Cranbrook School Redevelopment
Cranbrook School
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Cranbrook School

Stormwater Management and Civil Design Report

State Significant Development Application (SSDA) Submission

Stormwater Management and Civil Design Report

Cranbrook School

Client: Cranbrook School

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1.0 Introduction

This report has been prepared to summarise the design approach, key assumptions, relevant references and standards applied to the development of Civil and Stormwater State Significant Development Application (SSDA) documentation for the Cranbrook Senior School Redevelopment.

The Cranbrook School is undertaking a redevelopment project, which involves the delivery of a new sports and fitness centre under Hordern Oval and a new integrated learning centre known as the Centenary Building (to replace the existing Mar Memorial Hall and Mansfield buildings).

A site plan of the existing Cranbrook School is shown below in Figure 1.

Figure 1 Site Plan

Flood studies relevant to the redevelopment of the Cranbrook site, were prepared by WMA Water (formerly Webb, McKeown & Associates) in September 2010 and January 2014 as part of stages 1 to 3 of a 4 stage process to establish Woollahra Council's framework for sustainable floodplain management. These studies aimed to outline solutions to the flooding issues and to ensure that future development does not exacerbate the flood hazard.

A Report on Geotechnical Investigation was conducted by Douglas Partners in February 2016 for the assessment of options for Stage 1 of Cranbrook School's redevelopment and to provide detailed information on the subsurface conditions. The key civil considerations are to ensure the proposed development complies with existing council design parameters.

Stormwater management and civil design throughout the Cranbrook School site involves the interface with a number of stakeholders including the following:

- Woollahra Council – Responsible for the drainage network within the dedicated road and public realm;
- Waterways Authority – Responsible for approval to discharge stormwater into Sydney Harbour;
- Sydney Water;

Consultation has been undertaken with each of these stakeholders as part of the Cranbrook School redevelopment project and the outcomes of this consultation are reflected in this report.

2.0 Background

2.1 Existing Site Conditions

The Cranbrook School senior campus is located in the Eastern Sydney suburb of Bellevue Hill. It is approximately 5km East from Sydney CBD and is bounded by New South Head Road to the north, Victoria Road to the south and Rose Bay Avenue to the east. The site is approximately 4.2ha in size and is situated on a hill that slopes in a northerly direction. The Surface levels vary between RL 40m AHD along the southern periphery to 15m AHD on the northern side with an average slope of approximately 7%.

The current site consists of significant impervious areas including paved roads, bitumen driveways, paved footpaths and buildings. Pervious areas include the grassed oval and garden beds.

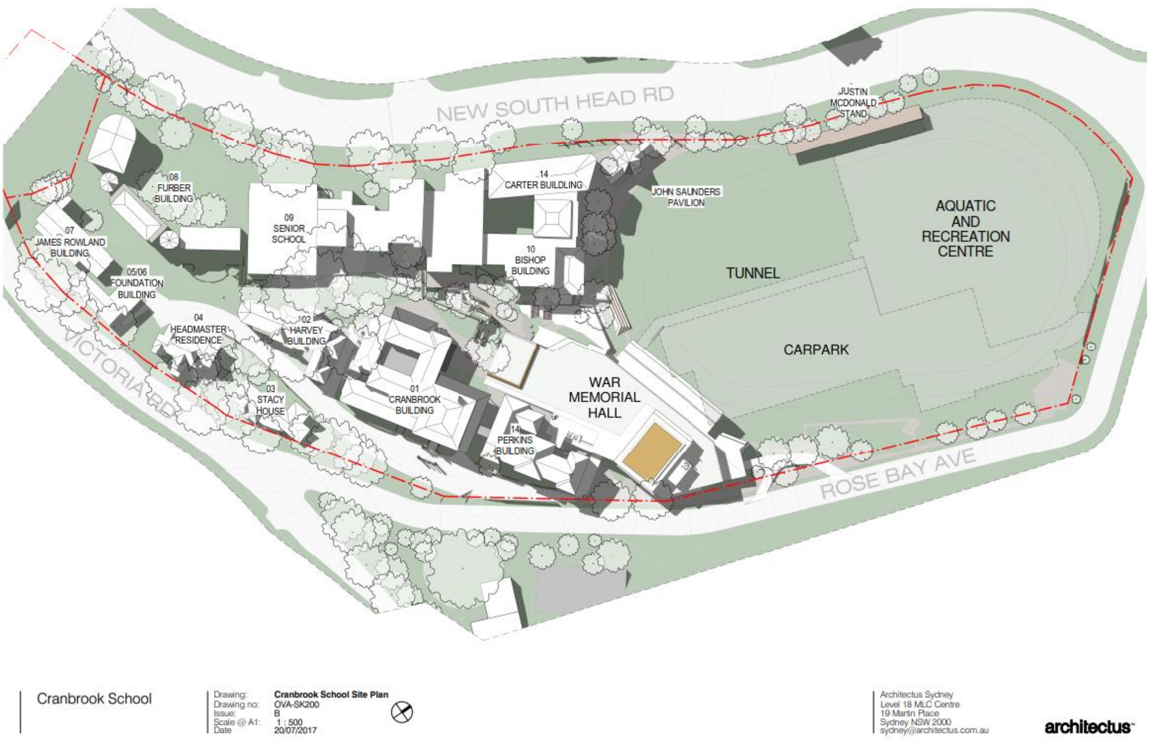
2.2 Proposed Development

The Cranbrook School senior campus redevelopment project will comprise of the following:

- New Aquatic and Fitness Centre (AFC) beneath the Hordern Oval;
- New integrated learning building – Centenary Building (CB);
- New underground carpark accessible from Rose Bay Avenue for staff and students; and
- Civil and Landscaping works for new lay-bys and footway works in Rose Bay Avenue and New South Head Road.

An overall concept plan for the development site is presented in Figure 2.

Figure 2 Site Concept Plan



3.0 Design Criteria

The following sections detail the criteria and standards that have been used to guide stormwater management principles. Note that for the present document; 'pre-development' refers to conditions prior to The Cranbrook School redevelopment works.

3.1 State Significant Precinct Study Requirements

Stormwater requirements for the development outlined in the 'State Significant Precinct Study Requirements' are as follows:

12 Water Quality:

> *Provide a concept Stormwater Management Plan outlining the general stormwater management measures for the proposal, with particular emphasis on possible WSUD options.*

13 Flooding;

> *Provide concept level details of the drainage associated with the proposal, including stormwater drainage infrastructure and address the impact of stormwater flows on the site from other catchments, overland flow paths and mainstream flooding.*

3.2 Woollahra Municipal Council Requirements

The Woollahra Council Development Control Plan (2015) provides detailed requirements to be addressed as part of a stormwater concept plan. These require the following management measures to be addressed where applicable:

- Water Sensitive Urban Design (WSUD);
- Stormwater Treatment;
- On site detention (OSD) of stormwater;
- Connection to Council's drainage systems;
- Diversion of Council's drainage
- Structures over or near drainage lines and easements;
- Connection to Council's parks, reserves, bushland and natural waterways; connection to Sydney Harbour; and connection to Sydney water channels;
- Low level properties and easements;
- Groundwater (or hydrogeology)
- Absorption systems;
- Pump and sump systems;
- Charged or siphonic systems; and
- Activities on a public road.

This stormwater management and civil design report outlines how the proposed development will comply with these requirements where relevant.

3.3 Stormwater Design Standards

Woollahra Council design standards have generally been adopted for the new development, as the existing downstream stormwater is owned and maintained by Woollahra Council.

A summary of each of the standards, codes and other additional design documents used in the design of stormwater infrastructure for the development is presented in Table 1.

Table 1 Stormwater drainage reference documents and standards

Reference Number	Title
WDCP E2	Woollahra Council - Stormwater and Flood Risk Management (2015)
RoseBayFPRMS	Rose Bay Floodplain Risk Management Study and Plan (2014)
RoseBayCFS	Rose Bay Catchment Flood study (2010)
QUDM	Queensland Urban Drainage Manual (2013 Provisional)
CoS A4	City of Sydney Design Specification A4 Drainage Design
RMS R11	RMS Specification R11.
CPA	Concrete Pipe Association's "Concrete Pipe Selection and Installation" Guide
AR&R Vol 1	Australian Rainfall and Runoff "A Guide to Flood Estimation" Volume 1, 1987.
AR&R Vol 2	Australian Rainfall and Runoff "A Guide to Flood Estimation" Volume 2, 1987.
AR&R – Project 10	Australian Rainfall and Runoff – Revision Projects "Appropriate Safety Criteria for People"
AR&R – Project 11	Australian Rainfall and Runoff – Revision projects "Blockage of Hydraulic Structures"
AS 3500.3	Australian Standard AS3500.3: Plumbing and Drainage Code – Stormwater Drainage (2003)
AS 3725	Australian Standards AS3725: Design for Installing of Buried Concrete Pipes
WMC spec	Woollahra Council Specification For Roadworks, Drainage And Miscellaneous Works. (2012)
NSW FDM	New South Wales Floodplain Development Manual

3.4 Adopted Stormwater Design Criteria

Based on the planning commitments and the requirements of the various design standards, the stormwater drainage design criteria adopted for the development is summarised in Table 2.

Table 2 Stormwater drainage design criteria

Item	Standard	Adopted	Comment
Hydrology			
Hydrological Model	WDCP E2	DRAINS model	Using the Time Area method – ILSAX
Time of concentration	QUDM	Modified Friends equation Minimum ToC: Paved: 5 minutes Grassed: 6 minutes	
Minor Design Storm	WDCP E2	20 year ARI	Where an overland flow system is available, the drainage system is designed to cater to a minimum 1 in 20 ARI event.
Major Design Storm	WDCP E2	100 year ARI	The drainage system in combination with the overland flow system is designed to cater to a minimum 1 in 100

			ARI event.
Hydraulics			
Pipe class/size	WDCP E2	Min. class 4, 375mm diameter	Pipes within the road carriageway owned by Woollahra Council to be class 2 and have 375mm diameter.
Boundary conditions (tailwater) at Council connection points	QUDM	Pipe obvert	-
Pit losses	QUDM	Missouri Charts, (Sangster et al, 1958)	
Pit blockage factors	QUDM	Kerb Inlet Pits - On-Grade: 20% - Sag: 50%	Applied to proposed infrastructure only
Flood Hazard			
Appropriate Safety Criteria for People	AR&R – Project 10	Max. Depth x Velocity = $0.4m^2s^{-1}$	

3.5 Stormwater Quantity Control Requirements

Woollahra Council requirements for on-site detention (OSD) of stormwater aim to reduce and mitigate the peak stormwater flow from a developed site and to allow a controlled release of stormwater to the public stormwater system. For basic developments, Woollahra Council (the authority responsible for the downstream drainage network) has advised of the required stormwater quantity controls for the site:

- On-site Detention volume 20 m^3 per 1,000 m^2 site area
- Permitted Site Discharge limited to 34 l/s per 1,000 m^2 site area

Consultation with Council indicates that an alternative OSD strategy may be adopted for the purposes of this development. Council is in principle supportive of removing the requirement for a formalised OSD tank, provided a sufficient green roof area and retention tank or irrigation tank volume is provided. Detailed justification has been provided and subsequently agreed by Council. Refer to Appendix A for related correspondence.

The overall development will provide stormwater quantity controls to comply with Woollahra Council requirements for post development stormwater discharge from the site to not exceed pre-development flowrates. In addition, the development lots will provide stormwater quantity controls to comply with the Woollahra Council storage and discharge requirements.

3.6 Stormwater Quality Control Requirements

The Sydney Regional Environmental Plan (REP) encompasses developments with runoff into Sydney Harbour. The plan aims to:

> *'Establish a balance between promoting a prosperous working harbour, maintaining a healthy and sustainable waterway environment and promoting recreational access to the foreshore and waterways.'*

Woollahra Council details the water quality requirements for developments discharging into Sydney Harbour and requires stormwater treatment for:

- All properties with connections to Sydney Harbour, waterways and open watercourses;
- All new commercial developments and residential flat buildings; and
- All major alterations and additions to commercial developments and residential flat buildings

The environmental targets for stormwater runoff leaving the site are:

- 90% removal of gross pollutants (>5mm);
- 85% removal of total suspended solids;
- 65% removal of total phosphorous; and
- 45% removal of total nitrogen.

Several WSUD measures are proposed to be integrated into the stormwater management strategy for the development. These are detailed in section 5.3.5.

4.0 Earthworks and Levels Design

The primary feature of the Cranbrook School redevelopment includes construction of the new Aquatic and Fitness Centre (AFC) under Hordern Oval, and construction of the new Centenary Building (CB). As part of this development, local roads and earthworks design will include widening of surrounding streets and providing appropriate pedestrian amenities.

