600-660 Elizabeth Street

New South Wales Land and Housing Corporation

31-Feb-2020

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Stormwater Strategy Report

600-660 Elizabeth Street, Redfern NSW

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600-660 Elizabeth Street, Redfern NSW

Client: New South Wales Land and Housing Corporation

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Executive Summary

The site, at 600 to 660 Elizabeth Street, Redfern, forms part of the wider Redfern social housing estate. This Report has been developed to assess the site and context, delve into historical flooding issues, identify relevant constraints and opportunities and discuss preliminary flood analysis results which will inform the potential flood management approaches. This Report responds to the City of Sydney Council Planning Proposal Requirements issued for 600 to 660 Elizabeth Street, Redfern (Water Quality, Flooding and Stormwater). The report includes details on the existing flooding context, hydrological context along with Water Sensitive Urban Design (WSUD) responses.

Flooding

Initial modelling of the site under existing conditions, as well as a preliminary developed case scenario, have been undertaken using a modified version of the City of Sydney TUFLOW model for the *Alexandra Canal Flood Study* (Cardno, 2014). This was undertaken to assess the site suitability with respect to flooding, as well as the potential for impacts to the surrounding area, as required by the Planning Proposal Requirements.

Under existing conditions, there is a significant area of ponding on Phillip Street between the intersection of Elizabeth Street and Morehead Street. The depth of flooding in this area is up to 0.9 m for the 100 year ARI and up to 2.8 m deep for the Probable Maximum Flood (PMF). The area of flooding encompasses the southern portion of the site during the 100 year Average Recurrence Interval, and the entire site during the PMF.

As a result of this local flooding, flood planning level (FPL) requirements for habitable floor levels are elevated significantly above street level as required by the City of Sydney. At the southern portion of the site, the FPL is approximately 1.5 m above the street level, while at the north it is up to 0.8 m above the street. At most locations around the site, the FPL is influenced by the ponding area in Phillip Street.

According to the existing guidelines, the entrances to underground areas such as carparks are also required to be elevated above the PMF (as well as raised to the FPL) under the City of Sydney *City of Sydney Interim Floodplain Management Policy* (2014). Due to the local topography, carpark entrances are favoured to be in Kettle Street or northern part of the Walker Street where the street elevation is the highest. The entrance to the underground areas would still need to be approximately 1.5 m above the street level.

The extensive ponding noted during the PMF also presents evacuation concerns. The depth potentially exceeds the stability thresholds for even large vehicles. As a result, residents will be required to either shelter in place or move to an area above the PMF within the building. Suitable facilities will be required to support this.

Stormwater

The strategy from MUSIC modelling suggests using stormwater filter cartridges, a mix of gross pollutant traps and rainwater tanks to achieve the relevant stormwater quality requirements. A rainwater tank is to be used for (at minimum) outdoor and irrigation water demands which will provide at-source stormwater controls along with a landscaping and a green roof. Additionally, an integrated water cycle management approach may be adopted for the site in order to maximize stormwater harvesting, reuse and recycle to achieve desirable outcomes for a highly green and sustainable development. To achieve stormwater quantity management targets, an onsite stormwater detention basin is also required.

Planning Proposal Requirements

Based on the investigations undertaken, relevant Planning Proposal Requirements have been satisfied for the concept level Reference Scheme with detailed design development related investigations identified in the report wherever appropriate. Considering the buildings can be safely occupied, flooding risks at Elizabeth Street site can be mitigated using appropriate FPLs, setbacks and emergency response frameworks and WSUD measures can be readily implemented for water quality

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enhancement, the site is suitable to be a mixed-use development comprising residential, commercial, open spaces and community facilities.

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1.0 Introduction

The Flooding and Stormwater Study report has been prepared on behalf of NSW Land and Housing Corporation (LaHC) to accompany a Planning Proposal to be lodged with the City of Sydney (CoS).

This Planning Proposal relates to land at 600-660 Elizabeth Street, Redfern (the Site). The Planning Proposal seeks to rezone the Site to allow redevelopment for a mix of social, affordable and private housing in an integrated residential community. The aims of the Planning Proposal are to rezone the Site to R1 General Residential.

An indicative reference scheme and urban design report has been prepared by Architectus, Silvester Fuller and Tyrell (the Project Team) to support the Planning Proposal and demonstrates how the Site may be redeveloped. The indicative reference scheme comprises:

- Approximately 327 dwellings, with building heights ranging between 6 and 14 storeys;
- A mixed-use development, with over 1,500m^2 of non-residential floor space for local shops, cafes, community space and other services; and
- Three ground floor communal courtyard spaces.

The purpose of the Flooding and Stormwater Study is to provide a flooding and stormwater solution consistent with the overall objectives sought for the Site and meets the CoS Council Planning Proposal Requirements.

The renewal of the site presents itself as a unique opportunity to manage existing flooding issues and improve water quality with an integrated approach, to be delivered as part of the overall urban design of the public realm, providing benefits for both the existing and future local community.

1.1 Planning Proposal Requirements

The Planning Proposal Requirements issued by the CoS Council guide the development of various plans and technical reports in support of the rezoning application. LaHC has commenced the investigations for the preparation of a new planning framework for the site to allow for the development of a mix of new social, affordable, and private housing and other uses.

Of relevance to this study are the following requirements that relate to Water Quality, Flooding and Stormwater summarised in Table 1.

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Table 1 Planning Proposal Requirements

Flooding, Stormwater and Water Quality, Contamination and Geotechnical Analysis	Addressed in Section
In accordance with study requirements issued by DPIE and to address matters under s3.33 of the EP&A Act 1979, including: • Assessment of the local soil, outlining its suitability for the proposed uses with respect to erosion, salinity and acid sulphate soils.	Addressed in separate report
• Assessment of the proposed land uses in accordance with State Environmental Planning Policy No 55 – Remediation of Land (SEPP 55).	Addressed in separate report
• Survey for underground infrastructure beneath the site and provide an assessment of impacts on the proposed development. If relocation of services is required, outline the scope of this work.	Addressed in separate report
• Develop a flood risk assessment for the site, with reference to the City of Sydney's Interim Floodplain Management Policy and all relevant flood studies.	6.0, 8.0
• Demonstrate built form massing and sensitive uses, provide reference to 5% Annual Exceedance Probability, 1% Annual Exceedance Probability and Probable Maximum Flood mapping and data.	6.0, 7.0
• Develop a Water Sensitive Urban Design (WSUD) to meet the objectives of: o Capturing and slowing down water movement during heavy downpour events o Capture rainwater for use on the site to reduce use of potable water	7.0, 7.1
Notes: • *In cases where land is potentially contaminated, the investigation and any remediation and validation work is to be carried out in accordance with guidelines made or approved by the EPA under Section 105 of the Contaminated Land Management Act 1997 and be in accordance with the requirements and procedures in the Contaminated Land Management Act 1997, Contaminated Land Management Regulation 2013 and SEPP 55.* • *The proposal should demonstrate how it can meet the water quality requirements of Sydney DCP 2012:* o *Reduce the baseline annual pollutant load for litter and vegetation larger than 5mm by 90%* o *Reduce the annual pollutant load for total suspended solids by 85%* o *Reduce the baseline annual pollutant load for total phosphorus by 65%* *Reduce the baseline annual pollutant load for total nitrogen by 45%*	7.1 and 7.2

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2.0 Overview of the Project

2.1 Study Area

The precinct located at 600-660 Elizabeth Street, Redfern (the site) includes government-owned land of state importance for delivering government policies relating to jobs, homes, and the provision of social and affordable housing in an inner-city location and close to existing and future public transport.

LaHC has initiated a rezoning investigation and Planning Proposal Requirements have been developed in collaboration with CoS Council and other government agencies. The requirements outline a range of investigations needed to analyse the potential impact of any planning control changes.

The project involves the residential redevelopment of the site which occupies a discrete block bounded by Kettle Street (north) and Phillip Street (south) each with 70m frontages, and Walker Street (east) and Elizabeth Street (west) each with 146m frontages (Figure 1). Located approximately 3km south of Sydney CBD in the suburb of Redfern, the precinct is entirely within the City of Sydney local government area (LGA) and has a gross site area of 10,850 sqm. The site is part of the wider social housing estate at Redfern in the vicinity of the Waterloo State Significant Precinct.

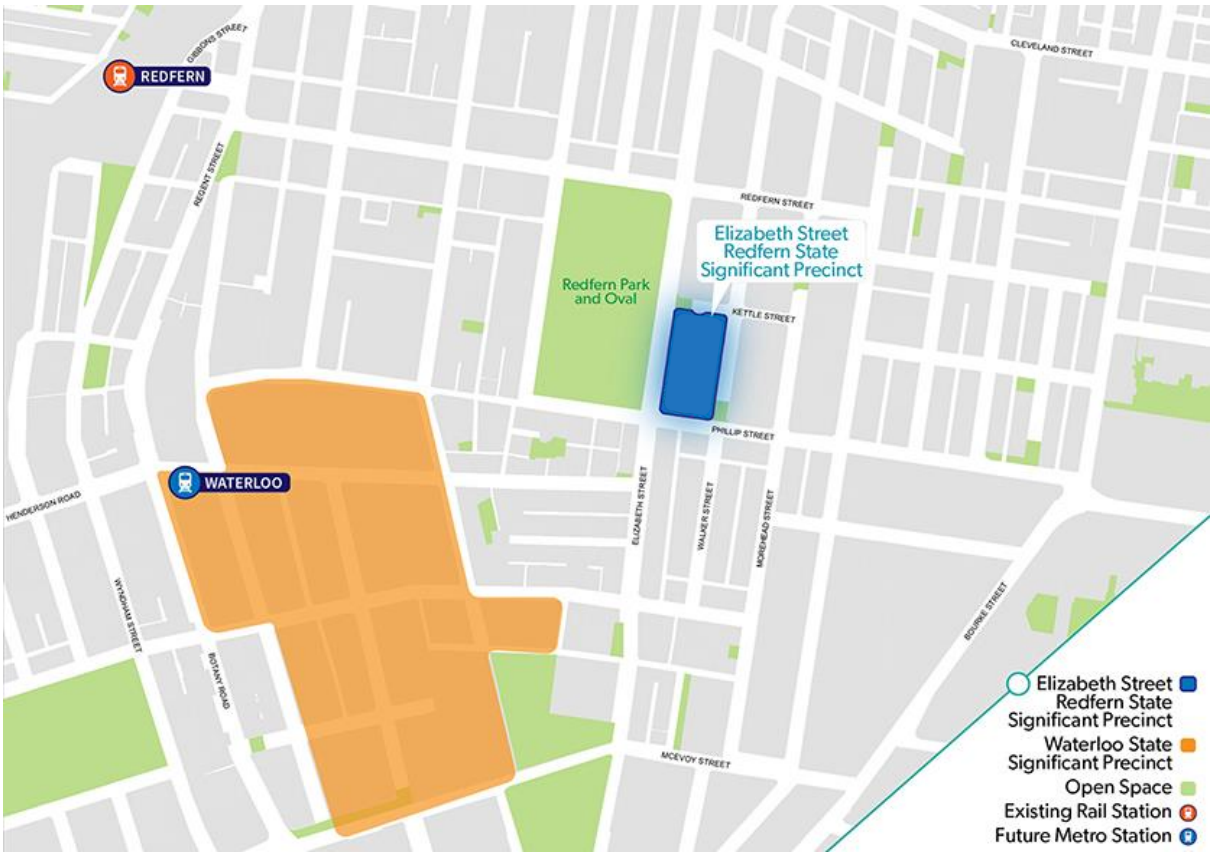

Figure 1 Map of Elizabeth Street, Redfern State Significant Precinct

2.2 Site context

The precinct is located opposite Redfern Park and Oval, and currently comprises two thirds of vacant land with some mature trees and the remaining third portion, at the southern end, is occupied by facilities including a building currently leased to the Police Citizens Youth Club (PCYC) and occupied by the South Sydney Aboriginal Corporation Resource Centre (refer to Figure 2).

