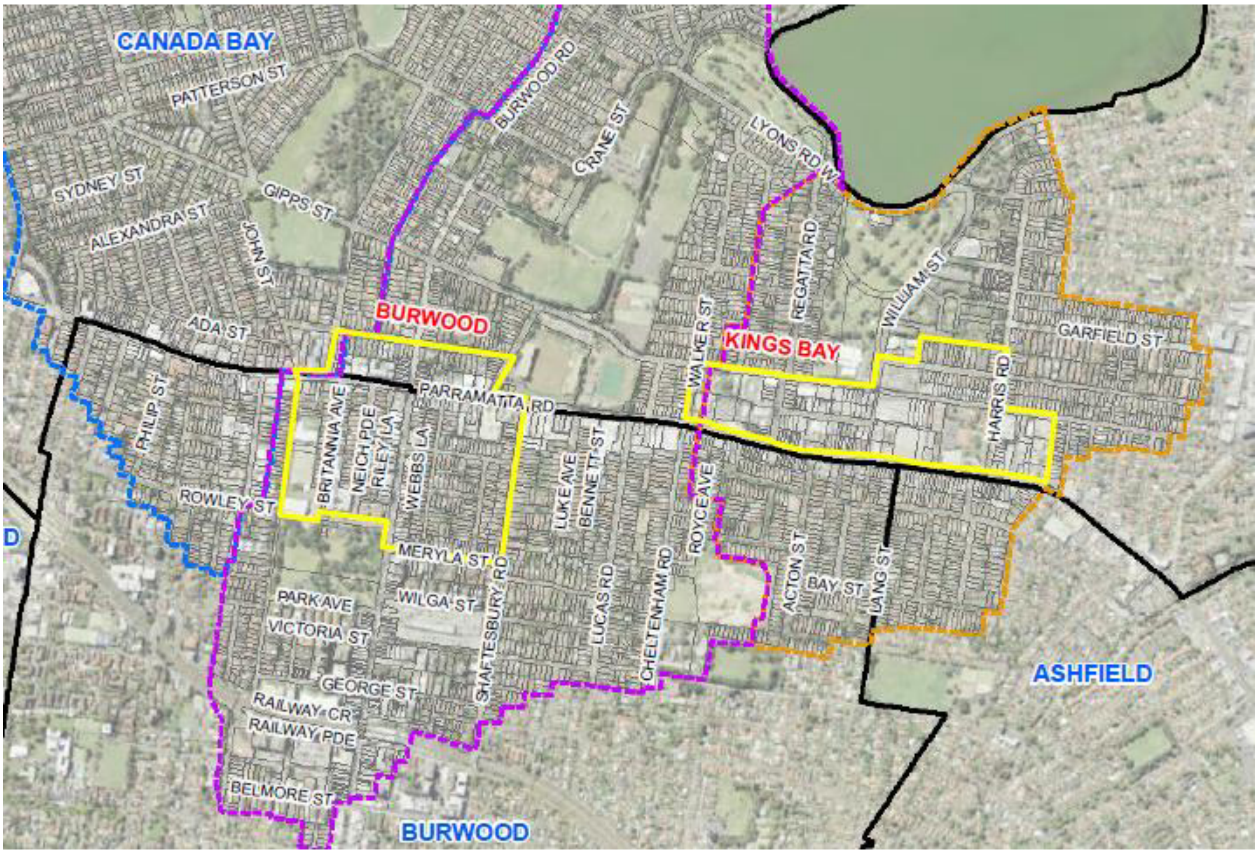
PARRAMATTA ROAD CORRIDOR - FLOOD RISK ASSESSMENT FOR CITY OF CANADA BAY COUNCIL

Final



SEPTEMBER 2020

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FINAL

SEPTEMBER 2020

Project **Parramatta Road Corridor - Flood Risk Assessment for City of Canada Bay Council**	**Project Number** **120021**
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Date 4 September 2020	**Verified by**

Revision	Description	Distribution	Date
1	1st Draft	Helen Wilkins	12 June 2020
2	2nd Draft	Helen Wilkins	10 July 2020
3	Final	Helen Wilkins	4 September 2020

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AAD	Annual Average Damages
ABCB	Australian Building Codes Board
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARF	Aerial Reduction Factor (for rainfall)
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff 1987 / 2019 editions
BCA	Building Code of Australia
BoM	Bureau of Meteorology
DCP	Development Control Plan
DPIE	Department of Planning, Industry and Environment
DRAINS	Hydrologic Model
ERP	Emergency Response Planning
EP&A Act	Environmental Planning and Assessment Act
ESD	Ecologically Sustainable Development
EY	Exceedances per Year
FIA	Flood Impact Assessment
FPA	Flood Planning Area
FPL	Flood Planning Level
FRMS	Floodplain Risk Management Study
GIS	Geographic Information System
HHW	Higher High Water Tidal Level
IFD	Intensity Frequency Duration
LEP	Local Environmental Plan
LGA	Local Government Area
LiDAR	Light Detection and Ranging or known as ALS (Airborne Laser Scanning)
m AHD	meters above Australian Height Datum
OSD	On Site Detention
PMF	Probable Maximum Flood
PSD	Permissible Site Discharge
PRCUTS	Parramatta Road Corridor Urban Transformation Strategy
RMS	Roads and Maritime Services
SES	State Emergency Services
SMS	Short Messaging Service
SSR	Site Storage Requirements for OSD
SWC	Sydney Water Corporation
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood hydraulic computer model
WSUD	Water Sensitive Urban Design

FOREWORD

The NSW State Government's Flood Policy provides a framework to ensure the sustainable use of floodplain environments. The Policy is specifically structured to provide solutions to existing flooding problems in rural and urban areas. In addition, the Policy provides a means of ensuring that any new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the Policy, the management of flood liable land remains the responsibility of local government. The State Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist councils in the discharge of their floodplain management responsibilities. The Federal Government may also provide subsidies in some circumstances.

The Policy provides for technical and financial support by the Government through four sequential stages:

1. **Flood Study**
   - Determine the nature and extent of the flood problem.
2. **Floodplain Risk Management Study**
   - Evaluates management options for the floodplain in respect of both existing and proposed development.
3. **Floodplain Risk Management Plan**
   - Involves formal adoption by Council of a plan of management for the floodplain.
4. **Implementation of the Plan**
   - Construction of flood mitigation works to protect existing development, use of Local Environmental Plans to ensure new development is compatible with the flood hazard.

WMAwater has been engaged by the City of Canada Bay Council to prepare this flood risk assessment of the Parramatta Road Corridor Urban Transformation Strategy (PRCUTS). The PRCUTS includes several precincts with two, Burwood and Kings Bay Precincts located adjacent to Parramatta Road and within Burwood and City of Canada Bay Councils' Local Government Areas (LGA).

Typically Councils prepare Flood Studies and Floodplain Risk Management Studies and Plans in accordance with the above outline. A Draft 2019 Exile Bay, St Lukes and Williams Street Flood Study (Reference 1) has been prepared for Burwood Council and part funded by the Department of Planning, Industry and Environment (DPIE) which includes part of the above precincts. This report adopts that Flood Study and extends it to include the entire St Lukes and Williams Street catchments.

TERMINOLOGY USED IN REPORT

Australian Rainfall and Runoff (ARR) have produced a set of guidelines for appropriate terminology when referring to the probability of floods. In the past, Annual Exceedance Probability (AEP) has generally been used for those events with greater than 10% probability of occurring in any one year, and Average Recurrence Interval (ARI) used for events more frequent than this. However, the ARI terminology is to be replaced with a new term, Exceedances per Year (EY). EY is a technical term and AEP or ARI would generally be used in Council's planning documents.

AEP is expressed using percentage probability. It expresses the probability that an event of a certain size or larger will occur in any one year, thus a 1% AEP event has a 1% chance of being equalled or exceeded in any one year. For events smaller than the 10% AEP event however, an annualised exceedance probability can be misleading, especially where strong seasonality is experienced. Consequently, events more frequent than the 10% AEP event are expressed as X EY. Statistically a 0.5 EY event is not the same as a 50% AEP event, and likewise an event with a 20% AEP is not the same as a 0.2 EY event. For example an event of 0.5 EY is an event which would, on average, occur every two years. A 2 EY event is equivalent to a design event with a 6 month average recurrence interval where there is no seasonality, or an event that is likely to occur twice in one year.

While AEP has long been used for larger events, the use of EY is to replace the use of ARI, which has previously been used in smaller magnitude events. The use of ARI, which indicates the long term average number of years between events, is now discouraged. It can incorrectly lead people to believe that because a 100-year ARI (1% AEP) event occurred last year it will not happen for another 99 years. For example there are several instances of 1% AEP events occurring within a short period, for example the 1949 and 1950 events at Kempsey.

Where the % AEP of an event becomes very small, for example in events greater than the 0.02 % AEP, the ARR terminology suggest the use of 1 in X AEP so a 0.02 % AEP event would be the same as a 1 in 5,000 AEP.

The PMF is a term also used in describing floods. This is the Probable Maximum Flood that is likely to occur. It is related to the PMP, the Probable Maximum Precipitation.

This report has adopted the approach of the ARR terminology guidelines and uses % AEP for the 50% AEP and greater events. EY is used for all events smaller and more frequent than this. The image below provides the relationship between the various terminologies. The term Extreme has been adopted to describe an event of rarer frequency than Very Rare.

The above terminology has been adopted to ensure consistency amongst engineers and the scientific community. For layman's usage the use of ARI is still appropriate but for consistency Council should replace ARI with AEP in all documentation. Of importance is the consistent use of a single term (either ARI or AEP). Council's LEP uses ARI whilst the DCP uses AEP and ARI. A check should also be made on other Council engineering documentation and also whether the information should be updated for ARR2019.

Appendix A provides a glossary of terms taken from the 2005 Floodplain Development Manual (Reference 2).

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI
Very Frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
	1	63.21	1.58	1
	0.69	50	2	1.44
Frequent	0.5	39.35	2.54	2
	0.22	20	5	4.48
	0.2	18.13	5.52	5
	0.11	10	10	9.49
Rare	0.05	5	20	20
	0.02	2	50	50
	0.01	1	100	100
	0.005	0.5	200	200
Very Rare	0.002	0.2	500	500
	0.001	0.1	1000	1000
	0.0005	0.05	2000	2000
	0.0002	0.02	5000	5000
Extreme			↓	
			PMP/ PMPDF	

The blue shaded areas represent the terminology adopted in this report.

The terms flood planning level (FPL), flood levels and design flood levels are used frequently in this report and a description of these terms is provided as follows. All levels (flood levels, ground levels, building floor levels etc.) are given in metres to a common datum termed Australian Height Datum (AHD). 0m AHD is approximately mean sea level and thus a flood level of 4m AHD indicates that the flood level is 4m above mean sea level. Flood levels in m AHD decrease from the upper to the lower parts of the catchment.

Flood level is the term used to describe the m AHD height reached by a body of water. This body of water could be across a road or escaping from a creek, river or channel. Flood level in m AHD should not be confused with flood depth, which is the depth of the water above the ground.

Floods levels can be subdivided into historical, which are levels recorded from an actual flood (e.g

9 February 2020) or design floods. Design floods are events which have a known probability of occurrence derived as part of a flood study, such as the 1% AEP flood. The AEP of a historical event can be determined by comparing the historical flood level to the design flood levels at the same location.

FPLs are the combinations of flood levels (derived from significant historical flood events but generally from design floods) and freeboards selected for floodplain risk management purposes. FPLs are generally provided in a Council's Development Control Plan (DCP) or some other Council planning regulation or guideline. Councils have a range of FPLs for different floodplain users. A residential house floor FPL is typically the 1% AEP level plus a 0.5m freeboard whilst a residential garage floor FPL may be the 1% AEP level with no freeboard.

The FPL is also used to define the Flood Planning Area (FPA) which is the area of land below the FPL and thus subject to flood related development controls (properties within the FPA are termed flood control lots). The FPL used to define the FPA is determined by Council but is typically the residential floor FPL (typically the 1% AEP level plus a 0.5m freeboard) for mainstream flooding.

Mainstream flooding describes flooding occurring from a defined watercourse such as a channel, creek, river or small grassed lined swale. However, flooding also occurs in urban areas where there are no defined watercourses, as these have been filled in as part of urban development and replaced by an underground piped network. Flooding in these areas is termed overland flooding and occurs throughout Sydney, including in the Sydney CBD. Overland flooding causes inundation of roads, houses and shops and disruption to everyday activities. It can occur very quickly, within an hour of rainfall but also dissipates just as fast. The depths, velocities and duration of overland flooding are generally much less than in mainstream flooding. Overland flooding has become more apparent as the density of urban development has increased and thus narrowing the overland flow paths. Nearly all parts of Sydney have been investigated in Council and State Government funded overland flow studies. The criteria for determination of flood control lots in overland flow areas is generally different to the criteria adopted in mainstream flooding areas.

BRIEF OUTLINE OF HOW DESIGN FLOOD LEVELS ARE CALCULATED

There are two broad approaches for calculating design events (floods of a known probability of occurrence such as the old 100 year event now termed the 1% AEP). The first is to undertake statistical analysis (termed flood frequency analysis) of a long record of peak flood levels (such as recorded for over 100 years at Windsor). This approach is rarely used (and not possible for this catchment) as there are few places where these accurate long term records exist. The alternative method (termed rainfall runoff modelling) is to use computer models of the catchment which calculate peak flood levels (based on equations of flow) from design rainfall data provided by the Bureau of Meteorology (BoM). The BoM is able to calculate design rainfall depths across Australia based on an extensive and long term record of historical rainfalls. The accuracy of the computer models is increased by "calibrating" them to historical flood height data using the actual rainfall records from that historical event. The models include detailed definition of the topography derived from laser aerial scanning of the ground (this data has a vertical accuracy of around +/- 150mm and is available at approximately 1m spacings).

The Draft Exile Bay, St Lukes and Williams Street Flood Study prepared for Burwood Council (Reference 1) was undertaken using the rainfall runoff modelling approach in accordance with guidelines provided in the NSW Floodplain Development Manual (Reference 2) and Australian Rainfall and Runoff (References 3 and 4).

All levels in this report are in metres to Australian Height Datum (AHD). Mean sea level is approximately 0 mAHD and an approximate tidal range in the Parramatta River at this location is +0.6 mAHD to -0.4 mAHD.

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EXECUTIVE SUMMARY

STUDY OBJECTIVE

The Parramatta Road Corridor Urban Transformation Strategy (PRCUTS) is an urban renewal project that seeks to renew Parramatta Road and adjacent communities through investments in homes, jobs, transport, open spaces and public amenity. Two of the Precincts under consideration are Burwood and Kings Bay (Figure 1) which are located within Burwood and the City of Canada Bay local government areas (LGA). Parts of these precincts have previously been identified as flood liable in a 1% AEP event in the Draft 2019 Exile Bay, St Lukes and Williams Street Flood Study (Reference 1) prepared for Burwood Council.

The main objective of this flood risk assessment of the PRCUTS is to identify floodplain risk, analyse floodplain strategies for the management of risk and identify compliance with the relevant State Government and City of Canada Bay Council floodplain management planning policies.

This report follows the technical requirements for undertaking a Flood Study in accordance with the NSW Floodplain Development Manual 2005 (Reference 2). However, this report is limited in that it does not comply with other non technical requirements, such as public exhibition and review by a technical committee. Also, whilst modelling results have been provided for the entire St Lukes and Williams Street catchments in this report the results should strictly only be used for the land in the City of Canada Bay Council LGA within the two precincts (Section 4.4).

CATCHMENT DESCRIPTION

The Burwood Precinct (30 hectares) is located within the St Lukes 2.25 km^2 catchment (there are 100 hectares in 1 km^2) and the Kings Bay Precinct (22 hectares) is located within the William Street 1.18 km^2 catchment (Figure 1). The two catchments are adjacent to each other and alongside Parramatta Road in the Burwood and City of Canada Bay LGAs. Both catchments comprise largely urban residential developments with commercial developments along transport routes. Parramatta Road forms the divide between the two council areas and is the main east – west transport link. Runoff from both precincts exit into a bay off the Parramatta River located immediately downstream of Lyons Road and approximately 700 metres downstream of Parramatta Road.

FLOOD HISTORY

There has been a number of instances of flooding in the past, including 19 May 1946, 24 November 1961 and 2 January 1996. More recent events appear to not have caused significant damage or hardship. In examining the flooding history, it must be noted that the drainage characteristics of the catchments have been significantly altered as a result of urbanisation in the area and as such older flood extents and depths for a given storm may not apply to present day conditions.

PAST STUDIES

A 2019 Draft Exile Bay, St Lukes and Williams Street Flood Study (Reference 1) was prepared for Burwood Council with part funding by the Department of Planning, Industry and Environment (DPIE). This study established a DRAINS hydrologic model (converts rainfall into runoff) and a TUFLOW hydraulic model (converts runoff into levels, velocities and extents). The models were calibrated to historical flood data and used to determine design flood levels, depths and velocities for a range of design flood events. This study was based on Australian Rainfall and Runoff (ARR) 1987. The study identified that parts of the two precincts are inundated in the 1% AEP event.

HYDROLOGIC AND HYDRAULIC MODELLING

The same DRAINS hydrologic model and TUFLOW hydraulic model, as used in the 2019 Draft Exile Bay, St Lukes and Williams Street Flood Study, were adopted but extended to cover both catchments down to the Parramatta River. The modelling was also updated to be in accordance with the updated ARR 2019. The key difference between the 1987 and 2019 ARR methodologies is the change in design rainfall estimates and temporal patterns.

Design flood contours, depths and extents are provided for the 5% and 1% AEP and the PMF events as well as hydraulic hazard and categorisation for each event.

FLOOD RISK ASSESSMENT OF PROPOSED REDEVELOPMENT

The flood risk assessment of the proposed development was undertaken as follows:

- Review of Part C7: Flooding Control of Council's DCP. This included review of the compliance of the proposal with the objectives and design principles as well as review of Part C7 itself;
- Hydraulic modelling of the design building outlines was undertaken, and flood impact figures provided for the 5% and 1% AEP and the PMF events;
- A review and applicability of all possible floodplain management measures as indicated in the table below was undertaken;

Flood Modification	Property Modification	Response Modification
Levees	House raising	Flood warning
Temporary defences	Voluntary purchase	Flood emergency management
Channel construction	Flood proofing	Community awareness
Channel modification	Land use zoning	Improved evacuation access
Major structure modification	Flood planning levels	Flood plan / recovery plan
Drainage network modification	Flood planning area	
Drainage maintenance	Changes to planning policy	
Retarding basins	Modification to S10.7 Certificate	
	Flood Insurance	

- Review and comment on the applicability of on site detention;
- Review and comment on the applicability of water sensitive urban design.

FLOOD RISK ASSESSMENT OUTCOMES

1. A review of Part C7: Flooding Control of Council's DCP indicated that the following parts should be considered and where required reviewed. The details of which are provided in the relevant sections:
    - The development proposal at this stage generally complies with the objectives and

design principles of the DCP. However, these issues will need to be reassessed as the design progresses and more detail becomes available;

- The requirements for flood warning (Evacuation C6) cannot generally be complied with in many localities in the two Precincts due to the short or effectively nil warning time (Section 4.7.3) and requires rewording (Section 5.3.3);
- The evacuation requirements for people and vehicles (Section 4.7.1) in the DCP (Section 5.3.3) cannot all be complied with and needs rewording;
- Shelter in place is a requirement for all properties in the PMF (Section 5.3.3);
- Review the list of Flood Planning Levels adopted by Councils such as the City of Sydney (Appendix B and Section 5.3.4);
- The inclusion of climate change in determination of Flood Planning Levels (Section 5.3.5);
- Adoption of criteria for identification of Flood Control Lots in both mainstream and overland flow areas (Section 5.3.6);
- Review of policy for fencing in the floodplain (Section 5.3.7);
- Provision of guidelines for flood impact assessment reporting (Flood Affectation C1) (Section 5.3.8);
- The H4, H5 and H6 hazard categorisation should be taken as equivalent to High Hazard in Council's DCP.

2. Hydraulic modelling indicates that within the City of Canada Bay LGA there are:
    - increases in flood level near the intersection of Parramatta Road and Luke Avenue downstream of the Burwood Precinct. Mitigation of these increases will require works within Burwood LGA;
    - increases in flood level downstream of Queens Road and the Kings Bay Precinct. Mitigation of these increases can be reduced by increasing the flood levels within the Precinct itself which presently show a reduction in level of greater than -0.1m in the 1% AEP event. Increasing flood levels, by increasing the building density within the Kings Bay Precinct, will increase the volume of temporary floodplain storage through higher flood levels and so attenuate the peak flows travelling downstream which cause the increases in level downstream.
3. A review of all possible floodplain risk management measures indicates that all viable response modification measures should be employed as part of the redevelopment in accordance with Part C7: Flooding Control of Council's DCP. The exact details of these measures can only be determined once full definition of the redevelopment works becomes available. Of the property modification measures flood planning levels are already incorporated in Part C7: Flooding Control of Council's DCP. The possible reduction in design flood levels is only possible with application of flood modification measures and the most viable are the upgrading of Council's existing drainage network. This measure should be considered, regardless of whether it is required to mitigate flood increases or not, as redevelopment of this magnitude provides the only viable opportunity for such measures to be cost effectively undertaken. Also drainage maintenance is a key issue identified in all public consultation on flooding. Council should review their drainage maintenance program and ensure that it is compatible with best practice.
4. The implementation of OSD within this redevelopment proposal and throughout the LGA should be reviewed to accord with best practice. As the project progresses and the design

of OSD is being undertaken, it is important that the implementation of the works is fully considered to optimise their potential.

5. WSUD implementation should be investigated further as the design progresses to ensure compliance with Council's requirements and best practice.
6. Further more detailed hydraulic modelling should be undertaken once the design has been progressed to mitigate any increases in flood level (Section 5.4) in accordance with the DCP.
7. Drainage easements should be defined for all underground drainage structures and consideration given to introducing overland flow drainage easements.
8. Council's flood related documentation should be checked to ensure consistent use of either ARI or AEP terminology and updated for ARR2019 where applicable.
9. Developers or others enquiring about flood level information should not interpret levels from this report but should request this information directly from Council. This will ensure consistent and updated information is always provided with a record of the date provided.
10. Compliance with the objectives and design principles of Part C7 of the DCP will have to be further undertaken at the detailed design stage.
11. The installation of flood depth indicator boards should be considered for frequently inundated road crossings. However, their actual locations can only be determined at the detail design stage.
12. Council should consider introduction of a flood awareness plan for the two precincts.
13. The updated flood hazard classifications should be used by Council for determining the appropriateness of development in flood liable areas and should be incorporated in the DCP.
14. Sea level climate change increases should be included in determination of Flood Planning Levels but not rainfall increases (Section 5.3.5).
15. An assessment of potential flood damages should be undertaken as part of the approval process for the redevelopment, to quantify the benefit in terms of reduction in tangible annual average damages and reduction in non tangible damages.
16. A rigorous flood risk assessment, including a potential flood damages analysis must be undertaken if developers wish to justify flood planning levels for non residential developments below those provided in the DCP.
17. All viable response modification measures should be employed as part of the redevelopment in accordance (Section 5.5).

1. INTRODUCTION

1.1. Parramatta Road Corridor Urban Transformation Strategy

In November 2016, Urban Growth NSW released the Parramatta Road Corridor Urban Transformation Strategy (PRCUTS). The Strategy applies to land within six local government areas, including the City of Canada Bay. A Section 117 Ministerial Direction gives the Strategy and Implementation Tool Kit statutory weight.

PRCUTS is an urban renewal project that seeks to renew Parramatta Road and adjacent communities through investments in homes, jobs, transport, open spaces and public amenity. In response to PRCUTS, the City of Canada Bay, Strathfield and Burwood Councils have commenced additional urban design, traffic and transport and environmental investigations. This work seeks to ensure that all future decisions to rezone land will be made with an understanding of potential cumulative impacts and will achieve orderly, transparent and high-quality design outcomes.

The urban design testing of the PRCUTS planning and design controls has been undertaken and consists of a suite of documents prepared by urban design consultancy Roberts Day, titled: Transformation: PRCUTS Controls Built Form Testing (these are internal Council documents only). It includes built form outcomes and proposed building footprints.

1.2. Objectives of Report

Parts of the Burwood and Kings Bay Precincts within the PRCUTS were identified in the Draft 2019 Exile Bay, St Lukes and Williams Street Flood Study (Reference 1) as impacted by flooding. The City of Canada Bay engaged WMAwater to prepare a flood risk assessment for these two precincts (Figure 1). The project is focused on the PRCUTS Stage 1 development (originally due for completion 2016-2023, now likely to occur 2021-2026) and will have regard to the Parramatta Road Corridor Urban Transformation Strategy and related documents. The study will also be informed by the Roberts Day Transformation: PRCUTS Controls Built Form Testing suite of documents (not reviewed), which provides an indication of built form, density, street layout, open space and pedestrian networks.

The flood assessment must meet the following requirements:

- Satisfy Direction 4.3 Flood Prone Land of the Ministerial Directions issued under Section 9.1 (previously section 117 (2) of the EP& A Act).
- Be in accordance with all relevant requirements contained in the 2005 Floodplain Development Manual (Reference 2) including the aims:
    - "to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods wherever possible."
    - "to ensure that the proposed re-development of the precincts does not lead to increased flood risk to property. It should also ensure that proposed planning controls

relating to flooding are part of a consistent and coordinated strategy to reduce flood risks."

- Provide an overview of the nature and extent of flooding for the precincts. It will identify flooding issues in the precincts and outline the constraints and opportunities from a drainage and flooding perspective.
- Review existing and provide any necessary recommendations for new and amended planning controls for the City of Canada Bay Local Environmental Plan (LEP) and Development Control Plans (DCP) – to apply to new residential and commercial development in the corridor. Recommendations should be in line with best practice in sustainable flood management.
- Provide recommendations for the Public Domain Concept Plan (being undertaken concurrently e.g. Water Sensitive Urban Design - WSUD solutions) where necessary.
- The assessment should identify, at the earliest convenience, whether any land take or easement requirements to achieve flood risk management solutions might be required.

The Flood Risk Assessment will become part of the evidence base for a planning proposal and will be used to inform amendments to the Canada Bay LEP and a DCP to be prepared for each precinct, as well as development contributions funding. It may also inform future planning controls in the Stage 2 portions of the precincts and in other locations in the LGA.

1.3. Description of the Catchments

The Exile Bay, St Lukes and William Street catchments are adjacent to each other (listed west to east) that drain north into a bay off the Parramatta River (Figure 1). The upstream areas of the three catchments are within Burwood Council LGA and the downstream catchment areas are within the City of Canada Bay LGA. Parramatta Road is the boundary between the two LGAs.

The local area includes the suburbs of Burwood, Canada Bay, Five Dock and Croydon. The area is fully urbanised with the majority zoned residential with commercial and public recreation in the remainder.

Elevations in the upper part of the catchments reach approximately 35 m AHD near Livingston Street with moderate land grades of 3%. In the lower parts of the catchments, slopes are relatively low, in the order of 0.5% (Figure 2). The St Lukes and William Street catchments are tidal up to approximately Queens Road.

1.4. Proposed Development

The proposed development is located within the two precincts termed Burwood and Kings Bay (Figure 1). At this time the only flood related design information that is available and has been considered in this flood risk assessment is the building footprints. Other such design information (upgraded pit and pipe infrastructure, significant terrain changes, road realignments, re design of fences etc.) will become available over time and may need to be considered in the future.

The existing and proposed design building footprints within the two precincts are shown in Figure 1A and Figure 1B.

1.5. Accuracy of Flood Modelling Results

The accuracy of all flood model results provided in this report is dependent on the input data sets and the ability of the modelling approach to replicate recorded historical flood data. As modelling approaches improve over time and additional flood data becomes available from future flood events the accuracy of the results will improve.

A key input data set is the topographic information provided by Sydney Water (SWC), Burwood and the City of Canada Bay Councils for use in this study. The topographic information was derived from Airborne Light Detection and Ranging (LiDAR) survey with an estimated accuracy of ± 0.15m in cleared areas, such as car parks or on roads. In locations with more complex terrain, such as vegetated areas, the accuracy is likely to be much lower and could vary significantly, by up to ± 1m. It is cost prohibitive to obtain detailed field survey throughout the entire study area and the LiDAR is assumed to be correct. However due to these potential accuracy limitations, some of the floodway extents, depth estimates and design flood levels may change if more accurate field survey is obtained. It is estimated that an order of accuracy of the design flood levels is ± 0.3 m where quality historical calibration data are available nearby and up to ± 0.5 m where no such data are available.

The results from the present study incorporate best practice in design flood estimation at this time but it is acknowledged that changes in approach in the future will cause changes to design flood levels. A good example of this is the collection of rainfall data which forms the basis of design flood estimation. As more rainfall data are collected and analysed (and particularly from continuously read gauges termed pluviometers) the BoM will provide new estimates of design rainfalls and design temporal patterns over NSW.

It should also be noted that flood modelling, however sophisticated, can only provide an approximation of reality. For this reason, the collection of historical flood information and the comparison of that data with the results from computer modelling is very important. Unfortunately, in urban catchments (as compared to towns on large river systems) there is a lack of quality historical data which means that verification of the modelling process is extremely limited. A further issue is that in an urban area, small local obstructions such as fences can significantly alter flow paths and these cannot be accurately defined. Particularly, as these structures change over time (paling to colorbond or brick fencing) and do not require Council approval.

1.6. Current Flood Related Planning Instruments and Legislation

1.6.1. National Provisions – Building Code of Australia

The Building Code of Australia (BCA) is a uniform set of technical provisions for the design and construction of buildings and other structures throughout Australia. The goals of the BCA are to enable the achievement and maintenance of acceptable standards of structural sufficiency, safety, health and amenity for the benefit of the community now and in the future.

The BCA contains requirements to ensure new buildings and structures and, subject to State and

Territory legislation, alterations and additions to existing buildings located in flood hazard areas do not collapse during a flood when subjected to flood actions resulting from the defined flood event. The Standard provides additional requirements for buildings in flood hazard areas consistent with the objectives of the BCA which primarily aim to protect the lives of occupants of those buildings in events up to and including the defined flood event. Flood hazard areas are identified by the relevant State/Territory or Local Government authority.

The BCA is produced and maintained by the Australian Building Codes Board (ABCB), and given legal effect through the Building Act 1975, which in turn is given legal effect by building regulatory legislation in each State and Territory. Any provision of the BCA may be overridden by, or subject to, State or Territory legislation. The BCA must therefore be read in conjunction with that legislation.

1.6.2. State Provisions

The NSW Environmental Planning and Assessment Act 1979 (EP&A Act) provides the framework for regulating and protecting the environment and controlling development.

Pursuant to Section 117(2) of the EP&A Act, the Minister has directed that Councils have the responsibility to facilitate the implementation of the NSW Government's Flood Prone Land Policy. The objectives of Direction 4.3 are:

(a) to ensure that development of flood prone land is consistent with the NSW Government's Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005, and

(b) to ensure that the provisions of an LEP on flood prone land is commensurate with flood hazard and includes consideration of the potential flood impacts both on and off the subject land.

Various clauses within Direction 4.3 provide additional legislation in regard to development on the floodplain. This includes restrictions that do not allow for development in the floodway, flood impacts on adjoining properties, and development intensification within the flood planning area.

The primary objectives of the NSW Government's Flood Prone Land Policy are:

- to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone land, and
- to reduce public and private losses resulting from floods whilst utilising ecologically positive methods wherever possible.

The NSW Floodplain Development Manual 2005 (Reference 2) relates to the development of flood prone land for the purposes of Section 733 of the Local Government Act 1993 and incorporates the NSW Flood Prone Land Policy. The Manual outlines a merits approach based on floodplain management. At the strategic level, this allows for the consideration of social, economic, cultural, ecological and flooding issues to determine strategies for the management of flood risk.

The Manual recognises differences between urban and rural floodplain issues. Although it maintains that the same overall floodplain management approach should apply to both, it recognises that a different emphasis is required to address issues particular to a rural floodplain.

Section 10.7 Planning Certificates are issued in accordance with the EP&A Act 1979. They contain information on how a property may be used and the restrictions on development. A person may request a Section 10.7 certificate to obtain information about his or her own property but generally a Section 10.7 certificate will be requested when a property is to be redeveloped or sold. When land is bought or sold the Conveyancing Act 1919, requires that a Section 10.7 Planning Certificate be attached to the Contract for Sale.

1.6.3. Council Provisions

Appropriate planning restrictions, ensuring that development is compatible with flood risk, can significantly reduce flood damages. Planning instruments are used as tools to guide new development away from high flood risk locations and ensure that new development does not increase flood risk elsewhere. They can also be used to develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population. Councils use LEPs and DCPs to control development on flood prone land.

A LEP guides land use and development by zoning all land, identifying appropriate land uses that are allowed in each zone, and controlling development through other planning standards and DCPs. LEPs are made under the EP&A Act 1979 which contains mandatory provisions on what they must contain and the steps a Council must go through to prepare them. In 2006 the NSW Government initiated the Standard Instrument LEP program and produced a new standard format which all LEPs should conform to.

The City of Canada Bay Council's LEP 2013 was prepared under the Standard Instrument LEP program. The purpose of the DCP (last adoption in February 2020) is to supplement the Canada Bay LEP 2013 and State Environmental Planning Policies (SEPPs) and provides more detailed provisions to guide development. If there is any inconsistency between the DCP and the LEP 2013, the LEP 2013 will prevail to the extent of the inconsistency.

A DCP specifies detailed guidelines and environmental standards for new development, which need to be considered in preparing a Development Application. The DCP provides a layered approach – some parts are relevant to all development, some to specific types of development, and some to specific land. Part C7: Flooding Control of Council's DCP describes the background and controls necessary to comply with development on flood liable lands.

2. AVAILABLE DATA FOR FLOOD STUDY

2.1. Overview

The first stage in the investigation of flooding matters is to establish the nature, size and frequency of the problem. On large river systems such as the Parramatta River there are generally stream height and historical records dating back to the early 1900's, or in some cases even further. However, in small urban catchments such as that of Exile Bay, St Lukes and William Street catchments there are no stream gauges or official historical records available. A picture of flooding must therefore be obtained from an examination of Council records, previous reports, rainfall records and local knowledge.

2.2. Topographic Data

LiDAR survey of the catchment and its immediate surroundings was obtained from NSW Land Registry Services, which is a division of the Department of Finance, Services and Innovation (NSW Government). It was indicated that the LiDAR data were collected in 2013. These data typically have accuracy in the order of:

- +/- 0.15m (for 70% of points) in the vertical direction on clear, hard ground; and
- +/- 0.75m in the horizontal direction.

The accuracy of the LiDAR data can be influenced by the presence of open water or vegetation (tree or shrub canopy) at the time of the survey. The 1 m by 1 m Digital Elevation Model (DEM) was generated from the LiDAR and this formed the basis of the two-dimensional hydraulic modelling undertaken in this study.

2.3. Pit and Pipe Data

SWC provided dimensions for SWC owned underground pipes, in addition to the open channel cross-sections within the catchment area downstream of the Burwood LGA boundary. Appended to this SWC drainage network are underground pipes owned by Burwood and the City of Canada Bay Councils. Both Councils supplied all available pipe dimensions, as well as the pit inverts and dimensions. However, it should be noted that in places, data were missing and had to be interpolated. The derived pit and pipe network is the best that is known however if exact locations and dimensions are required field inspection must be undertaken.

2.4. Historical Flood Level Data

2.4.1. SWC and Council Databases

SWC and Burwood City Council have records of historical flooding in the two catchments and these are described below.

As part of the Draft 2019 Exile Bay, St Lukes and Williams Street Flood Study (Reference 1) an historic flood database was supplied by SWC and this provided information on flooding within the St Lukes and William Street catchments from 1946 to 1996 (Table 1).

Table 1: Summary of Historical Flood Data – Sydney Water Corporation Database

Flood Events	Total Records	Number of Observed Flood Levels
19 May 1946	1	0
24 November 1961	1	0
2 January 1996	3	1

An historic flood database also supplied by Burwood City Council as part of the Flood Study (Reference 1) provided information on flooding from 2003 to 2015 (Table 2). However, many of these reports were concerned with stormwater and drainage issues and are not relevant for this flood assessment.

Table 2: Summary of Historical Flood Data – Burwood City Council Database

Location	Catchment	Total Records	Location	Catchment	Total Records
Belmore Street	St Lukes	4	Railway Crescent	St Lukes	1
Belmore Street (Corner Wynne Avenue)	St Lukes	2	Railway Parade	St Lukes	3
Burwood Road	St Lukes	13	Rostherne Avenue	St Lukes	1
Burwood Road (Nr Station)	St Lukes	1	Royce Avenue	St Lukes	3
Cheltenham Road	St Lukes	7	Royce Avenue (Corner Monash Parade)	St Lukes	2
Clarendon Place	St Lukes	3	Shaftesbury Road	St Lukes	4
Comer Street	St Lukes	2	Shaftesbury Road (Corner Wilga Street)	St Lukes	1
Conder Street	St Lukes	1	Simpson Avenue	St Lukes	2
Conder Street (Corner Hornsey Street)	St Lukes	2	Sym Avenue	St Lukes	4
Elsie Street	St Lukes	1	Victoria Street	St Lukes	5
Gladstone Street	St Lukes	1	Wilga Street	St Lukes	2
Ilfracombe Avenue	St Lukes	1	Wynne Avenue	St Lukes	7
John Street	St Lukes	1	Youth Lane	St Lukes	1
King Edward Street	St Lukes	1	Acton Street	William Street	11
Lucas Road	St Lukes	13	Bay Street	William Street	3
Luke Avenue	St Lukes	11	Dawson Street	William Street	1
Luke Street (Corner Bennett Street)	St Lukes	1	Grogan Street	William Street	1
Marmaduke Street	St Lukes	1	Monash Parade	William Street	1
Meryla Street	St Lukes	9	Short Street	William Street	2
Neich Parade	St Lukes	4	Wychbury Avenue	William Street	8
Park Road	St Lukes	3	Wychbury Lane	William Street	1
Parramatta Road	St Lukes	1	Corner of King Edward Street and Parramatta Road	William Street	1

2.4.2. Community Consultation by Burwood City Council

A community consultation process was undertaken in collaboration with Burwood City Council as part of the Draft 2019 Exile Bay, St Lukes and Williams Street Flood Study (Reference 1). This included distribution of an information sheet and a questionnaire to gather information pertaining to the community's experience of flooding within the Burwood City Council LGA. The response rate was on average 4% across the study area.

Two reports of flooding within a house were reported; with indications that at these locations the floor level is elevated and flood waters entered the cavity beneath the floor. The flood waters reported beneath the houses were said to drain slowly and resulted in rising damp within the walls of the house. In both instances, no date was given and the flooding experienced was described as occurring any time there is heavy rainfall.

2.5. Historical Rainfall Data

2.5.1. Rainfall Stations

Rainfall data is recorded either daily (24hr rainfall totals to 9:00 am) or continuously (pluviometers measuring rainfall in small increments – less than 1 mm). Daily rainfall data have been recorded for over 100 years at many locations within the Sydney basin. In general, pluviometers have only been installed since the 1970's. Together these records provide a picture of when and how often large rainfall events have occurred in the past.

