U-02	0.085	1.32	58.403	57.717	1% AEP, 10 min burst, Storm 1
P U-03	0.108	2.64	57.641	56.99	1% AEP, 5 min burst, Storm 1
P U-04	0.147	1.82	56.772	56.63	1% AEP, 20 min burst, Storm 10
P U-05	0.173	2.08	56.566	55.608	1% AEP, 20 min burst, Storm 10
P U-06	0.18	5.49	55.509	54.338	1% AEP, 20 min burst, Storm 10
P V-01	0.053	2.33	53.252	51.503	1% AEP, 5 min burst, Storm 1
P W-01	0.034	1.08	50.625	50.585	1% AEP, 20 min burst, Storm 10
P X-01	0.22	1.75	50.627	50.168	1% AEP, 25 min burst, Storm 6
P X-02	0.297	2.86	49.999	49.837	1% AEP, 25 min burst, Storm 7
P Y-01	0.043	2.51	48.759	48.324	1% AEP, 20 min burst, Storm 8
P Z-01	0.015	1.84	49.45	49.063	1% AEP, 20 min burst, Storm 10
P Z1-01	0.059	1.15	61.106	60.878	1% AEP, 5 min burst, Storm 1
P Z2-01	0.04	1.09	60.043	59.821	1% AEP, 5 min burst, Storm 1
P Z3-01	0.033	0.31	55.675	55.674	1% AEP, 10 min burst, Storm 1
P Z4-01	0.016	0.58	53.771	53.048	1% AEP, 5 min burst, Storm 1
P Z5-01	0.016	0.38	51.106	51.101	1% AEP, 5 min burst, Storm 1
P Z5-02	0.02	0.49	51.073	51.056	1% AEP, 5 min burst, Storm 1
P Z6-01	0.033	1.77	52.889	52.425	1% AEP, 5 min burst, Storm 1
P Z6-02	0.06	2.67	52.319	50.381	1% AEP, 5 min burst, Storm 1
P Z7-01	0.132	4.49	50.958	48.409	1% AEP, 5 min burst, Storm 1

OVERFLOW ROUTE DETAILS

Name	Max Q U/S	Max Q D/S	Safe Q	Max D	Max DxV	Max Width	Max V	Due to Storm
OF a01	0	0.003	1.28	0.041	0.02	0.34	0.49	1% AEP, 5 min burst, Storm 1
OF a-05	0	0	0.708	0	0	0	0	
OF b-01	0	0.011	1.258	0.062	0.04	0.7	0.67	1% AEP, 5 min burst, Storm 1
OF d-01	0.001	0.01	12.932	0.011	0.01	3.74	0.47	1% AEP, 20 min burst, Storm 3
OF d-02	0	0.002	1.442	0.037	0.01	0.31	0.34	1% AEP, 5 min burst, Storm 1
OF d-03	0	0.003	0.066	0.015	0	4.88	0.09	1% AEP, 5 min burst, Storm 1