4.1 General Description

The following are the main features of the road and earthworks design for the project:

- Kerb alignments for driveways and new loading zones to suit the turn path of the design vehicle (vehicle tracking – refer to Traffic Engineer's documentation);
- Footpath cross-fall designed to meet Woollahra Council standards (at interfaces to public domain only);
- Landscaping and earthworks to suit new building designs;

4.2 Cut/Fill

The cut/fill volumes for the works are presented in Table 3.

Table 3 Cut/Fill Volumes

CUT AND FILL VOLUME

	AQUATIC CENTRE	CARPARK	CENTENARY BUILDING	TOTAL
CUT (m)	-40,649	-15,377	-29,073	-85,099
FILL (m)	0	0	33	33
TOTAL BALANCE	-40,649	-15,377	-29,040	-85,066

This cut/fill volume has been based on the following assumptions:

- No bulking factors have been applied;
- The cut/fill balance is pending in-fill survey requirements (note this will only have a minor impact);
- Cut to fill quantities are from existing surface to top of finished surface. Boxing for structural slab is assumed to be 0.2m. No allowance for, services, stormwater or topsoil removal has been made.
- The cut/fill balance does not include bulk earthworks for the AFC frontage

There are a number of different materials that may be required, these are summarised below in Table 4.

Table 4: Materials

Material Type	Source
Topsoil	Reused from Site
Engineered Fill	Reused from Site
Select Material (SMZ)	Imported
Dense Graded Base (DGB 20)	Imported

Concrete	Imported
Sand	Imported
Turf	Imported
Ballast Gravel Mulch	Imported

5.0 Stormwater Management

The following sections present the stormwater management strategy for the Cranbrook School development. This report sets out the assumptions and key stormwater and flooding considerations to be developed into the detailed design. The general goals of the stormwater management strategy are as follows:

- To ensure new development can be safely drained in large storm events – providing a subsurface drainage system to 20yr ARI and formalised overland flow system up to the 100yr ARI event (where possible); and
- To ensure new development has no adverse flooding/drainage impacts on:
  - Adjacent properties; and
  - Existing downstream Council drainage system

5.1 Previous Technical Investigations

5.1.1 Rose Bay Catchment Flood Study (September 2010)

The Rose Bay Catchment Flood Study was initiated as a result of flooding of roads and residential areas most recently in January 1991. WMAwater developed a Catchment Flood Study in 2010 to provide a firm basis for the development of targeted stormwater management strategies.

Specifically, the study helped to define flood behaviour within the Rose Bay Catchment, providing flood extents and hazard mapping for events up to the Probably Maximum Flood (PMF) and to assist in developing the subsequent Floodplain Risk Management Study and Plan. Additional analyses were undertaken to assess the impact of varying model parameters.

The main outcomes of this study were;

- A full documentation of the methodology and results;
- Preparation of flood contour, hazard and extent maps for the Rose Bay Catchment within Woollahra LGA; and
- A modelling platform that will form the basis for subsequent Floodplain Risk Management Study Plan.

A recommendation raised in the study highlighted the importance of collecting and maintaining a database of historic rainfall and flood height data.

5.1.2 Rose Bay Floodplain Risk Management Study and Plan (January 2014)

Subsequent to the 2010 Catchment Flood Study, the Rose Bay Floodplain Risk Management Study and Plan was developed by WMAwater to investigate methods for the local community to best manage its flood risk and flood prone land. This study aimed to:

- Review the results from the Flood Study;
- Identify development and planning controls to regulate redevelopment in the flood prone area;
- Make recommendations to adopt Flood Planning Levels (FPL) appropriate for the catchment; and
- Investigate available floodplain risk management measures along with prioritisation, staging of works and preliminary costings.

DRAINS hydrologic and hydraulic computer models simulating pipe and overland flow through private property within the Woollahra LGA were developed. The models were run for a number of design events and areas with drainage problems that have the potential to flood were isolated. This report noted that the areas that were likely to experience large overland flows during heavy rainfall events within the vicinity of Cranbrook School. The peak depths and extent of flooding in the 100 year ARI and PMF storm events are shown below in Figure 3 and Figure 4.

For the 100 year ARI and PMF events, the figures produced for this study indicates that Cranbrook School and its surrounding roads area outside of the flood zones, or experience flood depths that are less than 0.2m.

Figure 3 100 year ARI Flood Extents (source: Rose Bay Catchment Flood Study – Woollahra Municipal Council)

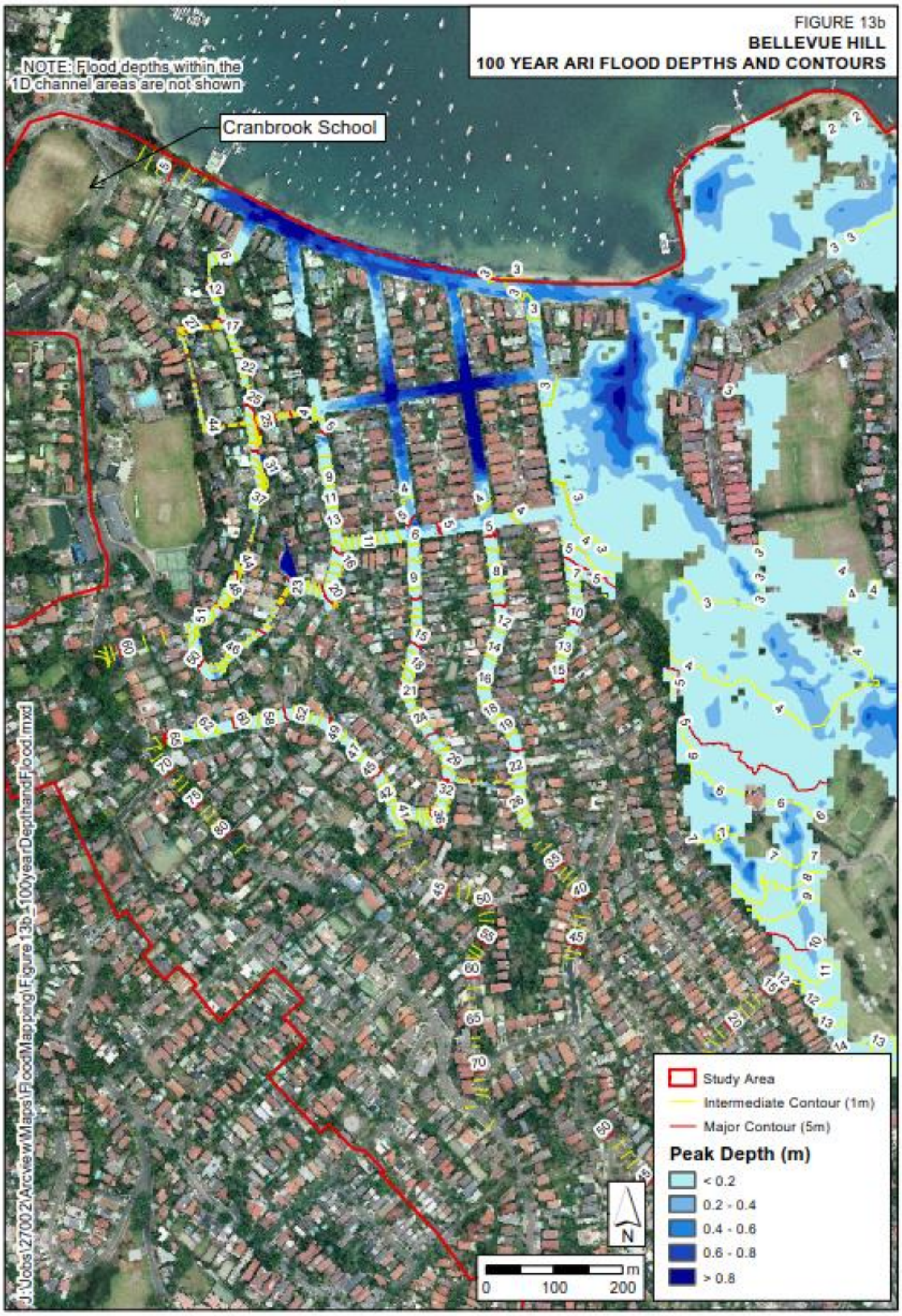
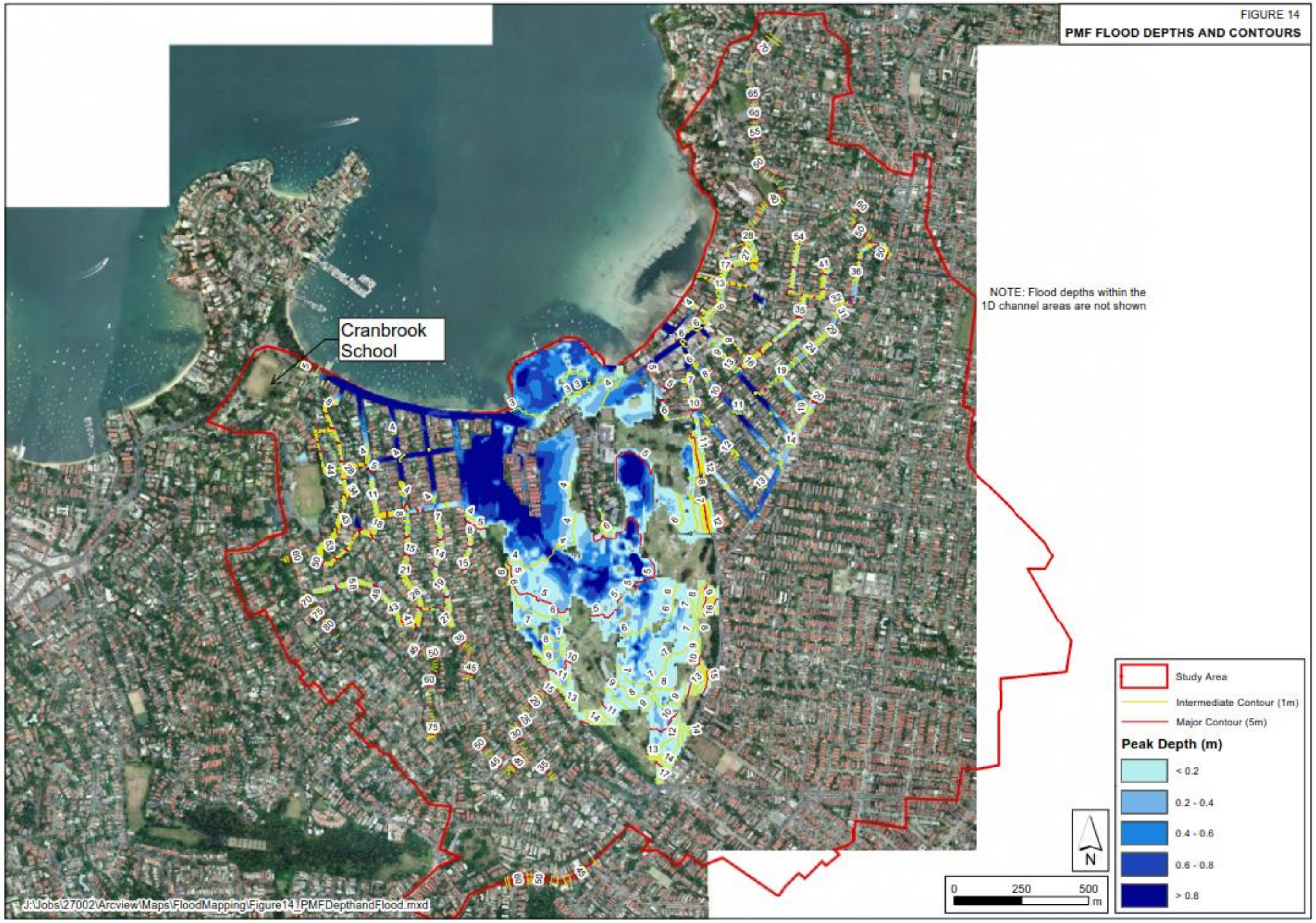


Figure 4 PMF Flood Depths (Source: Rose Bay Catchment Flood Study – Woollahra Municipal Council)



5.1.3 Report on Geotechnical Investigation, Cranbrook School (February 2016)

A report on geotechnical investigation was compiled in 2016 by Douglas Partners to assess the options for Stage 1 of the proposed redevelopment site and to provide detailed information on the subsurface conditions of the site. Previous geotechnical studies include the extraction of borehole samples near the south western boundary of the site and a risk assessment of the Horden Embankment. The works conducted for this report involved six cone penetration tests, the drilling of three cored boreholes and the drilling of four augered boreholes. The cored boreholes drilled on site encountered:

- Filling – Concrete, silty sand topsoil and sand filling (2.0m-4.9m)
- Natural soils – Medium dense to dense sand/silty sand (10.9m – 19.8m)
- Bedrock – Sandstone typically low and medium strength (14.3m – 22.2m)

Groundwater is likely to flow through the sandy soils until it hits bedrock which then directs the flow towards the north-east to Rose Bay.

