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Cranbrook School Redevelopment
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Cranbrook School

Stormwater Management and Civil Design Report

State Significant Development Application (SSDA) Submission

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Stormwater Management and Civil Design Report

Cranbrook School

Client: Cranbrook School

ABN: 000 007 723

Prepared by

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			Name/Position	Signature
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1.0 Introduction

The Cranbrook School is undertaking a redevelopment project, which involves the delivery of a new sports and fitness centre under Hordern Oval, a new integrated development of the War Memorial Hall site, and a new formalised drop off and pick up zone at the current 'Heritage Driveway'.

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

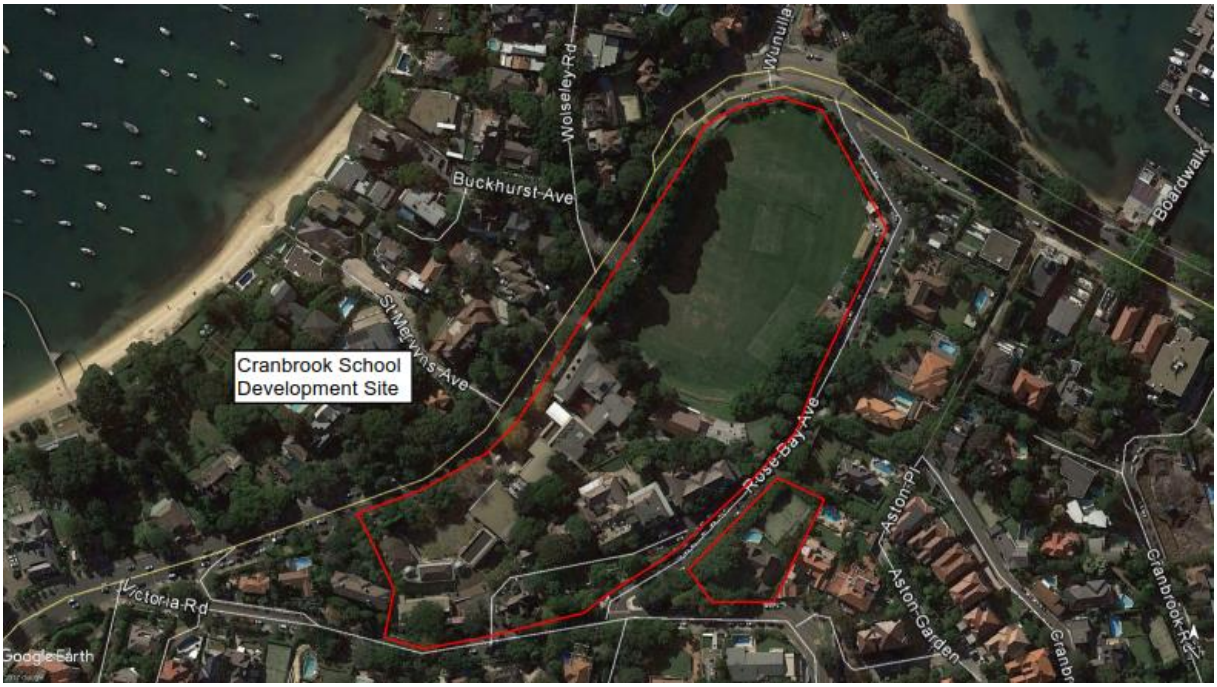

Figure 1 Site Plan

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.

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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.