Redfern train station is located approximately 900m to the east-north-east of the site, and the future Waterloo Metro station approximately 700m to the east. The site is currently directly serviced by the

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301, 302, 303, 343, 355 and M20 bus routes, with a southbound bus stop on the Elizabeth Street boundary. These routes connect the site with Sydney CBD, North Sydney and Chatswood to the north, with Waterloo, Zetland, Roseberry, Mascot and Botany to the south, with Newtown and Marrickville to the west, and with Moore Park and Bondi Junction to the east.

Figure 2 Aerial photograph of the site[1]

The vacant land was previously occupied by eighteen duplexes, until their demolition in mid-2013 (refer Figure 3). While the site is still in the planning phase it is expected to deliver approximately 327 dwellings, of which up to 30% could be allocated to be social housing.

Figure 3 Aerial imagery 600-660 Redfern taken 30/3/2013 (left) and 6/11/13 (right)[2]

[1] Land and Housing Corporation, *Communities Plus Industry Briefing* presentation, 27 February 2018.
[2] Google Earth v7.3.2.5491

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2.3 Key Considerations for the proposed development

To arrive at a flooding and stormwater solution for the site, a number of baseline investigations were undertaken and the following key considerations inform the overall strategy for the site:

- Historical flooding issues around the site create development constraints. The site is part of Alexandra Canal catchment
- Water quality improvement for stormwater discharged into the Alexandra Canal / Sheas Creek, a tributary of the Cooks River, in line with NSW Water Quality Objectives.
- Sustainability and climate change adaptation measures, including Water Sensitive Urban Design, for a green and resilient urban development.

2.4 Alexandra Canal Floodplain Risk Management Study

In 2014 the City of Sydney commissioned the *Alexandra Canal Floodplain Risk Management Study and Plan* (Cardno 2014) for the Alexandra Canal Catchment. The overall objective of the Floodplain Risk Management Study and Plan was to devise a strategy that addresses the existing, future and continuing issues in the Alexandra Canal catchment in accordance with the NSW Government's Flood Policy, as detailed in the *NSW Floodplain Development Manual* (NSW Government, 2005).

The 2014 report identified that the majority of flooding within the Alexandra Canal catchment is characterised by overland flow with critical storm durations between 1 and 3 hours across the catchment, and the peak of the flood reached approximately 30 minutes to 1 hour after the start of the storm. This is considered short duration "flash" flooding. The short period of time between the onset of extreme rainfall and overland flows occurring does not allow sufficient time to evacuate all residents from their properties.

While the site is located centrally in the Sheas Creek sub-catchment (Figure 4), it is close to the sub-catchment boundary in an area that is noted to be flood prone.

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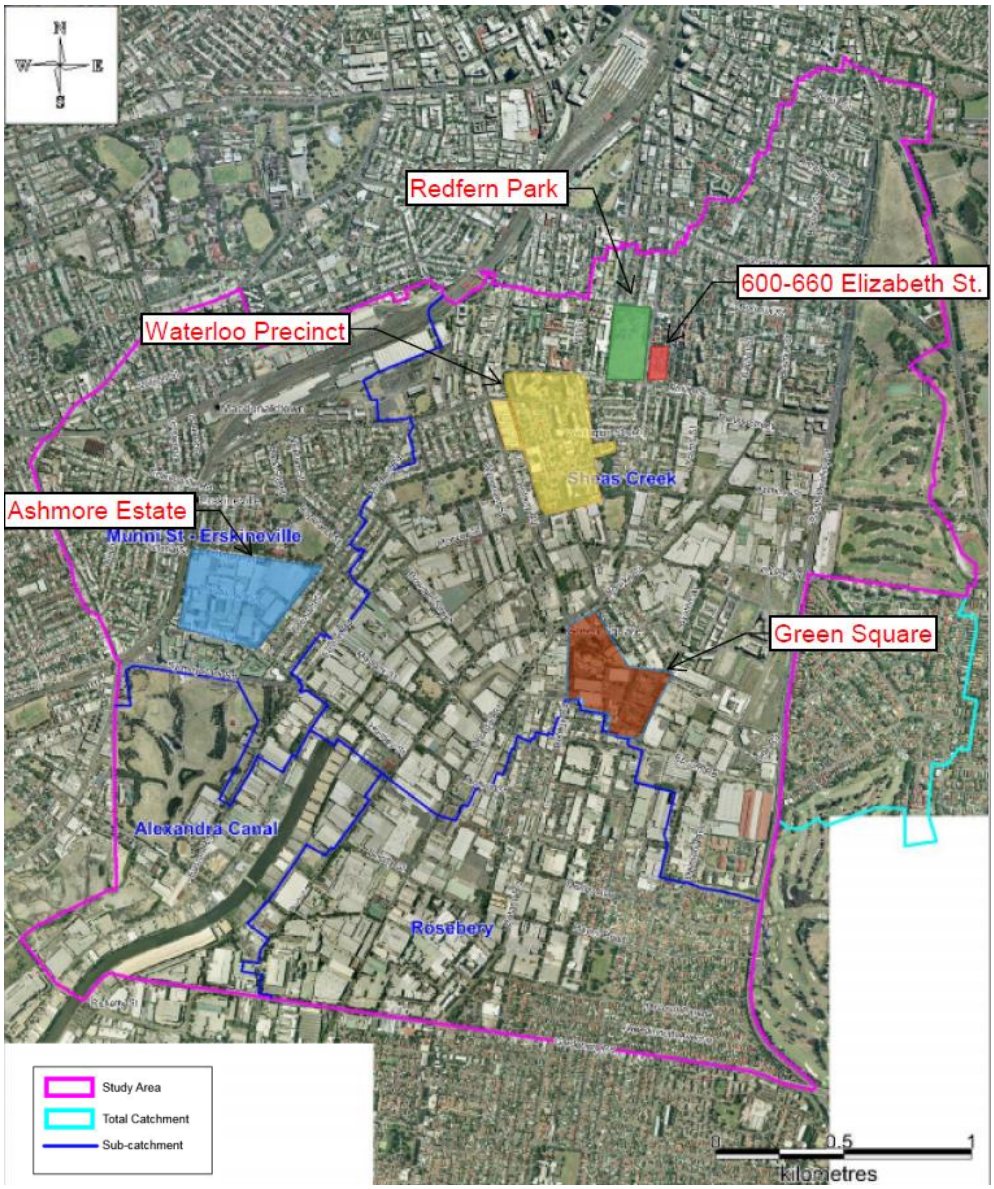

Figure 4 Alexandra Canal Floodplain Risk Management Study extents and catchment delineation

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3.0 Flooding Context

3.1 Catchment Characteristics

The site forms part of the Sheas Creek sub-catchment for the Alexandra Canal. The majority of the Sheas Creek sub catchment is fully developed and consists of a range of development types including medium to high-density housing, commercial and industrial development with some large open spaces and recreational parklands. The catchment is however characterised by a high degree of established urbanization.

The site measures approximately 1.1 hectares and represents less than 1% of the overall 775 hectares Sheas Creek sub-catchment area. Preliminary analysis suggests that the effective site catchment is delineated by a topographical ridge line extending from the intersection of Redfern Street and Pitt Street to the north and the intersection of McEvoy Street and Elizabeth Street to the south. The site is located at a trapped low point as shown Figure 5.

3.2 Existing Drainage Networks

The formal drainage systems around the site area consist of overland flow paths, the road kerb and gutter systems, local piped drainage system owned and maintained by the City of Sydney and a trunk drainage system. The trunk drainage system is owned by Sydney Water Corporation and discharges to Sheas Creek, which is a tributary of the Alexandra Canal, which itself is a tributary of the Cooks River.

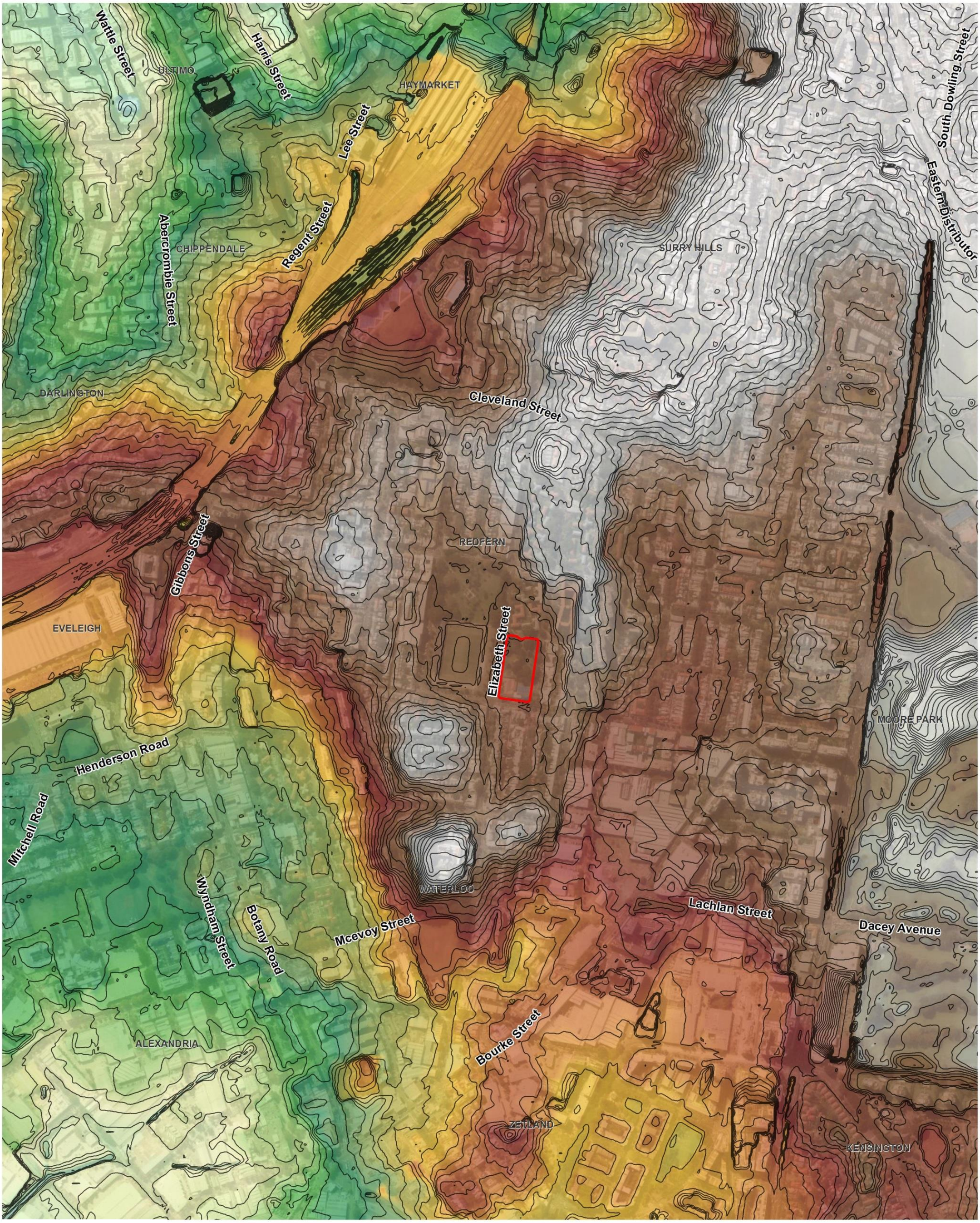

Figure 5 Site topography

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0 125 250 m

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KEY

- Site boundary
- 1m contour

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3.3 Historical Flooding Issues

A local resident and landowner questionnaire was distributed to over 7,000 known flooding areas within the Alexandra Canal Catchment area as part of the *Alexandra Canal Floodplain Risk Management Study* commissioned by City of Sydney in 2014 (Cardno, 2014).

The area in which the site is located is known for historical flooding issues. The images shown in Figure 6 show such an instance of a flash flood in February 2017, which severely disrupted traffic operations. In particular, water has accumulating in trapped low points and is unable to drain via the underground drainage system.

Figure 6 Chalmers Street (Left), Intersection of Chalmers and Redfern Street (Right)

Source: Social Media and The Guardian, February 2017

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4.0 Development Proposal

600-600 Elizabeth Street, Redfern will be transformed into a market leading build-to-rent redevelopment featuring contemporary urban and architectural design and creating a high-quality integrated community of social, affordable and private housing.