5.2 Pre-development Conditions

5.2.1 Flooding Context

The current site conditions and topology show that the broader Rose Bay catchment drains towards a low point along New South Head Road bordering the northern side of Cranbrook School site. The Council adopted flood study for the site (prepared by WMAwater dated 2010) shows the site lying outside of the 100yr ARI and PMF flood extents, as well as any ‘flood risk precincts’.

While the development site is outside of the flood risk precincts, it is noted that New South Head Road immediately to the north acts as a major overland flow route for the broader catchment. As such, part of the stormwater management approach adopted includes ensuring this overland flow path is not impacted by the development, and the new development has been adequately designed to ensure elimination or adequate mitigation of the risks associated with the known overland flow path.

5.2.2 Existing Sub-Catchments

The Cranbrook School site itself consists of four main sub-catchments, differentiated by their existing points of discharge across surrounding roads. The sub-catchments have been delineated through review of survey contours, existing drainage plans provided by council and through analysis of GIS and LIDAR data. The site comprises the following main sub-catchments:

1. *South-western sub-catchment* draining to New South Head Road along existing Council stormwater drainage pipes within an easement through the site;
2. *Western sub-catchment* draining to New South Head Road along existing stormwater drainage system to the west of the site;
3. *Eastern sub-catchment* draining towards Rose Bay Avenue to the east of the site along an existing pipe and pipe system; and
4. *Northern sub-catchment* draining to New South Head Road to the north of the site. It is noted that discharge of the catchment is likely to be at several locations due to the flat geometry and lack of formalised drainage structures.

The overall internal sub-catchments as outlined above are presented in Figure 5. It is noted that sub-catchments 2,3 and 4 discharge to Rose Bay Avenue or New South Head Road and ultimately outlet to Rose Bay, while sub-catchment 1 discharges through St Mervyns Avenue and outlets to Double Bay.

Figure 5 Site sub-catchment layout

5.2.3 Pre-development Stormwater Management Approach

A review of site infrastructure audit reports, topographical survey information, Dial-Before-You-Dig information and data collected during visual site inspections has been undertaken to determine the existing on-site stormwater management system. This has been assessed to consist of multiple pit and pipe drainage network and informal overland flow paths.

The south-western sub-catchment (1) is drained by a Council drainage line within an easement running through the southern portion of the site, traversing from Victoria Road to St Mervyns Avenue.

The western sub-catchment (2) is collected by an existing pit and pipe system discharging to the existing Council drainage pit in New South Head Road.

The eastern sub-catchment (3) is partially collected by an existing pit and pipe system within the existing main driveway, ultimately discharging to Rose Bay Avenue as overland flow via a pipe connected directly to the existing Council kerb and gutter.

The northern sub-catchment (4) collects within the existing sporting oval which is likely to pond to a nominal level before spilling at multiple locations to New South Head road and the northern segment of Rose Bay Avenue. For the purposed of modelling of this sub-catchment, three main spill points have been assumed as follows:

- 4(a) – western spill point – at the existing driveway, behind existing ‘Justin McDonald Stand’
- 4(b) – northern spill point – near the existing north-western stairway.
- 4(c) – eastern spill point at rose bay avenue – collects at existing grated pit adjacent the existing maintenance sheds

This layout is presented schematically in Figure 6.

Figure 6 Pre-development stormwater conditions

5.2.4 Pre-development Hydrologic and Hydraulic Performance

The pre-development hydrological and hydraulic performance has been assessed using the DRAINS software. The DRAINS model has been used to assess the existing stormwater flows for the 20 and 100 year ARI design storm events. This has been used to form the baseline conditions against which the proposed development will be assessed.

Estimated flow rates at key discharge points on the site are presented in Table 5 for the relevant catchments displayed in Figure 5. These have been selected to provide baseline conditions against which the proposed development will be assessed.

Table 5 Pre-development Peak Site Discharge

ARI	Catchment	Piped Flow (l/s)	Overland Flow (l/s)	Total (l/s)
20 year	1	200	579	779
	2	202	323	525
	3	-	203	203
	4(a)	-	333	333
	4(b)	-	328	328
	4(c)	14	472	486
	Combined	**416**	**2238**	**2654**
100 year	1	200	706	906
	2	203	415	618
	3	-	242	242
	4(a)	-	339	339
	4(b)	-	336	336
	4(c)	14	480	494
	Combined	**417**	**2518**	**2935**

5.3 Proposed Stormwater Management

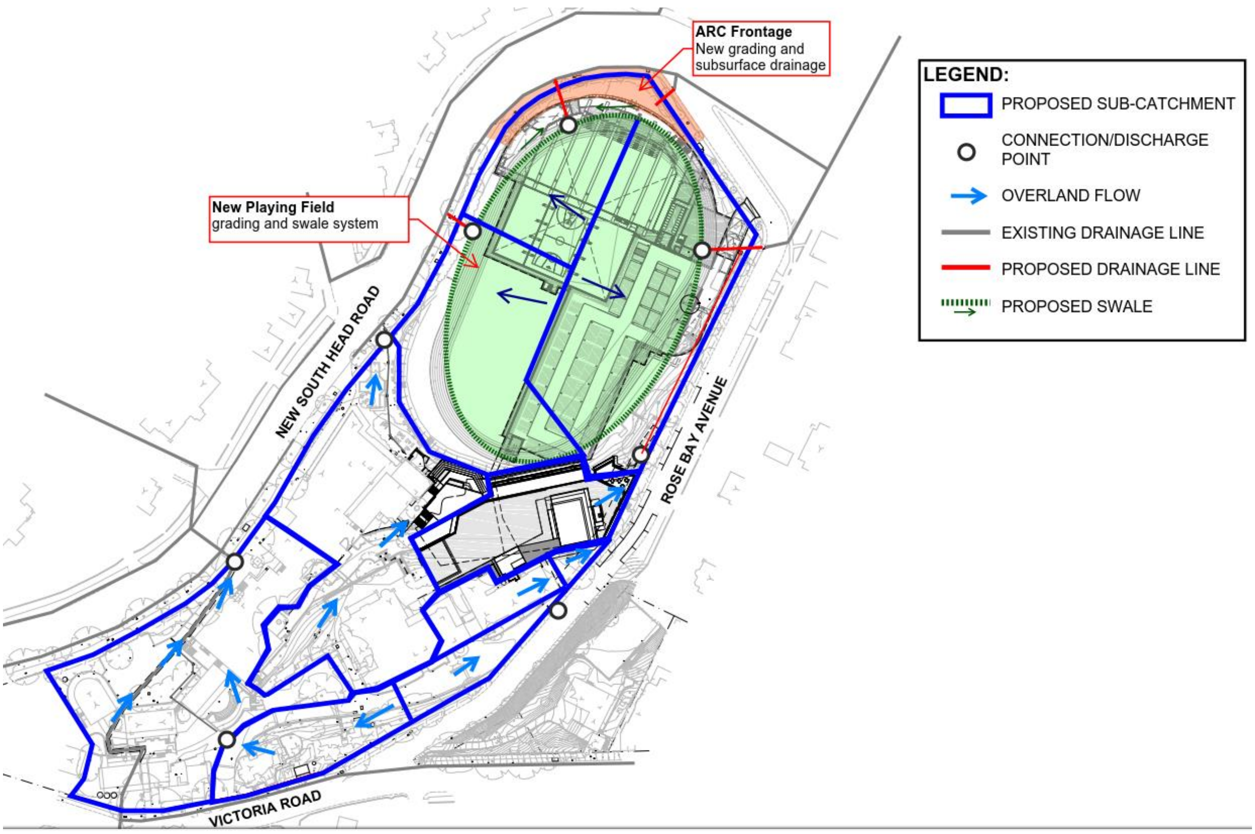
5.3.1 Proposed Stormwater Management Approach

The main design considerations have formed the basis for the Cranbrook School Development stormwater management approach:

- Provision of a pit and pipe drainage network with capacity to convey the 20 year ARI (minor) design storm event;
- Provision of overland flow routes to safely convey runoff from the 100 year ARI (major) design storm event. Overland flow paths under the proposed development conditions have also been analysed up to the PMF event in order to ensure that sufficient input has been provided into Cranbrook's Emergency Response Plan (ERP) (refer section 6.0 for details);
- Where the above requirements are not feasible due to downstream conditions, the stormwater system is designed to allow the maximum flow, ensuring no adverse impacts to adjacent properties and downstream conditions, whilst allowing a safe conveyance of stormwater from the developed site to the existing Council system
- Management of water quality through the incorporation of Water Sensitive Urban Design (WSUD) techniques; and
- Management of water quantity to ensure no increase in peak stormwater discharge from the site for the 20- and 100-year ARI storms.

Figure 7 presents a schematic of the proposed stormwater management strategy detailed in the following sections.

Figure 7 Proposed stormwater management approach



5.3.2 On-Site Detention

While the development site lies outside of the OSD exclusion zone for Woollahra Council, consultation with Council has indicated that an alternative OSD strategy may be adopted for the purposes of this development. Council is in principle supportive of removing the requirement for a formalised OSD tank, provided a sufficient green roof area and retention tank or irrigation tank volume is provided.

5.3.3 Proposed Infrastructure

New stormwater infrastructure is proposed for the development comprising:

- New grassed swale and surcharge pits within connections to existing Council drainage infrastructure to collect stormwater flows from playing field run-off (where discharge is in excess of the proposed playing field subsurface drainage system); and
- New on site drainage and adjustment of existing on-site stormwater infrastructure to direct to new network.

Details of the proposed stormwater infrastructure as required by the stormwater management approach are provided in the following sections.

5.3.3.1 Building Connections

2 no. connection pits have been provided for potential connection to building downpipes. Discharge allowances for each connections point are provided in Table 6.

Table 6 Summary of proposed building connections and assumed peak discharge rates

No.	Building connection	Pit reference	Peak discharge flow rate	
			Minor (m^3/s)	Major (m^3/s)
1	Perkins Building (existing drainage to be intercepted)	4\01	**0.049**	**0.055**
2	Centenary Building (proposed)	3\01	**0.189**	**0.214**

5.3.3.2 Aquatic and Fitness Centre Frontage Drainage

Significant level changes are proposed at the AFC frontage to allow access to the new foyer floor level. Levels are proposed to fall away from the new building entrance to a low point as shown in Figure 9. A grated drain has been provided falling to the low point with a sag pit and pipe discharging to the existing Council drainage pit in Rose Bay Avenue. In addition, multiple outlets are proposed at a higher level to connect at the Council kerb and gutter in Rose Bay Avenue to provide an emergency overflow route in the case of blockage, or in storm events beyond the existing pipe capacity. The level of the overflow outlets is proposed to be set at a level such that the overflow will to spill to Rose Bay Avenue prior to spilling to the new AFC.