OF e-01	0.001	0.002	0.856	0.024	0.02	0.27	0.74	1% AEP, 10 min burst, Storm 1
OF e-02	0	0.003	0.857	0.027	0.02	0.31	0.82	1% AEP, 10 min burst, Storm 1
OF f-01	0	0.017	0.088	0.024	0	5.9	0.2	1% AEP, 5 min burst, Storm 1
OF f-02	0.001	0.001	0.449	0.004	0	1.42	0.27	1% AEP, 5 min burst, Storm 1
OF g-01	0.002	0.023	1.58	0.05	0.06	0.83	1.11	1% AEP, 5 min burst, Storm 1
OF g-03	0.004	0.004	0.691	0.006	0	2.05	0.61	1% AEP, 5 min burst, Storm 1
OF h-01	0	0.025	0.252	0.019	0.01	5.38	0.44	1% AEP, 5 min burst, Storm 1
OF i-01	0.001	0.022	0.252	0.018	0.01	5.27	0.43	1% AEP, 5 min burst, Storm 1
OF48551	0	0.025	0.235	0.019	0.01	5.38	0.44	1% AEP, 20 min burst, Storm 10
OF j-02	0.004	0.068	0.186	0.032	0.02	6.73	0.51	1% AEP, 20 min burst, Storm 2
OF j-03	0	0.017	1.063	0.064	0.06	0.77	0.95	1% AEP, 20 min burst, Storm 3
OF j-04	0.004	0.019	0.2	0.018	0.01	5.27	0.36	1% AEP, 20 min burst, Storm 3
OF j-06	0.001	0.054	0.404	0.021	0.02	5.59	0.8	1% AEP, 5 min burst, Storm 1
OF j-07	0.038	0.043	0.419	0.019	0.01	5.38	0.75	1% AEP, 20 min burst, Storm 3
OF j-08	0.002	0.007	1.34	0.031	0.03	0.51	0.92	1% AEP, 20 min burst, Storm 3
OF j-09	0.005	0.017	1.39	0.043	0.05	0.7	1.16	1% AEP, 5 min burst, Storm 1
OF j-10	0.001	0.008	1.424	0.032	0.03	0.52	0.92	1% AEP, 5 min burst, Storm 1
OF j-11	0	0.008	1.192	0.03	0.03	0.5	1.02	1% AEP, 5 min burst, Storm 1
OF j-12	0	0.006	0.481	0.026	0.04	0.3	1.47	1% AEP, 5 min burst, Storm 1
OF j-13	0.035	0.051	0.81	0.067	0.1	1.36	1.49	1% AEP, 20 min burst, Storm 8
OF j-14	0.166	0.171	0.603	0.09	0.21	2.12	2.32	1% AEP, 10 min burst, Storm 1
OF j-15	0.22	0.224	0.597	0.099	0.24	2.4	2.42	1% AEP, 10 min burst, Storm 7
OF j-16	0.155	0.158	1.318	0.09	0.14	3.31	1.57	1% AEP, 10 min burst, Storm 7
OF j-17	0	0	1.322	0	0	0	0	
OF k-01	0.013	0.017	0.026	0.041	0	7.77	0.08	1% AEP, 5 min burst, Storm 1
OF k-02	0.03	0.034	0.429	0.017	0.01	5.17	0.72	1% AEP, 10 min burst, Storm 5
OF48737	0	0.005	1.415	0.054	0.02	0.44	0.38	1% AEP, 5 min burst, Storm 1
OF l-01	0.001	0.02	0.393	0.048	0.1	0.4	2.09	1% AEP, 5 min burst, Storm 1
OF l-03	0.041	0.068	0.08	0.1	0.45	0.3	4.53	1% AEP, 5 min burst, Storm 1
OF l-02	0.002	0.02	0.081	0.081	0.17	0.24	2.07	1% AEP, 5 min burst, Storm 1
OF m-01	0	0.02	0.481	0.042	0.09	0.5	2.08	1% AEP, 5 min burst, Storm 1
OF m-02	0	0.011	1.461	0.022	0.01	4	0.38	1% AEP, 5 min burst, Storm 1
OF m-03	0	0.02	0.525	0.043	0.08	0.55	1.92	1% AEP, 5 min burst, Storm 1
OF m-04	0.002	0.008	0.623	0.033	0.04	0.37	1.3	1% AEP, 5 min burst, Storm 1
OF n-01	0	0.005	7.665	0.011	0	3.74	0.24	1% AEP, 20 min burst, Storm 10
OF n-02	0	0.005	14.113	0.009	0	3.14	0.33	1% AEP, 20 min burst, Storm 10
OF n-03	0	0.005	11.076	0.008	0	2.54	0.54	1% AEP, 20 min burst, Storm 10
OF n-04	0	0.006	10.051	0.008	0	2.54	0.58	1% AEP, 20 min burst, Storm 10
OF n-05	0	0.022	0.515	0.044	0.09	0.58	2.04	1% AEP, 5 min burst, Storm 1