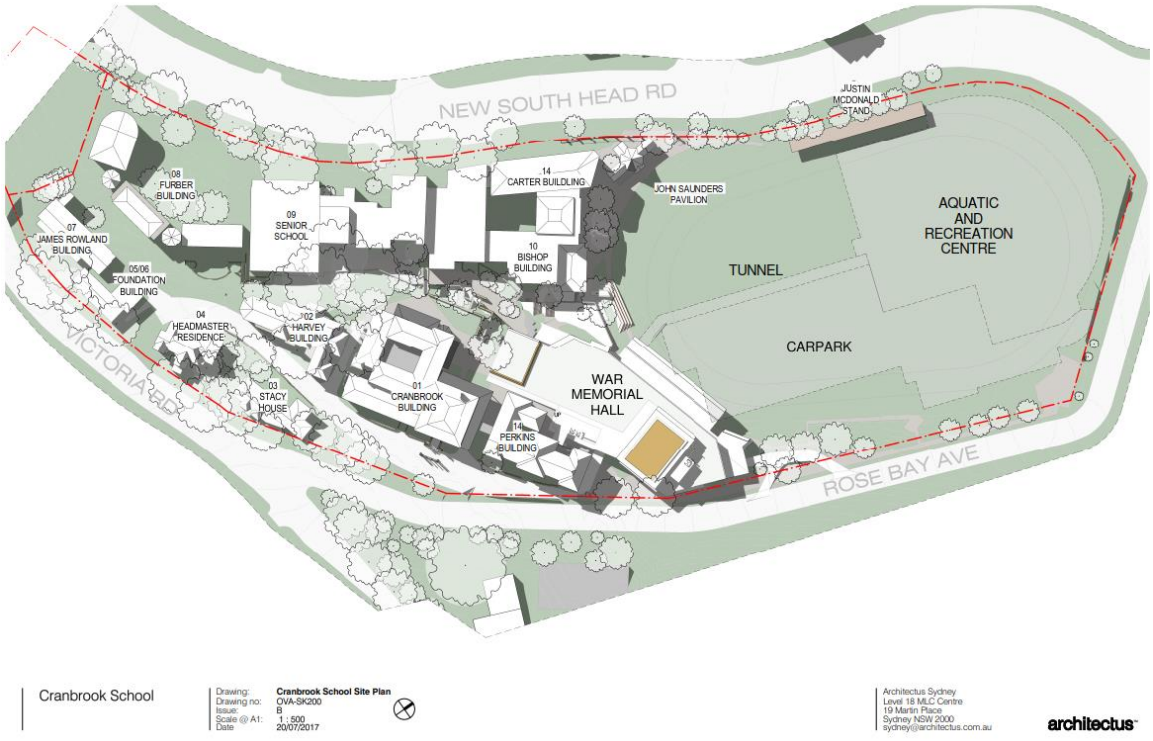
2.2 Proposed Development

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

- New Aquatic and Recreational Centre (ARC) beneath the Hordern Oval;
- New integrated learning building – War Memorial Hall (WMH);
- New formalised on-site drop off and pick up along the main driveway ('Heritage Driveway');
- New underground carpark accessible from Rose Bay Avenue for staff and students.

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

Figure 2 Site Concept Plan



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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.

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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

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			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 spacing	CoS A4	Max. 40m Max. 100m	Maximum spacing increases with increasing pipe sizes
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
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 for this has been provided to Council for review.

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

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- 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.

3.7 Road Design Criteria

The civil design criteria applied to the road and levels designed are summarised in Table 3

Table 3 Road Design Criteria

Item	Standard	Adopted	Comment
Horizontal Road Alignment			
Vehicle Design Speed		Refer traffic engineer's documentation	Assumed maximum 'shared environment' speed
Turning Paths		Refer traffic engineer's documentation	Generally horizontal alignment follows existing geometry, with vehicle tracking used to check against adopted design vehicles.
	Austroads 2008	Emergency response vehicles and service vehicles	L = 19.0m
Road Reserve Width			
Lane Width		Refer traffic engineer's documentation	Width to suit residual space given minimum footpath width.
Parking Lane	AS 2890.5 – 1993 On Street Car Parking	Min Width = 2.1 m Length 1 space = 6.3m	Allows for kerbs and/or obstructions at either end of the parking spaces.
Footpath	AS 1428.2 – Design for access and mobility Enhanced and additional requirements	Min Width = 1.2m Preferred width = 2.0m	For road widenings at proposed loading bays, footpath widths to match existing at tie-in points
Kerb Types			
Road	RTA RDG	Kerb Only (Type KO) Kerb and Gutter (Type SA)	
Vertical Road Alignment			
Maximum Longitudinal Grade	COS D1	Roads	City of Sydney requirements adopted where not available

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		Desirable = 12% Acceptable = 16%	for Woollahra LGA
		Footways Desirable = 5% Acceptable = 7%	Usually parallel to road grade but where possible use these values
Minimum Longitudinal Grade	Cos D1	Desirable = 0.5% Acceptable = 0.3%	
% change in grade requiring a Vertical Curve	Cos D1	1%	
Min VC lengths	Cos D1	Desirable = 25m Acceptable = 6m	
Cross fall	Cos D1	Roads 2.0 to 3.0%	
Vertical Footpath Alignment			
Maximum Longitudinal Fall		3%	To achieve DDA compliance without need for hand rails or landings Grades have been set to match existing for areas of footpath reinstatement.
Minimum Footpath Cross Fall		1%	
Maximum Footpath Cross Fall		2.5%	

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4.0 Roadworks, Earthworks, Levels Design

The primary feature of the Cranbrook School redevelopment includes construction of the new Sports and Fitness Centre under Hordern Oval, extension of the war Memorial Hall and provisions for a new drop off and pick up site at 'Heritage Driveway'. 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:

- Design of internal roads with 1-way or 2-way cross-fall to suit stormwater management requirements;
- 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 4.

Table 4 Cut/Fill Volumes

CUT AND FILL VOLUME

	AQUATIC CENTRE	CARPARK	TUNNEL	TOTAL
CUT (m)	-57972	-16166	-4028	
FILL (m)	0	0	0	
TOTAL BALANCE	-57972	-16166	-4028	-78167

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 (not this will only have a minor impact);
- Cut to fill quantities are from existing surface to top of finished surface. No allowance for pavement boxing, footings, services, stormwater or topsoil removal has been made.
- The cut/fill balance does not include bulk earthworks from the new 'drop-off/pick-up road' and is subject to finalisation of road design strategy to be agreed with the client.

There are a number of different materials that may be required, these are summarised below in Table 5

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Table 5: 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

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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 included Cranbrook School.

The peak depths and extent of flooding in the 100 year ARI storm event is shown below in Figure 3.