A detailed analysis of the historical rainfall data was undertaken as part of the Draft 2019 Exile Bay, St Lukes and Williams Street Flood Study (Reference 1) and a summary of the assessment is provided below.

Table 3 provides a summary of the official rainfall gauges (sourced from the BoM) located close to or within the catchment. This includes daily read stations, continuous pluviometer stations, operational stations and synoptic stations, however a number are now closed. These gauges are operated either by SWC or the BoM however it is likely there are several other "unofficial gauges" operating within the study area.

Table 3: Rainfall Stations within approximately 4km of the Centroid of the Study Area

Station Number	Station Name	Operating Authority	Distance (km) from centre of catchment	Elevation (m AHD)	Date Opened	Date Closed	Type
66017	Barnwell Park Golf Course	BOM	1.11	4	29/11/1929	28/11/2003	Daily
66150	Canterbury Heights	BOM	1.29	61	30/08/1906	29/12/1916	Daily
566064	Concord Greenlees BC (formerly Wests Rugby Club)	SWC	2.05		1/06/1988		Continuous
66091	Burwood 2 Public School	BOM	2.49		29/09/1911	29/12/1923	Daily
66165	Ashfield Prospect Rd	BOM	2.49	43	01/01/1894	1/01/1904	Daily
66013	Concord Golf Club	BOM	2.56	15	1/01/1930		Daily
66113	Burwood 1	BOM	2.61		01/01/1884	1/01/1922	Daily
66026	Homebush	BOM	2.61		30/10/1924	29/12/1952	Daily
66000	Ashfield Bowling Club	BOM	2.67	25	30/03/1896		Daily
566112	Ashfield (Ashfield Park Bowling Club)	SWC	2.70		2/12/1993		Continuous
66111	Croydon	BOM	2.72		30/01/1879	29/12/1921	Daily
566022	Homebush SPS041 (formerly Homebush BC)	SWC	3.16		9/05/1969		Continuous
66034	Abbotsford (Blackwall Point Rd)	BOM	3.17	15	1/01/2004		Daily
566020	Enfield (composite site)	SWC	3.57		18/06/1983		Continuous
66194	Canterbury Racecourse AWS	BOM	3.58	3	2/10/1995		Synop
566113	Canterbury Racecourse	SWC	3.78		9/12/1993		Continuous
566066	Five Dock SPS065	SWC	3.80		19/10/1989		Continuous
66071	Gladesville Champion Rd	BOM	3.99	10	27/02/1997	29/09/2000	Daily

2.5.2. Analysis of Daily Read Data

An analysis of the records for the nearest daily rainfall stations, namely Barnwell Park Golf Course (66017) and Concord Golf Club (66013) was undertaken and all records of daily rainfalls greater than 150mm are shown in Table 4.

Table 4: Daily Rainfalls greater than 150mm at Barnwell Park Golf Club and Concord Golf Club

Barnwell Park Golf Course (66017) Nov 1929 – Nov 2003			Concord Golf Club (66013) Jan 1930 – to date		
Rank	**Date**	**Rainfall (mm)**	**Rank**	**Date**	**Rainfall (mm)**
1	30/03/1942	315	1	28/03/1942	295
2	11/06/1991	253 (5 day total)	2	6/08/1986	249
3	6/08/1986	250	3	3/02/1990	234
4	5/02/1990	245 (3 day total)	4	20/03/1978	222 (2 day total)
5	11/02/1992	238 (3 day total)	5	10/02/1956	221
6	30/04/1988	228	6	11/06/1991	220 (2 day total)
7	10/02/1956	201	7	10/01/1949	208
8	9/04/1973	197	8	16/06/1952	208 (2 day total)
9	16/02/1988	164 (4 day total)	9	27/11/1955	206
10	19/11/1961	163	10	22/02/1954	198
11	10/01/1949	156	11	16/04/1946	187
12	1/05/1955	156	12	26/07/1952	176

Barnwell Park Golf Course (66017) Nov 1929 – Nov 2003			Concord Golf Club (66013) Jan 1930 – to date		
13	27/11/1955	155	13	19/11/1961	154
14	8/08/1998	152	14	11/03/1958	153
15	15/06/1952	151	15	16/06/1950	151

The results indicate that the 1942, 1986 and 1990 events were the largest daily rainfall events since records began in 1930. The 1986 event was reported (via the community consultation survey) as resulting in flooding within the William Street catchment and SWC records reported flooding to have occurred in the adjacent Dobroyd Canal catchment during this period. It should also be noted for the larger events similar totals are recorded at each gauge. However, for other events there is a wide variation in rainfall totals for the same event between each gauge, even though the gauges are only 2.5 kilometres apart. Possibly this may be due to an error in recording as a result of the high rainfalls.

However, high daily rainfall totals will not necessarily result in widespread flooding of the catchments, particularly if the rainfall was fairly evenly distributed throughout the day. Also if the rainfall occurred at around 9am (when the gauges are read) the total will be split into the two days and therefore may not be shown in Table 4.

2.5.3. Analysis of Pluviometer Data

Continuous pluviometer records provide a more detailed description of temporal variations in rainfall. As such, the Concord Greenlees BC, Ashfield Park Bowling Club, Homebush SPS041, Enfield and Canterbury Racecourse pluviometer stations were analysed. The highest approximate AEP recorded at each station is shown in Table 5.

Table 5: Approximate AEP Recorded at Pluviometer Stations

Station Name	Years of Record	Highest Approximate AEP (ARR 1987)	
		30 minute storm burst	1 hour storm burst
Concord Greenlees BC (formerly Wests Rugby Club)	27	0.5EY – 20% AEP	0.5EY – 20% AEP
Ashfield Park Bowling Club (566112)	7	0.5EY – 20% AEP	1EY – 0.5EY
Homebush SPS041 - formerly Homebush BC	46	5% – 2% AEP	2% – 1% AEP
Enfield (composite site)	32	5% – 2% AEP	10% – 5% AEP
Canterbury Racecourse	22	20% – 10% AEP	0.5EY – 20% AEP

Table 5 indicates that the Homebush pluviometer recorded the highest approximate AEP for the 30 minute and 1 hour storm burst. This occurred on the 20th June 1978 (for the 30 minute storm burst) and the 31st March 2015 (for the 1 hour storm burst).

The January 1996 event resulted in 3 reports of flooding (1 of which was above floor flooding) within the William Street catchment according to SWC records. Table 6 provides an analysis of the January 1996 event and indicates a high intensity, short duration storm event; with relatively high approximate AEP's for the 30 minute duration at the Enfield gauge. The 1996 event also appears to have been highly localised as the other proximate gauges recorded low approximate

AEP's across the 30 minute, 1 hour and 2 hour storm durations.

Table 6: Rainfall Intensities for the 2nd January 1996

	Duration (minutes)		
	30	**60**	**120**
Concord Greenlees BC (566064)			
Max Rainfall (mm)	30	34	50
Intensity (mm/hr)	59	34	25
Approximate AEP	0.5EY – 20% AEP	1EY – 0.5EY	0.5EY – 20% AEP
Rank comparative to gauge records for relevant duration	3	5	2
Ashfield Park Bowling Club (566112)			
Max Rainfall (mm)	25	28	32
Intensity (mm/hr)	50	28	16
Approximate AEP	1EY – 0.5EY	~ 1EY	< 1EY
Rank comparative to gauge records for relevant duration	4	6	9
Homebush SPS041 (566022)			
Max Rainfall (mm)	31	33	40
Intensity (mm/hr)	61	33	20
Approximate AEP	0.5EY – 20% AEP	1EY – 0.5EY	1EY – 0.5EY
Rank comparative to gauge records for relevant duration	6	9	13
Enfield (566020)			
Max Rainfall (mm)	49	49	50
Intensity (mm/hr)	97	49	25
Approximate AEP	5% – 2% AEP	20% – 10%AEP	0.5EY – 20% AEP
Rank comparative to gauge records for relevant duration	2	3	6
Canterbury Racecourse (566113)			
Max Rainfall (mm)	36	38	45
Intensity (mm/hr)	71	38	22
Approximate AEP	20% – 10%AEP	0.5EY – 20% AEP	1EY – 0.5EY
Rank comparative to gauge records for relevant duration	2	4	7

2.6. Previous Studies Reviewed as Part of the Flood Study (Reference 1)

2.6.1. Hydraulic Study and On-Site Detention Modelling for Burwood Council Catchments (Reference 5)

Robinson GRC Consulting prepared this report on behalf of Burwood City Council from 2000 to 2002. The primary objective of this study was to develop a computer model to assess the 1% AEP event and from this determine insufficiencies in the drainage system, as well as identify frequently occurring overland flow paths. Once these "hotspots" were identified, possible mitigation measures were proposed with further modelling undertaken to assess these. Additional modelling was undertaken to propose Permissible Site Discharge (PSD) and storage volumes for potential On-Site Detention (OSD) systems.

A DRAINS hydraulic model was established and calibrated to the flow gauge and rain gauge records that were collected for the purpose of this study. However, as these events were not of a significant magnitude, the calibration was determined to be inconclusive.

The hotspots identified in the St Lukes catchment were:

- Railway Parade;
- Elsie Street;
- John Street and Dunns Lane;
- New Street;
- Park Road;
- Britannia Avenue;
- Neich Parade;
- Milton Street;
- Royce Avenue;
- Cheltenham Road; and
- Parramatta Road and Lucas Road.

The hotspots identified in this report for the William Street catchment were:

- Bay Street;
- Wychbury Avenue and Wychbury Lane;
- Parramatta Road; and
- Acton Street.

2.6.2. Sydney Water Stormwater Capacity Assessment Reports

SWC has prepared various reports that investigated the capacity performance of the SWC owned infrastructure. The reports were:

- St Lukes Park (SWC 90) Capacity Assessment – June 1997; and
- William Street (SWC97) Capacity Assessment – June 1997.

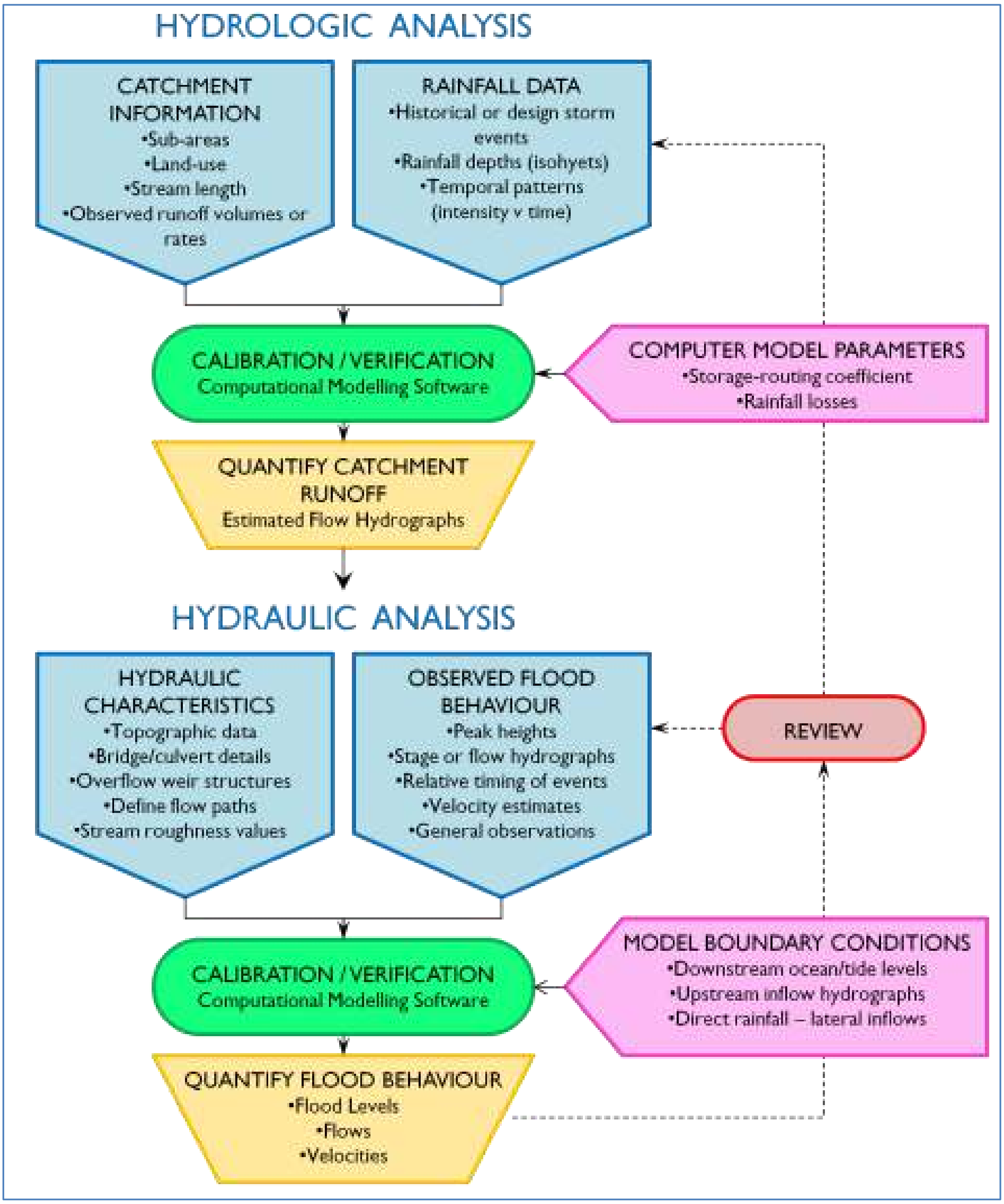
The SWC Capacity Assessment reports have been used in the present study for informing the SWC owned pit and pipe details (discussed in Section 2.3).

3. FLOOD STUDY METHODOLGOGY

3.1. Overview

A diagrammatic representation of the flood study process is shown in Diagram 1. The urbanised nature of the study area with its mix of pervious and impervious surfaces, and existing piped and overland flow drainage systems, has created a complex hydrologic and hydraulic flow regime.

Diagram 1: Flood Study Process



The estimation of flood behaviour in a catchment is undertaken as a two-stage process, consisting of:

1. hydrologic modelling to convert rainfall estimates to overland flow and stream runoff; and
2. hydraulic modelling to estimate overland flow distributions, flood levels and velocities.

As such, the hydrologic model, DRAINS, was built and used to create flow boundary conditions for input into a two-dimensional unsteady flow hydraulic model termed TUFLOW.

Good historical flood data facilitates calibration of the models and increases confidence in the estimates. The calibration process involves modifying the initial model parameter values to produce modelled results that concur with observed data. Validation is undertaken to ensure that the calibration model parameter values are acceptable in other storm events with no additional alteration of values. Recorded rainfall and stream-flow data are required for calibration of the hydrologic model, while historic records of flood levels, velocities and inundation extents can be used for the calibration of hydraulic model parameters. In the absence of such data, model verification is the only option and a detailed sensitivity analysis of the different model input parameters constitutes current best practice.

There are no stream-flow records in the catchment, so the use of a flood frequency approach for the estimation of design floods or independent calibration of the hydrologic model was not possible.

The sub-catchments in the hydrologic model were kept small (on average approximately <2 ha) such that the overland flow behaviour for the study was generally defined by the hydraulic model. This joint modelling approach was verified against previous studies and alternative methods.

3.2. Hydrologic Model

DRAINS is a hydrologic/hydraulic model that can simulate the full storm hydrograph and describes the flow behaviour of a catchment and pipe system for real storm events, as well as statistically based design storms. It is designed for analysing urban or partly urban catchments where artificial drainage elements have been installed.

The DRAINS model is broadly characterised by the following features:

- the hydrological component is based on the theory applied in the ILSAX model which has seen wide usage and acceptance in Australia;
- its application of the hydraulic grade line method for hydraulic analysis throughout the drainage system; and
- the graphical display of network connections and results.

DRAINS generates a full hydrograph of surface flows arriving at each pit and routes these through the pipe network or overland, combining them where appropriate. It should be noted that DRAINS is not a true unsteady flow model and therefore does not account for the attenuation effects of routing through temporary floodplain storage (down streets or in yards). As such the use of DRAINS within the study is limited to some minor upstream routing and development of hydrological inputs into the downstream TUFLOW model.

3.2.1. Sub-catchment Definition

Details of the sub catchment definition (Figure 3) are provided in Table 7.

Table 7: Sub Catchment Definition

Catchment	Catchment Area (km^2)	No. Sub catchments	Average Sub catchment size (ha)
St Lukes	2.25	136	1.64
Williams Street	1.18	60	1.96

Runoff from connected impervious surfaces such as roads, gutters, roofs or concrete surfaces occur significantly faster than from vegetated surfaces. This results in a faster concentration of flow within the downstream area of the catchment and increased peak flow in some situations. It is therefore necessary to estimate the proportion of the catchment area that is covered by such surfaces.

DRAINS categorises these surface areas as either:

- paved areas (impervious areas directly connected to the drainage system);
- supplementary areas (impervious areas not directly connected to the drainage system; instead connected to the drainage system via the pervious areas); and
- grassed areas (pervious areas).

3.2.2. Impervious Surface Area

Within the study area, a uniform 5% was adopted as a supplementary area across the catchment. The remaining 95% was attributed to impervious (or paved areas) and pervious surface areas, as estimated for each individual sub-catchment. This was undertaken by determining the proportion of the sub-catchment area allocated to a land-use category and the estimated impervious percentage of each land-use category as indicated in Table 8.

Table 8: Impervious Percentage per Land-use

Land-use Category	Impervious Percentage
Property	50% Impervious
Vegetation (such as public parks)	0% Impervious
Roadway	100% Impervious

The proportion of each land-use category within a sub-catchment was determined based upon the hydraulic model roughness schematisation, shown in Figure 5. The impervious percentages attributed to each land-use category were estimated based on aerial observation of a representative area.

3.3. Hydraulic Model

3.3.1. Overview

The availability of high quality LiDAR data means that the study area is suitable for two-dimensional (2D) hydraulic modelling. Various 2D software packages are available and the TUFLOW package was adopted as it is widely used in Australia.

The TUFLOW software is produced by BMT WBM and has been widely used for a range of similar projects. The model is capable of dynamically simulating complex overland flow regimes. It is especially applicable to the hydraulic analysis of flooding in urban areas which is typically characterised by short duration events and a combination of supercritical and subcritical flow behaviour.

The study area consists of a wide range of developments, with residential, commercial and open space areas. For this catchment, the study objectives require accurate representation of the overland flow system including kerbs and gutters and defined drainage controls.

For the hydraulic analysis of complex overland flow paths (such as the present study area where overland flow occurs between and around buildings), an integrated 1D/2D model such as TUFLOW provides several key advantages when compared to a 1D only model.

Importantly, a 2D hydraulic model can better define the spatial variations in flood behaviour across the study area. Information such as flow velocity, flood levels and hydraulic hazard can be readily mapped across the model extent. This information can then be easily integrated into a GIS based environment enabling the outcomes to be readily incorporated into Council's planning activities. The model developed for the present study provides a flexible modelling platform to properly assess the impacts of any overland flow management strategies within the floodplain.

In TUFLOW (HPC, 2018-03-AD-iDP-w64), the ground topography is represented as a uniform-spaced grid with a ground elevation and a Manning's "n" roughness value assigned to each grid cell. The grid cell size is determined as a balance between the model result definition required and the computer run time (which is largely determined by the total number of grid cells). A 2 m grid size was adopted and the model schematisation is shown on Figure 4.

The downstream hydraulic model boundary was taken as the Parramatta River.

3.3.2. Roughness Co-efficient

The hydraulic efficiency of the flow paths within the TUFLOW model is represented in part by the hydraulic roughness or friction factor formulated as Manning's "n" values. This factor describes the net influence of bed roughness and incorporates the effects of vegetation and other features which may affect the hydraulic performance of the particular flow path.

The spatial variation in Manning's "n" values is shown on Figure 5. The Manning's "n" values adopted for these areas, including flowpaths (overland, pipe and in-channel), are shown in Table

9. These values have been adopted based on site inspection and past experiences in similar floodplain environments and are consistent with typical values in the literature.

Table 9: Manning's "n" values adopted in TUFLOW

Surface	Manning's "n" Adopted
Pipes	0.015
Roads and Footpaths	0.02
Light Vegetation	0.03
Properties	0.05

3.3.3. Buildings, Fencing and Obstructions

Buildings and other significant features likely to act as flow obstructions were incorporated into the model network based on building footprints, defined using aerial photography. These types of features were modelled as impermeable obstructions to the floodwaters.

Smaller localised obstructions within or bordering private property, such as fences, were not explicitly represented within the hydraulic model as these features change over time. The cumulative effects of these features on flow behaviour were assumed to be addressed partially by the adopted roughness parameters.

3.3.4. Sub-surface Drainage Network

Figure 4 shows the location and extent of drainage lines within the study catchment that have been included in the TUFLOW model. The drainage system defined in the model comprises:

- 1075 pipes;
- 90 open channel segments; and
- 1107 pits and nodes.

3.3.5. Blockage Assumptions

Blockage of hydraulic structures can occur with the transportation of a number of different materials by flood waters. This includes vegetation, garbage bins, building materials and cars, the latter of which has been seen in the June 2007 event at Newcastle. However, the disparity in materials that may be mobilised within a catchment can vary greatly.

Debris availability and mobility can be influenced by factors such as channel shear stress, height of floodwaters, severity of winds, storm duration and seasonal factors relating to vegetation. The channel shear stress and height of floodwaters that influence the initial dislodgment of blockage materials are also related to the magnitude of the event. Storm duration is another influencing factor, with the mobilisation of blockage materials generally increasing with increasing storm duration.

The potential effects of blockage include:

- decreased conveyance of flood waters through the blocked hydraulic structure or drainage system;

- variation in peak flood levels;
- variation in flood extent due to flows diverting into adjoining flow paths; and
- overtopping of hydraulic structures.

Existing practices and guidance on the application of blockage can be found in various texts and the policies of various local authorities and infrastructure agencies. Current modelling has been undertaken assuming no blockage of pipes, culverts and bridges greater than 300 mm in diameter. Pipes less than or equal to 300 mm in diameter were conservatively assumed to be completely blocked.

3.4. Verification of Modelling

Prior to use for defining design flood behaviour it is important that the performance of the overall modelling system be substantiated. Calibration involves modifying the initial model parameter values to produce modelled results that concur with observed data. Validation is undertaken to ensure that the calibration model parameter values are acceptable in other storm events with no additional alteration of values. Best practice is that the modelling system should be calibrated to one historical event and validated using multiple historical events. To facilitate this there needs to be adequate historical flood observations and sufficient pluviometer rainfall data.

Typically in urban areas such information is lacking. Issues which may prevent a thorough calibration of hydrologic and hydraulic models are:

- there is only a limited amount of historical flood information available for the study area. For example, in Sydney (east of Parramatta) there are only two water level recorders in urban catchments similar to that of the study area;
- both Councils and SWC have few flood records that can be used for calibration; and
- rainfall records for past floods are limited and there is a lack of temporal information describing historical rainfall patterns within the catchment.

In the event that a calibration and validation of the models is not possible or limited in scope, it is best practice to undertake a verification of the models and a detailed sensitivity analysis. Due to the limited amount of available historical peak height and rainfall data only a very basic model verification was possible and this is discussed in the Draft 2019 Exile Bay, St Lukes and Williams Street Flood Study (Reference 1). A comparison of peak flows and peak depths was also undertaken with the results of past studies on this catchment. No additional model verification was undertaken as part of this present study.

4. DESIGN FLOOD MODELLING

4.1. Overview

There are two basic approaches to determining design flood levels, namely:

- flood frequency analysis – based upon a statistical analysis of the flood events; and
- rainfall and runoff routing – design rainfalls are processed by hydrologic and hydraulic computer models to produce estimates of design flood behaviour.

The flood frequency approach requires a reasonably complete homogenous record of flood levels and flows over a number of decades to give satisfactory results. No such records were available within this catchment. For this reason, a rainfall and runoff routing approach using DRAINS model results was adopted for this study to derive inflow hydrographs for input to the TUFLOW hydraulic model, which determines design flood levels, flows and velocities. This approach reflects current engineering practice and is consistent with the quality and quantity of available data.

Guidelines for design flood estimation are provided in Australian Rainfall and Runoff (ARR). The 1987 version (Reference 4) was adopted for use in the Draft 2019 Exile Bay, St Lukes and Williams Street Flood Study (Reference 1) however this was superseded by ARR 2019 (Reference 3).

4.2. Australian Rainfall and Runoff

4.2.1. Overview

The ARR guidelines were updated in 2019 due to the availability of numerous technological developments, a significantly larger rainfall dataset since the previous edition in 1987 and development of updated methodologies. The rainfall dataset includes a larger number of rainfall gauges which continuously recorded rainfall (pluviometers) and a longer record of storms (events from 1985 to approximately 2015 are included).

4.2.2. ARR 2019 – Design Rainfall Update

Three major changes have been made to the approach adopted in ARR 1987 (Reference 4) for ARR 2019 (References 3 and 6):

1. The recommended Intensity, Frequency and Duration (IFD) rainfall data across Australia have been updated based on analysis of available records (BoM website), together with revised initial and continuing loss values;
2. ARR 2019 recommends the analysis of 10 temporal patterns for each storm duration to determine the critical storm event;
3. The critical storm event for a duration corresponds to the temporal pattern which produces the maximum average peak value from the 10 storms;
4. The inclusion of Areal Reduction Factors (ARFs) based on Australian data for short (12 hours and less) and long durations (larger than 12 hours). ARFs are an estimate of how design rainfall intensity varies over a catchment, based on the assumption that large catchments will not have a uniform depth of rainfall across their entire area.

Based on the small size of the subject catchments an ARF was not used for this study.

4.2.3. Design Rainfall Data

The design rainfall IFD data (shown in Table 10) was obtained from the BoM's online design rainfall tool. A comparison between ARR 1987 (Reference 4) and 2019 (Reference 3) IFD data is provided on Diagram 2.

Table 10: Rainfall ARR 2019 IFD data (mm depth)

Duration (min)	Annual Exceedance Probability (AEP)						
	63.20%	50%	20%	10%	5%	2%	1%
5	7.8	8.7	11.2	13.0	14.7	16.9	18.6
15	15.4	17.2	22.7	26.3	29.9	34.6	38.1
30	21.1	23.4	30.6	35.4	40.1	46.3	51.0
45	24.6	27.2	35.2	40.7	46.0	53.1	58.5
60	27.3	30.0	38.7	44.6	50.4	58.2	64.2
90	31.5	34.5	44.1	50.8	57.4	66.3	73.3
120	34.8	38.1	48.6	55.9	63.2	73.2	81.0
180	40.3	44.0	56.2	64.8	73.5	85.4	94.8
270	47.0	51.4	66.0	76.4	87.1	102.0	113.0
360	52.7	57.8	74.8	86.9	99.4	117.0	131.0
540	62.2	68.8	90.2	106.0	122.0	144.0	162.0
720	70.2	78.1	104.0	122.0	141.0	168.0	189.0

Diagram 2: Change in Rainfall Depths ARR 2019 versus ARR 1987

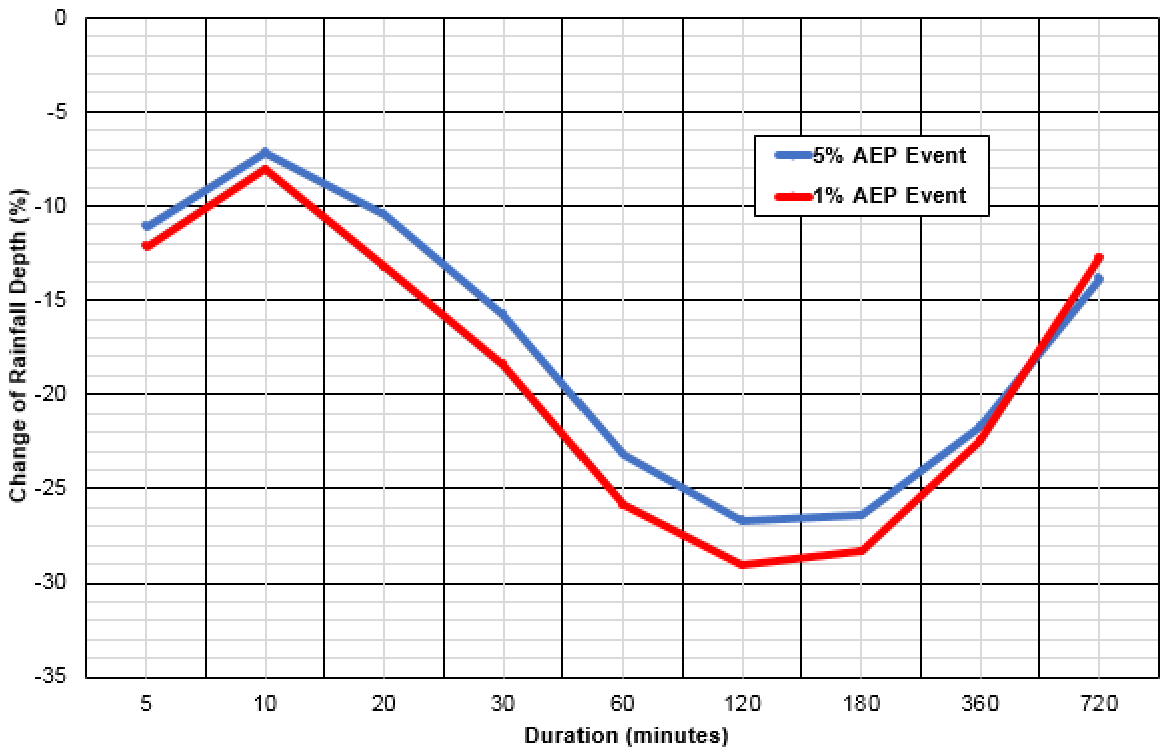


Diagram 2 indicates that design rainfalls have decreased by up to 30% for durations between 40 minutes and 4 hours using ARR2019. For 360 to 720 minutes the reduction ranges from 25% to

15%. For 10 to 40 minutes the reduction ranges from 10% to 20%. These changes are as a result of approximately 30 years of additional rainfall data from 1987 to 2015 and in particular data from the large number of post 1987 pluviometers which provide increased knowledge of sub daily rainfall intensities.

4.2.4. Accuracy of the 2019 IFD Data

The 2019 IFD data can vary significantly from the previous 1987 IFD data. This issue is addressed by the text below taken from the BoM's web site (May 2019).

> The 2016 IFDs are based on a greatly expanded rainfall database and use contemporary methods for analysis of the rainfall data. In addition, the length of record available for each station has been maximised through quality control processes and Region of Influence methods. The 2016 IFDs provide a better overall fit to the current rainfall database than the old IFDs.
>
> As with all statistical methods, there is a level of uncertainty in the derived results due to the variability inherent in the data sample. In the 2016 IFDs this uncertainty has been reduced through the increased sample size afforded by the additional years of recorded data and inclusion of significant amounts of rainfall data from water agencies around the country.
>
> The process of developing the new IFDs was guided and reviewed by a panel of experts set up by Engineers Australia. The differences in methods between the new IFDs and the ARR87 IFDs are summarised in the table below:

Method	New IFDs	ARR87 IFDs
Number of rainfall stations	Daily read - 8074 Continuous - 2280	Daily read - 7500 Continuous - 600
Period of record	All available records up to 2012	All available records to up ~ 1983
Length of record used in analyses	Daily read >= 30 years Continuous > 8 years	Daily read >= 30 years Continuous > 6 years
Source of data	Bureau of Meteorology & other organisations collecting rainfall data	Primarily Bureau of Meteorology
Extreme value series	Annual Maximum Series (AMS)	Annual Maximum Series (AMS)
Frequency analysis	Generalised Extreme Value (GEV) distribution fitted using L-moments	Log-Pearson Type III (LPIII) distribution fitted using method of moments
Extension of sub-daily rainfall statistics to daily read stations	Bayesian Generalised Least Squares Regression (BGLSR)	Principal Component Analysis
Gridding	Regionalised at-site distribution parameters gridded using ANUSPLIN	Maps hand-drawn to at-site distribution parameters, digitised and gridded using an early version of ANUSPLIN

4.3. Rainfall Losses

Methods for modelling the proportion of rainfall that is “lost” to infiltration are outlined in ARR. The methods are of varying degrees of complexity, with the more complex options only suitable if sufficient data are available. The method most typically used for design flood estimation is to apply an initial and continuing loss to the rainfall. The initial loss represents the wetting of the catchment prior to runoff starting to occur and the continuing loss represents the ongoing infiltration of water into the saturated soils while rainfall continues.

Rainfall losses from a paved or impervious area are considered to consist of only an initial loss (an amount sufficient to wet the pavement and fill minor surface depressions). Losses from grassed areas are comprised of an initial loss and a continuing loss.

The adopted rainfall loss parameters are in accordance with ARR (Reference 3 and Reference 6). A continuing loss of 0.72 mm/h was adopted based on 1.8 mm/h taken from the ARR Datahub x 0.4 (reduction of 0.4 based on updated analysis) and initial losses are shown in Table 11.

Table 11: Adopted DRAINS Initial Losses for Urban and Park Areas

Urban remaining Area Loss						
Duration Minutes	50 % AEP	20 % AEP	10 % AEP	5 % AEP	2 % AEP	1 % AEP
60	12.5	6.5	6.3	6.9	6.4	5.0
90	11.2	6.6	6.7	7.4	7.2	6.4
120	11.5	6.6	6.8	7.1	6.4	5.0
180	12.1	7.2	7.5	7.4	7.0	4.9
360	12.0	7.1	7.7	7.2	6.5	3.0
Park remaining Area Loss						
Duration Minutes	50 % AEP	20 % AEP	10 % AEP	5 % AEP	2 % AEP	1 % AEP
60	16.1	8.4	8.1	8.9	8.3	6.4
90	14.5	8.6	8.6	9.5	9.2	8.3
120	14.8	8.6	8.7	9.1	8.3	6.5
180	15.6	9.2	9.7	9.5	9.0	6.3
360	15.5	9.1	10.0	9.2	8.4	3.9

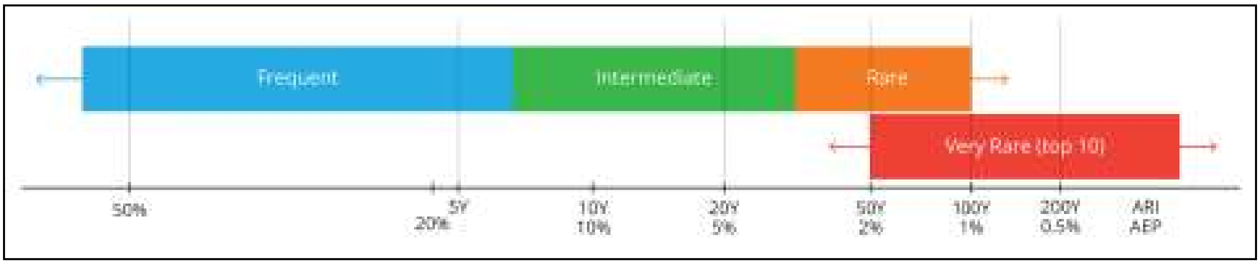
4.3.1. Storm Temporal Patterns

ARR 1987 provided a single temporal pattern for each storm duration for:

- events less than a 30 year ARI; and
- for events greater than a 30 year ARI.

ARR 2019 provides several patterns for each storm duration. These temporal patterns were extracted from storms occurring across Australia and are different for each region. The ARR data hub provides a table with all the temporal patterns that could be used at a given location. The temporal patterns are grouped in bins based on the frequency of the recorded storms as shown in Diagram 3.

Diagram 3: Temporal Pattern Bins



ARR 2019 recommends the use of 10 temporal patterns for design storm analysis. The 10 patterns have the same total rainfall depth, but there are differences in rainfall distribution across the storm duration. Some patterns may represent storms with intense bursts at the start, middle or end of the storm duration, others represent storms with multiple bursts, and some may represent storms with constant rainfall. Different patterns can produce different peak flood levels for the same catchment area depending on the catchment topography and response.

The representative temporal pattern (used as part of the critical duration analysis) is the pattern which produces peak flood levels just greater than the average of the 10 temporal patterns (not the temporal pattern which produces the largest peak level) for each storm duration. This can be determined by running each of the 10 temporal patterns through the hydrologic and hydraulic models and obtaining the average flood level or peak flow produced. The critical storm duration is the duration whose representative temporal pattern produces the maximum flow or level (i.e the highest of the average values for all storm durations).

4.4. Critical Storm Duration

The critical storm duration is the duration which produces the peak flood levels in the area of interest. In a catchment wide study the critical duration will vary, for example, from the 15 minute storm in the upper catchment to the 1 hour in the middle and to the 2 hour at the catchment outlet. The areas of interest in this study are the two precincts and the critical durations for each event adopted were:

- 5% AEP = 30 minutes;
- 1% AEP = 45 minutes;
- PMF = 30 minutes.

A similar critical approach was undertaken in the Flood Study (Reference 1) based on ARR 1987 (Reference 4) and slightly different critical durations were adopted due to the different ARR approaches.

It should be noted that whilst results have been provided for the entirety of the two catchments, the results are technically only valid for the two precincts within the City of Canada Bay Council LGA as different critical storm durations may apply outside these two precincts.

4.5. Downstream Boundary Conditions

In addition to runoff from the catchment, downstream areas can also be influenced by high water levels within the Parramatta River. Consideration must therefore be given to accounting for the joint probability to coincident flooding from both catchment runoff and backwater effects.

The combined impact of these two sources on overall flood risk varies significantly with distance from the ocean and the degree of ocean influence. A rigorous joint probability analysis is required to assess the true likelihood of a flood in the two catchments in conjunction with an elevated water level in the Parramatta River. The Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways guide (Reference 7) presents a multivariate approach for hydraulic modelling purposes and was applied in this study.

Given the short duration of the critical storm burst, the simplistic approach using a steady state ocean boundary was considered sufficient for use in the Flood Study (Reference 1) and this report. The catchment was defined as Entrance Type A (open oceanic embayment) and was located south of Crowdy Head; resulting in the 1% AEP and 5% AEP ocean levels as those shown in Table 12 (note combinations for all AEP events are shown whilst only results for the 5% and 1% AEP and the PMF are provided in this report).

Table 12: Combinations of Catchment Flooding & Oceanic Inundation Scenarios (Reference 1)

Design AEP for Peak Flood Levels	Catchment Flood Scenario	Ocean Water Level Boundary
0.2 EY	0.2 EY Rainfall	HHW Ocean Level 1.25 m AHD
10% AEP	10% AEP Rainfall	HHW Ocean Level 1.25 m AHD
5% AEP	5% AEP Rainfall	HHW Ocean Level 1.25 m AHD
2% AEP	2% AEP Rainfall	5% AEP Ocean Level 1.40 m AHD
1% AEP	1% AEP Rainfall	5% AEP Ocean Level 1.40 m AHD
PMF	PMF Rainfall	1% AEP Ocean Level 1.4 m AHD

4.6. Results

The results from this study are presented as:

- Peak flood depths and level contours on Figure 6 to Figure 8 and Table 13;
- Hydraulic hazard on Figure 9 to Figure 11;
- Provisional hydraulic categorisation on Figure 12 to Figure 14.

4.6.1. Peak Flood Levels and Depths

Peak flood levels vary significantly across the City of Canada Bay Council part of the two Precincts (Table 13) with shallow depths of inundation in many places. This is due to the relatively steep slopes and the wide roads and is most noticeable in the Burwood Precinct (St Lukes catchment). In the Kings Bay Precinct (William Street catchment) the flood gradient is less steep as the downstream parts within Barnwell Park golf course are tidal.