4.1 Communities Plus Build to Rent

Communities Plus is a key program under NSW Government's *Future Directions for Social Housing in NSW*, delivering integrated social, affordable and private housing by partnering with the private and not for profit sectors including registered Tier 1 or Tier 2 Community Housing Providers (CHPs).

The Redfern project aligns with Future Directions, by providing innovative options for private sector investment in social housing under a long term lease. The project presents an opportunity to renew and increase social housing in a well-located integrated community with good access to education, training, local employment, and close to community facilities such as shopping, health services and transport.

On 6 July 2018, the NSW Government announced the Site as the pilot for Communities Plus build-to-rent. The Project provides an opportunity for the private sector, in partnership with the not-for-profit sector, to fund, design, develop and manage the buildings as rental accommodation under a long-term lease.

Build-to-rent is a new residential housing delivery framework that is capable of providing access to broader housing choices. Established in overseas markets such as the UK and the USA, locally, build-to-rent has significant scope to provide increased rental housing supply and the opportunity for investment in residential housing in NSW.

4.2 Vision, Reference Scheme and Planning Framework

The study has been prepared to formulate and assess a suitable suite of planning controls to guide the redevelopment of the Site. A design, technical analysis and consultation process was undertaken to prepare a reference scheme which indicates how the future public domain, building form and connections could be delivered. The reference scheme (shown at Figure 7) balances the challenges and opportunities of the Site, particularly the desire to deliver high quality urban design while providing new and modern social housing in an integrated mixed tenure environment.

The reference scheme was prepared to indicate how the Site could, rather than will, be redeveloped and has been used as a basis to prepare draft amendments to the Sydney Local Environmental Plan 2012 (including zoning, height, floor space ratio and car parking controls) and the development of a new site specific Development Control Plan which will guide the detailed design of the Site.

The proposed planning framework has regard to:

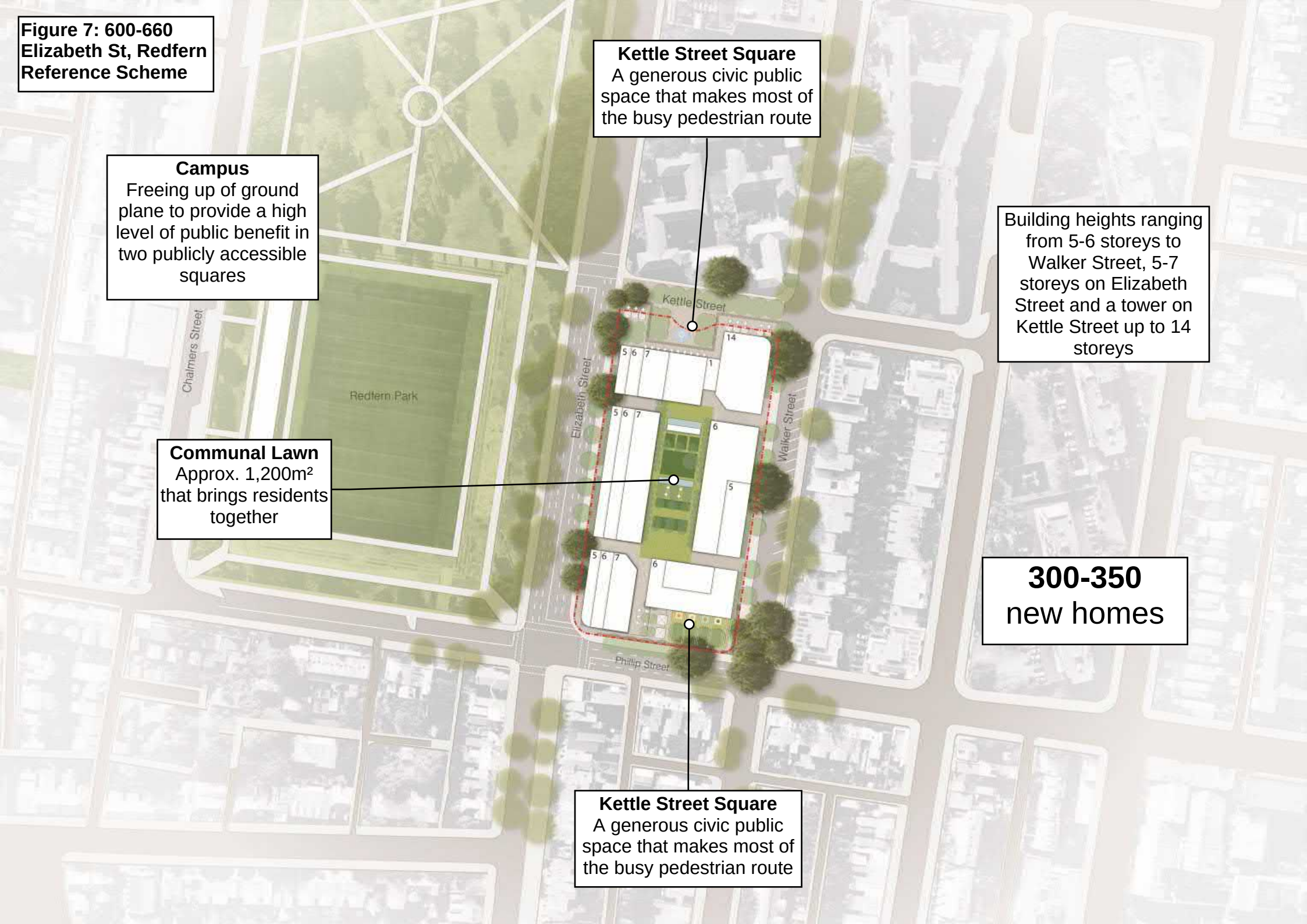
- accessibility and connectivity of the Site to public transport, employment, shops, education and other services,
- the site and local area's rich history and cultural significance,
- the surrounding urban form and context, and
- the environmental and servicing considerations, including flooding, stormwater, traffic, utilities, noise, air quality and wind.

The proposed planning framework will guide future development applications for the Site which are anticipated to achieve the following:

- Approximately 327 dwellings, with a maximum floor space ratio of 2.75:1;
- Buildings with a predominant height of 6 to 7 storeys with a single tower up to 14 storeys; and
- Some supporting retail and communal floor space to support the incoming population.

It is expected the Site will be developed over a period of three years, once the site has been rezoned.

Figure 7: 600-660 Elizabeth St, Redfern Reference Scheme



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4.3 Stormwater and Flood Assessment

For flexibility the stormwater and flooding assessment was based on an assumption that the proposed development will result in maximum imperviousness and will block out the site to completely remove the area from the floodplain as confirmed with the City of Sydney.

This provides a conservative assessment that maximises the envelope of possible development. For the purpose of flooding and stormwater assessment, the differences between the three proposed designs would not have a significant impact on the preliminary hydrology and hydraulic assessment. In this report, all the design options were assessed as one condition where the site will be almost 100% impervious and will completely block out the site from the floodplain for the developed condition.

The WSUD approach adopts a modular stormwater filtration solution that can be allocated and scaled between various building and landscape configurations. In this way, the WSUD strategy demonstrates that the stormwater management approach can achieve the targets without constraining development patterns or burdening public areas.

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5.0 Design Criteria

The development is located in the City of Sydney local government area. The assessment is based on the City of Sydney requirements. The development needs to also comply with existing emergency response plans so that the residual risk associated with flooding can be managed across the site and the wider LGA.

5.1 Planning Proposal Requirements

On December 2019, the CoS Council issued Planning Proposal Requirements for the site that guides the matters for consideration. Those listed in Table 1 of this report have been considered in this report.

5.2 City of Sydney Development Control Plan 2012

The City of Sydney Development Control Plans (DCPs) provide detailed planning and design guidelines to support the planning controls throughout the local government area. These plans include the management of stormwater. The DCP requirements are outlined in Section 3.7 of the C*ity of Sydney Development Control Plan 2012* (City of Sydney 2012).

Specific key requirements in the DCP which relate to stormwater include:

- A site-specific flood study should be prepared to support the development of the site;
- The connection to the existing stormwater network is not to reduce the capacity of that infrastructure by more than 10%; and
- Post development run-off is to be managed in accordance with the principals of WSUD. These principals include stormwater source measures that: contain frequent low-magnitude flows; remove some pollutants prior to discharge into receiving waters; prevent nuisance flows from affecting adjacent properties; and enable appropriate use of rainwater and stormwater.

5.3 City of Sydney Interim Floodplain Management Policy

The *Interim Floodplain Management Policy* has been developed by the City of Sydney (2014) to document the requirements for the management of flood risk for all new developments within the City's LGA. City of Sydney has a responsibility to manage floodplains to ensure that any:

- New development will not experience undue flood risk; and
- Existing development will not be adversely flood affected through increased damage or hazard as a result of any new development.

Table 2, extracted from the *Interim Floodplain Management Policy* (City of Sydney, 2014), describes the permissible minimum building floor levels and below ground development Flood Planning Levels (FPLs) for the site development. Considering the flood conditions surrounding the site, the majority of the site would be subject to FPL of the 100 year ARI + 0.5 m (corresponding to mainstream flooding) in Table 2.

However, it may be possible to adopt a FPL corresponding to local drainage flooding for some portions of Kettle Street as well as the northern portions of Walker Street and Elizabeth Street. The depth of flow in the 100 year ARI flood is less than 0.25 m. In these areas it may be possible to reduce the FPL to twice the depth of flow, or 0.3 m (whichever is greater).

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Table 2 Flood Planning Level Criteria for the site (*Interim Floodplain Management Policy, City of Sydney 2014*)

Development Type		Type of Flooding	Flood Planning Level	Comments
Residential	Habitable rooms	Mainstream flooding (flood depth greater than 0.25 m)	100 year ARI flood level + 0.5 m	
		Local drainage flooding (flood depth less than 0.25 m)	100 year ARI flood level + 0.5 m or Two times the depth of flow with a minimum of 0.3 m above the surrounding surface if the depth of flow in the 100 year ARI flood is less than 0.25 m	
	Non-habitable rooms such as a laundry or garage (excluding below-ground car parks)	Mainstream or local drainage flooding	100 year ARI flood level	
Industrial or Commercial	Retail Floor Levels	Mainstream or local drainage flooding	Merit approach presented by the applicant with a minimum of the 100 year ARI flood. The proposal must demonstrate a reasonable balance between flood protection and urban design outcomes for street level activation.	
Below ground garage/ car park	All other below-ground car parks	Mainstream or local drainage flooding	100 year ARI flood level + 0.5 m or the PMF (whichever is the higher).	The below ground garage/car park level applies to all possible ingress points to the car park such as vehicle entrances and exits, ventilation ducts, windows, light wells, lift shaft openings, risers and stairwells

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5.4 Design Standards

City of Sydney design standards have generally been assumed for the site development, as the stormwater infrastructure external to the buildings will eventually be dedicated to Council. A summary of each standard, code and other additional documents used in the design of stormwater infrastructure for the development is presented in Table 3. These standards are to be confirmed by later design stages, and included here for reference only.

Table 3 Stormwater Drainage Reference Documents and Standards

Reference Number	Title
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
BBCW IP	Botany Bay & Catchment Water Quality Improvement Plan. Sydney Metropolitan CMA, 2011
NSW FDM	New South Wales Floodplain Development Manual

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5.5 Adopted Design Criteria

The stormwater drainage design criteria for the development were assumed based on the City of Sydney stormwater drainage design requirements as summarised below in Table 4. These will be used to inform the proposed flood mitigation strategies.