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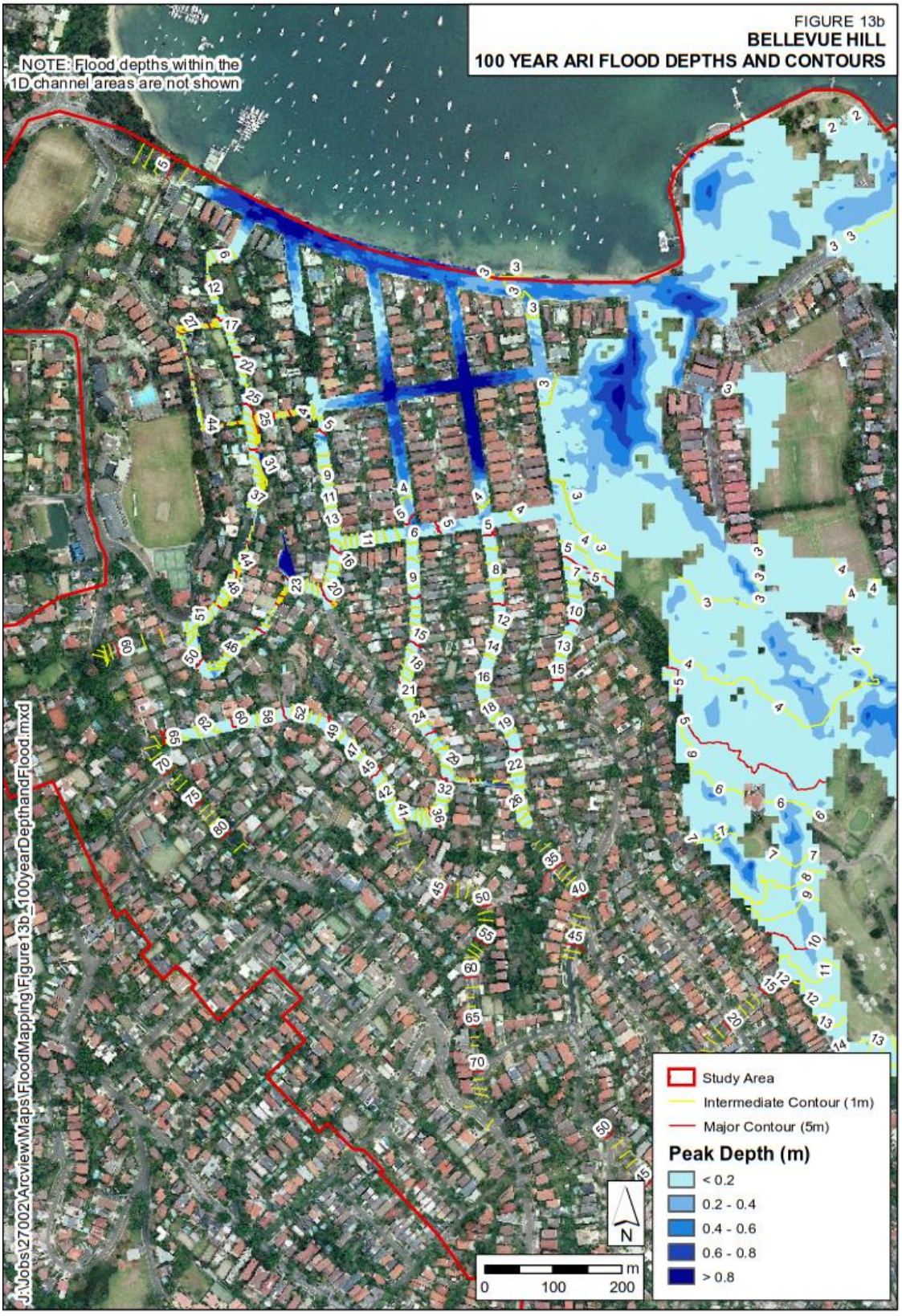
Figure 3 100 year ARI Flood Extents (source: Rose Bay Catchment Flood Study – Woollahra Municipal Council)



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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.

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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 4. 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.

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Figure 4 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. Three main locations have been assumed for the purposes of this report:

- 4(a) – western spill point – at the existing driveway, behind existing ‘Justin McDonald Stand’
- 4(b) – northern spill point – at the localised low point near northern-most point of site, spilling near existing 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 5.

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Figure 5 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 6 for the relevant catchments displayed in Figure 4. These have been selected to provide baseline conditions against which the proposed development will be assessed.

Table 6 Pre-development Peak Site Discharge

ARI	Catchment	Piped Flow (l/s)	Overland Flow (l/s)	Total (l/s)
20 year	1	200	525	725
	2	202	282	484
	3	-	203	203
	4(a)	-	333	333
	4(b)	-	328	328
	4(c)	14	376	390
	Combined	**416**	**2,047**	**2,463**
100 year	1	200	660	860
	2	202	372	574
	3	-	242	242
	4(a)	-	339	339
	4(b)	-	336	336
	4(c)	14	381	395
	Combined	**416**	**2,330**	**2,746**

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5.3 Proposed Stormwater Management