Figure 8 AFC Frontage Stormwater Management Approach

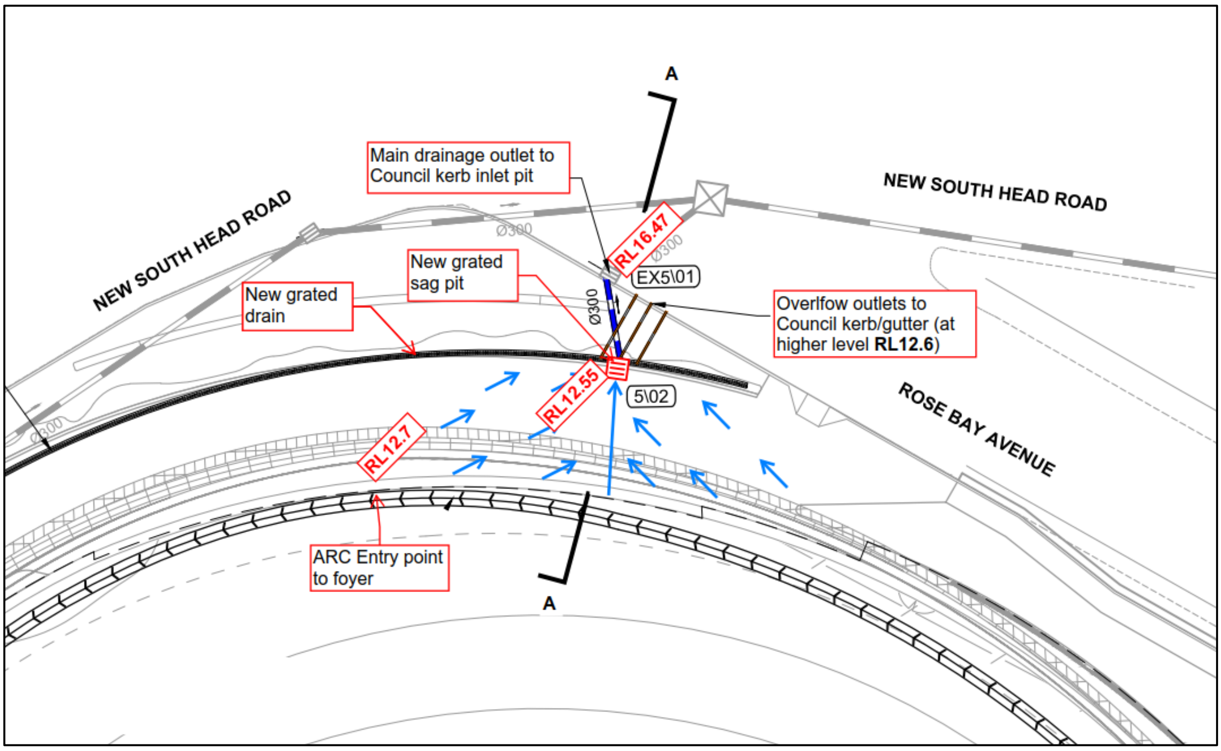
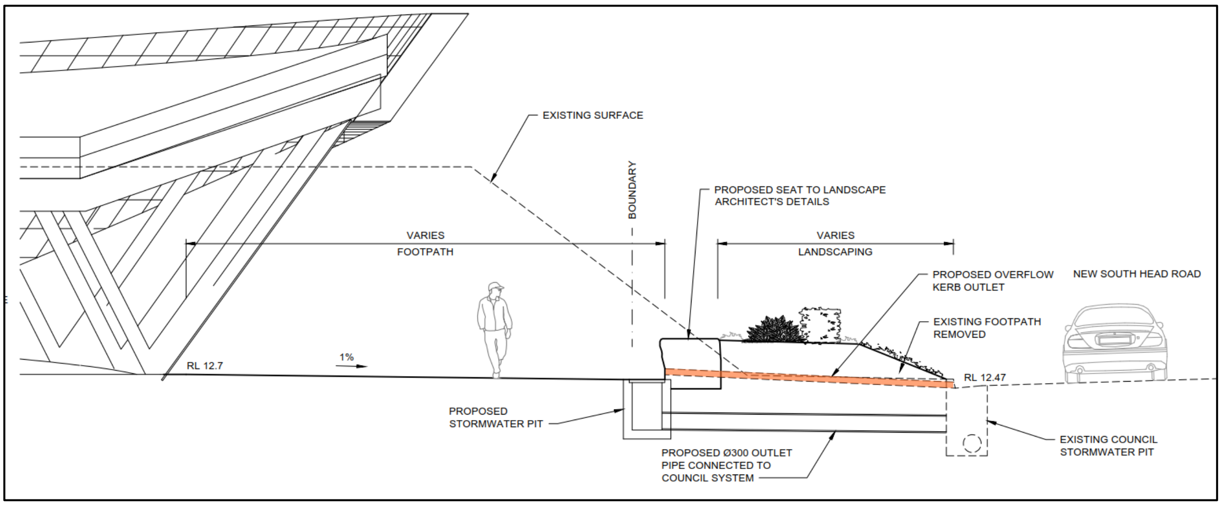


Figure 9 Typical section through AFC frontage to New South Head Road (section A-A)



5.3.3.3 Playing Field Drainage

At this stage it has been assumed that the playing field will incorporate a specialist drainage design with either a network of subsoil pipes or drainage cells. It is assumed that this system will not be adequately sized for the design storm event. As such, an overland flow and swale system has been proposed to direct to any overland flow beyond the capacity of the subsoil system to the Council drainage system.

The playing field is proposed to outlet to the Council stormwater system at three points. These generally correspond to existing oval discharge points described in section 5.2.3 (currently overflowing from playing field as uncontrolled overland flow) and are as follows:

- New South Head Road west
- New South Head Road north

- Rose Bay Avenue

The general stormwater approach for the playing field comprises:

- Provision of a main high point near the centre of playing field
- Provision for field grading at 1% outwards toward proposed field perimeter
- Provision for a grassed swale to convey playing field surface runoff to the discharge points as outlined above
- Provision of sag pits allowing nominal ponding to allow some attenuation of the flow generated from the oval runoff.

At each discharge point, a grated sag pit is proposed to collect main playing field surface runoff. Sag pits are assumed to allow 0.2m ponding, corresponding to approximately 10m^3 of storage volume. This volume is considered achievable at each of the discharge locations within the available space at the playing field boundary, assuming the ponding extent is limited to outside the playing field area or contained wholly within the proposed swale.

The provision of sag pits and grassed swale presents an opportunity to attenuate flows generated by the before discharging to the Council system. This reduction has been quantified as part of DRAINS modelling and presented in section 5.3.4.1.

It is understood that detailed playing field grading and subsurface drainage is to be prepared under separate documentation; however the above assumptions have been used to define the broader stormwater strategy for the site.

Refer to Figure 10 for details of the proposed playing field drainage strategy.

Figure 10 Playing Field Stormwater Management Approach

5.3.4 DRAINS Modelling

Hydraulic modelling using the DRAINS software has been undertaken to support the stormwater management approach detailed in the sections above. A model has been developed for the existing and proposed conditions and used identify peak discharge rates pre-development and post-development.

The peak discharge is compared for each of the catchment discharge points described in section 5.2.2, compared with the corresponding discharge under developed conditions for both the 20- and 100yr ARI storm events. The results are presented in section 5.3.4.1 below.

Results of the DRAINS modelling are also presented schematically in the figures below:

Figure 11 Pre-Development 20 year ARI

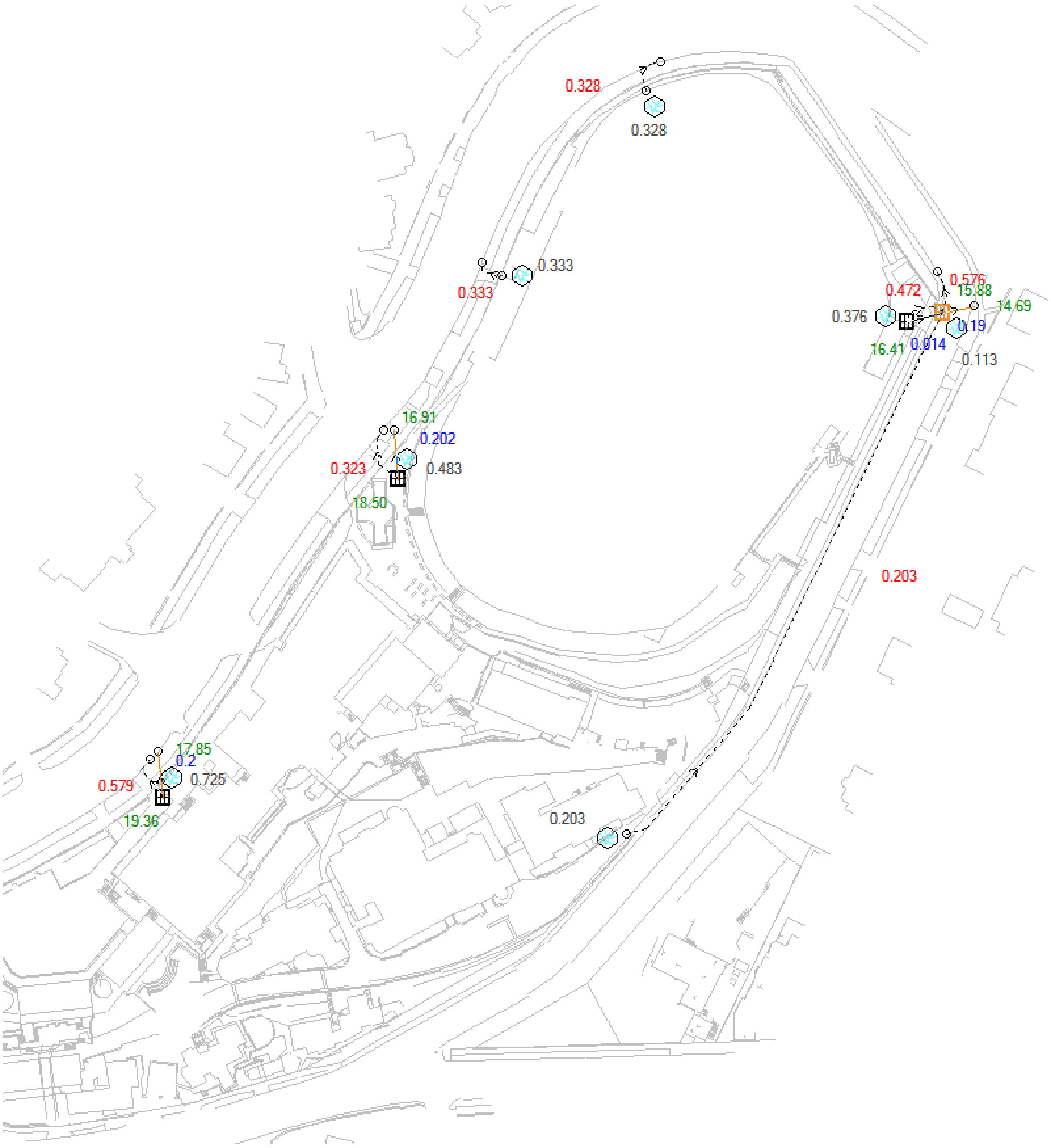


Figure 12 Pre-Development 100 year ARI

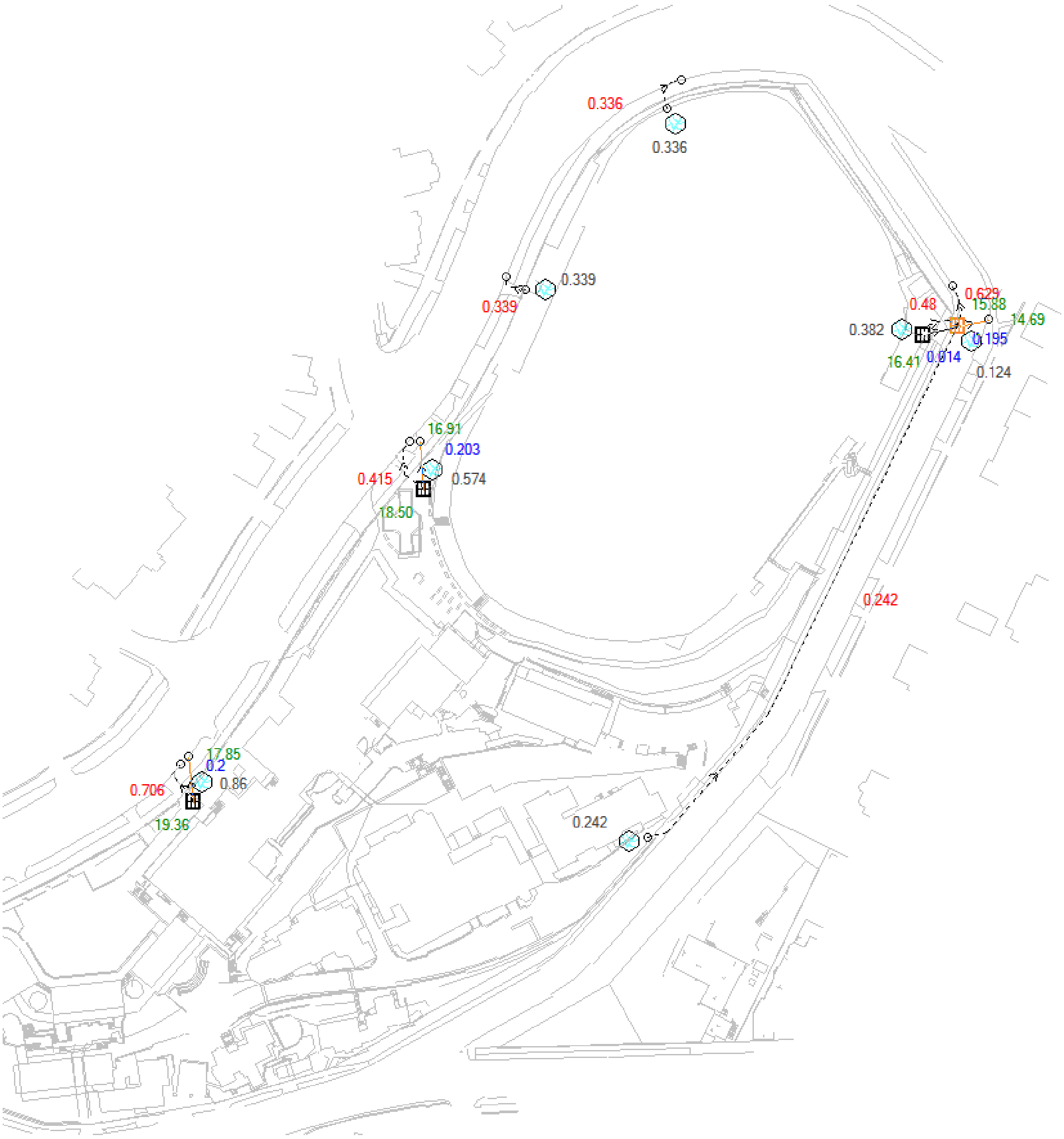


Figure 13 Post-Development 20 year ARI

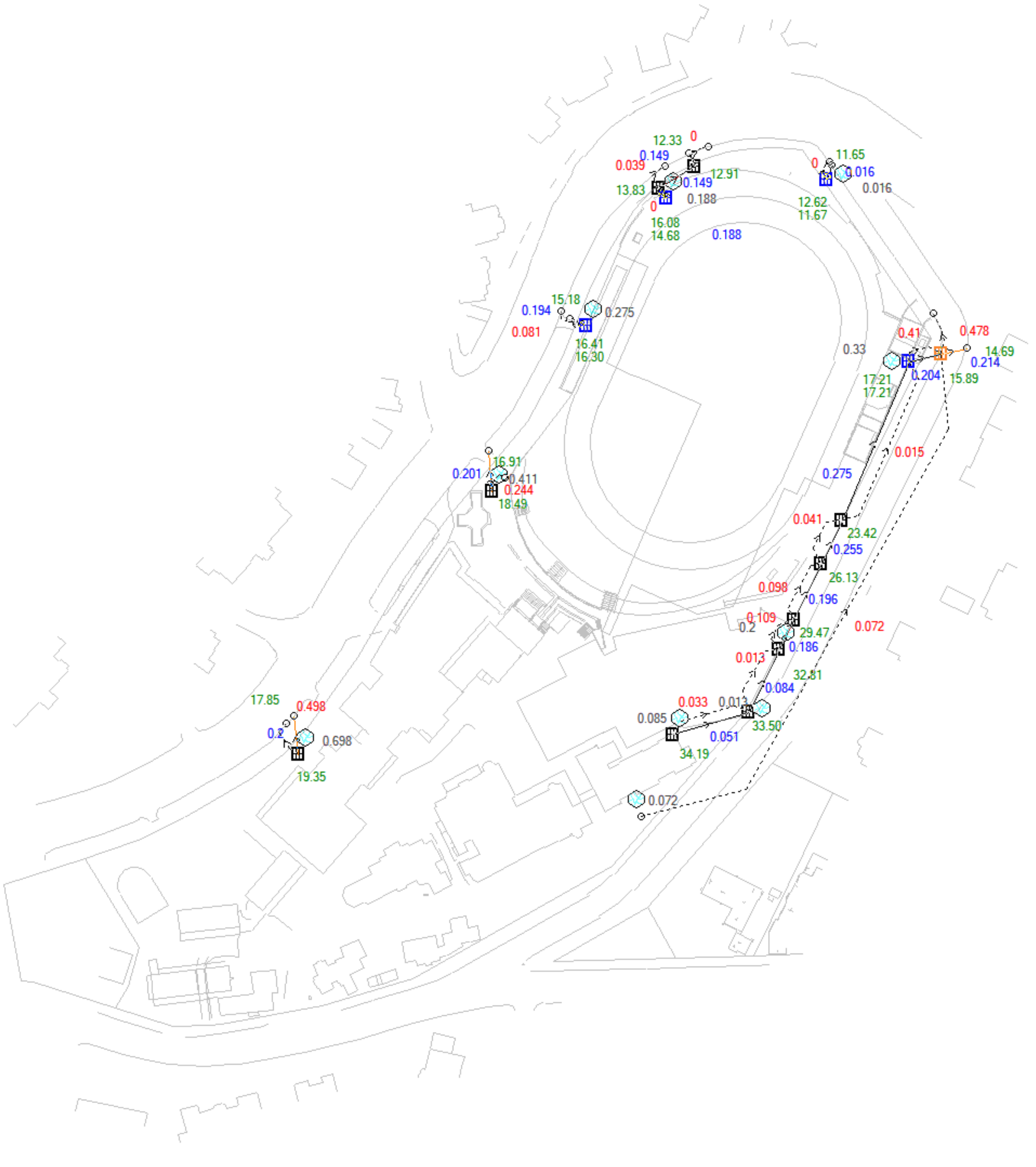


Figure 14 Post-Development 100 year ARI

5.3.4.1 Post-Development Stormwater Performance

The DRAINS results for site discharge under post-development conditions are presented in Table 7 below. The total peak discharge from site is reduced by 12% in the minor storm and 6% in the major storm event. By providing new pipe drainage within the site and connections to Council subsurface system, the total overland flow has been dramatically reduced from baseline conditions.

Table 7 Post-development Peak Site Discharge and Comparison to Baseline Results

ARI	Catchment	Piped Flow (l/s)	Overland Flow (l/s)	Total (l/s)	Reduction from baseline	Overland flow reduction from baseline	Comments
20 year	1	200	530	730	6%	8%	
	2	201	244	445	15%	24%	Portion of catchment redistributed to (3)
	3	0	72	72	65%	65%	Portion of pre-development catchment redistributed to (4c) – via proposed drainage line 2
	4(a)	194	81	275	17%	76%	
	4(b)	149	39	188	43%	88%	
	4(c)	208	409	617	-27%	13%	Increase in total flow due to catchments redistributed from (3). Reduction in overland flow achieved.
	Combined	**952**	**1375**	**2327**	**12%**	**39%**	
100 year	1	200	669	869	4%	5%	
	2	201	336	537	13%	19%	Portion of catchment redistributed to (3)
	3	0	83	83	66%	66%	Portion of pre-development catchment redistributed to (4c) – via proposed drainage line 2
	4(a)	194	123	317	6%	64%	
	4(b)	149	59	208	38%	82%	
	4(c)	204	547	751	-52%	-14%	Increase in total flow due to catchments redistributed from (3). Reduction in overland flow achieved.
	Combined	**948**	**1817**	**2765**	**6%**	**28%**	

5.3.5 Proposed Stormwater Quality Control

The stormwater quality management approach will involve incorporation of Water Sensitive Urban Design (WSUD) techniques in the proposed stormwater drainage system.

The WSUD measures described below ensure water quality targets are met, considering stormwater runoff from roads, parks, vegetated areas and the remaining site.

5.3.5.1 WSUD Implementation

WSUD measures including Gross Pollutant Traps, Grassed Swales, Passive Irrigation and Rainwater Harvesting have been considered for the development. General layouts have been adopted for the current design, and further details including subsoil drainage and exact infrastructure layouts will be further developed in detailed design.

Passive irrigation

The drainage design for the site ensures that the majority of site runoff on to will be directed into vegetated areas or green roofs prior to discharging to outlet locations. These areas will provide passive irrigation to stormwater before being collected by inlet pits throughout the site, or running off to. Given the extent of landscaped areas, it is expected that passive irrigation will provide the majority of treatment to stormwater flows for the site.

If run-off exceeds the infiltration or temporary storage capacity of the planted areas, run-off will be directed as overflow toward the existing on-site pit and pipe network. Run-off exceeding the on-site stormwater network capacity will discharge to Hordern Oval ultimately being directed to the outlet point at New South Head Road.

Grassed Swales

Grassed swales are proposed along the perimeter of the Horden Oval to control runoff from the oval, towards the main outlets. The intent of these grassed swales is to provide a formalised overland flow path, where runoff exceeds the playing field infiltration rate. The swales also provide a location for water to pond away from the playing field, providing an opportunity for water quality control.

Rainwater Harvesting

A number of existing rainwater and retention tanks are located within the Cranbrook School development site. These are used to supply rainwater for irrigation of Hordern Oval and surrounding lawns and landscaped areas.

The total proposed rainwater harvesting volume is currently under design development and will be incorporated into the water quality model as part of detailed design.

Gross Pollutant Trap

It is likely that a minor catchment will likely bypass the above treatment measures which will inevitably have an impact on the overall WSUD performance of the development. This is anticipated from the new ‘Drop-off road’ into Rose Bay Avenue and may be unavoidable due to existing site and road grading.

As a final water treatment measure, a gross pollutant trap (GPT) may be required to meet the WSUD treatment requirements. Provision of a GPT will be investigated as part of detailed design if warranted by the resulting treatment performance of the above measures.

5.4 Overland Flow Study

The DRAINS model for Bellevue Hill and Rose Bay (provided by Council on 20th July 2017) indicates that there is an existing major overland flow route along New South Head Road and Rose Bay Avenue which conveys overland flow from a significant upstream catchment. To assess the impact of this overland flow routes on the proposed development, a post-development DRAINS model using the PMF storm event was produced as shown in Figure 15, highlighting peak flows and flood depths. These results indicate that overland flow along New South Head Road will largely remain within the channel formed by the roadway kerb to kerb, to the west of the site. However, towards the north, the DRAINS model suggests that overland flow will likely overtop the kerb and convey flow across the adjacent footpath at a level that is deemed unsafe (VxD > 0.4 m^2/s). This may produce a minor flow path entering the frontage area outside of the aquatic and fitness centre.

Similarly, the overland flow path along Rose Bay Avenue may experience unsafe flows with potential overtopping of kerbs during the PMF event as shown in Figure 16 and may create a hazardous area towards the north eastern side of the site. Approximate maximum flood depths have also been included in Figure 17 but may be subject to change as design progresses. The levels of the proposed new driveway should take into account modelled PMF flood depths.

This study has been used to develop particular areas of hazard which are proposed to form part of the Cranbrook Emergency Response Plan. It is noted that these areas of hazard are limited to the north of the site and are highlighted in the flood exclusion zone in Figure 18.

The proposed raised landscaping along the frontage will offer some flood protection to prevent overland flow entering the AFC frontage footway and underground aquatic and fitness centre, however it should be ensured that sufficient levels are considered to avoid overtopping of the frontage protection. It is further noted that the levels and grading design have considered ensuring the natural overflow point occurs toward the street and not backing toward the building as described in section 5.3.3.2. This is proposed to be developed further as part of detailed design