Table 4 Stormwater Drainage Design Criteria

Item	Standard	Adopted	Comment
Hydrology			
Hydrological Model	Sydney Streets Technical Specifications: A4 Stormwater Drainage (City of Sydney, 2016)	DRAINS model	Taken from the Alexandra Canal Floodplain Risk Management Study
Minor Design Storm	Sydney Streets Technical Specifications: A4 Stormwater Drainage (City of Sydney, 2016)	20 year ARI	
Major Design Storm	Sydney Streets Technical Specifications: A4 Stormwater Drainage (City of Sydney, 2016)	100 year ARI	
Hydraulics			
Pipe size	Sydney Streets Technical Specifications: A4 Stormwater Drainage (City of Sydney, 2016)	Min. 150mm diameter (Private) Min. 375mm diameter (City)	150 mm pipe diameter is the absolute minimum for pipes located in private property. 375 mm pipe diameter is the minimum for pipes owned by City of Sydney.
Pit spacing	Sydney Streets Technical Specifications: A4 Stormwater Drainage (City of Sydney, 2016)	Max. 40 m (pipes 375 mm to 750 mm dia.) Max. 60 m (pipes 750 mm to 1500 mm dia.) Max. 100 m (pipes greater than 1500 mm)	
Pit losses	Sydney Streets Technical Specifications: A4 Stormwater Drainage (City of Sydney, 2016)	Missouri Charts, (Sangster et al, 1958)	
Pit blockage factors	Sydney Streets Technical Specifications: A4 Stormwater Drainage (City of Sydney, 2016)	Grated Inlet Pits: 90% Kerb Inlet Pits <=1.0 m • On-Grade: 50% • Sag: 70% Kerb Inlet Pits > 1.0 m • On-Grade: 20% • Sag: 50%	Applied to proposed infrastructure
Flood Hazard			
Appropriate Safety Criteria for People	AR&R – Project 10	Max. Depth x Velocity = $0.4 m^2 s^{-1}$	More details provided in ARR 2016 document.

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5.6 Stormwater Quantity Control Requirements

5.6.1 Permissible Site Discharge (PSD) and OSD requirements

Sydney Water, as the responsible authority for the downstream drainage network, advised the required stormwater quantity controls for the 11,000 m^2 site in accordance with the details as summarised in Table 5 (email received on 28 February 2019 and presented in Appendix B).

Further to this, there are a *Sydney DCP 2012* (City of Sydney 2012) requirements that the connection to the existing stormwater network are not to reduce the capacity of that infrastructure by more than 10%; and the post-development stormwater peak discharge event should not exceed the pre-development event.

Table 5 Sydney Water requirements for the 600 – 660 Elizabeth Street, Redfern development

On-Site Detention (m^3)	Permitted Site Discharge (PSD) (L/s)
253	317

5.7 Stormwater Quality Control Requirements

The NSW Water Quality objectives establish ambient water quality targets to protect the community values of waterways.

The water quality objectives do not define discharge standards, and should not be directly applied to stormwater concentrations leaving a development site. Rather, modelling of receiving water bodies is required to establish stormwater management benchmarks for new development.

Conceptual models of stormwater management approaches for development sites (*MUSIC* software), can then be used to demonstrate whether a development will achieve those benchmarks and therefore contribute to meeting the NSW Water Quality Objectives in that catchment.

5.7.1 Botany Bay and Catchment Water Quality Improvement Plan

The site is within the Alexandra Canal and Botany Bay catchments and water quality benchmarks were established by The *Botany Bay and Catchment Water Quality Improvement Plan* which was completed by the Sydney Metropolitan Catchment Management Authority (2012).

5.7.1.1 Risk Based Framework

This Plan predates the Office of Environment and Heritage's Risk Based Framework (the Framework), but the use of an estuary response model to test the impact pollutant load reductions on the ambient water quality is consistent with the catchment management approach prescribed by the Framework.

The *Botany Bay and Catchment Water Quality Improvement Plan* established stormwater pollution reduction benchmarks based on a range of scenarios and improvement options to measure the impact on total nitrogen reduction within Botany Bay over the 2030 and 2070 timeframes. Stormwater pollution reduction benchmarks set for 'large redevelopments' are described in Table 6. Achieving these targets can therefore satisfy the requirements of the Risk Based Framework.

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Table 6 Stormwater Pollution Reduction Targets for Redevelopment in the Botany Bay catchment

Water Quality Parameters	Large Developments (% reduction) (BBWQIP)
Gross Pollutants	90
Total Suspended Solids (TSS)	85
Total Phosphorous (TP)	60
Total Nitrogen (TN)	45

5.7.2 Sydney Development Control Plan 2012

Section 3 of the Sydney Development Control Plan (DCP) requires development sites greater than 1,000 m^2 must reduce the baseline annual pollutant loads as summaries in Table 7.

Table 7 Stormwater Pollution Reduction Targets for Redevelopment in accordance with the Sydney DCP 2012

Water Quality Parameters	Large Developments (% reduction) (Sydney DCP)
Gross Pollutants	90
Total Suspended Solids (TSS)	85
Total Phosphorous (TP)	65
Total Nitrogen (TN)	45

5.7.3 Other relevant guidelines

The stormwater quality management approach required to achieve the benchmarks above will involve integrating WSUD into the proposed stormwater management system. This also reflects the obligations noted in the Planning Proposal Requirements and the approach detailed in the *City of Sydney Decentralised Water Master Plan* (City of Sydney, 2012).

The following documents relevant to WSUD are considered relevant in the overall assessment.

- Local Planning for Healthy Waterways using NSW Water Quality Objectives June 2006
- Managing Urban Stormwater – Harvesting and Reuse Guidelines December 2006

Local Planning for Healthy Waterways Using NSW Water Quality Objectives June 2006

This document outlines a six-step framework for local councils to establish a water quality strategy and collectively contribute to the health of waterways in NSW:

1. Recognizing the community's values for waterways in LEPs – Water quality objectives should be readily included in LEPs and DCPs as high-level objectives to reflect their important in planning decisions.
2. Assessing the current condition of waterways – Councils should consider condition of waterways, key pressured on their health and potential risks to water quality during assimilation of information for their LEPs and DCPs.
3. Identifying significant risks to water quality – Review of existing and potential activities and use of conceptual and predictive models for decision-making.

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4. Identifying zones that protect river corridors, wetlands and sensitive landscapes – Identifying buffer zones of natural vegetation should be a key priority to support water quality objectives and their protection and enhancement should be facilitated through planning controls.
5. Planning for higher risk developments – Identifying sensitive locations that would cause high risk to water quality, establish best land use for designated areas during such assessments.
6. Setting benchmarks for design and best practice – Setting performance benchmarks to minimize impacts on water quality and river health during ongoing activities for development, such as the NSW Building Sustainability Index (BASIX).

Managing Urban Stormwater – Harvesting and Reuse Guidelines December 2006

This guideline outlines the following main considerations for stormwater harvesting and reuse projects, based on experience gained from previous projects:

- Planning – Relevance of the project under consideration within the overarching integrated urban water cycle management strategy.
- Project design – Meeting end-use requirements and treatment of Stormwater to address public health and environmental risks.
- Operations, maintenance and monitoring – Assessing the sustainability of the project and monitoring impacts to public health and the environment.

The following key considerations in the design of stormwater storage are specified in the document:

- Store sufficient water to balance supply and demand, and meet reliability of supply objectives; and
- Design above-ground storages to minimise mosquito habitat (virus control), risks to public safety and risks to water quality (e.g. eutrophication), and address dam safety issues.

The default stormwater quality criteria for managing public health risks for various applications are outlined in

Table 4.5 and Table 6.4 of the guideline extracted below in Figure 8 and Figure 9 respectively. The treatment adopted for a stormwater reuse project should relate to the stormwater quality criteria. Indicative levels of pollution retention for various stormwater treatment measures can be found in Table 6.7 of the document, extracted in Figure 10.

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Table 4.5 Specific management measures for default risk management approach

Application	Access restrictions	Stormwater quality criteria	Specific operational practices
Residential (non-potable)	Nil	Level 1	Above-ground storage design and management Additional plumbing controls
Irrigation of open spaces	Nil	Level 2	Irrigation scheme design and operational controls
	Controlled public access or subsurface irrigation	Level 3	
Industrial	Nil	Level 2	
	Controlled public access	Level 3	
Ornamental waterbodies	Nil	Level 2	
	Controlled public access	Level 3	
Aquifer storage and recovery	Not applicable	Level 3	ASR scheme operational controls

Figure 8 Specific management measures for various applications (Source: Managing Urban Stormwater – Harvesting and Reuse Guidelines Dec 2006)

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Table 6.4 Stormwater quality criteria for public health risk management

Level	Criteria[1]	Applications
Level 1	*E. coli* <1 cfu/100 mL Turbidity ≤ 2 NTU[2] pH 6.5–8.5 1 mg/L Cl_2 residual after 30 minutes or equivalent level of pathogen reduction	Reticulated non-potable residential uses (e.g. garden watering, toilet flushing, car washing)
Level 2	*E. coli* <10 cfu/100 mL Turbidity ≤ 2 NTU[2] pH 6.5–8.5 1 mg/L Cl_2 residual after 30 minutes or equivalent level of pathogen reduction	Spray or drip irrigation of open spaces, parks and sportsgrounds (no access controls) Industrial uses – dust suppression, construction site use (human exposure possible) Ornamental waterbodies (no access controls) Fire-fighting
Level 3	*E. coli* <1000 cfu/100 mL pH 6.5–8.5	Spray or drip irrigation (controlled access) or subsurface irrigation of open spaces, parks and sportsgrounds Industrial uses – dust suppression, construction site use, process water (no human exposure) Ornamental waterbodies (access controls)

[1] values are median for *E. coli*, 24-hour median for turbidity and 90th percentile for pH

[2] maximum is 5 NTU

Source: derived from NSW RWCC (1993), DEC (2004), ANZECC & ARMCANZ (2000)

Figure 9 Stormwater quality criteria (Source: Managing Urban Stormwater – Harvesting and Reuse Guidelines Dec 2006)

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Table 6.7 Indicative levels of pollution retention and outflow concentrations for different stormwater treatment measures					
Stormwater treatment measure	**Suspended solids**	**Total phosphorus**	**Total nitrogen**	**Turbidity**	***E. coli***
Retention					
GPT	0–70%	0–30%	0–15%	0–70%	Negligible
Swale	55–75%	25–35%	5–10%	44–77%	Negligible
Sand filter	60–90%	40–70%	30–50%	55–90%	–25–95% (up to 1.5 log)
Bioretention system	70–90%	50–80%	30–50%	55–90%	–58–90% (up to 1 log)
Pond	50–75%	25–45%	10–20%	35–88%	40–98% (0.5–2 log)
Wetland	50–90%	35–65%	15–30%	10–70%	–5–99% (up to 2 log)

Figure 10 Figure 24: Indicative levels of pollution retention (Source: Managing Urban Stormwater – Harvesting and Reuse Guidelines Dec 2006)

Sustainability Targets and Planning Controls

A number of targets have been developed to inform planning controls with the aim of achieving sustainable outcomes for the Elizabeth Street, Redfern precinct.

For each target, two sets of goals have been identified for the following purposes:

- A '*minimum goal'* is nominated to outline minimum commitments for master planning and planning approvals;
- A *'stretch goal'* is nominated to guide property developer/tenderer options and enable a point of sustainability differentiation among developers/tenderers.

The following targets have been set based on the *Sydney DCP 2012* (City of Sydney 2012) to ensure best practice stormwater management measures are implemented and potable water demand is reduced to best practice levels in the precinct:

- Post-development stormwater peak discharge event does not exceed the pre-development event;
- Minimum Goals is to reduce stormwater pollutant load when compared to untreated by: 85%; for Total suspended solids, 65% for total phosphorous; 45% for total nitrogen; and 90% for gross pollutants
- Stretch Goals is to reduce stormwater pollutant load when compared to untreated by: 90%; for Total suspended solids, 85% for total phosphorous; 65% for total nitrogen; and 90% for gross pollutants
- BASIX Water target of 40.

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6.0 Preliminary Flood Analysis

To support the redevelopment of the site, a flood impact assessment has been undertaken. For this report, the modelling has been used to establish the existing case conditions and to undertake an initial flood impact assessment. This should be revisited during the detailed development application stage.