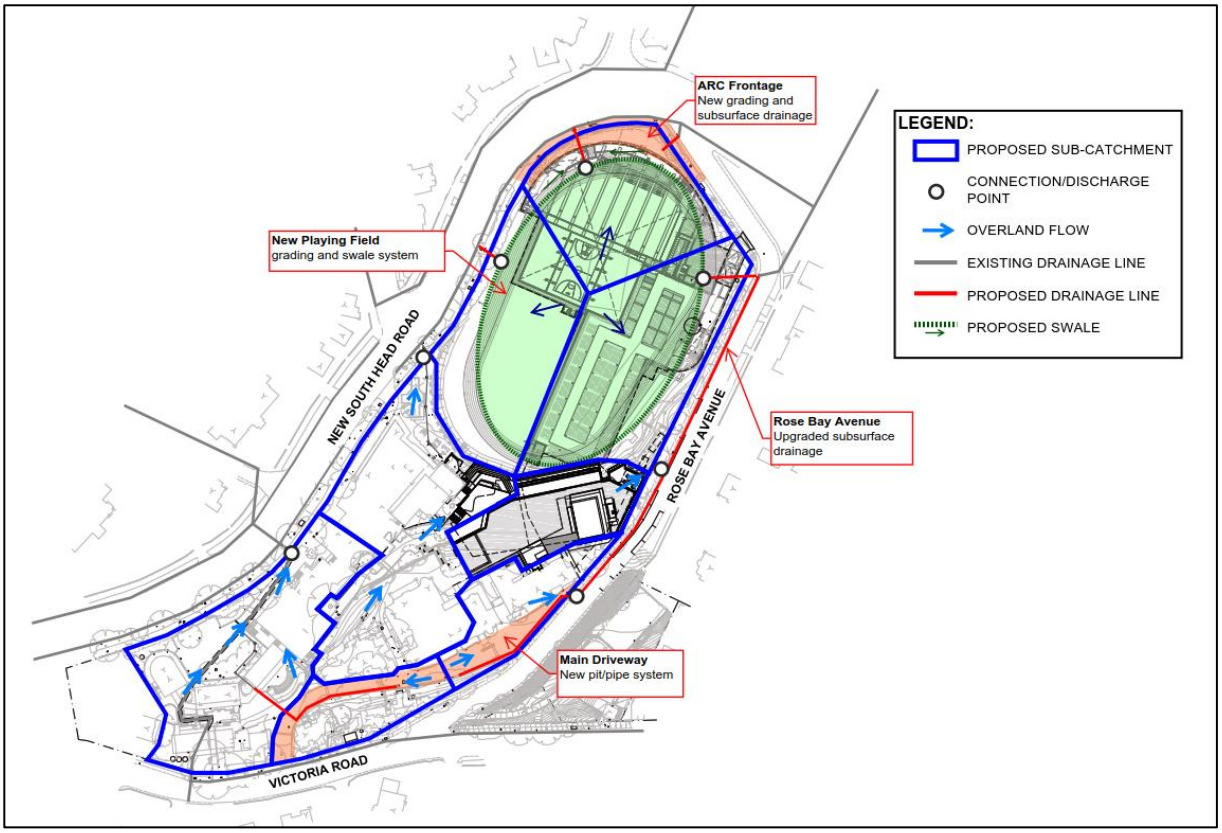
5.3.1 Proposed Stormwater Management Approach

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;
- 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 6 presents a schematic of the proposed stormwater management strategy detailed in the following sections.

Figure 6 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.

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5.3.3 Proposed Infrastructure

New stormwater infrastructure is proposed for the development comprising:

- A new pit and pipe system in Rose Bay Avenue to convey stormwater to the existing Council stormwater network (to be dedicated to Council)
- New pit and pipe system within the new 'pick-up/drop-off road' to collect localised stormwater flows from the road and adjacent existing building to the upgraded system in Rose Bay Avenue
- 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
- Adjustment of existing on-site stormwater infrastructure to direct to new network (where required).

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

5.3.3.1 Main Driveway Drainage

The upgraded pick-up/drop-off road is proposed to incorporate a new pit and pipe network to convey the local catchment to the new proposed system in Rose Bay Avenue. It is noted that an existing pit/pipe system is available and may pending further investigation of size and connection points. Drinage is proposed to maintain the existing catchment discharge

5.3.3.2 Rose Bay Avenue Drainage

The roof drainage for the new War Memorial Hall is proposed to discharge to Rose Bay Avenue. This effectively increases the catchment discharging at this location. To ensure no adverse impacts to the existing street stormwater system, a new pit and pipe system is proposed on the western side. This also provides a piped connection point for the proposed main driveway drainage (which currently discharges as overland flow to Rose Bay Avenue). The additional discharge is conveyed as pipe flow, effectively reducing the overall overland flow under post-development conditions.

5.3.3.3 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 7.

Table 7 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	War Memorial Hall	3\01	**0.189**	**0.214**

5.3.3.4 Aquatic and Recreational Centre Frontage Drainage

Significant level changes are proposed at the ARC 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 8. 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

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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 ARC.