Of note is that within the City of Canada Bay part of the Burwood Precinct, flooding is largely confined to the roads and thus flooding is unlikely to be an issue for the redevelopment in the City of Canada Bay LGA. Within the Kings Bay Precinct flooding is of more importance as the central part of the precinct receives significant overland flow from the upstream Burwood LGA. The lower parts are also low lying and thus affected by high tailwater levels in the Parramatta River which restrict the outflow of floodwaters.

Table 13: Peak Flood Levels and Depths

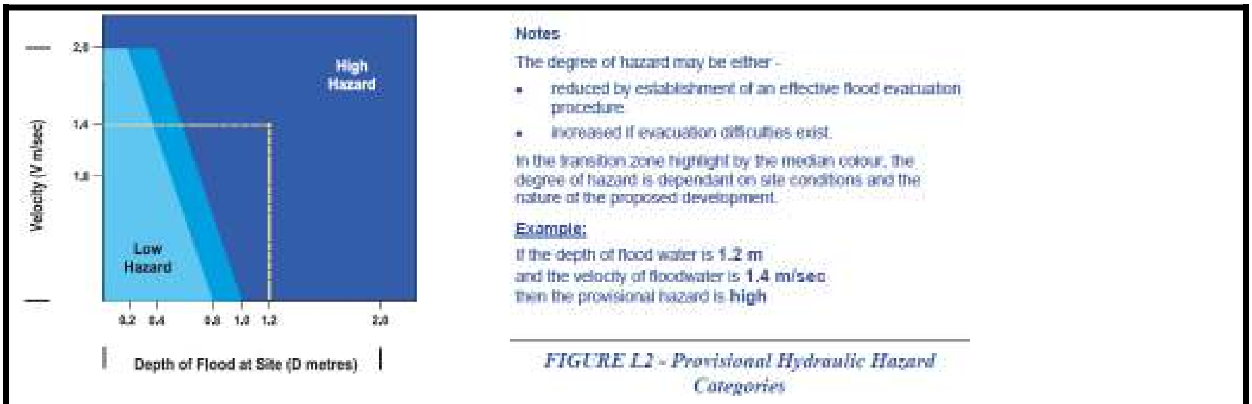
ID	Location (refer Figure 1)	Peak Flood Level (m AHD)		Peak Flood Depth (m)	
		1% AEP	5% AEP	1% AEP	5% AEP
SL1	Parramatta Rd X Shaftsbury Rd	4.67	4.58	0.21	0.12
SL2	Parramatta Rd X Burwood Rd	14.77	14.76	0.02	0.01
SL3	Parramatta Rd (near Britannia Ave)	20.17	20.17	0.02	0.02
SL4	Burton St X Loftus St	7.25	7.25	0.00	0.00
SL5	Burton St X Burwood Rd	18.64	18.64	0.00	0.00
WS1	William St X Parramatta Rd	3.83	3.73	0.44	0.35
WS2	Regatta Rd X Parramatta Rd	8.20	8.19	0.01	0.01
WS3	William St X Spencer St	2.60	2.44	0.42	0.27
WS4	William St X Queens Rd	2.29	2.19	0.58	0.49
WS5	William St X Kings Rd	2.23	2.21	0.20	0.19

Flood contours and depths provided on Figure 6 to Figure 8 can be difficult to read at the scale provided. These figures should not be used to determine flood levels for design purposes and developers should contact Council who will be provided with all the results from this study. This approach will ensure that the appropriate and consistent design levels are used, if any updates to the flood levels are undertaken these will be incorporated together with a record of the date of supply of the data by Council.

4.6.2. Hydraulic Hazard Categorisation

The Flood Study defined provisional flood hazard categories in accordance with the NSW Floodplain Development Manual (Reference 2). Provisional hazards only take account of the hydraulic aspects of flood hazard; depth and velocity (Diagram 4), while true hazard takes into account additional factors such as size of flood, effective warning time, flood readiness, rate of rise of floodwaters, duration of flooding, evacuation problems, effective flood access, type of development within the floodplain, complexity of the stream network and the inter-relationship between flows.

Diagram 4: Provisional Hydraulic Hazard Categories (Reference 2)



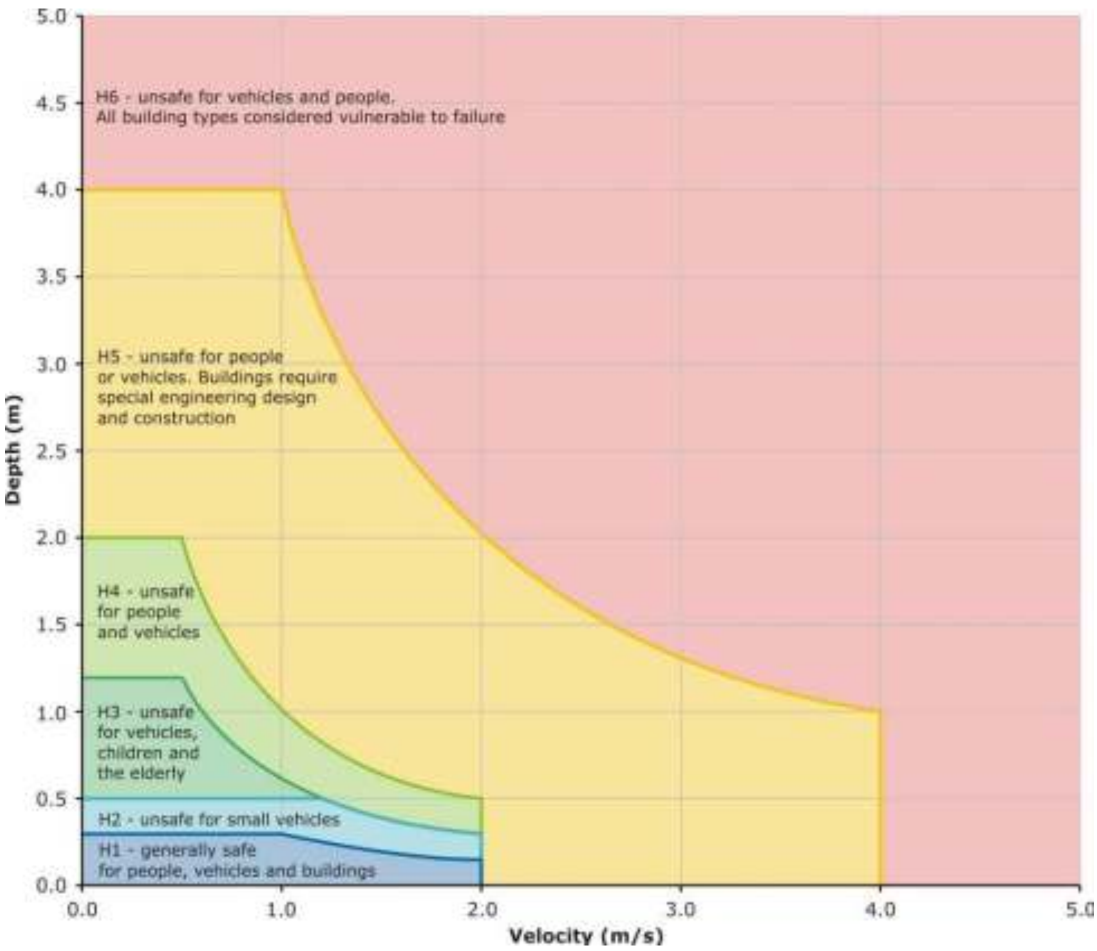
Extracted from The Floodplain Development Manual (Reference 2)

In recent years there has been a number of developments in the classification of hazard. Managing the floodplain: a guide to best practice in flood risk management in Australia (Reference 8) provides revised hazard classifications. These add clarity to the description of hazard categories and what they mean in practice. This new methodology for determining hazard has been used in this study. These classifications should be used by Council for determining the appropriateness of development in flood liable areas and should be incorporated into the DCP.

The hazard classifications are divided into six categories (Diagram 5) which indicate the restrictions on people, buildings and vehicles:

- H1 - Generally safe for vehicles, people and buildings;
- H2 - Unsafe for small vehicles;
- H3 - Unsafe for vehicles, children and the elderly;
- H4 - Unsafe for people and vehicles;
- H5 - Unsafe for people or vehicles. Buildings require special engineering design and construction; and
- H6 - Unsafe for vehicles and people. All buildings types considered vulnerable to failure.

Diagram 5: Hazard Classifications (Reference 8)



4.6.3. Hydraulic Categorisation

The NSW Government's Floodplain Development Manual 2005 (Reference 2) defines three hydraulic categories which could be applied to the study area, namely floodway, flood storage or flood fringe. These categories can be used for assessing the suitability of future land use and development in the formulation of floodplain risk management plans.

Floodways

"those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood *levels."*

Flood storage areas

"those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas."

Flood fringe

"the remaining area of flood prone land after floodway and flood storage areas have been defined"

There is no precise definition of floodway, flood storage and flood fringe or accepted approach to differentiate between these areas. For this study, hydraulic categories were defined by the following criteria, which correspond in part with the criteria proposed by Howells et. al. (Reference 9):to the following approach, namely:

Floodway = Velocity * Depth > 0.25m^2/s AND Velocity > 0.25m/s OR Velocity > 1m/s

The remainder of the floodplain outside the Floodway becomes either Flood Storage or Flood Fringe. Flood Storage was defined as the land outside the Floodway if the depth is greater than 0.5m and Flood Fringe if the depth is less than 0.5m. As noted in Reference 3 *"it is impossible to* provide explicitly quantitative criteria for defining floodways and flood storage areas, as the significance of such areas is *site specific"*.

4.6.4. Sensitivity Analysis

The following sensitivity analyses were undertaken for the 1% AEP rainfall event to establish the variation in design flood levels and flows that may occur if different parameter assumptions were made:

- Manning's "n": The hydraulic roughness values were increased and decreased by 20% (Table 14);
- Blockage (pipes): Sensitivity to blockage of all pipes was assessed for 20% and 50% blockage (Table 15);
- Climate Change (Rainfall Increase): Sensitivity to rainfall/runoff estimates were assessed by increasing the rainfall intensities by 10%, 20% and 30% as (Table 16);
- Climate Change (Sea Level Rise): Sea level rise scenarios of 0.4 m and 0.9 m were assessed (Table 16).

Table 14: Results of Roughness Analysis – Change in Peak Depth (m) 1%AEP

ID	Location (refer Figure 1)	Peak Flood Depth 1% AEP	Difference with 1% AEP (m)	
			Roughness Decreased by 20%	Roughness Increased by 20%
SL1	Parramatta Rd X Shaftsbury Rd	0.21	+0.01	-0.01
SL2	Parramatta Rd X Burwood Rd	0.02	0.00	0.00
SL3	Parramatta Rd (near Britannia Ave)	0.02	0.00	0.00
SL4	Burton St X Loftus St	0.00	0.00	0.00
SL5	Burton St X Burwood Rd	0.00	0.00	0.00
WS1	William St X Parramatta Rd	0.44	0.00	+0.01
WS2	Regatta Rd X Parramatta Rd	0.01	0.00	0.00
WS3	William St X Spencer St	0.42	-0.01	+0.01
WS4	William St X Queens Rd	0.58	0.00	0.00
WS5	William St X Kings Rd	0.20	0.00	0.00

Table 14 indicates that changing the roughness produces minimal impact on flood levels in the 1% AEP event.

Table 15: Results of Blockage Analysis – Change in Peak Depth (m) 1%AEP

ID	Location (refer Figure 1)	Peak Flood Depth 1% AEP	Difference with 1% AEP (m)	
			Blockage (Pipes) by 20%	Blockage (Pipes) by 50%
SL1	Parramatta Rd X Shaftsbury Rd	0.21	0	0
SL2	Parramatta Rd X Burwood Rd	0.02	0	0
SL3	Parramatta Rd (near Britannia Ave)	0.02	0	0
SL4	Burton St X Loftus St	0.00	0	0
SL5	Burton St X Burwood Rd	0.00	0	0
WS1	William St X Parramatta Rd	0.44	0	0
WS2	Regatta Rd X Parramatta Rd	0.01	0	0
WS3	William St X Spencer St	0.42	0	0
WS4	William St X Queens Rd	0.58	0	0
WS5	William St X Kings Rd	0.20	0	0

Table 15 indicates that blockage of pipes makes no significant difference on flood levels in the 1% AEP event.

Table 16: Results of Climate Change Analysis – Change in Peak Depth (m) 1%AEP

ID	Location (refer Figure 1)	Peak Flood Depth 1% AEP	Difference with 1% AEP (m)				
			Rainfall Increase 10%	Rainfall Increase 20%	Rainfall Increase 30%	2050 Sea Level Rise + 0.4 m	2100 Sea Level Rise + 0.9 m
SL1	Parramatta Rd X Shaftsbury Rd	0.21	0.05	0.10	0.15	0.00	0.00
SL2	Parramatta Rd X Burwood Rd	0.02	0.00	0.01	0.01	0.00	0.00
SL3	Parramatta Rd (near Britannia Ave)	0.02	0.00	0.00	0.00	0.00	0.00
SL4	Burton St X Loftus St	0.00	0.00	0.00	0.00	0.00	0.00
SL5	Burton St X Burwood Rd	0.00	0.00	0.00	0.00	0.00	0.00
WS1	William St X Parramatta Rd	0.44	0.05	0.09	0.12	0.01	0.02
WS2	Regatta Rd X Parramatta Rd	0.01	0.00	0.00	0.01	0.00	0.00
WS3	William St X Spencer St	0.42	0.09	0.16	0.23	0.03	0.13
WS4	William St X Queens Rd	0.58	0.04	0.07	0.09	0.04	0.14
WS5	William St X Kings Rd	0.20	0.02	0.03	0.05	0.02	0.17

Table 16 indicates:

- Sea level rise only has a significant impact on flood levels in the lower part of the Kings Bay Precinct;
- Climate induced rainfall increase generally makes little difference to the peak 1% AEP flood levels as the existing depths of inundation are relatively shallow and the flow paths are largely wide and unconfined.

4.7. Risk Mitigation

4.7.1. Road Inundation and Access

Understanding flood access issues is critical to effective evacuation and flood response planning for existing and proposed developments. Research undertaken for ARR 2019 indicates that if velocities approach 3 m/s, vehicles can become unstable in shallow depths of floodwaters (~0.1 m) and small cars can float in still water depths of only 0.3 m.

Information about the depths and velocities of road inundation and likely timing of road closures can aid flood response planning, and ensure that evacuation and or emergency access occurs in a timely fashion. Additionally, early warning can allow motorists to better plan their route, make informed choices and thus avoid flood affected areas and road crossings. In many rural catchments flood depth indicator boards are located at frequently inundated crossings to warn motorists of the depth of flood waters. However, the SES advises that driving or walking through any depth of floodwaters should not be undertaken. In the Sydney basin these flood depth indicator boards are frequently found in rail or road bridge underpass areas where significant depths of floodwaters occur or in high risk areas where motorists have had to be rescued in the past.

The installation of flood depth indicator boards should be considered for frequently inundated road crossings. However, their actual locations can only be determined at the detail design stage. In addition, road access for flood access in compliance with SES guidelines needs to investigated as this is a requirement in the DCP (Section 5.3).

4.7.2. Flood Awareness

The flood awareness of the community and the available flood warning time are important factors in reducing the likely flood damages. Whilst some residents will have experienced small floods many of the affected properties in large floods will not have. People generally become aware of certain types of flooding and flood behaviour and are therefore less likely to be prepared for the impacts of a different magnitude flood such as the 1% AEP event as they are so familiar with smaller events. Council's DCP requires developments to give consideration to evacuation and flood risk and this can only be achieved if the community is aware of the flood risk throughout the catchment.

The low level of awareness combined with a relatively short warning time (less than 1 hour from the start of the rainfall) is typical of flash flooding in urbanised areas of Sydney. As warning times are limited, and there are no means of making significant improvements, a strong emphasis should be put on community flood awareness strategy as a risk management measure for existing and proposed developments. This will ensure that residents can make best possible use of any information on flooding to minimise risk to life and tangible damages. It is understood that Council does not have a flood awareness plan or strategies for the two precincts. Examples of possible flood awareness strategies are provided in Table 17. Council should consider introduction of a flood awareness plan for the two precincts.

Table 17: Possible Flood Awareness Strategies

Method	Comment
Letter/pamphlet from Council	These may be sent (annually or biannually) with the rate notice or separately. A Council database of flood liable properties/addresses makes this a relatively inexpensive measure which can be effective if residents take the time to absorb and apply the suggestions. The pamphlet can inform residents of ongoing implementation of the management measures, changes to flood levels, climate change or any other relevant information.
Council website	Council should continue to update and expand their website to provide both technical information on flood levels as well as qualitative information on how residents can make themselves flood aware. This would provide an excellent source of knowledge on flooding within the study area (and elsewhere in the LGA) as well as on issues such as climate change. It is recommended that Council's website continue to be updated as and when required.
Community Working Group	Council could initiate a Community Working Group framework (undertaken in other catchments elsewhere) and this would provide a valuable two way conduit between the local residents and Council.
School project or local historical society	This provides an excellent means of informing the younger generation about flooding and climate change. It may involve talks from various authorities and can be combined with topics relating to water quality, floodplain management, etc.
Displays at key locations or similar	This is an inexpensive way of informing the community and may be combined with related displays.
Historical flood markers and flood depth markers	Signs or marks can be prominently displayed on telegraph poles or such like to indicate the level reached in previous floods. Depth indicators advise of potential hazards. These are inexpensive and effective but in some flood communities not well accepted as it is considered that they affect property values.
Articles in local newspapers	Ongoing articles in the newspapers will ensure that the flood and climate change issues are not forgotten. Historical features and remembrance of the anniversary of past events are interesting for local residents.
Collection of peak water level data from future floods	Collection of data (photographs) assists in reinforcing to the residents that Council is aware of the problem and ensures that the design flood levels are as accurate as possible. This might also include establishment of peak water level marker poles and which house floors are inundated.
Types of information available	A recurring problem is that new owners consider they were not adequately advised that their property was flood affected on the 10.7 Certificate during the purchase process. Council may wish to advise interested parties, when they inquire during the property purchase process, regarding flood information currently available, how it can be obtained and the cost. This information also needs to be provided to all tenants and visitors who may rent for a period. Some Councils have conducted "briefing" sessions with real estate agents and conveyancers.
Establishment of a flood affectation effects database	A database would provide information on (say) which houses have been inundated above floor in the past and required assistance, which public structures will be affected (e.g. telephone or power cuts). This database should be reviewed after each flood event with input from the community.
Flood preparedness program	Providing information to the community regarding flooding helps to inform it of the problem and associated implications. However, it does not necessarily adequately prepare people to react effectively to the problem. A Flood Preparedness Program would ensure that the community is adequately prepared. The SES would take a lead role in this.
Develop approaches to foster community ownership of the problem	Flood damages in future events can be minimised if the community is aware of the problem and takes steps to find solutions. The development of approaches that promote community ownership should therefore be encouraged. For example, residents should be advised that they have a responsibility to advise Council if they see a problem such as debris blockage or such like. This process can be linked to water quality or other water related issues including estuary management. The specific approach can only be developed in consultation with the community. Consideration and reference should be made to engaging the community as per the community engagement International Association for Public Participation spectrum framework and associated methods and activities, which seeks to promote and improve the practice of public participation or community and stakeholder engagement, incorporating individuals, governments, institutions and other entities that affect the public interest (https://www.iap2.org.au/Home).

4.7.3. Flood Warning

There is no specific warning system for small catchments such as St Lukes and William Street as the time from the rain falling until the flood occurs is of the order of 1 hour, thus this is too short a time to issue a warning. Severe Weather Warnings and Flood Watches and Warnings are issued by the BoM and evacuation warnings and orders are issued by the SES. The SES is the legislated combat agency for floods in NSW and is responsible for the control of flood response operations. It maintains a flood intelligence system for key flood warning gauges in NSW on major river systems and develops specific flood emergency plans for LGAs which are subject to flooding.

Adequate warning gives residents time to move goods and cars above the reach of floodwaters and to evacuate from the immediate area to high ground. The effectiveness of a flood warning scheme depends on:

- the maximum potential warning time before the onset of flooding;
- the actual warning time provided before the onset of flooding. This depends on the adequacy of the information gathering network and the skill and knowledge of the operators;
- the time required to complete a safe evacuation;
- the flood awareness of the community responding to a warning.

Flood warning is an excellent floodplain management measure on large catchments where the time for the rain to fall and reach the flood prone area is at least six hours. However, for small catchments such as St Lukes and Williams Street the time from the start of the flood producing rainfall until flooding occurs downstream is less than 2 hours. Thus, there is insufficient time for the BoM or others to observe that heavy rainfall has occurred and then time to issue a flood warning.

It is likely therefore that in a future major flood the majority of the people within the two precincts, and likely that no one in the entire LGA, will have any warning time to evacuate or undertake any flood preventative measures until they see floodwaters in the streets. Certainly, if the flood occurs at night, the first time residents will likely become aware of a flood will be when they look outside in the morning.

4.8. Economic Impacts of Flooding

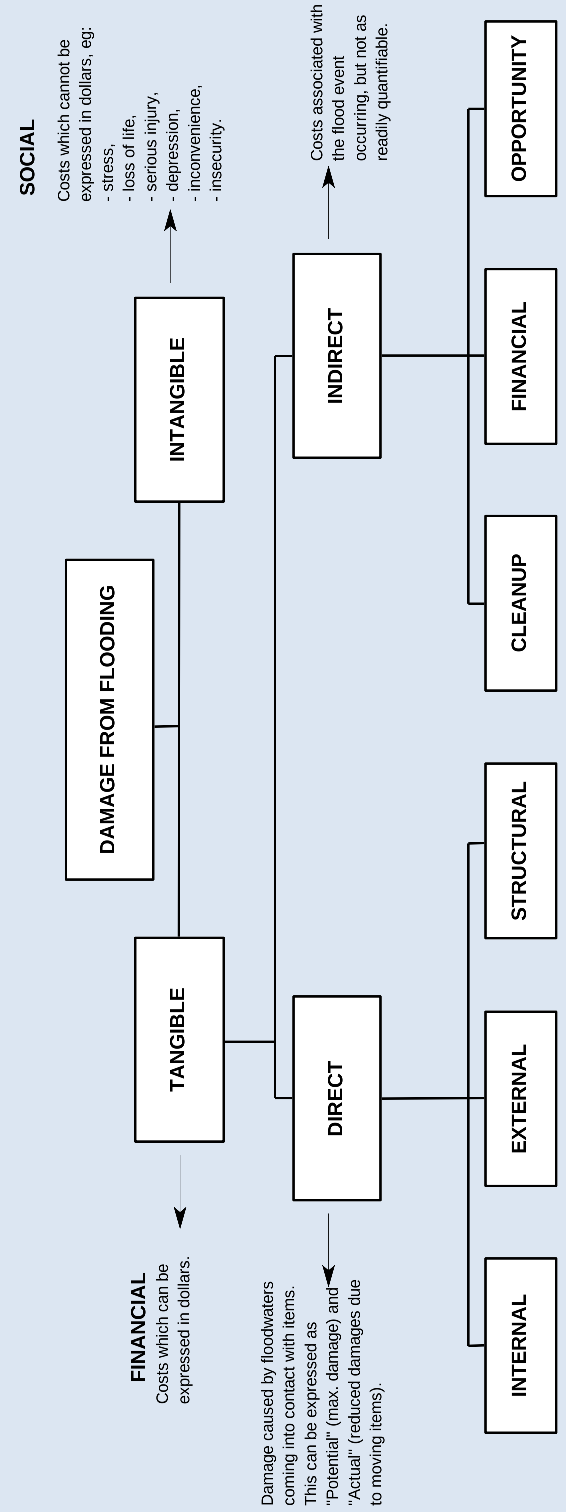
The impact of flooding can be quantified through the calculation of flood damages. Flood damage calculations do not include all impacts associated with flooding (for example it does not include worry, risk to life or injury). They do, however, provide a basis for assessing the economic loss of flooding and also a non-subjective means of assessing the merit of flood mitigation (retarding basins, levees, drainage enhancements) or development works (reduce damages by removing existing low lying buildings).

The quantification of flood damages is an important part of the floodplain risk management process. The cost of damage and the degree of disruption to the community caused by flooding depends upon many factors including:

- the magnitude (depth, velocity and duration) of the flood;
- land use and susceptibility to damages;
- awareness of the community to flooding;
- effective warning time;
- the availability of an evacuation plan or damage minimisation program;
- physical factors such as failure of services (sewerage), flood borne debris, sedimentation; and
- the types of asset and infrastructure affected.

Flood damages can be defined as being tangible or intangible. Tangible damages are those for which a monetary value can be easily assigned, while intangible damages are those to which a monetary value cannot easily be attributed. Types of flood damages are shown in Table 18.

Table 18: Flood Damages Categories



	INTERNAL	EXTERNAL	STRUCTURAL	CLEANUP	FINANCIAL	OPPORTUNITY
RESIDENTIAL	Contents of Buildings: Clothes, Carpets, Furniture, Valuables, Fittings, Appliances	External Items: Vehicles, Laundries, Caravans, Sheds, Tools, Gardens, Fences	Physical Damage to Buildings: Gyprock, Cupboards, Scour of Footings, Houses becoming buoyant (floating off footings)	Clean Carpets, Walls, Clothes; Re-instate Furniture; Remove Mud and Debris	Loss of wages, Living costs (temporary accomodation and food), Time to repair/replace damaged items	Not Applicable
RURAL	Contents of Buildings: Clothes, Carpets, Furniture, Valuables, Fittings, Appliances	External Items: Vehicles, Sheds (stables/barns), Machinery, Tools, Fences, Feed storage, Saddles, Crops &/or Stock, Irrigation Systems	Physical Damage to Structures: Damage to Homestead, Sheds, Access tracks, Protection levees	Clean Homestead and Out-buildings; Remove Debris; Dispose of affected crops &/or stock	Loss of Farm Production and Income, Re-instatement of Pastures, Supplementary feeding of stock (by hand or outside agistment), Stock movement/ transport, Living costs (temporary accomodation and food)	Sowing or harvesting of Crops, Sale of Stock (at depreciated value or dependent on market influences)
COMMERCIAL	Contents of Buildings: Products, Stock, Fittings, Tools, Machinery, Raw Materials	External Items: Vehicles, Machinery, Display, Raw Materials/Stockpiles, Fences	Physical Damage to Buildings	Dispose of damaged products, stock, materials; Cleaning and Re-instatement	Loss of Productivity and Income, Bank Interest Charges	Loss of existing &/or Potential Trade
PUBLIC AUTHORITIES	Contents of Public Buildings and Facilities	Public Property and Facilities: Parks, Signs, Machinery, Equipment	Physical Damage to Infrastructure: Electricity, Water, Telephone, Gas, Road & Rail Transport Links	Remove Mud & Debris from Facilities, Public & Private Property Repairs (temporary & permanent)	Disruption of Services, Community Service Relief Grants	Provision of Public Service

Tangible flood damages are comprised of two basic categories; direct and indirect damages (refer Table 18). Direct damages are caused by floodwaters wetting goods and possessions thereby damaging them and resulting in either costs to replace or repair or in a reduction to their value. Indirect damages are the additional financial losses caused by the flood for example the cost of temporary accommodation, loss of wages by employees, etc.

In order to quantify the damages caused by inundation for an existing development a floor level survey of existing buildings is required. To date this has not been undertaken as part of this study.

Public sector (non-building) damages include; recreational/tourist facilities; water and sewerage supply; gas supply; telephone supply; electricity supply including transmission poles/lines, sub-stations and underground cables; rail; roads and bridges including traffic lights/signs; and costs to employ emergency services and assist in cleaning up. Public sector damages can contribute a significant proportion to total flood costs but are difficult to accurately calculate or predict.

In addition to the tangible damages discussed previously, additional costs/damages are incurred by residents affected by flooding, such as stress, risk/loss to life, injury, loss of sentimental items, etc. It is not possible to put a monetary value on the intangible damages as they are likely to vary dramatically between each flood and depend on a range of factors such as the size of flood, the individuals affected, and community preparedness. However, it is still important that the consideration of intangible damages is included when assessing the impacts of flooding on a community. Post-flood damages surveys have linked flooding to stress, ill-health and trauma for the residents.

Flood affectation of the critical infrastructure and vulnerable facilities in the catchments may also result in significant intangible damages. The flood affectation to these facilities will not necessarily occur at the site of the facility. With service infrastructure (sewer, water, electricity) the main facility will likely not be directly affected by floodwaters but the supply will be affected by say fallen trees hitting power lines or closure of the sewer system as floodwaters are entering the system in the flooded area. Many of these affectations to the critical infrastructure and vulnerable facilities are variable and will not necessarily occur in all floods or at the same locations. It is only through review of past floods that the true affectation to critical infrastructure and vulnerable facilities can be addressed.

An assessment of potential flood damages should be undertaken as part of the approval process for the redevelopment, to quantify the benefit in terms of reduction in tangible annual average damages and reduction in non tangible damages.

A flood risk assessment, including a potential flood damages analysis must be undertaken if developers wish to justify flood planning levels for non residential developments below those provided in the DCP.

5. FLOOD RISK ASSESSMENT OF PROPOSED REDEVELOPMENT WORKS

5.1. Overview

This assessment is based on the comparison between the existing building layout and the design building layout provided by Roberts Day (Figure 1a and b). No other design information has been incorporated in this assessment. Whilst this is appropriate for a preliminary assessment it should be noted that fences, minor paths, ground surfaces and other yet to be determined features can play a significant role in flooding. These features would need to be evaluated at a later date.

5.2. Review of Part 6.8: Flood Planning of Council's LEP 2013

An LEP is a legal document prepared by Council and approved by the State Government to regulate land use and development. LEPs guide planning decisions for local governments. The plan allows Council to regulate the ways in which all land both private and public may be used and protected through zoning and development controls. All Councils in NSW have revised their LEPs to comply with the State Government's Standard Instrument Order 2006 and Part 6.8: Flood Planning in the City of Canada Bay's LEP 2013 thus complies.

In May and June 2020 the State Government has on public exhibition proposed changes to the consideration of flooding in land use planning. This includes suggested LEP clauses regarding flooding. Two notable changes are the inclusion of the consideration of climate change and consideration of sensitive, vulnerable, critical or hazardous usage on land between the FPA and the PMF flood extent. In addition, there are proposed changes to information provided on the Section 10.7 certificate.

5.3. Review of Part C7: Flooding Control of Council's DCP

5.3.1. Compliance with Part C7: Flooding Control

Part C7: Flooding Control of Council's DCP outlines if and how flooding should be addressed with the redevelopment works. Figure 6 to Figure 8 and other figures indicate that parts of both precincts are deemed as High, Medium and Low Flood Risk (as described in Part C7 as defined below):

- **High:** Land within the 1% AEP extent and subject to high hydraulic hazard or presents significant evacuation difficulties;
- **Medium:** Land within the 1% AEP extent, not subject to high hydraulic hazard and presents less than significant evacuation difficulties;
- **Low:** Land above the 1% AEP extent up to the PMF extent.

Mapping of the above flood risk groups is shown on Figure 18 assuming:

1. High hazard is taken as the H4, H5 and H6 hazard classifications as described in Section 4.6.2;
2. Evacuation difficulties have not been considered as their definition is subjective, there is limited ability to evacuate to a safe place and any evacuation is dependent on local conditions.

Thus flooding must be considered as part of the development approval process for both precincts. Initially this has been undertaken by assessing whether development of the two precincts at this preliminary stage is in compliance with the objectives and design principles of Part C7. Due to the preliminary nature of the precinct development, it is not possible to provide a complete response to each issue and this assessment will have to be completed in full at a later date.

The objectives and compliance of the development with those objectives of Part C7 are listed in Table 19.

Table 19: Compliance with Objectives of Part C7: Flooding Control of Council's DCP

Objectives	Response
O1. To ensure the proponents of development and the community in general are aware of the potential flood hazard over the whole range of AEP and of the consequent risk and liability associated with the development and use of flood liable land.	This study has assessed the potential flood hazard over the whole range of AEP events. The consequent risk, ongoing awareness / education and liability will be addressed as part of the approval process once the details of the redevelopment are finalised.
O2. To manage flood liable land in a manner that is economically and environmentally sustainable and socially responsible.	These issues will be addressed as part of the approval process once the details of the redevelopment are finalised.
O3. To establish whether or not a proposed development or activity is appropriate to be carried out having regard to the economic, property, environmental and human impacts of flooding.	These issues will be addressed as part of the approval process once the details of the redevelopment are finalised and the flood impact and damages assessment undertaken. This assessment will rely upon considering the appropriateness of each development to the hydraulic hazard classification (Section 4.6.2). The economic, social and environmental issues will have to be addressed in a merits based assessment as indicated in the NSW Floodplain Development Manual (Reference 2).
O4. To protect community by ensuring that developments with high sensitivity to flood risk (e.g. critical public utilities) are sited and designed to provide reliable access, continued operability during emergencies, quick recovery and to generally minimise risk from flooding.	These issues will be addressed as part of the approval process once the details of the redevelopment are finalised.
O5. To allow development with a lower sensitivity to the flood hazard to be located within the floodplain, subject to appropriate design and siting controls and provided that the potential consequences that could still arise from flooding remain acceptable.	These issues will be addressed as part of the approval process once the details of the redevelopment are finalised. This assessment will rely upon considering the appropriateness of each development to the hydraulic hazard classification (Section 4.6.2).
O6. To prevent intensification of inappropriate development.	These issues will be addressed as part of the approval process once the details of the redevelopment are finalised.
O7. To control the use of 'High Hazard' areas and Floodways, and wherever appropriate and feasible, allow for their conversion to natural	High Hazard and Floodways have been identified as part of this study. As the precincts are existing highly developed areas it is unlikely that it will be

Objectives	Response
waterway corridors.	appropriate or feasible to convert High Hazard and Floodways to natural waterway corridors. However opportunities should be explored during preparation of the design plans.
O8. To ensure that proposed development does not expose existing development to increased risks associated with flooding.	The issue of exposing existing development to increased risks associated with flooding has been investigated as part of this study with the impact assessment (Section 5.4). This issue will be further addressed as part of the approval process once the details of the redevelopment are finalised.
O9. To ensure building design and location address flood hazard.	These issues will be addressed as part of the approval process, using constraint information from this study, once the details of the redevelopment are finalised.
O10. To ensure that development does not result in unreasonable flood impacts upon the amenity or ecology of an area.	These issues will be addressed as part of the approval process based on a flood impact assessment (Section 5.4) once the details of the redevelopment are finalised.
O11. To incorporate the principles of Ecologically Sustainable Development (ESD).	These issues will be addressed as part of the approval process once the details of the redevelopment are finalised.
O12. To minimise the risk to life and property arising from flooding.	These issues will be addressed as part of the approval process once the details of the redevelopment are finalised.
O13. To ensure the provision of appropriate access to and egress from areas affected by flooding including for extreme events.	It is unlikely that the provision of appropriate access to and egress from areas affected by flooding including for extreme events will be possible due to the short available warning time. These issues will be addressed as part of the approval process once the details of the redevelopment are finalised. The issue of evacuation requirements in the DCP is further considered in Section 5.3.3.
O14. To provide controls to ensure that development is carried out in accordance with this Policy.	This present study provides the relevant flood information which will be adopted in applying the flood controls as given in Part C: Flooding Control of Council's DCP (Section 5.3.2).
O15. To implement the principles of floodplain risk management as defined by the NSW Government's Flood Prone Land Policy and the FDM 2005.	The principles of floodplain risk management as defined by the NSW Government's Flood Prone Land Policy and the FDM 2005 have been incorporated in preparing this report and will be addressed as part of the approval process once the details of the redevelopment are finalised.

The design principles and compliance of the development with those design principles of Part C7 are listed in Table 20.

Table 20: Compliance with Design Principles of Part C7: Flooding Control of Council's DCP

Design Principles	Response
D1. Development should not result in any increased risk to human life.	This issue will be addressed as part of the approval process once the details of the redevelopment are finalised.
D2. The additional economic and social costs which may arise from damage to property from flooding should not be greater than that which can reasonably be managed by the property owner, property occupants and general community.	These issues will be addressed as part of the approval process once the details of the redevelopment are finalised based on a pre and post flood damages and merits based assessment.
D3. Development should only be permitted where effective warning time is available for the evacuation of an area potentially affected by floods	There is insufficient warning time for the effective evacuation of either precinct potentially affected by floods to an area free of risk from flooding. Reliance

Design Principles	Response
to an area free of risk from flooding.	will have to be on shelter in place as a means of security during a flood.
D4. Development should only be permitted where reliable egress is available for the evacuation of an area potentially affected by floods to an area free of risk from flooding.	There is insufficient warning time for the reliable egress for the evacuation of either precinct potentially affected by floods to an area free of risk from flooding. Reliance will have to be on shelter in place as a means of security during a flood.
D5. Evacuation should be consistent with any relevant flood evacuation strategy or flood risk management plan where in existence.	There is no relevant flood evacuation strategy (other than detailed in the DCP) or flood risk management plan in existence.
D6. Development should not adversely increase the potential flood affectation on other development or properties, either individually or in combination with similar developments(s) that are likely to occur within the same catchment.	The issue of adversely increasing the potential flood affectation on other development or properties has been investigated as part of this study (Section 5.4). This issue will be further addressed as part of the approval process once the details of the redevelopment are finalised.
D7. Developments must make allowances for motor vehicles to be relocated to an area with substantially less risk from flooding within an effective warning time.	There is insufficient warning time to make allowances for motor vehicles to be relocated to an area with substantially less risk from flooding. Reliance will have to be on shelter in place as a means of security during a flood.
D8. Developments must provide an evacuation plan detailing procedures that would be in place for an emergency (such as warning systems, signage or evacuation drills).	These issues will be addressed as part of the approval process once the details of the redevelopment are finalised.
D9. Flood mitigation measures associated with new developments should not result in significant impacts upon the amenity of an area by way of unacceptable overshadowing of adjoining properties, privacy impacts (e.g. by unsympathetic house raising), alienation of otherwise usable open space or by being incompatible with the streetscape or character of the locality (including heritage).	No significant flood mitigation measures associated with the redevelopment of the two precincts are proposed.
D10. Raised structures shall be designed to cater for the forces of floodwaters. An Engineer's Certificate will be required for the structural design.	These issues will be addressed as part of the approval process once the details of the redevelopment are finalised.
D11. Development is to be compatible with any relevant Floodplain Risk Management Study, Floodplain Risk Management Plan, Flood Studies, or Sub-Catchment Management Plan.	There are no relevant Floodplain Risk Management Study, Floodplain Risk Management Plan, Flood Studies, or Sub-Catchment Management Plan within the City of Canada Bay parts of the two precincts.
D12. Development must not divert flood waters, nor interfere with floodwater storage or the natural function of waterways.	No significant diversion of flood waters or significant interference with floodwater storage or the natural function of waterways associated with the current redevelopment of the two precincts are proposed.
D13. Filling of land up to the Probable Maximum Flood (PMF) must not adversely impact upon flood behaviour. This must be demonstrated by appropriate modelling.	No significant filling of land up to the PMF associated with the redevelopment of the two precincts are currently proposed.
D14. Development must consider the impact of flooding resulting from local overland flooding whether it is a result of Local Drainage or Major Drainage.	Overland flow has been investigated as part of this study. Local drainage will be addressed as part of the approval process once the details of the redevelopment are finalised.
D15. Where hydraulic flood modelling is required, flow hazard categories should be identified and adequately addressed in the design of the development.	Hydraulic modelling has been undertaken as part of this study and hazard and hydraulic categorisation have been identified. These issues will be addressed as part of the approval process once the details of the redevelopment are finalised.