6.1 Methodology

AECOM has adopted the TUFLOW model for *The Alexandra Canal Catchment Flood Study* (Cardno, 2014) as the basis for undertaking the flood study. As part of this project, a number of modifications have been made to the model to produce representative results for existing conditions noting changes or modifications that may have occurred in the catchment since the completion of the flood study. Modifications to the model have included:

- Modifying the existing building outline polygons to represent the current building footprints as shown in recent aerial photographs.
- Updating relevant Manning's roughness layer to represent latest conditions around the site.
- Refining the catchment inflows to provide a better representation of flow paths on the site and enable the AECOM DRAINS model to be used to represent the drainage on the site.
- For the developed case scenarios, blocking out the site to completely remove the area from the floodplain. This provides a conservative assessment that includes the envelope of possible development.
- Undertaking a number of other minor adjustments to improve the numerical stability of the TUFLOW model.

For the 100 year ARI and PMF events, the TUFLOW model was run for a range of durations as outlined in the Alexandra Canal Catchment Flood Study (Cardno 2014). For the 100 year ARI events, 60 and 90 minute events were identified as being critical, while the 180 minute duration is critical for for the PMF event at the area of interest. For this project, flood levels are taken as an envelope of maximum levels resulting from all storm event durations.

In addition, a provisional post-development flood conditions and impact assessment has been undertaken which should be revisited during the detailed development application stage.

6.2 Modelling Results for Existing Conditions

From the mapping of existing case flooding, it can be seen that there is a significant area of ponding on Phillip Street between the intersection of Elizabeth Street and Morehead Street, with flooding extending further downstream on Walker Street and to a lesser extent, Beaumont Street (Figure 11). Flood level contours indicate that this is a single pool of water associated with the low point in the topography (Figure 12). The peak ponding depth on Phillip Street is approximately 0.9 m. This ponding is the result of significant catchment flows coming from Chalmers Street, Elizabeth Street and Walker Street from the north.

During extreme events, such as the PMF, flood depths are greater and the area of flooding surrounds the entire site (Figure 13). As with the 100 year ARI, the flood level contours (Figure 14), this is a single area of ponding. Flood depths of up to 2.4 m are noted around at the low point in Phillip Street.

The results of the preliminary flood analysis highlight a number of constraints. The primary constraint pertains to the site's location, as highlighted in Section 3.1 it lies in the bottom of a trapped low point. As such, stormwater is not able to escape the catchment west of Morehead Street and pools in this low point.

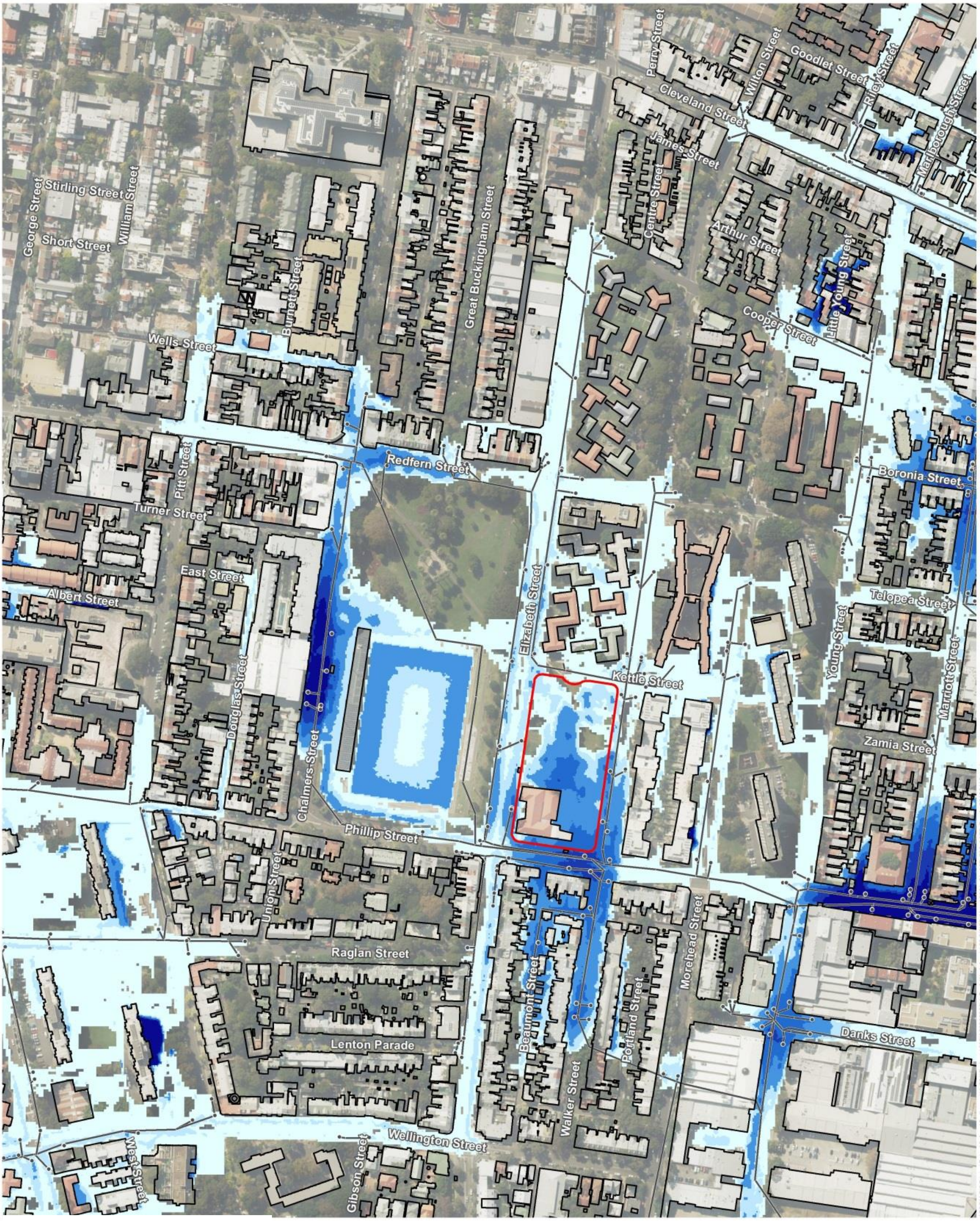

Figure 11 Existing case 100 year ARI peak flood depth

KEY

- Site boundary
- Building outline
- Stormwater inlet
- Stormwater pipe

Peak Flood Depth (m)

- < 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- > 1

AECOM

0 25 50 100 m

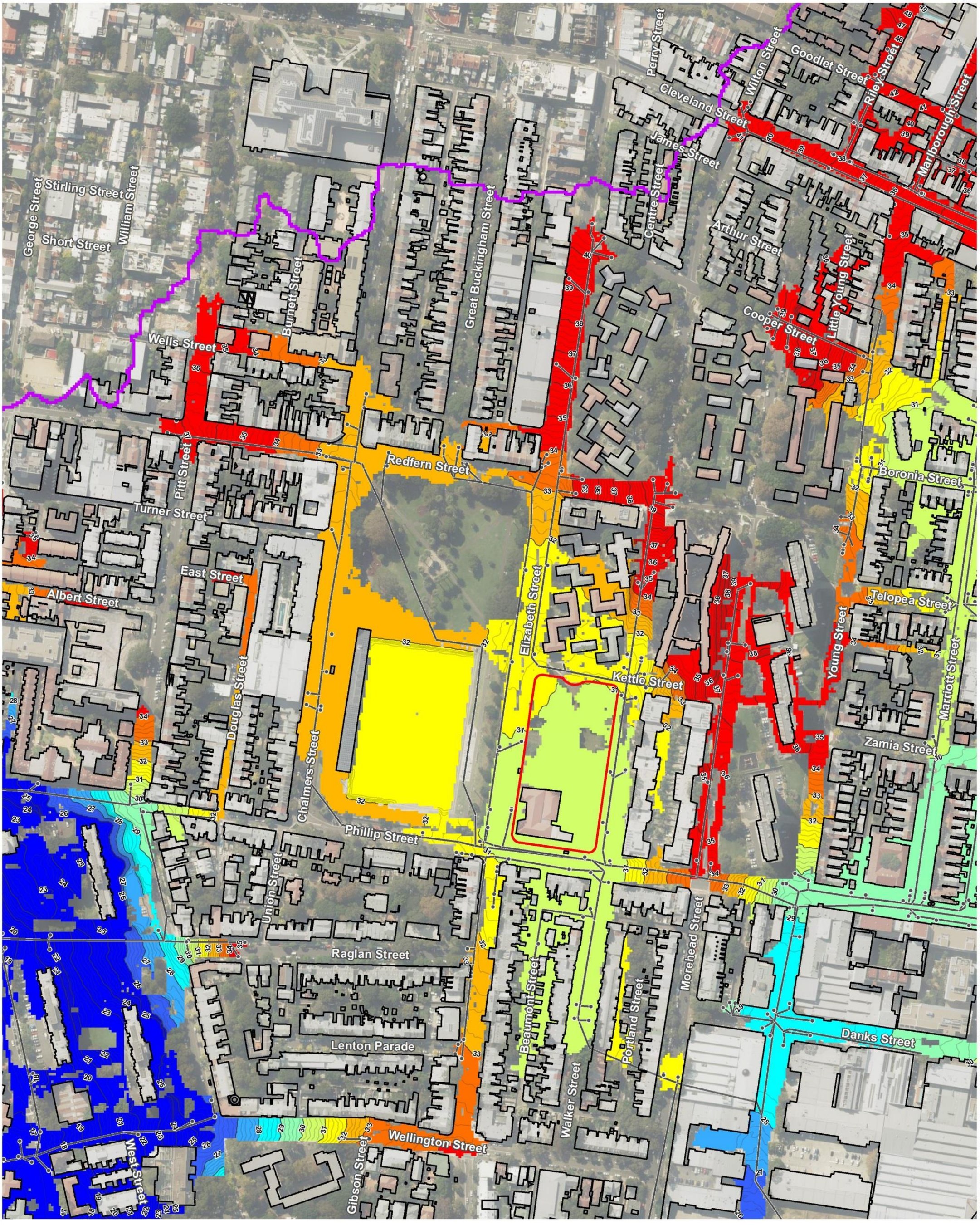

Figure 12 Existing case 100 year ARI peak flood level

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Figure 13 Existing case PMF peak flood depth

KEY

- Site boundary
- Building outline
- Stormwater inlet
- Stormwater pipe

Peak Flood Depth (m)

- < 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- > 1

AECOM

N 0 25 50 100 m

Figure 14 Existing case PMF peak flood level

KEY

- Site boundary
- Model extent
- Building footprint
- Stormwater inlet
- Stormwater pipe
- 1m flood level contour
- 0.2m flood level contour

Flood Level (m AHD)

- < 26
- 26 - 27
- 27 - 28
- 28 - 29
- 29 - 30
- 30 - 31
- 31 - 32
- 32 - 33
- 33 - 34
- > 34

AECOM

0 25 50 100 m

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6.3 Flood Conditions of Reference Scheme

The existing case flood model was modified to simulate the post-developed site condition by blocking out the entire development site. This development scenario simulates the impact of filling the entire site above the 100 year ARI and PMF flood levels or building out to the maximum development footprint. This scenario is conservative but demonstrates the maximum development outcome where all areas of the site are utilised by flood free development.

The resulting flood conditions are shown in Figure 15 and Figure 16 for the 100 year ARI, and Figure 17 and Figure 18 the PMF event. As with the existing conditions, there is a significant area of ponding on Phillip Street between the intersection of Elizabeth Street and Morehead Street, with pooling extending further downstream on Walker Street and to a lesser extent, Beaumont Street. The peak ponding depth on Phillip Street is approximately 0.9 m during the 100 year ARI. This ponding is the result of significant overland flows coming down Chalmers Street, Elizabeth Street and Walker Street from the north.

6.3.1 Flood Impacts of Reference Scheme

Provisional flood impacts during the 100 year ARI are presented in Figure 19. Due to the removal of flood storage at the site under the modelled scenario, peak flood levels are impacted within the vicinity and downstream of the site, namely on Phillip Street, Walker Street, and Beaumont Street. The provisional flood impact show peak impacts between 0.1 m to 0.2 m.