Figure 7 ARC Frontage Stormwater Management Approach

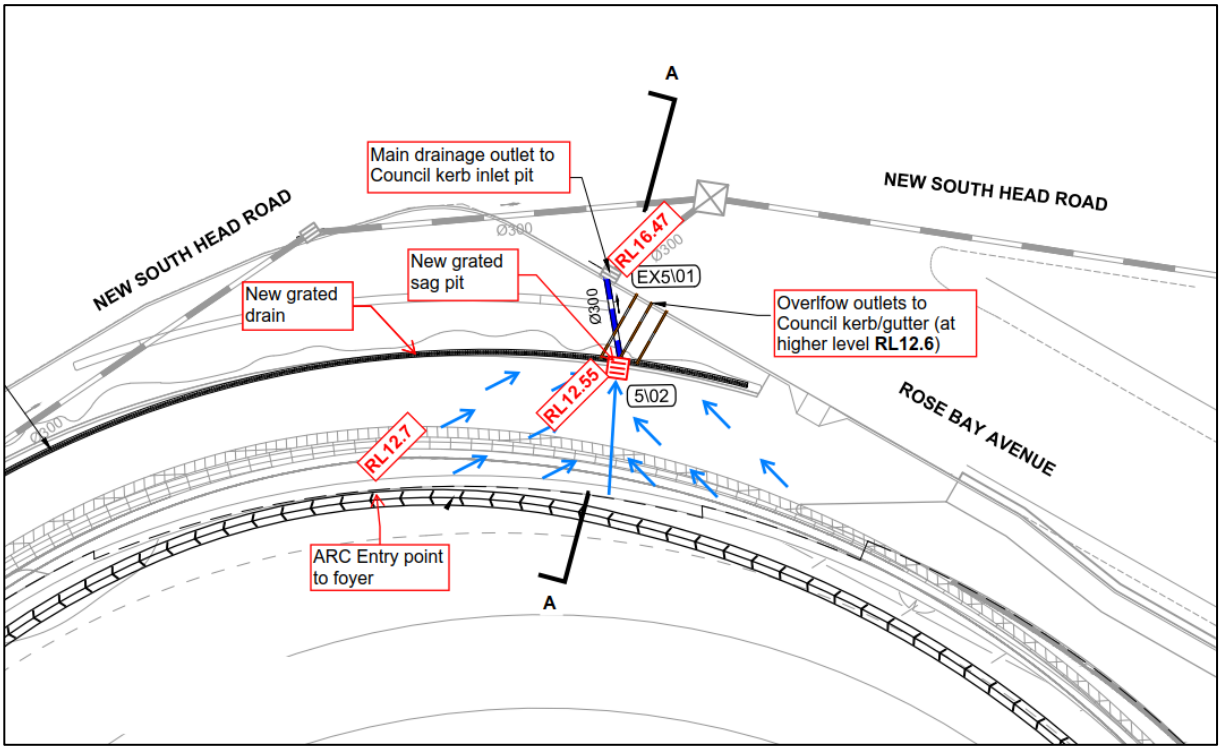
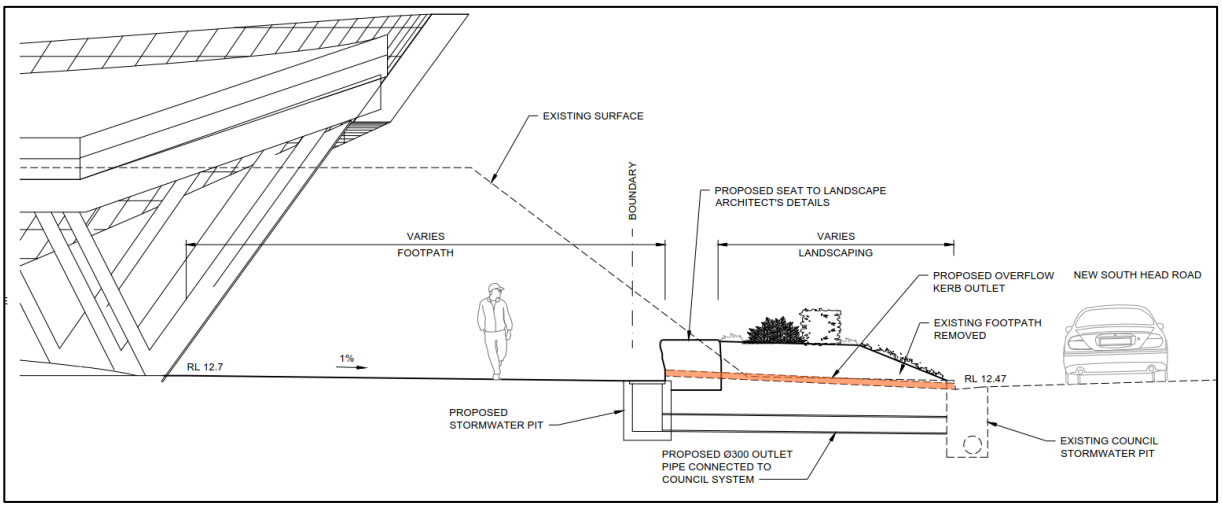


Figure 8 Typical section through ARC frontage to New South Head Road (section A-A)



5.3.3.5 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:

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- New South Head Road west
- New South Head Road north
- Rose Bay Avenue

The general stormwater approach for the playing field comprises:

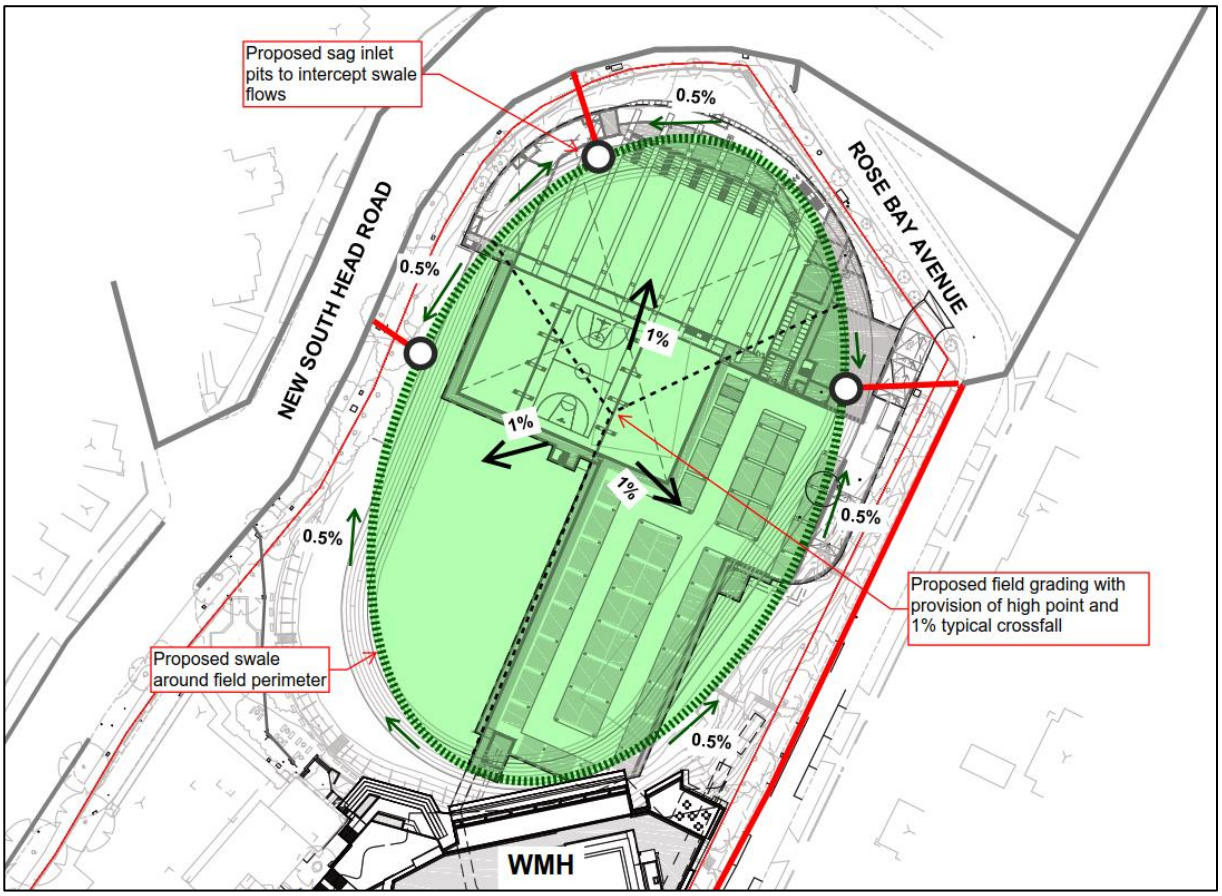
- Provision of a main high point near the centre of playing field
- Provision for field grading at 1% outwards toward proposed field perimeter
- Provision for a grassed swale to convey playing field surface runoff to the discharge points as outlined above
- Provision of sag pits allowing nominal ponding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

Refer to Figure 9 for details of the proposed playing field drainage strategy.

Figure 9 Playing Field Stormwater Management Approach



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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:

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Figure 10 Pre-Development 20 year ARI