Design Principles	Response
D16. Council strongly discourages basement car parks on properties within the floodplain. Where site conditions require a basement car park on a property within the floodplain, development applications must provide a detailed hydraulic flood study and design demonstrating that the proposed basement car park has been protected from all flooding up to and including the PMF event. An adequate emergency response and evacuation plan must also be provided where basement car parks are proposed in the floodplain.	These issues will be addressed as part of the approval process once the details of the redevelopment are finalised.

5.3.2. Review of Part C7: Flooding Control

Part C7: Flooding Control of Council's DCP outlines a similar approach to that adopted by many Councils in Sydney. The approach requires identification of land into a Flood Risk category (High, Medium and Low) and uses a flood planning matrix to define the relevant planning controls. High flood risk is land under the 1% AEP.

The State Government has proposed changes to its "Flood Prone Land" package and is on public exhibition in June 2020. These changes should be considered in any review of Council's LEP and DCP flood related development controls. In addition, the following should be considered:

- The requirements for flood warning (Evacuation C6) cannot generally be complied with in many localities in the two Precincts due to the short or effectively nil warning time (Section 4.7.3) and requires rewording (Section 5.3.3);
- The evacuation requirements for people and vehicles (Section 4.7.1) in the DCP (Section 5.3.3) cannot all be complied with and needs rewording;
- Shelter in place is a requirement for all properties in the PMF (Section 5.3.3);
- Review the list of Flood Planning Levels adopted by Councils such as the City of Sydney (Appendix B and Section 5.3.4);
- The inclusion of climate change in determination of Flood Planning Levels (Section 5.3.5);
- Adoption of criteria for identification of Flood Control Lots in both mainstream and overland flow areas (Section 5.3.6);
- Review of policy for fencing in the floodplain (Section 5.3.7);
- Provision of guidelines for flood impact assessment reporting (Flood Affectation C1) (Section 5.3.8);
- The H4, H5 and H6 hazard categorisation should be taken as equivalent to High Hazard in Council's DCP.

5.3.3. Flood Warning Evacuation Requirements in DCP

Flood warning is discussed in Section 4.7.3 and it is a requirement to implement the six controls listed in the DCP regarding evacuation requirements (Table 21). However, there is effectively no available flood warning for the two precincts due to the short time from the start of the rainfall until flooding occurs (less than two hours).

Table 21: Evacuation Controls in DCP

C1. Reliable access for pedestrians required during a 20 year ARI peak flood.
C2. Reliable access for pedestrians and vehicles required to a publicly accessible location during the PMF peak flood.
C3. Reliable access for pedestrians and vehicles is required from the site to an area of refuge above the PMF level, either on site (e.g. second storey) or off site.
C4. Applicant is to demonstrate the development is consistent with any relevant flood evacuation strategy or similar plan.
C5. Applicant is to demonstrate that evacuation in accordance with the requirements of this DCP is available for the potential development resulting from the subdivision.
C6. Adequate flood warning is available to allow safe and orderly evacuation without increased reliance upon SES or other authorised emergency services personnel.

There are a number of issues with these controls that require addressing, namely:

- C1 does not specify access to where;
- The SES does not approve of any pedestrian or vehicle movements through flood waters. Thus reliable access is in theory only possible with a route at the PMF level which is unrealistic;
- Our understanding is that there are few, if any, relevant flood evacuation strategies or similar plans in the two Precincts. The SES does not have an evacuation plan for properties within the two precincts and consideration needs to be given to whether a strategy should be developed;
- Council requires individual development evacuation plans as a condition of DA approvals. Council must keep a record of these approvals;
- As safe evacuation is not possible, the alternative is Shelter in Place which is where there is an area in the building above the PMF and suitable for all occupants to remain for the duration of the flood (say 2 hours). Thus, Shelter in Place is a requirement, including services, for all occupied buildings in the PMF flood extent;
- C6 refers to adequate flood warning. This is discussed in Section 4.7.3.

5.3.4. Flood Planning Levels

FPLs are an important tool in floodplain risk management. Appendix K of the Floodplain Development Manual (Reference 2) provides a comprehensive guide to the purpose and determination of FPLs. The FPL provides a development control measure for managing future flood risk and is derived from a combination of a flood event and a freeboard.

The purpose of the freeboard, as described in the Manual, is to provide reasonable certainty that the reduced flood risk exposure provided by selection of a particular flood as the basis of the FPL, is actually provided given the:

- uncertainty in estimating flood levels;
- differences in water level because of local factors; and
- potential changes due to climate change (refer Section 5.3.5).

The FPL is used in planning control primarily to define minimum habitable floor levels but also for other factors such as evacuation requirements, car parking levels, storage of hazardous goods, etc.

The standard FPL for residential development as suggested in the Manual is the 1% AEP event plus 500 mm freeboard. Depending on the nature of the development and the level of flood risk, individual FPLs can be adopted for a local area within a greater floodplain area. For example, in areas prone only to shallow overland flooding, application of the 500 mm freeboard can be excessive.

Selecting the appropriate FPL for a particular floodplain involves trading off the social and economic benefits of a reduction in the frequency, inconvenience, damage and risk to life caused by flooding against the social, economic and environmental costs of restricting land use in flood prone areas and of implementing management measures.

The FPL can be varied depending on the use, and the vulnerability of the building / development to flooding. For example, residential development could be considered more vulnerable due to people being present, whilst commercial development could be considered less vulnerable, or it could be accepted that commercial property owners are willing to take a higher risk. Less vulnerable development could therefore be prescribed lower floor levels but may then be subject to other controls, such as flood proofing, up to the level of the FPL. For developments more vulnerable to flooding (hospitals, schools, electricity substations, seniors housing, etc.) consideration should be given to events rarer than the 1% AEP when determining their FPL or situating those developments outside the floodplain where possible.

According to the 2005 NSW Government Floodplain Development Manual (Reference 2) the purpose of the freeboard is to provide reasonable certainty that the reduced flood risk exposure provided by selection of a particular flood as the basis of a FPL (Flood Planning Level) is actually provided given the following factors:

- uncertainties in estimates of flood levels;
- differences in water level because of “local factors”;
- increases due to wave action;
- the cumulative effect of subsequent infill development on existing zoned land, and
- climate change. This largely relates to rainfall increase as future sea level rise has been relatively accurately determined by the Intergovernmental Panel for Climate Change (IPCC) and should not be included within the 0.5m freeboard. For this study area sea level rise will only affect the very lower parts of the William Street catchment which are generally used for open space or recreational uses (golf course).

In a real flood some of these factors may reduce the flood level (local factors) or not apply at all (no wave action). For example, in a future flood 1% AEP event blockage (due to say fallen trees) may elevate the peak level just upstream. However, such an event would be considered as rarer than the 1% AEP as that type of blockage is an exception, as it would not always occur in every flood.

There is no scientific reason for assuming a 0.5m allowance for freeboard. In some locations (say Windsor on the Hawkesbury River) it could be argued that a greater freeboard should be applied as the PMF is several metres above the 1% AEP, thus 0.5m represents only a relatively small increase in flood magnitude. At other locations a 0.5m increase above the 1% AEP may approach the PMF level and thus represents a very large increase in flood magnitude (this is particularly the case for overland flooding). Council could adopt varying freeboards across its LGA however this is likely to be confusing to manage by Council staff and it is difficult, if not impossible, to justify the criteria as to why one area should have a different freeboard to another. For simplicity a 0.5m freeboard is adopted by nearly all Councils in NSW for mainstream flooding. Some Councils adopt a smaller freeboard when the depths of inundation in urban areas, with no defined creeks or channels (i.e overland flooding), are shallow (less than 0.3m).

Council has FPLs for floor levels, building components, structural soundness, car parking, evacuation and management/design. However, these could be expanded upon to add clarity. The City of Sydney's Interim Floodplain Management Policy is provided as Appendix B as an example and this includes (Section 5, page 13 of 17) their FPLs.

5.3.5. Climate Change

Whilst there is general consensus that the climate in the future will be different from current conditions, there is uncertainty in the magnitude, and even the direction, of that change. Climate change has the potential to impact flooding through changes in the frequency, intensity, spatial extent, duration and timing of extreme weather and climate events, and through sea level rise. However, quantifying the effects of climate change on these factors is a difficult task, and includes large uncertainties. As such, using an approach based on a sensitivity analysis of different scenarios, and focusing on the consequences facilitates an assessment of the potential impacts of climate change despite this uncertainty.

The NSW Government issued a policy statement in 2009 which required Councils to consider sea level increase and undertake a sensitivity analysis of increases in rainfall intensity. Whilst this policy has now been repealed and Councils are required to make their own assessments, the estimates in this policy are still widely used in NSW.

For sea level rise, current estimates vary between 0.13 m increases by 2050 for low emissions scenarios, to as high as 0.98 m for high emission scenarios in 2100. The Floodplain Risk Management Guideline: Practical Consideration of Climate Change (Reference 10) recommends undertaking a sensitivity analysis which includes 0.18 m, 0.55 m and 0.91 m increases in sea level rise, whilst information provided by CSIRO and the BoM (Climate Change in Australia website) suggests increases ranging from 0.22 m to 0.88 m by 2090 for Eastern Australia. Therefore, the commonly applied estimates of +0.4 m (2050) and +0.9 m (2100) remain reasonable factors to use in sensitivity analyses as they encompass a significant portion of the range in estimates.

Section 3.7.4 of the Floodplain Risk Management Guide (Reference 6) provides guidance on the consideration of climate change. The guidance notes that studies under the NSW floodplain management program are to take a practical approach to consideration of flood-producing rainfall events on flood behaviour.

Considering the short, medium and long term timeframes, the following scenarios have been modelled (Section 4.6.4):

- Climate Change (Rainfall Increase): Sensitivity to rainfall/runoff estimates were assessed by increasing the rainfall intensities by 10%, 20% and 30% (Table 16);
- Climate Change (Sea Level Rise): Sea level rise scenarios of 0.4 m and 0.9 m were assessed (Table 16).

Through a consideration of consequences to both property and flood hazard, the sensitivity of the catchment to changing hydrologic and sea level rise conditions can be determined.

Section 5.3.4 indicates that climate change is one of the factors included in the freeboard allowance. However, at some point the uncertainty of climate change becomes a certainty if it is acknowledged by experts that it will occur. Whilst some still do not acknowledge anthropomorphic sea level rise, the IPCC is of the view that it will occur and provide continual updates of the timeframes and the amount of rise. Thus sea level rise should not be included as part of the freeboard allowance but should be included as a separate component in setting FPLs taking into account the lifespan of the proposed structure.

However, to date the BoM has not provided definitive advice that flood producing rainfall intensities and temporal patterns will change with climate change. The impact of potential rainfall increases due to climate change are also relatively small (Table 16), thus can still be included in the freeboard allowance for the two precincts.

5.3.6. Flood Control Lots

A Flood Control Lot means a lot to which flood related development controls apply in respect of development for the purposes of industrial buildings, commercial premises, dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (other than development for the purposes of group homes or seniors housing). In the 2005 NSW Government Floodplain Development Manual (Reference 2) the FPL (typically the 1% AEP + 0.5m) was used to define the FPA and all land within were identified as subject to flood related development controls and included on the Section 10.7 (old 149) planning certificate. The term flood control lot is now used.

As previously the policy for determination of flood control lots rests with Council. It should take into consideration all flood situations (mainstream, overland and estuary / Parramatta River flooding) as well as incorporating climate change (sea level rise and wave action where appropriate). The resultant policy must be supported by Council legal officers and involve a community engagement program that appropriately responds to issues that arise.

The following provides some suggested criteria for identifying flood control lots:

- flood levels should only be quoted to 1 decimal place;
- the criteria must be simple to apply and thus generalisations may have to occur in places;
- a consistent approach is required across the LGA;

- the criteria must be easily understood by residents;
- the criteria must be able to be easily amended if issues arise and this will likely mean that the determination has to be by a quantitative rather than a qualitative approach;
- the approach must recognise that different hydraulic modelling approaches in other parts of the LGA (direct rainfall as opposed to the more traditional approach) may require a different criteria to be adopted;
- different criteria may be required for mainstream creeks, overland, and Parramatta River flooding;
- the criteria must identify the design event on which it is based, the freeboard applied, any climate change sea level rise components and the timeframes for introduction of climate change;
- climate change sea level rise should be listed in 0.1m increments with < 0.1m assumed to be in the freeboard;
- the majority of LGAs in NSW adopt a FPL of the 1% AEP + 0.5m freeboard for residential properties affected by mainstream flooding (Cooks River, Hunter River) but adopt a lesser standard for overland flooding. This is particularly the case in urban areas such as the two Precincts under consideration where flood waters crossing Parramatta Road are a shallow depth and cover a relatively wide area due to the low grade on the road. Thus increasing the 1% AEP level by 0.5m would extend the floodplain a considerable distance outside the PMF flood extent. Also in overland flow areas the modelling may show only a very small part of the property inundated or to only a very shallow depth. To overcome these issues of identifying lots where overland flooding is not a significant issue different criteria have been adopted and examples are provided in Table 22;

Table 22: Possible Criteria for Definition of Flood Control Lots

	Precinct	
Criteria	**Burwood**	**Kings Bay**
Within 1% AEP Extent	2	58
Within 1% AEP Extent AND Max Depth > 150mm	0	48
Within 1% AEP Extent AND > 10% of Land Outside Building Footprint Inundated	0	29
Within 1% AEP Extent AND Max Depth > 150mm AND >10% of Land Outside Building Footprint Inundated	0	27
Within 1% AEP Extent AND >10% of Land Outside Building Footprint Inundated by >150mm	0	21

5.3.7. Fencing in the Floodplain

Fencing in the floodplain can have a significant influence on floodwaters and on the fence structure itself. In rural areas the main consideration is destruction of fencing due to excessive debris loads. In urban areas loss of fencing is of much lesser importance due to the relatively shallow depths of floodwaters and limited amount of debris. Of greater importance is the potential for fencing to raise and / or divert floodwaters onto adjoining properties. This issue has become of greater significance due to the greater occurrence of colorbond and brick fencing in the last 20 years replacing the traditional wooden paling fencing.

Whilst paling fences do divert floodwaters they do not form a solid barrier as colorbond and brick fencing generally does. As a DA is not required to change fencing this has become a significant flood issue. Council's DCP states "Any fencing that forms a part of a proposed development is subject to the relevant Flood Effects and Structural Soundness planning considerations of the applicable land use category. Fences may need to be of open design to address this cause". This statement needs clarification and a suggested approach taken from Sutherland Shire Council's Flood Risk Management DCP 9.3/17 is provided below.

2.5 Are There Special Requirements for Fencing?

2.5.1 <u>Objectives</u>

(a) To ensure that fencing does not result in the undesirable obstruction of the free flow of floodwaters.

(b) To ensure that fencing does not become unsafe during floods and potentially become moving debris which threatens the integrity of structures or the safety of people.

2.5.2 <u>Performance Criteria</u>

(a) Fencing is to be constructed in a manner which does not affect the flow of floods so as to detrimentally increase flood affect on surrounding land.

(b) Ability to be certified by a suitably qualified engineer, that the proposed fencing is adequately constructed so as to withstand the forces of floodwaters, or collapse in a controlled manner to prevent the undesirable impediment of flood waters.

5.3.8. Guidelines for Flood Impact Assessment Reporting

Council's DCP contains a section on addressing flood affectation however this could be expanded upon to provide greater clarity for Council and engineers undertaking the assessment, providing a more efficient methodology for both parties.

Flood impact assessment (FIA) is the process of determining whether the proposed works will affect flood levels on surrounding properties. Issues that need to be addressed are:

- What criteria is used to determine if a FIA is required. Is it required for all DAs or can small scale works be omitted (e.g filling of less than 5m^3 can be ignored)?
- What are the required qualifications and experience of the engineer undertaking the assessment? These need to be specified?
- What assessment or modelling approach is required (HEC-RAS, TUFLOW, DRAINS). The approach will vary depending upon the nature of the works.
- Does concessional development need to be treated differently?
- Suggested information to be provided in a FIA are listed below.
    - A catchment map showing the property, ground contours and drainage networks.

- The methodology and flow calculations for the 1% AEP and PMF (if required). All pits should be considered 50% blocked. ARR 2019 data and methodology is to be used.
- No more than 0.01m increase in the 1% AEP flood level (existing v developed) outside the subject property is acceptable.
- No pre and post development impact mapping is required for PMF but an assessment must be undertaken to determine if there will be a significant change in flood extents, velocities, duration and levels in the PMF.
- A map must be included showing the 1% AEP extent and hazard map for pre and post development.
- A section demonstrating the compliance of the proposed development with flood related development controls outlined in Council's DCP.

5.4. Hydraulic Modelling Assessment

The TUFLOW hydraulic model established to determine design flood levels (Section 4) has been used to determine the effect of the changed building outlines as shown on Figure 1a and b. Within each precinct not all the existing buildings have been removed and those that are to be retained are shown in red on these figures. Flood impact figures for the 5%, 1% AEP and PMF events are shown on Figure 15, Figure 16 and Figure 17. The results are summarised as follows:

- In all three design events there is no flood impact (taken as greater than +/- 0.01m) within the City of Canada Bay part of the Burwood Precinct. However in the 5% AEP and PMF events there is an impact of less than 0.1m near the intersection of Parramatta Road and Luke Avenue. These impacts are due to the redevelopment works within the Burwood LGA part of the precinct, thus to eliminate these impacts would require changes within the Burwood City LGA;
- In the 5% AEP event, within the City of Canada Bay part of the Kings Bay Precinct, the majority of the affectation is a reduction in flood level. This occurs as there is a general reduction in building density on either side of William Street near the intersection with Spencer Street. There is no increase in flood level downstream;
- In the 1% AEP event, within the City of Canada Bay part of the Kings Bay Precinct, the majority of the affectation is a similar reduction in flood level as in the 5% AEP due to the general reduction in building density. However, in the 1% AEP there is a resulting increase in flood level downstream of Queens Road of up to 0.05m. This occurs because the reduction in peak level within the Kings Bay Precinct produces a reduction in temporary floodplain storage capacity. This results in less flood attenuation within the Kings Bay Precinct and so peak flows and therefore peak flood levels increase downstream;
- In the PMF event within the City of Canada Bay part of the Kings Bay Precinct the majority of the affectation is a similar but much larger extent of reduction in flood level as in the 5% and 1% AEP events. However in the PMF there is a much more extensive increase in flood level downstream of Queens Road and across Barnwell Park golf course.

Typically most Councils in NSW assume an increase in flood level outside of the subject property of greater than 0.01m as of issue. Thus increases of less than 0.01m are assumed as within the order of accuracy of the hydraulic modelling. Reference 11 states "Typically, results are not reported to the nearest millimetre, and impacts less than 0.01m are not reported, as they are considered to be within the precision of the numerical model and data". The above criteria is typically assumed as the impacts from an individual development being so small, will ensure that a number of individual developments (cumulative developments) will not result in a significant impact. However this assessment in this study is for the cumulative impact of a number of individual developments.

Increases in flood level on the land which is to be developed are generally acceptable as these can be accounted for in the design of the building (e.g slightly raised floor levels). However on existing properties outside the subject properties increases above 0.01m are generally not acceptable. Thus within each precinct consideration needs to be given to the remaining existing buildings. As shown on Figure 15, Figure 16 and Figure 17 the remaining buildings within the City of Canada Bay LGA part of each precinct are not adversely affected, even in the PMF.

Of issue (within the City of Canada Bay LGA) are:

- increases in flood level near the intersection of Parramatta Road and Luke Avenue downstream of the Burwood Precinct. Mitigation of these increases will require works within Burwood LGA;
- increases in flood level downstream of Queens Road and the Kings Bay Precinct. Mitigation of these increases can be reduced by increasing the flood levels within the Precinct itself which presently show a reduction in level of greater than -0.1m in the 1% AEP event. Increasing flood levels, by raising the now vacant land within the Kings Bay Precinct, will increase the volume of temporary floodplain storage through higher flood levels and so attenuate the peak flows travelling downstream which cause the increases in level downstream (Figure 16 and Figure 17). The raising of the land can be achieved by either constructing a building on the now vacant land or filling the land to above the flood level (thus allowing the land to still be used as open space). This has been simulated with the results shown on Figure 19. These results are preliminary and demonstrate that “nil” impact downstream can be achieved in the 1% AEP. Thus further, more detailed modelling is required at the detailed design stage.

5.5. Possible Floodplain Risk Management Measures

The proposed redevelopment will require significant earthworks and construction. Thus consideration should be given to whether flood mitigation measures should be incorporated in the redevelopment to reduce the flood levels for the proposed and existing developments.

5.5.1. Categories of Floodplain Risk Management Measures

The 2005 NSW Government’s Floodplain Development Manual (Reference 2) separates risk management measures into three broad categories.

- **Flood modification measures** modify the physical behaviour of a flood including depth, velocity and redirection of flow paths. Typical measures include flood mitigation dams, retarding basins, channel improvement, levees or defined floodways. Pit and pipe improvement and even pumps may also be considered where practical.

- **Response modification measures** modify the response of the community to flood hazard by educating flood affected property owners about the nature of flooding so that they can make better informed decisions. Examples of such measures include provision of flood warning and emergency services, improved information, awareness and education of the community, and provision of flood insurance.

- **Property modification measures** modify the existing land use and development controls for future development. This is generally accomplished through such means as flood proofing, house raising or sealing entrances, strategic planning such as land use zoning, building regulations such as flood-related development controls, or voluntary purchase / voluntary house raising.

Table 23 provides a summary of typical floodplain risk management measures. It should be noted that many of these management measures are not appropriate for the two catchments under consideration.

Table 23: Floodplain Risk Management Measures

Flood Modification	Property Modification	Response Modification
Levees	House raising	Flood warning
Temporary defences	Voluntary purchase	Flood emergency management
Channel construction	Flood proofing	Community awareness
Channel modification	Land use zoning	Improved evacuation access
Major structure modification	Flood planning levels	Flood plan / recovery plan
Drainage network modification	Flood planning area	
Drainage maintenance	Changes to planning policy	
Retarding basins	Modification to S10.7 Certificate	
	Flood Insurance	

5.5.2. Applicability of Floodplain Risk Management Measures

All viable response modification measures should be employed as part of the redevelopment in accordance with best practice. The exact details of these measures can only be determined once full definition of the redevelopment works becomes available. However, it is impossible to provide sufficient flood warning to undertake effective evacuation during a flood due to the short time from the start of rainfall until flooding occurs (less than 2 hour).

Of the property modification measures flood planning levels and associated measures are already incorporated in Part C7: Flooding Control of Council’s DCP (Section 5.3.2) and flood insurance is available for all residential properties.

A reduction in design flood levels is only possible with application of flood modification measures and these are reviewed in Table 24.

Table 24: Review of Applicability of Flood Modification Measures to Reduce Flood Levels

Flood Modification Measure	Applicability
Levees	No suitable location to protect existing developments and unsuitable to mitigate the risk for new developments
Temporary defences	Only suitable to protect existing developments
Channel construction	No suitable viable location
Channel modification	No suitable viable location
Major structure modification	No applicable major existing structures
Drainage network modification	Upgrading of Council's existing drainage network can lower flood levels by reducing the amount of overland flow. This measure should be considered, regardless of whether it is required to mitigate flood increases or not, as redevelopment of this magnitude provides the only viable opportunity for such measures to be cost effectively undertaken.
Drainage maintenance	Drainage maintenance is a key issue identified in all public consultation on flooding. Council should review their drainage maintenance program and ensure that it is compatible with best practice.
Retarding basins	No suitable viable location within the catchment

5.6. On Site Detention

On Site Detention (OSD) is a requirement to control the post development rate of runoff to existing conditions or better and is implemented by all Councils in Sydney. OSD is not intended to and cannot reduce existing flood levels. It is a means of ensuring that approval can be given for developments which without OSD, would increase the rate and volume of runoff from the developed site compared to the existing or non-developed site. The City of Canada Bay has a comprehensive list of guidelines for OSD outlined in its Appendix 2: Engineering Specifications.

The application of OSD raises many issues including:

- OSD in any flood liable area or within downstream areas of catchments is of questionable benefit and this is recognised in the guidelines which indicates an exemption where "The development is located within a known flood affected area or subject to tidal influence. This does not include areas where it is affected by nuisance flooding caused by inadequate capacity of the drainage system. Council should be consulted on this matter for further *clarification"*. It needs to be determined whether some sites in the two Precincts do not require OSD;
- Application of OSD on individual properties is much less cost effective and likely more prone to failure due to inadequate maintenance than if applied for a group of properties. There is benefit therefore in combining OSD systems where possible and this should be considered;
- An OSD system is only infrequently used for the purpose it is designed for, notably if designed to reduce peak flows in the 1% AEP event. The system also provides no direct benefit to the property on which it is located. For this and other reasons some Councils, such as the City of Canada Bay, have allowed OSD requirements to be reduced in lieu of additional rainwater re use. However, with the proposed large scale re development there

may be an opportunity to consider more extensive in lieu drainage works, such as upgrading of street drainage or similar;

- Council's OSD storage volume and peak outflow requirements were derived based on ARR1987 and using outdated technology. These should be updated in accordance with best practice and technology;
- In some OSD policies land within the 1% AEP flood extent is excluded from requiring OSD, as under pre-development conditions there is no runoff attenuation as the rain falls directly onto floodwaters;
- OSD is not viable to be used as a flood mitigation measure to reduce existing flood levels.

5.7. Water Sensitive Urban Design

Water sensitive urban design (WSUD) is a land planning and engineering design approach which integrates the urban water cycle, replicating as far as possible the natural system to:

- improve the environmental performance by slowing and reducing the rate of runoff as well as reducing the pollutant load;
- enhancing the aesthetic and recreational appeal of the urban environment.

WSUD can include a variety of methods such as stormwater detention or retention, water re-use, water efficiency, reduction in nuisance flooding, minimising stormwater pollution, enhancing groundwater infiltration and overall improve the visual amenity of the area. Council's DCP outlined in Appendix 2: Engineering Specifications advises that all developments are encouraged to implement the principles of WSUD. The DCP outlines various approaches that should be considered and modelled using appropriate software such as MUSIC.

However, the implementation of effective and durable WSUD systems in a dense urban environment, such as in the two precincts, is challenging, particularly for small scale redevelopments. Redevelopment on a large scale as proposed, provides an excellent opportunity for WSUD to be implemented in a rigorous and effective manner which will enhance the quality of the environment in the two precincts.

WSUD can be applied in a multitude of ways, there is no single approach that can be costed and recommended for adoption as it will depend on the designer and the building, site and other components available. WSUD implementation should be investigated further as the design progresses to ensure compliance with Council's requirements and best practice.

5.8. Stormwater Management

Council's DCP outlined in Appendix 2: Engineering Specifications provides a comprehensive guideline for stormwater management. The Brief for this present report excludes review of stormwater management, however quality stormwater design is supported and should be incorporated within the recommendations of this flood risk assessment report.

5.9. Drainage Easements

An easement is the right to cross or otherwise use someone else's land for a specific purpose. It is important that all existing and new sub surface pipes or other public drainage structures must be within an easement. In addition, it may be prudent to identify all overland drainage paths through private property within an easement to ensure that the flow conveyance, and thus a change in flood level, is never affected.

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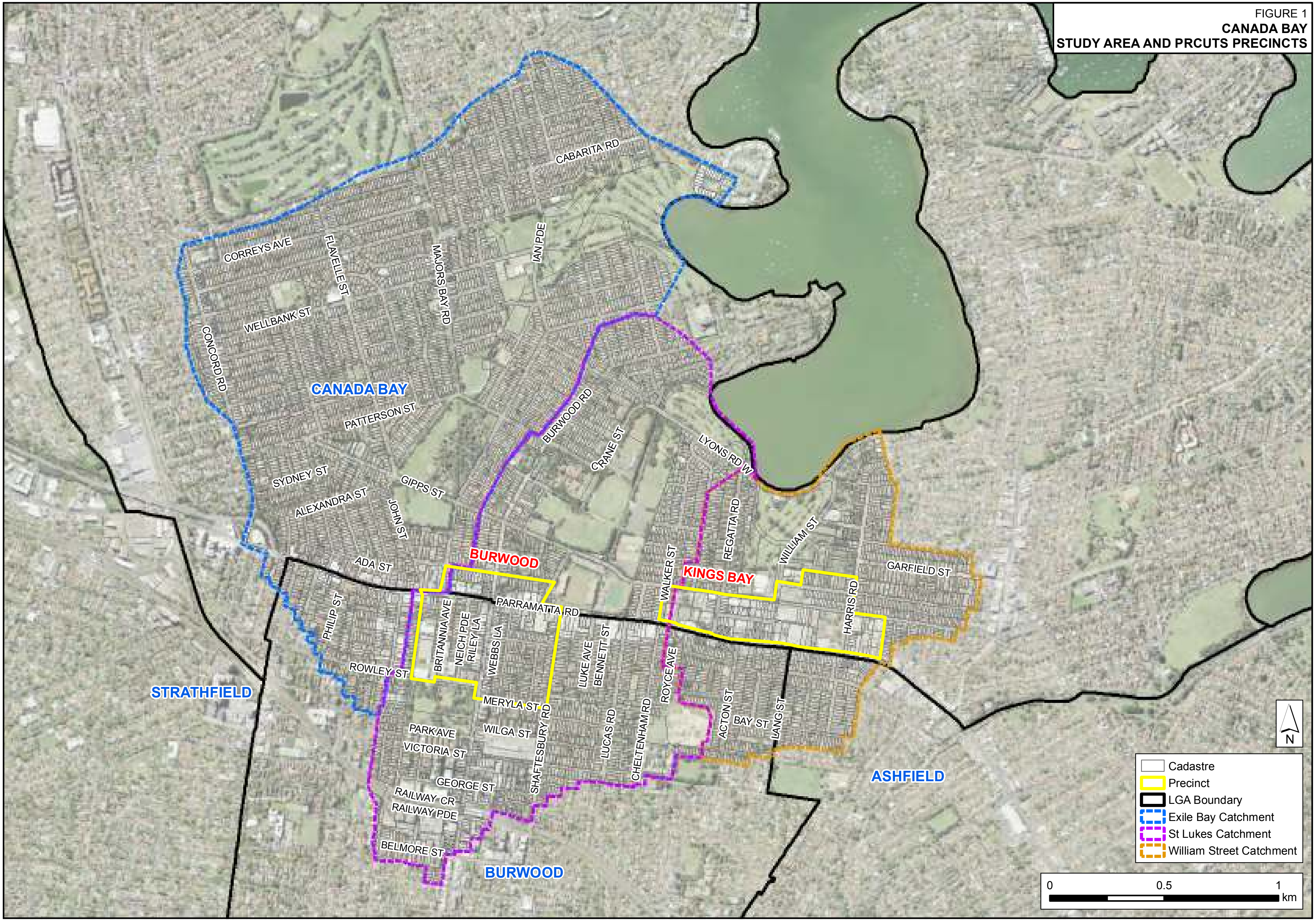
Figures

FIGURE 1
CANADA BAY
STUDY AREA AND PRCUTS PRECINCTS



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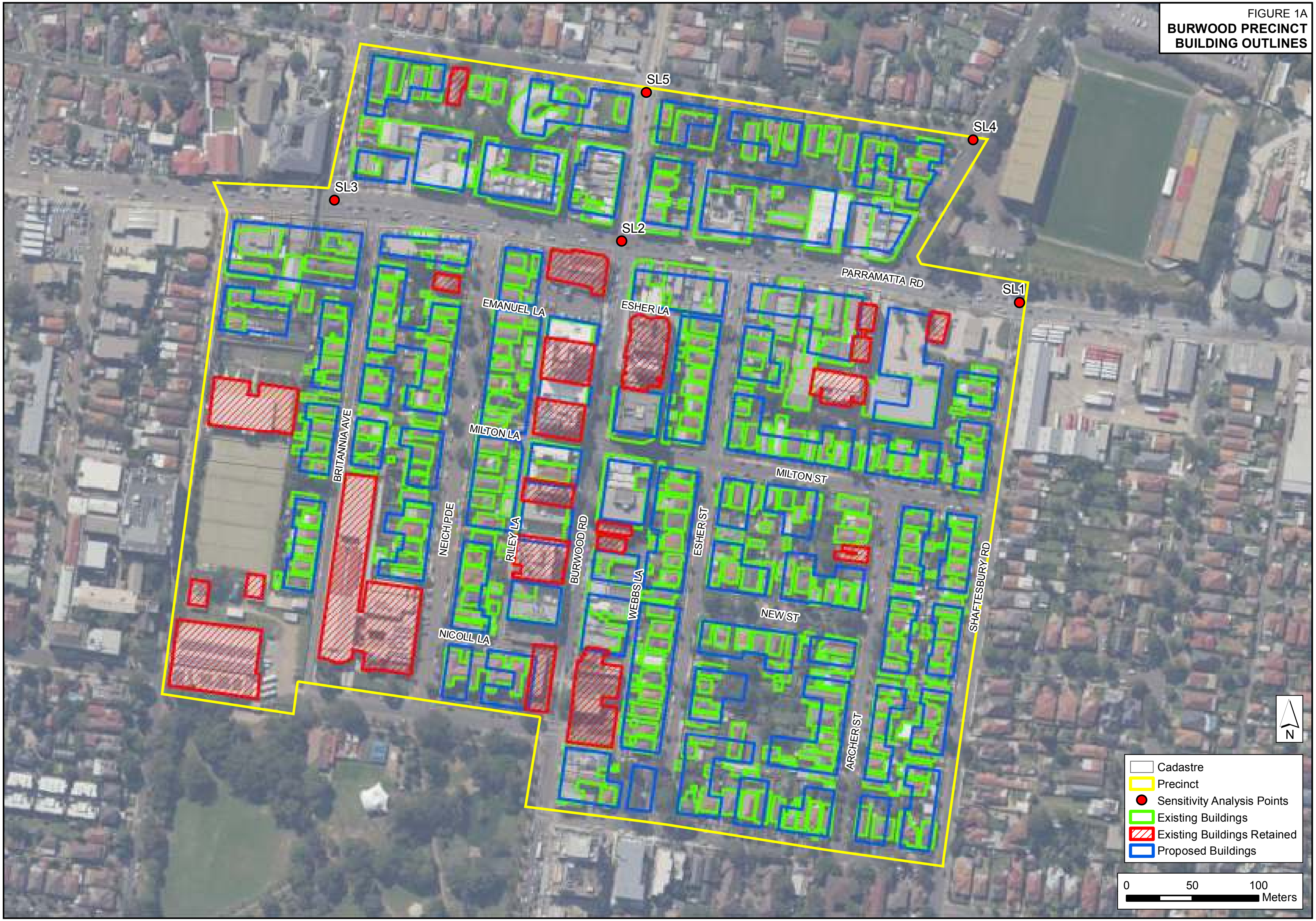

FIGURE 1A
BURWOOD PRECINCT
BUILDING OUTLINES

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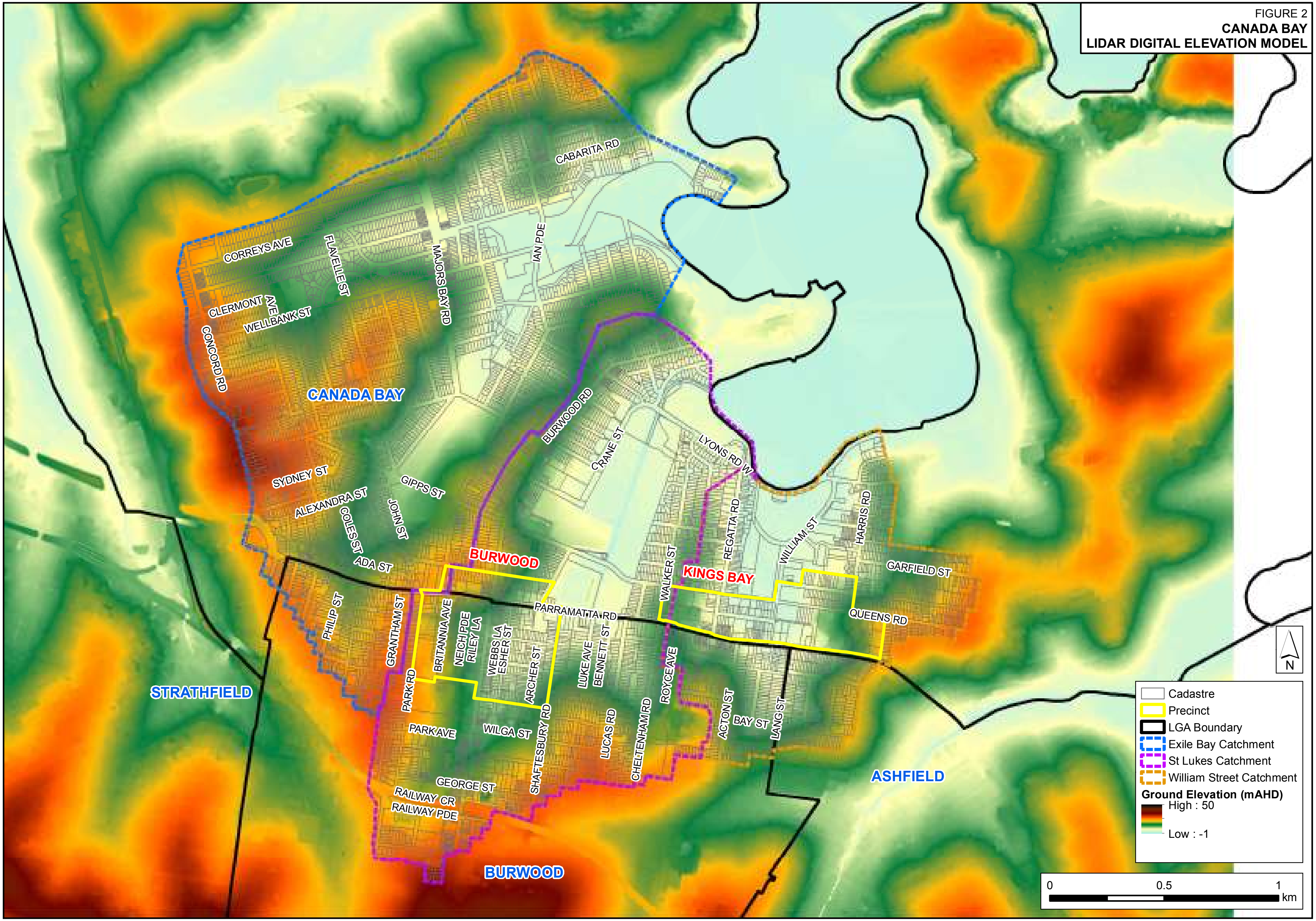