Figure 15 DRAINS - PMF event results

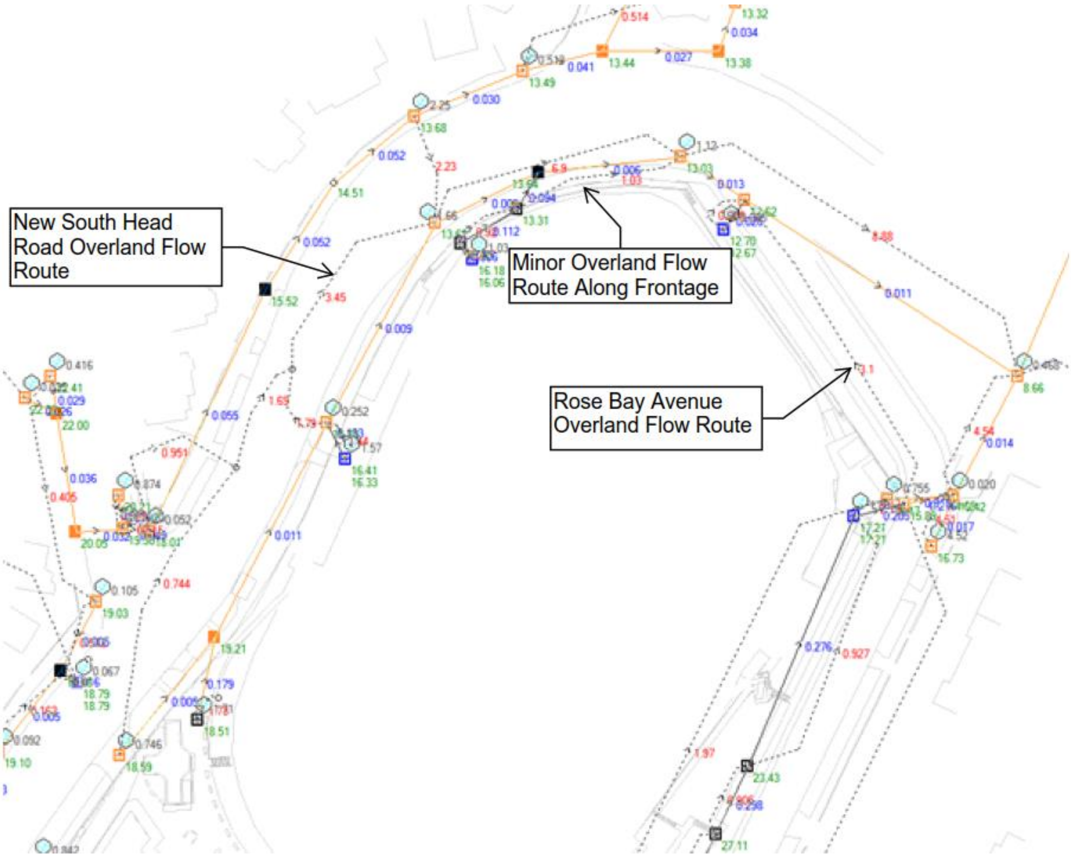


Figure 16 PMF - Overland flow routes

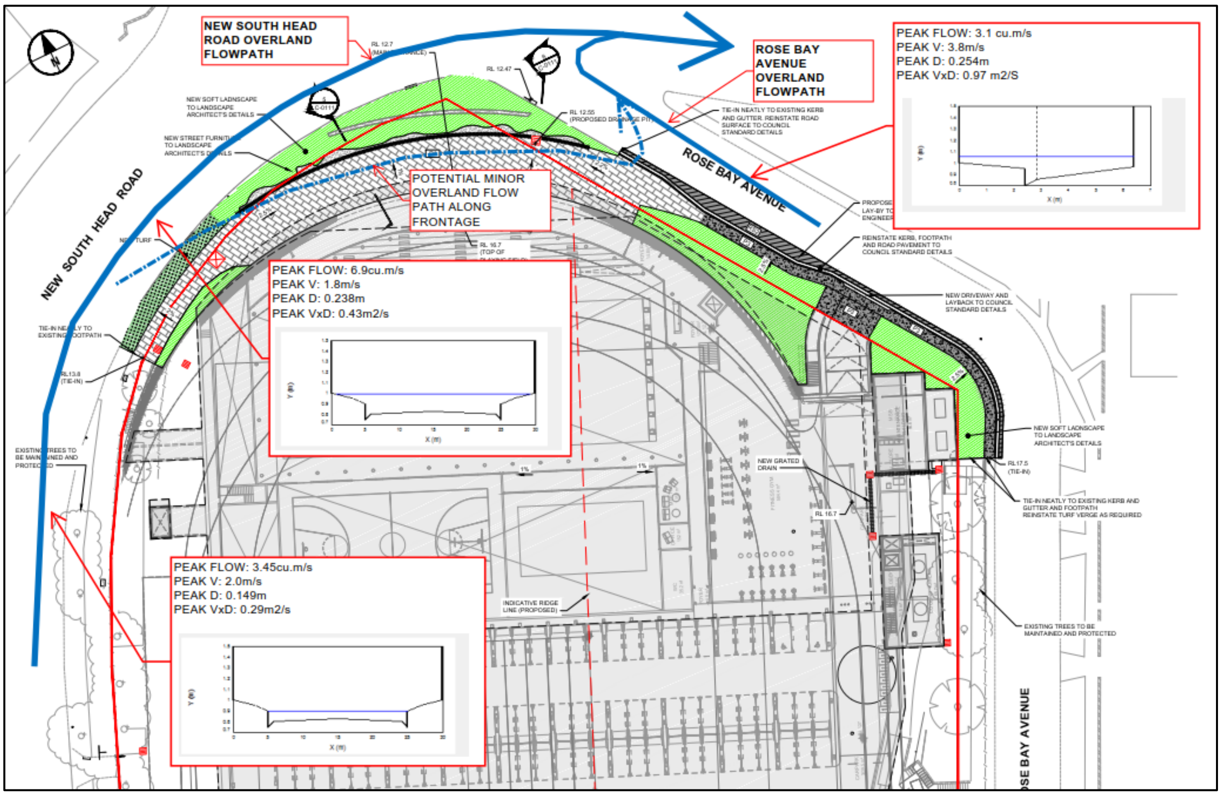


Figure 17 PMF - Max Flood Depths

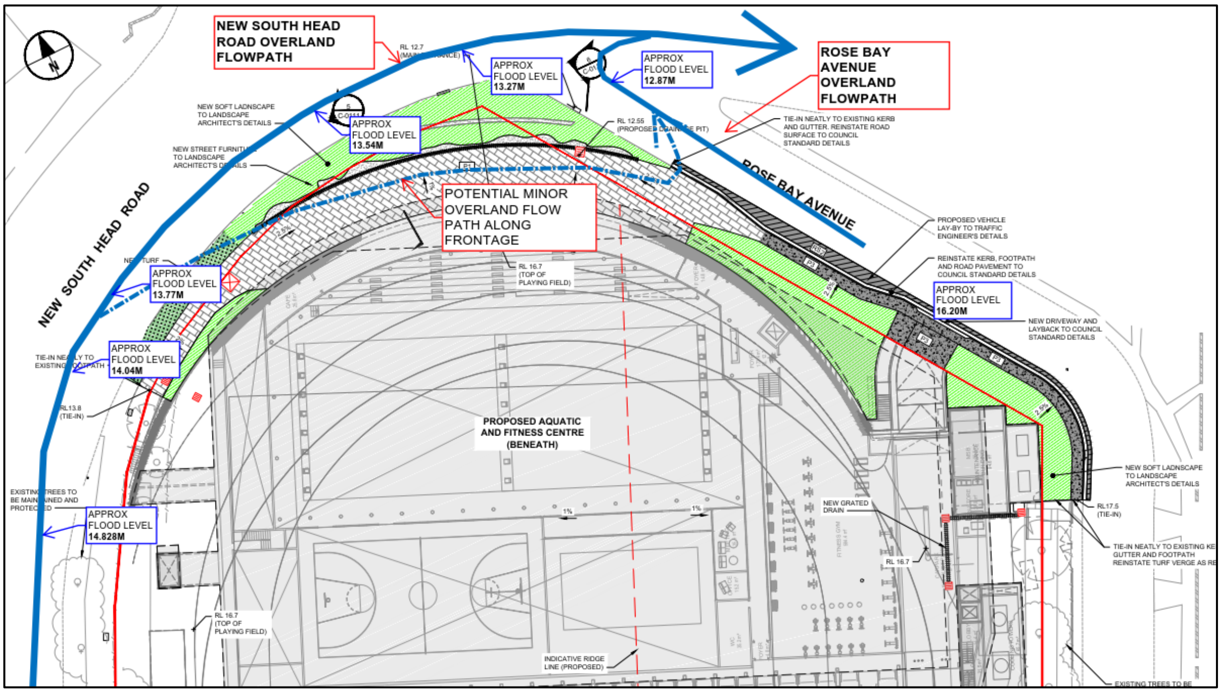
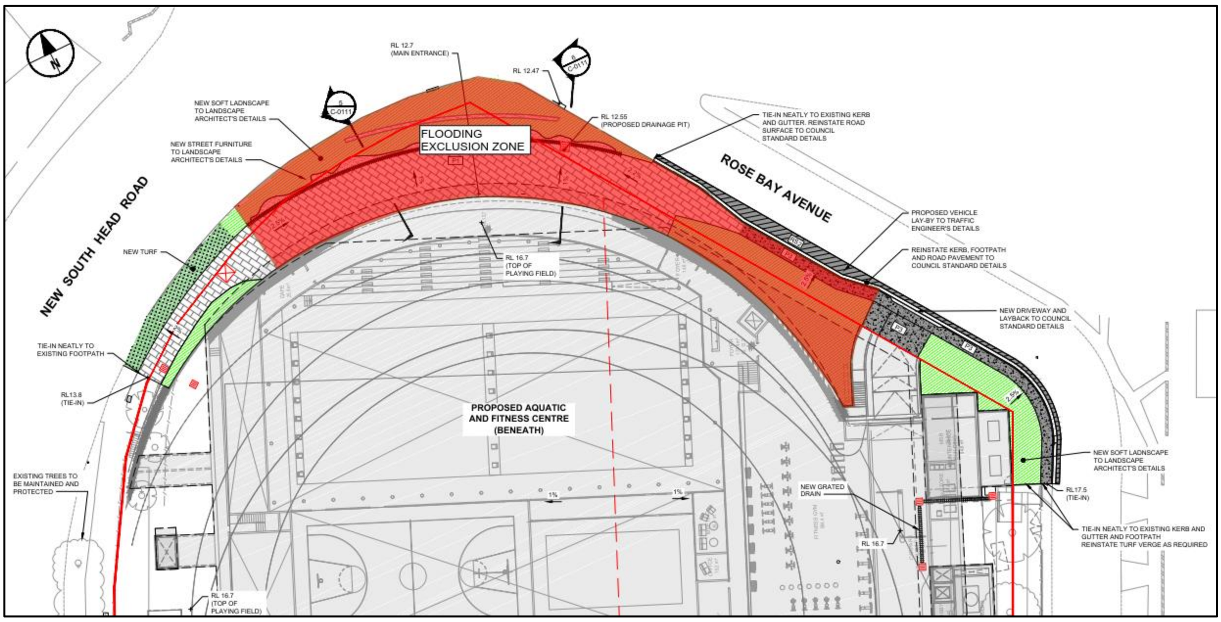


Figure 18 Flooding Exclusion Zone



6.0 Emergency Response Plan

6.1 Emergency Response Plan

Potential emergency response measures have been identified to assist in reducing the consequences of flood risks at Cranbrook School. The purpose of these measures are to ensure the safety of students, teachers, parents, carers and other members of the school as well as members of the broader community whom utilise the school's facilities.

A DRAINS model accounting for the PMF event as shown in Figure 15 has been produced for the site to inform this Emergency Response Plan on a worst case scenario basis. The flood depths and velocities generated from PMF storms were assessed against post development levels to determine a suitable strategy, with the following key measures recommended for incorporation into the existing Cranbrook School "Senior School Evacuation Plan dated January 2018":

- The BoM should be monitored for warnings related to severe storms and flash flooding conditions. Staff should be notified if relevant warnings are issued.
- During a storm event with the potential to cause flooding, all persons should remain indoors within the school buildings, all persons that are south of Hordern Oval should remain in place or use an inside assembly point that is not the oval.
- Significant overland flows along New South Head Road and Rose Bay Avenue (as identified in Section 5.4 above) adjacent to the frontage area may create hazardous conditions making evacuation through these areas unsafe. Areas that are potentially subject to unsafe flooding are shown in Figure 18. If it is safe to do so, Marshals or Area Wardens should confirm that all persons have left these areas during a storm event. People should not be directed to evacuate through these areas any time there is a flood or sever storm warning. Proper signage should be put in place to exclude people from hazardous areas during flooding.
- If required due to a complex emergency, or to account for students not in class, an alternative emergency assembly area is recommended for use during flood events.

- For persons inside the proposed Aquatic and Fitness Centre north of the site, they should remain in place until flooding has subsided.
- Communication to Marshals or Area Wardens over the Public Address system or by mobile phone device to be made to ensure all persons within their immediate area are safe and accounted for.
- Isolated ponding areas may remain towards the north of the site which may contribute to more widespread traffic issues. Parents are advised not to pick up their children until flooding offsite subsides.

The expected duration of flooding is expected to be relatively short, with flooding along New South Head Road responding quickly to local rainfall. As a consequence, flood levels will recede relatively quickly (approximately 45mins following storm commencement) which will allow evacuation of occupants from the Aquatic and Fitness Centre if required.

It should be noted that any changes to the detailed design of the site may necessitate formulation of alternative emergency response frameworks in which additional studies will be required. The above recommendations should be considered in the context of the schools existing emergency response protocols, and the decision to include (or otherwise) specific measures remains with the school.

7.0 Conclusion

This report presents the proposed stormwater management approach for the Cranbrook School development site. The proposed management approach will ensure that the development complies with both the State Significant Development requirements, as well as addresses Woollahra Council requirements. **Table 8** provides a summary of how these requirements have been addressed.

Table 8 Response to SEARs requirements

Item	Description	Action	Response
24	Sediment, Erosion and Dust Controls	Civil Engineer to provide drawings and specifications to detail these requirements	• Erosion sediment control plans have been included as part of the Cranbrook School Redevelopment Civil & Stormwater Package.
28	Drainage	As per item 23; AECOM to contact Sydney Water, review local planning requirements, and provide Report & Stormwater Concept Plan	• AECOM have consulted with Woollahra Council which owns drainage assets adjacent to the project site. A DRAINS model has been prepared to assess pre-development and post-development conditions. Preliminary results have been reviewed in Section 5 of this report. • Relevant local planning requirements have been considered by AECOM and are outlined in Section 3 of this report.

Appendix A

Woollahra Council Correspondence

Hammond, William

From: Michael Casteleyn <Michael.Casteleyn@woollahra.nsw.gov.au>
Sent: Wednesday, 7 February 2018 10:08 AM
To: Hammond, William
Subject: RE: Cranbrook School Development - Stormwater Goals and Strategy

Will
I have do objections to the strategy.
Just provide a design report detailing the proposed systems performance/ benefits.
regards

From: Hammond, William [mailto:William.Hammond@aecom.com]
Sent: Tuesday, 6 February 2018 11:18 AM
To: Michael Casteleyn <Michael.Casteleyn@woollahra.nsw.gov.au>; Robert Lam <Robert.Lam@woollahra.nsw.gov.au>; Chris Munro <Chris.Munro@woollahra.nsw.gov.au>; Paul Fraser <Paul.Fraser@woollahra.nsw.gov.au>; Aurelio Lindaya <Aurelio.Lindaya@woollahra.nsw.gov.au>
Subject: RE: Cranbrook School Development - Stormwater Goals and Strategy

Michael/All,

Just following up on the emails below. Were there any objections to the OSD strategy as proposed below? We would like to avoid any issues down the line, so any comments would be appreciated.