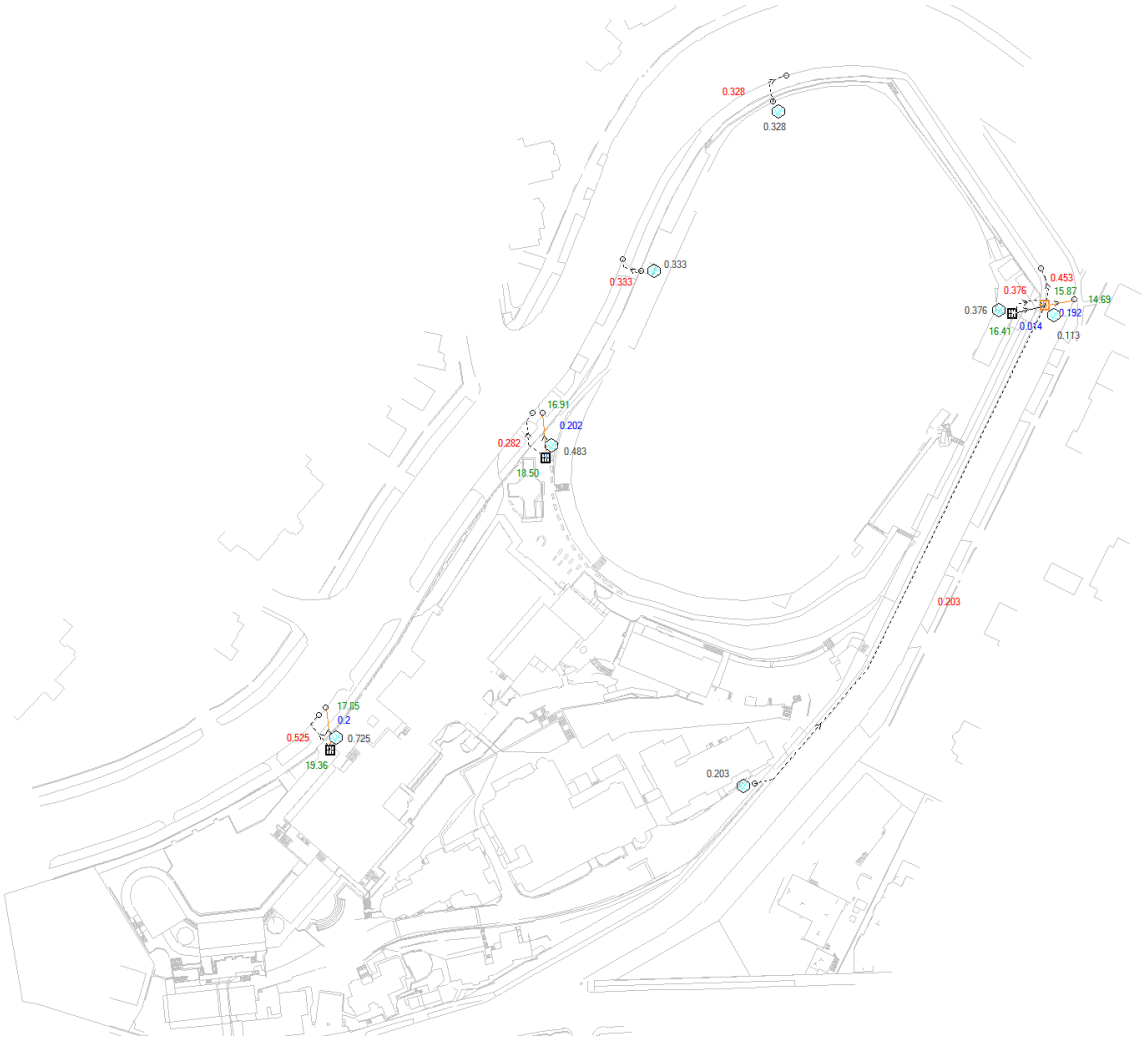

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Figure 11 Pre-Development 100 year ARI

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Figure 12 Post-Development 20 year ARI