FIGURE 2
CANADA BAY
LIDAR DIGITAL ELEVATION MODEL

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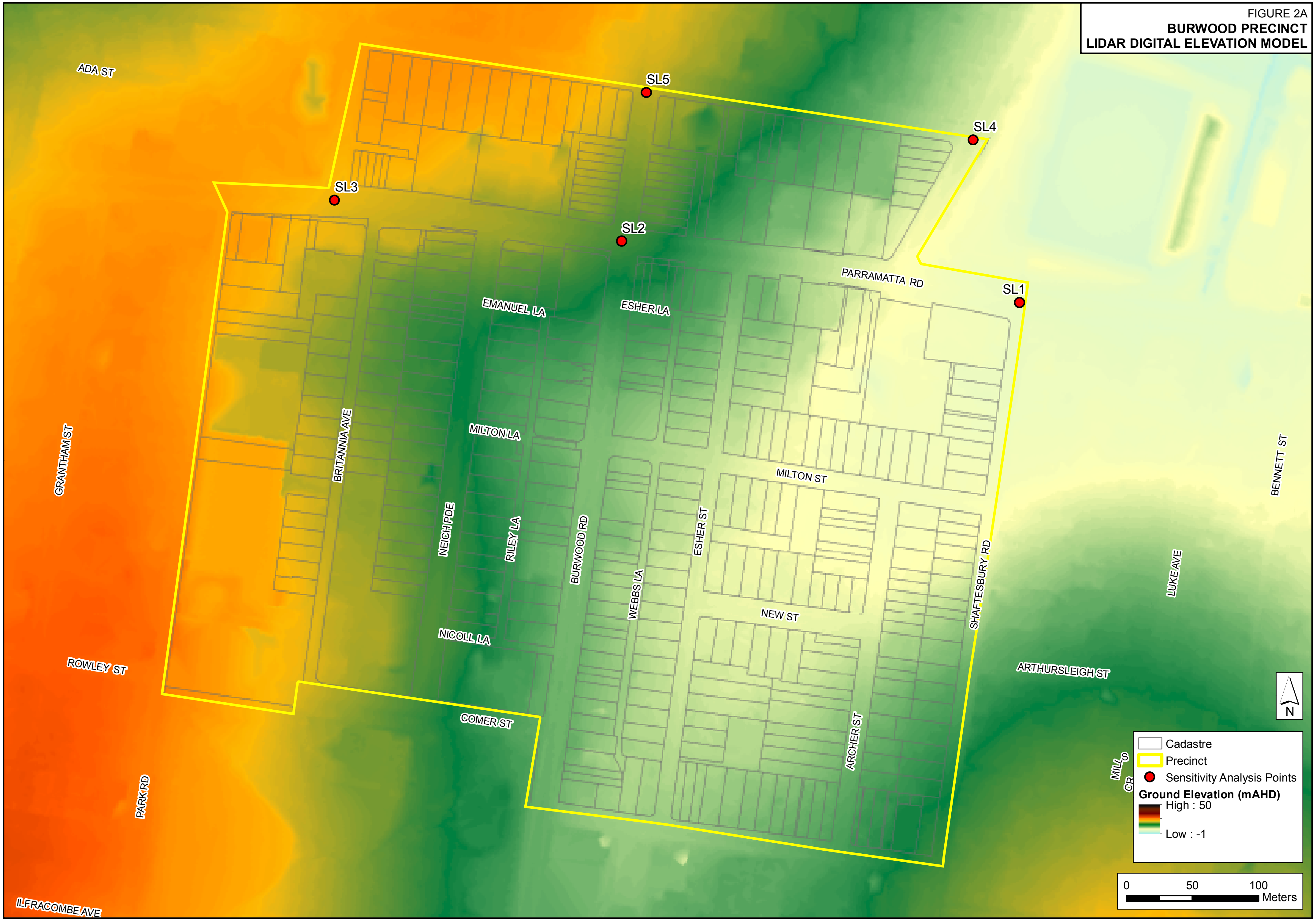

FIGURE 2A
BURWOOD PRECINCT
LIDAR DIGITAL ELEVATION MODEL
SL1
SL2
SL3
SL4
SL5
ADA ST
PARRAMATTA RD
EMANUEL LA
ESHER LA
MILTON LA
MILTON ST
BRITANNIA AVE
GRANTHAM ST
NEICH PDE
RILEY LA
BURWOOD RD
ESHER ST
WEBBS LA
NEW ST
SHAFTESBURY RD
LUKE AVE
BENNETT ST
NICOLL LA
ROWLEY ST
COMER ST
ARTHURSLEIGH ST
ARCHER ST
PARK RD
ILFRACOMBE AVE
N
Cadastre
Precinct
Sensitivity Analysis Points
Ground Elevation (mAHD)
High : 50
Low : -1
0
50
100
Meters
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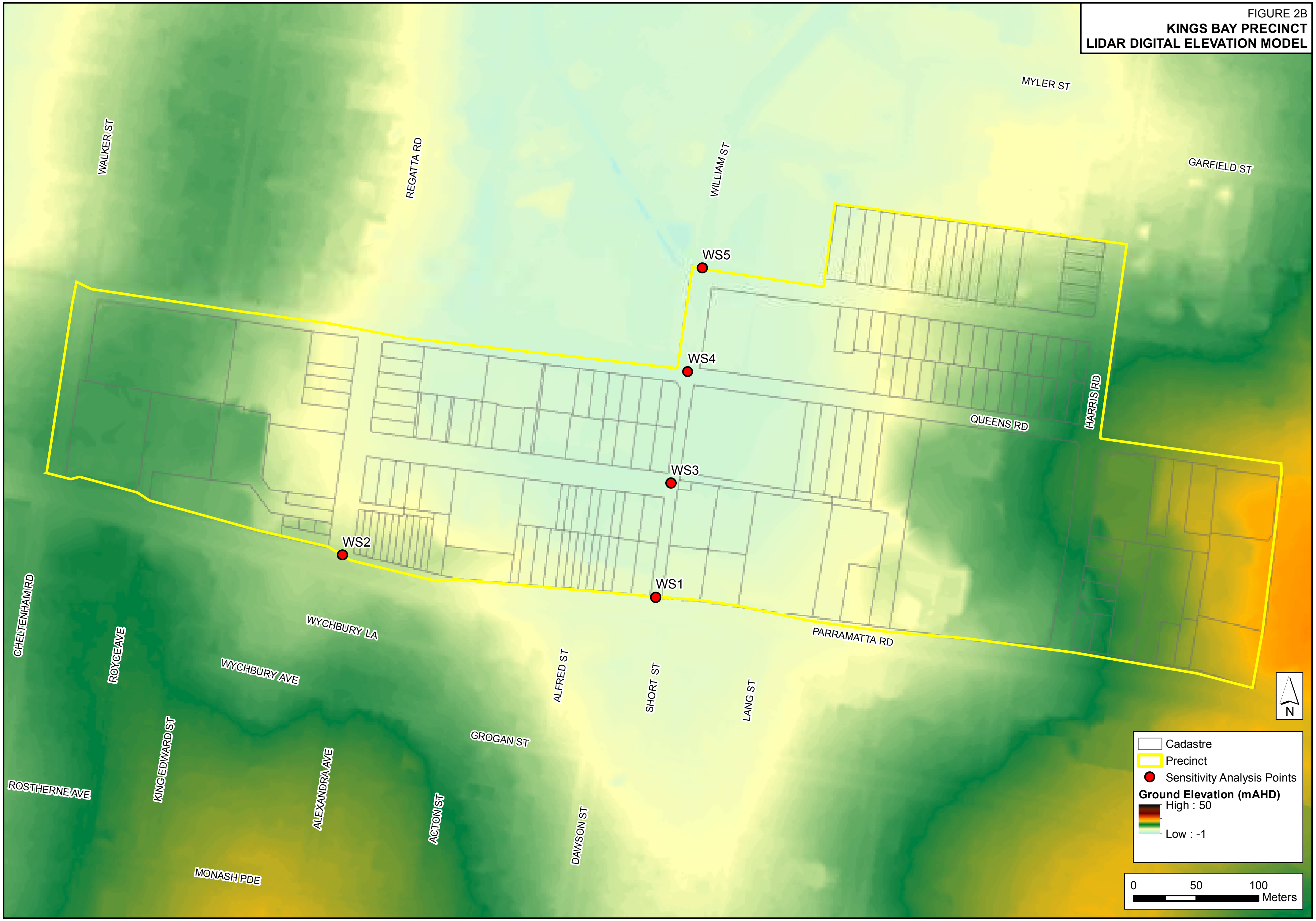

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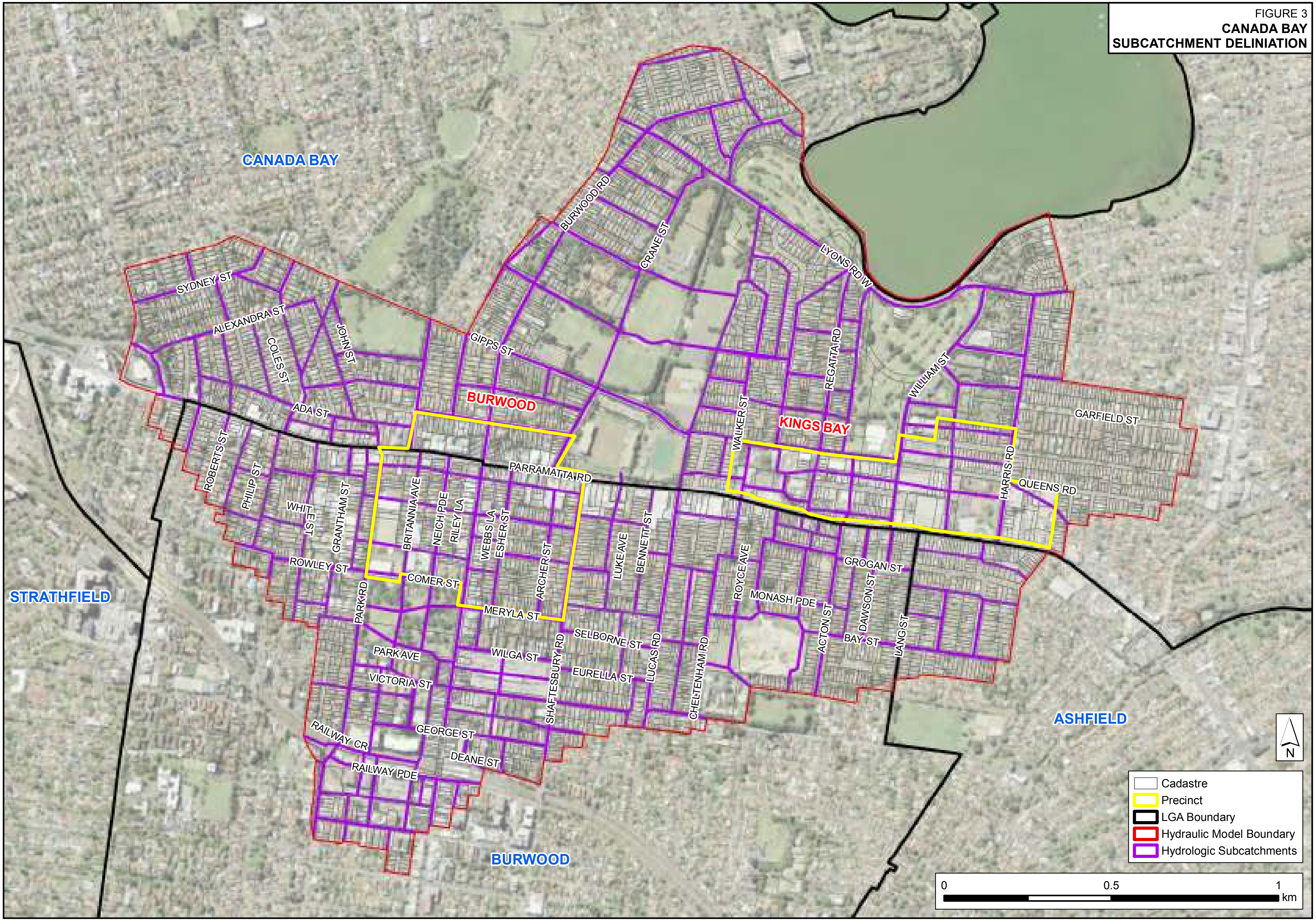

FIGURE 3
CANADA BAY
SUBCATCHMENT DELINIATION

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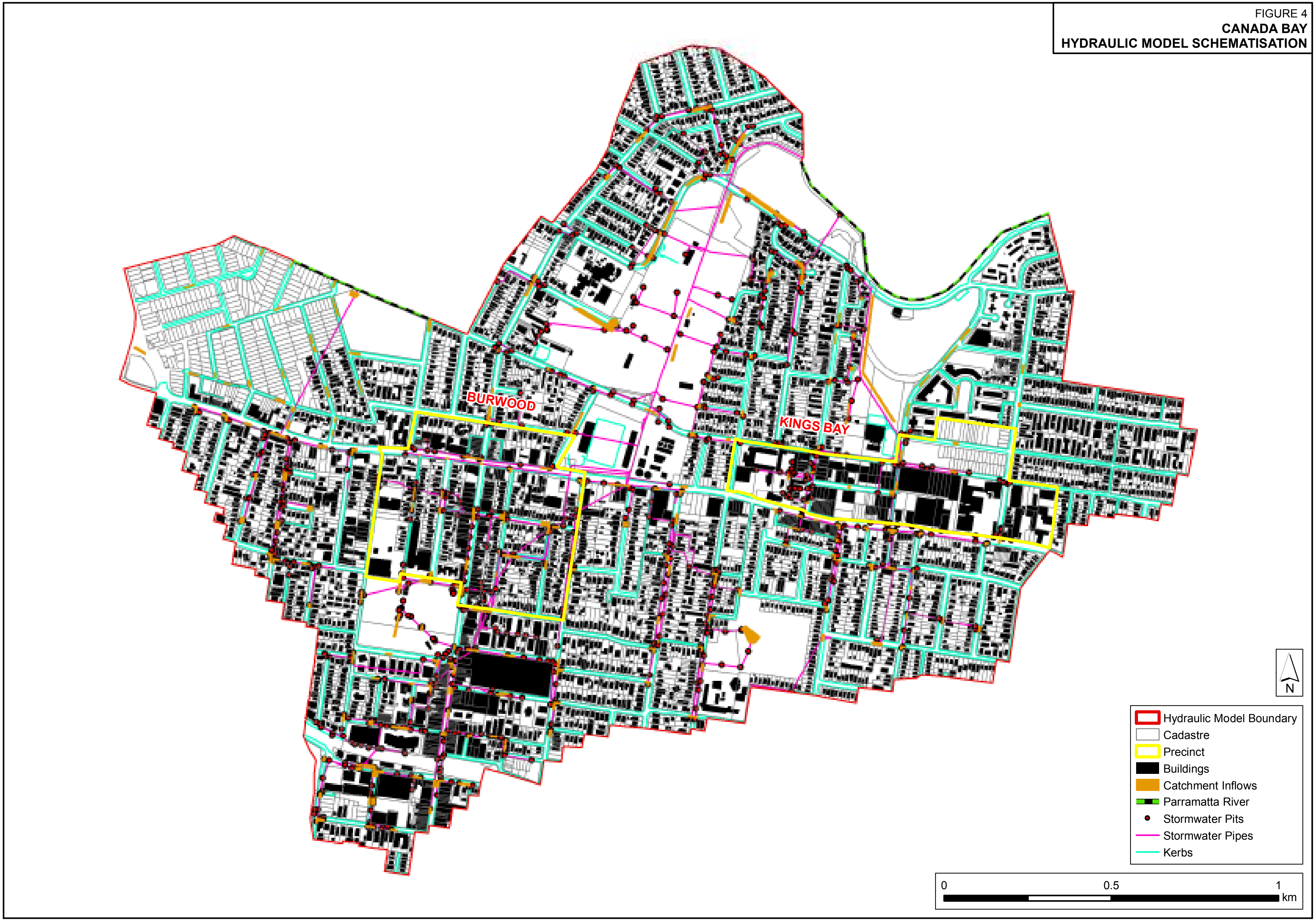

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FIGURE 5
CANADA BAY
HYDRAULIC MODEL ROUGHNESS

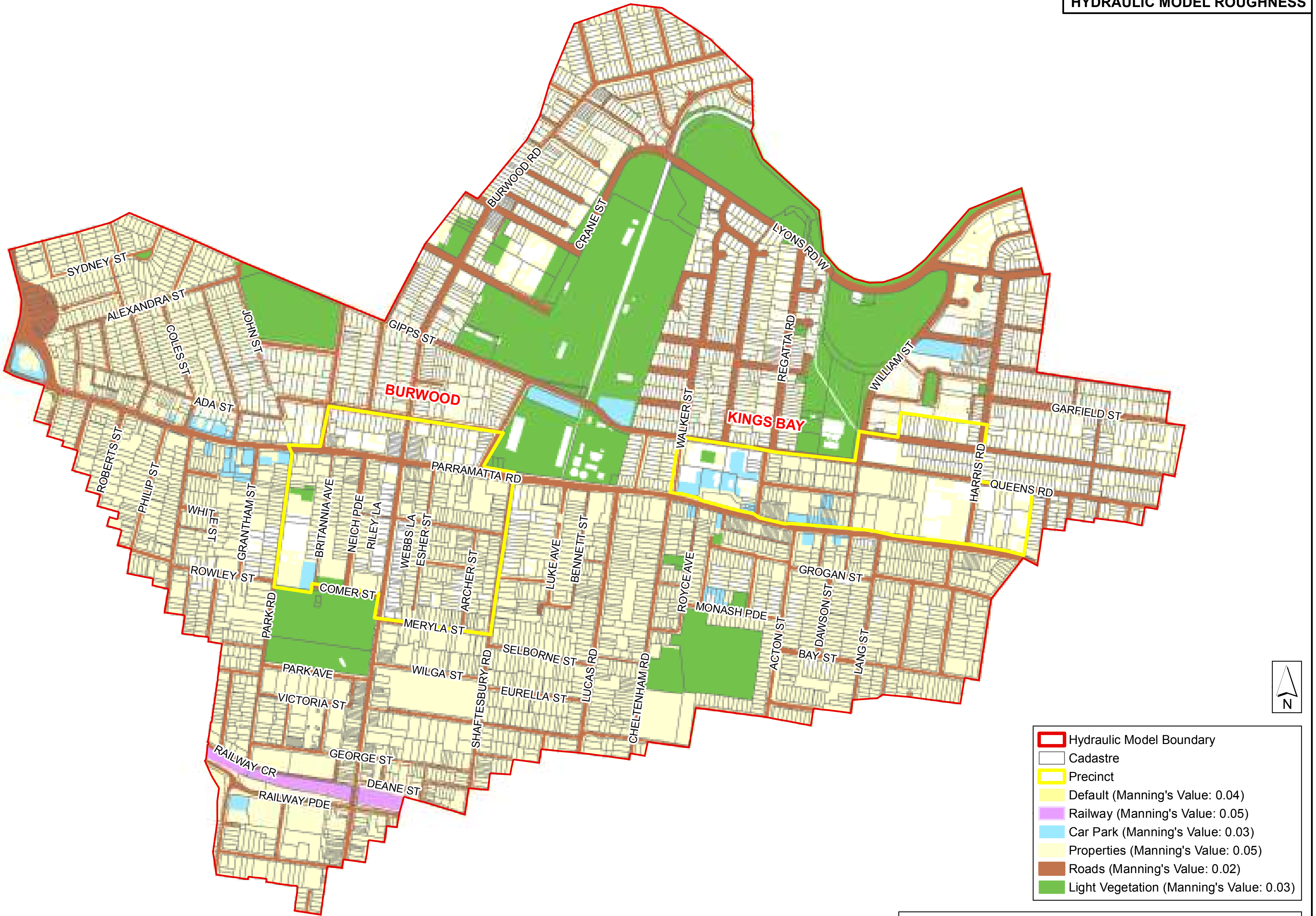

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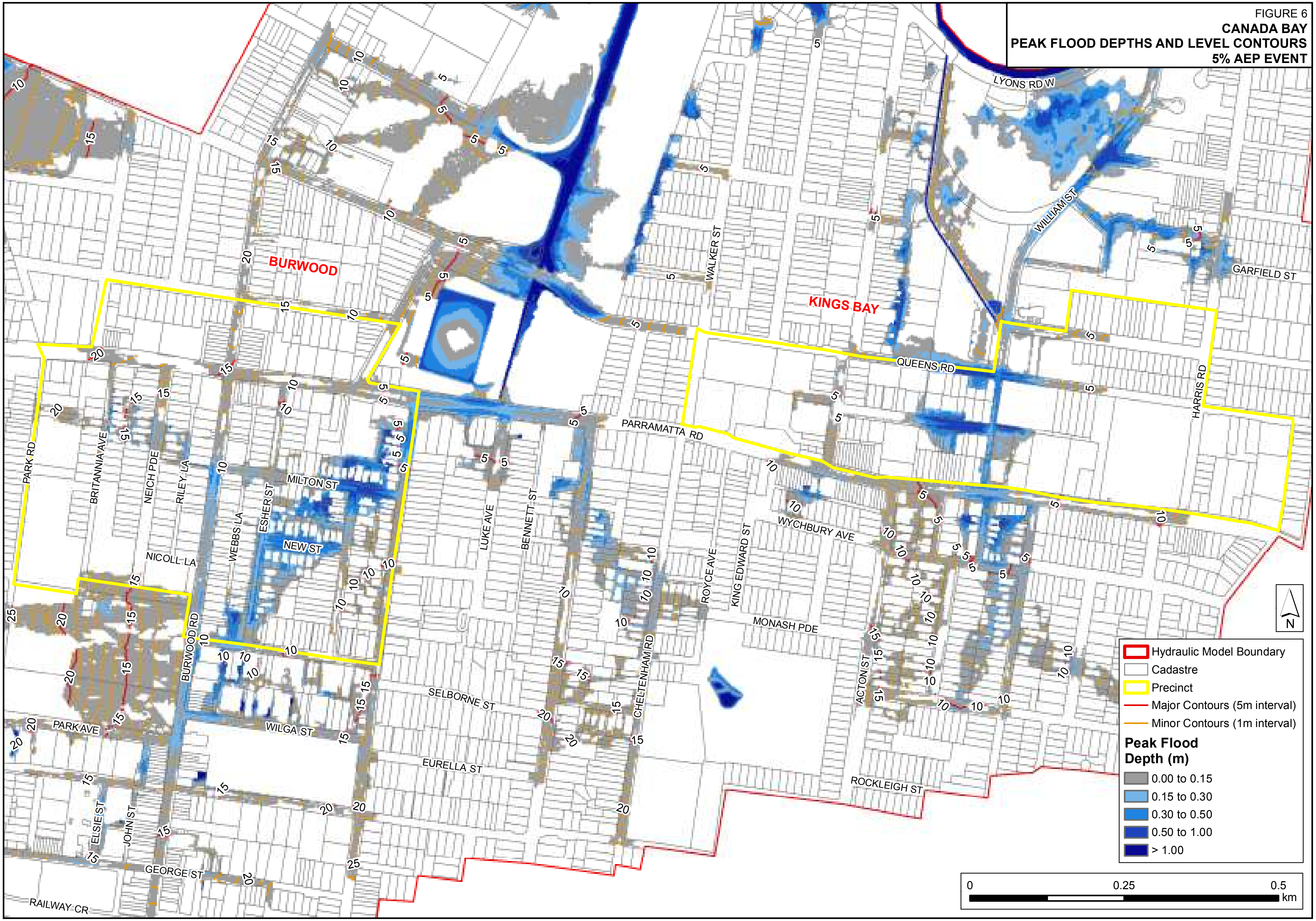
FIGURE 6
CANADA BAY
PEAK FLOOD DEPTHS AND LEVEL CONTOURS
5% AEP EVENT



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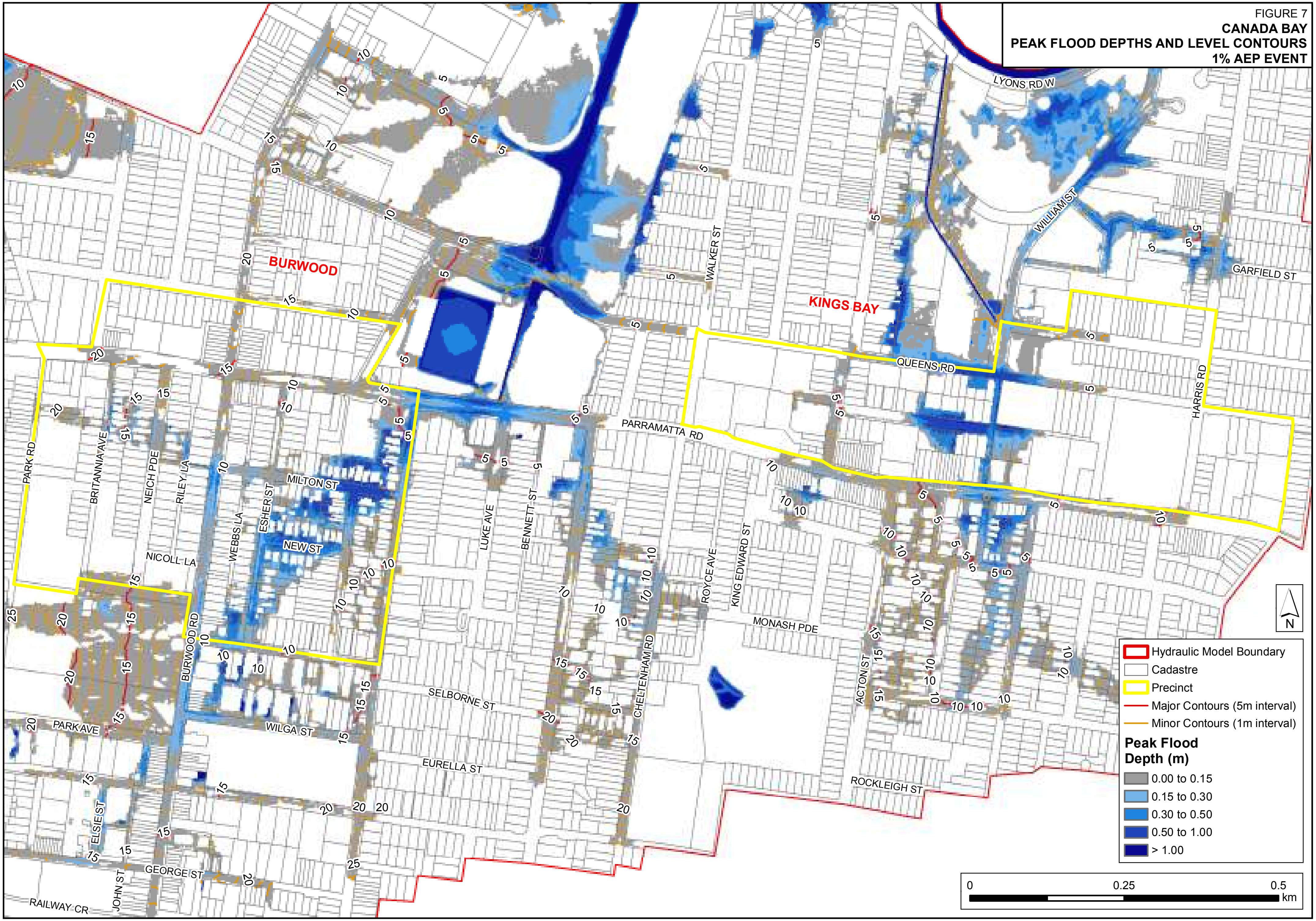

FIGURE 7
CANADA BAY
PEAK FLOOD DEPTHS AND LEVEL CONTOURS
1% AEP EVENT

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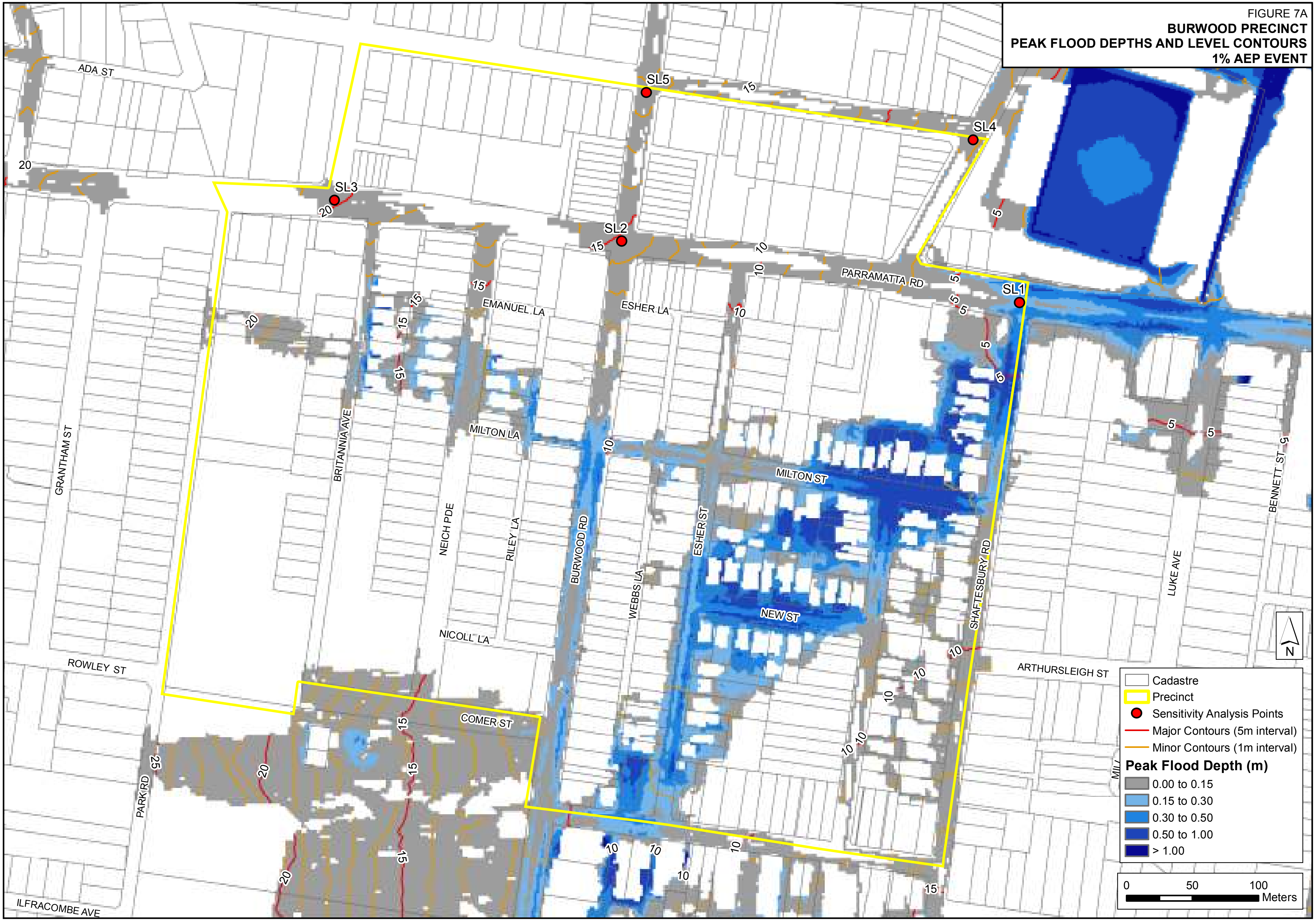
FIGURE 7A
BURWOOD PRECINCT
PEAK FLOOD DEPTHS AND LEVEL CONTOURS
1% AEP EVENT
ADA ST
PARRAMATTA RD
EMANUEL LA
ESHER LA
MILTON LA
MILTON ST
BRITANNIA AVE
GRANTHAM ST
NEICH PDE
RILEY LA
BURWOOD RD
WEBBS LA
ESHER ST
NEW ST
SHAFTESBURY RD
LUKE AVE
BENNETT ST
ARTHURSLEIGH ST
NICOLL LA
ROWLEY ST
COMER ST
PARK RD
ILFRACOMBE AVE
SL1
SL2
SL3
SL4
SL5
N
Cadastre
Precinct
Sensitivity Analysis Points
Major Contours (5m interval)
Minor Contours (1m interval)
Peak Flood Depth (m)
0.00 to 0.15
0.15 to 0.30
0.30 to 0.50
0.50 to 1.00
> 1.00
0
50
100
Meters
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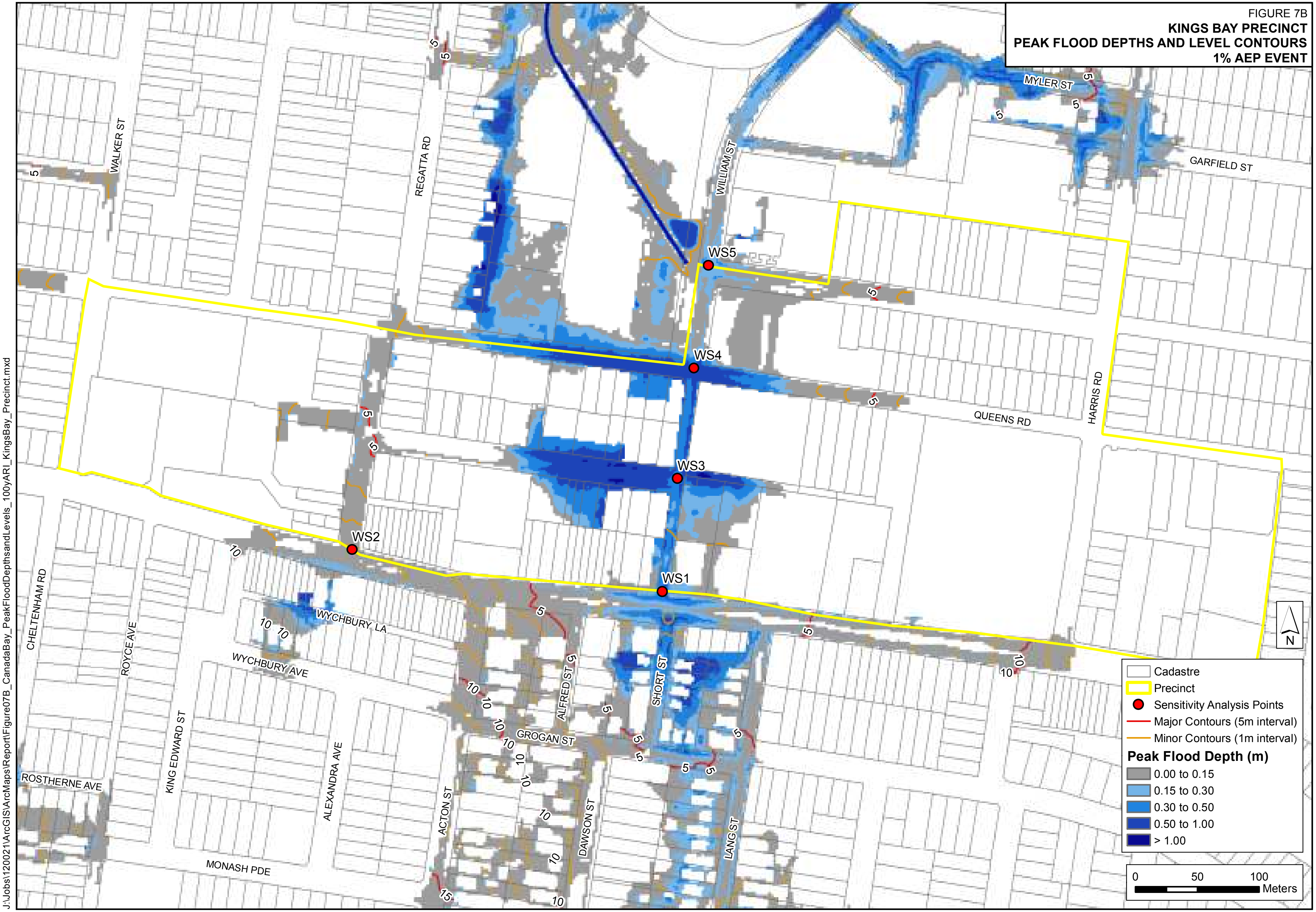
FIGURE 7B
KINGS BAY PRECINCT
PEAK FLOOD DEPTHS AND LEVEL CONTOURS
1% AEP EVENT
WS1
WS2
WS3
WS4
WS5
MYLER ST
GARFIELD ST
WALKER ST
REGATTA RD
WILLIAM ST
QUEENS RD
HARRIS RD
CHELTENHAM RD
ROYCE AVE
WYCHBURY LA
WYCHBURY AVE
KING EDWARD ST
ALEXANDRA AVE
ACTON ST
ALFRED ST
GROGAN ST
DAWSON ST
SHORT ST
LANG ST
ROSTHERNE AVE
MONASH PDE
N
Cadastre
Precinct
Sensitivity Analysis Points
Major Contours (5m interval)
Minor Contours (1m interval)
Peak Flood Depth (m)
0.00 to 0.15
0.15 to 0.30
0.30 to 0.50
0.50 to 1.00
> 1.00
0
50
100
Meters
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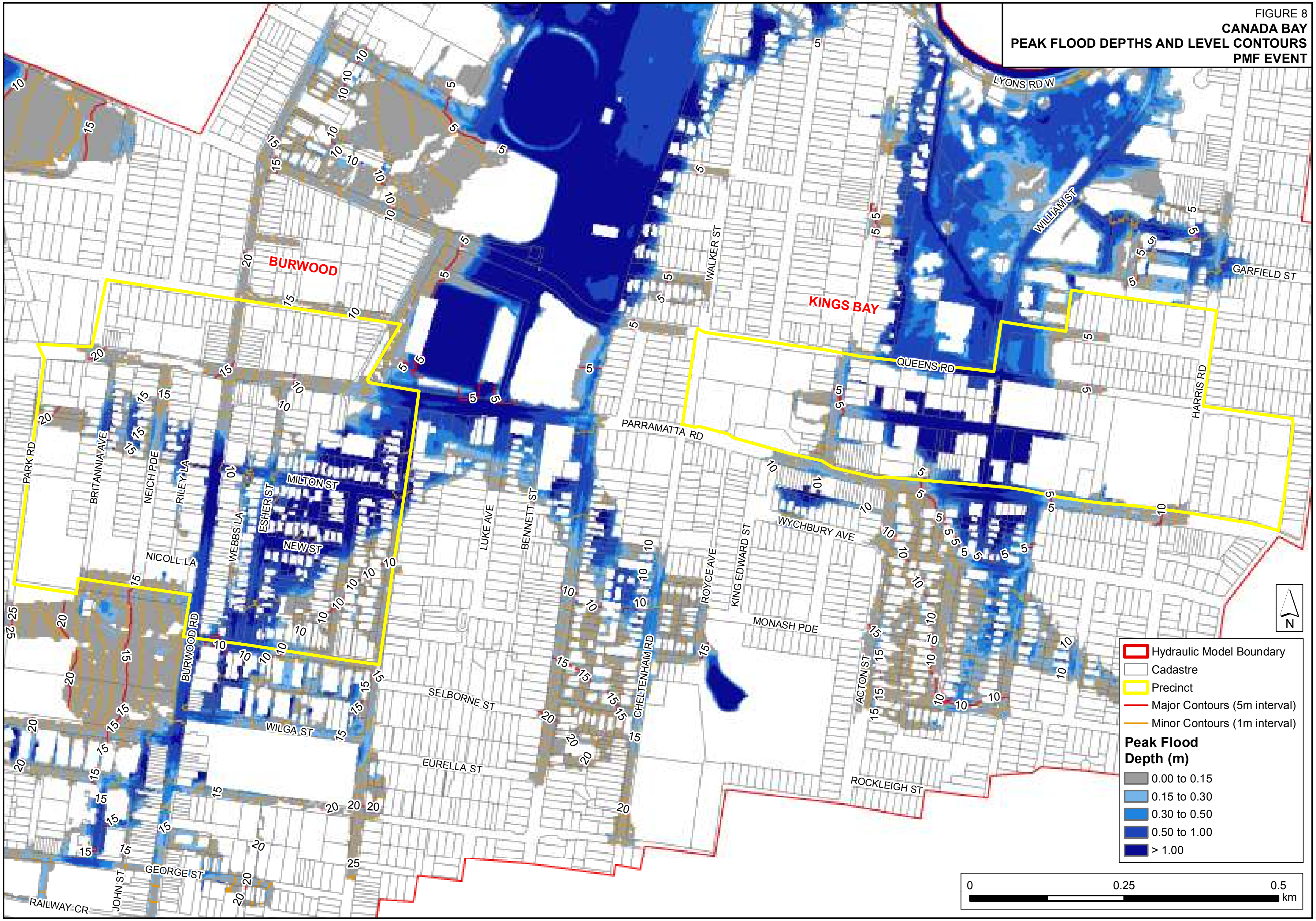