By developing the entire footprint as shown in Figure 19, either through the provision of a large building footprint or podium landscaping above the 100 year ARI flood level, approximately 3200 m^3 of floodplain storage is displaced resulting in a net loss of flood storage and potential impacts on flood levels within adjacent streets. The flood models also indicate that the entire footprint will provide an obstruction to the overland flow passing across the site, resulting in deeper zones of flood water flowing around the site. Preliminary modelling tested the flood impacts associated with the site completely blocked out, which is the worst case development scenario for flooding.

As the flood impacts affect surrounding properties and streets, these flood impacts are not acceptable since the *Sydney DCP 2012* (City of Sydney 2012) requires that the impact of stormwater and flooding on other developments and the public domain both during the event and after the event be minimised. The DCP also requires that any impacts address public safety and protection from flooding. As the flooding potentially increases the number of properties with over floor flooding, and would potentially increase the extent of hazardous flood conditions, these flood impacts would be deemed unacceptable under the DCP.

A combination of flood storage and flood conveyance through the site is likely to be necessary to remove flood impacts on neighbouring sites.

Figure 15 Developed case 100 year ARI peak flood depth

KEY

Site boundary
Building outlines
Stormwater inlet
Stormwater pipe

Peak Flood Depth (m)

< 0.1
0.1 - 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
> 1

AECOM

0 25 50 100 m

Figure 16 Developed case 100 year ARI peak flood levels

KEY

- Site boundary
- Model extent
- Building footprint
- Stormwater inlet
- Stormwater pipe
- 1m flood level contour
- 0.2m flood level contour

Flood Level (m AHD)

- < 26
- 26 - 27
- 27 - 28
- 28 - 29
- 29 - 30
- 30 - 31
- 31 - 32
- 32 - 33
- 33 - 34
- > 34

AECOM

0 25 50 100 m

Figure 17 Developed case PMF peak flood depths

KEY

Site boundary
Building outlines
Stormwater inlet
Stormwater pipe

Peak Flood Depth (m)
< 0.1
0.1 - 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
> 1

AECOM

0 25 50 100 m

Figure 18 Developed case PMF peak flood level

KEY

Site boundary
Model extent
Building footprint
Stormwater inlet
Stormwater pipe
1m flood level contour
0.2m flood level contour

Flood Level (m AHD)
< 26
26 - 27
27 - 28
28 - 29
29 - 30
30 - 31
31 - 32
32 - 33
33 - 34
> 34

AECOM

0 25 50 100 m

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Figure 19 Provisional 100 year ARI flood level impacts without mitigation works

KEY

- Site boundary
- Building outline
- Stormwater inlet
- Stormwater pipe
- Was wet, now dry
- Was dry, now wet

Provisional Impact (m)

- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.2
- > 0.2

AECOM

N 0 25 50 100 m

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6.3.2 Potential Mitigation Measures for the Proposed Development

To offset the potential flood impacts, mitigation measures will likely comprise a combination of on-site detention, compensatory floodplain storage and conveyance works that minimise or counteract the impact of obstructions placed within the existing flow paths across the site. The optimal combination of works can be determined at the development application stage through iterative design modelling by testing underground detention tanks, appropriate building set-backs in zones of high flowing water or potentially retaining overland flow paths through the site by integrating flow paths within landscaped areas.

Preliminary testing indicated that a flood storage volume of approximately 3200 m^3 will be require to off-set the noted flood impacts shown in Section 6.3 above. The storage should be located at a level lower than the 100 year ARI flood level and above the downstream invert level. The mitigated case flood impact assessment is shown in Figure 20.

Additionally, some drainage improvements will be required along Elizabeth Street, Kettle Street and Walker Street, to compensate for the loss of the overland flow paths across the site. These requirements will also require consideration as part of the detailed design. A simplified representation of these features is included in the preliminary flood assessment.

Opportunities to maximise the development outcomes of the site are further discussed in Section 7.0.

6.3.3 Flood Planning Level and Property Breach Points

Buildings within the site will need to be designed to account for the internal flood risks during rare floods such as the 100 year ARI in the streets surrounding the site. Proposed entry levels and minimum habitable flood levels will be raised to ensure that the risk of floodwater breeches from significant storm events at the building entrances is manageable. From Table 2 the minimum breach points and FPLs are:

- FPL will be 100 year ARI flood level + 0.5 m freeboard for entrances to habitable areas
- 100 year ARI flood level to above ground carparks;
- Where the depth of flow is less than 0.25 m, the FPL may be reduced to twice the flow depth, or at least 0.3 m, above the 100 year ARI flood level; and
- FPL will be 100 year ARI flood level + 0.5 m or the PMF (whichever is the higher) for below ground garages and carparks.

From the developed case flood level contours shown in Figure 16, habitable flood levels will need to be at or above approximately 31.3 m AHD for most locations around the perimeter of the site in order to be 0.5 m above the 100 year ARI. Entrances to underground areas will need to be at or above the PMF levels shown in Figure 17, which is at 32.7 m AHD.

A detailed discussion of site constraints is provided in Section 7.0.

Figure 20 Provisional 100 year ARI flood level impacts with mitigation measures in place

KEY

- Site boundary
- Building outline
- Stormwater inlet
- Stormwater pipe

Provisional Imapct (m)

- < -0.5
- -0.5 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.2
- > 0.2
- Was wet, now dry
- Was dry, now wet

AECOM

N 0 25 50 100 m

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6.4 Emergency Response

Potential emergency response measures have been considered to assist in reducing the consequences of flood risks. For the site, this will primarily rely on adopting an appropriate Flood Planning Level (FPL), and ensuring that developments are sufficiently raised to enable a shelter in place strategy to be effective. The FPL requirements are discussed in Section 6.3.3.

During infrequent and rare flood events, potentially hazardous flood conditions will temporarily impede emergency vehicles from accessing the site, as flood depths exceed 1 m around the site perimeter during extreme events such as the PMF. Access will be dependent on the flood conditions in the surrounding streets, as well as the judgment of the vehicle operator. The flooding is expected to recede within a few hours, even for rare and extreme events. Isolated flooding may remain throughout the catchment that take longer to recede, and these may contribute to traffic issues.

In the case of this site, the flood hazard is most appropriately managed for residents with a shelter in place strategy, as the duration of inundation is relatively short and the rate of rise is relatively rapid. Residents located below the PMF level will need to evacuate to an area above the PMF level within the buildings in order to safely respond to flooding in the surrounding area. This may be achieved by providing a common area that is sufficiently elevated to remain flood free. The effectiveness of this approach should consider that the residents' evacuation is often subject to significant stress, and that some residents may need to be housed above the PMF level. Residents may remain isolated within the site for several hours until flood waters recede to depths that are trafficable by emergency vehicles.

Any residual risks to the residential areas will require an operational flood emergency response plan, and should be supported with appropriate design features. Future work should be undertaken to:

- Develop an operational flood emergency response plan. The plan will, at a minimum, confirm the most appropriate response strategy, nominate shelter locations or muster points, plot the recommended evacuation routes, consider the timeline to execute the plan, identify trigger conditions for initiating the plan, and assign specific responsibilities;
- Provide appropriate facilities and shelter spaces to support the response strategy; and
- Consult the local State Emergency Service (SES) and other emergency services.

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7.0 Preliminary Stormwater Analysis

7.1 Stormwater Quality Management

Available site information, climate data and relevant guidelines were reviewed to develop a conceptual WSUD model using MUSIC software. Modelling provides an assessment of pollutant load reductions and a comparison against stormwater pollutant loads from the existing site.

To setup the model, source nodes were setup using the default values adopted from the *NSW MUSIC Modelling Guidelines* (August 2015). Table 8 summarises the catchments as modelled in MUSIC.

Table 8 Summary of Source nodes as modelled in MUSIC for the existing and developed scenarios

Scenario	Land use	Total Area (ha)	Adopted MUSIC Node Type	Imperviousness
Developed	Roof	0.9	Roof	90%
	Landscape	0.2	Paved roads and paved landscape	100%
Existing	Roof	0.15	Roof	100%
	Landscape	0.95	Paved roads and paved landscape	50%

7.1.1 Rainwater Harvesting

As part of at-source stormwater control assessment, a preliminary water balance was also carried out for the site to determine the potable and non-potable water demands for the site, and identify the potential for rainwater harvesting. Annual water usage was adopted to be consistent with the City of Sydney Decentralised Water Master Plan.

The water balance (Table 9) indicates that 327 apartments would generate an annual non-potable water demand of 5 ML/year for outdoor and irrigation uses. There would be a daily water demand of approximately 46 kL for toilet and laundry uses.

Rainwater harvesting for these uses is considered to be a cost-effective means for offsetting stormwater pollution loads. MUSIC modelling was carried out to show that a 9000 m^2 roof drained to a 20 m^3 rainwater tank would provide 12% of the annual water demands and reduce the stormwater runoff volume from the site by 33%, reducing the stormwater runoff volume requiring filtration and treatment to meet pollution reduction targets.

Since the roof area can only achieve a limited proportion of the annual water demand, potable or recycled water should be provided to top up the rainwater tank once it drops below a set volume.

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Table 9 Water balance

	Water Uses (kL/dwelling/yr)	Residential Water Demand Split	Water Demand	Non Potable Water Demand	Potable Water Demand	Waste Water
Non Potable	Toilet	18%	28.1	28.1	0	28.1
	Laundry	15%	23.4	23.4	0	23.4
	Irrigation	4%	6.2	6.2	0	0
	Outdoor	5%	7.8	7.8	0	0
	Total	42%	**65.5**	**65.5**	**0**	**51.5**
Potable	Basin	5%	7.8	0	7.8	7.8
	Kitchen	5%	7.8	0	7.8	7.8
	Leaks	5%	7.8	0	7.8	7.8
	Shower	37%	57.7	0	57.7	57.7
	Bath	4%	6.2	0	6.2	6.2
	Dishwasher	2%	3.1	0	3.1	3.1
	Total	**58%**	**90.5**	**0**	**90.4**	**90.4**
Total Usage / Dwelling (kL/yr)			**156**	**65.5**	**90.4**	**141.9**
Total Usage for 327 dwellings (ML/yr)			**51**	**21**	**30**	**46**

7.1.2 Stormwater Filtration

Stormwater that is not intercepted by rainwater tanks will be filtered through gross pollutant traps and proprietary cartridge filters located within the site OSD tanks.

MUSIC modelling shows a notional treatment train downstream of the 20kL rainwater tank should comprise gross pollutant traps with 240 L/s capacity and filtration cartridges with 30 L/s capacity housed within a 3.8 m^3 storage.

It should be noted that due to the large roof area adopted, which has a relatively low pollutant concentration, it is difficult to remove 85% of suspended solids as required by the *Sydney DCP 2012* and *Botany Bay Water Quality Improvement Plan* (Sydney Metropolitan Catchment Management Authority 2011). The rainwater tank plays an important role in minimising the number of proprietary cartridges required.

7.1.3 Performance

The results of the MUSIC model are summarised in Table 10 and show that the proposed treatment train will achieve

- The *Botany Bay Water Quality Improvement Plan* benchmarks for large development sites.
- The water quality requirements in the Sydney DCP 2012; and
- An improvement in stormwater quality when compared to the existing site, and therefore will work towards delivering the NSW water quality objectives.

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Table 10. WSUD strategy performance

Stormwater Constituent	Pre development	Post development		% Reduction	
	Source Load	Source Load	Residual Load	Against Pre Development	Against Post Development
Flow (ML/yr)	10.8	14.8	10.8	0%	100%
Total Suspended Solids (kg/yr)	1580	1230	190	88%	85%
Total Phosphorus (kg/yr)	2.7	3.46	0.91	66%	74%
Total Nitrogen (kg/yr)	22.5	32.8	12.3	45%	63%
Gross Pollutants (kg/yr)	272	374	0	100%	100%

7.2 Proposed Stormwater Quantity Management

The proposed stormwater drainage and runoff system for the site should comply with the design requirements as identified in Section 5.0 with the main design considerations being:

- Ensure no increase in stormwater discharge rate from the site for the 20 and 100 year ARI storms;
- On-Site Detention is to be situated above the 100 year ARI flood levels to facilitate discharge into potentially fully charged stormwater pipes; and
- Sizing of On-Site Detention areas, including bypass areas, must cater for staged construction.