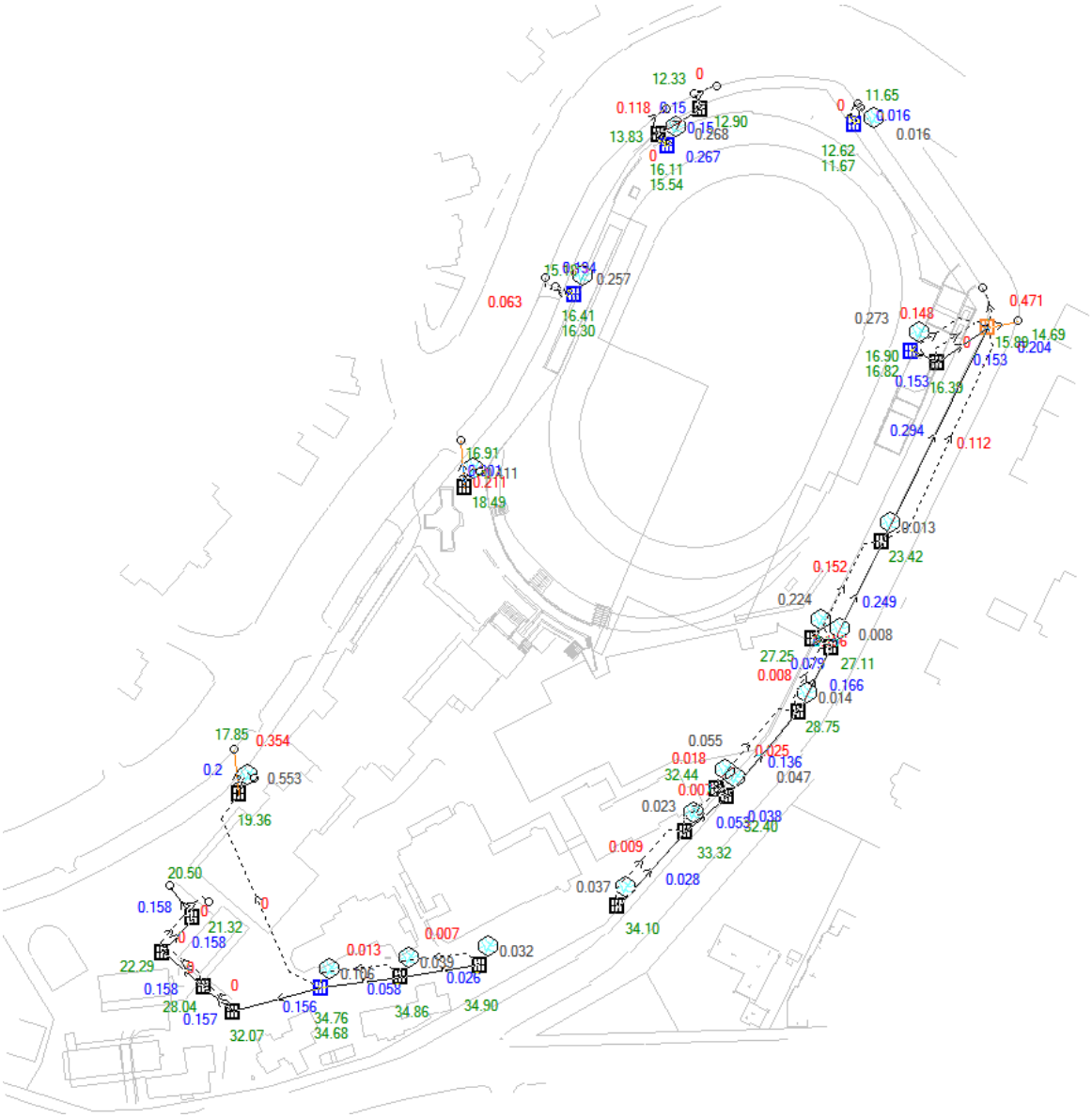

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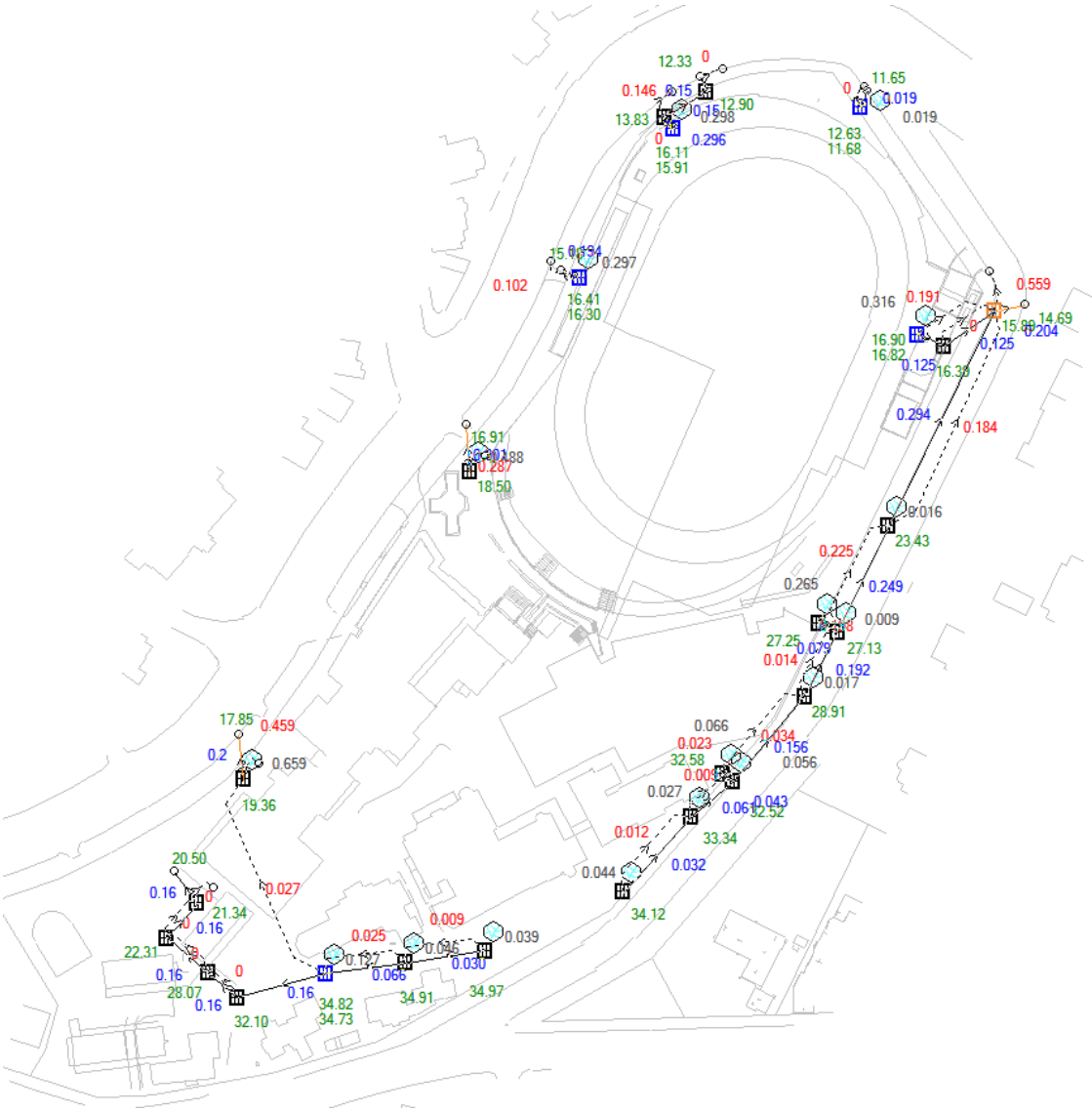
Figure 13 Post-Development 100 year ARI



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5.3.4.1 Post-Development Stormwater Performance

The DRAINS results for site discharge under post-development conditions are presented in Table 8 below. The total peak discharge from site is reduced by 5% in the minor storm and 2% 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 8 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	358	354	712	2%	33%	Additional pipe drainage included in main driveway
	2	201	211	412	15%	25%	Portion of catchment redistributed to (3)
	3	249	152	401	-98%	25%	Total flow increased, overland decreased
	4(a)	193	64	257	23%	81%	New pipe drainage and attenuation of flows from proposed grassed swale and ponding storage
	4(b)	149	118	267	19%	64%	
	4(c)	138	149	287	26%	60%	
	Combined	**1288**	**1048**	**2336**	**5%**	**49%**	
100 year	1	360	459	819	5%	30%	Additional pipe drainage included in main driveway
	2	201	287	488	15%	23%	Portion of catchment redistributed to (3)
	3	249	225	474	-96%	7%	Total flow increased, overland decreased
	4(a)	193	105	298	12%	69%	New pipe drainage and attenuation of flows from proposed grassed swale and ponding storage
	4(b)	149	147	296	12%	56%	
	4(c)	125	191	316	20%	50%	
	Combined	**1277**	**1414**	**2691**	**2%**	**39%**	

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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.

6.0 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 9**provides a summary of how each of these requirements is addressed in this management plan.

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Table 9 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.