FIGURE 8
CANADA BAY
PEAK FLOOD DEPTHS AND LEVEL CONTOURS
PMF EVENT

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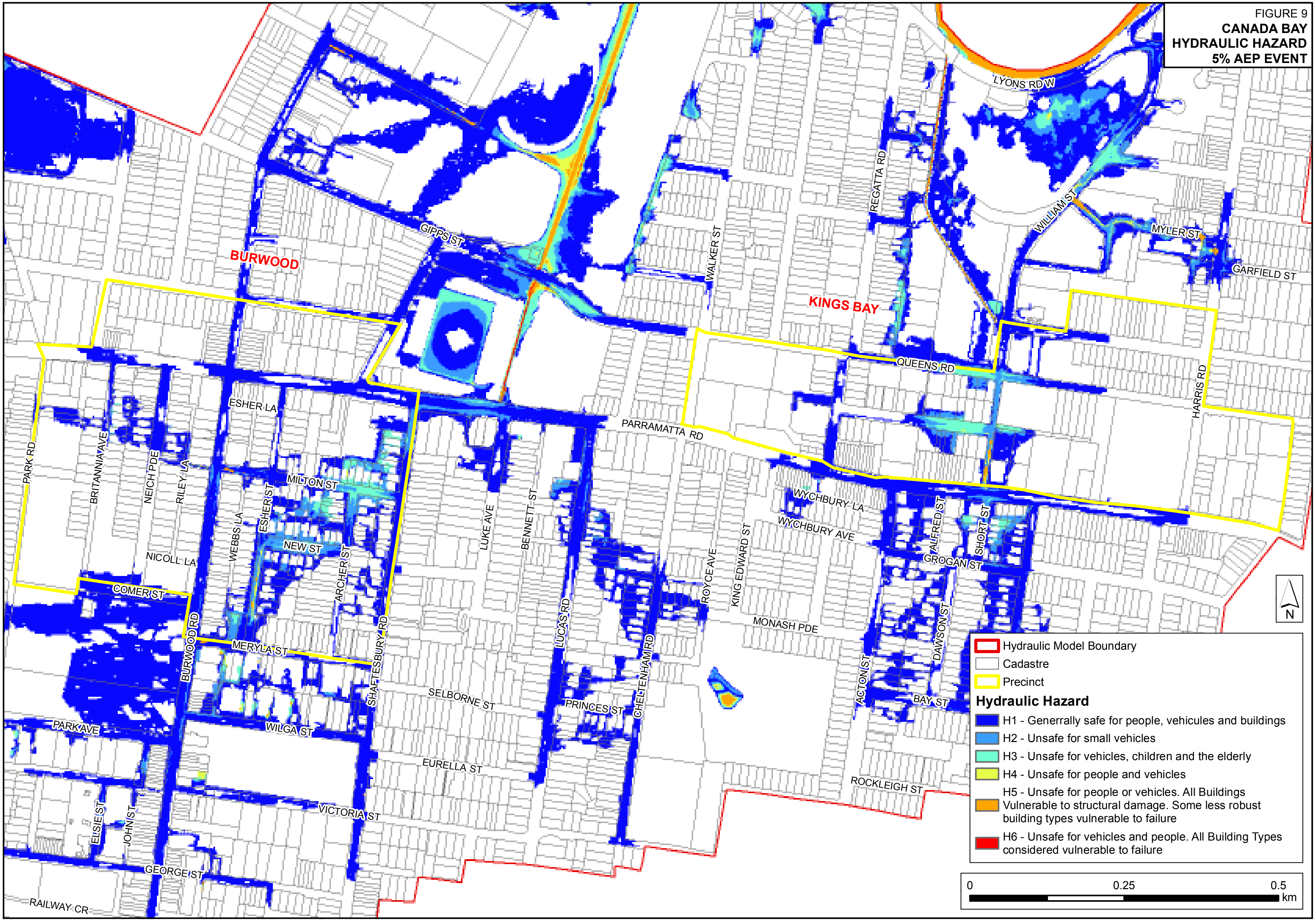


Hydraulic Model Boundary
Cadastre
Precinct

Hydraulic Hazard

- H1 - Generally safe for people, vehicules and buildings
- H2 - Unsafe for small vehicles
- H3 - Unsafe for vehicles, children and the elderly
- H4 - Unsafe for people and vehicles
- H5 - Unsafe for people or vehicles. All Buildings Vulnerable to structural damage. Some less robust building types vulnerable to failure
- H6 - Unsafe for vehicles and people. All Building Types considered vulnerable to failure

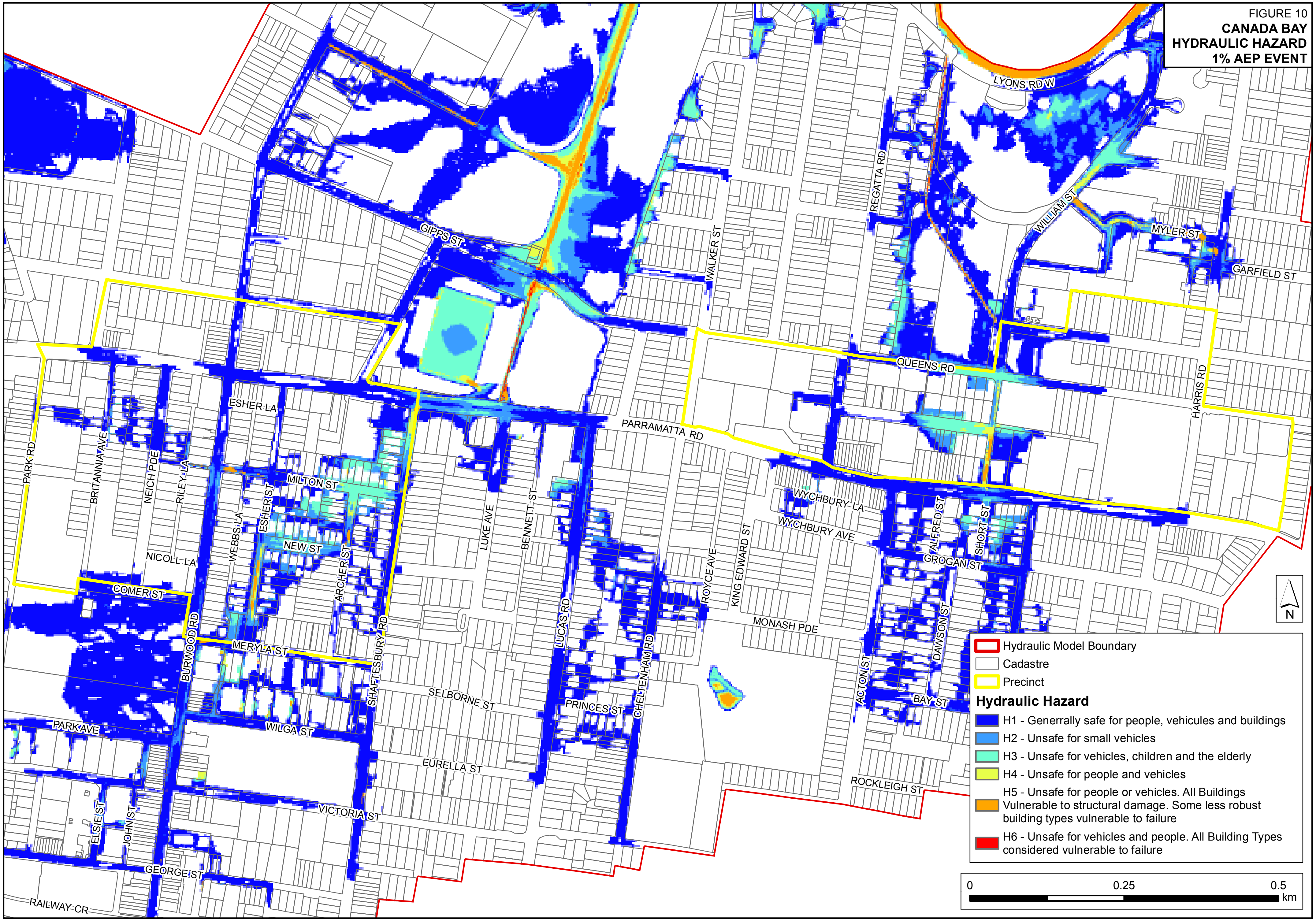
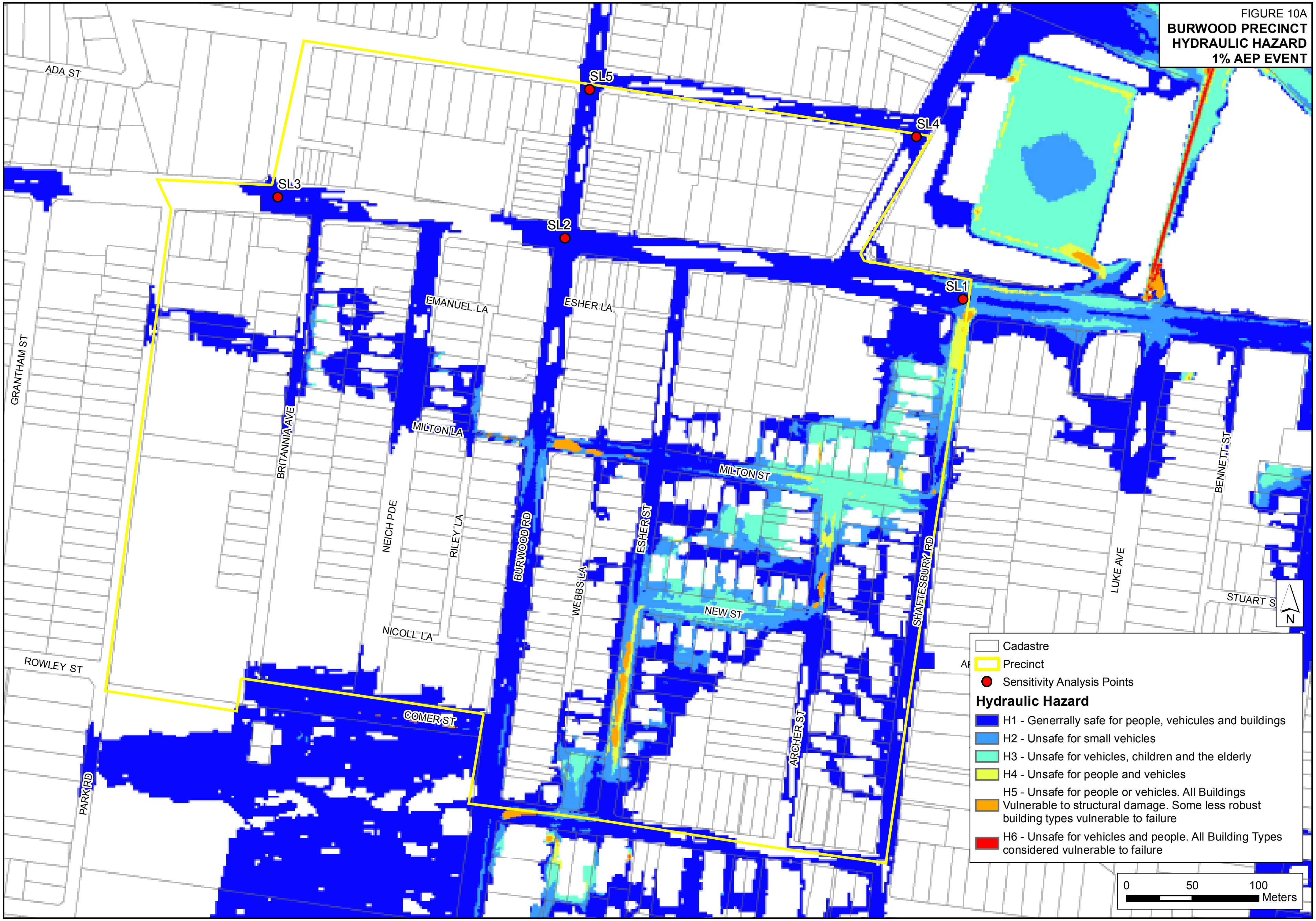


FIGURE 10
CANADA BAY
HYDRAULIC HAZARD
1% AEP EVENT
LYONS RD W
REGATTA RD
WILLIAM ST
MYLER ST
GARFIELD ST
GIPPS ST
WALKER ST
QUEENS RD
HARRIS RD
PARRAMATTA RD
ESHER LA
PARK RD
BRITANNIA AVE
NEICH PDE
RILEY LA
MILTON ST
ESHER ST
WEBBS LA
NEW ST
NICOLL LA
ARCHER ST
LUKE AVE
BENNETT ST
WYCHBURY LA
WYCHBURY AVE
ALFRED ST
SHORT ST
GROGAN ST
KING EDWARD ST
ROYCE AVE
COMER ST
BURWOOD RD
MERYLA ST
SHAFTESBURY RD
LUCAS RD
CHELTENHAM RD
MONASH PDE
DAWSON ST
ACTON ST
BAY ST
SELBORNE ST
PRINCES ST
PARK AVE
WILGA ST
EURELLA ST
ROCKLEIGH ST
VICTORIA ST
ELSIE ST
JOHN ST
GEORGE ST
RAILWAY CR
N
Hydraulic Model Boundary
Cadastre
Precinct
Hydraulic Hazard
H1 - Generrally safe for people, vehicules and buildings
H2 - Unsafe for small vehicles
H3 - Unsafe for vehicles, children and the elderly
H4 - Unsafe for people and vehicles
H5 - Unsafe for people or vehicles. All Buildings Vulnerable to structural damage. Some less robust building types vulnerable to failure
H6 - Unsafe for vehicles and people. All Building Types considered vulnerable to failure
0
0.25
0.5
km
J:\Jobs\120021\ArcGIS\ArcMaps\Report\Figure10_CanadaBay_Hydraulic_Hazard_100yARI.mxd



J:\Jobs\120021\ArcGIS\ArcMaps\Report\Figure10A_CanadaBay_Hydraulic_Hazard_100yARI_Burwood_Precinct.mxd

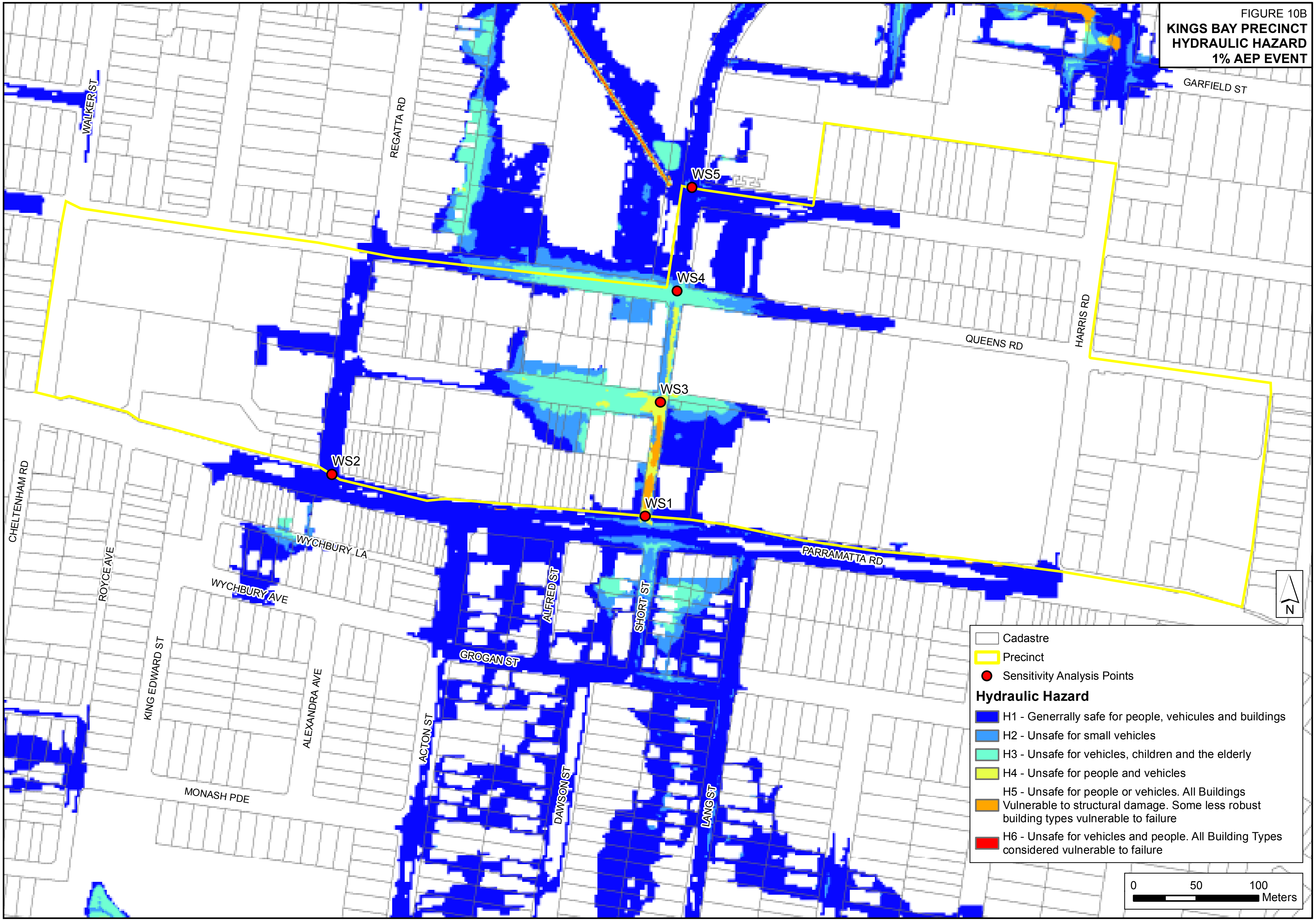


FIGURE 10B
KINGS BAY PRECINCT HYDRAULIC HAZARD 1% AEP EVENT

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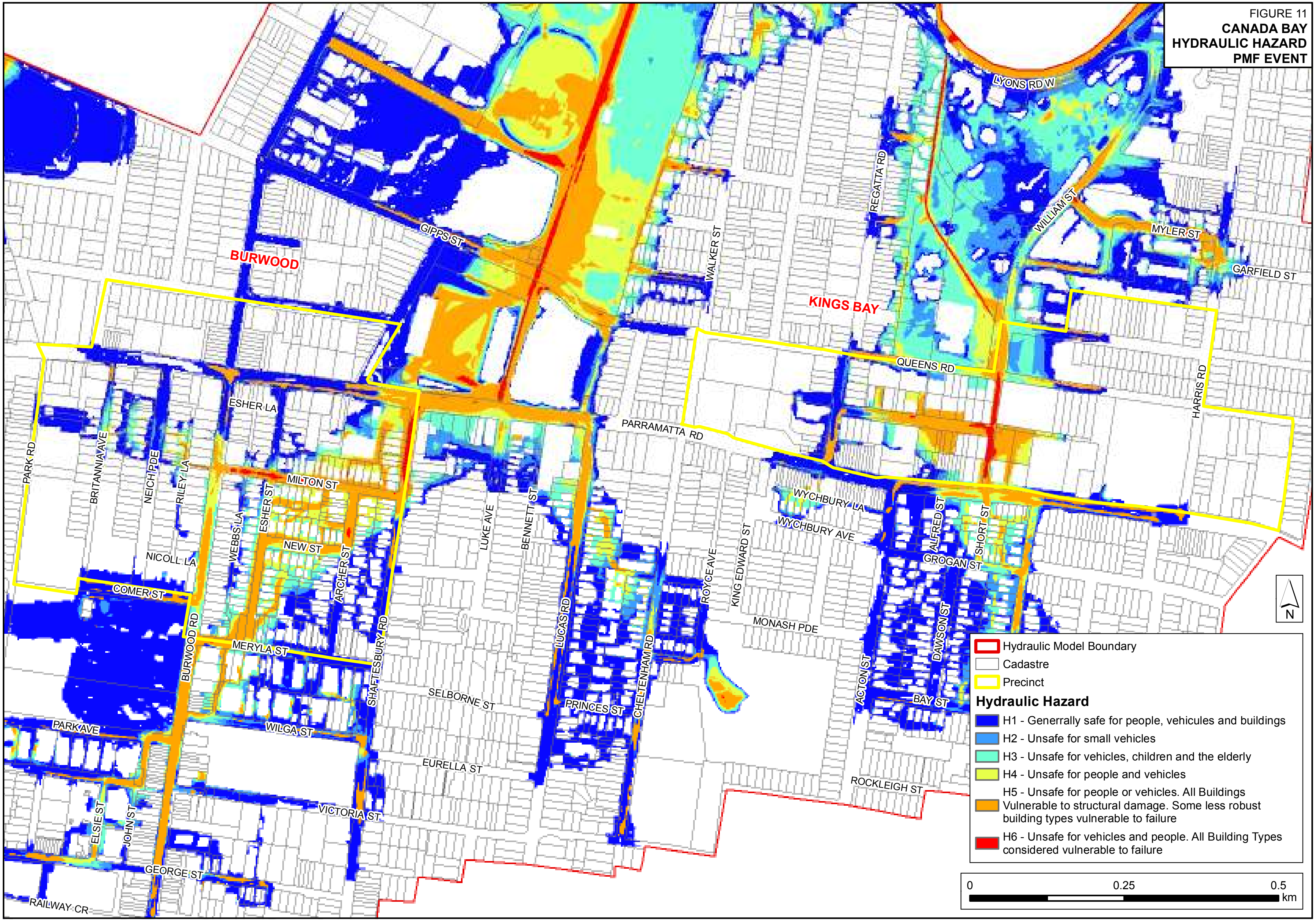

J:\Jobs\120021\ArcGIS\ArcMaps\Report\Figure11_CanadaBay_Hydraulic_Hazard_PMF.mxd

FIGURE 12
CANADA BAY
HYDRAULIC CATEGORISATION
5% AEP EVENT

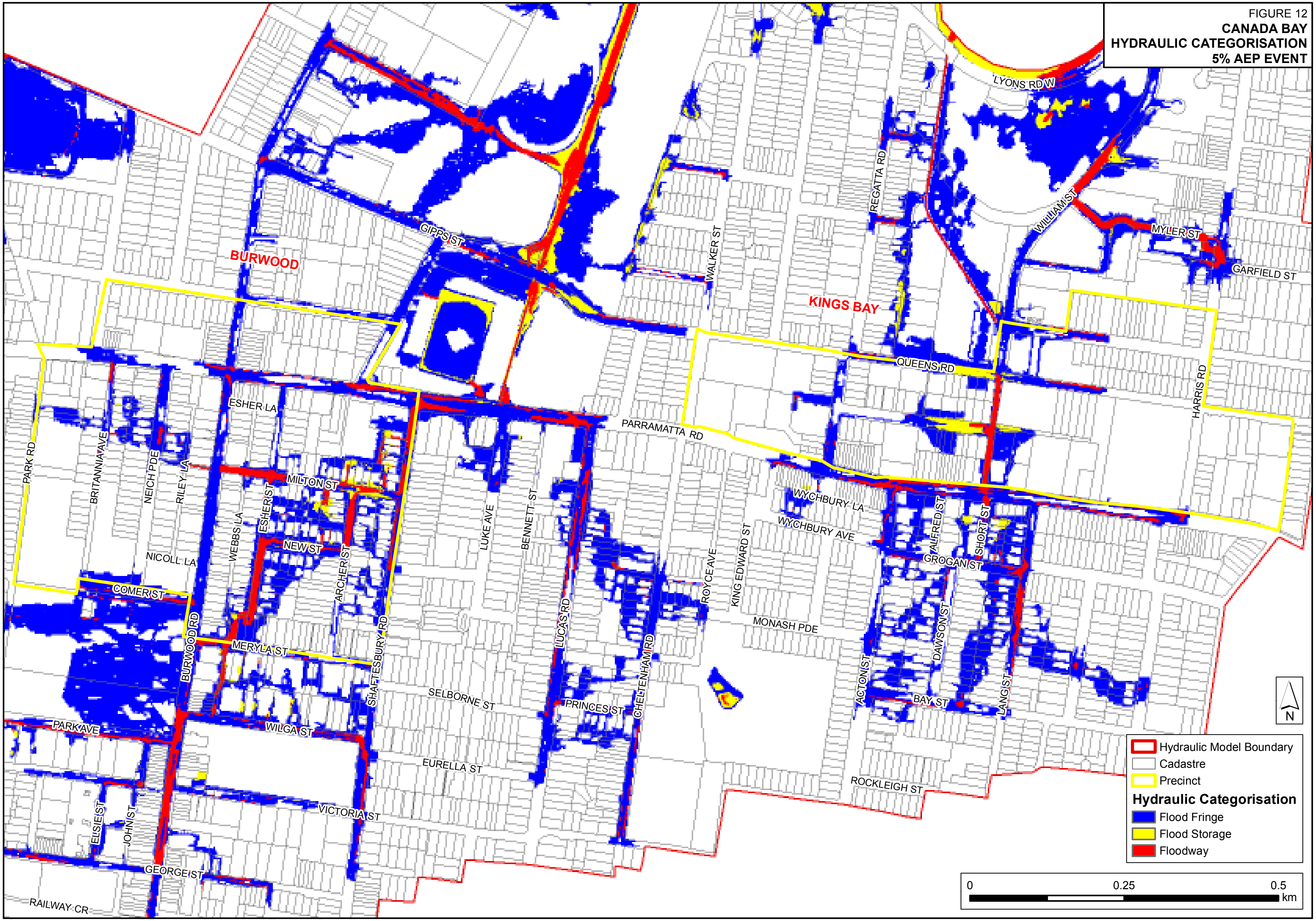

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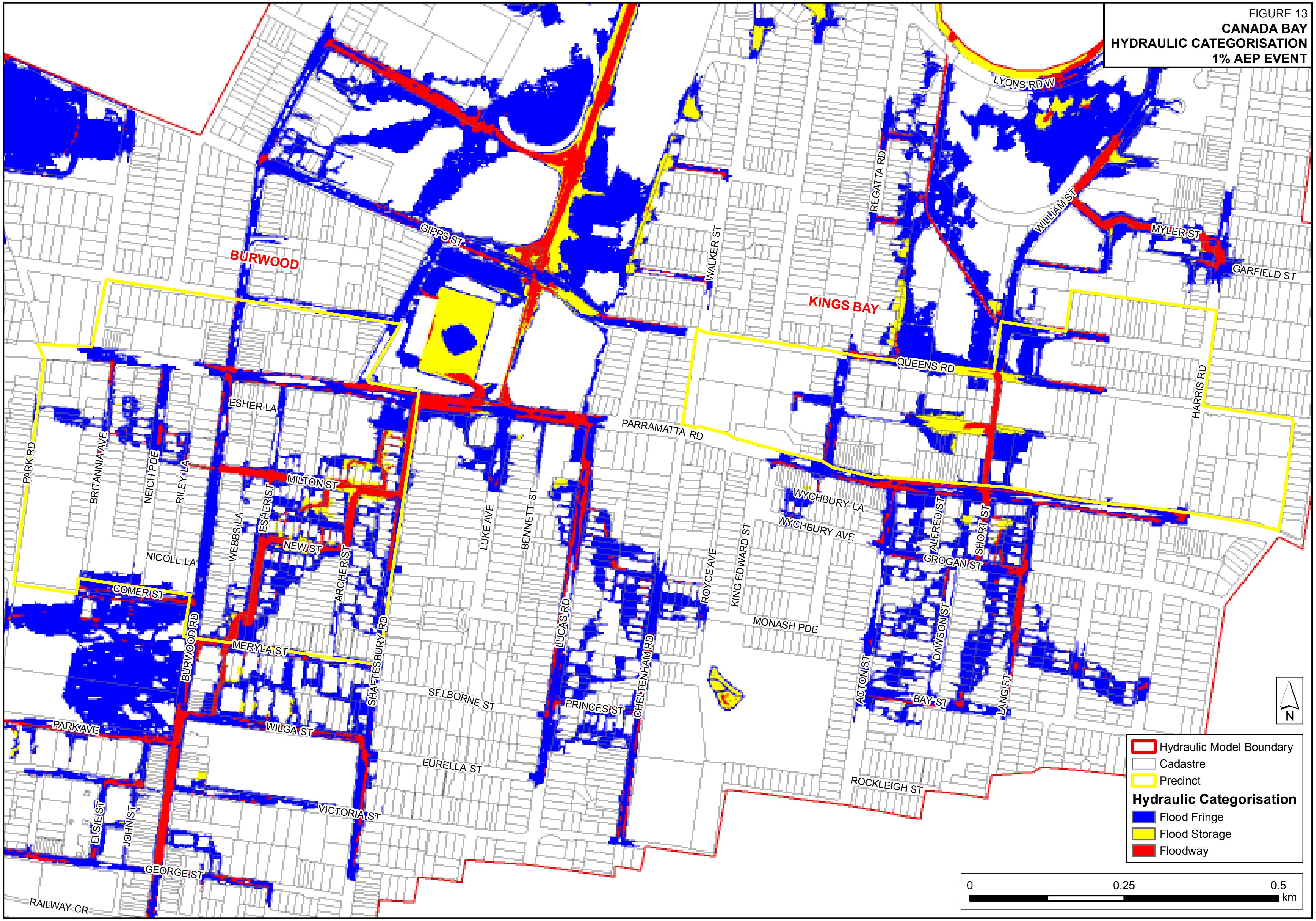
FIGURE 13
CANADA BAY
HYDRAULIC CATEGORISATION
1% AEP EVENT



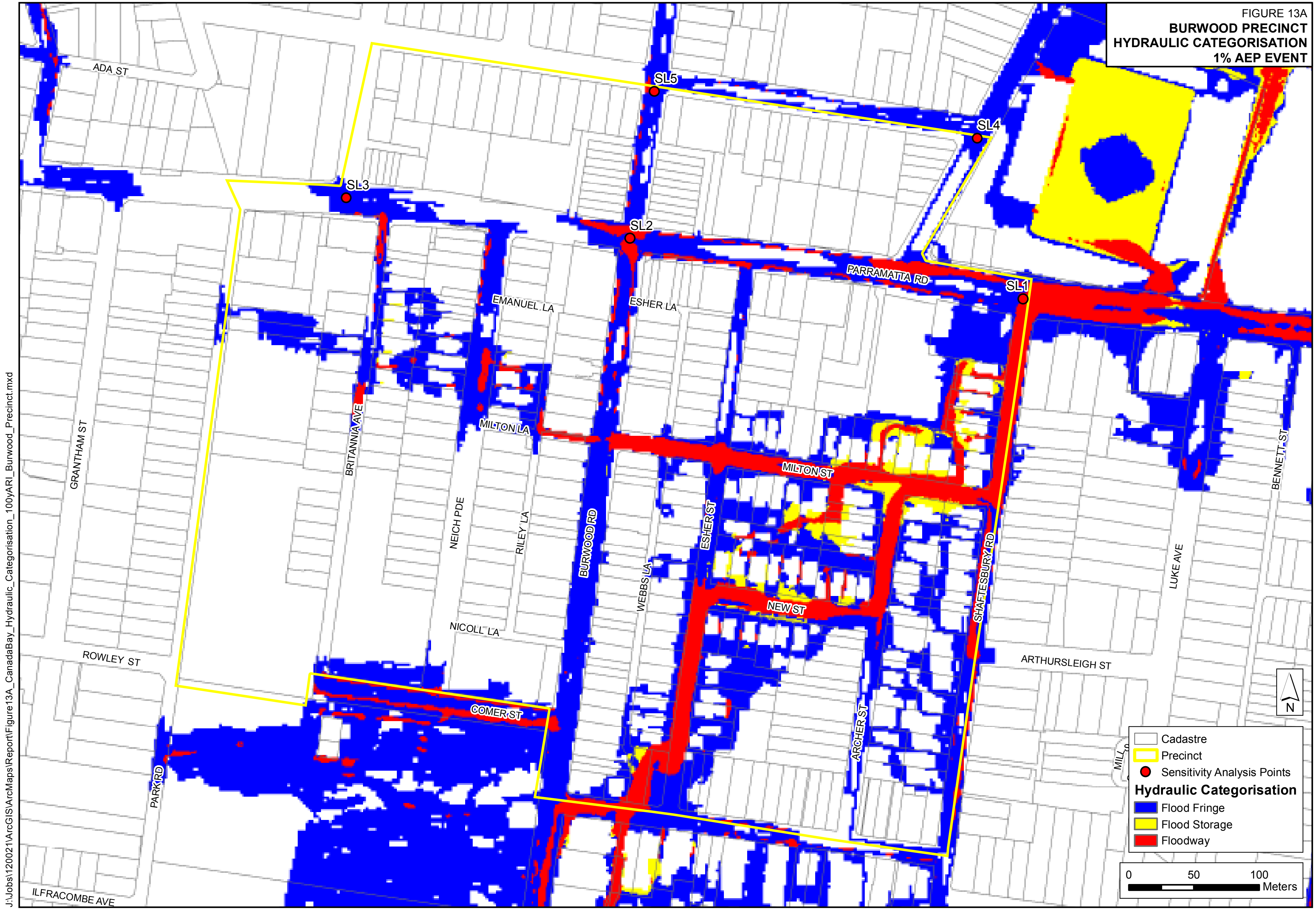


FIGURE 13A
BURWOOD PRECINCT
HYDRAULIC CATEGORISATION
1% AEP EVENT
ADA ST
SL5
SL4
SL3
SL2
SL1
PARRAMATTA RD
EMANUEL LA
ESHER LA
MILTON LA
MILTON ST
GRANTHAM ST
BRITANNIA AVE
NEICH PDE
RILEY LA
BURWOOD RD
ESHER ST
WEBBS LA
NEW ST
SHAFTESBURY RD
LUKE AVE
BENNETT ST
NICOLL LA
ROWLEY ST
ARTHURSLEIGH ST
COMER ST
ARCHER ST
PARK RD
ILFRACOMBE AVE
N
Cadastre
Precinct
Sensitivity Analysis Points
Hydraulic Categorisation
Flood Fringe
Flood Storage
Floodway
0
50
100
Meters
J:\Jobs\120021\ArcGIS\ArcMaps\Report\Figure13A_CanadaBay_Hydraulic_Categorisation_100yARI_Burwood_Precinct.mxd

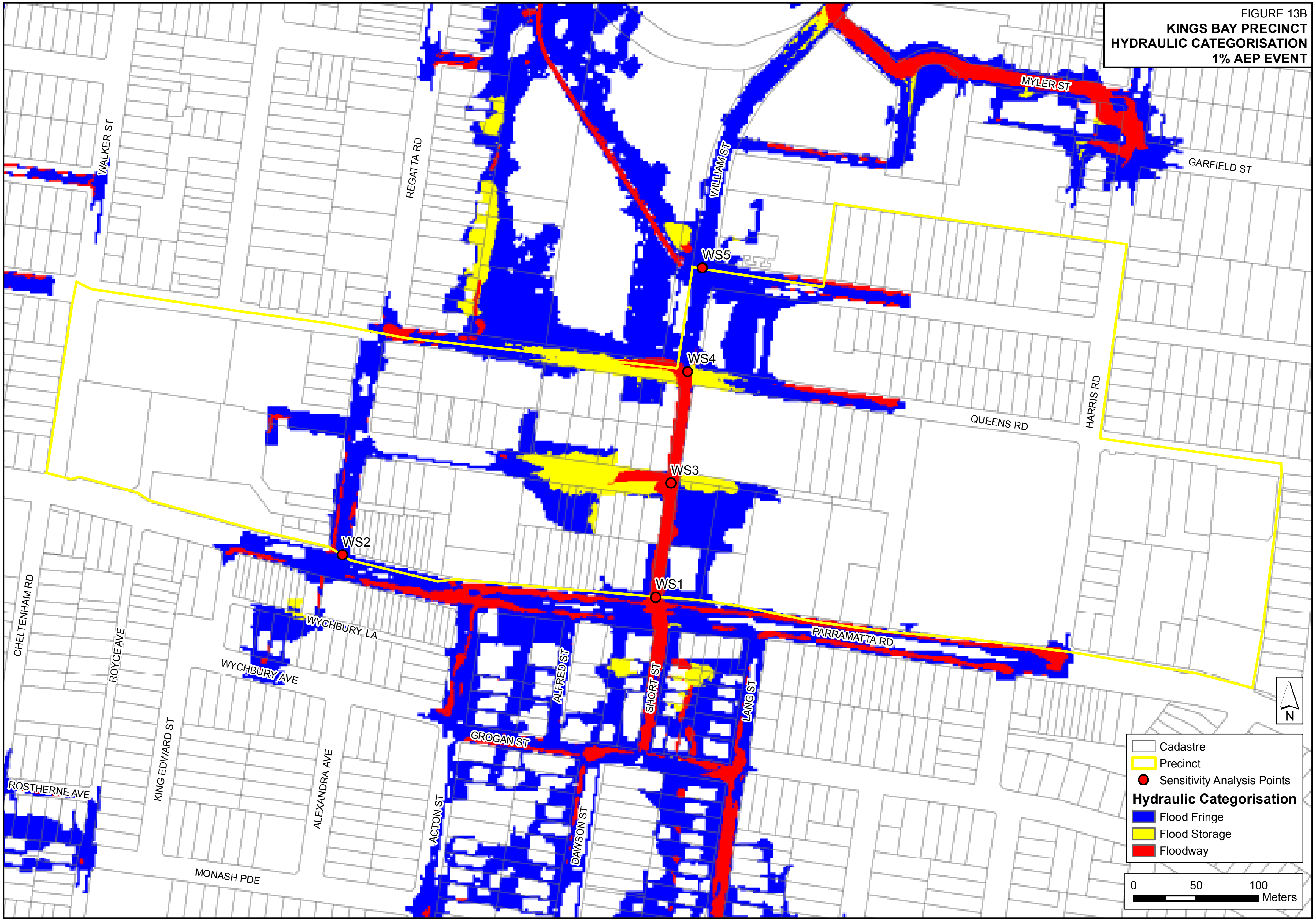


FIGURE 13B
KINGS BAY PRECINCT
HYDRAULIC CATEGORISATION
1% AEP EVENT
WS1
WS2
WS3
WS4
WS5
MYLER ST
GARFIELD ST
WILLIAM ST
REGATTA RD
WALKER ST
QUEENS RD
HARRIS RD
PARRAMATTA RD
WYCHBURY LA
WYCHBURY AVE
CHELTENHAM RD
ROYCE AVE
KING EDWARD ST
ALEXANDRA AVE
ACTON ST
DAWSON ST
ALFRED ST
SHORT ST
LANG ST
GROGAN ST
ROSTHERNE AVE
MONASH PDE
N
Cadastre
Precinct
Sensitivity Analysis Points
Hydraulic Categorisation
Flood Fringe
Flood Storage
Floodway
0
50
100
Meters
J:Jobs\120021\ArcGIS\ArcMaps\Report\Figure13B_CanadaBay_Hydraulic_Categorisation_100yARI_KingsBay_Precinct.mxd