OF n-06	0	0	1.403	0	0	0	0	
OF o-01	0.008	0.008	1.294	0.012	0.01	1.23	1.09	1% AEP, 10 min burst, Storm 7
OF p-01	0	0.01	0.637	0.009	0.01	2.99	0.72	1% AEP, 5 min burst, Storm 1
OF q-01	0	0	0.384	0	0	0	0	
OF q-02	0	0.047	0.941	0.052	0.08	1.46	1.5	1% AEP, 5 min burst, Storm 1
OF q-03	0	0.018	0.977	0.037	0.05	0.94	1.24	1% AEP, 5 min burst, Storm 1
OF r-01	0	0.047	0.235	0.025	0.01	6	0.52	1% AEP, 5 min burst, Storm 1
OF r-02	0.005	0.046	1.016	0.053	0.07	1.5	1.39	1% AEP, 5 min burst, Storm 1
OF r-03	0	0.021	1.039	0.041	0.05	1.07	1.16	1% AEP, 5 min burst, Storm 1
OF48324	0.003	0.044	0.261	0.023	0.01	5.79	0.56	1% AEP, 20 min burst, Storm 3
OF s-02	0.004	0.023	0.29	0.017	0.01	5.17	0.48	1% AEP, 10 min burst, Storm 1
OF s-03	0	0	0.766	0	0	0	0	
OF t-01	0.006	0.006	0.331	0.01	0	3.31	0.36	1% AEP, 20 min burst, Storm 8
OF t-02	0	0	0.055	0	0	0	0	
OF t-03	0	0.008	0.831	0.044	0.05	0.36	1.06	1% AEP, 5 min burst, Storm 1
OF t-04	0.064	0.117	0.782	0.073	0.13	1.76	1.81	1% AEP, 20 min burst, Storm 3
OF u-01	0.004	0.05	0.462	0.02	0.02	5.48	0.81	1% AEP, 5 min burst, Storm 1
OF u-02	0.004	0.021	0.452	0.014	0.01	4.57	0.64	1% AEP, 5 min burst, Storm 1
OF p-03	0.001	0.074	4.103	0.079	0.09	2.58	1.09	1% AEP, 20 min burst, Storm 8
OF u-04	0.021	0.032	0.197	0.023	0.01	5.79	0.4	1% AEP, 20 min burst, Storm 8
OF u-05	0	0.008	0.207	0.014	0	4.57	0.26	1% AEP, 5 min burst, Storm 1
OF u-06	0	0.034	0.808	0.046	0.09	0.76	1.93	1% AEP, 20 min burst, Storm 10
OF u-07	0.171	0.225	0.601	0.104	0.18	2.49	1.74	1% AEP, 25 min burst, Storm 7
OF v-01	0.005	0.005	0.469	0.008	0	2.68	0.45	1% AEP, 5 min burst, Storm 1
OF w-02	0	0.051	1.041	0.088	0.1	1.58	1.09	1% AEP, 5 min burst, Storm 1
OF x-01	0.061	0.091	0.447	0.025	0.03	6	1.01	1% AEP, 25 min burst, Storm 6
OF x-02	0.008	0.008	0.597	0.009	0.01	2.99	0.6	1% AEP, 25 min burst, Storm 6
OF y-01	0.003	0.003	0.93	0.005	0	1.73	0.67	1% AEP, 20 min burst, Storm 8
OF z-01	0	0	0.955	0	0	0	0	
OF z1-01	0.005	0.025	0.635	0.014	0.01	4.57	0.78	1% AEP, 5 min burst, Storm 1
OF z2-02	0.003	0.009	0.652	0.009	0.01	2.99	0.64	1% AEP, 10 min burst, Storm 1
OF z-03	0	0.007	0.539	0.031	0.04	0.35	1.39	1% AEP, 5 min burst, Storm 1
OF z4-01	0	0.02	1.364	0.022	0.02	4	0.7	1% AEP, 5 min burst, Storm 1
OFz5-01	0.001	0.007	1.489	0.023	0.01	4	0.22	1% AEP, 5 min burst, Storm 1
OF z5-02	0	0.007	1.452	0.019	0.01	1.92	0.38	1% AEP, 5 min burst, Storm 1
OF z6-01	0.003	0.003	0.47	0.006	0	2.05	0.42	1% AEP, 5 min burst, Storm 1
OF z6-02	0.002	0.002	0.496	0.006	0	2.05	0.33	1% AEP, 5 min burst, Storm 1
OF z7-01	0.025	0.025	0.664	0.013	0.01	4.25	0.88	1% AEP, 5 min burst, Storm 1

Upwelling occurred at: L-02, J-15, J-14,
J-13

Freeboard was less than 0.05m at J-07, J-02

The maximum flow in these overflow routes is unsafe: OF l-03

APPENDIX C – CIVIL ENGINEERING DRAWINGS