Regards,
Will Hammond
Civil Engineer
D +61 2 8934 0925
William.Hammond@aecom.com

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From: Michael Casteleyn [mailto:Michael.Casteleyn@woollahra.nsw.gov.au]
Sent: Wednesday, 20 September 2017 8:00 PM
To: Robert Lam; Chris Munro; Paul Fraser; Aurelio Lindaya
Cc: Fettell, Daniel; Hammond, William
Subject: RE: Cranbrook School Development - Stormwater Goals and Strategy

Michael Casteleyn

Investigations Engineer – Stormwater and Environment
Woollahra Municipal Council
536 New South Head Road, Double Bay NSW 2028
P 02 9391 7131
W www.woollahra.nsw.gov.au
E Michael.casteleyn@woollahra.nsw.gov.au
Our values: Respect for people | Integrity and Excellent Performance | Professional Quality Service | Open Accountable Communication

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From: Hammond, William [mailto:William.Hammond@aecom.com]
Sent: Wednesday, 20 September 2017 4:42 PM
To: Michael Casteleyn <Michael.Casteleyn@woollahra.nsw.gov.au>
Cc: Fettell, Daniel <Daniel.Fettell@aecom.com>
Subject: RE: Cranbrook School Development - Stormwater Goals and Strategy

Michael,

Just following up on my email below. Did you, or any other Council stakeholers have any comments regarding our strategy?

Regards,
Will Hammond
Civil Engineer
D +61 2 8934 0925
William.Hammond@aecom.com

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From: Hammond, William
Sent: Tuesday, 12 September 2017 1:07 PM
To: 'Michael.casteleyn@woollahra.nsw.gov.au'
Cc: Fettell, Daniel
Subject: Cranbrook School Development - Stormwater Goals and Strategy

Hi Michael,

Thanks for taking my phone call today. As discussed, please see below for the general goals for the stormwater strategy we intend to implement as part of the development. Also see below of proposed development overlay for context.

- No provision of formalised OSD for the development site for the following reasons:
  - The site lies right on the boundary of the OSD exemption area for Woollahra LGA; and
  - The site also sits very close to the outlet at Rose Bay – provision of OSD in this instance appears to increase the peak discharge in New South Head Road resulting in increased overland flow in the roadway. I can provide the DRAINS model showing these results if required.
- Total provision of greater than 130m3 of rainwater storage/harvesting tanks for irrigation and recycling
- Provision of WSUD measures (grassed swales, passive irrigation and GPTs) to meet Council treatment requirements prior to discharge to Rose Bay
- Upgrade of pit and pipe system in Rose Bay Avenue to ensure no adverse impact to existing Council infrastructure

Further to this, we will consult with the client on ground water impact and hydrogeological analysis – I expect this may be form part of the detailed design.

Can you please pass on to relevant Council stakeholders to provide support/objections to the above?

Any questions, please let me know.

Regards,
Will Hammond
Civil Engineer
D +61 2 8934 0925
William.Hammond@aecom.com

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Appendix B

DRAINS Results

CRANBROOK DEVELOPMENT
DRAINS Model - SSDA
Minor 20yr Results

DRAINS results prepared from Version 2018.04

PIT / NODE DETAILS

Name	Max HGL	Max Pond HGL	Max Surface Flow Arriving (cu.m/s)	Version 8 Max Pond Volume (cu.m)	Min Freeboard (m)	Overflow (cu.m/s)	Constraint
2\08	34.19		0.085		0.99	0.033	Inlet Capacity
2\07	33.5		0.047		0.91	0.013	Inlet Capacity
2\06	32.81		0.213		0.33	0.109	Inlet Capacity
2\05	29.47		0.109		0	0.098	Outlet System
2\04	26.13		0.098		0.98	0.041	Inlet Capacity
2\03	23.42		0.041		0.01	0.015	Inlet Capacity
8\01	17.21	17.21	0.342	0.8	0	0.41	Outlet System
2\02	15.89		0.468		0	0.478	Outlet System
2\01	14.69		0				
5\02	11.67	12.62	0.016	0.1	0.93	0	Inlet Capacity
5\01	11.65		0				
6\02	16.3	16.41	0.275	0.8	0	0.081	Outlet System
6\01	15.18		0				
7\04	14.68	16.08	0.188	0.2	1.3	0	Inlet Capacity
7\03	13.83		0		0	0.039	Outlet System
7\02	12.91		0		0.4	0	None
7\01	12.33		0				
EX3\02	19.35		0.698		0.02	0.498	Inlet Capacity
EX3\01	17.85		0				
EX4\02	18.49		0.411		0.01	0.244	Inlet Capacity
EX4\01	16.91		0				

SUB-CATCHMENT DETAILS

Name	Max Flow Q (cu.m/s)	Paved Max Q (cu.m/s)	Grassed Max Q (cu.m/s)	Paved Tc (min)	Grassed Tc (min)	Supp. Tc (min)	Due to Storm
C 2\08	0.085	0.077	0.008	3.93	7.39	0	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
C 2\07	0.013	0.012	0.001	2.06	3.88	0	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
C 2\06	0.2	0.18	0.019	2.06	3.88	0	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
C 8\02	0.33	0.044	0.294	7.41	13.91	0	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
C 5\02	0.016	0.015	0.001	5	6	0	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
C 6\02	0.275	0.037	0.245	7.45	13.98	0	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
C 7\04	0.188	0.024	0.167	7.02	13.19	0	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
C EX3\02	0.698	0.632	0.066	2.99	5.61	0	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
C EX4\02	0.411	0.374	0.037	3.82	7.17	0	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
2\09	0.072	0.023	0.049	5	6	5	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1

Outflow Volumes for Total Catchment (2.35 impervious + 2.03 pervious = 4.39 total ha)

Storm	Total Rainfall cu.m	Total Runoff cu.m (Runoff %)	Impervious Runoff cu.m (Runoff %)	Pervious Runoff cu.m (Runoff %)
AR&R 20 year, 5 minutes storm, average 210 mm/h, Zone 1	768.04	621.20 (80.9%)	388.50 (94.3%)	232.70 (65.4%)
AR&R 20 year, 10 minutes storm, average 165 mm/h, Zone 1	1206.92	1048.37 (86.9%)	623.96 (96.4%)	424.41 (75.9%)
AR&R 20 year, 15 minutes storm, average 141 mm/h, Zone 1	1547.05	1377.53 (89.0%)	806.44 (97.2%)	571.10 (79.6%)
AR&R 20 year, 20 minutes storm, average 124 mm/h, Zone 1	1814.04	1634.24 (90.1%)	949.67 (97.6%)	684.57 (81.4%)
AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1	2048.11	1857.30 (90.7%)	1075.24 (97.9%)	782.05 (82.4%)
AR&R 20 year, 30 minutes storm, average 103 mm/h, Zone 1	2260.23	2058.65 (91.1%)	1189.05 (98.1%)	869.60 (83.0%)
AR&R 20 year, 45 minutes storm, average 84 mm/h, Zone 1	2764.94	2532.30 (91.6%)	1459.83 (98.4%)	1072.47 (83.7%)

CRANBROOK DEVELOPMENT
DRAINS Model - SSDA
Minor 20yr Results

AR&R 20 year, 1 hour storm, average 73 mm/h, Zone 1	3203.82	2941.37 (91.8%)	1695.28 (98.6%)	1246.09 (83.9%)
AR&R 20 year, 1.5 hours storm, average 56 mm/h, Zone 1	3686.59	3363.09 (91.2%)	1954.29 (98.8%)	1408.80 (82.4%)
AR&R 20 year, 2 hours storm, average 46.7 mm/h, Zone 1	4099.14	3712.70 (90.6%)	2175.60 (98.9%)	1537.10 (80.9%)
AR&R 20 year, 3 hours storm, average 35.8 mm/h, Zone 1	4713.57	4214.08 (89.4%)	2505.25 (99.1%)	1708.83 (78.2%)

PIPE DETAILS

Name	Max Q (cu.m/s)	Max V (m/s)	Max U/S HGL (m)	Max D/S HGL (m)	Due to Storm
P 2\08	0.051	1.93	34.029	33.497	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
P 2\07	0.084	3.1	33.24	32.814	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
P 2\06	0.186	4.56	32.065	29.472	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
P 2\05	0.196	4.58	28.345	26.133	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
P 2\04	0.255	5.24	26.024	23.419	AR&R 20 year, 20 minutes storm, average 124 mm/h, Zone 1
P 2\03	0.275	3.9	23.264	17.212	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
P 8\01	0.204	2.89	16.73	15.893	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
P 2\02	0.214	3.03	15.171	14.699	AR&R 20 year, 1 hour storm, average 73 mm/h, Zone 1
P 5\02	0.016	0.25	11.654	11.653	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
P 6\02	0.194	2.75	15.42	15.186	AR&R 20 year, 1.5 hours storm, average 56 mm/h, Zone 1
P 7\04	0.188	2.66	13.995	13.833	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
P 7\03	0.149	2.11	13.269	12.908	AR&R 20 year, 20 minutes storm, average 124 mm/h, Zone 1
P 7\02	0.149	2.17	12.451	12.325	AR&R 20 year, 30 minutes storm, average 103 mm/h, Zone 1
P EX3\02	0.2	2.83	18.458	17.863	AR&R 20 year, 30 minutes storm, average 103 mm/h, Zone 1
P EX4\02	0.201	2.84	17.548	16.919	AR&R 20 year, 10 minutes storm, average 165 mm/h, Zone 1

CHANNEL DETAILS

Name	Max Q (cu.m/s)	Max V (m/s)	Due to Storm

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
F 2\08	0.033	0.033	0.19	0.083	0.07	1.43	0.84	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
F 2\07	0.013	0.013	0.19	0.062	0.05	0.72	0.78	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
F 2\06	0.109	0.109	0.19	0.119	0.12	2.6	0.99	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
F 2\05	0.098	0.098	0.19	0.115	0.11	2.47	0.97	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
F 2\04	0.041	0.041	0.19	0.088	0.08	1.58	0.87	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
F 2\03	0.015	0.015	0.19	0.065	0.05	0.82	0.79	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
F 8\01	0.41	0.41	0.19	0.18	0.21	5.48	1.18	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
F 2\02	0.478	0.478	0.19	0.186	0.23	5.82	1.24	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
F 5\02	0	0	0.19	0	0	0	0	
F 6\02	0.081	0.081	0.19	0.109	0.1	2.26	0.94	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
F 7\04	0	0	0.19	0	0	0	0	
F 7\03	0.039	0.039	0.19	0.087	0.08	1.54	0.87	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
F 7\02	0	0	0.19	0	0	0	0	
F EX3\02	0.498	0.498	0.19	0.188	0.24	5.92	1.25	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
F EX4\02	0.244	0.244	0.19	0.154	0.17	4	1.09	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1
F 2\09	0.072	0.072	0.256	0.031	0.01	10.2	0.45	AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1

DETENTION BASIN DETAILS

Name	Max WL	MaxVol	Max Q Total	Max Q Low Level	Max Q High Level

CONTINUITY CHECK for AR&R 20 year, 25 minutes storm, average 112 mm/h, Zone 1

Node	Inflow	Outflow	Storage Change	Difference

CRANBROOK DEVELOPMENT
DRAINS Model - SSDA
Minor 20yr Results

	(cu.m)	(cu.m)	(cu.m)	%
2\08	63.45	63.47	0	0
2\07	73.46	73.51	0	-0.1
2\06	222.17	221.96	0	0.1
2\05	221.96	221.71	0	0.1
2\04	221.71	221.23	0	0.2
2\03	221.23	221.51	0	-0.1
8\01	534	535.14	0	-0.2
2\02	586.4	595.41	0	-1.5
2\01	328.69	328.69	0	0
5\02	12.01	12.02	0	-0.1
5\01	12.02	12.02	0	0
6\02	260.16	262.24	0	-0.8
6\01	235.16	235.16	0	0
7\04	170.58	170.97	0	-0.2
7\03	170.97	171.18	0	-0.1
7\02	159.94	160.08	0	-0.1
7\01	160.08	160.08	0	0
EX3\02	520.53	520.74	0	0
EX3\01	237.3	237.3	0	0
EX4\02	308.16	315.06	0	-2.2
EX4\01	210.62	210.62	0	0
O 2\02	266.72	266.72	0	0
O 5\02	0	0	0	0
O 6\02	27.09	27.09	0	0
O 7\03	11.24	11.24	0	0
O 7\02	0	0	0	0
O EX3\02	283.44	283.44	0	0
O EX4\02	104.45	104.45	0	0
N29731	51.26	51.26	0	0