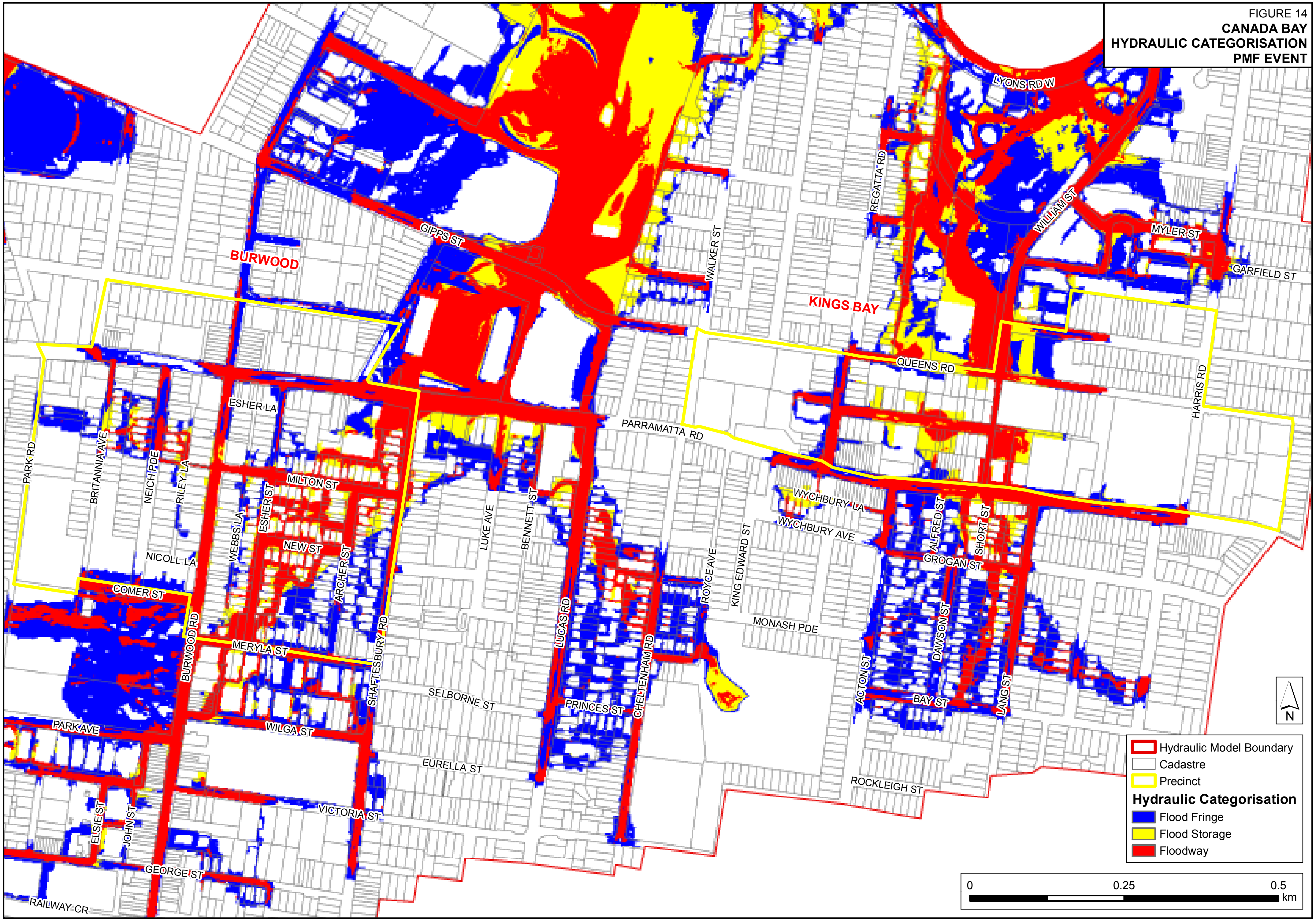


FIGURE 14
CANADA BAY
HYDRAULIC CATEGORISATION
PMF EVENT

J:\Jobs\120021\ArcGIS\ArcMaps\Report\Figure14_CanadaBay_Hydraulic_Categorisation_PMF.mxd

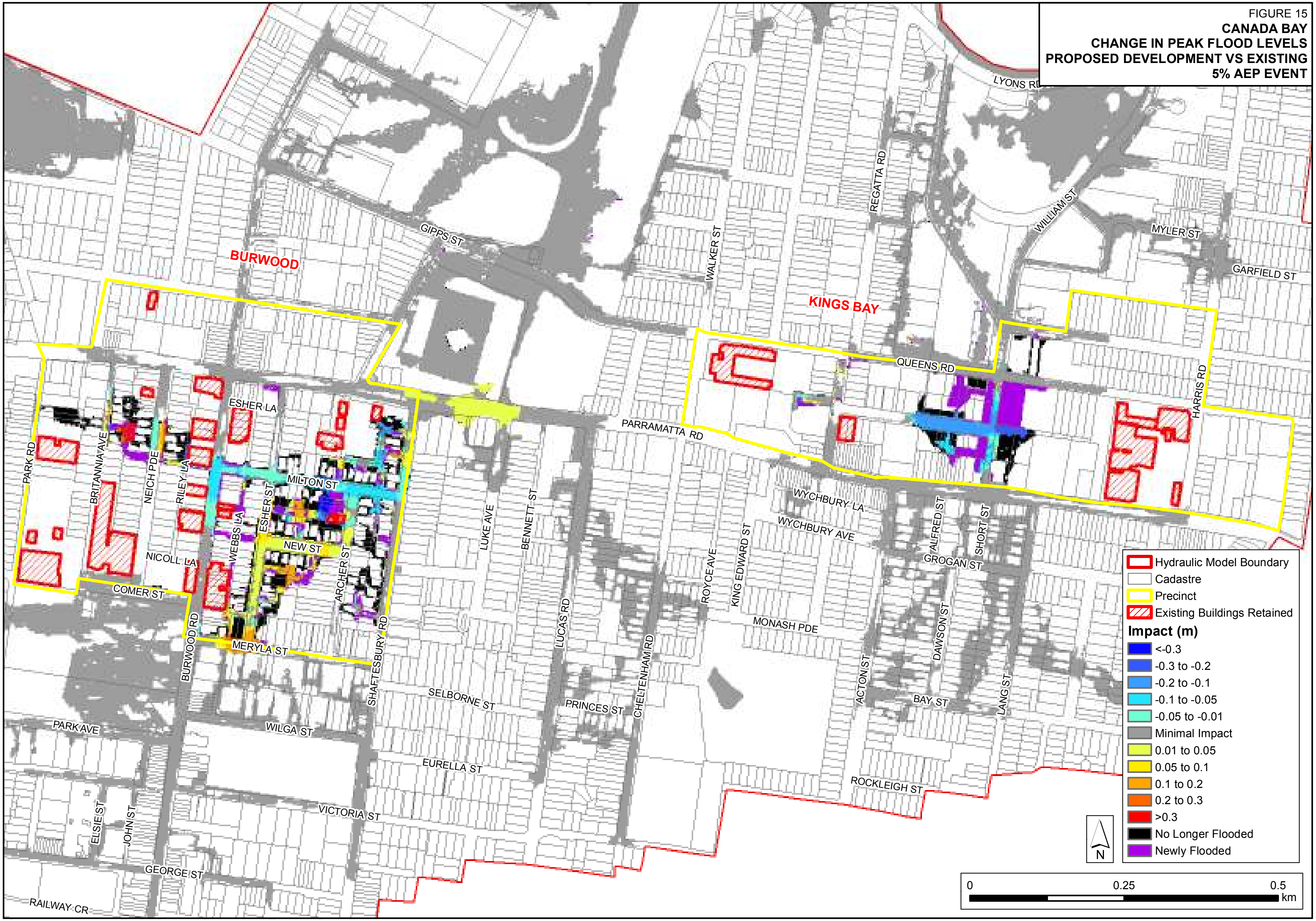


FIGURE 15
CANADA BAY
CHANGE IN PEAK FLOOD LEVELS
PROPOSED DEVELOPMENT VS EXISTING
5% AEP EVENT
BURWOOD
KINGS BAY
LYONS RD
GIPPS ST
REGATTA RD
WILLIAM ST
MYLER ST
GARFIELD ST
WALKER ST
QUEENS RD
HARRIS RD
PARRAMATTA RD
ESHER LA
MILTON ST
NEW ST
NICOLL LA
COMER ST
MERYLA ST
PARK RD
BRITANNIA AVE
NEICH PDE
RILEY LA
WEBBS LA
ESHER ST
ARCHER ST
SHAFTESBURY RD
BURWOOD RD
LUKE AVE
BENNETT ST
LUCAS RD
CHELTENHAM RD
ROYCE AVE
KING EDWARD ST
WYCHBURY LA
WYCHBURY AVE
ALFRED ST
SHORT ST
GROGAN ST
DAWSON ST
MONASH PDE
ACTON ST
BAY ST
LANG ST
SELBORNE ST
PRINCES ST
PARK AVE
WILGA ST
EURELLA ST
ROCKLEIGH ST
VICTORIA ST
ELSIE ST
JOHN ST
GEORGE ST
RAILWAY CR
Hydraulic Model Boundary
Cadastre
Precinct
Existing Buildings Retained
Impact (m)
<-0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
Minimal Impact
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
>0.3
No Longer Flooded
Newly Flooded
N
0
0.25
0.5
km
J:Jobs\120021\ArcGIS\ArcMaps\Report\Figure15_CanadaBay_Impact_Development_vs_Existing_020yARI.mxd

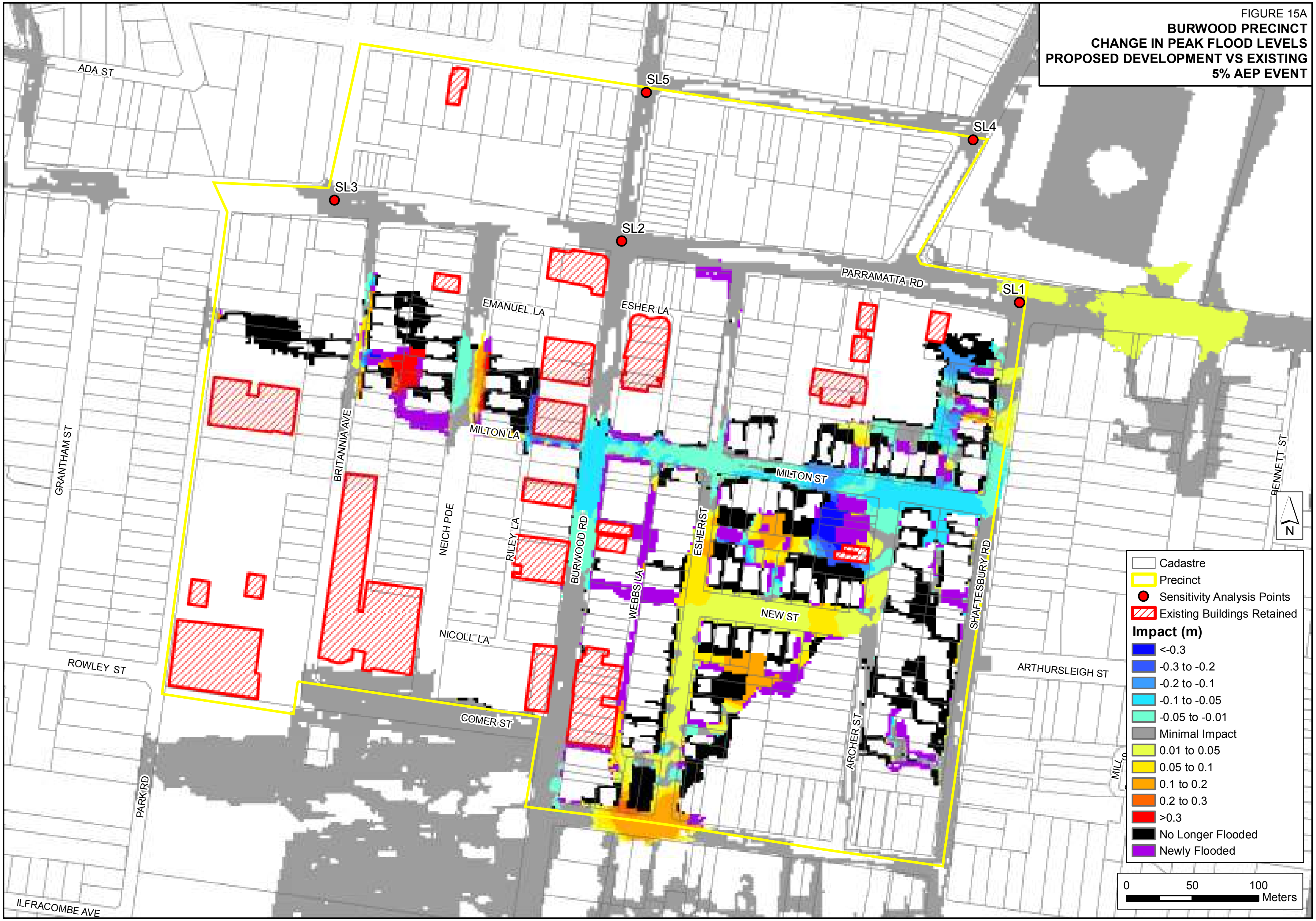


FIGURE 15A
BURWOOD PRECINCT
CHANGE IN PEAK FLOOD LEVELS
PROPOSED DEVELOPMENT VS EXISTING
5% AEP EVENT
ADA ST
SL5
SL4
SL3
SL2
SL1
PARRAMATTA RD
EMANUEL LA
ESHER LA
MILTON LA
MILTON ST
BRITANNIA AVE
GRANTHAM ST
NEICH PDE
RILEY LA
BURWOOD RD
WEBBS LA
ESHER ST
NEW ST
SHAFTESBURY RD
BENNETT ST
ARTHURSLEIGH ST
ARCHER ST
NICOLL LA
ROWLEY ST
COMER ST
PARK RD
ILFRACOMBE AVE
N
Cadastre
Precinct
Sensitivity Analysis Points
Existing Buildings Retained
Impact (m)
<-0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
Minimal Impact
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
>0.3
No Longer Flooded
Newly Flooded
0
50
100
Meters
J:Jobs\120021\ArcGIS\ArcMaps\Report\Figure15A_CanadaBay_Impact_Development_020yARI_Burwood_Precinct.mxd

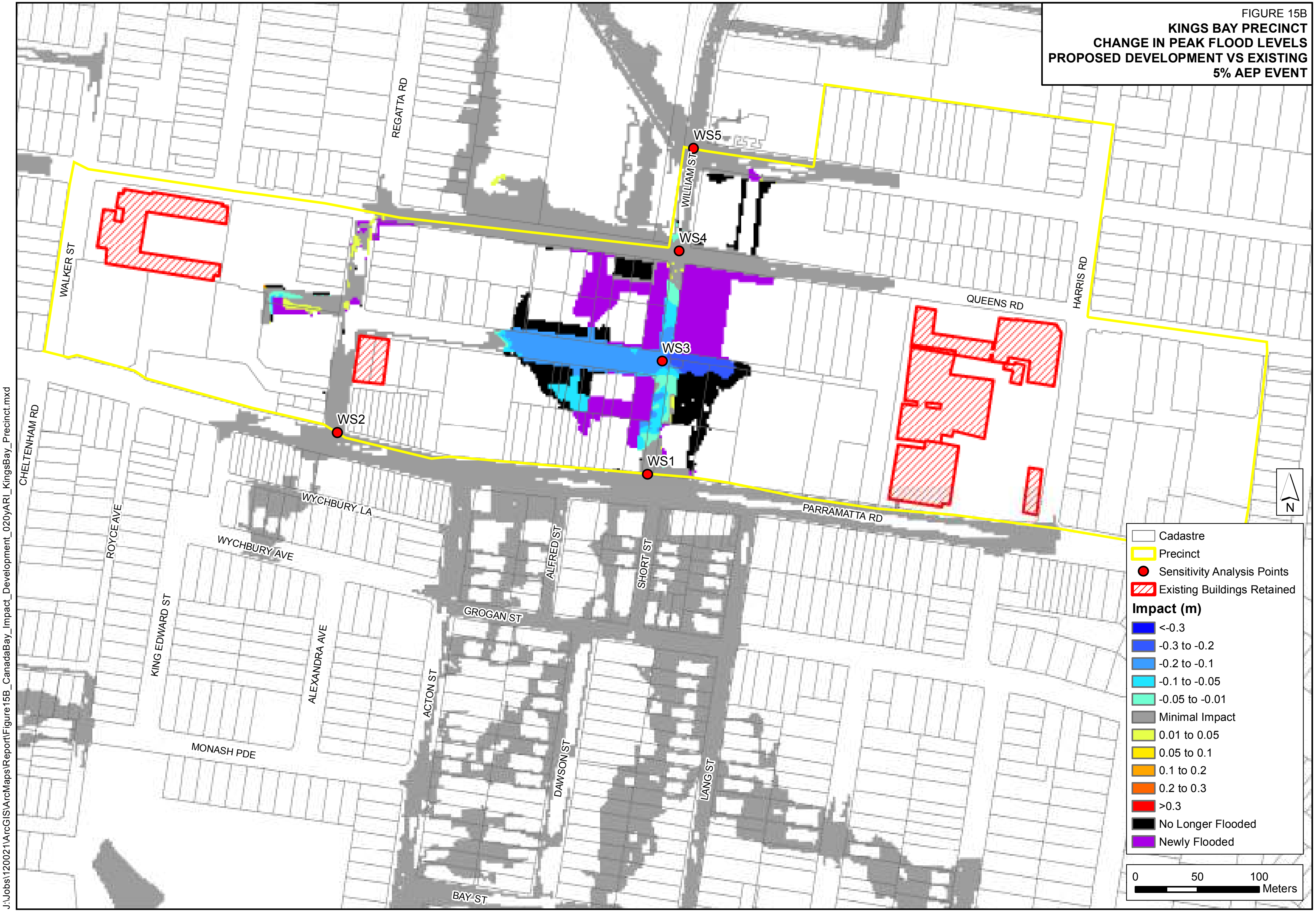


FIGURE 15B
KINGS BAY PRECINCT
CHANGE IN PEAK FLOOD LEVELS
PROPOSED DEVELOPMENT VS EXISTING
5% AEP EVENT
REGATTA RD
WS5
WILLIAM ST
WS4
WALKER ST
QUEENS RD
HARRIS RD
WS3
WS2
WS1
CHELTENHAM RD
WYCHBURY LA
PARRAMATTA RD
WYCHBURY AVE
ROYCE AVE
ALFRED ST
SHORT ST
KING EDWARD ST
GROGAN ST
ALEXANDRA AVE
ACTON ST
MONASH PDE
DAWSON ST
LANG ST
BAY ST
N
Cadastre
Precinct
Sensitivity Analysis Points
Existing Buildings Retained
Impact (m)
<-0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
Minimal Impact
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
>0.3
No Longer Flooded
Newly Flooded
0
50
100
Meters
J:\Jobs\120021\ArcGIS\ArcMaps\Report\Figure15B_CanadaBay_Impact_Development_020yARI_KingsBay_Precinct.mxd

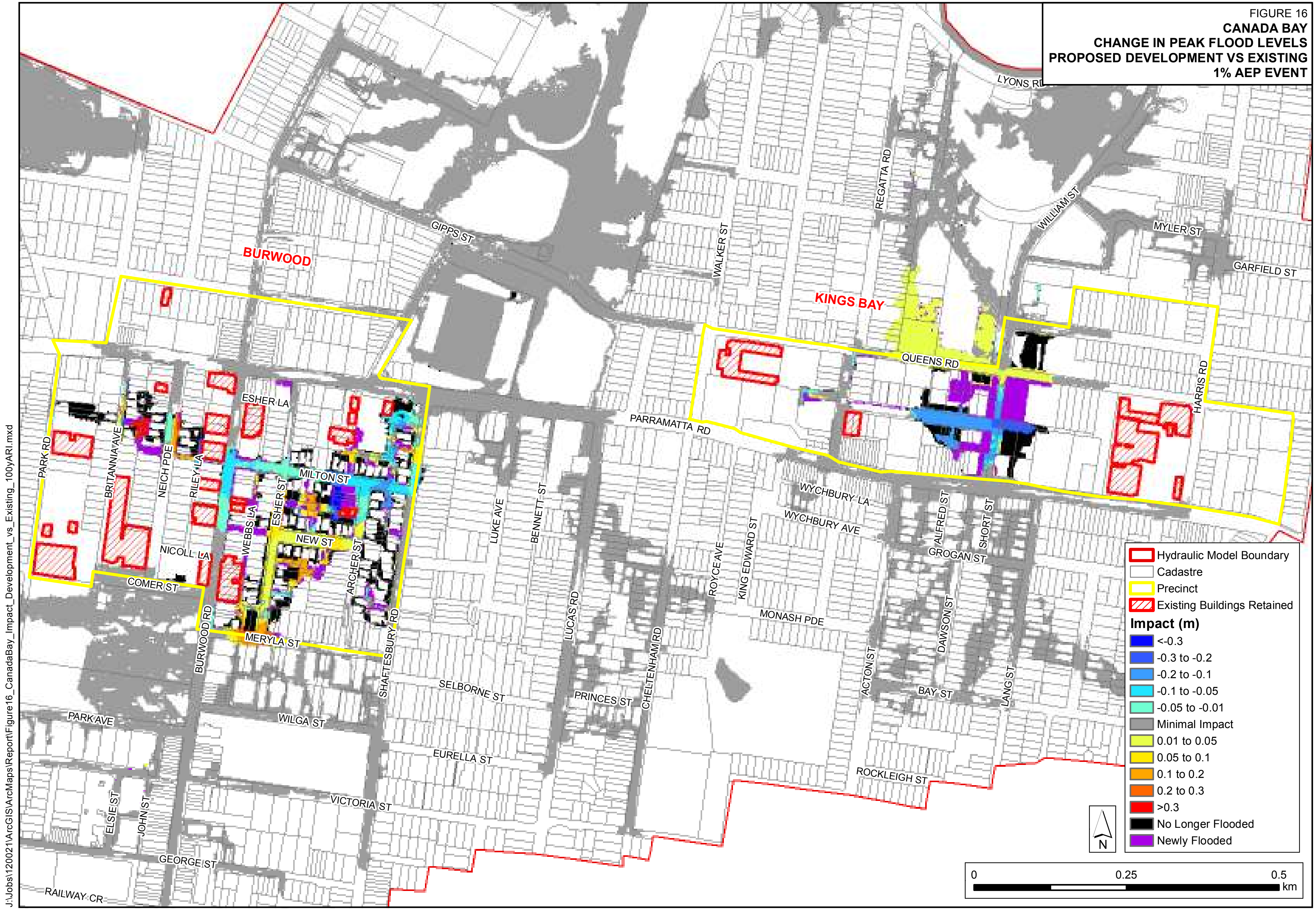


FIGURE 16
CANADA BAY
CHANGE IN PEAK FLOOD LEVELS
PROPOSED DEVELOPMENT VS EXISTING
1% AEP EVENT
BURWOOD
KINGS BAY
LYONS RD
REGATTA RD
WILLIAM ST
MYLER ST
GARFIELD ST
GIPPS ST
WALKER ST
QUEENS RD
HARRIS RD
PARRAMATTA RD
ESHER LA
PARK RD
BRITANNIA AVE
NEICH PDE
RILEY LA
MILTON ST
ESHER ST
WEBBS LA
NEW ST
ARCHER ST
NICOLL LA
COMER ST
BURWOOD RD
MERYLA ST
SHAFTESBURY RD
LUKE AVE
BENNETT ST
WYCHBURY LA
WYCHBURY AVE
ALFRED ST
SHORT ST
GROGAN ST
ROYCE AVE
KING EDWARD ST
MONASH PDE
DAWSON ST
LUCAS RD
CHELTENHAM RD
ACTON ST
BAY ST
LANG ST
SELBORNE ST
PRINCES ST
PARK AVE
WILGA ST
EURELLA ST
ROCKLEIGH ST
VICTORIA ST
ELSIE ST
JOHN ST
GEORGE ST
RAILWAY CR
Hydraulic Model Boundary
Cadastre
Precinct
Existing Buildings Retained
Impact (m)
<-0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
Minimal Impact
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
>0.3
No Longer Flooded
Newly Flooded
N
0
0.25
0.5
km
J:\Jobs\120021\ArcGIS\ArcMaps\Report\Figure16_CanadaBay_Impact_Development_vs_Existing_100yARI.mxd

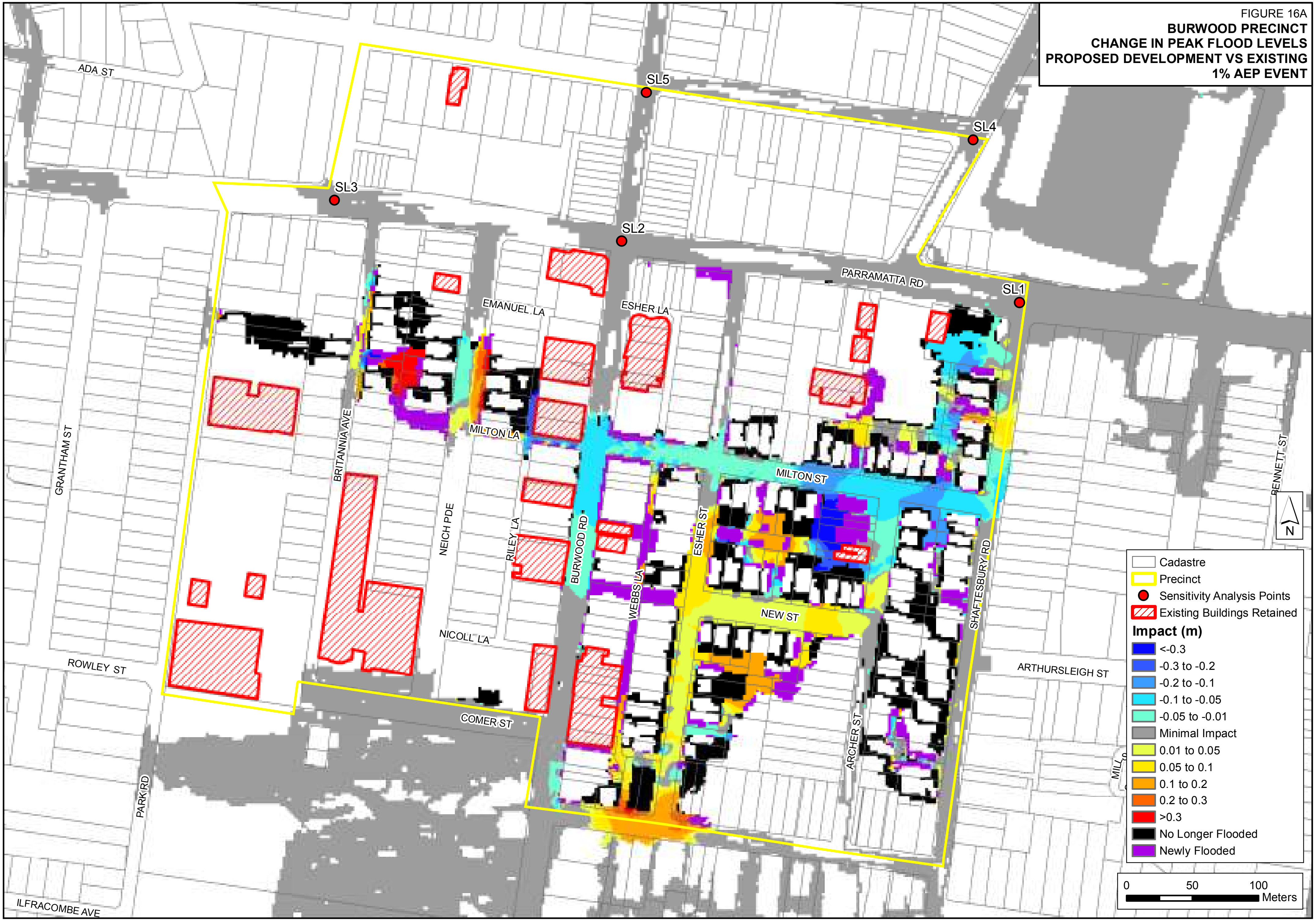


FIGURE 16A
BURWOOD PRECINCT
CHANGE IN PEAK FLOOD LEVELS
PROPOSED DEVELOPMENT VS EXISTING
1% AEP EVENT
ADA ST
SL5
SL4
SL3
SL2
SL1
PARRAMATTA RD
EMANUEL LA
ESHER LA
MILTON LA
MILTON ST
BRITANNIA AVE
GRANTHAM ST
NEICH PDE
RILEY LA
BURWOOD RD
WEBBS LA
ESHER ST
NEW ST
SHAFTESBURY RD
ARCHER ST
NICOLL LA
ROWLEY ST
COMER ST
ARTHURSLEIGH ST
BENNETT ST
PARK RD
ILFRACOMBE AVE
N
Cadastre
Precinct
Sensitivity Analysis Points
Existing Buildings Retained
Impact (m)
<-0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
Minimal Impact
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
>0.3
No Longer Flooded
Newly Flooded
0
50
100
Meters
J:Jobs\120021\ArcGIS\ArcMaps\Report\Figure16A_CanadaBay_Impact_Development_100yARI_Burwood_Precinct.mxd

FIGURE 16B
KINGS BAY PRECINCT
CHANGE IN PEAK FLOOD LEVELS
PROPOSED DEVELOPMENT VS EXISTING
1% AEP EVENT

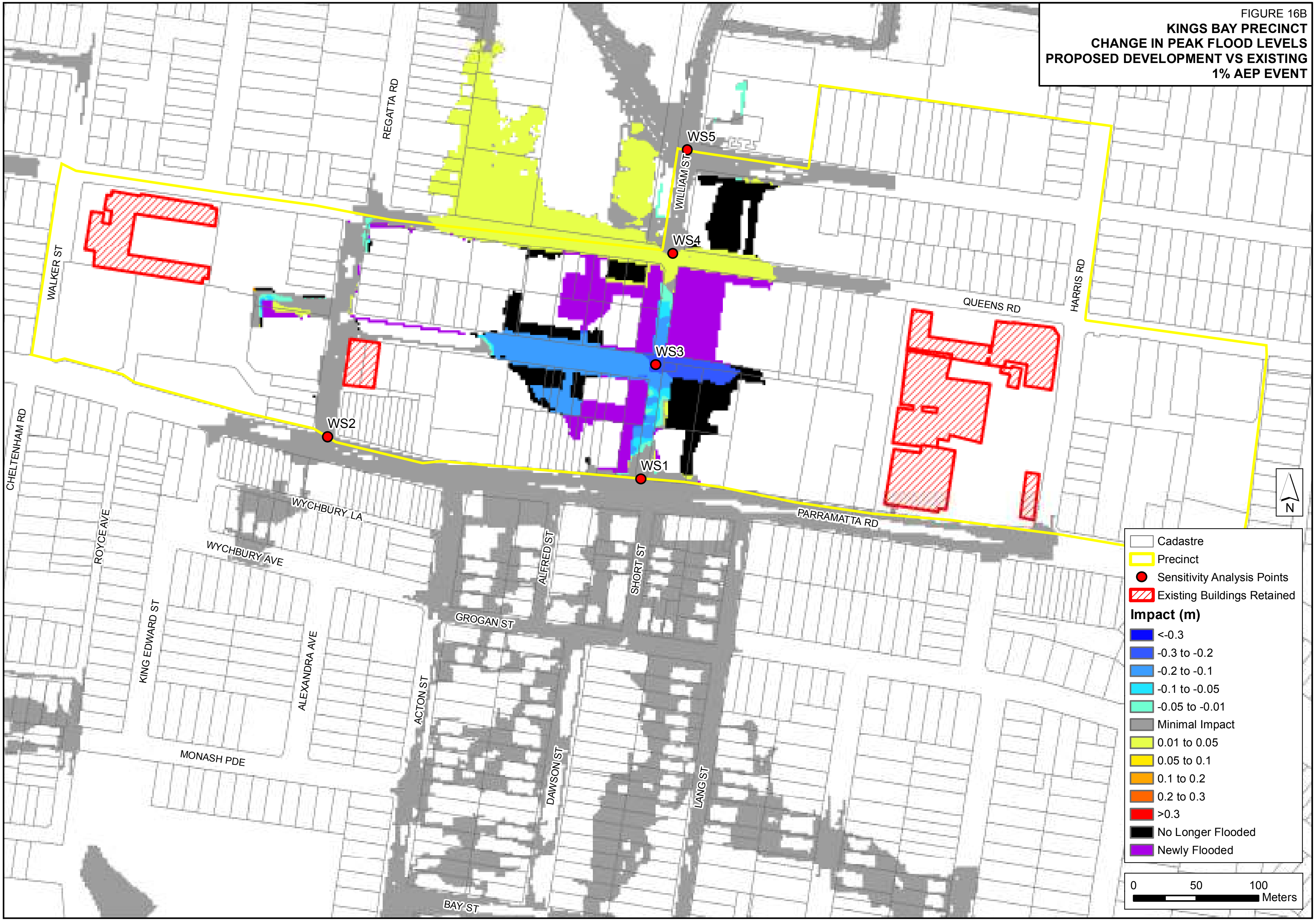


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FIGURE 17
CANADA BAY
CHANGE IN PEAK FLOOD LEVELS
PROPOSED DEVELOPMENT VS EXISTING
PMF EVENT

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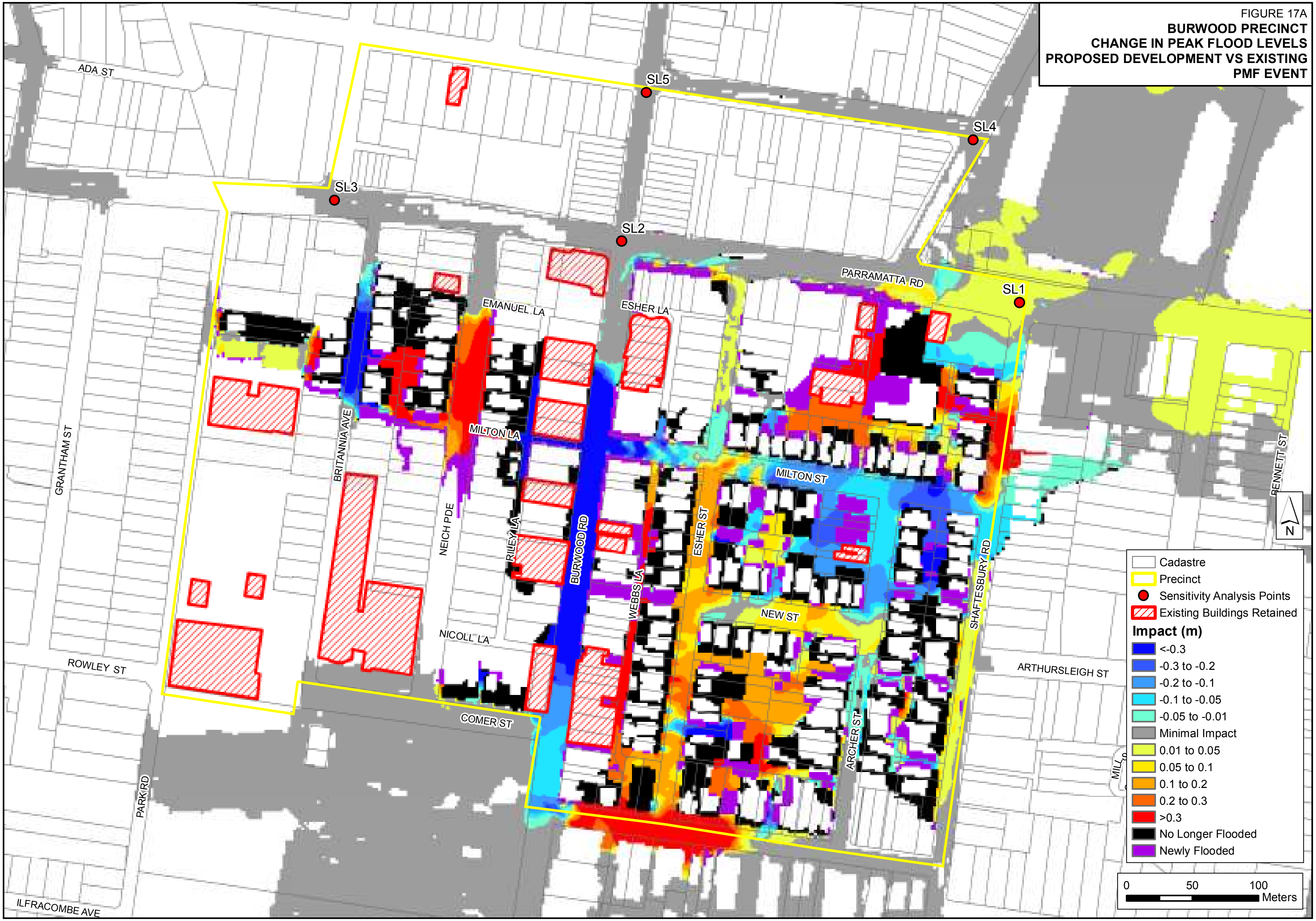

J:\Jobs\120021\ArcGIS\ArcMaps\Report\Figure17A_CanadaBay_Impact_Development_PMF_Burwood_Precinct.mxd

FIGURE 17B
KINGS BAY PRECINCT
CHANGE IN PEAK FLOOD LEVELS
PROPOSED DEVELOPMENT VS EXISTING
PMF EVENT

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High Flood Risk Precinct = Land within the 1% AEP Hazard categories H4, H5 and H6
Medium Flood Risk Precinct = Remaining land within the 1% AEP extent and not in the High Flood Risk precinct
Low Flood Risk Precinct = All land outside the 1% AEP and within the PMF extent

Note: Evacuation difficulties have not been considered in the above assessment.