7.2.1 Stormwater Discharge and On-site Detention

As detailed in Section 5.6, to comply with the *Sydney 2012 DCP* (City of Sydney 2012) and Sydney Water, redevelopment of the site and increasing the extent of impervious surfaces will require the provision of On-Site Detention (OSD) for stormwater.

Advice from Sydney Water, attached in Appendix B, specifies that the minimum On-Site Detention (OSD) requirements include a Permissible Site Discharge (PSD) of 317 L/s (for 10,850 m^2 area) and OSD storage volume of 253m^3;

A 350 m^3/ha detention area is considered as a preliminary estimation for required OSD that would be 385 m^3 for the proposed development (assuming 1.1 ha area). In addition Sydney Water has a requirement of minimum 253 m^3 OSD. These two values can be used as a guide for the minimum on-site stormwater detention required. However, these estimation are based on preliminary assessment and has to be revised at the detail design stage based on the final design to reflect the actual stormwater discharge from the site and to comply with the Sydney Water PSD requirement of 317 L/s and the *Sydney DCP 2012* (City of Sydney 2012) requirements detailed in Section 5.6

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8.0 Opportunities and Constraints

The existing flood conditions were overlaid on-top of other information that is known about the site, such as existing services information (Figure 21) to prepare a map of the flooding and stormwater opportunities and constraints. This will assist with the later stage of detailed design.

Existing services information is taken from *Dial Before You Dig*, and is quality level D. As such, it is unverified, and further investigations are required as part of the detailed design.

The ponding which occurs at the corner of Phillip Street and Walker Street is a significant constraint. A FPL of 31.3 m AHD is required to ensure that the lowest habitable floor level is sufficiently elevated above the 100 year ARI flood, although this is to be confirmed once the developed case has been modelled as part of later stage assessments demonstrating that the proposed design is compliant with the required conditions. In accordance with the City of Sydney *Interim Floodplain Management Policy*, this minimum FPL is applied across the site, even though at some locations the flooding may be classified as local drainage flooding, as the FPL must be 0.5 m above the 100 year ARI flood level in the nearest downstream trapped low point, which in this case is the ponding at the corner of Phillip Street and Walker Street

As a consequence, the flood planning level is approximately 1.5 m above the street level for the southern portion of the site. This reduces 0.8 m above street level due to the upwards grade of the existing terrain.

To offset the anticipated flood impacts, flood detention and compensatory flood storage will be required. This will be sized and integrated as part of the detail design stage. The invert of this storage is restricted by the invert of the downstream stormwater pipe to enable the tank to drain under gravity, while the flood level in Phillip Street restricts the effective obvert or maximum storage level. A preliminary estimate indicates that approximately 3200 m^3 of storage is required.

To compensate for the blockage of the site due to the development, additional drainage will be required to allow some flood water to cross the site from Elizabeth Street, Kettle Street and Walker Street. To maximize the opportunities for development, these are to be connected to pipes running either along the western and eastern boundaries of the site as indicated, or in the road reserve.

Site drainage is anticipated to also drain to the flood storage tank, although this will drain through a separate system. This drainage system will contain provisions for water quality improvement. These improvements could be in the form of bioswales and integrated in to the landscaping, or other treatment devices such as cartridge filters or micro filtration. This local stormwater collections system could also present an opportunity for stormwater harvesting.

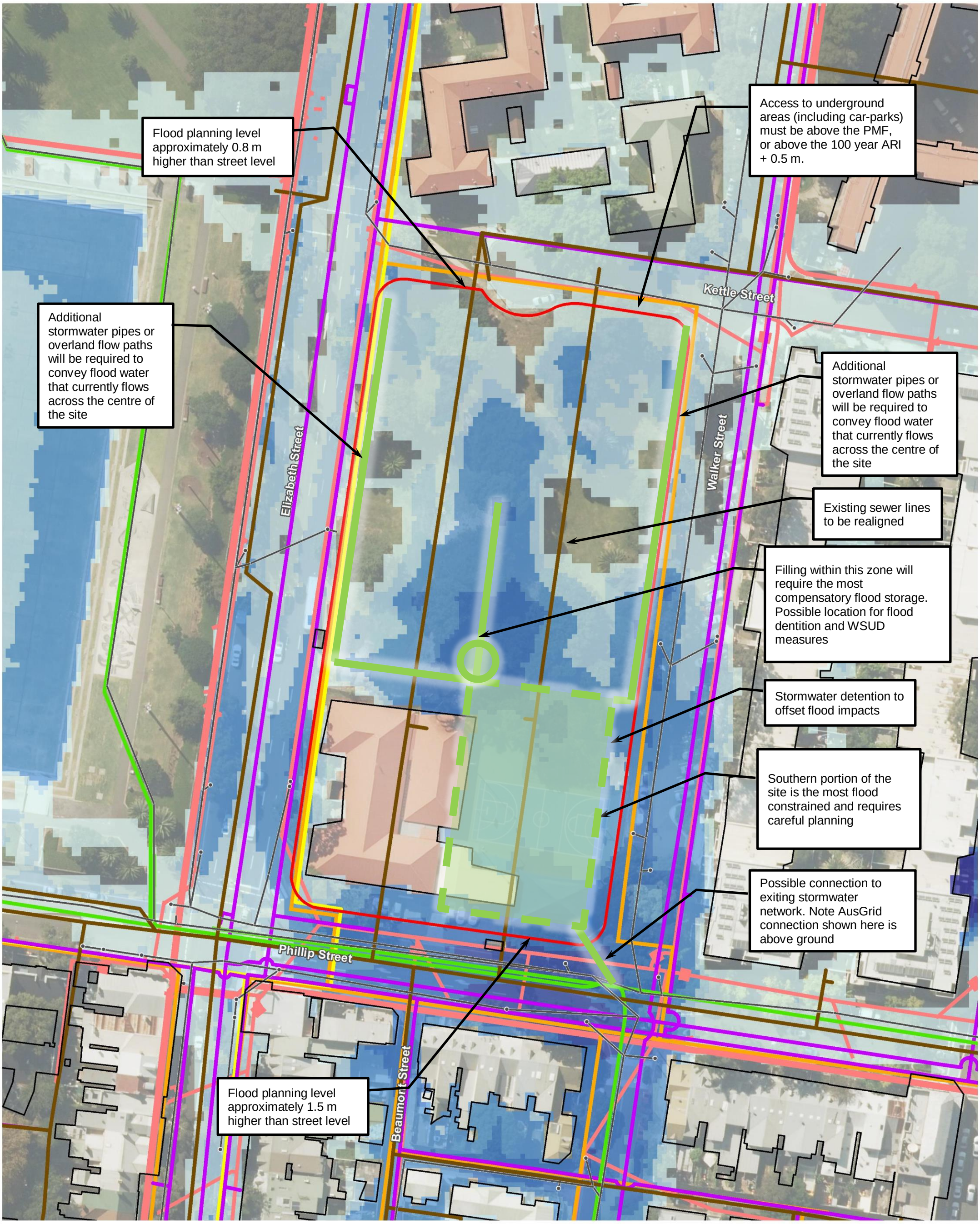

Figure 21 Site opportunities and constraints

KEY

- Site boundary
- Building outline
- Stormwater inlet
- Stormwater pipe
- AusGrid
- Gas
- Optus
- Sewer main
- Stormwater channel
- Water main

Peak Flood Depth (m)

- < 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- > 1

AECOM

N 0 5 10 20 m

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9.0 Climate Change

This section should be read in conjunction with the climate change adaptation report prepared by AECOM.

Climate change is expected to have adverse impacts on rainfall intensity. The NSW Department of Environment, Climate Change and Water guideline titled *Practical Consideration of Climate Change* (2007) provides advice for consideration of climate change in flood investigations, recommending specifically that 10%, 20% and 30% increase in peak rainfall and storm volume to be considered.

A sensitivity analysis for climate change was undertaken for the existing case by scaling the rainfall intensity up by 10%, 20% and 30% for the 100 year ARI as part of finalising the study. A 10% increase in rainfall intensity corresponds to 2090 conditions predicted under the RCP 4.5 emissions scenario, while a 20% increase corresponds to the 2090 conditions predicted under the RCP 8.5 emissions scenario (ARR 2016). Figure 22 to Figure 24 show the provisional 100 year ARI flood level impacts considering the three climate change sensitivity scenarios.

Based on the modelling, in the vicinity of the Site, the magnitude of increase in flood level was mainly less than 0.1 m for the 10% rainfall intensity increase and less than 0.18 m and 0.26 m for the 20% and 30% rainfall intensity increase respectively.

As the results indicate that the flood levels will increase by more than 40 mm as a result of a 10% in rainfall intensity, the FPL will require review to ensure that adequate freeboard is provided to accommodate future climate change.

An integrated water cycle management approach that maximizes stormwater harvesting, reuse and recycle will help to meet water security and stormwater management climate change adaptation requirements. These options are discussed in more details in the *Climate Change Adaptation* report (AECOM, 2019).

Figure 22 The Provisional 100 year ARI flood level impacts considering 10% rainfall intensity increase

KEY

- Site boundary
- Building outline
- Stormwater inlet
- Stormwater pipe
- Was dry, now wet

Provisional Impact (m)

- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.2
- > 0.2

AECOM

0 25 50 100 m

Figure 23 The Provisional 100 year ARI flood level impacts considering 20% rainfall intensity increase

KEY

- Site boundary
- Building outline
- Stormwater inlet
- Stormwater pipe
- Was dry, now wet

Provisional Impact (m)

- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.2
- > 0.2

AECOM

0 25 50 100 m

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Figure 24 The Provisional 100 year ARI flood level impacts considering 30% rainfall intensity

KEY

- Site boundary
- Building outline
- Stormwater inlet
- Stormwater pipe
- Was dry, now wet

Provisional impact (m)

- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.2
- > 0.2

AECOM

0 25 50 100 m

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10.0 Conclusion

Initial modelling of the site under existing conditions, as well as a preliminary developed case scenario, has been undertaken using a modified version of the City of Sydney TUFLOW model for the *Alexandra Canal Flood Study*. The results of these initial scenarios are presented in conjunction with information regarding existing stormwater infrastructure and other services.

Under flood conditions, a significant area of ponding occurs on Phillip Street between the intersection of Elizabeth Street and Morehead Street. The depth of pooling in this area is up to 0.9 m for the 100-year ARI, and up to 2.8 m deep for the PMF. The area of pooling encompasses the southern portion of the site during the 100-year ARI, and the entire site during the PMF.

As a result of this area of ponding, flood planning level (FPL) require habitable floor levels are elevated significantly above the street. At the southern portion of the site, the FPL is approximately 1.5 m above the street level, while at the north it is up to 0.8 m above the street. At most locations around the site, the FPL is influenced by the ponding area in Phillip Street.

Entrances to underground areas such as carparks are also required to be flood free in the PMF event. Due to these requirements, the entrance to the underground areas may be at street level but would need to ramp up at least 1.5 m above the street level before ramping down into basement areas.

The extensive ponding noted during the PMF also presents evacuation consideration. The PMF depth potentially exceeds the stability thresholds for even large SES rescue vehicles. As a result, residents located below the PMF level will need to evacuate to an area above the PMF level within the buildings in response to flooding. This may be achieved by providing a common area sufficiently elevated to remain flood free. Residents can remain isolated within the site for several hours until flood waters recede to depths that are trafficable by emergency vehicles. Suitable facilities and a flood management plan will be required to support this.

The existing conditions and an initial developed case have been investigated which represents the maximum development potential within the site. Flood impacts are noted as a result of the initial developed case, which is the result of the development both blocking overland flow paths across the site and displacing a volume of floodwater from within the local floodplain.