Run Log for Cranbrook School run at 21:45:27 on 7/5/2018
Upwelling occurred at: EX4\02, 8\01, 7\03, 2\02
Freeboard was less than 0.15m at EX3\02, 6\02, 2\03, 2\05
The maximum flow in these overflow routes is unsafe: F 2\02, F 8\01, F EX3\02, F EX4\02

CRANBROOK DEVELOPMENT
DRAINS Model - SSDA
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DRAINS results prepared from Version 2018.04

PIT / NODE DETAILS

Name	Max HGL	Max Pond HGL	Max Surface Flow Arriving (cu.m/s)	Version 8 Max Pond Volume (cu.m)	Min Freeboard (m)	Overflow (cu.m/s)	Constraint
2\08	34.25		0.102		0.93	0.043	Inlet Capacity
2\07	33.65		0.06		0.75	0.019	Inlet Capacity
2\06	33.09		0.265		0.05	0.145	Inlet Capacity
2\05	29.51		0.145		0	0.155	Outlet System
2\04	26.58		0.155		0.54	0.076	Inlet Capacity
2\03	23.43		0.076		0	0.074	Outlet System
8\01	17.21	17.21	0.486	0.8	0	0.547	Outlet System
2\02	15.89		0.619		0	0.634	Outlet System
2\01	14.69		0				
5\02	11.68	12.63	0.019	0.1	0.92	0	Inlet Capacity
5\01	11.65		0				
6\02	16.3	16.41	0.351	0.8	0	0.158	Outlet System
6\01	15.18		0				
7\04	15.15	16.09	0.236	0.3	0.83	0	Inlet Capacity
7\03	13.83		0		0	0.085	Outlet System
7\02	12.91		0		0.4	0	None
7\01	12.33		0				
EX3\02	19.35		0.856		0.02	0.657	Inlet Capacity
EX3\01	17.85		0				
EX4\02	18.5		0.498		0.01	0.347	Inlet Capacity
EX4\01	16.91		0				

SUB-CATCHMENT DETAILS

Name	Max Flow Q (cu.m/s)	Paved Max Q (cu.m/s)	Grassed Max Q (cu.m/s)	Paved Tc (min)	Grassed Tc (min)	Supp. Tc (min)	Due to Storm
C 2\08	0.102	0.096	0.007	2.76	5.19	0	AR&R 100 year, 5 minutes storm, average 271 mm/h, Zone 1
C 2\07	0.017	0.015	0.001	1.45	2.72	0	AR&R 100 year, 5 minutes storm, average 271 mm/h, Zone 1
C 2\06	0.246	0.224	0.022	1.45	2.72	0	AR&R 100 year, 5 minutes storm, average 271 mm/h, Zone 1
C 8\02	0.422	0.055	0.375	6.35	11.91	0	AR&R 100 year, 20 minutes storm, average 165 mm/h, Zone 1
C 5\02	0.019	0.018	0.002	5	6	0	AR&R 100 year, 1.5 hours storm, average 75 mm/h, Zone 1
C 6\02	0.351	0.046	0.312	6.38	11.98	0	AR&R 100 year, 20 minutes storm, average 165 mm/h, Zone 1
C 7\04	0.236	0.031	0.21	6.02	11.29	0	AR&R 100 year, 20 minutes storm, average 165 mm/h, Zone 1
C EX3\02	0.856	0.784	0.072	2.1	3.94	0	AR&R 100 year, 5 minutes storm, average 271 mm/h, Zone 1
C EX4\02	0.498	0.464	0.033	2.68	5.04	0	AR&R 100 year, 5 minutes storm, average 271 mm/h, Zone 1
2\09	0.083	0.027	0.055	5	6	5	AR&R 100 year, 25 minutes storm, average 150 mm/h, Zone 1

Outflow Volumes for Total Catchment (2.35 impervious + 2.03 pervious = 4.39 total ha)

Storm	Total Rainfall cu.m	Total Runoff cu.m (Runoff %)	Impervious Runoff cu.m (Runoff %)	Pervious Runoff cu.m (Runoff %)
AR&R 100 year, 5 minutes storm, average 271 mm/h, Zone 1	991.14	775.14 (78.2%)	508.19 (95.6%)	266.95 (58.1%)
AR&R 100 year, 10 minutes storm, average 214 mm/h, Zone 1	1565.34	1304.91 (83.4%)	816.25 (97.2%)	488.66 (67.4%)
AR&R 100 year, 15 minutes storm, average 185 mm/h, Zone 1	2029.82	1733.05 (85.4%)	1065.44 (97.8%)	667.61 (71.0%)
AR&R 100 year, 20 minutes storm, average 165 mm/h, Zone 1	2413.84	2086.05 (86.4%)	1271.46 (98.2%)	814.59 (72.8%)
AR&R 100 year, 25 minutes storm, average 150 mm/h, Zone 1	2743	2382.61 (86.9%)	1448.05 (98.4%)	934.56 (73.5%)
AR&R 100 year, 30 minutes storm, average 138 mm/h, Zone 1	3028.27	2640.79 (87.2%)	1601.10 (98.6%)	1039.69 (74.1%)
AR&R 100 year, 45 minutes storm, average 113 mm/h, Zone 1	3719.51	3266.26 (87.8%)	1971.94 (98.8%)	1294.32 (75.1%)
AR&R 100 year, 1 hour storm, average 96 mm/h, Zone 1	4213.25	3708.44 (88.0%)	2236.84 (99.0%)	1471.61 (75.4%)

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AR&R 100 year, 1.5 hours storm, average 75 mm/h, Zone 1	4937.4	4349.46 (88.1%)	2625.34 (99.1%)	1724.12 (75.3%)
AR&R 100 year, 2 hours storm, average 63 mm/h, Zone 1	5529.89	4871.62 (88.1%)	2943.20 (99.2%)	1928.42 (75.2%)
AR&R 100 year, 3 hours storm, average 48 mm/h, Zone 1	6319.87	5538.98 (87.6%)	3367.03 (99.3%)	2171.95 (74.1%)

PIPE DETAILS

Name	Max Q (cu.m/s)	Max V (m/s)	Max U/S HGL (m)	Max D/S HGL (m)	Due to Storm
P 2\08	0.059	2	34.038	33.654	AR&R 100 year, 5 minutes storm, average 271 mm/h, Zone 1
P 2\07	0.105	2.45	33.293	33.09	AR&R 100 year, 5 minutes storm, average 271 mm/h, Zone 1
P 2\06	0.216	4.71	32.082	29.515	AR&R 100 year, 5 minutes storm, average 271 mm/h, Zone 1
P 2\05	0.197	4.58	28.346	26.576	AR&R 100 year, 5 minutes storm, average 271 mm/h, Zone 1
P 2\04	0.275	3.89	26.422	23.433	AR&R 100 year, 25 minutes storm, average 150 mm/h, Zone 1
P 2\03	0.276	3.9	23.278	17.212	AR&R 100 year, 25 minutes storm, average 150 mm/h, Zone 1
P 8\01	0.204	2.89	16.729	15.893	AR&R 100 year, 10 minutes storm, average 214 mm/h, Zone 1
P 2\02	0.214	3.03	15.171	14.699	AR&R 100 year, 45 minutes storm, average 113 mm/h, Zone 1
P 5\02	0.019	0.3	11.655	11.653	AR&R 100 year, 25 minutes storm, average 150 mm/h, Zone 1
P 6\02	0.194	2.75	15.42	15.186	AR&R 100 year, 1 hour storm, average 96 mm/h, Zone 1
P 7\04	0.235	3.32	14.08	13.833	AR&R 100 year, 20 minutes storm, average 165 mm/h, Zone 1
P 7\03	0.149	2.11	13.269	12.908	AR&R 100 year, 20 minutes storm, average 165 mm/h, Zone 1
P 7\02	0.149	2.17	12.452	12.325	AR&R 100 year, 1 hour storm, average 96 mm/h, Zone 1
P EX3\02	0.2	2.83	18.457	17.863	AR&R 100 year, 2 hours storm, average 63 mm/h, Zone 1
P EX4\02	0.201	2.84	17.552	16.919	AR&R 100 year, 15 minutes storm, average 185 mm/h, Zone 1

CHANNEL DETAILS

Name	Max Q (cu.m/s)	Max V (m/s)	Due to Storm

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
F 2\08	0.043	0.043	0.19	0.09	0.08	1.65	0.87	AR&R 100 year, 5 minutes storm, average 271 mm/h, Zone 1
F 2\07	0.019	0.019	0.19	0.071	0.06	1	0.81	AR&R 100 year, 5 minutes storm, average 271 mm/h, Zone 1
F 2\06	0.145	0.145	0.19	0.129	0.13	2.94	1.04	AR&R 100 year, 5 minutes storm, average 271 mm/h, Zone 1
F 2\05	0.155	0.155	0.19	0.132	0.14	3.03	1.05	AR&R 100 year, 25 minutes storm, average 150 mm/h, Zone 1
F 2\04	0.076	0.076	0.19	0.107	0.1	2.2	0.93	AR&R 100 year, 25 minutes storm, average 150 mm/h, Zone 1
F 2\03	0.074	0.074	0.19	0.105	0.1	2.15	0.94	AR&R 100 year, 25 minutes storm, average 150 mm/h, Zone 1
F 8\01	0.547	0.547	0.19	0.193	0.25	6.16	1.28	AR&R 100 year, 25 minutes storm, average 150 mm/h, Zone 1
F 2\02	0.634	0.634	0.19	0.2	0.27	6.4	1.35	AR&R 100 year, 25 minutes storm, average 150 mm/h, Zone 1
F 5\02	0	0	0.19	0	0	0	0	
F 6\02	0.158	0.158	0.19	0.133	0.14	3.06	1.06	AR&R 100 year, 20 minutes storm, average 165 mm/h, Zone 1
F 7\04	0	0	0.19	0	0	0	0	
F 7\03	0.085	0.085	0.19	0.11	0.11	2.31	0.96	AR&R 100 year, 20 minutes storm, average 165 mm/h, Zone 1
F 7\02	0	0	0.19	0	0	0	0	
F EX3\02	0.657	0.657	0.19	0.202	0.28	6.4	1.36	AR&R 100 year, 5 minutes storm, average 271 mm/h, Zone 1
F EX4\02	0.347	0.347	0.19	0.172	0.19	5.1	1.13	AR&R 100 year, 5 minutes storm, average 271 mm/h, Zone 1
F 2\09	0.083	0.083	7.665	0.033	0.02	10.56	0.46	AR&R 100 year, 25 minutes storm, average 150 mm/h, Zone 1

DETENTION BASIN DETAILS

Name	Max WL	MaxVol	Max Q Total	Max Q Low Level	Max Q High Level

CONTINUITY CHECK for AR&R 100 year, 1.5 hours storm, average 75 mm/h, Zone 1

Node	Inflow (cu.m)	Outflow (cu.m)	Storage Change (cu.m)	Difference %
2\08	153.59	153.65	0	0

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2\07	177.81	177.83	0	0
2\06	537.62	537.55	0	0
2\05	537.55	538.15	0	-0.1
2\04	538.15	538.17	0	0
2\03	538.17	538.34	0	0
8\01	1236.44	1238.86	0	-0.2
2\02	1355.68	1373.22	0	-1.3
2\01	872.41	872.41	0	0
5\02	29.07	29.07	0	0
5\01	29.07	29.07	0	0
6\02	581.17	582.87	0	-0.3
6\01	531.98	531.98	0	0
7\04	380.9	381.27	0	-0.1
7\03	381.27	381.83	0	-0.1
7\02	364.95	365.03	0	0
7\01	365.03	365.03	0	0
EX3\02	1259.91	1260.05	0	0
EX3\01	665.02	665.02	0	0
EX4\02	745.94	756.57	0	-1.4
EX4\01	553.07	553.07	0	0
O 2\02	500.81	500.81	0	0
O 5\02	0	0	0	0
O 6\02	50.88	50.88	0	0
O 7\03	16.88	16.88	0	0
O 7\02	0	0	0	0
O EX3\02	595.02	595.02	0	0
O EX4\02	203.5	203.5	0	0
N29731	116.82	116.82	0	0

Run Log for Cranbrook School run at 21:49:09 on 7/5/2018
Upwelling occurred at: EX4\02, 8\01, 7\03, 2\02, 2\03, 2\05
Freeboard was less than 0.15m at EX3\02, 6\02, 2\06
The maximum flow in these overflow routes is unsafe: F 2\02, F 8\01, F EX3\02, F EX4\02