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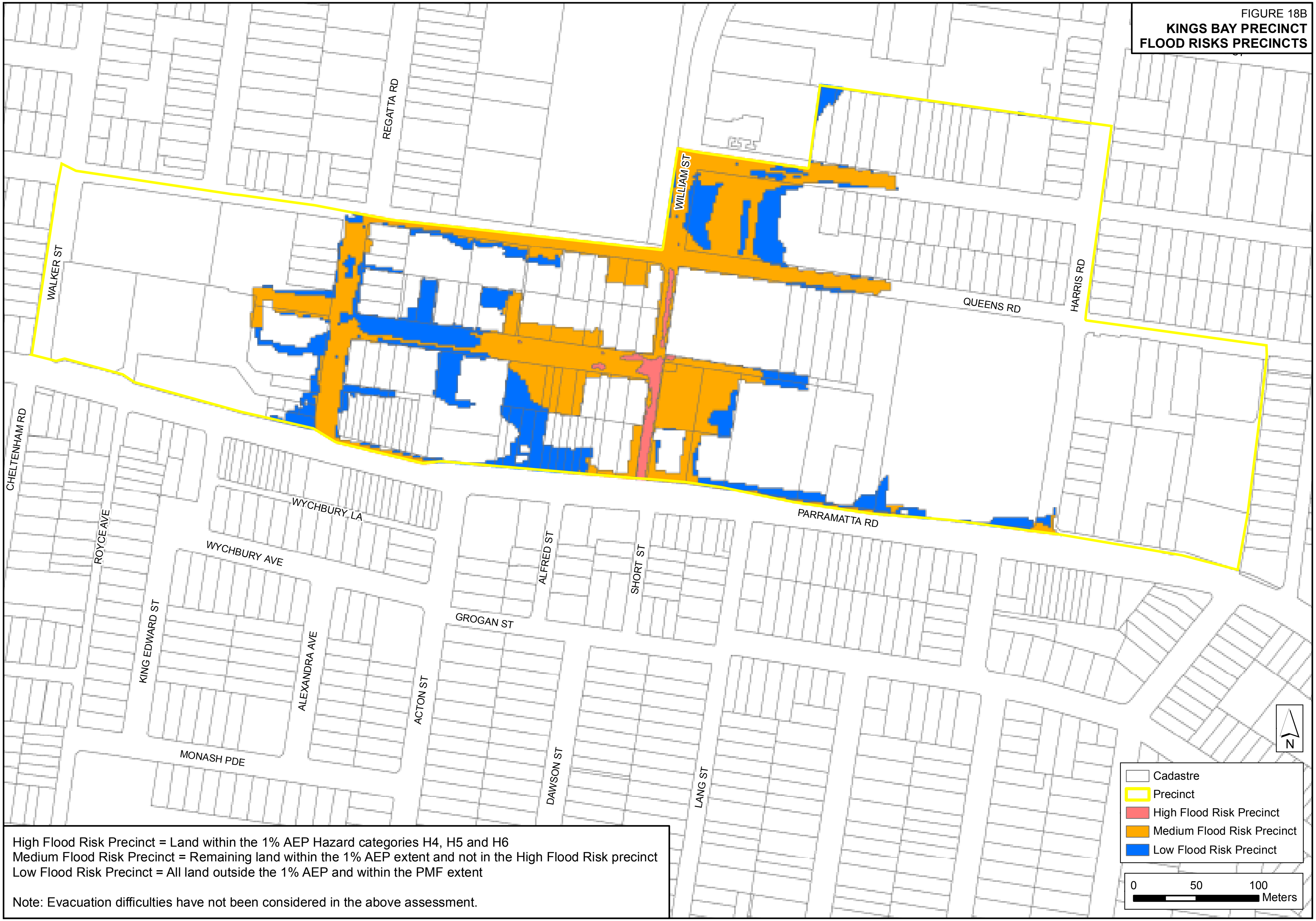
FIGURE 18B
KINGS BAY PRECINCT
FLOOD RISKS PRECINCTS



High Flood Risk Precinct = Land within the 1% AEP Hazard categories H4, H5 and H6
Medium Flood Risk Precinct = Remaining land within the 1% AEP extent and not in the High Flood Risk precinct
Low Flood Risk Precinct = All land outside the 1% AEP and within the PMF extent

Note: Evacuation difficulties have not been considered in the above assessment.

J:\Jobs\120021\ArcGIS\ArcMaps\Report\Figure18B_CanadaBay_Flood_Risk_Precincts_KingsBay_Precinct.mxd

FIGURE 19A
KINGS BAY PRECINCT
CHANGE IN PEAK FLOOD LEVELS
AMENDED DEVELOPMENT VS EXISTING
1% AEP EVENT

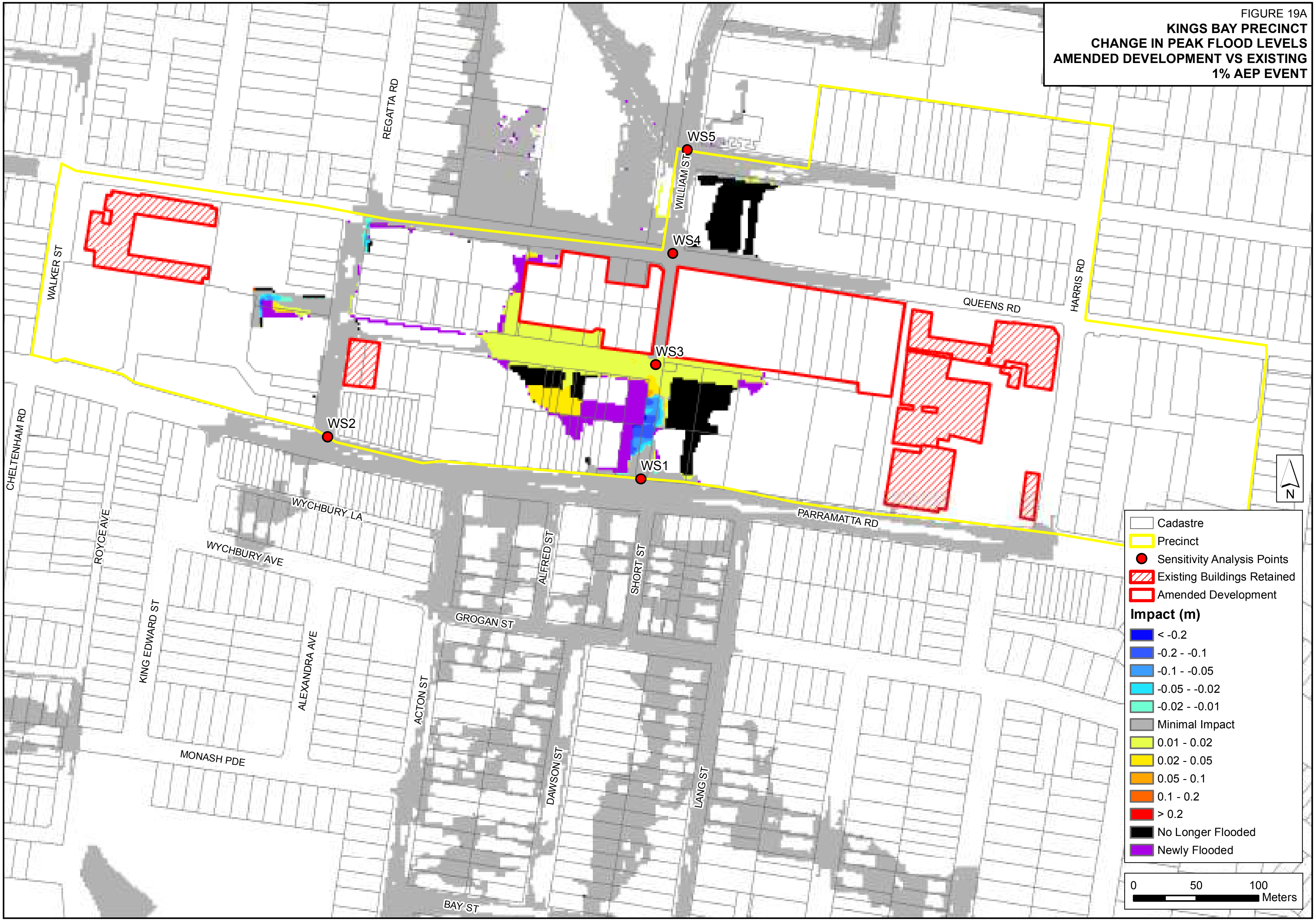


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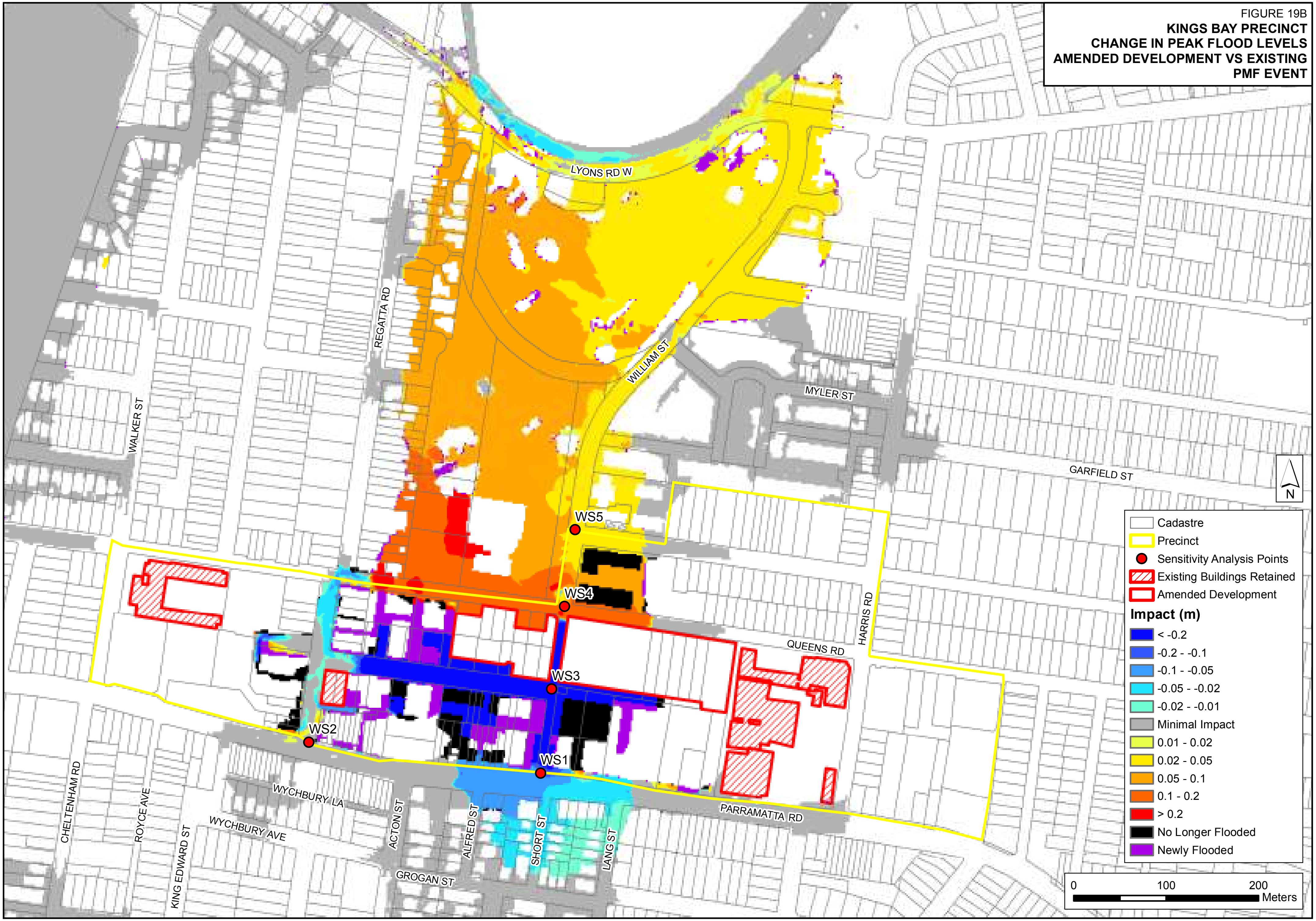
FIGURE 19B
KINGS BAY PRECINCT
CHANGE IN PEAK FLOOD LEVELS
AMENDED DEVELOPMENT VS EXISTING
PMF EVENT



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Appendix A: Glossary of Terms

Appendix A

APPENDIX A: GLOSSARY

Taken from the Floodplain Development Manual (April 2005 edition)

acid sulfate soils	Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	The Council, Government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. **new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. **redevelopment:** refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.
disaster plan (DISPLAN)	A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.

discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
ecologically sustainable development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual relate to ESD.
effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves and their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
flood liable land	Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).
flood mitigation standard	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.

flood planning area	The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the flood liable land concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPLs are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the standard flood event in the 1986 manual.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
flood readiness	Flood readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. **existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain. **future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain. **continuing flood risk:** the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.
freeboard	Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
habitable room	**in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. **in an industrial or commercial situation:** an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.

hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
major drainage	Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves: • the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or • water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or • major overland flow paths through developed areas outside of defined drainage reserves; and/or • the potential to affect a number of buildings along the major flow path.
mathematical/computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
merit approach	The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains. The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.
minor, moderate and major flooding	Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood: **minor flooding:** causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded. **moderate flooding:** low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered. **major flooding:** appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.

modification measures	Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.
peak discharge	The maximum discharge occurring during a flood event.
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
probability	A statistical measure of the expected chance of flooding (see AEP).
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	Equivalent to water level. Both are measured with reference to a specified datum.
stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	A plan prepared by a registered surveyor.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	The horizontal distance in the direction of wind over which wind waves are generated.

Appendix B: City of Sydney Interim Floodplain Management Policy

Appendix B

Interim Floodplain Management Policy

Purpose

The Floodplain Management Policy provides direction with respect to how floodplains are managed within the Local Government Area (LGA) of the City of Sydney Council (the City).

The City 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.

The Policy provides controls to facilitate a consistent, technically sound and best practice approach for the management of flood risk within the City's LGA. In forthcoming years the City will complete Floodplain Risk Management Plans and then integrate outcomes from these plans into planning controls. Once this process is completed this interim policy will be withdrawn.

Scope

This Policy applies to all new developments within the City of Sydney.

Definitions

Term	Meaning
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. 1% AEP flood is approximately equal to 1 in 100 year Average Recurrent Interval (ARI) flood event (or simply 100 year flood). It has 1% chance to occur in a given year.
Australian Height Datum (AHD)	A common national plan of level corresponding approximately to mean sea level.
Average Recurrence Interval (ARI)	The long-term average number of years between the occurrence of a flood as big as or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event may occur on average once every 20 years.

Term	Meaning
Basement Car Parking or Below-Ground Car Parking	The car parking area generally below ground level where inundation of the surrounding areas may raise water levels above the entry level to the basement, resulting in inundation. Basement car parks are areas where the means of drainage of accumulated water in the car park has an outflow discharge capacity significantly less than the potential inflow capacity.
Below-Ground Garage/Car park	Applies where the floor of the parking and/or access surface is more than 1 m below the surrounding natural ground.)
Carport	A structure used to house motor vehicles, which has a minimum of two sides "open" and not less than one third of its perimeter "open".
Critical Facilities	Includes hospitals and ancillary services, communication centres, police, fire SES, major transport facilities, sewerage and electricity plants; any installations containing critical infrastructure control equipment and any operational centres for use in a flood.
Effective Warning Time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to raise furniture, evacuate people and transport their possessions.
Evacuation	The transfer of people and or stock from areas where flooding is likely, either close to, or during a flood event. It is affected not only by warning time available, but also the suitability of the road network, available infrastructure, and the number of people that have to evacuate during floods.
Extreme Flood	An estimate of the probable maximum flood (PMF), which is the largest flood that could conceivably occur at a particular location, generally estimated from the probable maximum precipitation (PMP). Generally it is not physically or economically possible to provide complete protection against this event.
Flood	A relatively high stream flow that overtops the natural or artificial banks in any part of a stream, channel, river, estuary, lake or dam, and/or local overland flooding associated with major drainage as defined by the NSW Floodplain Development Manual (FDM) before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
Flood Compatible Materials	Those materials used in building which are resistant to damage when inundated. A list of flood compatible materials is attached.
Flood Evacuation Strategy	The proposed strategy for the evacuation of areas with effective warning time during periods of flood as specified within any policy of Council, the floodplain risk management plan (FRMP), the relevant state government disaster plan, by advices received from the State Emergency Services (SES) or as determined in the assessment of individual proposals.
Floodplain	The area of land which is subject to inundation by floods up to and including the probable maximum flood (PMF) event.

Term	Meaning
Floodplain Development Manual (FDM)	The document dated April 2005, published by the New South Wales Government and entitled 'Floodplain Development Manual: the management of flood liable land'.
Flood Planning Area	The area of land below the FPL and thus subject to flood related development controls.
Flood Planning Level (FPL)	The combinations of flood levels and freeboards selected for floodplain risk management purposes, as determined in flood studies and floodplain risk management studies and plans.
Floodplain Risk Management Plan (FRMP)	A plan prepared for one or more floodplains in accordance with the requirements of the FDM or its predecessor.
Floodplain Risk Management Study (FRMS)	A study prepared for one or more floodplains in accordance with the requirements of the FDM or its predecessor.
Flood Storage	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Floodway	Those areas, often aligned with obvious naturally defined channels, where a significant discharge of water occurs during floods. They are also areas where, if only partially blocked, will cause a significant redistribution of flood flow or significant increase in flood levels, which many impact on other properties.
Freeboard	A factor of safety expressed as the height above the design flood level. Freeboard provides a factor of safety to compensate for uncertainties in the estimation of flood levels across the floodplain, such as wave action; localised hydraulic behaviour and impacts that are specific event related, such as levee and embankment settlement; cumulative impacts of fill in floodplains and other effects such as changes in rainfall patterns as a result of climate change.
Garage	A private building or part of a building used to park or keep a motor vehicle and that is not defined as a carport.
Habitable Floor Area	• in a residential situation: a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom; • in an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
Hazardous Materials	Solids, liquids, or gases that can harm people, other living organisms, property, or the environment. These may include materials that are radioactive, flammable, explosive, corrosive, oxidizing, asphyxiating, bio-hazardous, toxic, pathogenic, or allergenic. Also included are physical conditions such as compressed gases and liquids or hot materials, including all goods containing such materials or chemicals, or may have other characteristics that render them hazardous in specific circumstances.
Large Scale Development	For the purposes of this document refers to a proposal that involves site disturbance 1000m2 of land or greater.
Local Overland Flow Path	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.

Term	Meaning
Probable Maximum Flood (PMF)	The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation.
Probable Maximum Precipitation (PMP)	The greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to the estimation of the probable maximum flood.
Reliable Access During A Flood	The ability for people to safely evacuate an area subject to imminent flooding within effective warning time, having regard to the depth and velocity of flood waters, the suitability of the evacuation route, and without a need to travel through areas where flood hazard increases
Section 149 Planning Certificate	Information, including the statutory planning controls that apply to a parcel of land on the date the certificate is issued.
Shed	Includes machinery sheds, garden and storage sheds but does not include a garage or car park.
Suitably Qualified Engineer	An engineer who is included in the National Professional Engineers Register, administered by the Institution of Engineers Australia.
Survey plan	A plan prepared by a Registered Surveyor which shows the information required for the assessment of an application in accordance with the provisions of this Policy.

Policy statement

1 Introduction

The Policy has been prepared in accordance with the guidelines provided in the NSW Government Floodplain Development Manual (2005) (FDM). This manual guides Council in the development and implementation of local Floodplain Risk Management Plans to produce robust and effective floodplain risk management outcomes.

In accordance with the FDM, the Flood Risk Management Process entails four sequential stages:

- Stage 1:Flood Study
- Stage 2:Floodplain Risk Management Study
- Stage 3:Floodplain Risk Management Plan
- Stage 4:Implementation of the Plan

The City is progressively producing Floodplain Risk Management Plans for each of the individual drainage catchments within the City's LGA. Floodplain Risk Management Plans consider the existing flood environment and recommend specific measures to manage the impact of flooding. In assessing the flood environment, elements such as known flood behaviour, evacuation issues, site access and the potential impact of sea level rise are taken into consideration. This information is used to create floodplain risk mapping for each catchment.

Floodplain Risk Management Plans provide a range of measures that can be used to mitigate the impact of flooding. Invariably one of the most successful measures is the implementation of effective land use planning. This document provides the means for implementing the Floodplain Risk Management Plans and associated mapping for the control of development on the floodplain within the City.

1.1 Aims and Objectives of the Policy

- To inform the community of the City's Policy with regard to the use of flood prone land;
- To establish guidelines for the development of flood prone land that are consistent with the NSW Flood Policy and NSW Floodplain Development Manual (2005) as updated by the Floodplain Management Guides;
- To control development and activity within each of the individual floodplains within the City having regard to the characteristics and level of information available for each of the floodplains;
- To minimise the risk to human life and damage to property by controlling development on flood prone land;
- To apply a merit based approach to all development decisions taking into account ecological, social and environmental considerations;
- To ensure that the development or use of floodplains does not adversely impact upon the aesthetic, recreational and ecological values of the waterway corridors;
- To ensure that all land uses and essential services are appropriately sited and designed in recognition of all potential floods;
- To ensure that all development on the floodplain complies with Ecologically Sustainable Development (ESD) principles and guidelines; and
- To promote building design that considers requirements for the development of flood prone land and to ensure that the development of flood prone land does not have significant impacts upon the amenity of an area.

1.2 Background

This Policy has been prepared having regard to the provisions of the NSW Flood Policy and NSW Floodplain Development Manual (2005).

Sydney Local Environmental Plan 2012 (Sydney LEP 2012) requires the consent authority to be satisfied that all new development adequately protects the safety of property and life, and avoid significant adverse impacts on flood behaviour and the environment. Specified flood planning controls apply to all land which is at or below the flood planning level. The requirements set out in Sydney LEP 2012 must be met before development consent is granted.

This Policy is to be read in conjunction with the provisions of Sydney LEP 2012 and Sydney DCP 2012.

1.3 Relationship to other Policies

This Policy is to be read in conjunction with Sydney LEP 2012 and Sydney DCP 2012. It includes but is not limited to the development types listed below:

- Single dwellings, terraces, and dual occupancy buildings;
- Residential flat, commercial and mixed use developments;
- Industrial developments; and
- Other development types and uses, as detailed in the Sydney DCP 2012.

In conjunction with the development type requirements, the Sydney LEP 2012 and Sydney DCP 2012 also require:

- Sustainable water use practices;
- The reduction of stormwater pollution on receiving waterways; and
- That development does not exacerbate the potential for flood damage or hazard for existing development or public domain.

1.4 Application of Policy

The policy is written in an objectives/requirements format. Where an applicant seeks variation from the requirements, appropriate written justification indicating how the proposal meets the relevant objectives, must be provided for the consideration of Council.

2 Application Requirements

2.1 Required Information

Applications must include information that addresses all relevant controls listed within this document and the following matters as applicable:

a Development applications affected by this Policy shall be accompanied by a survey plan showing:

- i the position of the existing building/s or proposed building/s;
- ii the existing ground levels and features to Australian Height Datum around the perimeter of the site and contours of the site; and
- iii the existing or proposed floor levels to Australian Height Datum.

b Applications for earthworks, filling of land, infrastructure and subdivision shall be accompanied by a survey plan (with a minimum contour interval of 0.25m) showing relative levels to Australian Height Datum.

c For large scale developments, or developments that in the opinion of the City are in critical situations, where an existing catchment based flood study is not available, a flood assessment report prepared by a suitably qualified engineer using a hydrologic and hydraulic dynamic one or two dimensional computer model.

d Where the controls for a particular development proposal require an assessment of structural soundness during potential floods, the following impacts must be addressed:

- iv hydrostatic pressure;
- v hydrodynamic pressure;
- vi impact of debris; and
- vii buoyancy forces.

Foundations need to be included in the structural analysis. Scour protection may be required at foundations.

3 Development Provisions

The Department of Planning and Infrastructure has produced a group of Model Local Provisions for inclusion in Local Environmental Plans. The Model Local Provisions have been produced to address common topics raised by Councils in Local Environmental Plan preparation and provide them with guidance in what is to be considered in the assessment of development proposals. The Model Clause for Flood Planning has been adopted as clause 7.15 in Sydney LEP 2012. The Performance Criteria listed under Section 3.2 below reflects the considerations specified in Sydney LEP 2012.

Sydney DCP 2012 provides prescriptive planning controls in Section 3.7. The objectives of these planning controls are to:

- Ensure an integrated approach to water management across the City through the use of water sensitive urban design principles.
- Encourage sustainable water use practices.
- Assist in the management of stormwater to minimise flooding and reduce the effects of stormwater pollution on receiving waterways.
- Ensure that development manages and mitigates flood risk, and does not exacerbate the potential for flood damage or hazard to existing development and to the public domain.
- Ensure that development above the flood planning level as defined in the Sydney LEP 2012 will minimise the impact of stormwater and flooding on other developments and the public domain both during the event and after the event.

Note: A number of flood studies and associated flood risk management plans are currently under development. New development will be required to conform to the requirements of these flood studies and associated flood risk management plans once endorsed by Council.

3.1 Performance Criteria

If a proposal does not meet the requirements of the relevant Prescriptive Provisions, consent must not be granted to development unless the consent authority is satisfied with the following the provision and assessment of information relating to the development. The development:

a is compatible with the established flood hazard of the land. In areas where flood hazard has not been established through previous studies or reports, the flood hazard must be established in accordance with the Floodplain Development Manual considering the following:
- i Impact of flooding and flood liability is to be managed ensuring the development does not divert floodwaters or interfere with flood storage or the natural function of the waterway;
- ii Flood behaviour (for example, flood depths reached, flood flow velocities, flood hazard, rate of rise of floodwater);
- iii Duration of flooding for a full range of events;
- iv Appropriate flood mitigation works;
- v Freeboard;
- vi Council's duty of care – Proposals to address or limit; and
- vii Depth and velocity of flood waters for relevant flood events.

b will not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties;

c incorporates appropriate measures to manage risk to life from flood considering the followings:
- i The proposed development should not result in any increased risk to human life
- ii Controls for risk to life for floods up to the Flood Planning Level
- iii Controls for risk to life for floods greater than the Flood Planning Level

iv Existing floor levels of development in relation to the Flood Planning Level and floods greater than the Flood Planning level

v Council's duty of care – Proposals to address and limit

vi What level of flooding should apply to the development e.g. 1 in 100 year, etc

vii Effective flood access and evacuation issues

viii Flood readiness – Methods to ensure relative flood information is available to current and future occupants and visitors;

d will not significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of creek or channel banks or watercourses;

e is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding;

f is consistent with the principles of Ecologically Sustainable Development; and

g adequately considers the impact of climate change.

It is to be noted that with regard to climate change, appropriate benchmarks based on the best available current information have been used in producing the flood risk management plans that inform this document.

Some prescriptive requirements such as flood planning level requirements may be relaxed if Council can be satisfied that the projected life of the proposed development is for a relatively short-term and therefore does not warrant the imposition of controls that consider impacts beyond the cessation of the proposed development. This will only be considered for uses where the residual risk to the occupation of the development is considered to be low. This may include certain temporary or demountable structures but would not include residential developments.

3.2 Concessional Development – Minor Additions

a. The City acknowledges that in some instances, relatively minor building additions will have minimal impact on the floodplain and will not present an unmanageable risk to life. Council will give consideration for the following forms of development on suitable sites:

i attached dwelling additions of up to 40m^2 of habitable floor area at or above the same level as the existing adjoining approved floor level for habitable floor area. The allowance for additions shall be made no more than once for any given development;

ii additions to Commercial and Industrial Uses of up to an additional 100 m^2 or 20% (whichever the less) of the Gross Floor Area of the existing building at no less than the same level as the existing adjoining approved floor level. The allowance for additions shall be made no more than once for any given development.

b. As part of any consent issued pursuant to this section Council will require:

i a restriction on the property title requiring compliance with the flood studies and associated flood risk management plans.

ii the existing development is to be suitably upgraded to address the potential impacts of flooding.

3.3 Heritage Considerations

The City acknowledges that certain buildings or structures require preservation due to their heritage significance. Developments with heritage significance can be assessed on a merit based approach provided the following requirements are satisfied:

i. Expert assessment has identified the structure or development as having heritage conservation value;

ii. Planning instruments have specifically identified the existing developmentas having heritage conservation value and provide the appropriate level of statutory protection;
iii. The highest practical level of flood protection is provided while maintaining an appropriate balance with heritage conservation;
iv. The proposed development will not be subject to frequent flooding risk that may jeopardise the long term viability or heritage conservation of the development. Comprehensive assessment would be required where the development is subject to flooding in storms more frequent than the 5% AEP flood;
v. A restriction shall be placed on the property title, identifying the flooding risk and requiring conservation of heritage values.

4 General Requirements

The following ancillary development issues are to be considered in the assessment of proposed development of flood prone land.

Development Type/ Aspect	Objective	Requirement
Fencing	• To ensure that fencing does not result in any significant obstruction to the free flow of floodwaters; and • To ensure that fencing will remain safe during floods and not become moving debris that potentially threatens the security of structures or the safety of people.	Fencing is to be designed and constructed in such a manner that it will not modify the flow of floodwaters and cause damage to surrounding land.
Residential Properties	• To minimise the damage to residential properties from flooding; and • To minimise risk to human life from the inundation of residential properties and to minimise economic cost to the community resulting from flooding.	• The proposed residential building or dwelling must be free from flooding up to and including the 1% AEP flood and must meet the Flood Planning Level Requirements detailed in Section 5; and • The proposed residential building or dwelling should not increase the likelihood of flooding on other developments, properties or infrastructure.
Industrial and Commercial Properties	• To minimise the damage to industrial and commercial properties from flooding; and • To minimise risk to human life from the inundation of industrial and commercial properties and to minimise economic cost to the community resulting from flooding.	• The City may consider merits-based approaches presented by the applicant. The proposed industrial or commercial buildings must meet the Flood Planning Level Requirements detailed in Section 5; and • The proposed industrial or commercial development should not increase the likelihood of flooding on other developments, properties or infrastructure.

Development Type/ Aspect	Objective	Requirement
Car Parking	• To minimise the damage to motor vehicles from flooding; • To ensure that motor vehicles do not become moving debris during floods, which threaten the integrity or blockage of structures or the safety of people, or damage other property; and • To minimise risk to human life from the inundation of basement and other car park or driveway areas.	• The proposed car park should not increase the risk of vehicle damage by flooding inundation; • The proposed garage or car park should not increase the likelihood of flooding on other developments, properties or infrastructure; • The proposed garage or car park must meet the Flood Planning Level Requirements detailed in *Section 5*; and • Open car parking - The minimum surface level of open space car parking subject to inundation should be designed giving regard to vehicle stability in terms of depths and velocity during inundation by flood waters. Where this is not possible, it shall be demonstrated how the objectives will be met.
Filling of Flood Prone Land	To ensure that any filling of land that is permitted as part of a development consent does not have a negative impact on the floodplain.	Unless a floodplain risk management plan for the catchment has been adopted, which allows filling to occur, filling for any purpose, including the raising of a building platform in flood-prone areas is not permitted without Council approval. Application for any filling must be supported by a flood assessment report from a suitably qualified engineer which certifies that the filling will not increase flood affectation elsewhere.
On-Site Sewer Management (Sewer mining)	• To prevent the spread of pollution from on-site sewer management systems during periods of flood; and • To assist in the ongoing operation of on-site sewer management systems during periods of flood.	The treatment facility must be located above the 1% AEP flood level and must comply with Flood Planning Level requirements, or are otherwise protected and may function if below this level.
Storage of Hazardous Substances	To prevent the potential spread of pollution from hazardous substances.	The storage of products which, in the opinion of the City, may be hazardous or pollute floodwaters, must be placed above the 1% AEP flood level or placed within an area protected by bunds or levels such that no flood waters can enter the bunded area and must comply with the Flood Planning Level requirement for such a facility.

Development Type/ Aspect	Objective	Requirement
Consideration of the Impact of Climate Change	To prevent the potential impact of climate change.	• For those developments which have a lifespan of more than fifty years the impact due to sea level rise and impacts due to increased rainfall intensities shall be considered. • Meet the allowances for sea level rise as recommended in the NSW Government Coastal Planning Guideline: Adopting Sea Level Rise 2010 (recently withdrawn from publication). Specifically, this shall include and allowance of 40cm by 2050 and a 90cm by 2100 from the 2009 Mean Sea Level. • Where in the opinion of the City the proposed development is of reasonable impact to regional or catchment trunk drainage, the drainage system design shall allow for a minimum of 10% increased rainfall.

5 Flood Planning Levels

A Flood Planning Level refers to the permissible minimum building floor levels. For below-ground parking or other forms of below-ground development, the Flood Planning Level refers to the minimum level at each access point. Where more than one flood planning level is applicable the higher of the applicable Flood Planning Levels shall prevail.

Development		Type of flooding	Flood Planning Level
Residential	Habitable rooms	Mainstream flooding	1% AEP flood level + 0.5 m
		Local drainage flooding (Refer to Note 2)	1% AEP 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 1% AEP flood is less than 0.25 m
		Outside floodplain	0.3 m above surrounding ground
	Non-habitable rooms such as a laundry or garage (excluding below-ground car parks)	Mainstream or local drainage flooding	1% AEP flood level
Industrial or Commercial	Business	Mainstream or local drainage flooding	Merits approach presented by the applicant with a minimum of the 1% AEP flood level
	Schools and child care facilities	Mainstream or local drainage flooding	Merits approach presented by the applicant with a minimum of the 1% AEP flood level + 0.5m
	Residential floors within tourist establishments	Mainstream or local drainage flooding	1% AEP flood level + 0.5 m
	Housing for older people or people with disabilities	Mainstream or local drainage flooding	1% AEP flood level + 0.5 m or a the PMF, whichever is the higher
	On-site sewer management (sewer mining)	Mainstream or local drainage flooding	1% AEP flood level
	Retail Floor Levels	Mainstream or local drainage flooding	Merits approach presented by the applicant with a minimum of the 1% AEP flood. The proposal must demonstrate a reasonable balance between flood protection and urban design outcomes for street level activation.
Below-ground garage/ car park	Single property owner with not more than 2 car spaces.	Mainstream or local drainage flooding	1% AEP flood level + 0.5 m

Development		Type of flooding	Flood Planning Level
	All other below-ground car parks	Mainstream or local drainage flooding	1% AEP flood level + 0.5 m or the PMF (whichever is the higher) See Note 1
	Below-ground car park outside floodplain	Outside floodplain	0.3 m above the surrounding surface
Above ground car park	Enclosed car parks	Mainstream or local drainage flooding	1% AEP flood level
	Open car parks	Mainstream or local drainage	5% AEP flood level
Critical Facilities	Floor level	Mainstream or local drainage flooding	1% AEP flood level + 0.5m or the PMF (whichever is higher)
	Access to and from critical facility within development site	Mainstream or local drainage flooding	1% AEP flood level

Note*s*

1) 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.

2) Local drainage flooding occurs where:

- The maximum cross sectional depth of flooding in the local overland flow path through and upstream of the site is less than 0.25m for the 1% AEP flood; and
- The development is at least 0.5m above the 1% AEP flood level at the nearest downstream trapped low point; and
- The development does not adjoin the nearest upstream trapped low point; and
- Blockage of an upstream trapped low point is unlikely to increase the depth of flow past the property to greater than 0.25m in the 1% AEP flood.

3) Mainstream flooding occurs where the local drainage flooding criteria cannot be satisfied.

4) A property is considered to be outside the floodplain where it is above the mainstream and local drainage flood planning levels including freeboard.

6 Flood Compatible Materials

Where required for development, the following materials are to be applied. Materials not listed may be accepted by Council subject to certification of the suitability of the material of the manufacturer.

Component	Flood Compatible Material
Flooring and Sub-floor	▪ Concrete slab-on-ground monolith construction ▪ Suspended reinforced concrete slab
Wall Structure	▪ Solid brickwork, blockwork, reinforced concrete or mass concrete
Wall and Ceiling Linings	▪ Fibro-cement board ▪ Brick, face or glazed ▪ Clay tile glazed in waterproof mortar ▪ Concrete ▪ Concrete block ▪ Steel with waterproof applications ▪ Stone, natural solid or veneer, waterproof grout ▪ Glass blocks ▪ Glass ▪ Plastic sheeting or wall with waterproof adhesive
Roof Structure	▪ Reinforced concrete construction ▪ Galvanised metal construction
Doors	▪ Solid panel with water proof adhesives ▪ Flush door with marine ply filled with closed cell foam ▪ Painted metal construction ▪ Aluminium or galvanised steel frame
Insulation	▪ Closed cell solid insulation ▪ Plastic/polystyrene boards
Windows	▪ Aluminium frame with stainless steel rollers or similar corrosion and water resistant material.
Nails, Bolts, Hinges and Fittings	▪ Brass, nylon or stainless steel ▪ Removable pin hinges ▪ Hot dipped galvanised steel wire nails or similar
Main Power Supply	▪ Subject to the approval of the relevant authority the incoming main commercial power service equipment, including all metering equipment, shall be located above the designated flood planning level. Means shall be available to easily disconnect the dwelling from the main power supply.
Wiring	▪ All wiring, power outlets, switches, etc., should be located above the designated flood planning level. All electrical wiring installed below this level should be suitable for continuous underwater immersion and should contain no fibrous components. This will not be applicable for below-ground car parks where the car park complies with flood planning level requirements. ▪ Earth leakage circuit-breakers (core balance relays) or Residual Current Devices (RCD) must be installed. ▪ Only submersible type splices should be used below maximum flood level. ▪ All conduits located below the relevant designated flood level should be so installed that they will be self-draining if subjected to flooding.
Electrical Equipment	▪ All equipment installed below or partially below the designated flood planning level should be capable of disconnection by a single plug and socket assembly.

Component	Flood Compatible Material
Heating and Air Conditioning Systems	▪ Heating and air conditioning systems should be installed in areas and spaces of the house above the designated flood planning level.
Fuel storage for heating purposes	▪ Heating systems using gas or oil as a fuel should have a manually operated valve located in the fuel supply line to enable fuel cut-off. ▪ The heating equipment and related fuel storage tanks should be mounted on and securely anchored to a foundation pad of sufficient mass to overcome buoyancy and prevent movement that could damage the fuel supply line. The tanks should be vented above the flood planning level.
Ducting for heating/cooling purposes	▪ All ductwork located below the relevant flood level should be provided with openings for drainage and cleaning. Self-draining may be achieved by constructing the ductwork on a suitable grade. Where ductwork must pass through a water-tight wall or floor below the relevant flood level, a closure assembly operated from above relevant flood level should protect the ductwork.

Responsibilities

The Technical Services Manager is responsible for the development and revision of the policy. The City's Planning team together with the Public Domain team are responsible for communicating the policy and ensuring systems are in place to validate its compliance.

Consultation

The initial draft edition of the Interim Floodplain Management Policy was first reviewed by internal stakeholders of the City including City Operations and City Planning divisions. The Policy was then revised to take account of this input.

The City's Floodplain Risk Management Committee was initially informed regarding the need for the interim policy in December 2012. During the March 2013 Floodplain Risk Management Committee meeting a presentation was made by City staff regarding the draft policy. Copies of the policy were then provided to all Committee members for comment. Some minor changes were then made to the draft policy following feedback from committee members.

References

Laws and standards	• Local Government Act 1993, Section 733 • Environment Planning and Assessment Act 1979
Policies and procedures	• *Floodplain Development Manual: the management of flood liable land*, New South Wales Government, Published April 2005 • Sydney LEP 2012 • Sydney DCP 2012 • South Sydney DCP 1997, Green Square precinct amended 2006

Approval

Council approved this policy on 12 May 2014.

Review

Review period	Next review date	TRIM reference
City Operations will review this policy every 2 years	May 2016	2014/216277