The strategy from MUSIC modelling suggests using stormwater filter cartridges a mix of gross pollutant traps and stormwater harvesting rainwater tank to achieve the stormwater quality requirements. Rainwater tank is to be used for irrigation demand and minimum 10% green roof is required. To achieve stormwater quantity requirements, stormwater detention basin is required that should be sized in accordance with requirements detailed in this report and based on the final design. Additionally, an integrated water cycle management approach may be adopted for the site in order to maximize stormwater harvesting, reuse and recycle to achieve desirable outcomes for a green and sustainable development.

Further investigation will be required in regards with the potential mitigation measures to offset the impacts as outlined in Figure 14 that should be considered in the upcoming detail design stage. These mitigation measures include a stormwater detention tank and drainage along the site perimeter. Preliminary testing has indicated that these impacts are able to be managed with an appropriately sized flood attenuation volume located in the basement level of the development.

The detail design stage will require further consideration of climate change, as well as a flood assessment of frequent flood events such as the 5% AEP event which is the design standard for minor stormwater drainage networks. Preliminary investigations have indicated that these can be achieved, but this is to be confirmed by later stage investigations.

As part of the upcoming detail design stage, revised reporting will be produced that documents the flooding and stormwater requirements for redevelopment which includes concept sizes for the mitigation measures and WSUD features. Flood planning levels will be revised based on the proposed development, including flood mitigation measures. This work should be of a suitable level of detail to support a development application for the site.

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11.0 References

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Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) 2016, *Australian Rainfall and Runoff: A Guide to Flood Estimation*, © Commonwealth of Australia (Geoscience Australia).

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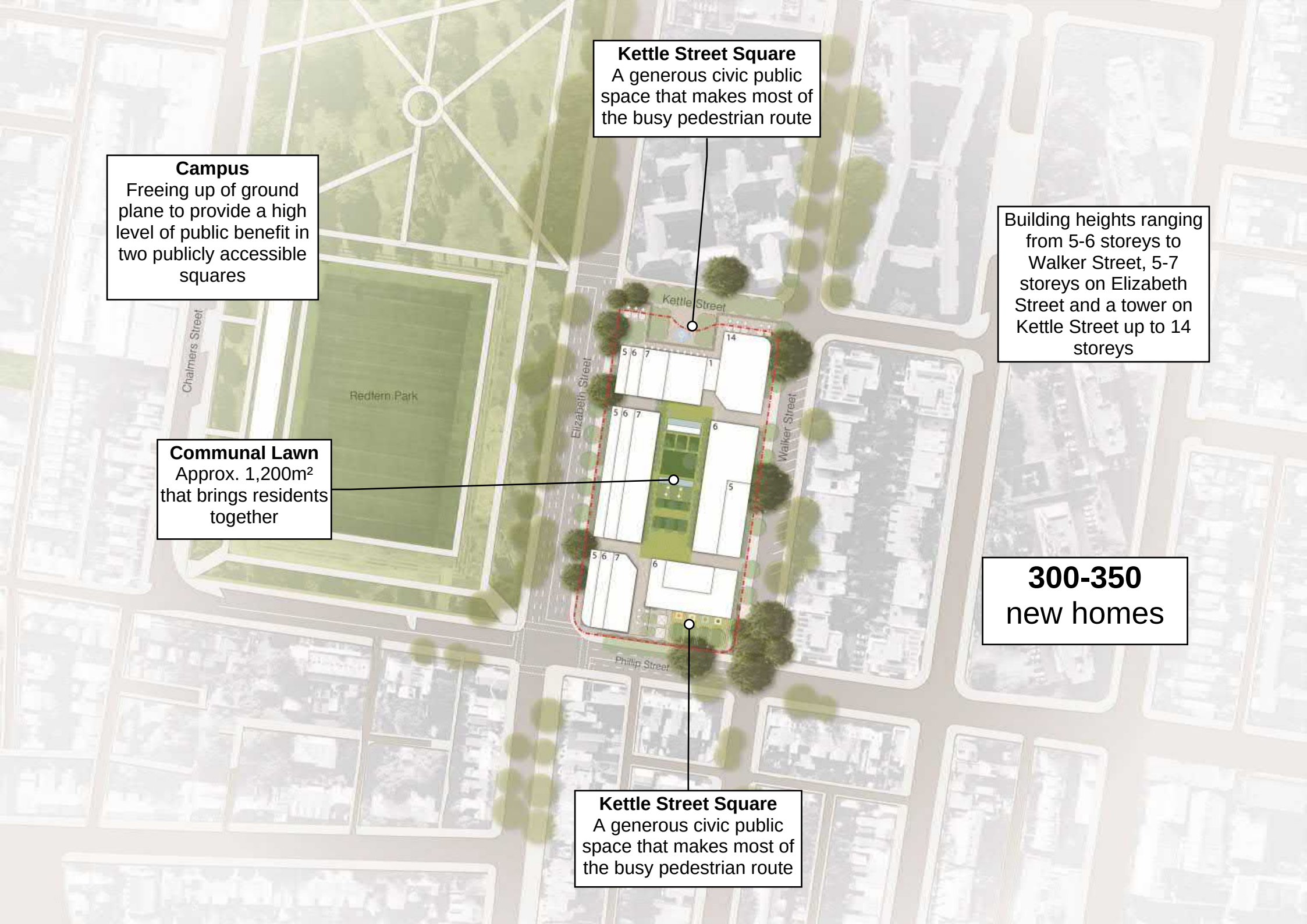
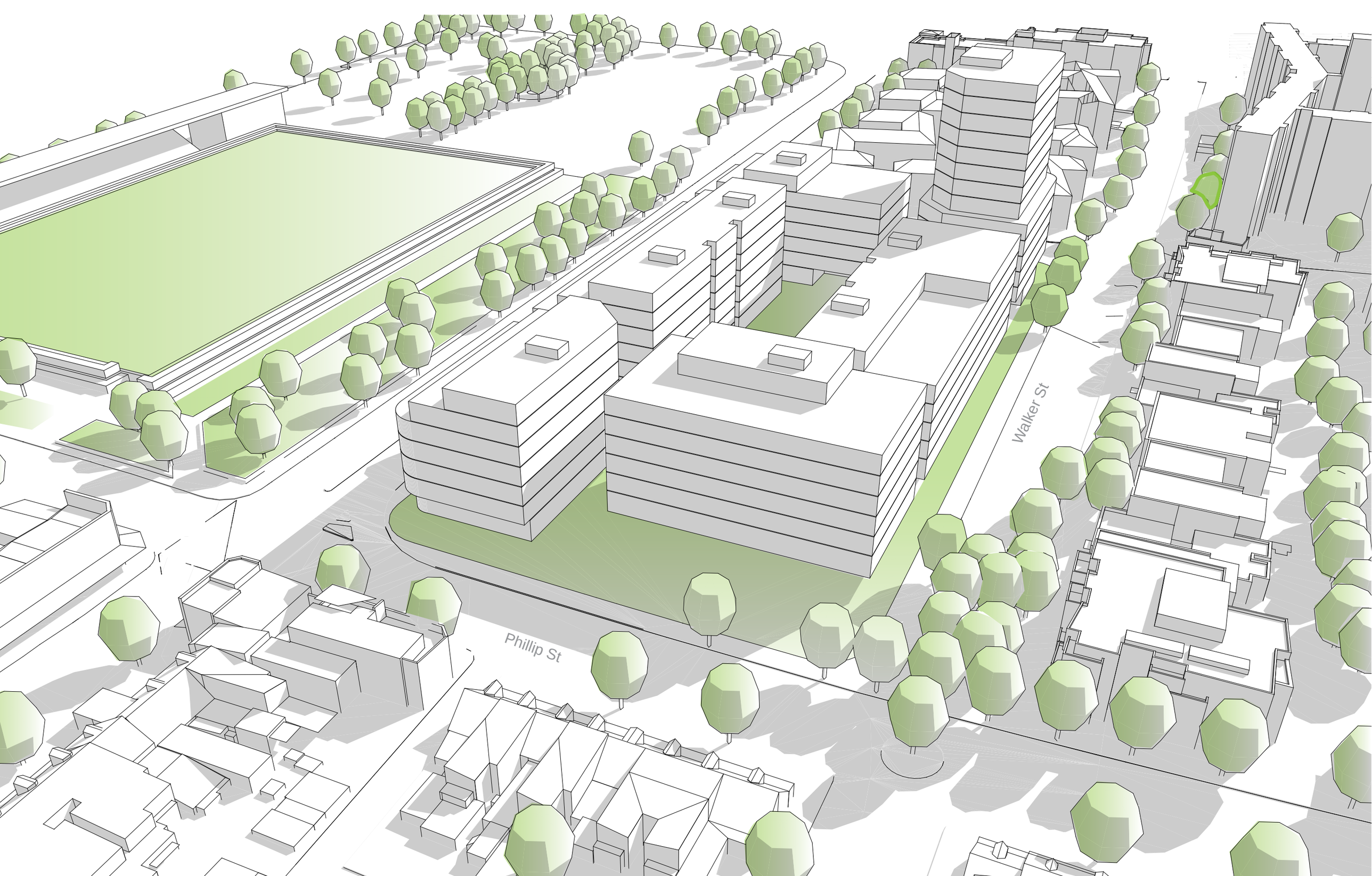
Appendix A 600-660 Elizabeth Street Redfern Reference Scheme


Kettle Street Square
A generous civic public space that makes most of the busy pedestrian route
Campus
Freeing up of ground plane to provide a high level of public benefit in two publicly accessible squares
Building heights ranging from 5-6 storeys to Walker Street, 5-7 storeys on Elizabeth Street and a tower on Kettle Street up to 14 storeys
Communal Lawn
Approx. 1,200m² that brings residents together
300-350
new homes
Kettle Street Square
A generous civic public space that makes most of the busy pedestrian route
Kettle Street
Chalmers Street
Redfern Park
Elizabeth Street
Walker Street
Phillip Street
14
5 6 7
1
6
5


Walker St
Phillip St

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Appendix B Preliminary advice from Sydney Water regarding permissible site discharge

From: Stormwater <Stormwater@sydneywater.com.au>
Sent: Thursday, 28 February 2019 11:04 AM
To: Roshani, Atena
Subject: RE: 600-660 Elizabeth Street, Redfern Development _ Permitted Site Discharge (PSD) and On-Site Detention (OSD) Requirements

Atena,

The On Site Detention requirements for the 11,000 square meters site at 600-660 Elizabeth Street, Redfern, are as follows:

On Site Detention	253 cubic meter
Permissible Site Discharge	317 L/s

The approval for the On Site Detention would only be given as part of the Section 73 application for this development. The On Site Detention is to be designed according to the above values and submitted to Sydney Water for approval with the Section 73 application. The following details are to be included in your submission for On Site Detention approval:

Location of the On Site Detention in relation to the development
Location of the On Site Detention in relation to overall stormwater network of the property
Plan and Elevation of the On Site Detention tank with all dimensions
Orifice plate calculation

Best Regards

Jeya Jeyadevan | **Senior Capability Assessor**
Liveable City Solutions | Sydney Water
Level 7, 1 Smith St Parramatta NSW 2150
PO Box 399 Parramatta NSW 2124
T 8849 6118 | **Mobile** 0409 318 827 | **Email** jeya.jeyadevan@sydneywater.com.au
sydneywater.com.au

From: Roshani, Atena <Atena.Roshani@aecom.com>
Sent: Tuesday, 26 February 2019 3:56 PM
To: Stormwater <Stormwater@sydneywater.com.au>
Subject: 600-660 Elizabeth Street, Redfern Development _ Permitted Site Discharge (PSD) and On-Site Detention (OSD) Requirements

Dear Sir/Madam,

Hope this email finds you well.

We are undertaking a Flooding and Stormwater Study for a proposed development located at 600-660 Elizabeth street, Redfern which is a State Significant Precinct (As shown in Figure below). I would like to enquire regarding the PSD and OSD requirements for this proposed development. A summary of the site is:

Total Site Area = 11,000 m^2
Pre-development Impervious Area = 3,200 m^2
Post-development Impervius Area = 11,000 m^2

I would rellay appreciate if you can advise us regarding the OSD and PSD requirements. Thanks for your time and consideration beforehand

Best Regards,
Atena Roshani

Atena Roshani
Water Resources Engineer

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